

# Astronomy and cosmology in Spain in the Seventeenth century: the new practice of astronomy and the end of the Aristotelian-Scholastic cosmos

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According to Koyré, one of the ways of characterizing the Scientific Revolution of the Seventeenth Century would be through the changes of the closed and hierarchic world of Aristotle and the Middle Ages to the undefined or infinite Universe of the modern cosmology. The purpose of this work is to describe some relevant aspects of the astronomical activity and cosmological ideas of a series of Spanish authors that practiced the astronomy in the Seventeenth century. Our study shows that these authors assimilated the techniques and methods developed in Europe and participated in its development and discussions. On the other hand, the cosmological ideas of the Spanish authors were moving away increasingly from the Aristotelian-Scholastic tradition, showing also the impact of the Scientific Revolution, even though they did not become yet in this period the ones of the infinite Universe of which Koyré spoke.

*Según Koyré, una de las formas de caracterizar la Revolución científica del siglo XVII sería mediante el cambio del mundo cerrado y jerárquico de Aristóteles y la Edad Media al Universo indefinido o infinito de la cosmología moderna. El propósito de este trabajo es describir algunos aspectos relevantes de la actividad astronómica y las ideas cosmológicas de una serie de autores españoles que practicaron la astronomía en el siglo XVII. Nuestro estudio muestra que estos autores asimilaron las técnicas y métodos de la práctica de la astronomía desarrollada en el resto de Europa y participaron en su desarrollo y debates. Por otra parte, las ideas cosmológicas de los autores españoles muestran el impacto de la Revolución científica, alejándose cada vez más de la tradición aristotélico-escolástica, sin llegar a ser todavía, en esta época, total y plenamente, las del universo infinito de que hablaba Koyré.*

**I**N ORDER TO STUDY the cultivation of astronomy and its links to cosmology in seventeenth century Spain, we have to take into account the changes that took place in these fields in Europe, changes that were unquestionably very marked and managed to deeply alter the traditional schemes; the «closed world» of Aristotle and the Middle Ages was finally replaced by the «Infinite Universe», in the words of Koyré.<sup>1</sup> We must also consider the Spanish tradition and elements promoting the change that had already been introduced in the sixteenth century.

We must especially remember the work and contribution of Jerónimo Muñoz due to the enormous influence he had on Spanish astronomers. Apart from his work and proposals in the field of mathematical astronomy, Muñoz also contributed to cosmological questions, supporting a

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<sup>1</sup> Koyré (1957).

geocentric cosmology but anti-Aristotelian in important aspects such as the relative to the incorruptibility of the heavens, the existence of celestial spheres or (the existence) of the Sphere of fire as a demarcation between the terrestrial and celestial regions. As I have explained in other works, the cosmology of Muñoz was much closer to the Stoic tradition than to the Aristotelian-Scholastic. And it is not necessary here to insist on the importance of the Stoic tradition, as different authors have already given it prominence in the construction of modern cosmology from Copernicus to Newton.<sup>2</sup>

Moreover, in the same Scholastic tradition (or Aristotelian), without yet openly breaking with the basic Aristotelian framework, the treatment of cosmological questions was far from uniform, continuing the debate on these questions, initiated in the Middle Ages; or confronting the new challenges introduced by the work of Copernicus, and the new facts such as the nova of 1572 or the comets of 1577 and subsequent years. There are some especially interesting Spanish cases, such as Francisco Valles or Diego de Zúñiga, who revised different aspects of traditional cosmology, exemplifying the crisis in this tradition and the relevance of those challenges.<sup>3</sup>

In Spain between 1601 and 1700, the following works were published: 31 papers on comets, 76 concerning all types of astrological predictions, 55 on almanacs (lunaria mainly), 43 about cosmography and the art of navigation, 31 concerning calendars, 31 on astronomy in general, 10 on instruments, and 4 on astronomical tables. These were written by 172 authors plus some anonymous ones. To these, we must add 101 texts on natural philosophy, and 58 on antisuperstitious literature, of various content including astronomical questions. From this total of 539 texts—all including some aspect of astronomy or cosmology—95 were from Madrid, 71 from Valencia, 41 from Barcelona, 33 from Alcalá, 30 from Zaragoza and 17 from Sevilla. A significant number of manuscripts must be added to these texts.<sup>4</sup>

One of the most important places for astronomical activity in sixteenth century Spain was Madrid, in the Academia de Matemáticas founded by Philip the Second and the cosmographical activity of the Consejo de

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<sup>2</sup> On Muñoz, see Navarro Brotóns (1998), Navarro Brotóns (2006). On Stoics influence, see Barker (1985, 1991), Moreau, dir. (1999), Granada (1997, 1999).

<sup>3</sup> On Valles cosmological ideas, see Navarro Brotóns (2002c); and on Zúñiga, see Navarro Brotóns (1995).

<sup>4</sup> Provisional figures based on Navarro Brotóns *et alii* (in press). An extract relating to astronomy was published by Rosselló (2000). As this is a work in progress, the figures we have now are markedly different: 117 on comets, 75 on lunari and 157 on all kind of astrological topics (we consider the edition as an individual book). We understand works published in Spain or in other European places by Spanish authors.

Indias. As I have explained in another paper, the revision of instruments and tables related to navigation begun in the 1570s, implied a significant collection of astronomical observations, carried out with new instruments especially designed for this purpose, to calculate again the parameters of the solar eccentric. Added to this is the collection of eclipse observations carried out to determine the geographical longitude of different places of the Peninsula and of the West Indies. The question of determining the geographical longitude in a ship continued until the eighteenth century without a satisfactory procedure despite the efforts of many astronomers and cosmographers and the rewards that were offered for a solution. On the other hand, to determine latitude, there were tables of notable precision such as that published by García de Céspedes or the derivatives of the *Ephemerides* carried out by Magini and other authors from the data of Tycho Brahe.<sup>5</sup>

García de Céspedes' successor in the Academy's mathematics chair and in the position of «Cosmógrafo Mayor» of the Consejo de Indias was Juan Cedillo Díaz, who obtained the post in 1611. He was instructed to give the same three-year course established by García de Céspedes of astronomy and mathematics and to translate into Spanish anything that was necessary, apart from his obligations as «Cosmógrafo Mayor» (cosmographer Major) of the Indias.<sup>6</sup>

Cedillo was born in Madrid around 1560. We know that he studied in the University of Salamanca where he obtained the degree of doctor in theology. If this were the case, he must have attended the mathematic and astronomy classes given by Jerónimo Muñoz. At the head of the Academy, Cedillo continued the work begun by Pedro Ambrosio de Ondérez of translating works for the teaching that took place there. Among the works that Cedillo translated into Spanish is Copernicus' *De revolutionibus*, of which he managed to translate up until chapter thirty-five of the Third Book. It is therefore the first Spanish translation of the great work of Copernicus.<sup>7</sup> Cedillo entitled his translation *Idea astronómica de la fabrica del mundo y movimiento de los cuerpos celestials* (*Astronomical idea on the construction of the world and movement of celestial bodies*) but put neither his name nor Copernicus' on the cover. So Cedillo's name does not feature on any part of the manuscript. On the other hand, from

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<sup>5</sup> See Navarro Brotons (2000). On the activities in the Academy of Mathematics of Madrid, see also Vicente Maroto, Esteban Piñeiro (1991).

