THE TRANSFORMATION OF ASTRONOMICAL CULTURE IN THE SEVENTEENTH CENTURY

Roberto de Andrade Martins

Abstract: There is a remarkable difference between the cultural roles of astronomy in Antiquity and in modern times. Before the scientific revolution, astronomy belonged to an intricate network of knowledges, including religion, mythology, geography, astrology, medicine and other fields. That network was broken after the seventeenth century and astronomy was thereafter regarded as just the study of heavenly phenomena, without much relevance for other fields. The Copernican revolution also entailed a complete change of astronomical terminology, with the loss of terms such as "orb", and the simultaneous substitution by other words, such as "orbit". The terminology changes are analyzed in this paper with the use of Google Books N-gram Viewer. The transformation of astronomical culture that accompanied the Copernican revolution is more substantial than a paradigm shift, because it is not limited to a scientific discipline – it encompasses a whole world view (*Weltanschauung*). This transformation also entailed many losses, as shown in this paper.
Keywords: scientific revolution; Copernican revolution; history of astronomy; cultural astronomy; astronomical terminology

1. INTRODUCTION

This paper describes the deep changes of the relevance of astronomy to European everyday life accompanying the

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Copernican revolution. From Antiquity up to 1600 astronomy was a relevant component of European culture, in several ways. It was taught at the universities both as part of the basic liberal arts and as the technical prerequisite for studying the astrology required in the medical profession. Astronomical knowledge was studied by pilots since it was crucial for oceanic navigation. Astronomy was strongly linked to religious thought and there was a tenuous line of separation between the astronomical heavens and the paradise, in Christian thought. The most common method of measuring time was the sundial, and its construction involved sophisticated knowledge of geocentric astronomy. The apparent motion of the Sun during the year and its connection with the seasons and the variable duration of day and night were well known. Both classical and early modern literature made use of astronomical knowledge. Acquaintance with celestial phenomena and the constellations and their lore was part of culture.

At a time when people spent much time in open spaces and artificial lighting was feeble, knowledge of the apparent motion of the Sun and the study of the shadows it produces, the variable duration of the day and night during the year, the phases of the Moon and other conspicuous phenomena were well known. The motion of the planets, on the other hand, was not described in the oldest extant Greek literature. Notice that the Moon moves around the Earth both in geocentric and heliocentric astronomies; and the apparent motion of the Sun is much easier to understand from the point of view of a geocentric theory, which can deal with all its phenomena.

The situation changed completely during the astronomical revolution. Its emphasis was the study of the motion of the Earth and planetary theory – two subjects with no direct link to everyday life. The heliocentric point of view made it extremely difficult to understand the yearly apparent motion of the Sun and the variation of day and night, or the detailed working of sundials – which became outdated, being replaced by mechanical clocks. Solar tables were still used by the pilots, but

their geocentric interpretation was just dropped down – it was not replaced by the heliocentric one. By the end of the seventeenth century, the study of astrology in the universities had declined and the link between the religious heaven and the astronomical sky had been severed.

Any change of paradigm entails both gains and losses, according to Thomas Kuhn. The transformation of astronomical culture that accompanied the Copernican revolution is more substantial than a paradigm shift, because it is not limited to a scientific discipline – it encompasses a whole world view (*Weltanschauung*). This transformation also entailed many losses, as will be shown in this paper.[1]

2. ASTRONOMICAL CULTURE IN THE TRANSITION FROM THE 15TH TO THE 16TH CENTURY

In a former paper I studied the situation of astronomical culture in classical Antiquity.[2] The Middle Ages were not dealt with in that article and will not be discussed here, either, because the main target of this paper is the changes that happened during the so-called Copernican astronomical revolution. The importance of astronomy and astrology at the universities, during the late middle ages and Renaissance, can be summarized thus:

> The formal study of both astronomy and astrology in later medieval Europe was firmly based in the universities. Astronomy had by this time become the dominant – and perhaps also the liveliest – portion of the old *quadrivium*, the mathematical portion of the liberal arts, whose subject fields

[1] This paper and its first part (the previous essay in this volume) were written for presentation at the conference *Oxford Scientiae 2016: Disciplines of knowing in the early modern world* – St Anne's College, University of Oxford, 5-7 July 2016. It was circulated at that time, but it had not been published until now.

[2] MARTINS, Roberto de Andrade. The cultural relevance of astronomy in classical Antiquity, in this volume.

> still survived in the diversity of university subjects and texts. In disciplinary terms astrology was widely portrayed, as it had been in antiquity, as an *ars* or *techne*, a practical application of astronomy and astronomical principles. This distinction between the two fields as science and art was maintained more consistently than was the nomenclature; a scholar might use the two terms 'astronomy' and 'astrology' in ways consistent with modern usage, but might also reverse them. Other fields also kept this division between science and art, especially those of the old *quadrivium*. The study of the heavens, then, still formed part of the general studies of philosophy and liberal arts that led to the bachelor's degree. It also held particular and more specialized interest for the medical faculty, because of the fields' perceived abilities to account for celestial influences on health. An expert physician's training and practice included astrology to some degree; the careers of practicing physicians kept astrological practice active in cities and courts. Important courts, in fact, increasingly retained prominent physician/astrologers, a custom established significantly earlier. Astrological practice could also be found at lower social levels, of course, just as other aspects of medical education and practice were not the exclusive province of university-trained experts. (Moyer, 1999, pp. 228-229)

The youth of Nicolaus Copernicus (1473-1543) matched the early phase of the typographical revolution of scientific knowledge. Jérôme de Lalande's restrictive[3] and incomplete *Bibliographie astronomique* lists 160 astronomical publications from that time to the end of the 15th century (Lalande, 1803, pp. 9-29). The correct number is about five times larger.

