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Clerics and Priests as Scientists in the Spanish Golden Age

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Abstract: The Spanish Golden Age was a very fruitful period in disciplines as varied as literature, painting and religion, while giving rise to the first global empire. However, the scientific-technological aspect of this period is little known, especially with regard to clerical and religious scientists, among whom are figures such as the Dominican Domingo de Soto, who contributed to physics with the concept of mass and the uniform acceleration of bodies in free fall; the Jesuit José de Acosta, which can be regarded as a precursor of biogeography; Nicolás Monardes, a pioneer in pharmacognosy who in his later years wore the habit of St. Peter and likely became a priest; Benito Daza de Valdés, who was most likely a Dominican and authored the first treatise on physiological optics; and Juan Caramuel, a bishop and polymath who conceptualized the binary system. This could support the idea expressed by some authors that scientific questions often arise in an environment with a deep interest in the transcendental, as is the case with these clerics presented here.

Contribution: This article provides a comprehensive analysis of the scientific contributions of Spanish clerics during the Golden Age, incorporating previously unexplored perspectives and emphasizing the interplay between their religious faith and scientific endeavors.

Keywords: Spanish Golden Age, science, technology, religion, patents.

Introduction

Spain has historically played a more discreet role in science compared to countries such as France and England. However, this does not diminish its significant contributions. During the Spanish Golden Age, the focus was on applied science, driven by the practical needs of the empire. Among Spain's monarchs, Felipe II stood out as the most committed to advancing science. Supported mainly by mathematicians and engineers, he used it to drive progress in the political and military domains, such as fortifications and tools for war; in the economy, through improved exploitation of mineral resources; in navigation, by developing instruments and nautical charts; and in the social domain, with civil works like water dams (Vicente Maroto and Esteban Piñeiro 2006). This resulted in a clear engineering and technical progress (Silva Suárez 2004), while the previous domains can be expanded to others such as medicine, pharmacy, agriculture, veterinary science, the art of horsemanship, and hunting (López Piñero 1979).

The applied science perspective in the Spanish Golden Age is also in line with the interest in inventions. While Venice was the first country that established in 1474 a law regarding privileges for inventions, in 1478 Isabella I of Castile granted the first "cédula de privilegio de invención" (Belfanti 2006), a precursor of today's patents, and until the early 17th century numerous patents and around thirty inventors have been documented in Spain (García Tapia 1994), including foreigners attracted by the prestige of the most powerful kingdom of the time. Many of these patents are preserved in the Simancas archive, highlighting the 50 of Jerónimo de Ayanz y Beaumont (1553–1613) (García Tapia 2016), a character with a distinguished military career who received the title of commander of the Order of Calatrava, a position that implied a commitment to the defence of the Catholic faith, and also that of general administrator of the mines of the Kingdom of Spain, where he introduced revolutionary innovations. Among his inventions are the first steam engine for industrial use, designed to drain mines, almost two centuries before Thomas Savery 's in England; the development of an air conditioning system, a device that did not become widespread until the 19th century; and equipment that could keep a man underwater for more than an hour, in the first prolonged immersion in history (García Tapia 2010). He even demonstrated the impossibility of perpetual motion by creating a machine that measured the loss of its force (García Tapia et al. 2016), also nearly two centuries ahead of James Watt.

A first example of a scientific cleric, in line with the subject to be discussed in this work, is Alonso Barba, a priest who was interested in engineering and metallurgy. His book *Arte de los metales (Art of Metals), which teaches the true benefit of gold and silver by quicksilver, the way to melt them all and how they must be refined and separated from each other* (Barba 1729)*,* was translated into several languages and explains a method that was used for many years to extract silver.

In the academic sphere, the University of Salamanca was a key center. It was here that the School of Salamanca emerged, an intellectual movement led by the Dominican Francisco de Vitoria (Grice-Hutchinson 1952, 1989) and whose main members were practically all clerics and priests: Juan de Mariana, Francisco Suárez, Luis de Molina, Martin de Azpilcueta, Diego de Covarrubias, Melchor Cano, Luis de Alcalá, Tomás de Mercado, Pedro de Valencia and Domingo de Soto.

