HoST - Journal of History of Science and Technology
Vol. 18, no. 2, December 2024, pp. 143-157
10.2478/host-2024-0017

DISTINGUISHED LECTURE

The Empiricist Impulse: Doers and Thinkers in Sixteenth-Century Spain[1]

María M. Portuondo

Professor Emerita
The Johns Hopkins University, Baltimore, USA

mportuondo@jhu.edu

Abstract: This essay explores the tension that existed between empiricism and the metaphysical underpinnings of Aristotelian natural philosophy in Spain during the sixteenth century. This tension was most apparent in the range of science practitioners described in this essay as "Doers" and "Thinkers." Using the figures of cosmographer Andrés García de Céspedes, architect Juan de Herrera, and theologians Benito Arias Montano and Francisco Suárez, this essay explains how they engaged with the limitations, but also the strengths of pre-Galilean natural philosophy.

Keywords: natural philosophy; empiricism; Spanish science; early modern

[1] This paper was presented in Lisbon as the 6th CIUHCT (Centro Interuniversitário de História das Ciências e da Tecnologia) Distinguished Lecture, "The Empiricist Impulse: Doers and Thinkers in 16th Century Spain" at the Faculdade de Ciências da Universidade de Lisboa, on March 7, 2024.

In many ways, this talk is a recapitulation of my academic career as a historian of science whose attention was been focused on sixteenth-century Spain. I don't need to remind the readers of this journal that the sixteenth century was truly transformative for those countries at the forefront of European overseas expansion, namely Spain and Portugal. Newness or *novedades* were the order of the day. True, not many persons stopped to think profoundly about what all this meant—the same is true today when we face the present and future of, say, Artificial Intelligence —but some did reflect on the implications of these discoveries, and to them, it became apparent that new approaches were needed to take on the many challenges the discoveries presented.

Throughout my career as a historian, I have—for better or worse—divided them into two camps: Doers and Thinkers. I could just as easily label them "empiricists" and "philosophers," but I prefer the former because the terms signal the objective of their endeavors—get something done or lay theoretical foundations. Am I setting up a false dichotomy in thinking of early modern practitioners of science as within a spectrum of thinkers to doers? To further refine what I mean by these terms, we can also think of these terms as laying on a gauge of the degree to which practitioners engaged with the theoretical precepts of their disciplines, and in particular, with the metaphysical underpinning of them (Fig. 1). At the gauge's empty we find individuals who operated quite contently without *seeming to* problematize underlying principles and in a zone of empirical practice. At the gauge full mark, are individuals who wouldn't conceive of the study of nature without questioning their epistemological and metaphysical foundations. (I use 'metaphysics' in the early modern sense to mean first principles.) What I would like to do today is discuss several examples drawn from my earlier work that I hope will illustrate a tension inherent in Doers and Thinkers. Please allow me the conceit of situating these four individuals in this arc from doer to thinker: Andrés García de Céspedes at the extreme of the doers and Francisco Suárez as the quintessential thinker and with Juan de Herrera and Benito Arias Montano hovering in the ¼ and ¾ gauge spots. When I place an individual within this spectrum of doers to thinkers, I do so to try to understand what they saw as the limitations, but also the strengths of pre-Galilean and pre-Newtonian natural philosophy. There is always a tension where limitations and strengths coexist, and it is this fascinating tension that I found again and again among the historical actors I have studied over the years.

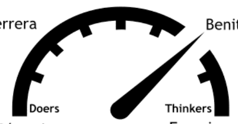

Figure 1 Doers and Thinkers

To start, it is important to differentiate the role of empirical knowledge in finding explanations about the natural world from the development of empiricism as a modern wholly formed, and coherent philosophical posture. During the early modern era empirical knowledge was gleaned from the observation of nature through sense experience. Most ancient natural philosophies saw empirical knowledge as first knowledge, standing unmediated by reason but which needed to be interpreted through a natural philosophical lens. By the seventeenth century, empirical knowledge became the cornerstone of the new experimental sciences. Its epistemic value has gone from being approached with suspicion, to being the basis of all knowledge in a new science that favored induction rather than logical demonstration as a way of arriving at explanations about nature; and where induction meant moving cautiously from the particular instance to general conclusions (or the formulation of a hypothesis). Yet, before natural philosophers expressed their commitment to empiricism in the strong terms we associate with the new experimental science of the seventeenth century, they engaged in a long process of re-evaluation of the role of epistemic knowledge and its underlying metaphysics. This is the story I would like to discuss today through these four individuals. The intellectual backdrop for them is the state of Scholastic Aristotelianism at the start of the early modern era, where we next turn our attention.