The presence of astronomical and astrological works among incunabula is significant. In 2015, the *Incunabula Short Title*

[3] Lalande did not include in his bibliography popular publications (such as calendars and almanacs) or books on other subjects that contained astronomical information (for instance, medicine books).

Catalogue included 27,400 titles[4]. About 16.5% of the incunabula correspond to Klebs' classification of "scientific and medical" (Klebs, 1938), and nearly 20% of the titles analyzed by Klebs correspond to astronomical and astrological works (Klebs, 1932, p. 86; Bühler, 1948).

We can learn a great deal about the astronomical interests in Europe in that period by analyzing the content of those incunabula. The earliest known printed books that could be described as astronomical or astrological were:
1470? – Thomas Aquinas, *De judiciis astrorum*
1472 – Angelus Cato, *De cometa anni 1472*
1472 – Johannes de Sacro Bosco, *Tractatum de spera*
1472 – Johannes de Sacro Bosco, *Spaera mondi*
1472 – Isidore of Seville, *Liber de responsione mundi et astrorum ordinatione*
1472? – Marcus Manilius & Aratus, *Astronomicon*; *Phaenomena*
1472 – Gerard of Cremona, *Theorica planetarum*
1473 – al-Kabīsī, *Introductorium ad scientiam judicialem astronomiae*
1473 – Aristotle & Averroes, *De caelo et mundo*
1473? – Johannes Regiomontanus, *Kalender*
1474 – Marcus Manilius & Aratus, *Astronomicon*; *Phaenomena*
1474 – Jean Gerson, *Trilogium astrologiae theologisatae*
1474 – Georg von Peuerbach, *Theoricae novae planetarum*
1474 – Johannes Regiomontanus, *Kalender*
1474 – *Thurecensis physici tractatus de cometis*
1474 – Johannes de Sacro Bosco, *Opusculum spericum*
1474? – Gaietanus de Thienis, *Expositio in libros Aristotelis De coelo et mundo*
1474? – Johannes Regiomontanus, *Disputationes contra Cremonensia in planetarum theoricas deliramenta*
1475 – Johannes Regiomontanus, *Kalender*

[4] Most numerical information presented in this section of the paper was obtained by consulting the British Library's *Incunabula Short Title Catalogue*, available online: <http://www.bl.uk/catalogues/istc/index.html>

1475 – Albrecht Kunne, *Calendarium perpetuum*
1475 – Andalo de Nigro, *Opus praeclarissimum astrolabii*
1475 – Jean de Gerson, *Astrologia theologisata*
1476 – Johannes Regiomontanus, *Calendarium*
1476? – Johannes de Sacro Bosco, *Tractatum de spaera*

This list is representative of this period. Notice the presence of authors from classical antiquity (Aritotle, Aratus, Manilius); of some medieval works that were widely used in universities up to the 17th century (Sacrobosco, Gerard of Cremona – later replaced by Peurbach); of ecclesiastical and common calendars; and several astrological works. In the same period we find the publication of non-astronomical works that are relevant for our study of astronomical culture, such as Hesiod's *Works and days*, published in Latin in 1471, and in Greek in 1480. This work was printed 14 times, before 1500. Virgil's *Georgica*, Columella's *De re rustica* and other Roman works on agriculture and farming (by Cato, Varro and others) that make use of astronomical lore, were also printed several times in this period. There were 113 editions of the *Georgics* up to 1500 (the first one in 1469), and 15 editions of Columella's work.

According to George Sarton's census,[5] the twelve most published authors of scientific works in the 15th century were: Albert the Great (151 publications, including any works attributed to him), Aristotle (98 publications, also including spurious works), Hippocrates (52), Arnaldo da Villanova (40), Wenzel Faber (40), Regiomontanus (38), Anianus (37), Jean de Mandeville (36), Canutus (34), Rhazi (34), Bernat de Granollachs (34), Sacrobosco (31) (Sarton, 1938, p. 183). Of these, Albert the Great, Aristotle, Wenzel Faber, Regiomontanus, Anianus, Granollachs and Sacrobosco wrote on astronomy and astrology; some of the other ones included astral information in their books.

[5] The numbers cited here are those presented by Sarton. The *Incunabula Short Title Catalogue* identifies a larger number of editions. For information about the *Regimen*, see Ordronaux, 1871.

The most frequently published scientific works in the 15th century (according to Sarton's census) that included astronomical content were: *Regimen Sanitatis* (75 editions), *Liber Aggregationis* ascribed to Albert the Great (61 editions), astrological predictions by Wenzel Faber (38), *Compotus* by Anianus (37), *Lunarium* by Granollachs (34), anonymous prognostications (33), *Sphaera Mundi* by Sacrobosco (31), astrological predictions by Avogario (29), *De Proprietatibus Rerum* by Bartholomew the Englishman (24), astrological predictions by Girolamo Manfredi (20), *Historia Naturalis* by Pliny the Elder (18), *Sfera* by Gregorio – or Leonardo – Dati (17), astrological predictions by Scribanario (17), *Canon Medicinae* by Avicenna (15), *Calendarium* by Regiomontanus (15), *Ephemerides* by Regiomontanus (15), astrological predictions by Novara (14), *De Re Rustica* by Columella (12), *Prognostication* by Lichtenberger (12), astrological predictions by Paulus de Middelburg (11), astrological predictions by Pollich of Mellerstadt (11), *Cosmographia* of Poponius Mela (10), and the anonymous *Compost et Calendrier des Bergers* (10) (Sarton, 1938, pp. 189-191). Notice the large number of highly popular astrological works, in the period. Some other relevant works did not attain the threshold of 10 editions.