The School of Salamanca dealt with a wide range of humanistic subjects: theology, philosophy, human rights and international law. In astronomy, Jerónimo Muñoz was, along with personalities such as Tycho Brahe and Thomas Digges, one of the scientists who detected the supernova of 1572 (Navarro Brotons and Rodríguez Galdeano 1998), and Rome counted on the collaboration of the University of Salamanca to reform the Gregorian calendar (Carabias Torres 2012), although there is debate about how much influence this contribution had (Nothaft 2013).

In economics, the School of Salamanca made one of its most notable scientific contributions (Grice-Hutchinson 1952). It contributed to the modern understanding of economic relations, emphasising a rational trust in free trade (Gómez Rivas 2019). Moreover, the theory of the just price, grounded in ethical principles surrounding the exchange of goods, was developed by Luis de Molina in a book entitled *La teoría del* *justo precio* (De Molina 1597), in line with ideas defended by Francisco de Vitoria (Cendejas-Bueno 2018). In addition, Martín de Azpilcueta, although preceded by Copernicus, developed a more in-depth quantitative theory of money, taking into account the inflationary effects of the influx of precious metals from the new Spanish territories in America (Grice-Hutchinson 1989; Riera i Prunera and Blasco 2016).

One of the scientific clerics described here, the Dominican Domingo de Soto, is precisely drawn from the School of Salamanca, but we will also talk about others, such as Daza de Valdés, José de Acosta, Juan Caramuel, and Nicolás Monardes.

1. Domingo de Soto (1494–1560)

Born in Segovia to a humble family, he studied in Paris and at the University of Alcalá, where he first took up the chair of metaphysics. Finally, in 1526, he was appointed professor of theology at the University of Salamanca (Beltrán de Heredia 1961). Shortly before, in 1525, he had joined the Order of Preachers, the Dominicans.

In the domain of law, he wrote the treatise *Deliberación en la causa de los pobres*, *Deliberation on the Rights of the Poor,* thus becoming the first to address this issue (De Soto 1545). Furthermore, in line with Francisco de Vitoria, he contributed to the development of the *ius gentium* in support of the rights of indigenous people, a concept considered one of the foundations of international law, and published the treatise *De iustitia et iure* (Ramos-Lissón 1980).

In the theological field, he participated in the Council of Trent, where he defended scholastic theology (Belda-Plans 1995), and also stood out for addressing the issue of the harmonious conjunction between grace and nature (Prieto 2022). This search for an order in theology probably boosted Domingo de Soto to find an order in nature, where he also left his mark, both in kinematics and dynamics (Camacho and Sols 1994; Mira-Pérez 2009). More specifically, he helped lay the foundations for modern physics by describing the free fall motion of a body as a uniformly accelerated motion in time (Duhem 1910). Domingo de Soto's specific contribution was to affirm that, in the free fall of a body, the speed is proportional to the elapsed time; he even added that only in a vacuum will this law be fulfilled exactly.

Although Galileo confirmed this law experimentally decades later (Galileo Galilei 1638), Domingo de Soto's originality lies in his theoretical statement and his conceptualization of this motion as uniformly accelerated. He referred to it as *uniformiter disformis*, meaning a motion that experiences variation, but this variation remains uniformly distributed. Moreover, he explained it by pointing to infinitesimal calculus (López Díaz 2013), when this had not yet been invented: dividing time into "little portions" or "portiunculae", which would later be called infinitesimals, the increase in speed from the beginning of the little portion to its middle of the little portion is equal to the increase from the middle to the end (Pérez Camacho and Sols 1994). He even provided an example: "if the moving object A keeps increasing its velocity from 0 to 8, it covers just as much space as [another object] B moving with a uniform velocity of 4 in the same period of time" (De Soto 1551; Wallace 1968).

Domingo de Soto also contributed the notion of inert mass as internal resistance to motion, not just resistance from the external environment, an idea that was thought to be exclusive to Galileo (Pérez Camacho and Sols 1994). This notion was essential for Descartes' statement of the principle of conservation of motion and for all of Newtonian mechanics, which was published in 1687.

Domingo de Soto's theory of motion, with his crucial contributions, was expounded at the University of Alcalá in 1522–1523. Soto then taught at Salamanca, where he presented his theory and published in 1545 a first version of his complete work of 1551, *Super octo libros Physicorum Aristotelis questions* (De Soto 1551). The dissemination of these ideas occurred through Francisco de Toledo and Francisco Suárez, who brought Soto's teachings to the Roman College in Rome (Pérez Camacho and Sols, 1994). Moreover, there is little doubt that the notes of Galileo during his youth were based on the lecture notes from the Roman College (Wallace 1984), based on Soto's teaching. In addition, the ideas of Soto remained present in several scientists around Galileo. Riccioli, for instance, uses the terminology *uniformiter disformiter*, related to the motion of the falling bodies, that Soto employed in his lectures (Pérez Camacho and Sols 1994). All this supports the connection between Soto and Galileo.

