

Topic 7: Early Models of the Solar System





Celestial History

Even ancient civilisations considered the movement of the Sun, Moon and Stars.

The **Babylonians** developed a **lunar calendar**, dividing the year into 12 months based on the Moon's cycle.

The appearance of comets was often seen as an omen or herald of change.



Omens in the Sky

1066:

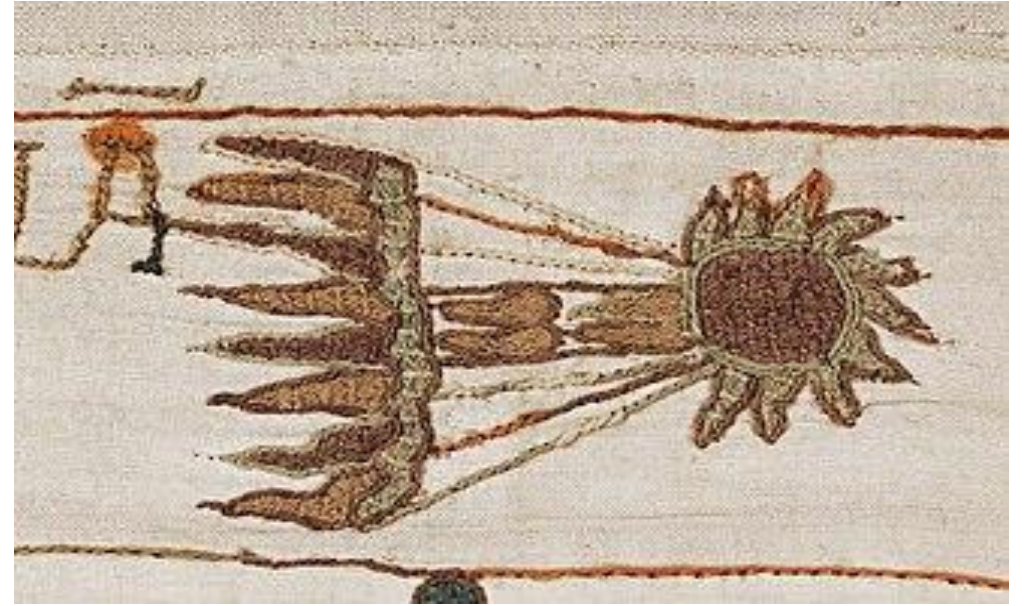
Halley's Comet appeared before the Hastings; its image was famously recorded on the Bayeux Tapestry as a sign of the fate of King Harold.

1222:

Genghis Khan interpreted the comet's path as a sign to expand his conquests westward.

1347:

Many believe that the appearance of another Comet heralded the coming of the 'Black Death'.



Precession

to Vega
(North Star in
the year 14,000)

to Polaris
(North Star now)

Precession: every 26,000
years Earth's axis of
rotation completes a circle.

$23\frac{1}{2}^\circ$

Approximately 12,000 years
from now, Earth's axis of
rotation will line up with
the star Vega.

plane of Earth's orbit
around sun

Earth's
axis of
rotation

The Earth's axis **wobbles** in a slow motion known as **precession**. This causes the position of stars and constellations to shift over thousands of years.



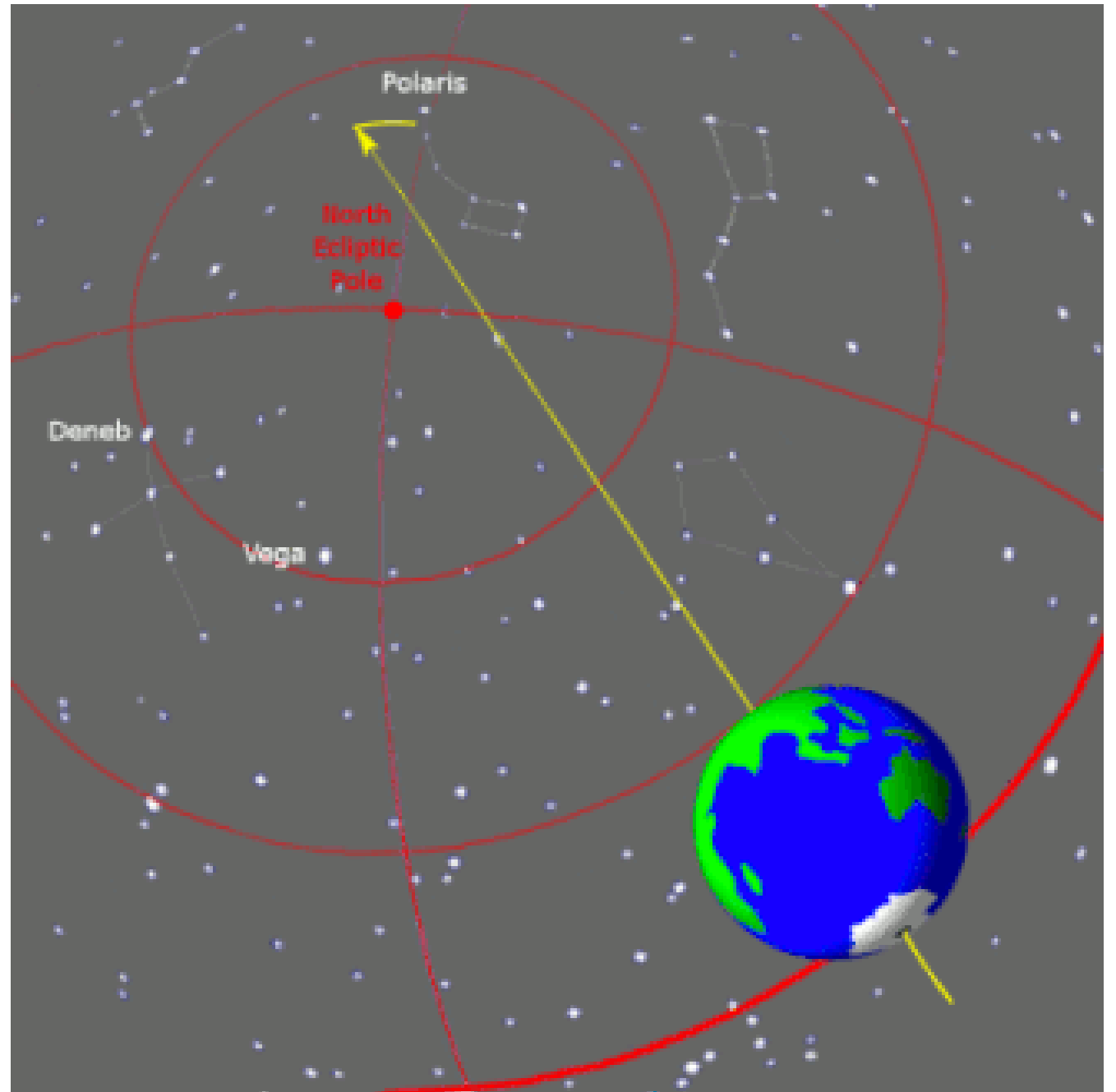
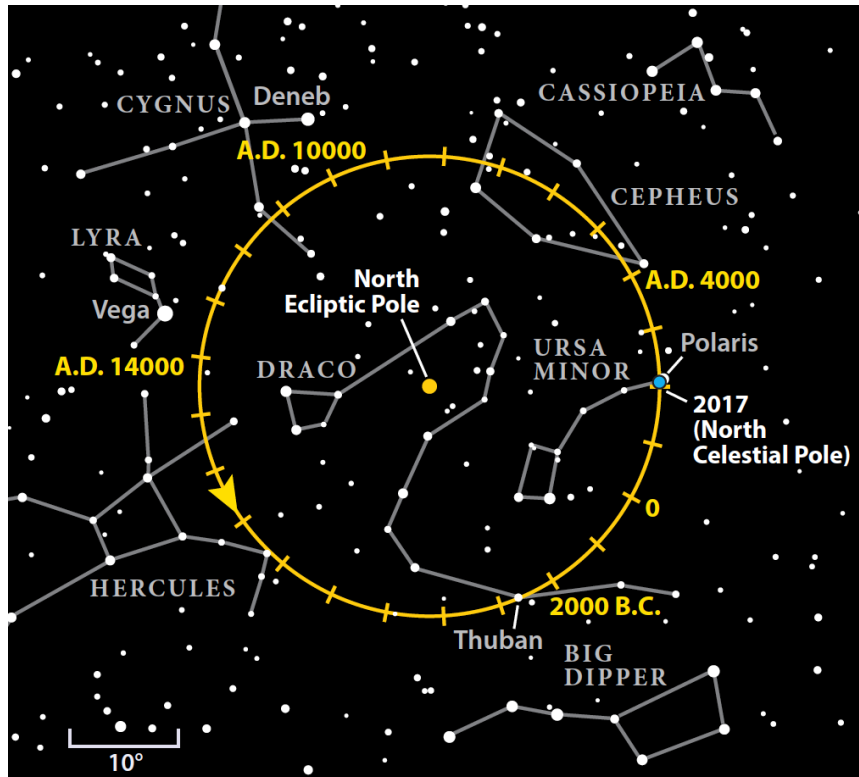
Earth is an **oblate spheroid** in an **elliptical orbit**.

