ELEMENTS OF NATURAL HISTORY IN *SIDEREUS NUNCIUS*

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Abstract. Scholars often saw *Sidereus nuncius* as inaugurating a novel genre of scientific writing; one that mixes elements of astronomy and natural philosophy, mixed-mathematics and travel reports, cosmography and the conventions of baroque drawing, elements of humanist pedagogy and elements of natural history. Although some of these influences were subject of extensive treatment, the natural historical elements of *Sidereus nuncius* were, comparatively, less carefully investigated. And yet, as I will show in this paper, the natural historical outlook of *Sidereus nuncius* played a significant role in its reception. My purpose in this paper is to investigate some of the elements of natural history present in *Sidereus nuncius*. Firstly, I show that in writing *Sidereus nuncius* Galileo often made appeal to the "specialized observations" and "expert reports" of natural historians. Secondly, I show that some of the early readers of *Sidereus nuncius*, such as Johannes Kepler and Francis Bacon, read Galileo's book as a natural history. I also discuss the ways in which some of them were read and interpreted in the same vein by some of Galileo's early readers, such as Johannes Kepler and Francis Bacon.

Key words: Galileo, natural history, *Sidereus nuncius*.

1. INTRODUCTION: THE ADVANTAGE OF TRESPASSING DISCIPLINARY BOUNDARIES

Scholars tend to agree that *Sidereus nuncius* inaugurates a novel genre of scientific writing; that it is quite unlike all the other forms of (scientific) writing extant at the beginning of the seventeenth century. Some have remarked that in writing

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Abbreviations: SEH = *The Works of Francis Bacon, Baron of Verulam, Viscount St. Alban, and Lord High Chancellor of England.* (14 vols.) Collected and edited by James Spedding, Robert Leslie Ellis and Douglas Denon Heath. London: Longman, 1857–1874 (facsimile reprint Stuttgart-Bad Cannstatt: Frommann-Holzboog, 1961–1963); OFB = *The Oxford Francis Bacon.* (15 vols. planned, 6 vols. to date) General editors: Graham Rees and Lisa Jardine (1996–2006); Sir Brian Vickers (2006–). Oxford: Clarendon Press.

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his famous "message" from the starts, Galileo departed from the conventions of astronomical literature, drawing heavily on the advantages of more practical treatises of mechanics and trades.[2] Others have emphasized Galileo's use of the conventions of *disegno* and perspective in his attempts to persuade the reader that the Moon has forms of relief just like the Earth.[3] Others, yet, have remarked the natural philosophical stakes of this small book and the ways in which Galileo transformed the traditional meanings of experience in order to make it a powerful tool of investigation and persuasion.[4] In fact, *Sidereus nuncius* has a composite character; it mixes in an interesting and fertile manner elements coming from different disciplines: natural philosophy, mixed-mathematics, cosmography and natural history. It is also a composite in terms of style; Galileo seems to borrow freely literary conventions and tropes of travel literature, humanist pedagogy, cosmography and natural history. If some of these elements were amply documented, the natural historical aspects of this writing were never subject of a thorough contextual investigation.[5] And yet, as I will show in this paper, they have played an important role both in the construction of *Sidereus nuncius* and in its early reception. I make two claims. First, that in communicating his discoveries to the world, Galileo had purposefully chosen to coach the results of his astronomical discoveries in the more familiar language of natural history. Second, that some of the early readers of *Sidereus nuncius* took seriously these elements of natural history; they read Galileo's message as communicating first-hand reports and specialized instrumental observations to be further integrated into larger, collaborative and comprehensive natural histories of the heavens. My paper builds on recent research coming from various fields and aims to prove the advantages of trespassing disciplinary boundaries. On the one

[2] Giorgio Strano, "Galileo's Telescope: History, Scientific Analysis, and Replicated Observations", *Experimental Astronomy* 25, no. 1–3 (2009); Mary G Winkler and Albert Van Helden, "Representing the Heavens: Galileo and Visual Astronomy", *Isis. Journal ofthe History of Science Society* 83(1992); Eileen Reeves and Albert van Helden, "Verifying Galileo's Discoveries: Telescope-Making at the Collegio Romano", *Acta Historica Astronomiae* 33(2007); Albert Van Helden, "The Telescope in the Seventeenth Century", *Isis* (1974).

[3] For a survey of these arguments I have found extremely useful Ioana Magureanu's PhD dissertation: Ioana Magureanu, "Arta în competiție cu natura în literatura artistică italiană a secolului al XVII-lea" (Universitatea de Arte Plastice, 2012).

[4] William Shea, "Looking at the Moon as Another Earth: Terrestrial Analogies and Seventeenth-Century Telescopes", in *Metaphor and Analogy in the Sciences* (Springer, 2000); Owen Gingerich and Albert Van Helden, "From Occhiale to Printed Page: The Making of Galileo's Sidereus Nuncius", *Journal for the History of Astronomy* 34(2003).

[5] This is even more surprising in view of the fact that Galileo's relation with Frederico Cesi's academy and his part in the natural historical investigations of the Accademia dei Lincei has been amply documented. As David Freedberg has shown, Cesi and his friends recognized in Galileo's investigations the same approach they used for the exploration of nature. Although a valuable source of information on the members of the Lynx Accademy and their response to Galileo's instrumental investigations of nature, Freedberg's book is not engaging the kind of questions I am trying to address here and have little to say about Galileo's engagement with other works and traditions of natural history. See *David Freedberg, The Eye of the Lynx: Galileo, His Friends, and the Beginnings of Modern Natural History* (Chicago, Ill; London: University of Chicago Press, 2002).

hand, I draw on recent developments in the field of early modern empiricism.[6] On the other, I offer here a continuation of my own investigations into forms of early modern natural history.[7] Last but not least, I draw on recent discussions which have clarified our understanding of "expert knowledge" in mechanical arts.

2. NATURAL HISTORY, "SPECIALIZED OBSERVATION," AND EXPERT REPORTS

Recent studies have investigated the complex (and somewhat parallel) early modern emergence of the specialized instrumental observation in fields such as astronomy, natural history and medicine. A series of authors have shown how, in all these fields, observations and descriptions of experimental procedures gradually gained epistemic independence from explanations and theories.[8] Parallel developments have drawn attention to the importance of investigating various "philosophical instruments," i.e. artefacts which were at the same time tools and objects of inquiry.[9] Both these directions of investigation had drawn attention towards the

[6] Here is a relevant selection: Alan Salter, "Early Modern Empiricism and the Discourse of the Senses", in *The Body as Object and Instrument of Knowledge*, ed. Ofer Gal and Charles Wolfe (Springer, 2010); Ofer Gal and Raz Chen-Morris, "Empiricism without the Senses: How the Instrument Replaced the Eye", in *The Body as Object and Instrument of Knowledge* (Springer, 2010); Gianna Pomata, "Sharing Cases: The Observationes in Early Modern Medicine", *Early science and medicine* 15, no. 3 (2010); Gianna Pomata and Nancy G. Siraisi, *Historia: Empiricism and Erudition in Early Modern Europe, Transformations* (Cambridge, Mass.: MIT Press, 2005).

[7] Sorana Corneanu, Guido Giglioni, and Dana Jalobeanu, "Introduction: The Place of Natural History in Francis Bacon's Philosophy", *Early Science and Medicine* 17(2012); Dana Jalobeanu, "Francis Bacon's Natural History and the Senecan Natural Histories of Early Modern Europe", *ibid*; "The Philosophy of Francis Bacon's Natural History: A Research Program", *Studii de stiinta si cultura* 4(2010); "The French Reception of Francis Bacon's Natural History in Mid Seventeenth Century France", in *Bacon et Descartes: Genèses de la Modernité Philosophique*, ed. Elodie Cassan (Lyon: ENS, 2014 (forthcoming)); *The Hunt of Pan: Francis Bacon's Art of Experimentation and the Invention of Science* (Bucuresti: Zeta Books, 2014 (forthcoming)).