2. Nicolás Monardes (1508–1588)

Born in Seville, he graduated in Medicine in 1533 from the University of Alcalá de Henares (Fresquet Febrer 2024). Years later, in 1547, already in his homeland, he obtained his doctorate (Díaz Delgado-Peñas 2015).

Monardes was widely read in Europe and America (Bleichmar 2007). In just over a hundred years his works reached forty-two editions and were translated into Latin, English, Italian, French, German and Dutch (Battaner, 2020; Rankin, 2022). Among his writings we can highlight *Historia Medicinal*, *Medical History*, a work whose final version was published in 1574 under the title: *First, Second, and Third Parts of the Medical History of the Things Brought from Our Western Indies That Are Used in Medicine*, and to which he added some other works of his: the *Treatise on the bezoar stone and the escuerçonera's herb,* the *Book that deals with snow and its properties* and the *Dialogue of iron*.

Historia Medicinal describes a large number of medicinal products, almost a hundred, originating from various places in the Spanish Empire: Florida, Peru, Tierra Firme, New Spain and the Antilles (López Piñero 1990). Among these, one can distinguish exotic elements such as purgative hazelnuts, *guayacan*, *palo santo*, urine stick and Michoacán root, as well as others that, although they are better known today, were new at that time, such as peppers, tobacco or tropical pineapples. A complete list can be found in a summary table at the end of the three parts of the book, with 24, 14 and 35 products listed in each part (Monardes 1574a).

On the other hand, Monardes' writings were not mere compilations of information, but also reflected his personal observations and experiences, while laying the foundations for understanding the medicinal properties of many plants. Precisely, his style of description has earned Monardes the status of a reference in the field of pharmacognosy (Fresquet Febrer 2024), the science that studies natural substances that have medicinal effects and are used in the production of medicines.

The perspective that interests the Spanish doctor is therapeutic, such as a tree bark to combat rheumatism or an herb for kidney ailments (Monardes 1574b). Thus, he deals with describing the product, the method of preparing it, administering it and its curative uses (Fresquet Febrer 2024), hence he is considered one of the pioneers in tropical medicine (Boxer 1963). In addition, through his writings we began to learn about the medical practices of the indigenous people in America, and this knowledge reached European countries through vernacular translations that transformed and adapted his work according to local intellectual, political, and commercial interests. Translators shaped Monardes's texts for their specific contexts, often erasing references to the indigenous practices that were the original basis of his observations, and serving as tools to introduce and legitimize new medicines while reinforcing the authority of translators or addressing the needs of their communities (Rankin 2022). Even in the Ottoman empire, very distant and culturally different, the use of tobacco was disseminated based on the work of Monardes, where he explained the medicinal uses of this plant, and the same debate as in the West occurred on the morality of the use of this product (Gürbüzel 2021). On the other hand, even in such striking subjects as iron, Monardes devoted special attention to the question of how to use it for curative purposes. Furthermore, just by making such varied plants known, Monardes holds an important place in the world of botany. He even thought about issues that are no longer of a curative nature but of a more dietary and well-being scope, such as a series of advice on the application of cold to chilled drinks included in his *Book dealing with snow*, or his efforts to reconcile the different medical perspectives of the time on how to treat pleurisy, in his treatise *De secanda vena in pleuriti*, *On venipuncture in pleurisy.* (Olmedilla 1897).

Nicolás Monardes also paved the way for the discovery of the phenomenon of fluorescence (Acuña and Amat-Guerri 2007). He remarked on *Historia medicinal* the strange behaviour of the wood of a Mexican tree in infused water, used to treat kidney ailments. The infusion emitted a bluish colour, something that had already been noticed by indigenous doctors, but it was Nicolás Monardes who was the first to document it. The unusual optical properties of the wood, known as *Lignum nephriticum* or kidney wood, were later investigated by scientists in subsequent centuries and in 1852 George Gabriel Stokes published the first correct explanation of the relationship between light absorption and fluorescence (Stokes 1852).