<sup>6</sup> On Cedillo, see Vicente Maroto, Esteban Piñeiro (1991) and Esteban Piñeiro, Gómez Crespo (1991).

<sup>7</sup> The Cedillo's translation of Copernicus work is preserved in the National Library of Madrid (BNM), Ms.9091, in two copies. See on this translation Esteban Piñeiro, Gómez Crespo (1991). Also, Navarro Brotons (2001, 2002b). My interpretation of Cedillo's manuscript is not strictly coincident with that one offered by these authors, even though I have based it on their work.

the second book of *De revolutionibus*, where Copernicus speaks of «us» as a reference to his observations, Cedillo puts «Copernicus». That is to say, Cedillo appears unsure as to how to present the work: was he thinking about presenting it as an original work and therefore wanted to conceal the fact that Copernicus was the author? Did he fear the censorship he could be subjected to for translating Copernicus? The first hypothesis is supported in the strange introduction that appears in the translation: In it he says: «I well knew, when I decided to bring to light the results of my studies, that many learned men would reprehend me for appearing to be one of them that introduced this news to the world that up until that time nobody had known.»<sup>8</sup> As this is not included in Copernicus' work, it could be understood as a literary exercise in which Cedillo recreates the feelings that Copernicus would have experienced if he had known the condemnation that his theory was object to by the Catholic church. Does it mean that Cedillo had already been criticized and consequently did not publish the translation? This is probable given the fact that this introduction does not appear in the translation's final version.

In the same introduction, Cedillo presents some cosmological ideas which do not totally coincide with those of Copernicus, since although he situates the sun as being the centre of the cosmos, he says that the planets move through the cosmic air as fish in water just as Jerónimo Muñoz affirmed (his probable astronomy teacher). He also stated very clearly that the epicycles and the excentrics are not spheres but circles moved by «intelligences» situated in the centre of the excentrics, or in the centre of the same planet, in the epicycles.

Among Cedillo's manuscripts, there is also a fragment of a treatise on the *Sphaera*, exposed in a traditional form, with the earth in the centre, the four elements, the primum mobile, the firmament etc. probably intended to introduce his students to these themes.<sup>9</sup> There is also a text dedicated to the «aspects» in which is patent the influence of Tycho Brahe, to which Cedillo follows in the distance of the planets. In this work, he appears to follow a Capellian system: Mercury and Venus turn around the Sun and the other planets around the Earth which is situated in the centre of the world.<sup>10</sup> Finally, there is a manuscript on «the theories of the

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<sup>8</sup> See the cited Ms. 9091 (BNM), fol. 180a. This introduction is included in the first copy that seem a rough draft. In the cleaner copy, perhaps prepared to be printed, it is not included.

<sup>9</sup> See the Ms. 9093 (BNM), fol. 5r and ff. After this manuscript of 7 pages, there is also a short *Treatise of astrology*, fol. 14r-19r. See Lanuza Navarro (2005), pp. 142 and ff. on this treatise.

<sup>10</sup> See the Ms. 9092 (BNM), fols. 8r-19v: «Dianoia de los aspectos de los planetas, pensamiento nuevo de D. Juan Cedillo Díaz, 1620».

planets», which is a translation of the «theories» (*Theoricae*) of Antonio Magini.<sup>11</sup>

Cedillo's notes on astronomical observations have also been preserved which include information on the comet of 1618. This comet, which was the cause of the controversy between Galileo and Grassi, the result of which was Galileo's *Il Saggiatore* de Galileo, was followed closely in Spain by various authors. Apart from the observational data, in a manuscript written by a pupil of Cedillo, there is a discussion on the theory of the formation of comets, the character of signs and the causes of certain events. Cedillo's pupil tells us that his teacher accepted that comets could be celestial, formed by planetary exhalations, or sublunar, (in this case). formed by terrestrial exhalations.<sup>12</sup>

In Cedillo's manuscripts, which include translations of different works, there is a translation of the treaty on the comets of Giovanni Camillo Glorioso *Cometis dissertatio astronomico-physica* (1619).<sup>13</sup> We do not know if the translation was done by Cedillo in connection with the Academy or if it was translated by the Jesuits of the Colegio Imperial.

Included in the authors that accompany Cedillo with his observation of the comet of 1618 are the «doctor» Juan Bautista Vélez and the «Procurador» (the law Procurator) Arguello. The latter, a lawyer by profession and an amateur astronomer, produced a book of *Ephemerides*, published in 1608 and based on different authors, among whom feature Jerónimo Muñoz, Garcia de Cespedes, Tycho Brahe and Copernicus.

The other author mentioned by Cedillo, «the doctor Juan Bautista Vélez», was also a lawyer and amateur astronomer. In the Biblioteca del Escorial, there is a voluminous manuscript of 378 folios by this author with a translation with notes on the first six books of the *Almagest* of Ptolemy apart from an index of the themes of the complete work.<sup>14</sup> Vélez, about whom we know very little, apparently studied with the Jesuits in the Colegio Imperial in Madrid.<sup>15</sup> The said work must have been started around 1621. In 1631, the work must have been well advanced, although he continued adding annotations, at least until 1635. Vélez inten-

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<sup>11</sup> See Ms. 8896 (BNM).

<sup>12</sup> See in Ms. 9092 (BNM) fols.90 r-100r., observations and calculations on the comet and in fols. 102r-105v. on the same comet by a Cedillo student.

<sup>13</sup> Ms. 9093 (BNM). fols.20r.-173v.

<sup>14</sup> *Tratados de astronomía y matemáticas tomados de Ptolomeo y otros autores*. Library of El Escorial, K-1-11. The first news of this manuscript was given by Sánchez Pérez (1929), pp.214 y 241. I presented a first description of this manuscript in Navarro Brotons (1996). See also Navarro Brotons (2002a).