[8] Here is a relevant selection of articles treating this important development of early modern science: Arianna Borelli, "Thinking with Optical Objects: Glass Spheres, Lenses and Refraction in Giovan Battista Della Porta's Optical Writings", *Journal of Early Modern Studies* 3, no. 1 (2014); Gianna Pomata, "Observation Rising: Birth of an Epistemic Genre, 1500–1650", in *Histories of Scientific Observation*, ed. Lorraine Daston and Elizabeth Lünbeck (Chicago: University of Chicago Press, 2011); "A Word of the Empirics: The Ancient Concept of Observation and Its Recovery in Early Modern Medicine", *Annals of science* 68, no. 1 (2011). Such investigations are adding depth and a contextual reconstruction to previous discussions which tended to treat natural historical investigations in terms of "facts". See Lorraine Daston, "Baconian Facts, Academic Civility, and the Prehistory of Objectivity", *Annals of Scholarship* 8(1991); Barbara Shapiro, *A Culture of Fact: England*, 1550–1720 (Ithaca: Cornell University Press, 2000).

[9] Borelli, "Thinking with Optical Objects: Glass Spheres, Lenses and Refraction, in Giovan Battista, Della Porta's Optical Writings, 42. On canons as "philosophical instruments" see Mary Heningen Voss, "Commets and Cannonballs: Reading Technology in a Sixteenth Century Library", in *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation, History of Science and Scholarship in the Netherlands*, ed. Lissa Roberts, Simon Schaffer, and Peter

emergence, at the end of the sixteenth century, of novel genres of writing, such as the medical and astronomical *observationes*,[10] and the "expert reports" in mechanical arts.[11] Although different in style, such writings testify the emergence of a category of "specialized observations," recorded in writings which, although varying from one field to another, contain, in general, at least brief instructions on "how-to:" how-to use an instrument, how to make accurate observations, how to calibrate instruments in order to achieve repeatable or simultaneous observations etc. They can also be collections of observations, natural histories of a particular kind, supplemented with a particular methodology. Whichever is the case, these novel genres of "scientific" writing renegotiate the relation between the book and the practise (between the laboratory and the library).[12]

All these results coming from various fields (history of medicine, histories of scientific observation, history of instruments and instrumental practices) have begun to make an impact within the related field of natural history. For example, Brian Ogilvie has convincingly shown how natural historical investigation has evolved during the sixteenth century from a more general, non-specialized investigation (of books and nature) into a discipline properly speaking. Ogilvie claims that natural history became, by the end of the sixteenth century a "science of describing," characterized by the development of a "sophisticated technology of observation and description,"[13] which contributed, in turn, to the aggregation of a specialized research community. Ogilvie's investigations of botanical collections and natural histories of plants seem to confirm his claim; namely, that by the end of sixteenth century naturalists developed a novel genre of writing, which combined in a characteristic manner textual descriptions of species with a "scientific" imagistic representation of the object described.[14] Ogilvie's claim is that such "new"

Dear (Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen, 2007). For the novel trends in discussing the intricate relation between manufacturing instruments and knowledge production, see Lissa Roberts, Simon Schaffer, and Peter Dear, *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation, History of Science and Scholarship in the Netherlands* (Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen, 2007). See also Mihnea Dobre "On Glass-Drops: A Case Study of the Interplay between Experimentation and Explanation in Seventeenth-Century Natural Philosophy", *Journal of Early Modern Studies* 2(2013).

[10] Pomata, "Observation Rising"; "Sharing Cases: The Observationes in Early Modern Medicine"; "Praxis Historialis: The Uses of Historia in Early Modern Medicine", *Historia: Empiricism and Erudition in Early Modern Europe* (2005).

[11] On the role of experts and expertize (and the formulation of experts reports), see Eric H. Ash, *Power, Knowledge, and Expertise in Elizabethan England* (Baltimore: Johns Hopkins University Press, 2004); Cesare Pastorino, "The Mine and the Furnace: Francis Bacon, Thomas Russell, and Early Stuart Mining Culture", *Early Science and Medicine* 14(2009); "Weighing Experience: Experimental Histories and Francis Bacon's Quantitative Program", *Early Science and Medicine* 16(2011).

[12] Heningen Voss, "Commets and Cannonballs: Reading Technology in a Sixteenth Century Library; Jalobeanu, *The Hunt of Pan: Francis Bacon's Art of Experimentation and the Invention of Science*. Chapter 3.

[13] Brian W. Ogilvie, *The Science of Describing: Natural History in Renaissance Europe* (Chicago: University of Chicago Press, 2006), 209.

[14] Ogilvie claims that this form of representation was elaborated through a purposeful departure from the naturalistic, perspectival style so common in the "scientific" engravings at the time.

histories of plants were the result of specialized field observations; written in what we would call today a "technical jargon," and addressed to colleagues and peers.[15] The trademark of this specialized language is the particular recording of the "specialized observation." This is done in terms of *relevant features* of the phenomenon observed. As Ogilvie has shown, for sixteenth century naturalists such relevant features were the particular *differentiae* of the object (species) investigated with respect to others, of the same genre. This means that naturalists functioned within a general accepted taxonomy (of natural kinds) and extended this given framework by various forms of analogical thinking, by detecting resemblances (with known elements of the general taxonomy) and significant differences. Although Ogilvie's investigations focus on histories of plants and animals, it is clear that this kind of recording of specialized observations is more general and extend at least to anatomy, *materia medica*, medicine, and cosmography. Gianna Pomata has documented a strikingly parallel development of specialized observation in medicine and astronomy.[16] Although similar in many respects, specialized observations in all these fields also had their own conventions of representations and "technical language." In conclusion, rather than seeing natural history as one early modern discipline, it is perhaps more accurate to regard it as a disciplinary cluster; an aggregate of differently oriented "sciences of describing," each with its own specialized community of practitioners. I have attempted to call this view "the research oriented view on natural history."[17]

It is important to emphasize that these "sciences of describing"[18] were as much about books as about nature. The kind of knowledge necessary for specialized observations came from learning the tools of the trade, such as the humanist methods of reading, note-taking, recording, corresponding and collaborating with peers and students. The intricate relationship between humanist methods of research and the empirical exploration of nature, the fluctuating borders between the library and the laboratory have only recently became subject of extended investigations.[19] We are only beginning to understand the multiple ways in which complex activities characteristic of humanist historical research were used to supplement and inform the empirical (sometimes even the experimental and interventionist) exploration of nature. One level of interaction was that of collaboration. Natural historical research was often a collective enterprise; sometimes it was straightforwardly collaborative.

[15] Contrary to the received view which sees natural history as a non-specialized discipline, a leisurely study of nature sometimes associated with the elite and the aristocracy, Ogilvie argues for the professionalization and specialization in the field. This specialization also marks the limit of his "science of describing". Once the naturalists are confronted with the exotica brought by travelers from newly discovered land, they found themselves outsides the borders of their own methodology.

[16] Pomata, "Observation Rising".

[17] Jalobeanu, *The Hunt of Pan: Francis Bacon's Art of Experimentation and the Invention of Science*, Chapter 3.

[18] *Ibid*., Chapter 3.

[19] See for example Heningen Voss, "Commets and Cannonballs: Reading Technology in a Sixteenth Century Library"; Richard Yeo, *Notebooks, English Virtuosi, and Early Modern Science* (Chicago: University of Chicago Press, 2014).

Observations, travel reports, recipes, technologies and written reports about instruments freely travelled from one book to another and got sometimes incorporated in more ambitious treatises of cosmography and natural philosophy.

Last but not least, a characteristic feature of all the "sciences of describing" evolving within this larger framework of a research-oriented natural history was their programmatically provisional character. Even the most complex and sophisticated treatises of natural history claim from the very beginning that they are merely provisional (sometimes even preliminary) undertakings in a larger, collaborative and collective exploration of nature.[20] One result of this attitude is the complex relationship between natural historical investigations and the corresponding theories. I have suggested that for research oriented natural history theories functions as a sort of background knowledge. This means that, even when drawing on corresponding background knowledge, empirical investigations and experimental procedures have a high degree of epistemic independence which makes them "detachable" from the background and "transferable" in a very different context.[21]

This is the context in which I would like to discuss some of the characteristic elements of Galileo's *Sidereus nuncius* in order to show how well they fit into the general framework of the research oriented natural history. My claim is not that *Sidereus nuncius* is a natural historical treatise. Instead, I suggest that Galileo was purposefully exploiting a familiar way of writing in order to engage a larger community. *Sidereus nuncius* notoriously opens with an address to "all observers of natural phenomena." It is to their benefit that Galileo records the results of his specialized observations within the framework – and using some of the widespread conventions – of (research oriented) natural history.

