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FIELDWORK – A CONCEPTUAL METHODOLOGY LINKING SCIENCE AND ART

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Declaration of Originality

I,   May 13, 2019   [sign and date]

hereby declare that the thesis here presented is the outcome of the research project undertaken during my candidacy, that I am the sole author unless otherwise indicated, and that I have fully documented the source of ideas, references, quotations and paraphrases attributable to other authors.

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Abstract

Fieldwork – A Conceptual Methodology Linking Science and Art

This exegesis presents the outcomes of artistic fieldwork in the Arctic and the Antarctic – locations which are the focus of intensive scientific exploration and research. The primary fieldwork site for my research was the South Pole and fieldwork there in the austral summer of 2006/17 was completed under a US National Science Foundation Antarctic Artists and Writers Fellowship in collaboration with the IceCube Neutrino Observatory.

This project researches interconnections between the aspirations, methodologies, and outcomes of scientific and artistic inquiry as demonstrated through the mode of fieldwork. The field provides a cleared space of work for comparative investigation of the methodologies and approaches of science and art. Artmaking and astrophysics are approached as two congruent practices of fieldwork. Both entail challenging logistics, the deployment of sensitive, hand-made and untried instruments, improvisation and adjustment to accommodate field conditions and unexpected contingencies, and comprehending and interpreting the resulting data.

Objectivity is as a key aspect of both contemporary art and science, and instruments act as devices of constraint to reduce subjectivity in both. The conceptualisation of instruments as devices of constraint within both science and the visual arts proved to be an effective research strategy. This approach has allowed me to consider scientific instruments from an artist's perspective, to design and create my own instruments for deployment in conjunction with scientific instruments, to develop collaborations with scientists and to locate my research within an original analysis of aspects of contemporary art practice.

The artistic outcomes of my fieldwork take a conceptual approach to making art connected to the Antarctic and Arctic environments that goes beyond the pictorial, narrative and didactic. The outcomes are analysed using original perspectives derived from scientific analysis. My approach has been to reconsider the terms 'field', 'noise', 'signal', 'pareidolia', 'artefact', 'instrument', 'transcription' and 'transduction'. These terms are used as lenses through which to examine contemporary artistic practice and the outcomes of my own research. It is argued that the circumscription of these concepts and the location of cultural and physical fields in which they can operate delineates a common ground between science and art.

Acknowledgements

One of the findings of my research has been that, despite the myth of the solo genius, art practice and academic research like scientific research are collaborative activities. My Ph.D. research was undertaken on four continents over a five year period and I was encouraged, helped and nurtured along the way by many people.

The Poles

Early advisors who helped me contextualise my research and sowed the seeds for my polar expeditions included fellow artists and polar explorers Christina Seely, Stephen Hilyard, Michael Bartalos, David Ruth and Cheryl Leonard. My research in the Arctic, off the coast of Svarlabard, was supported by an Arctic Circle Residency (arcticcircle.org) and everyone aboard the *Antigua*.

My research in Antarctica, and my fieldwork at McMurdo and Amundsen-Scott South Pole stations in the austral summer of 2016/2017, was supported by the United States National Science Foundation (NSF) through an Antarctic Artists and Writers Fellowship. Staff at the NSF and the US Antarctic Program gave immense amounts of advice and support to help me prepare for my fieldwork and to deploy on the Ice. Particular thanks go to Valentine Kass (NSF), Elaine Hood, Mike Lucibella and Yuki Takahashi who all went far beyond the call of duty in their support and interest in my fieldwork. For friendship during my time at McMurdo and insights into science activities in Antarctica apart from astrophysics I am indebted to the 'Devonian fish mob'; Tim Senden, John Long, Neil Shubin, Adam Maloof and Ted Daeschler; and to Paul Bedrossian who was working on the geophysics of Mt. Erebus. At the South Pole, Lorenzo Moncelsi and Howard Hui took time out of their busy summer schedules to provide introductions to the South Pole Telescope and the Keck Array instruments and their research – and to compare cappuccino making skills.

Particular thanks go to the scientists and staff of the IceCube Neutrino Observatory for their advice and assistance prior to my deployment and for hosting me at the South Pole. The data used in my research was generously provided by and used with the permission of the IceCube Collaboration. This project would never have gotten off the ground without the direct support of Dr. Jim Madsen (Associate Director for Education & Outreach at the IceCube Neutrino Observatory). Jim responded immediately and enthusiastically to a general email enquiry regarding the possibility of a collaboration and has been an ongoing supporter, advisor and facilitator of my research ever since. At the South Pole I worked closely with Martin Rongen and Gwenhaël de Wasseige, who were working towards their PhDs, and were deployed at the Pole at the same time as me. Their patience in describing the IceCube Observatory and its operation to a layman and their enthusiasm for collaboration at the Pole was a highlight of my fieldwork. Dr. Gwenhaël de Wasseige (IceCube and KM3Net) has been an ongoing collaborator in the development of audio works resulting from my fieldwork. She has helped me understand (and wrangle) the data and the underlying physics and her enthusiasm for our collaboration continued well beyond our work together at the Pole.

Australia

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USA

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Finally, but most significantly, I want to acknowledge the support, encouragement and perceptive critique of my wife Sandra Kelch. We decided 5 years ago to undertake our PhDs together at ANU (despite wise counsel to the contrary). We thought it would provide us both with an amazing opportunity to grow as artists and scholars and to share that experience as a couple – and we were right!

Chapter One Introduction

1.1 Research Topic

1.2 Research Questions

1.3 Defining the Field

1.4 The Common Ground – A Conceptual Methodology

My goal has been to research the interconnections between the aspirations, methodologies, and outcomes of scientific and artistic inquiry as demonstrated through the action of fieldwork.

Art and science are conventionally seen as diametrically opposed modes of enquiry. Science is stereotypically deemed rational, objective, undertaken by teams and resulting in accumulated verifiable knowledge. Conversely, art is seen as irrational, subjective, individual and constantly undermining existing knowledge through the activities of an avant-garde.[1] I argue that there is a nuanced common ground connecting the two. Both methodologies share histories and ambitions, are striving to understand the unknown and ineffable, and work to re-present the experience and outcomes of research to a broader audience.

In this exegesis, I discuss how artists and scientists worked closely together during the eighteenth and nineteenth centuries to collaboratively develop the practice of fieldwork in the natural sciences. Intriguingly, this was also the period when notions of objectivity and subjectivity acquired their contemporary meanings and when objectivity became a defining virtue of science while subjectivity came to embody artistic practice.[2] In the second half of the twentieth century, many artists strove to remove subjectivity and their own direct agency from their work. As well, artists embraced new technologies and began to work closely with scientists and engineers. This increased objectivity and engagement with technology in contemporary art practice has once again brought art and science into alignment.

Commonalities between the practices of science and art have been of long-standing personal and professional interest as I have studied academically and worked professionally as both a scientist and an artist. In both cases working in the field has been a central activity. My artistic practice has increasingly involved operating for periods in isolated locations distant from my studio and then using the work done in

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[1] C.P. Snow is renowned for having framed this dichotomy in his Rede lecture of 1959 and subsequent writings. C.P. Snow, *The Two Cultures and the Scientific Revolution* (New York: Cambridge University Press, 1959).

[2] This is discussed in detail in Chapter Three.

the field as a basis for work finalised in the studio. These experiences have resonated with my experience of conducting fieldwork in the Australian bush when I was working as a research botanist.

While planning fieldwork there were always key questions to be answered:

> Which sites would be the most productive for research?
> What gear, equipment, and instruments would I need?
> How should I best approach the site? How would it be sampled?
> What would I bring back to the lab from the site – samples, measurements, drawings, etc.?
> How did my experience in the field and my subsequent analysis shape the future path of my research?

Considering and working towards these tangible goals was overlaid with the excitement of going into the field, of leaving home and going to unfamiliar places, with the potential for surprising new discoveries, or perhaps unexpected disasters. One thing that was always on my mind was the acknowledged adage that "each week of work in the field results in a year of work in the lab" – time in the field is precious, unique and unpredictable. Decisions and actions in the field are critical and shape the future course of one's research. These considerations are clearly logistical and practical but they also arise directly from the basic process of inquiry. The ways both artists and scientists engage with the world and make work as a result of this engagement is a direct manifestation of their underlying attitudes, expectations, approaches, and philosophies. And these approaches and their conceptual underpinnings are most clearly revealed in the intense, focused, pared down activity of working in the field.

1.1 Research Topic

This focus on the field led to my research topic – Fieldwork: A Conceptual Methodology Linking Science and Art.

In this introduction, I discuss the term fieldwork as it is has come to be defined in anthropology – arguably the science most clearly defined by fieldwork and that has examined the practice and its definitions most thoroughly. Perspectives from anthropology have helped shape my own understanding of and inquiry into the field.

Chapter Two outlines how artists and scientists historically collaborated to develop a set of practices around fieldwork and discuss how these practices have changed with the evolving scope of scientific exploration – particularly in reference to Antarctica, my primary fieldwork site. The changing definition of objectivity in science is discussed in Chapter Three, where I analyse the perceived dichotomy between art and science in more detail. I conclude that chapter with the observation that as a consequence of the prominence of quantum theory in physics and postmodernism in contemporary art we now find ourselves in the position where both art and science are dealing directly with a reality that is in constant flux and contingent on the way it is experienced. This commonality provides a renewed bridge between the methodological approaches and conceptual underpinnings of art and science.

To effectively develop a conceptual methodology linking science and art I need to narrow my focus to a manageable inquiry and thus circumscribe which arenas of art and science to investigate.[3] My practice as an artist is located within an interdisciplinary contemporary fine arts approach involving a range of media. In my current research I have maintained this approach and have used sculpture, installation, photography, digital printing, video and sound as practical artistic methodologies. In Chapter Four I position my own current research within the broader field of art practice.

I have chosen astrophysics as the arena of scientific inquiry to investigate in my research for several reasons.[4] Those that relate to my own experience and art practice are explored in Chapter Six. Others that are related to the use of specific concepts and terminology in astrophysics are discussed in Chapter Five. The overarching reason, however, is that, in my view, astrophysics is engaged with our most profound existential questions and in pursuing answers to these questions, constantly confronts our capacity to comprehend the world around us. The conceptual scope of astrophysics is the entire physical universe over the duration of its existence (from its beginning in the Big Bang to its entropic end when all energy and information will wind down to zero) – things that we can never experience directly. Almost everything we understand about the universe is inferred from electromagnetic signals received on the surface of our planet or from satellite telemetry.[5] Astrophysics relies on analyzing increasingly subtle data gathered indirectly and in doing so it is constantly working at the very edges of what can be perceived – at the boundary of noise and signal.

It is my proposition that astrophysics' engagement with intangibles, constant effort to find meaning in a vast sea of complex data, and express desire to understand the entire scope of the universe throughout its history (and into its distant future) brings it into alignment with the ambitions and practice of contemporary art. Both are deeply concerned with understanding the position of humanity in the larger world (or cosmos), both are constantly pushing against the boundaries of our ability to perceive and understand, and both require leaps of imagination to achieve their goals.

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[3] This is covered in detail in Chapters Three and Five.

[4] Throughout this exegesis I generally use the expedient of referring to the distinct but interconnected scientific fields of astrophysics, astronomy and cosmology under the single term astrophysics.

[5] Data from cosmic rays, neutrinos and gravity waves provide the remaining data. Instruments detecting the last two have proved effective only within the last few years.

1.2 Research Questions

Three key research questions are central to my exegesis.

Firstly, where is the common ground between the processes, methodologies and conceptual underpinnings of art and science? This is too broad a question to be undertaken in its entirety. Instead, I take a more focused view, and investigate the possibility of a common ground between astrophysics and contemporary visual arts practice.

Secondly, are there particular concepts, methodologies and processes that have meaning in both fields which can be used to provide an original perspective on contemporary art practice and be used to develop original works of art?

And lastly, in what ways does fieldwork provide unique conditions and opportunities for the practice of both astrophysics and contemporary visual art and for cross-disciplinary collaboration between them?

1.3 Defining the Field

The term 'field' requires definition both conceptually and practically.

The definition of a field in scientific fieldwork might seem apparent – outside the laboratory, in nature. The term fieldwork still evokes its agricultural origins – entailing physical work in a clearly demarked site set aside for a distinct purpose. Though not generally referred to as fieldwork, the making of art in a distant place located a long way from 'home' has a long and storied tradition in the visual arts – a well-documented example would be Paul Gauguin's escape to the exotic 'other' of Tahiti.[6]

The question of how to define a field has been considered in great detail within contemporary anthropology. In developing my thinking around this issue, I am indebted to the work of James Clifford, who has emphasised that anthropology is a 'field defined by its field' – a scientific discipline defined by both its social context and its physical site.[7]

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[6] "Gaugin's voyage of life was perceived in both the most literal and gratifyingly symbolic sense as a voyage ever further outward, to the periphery and margins, to what lies outside the parameters of the superego and the polis." Abigail Solomon-Godeau, "Going Native: Paul Gauguin and the Invention of the Primitivist Modernism," in Norma Broude and Mary Garrard, eds. *The Expanding Discourse* (New York: Westview Press,1993), 315-329.

[7] James Clifford, *Routes: Travel and Translation in the late Twentieth Century (*Cambridge: Harvard University Press, 1997), 53.

Conventionally, anthropological fieldwork has required distant travel to a culturally 'other' destination for an extended period of immersion and analysis. As Clifford describes it, "going out into a cleared space of work … [for] specific practices of displacement and focused disciplined attention."[8]

However, in contemporary anthropology the definition of the field has become much more problematic. Clifford points out that increasingly the "multiplicity of practices blurs any sharp, referential meaning for 'fieldwork'."[9] As the twentieth century has progressed there has been an increasing use of more and more sophisticated remote sensing apparatus in all of the natural sciences – from cameras attached to underwater devices through to semi-autonomous robots roaming the regolith of Mars. In these latter cases, fieldwork might now consist of logging on to a data server from a laptop in an office or living room. Defending the notion of an earth scientist assessing earthquake damage in Los Angeles by helicopter as fieldwork, Clifford says that what

> made this field work was the act of physically going out into a *cleared place of work.* Going out presupposes a spatial distinction between home base and an exterior place of discovery. A cleared space of work assumes that one can keep out distracting influences.[10]

This notion of a 'cleared place of work' derives from the original meaning of the field as a clearing in the woods (a place with a defined boundary and clear lines of sight, a place both part of and separate from its surroundings) but has now been extended to a conceptually cleared space (one without distractions or unwanted influences).

Clifford goes on to define fieldwork as a distinctive subset of the broader cultural practice of travel. He concludes that

> in tracking anthropology's changing relations with travel, we may find it useful to think of the 'field' as a habitus rather than a place, *a cluster of embodied dispositions and practices*.[11]

Such fieldwork may result, he asserts, in

> cultural understanding … based on powerful techniques, including at least the following: extended co-residence; systematic observations and recording of data; effective interlocution in at least one local language; a specific mix of alliance, complicity, friendship, respect, coercion, and ironic toleration leading to 'rapport'; a hermeneutic attention to deep or implicit structures and meanings.[12]

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[8] Clifford, *Rout*es, 53.

[9] Clifford, *Routes,* 54.

[10] Clifford, *Routes,* 53. My italics.

[11] Clifford, *Routes,* 69. My italics.

[12] Clifford, *Routes,* 71.

Fieldwork differs from mere travel (with its associated notions of pilgrimage, othering, or idle pleasure) through its requirements for duration and a set of 'embodied practices' engaged with local culture and conditions. With this nuanced analysis Clifford has circumscribed fieldwork in a way that is very useful for art practice that engages directly with other types of cultural practice – such as science.

Many other authors have pursed Clifford's line of interrogation. Akhil Gupta and James Ferguson have edited a collection of several approaches and concluded that the field "is a clearing whose deceptive transparency obscures the complex processes that go into constructing it. In fact, it is a highly over-determined setting for the discovery of difference."[13] One implication of this conclusion for my own research is that the field is just as likely to reveal differences as commonalities – to disrupt my view of science in the field and to expose my own preconceptions.

Another pertinent meaning of field is 'field of study'. Interestingly, the fields of both science and art have been taken by anthropologists as their field of study.[14] Taking a social anthropological approach, Pierre Bourdieu has theorised the field of art and portrayed it as a battlefield.[15] Nick Prior taking up a systems approach has concluded that

> the field [of art] becomes a network of objective relations between agents, but also larger groupings and institutions distributed within a space of possible positions. Its function is not merely to describe a logic of struggle between agents, but also a grander attempt to examine how modern societies are themselves defined by an architecture of overlapping spheres such as artistic fields, economic fields and scientific fields.[16]

Boris Groys has concluded that a systems approach makes it clear that

> individual artistic decision is no longer understood as sovereign, as fully autonomous [to the artist] but, rather, as an individual application of the existing set of rules, as a realisation of an option that is already given.[17]

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13 Akhil Gupta and James Ferguson (eds.), *Anthropological Locations: Boundaries and Grounds of a Field Science* (Berkeley: University of California Press, 1997), 5.

14 Emily Martin, "Anthropology and the Cultural Study of Science: From Citadels to String Figures," in *Anthropological Locations: Boundaries and Grounds of a Field Science*, ed. Akhil Gupta and James Ferguson (Berkeley: University of California Press, 1997).

15 Pierre Bourdieu, "The Field of Cultural Production, or the Economic World Reversed," in *Systems*, ed. Edward A. Shanken (London: Whitechapel Gallery, 2015), 204.

16 Nick Prior, "Putting a Glitch in the Field: Bourdieu, Actor Network Theory and Contemporary Music," in *Systems*, ed. Edward A. Shanken (London: Whitechapel Gallery, 2015), 206.

17 Boris Groys, "The Mimesis of Thinking," in *Open Systems: Rethinking Art c.1970*, ed. Donna De Salvo (London: Tate Publishing, 2005), 54.

This observation, that art arises from an existing set of cultural conditions, is relevant to my research in several ways. It requires that I critically examine key precedents in contemporary visual art and analyse how they inform my approach or provide 'an existing set of rules' – this analysis is the focus of Chapter Four. As well, it foregrounds the complex interplay of agencies that determine the scope and operations within a field – the particular influences and limitations placed on my own artistic fieldwork as it was carried out within the context of scientific research funding and fieldwork is discussed in Chapter Six. And finally it suggests that the meeting of art and science through fieldwork could engender a rethinking of art practice – its location, formation, agency and autonomy.

I have established that the field is both a physical location and a complexly determined cultural space. I will now discuss both of these aspects in connection with my own chosen fields. In my own research both the physical sites selected and the discipline of astrophysics can be considered as my fieldwork locations.

I selected two physical sites which, *a priori*, appeared to provide suitable locations for the development of my research and for investigating the common ground between science and art – locations which are perceived as physically extreme and are typically reserved for scientific exploration and research. These were the Arctic and the Antarctic – specifically the Svalbard Archipelago north of Norway and the South Pole respectively.

The polar regions have a rich history of both scientific and artistic activity – often conducted in tandem. This history and its current manifestations are discussed in detail in Chapter Two. My fieldwork in the Arctic was conducted in a structured setting where artists and scientists were expected to collaborate and it provided a proof of concept for both my conceptual approach and my working methodologies. This experience allowed me to develop a successful proposal for fieldwork in collaboration with a major astrophysical observatory at the South Pole – the IceCube Neutrino Observatory. My fieldwork at the South Pole over the austral summer of 2016/17 forms the major part of my practical research. I will discuss in detail why this location is so apt for both artistic and scientific (particularly astrophysical) fieldwork in Chapters Two and Five.

The cultural space of contemporary astrophysics was chosen as the field for my artistic research. I discussed broad philosophical reasons for this earlier. The complex use of the term field within astrophysics provides another justification and provided my entry point to develop a methodology to reflect on, engage with, and ultimately to collaborate with astrophysical research. In astrophysics, the term field is used in many different but interconnected ways. For example, a 'field of view' and a 'field of stars' are examples of two quite different ways of defining a field. A field of stars is a selected location for study (a distant, 'other' place) and a field of view is an instrumentally constrained area of attention. Also in astrophysics, a field is a mathematically (conceptually) definable space with distinctive attributes – electromagnetic field, gravitational field, scalar field, vector field, etc. All of these various fields are detected and analysed by instruments.

The use of instruments in science can effectively define a field. Entire disciplines of scientific research are defined by the instruments that they employ (e.g. radio astronomy).[18] Instruments define a field, by becoming a metonym of the field (telescopes signify astronomy), by circumscribing the physical field of study (the field of view of the telescope), and by providing the data required by researchers (by sampling discrete portions of the electromagnetic field for example). In Chapter Five I examine the nature of scientific instruments and why I consider them to be devices of constraint – devices that limit and define a field of investigation and so create a 'cleared space'. In Chapter Four I argue that the use of constraint systems in contemporary art is analogous to the use of scientific instruments – both are used as ways to focus attention within a sea of possibilities and to remove subjectivity and agency.

This conceptualisation of instruments as devices of constraint within both science and the visual arts proved to be an effective research strategy. This approach has allowed me to think about scientific instruments from an artist's perspective, to design and create my own instruments for deployment in conjunction with scientific instruments, to develop collaborations with scientists and to locate my research within an original analysis of aspects of contemporary art practice.

1.4 The Common Ground – A Conceptual Methodology

My research project engaged with the notion of the field in complexly interconnected ways – I collaborated with and examined a particular field of science (astrophysics) with its own multilayered definitions of a field, I analysed various fields within the visual arts to locate my own work, and created work in connection with fieldwork conducted at remote sites. Teasing apart these layered notions of the field was at the core of my research and finding strategies to weave them back together to identify a common ground between science and art in which to operate was my goal.

My research consisted of both practical and conceptual approaches. Practically, I employed a set of general purpose instruments in the field – including a variety of cameras (GoPro and digital SLR cameras with various turntables and shutter controllers), sound recording devices (including binaural, bayonet and contact microphones, hydrophones and accelerometers), and notebooks. From the raw data and materials I collected in the field, I produced digital prints on paper, photographic images on metal, video, and sound works. I also constructed specifically designed instruments to deploy in the field to gather data, to signify

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[18] See Chapter Five for more on the birth of radio astronomy.

human presence in the landscape and to embody the field experience when exhibited. These instruments ranged in scale from the hand-held to the size of a small portable building and were constructed in a wide range of materials including wood, metal, sail cloth, paint, glass and ice.

These diverse approaches to art-making allowed me to investigate and apply various strategies all of which share a common conceptual approach. Rather than approach scientific methodologies and ways of understanding purely from the perspective of an artist, I have endeavoured to establish a common ground by approaching art making from the perspective of a scientist – applying objective constraints and using concepts which have value in both disciplines but which have not been widely used in analysing art. My strategy was to borrow concepts from science disciplines and while retaining their original meanings, apply them to situations and processes in the visual arts. In Chapter Four I employ the notions of 'transcription' and 'transduction' to classify and analyse contemporary artworks and identify underlying conceptual connections between diverse practices. In Chapter Five I discuss the key terms 'artefact', 'noise' and 'signal' and in Chapter Six, I discuss the term 'pareidolia'. Chapter Six details the work I completed in the field in the Arctic and the Antarctic, lays out the major trajectories of my practical research and documents the outcomes. Each body of work is gathered under the rubrics of these key terms and I interweave analysis of these terms with discussions of the fieldwork undertaken. The concluding Chapter Seven presents a critical summary of the research undertaken to establish a conceptual methodology linking science and art, and offers an evaluation of the success of my approach.

Following page – Figure 1.1 *Instrument (90ºS)*. 2017.

Art and science have been seen as diametrically opposed modes of enquiry. Science is stereotypically deemed rational, objective, undertaken by teams and resulting in accumulated knowledge. Conversely, art is seen as irrational, subjective, individual and constantly undermining existing knowledge through the activities of an avant-garde.[19] However, until quite recently, art and science were widely perceived as complementary aspects of human inquiry.[20] Discoveries in each field strongly influenced the other,[21] and artists were integral parts of scientific expeditions from the beginning of the eighteenth century up until early in the twentieth century. Only during the second half of the twentieth century has the dichotomy between the arts and sciences come to be seen as pronounced and supposedly insurmountable.

In this chapter, I will briefly examine the rich history of artists and scientists collaborating in the field and go on to discuss this connection in the particular case of the Antarctic – the field I have selected for my main body of research. I will discuss the notion of 'convergence' whereby motifs and ways of seeing are established, and then resonate through artistic culture. Finally, the changing modes of artistic practice in Antarctica will be related to the changing modes of its exploration.

2.1 Fieldwork in Natural History – The Artist and Scientist on Expedition

In the field is traditionally where artists and scientists have worked most closely together. I will look at two seminal examples of how artistic practice has been integral to both the content and formulation of science conducted in the field and the main vehicles for cultural understanding of these locations.

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[19] C.P. Snow, *The Two Cultures and the Scientific* Revolution (Cambridge University Press, 1959).

[20] See particularly Lorraine Daston and Katherine Park, *Wonders and the Order of Nature: 1150–1750* (New York: Zone Books, 1998) and Barbara Maria Stafford, *Artful Science: Enlightenment Entertainment and the Eclipse of Visual Education* (Cambridge, Mass.: MIT Press, 1994).

[21] This is the primary thesis of Leonard Shlain, *Art & Physics: Parallel Visions in Space, Time & Light* (New York: William Morrow & Co., 1991).

A key example is Alexander von Humboldt (1769–1859), the Prussian naturalist, geographer and explorer who essentially defined the modern concept of scientific fieldwork. Between 1799 and 1804, Humboldt and his steadfast companion Aimé Bonpland travelled extensively in Latin America, exploring and describing it for the first time from what we now consider to be a modern scientific perspective. His description of the journey was written up and published in the enormous set of volumes entitled *Kosmos*, published over a 21-year period. Humboldt viewed nature holistically and tried to explain natural phenomena without appeal to religious dogma. He believed in the central importance of observation and, as a consequence, amassed a vast array of the most accurate and portable scientific instruments then available – nothing quantifiable escaped his measurement. According to Humboldt, everything should be measured with the finest instruments and most sophisticated techniques available, as collected data was the basis of all scientific understanding.[22] This quantitative methodology would become known as 'Humboldtian' science.[23]

Humboldt's work straddled both science and the arts. Daniel Velasco has pointed out that "Humboldt formed in his mind an aesthetic theory of landscape rooted in the interaction of emotional feeling and intellectual knowledge as a mutual reinforcement of artistic expression."[24] He was the first exemplar of the explorer/savant and his writings and experiences were formative in the ambitions and thinking of many of the Enlightenment's explorers and natural philosophers who followed.

2.2 Cook, Hodges and the First Representations of Antarctica.

Humboldt embodied the explorer, scientist and artist in one man. The more common paradigm in voyages of discovery was a crew comprised of navigators, seamen, artists and natural philosophers. One of the most renowned Western explorers in this mode and the first to approach the Antarctic continent was James Cook (1728–1779). Cook was a British explorer, navigator and cartographer who made three voyages to the Pacific Ocean, during which he achieved the first recorded European contact with the eastern coastline of Australia and the Hawaiian Islands, and the first recorded circumnavigation of New Zealand. He also sailed deeper than any previous Western sailor into Antarctic waters.

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[22] Humboldt's methodologies and fascination with the latest scientific apparatus are outlined in Andrea Wulf, The Invention of Nature: Alexander von Humboldt's New World (New York: Knopf Doubleday, 2015), 93.

[23] http://en.wikipedia.org/wiki/Alexander_von_Humboldt. Accessed November 23, 2014.

[24] Daniel Velasco. "Island Landscape: Following Humboldt's Footsteps through the Acoustic Spaces of the Tropics." *Leonardo Music Journal*, Vol.10 (2000): 21–4.

Interestingly, the primary mission of Cook's first Pacific voyage was astronomical fieldwork – the observation of the transit of Venus from the South Pacific. During this voyage the nature of the fabled southern continent of *Terra Australis* was clarified through the mapping of the east coast of what was to become Australia and a vast new realm of natural history was revealed through the work of the on-board naturalists Joseph Banks and William Solander, and the artist Sydney Parkinson.

An even greater clarification of the limits of *Terra Australis* was the explicit mission of Cook's second voyage (1772–5) which provided the first detailed survey of the extent and nature of the Antarctic continent. A secondary aim of this voyage was to test a newly developed naval chronometer. Prior to Cook's day, an accurate measurement of longitude was virtually impossible as there was no way to determine the exact time of day at sea. After 1735, the chronometer invented by the Englishman John Harrison made this possible. Cook carried four chronometers aboard his ships the *HMS Resolution* and the *HMS Adventure*.[25] Thanks to this newly invented scientific instrument (almost computer-like in its complexity and self-governing capacity) Cook was one of the first naval commanders to know his exact position on the globe while sailing uncharted seas. He was in command of the most technically advanced ships to have ever sailed and set the precedent for future expeditions to carry and field test cutting edge instruments and technology.

After passing the Antarctic Circle in January 1774, Cook sailed farther south than any previous explorer. But he never sighted the actual continent of Antarctica as it was surrounded by impenetrable ice. Stephen J. Pyne, historian of exploration and the environment, points out that

> several centuries of exploration by Western civilisation had established expectations that certain kinds of information would be discovered and that certain intellectual disciplines would process those data. The map, the ship's log, the captain's (or chief naturalist's) travelogue, the collection of specimens, and illustrations of people and places – all comprised the intellectual stuff of exploration.[26]

The professional artist aboard the *HMS Resolution*, William Hodges (1744–1797), drafted some of the first views of icebergs in the Southern Oceans. Cook's illustrated account of his voyage was a publishing success and became a bestseller. The images of ships and men dwarfed by mountains of floating ice sent shivers up the spines of late eighteenth century readers and set the mold for future imagery and expectations of the Antarctic. [27]

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[25] The *HMS Resolution* carried a copy of Harrison's prize-winning chronometer *H4* built by Larcum Kendal. https://maas.museum/observations/2012/04/17/cooks-three-voyages-of-exploration/. Accessed June 29, 2017.

[26] Stephen J. Pyne, *The Ice: A Journey to Antarctica* (London: Arlington Books. 1987), 155–6.

[27] Francis Spufford, *I May be Some Time: Ice and the English Imagination (New York:* St. Martin's Press, 1997).

Figure 2.1
The ice islands, seen the 9th of Janry, 1773.
William Hodges.

The art historian Lawrence Weschler has coined the term 'convergence' for the tendency of artists to gravitate towards iconic imagery, forms and typologies in their work – consciously or unconsciously.[28] Disappointingly, Weschler hasn't hypothesised mechanisms for his observation of repeated formal echoes through art history – he simply posits a nebulous field of pervasive, subconscious artistic influence. But other writers have been more specific in this regard, especially with respect to the imagery and literature connected to the revelation of the Antarctic.[29] Francis Spufford, in his revealing analysis of the influence of the Poles on the English imagination, has shown that this iconic imagery (and literature) affects more than the predispositions of artists who create new works engaged with the same topic.[30] It also pervades the wider culture and shapes the way all of us perceive the world and our connection to it. This was especially pertinent for several early polar explorers, like Robert Falcon Scott (1868–1912), who were so deeply involved in a romantic view of their own exploits and of the polar landscape (largely constructed from popular literature and imagery) that they were, arguably, ill-equipped for and insensitive to the reality that they were actually experiencing.[31] This idea of seeing what we think we will see, will be discussed again in Chapter Six when I discuss the phenomenon of 'pareidolia'.

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[28] Lawrence Weschler, *Everything That Rises: A Book of Convergences* (San Francisco: McSweeney's, 2007).

[29] Notable in this regard is Spufford's *I May be Some Time: Ice and the English Imagination,* William Fox, *Terra Antarctica: Looking into the Emptiest Continent (*San Antonio: Trinity University Press, 2005) and, with respect to Hurley's work, Helen Ennis, *Frank Hurley's Antarctica (*Canberra: National Library of Australia, 2010).

[30] Spufford, *I May be Some Time*.

[31] This is the central focus of Huntford's critique of Robert Falcon Scott. Roland Huntford, *The Last Place on Earth* (New York: Modern Library, 1999).

By analysing the convergences present in polar literature and imagery we begin to apprehend a distinctive aesthetic or set of tropes defining the art and literature of the Antarctic. For example, we can see echoes from William Hodges appearing one hundred year later in Gustav Doré's superb illustrations for Coleridge's epic poem *The Rime of the Ancient Mariner* (1876).[32]

These convergences have accumulated over the intense intervening years of Antarctic imagery and have developed into an expectation of artwork connected with the continent. It is one of the ambitions of my current research to step outside these expectations and to develop new works which arise from fresh perspectives on Antarctic fieldwork.

Figure 2.2
"The ice was here, the ice was there,
The ice was all around."
Gustav Dore.
1876.

[32] Samuel Taylor Coleridge. *The Rime of the Ancient Mariner* (New Jersey: Chartwell, 2008). The edition with illustrations by Gustave Doré was first published 1876.

2.3 The Great Ages of Exploration

Stephen Pyne outlined Three Great Ages of [Western] Exploration in his exposition of the interplanetary *Voyager* expedition of the late twentieth century.[33] According to Pyne, the First Great Age came with the outpouring of explorers initially from Portugal and Spain, and later from the Netherlands and Britain.

> It was the world sea that defined the scope and achievements of the First Age. Mapping its littoral was the era's finest intellectual achievement. The voyage of discovery became a metaphor for an age of inquiry that would venture far beyond the dominion of the Mediterranean and the inherited wisdom of the ancients. The discoveries overwhelmed a text-based scholarship. Scholasticism, that arid discourse that resulted from too many scholars and not enough texts, collapsed as new information poured into Europe like New World bullion into Spain, and like it, caused an inflationary spiral of knowledge.[34]

Cook's voyages arguably marked the climax of this First Age. His second voyage made the closest approach to Antarctica in recorded history. The coastline of Antarctica was the last to be drawn accurately on the world map: thus concluding the mission of the First Great Age.

Pyne characterises the Second Great Age by cross-continental traverses – when the interiors of the coastal outlines were filled in. Humboldt's explorations of the interior river systems and mountain ranges of South America are exemplars of this Age. Pyne concludes the Second Great Age with the close of the nineteenth century: "by the 1870s, explorers had managed comprehensive traverses … for every continent *save Antarctica*."[35]

The Third Great Age as defined by Pyne had a very clear start date, the International Geophysical Year (IGY) (1957–8). Three months into that year, the Russian government successfully launched *Sputnik 1* and so launched of the *Space Age* and the Third Great Age of Exploration. Pyne notes that

> it was here [during the IGY], for the first time, that the contours of a new age of discovery came together. IGY's explorers would visit places inimical not only to humans but to life itself. They would rely on remote-sensing instruments, tracked vehicles, rockets, and robots. They would inventory a planet whole, of which Earth would be the prototype: the home planet became, intellectually, a new world, the first of a dawning age of discovery that would propagate to the fringe of the solar winds. The voyages that followed to planets such as Venus, Jupiter, and

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[33] Stephen J. Pyne, *Voyager: Exploration, Space, and the Third Great Age of Discovery* (New York: Penguin, Kindle edition, 2010).

[34] Pyne, *Voyager*, 37.

[35] Pyne, *Voyager*, 41. My italics.

> Neptune would carry essentially the same instruments and ask the same questions of them as IGY did for Earth.[36]

Pyne posits the Antarctic as a key locus of each of the Three Great Ages of Exploration – the last continent to have its borders delineated, the last to have its interior traversed and the proving ground of the Third Great Age.

> Antarctica was an ideal venue—the geographic and historical transition from the Second Age to the Third. No one has ever truly lived there; no enduring natural assets bind it to the world economy; no colonisation or claims to sovereignty have global recognition. Its population is scientists; its trade, information; and only an immense expenditure of will and money has forged even these tenuous links. The Antarctic's isolation is so complete that it seems less an intrinsic feature of the planet than an extraterrestrial presence accidentally slapped onto its surface, as though an icy moon of Uranus had slammed into Earth.[37]

Antarctica has presented both physical and conceptual barriers to understanding and has catalysed fundamental paradigm shifts for each age of exploration that encountered it.

Pyne points out that artists, chroniclers and writers have documented each Great Age, and

> placed it into a national (and civilisational) narrative, they created valences with other vigorous elements of the culture, they implanted it into the minds of the educated and governing classes. They helped institutionalise exploration. They ensured that the Great Age of Discovery could lead to others. Exploration became complex, and because of that cultural complexity, it could survive. It endured in part because Western civilisation could no longer imagine itself not exploring.[38]

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[36] Pyne, *Voyager*, 46.

[37] Pyne, *Voyager*, 163.

[38] Pyne, *Voyager*, 121.

2.4 Artists in the Field in Antarctica

The history of artists interacting with both polar regions has been well documented and analysed.[39] Though the curator, writer, and Antarctic expert William Fox estimates that at most three hundred professional artists have spent time in the Antarctic, one could make a strong argument for the definition of a Polar or Antarctic genre within contemporary art.[40] Consider the rich histories of artistic encounter over the last century, the number of artists worldwide who are currently making active contributions in this field, and the unique methodologies and conceptual interests of these contemporary artists. I will discuss this in more detail in Chapter Four when I consider the genres (or fields) of art are most closely connected with my research.