The Earth's tilt varies from 22.1 to 24.5° every 41,000 years.

Changing Poles

The effects over the course of a precession cycle on observing is that the celestial poles move and all stars shift ever so slightly from one year to the next.

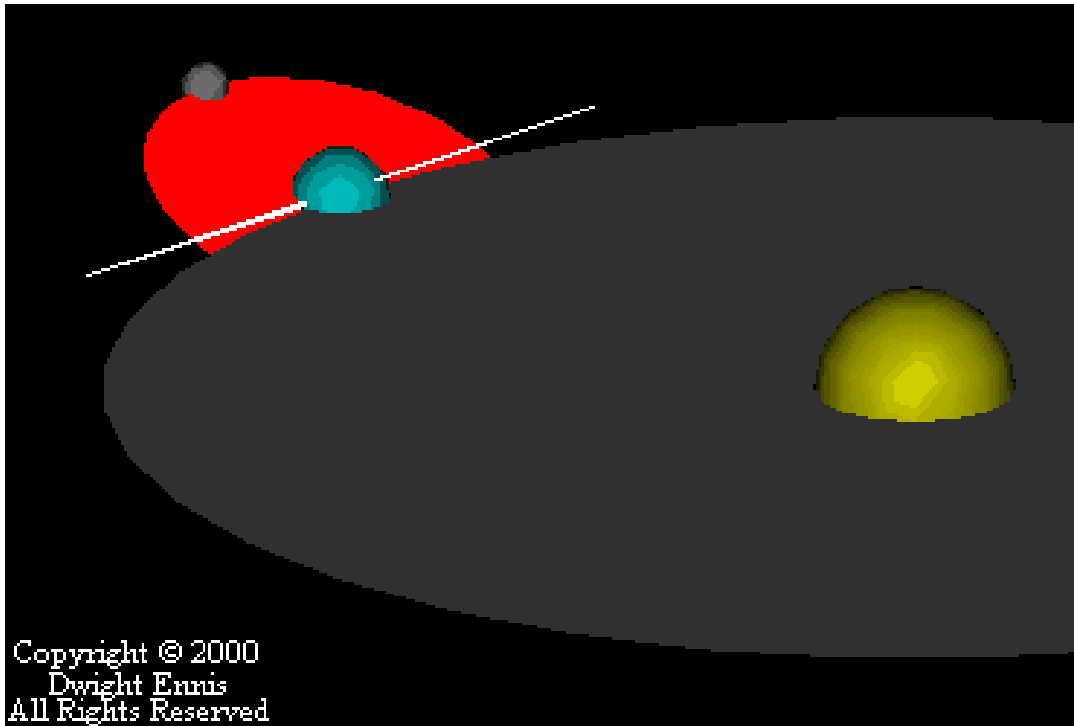
This is only noticeable to the casual naked eye observer over millennia.