Personally, Monardes devoted himself to trade with America, which allowed him to develop these scientific works, although it must be acknowledged that this trade included slaves. However, he did not do well with this practice and was ruined (Fresquet Febrer 2024). Thus, he had the opportunity to redeem himself. In fact, over the years he recovered financially and managed to leave a good inheritance for his descendants. Furthermore, despite his scientific and commercial occupations, Nicolás Monardes was not a doctor removed from everyday life. He practiced his profession with great success and also married and had seven children, some of whom left for America (Díaz Delgado-Peñas 2015a).

After the death of his wife in 1577, he took on the habit of St. Peter and probably became a priest, since in his testament he distributed vestments and religious utensils for celebrating Mass (Díaz Delgado-Peñas 2015b). This is logical given his close friendship with relevant priests of his time, such as Juan de Quirós, an important poet who was one of the godfathers of his daughter Isabel (Pascual Barea 2012). Monardes transitioned from healing the body to healing the soul, in preparation of his death, which occurred in 1588 due to a cerebral haemorrhage (Fresquet Febrer 2024).

3. Jose de Acosta (1540–1600)

He was born in Medina del Campo and, at just 22 years of age, was ordained a priest of the Society of Jesus (Sequeiros 2000). In 1571, at the age of 31, he was assigned to the missions in America. There he founded several colleges, including those of Panama, Arequipa, Potosí, Chuquisaca and La Paz. Later, he held the chair of theology at the University of San Marcos in Lima, where he demonstrated his great oratory skills. He was even elected provincial of the Society of Jesus in Peru.

José de Acosta was a very capable man. He is mentioned as supervising the casting of a large bell and as investigating the tides of the straits in preparation for a possible attack by the Englishman Francis Drake. He also produced the *Christian Doctrine* and the *Catechism for the Instruction of the Indians*, which were published in Spanish, Aymara and Quechua (Gómez Díez 2005). In addition, he made at least three long trips through the interior of Peru, visiting the missions established there. This allowed him to learn about the nature and social life of the natives, which fuelled his scientific interest, highlighted in two aspects. The first is the discovery of the Humboldt current, at the east of the Pacific Ocean near South America (250 years before the Prussian scientist Alexander von Humboldt) (Olcina 2014). The description of the current, along with other phenomena such as *El Niño*, appears in Book II (De Acosta 1590a) and Book III (De Acosta 1590b) of his second major scientific achievement: *Historia natural y moral de las Indias*, *The Natural and Moral History of the Indies, where he deals with the notable things of the Sky, elements, metals, plants and animals; and the rites, ceremonies, laws and government and wars of the Indians*. This work earned him the nickname "Pliny of the New World" (Matus 2017), in reference to the Roman author Pliny the Elder, known for his *Historia Naturalis*, which also covered a wide range of scientific, geographical, and cultural topics of the known world at the time. Acosta addresses the same issue in the Americas, tackling the difficult question of how it is that animals and plants in America differ from those in Europe.

He proposes three possible solutions (Sequeiros 2009), demonstrating his effort to reconcile the Book of Revelation with the Book of Nature:

The first one is theological and is presented in two variations: "The Creator produced them there" and "God created a new formation of animals" (De Acosta 1590c). This solution requires belief in a new creation distinct from the original, an idea that Acosta himself does not support.

The second solution is "They were preserved in Noah's Ark," and "by natural instinct and heavenly Providence, various genera went to various regions, and in some of them they were so well off that they did not want to leave, or if they did leave, they were not preserved" (De Acosta 1590c). This solution complements theology with a pioneering historical formulation of the theory on geographic dispersion and the biological adaptation of species to different environments, anticipating the foundation of the science of biogeography. However, according to this hypothesis, there is no room for evolution or biological change. Instead, the migration and adaptation of animals to new ecological niches are seen solely as a matter of survival, not biological transformation. Animals in the Americas once had a broader distribution but became extinct elsewhere, surviving only in the New World. It is therefore unnecessary to invoke other theories, such as independent creations on each continent. Furthermore, Acosta argues that adaptation and confinement to what we now call an ecological niche is not unique to the Americas but applies to other regions as well, making it a general biological principle.

