SCIENCE IN PIECES:
PUBLIC SCIENCE IN THE DEFORMATION AGE

J. Scott Brennen

A dissertation submitted to the faculty at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy In the School of Media and Journalism.

Chapel Hill
2018

Approved by:

Daniel Kreiss

Chris Anderson

Barbara Friedman

Ben Peters

Adam Saffer

ABSTRACT

J. Scott Brennen: Science in Pieces: Public Science in the Deformation Age
(Under the direction of Daniel Kreiss)

This dissertation investigates how public information about new scientific research flows through the contemporary media system. Arguing that public science is governed more by entropy than inertia, this project investigates the people, technologies, and processes through which *difference* is brought into flows of information about direct detection of dark matter experiments. Over six empirical chapters, the project considers how three types of organizational mediators of public science—multi-institution collaborations, communication offices at national laboratories, and science journalists—translate, move, preserve, and/or deconstruct information. To do so, it draws on diverse methods, including 62 semi-structured interviews with members of these organizations and an interpretive textual analysis of hundreds of news articles, press releases, and organizational documents. This project makes three broad contributions. First, it provides a detailed account of how science organizations are adopting new practices, structures, and formats to reach new audiences amid changing technologies, economic pressures, and cultures. Second, it extends Bruno Latour's circulating reference to present a new descriptive and normative model of the epistemology of public science communication that acknowledges how the reduction of technical complexity can productively afford an expansion of public meaning. It argues that good public communication must shepherd the relationships and connections that allow truth to circulate across time, space, and reference, while simultaneously working to open content for public discussion, consideration, and meaning making. Finally, this project considers what happens when these mediations go *wrong*. Instead of mis or disinformation—information lacking *truth*—this project recognizes *another* form of information degradation: *deformation*. Deformations are structural artifacts of the contemporary media system: pieces and fragments broken off in the grinding of disparate logics, systems, technologies, and messages. They emerge when information loses its *organization*, its *formation*. Observing deformation in science and beyond, this project ultimately argues that despite decades of scholarship on the "information society," ours is better recognized as the "deformation society."

For Nigel,
B.A., M.A., J.D., Ph.D.

ACKNOWLEDGEMENTS

It's sobering to behold the result of years' worth of work—more so in recognizing how many others have helped me along the way. This dissertation simply does not do justice to the abundance of help and good advice I have received over the past several years.

It is no exaggeration to say that without Daniel Kreiss, not only would this dissertation not exist, but I would never have pursued a Ph.D. I might very well now be a science press officer somewhere, writing the same press release again and again and taking my weekends off. For seven years, Daniel has inspired me, pushed me, and found sense when I made none; he has been my best advocate and my worst critic. Daniel has reshaped not only how I think about the world, but who I am in the world, too.

Each member of my dissertation committee has played a notable role in this project. Chris Anderson has shown me what good, rigorous, and theoretically expansive journalism scholarship can and should be. But also, he has been a generous and supportive advocate of my work. As has been Ben Peters, whose enthusiasm and support has helped as much as his exhortations to think expansively about media, to ask big questions, and to look for good stories to tell. Barbara Friedman showed me the pleasure of getting lost in archives and the power that scholarship can wield in the world. Adam Saffer has pushed me to expand my toolkit and my scholarship. He has shown me the potential of mixed methods work—even if I have been slow to follow.

Beyond my committee, I have benefited from the help of many others. Allison Lazard came to my rescue when I most needed it. And along the way, she has taught me a great deal about doing rigorous, grounded collaborative research. Had I not met Grayson Rich in a bar, I never would have found my way to particle physics. He has made introductions, corrected my science, patiently explained both the complex and the simple, and has never been afraid to tell me when I was far out of my depth.

I also could not have made it through graduate school without the help and support of my family. My mother, Bonnie Brennen, has been a shadow-advisor, a voice of reason, and a tireless promoter of sleep, days off, and the "so what." Bringing me into the family business, her patience and support has been legion. My partner, Lorelle Babwah Brennen, has grown nearly as sick of dark matter as I have. She has put up with my monologues, my strict routines, my ebullience and my hopelessness. She has read papers, emails, and cover letters, watched presentations, listened to far more stupid ideas than good ones, and braved my thin-skinned sulking to give me honest feedback. For years she has put aside her plans for me: standing still when she wanted to move, and now moving when she wants to stand still. She has made bearable long days alone at the computer.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES xi

CHAPTER 1: INTRODUCTION 1
Case Study: LUX 5

How Science Communication is Changing 10

The Value of Difference: Translations, Reference, and a New Model of Science Communication 13

The Perils of Difference: Information, Misinformation, and Deformation 20

Science and the Deformation Society 24

Guiding Research Questions 26

Methodological Approach 26

Chapter Breakdowns 34

CHAPTER 2: MAGNETOLOGISTS ON THE BEAT: THE EPISTEMOLOGY OF SCIENCE COMMUNICATION RECONSIDERED 37

Introduction 37

Literature Review 40

A New Model 46

Case Study: Methods and Background 52

Conclusion 64

CHAPTER 3: ALWAYS ALREADY MEDIATED: SCIENCE AND MEDIA 67

Introduction 67

Literature Review and Theoretical Framework 69

Methods 73

Findings: Three Translations 74

Discussion and Conclusion 91

CHAPTER 4: THE PUBLIC COMMUNICATION PRACTICES OF MULTI-INSTITUTION COLLABORATIONS 93

Introduction 93

Literature Review 96

Methods 101

Findings 102

Discussion 126

CHAPTER 5: PARTICLE PHYSICS COMMUNICATION: FIELDS IN INTERACTION 131

Introduction 131

Literature Review 133

Methods and Theoretical Framework 138

Case Study: the InterAction Collaboration 140

Discussion and Conclusion 153

CHAPTER 6: THE JOURNALIZATION OF NATIONAL LABORATORIES 155

Introduction 155

Literature Review 158

Theoretical Framework 160

Methods 162

Findings 164

Discussion 178

CHAPTER 7: SCIENCE NEWS AGGREGATORS: THE EPISTEMOLOGY OF AGGREGATION AND AGGREDUCTION 181

Introduction 181

Literature Review 184

Methods 193

Findings 193

Discussion 207

CHAPTER 8: CONCLUSION: THE DEFORMATION AGE 212

APPENDIX A: METHODS IN DETAIL 221

APPENDIX B: SELECTED ORGANIZATIONAL STORIES AND HISTORIES 238

CDMS 238

LUX 256

Space.com 262

REFERENCES 271

LIST OF FIGURES

Figure 1.1 - Tweet from @luxdarkmatter 10/30/2013 8

Figure 1.2 - Relations amongst collaborations 12

Figure 3.2 - Plots from three dark matter experiments 77

Figure 3.1 - Types of direct detection instruments 88

Figure 4.1 - CDMS website, from June 19th, 2000 102

Figure 4.2 - Twitter Activity by Collaboration 103

Figure 4.3 - Twitter connections amongst collaborations and shared collaboration membership 104

Figure 4.4 - Tweet from @luxdarkmatter 10/30/2013 106

Figure 4.5 - Tweet from @luxdarkmatter 10/30/2013 106

Figure 4.6 - Tweet from @XENON1T 8/28/2017 107

Figure 4.7 - Tweet from @luxdarkmatter 8/24/2013 107

Figure 4.8 - Tweet from @luxdarkmatter 10/30/2013 108

Figure 6.1 - Fermilab's first public-facing website 166

Figure 7.1 - Typology of News Aggregation 191

Figure A.1 - Interview informants 224

Figure A.2 - Collaborations 228

Figure A.3 - The 20 most cited physicists 230

Figure A.4 - Collaboration citation frequency 232

Figure A.5 - Distribution of press releases 233

Figure B.1 - Organizational Initiatives of the CfPA 243

Figure B.2 - *Space.com* 10/13/1999 264

CHAPTER 1: INTRODUCTION

On October 30th 2013, dozens of journalists, politicians, administrators, and physicists gathered in the seminar room of the newly built Sanford Underground Research Facility at the Homestake gold mine outside of Lead, South Dakota. They had assembled to hear a special announcement from the Large Underground Xenon (LUX) experiment, a prominent physics initiative attempting to finally detect the particles that constitute dark matter—the mysterious hidden substance that makes up as much as 27 percent of the Universe (NASA, 2018). These sorts of experiments have been running since the early 1980s—but astronomers have cataloged other more indirect forms of evidence of dark matter since the 1920s.

Although this event had all the trappings of a press conference, its organizers had been very careful to refer to it only as a "seminar" or a "talk" (e.g. Walter, 10/15/2013). When the time came, the two spokespersons of the experiment stood before both an audience in South Dakota and a much larger one watching online. After a detailed introduction of the experiment, they announced that after years of planning and months of data collection, the experiment had finally seen…nothing.

This non-press-conference press conference raises many questions about the ongoing changes occurring in science communication—changes this dissertation addresses. First, why should scientists put so much effort into a press conference to announce null results? Despite increasing interest from scholars of science communication and the science of science communication, there remains a great deal we do not understand about how collaborations, alone and in partnership with institutional communication offices, are adopting new communication practices and formats to target new audiences. More broadly, we still have a poor understanding of the changing organizational landscape in both science journalism and science communication. Drawing on scholarship in science communication and sociological field theory, this project investigates how three different types of organizations in science communication—collaborations, communication offices at national laboratories, and science journalism outlets—are adopting new structures and practices as they respond to changes in the larger media environment.

Second, this press conference is a moment of translation in science communication: when expert results are turned into public information; when null results are made meaningful; when scientific findings are turned into social and economic capital. Translations have been described as acts of communication (Serres, 1982; Brown, 2002), the soul of scientific research (Latour, 1999), and the constituting elements of "both the social and natural worlds" (Callon, 1986: p. 7; see also Latour, 2005). There have been many studies of different formats, actors, and processes of science communication. There have been far fewer examinations of the translations and relations *between* those components. Yet these moments of translation—animated by *media* technologies and processes—can reveal much about both the changing landscape of the public communication of science and about broader changes in social life.

Third, translations alter inputs; they embrace and interject *difference*. Indeed, as philosophers of information attest (e.g. Floridi, 2011), difference is intrinsic to information itself. Public science communication has never had an easy relationship with difference. For decades, if not centuries (Burnham, 1986), many have chastised public science as too inaccurate or too sensational (see Kreighbaum, 1967)—too *different* from expert science communication. Others have complained when it is too complicated or too jargon-filled (Rakedzon et al., 2017)—*not different enough* from expert science communication. How different do we want public communication of science to be? How do we think about difference as part of the promise and part of the peril of public science communication?

Scholars of the "information age" or the "information society" (e.g. Castells, 2010; Beniger, 1986; Bell, 1976) have also had a rocky relationship with difference. As they describe massive economic, social—even metaphysical (Floridi, 2014) shifts associated with information, many ultimately assume the stability of information flows over time and space. Few have recognized that information flows are made from series of mediators, each altering inputs in producing outputs (Latour, 2005)—and that, like fields of social organization, the stability of flows takes *work* to achieve (Fligstein & McAdam, 2012: p. 7).

Dark matter experiments help us understand difference in science communication because they are themselves efforts to establish difference. Instead of a sterile homogeneity, space for astro-particle physicists is a roiling miasma of particle-life. Thematically, dark matter experiments help us see the promise that difference can bring to all forms of science communication—expert or public.

Synthesizing these concerns, this dissertation offers an empirical and theoretical investigation of the changing relations between different forms and formats of science communication in the contemporary media environment. Through an in-depth look at direction detection of dark matter experiments, this project investigates the translations through which informational flows about science are altered in form and moved in space. Unlike many studies in science communication, this dissertation investigates the communication surrounding "normal science" (Kuhn, 2012), rather than science involved in public controversies, such as climate change (Boykoff & Boykoff, 2004), or science that holds a special place in the public imagination, such as the Human Genome Project (Hilgartner, 2013) or the space program (Vertesi, 2014). By studying more mundane or everyday science, this dissertation provides needed insight into the broader shifts occurring across the landscape of science communication. Doing so also provides new theoretical tools for scholarship in (the science of) science communication and media/um studies to help us make sense of how information about science flows within a rapidly shifting media environment. Together these insights not only help us better understand science communication; they also illuminate the changing knowledge and informational infrastructures of public life.

After returning to the case introduced above, this introduction lays out three of the key empirical and theoretical arguments of this dissertation. Then, this introduction provides a brief description and justification of the methods employed in this project, before providing detailed chapter breakdowns.

Case Study: LUX's Non-Press-Release Press Release

LUX began with a mutiny. Experiments like LUX in (astro-)particle physics are almost exclusively run by collaborations of scientists, engineers, and administrators from institutions all over the world (see Shrum et al., 2007). Social scientists have observed that these sorts of collaborations in particle physics have long embraced a more democratic structure (Galison, 1997; Knorr-Cetina, 1999; Traweek, 1988). A decade before the LUX press conference, the XENON10 collaboration was pioneering a new technological approach to detecting dark matter (see Chapter 3). Dissatisfaction with the less cooperative leadership style of the Italian experiment, along with an argument over the project's ambitions, and growing pressure by the US National Science Foundation (NSF) to begin a new American-based experiment, all helped push half of XENON10's institutions to leave the collaboration and form LUX (see Appendix B for a fuller discussion of the origins of LUX).

From the beginning, LUX embraced a level of media orientation and savvy that distinguished it from other experiments. LUX was the first direct detection experiment to be on Twitter (see Chapter 4). Similarly, LUX's scientists have been cited in news articles (and PR content) more than those from any other collaboration (See Appendix A, Table A.4). Indeed, one of its spokespersons, Rick Gaitskell, has consistently courted press attention, emerging as the single most cited scientist in news and public relations articles collected for this project—almost doubling the second-place scientist (See Appendix A, Table A.3). At the same time, LUX quickly became one of the key projects at the new Sanford Underground

Research Facility (SURF)[1], which officially opened in 2011. Even as the facility was being built, SURF's communication office worked closely with LUX and its member institutions to have a consistent media presence. A number of LUX physicists and SURF communication officers admitted in interviews that the LUX press conference in October 2013 was specifically designed in order to help bring publicity to the new laboratory (R. Gaitskell, personal communication, 9/22/2016, D. McKinsey, personal communication, 11/3/2015; B. Harlan, personal communication, 3/25/2016; C. Walter, personal communication, 6/8/2016).

Even before LUX had finished building its instrument, collaboration members were already planning the *next* iteration of the project. In late 2012, before LUX began collecting data, the collaboration filed a proposal to fund a future iteration of the experiment to be called LZ.[2] In a joint call, the Department of Energy (DOE) and the National Science Foundation (NSF) solicited proposals for a major new round of funding, generation-2, which would be announced in early 2014. Both Rick Gaitskell and Dan McKinsey, LUX's co-spokespersons, admitted in interviews (personal communications, 11/3/2015; 9/22/2016) that the collaboration believed announcing a result that October would help LUX demonstrate its value and bolster its chances of winning this new funding. Notably, in order to make this deadline, LUX had to make a series of decisions and accommodations about how to design and run the experiment—choosing to streamline some processes and delay others. And it worked; LZ was one of three experiments to be awarded generation-2 funding.

---

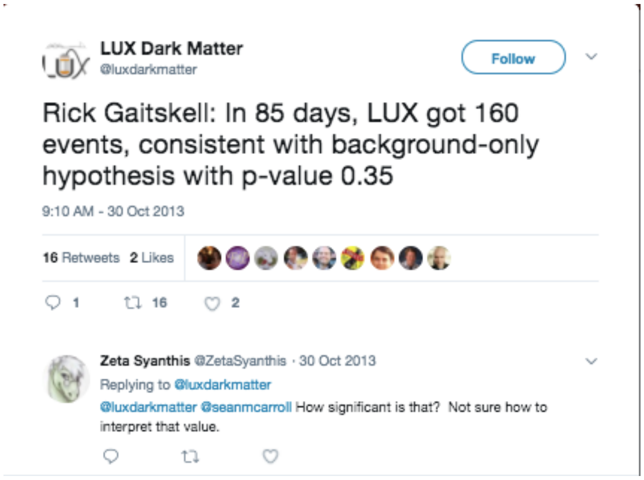
[1] LUX, actually had first been associated with the NSF's new facility, DUSEL. When DUSEL fell through, SURF eventually arose in its place.

[2] LZ stands for LUX-Zeplin, as the experiment is a consolidation of those two experiments

Two weeks before the press conference, SURF circulated a brief press release announcing an upcoming "Event to announce the first physics result at the Sanford Lab" (Walter, 10/15/2013). However, the release did not reveal what exactly those results would be. At the same time, the PIOs at SURF worked with LUX and the communication departments at many of LUX's 15 other institutional members to produce a second press release revealing the results. Several days before the press conference, the release was circulated, under embargo, to journalists across the world. Sidestepping its null results, this release announced that LUX has "proven itself the most sensitive dark matter detector in the world" (Walter, 10/30/2013). Rather than a single organized effort, each institutional member was responsible for distributing the release through its own network of contacts. These networks included both local and national journalists, institutional publications (see Chapter 4), and the prominent science news aggregator and wire service *EurekaAlert!* (see Chapter 7).

Importantly, however, before distributing the press release, many communication departments *rewrote* it. What had been carefully negotiated and written—having been reviewed dozens of times to ensure both that the science was accurate and that credit was justly apportioned—was deconstructed and used for parts. These press releases took phrases, paragraphs, quotations, ideas, and frames from the original, but reworked and re-contextualized them to better highlight the contributions of their own researchers (see Chapter 4).

During the press conference, which was streamed through South Dakota Public Broadcasting's website, LUX live-tweeted the event. One of these tweets attempted to condense and communicate the findings:



LUX Dark Matter
@luxdarkmatter

Rick Gaitskell: In 85 days, LUX got 160 events, consistent with background-only hypothesis with p-value 0.35

9:10 AM - 30 Oct 2013

16 Retweets 2 Likes

Zeta Syanthis @ZetaSyanthis · 30 Oct 2013
Replying to @luxdarkmatter
@luxdarkmatter @seanmcarroll How significant is that? Not sure how to interpret that value.

Figure 1.1: Tweet from @luxdarkmatter 10/30/2013

Simply put, this tweet, as the reply included noted, is unclear. Near every phrase contradicts the next. "160 events" initially sounds like LUX found dark matter. However, the "consistent with background-only hypothesis" is a jargon-heavy way of saying they did *not* find dark matter. But, with such a high p value, it is unclear if the results are significant or what that might mean (see Chapter 4).

On the day of the press conference, *Symmetry Magazine* published a brief news-style article about the release. *Symmetry Magazine* is a joint effort between two US National Laboratories, *SLAC* and *FermiLab*. Although it is, ultimately, an institutional publication, it has broadly adopted the format and style of a *news magazine*. While employing many former journalists, the outlet assigns beats, holds editorial meetings, and adopts journalistic writing conventions. *Symmetry Magazine* is not unique in doing so. As Chapter 6 describes, many communication offices at national laboratories have been increasingly adopting journalistic structures and practices. A key dimension of this change is that while offices used to focus far more of their attention on publicizing stories about the organizational or administrative happenings at their laboratories, today, most offices publicize the *science* being pursued.

In preparation for the day of the release, at least 19 different journalistic outlets, ranging from the *New York Times* to *New Scientist,* prepared stories. In the days that followed, at least ten more news outlets published stories about the results. While some articles clearly adopt the press release's framing, far more focus on the fact that the "LUX dark-matter search comes up empty" (Johnston, 10/31/2013)*.* That being said, given the timing of the release of these news articles, it is hard to deny that the press conference and the press releases were successful in driving some news coverage. Indeed, most of the science journalists interviewed for this project admitted being heavily influenced by press conferences and releases (Chapters 2 & 7).

On the day of the press conference the website *Universe Today* published an article credited to Elizabeth Howell. Although Howell wrote a new lede for the story, every single quote, and many of the paragraphs were lifted directly from the press release (rewritten and) distributed by Lawrence Berkeley National Laboratory. Unfortunately, this was neither the only *Universe Today* story to lift content straight from a press release or news story, nor was *Universe Today* the only outlet to do so. A number of news articles take quotes, metaphors, explanations, or entire paragraphs from press releases (see Chapter 7). Similarly, in the days and weeks that followed, a number of blogs and other digital outlets across the Web reprinted many of these news stories and press releases verbatim.

How Science Communication is Changing

LUX's press conference indicates some of the notable shifts happening across science communication that are discussed in the following chapters. This dissertation presents six empirical chapters, treating different organizational intermediaries or mediators of the public communication of science: research collaborations, national laboratory communication offices, and science journalism outlets.

Literature in science communication, and the more recent science of science communication, has offered important insights into some of the changes signaled by the case above and explored across this project. In particular, a number of scholars have observed changes in science journalism—for example, demonstrating that while more is now expected of science journalists (Brumfiel, 2009), they are given less time and money for their work (Schäfer, 2017). Others have observed that news content increasingly details science mired in public controversies while also increasingly being seen as politically polarized (Feldman, Hart, and Milosevic, 2017). Yet, fewer scholars have looked at the changing *organizational landscape* of science journalism. Combining analysis of hundreds of articles from more than a hundred outlets with interviews with science journalists, Chapter 7 considers the increasingly diverse landscape of science journalism outlets by investigating science news aggregators.

The LUX example above also highlights the role that communication offices at national laboratories and research universities play in the public communication of collaborative physics. While there has been a slight increase in scholarly interest in science communication at scientific institutions (Lohwater & Storksdieck, 2017; Autzen, 2014), there remains much we do not know about these offices. Existing literature has obliquely recognized a "professionalization" that occurred across communication offices (Borchelt & Nielsen; Nelkin, 1995; Traweek, 1988). This project provides a needed in-depth exploration of the specific ways that offices have been adopting both professional public relations and journalistic practices and structures. Notably, the project finds that while digital and social media have facilitated a recent "journalization" of communication offices, there remains a great deal of confusion and uncertainty in how best to leverage media change for strategic advantage.

Far less existing research in science communication has looked explicitly at the ways that scientific collaborations, increasingly one of the most common forms of scientific organization (see Shrum et al., 2007), are adopting communication practices to target lay publics directly. This dissertation offers the first explicit investigation of the ways that multi-institution collaborations are embracing public media practices and strategies. It also observes that collaborations are deeply interconnected with *other* collaborations—sometimes across disciplines. Figure 1.2 shows the interrelations amongst the different (iterations) of direct detection collaborations since the late 1980s (see below and Appendix A for a description of methods).

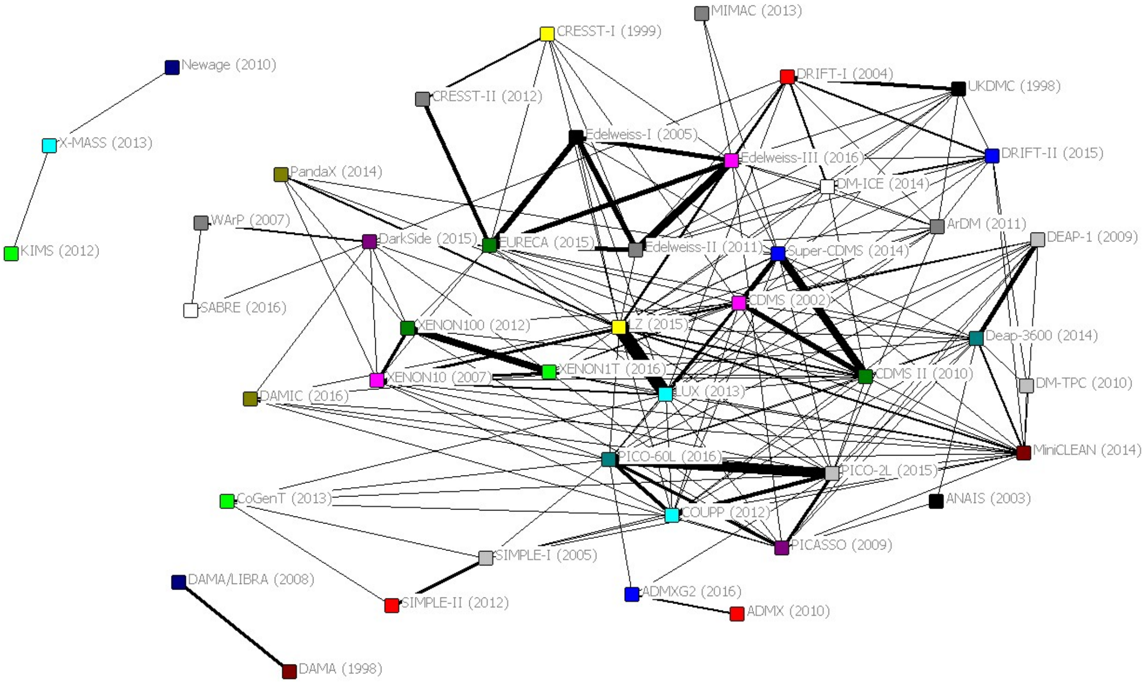


Figure 1.2: Relations amongst collaborations. Lines indicate number of shared researchers.

Surprisingly, this dissertation finds that collaboration communication efforts have often been poorly handled. Collaborations usually look to communication offices at member institution to lead public communication. Doing so involves coordinating between dozens of offices. At the same time, this project shows that as these communication offices have become increasingly savvy communicators, they have grown more focused on advancing both the needs of their own organizations and of the wider field of particle physics (see Chapter 5)—sometimes at the expense of individual collaborations.

The Value of Difference:
Translations, Reference, and a New Model of Science Communication

The LUX press conference related above is a story of translation. It involved physicist, communicators, and journalists—not to mention, politicians, administrators, and many others—all working to convert expert-directed science for new audiences. Indeed, there were many translations occurring simultaneously: translating scientific results for public consumption; translating negative results into positive PR; translating results into grant funding.

This dissertation studies the translations through which public and expert knowledge about dark matter is produced. In foregrounding these translations, it adopts an approach from actor-network theory (ANT) (Latour, 2005; Callon, 1986). Broadly, this ANT-inspired approach stresses the heterogeneity of knowledge production: helping to identify the complex relations amongst people, things, organizations, ideas, discourses, and cultures that are involved (see below for a fuller description and defense of methods).

Translations are mediations (Latour, 1999)—they involve media. Rather than limit media to mass media, this project follows the tradition in medium theory of defining media far more broadly (see Chapter 3; Packer, 2013). This recognition makes it possible to draw theoretical connections between the various actors, processes, and technologies across expert and public science communication—recognizing they are all constituted by media (Chapter 3; see also Bucchi, 1996; 2008).

As mediations, translations are processes of change: “act[s] of invention brought about through combining and mixing varied elements” (Brown, 2002: p. 6). They are means of producing *difference* in the world. John Law took this a step further, suggesting, “the idea that translation is also a betrayal is built into the character of actor-network theory (if we may allow ourselves to imagine that it has a character)” (2006: p. 57).

But difference has, of course, been a persistent theme of social and cultural theory for decades. For example, Derrida (1978) famously accelerates the foundational role of difference in structuralism (Saussure, 1916; Lévi-Strauss, 1958) to an extreme through *diffêrance*. Deleuze (e.g. 1994) claimed to be fashioning a “philosophy of difference” that formulates a new history of philosophy rooted in difference as positivity.

But difference has long been associated with *communication* as well. In *Speaking into the Air*, John Durham Peters traces a long and varied history of understandings of communication, before attempting to find a “middle position” balancing in part between pragmatic and phenomenological traditions that “erases neither the curious fact of otherness at its core nor the possibility of doing things with words” (p. 21). For Peters, this begins by defining communication as the attempt to annihilate difference “as the project of reconciling self and other” (p. 9).

While Michel Serres has stood on the periphery of communication scholarship and theory, his account of communication in *The Parasite* (1982) similarly centralizes difference. However, Serres does so not in the reconciliation of the self and other, but in the fundamental *constitution* of the self. As in English, in

French, *parasite* refers to the animal that feeds off of a host as well as a mooching guest. In French, however, the word also refers to a noise or an interruption. Serres recognizes the parasite—as noise, interruption, or difference—as fundamentally constitutive of communication itself. Rather than a sender-receiver dyad, for Serres communication is a triad of sender, receiver and parasite. On one hand, Serres asserts that there can be no a priori distinction made amongst these three components (1982: p. 14). On the other, the parasite constitutes the *difference* between sender and receiver: without noise, the sender and receiver are the same. Explicating Serres, Steven Brown tries to image a scenario of "perfect communication," recognizing that

> For this to happen, there must be no possible equivocation in the reception of the signal. The only logical guarantee of such a state of affairs is an identity between sender and receiver. Such a relationship is, of course, not really a 'relation', but rather the absolute harmony of similarities (Brown, 2002: p. 7).

Ultimately, for Serres, within communication and beyond, "The difference is part of the thing itself, and perhaps it even produces the thing. Maybe the radical origin of things is really the difference, even though classical rationalism damned it to hell. In the beginning was the noise" (Serres, 1982: p. 13).

To understand translations, however, we have to look not only at the processes of communication but at the content as well: the knowledge or information that is (re)produced. While communication has long been associated with difference, arguably so has information.

There have been many definitions of (semantic) information—perhaps as many as communication. Floridi (2011) argues that many theorists have supported what he calls a *"General Definition of Information (GDI)*" as simply "*data + meaning"* (p. 83, emphasis in original; Checkland and Scholes, 1990: p. 303), to which he adds the requirement that information also be true (p. 92). The GDI also recalls Marc Porat's famous definition of information as "Information is data that have been organized and communicated" (1977: p. 2), a definition that Manuel Castells also adopts his influential *The Information Age* (2010: p. 17 n. 25).

These definitions suggest that to understand information, we first need to look at *data*. To better understand what data *is,* Floridi offers a thought experiment in which someone attempts to erase all possible data contained in a book written in indecipherable pictograms (p. 85). Floridi walks through erasing the symbols until left only with a blank page. He observes this does not mean there is no data, "For the presence of a white page is still datum, as long as there is a difference between the white page and the page on which something is, or could be, written" (p. 85). Floridi concludes, therefore, "a genuine, complete erasure of all data can be achieved only by the elimination of all possible differences" (p. 85). Floridi argues that this "diaphoric"[3] definition of data ontologizes data as difference, not only as "fractures in the fabric of Being" (p. 85), but also as a "lack of uniformity between (the perception of) at least two *signals*" or between two "*symbols"* (p. 86, emphasis in original)

If data and communication both fundamentally are or at least involve *difference*, returning to Porat's definition of information as "data that have been organized and communicated" (1977: p. 2), we must accept *information* as

---

[3] As Floridi notes, "*diaphora* is the Greek word for 'difference'" (p. 85)

difference as well—or difference that has been organized. This aligns with Bateson's dictum that "In fact, what we mean by information—the elementary unit of information—is a difference which makes a difference" (Bateson, 1973, cited by Floridi, 2011: p. 85).

While this project is somewhat narrowly interested in *semantic* information, it is worth nothing that Shannon's famous "mathematical theory" of information (1948) is *also* articulated on an understanding of difference. For Shannon, information is a measure of entropy or disorder of a system and is connected to the probability that a given message will occur. The more probable a message, the *less information* it provides. This is to say, the amount of information is fundamentally tied to the difference from what is expected.

Defining information in terms of difference also aligns with Yaron Ezrahi's far simpler, if more critical discussion of information (2004), in which he observes that information literally is "in-formation," an ordering of content that "is more mechanically organized and communicable" (p. 258). For Ezrahi this ordering comes at a high cost, involving a "thinning out of layers of meanings, references and associations, a process of impoverishing human understanding and experience" (p. 257). To return again to Porat and the GDI, Ezrahi's emphasis is on the *organization* of data, the formations into which it is aligned.[4]

Ezrahi's discussion interjects an important normative dimension into the consideration of information and difference. Ezrahi's larger project involves tracing the social shifts inherent in the transformation of wisdom to knowledge, knowledge

---

[4] There's a strong, though unstated connection here to Heiddegger's standing reserve, or *gestell* (1977).

to information, and finally information to “outformation,” which are “dense configurations of meanings and associations [that] are characteristically more eclectic and directly accessible” (2004: p. 258), but “often represent[s] the sacrifice of depth and perhaps also accuracy to accessibility” (p. 260).

Despite Ezrahi’s somewhat dour views, this dissertation asserts that the necessary degree of difference that exists within scientific information (flows) can be seen as *generative* or even positive. Just as Serres recognizes that it is the interruption of the parasite that constitutes the difference between sender and receiver, this project argues that we should recognize that the differences between expert and public communication of science can be *productive*. Indeed, public communication of science is, in a sense, defined by its degree of difference from expert communication. Were Dennis Overbye, for example, to reprint in the *New York Times* the academic paper LUX eventually published about their results, he would have failed as a science journalist. We expect—we want—science journalism and public science communication to stand distinct from how scientists communicate with each other. This, however, is a point often lost amid frequent condemnations of public science communication in terms around “accuracy” (e.g. Weigold, 2001). The challenge is to understand how exactly the difference between a piece of expert and of public science communication is productive.

This project offers an account of the productivity of difference in science communication by extending a model of science production from Bruno Latour’s well known discussion of “circulating reference” (1999) to science communication more broadly (see Chapter 2 for a fuller discussion of this model). For Latour, (some) science works through the production of successive representations of the natural world. As each representation pares away some of the complexity of the previous, it makes visible hidden relationships or connections. It is the job of scientists to both craft these representations and ensure that they preserve the connections *between* them. Truth, for Latour, rather than being a product of the correspondence between any one representation and the natural world, "*circulates* here like electricity through a wire, so long as this circuit is not interrupted" (Latour, 1999: p. 69).

This project suggests that Latour's account can be extended to public science communication more broadly. The key insight is the recognition that successive representations work *because* they reduce much of the complexity of antecedent representations (and the natural world). Doing so not only allows consumers to see otherwise hidden relationships, but to interject new meaning into the science. The point of this model is to recognize that science communication works *because* it simplifies. But at the same time, in adding new potential for public meaning making, it adds something important as well. Ultimately, this model of science communication offers a more rigorous acknowledgment of the necessary benefit of difference in informational flows about science.

This project applies this model across science communication around dark matter. In Chapter 4, it employs the model to investigate and assess the ways in which dark matter collaborations are adopting public communication practices. On one hand the model directs empirical investigation to consider what is *added*, what is *subtracted,* and what *remains the same* when collaborations translate their results for lay audiences. On the other hand, the model's imperative to allow for the circulation of truth-values, while opening scientific information to public meaning making, provides a means of assessing the success and value of public information efforts. Notably, this project finds that by any measure, collaborations are failing to produce consistent, high-quality public-directed communication that takes advantage of digital and social media. Similarly, the project applies the model to science journalism epistemology to gain new understanding into the ways that journalists work to produce public information about dark matter.

The Perils of Difference: Information, Misinformation, and Deformation

Although this project recognizes a fundamental epistemological productivity of chains of scientific references or representations, it also acknowledges that dangers abound for public science communication. Frankly, it would be ridiculous to claim that decades (if not centuries) of worry about public science communication have been unwarranted. There is bad public science—quite a bit of it; there is a very long history of hoaxes, sensationalism, propaganda, and outright lies about science (Walsh, 2007).

That being said, this dissertation identifies a *different* danger of public science communication. As seen above in the case of the LUX release, in some instances the contemporary science media system promotes or facilitates a fragmentation of informational flows. Specifically, the dissertation observes how communication offices strip quotes, examples, frames, etc. from collaboratively produced press releases in order to better publicize their own researchers.

Similarly, as research collaborations experiment with how best to deploy digital and social media to achieve their goals, such as the few times collaborations have held press conferences, they often lack the expertise to produce coherent narratives. For example, news coverage of CDMS's 2009 press conference suggests there remained a great deal of confusion in what CDMS had found and what those findings meant. Similarly, in trying to conform to Twitter's limitations, LUX produced tweets that attempted to combine several discrete pieces of data—but ended up generating only confusion. This project also witnesses how some journalists are pulling bits and pieces from other news or institutional stories to quickly produce new-seeming content. In doing so, these "aggreducers" (see Chapter 7) are helping further fracture informational flows.

If information is organized (and communicated) data, what happens when it looses its *formation*? If information fundamentally involves difference—what happens when its difference—its entropy runs amok, when constitutive difference goes too far? This is not described by misinformation, what Floridi defines as "well-formed and meaningful data (i.e. semantic content) that is false" (2011: p. 260). Instead, this dissertation argues this should be called *deformation*.

Floridi's straightforward definition of sematic information as well formed, meaningful and true provides a means to similarly define *deformation*.

"**Well Formed"** Deformations are *not* well formed. Or perhaps it would be more accurate to say they are *differently formed*. In a sense, Floridi's definition of information as "well formed" misses the necessary referent that would answer, "well formed in comparison to what?" Here, however, we see that deformation is *poorly* or de-formed in relation to its representational antecedents.

Importantly, recognizing that difference must be theorized as *internal* to informational flows (and chains of reference) means prioritizing change rather than stability. It is to recognize that the stability of information as it moves from place to place, or time to time, must be achieved rather than assumed. This is, in many ways, one of the key insights of actor-network theory, well demonstrated in Latour's *The Pasteurization of France* (1993). Latour shows how the circulation of Pasteur's revolutionary ideas about bacteria and yeast first required the extension of Pasteur's *laboratory* across France. Without the material infrastructures first in place, there was no way for Pasteur's work to be tested and integrated. Latour shows how it took the extension of complex, diverse infrastructures in order for Pasteur's new informational flows to circulate.

That being said, deformation is often intentional. Chapter 7 identifies aggregation and *aggreduction* as prevalent epistemological strategies of journalistic organizations. Aggreduction, in which journalists de and re-contextualize existing (aggregated) content to produce something that appears to be new, is in many ways characteristic of the spread of deformation. Yet, this project argues that aggreduction and deformation are not *only* artifacts of changing economic or organizational pressures. Rather, aggreduction is situated in a wider culturally rooted set of practices concerning *remixing* (Gunkel, 2015; Lessig, 2008) or bricolage (Markham, 2017; Levi-Strauss, 1966). In the broader cultural milieu, creative repurposing is highly valued as productive. Yet while we may recognize the value in music sampling or found-art, there is far more reason to be suspicious of remixing applied to knowledge (or information) production.

“Meaningful” Even though it is defined in part by its lack of order, deformation nonetheless can be meaningful. Despite structuralism’s association of meaning with order and structure, cultural studies scholars have long recognized the contingency of “decoding” (Hall, 1973). Deformation arguably further shifts some of the burden of meaning making to consumers. Having lost the organization that provides some help in meaning making, deformation requires consumers (and mediators) to fit together the bits, pieces, and fragments into something coherent and meaningful. Although outside the scope of this project, there is reason to see deformation underwriting the growing prominence of both fan and conspiracy theories. Scholars across fields are increasingly investigating the ways in which political (Warner & Neville-Shepard, 2014), scientific (e.g. Bricker, 2013), or social (Bjerg & Presskorn-Thygesen, 2017) conspiracy theories are increasingly structuring public discussion. Similarly, entertainment websites and social media discussion is increasingly dominated by “fan theories,” that postulate bizarre and, frankly unlikely, explanations or predictions for movies, TV, comics, or other media. Scholars have suggested diverse explanations for the increasing commonality of conspiracy theories (e.g. Bjerg & Presskorn-Thygesen, 2017). Deformation, however, provides a way to contextualize fan and conspiracy theories as part of broader changes in the media system’s shifting of the burden to construct meaningful informational flows out of deformations.

"True" Although it is a contentious position (e.g. Fetzer, 2004), for Floridi misinformation is defined by its falseness. Assessing the truth-value of deformation(s) is far more difficult. The model offered above that extends Latour's model of circulating reference to all forms of science communication provides some assistance. Once we move away from a correspondence theory of truth—the sort implicitly assumed by Floridi—we gain more sophisticated ways of considering the truth of deformations. For Latour, as discussed above, truth is neither a binary state nor an adjective; truth instead is a verb of circulation. The same can be said of deformations. Deformation is once and future information. The important question is not how well do deformations correspond to some external reality, but rather, how and how well do they allow truth to circulate. Rather than assuming that all deformation is necessarily false, deformations must be considered in the wider context of their de- and re-contextualization. In a sense, the re-contextualization of deformation is like trying to build a new electrical circuit from the scavenged pieces of several others—a bit of wire from one, some solder from another, a light bulb from a third. While rebuilding a working circuit from these bits and pieces might be difficult, it can be done.

Science and The Deformation Society

Once we recognize that difference should be considered as internal to information (as well as communication and data), we can no longer assume that informational flows can hold their integrity and consistency. The stability of information over time and space is something that has to be *earned*—something that has to be built. This dissertation investigates the *ways* that information flows about dark matter are changed in the contemporary media system: the organizations, processes, and technologies through which flows are altered and those through which flows are maintained.

This dissertation concludes by reconsidering some of the decades worth of literature on the "information society" or "information age" in light of this recognition. Rather than recognizing a society defined by information, this dissertation argues that ours is better described by the prevalence of *deformation(s)*. Everywhere we look, information is being pulled apart and fragmented, chopped into bits and pieces. Sometimes it is re-contextualized, often it is left to circulate as fragments. Politics is rife with words, ideas, votes, and actions taken out of context. So is bad journalism—and bad science. Twitter is made for deformation. For an age supposedly defined by the flows and circulation of information, it is notably rare in the actual experience of the contemporary media system.

But recognizing deformation also challenges our underlying assumptions about the ways in which we should study science communication in the contemporary media environment. In particular, it suggests that we focus more on the work that goes into allowing information to flow and circulate. Doing so, however, requires that we understand better how technical, economic, and cultural change affects the mediation of information flows in science and beyond. This dissertation works to expose the fine-grained details through which scientific inputs become scientific outputs, the ways that mediation moves science in time and space and opens it to new reserves of public meaning.

Guiding Research Questions

Synthesizing these concerns, this project asks three general research questions. Individual chapters ask more targeted questions as well.

1. How are the practices, organizations, and cultures of science communication changing within the contemporary digital media environment?
2. What forces, processes, actors, and technologies interject *difference* into informational flows about dark matter, compelling them to change over time and space?
3. How do dark matter informational flows change? How are these changes productive or generative*?* How are they counter-productive?

Methods

Situating the Method

In investigating the relations between different forms and formats of science communication, this project adopts a methodological approach adapted from actor-network theory (e.g. Latour, 2005) and the "sociology of translation" (Callon, 1986). Broadly, actor-network theory resolves the world as preformed relations amongst many different and different types of actors. Latour once wrote that a better name for ANT would be "actant-rhizome ontology (Latour, 1999: p. 19). Rather than a theory, ANT is better seen as an ontology, a flattened one that eschews *a priori* assumptions or categorizations while resolving being in relational terms. Rather than actors as autonomous individuals, actants are those "made to act," a recognition that stresses how all components of actor-networks, human and non-human alike are constituted through a diverse set of relations. Finally, if the term network "means transport *without* deformation…" Deleuze and Guattari's notion of the rhizome speaks more to "a series of *transformations*—translations, transductions" (Latour, 1999: p. 15). ANT holds that actors, as "mediators," "transform, translate, distort, and modify the meaning or the elements they are supposed to carry." In this way "their input is never a good predictor of their output" (Latour, 2005: p. 39).

Similarly, Michel Callon's related "sociology of translation" (1986), highlights how identifying and tracing translations can help us disentangle the relations through which we constitute both the natural and the social. For Callon, translations are constituted through specific moments, "during which the identity of actors, the possibility of interaction and the margins of manoeuvre are negotiated and delimited" (p. 6). It should be noted, however, these are not the only approaches in social theory to focus on translations. Michel Serres has also, somewhat independently, developed an approach that follows translations (e.g. 1982). While Serres aligns in many ways with ANT, as Brown acknowledges, Serres ultimately treats "translations as a form of communication, a message passing between points" (2002: p. 7).

While journalism studies scholars have begun taking up ANT and ANT-inspired methodologies over the last 10-15 years (e.g. Anderson & Kreiss, 2012;

Plesner, 2009; See also Turner, 2005), Domingo et al., (2015) recently called for a fuller integration of ANT in journalism studies. Much of the existing efforts to port in ANT in journalism studies have been somewhat narrowly focused on investigating the integration of digital tools and formats in newsrooms (e.g. Hemmingway, 2008; Plesner, 2009; Spyridou et al. 2013). Domingo et al. suggest that a broader adoption of ANT could help the field better address and investigate the rapid and widespread changes in journalism. Specifically, they see that ANT can be used to help scholars better trace "news networks" a concept that denotes the widening range of actors, organizations, practices, discourses, and symbols through which news is produced, circulated, and used (p. 56). Domingo et al. suggest that used in this way, ANT can bring three needed interventions to journalism studies. First, ANT can help the field get beyond constraining theoretical paradigms by undermining "*a priori* assumptions that specific human and non-human actors are expected to perform specific actions based on predefined categories such as *journalist* or *audience*" (2015: p. 57). They suggest that doing so will help scholars better situate journalism "in the wider context of everyday life" (p. 61). Second, ANT allows scholars to "bridge the gap" between long running research traditions in journalism studies, including: sociological investigations of newswork, text-based studies of content, and audience studies. Third, "instead of taking normativity for granted, as the benchmark to criticise the shortcomings of contemporary journalism, ANT suggests focusing on how normativity is performed and constructed" (p. 62).

Broadly, this project takes up Domingo et al.'s call for a more rigorous integration of ANT in journalism studies—yet it does so with three notable caveats.

First, while there is value in recognizing that “there may be many different normativities, different definitions of what journalism should be” (p. 62) that ANT can help us identify, this project is far more suspicious of jettisoning long-held normative assessments and lines of critique. There may be new forms, roles, and functions of journalism; yet, we don’t need a wholesale do-over of theorizing about the value of journalism. There is strong empirical and theoretical support for the fundamental value of good journalism in democratic and civic life. Holding on to a clear understanding of what journalism and public information can and should achieve in democracy provides an important normative foothold in analyzing contemporary newswork.

Second, ANT advocates focusing empirical studies on [scientific] controversies (e.g. Latour, 2005: p. 21; Callon, 1981). Domingo et al. suggest that journalism studies scholars should likewise attempt to use controversies, “when actors are struggling over the definition of a social issue” to “trace a specific news network” (p. 63). Although Latour appears to define controversies widely as moments of ongoing negotiation, Domingo et al. seem to be more narrowly concerned with social or political controversies. A great deal of existing scholarship in science communication has been focused on these sorts of controversies, such as around climate change, GMOs, fraking, or vaccines (e.g. Boykoff & Boykoff, 2004; Bode & Vraga, 2015). This project recognizes that not all science communication works like climate change. We need to have a better understanding of how “normal science” (Kuhn, 2012) communication actually works.

This project follows information about dark matter *because* it is not the center of a political controversy, yet still presents a case of unsettled science when actants are still attempting to "defin[e] and order[] the social" (Latour, 2005: p. 23). That is to say, dark matter presents an opportunity to study "science [communication] in action" (Latour, 1987). At the same time, unlike other major physics initiatives[5], dark matter has attracted a consistent amount of public and news interest.

That being said, few social scientists have investigated dark matter, and fewer have studied direct detection of dark matter experiments. There have been a handful of general-audience books on dark matter, most of which have been written by scientists. Vera Rubin, one of the most influential dark matter astronomers, collected a series of her popular essays on dark matter in *Bright Galaxies, Dark Matter* (1996). Freeman and McNamara's *In Search of Dark Matter* (2006), and Dan Hooper's *Dark Cosmos* (2009) both provide a broad introduction to the science behind dark matter. Sanders's *The Dark Matter Problem* (2010) provides one of the best historical accounts of dark matter science; however, it focuses far more on astronomy than particle physics. Katherine Freese, a well-known particle theorist, provides one of the few explicit descriptions of direct detection in her hybrid memoir/popular science book *The Cosmic Cocktail: Three Parks Dark Matter* (2014).

---

[5] A great comparison would be double-beta decay experiments. These experiments are very similar to direct detection of dark matter experiments: not only sharing similar detector technology, but often times sharing *physicists* as well. Yet, while dark matter experiments promise to solve what is almost a metaphysical question of the constitution of the universe, the importance of double-beta decay experiments is somewhat harder understand and publicize.

Third, while Domingo et al. look to ANT to study the wider (social) life of journalism, this project suggests the need to take this a step further. If ANT eschews the application of a priori categories, *journalism* must be included in this. Domingo et al. note that ANT offers an imperative to study those not traditionally seen as journalists. This project argues it is necessary to go beyond *journalism* itself to investigate the wider universe of public knowledge and information production. Rather than only study "news networks," this project looks broadly at *public information* about science. The networks shouldn't just a priori "deactivate" the producer-consumer "dichotomy" (p. 57), but also that between journalism and other forms of information production.

The Method in Detail

More specifically, this project adopts an ANT-inspired approach that traces *translations* in the production and circulation of public information about dark matter. Embracing ANT's imperative to make no a priori assumptions about the relevant actors and relationships, this project starts *in media res*—with news articles about direct detection collaborations, and then traces backward, forward, and sidewise, to understand the different people, things, organizations, relationships, cultures, practices, discourses, and symbols involved. Taken as a whole, the project maps the trajectory of pieces of information about dark matter from the work that collaborations perform in producing them, to the circulation of news articles about them. One of the dangers or drawbacks of this ANT-inspired approach is the lack of a strong theoretical guide as to what deserves empirical focus. While this project traces the movement of information flows it takes some detours, left-turns, and dead ends. Yet, more broadly, while the *method* involved mapping out the key translations in the life course of public information about dark matter, the actual chapters treat specific organizations. The method made it possible to identify analytically and empirically interesting sites and stories that the chapters then explore. Two chapters look at collaborations, two examine national laboratory communication offices, and two consider journalistic outlets.

Each of the following empirical chapters includes its own brief methods section that identifies the specific approaches and data employed. Appendix A also offers a more detailed breakdown of employed methods. Speaking broadly, however, the dissertation involves a set of 62 semi-structured interviews with physicists, journalists, and communication professionals (see Figure A.1 in Appendix A for a list of a informants with organizational affiliations). Informants were identified in several ways. First, physicists were identified by collecting membership lists for all current and former collaborations (counting iterations of projects as unique collaborations). Influential members of collaborations were identified through references in press releases and journalistic articles or through other interviews with physicists. Most physicists interviewed have held leadership roles in experiments. For the most part, communication policies and activities are designed and undertaken by those in leadership roles. Journalists and communication officers were identified either through bylines of published content, or through snowball sampling. As the project proceeded, specific informants who could address important questions were pursued. With only two exceptions, all informants agreed to be cited by name. Rather than providing pseudonyms, the names of these two have been omitted.

Data also come from a large corpus of collected texts about direct detection experiments. This corpus includes 470 news and 322 institutional articles. Rather than attempting to sample stories, the project simply collected every news article it could find. Articles were identified in a number of ways—including a modified snowball approach. When an article about a direct detection experiment was found, the organization's archives were searched for any other mention of direct detection experiments. Google and Lexis Nexis searches were also completed, searching both by collaboration names as well as words associated with direct detection experiments. Collaborations themselves also provided lists of some of the news coverage they have received. That being said, this project does not, of course, purport to have captured every English language news article. Most importantly, this project only captured stories that had been archived digitally. Even still, articles from 113 news organizations and 66 scientific institutions were collected. These numbers do not include non-news-outlet blogs. However, posts from several prominent blogs were also collected. All articles were coded for basic data including publication date, source publication, author, and main subject. Also, each article was coded for unique sources. Every source that provided a direct quote was identified.

Texts were also analyzed for recurrent themes, structural components, and approaches. Codes were generated both inductively, arising through immersion "in the texts and let[ing] the themes of analysis slowly emerge" (B. Brennen, 2017: p. 208), as well as deductively from the model offered above. Specifically, the model directed analysis to consider the ways that journalists modified content and meanings in producing articles. Overall, following Kracauer (1952), analysis focused on both "the surface meanings and the underlying intentions of a text" in order to "bring out the entire range of potential meanings in texts" (B. Brennen, 2017: p. 205).

Finally, data also derive from a wide range of institutional documents, including annual reports, grant filings, committee reports, etc. These helped fill in some needed historical detail.