<sup>15</sup> The data on Juan Vélez has been obtained from the same manuscript. In Simón Díaz (1952-59), vol.I, p.536 there is a reference to Juan Vélez as a student of the Colegio Imperial.

ded to dedicate the work to Philip the Fourth. To his excellent translation of the *Almagest*, Vélez added ample and varied expositions of data, calculus techniques, models and theories proposed by Arab astronomers (al-Battani, al-Fargani, Thabit Ibn Qurra etc), Medieval Christians (mainly Alphonsine astronomy), Renaissance scholars (Regiomontano, Peurbach, Copernicus, Pedro Nuñez, Reinhold and the Prutenic Tables, Maestlin, Clavius, Magnini etc) and late Sixteenth and early Seventeenth century authors (Tycho Brahe above all but also Longomontano, Kepler, Lansberg and Spaniards such as García de Céspedes).

In the commentary of the first book of the *Almagest*, Vélez includes an extended discourse on the movement of the Earth, in which he exposes in detail the usual arguments, pro and contra, that appear in literature on this theme. Namely, astronomical- cosmological, physical and biblical.<sup>16</sup>

In this way, what is notable is the clarity and rigour with which Vélez explains the various movements that Copernicus attributed to the Earth: rotation, translation and movements of the terrestrial axis introduced by Copernicus to explain both the parallelism of the axis of terrestrial rotation and the precession of the equinoxes, its supposed irregularity and the variation in the obliquity of the ecliptic. Similarly, Vélez describes the advantages of Copernicus' system over Ptolemy's. And to conclude and after pondering the different arguments, he made it clear that the only decisive against the movement of the earth came from «the dogmas of our sacred religion». With respect to this, he reproduces the decree of the Roman Catholic Inquisition condemning the heliocentric theory.<sup>17</sup>

The author for whom Vélez showed the greatest admiration was without doubt Tycho Brahe, whose work he knew very well. Consequently, all the data prior to Tycho Brahe concerning the precession of the equinoxes, the obliquity of the ecliptic and the models of the sun and moon were revised in light of the information collected by the Danish astronomer. As for cosmological matters, Vélez denied, agreeing with Brahe, the existence of celestial spheres and considered celestial matter to be fluid and «penetrable», mentioning the observations of comets and other astronomical phenomena.<sup>18</sup> He also talks about the phases of Venus and the satellites of Jupiter discovered by Galileo, although he does not mention him.<sup>19</sup> Concerning the planetary distances, he acknowledges the

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<sup>16</sup> Vélez, *Tratados de astronomía*, fol. 48v. and ff.: «Discurso sobre la inmovilidad de la Tierra».

<sup>17</sup> See Vélez, *Tratados de astronomía*, fol. 62v. and ff.: «Where he discusses and refutes the compound movement of the Earth».

<sup>18</sup> Vélez, *Tratados de astronomía*, fol.98v.

<sup>19</sup> Vélez, *Tratados de astronomía*, fol.98r, on Venus and Mercury moving around the sun.

advantages of the Copernicus system. He then explains the ideas of Brahe, and as for the fixed distances, he states that the distance to the Earth is impossible to calculate, as if they are or not the same distance.<sup>20</sup> As for Kepler, Vélez often quotes his work, including the *Rudolphine Tables*, and refers to the planetary movements according to ellipses and he comments also on the physics theories of the said author, although he is very sceptical about them.<sup>21</sup>

Among the authors quoted by Vélez are two Jesuits, Juan Eusebio Nieremberg and Hugo Sempilius, both attached to the Colegio Imperial of Madrid and to the Reales Estudios established there around 1625. Among these studies were included chairs in natural philosophy, natural history, military art and two mathematic chairs, one of them devoted to «spheres, astrology, astronomy, astrolabe, perspective and forecast». The study of the works and manuscripts of Nieremberg, Sempilius, and the teachers of mathematics and astronomy of the Reales Estudios: Claude Richard and Jean Charles della Faille, in particular, show that they followed closely the progress in astronomy and its cosmological implications, with the necessary caution that their position as Jesuits required concerning matters related to the movement of the Earth.<sup>22</sup>

In the middle of the century, one has to single out the work of Vicente Mut, the most distinguished Spanish astronomer of the seventeenth century. Mut was born in Palma de Mallorca in 1614. He was a doctor in law and was also an expert on military engineering. He was town councillor («jurado») in Palma and was administrator of the same city. He completed works on cartography and was also a historian and chronicler.<sup>23</sup> We do not know how he acquired his training in astronomy. His interest must have begun quite early, because already in the *Efemérides Generales de los movimientos de los cielos por LXIV años, desde el de 1637 hasta el 1700 según Tichón y Copérnico* (General Ephemerides of the movements of the skies for LXIV years, from 1637 until 1700, according to Tycho and Copernicus) (Barcelona, 1638), of the Portuguese Luis Freire de Silva, there features a sonnet by the autor Vicente Mut. In the 1640s, Mut began his epistolary relation with Athanasius Kircher and Giovanni Battista Riccioli about scientific questions, becoming one of Riccioli's main correspondents on astronomical matters. The original letters between Mut and Riccioli have not been able to be located. However, Riccioli,

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<sup>20</sup> Vélez, *Tratados de astronomía*, fol.51r and ff.

<sup>21</sup> On Kepler's cosmos, see Vélez, *Tratados de astronomía*, fol 69 r. and ff. and *passim*.

<sup>22</sup> On the Jesuits of the Colegio Imperial and Reales Estudios, see Navarro Brotons (1996, 2002d, 2003).

<sup>23</sup> For Mut's biographical data, see Bover (1868). On Vicente Mut scientific works, see Navarro Brotons (1979, 1996, 2003). An on Mut and Riccioli, see Navarro Brotons (2002a). See also, Navarro Brotons, Rosselló Botey (2006).

in his works, mentions Mut very frequently and reproduces various parts of these letters or theories, and data of observations carried out by Mut. In the «Chronicon» of the *Almagestum Novum*, Riccioli says of Mut: «Maioricensis, Astronomiae, pertissimus observat sedulò Mairoicae, scripsit egregium opusculum de Sole Alphonsino: Huic ego plurimum debeo», and in a lunar map, he dedicates a lunar formation to Mut. We can consider Mut to be one of Riccioli's closest collaborators in the ambitious undertaking of revising the astronomy and geographical mathematics of the era and producing a «New Almagest» and a «revised» astronomy and geography. In fact, the programme of observations carried out by Mut over several decades coincides neatly with those realised by Riccioli and Grimaldi.

