RENAISSANCE ASTRONOMY

Questions

How do scientists choose between competing theories?

Let’s stretch our minds! – How big is the Universe?
Nicholas Copernicus

Trained in law and medicine, but his interest was in math and astronomy. He developed the heliocentric (Sun-centered) model, and he published his results in the *De Revolutionibus*. His postulates included: (a) the Universe is spherical and (b) motions of objects were combinations of uniform circular motion.

Observations & Results

A. Reasoned that the apparent rotation of the Celestial Sphere could be accounted for by assuming that the Earth rotated about a fixed axis while the Celestial Sphere was stationary.

B. Determined the Earth is 1 of 6 (then known) planets circling the Sun, in the order Mercury, Venus, Earth, Mars, Jupiter, and Saturn.

C. Recognized that objects nearer to the Sun had faster orbital speeds, which accounts for retrograde motions.

D. Computed the scale of the Solar System.
Inferior Planet Distance

At Greatest Elongation, the view from the Earth to the planet’s orbit is a tangent line. Therefore, that angle is $90^\circ$. The angle from the Earth-Sun line to the Earth-tangent line is observed. The Earth-Sun distance is 1 AU.

Example:

\[
\frac{1 \text{ AU}}{\sin 90^\circ} = \frac{X}{\sin 15^\circ}
\]

\[X = \sin 15^\circ = 0.26 \text{ AU}\]

Superior Planets
Superior Planets

Superior Planet Distance

Need to know the Time it takes to go from point E (opposition) to point E' (quadrature). Angles PSP' and ESE' are determined from Time. Earth-Sun distance is 1 AU.

Example:
If it takes 120 days to go from E to E', then angle ESE' = 120 / 365.25 x 360°. Do the same for PSP' and compute the angle PSE'. Then use the Law of Sines.
Example

Earth: \( P = 365.25 \) days  
Mars: \( S = 780 \) days (Opp to Opp)

Observe that Opposition to Quadrature = 95 days

Earth Angle = 94°  
Mars Angle = \( \frac{95}{780} \times 360 = 44° \)

\[
\frac{1 \text{ AU}}{\sin [90 - (94 - 44)]°} = \frac{X}{\sin 90°}
\]

\[
X = \frac{1}{\sin 40°} = 1.56 \text{ AU}
\]

Average Distances

<table>
<thead>
<tr>
<th>Planet</th>
<th>Copernican value (AU*)</th>
<th>Modern value (AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.38</td>
<td>0.39</td>
</tr>
<tr>
<td>Venus</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>Earth</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Mars</td>
<td>1.52</td>
<td>1.52</td>
</tr>
<tr>
<td>Jupiter</td>
<td>5.22</td>
<td>5.20</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.07</td>
<td>9.54</td>
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<tr>
<td>Uranus</td>
<td>—</td>
<td>19.19</td>
</tr>
<tr>
<td>Neptune</td>
<td>—</td>
<td>30.06</td>
</tr>
<tr>
<td>Pluto</td>
<td>—</td>
<td>39.53</td>
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</tbody>
</table>

*1 AU = 1 astronomical unit = average distance from the Earth to the Sun.
**Synodic Periods: Inferior Planets**

Inferior Planets will make one more orbit than the Earth before they realign.

\[
\frac{1}{P} = \frac{1}{E} + \frac{1}{S}
\]

- \(P\) = planet’s sidereal period
- \(E\) = Earth’s sidereal period
- \(S\) = planet’s synodic period

**Synodic Periods: Superior Planets**

Example: Jupiter

- \(S = 398.9\) days = 1.092 years

\[
\frac{1}{P} = \frac{1}{1} - \frac{1}{1.092} = 0.084
\]

\[
P = \frac{1}{0.084} = 11.87 \text{ years}
\]

The Earth will make one more orbit than the Superior Planets before they realign.

\[
\frac{1}{P} = \frac{1}{E} - \frac{1}{S}
\]

- \(P\) = planet’s sidereal period
- \(E\) = Earth’s sidereal period
- \(S\) = planet’s synodic period
Synodic & Sidereal Periods

<table>
<thead>
<tr>
<th>Planet</th>
<th>Synodic period</th>
<th>Sidereal period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>116 days</td>
<td>88 days</td>
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<tr>
<td>Venus</td>
<td>584 days</td>
<td>225.5 days</td>
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<tr>
<td>Earth</td>
<td>—</td>
<td>1.0 years</td>
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<tr>
<td>Mars</td>
<td>780 days</td>
<td>1.9 years</td>
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<tr>
<td>Jupiter</td>
<td>999 days</td>
<td>11.9 years</td>
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<tr>
<td>Saturn</td>
<td>378 days</td>
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<tr>
<td>Uranus</td>
<td>370 days</td>
<td>84.0 years</td>
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<tr>
<td>Neptune</td>
<td>368 days</td>
<td>164.8 years</td>
</tr>
<tr>
<td>Pluto</td>
<td>367 days</td>
<td>248.5 years</td>
</tr>
</tbody>
</table>

Retrograde Motion Explained
Observations & Results

E. But because Copernicus used circular motion, he still needed epicycles for “details” of planetary motion.

The heliocentric model of Copernicus did not prove that the Earth revolves around the Sun. In fact, with some adjustments, the old Ptolemaic system could have accounted as well for the motions of the planets in the sky. But the Ptolemaic cosmology was clumsy and lacked the beauty and symmetry of its successor.

Copernicus made the Earth an astronomical body, which brought a kind of unity to the universe. Also, his new cosmology had the revolutionary implication that the Earth was small, while the universe was large.