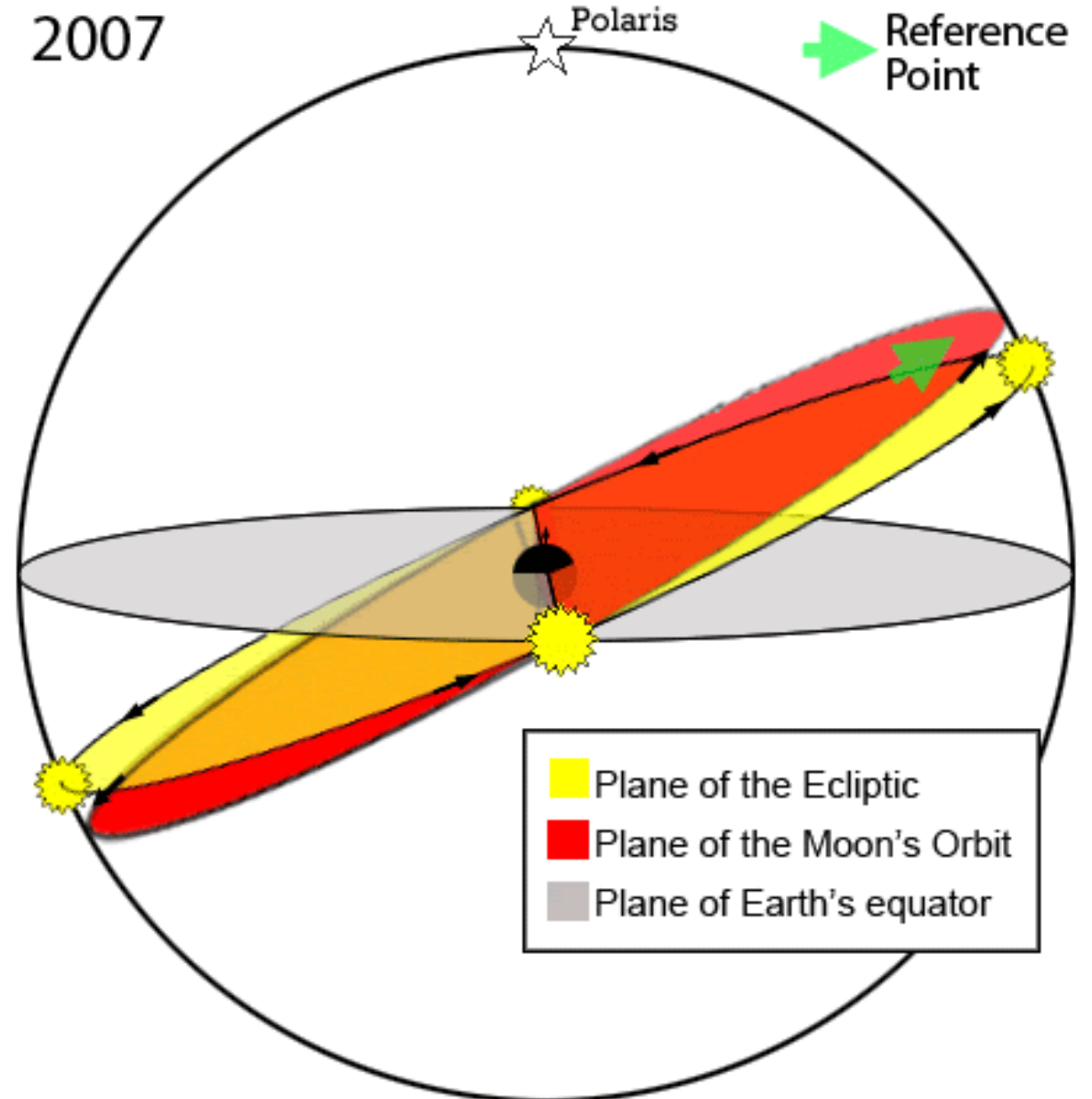
More Precession

The moon and other planets have their own precessional patterns.

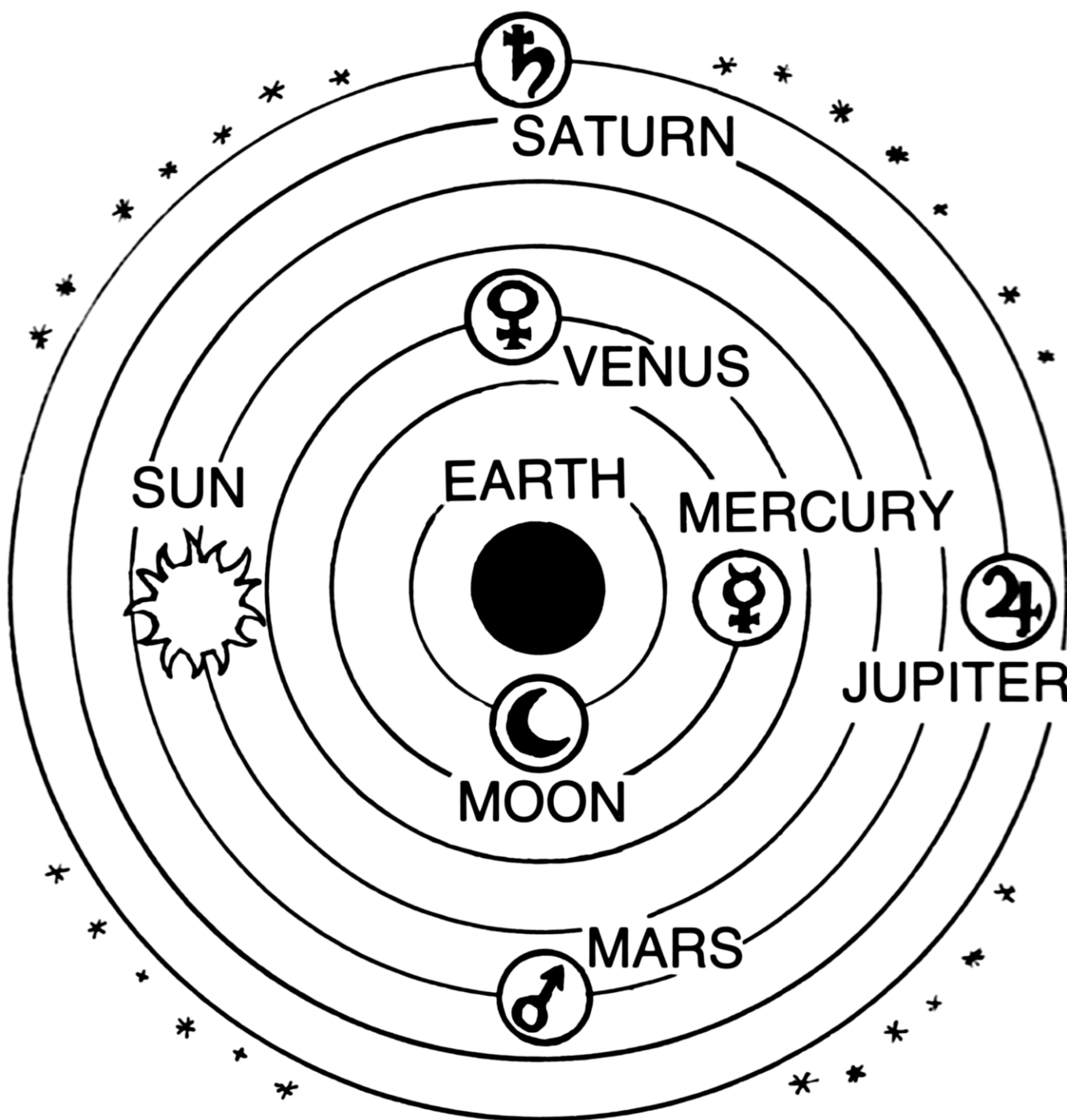
(But don't worry you don't need to know all this or why it happens)



2007



The Solar System



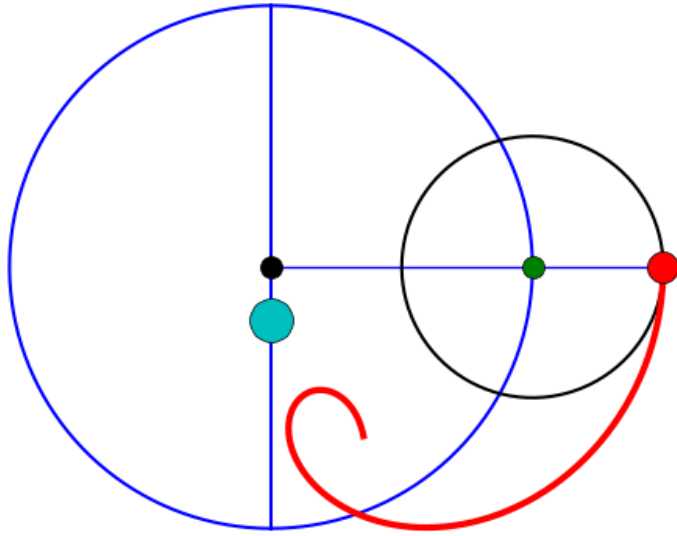
Some ancient astronomers such as Aristarchus of Samos and Seleucus of Seleucia proposed that Earth orbits the Sun. But observational evidence did not support their argument.