The first work published by Vicente Mut, *De Sole Alfonsino restituto* (Palma, 1649), was dedicated, as the title suggests, to revise the model or «theory» of the Sun and to check if the parameters of the model are still in force. One of the key questions of the era, as is well known, was relative to solar eccentricity and whether it should be considered bisected, just as Kepler had suggested adapting the equant model, used by Ptolemy for the planets but not for the Sun. An empirical test of the bisection was based on the measurement of the apparent diameter of the Sun observed from the apsides, as the difference between the apsidal distances from the Earth to the Sun is proportional to the excentricity in the equant model and is proportional to double the excentricity in the Ptolemy model. The data obtained by astronomers, from Ptolemy, concerning the apparent diameter of the Sun were not decisive, as the data varied for the mean distances from 30'30" to 32'44" and some Jesuit astronomers such as Scheiner, had obtained an even greater variation due to the use of diaphragms with a very small aperture using a dark camera. Between 1665 and 1661, Riccioli and Grimaldi, using the great gnomon of the Church of San Petronio in Bologna, carried out a series of measurements of the solar diameter. The best results, concluded Riccioli, were 31'0" for the apogee and 32'4" for the perigee diameter, which was an excentricity of 0.0169, very nearly half the excentricity of the equant as determined by the usual Ptolemaic procedure. Around the same time, Cassini obtained data of 31'8" and 32'10".<sup>24</sup>

Vicente Mut carried out his observations of the solar diameter in 1648, according to the *De sole Alfonsino restituto*. Firstly, he went over the different methods used by astronomers for this purpose and then commented on the defects. He particularly went into detail on the *Camera obscura* method used by Scheiner, and especially the small aperture through which the result of the diameter was excessively large. On the

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<sup>24</sup> See Wilson (1970), reprinted in Wilson (1989), VIII. See also Heibron (1999).

other hand, with a bigger aperture, the result obtained was too small. Mut, even if he did not understand completely the problem of diffraction, pointed out the optical confusion that was produced in the screen in the edges of the solar image. The procedure used by Mut was based on a device used by Scheiner to observe the sun spots. It consisted of obtaining the image of the Sun as it passed through the meridian on a screen which was perpendicular to the optical axis of the telescope. The variation of the declination of the Sun on successive days gave the angle that this travelled in the meridian. At the same time, to this variation in the declination, there is a displacement proportional to the image on the screen. To estimate the apparent diameter of the Sun, you only had to observe when the sun's image was displaced on the screen at a distance identical to the diameter of the said image and use the proportional relations mentioned. Mut also pointed out the precautions that had to be taken to achieve stability in the device and maximum image clarity. The results obtained by Mut were not as good as those of Cassini and Riccoli, but without doubt feature among the best of the time before the results cited above by these two astronomers:  $31'38''$  in the apogee and  $32'46''$  in the perigee. With these figures, the excentricity would be 0,02289. Mut concluded, therefore, that «the Sun's distance from the earth is neither all the excentricity nor bisected excentricity- *viam ellipticam*». <sup>25</sup>

Riccioli comments on Mut's procedure in the appendix of the *Almagestum Novum* (published in the same year as Mut's work), praising Mut's skill and ingenuity but pointing out, nevertheless, reservations and doubts concerning the reliability of the procedure, similar to the precautions recommended by Mut. <sup>26</sup>

In a later work entitled *Observationes planetarum, cum adnotationibus astronomicis, prasertim circa motus per Ellipses*, Mut accepted that the results obtained on the apparent diameter of the Sun, demanded, in accordance with Kepler, that the excentricity of the Sun was almost «bisected». He also accepted the use of ellipses to represent the movement of the planets, also reaffirming his conviction of the priority of circular movement: «but to facilitate the calculation (he writes), the set of circles can be resolved in ellipses». <sup>27</sup> Like many astronomers of his time, Mut did not understand the real scope and significance of Kepler's work. So, facing the undoubted difficulty of Kepler's method, in place of the second law Mut refers to the so-called simple elliptical hypothesis of Boulliau-Ward, consistent in supposing that the planet moves uniformly

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<sup>25</sup> Mut, *De Sole alphonsino restituto*, p.23. On Scheiner's technique to observe the sun spots, see Schreiber (1898); on the use of this technique by the Seventeenth Century astronomers to several objectives, see McKeon (1971).

<sup>26</sup> See Riccioli (1651), Appendix ad partem I, Tomi I, pp. 735-736, on Mut technique.

<sup>27</sup> Mut, *Observationes motuum coelestium*, p.63.

with respect to the second focus of the ellipse. Furthermore, he incorporates the correction introduced by Boulliau to this method that achieves an excellent level of precision in the longitudes of Mars.<sup>28</sup>

As we have pointed out, Mut carried out numerous observations, many of which have been recorded by Riccoli, both in the *Almagestum Novum* as in the *Astronomia Reformata* and the *Geographia Reformata*. In the prologue to his *Observationes*, he stated that his work was «for those who wanted to put the tables of celestial movement to the test». Throughout this work, Mut contrasts his observational data and calculations with the predictions of the tables of Copernicus, Tycho Brahe, Longomontanus, Kepler, Lansberg, Wendelinus and Boulliau and with other contemporary astronomers. Mut used a Keplerian telescope (two convex lenses) of 160 cms that he fitted with a micrometer in the 1650s. (Mut affirms that he used a micrometer from 1653, but this is doubtful). He also used a pendulum to measure time. Among his best calculations features the diameter of Jupiter (48"; Riccioli and Grimaldi calculated 46") and the distance between the Pleiads and their coordinates.

One of the urgent tasks in geographical reform and in the project of constructing a modern *Atlas* of the World was to revise geographical longitudes, which had serious errors, not only in the geography of Ptolemy but also in the most recent Atlases of Ortelius, Mercator, and Blaeu, and of course to substantially increase the territorial range of the old geography. Jesuit scientists such as Kircher and Riccioli, took on this task and took advantage of the network of potential collaborators that the Society afforded them.<sup>29</sup> In this task, one of Riccioli's closest collaborators was Vicente Mut.<sup>30</sup> Mut carried out numerous eclipse observations and collated abundant information of other authors, subjecting everything, which included both foreign and Spanish observers, to a scrupulous examination. Also, he provided a table of geographical longitudes and pointed out the necessity of shortening the Mediterranean longitude of 44° 15', which was traditionally too long.<sup>31</sup>

Finally, Mut focused on comet observations, particularly the ones that appeared in 1664 and 1665. In this study of comets, Mut suggested that the comet's trajectory could be similar to a parabolic line of a projectile.<sup>32</sup>

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<sup>28</sup> On Boulliau, see Wilson (1968, 1970), works included in Wilson (1989).

