Earth in space: the solar system

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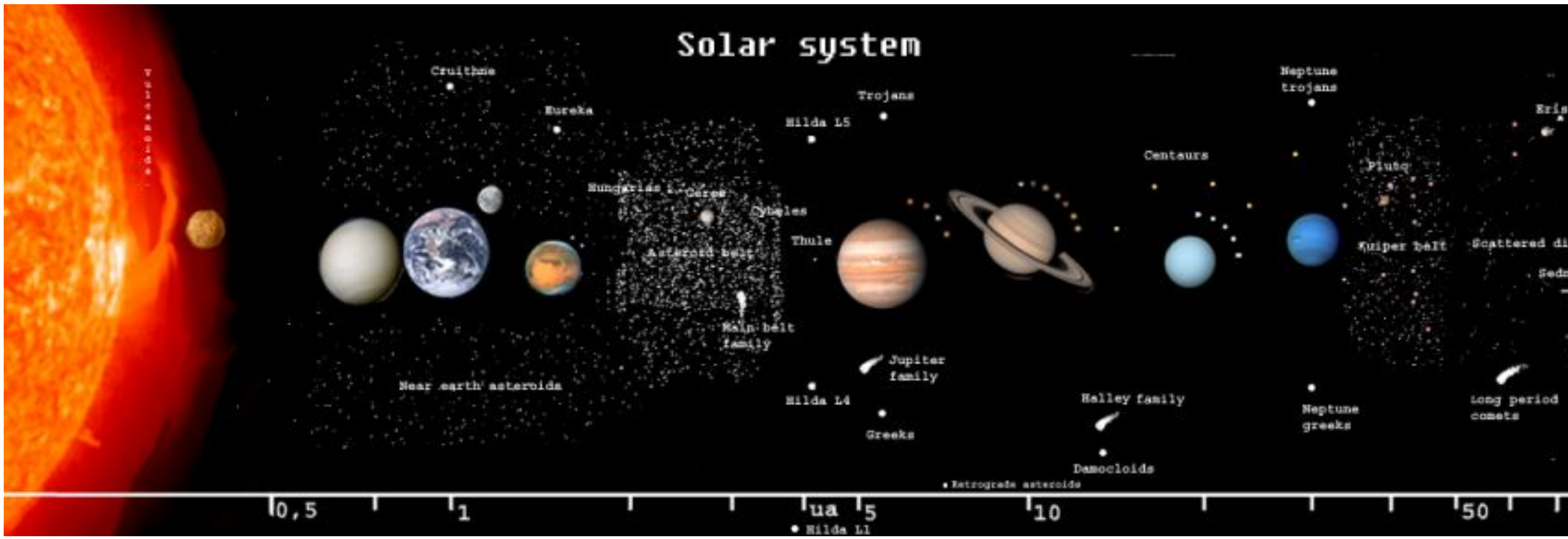
Overview



- explaining day & night, seasons, Moon’s phases, motion of stars & planets, solar & lunar eclipses, scaling planets and orbits
- some big ideas – relative motion, space, time, gravity
- common misconceptions
- teaching approaches, example resources

Learning outcomes

- recall the apparent motions of Sun, Moon, planets, and distant stars
- explain their motions using a heliocentric model of Solar System
- explain day & night, phases of the Moon and seasons
- recall that gravity acts as a force throughout the Universe
- explain the weight of an object on different planets in terms of gravitational fields and $W = mg$
- give relevant examples from the history of astronomy
- exploit student's natural curiosity about our place in the Universe while also challenging commonsense
- describe astronomical distances in light years and explain how astronomers look back in time
- use plus (linear) and times (logarithmic) scales appropriately to describe distances on Earth and in space
- explore a variety of astronomical websites

‘The Universe is a procession with measured and beautiful motion.’
- Walt Whitman

‘The Universe: a device contrived for the perpetual astonishment of astronomers.’ - Arthur C Clarke

No one will be able to read the great book of the Universe if he does not understand its language which is that of mathematics.’
– Galileo Galilei

‘In the beginning the Universe was created. This has made a lot of people angry and has been widely regarded as a bad move.’
- Douglas Adams

Questions, questions!

Diagnostic questions

Try these:

Ideas in astronomy

Astronaut on the Moon

Astronomy survey

What's taught at KS2 (Y5)

Earth, Sun and Moon - spherical shapes, relative sizes

How the position of the Sun appears to change during the day, and how shadows change as this happens

- How day and night are related to the spin of the Earth on its axis
- Earth's yearly journey round the Sun
- Moon orbits Earth every 28 days (phases of Moon as evidence)
- **What's actually <u>learned</u> about the more abstract ideas?**

Teaching challenges

Many people have never carefully observed the paths of Sun, Moon, stars or planets across the sky.

A heliocentric model of the solar system is counter-intuitive.

Space is mind-boggling in size and composition.

In pairs:

Read and discuss pupil explanations of day & night.

Feature	Intuitive concept	Scientific concept
relative sizes	The Earth is larger that the Sun and Moon which are larger than the stars.	Stars are suns which are larger than the Earth which is larger than the Moon.
Earth's shape	The Earth is flat.	The Earth is a sphere.
Earth's movement	The Earth is stationary.	The Earth rotates on its axis every 24 hours, orbits the Sun in a year.
day & night	Sun moves, rising & setting.	Earth rotates, Sun stays still
solar system	The Sun & planets orbit the Earth (geocentric).	The Earth orbits the Sun (heliocentric).
gravity	There exists an absolute 'down', same everywhere.	'Down' is towards the centre of the Earth, so its direction varies.

Research evidence

Primary school leavers' explanations for

why the day length varies throughout the year

Partial science explanation	49 %
Scientifically incorrect	28 %
No response/don't know	23 %

why it's hotter in summer than winter

Sun nearer	56 %
Climatic	13 %
No response/don't know	28 %
Other	3 %

J Osborne, P Wadsworth, P Black & J Meadows (1994) Primary Space Project research report 'The Earth in Space'. Liverpool University Press

Astronomy – a very brief history

The Earth is not always cloud-covered.

Watching the sky, you see that the Sun, stars, Moon & planets all move in regular cycles.