The third solution is to "reduce them to those of Europe" and is the evolutionary one. All the animals in America would be modifications of the original European ones:

"It is also worth considering whether such animals differ specifically and essentially from all others, or if their differences are accidental, possibly caused by various circumstances. For example, in the human lineage, some are white and others black, some are giants and others dwarfs. Similarly, in the lineage of apes, some are tailless while others have tails, and in the lineage of sheep some are smooth and others are woolly; some are large and strong, with very long necks, like those of Peru, while others are small and weak, with short necks, like those of Castile" (De Acosta 1590c).

José de Acosta was sensing that differences in the characters of animals could be caused by various accidents, resulting in accidental changes that were transmitted to their descendants. Thus, this paragraph has been cited as one of the texts that anticipated, although without accepting it, the evolutionary possibility that Wallace and Darwin would describe and accept nearly three centuries later (Aguirre 1957; Sequeiros 2009).

4. Benito Daza de Valdes (1591–1634)

He was born in Córdoba, one of five children of Doña Elvira de Daza and Don Lucas de Valdés. The latter was a silversmith. This indicates that he came from a good family, which is confirmed by the attendance of two canons and a public notary at his baptism in the Cathedral of Córdoba (Gener Galbis 2024). In addition, he graduated with a bachelor's degree in Arts and Philosophy from the Colegio Mayor de Santa María at the University of Seville.

In 1623 he published the first treatise on physiological optics in the history of science, *The Use of Spectacles* (*Uso de los antoios*, Daza de Valdés 1623), where the term *antoios* refers to glasses or spectacles. To write it, Daza de Valdés probably relied on the knowledge he acquired at the Casa de la Contratación in Seville, where spectacle makers worked (Gener Galbis 2024; Jiménez Benito 2013).

The work is divided into three books. The first deals *with the nature and properties of the eyes* and explains the conditions for good eyesight and visual defects (Chapter II), differentiating between natural and acquired ones (Chapter III). It also describes the main types of glasses: concave and convex (Chapter IV), and considers that there are two defects that can be corrected: weakened vision or presbyopia in older people (Chapter V) and nearsightedness or myopia in young people (Chapter VI). Acquired defects, (Chapters VII–IX), which are caused by illness, can no longer be corrected with glasses. In addition, it explains why short-sighted people can see up close and not far away (Chapter X); and why older people can see far away and not up close (Chapter XI).

In Book Two, *On Remedies for Sight Using Spectacles*, he explores the materials used for spectacles (Chapter I), among which he prefers rock crystal. He also explains that spectacles do not make things bigger or smaller, but rather represent them as closer or farther away by means of refraction (Chapters II–IV). He even establishes a scale of degrees similar to the modern diopter scale (Chapters V–X).

Book Three presents four dialogues where common clinical cases are discussed. The characters who participate in the dialogues are the person who wants to find a solution to an eyesight problem, an optician and a doctor. Daza de Valdés explores topics such as myopia, presbyopia, and other visual impairments. He also describes in the third dialogue, on page 67, how to operate on cataracts.

Although *Uso de los antoios* went unnoticed in its time, at the end of the 19th century and beginning of the 20th century it was rediscovered by several historians of science and can be considered an exceptional scientific work due to the innovation it represented in the field of optics (Jiménez Benito 2013). It is therefore not surprising that the Institute of Optics of the Spanish National Research Council (CSIC), since its foundation in 1946, has been called the Daza de Valdés Institute (Gener Galbis 2024).

But the most curious thing about Daza de Valdés is his profession: jurist. Specifically, he worked as a notary in Seville at the Inquisition tribunal, which represents the first argument to deduce that he was a Dominican cleric, since this institution was governed mainly by Dominicans. In addition, there are three other reasons that support this hypothesis (Simón Tor 2016): the censor of *Uso de los antoios* was a Dominican, a common practice when the author belonged to a religious order; the only portrait of Daza de Valdés shows a cross that seems to be the Dominican one; and the diffusion of glasses began among the Dominicans (Bardell 1981), an Order founded with a focus on education, preaching, and scholarship. Their emphasis on intellectual pursuits made them natural proponents of technologies that supported reading and study, such as eyeglasses, and this could have inspired Daza de Valdes to write a treatise on this topic. What is no longer so clear is that he could also be a priest.