- If the Earth did spin then why don't we fly off it?
- Why would birds be able to fly from one position to another without flying backwards?
- Why did the stars not move from one half of a year to another?

This was before any understanding of the forces of gravity and celestial motion.

The pre-eminent model – proposed by Aristotle was the **GEOCENTRIC SOLAR SYSTEM**.

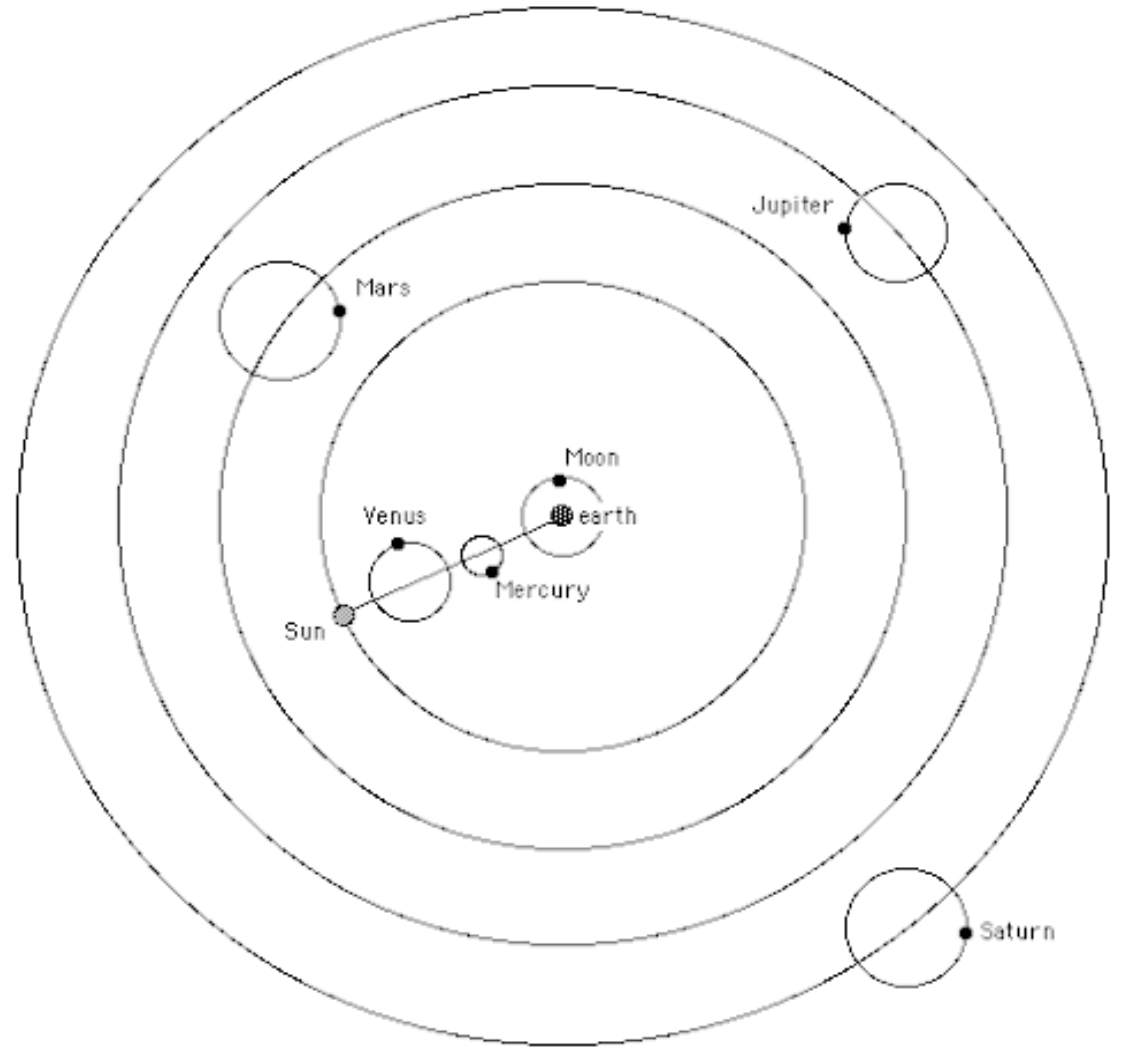
Epicycles



Ptolemy **small circular orbits** that moves along a larger circular path known as **epicycles**.

Even though the model was incorrect, it was accepted for over **1,400 years** with Ptolemy's adjustments. It was the best fit for available observations.

Ptolemy's Model of the Solar System

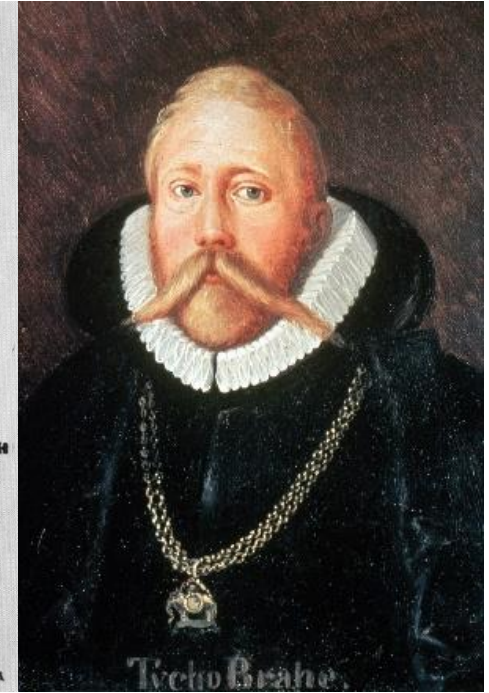
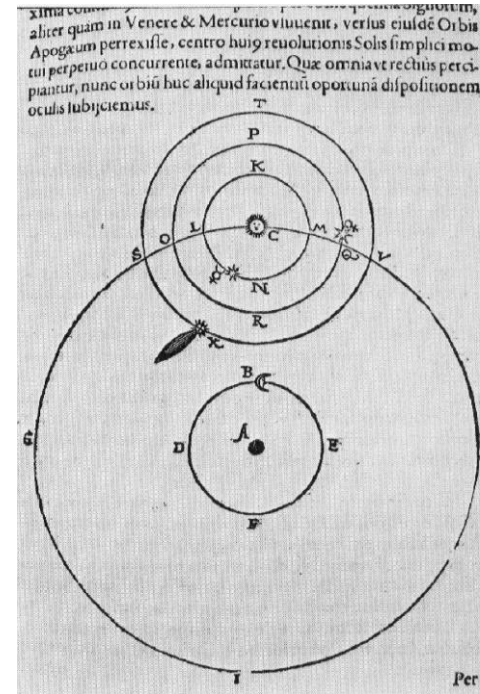


The Heliocentric Model



In 'De revolutionibus orbium coelestium' Copernicus claimed all bodies moved around the Sun (with the exception of the Moon orbiting Earth) and had circular orbits.