Chapter Breakdowns

Expanding on the theoretical arguments made in the introduction, **Chapter 2** offers a new descriptive and normative model of science communication epistemology based on an extension of Latour's circulating reference (1999). The model resolves the public communication of science as a series of functional representations. As each simplifies the complexity of antecedents, it both reveals otherwise hidden relationships and opens content to new audiences and new reserves of public meaning. The chapter demonstrates the utility of this model through a case study of science journalism surrounding direct detection experiments.

Chapter 3 traces three translations through which dark matter collaborations produce expert findings. Each translation demonstrates a different way in which scientific practice is *always already* infused with media. Simultaneously, these translations demonstrate how *difference*-as-mediation is fundamental to the production of science and its communication within the expert field. On one hand, this chapter further justifies the model offered in Chapter 2 by showing the continuity across forms of scientific communication. On the other, it demonstrates how data is initially produced, ordered, and communicated as information (Porat, 1977).

Chapter 4 investigates how the multi-institution collaborations behind direct detection experiments are beginning to adopt public relations practices in order to communicate their results to non-expert publics. This chapter demonstrates how the translations involved in communication across fields can be a source of difference in information flows. While considering how collaborations have become important mediators of public information, it also ultimately demonstrates how circulating reference can go *wrong*. It identifies three different forces that can disrupt scientific information flows and produce *deformation(s)*.

Chapter 5 investigates how field development and change can motivate change in public science information flows. In providing a case study of the InterAction Collaboration, this chapter traces the establishment and stabilization of a new field of particle physics communication. In doing so, this chapter provides a contextualized account of how national laboratories have become important mediators that extend the flows of public science information.

Chapter 6 continues the investigation of the transformation of national laboratory communication offices into important mediators of public science information by exploring how national laboratories have recently been adopting the formats, practices, and structures of *journalism.* In doing so, it demonstrates how change within organizations can also serve as a source of transformation of information flows.

Chapter 7 provides one of the first empirical investigations of science news aggregators. Building on the model offered in Chapter 2, this chapter explores the epistemological similarities in science news reporting and aggregation. In offering a new distinction between news aggregators, which collect articles, and news *aggreducers*, which combine pieces and fragments of existing content to produce new seeming articles, this chapter investigates another mechanism through which deformation about science is produced and circulated.

Chapter 8 concludes the dissertation by considering the larger implication of theorizing difference as internal to information (flows), and recognizing the ways that structural changes in the science media system are facilitating *deformation*.

CHAPTER 2
MAGNETOLOGISTS ON THE BEAT:
THE EPISTEMOLOGY OF PUBLIC SCIENCE COMMUNICATION RECONSIDERED

Introduction

When a spokesperson for the White House trumpets “alternative facts” and political leaders voice expedient, yet entirely unsupported claims, it is not surprising that scholars, politicians, and even late-night talk show hosts have begun to wonder if we are living in a “post-truth era” (Tanz, 2017). Amid debates concerning climate change, biotechnology, and vaccines, scientific facts and findings are increasingly at the center of public discussion and negotiation. Yet, as our hold on truth becomes more tenuous, it is not just science that is at stake, but also the epistemological foundations of contemporary public life.

Recognizing that science journalism is one of the main sources of public information about science, communication scholars have given consistent attention to news reporting on scientific research (e.g. Dunwoody, 2008; Nelkin, 1995). Many studies have looked at how the public press treats scientific issues (e.g. Boykoff & Boykoff, 2004), how the practice of science journalism is changing along with new technologies (Allan, 2011; Trench, 2007), or the wider functions that science journalism plays in public life and democracy (e.g. Brossard & Lewenstein, 2010; Secko, et al, 2013). Few, however, have asked about the underlying *epistemology* of science journalism and broader forms of public science communication: how it is, exactly, that public communicators construct and justify knowledge claims. However, understanding the epistemology of public science communication can help us better understand the changing knowledge infrastructures of the current age.

Existing models treat only part of the story of the epistemology of science communication. Accounts such as the “continuity model” of science communication (Bucchi, 1996, 2008) tend to highlight either the simplification of scientific detail accomplished in translating content for lay publics or the continuity of scientific fact maintained in doing so. These models, however, miss the *productive* work that public science communication accomplishes in generating meaning by reducing technical detail and adding content and context.

Extending and building on Bruno Latour’s (1999) account of science as “chains of reference,” this article offers a new model of the epistemology of public science communication. Grounding this epistemology in a balance of stasis and change, the model attends to the complex interrelations between fact and meaning. For Latour, science works through the production of successive representations. Each pares away the complexity and detail in a way that preserves key relationships while also allowing scientists to recognize and produce new insights and relationships. Truth is not something that inheres in any one representation, but rather something that circulates across the whole chain, like electricity through a circuit. Although Latour is somewhat ambiguous about meaning, this article offers a reading of Latour’s account of articulation, which leaves meaning generating like a magnetic field around that circuit. There can be different sorts of relationships between truth and meaning, yet the field of potential meanings is constantly changing along with each new constituting relation among people, things, and ideas. As a result, science communicators are like *magnetologists*, attempting to build operational circuits of truth that link together diverse people, things, and ideas and to generate meaning-fields.

In order to articulate and investigate this model, this chapter presents a case study involving one major initiative in astro-particle physics: the direct detection of dark matter. Combining semi-structured interviews with both the scientists behind these experiments and the science journalists who have covered them with a thematic textual analysis of a large collection of news articles about these experiments, the case grounds this new model in contemporary journalistic practice.

Ultimately, this project offers not only a descriptive, but also a normative account of public science communication. This model provides a way to recognize that good science communication must balance between maintaining the important connections from antecedent representations, while also adding and arranging content to help produce new perspectives and new meanings for articles. Good public communication, like journalism, science or otherwise, can escape neither its democratic responsibility to shepherd the relationships and connections that allow truth to circulate across time and space, nor its role in opening up content for public discussion, consideration, and meaning making—in making things public.

Literature Review

Models of science journalism

There are many different forms of public-directed science communication, from museums, to education, to popular culture (Perrault, 2013). The case study below narrowly considers science journalism, which it defines pragmatically as articles in periodicals that describe timely scientific research and are meant for non-expert audiences. Scholars have begun to recognize that science journalism achieves a range of social and democratic functions beyond simply communicating news about timely research (Fahy & Nisbet, 2011; Secko, Amend, & Friday: 2013). Yet, arguing that journalism's role as a unique form of public knowledge is central to many of these broader social functions, this paper focuses on the *epistemology* of science journalism, the assumptions and practices through which public information about timely research is produced.

One journalism textbook describes science writers as, "first of all, bridging the jargon gulf, acting as translators between the sciencespeak of the researcher and the short attention spans of the public at large" (Blum, Knudson, & Hening, 2005, p. vii). This textbook is not unique in describing science journalism as a simplification or a reduction in complexity—this is a thread that runs through many accounts of science journalism.

A number of scholars have offered models that speak to the roles or functions that science journalism plays in society. Drawing on Brossard and Lewenstein's (2009) models of the public understanding of science, Secko, Amend, and Friday (2013) recognize four models of science journalism in the literature. Two models address "information delivery" and two "public engagement" (p. 67). Similarly, Fahy and Nisbet (2011) offer a nine-part typology of the "roles" of science journalist, from "conduit" to "watchdog" to "advocate" (p. 780). In addressing the functions that it plays in society, both accounts, however, bypass the underlying epistemological processes through which science journalism operates.

The "continuity model" of science communication includes an implicit epistemological treatment of science journalism (Bucchi, 2008; Cloître and Shinn 1985). This framework "presents science communication as a continuity of texts with differences in degree, not in kind, across levels, [and] invites us to imagine a sort of trajectory for scientific ideas that leads from the intraspecialist expository context to the popular one, passing though the intermediate levels" (Bucchi, 2008: p. 61). This model, however, ultimately, follows Fleck (1935/1981]) in seeing that as scientific knowledge is translated for wider audiences, it loses its history, complexity, and contingency, and instead "becomes incarnated as an immediately perceptible object of reality" (p. 125). This means "the communicative path from specialist to popular science can thus be illustrated as like a funnel that removes subtleties and shades of meaning from the knowledge that passes through it, reducing it to simple facts attributed with certainty and incontrovertibility" (Bucchi, 2008: p. 62).

This model highlights the reduction or simplification of content—both in terms of scientific complexity and "shades of meaning." That journalism reduces the level of scientific detail is undeniable. Yet, as discussed in more detail below, science journalists *add* something too: they can make new connections, bring in new ideas, and add new perspectives. That is, science journalists *generate* "shades of meaning." It isn't enough to recognize the reduction inherent in science journalism—we must attend to its *complexification* as well. Also, Bucchi and Fleck's assertion that science journalism brings with it a "certainty and incontrovertibility" is incongruous with wide-scale attacks on (journalistic coverage of) science.

Journalistic Epistemology

For more than 75 years, scholars have recognized news as a distinct "form of knowledge" (Park, 1940). Influenced by early work in the sociology of knowledge, Park's approach continues to be influential in the recognition that journalistic practice is constrained and enabled by disparate social and structural forces, from economic pressures to technological changes (e.g. Bourdieu, 1999). These dynamics have become increasingly visible amid radical structural changes in traditional (see Boczkowski & Anderson, 2017) and science and health journalism (e.g. Allan, 2011; Trench, 2007). Similarly, over the past several decades, epistemologists have been increasingly considering the "epistemic properties of individuals that arise from their relations to others, as well as epistemic properties of groups or social systems" (Goldman, 2010, p. 1), as part of a "social epistemology."

Ettema and Glasser (1984) adopt aspects of Park's sociological approach to analyze the epistemology of investigative journalism through a phenomenological "sociology of epistemology" (p. 5). Rather than attempt to "determine whether journalists' knowledge claims are valid assertions," they ask, "(i) what counts as empirical evidence and (ii) how that evidence becomes justified empirical belief" (p. 6).

By inquiring into the *justification* of knowledge, Ettema and Glasser actually align themselves with what was for a long time the dominant approach in analytic epistemology. Going back to Plato's *Theaetetus*, scholars adopted a three-part definition of knowledge as "justified, true belief." As a result, analytic philosophers originally defined epistemology as the study of *justification* (Pollack and Cruz, 1999: p. 11). This three-part understanding of knowledge as justification was famously undermined by the publication of Edmund Gettier's three-page "Is Justified True Belief Knowledge?" in 1963. Gettier offered two counter-examples that show how someone can have justified belief of a true proposition, but it *still* should not count as knowledge.[6] Gettier's article touched off a search for an additional, fourth condition of knowledge (e.g. Creath, 1992), but also shifted the focus in analytic philosophy away from looking for better understandings of epistemic justification (Pollock & Cruz, 1999: p. 14), to producing a more rigorous treatment of a range of

---

[6] For example: a graduate student looks out his window to see if his cat is in the backyard. He sees a round grey shape in the distance in a spot known to be the cat's favorite place to sun herself. Given this visual evidence, he concludes that the cat is in the backyard. Yet, what he saw was *not* actually his cat, but a dirty tarp that had been blown onto the fence. However, the cat, was, in fact, sitting behind a tree in a different corner of the backyard. Thus, the graduate student had justified belief the cat was in his yard—owing to his usually trust worthy visual perception, and his statement *was true*. However, given that he mistook a tarp for his cat, this hardly can be seen as knowledge.

diverse epistemological problems spanning from the ontology to the "value" of knowledge (Williams, 2001: p. 2).

Put in terms of science journalists, rather than asking like Ettema and Glasser (1984), "what journalists regard as acceptable knowledge claims," it is to ask how journalists produce "valid assertions" in the first place (p. 5). Importantly, this concern has a necessary ethical or normative dimension (see Bok, 2011; Maras, 2013). Epistemological problems "are not just about how what we *do* believe but what (in some sense) we *must, ought,* or are *entitled* to believe; not just with how we in fact conduct our inquiries but how we *should* or *may* conduct them" (Williams, 2001, p. 11). Epistemology therefore requires that we ask not only how science journalists produce public knowledge about science, but also what practices and approaches best achieve the outcomes we desire.

Recently, a number of journalism scholars have also moved away from questions of justification to give more consideration to if and how journalists produce *valid* knowledge claims (Goldstein, 2007; Maras, 2013). In his recent book *Journalism and the Philosophy of Truth*, Jesse Owen Hearns-Branaman (2016) identifies four models of truth that are found in or relevant to journalism. Yet, none of these models do justice to the complexity and specificity of science journalism.

Hearns-Branaman suggests that the "normative epistemology of Anglo-American journalism lies in the dialectical relationship between two different epistemic practices, Realism and Pragmatism" (p. 66). Realism, associated with Positivism, is grounded in the idea that truth inheres in a proposition's correspondence to reality. Realism, however, provides neither a descriptive nor a normative account of truth in science journalism. Science journalists are not attempting to align their reporting to the complexity of the natural world but rather to what (expert) sources tell them. Yet even then, journalists do not necessarily attempt to treat complex science with the same level of detail as scientists. This is to say, whether we use the real or the science as the metric against which to judge science journalism, it is *always* going to come up short.

Rather than focusing on the correspondence to reality, pragmatist conceptions of truth turn on the *difference* a proposition makes (James, 1907). For Hearns-Branaman, American journalism embodies pragmatist ideas in the continued invocation for "balance" in reporting, in which the news acts as a "marketplace of ideas" (Douglas, 1953). Here, the goal is not to discover a transcendental truth, but rather to understand "what best serves our pragmatic needs now" (Hearns-Branaman, 2016: p. 54). While science journalism does seem to reject transcendental truth in favor of the best *current* description—always subject to revision with new data—science journalism rarely acts like a "marketplace of ideas." Instead, science reporters attempt to offer clear, accurate descriptions and explanations of scientific research.

Hearns-Branaman identifies two additional frameworks more associated with academic scholarship of journalism, what he calls the "anti-realist" and the "hyper-realist" models. Hearns-Branaman associates these epistemologies with a wide range of (post)structuralist and social constructivist thinkers. However, these approaches offer little purchase on a science journalism that fundamentally holds to *some* sort of notion of knowable external truth.

A New Model

Latour and Scientific Representations

Following the "continuity model" (e.g. Bucchi, 1996, 2008) discussed above, this chapter assumes that models of public science communication epistemology must in some sense contend with *scientific truth*. However, rather than draw on accounts in the analytic philosophy of science, this paper looks to recent work in science and technology studies for a productive account of truth in science. Unlike the philosophy of science, which has worked for centuries to ground and understand the epistemology of science, science studies scholars have been far more willing to engage with the empirical reality of scientific practice (Fuller & Collier, 2004).

Public science communication traffics in *representations* of scientific information or content. Bruno Latour, one of the founders of science studies, offers a treatment of scientific practice and truth that recognizes the epistemological function of representations in "Circulating Reference" a chapter in his book *Pandora's Hope* (1999). For Latour, science is a set of practices through which successive representations of the natural world are produced. However, these representations must be recognized as complex "actor-networks" that are simultaneously social, material, and discursive. It is the job of the scientist to ensure that the important relationships are preserved across successive representations. Each representation is necessarily a simplification of the complexity of the one before. Yet, *because* representations pare away certain information, they not only make it possible to observe relationships that might otherwise have been hidden, they also permit the extension of *new* connections and relationships.

For example, dark matter physicists build instruments that can detect particles far too small to see. These instruments supply huge volumes of data about the particles they encounter. These data do not do justice to the utter complexity of the world, but they produce reliable information about some of the relationships of interest to physicists. To make sense of this data, physicists might produce a graph that shows different characteristics of detected particles. This graph captures neither the complexity of the data, nor that of the world. However, if well made, the graph permits physicists to recognize something about particles that couldn't otherwise be seen—perhaps that some of these particles are dark matter.

Since each representation is undeniably a simplification, truth cannot be seen as cohering in the correspondence of a given representation to the real world. Instead, "Truth-value *circulates* here like electricity through a wire, so long as this circuit is not interrupted" (Latour, 1999: p. 69). The "circuit" is the whole chain of representations, stretching back to the real. What matters are the connections between representations—connections that, like the wires in a circuit, allow truth-value to move between representations. If necessary, scientists can follow the circuit back to the real. Ultimately, this means that truth is an ongoing and active process—one that depends on an entire assemblage of different people, things, situations, and ideas.

Science Communicators as Magnetologists

This chapter posits that good public science communication can be seen as a continuation of this scientific chain of reference. While a piece of public science will always be a simplification of the complexity of those representations before it, simplification not only serves a functional role in helping make clear certain relationships and ideas, but can also preserve the key relationships between people, findings, and propositions to permit truth-value to circulate.

When described in these terms, it becomes necessary to recognize the role that meaning plays both in "circulating reference" and in science communication. Each representation in the chain is intentionally produced to reduce complexity and reveal certain relationships—ultimately, to help elicit certain meanings.

Latour is far less clear about meaning than he is about truth in actor-networks. Perhaps the clearest discussion of meaning for Latour is through his concept of *articulation*. As for others, articulation for Latour extends beyond the linguistic sense of an enunciation. For Latour, articulation is broadly construed as the way in which propositions relate to each other. Drawing on Whitehead, Latour (1999) defines propositions "in the ontological sense of what an actor offers to other actors" (p. 309)—propositions can be discursive, material, human, or some combination of the three. Articulation is what replaces correspondence when we give up necessary ontological differences between language and the world, body and mind, or things and people. In a sense, meaning is the product, result, or content of articulation.[7]

---

[7] While Latour rejects scientific translations as metonymy (Latour, 1999: p. 63), his account shares similarities with Jakobson's account of meaning as occurring through the intersection of metaphor and metonymy if one accepts more expansive accounts of metonymy (e.g. Bredin, 1984).

Three things stand out in Latour's articulation-based sense of meaning. First, articulation is *heterogeneous*. This is an idea that goes back to one of the founders of American Pragmatism, C. S. Peirce (1878), who associates meaning with *semiosis*, a signifying practice broader than linguistic semiotics. Second, articulation is *active*. It is no mistake that the term also refers to enunciation. Again, this is also the case for Peirce, for whom Floyd Merrell (1997) observes, "meaning is not in the signs, the things, or the head; it is in the processual rush of *semiosis*" a "translation" or "becoming" of signs (p. xi, xiv). Finally, articulation is *multiple* yet *contingent*. This is an idea that brings Latour in-line with Stuart Hall's notion of articulation. In an interview, Hall observes about religion, "[I]ts meaning—political and ideological—comes precisely from its position within a formation. It comes with what else it is articulated to. Since those articulations are not inevitable, not necessary, they can potentially be transformed, so that religion can be articulated in more than one way" (Grossberg, 1986: p. 54). Ultimately, if truth is something that runs like electricity through an assemblage of people, ideas, and things (Latour, 1999: p. 69), meaning can be seen like the magnetic field generated *around* that electrical circuit. This is not to say that meaning is super-structural or less real—indeed it is as real as a magnetic field. Yet meanings, as products of articulations of propositions, can mutate and change with each new relation. Meanings, therefore, are complex and shifting: overlapping, conflicting, and metamorphosing.[8]

---

[8] Importantly, this metaphor overstates a causal determinism. As has been well documented and theorized, readers of journalistic texts will ultimately decode articles in complex and often unexpected ways.

In science, chains of references must articulate consistent meanings—leaving science as a project where truth and meaning often align. Latour (1999) observes of chains of references, “[W]hat a beautiful move, apparently sacrificing resemblance at each stage only to settle again on the same meaning, which remains intact through sets of rapid transformations” (p. 58). Yet, to extend this continuity between meaning and truth beyond science would be a mistake. Meaning, especially for nonscientist publics, is far more complex, fickle, and mutable. It is the job of science journalists, in producing public knowledge about science, to extend articulation beyond scientific truth and bring in disparate connections and possibilities. Understanding truth and meaning in this way casts journalists as *magnetologists*, who, balancing stasis and change, attempt to produce a representation of science that can fit into a larger system through which truth can circulate and around which new meanings can be generated.

More concretely, this model of public science communicators as magnetologists offers an account that, like Bucchi’s (1996, 2008) continuity model, recognizes relations between different forms of science communication. Yet, this model brings to the fore two balancing tendencies that structure the production of science journalism: stasis and change. On one hand, translations between formats, whether in the production of scientific results, articles, or pieces of science journalism, must maintain some connection to the real. As discussed in detail below, pieces of public science can accomplish this in a number of ways, yet this means ultimately preserving both traceable connections to antecedent representations and key relationships as other material is pared away. This maintenance or stasis is what allows a text to preserve its hold on the truth, to allow its "truth-value" to circulate back across the whole chain. At the same time, however, these connections mean that structural dynamics and pressures of science, PR, policy, and journalism constrain and enable the production of public science communication (Bauer & Bucchi, 2007; Gandy, 1980). On the other hand, translations are transformations: processes of change. In producing articles, public communicators, like scientists, must strip away detail to *reveal* otherwise unseen connections and relationships. The reduction in technical complexity, like that which occurs in science itself, helps a public directed text reveal otherwise occluded relationships. Finally, in producing an article, public communicators *add something* as well. A text can bring new ideas, details, and voices, introducing and revealing new relationships, understandings, and perspectives. All together, this balance of stasis and change, effected in the preservation, removal, and addition of content, not only preserves truth but also helps to produce new meaning possibilities for public science.

Importantly, public science texts are rarely produced in isolation; not only do articles influence each other, journalists routinely swap stories, sources, and content (Boczkowski, 2010). Similarly, readers are increasingly encountering multiple articles about a single topic or finding (Su, Akin, Brossard, Scheufele, & Xenos, 2015). As a result, it is important to recognize that the meaning-field surrounding different articles can overlap and the complex interplay of constructive and destructive interference reshapes the meaning field further.

Ultimately, the model adds four things to our understanding of public science communication. First, as Latour (1999) acknowledges for scientific research, this model describes science communication as being composed of a series of translations between a succession of different forms and formats. Second, the model acknowledges that good public communication rests on maintaining those connections such that truth-values can circulate up and down the chain. Third, the model holds that each addition, subtraction, or translation modifies the meaning field generated across the circuit.

Finally, the model asserts a normative position. Existing models focus on the way public communicators reduce the complexity of science; at their best, they are seen to hold fact and truth *constant*. In contrast, this model understands communicators as also playing an important generative role in public knowledge and therefore democracy—not only bringing science to the public, but *making* it public (Latour & Weibel, 2005) by facilitating the articulation of diverse public meanings to science. Recognizing this endows science communicators with a democratic and normative responsibility to (re)produce accurate facts while simultaneously opening science to diverse publics and meanings.

Case Study

Methods and Background

In order to better explicate and defend this model of public science communication epistemology, this project offers a detailed look into journalistic coverage of dark matter direct detection experiments. Since the early 1930s, astronomers have calculated that as much as 27 percent of the mass in the universe cannot be directly seen (NASA, 2017; Zwicky, 1933). One of the most prominent hypotheses holds that this dark matter is composed of hard-to-detect particles, descriptively called Weakly Interacting Massive Particles (WIMPS). Since the 1980s (see Ahern, et al., 1987) dozens of collaborations of physicists have built instruments to attempt to detect these particles. However, despite decades and millions of dollars, physicists have not yet seen convincing evidence of WIMPS in their detectors.

Direct detection of dark matter experiments provide a strong case to study contemporary science journalism. Although these experiments are not the center of broad public debate, they have received consistent media attention over the past thirty years. Somewhat counter-intuitively, much of the recent scholarship on science journalism has addressed either coverage of research initiatives at the center of public debate, such as climate change (e.g. Boykoff & Boykoff, 2004), or coverage of major and successful scientific topics, like the human genome project (e.g. Hilgartner, 2012). Far less research has studied coverage of more "normal" (Kuhn, 2011) science. Direct detection of dark matter experiments can, however, provide a look into the ways that science that is *not* heavily politicized—the vast majority of scientific research—is covered by journalists.

This case study is based on data collected for a larger project that explores changes in science production and communication in the contemporary media environment through a detailed analysis of direct detection of dark matter experiments. This paper draws on sixty semi-structured interviews with journalists, physicists, and public information officers who have been involved with or covered dark matter research. After collecting a large corpus of journalistic articles about direct detection experiments (see below), articles were coded for basic information including publication, author, date, and main subject. Sources of direct quotations were also identified and coded in each article. After the data was consolidated, journalists and communication specialists who had written several articles were identified and then contacted. Interviews addressed both the day-to-day work of science journalism as well as the specific work of covering direct detection experiments. Informants were given a choice to be named or be provided with pseudonyms. Every informant cited below gave explicit permission to be identified by name.

This project also employs a thematic textual analysis of 470 English-language news articles about direct detection experiments from August 1991 to July 2016. Rather than constructing a sample, this project attempted to collect, catalogue, and analyze every available article produced about these experiments through 2016. Stories were collected through searches of a variety of archives, including Lexus Nexus, Web, News Wire, and individual news organizations. Searches used the names of each collaboration along with more generic terms like “direct detection,” “dark matter,” or “weakly interacting massive particles.” Texts were also collected through a modified snowball approach. Every time an article from a new news site was identified, that site’s archives were searched for additional articles about other direct detection searches. Collaborations themselves also archived news articles on their websites. Articles derive from a range of publications, 113 in total, including the *New York Times*, *Popular Science*, *Gizmodo*, and *Futurism.com*.

Texts were analyzed for recurrent themes, structural components, and approaches. Codes were generated both inductively, arising through immersion "in the texts and let[ing] the themes of analysis slowly emerge" (B. Brennen, 2017: p. 208), as well as deductively from the model offered above. Specifically, the model directed analysis to consider the ways that journalists modified content and meanings in producing articles. Overall, following Kracauer (1952), analysis focused on both "the surface meanings and the underlying intentions of a text" in order to "bring out the entire range of potential meanings in texts" (B. Brennen, 2017: p. 205).

The Epistemology of Dark Matter Journalism

The model of science journalism epistemology introduced above asserts a balance of stasis and change: the way journalists, constrained by specific structures and pressures, maintain elements of antecedent representations to allow "truth-values" to circulate while also removing and adding content to reveal hard-to-see relations and produce new potential meanings. But what does this balance actually look like? How do journalists actually maintain a hold on truth, even as they introduce new elements?

To understand better the way science journalists manage this dynamic of stasis and change in producing public knowledge about science, this section asks three questions of the data collected through interviews and textual analysis:

1. What do science journalists preserve?
2. What do science journalists remove?
3. What do science journalists add?

It is important to note that many actual journalistic practices could be placed in several of these categories. For example, in selecting article subjects, journalists both preserve topics selected by scientific experts[9] as notable stories and also reject many others (e.g. Shoemaker, Vos, & Reese, 2009). That being said, these three questions help identify key elements of the epistemology of science journalism that might otherwise remain hidden.

What do science journalists preserve? Even as they translate complex scientific content into something more widely understandable, journalistic articles should preserve key informational, personal, and material relationships. The model highlights two key elements to this preservation: providing references to antecedent content and maintaining key scientific relationships.

Writing about scientific practice, Latour recognizes that it is essential that scientists can trace representations along chains of references so they can know how exactly each translation has been produced. Arguably, the same is true for science journalism, where references to antecedent content should be, and often are, preserved across translations. This can be as simple as providing a reference or link to an existing scientific article, press release, or other piece of news content. When there isn't simply a text that can be referred to, journalists find other ways of referencing source content. For example, in one piece, Dennis Overbye writes,

> The team, known as the Cryogenic Dark Matter Search, announced its results in a pair of simultaneous talks by Jodi Cooley from Southern Methodist University the SLAC National Accelerator Laboratory in California and by Lauren Hsu of the Fermi National Accelerator

---

[9] Journal editors (Nelkin, 1995) and public relations professionals (Gandy, 1980) also play a notable role in story selection.

> Laboratory in Illinois at Fermilab, and they say they
> plan to post a paper on the Internet (2009).

Overbye carefully—if somewhat awkwardly—includes each institutional affiliation, while also specifying where the results were already released, and where they will be released in the future.

Second, simply put, journalists have to get the science right. Good journalism does this by preserving the general relationships, even while dropping much of the fine-grained detail. This is most clear in what science journalism textbooks call an "explainer" graph (Blum et al., 2006), a paragraph (or more) that provides the reader with some of the background necessary to make sense of a particular scientific result or event. For example:

> A dark matter particle striking a xenon nucleus causes it
> to recoil, prompting the emission of light and ionization.
> The ratio of the amount of light emitted to the amount
> of ionization indicates whether a particle of dark matter
> has been found" (Wired, 2011).

While many of the specific technical details that a scientist would consider necessary to making these statements "true" are missing, nearly every phrase here elides a great deal of complex science. Just as an interested reader could trace back to an antecedent piece of science through references, here, she could trace from these statements to more technical descriptions. In this sense, while a scientist might rely on tacit knowledge (Polanyi, 1998) to fill in the gaps, here gaps are left as potential connections—virtually validated truth claims.

Including direct quotations from knowledgeable sources is another important strategy that journalists employ to maintain continuity in reporting both science news and feature articles. As with other forms of journalism, quotations often serve as a key currency of articles. Usually journalists will reach out to lead authors of scientific articles or collaboration leaders, usually called “spokespersons.” Within the articles collected for this project, 8 of the 10 most commonly quoted scientists in journalist articles were spokespersons for experiments.

Adopting public relations strategies that are increasingly common in other scientific fields (Bauer & Bucchi, 2007; Gandy, 1980), dark matter collaborations have been working with press offices to produce press or media releases. These releases almost always include quotations from collaboration spokespersons or PIs. There are varying norms about using quotations included in press releases or institutional stories. While working at *Space.com* and writing short news articles, Clara Moskowitz (personal communication, August 15, 2016) remembered, “I wouldn’t talk to anybody, it would be kind of a straight-forward story, so I’d read the press release, and I’d read the paper, and then I’d just use the quotes from the press release from the story and say: ‘so and so said in a statement,’ so then, some times you did no reporting.” In contrast, Davide Castelvecchi (personal communication, August 24, 2016) strongly rejected the implication that he would ever use institutionally supplied quotes.

In maintaining these elements from scientific articles or results, journalists help to preserve the *meanings* around articles. In many ways, there remains a tight coupling between meaning and truth in scientific research—the meaning or relevance of a finding has a close connection to its scientific import, functionality, or success against “trials of strength” (Latour, 1999). Direct detection experiments provide a telling example of this. Although they have failed to find dark matter, many physicists would argue that experiments have held great value and meaning in helping to incrementally narrow the range of possible dark matter candidates (R. Gaitskell, personal communication, September 22, 2016).

In maintaining connections to and elements of antecedent representations or texts, journalists help to preserve these scientific meanings. For example, one news article from *New Scientist* begins, "One of the world's leading dark matter detectors has wrapped up a nearly two-year-long search for the mysterious particles, without finding a single whiff. The results suggest that the days may be numbered for the dominant model of dark matter" (Aron, 2016). The rise and fall of technical models of dark matter are usually more important to scientists than to laypersons. Yet, this piece asserts that this finding is meaningful to its audience, the lay public, *because* of its scientific import.

What Do Science Journalists Remove? As noted above, Latour recognizes that in scientific practice, the paring away of detail that happens across successive representations allows scientists to reveal hard-to-see relations. The same is true of science journalism where, by removing much of the technical detail, journalists can help readers better understand complex material and ideas.

In interviews, journalists frequently referenced the work they put into making their articles "clear." Adrian Cho (personal communication, March 3, 2016) observed, "I try my level best to really understand what's going on and explain it as clearly as I can." Speaking about her readers, Clara Moskowitz (personal communication, August 15, 2016) noted, "I think they appreciate a clear story that defines its terms and explains everything well." As C.S. Peirce (1878) recognized long ago, clarity and meaning are inextricably linked. He famously observed that understanding “how to make our ideas clear” is “to know what we think, to be masters of our own meaning.”

For science journalists, the quantity of technical detail is less important than clear and understandable explanations. Aside from writing simply, journalists suggested two additional approaches they employ to produce clear explanations. First, Clara Moskowitz observed:

> some things can only be understood by math, and so I run up against this problem, where you kinda just have to wave your hands and hint at things that are really only clear when you look at the equations (Clara Moskowitz, personal communication, August 15, 2016).

Moskowitz’s strategy of “waving your hands” to elide or bypass complexity, can be seen across the corpus of texts. For example, one article from the BBC’s online platform stated,

> In short, if you do the maths on the universe, something strange happens. No matter how many times you check the figures, the answer always comes out the same…the Universe should weigh a lot more than it does. The best explanation scientists can come up with is that there is a lot of ‘stuff’ in the universe that we can’t see or hear or touch, but which makes up for that extra weight. They call this stuff ‘dark matter’ (BBC, 2010).

“Waving your hands” isn’t about ignoring the detail; it’s more about being comfortable making large leaps over the complex math or detail through which scientists originally discovered or demonstrated connections.

Mathew Francis suggested an alternative approach while describing writing an article about an “esoteric” paper on neutrino masses:

> [S]o I’m not going to get into the mathematical structures and grand unified theories and why this all matters. I’m just going to talk about what are the implication of this, why would people consider this, what’s cool about it (M. Francis, personal communication, March 4, 2016).

While Francis might similarly try to condense down the key relationships, he suggests it can be useful to focus on what is “cool” or most interesting about a story. Other journalists also adopt this approach. In one article from the *L.A. Times*, Amina Khan describes dark matter this way: “Dark matter outnumbers normal matter in the universe 5 to 1, yet remains one of physics' ultimate mysteries. It can't be seen or felt, and passes through Earth like a phantom” (Khan, 2013). Rather than getting bogged down in complex description of the science behind this fact, Khan picks out what is most compelling or interesting about dark matter.

What Do Science Journalists Add? In addition to removing or simplifying content, science journalists also add detail and context to scientific stories in order to expand the scope and meaning of scientific research. To return to Latour’s (1999) material semiotics (see also Lenoir, 1994), journalists align textual signs, but also quotations, objects, actors, and ideas to produce fertile and complex ground for meanings.

As discussed above, quotes from expert sources are key components of science journalism articles. While some journalists regularly incorporate quotes from statements or press materials, others refuse. Tushna Comissariat explained her hesitation,

> It just sounds so boring as compared to what researchers actually say to us, which is a lot more exciting. We

> recently had an actual quote in a news story where [a scientists] said they were so excited they punched the wall, I don't think you'll find that in the press release (T. Comissariat, personal communication, August 31, 2016).

For Comissariat the concern is less an ethical prohibition against canned statements, and more the worry that they do not *add* anything to a story. For her, quotes not only serve as a key form of evidence to maintain scientific integrity, they also add detail, color, and perspective to articles. These details help readers grasp fundamental ideas or relationships while also expanding the scope and meaning of scientific research.

There are many ways that journalists add this sort of detail or perspective. Matthew Francis explained that he often tries to interview less senior collaborations members such as PhD students and postdoctoral researchers, who are rarely given voice in academic papers or institutional press releases, but who

> are the ones who actually know how it [the experiment] works….The people who are the spokespeople, part of their job is PR, they're going to tell me things about how they're thinking, they've always got one eye pointed at the funded agency (M Francis, personal communication, March 4, 2016).

Another way journalists seek out new connections and relations for their stories is by securing quotes from scientists not associated with collaborations. For example, across the journalistic coverage of the LUX experiment's October 30, 2013 release, journalists cited six different members of the LUX collaboration, and thirteen physicists—more than twice as many—who were *not* members of LUX.[10] Set within a journalistic article, these voices can help situate findings in larger fields or

---

[10] 44 stories concerning this release were identified. Of the six collaboration scientists quoted, five were also quoted in press materials (9 different releases). The sixth was a graduate student.

disciplinary contexts. Judging by interviews and collected articles, theorists are one of the more common types of outside sources.[11] Peter Graham, a theorist at Stanford University, described serving as a source for journalists in a similar way to how he works with experimentalists, "kind of putting it all together and trying to see kind of where each piece fits it, I would say that's what theorists should be doing, what the use of a theorist is, also what I think is useful to a journalist in an article" (P. Graham, personal communication, August 23, 2016).

There are a number of other strategies, beyond including outside voices, that journalists employ to add context to a current piece of research. Some articles situate direct detection experiments within the larger universe of scientific studies of dark matter (see Morelle, 2013). Other articles provide historical detail of our understanding of dark matter (e.g. *The Seeker*, 2011), or of the locations central to dark matter research. For example, a 2015 piece by the freelance writer and novelist Kent Meyers in *Harper's Magazine* details the long history of the Homestake gold mine in South Dakota, the site of the Sanford Underground Research Faculty.

In other instances, journalists highlight the philosophical, or even metaphysical aspects of dark matter research. One article in *The Guardian* quotes a Cambridge astronomer: "Dark matter is what created the structure of the universe and is essentially what holds it together…Without it, we wouldn't be here" (Sample, 2009). Finally, rather than going broad, some go deep—providing a behind-the-scenes look at the actual practice of science (Overbye, 2011; Wired, 2011).

---

[11] Direct detection collaborations do not usually include theorists.

Conclusion

Amid declining public trust in media and an outright attack on the credibility of mainstream news organizations, it is all the more important that we understand what is it that journalism does—how exactly it produces its unique form of knowledge. The model of journalists and public science communicators as magnetologists developed here describes a set of practices composed of distinct tendencies: stasis and change, fact and meaning. Good pieces of public science must maintain connections to antecedent references to allow truth-values and facts to circulate through them, even while they expand the scope of possible meanings. In this account, these two tendencies work in concert: meanings are generated, in part, out of the same connections that allow truth to circulate, yet journalists also maintain and build truth-carrying circuits to *produce* meanings.

Understanding the productive work of public science can help us celebrate rather than lament the differences between scientific and journalistic articles. Rather than providing another reason to distrust (science) journalism, we should see these differences as part of journalism's power and promise. Unfortunately, some of the loudest critics of science media are scientists themselves, who often lack a complex understanding of or vocabulary for how science journalism works and what it is trying to accomplish. Part of the issue might rest with increasingly ubiquitous media trainings that teach scientists how to sell or promote their work, but say little about the value of science journalism. At the same time, we need science journalists to be better—and louder—public advocates for the work that they do.

This project has argued that science journalism is, in many ways, distinct from other forms of journalism. Even still, there is reason to suspect this model may provide insight into our understanding of truth and meaning in journalism more broadly. There have been many models and accounts of journalism over the past century—many that highlight how journalism is much more than just a source of information (e.g. Deuze, 2005; Zelizer, 2004). Yet, despite its multivalent complexity, journalism remains a unique form of knowledge. As such, better understanding the epistemology of science journalism raises a number of key questions about how that form of knowledge works. How can we think of truth in journalism such that it is not left necessarily deficient against expert knowledge? What is it, exactly, that journalism as a particular type of knowledge produces*?* How does journalism cover other forms of knowledge?

At the same time, in describing the unique and relational epistemology of public science communication, this chapter suggests the importance of understanding better the ways that changing structural dynamics of the contemporary media system, including technological, economic, and cultural changes, are affecting the epistemological foundations of science news. Equipped with a more rigorous account of science communication epistemology, future work will address these questions.

Democracy hinges on "making things public" (Latour & Weibel, 2005). There is always a cost in doing so: at a minimum, a sacrifice of technical complexity. Yet it is a price we pay because what we lose in technical detail, we gain in symbolic complexity. Bringing a story into the public—whether it is about science, politics, or a new TV show—opens it to a near-infinite reserve of perspectives, ideas, people, things, and, ultimately, meanings. Some might argue such an opening is a good in itself, others might see it more practically as a source of innovation (Benkler, 2006). This is the part that journalism must play in democracy: to hold strongly enough to its antecedents so that truth can circulate widely, but also to open the truth to new connections and relationships. Ultimately, we look to journalism to help build the infrastructures that give meaning to public life.

CHAPTER 3
ALWAYS ALREADY MEDIATED: SCIENCE AND MEDIA

Introduction

The magnetologists model described in the previous chapter treats all forms of science communication through the same conceptual apparatus. However, for the past several decades, both philosophers of science (Cartwright, 1999; Hacking, 1996) and science studies scholars (Knorr-Cetina, 1999; Pickering, 1995) have stressed the need to recognize the *disunity* of science: that no single method, approach, or even epistemology grounds all forms and disciplines of science. While there have been other efforts to connect expert and public forms of science communication (Bucchi, 1996, 2008; Fleck, 1935), in challenging this prevailing theoretical consensus, the magnetologists model requires a more rigorous theoretical grounding.

This chapter grounds the extension of Latour's account of science production to science communication through the recognition that, as Lisa Gitelman might say, scientific practice is *always already* (2008) infused with *media*. In a sense, this recognition fills in a gap left in the pervious chapter: media enact and/or facilitate the translations through which successive functional representations are produced. Taking a cue from medium theory, this chapter adopts a definition of media that extends far beyond popular associations of media with "mass media" (see McQuail, 2010). Rather, media are considered here to be minimally data processors (Kittler 2010; Peters, 2010, p. 12), and maximally, “our infrastructures of being, the habitats and materials through which we act and are” (Peters, 2015: p. 15).

In order to empirically demonstrate the mediation inherent in both the magnetologists model and scientific practice and communication more generally, this chapter considers three different translations involved in the production of scientific findings by research collaborations. These translations have been specifically selected in order to demonstrate three *different* dimensions of media at play in dark matter physics.

The first translation involves *instruments* extending human sense capacity and collapsing time and space to produce representations of nature. Time projection chambers, calorimetric bolometers, and scintillating crystals are all means of (potentially) revealing hidden dark matter particles by hearing, seeing, and feeling—sensing well beyond the limits of the human body.

The second translation involves *techniques* through which physicists process signals from noise to organize data. This section looks at how two specific techniques prefigure the building of instruments, and how they are prefigured by specific assumptions and ideas about the natural world.

The third translation involves media *processes* and *logics* in the ways that physicists circulate their findings beyond collaborations. It considers how a single type of data plot, as a “boundary object” (Star & Greimser, 1989), allows different collaborations both to compare their findings despite different instruments, and to make strategic arguments about the unique value of their own work.

Each translation has also been selected to demonstrate a unique moment in the production of *information*—the beginning of information flows that will be traced across the rest of this dissertation. Each translation corresponds to a different moment of Porat's simple (see Chapter 1) definition of information as "data that have been organized and communicated" (Porat, 1977: p. 2). The first translation demonstrates the production of data; the second, how it is organized. Finally, the last translation considers one way in which that data is communicated beyond the bounds of collaborations.

This chapter ultimately shows how media, as instruments, techniques, and processes, produce the functional, if reductive representations that animate scientific communication: from producing results to pieces of science journalism. In doing so, this chapter not only strengthens the theoretical justification for the model offered in Chapter 2, it also provides a means of porting in theoretical concepts and resources from media and medium theory into science communication. In particular, we gain new ways of discussing how scientific media extend sense capacities, manipulate time and space, process data, and ultimately, serve as our "infrastructures of being" (Peters, 2015: p. 15).

Literature Review and Theoretical Framework

As discussed at length in chapter 2, Latour offers a limited model of scientific production in his famous "Circulating Reference" chapter of *Pandora's Hope* (1999). After following a group of field scientists studying the changing boundary of a Brazilian rain forest, Latour suggests that some science operates through the production of successive representations or references. This dissertation expands this account to public science communication. Yet, on what grounds is this extension made? What is it, precisely, that connects expert and public science communication?

Simply put, the instruments and devices through which scientists produce functional representations can be seen as media technologies—or at least as being "medial" (Vogl, 2007: p. 15). This recognition requires adopting a far wider understanding of media than as "mass media," the sort of expansive conceptualization found across medium theory (see below; also McLuhan, 1964). As Jeremy Packer observes, scientific "instruments look an awful lot like what are often thought to be media technologies" (2013: p. 11). However, media studies and the history of science have not always had an easy relationship. As media theorist and historian Berhnard Siegert has argued, media historians often draw heavily on accounts of the development of scientific instruments, especially as it concerns the origins of (communication) media, such as the telegraph, radio, or Internet. Even still, most "usually shy away from studying the question of how instruments can turn into media" or even the difference between the two (Siegert, 2013: p. 107-8). That being said, Siegert, along with other scholars affiliated with the "cultural techniques" approach (see Winthrop-Young, 2014; Macho, 2013), see a linkage between the two within a larger move to prioritize techniques as "operative chains" (Siegert, 2015a) or the "basic operations and differentiations that give rise to an array of conceptual and ontological entities which are said to constitute culture" (Winthrop-Young, 2013: p. 3). For example, Siegert grounds the development of the clock as a contemporary medium and physics instrument in older time keeping techniques for determining longitude at sea (2015b).

That being said, elsewhere, scholars have observed a more fundamental relationship between science and media. For Latour and Woolgar, famously, scientific practice often involves "inscription devices" that translate inputs into written form (1979). For Shapin and Schaffer, the production of scientific knowledge has always required some form of "public witnessing," first by ensuring that laboratories were public (at least to wealthy, white, and educated males), and later by adopting forms of "virtual witnessing" such as correspondence and journal publications (2011). Others have studied the ways in which scientific practice fundamentally involves the production of representations (Burri and Dumit, 2008), or "*drawing* a natural object *as* an analytical object" (Vertesi, 2014a: p. 18, emphasis in original). Summing up this observation, Packer recently observed:

> Media are fundamental to knowledge production; from how data are collected, how they are made visible, their form, the life of their existence, their degree of malleability, the extent to which they can be translated from machine to machine to machine, and ultimately how they can be processed to make things happen (Packer, 2013: p. 10).

Looking more closely at the ways in which the model offered in the previous chapter involves the production of successive representation helps us also recognize a fundamental entwining of scientific knowledge production and media. Media is a deeply contested term—having as complex a conceptual history as culture (Siegert, 2015a), yet judging by any one of a number of different accounts, scientific instruments within the production of successive representations act like media. In producing each reference they convert inputs to outputs: they order, filter, slow, or re-form (Siegert, 2015a)—they process data (Kittler, 2010). Yet, in order to do so and to produce representations, scientific instruments also allow us to feel, see, or manipulate the world "at a distance" (Packer, 2013: p. 11). Particle detectors like those in direct detection experiments (see below) reveal particles far too small to see—while particle accelerators gives us a means of literally redirecting particle flows and circulations (Virilio, 1986). Broadly, instruments extend "our senses and our nerves" (McLuhan, 1964: p. 2).

Chapter 2 also observed that as successive representations reduce the complexity of inputs, they both reveal hidden relationships and open the natural world to new reserves of meaning. An important corollary of doing so is that in producing successive references, scientists (and journalists) open the natural world to new *audiences*. WIMPs, for example, move about unheeded. It is through an instrument that produces representations of their collisions with target materials that they gain a new audience. This new audience or public might be a group of scientists huddled around a computer display, or perhaps colleagues at a scientific conference. But as each representation simplifies the natural, it also delivers it to a larger and more varied public. In this way, instruments share much with far more traditionally defined media. For example, McQuail adopts a pragmatic understanding of media as components of mass communication: the "technologies for communicating publicly to many at a distance" (2010: p. 29).[12]

---

[12] McQuail doesn't exactly provide a clear definition of media, as much as a more tangential distinction between "a *process* of mass communication and the actual *media* that make it possible" (p. 28)

In order for representations to simplify, expand, and open, they also involve transformations of space and time. For example, as discussed below, many dark matter instruments will collect and consolidate signals over the course of months or years. In this way, instruments collapse time into an instant, or perhaps pull the natural *out of* time by placing it into the timelessness of the database (Manovich, 1999). Having vanquished time, data also becomes *portable*. Data can be analyzed, manipulated, and moved across space. For medium scholars, such as Innis (2008) and Kittler (e.g. 1999, 2010), media are defined by their ability to manipulate time and space; it is through this capacity that they reshape discourse networks, culture, or, more grandly, "civilization" itself (Innis, 2008).

Finally, in the broadest sense, if it is through the production of successive representations that science functions and that the natural is represented and delivered, we must assign instruments ontological potency. Like media, they serve as "infrastructures of being, the habitats and materials through which we act and are" (Peters, 2015: p. 15).

Methods

Continuing the approach articulated in Chapter 1, this chapter traces moments of translation within scientific practice. Data for the empirical investigation of three of these translations derives mostly from a series of semi-structured interviews with 21 dark matter physicists. Informants were selected through their affiliation with different collaborations. Several informants were selected through snowball sampling, after other informants either specifically identified researchers to interview, or, in a few cases, made introductions. Of the 21 interviews, 1 was completed over email. While this was far from ideal, the DAMA collaboration is notoriously reluctant to grant interviews. After some effort, the long-time spokesperson, Rita Bernabei, agreed to answer questions submitted over email. Two interviews were conducted in person. The remaining 18 were conducted either over the phone or Skype. Interviews asked about physicists' personal stories and histories as well as their participation in collaboration research, administration, and communication efforts (See Appendix A for further detail).

Findings: Three Translations

Having offered a brief theoretical justification for the claim that science is always already entangled with media, this section empirically investigates three important translations involved in dark matter research. Each translation directly involves the production of successive functional representations as part of a larger effort to produce findings about dark matter. As noted above, these translations have been selected from fieldwork to highlight three different conceptual dimensions of media. Scholars like Siegert (2015b), Packer (2013), and even Galison (2004) have identified scientific instruments as media. The first translation looks at how certain instruments are involved in producing data in dark matter research. As noted above, scholars within the "cultural technique" tradition have argued that techniques precede both the technologies and concepts through which they are expressed. Following this, the second translation considers two distinct techniques through which experiments process and order data. Finally, as Shapin and Schaffer

(2011) argue, scientific epistemology has always hinged on public witnessing, which can be seen as a media process or logic (Atheide & Snow, 1979). The third translation looks at one process—which ultimately involves *both* technology and technique—through which collaborations bring their findings to new publics. In addition to considering different ways in which media and science are entangled, taken together, these translations correspond to three different types of work involved in the production of *information*, as ordered and communicated data (Porat, 1977).

Translation 1: Producing Data with Instruments

Direct detection experiments are all about instruments. Collaborations spend years designing, funding, building, and testing instruments before any data are collected. Different types of instruments provide different identities for both collaborations and the physicists involved. Understanding how pieces of knowledge about dark matter—or arguably any similar science (Galison, 1997; Knorr-Cetina, 1999; Traweek, 1988)—are produced requires looking closely at how instruments work. The dozens of different direct detection of dark matter collaborations over last past 40 years have employed a number of different types of instruments. Rather than consider each in turn, this section first provides a brief overview of how these instruments work in general, before focusing on three different detectors. McLuhan (1964) famously defined media as extensions of human senses. Following this, this first section highlights three distinct instruments that each appear to extend a *different* human sensory capacity: sight, hearing, and touch.

In their excellent review article of direct detection experiments, Teresa Undagoitia and Ludwig Rauch (2015) repeat a common scheme for classifying WIMP[13] direct detection experiments, summarized in their chart reprinted below (Figure 3.1). Here, they recognize that most (there are a few notable exceptions) direct detection experiments looking for WIMPs do so by attempting to detect one or two of three different types of signals: charge, light, or heat. These properties are what ultimately mediate physicists' ability to observe and study WIMPs. Broadly speaking, these instruments all contain a target material: such as a solid crystal of sodium iodide, or a "big bucket of xenon" (R. Gaitskell, personal communication, 9/22/2016). When a WIMP collides with atoms of that target material, light, heat, or charged atoms are produced. While we might not be able to detect WIMPs directly, we can see or detect the products of these collisions.

---

[13] Weakly Interacting Massive Particles. WIMPs are one dark matter candidate. During the time period considered here, almost all experiments looked for WIMPs.