By the early modern era doers and thinkers had to contend with a rather tired Aristotelian corpus. From Erasmus to Descartes, to say nothing of Paracelsus, criticism of Scholastic Aristotelianism was the clarion call of many humanists and empirics alike. Several centuries of criticism had revealed fissures in Aristotle's natural books which medieval scholars had been happy to point out and address (ex. projectile problem). Yet, these did not dissuade scholars from teaching the corpus, particularly after it was properly baptized by Saint Thomas Aquinas. The argumentative power of logic when well deployed was hard to overlook, and Scholastics were happy to apply logical rules to natural philosophical arguments – whether or not this was what Aristotle had ever intended. Constructing elegant arguments according to the rules of logic became the *methodology* associated with how to answer questions in natural philosophy. Scholastics claimed that Aristotle presumed that all such knowledge must be derived from what is already known, so the objective of the logic was to relate anything new to premises that were taken as unquestioned verities drawn from the common course of nature.

For Aristotelian Scholastics, a proper explanation for a natural problem involved answering 'why'? That is, finding a causal explanation that ultimately could be supported by known, unquestionable premises. These premises could be derived after a causal analysis involving the Aristotelian four causes: final, formal, efficient, and material or they could stand simply as the common course of nature, as in heavy objects fall because they are seeking the center of the universe.

So, how did scholastics deal with empirical evidence? When we ask historical questions about the relationship between natural philosophy and empiricism it is important to work with a definition of empiricism that early modern actors would recognize. Modern empiricism implies that the phenomenon is replicable, classifiable, quantifiable, and homogeneous. It is also taken as ontologically *real*. The phenomena meeting these criteria can then form the basis of inductive reasoning leading to generalizations about natural laws. In the early modern world, however, the definition was very different. Things that were bizarre, wondrous, and possibly not real were all within the purview of empirical study, as were unique and non-replicable phenomena. An observation of such a phenomenon was taken as a describing a one-time event. Because it was assigned epistemic value as a discreet event, it could not be integrated into a general formulation using induction. They stood as data points, if you pardon the anachronism, as entries in an encyclopedia, or as so many results of a Google search. Even for thinkers who trusted sensorial impressions, such as Aquinas, experiential knowledge should never be the basis for natural philosophical formulations. While the sense provides the mind with a trustworthy image of the world, this image should be interpreted through universal principles that give meaning to sensory perceptions. Another way to understand the relationship between early modern natural philosophy and empirical knowledge is by identifying the purpose assigned to each body of knowledge. The purpose of natural philosophy was to propose universal claims (*scientia*); empirical knowledge only constituted descriptions of sensorial experiences of particular instances or informed a general truism about the regular course of nature. Until the advent of the experimental New Science, the epistemic value of natural philosophy was considered higher than that of empirical knowledge.

Thus, was the relationship between natural philosophy and empirical knowledge at the start of the sixteenth century. By the end of the following century, empirical knowledge would have claimed and earned its place as the cornerstone of science. How did this happen? The first step was the gradual disenchantment with Aristotelian natural philosophy. My investigations into the Spanish response to the flood of information arriving from the New World show that for the most part, the processes of experiential re-creation involved in describing, cataloging, and understanding this empirical knowledge coexisted comfortably with the paradigms of

Aristotelian natural philosophy. It rarely required the naturalist, doctor, or cosmographer to venture into the field of philosophical speculation. Naturalists and many astronomers used empirical observation as an epistemological tool that facilitated compiling useful information about nature. For the most part, this activity did not entail formulating new natural philosophical postulates nor challenging existing ones. This does not mean that the work of empiricist naturalists or physicians was in any way simplistic, rather it was incredibly careful and aimed at creating systems of classification that helped organize a world where there was too much to know. Yet for natural philosophers, the situation was entirely different. Empirical knowledge had to be interpreted and related to universal principles not just simply described and catalogued. Furthermore, this natural philosophy has to sit, if you will, on a sound metaphysical foundation.

In what follows I would like to explore the contours of an attitude toward prevailing natural philosophical systems I have referred to as the "Spanish Disquiet": a preoccupation with the ability and validity of prevailing natural philosophical systems to explain the natural world. The "Spanish Disquiet" also extended to the purely empirical and theory-free understanding of nature that gained momentum in Spain during the century of discovery and that was seen by some as philosophically unsound and potentially morally dangerous.[1] To preempt discussion as to whether it was a uniquely "Spanish" instance, the response is a categorical "no." We find similar disquiets in other Western countries and regions. It's "Spanish" insofar as these are the cases I've studied the most and which inform my academic work.