Such cycles became the basis of calendars – prediction (planting crops, ritual observances, astrology). Early civilisations built costly monuments aligned with the heavens.

Astronomy the oldest science – from ~4000 BC

Exact measurements

- time intervals – requires a reliable clock (water clocks)

- angles – locate any celestial object with 2 coordinates (angles) e.g.
  - azimuth, its deviation measured from North rotating eastwards
  - altitude (elevation), its angle above the horizon

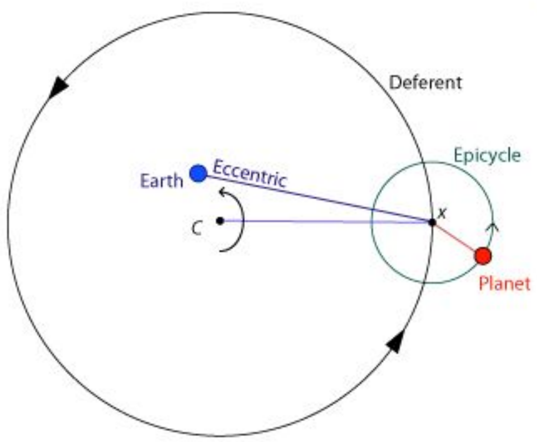
  (using devices such as plumb line, quadrant, astrolab)

Greek astronomy

geometry of the heavens and Earth

- Estimating the siEstimating the size of the Earth
- Diameter of the Moon
- The Moon's distance from Earth
- Distance to the Sun

Ptolemy's **geocentric** model



The Epicycle and Deferent and the Eccentric in Ptolemy's Model of Planetary Orbits

Earth is a sphere

Evidence known to Greeks:

- ships leaving port ‘sink’ below the horizon
  - sun’s shadow cast by a stick
  - altitude of Pole star
  - visible constellations
- Earth’s shadow, cast on the Moon during eclipse, is circular

Modern evidence

- photos taken from artificial Earth satellites
- geodetic study of Earth’s tectonic plates motion, tides, etc

Modelling the Earth & Sun

A class activity to bring out misconceptions.

Student pairs – one is the Sun, the other is the Earth.

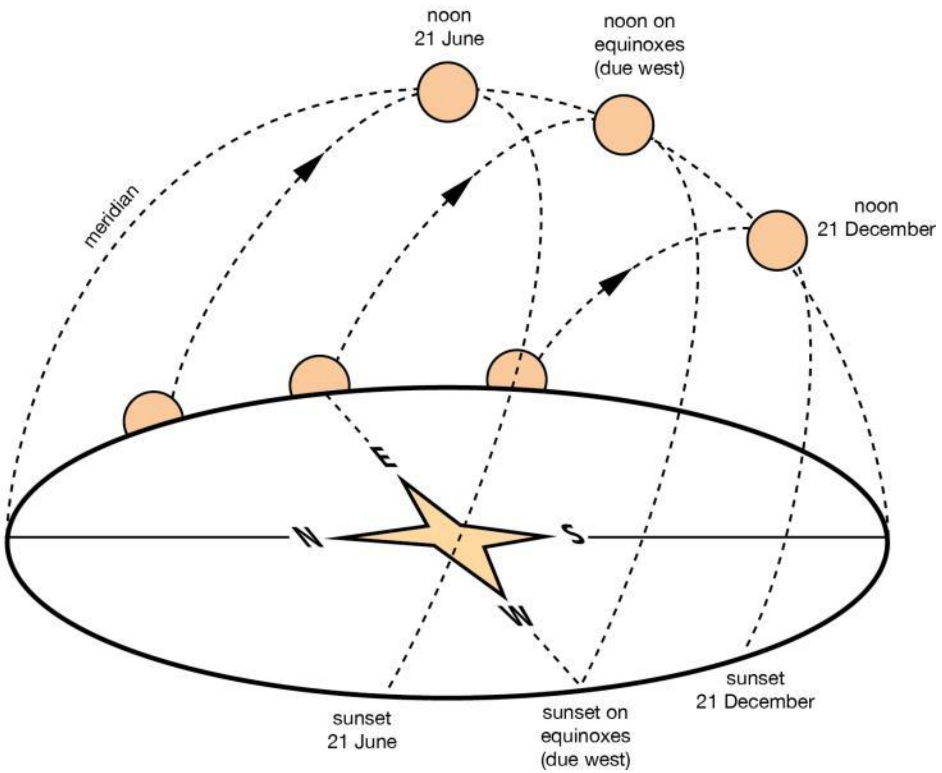
- ‘Sun’ writes down instructions for how the Earth should move over a 24h period.
- ‘Earth’ writes down instructions for how Sun should move over a 24h period.
- ‘Earth’ and ‘Sun’ compare notes & agree what to do.

Teacher calls out hours of day – pupils move according to their written instructions.


The Sun’s path across the sky, over a six month period.

Sun’s path across the sky

in the northern hemisphere



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Model-making

rotates every 23 hr 56 min

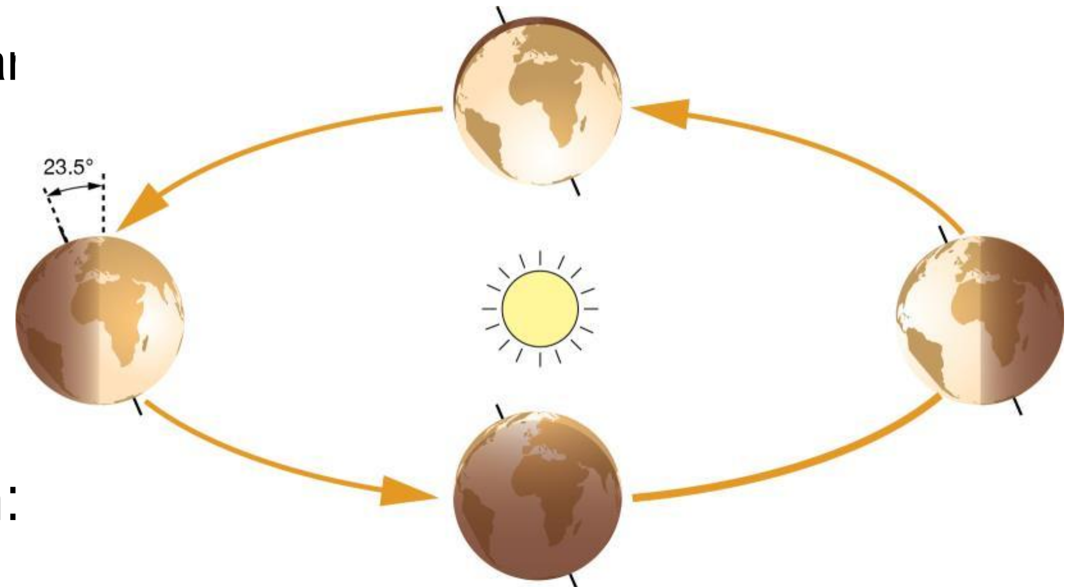
What direct evidence is there of the Earth’s rotation?