3. ELEMENTS OF NATURAL HISTORY IN *SIDEREUS NUNCIUS*

Despite being relatively short, *Sidereus nuncius* is a very composite writing, bearing many signs of being composed of parts put together in haste.[22] Scholars have amply documented the stages of its composition; and have indicated some of the last minutes additions and changes with which Galileo attempted to make this

[20] For a discussion, see Jalobeanu, "Francis Bacon's Natural History and the Senecan Natural Histories of Early Modern Europe".

[21] Dana Jaboleanu, Learning from Experiment: Classification, Concept Formation and Modeling in Francis Bacon's Experimental Philosophy, *Revue Roumaine de Philosophie 57, no. 1 (2013);* Dana Jaboleanu, *The Hunt of Pan: Francis Bacon's Art of Experimentation and the Invention of Science*.

[22] For the composition of *Sidereus nuncius,* see Gingerich and Van Helden, "From Occhiale to Printed Page: The Making of Galileo's *Sidereus Nuncius*". See also: Galileo Galilei, *Sidereus Nuncius (or the Sidereal Messenger)*, trans. Albert Van Helden (Chicago: University of Chicago Press, 1989). Eileen Adair Reeves, *Galileo's Glassworks: The Telescope and the Mirror, Introduction* (Cambridge, Mass. ; London: Harvard University Press, 2008); Eileen Reeves, "Kingdoms of Heaven: Galileo and Sarpi on the Celestial" (2009).

book a more successful application in his quest for a job at the court of the Grand Duke of Tuscany.[23] The most carefully written part of the book contains Galileo's description of the telescope and his results in surveying, through the telescope, the rough surface of the moon. The second part of the book refers to the telescopic observations of constellations; this part is much shorter and bears signs of being hastily interpolated and less carefully drafted than the others.[24] Last but not least, the third part contains reports on Galileo's daily observations of the four new stars. Differences between the three parts extend from the language, to the kind of drawings and diagrams attached. As it was often remarked, Galileo used etchings to represent the rough surface of the moon,[25] and much simpler, schematic drawings for the wooden plate engravings representing the disposition of Jupiter's satellites.[26] The language for describing the moon and the stars is at least as different as the engravings are. In the letter dedicatory and the prefatory material, Galileo himself emphasizes the composite material of his "astronomical message;" and claims that his "small treatise" contains "matters of great interest for *all observers of natural phenomena*."[27] The book is thus presented from the beginning as a *collection* of discoveries, made with the help of a wonderful instrument. Moreover, exploiting further the same language, Galileo clearly states that what he has offered are merely first fruits of his explorations with the novel instrument. He even claims that "more excellent things will be discovered in time, either by me or by others, with the help of a similar instrument."[28] All this is typical language of natural historical research; and Galileo is clearly exploiting it, placing his discoveries in

[23] One such last minute change seemed to have been the name of the four new stars discovered; they were initially called *Cosmica Siderea*. The error was corrected by pasting slips of paper with the word *Medicea* over *Cosmica*. A letter from Galileo to the secretary of the Grand Duke is exploiting the trope of the "first discoverer" of the new stars about to give names to his discoveries. Galileo claims: "I wish, in imitation of the ancient sages who placed the most excellent heroes of that age among the stars, to inscribe these with the name of the Most Serene Grand Duke". See Galileo, *Opere* 10: 281 and A. Van Helden's Introduction to Galilei, Sidereus Nuncius (or the Sidereal Messenger). For Galileo's attempt to present his discoveries in the learned humanist context of the particular political mythology supported by the Medici see Mario Biagioli, "Galileo the Emblem Maker", *Isis* 81, no. 2 (1990).

[24] Eileen Reeves also suggested that this part displays interesting details which might have been the results of observations done with an older, more primitive device than the Galilean telescope. See Reeves, *Galileo's Glassworks: The Telescope and the Mirror*, Chapter 5.

[25] On the original drawings of the moon and the relation between the originals and the engravings eventually published see Gingerich and Van Helden, "From Occhiale to Printed Page: The Making of Galileo's *Sidereus Nuncius*".

[26] For Galileo's observations of Jupiter's satellites and their representation, see Enrico Bernieri, "Newly acquired and traditional knowledge of Galileo's observations", *Revue roumaine de philosophie*, tome 58, 1, 2014.

[27] The Latin reads: *Magna equidem in hoc exigua tractatione singulis de Natura speculantibus inspicienda, contemplandaque propono* (Galileo Galilei, *Sidereus Nuncius*, [Cambridge] Magna, Longeque Admirabilia Spectacula Pandens ... , [Another edition.] ed., vol. Jacobi Flesher; [Cambridge:] prostant apud Gulielmum Morden (Londini, 1653), 9.

[28] Sidereus Nuncius, 11. This trope of the unfinished and perfectible first inquiry can and was further exploited. In a couple of places in the book Galileo refers to his present exploits as merely introductory and send the reader to his work in progress, a "system of the world."

the same tradition of the introductory, empirical and collective exploration of nature.[29] Numerous other stylistic elements of *Sidereus nuncius* are similarly selected from the contemporary travel literature, natural history and cosmography.[30] Such rhetorical elements give a very interesting outlook to Galileo's epistle dedicatory where the same discoveries are introduced with a typically humanist discussion of memory and history.

3.1. Giving names, memorials and the art of memory

The letter dedicatory to the Grand Duke begins with a curious passage on the weak state of human memory and the need for a good collection of "memorials."

> For the state of the human mind is such that unless it be continually stirred up by the likeness of things obtruding themselves upon it from without, all recollection of them easily passes away from it.[31]

In true humanist fashion, the purpose of this passage is twofold. On the one hand, Galileo uses it to emphasize the distinction between the truly lasting memorials "on the sky" and the transitory human creations and hence the value of placing the name of Medici on the heavens.[32] On the other, Galileo uses the same passage to give a mnemonic value to his own discoveries. He refers to the "especially noble and admirable invention of human sagacity," which devised "incorruptible symbols" and prompts for memory, linking thus the celestial symbols to historical names. This art, he claims "has been out of use for many generations," due to the seemingly eternal configuration of the sky. In this way, Jupiter's satellites have a double role: besides glorifying the name of Medici, they also provide prompts for the restoring the ancient art of memory to perfection. Since the

[29] Jalobeanu, "Francis Bacon's Natural History and the Senecan Natural Histories of Early Modern Europe".

[30] For a discussion (but not so many examples), see Pierce Brown, "That Full-Sail Voyage": Travel Narratives and Astronomical Discovery in Kepler and Galileo", in *The Invention of Discovery 1500–1700*, ed. James Fleming (London: Ashgate, 2011).

[31] Galileo Galilei, *The Essential Galileo*, trans. Maurice A. Finocchiaro (Indianapolis, Ind.: Hackett ; Lancaster, 2008), 45.