In Andrés García de Céspedes (c. 1545-1611), the Spanish Council of Indies found a uniquely qualified cosmographer and a hardworking problem solver for the empire.[2] Céspedes, son of *hidalgos*, entered the clergy after university studies, earning the degree of *Licenciado*. He spent time at the castle in Burgos while the fortress contained an artillery school and cannon foundry. In 1582-3 he came to Lisbon in the service of the Archduke Albert when the king's nephew served as viceroy of Portugal (1583-1593).[3] While at Lisbon, he mentions discussing astronomical navigation and cartography with Portuguese pilots and studying the works of Pedro Nunes. After 1596, once named royal cosmographer of the Council of Indies, he spearheaded the reform of the Padrón Real, the master navigation charts for oceanic navigation. He published the definitive navigation manual of the Casa de la Contratación.

[1] María M. Portuondo, *Spanish Disquiet: The Biblical Natural Philosophy of Benito Arias Montano* (Chicago, The University of Chicago Press, 2019), 2.

[2] The following draws from María M. Portuondo, *Secret Science: Spanish Cosmography and the New World* (Chicago, The University of Chicago Press, 2007), 271-76.

[3] Céspedes explains in his *Regimiento de Tomar la Altura de Polo* that he lived in Lisbon for twelve years. Biblioteca Nacional de España (BNE), MS 3036, f. 2.

He wrote several technological works, on subjects such as, finding latitude, on theoretical and practical perspective, on the theory and construction of the astrolabe and Jacob's staff with a discussion of its ingenious uses in astronomy and perspective,[4] on sundials, and mechanics and the theory of machines. He also listed two manuscripts on planetary theory according to Copernicus and Ptolemy, as well as a commentary on Peurbach's planetary theory.

From his list of works, it is clear that Céspedes was most interested in astronomy, and it is as an astronomer that he first tried to get the attention of Philip II. In late 1593, Céspedes was tending to the king's astronomical clocks at the royal palace in Madrid. It was likely that during this period Céspedes wrote to Philip II proposing an astronomical observatory for El Escorial. In the document, Céspedes portrayed himself as someone who combined mechanical ability and mathematical knowledge and offered to build several large astronomical instruments to equip the proposed astronomical observatory.[5] These would be used to "observe and investigate the true location of the sun and moon." Céspedes envisioned astronomers from all over Europe coming to El Escorial to conduct astronomical observations, just as "Hipparchus had traveled from Rhodes to Alexandria." The primary objective of the observatory, however, was to correct the Alphonsine tables, "for these no longer show the true locations of the planets nor the fixed stars." He repeatedly reiterated his distrust by pointing out how on countless occasions his observations (made, as he notes, with very large and precise instruments and always corroborated by other observers) showed the canonical tables to be incorrect.

Yet, there is a glaring omission among Céspedes surviving works or those he described having written. None of them speculate on the nature of the heavens nor on natural philosophical principles. Which is what has let me to place him as a through and through doer and empiricist. Empiricists like Céspedes, responsible for offering solutions to real-world problems wanted to attain some measure of predictability and, perhaps, control over nature. This presented a problem to the more thoughtful empiricists; understanding particulars might account for a given instance, but it might not prove convincing when this experience was applied by extension to other cases. As a minimum, the empiricist sought to, as Céspedes explained, *dar regla* (create rules) about how something worked, better yet if the predictive power of mathematics and geometry could be brought to bear. As he explained, he had shown all the mathematical proofs necessary in his art of navigation because "he who makes the rules has the obligation of making them accurate and just."[6] On other subjects, such as the deviation of the compass needle (due to magnetic declination), he chose not to speculate: "Although

[4] Andrés García de Céspedes, *Libro de Instrumentos Nuevos de Geometría* (Madrid, 1606).
[5] Martín Fernández de Navarrete, *Disertación Sobre la Historia de la Náutica y de las Ciencias Matemáticas que Han Contribuido a Sus Progresos Entre los Españole*s. Biblioteca de autores españoles, ed. Carlos Seco Serrano (Madrid: Ediciones Atlas, 1954-5), 77:365–57.
[6] Portuondo, *Secret Science*, 284.

some have sought to make rules about the deviation of the needle from North, because—as we will explain later—this is an uncertain thing, here I am simply giving some reports of what I know about it." The observation of the phenomenon was left to stand on its own rather than accommodate it to a particular natural philosophical interpretive scheme.

Thus, for a very busy "doer" such as Céspedes, the empiricist approach to collecting, organizing, and making sense of natural knowledge was often accompanied by a pragmatic and utilitarian attitude. For a pragmatist like Céspedes, the criteria of truth lay in the merit of the practical outcome of a conceived notion, rather than on the metaphysical underpinning of the theoretical explanation. Mathematics proved a valuable tool for modeling those aspects of nature not readily apparent to the senses.