<sup>29</sup> On Kircher and Riccioli "Geographical Plan", see Gorman (2004).

<sup>30</sup> See Riccioli (1661), book VIII, pp.364 y ss., where there are data of eclipses of the moon sent by letter by Mut to Riccioli, the first eclipse taking place on the first of October, 1642 and the subsequent ones in 1643, 1645, 1647, 1649 and 1650.

<sup>31</sup> See Mut (1666b), Caput III: "Locorum Longitudines a superioribus eclipsis deductae", pp.69 and ff. The table in pp.82-83.

<sup>32</sup> See the works cited in note 24.

As for Vicente Mut's cosmological ideas, although in his work there is scarce reference to this type of question, one suspects that they were not that different from his friend and correspondent Riccoli. As we have indicated, Mut did not appear to share the celestial physics of Kepler. He classified the planetary theories as imaginary constructions or «falsae positiones» adding that «planetæ non geometrizarant», which suggests that he shared Riccoli's ideas that astronomy should confine itself to «saving appearances» with geometrical models.<sup>33</sup> For Riccoli, and perhaps Mut, the real planetary movements are beyond human understanding. On the other hand, neither does Mut appear to agree with the traditional ideas of the incorruptibility of the heavens. In his study on comets, Mut wrote that «only the peripatetics believe in the impenetrability of the heavens», and is in agreement with modern authors «such as Kepler, Galileo, Cysatus, and Gassendi( in line with Seneca)», who locates these objects in the ether.<sup>34</sup>

Another of Vicente Mut's correspondents who is frequently named in his writings is the Jesuit mathematician José de Zaragoza y Vilanova. Zaragoza was an outstanding protagonist of the renovation of Spanish science in the second half of the seventeenth century and is one of the most outstanding Spanish mathematicians of all time. Zaragoza lived for some years in Mallorca, teaching arts and theology in a Jesuit college of this locality. It must have been there that his close relationship with Vicente Mut began. Between 1660 and 1670 he resided in Valencia where he officially taught theology but in private he devoted himself to the teaching of mathematical disciplines and research along with his pupils and collaborators. The scientific activity of the Jesuit in Valencia in this decade was of the greatest importance for the renovation of Valencian science. Finally, Zaragoza moved to Madrid where he occupied the mathematics chair in the Reales Estudios del Colegio Imperial of Madrid where he remained until his death, carrying out other official duties, as cosmographer Major of the Consejo de Indias, scientific and technical adviser and the king's mathematics teacher.<sup>35</sup>

In the astronomy field, Zaragoza was an excellent observer, without ever reaching the level of Vicente Mut. In fact, a study of the writings and manuscripts of Zaragoza in this respect does not reveal a consistent plan of observation like Mut carried out (sharing Riccoli's plan) in order to

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<sup>33</sup> Mut (1666b), p.68. On Riccioli cosmological ideas, see Wilson (1970), p.104; Grant (1984), p.136; Heilbron (1999) and Siebert (2006).

<sup>34</sup> See Mut (1666a), p.13.

<sup>35</sup> For Zaragoza's biographical data, see Cotarelo (1935), that include a list of Zaragoza's manuscripts. For his influence in the Valencian scientific renovation, see Navarro (1978, 1985, 1996, 2003) and Navarro Brotons, Recasens Gallart (2007). For Zaragoza's mathematical works, see also Recasens Gallart (1991a, 1991b).

test the various tables, models and astronomical parameters. Zaragoza carried out observations mainly to compare the most notable events described by astronomers of his time (such as Jupiter's satellites, Saturn's ring or sun spots); furthermore, in the 1660s, he carried out observations of eclipses recorded by Vicente Mut in his text of *Observationes*, and in 1664-65 and 1667 observations of the comets that appeared in those years, which are conserved in manuscripts. The report on the first, sent to the Academy de Science in Paris, contains a very detailed report on the phenomenon.<sup>36</sup>

In this work on the comet of 1664-65, apart from his own, Zaragoza also describes other astronomers' observations: Vicente Mut, Miguel Fuster, Enrique de Miranda, Claude François Milliet Dechaes, the professor of mathematics at the Collegio Romano F. Gilles de Gottingnies and the Italian astronomer Geminiano Montanari. He studied in detail the apparent movements of the comet and tried to analyse its trajectory, concluding that it was more like a straight line and is intermediate between this and the circumference, and he adds: «I leave the elliptic because it can be created from the two».<sup>37</sup> Concerning the «true» place of the comet, Zaragoza demonstrates that it was always «above the Moon», from which he deduces «contrary to common peripatetic philosophy and its prince Aristotles» that the heavens are fluid and corruptible.<sup>38</sup> In agreement with Riccioli, Zaragoza affirms that the tail of the comet is made of consistent material like the head and the nucleus and is not ignited, but illuminated by the sun's rays. The opposition of the tail to the sun is explained supposing that the comet's material is heliotropic, in the way that the head of the star is always facing the Sun like «the compass North».<sup>39</sup> This idea was adapted from Riccioli.<sup>40</sup> As for Zaragoza's observations of the 1667 comet, according to Cassini, they were the first to be carried out in Europe, being mentioned in the *Journal des Savants* and in the *Memoires* of the Academy of Science in Paris.<sup>41</sup>

<sup>36</sup> In Ste. Geneviève Library of Paris, Ms.n° 1045, fols. 42-92, with the title *Discurso del cometa del año 1664 y 1665*. We have found another copy in the Academia de la Historia de Madrid, Col. Cortes, 9/2705. Pingré (1783-84), vol.II, pp.13-21, discuss this work and includes a summary of it (the first chapter) in French. A study of this manuscript in Rosselló (2000), pp.59 and ff.

<sup>37</sup> Zaragoza, *Discurso del cometa*, fols. 73v-74r.

<sup>38</sup> Zaragoza, *Discurso del cometa*, fols 76r and ff.

<sup>39</sup> Zaragoza, *Discurso del cometa*, fol. 88r and ff.

<sup>40</sup> Riccioli (1651), p.128.

