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"A Portal to the Universe: The Astrolabe as a Site of Exchange in Medieval and Early Modern Knowledge"

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"Little Lewis my son, I perceive well by certain evidences thine ability to learn sciences touching numbers and proportions," Geoffrey Chaucer (c.1343–1400) wrote to his son Lewis in approximately 1391, in the prologue of his essay *A Treatise on the Astrolabe* (Chaucer, 2002, 103-104).[1] Chaucer proceeded:

> And as well consider I thy constant prayer in special to learn the treatise of the Astrolabe…therefore I have given thee a sufficient Astrolabe as for our horizons, compounded after the latitude of Oxford; upon which, by means of this little treatise, I purpose to teach thee a certain number of conclusions pertaining to the same instrument. (Chaucer, 2002, 104-105)

The Astrolabe: Structure and Historical Context

Though the astrolabe may seem foreign and inaccessible today, for Chaucer in medieval England, the tool was so crucial to understanding one's place in the universe that he wrote an essay describing how to use the instrument. As a tool for astronomy education in the late Middle Ages, the astrolabe held a central role in promoting a scientific understanding of the Universe and Earth. During the Middle Ages, an educated child in either England or Continental Europe was expected to understand how to use and build an astrolabe ("The Astrolabe," 2013). Thus, Chaucer engaged in a typical practice of his age in bestowing an astrolabe unto his son.

The instrument Chaucer bequeathed to his son was invented sometime before the late fourth century CE, when Theon of Alexandria (c.335–c.405 CE), a Greco-Egyptian scholar and mathematician, wrote a tract on it. From its origins based in a western geographical context, the astrolabe gradually moved eastward. In the middle of the seventh century CE, Severus Sebookht composed the first non-Greek treatise on the astrolabe in Syriac, in imitation of Theon's essay (Pingree, 2009, xii). By 1267, the astrolabe reached Kublai Khan (1215–94) in China via the travels of the

[1] Roughly translated from the original Middle English touching nombres: "Lyte Lowys my sone I aperceyve wel by certenye evydences thyn abilite to lerne sciences proporciouns."

Persian astronomer Jamal al-Din. In 1370, the first Sanskrit treatise on the astrolabe was composed (Webster, 1998, 3-4).

With an elaborate construction in its composition of three principal components–rete, plate, and mater–and collection of various calendric and mathematical tables, the astrolabe may be perceived as an intimidating scientific tool. The rete is essentially an openwork star map, as it aids the user in his or her calculation of the stars' positions. The plate functions as the main body of the astrolabe, and hosts the astronomical coordinate system of the night sky. In most classic astrolabes, the backside of this plate houses two circular calendars: one shows the zodiac, and the other displays the civic calendar. Lastly, the mater fuses everything in the instrument together. A circular brass piece, it lines the perimeter of the astrolabe plate, puts all the constituent parts of the instrument together, and displays a variety of computational scales [Fig. 1]. The origins of the astrolabe lie in the natural philosophy and technological innovations of ancient Greece, but it was not until the Middle Ages that the tool came into prominent use across a number of different geographies and cultures.

The diverse and complex methods of calculation that the astrolabe facilitated characterize the instrument as an ancestor of the modern computer. With its etymology comprising the Greek *astro* ("star') and *labio* ("taker," "finder," or "their), *astrolabe* is literally defined as "star finder." The open-endedness of this word derivation reflects the instrument's multifarious functions. In the Middle Ages, the astrolabe was typically used for determining the position of the zodiac and various stars, ascertaining the calendric date, calculating the time of day, and measuring the dimensions of earthbound objects (Chaucer, 2002, 3). Older astrolabes also functioned as astrological tools, and a common variation of the instrument, called the mariner's astrolabe, was widely used as a navigational device in the Renaissance.

FIGURE 1. This is understood to be the earliest Western astrolabe in the Oxford collection. Muslim influences are seen in the design of this astrolabe's rete, and it may have been made in Spain, ca. 1260.

The astrolabe is one of the most important scientific instruments to study, both in the context of contemporary society and in its use through millennia of history. It reflects what George Saliba (2007), a historian of Arabic and Islamic science, describes as "the history of science for our modern times" (p. ix).

Specifically, such a history "keeps an eye on the technical intricacies of scientific thought itself," in combination with an investigation of the "social, political, and economic mechanisms that allowed, and may still allow, this [technical] thought to flourish" (Saliba, 2007, ix). The astrolabe effectively corresponds to this definition, as it bridges scientific complexity with interactions in the extra-scientific contexts.

With its constant dissemination throughout Europe and Asia, a review of the astrolabe's early history from ancient times until the seventeenth century makes for a fuller appreciation of the diversity of functions it held as a significant technology at the intersection of various geographies, religions, and cultures. Stereography, which allows for the representation of the three-dimensional universe and Earth by projection onto the astrolabe's two-dimensional surface, originated in ancient Greece, and continued to develop in the Roman Empire. Hipparchus (c.170–c.126 BCE), a Greek astronomer and geographer of the Hellenistic period, incorporated stereographic projection in his cartographic works. Readers of the Roman architect Vitruvius's treatise *De architectura* would have learned about it through the work's description of an anaphoric clock that used stereographic projection on its dials (Webster, 1998, 2).

