Copernicus on Precession

In *De Revolutionibus (On the Revolutions)* published nearly five centuries ago in 1543, Nicholas Copernicus established the heliocentric system at the foundation of modern astronomy, the forebear of the theory of gravity and our modern knowledge of the universe. *On The Revolutions* also provided a largely accurate description and measurement of the axial spin wobble that causes precession of the equinoxes, which he terms the third motion of the earth, after the first motion of the day and the second motion of the year. Such was the importance of his work on precession that we might imagine Copernicus saying 'but it wobbles', just as Galileo was later reported as saying 'but it moves'. Aiming to provide an "incontrovertible result in absolute agreement with the phenomena", Copernicus sought to explain precession according to modern scientific method, using what he called "the first principles of uniform motion."

In this post I quote material on precession from *On the Revolutions* to explore and describe this major terrestrial movement. As well, I suggest that the overall correct description of precession given by Copernicus, using the term 'motion in inclination', applies a solar frame of reference where a terrestrial frame is now known to be simpler and clearer. Working without telescopes, Copernicus was a pioneer of modern astronomy. His text repays close attention for those who wish to understand the founding perspective on cosmology at the dawn of modern astronomy.

To start, I quote text from *On the Revolutions* that helps set the context for the precession analysis. Then I provide commentary on key statements from Chapter 11, Proof of the Earth's Triple Motion. This material could provide the basis of a scientific paper. I would welcome questions, comments, help and suggestions. The translation used is the 50 page extract at *http://www.webexhibits.org/calendars/year-text-Copernicus.html*.

Drawing from Platonic philosophy, Copernicus took as his epigraph the lintel text at the door of Plato's Academy: "*Let no one untrained in geometry enter here.*" The religious environment of his day made Copernicus fearful of publishing ideas about astronomy that refuted Christian dogma. However, the scale of change he proposed from a geocentric to a heliocentric cosmology drew on philosophical principles of reason that overrode any dogmatic belief. Copernicus therefore assessed the empirical data while accepting the spiritual idealism of Plato's mathematical logic, providing a reverential vision of the awesome scale and power

of material cosmology. He sought to show how a sense of divinity may still be retained in a mechanical philosophy, revealed in the true scientific observation of the sun and planets and the three motions of the earth.

De Revolutionibus provides this lyrical allegory of the sun:

> "At rest in the middle of everything is the sun. For in this most beautiful temple, who would place this lamp in another or better position than that from which it can light up the whole thing at the same time? For, the sun is not inappropriately called by some people the lantern of the universe, its mind by others, and its ruler by still others. Hermes the Thrice Greatest [from Thoth the Egyptian God of astronomy and writing] labels the sun a visible god, and Sophocles' Electra, the all-seeing. Thus indeed, as though seated on a royal throne, the sun governs the family of planets revolving around it."
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> Copernicus summarised his findings with the statement "Since the sun remains stationary, whatever appears as a motion of the sun is really due rather to the motion of the earth."
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> On scientific method: "It will be realized that the sun occupies the middle of the universe by the principle governing the order in which the planets follow one another, and by the harmony of the entire universe, if only we look at the matter, as the saying goes, with both eyes."
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> On Plato: "According to Plato it is highly unlikely that anyone lacking the requisite knowledge of the sun, moon, and other heavenly bodies can become and be called godlike. However, this divine rather than human science, which investigates the loftiest subjects, is not free from perplexities."
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> On the scale of the heavens: "The fixed stars' immense height makes even the sphere of the annual motion vanish from before our eyes. From Saturn, the highest of the planets, to the sphere of the fixed stars there is an additional gap of the largest size. So vast, without any question, is the divine handiwork of the most excellent Almighty."

Commentary on De Revolutionibus Chapter 11, Proof of the Earth's Triple Motion

Here I provide edited quotes from this chapter of *On the Revolutions* describing the day, the year and the spin wobble, each followed by my comments.

"The planets bear witness to the earth's mobility. I shall now give a summary of this motion, insofar as the phenomena are explained by it as a principle. As a whole, it must be admitted to be a threefold motion."

- Copernicus explains that naked eye astronomy reveals three motions of the earth. These three motions are the day, the year and the axial wobble. We are accustomed to understanding the day and year, but the wobble is so slow that its existence and nature are largely unknown outside astronomical circles.

"The first motion is the rotation which is the characteristic of a day plus a night. This turns around the earth's axis from west to east, just as the universe is deemed to be carried in the opposite direction."

- The earth daily rotates towards the east, giving the appearance that the sun and planets and stars are moving west at 15° per hour less the annual movement of almost one degree per day.

"The axial spin describes the equator, which some people call the "circle of equal days"."

- The equator, the circle at the right angle bisect to the earth's polar axis, marks the daily motion of the earth, projected on to the apparent turning of the stars at the celestial equator. When the sun crosses the equator at the equinoxes, day and night are equal.
- The celestial equator appears always at the same elevation from any given latitude, with its movement against the background stars only varying with the regular slow cycles of axial wobble and tilt. By contrast the elevation of the zodiac changes every day except at the solstices. When the sun is south of the equator from September to March, days are longer in the southern hemisphere and shorter in the northern hemisphere, and vice versa when the sun, and its zodiac position, are north of the equator from March to September.

