Peter Apianus's "Cosmographia" (1551). Notes on Renaissance Astronomical Book Session at the Marriott Library Special Collections - January 2025

Kurt Fisher fisherka@ipns.com

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Introduction

In January 2025, a group from the Utah Astronomy Club examined rare books at the Special Collections Department of the Marriott Library, University of Utah, at the invitation of Lybua Basin, curator of the rare books collection. Three items related to astrolabes were reviewed:

- Regiomontanus. Published 1482. "Calendarium".
- Peter Apianus. Published 1551, first published 1524. "Cosmographia".
- Gallucci. Published 1607. "Theatro del Mvndo".

Only Apian's (Latinized as Apianus) "Cosmographia" (b. 1495 – d. 1552) is discussed. Based on crude hand-held cell phone photos, rectified and cropped the images were created. In some instances, rough automated translations were rendered from Latin to English using Google Translate®. Those images are collected as numbered plates in the Appendix. Use of images reproduced in the Appendix was granted by Special Collections, J. Willard Marriott Library, The University of Utah.

Apianus's "Cosmographia" provides insight into the development of astronomy, geography, and navigation around 1524, during the pre-heliocentric paradigm shift brought on by the Galilean revolution in the first half of the 1600s. His book is best interpreted as a navigation school or first-year university text, although there is no direct evidence of its use in either context. Gadia (2016) classifies "Cosmographia" as in gray area between the "trade practice" by mathematicians, geographers, and sailors, and popular books directed to educated lay persons who also hungered for information on the new navigational techniques during the beginnings of the Age of Exploration. In the 1500s, lines between universities, instrument makers, professional practitioners and the public were blurred (id). The core of "Cosmographia" are explanations on how to use five common navigation and astronomical instruments rendered as movable 3D paper constructions called "volvelles."

Comparing this work to a modern first-year astronomy text helps illustrate the scientific advancements between 1524 and the present day. Publication of "Cosmographia" resulted in Apianus receiving an appointment as a university professor. Holy Roman Emperor Charles V. Charles V awarded Apianus 3,000 golden guilders for the original 1524 publication – a sum equal to about 180,000 U.S. dollars today.

I. Historical Context of “Cosmographia”

"Cosmographia" is best understood in its European historical context. This was both an exciting and tragic time in European history. Columbus had crossed the Atlantic in 1492; da Gama rounded the Southern Horn of Africa and reached India in 1498; Magellan's expedition (sans Magellan) completed its circumnavigation of the Earth in 1522. Before Apianus, Regiomontanus published an updated and corrected version of Ptolemy's star tables – the first since the 2nd century CE (see appendices in *Calendarium*). Regiomontanus taught Copernicus, who had already written his heliocentric masterpiece “On the Revolutions of the Celestial Spheres” by the time Apianus was actively publishing, though Copernicus delayed its publication until he was on his deathbed in 1543.

This era also marked the beginning of the European Wars of Religion (1500–1645), including the rise of Lutheranism, the Reformation, and the Counter-Reformation. Luther posted his "95 Theses" in 1517. The German Peasants' War followed (1524–1525), which was suppressed by Apianus's patron, Charles V (1500–1558), a staunch Catholic Habsburg king and also the Emperor of the Holy Roman Empire. During these wars, armies crisscrossed Europe. On his father Phillp’s death in 1506, Charles V became the hereditary monarch of Spain. The Guelders Wars ranged from 1502 to 1556. States under the control of Phillip I and then his son Charles V – Spain, the Dutch southern low-counties of the Duchy of Luxemberg and Duchy of Flanders – sought to recover what Charles V viewed as his hereditary monarchical inheritance, i.e. – the break-away states in the North Low Countries of Gelderland, Freisland and Groningen. During the 1500s, Gelderland and Freisland were increasingly Calvinist.

The other major belligerents of the early Wars of Religion were the Schmalkaldic League (formed 1530) to the east of the low countries. The league was a series of northern Germanic states that had adopted the new Lutheran religion.