Fox has examined the history of artistic engagement with Antarctica in detail.[41] He follows and expands on Pyne's notions of three Great Ages of Western Exploration and corelates these to three different approaches to art making in Antarctica. According to Fox, the First Age of artistic engagement was typified by painting (and the associated media of drawing, engraving and printing). The long tradition of painting in the Antarctic continues to this day. Even as recently as 2007, Lynne Andrews' well-researched survey of Australian artists who have worked in the Antarctic listed mostly painters (including influential Australian artists such as Sidney Nolan, Jørg Schmeisser and Bea Maddock) and only one photographer.[42]

Fox points out that painting and sketching were more adaptable to the challenges of the Antarctic environment than early photography and cites the example of Edward Wilson (1872–1912) – who famously died beside Robert Falcon Scott on his return from the South Pole. Earlier, while travelling with Scott and Shackleton along the Ross Ice shelf on the *Terra Nova* expedition (1910–13), Wilson "kept a running sketch portfolio of the mountains forming the horizon, which he later estimated would stretch for 80 metres if pasted together,"[43] a task which was beyond the abilities of Herbert Ponting (1870–1935), who was the accomplished photographer on the expedition and the first professional photographer to set foot on the continent.

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[39] To cite just a few anthologies: Lynne Andrews, *Antarctic Eye – The Visual Journey* (Hobart: Studio One,Tasmania, 2007); Fox, *Terra Antarctica*; Jane D Marsching and Andrea Polli, eds. *Far Field: Digital Culture, Climate Change, and the Poles* (Chicago: University of Chicago Press, 2012); Nancy Sever, Caroline Turner and Anthony Oates, eds. *Antarctica: Sidney Nolan, Bea Maddock, Jorg Schmeisser, Anne Noble, Phillip Hughes, Chris Drury* (Canberra: ANU Drill Hall Gallery, 2012).

[40] William Fox, "Every New Thing: The Evolution of Antarctic Technologies in the Antarctic – or How Land Arts Came to the Ice," in *Far Field: Digital Culture, Climate Change, and the Poles,* eds. Jane D. Marsching and Andrea Polli (Chicago: University of Chicago Press, 2012), 21.

[41] Fox, *Terra Antarctica.*

[42] Andrews, *Antarctic Eye.*

[43] Fox, "Every New Thing," 21.

Fox posits photography to be the marker of Pyne's Second Great Age of Exploration. Photography entered Antarctica as explorers started to delve deeper into the continent with the Second Great Age of Exploration. The technology of photography had been under constant development from the 1830s onwards and it was still evolving at the beginning of the twentieth century, especially as a field practice in extreme conditions such as at the poles.

Frank Hurley (1885–1962) was an important figure in both the history of photography and Antarctic exploration. At the age of 25, Hurley was selected for the position of official photographer to Douglas Mawson's Australasian Antarctic Expedition (1911–1914) – the first Antarctic expedition conducted with primarily scientific ambitions.[44] On his return, Hurley edited and released a feature length documentary, *Home of the Blizzard*, using his technically masterful footage from the expedition.[45] A year later, Hurley was back at the Pole with Shackleton on his expedition. Their ship the *Endurance* was crushed and destroyed in the ice in November 1915. We see striking convergence with the imagery of Hodges and Dore, in the images by Frank Hurley of the *Endurance* encased in ice (Figures 2.3 and 2.4).

Hurley experimented with cutting edge processes in his work: 3D imagery, colour photography, moviemaking, and carefully constructed images made from several exposures sometimes from different locations and times. All were taken in a physically and psychologically challenging environment where chemistry and the properties of materials (so vital to photography) behave erratically. [46]

Early Antarctic photographers like Ponting and Hurley, and later Emil Sculthess (1913–1996), were using photography not just to document the strange new landscape but rather to capture the subjective experience of the men (at this stage just men) who were engaging with this hostile and alien environment. They were not so much documenting the interiors of the newly discovered continents as revealing the psychological interiors of the men who were struggling to comprehend and survive this new world.

At the turn of the twentieth century photography documented the transition between the Second and Third Great Ages of Exploration in the Antarctic. At the same historical moment, photography was pivotal in both the evolving notions of scientific objectivity and in the changing relationship between representation and abstraction in artistic practice, as I will discuss in the next chapter.

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[44] Douglas Mawson, *The Home of the Blizzard: Being the Story of the Australasian Antarctic Expedition, 1911–1914* (Public Domain, Kindle edition, 1914).

[45] Frank Hurley, *Home of the Blizzard* (Canberra: Australian Film and Sound Archive Collection, 1914). 16mm silent movie.

[46] Helen Ennis. *Frank Hurley's Antarctica* (Canberra: National Library of Australia, 2010), 92.

Figure 2.3
The returning sun [and the Endurance, Shackleton expedition, 7 August 1915].
Frank Hurley.
1915.

Figure 2.4
Endurance battling with high blocks of pressure ice.
Frank Hurley.
1915.

A key point of Pyne's thesis was to propose a Third Great Age of Exploration in which we are currently actively engaged. In this Great Age we are no longer physically venturing to distant shores or mysterious interiors, previously undiscovered by Western man. This Third Great Age has no living explorers – nor local guides to employ or conscript. Pyne emphasises that

> amid ice, abyss, and space it is possible to shear away the moral ugliness and ultimately tragic core of exploration because there is no Other to confront, and without an Other, there is no need for a human self.[47]

[47] Pyne, *Voyager,* 133.

The Third Age is typified by remote sensing – the use of sophisticated scientific instruments that permit virtual exploration of environments that are inimical to human life. The advent of Pyne's Third Great Age of Exploration with its focus on remote sensing has opened up new opportunities for artists. The third age of artistic endeavour in Antarctica, according to Fox, is exemplified by the use of new media – installation, film, performance, video, sound, etc. These diverse modes of artistic practice permit a wider range of artistic engagement with both the Antarctic landscape and the human culture of Antarctica, which since the mid-twentieth century has been focused on scientific discovery. As well, the fluency of contemporary artists with new media facilitates direct access to and engagement with contemporary modes of scientific research in the Antarctic and elsewhere.

Work by contemporary artists in Antarctica is largely supported by national scientific funding organisations – most notably by the National Science Foundation (NSF) in the USA, and its equivalents in Australia, New Zealand, and the United Kingdom. Contemporary artists working in Antarctica are practically obliged to engage collaboratively with scientific teams to have access to the continent. This has helped bring contemporary artists once more into the role of collaborators in the field embedded with scientific expeditions.

2.5 Conclusion

This chapter has established fieldwork as an historical practice common to both art and science, and the field as the place where diverse ways of seeing, depicting, understanding and thinking about the world intermingle. A place where science and art are both actively engaged – often with each other.

The changing nature of Antarctic exploration, as delineated through Pyne's analysis, has been matched by distinctive modes of artistic documentation and interpretation. In each mode artists were working at the innovative edge of the media that they were employing. This was partly due to the environmental rigors of the Antarctic testing the material limits of their media but also because the artists were developing new techniques and modes of representation to engage with a continent that was challenging to inhabit and comprehend. In each case, the artists were deeply imbedded in the act of exploration and scientific enquiry. This collaborative effort between artists, scientists and explorers continues to this day and is a key reason that Antarctic is a perfect field in which to explore the common ground between scientific and artistic practice.

> The much vexed inquiry as to whether science and art are incommensurable realms of knowledge is misplaced. What promises more is a view of history that asks: What are the conditions under which objects become visible in culture, and in what manner are such visibilities characterised as 'science' or 'art'?[48]

In the preceding chapter I established that our understanding and experience of the world has been both documented and shaped by the work or artists in collaboration with scientists and explorers on expeditions of discovery. Considering this, can art and science be considered antithetical approaches to understanding the world?

In this chapter, I will provide a brief overview of how this perceived dichotomy arose through the traditions of Western epistemological philosophy. I will investigate the changing definitions of subjectivity and objectivity and consider how our concept of an external independent reality have been called into question in the last 100 years. During this same period, the transition from representation to abstraction combined with postmodernist perspectives have taken art into a realm of relativity and uncertainty that in many ways parallel changes in the perspectives of science. In the early years of the twenty-first century we find ourselves in the position where both art and science are dealing directly with a reality that is in constant flux and contingent on the way it is experienced. This commonality provides a renewed bridge between the methodological approaches and conceptual underpinnings of art and science.

3.1 The Two Cultures

There is a long and significant history of collaboration between artists, explorers and scientists in the field. Similarly there is a rich history of artists in their studios engaging with the latest discoveries in science and incorporating those into their work. In the early 1880s, Seurat was influenced by scientific research on optics and the physics of light to create, for example, *A Sunday on La Grande Jatte* (1884). Early in the twentieth century Duchamp described his iconic painting *Nude Descending a Staircase, No.2* (1912) as "an

[48] Caroline A. Jones and Peter Galison, eds. *Picturing Science, Producing Art* (London: Routledge, 1998), 1.

expression of time and space through the abstract presentation of motion." [49] The art critic Arthur I. Miller concludes, that in

> the early days of the twentieth century … artists such as Picasso and Kandinsky took on board the latest scientific developments, while scientists found themselves driven by questions like the relevance of aesthetics to science and what makes a scientific theory beautiful.[50]

However by the middle of the twentieth century there was a burgeoning perspective that art and science were diametrically opposed. In his seminal Rede Lecture at Cambridge in 1959, *The Two Cultures and the Scientific Revolution*, the noted scientist and writer C.P. Snow brought attention to the widening dichotomy between the humanities and the sciences. In his lecture and subsequent publication, Snow bemoaned the division which he attributed to mutual ignorance of the each other's fields, urged a more cohesive approach to inquiry and felt that each discipline needed the other to move forward.[51]

The British contemporary art critic, Sîan Ede points out that the rift was more fundamental than Snow indicated and arose from the

> two epistemological traditions concerned with the nature of knowledge itself. On one hand is the view that there is an implicit reality out there waiting to be discovered, independent of the observer's mental state, as very many scientists maintain. On the other hand is the idea that reality is all or at least partly a construction of the human mind, phenomenologically and linguistically determined and therefore unfixed, and whether we are aware of it or not, viewed in accordance with the prevailing values and beliefs of particular times and places.[52]

The origin of these two traditions are traditionally ascribed to the Ancient Greek philosophers Plato and Aristotle. Plato posited that there was an external world 'out there' which lay largely beyond our ability to perceive and experience and that our senses only gave us a partial and imperfect view of this external reality. Aristotle disagreed with the notion of the Platonic ideal and postulated that reality is constituted entirely of our experience of it. As Ede summarises: "Although we might subscribe to the vision of underlying coherence in nature, we can only trust the evidence of our own perceptions in investigating it."[53] These two epistemic traditions have continued to play off each other throughout the Western philosophical tradition. Immanuel Kant (1724–1804) argued that it is impossible for the human mind to deny, confirm or scientifically demonstrate the nature of reality and furthermore "that through the very process of perceiving and acquiring

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[49] Leonard Shlain, *Art & Physics: Parallel Visions in Space, Time & Light* (New York: William Morrow & Co., 1991), 210.

[50] Arthur I. Miller, *Colliding Worlds: How Cutting Edge Science is Redefining Contemporary Art* (New York: W.W. Norton, 2014), xx.

[51] C.P. Snow, *Two Cultures*, 2–5.

[52] Sîan Ede, *Art and Science* (London: I.B.Tauris, Kindle Edition, 2008), 5.

[53] Ede, *Art and Science*, 18.

knowledge, we partly invent the world by our means of measuring it."[54] Georg Wilhelm Friedrich Hegel (1770–1831) and his followers concluded that we invent the world we experience and went so far as to deny the existence of an independent reality, proposing that "history, time and religion were all human constructs" – a philosophy that underlies late twentieth century art theory.[55]

In the 1930s, the philosopher of science Karl Popper (1902–1994) argued that a theory can never be proven true as the infinite number of possible predictions from that theory could never be tested. Instead, the scientific method is built on the principal of falsifiability.[56] If a hypothesis can be proven false then it is replaced by another until one is found that resists all efforts to be disproved and hence can be considered, for the moment, valid. Sîan Ede has pointed out that, "in practice, then, scientists operate in a culture not of explicit certainties, but of doubt and question."[57] The physicist Carlo Rovelli sees this as science's great strength and calls this condition of perennial doubt "the deep source of science."[58]

The notion that science deals with an objectively verifiable reality that exists independent of human awareness and culture has been called into question throughout the twentieth century by scientists themselves, particularly through the development of the theories of quantum physics. According to Rovelli, quantum mechanics can be summarised by three fundamental principles – Granularity, Indeterminacy and Relationality.[59] Granularity is the fundamental indivisibility of the real world at its smallest scales. Matter, energy, time and space can be dissected and analysed down to the tiniest imaginable scales but there comes a point where they cannot be divided any further and we reach the quantum character of reality. As Rovelli summarises, "information in the system is finite – not infinitely divisable".[60] Indeterminacy limits our ability to predict future events. All the variables of a system fluctuate continuously: "It is a world of vibrations, a continuous fluctuation, a microscopic swarming of fleeting microevents".[61] The most famous expression of this notion is Heisenberg's Uncertainty Principle which recognises the inherent impossibility of simultaneously fixing all of the characteristics of a quantum level situation and perhaps most importantly affirms that the observer plays a critical part in what is observed. Finally, Relationality is the principle that "the events of nature are always interactions", so that "all events of a system occur in relation to another

[54] Ede, *Art and Science*, 19.

[55] Ede, *Art and Science*, 20.

[56] Karl R. Popper, *The Logic of Scientific Discovery* (London: Routledge, 1992).

[57] Sîan Ede, ed., *Strange and Charmed: Science and the Contemporary Visual Arts* (London: Calouste Gulbenkian Foundation, 2000), 36.

[58] Carlo Rovelli, *Reality is Not What it Seems: The Journey to Quantum Gravity,* trans. by S. Carnell and E. Segre (New Jersey: Riverhead Books, 2017), 141.

[59] Rovelli, *Reality*, 136.

[60] Rovelli, *Reality*, 136.

[61] Rovelli, *Reality*, 132.

system."[62] This stems largely from Einstein's Special Relativity which also theorised that the condition of the observer determines what is observed – or more precisely that each observer has a unique but relative frame of reference.

Together these principles demonstrate that at the most fundamental level reality is constantly in flux, subject to a complex interplay of probabilistic forces and, most significantly, our understanding of it is contingent on the state of the observer. When considering scales larger than the quantum level, reality seems stable and predictable, but even here this can be illusionary. Nancy Cartwright in her influential sociological study of the practice of particle physics, *The Dappled World*, develops the notion of the 'nomoligical machine' to encompass the fact that even at everyday scales physical theories and predictions only work within severely limited constraints.[63] In Cartwright's definition, a nomoligical machine is

> a fixed (enough) arrangement of components, or factors, with stable (enough) capacities that in the right sort of stable (enough) environment will, with repeated operation, give rise to the kind of regular behavior that we represent in our scientific laws.[64]

To keep the "machine running properly" requires strictly defined and limited constraints or 'shielding conditions' – beyond these constraints reality becomes too complicated to predict.[65]

Cartwright sees the world as 'dappled' because

> the laws that describe this world are a patchwork, not a pyramid. They do not take after the simple, elegant and abstract structure of a system of axioms and theorems. Rather they look like – and steadfastly stick to looking like – science as we know it: apportioned into disciplines, apparently arbitrarily grown up; governing different sets of properties at different levels of abstraction; pockets of great precision; large parcels of qualitative maxims resisting precise formulation; erratic overlaps; here and there, once in a while, corners that line up, but mostly ragged edges; and always the cover of law just loosely attached to the jumbled world of material things.[66]

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[62] Rovelli, *Reality*, 136

[63] Nancy Cartwright, *The Dappled World: A Study of the Boundaries of Science* (New York: Cambridge University Press, 1999).

[64] Cartwright, *Dappled World,* 50.

[65] Cartwright, *Dappled World,* 50.

[66] Cartwright, *Dappled World,* 1.

3.2 Observation and Objectivity

We have seen that both the Western epistemological tradition and developments in quantum theory in the early twentieth century have called into question the notion of an independent, deterministic reality outside of human observation. As well, contemporary sociologists studying the history of science have revealed the changing meanings of seemingly well-understood and established notions in science such as 'experiment', 'observation' and particularly 'objectivity' as science has developed.[67] Not only is our ability to fully understand or even perceive an objective reality called into question but so too the very concept of objectivity itself.

Daston and Lunbeck propose that observation has always been "a form of knowledge that straddled the boundary between art and science" and that its meaning remains layered, "at once a process, a product, [and] an all-consuming pursuit".[68] They have emphasised that

> like experiment, observation is a highly contrived and disciplined form of experience that requires training of the body and mind, material props, techniques of description and visualisation, networks of communication and transmission, canons of evidence, and specialised forms of reasoning.[69]

When the word 'observation' first came into use in the late Middle Ages it was linked with 'observance' – devoted and disciplined religious practice. It was initially connected to what today we would call meteorology and astronomy (used at the time particularly for divination and the regulation of monastic life and religious calendars). This association with focused, attentive, ongoing and even religious devotion still clings to the meaning of observation today. Observing also carries the connotation of 'observing the law', that is, following along with the teachings of a recognised (or model) author "who upheld the rules of scholarship."[70] Thomas Kuhn emphasised that scientific observation is necessarily 'theory-laden', because the trained observer sees differently: "The infant and the layman can see: they are not blind. But they cannot see what the physicist sees; they are blind to what he sees."[71] The experienced scientist's observations can be trusted because of his/her trained senses, near-religious devotion to observation and authoritative voice.

While the term 'observation' has accumulated layers of congruent meaning over time, the term 'objectivity' has significantly changed meaning in the context of natural philosophy and science. Daston and Galison

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[67] This section relies largely on the research of Lorraine Daston and Peter Galison and their colleagues.

[68] Lorraine Daston and Elizabeth Lunbeck, eds., *Histories of Scientific Observation* (Chicago: University of Chicago Press, 2011), 7.

[69] Daston and Lunbeck, *Scientific Observation,* 3.

[70] Gianna Pomata, "Observation Rising: Birth of an Epistemic Genre, 1500–1650," in Daston and Lunbeck, *Scientific Observation*, 50.

[71] Quoted in Daston and Lunbeck, *Scientific Observation,* 5.

point out that it only acquired its current meaning in the mid-nineteenth century. The word objectivity has always been paired with subjectivity, but initially they held the almost opposite meanings of what they do today – "objective referred to things as they are presented to consciousness, whereas subjective referred to things in themselves."[72] The words fell into disuse in the seventeenth century to be resurrected by Immanuel Kant in the eighteenth. By 1817, Samuel Taylor Coleridge interpreted the words in the way we now understand them:

> Now the sum of all that is merely OBJECTIVE we will henceforth call NATURE, confining the term to its passive and material sense, as comprising all the phenomena by which its existence is made known to us. On the other hand the sum of all that is SUBJECTIVE, we may comprehend in the name of SELF or INTELLIGENCE. Both conceptions are in necessary antithesis.[73]

And thus, in one paragraph, Coleridge circumscribed the epistemological divide that places our intelligence and ourselves outside the scope of nature, and objectivity and subjectivity as antithetical.

Throughout their analysis of the evolution of objectivity Daston and Galison emphasise the importance of scientific image-making. They point out that each image

> is the product of a distinct code of epistemic virtue, codes that we shall call, … truth-to-nature, mechanical objectivity, and trained judgement. … this is a historical series. There was a science of truth-to-nature before there was one of [mechanical] objectivity; trained judgement was, in turn, a reaction to [mechanical] objectivity.[74]

These were developed sequentially and in reaction to the perceived shortcomings of the previous paradigm, but each shift also incorporated rather than replaced its predecessor. All of these elements are still in interaction with each other and constitute the nuanced meanings that objectivity holds for us today.

To briefly summarise this historical evolution of objectivity, truth-to-nature was the aspiration to portray the underlying 'type' of an organism or phenomenon rather than any individual specimen or event. It strove for the characteristic and the essential – the Platonic ideal. In the case of botanical illustrations for example, no individual plant was perfectly copied, the living (or dried) plant acted as a model with each drawing modified by the artist in consultation with the scientist to depict the more 'typical' dimension, form or structure of the species.[75] This was understood as the best possible view of nature and relied on the

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[72] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010), 29.

[73] Daston and Galison, *Objectivity*, 30.

[74] Daston and Galison, *Objectivity*, 18.

[75] An example I'm very familiar with having worked as a scientific illustrator for botanical monographs and journals for over a decade.

credibility and experience of the researcher and the ability of the artist – people who 'upheld the rules of scholarship'.[76]

Mechanical objectivity was a reaction to the possibility that human judgement could be subject to error or even fantasy – the scientist, or his artist collaborator, could be deluded.[77] As Daston and Galison put it, "starting in the mid-nineteenth century, men of science began to fret openly about a new kind of obstacle to knowledge: themselves."[78] They strove to remove all subjective influences and developed techniques that left as little as possible to the discretion of either artist or scientist. As well, with the development of new and improved instruments it became obvious that human senses and subjective judgements did not have the precision or acuity required for the ongoing development of science.[79]

Mechanical objectivity strove to portray individual events and natural objects as precisely as possible, 'warts and all', with the ambition to capture nature in all its variety with as little human intervention as possible. It also strove to capture aspects of nature previously invisible to us due to their scale (using telescopes, microscopes and later cloud chambers and particle accelerators), development over time (with high speed cameras and time-lapse photography) or their literal invisibility (following the discovery that the electromagnetic spectrum extends far beyond the range of human perception, a huge range of new imaging possibilities opened up). Here photography moved into its continuing role as the opportune substitute for the fallible illustrator.[80]

Mechanical objectivity presented its own challenges. With the proliferation of data from innumerable sources and with the inevitable condition that instruments capture 'noise' (artefacts and individual oddities) as well as 'signal', the need developed to sort through all the data to find the valid observation. The mechanically objective image was "cluttered with incidental detail, compromised by artefacts, [and] useless for pedagogy".[81] Scientists realised the need for 'trained judgement'. This wasn't a return to the idealised or type image sought in truth-to-nature, the new ideal was to separate signal from noise in order to produce an 'interpreted image'.[82] The scientist was no longer the conduit for the data to come into the world (through direct observation and recording of data) but had become the curator and analyst of data that was mechanically gathered with minimal human interference. Although even the ideal of non-interference can

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[76] Pomata,"Observation Rising," 51.

[77] See the discussion in Chapter Six on the significance of pareidolia in scientific observation.

[78] Daston and Galison, *Objectivity*, 34–35.

[79] Lorraine Daston, "The Empire of Observation, 1600–1800," in Daston and Lunbeck, *Scientific Observation*, 93.

[80] The earliest surviving photograph created in a camera was made in 1829, just 10 years after Coleridge fixed the modern meaning of objectivity.

[81] Daston and Galison, *Objectivity*, 46.

[82] Daston and Galison, *Objectivity*, 46.

be questioned as we have seen with Cartwright's notion of the nomological machine in which particular results or outcomes can only be observed within tight experimental constraints specified and controlled by the experimenter/observer. The development of photography was critical in the increased instrumentalisation and removal of the fallible human observer from the interpreted image.

This trajectory has continued with the increasing dominance of instrumentalised data collection over direct observation. Within astronomy, this has been most evident through the increasing physical distance between the observer and the instrument employed. Up until the mid-twentieth century, even the largest telescopes were constructed with an observation cage attached to the focal point, where the astronomer would sit for hours on cold, lonely nights either physically looking through the telescope or attending to the attached cameras and other recording instruments – suffering physical mortification befitting their dedication and observance (see Figure 3.1).

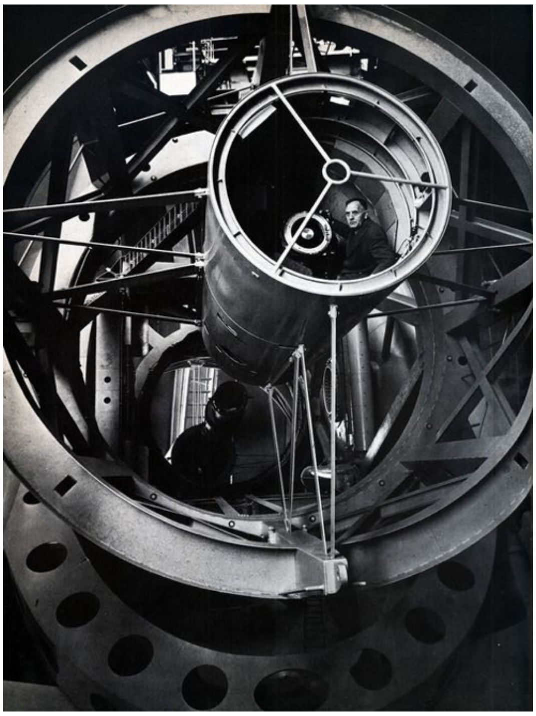

Figure 3.1
Edwin Hubble inside the prime focus cage of the Mt. Palomar 200-inch Hale Telescope (1949).

By the end of the twentieth century visual and other data were transmitted to increasingly remote sites. Today data from land and space-based instruments are sorted by computer algorithm in real-time and broadcast around the world for access by potentially hundreds of observers. The latest development in objectivity seems to strive to remove human judgement even further from analysis. Increasingly, in the twenty-first century, sophisticated mathematical models are used directly in the observation process – data are compared with computer models, often in real-time, to determine their validity and are sorted by algorithm before being brought to the notice of scientists.

3.3 Representation, Abstraction and Postmodernism

Artists became less useful to scientists as their ability to render images, visualise data and record experience was replaced by mechanically objective instrumentation and photography. As well, the changing demands of objectivity made accurate recording of particular organisms and events more desirable than a synthetic overview portrayed through artists' renderings of hypothetically typical forms.

Photography played a key role in the evolution of both science and art in the nineteenth century. With the advent of photography painting's role as a representational medium began to shift. As Daston has observed:

> Paradoxically, photography seemed to liberate art from mimesis while at the very same time apparently enslaving science – at least in the eyes of influential romantics like Charles Baudelaire, who exhorted artists to paint what they dreamed, not what they saw, but in the next breath commended photography to scientists in the interests of 'absolute material exactitude'.[83]

Representation was perfected through the photographic process, freeing art from this role and opening it up to explore our subjective experience. Similarly, the adoption of objectivity as a core epistemic virtue of science left subjective approaches open for artists to explore. This shift has been summarised by Daston:

> The subjectivity that nineteenth century scientists attempted to deny was, in other contexts, cultivated and celebrated. In notable contrast to earlier views held from the Renaissance through the Enlightenment about the close analogies between artistic and scientific work, the public personas of artist and scientists polarized during this period. Artists were exhorted to express, even flaunt, their subjectivity, at the same time that scientists were admonished to restrain theirs.[84]

Subjectivism in art blossomed through the late nineteenth century with the development of Romanticism, Impressionism and Expressionism. Artists strove to express the emotional and subjective aspects of human experience and the forms of traditional representation started to dissolve. The beginning of the twentieth century saw the Post-Impressionists and Fauvists take this trajectory through to a point were representation was left almost as a vestigial component of a work – the remnant of its connection to reality.

Early in the twentieth century abstraction came to be the key mode for artistic expression. It is beyond the scope of this exegesis to delve too deeply into the development of abstraction in art and its connections to

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[83] Lorraine Daston, "Beyond Representation," in *Representation in Scientific Practice Revisited (Inside Technology)*, eds. Catelijne Coopmans, Janet Vertesi, Michael E. Lynch and Steve Woolgar (Cambridge: MIT Press, 2014) 319.

[84] Daston and Galison, *Objectivity*, 37.

our changing understanding of the structure of reality as revealed through scientific inquiry.[85] But clearly abstraction captured the zeitgeist of a profound shift in our understanding of reality. Pablo Picasso, Georges Braque, Umberto Boccioni and other key artists who developed the movements we now refer to as Cubism and Futurism created imagery that atomised experience, and conflated space and time – much as their contemporary Albert Einstein was doing in physics. They strove to look deeper into human experience and the nature of reality beyond surface appearances. One key consequence of the evolution of abstraction (in both visual art and music) through the twentieth century that has had a lasting effect on both art and science has been the increased willingness and ability for viewers to comprehend abstracted visual and acoustic information.

By mid-century the certainties of Modernism too had begun to dissolve. Postmodernist thinking and philosophy blossomed in the uncertain social context of the West following two cataclysmic world wars and the detonation of the A-bomb – the shockingly visceral embodiment of the seemingly abstract scientific theories of the fundamental structure of matter. I won't expound on the development of Postmodernism here, but its key tenets are important to my argument. Sîan Ede tells us that postmodernism

> questions the notion that there is a fixed and universal truth for all humankind, everywhere and at all times. In its regard for art, it denies the existence of a dispassionate reality beyond the artist's individual representation. With this in mind it examines the social, political, geographic, economic and historical context of the act of creation and also that of the reader or viewer who brings continually changing meanings to the unfixed work. The artist may work intuitively but the work itself, in theorist Roland Barthes's words, is 'always, already, written' because of its precise genesis in person, time and place.[86]

In this way, Postmodern thinking can be seen as providing a close parallel to the relativism of quantum theory. The artist and the viewer are mutually imbedded in the act of creation and interpretation and this cannot be divorced from the cultural and physical context in which the work of art is manifested. In fact, it makes no sense at all to consider the work of art as in any way separate from this context. Furthermore, this cultural context is not one monolithic construct but a 'dappled world' of disjunct sub-cultures and individual human experiences in constant flux.

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[85] This has been explored thoroughly by other authors. For example, Leonard Shlain, *Art & Physics*.

[86] Ede, *Strange and Charmed,* 36.

James Gleick reminds us, in his biography of the great physicist Richard Feynman, that

> scientists still speak unashamedly of reality, even in the quantum era, of objective truth, of a world independent of human construction, and they sometimes seem the last members of the intellectual universe to do so.[87]

Correspondingly, Sîan Ede also claims that many scientists share the idea that the function of art is to "show us the intrinsic beauty of the world". Scientists are often surprised to learn that beauty is a word used rarely by contemporary artists. As Ede says, artists are "rooted in the directionless world of the here and now" and "see mostly fracture, fragmentation and disarray." In contrast to the implicit order of reality that scientists still believe in and strive to prove, artists see implicit disorder. According to Ede, "Postmodernist discourse, for all its contortions, tries to articulate this in theory: artists make it in practice."[88]

We now find ourselves in the position where both art and science are dealing directly with a reality that is in fundamental flux and is contingent on the way it is experienced. This commonality provides a renewed bridge between the methodological approaches and conceptual underpinnings of art and science. The changing definition of objectivity as we have discussed, provides a key here. In the next chapter I will discuss how the notion of objectivity can be used to analyse contemporary art practice and so provide a basis for a conceptual methodology linking science to art.

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[87] James Gleick, *Genius: The Life and Science of Richard Feynman* (Open Road Media, Kindle Edition, 2011).

[88] Ede, *Strange and Charmed,* 47.

Chapter Four The Field of Art

In the preceding chapter, I explored how the notion of objectivity developed in science and in this chapter I consider how objectivity has played an important role in the visual arts. I discuss how artists have developed instruments as a means to restrict agency and develop a form of objectivity in art practice. The artistic instrument is a key focus of my research. I see it as a perfect intermediary between the fields of science and art. I contend that by thinking about certain objects, modes of presentation, and conceptual approaches in the visual arts as instruments we can develop new perspectives on artistic practice.

Contemporary visual art is a complex, multi-layered, discontinuous field. Locating my own research within its broad scope could be done by identifying with existing defined genres (Land Art, ArtSci, etc.) but this could become an exercise in typology rather than a fruitful analytic strategy. I propose an alternative approach based on the recognition of various artistic strategies as 'instruments'. I develop a broad definition of artistic instruments and consider they ways in which they operate. Focusing more closely, I then consider several contemporary works of art in terms of two primary modes in which instruments operate, namely 'transcription' and 'transduction'. These two terms, borrowed from scientific contexts, have proved effective in developing an understanding of my own practical research. This approach leads to the conclusion that one way to circumscribe a common ground between science and art is to identify the space where this borrowing and redeployment of terminology is both possible and effective.

4.1 Objectivity in Art

The blossoming of subjectivism in the visual arts through the late nineteenth and early twentieth centuries arguably reached its peak with Abstract Expressionism – where the subjective experience of the artist was embodied in the abstracted marks on the painting. As the contemporary critic Harold Rosenberg wrote, "a painting that is an act, is inseparable from the biography of the artist. The painting itself is a 'moment' in the adulterated mixture of his life."[89] Ede describes this mode as "a non-representational, abstract and subliminal way of seeing and making work."[90] I will call this mode 'subjective', as it is centred on the subjective experience of the individual artist and its expression.

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[89] Rosalind Krauss, *Passages in Modern Sculpture* (Cambridge: MIT Press, 1977), 256.
[90] Ede, *Strange and Charmed*, 21.

There is another lineage in the visual arts that followed a parallel path to science in its increasing search for a type of objectivity. Works that strove for a detachment from human interference and were created in a context of ongoing criticism and re-evaluation – where the artistic critique can be seen as a corollary of the scientific method. I propose that a critical tool in this increased objectivity was the instrument. Just as the development and increasing sophistication of instruments facilitated the development of mechanical objectivity in nineteenth century science, instruments were developed by twentieth century artists to curtail rampant subjectivity in art practice.

What do I mean by 'instruments' in this context? These instruments were construed under many guises, both physical and conceptual. Some were literally machines, intended as human simulacra and as representations or stand-ins for the actions of the artists. Critical pioneering works in this regard were Laszlo Maholy-Nagy's *Light Prop for a Ballet* (1923–30) also called the *Light-Space Modulator*, and later Jean Tinguely's fabulously absurd, self-destructive contraption *Homage to New York (self-constructing, self-destroying)* (1960). These engineered contraptions were the forebears of the closer collaborations between artists and engineers that blossomed in the 1960s which I will discuss later in this chapter.

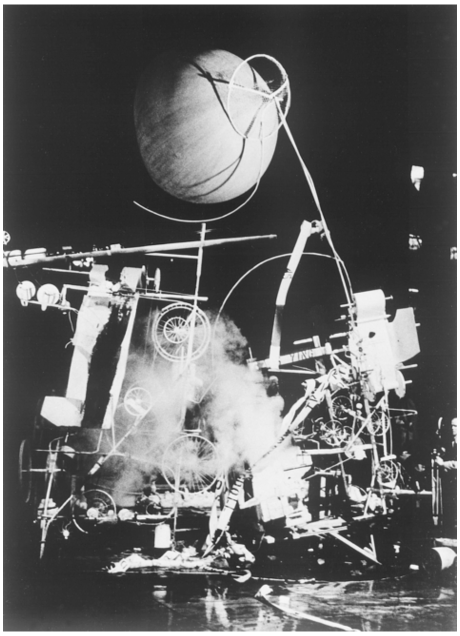

Figure 4.1
Homage to New York (self-constructing, self-destroying).
Jean Tinguely.
1960.

There were other, more conceptual forms of instrument developed by artists in the twentieth century. I propose that the first 'readymades' by Marcel Duchamp can be considered as instruments to help us develop a clearer definition of that term.

Figure 4.2
Bottle Rack (Porte-Bouteilles),
Marcel Duchamp.
1958–1959.[91]

Famously Duchamp's readymades (or in the original French *objet trouvé* whose meaning implies that the object was waiting to be found or discovered) transitioned from the world of the ordinary object into that of the art object through inscription and re-contextualisation by the artist. The critic Rosalind Krauss has pointed out that this was part of Duchamp's "project to make certain kinds of strategic moves – moves that would raise questions about what exactly is the nature of work in the term 'work of art'."[92] Krauss discusses how analysis of Duchamp's work has mostly taken a Freudian approach in an attempt to see these works as subjective expressions of the artist's inner self. But Krauss asserts that to take this approach denies the very meaning of the work and of Duchamp's intention which was to "negate a traditional sense of narrative" and to replace it with the a more objective meaning – "and that meaning is simply the curiosity of production – the puzzle of how and why this should happen."[93]

The object is no longer a metaphor, or a cipher of the artist's subjective experience but a sample of the objective world presented in a new context which forces us to question its meanings. In this way, the *objet trouvé* can be seen as a strategy (or instrument) that enables a different view of the work of an artist, the art world itself and in a wider context the ways in which we construct human culture.

Questioning the role of the artist in the creation of both the form and the meaning of a work became a central focus of Minimalism in the 1960s and 70s. Krauss has pointed out that Minimalists such as Donald Judd and Robert Morris were reacting against the illusion of sculpture which traditionally treated one material as the signifier of another – stone as flesh, for example. They "refused to … shape an object so that its external image would suggest an underlying principle of cohesion or order or tension", instead

[91] This version, in the collection of the Art Institute of Chicago, was selected by Duchamp for the 1959 exhibition *Art and the Found Object* in New York.

[92] Krauss, *Passages*, 73.

[93] Krauss, *Passages*, 77.

generating an "extraordinary dependence on the facts of an objects exterior, in order to determine what it is." [94] The contemporary critic Hal Foster has affirmed this objective interpretation:

> The minimalist suppression of anthropomorphic images and gestures is more than a reaction against the abstract-expressionist model of art; it is a "death of the author" (as Roland Barthes would call it in 1968) that is at the same time a birth of the viewer.[95]

This was a definitively objective approach and resulted in a radical approach to authorship. The minimalists employed, what Krauss has characterised as, "a host of compositional strategies (that) resist being interpreted as something that wells up from within the personality of the sculptor." [96] The approach of setting up external systems to remove both the agency of the artist and the illusory, referential and metaphorical qualities of the work of art was carried through into Conceptual Art. Sol LeWitt's approach was fundamental. In his *Paragraphs on Conceptual Art* he states that

> in conceptual art the idea or concept is the most important aspect of the work. When an artist uses a conceptual form of art, it means that all of the planning and decisions are made beforehand and the execution is a perfunctory affair. The idea becomes *a machine that makes the art*.[97]

And more specifically:

> To work with a plan that is preset is one way of avoiding subjectivity. It also obviates the necessity of designing each work in turn. The plan would design the work. Some plans would require millions of variations, and some a limited number, but both are finite. Other plans imply infinity. In each case, however, the artist would select the basic form and rules that would govern the solution of the problem. After that the fewer decisions made in the course of completing the work, the better. This eliminates the arbitrary, the capricious, and the subjective as much as possible. This is the reason for using this method.[98]

As established in Chapter Three, the "arbitrary, the capricious, and the subjective" were exactly the conditions that mechanical objectivity strove to eradicate from scientific observation and analysis in the nineteenth century.