Uso de los antoios ends with "Soli Deo Honor et Gloria" ("honor and glory to God alone") and also has a dedication to Our Lady of Fuensanta, which reveals the author's profound faith (Gener Galbis 2024):

"You, most holy Queen (so that everyone may understand the particular obligations I have in your service), when I was crippled at the age of six, imploring your help, you gave me miraculous health; hanging in your temple the crutches that served me then as feet. And continuing my needs and your mercies, seeing myself at the gates of death, led to them by a mortal stone lodged in my entrails, I appealed to your mercy. You then miraculously healed me, placing before your divine eyes the fatal stone, so that the memory of your clemency and my gratitude may endure in it.”

5. Juan Caramuel Lobkowitz (1606–1682)

His father was from Luxembourg and his mother from Bohemia (Fleming, 2006). However, he was born in Spain. This curious mix helped him to learn many languages, which led him to develop a project for a universal language (Martínez Gavilán 2016). Moreover, he proposed in his work *Apparatus Philosophicus* a system of symbols and inclined lines to accompany Chinese characters and thus facilitate learning Chinese (Paternicò 2017).

He travelled to many countries (Navarro Brotons 2007), which allowed him to meet great scientists and intellectuals such as René Descartes, Pierre Gassendi and Athanasius Kircher (Borrego Hernández 2012).

As for his ecclesiastical career, he was received into the Cistercian Order at the monastery of La Espina, Valladolid (Velarde Lombraña 1989a). Later he earned a Doctorate in Theology from the University of Louvain (he had previously studied at Alcalá) (Gillet 1928), was abbot of Melrose (Scotland), abbot of the Benedictines in Vienna and vicar general of the archbishop of Prague, where he led and armed a group of ecclesiastics to defended the city, which earned him a gold collar from the emperor for his bravery (L. O’Neil 1908). In addition, he did great pastoral work through which he recovered Catholicism in the region (Fleming 2006). Likewise, he fought with his preaching against Jansenism, condemned by Rome in 1653, but Jansen’s followers took revenge by accusing Caramuel of laxity. So, the Pope decided to assign him to a more discreet position, appointing him bishop of Campagna and Satriano in the kingdom of Naples (Velarde Lombraña 1989). Finally, in his last years of life he occupied the seat of Vigegano (Navarro Brotons 2007). There he designed the façade of the city’s cathedral, which was completed in 1680, and wrote *Architectura civil recta y obliqua,* where he addresses, among other issues, how to rebuild Solomon’s Temple (Buján 2007).

Caramuel's production is immense and spans multiple disciplines: mathematics, astronomy, grammar, music and natural philosophy (Gutierrez Cuadrado 1980). His main contributions in astronomy and physics are described in (Borrego Hernández, 2012). Caramuel achieved precise measurements of the increasing and decreasing magnitudes of the Sun, the Moon and Venus and also intervened in scientific debates such as the one that took place between Rheita and Gassendi regarding the discovery of new satellites of Jupiter. In addition, he criticized Galileo's theory on the fall of bodies in his work *Sublimium ingeniorum crux*. Although this work contained mistakes, it served to confirm an error that the Italian scientist had initially made and would later rectify: considering the acceleration in free fall as proportional to the distance travelled, when it is proportional to time. Moreover, he also pointed to the need to perfect Galileo's theory.

Related to this, Caramuel considered that gravity was more passion than action, which implies a centre of gravity, an idea close to Newton's theory of universal gravitation and contrary to Descartes' theory of vortices, whose falsity Caramuel demonstrated experimentally in *De perpendiculorum inconstantia*. Finally, he developed methods for the precise measurement of time in his work *Solis & artis adulteria*.

But it is in mathematics where his contributions are most outstanding. In keeping with his encyclopaedic character, he wanted to systematize the arts and sciences in five courses, one of which he titled *Cursus Mathematicarum*, in four volumes. The first two volumes were published under the title *Mathesis Biceps, Vetus et Nova* in the form of two thick volumes. Moreover, in another important work of his, Mathesis Audax, he showed his interest in establishing a link between science and religion, attempting to mathematize problems of logic, physics and theology (Borrego Hernández 2012).

This perspective can also be found also in the field of probability, where he became the author of the second treatise in history, after that of Huygens in 1657. He entitled it *Kybeia*, a Greek term referring to the game of dice. There he postulated that a game of chance was morally licit only if it complied with the principle of fairness, that is, that the money wagered should correspond to the risk assumed. Caramuel approached the subject in a qualitative manner, without developing precise formulas such as those that would emerge later. On the other hand, he also explored moral probabilism, that is, the application of probability in moral decision-making in situations of uncertainty, which generated intense debates with other thinkers of the time, including Blaise Pascal (Fleming 2006).