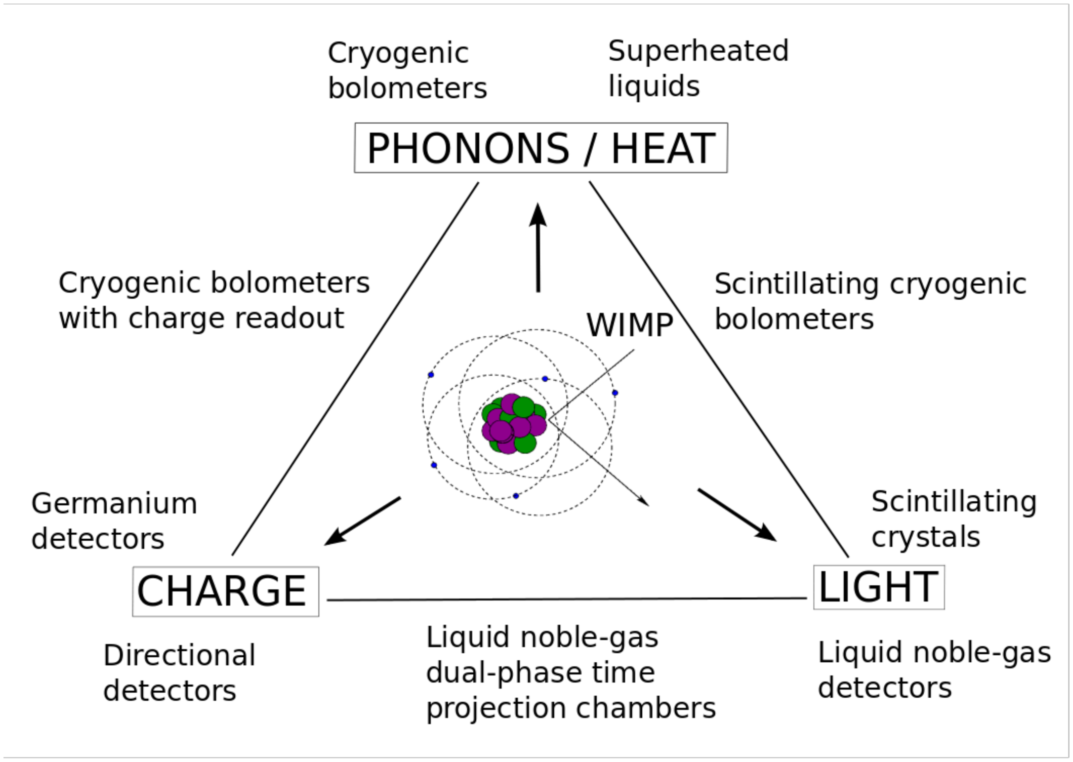


Figure 3.1: Types of direct detection instruments. From Undagoitia and Rauch, 2014

Sight Detectors clustered around the bottom right corner of Figure 3.1, all, in some way or another, extend human sight. These detectors are designed so that the collision of a WIMP and the target produce *photons* of light. While human eyes are unable to do much with these tiny, fleeting photons of light, photomultiplier tubes (PMT) can detect and characterize individual photons produced.[14] The clearest examples are "scintillating crystals," such as the sodium-iodide crystals "doped" with thallium used in the DAMA experiments. These are specially grown

---

[14] While a PMT can now detect individual photons, they cannot detect *all* of them. The efficiency of PMTs depends on the wavelength of light to be detected. Current PMTs detectors observe around 35 percent of photons emitted by targets in direct detection experiments. See below, and Appendix B for a discussion of the connection between the PMT efficiency rates and direct detection detector design.

crystals of what is essentially table salt, with trace amounts of thallium that are surrounded by PMTs.

The most famous experiment to use these crystals, DAMA, acquired them from the French company Saint Gobain in the late 1990s. When they did so, the company gave DAMA exclusive rights to the crystals, which prevented other collaborations from also buying them. By the time the arrangement expired, the people who had made the crystals had left Saint Gobain, leaving the company unable to produce any additional crystals (L. Hsu, personal communication, 4/7/2016). Together, the exclusive agreement and the lost capacity have seriously hamstrung other experiments from trying to replicate DAMA's results—notably the *only* experiment to consistently claim to have seen dark matter (C. Cuesta, personal communication, 4/7/2016; L. Hsu, personal communication, 4/7/2016). Importantly, DAMA has also used the fact that other experiments do not use the same detector components to explain the contradiction of DAMA's findings by myriad other experiments (P. Barbeau, personal communication, 10/21/2015).

"Liquid noble-gas dual phase time projection chambers" at the bottom of the diagram use large quantities of liquid xenon or argon as their targets. These instruments are designed to register two separate signals, light and charge. Being able to do so allows experiments to better distinguish between (potential) WIMP collisions and those involving other particle. Time projection chambers have become one of the most promising detector technologies in dark matter experiments. Rather than having to grow or construct bigger and bigger targets, these experiments can more or less simply acquire more liquid xenon or argon and dramatically increase the sensitivity of their experiments. Importantly, these detectors were not technically feasible until dramatic increases in the efficiency of photo-multiplier tubes (PMTs) in the late 1990s (P. Meyers, personal communication, 8/22/2016).

Sound In the early 2000s, Juan Collar (who would go on to also lead COUPP as well as CoGenT) and Tom Girard led a small collaboration called SIMPLE (Superheated Instrument for Massive Particle Experiments). SIMPLE was based on what could be described as a resurrected and updated bubble chamber. Bubble chambers, which date back to the 1950s (Glaser, 1952), involve a vessel of liquid heated *beyond* its boiling point yet kept in the liquid phase. When incoming particles collide with molecules of the liquid, they transfer a tiny amount of energy, which causes the liquid to instantly vaporize. Different types of particles will produce different signals or tracks in the liquid, which can be clearly seen, identified, and compared.[15] SIMPLE, along with several other experiments, created a detector that suspends individual droplets of superheated liquid in a gel matrix (see the top of Figure 3.1). When particles interact with the droplets, the droplets burst, and produce *sounds* that are picked up by special recording equipment. When different particles burst the droplets, they produce different sounds.[16] Sensitive recording

---

[15] Interestingly, these devices are designed to take photographs of particle tracks—meaning that rather than produce numerical or digital data, they produce a series of photographs that have to be analyzed by hand. This is one of the main reasons that bubble chambers have fallen out of use since the 1980s, with the development of instruments like spark chambers, wire chambers, and time projection chambers (Galison, 1997). In a sense bubble chambers are the epitome of what Galison (1997) refers to as the "image tradition" in particle physics.

[16] Importantly, these sorts of detectors are sensitive to *spin-dependent* WIMP scattering—while TPCs, calorimetric bolometers, and scintillating crystals are sensitive to *spin-independent* WIMP scattering.

equipment captures the different sounds of popping bubbles, which can then be used to distinguish between different types of particles.

Touch The American experiment CDMS was one of the first major direct detection experiments (see Appendix B for the history behind its development). CDMS pioneered the first cryogenic bolometers, followed by "cryogenic bolometers with charge readout" (see top of Figure 3.1). Basically, CDMS and its successors, CDMS-II and SuperCDMS, place small germanium crystals in very powerful refrigerators that bring the crystals within fractions of absolute zero.[17] One early member of CDMS, remembered, "yeah, well the workhorse technology is called the BlueShore refrigerator, those things are a pain the butt. I basically got married to one. They've gotten a lot more reliable, but they used to be a labor of love" (T. Shutt, personal communication, 3/9/2016). When a WIMP collides with the germanium target, a tiny bit of heat is produced. While this amount of heat is far too little to be detected by human skin, the instrument can precisely observe this change.

Interestingly, in the late 1980s, as early members of (what would become) CMDS were first designing these instruments, Bernard Saudulet remembered that

> one of my students wired a detector the wrong way—in part because of laziness, he had fewer solders to make if he did it that way. And we saw in addition to phonon pulses very sharp pulses, and when I saw that, immediately I said that looks like ionization" (B. Sadoulet, personal communication, 4/6/2016)

This mistake meant that detectors could now register *both* heat and charge, making them far more sensitive to WIMP collisions. This is an approach that CDMS has been

---

[17] The lowest possible temperature

using for the past thirty years.

Time, Space, Speed However it is, exactly, that these instruments work—however they attempt to reveal hidden particles and whichever human sense capacity they extend—the ultimate result can be seen as involving modulations of time, space, and speed. DAMA has been collecting data for nearly two decades, watching how the frequency of scintillation changes across each year (see next section). Time projection chambers, like the one used in LUX, collect data for months, if not years. By the end, however, these instruments help produce data that collapses these long time spans into timeless data sets or databases (Manovich, 1999). Having pulled WIMPs (or really, non-WIMP particles) out of time, instruments also make them *portable*, being able to be analyzed, shared, communicated, and moved from one place to the other. Or rather, these instruments produce functional representations of collisions that, while losing much of the complexity of the real world, nonetheless allow physicists to see otherwise hidden connections and relations. It is the particular medial *capacities* of these instruments, their ability to extend senses and to collapse time and space, that allow them to produce functional, if reductive representations.

Translation 2: Techniques Process and Organize Data

For the German media theorist Friedrich Kittler media are ultimately “data processors” (2010). As noted above, this is a view that has been adopted and greatly expanded by recent scholarship on “cultural technique” (Withrop-Young, 2014;

Macho, 2013; Siegert, 2015). These scholars investigate the "chains of operations" (Siegert, 2015: p. 1) that prefigure media concepts and media technologies. Minimally, this work highlights the necessity to not only consider the technologies or instruments, but also the *techniques* through which science works.

This section identifies two different techniques that are integral to the organization or formation of data. Both techniques are ways of circumventing limitations in particle detectors—ways of better processing instrument data to produce useful and important results. That this section follows the consideration of instruments should not be seen as suggesting that techniques are secondary to technologies. Without these techniques for "filter[ing] the symbolic from the real, or messages from channels full of noise" (Siegert, 2014: p. 16), there would be no instruments and no experiments. Experiments are designed, built, and tested in order to apply these techniques. As scholars of cultural techniques argue, techniques are better seen as *prior* to (direct detection) instruments.

Running Against the WIMP Wind In 1986, Katherine Freese, Andrej Drukier, and David Spergel postulated that as the Earth orbits the sun, it passes through regions of greater and lessor density of dark matter. Theoretically, dark matter particles (i.e. WIMPs) are gravitationally attracted by the sun, and so are not distributed equally throughout the solar system. As the Earth passes through areas of the solar system with higher and lower densities of WIMPS throughout the year, it should be possible to detect more and fewer overall numbers of WIMPs. At certain times of the year there should be more overall collisions (including WIMP and non-

WIMP) than at other times. This is to say, even when detectors are unable to discriminate between WIMPS and other particles, by looking at the changes in the total number of particle interactions across years, it might be possible to see evidence of WIMPs. Theoretically, it should be possible to work backwards, to then identify some of the characteristics of WIMPS themselves.

The DAMA experiment at the Gran Sasso underground laboratory in Italy has been looking for this annual modulation by running detectors over the course of many years. DAMA first announced positive results in 1999, and its data have continued to show an annual modulation since then. While DAMA takes this to be strong indication of dark matter, there are several reasons why other researchers have approached DAMA's results with some skepticism. First, this technique hinges on an untested assumption about the ways that WIMPs coalesce in the solar system. Since DAMA cannot discriminate between a WIMP and another particle hitting the detector, there is no real way to ensure that the annual modulation they have been seeing is actually the result of WIMP collisions, rather than some *other* poorly understood annual modulation. Second, the signals with the strongest annual modulation in DAMA's data have a certain set of characteristics (mass and cross section, see below). However, other dark matter experiments, starting with CDMS (2000), have failed to see WIMPS with those characteristics. In fact, with a few exceptions[18], all direct detection experiments have eventually contracted DAMA's findings. This helps explain why the larger community still does not accept DAMA's

---

[18] In 2013 CoGeNt, which also looked for annual modulation, released results that suggested WIMP signals that would correspond with DAMA. However, the experiment has since reinterpreted these results to be background signals.

results even after two decades of consistent findings.

Background Discrimination All of the instruments described above face the same two problems: first, when instruments are sensitive enough to potentially detect a WIMP, they will also register all sorts of other particles. Second, given that WIMPs remain theoretical, no one knows either what specific characteristics WIMPs have, or what sort of signals they will produce in a given detector. These two issues present a notable epistemological challenge in making it difficult for researchers to know when they have actually detected a WIMP.

To solve these challenges, researchers attempt to identify or account for each signal produced by their instruments. There are two main techniques that physicists employ to do this. One is to try and shield detectors from as many non-WIMP particles as possible. This is why many experiments are run deep underground—where cosmic rays will not reach the detector. Experiments will also use shielding—such as lead bricks like in SuperCDMS or water tanks in LUX, to help keep out other particles. Second, detectors are specifically designed to be able to discriminate between different types of particles. Researchers spend a great deal of effort attempting to understand their instruments well enough to be able to identify the *known* particle contaminants or "backgrounds."

After they have shielded the detectors and identified and subtracted known particle signals, researchers can assume any remaining signals correspond to WIMPs. That is to say, they work to sort out what initially appear as un-differentiated data into signals (WIMPs) and noise (everything else that is known).

Or perhaps more precisely, the researchers must work to *produce* signals *from* noise.

There are a number of assumptions that experiments must make about their instruments in order for this approach to be logically sound. Most importantly, this approach requires that researchers be able to completely understand their data, instruments, and systems. This sort of subtractive identification of WIMPs only works if researchers can be sure that they understand their systems *completely*, except for one thing: WIMPs. If there are, for example, *two* unknown particles: WIMPs and something else, it will not be possible to use this approach. Indeed, of the handful of experiments that have claimed to see dark matter, most have subsequently determined that those signals that were briefly thought to be WIMPs actually corresponded to some other, previously unidentified "background" (CDMS, 2009; CRESST, 2011; CoGeNT, 2013).

Translation 3: Communicating Data Beyond Collaborations

Having considered some of the translations through which instruments produce data, and those through which techniques organize it, the final translation discussed here concerns how scientist begin to communicate data beyond the boundaries of their collaborations. At the same time, where previous sections considered media technologies and media techniques, this section looks at the media *processes* or *logics* that dictate the opening of data to new publics. As noted above, historians have observed that scientific epistemology has *always* included a moment of publicizing, of making public. Data and findings kept secret or "cloistered" (Callon et al., 2009) are, ultimately, meaningless. The magnetologists model notes that simplification is productive in part *because* it facilitates a making-public.

There are many ways that collaborations distribute their findings across the expert community, perhaps the two most notable being by producing scientific journal articles and by giving conference presentations. Famously, Latour and Woolgar identify writing scientific papers as the ultimate goal of science itself (1979). However, when informants were asked to describe how they write papers or give presentations, many redirected the conversation by describing how *plots* are made. Plots or charts are graphic representations of key findings. Across dozens of different presentations and papers reviewed for this project, one type of plot stood out. This same plot, showing a maximum *possible* relation of WIMP cross section (see below) and mass, appears across experiments, papers, and releases. Interestingly, collaborations have began using this plot to directly compare their findings to the findings of other experiments. This section unpacks this single plot as a way to better understand how data are translated into forms such that they can be made public.

On Plots Simply put, a plot displays the results produced in an experiment; it is "the end result, but what was behind it was all of this work and cross checks" and "vetting process" (T. Shutt, personal communication, 3/9/2016). That vetting process is usually run by an "analysis coordinator," who leads an analysis team or committee. The committee both decides which plots need to be produced and then distributes the work across members. The committee also holds regular meetings where

> the maker of the plots shows up and they've got a note, or a set of slides that defend all of their work, and people will show up and critique it. And in fact, it's kinda of a nicely well-structured thing where basically, they present their work in a meeting, there's a comment period for a couple of week and they have to respond to every single comment…. Sometimes there's fights and things like that, but you know, mostly it goes pretty smoothly, and it's all about getting the bugs out, or finding big problems, or deciding if this approach is wrong we've got to try something else (T. Shutt, personal communication, 3/9/2016)

Although committees will often produce many different plots, perhaps the most important one for many experiments expresses maximum limits of WIMP-nucleon cross section[19] against WIMP mass.[20]

Over the past several decades, this chart has been passed from experiment to experiment, growing in size and complexity. To demonstrate this, three plots from the past 18 years, one from CDMS's 2000 release, one from Picasso's 2009 release, and one from LUX's 2013/4 release, are shown below. [21]

---

[19] This is a measure of the probability that the WIMP will interact with the nucleus of a target material. Here "cross section" is an archaic holdover from pre-quantum models of particles.

[20] The line of the graph sets a limit above which WIMPs can not exist.

[21] Importantly, I have selected three plots that demonstrate increasingly complexity. It would have been possible to choose three plots that all only show a few different results. However, over time, on the whole, plots have gotten more complex. The LUX result was first released in October 2013; the paper wasn't published until 2014.

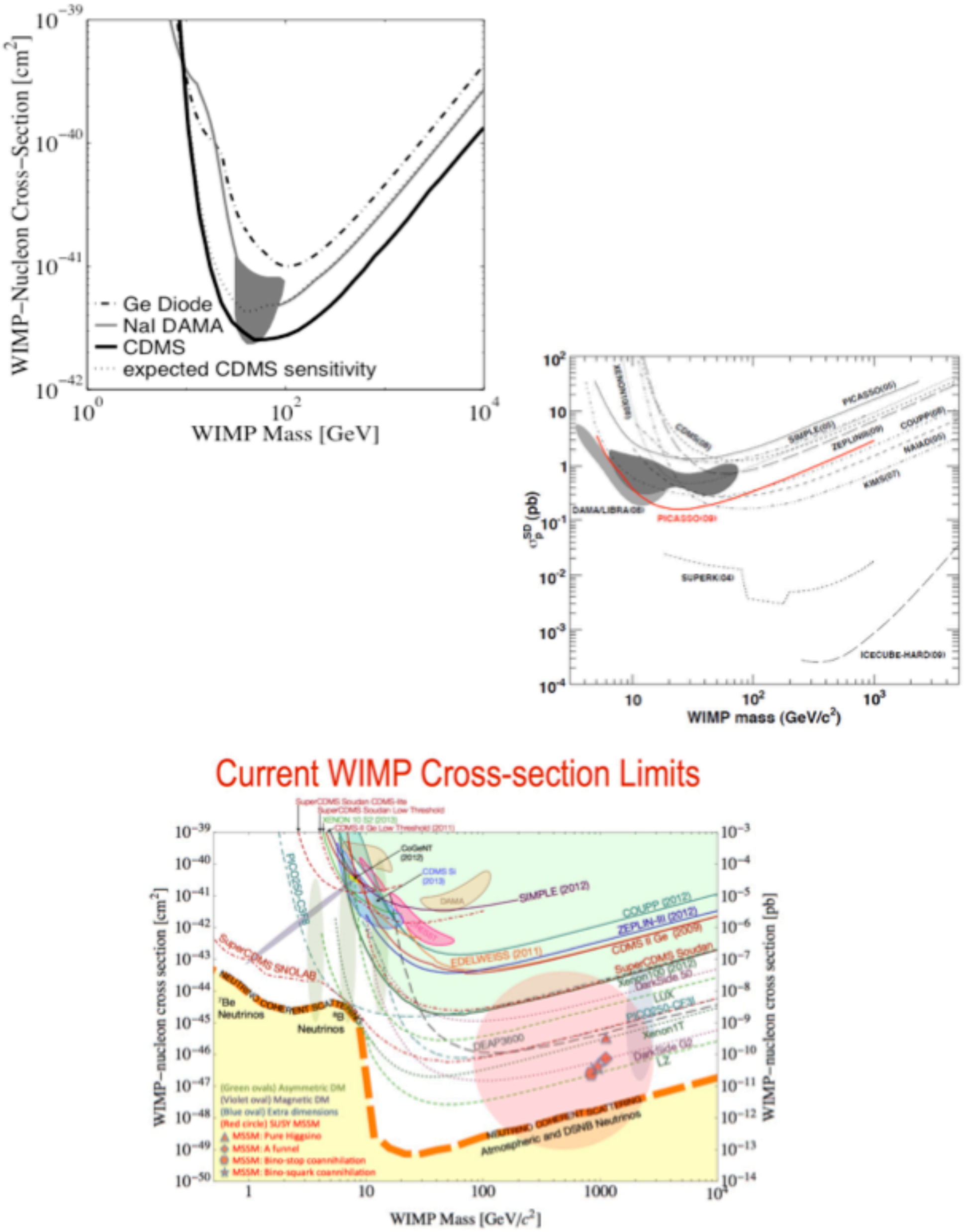


Figure 3.2: Plots from papers from three experiments: CDMS, (Abusaidi, et al., 2000), Picasso, (Archambault et al., 2009), and LUX (LUX Collaboration, 2014), respectively.

Without getting too far into the technical details behind these charts, it is necessary to ask why *this* chart—what is special about the relations depicted here? One article from *Fermilab Today* explains what is valuable about cross section as a measure.[22]

> But why use "cross section" when alternatives like "probability" and "reaction rate" exist? Cross section is independent of the intensity and focus of the particle beams, so cross section numbers measured at one accelerator can be directly compared with numbers measured at another, regardless of how powerful the accelerators are (Pivarski, 3/1/2013).

Arguably, the plots permit different collaborations—with different approaches, technologies, and techniques—to compare and relate their results. Cross section and mass are measures that smooth out the unique differences of different experiments. In effect, these measures help translate an experiment's findings into a form that allows them to be distributed across the larger field. Being able to compare results from different experiments helps physicists compare and validate experimental results—in effect, to make sure that experiments are functioning properly (Galison, 1987).

At the same time, experiments continue to *not* find dark matter. This plot, however, allows experiments to propose limits to the range of *possible* dark matter particles. To simplify somewhat, these limits derive from arguments that as experiments search certain mass and cross-section ranges, they can rule out dark matter particles having those characteristics. In a sense, by reporting a maximum limit, this plot therefore provides a way for collaborations to produce results even when they haven't seen dark matter.

---

[22] The article writes about cross section in the context of particle accelerator experiments, as opposed to the particle detectors of direct detection experiments. However, the point still holds.

Third, plots are also plastic enough to permit experiments to make strategic arguments about their own unique contribution to the field. For example, looking at the third chart above, while LZ can claim to potentially be the most sensitive experiment, SuperCDMS can claim to be the best experiment for studying low mass WIMPS—which is one of the key reasons they were selected for generation-2 funding (B. Cabrera, personal communication, 11/16/2015; P. Barbeau, personal communication, 10/21/2015). Also, looking at a similar plot, the leaders of DRIFT can claim that they are the best in *directional detection* (identifying the direction particles travel), and those of SIMPLE could claim to be the best at spin-dependent detection, even as neither is the most sensitive experiment overall. That is to say, the complexity and plasticity of this plot is such that different experiments can continue to make strategic arguments about how they are uniquely succeeding—and therefore deserve additional funding. In that sense, we see that even as the plots help align different experiments; the experiments retain unique ways of making them *meaningful*.

Putting these findings together suggests that these plots serve as what Star and Greismer would call "boundary objects" (1989). Boundary objects are "those scientific objects which both inhabit several intersecting social worlds …*and* satisfy the informational requirement of each of them" this means that "the creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds" (Star & Greisemer, 1989: p. 393). Boundary objects are material objects around which diverse "social worlds" can gather and communicate. While boundary objects are "plastic" enough to take on different meanings, they are “robust enough to maintain a common identity across sites” (ibid.). Here, this plot inhabits the different social worlds of collaborations, while still maintaining informational fidelity. In doing so, it provides a bridge amongst collaborations that are otherwise separated by employing different techniques and technologies. However, the plots are diverse and plastic enough that each collaboration can strategically deploy them in beneficial ways. Not only can this plot help a collaboration turn *null* results into something meaningful, but it helps an experiment be able to identify and articulate its own unique contribution as it seeks funding and social status. In this way, this plot not only facilitates the making-public of data, it provides a means for collaborations to make those results meaningful.

Discussion and Conclusion

Following the overall approach of this project, this chapter traces and investigates three specific translations through which expert knowledge about dark matter is produced. On one hand, it does so in order to better understand and defend the model offered in the previous chapter—specifically the claim that it is possible to extend an account of science production to that of public science communication. On the other, it provides specific empirical insight into the ways that dark matter science is produced, while bringing to bear theoretical concepts from medium theory.

Each of the three specific translations in dark matter physics discussed above highlights a different dimension of media at play. The first shows how instruments, such as time projection chambers or calorimetric bolometers, extend sight, hearing, touch to (potentially) allow physicists to reveal WIMPs. The second shows how the *techniques* of background discrimination and annual modulation, allow physicists to separate signals from noise, and to process data into ordered form. The third translation shows how plots help open science to new (expert) publics, by linking together different collaborations as boundary objects.

In recognizing that scientific practice is deeply and fundamentally mediated, we gain news ways to draw connections between different forms of science communication. Doing so helps break down the categorical distinction between expert and public science—to see them as differences of degree rather than kind. It is this connection that animates the rest of this dissertation. At the same time, is also a minor step in the direction of recognizing the continuity of science—a position that has been strongly pushed against by the so-called "Stanford School" of philosophers of science (Hacking, 1983, 1996; Galison & Stump, 1996; Cartwright, 1999) as well as many influential STS scholars (e.g. Pickering, 1995). Together, these scholars have argued that there are many sciences that cannot be unified by any single method, history, or culture. While this is an important argument, there is reason to wonder if this focus on the *disunity* of science hasn't been taken too far; that we have lost sight of what it is, exactly, that the sciences share.

CHAPTER 4
THE PUBLIC COMMUNICATION PRACTICES OF MULTI-INSTITUTION COLLABORATIONS

Introduction

Continuing to trace information flows about direct detection experiments, this chapter investigates how the multi-institution collaborations behind direct detection experiments are beginning to adopt public relations practices in order to communicate their results to non-expert publics. This chapter provides the first in-depth consideration of the public relations practices of multi-institution collaborations. The two previous chapters showed how journalists and physicist produce representations within chains of references that simultaneously reduce and open scientific research. Similarly, this chapter shows collaborations attempting to extend chains of representations of research findings. However, this chapter ultimately demonstrates what happens when the process *fails*—when information flows begin to unravel.

Scholars of (the science of) science communication have begun to recognize that many scientific institutions are increasingly embracing public relations practices (Lohwater & Storksdieck, 2017; Borchelt & Nielsen, 2014). However, there are three important areas that remain poorly investigated in this growing body of work. First, there has been very little scholarship on how multi-institution collaborations, like those that run direct detection experiments, are adopting public relations practices. Second, scholarship has yet to fully investigate how scientific PR is changing amid the broader embrace of social and digital media (notable exceptions: Su et al., 2017; Trench, 2007). Third, much of the existing scholarship has narrowly investigated press releases; yet scholars have mostly attempted to assess their accuracy and quality (e.g. Woloshin & Schartz, 2002; Woloshin et al., 2009; Riesch and Spiegelhalter, 2011; Brechman et al., 2009), rather than explore the conditions of their production.

As a result, this chapter addresses how multi-institution collaborations, alone and in partnership with partnering organizations, are embracing PR practices within a media landscape increasingly defined by digital and social media. It does so in order to better understand how scientific research organizations mediate and extend information flows about dark matter science. That is to say, the model offered in Chapter 2 presents a useful way of studying and assessing the PR initiatives of dark matter collaborations.

Fieldwork suggests that collaborations devote their time and resources to three main PR approaches: social and digital media—mostly in the form of websites and Twitter; press releases; and in rare instance, press conferences. This chapter examines each of these PR strategies in turn. First, it considers how collaborations have begun to embrace Twitter. Next, it investigates how collaborations work with communication offices at member institutions to produce and distribute press releases. Finally, the chapter provides a brief case study of one press conference (or really, two simultaneous press conferences) held in 2009 to announce news results from the CDMS collaboration.

The public relations practices identified and investigated here demonstrate what happens when circulating reference is pushed to, and then past its limits. Each PR practice discussed ultimately shows different ways in which circulating reference fails, deforming information chains about dark matter. The chapter shows how on Twitter, some collaborations have begun to announce results by circulating a single plot, a single statement of findings, or a single quote. These bits and pieces simply cannot achieve what the model described in Chapter 2 holds as important for representations within chains of references. At best, collaborations tweet out links to scientific papers (or news stories). At worst, they leverage Twitter's limitations to be strategically cagey about negative results.

At the same time, the social-technical realities of the distribution of press releases within the contemporary media landscape encourage individual institutions to *rewrite* press releases that have previously been carefully negotiated and reviewed. Before distributing releases through their own local networks, communication offices pull out bits and pieces of press releases—quotes, metaphors, ideas, fames, and data—and then attempt to re-contextualize them in ways that better aid their own organizational goals.

This chapter also shows how one collaboration's lack of *skill* in organizing, promoting, and managing a press conference perpetuated confusion, uncertainty, as well as conflicting frames, stories, and accounts, about their experimental findings.

Placed together, the three sections below demonstrate different forces disrupting information flows: the material affordances of a social media platform, the complex dynamics of socio-technical distribution systems, and finally, the lack of communication expertise or skill. In doing so this chapter provides an important counterpoint to the two previous. It shows how circulating reference can *fail*—and what that failure means for information flows about research science.

Literature Review

Multi-Institution Collaborations

Scientific collaborations have grown in size and frequency over the past century (Lariviére et al., 2010; Walsh and Maloney, 2007). As experiments in many disciplines have become more expensive and more technically complicated, collaborations have had to pull together more and more diverse members (Galison & Hevly, 1992). Collaborations tend to be composed of scientists, engineers, and administrators from institutions all over the world (Shrum et al., 2007). This has led to a number of network analyses of collaborations, many of which look at linkages amongst different collaborations (e.g. Bozemann et al, 2013).

Given the distributed nature of collaborations, a number of scholars have explored how new media technologies allow collaborations composed of scientists all over the world to function. Studies have looked at how technologies such as blogs, wikis, telephones, email, software, and the Internet (see Cheng & Chau, 2011; Kouzes et al, 1996; Walsh and Mahoney, 2003) facilitate collaboration. Interestingly, while some have argued that the development of these communication technologies has specifically permitted the growth of collaborations (e.g. Finholt & Olson, 1997), Cummings and Kiesler found evidence that "technology is an imperfect substitute for collocation" (2007: p. 8), and that collaborations that required more technological coordination had worse the outcomes overall.

Rejecting the implicit technological determinism in much of this work, Vertesi focuses on the *practices* that collaboration members employ as a means of “stitching together” the various socio-technical infrastructures within heterogeneous collaborations into temporary alignment (2014b: p. 277). Beginning, arguably with Latour’s discussion of immutable mobiles (1986), there has been a well-developed tradition in science and technology studies exploring how objects and practices permit heterogeneous actors to collaborate and share knowledge. For Latour, immutable mobiles are stabilized to maintain their truth-value even when dislocated from their original contexts. Similarly, for Star and Greisemer, the creation of boundary objects, “those scientific objects which both inhabit several intersecting social worlds …*and* satisfy the informational requirement of each of them” is a “key process in developing and maintaining coherence across intersecting social worlds” (1989: p. 393). Boundary objects, which are shared by many different groups, are able to take on different and even conflicting meanings, but permit different groups or epistemic cultures (Knorr-Cetina, 1999) to communicate and work together. Galison expands beyond Star and Greisemer’s focus on objects, noting, “locally shared *procedures* and *interpretations* (1997: p. 47 n48, emphasis in original) can also facilitate cooperation amongst heterogeneous actors. Adopting a term from anthropology, Galison describes the “trading zone,” as a space in which different actors, often adopting common trading languages or “creoles,” “can hammer out a *local* coordination despite vast *global* difference" (p. 783, emphasis in original).

Despite the significant literature on how (media) technologies facilitate collaboration, far less research has investigated how collaborations are adapting mass media or public communication practices. Most notably, Shrum et al. briefly observe that collaborations with less secure funding, on average, produce more press releases (2007: p. 56)—a finding that receives far too little discussion in their book. As noted above, Knorr-Cetina observed, in a similarly offhanded way, that the ability to control public communication can be a source of power within collaborations (1999: p. 224). That being said, if collaborations have become an important institution across scientific research, and there is strong evidence that research broadly is more oriented to mass media, we still need to understand how and to what extent collaborations are changing their public communication or public relations practices.

Public Relations in Science

As noted in Chapter 1, there is strong empirical evidence of "processes of structural change" producing an "increasing orientation of science toward media" (Rödder, 2008: p. 453). Scholars have grouped a range of phenomena, from increasing prominence of public communication offices (Peters et al., 2008; Rödder & Shaffer, 2010), to rhetorical changes in how scientists speak to the press (Nelkin, 1994; Plesner, 2010) under the term "medialization."

Put in other terms, scholars of (the science of) science communication have noted that public relations have become an increasingly powerful force in scientific research (e.g. Bucchi & Bauer, 2007; Borchelt and Nielsen, 2014). As a result, there has been a growing interest in studying the public relations practices of scientific organizations (Lohwater & Storksdieck, 2017).

Within this research, there is some consensus that, despite the growing adoption of digital and social media, public relations at scientific institutions remains "one-way" and "asymmetrical" (Su et al., 2017; Borchelt, 2008; Dorey, 2016). Importantly, Su et al. note this is not unique to science, but is also seen across forms of public relations (2017: p. 574). For Borchelt and Nielson, science PR should adopt a more symmetrical approach because PR needs to both "keep the public informed about science topics and maintain the trustworthiness of the scientific enterprise (2014: p. 62; Besley and Nisbet 2013). They suggest that in order to "manage the trust portfolio" organizations need to attend simultaneously to "accountability, competence, credibility, dependability, integrity, legitimacy and productivity" (p. 63). Similarly, for Su et al. (scientific) PR needs to involve both "information-sharing and public engagement" (p. 572); yet, even as they adopt social media tools like Twitter, many organizations emphasize the former rather than the later.

Some of the earliest scholarship on science PR addressed the role that public relations offices and officers (PIOs) play as "bridges" (Lynch et al., 2014) or "boundary spanners" (Ankney and Curtin, 2002: p. 232) between scientists and journalists (see also Dunwoody & Ryan, 1983; Nelkin, 1995, Gandy 1980). These offices are addressed in detail in the following two chapters.

More of the research on scientific PR has addressed press releases. Within this, it is more common for scholars to trace and assess press releases than to examine *how* they are produced (for an exception see Dorey, 2016). Like studies of PIOs, some of this scholarship has noted the ways that press releases mediate between scientists and journalists (Lynch et al. 2009). Yet, much of the research ultimately finds that press release do a *poor* job mediating and representing scientific research. Brechman et al. argue that press releases are a source of "distortion" in science news flows, in that they "overinterpret [*sic*] partial and/or preliminary findings," "overgeneralize" results, and fail to qualify provisional results (Brechman et al, 2009: 463-5). Others have found that press releases introduce confusion (Riesch and Spiegelhalter, 2009), distort implications and risks (McInerney et al. 2004), fail to address study limitations (Woloshin and Schwartz 2002; Woloshin et al., 2009), and exaggerate research findings or implications (Woloshin and Schwartz 2002).

Despite a consistent interest in organizational press releases, scholars have had less of an interest in press *conferences*. In making a larger argument about the increasing media orientation of scientific research, Hilgartner provides a detailed case study of press conference from the late 1990s by the Human Genome Project (2012). Similarly, Weingart (1998) briefly references the press conference held as part of the famous 1989 cold fusion hoax while also making an argument about scientific "medialization."

Overall, despite increasing interest in science PR, there remains much we do not know. In particular, we lack clear a clear understanding of if and how scientific organizations are adopting digital and social media in their PR efforts (Su et al., 2017). At the same time, we need more research on both *how* press releases are produced, and on *other* forms of public relations by scientific organizations. Finally, while research has investigated scientific societies (Lohwater and Storksdieck, 2017), national laboratories (Dorey, 2016), science festivals and museums (Su et al., 2017), we know almost nothing about PR practices of research collaborations.

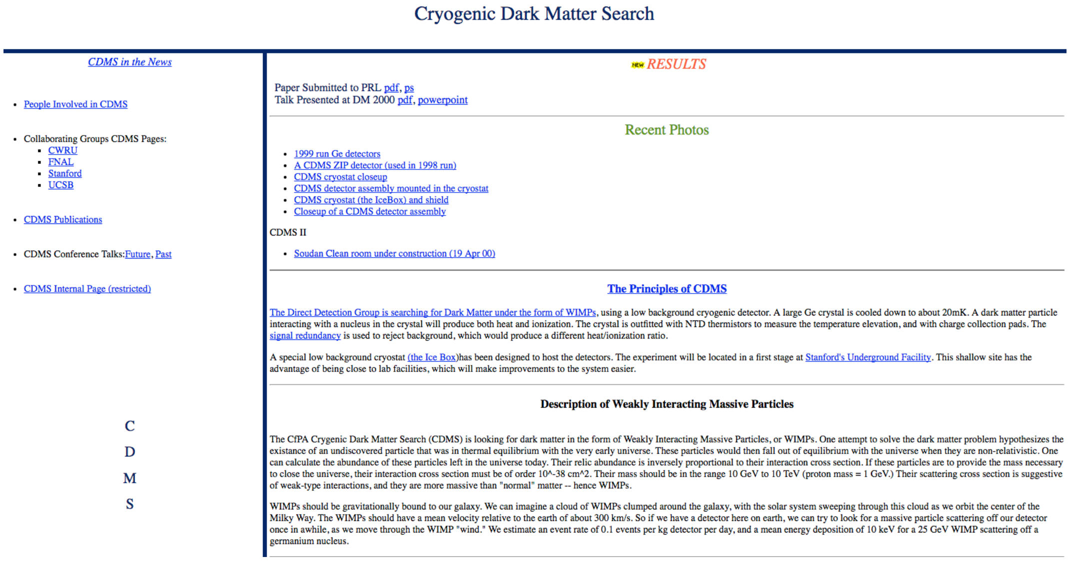
Methods

Findings in this chapter derive mostly from a set of semi-structured interviews with dark matter physicists and PIOs at national laboratories and research universities. This includes 20 interviews with physicists and 22 with PIOs. For a fuller description of informant selection see Appendix A. Interviews with physicists probed the range of public relations practices collaborations have been adopting, as well as how physicists worked with different institutional partners. Similarly, interviews with PIOs covered how they work with collaborations. Data also derives from interpretive analysis of a range of PR-related materials. This includes 338 tweets produced by 5 different collaborations (see Figure 4.2), as well as 120 press releases produced by 52 organizations on behalf of 14 collaborations. These materials were analyzed for recurrent themes, as well as for rhetorical devices, patters, and frames.

Findings

PR Approach 1: Digital and Social Media

Websites Websites are one of the most common forms of public relations pursued by dark matter collaborations. CDMS, one of the earliest experiments, has maintained a website for nearly two decades.



Cryogenic Dark Matter Search

CDMS in the News

- People Involved in CDMS
- Collaborating Groups CDMS Pages:
  - CWRU
  - FNAL
  - Stanford
  - UCSB
- CDMS Publications
- CDMS Conference Talks:Future, Past
- CDMS Internal Page (restricted)

C
D
M
S

NEW *RESULTS*

Paper Submitted to PRL pdf, ps
Talk Presented at DM 2000 pdf, powerpoint

Recent Photos

- 1999 run Ge detectors
- A CDMS ZIP detector (used in 1998 run)
- CDMS cryostat closeup
- CDMS detector assembly mounted in the cryostat
- CDMS cryostat (the IceBox) and shield
- Closeup of a CDMS detector assembly

CDMS II

- Soudan Clean room under construction (19 Apr 00)

The Principles of CDMS

The Direct Detection Group is searching for Dark Matter under the form of WIMPs, using a low background cryogenic detector. A large Ge crystal is cooled down to about 20mK. A dark matter particle interacting with a nucleus in the crystal will produce both heat and ionization. The crystal is outfitted with NTD thermistors to measure the temperature elevation, and with charge collection pads. The signal redundancy is used to reject background, which would produce a different heat/ionization ratio.

A special low background cryostat (the Ice Box)has been designed to host the detectors. The experiment will be located in a first stage at Stanford's Underground Facility. This shallow site has the advantage of being close to lab facilities, which will make improvements to the system easier.

Description of Weakly Interacting Massive Particles

The CfPA Crygenic Dark Matter Search (CDMS) is looking for dark matter in the form of Weakly Interacting Massive Particles, or WIMPs. One attempt to solve the dark matter problem hypothesizes the existance of an undiscovered particle that was in thermal equilibrium with the very early universe. These particles would then fall out of equilibrium with the universe when they are non-relativistic. One can calculate the abundance of these particles left in the universe today. Their relic abundance is inversely proportional to their interaction cross section. If these particles are to provide the mass necessary to close the universe, their interaction cross section must be of order 10^-38 cm^2. Their mass should be in the range 10 GeV to 10 TeV (proton mass = 1 GeV.) Their scattering cross section is suggestive of weak-type interactions, and they are more massive than "normal" matter -- hence WIMPs.

WIMPs should be gravitationally bound to our galaxy. We can imagine a cloud of WIMPs clumped around the galaxy, with the solar system sweeping through this cloud as we orbit the center of the Milky Way. The WIMPs should have a mean velocity relative to the earth of about 300 km/s. So if we have a detector here on earth, we can try to look for a massive particle scattering off our detector once in awhile, as we move through the WIMP "wind." We estimate an event rate of 0.1 events per kg detector per day, and a mean energy deposition of 10 keV for a 25 GeV WIMP scattering off a germanium nucleus.

Figure 4.1: CDMS website, as captured on June 19th, 2000 by the Internet Archive

Generally, websites have been simple and descriptive. Many contain the same features and sections: basic information about the experiment, a list of current members, a list of papers, and a section on "News." There is notable variation, however, in what collaborations include in this news section. For some, this section contains a running list of journalistic articles *about* the experiment. For others, like XENON1T, it is a space to publish the collaboration's *own* "news," brief updates the experiment—mostly announcing papers published in journals or uploaded to the

ArXiv. For LUX, the news section is simply its Twitter feed @luxdarkmatter (see below). Some websites include multimedia content, including photos or videos. There is no indication that these websites, including news sections, are frequently updated or frequently visited. Websites do not reliably include press releases for major releases.

Twitter Far more telling, however, is the use of social media by (some) collaborations. Simply put, direct detection experiments have not widely embraced social media. The only platform that experiments appear to use with any regularity is Twitter. While the ADMX experiment does have a rarely used Facebook page, this project could find no indication that other experiments have a presence on other social media platforms. Even still, despite there being dozens of currently existing experiments, only five have had a Twitter account, of these only *one* experiment is currently (as of early 2018) active on the platform. Figure 4.2 lists these five accounts with informative metrics.

	Join Date	Date of Last Tweet	Total Tweets	Followers	Following
LUX	Feb 2011	Oct 2016	154	1672	3
LZ	July 2014	Nov 2017	19	501	3
ADMX	July 2015	Aug 2015	28	190	610
MIMAC	Sept 2015	Dec 2016	12	12	9
XENON1t	February 2017	Feb 2018	125	536	151

Figure 4.2: Twitter Activity by Collaboration as of 2/12/2018

In a basic sense, these data are telling. Even though LUX has had an account for 7 years, they have only produced 154 tweets. Even still, LUX has drawn the largest following. Xenon1T, though younger, has been proportionally far more active. ADMX presents a strange case: it appears to have started the Twitter account in the summer of 2015 to promote its new, professionally designed website. After three months, it stopped tweeting altogether. Yet the flurry of activity and the high number of accounts that ADMX follows, suggest a very concerted effort was made to use Twitter for three months, before stopping. It is possible that the professional web designer also briefly ran the Twitter page, or that the collaboration hired/tasked a student with running the Twitter feed for the summer.

The relationships amongst these five accounts is also somewhat instructive. Using following/followed relationships generates the following diagram (left).

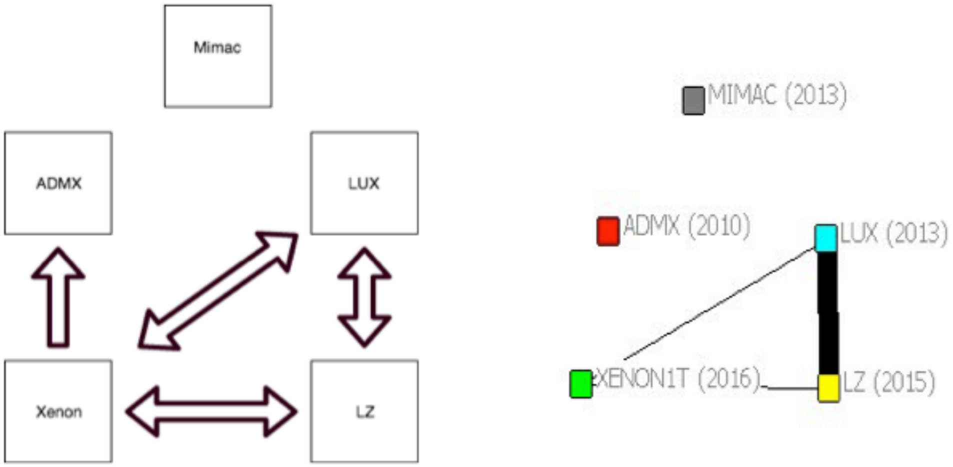


Figure 4.3: (L) Twitter relationships as of December 2017. (R) Shared collaboration membership (adapted from Chapter 1, Figure 1, see Appendix A). Lines indicate shared members.

Although extremely limited, this graph repeats some of the inter-collaboration relations shown by shared personal (right; see Chapter 1, Figure 1.1). Relationships on Twitter seem to more or less replicate offline relationships, at least in a very general sense.

MIMAC is a France-based collaboration, and while most collaborations have members from across the world, these data suggests some separation between the social worlds of MIMAC and the other experiments. Similarly, unlike the other four experiments listed above that search for WIMPs, ADMX is trying to find axions, a very different sort of dark matter candidate. ADMX uses different types of detectors and a different approach (see Chapter 3). Given this, it is not surprising ADMX has shared few members with WIMP experiments

As noted, above Su et al. (2017) found that scientific organizations continue to use Twitter primarily as a means of "information-sharing" (p. 573) rather than in the service of community or relationship building. Broadly, collaborations studied here have used twitter the same way. Looking across the 338 tweets of these five organizations reveals that the majority of unique tweets (not retweets) serve as some form of *announcement*. In a sense, doing so is an act of representation—attempting to add to the chain of reference. Yet in announcing experimental results, a new paper published (or uploaded), an organizational achievement, or a news story, collaborations have to work within Twitter's severe content restrictions.

Some tweets more or less sidestep the task of representation by simply posting a link to an article:

LUX Dark Matter
@luxdarkmatter

The paper is now in the arxiv: arxiv.org/abs/1310.8214

10:36 PM - 30 Oct 2013

11 Retweets 7 Likes

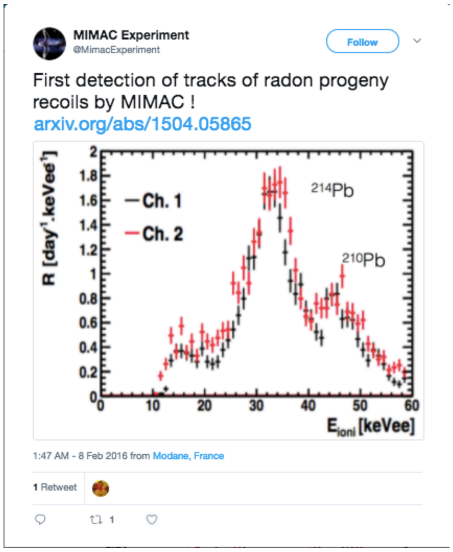
1 11 7

Katie Mack @AstroKatie · 30 Oct 2013
Replying to @luxdarkmatter
Get it while it's hot... RT @luxdarkmatter: The paper is now in the arxiv: arxiv.org/abs/1310.8214

2

Figure 4.4: Tweet from @luxdarkmatter 10/30/2013

Yet, it is more common for tweets to attempt to pull key findings from the linked paper.



MIMAC Experiment
@MimacExperiment

First detection of tracks of radon progeny recoils by MIMAC ! arxiv.org/abs/1504.05865

1:47 AM - 8 Feb 2016 from Modane, France

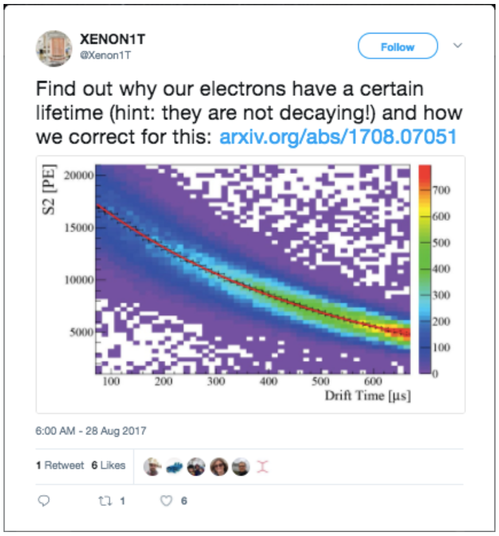
1 Retweet

1

Figure 4.5: Tweet from @luxdarkmatter 10/30/2013

Yet, this is simply inadequate. Twitter does not provide the space to contextualize this plot in a way that is going to be useful to anyone who is not already deeply familiar with astroparticle physics.

Other tweets attempt to get around this by using the brief space to try and draw readers in:



XENON1T
@Xenon1T

Find out why our electrons have a certain lifetime (hint: they are not decaying!) and how we correct for this: arxiv.org/abs/1708.07051

6:00 AM - 28 Aug 2017

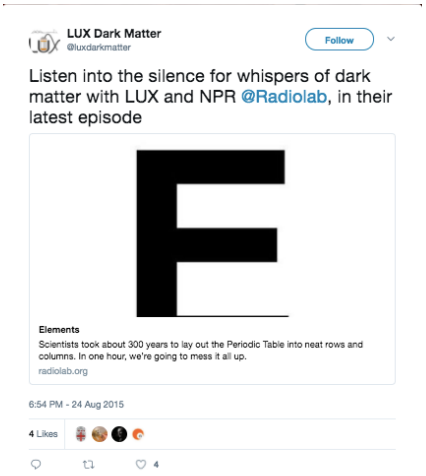
1 Retweet 6 Likes

1 6

Figure 4.6: Tweet from @Xenon1T 8/28/2017

However, in doing so, Xenon1T pulls out a finding, wholly divorced from any explanation or meaning. Here, it remains unclear why we should care that electrons have a "certain lifetime" or what this plot means.

Similarly, a number of other tweets were written to announce news coverage of the experiment. Like with experimental results, some of these tweets attempt to provide some sort of summary statement of the news release. For example,



LUX Dark Matter
@luxdarkmatter

Listen into the silence for whispers of dark matter with LUX and NPR @Radiolab, in their latest episode

Elements
Scientists took about 300 years to lay out the Periodic Table into neat rows and columns. In one hour, we're going to mess it all up.
radiolab.org

6:54 PM - 24 Aug 2015

4 Likes

4

Figure 4.7: Tweet from @luxdarkmatter 8/24/2013

Here LUX appears to be pulling a phrase from the episode itself to represent the gist of the story piece. Notably, other tweets announce *press releases*, or link to lab-produced multimedia, including videos of instrument construction, images, or interviews.

A handful of tweets announced results directly, *without* even providing a link to an antecedent article or document. Perhaps the most notable example was tweeted by LUX during the 10/30/2013 press conference (see Chapter 1). This tweet was one of a handful produced over several hours.

LUX Dark Matter @luxdarkmatter

Rick Gaitskell: In 85 days, LUX got 160 events, consistent with background-only hypothesis with p-value 0.35

9:10 AM - 30 Oct 2013

Zeta Syanthis @ZetaSyanthis · 30 Oct 2013

Replying to @luxdarkmatter

@luxdarkmatter @seanmcarroll How significant is that? Not sure how to interpret that value.

Figure 4.8: Tweet from @luxdarkmatter 10/30/2013

Instead of a link, the tweet provides a source. While Gaitskell is well known within the community, as the tweet lacks credentials or affiliations it would be unclear to many who exactly he is. Next, the tweet distills down the key findings from this release into a single sentence with three pieces of data. Yet, juxtaposed, these three pieces of data are confusing. “In 85 days, LUX got 160 events,” highlights that LUX found *something*. In interviews, both LUX spokespersons and two PIOs working on the release all admitted that that they were aware holding a press conference encouraged some people to expect LUX had found dark matter (R. Gaitskell, personal communication, 9/22/2016, D. McKinsey, personal communication, 11/3/2015; B. Harlan, personal communication, 3/25/2016; C. Walter, personal communication, 6/8/2016). However, the next phrase, "consistent with background-only hypothesis" is a jargon-filled way of saying that these 160 events were *not* dark matter. While those familiar with direct detection would understand this, many laypersons might not. Finally, the last piece of data is "with p-value 0.35"—a value that makes the findings appear to not be statistically significant. The one reply to the tweet (see above) noted this confusion. If not statistically significant does this mean these events might *not* be backgrounds? Could they have found dark matter? Or does this simply mean the collaboration cannot be certain of their results. If so, why are they holding an announcement? The subsequent tweets produced during the press conference do little to clear up the confusion.