"The second [movement of the earth] is the yearly motion of the center, which traces the ecliptic around the sun. Its direction is likewise from west to east, that

is, in the order of the zodiacal signs. Because of it, the sun seems to move through the zodiac in a similar motion."

- The center referred to here is the core of the earth, orbiting around the sun as the center of the solar system. The sun is conceived by Copernicus as the frame of reference for the movement of the planets. The sun appears to move through the twelve constellations of the zodiac along the ecliptic each year, an apparent motion of 30° of arc per month, caused by the orbit of the earth. Copernicus wrongly held to the Platonic idea that orbits are circular. The true elliptical shape would not be discovered until Kepler a century later.

"Thus, for example, when the earth's center is passing through the Goat, the sun appears to be traversing the Crab; with the earth in the Water Bearer, the sun seems to be in the Lion, and so on."

- Copernicus here explains how the earth and sun make a vector linking opposite zodiac signs. The zodiac stars opposite the sun rise at dusk. Viewed from the sun, Earth would appear to pass through Capricorn the Goat in the month when this constellation rises at sunset. For this month, which in Christ's day began at the June 21 solstice but now begins about 18 July, the sun appears in Cancer the Crab, producing the name for the Tropic of Cancer, the northernmost latitude on earth where the sun reaches the zenith. Similarly, from the sun the earth appears to move through Aquarius the Water Bearer when the sun appears to us in Leo the Lion. Here Copernicus is combining the solar and terrestrial reference frames.

"To this circle, which goes through the middle of the signs, and to its plane, the equator and the earth's axis must be understood to have a variable inclination."

- The zodiac ecliptic circle around the sky is at an angle of about 23°to the celestial circle formed by the earth's equator. This inclination is formed by and equal to the angle between the polar axes of the earth and sun.

"The third motion in inclination is consequently required."

- Copernicus here introduces axial wobble as the third motion of the earth, terming it 'motion in inclination'. As well as spinning on its axis to form the day, and orbiting the sun to form the year, the earth wobbles slowly like a top, precessing against the fixed stars with a period of 25765 years, known as the Great Year. As far as Copernicus could see, these three motions provided a comprehensive picture of earth's orbital mechanics.

"This [motion in inclination] also is a yearly revolution, but it occurs in the reverse order of the signs, that is, in the direction opposite to that of the motion of the center. These two motions are opposite in direction and nearly equal in period.

- This statement is unclear. It does not refer to the period of precession, but rather to the distance the axis precesses in a year. In fact the third motion takes 25765 years to traverse the ecliptic stars, moving the equinoxes along the ecliptic in reverse order. What Copernicus means is that the axial wobble generates the tiny difference between the tropical year, formed by the equinoxes and solstices, and the sidereal year, the time taken by the sun to return to the same point against the stars. This difference is about 50 arc seconds per year, one degree in 71.7 years. So the 'near equality' he describes is between the tropical and sidereal years, not the year and the Great Year, which are actually the respective periods of the second and third motions of the earth. From a solar reference frame, the 'motion in inclination' moves the earth's axis to and fro over a period 20 minutes shorter than the sidereal year, causing the annual fifty arc seconds of precession.

"The result is that the earth's axis and equator, the largest of the parallels of latitude on it, face almost the same portion of the heavens, just as if they remained motionless."

- "Almost the same" means that although the pole star and celestial equator appear motionless on an individual human time frame, over centuries and millennia their regular precession may be detected against the fixed stars.

"Meanwhile the sun seems to move through the obliquity of the ecliptic with the motion of the earth's center, as though this were the center of the universe."

- Obliquity is tilt. The path of the sun moves north and south in the sky through the seasons from the viewpoint of the earth. Copernicus' phrase "as though" indicates this annual motion of the sun is apparent and not real.

"The axial rotation generates a conic surface, having its vertex in the center of the earth, and its base in a circle parallel to the equator. Also at the opposite point, everything works out in like manner, but is reversed."

- This conic shape is the essential visual model of precession. It accurately describes axial wobble, with the apex of the cone at the center of the earth and its base a circle at each pole parallel to the equator. The 'circle parallel

to the equator' is the path traced by the celestial poles over the course of a Great Year, one stellar cycle of precession. Mirrored axial cones and circles are formed by the North Pole and the South Pole. These circles are 23° of arc in radius, equal to earth's tilt. They have their centers at the points called the ecliptic poles, the north and south poles of the sun, the positions in the sky furthest from the zodiac. The north ecliptic pole is at the front left foot of the dragon Draco, while the south ecliptic pole is at the Large Magellanic Cloud, a neighbour galaxy which forms a big smudge in the sky that can usefully be visualised as the mythical Hindu turtle Kurma upon which the entire universe rests. The stellar positions of the ecliptic poles are very stable, at the centers of the circles Copernicus describes as the base of the cones generated by the axial rotation.