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[94] Krauss, *Passages*, 266.

[95] Hal Foster, *The Return of the Real: The Avant-Garde at the End of the Twentieth Century* (Cambridge, Mass.: MIT Press, 1995), 50.

[96] Krauss, *Passages*, 270.

[97] Sol LeWitt, "Paragraphs on Conceptual Art", *Artforum*, 5/10, Summer 1967. My italics. http://www.tufts.edu/programs/mma/fah188/sol_lewitt/paragraphs%20on%20conceptual%20art.htm. Accessed November 14, 2014.

[98] LeWitt, "Paragraphs".

The conceptual artwork is created within a series of constraints whereby the artist abnegates control of the outcome or in which control is beyond the artist's capability. Another example of this approach is John Cage's composition *4'33"* from 1952. This seminal work used a very clearly defined framing device or constraint.[99] A performance space was established and then what happened within that space over a precise time period was largely out of control of the composer, performer or observer(s). This reduction of agency was core to many of Cage's works based on chance.[100] The constraints set up by Cage can be considered as the instrument in this performance – not the unplayed piano. The piano that the performer sits at is merely a framing device – the opening and closing of its keyboard cover is the constraint placed on the period of listening and the presence of the piano in a concert hall sets up the condition for careful listening by the audience. This strategy of defining constraints to remove artistic agency and eradicate the "arbitrary, the capricious, and the subjective" is at the core of diverse artistic approaches to this day – sometimes implicit, sometimes explicit.

A contemporary example of this approach is provided by Matthew Barney's ongoing series of performative works entitled *Drawing Restraint* (1987–present). Barney's *Drawing Restraints* are undertaken within the constraints of various apparatus (instruments) that shape and determine the possibilities of his action. In Barney's terminology, the apparatus provides 'resistance' against the 'hypertrophic athlete'. Barney sees this resistance and his body's response to it as critical in his form-building process.[101] In this series of works Barney has some control over the output but is severely limited by his conceptual and physical restraints. Barney underlies the visceral quality of these works by proposing that they travers a path with three distinct phases: Situation, Condition and Production.[102]

Figure 4.3
Drawing Restraint 1.
Matthew Barney.
1987.

[99] A strategy similar to the use of a quadrat in the biological sciences as we will see in the next chapter.

[100] John Cage, *Silence: Lectures and Writings by John Cage* (Middletown: Wesleyan University Press, 1961).

[101] Matthew Barney on the origins of "Drawing Restraint". http://www.youtube.com/watch?v=83WTxmkye04. Accessed November 28, 2014.

[102] Matthew Barney. http://www.drawingrestraint.net. Accessed November 18, 2014.

Perhaps Barney's own personal athletic physicality in these performative works implies a return to subjectivity – providing a visceral dimension to each work and provoking a sympathetic response in the viewer. However, I understand his three phases as analogous to the objective scientific process of encountering raw data, the filtering of that data through an instrument, and then creating observations or output. Barney's body has become part of the instrument – comparable to an observer suffering long cold nights in the focal cage atop a telescope.

The key concept linking these examples is constraint – the instrument establishes a field of action within which the artist (or his agent) can act and establishes constraints which reduce subjectivity by removing the artist's direct agency.

In the context of artistic practice then, an instrument can be defined as a mechanism or strategy that through establishing objective constraints removes the artist from direct agency. Artistic instruments can be physical objects, processes or conceptual frameworks. They have the dual function of removing subjectivity (and metaphor) from the work and of focusing a viewer's attention onto a particular site, sensory experience or perspective.

4.2 Transdisciplinary Approaches

Following this conceptual thread of increased objectivity in contemporary art and the use of both physical and conceptual instruments as a means of constraint to reduce subjectivity has provided me a clear path to navigate amongst a diverse range of contemporary art practices to find exemplars that shed light on my own research approach and has enabled a transdisciplinary approach in my own art making that crosses well-established art genres.

There are a several other genres of contemporary art that provide contexts for my work. As my research is conducted in both the studio and in the field it has been valuable to look to the history and practices of Land Art for possible precedents and contemporary analogs. In hindsight, it is hard not to be critical of the founding American artists of this genre and their heroic, muscular and egotistical imposition of their will on the 'canvas' of the American landscape. Their gestures can be seen as an extension of the subjectivism epitomised by Abstract Expressionism. However, Land Art has established precedents relevant to my research.[103] The gesture of taking art out of the gallery or museum was critical and opened up the field of contemporary art to direct engagement with the physical landscape of our planet. It marked the moment when being an artist in the field once again became legitimate practice.

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[103] I will discuss these specifically later in this chapter.

On the basis of an established history of artists working in the polar regions one could propose a valid genre of Polar or even Antarctic Art.[104] Though only a few hundred artists have worked in Antarctica, their approaches and conceptual interests are widely diverse. My intention is not to propose using the continent itself as a definition of a genre, but more in identifying those characteristics unique to working in Antarctica that place constraints on the nature of the work created there. I will discuss these in the next chapter when I detail the merits of Antarctica as an appropriate field location for my own research.

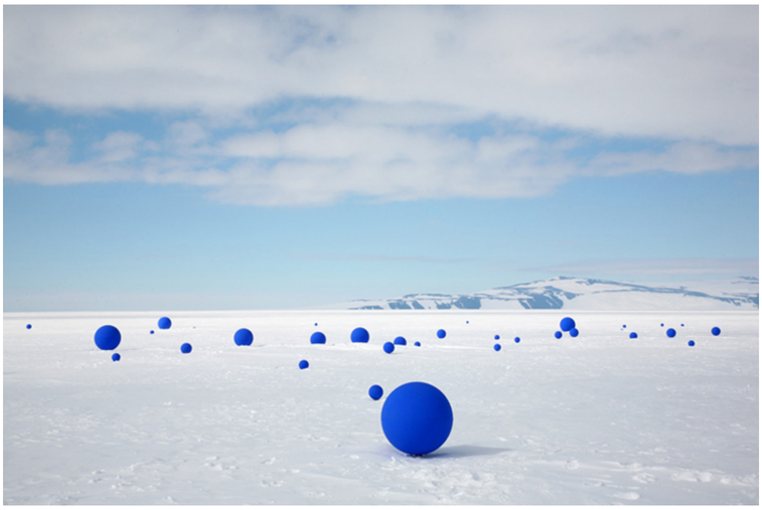

Figure 4.4
Stellar Axis: Antarctica.
Lita Albuquerque.
2006.

The contemporary data driven approach to science that typifies Pyne's Third Great Age of Exploration is echoed in Fox's Third Age for artistic encounters at the Pole where artists are increasingly using data (often remotely sourced) as a basis for their work, but also analysing (and critiquing) scientific approaches to the construction of reality. Fox cites Lita Albuquerque as one of the pioneer artists of this Third Age of Antarctic art. She is also widely recognised as a pioneering artist in the American Land Arts genre. In 2006, Albuquerque created the first large scale ephemeral installation on the continent – consisting of 99 fabricated fiberglass spheres (coloured in her signature cobalt blue) anchored into the McMurdo Ice Shelf on the edge of the continent. The spheres were arrayed and sized corresponding to the arrangement of the 99 brightest stars in the southern sky as they would be seen without the perpetual sunshine of the Antarctic summer.[105]

[104] There are many reviews of contemporary art practice in Antarctica – see Footnotes 41 and 42. As part of the preparation for my own field work, I have spoken extensively with many artists who have worked in Antarctica – see Acknowledgements.
[105] Ann M. Wolfe, Lita Albuquerque and William L. Fox, *Lita Albuquerque: Stellar Axis* (New York: Rizzoli, 2014).

Albuquerque essentially 'transcribed'[106] the celestial sphere onto the terrestrial one. By directly transcribing the heavens onto the blank canvas of the ice shelf Albuquerque drew attention to the physical location of the poles[107] on the axis of rotation of the earth and emphasised Antarctica's direct connection to outer space – both the otherworldly and hostile environment of Antarctica and the predominance of astrophysical science conducted there. *Stellar Axis* acts as a model or an instrument to help us comprehend our location in the cosmos. Astrophysicists work in Antarctica because it's as close as you can get to being in space without launching out of our gravity well, similarly for Albuquerque this was as close as a land artist could get to working on alien soil.

The contemporary art genre that most closely engages with my own research interests and which focusses on the engagement of artists with science, technology and engineering has been termed ArtSci. This genre emerged in the mid-1960s and has continued to develop and expand.[108] Currently there is a plethora of different approaches, projects and educational programs dedicated to exploring the connections between science, technology and art. Aspects of this research have been detailed in a number of recent survey publications.[109] Arthur I. Miller's comprehensive guide, *Colliding Worlds: How cutting edge science is redefining contemporary art*, describes this rapidly evolving field or genre as a "new field of avant-garde art" and argues that it will not readily find a place in museums and galleries in keeping with its position as an avant-garde.[110] This seems to be a political tautology to posit its current exclusion from the mainstream of the art world as a credential for its avant-gardism and hence to secure its place as a valid contemporary art practice. But there are distinctive aspects to ArtSci that would argue for it to be considered a genuine hybrid between the practices of science and art rather than just a new development in the ongoing evolution of contemporary art.

Art is primarily (perhaps mythically) seen as a private and solitary activity, whereas science is inherently collaborative as it builds on actions and conclusions of other researches and usually involves teams of

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[106] This is the first time I've used this term in this exegesis. I will clarify its use later in this chapter.

[107] Albuquerque intended to reproduce this act at the North Pole.

[108] One of the founding events of this genre was the art and technology collaboration *9 Evenings: Theater and Engineering*, held at the Armory on Lexington Avenue, New York, in October 1966. It was the first large scale collaboration between artists, engineers and scientists. Ten artists and thirty engineers participated. This collaboration involved key people in both fields (including the artists John Cage, Robert Rauschenberg and Robert Whitman and the engineer Billy Klüver, from Bell Laboratories) and set a precedent both for artists embracing cutting edge technology and collaboration between artists and scientists and engineers. Evidence of this ongoing collaborative effort is provided by the MIT-published journal *Leonardo*. Founded in 1968 in Paris by the kinetic artist Frank Malina. http://www.leonardo.info/leoinfo.html. Accessed November 28, 2014.

[109] See Ede, *Strange and Charmed*; Miller, *Colliding Worlds;* and JoAnne Northrup, ed., *Late Harvest* (Munich: Hirmer and Nevada Museum of Art, 2014).

[110] Miller, *Colliding Worlds*.

engineers and researchers working on long-term projects (sometimes across generations).[111] ArtSci is also characterised by teamwork (amongst groups of artists and through collaborations between artists, scientists and engineers) and this characteristic distinguishes it from much of contemporary art practice.

The embrace of contemporary scientific technology and processes is another distinguishing feature of ArtSci. Artists working in close connection with scientific technology have developed fluency with both the technology and the language that accompanies its use. One key consequence of this has been the bleeding of science and technology jargon into the language of contemporary art practice. Terms such as 'glitch', 'network' and 'cybernetics' have their origins in technology but now also have valid meanings (and even genres) within the contemporary art world.

4.3 Transcription and Transduction

4.3.1 Transcription
4.3.2 Instrumental Transcription
4.3.3 Transduction

Following this precedent in my own research, I have found it invaluable to examine and appropriate certain scientific terminologies. The use of unexpected and fresh terminology can provoke unexpected and fresh perspectives and provide an alternative to the established jargon of contemporary art criticism and discourse. My strategy has been to borrow terminologies from science disciplines and, while maintaining their original meanings, apply them to situations and processes in the visual arts. In the preceding chapters I have analysed the concepts of 'fieldwork', 'objectivity' and 'subjectivity' in both science and the arts. Now I will dissect the notions of objectivity and instrument in more detail through the concepts of 'transcription' and 'transduction' – two processes which can be used to interrogate the operations of both scientific and, I will argue, artistic instruments.

For my purposes I propose the definition of transcription as the process and result of copying, transposing or translating from one format or condition to another, typically within the same medium – that is, a physical state analogous to the original. An example would be copying a text from papyrus, to parchment, to paper or even into a Word document – each medium is physically very different from its predecessor but we use each in the same way and the information in each case is graphically arrayed on a flat surface to be viewed and read. Transposing musical compositions up or down the scale, is another example – both the transcription onto paper and the resulting music are rendered in the same medium as the original. Translation of languages (either spoken or written) is another example. This last case highlights the fact

[111] Northrup, *Late Harvest.*

that the transcription may not be a perfect copy of the original – something will be gained or lost in translation. This also reveals the potentially subjective aspect of transcription as it always requires human intervention and decision making, even if this can be automated. Transcription errors are an important source of noise – another term that will be discussed in more detail in future chapters.

Photography or representational painting could also be considered as transcription. Even though silver particles embedded in an emulsion or a layer of pigments on a stretched canvas are very different from a physical landscape, both the subject of the photograph and the resulting image are surfaces that absorb, refract and reflect visible light.

Transduction on the other hand involves a more fundamental transformation in kind. The Australian theorist and critic Douglas Kahn has defined transduction as "the movement from one energy state to another, either within or between larger classes of energy (mechanics or electromagnetism)."[112] I will define transduction as the transformation of data, information or energy from one state to another through a process requiring an instrument or apparatus. We can't transduce directly through human action, we need to create and employ a transduction device. One classic example of transduction is radio, where sound (compression waves in air) is transduced into electrical currents in metal wires that generate electromagnetic fields which can travel through air (or a vacuum) and induce a current in another circuit which can then, through its effect on a magnetic element in a speaker, generate vibrations in air which can be received as sound into our ears (which we then experience through another complex process of transduction into neuronal activity). Sound is transduced into (and from) electromagnetic waves through the action of an instrument – the radio transmitter or receiver. Transduction has permitted us to explore aspects of reality which otherwise would be hidden from us. Transduction by its nature is inherently objective as the transformation is mediated by non-human instruments. However, it is still subject to noise, as all information that is received in the process of transduction is transformed into the new mode – some of this information is what we are looking for (signal) and some of it is unwanted or superfluous (noise). The noise associated with instruments is often referred to as an 'artefact' – a term that I will unpack further in Chapter Six. Although these concepts have not been used widely to analyse contemporary art practice, I have found they provide useful tools for finding connections between artist working across a wide variety of genres and for understanding deeper connections between science and art.

[112] Douglas Kahn, *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts* (Berkeley: University of California Press, 2013), 7.

4.3.1 Transcription

Earlier in this chapter the work *Stellar Axis,* created by Lita Albuquerque on the McMurdo Ice Shelf in 2006, was understood to be a graphic transcription of the then hidden stars of the southern sky onto the Antarctic ice sheet. Albuquerque worked closely with British astronomer Simon Balm to ensure the work was as accurate a representation as possible.[113] The brightness of the stars was represented by the volume of the blue spheres, a tradition derived from the coded transcriptions of historical star atlases – an abstracted coding of data.

Albuquerque followed a long tradition of transcribing the heavens in artworks, from ancient times up until the contemporary Land Art movement. As so much of the early Land Art was carried out in deserts and other locations far from cities, the vibrancy of the night sky must have been both shocking and inspiring for artists escaping from the night-time glare of cities like New York, Los Angeles and London. Furthermore, surviving ancient monumental works that were aligned to significant astronomical events set both a precedent and a challenge for the land artists. Land artists have endeavoured to construct monumental instruments to facilitate our awareness of our position in space – instruments which model the geometry of our orbit and location in space. Nancy Holt's *Sun Tunnels* (1973–76) is a prominent early example – large diameter concrete tubes aligned along solar transits (like Stonehenge) and inscribed with prominent northern constellations, which she described as "bringing the sky down to the earth."[114]

Charles Ross's *Star Axis*, (began in 1976 and due for completion in 2020) aligns with the north celestial pole and acts as an instrument to witness the 26,000 year precession of the earth's axis.[115] As Ross says, "I am interested in how we personally interface with the larger order; and I think it is possible to have direct experience of how we are fitted to the stars."[116] James Turrell's even more ambitious and much anticipated *Roden Crater Project* (Figure 4.6), also nearing completion, recalls the traditions of the great naked eye observatories such as Tycho Brahe's now lost sixteenth century *Uraniborg*, and Jai Singh's series of monumental stone instruments, the *Jantar Mantars*, built across five sites in Northern India in the eighteenth century (Figure 4.5).[117] All of these works can be considered as both instruments of observation and direct physical transcriptions of celestial geometry.

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[113] Wolfe, *Stellar Axis*, 174.

[114] This phrase resonates with the practice of 'drawing down the sun' in geodesy discussed in Chapter Six. Saad-Cook, Janet, Charles Ross, Nancy Holt, James Turrell, "Touching the Sky: Artworks Using Natural Phenomena, Earth, Sky and Connections to Astronomy" *Leonardo* 21, no. 2 (1988).

[115] http://charlesrossstudio.com/collection/star-axis/. Accessed September 15, 2017.

[116] Saad-Cook, Ross, Holt and Turrell, "Touching the Sky."

[117] http://rodencrater.com. Accessed September 15,2017.

Figure 4.5
The Observatory at Delhi.
Thomas Daniell.
1808.

Figure 4.6
Site Plan with Elevation (Roden Crater).
James Turrell.
1988.

Other contemporary artists have worked on a more intimate scale while directly transcribing particular aspects of their cosmological subject matter. The contemporary glass artist Josiah McElheny created *An End to Modernity* (2005) in collaboration with the physicist David Weinberg. Using precise data sets as its starting point, the work depicted the then current understanding of one possible form for the Big Bang. The work's materials and structure also reference an archetypical mid-century piece of design, the huge candelabras in the Metropolitan Opera lobby in New York that were "created in 1965, the year that the discovery of the cosmic microwave background provided the linchpin evidence for the Big Bang theory".[118]

[118] Lynne Cooke and Josiah McElheny, eds. *Josiah McElheny: A Space for an Island Universe* (Madrid: Museo Nacional Centro de Arte Reina Sofia, 2009).

This conflation of mid-century modernist design tropes onto the mid-century scientific discovery of the Big Bang (with a liberal dose of Sputnik/Cold War aesthetic) draws the work into a broader cultural context.

Figure 4.7
An End to Modernity.
Josiah McElheny.
2005.

Transcriptions can be less obviously representational. Katie Paterson, the Berlin-based Scottish artist, has created many works engaging with cosmological perspectives. Erica Burton, curator at Modern Art Oxford, wrote at the time of her solo exhibition in 2008, "she creates an expanded sense of reality beyond the purely visible."[119] Her work *History of Darkness* (2010–) transcribes not the stars but the voids between them into a huge archive of photographic slides. Each slide is pitch black, seemingly identical to its neighbour, but each is a direct transcription of a distinct (but seemingly empty) portion of space.[120] Here Paterson is transcribing the emptiness of space.

Figure 4.8
History of Darkness.
Katie Patterson.
(2010–).

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[119] http://www.jamescohan.com/artists/katie-paterson. Accessed September 29, 2017.
[120] Jon Bewley and Jonty Tarbuck, eds. *Katie Paterson* (Newcastle: Locus+, 2016). 236.

Stepping away from visual modes, John Cage's first orchestral work entailed an inspiring act of transcription. To create *Atlas Eclipticalis* (1961) Cage transcribed visual data from Antonín Becvǎr's 1950 star atlas into musical notation by laying a piece of translucent paper with inscribed musical staves onto a page of the atlas. The magnitude of each star (encoded as dot size on the atlas) determined the volume and duration of the note and its location on the stave set the pitch. The resulting score can be considered a transcription from the original visual data into musical notation.[121]

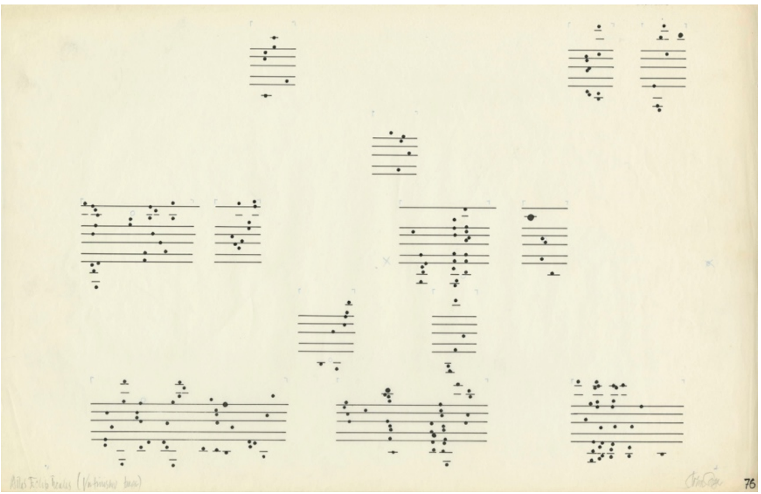

Figure 4.9
Score for *Atlas Eclipticalis*.
John Cage.
1961.

4.3.2 Instrumental Transcription

These previous example of transcription are analogous to copying a text from one surface or medium to another – where the artist has subjectively mapped one set of texts or data onto another medium by interpreting data and making aesthetic choices about which data are selected and how that data is represented. Transcriptions can also be facilitated directly with instruments so as to remove the artist as interpreter, through a process of 'instrumental transcription'.

The Australian sculptor Cameron Robbins has devised drawing instruments that are driven by natural forces such as wind, tides, ocean swells and changing sunshine.[122] He relies on the inherent fragility of his instruments to introduce subtle glitches in the mark-making that resemble the variability of human gesture (Figure 4.10).

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[121] http://www.rouvelle.com/mySite_Syllabi/sound_art_wk_3.htm. Accessed December 18, 2018.

[122] Cameron Robbins, *Field Lines* (Hobart: Museum of Old and New Art, 2016).

Figure 4.10 *Wind Section Instrumental, 14–24 March 2014 (Tightly Furled Light to Fresh)*.
Cameron Robbins. 2014. Detail.

The California-based sculptor Lawrence LaBianca has also created a variety of environmentally activated drawing instruments. *Drawing Machine* (2011) catches the movement of air with helium balloons tethered to weighted pens that record the movements on sheets of paper. His *Sea Float Project* (2015–17) entails a specifically designed and fabricated buoy deployed at sea from a modified rowboat. *Sea Float Project* transcribes the movement of the surface of the water directly onto copper printing plates which are retrieved and used to create prints that are abstract transcriptions of the weather conditions of that day (Figure 4.11).

Figure 4.11 *Sea Float Project***.** Lawrence LaBianca**.** 2015–17.

One particular form of instrumental transcription which has a lineage in contemporary art is solar burning – where a lens is used to concentrate the sun's rays to create a burn mark in a medium. Early proponents of this approach include the British artist Robert Ackling (1947–2014) who used a magnifying glass to burn abstract patterns into driftwood panels. He controlled the movement of the lens by hand but the intensity of the mark made and the pace of his work were determined by the vagaries of the British sunshine.

Richard Long recalled that Ackling "made these works like a meditation, with a zen-like calm and concentration."[123] Ackling used the lens as a tool but it was still at the control of the artist and so his process was still largely subjective. Others have used the lens in a more instrumental fashion. The American Land Artist Charles Ross's work *Solar Burn (1971–2)* recorded the passage of the sun every day for a year. Ross set up a Fresnel lens over a new piece of wood each day. At the end of the year, all the wooden elements pieced together generated a double reversed spiral form – transcribing not only the changing local weather patterns but also the varying orbit of the earth.[124] The character of the line was an artefact of the instrument created by Ross and the geometry of the sun's passage in the sky, not an arbitrary, representational line drawn in space by the artist.

Californian photographer Chris McCaw, has constructed unique cameras that hold paper photo-stock and allow very long exposures. In McCaw's images a wider range of the electromagnetic spectrum is employed than in regular photography, extending into the infra-red where the heat of the sun is focused. The resulting images record the passage of the sun directly both as image and as mark as the sun burns through the photographic paper – image and transcription in one. This work highlights the particular case of the camera as an instrument and the photographic image as a form of transcription.

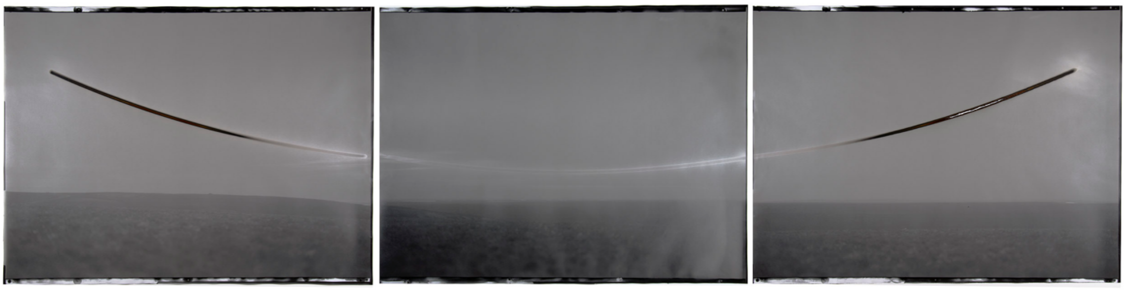

Figure 4.12 *Sunburned GSP#486 (Sunset/sunrise, North Slope, Alaska).* Chris McCaw. 2011.

William Lamson took the instrumentisation of the solar burn to the next level in his work *A Line Describing the Sun* (2010). Lamson constructed a wheeled instrument with a large Fresnel lens which focusses the sun's rays onto a tiny patch of desert sand which is then fused by the sun's heat into a line of rough glass-like silicates. The final exhibited outcome consisted of a two-channel video documenting his multi-day performance, the instrument itself, and a portion of the 111 metre long line of fused sand which was carefully removed from the Mojave desert and redeployed in its original geometry – a long curve which was the direct

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123 From Richard Long's obituary of Ackling in the Independent, Wednesday June 18, 2014. http://www.independent.co.uk/news/obituaries/roger-ackling-artist-who-concentrated-the-suns-rays-on-driftwood-with-a-magnifying-glass-to-make-9547227.html. Accessed September 19, 2017.

124 Saad-Cook, Ross, Holt and Turrell, "Touching the Sky."

result of the geometry of the sun's movement.[125] The critic Katie Kitamura has pointed out how the work refers to "the weighty anthropological and art-historical lineage of mark-making" and proposes that "the purpose of Lamson's apparatus is to transform the immaterial into the material, through the process of alchemy."[126] I understand this work less as alchemy and more as an instrumental process transcribing the sun's movement and directly manifesting the role of the sun as the foundation of the earth's geochemical processes.

Figure 4.13
A Line Describing the Sun.
William Lamson.
2010.

Lamson's *A Line Describing the Sun* and LaBianca's *Sea Float Project* have been inspiring for my research. The instruments that these artists created have their own sculptural integrity and were employed at specific locations for specific durations to transcribe environmental and astronomical data into physical residues which were exhibited together with documentation of the artist's performance or act of observing/recording. This revelation of the process of creation along with the transcriptions of environmental data seem directly analogous to scientific methodology and allows for a more direct comparison between the two.

The preceding examples show that transcription can be directly mediated and influenced by the artist and so be a subjective representation or mapping of one set of images or data onto another. Or it can be rendered more objectively or removed from the direct agency of the artist altogether through the use of instruments. These instruments can be glitchy and so produce marks that resemble or mimic the marks made by artists, or they can generate marks and patterns that we might not have anticipated in advance due to changing environmental conditions and the larger geometries of the cosmos. As the scale of instruments increases the physical trace of transcription is augmented by the presence of the instruments themselves as freestanding artworks.

[125] Silke Optiz, ed., *William Lamson: On Earth*. (Bielerfeld: Kerber Verlag, 2011).

[126] Katie Kitamura, "William Lamson," *Frieze*, Issue 139 (May 2011). https://frieze.com/article/william-lamson. Accessed June 21, 2015.

4.3.3 Transduction

There is one further step along this spectrum from subjective representation to instrumental objectivity. This happens when an instrument is used to reveal and make concrete energies or events that are beyond human perception. This can be a matter of scale (much as a microscope or telescope reveals the otherwise invisible) or through converting one set of imperceptible signals into a mode that we can perceive (such as converting radio waves to sound). This change of mode or form is called transduction.

A large component of contemporary art that aligns itself with scientific practice (ArtSci) engages with transduction. This is to be expected as a large part of contemporary science (especially particle physics and astrophysics) depends on transduction to make phenomena discernible. As scientists employ transduction to reveal hidden patterns in nature, artists with similar interests employ the same methodologies and technologies, but also utilise other modes of transduction to engage other forms of perception and so prevent their work from becoming simply scientific illustration.

One perceptual mode that many artists have explored extensively in this regard is sound. Artists have captured the real-time experience of working with scientific instruments or have used ‘sonification’ (the transduction of digital numeric data to sound) and ‘audification’ (rendering vibrations and ultra- or sub-sonic sounds audible to the human ear) to reinterpret scientific data sets. Scientists generally use sonification and audification for two rather different purposes – the first is used to gain a different perspective on data sets and the second is used primarily to monitor vibration in equipment.[127]

In 2011, British artist Jo Thomas spent six months at the Diamond Light Source, the UK’s national synchrotron facility. One outcome was the thirty eight minute sound piece *Crystal Sounds of a Synchrotron Storage Ring* (2011).[128] Thomas says it was “composed directly from frequencies generated by the electron storage ring, [together with] binaural recording from locations inside Diamond’s experimental hall, storage ring and beamlines.” Interestingly she was fascinated by some sounds produced by audification of the beamline monitoring data that the host scientists considered “rubbish – just problems in the beam line, malfunctions in the machinery.”[129]

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[127] It seems that we have a natural predilection to listen for rattles and bangs when monitoring machinery and this engineers ear has been exploited in monitoring both mechanical and electronic equipment.

[128] Jo Thomas, *Crystal Sounds of a Synchrotron Storage Ring*, 2011. https://soundcloud.com/jo-thomas/crystal-jo-thomas-2011. Accessed February 18, 2018.

[129] Jo Thomas quoted in Miller, *Colliding Worlds,* 249.

Artists have used accelerometers as microphones, the same accelerometers that are used by scientists and engineers to monitor microscopic vibrations in their equipment. The San Francsico-based sound artist Bill Fontana pioneered the use of accelerometers in sound work and was an artist in residence at the Large Hadron Collider at CERN, near Geneva, in 2012–3.[130] Fontana studied with Cage in New York in the 1960s and has followed his approach that music is what we 'attend to' in the sea of noise around us. Fontana's and Thomas' methodologies and their focus on scientifically uninteresting but artistically engaging noise are closely attuned to my own research approach.

The British artist Caroline Devine uses sound to

> explore voices, signals and sounds that are ordinarily imperceptible or in some way absent, such as VLF natural radio transmissions, solar and stellar resonances, the orbital periods of exoplanets, electromagnetic signals and hidden voices.[131]

In her work *5 Minute Oscillations of the Sun* (2012) Devine collaborated with Prof. Bill Chaplin of the BiSON helioseismological research team at the University of Birmingham.[132] In seismological studies of the sun, scientists convert Doppler shifts in light received from the oscillating surface of the sun into frequency spectrograms analogous to earthbound seismological data.[133] Devine sonified and transposed these data to create sound so that we can hear the sun "ringing like a bell". To complete the final composition, she mixed these "natural solar resonances [with] naturally occurring radio signals in the VLF range to form a composition that oscillated every 5 minutes between acoustic and electromagnetic modes".[134]

Both Devine and Thomas produced sound works resulting from their collaboration with scientists and engagement with their research instruments. They brought an oblique perspective to the data that they accessed and treated both signal and noise as potentially valuable material. However the instruments that they engaged with were designed and fabricated purely for scientific ends and their final creative outcomes were sound pieces with no physical embodiment. In my own research I have taken a more layered approach. I designed and deployed my own instruments as analogs of the scientific instruments I was

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130 Bill Fontana, *The Universe of Sound*, presentation July 4,2013, in the CERN Globe of Science & Innovation Series. http://www.youtube.com/watch?v=6Zjy8v7BRaQ. Accessed November 5, 2014.

131 Artist quoted in interview. http://www.listeningacrossdisciplines.net/resources/interviews/composing-with-sounds-that-are-ordinarily-imperceptible/. Accessed July 27, 2017.

132 https://soundcloud.com/caroline-devine/5-minute-oscillations-of-the-sun-by-c-devine-on-bbc-world-service-sounds-of-space. Accessed July 27, 2017.

133 https://soundcloud.com/ikon-gallery/artists-talk-caroline-devine. Accessed February 2, 2018. Prof. Bill Chaplin explains this phenomenon in detail from 10m:30sec onwards.

134 https://carolinedevine.co.uk/portfolio/5-minute-oscillations-of-the-sun-2012/. Accessed February 18, 2018.

encountering as well as working with the data (and ambient sound qualities) of these existing scientific instruments. As part of this process, I searched for other artists who have developed their own instruments to transduce trans-sensory environmental signals and fields.

The Australian artists David Haines and Joyce Hinterding explore transduction deeply through their inquiry into electromagnetism, electricity, sound and the supernatural. Joyce Hinterding laid the groundwork for this research with her seminal work *Aeriology* (1995–2015) which consists of kilometres of fine copper wire wrapped around the columns of the gallery and connected to a speaker.

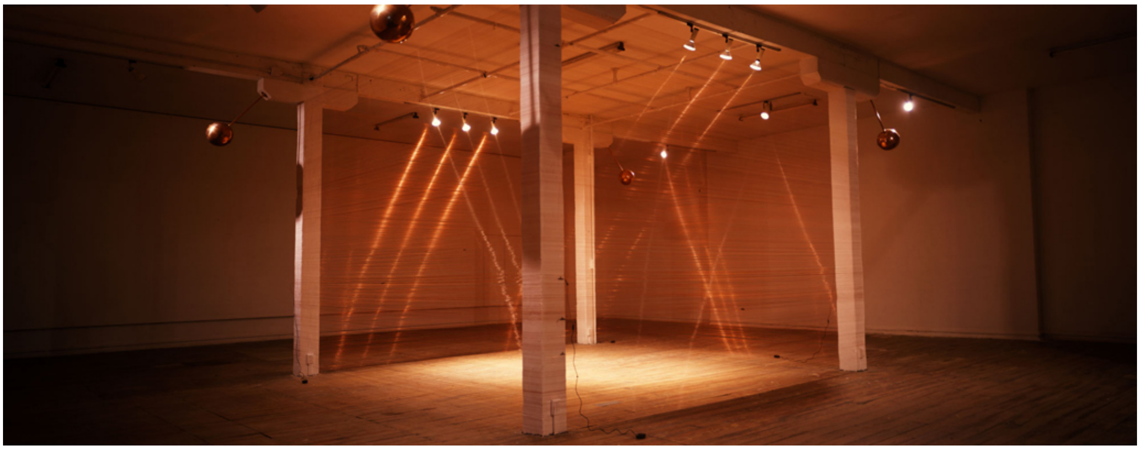

Figure 4.14 *Aeriology*. Joyce Hinterding. 1995–2015.

As Anna Davis describes it, *Aeriology*

> resonates in sympathy to inaudible radio frequencies in the environment that are related to the wire's length and physical dimensions. The frequencies *Aeriology* attracts arise firstly from its local site – the fields emanating from the electrical wiring in the gallery and from nearby electronic equipment. Beyond this, the huge coil also picks up radio waves originating from the rest of the … building, the city's electrical grid, the sun and other stars deep in the galaxy.[135]

Importantly, the energy captured in the wire provides both the signal and the energy required to drive the speakers. *Aeriology* isn't plugged into the grid, it resonates with it and all of the energy flowing through the space where it is housed. Hinterding describes it as "a kind of aerial capacitor that stores enough energy to amplify the signal it resonates to".[136] It is an instrument that makes audible the full spectrum of electromagnetic radiation flowing through the space (and us), and makes apparent both the strength and complex composition of that energy. As Douglas Kahn points out, it "marks off an ostensibly vacant volume

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[135] Anna Davis and Doug Kahn, *Energies: Haines and Hinterding* (Sydney: Museum of Contemporary Art Australia, 2015), 8.

[136] Joyce Hinterding. May 6, 1995. http://www.haineshinterding.net/1995/05/06/aeriology/. Accessed April 21, 2018.

that itself takes on quasi-object status, resonating in several energetic registers".[137] Intriguingly, *Aeriology* is hardly present itself, the gossamer wires catch the gallery lighting but only just. It is an instrument that is almost as imperceptible as the signals it transduces.

In this chapter, I have followed the thread of objectivity in contemporary art and seen how reducing subjectivity and direct agency of artists has been accompanied and enabled by the development of instruments which provide constraints on practice. These instruments can be physical objects, ways of working, or conceptual approaches. I argue that these instruments can be seen as analogous in purpose (and sometimes in form and function) to scientific instruments. I identified a set of terminologies (instrument, noise, signal, artefact, transcribe, transduce) which allow me to identify and interrogate artistic practice from across a range of genres and which provide a pathway to analyse my own work and to explore the common ground between science and art.

[137] Kahn, *Earth Sound Earth Signal,* 248.