Next, we consider Juan de Herrera (1530-1597), perhaps best known as an architect.[7] Herrera also acted as the king's advisor on cosmographical matters. The son of an impoverished hidalgo, Herrera's future, like that of many proud nobles of reduced means, lay in the career of arms. In 1548, Herrera served in the royal guards during the future Philip II's tour of the domains he would inherit in Italy and Flanders. For the intelligent and observant Herrera, this was both an educational grand tour and a chance to gain entry to the future monarch's service.[8] By 1563, he was working as an assistant and draftsman to Philip's architect, Juan Bautista de Toledo, who himself had apprenticed under Michelangelo.[9] After the architect died in 1567, Herrera became the de-facto architect of the many royal projects, most impressive among them the monastery/palace of El Escorial.[10]

Throughout his life, Herrera would be involved in solving cosmographical problems. Records from 1573 show he requested and was granted a royal license to sell some navigational instruments he invented and claimed were useful for determining latitude and longitude.[11]

[7] María I. Vicente Maroto and Mariano Esteban Piñeiro, *Aspectos de la Ciencia Aplicada en la España del Siglo de Oro*, 2nd ed. (Valladolid: Junta de Castilla y León, Sever-Cuesta, 2006), 8, and Catherine Wilkinson-Zerner, *Juan de Herrera: Architect to Philip II of Spain* (New Haven: Yale University Press, 1993), 14.

[8] Wilkinson-Zerner, *Juan de Herrera*, 3.

[9] Wilkinson-Zerner, *Juan de Herrera*, 7, 9 and Nicolás García Tapia and María I. Vicente Maroto, "Juan de Herrera, un Científico en la Corte Española," in *Instrumentos Científicos del siglo XV: La Corte Española y la Escuela de Lovaina*, ed. Fernando Villaverde, 41-54 (Madrid: Fundación Carlos de Amberes, 1997), 42, 45.

[10] An appreciative Phillip II granted Herrera honors and financial rewards throughout his life. Herrera enjoyed a yearly income from grants and salaries of 1,050 ducats. He died a wealthy man in 1597. For an inventory and study of his possessions see Luis Cervera Vera, *Inventario de los Bienes de Juan de Herrera* (Valencia: Albatros, 1977).

[11] Archivo General de Indias, IG-426. f. 275. "Privilegio a Juan de Herrera para instrumentos de navegación." December 13, 1573. Published in, Luis Cervera Vera, "Instrumentos Náuticos Inventados por Juan de Herrera para Determinar la Longitud de un Lugar," *Llull* 20, no. 38 (1997): 151–52.

Between 1581 and 1583 he accompanied Philip II to Portugal where alongside the king, they compared Portuguese and Spanish maps and found fundamental and alarming discrepancies between them.[12] While in Portugal, Herrera recognized that persons with the required mathematical skills were rare in late sixteenth-century Spain and he resolved to remedy the situation.

He became the driving force behind the Royal Mathematics Academy in Madrid, an institution whose mission was to prepare young men to practice professions based on mathematics.[13] Herrera's approach was to tailor the course of study to suit the demands of a particular profession and thus produce men "useful" to the empire. Herrera conceived of mathematics as the foundation of all sciences. In keeping with these principles, Herrera envisioned a curriculum that taught the fundamental elements of mathematics, arithmetic, and geometry as the basis for preparing students for several professions: arithmeticians, geometricians and surveyors, mechanics, astrologers, experts in gnomics, cosmographers and pilots, experts in perspective and optics, musicians, architects, painters, fortification-builders, waterworks-builders, and gunners.

Throughout his life Herrera was willing to take on technical challenges, often beyond his range of expertise. Self taught (as far as we can tell), his surviving writings that reflect his interest in mathematics show that he turned to Renaissance classics and ancient texts for models. In the manuscript treatise, *Architectura y Machinas,*[14] the very first sentences suggest he was, if not translating directly from the pseudo-Aristotelian *Mechanical Problems*, he was certainly making a summary of the introductory paragraphs and following its model of the *problemata*.[15] In Herrera's manuscript, the objective was to explain to the king how cranes worked. The manuscript neither contains mathematical formulae nor does it develop completely a theory of crane mechanics, perhaps because it was left unfinished, yet it demonstrated enough knowledge of the principles of the crane to make its point before the king.[16] This type of practical analysis served Herrera's technical problems well, founded as they were on the theory of the lever, geometry, and the Aristotelian understanding of the fall of heavy bodies.

---

[12] Juan de Herrera, *Institución de la Academia Real Mathemática*, ed. José Simón Díaz and Luis Cervera Vera (Madrid: Instituto de Estudios Madrileños, 1995), 17–18.

[13] Vicente Maroto and Esteban Piñeiro, *Aspectos de la Ciencia*, 65–219.

[14] Archivo General de Simancas, Casas y Sitios Reales, leg. 258, fol. 488.