See SPT animation

Seasons

False explanations that people commonly give:

- clouds stop heat in winter
- the Earth - Sun distai



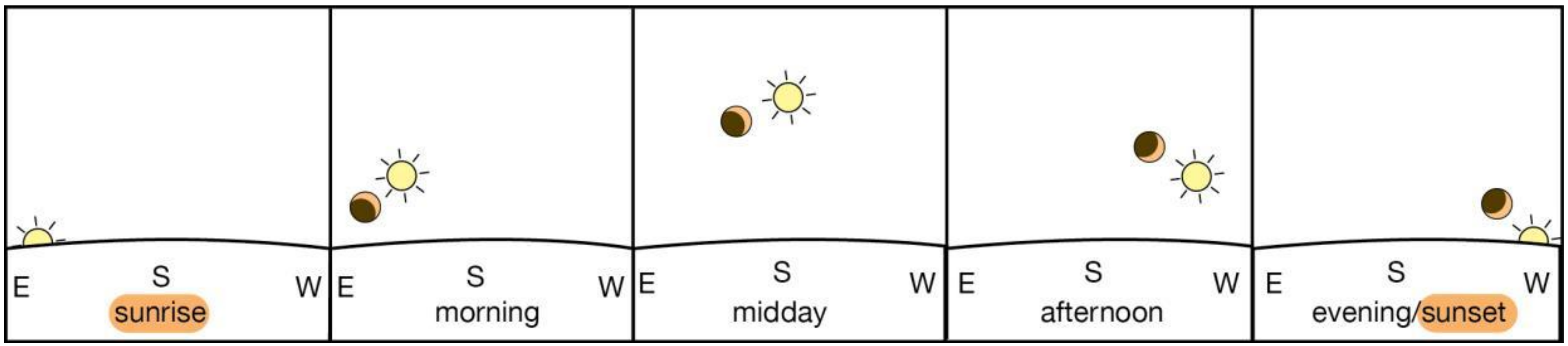
Correct explanation:

Demonstration with hooded lamp & a sheet of paper.

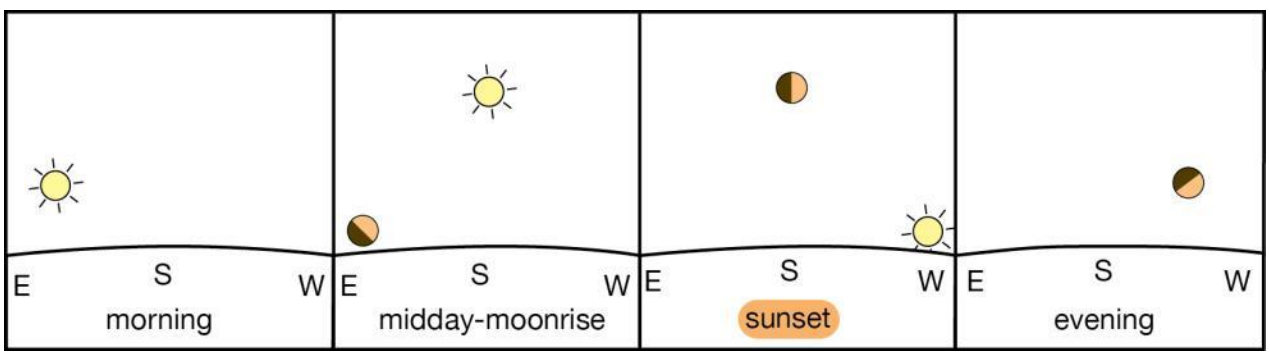
SPT animations [Solar warming over the year]and [Angle, area and warming]

Moon's cycle

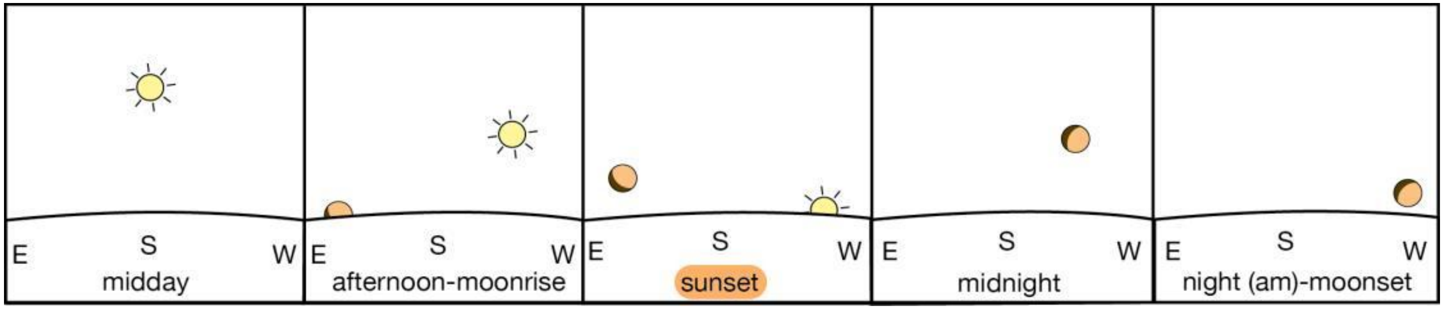
a few days after a 'new moon' … …a small waxing crescent