- The circles of the axial precessional cones show the slow movement of the celestial poles. The north celestial pole is at Polaris in the small bear. It will reach Vega in the Lyre at the opposite point of the circle in about 12,800 years. The south celestial pole, found by dropping an equal line from the line connecting the two brightest stars in the sky, Sirius and Canopus, will similarly be near Canopus in about 12,800 years, in its majestic slow rotation around the turtle base point of the south ecliptic pole near the Large Magellanic Cloud.

"It is clear therefore how the two motions, I mean, the motion of the center and the motion in inclination, by their combined effect make the earth's axis remain in the same direction and in very much the same position, and make all these phenomena appear as though they were motions of the sun."

- The term 'motion in inclination' appears to be based on the sun as reference point, since the inclination points toward the sun in summer and away from it in winter. But considering the earth as reference point for this actual wobble motion, impelled by lunisolar torque on the equatorial bulge around the earth, it appears that Copernicus describes this motion in an unclear way, setting its period at one year rather than 25765 years, while recognising its importance and measuring it quite accurately at one degree of sidereal arc every 72 years.

"I said, however, that the annual revolutions of the center and of inclination are nearly equal. For if they were exactly equal, the equinoctial and solstitial points as well as the entire obliquity of the ecliptic would have to show no shift at all with reference to the sphere of the fixed stars."

- Precession is accurately defined here as the difference between the sidereal and tropical years. Copernicus points out that without precession the stars would stay in the same place against the seasons.
- He was not aware that obliquity of the ecliptic also varies from 21 to 24 degrees in a regular pattern of period 41,000 years. Since Milankovitch, science understands that the regular cycles of axial precession (21765 years), apsidal precession (113,000 years), axial obliquity (41,000 years) and elliptical eccentricity (100,000 years) are the orbital drivers of climate change.

"But since there is a slight variation, it [the third motion of the earth] was discovered only as it grew larger with the passage of time."

- Discovery of precession is known to have been accomplished by the Greek astronomer Hipparchus in the second century BC, comparing old Babylonian star maps to observation. Earlier knowledge of precession was possibly attained in India, Babylon, Egypt and Mesoamerica, at least in recognition of the slow shift of the equinoctial points against the background stars of the zodiac and the shifting rising and setting points of all the stars.
- Mythology appears to indicate knowledge of precessional ages, such as the shift of the spring point from Taurus to Aries in 2300 BC, and then the vivid but little known use of precession as the structuring celestial framework for time in the Bible.
- Copernicus wrote a commentary immediately following this precession section which was not included in editions until three hundred years after the book was published, explaining why Pythagoreans kept their most important knowledge secret. We may infer that he sees the observation of precession as central to this secret mystery tradition.

"From Ptolemy to us the precession of the equinoxes amounts to almost 21°."

- And in the 470 years since Copernicus, the equinoxes have precessed by a further 7°, placing them nearly 28°on from their positions when Ptolemy wrote in the second century. 30°of precession constitutes a zodiac age of 2147 years. If we designate the point when the sun moved across the first line of stars in Pisces in 21 AD as the beginning of the zodiac Age of Pisces, the Age of Aquarius is due to begin 2147 years later, in 2168 AD.

"I shall use the earth's motion as a principle and hypothesis in the demonstration of the other motions."

- Copernicus applies the modern scientific method of basing findings on evidence and logic. Calculation of the motion of the earth, replacing the previous belief that the earth did not move, provides an elegant and parsimonious basis to understand all celestial motion.
- To the three motions described by Copernicus of the day, the year and the axial wobble, modern astronomy can add axial obliquity, apsidal precession of the perihelion, elliptical eccentricity, and the great 220 million year sinusoidal orbit of the sun around the Milky Way galaxy, a journey that our oldest genes have completed some eighteen times since the birth of life on earth four billion years ago. Moving above and below the galactic plane every 80 million years, our solar system moves along the perfect arc of its centre of mass.
- This arc of solar system motion is called the solar system barycenter. The sun performs a celestial ballet, to use a term Copernicus applies to the whole spectacle of the sky, around the barycenter. My own research indicates this solar radius wave function is driven primarily by the 178.9 year triple conjunction cycle of Jupiter, Saturn and Neptune. The wave period of the solar distance from the barycenter is one twelfth as long as the earth's zodiac age period of 2147 years, which is one twelfth of the axial wobble period.
- Our galaxy itself is interacting with its local group, including Andromeda and the Magellanic Clouds, which together are all receding at an accelerating pace from the Big Bang around 14 billion years ago.
- Copernicus laid the foundation for modern astronomy. Of all the celestial motions now known, the three he describes, the day, year and wobble, are the primary motions of the earth that were discernible to naked eye astronomy in the days before telescopes. Copernicus' work on precession may be as important as his heliocentric system overall, quantifying a slow movement that appears to drive life cycles, as seen in climate records, making the third motion of the earth as powerful as the year and the day.

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