Upon analyzing the instrument in a variety of historical settings beyond Chaucer's England, it becomes evident that the astrolabe is an exceptional technology in world history, as a site of cross-cultural interactions in the medieval and early modern world. In addition, the instrument's lengthy lifespan makes it a fascinating historical object of study, as its presence in various historical, geographical, and cultural settings encouraged it to modify according to each particular context. This essay analyzes the astrolabe as a catalyst for the interaction between different cultures, promoter of evolution in scientific thought, and stimulus for transformation in the accessibility of scientific knowledge. In particular, it examines the tool in the historical context of the *Convivencia* era in early medieval Spain, with its characteristic inter-cultural dialogue between Muslims, Christians, and Jews, as well as in the printing revolution of early modern Germany.

The Astrolabe in the Medieval and Early Modern European Context

As the astrolabe became disseminated in various locations throughout Asia, its presence strengthened in Europe and Northern Africa. By the tenth century CE, knowledge of the instrument spread western from Greece, Rome, and Egypt, to the *Maghreb* (North Africa) and Andalusia (Muslim Spain). By the mid-thirteenth century, with the transmission of

Islamic astronomy to Christian Western Europe, the astrolabe spread as far as England and became widely used as an instrument for the varied functions of teaching, calculating, and observing. The fifteenth and sixteenth centuries saw the apogee of astrolabe production in Europe. In the seventeenth century, Europeans adopted new technological tools, each carrying a specific scientific function. In effect, this shift towards specialization overthrew the astrolabe as the king of medieval and early modern instruments (Webster, 1998, 6-7).

A Hebrew astrolabe, housed in the British Museum and probably created in Spain between about 1345 and 1355, provides perhaps the most potent evidence of the instrument's status as a forum for cross-cultural exchange [Fig. 2]. Scientific instruments with Hebrew text are extremely rare, and only a few have survived. This astrolabe is one of those limited artifacts, as it features a fascinating combination of Hebrew, Arabic, and Spanish elements. Hebrew lettering lines the perimeter of the mater and grants the astrolabe its "Hebrew" namesake, but the instrument's face also contains Arabic and Spanish text. For example, next to a star in the constellation that we call Aquila sits the Hebrew phrase, "*nesher me'offel*," which translates as, "the flying eagle." On the same plate, other star names are titled according to their Arabic form. The star Aldebaran in Taurus retains its Arabic name, "al-dabaran," but this title is written in Hebrew letters. Meanwhile, decorative elements from artistic traditions of both medieval Islam and Europe adorn the instrument ("Hebrew Astrolabe"). Even in these simple tasks of labeling the stars and decorating the faces of the instrument, this Hebrew astrolabe's composition reflects interactions between the divergent cultures and religions of the Iberian Peninsula.

FIGURE 2. The main "Hebrew" characteristic about the Hebrew Astrolabe is its inscribed in Hebrew lettering. However, it also contains Spanish and Arabic words, and combines Islamic and European decorative traditions. Reproduced from "Hebrew Astrolabe," *British Museum.*

Though the Hebrew astrolabe's dates and location of origin are somewhat ambiguous, this unique artifact serves as portal into the "Golden Age" of medieval Spain, a historical setting that uniquely promoted the relatively peaceful coexistence of Christianity, Judaism, and Islam. Situated in its native historical context, the Hebrew astrolabe clarifies how Jewish and Islamic scholars revitalized science and astronomy through reinterpretation of their inheritance from the intellectual traditions of classical Greece and Rome ("Hebrew Astrolabe," 2013). Extending from this revivification of ancient scientific knowledge, it reflects the cross-cultural and cross-religious interactions that this era of tolerance in Spain encouraged.

From the eighth century until the beginning of the Spanish Inquisition in 1492, the mixing of the people of Christianity, Islam, and Judaism characterized medieval Spain as a uniquely tolerant society. Termed *La Convivencia* ("The Coexistence"), Spain in this period was not organized as a single, unified state, but rather as a patchwork of republics – some under Muslim control, and others under Christian authority. Both the Muslim- and Christian-controlled republics hosted the diverse religious beliefs and cultural practices of Muslims, Christians, and Jews ("Hebrew Astrolabe," 2013).

The substantial scientific innovations that Muslims contributed to medieval Spain challenge the "classical narrative" of the Islamic scientific tradition. This traditional historical interpretation holds that throughout history, science in Islamic civilization was short lived because it began in the context of isolated religious groups in desert environments. In addition, this traditional framework claims that when Muslim scholars did make strides in scientific discovery, they were wholly spurred by extensive translation of classical sources, and thus lacked any innate innovation.