Hyginus' *Poetica Astronomica*, the first printed astronomical work presenting many symbolic images of the constellations and of the planets, was published five times before 1500. Of course, Greek and Roman mythology was not acceptable as true, in the Christian context. However, in the middle ages, Dante Alighieri (1265-1321) had provided a new vision of the sacred space of the sky, in his *Divina Commedia*, by populating the heavenly spheres with angels, saints and the Judaico-Christian god. By translating the ancient astral religion into Christian terms, and retaining many of the old astrological ideas, Dante incorporated the continuity of the relationship between the sky and religion (Kay, 1994). Dante's *Divina Commedia* has always been very influential, and it was printed fifteen times before 1500.

Although the massive presence of astrological works is easily perceived, this does not mean that astrology was accepted by everyone – and the same was also true in classical antiquity. Among incunabula we find attacks against astrology by Pierre d'Ailly (*De legibus et sectis contra superstitiosos astronomos*, ca. 1480, ca. 1489), Girolamo Savonarola (*Tractato contra li astrologi*, 1497) and Giovanni Pico della Mirandola (*Compendium sententiarum praeclarissimarum adversus astrologiam*, ca. 1498) – and its defense by Giovanni Abiosi (*Dialogus in astrologiae defensionem*, 1494) and Lucio Bellanti (*Liber de astrologica veritate: et in disputationes Ioannis Pici aduersus astrologos responsiones*, 1498). Most doubts and criticisms of astrology concerned horoscopes (the so-called *judicial astrology*), because the determination of the individual future was sometimes interpreted as contrary to the doctrine of free will (Boas, 1962, p. 168); however, the influence of the stars and planets on the weather, crops, earthquakes, diseases and other physical phenomena was accepted by nearly everyone.

Sarton's analysis of incunabula, based upon Klebs' inventory of scientific and medical incunabula (Klebs, 1938), did not comprise other very popular works, such as the anonymous calendars and almanacs, which always included astronomical content. The earliest known publication of this kind was the *Mainz Kalender*, printed in 1456 or 1457. It was a bleeding and purgation calendar (called *Aderlasskalender* or *Laxierkalendar* in German), which gave details of the lucky and unlucky days on which to bleed or take medicine in a given year (Green, 2012, p. 29; Luke, 1989, p. 56). Printed in a single paper sheet, those medical calendars were very popular. At least 46 were printed before 1480, and more than one hundred up to 1500 (Berry & Poole, 1966, p. 13; Sudhoff, 1908, pp. 261-432). Those medical calendars introduced for the first time, in printing, the famous images of the cosmic man (or woman) with the relation between the Zodiac and the parts of the body. If we include all types of calendars and almanacs published up to the end of the 15th

century, their number exceeds 500. Almanacs were published both in Europe and in the New World (Guerra, 1961).

Islamic medicine, that was highly influential in Europe and well represented in books published during this period, accepted the humoral theory of Hippocrates, developed by Galen, its association with the Aristotelian theory of the four elements and four qualities, together with the theory of individual temperaments, influenced by the time of birth, and the consideration of man as a microcosm. The seven cervical and the twelve dorsal vertebrae corresponded to the seven planets and twelve signs of the Zodiac, as well as the days of the week and the months of the year; and the total number of discs of the vertebrae, which they considered to be 28, to the stations of the Moon. The correspondence and "sympathy" between various orders of cosmic reality form the philosophical background of Islamic medicine (Nasr, 1968, pp. 219-224).

Astrology had become highly influential in medieval Europe after the introduction of Islamic works, such as those translated under Alfonso X (Harvey, 1977; Rodríguez, 2007). The level of popularity of astrology during that period can be recognized, for instance, in the heavy use of astrological references in Chaucher's *Canterbury Tales* (Wood, 1970; Cartwright, 2005). The most influential Islamic astronomical/astrological authors whose books were printed in the 15th century were Alchabitius (1473, 1485, 1491), Albohazen (1485), Abdilaziz (1482, 1485), Albumasar (1488, 1489), Messahalla (1493), Almanzor (1493).

Ptolemy's *Almagest* was not printed during the 15th century, but his geographical work (*Cosmographia*) was printed seven times, and his astrological treatise (*Quadripartitum*, or *Tetrabiblos*) had two editions. There were also six editions of Strabo's *Geographia*. Regiomontanus's abridgment of the *Almagest* (*Epitoma in Almagestum Ptolemaei*) was first printed in 1496. At the universities, up to the 17th century, the study of astronomy followed Sacrobosco's *Tractatus de Sphaera* (and commentaries) for the general description of the world (Gingerich, 1988), complemented by the *Theorica Planetarum*

of Gerard of Cremona or the *Theorica Nova* of Peurbach, that supplied the technical discussion of the motion of the planets (Pedersen, 1981). Astrologers usually relied on tables such as those of Regiomontanus' *Ephemerides* for numerical data, instead of calculating the locations of the planets (Boas, 1962, p. 169).