[32] For a more elaborate "emblematic" and astrological significance of this move see Biagioli, "Galileo the Emblem Maker", 244. Galileo inserts his discovery into a providential history in which he is merely a "mediator," bringing to light a "proof" of Medici's dynastic horoscope. Biagioli reconstructed this episode as a successful bid for patronage. On the other hand, Darrek Rutkin has convincingly shown that the strategy of associating a the name of a potential patron with celestial memorials in the heavens was not Galileo's invention, but was also practiced by Tycho Brahe in the letter dedicatory of *Astronomiae Instauratae Mechanica* (1598) and by Kepler, in *Astronomia Nova* (1609). See H. Darrel Rutkin, "Celestial Offerings: Astrological Motifs in the Dedicatory Letters of Kepler's Astronomia Nova and Galileo's Sidereus Nuncius", in *Secrets of Nature. Astrology and Alchemy in Early Modern Europe*, ed. William Newman and Anthony Grafton (Cambridge: MIT Press, 2001), 139–43.

spyglass revealed not only four new stars circling around Jupiter, but many "ten times more stars" than previously known,[33] the reader is left to draw the implicit inference: a more accurate catalogue of the stars (or a natural history of heavens) will be able to provide, in the future, a grand scale collection of "memorials;" and a lasting record of (human) history.[34]

3.2. The spyglass: from a marvellous device to a philosophical instrument

Much has been written about the way in which Galileo has presented his discoveries as following "naturally" from the appropriate use of his new instrument. It has been rightly suggested that Galileo's attitude towards the telescope was neither that of an astronomer, nor that of an optician; it was that of a practitioner of mixed mathematics towards his tools of the trade.[35] This means that he saw the telescope mainly as a problem-solving device; something to be improved and put to work, perhaps in an entirely different field than initially planned. This is why some still tend to read *Sidereus nuncius* as the associated set of instructions on how to construct, how to calibrate and how to use the novel instrument; the perfect correspondent of Galileo's earlier mechanical textbook on the military compass.[36] Meanwhile, if one pays attention to Galileo's prose, one cannot miss the similarities between his way of introducing the telescope and natural historical reports of marvellous objects and devices. The spyglass is introduced by means of a natural historical report: "rumour" of a remarkable and wonderful device reached Venice; then the object itself, an artefact with marvellous properties and yet unexplored features.

> About ten months ago a report reached my ears that a Dutchman had constructed a spyglass, by the aid of which visible objects, although at a great distance from the eye of the observer, were seen distinctly as if near; and some demonstrations of its wonderful performances were reported, which some gave credence to, but others contradicted. A few days later I received confirmation of the report in a letter written from Paris by a noble Frenchman, Jaques Badovere. This finally determined me to give myself up first to inquire into the principle of the spyglass, and then to consider the means by which I might arrive at the invention of a similar instrument.[37]

[33] Galilei, *The Essential Galileo*, 48.

[34] It is worth noting that in subsequent writings Galileo continue to claim that his telescope reveals the true constitution of the universe, that it keeps the book of nature "open to our gaze," or that the telescope "demonstrate" things, making them plain for everyone to see and to "grasp it as if by hand" (*ibid*., 184).

[35] Strano, "Galileo's Telescope: History, Scientific Analysis, and Replicated Observations", 19. On the history of the telescope in the seventeenth century, see also Van Helden, "The Telescope in the Seventeenth Century".

[36] Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (Chicago, London: University of Chicago Press, 2006).

[37] Galilei, *The Essential Galileo*, 49–50.

What Galileo presents here is a classical scenario one can find in natural histories of *exotica* and in the tradition of the books of secrets; the report of the marvellous device is first confirmed and certified by a credible witness before being personally investigated and tried repeatedly in order to understand fully the new device.[38]

> After a little while I succeeded, through deep study of the theory of refraction. I prepared a tube, at first of lead, in the ends of which I fitted two glass lenses, both plane on one side, but on the other side one spherically convex, and the other concave. Then bringing my eye to the concave lens I saw objects satisfactorily large and near, for they appeared one-third of the distance and nine times larger than when they are seen with the natural eye alone. Shortly afterwards I constructed another more precise spyglass, which magnified more than 60 times. Finally, by sparing neither labour nor expense, I succeeded in constructing for myself an instrument so superior that objects seen through it appear magnified nearly 1000 times […] than if viewed by the natural powers of sight alone.[39]

In other words, Galileo claims that he has tried the marvellous device and that he has learned how to improve it. Thus, the telescope is presented as a newly discovered, wonderful artefact with unexplored potentialities, capable of producing knowledge. This familiar way of describing a philosophical instrument was not lost on Galileo's readers. In his response to *Sidereus nuncius*, Kepler claims that the wonderful instrument was "announced" by Giovan Battista della Porta in his *Magia naturalis* and even gives an extended quote from chapter XVII, where Porta suggests using a combination of convex and concave lenses in order to see at great distances.[40] Kepler also suggests that Della Porta's description of a marvellous instrument with which one can "see very far, beyond imagination," might have been something similar with Galileo's telescope, but that Della Porta description of

[38] Compare for example with the description of marvelous instruments and recipes in book XVII of Della Porta, *Magia naturalis* (on optics and optical devices) and the marvelous burning mirrors described in book IV of Cardano *De subtilitatis*. See also Reeves, *Galileo's Glassworks: The Telescope and the Mirror*. Reeves suggests that Galileo himself had other optical devices for surveying the sky, previous to the "spyglass;" even more similar than the ones described by Cardano and Della Porta.

[39] Galilei, *The Essential Galileo*, 50.

[40] Della Porta himself has accused Galileo of stealing his discovery and claimed to be the first inventor of the miraculous instrument. Even after recognizing that Galileo has perfected and put to another use his initial device, Porta still claimed that the telescope was developed on the principles put forward in *Magia naturalis* and *De refractione*. See Freedberg, *The Eye of the Lynx: Galileo, His Friends, and the Beginnings of Modern Natural History*, 103–05. It is worth noting that Chapter XVII, like most of the chapters added to the second edition of Magia naturalis, contains some of Della Porta's more experimental and natural historical investigations. On Della Porta and natural history see Laura Balbiani, *La Magia Naturalis di Giovan Battista della Porta. Lingua, cultura e scienza in Europa all'inizio dell'età moderna* (Bern: Peter Lang, 2001); Borelli, "Thinking with Optical Objects: Glass Spheres, Lenses and Refraction in Giovan Battista Della Porta's Optical Writings".

the construction of such an instrument was deliberately obscured, so that no one could really understand it.[41] To Della Porta's speculations, Kepler adds his own principles and theories, developed in the *Optical part of astronomy.* He claims that:

> In my fifth chapter, where I set forth the details of the process of vision, there may be seen […] a diagram in which drawings of a concave and convex lens are joined exactly as they are generally combined nowadays in the familiar tubes. Did the reading of Della Porta's *Magic* give rise to this device? Or did some Dutchman, following Della Porta's instructions, manufacture many examples of this instrument as commodities for sale? […] Even if not, that diagram on page 202 of my book could itself surely have indicated the construction to an alert reader, especially if he examined my proofs in conjunction with Della Porta's text.

Even more interesting is Kepler's justification for this kind of reading. This attempt of placing the new instrument in relation to a theoretical background is not supposed to diminish the merit of the technical invention, but, rather, to establish its credibility. Kepler argues for the new instrument's *plausibility*.[42] It is also worth emphasizing that Kepler's attempt to argue in favour of an instrument he has not even seen also abounds in the tropes of natural history and travel literature. Kepler claims:

> I do not advance these suggestions for the purpose of diminishing the glory of the technical inventor, whoever he was. I am aware how great a difference there is between theoretical speculation and visual experience; between Ptolemy's discussion of the antipodes, and Columbus' discovery of the New World, and likewise between the widely distributed tubes with two lenses and the apparatus with which you, Galileo, have pierced the heavens. But here I am trying to induce the sceptical to have faith in your instrument.[43]

Kepler's discussion shows him fully aware of the serious technical and conceptual difficulties springing from the big gap between the theoretical principles of optics and the practical realization of the telescope.[44] Meanwhile, his

[41] Johannes Kepler, *Kepler's Conversation with Galileo's Sidereal Messenger*, trans. Edward Rosen (New York: Johnson Reprint Corporation, 1965), 16–17. See also Reeves, *Galileo's Glassworks: The Telescope and the Mirror*.

[42] It is important to emphasize that at the time of writing his *Dialogues with Sidereus nuncius* Kepler had not seen the instrument. There are quite a number conflicting interpretations of Kepler's response to Galileo's discoveries. Here is a relevant sample of them: Edward Rosen, "Galileo and Kepler: Their First Two Contacts", *Isis* (1966); Massimo Bucciantini, *Galileo e Keplero: Filosofia, cosmologia e teologia nell'età della controriforma* (Torino: G. Einaudi, 2003); Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy*. I think that they are equally neglecting the natural historical key in which Kepler is reading Galileo's text.