<sup>41</sup> *Journal pour l'année MDCLXXVII (Paris, 1718)*, vol.4, p.120; *Memoires de l'Academie Royale des Sciences*, vol.X (Paris, 1730), p.592. In the *Memoires*, there is a report by Cassini. According to this report, Zaragoza's observations "have superseded those of other astronomers" ("ont precedé celles des autres astronomes".) In the Observatory Library in Paris, there is a letter from Zaragoza to Cassini on the comet and other astronomical questions (B-4, 12, suite) and a memorandum by Cassini acknowledging Zaragoza as the first astronomer to observe the comet (B4-1, P175) Cassini pointed out that he had discussed the

Apart from these observations, Zaragoza prepared new texts for the renovation of the teaching of astronomy, that are conserved in manuscript copies. One of them was published under the title of *Esphera en común celeste y terráquea* (Madrid, 1675). This work intended to be a renewed version of the traditional texts on the *Sphera*, adapted to the new knowledge in astronomy and geography; the scheme of the book is the usual in this type of treatise: 1 On the Sphere in commun. 2 On the celestial Sphere. 3 On the Terraqueous Sphere. In general, Zaragoza limits himself to collecting and synthesising the information and ideas contained in texts about this theme published in Europe in the seventeenth century by his coreligionists and, in particular, by Riccioli, although he occasionally offers his own observations. Riccioli's work, especially the *Almagestum Novum*, was invaluable for Spanish mathematicians, Jesuits or not, both for its encyclopaedic reference of astronomical knowledge in the middle of the seventeenth century and as a way of providing Spanish authors with a reference and authority to support them in establishing the scope and limits of the astronomical-cosmological discourse of Spain at this time.<sup>42</sup>

In the description of the various astronomical systems, Zaragoza includes the heliocentric theory, of which he says, «it is condemned by the S.S Inquisitor Cardenals as contrary to the Holy Scripture, although as a hypothesis or supposition, it is sound from the calculation of the planets, for only the reality of this construction is condemed. not its possibility».<sup>43</sup> And he adds that if the systems of Copernicus and Tycho are compared, the only difference is that Copérnicus locates the Sun at the centre of the Universe and Tycho the Earth. Zaragoza also describes the system proposed by Riccoli in the *Almagestum Novum*.

On general cosmological questions, Zaragoza basically coincides with Riccioli. He supports the corruptibility of the heavens, without going into the subtle details of Riccioli of the nature «accidentally incorruptible» of the celestial region; he affirms that the skies are fluid, although the firmament and the aqueous crystalline are solid, not without adding the possibility these also could be fluid. As for the planetary dynamic, Zaragoza, like Riccioli, considers angels or superior intelligences. Concerning the magnitude of the heavens, Zaragoza states the following figures: more than 100,000 terrestrial semi-diameters for the fixed spher-

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matter with Zaragoza. In the Academia de la Historia (Madrid) there is a copy of Zaragoza's manuscript. Sommervogel (1890-1904), vol VIII, p. 1468 indicates that in the Vatican Archive (ASV Spagna n°149), there is a preserved Zaragoza manuscript on this comet entitled: *Observationes cometac habitae in oppido Argandae ab Astrophilo anno 1677*.

<sup>42</sup> See Navarro (2002a).

<sup>43</sup> Zaragoza (1675), pp. 42-43.

res and 7,400 the average distance to the Sun, adapting Riccoli's figures.<sup>44</sup> Concerning the models used to describe the planetary movements, Zaragoza, like Vicente Mut, addresses Kepler's first law and expound the so-called elliptic hypothesis of Boulliau-Ward. Furthermore, when discussing magnetism, in the third part of the work, he states that «even Kepler attributed the course of the planets to the Sun's magnetism».<sup>45</sup> However, for the Jesuit, «all the appareances of planetary motion are saved through a spiral motion». This theory of remote origins is to be found in the works of Biancani and other Jesuit authors (included Riccioli).<sup>46</sup>

Zaragoza also comments on new astronomical discoveries, such as the relatives of the phases of Venus and Mercury, the satellites of Jupiter, appearances around Saturn, Sun spots, the lunar topography, and observations of «novae» and comets and he also discusses their cosmological consequences, although cautiously and not without ambiguity and vacillation. He thus rejects the notion of celestial spheres and states that the

<sup>44</sup> Zaragoza (1675), pp. 55 and 175. Riccioli estimated the distances of the Sun to the Earth in 7260 and 7572 Earth radii (e.r.), being decided by a mean distance of the Sun of 7300 e.r.. On the other hand, the great expansion of the sphere of Saturn persuaded him to propose a distance of 200.000 e.r. for the sphere of fixed stars. See Riccioli (1651), Part 1, Book VI, cap. VII, p.419 where Riccoli calculates the distance to the fixed points to be 100.000 e.r. according to one method and 200,000 e.r. according to another. See Van Helden (1986) pp. 114 and ff.

<sup>45</sup> Zaragoza (1675), p.199. Zaragoza echoes the reservations of his coreligionists concerning the ideas of Gilbert and Kepler and status that "experiments show that the Earth probable has a magnetic field but it does not exceed the terms of probabily" being able to explain, in his opinion the said experiments for the existence of the hidden magnetic stone mines that are all over the Earth."

<sup>46</sup> Zaragoza (1675), p.73. A theory of the so-called "spiral motion" was articulated in the mediaeval period by al-Bitruji (Alpetragius). In his *Thema coeli*, Bacon proposes a spiral motion, no doubt basing it on al-Bitruji (Alpetragius), although without recourse to spheres (*The Works of Francis Bacon*, 7 vols., London, 1857-74, III, pp. 779-780). This solution was adopted in Spain in the sixteenth century by Jerónimo Muñoz and Diego Pérez de Mesa. On Muñoz, see Navarro Brotons (1998). On Pérez de Mesa, see Navarro Brotons (1983, 2002b). On the Jesuits and the spiral movement, see Lattis (1989). On Biancani and the spiral motion, see also Donahue (1981), p. 195. See also, on the spiral movement, Riccioli (1651), Part. 1, Bk. III, p.152 p.152, on the movement of the Sun; Part. 1, Bk. VI, pp. 454-55, on the movement of the fixed stars; Bk. VII, pp. 504-505, where he cites Kepler, who in the *Astronomia nova* observed that in geostatic astronomy the trajectories of the planets, compound of several movement, must be spirals. Also Riccioli (1651), Part 2, Bk.IX, Chap.III, p.254 y ss. In the Conclusion III of the Chap. III of this Book, p. 260, Riccioli says: "Probabilius est non dari corpus ullum, quod sit Primum Mobile, nec duos motus in stellis simul factos ad oppositas Mundi plagas, sed unicum versus Occidentem per spiras helicoidales, Fixarum quidem in caelo solido, Planetarum autem in fluido. Primi autem Mobilis vicem praestare tempus intelligibile, seu ideam diurni motus menti cuiusvis Intelligentia motricis insumam". After, Part. 2, Bk.IX, chap.IX, pp.288-289, upon introducing his own system, says: "supra Saturnum est solida fixarum sphaerae per unicum spiralem item motum ab Intelligentia una vel pluribus, triplicem motum apparenter exhibens, nempe in longitudinem versus Occasum, in longitud. versus Ortum, et in latitudinem ob declinationis variationem, qui tamen revera unicus est in Occidentem" and recalls what he has said in others parts of the work on the spiral movement. In the *Astronomia reformata* Riccioli will abandon his system and come back to Tycho's, reaffirming the unidirectionality of all the trajectories of the heavenly bodies by spires, as Lerner has remarked (1995).