According to Seyyed Hossein Nasr, in medieval Islam, alchemy and astrology were described as complementary. Although astrology describes the direct celestial influences, alchemy deals with substances of the sublunary world that were generated under astral influences and that are directly related to the planets. The seven planets were represented by seven metals, being represented by the same symbols as a part of the wide astral symbolic network: lead (Saturn), tin (Jupiter), iron (Mars), gold (Sun), copper (Venus), quicksilver (Mercury), silver (Moon) (Nasr, 1968, pp. 250-251). The astral influence upon terrestrial materials was also the basis of the wide development of talismans, or *Scientia imaginum* developed by Islamic authors and that was treated, for instance, in the books *De mineralibus* and *Speculum astronomiae* ascribed to Albertus Magnus (Weill-Parot, 1999). Hieronymus Torrella's *Opus praeclarum de imaginibus astrologicis* (1496) and other later works were dedicated to this subject.

The study of geography and the sea navigations were still strongly dependent on astronomy. The observation of the stars or the Sun, using an astrolabe, was the only available method for determining the geographical latitude. However, although the Portuguese and Spanish long distance voyages were already starting, we find no publication devoted to astronomical navigation in the late 15th century. It is true that Abraham ben Samuel Zacuto and José Vizinho authored the *Almanach perpetuum* first published in Portugal in 1496 and that this work was used by Portuguese pilots; explicit manuals for astronomical navigation were only published in the 16th century, by Fernandez de Enciso, Francisco Faleiro, Pedro de Medina, Martin Cortes and others (Proverbio, 1994). We should

point out that, in the 16th century, the epic poem *Lusíadas*, by Luís de Camões (1524-1580), describing the Portuguese voyages and conquests, was full of astronomical references (Silva, 1915). This shows both the relevance of astronomy for the long distance travels and the acquaintance of educated persons of the period with astronomical knowledge.

Since the 12th century, contrary to the situation in antiquity, European pilots were acquainted and used the magnetic compass for the determination of geographical directions (Smith, 1992). However, this instrument did not replace the astronomical means of orientation. First, it is relevant to point out that Islamic authors had associated the orientation of magnetic bodies to an astral effect (Weill-Parot, 2015). Up to Gilbert's 1600 work on the magnet, the compass was not a replacement for astronomical orientation: it was a special instrument acted by the stars. Most authors accepted that the magnetic needle pointed to the celestial pole. Besides that, in the 16th century pilots perceived that the magnetic compass was not reliable (at some places it had a large deviation from the astronomical meridian) and only the Sun and the stars provided the true north-south direction (Mitchell, 1937).

Hence, in the early 16th century, astronomy and astrology were relevant components of the European culture. They were taught at the universities; many publications on those subjects – both technical and popular ones – had a wide circulation; astrology and astronomy were the basis of medical and agricultural practices; the stars, the Sun and the Moon remained the basic references for the measurement of time, the establishment of geographical data and the prediction of weather; calendars and almanacs established the adequate days for several activities – including religious ones; navigation was guided by sky observations; astronomy and astrology references frequently appeared in literature; astral mythology and celestial symbolism was still influential; and belief of the influence of the heavens upon matter was the basis of talismanic magic and part of the alchemical theory of that time.

3. THE COPERNICAN REVOLUTION AND THE CHANGES OF ASTRONOMICAL CULTURE

The so-called astronomical revolution started with the publication of Nicolaus Copernicus' *De revolutionibus orbium coeslestium* in 1543, received important contributions from Giordano Bruno, Johannes Kepler, Tycho Brahe, William Gilbert, Galileo Galilei, René Descartes and several other authors, and concluded in the middle of the 18th century, with the general acceptance of Isaac Newton's mechanics and theory of gravitation. The change was already complete when the *Encyclopédie ou dictionnaire raisonné des sciences, des arts et des métiers* was published, in 1745-1756 (Kuhn, 1957; Koyré, 1961; Boas Hall, 1962; Rupert Hall, 1983; Gingerich, 2004).

It is impossible to describe this revolution in detail, here. Copernicus' main contribution was a change from geocentrism to a heliocentric theory of the motion of the planets; however, from the middle of the 16th century to the beginning of the 18th century there were several other fundamental contributions that provided a complete cosmological upheaval. The rational acceptance of the motion of the Earth around the Sun required a new mechanics, with the abandonment of the distinction of natural and violent motions and a novel interpretation of gravity. The whole theory of the five elements had to be abandoned, since there was no essential difference between the matter around us and the celestial bodies. Although Copernicus still accepted the celestial spheres and tried to explain the motion of the planets using a combination of circular motions, those principles were gradually dropped out, being ultimately replaced by the idea of celestial bodies moving in empty space (or in a very rarefied ether) according to the laws of Newtonian mechanics and acted upon by gravitational forces. The sphere of the stars was abandoned, and those celestial bodies were regarded as hanging in infinite (or indefinite) space at widely different distances of the Earth. Although the Sun became the center of the planetary system, the universe had no central point.

It became conceivable that there were other worlds similar to the Earth, with living beings, rotating around some of the stars.