Tycho Brahe had issues with the Copernican model and proposed a Geo-Heliocentric Model where the Moon and Sun orbited Earth but everything else orbited the Sun.



Kepler refined the heliocentric proposing elliptical orbits rather than circular.
(And more importantly doing the Maths to prove it)

Galileo – The Telescope

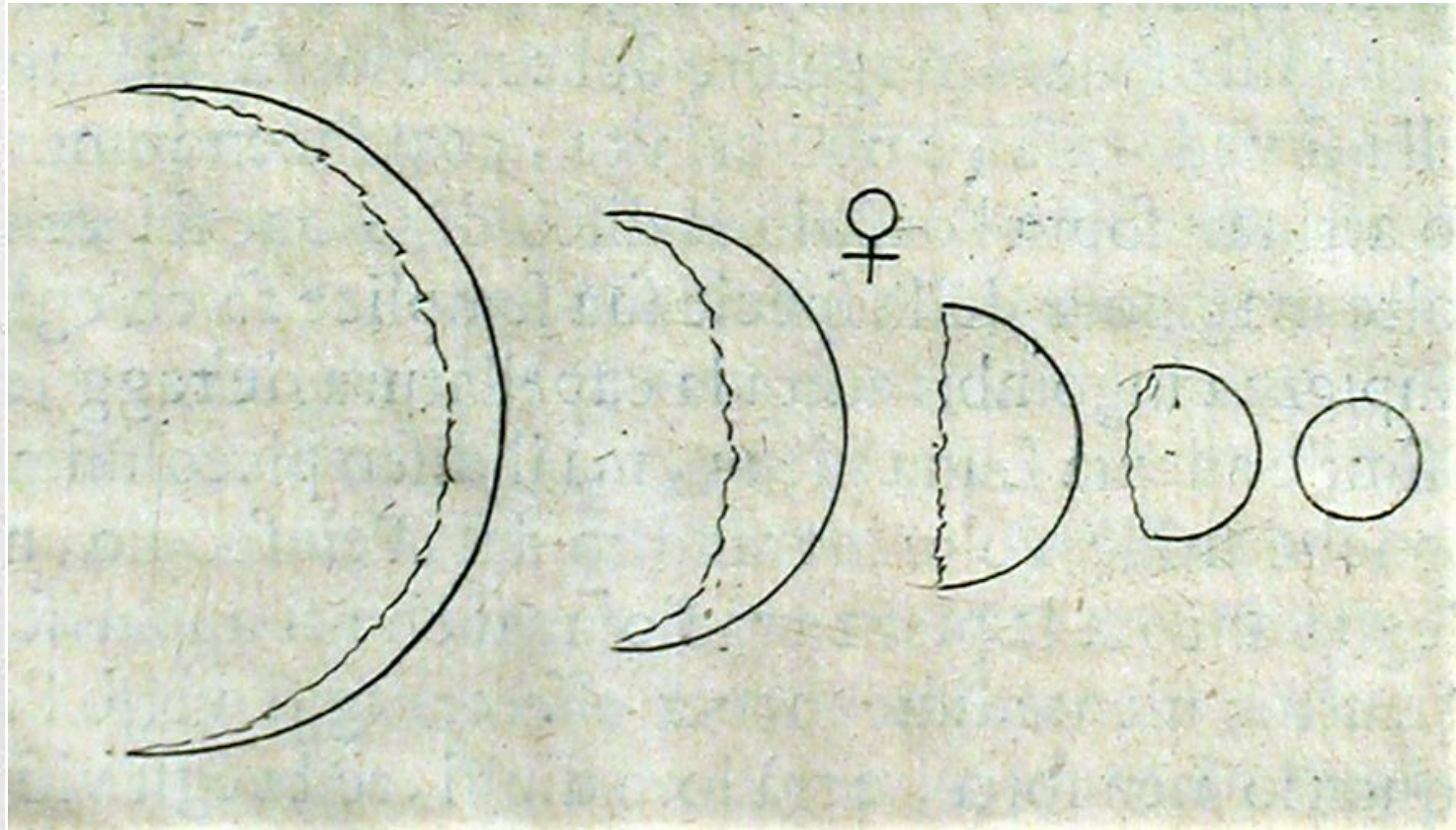


Galileo's Observations

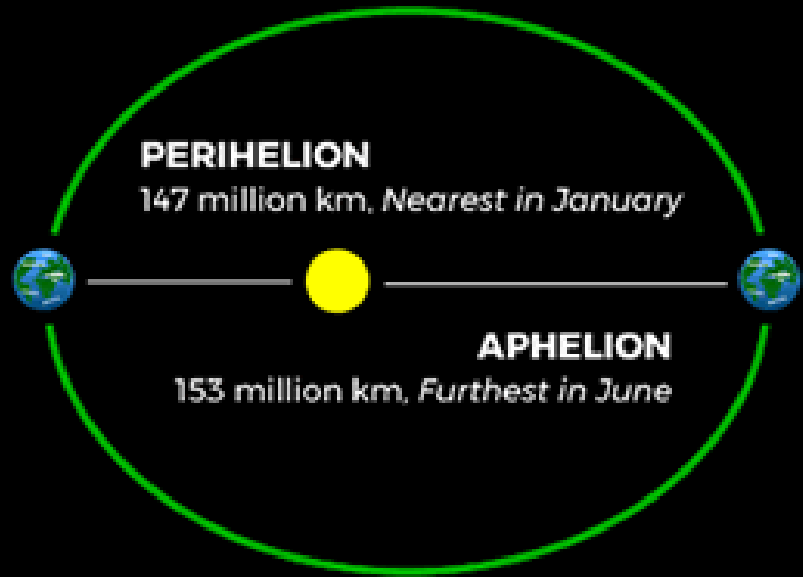
- Discovery of Jupiter's main moons - if everything orbited Earth, why did these obviously orbit Jupiter?
- Venus had phases (see Topic 5) - How could this occur if it orbited Earth rather than the Sun?