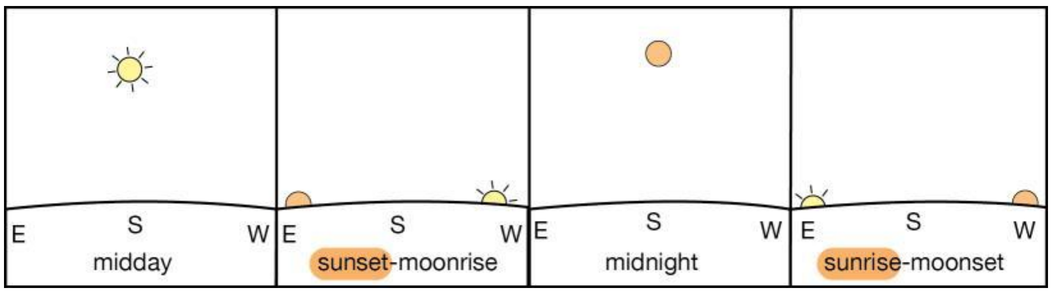
one week later… …half moon, facing west



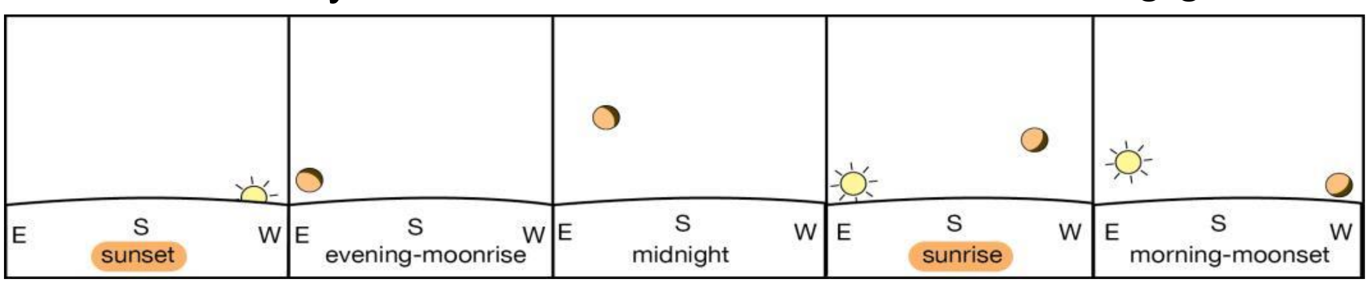
a few more days ….   …waxing gibbous



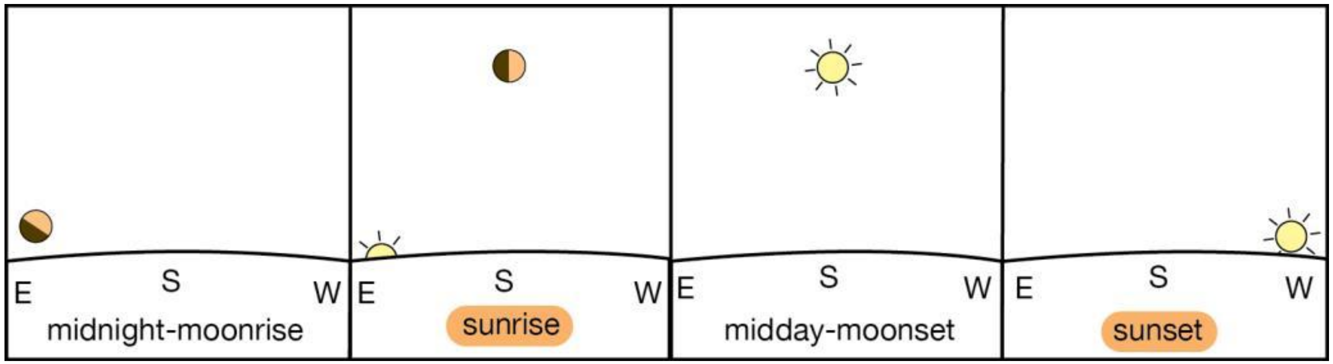
after 2 weeks….   …full moon



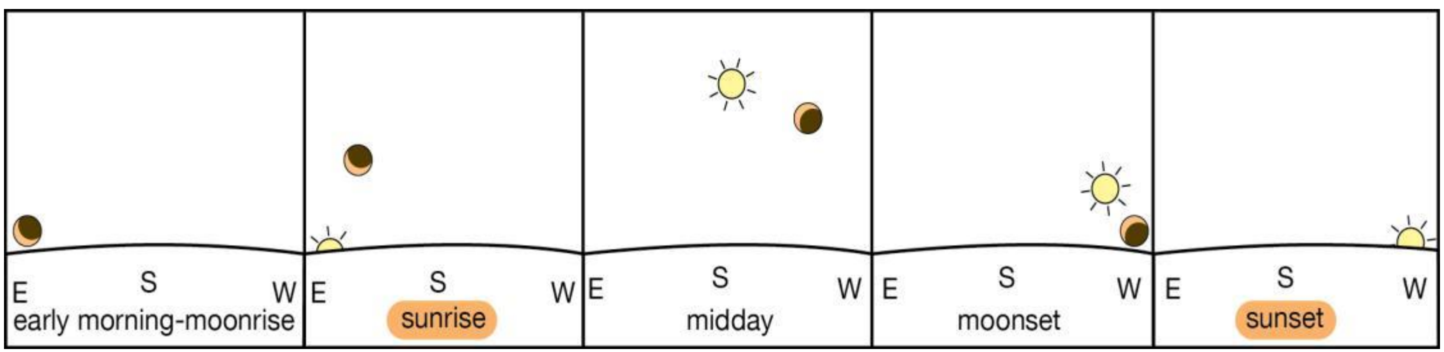