Chapter Five The Field of Science

> In Antarctica you are intensely aware of the celestial Earth … From the mid-twentieth century, Antarctica was the site of the transformation of earth science into planetary science. The continent of ice was no longer just the end of the Earth; it became a place from which to intellectually encompass the planet and a privileged human window on the universe.
>
> Tom Griffith[138]

Antarctica has barely 100 years of human culture connected with it. Even with a rich history of artistic encounters with Antarctica over that time, there are still probably only a few hundred artists who have spent time on the continent and only a handful who have visited on multiple occasions or who have overwintered.[139] It's still a relatively blank page. As an artist, I find this incredibly attractive – Antarctica is still an open field for original conceptual approaches and ways of working.

In this chapter I will discuss particular characteristics of the Arctic and Antarctic that make them ideal sites for both artistic and scientific research. To focus this discussion I will consider important concepts that I've used throughout my analysis – including isotropism, information gradient, artefact, noise and signal. These concepts are strongly connected to both the Antarctic landscape and the pursuit of scientific inquiry that happens there. I conclude with an overview of the science conducted at the IceCube Neutrino Observatory at the South Pole (my primary scientific collaborator and hosted my fieldwork in the austral summer of 2016/17) and outline the rationale for its suitability as a context for artistic fieldwork.

[138] Tom Griffiths, *Slicing the Silence: Voyaging to Antarctica* (Cambridge: Harvard University Press, 2007). The Australian historian Tom Griffiths visited Antarctica in 2002/3.
[139] Fox, "Every New Thing," 21.

5.1 Defining my Field – the Arctic and the Antarctic

I have embraced Clifford's definition of the field as "a cleared space of work … [for] specific practices of displacement and focused disciplined attention."[140] Defining a field requires the selection of both a physical location for the field work and a set of practices to examine.

I selected two physical locations for my field work.[141] The first site was the Arctic Archipelago of Svalbard – specifically the western seaboard of the island of Spitsbergen, north of Norway and deep within the Arctic Circle. The second, and principle, location was the Antarctic – specifically at McMurdo Station on the edge of the Ross Ice Shelf and at the South Pole.

These sites were chosen for specific reasons. Firstly, they are both isolated field sites in the classic anthropological sense. Both have always presented challenges for explorers and have been attractive to artists due to their otherworldliness and isolation. These locations require careful, advanced, fieldwork planning and provide limited opportunity for equipment modifications or improvisations. Artists and scientists need to be both self-reliant and to work collaboratively to achieve their goals in these environments. Further, it remains a fact that the most effective way for artists to access these locations has been and still is by joining scientific expeditions. This situation provides ready access to scientists, and their processes, instruments and research. And, finally, artists working in polar regions have always, of necessity, developed innovative technologies and technical solutions with minimal supporting resources to create their works in these difficult environments. The isolated and challenging conditions are conducive to original approaches and outcomes.

In the northern summer of 2014, I was invited aboard the 50 metre, three-masted, barquentine *Antigua* as recipient of an Arctic Circle Residency along with 26 other artists and scientists for a three-week expedition along the Western coast of Spitsbergen – the largest island in the Svalbard Archipelago, located within the Arctic Circle, c.1000 km from the North Pole. [142]

There were three main goals for this fieldwork. It afforded me an opportunity to field test my photographic, video and sound equipment in the challenging Arctic conditions. Secondly, I could evaluate fieldwork practices within the stringent logistical constraints of working aboard a sailing vessel, which changed location on a daily basis, required sharing of limited resources (such as a Zodiac inflatable boats) and

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[140] Clifford, *Routes*, 53.

[141] The selection of the Poles as interesting fieldwork locations was supported by personal encounters with artists and writers with first-hand experience, who provided the foundational network for my research and helped me envision opportunities to develop my own artistic practice through fieldwork at the Poles – see the Acknowledgements.

[142] Provided by the US-based non-profit organisation The Arctic Circle. http://thearcticcircle.org.

provided limited time ashore. Thirdly, I was able to work collaboratively with other artists and scientists under field conditions and get a clearer idea of how to optimise outcomes within a collaborative context. I will discuss outcomes of this fieldwork in Chapter Six.

My primary field research site, however, was the South Pole. This site provides unique cultural and physical conditions in support of contemporary astrophysical research. It is a long way from established human communities which produce light and other electromagnetic noise, it enjoys favorable atmospheric and geophysical conditions such as high altitude, minimal atmospheric turbulence and extreme dryness, and it provides four months of perpetual darkness every year together with unrestricted access to the sky of the southern hemisphere.

In the austral summer of 2016/17 I was awarded an Antarctic Artists and Writers Fellowship by the US National Science Foundation (NSF) which supported my four-week long field trip to McMurdo Station on Ross Island on the edge of the Antarctic continent (1360 km from the South Pole) and to the Amundsen-Scott South Pole Station where I worked in collaboration with the IceCube Neutrino Observatory (IceCube).[143] My goal was to develop and deploy my own series of sculptural instruments and to work directly with IceCube to develop a deeper understanding of their research and of the flux of energies flowing though the Pole. I was interested in using the data from IceCube as part of my work and, if possible, develop a lasting collaboration that could continue beyond the current project.

In Chapter Six I discuss my polar fieldwork and its outcomes in detail. Prior to that it is necessary to outline both the conceptual and physical parameters of my fieldwork investigation and elucidate why the polar regions provide ideal conditions for my particular research goals.

5.2 Isotropism and Information Gradients

> [Antarctica] is a place that is isolated, abiotic, acultural, and profoundly passive. One goes there in defiance of natural impulses. The scene reflects, absorbs, and reduces. It acts as a geophysical and intellectual sink. It takes far more than it gives. With implacable indifference it simplifies everything: that is its essence, the synthesis of the simple with the huge. It reduces an entire continent to a single mineral taller than Mount Whitney and broader than Australia.
>
> Stephen J. Pyne [144]

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[143] I will discuss IceCube in detail later in this chapter.

[144] Pyne, *The Ice*, 163.

Both the Arctic and the Antarctic have been compared to blank pages – the Arctic was described by the author Jack London as a "large sheet of foolscap".[145] The explorer Richard Byrd described the South Pole after his visit 1930 in this way, "The Pole lay in a limitless plain … One gets there, and that is about all there is for the telling."[146] The apparent blankness of a landscape free of familiar markers and human culture results in a sublime awe – all sense of scale, distance and perspective can collapse and invert in the isotropic field of whiteness.[147]

This isotropism can be linked to physical and conceptual gradients across the Antarctic. In Pyne's poetic analysis of Antarctica entitled *The Ice: A Journey to Antarctica* he postulates that "the journey from core to margin, from polar plateau to open sea, narrates an allegory of mind and matter."[148] He continues:

> Antarctica is the earth's great sink, not only for water and heat but for information. Between core and margin there exists powerful gradients of energy and information… The extraordinary isolation of Antarctica is not merely geophysical but metaphysical. Cultural understanding and assimilation demand more than the power to overcome the energy gradient that surrounds The Ice: they demand the capacity and desire to overcome the information gradient.[149]

Here Pyne describes two separate gradients that run in parallel. As the Pole is approached the physical landscape becomes increasingly isotropic and featureless (the information gradient approaches zero), and venturing there requires us to exert our imaginations as well as physical energy. As the Pole is approached the scope for the human imagination to write its own meanings into the landscape increases. The lack of physical reference for gaining our bearings can unmoor us from the real world, and we enter into a world of metaphor and imagination. It is an attractive place for artists!

The tendency for energy (particularly heat) and information to approach zero at the South Pole is also what attracts scientists. The South Pole is home to some of the most sophisticated astrophysical instruments we have created and is the site for some of our most ambitious scientific endeavours. I will discuss one particular instrument, the IceCube Neutrino Observatory, in detail in Chapter 5. In the following section I clarify some of my thinking around instruments as devices of constraint and as tools for shaping our thinking.

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145 Jack London, "An Odyssey of the North," *Atlantic Monthly*, January, 1900, 87.

146 Richard E. Byrd*, Little America.* Quoted in Pyne, *The Ice,* 65.

147 William Fox has discussed the isotropism of Antarctica and its effect on our senses and psychology in great detail. Fox, *Terra Antarctica.*

148 Pyne, *The Ice,* 2.

149 Pyne, *The Ice,* 7.

5.3 Instruments of Constraint – Noise, Signal and Artefact.

> The world (is) filled with extraordinary instruments, handheld sensors, mechanisms, experimental arrays, and other, often semi-autonomous, networked machines through which humans, on a continual basis, without pause, on every continent of the Earth and even at the bottom of the sea, have been recording and interpreting the world around them. These are "devices of wonder," in the words of art historian Barbara Maria Stafford, machines that "not only constrain what is possible to see but also determine what can be thought" by those dependent on them.
>
> Geoff Manaugh. [150]

The practice of science is defined by its instruments. Science has both observational and experimental modes and instruments are used in both arenas. In the case of observational science, the input is given (it's the world around us in all its complexity), how it is sampled is up to the scientist. Observations are under conscious control of the observer, who can decide what to look at and with what sort of device or methodology. In experimental science, the input parameters are also under conscious control (at least to some extent) – specific situations can be created and observers can manipulate many aspects of the experimental process along the way.[151] And so experimental instruments have both input and output components – some instruments create a situation or process and others monitor or observe it. Scientists strive to make their choices of parameters and constraints as objective as possible and strive for outcomes which are accurate, consistent and reproducible.

Observational scientists use instruments to gather data that is inaccessible to our unaugmented senses (through amplification and transduction) and to constrain their field of view to a comprehensible and yet significant sample. To help clarify this process it is worth considering what is perhaps the simplest and most quintessential instrument used by natural scientists – the 'quadrat' and 'transect'. To give an example of their use, to evaluate the distribution and abundance of ant species found in a section of grassland a scientist might draw a line across a local topographic map and then determine a series of points along that line where a survey will be taken – this line is the transect. Then, in the field, at each location specified on the transect, the scientist will set up a sampling device that takes an equivalent sample at each point – this is the quadrat. The simplest form of the quadrat might be a small frame of defined size dropped at the set location within which the number of species or individuals found can be observed, counted and/or captured. The two together, the transect and quadrat, form a framing device – a way of reducing the huge amount of

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[150] Geoff Manaugh, ed., *Landscape Futures: Instruments, Devices and Architectural Inventions (Nevada:* Center for Art + Environment, Nevada Museum of Art. 2013), 25.

[151] This is Cartwright's 'nomological machine' discussed in detail in Chapter Three.

data available in the field down to a manageable but still statistically significant sample. The transect and quadrat combined can be considered as an instrument of constraint – constraining the work to a manageable scale, removing extraneous information (or noise) and at the same time removing the subjectivity of the observer and increasing objectivity by providing a basis for statistical evaluation of the observations. All scientific observational devices share these qualities; they focus attention on a specific sample or field of view to allow that sample to be analysed closely with the understanding that that sample will reflect the larger reality. Instruments are at once an apparatus and an embodiment of a methodology.

The transect and quadrat are simple devices. However some scientific instruments are incredibly complex and sophisticated. They are amongst the most unique, complicated, rigorously engineered and expensive machines humans have ever made. They can be considered the most outstanding technological artefacts of contemporary human culture. I am very interested in the notion of ‘artefact’ and I will use this term extensively in the discussion that follows.

Artefact has two distinct meanings within science – though they are connected etymologically. The more familiar definition of an artefact is an object shaped by human workmanship which has historical or archaeological interest. Artefacts are the physical evidence of human culture. Pottery shards or stone axes might be the first thing that comes to mind when this term is used, however iPhones and radio telescopes can be considered artefacts as well – and presumably their remnants will be pondered over by future archeologists.

The second and more specialised meaning of artefact is connected to two other important notions that I have touched on briefly and which underlie much of my analysis – noise and signal. Every instrument, or instrumental process, gathers input of which only a portion is of interest or value. In science that input is normally broken down into two mutually exclusive conditions, noise and signal – where, simply put, signal is what is of interest and noise is not. Unexpected or inexplicable data recorded on a device might be a signal (of something unexpected but of interest) or unexplained noise (arising from natural processes or an instrumental effect). This instrumental noise is also called an ‘artefact’. So the second meaning of artefact is an unintended or unexpected (and mostly unwanted) side effect or consequence of a device or process – a human generated signal. And here we can see the etymological connection between the different meanings – in both cases an artefact is the result of human action, an unnatural element. Instruments are artefacts and they produce artefacts.

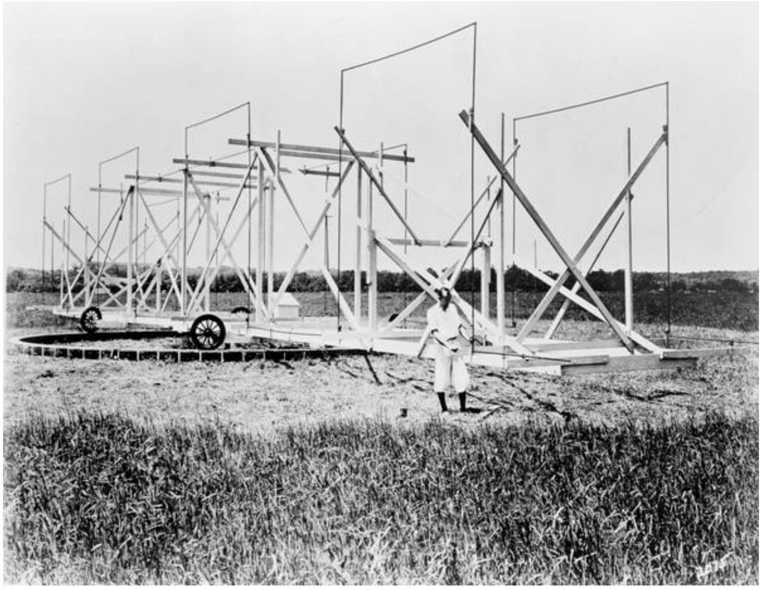

Figure 5.1
Karl Jansky inspecting the first antenna used to receive radio waves from outer space.

There have been innumerable occasions in the history of science when what initially seemed to be unwanted noise, was suspected of being an instrumental artefact and then was subsequently proved to be an interesting new signal. One iconic example was Karl Jansky's 1931 discovery of the first astronomical radio source following his investigation of static (noise) on transatlantic radio transmissions. By timing cycles in the static he was able to identify the source as coming from beyond the solar system and, as a consequence, the whole field of radio astronomy was born.[152] In 1964, Robert Wilson and Arno Penzias working at Bell Labs Crawford Hill facility in New Jersey, only a mile from the site of Jansky's antenna, were puzzled by a constant diffuse microwave signal that came from all parts of the sky simultaneously. They did their best to remove all possible sources of the noise – to identify instrumental artefacts. They even reportedly shooed pigeons that were nesting in their antenna. Penzias later said "It wasn't until we exhausted every possible explanation for the sound's origin that we realised we had stumbled upon something big."[153] They had confirmed the theoretically predicted thermal echo of the Big Bang, now known as the Cosmic Microwave Background (CMB). The noise was revealed as an important signal.

Noise, signal and artefact are fundamentally inter-connected concepts. Instruments receive unfiltered input which is composed of signal and noise. The noise consists of naturally occurring input, often mixed with anthropogenic input, and accompanied with artefacts generated by the observing instrument and by how the input is processed. It is the role of instrument designers and data analysts to identify which is which – to distinguish signal from noise. At the most fundamental level, instruments must be designed so that they

[152] http://www.bell-labs.com/radio-astronomy-celebration/. Accessed October 15, 2014.

[153] Mike Wall, "Cosmic Anniversary: 'Big Bang Echo' Discovered 50 years ago." May 20, 2014. https://www.space.com/25945-cosmic-microwave-background-discovery-50th-anniversary.html. Accessed April 28, 2018.

are sufficiently sensitive to distinguish a potential signal from expected noise.[154] These challenging problems are compounded by the fact that what is one scientist's noise could well be another's signal.

One significant group of artefacts that impinge on both artistic and scientific practice are those that arise from the instruments used in image production. Some of these are analog and arise from the physical attributes of the instrument – lens flare, the star shaped patterns that arise from secondary mirror supports in astrophotography, the granularity of silver crystals in film, etc. And some are digital – pixilation, file compression effects, false colour enhancements. In Chapter Six I will discuss how scientific journals now place strict guidelines on image manipulation and the removal of artefacts so as to avoid visual modifications that can mask or alter important data.

The notion of artefact can also be applied to art practice. In science an artefact is an unintended consequence of a technology. Similarly, in art, an artefact can be considered the consequence of a process that arises unintentionally and freely from the act of making. This can be the mark of the human hand (perhaps the trace of a finger left on the surface of a hand-thrown pot or the sweep of a calligrapher's brush stroke) but should also include machine made artefacts (such as the pixels in a digital image or the complex lattice of substrate laid down in a CNC printed object). Mark-making is a fundamental and highly valued component of any artwork and is widely seen as intentional and under the control of the artist – e.g. the brush stroke of the great painter. But I would argue that it is largely out of our conscious control and arises through habitual action – either from the trained hand of the artist or the tightly controlled (but often still glitchy) output of a machine. Art objects are artefacts and the marks they are composed of and the traces of their making are also artefacts.[155]

I have adopted these interconnected concepts of noise, signal and artefact to analyse both scientific practice and my own artistic output resulting from my field work in Antarctica.

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[154] In any instrument that uses photons (optical, radio, microwave or gamma ray telescopes) or electrons (that is, any electronic instrument) the random movements of these particles itself constitutes a form of noise – the so-called Poisson or shot noise. This can be estimated statistically for any system and overcome through instrument design. Personal discussion with Prof. Ken Freeman, Duffield Professor of Astronomy in the Research School of Astronomy and Astrophysics at the Mount Stromlo Observatory of the Australian National University, October 2, 2018.

[155] I consider this correlation in more detail in Chapter Six where the digital artefacts resulting from software algorithms are considered as analogous to artistic mark making.

5.4 Astrophysics at the South Pole.

5.4.1 Neutrinos 101

5.4.2 The Array

5.4.3 The Signal

5.4.4 Conclusion

> The only true voyage of discovery … would not be to travel to new lands, but to possess other eyes, to see the universe through the eyes of another, of a hundred others, to see the hundred universes that each of them sees, that each of them is.
>
> Marcel Proust.[156]

The field of science that I have chosen to focus on in my research is astrophysics. Unique among the natural sciences, astrophysics deals almost exclusively with remote events – remote in distance and in time and, most significantly, remote from our own direct tangible experience. The signals that astrophysics rely on must be filtered from a complex and almost overwhelming sea of noise. And complex, mostly one-of-a-kind, hand-made instruments are required to capture this signal.

I have discussed the energy and information gradients that head towards zero as the South Pole is approached and have noted that this is what attracts scientists there. The primary science conducted at the Pole concerns atmospheric analysis, glaciology and astrophysics. All rely on the pristine conditions, the clean air and the relative absence of humans and their technology. In the case of astrophysics, the high altitude, the dryness of the air, the four month long night-time, unfettered access to the southern skies, and the lack of polluting light, heat and other electromagnetic interference are unmatched on earth. I will discuss the consequences of these cultural and physical contexts on my research in more detail.

I was fortunate to have close involvement with one of the most extraordinary scientific instruments at the Pole, or for that matter on the planet – the IceCube Neutrino Observatory. IceCube was built to detect and analyse high energy neutrinos from cosmological sources. Unlike the other astrophysical observatories at the Pole, all of IceCube's vital detection devices are invisible and inaccessible. In fact, they are buried up to 2.5 km deep in the ice of the Polar plateau. The Pole is quite high in altitude (2,800m), but the extraordinary thing is that below the surface, the polar ice extends all the way down to sea level, almost 3 km down. At depth, the ice is incredibly clear. Below 1.5 km depth, the pressure is so great that the trapped air bubbles that give ice its milky opacity dissolve into the crystal matrix of the ice and the transparency increases dramatically. It becomes essentially the clearest natural material we know – the absorption length

[156] Marcel Proust, "The Captive" in *Remembrance of Things Past* (À la Recherche du temps perdu). Translated from the French by C. K. Scott Moncrieff, (New York: Random House, 1981), 559.

of light in this ice has been measured as 210m, that's almost three times clearer than the purest water we can make.[157] This large volume of exceptionally transparent ice is the main reason the Pole was chosen for the neutrino observatory. To understand this more fully, in the following section I will outline some of the basic physics involved.

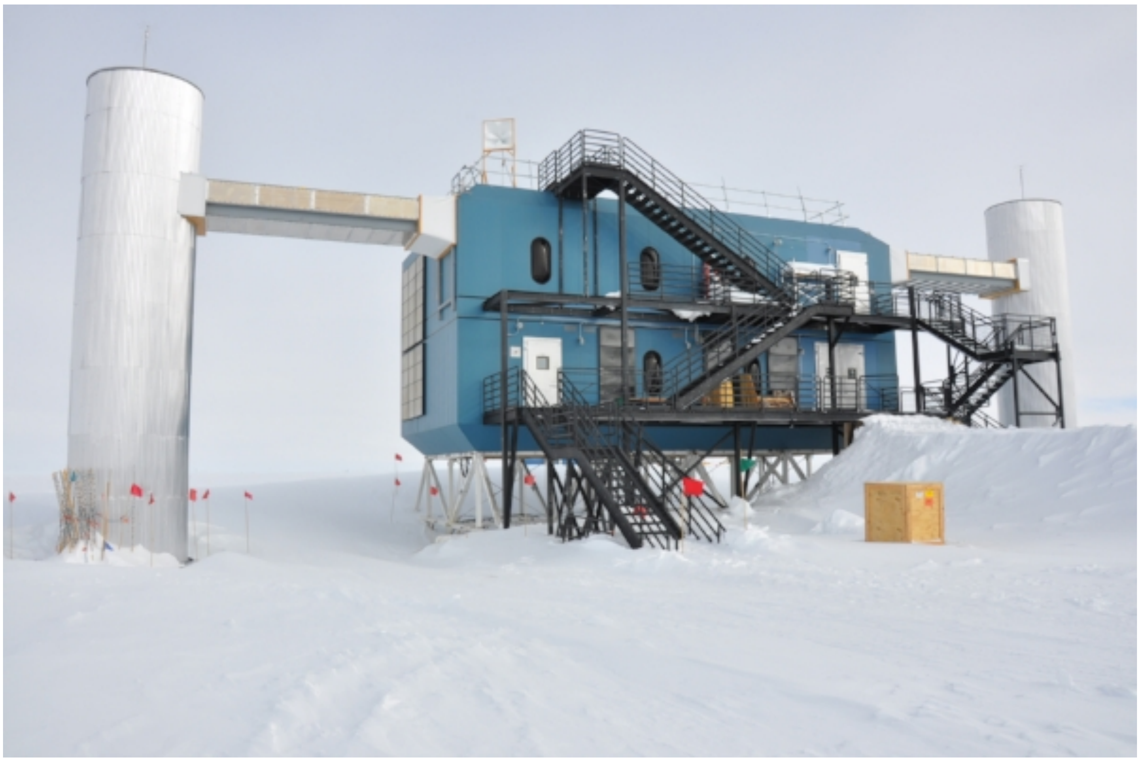

Figure 5.2 The IceCube Lab.

[157] Francis Halzen, presentation at the 2015 APS April Meeting 2015. "IceCube and the Discovery of High-Energy Cosmic Neutrinos." https://www.youtube.com/watch?v=Em_2HqIlr64. Accessed May 4, 2018.

5.4.1 Neutrinos 101

What are neutrinos and how are they detected?[158] Neutrinos are elementary subatomic particles that interact with other matter only through the weak subatomic force which is one of the four forces of the so-called Standard Model along with gravity, electromagnetism, and the strong force (which binds quarks together to form protons and neutrons). The weak force is so named because it is orders of magnitude weaker than either the electromagnetic or strong force and operates only at very close range.

Neutrinos have no electric charge (and so are not affected by the electromagnetic force) and have minuscule mass (and so are practically unaffected by gravity). Consequently, they have to essentially collide with another subatomic particle to have any effect on it. This results in the unique (and frustrating) property that they hardly interact with other matter at all. They arise through radioactive decay and other subatomic interactions and are created in huge quantities in the sun, the atmosphere and the core of the earth, and in high energy cosmic events such as novae, super-novae and gamma ray bursts. They are, in fact, the most common subatomic particle in the universe, outnumbering protons and neutrons by a factor of 100 million, and are approximately equal in number to the photons of electromagnetic energy pervading the universe.[159] However, as they are one of the least interactive particles they have to accidentally make a direct hit on another subatomic particle to be observed. This happens so rarely that we need a huge detector to ensure that enough events will occur for us to be able to record them. This is what the South Polar ice cap offers. The polar ice cap is an immense slab of transparent material – a perfect net for catching neutrinos.

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[158] The following discussion of neutrino physics and the description of the IceCube Neutrino Observatory was gathered from various sources. Including discussions with various IceCube scientists in the US and in Antarctica (in particular James Madsen, Gwenhaël de Wasseige, and Martin Rongen – see Acknowledgements) and many published resources including the following – Christine Sutton, *Spaceship Neutrino* (New York: Cambridge Press, 1992).

Ray Jayawardhana, *Neutrino Hunters: The Thrilling Chase for a Ghostly Particle to Unlock the Secrets of the Universe* (New York: Farrar, Straus and Giroux. Kindle Edition. 2013).

E. Andreas, P. Askebjer, X. Bai, et.al., "Observation of high-energy neutrinos using Cherenkov detectors embedded deep in Antarctic ice." *Nature*. Vol. 410. 22 March 2001. https://www.nature.com/articles/35068509. Accessed on December 5, 2017.

Francis Halzen. Interview in *Uncharted Cosmos: Mapping the Universe with Icecube.*
https://icecube.wisc.edu/gallery/press/view/2169/. Accessed November 12, 2017.

Francis Halzen, "Antarctic Dreams," in *The Best American Science Writing 2000*, ed. James Gleick (New York: Harper Collins, 2000).

[159] Halzen, "Antarctic Dreams," 68.

5.4.2 The Array

The IceCube Neutrino array occupies a cubic kilometre of ice and is buried over 1.5 km below the ice surface. This huge volume of ice (c.1 million cubic metres) captures several hundred neutrino interactions every day. The array consists of 5,160 photo-sensitive Digital Optical Modules (DOMs) arrayed on 86 vertical 'strings'. that have been lowered into deep holes drilled into the ice. The strings are in a hexagonal grid spaced 125 metres apart and each string holds 60 DOMs spaced 17 metres apart.

The logistics involved in creating the array are impressive. Between 2003 and 2011, over 2 million kilograms of cargo were shipped from across the globe to the South Pole, requiring 181 LC-130 flights. That's a remarkable feat in itself before you add in the logistics to support the people to make it all happen. Each bore hole required two days of constant drilling, and 18,000 litres of gasoline to create, melting 750,000 litres of ice in the process. At its completion in 2010, the Observatory had cost US$279 million.

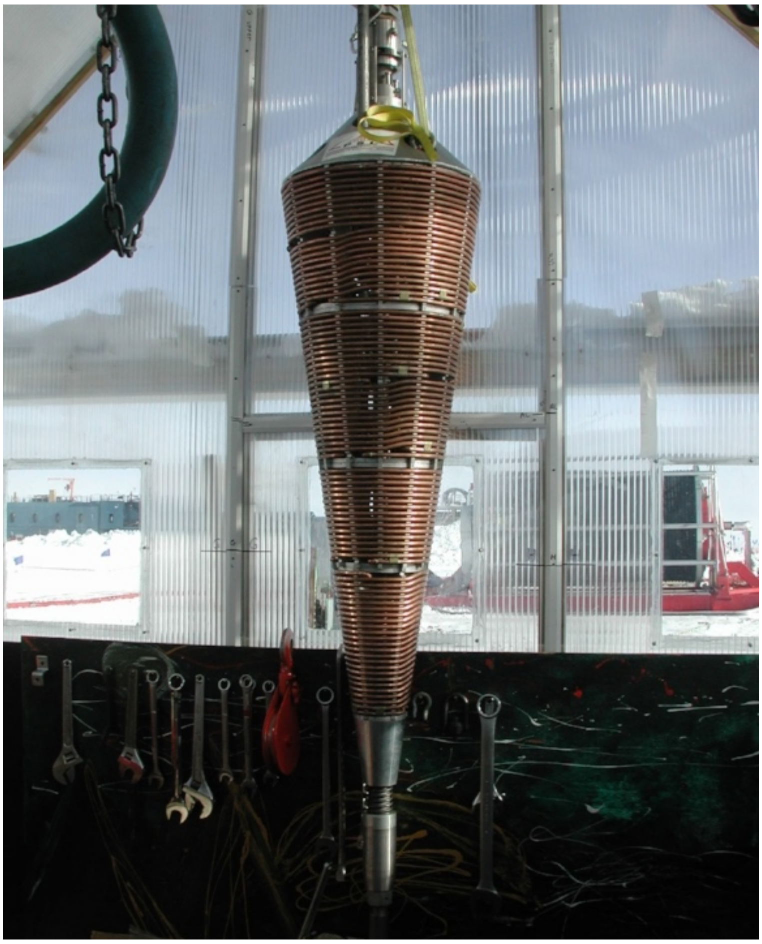

Figure 5.3
The Fern Drill used to drill through the upper layers of compacted snow. Hot water is pumped through the copper tube to melt through the ice as the drill is slowly lowered.

Figure 5.4
Checking on each DOM's connection and spacing as it is lowered into the ice.

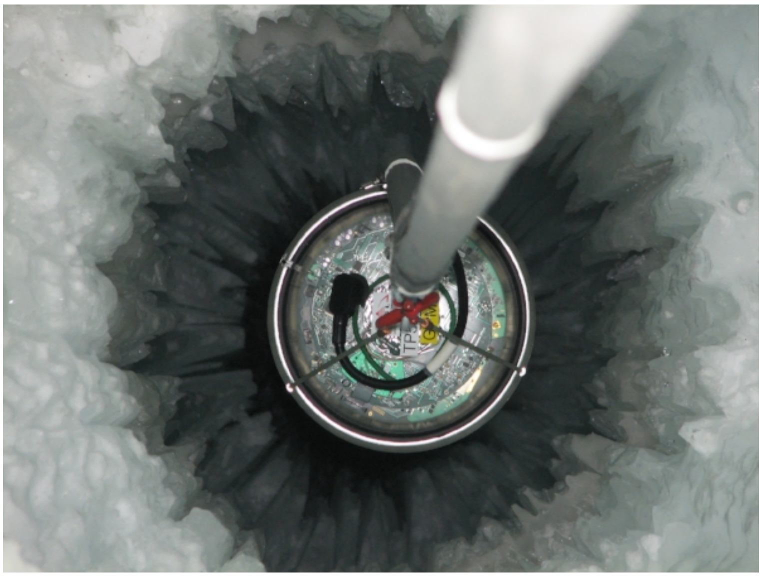

Figure 5.5
DOM (063A – Golden) being lowered into the ice.

Figure 5.6
An artist's impression of the DOM array under the ice.

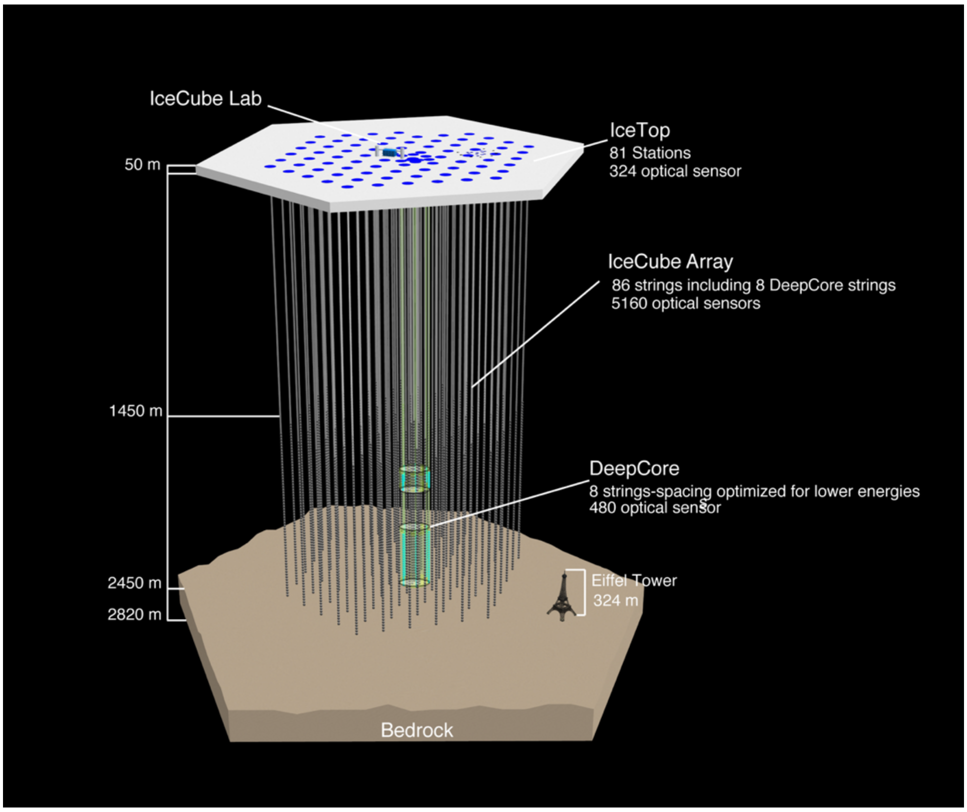

Figure 5.7 Diagram of the complete IceCube array.

Once the DOMs were lowered on their cables, the holes were refilled with the melted water and refroze. The array is now frozen permanently into the ice. All that appears above the surface is the thick braid of cables which are routed across the ice surface and then into the main building of the IceCube Lab (ICL). At the ICL, the cables are divided up and distributed to banks of processors that do the initial processing, event reconstruction and filtering of the data to see if any recorded event is worth examining in greater detail (see Figure 5.8). These events are uploaded to the IceCube servers and then transmitted during the short daily period of satellite connection to the scores of scientists across the world who are taking part in the collaboration at any one time. Hard-drives recording all of the events and more detailed data are shipped back to the USA every few months.

Figure 5.8

The data processing room of the IceCube Lab.

5.4.3 The Signal

The questions remains; what do the scientists 'see'? Or more directly, what do the DOM's capture? When neutrinos or other subatomic particles collide with protons in hydrogen or oxygen nuclei in the ice, they result in the emission of charged leptons (electrons, muons or taus). "In order to detect neutrinos, IceCube exploits the fact that charged particles resulting from neutrino interactions move through the ice faster than the phase velocity of light in ice, and therefore emit Cherenkov photons."[160] Although we all take it as an article of faith that nothing can travel faster than the speed of light, we mostly overlook the essential proviso 'in a vacuum'. In ice, photons travel at only 75% of their velocity in a vacuum. And so, in our terrestrial environment, it is possible for subatomic particles to travel faster than light in a particular medium – this is called the 'phase velocity' in that medium. When a charged particle (such as the muon resulting from a neutrino collision) exceeds the phase velocity of light, a cone of ultraviolet photons is emitted in its wake. This deep blue flash is what the DOMs in the array detect. The DOMs can detect a single photon of light and so when this tiny flash occurs, multiple DOMs register its passing and so can map its intensity and direction.

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[160] IceCube Collaboration, *The IceCube Neutrino Observatory: Instrumentation and Online Systems*, arXiv:1612.05093 [astro-ph.IM], 2017, 2.

Figure 5.9 shows a record of a high energy event from October 21, 2012 – an electron neutrino cascade. This image is a screenshot from an animation of the event that was generated in the data visualisation software program Steamshovel. In it you can see each of the 86 strings in the array and each DOM indicated by a tiny white dot. The coloured circles indicate DOMs registering photons. The size of the circles indicates the number of photons and the colour represents when the photon was received – red first, blue last. This event occurred within the array like the burst of a flashbulb – the light spreading out through an area of the array about as large as 6 city blocks. This pattern indicates that the source of the event was a neutrino.

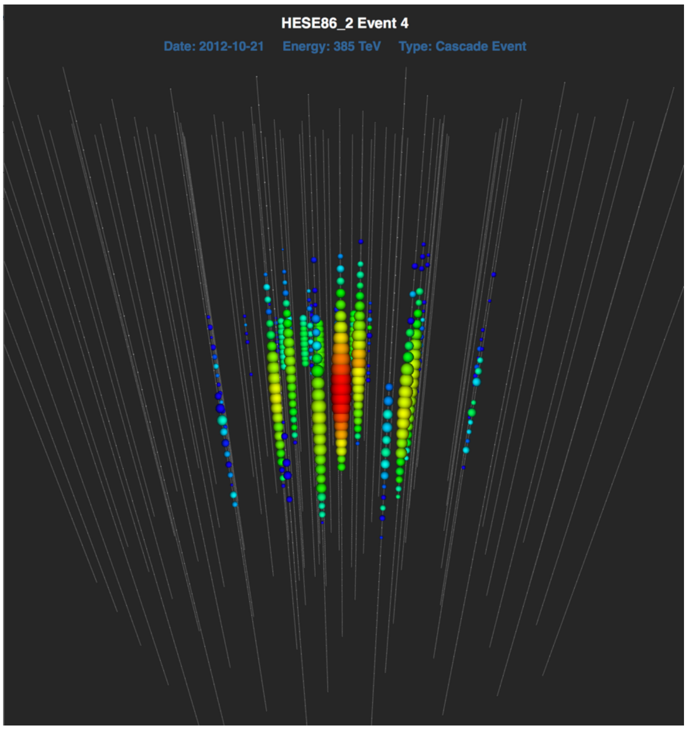

Figure 5.9
HESE86_2 Event 4.
A cascade event recorded on October 21, 2012.