Observations of Jupiter
1610

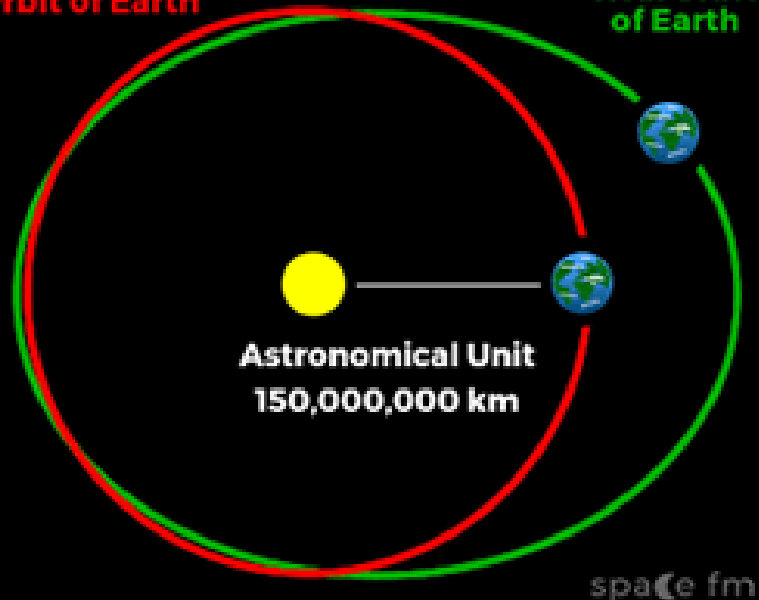
2. J. Jovis. max. H. 12	○ * *
30. mare	* * ○ *
2. Jovis	○ * * *
3. mare	○ * *
3. Ho. J.	* ○ *
7. mare	* ○ * *
6. mare	* * ○ *
8. mare H. 13.	* * * ○
10. mare	* * * ○ *
11.	* * ○ *
12. H. J. Jovis	* ○ *
17. mare	* * ○ *
14. Jovis	* * * ○ *



ORBIT OF EARTH








Mean Average
Orbit of Earth



Units of Distance

DISTANCES

LIGHT YEAR / PARSEC

Earth / Moon			1.3 light seconds
Sun / Earth			8 light minutes
Sun / Neptune			4 light hours
Sun / Proxima Centuri (Nearest Star)			4.2 light years
Sun / Polaris			433 light-years
Sun / Centre of Milky Way			100,000 light years
Milky Way / Andromeda Galaxy			2.537 million light years

1 AU – 150,000,000 km

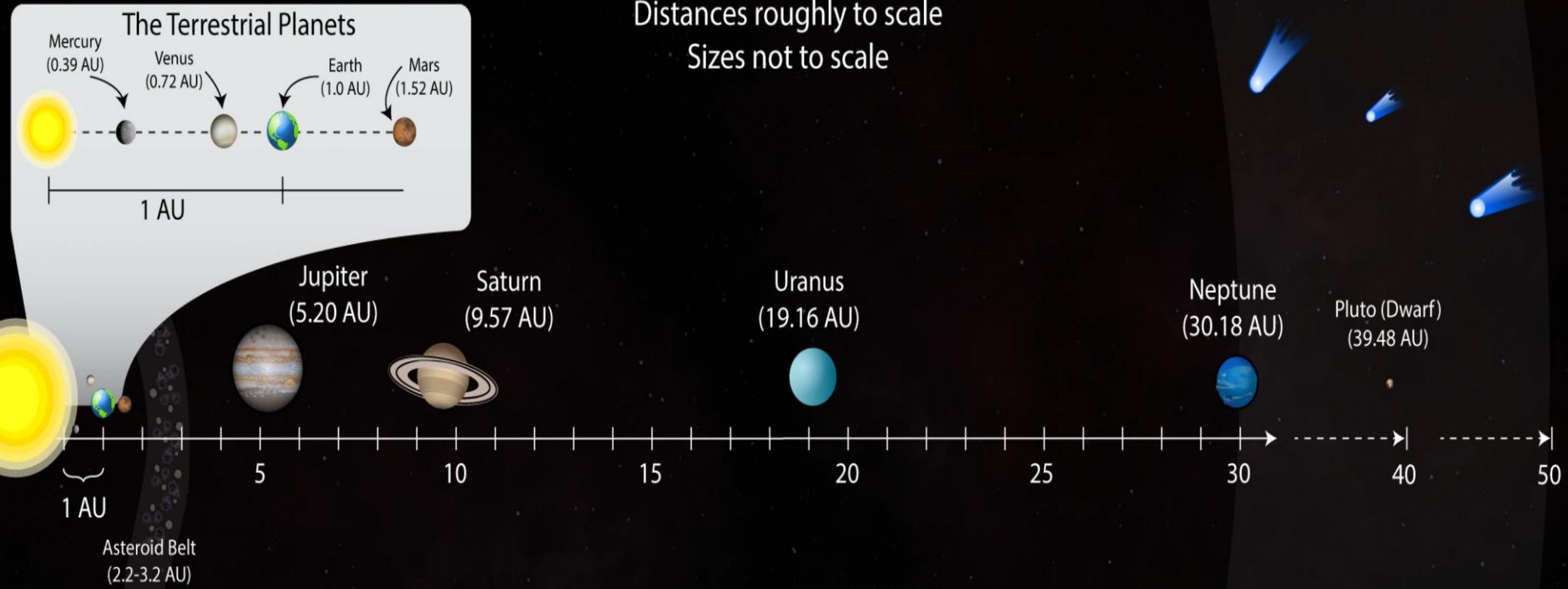
1 ly - 63,241 AU

1 pc - 3.26 ly.

The Solar System

Distances roughly to scale

Sizes not to scale



Scale of the Solar System

- **Earth to Moon:** ~ 0.0026 AU ($\sim 384,400$ km)
- **Earth to Neptune:** ~ 30 AU
- **Oort Cloud (outer edge of Solar System):** $\sim 100,000$ AU

