Sun-centred Universe

Higgledy-piggledy
Nic'laus Copernicus
Looked at the Universe
Spoke to the throng
Give up your Ptolemy
Rise up and follow me,
Heliocentrically
Ptolemy's wrong
Nancy Stark

Nicolaus Copernicus (1473 - 1543)

- *De Revolutionibus Orbium Coelestium*
  - Sun-centred planets
  - planets move at constant speed in circles
  - epicycles are used
  - stars are on a distant celestial sphere (*animated*)

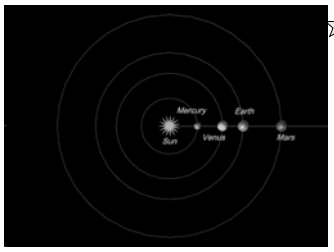


Illustration: K & K

- A revolution in thought, masked by being presented as a 'working hypothesis'

Copernicus' Homeland

Copernicus monument Warsaw

Pictures: JSR

Frombork cathedral

Digression on Copernicus

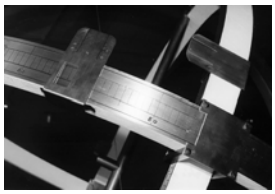
Jan Matejko's 19th century picture of Copernicus

Tycho Brahe (1546 - 1601)

- Tycho had a private observatory funded by the King of Denmark
- Tycho made observations correct to better than 0.1°, commonly to 1′ arc, the most accurate in his time. He worked before the invention of the telescope
  - Tycho particularly studied Mars, whose position was sometimes poorly predicted by official tables. This led him to propose his own variants of Ptolemaic models of the heavens.
- Tycho employed Johannes Kepler in 1600

Tycho's Celestial Coordinate Measurer

Full – scale replica in Steno Museum, Aarhus →

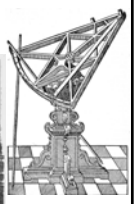


Detail of scale and observing sights

Pictures: JSR

Uraniborg

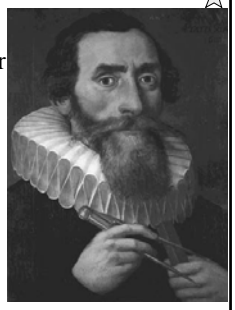
↑ Great mural quadrant



Sextant ↑

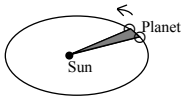
Johannes Kepler (1571 - 1630)

- [Recommended reading: *The Sleepwalkers* by Arthur Koestler (1959)]
- Kepler worked for 4 years trying to make Tycho's models fit the planets
  - he almost succeeded, but not quite
- After many further years trying his own ideas, he produced his 3 laws of planetary motion



Kepler's Laws

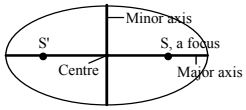
- Each planet travels in an ellipse around the Sun. The Sun is at a focus of the ellipse
- A planet moves at a changing speed around its orbit. As it moves, the area it sweeps out in space in a given time is constant



- The square of the period of a planet is proportional to the cube of its average distance from the Sun

On the Ellipse

- An ellipse is a symmetrical oval. It is what you see when looking at a circle in perspective
  - an ellipse has a **major axis**, a **minor axis**, an **eccentricity** (e) and two **foci**
  - a circle is an ellipse with e=0
  - for Mars, e=0.0934
    - the orbit looks almost circular but the Sun is 9.3% from the centre



e is the eccentricity
a is half the length of the major axis
b is half the length of the minor axis
CS = ae
$b^2 = a^2(1-e^2)$
(CS is the distance from centre to focus)

Kepler's 2nd Law

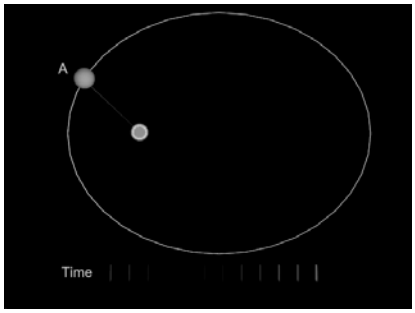


Illustration: K & K

(*animated*)

Kepler's 3rd Law

- The *period* (P) of a planet is the length of time it takes to go around the Sun once. It is the *year* for that planet
- The *average distance* of a planet from the Sun is *a*, half the major axis of its orbit
- Kepler's 3rd law can be written:

$$P^2 = a^3$$

where P is in earth years and a in AU

- Mars, a = 1.52 AU, therefore P = 1.88 yr

Testing Kepler's 3rd Law

Planet	Distance from Sun (a) in AU	Sidereal Period (P) in yr	Distance cubed	Sidereal Period squared
Mercury	0.387	0.241	0.058	0.0581
Venus	0.723	0.615	0.378	0.378
Earth	1	1	1	1
Mars	1.524	1.881	3.54	3.538
Jupiter	5.203	11.86	140.9	140.7
Saturn	9.539	29.46	868	867.9

After K & K table, chpt. 2