Apianus’s academic career began in 1527 on his appointment as a professor at the University of Ingolstadt in Bavaria where he remained for the rest of his life. In 1540, he was appointed royal mathematician by Charles V, and in 1544, Charles named him an Imperial Count Palatine (one of 5,000) with quasi-monarchal powers. In contrast, other key scientific figures in this narrative - Gemma Frisius and Geradus Mercator - worked in and near the Old University of Leuven. Leuven lies between Duchy of Luxemberg and Duchy of Flanders. Frisius, Mercator, and Apianus all resided in lands controlled by Charles V.

The new Age of Exploration was dependent on skill in navigation. During the 1500s, maritime technical and geographic research centers grew associated with the major nation states. An informal version of this navigation schools was the Netherlands’s Old University of Leuven. At Leuven, Frisius emphasized navigation using the astrolabe, cross-staff and quadrant as aides to dead reckoning. Also in the sphere of the Holy Roman Empire of

Charles V was the Spanish *Casa de la Contratación* (House of Trade), founded in 1503. The *Contratación* trained and licensed ship pilots and navigators. All Spanish ships were required to turn their logs to the *Contratación* on return to home port, and the center compiled data from those voyages into the *Padrón Real* – a master map of the world. The *Contratación* maintained a staff of professional geographers and cartographers drawn from throughout Europe. Outside of the Holy Roman Empire, the independent Kingdom of Portugal's *Escola de Sagres* (School of Sagres) was 1500s was located near the royal court in Lisbon. It was a leading center of geography and maritime studies. England had no corresponding schools. The Royal Observatory at Greenwich would not be established for another 175 years.

Gemma Frisius is most remembered for his 1529 map and globe of the world that includes a depiction of the Americas. Derived from positions in several hundred ship logs, Frisius's globe was considered the most accurate of its day. I was unable to determine if Frisius relied on logs from Low Country flag ship masters or whether, as a result of his residency in the Holy Roman Empire, he was able to access the ship logs of the *Contratación.*

Beginning in 1492 and continuing into the 1500s, the Columbian Exchange of gold, populations, vegetables, and animals matured, driven by the genocidal Spanish conquest of the Americas. In 1540, Coronado explored the southwestern United States—a mission dependent on improved celestial navigation. One estimate of the amount of precious metals that flowed from Central and South America between 1500 and 1650 is 180 tonnes of gold and 16,000 tons of silver. That amount of gold and silver does not have a large monetary value in today's economy – about 50-60 billion dollars. But in the 1500s, Europe's mercantile economy had currencies tied to physical precious metals in its treasuries. The New World precious metal tonnages transferred to Europe have been estimated at three times the existing precious metal treasury reserves held by all the European nation states.

That influx of new wealth from the Americas also allowed Charles V to prosecute many of the religious wars of the era including his attempts to retake control of the Northern Low Countries and to conquer the Lutheran breakaway states of the Schmalkaldic League. This influx of new state capital also initiated the European Price Revolution of 1500s. Prices tripled or quadrupled from 1500 to 1600. At the same time, the expensive conquest of the Americas continued. As a result, Spain declined from Europe's leading economy between 1500 and 1550. By 1555 and between inflation, wars of expansion and wars of religion, the Spanish economy and treasury controlled by Charles V were exhausted. This occurred despite of and in part because of the massive influxes of precious metals from the Americas.

By 1555, the war against the Schmalkaldic League was lost. The Spanish and Holy Roman Empire economic collapse led to Charles V's forced abdication in 1556 and his retirement to a monastery. On abdication, he appointed his son Philip II as King of Spain, and the title of Holy Roman Emperor passed to Charles V's brother, Ferdinand I. The Spanish economic collapse also ended the first wave of the Religious Wars through Charles V's Peace of

Augsburg Treaty in 1555. The Treaty of 1555 recognized Lutheranism as a legal religion within countries of the Holy Roman Empire where the head of state was Lutheran, i.e. the Schmalkaldic League. Lesser waves of plague, echoing the Great Plague of the 1300s that killed one-half of Europe's population, also occurred throughout the 1500s. In 1588, King Philip II of Spain attempted to invade England with the Spanish Armada.