[15] Víctor Navarro Brotóns, "Mechanics in Spain at the End of the 16th Century and the Madrid Academy of Mathematics," in *Mechanics and Natural Philosophy Before the Scientific Revolution*, ed. Walter Roy Laird and Sophie Roux, Boston Studies in the Philosophy of Science, vol. 254:239-258 (Springer, Dordrecht, 2008), 245-46

[16] Tapia, Nicolás García. "The Manuscript 'Architectura y Machinas of c. 1564 of Juan de Herrera" *Icon* 2 (1996): 176–98.

Yet, Herrera took his love of mechanics and geometry in unexpected directions. For him, mathematics also prepared the mind for learning, not only about the material world but also about the spiritual world. As Herrera's stature grew he also collaborated with humanists at court to assemble a world-class library at El Escorial. In the process he accumulated an impressive scientific and technical library for himself – and it is telling that a fourth of his collection was on the Llullian art. A lifelong follower of the Catalan philosopher Raymond Llull (c.1232-c.1315), Herrera obeyed the principal tenet of Llullist philosophy which maintained that all knowledge stems from a single Art.[17] The Llullian Art consisted of a logical system that combined different terms to construct philosophical and theological arguments. Thus, the Art served as the organizing principle for all forms of knowledge, and also functioned as a method of spiritual contemplation.

In his best-known mathematical writing, "El discurso de la figura cúbica,"[18] Herrera applied Euclidean principles of the cubic figure to Llullian metaphysics. In the first part of the treatise, he develops in lengthy proofs the Euclidean geometry of the cube and how cubic mathematical operations take place. In the second part of the treatise, he shows how nature uses the cube and how cubic operations are how entities are applied to beings in order to create them. His objective was to show that nine Llullian universal & absolute divine dignities (or universal principles)[19]—B. goodness, C. greatness, D. duration, E. power, F. wisdom, G. will, H. virtue, I. truth, K. glory—were also the organizing principles of nature and in conformity with Aristotelian philosophy.

In Herrera's scheme, the divine virtues relate to the world by 3-dimensional extension of the cubic figure, as understood by the Llullian correlates (-tivum/longitudinal, -bile/latitudinal y -are/profunditudinal).[20] Herrera proposed that these correlated to physical natural beings since these are composed of cubic figures and are the product of three functions (active, passive, and mixing). Thus, the Llullian cubic form also supported all Aristotelian accidents or predicates (quantity, quality, relation, place, time, position, state, action, and passion). As Herrera explained, the Llullian principles as related by the cubic figure formed the basis of the Aristotelian ones. What he has done in this treatise, in my opinion, was relate Llullian principles to Aristotelian accidents, not by establishing a 1:1 correspondence, but by showing

[17] Cervera Vera has pointed out the importance of Herrera's Llullist philosophy in formulating the academy. Introduction to, Juan de Herrera, *Institución de la Academia Real Mathemática*, 50.

[18] Biblioteca del Monasterio de El Escorial, d.iii.25, fols. 111-153; BME, g-iv-39, fols. 20-79. Published in, Juan de Herrera, *Discurso del Señor, Aposentador Mayor de S.M., sobre la Figura Cúbica.* Edison Simons and Roberto Godoy, eds. (Madrid: Editora Nacional, 1976)

[19] Josep E. Rubio, "Llull's 'Great Universal Art'," in *A Companion to Ramon Llull and Lullism*, ed. Amy M. Austin, Mark D. Johnston, and Alexander Ibarz, 81–116 (Leiden: Brill, 2018), 103-04.

[20] Mariano Carbonell Buades, "Ramon Llull y el *Discurso* de Juan de Herrera», *Acta/Artis. Estudis d'Art Modern*, 4-5 (2016-2017): 13-26, on 21.

DOI 10.2478/host-2024-0017

that they operate similarly through the cubic relationship of the terms and thereby ontologically grounding all accidents of nature in Llullian philosophy. As he explained,

> The foregoing shows how by means of cubic plenitude the necessity nature has of all Aristotle's predicates and the other principles of Raymond has been discovered, which was the principal aim for which we have brought forth all the doctrine of the cube. [21]

Herrera resolved the tension between the empirical and the natural philosophical by finding within the Llullian philosophy the foundation of Aristotelian natural philosophy. As with Céspedes, mathematics proved very useful, but in his case as a link between the empirical world, Aristotelian natural philosophy, and Llullian metaphysics. Rather than discarding the existing epistemic and methodological apparatus of Scholastic Aristotelianism, Herrera chose instead to place it upon a Llullian scaffolding. Why do so? This way he retained the Aristotelian search for causality as the ultimate objective of the natural philosophical enterprise, a causality that through Llull's propositions testified to the divine presence in nature. Llull had intended his Art to be the path to theological and material knowledge, Herrera believed he had shown that it was also compatible with Aristotelian epistemology.