This last tweet puts into the sharp focus how Twitter encourages users to pull images, quotes, ideas, frames, from antecedent content. That is to say, Twitter encourages the *de-forming* of information. While it is possible that this tweet was simply produced with little thought, given the extent of PR activity surrounding this release (see Chapter 1), there is reason to suspect that LUX is strategically exploiting Twitter's word limits to craft tweets that would perpetuate some confusion about the release. However, in a larger sense, it is Twitter's severe technical/design affordances that actively encourage the production of deformation.

PR Strategy 2: Press Releases

While few collaborations have embraced social media, most have consistently produced press releases over the past several decades. This chapter pragmatically defines press or news releases as documents specific to individual experiments that are meant to publicize key events by facilitating journalistic coverage (See Autzen, 2014). Of the 322 institutional stories collected for this project, 120 press releases were identified.[23]

As noted above, little has been written about press releases produced by scientific organizations—and even less about those produced by collaborations. Most existing research (Brechman et al, 2009; Lynch et al, 2014) focuses more on the content of releases, without considering *how* they are produced. Within this work, some have observed that press releases are effective in generating news content (Shrum et al., 2007), but more have argued that press releases can be a source of "distortion"(Brechman et al., 2009) in science journalism (see also Woloshin & Schwartz, 2002). Those few studies that look more closely at production of press releases have focused narrowly on press offices, without discussing the relations between researchers and press officers. Following this dissertation's interest in tracing information flows about direct detection experiments, this chapter treats press releases as *representations* within chains of reference that can, if well made, productively expand information about dark matter.

---

[23] Importantly, the Web has provided a distribution mechanism that can simultaneously reach journalists and laypersons, helping to fundamentally change the nature of press releases and degrade the boundary between press releases and other institutional content. This story is told in detail in the following two chapters. That being said, as discussed above, it is still possible to identify press releases from other institutional content.

As a result, this chapter asks two questions concerning press releases: first, how are they *made*: what sorts of people, things, and organizations must be pulled together to turn a piece of news into a release? Second, how are press releases *written:* how do the different authors solve the twin problems of making negative results interesting and meaningful, while properly representing not only the science but the many different institutional players involved? As it answers these questions and provides the first rigorous investigation of the production of press releases by collaborations, this section also demonstrates another way that chains of references can fall apart. Here, it is not only the material affordances of a social media platform, but rather the larger socio-technical distribution system that activity encourages collaboration partners to deform information flows.

Production With only a single exception[24], all press releases collected for this project were produced by collaborations working with institutional press or communication offices at member institutions (see Chapters 5 and 6). Producing press releases in this way provides both advantages and disadvantages. While institutional members supply professional writers and diverse distribution systems, trying to coordinate amongst many different communication offices can be challenging.

---

[24] In 2009, CDMS-II produced a "summary of results" for a major release of findings (http://cdms.berkeley.edu/papers/results_summary.pdf). This summary is two single-spaced pages and contains no figures, graphs, or numbers. Frankly, it is less a "summary of results" than it is a background of the experiment itself: six of its eight paragraphs provide general background on dark matter and the experiment. Even stranger is how Fermilab, the lead lab for CDMS, *also* produced and distributed a press release the same day.

Broadly speaking, that press releases involve many different and different types of organizational actors means that there is no single way that press releases are produced. According to Glen Roberts, Jr., a science writer at Lawrence Berkeley National Lab, "It works in different ways for different collaborations… every collaboration is different. So I've been a part of press releases for a few different collaborations now, and it does tend to work in different ways" (G. Roberts Jr., personal communication, 6/30/2016). That being said, there are some notable similarities for press releases of dark matter experiments.

In that many institutions are involved in producing a press release, the first challenge, therefore, is to determine *which* office is going to direct the process (G. Roberts Jr., personal communication, 6/30/2016). In most cases, the "lead" laboratory takes charge. Sometimes, the lead lab is specifically identified in government grants as the institution tasked with leading the collaboration—at least as far as communicating with the granting agency. Not all collaborations, however, have a clearly identified lead lab. It is, perhaps, more common for the lead lab to shift to the home institution of the current elected spokesperson.

After figuring out which institution will take charge, the process begins with initial conversations between the communication office at the lead institution and the researchers in the collaboration. As Manuel Gnida, a communication specialist at Stanford Linear Accelerator Laboratory (SLAC)[25] observed,

> So the process, how it all starts, is we invite the researchers to come to the communications [office] and then we meet with the larger group and we talk about the research, we involve people from the graphics

---

[25] The original name was Stanford Linear Accelerator Center. Although the name has changed, the acronym has not.

> department, that can make images or animations—so that we can prepare a whole package for that press release (M. Gnida, personal communication, 6/28/2016).

Just as there is input from across the lead laboratory communication department, there is also input from scientists across the research collaboration as well. Usually, all of the Principal Investigators (PIs) from member institutions in collaborations are able to give input on a press release.[26] Yet, depending on the size of the collaboration this can be quite challenging.

> Press releases are also collaborations, you gotta get input from all the different parties, and yeah, those are challenging, but it's a necessary thing…I've seen some where its like a Googledoc, where everyone is just kinda weighing it all at the same time, and it all works somehow, it all works together. There are different ways, sometimes you are working with the top leadership on the releases first, and you get others to weigh in after that, or sometimes the reverse is true, its yeah, it comes together in a lot of different ways (G. Roberts Jr., personal communication, 6/30/2016).

Although the lead lab often organizes the process, the other ("follow") institutions are usually included as well. Constance Walter, the communication director at SURF, provided two distinct explanations for why collaborations produce press releases in this way: "We all work together on it so we don't make mistakes, we don't want the wrong message going out, we want to make sure the right message is promoted" (C. Walter, personal communication, 6/8/2016). On one hand, allowing many different scientists to contribute to the press release helps ensure that the technical information is as accurate as it can be. On the other, allowing researchers and communication departments to participate helps guarantee that results are framed

---

[26] The PIs are usually faculty (often associate or full professors) at institutions who lead research groups as part of the collaboration. Often, all the PIs in a collaboration sit in a special governing committee.

in the most advantageous way—a decision that also must be worked out by many different parties.

Once a (first) draft has been laboriously worked out amongst the key stakeholders, each press release must *still* go through a rigorous review process. Andrew Gordon, the External Communications Manager at SLAC, describes the review process at his laboratory:

> the writer writes the feature, or the press release, it then goes to the editorial manager, and the editor for review, if it's a press release, it also goes to me for review. And then once we look at it, if it's a press release, it also goes to the director of communications for review. Then it goes back to the researchers to make sure everything is accurate and correct, and once they've had a look at it, then it goes to the overall lab director…and then the Department of Energy for approval, for a review and approval (A. Gordon, personal communication, 6/16/2016).

Gordon describes *seven* different steps of review after all the different scientists and institutions have already collaborated to produce the release. While it is not uncommon for press releases to go through extensive institutional review, this is compounded by the size and heterogeneity of collaborations. Gordon suggested that across these different stages of review "everyone is looking for something a little bit different," from the researchers looking to make sure the science is accurate, to the DOE making sure that the agencies involved are properly named and represented. At the same time review helps

> to make sure that everyone is represented…it's important that it doesn't sound like its coming from any one lab, you don't want to give anyone short shrift, it's just fairness and equality, rule and collaboration at least (G. Roberts Jr., personal communication, 6/30/2016).[27]

---

[27] The process of writing (and distributing) a press release is somewhat complicated if the results are being published in a journal with a strict embargo policy. Embargos prevent materials from being

Press Release Framing Part of the challenge of producing releases is negotiating *how* the results will be discussed or framed. A close reading of the set of 120 direct detection press releases suggests a small number of distinct framing strategies. Many releases employ several of these strategies. For the most part, releases cover one of three scenarios: negative results (no dark matter), inconclusive and non-statistically significant positive results, or "pseudo-events" (Boorstin, 2012), such as experiment inaugurations. Each of these scenarios engenders unique problems in producing press releases. Most notably, negative results and pseudo-events must be made interesting and inconclusive results must balance between being accurate and being interesting (see Lynch et al., 2014).

First, when possible, press releases stress the sensitivity of the experiment compared to others. At different times different instruments have been able to lay claim to being the "world's most sensitive dark matter detector" (Stacey, 7/21/2016). As noted in the previous chapter, sensitivity, which can refer to either the ability to see very small particles (mass), or very unlikely collisions (cross section), itself isn't as obvious as might be imagined. Similarly, for LZ, even when it was not the *most* sensitive, one press release announced, "Researchers have come a step closer to building one of the world's best dark matter detectors…." (SLAC, 5/20/2015). In a sense, this frame is about competition with the larger group of

---

released until a set date. The biggest journals, such as *Science* and *Nature*, not only have strict embargos, but also can be deeply involved in the writing of press releases as well. Through 2016, however, there were only two dark matter experiment that made it into one of these journals, the 2009 CDMS-II and the 2015 XENON100 papers both published in *Science*.

experiments. One release literally opens by noting that CDMS has "regained the lead in the worldwide race" (Riesselmann, 2/25/2008) to find dark matter particles. This strategy shares much with the infamous "horse race" frame of political journalism (Bennett, 1996)—which seeks to interject drama and excitement into [political] competition.

A second related frame also concerns scale, but in terms of the physical size of the detector, location, or even dark matter itself. Since most direct detection experiments occur underground, some press releases stress how deep they are, or the effort and materials that go into shielding detectors. Another LUX release observes the "70,000 gallons of water nearly a mile beneath the Black Hills of South Dakota" (Gershon, 11/16/2012). A third release notes the "100m long, 20m wide and 18m high hall B of LNGS" where XENON1T is located (XENON, 11/11/2015). Others focus on the scale of the *problem* these experiments tackle:

> Recent calculations indicate that ordinary matter containing atoms makes up only 4 percent of the energy-matter content of the universe. "Dark energy" makes up 73 percent, and an unknown form of dark matter makes up the last 23 percent.
> 'It is often said that this is the ultimate Copernican Revolution,' said David Caldwell, a physicist at the University of California at Santa Barbara and chair of the CDMS Executive Committee. "Not only are we not at the center of the universe, but we are not even made of the same stuff as most of the universe" (Hutson, 11/19/2003).

A third frame hinges on the uniqueness of a given experiment or detector. One press release for the COUPP experiment, which has helped pioneer a new detector approach (see Chapter 3), observes, "Scientists this week heard their first pops in an experiment that searches for signs of dark matter in the form of tiny bubbles" (Fellman, 5/3/2013). The release plays on the unusualness of the experiment, later calling it “one-of-a-kind,” helping to differentiate it from the dozens of other experiments.

Finally, some releases eschew more journalistic conventions and supply large amounts of scientific detail:

> The CDMS II result, described in a paper submitted to Physical Review Letters, shows with 90 percent certainty that the interaction rate of a WIMP with mass 60 GeV must be less than 4 x 10 -43 cm 2 or about one interaction every 25 days per kilogram of germanium, the material in the experiment's detector (Perricone, 5/5/2004).

These numbers mean little to anyone who is not a dark matter physicist. Presumably, the writers are most interested in asserting the scientific rigor of the experiment and the findings.

Distribution Once a press release has been written and reviewed, and the embargo date, if there is one, is at hand, the release is ready to be sent into the world. If a major journal is involved, it will often send the release to the biggest science news wires: EurekaAlert!, News Wire, and Alpha Galileo. If not, the lead laboratory often will do this.[28] The lead laboratory will also send the release to its own network of journalists and connections. Like in any organization, good communication or media relation officers maintain relationships with science journalists.

Yet, lead labs also tap into the networks at each member institution to help distribute press releases. Katie Jurkewicz, the director of communications at

---

[28] See Appendix D, Figure 1, for a breakdown of wire service placement of each press release.

Fermilab, explained that keeping all of the follow institutions involved throughout the process of producing a press release also helped this aim:

> as lead [lab] we need to try to be as inclusive as possible, because if you want to raise a national or international profile about a given project and you want to have it in markets all over the country, the best way to do that is by using the universities that are in those markets, because they know their journalists, they can get their information out in the media in a way that we, sitting in Chicago, couldn't for example (K. Jurkewicz, personal communication 5/6/2016).

Collaborations often involve institutions from across the country and world—and each institution usually has its own communication, media relations, or public affairs office that has its own network of journalists and publications. These networks can include an institution's own set of publications, as well as journalistic outlets in local communities, or even connections with journalists at national outlets. Importantly, having locally rooted distribution networks can help stories stand out in a crowded media landscape.

Yet, in order to motivate follow labs to tap into their local networks, they are allowed—and often expected—to *rewrite* press release before distributing them across their own networks. Usually this means highlighting the work that their researchers have done and the contributions they have made to the experiment. Yet, this can also mean more substantive changes as well. As Manuel Gnida observed for one press release about LUX:

> I think I tried to make it less technical, and of course I wanted to flag SLAC higher in the text than the original press release, [which] didn't quote one of our SLAC researchers who was the cofounder of LUX, Tom Shutt, so I included something from him. But I see here I did keep quotes from the original, it's always good if you already have a good draft that has already been reviewed so it's something you can work with (M. Gnida, personal communication, 6/28/2016).

One of the most common ways that follow labs modify releases is by inserting or moving up quotations from their own faculty. For example, in one set of nine press releases concerning the 10/30/2013 release of results by the LUX collaboration, five follow-institution press releases re-wrote the copy such that a quote from one of their own researchers was the *first* quote in the piece. While this can be seen as a means of simply highlighting the work that their own researchers have done, there is something interesting about the way that the modification comes in terms of including direct quotes. Sourcing not only draws on the expertise of scientists, it also helps to *produce it*. For a press release to prominently quote a researcher is to certify that the researcher is a respected expert about the topic. In this way, institutions are able to better deploy press releases as means of gaining social capital related to employing notable public experts.

Once a follow lab has revised the release, it might be reviewed by the administration of that institution, but it usually is not reviewed by the research collaboration or the other institutions. This means that after weeks of collaborative work and review, science writers at follow institutions can essentially throw out the carefully worded releases to promote the role their researchers and institutions have played in the collaboration. Yet, being able to rewrite releases provides incentive for organizations to work their own distribution networks on behalf of the collaboration.

The release around the “inauguration” of the XENON1T instrument on 11/11/2015 at the INFN-Gran Sasso Underground Laboratory, provides an example of how exactly press releases are rewritten.

The day of the inauguration, INFN-Gran Sasso published a press release on their website. The press release begins:

> There is five times more dark matter in the Universe than "normal" matter, the atoms and molecules that make up all we know. Yet, it is still unknown what this dominant dark component actually is. Today, an international collaboration of scientists inaugurated the new XENON1T instrument designed to search for dark matter with unprecedented sensitivity, at the INFN Gran Sasso Underground Laboratory in Italy (XENON, 2015).

Over the next week, two member institutions, Purdue and Columbia University, circulated the press release verbatim. The next day, however, Purdue posted a *second*, follow-up piece that folds selected content from the release content into a profile of Rafael Lang, a Purdue faculty member who was the analysis coordinator of the experiment (Gardner, 11/12/2015).

Another eight institutions distributed modified versions of the release. For example, the University of Chicago kept the lead, but dropped much of the extraneous detail in favor of direct quotes from Luca Grandi, a University of Chicago physicists who is part of the collaboration, and from Elaine Aprile, the collaboration spokesperson. Similarly, the Oscar Klein Centre not only introduced an entire section about their researchers, it included a picture of them along with a new diagram of how the experiment operates.

Ecole des Mines de Nantes linked to the original release, but introduced it with graph that reframed the experiment in this way:

> An international collaboration of scientists involving in particular the Laboratory for Subatomic Physics and associated technologies (Subatech, CNRS / Ecole des Mines de Nantes / University of Nantes) (1) inaugurated the Gran Sasso underground laboratory in Italy, the new XENON1T instrument" (N/A, 2015).

Similarly, the University of Amsterdam released a version with the lede:

> An international collaboration of scientists, with UvA professor Patrick Decowski and his team, inaugurated the new XENON1T experiment in the underground Gran Sasso laboratory in Italy (N/A, 2015).

A few days later, the University of Zurich entirely rewrote the release to focus on how "UZH Physics Professor Laura Baudis and her team played a significant role in the development and construction of this detector" (Serck-Hanssen, 11/16/2015).

Ultimately, it is in a collaboration's best interest to tap into the diverse distribution networks of members. However, member organizations have little incentive to distribute releases that do not explicitly support their researchers. As a result, collaborations permit member institutions to deform carefully written and reviewed press releases in order to gain their help in distributing releases. As seen above, in rewriting releases, communication offices pull sentences, quotes, ideas, frames from releases, and then attempt to re-contextualize them in ways that they believe will better support their own organizational interests. In this sense, supports scholarship that argues that press releases can "distort" informational flows (Brechman et al, 2009; Lynch et al., 2014) about science. However, this chapter finds this distortion happening in a way not previously acknowledged, and for reasons not previously recognized.

PR Strategy 3: Press Conference

Press conferences are not common in direct detection research. The vast majority of experiments have never held a press conference. This project recognized only *two* press conferences surrounding release of direct detection results. In fact, there seems to be some resistance to the idea of holding press conferences. In describing the two examples of press conferences held by direct detection experiments, neither informants in interviews, nor physicists or PIOs in press materials ever referred to them as press conferences. Instead, they described these events as "seminars" or "talks." However, both of these events had all the trappings of a press conference: an audience of journalists, policy makers, politicians, and laypersons; public-directed language, metaphors, and explanations; and a lack of highly detailed scientific information of the sort found in academic presentations.

One of the two press conferences is discussed in detail in Chapter 1. This section provides a detailed description of the second press conference. This section shows how CDMS more or less stumbled into giving a press conference, yet was largely unprepared to do so. Its leaders did not understand how such an event would be interpreted by media outlets, nor did they understand how to communicate their findings clearly. As a result, the press conference helped disrupt and mutate information flows about the releases, perpetuating what this project recognizes as *deformation* about CDMS's findings.

CDMS On December 17th 2009, the CDMS collaboration released results from a run of its CDMS-II detector, results that included possible, though not-statistically significant, dark matter signals. These results were announced at two simultaneous "announcement talks," one held at SLAC and given by Jodi Cooley, a PI from Southern Methodist University, and one given at Fermilab by Lauren Hsu, a post-doc at the lab. Videos of the presentations have been archived on the SuperCDMS website, along with PDFs of the PowerPoint presentations.[29]

Leading up to the seminars, rumors had been circulated through the community that CDMS might announce they had found dark matter. The rumors were stoked by scientific blogs, including the influential particle physics blog *Résonaances*. The blog, written by the French physicist Adam Falkowski, under the pseudonym Jester, published an article more than a week before the presentations titled "What the hell is going on in CDMS???" The post begins,

> The essence of blogging is of course spreading wild rumors. This one is definitely the wildest ever. The particle community is bustling with rumors of a possible discovery of dark matter in CDMS (Falkowski, 12/7/2009).

As evidence, Falkowski cited general gossip along with two "facts:" that *Nature* was going to publish an article corresponding to the release that was currently under embargo until December 18th, and that CDMS had told a film crew that was scheduled to film the experiment in December to reschedule until January. A few days after the post, Falkowski received an email from the senior physical sciences editor at *Nature*, Dr. Leslie Sage, denying that *Nature* would publish a paper by CDMS on November 18th, writing "Your 'fact' therefore contains as much truth as the average Fox News story, and I would be grateful if you would correct it immediately" (Falkowski, 2009b).

Yet, Lauren Hsu also chalked these rumors to the fact that "people thought we were going to have a result because we had scheduled simultaneous

---

[29] http://cdms.berkeley.edu/press.html

presentations at Fermilab and SLAC" (personal communication, 4/14/2016) something that was uncommon for results releases.

When asked why CDMS would schedule these two simultaneous talks, rather than simply present results at a conference, Hsu explained:

> it was only because we had originally been targeting some summer conferences for the result, but we missed the deadlines because we didn't have the results ready in time. And we thought that having two simultaneous talks at the national labs would be high enough profile—that's comparable to showing it at a prestigious conference. But I think people took it out of context and someone thought that, yeah, so people were saying we were being secretive, but it's a normal thing for a collaboration to not comment on anything until the result is done, and we don't want to say anything when we are still working on it because the result could change (personal communication, 4/14/2016).

Hsu's response ultimately characterized the rumors as the result of a conflict in changing communication norms and practices. CDMS tried to figure out what would have equal "profile" as a "prestigious conference," deciding to hold what essentially became *press conferences*. Yet, they did not seem to understand that by choosing this format, many would assume that the collaboration must have something very significant to report.

These rumors put CDMS in an awkward spot: while they hadn't seen statistically convincing evidence of dark matter, they had observed several events that could not be explained as backgrounds. While the press conferences/seminars were not meant to be announcements of a discovery, the collaboration did want to signal the possibility that the experiment had seen WIMPs.

In response, the day of the seminars, the collaboration posted what *resembled* a press release, titled “Summary of the Results,” in the “In the News” section of their website (see above, fn 28).

These rumors also influenced how Hsu and Cooley conducted their talks.

> At that point we had realized that everybody was going to watch the talk because they had this mistaken rumor that we were going to discover dark matter, so we were very careful about what we said in the conclusions of the talk. So there was you know, a lot of scrutiny and a lot of feedback given to me on my talk before I gave it. So I had to interact with like a large number of people in the collaboration to make sure, because the talk I’m giving is representing the entire collaboration, So I have to make sure that everybody is happy with it, so it requires many iterations (L. Hsu, personal communication, 4/14/2016).

The talks that Cooley and Hsu gave, however, were not only quite technical, but also, arguably, failed to offer a clear rebuttal to these misconceptions. Jodi Cooley concluded the talk with a slide:

> Final Comments on this Analysis
> Our results cannot be interpreted as significant evidence for WIMP interactions.
> However, we cannot reject either event as signal. (Cooley & Hsu, 12/17/2009)

While she did clearly caution against interpreting this result as evidence for dark matter, the last line seems to contradict the previous, leaving the result in some sort of uncomfortable purgatory, neither accepted nor rejected. It is no wonder that much of the journalistic coverage of the talks framed the release in terms of detection. “At a Mine’s Bottom, Hints of Dark Matter,” (Overbye, 12/17/2009), or “Dark Matter Detected for First Time?” (Than, 12/18/2009).

Taken all together, the CDMS collaboration seems to have stumbled their way into giving what was for all intents and purposes a press conference. However, the collaboration was ultimately unprepared to deal with the full implications of doing so. This combined with an ambiguous result, helped spread confusion about the meaning of the results.

Discussion

In providing one of the first in-depth accounts of the public relations practices of multi-institution collaborations, this chapter has looked at three of the most common public relations strategies: digital and social media use, press releases, and press conferences. By increasingly adopting these sorts of strategies, collaborations are becoming important mediators of public information flows. While scholars have long recognized public information officers as "bridges" between scientists and journalists (Lynch et al., 2014), collaborations are increasingly inserting themselves into a different mediating role. Collaborations are now contributing to the chains of representations that constitute information flows in new ways. Each of the three PR strategies described here ultimately involves collaborations producing simplifying representations of their research as they bring it to new audiences and open it to new publics.

However, despite a clear increase in the recognition that public communication is important, collaborations do not seem to have quite figured out how best to proceed. Each of the three forms of PR described above is marked by inefficiency, confusion, and disorganization. Arguably, no collaboration has truly embraced the communication potential of the digital and social media. Few collaborations have used social media platforms, and those that have, have done so almost exclusively to distribute information rather than achieve other PR goals (Su et al, 2017). Although it is understandable that collaborations look to institutional communication offices for help with public relations, these offices seem more concerned with supporting their home organizations than collaborations. While these two goals might align, arguably, collaborations would be better served by working with communication professionals who can make collaborations their first priority.

That being said, the collaborations' communication shortfalls should be contextualized by the recognition that producing *timely* public facts about their ongoing research represents an alternate knowledge project for collaborations. While physicists have worked with journalists and popularizers since nearly the beginning of physics itself (Burnham, 1987), choosing to actively control public messaging represents a notable departure. As might be expected, this shift is progressing gradually. Indeed, there remain social norms *against* aggressive public communication efforts. Across interviews, physicists both expressed hesitation about being seen as spending too much time on public communication and narrated cautionary tales of physicists ostracized for de-prioritizing research in favor of public communication. Yet those norms are changing. Although not technically part of the sample/subject of this chapter, a particle physicist interviewed for another project, who belongs to a neutrino experiment, started a twitter feed from the perspective of the *instrument* in the experiment. He recently brought a small model of the instrument with him on a trip to Russia, taking and then posting pictures of the model in front of notable landmarks.[30]

While this chapter has also shown how information flows are mediated through the practices of public communication, each strategy discussed here demonstrates a different way in which circulating reference can go *wrong*. First, in using Twitter, collaborations are heavily constrained in their ability to produce representations that preserve key relationships while opening up their findings for new audiences and meanings. Indeed, Twitter itself seems to facilitate the deconstruction of content: requiring users to strip out ideas, phrases, quotes, or plots, without providing a means of resituating them in any coherent way. This is exacerbated when LUX combined these material constraints with a strategic—or perhaps duplicitous—communications approach that downplays negative results in order to better promote the collaboration.

Second, collaborations have good reason to work with their institutional members to distribute press releases: each institution can offer access to local networks and personal relationships with journalists. However, as offices have professionalized (see Chapter 5), they have become savvier about advancing their own interests (Bucchi & Bauer, 2007; Borchelt and Nielsen, 2014). As a result, in order to encourage institutional members to help distribute releases, they are allowed to *rewrite* content as they see fit. As shown above, this often entails selecting key details, lines, or quotations, and reframing them in ways that better support their own goals. In the end, it is the complex intersection between the

---

[30] @theLeadNube

changing material realities of the science media system and social shifts in press offices that here deforms information flows.

Third, CDMS more or less fell into holding two simultaneous press conferences. However, they seem to have been unprepared for how doing so would be interpreted. The collaboration already had a somewhat ambiguous result; the swirling rumors ahead of the release only helped spread confusion. Here, it was the lack of communication *skill* that helped fracture information flows about the release.

Thanks in part to changes in science journalism (see Chapter 7), public relations is increasingly influential in journalistic coverage (Allan, 2011; Autzen, 2014). As science journalists are required to turn around more and more stories in less and less time (Schäfer, 2017), they often look to press releases and institutional stories for content. There is reason to suspect that diversity in press releases therefore helps engender diversity in news coverage. On one hand this diversity might be considered positive, helping to show different components, actors, and aspects of experiments. On the other, it could be helping to produce a confusing landscape of slightly different treatments of a single release. While this project does not explore audiences in detail, future research will look at how audiences deal with encountering multiple news stories about a single topic, all with slight variations.

One possible scenario is that audiences are forced to work to try and fit together these diverse pieces into a coherent narrative. There is still a great deal that we do not know about how audiences react to and interpret multiple articles about the same subject, each with slightly different framing. This is made all the more complicated by the fact that the readers might not encounter these multiple articles at the same time, but rather over the course of days. Do readers pay attention to duplicates? Are they troubled by slightly different frames? Far more research has considered the ideological fragmentation of news than other forms of news heterogeneity. Indeed, journalism studies scholars have recently been more attentive to news homogeneity and organizational isomorphism (Boczkowski, 2010). These discussions don't usually account for the *subtle* variations in articles about the same topic that arise as journalists must attempt to distinguish their story from others. Far more work is needed to understand if these small variations help produce a panoramic perspective (Hepp, 2013), or undercut news authority (Carlson, 2017).

CHAPTER 5
PARTICLE PHYSICS COMMUNICATION: FIELDS IN *INTERACTION*

Introduction

As observed in the previous chapter, national laboratories have become an important and influential intermediary in the production and flow of public information about science. Very little research, however, has specifically investigated the developing communication functions at national laboratories (for exceptions see Trench, 2007; Dorey, 2016). The next two chapters consider different moments, initiatives, and trends in the recent history of national laboratory communication offices. Together, these chapters provide needed insight into how national laboratories have become influential mediators of public science communication, injecting difference into public science information flows.

Over the past several decades, public communication at national laboratories has undergone notable changes. What was once a poorly organized, ad hoc effort, mostly dedicated to giving laboratory tours and often forced upon researchers at the end of their careers, has become increasingly professionalized across the world (Trench, 2007). Laboratories have increasingly hired former journalist or PIOs, adopted standard communication practices, and collaborated with laboratories. Importantly, these changes mean that national laboratories are increasingly enmeshed in mediating public information about new scientific research. While a handful of scholars have acknowledged this shift (Trench, 2007; Nelkin, 1995; Borchelt & Nielsen, 2014), there has yet to be an in-depth, historically situated discussion of these changes at national laboratories.

To tell the story of how national laboratories have come to insert themselves in flows of public science, this chapter offers a case study that tracks *one* organizational initiative, the InterAction Collaboration. Begun at the end of 2001, this organization has not only played a key role in professionalizing national laboratory communication practices, but has been instrumental in creating what Fligstein and McAdam (2012) would identify as a wider strategic action field of particle physics communication. As a "meso-level social order" (2012: p. 3), this field of particle physics communication has developed a set of standardized practices, norms, and perhaps most importantly, meanings, about the value of the public communication of science. While this one collaboration does not exhaust particle physics communication, it has been deeply influential in establishing the field. This chapter follows the InterAction Collaboration as a way to understand the emergence of the field of particle physics communication, situate the wider professionalization of national laboratory communication offices, and trace the development of a new mediator of flows of public information about science.

Providing one of the first efforts to bring strategic action fields to science communication, this chapter demonstrates how the field of particle physics communication has consistently been influenced by, entangled with, and related to a number of "distal" and "proximate fields" (Fligstein & McAdam, 2012), including science journalism, particle physics, and science policy. More broadly, this suggests that understanding national laboratory communication offices requires attending to this wider context while recognizing science communication is best thought of as an "ecosystem" defined by "heterogeneity and multiplicity" (Davies & Horst, 2016: p. 5).

This chapter also demonstrates the central role that "meaning projects" (Fligstein and McAdam, 2012: p. 44) have played in the development of this field. The emergence of the wider field of particle physics communication has gone hand-in-hand with a new articulation of science communication as *supporting the wider field of particle physics*. While individual communication offices remain committed to advancing their own organizational best interests, part of the collaboration's influence has been to provide a collective goal and meaning to their work. Simultaneously, this chapter demonstrates that although the collaboration was first conceptualized in terms of aiding the field of particle physics, it took a re-articulation of that mission by Petra Folkerts following 9/11 in terms of peaceful international collaboration for the collaboration to actually begin.

As it tracks the emergence of a new field and a new mediator of science communication, this chapter ultimately demonstrates the ways that changes in social fields can mediate and modulate information flows about public science.

Literature Review

National Laboratory Communication

After the end of World War II, the newly created U.S. Atomic Energy Commission took over the nascent national laboratory system, expanding existing laboratories and founding others (Hewlett & Hall, 1989). While many of these labs had some sort of public communication, information, or affairs offices they were often understaffed. Lab administrators

> would get some sort of physicist at the end of their career and say okay you're now in charge of communication, and usually they were pretty clueless and adopted this mentality of being very careful, never taking any risks (N. Calder, personal communication, 8/29/2016).

Even so, these offices mostly devoted their time to organizing interviews between journalists and researchers, responding to information requests about the laboratories, and organizing and leading tours for laboratory visitors (Dunwoody & Ryan, 1983; Fermilab, 1980: p. 40; J. Garberson, personal communication, 5/10/2017). Offices also published employee newsletters, which in some instances date back to the beginnings of labs themselves. For example, The *Bulletin* at Brookhaven National Laboratory began in 1947, the year of the lab's founding. The *Village Crier* began just two years after the founding of the National Accelerator Laboratory, which would be renamed Fermilab a few years later. Originally, these publications were focused on providing organizational news and information.[31]

Some publication offices, which for many laboratories were distinct from the public affairs office, also routinely published research-focused technical publications, such as the *Energy and Technology Review* at Lawrence Livermore National Lab, the *Fermilab Report*, or Berkeley National Laboratory's *LBL Newsmagazine*, which became the *Research Review* in 1985. Generally speaking,

---

[31] In fact, the first issue of The *Bulletin* was published untitled, because, "The responsibility for naming an employees' magazine should rest with employees as a whole," (June 15 1947) and the editors asked readers to send in suggestions.

these publications were targeted at researchers in the laboratory, and published articles written by researchers about their own work.

Professionalization in Context

For decades following the second world war, scholars, politicians, and policy makers had argued that increasing the public understanding of science would provide broad social benefit, including helping to maintain a supply of scientists and funding for the cold war (Gregory and Miller, 2001: p. 4). However, in the mid 1980s, there emerged a renewed interest in addressing what was seen as notable gap in the public knowledge about science (Bodmer et al., 1985). As Gregory and Miller begin their book on this movement,

> In the recent past, many scientists looked at involvement in the popularization of science as something that might damage their career; now, they are being told by the great and the good of science hat they have no less than a duty to communicate with the public about their work. There are even cash inducements, from agencies funding scientific research, for scientific to popularize science (2001: p. 1).

A key component of this push involved a shift from a narrow concern with "public deficit" of *knowledge* (Wynne, 1992) to one that also recognized (a deficit in) attitudes toward science (Bodmer et al., 1985; Raza & Bauer, 2009). This new approach acknowledged that simply supplying scientific knowledge could not, on its own, reliably secure public support for science. Instead, more active efforts to change attitudes and ideas about science were needed—the sort of strategic communication practices that could be supplied by professional communicators.

These shifts in the value and strategy of public communication of science occurred amid changes in the broader political and cultural dimensions of national scientific research. The shift to addressing public "attitudes" in addition to public knowledge came, in part, as a result of declining public trust and support for science and technological research (Wynne, 2006). Although arguably part of a radical reshaping of public knowledge practices (Latour, 2007), this declining trust was also rooted in a series of public events including the publishing of Rachel Carson's *Silent Spring* in 1962, American failure in Vietnam in the early 1970s, increasing skepticism about and opposition to nuclear weapons and energy (see also Ziman, 1991: p. 99), and perhaps most importantly, the Three-Mile Island disaster in 1979 (J. Garberson, personal communication, 5/10/2017).

Similarly, in the beginning of the 1980s, national politics entered National Laboratory management in a notable way. After Carter began the Department of Energy (DOE) in 1977, he consolidated the work of several different government agencies, including that of the Energy Research and Development Administration, which had taken over the running of most of the national laboratories from the Atomic Energy Commission several years earlier (Fehner & Hall, 1994). A few years later, Reagan, who saw the large new federal agency as a prime example of government bloat, campaigned on shutting down the DOE, something he tried to do in the first few years of his presidency (see Raines, 12/17/1981). Reagan's ability to do so, however, was stymied by congressional opposition (Grier, 1/4/1983).

Reagan's antagonism toward the federal science administration, the tightening of federal research budgets, and the declining public trust in (federal) science, all helped push communication offices to adopt a more strategic and defensive set of communication strategies. In her influential 1995 book *Selling Science*, Dorothy Nelkin observes that starting in the late 1970s and early 1980s there was a broader professionalization of public information offices at national laboratories. Laboratories began hiring communication professionals to lead and staff communication offices while increasingly adopting communication practices common in other fields (see also Borchelt & Nielsen, 2014). This professionalization also involved a "shift from passive dispensation of information upon request to more assertive public relations" (Traweek, 1988: p. 22). One of the key changes was the increasing emphasis on producing press releases about notable organizational and research events and accomplishments (Autzen, 2014). Originally, these releases were mailed, on laboratory letterhead, directly to newspaper science editors, in the hope of encouraging public directed stories (J. Garberson, personal communication, 5/10/2017). These strategies also adopted a pragmatic ethos or culture of promotional communication. Neil Calder, who was deeply involved in this professionalization at laboratories around the world, was upfront about the ultimate mission of communication work:

> no bones about this, I have no interest in informing the general public about how wonderful science is. I really don't care whether young kids, I'm being fairly cynical here, whether young kids like science, and STEM becomes more popular in schools. I really don't see that as my job: I work for organizations, whether they are CERN or Stanford [SLAC] or OIST here, and my job is to gain respect and support for the organization I'm working for, to get funding (personal communication, 8/29/2016).

Even while we understand in broad terms the shift that has occurred in national laboratory communication offices, we still lack a more fine-grained account of professionalization. Existing scholarship treats this professionalization more as an aside than as a main object of analysis. As scientific institutions become more and more influential in public science communication, is it essential that we have a clear understanding of how they have developed and how they currently function.

Methods and Theoretical Framework

In order to better understand how professionalization of national laboratory communication offices has proceeded, and what it has meant for way offices mediate public communication of science, this chapter adopts a case study approach. Across interviews, the InterAction Collaboration was identified as a key organizational actor within professionalization. As such, it serves as a "critical case," (Flyvberg, 2006), holding "strategic importance in relation to the general problem" (p. 229). Understanding more about the collaboration therefore can provide useful insight into the larger phenomenon.

This case study consolidates a variety of data. First, it draws on a set of 23 semi-structured interviews with PIOs at national laboratories, including 7 who are now or have been directly affiliated with the InterAction Collaboration. Second, it draws on a range of articles and texts both produced by and about the collaboration, including archived peer review reports (see Appendix A).

Strategic Action Fields

Social movement scholars Neil Fligstein and Doug McAdam have offered a variation of field theory based on "strategic action fields" which are

> constructed meso-level social order[s] in which actors (who can be individual or collective) are attuned to and interact with one another on the basis of shared (which is not to say consensual) understandings about the purposes of the field, relationships to others in the field (including who has power and why), and the rules governing legitimate action in the field (Fligstein & McAdam, 2012: p. 9).

While Bourdieu (e.g. 1983, 2013) famously described fields as large and somewhat autonomous areas of social life, Fligstein and McAdam see strategic action fields as far smaller, more localized, and deeply nested within and entangled with other adjacent fields. Perhaps most importantly, fields are composed of actors who

> are constantly jockeying for position. Challengers and incumbents are undertaking strategic actions to sustain and slightly improve their current position in the strategic action field, finding new accommodations with other groups, and working to reduce their resource dependencies on both groups within the field and outside of the field (p. 113).

At the same time, Fligstein and McAdam emphasize the "crucial importance of the 'existential dimension" of fields and field settlement, "the cultural creativity of the meaning project that grounds the field" (2012: p. 92).

Strategic Action Fields attempt to answer what Fligstein and McAdam recognize as a persistent problem across prior scholarship on fields: understanding how fields *change*. While other accounts focus more on field stability, their approach combines two existing perspectives: that fields change mostly as a result of exogenous forces from outside, and conversely that they do so through endogenous forces within (pp. 83-4). Fligstein and McAdam "argue that stability is relative and even when achieved is the result of actors working very hard to reproduce their local social order" (p. 7). Their point is to unsettle our assumptions about the stability of fields—to see that entropy rather than inertia often guides fields.

SAFs provide a useful analytic for describing the ways that the InterAction Collaboration has helped pull together national laboratories that specialize in particle physics while building a broader set of best practices, norms, and expectations about how communication should be done. Therefore, the following case study approaches the field of particle physics communication through this analytic. Adopting two key moments in the life course of fields, this project considers first how the field initially *emerged* and then how it has been *stabilized.*

Case Study: The InterAction Collaboration

Field Emergence

The Context of Emergence The emergence of strategic action fields “is best characterized as a social movement process” (Fligstein, 2013: p. 44). As such, SAF require “a political opportunity” amid ongoing dynamics between incumbents and challengers, while also hinging on “framing.” Frames, are “a set of concepts and theoretical perspectives that organize experiences and guide the actions of individuals, groups and societies” (Goffman 1974: p. 21, cited by Fligstein, 2013: p. 45). Frames offer news ways for (potential) field members to see the world and redefine the value of collective action. Broadly, this recognition provides a useful theoretical lens to study the emergence of the field of particle physics communication.

As individual laboratories began hiring more professional communicators and began adopting more professional strategic communication practices, the relationships amongst laboratories remained somewhat contentious. In a 2007 journal article, Judith Jackson and Neil Calder observe

> Until 2001, each laboratory communicated as an independent entity, apparently oblivious to, and, in the worst cases, at cross-purpose with, other laboratories engaged in this worldwide scientific endeavor. Competitiveness, suspicion, and one-upmanship characterized the policy and practice of particle physics communication" (Jackson & Calder, 2007: p. 448).

Similarly, in an interview Calder observed that laboratories, persisted

> as independent kingdoms, essentially CERN was a rival and competitor, and they all loved this, taking the piss out of each other… it was really quite childish, gang sort of stuff, particle physicists can behave in an extraordinarily childish way, so we were in competition (N. Calder, personal communication, 8/29/2016).

While it is possible that Jackson and Calder are overselling the fractiousness to better praise the later success of their collaboration, other informants also referenced conflicts amongst different organizations. For example, Ziba Mahdavi is the communication director at the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), an organization that links together SLAC National Accelerator Laboratory and Stanford University. She explained that from its founding in 2003, KIPAC was meant to bridge the two organizations which have had a bad relationship "since the moment that SLAC opened its doors" (Z. Mahdavi, personal communication, 6/29/2016). Mahdavi ascribes this conflict not only to academic competition, but also more to a radical cultural difference between a university that advances open science, and a national laboratory heavily concerned with security.

In 1996 Neil Calder, the communication director at CERN, asserted incorrectly in a lab publication that CERN was the first laboratory to produce large quantities of W bosons, a type of elementary particle. Judith Jackson, the communication director at Fermilab, contacted Calder to inform him that, in fact, her laboratory had beaten CERN to the punch. When, as a result, Jackson invited Calder to visit Fermilab, the two "got on very well and determined that Fermilab and CERN would work together to make sure that there were no more stupid mistakes," (Neil Calder, quoted in Wisniewki, 2011, np). Although the InterAction Collaboration wouldn't formally begin for another five years, according to Calder and Jackson, this event was the beginning.

Judith Jackson soon began to reach out to other communication directors at national laboratories. In an interview, she remembered that these conversations were facilitated by a series of trips she took with her husband, a particle physicist also employed at Fermilab (J. Jackson, personal communication, 7/14/2016). Accompanying her husband to conferences and collaboration meetings provided Jackson the chance to meet counterparts at other national laboratories around the world. Most notably, she met Petra Folkerts, the communication director at the German laboratory Deutsches Elektronen-Synchrotron (DESY), who along with Jackson and Calder would help establish the collaboration. Meeting these other communication directors, Jackson realized that

> we were all more or less trying to do the same thing, but we were often doing it at cross purposes, not only all having to independently invent how to do this stuff, but so often doing communication that was really not recognizing the international nature and the need that for us all to work as a single international community... rather than competing and reinventing the wheel each time at our own laboratories why not pool our resources, pool our images, pool our metaphors, pool our insights, our experiences, and communicate as the international community that we actually are (J. Jackson, personal communication, 7/14/2016).

Jackson saw that even though national laboratories oversee a wide range of scientific research, it would be possible to pull together certain communication personnel into a distinct field narrowly dedicated to particle physics communication. Rather than competing with one another and having to independently innovate communication strategies and materials, coordination could help improve the efficiency and quality of public communication. This is to say, Jackson recognized the strategic advantage of cooperation amongst laboratories—the benefits that would accrue through field emergence.

Yet beyond simply providing a pool of common resources, Jackson recognized a way to *frame* cooperation to allow all laboratories to work together to support the broader field of particle physics itself. Several years later, Jackson and Calder explained this point:

> The goal of particle physics communication in the United States is to strengthen support for particle physics to ensure a strong and healthy future for the field, so that the nation can continue in its historic role as a leader in this fundamental field of science…(2007, p. 444).

This is, in a sense, a radical shift from the narrow focus on supporting one's own institutional best interest referenced above. This goal, however, goes hand-in-hand with consolidating different laboratories into a field of particle physics communication: a collective goal for a collective organization. More, this frame furnished a new *meaning* to particle physics communication. Instead of only being about supporting a single organization, it became about supporting an entire (sub)discipline of physics. As noted above, for Fligstein and McAdam, meaning, or "the cultural creativity of the meaning project" (2012: p. 92) is central to the formation of strategic action fields. "As much as anything, field settlements embody the seemingly unique human capacity for collaborative symbolic activity and need for meaning and membership" (p. 92).

Of course, while cooperation among institutions might serve a (public) good in advancing particle physics, given the specifics of federal funding, working together also provides a distinct funding advantage.

> In the US every single year it's a new budget, so every single year, there's not a moment in the day when something isn't happening in Washington or somewhere that determines what your laboratories budget, or your discipline's budget or your experiment's budget is going to be next year. And you have to never take your eye off that ball because its all in the margins, it's a billion dollars roughly, or at times about a billion dollars a year, us funding for particle physics, but 200 million here and there really makes a huge difference, the dark matter people know that really well" (J. Jackson, personal communication, 7/14/2016).

While different labs can be awarded more or less funding in a given year, in some sense, a rising tide lifts all boats. The founders of the collaboration realized that by advocating for particle physics as a whole, not only would laboratories benefit, but so would the science.

Building the Field As noted above, Fligstein and McAdam assert that SAFs are deeply enmeshed within other, proximate fields. These nearby fields not only provide useful resources to emerging SAF, they can provide models for how fields should operate. From the beginning, what would become the InterAction collaboration was explicitly modeled on physics research collaborations (J. Jackson, personal communication, 7/14/2016). Over the past several decades, multi-institution collaborations have become a key organizational actor in physics research (Shrum, et al, 2007). Communication directors at national laboratories were therefore extremely familiar with these organizations. One early document suggested,

> Just as collaboration is crucial to the future of particle physics research, it is equally important in the area of particle physics communication. It strengthens the current worldwide program by fostering the efficient use of resources, reducing parallel efforts and making the most of communication opportunities. and [sic] it is critical for the future" (Jackson, 2003).

Particle physics collaborations also provided a model of how to draw the boundaries of a field distributed across space. Collaborations in physics pull members from organizations, mainly universities and national laboratories, across the world. Indeed, in some ways, institutional home is less important than position within the collaboration for many physicists. Even as they change jobs, many physicists may retain their membership in collaborations. The InterAction collaboration attempted to similarly deemphasize individual laboratories to support the larger field of particle physics by creating an allied field of particle physics communication.

While Jackson indicated that many of the other communication officers she spoke to were intrigued by the idea of the collaboration, according to the way the group now commonly narrates its founding story, it took the terrorist attacks of September 11th, 2001 to actually catalyze the beginning of the group. On September 12th, 2001, Petra Folkerts sent an email, which was reprinted in an article several years later

> From my point of view NOW it's absolutely important that we HEP [High Energy Particle] Outreach people [a]round the world will meet as soon as possible in the United States. Not only to figure out how to help international particle physics stay alive but also how we, in our field of activity, can set visible footprints for the significance of

> peaceful collaboration across all borders. (quoted in Jackson & Calder, 2007: p. 448).

In this telling, the "exogenous shock" (Fligstein & McAdam, 2012: p. 20) of 9/11 helped to mobilize the formation of the field by providing the opportunity for an "entrepreneur" to reframe the *meaning* of collaboration. While initially the group was framed in terms of supporting particle physics science, following 9/11, the group was reframed in terms of the "peaceful collaboration across all borders."

It took a few more months, but on Saint Nicholas Day, 2001, the communication directors from six national laboratories around the world[32] met in Hamburg, Germany to formally initiate the InterAction Collaboration.

Stabilizing the Field

Key Initiatives of the InterAction Collaboration Strategic action fields were first developed in order to explain better how social orders *change* (Fligstein & McAdam, 2012: p. 3). In offering an account of change that involves both external forces and internal processes, Fligstein and McAdam ultimately argue, "stability is relative and even when achieved is the result of actors working very hard to reproduce their local social order" (p. 7). This recognition highlights the work that the InterAction Collaboration has done over past 16 years to both maintain the organization and help to homogenize and professionalize the nascent field of particle physics communication.

Over the past 16 years, the InterAction Collaboration, which has grown to include and link more than 20 different national laboratories across the world, has

---

[32] Fermilab, CERN, SLAC, Gran Sasso, DESY, Brookhaven National Laboratory

pursued a number of initiatives. Perhaps most notably, the collaboration has held biannual meetings at one of its member institutions. These meetings allow members to share ideas and experiences and to talk "about what's happening in the world of particle physics. We talk about how to promote it. And so it's a way for me to learn about what's happening in other experiments around the world" (C. Walter, personal communication, 6/8/2016). Keeping members apprised of important physics experiments and communication projects plays an important role in turning a group of individuals into a cohesive field—one in which members can coordinate projects and strategies.

These meetings also help to coordinate materials and practices. According to a presentation given in 2003 by Folkerts and Jackson, collaboration meetings have three main goals, "Develop a common science message; speak with one voice* (*recognizing need for scientific competition and different points of view); Share resources" (EPOG, 2003: p. 7).

Informants also stressed the importance of the social aspects of these meetings in helping to draw members into a cohesive field:

> I think one of the things they realized, which I have really appreciated having come into this job is that in order for us to communicate together in the atmosphere of trust we have to know each other, and so that is one of the reasons that we actually physically gather, not everybody comes to every meeting, but the majority of people try to come to one meeting a year to get to know each other, and work on joint projects, like the website that you saw, and things like that" (K. Jurkewicz, personal communication 5/6/2016)

Jackson also asserted the importance of evening social events:

> And what we quickly realized was those collaboration dinners—there would usually be two collaboration dinners, really were an important aspect of this whole thing. And that eating and drinking together as a

> collaboration was vital to making the collaboration work, they always are, in any collaboration, scientific collaboration or whatever (J. Jackson, personal communication, 7/14/2016).

Since 2003, the collaboration has also run a website, Interactions.org, that was originally designed as a "new communication resource for particle physics around the world," (Jackson, 2013b: np). Currently, the website defines itself this way:

> The Interactions Collaboration seeks to support the international science of particle physics and to set visible footprints for peaceful collaboration across all borders.
> The Interactions.org website is designed to serve as central resource for information about particle physics, including press releases, articles, news, event listings and images. (It seems fitting that the World Wide Web, which came from particle physics, should have a role in supporting the science that created it.) (Interactions, 2018)

The website provides a range of materials about both science communication and particle physics. For example, it hosts a "Dark Matter Hub," which includes a brief introduction about dark matter before listing many of the major direct and indirect detection experiments. For each experiment, the feature includes a link to the collaboration website, along with a short paragraph describing the experiment. Katie Jurkewicz, the current communication director at Fermilab explained that the dark matter hub was meant to help fill some of the "gaps in the information that's online…before we made that dark matter hub there was not really a place where you could go and get a comprehensive, somewhat easy to understand list of all the dark matter experiments" (K. Jurkewicz, personal communication 5/6/2016).

The website also includes the "Interactions NewsWire," which aggregates and distributes press releases and institutional news stories produced by member institutions. Currently, it is possible to search for this content from member institutions directly on the website. Also, the website periodically sends out emails containing important press releases from member organizations. In an early discussion of the collaboration published on the website, Jackson observed that the InterAction Collaboration's newswire has a wide international audience of "reporters, representatives of funding agencies, government officials and members of the particle physics community" (Jackson, 2003b: np).

Beyond the website, the collaboration has played a role in the founding and running of *Symmetry Magazine*. Technically, *Symmetry Magazine* is a joint venture between Fermilab and SLAC. However, it was the strong professional relationship between Judith Jackson at Fermilab and Neil Calder (who in the early 2000s moved from CERN to SLAC) that helped propel the creation of the magazine (K. Jepsen, personal communication, 3/12/2016). The next chapter provides a more detailed account of the magazine. However, the publication, which is explicitly modeled as a public-directed news magazine about particle physics, has remained deeply intertwined with the InterAction Collaboration, sharing personnel, content, and practices. Importantly*, Symmetry Magazine* serves as a key touchstone for the nascent field of particle physics communication. In many ways, it embodies the vision of the InterAction collaboration, providing accessible, strategic communication meant to advance the field of particle physics.

Finally, and perhaps most importantly, the group conducts "Peer Reviews" of communication departments at allied organization. These are formal reviews of an organization's communication department and activities. They employ the Lehman

Review Format a method of organizational review developed by the DOE's office of Science. When a member institution requests an audit, the collaboration forms a committee made up of representatives from a range of organizations. The committee completes a site visit and then produces a final report containing a list of recommendations for improvement.

