The Copernican Revolution
("The Earth Moves")

Nicolaus Copernicus (1473 - 1543)

but also

Tycho Brahe (1546 - 1601)
Johannes Kepler (1571 - 1630)
Thomas Digges (1546 - 1595)

and even

Edwin Hubble (1889 - 1953)

But let's not forget the first advocate of a heliocentric universe:
Aristarchus of Samos (310 - c. 230 BCE)

Motivations

The Evolving Unwieldiness of the Ptolemaic Model
The Brightness Problem
Reconsideration of Aristarchus' Ideas *(cf. The Almagest)*
Doubts about aspects of Aristotle's Physics?

The Copernican Model

The Copernican Model is Heliocentric and Geodynamic

Heliocentric = "Sun Centered"
Geodynamic = "Earth in motion"
(The Ptolemaic Cosmology was Geocentric and Geostatic.)

The Earth rotates eastward about its axis.

The rotation period with respect to the stars is the Sidereal Day.

The Sidereal Day is $23^h\ 56^m\ 04^s$

The Earth, like all other planets, revolves about the Sun.

The Earth orbits the Sun with an orbital period of one year.

The Sidereal Year is 365.256.. Sidereal Days

Its Rotation Axis is Inclined with respect to its Orbital Axis

The inclination angle remains (essentially) fixed

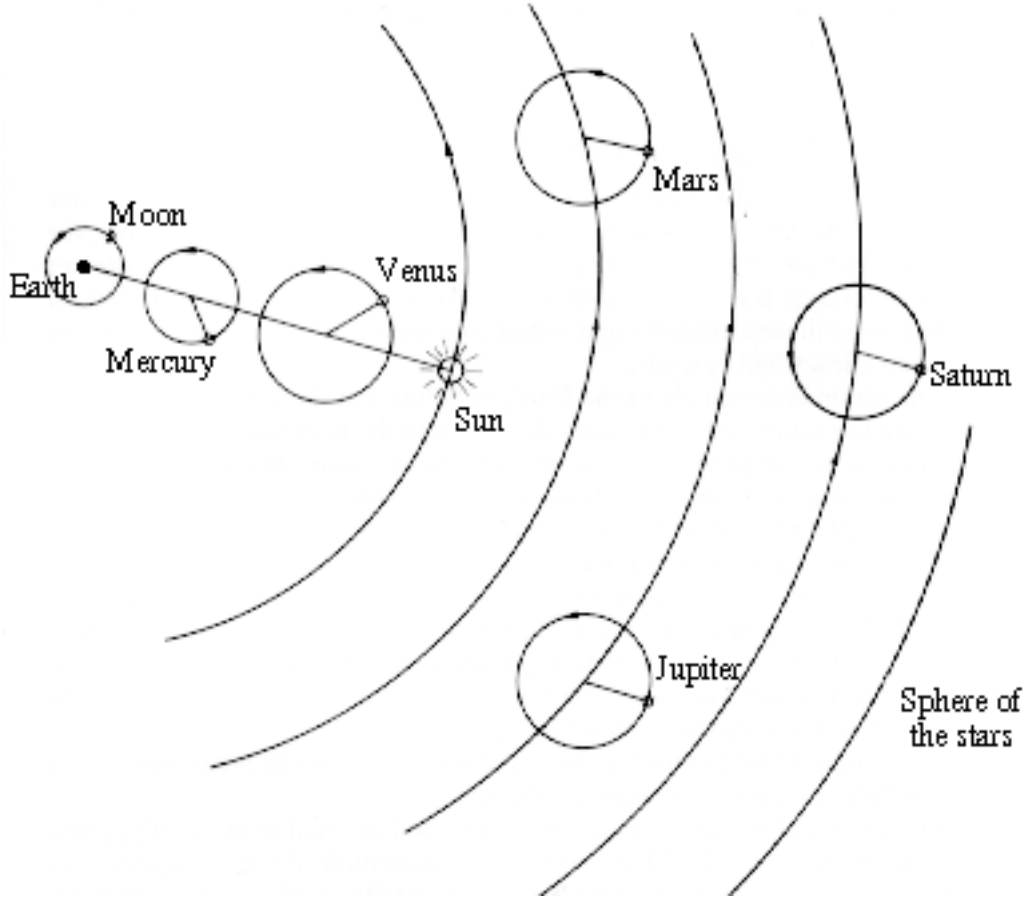
The "Obliquity of the Ecliptic" is 23.45°

The inclination direction slowly changes

The Precession Period is about 25,700 years (*cf.* Hipparchus)