The history of the Copernican revolution has usually being studied by analyzing the contributions and opinions of a small number of relevant individuals. In recent years, it became possible to apply new computational tools to the study of history, allowing us to have a different view of collective cultural changes, through the analysis of thousands (or millions) of publications. One of those recent tools is the *Google Books Ngram Viewer* (Michel *et al*., 2011)[6]. It has been described, discussed and applied to historical research by several authors (wee, for instance: Yeung & Jatowt, 2011; Gibbs & Cohen, 2011; Virues-Ortega & Pear, 2012; Greenfield, 2013; Solée et al., 2013; Genovese, 2015; Milligan, 2012).

Fig. 1. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the words "orb" and "orbs" in English books, relative to the appearance of the words "star", "planet" (and their plurals), "astronomy", "astronomical" and "astronomic".[7]

[6] Available at <http://books.google.com/ngrams>.

[7] All graphs presented in this paper were obtained in March 2016, when this essay was prepared.

Using the *Ngram Viewer* it is possible to perceive, for instance, the fast drop of the use of "orb" (or "orbs") in the astronomical context, in the 17th century (Fig. 1). Up to that time, this word had been used to describe the invisible celestial spheres that held and were responsible for the motions of the stars and planets. Shortly before 1700, it had almost disappeared, due to the ongoing astronomical revolution.

Fig. 2. *Google Books Ngram Viewer* frequency of appearance (three years smoothing) of the phrases "orb of Mars" and "sphere of Mars" in English books, relative to the appearance of the word "Mars", and corresponding frequencies for Venus and Jupiter. The main trend does not depend on the planet.

Up to 1600, the motion of the planets was described as produced by their orbs. In the 17th century, phrases such as "orb of Venus" or "sphere of Venus" vanished (Fig. 2)[8]. A similar trend can be noticed regarding the phrases "celestial sphere" and "heavenly sphere" (and their plurals), that suffered a sudden drop in the 17th century and had almost disappeared in the early 18th century – around 1720 or 1730 (Fig. 3).

Until the beginning of the 17th century, the Sun was supposed to be carried around the Earth by its deferent or

[8] Unfortunately, the statistics provided by the *Google Books Ngram Viewer* for English books prior to 1600 is poor.

eccentric circle. Around 1650, the phrases “deferent of the Sun” and “eccentric of the Sun” disappeared (Fig. 4). Likewise, the words epicycle, eccentric and deferent that were used to describe the motion of the planets practically vanished around 1680, reappearing, however, in historical accounts after that time (Fig. 5).

Fig. 3. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the phrases “celestial sphere” and “heavenly sphere” (and their plurals) in English books, relative to the appearance of the word “planets” (lower line), and relative to the appearance of the word “stars” (upper line).

Fig. 4. *Google Books Ngram Viewer* frequency of appearance (three years smoothing) of the phrases “deferent of the Sun” or “eccentric of the Sun” in English books, relative to the appearance of the word “Sun”.

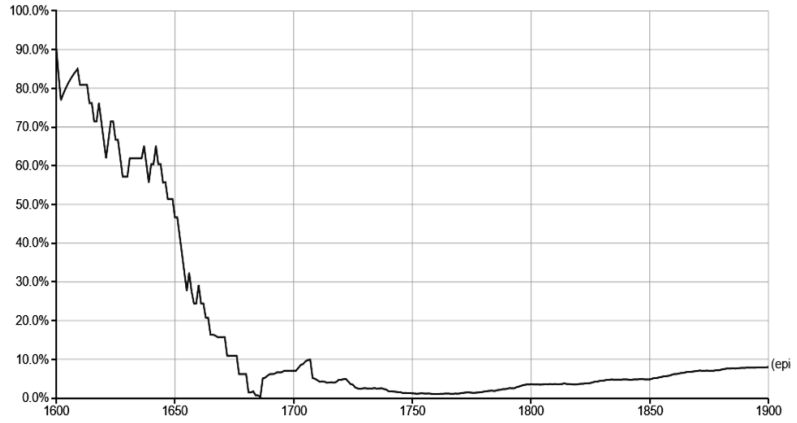

Fig. 5. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the words epicycle, eccentric or deferent in English books, relative to the appearance of the words "planet", "planets", "astronomy", "astronomical" and "astronomic".

Those statistical results confirm what one would expect from the current view of the Copernican revolution. Observe, however, that the analysis of different words of phrases provide dissimilar extinction curves and distinct disappearance dates. Notice, also, that some specific terms (such as "orb") die very hard (Fig. 1).

In the same period, it is possible to discern some changes that were not directly produced by the Copernican revolution, although they accompanied it. Up to the end of the 16th century, sundials were the most common instrument for measuring time, and they were described in astronomical books. The improvement and dissemination of mechanical clocks – and, especially, pendulum clocks – during the 17th century entailed the disappearance of interest in sundials around 1730 (Fig. 6). Of course, the development of the new mechanical clocks could have occurred one century before the Copernican revolution; it is just a contingency that the two historical trends occurred at about the same period.

Fig. 6. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the word "sundial" (or "sun dial", or "sundials") in English books, relative to the appearance of the words "astronomy" or "astronomical" or "astronomic".

With the abandonment of the sundial, the division of the bright part of the day in 12 parts was abandoned, and the very concepts of "artificial hour" and "natural hour" disappeared from the astronomical literature around 1730 (Fig. 7).