a few more days …   …waning gibbous



after 3 weeks… half moon, facing east

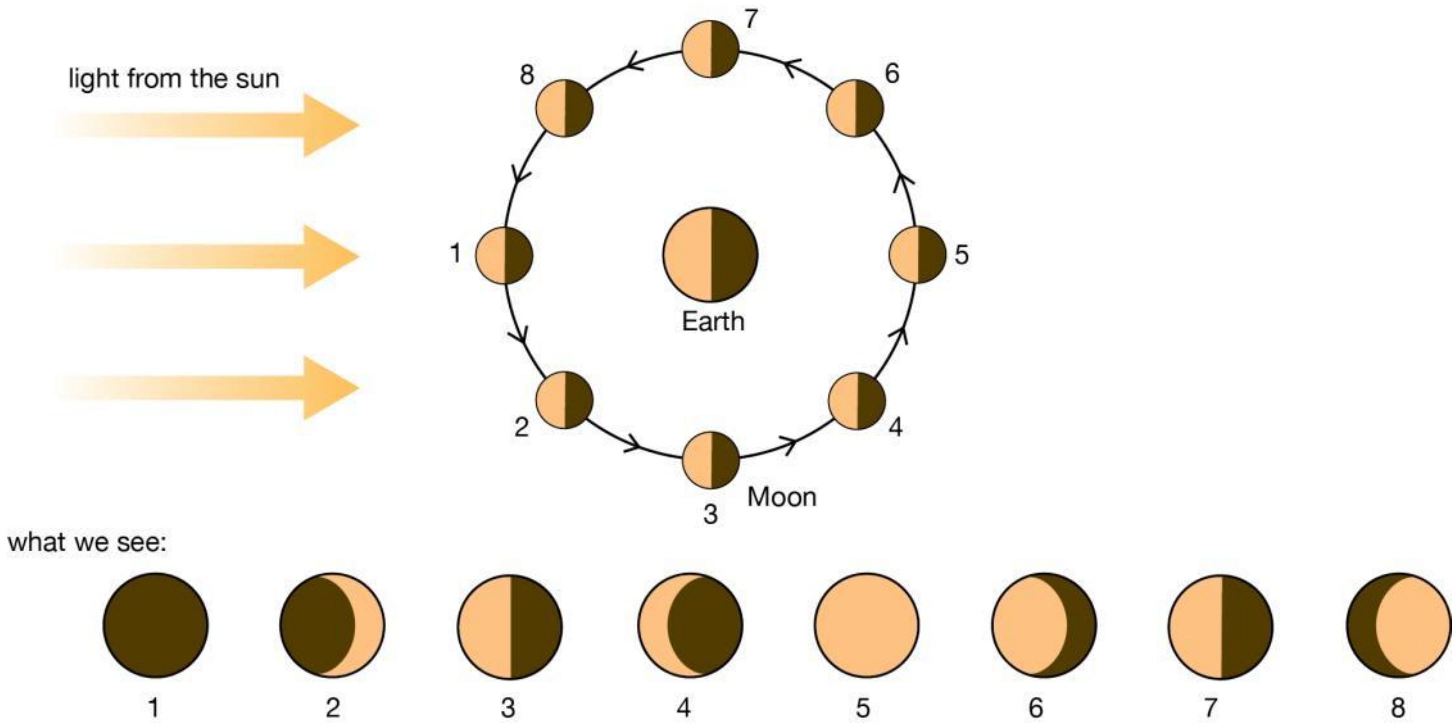


after almost 4 weeks … …small, waning crescent



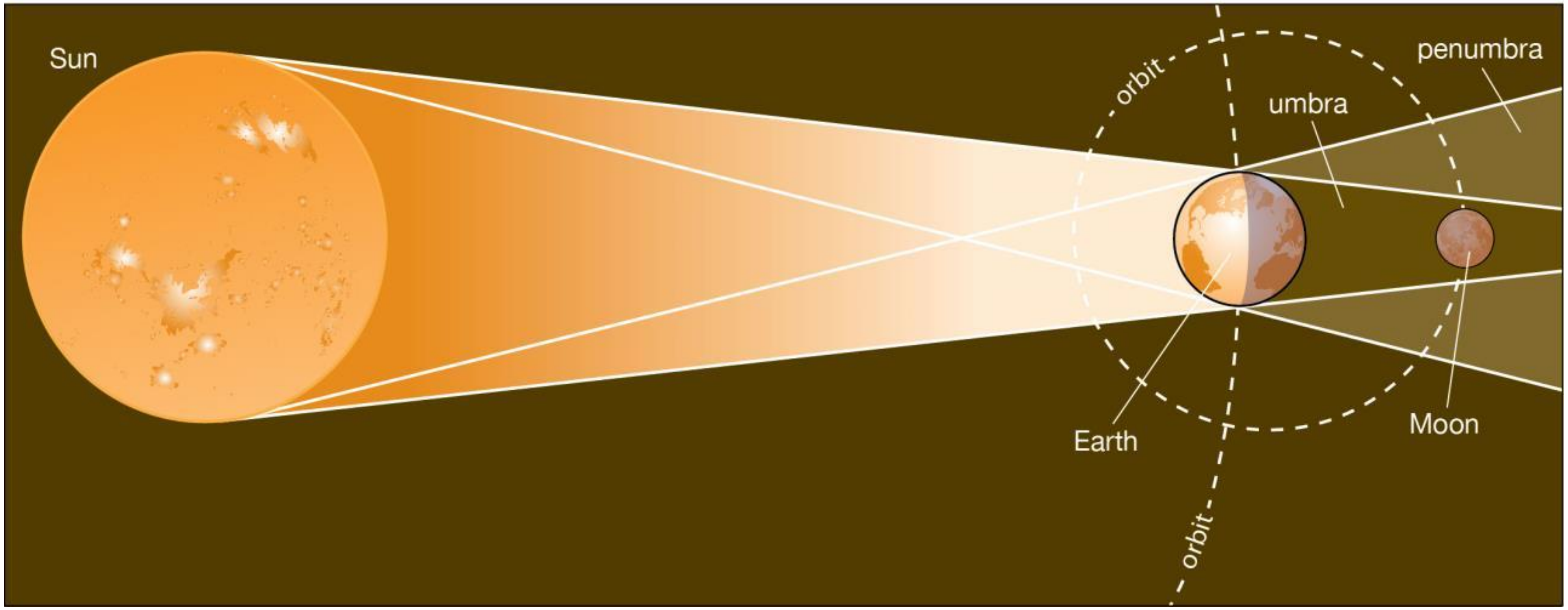
‘Moonth’: orbit 27.3 days, relative to fixed stars. phases cycle in 29.5 days