One reason the array is buried so deep in the ice is to filter out the noise from cosmic ray muons cascading though our atmosphere. Another ingenious filtering device employed by IceCube is that its DOMs face down, not up. Charged particles created by a neutrino follow the same path as the original neutrino. Any charged particle path that shoots upward through the ice as seen by the DOMs could only have been generated by a neutrino following the same path. If the particle managed to get through the earth it must be a neutrino – anything else would have been absorbed along the way. The neutrino may have arisen through cosmic ray interactions on the other side of the planet, but if it is very high energy it probably has an astronomical source. These very high energy cosmogenic neutrinos are what IceCube was primarily designed to detect.

IceCube detects one neutrino every 6 minutes on average and 3000 muons per second.[161] Every year IceCube detects 10^{11} atmospheric muons (produced by the interaction of cosmic rays with the Earth's atmosphere), 10^5 atmospheric neutrinos (generated in our atmosphere by cosmic rays and capable of passing through the earth), and only approximately 10 high energy (>100 TeV) neutrinos.[162] There have to date only been only a few very high energy (>PeV), astrophysical, neutrino detections – the first three were observed in 2003 and were named Bert, Ernie and Big Bird. [163,164] Even with this many detections, IceCube only detects one in a million neutrinos, the rest pass through the array undetected.

One of the key attributes of neutrinos, resulting from their lack of interactivity, is that they are not deflected by the matter and energy fields that they are travelling through (unlike photons) – they come straight from their source – this makes them invaluable as astrophysical messengers. The scale of the IceCube array coupled with its use of the planet as a filter allows the array to operate as a neutrino telescope to detect not only the energy and mode of a neutrino but also the direction from which it came within an accuracy of one degree of arc.[165] Neutrinos have been moving through the universe since the moment of the Big Bang (370,000 years earlier than when photons first began to travel freely in the universe) which allows astronomers to see beyond even the visible universe and even closer in time to the Big Bang than with other telescopes. At the same time the array detects muons coming from all directions and so acts as a discreet cubic kilometre sample of the local particle and energy flux. This allows astrophysicists using the array to observe the fundamental nature of neutrinos and their interactions with other matter and the very fabric of space time.

In summary, the IceCube Neutrino Observatory is a truly unique instrument. It is a gigantic neutrino telescope which uses a cubic kilometre of ice as its primary receiver and our entire planet as a filter. It has the capability to detect individual photons deep in the Antarctic ice, to process huge volumes of data, analyse it in real time and then transmit that data by satellites to digital networks accessible by the collaboration scientists. It is representative of the kind of complex multi-user, multi-experiment instrument typical of contemporary astrophysics (and so-called Big Science in general).

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[161] Francis Halzen, Interview in *Uncharted Cosmos.*

[162] The energy (and hence mass) of subatomic particles is measured in electron volts (eV). 1 TeV = 10^{12} eV. 1 PeV = 10^{15} eV.

[163] Adrian Cho, "Physicists Snare a Precious Few Neutrinos From the Cosmos," *Science* 342, no. 6161 (2013), 920–22.

[164] Francis Halzen, presentation at the 2015 APS April Meeting 2015. "IceCube and the Discovery of High-Energy Cosmic Neutrinos." https://www.youtube.com/watch?v=Em_2HqIlr64. Accessed May 4, 2018. To detect even higher energy neutrinos (like the so called GZK neutrinos produced by high energy cosmic rays interacting with the Cosmic Microwave Background (CMB), an even larger detector would be required. Personal communication Dr. G. de Wasseige, November 19, 2018.

[165] Anil Ananthaswamy, *The Edge of Physics: A Journey to Earth's Extremes to Unlock the Secrets of the Universe* (New York: Houghton Mifflin Harcourt. Kindle Edition. 2010), 205.

5.4.4 Conclusion

The IceCube Neutrino Observatory has been an incredibly successful instrument to date and its useful life has only just begun.[166] But why would an artist be interested in working with IceCube? Or more specifically, how does this instrument and its location provide a suitable field for my own research?

As I have emphasised, a key focus of my research is the relationship between noise and signal. IceCube is striving at the very edge of perceptible signal. The huge amount of noise that must be sorted through to find the signal of neutrinos is almost overwhelming. Placing the array under more than a kilometre of ice in one of the remotest places on earth cuts some of the noise. Pointing the DOMs downward to use the earth as a cosmic ray filter cuts more of the noise. Even then, high energy events coming from astronomical sources are a tiny fraction of the total number of recorded events. With this scant data scientists then strive to understand what these rare events might tell us about the physics of the formation of the universe or the demise of massive stars. The capacity to sort through layer, after layer, after layer of noise to discern the faintest of signals and then extrapolate from that signal to understand the nature and history of the universe is the signature achievement of contemporary astrophysics. And I would assert that this search for understanding is one of the most significant goals of contemporary human culture.

Some of the noise that IceCube is trying to filter is proving to be interesting to other scientists studying glaciology and the solar wind. This leads to the observation that all noise is essentially signal – it depends on what you are looking for and which constraints you choose to apply. One person's noise is another's signal.

The engineering required to create the IceCube and the physics underlying the project are awe inspiring. The scope of the instrument itself, not to mention the huge amount of research, collaboration, testing, unique engineering and shear hard work required to bring it to fruition and continue its development are very impressive. In connection to my own research, understanding how the IceCube Observatory operates as an instrument, opens up a dialogue with my own instruments and their functionality. Both sets of instruments have required complex logistics to get them to the Pole, and have been designed for deployment in challenging environmental conditions. And both engage with notions signal and noise.[167]

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[166] The IceCube collaboration website lists highlights of their scientific findings to date. https://icecube.wisc.edu/science/highlights.

[167] I discuss this in more detail in Section 6.5.

Prof. Francis Halzen, the primary instigator of the IceCube project, said this about the project:

> To have your career on the line half a world away is hard enough. But to know that you have embroiled so many others in the same improbable adventure, that your funders and colleagues expect results, and that you are totally powerless to affect the outcome, is a form of exquisite torture.[168]

The ability of Prof. Halzen to garner the support of the NSF and to develop the complex international collaboration that IceCube entails today is impressive. As discussed in Chapter Two, the myth of the solo genius struggling in the atelier is still dominant in the visual arts. Working in collaboration with IceCube has provided me with insights into a different model of art practice – one involving complex international collaborations.

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[168] Jayawardhana, *Neutrino Hunters*, 20.

Chapter Six Investigations and Outcomes

6.1 Introduction – Revealing Terminologies

I have set the historical, conceptual and methodological context for my research in the preceding chapters. Now I will discuss my research and its outcomes in detail. I have found the strategy of considering and repurposing specific scientific terminologies to be an effective way to provide new perspectives for analysis and to open up pathways for comparison between artistic and scientific approaches and methodologies. Each section of this chapter will document a particular body of work developed for, during and as a consequence of fieldwork expeditions and each body of work will be discussed through the lens of a specific framing terminology.

The first term that drew my attention to the potential of this strategy was 'pareidolia'. Pareidolia is the psychological phenomenon whereby a vague or random stimulus (an image or sound) is perceived as being significant or recognisable. It is primarily experienced when the background information (visual or auditory) is either minimal or confusingly complicated and difficult to analyse. Its most widely recognised and discussed manifestation is in our inherent tendency to see faces in places where there are none – classic examples include the man in the moon, the face on the Cydonia region of Mars and, arguably, the Shroud of Turin. Pareidolia is deeply connected with pattern recognition, the evolution of human thinking, and most of all, imagination and creativity. Thinking through the physical and psychological conditions that underlie pareidolia led me to the core notion that underlies much of my research – the relationship between noise and signal. Pareidolia is critical to any discussion of signal and noise, as it calls into question whether a perceived signal is real or an artefact of our human imagination.

In Section 6.2, I discuss pareidolia in relation to scientific objectivity and to the particular contexts of the landscapes of the Arctic and the Antarctic. The Poles are famously isotropic, disorienting and confounding which makes them perfect places to both experience and research pareidolia. I draw a parallel between the human tendency to find pattern in fields of visual noise or minimal signal and the programming of computer algorithms to find pattern in fields of data. In my research, I use image manipulation algorithms to distinguish pattern in photographic images and create digital prints which in turn present complex fields of visual data which are open to creative interpretation. I discuss the role of computer algorithms in augmenting pareidolia and the ways in which contemporary scientific practice constrains the use of image manipulation software to ensure objectivity.

In Section 6.3, I discuss fieldwork carried out in Canberra during the winter solstice of 2015 when I developed a conceptual framing based on the concept of 'shimmer'. This fieldwork provided an opportunity to develop a series of prints that question the role of noise in our understanding of astrophysical data and which lead on to a discussion of how noise can be considered as inherently interesting rather than an unwanted distraction.

I introduced the notions of noise, signal and artefact in Chapter Five and discussed how instruments allow us to detect increasingly imperceptible signals in an overwhelming sea of noise. Instruments simultaneously provide a source of noise – or instrumental artefacts. These terms are interrogated in greater detail in Section 6.4 in the context of the instruments I deployed and created at the Pole and in regard to IceCube's instrumentation.

In Sections 6.5 and 6.6, I return to the notions of transcription and transduction which were discussed in the context of contemporary art practice in Chapter Four. These terms have proved invaluable not just as a way to categorise and analyse contemporary practice by artists at the interface of science and art but as tools to interpret my own research and to establish adjacencies with the astrophysical research of the IceCube Neutrino Observatory.

Following page – Figure 6.2.1 *Growler #2*. Detail

6.2 Pareidolia

6.2.1 Pareidolia and Objectivity
6.2.2 'Seeing as' and 'Drawing as'.
6.2.3 Software, Pareidolia, and Abstraction.
6.2.4 Fieldwork in the Arctic and Antarctic.
6.2.5 Outcomes.
6.2.6 Conclusion.

In this section I will discuss the conceptual underpinning of the approach to digital image-making that I developed during my research. This approach considers the notions of pareidolia and 'drawing as', and the guidelines for the use of image manipulation software developed by scientific journals to ensure objectivity and reproducibility.

6.2.1 Pareidolia and Objectivity

As I defined it previously, pareidolia is the psychological phenomenon whereby a vague or random stimulus (an image or sound) is perceived as having significant or recognisable form. It is primarily experienced when the background information (visual or auditory) is either minimal or confusingly complicated and difficult to analyse. Once considered a symptom of delusion it is now widely recognised as a normal part of our psychology. Carl Sagan hypothesised that this tendency in humans is an adaption to our complex social life:

> As soon as the infant can see, it recognises faces, and we now know that this skill is hardwired in our brains. Those infants who a million years ago were unable to recognise a face smiled back less, were less likely to win the hearts of their parents, and less likely to prosper.[169]

The ability to quickly recognise faces (friendly or otherwise) or predators in the surrounding undergrowth was an important survival adaption. And presumably, it would have been better to make a false identification of a threat that wasn't there than to not identify a deadly threat that was. Sagan explained pareidolia as an "inadvertent side effect [of] the pattern-recognition machinery in our brains."[170] We have evolved to seek pattern or signal even where there is none. Pareidolia doesn't only apply to imagining faces, it can extend to the tendency to perceive any sort of recognisable pattern in diffuse or complicated backgrounds. This tendency was relevant to the development of scientific objectivity, as pareidolia was one of the idiosyncratic

[169] Carl Sagan, *The Demon Haunted World : Science As a Candle in the Dark* (New York: Random House, 1995), 45.
[170] Sagan, *Haunted World,* 45.

human tendencies that could bias observation and which scientists tried to remove through mechanical objectivity. Pareidolia has particular relevance for astronomy, which is always searching for patterns in fields of complex, confusing and sometimes minimal data. Since pre-history humans have created myths about the grouping of stars into recognisable shapes or constellations and read meaning into subtle patterns seen on the surface of the moon.[171] Even with the development of the telescope, the first astronomers saw the dark patches on the moon as seas (*mare*) imagining a planet similar to our own.

One of the most interesting instances of pareidolia in the history of astronomy is the case of the canals of Mars. In 1877, the Italian astronomer Giovanni Schiaparelli (1835–1910) described and drew detailed maps of a network of straight line markings on the surface of Mars. Schiaparelli and his contemporaries called these *canali*. This was readily translated into English as canals; though it also carries the less loaded meaning of channels or gullies. In the late nineteenth century it was widely believed that Mars was a living planet similar to Earth with seas, seasonal ice caps and greenery.[172] The proposition that these channels might be made by intelligent beings to manage dwindling water resources caught on in the popular imagination and was fed by fantasy authors in the nineteenth century (such as H.G. Wells and Camille Flammarion) and into the twentieth century.[173]

The American astronomer Percival Lowell (1855–1916) perpetuated the belief in the Martian canals into the twentieth century but was essentially the last professional scientist to assert their existence. He was an experienced and well-equipped observer (with his powerful 24-inch refracting telescope located in Flagstaff, Arizona) but his observations were influenced by his beliefs (he read Flammarion in his youth and was inspired by Schiaparelli's observations) and he saw patterns where there were none. In the early decades of the twentieth century with the development of larger telescopes and the use of photography, the notion of canals began to fade as more and more observers disputed the observation. Essentially mechanical objectivity won out over the imaginings of a subjective human observer.

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[171] In the West we see the man in the moon; in Japan the moon is occupied by a rabbit who is pounding rice.

[172] The nineteenth century was also the great age of canal building on Earth – the Eerie Canal was constructed 1817–21, the Suez Canal 1859–1869, and the first attempt at the Panama Canal began in 1881, though it wasn't completed until 1914. So the notion of planet spanning canals didn't seem far-fetched at the time.

[173] In the twentieth century, most famously with Edgar Rice Burroughs' series of novels celebrating the adventures of John Carter of Mars and then, during the golden age of sci-fi in the late 40s and early 50s, with authors such as Robert A. Heinlein and Ray Bradbury.

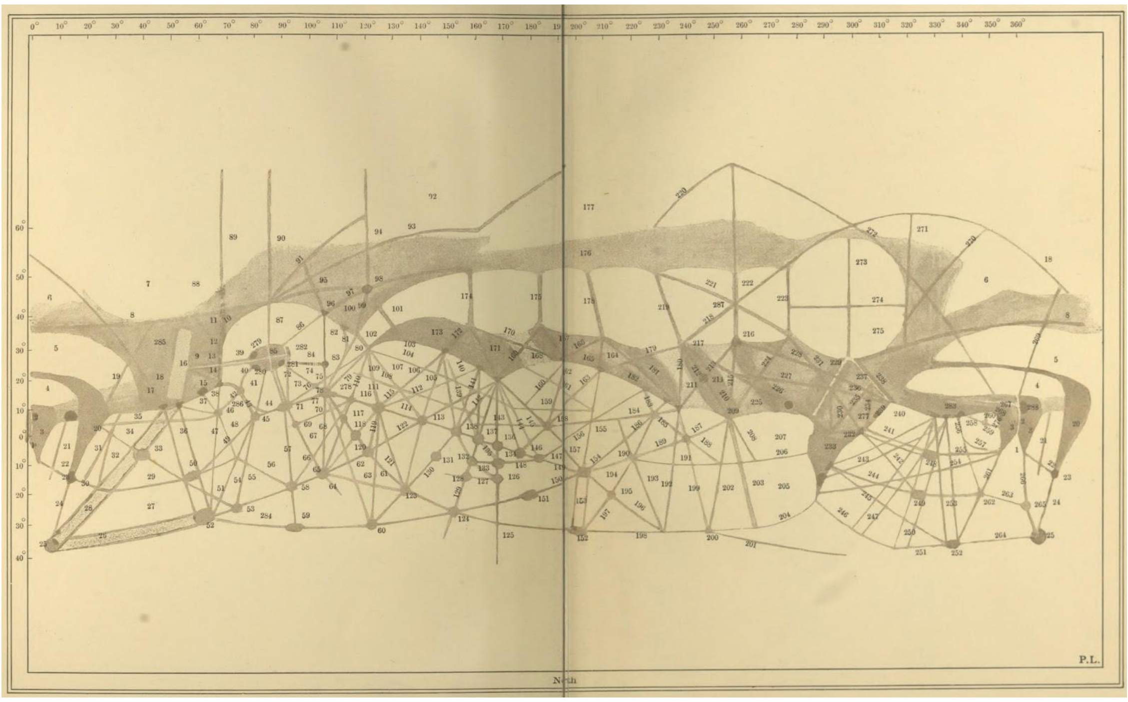

Figure 6.2.2 Map of the canals on Mars drawn by Percival Lowell, 1895.

This aspect of the history of Mars observation might be dismissed simply as wishful thinking or a lively imagination on the part of the observers, but it underlines two important aspects of scientific observation that relate to objectivity, subjectivity and the processes of image making (which is pertinent to both scientists and artists). The first is pareidolia (our predilection to see pattern and signal in fields of noise) and the second is the idea of 'drawing as' (the potential for images to both encapsulate and shape our thinking with regard to new information or environments).

6.2.2 'Seeing as' and 'Drawing as'.

The creation and use of imagery in scientific representation and observation is relevant in any discussion of the common ground between science and art – particularly when many contemporary science images are hailed as art.[174]

[174] Popular scientific literature provides multiple examples. 'Artist's impressions' generally taking pride of place over carefully annotated transductions of original data and there are annual awards for 'artistic' scientific image making. See Mary Beth Griggs, "22 stunning images that turn science into art; The 2017 Wellcome Image Award winners," *Popular Science* (online), March 7, 2017. https://www.popsci.com/2017-wellcome-image-awards#page-2. Accessed October 20, 2018.

In her analysis of historical and contemporary astronomical images, sociologist of science Janet Vertesi observes that "representation in scientific practice is always a question of 'drawing' a natural object 'as' an analytical object; of conflating epistemological and ontological work in the world through purposeful visual construal" and that "such a stance brings the practices of drawing and seeing ever closer together."[175]

An image isn't simply a given or revealed object but a culturally constructed one. Vertesi coined the neologism 'drawing as' to parallel the notion of 'seeing as' proposed by Ludwig Wittgenstein (1889–1951) in the mid-twentieth century.[176] Wittgenstein used the example of 'gestalt figures' such as the duck/rabbit image where one can see the image either 'as' one thing or the other. Even though the image is unchanged, 'seeing as' produces a different observation – as Wittgenstein observed, "quite as if the object had altered before my eyes."[177] Vertesi connects 'seeing as' to one of key epistemic virtues of objectivity, 'theory-laden observation', and proposes 'drawing as' as the practice of 'theory-laden representation' – creating imagery that embodies ways of seeing and ways of thinking and foregrounds the process involved in making the images. [178] To draw also connotes "to pull or guide, to reveal and conceal, to work with and around material objects, to produce new configurations of space and movement."[179] It is a physical and embodied process.

Vertesi cites two examples to make her point. The first is one of the earliest drawings of the moon using a telescope by Galileo Galilei (1564–1642): published in his *Siderius Nuncius* of 1610. Galileo clearly 'drew' the moon 'as' a spherical body with a topographic surface which reflected his Copernican viewpoint as much as what he saw. Galileo's drawings "demonstrate how visual and theoretical insight is produced in and through representational technique."[180]

Vertesi concludes

> Galileo's image of the moon in 1610 was remarkable not only as a singular drawing, but because it clearly showed others a new way of *seeing* the moon *as* a topographical object, and *drawing* it that way ever after.[181]

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[175] Janet Vertesi, "Drawing as: Distinctions and Disambiguation in Digital Images of Mars," in *Representation in Scientific Practice Revisited (Inside Technology)*, edited by Catelijne Coopmans, Janet Vertesi, Michael E. Lynch and Steve Woolgar (Harvard: The MIT Press, 2014), 18.

[176] Janet Vertesi, *Seeing Like a Rover* (Chicago: University of Chicago Press, Kindle Edition, 2015), Kindle Locations 6095-6097.

[177] Ludwig Wittgenstein, *Philosophical Investigations*. 1953. Translated by G. E. M. Anscombe. Reprint, (Oxford: Blackwell Press, 2001),195.

[178] This is an aspect of 'trained judgement' as discussed in Chapter Three.

[179] Vertesi, "Drawing as," 19.

[180] Vertesi, "Drawing as," 18.

[181] Vertesi, "Drawing as," 19.

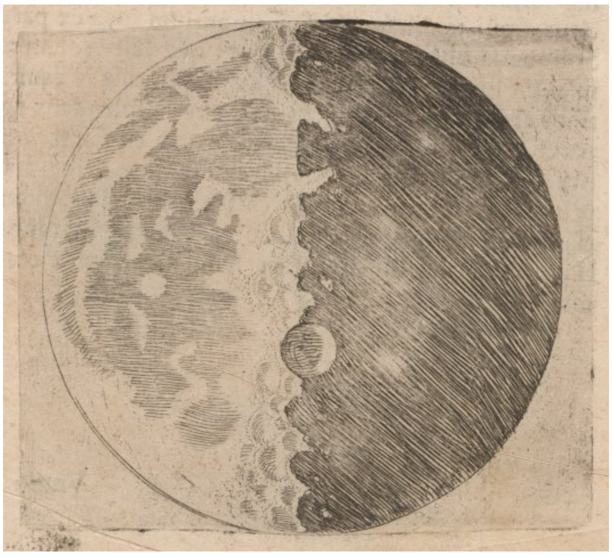

Figure 6.2.3
Sketch of the Moon from *Siderius Nuncius.*
Galileo Galilei.
1610.

Vertesi's second example, drawn from contemporary scientific image analysis, takes us back to Mars. She discusses in detail the work of Susan Lee, a scientist working with the panoramic stereo cameras on NASA's Mars Exploration Rover mission. By using a series of digital filters Lee showed that layers in the regolith exposed by the tires of the Rover were not homogenous – the layers varied in chemical composition and were gradually changing over time. As Vertesi stresses

> this vision of Mars did not come from 'just seeing' the terrain. It was the result of purposeful practices of image construal using image-processing software that drew the soil such that the distinction could be seen.[182]

'Drawing as' highlights the constructed nature of scientific images crafted through image processing. Vertesi concludes that "these actions and interactions compose the image into something meaningful, distinguishing foreground from background and object from artifact."[183] And that the resulting drawings "not only revealed an otherwise invisible phenomenon; they also transformed an observation into a collective vision."[184]

These examples reveal how powerful a tool 'drawing as' can be. But we have also seen how easily images can be selectively manipulated and constructed to lead to false conclusions. Daston and Galison remind us that "objectivity is an epistemic virtue that is not simply manifest on the surface of a published image, but is produced and performed through the methods, morals, and metaphysics associated with that

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[182] Vertesi, "Drawing as," 30.
[183] Vertesi, *Seeing like a Rover,* Kindle location 1534–1538.
[184] Vertesi, "Drawing as," 16.

representation."[185] Accordingly, there is considerable controversy currently in scientific literature regarding the use of photo-manipulation techniques in scientific imagery. Recently editors of leading scientific journals have expressed their concerns about the proliferation of digitally manipulated, aesthetically pleasing images that can be scientifically misleading. Several journals have produced stringent guidelines that require the processes used in image making to be transparent, verifiable and governed by data rather than aesthetic considerations.[186] Social scientist Emma Frow has emphasised that these guidelines "strive to anchor 'surface' representation to underlying data [and] associate image-making practices with ideas about accountability and trust".[187]

Frow's analysis of several leading journals reveals four common editorial guidelines. Firstly, adjustments to an image should be made across the whole image and no global adjustments should be made that mask or remove information present in the original image. This forbids the removal of cosmetic defects (dust specks, etc.) or instrumental artefacts. Secondly, composite images are only acceptable if the various components are clearly delineated and the nature of the composite image is clearly described in the image text. Thirdly, all aspects of the image making process should be detailed. Specifically, "authors should list all image acquisition tools and image processing software packages used, [and] document key image-gathering settings and processing manipulations."[188] And finally, all original data must be retained. These guidelines amount to outlining a repeatable and therefore verifiable methodology – a key aspect of all scientific research. Provided that these guidelines are followed, an image can be improved, enhanced and made more legible by using mathematical algorithms that remove noise from the original image or enhance its legibility (as in the case of Lee's enhancements of the Mars Rover imagery).

Frow quotes Peter Taylor and Emily Blum's observation that

> just as historically the advent of photography promised an escape from the 'fallibility' of drawing, so today the availability of the of computer-generated imagery may be transferring the mantle of trustworthiness from the passive lens and film to the interactive program.[189]

This new form of objectivity, which Anne Beaulieu calls 'digital objectivity' is an augmentation of the mechanical objectivity of instruments and imaging devices by "computer-supported statistical and quantitative apparatus, which provide a further mechanism for validation and for guaranteeing

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[185] Daston and Galison, Quoted in Emma K. Frow, "In Images We Trust? Representation and Objectivity in the Digital Age," in *Representation in Scientific Practice Revisited (Inside Technology)*, edited by Catelijne Coopmans, Janet Vertesi, Michael E. Lynch and Steve Woolgar (Harvard: The MIT Press, 2014), 258.

[186] Frow, "In Images We Trust?," 249.

[187] Frow, "In Images We Trust?," 251.

[188] Frow, "In Images We Trust?," 252.

[189] Taylor and Blum quoted in Frow, "In Images We Trust?," 252.

objectivity."[190] Frow concludes that digital image processing can "contribute to the epistemic ideal of objectivity through the deployment of automated processes that have been mathematically validated."[191] This layering of and reliance upon algorithms has been extended so far that only data that conforms to computational simulations of predicted phenomena is even considered worth examining and evaluating (as is the case with IceCube data).

Frow's guidelines within an artistic context can be considered a 'mode of constraint' – a methodological approach to increasing objectivity and decreasing the subjective agency of the artist. I have brought these principles into my own current research both as a mode of constraint and as a methodology that allows a closer comparison between the images I produce and their analogs in the realm of scientific representation.[192]

6.2.3 Software, Pareidolia, and Abstraction.

Entrusting to algorithms is a key aspect of contemporary scientific image-making.[193] Programs are set up to make decisions and choices independent of the observer. A key question at this juncture is, if the programs have been developed with the sole purpose to recognise pattern in a sea of data will they be as susceptible to pareidolia as a human observer?

The English software developer Phil McCarthy explored this directly by combining random polygon generation software with a facial recognition program.[194] In his program *Pareidoloop*, random grey-scale polygons are layered as the facial recognition program looks for a match. After the first match is 'recognised' the program continues to run for thousands of generations, essentially fine-tuning the image. His program generates recognisable faces from random noise – faces that are recognisable both by us and to the program.[195]

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190 Anne Beaulieu quoted in Frow, "In Images We Trust?," 258.

191 Frow, "In Images We Trust?," 258.

192 See the discussion of *Growlers* later in this section and of the *Nebulae* series of prints in the following section.

193 Consider the colour-enhanced images we see from the surface of Mars transmitted from the Rover – the brightness, the contrast, the colours, the resolution, even way the image is mapped out onto screens or prints are all determined and modified through algorithms.

194 Rebecca Rosen, "Pareidolia: A Bizarre Bug of the Human Mind Emerges in Computers." *The Atlantic* (online). August 7, 2012. https://www.theatlantic.com/technology/archive/2012/08/pareidolia-a-bizarre-bug-of-the-human-mind-emerges-in-computers/260760/. Accessed January 8, 2018.

195 Phil McCarthy's *Pareidoloop* can be run in real-time at http://iobound.com/pareidoloop/.

Although attributing emotional attributes to software programs is inherently anthropomorphic, I find their focus, determination and ability to make guesses and mistakes endearing. We have programmed 'behaviours' into the algorithms and then let them loose with limited tool sets with a human-like unquenchable drive to search for patterns.

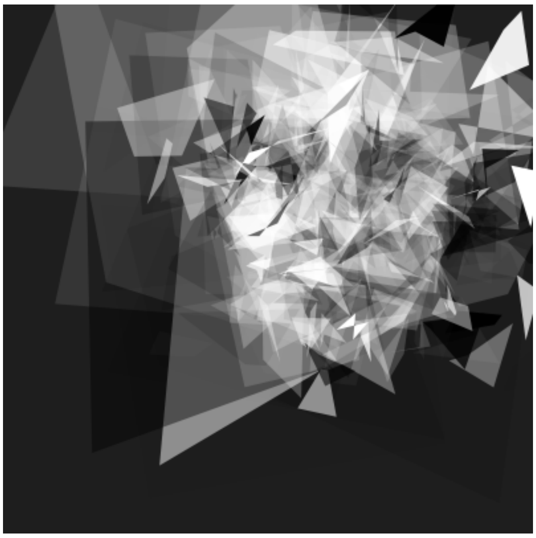

Figure 6.2.4
Pareidoloop output.
Phil McCarthy.
2018.

In my own research I've used more simple image processing algorithms that are not designed to mimic human awareness, but still make 'decisions' based on available data. These algorithms can also be considered as constraints, or sampling systems. One software tool I've worked with extensively is the LiveTrace filter within the Adobe Illustrator software suite. LiveTrace creates a vector mapping of the colour and shade within a visual image. Essentially it makes a topographical map of the colour distribution in the image and draws lines around areas of similar colour and shade. The complexity of the shapes produced, the number of colours distinguished within the image and the resolution of the discrimination of the program are all user determined variables (within constraints). The program makes decisions about where to draw the vector lines and in doing so abstracts the image.[196] The subsequent vector patterns can be enlarged indefinitely without any loss of resolution, unlike bitmapped or pixelated images.

The loss of information and increasing distance from representation resulting from image altering algorithms can be considered a form of abstraction – "an abstraction of the most telling information from the visual field" according to the architect William J. Mitchell.[197] By reducing the complexity of the image and drawing patterns based on its own discrimination LiveTrace works towards encouraging pareidolia. As the complexity is reduced and the image is abstracted through LiveTrace, the tendency for us to fill in the

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[196] Following Frow's precepts I have kept the original images together with detailed records of the global image modifications used to generate my images.
[197] William J. Mitchell, *The Reconfigured Eye* (Harvard: MIT Press, 1992), 109.

blanks, to reach for associations, to imagine, increases. The patterns it creates are remarkably provocative to human observers and it is very easy to imagine representative forms in the patterns.

Throughout the twentieth century artists have consistently followed a trajectory of increasing abstraction – not just visual artists, but artists in every media from literature to sound. Synchronously, the data sets and theoretical constructs that many scientists are working with have become increasingly complex, difficult to interpret and remote from representation – hence abstracted. Algorithmic image modification software is useful to both fields and provides a link between the methodologies of scientific and artistic image-making.

6.2.4 Fieldwork in Arctic and Antarctic.

I have applied these algorithmic image abstracting processes to a variety of subjects over the last ten years.[198] I was interested in applying them to both Arctic and Antarctic landscapes as a fieldwork methodology. As discussed in Chapter Five, both the Arctic and Antarctic have been compared to blank pages. Over the years, through our imagining of and encounters with both Poles, we have written our meanings on them in an act of cultural pareidolia. The isotropic and information poor landscapes of the Poles inspire our imaginations and have reflected our cultural anxieties – from the great unknown at the edge of the world, to the threats of nationalistic territoriality, to the consequences of anthropogenic climate change. To discuss these varied cultural readings of the Poles in detail is beyond the scope of this exegesis but they underlie any contemporary image made of or in these landscapes.[199]

Several contemporary artists have directly pointed to pareidolia in the polar landscape by photographing ice formations which resemble human faces.[200] I've taken a more abstract approach trying to understand and exploit both the physical and psychological basis for pareidolia. I focused on the decreasing information gradient in the polar landscapes and emphasised their illusory quality by applying the LiveTrace algorithm to create images which reflected the isomorphic and fractal nature of the landscape and our tendency to read information into it.

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[198] Including expanses of beach sand, moving water (both in the ocean and in rivers), landscape fragments, found natural materials (rocks, tree bark) and fabricated objects.

[199] There are several excellent analyses of how we have written meanings onto the polar landscapes, including Spufford, *I May be Some Time*; Pyne, *The Ice*; and Fox, *Terra Antarctica*.

[200] See Joyce Cambell's *Ice Ghoul Antarctica* (2006) in Susan Ballard, "Inorganic Life: Frequency, Virtuality and the Sublime in Antarctica," in *Far Field: Digital Culture, Climate Change, and the Poles*, edited by Jane D. Marsching and Andrea Polli (Chicago: University of Chicago Press, 2012), 171.

6.2.5 Outcomes.

The digital print series *Growlers* (Figures 6.2.4 and 6.2.5) was constructed by photographing floating glacier-wall fragments ('growlers') in the Arctic seas of the Svalbard Archipelago. The growlers photographed vary in size from 20 cm to 5 m in length. Each image is scaled so that the smallest element is the same size as the largest – the last remaining ice fragment about to melt away is rendered equivalent to a large chunk just fallen from the glacier face. The true scale of each fragment is made irrelevant. Each image might be of a tiny ice crystal, a 'bergy bit',[201] a tabular iceberg, or even an ice covered island or continent. The image might be taken from a few inches away or from earth orbit. Scale, perspective and location are all called into question as the viewer's imagination is relocated to the isotopic polar regions. The conflation of scales from the global to the local draws our attention to the interconnectedness and fragility of both local and global ecosystems. Each image is minimally treated in Photoshop – colours from the original RAW images are unchanged, only contrast is accentuated slightly to facilitate the operation of LiveTrace. Each image is then modified by applying LiveTrace with fixed set of parameters globally across the whole image and across the entire series of images. Following the precepts outlined by Frow, I have retained the original images together with detailed records of the global image modifications used to generate the final images. The images are minimally altered from the original raw data and the image modification software has been applied globally to create scaleable vector images. Each fractal crystalline form is rendered through an algorithm that creates an image that is itself fractal – that is, self-similar at varied scales. These images provide an opportunity for 'seeing' the image 'as' an abstraction of the isomorphic polar landscape

In another experiment with confounding scale, the glacier front of the Fridtjovbreen glacier on the West Coast of Sptizbergen Island was photographed with multiple exposures from a Zodiac inflatable boat. These images were then stitched together in Photoshop and the glacier front was visually isolated from the surrounding environment. By applying LiveTrace, the artefacts of the original pixelated image are removed and the image becomes scaleable again. Potentially the digital image could be enlarged up to the scale of the original glacier front without loss of data. *Fridtjovbreen (Glacier)* (Figures 6.2.6 and 6.2.7) is printed out as wallpaper and the resulting image dwarfs the viewer. Each time the print is removed, it is destroyed, highlighting the fragility and ephemeral nature of its subject matter.

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[201] A 'bergy bit' is a medium to large fragment of an ice floe or berg 10–30 m^2 in area, while 'growlers' are smaller fragments roughly 2–10 m^2.

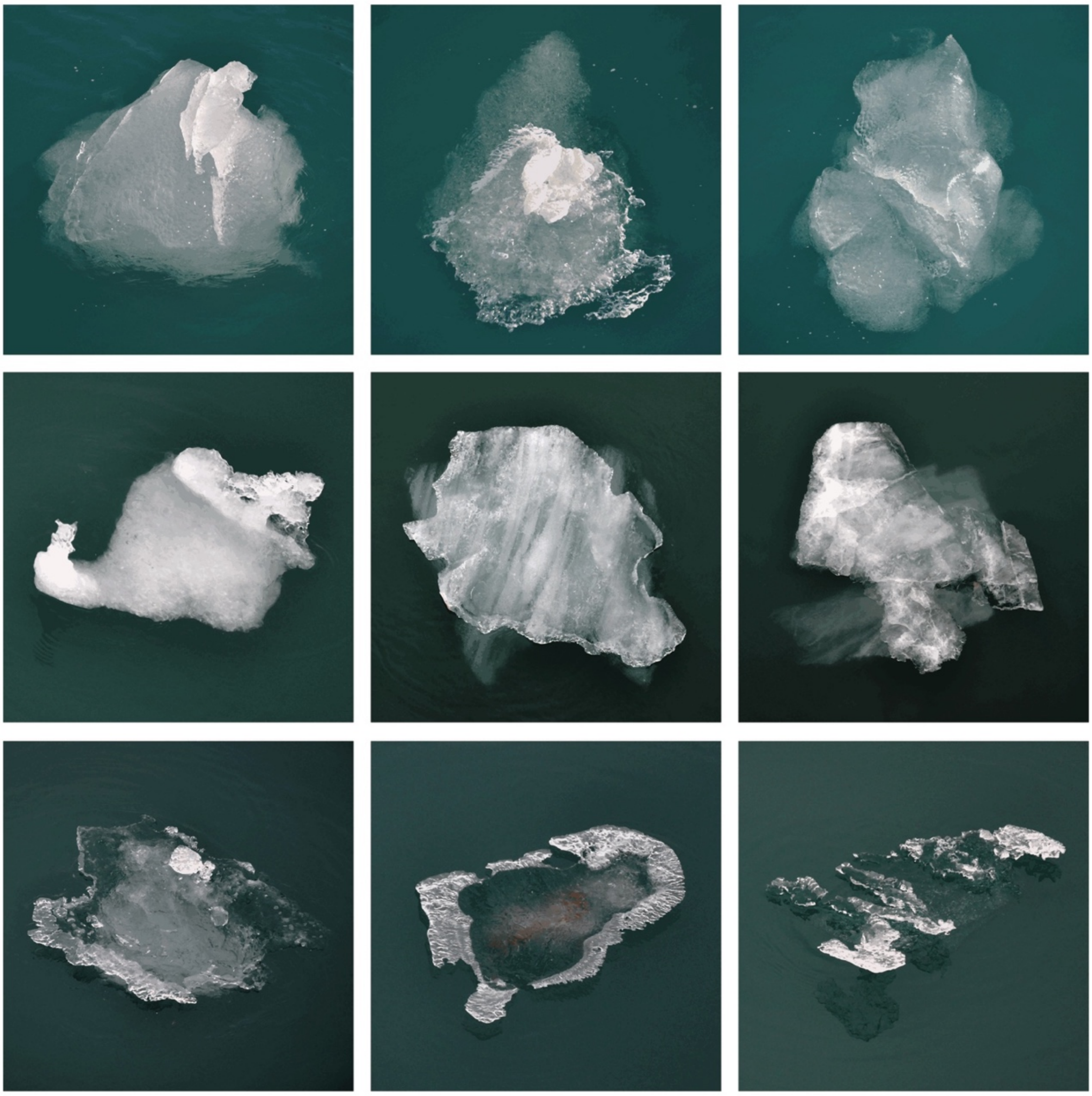

Figure 6.2.5

Growlers (Svalbard Archipelago).