Fig. 7. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the phrases "natural hours" or "artificial hours" in English books, relative to the appearance of the words "astronomy" or "astronomical" or "astronomic".

From Antiquity to the Renaissance, the determination of the periods of the year and its cyclical phenomena were associated

to the observation of the rising and setting of the stars. However, the very *description* of helical, cosmical and acronychal rising and setting of the constellations disappeared from the astronomical literature around 1730, accompanying the Copernican revolution (Fig. 8).

Fig. 8. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of phrases containing helical or cosmical or acronychal and rising or setting in English books, relative to the appearance of the words "astronomy" or "astronomical" or "astronomic".

Besides the constellations of the Zodiac, there were other constellations or stars that had been relevant signposts of the divisions of the year, since Antiquity: the Pleiades, Sirius (or Dog Star), Orion, Arcturus, Bootes, the Hyades. References to those stars did not disappear, but reached a small level around 1680, and after a rise around 1710, they collapsed to a very low level after 1750 (Fig. 9). A very similar trend can be observed regarding the presence of the classical names of the winds (Boreas, Notos, Zephyros, Euros), which had been associated to the seasons and to astronomical phenomena since Antiquity. The frequency of occurrence of those names becomes small around 1650-1690, has an increase around 1700, and drops to negligible frequencies after 1750 (Fig. 10).

Fig. 9. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the names of some common stars and constellations (Pleiades, Sirius or Dog Star, Orion, Arcturus, Bootes, Hyades) in English books, relative to the appearance of the words “astronomy” or “astronomical” or “astronomic”.

Fig. 10. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the traditional names of the four main winds (Boreas, Notos or Notus, Zephyros or Zephyrys, Euros or Eurus) in English books, relative to the appearance of the words “astronomy” or “astronomical” or “astronomic”.

Fig. 11. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the phrases "length of the day" or "duration of the day" (or night) in English books, relative to the appearance of the words "astronomy" or "astronomical" or "astronomic".

The variation of the lengths of day and night during the year and in different places of the Earth was an important phenomenon presented in most astronomical works before the Copernican revolution. Unexpectedly, this subject virtually disappeared from the books around 1730 (Fig. 11). The *explanation* of the effect is, of course, different in the geocentric and in the heliocentric theories; but the phenomenon itself is relevant and observable, and there was no evident reason for dismissing its study in the 18th century.

From the Middle Ages to the Renaissance, the most popular astronomical textbook was Sacrobosco's *Tractatus de Sphaera*, together with its commentaries and complements. In the beginning of the 17th century Sacrobosco was still highly cited, but around 1680 his name virtually vanished from the literature (Fig. 12). It was never replaced by any other equally popular astronomical textbook.

Interest in astrology, as shown by the frequency of appearance of this word, decreased in the 17th century, suffered a strong revival in the early 18th century and was still sizeable in the early 19th century (Fig. 13). It is clear that the Copernican

revolution did not "kill" astrology. The causes behind the decreasing interest in astrology during this period are still open to debate, although many different explanations have been suggested (Ferreira, 2005).

Fig. 12. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the name Sacrobosto (with the variants Sacrobusto and Sacro Bosco) in English books, relative to the appearance of the words "astronomy" or "astronomical" or "astronomic".

Fig. 13. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the words "astrology" or "astrological" or "astrologic" in English books, relative to the appearance of the words "astronomy" or "astronomical" or "astronomic".

Fig. 14. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the phrase "magnetic influence" in English books, relative to the appearance of the words "astrology" or "astrological" or "astrologic".

Before the scientific revolution, the concept of astrological effects was usually linked to the notion of magnetic influences – an idea that had been reinforced by the discovery of the directional property of magnets in the Middle Ages. Even after Gilbert's work on magnetism, this idea was still highly influential, but nearly disappeared around 1760 – reappearing later, with other magnetic beliefs, such as Mesmerism (Fig. 14).

Fig. 15. *Google Books Ngram Viewer* frequency of appearance (ten years smoothing) of the phrase "critical day" and its plural, in English books, relative to the appearance of the word "medicine".

The traditional astrological medicine also declined, during the 17th and 18th centuries. This can be noticed, for instance, by the decrease of the presence of the phrase "critical day" (and its plural). After frequency oscillations during the 17th century, this expression decreased markedly during the early 18th century and vanished around 1750 (Fig. 15).

The statistical data used in the analysis presented above has some shortcomings. The *Google Books Ngram Viewer* does not include books in Latin, which was a relevant scientific language during that period. Only English books were used for producing the graphs shown in this paper; different results arise for other languages. Besides that, the database does not accept the full use of Boolean operators. Even with those limitations, this tool provides relevant results. Of course, the data provided by this instrument does not offer *explanations*, but it supplies relevant information that requires historical interpretation.

4. FINAL COMMENTS

In classical antiquity, astronomy had a strong connection with everyday life and was deeply embedded in the philosophical and religious culture. Although this relationship changed during the Middle Ages, due to both Islamic and Christian influences, astronomy remained of paramount importance in the culture and practical life until Renaissance.