These reviews serve as a way for the collaboration to physically distribute a set of standardized communication practices and strategies across the field. The collaboration website has archived a set of six peer review reports. These reports provide insight into the specific practices that have come to define the field of particle physics communication.

Peer Review Recommendations

One of the most common recommendations made in reports is to produce "a single communications strategy" (DESY, 2015 p. 4) or a "strategic communications plan" (FERMILAB, 2014: p. 1) that is geared toward the laboratory's "vision" (DESY, 2015: p. 4) or mission, and that articulates very clear goals (TRIUMF, 2009: p. 19). Reports also stress that communication strategies should identify clear outcomes, target audiences, and metrics by which to assess success.

Importantly, there is some variation in the specific goals that reviews suggest communication strategies should pursue. For DESY, a German laboratory, the collaboration suggested:

> Communications should re-allocate a significant percentage of effort from "traditional" science communications to demonstrating to decision makers (and industry) the "impact" of the lab's science, technology and skills (DESY, 2015: p. 9).

In contrast, another review suggested that CERN should do a better job of “utiliz[ing] the power of the Web to reach the general public” (CERN, 2010: p. 9). And in contrast to both, the collaboration exhorted Fermilab to prioritize “communicating the P5 vision, and the lab’s role within it, to the widest possible group of stakeholders” (Fermilab, 2014: p. 14). The Particle Physics Prioritization Panel (P5) is an advisory committee that makes recommendations to congress about field funding priorities. The DESY review helps provide some guide to these differences: “The new communications strategy should be based on a rigorous and ruthless prioritization of target audiences, which the panel acknowledges will firstly require research to fully understand the laboratory’s audiences” (DESY, 2015: p. 7)—in other words, communication should be intentional, but the review committee is not necessarily going to supply what that intention *is*.

Many reviews have suggested that laboratories should dedicate more effort to supporting their own *brand*, either by “developing a short, concise tagline that expresses the lab vision (Triumf, 2009: p. 7), or by developing “a visual identity with graphic standards” (Princeton, 2010: p. 1). With a clear brand, communicators were then encouraged to work to keep their laboratories in the “political spotlight” by using “strategic placement of promotional ads and free-space opinion articles in the local newspapers” (Triumf, 2009: p. 5), or by “Promot[ing] CERN science expertise and be[ing] able to provide experts to help explain non-CERN scientific announcements or general news that have a science connection” (CERN, 2010: p. 11).

Review committees also repeatedly suggested that laboratories consolidate all communication activities across departments “in one physical space” (TRIUMP, 2009: p. 19). As noted above, historically, communication activities have been spread out amongst many different offices at national laboratories, such as the “public information office” and “publication office” (Fermilab, 1980). When Judith Jackson took over as the communication director at Fermilab in 1995, she oversaw a consolidation of communication into a “public affairs office” (Fermilab, 1995: p. 33). Similarly, reviews have consistently suggested that laboratories: “bring together in a single physical location all of the people in the Communication Group, like a newsroom” (CERN, 2010: p. 11; see also Chapter 6).

Finally, and perhaps most notably, reviews routinely suggested that laboratories prioritize and improve their digital communication initiatives. This ranges from improving websites, to producing “constantly evolving web content” (TRIUMP, 2009: p. 9), to “Develop[ing] social media guidelines, and offer[ing] social media training” (Fermilab, 2014: p. 18). Yet, despite these frequent appeals to improve digital communication, reviews neither agreed on the purpose of improving digital communication, nor on the specific means of doing so. For DESY, improved digital communication allows “a wider, more measureable audience to appreciate the excellent science of the laboratory and its benefits to society” (DESY, 2015: p. 19). For CERN, it would “strengthen the brand image of CERN” (2010: p. 9), while for TRIUMF it would “provide new opportunities for publishing headline news and information” (2009: p. 7), while for CERN it would help “reach the general public” (CERN, 2010: p. 9). Perhaps more notably, reviews were almost entirely silent on *how* laboratories should improve their digital communications. Reviews have little to say about what a digital strategy, a social media plan, or even a website should include.

Discussion and Conclusion

This chapter has tracked the emergence and development of the InterAction Collaboration in order to better understand how professionalization has helped position national laboratory communication offices as important mediators of public science. It details how the group grew out of larger changes occurring in the 1980s and 1990s, before helping to found and shape a new *field* of particle physics communication at national laboratories. It took the work of institutional entrepreneurs (Dimaggio, 1988; Fligstein and McAdam, 2012: p. 83) like Judith Jackson, Neil Calder, and Petra Folkerts to recognize the value in pulling together people and practices from across national laboratories into a structured organization. However, since then, the collaboration has engaged in a range of efforts to further develop the field. This case study provides needed detail to what had been a skeletal understanding of professionalization in existing literature.

More broadly, this chapter is also one of the first efforts to bring Fligstein and McAdam's work on strategic action fields to the study of science communication. Two elements of their work stand out as useful in both explaining the development of the field and contributing more broadly to our understanding of science communication. First, particle physics communication remains deeply tied to a series of "proximate" and "distal fields." The InterAction Collaboration was explicitly modeled on collaborations in particle physics, it has consistently drawn practices and personnel from corporate PR, and as will be discussed in more detail in the following chapter, from journalism. Recognizing this embeddedness asserts the ways in which making sense of any one strategic action fields requires attending to the broader social (field) context in which it is situated. Fligstein and McAdam operationalize this context as the universe of other strategic action fields, each with its own meanings, cultures, practices, and actors.

Second, the collaboration and the wider field described here offer a new meaning for public science communication: supporting the wider field of particle physics. Recognizing the role that the meaning of science communication plays in organizational dynamics opens up new avenues for research. However, both the diverse meanings and goals discussed in peer review documents, and the *failure* of the collaboration to initially form, suggest that it took a second re-articulation following 9/11 for both to actually emerge. 9/11 provided an opportunity to frame and define the collaboration in terms of peaceful international collaboration—a meaning for the group that resonated with the broader cultural moment.

CHAPTER 6
THE JOURNALIZATION OF U.S. NATIONAL LABORATORIES

Introduction

It has recently become commonplace to recognize that, thanks to digital and social media, scientists are increasingly communicating directly to lay publics (e.g. McKnight & Coronel, 2017; H. D. Peters, 2013). Although there is strong empirical support for this, two caveats should be noted: first, there is, in fact, a long history of scientists communicating their research directly to lay publics (Perrault, 2013; Broks, 2007; Burnham, 1987), and second, scientific research *organizations* have become deeply involved in mediating this "direct" communication between scientists and lay publics. National laboratories, private research firms, and research universities have been developing active communication and/or media offices that are now deeply involved in public outreach and communication (Bauer & Bucchi, 2007). Understanding both the changing relationships between scientists and publics and recent changes in the larger field of science communication therefore requires investigating the roles these institutions are playing.

U.S. national laboratories have long been at the forefront of research across scientific disciplines (Westfall, 2008). Every national laboratory has a public information, communication, publication, or media relations office; these offices have served as active intermediaries in the public communication of science for decades (Fermilab, 1980), even as they have received far less scholarly attention than other organizations in science communication (e.g. Lohwater & Storksdieck, 2017; Su et al., 2017).

However, over the last several decades, national laboratories have been refashioning themselves in the image of journalistic outlets. Not only have offices been hiring more journalists, but they have been adopting journalistic structures and practices, including indexing stories to timely news pegs, using an inverted pyramid structure, holding regular editorial meetings—evening publishing corrections when necessary. Perhaps most notably, they have begun producing journalistic-style articles about *research*. Not only are these articles being consumed directly by laypersons, but they are also increasingly being rewritten and/or reprinted by news outlets (Göpfert, 2008; Chapter 7). These changes insert national laboratories into flows of public information about science in new ways. Seen through the lens of the magnetologists model presented in Chapter 2, this *journalization* means that national laboratory communication offices are contributing to chains of representations about public science in new ways.

Employing a mixed-methods approach that combines semi-structured interviews with quantitative content analysis, genre textual analysis, and archival analysis, this chapter tells the story of the *journalization of* national laboratories communication offices. At heart, this is a story of how fields *change*. As such, this chapter investigates and interprets this shift through Fligstein and McAdam's strategic action fields (SAF) (2012). This recent variation of sociological field theory has been designed to address how social fields change over time. This framework helps identify some of the key forces that have propelled these changes at national laboratories. While field change for Fligstein and McAdam comes in part from "exogenous shocks" (p. 99), they recognize that change must also come from within, as "incumbents worry daily about how to maintain their advantage, and challengers search for and seek to exploit any 'cracks' they discern in the system. Constant adjustments are being made, and the field is always in some form of flux or negation" (p. 97). For national laboratories, this helps make clear that while the development of the Web brought a serious disruption to the field, this new technology first had to be articulated in terms of existing organizational dynamics and needs. In explicating the complexity of the Web's influence, this chapter provides needed insight into the role that technologies can play in field change. Arguably, much field theory has characterized technologies either as outside influences (Fligstein and McAdam, 2012), or as "little crystallized parts of habitus" (Sterne, 2003: p. 376). The Web in this case was a little bit of both: a disruptive force that exerted influence by changing the grounds of strategic action.

In a broader sense, this project tells a story of the changing relationship between two fields: science journalism and science communication. While many have noted the increasing influence that strategic communication has had on journalism through concepts like "churnalism," (Davies, 2009; Jackson & Moloney, 2016; Allan, 2011), this chapter tells the other half of that story. Even as journalists are increasingly adopting content from institutional sources, some of those institutional sources have been adopting aspects of journalism itself. While Powers (2016) has recently observed a similar dynamic playing out in international NGOs, this chapter is unique in recognizing that this is also happening in scientific research organizations. This shift, therefore, describes the birth of a new and new sort of mediator in the circulation of public information about new scientific research.

Literature Review

Recently, scholars of science communication have observed notable changes within scientific research practice, where there has been, "an increasing orientation of science toward media" (Rödder, 2008: p. 453). Scholars recognize this change in a range of phenomena, such as how scientists are increasingly holding press conferences and other media events (e.g. Hilgartner, 2012), adopting easily understandable and media-ready "promotional metaphors" (Nelkin, 1994) and explanations (Plesner, 2010), publishing scientific results in popular or public media *before* publication in academic journals (e.g. Weingart, 1998; Weingart, 2012), and appearing in media as celebrities (Weingart, 1998; Rödder, 2008; Hilgartner, 2012).

Fewer scholars have begun to address the public relations practices of scientific organizations (e.g. Lohwater & Storksdieck, 2017). Some have noted that many universities and research centers have dedicated communication offices (e.g. Peters et al., 2008; Rödder & Shaffer, 2010). Yet, most scholarship tends to consider PIOs as "bridges" (Lynch et al., 2009) or "mediators between scientists and journalists" (Dunwoody & Ryan, 1983; see also Ankney and Curtin, 2002: p. 232; Neklin, 1995; Gandy, 1980). Scholars have explicated this intermediary role of communication offices in a number of different ways. Some of the earliest scholarship considered the ways PIOs helped facilitate *personal* or *social* connections between scientists and journalists. Interestingly, Dunwoody and Ryan conclude that while scientists “generally seem to have positive feelings about” PIOs, scientists “perceive the public information office to play an almost nonexistent role in the scientists’ interactions with the press” (1983: p. 655).

Other scholars have studied PIOs’ meditating role in terms of producing media content—mostly press releases (Bauer & Bucchi, 2007). Some have observed that over the last several decades, press releases have become increasingly important in science journalism (Autzen, 2014; Rödder et al., 2012). Göpfert associates this with a broader weakening of science journalism, largely tied to economic troubles of the past decade and a half (2008). For others, the rising importance of press releases is tied to the easy and cheap distribution of press material through the Web (Trench, 2007; Riesch & Spiegelhalter, 2011: p. 62). Others have looked more directly at the content produced by PIOs, arguing it is *rhetorically* located in the middle between scientists and journalists (Lynch et al, 2014: p. 479).

Amid a discussion of the ways that the Internet and “electronic publishing” have reshaped science communication, Brian Trench briefly observes that communication offices

> have adopted a public communication model, that of journalism, in the distribution of information. ‘News’, or some close equivalent, is a standard feature on websites generally, and many scientific institutions have adopted a journalism style of presentation to disseminate information about new developments, even where their primary purpose seems to be providing information from professional sources to professional audiences (Trench, 2008: p. 191).

Supporting this claim, Trench observes that many websites of national labs and research centers “have News, Research News, Actualités, Updates or News and

Features directly at their home page, or easily accessible from that page" (p. 191). Trench's brief account, however, leaves many questions unanswered, such as what exactly does he mean by "journalism style?" Why has this shift occurred? Have these changes been associated with shifts in the structures and practices at communication offices? What exactly do these changes mean for broader understandings or theoretical models of science communication?

Theoretical Framework

Field Theory

Although it has not been widely employed in science communication, field theory provides a useful set of theoretical resources for investigating how press or communication offices have changed over the last several decades. Broadly speaking, field theories consider the relations amongst actors within stable meso-level social orders. In a recent chapter, Kluttz and Fligstein (2016) recognize three main articulations of field theory. For Bourdieu, fields constitute and ultimately replace society; he recognizes that "a differentiated society is not a seamless totality…but an ensemble of relatively autonomous spheres of 'play' that cannot be collapsed under an overall society logic, be it that of capitalism, modernity, or postmodernity" (Bourdieu & Wacquant, 1992: p. 16-17). Each sphere, or field, "consists of a set of objective, historical relations between positions anchored in certain forms of power (or capital)" (p. 16). Fields are not reified, bounded objects, but clusters of relations that gain structure through *habitus* "a system of lasting and transposable dispositions which, integrating past experiences, functions at every moment as a matrix of perceptions, appreciations and actions and makes possible the achievement of infinitely diversified tasks" (p. 18).

Second, the neo-institutional approach to "organizational fields" has been associated most strongly with DiMaggio and Powell (see 1991; 1983). Broadly, work in this area defines organizational fields as composed of "those organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products" (Dimaggio and Powell 1983: p. 148).

In a recent book, social movement scholars Neil Fligstein and Doug McAdam recognize, however, that both Bourdieusian and neo-institutionalist field theories do a better job of explaining the stasis of fields than how they change (2012). Fligstein and McAdam offer a version of field theory grounded in "strategic action fields," which are

> constructed mesolevel social order[s] in which actors (who can be individual or collective) are attuned to and interact with one another on the basis of shared (which is not to say consensual) understandings about the purposes of the field, relationships to others in the field (including who has power and why), and the rules governing legitimate action in the field (p. 9).

That is, compared to other field approaches, strategic action fields are smaller and more intertwined with adjacent fields.

Yet, perhaps most importantly, fields for Fligstein and McAdam, are defined by "strategic action," meaning that in fields "Contestation is endemic. Challengers are pushing the limits of the field in order to better their situation. New resources or opportunities may work to undermine some aspects of what allow incumbents to dominate" (Fligstein, 2013: p. 45).

Given this, Fligstein and McAdam offer a complex account of how fields change, one that combines two existing perspectives: that fields change mostly as a result of exogenous forces from outside, and conversely that they do so through endogenous forces within (p. 83-4). Fligstein and McAdam suggest that there are three types of external shocks or destabilizations that can lead to field change:

> (1) invasion by outside groups, (2) changes in fields upon which the strategic action field in question is dependent, and (3) those rare macroevents (e.g., war, depression) that serve to destabilize the broader social/political context in which the field is embedded (p. 99).

During these unsettled times, "entrepreneurs"—"skilled social actors who can form new identities, coalitions, and hierarchies—wield maximum influence" (p. 83). Yet,

> our theory also provides for constant, albeit piecemeal, change in stable fields. Here, the actors in strategic action fields are constantly jockeying for position. Challengers and incumbents are undertaking strategic actions to sustain and slightly improve their current position in the strategic action field, finding new accommodations with other groups, and working to reduce their resource dependencies on both groups within the field and outside of the field (p. 113).

In providing an account that acknowledges change is both from without and within simultaneously, strategic action fields provide a useful set of tools for investigating the factors that that led to national laboratory communication offices adopting structures, practices, and formats of journalism.

Methods

This chapter employs a mixed methods approach. First, twenty-two semi-structured interviews were held with current and former members of national laboratory communication offices, as well as with several PIOs at similar organizations. Interviews addressed current structures and practices as well as organizational histories of offices. Informants were mostly identified through by-lines on pieces of organizational communication or through online organizational charts. Some snowball sampling was employed to identify those recognized as deeply influential in particular national laboratories. The informants, who all agreed to be referred to by their real names, are listed below in Appendix A, Table A.1.

This project also involves a content analysis of a single publication, *Ferminews*, produced by Fermilab between 1978 and 2004. This represents the entirety of *FermiNews's* run under this name. From its beginning as the *Village Crier* in 1969, this publication was conceived as a source of organization news and information for lab employees. However, in 2004, the publication split into two, *Fermilab Today*, which continued to provide organizational information, and *Symmetry Magazine*, a self-described "news magazine" that covers research in the lab and the wider field of particle physics. Before the content analysis, a pilot study was undertaken of each issue in both the first and final years of the publication's run. These issues were inductively analyzed to produce a series of article types. Then, the first (and in some cases only) issue each month of the publication were collected across the whole run time of 26 years. This sample (N=329) was coded according to the categories inductively generated. Linear regressions were employed to characterize article frequency over time.

In addition, the content analysis was used to identify and select specific examples of different article types. A qualitative genre textual analysis was undertaken on the set of research-related articles, tracing "broad patterns within specific texts…[and] changes that occur in different genres and they assess what those changes may say about social and political issues in society" (B. Brennen, 2017: p. 215). Simultaneously, in order to better trace the history of communication offices, this project draws on a range of archival documents, including organizational memos, news stories, and laboratory annual reports. Please see Appendix A for a more detailed discussion of methods.

Findings

Fligstein and McAdam identify three distinct external forces that can facilitate field change: macroevents, changes in related fields, and invasion by outside groups. However, Fligstein and McAdam recognize that these "exogenous" forces act in concert with "endogenous" ones involving the ongoing strategic jockeying of field members to alter fields. This recognition helps highlight some of the key forces that have propelled the change in national laboratory communication offices.

Macroevent: The Web

The World Wide Web was born in a national laboratory. As has been told in detail elsewhere (e.g. Berners-Lee & Fishcetti, 2000), the Web was first developed at CERN by Tim Berners-Lee in 1989, in part to help facilitate data sharing amongst physics collaborators. Almost immediately, the Web spread from CERN to other national laboratories around the world.

A great deal has been written about the revolutionary influence the Web has had across areas of social life (e.g. Floridi, 2014; Castells, 2010). And while the Web clearly has altered the landscape of science communication at national laboratories and beyond (Trench, 2007; Su et al., 2017), its influence was neither immediate nor direct.

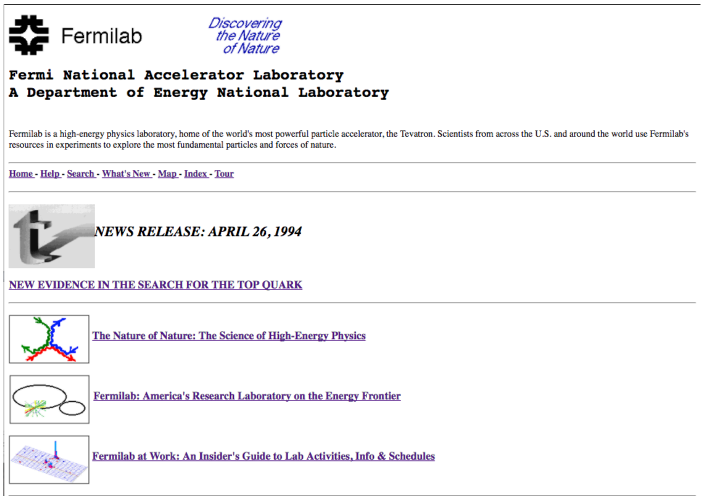
As physicists and other researchers at national laboratories embraced the Web, communication officers at those institutions slowly began to see some promise in the new technology. Yet rather than a radical disruption, initially, PIOs saw the Web as a useful means of optimizing existing communication efforts. Two brief stories highlight this point.

Before the Web came to Lawrence Berkeley Laboratory, Jeff Kahn, a PIO at the organization, had a series of conversations with two researchers at the lab, Bill Johnson and Van Jacobson. Both Johnson and Jacobson had been influential in developing and advocating for the early Internet. Kahn had been growing frustrated with the required effort of both organizing evening “mailing parties” to send new press releases to journalists, and the time it took to fulfill requests for old press releases. Berkeley Lab received so many of these requests, that by this time, they had to hire someone to handle them all (J. Kahn, personal communication, 9/13/2016). In talking to Johnson and Jacobson about new Internet protocols, however, Kahn realized that

> we are getting all of these calls from people all of the time from people who want these old news releases, we have an archive here that nobody can get at, lets put it online, let’s organize it where people can find what they want. And so we set up a GOPHER site (personal communication, 9/13/2016).

GOPHER was a pre-Web protocol that allowed for the sharing of information across systems—in a way similar to what the Web would do a few years later. Kahn worked with Johnson to help first set up a GOPHER site, which stored and transmitted press releases. When the World Wide Web was introduced to Berkeley Lab, Kahn recognized that it was a notable improvement over GOPHER. The Lab's GOPHER site quickly turned into one of the first 250 Websites in the world.

Across the country from Berkeley in Batavia, Illinois, Judith Jackson, the communication director at Fermilab, was tasked with publicizing an important result in the search for the top quark in April 1994. Fermilab had been running a Web page for researchers for several years, and by this time, the Web had spread far beyond national laboratories. However, for the first time, Jackson realized that a public-directed Web page could help the researchers "make a big splash at the meeting in San Francisco that year" (L. Quigg, personal communication, 9/14/2016). Jackson contacted Liz Quigg, a computer programmer who had helped set up Fermilab's first scientific Web page, to produce a public-facing one (see Figure 6.1 below). The website included a news releases, which was also sent directly to journalists and published in a two-page special issue of *Ferminews*, albeit with an altered lead sentence.



Fermilab

Discovering
the Nature
of Nature

Fermi National Accelerator Laboratory
A Department of Energy National Laboratory

Fermilab is a high-energy physics laboratory, home of the world's most powerful particle accelerator, the Tevatron. Scientists from across the U.S. and around the world use Fermilab's resources in experiments to explore the most fundamental particles and forces of nature.

Home - Help - Search - What's New - Map - Index - Tour

NEWS RELEASE: APRIL 26, 1994

NEW EVIDENCE IN THE SEARCH FOR THE TOP QUARK

The Nature of Nature: The Science of High-Energy Physics

Fermilab: America's Research Laboratory on the Energy Frontier

Fermilab at Work: An Insider's Guide to Lab Activities, Info & Schedules

Figure 6.1: Version of Fermilab's first public-facing website, archived by Liz Quigg

Both of these examples highlight that the Web, despite being broadly regarded as a disruptive "macroevent" across sectors, first had to be connected to existing organizational needs. As Fligstein and McAdam recognize more generally, here, this exogenous force provided those already within the field new opportunities to undertake "strategic actions to sustain and slightly improve their current position" (2012: p. 113). However, once they had first produced public-facing websites, the communication teams at Fermilab and Berkeley Lab soon both realized that these websites could do far more than simply archiving and distributing old and new press releases.

First, websites provide a great deal of extra space that PIOs could use to produce new and new types of content. This can be seen in Figure 6.1; even though Fermilab's website was originally meant to circulate a "News Release," it also included sections on High-Energy Physics and the laboratory more generally. Similarly, the Web provided a place for laboratories to cheaply publish its organizational news, freeing up space in publications for *other types* of content. In September 2003, Berkeley lab renamed their long running employee newsletter *Currents* to *The View*. In the last issue of *Currents*, the editors acknowledge that this change was a response to the success of a new "daily electronic bulletin," they had been using to distribute organizational and administrative news and updates. This meant that they could use now use *The View* for other, more interesting content. The editors promised to provide a "more 'featury' publication," with more information about "Lab life, about people, about the story behind the story, the why's and how's of what's happening at the Laboratory" (Friedlander, 8/8/2003).

Second, rather than have to keep lists of reader addresses or pay printing costs and mailing fees, the Web provided a simple and direct means of distributing content directly to the public. In an interview, Neil Calder, who has led communication offices at CERN, SLAC, and OIST, summed up the radical changes that the Web brought:

> when the Web came, that just became wonderful because you could write these great things and just wham them up on the web, and so you could have this constant feed of stories, and you had somewhere to publish them. And if you could draw attention to your webpage, then you had a distribution technique of your own, you weren't so reliant on the newspapers anymore; you could broadcast your own news without having to go through the extra medium of the press (personal communication, 8/29/2016).

Here Calder signals a further change in the communication practices of national laboratories: covering the *research* done at the laboratory.

Ferminews, another publication of Fermilab, helps demonstrate this shift. According to the results of a content analysis of the publication from 1978, to 2004, there was a significant increase in the proportion of articles in issues dedicated to research being pursued either at Fermilab or at other institutions.[33]

Although *Ferminews* had occasionally published articles that dealt with the science, when it did, it usually adopted a style that was simultaneously familiar and technically detailed. For example, one research feature on the construction of a new accelerator from 10/14/1982 is titled "No, It is Not a New Yellow Wienermobile" by Tim Toohig, the physicist (and Jesuit priest) in charge of accelerator construction. On one hand, the article includes technical information with little explanation:

> Over 60% of the full complement of superconducting dipoles and quadrupoles have ben installed in the tunnel and surveyed in place within a few thousandths of an inch. In E and F sectors 4 (of 8) cryoloops, consisting of 40 magnets each, are vacuum tight (Toohig, 1982: p.1).

On the other, the piece also includes inside-jokes and references that only lab members might understand. The article begins:

> In case you are wondering about the large yellow objects lurking behind the Main-Ring shielding berm near the Central Helium Liquefier, they are not Oscar Mayer wieners (although some of Claus Rode's people were apprehended making a stealthy approach along the Main Ring Road in possession of an "Oscar Mayer" stencil) (Toohig, 1982: p. 1).

In contrast, one research feature from 12/1/2003 titled "SNS: A Camera for Molecular Structures" describes how neutron beams can help physicists probe the structures of tiny objects. The piece was written by Kurt Riesselmann, a member of the office of public affairs, and employs a number of accessible metaphors and explanations that would be at home in a piece of science journalism, "Similar to x-

---

[33] Total research content includes any type of article coded to treat research done at the laboratory. Number of articles were corrected for total number of articles in each issue: $b= 0.061$ $t(329)=10.91$, $p<0.0001$.

rays illuminating the inside of the human body, bunches of neutrons can unveil the interior of materials in a non-destructive way" (p. 2). Unlike Toohig's article, this one also includes quotes from several physicists.[34]

By the end of its run in 2004, the editors realized that *Ferminews* was essentially attempting to serve two different functions: providing organizational news to laboratory members, and spreading news about the research done at Fermilab. Acknowledging this, the editors replaced *Ferminews* with *two* separate publications, *Fermilab Today*, "a daily online publication for employees and users" (Clements, 6/2004: p. 3), which provides regular organizational information, and *Symmetry Magazine,* which exclusively includes public-directed scientific news(-style) articles. "SYMMETRY hopes to introduce a communication style to keep pace with the coming revolution in particle physics—becoming a newsmaker in its own right" (Clements, 6/2004: p. 3, emphasis in original).

"Change in Related Field" and "Invasion by Outside Group"

In addition to macroevents, Fligstein and McAdam identify two other external forces that can facilitate field change: a change in an aligned field and invasion by an outside group. As noted above, strategic action fields are deeply

---

[34] Interestingly, the article is part of a series on the Spallation Neutron Source (SNS), which was being constructed at a *different* laboratory, Oak Ridge national laboratory. Across its run, there was a notable and significant increase in the percentage of published articles about outside research or about the larger field of particle physics (*b*= .002, t(329)=6.97 p<.0001). While at Fermilab, this can be traced to the increasing cooperation between Fermilab and other labs at this time (J. Jackson, personal communication, 7/14/2016), other laboratories similarly began covering outside research. Glen Roberts Jr., currently a writer at Berkeley lab noted,

> we'll look for things that are just interesting even if our lab isn't involved, we'll keep our eye out for just what is going on in the world of science, and sometimes we'll see oh this was a big story, did we have any part of that, and we'll reach out to our contact and well say did we have any scientists one that project and that can lead to stories (personal communication, 6/30/2016).

While covering outside research does little to further the promotional mission of the laboratory, it helps laboratories better position themselves as purveyors of interesting *news*.

interrelated with other fields. Science communication scholars have long recognized that PIOs serve as “bridges” between scientists and journalists (Lynch et al., 2009; Dunwoody & Ryan, 1983). Yet, put into field terms, this means that communication offices are deeply enmeshed and interrelated with these other fields. The changes that the Web brought to communication offices across the 1990s were further compounded by changes in science journalism, which then catalyzed an “invasion” of national laboratory offices by science journalists.

Not long after they began adopting the Web, many national laboratories began reorganizing their communication departments. For example, immediately following the creation of the first public website in 1994, what had been the “public information office” at Fermilab, was expanded and renamed the “public affairs office” (Fermilab, 1995). In addition to being “responsible for all nontechnical publications,” which had previously been produced by the Publications Office, “The office also works with the press and public, and serves as the Lab's Webmaster, updating Fermilab's World Wide Web site” (Fermilab, 1995: p. 33).

Yet, with these newly reorganized offices, national laboratories began hiring more and more journalists. While communication offices had always hired some former journalists (J. Garberson, personal communication, 5/10/2017), from the mid 1990s onward, this has become far more common (see also Weigold, 2001). In part, this is a result of changes occurring in science journalism. As journalistic outlets have faced difficult economic times (see Chapter 7), science desks have been one of the first to be cut (Allan, 2011). Dunwoody tracks major reductions in dedicated science sections in major US newspapers (2014). When outlets cover science news, they increasingly task general reporters with doing so (Schäfer, 2017; Scheufele, 2014). Those science journalists that remain are being paid less and asked to do more (Bauer et al. 2013; Allan, 2011).

These changes in science journalism have driven many science journalists to "invade" institutional news offices, looking for better pay and job security (Weigold, 2001: p. 171). Glen Roberts Jr., a current science writer at Berkeley Lab, explained his transition from journalism to science communication in this way:

> [working in newspapers] was a fun hobby, but it was difficult to make a living…it hasn't been pretty, I mean it's been pretty much in perpetual downsize mode… It was just a tough life, and I think it was often thankless, there's not a lot of people who were in newspapers who I think were still in it, and it's not just a money thing, it's just when you see the walls crumbling around you, it wasn't as fun (personal communication, 6/30/2016).

Yet, these science journalists have been successful in getting hired because of *ongoing* changes already occurring at national laboratories.

Organizational Practices and Structures As journalists have increasingly been hired to work on laboratory publications, they have brought with them a set of norms, structures, and practices. Today, many public affairs or communication offices are organized into beats, similar to those in journalistic organizations (e.g. Tuchman, 1978). As Lynda Seaver, the Director of Public Affairs at Lawrence Livermore National Laboratory described it, "most of these [science writers] are former journalists, the way they used to do this when they worked at a newsroom, it's confined, our covered area is confined to this one square mile that we sit on" (personal communication, 7/15/2016). These beats vary with the laboratory, and often can be rearranged depending on the expertise of specific science writers employed at the time. With so much to cover, and so few staff writers, beats are rarely set in stone. As Glen Roberts Jr., a writer at Berkeley Lab, observed, "the beats are a little fluid too, so if there's something you are interested in and your colleague is not going to be working on—we work outside our beats, so I've done bio[ology] stuff, I've done material science, chemistry, it's pretty fluid" (personal communication, 6/30/2016). Interestingly, this fluidity mirrors recent changes in journalism beat structure, where converging news rooms are unsettling traditional beats and hiring freelancers (see Singer, 2014; Klinenberg, 2005).

Since beats usually provide far more stories than a single PIOs can cover, most organizations hold regular editorial meetings to help determine which stories to cover (J. Weiner, personal communication, 5/23/2016). As in journalistic organizations (e.g. Gans, 1979), editorial meetings are ways for managers or editors to do basic gatekeeping. Strangely, when asked what they look for in stories, most informants did not speak about what stories made the institution look best. Andrew Gordon, the external communications manager at SLAC, spoke about trying to take the perspective of the audience. "For me I'm listening to who is the audience for this, is this going to be of interesting to a public audience, to a scientifically interested public audience, or is it only going to be interesting to the scientific community" (personal communication, 6/16/2016).

Some communication offices—like many contemporary news organizations (e.g. Anderson, 2011, 2013a)—also employ digital metrics to help decide what stories to cover. "Metrics are big, I think they are big all over, they are big in journalism, they are for communications for us, when I was at SLAC we paid a lot of attention to them" (G. Roberts Jr., personal communication, 6/30/2016).

Producing Content When asked how he and the PIOs in his department approach stories, Jon Weiner, the communication manager at Lawrence Berkeley National Lab, responded: "we come at it as journalists. In fact most of our science writers came from journalism, from print journalism mostly." Judith Jackson quoted a reporter friend to describe her process: "I prepare my reports for my Uncle John, who is intelligent, but he has a very short attention span and he's very often drunk" (personal communication, 7/14/2016). For Weiner what matters most is articulating "the why should I care, why should my audience care, why is it important" (personal communication, 5/23/2016).

Yet rather than looking to researchers to help identify why a piece of science matters, Weiner observed,

> well it's usually the other way around to be honest. We have to help [scientists] find the 'why should I care' you know, really, often times, that's what I do, … we have to try to pull the interesting and important elements from them (personal communication, 5/23/2016).

Rather than simply following scientists in assessing the meaning of a finding, Weiner adopts a journalistic-type approach by actively working to frame scientific content. As many scholars have observed, the way a journalistic article is framed is one of the sources of "the power of a communicating text" (Entman, 1993: p. 51). Science writers indicated a number of different strategies for framing stories, including focusing on research processes, milestones, or research scale (K.

Jurkewicz, personal communication 5/6/2016). Another strategy is to use interesting detail and comparisons. "You can't make it too simple, straightforward or colorful" (J. Jackson, personal communication, 7/14/2016).

In covering a specific beat, PIOs, like science journalists (see Dunwoody, 2014), look for story ideas from a variety of sources. Many informants related how they spend much of their time "going out into the lab and talking to people and listen[ing] to what they are working on, and then decid[ing] if that's something we want to cover" (M. Gnida, personal communication, 6/28/2016). A big part of the job involves talking to division heads, post-doctoral researchers, staff scientists, or principal investigators (G. Roberts, personal communication, 6/30/2016). Several informants stressed "the key thing you need to do at a lab like Fermilab is to really have strong personal and good relations with the scientists who are doing the work" so they get to "know you and trust you and believe that you are there to make them look good and help them, help them get funding, and that you are going to be able to help them succeed at the things they want" (J. Jackson, personal communication, 7/14/2016), an invocation that echoes normative practices of science journalism (e.g. Nelkin, 1995). Meetings with researchers also function as opportunities to gather "evidence" in the form of quotations and explanations from researchers. Together, direct quotes and "explainer graphs" serve as the main forms of evidence within articles, as is true for journalistic articles as well (Blum et al., 2005).

In addition to in-person meetings with researchers, story ideas often derive from upcoming journal articles. Jon Weiner estimates that as much as 60 percent of the stories his office produces are tied to journal publications. Importantly, over the past several decades, science journalists have increasingly become “slaves to journals” (Granado, 2011: p. 794), deriving most of their stories from journal articles, often publicized by press releases distributed through wire services like AlphaGalileo, Eurekalert!, or NewsWire.

Review While beats, editorial meetings, and metrics are all common in journalism, the influence that incoming journalists have had on national laboratories has been tempered. As Fligstein and McAdam might describe it, national laboratories have their own “shared understandings” “rules governing legitimate action in the field” (2012: p. 9). Judy Jackson, explained the ultimate goal of communication work in this way:

> the whole point of what the communication you are doing is strategic, you’re not communicating for the fun of it, or because you just want to turn everyone in the world into a science fan, or let everyone in the world know the difference between quarks and the leptons, that’s nice if you can do it but you are there because it costs money to do scientific research, to do particle physics research, it really costs a lot of money” (J. Jackson, personal communication, 7/14/2016).

On one hand, this reasserts the way that the external influence that journalists have brought to the field are effective for helping existing field members make plays for strategic advantage. On the other, this shows how laboratories have held on to some practices and structures that would not be acceptable in a (good) journalism organization. Most notably, all communication offices have extensive review processes. This review extends far beyond the editorial review of journalistic organizations. Although each institution seems to work differently, all subject each piece to multiple levels of review. Importantly, while communication offices are adopting many of the structures of journalism, in holding tightly to extensive review of articles, these offices undercut the editorial independence that, for many, defines journalism (e.g. Deuze, 2005).

Most informants described sending not only individual quotes, but also entire articles to the scientists about whom they are writing. Andrew Gordon explained that this is done to make sure that "specifics of their research, their experiments, their instruments are correct" (personal communication, 6/16/2016). Others recognized that working at an institutional communication office implies a certain sort of dynamic with scientists. Kathryn Jepsen, the editor of *Symmetry*, explained

> if we're writing about a scientific result, then we'll send the article back to every scientist who is quoted, and lots of news organizations will not do that, because they're worried that the scientist will say I want you to change my quote, or sully the article some how. But we are a laboratory publication, so, I'm okay with that. And if they say things like I want you to change my quote and make me sound like a robot, I can usually talk them down and say actually that doesn't make any sense (personal communication, 3/12/2016).

Importantly, scientists retain the ability to cancel an article.

> It'll also depend, if they [the researchers] intend to write a paper on that, we'll see if we can time that for when the paper comes out, if not it's really the scientists' prerogative, sometimes the scientists will say no, I want to wait until I've produced my paper until we publish anything for the general public
> (L. Seaver, personal communication, 7/15/2016).

After being sent to scientists, stories weed their way through a number of different administrative levels. This ends at the Department of Energy, which checks, among other things, that government bodies are properly named and described.

Discussion and Conclusion

Adding detail to growing scholarship in the public relations practices of scientific institutions (e.g. Lowhwater & Storksdieck, 2017; Borchelt & Nielsen, 2014), this chapter has demonstrated the ways that national laboratory communication offices have increasingly fashioned themselves as *journalistic outlets*. This has meant producing content about the research completed at national laboratories, while also adopting practices and structures traditionally associated with journalism, such as holding editorial meetings, assigning beats, and issuing corrections.

In telling this story of transformation, this chapter describes the entrance of a new mediator into the information flows about new scientific research. Rather than remaining only "bridges" (Lynch et al., 2014) or "boundary spanners" (Ankney and Curtin, 2002, p. 232) between scientists and journalists, PIOs at national laboratories have become far more active producers of new content. While they have long played a role in circulating reference of public science, national laboratories are now increasingly producing the representations of research that reach lay audiences. The next chapter describes some of the changes occurring in science journalism outlets—changes that mean stories produced by national laboratories are far more likely to be reprinted or repurposed. In this way, even if the immediate audience for national laboratory produced content is limited, there is strong indication that there are new vectors through which it makes its way to lay publics. As discussed in the next chapter, some of this repurposing can be done in ways that preserve the integrity of information flows. However, in some cases, this repurposing deforms information flows.

Fligstein and McAdam's theory of strategic action fields has helped demonstrate the complexity involved in this transformation of communication offices. SAF acknowledges that while field change hinges on external forces and shocks, ultimately, these influence fields by facilitating or mediating ongoing internal struggles. Frankly, explaining the journalization of national laboratory communication offices requires attending to both radical disruption brought by the Web or the invasion by science journalists as well as the way those changes have been articulated into ongoing needs, dynamics, and "strategic action."

That being said, this case does highlight a more general weakness of field theory in treating the role that technologies play in field change. While SAF does in some ways do justice the complex role that the Web played here, this case suggests the need for more detailed and specific theoretical resources for treating technologies in fields. Broadly speaking, none of the three dominant approaches in field theory discussed above offer a detailed account of the ways that technologies figure into field change. Bruno Latour castigates Bourdieu, for example, for espousing a "socialization" that reduces everything to social forces within "fields of power" such that "science, technology, texts, and the contents of activities disappear" (1993: p. 6). Jonathan Sterne puts it another way, suggesting that for Bourdieu, "Understood socially, technologies are little crystallized parts of habitus" (Sterne, 2003: p. 376), a perspective that Sterne argues offers a useful imperative to "consider the domain of struggle over what is and is not 'technological'. It forces us to wrestle with the messy process of constructing technology as an object of study each time we ask a new intellectual question" (p. 370). Reducing technology to social struggles of power prevents them from playing any independent role in field change. Yet at this case demonstrates, the Web, and the particular material affordances in brought to communication offices—namely, space for content and cheap distribution—played an independent and agentic role in facilitating field change. More work is needed to better theorize the role that technologies can play in motivating field change.

Ultimately, Fligstein and McAdam offer an account of fields as being always in motion—filled with actors who are always vying for strategic advantages. "A working definition of stability is that the set of arrangements in the field more or less work to produce the reproduction of the largest and most powerful actors" (Fligstein, 2013: p. 45). Conceptually, strategic action fields share this with information flows as they move through time and space. As Chapter 1 argued, information must also be constantly be re-made, re-fashioned, and re-presented. Without overstating their similarities, we see that both field and flows are composed of roiling conflict and interaction. For both, stability is an achievement; for both, inertia holds little sway.

CHAPTER 7

SCIENCE NEWS AGGREGATORS: THE EPISTEMOLOGY OF AGGREGATION AND AGGREDUCTION

Introduction

Crises abound in science journalism. A growing list of topics, from climate change, to vaccines, to GMOs, have become deeply polarized and contested (Bucchi & Trench, 2014). Disinformation campaigns by industry-backed think tanks, media organizations, and bought-scientists (Orekes & Conway, 2010) flood the media system. Economic pressures, the same faced across journalism, have hit specialty reporting especially hard (Allan, 2011: 773; Schäfer, 2017). Technological change has deeply unsettled work conditions and practices (Bauer et al., 2013), production (Trench, 2007) and consumption (Brossard 2013; Brossard & Scheufele, 2013). And while some argue that despite—or perhaps because of—these challenges, science journalism is thriving (Hayden and Check Hayden, 2018) many more scholars and commentators have serious concerns about the state of science journalism (Schäfer, 2017).

While some attempt to understand how science journalism is changing, others consider the roles or functions that science journalism does and should play in social life (Brossard & Lewenstein, 2010; Fahy & Nisbet, 2011; Secko et al., 2013). These models tell us much about how science journalism is doing and how journalists should proceed. However, as argued in Chapter 2, these models fail to treat the underlying epistemology of science journalism in a rigorous way. In addition to the myopia described in Chapter 2, most existing models have treated science journalistic outlets exclusively as *producers* of unique content. In contrast, journalism studies scholars have recently been investigating journalistic *aggregators* (Chyi et al., 2016; Anderson, 2013b; Coddington, 2015). While the definition of aggregation remains somewhat contested, Lee and Chyi define it minimally as "the practice of redistributing news content from different established news outlets on a single website" (2015: p. 5). For some this means consolidating entire articles or links (e.g. Bakker, 2009, p. 635; Isbell, 2010: p. 2); for others it can also involve consolidating bits and pieces of texts into a single article (e.g. Coddington, 2015: p. 20). Despite this growing interest in news aggregation, there has been far less scholarship on *science* news aggregation. This failure to consider science news aggregators in favor of an emphasis on science news *producers* has meant that science communication scholars have neglected to investigate the full range of organizations that mediate, reprint, and rework existing public science content. This is to say, we lack a clear understanding of the diversity of science journalism organizations.

In order to address these issues, this chapter investigates the epistemology of science news aggregators. It does so by analyzing 470 science news articles about direct detection experiments and 18 semi-structured interviews with science journalists.

Recognizing that recent conceptualizations of aggregation describe (at least) two very different practices: the aggregation of texts and the aggregation of fragments of texts, this chapter proposes a new descriptive category. Reserving "aggregator" for those organizations that collocate articles or links, this chapter offers "aggreducer," a portmanteau of aggregator and producer, as those organizations that combine bits, pieces, and fragments of existing content into new *seeming* articles.

Having made this distinction, this chapter first considers three specific strategies aggregators employ to solve two problems of aggregation: how to add *value* to existing stories and how to ensure *validity* as they collect existing content.

Second, in order to better understand aggreduction, the chapter investigates the specific components of texts that aggregators consolidate in producing new (seeming) articles. However, given that both traditional science reporting and aggreduction involve the reworking of existing content, this section looks at the fragments and "shards" (Anderson, 2013b: p. 1021) that *both* sorts of organizations adopt and modify. Doing so helps to better identify and distinguish the unique approach and epistemology of science news aggreduction.

In demonstrating the differences between aggregators and aggreducers, this chapter demonstrates how aggregators *embrace* the epistemic power of traditional forms of evidence and textual structures. They appear to accept that these components hold epistemic validity even once removed from the context of their original production. In contrast, aggreduction is grounded in a particular epistemology that not only has "accepted the website and the link, and categories of digital evidence more broadly, as valid items which can be rationally processed through the news network" (Anderson, 2013b: p. 1022), but that has also embraced an *informational* epistemology that fully devolves knowing as an ephemeral "sequence of particulars, a collage of particulars" (Lash, 2002: p. 145). While aggreduction (like aggregation) is often a result of economic pressures, it also shares much with broader forms of *remix* (Navas and Gallagher, 2017; Gunkel, 2015). While most have studied remixing as an aesthetic approach (Gunkel, 2015), some, rooting remix in "bricolage" (Levi-Strauss, 1966) have noted it embodies a distinct epistemology as well (Kincheloe, 2001; Markham, 2017).

Yet, aggreduction proceeds by first deconstructing informational flows—by producing *deformations*. In this, aggreducers embrace a discrete, or *digital ontology* (see Floridi, 2009) that resolves the world as interchangeable and distinct pieces or components, waiting to be de- and re-contextualized at will. This chapter argues that beyond epistemological differences, it is this embrace of a digital ontology that distinguishes science news aggregation, aggreduction, and traditional reporting. Ultimately, like the six previous, this chapter confronts the question of how and how much difference is, can, and should be introduced into public information about science.

Literature Review

The Changing Landscape of Science Journalism

As noted in previous chapters, scholars investigating the medialization of science have considered not only the ways that science is more oriented to media, but also how media is increasingly oriented to science. These scholars discuss this second concern in three distinct ways. First, some have observed a greater amount and frequency of science coverage (Rödder, 2008: p. 453). A number of empirical studies have supported this claim, finding increasing coverage of science in a range of media formats (e.g. Bucchi, 1998; Clark & Illman, 2006). Second, some suggest science coverage is becoming more "pluralized"—including a wider diversity of voices. Third, coverage is considered to become more controversial—weighing in on larger scientific debates in society (Schäfer, 2008).

Somewhat tangential to this medialization literature, scholars of science communication and the science of science communication, have observed similar changes in science journalism. Such scholars have tended to focus on two factors motivating the changes occurring in the science media environment: the influence of digital media and that of economic change (Fahy & Nisbet, 2011). As in discussions of the broader media system, many scholars observe that the rise of digital media has accompanied radical shifts in news content as well as journalistic production and consumption.

Many scholars have observed that science news content is becoming more polarized—especially when covering topics at the heart of controversies, such as climate change of GMOs (e.g. Feldman, Hart, Milosevic, 2017). And while Hayden and Check Hayden (2018) assert otherwise, Schäfer (2017) and Bauer (2011) argue that that despite increasing until the early 2000s, *"growth in the amount of media coverage dealing with science and related topics seems to have stopped* (Schäfer, 2017: p. 7, emphasis in original).

Others have observed that the number of job positions for science journalists is decreasing (Allan, 2011; Dunwoody 2015). As this occurs, existing journalists are required to produce more content (Brumfiel, 2009), to be "multi-skilled" and to work across different formats and platforms (Allan, 2009: p. 282), and to do it all faster (Allan, 2011). Fahy and Nisbet see these changes accompanied by a broadening of the "roles" of science journalists, from simple reporting to "information specialist" (2011) or "dialogue brokers" (2017). While this occurs, however, science journalists are increasingly turning to the Internet for story ideas, sources, and factual information (Granado, 2011). Bauer and Gregory suggest science journalism is becoming more "source-driven" (2007: p. 33), relying not only on scientists, but also on scientific articles, as well as PR releases or wire stories. More broadly, some scholars have seen scientific institutions and business exerting more influence on science journalism (Bauer and Bucchi, 2007)—in part by producing more and better content. Some have observed that this allows journalists to pump out poorly researched stories as fast as possible in what some have called "churnalism" (e.g. Davies, 2009; Allan, 2011).

Other scholars have been more sanguine about the recent changes in science journalism—focusing more on the benefits of the digital transformation. Holliman, echoing some of the medialization scholars (e.g. Schäfer, 2008: p. 477), notes that the digital, globalized science media landscape brings together diverse voices (2011). Trench (2007) observes the rise of new and new types of journalistic organizations in response to the Internet—such as specialized outlets and science news aggregators. Many more have been investigating blogs and comment forums on news sites (e.g. Shanahan, 2011; Laslo et al, 2011). There has been a persistent expectation that blogs run by non-journalists will greatly improve both the quality and democratic potential of science reporting. Some have noted that blogs can fact-check science journalism (Allan 2009; Holliman, 2011)—holding journalists accountable for accurate reporting. Others envision blogs as a “boundary layer” between scientist, journalists, and publics (Shanahan, 2011) that facilitate engagement amongst those groups. Similarly, several have noted that blogs generally present a challenge to the authority of science journalists by allowing scientists to speak directly to publics (Allan, 2009; Secko et al., 2011). That being said, several empirical studies have cast some doubt on the ability of blogs to be a positive force in science reporting. Coulson (2011) finds that (non-journalist) blogs and science journalism tend to be “competing channels” that do not overlap, engage, or even share readership. Kouper (2010) notes that there are so many blogs, and they are so different that on the whole they are not able to facilitate engagement amongst different types of publics.

Two deficiencies stand out against existing scholarship. First, despite growing evidence of widespread changes in science journalism, we still lack a clear picture of how the *organizational* landscape of science journalism is changing. That is, what sorts of news outlets exist and how are they changing?

Second, although we have data on how some of the shifting practices of science journalism (Allan 2009, 2011; Granado, 2011), we don’t understand how the *epistemology* of science journalism is changing—or even what the epistemology of science journalism is or should be. Here epistemology is a seen as a coherent set of practices, ideas, and norms about how knowledge is and should be produced (Lewis and Westlund, 2015: p. 452). Existing scholarship has focused more on “roles” for science journalists rather than epistemology. Fahy and Nisbet (2011) present nine different roles that science journalists can play in democracy (2011, p. 780; Nisbet and Fahy, 2017). Secko et al, building on Brossard and Lewenstein (2010), consider four models that span both "traditional" and "non-traditional" accounts of science journalism and those that focus on "information delivery" and "public engagement" (p. 67). All of these models consider different functions that science journalism does and *should* preform. Some of these models include implicit epistemological dimensions or prescriptions. For example, in Secko et al.'s Science Literacy Model, "use of the science literacy model involves employing traditional journalistic norms, such as objectivity, and viewing audiences as lacking knowledge" (p. 67). Or the lay-expertise model, knowledge "is validated through other social systems…requiring 'expertise' from other sources outside of science to examine issues" (p. 68).

Across these models of science journalism, scholars narrowly consider journalists as *producers* of content. Each model presupposes that journalists are completing fully independent reporting. Not only does this fail to offer a realistic treatment of science news epistemology, it does not leave space to map the broader landscape of types of science news outlets. In particular, this myopia has led to a lack of consideration of science news *aggregators*.