Donald Fortescue. 2015.

Digital pigment prints on paper.

Each image 50 x 50 cm. Overall size of grid 160 x 160 cm.

Figure 6.2.6 *Fridtjovbreen (Glacier)*. Donald Fortescue. 2015. Digital wallpaper**.** 122 x 1500 cm.

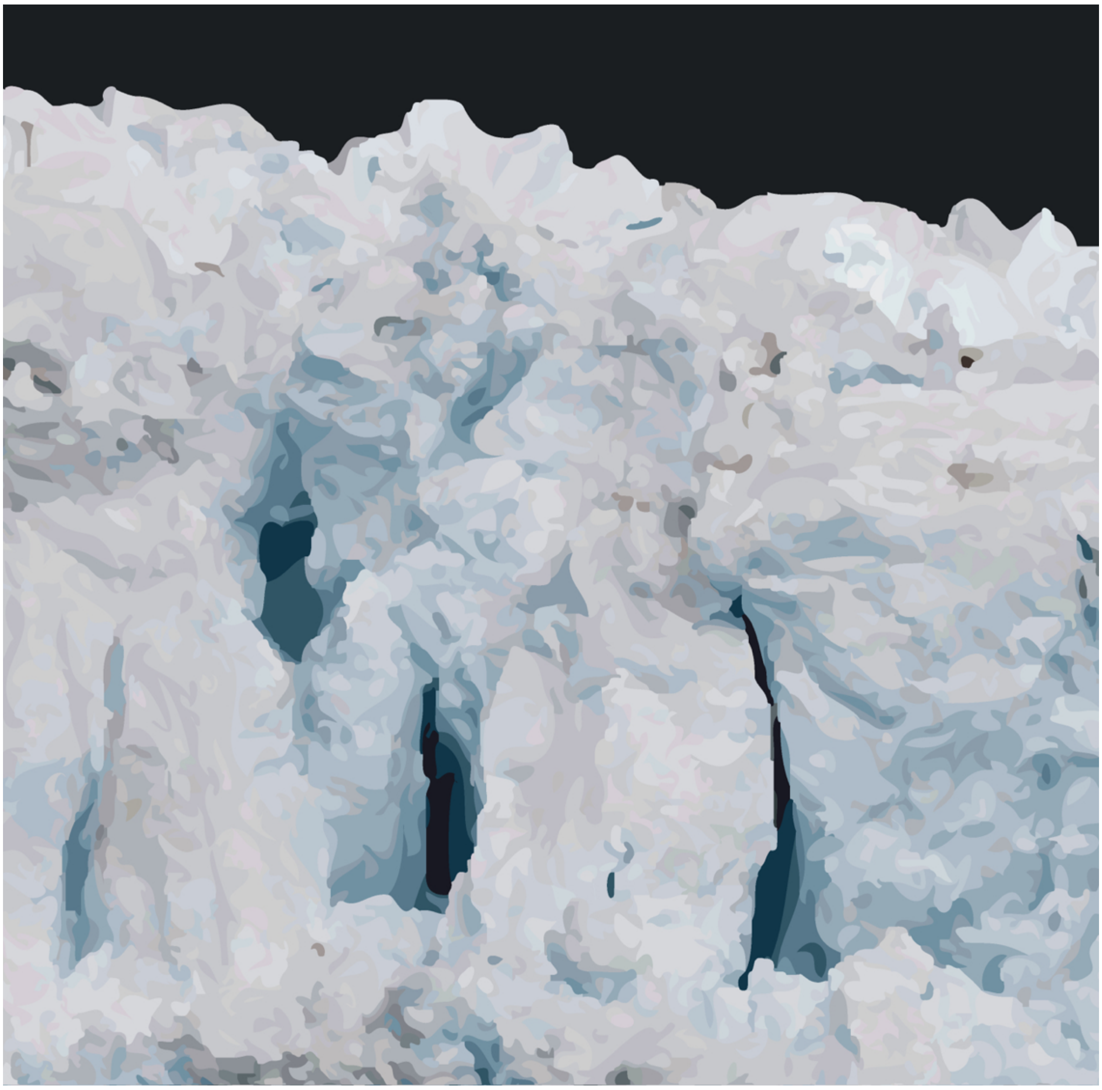

Figure 6.2.7 *Fridtjovbreen (Glacier).* Detail.

Figure 6.2.8 *Sheet.* Donald Fortescue. 2017. Digital pigment print on paper. 106.5 x 106.5 cm.

In *Sheet* (Figure 6.2.9), a late evening view across the still frozen sea ice of McMurdo Sound towards the unsetting mid-summer Antarctic sun was photographed. The ice sheet bears the marks of the last few snowmobiles returning to McMurdo Base prior to the closing of the ice sheet to transportation due to summer melting. The marks on the ice are artefacts of our human presence in Antarctica but can readily be confused with natural fissures in the ice. However, even seemingly natural fissures in the ice might be symptomatic of anthropogenic climate change.[202] Humans leave traces on the landscape even in the most remote locations, both physically and through our imagination.

[202] During my field work the ice was closed to transportation earlier than usual due to aseasonal melting – at least partially attributable to anthropogenic climate change.

6.2.6 Conclusion

In my research I have found LiveTrace image manipulation to be invaluable for the several reasons. It reduces complexity and representation in the modified image, encouraging human imagination to search for associations and meanings. This same reduced complexity and loss of representation resonates with the isotropic and decreasing information gradients of the Arctic and Antarctic landscape where the original images were recorded. The software's limitations act as a constraint system analogous to those developed by the minimalists and so continues the particular trajectory in contemporary art towards increased objectivity and the reduced agency of the artist, as the algorithm restricts the artist's ability to make arbitrary or purely aesthetic decisions.

The image manipulation algorithm extends the 'mechanical objectivity' afforded by the camera into a form of 'digital objectivity', analogous to the process used to create contemporary scientific imagery. The resulting imagery conforms to the guidelines of scientific image making in that minimal changes to the original data were employed (only image resolution and contrast were modified), all transformations were global across the whole image and the processes employed as well as the original data (the photographic image) were archived.

The abstracted landscapes that result have clearly rendered by a software algorithm. I contend that the 'marks' made by the software filter (the vector mapped areas of homogenous colour) are analogous to the marks made by an artist subjectively interpreting (or transcribing and abstracting) the landscape in a painting or drawing. Both sets of marks can be considered as artefacts.

My use of the LiveTrace algorithm simplifies and abstracts the landscape. Scale and context are confounded and pareidolia starts to 'fill in the blanks'. Our tendency to read meaning into these abstracted images is a corollary to how we read the isotropic and 'information poor' landscapes of the Poles. I contend that this process is also connected to the ways in which scientists may read meaning in large complex data sets, where it can be all too easy to see what one expects. These images bring attention to our tendency to read pattern and construct (possibly misleading) meanings in fields of complex (or minimal) data but also allow that these meanings are deeply reflective of our own systems of thought.

Following page – Figure 6.2.9 *Sheet.* Detail.

6.3 Shimmer

> You delve inside the system whilst also maintaining, quickly and restlessly, a reflective vantage on it. You put yourself both inside it and outside it. Although these two modes of cognition are consciously distinct, they need to be occurring almost simultaneously, firing off each other so that you can experience a kind of intelligent shimmer.
>
> Ross Gibson, *The Known World*.[203]

> Content is a glimpse of something, an encounter like a flash.
>
> William de Kooning.[204]

Figure 6.3.1
Lake Burley Griffin looking west, June 21, 2015.[205]

I'm attracted to Gibson's notion of 'intelligent shimmer'. The Oxford English Dictionary defines shimmer simply as "to shine with a tremulous or flickering light; to gleam faintly", but also gives a more obscure second definition of "to move effortlessly; to glide, drift." Gibson implies something much more potent and charged in his usage. For me shimmer is similarly poetically loaded. It implies an energised space charged with potential and yet not quite readily seen or grasped, as if flickering in and out of visibility.

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[203] Ross Gibson, "The Known World," *TEXT (Website Series)* Number 8 (October, 2010), 9.

[204] Quoted in Howard Morphy, "From Dull to Brilliant: The Aesthetics of Spiritual Power among the Yolngu," *Man, New Series* 24, no. 1 (March, 1989), 21.

[205] A 3 minute long exposure taken by Lake Burley Griffin looking west. The Moon and the planets Jupiter and Venus are in a rare close conjunction on the evening of the winter solstice.

The word itself glimmered on the edge of my attention in June 2015 and has come to be a marker for a set of concurrent thoughts, a strategy for work and a series of images. I was in Canberra for a month of intense reading and writing at the Australian National University (ANU) in June 2015. I needed some fieldwork to escape my books and laptop for a while. So on the evening of the winter solstice I took cameras and tripod to the shores of Lake Burley Griffin to observe a rare conjunction of planets in the early evening sky.

When you look out from the earth all sorts of things obscure your view of the cosmos. First there is the limitation of our eyes. We build telescopes and other instruments to magnify our vision and allow us to perceive and record other forms of light that our eyes can't see. Then there's the atmosphere, loaded with moisture and dust, which even on the clearest nights, moves about like the ocean causing the stars to blur and twinkle – to shimmer.

There is a term that astronomers use which is an objective measure of shimmer – 'seeing'. Seeing is a measure of the steadiness and clarity of the atmosphere – a measure of visual noise. The historic Pickering Scale of Seeing was measured on a subjective scale (like Beaufort's scale for wind) from 0–10.[206] Contemporary astrophysicists have developed an instrumentally determined, statistically calculated and objectively quantifiable measure of seeing.[207]

Another useful term from the analog days of visual astronomy is 'averted vision'. Looking directly at a faint object is less productive than looking at it out of the corner of your eye. Due to the distribution of light receiving cones and rods in our eyes, our central vision, while efficient in full daylight, fails in the dark and our more sensitive peripheral vision kicks in to keep us aware of movement and subtle changes in light intensity – such as the glow of a predator's eyes across the savannah. So peering through the telescope is most effective if you don't look directly at your subject.

Glancing indirectly, however, seems antithetical to the penetrating gaze of objective, rational science. To examine their field astronomers crave bigger and better instruments to see finer detail and smaller and dimmer objects. These increasingly sophisticated instruments are designed to reduce noise and boost signal. But everything that's causing the noise is actually vitally important. The air we breathe, the almost unimaginable distances we are trying to cross with our vision and imagination, the incredible length of time that light takes to pass through the universe and the consequence that our vision across space is also a vision back in time. The noise that obscures the signal is, I maintain, a vitally interesting matter.

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[206] The Pickering Scale is named after American astronomer William H. Pickering (1858-1938) who worked for a time alongside Percival Lowell in his Flagstaff observatory.

[207] Measured in arc seconds.

Another aspect of noise is the noise in one's own mind. I have discussed how pareidolia has influenced scientific observation and how scientific objectivity has striven to remove the unreliable and easily distracted observer from data collection. But the thoughts of the observer are also the well-spring of the scientific impulse and shouldn't be so readily overlooked. My mind wandered that night, back in time to my early teenage years, when I would stare for hours through my own handmade telescope. I hadn't been out of doors at night with a camera looking at stars for over 30 years and all I had with me in the field was my camera and a tripod. I needed to focus on what I would focus on with my limited equipment. My lens was hardly even up to the task of catching the phases of the moon let alone the crescent of Venus. I was clearly way behind on the signal to noise stakes. So I decided to focus on the noise.

The light that made the images that I used to create the *Nebula* series of prints, comes from the Moon, Jupiter and Venus, passed through a standard camera lens and captured on my camera's CCD image sensor. The only thing I did to each image was crop, rotate and enlarge. So these are direct images of those bright objects slowly sliding to the horizon on the evening of the Winter Solstice. But between me and those objects lay the Earth's atmosphere. The atmosphere is fundamentally a liquid: light passing through it behaves like light passing through water. Realizing this prompted me to point my camera down into the lake rather than up towards the sky.[208] The images you see (Figure 6.3.2 and Figures 6.3.4 – 6.3.7) are long exposures of planet light reflecting off the surface of the dark lake water. The shimmer arises from an added layer of naturally occurring noise and the element of extended time through long exposure. I included the liquid of the lake as well as the liquid of the atmosphere to boost the noise – to encapsulate even more of the life sustaining biosphere that lies between us and the planets.

The images are hard to pin down and difficult to locate. The nebulous lines traced across a coal-black background conjure images of distant galaxies or star clusters. But close examination reveals that they aren't direct images of those now familiar cosmic objects. They seem almost like smoke caught in a bright light. In some sense, they are: photons caught in a dance as they negotiate complex liquid turbulence. The images shimmer in and out of understanding.

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[208] I was also reflecting on my upcoming fieldwork at the South Pole and the downward looking IceCube array imbedded in long-frozen water.

Figure 6.3.2 *Nebula #1*. Donald Fortescue. 2015. Digital pigment print on aluminium. 102 x 153 cm.

That winter at ANU, my use of the word shimmer generated various ripples and reflections. I was fortunate enough to work with the artist and writer Kim Mahood who referred to 'shimmer' in a lecture at ANU in conjunction with her 2014 Coombs Fellowship.[209] Mahood talked about her fieldwork experience at the Balgo Art Center, where she

> encountered digital photography, acrylic paint and the daily confrontation with the discomforts of the cultural faultline. Together they contributed to a destabilising of my painting practice, tilting me towards forms of experimentation I hadn't imagined, forcing me to think about the elements of Aboriginal art I could legitimately reproduce, and the definitive elements of Western landscape art I could incorporate.[210]

She noted in her field journal:

> Although my own perceptions have undergone all sorts of modifications, I know that the horizon is more than a visual dimension. … The horizon is a fault-line, a fracture line in the consciousness. Horizon and surface, and the numinous zone between them of mirage and reflection, the floating

[209] Kim Mahood, "Keynote Address," at *Post-Grad* Conference, College of Art and Social Sciences (CASS), ANU. Canberra, June 2015.

[210] Mahood, "Keynote Address."

> duplicate image. It is not so much a visual landscape as a place, a pattern, a story. What I can try to replicate from the Aboriginal painting tradition is the visual shimmer, the repetition of motifs.[211]

Here Mahood compares the shimmer at the edge of the horizon, the movement and blurring of reality and reflection, the compressed contrasts of the powerful colours of the dessert, with a "fracture line in consciousness" and a shared and contested line in the sand between aboriginal and white aesthetics and culture. Mahood is striving to establish a territory where she can be true to her own lived experience as well as respectful of traditional culture.

Digging deeper led me to the use of the term shimmer in reference to the aesthetics of central Australian Aboriginal art. The noted Australian anthropologist Howard Morphy coined the term as an English language equivalent to the Yolgnu notion of *bir'yun,* which "is the visual effect of the fine cross-hatched lines that cover the surface of a sacred painting … (that) project(s) a brightness that is seen as emanating from the *wangarr* (Ancestral) beings themselves – this brightness is one of the things that endows the painting with Ancestral power."[212] Morphy credits David Thomson's field studies of the 1930s with the original connection of b*ir'yun* with brilliance or shimmer. *"*Thomson (field notes 5.8.37) writes that the mundane or secular meaning of *bir'yun* refers to intense sources and refractions of light, the sun's rays, and to light sparkling in bubbling fresh water."[213] The power of b*ir'yun* to connect to Ancestral time is also emphasised by Morphy. The shimmer is not just visual and spiritual but in some ways temporal. Ancestral time and lived time are conflated in the artwork and the Yolngu experience of it.

Morphy continues:

> Although the majority of paintings are done in contexts that are only semi-restricted, where they could be observed by anyone who tried to look, people tend to avert their eyes. Hence much of people's experience of painting consists of images fleetingly glimpsed through the corner of their eyes.[214]

So averted vision has a corollary in Yolngu culture. By not looking directly at the artwork, its true nature can be more clearly discerned. Morphy is clear in his distinction between the cultural effects of shimmer in artworks from different traditions, but he also argues that shimmer can act cross-culturally due to its inherent "neuro-physiological" effects. I contend that the more metaphorical aspects of shimmer also extend across cultures – the power inherent in activating art objects visually, connecting the effects of human mark making

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[211] Mahood, "Keynote Address."

[212] Howard Morphy, "From Dull to Brilliant: The Aesthetics of Spiritual Power among the Yolngu," *Man, New Series* 24, no. 1 (March, 1989), 28.

[213] Morphy, "From Dull to Brilliant," 28.

[214] Morphy, "From Dull to Brilliant," 26.

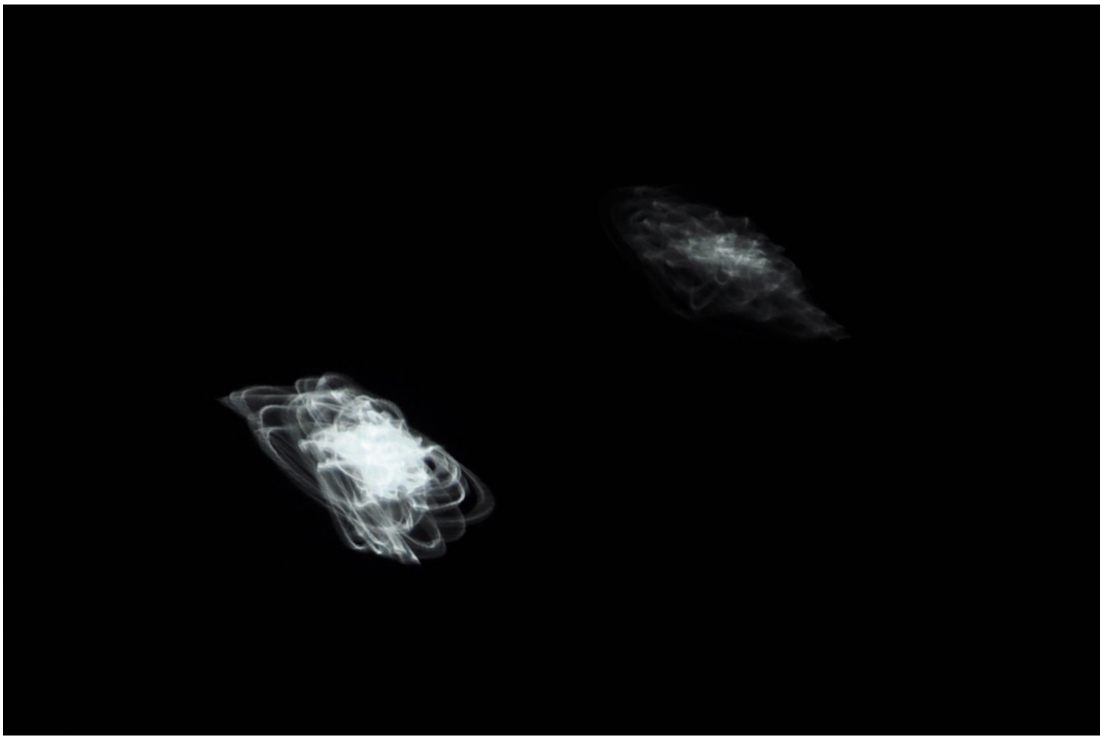
and our perception of reflected and refracted light, the value of not looking at something directly but with averted vision to be able to more fully experience it, and finally the significance of shimmer as a conflation of distant and present time. Shimmer is a wonderfully complex notion that elides visual, physical and the cultural meanings and allows them to flicker in and out of focus.

The notion of shimmer provides perspective on my own images. Lines engraved on flat planes have the latency (empowered by human culture) to conjure energy, memory, time, myth and joy. The abstraction generated by noise, the shimmer as we lose close focus on something, as it drifts in and out of our attention (and time), is what permits our imagination to enter and metaphor and meaning to arise.

Figure 6.3.3
Garak IV (The Universe).
Gulumbu Yunupingu. 2004.
Natural earth pigments and binder on eucalyptus bark.
146 x 54 cm.

Figure 6.3.4
Nebula #3.
Donald Fortescue. 2015.
Digital pigment print on aluminium.
102 x 153 cm.

Figure 6.3.5
Nebula #5.
Donald Fortescue. 2015.
Digital pigment print on aluminium.
102 x 153 cm.



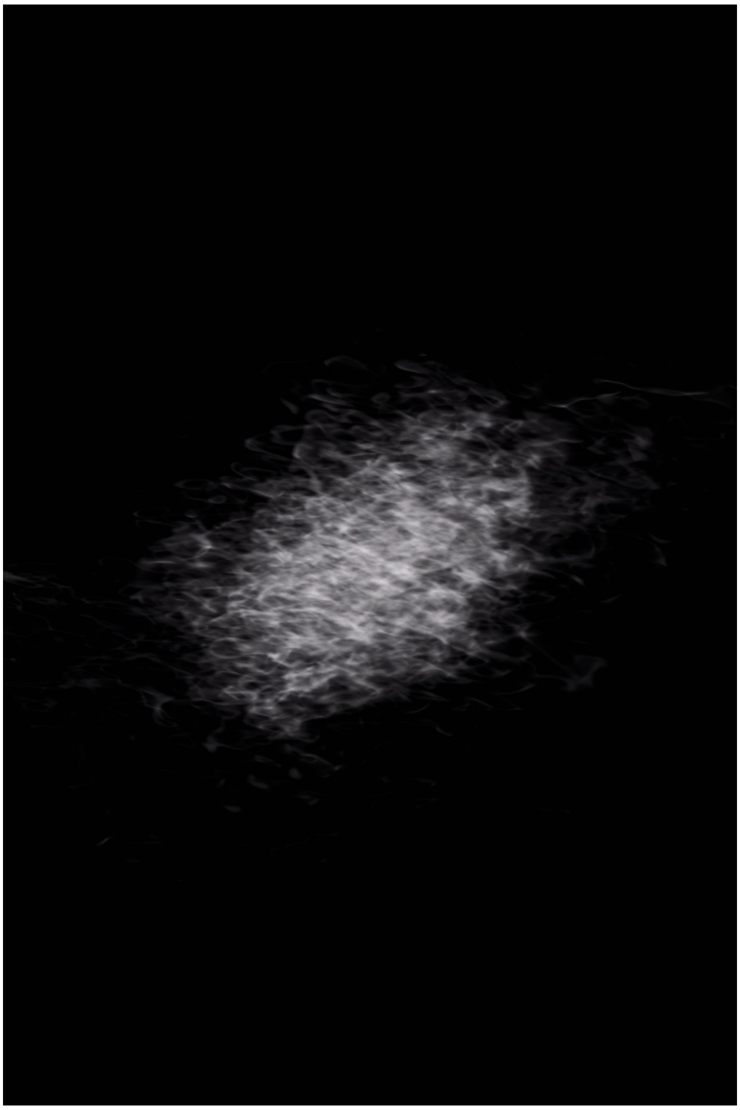
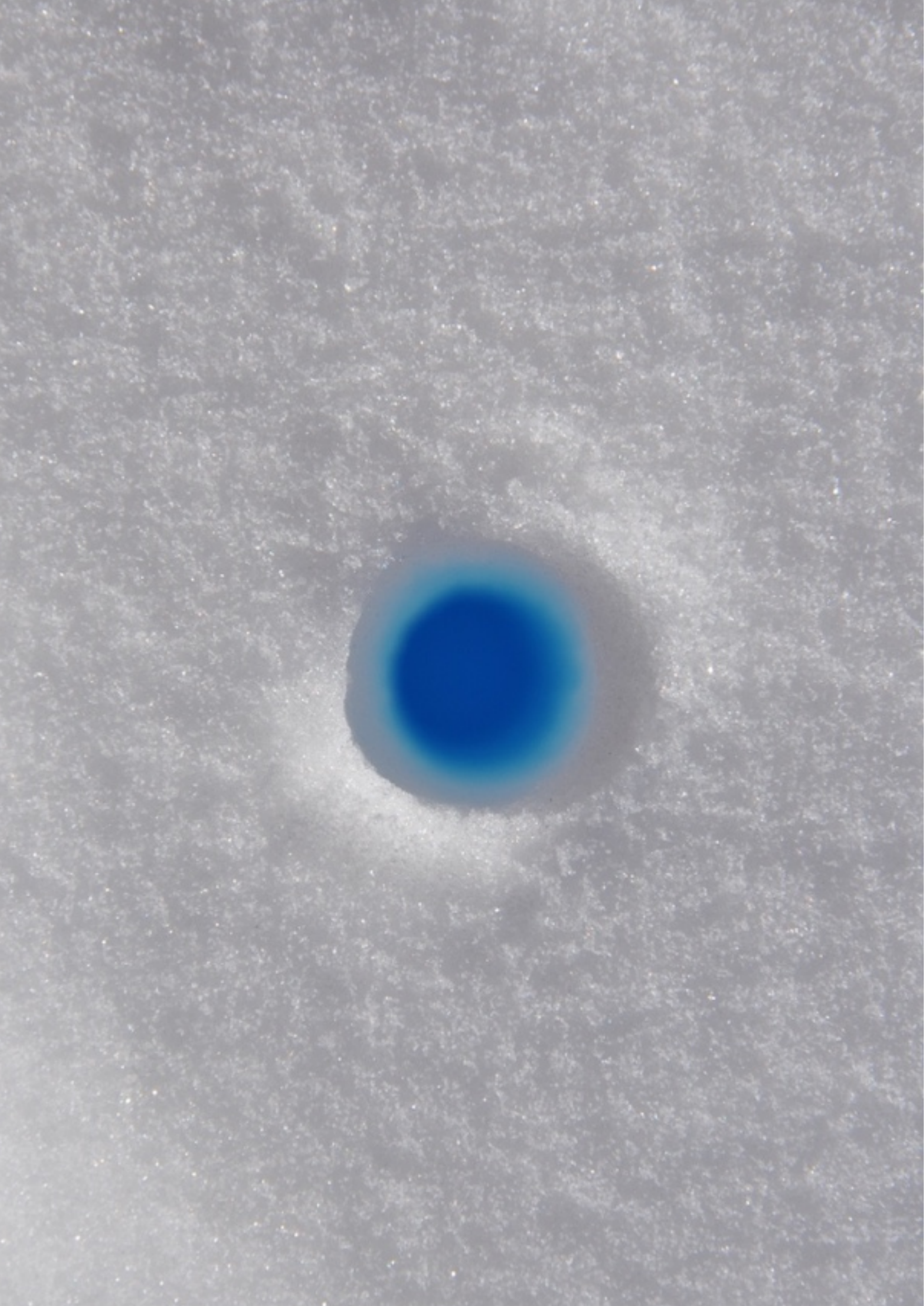


Figure 6.3.6
Nebula #4.
Donald Fortescue. 2015.
Digital pigment print on aluminium.
102 x 153 cm.

Figure 6.3.7
Nebula #2.
Donald Fortescue. 2015.
Digital pigment print on aluminium.
102 x 153 cm.



6.4 Transcription

In this section I will discuss three different projects that were undertaken during my fieldwork at the Amundsen-Scott South Pole Station in the austral summer of 2016/17. Each project fits within the rubric of 'transcription'.

6.4.1 Imperfect Instruments

The notions of artefact, noise and signal have been explored in some detail. I emphasised that scientists seek to extract signal from noise by constantly improving the design of their instruments and by modeling physical systems to anticipate expected data so as to be able to distinguish signal from noise. Instruments are the key to this endeavour and they are continually being redesigned and refined to detect and resolve increasingly subtle signals.

I explained the complex process of locating, building and then using the IceCube array buried deep in the polar ice. During my fieldwork, I had opportunity to discuss the other major instruments deployed at the Pole with the scientists who were hard at work in the short summer season to modify and enhance the sensitivity and accuracy of their equipment. Every summer season scientists and postdocs from around the world fly into Amundsen-Scott South Pole Station with pallet-loads of sensitive equipment and laptops packed with code to add extra sensitivity and new levels of processing to their instruments. Years of research (and successfully completed doctorates) are reliant on the design, deployment and interpretation of the results from new instruments or improvements and add-ons to existing instruments. My fieldwork at the South Pole paralleled these efforts (and anxieties).

A unique feature of the IceCube array is that its detectors are buried deep in the Polar Ice. They are frozen in both place and time. Like satellites launched into deep space, they cannot be replaced with new sensors nor can their hardware be updated. Only the software that processes the incoming signals can be tweaked and improved.

Previous page – Figure 6.4.1 Scattered blue light visible in holes poked into compacted snow at the South Pole.

The IceCube Observatory however, is not just the Digital Optical Modules (DOMs) and the accompanying technology imbedded in and stationed above the ice, the Polar Ice itself is an integral part of the instrument. A cubic kilometre of natural material forms an integral part of a very sophisticated, expensive and sensitive scientific instrument. The ice is the actual detector – the DOMs just allow us to catch the signal. This use of the natural landscape as an integral part of a technological instrument is one of the most intriguing qualities of IceCube.

Previous neutrino detectors used immense artificial tanks of water buried deep in mines as their detectors.[215] More recent detectors have incorporated large natural volumes of water to detect neutrino fluxes.[216] The British artist Jol Thomson has described these very large-scale detector assemblages as located within vast "laboratory landscapes" and notes that in such

> post-human sensory assemblages … technology becomes planetary body and, amongst other things, this transmutation complicates traditional longstanding binaries between, for example, technology and nature.[217]

He concludes that

> human and non-human relationships between landscape, technology, elements, and the cosmos explicitly coalesce at these sites into palpable philosophical engagements with scale, ecology, agency, and even ethics.[218]

IceCube represents the most extreme example in contemporary experimental science of the hybridisation of natural and technological components in one instrument. The vast majority of telescopes, including other instruments deployed at the South Pole, have lenses and detectors which are crafted from exceedingly refined elements with the highest possible machining tolerances. In contrast the IceCube Observatory uses a cubic kilometre of natural ice as its lens and the entire planet Earth as a filter to block out cosmic rays.

The extraordinary thing about the deep polar ice is that it's the clearest natural material we know – almost 3 times clearer than the purest water we can make.[219] But it is still a natural material, accumulated from drifting ice crystals, compressed into ice over tens of thousands of years and slowly sliding towards the

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215 Such as Super-Kamiokande in Japan and the Sudbury Neutrino Observatory (SNO) in Canada.

216 Examples include KM3NeT in the Mediterranean Ocean and the Gigaton Volume Detector (GVD) in Lake Baikal. For a detailed overview of these and other extreme instruments see Ananthaswamy, *The Edge of Physics.*

217 Jol Thomson, "Phase Velocity & F-T-L in the G.V.D.," in *The Live Creature and Ethereal Things*, eds. Fiona Crisp and Nicola Triscott (London: Arts Catalyst, 2018), 78.

218 Thomson, "Phase Velocity," 78.

219 Francis Halzen, "IceCube and the Discovery of High-Energy Cosmic Neutrinos," presentation at the 2015 APS Meeting, April 2015. https://www.youtube.com/watch?v=Em_2HqIlr64. Accessed May 4, 2018.

Weddell Sea by about 10 metres every year. The natural mass of polar ice incorporated into the technological-natural hybrid instrument of IceCube varies in density and transparency due to its long history of accumulation and is imprinted with the history of changing global environmental conditions over that time period. It incorporates layers of dust blown onto Antarctica from South America tens of thousands of years ago at the peak of aridity accompanying the last glacial maximum.[220] Mapping the density, transparency and variation of the ice incorporated in the detector has been an important aspect of quantifying and analyzing the noise in the instrument. These material inconsistencies are considered instrumental artefacts by the scientists (despite their natural origins), but they are also evidence of the global climate over tens of millennia. As I found in developing my *Nebula* series of prints, the noise is actually very interesting.

Figure 6.4.2
Swedish camera image from the lower end of an IceCube string.

Drilling 86 deep holes into the ice to accommodate the strings of DOMs has also complicated the picture. When the holes that were drilled for the IceCube array were filled with water, the ice reformed under minimal pressure. Consequently, it's like normal ice, full of bubbles and inclusions. On two of the lowest DOMs in the array are mounted digital cameras looking up into the ice – the so called Swedish cameras. They are operated for a very short time each year to examine the slowly clarifying ice.[221] Figure 6.4.2 is an image that my collaborators and I took during my fieldwork using one of the Swedish cameras looking upward into the ice core that has refrozen around the string lowered into the Polar Ice. You can see that it's pitch black looking out into the ice, but that above the DOM, it's cloudy – this is the blurry tube of fresh ice rising above the DOM. So the lens of IceCube is cloudy on a local scale due to flaws in its manufacture.

220 AMANDA collaboration, "On the age vs depth and optical clarity of deep ice at South Pole," January 23, 1995. arXiv:astro-ph/9501072v2.

221 The entire IceCube array must be temporarily taken off-line as the flash lights required for the cameras would overwhelm the sensitive DOMs. The scientists resent the instrument being off-line even for a moment.

One of the first projects I undertook on arrival at the Pole was the construction of a series of ice lenses that were also flawed or 'noisy' due to the conditions of their creation. Each ice lens was formed by filling the void between two watch glasses with water (supplied from South Pole Station's current water source or 'Rodwell', located about 100 metres deep in the ice).[222] This water froze in about 2 hours when left outside. I then had limited time to use the lenses before the warmth of my hand melted the lenses or the numbness in my fingers made the task impractical. Grasping these lenses in my bare hands enabled a haptic appreciation of the unique conditions of the Pole. One reason that the instruments probing the Cosmic Microwave Background (CMB) radiation are located at the Pole is to reduce the influence of heat noise – these instruments must be supercooled to fractions of a degree above absolute zero to distinguish the tiny signals from background noise. The *Ice Lenses* also were also rendered useless by excess heat – from my body in their case.

Field work in both science and art always requires improvisation and utilisation of local resources – spontaneous, creative action in response to challenging physical conditions. This can be considered a 'constraint' in the sense that I discussed in Chapter Four. In the field, both scientists and artists have limited time and resources available to attain valid data and meaningful outcomes. The *Ice Lenses* were not planned for in my initial proposals but emerged readily from my deepening understanding of the structure, operation and constraints of the IceCube Observatory. Field improvisation precipitates (or constrains) unique types of action which arise from a developing understanding of the essentials of a particular site.

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[222] The Rodwells of the Amundsen Scott Base are a fascinating aspect of life at the Pole. Fresh water is released from deep in the ice by drilling down about 80 metres into pure ice that was deposited approximately 2000 years ago. This ice is then melted by pumping in hot water. The liquid water is then extracted and used for all water needs on the base – the so called 'Jesus water' named for its age. The void left from the previous Rodwell is filled in with human waste from the base creating a gigantic frozen 'poopsicle' which will move slowly towards the Weddell Sea over the next 10,000 years or so. A lasting record of our human presence in Antarctica. Bill Spindler, "Down the hole – Rodwell adventure videos". http://www.southpolestation.com/trivia/rodwell/rodwell.html. Accessed January 30, 2016.

Figure 6.4.3 *Ice Lenses*. Donald Fortescue. 2017. Digital pigment print on paper. 69 x 160 cm.

6.4.2 Indexical Transcriptions – *Heliographs*

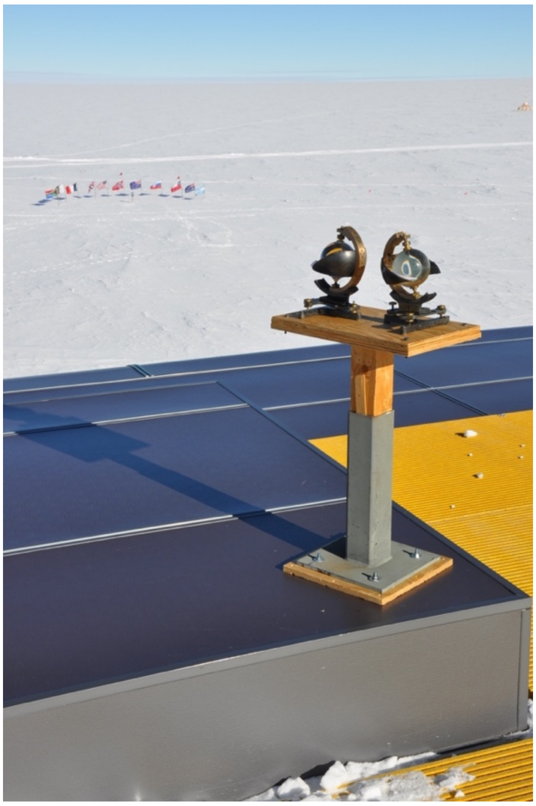

Figure 6.4.4

Paired Campbell-Stokes heliographs deployed atop the Amundsen-Scott South Pole Station.

Another sun-focusing, lens-based apparatus that I constructed to deploy at the Pole was inspired by a strangely anachronistic analog instrument still actively in use at the Pole – the Campbell-Stokes heliograph.[223] It is practically the only analog scientific instrument still in use at the Pole today. It records the brightness of the sun on strips of paper that must be collected and catalogued every 24 hours. The spherical lens of the heliograph focuses the sun onto the mounted paper strips and burns a mark into the paper. The resulting burn mark encodes the intensity of the sunlight. The paper strips collected at the Pole are stockpiled and sent back to the USA several times every year.[224] Discussion with the resident meteorologists revealed that the data record from the heliographs is one of the longest continuous scientific records from the Pole and is maintained primarily for that reason. Equivalent and more reliable (i.e. less noisy) data is continuously being recorded on digital devices as well. By correlating this data with the analog data from the heliographs the solar intensity record can be extrapolated back to the middle of the twentieth century when the heliographs were first deployed at the Pole.