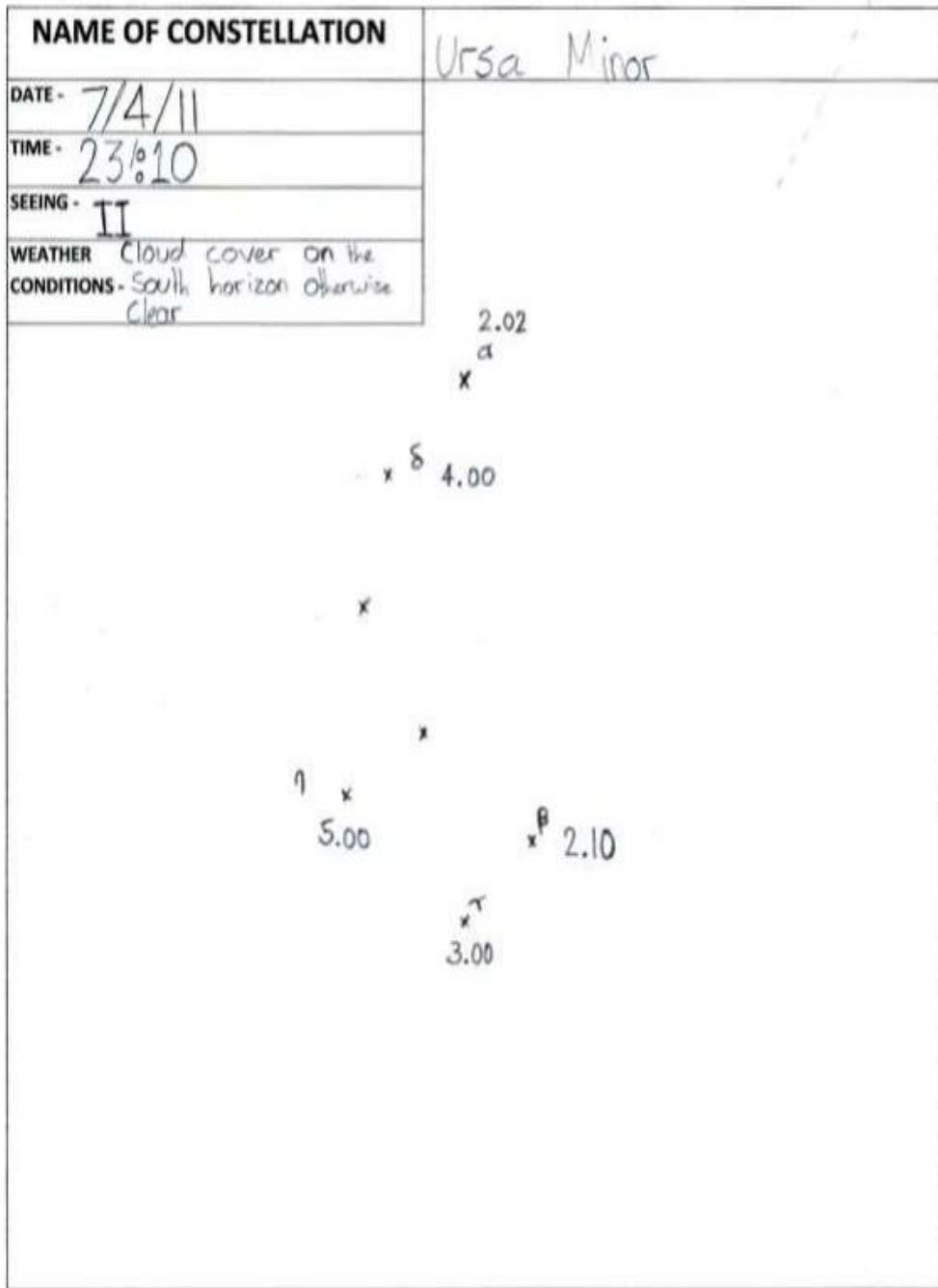
Observation Tasks in GCSE Astronomy



Observation Options

Unaided tasks	Aided tasks
<p>A1 Demonstrate the changing appearance of lunar features</p> <p>Use a series of naked-eye drawings of individual lunar features to demonstrate their changing appearance during the lunar phase cycle</p>	<p>B1 Demonstrate the changing appearance of lunar features</p> <p>Use a series of telescopic drawings or photographs of individual lunar features to demonstrate their changing appearance during the lunar phase cycle</p>
<p>A2 Finding the radiant point of a meteor shower</p> <p>Use naked-eye drawings of the paths of meteors to determine the radiant point of a meteor shower</p>	<p>B2 Finding the radiant point of a meteor shower</p> <p>Use photographs of the paths of meteors to determine the radiant point of a meteor shower</p>
<p>A3 Assess the accuracy of stellar magnitude estimates</p> <p>Using reference stars, estimate the magnitude of a range of stars from naked-eye observations and thus assess the accuracy of this technique</p>	<p>B3 Assess the accuracy of stellar magnitude measurements</p> <p>Using reference stars, estimate the magnitude of a range of stars from photographs and thus assess the accuracy of this technique</p>
<p>A4 Estimate a celestial property using drawings of a suitable event</p> <p>Use naked-eye drawings or measurements of a celestial event such as a comet or eclipse to determine a celestial property such as the relative size of the Earth and Moon</p>	<p>B4 Measure a celestial property using telescopic drawings or photographs of a suitable event</p> <p>Use telescopic drawings, measurements or photographs of a celestial event such as a comet, transit, eclipse or occultation to determine a celestial property such as the Earth-Sun distance or the orbital period of a Jovian satellite</p>
<p>A5 Estimating levels of light pollution</p> <p>Use estimates of the magnitude of the faintest stars visible with the naked eye to conduct a survey of the astronomical effects of light pollution in an area</p>	<p>B5 Measuring levels of light pollution</p> <p>Use estimates of the magnitude of the faintest stars visible on photographs to conduct a survey of the astronomical effects of light pollution in an area</p>

<p>A6 Estimate the solar rotation period using drawings of sunspots</p> <p>Use a series of drawings from pinhole projections of sunspots to estimate the length of the Sun's average rotation period</p>	<p>B6 Determine the solar rotation period using photographs of sunspots</p> <p>Use a series of photographs or drawings from telescopic projections of sunspots to estimate the length of the Sun's average rotation period</p>
<p>A7 Estimating the period of a variable star</p> <p>Use estimates of stellar magnitude from naked-eye observations to produce a light curve for a variable star and thus estimate its period</p>	<p>B7 Measuring the period of a variable star</p> <p>Use estimates of stellar magnitude from telescopic observations or photographs to produce a light curve for a variable star and thus estimate its period</p>
<p>A8 Comparing stellar density estimates</p> <p>Use naked-eye estimates of stellar density taken in and outside the plane of the Milky Way to estimate their relative sizes</p>	<p>B8 Comparing stellar density measurements</p> <p>Use telescopic measurements of stellar density taken in and outside the plane of the Milky Way to estimate their relative sizes</p>
<p>A9 Finding longitude using a shadow stick</p> <p>Use measurements of shadow length around local noon to estimate the observer's longitude</p>	
<p>A10 Assess the accuracy of a sundial</p> <p>Use a log of sundial and clock times to assess the accuracy of a sundial</p>	
	<p>B11 Demonstrate the range of objects in the Messier Catalogue</p> <p>Use detailed drawings or photographs of objects from the Messier Catalogue to demonstrate the range of different objects it contains</p>
	<p>B12 Calculation of the length of the sidereal day</p> <p>Use long-exposure photographs of the area around the celestial pole to produce an accurate measurement of the length of the Earth's sidereal period</p>