News Aggregators

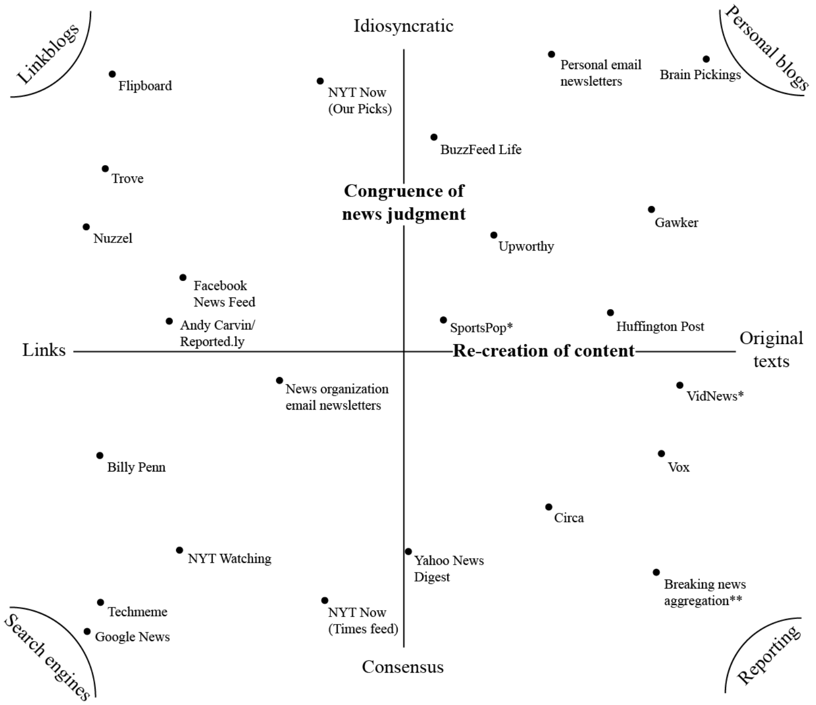
Thanks to the rise of digital aggregators such as Google News and the *Huffington Post*, a small number of journalism scholars have recently been investigating the work and practices of news aggregators. Importantly, aggregation remains a more marginal concern in journalism studies; Lee and Chyi propose it is “because these aggregators produce little original content and thus are not often perceived as news media” (2015: p. 4).

As such, there has not yet emerged a clear consensus definition of news aggregation. Isbell offers a minimal definition as “a website that takes information from multiple sources and displays it in a single place” (2009: p. 2), a definition that Lee and Chyi echo (2015: p. 5). While some have taken this to mean that aggregation is the consolidation of different articles (or links) onto a website, others have seen aggregation as also including the consolidation of *pieces* of articles into a single text (Anderson, 2013b; Coddington, 2015).

Much existing research has considered the broader economic and/or legal implications of news aggregation. Bakker contextualizes aggregation as part of “the rise of low-pay and no-pay journalism” (2012: p. 627), in part as a result of larger economic pressures facing journalism. Others look to understand the economic relationship between aggregators and traditional news sites. While some blame aggregators for worsening the financial woes of traditional news outlets (Keller, 2013), others have found evidence that the two serve different roles, making aggregators often “non-competitive” with traditional news sites (Lee & Chyi, 2015).

More interested in understanding what makes news aggregation distinct from traditional reporting, Anderson investigates (human led) aggregation as a form of newswork (2013b). For Anderson, while both ultimately consolidate disparate “shards of facts, quotes, documents, and links” (p. 1021) to produce new narratives, there is an important difference between the two. While reporting and aggregation often engage in strategic boundary work against the other, they are also distinguished by the types of objects and forms of evidence they employ: “aggregators have accepted the website and the link, and categories of digital evidence more broadly, as valid items which can be rationally processed through the news network” (p. 1022).

In contrast, Coddington concludes that aggregation is a “form of second-order newswork built atop the epistemological practices and values of modern journalistic reporting” (2015: p. ix-x). Given this, Coddington presents a two-axes typology of aggregation (see Figure 7.1) in order to better show the range of aggregators. The horizontal axis assesses the “degree of *re-creation of content*…the extent to which the aggregator reassembles the information gathered from its sources into a new narrative form or a reproduced account” (p. 24, emphasis in original). The vertical axis considers “*congruence of news judgment”* (2015: p. 25, emphasis in original), and runs from consensus to idiosyncratic. Having a two-dimensional typology allows Coddington to demonstrate the continuum of practices that characterize aggregation. That being said, having a single axis devoted to content re-creation limits the discussion to nearly quantitative terms of *how much* content is repurposed. It does not leave room to consider what precisely is being aggregated and how it proceeds.



*Pseudonym for an organization studied in this dissertation

**Commonly referred to within the news industry as "breaking news reporting"; work consists primarily of aggregating breaking news published elsewhere online and adding confirmatory reporting.

Note: All placements of aggregators are approximate, intended primarily for illustration. See Glossary for descriptions of listed organizations.

Figure 7.1: A Typology of News Aggregation, from Coddington (2015)

At the same time, given the discussion of aggregation in science journalism below, this chapter suggests Coddington's typology would benefit from an *additional* axis. This third axis should specify *attribution*. One end of this axis would cover organizations that give full and complete attribution. For example, when the news wire service *EurekaAlert!* distributes a press release, it very clearly identifies the source organization. The other extreme would cover organizations that routinely reprint entire (or nearly entire) articles but with new/altered bylines. For example one *RedOrbit* article reprints a Queen's University press release (2/18/2010) word for word, but changes the byline to "Sam Savage" (2/19/2010). *Physics Inventions* also routinely replaces bylines with those of their own "reporters." *Space Daily*, which pulls press releases from across the Web, replaces some bylines with "Staff Writers." This axis could also plot articles according to how and how well they attribute component pieces of articles: ledes, quotes, frames, ideas, etc.

Including this attribution axis would not only help to further distinguish amongst the wide variety and forms of aggregation—including between aggregation and aggreduction (see below), it better injects a *normative* dimension into the typology. There is, arguably, a distinction to be made between organizations that engage in Coddington's "second-order news work" (2015: p. ix) of creatively recombining articles, and those that are taking advantage of existing content for their own gain. Although not a perfect metric of this distinction, attribution can help tease apart organizations that cling to some minimal journalistic standards, and those that are simply plagiarizing.

Even still, this chapter retains deep concerns about the value and validity of plotting *organizations* on such a diagram. Doing so requires attempting to generalize across all the different ways that an organization aggregates content. This project observes evidence that individual organizations employ a range of different sorts of practices. For example, while *Futurism* has previously adopted practices that approach plagiarism, they have also done solid, independent reporting. The same is true for *Universe Today*. As organizations hire different reporters and editors, and move through different contextual conditions, their practices will change. Given this, it would be more accurate to plot individual *articles* on Coddington's axes. Perhaps once individual articles are assigned locations on these three axes, they could collectively be used to assess individual authors or organizations. Plotting individual articles would also better ground this typology in specific empirical (and potentially quantifiable) evidence.

Methods

Given the lack of literature both on the changing organizational landscape of science journalism and on science news aggregations, this project investigates forms of science news aggregation. To do so it draws on a set of 18 interviews with science journalists/aggregators as well as a qualitative textual analysis of 470 science news articles about direct detection experiments. This corpus contains both traditional news stories as well as stories produced through what some would consider as aggregation. See Appendix A for a more detailed discussion of how these articles were collected and analyzed as well as for a specific explanation of how texts were collected and analyzed.

Findings

Aggregation and Aggreduction

As noted above, there remains disagreement over the boundaries of aggregation. Some see it referring more narrowly to the consolidation of *articles* on a single website or platform (Isbell, 2009; Lee & Chyi, 2015). Others also include the rewriting of articles or the knitting together of *pieces of articles* (Anderson, 2013b; Coddington, 2015) into a single new text. This chapter argues, however, that while similar, these two phenomena, which lie in different quadrants of Coddington's typology, should be analytically separated.

In order to better clarify the terminology, this chapter introduces a new term to specifically refer to the ways that individual articles are being rewritten by combining disparate pieces. Combining production and aggregation, this chapter offers *aggreduction* as the act of rewriting and/or synthetizing bit and pieces of existing texts to produce new *seeming* content. In describing their approach, one aggreducer noted they had learned that, "There's a way to write it so it doesn't look like its coming from anther site" (Anon, personal communication, 12/13/2016).

Introducing this term frees up "aggregation" to refer simply to collocating different articles or links onto a single website (Isbell, 2009; Chyi et al., 2014). Unlike "churnalism," aggreduction recognizes that some are not only rewriting press releases, but also news content as well (Davies, 2009; Allan, 2011). Introducing this term is not meant to suggest that aggreduction is a new phenomenon. Newspapers have revised and reprinted wire stories, press releases, and other pieces of journalism for a very long time (e.g. White, 1950). Instead, recognizing this distinction makes it possible to better identify the unique epistemologies grounding different forms of newswork.

Science News Aggregation

Drawing mostly on interviews with journalists and aggregators, this section interrogates the underlying approaches that aggregators employ in their work. Specifically, this section asks about the distinct ideas that aggregators hold about how they can preserve or add *value* to and preserve the validity of collected (or collectively produced) stories. In this sense, as Latour (2005) would say, rather than see aggregators as transparent intermediaries that simply pass along inputs, this sections asks how aggregators function as mediators. Three (related) strategies stand out from interviews.

"Go to the Source" *EurekaAlert!* is one of the best known and respected science news wire services. It publishes press releases from certified research organizations. *EurekaAlert!* editors do not edit or modify releases uploaded to their site, nor do they gatekeep by rejecting press releases from member organizations. Similarly, they do not have the resources "or the expertise to actually look at the press releases and say, this piece of science news is inaccurate or invalid" (B. Lin, personal communication, 8/9/2017). Yet, the organization still attempts to ensure that they are producing quality content. Since they cannot intervene at the level of content, "we kinda go to the source" (B. Lin, personal communication, 8/9/2017). *EurekaAlert!* acts on the organizational producers of content. There are several ways they do this. First, they require every content submitter to be approved. This not only ensures that PIOs actually represent the organizations they claim to, but to form better relationships with the organizations themselves.

Second, *EurekaAlert!* works to develop *new* institutional producers of releases—especially abroad. They want to make sure that

> there is a good diverse stream of content coming in every day, and that means we're not just getting press release about major journals, we're maybe getting press releases about specific disciplines that may not be very well represented in science communication, we want to make sure we have a range of reporters from different countries and different types of outlets using EurekaAlert! so that science news gets into different parts of the world, and different communities in the

> world. So that is, basically editorial content strategy, and that is what I do (B. Lin, personal communication, 8/9/2017).

Interestingly, organizations themselves make strategic decisions about which releases they should send to which newswires. In the U.S. *EurkeaAlert!* and *Newswire* are the two most common aggregators. Figure A.6 in Appendix A shows the wire service distribution of each press release collected for this project. Interestingly, few press releases ran in both the wire services, and many press releases were not submitted to either.

Story Selection/Gatekeeping The second way that aggregators attempt to influence content creation is through story selection or gatekeeping (e.g. Shoemaker, Vos, & Reese, 2009). Relatedly, Anderson identifies "news judgment" (2013b: p. 1016) as one of the key news working skills required for aggregators.

While news wire services like *EurkeaAlert!*, *Newswise*, or *AlphaGalileo* print all articles that pass their editorial guidelines, other services can be more discriminating. For example, *SpaceDaily*, a long-running trade-oriented space publication, pulls press releases from many different sources. In an interview, the site's founder and sole employee, Simon Mansfield, refused to "go on the record" with specific information about his system, worried that it would help his competitors (personal communication, 12/21/2017). He did note, however, that while automated tools pull content from many sources, he ultimately decides which stories to include and when to print them. He gave the example of cube satellites, small satellites that can be cheaply placed into orbit. This is a very popular topic, and if his system collects multiple stories about them on a single day, he will try to apportion them over the rest of the week to help draw readers on multiple days.

Preserving Value by Doing Nothing Some aggregators care less about adding value than simply *preserving* it. Several informants spoke about the quality of press release material produced across organizations. Simon Mansfield of *SpaceDaily* observed that as a trade publication his readers "want to know basic facts and information," and that

> I found many years ago that a good press release from a good company is 90% of the story and the worst thing you can do is start trying to rewrite it if you don't know what you're writing about. And in the U.S., press releases of a public company—they can't contain lies (S. Mansfield, personal communication, 12/21/2017).

Here Mansfield underscores a third way of balancing value and validity: by *not* producing content. He argues that given the technical difficulty of these topics, having a small staff and few resources means that he can help ensure factual accuracy by *not* doing real reporting, but outsourcing that work to expanding public communication professionals and offices.

While Mansfield's high opinion of the technical accuracy of press releases is somewhat reasonable (especially given the findings of Chapters 5 and 6), his faith that public relations professionals provide only "basic facts" seems more naïve. That being said, Mansfield explained that the particular context of the space sector does alter the metrics of good journalism.

> I don't really have an agenda about the space industry, there are a lot of people in the space media who have an agenda—have an ideological view of space. I don't have an ideological view of space; it's just another business sector, no different than energy or shipping, just

> business. So I take a pretty straight-line sort of approach. And that's one of the things that really appeals to our industry readership. They can read news without having to wade through ideological agendas, a lot of people in the new space business are into all that ideological thing, there's a bit libertarian streak in space" (S. Mansfield, personal communication, 12/21/2017).

Mansfield argues that there is a specificity to the space field such that his industry readership is less concerned about industry spin than *political* spin. Given this, industry publications that ostensibly sidestep politics have value irrespective of industry bias.

Science News Aggreduction

While Coddington (2015) collapses the "re-creation of content" into a single (essentially) quantitative axis, this chapter looks more specifically at *what* is being re-created in science news aggreduction and *how* it is occurring. This section draws mostly on the corpus of texts to look at what it is specifically that organizations adopt and adapt in producing and/or aggreducing science news. Subsections consider different forms or pieces of content that are involved. Considering both traditional reporting and aggreduction practices in science journalism helps better describe the unsettled and somewhat fluid boundaries between the two (Coddington, 2015; Anderson, 2013b).

Story Topics In interviews, journalists reported deriving story topics from a number of different sources. First, and *least* commonly, some informants noted that they occasionally find story topics or ideas through talking directly to scientists. Adrian Cho of *Science Magazine*, suggested, "the best stories are the ones that you find out from talking to scientists" (A. Cho, personal communication, 3/3/2016). Clara Moskowitz of *Scientific American*, expressed how important it is for her and her colleagues to "hunt[] down stories that nobody else has , or that few people have written about so that we can kinda do our own take and take our time" (C. Moskowitz, personal communication, 8/15/2016). Across the collected corpus, these stories were quite rare. In one notable example, Elena Aprile, the spokesperson of XENON100, invited Dennis Overbye of the *New York Times* and Ron Cowen of *Wired* to witness the moment in the laboratory when the collaboration first unblinded their data to see if they had detected dark matter. While the results ultimately showed no WIMPs, the reporters used the articles to give a behind-the-scenes look at science in action:

> Finally, the promised graph appeared on the screen, showing the first of 91 batches of data. A red dot appeared, the first event signal. It was rapidly joined by another, and then another, each accompanied by a sharp intake of breath in the room.
>
> "Oh, God," Dr. Aprile said as the count rose to four. "I can't sit anymore." She got up from her chair.
>
> There were more oohs and ahs as the count climbed to six, more than would be expected from background radioactivity in the detector, and finally stopped (Overbye, 4/14/2011).

That being said, judging both by collected articles and from interviews, journalists derive far more story ideas from existing *texts*. Broadly speaking, two different types of texts stand out.

Freelancer Mathew Francis noted that "every week you have a list of new papers from journals like nature, science, or a number of other subjects, physical review letters that sort of thing" (M. Francis, personal communication, 3/4/2016) that furnish ideas for articles. Davide Castelvecchi of *Nature Magazine*, noted that he routinely follows papers posted to the ArXiv, an online pre-print repository (personal communication, 8/22/2016).

Far more common, however, are stories that derive from *press releases*. Davide Castelvecchi observed, “Press releases from major journals are the bread and butter for science news magazines which cover a lot of research papers” (D. Castelvecchi, personal communication, 8/22/2016). Nearly every journalists interviewed noted how many press releases are now circulated every day. Damond Benningfield, who writes for the radio program *Star Date*, observed that “I get probably several hundred press releases a month, some of those are gonna turn into script ideas” (D. Benningfield, personal communication, 4/5/2016). Even Adrian Cho, one of the foremost science journalists working today, broadly estimates that as much as 60% of the stories he writes come from press releases (A. Cho, personal communication, 3/3/2016).

Yet, that journalists derive story topics from journals or press releases does not necessarily mean they are simply copying or rewriting them. Several journalists described how press releases are simply starting points, and they make sure to read the original paper and interview the study’s authors and/or outside experts. Cho observed, “I try to depend on the press release as absolutely little as I can, I try to, you know, I mean, they don’t pay us to literally rewrite the press release” (Cho, personal communication, 3/3/2016). Similarly, as discussed at length in Chapter 2, while science journalists frequently write from existing journal articles, they often put a great deal of work into translating those articles into forms that are more publically accessible and meaningful.

In contrast to traditional news outlets' practices of story selection, some organizations adopt a different approach. A former employee of the young science news site *Futurism*, who requested anonymity, described how they "selected" story topics. As a writer, the informant, who lives abroad, was required to log into the content management system for 4-hour shifts. Editors would submit news articles or press releases about topics that are "trending on social media" (Anon, personal communication, 12/13/2016). The writers would then be required to select topics/stories from the list and produce new seeming articles as quickly as possible. Here, not only was the writer afforded no "news judgment," but, editors were mostly concerned with selecting stories that are already popular. As per Coddington's typology, this would place *Futurism* on the extreme southern pole of "consensus" news judgment (2015: p. 25).

Story Frame In addition to story topics deriving from existing texts, some journalists adopt *frames* for articles from press releases. Across the corpus, there are numerous examples of more mainstream outlets clearly adopting story topics from press releases while *rejecting* the frames. One of the clearest examples of this comes from the 2013 LUX result release discussed in Chapter 1. Although there were nearly 10 (slightly different, see Chapter 4) press releases produced about this releases, all more or less suggested that the LUX experiment "has proven itself the most sensitive dark matter detector in the world" (Walter, 10/30/2013). Much of the news coverage, however, chose to frame the story by highlighting "LUX dark-matter search comes up empty" (Johnston, 10/31/2013). By most measures, this is the proper news framing here, and this example shows the willingness of some journalists to cut through the PR to see what really mattered in this story.

That being said, there are plenty of examples of reporters adopting frames supplied by press releases, even when there was a more traditional, or perhaps, important news frame. For example, the headline of a UCLA press release for a XENON100 result in April, 2011 trumpets how the "search for dark matter moves one step closer to detecting elusive particle" (DeRose, 4/14/2011). And while this experiment also did not find any evidence of dark mater, *Scientific American* nonetheless published an article the same day with the headline "Underground XENON100 experiment closes in on dark matter's hiding place" (Matson, 4/14/2011).

Lede Lede sentences are one of the most important components of an article. Not only are they supposed to supply the most important factual information, but they also help frame a story. Lede sentences are also routinely lifted from existing content or adopted with slight modifications. One article from *RedOrbit* includes this lede:

> Nearly a mile underground beneath the Black Hills of South Dakota, scientists from Lawrence Livermore National Laboratory (LLNL) are using a tank to make key contributions to a physics experiment that will look for one of nature's most elusive particles, dark matter (Flowers, 11/16/2012).

Here's the lede from a Lawrence Livermore National Laboratory (LLNL) press release:

> Lawrence Livermore National Laboratory researchers are making key contributions to a physics experiment that will look for one of nature's most elusive particles, "dark matter," using a tank nearly a mile underground beneath the Black Hills of South Dakota (Stark, 11/16/2012)

Notably, after slightly modifying the lede, the *RedOrbit* story then copies the LLNL release word for word.

This is the lede from an ABC News story (itself adapted from an AP story)

> Far below the Black Hills of South Dakota, crews are building the world's deepest underground science lab at a depth equivalent to more than six Empire State buildings — a place uniquely suited to scientists' quest for mysterious particles known as dark matter (Lammers and AP, 6/23/2009).

This is *Redorbit's* lede:

> The world's deepest underground science lab is being built below the Black Hills of South Dakota.
> With a depth equal to more than six Empire State buildings, the space is perfectly tailored to the needs of scientists in their quest for mysterious particles known as dark matter (Savage, 6/23/2009).

Source Quotes Interviews have been an important news practice since the mid 19th century (Schudson, 1994; Coddington, 2015). Including quotations from those interviews not only grounds fact claims in public witnessing, it bolsters journalistic authority. More pragmatically, source quotations have long structured news articles. In this sense, it is part of a journalist's work to combine quotations from multiple sources into a single document—an approach that aligns with some minimal definitions of aggregation (Isbell, 2009).

Yet, at the same time, the corpus of collected texts suggests that quotes themselves are sometimes re-worked into news stories. That is to say, quotes from knowledgeable sources, here dark matter physicists and administrators, have been pulled from press releases and other news content and repackaged as part of new (seeming) content. It should be noted that several informants expressed in strong words their opposition to this practice. For example, when asked about pulling quotes from press releases, Davide Castelvecchi responded, “no, never; I don’t think I ever used a quote from a press release in my life” (personal communication, 8/22/2016).

That being said, there are a number of articles in the corpus that appear to pull quotations directly from press releases. In many articles these quotations are properly attributed to both the original *speaker* and the original (textual) source. For example, one article by *RedOrbit* pulls a quote from a LUX release, noting it was “said in a statement” (Bednar, 7/21/2016). Less frequently, some aggregators have taken quotes from other *news* stories. Another *RedOrbit* story prints two quotes from collaboration physicists, noting that the quotes were “told to the associated press” (Flowers, 4/16/2013).

Aggregators will also pull quotes from a press release and while attributing them to the speaker, make no mention of having taken them from an earlier text (e.g. De Jesus, 7/22/2016). Oddly, one *Futurism* article first includes a quote from Rick Gaitskell, a LUX physicist, noting it was said “in the press release.” Several graphs later, the article includes a quote from another LUX physicist, but cites this one only as “Dan McKinsey, a UC Berkeley physics professor and co-spokesperson for LUX, said," even though this quote was included in the *same* press release (Santos, 12/16/2015).

Finally, some articles bizarrely turn press releases *into* quotations. One *Universe Today* article lifts three paragraphs from a press release from Lawrence Berkeley National laboratory, which it quotes from the collaboration as said "in a statement" (Howell, 10/30/2013). A *RedOrbit* article reprints whole sentences from a *BBC* article, and then cites the "according to BBC Science reporter Paul Rincon" (Savage, 7/26/2010). Interestingly, the article then proceeds to the lift and cite two graphs from the CDMS-II *website*.

Explanations Explainer paragraphs or sections are where journalists attempt to explain some of the science behind a piece of research or new finding (Blum et al., 2006). These are also sometimes poached by aggreducer. One *Universe Today* article lifts the explanation graphs from a Lawrence Berkeley National Laboratory press release, which it quotes from the collaboration "in a statement" (Howell, 10/30/2013). Other articles slightly rework science sections; yet keep much of the same structure and many of the same details. For example, here is an explainer graph from a press release by Texas A&M and SuperCDMS:

> Notoriously elusive, WIMPs rarely interact with normal matter and therefore are difficult to detect. Scientists believe they occasionally bounce off, or scatter like billiard balls from, atomic nuclei, leaving behind a small amount of energy capable of being tracked by detectors deep underground, particle colliders such as the Large Hadron Collider at CERN and even instruments in space like the Alpha Magnetic Spectrometer (AMS) mounted on the International Space Station (ISS) (Hutchins, TAMU, 4/15/2013).

And here is a graph from an article on *Redorbit*:

> WIMP's are notoriously elusive and rarely interact with normal matter, making them very difficult to detect. They are thought to occasionally bounce off of, or scatter like billiard balls struck by the cue, atomic nuclei. This leaves behind small amounts of energy capable of being tracked by particle colliders, like the Large Hadron Collider (LHC) at CERN, buried deep underground, or even by the Alpha Magnetic Spectrometer (AMS) mounted on the International Space Station (ISS) (Flowers, 4/16/2013).

While in some cases, the changes made from the press releases to the new articles make little difference beyond obscuring the source. Other times, intentionally or not, there are notable substantive changes. For example, one article about XENON1T in *Futurism* reworks another from *Nature*. The *Nature* article wrote,

> Either way, within a few weeks of switching on, the new detector could in principle detect dark matter at any moment. The longer it goes without doing so, however, the lower the limits it will impose on the strength of WIMP interaction with normal matter" (Cartlidge, 11/12/2015).

When an author from *Futurism* rewrote this article, this graph became simply, "It is hoped that the new detector will find dark matter after just a few weeks of operation" (Libunao, 11/15/2015). There is an important difference between "in principle" and "it is hoped." The *Futurism* piece not only makes it sound more likely that the detector would find dark matter, but it further ignores the actual contribution that the detector will make in helping to provide a new limit on WIMPs mass/cross section (see Chapter 4).

Multimedia Content It is not only print articles that are subject to these practices. Some organizations also apply aggreduction practices to multimedia content. *Futurism* posts a great deal of video content. It recently partnered with

XPrize and All Nippon Airlines, to produce a series of short documentaries about XPrize competitors. They also have created a series of interviews by *Futurism* staff with scientists and engineers. The site also, however, re-hosts content that is clearly produced by other outlets. For example, in recently posting a video about gravity, the site included no explicit indication that the video was from another source. However, the video itself is clearly branded to NOVA.[35] Perhaps more interesting, some of their own branded videos (that include a "*Futurism*" watermarks) use video content provided by institutional press offices. For example, a recent video about 3-D printed bacteria uses slightly re-edited video from the University of Zurich. The video does include a small, hard-to-read tag "ETH Zurich" in the bottom right corner. Oddly, while the *Futurism* video does not use the original music from the university's video release, it uses very *similar* electronic music. *Mashable* also produced its own re-edited video from Zurich's footage, and *also* added new, yet very similar electronic music.[36]

Discussion: The Epistemology of Science News Aggregation and Aggreduction

Even more than general news, science news complicates the boundaries between aggregation and reporting. Facing financial pressures, many outlets have cut back on science desks. In response, they are reprinting more wire stories,

---

[35] https://futurism.com/videos/what-is-gravity-made/.

[36] Original release with video: https://www.ethz.ch/en/news-and-events/eth-news/news/2017/12/3d-printed-minifactories.html
Futurism: https://futurism.com/videos/future-printing-one-3d-printer-uses-live-bacteria-ink/
Mashable: http://mashable.com/2017/12/06/fling-living-bacteria-3d-printing-ink-eth-zurich/ - TXJVQGQ7nPqO

requiring general purpose reporters to cover science, and asking their remaining science journalists to cover far more content (Brumfiel, 2009; Allan, 2011; Schäfer, 2017). As this happens, more and more reporters rely on press releases in writing stories (Autzen, 2014; Bauer & Bucchi, 2007). At the same time, whether based on press releases or not, most science news stories are catalyzed by the publication of a journal article. In translating the findings of these articles, science journalists, arguably, engage in a form of aggregation. By functioning as mediators of successive representations, journalists help to extend chains of reference by maintaining or preserving references, even while opening science to new publics and meanings. Within the model offered in Chapter 2, validity derives from the *connection* with antecedents. Ultimately, all of this suggests that in many ways, the distinction between traditional reporting and aggregation is one of degree rather than kind.

Yet, beyond maintaining a connection to antecedent texts, there remain important epistemological differences between traditional science reporting, aggregation, and aggreduction. Each of the strategies identified above as part of science news *aggregation*, defined here simply as the collocating of stories on a single website, ultimately acknowledge the epistemic *value* of the structure of existing texts. Rather than editing or rewriting content, these aggregators have to innovate ways of ensuring value and validity that do not modify the texts themselves. In a sense these aggregators continue to embrace traditional forms of journalistic evidence—"analog evidence—quotes, official government sources, first-person observations, analog documents and files" (Anderson, 2013b: p. 1022). Indeed, these aggregators ultimately assert that these pieces of evidence hold validity even when they are a step further removed from their initial production. Indeed, their reverence for these forms of evidence, arranged in text, indicates a faith that goes *beyond* traditional newswork.

In contrast, aggreducers more directly embrace the forms of digital evidence Anderson identifies as part of aggregation. Yet, arguably, for aggreducers it is not only an acceptance of digital evidence, it is acceptance of a more basic discrete or fragmented epistemology.

For Scott Lash, all news embodies an informational epistemology that dissolves knowledge into discrete, interchangeable units. Like information, news has "no logical or analytic ordering. The newspaper headlines are ordered perhaps only by what sells papers: telegraph and newspaper ordered by urgency" (Lash, 2002: p. 145). Yet, Lash's description applies more to aggregators than aggreducers. News may collocate diverse stories, but there is a structural (narrative) logic within stories themselves. Aggreducers, however, extend the bounds of fragmentation further than traditional reporters (or aggregators). For Aggreducers, anything can be de and re-contextualized as needed. Textual structures are nothing more than accumulations of pieces, which can be freely rearranged.

In some ways, aggreduction is also a form of *remixing* (Navas & Galiagher, 2017), which Gunkel simply defines as "the practice of recombining preexisting media content—popular songs, films, television programs, texts, web data—to fabricate a new work" (2015: p. xvii). For most, remix has been most associated with art or creative industry (see also Lessig, 2008; McLeod & DiCola, 2011), and can be seen across formats and genres, from sampled music, to found art, to making free-form poetry from Donald Rumsfeld's memos as secretary of defense (Seely, 2009). For Sinnreich (2010), the prevalence of remix suggests a broader "configurable" or "remix culture."

Annette Markham (2017) draws out the epistemology of this form by recognizing in remix the constituting concept of bricolage. Bricolage originally derives from Levi-Strauss's *The Savage Mind* (1966) and "can be characterized as *an action* one takes (as a bricoleur), *an attitude* (or epistemology), and the resulting *product* or outcome of both" (Markham, 2017: p. 43). Markham suggests that as an epistemology, bricolage relates to how "we comprehend the world in moments, fragments, glimpses" (2017: p. 45). Kincheloe adopts bricolage as an organizing mode of interdisciplinary qualitative social science, one that "is concerned not only with multiple methods of inquiry but with diverse theoretical and philosophical notions of the various elements encountered in the research act" (p. 682).

That being said, while the products of remixed art or music attest to its creative promise, there is far more for concern in its adoption in knowledge production. Remixing, bricolage, and aggreduction all ultimately hold that truth can be maintained even as the organization or formation of information is lost. Data points, metaphors, explanations, quotations are taken to be autonomous entities that can be dis- and relocated in time, space, and context with no disruption to truth-value.

Similarly, aggreducers, as shown above, must first *produce* the shards and fragments they repurpose. Aggreducers, far more than journalists, actively pull apart the information flows and chains they encounter—they produce *deformations*.

Like shady mechanics, they strip content down for parts—often building something much worse. In doing so, aggreducers radicalize remix's discrete or Lash's informational epistemology into a corresponding *ontology* that decomposes being itself into bits, pieces, fragments, and shards—components able to be scrapped and used for parts because there is nothing important holding them together. Indeed, this is what many have recognized as a *digital ontology*, one that ultimately asserts, "The nature of the physical universe (time, space and every entity and process in space-time) is ultimately discrete" (Floridi, 2009: p. 152; alternatively, see Chun, 2011).[37] It is in this way that science aggreducers ultimately distinguish themselves from both aggregators and traditional reporters. It is also in this way that aggreducers join mediators, practices, and technologies described across this dissertation as injectors of *difference* into public science informational flows.

---

[37] Floridi follows this with three additional theses "(2) the physical universe can be adequately modeled by discrete values like the integers; (3) The evolution (state transitions) of the physical universe is computable as the output of a (presumably short) algorithm; and (4) The laws governing the physical universe are entirely deterministic." (p. 152-153)

Chapter 8
Conclusion: The Deformation Society

For the better part of a century, we have celebrated, lamented, and opined on the power of information to define, not only our economy, but our culture—sometimes even *being* itself. In recognizing this, generations of scholars have claimed, in one way or another, that we now live in an "information society" or an "information age" (Machlup, 1962; Beniger, 1986; Castells, 2010).

Across six empirical chapters this dissertation has shown that, for good and bad, information *changes*. In tracing information flows about direct detection experiments, it has described a science media system in which the stability of information cannot be assumed. Instead, constituted by mediators translating and transforming representations of science, information flows face internal and external challenges. This dissertation has traced the specific people, processes, and things that engender difference in information flows.

But what does it mean for the "information society," when the stability of information cannot be assumed? Similarly, what does it mean when what circulates is not information, but *deformations*: meaningful but disordered data? What do we lose and what do we gain when we recognize that information is constituted through and by difference?

In its long history, the "information society" has seen many different formulations (Webster, 2006). Some of the earliest saw the information society as primarily an economic or labor transformation, in which advanced economies had switched from manufacturing to "information-directed" industry (e.g. Machlup, 1962), and the majority of jobs have turned to the service sector (Bell, 1973). Other scholars have associated the information society with the development of information communication technologies (ICTs), which they see as reconfiguring nearly all aspects of society (Toffler, 1980; Floridi, 2014). For Castells, it isn't only ICTs, but more specifically the ways that ICTs have strengthened the benefits of networked forms of social organization that has led to such a radical reshaping of contemporary society.

In *The Fourth Revolution* (2014), Luciano Floridi traces the influence that ICTs have had across social life while also demonstrating "a quieter, less sensational, and yet more crucial and profound change in our conception of what it means to be human" (p. 96). Floridi identifies the development of ICTs' "*processing* capabilities" (p. ix, emphasis in original) as motivating the establishment of a new "hyperhistorical" period of history (p. 3). For Floridi, we now exist in an "infosphere," "the whole informational environment constituted by all informational entities, their properties, interactions, processes, and mutual relations" (p. 41), and we have become "informational organism" or "inforgs" (p. 94).

Yet, while centering ICTs in these massive social shifts, Floridi, like many theorists of the information society, arguably under-theorizes the link between ICTs and *information*. For Floridi, the changing capacities of ICTs unsettle nearly all aspects of social life and identity—yet, he grants information no theoretical autonomy from ICTs. What is it, exactly that circulates in our contemporary media system? How do the internal complexities of information itself play out as it moves in time and space?

For example, rather than a full theorization of information breakdown, Floridi offers "information friction," defined as "the forces that oppose the flow of information within a region of the infosphere" (p. 103). "Information friction" is a purely external impediment, moderating only speed and flow. Here, information has speed but no interiority: information friction reaches neither the content nor the coherency of flows. Perhaps the problem is rooted in Floridi's narrow definition of information, as necessarily "well-formed, meaningful, and true" (2011: p. 260). As soon as these rigorous criteria are disrupted, information ceases to be information and therefore has no place in Floridi's theorization (or in the infosphere, presumably).

Yet, what Floridi neglects in *The Fourth Revolution* is precisely what he demonstrates in *The Philosophy of information*: the degree to which information ontologically hinges on *difference*. Following MacKay (1969) or Bateson (1987[1973]) in recognizing that information is a "difference that makes a difference" (cited by Floridi, 2011: p. 85), should mean that we include difference in our theorization of information *flows* too. As Serres does for communication (1982), we should prioritize the disruption, the entropy, the *change* that is necessarily part of information as it moves through time and space.

Chapter 1 argued the necessity of recognizing change and difference as *internal* to information. Yet in describing information as successive functional representations, this project has essentially collapsed the distinction between information and information *flows*. Both are constituted by *mediators* who transform information while processing inputs into outputs. For Latour the distinction between mediators and intermediaries is central to Actor-Network Theory (ANT). Intermediaries transport "meaning or force without transformation" while for mediators "their input is never a good predictor of their output" (2005: p. 39). ANT presupposes that

> there exist endless number of mediators, and when those are transformed into faithful intermediaries it is not the rule, but a rare exception that has to be accounted for by some extra work— usually by the mobilization of even more mediators! (p. 40).

When we recognize that information is composed of mediators, we see that, as for strategic action fields (see chapters 5 & 6; Fligstein & McAdam, 2012: p. 7), stability or consistency is an achievement, one that takes *work*. Even as he centralizes ICTs, Floridi fails to see the broader universe of mediators through which information is translated and moved. For Floridi, as for other information society theorists granting information flows safe passage, it is *change* that requires work. This is the difference between invoking entropy rather than inertia as the ordering logic of information. Perhaps this is rooted in some of the earliest theorizations of the information society as an economic or industrial phenomenon, which treated information like any other commodity (Machlup, 1966) that could be packaged and trucked across the country.

In contrast to theorists who take it for granted that information can seamlessly flow over time and space, this dissertation has shown that [public science] information flows *because* it is passed amongst mediators. Media technologies, instruments, physicists, PIOs, and journalists, as mediators, are responsible for producing and circulating information. Each of these has the ability to transform information. On one hand, the change these mediators bring can be good—it can be *productive*. As the magnetologists model argues, we look to these mediators to help reveal hidden relationships while opening science to new meanings and new publics. On the other, these processes of mediation are risky, too. This dissertation has shown that both intentionally and unintentionally, these mediators can strip away the organization that defines information, leaving *deformations.* These bits, pieces, and fragments—informational-has-beens—have lost their contextual structuring that had once endowed them with meaning and truth. Once we recognize this, the so-called information society is more accurately described as the *deformation* society.

This recognition of deformation shares much with Scott Lash's description of contemporary information in his, aptly named *Critique of Information* (2002). For Lash, attempting to reconstruct the possibility for critical theory in the information society (p. vii), information

> is ephemeral. It works through a sequence of particulars, a collage of particulars, *Fait divers* are indeed news items, news in brief. They have no particular order: like an unconnected set of newspaper headlines or telegraph messages (McLuhan, 1997: p. 62-3). There is no logical or analytic ordering. The newspaper headlines are ordered perhaps only by what sells papers: telegraph and newspaper ordered by urgency (p. 145).

Here information is defined by difference taken to an extreme. For Lash, information is fundamentally disordered—deformed, held together only by "immediate temporality" (p. 145). But

> Outside the immediacy of real time, news and information are, literally, garbage. You throw out the newspaper with the disused food and the baby's disposable nappies (p. 145).

However, even as he sets limits on information in ways that few others do, for Lash information is garbage *only* because it looses its temporal context. Lash has no more account of how information *changes* as it flows than does Castells or Floridi. In contrast, this dissertation has shown that each of the many mediators responsible for producing and circulating information can change it as well. This means there are myriad sources of breakdown: economic pressures and labor relations, technologies and cultures; actors, in good and bad faith, can *intentionally* deform flows.

At the same time, old information, as garbage, has little use to Lash. Yet, deformations do not necessarily lose their value—there are enough viral tweets to attest to that. There is little indication that order is a precondition of value—indeed, the plasticity afforded by the dis-ordered incompleteness of deformations helps *generate* value. Deformations can be ordered and made meaningful in many different ways.

While some have described the key struggle of the information society as to process through, cull, or reduce information (Postman, 1993), in the deformation society the struggle is to *produce* information. It is to fashion together the bits and pieces in circulation into coherent structures that can lay claim to both truth and meaning. The deformation society gives *bricolage* or *remix* new urgency, not just as a creative endeavor, but as an epistemological—maybe even ontological imperative (Markham, 2017). While for Lash, old news loses its use value; deformations are as useful as what you can do with them.

But importantly, not all rebuilding is equal. It can and does often go awry. Truth claims can be weak or strong, even as meanings undergo not only evolution but involution. This is why political commentary drags with conspiracy theories while entertainment sites collect and pose "fan theories." Both are efforts to generate meaning from disconnected fragments and pieces. For both, that meaning often quickly loses touch with whatever little grounding it once had.

Communication scholars have long made room for misinformation as errors, and disinformation as intentional lies or fraud (Stahl, 2006). Indeed, our field was in part *founded* on early propaganda studies (e.g. Bernays, 1928; Laswell, 1938). Today scholars are recognizing that companies, politicians, think tanks, even governments, are building and adopting new tools, outlets, and strategies to circulate disinformation for political, financial, or ideological gain (e.g. Southwell, Thorsen, & Sheble, 2018).

In some sense, deformation names another danger we face: structural artifacts of the contemporary media system, pieces and fragments broken off in the grinding of disparate logics, systems, technologies, and messages. Deformation asserts the social utility of even partial or broken flows. Yet, some scholars have made similar arguments about disinformation. For Polletta and Callahan, consumers of fake news—of disinformation—are less passive "dupes" than active participants in larger "deep stories" (see also Hochschild, 2016) or "political common sense" (Polletta and Callahan, 2017: p. 1). Here, stories are both "allusive" and social: enigmatic and participatory (p. 3). Rather than believing every falsehood, audiences "often interpret outrageous stories as evidence of a broader phenomenon" (p. 14). Put a little differently, people do *work* in fitting together bits and pieces of information "from diverse sources" (p. 2) into larger ongoing stories and narratives. For Polletta and Callahan, the power of fake news comes less from its overt persuasiveness and more from its *utility* in allowing audiences to participate in social storytelling.

At the same time, savvy manipulators have become skilled at turning deformations into disinformation: to craft lies from the morass of circulating fragments. To be fair, this project found little evidence of this occurring around direct detection experiments. Yet, looking more broadly, we can see how common it has become for some to produce intentional disinformation by re-contextualizing bits and fragments, combining half and part-truths into whole lies. It may be that lying has become so easy *because* deformations populate our world. Yet, we have also come to value creative re-forming; it is the cultural capital of remix (Gunkel, 2015) and of the entrepreneur (Boltanksi & Chiapello, 2005). But deformation bears witness to the dark side to remix: we can forgive lies as long as they are well done.

And yet, not all hope is lost: deformations do not, necessarily, preclude information. Information persists as a nostalgic *once-was* and an aspirational *yet-to-be*. The real work of the deformation age is to build meaning out of ruins. Amid the deformations that define us, we are left to labor on behalf of once and future information.

APPENDIX A
METHODS IN DETAIL

This project adopts a mixed-method approach in order to trace informational flows about direct detection experiments. As discussed and justified in Chapter 1, this dissertation draws heavily on actor-network theory as a methodological framework that proscribes following the specific translations through which knowledge is produce and circulated.

Each chapter above lays out a brief discussion of the methods most relevant to that chapter. This appendix consolidates and expands these brief method sections. It is organized according to the major methodological approaches.

Semi-Structured Interviews

Data for this project derives from 62 semi-structured interviews. For the most part informants belong to one of three groups: dark matter physicists, public information or communication officers at national laboratories or research universities, and science journalists. Figure A.1 lists each informant along with organizational affiliation. It also lists the collaborations to which physicists currently belong or have at one time belonged. All but two informants gave explicit permission to be referenced by name in this project. The two exceptions are indicated with an asterisks (*).

Selection

Informants were selected in several ways. First, a list of every direct detection collaboration (with each major iteration) was produced by pulling together news articles, information from pilot interviews, and other available information (for example, the Dark Matter Hub on InterAction.org lists many collaborations). See Figure A.2 for a list of collaborations. Next, leaders of each collaboration were identified. Collected news articles (see below) were coded for sources. A list of physicists who have led collaborations and/or been frequently cited in news articles was constructed. A large number of these physicists were contact through email (without exception, email addresses of potential informants were found online), asking for an interview. At the same time, after completing initial interviews, informants were asked for suggestions of additional informants. They were also asked to provide email address and/or introductions. In this way, this project followed a modified snowball sampling approach. As interviews progressed, an effort was made to interview at least one member of every collaboration.

Journalists were identified through collected news articles. Articles were coded for authorship, and those authors who had written multiple articles were contacted. As with physicists, informants were asked for suggestions for additional informants, along with introductory emails. Notably, not only was it far harder to find journalists' contact information, but they were far less responsive to interview requests. As the project progressed, specific journalists at specific organizations were specially pursued.

PIOs or communication officers were identified in a similar way. Press releases and other institutional materials were collected and coded for authorship. Authors of multiple pieces were contacted. Similarly, informants were asked for recommendations.

Questions

Most interviews were held over Skype or on the telephone. Several were done in person. One interview was held entirely over email. After being unable to secure an interview with any member of DAMA, the spokesperson, Rita Bernabei, ultimately agreed to answer specific emailed questions. A set of 10 questions was emailed, and she provided written responses.

Interview questions began by having informants narrate their entrance into the field. Interviews with physicists asked them to describe how collaborations are structured and organized and about organizational histories of collaborations. Informants were asked to describe different aspects of experimental design, analysis, and communication. Interviews also asked specifically about public communication practices. Some informants had much to say about these (e.g. Rick Gaitskell), others, even with repeated probing, had little to say.

Journalists were asked to describe in general where and how they find story ideas, and to describe their organizations. There were specifically asked about interacting with physicists and PIOs. Journalists were also asked to look at pieces they had written, and to answer specific questions about the choices they had made.

Broadly, PIOs were asked similar questions as journalists. PIOs were also asked to describe their relationships/interactions with collaborations and journalists (as well as administrators, policy makers, etc.). They were also asked specific questions about pieces they had written.

Interviews also gave informants some latitude in following tangents. Some informants, especially physicists, were hesitant to talk about anything other than the *science* behind their experiments. In several instances, interviews asked detailed questions about these technical specifications. That not only provided important background information, it helped built rapport with informants, setting up future questions.

Several informants were asked follow-up questions via email. Information from these interviews has been noted.

Interviews were transcribed, and then analyzed in MAXQDA 12. Common themes were inductively generated, and then used to (re)code interviews.

Table A.1 Informants

Physicists	**Name**	**Organization**	**Collaborations (physicists)**
1	Bernard Sadoulet	UC Berkeley	CDMS
2	Blas Cabrera	Stanford	CDMS
3	Clara Cuesta	CIEMAT	ANAIS
4	*	*	DarkSide

5	Dan Akerib	Stanford	CDMS; LZ
6	Dan McKinsey	UC Berkeley	CLEAN;XENON; LUX; LZ
7	Daniel Snowden-Ifft	Occidental College	DRIFT
8	Robert Webb	Texas A&M	LUX; LZ
9	Hugh Lippincott	Fermilab	DEAP; COUPP; PICO
10	Juan Collar	U of Chicago	SIMPLE; CoGeNT; COUPP; PICO
11	Lauren Hsu	Fermilab	SuperCDMS; DM-ICE
12	Leslie Rosenberg	U of Washington	ADMX
13	Peter Graham	Stanford	Theorist; CASPER
14	Peter Meyers	Princeton	Darkside
15	Phil Barbeau	Duke	CoGeNT
16	Pricilla Cushman	U of Minnesota	CDMS
17	Rafael Lang	Purdue	CRESST; XENON
18	Rick Gaitskell	Brown University	CDMS; XENON; LUX; LZ
19	Rita Bernabei	Roma Tor Vergata	DAMA
20	Thomas Shutt	Stanford	CDMS; LUX; LZ
21	Tom Girard	U of Lisbon	SIMPLE
PIOs			
22	Andrew Gordon	SLAC	
23	Bill Harlan	SURF	
24	Brian Lin	EurekaAlert!	

25	Connie Walter	SURF	
26	Glen Roberts Jr.	LBL; SLAC	
27	Jeff Garberson	LLNL	
28	Jeff Kahn	LBL	
29	Jenny Leonard	U of Rochester	
30	Jon Weiner	LBL	
31	Judith Jackson	Fermilab	
32	Kathryn Jepsen	SLAC; Fermilab	
33	Katie Jurkewicz	Fermilab	
34	Kevin Munday	Xeno Media	
35	Liz Quigg	Fermilab	
36	Lynda Seaver	LLNL	
37	Manuel Gnida	SLAC	
38	Michael Schoenfeld	Duke	
39	Neil Calder	OIST; SLAC; CERN	
40	Richard Fenner	Fermilab; Argonne	
41	Rob Enslin	Syracuse University	
42	Steve Koppes	U of Chicago	
43	Ziba Mahdavi	KIPAC	
Journalists			
44	Adrian Cho	Science	
45	*	Futurity	
46	Clara Moskowitz	Scientific American;	

		Space.com; Livescience; Discover	
47	Damond Benningfield	StarDate	
48	David Voss	APS News	
49	Davide Castelvecchi	Nature; Scientific American; Freelance	
50	Dennis Overbye	NYTimes; Sky and Telescope	
51	Emily Conover	Science News; APS: Science Magazine	
52	Hamish Johnston	Physics World	
53	Lisa Grossman	Wired; New Scientist	
54	Marcel Pawlowski	The dark matter crisis blog	
55	Mathew R. Francis	freelancer	
56	Ramin Skibba	Inside science; Nautalus; new scientist	
57	Rich Zahradnik	Space.com	
58	Richard Chirgwin	The Register (Australia)	
59			

60	Simon Mansfield	SpaceDaily	
61	Tariq Malik	Space.com	
62	Tushna Commissariat	Physics World	

Table A.2: Collaborations

Name	**Year Sampled**	**Name**	**Year Sampled**	**Name**	**Year Sampled**
ADMX	2010	DEAP-1	2009	PICASSO	2009
ADMX Gen2	2016	MiniCLEAN	2014	PICO-2L	2015
ANAIS	2003	DM-ICE	2014	PICO-60L	2016
ArDM	2011	DM-TPC	2010	SABRE	2016
CDMS	2002	DRIFT-I	2004	SIMPLE-I	2005
CDMS II	2010	DRIFT-II	2015	SIMPLE-II	2012
Super-CDMS	2014	Edelweiss-I	2005	UKDMC	1998
CoGenT	2013	Edelweiss-II	2011	WArP	2007
COUPP	2012	Edelweiss-III	2016	X-MASS	2013
CRESST-I	1999	EURECA	2015	XENON10	2007
CRESST-II	2012	KIMS	2012	XENON100	2012
DAMA	1998	LUX	2013	XENON1T	2016
DAMA/LIBRA	2008	LZ	2015	ZEPLIN-I	2005
DarkSide	2015	MIMAC	2013	ZEPLIN-II	2007
DAMIC	2016	Newage	2010	ZEPLIN-III	2009
Deap-3600	2014	PandaX	2014		

Textual Analysis

News + PR Corpus

This project also employs a thematic textual analysis of 470 English-language news articles about direct detection experiments from August 1991 to July 2016.

Rather than constructing a sample, this project attempted to collect, catalogue, and analyze every available article produced about these experiments through 2016. Stories were collected through searches of a variety of archives, including Lexus Nexus, Web, News Wire, and individual news organizations. Searches used the names of each collaboration along with more generic terms like "direct detection," "dark matter," or "weakly interacting massive particles." Texts were also collected through a modified snowball approach. Every time an article from a new news site was identified, that site's archives were searched for additional articles about other direct detection searches. Collaborations themselves also archived news articles on their websites. Articles derive from a range of publications, 113 in total, including the *New York Times*, *Popular Science*, *Gizmodo*, and *Futurism.com*.

This project also collected a corpus of institutional content. This included 120 press releases produced by 52 organizations on behalf of 14 collaborations. It also included a further 206 stories produced by 88 additional national laboratories, research universities, or research institutes. These materials were collected in a similar manner as news articles. Also, after identifying every dark matter collaboration, and generating membership lists for major iterations (see below), the online archive of each organization was searched for materials about related collaborations.

This project also analyzed 338 tweets produced by 5 different collaborations. Collaboration names and variations of names were used as search terms to identify twitter accounts (see Figure A.5). Also, the followed and following lists of identified accounts were carefully parsed to identify additional direct detection accounts.

Texts were analyzed for recurrent themes, structural components, and approaches. Codes were generated both inductively, arising through immersion "in the texts and let[ing] the themes of analysis slowly emerge" (B. Brennen, 2017, p. 208), as well as deductively from the model offered in Chapter 2. Specifically, the model directed analysis to consider the ways that journalists modified content and meanings in producing articles. Overall, following Kracauer (1952), analysis focused on both "the surface meanings and the underlying intentions of a text" in order to "bring out the entire range of potential meanings in texts" (B. Brennen, 2017: p. 205).

Texts were also coded for *sources*. Every source that provided a quotation for an article was coded and tagged. Table App A.3 lists the top 20 most frequently cited physicists. Table App A.4 lists the total number of unique instances that members of collaborations were cited in news articles and press releases.