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[223] First developed in the 1860s.

[224] Practically all other forms of data recorded at the Pole are transmitted digitally via satellite or shipped back to labs on hard drives.

The continued use of this analog recorder and the indexical nature of the paper records was very intriguing to me to me. I decided to create my own abstracted version of the heliograph to take with me to Antarctica and deploy at the Pole in conjunction with the existing Campbell-Stokes heliographs. For my apparatus, I drew inspiration from Campbell's original prototype in the collection of the Greenwich Observatory.

Figure 6.4.5
Sunshine recorder made by
Mr. J. F. Campbell.[225]

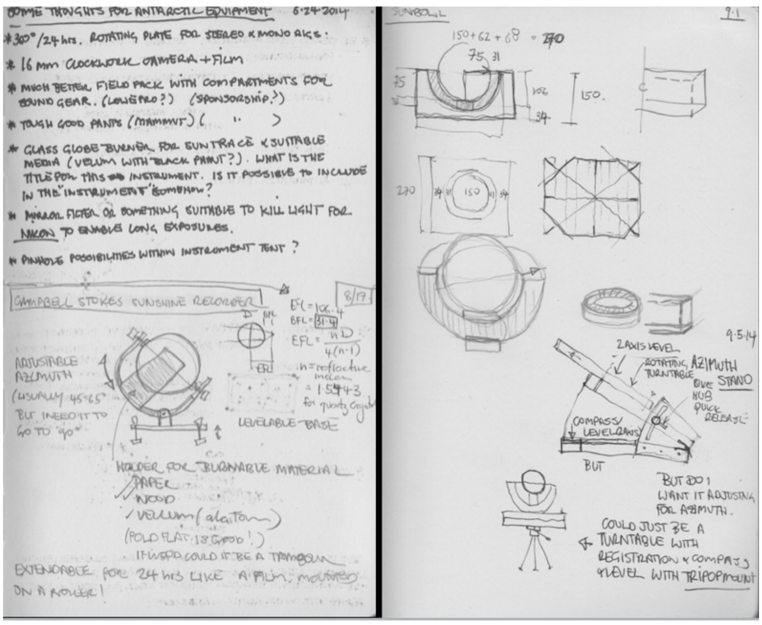

Figure 6.4.6
Sketchbook images showing the development of my *Heliographs*.

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225 The inscription around the rim reads: "HORAS NON NUMERO NISI SERENAS", which translates as "I count only the sunny hours". http://collections.rmg.co.uk/collections/objects/10932.html. Accessed May 13, 2016.

Figure 6.4.7

A pair of my *Heliographs* deployed on the roof of the Scott-Amundsen base.

Figure 6.4.8

The sun's path being recorded by a *Heliograph*.

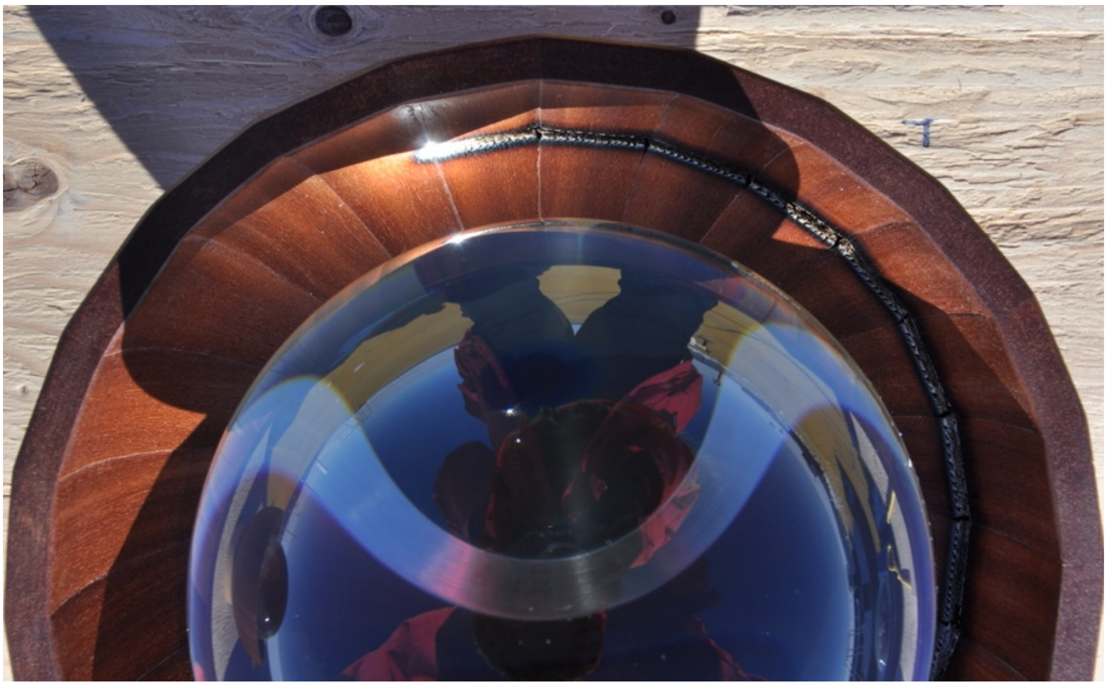

Figure 6.4.9 Two of four *Heliographs* exposed at the Pole. Left – December 25, 2016. Right – December 26, 2016.

Each *Heliograph* creates a transcription of the sun's passage. As the sun doesn't rise or set in the summer, it burns a closed circular path inside the *Heliograph* over a 24-hour period. The *Heliographs* conform to a precise geometry so that the sun's light and heat is focused to a point – much like a camera body does for its attached lens.[226] The burn is an artefact of the lenses operation with its own unique characteristics. There are 24 segments in each *Heliograph* and so it takes an hour for the sun to cross each segment.

The *Heliograph* is at once a camera, a timepiece, a photographic plate and an inverted model of the sky. The use of burning places the *Heliographs* within the long tradition of using the sun in mark-making transcriptions developed by contemporary artists.

The *Heliographs* share an indexicality with both the half century of records from the Campbell-Stokes instruments at the Pole and the photographic records created at the Pole stretching back to the first images recorded by Roald Amundsen and his team in 1911. The British photographer Fiona Crisp has cited indexicality as an important goal for contemporary art practice carried out in conjunction with particle and astrophysics to enable a "haptic relation to fundamental physics".[227]

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[226] The diameter of the spherical glass lens determines the focal distance between the lens and the inner surface of the *Heliograph*, and the anticipated strength of the sun's heat at the Pole combined with the burning properties of the laminated mahogany of the *Heliograph* determined their optimal wall thickness.

[227] Fiona Crisp, "Material Sight," in *The Live Creature and Ethereal Things*, eds. Fiona Crisp and Nicola Triscott (London: Arts Catalyst, 2018), 25.

Crisp points out that

> the science being performed [in these remote locations] is abstract, imperceptible and often lies beyond the lay public's cognitive and imaginative grasp. The scales, distances and time-frames that fundamental physics and cosmology trade in, from the sub-atomic to the multiverse, cause a kind of vertigo when we try and scale them against the measure of our bodies or the range of our perceptual senses.[228]

Crisp goes on to question if we can make science 'intimate'. Her solution has to been to photo-document these remote and inaccessible sites where science is 'performed' with the hope that the indexicality of her images engenders a physical connection for audiences. I am not convinced by Crisp's analysis. Traditional photographs are indexical by their nature, and arguably even digitally rendered images have inherited this capacity to help viewers feel that they were present when the image was created. However, with the widespread use of digitally modified imagery our inherent trust in the veracity of imagery is deeply eroded.[229]

Sculptural approaches can reinvigorate the indexical and present viewers with fresh avenues for embodied experience. The indexicality of the *Heliographs* is paired with the added sensory experience of the warmth of the wooden forms and the lingering, residual smell of burning. The perpetual rotation of the sun above the South Pole is transcribed into the *Heliographs* and the heat of burning feels freshly rendered.

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[228] Crisp, "Material Sight," 25.

[229] The challenge of the veracity of both scientific and artistic imagery is discussed in detail in Chapters Three and Four.

6.4.4 *Anamorphic Projection*

Figure 6.4.10 Roald Amundsen and team with the *Polheim*. December 17, 1911.

Figure 6.4.10 shows Roald Amundsen and his team with the *Polheim* – the marker that Amundsen left at the Pole to record the first human arrival there in late 1911. He knew that Robert Falcon Scott was close on his heels. He wanted to ensure that his precedence was unquestioned and to leave a request that Scott communicate Amundsen's victory to the wider world in the case that Amundsen and his party perished on their return trip.[230] But Amundsen faced a problem, how could he be sure that he was actually at the Pole?[231] The lines of longitude converge at the Pole and the way to determine your location in those pre-GPS days was to read your latitude using a theodolite. However Amundsen's theodolite had been damaged during his trek from the Antarctic coast, requiring him to use a sextant instead. The sextant is an instrument designed to work at sea where a level horizon is always available. In using the sextant, the angle of the sun above the horizon is determined by physically moving a small mirror attached to a graduated scale so that the reflection of the sun is superimposed on the horizon.[232] This process is called 'drawing down the sun'.[233] However, the South Pole is over 3,000 metres above sea level and though the terrain is fairly flat, it isn't

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[230] I will discuss the *Polheim* and its significance both culturally and for this body of research in the next chapter.

[231] Amundsen performed a series of careful observations and calculations (with pencil, paper and slide rule in a cold and crowded tent over a smoky paraffin stove) to determine the location of the Pole. He knew his reading had a wide margin of error so he had his men pace out 20 km in each direction and leave markers to ensure that he had 'boxed' the Pole, and that there could be no doubt as to his precedence to the Pole. Roland Huntford, *The Last Place on Earth* (New York: Modern Library, 1999).

[232] http://www.idea2ic.com/Manuals/YOUR%20POSITION%20WITH%20A%20SEXTANT%20.pdf. Accessed May 13, 2018.

[233] This evocative term reminds me of those artists who have transcribed the heavens onto the surface of the earth as discussed in detail in Chapter Four.

actually level and it can't be relied on to provide a true horizon. Amundsen had the foresight to bring a container of mercury which he poured into a bowl to create a false horizon so that he could 'draw down the sun'.

Figure 6.4.11 Roald Amundsen staging his latitude reading at the Pole.[234]

Amundsen's use of the liquid metallic reflective surface to construct a virtual horizon provided the inspiration for me to develop an anamorphic mirror to capture the entire polar sky from one vantage point. I initially proposed taking a flask of mercury for this purpose but was quickly informed that transporting the poisonous metal would prove challenging under contemporary airfreight restrictions. Instead I fabricated a stainless steel conical anamorphic mirror which was designed to capture a large portion of the polar sky (including the ecliptic) so that the passage of the sun would be recorded. A GoPro camera was mounted at the precise focal distance from the mirror to make timelapse recordings over several full 24-hour periods.

[234] This image shows Amundsen using a small bowl of mercury as an artificial horizon..

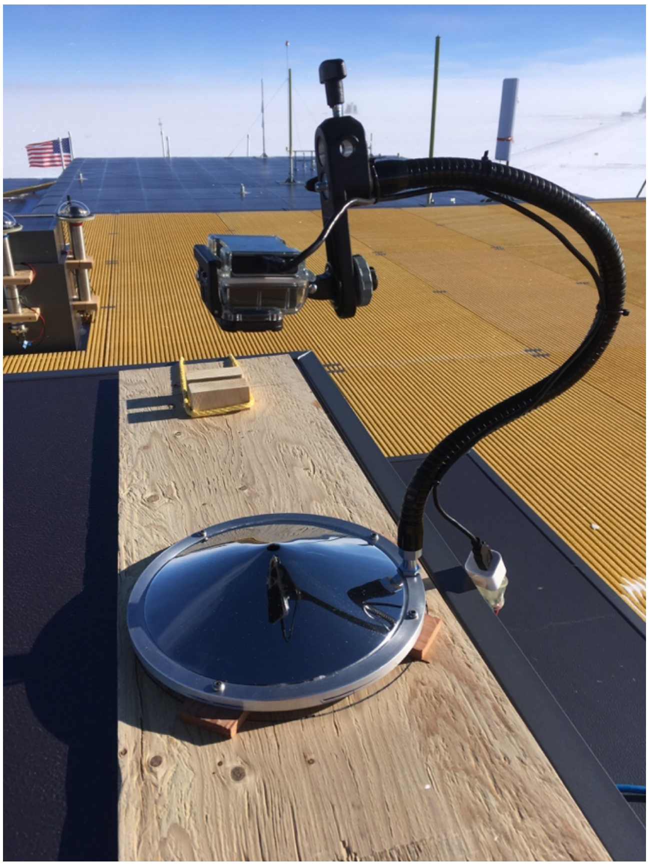

Figure 6.4.12
Anamorphic GoPro rig set up on the roof of the Amundsen-Scott South Pole Station showing the conical stainless steel anamorphic mirror.

My initial intention was to project the resulting anamorphic timelapse movies onto the surface of the *Instrument.*[235] However, I decided after some experimentation that this would overly complicate a viewer's experience of the *Instrument.* Instead, I have designed a viewing apparatus (or instrument) that employs the same anamorphic mirror (see Figure 6.4.12) used in recording at the Pole as a projection lens. The geometry of the viewing apparatus reproduces the geometry of the recording device and 'corrects' the anamorphic distortion as it projects onto a cylindrical screen. In a manner analogous to the *Heliographs*, the anamorphic projector becomes a model of the local cosmos and the cylindrical screen carries a transcription of the ecliptic plane and the sun's transit across it.

[235] The *Instrument* will be discussed in detail in the next Section.

6.4.3 Conclusion

Several interesting aspects of my fieldwork in the Antarctic, and fieldwork in general, have been revealed through these three connected projects. The *Ice Lenses* were not pre-planned in any way, they were an improvisation based on the peculiar local conditions and my deepening understanding of the nature of IceCube.[236] The *Heliographs* were planned from early on. They were inspired by my research into the science conducted at the Pole and my long-standing interest in the history of scientific instruments. Their geometry was carefully configured for the Polar conditions and a successful outcome was expected.[237] The mirror and timelapse rig for the *Anamorphic Projection* were also built in advance and designed with the geometry of the sun's movement at the Pole in mind. I was anticipating using the resulting imagery in one way but changed my mind as the project developed and other outcomes of my Polar research came to fruition. These three modes – expected outcomes realised, spontaneous improvisations revealing emerging understanding and valid data still under ongoing consideration – are intrinsic to fieldwork in both science and art.

Each of these three projects entail instruments and involve transcription.[238] They are physical objects created for and by the particular conditions of my chosen fieldwork site. Each records the presence and apparent movement (and associated properties) of the sun around the South Pole at mid-summer. As sculptural objects (or photographic records of physical actions) they are indexical of the physical conditions at the Pole and re-present these as haptic experiences for viewers.

These sculptural instruments delineate a common ground between scientific and artistic approaches to fieldwork by providing conceptual connections and physical corollaries to scientific instruments currently deployed at the Pole. The *Ice Lenses* engage with the physical conditions of the Pole and draw on one of the defining characteristics of IceCube by using natural ice as a medium. The *Heliographs* reflect on the history of analog instruments deployed at the Pole, particularly the remaining relict heliographs still in use, while contributing to the contemporary artistic body of work harnessing transcriptive solar burning. And the *Anamorphic Projection* utilises the recording instrument as a playback instrument and reconstructs both the celestial geometry and the disorienting experience of perpetual summer sunshine at the Pole.

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[236] I had borrowed some watch glasses from McMurdo Station thinking that they might prove useful but I didn't anticipate how.

[237] The one doubt in my mind was that the low temperatures at the Pole might inhibit the extent of the burning. But this doubt was eliminated as soon as I set the *Heliographs* up and the powerful high-altitude sun started to scorch the pieces.

[238] In the sense that I have defined in Chapter Four.

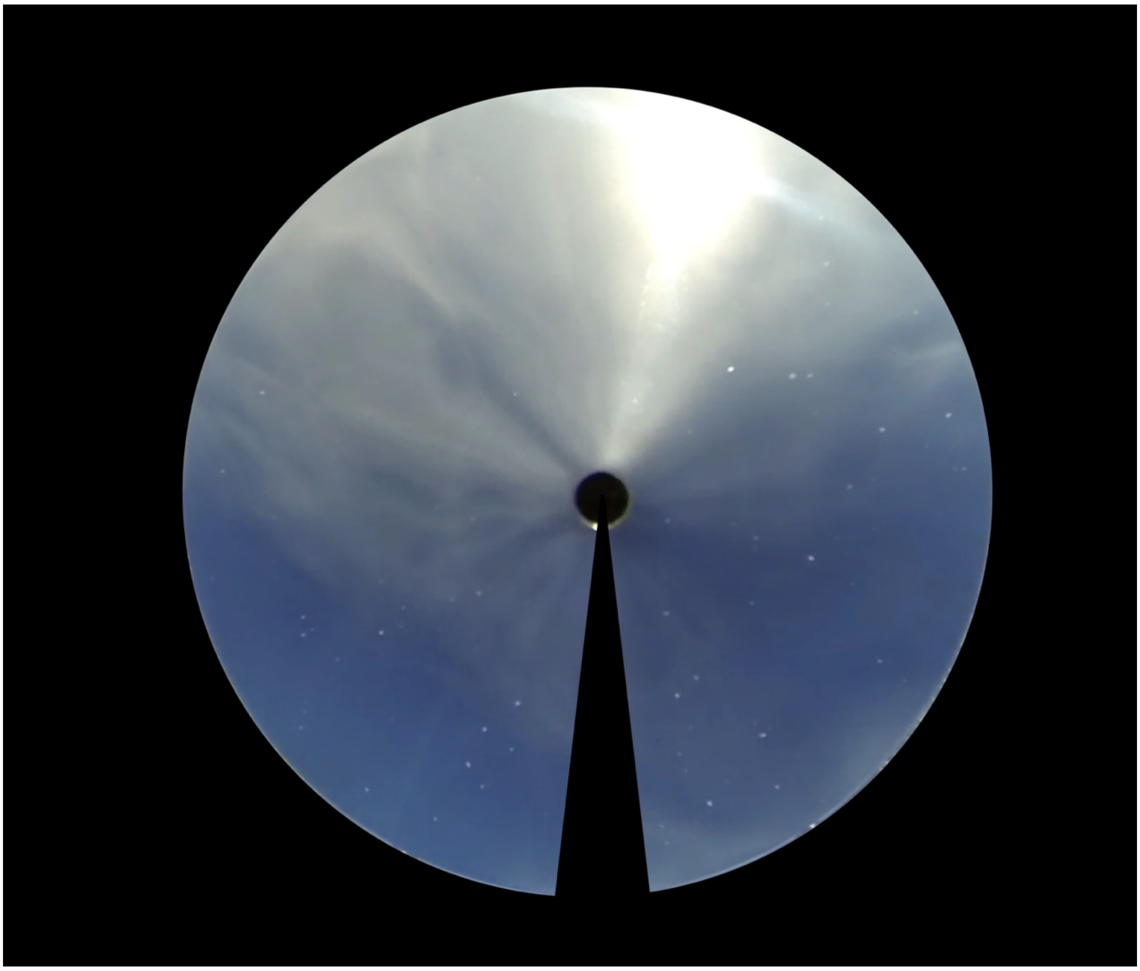

Figure 6.4.13 Video still from *Anamophic Projection #1.*

6.5 Transduction

6.5.1 *Instrument (90ºS)*

Figure 6.5.1 Roald Amundsen and his team with the *Polheim*. December 17, 1911.

I introduced the *Polheim* at the end of the previous chapter – the marker that Roald Amundsen left at the Pole to record the first human arrival there in late 1911. The tent-like structure marks Amundsen's success, Scott's party's failure and the notional goal of their quest – the South Pole. Days later, after Amundsen had departed and Scott's party had arrived at the Pole to disappointment, Edward Wilson, Scott's enduring right-hand man, completed several sketches of the *Polheim*. He recorded its properties with the dispassionate observation of a seasoned scientific illustrator – as if it was part of the natural landscape, a specimen to be analysed. After this, the *Polheim* was never seen again.[239] It was buried under the accumulating ice. Exactly 100 years after Amundsen's efforts and to mark the centennial, several overwintering South Pole scientists went in search of the *Polheim* with remote sensing equipment. The ice moves about 10 metres per year in the direction of the Weddell Sea and it is estimated that the *Polheim* is

[239] Wilson souvenired some of the Polheim's tent material which was found on his frozen body when the Scott party was discovered a year later. These surviving remnants of the structure are in the collection of the Scott Polar Research Institute, Cambridge, UK.

now buried under 17 metres of snow and ice.[240] No trace of it could be discerned. The *Polheim* is 'lost' and unrecoverable with current technology.

The *Polheim* (or now, the indexical photographic evidence of its existence) is a marker of many things. It records an historic moment and the ways of thinking about and seeing the Antarctic typified by that moment. It signifies two heroic enterprises with both nationalistic and scientific justifications and the more general Western project to territorialise contested and 'empty' landscapes. Finally, it marks both a notional location and an attempt to map the imagined onto the real.

More significantly for this analysis however, it can be considered as a marker of absence – or more precisely several absences. At first glance it marks the absence of the (now lost) *Polheim* itself, the people who put it there and their world view. More conceptually, it marks the absence of information at the endpoint of the information gradient running from the Antarctic coast to the Pole, and the absence of orientation, definition and territory within the 'smooth' and isotropic space of the South Pole. The *Polheim* is representative of a typology of absent spaces – spaces which require human culture to achieve definition and which resist that definition to maintain their 'smoothness'.[241]

The *Polheim* has limited interest as a misplaced artefact of Antarctic history. However it is invaluable if understood as an iconic first attempt at creating a space for humanity (physically and culturally) in an environment that continues to withstand our efforts to comprehend, define and territorialise. If this act is the lasting achievement of Amundsen, then the *Polheim* can be seen as a marker for a more enduring cultural act – the attempt to inscribe human culture onto a space that has always and will continue to confound our engagement with it. This act finds parallels in the work of conceptual artists and contemporary artists working in Antarctica.

The iconic image of the *Polheim* converges with another iconic image from later in the century, created by another twentieth century figure whose life was characterised by bravura, nationalism and a personal history marked by close encounters with indigenous peoples.[242] In his renowned 1974 action, the fluxus

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240 Dale Mole, "In Search of Amundsen's Tent," http://southpoledoc.wordpress.com/2012/06/03/in-search-of-amundsens-tent. Accessed April 10, 2014.

241 As a contested space open to definition, Antarctica fits within the philosophical framework of 'smooth' space as defined by Deleuze and Guattari. Smooth space is 'open' and 'deterritorialized' as opposed to closed and defined 'striated space'; it is constantly being redefined and has no clear boundaries. Gilles Deleuze and Felix Guattari, *Nomadology : The War Machine*, trans. Brian Massumi (New York: Semiotext(e), 1986).

242 Beuys' central personal mythology (now debunked) was that he was rescued from a WW2 air crash by Tartar shamans who restored him in their felt yurts with applications of animal fat and felt wrappings. Olivia Laing, "Fat, felt and a fall to Earth: the making and myths of Joseph Beuys," *The Guardian* (online), January 30, 2016.

artist Joseph Beuys flew to New York, was wrapped in felt and taken by ambulance to a room in the René Block Gallery. For three days he shared the room with a half-wild coyote and several props (instruments perhaps): a thick felt blanket, bales of hay, a cane shaped like a shepherd's crook, a flashlight and a daily delivery of the Wall Street Journal (see Figure 6.5.2). After three days, Beuys returned to the airport. Again he rode in the ambulance, leaving America without having set foot on its ground. As Beuys later explained, "I wanted to isolate myself, insulate myself, see nothing of America other than the coyote."[243] This 'heroic', tightly focused and efficiently executed expedition to America with limited equipment to hand, a defined though ambiguous goal, and an intention to return home (unscathed) resonates closely with Amundsen's polar action. The blank space inscribed by Beuys was the abstracted white space of the gallery.

Figure 6.5.2 *I like America and America likes me.* Joseph Beuys. 1974.

The *Polheim* persisted as a clear marker in my own imagination as I developed the actions I planned to undertake during my fieldwork at the South Pole. I also had in mind the magnitude of the IceCube experiment – the years of planning, experimentation and development of the array, the investment of man-hours and dollars, the extended international collaboration of hundreds of scientists and technicians. I wondered what I could create and deploy at the Pole as a solo artist to understand my location and to leave a 'mark', with limited funds, no previous experience of, and limited time in, Antarctica.

Considering my activity as analogous to the deployment and use of complex scientific instruments at the Pole, it was clear to me that I should build a significant instrument to deploy at the Pole. As my own

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https://www.theguardian.com/artanddesign/2016/jan/30/fat-felt-fall-earth-making-and-myths-joseph-beuys. Accessed July 25, 2018.

[243] Joseph Beuys. http://en.wikipedia.org/wiki/Joseph_Beuys#.

instrument developed, my research around the notion of instrument expanded and deepened and, as a consequence, I developed a set of constraints for my proposed instrument. As the scale of my endeavour was more akin to Amundsen's (or Beuys's) than to that of IceCube's, I drew on the form and structure of the *Polheim* and the craftsmanship of Amundsen's time. It was important that the instrument would be portable, free-standing and durable in inclement weather – high winds, extreme cold and dryness. I wanted its output to be analog and not digital, to obviate the need for power and increase its haptic qualities both in the field and on exhibition. And finally the instrument would be indexical – it would stand as a marker of my presence at the Pole (as the *Polheim* did for Amundsen) and it would be inscribed by its passage to and deployment at the Pole.

I decided early on that the instrument would involve sound.[244] There were many reasons for this. When one thinks of instruments in the context of art, musical instruments come readily to mind. As well, the rich traditions of musical instrument building would provide a comparison with the craft of contemporary scientific instrument making. I wanted to play on these association to create an instrument that would operate in the common ground between art and science.

I anticipated that the sound of the Pole would be extraordinary and I expected that my instrument would engage with the local soundscape in intriguing ways. Sound is a fundamental vibration that we experience with our whole bodies as well as our ears. Sound would be an excellent vehicle to carry haptic experience to exhibition viewers. Sound can also stand in for other harmonic resonances that are more difficult for us to perceive. As the focus for my collaboration was particle astrophysics I anticipated that thinking about and working with harmonic vibrations, wavelengths, frequencies and sympathetic materials would provide fertile ground for interdisciplinary understanding and collaboration. And finally, sound is directly connected to the notion of noise – a central focus of my research.

In a kindred process to what scientists undertake in developing viable instruments for deployment, I undertook a long process of iteration in my studio to develop an effective sound generating component for my instrument. I created four separate prototypes of the central mast of the instrument to test materials, mechanisms, structures, scale and sound quality. These prototypes were tested in the field in Northern California and were invaluable in developing the final instrument.

The instrument was designed to pack away and be portable but also to expand as it was deployed. It needed to be as compact and lightweight as possible. And it needed to be self-contained and include

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[244] A large portion of my experimentation in the studio and literature research and was dedicated to investigating sound production and the development of contemporary sound art. This exegesis could have focused more closely on sound as its basis but I chose instead to contextualise my research within the visual arts.

everything required for assembly, tuning and repair at the Pole. The crate, with all of my equipment and instruments inside, was shipped to the South Pole in early October 2016, months before my departure (Figure 6.5.3). As nothing could be redundant, the crate itself needed to be an important part of the instrument – it dismantled and reassembled as the instrument's supporting platform (Figure 6.5.4). Once assembled, the platform was deployed on the Polar Ice directly above the IceCube array (imbedded over 1.5 km below the surface) and oriented towards the sun's position at midnight on the summer solstice – this is called 'north' at the South Pole (Figure 6.5.5).

The instrument consisted of three major components – the 'platform', the 'mast' which was the main sound producing structure and the 'shroud' which was a tent-like structure fabricated from sail cloth that was supported by the mast and guyed out to anchors on the platform.


Figure 6.5.3 (Left) The densely packed crate leaving my studio.

Figure 6.5.4 (Right) The unpacked crate reassembled to form the instrument's platform. View of the underside of the platform revealing the markings from the instrument's passage to the Pole.

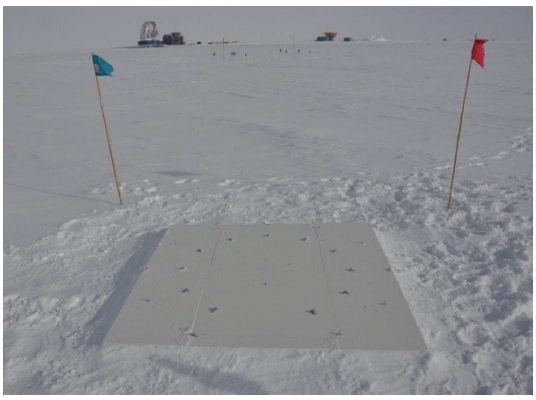

Figure 6.5.5 The platform deployed on the Ice above the IceCube array.

Figure 6.5.6 Assembling and tuning the mast.

All of the instrument components were packed together tightly in the crate. The mast sections were designed to nest inside each other to conserve space. In the relative comfort of the IceCube Lab, I was able to assemble the remaining components of the instrument. The complete assembly took about 90 minutes (Figure 6.5.6).

Figure 6.5.7

The mast installed on the platform.

The mast was then mounted to the platform (Figure 6.5.7). The machined aluminium top piece is set on grease-free, low-temperature tolerant, bearings and powers a drive shaft running the full length of the mast. Attached to the drive shaft is a 3:1 step-down mahogany gear train. The gears connect to a laminated, rosin-coated, mahogany disk which emerges from the lowest segment of the mast (Figure 6.5.8). When the top piece is driven by the wind it powers the gears and the mahogany disk rotates and 'bows' four long piano-wire strings that can be lowered into contact with the disk from an aluminium bridge. The tension in these four primary strings is balanced by six drone strings that run the full length of the back of the instrument. This string tension secures the telescoping mast sections together and places the mast under load to increase its resonance. The drone strings can be tuned with movable bridges – much like a Japanese *koto*. The drone strings are tuned to resonate in harmony with the bowed primary strings and also respond directly to air movement – creating an aeolian instrument. To protect the mast (and the instrument operator) from wind and cold the instrument can be housed within a sail cloth shroud which is lashed to the top of the mast and guyed to the perimeter of the platform (Figures 6.5.8 and 6.5.9).

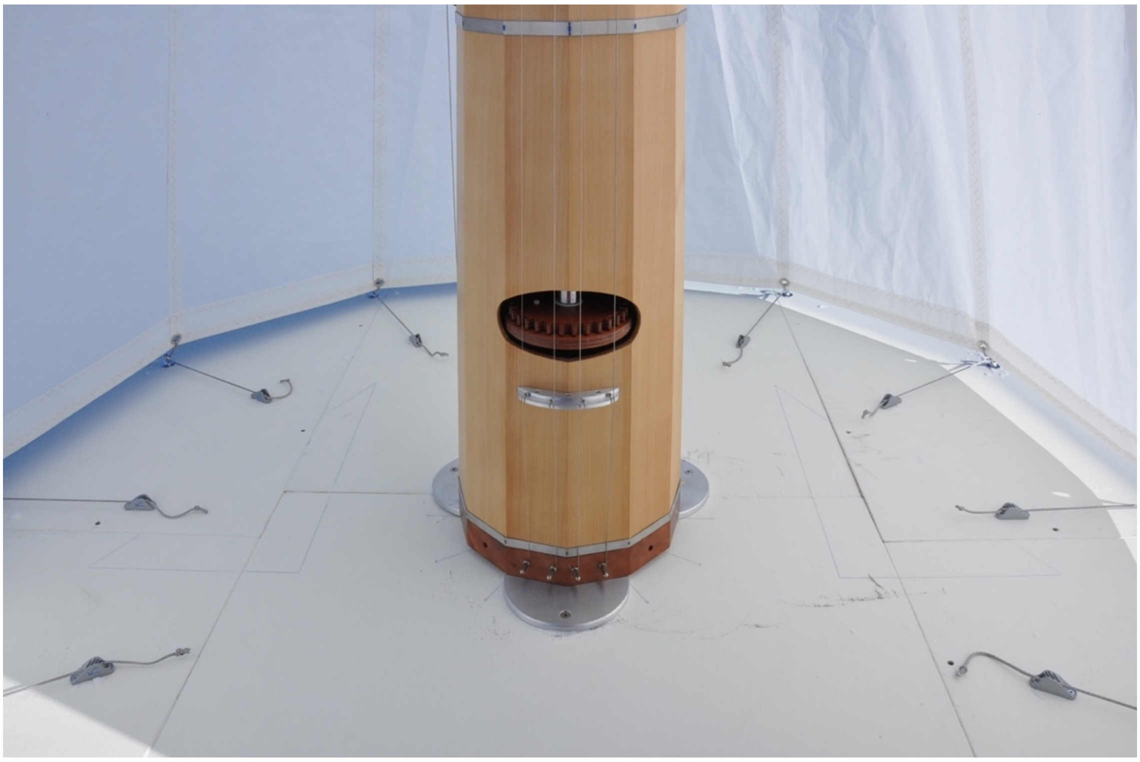

Figure 6.5.8 The mast attachment to the platform, the bowing mechanism and the shroud lashings.

Figure 6.5.9 The upper mast and shroud.

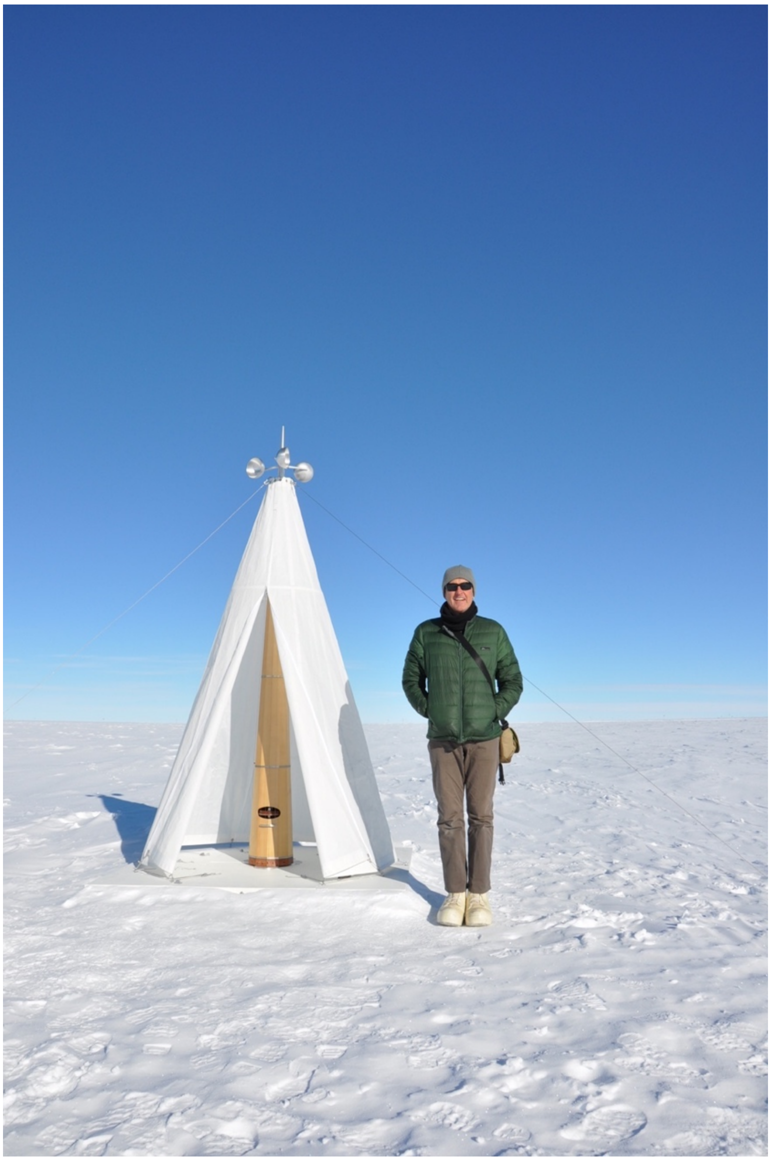

Figure 6.5.10
Polheim 2.0.

The *Instrument* was a very visible element of my fieldwork (Figure 6.5.10). This was important for several reasons. It drew other station personnel out onto the Ice to spend time with me and the *Instrument*. It provided an opportunity to work closely with my collaborators at IceCube – we each had our own instruments to set-up and trouble shoot and we helped each other in that process. And it provided a tangible corollary to the other scientific instruments deployed at the Pole and a topic for discussion with the scientists working on those instruments.

In situ, the sound produced by the *Instrument* could only be experienced by the intrepid and curious few who were willing to make the 2 km trek out from the Amundsen-Scott base. Due to my limited time at the Pole, the *Instrument* was only in place for a few days.[245] I was perversely disappointed by the fact that the

[245] My 15 days at the Pole was very tightly scheduled. I was required to provide a detailed and comprehensive plan of my proposed daily activities before receiving final approval from the US National Science Foundation.

weather during my fieldwork was relatively balmy and calm – temperatures ranged from -25ºC to -17ºC, with winds at only 0–8 km/h. The *Instrument* was designed to withstand more extreme conditions, with optimal operating conditions of 8–15 km/h wind speeds. The wind only touched the lower end of this range a few times during my polar fieldwork. For the *Instrument* to operate in sub-optimal wind speeds the shroud was removed so that all of the strings could operate in fully aeolian mode – bowed by the light winds that zephyred around the *Instrument* and stirred ice crystals into the air. Although the full experience of the *Instrument* operating at the Pole was only witnessed directly by a few, I recorded the sound of the *Instrument* for future use.