During the period of the Copernican revolution, it is possible to notice the decline of astrology and of all beliefs concerning the celestial influence on health, weather and other phenomena – although almanacs and other popular publications were still published and read. Some explanations can be offered for this change. According to the new cosmology, the planets could not be interpreted as special and almost supernatural bodies: they were just big rocks; the stars (including the Sun) were just big fiery material bodies. They did not emit any special rays – only light and heat. They did not act upon other bodies by a mysterious magnetic influence – they just had a gravitational power that was unable to produce any strong physical effect on

terrestrial bodies, except in the case of some special phenomena, such as the tides. The constellations were not real groups of stars with special powers: they only appeared to be near to one another when observed from a particular point of space – our position. The motion of the planets could be explained using physics and mathematics, without any additional assumption about intelligent beings (such as gods or angels) associated to them. The concept of a finite universe with an outer spherical shell was discarded, leaving no place in the astronomical scheme for God, saints or angels. The sky lost its mysterious and sacred status and became just a set of material bodies moving under physical laws.

So, this new *Weltanschauung* may account for several differences between the old and new astronomical and astrological cultures. Other changes, although they occurred at the same time, require a different explanation.

Time became a completely artificial device, on all scales. The month was not related anymore to the phases of the Moon, the beginning of the year and its important periods were not related to the rise and setting of the stars. The religious festivals were not explicitly related to astronomical events, anymore. Hours were now measured by a mechanical device, that seemed to have no relation whatever to the sky and astronomical phenomena. The astronomical division of the time between successive midnights in 24 parts replaced the observation of the rising and setting of the Sun and the use of different hours in each period of the year. The fundamental phenomenon of the variation of the length of day and night was not studied any more. The neglect of this last astronomical topic may have a specific explanation. In the geocentric theory, it was very easy to understand how the motion of the Sun around the Earth produced this variation of the duration of day and night, and its relation to the latitude of the observer. The analysis was not quite simple in the heliocentric theory, and perhaps for that reason the astronomical books left this phenomenon out of their scope.

The geographical directions were related to the structure of the celestial sphere and its motion. The heavenly poles were directly observable. Once the sky became a set of detached stars and there was no sphere rotating around the Earth, there were no celestial poles, according to the original meaning of this word. The Earth was supposed to rotate and to have poles, but they were not observable. Accordingly, most people began to attach an absolute meaning to the magnetic meridian, as if it were the original and meaningful definition of the north-south direction. Only pilots and specialists knew that the magnetic compass could suffer deviations, and they kept the astronomical meaning of the main geographical directions. The popular awareness of the relation between the four main directions and the structure of the sky vanished.

From Antiquity to the Renaissance, the popular astronomical knowledge was strongly associated to observations. Everyone could perceive the motion of the Sun, of the stars, of the Moon. After the Copernican revolution, direct observations were not meaningful anymore, because the Sun and the stars did not move. A scientific knowledge that had direct connection to the observable world around us was replaced by an abstract knowledge that had no relation to the visible world, for the general population. We do not observe the motion of the Earth; we do observe the motion of the Sun; but we are mistaken, only the astronomers know the truth, by some mysterious methods. Of course, everybody knew that naked eye observations had been improved and replaced by the use of the telescope. As a matter of fact, the telescope does not show that the Earth moves and the Sun is still – but the general public thought (and still thinks) that astronomers can *see* that this is true.

In the 18th century, the study of the sky became a highly specialized knowledge, and the astronomical culture of the general population decreased. The losses produced by the Copernican revolution were significant, and they deserve more attention by historians.

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BIBLIOGRAPHICAL REFERENCES

BERRY, William Turner; POOLE, Herbert Edmund. *Annals of printing: a chronological encyclopaedia from the earliest times to 1950*. London: Blandford Press, 1966.

BOAS, Marie. *The scientific renaissance, 1450-1630*. New York: Harper & Brothers, 1962.

BÜHLER, Curt F. The statistics of scientific incunabula. *Isis*, 39 (3): 163-168, 1948.

CARTWRIGHT, John. Medieval cosmology and European literature: Dante and Chaucer. Pp. 1-30, in: CARTWRIGHT, John H.; BAKER, Brian (eds.). *Literature and science: social impact and interaction*. Santa Barbara: ABD-Clio, 2005.

FERREIRA, Juliana Mesquita Hidalgo. *As influências celestes e a Revolução Científica: a astrologia em debate na Inglaterra do século XVII*. PhD Dissertation in Philosophy. São Paulo: Pontifícia Universidade Católica de São Paulo, 2005.

GENOVESE, Jeremy E. C. Interest in astrology and phrenology over two centuries: a Google Ngram study. *Psychological Reports*, 117: 940-943, 2015.

GIBBS, Frederick W.; COHEN, Daniel J. A conversation with data: prospecting Victorian words and ideas. *Victorian Studies*, 54 (1): 69-77, 2011.

GINGERICH, Owen. Sacrobosco as a textbook. *Journal for the History of Astronomy*, 19: 269-273, 1988.

GINGERICH, Owen. *The book nobody read: chasing the revolutions of Nicolaus Copernicus*. New York: Walker, 2004.

GREEN, Jonathan. *Printing and prophecy: prognostication and media change 1450-1550*. Ann Arbor: University of Michigan Press, 2012.

GREENFIELD, Patricia M. The changing psychology of culture from 1800 through 2000. *Psychological Science*, 24 (9): 1722-1731, 2013.

GROSCHWITZ, Helmut. *Mondzeiten. Zu Genese und Praxis moderner Mondkalender*. Münster: Waxmann Verlag, 2008.

GUERRA, Francisco. Medical almanacs of the American colonial period. *Journal of the History of Medicine and Allied Sciences*, 16 (3): 234-255, 1961.