Political and religious conflicts reignited in the Thirty Years' War beginning in 1600 and culminated in the Great Plague of 1665–1666 and the Peace of Westphalia Treaty of 1648. Between war and pestilence, half of Europe's population perished between the Peace of Augsburg in 1555 and the Peace of Westphalia in 1648. This was the second time in 300 years that Europe lost one-half of its population to war and pestilence.

During Apianus's life, land and sea navigation were prized skills that formed the technological basis for European exploration, economic expansion, and warfare. That is the context within which his "Cosmographia" was written.

II. The Structure of and Implicit Advancements in "Cosmographia"

"Cosmographia" is similar to texts written by national mathematicians, astronomers, and geographers of European powers such as Italy, the Netherlands, Germany, France, and England, in Latin—the lingua franca of the day. Like other texts, "Cosmographia" begins with a chapter on cosmology, focusing on the relationship among Earth, the Moon, the Sun, and stars. Apianus's first chapter concerns the theory for relating the positions of the Sun and stars to celestial and geographic latitude. This is followed by an appendix demonstrating the practical use of astrolabes and other measuring instruments for navigation. Regiomontanus's "Calendarium" and Gallucci's "Theatro del Mvndo" follow similar outlines.

A major yet subtle advance in "Cosmographia" is its use of Arabic numerals, including the "zero" placeholder. See Plates 11, 12, 22 and 23. Though Arabic numerals reached Europe by the 900s, they were not widely used until the 1200s. By the 1500s, major scientific texts like "Cosmographia" had adopted them. This made performing complex arithmetic and trigonometric calculations less labor intensive than doing computations using Roman numerals.

Another significant technological advance is the use of the printing press to publish "Cosmographia." Gutenberg printed his Bible in 1454, and his European re-invention of the movable-type press quickly spread across Europe. By 1500, an estimated 20 million books and pamphlets had been printed; by 1600, that number had grown to 150–200 million. Apianus, born in 1495, published "Cosmographia" in 1524.

III. Contents

A. Cover Dedication

On the cover of "Cosmographia," Apianus dedicates the work to "Gemma," referring to his contemporary, Gemma Frisius (b. 1508), the great Flemish mathematician and cartographer. Plate 4 mentions "George de Cofmogra," likely referring to Geradus Mercator (b. 1512), another prominent Flemish mathematician and student of Gemma Frisius. Along with engraver Van der Heyden, Gemma Frisius and Mercator produced a 1529 world globe based on ship reports from the late 1400s. Gemma Frisius also ran a studio that published maps and globes and manufactured scientific instruments. A version of the Frisius globe appears as the base plate of Apianus's navigation astrolabe in Plates 20-21. See Plate 32.

B. Cosmology

The book presents an Earth-centered cosmology. Plate 1, the title page, shows celestial latitude and longitude lines above a depiction of the night sky. Plate 3 illustrates how to project Earth's globe and the celestial sphere onto a flat surface. Plate 6 merges these into a geocentric model, and Plate 13 combines the Earth and the stellar celestial sphere in an armillary sphere. In the lower right of Plate 13 sits a pocket sundial, a common timekeeping device before accurate mechanical watches.

Plates 9-10 explore implications of an Earth-centered model, showing the Earth's shadow projected on the Moon to argue for a spherical Earth. Plates 11-12 link a spherical Earth to climate zones, dividing the globe into nine zones with numerical latitude estimates—an observational refinement of earlier Greek ideas in the 2nd century BCE.

C. Instruments

Gaddis (2016) notes that "Cosmographia" was advertised, to travelers as a means by studying the instruments in its appendix, to safely navigate between major cities of the world, including Europe.

1) Terrestrial and Nautical Astrolabes

Plate 14 introduces instrumentation. Apianus reintroduces the Arabian astrolabe in the context of a comprehensive Earth-centered cosmology (id.) Plate 14 includes a 3D movable paper model (a volvelle) of an astrolabe. At the 1 o'clock position is the apex of the rotating rete, topped with the "Throne of Heaven" pointer—depicted as a pope-like figure—standing on a projected world globe. Since the paper volvelle astrolabe, Plate 14, does not have the usual reverse plate on a metal astrolabe. The volvelle in Plate 15 provides a 3D paper instrument by which the altitude of the Sun during the day and the pole star at night can be determined regardless of the observer's longitude. Gaddis (2016, 296). The land astrolabe (Plate 14) is tied to a particular geographic latitude and longitude, and uses interchangeable baseplates for different cities. This nautical version has a fixed baseplate and uses a drum-shaped scale for determining latitude at all longitudes. The geographic location for which the astrolabe depicted in Plate 14 was produced is unclear.