Benito Arias Montano (c. 1525-1598) is still considered one of the towering figures of European humanism. His life's trajectory and intellectual development prepared him, not just to edit the Antwerp Polyglot Bible, but also to attempt an ambitious reform of how humanity approached the study of nature. In so doing, he partook in the reformist ethos of the era that found Aristotelian Scholastic natural philosophy unsatisfactory. He was well aware of what a cohesive natural philosophical system entailed and developed epistemic approaches and methodological tools that allowed him to formulate new metaphysics, cosmology, physics, and natural history. He presented these ideas in an unconventional and novel natural philosophical work he wrote late in life—his self-titled *Magnum opus*.[22] It was an attempt to fashion an entirely new natural philosophy derived from the first principles he identified in the Hebrew Bible, particularly in the book of Genesis. Although his approach to reform—recapturing a 'lost' philosophy of Moses—was unusual and his exegetical methodology unconventional, his motivation was in complete concert with the principal objectives of reformers of natural philosophy during the early modern era. He was the first European, I argue, to fashion a complete natural philosophical system based on the Sacred Scriptures AND on empirical

---

[21] "[D]e todo lo cual consta como por la plenitude cubica se descubre la necessidad que ay en la naturaleza de todos lo(s) predicamentos de Aristoteles y los demas principios de Raymundo que a sido el fin principal pa(ra) que havemos traydo toda esta doctrina del cubo." Herrera, *Discurso*, 150.

[22] His *magnum opus* survives in two published volumes: Benito Arias Montano, *Liber Generationis et Regenerationis Adam, sive De Historia Generis Humani: Operis Magni Pars Prima, id est Anima* (Antwerp: Plantin, 1593), and Benito Arias Montano, *Naturae Historia, Prima in Magni Operis Corpore Pars* (Antwerp: Plantin, 1601). A third part, the *Vestis*, appears never to have been written or has been lost.

observations. In comparison to Herrera, he was happy to seemingly dispose completely of Aristotle, but as we will see he could not entirely do so.

Only three things met Montano's criteria as valid sources of 'certain knowledge' upon which to base such a program: divine revelation, the Word as revealed in the Bible, and nature. He thus began the *magnum opus* at what constituted a philosophical clean slate: the very beginning of the world—the Creation—and proceeded chronologically from there. There are five core premises or presuppositions that inform the *Magnum opus* and that Arias Montano derived directly from the historical narrative of the biblical text.[23] Their stature as premises derived from what he considered to be their origin as unassailable historical verities that were the result of divine actions and words. The fundamental premise concerned the purpose of humanity—to know God—which also had the prerequisite knowledge of human nature and of the natural world. His second premise was the belief that prelapsarian Adam had enjoyed complete knowledge of nature, but that this knowledge had been largely lost after the Fall. Yet Hebrew—the language of Adam—had retained vestiges of this knowledge. Moses, as prophet and scribe, although not writing for this purpose, had recorded vestiges of the *rerum natura* in the Sacred Scriptures. This knowledge could be recovered by deciphering the 'arcane language' of the Bible. Arias Montano's third premise concerned the immutability of the order and genus of all things in nature as established by God at the Creation. This assured Arias Montano that observations made now corresponded to the same reality described in the Bible. The fourth premise derived from God having placed all of nature under humanity's dominion. This implied that the purpose of everything in the world was to be useful to man. Therefore, finding a thing's essential nature also meant identifying its utility (and vice versa). The fifth premise—this one an epistemological issue informed by historical circumstances—concerned the role of sense perception in the Montanian program. Human sense perception and empirical knowledge was a diminished human capacity, helpful for living in the world, but since it was intrinsically flawed it could not be the sole basis for natural philosophy. These premises gave Arias Montano the necessary scaffolding upon which to build his biblical natural philosophy. We will only have time to discuss some of his proposals today, but I hope they suffice to give you a sense of how radical the Montanian project was.

Despite his notorious disdain for scholasticism, Arias Montano approached his project from a premise that was fully in concert with the Schools. All knowledge should be based on first principles that are known to be certain. Certainly, a kind God would have revealed these to his chronicler, Moses, and thus these should be found in Genesis. Montano found these in the first three verses of Genesis. His "correction" of Pagnino's translation of the Hebrew Bible that was included in the Antwerp Polyglot has clues of how he got these ideas. Without entering into the details of the Hebrew roots he relied upon, in his translation the space above the

[23] This section follows Portuondo, *Spanish Disquiet*, 189-224.

DOI 10.2478/host-2024-0017

waters now contained matter in the form of some sort of cloudy substance.[24] This matter was operated upon continuously by the moving agency of the Spirit of God or Elohim. From this interpretation he derived the following principles of nature.