[43] Kepler, *Kepler's Conversation with Galileo's Sidereal Messenger*, 17.

[44] As Ariana Borelli has convincingly shown how this wide gap was filled with procedures of manipulating of and learning from "philosophical instruments." See also Domenico Bertoloni Meli, *Thinking with Objects: The Transformation of Mechanics in the Seventeenth Century* (JHU Press, 2006).

attitude is no different from the one advocated by Galileo's report: after assessing the credibility of the witness, Kepler devises a complex "trial". And since he does not have the instrument itself, the trial is directed towards evaluating the reported performances and formulating further questions of research. Like Galileo, Kepler also imagines theoretical and practical developments destined to improve the instrument, to increase its magnifying power and to correct its aberrations.

3.3. Craters, mountains and other geographical features of the moon

The most striking elements of natural history of *Sidereus nuncius* are to be found, unsurprisingly, in Galileo's description of the moon's surface. After all, the major aim of this first part of the small treatise is to establish that the moon is similar in many relevant ways with the earth (being, thus, subject to cartography and descriptive geography/selenography).[45] No wonder, therefore, that Galileo's argument is filled with analogies coming from geography, map-making,[46] travel literature,[47] and mechanical arts.[48] Meanwhile, as Roger Ariew has convincingly shown, this part of *Sidereus nuncius* was also the most contested. Jesuit astronomers who accepted almost immediately that Venus has phases and confirmed Jupiter's satellites were, in turn, much more reserved regarding the mountains of the moon.[49] At least some of Galileo's first readers tended to consider that his claim that there are mountains on the moon was of a different kind than his other discoveries; and

[45] Galileo was probably not the first to draw a map of the moon; at the date of his first telescopic observations, Thomas Harriot and William Gilbert had already begun to draw moon maps; Gilbert also included a "selenography" in his manuscript of *De mundo*. However, as has been pointed out, Gilbert first map of the moon is very different from Galileo's drawings; while his subsequent "maps" reproduce the conventions of drawing he has obviously learned from *Sidereus nuncius*. See Stephen Pumfrey, "Harriot's Maps of the Moon: New Interpretations", *Notes and Records of the Royal Society* 63, no. 2 (2009); Terrie F Bloom, "Borrowed Perceptions: Harriot's Maps of the Moon", *Journal for the History of Astronomy* 9(1978).

[46] See Eileen Reeves' discussion of Galileo's analogy between one of the moon crater and the position and shape of Bohemia on the current maps of the earth. I will give a slightly different interpretation to Galileo's analogy than the political interpretation formulated by Reeves. Reeves, "Kingdoms of Heaven: Galileo and Sarpi on the Celestial".

[47] Brown, "That Full-Sail Voyage": Travel Narratives and Astronomical Discovery in Kepler and Galileo"; Frédérique Aït-Touati, *Fictions of the Cosmos: Science and Literature in the Seventeenth Century* (Chicago, Ill.: University of Chicago Press, 2011). However, it is worth mentioning that although both authors are suggesting a strong similarity between Galileo's prose and that of the travel literature, they do not discuss the particular examples I am discussing here.

[48] Here is an interesting example: "This part of the surface of the moon, where it is marked with spots like a peacock's tail, with its azure eyes, looks like those glass vases that, through being plunged while still hot from the kiln into cold water, acquire a crackled wavy surface, from which circumstance they are commonly called frosted glasses" (Galilei, *The Essential Galileo*, 54).

[49] Roger Ariew discusses some of the early responses to Galileo's discoveries in Roger Ariew, "The Initial Response to Galileo's Lunar Observations", *Studies in History and Philosophy of Science* Part A 32, no. 3 (2001). See also "Galileo's Lunar Observations in the Context of Medieval Lunar Theory", *Studies in History and Philosophy of Science*, part A, 3 (1984).

some, at least, thought it was based on false assumptions.[50] As it has been already pointed out, Galileo's argumentation in favour of his claim is intricate and complex;[51] it involves various forms of analogical thinking but also an interesting interplay between the information provided by the text and the famous drawings of the moon's surface.[52] The two are complementing each other; and they are clearly not saying the same things. The drawings show us interesting reconstructed images of the moon's surface as seen through the telescope. Meanwhile, the text recounts observations of a dynamic process; they describe the variation of the light/dark patterns of moon's spots, as they unfold, during an interval of several hours. The language is reminiscent of descriptions of natural phenomena given by naturalists and travellers:

> And here I cannot refrain from mentioning what a remarkable spectacle I observed while the moon was rapidly approaching her first quarter, a representation of which is given in the same illustration given above. A protuberance of the shadow, of great size, intended the illuminated part in the neighbourhood of the lower cusp. When I had observed this indentation a while, and had seen that it was dark throughout, finally, after about two hours, a bright peak began to arise a little below the middle of the depression. This gradually increased, and presented a triangular shape, but was as yet quite detached and separated from the illuminated surface. Soon around it three other small points began to shine. Then when the moon was just about to set, that triangular figure, having now extended and widened, began to be connected with the rest of the illuminated part, and, still girt with the three bright peaks already mentioned, suddenly burst into the indentation of shadow like a vast promontory of light.[53]

What we have here is a vivid and quite dynamic description of a natural phenomenon (the sunrise seen "on the moon"). It is a process described almost "in

[50] The false assumption is that earth and moon are similar. The standard answer to Galileo's claim was that one can interpret the pattern of spots otherwise than by assuming that there are mountains and valleys on the moon. As Ariew has shown, the scholastics explained the spots in terms of differences of densities between different regions of lunar matter. Galileo's theory offered an alternative account for the same phenomenon; by themselves his observations cannot (and do not) refute the received, "standard" theory. See "Galileo's Lunar Observations in the Context of Medieval Lunar Theory", "The Initial Response to Galileo's Lunar Observations", 578.

[51] Shea, "Looking at the Moon as Another Earth: Terrestrial Analogies and Seventeenth-Century Telescopes".

[52] Gingerich and Van Helden, "From Occhiale to Printed Page: The Making of Galileo's Sidereus Nuncius", 260. Gingerich and Van Helden claim that the illustrations are "visual aids to the text". My claim is slightly different; I see text and images providing different kind of information and reconstructing together the actual observation. On the accuracy of Galileo's moon maps, see Ewan A Whitaker, "Galileo's Lunar Observations and the Dating of the Composition of Sidereus Nuncius", *ibid.* 9(1978). See also Winkler and Van Helden, "Representing the Heavens: Galileo and Visual Astronomy".

[53] Galilei, *The Essential Galileo*, 53–54.

real time." And yet Galileo claims that he has given a "representation" of this "remarkable spectacle" on the first of his four illustrations. The text is slightly misleading here; there is no way in which the first lunar drawing can "represent" the phenomenon. The only connection between the text and the image is that both contain the relevant feature which has to be explained, namely the small dark shadows present in the bright area of the new moon. In fact, what the first image of the moon's surface does represent is a collection of all the relevant features of "Galileo's discovery" regarding the moon, namely four distinctive features of the moon's spots. The first feature is the irregular appearance of the terminator. The second feature is represented by the larger spots; or what Galileo calls the "great" or "ancient" spots of the moon, well known to all and visible also to the naked eye. The third feature is represented by the smaller and darker spots, which are only visible if one observes through the telescope the bright side of lunar surface; while the fourth refers to the small luminous spots one can observe, through the telescope, on the shadowy part of the moon. All these features are represented in the first engraving of the moon from *Sidereus nuncius*. Thus, this particular image becomes the representation of a collection of problems. But the way in which Galileo formulates these problems is highly relevant. He does not write like an astronomer, who would have simply stated that the pattern of spots is new and unexpected. He does not write like a natural philosopher, because he refuses to engage directly with the standard theory of the lunar spots. The interplay of text and image in the corresponding passages of *Sidereus nuncius* is that of a naturalist who attempts to describe his new objects in terms of relevant features, resemblances and *differentiae* within a larger category of similar objects.