Table A.3: The 20 most cited physicists

Physicist	**Affiliation Cited**	**Total Citations**	**News Citations**	**PR Citations**
Rick Gaitskell	LUX, LZ, CDMS, XENON10	97	71	26
Juan Collar	Cogent, PICO, COUPP	56	48	8
Blas Cabrera	CDMS, CDMS-II, SuperCDMS	47	29	18
Dan McKinsey	LUX; XENON10	38	21	17

Dan Bauer	CDMS-II, SuperCDMS	32	21	11
Harry Nelson	CDMS-II, LUX, LZ	32	10	22
Elena Aprile	XENON10, 100, 1T	31	23	8
Bernard Sadoulet	CDMS, CDMS-II	29	15	14
Dan Hooper	LUX; Fermilab	26	26	0
Tom Shutt	CDMS, LUX, LZ	23	17	6
Kevin Lesko	LUX	19	6	13
Rafael Lang	XENON100, 1T	17	10	7
Mike Headley	Sanford Lab	17	1	16
Neal Weiner	Theorist (NYU)	16	16	0
Leslie Rosenberg	ADMX, gen2	15	10	5
Chamkaur Ghag	DarkSide, LUX	13	12	1
Rita Bernabei	Dama	12	12	0
Jodi Cooley	CDMS-II, SuperCDMS	12	7	5
Simon Fiorucci	LUX; LZ	11	8	3
Michael Turner	NSF	11	7	4

Table A.4: Number of times that members of collaborations are directly cited in news and PR articles

Collaboration	**News**	**PR**	**News/PR**
LUX	125	88	1.42
CDMS-II	92	54	1.70
Cogent	35	3	11.67
XENON100	28	19	1.47
Darkside	23	6	3.83
Dama	17	0	*
LZ	17	52	0.33
Zeplin-III	17	0	*
COUPP	16	15	1.07
Sabre	14	0	*
XENON1T	12	12	1.00
SuperCDMS	11	9	1.22
ADMX	10	13	0.77
CDMS	9	4	2.25
UKDMC	9	3	3.00
ADMX(Gen2)	7	2	3.50
CRESST-II	7	3	2.33
DEAP 3600	7	4	1.75
XENON10	7	1	7.00
PandaX	6	4	1.50
DNA	5	0	*
Edelweiss	3	0	*
MiniClean	3	0	*
Picasso	3	1	3.00
XMASS	3	1	3.00
DM ICE	2	2	1.00
DRIFT	2	0	*
CRESST-I	1	1	1.00
Damic	1	0	*
EDELWEISS-II	1	1	1.00
Pico	1	0	*
DRIFT-II	0	1	0.00

Figure A.5: Distribution of press releases through news aggregators.

Experiment	Date	Total # Press Release	Eureka Alert	News Wise	Alpha Galileo	InterActions	Unique News Articles
ADMX	5/16/12	1	DOE/LLNL				0
ADMX	11/23/06	1					0
ADMX	3/15/15-4/8	4					0
CDMS	4/15/13	3	TAMU; SLAC; Fermilab				14
CDMS	2/25/00	2					0
CDMS	11/12/03	3				Fermilab	0
CDMS	5/2/04	3				Fermilab	1
CDMS	4/10/14	1	Syracuse				1
CDMS-II	2/24/08	3				Fermilab	0
CDMS-II	12/17/09	2					26
CDMS-II	10/2/12	2					0
CoGeNT	6/6/11	2	U of Chicago; Kavli	U of Chicago; Kavli			6
COUPP	2/14/08	1				Fermilab	1
COUPP	5/1/13	3				Fermilab	0
COUPP	9/11/12	1					0
CRESST	9/8/15	4	TUM				1
CRESST	2/1/16	1	Springer				0
DAMA	8-Apr	1					0
DarkSide	2/27/14	1					0
LUX	11/15/12	6	LLNL/DOE				2
LUX	10/30/13	10	U of Chicago; Brown; Imperial College			Sanford Lab	28
LUX	2/20/14	1	Brown				0

LUX	12/14/15	11	LBNL/DOE; UCSB	SLAC		LBNL/DOE	5
LUX	7/21/16	2	LBNL/DOE; Brown	LBL		LBNL	27
LUX	10/15/09	1					0
LUX	5/24/12	1					0
LZ	5/23/12	2	LBNL/DOE				0
LZ	7/18/14	5	Yale				0
LZ	9/25/16	1		LBL		LBNL	0
LZ	6/1/16	2		SLAC			0
LZ	5/20/15	2		SLAC			0
Panda X	7/22/14	1	Science China Press				0
Panda X	7/6/14	1	Science China Press				0
Panda X	9/30/14	1	Science China Press				0
PICASSO	10/16/08	2			IOP		3
XENON100	4/14/11	5	NSF; UCLA; Weizmann		Max-Planck	INFN	0
XENON100	8/20/15	8	Purdue; AAAS; RPI		Bern		1
XENON100	5/6/10	2					1
XENON100	7/18/12	2					2
XENON100	2/3/11	1			Universitat Mainz		0
XENON1T	11/11/15	12				INFN-LNGS	6
XMASS	10/6/14	1	Kavli				0
XMASS	9/8/15	1					0

Assorted Other Documents

As noted above, this project also draws on a range of other assorted documents. Far more documents were collected and read than are explicitly cited. Below is a list of some of these:

- Assorted physics journal articles about direct detection experiments, as well as other particle physics experiments.
- Fermilab Annual Reports from 1979-2007
- Assorted articles, documents and presentations relating to the InterAction Collaboration, including 6 peer review reports.
- A set of news articles about *Space.com*, especially about its early history. These were mostly drawn from Lexis Nexis.
- A set of press releases produced by *space.com*, and archived on the Internet Archive.
- A series of DOE and NSF funding announcements and award descriptions for various collaborations.
- DOE and NSF guidelines and reports or relevant divisions, including cosmic frontier.
- Reports from NSAC and P5
- Materials produced by and about the Center for Particle Astrophysics at Berkeley, including
    - Original and subsequent grant applications, obtained through FOIA request
    - A report from the 1992 conference "The Changing Culture in Science."

Content Analysis

This project draws on a content analysis of a single publication, *Ferminews*, produced by Fermilab between 1978 and 2004. This represents the entirety of *FermiNews's* run under this name. From its beginning as the *Village Crier* in 1969, this publication was conceived as a source of organization news and information for lab employees. However, in 2004, the publication split into two, *Fermilab Today*, which continued to provide organizational information, and *Symmetry Magazine*, a self-described "news magazine" that covers research in the lab and the wider field. This publication therefore presents a useful case study to trace the journalization of national laboratories (see Chapter 6). Before the content analysis, a pilot study was undertaken of each issue in both the first and final years of the publication's run. These issues were inductively analyzed to produce a series of article types which furnished a series of codes. Then, the first (and in some cases only) issue each month of the publication were collected across the whole run time of 26 years. This sample (N=329) was coded according to the categories inductively generated. Linear regressions were employed to characterize article frequency over time.

Collaboration Membership

Collaboration membership data derives from published scientific journal articles. While websites publish collaboration lists, there was no way to ensure these were inclusive or up to date. After every major iteration of an experiment was identified, Google Scholar was used to identify the most cited article by that iteration of the collaboration (see A.4 for year of that publication). In nearly every case, this article was a major release of findings. Collaborations produce many different research papers; according to informants, not every collaboration member is included on every paper. However, informants suggested that major releases would have the most comprehensive author lists. In fact, informants suggested that this approach would be over-inclusive, as there are political reasons to include certain authors. That being said, authorship data is ultimately indicative of persistent relationships amongst collaboration members.

Membership lists were used to show relations amongst collaborations. Shared members were taken as a relation between two collaborations. A figure constructed from these data (Chapter 1, Figure 1.1; also Figure A.6). Thickness of the relation corresponds to the number of shared members.

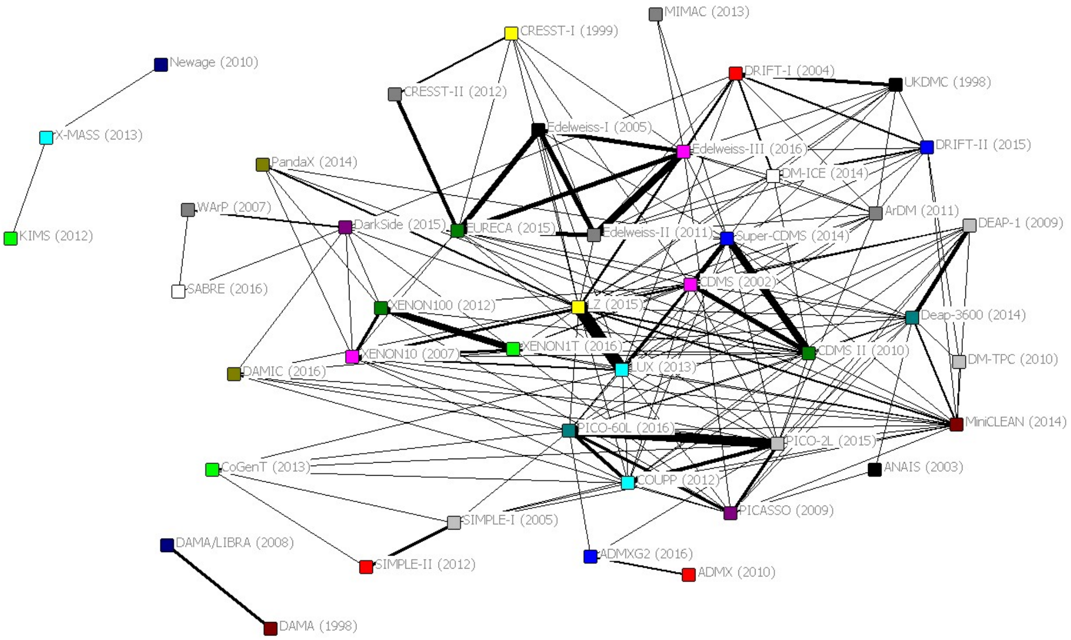


Figure App A.7: Relations amongst collaborations. The number of shared researchers is indicated by thickness of the line between collaborations.

Appendix B
Organizational Case Studies

The Cryogenic Dark Matter Search (CDMS)

The Berkeley Group

After working for more than a decade at CERN on the UA1 and UA2 experiments, Bernard Sadoulet needed a break. The two leaders of the UA1/UA2 experiments, Carlo Rubbia and Simon van der Meer had just been awarded the 1984 noble prizes in physics for discovering the W and Z bosons—the particles that carry and mediate the weak nuclear force. These experiments had been huge, complicated organizations, involving hundreds of physicists. Sadoulet, who had been working directly under Rubbia, had increasingly been taking on logistical and administrative responsibilities, responsibilities he had come to resent. Also, after more than a decade of working closely with him, Sadoulet was "a little tired of interactions with my advisor Carlo Rubbia," (personal communication, 4/6/2016) who has long had a reputation for being difficult to work with (Taubes, 1986). When the opportunity presented itself, Sadoulet gladly accepted a sabbatical at University of California at Berkeley.

For Sadoulet this sabbatical was not only a vacation from accelerator physics, it was also a chance to branch out into a different field: cosmology. Sadoulet was trained as an experimental particle physicist, someone who attempts to uncover laws and properties of fundamental particles through experiments. Cosmology, broadly, “deals with the large-scale structure and the temporal evolution of the universe” (Falkenburg, 2014: p. 98) however, for many years, cosmology had very little empirical data to work from. One dark matter physicists described it this way,

> the problem is that cosmology had almost no data, okay?.... in fact my father had a physics master’s [degree], when I told him I was going to do cosmology in grad school, he was like, oh my god! Cosmologists are flakes! (T. Shutt, personal communication, 3/9/2016).

By the early the early 1980s, however, two solutions to cosmology’s data problem appeared. First, there were several new astronomical data sets, most notably the CFA Red Shift Survey (1982), that provided new empirical insight into astronomical structures. On the other hand, advances in computing made it possible to model massive astronomical structures in terms of individual particles.

Along with these new sources of data, physicists had been working to better understand the connections between particle physics and cosmology (Cirkel-Bartelt, 2008: p. 32)[38]. Not only did these connections help strength the ties between the two fields, it helped to animate the beginning of a *new* field of physics: astroparticle physics (Cho, 2007; Cirkel-Bartelt, 2008; Falenburg, 2014)[39]

Sadoulet, who would eventually play a large role in the nascent field of astroparticle physics, originally saw an opportunity to bring some of his expertise in particle physics to cosmology. At the end of the year,

---

[38] For example, insights into the relationship between the amount of helium in the universe and certain neutrino characteristics.

[39] Importantly, the roots of astroparticle physics go back back to the first cosmic ray experiments of the early 1900s. However, it took these new data and theoretical connections between cosmology and particle physics to help formally found the field of astroparticle physics. In 1987, a group of prominent physicists and cosmologists held the “First International School on Astroparticle Physics,” (Shaver, 1987).

> I was lamenting actually going back to CERN after only a year of cosmology and some were not particularly interested in getting involved in cosmology [at CERN], and I had some particularly discouraging discussions with the director general [of CERN] at that time…, and the physics department at Berkeley said, look if you want to stay we can give you a position of full professor at Berkeley; I was weak enough to accept it (B. Saudulet, personal communication, 4/6/2016).

Although a full professorship at Berkeley might not seem like a risky career move, taking the position meant Sadoulet had to leave one of particle physics most celebrated experiments, led by noble laureates, to pursue a new and therefore risky area of physics.

One of the most pressing questions in this new field was dark matter. Some had begun to suspect that dark matter might be constituted by particles (Piet Hut, 1977; Pagel & Primack, 1982; Steigman, Turner & Krauss, 1984)—and therefore required bringing both cosmological and particle physics approaches to tackle the problem.

Experimental interest in WIMPS, which quickly became the most promising dark matter candidate, received a large boost after the first direct detection experiment was completed at the Homestake Mine in South Dakota (Ahlen et al., 1987) (where, 20 years later would be located the Sanford Underground Research Facility). The logic behind their experiment was summed up in a review article co-written by Sadoulet a few years later:

> The idea is that in an elastic collision with a nucleus the WIMP may impart a few keV of energy to the nucleus. That energy might be detected via a small current arising from ionization, as a small increase in temperature, or perhaps as a shower of phonons, all from the recoil nucleus (Primack, Seck & Sadoulet, 1988: 768).

Put more simply, Ahern et al. realized that it might be possible to build a detector that could register collisions between a WIMP and an atom of a target material in the detector. This first experiment chose to build their target out of the metal germanium and to look for ionization signals.

In California Sadoulet found a growing interest in dark matter: there were beginning to be regular meetings, conferences, and discussions about new directions for research. From his position at Berkeley, Sadoulet began collaborating with research groups at other institutions on dark matter research. Most notably, Sadoulet began working with David Caldwell at University of California at Santa Barbara. Caldwell had been trained as a nuclear physicist, and brought expertise in understanding nuclear recoils to dark matter work. After the two groups completed some initial experiments on these solid state detectors (e.g. Caldwell et al. 1988), Sadoulet and Caldwell began investigating a suggestion originally made in the Ahlen et al experiment, that "It will be difficult to reduce the energy threshold below 1keV, thus the detection of particles of lower mass will require cryogenic detectors" (1987: p. 607).

Cryogenic detectors are those that operate at very cold temperatures—only fractions of a degree above absolute zero[40]. Attempting to keep and run an experiment for days, weeks, or months at such low temperatures presents a notable technical and *organizational* challenge. Tom Shutt, who was one of Sadoulet's earliest graduate students at Berkeley and has continued to work in the field, remembered, "yeah, well the workhorse technology is called the BlueShore

---

[40] The absolute lowest temperature that is physically possible.

refrigerator, those things are a pain the butt. I basically got married to one. They've gotten a lot more reliable, but they used to be a labor of love" (T. Shutt, personal communication, 3/9/2016).

Despite the difficulties they presented, cryogenic detectors allowed experiments to detect WIMP collisions by watching for the tiny bits of heat produced when a WIMP collides with the target in the detector.

While Sadoulet's team was working on these detectors,

> one of my students wired a detector the wrong way—in part because of laziness, he had fewer solder to make if he did it that way. And we saw in addition to phonon pulses very sharp pulses, and when I saw that immediately I said that looks like ionization and okay, we did a few experiments. We convinced ourselves that this was the ionization we could show that this was actually this commutation between electron recoils and nuclear recoils and we thought that we were on our way" (B. Sadoulet, personal communication, 4/6/2016).

As Sadoulet relates here, it was an *accident* that helped motivate what would become the basic idea that would drive the CDMS experiments for decades: building detectors that could detect *both* ionization and heat change simultaneously.[41] Doing so allows physicists to better discriminate between what is a WIMP collision, and what is a collision between another particle and the detector.

In the late 1980's, Bernard Sadoulet was selected by the NSF to begin an institute at Berkeley, which came to be named the Center for Particle Astrophysics (CfPA). This institute was part of a NSF program called Physics Frontier Centers that funded short-term centers at major institutions to

---

[41] Importantly, Sadoulet reported that while at the time, it was unclear if these phonon (heat) detectors could register ionization as well, conversations with theorists had convinced him that it would be theoretically possible—though unclear how to achieve that technically.

> foster major breakthroughs at the intellectual frontiers of physics by providing needed resources such as combinations of talents, skills, disciplines, and/or specialized infrastructure, not usually available to individual investigators or small groups, in an environment in which the collective efforts of the larger group can be shown to be seminal to promoting significant progress in the science and the education of students (NSF, 2018).

While the CfPA supported a range of projects[42], dark matter remained the center's main focus. Figure 1 shows how the center was originally conceptualized such that each main research area related to dark matter.

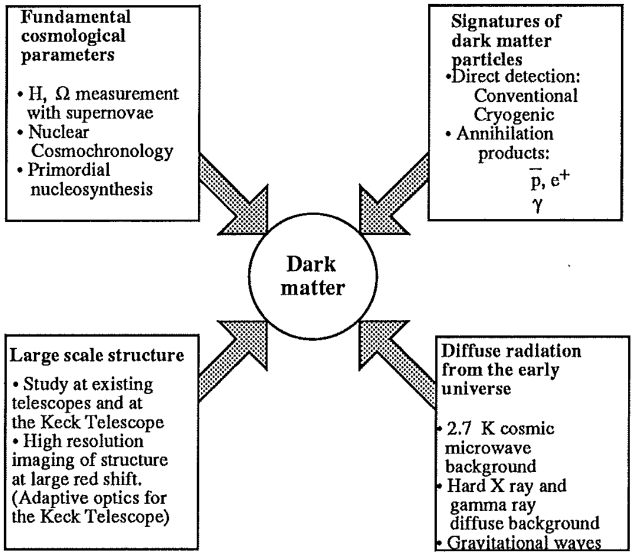


Figure 4.1. Center research directions.

Figure B.1: From the CfPA original 1988 grant filing.

The founding of the center also provided financial and logistical motivation to consolidate some of the different groups in the area into a single experiment. As

---

[42] Rick Gaitskell, former post-doc at the institute, remembered that some used to jokingly call it the Center for Practically Anything (R. Gaitskell, personal communication, 9/22/2016),

Tom Shutt describes it,

> Bernard [Sadoulet] came from a particle physics background so, you know, he saw you got to collaborate—you need a big experiment, so uh, you know, he, they basically formed a collaboration, so it was Berkeley, Stanford, and Santa Barbara (T. Shutt, personal communication, 3/9/2016).

As noted above, Sadoulet had already been working with David Caldwell at UC Santa Barbara. Yet the true beginning of the CDMS collaboration was in many ways the addition of Blas Cabrera's group from Stanford, a group that had for many years been a friendly "rival" (T. Shutt, personal communication, 3/9/2016).

The Stanford Group

Just thirty miles away from Berkeley, Blas Cabrera, a well respected condensed matter physicists at Stanford, had spent much of the second half of the 1980s becoming interested in dark matter research. Cabrera is a third generation physicists, his grandfather, Blas Cabrera Felipe, was a famous pioneer of condensed matter physics, specializing in magnetism. His father, Nicolás Cabrera was a well-known physicist in materials science.

Blas Cabrera had worked for years on a project that used highly sensitive instruments to attempt to detect magnetic monopoles, a theoretical particle that has a net magnetic charge. On Valentines Day 1982, Cabrera's experiment detected a signal that seemed, for all intents and purposes, to be a monopole (Cabrera, 1982). However, after continuing to run the experiment for years, his team never saw a second signal. In an interview, Rick Gaitskell quoted a poem apparently written by one of the researchers on the one-year anniversary of the “valentines day monopole”

> Roses are red and violets are blue
> Isn’t it time now for a monopole two?[43]

By the mid 1980s, frustrated with the direction of his work, Cabrera began researching the possibility of applying some of the instrument technology that he had been using to other ends—in particular to the search for dark matter (e.g. Cabrera, Krauss, Wilczek, 1985). Cabrera realized that the instruments his group had been using to look for monopoles—instruments that could register tiny changes in magnetic charge, could be used to make highly sensitive dark matter detectors.

Realizing that there would be value in bringing together the increasing number of scholars interested in cryogenic approaches to dark matter, Cabrera organized quarterly meetings what he called the Bay Area Low Temperature Informal Conference (BALTIC).

Between the well-funded CfPA and the relationships developed at conferences like BALTIC, the impetus grew to formally consolidate the groups at Berkeley, Stanford, and Santa Barbara into a single experiment. Initially the group was named simply “the dark matter pilot experiment” (B. Sadoulet, personal communication, 4/6/2016), but eventually it became the Cryogenic Dark Matter Experiment (CDMS), a name which Cabrera remembers as simply the “lowest common denominator” (B. Cabrera, personal communication, 11/16/2015) amongst the different experimental groups. While each of the major groups offered

---

[43] This is also cited in the book *The Early Universe: Facts and Fiction* by G. Börner, 2013

a slightly different approach and expertise[44], the Stanford group also supplied the use of an experimental site, in the form of a shallow underground laboratory beneath SLAC. As discussed in more detail below, operating these experiments underground helps limit some of the most troubling backgrounds, potentially making it easier to identify WIMP signals.

Throughout the rest of the 1990s, CDMS continued to grow—attracting more and more graduate students and post docs, as well as new institutional counterparts. Around 2000, the collaboration released its first major results (Abusaidi et al, 2000)—results that gained both expert and public attention for contradicting the findings of the DAMA collaboration, which for several years had claimed to have seen evidence of WIMPS (Bernabei et al, 2000).[45]

The release of these major results, more or less represented the end of an era for CDMS. Not only would CDMS's attention turn to the next iteration of the experiment, a project that would be known as CDMS-II, and would occupy the collaboration for much of the next decade, but also the funding and organizational landscape of the collaboration began to shift notably.

First, while much of the funding for CDMS had come from the CfPA (along with several grants from the NSF and DOE), by 2000 the CfPA had closed down. With the end of the CfPA, CDMS-II had to look elsewhere for funding and

---

[44] To review, Sadoulet was a particle physicists, Caldwell a nuclear physicist, and Cabrera a condensed matter physicist.

[45] See chapter 3 for a deeper discussion of DAMA. Basically, DAMA uses a different approach: rather than discriminate against non-WIMP signals, they use instruments that detect many particles. There is theoretical justification for believing that as the Earth moves through space around the sun, it will run through different numbers of WIMPS, depending on its position around the Sun. This means that over the span of years, it should be possible to see annual modulations in the total number of particles detected. The issue, however, is being sure the annual modulation is a result of WIMPs.

institutional support. Eventually, CDMS-II won significant support from both the NSF and DOE.

As part of this funding, however, the agencies required CDMS-II to choose between two separate approaches it had been pursuing simultaneously. Basically, even though CDMS had consolidated several different groups, there were still two different approaches being employed by collaboration members. The Berkeley group had pioneered an approach using

> thermistors on crystals to measure the very small temperature rise that you get [with WIMP collisions]. While at Stanford we were using thin film super conductors on the surface of the same sort of crystals, germanium and silicon, to detect the phonons[46], because of the position sensitivity, and various other sort of more information from the super conductors it was clear that you could do better, you understand a lot more about the event that were happening in the crystal, and then potentially be able to tell the difference between backgrounds and dark matter to a greater degree (R. Gaitskell, personal communication, 9/22/2016).

However, the Berkeley approach, while someone simpler, was better understood.

> essentially we had one technology that was very well established [the Berkeley technology] and had delivered many good results, and was clearly could be mass produced. We had a second technology [the Stanford approach] that potentially had greater ultimate performance, although at the time we were really trying to make a decision, the performance was still lagging the more established of the two technologies, but there was more headroom, ultimately, it could probably go higher (R. Gaitskell, personal communication, 9/22/2016).

The funding agencies argued that it was a waste of resources to simultaneously pursue two separate detector technologies to solve the same problem. After much discussion and debate, the collaboration chose to go with the Stanford approach—

---

[46] More or less, related to heat

the less established, though more promising technology.

The second major change that came with CDMS-II was in the location of the experiment. Collaboration leaders realize that in order to produce more sensitive results, they would need to move the experiment far deeper underground than the laboratory beneath SLAC. Searching for a new location for the experiment brought the collaboration to the Soudan mine in Northern Minnesota—an option that had been championed by Priscilla Cushman, a faculty member in the physics department at the University of Minnesota (P. Cushman, personal communication, 10/3/2016). The mine itself hadn't been in active use since the early 1960s, and had been donated to the state of Minnesota and turned into the Soudan Underground Mine State Park. In the early 1980s, the leaders of a large neutrino experiment, MINOS, realized the mine would provided a perfect environment shielded from background radiation. The experiment had worked with the University of Minnesota and Fermilab to develop the mine as an underground laboratory. That there was already an ongoing experiment in the mine meant that CDMS-II "was able to piggyback on that infrastructure" (B. Cabrera, personal communication, 11/16/2015). Running highly sensitive experiments deep underground in mines presents a number of difficult engineering and infrastructural challenges: as mundane as moving sensitive equipment or installing safety measures. That Soudan provided a technical infrastructure saved the experiment a good deal of time, money, and effort.

As it moved to the Soudan mine, CDMS-II grew from 12 to 18 institutions. At the same time, the leaders of CDMS negotiated for Fermilab to join the collaboration. Until that time, CDMS did not have a major national laboratory as a direct partnering institution. The leadership of CDMS was able to negotiate with John Peoples, the director of Fermilab, who

> encouraged several of the senior scientists at the lab to get involved and he arranged it in a way that the lab didn't overwhelm the collaboration. He set it up in a way that similar in scale to the university groups and that worked rather well….Basically, restricting the scale, the number of people involved, and so forth—and keeping it [that way]. When he set it up he kept it outside of the standard oversight process at Fermilab (B. Cabrera, personal communication, 11/16/2015).

Cabrera's concern that the national laboratory might overpower the other institutions in the collaboration hints at the persistent and unique culture of the collaboration. But to understand where this sentiment came from, it is necessary to return to the beginning of CDMS.

[Cyber]culture and CDMS

As described above, CDMS grew up and out of the Bay Area. While there were other institutions involved, Sadoulet's group at Berkeley and Cabrera's group at Stanford provided much of the intellectual and administrative leadership for the collaboration. Yet, arguably, there is more of a connection between CDMS and the Bay Area than just the fact that Sadoulet and Cabrera were employed at Berkeley and Stanford.

Sadoulet came to Berkeley, in part, to escape some of the challenges of working in a huge scientific collaboration. As larger and larger instruments were built in places like CERN, huge collaborations increasingly came to define the field of high-energy particle physics (Galison, 1992; 1997). The UA1/2 experiments that

Sadoulet helped run in the 1970 and 1980s, involved more than 150 people and 11 institutions (B. Sadoulet, personal communication, 4/6/2016)[47]. Sadoulet recollected that as one of the leaders of the experiment,

> I spent most of my time in budgets and pushing the construction through, and trying to organize—in spite of my boss—the communication within the team. And at that time I choked that this was my main goal in life, I should have joined general motors or IBM, not be in physics, so I felt somewhat removed from physics, even though I was really working at the frontier (B. Sadoulet personal communication, 4/6/2016).

Large accelerator research meant working on teams with dozens of members, "working on the subsystem of a subsystem, going to a lot of a meetings, things like that…it didn't seem as vital to me" (D. Akerib, personal communication, 11/30/2015). This ramped specialization helped separate individual physicists from the both experimental planning and design—but also from a more holistic and big-picture view of the experiment.

As big collaborations grew, researchers must also spend more and more time dealing with formal bureaucratic structures. "These big experiments there's tons of review, there tends to be a formal structure laid out for the experiments. Um, more 'Boxology.' In terms of rules, and a whole lot more meetings" (D. McKinsey, personal communication, 11/3/2015). As Dan Akerib explained his reason for leaving accelerator physics "And at the same time I had gotten a little disenchanted with working on really large particle physics experiments, and really large then—I guess

---

[47] Importantly, this would be seen as a medium-sized collaboration by today's standards. Currently at CERN, the AMS experiment involves over 1000 scientists. In fact, today, there are direct detection experiments that are this big—a dynamic that has caused some concern for long-time dark matter physicists.

the culture of it seemed to me a little bit corporate, a little bit depersonalized" (D. Akerib, personal communication, 11/30/2015).

In contrast, from the beginning dark matter physicists embraced a different approach to doing science. Instead of being part of an experiment running at some massive off-site location, "Dark matter used to be advertised as a bench top experiment" (T. Shutt, personal communication, 3/9/2016), meaning that experiments could be done down in the basement of a university physics building. At the same time, instead of working on a tiny piece of a huge experiment, dark matter research in the 1980s and 1990s meant being able to be involved in nearly all aspects of an experiment, from conceptualization, through building, and analysis.

> as far as the physics in atomic physics or condensed matter physics, or small astro-physics experiments they tend to be more sort of single PI, a professor and the professor's research group. And you know it's a small team you can pull off some projects, it's a very different thing, you know in the end there's one decision maker, whose the PI, so, things actually can be a lot more fun….you have a lot more autonomy, you can do whatever you want, you can move quickly, you can make decisions about what you want to do quickly, and uh, you know, an individual person is probably doing multiple things on the experiment, you have more control above what's going on (D. McKinsey, personal communication, 11/3/2015).

In this ideal of small teams, working autonomously, and having the ability to easily switch ideas, approaches, and goals, it is easy to recognize some of the ethos that defined many silicon valley start ups from the 80s on—an ethos that Fred Turner traces to west-coast counterculture movements of the 60s and 70s (Turner, 2008). For dark matter experiments, it wasn't only opting out of large-scale, bureaucratic accelerator research as it became increasingly dominant in particle physics; it was about having the opportunity to join "small experiments, clever experiments to look for new particle physics… I liked the idea of you know, doing some clever but daring small thing to make a big difference (D. McKinsey, personal communication, 11/3/2015).

Beyond the recognizable similarities in the ways that silicon valley technology firms and early west-coast direct detection experiments idealized work structures and imagined their role, the CfPA more actively worked to bridge the wider cultural movements of silicon valley and astroparticle physics. For example, from June 21-23, 1992, CfPA hosted a conference, titled, *The Changing Culture in Science—Bringing It into Balance*. The center published a "Conference Report and Call to Action," describing the conference and presenting its findings. It begins,

> There is a need for change in the scientific culture to accommodate a new population. The need for change is compounded by the fact that science itself has and is changing rapidly. We are faced with the creativity and greater sensitivity to societal needs (1992: p. ii).

The conference discussed ways of being more inclusive of diversity in science, and concluded "Diversity and excellence are not intrinsically opposed. To the contrary, diversity can be conducive to a more creative science and better linkages to society, and should be valued." It concludes by articulating "Guiding Principles of an Inclusive Community:"

> Dispense with the hierarchy
> Encourage communication
> Offer equal involvement to all members of the group in decision making
> Foster interconnectedness among the groups
> Replace competition with collaboration
> Avoid adversarial framing of the issues (1992).

These values not only help ground the types of formal governance structures that organizations like CDMS would adopt, but they speak to an ethos rejecting the bureaucratic hierarchies that had been increasingly defining large accelerator experiments and large corporations.

As an interesting side note, these early collaborations also adopted the other defining element of Silicon Valley: silicon. In July of 1985 Cabrera published a paper with Lawrence Krauss and Frank Wilczek that laid out one of the earliest theoretical discussions of the possibilities of measuring tiny changes in heat in a detector as a result of collisions of neutrons. Interestingly, in this article, the authors observe “at present no effective detector exists,” however

> We propose here the use of large quantities of silicon. This elemental material is especially well suited for thermometric detection both of recoil electrons and of lower-energy recoil nuclei from *v* interactions. Moreover, because of its large-scale use in the semiconductor industry, Si is readily available with extremely high purity in large amounts (p. 26).

The authors realized that the same reasons that silicon has been used in computer transistors, makes it a good fit for direct detection experiments.

Notable Organizational Structures of Multi-Institution Collaborations

In order to understand better the structure of CDMS—and how it differed from large accelerator experiments, this section looks at some of the key governance bodies and structures in place at CDMS, and its successor experiments, CDMS-II, and SuperCDMS.

CDMS is, ultimately, an association of universities and national laboratories. Institutional membership runs through principal investigators (PIs), university faculty members or staff research scientists at national laboratories, who brings along their research group. Currently SuperCDMS has 95 members representing 25 institutions. More broadly speaking, dark matter collaborations range in size, from one institution (ANAIS), to thirty-one (DarkSide and LZ)

Like nearly every direct detection collaboration, CDMS is and has been led by one or two "spokespersons." Spokespersons are generally elected to the position. The name "spokesperson" is no coincidence, "the spokesperson is the face of the collaboration pointing outward" (B. Cabrera, personal communication, 11/16/2015). Usually, spokespersons are senior scientists, who have experience with external communication. This idea of being the "face," was repeated by several informants.

> The spokesperson is the face of the collaboration and often times the intellectual driver, they are not always. Sometimes they are just the face of the collaboration to the funding agencies, but not always but sometimes there's something called the project manager, and often times they are the face of the collaboration to the rest of the scientific community and to the outside world, and that is outside true. No matter what, if you're named as spokesperson, and that's your title, you are the person whose responsible for organizing communication to the media and to universities, and to the scientists, you were the last say on the paper, you recognize that you may not be the person who wrote the paper, you may have some young person in the collaboration to help them out, give them credit, but this is your interpretation of how you should represent the collaboration onto the outside world. That is always true (P. Barbeau, personal communication, 10/21/2015).

As Knorr-Cetina observes, the spokesperson draws a great deal of power from serving as a bridge to the outside world (1999). Importantly, across direct detection experiments, most of the current and former spokespersons were also experiment founders.

In addition to a spokesperson, CDMS, like many direct detection collaborations, also has a "project manager," who is responsible for much of the day-to-day management of the collaboration—in particular how to deal with government bureaucracies. According to Leslie Rosenberg, the spokesperson and founder of the axion experiment ADMX,

> the regulations, rules, requirements [at the DOE] are so dense now that you need someone who understands the lingo, so what does it mean to have a CD1 review, what does it mean to have a layman review, what are the reporting requirements, etc. it means that you really need someone who is trained in that environment (L. Rosenberg, personal communication, 3/25/2016)

The current spokesperson of SuperCDMS, Dan Bauer, is also the leader of an "executive committee." This committee

> meets on a weekly basis, so the executive committee has been typically been 4, 5, or 6 people, it has grown somewhat in recent times. And they meet weekly. Discussing the issues that come up with the collaboration (B. Cabrera, personal communication, 11/16/2015).

In addition to the executive committee, SuperCDMS has a "board," which is made up of "all of the principal investigators in the collaboration. Mostly one per institutions, but in some instances there are two, or three depending on the size of the groups. And they're all principle investigators" (B. Cabrera, personal communication, 11/16/2015). Finally, SuperCDMS also has a "council, which is a somewhat larger group that also includes senior scientists… The council typically meets twice a month, the board once a month, something like that" (Blas). This all means that SuperCDMS not only has a spokesperson, but also *three* separate administrative bodies, an executive committee, a board of PIs, and a council of all senior scientists.

In addition to management committees, CDMS, like other collaborations, is also organized into working groups or divisions. These concern different aspects of building and running experiments, and vary widely depending on the collaboration.

One of the most important positions at CDMS is what is called the "analysis coordinator" or "analysis convener" (L. Hsu, personal communication, 4/14/2016). Analysis coordinators tend to be senior post-docs or new assistant professors. They are responsible for leading efforts to analyze the huge amounts of data produced by these experiments—efforts that can take months or years. Analysis can be very difficult, and requires a great deal of time—time that more senior faculty may not have given other administrative responsibilities. Similarly,

> a very young faculty is like swimming, just trying to stay, keep their head above water, they have typically may have little kids, they have moved their family, they are dealing with teaching for the first time, and trying to get their lab set up, and trying to recruit students, and trying to manage a budget all of that. You know, huge change in life style, so they're not, fresh, fresh, fresh young person, no way they could be analysis coordinator (T. Shutt, personal communication, 3/9/2016).

Yet, at the same time, the analysis coordinator needs

> A lot of skills, but they have to have been in a couple of different experiments, because until you have been in a couple of different experiments, its just like leaving high school and going to college until you have encountered a few different environments you don't have the understanding of group dynamics, and just you know, whatever, maturity, and you know, sense of stuff in order to do this job (T. Shutt, personal communication, 3/9/2016).

Given all of this, the position of analysis coordinator tends to serve as a springboard for top post-docs to help secure good faculty positions. For example Jodi Cooley served as the analysis coordinator for SuperCDMS ahead of its 2009 release, before taking a job at Southern Methodist University and Rafael Lang served as the analysis coordinator for both CRESST and XENON100, before landing a faculty job at Indiana University.

The Large Underground Xenon (LUX) Dark Matter Experiment

By the end of the 1990s, as it was becoming apparent that CDMS would not see evidence of WIMPS in its initial run, some members organized an informal meeting with theorists at CERN. According to Rick Gaitskell, "We needed greater guidance from theorists about… the possible candidates about dark matter" (R. Gaitskell, personal communication, 9/22/2016l). Based on recent work, these theorists suggested that WIMPs could, in fact, have a coupling strength several orders of magnitude (millions of times) weaker than previously thought. This meant that the experimental detectors would need to be significantly more sensitive than they were.

> I remember coming back from that and making a presentation to the CDMS collaboration, and saying look the theorists are telling us that we may need to build detectors at a 1-ton scale or even a 10-ton scale, I remember saying, in rather sort of hushed tones if you like because 10 tons—1 ton seemed kind of crazy, 10 tons seemed absolutely insane (R. Gaitskell, personal communication, 9/22/2016).

At the time, CDMS had been working at, roughly, the 0.5 to 1 kilogram scale—meaning the detectors would have be a *thousand*, or even *ten thousand* times larger. CDMS employed detectors composed of solid crystals of germanium and silicon that were physically limited by the ways that crystals could be grown. This means that to build a detector at this scale would require linking together huge numbers of smaller detectors: a nightmarish effort to coordinate all the detectors together. This encouraged Rick Gaitskell to begin investigating other sorts of detector technologies.

> It was just that scaling that many detectors was too hard, too expensive, too man-power intensive, and there were too many

> question marks about how to do that. Also, just fundamentally monolithic targets are better, homogeneous monolithic targets, and it doesn't get much more homogeneous and monolithic than a bucket of something. You know, a bucket of water, bucket of liquid scintillator, a bucket of liquid xenon. You are probably aware that at the time, the early naughties, the Japanese were just about to get their noble prize for the Super Kamiokanda, super KK, the ones that had come before, they demonstrated what you could do with a large bucket of water. The last one being 20 stories high (R. Gaitskell, personal communication, 9/22/2016).

Although CDMS was perhaps the most prominent American direct detection experiment at this time, there were a number of experiments investigating other detector technologies. Most notably, in the UK the Zeplin series of experiments, which had grown out of the United Kingdom Dark Matter Collaboration (UKDMC), had been developing time projection chambers with targets made out of liquid noble elements (see next chapter for a description of how these work), such as xenon (Lüscher et al., 2001). These experiments had never been wholly successful, in part because of limitations in commercially available photomultipliers tubes (PMTs), a key aspect of these detectors (P. Meyers, personal communication, 8/22/2016). PMTs are instruments that can detect and record photons. For decades PMTs have been able to detect individual photons,

> but their efficiency was always around 20 percent, so they could give you a signal for 1 photon, but they only do that for 1/5 of them, and Hamamatsu [the main global manufacturer of PMTs] found some magical way to increase that from 20 percent to like 35 percent, and for the previous, I would say, 40 years there had been essentially no improvement in that number, and a few years ago suddenly have these things available, it's like a miracle (P. Meyers, personal communication, 8/22/2016).

With better PMTs, dark matter detectors that looked for scintillation (photons) of large targets made up of liquid noble elements became a much more viable and competitive option. Perhaps most notably, Elena Aprile, a physicist at Columbia University, had started investigating ways to retool her xenon-based neutrino detectors for dark matter searches.

Based on his interest in exploring other detector technologies, and the fact that his post-doc at the CfPA ended, Rick Gaitskell quit CDMS. After a brief stint at London University, he took a faculty position at Brown University. Given his proximity to New York, Gaitskell joined Aprile in developing xenon detectors "rather than reinventing the wheel in six different locations simultaneously" (R. Gaitskell, personal communication, 9/22/2016). Along with several other PIs, they eventually formed the XENON collaboration, and began working on what would be called the XENON10 detector. Gaitskell and Aprile had significant success funding the new project: before leaving CDMS, Gaitskell had convinced the DOE to let him move his funding. Aprile also quickly won a large umbrella grant from the NSF.

Even before XENON10 had finished collecting and analyzing data, members of the collaboration began planning for the next iteration of the experiment, what was to be called XENON100—a larger, several-hundred Kg detector. However, during the process of writing a new funding proposal, five of the seven institutions ultimately decided they no longer wanted to be associated with the experiment, but instead wanted to form their own collaboration. Eventually, these groups split, forming the Large Underground Xenon or LUX collaboration.

In interviews, leaders of LUX provided several different justifications for deciding to split from the XENON collaboration. First, although mostly planned as an R&D effort, XENON10 had proved to be the most sensitive direct detection experiment in an increasingly crowded field. Part of what makes xenon-based detectors attractive is the ease of scaling-up—you basically just need to build a bigger tank of xenon. XENON100 was planned to have a detector mass of around 100 kg, but some in the collaboration believed this was not ambitious enough—and that they should build the largest detector that they could—perhaps something at the half-ton scale (R. Gaitskell, personal communication, 9/22/2016).

Second, although composed of many American research groups, XENON10 was actually housed and run at the Gran Sasso laboratory beneath the Apennine Mountains in central Italy. As Tom Shutt, who had been recruited to join XENON10 "we wanted to do a US experiment, and the Xenon program was clearly going to be in Gran Sasso" (T. Shutt, personal communication, 3/9/2016).

At this time, the NSF was developing a new underground laboratory—one that could pull together and house the increasing number of science experiments run underground.[48] The NSF named this the Deep Underground Science and Engineering Laboratory, or DUSEL. While the Department of Energy has run scientific laboratories for decades, the NSF generally does not operate facilities. In 2007 the NSF settled on the Homestake mine in South Dakota as the site for DUSEL—and had already been awarding grants for initial design work on the project. As planning for DUSEL proceeded, the NSF also tried to line up major projects for the new facility—LUX quickly become one of DUSEL's key initiatives (Riesselmann, 2/1/2010).

While dissatisfaction with the proposed size and location for XENON100

---

[48] These include direct detection searches along with a range of other initiatives, including, most notably, double-beta decay experiments.

helped motivate LUX's split, a number of informants suggested there was another reason. As Tom Shutt describes it "it was just a difference of philosophy on how to run the experiment" on a "sociological level" (T. Shutt, personal communication, 3/9/2016). Rick Gaitskell observed:

> there's a model for physics that's quite popular in Italy, certainty one that Elena [Aprile] likes, which is the rather autocratic system. In the US, I think, and its one of the strengths of the U.S. science, in US physics, is there's a more sort of level, equal, uh, meeting of equals, idea. You know, everybody is able to develop ideas and have them taken seriously, and then there's a great deal of discussion, and you usually you see a consensus establishing itself, even though people have, often nailed their heart to a particular idea, they understand that if they cannot convince a jury of their peers, or their colleagues that it's a good idea, that I don't care how bloody strongly you feel about something, you have to convince people within the group, within the wider collaboration that this is a good idea" (R. Gaitskell, personal communication, 9/22/2016).

A number of scholars (Galison, 1997; Knorr-Cetina, 1999; Traweek, 1988) have all observed that particle physics has a long tradition of more participatory or democratic structures, even beyond the US. Informants strongly suggested that they found Aprile's more authoritative management style somewhat untenable. Yet, it is worth noting hat many of the researchers who split from Xenon to form LUX had previously worked for CDMS (See FIGURE 2 for a map of collaboration membership). In this sense, specific cultural understandings about what an experiment should look like, rooted in either the wider field of fields, or in the specific culture of CDMS, were deeply influential in encouraging the split from XENON.

Space.com

On May 21st 1999 Rick Kaplan, the president of CNN, ordered the network to preempt the financial program *Moneyline News Hour* in order to air President Clinton's memorial speech at Columbine High School. Believing the speech didn't warrant such coverage, Lou Dobbs the program's anchor, instructed his production team to ignore the request. Kaplan, furious at being ignored, soon found himself in what the *New York Post* described as a "shouting match" between the "control rooms between Atlanta and New York." The fight ended when "Dobbs bowed and sarcastically went on the air, telling the show's nearly 900,000 viewers that 'CNN President Rick Kaplan wants us to return to Littleton'" (Tharp, 5/26/1999). Although the CNN power structure later backed Dobbs, the conflict exacerbated Dobb's growing displeasure with the network. Although Dobb's was one of CNN's most popular figures, there is some indication—or at least gossip—that he held a grudge at being denied the CNN Presidency in 1990 (Rutenberg, 1999). Several weeks later, Dobbs surprised both CNN and his future colleagues (Zahradnik, personal communication, 9/29/2017), by resigning from CNN to serve as the CEO of a new digital journalistic startup: space.com. Dobbs not only left behind a large salary, but also a stake in CNNfn.com, the financial site Dobbs had helped build.

When Dobbs left CNN for *Space.com*, he was joined by a number of other CNN employees, including Rich Zahradnik, who had helped Dobbs start CNNfn.com. Four years earlier, CNN had hired Zahradnik, who had been working primarily as a media and business journalists, to lead the new digital financial site. Zahradnik explained that while he had little experience running a news website, he had set up one of the first British soccer services in the early 1990s (personal communication, 9/29/2017). When Zahradnik and CNNfn succeeded, it meant that "I and twenty other people had built a large very popular financial news site for which our payoff was our salaries, we got nothing else for this, other people were building such sites in the IPO world and lots happened to them."

Although Dobb's departure from CNN was unexpected, Dobbs and Zahradnik had been working together on space.com for more than a year. When Dobbs had originally pitched the idea for a site devoted to all things space, Zahradnik and other CNN employees had jumped at their chance to make it big in the early Web. As Dobbs was feuding with CNN's president, he was also quibbling with the CNN administration over how much of an investment Dobbs could make and how much involvement he could have in the venture. A few days after he quit, Dobbs told the *New York Times*, "But the level of investment I want to maintain in this was incompatible with keeping the job I had…Frankly, a passive investment at the end of day wasn't what I wanted. I want active participation" (Mifflin, 6/10/99).

When Dobbs quit, he announced that *Space.com* would launch less than two months later, on July 20th, the 30th anniversary of the moon landing. Although Zahradnik, who was the site's president, had to scramble to hire staff, find temporary office space, and purchase equipment and software, the site successfully met the deadline.

From the beginning, *Space.com* was designed to be more than a space news site. When it launched it not only covered space news, but also had a section on science fiction, one on alien investigations, and an online store (see Figure 1). Not long after the site launched, however, it raised a great deal of money, and expanded rapidly.

Wednesday, October 13, 1999

news

The Sharpest-Ever (Publicly Available) Satellite View of Washington

Space Imaging showed off their new Ikonos Earth-imaging satellite for the first time today, releasing images of Washington D.C. landmarks.

Dutch Nobel Physics Prizewinner Has Many Interests

Gerardus 't Hooft, the Dutch scientist who shared the Nobel Physics Prize on Tuesday for his work at the frontiers of particle physics, takes a playful approach to the most fundamental issues of modern research.

Chandra Takes X-ray of Nebula and Star

A new image from the orbiting Chandra X-ray Observatory reveals details of Eta Carina, a nebula surrounding a massive star. The picture puts into broader context an earlier image of the star taken by the Hubble Space Telescope.

Figure B.2: Internet Archive capture from *Space.com* 10/13/1999, less than three months after launch.

Zahradnik left the organization in late August[49], and Dobbs hired Mitchell Cannold, a Sony executive as the site's COO, and a week later, former astronaut Sally Ride as the president (PR, 9/21/1999). With Dobbs and Sally Ride as the organization's public faces, *Space.com* attracted a great deal of public attention and initial financing, raising $50 million in second round funding from a group of firms including SpaceVest, Blue Chip Venture Company, NBC, PaineWebber, Greylock, and

---

[49] Zahradnik explained why he left:

> So [Dobbs] became the CEO, and I become the president, which wasn't a problem for me. What became a problem, about after a month, it's really just 20 of us, 20 people whom I'm trying to protect and get the work done, and Lou, and kinda on top of everybody, and I realized there's no solving this problem, Lou's not going to go away, and the funders aren't going to do anything about that, so that's when I left.

Venrock Associates, the venture capital arm of the Rockefeller Family (Space.com press release, 3/28/2000)[50].

This influx of money allowed the site to expand rapidly. Most notably, it increased its news operation, opening a series of news bureaus in Pasadena, near the Jet Propulsion laboratory, Houston, Cape Canaveral, and Washington (Space.com Press releases: 8/3, 10/20, 10/27, and 12/15/1999). The site also bought out several of its key competitors, including the popular trade magazine, *Space News* and its website Spacenews.com, *Space Online* (PR 10/26/2000), Starport.com (PR 6/20/2000), and Spacewatch.com, an early video streaming site built by Silicon Valley start up Pseudo.com (Blair[51], 7/14/2000). The company also bought a popular star watching and planetarium software called *Starry Night*. It also tried to reach beyond digital journalism, starting a print magazine with Hearst, *Space Illustrated* (PR 4/18/2000), and making deals to share content with NBC (PR 3/22/2000), and then MSNBC (PR, 9/18/2000).

By the end of 2000, however, as the dotcom bubble began to burst, the money ran out and there was little advertising revenue to replace it (R. Zahradnik, personal communication, 9/29/2017). Things began to turn. Sally Ride stepped down as president on September 27, 2000, and three days later the organization laid off 22 of its 108 employees (PR, 9/30/2000). Three months later, it cut another 12 people, and Mitchell Cannold, the COO and acting president, quit (Gallivan, 1/5/2001). By April, 2001, CNN, also struggling financially, had lured Lou Dobbs

---

[50] https://web.archive.org/web/20010827020334/http://www.space.com:80/php/siteinfo/pressrelease/secondround.php)

[51] This is the same Jayson Blair that was found to be fabricating stories in 2003

back with a large ($4million) deal, and while he remained on the board, he stepped down as CEO of Space.com (April 10, 2001 PR).

While it looked like the tech collapse would claim *Space.com* like it had many nascent digital news organizations, this was not the end. The executive board, still populated with members of the original backing VC firms, hired Mark Wright from the digital advertising company DoubleClick (PR, 9/2/99) as an interim CEO. Wright kept the site afloat by

> slashing overhead—like much of the real-time newsroom—and unloading underperforming print publications. What remained, he concluded, was a viable information and e-commerce business that needed better execution and a few key acquisitions to succeed (Nelson, 1/18/2006).

This is an important moment for *Space.com*—Wright not only believed that the only viable path forward was to give up a more traditional journalistic news room, but that having done so, it could remain an "information" business.

Tariq Malik, who has worked at *Space.com* since he was hired as an intern in September 2001, remembered that at the time they had a "skeleton crew," with "4 or 5 core editorial" personnel. Importantly,

> it was made clear to me that those types of investments early on, that were not editorial, one was a membership driven publication, the other was a commercial enterprise, had a large role in keeping the company afloat at that time. … [along with] investors to support the company in the lean years (T. Malik, personal communication, 12/15/2016).

Wright was followed as CEO by Dan Stone, from Scient[52], who respected Wright's plan and worked to turn *Space.com* from being a space-focused news organization into a broader information and commerce site. In 2003, Stone raised 4.7 million from many of the original investors, in part to launch Livescience.com, a science news site. Simultaneously, the board renamed the parent organization Imaginova to reflect its move away from space. A few months later, the company raised another 5.7 million to buy Orion Telescopes & Binoculars, further expanding on the sales and commerce side of the business. For a time, this strategy seemed to have worked, by 2005, Forbes reported Imaginova had 30 million in annual revenue (Nelson, 1/18/06), and by August 2006, the organization raised an addition 15 million (Carlsen, 8/10/2006).