Phases of the Moon

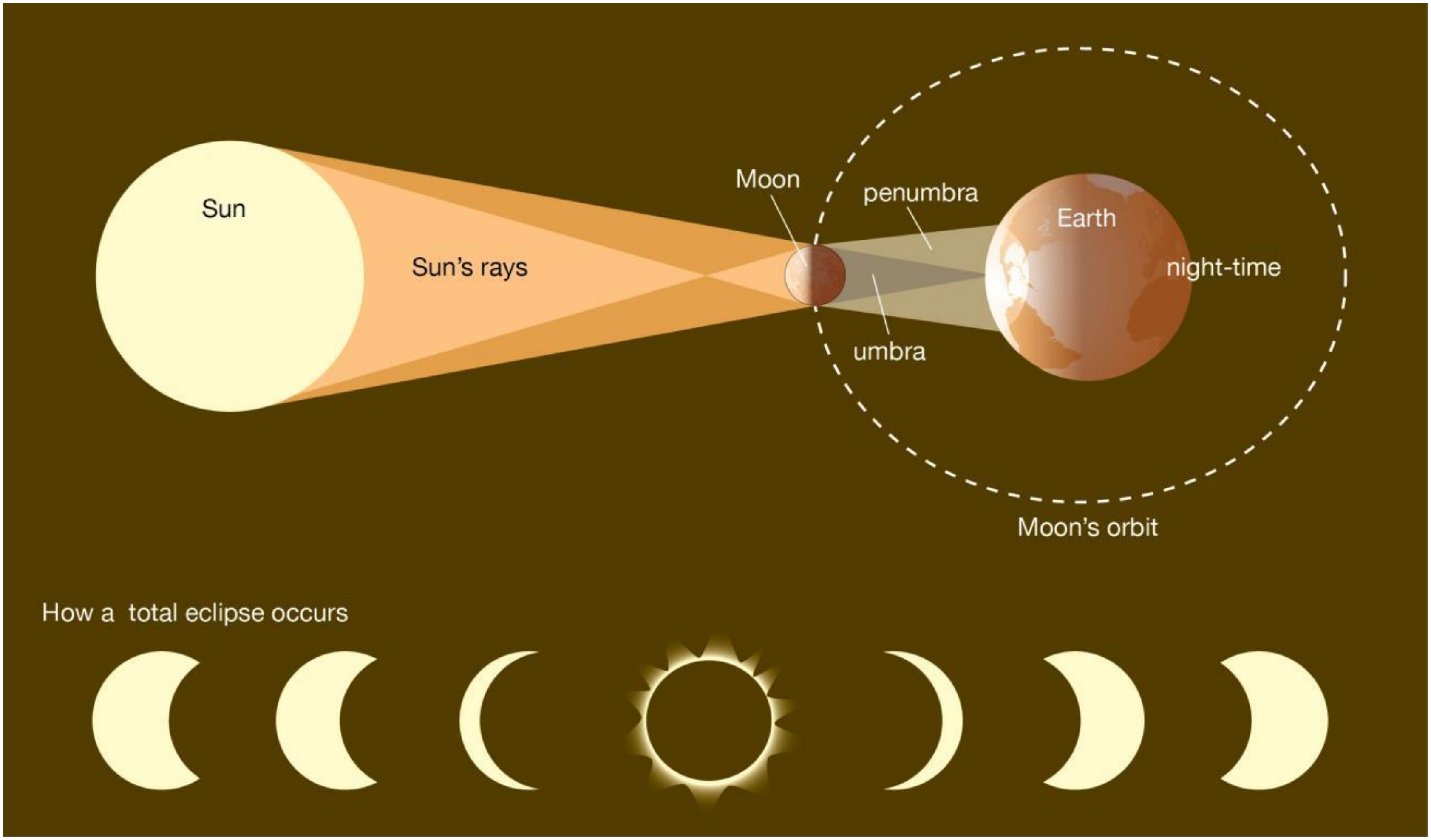


Physically model phases of the Moon using a lamp, tennis ball & globe.

Lunar eclipse



Solar eclipse



The planets

Visible to the naked eye

- Mercury
- Venus
- Mars
- Jupiter
- Saturn

Telescope observation

- Uranus, 1741
- Neptune, 1846

[Pluto, 1930 - demoted to 'dwarf planet' in 2006]

Scaling the solar system

Planet	Represented by	Distance from 'Sun'
Mercury	1 mm poppy seed	12 m
Venus	3 mm pinhead	23 m
Earth	3 mm pinhead	30 m
Mars	1.5 mm mustard sees	50 m
Jupiter	30 mm ball	167 m
Saturn	30 mm ball	300 m
Uranus	10 mm marble	600 m
Neptune	10 mm marble	900 m
Pluto	1mm poppy seed	1.25 km