Observations

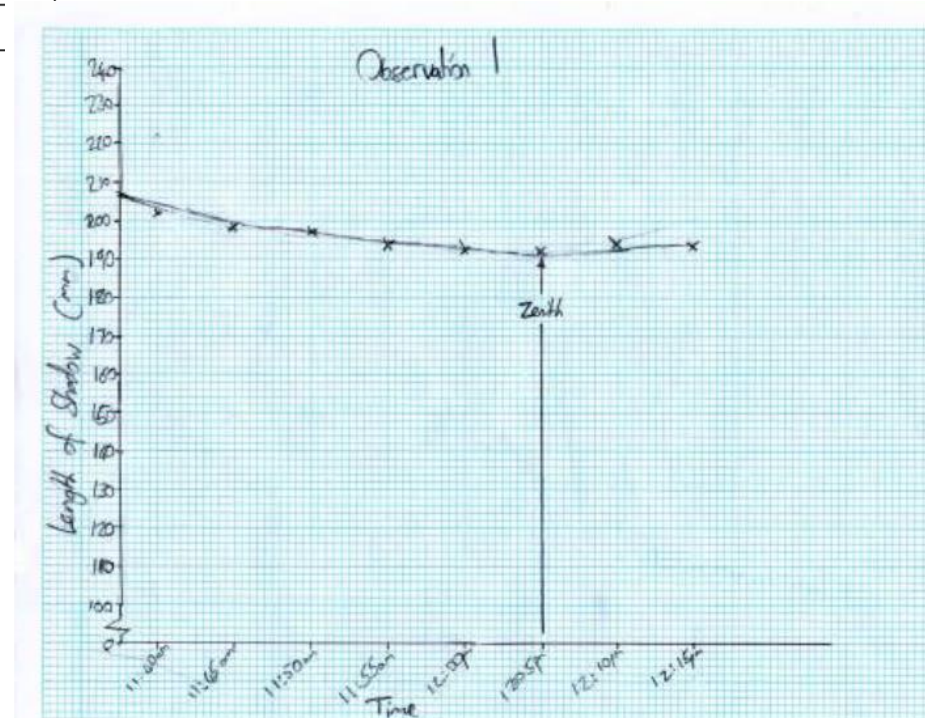
For my observations I used the Antoniadi Scaled to represent the viewing conditions.

Observation 1 – 26th March

Antoniadi II Lat.: 54⁰N Long.: 2⁰W

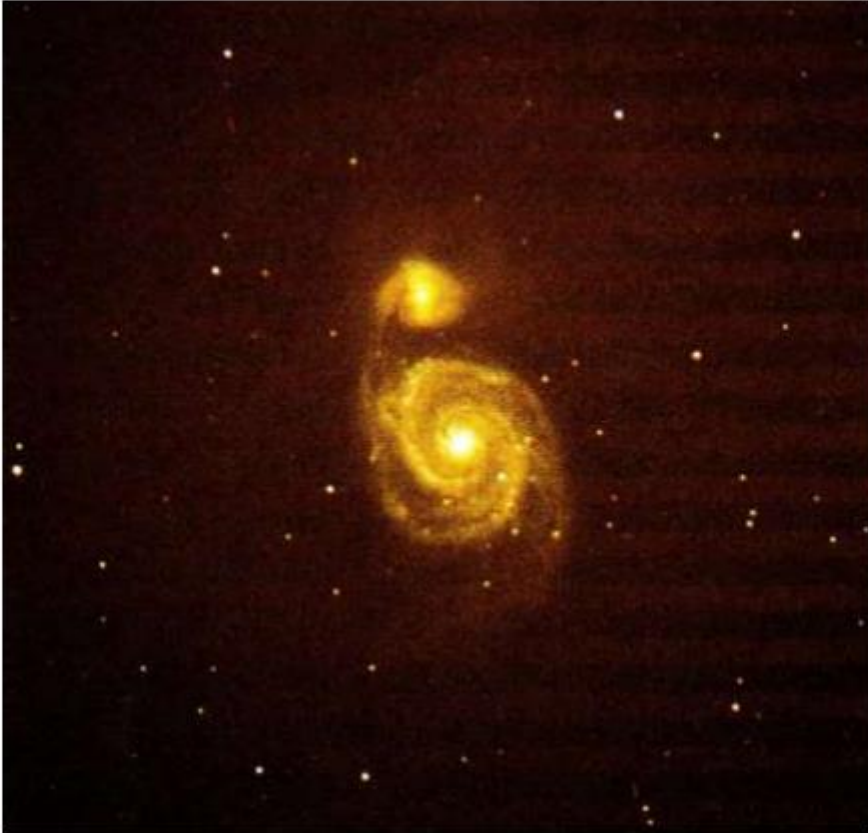
Time	Length of shadow
11:40	202
11:45	198
11:50	197
11:55	194
12:00	192
12:05	192
12:10	194
12:15	194

Observation Examples



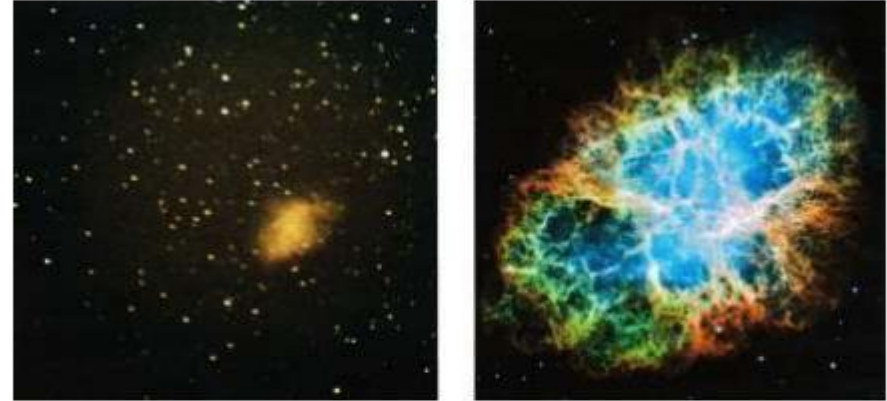
Observations

Observation #1: The Whirlpool Galaxy (M51)



Observation Examples

Observation #2: The Crab Nebula (M1)



Hubble Space Telescope image © NASA

The HST image is better than my robotic telescope image due to a number of factors. Firstly, the aperture on the HST is 2400mm whereas it is only 400mm. This allows for more detail in the image as the wider lens can take in more light. Secondly, the magnification on the HST is much greater than from my robotic telescope, so a more in-depth view of the subject can be taken.

Thirdly, the HST is in space whereas my robotic telescope is ground-based. This means that the HST does not get interference from the atmosphere (eg clouds etc). Finally the HST is maintained by NASA so more funding can be put into technology, hardware and personnel etc.