heavens are fluid and the stars are corruptible, locating the «novae» in the planetary sky to maintain the solidity of the firmament. However, he points out that it is in all probability fluid and that the «stars move through it as birds through the air». <sup>47</sup> Although he talks about Sun spots, he does not mention the Sun's rotation. Concerning the Moon, he accepts the existence of mountains and valleys but rejects the possibility that it is composed of the four terrestrial elements and, in agreement with Riccoli in the *Almagestum Novum*, considers it more likely to me made of elements or substances different and celestial. <sup>48</sup>

One must also point out Zaragoza's activity in the making of scientific instruments. His last work entitled, *Fabrica y uso de varios instrumentos matemáticos* (1675), concerns the description and use of a series of instruments, constructed by himself with the help of his collaborators, the Jesuits Baltasar de Alcázar and Juan Carlos Andosilla, of geometrical use, topographical and astronomical, that the Jesuit dedicated to the King. Moreover, his Valencian associates, friends and students, also possess instruments designed by Zaragoza during his stay in Valencia. <sup>49</sup>

Another distinguished Spaniard of the middle of the century is Juan Caramuel y Lobkowitz whose ample and diverse works have a certain similarity with that of Athanasius Kircher (apart from the encyclopaedic trends and projects of both authors it must be pointed out, among other similarities, his ambition to unify knowledge through the combinatory art, his tendency for doctrinal syncretism and his interest in languages). Caramuel concerned himself with all subjects of knowledge of his time and was actively involved in numerous controversies and debates, giving his personal point of view. From 1635, and after joining the Cistercian Order, he travelled to the Low Countries, France, Bohemia, Germany, Austria and finally, Italy. In 1673, he was appointed bishop of Vigevano, the city where he died in 1682. He maintained correspondence and collaborated with many learned men of the time including Gassendi, Marin Mersenne, Kircher, Michael Florent van Langren, Wendelinus Rheita, Van Helmont, and Marcus Marci, among others. His *Mathesis biceps vetus et nova*, published in 1670, is one of the largest pure and mixed mathematics encyclopaedias (to my knowledge, the largest) to have appeared in Europe up until that time. <sup>50</sup>

Caramuel devoted a lot of time to astronomy and cosmology. He took part in some well known debates, such as the relative concerning Jupi-

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<sup>47</sup> Zaragoza (1675), p.167.

<sup>48</sup> Zaragoza (1675), p.151. Riccioli (1651), Part 1, Book.IV, Chapter II, p.187.

<sup>49</sup> See Navarro Brotons (1978, 1985).

<sup>50</sup> On Caramuel, see Garma (1978, 1983), Ceñal (1953), Pastine (1975), Velarde (1989), Pis-savino, ed. (1990).

ter's satellites that Anton Maria Schyrleus of Rheita claimed to have discovered- Gassendi also participated in this as well as the question of ring of Saturn. He also set up and organised different projects such as a map of the Moon. He also carried out a number of sporadic observations, according to what interested him or concerned him at any given moment. This unsystematic approach is a general characteristic of his scientific work.

As Dino Pastine has pointed out, Caramuel could not decide between the old and new image of nature, an indecision which was the source of some of his errors or of the orientation at the end frequently unproductive of his work, but also was source of some of his virtues. The inclusion in his work of new experiences and theories, came in a disordered way, being difficult, if not impossible, to detect, any system that was not outside the very scientific debate, that is to say, rhetorical and pedagogical. Caramuel's different theories frequently contradict themselves; this did not bother him, as these contradictions prove the impossibility of clinging to a specific scientific theory and to consider it well established and definitive. Caramuel did not renounce the idea of progress in knowledge, but progress only removes doubt and uncertainty from one argument to another. Like Gassendi, Caramuel believed that progress is in the quantity of knowledge, that is to say, the inherited accumulation of man's observations, not progress of the human spirit. Whereas Descartes insisted that natural philosophy had to make a clear break with the past and begin anew, Caramuel, along with Gassendi and later Leibniz, believed that the progress of the knowledge would be a rebirth or continuation and extension of the most valuable features of the past.

Caramuel devoted a large part of his monumental *Mathesis biceps, vetus et nova*, to astronomical matters, both «theoretical astronomy» and instruments, observation techniques, the drawing up of tables and Ephemerides.<sup>51</sup> It is impossible here to describe the enormous wealth of material assembled by Caramuel, and his long-winded discussions on various proposals and astronomical questions of the time. We will only point out certain aspects which were particularly relevant to the astronomical and cosmological debate of the time. As to be expected of a Catholic and a man of the church, Caramuel did not accept the heliocentric theory as a true representation of the planetary system, although he recognised its usefulness as a mathematical hypothesis. According to Caramuel,

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<sup>51</sup> The "Sintagma decimum" of the *Mathesis biceps*, p.1337 and ff., treats of Astronomy with the title "Interim Astronomicum" and with three parts dedicated to discuss the planetary theories : "per circulos, per oscillationes et per lineas rectas". After we have three more parts dedicated to Tables, Ephemerides and Eclipses. But in other parts of the work, like the "Geometria specialis", Caramuel discusses also astronomical questions. See, on Caramuel astronomical work, Rosselló (2002-2003).