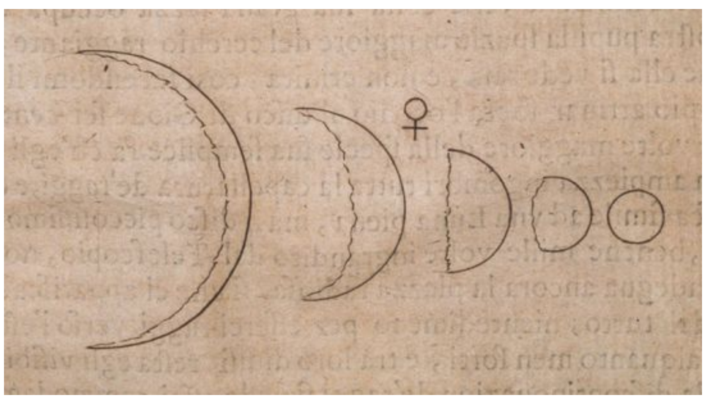
Sun ~109 x Earth's diameter

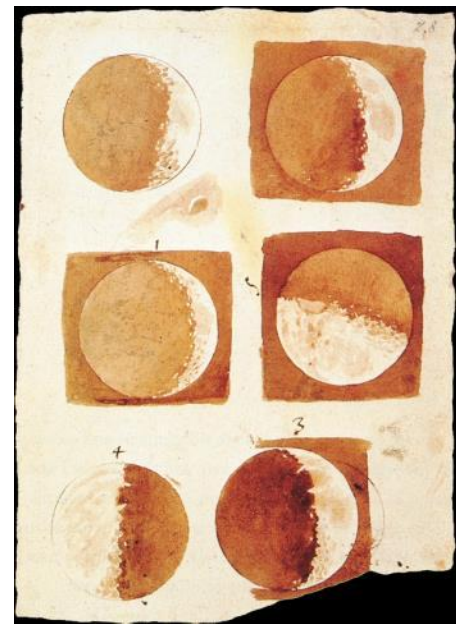
http://www.numbersleuth.org/universe/

Copernicus & Galileo

Problems to solve

- retrograde motion of outer planets
- Jupiter has Moons
- Venus has phases



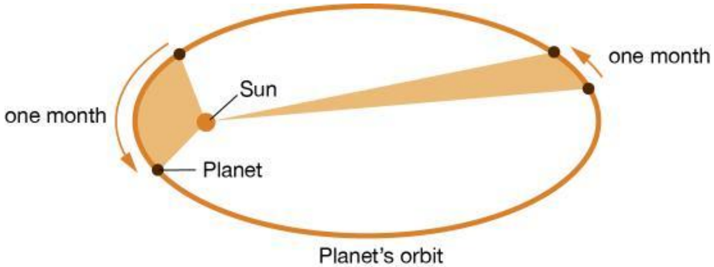


- A revolutionary(!) **heliocentric** model

Orbits

Brahe's Uraniborg observatory, 1576-97

- positions of stars & planets to within 1 arcminute

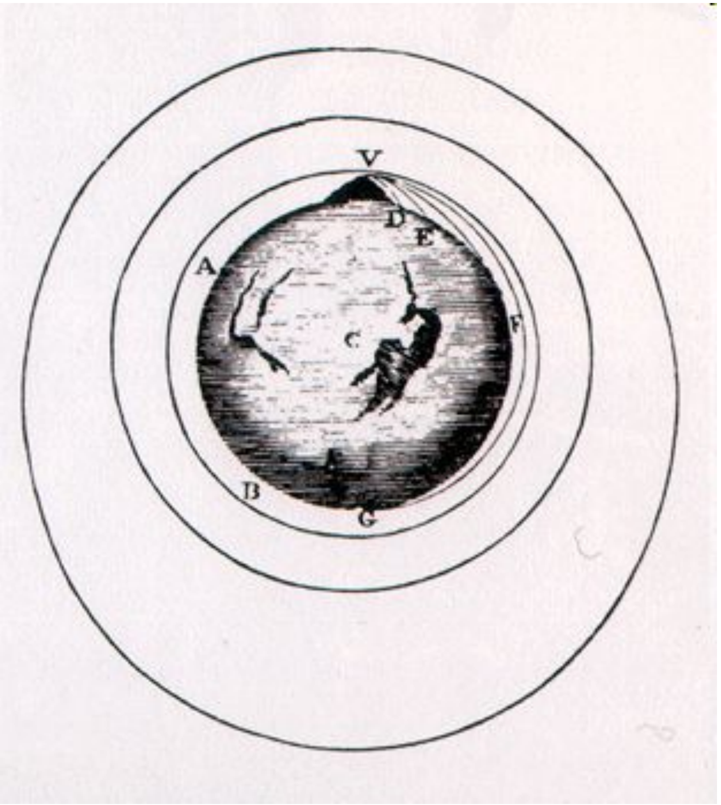


Kepler's laws of planetary motion ~1605

1. The orbit of every planet is an ellipse with the Sun at one focus.
2. The line joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. A planet's distance from the Sun, *R*, and its orbit period, *T*, are related.

$$R^3 \propto T^2$$

Orbits and satellites



$$F = G\frac{m_1 m_2}{r^2}$$

Newton, 1687: circular motion, universal gravitation

How do we know what we know?

Light is the main messenger bringing information from celestial objects.

Astronomers talk of several things:

- the perceived Universe (naked eye)
- the detected Universe (using instruments)
- the theoretical Universe (models, explanations)

Telescopes

- Bigger is better - collect more light.
- Mirror image can be less distorted than a lens image (reflection, rather than refraction of different colours/wavelengths).
- Magnification gives better resolution (separation of nearby objects) but does not make objects bigger (they're too distant!).
- Other problems to solve: temperature changes in large structures (telescopes), refraction of light passing through the Earth's atmosphere.