One of the key functions of historical astrolabes was the determination of more accurate bearings for navigation between known geographic points. If the date is known, tables or an analogue computer (on the back of the astrolabe) can be used to determine the altitude of the Sun as it transits the southern meridian on a particular day for a particular latitude. Using a cross-staff device, the altitude of the Sun can be observed to determine when the Sun reaches that altitude above the local southern horizon. (This can be done at sea without reference to geographic features.) Then the astrolabe can be used as a compass and a bearing set to the intended destination. Although magnetic compasses existed in and before the 1500s, they are not accurate due to variations in magnetic declination that were unmeasured during that era. A daily Sun sighting allowed a means by which a ship could calibrate its magnetic bearing for use until nighttime. At night, latitude and bearings could be determined using bright stars.

Plates 16-17 presents predicted eclipses from 1551 to 1563. This illustrates Apianus's sophistication in performing astronomical mathematics – assuming these are predictions and not observations that conflict with the 1551 publication date of "Cosmographia". See Plate 28. Apianus died in 1552.

Apianus in the text (Plates 17-18) discusses how to compute distances between two cities using known coordinates. Plate 17 is linked with a major innovation: a table of estimated latitudes and longitudes for Europe and latitudes for major global locations (Plates 22-23).

Plate 19 diagrams a nautical compass rose attributed to Frisius. Traditionally, compass roses are divided into 32 points (11.25° each). Mounted horizontally and rotated, the quadrant can be used to set a bearing from the daily Sun sighting. Mounted vertically, it can be used to estimate the altitude of the Sun, constellations and bright stars.

Plates 20-21 shows another volvelle – a 3D paper astrolabe with Frisius's world map projected on the base plate. Apianus calls this device a "Speculum cosmographicum" or cosmological mirror. This is in the form of an astrolabe, but on the baseplate it shows the "reflection" of the Earth as seen from the celestial dome. Unlike typical celestial projecting astrolabes, the rete in Plate 20 omits star positions and focuses on the positions of the constellations. Using known latitudes and longitudes, the distance between two cities can be roughly computed. *See* Plates 17-28 and 20-22. Gaddis (2016) notes that this volvelle can used with an estimated latitude and longitude data to compute the day and hour the sun transits the meridian. Presumably, the Sun's zodiacal longitude for the current day can be estimated from the interior celestial equator ring. From the perspective of the ordinary use of an astrolable, the "Speculum cosmographicum" is an analogue computer that provides the current solar longitude – information normally obtained from the reverse side of a metal astrolabe for a set geographic location. Plate 21 offers a detailed view of the front plate. But Plate 20 would work for all estimates longitudes.

The baseplate of the Sepculum is highly distorted by the trigonometric projection used in this and traditional celestial astrolabes. Plate 24 is a world map, not from "Cosmographia," but from a separate publication by Apinaus and Frisius. This map is recognized as the best state-of-art of the Earth's geography between 1524 and 1550. It is the first to correctly show the outline of South America. It is from this map that the baseplate projection of the "Speculum cosmographicum" (Plates 20-21) is drawn. Plate 24 also labels South America as "America" – one of the earliest such references. The name is attributed to Italian explorer and merchant Amerigo Vespucci who wrote a series of popular letters distributed through out Europe on his explorations of the New World between 1499-1503.

Plate 25 shows another advancement that first appeared in texts of the 1500s that we take for granted in the modern era: the 2D plot of cities in Cartesian space based on their latitude and longitude, e.g., a Google map zoomed into the level of a country. Plates 22-23 was one of the earliest compilations of latitude and longitudes of places. Apianus (and other authors) began demonstrating this type of plot, typically for their home nation state. It allows the taking of line-of-sight bearings and distance estimates between cities. Plate 25 shows the geographic relationship between Prague, Nuremberg, Ingolstadt, Vienna, and Venice.