Another contribution to the field of mathematics was the first publication relating to the binary system (1642 in his work *Mathesis Audax*), and the subsequent systematic development and exposition of the binary arithmetic in 1670, in *Mathesis Biceps*, where he explains the advantages and disadvantages of this system and shows an example of its application in music, all this before Leibniz, to whom the merit is attributed. Although Thomas Harriot had private writings on the binary system (Ares et al. 2018), in science the discovery is attributed to the first one who publishes, so the pioneer is Caramuel.

In addition to the binary system, which forms the basis for computing and the information society, Caramuel developed principles for systems in bases 3, 4, 5, …, 12 and 60, suggesting that some might be more useful than decimal (Ares et al. 2018). He also proposed a new approximation for the trisection of angles and created a system of logarithms complementary to base 10 that facilitated computation by avoiding the use of negative characteristics in trigonometric calculations (Høyrup 2019). Although these logarithms are not the modern cologarithms, he can be considered a pioneer in experimentation with alternative logarithms.

6. Discussion and conclusion

The American sociologist Rodney Stark drew an interesting statistic a few years ago from the 52 most famous scientists of the 16th and 17th centuries, the period in which the so-called scientific revolution took place. 50 of them, 96.2%, were Christians; 32 of them, 61.5%, were devout Christians; and 15 of them, 28.8%, were clerics (Stark 2015). There is no doubt that Europe, the birthplace of modern science, was predominantly Christian. But then the question arises as to why this was not the case in other cultures. Starting from Greek and Arab-Muslim knowledge, Christian society in the Middle Ages laid a solid foundation for mastering the art of reasoning, so that from the 16th century onwards a process could begin that continues into the present (Kuhn 1979; Rañada 1994; Stark 2015; Woods 2008).

But none of these 52 scientists were Spanish, which may lead one to think that Catholicism was the reason for this absence from the most important nation in that period. However, half of the 52 scientists were Catholics from other countries. So, there must be other reasons that explain this difference. The main one is that Spain, dominated for centuries by Muslims, had recovered the peninsula and was ready to dominate the seas and evangelize America. Hence, it promoted applied science focused on obtaining technological progress, rather than scientific development. This explains the high number of patents and the low number of famous scientists. Moreover, Spain experienced the concept of 'secret science' (Sánchez Ron, 2020), which involved the careful concealment of its scientific and technological achievements to prevent other countries from surpassing it and threatening the empire's dominance.

Even so, the Golden Age saw a few gems, such as Jerónimo de Ayanz, Domingo de Soto, Nicolás Monardes, Daza de Valdés, José de Acosta, and Juan Caramuel, whose scientific contributions, in some cases, did not find much resonance in a society focused on the expansion and consolidation of an empire that required good ships, the extraction of minerals, and so on. This suggests that further research could reveal more surprising findings, reaffirming Spain's significant role in the history of science. This role is intertwined with the profound faith held by many of its scientists, supporting the idea that modern science emerged within the framework of a deeply Christian society. In fact, a recent book titled The Penultimate Curiosity (Wagner, 2016) argues that the human quest to find meaning in the world, which is present in all religions, shapes and motivates scientific interest in the physical world. According to this perspective, ultimate questions about existence inspire penultimate questions, those that are scientific in nature. Thus, it is logical that within the context of the Spanish Golden Age, clerics, like those discussed here, raised scientific questions and contributed to progress in this field. Caramuel linked the concept of probability with moral philosophy, José de Acosta explored the differences in the fauna of Europe and America pointing to new sciences such biogeography or the theory of evolution as part of his effort to comprehend God's creation, and also described phenomena such as the Humboldt current or "el Niño" thanks to his dedication to the missions in the New World. Domingo de Soto, a cleric dedicated to questions of justice and the harmony between grace and nature, sought a harmony in the physical world through his study of the movement of falling bodies, reflecting a drive to understand universal principles. Daza de Valdés, a jurist serving in the Inquisition tribunal, combined his professional duties with the need for clear vision, which led him to write the first treatise on physiological optics in the history of science. This was consistent with his affiliation to the Dominican Order, which was deeply committed to intellectual development, where writing and reading were essential. Similarly, Monardes, one of the most renowned physicians of his time, later transitioned to becoming a healer of the soul, demonstrating the interplay between spiritual and scientific pursuits.

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