George Saliba (2007) problematizes this traditional framework, seeking to undermine the idea that translation of classical texts often conflicted with traditional forces within Islamic society, usually "designated as religious orthodoxies of one type or another" (p. 2). According to Saliba, Islamic science was certainly informed by Greek influences, but historiography should show greater respect towards genuine innovations that Muslim scientists created. In his book, *Islamic and Christian Spain in the Early Middle Ages*, the medievalist Thomas Glick (2005) illustrates the paradox of the classical narrative in the context of Medieval Spain. He argues that in the traditional characterization of the Islamic and Iberian transmission of science, "Receiving societies…have been characterized as the loci of cultural traditions inimical to the practice of science" (p. 295).

As a point of interaction for the three major religions of the West, Islamic contributions to the astrolabe in medieval Spain support Saliba's argument in favor of greater appreciation for the innate genius of Islamic contributions to Western science. Though Islamic innovation was in some measure inspired by the restoration of classical texts, it largely resulted as a consequence of cooperation between individuals from all three faiths in Spain. A complete understanding of the collaboration between the various religious groups in medieval Spain encourages a paradigmatic shift away from the classical narrative of Islamic science as a primitive discipline stuck in hot deserts and rigid religious strictures, towards a more nuanced understanding of Muslim innovations in the sea of medieval and early modern science. As Glick elucidates throughout his work, *La Convivencia* surely did not see perfect harmony between Christians, Muslims, and Jews in Medieval Spain. However, the benefits of collaboration and toleration that this era promoted furnish crucial lessons. Glick writes, “The mettle of a culture is manifested in its ability to adjust to other cultures without destroying them” (Glick, 2005, xii). The culture of inter-religious contact that Spain fostered in the Middle Ages reflects this thesis. The inter-cultural and inter-religious collaboration and tolerance characteristic of medieval Spain advocates a positive model of intercultural interactions, and appeals to the appreciation for multiculturalism we hold in Western society today.

In the sixteenth century, the German engineer Georg Hartmann (1489–1564) furthered the astrolabe’s transformative ability as an agent of cultural influence. Drawing upon his experience as a skilled instrument maker, as well as the concurrent printing revolution led by the advent of the printing press propelled in fifteenth-century Germany, Hartmann advocated for mass production of the astrolabe. In this new method of production, Hartmann and his workshop produced the astrolabe parts in small batches, which were then labeled for later assembly (Dackerman, 2011, 310). This manufacturing strategy led to the first astrolabe kit, which separated the astrolabe into its component pieces for sale [Fig. 3]. It made the process of production less expensive, and thereby expanded the market for astrolabes. By 1526, Hartmann began printing instruments on paper. The art historian Susan Dackerman (2011) describes that Hartmann likely sold his paper astrolabe in booklets that were ready for construction and was secure in his knowledge of the fact that his prints were as accurate as his original brass devices (pp. 311-12). In addition to making the astrolabe more accessible in affordability, Hartmann’s printed astrolabes became popular as artifacts, as individuals treasured and collected them.

FIGURE 3. Four paper drawings of Hartmann's astrolabe kit. Top left image – recto sheet with rete; top right – hour conversion dial; bottom left – verso sheet; bottom right – plate for 51º latitude. Reproduced from Dackerman, *Prints and the Pursuit of Knowledge in Early Modern Europe*, 313.

The printing revolution also led to the astrolabe's appearance in iconography characteristic of the European age of discovery, the fifteenth-century phenomenon of European state-sponsored voyages to unfamiliar territories in the west and the east. An engraving by the Flemish printmaker Jan Collaert (c.1561–1620) shows the explorer Amerigo Vespucci (1454–1512) using the astrolabe to survey the stars of the night sky [Fig. 4]. The image first appeared in the 1590s, in Jan van der Straet's *Nova reperta*. In this series of prints, Straet took on a radical strategy, embracing the mechanical nature of printmaking while also demonstrating that the technology could be used to make beautiful prints (Dackerman, 2011, 363). With Hartmann's recent transformations in the manufacture and transmission of the early modern astrolabe, Collaert's engraving served as an ideal image to express Straet's desire to increase knowledge about mechanical manufacturing processes such as printmaking.

FIGURE 4. "The Development of the Mariner's Astrolabe and the Discovery of America by Amerigo Vespucci (1454-1512)" – Plate 19 from *Nove Reperta* (New Discoveries), engraved by Jan Collaert (1566-1628), c.1600 (http://www.1st-art-gallery.com/).

With an understanding of the astrolabe's importance as a tool of cross-cultural interaction and as a site of scientific innovation in medieval and early modern Europe, it seems ironic that this singular instrument became so quickly forgotten in the seventeenth century. In fact, with the emergence of additional specialized technologies in the eighteenth century's industrial revolution, the instrument dissolved even further into the annals of world history. Though the world today is certainly filled with more technological complexities than the historical milieu of early modern Europe, the astrolabe reminds us how scientific and technical innovation can bridge boundaries of culture, religion, and socioeconomic class. The astrolabe shaped history. Furthermore, it reminds us that, in a general sense, scientific innovation carries tremendous power to shape the environment of the transmission of knowledge and information in society, to the extent that it was not unusual for Chaucer to write a treatise on the astrolabe, and encourage his son to learn how to operate the instrument himself.

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