3.4. Reconstructing images, drawing and the selection of relevant features

The next two engravings of the moon depicted in *Sidereus nuncius* are quite different from the first. They represent on the terminator a surprisingly large central round spot, and show how the relative ratio of light/dark on that particular round shape changes at various moments of time. In Galileo's words, the two images show the progressive changes in illumination of a large crater. This is how the text goes:

> There is one other point which I must on no account forget, and which I have noticed and rather wondered at. It is this. The middle of the moon, as it seems, it is occupied by a certain cavity larger than the rest, and in shape perfectly round. I have looked at this depression near both the first and third quarters, and I have represented it as well as I can in the two illustrations given above. It produces the same appearance with regard to light and shade as an area like Bohemia would produce on the earth, if it were shut in on all sides by very lofty mountains arranged on the circumference of a perfect circle; for this area of the moon is

> walled in with peaks of such enormous height that the furthest side adjacent to the dark portion of the moon is seen bathed in sunlight before the boundary between light and shade reaches halfway across the circular space.[54]

Mark again the descriptive language of the geographical exploration and the geographical analogy with a region on the earth. Galileo describes in detail the changes of illumination of this particular crater in order to infer from here a conclusion about the moon's surface. As it has been emphasized before, the visual representation of this particular feature of moon's relief is greatly exaggerated. The image is giving us an enlarged relevant feature of the Moon's surface, in the same way in which a naturalist would provide us with an enlarged representation of a particular feature of the plant he was drawing.[55] As Brian Ogilvie has shown, this particular process of selecting and enlarging relevant features was a characteristic of late sixteenth century natural historians. According to Ogilvie, naturalists developed not only technologies of observation and communication, but also specific (and standardized) representational conventions for both text and image.[56] Often the text gave the story of the plant; described its annual cycle and its uses, while the engraving represented in a conventional manner the (important) parts of the plant.[57] In many cases, special attention was given to what were considered to be the *relevant* features of the object under investigation. Ogilvie claims that these were mainly its particular *differentiae* within a larger taxonomic scheme (of natural kinds).[58] However, one can see situations in which the curious, unexplainable or the useful parts of a plant are enlarged and represented in a more careful manner than the rest of the ensemble.[59]

[54] *Ibid*., 56.

[55] Scholars disagree on the significance and particular conventions in Galileo's drawings. Some see the moon engravings as representatives for the disegno; and also as representative of a use of images that Galileo eventually abandoned. Others emphasize the primarily pedagogical use of such drawings and the similarities between the seemingly more "naturalistic and perspectival" drawings of the moon and later more conventional diagrams. For the later opinion see for example Renée Raphael, "Teaching through Diagrams", *Early Science and Medicine* 18. For a more general discussion of the different conventions of drawing in "scientific" treatises of the sixteenth and seventeenth centuries see Magureanu, "Arta în competiție cu natura în literatura artistică italiană a secolului al XVII-lea", *loc. cit.*

[56] Ogilvie, *The Science of Describing: Natural History in Renaissance Europe*, 200–201.

[57] Ogilvie shows (convincingly in my opinion) that late sixteenth century natural histories contained illustrations which departed from the naturalist and perspectival type of drawing in the direction of a more "scientific" (and conventional) representation. Conventions could differ from one naturalist to another but they were usually explained by the text.

[58] "Hence both text and image served to emphasize a focus on description of particular elements of a plant rather than its overall habit… They served the community of naturalists already familiar with the proper way to observe plants in the field, in gardens, and in herbaria, and already familiar with the basic forms that they would encounter. Newcomers to the discipline were to be accompanied by a teacher who could help them compare real plants with image and description". (Ogilvie, *The Science of Describing: Natural History in Renaissance Europe*, 202)

[59] This happens mostly in travel literature or natural histories of exotic lands. For a general survey of natural history and cosmography within the context of travel and exploration see Antonio Barrera-Osorio, *Experiencing Nature: The Spanish American Empire and the Early Scientific Revolution*, 1st ed. (Austin, TX: University of Texas Press, 2006).

In Galileo's case, the relevant features of the moon are not spots and shadows, but mountains and valleys, craters and zones of water.[60] The interplay between the text and the engravings is used in order to formulate a persuasive explanation of each of these features. It is not a full explanation; and Galileo himself refers to his "System of the world" for further clarification. But each of these relevant features can be observed, discussed and explained separately, in the familiar vocabulary of this "science of describing." For example, Galileo describes the mountains and valleys on the moon in terms of their specific differences from the corresponding relief of the earth. The moon has steeper mountains and deeper valleys, and in some cases its craters "as large as Bohemia". This particular description in terms of similarities and specific differences is further exploited by Kepler, in his *Dissertatio*. Kepler responds to Galileo's comparison between the mountains and valleys of the moon and those on earth, with examples which testify that such mountains and valleys are not impossible; that, indeed, similar mountains and valleys can be seen on earth. Characteristically, Kepler replaces Bohemia with regions he knows much better:

> You compare them [the spots] with the valleys on our earth. There are some valleys of this kind, I admit, especially in the province of Styria. They are almost round in appearance. Though very narrow passes they admit the Mur River at their upper end, and discharge it at their lower end. Such are the so-called Fields of Graz, Leibniz and Maribor on the Drava. There are others, in other regions. Round about these fields rise the lofty summits of mountains, creating the impression of a bowl, since the height of the surrounding peaks is no small fraction of the width of the fields.[61]

Kepler's discussion of such and similar features of terrestrial geography is quite extensive;[62] and his conclusion is to concede on the "possibility of such lunar valleys, carved by rivers."[63] This discussion is also quite typical for the kind of dialectic argumentation one can find in contemporary treatises of natural history and cosmography.[64] It is also typical for Kepler's general strategy in the *Dissertatio.* In

[60] Another relevant feature to be explained is moon's secondary light.

[61] Kepler, *Kepler's Conversation with Galileo's Sidereal Messenger*, 24.

[62] For example, he discusses the possibility of "virtually uninterrupted" valleys in order to account for some of the spots. *Ibid*., 24–25.

[63] *Ibid*., 24.

[64] A number of scholars have investigated the evolution of dialectics in sixteenth century and the way in which this evolution shaped the argumentative structure of cosmographies, natural histories and other "sciences." See for example Maria Portundo, *Secret Science: Spanish Cosmography and the New World* (Chicago: University of Chicago Press, 2009); Frank Lestringant and David Fausett, *Mapping the Renaissance World: The Geographical Imagination in the Age of Discovery* (Polity Press Cambridge, 1994). Raphaële Garrod has recently shown that dialectically shaped arguments played an essential role in debates that directly contributed to the redefinitions of celestial and terrestrial space in cosmography and cosmology. See Raphaële Garrod, *Heaven and Earth: The Transformations of Dialectic in Cosmography* (*French Prose: 1575–1632*) (Paris: Brepols, 2014 (forthcoming)).

it, Kepler takes Galileo's claims one by one, and assess them separately in terms of possibility and plausibility, within a larger dialectical structure of argumentation.[65]

3.5. Selenography, cosmography and interplanetary travel: natural historical explorations

The general structure of Kepler's argumentation is as follows: he begins by stating the two theoretical positions concerning the nature of the moon, namely that the moon is "like another earth" and that the moon is composed of a different substance altogether. He summarizes the traditional arguments and lists the authorities defending each position;[66] then he begins to integrate empirical and observational arguments in the whole structure, evaluating the way they strengthen or weaken each position, respectively.[67] Thus, Galileo's claims about the mountains in the moon are integrated and appropriated as arguments in favor of Kepler's own position in this debate. Meanwhile, Kepler is keenly aware that the matter is not settled yet; and here is a passage which illustrates quite clearly his own attitude. Kepler claims:

> But these suggestions (about cavities that are below the surface and not cut through the mountains) are not so weighty that I would deem them worthy of a stubborn defense, should they be rendered completely untenable by your subsequent reports. For you have established most firmly by brilliant observations in full accord with the laws of optics that many peaks tower above the body of the moon […][68]

In other words, although sympathetic to Galileo's views on the moon, Kepler is also aware that an explanation in terms of different densities of the lunar matter is not out of the question. Moreover, Kepler clearly sees Galileo's findings as merely provisional and subject to further improvement (by Galileo himself or by others). As in the case of the telescope, Kepler places Galileo's discoveries in the

[65] For a more general discussion on the application of such "patterns" of dialectical argumentation in sixteenth-century cosmographies, see *Heaven and Earth: The Transformations of Dialectic in Cosmography*, Chapters 1–3.