CAUSA is the first cause of everything. It simply stands for the goodness of God implied in the act of creation and referred to in Hebrew as 'Beginning' (RASHITH). Only God existed before the second principle appeared. The second principle is IEHI (*fiat* or *erit*) or the word of God (*verbum Dei*). Montano explains that it is the creating force in nature; a word that when used in relation to God gives perpetuity to form and constancy to things. It encompasses all and brings forth everything, cares for everything, and protects it. The third principle is ELOHIM, a divine force that is diligent, present and extends over everything and encompasses everything. Whereas IEHI creates, the designer and overseer of this creation is ELOHIM. The spirit ELOHIM prepares all forms, distinguishes among them, establishes them, and directs them; sets things in motion and agitates the surface of the abyss and the heavens. Through his motion, ELOHIM imparts onto other, lesser spirits power to determine the favorable moments for things to appear, increase, or diminish, which results in all the actions needed for things to generate, decay and regenerate.

The forth principle is MAIM, a form of matter capable of creating anything. Montano noted the sacred text uses the Latin word *agua* to describe MAIM. This was not entirely accurate in his opinion because the etymology of the word in Hebrew suggests things with a double nature because of the word's ending (mem). So, MAIM becomes in Montano's exegesis a liquid with the double nature. One is fertile, sweet and somewhat flexible; it can flow anywhere and not condense and resembles milk or oil. It is greasy (*pingue*) and can catch fire and is akin to sulfur. The other liquid is humid and salty (*salsum*), it can penetrate and fill voids; it is subject to cold and hot, and can condense. It is anathema to fire and akin to Mercury. All corporeal things are made from mixtures of these aqueous and unctuous liquids in proper proportions. (If this reminds you of alchemical Sulphur and mercury, you are not too far off the mark…) The principle MAIM allows Montano to fashion a matter theory that supported his notion of a common nature between the heavens and the Earth and that rejected the four Empedoclean elements and the fifth element. MAIM remains present in composite matter (both terrestrial and celestial) and takes on a variety of appearances. It is interesting, He also mentioned trying

[24] Arias Montano indicated his changes to Pagnino's text in italics in the interlineal text and moved Pagnino's original to the margin. In this case, "caligo super facies" superseded "tenebrae in superficie" and 'motabat' replaced 'flabat.' The passage was also annotated with three Hebrew roots, none of which serve to explain his change. In Arias Montano's translation the space above the waters now contained matter in the form of some sort of cloudy substance. This matter was operated upon continuously by the moving agency of the Spirit of God or Elohim. We will see in the *Naturae historia* how Arias Montano interpreted this as an efficient cause (a moving Spirit of God) acting upon a material cause (fog, mist) that initiated the process of creation.

to uncover these principles in nature by using artifice (experiments) and investigation, such as those of the chemists (c*hymicus*).

What at first glance appears as a novel formulation, soon reveals its Aristotelian roots upon closer examination. That Arias Montano found exactly four first principles was not a coincidence. These four principles map loosely to the four Aristotelian causes: CAUSA: Final; IEHI: Formal; ELOHIM: Efficient; and MAIM: Material. So, while dismissing the causal system of the Peripatetics, he still needed their functional equivalent to be able to explain how forms and species came into being. He looked in Genesis and found the original explanatory principles there.

In my estimation, Montano's strengths were his keen observation of nature, a profound curiosity about the principles underlying natural philosophy, and a healthy skepticism of ancient philosophies and in particular, Aristotelian solutions… And yet, he was not able to escape them. His biblical approach to natural philosophy led him into a tangled philological path in search of first principles, but he was unable to fully disengage natural philosophy from the anchor of Aristotelian first principles. We do not know if he recognized how much his biblical philosophical proposals owed Scholastic Aristotelianism, but we know his disciples invariably relied on them to explain to others what Montano had been up to.

Our final example is the Jesuit Francisco Suárez (1548–1617), the "eminent and pious" (*eximius et pius*) scholastic professor at most major Iberian universities—including eighteen years at Coimbra. [He had more jobs than a twenty-first century post doc!] His goal was to reestablish Aristotelian natural philosophy on a metaphysical foundation that was in concert with reality as experienced through the senses. It also had to point toward a theology where a better understanding of God was achieved through his role as Creator. [25] Like Arias Montano and Herrera, this perspective offered the proper point of departure for interpreting the natural world. In putting it forward, Suárez was also responding to what he saw as a dangerous misinterpretation of the Aristotelian corpus, or radical departures from that corpus that seemed to be overtaking natural philosophy, such as those of Italian Naturalism.[26]

Understanding metaphysics to be the starting point of any philosophical program, Suárez composed his most influential work, the *Metaphysical Disputations*, or *DM* (1597), as a program of study that although modeled after the commentary tradition, was in the style of

[25] This section follows Portuondo, *Spanish Disquiet*, 46-47. The purpose of his metaphysics was to lay the foundation setting the relationship between being (*ente*) and creation. Emmanuel J. Bauer, "Francisco Suárez (1548-1617): Scholasticism after Humanism," in *Philosophers of the Renaissance*, ed. Paul Richard Blum, 236-55 (Washington, D.C.: Catholic University of America Press, 2010), 244–5.