Taken together, the volvelles in Plates 15, 20, 21 and 25 are Apianus's solution for a general system to navigate globally by land or sea. It is not known whether metal versions of these instruments were produced in Frisus's workshops.

2) Determining Time using the Moon and a Ratcheting Altitude Gauge

Plate 26 introduces a tool for telling time at night by the Moon's phase—another 3D paper device. Gaddis (2106, 298-299) explains its operation. Plate 27 shows lunar phases based on geocentric theory. Curator Basin's summary notes that Apianus was the first to suggest using lunar distances for longitude (though accurate methods weren't perfected until the 18th century). Basin 2017.

Plate 28 shows Apianus's ratcheting altitude-measuring instrument that likely was more accurate than a plumb-line astrolabe or cross-staff. The plate demonstrates measuring Polaris' altitude to find one's latitude. Plate 29 shows the same instrument used for estimating artillery ranges—important in the gunpowder cannon age. Using two cross-staffs at a known distance, observers could triangulate the height and distance of a castle wall. That provides key information for firing cannons at fortifications and for planning siege towers to breach a castle.

IV. Backmatter Dedication and Poem

The inside back page includes a poem (Plates 30-31). Apianus praises his mentor: "Gemma is responsible for me. Who names the name of Gemma? As a Gemma become a shining gem more prominent than all…" In a reflective tone and referring to ordinary pastimes and entertainment as "toys," Apianus urges readers to focus on books that advance knowledge:

"Time passes, the fleeting hour flies, the age slips away like the swift furious water of a stream. He that doeth, he that readeth the good things with his eyes and soul, he casteth away the bad things. Therefore seek out good books, read them, and leave the toys in your good hours." (Plate 31 translated)

Conclusion

"Cosmographia" contains several weak parallels to modern times. First, is a lesson for present day physics and astronomy adjunct professors. The level of science needed to obtain a university appointment in the 1520s and a royal court scientific appointment was far lower than in the present.

There is also a parallel to the Oppenheimer dilemma. Apianus appears a thoughtful man, and historically he is described as a humanist. As a matter of speculative history, as the coffers of Charles V filled with gold and silver extracted from the enslavement of South American peoples, it is not plausible that Apianus, Frisius and Mercator would not have appreciated the potential evil and good that their collective works had enabled through improved mathematics, astronomy, geography and navigation.

Finally, Apianus published during the Gutenberg information explosion, and the scientific advances by Apianus, Frisius and Mercator would not have had the impact that they had absent their ability to communicate their results via inexpensive multiple copies of maps and books permitted by invention of the printing press. Today, we live in the Information Age. In 2015, it is estimated that 403 million terabytes of data are created every day – or the equivalent of 1.6 trillion daily written pages. At levels far beyond the 1530s, technological advances are communicated globally and instantaneously at the speed of light.

In conclusion, "Cosmographia" represents the state of geocentric cosmology in the mid-1500s, on the cusp of the heliocentric revolution. In 1524, Apainus building on Frisius and Mercator re-presented the Arabian astrolabe within a comprehensive European Earth-centered cosmology and expanded geographic knowledge. Copernicus published his heliocentric "Revolutions" in 1543; Giordano Bruno was burned at the stake in 1600 during the Counter-Reformation for supporting heliocentrism; Galileo was tried for heresy in 1633 during the Counter-Reformation for teaching heliocentrism; and Newton published "Principia" in 1687. "Cosmographia" illustrates how international collaboration in science and the exchange of astronomical, geographic, and navigation knowledge and instrumentation advances helped propel both commerce and broader human progress during the 1500s.

References and Further Reading

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There are several published editions of "Cosmographia." An online 1564 edition, which is not the same as the Marriott Library copy, can be viewed on the "The Internet Archive." https://archive.org/details/cosmographiaapia00apia/page/n3/mode/2up

Postscript: This author is an amateur astonomer and historian without degree residing in Salt Lake City, Utah.