In conclusion, The *Instrument* is a hybrid object. It served as a polar marker (in resonance with the long-absent *Polheim*) and remains an indexical artefact of my expedition. It is both a musical and an atmospheric instrument. It relies on technologies and craftsmanship developed for musical instruments (featuring a wooden pre-stressed resonator held in tension by piano strings which are tuned with both mechanical piano pegs and moveable bridges, and bowed by a rosined mechanical wheel much like a hurdy-gurdy) but it was specifically designed and constructed to respond to the harsh conditions of the Pole. Like scientific instruments it can be tuned, and it responds in different ways to different levels of input. And like all scientific instruments it produces data – in its case sound.[246] The *Instrument* is a transduction device – it converts energy from one form into another so that it can be perceived and recorded. It transduces the flow between air pressure differentials (i.e. wind), through harmonic vibration into sound which we can hear and can be recorded for future work. The *Instrument* operated in conceptual and physical adjacency with another transduction instrument (the IceCube Observatory) which catalyzed discussion, analysis, creativity and collaboration. Ultimately, the *Instrument* is a sculptural work, embodying an artist's strategy for experiencing and understanding a challenging and difficult to comprehend environment.

The IceCube observatory accepts huge quantities of raw data and uses various complex computer algorithms to sort through this sea of data to distinguish interesting candidate events – sorting out potential signal from a sea of noise. With the *Instrument*, there is no rational decision about what is desired and what is not – what is signal and what is noise. I accept what the *Instrument* produces as a whole experience. My aim was to encapsulate that experience, not to subdivide and analyse the totality for a particular defined purpose. The recording of the *Instrument* operating at the Pole is not melodic in any way. It has no regular rhythm or even clearly articulated notes. It produces a polyphonic, atonal drone. What many listeners would call simply noise. I view this noise as analogous to the total data input of the IceCube array which detects, transduces and registers all photons in the ice irrespective of their source or ultimate value as data useable by scientists.

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[246] Data streams from the *Instrument* recorded on December 30, 2016 can be accessed at http://www.donaldfortescue.com/antarctica.

Only a few people were fortunate enough to be present when the *Instrument* was actually operating at the pole. Its performance now exists only through documentation. The challenge I faced as an artist was how to present that documentation (or recorded data) in a way that gives an audience a haptic experience of the environment at the South Pole – a version of my own physical, emotional and intellectual experience.

For exhibition, the *Instrument* is set-up as it was at the Pole – the mast and shroud mounted and lashed to the platform. In the background, from hidden speakers, a 40 minute recording of the *Instrument* operating at the Pole on December 30, 2016 is played in a continuous loop. In the context of a museum or gallery, this can have the feel of a historical diorama – a mode not widely used in contemporary sculptural practice.[247] This is not unintentional. As part of my research I have visited historical dioramas of Arctic and Antarctic research exhibitions in Norway, the UK, the USA, Australia and New Zealand. Using this mode of exhibition helps conjure the Polar landscape and its human history and supports the indexical aspects of the *Instrument.*

Figure 6.5.11 *Instrument (90ºS).*

[247] Although notable examples of artists working with museum dioramas in the contexts of exploration and natural history would include Mark Dion, and the photographers Hiroshi Sugimoto and Anne Noble.

6.5.2 *Axis Mundi*

The *Instrument* was used as a polar marker in the video work *Axis Mundi*. The most visceral, disorienting and unearthly experience of being at the Pole comes from the fact that throughout the summer months the sun never goes below the horizon. From the summer solstice until polar sunset in late March, the sun spirals slowly down to the horizon from a maximum angular height above the horizon of 23.5º. The perpetual daylight disrupts one's personal circadian rhythm adding to the disorientation of the isotropic polar plateau. This is compounded by the visceral realisation that you are standing at the axis of rotation of the whole planet. I felt that the best way to capture this experience was through time-lapse video. This enhances the vertiginous spin of the globe, emphasises the sun's fixed altitude, and captures the changing atmospheric conditions visible in the evolving cloud and ice particle formations.

Figure 6.5.12 Video still from *Axis Mundi*. Donald Fortescue. 2017. HD (1080p) video with sound.

What I hoped to achieve with this particular work was an energetic snapshot of the Pole on one particular day. From the physical reality of being at the axis of the earth and the geophysical consequences of that location (sitting on a 3 km deep, ancient icecap with parhelia refracting through ice crystals swirling in the atmosphere) through to the swarm of subatomic particles flooding the icecap – all transduced into a sonic and visual work. To achieve this I developed a sound work derived from IceCube data to accompany the video component of *Axis Mundi.* I will discuss the development of this sound work in the following section.

6.5.3 *86 Strings*

Using the *Instrument* on the ice surface inspired me to use sound as a medium to experience the neutrino interactions that IceCube was monitoring deep within the ice. To achieve this required close collaboration with two IceCube scientists working with me at the South Pole – Martin Rongen and Gwenhaël de Wasseige. This ongoing collaboration and the sound works developed from it have been titled *86 Strings*.

In the IceCube Observatory, the Digital Optical Modules (DOMs) are arrayed in eighty six 2.5 km long 'strings' frozen into the polar ice. The number of strings in the array and the fact that the scientists call the long cables and attached instrumentation 'strings' led me to think of the IceCube as an enormous stringed instrument. This conceptualization led directly to the idea of mapping the 86 strings of the array onto the 88 keys of a grand piano, and envisioning the photon 'hits' on individual DOMs as strikes on the strings of the piano.

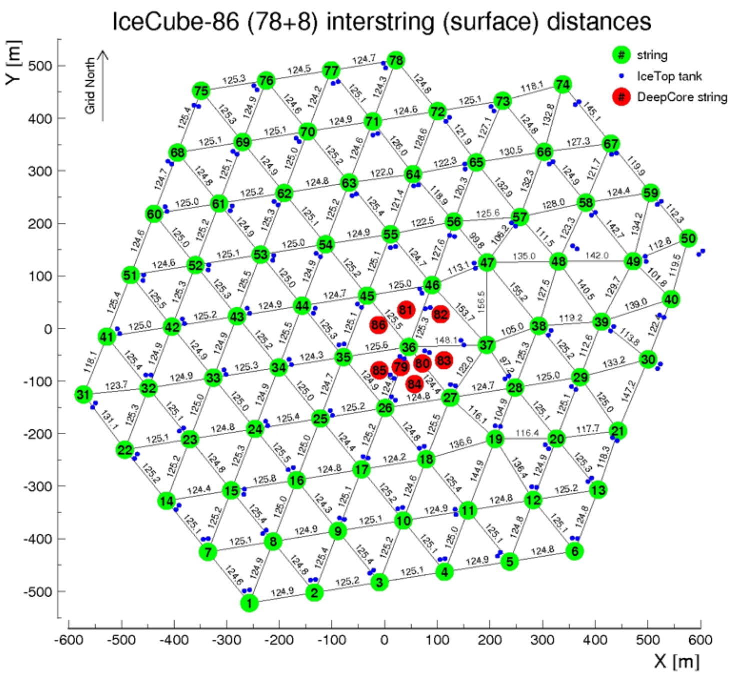

Figure 6.5.13
Map of the current arrangement of the 86 strings of DOMs in the IceCube array.

As discussed in Chapter Five, a neutrino interaction with an ice nucleon results in a super-luminal muon that generates Cherenkov photons which are detected by the DOMs. These photons are transduced by the DOMs into electrical impulses, converted to data streams and then sorted by computer algorithms at the IceCube Lab to identify potentially significant signals from the ever-present sea of noise. These particle interactions are visualised by IceCube through their purpose-built Steamshovel software program. Figure 6.5.14 shows a screen capture from a Steamshovel animation of a single muon event in the ice. The image shows the 86 strings of the array and the individual DOMs arranged like beads on each string. My project's aim was to hear what this data would 'sound' like rather than 'look' like, if it was transduced to sound instead of pixels on a screen.

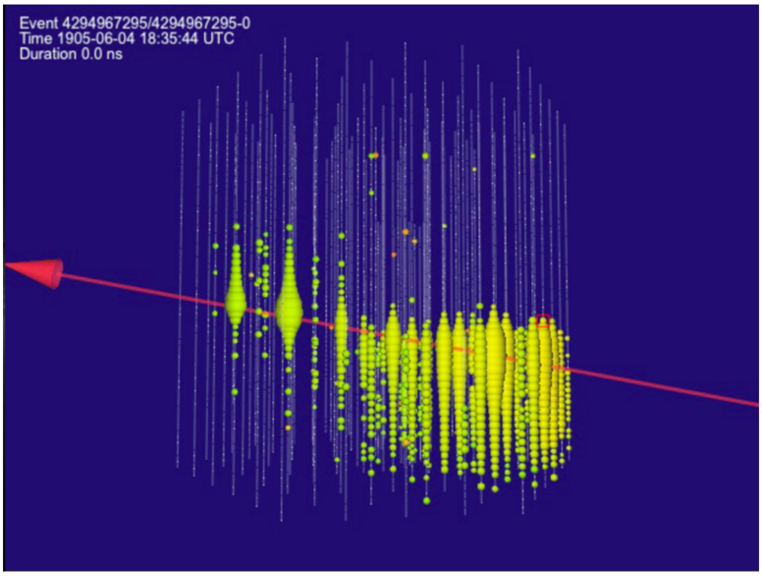

Figure 6.5.14
IceCube data visualisation in Steamshovel. The red arrow indicates the estimated pathway of a superluminal muon through the IceCube array.

As discussed in Chapter Four, two terms used by both scientists and sound artists working with converting data to sound are 'audify' and 'sonify'. Audification is the making audible of an inaudible sound through amplification or through transposing frequencies into the range that humans can hear – this is the process that makes whale song audible to us. Audification is essentially sound transcription. Sonification is the process of rendering other forms of data (such as electromagnetic, particle flux or even gravitational wave signals) into sound – a classic example would be the Geiger counter. Sonification involves transduction from a different form of energy into sound energy.

86 Strings involves the sonification (transduction) of digital signals derived from the detection of photons deep in the ice into sounds we can hear. There are innumerable ways that the neutrino data could be transduced into sound. Each requires the allocation of sound frequency, volume, duration and timing values to map the event rate, photon energy, photon flux and location values in the IceCube data. Some mappings are readily suggested by the shared characteristics of sound and light waves (such as frequency, intensity, and duration). Others (such as which events are sampled, the sampling rate and playback speed, for example) need to be selected to both reflect the underlying physics and to satisfy aesthetic considerations (to ensure the resulting work will be engaging).

In the case of the first iteration, *86 Strings #1 (December 31, 2017)*, we assigned the values of the timing, brightness and duration of the DOM signals to timing, loudness and sustain on each struck note. The choice to assign a particular note to a particular IceCube string highlights the physical movement of muons through the ice. Neutrino interactions which result in horizontal muon paths result in distinctive glissandos. Vertical neutrino paths result in repetitive strikes of the same or closely tuned notes.

The actual conversion of IceCube data to sound is relatively straightforward. IceCube scientists have developed software based on the versatile and widely used, open source software language Python to analyse data sets. They have ready access to the built-in Python libraries, one of which allows output to the MIDI format – the international standard software system for digital musical instrumentation. A delightful consequence of this software synergy is that IceCube data can be outputted to MIDI files which can then be used to activate a wide range of electronic instruments – including grand piano. Using standard MIDI software the sound can also be directly transcribed to Western musical notation (see Figure 6.5.15) – a transcription of the transduction of IceCube data.

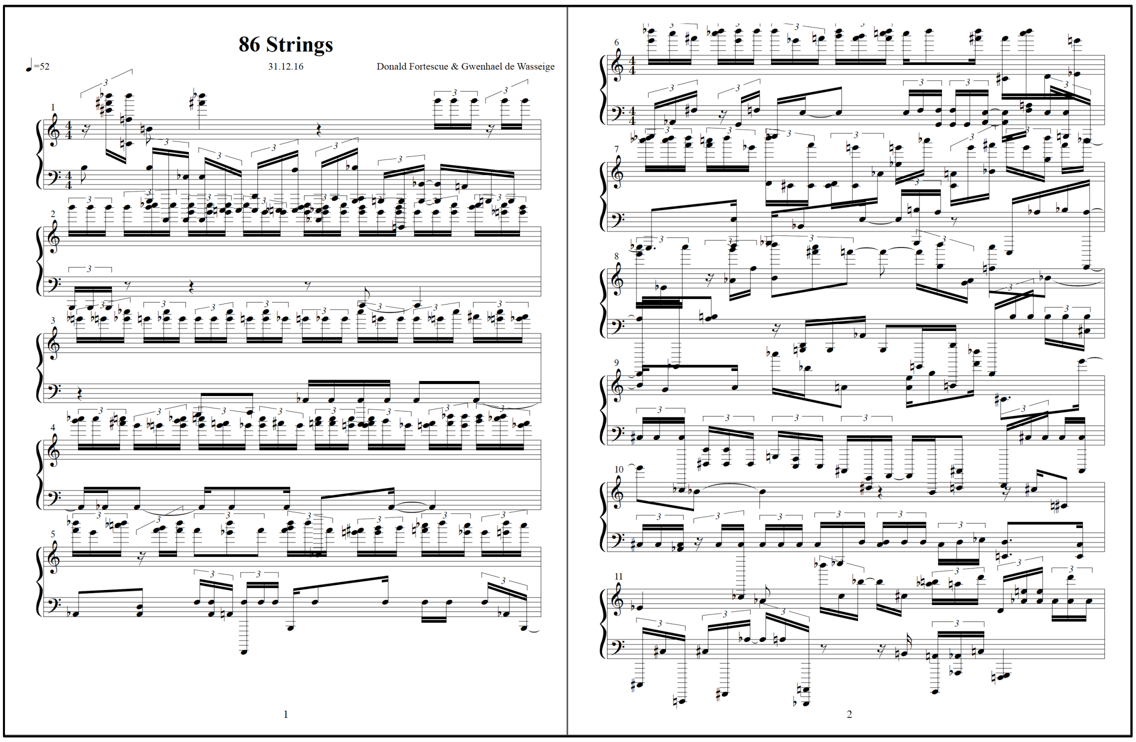

Figure 6.5.15 *86 Strings #1* transcribed to Western musical notation.

IceCube detects one neutrino every 6 minutes on average and 3000 muons per second. The critical decision as to which events are selected and the tempo at which they play can be aesthetically determined or constrained by other conditions.

I decided to pair *86 Strings #1* with *Axis Mundi* as a combined audio visual work, with the ambition to capture the rotation of the earth in space and the transient motions of the atmosphere, together with the passage of subatomic particles through the polar ice, to provide a means for us to physically engage with these phenomena. This provided an appropriate constraint for the selection and timing of events. As *Axis Mundi* is focused on the apparent movement of the sun it was decided to sample only solar muon events for the accompanying sound work.[248] The structure of *86 Strings #1* is based on a transect-like sampling of events occurring on the same day that was sampled by the timelapse video in *Axis Mundi*. Using data sets from the same day, we sampled a single solar muon event at the beginning of each hour. Each event was transduced to sound according to our specifically designed algorithm which resulted in 10–20 seconds of sound for each event. The starting points of these individual events were then evenly spaced across the duration of the timelapse.

86 Strings #1 is an audio timelapse of a day's worth of solar muon data from deep in the ice. It is combined with *Axis Mundi* which is the same 24 hour time period's worth of visual data from the ice surface – marked by the presence of the *Instrument*. Both timelapses last 4 minutes and 88 seconds and are precisely synchronised. The constancy of the sound in *86 Strings #1* captures the constant hum of muon interactions in the Ice – a consistent background noise. But also, of course, a signal.

The choices of which data sets were used and how they were rendered into sound for *86 Strings #1* was constrained by the pairing of the sound work with the video piece *Axis Mundi.* However, there are innumerable other possibilities sonic renderings of IceCube data. *86 Strings* is an ongoing collaboration that will result in a series or suite of works each with different characteristics. These could be based on purely aesthetic choices or preferably by adopting other constraints more closely aligned with scientific practice by taking different transect-like slices through the data sets.

By analogy with 'seeing/drawing as', *86 Strings* can be consider as a form of 'listening as'. And like 'drawing as', 'listening as' is both a 'theory-laden representation' and a physical and embodied process.[249] We readily discern sound as occurring in three dimensions so it is anticipated that listening to neutrino interactions could be more intuitively informative to scientists than looking at animated renderings on a 2D screen.[250] The potential for original approaches to sonification of data to be useful in scientific analysis has proven to be one incentive for scientists to continue the collaboration beyond this initial effort. The fact that *86 Strings* is engaging to my scientific collaborators and that they see its potential within their own research field demonstrates a true common ground between artistic and scientific approaches.

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[248] That is, events arising purely from solar sources.

[249] Vertesi, "Drawing as," 18.

[250] Interestingly, during my research, the first gravitational waves were detected by the LIGO array in the US. The data from the gravitational waves were rendered as sound (sonified) for both scientific analysis and presentation to the public.

One aspect of this work that dissatisfies me is that from the moment the photon signals deep in the ice are processed into digital data they remain digital. The transduction from light to sound is mediated by a long series of software programs each of which has constraints and parameters set by their designers and users. Scientists rigorously analyse these software pathways to ensure that no artefacts or inexplicable noise enters the data stream and its analysis. As a sculptor and shaper of tangible materials and haptic experiences, I crave less digital mediation between the initial flash of a photon in the ice and the experience of it by an observer/listener. To my mind, the perfect instrument would have the in-ice photon physically strike and sound a string. Clearly this is impossible, but my ongoing aim is to remove as much of this digital mediation as possible.

One ambition for future work is to render IceCube data directly onto paper player-piano rolls and then to play the data through an analog, mechanically driven player-piano. Such an instrument could (with relatively straightforward modifications) store and play very long works filtered from large data sets. The player-piano has the capacity to 'perform' incredibly complicated and rapid works far beyond the technical virtuosity of any human player.[251] As well, the punched player-piano roll is one historical precursor of the punch cards that digital data and the software to process it was initially stored on. The capacity of such an instrument to automatically render complex data into sound through the physical impact on 88 harmonically vibrating strings could result in an aptly poetic analog for the IceCube array.

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[251] Notable works exploiting this capability of the player piano have been created by György Ligeti and Conlon Nancarrow. For an introduction to Nancarrow's work see "Nancarrow at 100", *Other Minds* 2012 Festival website. https://www.otherminds.org/nancarrow-at-100/. Accessed December 20, 2018. A more comprehensive analysis of his work is provided by Kyle Gann, *The Music of Conlon Nancarrow* (New York: Cambridge University Press, 1995).

Chapter Seven Conclusion

There were three key research questions that I defined as central to my exegesis. In this conclusion I will summarise my findings in relation to these questions and evaluate how successful I have been in answering them. In considering what the common ground between the processes, methodologies and conceptual underpinnings of art and science might be, I initially researched the history of the role of the artist in scientific collaboration. I discussed the long-standing connections between artists and scientists in the field, and came to the conclusion that fieldwork practices in the natural sciences were developed collaboratively by scientists and artists. I detailed the changing nature of artistic engagement with the changing nature of scientific exploration and discovery, and noted how, with the shift of science towards mechanical objectivity and the increasingly instrumentalised recording of data, artists generally no longer had a direct role in the western scientific project.

To rediscover a common ground between art and science, I needed to look more deeply to find approaches common to both. A key moment in my research came when I identified objectivity as a core concept of both science and art. I discussed the changing nature of scientific objectivity and made the argument that objectivity is also one of the aims of contemporary art practice. Interrogating objectivity opened up several avenues for developing a deeper understanding of scientific practice, an original approach to analyzing contemporary art practice and a strategy for my own artistic research.

This lead directly to my second research question, which was to determine which concepts, methodologies and processes have meaning in both fields of inquiry and could be used to provide an original perspective on contemporary art practice. And further, if these concepts could be used to develop original works of art. I laid out the rationale for considering instruments as vehicles for objectivity. In science the development of mechanical objectivity went hand in hand with the development of new instruments which opened up new realms for scientific inquiry. But all instruments have limitations. They have limited fields of view, or limited wavelengths they can detect, or operate within a very limited range of conditions. They both apply and operate within very specific constraints.

I then detailed how, in the late twentieth century, visual artists developed various strategies and mechanisms to limit or constrain their direct agency. These strategies were designed to remove subjectivity from art practice. An original approach in my research has been to consider these devices of constraint as ‘instruments’. I defined an artistic instrument as a mechanism that stands in for the artist, or a strategy that has the same effect of removing the artist from direct agency. Artistic instruments can be physical objects, processes or conceptual frameworks. They have the dual function of removing subjectivity from the work and of focusing a viewer’s attention onto a particular site, sensory experience or perspective. This conceptualisation of instruments as devices of constraint within both science and the visual arts has proved to be an effective strategy. This approach has allowed me to think about scientific instruments from an artist's perspective, to design and create my own instruments for deployment in conjunction with scientific instruments, to develop collaborations with scientific research facilities and to locate my research within an original analysis of aspects of contemporary art practice.

Considering instruments, how they operate and the ways in which they mediate our view of the world led to several concepts that have become central to my analysis. These concepts relate to how instruments operate (transcription and transduction), the values we place on what they capture (noise and signal), and the ways that we interpret their output (artefact and pareidolia). I have used these concepts as lenses through which to view and analyse both scientific and artistic research and have applied them to my own artistic output. This has been the most fruitful outcome of my research and underlies all of the analysis.

This approach led to my conclusion that one effective way to circumscribe a common ground between science and art is to identify the space where this conceptual borrowing and redeployment of terminology is both possible and effective.

I explored this common ground through the creation, deployment and analysis of several works that I considered instruments. Instruments define a field, by becoming a metonym of the field (telescopes represent astronomy), by circumscribing the physical field of study (the field of view of the telescope), and by providing the data required by researchers (by sampling discrete portions of the electromagnetic field for example). As Barbara Maria Stafford has said, they "not only constrain what is possible to see but also determine what can be thought."[252]

All instruments require a field within which to operate. This led to my final research question, which was to investigate the ways fieldwork provides unique conditions and opportunities for the practice of both astrophysics and contemporary visual art. For artists, fieldwork provides the practical opportunity of working with and alongside scientists and access to challenging and remote sites for inspiration. However, this dependency can lead to the artists becoming mere illustrators in the service of scientific interpretation. Ariane Koek, who established the artist residency program at CERN and created its arts policy pointed out three "very dangerous strands" in the art works connected with science practice.[253] These can be when artists act simply as "communicators of science", or when they employ science and its accompanying

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[252] Quoted in Geoff Manaugh, ed., *Landscape Futures: Instruments, Devices and Architectural Inventions* (Nevada: Center for Art + Environment, Nevada Museum of Art. 2013), 25.

[253] Ariane Koek, "Cern: where art and science collide," *The Art Newspaper.* Online. October 4, 2011. http://www.theartnewspaper.com/articles/Cern:-where-art-and-science-collide/24678. Accessed November 28, 2014.

technology directly as a "means of production" and finally when scientific images, outcomes or instruments are considered as art works in their own right. In establishing the CERN residency and seeking artists to work in collaboration with the scientists, Koek was searching for a "fourth, more invisible, strand, where the arts and science are in fluid interchange. Here, the disciplines are honoured for their similarities as well as their essential differences." [254] It is this fourth mode that I have opted for in my collaboration with IcCube and underpins my research approach. The field has been the conduit for both my own artistic research and for the collaborative project that I developed with IceCube scientists.

I outlined my rationale for selecting the Antarctic and astrophysics as the physical and cultural fields in which to conduct my research. These choices provided a very fertile field for exploration. The opportunity to work at the South Pole in collaboration with one of the most outstanding astrophysical instruments of our day was extraordinary. I was able to create and deploy my own instruments at the Pole with the support of the US National Science Foundation and was fortunate in meeting young scientists who were working with IceCube at the Pole and who became as interested and actively engaged in my research as I was in theirs. This collaboration is continuing and is one of the durable outcomes of this research.

Although it wasn't one of my key research questions, one of my aims was to develop original approaches to art making at the Poles and particularly in Antarctica. There is a long tradition of art connected with Antarctica and a strong tendency, through convergence, for new art works (in particular imagery) to echo those previously seen. By the time most artists arrive in Antarctica they have encountered other artists' works (either through direct research or through general media saturation) and have already formed an image of the continent. It can be hard to see the landscape in any other way but that prescribed by the experiences of other's. One aspect to this prefiguring of Antarctica has been the tendency of each generation of explorers, scientists, artists and administrators to see the continent as the blank page on which they can write their own visions, ambitions and fears. Today we see Antarctica as the canary in the gold mine of global climate change – both evidence and symbol of our impact on the natural ecosystems of the earth. One of the challenges for an artist working in Antarctica is to step outside these imposing dominant cultural discourses. I have been successful in this regard by having defined a very specific field for my own interaction with Antarctica. Both the cultural and physical field for my own research provided a unique perspective and an original set of artistic methodologies to create new works engaging with the Antarctic environment.

Following page – Figure 7.1 *Instrument (90ºS),* almost lost in the isotropic landscape of the South Pole.

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[254] Koek, "Cern."

Illustration Credits

Images not otherwise credited are by the author.

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Chapter Seven

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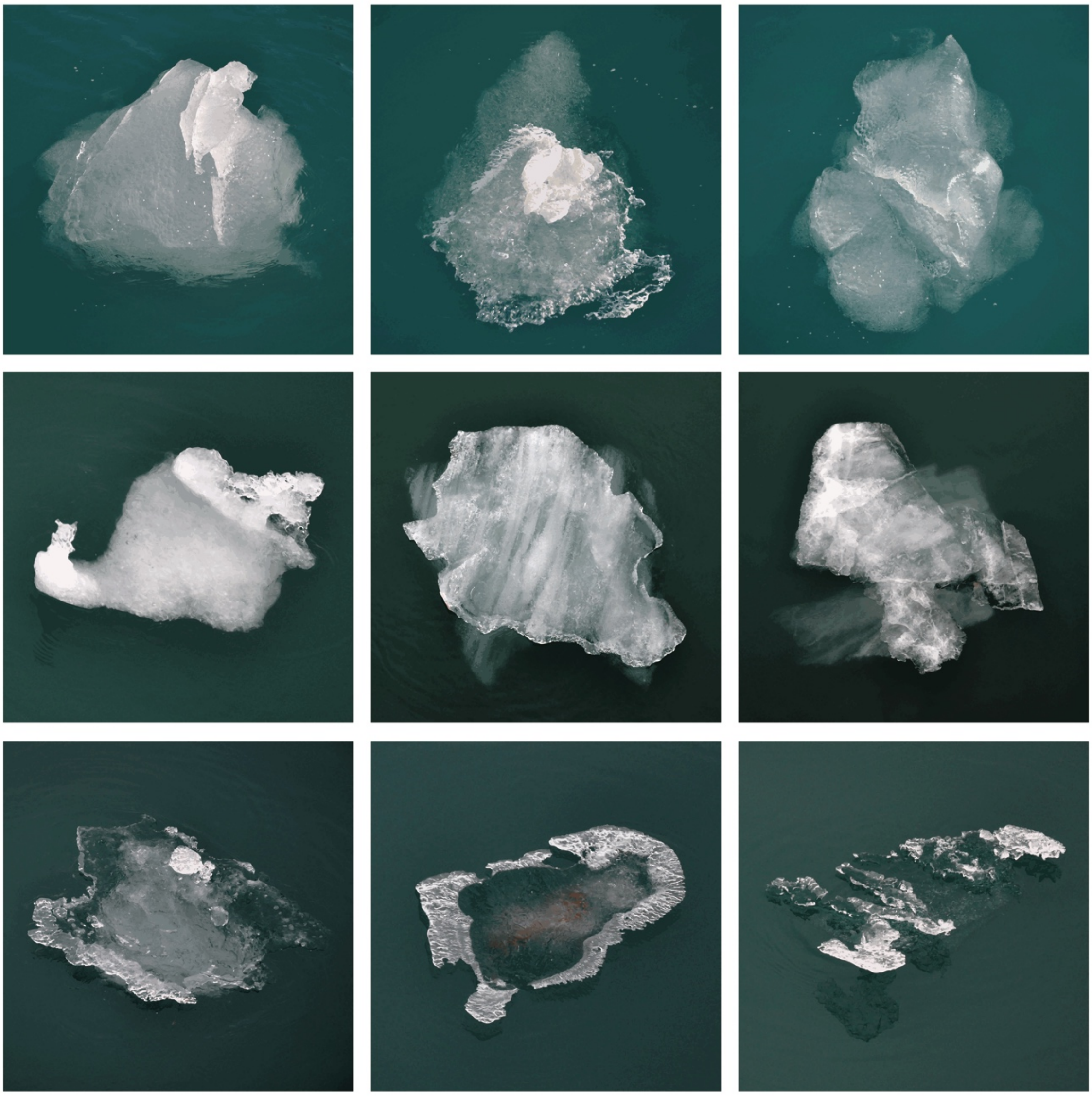
Appendix 1 List of Exhibited Works

Printed Works



Growlers (Svalbard Archipelago).

2015.

Digital pigment prints on paper.

Each print 50 x 50 cm.

Overall size of complete grid 180 x 180 cm.

Sheet.

2017.

Digital pigment print on paper.

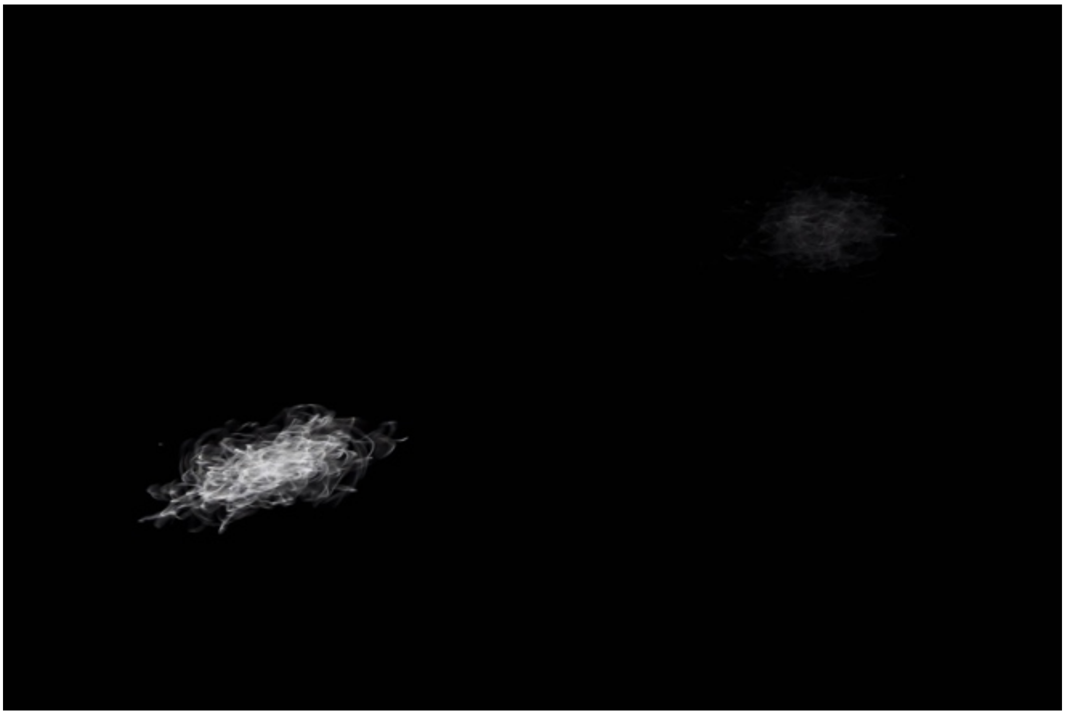
106.5 x 106.5 cm.

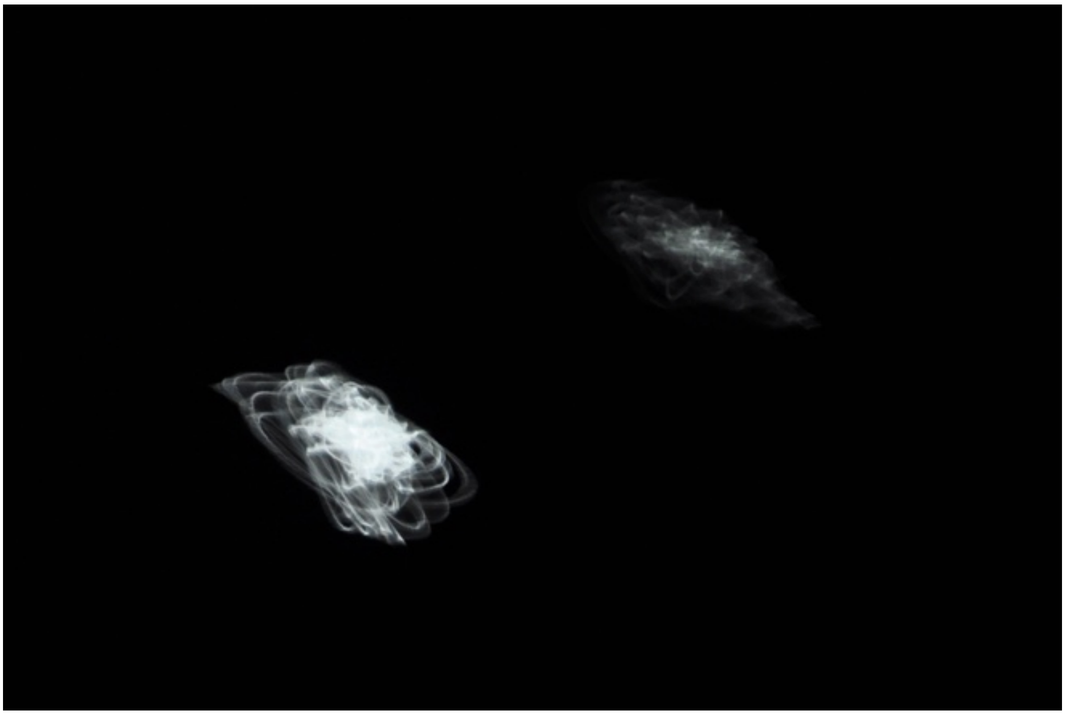
Nebula Series Prints #1-3.

2016.

Digital pigment prints on aluminium.

Each print 102 x 153 cm.





Ice Lenses.

2018.

Digital pigment print on paper.

69 x 160 cm.

Sculptural works

Heliographs #1-4.

2017.

Burned wooden coopered forms with spherical glass lenses (process images).

Each 15 cm tall x 25 cm diameter.

The Instrument (90ºS).

2017.

Mixed media – wood, metal, sailcloth, rope, plywood, sound.

Height 3m x 2.5m x 2.5m.

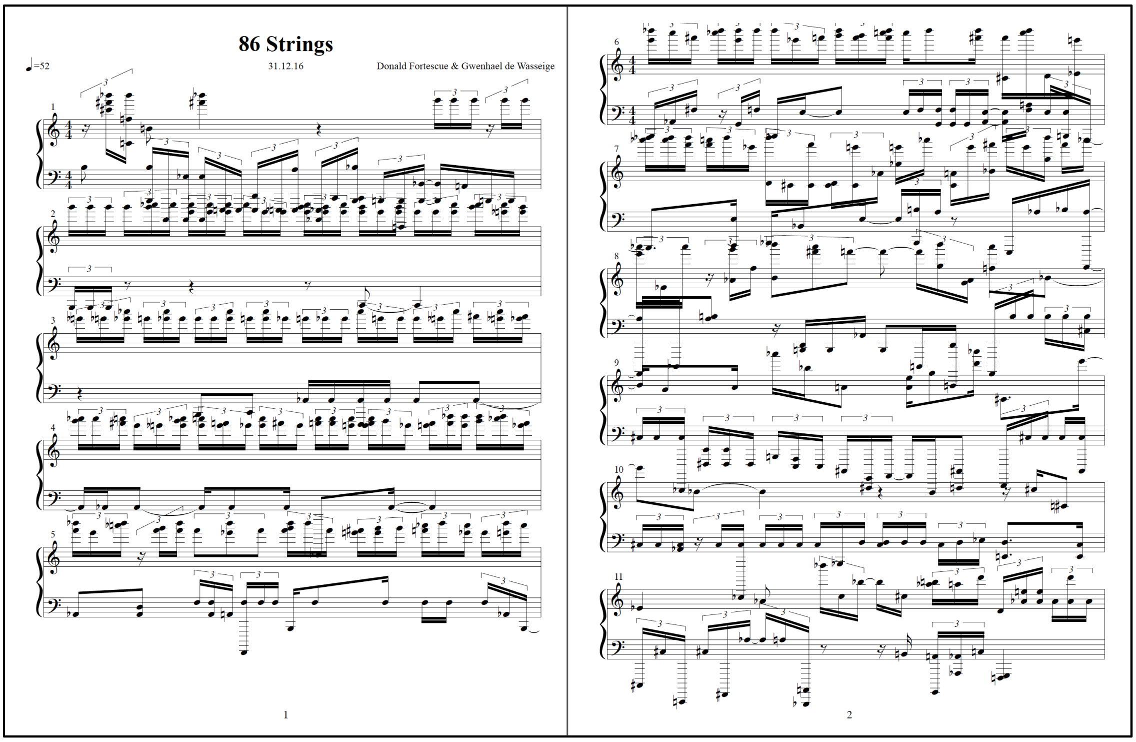
Sound and video work

Axis Mundi.

2017.

HD (1080p) digital video with sound.

Accompanied by



86 Strings #1 (transcribed to Western musical notation).

2018.

Musical manuscript on paper. Cloth bound.

A3.