Recollect: The Ptolemaic System (*c.* 140 CE)

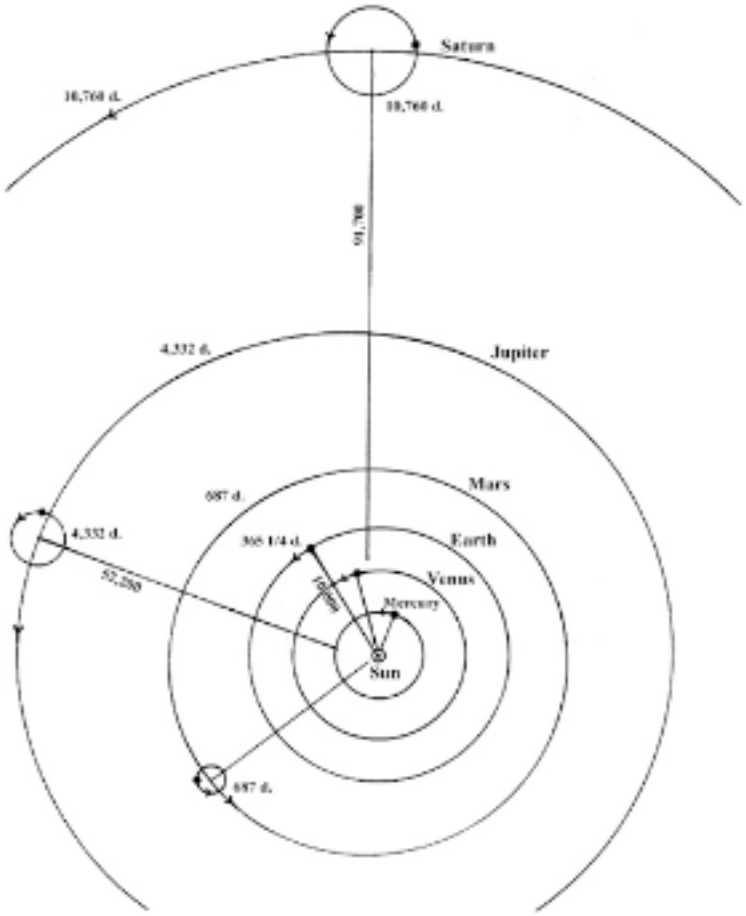
Fixed & Central Earth. Moving Moon, Sun, Planets, and the Celestial Sphere



The Celestial Sphere rotates clockwise or westward about the fixed Earth with a period of one sidereal day. The motions depicted in the above figure are then with respect to the Celestial Sphere. The Sun's period relative to the fixed stars is the sidereal year.

The Copernican System (1543 CE)

The Sun and Celestial Sphere are fixed. The Earth, Moon, and Planets all move.



Note that the deferent circles and epicycles can have central offsets and tilts. Only the epicycles associated with Mars, Jupiter, and Saturn are indicated.

The Copernican System

Nicolaus Copernicus (1473-1543)

De Revolutionibus Orbium Coelestium (1543)

["On the Revolutions of the Celestial Spheres"]

Virtues

Parsimony: One kind of planet, not three

Ptolemy: Earth, Inferior Planets, and Superior Planets all treated differently.

Simplicity: Planetary synodic motions explained naturally

Epicycles not needed to explain the sequence of direct and retrograde motions (but are needed for "fine tuning" of the model)

Planetary brightness variations explained

Planets as reflecting spheres. Distance and phase variations.

Shortcomings & Limitations

Remaining Complexities & Problems

The Aristotelian assumption of uniform circular motions was retained.

.... and what about the Stellar Parallax?

The Copernican System

Testing the Theory

The principal test of the Copernican System was in its successful prediction or explanation of planetary brightness variations.

That test rested on the assumption that the planets were, in fact, spherical objects shining by reflected sunlight. This assumption was not testable in 1543.
(Given this assumption the observed variations served to falsify the Ptolemaic Model.)

Other Predictions and Tests

Direct Observation of Planetary Phases (Galileo, 1610)
Only gibbous and full phases for superior planets, but all phases for inferior planets
Note that any direct proof of significant Terrestrial motion also falsifies significant parts and precepts of Aristotelian physics.

Direct detection of the Earth's Motions
The Stellar Parallax (1838), Aberration of Starlight (1680, 1725), Doppler Effect (1905+)

Shortcomings or Mistakes of the Model

- Unnecessary assumptions: Uniform Circular Motions (requiring "tuning" with epicycles)
- A spatially fixed celestial sphere (*cf. Democritus, Digges)*
- A heliocentric and possibly heliostatic universe.