[66] On his own (and Galileo's) position he quotes the authority of Pythagoras, Plutarch, but also a (lost) book by Michael Maestlin which, he claims, preceded and "predicted" Galileo's discoveries. The book seemed to have been published in 1606 at Tübingen under the form of a disputatio between Maestlin and Samuel Haffenrefer (*Disputation concerning the Manifold apparent Irregularities, or Regular non-Uniformities in the Motions of the Planets in the Heavens*). Kepler gives a number of extended quotes from the book. Quotes include interesting reports of pre-telescopic observations of the "new" (small) moon spots. See Kepler, *Kepler's Conversation with Galileo's Sidereal Messenger*, 30–31.

[67] The next step is to discuss the implications of the new position for philosophy, anthropology and theology.

[68] Kepler, *Kepler's Conversation with Galileo's Sidereal Messenger*, 25. The problem of the intense heat on the moon is treated by analogy with the intense heat on Peru (which, however, does not prevent life and human habitation) (*ibid.*, 31).

larger context of contemporary debates. His discussion touches not only the rough surface of moon, its mountains and valleys, but treats of other, more sophisticated features of selenography, such as: whether some of the dark spots are oceans, whether the moon has atmosphere and whether its inhabitants are larger than humans, perhaps in the same proportion in which mountains of the moon are larger than mountains on earth. Much of these questions are left open; others are proposed as hypotheses open to further research:

> I cannot help wondering about the meaning of that large circular cavity in what I usually call the left corner of the mouth. It is a work of nature, or of a trained hand? Suppose that there are living beings on the moon (following in the footsteps of Pythagoras and Plutarch, I enjoyed toying with this idea, long ago […]). It surely stands to reason that the inhabitants express the character of their dwelling place, which has much bigger mountains and valleys than our earth has. Consequently, being endowed with very massive bodies, they also construct gigantic projects. Their day is as long as 15 of our days, and they feel insufferable heat.[69]

The language of exploration has an important function in the construction of this particular argumentative structure. It emphasizes the "geographical" features of the moon and its similarities with the earth; and hence signals the need to discuss about the moon in a larger, more comprehensive cosmography, where the part on selenography would be constructed by analogy with the more traditional cosmography based on the two-sphere model of the universe. In other words, in virtue of the similar relevant features of the moon and the earth, one can establish the "geography" and natural history of the moon in the same way, and using the same language, as that used for the same type of investigations on earth. But Kepler goes beyond analogical reasoning; he suggests that the best way to settle the debate would be simply the interplanetary travel.

> It is not improbable […] that there are inhabitants not only on the moon but on Jupiter too or […] that those areas are now being unveiled for the first time. But as soon as somebody demonstrates the art of flying, settlers from our species of man will not be lacking. Who would once have thought that the crossing of the wide ocean was calmer and safer than of the narrow Adriatic Sea, Baltic Sea or English Channel? Given ships or sails adapted to the breezes of heaven, there will be those who will not shrink from even that vast expanse. Therefore, for the sake of those who, as it were, will presently be on hand to attempt this voyage, let us establish the astronomy, Galileo, you of Jupiter, and me of the moon.[70]

[69] *Ibid*., 28.
[70] *Ibid*., 39.

Mark how astronomy is subordinated here to a practical purpose: the cosmic navigation. Yet this paragraph has another important purpose in the economy of argumentation; it emphasizes the open-ended character of natural historical research and the need for further collaboration.

4. INTEGRATING GALILEO'S DISCOVERIES IN A LARGER NATURAL HISTORY OF THE HEAVENS

Kepler's larger dialectical structure of argumentation in the *Dissertatio* seems to delineate the scheme of a more ambitious project: the attempt to integrate all Galileo's new discoveries in a larger cosmographical project; or in a natural history of the heavens (and earth).[71] *Dissertatio* does not give us too much information on the genre of project that Kepler has in mind; but we can find precious hints about this in his preface to the second edition of his *Mysterium cosmographicum* (1621). There, he explains that his plan was to write a number of "cosmographical essays" encompassing traditionally separated discipline such as observational astronomy, physics and "geography" in order to offer the proper foundations for his "restoration of astronomy."[72] In a note, he clarifies his proposal for calling this integrative approach cosmography. He explains that "there are many cosmographies, written by Germans, such as Munster; and by other authors;" but that such works are concentrating too much on descriptions of particular lands and cities, and not enough on what they should, namely careful descriptions of heavens and its parts; and of earth and its parts.[73] Meanwhile, Kepler does not write a proper cosmography, but merely its introductory part; something he describes again in terms of geographical exploration as similar to the first circumnavigation of the world.

Of course, Kepler's *Dissertatio* is not a cosmography, not even this particular, modified form of "cosmographical essay." On the other hand, it clearly contains some of the materials Kepler has planned to integrate in his cosmographical essays.[74] It also has the peculiar dialectical structure so characteristic to other cosmographical projects. Although scholars have often remarked on the peculiar character of Kepler's *Dissertatio*, most tended to read it as a direct response to Galileo's

[71] Kepler takes cosmography to be a totalizing, mixed-science of the visible universe which borrows some of its arguments from astronomy, but it is at the same time less "precise" and accurate than astronomy. Kepler claims that "cosmographers borrow the arguments for their theories from the astronomers;" however, unlike the astronomers "they do not check them by calculations as precisely as the astronomers." In addition, cosmographers "are not so acute or so critical as to be influenced by… trivial differences". See James R. Voelkel, *The Composition of Kepler's Astronomia Nova*, Princeton, N.J.; Chichester: Princeton University Press, 2001, 51. For a more general discussion on various kinds of early modern cosmography see Jackie Biro, "Heavens and Earth in One Frame": Cosmography and the Form of the Earth in the Scientific Revolution (University of New South Wales, 2006); Garrod, *Heaven and Earth: The Transformations of Dialectic in Cosmography*.

[72] Johannes Kepler, *Le Secret du Monde*, trans. Alain Segonds (Paris: Gallimard, 1993, 13).

[73] *Ibid*., 19.

[74] James R. Voelkel, *The Composition of Kepler's Astronomia Nova* (Princeton: Princeton University Press, 2001, 51).

discoveries; or even as a symbolic "conversation" to Galileo.[75] I think more interpretative work is necessary in order to fully understand Kepler's response. This would involve, in particular, a thorough, closer reading of Kepler's discourse, perhaps in the larger context of Kepler's unfinished cosmographical projects, taking into considerations questions relating to genre and conventions of (dialectical) writing.

However this may be, I will close my investigation with another project of a natural history of the heavens which attempted to integrate Galileo's discoveries in a larger, more comprehensive framework of dialectical argumentation. This is Francis Bacon's project for a natural history of the heavens, as developed in *Descriptio globi intellectualis*. This is one of Bacon's many unfinished projects; a manuscript written most probably in 1611 and published only posthumously, in 1648. Bacon's cosmology is very different than Kepler; it is geocentric, explicitly anti-Copernican, and based on a very peculiar matter-theory.[76] Meanwhile, in order to substantiate his theory of the universe, Bacon began by assembling a proper natural history of it.[77] His plan seems to have been to divide this natural history of the heavens in an astronomical and a cosmographical part.[78] It was a large project; and unlike Kepler, Bacon wrote extensively and repeatedly on how proceed in assembling such a natural history. For example, in one of his surviving letters, Bacon tried to persuade his correspondent to compose a history,

> [..] in which only the phenomena themselves, and the different astronomical instruments, with their use, and then the principal and most celebrated hypotheses, both ancient and modern, things of that kind, shall be set forth plainly and simply, without any doctrine and theory whatsoever.[79]

[75] Edward Rosen's translation is entitled "Conversation with Galileo". See for example Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy; Rosen*, "Galileo and Kepler: Their First Two Contacts". Rosen's preface and notes to the English edition of Kepler's *Dissertatio* also tends to give the impression that the text is no more than Kepler's engagement in a conversation with Galileo. Robert Westman also reads the book quite literally, picturing Kepler's directly engaging with Galileo, positioning himself in a "complementary, yet superior role to Galileo by privileging theorizing." Robert Westman, *The Copernican Question: Prognostication, Skepticism, and Celestial Order* (Berkeley: University of California Press, 2011), 461. In my view, all these analyses are missing an important point. They fail to take into consideration the genre in which Kepler was writing.