Imaginova's success, however, didn't last through the Great Recession. In 2008, the division running the Starry Night software bought itself from Imaginova, forming Simulation Curriculum, which has become an independent and successful software company.

In October 2009, TopTenReviews (TTR) bought the website arm of Imaginova, including Space.com, Livescience.com, and Newsarama.com. At the time TopTenReviews was identified by the *Salt Lake Tribune* as "the fourth largest technology news site, according to September 2009 U.S. figures from comScore" with 12.2 million monthly visitors (Harvey, 10/26/2009). At the time, TTR was "primarily a product review company, and was looking to grow into editorial," (T. Malik, personal communication, 12/15/2016). TTR (which has since gone through

---

[52] Scient was a major Internet consulting company at the turn of the millennium that had a massive fall in the dot.com burst, before being resold a handful of times.

two name changes, first to TechMedia Networks, then to Purch Group) based its model on describing and reviewing products. This content included Amazon links to those products, which generated money when readers clicked through the links. Imaginova hadn't been turning a profit with Space.com and Livescience.com, but TopTenReviews had a new financial model that involved bringing their product-focused content to journalism. Clara Moskowitz who worked at Space.com and Livescience.com from January 2008 through August 2013, described how TTR believed their model was "a way to monetize the news. So whenever we mentioned telescopes we would link to their page that compared all of the like best backyard telescopes and helped you choose which one you wanted to buy" (C. Moskowitz, personal communication, 8/15/2016)

She observed, however, that this changed how reporters produced stories. Eventually she was instructed to

> keep in mind that we need to constantly find ways to tie these stories into things that we can sell, you know, so like at points like I felt kinda the conflict inherent in that, but I think they tried to keep everything above board and everything. I was never asked to do anything that I thought was unethical, but it was just like, it was a lot of pressure, I felt to, you know, to produce quick stories, as many as possible, so that we could try to link them to as many product reviews as possible. And sometimes we would cover areas that had good monetization potential, things like that" (C. Moskowitz, personal communication, 8/15/2016).

While many of the articles she wrote, such as those about dark matter, had minimal commercialization potential, "the whole philosophy was certain parts of these sites can keep the rest of them afloat" (C. Moskowitz, personal communication, 8/15/2016).

Tariq Malik, the current managing editor at Space.com, explained that

> a key part of that would be in addition to your regular news coverage you might want to include things that people might be able to share their passion with space with their kids, so having a space gift-guide for kids, or for adults, that is what that looks like. We have a telescope run-down: here are the new telescopes this year, here's what you might want to buy, here are the reasons why—it breaks it down for the users…and then if you write a story about a new space movie, maybe you include a link to our space movie page, which is all about space move that we like, or books, or if Estes released a new rocket that is accurate to old Apollo era rocket, so if you write a news piece about this rocket or a new Kickstarter you can just add those links in, where appropriate, you are not going to shove something that's commercial into a story that wouldn't belong, so we make sure that we keep it all appropriate to the reader experience" (T. Malik, personal communication, 12/15/2016).

While Malik downplayed the influence that this change has had on editorial strategy, Moskowitz did observe some notable shifts. While Moskowitz wrote a mix of stories, including some longer investigative pieces, the main sources for her stories was "probably mostly press releases there, so that place [had a] really fast turn around: these press releases would come out, and it was like we need something quick, do it in an hour, and then you'd mix it up…there was a lot of the press release churn out."

Swinging between exaggerated hopes and despair, between expanding and contracting, between traditional news practices and new ones, *Space.com* reveals some of the struggles faced by digital science journalism producers over the past several decades. *Space.com* emerged at a time when serious media professionals believed that there were billions of dollars to be made off of new digital journalism outlets. And when it couldn't live up to that potential (or, frankly, even turn a profit), *Space.com* might have gone the way of many other outlets. Yet it survived because it was able to marry its (evolving) content to other revenue streams beyond digital advertising, first becoming an information and commerce hub, and then a "decision-enablement company" (T. Malik, personal communication, 12/15/2016). Yet, these changes have not come without a cost: more and more, *Space.com* has been forced to give up producing independent reporting and focus on churning out content quickly.

REFERENCES

Abusaidi, R., Akerib, D. S., Barnes Jr, P. D., Bauer, D. A., Bolozdynya, A., Brink, P. L., … Castle, J. P. (2000). Exclusion limits on the WIMP-nucleon cross section from the cryogenic dark matter search. *Physical Review Letters*, *84*(25), 5699.

Ahlen, S. P., Avignone, F. T., Brodzinski, R. L., Drukier, A. K., Gelmini, G., & Spergel, D. N. (1987). Limits on cold dark matter candidates from an ultralow background germanium spectrometer. *Physics Letters B*, *195*(4), 603–608.

Allan, S. (2009). The future of science journalism. *Journalism*, *10*(3), 280–282. https://doi.org/10.1177/1464884909102570

Allan, S. (2011). Introduction: Science journalism in a digital age. *Journalism*, *12*(7), 771–777. https://doi.org/10.1177/1464884911412688

Altheide, D. L., & Snow, R. P. (1979). *Media Logic*. Beverly Hills, CA: Sage Publications.

Anderson, C. W. (2011). Deliberative, Agonistic, and Algorithmic Audiences: Journalism's Vision of its Public in an Age of Audience Transparency. *International Journal of Communication*, *5*(0), 19.

Anderson, C. W. (2013). *Rebuilding the News: Metropolitan Journalism in the Digital Age*. Philadelphia, PA: Temple University Press.

Anderson, C. W. (2013b). What aggregators do: Towards a networked concept of journalistic expertise in the digital age. *Journalism*, *14*(8), 1008–1023. https://doi.org/10.1177/1464884913492460

Anderson, C. W., & Kreiss, D. (2013). Black boxes as capacities for and constraints on action: Electoral politics, journalism, and devices of representation. *Qualitative Sociology*, *36*(4), 365–382.

Ankney, R. N., & Curtin, P. A. (2002). Delineating (and delimiting) the boundary spanning role of the medical public information officer. *Public Relations Review*, *28*(3), 229–241.

Archambault, S., Aubin, F., Auger, M., Behnke, E., Beltran, B., Clark, K., … Faust, R. (2009). Dark matter spin-dependent limits for WIMP interactions on 19F by PICASSO. *Physics Letters B*, *682*(2), 185–192.

Aron, J. (2016, July 21). Dark matter no-show puts favoured particles on death row. *New Scientist*.

Autzen, C. (2014). Press releases — the new trend in science communication. *Journal of Science Communication*, *13*(03), C02.

Bakker, P. (2012). AGGREGATION, CONTENT FARMS AND HUFFINIZATION: The rise of low-pay and no-pay journalism. *Journalism Practice*, *6*(5–6), 627–637. https://doi.org/10.1080/17512786.2012.667266

Bateson, G. (1987). *Steps to an Ecology of Mind*. Northvale, NJ: Jason Aronson, Inc.

Bauer, M., & Bucchi, M. (Eds.). (2007). *Journalism, Science and Society: Science Communication between News and Public Relations*. New York: Routledge.

Bauer, M. W., Howard, S., Ramos, R., Jessica, Y., Massarani, L., & Amorim, L. (2013). *Global science journalism report: working conditions & practices, professional ethos and future expectations*. Science and Development Network.

Bednar, C. (2016, July 21). World's most sensitive dark matter detector finishes search. *RedOrbit*.

Bell, D. (1976). The Coming of the Post-Industrial Society. *The Educational Forum*, *40*(4), 574–579. https://doi.org/10.1080/00131727609336501

Beniger, J. (1986). *The Control Revolution*. Cambridge, Mass.: Harvard University Press.

Benkler, Y. (2006). *The wealth of networks: How social production transforms markets and freedom*. N/A: Yale University Press.

Bennett, W. L. (1996). An introduction to journalism norms and representations of politics. *Political Communication*, *13*(4), 373–384. https://doi.org/10.1080/10584609.1996.9963126

Bernays, E. L. (1928). *Propaganda*. Brooklyn, New York: Ig publishing.

Berners-Lee, T., Fischetti, M., & Foreword By-Dertouzos, M. L. (2000). *Weaving the Web: The original design and ultimate destiny of the World Wide Web by its inventor*. New York: Harper Information.

Besley, J. C., & Nisbet, M. (2013). How scientists view the public, the media and the political process. *Public Understanding of Science*, *22*(6), 644–659.

Bjerg, O., & Presskorn-Thygesen, T. (2017). Conspiracy Theory: Truth Claim or Language Game? *Theory, Culture & Society*, *34*(1), 137–159. https://doi.org/10.1177/0263276416657880

Blum, D., Knudson, M., & Henig, R. M. (Eds.). (2005). *A Field Guide for Science Writers: The Official Guide of the National Association of Science Writers* (2nd edition). Oxford England ; New York: Oxford University Press.

Blumenthal, G. R., Pagels, H., & Primack, J. R. (1982). Galaxy formation by dissipationless particles heavier than neutrinos. Nature, 299(5878), 37.

Boczkowksi, P. (2010). *News at Work: Imitation in an Age of Information Abundance*. Chicago: University of Chicago Press.

Boczkowski, P. J., & Anderson, C. W. (2017). *Remaking the News: Essays on the Future of Journalism Scholarship in the Digital Age*. Cambridge, Mass.: MIT Press.

Bode, L., & Vraga, E. K. (2015). In Related News, That Was Wrong: The Correction of Misinformation Through Related Stories Functionality in Social Media. *Journal of Communication*, *65*(4), 619–638. https://doi.org/10.1111/jcom.12166

Bodmer, W. (2010). Public Understanding of Science: The BA, the Royal Society and COPUS. *Notes and Records of the Royal Society*, *64*(Suppl 1), S151–S161. https://doi.org/10.1098/rsnr.2010.0035

Bok, S. (2011). *Lying: Moral choice in public and private life*. New York: Vintage.

Boltanski, L., & Chiapello, E. (2005). The new spirit of capitalism. *International Journal of Politics, Culture, and Society*, *18*(3), 161–188.

Boorstin, D. J. (2012). *The image: A guide to pseudo-events in America*. New York: Vintage.

Borchelt, R., & Nielsen, K. (2014). Public relations in science Managing the trust portfolio. In M. Bucchi & B. Trench (Eds.), *Routledge Handbook of Public COmmunication of Science and Technology* (pp. 58–69). New York: Routledge.

Bourdieu, P. (1999). *On Television*. New York: The New Press.

Bourdieu, P., & Wacquant, L. J. D. (1992). *An Invitation to Reflexive Sociology*. Chicago: University of Chicago Press.

Boykoff, M. T., & Boykoff, J. M. (2004). Balance as bias: global warming and the US prestige press. *Global Environmental Change*, *14*(2), 125–136. https://doi.org/10.1016/j.gloenvcha.2003.10.001

Bozeman, B., Fay, D., & Slade, C. P. (2013). Research collaboration in universities and academic entrepreneurship: the-state-of-the-art. *The Journal of Technology Transfer*, *38*(1), 1–67.

Brechman, J., Lee, C., & Cappella, J. N. (2009). Lost in Translation?: A Comparison of Cancer-Genetics Reporting in the Press Release and Its Subsequent Coverage in the Press. *Science Communication*, *30*(4), 453–474. https://doi.org/10.1177/1075547009332649

Brennen, B. S. (2017). *Qualitative research methods for media studies*. New York: Taylor & Francis.

Bricker, B. J. (2013). Climategate: A Case Study in the Intersection of Facticity and Conspiracy Theory. *Communication Studies*, *64*(2), 218–239. https://doi.org/10.1080/10510974.2012.749294

Britain), R. S. (Great, & Bodmer, W. F. (1985). *The public understanding of science: Report of a Royal Society ad hoc group endorsed by the Council of the Royal Society*. London: Royal Society.

Broks, P. (2006). *Understanding popular science*. Berkshire, England: McGraw-Hill International.

Brossard, D. (2013). New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences*, *110*(Supplement 3), 14096–14101.

Brossard, D., & Lewenstein, B. (2009). *Communicating Science: New Agendas in Communication*. New York: Routledge. https://doi.org/10.4324/9780203867631

Brossard, D., & Scheufele, D. A. (2013). Science, New Media, and the Public. *Science*, *339*(6115), 40–41. https://doi.org/10.1126/science.1232329

Brown, S. D. (2002). Michel Serres: Science, translation and the logic of the parasite. *Theory, Culture & Society*, *19*(3), 1–27.

Brumfiel, G. (2009). Science journalism: Supplanting the old media? *Nature News*, *458*(7236), 274–277.

Bucchi, M. (1996). When scientists turn to the public: alternative routes in science communication. *Public Understanding of Science*, *5*(4), 375–394. https://doi.org/10.1088/0963-6625/5/4/005

Bucchi, M. (2008). Of deficits, deviations and dialogues: theories of public communication of science. In M. Bucchi & B. Trench (Eds.), *Handbook of public communication of science and technology* (pp. 57–76). London; New York: Routledge.

Bucchi, M., & Trench, B. (2014). *Routledge Handbook of Public Communication of Science and Technology*. New York: Routledge.

Burnham, J. C. (1987). *How Superstitution Won and Science Lost: Popularizing Science and Health in the United States*. New Brunswick: Rutgers University Press.

Burri, R. V., & Dumit, J. (2008). Social Studies of Scientific Imaging and Visualization. In E. J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies* (pp. 297–317). Cambridge, Mass.: The MIT Press.

Cabrera, B., Krauss, L. M., & Wilczek, F. (1985). Bolometric detection of neutrinos. Physical Review Letters, 55(1), 25.

Callon, M. (1980). Struggles and negotiations to define what is problematic and what is not. In *The social process of scientific investigation* (pp. 197–219). Springer.

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay. *Power, Action, and Belief: A New Sociology of Knowledge*, *32*, 196–223.

Callon, M., Lascoumes, P., & Barthe, Y. (2009). *Acting in an Uncertain World*. (G. Burchell, Trans.). Cambridge, Mass.: The MIT Press.

Carlson, M. (2017). *Journalistic Authority: Legitimating News in the Digital Era*. New York: Columbia University Press.

Cartlidge, E. (2015, November 12). Largest-ever dark-matter experiment poised to test popular theory. *Nature*.

Cartwright, N. (1999). *The dappled world: A study of the boundaries of science*. Cambridge, UK: Cambridge University Press.

Castells, M. (2010). *The Rise of the Network Society*. Malden, MA: Wiley-Blackwell.

Checkland, P. B., & Scholes, J. (1990). *SSM in Action*. New York: Plenum, New York.

Cheng, G., & Chau, J. (2011). A Comparative Study of Using Blogs and Wikis for Collaborative Knowledge Construction. *International Journal of Instructional Media*, *38*(1), 71–78.

Cho, A. (2013, October 30). New experiment torpedoes lightweight dark matter. *Science Magazine*.

Chun, W. H. K. (2011). *Programmed visions software and memory*. Cambridge, Mass.: MIT Press.

Chyi, H. I., Lewis, S. C., & Zheng, N. (2016). Parasite or Partner? Coverage of Google News in an Era of News Aggregation. *Journalism & Mass Communication Quarterly*, *93*(4), 789–815. https://doi.org/10.1177/1077699016629370

Cirkel-Bartelt, V. (2008). History of Astroparticle Physics and its Components. Living Reviews in Relativity, 11(1), 2. https://doi.org/10.12942/lrr-2008-2

Clark, F., & Illman, D. L. (2006). A longitudinal study of the New York Times Science Times section. *Science Communication*, *27*(4), 496–513.

Clements, E. (2004, June 1). No End in Sight. *Ferminews*.

Cloître, M., & Shinn, T. (1985). Expository practice. In *Expository science: Forms and functions of popularisation* (pp. 31–60). Springer.

Coddington, M. (2015). *Telling Secondhand-Stories*. University of Texas, Austin.

Cowen, R. (2011, May 4). Experiment Confirms Hints of Dark Matter. *Wired*, p. N/A.

Creath, R. (1992). Induction and the Gettier Problem. *Philosophy and Phenomenological Research*, *52*(2), 401–404. https://doi.org/10.2307/2107943

Cummings, J. N., & Kiesler, S. (2007). Coordination costs and project outcomes in multi-university collaborations. *Research Policy*, *36*(10), 1620–1634.

Davies, N. (2011). *Flat earth news: An award-winning reporter exposes falsehood, distortion and propaganda in the global media*. New York: Random House.

Davies, S. R. (2013). Constituting Public Engagement Meanings and Genealogies of PEST in Two U.K. Studies. *Science Communication*, *35*(6), 687–707. https://doi.org/10.1177/1075547013478203

Davies, S. R. (2014). Knowing and Loving: Public Engagement beyond Discourse. *Science & Technology Studies*, *27*(3).

Davies, S. R., & Hara, N. (2017). Public Science in a Wired World: How Online Media Are Shaping Science Communication. *Science Communication*, *39*(5), 563–568. https://doi.org/10.1177/1075547017736892

Davies, S. R., & Horst, M. (2016). *Science Communication - Culture, Identity and | Sarah R. Davies | Palgrave Macmillan*. London: Palgrave Macmillan.

DeJesus, C. (2016, July 22). The World's Most Sensitive Dark Matter Detector Just Found…Nothing. *Futurism*.

Deleuze, G. (1994). *Difference and repetition*. New York: Columbia University Press.

DeRose, K. (2011, April 14). Search for dark matter moves one step closer to detecting elusive particle. *UCLA*.

Derrida, J. (1978). *Writing and difference*. Chicago: University of Chicago Press.

Deuze, M. (2005a). What is journalism? Professional identity and ideology of journalists reconsidered. *Journalism*, *6*(4), 442–464.

Deuze, M. (2005b). What is journalism? Professional identity and ideology of journalists reconsidered. *Journalism*, *6*(4), 442–464.

DiMaggio, P. J., & Powell, W. W. (1983). The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review*, *48*(2), 147. https://doi.org/10.2307/2095101

Domingo, D., Masip, P., & Meijer, I. C. (2015). Tracing Digital News Networks. *Digital Journalism*, *3*(1), 53–67. https://doi.org/10.1080/21670811.2014.927996

Dorey, J. (2016). *When Public Relations and Particle Physics Collide: An Ethnographically Informed Account of Life in the CERN Communications Group* (PhD Thesis). The Open University.

Drukier, A. K., Freese, K., & Spergel, D. N. (1986). Detecting cold dark-matter candidates. Physical Review D, 33(12), 3495.

Dunwoody, S. (2008). Science journalism. In M. Bucchi & B. Trench (Eds.), *Handbook of public communication of science and technology* (pp. 15–26). New York: Routledge.

Dunwoody, S. (2014). Science Journalism. In M. Bucchi & B. Trench (Eds.), *Routledge Handbook of Public Communication of Science and Technology*. Routledge New York.

Dunwoody, S., & Ryan, M. (1983). Public information persons as mediators between scientists and journalists. *Journalism and Mass Communication Quarterly*, *60*(4), 647.

Ettema, J. S., & Glasser, T. L. (1984). On the epistemology of investigative journalism. Presented at the AEJMC, Gainesville, FL. Retrieved from http://eric.ed.gov/?id=ED247585

Ezrahi, Y. (2004). Science and the political imagination in contemporary democracies. In S. Jasanoff (Ed.), *States of Knowledge* (pp. 254–273). New York: Routledge.

Fahy, D., & Nisbet, M. C. (2011). The science journalist online: Shifting roles and emerging practices. *Journalism*, *12*(7), 778–793. https://doi.org/10.1177/1464884911412697

Falkenburg, B. (2014). On the contributions of astroparticle physics to cosmology. Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics, 46, 97–108.

Falkowski, A. (2009, December 7). What the hell is going on in CDMS. *Resonaances*.

Fehner, T., & Hall, J. (1994). *Department of Energy 1977-1994: A Summary History*. Washington, D.C.: Department of Energy.

Feldman, L., Hart, P. S., & Milosevic, T. (2017). Polarizing news? Representations of threat and efficacy in leading US newspapers' coverage of climate change. *Public Understanding of Science*, *26*(4), 481–497.

Fellman, M. (2013, May 3). Quest for Dark Matter Begins With a Few Tiny Bubbles. *Northwestern University*.

Fermilab. (1980). Fermilab 1980 Annual Report.

Fermilab. (1994). Fermilab 1995 Annual Report.

Fetzer, J. H. (2004). Information: Does it Have To Be True? *Minds and Machines*, *14*(2), 223–229. https://doi.org/10.1023/B:MIND.0000021682.61365.56

Finholt, T. A., & Olson, G. M. (1997). From laboratories to collaboratories: A new organizational form for scientific collaboration. *Psychological Science*, *8*(1), 28–36.

Fleck, L. (2012). *Genesis and development of a scientific fact*. Chicago: University of Chicago Press.

Fligstein, N. (2013). Understanding stability and change in fields. *Research in Organizational Behavior*, *33*, 39–51. https://doi.org/10.1016/j.riob.2013.10.005

Fligstein, N., & McAdam, D. (2012). *A theory of fields*. New York: Oxford University Press.

Floridi, L. (2009). Against digital ontology. *Synthese*, *168*(1), 151–178.
Floridi, L. (2011). *The philosophy of information*. New York: Oxford University Press.

Floridi, L. (2014). *The fourth revolution: How the infosphere is reshaping human reality*. Oxford, UK: Oxford University Press.

Flowers, A. (2012, November 16). Detector to Help in the Search for Elusive Dark Matter Material. *RedOrbit*.

Flowers, A. (2013, April 16). WIMP Experiment Points To First Concrete Evidence Of Dark Matte. *WIMP Experiment Points To First Concrete Evidence Of Dark Matter*.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245.

Friedlander, M. (2003). Farewell to Currents, Hello...? *Currents*.

Freeman, K., & McNamara, G. (2006). *In Search of Dark Matter*. New York: Springer Science & Business Media.

Freese, K. (2014). *The Cosmic Cocktail: Three Parts Dark Matter*. Princeton, NJ: Princepton University Press.

Fuller, S., & Collier, J. H. (2004). *Philosophy, rhetoric, and the end of knowledge: a new beginning for science and technology studies* (2nd ed). Mahwah, N.J: Lawrence Erlbaum Associates.

Galison, P. (1987). *How experiments end*. Chicago: University of Chicago Press.

Galison, P. (1997). *Image and logic: A material culture of microphysics*. Chicago: University of Chicago Press.

Galison, P. (2004). *Einstein's clocks and Poincaré's maps: empires of time*. New York: WW Norton & Company.

Galison, P., & Hevly, B. W. (1992). *Big science: The growth of large-scale research*. Stanford University Press.

Galison, P. L., & Stump, D. J. (1996). *The disunity of science: Boundaries, contexts, and power*. Stanford University Press.

Gandy Jr, O. H. (1980). Information in health: subsidised news. *Media, Culture & Society*, *2*(2), 103–115.

Gans, H. J. (1979). *Deciding what's news: A study of CBS evening news, NBC nightly news, Newsweek, and Time*. Chicago: Northwestern University Press.

Gardner, E. (2015, November 12). Purdue professor part of XENON1T experiment. *Purdue*.

Gershon, E. (2012, November 16). A gold mine, 70,000 gallons of water — and the hunt for WIMPS. *Yale*.

Gettier, E. L. (1963). Is Justified True Belief Knowledge? *Analysis*, *23*(6), 121–123. https://doi.org/10.2307/3326922

Gitelman, L. (2006). *Always already new: media, history and the data of culture*. Cambridge, Mass.: MIT Press.

Glaser, D. A. (1952). Some effects of ionizing radiation on the formation of bubbles in liquids. *Physical Review*, *87*(4), 665.

Goldman, A. I. (2010). Why social epistemology is real epistemology. In A. Haddock, A. Millar, & D. Pritchard (Eds.), *Social Episetmology*. New York: Oxford University Press.

Goldstein, T. (2007). *Journalism and Truth: Strange Bedfellows*. Chicago: Northwestern University Press.

Göpfert, W. (2007). The strength of PR and the weakness of science journalism. In M. W. Bauer & M. Bucchi, *Journalism, Science and Society* (pp. 215–226). New York: Routledge.

Granado, A. (2011). Slaves to journals, serfs to the web: The use of the internet in newsgathering among European science journalists. *Journalism*, *12*(7), 794–813.

Gregory, J., & Miller, S. (2000). *Science in Public: Communication, Culture, and Credibility*. Cambridge, Mass.: Basic Books.

Grier, P. (1984, January 4). Reagan's mixed success with energy policy. *The Christian Science Monitor*.

Grossberg, L. (1986). On postmodernism and articulation: An interview with Stuart Hall. *Journal of Communication Inquiry*, *10*(2), 45–60.

Gunkel, D. J. (2015). *Of Remixology: Ethics and Aesthetics after Remix*. Cambridge, Mass., UNITED STATES: MIT Press.

Hacking, I. (1999). *The Social Construction of What?* Cambridge, Mass.: Harvard University Press.

Hall, S. (1973). Encoding and decoding in the television discourse. *Training in the Critical Reading of Televisual Language*.

Hayden, T., & Check Hayden, E. (2018). Science Journalism's Unlikely Golden Age. *Frontiers in Communication*, *2*. https://doi.org/10.3389/fcomm.2017.00024

Hearns-Branaman, J. O. (2016). *Journalism and the Philosophy of Truth: Beyond Objectivity and Balance*. Routledge.

Heidegger, M. (1977). *The Question Concerning Technology*. (W. Lovitt, Trans.). New York: Garland Publishing, Inc.

Hemmingway, E. (2008). *Into the Newsroom*. New York: Routledge.

Hepp, A. (2013). *Cultures of Mediatization*. (K. Tribe, Trans.). Malden, MA: Polity.

Hewlett, R. G., & Holl, J. M. (1989). *Atoms for peace and war, 1953-1961: Eisenhower and the Atomic Energy Commission* (Vol. 3). Univ of California Press.

Hilgartner, S. (2012). Staging High-Visibility Science: Media Orientation in Genome Research. In S. Rodder, M. Franzen, & P. Weingart (Eds.), *The Sciences' Media Connection--Public Communication and its Repercussions*. New York: Springer.

Hochschild, A. R. (2016). Strangers in Their Own Land: Anger and Mourning on the American Right. New York: The New Press.

Holliman, R. (2011). Advocacy in the tail: Exploring the implications of 'climategate' for science journalism and public debate in the digital age. *Journalism*, *12*(7), 832–846. https://doi.org/10.1177/1464884911412707

Hooper, D. (2009). *Dark Cosmos: In Search of Our Universe's Missing Mass and Energy*. New York: Harper Collins.

Howell, E. (2013, October 30). New Dark Matter Detector Draws A Blank In First Test Round. *Universe Today*.

Hutchins, S. (2013, April 15). Dark Matter Search Results Indicate First Hint of WIMP-like Signal. *Texas A&M*.

Hutson, M. (2003, November 19). Physicists begin quest to unmask dark matter, and perhaps supersymmetry. *Stanford*.

Innis, H. A. (2008). *The Bias of Communication*. Toronto: University of Toronto Press.

Isbell, K. A. (2010). *The Rise of the News Aggregator: Legal Implications and Best Practices* (SSRN Scholarly Paper No. ID 1670339). Rochester, NY: Social Science Research Network.

Jackson, Judith. (2003, September). www.interactions.org Goes life. *Ferminews*.

Jackson, Judith. (2003b). Global Communication for a Global Community. *Interactions.Org*. (accessed through Internet Archive)

Jackson, J., & Calder, N. (2007). Quantum Communication. *Annual Review of Nuclear and Particle Science*, *57*(1), 441–462. https://doi.org/10.1146/annurev.nucl.57.090506.123030

James, W. (1975). *Pragmatism* (Vol. 1). Cambridge, Mass.: Harvard University Press.

Johnston, H. (2013, October 31). Lux dark-matter search comes up empty. *Physics World*.

Kahn, A. (2013, April 8). A hunt for dark matter in a former gold mine. *The L.A. Times*.

Keller, B. (2011, March 10). All the Aggregation That's Fit to Aggregate. *The New York Times*.

Kiesselmann, K. (2008, February 25). Crystal bells stay silent as physicists look for dark matter as U.S. experiment retakes the lead in competitive race. *Fermilab*.

Kincheloe, J. L. (2001). Describing the bricolage: Conceptualizing a new rigor in qualitative research. *Qualitative Inquiry*, *7*(6), 679–692.

Kittler, F. (1999). *Gramaphone, Film, Typewritter*. (G. Winthrop-Young & M. Wutz, Trans.). Stanford, California: Stanford University Press.

Kittler, F. (2010). *Optical Media*.

Klinenberg, E. (2005). Convergence: News Production in a Digital Age. *The ANNALS of the American Academy of Political and Social Science*, *597*(1), 48–64. https://doi.org/10.1177/0002716204270346

Kluttz, D., & Fligstein, N. (2016). Varieties of Field Theory. In S. Abrutyn (Ed.), *Handbook of Contemporary Sociology*. New York: Springer Publishing.

Knorr-Cetina, K. (1999). *Epistemic Cultures: How the Sciences Make Knowledge*. Cambridge, Mass.: Harvard University Press.

Kouper, I. (2010). Science blogs and public engagement with science: Practices, challenges, and opportunities. *Journal of Science Communication*, *9*(1), 1–10.

Kouzes, R. T., Myers, J. D., Wulf, W., & others. (1996). Collaboratories: Doing science on the Internet. *Computer*, *29*(8), 40–46.

Kracauer, S. (1952). The Challenge of Qualitative Content Analysis. *The Public Opinion Quarterly*, *16*(4), 631–642.

Kreighbaum, H. (1967). *Science and the Mass Media*. New York: New York University Press.

Kuhn, T. S. (2012). *The structure of scientific revolutions*. Chicago: University of Chicago press.

Lammers, D. (2009, June 22). Work Begins on world's deepest underground lab.

Larivière, V., Gingras, Y., Sugimoto, C. R., & Tsou, A. (2014). Team size matters: Collaboration and scientific impact since 1900. *Journal of the Association for Information Science and Technology*.

Lash, S. (2002). *Critique of Information*. London: SAGE.

Laslo, E., Baram-Tsabari, A., & Lewenstein, B. V. (2011). A growth medium for the message: Online science journalism affordances for exploring public discourse of science and ethics. *Journalism*, *12*(7), 847–870. https://doi.org/10.1177/1464884911412709

Lasswell, H. D. (1927). Propaganda technique in the World War.

Latour, B. (1986). Visualization and cognition. *Knowledge and Society*, *6*, 1–40.

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, Mass.: Harvard University Press.

Latour, B. (1993a). *The pasteurization of France*. Cambridge, Mass.: Harvard University Press.

Latour, B. (1993b). *We Have Never Been Modern*. (C. Porter, Trans.). Cambridge, Mass.: Harvard University Press.

Latour, B. (1999). *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, Mass.: Harvard University Press.

Latour, B. (2005). *Reassembling the Social: an introduction to actor-network theory.* New York: Oxford University Press.

Latour, B., & Weibel, P. (2005). *Making Things Public*. Boston: MIT Press.

Latour, B., & Woolgar, S. (1979). *Laboratory life: The social construction of scientific facts.* Thousand Oaks, CA: Sage.

Law, J. (2006). Traduction/trahison: Notes on ANT. *Convergencia*, *13*(42), 47–72.

Lee, A. M., & Chyi, H. I. (2015). The Rise of Online News Aggregators: Consumption and Competition. *International Journal on Media Management*, *17*(1), 3–24. https://doi.org/10.1080/14241277.2014.997383

Lenoir, T. (1994). Was the last turn the right turn? The semiotic turn and AJ Greimas. *Configurations*, *2*(1), 119–136.

Lessig, L. (2008). *Remix: Making art and commerce thrive in the hybrid economy*. New York: Penguin.

Lévi-Strauss, C. (1966). *The Savage Mind*. London: Weidenfeld & Nicolson.

Lewis, S. C., & Westlund, O. (2015). Big data and journalism: Epistemology, expertise, economics, and ethics. *Digital Journalism*, *3*(3), 447–466.

Libunao, J. (2015, November 15). The Quest for Dark Matter: New Experiment May Detect Elusive Particles in Weeks. *Futurism*.

Lohwater, T., & Storksdieck, M. (2017). Science Communication at Scientific Institutions. In K. H. Jamieson, D. Kahan, & D. A. Scheufele (Eds.), *The Oxford Handbook of the Science of Science Communication*.

Lüscher, R., Ahmed, B., Ali, T., Alner, G. J., Barton, J. C., Bewick, A., … Hart, S. T. (2001). The potential of liquid xenon for WIMP search: the ZEPLIN Diagnostic Array. Nuclear Physics B-Proceedings Supplements, 95(1–3), 233–236.

LUX Collaboration, Akerib, D. S., Araújo, H. M., Bai, X., Bailey, A. J., Balajthy, J., … Zhang, C. (2014). First Results from the LUX Dark Matter Experiment at the Sanford Underground Research Facility. *Physical Review Letters*, *112*(9), 091303. https://doi.org/10.1103/PhysRevLett.112.091303

Lynch, J., Bennett, D., Luntz, A., Toy, C., & VanBenschoten, E. (2014). Bridging Science and Journalism Identifying the Role of Public Relations in the Construction and Circulation of Stem Cell Research Among Laypeople. *Science Communication*, *36*(4), 479–501.

Machlup, F. (1962). *The Production and Distribution of Knowledge in the United States*. Princeton, NJ: Princeton University Press. Macho, T. (2013). Second-Order Animals: Cultural Techniques of Identity and Identification. *Theory, Culture & Society*, *30*(6), 30–47. https://doi.org/10.1177/0263276413499189

MacKay, D. (1969). *Information, Mechanism and Meaning*. Cambridge, Mass.: MIT Press.

Manovich, L. (1999). Database as Symbolic Form. *Convergence: The International Journal of Research into New Media Technologies*, *5*(2), 80–99. https://doi.org/10.1177/135485659900500206

Maras, S. (2013). *Objectivity in Journalism*. New York: John Wiley & Sons.

Markham, A. (2017). Bricolage. In E. Navas & O. Gallagher (Eds.), *Keywords in Remix Studies*. Routledge.

Matson, J. (2011, April 14). Underground XENON100 experiment closes in on dark matter's hiding place. *Scientific American Blog*.

McInerney, C., Bird, N., & Nucci, M. (2004). The flow of scientific knowledge from lab to the lay public: The case of genetically modified food. *Science Communication*, *26*(1), 44–74.

McKnight, J., & Coronel, J. C. (2017). Evaluating Scientists as Sources of Science Information: Evidence From Eye Movements. *Journal of Communication*, *67*(4), 565–585.

McLeod, K., & DiCola, P. (2011). *Creative license: The law and culture of digital sampling*. Duke University Press.

McLuhan, M. (1964). *Understanding media: the extensions of man*. New York: McGraw-Hill.

Mcquail, D. (2010). *McQuail's Mass Communication Theory*. Los Angeles: SAGE.

Merrell, F. (1997). *Peirce, signs, and meaning*. Toronto, Canada: University of Toronto Press.

Morelle, R. (2013, October 30). LUX results: Dark matter hunt nears final phase. *BBC*.

N/A. (2010, January 29). Searching for dark matter at Boulby Potash Mine. *BBC*.

N/A. (2011, May 4). Dark Matter debate heats up…Again, Seeker. *The Seeker*.

NASA. (2018, January 15). Dark Energy, Dark Matter - NASA Science. Retrieved October 26, 2015, from http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/

Navas, E., & Gallagher, O. (2017). *Keywords in Remix Studies*. London: Routledge.

Nelkin, D. (1994). Promotional metaphors and their popular appeal. *Public Understanding of Science*, *3*(1), 25–31.

Nelkin, D. (1995). *Selling Science: How the Press Covers Science and Technology*. New York: W.H. Freeman.

Nelson, B. (2006, January 18). Space.com is Back in Orbit. Forbes.Com.

Nisbet, M. C., & Fahy, D. (2017). New Models of Knowledge-Based Journalism. https://doi.org/10.1093/oxfordhb/9780190497620.013.30

Oreskes, N., & Conway, E. M. (2010). *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York: Bloomsbury Publishing USA.

Overbye, D. (2009a, December 17). At a Mine's bottom, hints of dark matter. *The New York Times*.

Overbye, D. (2009b, December 17). At a Mines Bottom, Hints of Dark Matter. *New York Times*, p. A28.

Overbye, D. (2011, April 13). Particle Hunt Nets Almost Nothing; the Hunters Are Almost Thrilled. *The New York Times*, p. A18.

Packer, J. (2013). The Conditions of Media's Possibility. *The International Encyclopedia of Media Studies*. Park, R. E. (1940). News as a Form of Knowledge: A Chapter in the Sociology of Knowledge. *American Journal of Sociology*, *45*(5), 669–686.

Peirce, C. S. (1868). Some Consequences of Four Incapacities. Retrieved from http://www.peirce.org/writings/p27.html

Perrault, S. (2013). *Communicating popular science: From deficit to democracy*. New York: Springer.

Perricone, M. (2004, May 5). Search for dark matter illuminates largest and smallest mysteries of universe. *Stanford*.

Peters, H. P., Brossard, D., de Cheveigne, S., Dunwoody, S., Kallfass, M., Miller, S., & Tsuchida, S. (2008). Interactions with teh Mass Media. *Science*, *321*, 204.

Peters, H. P., Brossard, D., De Cheveigné, S., Dunwoody, S., Kallfass, M., Miller, S., & Tsuchida, S. (2008). Science-Media Interface It's Time to Reconsider. *Science Communication*, *30*(2), 266–276.

Peters, H. P. (2013). Gap between science and media revisited: Scientists as public communicators. *Proceedings of the National Academy of Sciences*, *110*(Supplement 3), 14102–14109. https://doi.org/10.1073/pnas.1212745110

Peters, J. D. (2012). *Speaking into the Air: A History of the Idea of Communication*. Chicago: University of chicago Press.

Peters, J. D. (2015). *The marvelous clouds: Toward a philosophy of elemental media*. Chicago: University of Chicago Press.

Pickering, A. (1995). *The Mangle of Practice: Time, Agency, and Science*. Chicago: University of Chicago Press.

Plesner, U. (2009). An actor-network perspective on changing work practices : Communication technologies as actants in newswork. *Journalism*, *10*, 604.

Plesner, U. (2010). The performativity of "media logic" in the mass mediation of science. *Public Understanding of Science*, *21*(6), 674–688. https://doi.org/10.1177/0963662510385309

Polanyi, M. (1998). *Personal Knowledge: Towards a Post-critical Philosophy*. London: Psychology Press.

Polletta, F., & Callahan, J. (2017). Deep stories, nostalgia narratives, and fake news: Storytelling in the Trump era. *American Journal of Cultural Sociology*, *5*(3), 392–408.

Pollock, J. L., & Cruz, J. (1999). *Contemporary Theories of Knowledge*. New York: Rowman & Littlefield.

Porat, M. U. (1977). The Information Economy: Definition and Measurement.

Postman, N. (1993). *Technopoly: The Surrender of Culture to Technology*. Vintage Books.

Powers, M. (2016). Opening the news gates? Humanitarian and human rights NGOs in the US news media, 1990–2010. *Media, Culture & Society*, *38*(3), 315–331.

Primack, J. R., Seckel, D., & Sadoulet, B. (1988). Detection of cosmic dark matter. Annual Review of Nuclear and Particle Science, 38(1), 751–807.

Pvarski, J. (2013, March 1). Cross Section. *Fermilab Today*.

Raines, H. (1981, December 17). Reagan Adopts Plan to End Energy Dept. and Shift its Duties. *The New York Times*.

Rakedzon, T., Segev, E., Chapnik, N., Yosef, R., & Baram-Tsabari, A. (2017). Automatic jargon identifier for scientists engaging with the public and science communication educators. *PloS One*, *12*(8), e0181742.

Raza, G., & Bauer, M. W. (2009). The evolution of public understanding of science—discourse and comparative evidence. *Science, Technology and Society*, *14*(2), 221–240.

Riesch, H., & Spiegelhalter, D. J. (2011). 'Careless pork costs lives': Risk stories from science to press release to media. *Health, Risk & Society*, *13*(1), 47–64. https://doi.org/10.1080/13698575.2010.540645

Riesselmann, K. (2/1/2010). DUSEL: Big Plans for Deep Science. *Symmetry*. https://www.symmetrymagazine.org/article/february-2010/dusel-big-plans-for-deep-science

Rödder, S. (2008). Reassessing the concept of a medialization of science: a story from the "book of life." *Public Understanding of Science*, *18*(4), 452–463. https://doi.org/10.1177/0963662507081168

Rödder, S. (2011). Science and the Mass Media –'Medialization' as a New Perspective on an Intricate Relationship. *Sociology Compass*, *5*(9), 834–845. https://doi.org/10.1111/j.1751-9020.2011.00410.x

Rödder, S., & Schafer, M. (2010). Repercussion and Resistance: An Empirical Study in the Interrelations between Science and the Mass Media. *Communications*, *35*, 249–267.

Rubin, V. (1996). *Bright Galaxies, Dark Matters*. New York: Springer Science & Business Media.

Rutenberg, J. (1999, June 21). Lou Dobbs: Space Cowboy or Space Cadet? New York Observer, p. A1,A5.

Sample, I. (2009, December 18). Difficult to See…harder to explain. *The Guardian*.

Sanders, R. H. (2010). *The dark matter problem: a historical perspective*. New York: Cambridge University Press.

Santos, M. (2015, December 16). World's Most Sensitive Dark Matter Detector Releases New Results. *Futurism*.

Saussure, F. de. (1916). Course in general linguistics. *Course in General Linguistics*.

Savage, S. (2009, June 23). World's Deepest Underground Lab Hosts Hunt For Dark Matte. *RedOrbit*.

Savage, S. (2010a, February 19). Exploring The Secrets Of Dark Matter. *RedOrbit*.

Savage, S. (2010b, July 26). Dark Matter Project May Relocate To SNOLAB. *RedOrbit*.

Schäfer, M. S. (2008). From public understanding to public engagement: An empirical assessment of changes in science coverage. *Science Communication*.

Schäfer, M. S. (2017). How Changing Media Structures Are Affecting Science News Coverage. In K. H. Jamieson, D. Kahan, & D. A. Scheufele (Eds.), *The Oxford Handbook of the Science of Science Communication*.

Scheufele, D. A. (2014). Science communication as political communication. *Proceedings of the National Academy of Sciences*, *111*(Supplement 4), 13585–13592.

Schudson, M. (1994). Public Sphere and Its Problems: Bringing the State (Back) In, The. *Notre Dame JL Ethics & Pub. Pol'y*, *8*, 529.

Secko, D. M., Amend, E., & Friday, T. (2013). FOUR MODELS OF SCIENCE JOURNALISM: A synthesis and practical assessment. *Journalism Practice*, *7*(1), 62–80. https://doi.org/10.1080/17512786.2012.691351

Secko, D. M., Tlalka, S., Dunlop, M., Kingdon, A., & Amend, E. (2011). The unfinished science story: Journalist–audience interactions from the Globe and Mail's online health and science sections. *Journalism*, *12*(7), 814–831.

Seely, H. (Ed.). (2009). *Pieces of Intelligence: The Existential Poetry of Donald H. Rumsfeld*. New York: Free Press.

Serck-Hanssen, L. (2015, November 16). A new detector for dark matter. *University of Zurich*.

Serres, M. (1982). *The Parasite*. Baltimore, MD: Johns Hopkins University Press.

Shanahan, M.-C. (2011). Science blogs as boundary layers: Creating and understanding new writer and reader interactions through science blogging. *Journalism*, *12*(7), 903–919. https://doi.org/10.1177/1464884911412844

Shannon, C. E., & Weaver, W. (1948). A mathematical theory of communication. *Bell Syst. Tech. J*, *27*(3), 379–423.

Shapin, S., & Schaffer, S. (2011). *Leviathan and the Air-Pump: Hoobes, Boyle, and the Experimental Life*. Princeton, NJ: Princeton University Press.

Shoemaker, P. J., Vos, T. P., & Reese, S. D. (2009). Journalists as gatekeepers. *The Handbook of Journalism Studies*, *73*.

Shrum, W., Genuth, J., & Chompalov, I. (2007). *Structures of scientific collaboration*. Cambridge, Mass.: MIT Press. Siegert, B. (2013). Mineral Sound or Missing Fundamental: Cultural History as Signal Analysis. *Osiris*, *28*(1), 105–118. https://doi.org/10.1086/671365

Siegert, B. (2015a). *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*. (Geoffrey Winthrop-Young, Trans.). New York: Fordham University Press.

Siegert, B. (2015b). Longitude and Simultaneity in Philosophy, Physics, and Empires. *Configurations*, *23*(2), 145–163. https://doi.org/10.1353/con.2015.0011

Singer, J. B. (2014). User-generated visibility: Secondary gatekeeping in a shared media space. *New Media & Society*, *16*(1), 55–73.

Sinnreich, A. (2010). *Mashed up: Music, technology, and the rise of configurable culture*. Boston: Univ of Massachusetts Press.

Southwell, B. G., Thorson, E. A., & Sheble, L. (2018). *Misinformation and mass audiences*. University of Texas Press.

Spyridou, L.-P., Matsiola, M., Veglis, A., Kalliris, G., & Dimoulas, C. (2013). Journalism in a state of flux Journalists as agents of technology innovation and emerging news practices. *International Communication Gazette*, *75*(1), 76–98.

Stacey, K. (2016, July 21). World's most sensitive dark matter detector completes search. *Brown University*.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420.

Stark, A. (2012, November 15). LLNL scientists assist in building detector to search for elusive dark matter material. *Lawrence Livermore National Laboratory*.

Sterne, J. (2003). Bourdieu, Technique and Technology. *Cultural Studies*, *17*(3–4), 367–389. https://doi.org/10.1080/0950238032000083863

Su, L. Y.-F., Akin, H., Brossard, D., Scheufele, D. A., & Xenos, M. A. (2015). Science news consumption patterns and their implications for public understanding of science. *Journalism & Mass Communication Quarterly*, *92*(3), 597–616.

Su, L. Y.-F., Scheufele, D. A., Bell, L., Brossard, D., & Xenos, M. A. (2017). Information-Sharing and Community-Building: Exploring the Use of Twitter in Science Public Relations. *Science Communication*, *39*(5), 569–597.

Tanz, J. (2017, February 14). From Fake News to Disappearing Ad Revenue, Journalism Fights for Survival | WIRED. *Wired*.

Taubes, G. (1988). Nobel dreams: Power, deceit and the ultimate experiment. Microsoft Press.

Teresa Marrodan Undagoitia, & Rauch, L. (2015). Dark matter direct-detection experiments. *Journal of Physics G: Nuclear and Particle Physics*, *43*(1).

Than, K. (2009, December 18). Dar kMatter Detected for First Time. *National Geographic News*.

Toffler, A. (1981). *Future Shock: The Third Wave*. New York: Bantam Book.

Toohig, T. (1982, October 14). No It is not a new yellow wienermobile. *Ferminews*.

Traweek, S. (1988). *Beam times and Lifetimes: The World of High Energy Physics*. Cambridge, Mass.: Harvard University Press.

Trench, B. (2007). How the Internet changed science journalism. *Journalism, Science and Society*, 133.

Trench, B. (2008). Towards an analytical framework of science communication models. In *Communicating science in social contexts* (pp. 119–135). New York: Springer.

Tuchman, G. (1978). *Making news: A study in the construction of reality*. New York: Free Press.

Turner, F. (2005). Actor-Networking the News. *Social Epistemology*, *19*(4), 321–324.

Turner, M. S., Steigman, G., & Krauss, L. M. (1984). Flatness of the universe: reconciling theoretical prejudices with observational data. Physical Review Letters, 52(23), 2090.

Vertesi, J. (2014). Drawing as: Distinctions and Disambiguation in Digital Images of Mars. In C. Coopmans, J. Vertesi, M. E. Lynch, & S. Woolgar (Eds.), *Representation in Scientific Practice Revisited* (pp. 15–36). MIT Press.

Vertesi, J. (2014). Seamful Spaces: Heterogeneous Infrastructures in Interaction. *Science, Technology & Human Values*, *39*(2), 264–284. https://doi.org/10.1177/0162243913516012

Virilio, P. (1986). Speed and politics: An essay on dromology, translated by Mark Polizzotti. *New York: Semiotext (E)*.

Vogl, J. (2007). Becoming-Media: Galileo's Telescope. *Grey Room*, (29), 14–25.

Walsh, J. P., & Maloney, N. G. (2007). Collaboration Structure, Communication Media, and Problems in Scientific Work Teams. *Journal of Computer-Mediated Communication*, *12*(2), 712–732. https://doi.org/10.1111/j.1083-6101.2007.00346.x

Walsh, L. (2007). *Sins against Science: The Scientific Media Hoaxes of Poe, Twain, and Others* (Annotated edition edition). Albany: State University of New York Press.

Walter, C. (2013a, October 15). An event to announce the first physics results at the Sanford Lab. *Sanford Underground Research Facility*.

Walter, C. (2013b, October 30). First results from LUX experiment in South Dakota. *Sanford Underground Research Facility*.

Warner, B. R., & Neville-Shepard, R. (2014). Echoes of a Conspiracy: Birthers, Truthers, and the Cultivation of Extremism. *Communication Quarterly*, *62*(1), 1–17. https://doi.org/10.1080/01463373.2013.822407

Webster, F. (2006). *Theories of the Information Society*. New York: Routledge.

Weigold, M. F. (2001). Communicating Science: A Review of the Literature. *Science Communication*, *23*(2), 164–193. https://doi.org/10.1177/1075547001023002005

Weingart, P. (1998). Science and the media. *Research Policy*, *27*(8), 869–879. https://doi.org/10.1016/S0048-7333(98)00096-1

Weingart, P. (2012). The Lure of the Mass Media and Its repercussions on Science. In S. Rodder, M. Franzen, & P. Weingart (Eds.), *The Sciences' Media Connection--Public Communication and its Repercussions*. New York: Springer.

Westfall, C. (2008). Introduction to the Special Issue: Surviving the Squeeze: National Laboratories in the 1970s and 1980s. *Historical Studies in the Natural Sciences*, *38*(4), 475–478. https://doi.org/10.1525/hsns.2008.38.issue-4

Williams, M. (2001). *Problems of Knowledge: A Critical Introduction to Epistemology*. New York: Oxford University Press.

Winthrop-Young, G. (2013). Cultural Techniques: Preliminary Remarks. *Theory, Culture & Society*, *30*(6), 3–19. https://doi.org/10.1177/0263276413500828

Winthrop-Young, G. (2014). The Kultur of Cultural Techniques: Conceptual Inertia and the Parasitic Materialities of Ontologization. *Cultural Politics an International Journal*, *10*(3), 376–388. https://doi.org/10.1215/17432197-2795741

Wisniewski, R. (2011, January 25). Science communication pioneer Judy Jackson retires. *Fermilab*.

Woloshin, S., & Schwartz, L. M. (2002). Press Releases: Translating Research Into News. *JAMA*, *287*(21), 2856–2858. https://doi.org/10.1001/jama.287.21.2856

Woloshin, S., Schwartz, L. M., Casella, S. L., Kennedy, A. T., & Larson, R. J. (2009). Press releases by academic medical centers: not so academic? *Annals of Internal Medicine*, *150*(9), 613–618.

Wynne, B. (1992a). Misunderstood misunderstanding: social identities and public uptake of science. *Public Understanding of Science*, *1*(3), 281–304.

Wynne, B. (1992b). Sheep farming after Chernobyl: A case study in communicating scientific information. *When Science Meets the Public*, 43–68.

XENON100. (2015). XENON100 narrows the gap in the search for dark matter. *Gran Sasso National Laboratory*.

Zelizer, B. (2004). Defining Journalism. In *Taking Journalism Seriously: News and the Academy*. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc.

Ziman, J. (1991). Public Understanding of Science. *Science, Technology, & Human Values*, *16*(1), 99–105.

Zwicky, F. (1933). The redshift of extragalactic nebulae. *Helv. Phys. Acta*, *6*, 110.