..... and just to add some complications and competition:

The Tychonic System

Tycho Brahe (1546 - 1601)

Tycho's Observational Astronomy
• Astrometry: Positional Astronomy before the Telescope
Positions and Parallaxes to 1 arc-minute accuracy; Timekeeping

• **The Supernova of 11 November, 1572 (*De Stella Nova,* 1573)**
.....things do change in the celestial realm!

• **The Comet of 1577 ("Tycho's Comet")**
.....comets are astronomical objects!

• **Attempts to measure parallaxes***
.....the Earth probably doesn't move!

*Note: The Earth's radius (6370 km) would subtend 1 arc minute at a distance of 22 million km. This is about 57 times the Moon's distance - and about 1/7 that of the Sun.

The Tychonic System

The Tychonic System (1583)

- **Motivated by the failure to observe a stellar parallax.**
- **Theological motivations (Aristotle again.)**

- **The Moon, Sun, and Celestial Sphere move about the central Earth**
(exactly as in the Geocentric Ptolemaic System)

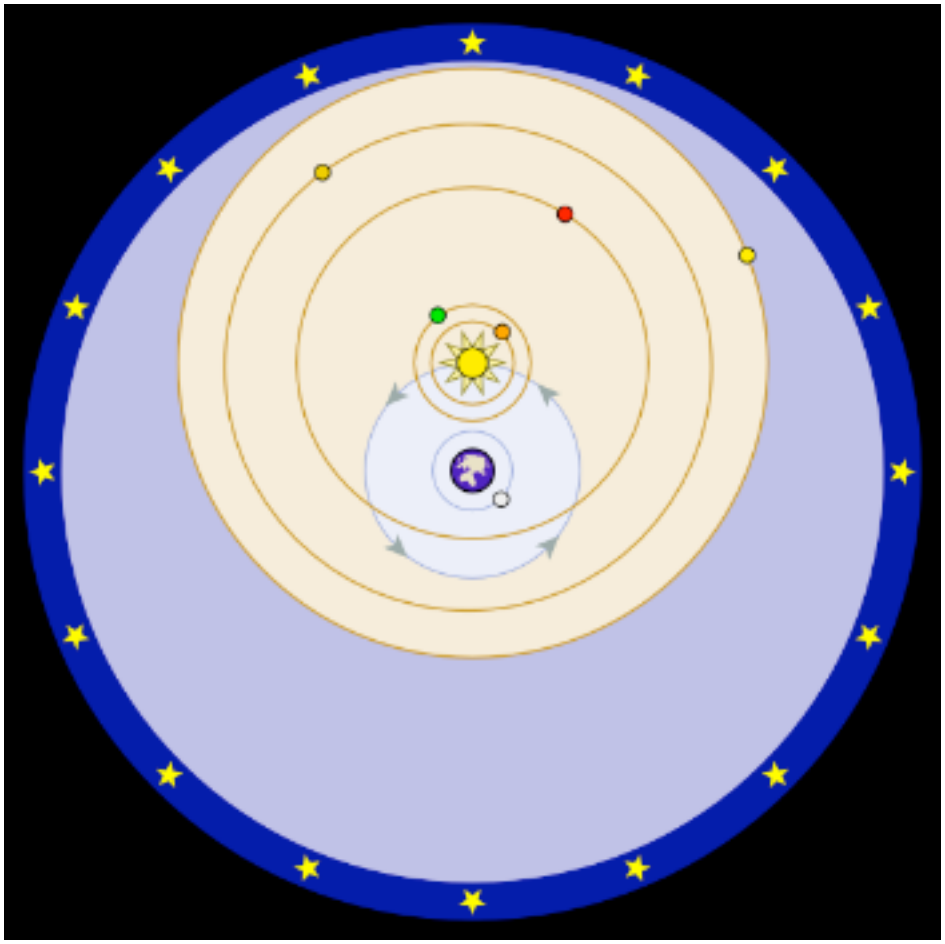
but

- **The (Other) Planets orbit the Sun**
(as in the Heliocentric Copernican System)

Some Related Bits of History

Tycho's Elk
Tycho's nose and Tycho's bladder
Tycho and Astrology
Tycho and Johannes Kepler
The Tychonic System and the Decrees of 1616

The Tychonic System



The requisite epicycles are not shown. This system retains the essential Geostatic feature of the Ptolemaic System (hence no stellar parallax is expected) while correctly predicting planetary brightness (and phase) variations. (Image from *Wikipedia*)