HALL, Alfred Rupert. *The revolution in science, 1500-1750*. London: Longman, 1983.

HALL, Marie Boas. *The scientific Renaissance, 1450-1630*. New York: Harper, 1962.

HARVEY, Leonard Patrick. The Alfonsine school of translators: Translations from Arabic into Castilian produced under the patronage of Alfonso the Wise of Castile (1221–1252–1284). *Journal of the Royal Asiatic Society of Great Britain & Ireland* (new series), 1: 109-117, 1977.

KAY, Richard. *Dante's Christian astrology*. Philadelphia: University of Pennsylvania Press, 1994.

KLEBS, Arnold C. Gleanings from incunabula of science and medicine. *Papers of the Bibliographical Society of America*, 26 (1/2): 52-88, 1932.

KLEBS, Arnold C. Incunabula scientifica et medica. *Osiris*, 4: 1-359, 1938.

KOYRÉ, Alexandre. *La révolution astronomique : Copernic, Kepler, Borelli*. Paris: Hermann, 1961.

KUHN, Thomas S. The Copernican revolution: planetary astronomy in the development of western thought. Cambridge, MA: Harvard University Press, 1957.

LALANDE, Jérôme de. *Bibliographie astronomique; avec l'histoire de l'astronomie depuis 1781 jusqu'à 1802*. Paris: De l'Imprimérie de la République, 1803.

LUKE, Carmen. *Pedagogy, printing and Protestantism*. Albany: State University of New York Press, 1989.

MICHEL, Jean-Baptiste: SHEN, Yuan Kui; AIDEN, Aviva Presser; VERES, Adrian; GRAY, Matthew K.; The Google Books Team; PICKETT, Joseph P.; HOIBERG, Dale ;CLANCY, Dan; NORVIG, Peter; ORWANT, Jon; PINKER, Steven; NOWAK, Martin A.; AIDEN, Erez Lieberman. Quantitative analysis of culture using millions of digitized books. *Science*, 331 (6014): 176-182, 2011.

MILLIGAN, Ian. Mining the 'Internet graveyard': rethinking the historians' toolkit. *Journal of the Canadian Historical Association*, 23 (2): 21-64, 2012.

MITCHELL, Alexander Crichton. Chapters in the history of terrestrial magnetism. II. The discovery of declination. *Terrestrial Magnetism and Atmospheric Electricity*, 42 (3): 241-280, 1937.

MOYER, Ann. The astronomers' game: astrology and university culture in the fifteenth and sixteenth centuries. *Early Science and Medicine*, 4 (3): 228-250, 1999.

NASR, Seyyed Hossein. *Science and civilization in Islam*. Cambridge, MA: Harvard University Press, 1968.

ORDRONAUX, John. *Regimen sanitatis Salernitanum. Code of health of the school of Salernum*. Philadelphia: J. B. Lippincott, 1871.

PEDERSEN, Olaf. The origins of the Theorica Planetarum. *Journal for the History of Astronomy*, 12: 113-123, 1981.

PROVERBIO, Edoardo. Astronomical and sailing tables from the second half of the XVth century to the middle of the XVIth century. *Memorie della Società Astronomica Italiana*, 65: 469-496, 1994.

RODRÍGUEZ, Ana Domínguez. Astrología y mitología en los manuscritos ilustrados de Alfonso X El Sabio. *En la España Medieval*, 30: 27-64, 2007.

SARTON, George. The scientific literature transmitted through the incunabula. *Osiris*, 5: 41-245, 1938.

SILVA, Luciano Pereira da. *A astronomia dos Lusíadas*. Coimbra: Imprensa da Universidade de Coimbra, 1915.

SMITH. Julian A. Precursors to Peregrinus: The early history of magnetism and the mariner's compass in Europe. *Journal of Medieval History*, 18 (1): 21-74, 1992.

SOLÉE, Ricard V.; VALVERDE, Sergi; CASALS, Marti Rosas; KAUFFMAN, Stuart; FARMER, Doyne; ELDREDGE, Niles. The evolutionary ecology of technological innovations. *Complexity*, 18, (4): 15-27, 2013.

SUDHOFF, Karl. *Deutsche medizinische Inkunabeln; bibliographisch-literarische Untersuchungen*. Leipzig: Johann Ambrosius Barth, 1908.

VIRUES-ORTEGA, Javier; PEAR, Joseph J. A history of "behavior" and "mind": use of behavioral and cognitive terms in the 20th century. *The Psychological Record*, 65 (1): 23-30, 2015.

WEILL-PAROT, Nicolas. Causalité astrale et "science des images" au Moyen Age: éléments de réflexion. *Revue d'Histoire des Sciences*, 52 (2): 207-240, 1999.

WEILL-PAROT, Nicolas. L'attraction magnétique entre influence astrale et astrologie en Moyen Âge (XIIIe-XVe siècle). *Philosophical Readings*, 7 (1): 55-70, 2015.

WOOD, Chauncy. *Chaucer and the country of the stars: poetic uses of astrological imagery*. Princeton: Princeton University Press, 1970.

YEUNG, Ching-Man Au; JATOWT, Adam. Studying how the past is remembered: towards computational history through large scale text mining. Pp. 1231-1240, in: *Proceedings of the 20th ACM International Conference on Information and*

Knowledge Management. New York: Association for Computing Machinery / ACM, 2011.

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