[26] Benjamin Hill and Henrik Lagerlund, eds. The *Philosophy of Francisco Suárez* (Oxford: Oxford University Press, 2012), 3.

a modern philosophical treatise.[27] Under its Scholastic trappings are some of the most radical reformulations of Aristotelian natural philosophy to take place during the 16th century. Suárez proposed restricting metaphysics to the study of real beings (both finite and infinite and who have a real essence), privileging the efficient and material causes over the formal (while making God the Creator always the final cause) and denying a real distinction between essence and existence.[28] Furthermore, he restricted the operation of the substantial form to bodies and thus reduced the formal cause to an operation: the joining of the substantial form with the body.[29]

He was a systematic thinker well-aware of the limitations but importance of Aristotelian natural philosophy to theology– as put in evidence by his defense of substantial form and final causes – and showed an inclination toward grounding natural philosophy on real causes and real things. Suárez used common experiences as supporting evidence for most of these changes in an effort to bring Scholastic Aristotelianism in line with the empiricism that characterized his era. And yet, with the benefit of hindsight, Suárez greatest limitation was that he was not willing to 'burn down the house," as it were, of scholastic argumentation. The *DM* was read widely by Catholics and Protestants alike and influenced natural philosophers who addressed the metaphysical aspects of the New Science, such as Descartes and Leibniz.[30] Whereas successors would deny the existence of substantial forms and final causes, Suárez defended them, arguing causality stemmed from Divine intentionality and substantial forms explained situations where no other explanation was possible.

So here we have four extraordinary Spanish doers and thinkers, all of whom recognized that the scientific paradigms at their disposal left many questions unanswered. I have argued elsewhere that Spain's scientific enterprise wrestled with fundamentally the same philosophical concerns that drove the development of science elsewhere in Europe, but, by having tested the bounds of empiricism early on and having identified its shortcomings, sought—perhaps longer than most—a cohesive and comprehensive natural philosophy through which to interpret the natural world.

Empiricism ceased to be the handmaiden to natural philosophy; the one vied for the same epistemic authority as the other. This tension turned Aristotelian natural philosophy into a legitimate and virtuous pursuit by countering the threat posed by a system-less quest into the secrets of nature, or worse yet, by one guided by an unsound natural philosophy with unclear

[27] John P. Doyle, *Collected Studies on Francisco Suárez, S.J. (1548-1617)*, Victor M. Salas, ed. (Leuven: Leuven University Press, 2010), 7.
[28] Doyle, *Francisco Suárez*, 8–11.
[29] Helen Hattab, "Suárez's Last Stand for the Substantial Form," in *The Philosophy of Francisco Suárez*, ed. Benjamin Hill and Henrik Lagerlund, 101-20 (Oxford: Oxford University Press, 2012), 118.
[30] José Luis Abellán, *Historia Crítica del Pensamiento Español* (Madrid: Espasa-Calpe, 1979), 3:529 and Doyle, *Francisco Suárez*, 18-20.

objectives. Purely empiricist approaches harbored perils that separated humanity from God and could potentially undermine the religious truths upon which Christianity was based. The stakes were very high, as Herrera, Arias Montano, and Suárez felt. For someone like Céspedes, the certainty of mathematical proofs and an instrumentalist approach to astronomy sufficed.

Earlier, I remarked that I found the tension between thinkers and doers, or more specifically, between doers searching for theoretical underpinnings and thinkers trying to get something done, quite fascinating. Why so? Tensions beg for resolutions. Exploring how these 16th-century practitioners of science dealt with it and the solutions they proposed, crystallized for me just how quickly the edifice built by Aristotelian natural philosophy was crumbling and how pressing finding solutions was for 'thinkers.' As far as 'doers' it also revealed how intentional a practitioner of science could be in sidestepping the Aristotelian Scholastic edifice to continue finding solutions to problems arising in the real, tangible world. I imagine them balancing on a tightrope that was about to break.

Acknowledgements

I would like to thank Ana Duarte Rodrigues for inviting me to present this paper at the 6th CIUHCT Distinguished Lecture and for the fruitful conversations we have had over the years on the state of our respective fields of study.

Competing interests

The author has declared that no competing interests exist.

Funding

This work was supported by The Johns Hopkins University during Professor's Portuondo tenure at the Department of History of Science and Technology.