Copernicus' argument is «ancient, easy, captivating in its understanding» and with this theory «the heavens are freed of many difficulties». <sup>52</sup> But the dimensions that are deduced from this theory for the sphere of the fixed stars, appear «monstruous» to Caramuel; It was also difficult to accept the existence of an enormous, empty space between Saturn and the stars that was also deduced from this theory. <sup>53</sup>

Caramuel favoured the system of Tycho Brahe, although he introduced modifications in the models and proposed as a general model for all the planets an eccentric that transported two epicycles, except in the case of Mercury, that would not adapt itself to this general model. <sup>54</sup> But for Caramuel, neither the homocentric spheres, nor the eccentrics, nor the epicycles, nor the circles nor the ellipses nor any other geometrical figure could precisely represent the position of the planets. <sup>55</sup> Caramuel also believed that the planets did not adhere to mathematical criteria but physical ones. As for these possible physical reasons, Caramuel discusses them in various places, but in particular in the section entitled «Oscillatory astronomy», where he proposes a theory clearly inspired by the vortices postulated by Descartes. So Caramuel suggested the existence of a universal vortex around the Sun, and particular vortices around each planet and its satellites. The planets travel through the ethereal ocean thanks to their own innate impetus and at the same time, subjected to the flowing and re-flowing of this ocean. Every planet possesses its own, particular ocean which grows and recedes in an oscillating and pendular movement. <sup>56</sup>

Alexander Koyré has pointed out that one of the crucial changes that resulted from the Scientific Revolution was that it replaced the closed finite, ordered and hierarchical cosmos of Aristotle and the Middle Ages, in which the component parts- the heavens and the Earth, were subjected to different laws, by the modern concept of the World: an open and infinite (or undefined) Universe, unified by the identity of its laws and the homogeneity of the material it contained. <sup>57</sup> This new concept of the Universe implied the heliocentric theory as a basic postulate,

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<sup>52</sup> Caramuel (1670), pp. 1391-1392.

<sup>53</sup> See the discussion in Caramuel (1670), p.752.

<sup>54</sup> See Caramuel (1670), p.1391 and ff. "De Tychonis sistemate", and p. 1459 on his "Theorica univeraslem (hic est, communem Planetis universis) proponens."

<sup>55</sup> Caramuel (1670), Appendix I, Tractatus I, p.1642.

<sup>56</sup> In the title of the *Astronomia oscillatoria* (Caramuel (1670), p.1449) we read: "Disserit de Oceanis Aethereis, illis fluxuum et refluxuum reciprocaiones accenset, et ut tumeant, et detumeant, permittit; tandemque veros apud medios oscillando Planetas, eorundem in Zodiaco loca quoad longum et latum determinat". Caramuel, as usual cites many authors, and in p.1476 refers to the "Philosophia cartesiana, quam hodie viri magni propungnat"; see also in p. 746 references to the Cartesian vortices.

<sup>57</sup> Koyré (1957).

even if was necessary to reform it in some aspects so as to accommodate it to the new celestial mechanics. The Roman Catholic's condemnation of the theory was without doubt an obstacle that prevented Catholic astronomers from fully participating in the articulation of astronomical reform with a new physics and cosmology. In countries such as Spain, which had experienced considerable decadence in scientific activity, along with a clear hegemony of the Aristotelian tradition—in the form of the Neo-Scholasticism—this obstacle was particularly powerful. But it did not prevent astronomers from assuming very relevant aspects of the new cosmology.

In this respect, we will conclude this exposition by commenting briefly on the ideas of a group of Valencian mathematicians active towards the end of the seventeenth century and the early decades of the eighteenth; they were clearly in favour of the scientific renovation, but within the framework of Catholic orthodoxy. Among the many publications of this group, we will focus on the *Compendio Matemático* by one of its members, Tomas Vicente Tosca. It is an encyclopaedic work in nine volumes, inspired by the «courses» of «pure» and «mixed» mathematics that appeared in the seventeenth century, such as the *Cursus seu Mundus Mathematicus* (1674, 1690) of Claude F. Milliet Dechaies. Tosca devotes various treatises to astronomy in this *Compendio*. Leaving aside the strictly technical side in which Tosca makes an effort to put discipline up-to-date, we will focus on the cosmology section.<sup>58</sup>

In chapter one of the *treatise* on «La Astronomía», dedicated to «the celestial region», Tosca offers an explanation of the «Order of the Creation of the World», in accordance with the Scriptures but introducing elements of corpuscular atomism and Cartesian philosophy. He tells us that God filled the space of the celestial region with «an almost infinite number of corpuscles or atoms... that make up the raw materials of all things.» By organising these corpuscles in different forms and thanks to the different movement that he gave these corpuscles, God made the different parts of the world. As for the movements of the stars, according to Tosca, they obey both the initial impulse that God bestowed upon them and the movements of the «subtle matter».

On the other hand, in Tosca's opinion, the supposed incorruptibility of the heavens must refer to the incorruptibility of the corpuscles that make up the «subtle matter», that are formed by atoms. Also, the celestial bodies, stars and planets, considered in their totality, are incorruptible, but their different parts are corruptible just like the Earth. The stars and the planets have their own centres of gravity towards which

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<sup>58</sup> On the Valencian group of “novatores”, see Navarro Brotons (1972, 1978, 1985, 2007).

all the parts move. Concerning the dimensions of the Cosmos, Tosca recognises that the parallax of the stars is «totally imperceptible» so that the distance of the stars is «inscrutable» and in all cases, much greater than the distance of Saturn to the Earth, estimated at 343.770 earth semi-diameters.

Concerning the system of the Universe, Tosca explains the main ones and in relation to Copernicus, even though it was condemned by the Sacred Congregation of the Cardinals, he says it should be admitted as a hypothesis or supposition.<sup>59</sup>

To sum up, the cosmos that Tosca presents us is still geocentric and maintains a certain distinction between the heavens and the Earth to preserve if possible the biblical scheme of creation. Nevertheless, this Universe was indefinably large and without limits; without any clear demarcation between the different regions of tradition; without natural places nor spheres that pulled the planets, with stars made up of the same material as the Earth and Sun( in the case of the stars), moving through the spaces of subtle material; material that, in turn, like the Cartesian vortexes, contributed by its movement to shape the different movements of the planets. This was certainly not yet the infinite Universe of which Koyré spoke, but was still very different from the Aristotelian-Scholastic cosmos.<sup>60</sup>

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<sup>59</sup> See Tosca (1757), vol.VII, p. 4 and ff. on “El orden de la creación del mundo”; p. 8 and ff., “Explicase de qué suerte sean los Cielos, y estrellas corruptibles”; p. 10 and ff: “Los cielos de las estrellas son fluidos”. On the distance of the stars to the Earth, see p. 451 and ff. On Copernican system, pp. 20-21. The first edition of the Tosca’s *Compendio Matemático* was in 1707-1715. I cite by the edition of 1757. There were no changes in the text between the two editions.

<sup>60</sup> See Randles (1999).

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