[76] Dana Jalobeanu, "A Natural History of the Heavens: Francis Bacon's Anti-Copernicanism", in Wolfgang Neuber, Thomas Rahn, Claus Zittel (eds.), *The Making of Copernicus*, special issue of *Intersections* (36), Leiden: Brill (forthcoming).

[77] In Bacon's theory of science, any proper scientia has to be constructed on the corresponding natural history. His works on heavens were planned to have two parts: a natural history of heavens and a "theory of the heavens." See Graham Rees, "Francis Bacon's Speculative Philosophy", in *Cambridge Companion to Bacon*, ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996); "The Fate of Bacon's Cosmology in the Seventeenth-Century", Ambix 24(1975).

[78] *His Catalogue of particular histories* from the closing pages of *Instauratio magna* (1620) lists three items relating to the natural history of the heavens. They are the *History of celestial phenomena, or astronomical history*; the *History of the configurations of heaven and its parts towards the Earth and its parts, or cosmographical history* and *a History of comets*.

[79] SEH XIV 375.

This passage delineates quite clearly a complex tripartite project. On the one hand, the natural history of the heavens was supposed to contain "phenomena" separated from "the force of doctrines" and theories.[80] For Bacon, the phenomenal field was large enough; it comprised positions and magnitudes of the stars, relative positions, motions and trajectories of the planets and tables of comets. In addition, he was interested in "accurate measurements" of all these phenomena. The second part of his planned natural history of the heavens was supposed to contain a section on astronomical instruments; the reference to the functioning and "use" of instruments refers, presumably, to descriptions of instruments and a description of their functioning, with a reference to measurement, calibration and the sources of error.[81] The third section is even more interesting; it is designed to collect "the most celebrated hypotheses" of previous astronomers. A similar claim can be found in *Descriptio globi intellectualis*, where Bacon states:

> […] the best history of the Heavenly Bodies would be that which could be extracted and elicited from Ptolemy, Copernicus and the more learned writers on astronomy, if you completely stripped the art from experiment and also added the observations of more recent authorities.[82]

Descriptio globi intellectualis is quite explicit as to whom Bacon had in mind when he referred to the more "recent authorities." They are the observational astronomers, who, "by means, as it were, of the skiffs and boats of optical instruments have begun just recently to do new trade with celestial phenomena'.[83]

[80] A natural history of celestial motions is also mentioned in Andreas Osiander's preface to Copernicus. According to Osiander, the astronomer's duty is "to compose the history of the celestial motions through careful and expert study. Then he must conceive and devise the causes of these motions or hypotheses about them. Since he cannot in any way attain to the true causes, he will adopt whatever suppositions enable the motions to be computed correctly from the principles of geometry for the future as well as for the past" (Nicolaus Copernicus, *On the Revolutions*, Baltimore: Johns Hopkins University Press, 1992, xix).

[81] A similar construction is described by Kepler, in his *Astronomia nova* (1604). Kepler identifies three different areas arising from observations: one is "the mechanical part, concerning instruments fit for observing the celestial motions and the manner of making use [of them]". Another is "the historical part", containing, for example, "the twenty-four books of most meticulous observations left by Tycho, encompassing nearly the past forty years". The third is the optical part. There is also a fourth part, the physical part of astronomy, but that goes beyond observation into investigating the physical causes, the formal causes and the material causes of the motions of the heavens. See Johannes Kepler, *Optics: Paralipomena to Witelo and the Optical Part of Astronomy* (Santa Fe: Green Lion Press, 2000, 15. See also G. Hon, "On Kepler's Awareness of the Problem of Experimental Error", *Annals of Science* 44(1987). On Bacon's theory of measurement see Dana Jalobeanu, "The Marriage of Physics with Mathematics: Francis Bacon on Measurement, Mathematics and the Construction of Mathematical Physics", in *The Language of Nature: Reconsidering the Mathematization of Science*, ed. Geoffrey Gorham, Edward Slowick, and Benjamin Hill (Minnesota Center for Philosophy of Science, 2014 (forthcoming)).

[82] OFB VI, 111.

[83] OFB VI, 115.

Mark Bacon's exploitation of the same familiar trope of geographical exploration; the reference to the "skiffs and boats of optical instruments" is clearly used to integrate Galileo's (and perhaps Harriot's) discoveries in the larger category of cosmographical explorations. As for the discoveries themselves, *Descriptio* integrates each of Galileo's reports from *Sidereus nuncius* and transforms them in arguments of the inquiry. The "starry" composition of the Milky Way becomes a question of an inquiry, with Galileo's reports playing the role of evidence to be further substantiated and discussed;[84] a similar treatment is given to Galileo's discovery of Jupiter's satellites and to the phases of Venus. *Descriptio globi intellectualis* also contains a reference to the mysterious nature of sunspots. In other words, Bacon proves to be an informed reader of *Sidereus nuncius* and seems acquainted with the early phases of the debate over the nature of sunspots.[85] On the nature of the moon, Bacon is more reserved; and he quotes Galileo's report within a larger discussion of Gilbert's lunar theory.

Meanwhile, Bacon integrates Galileo's reports in a clearly delineated dialectical structure. The natural history of the heavens is structured around questions, or topics of inquiry, such as: "Whether the world is a system, or whether the universe is composed of many systems, scattered and disconnected?" or "Whether the Earth or the Sun is the Centre of this System" etc. In summing up the arguments on each side of the debate, Bacon lists ancient and modern "discoveries," experiments and facts. He also suggests novel observations and experiments likely to clarify and advance the inquiry. In many places, the text bears the mark of Bacon's own hypotheses. It is beyond the purpose of this paper to discuss at length this fascinating (and relatively little explored) text. I will merely suggest that the general outline of Bacon's natural history of the heavens is in many ways similar with what we have seen so far in Kepler's "response" to Galileo: a traditional topical and dialectal structure is used in order to integrate Galileo's reports and discoveries within the larger framework of a natural history of the heavens. The structure comprises open-ended questions regarding the nature and motions of heavenly bodies; organized collection of theoretical, historical and empirical arguments; and further theoretical discussions containing hypotheses, questions regarding the theoretical implications of the new discoveries for philosophy, natural theology and the advancement of knowledge.

This interesting similarity between the ways in which two natural philosophers as different as Kepler and Bacon treat Galileo's *Sidereus nuncius* is quite striking; and perhaps it would deserve a separate investigation. My purpose so far was only to use it in order to illustrate my claim, namely that for some of its readers, *Sidereus nuncius* was a collection of observational reports in the tradition of the research oriented natural history.

[84] OFB VI 167: "new heads in the heavenly population have now been counted by Galileo, not only in that cluster called the Milky Way, but also among the very stations and ranks of the planets."

[85] On the various phases of the debate and their significance see Eileen Adair Reeves and Albert Van Helden, *On Sunspots* (Chicago: University of Chicago Press, 2010).

5. CONCLUSION

My purpose in this paper was to investigate some of the elements of natural history that make *Sidereus nuncius* such a particular, remarkable little work. I have shown that in reporting his discoveries, Galileo has drawn freely on popular literature of exploration and travel and natural historical investigations of the natural world. I do not claim that *Sidereus nuncius* is a natural history. I was rather suggesting that Galileo was purposefully exploiting a familiar way of writing in order to engage a larger community. And I have shown how two informed and interested readers of Galileo's reports read *Siderus nuncius* is a very similar manner, identifying in it elements of natural historical research fit to be integrated into their own projects for a complex and comprehensive natural history of the heavens natural history of the heavens.