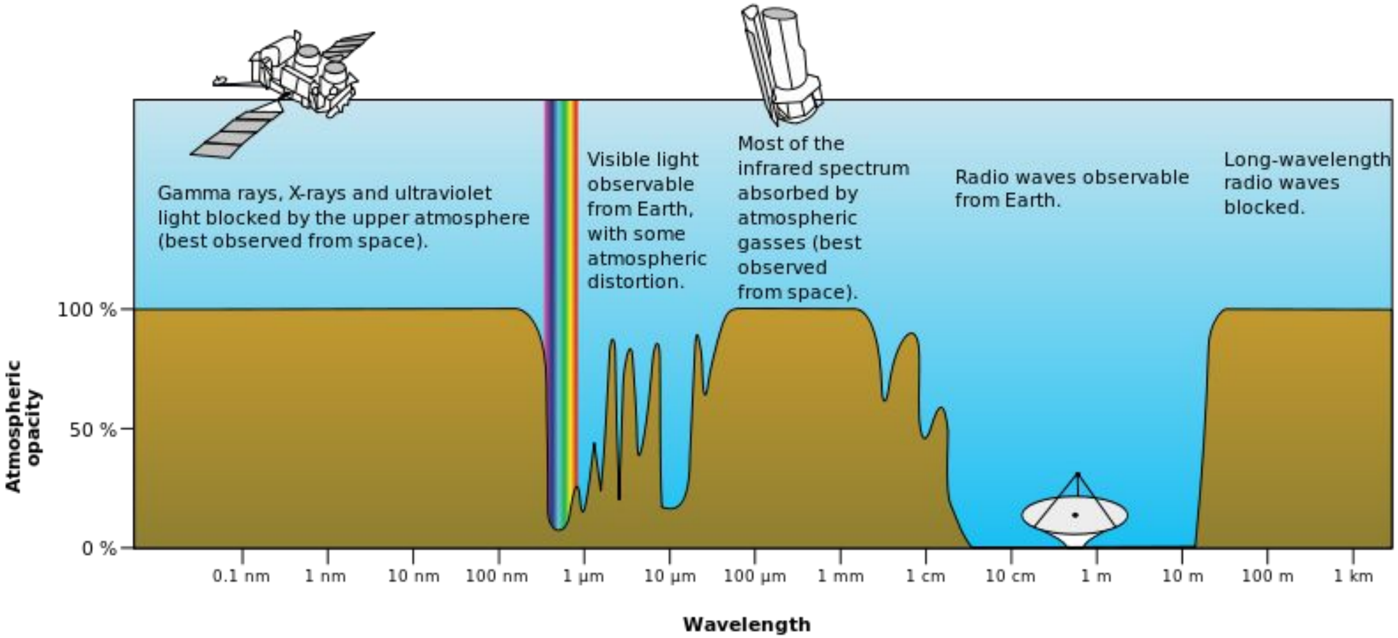
Modern astronomy

Processes & techniques

- Using the whole spectrum
- Remote control of telescopes
- Data capture, storage and imaging
- Image processing, computer modelling
- Distributed computing

Space telescopes & probes

Space telescopes: atmospheric gases selectively absorb electromagnetic radiation.



Space probes: local analysis, results transmitted back to Earth.

Planetary science

Current missions

NASA

- Cassini-Huygens (with ESA): Saturn
- Mars Odyssey, Curiosity: Mars
- Dawn: asteroids Vesta & Ceres
- Juno: Jupiter
- MESSENGER: Mercury
- New Horizons: Pluto
- plus many satellites observing Earth

ESA

- Rosetta: comet 67P

Student learning outcomes

Knowledge and understanding of

- physics concepts
- nature of science
- space-related technologies

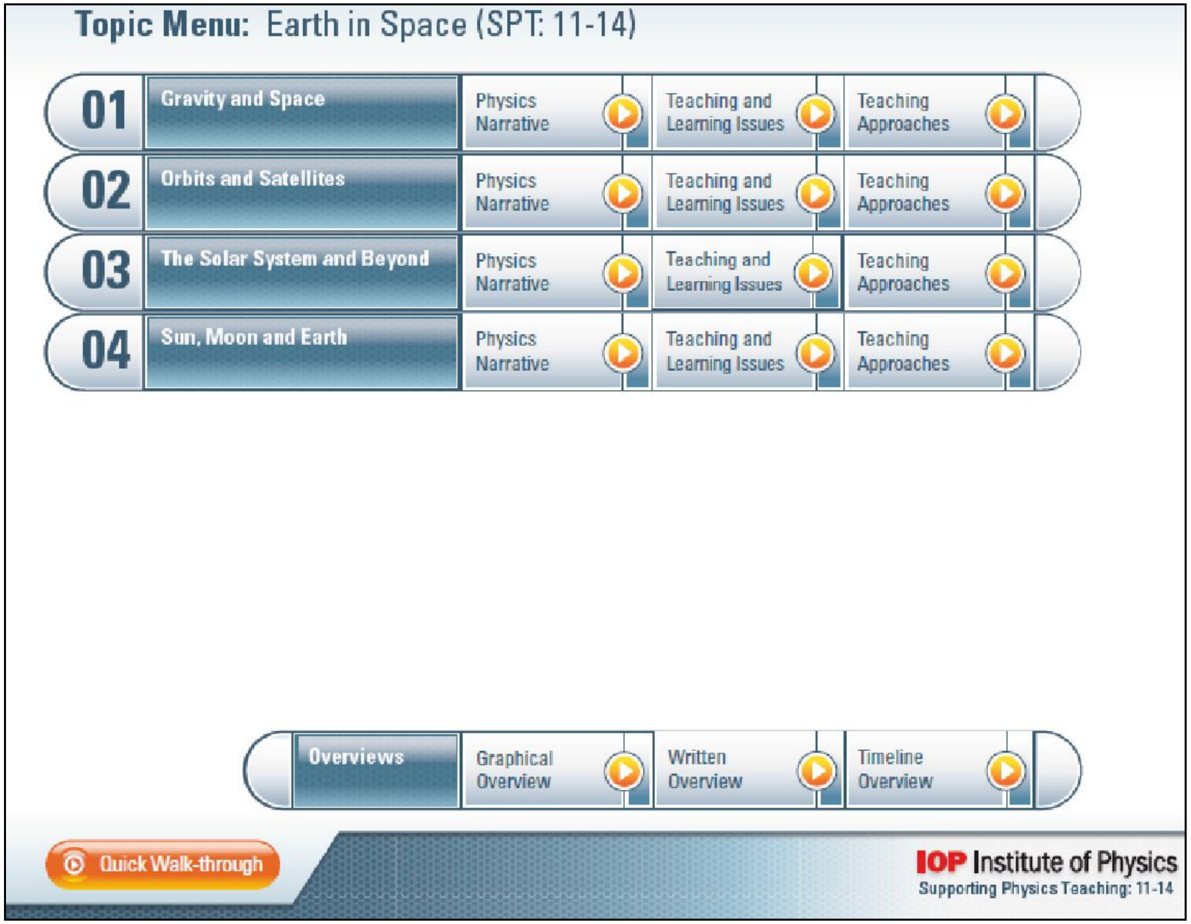
Skills development

- research & presentation
- observing astronomical objects

Careers possibilities

Rosetta, Philae and Comet 67P

SPT 11-14 *Earth in Space*



Support, references

talkphysics.org [incl free downloading SPT resources]

- websites
  - images, video clips
  - mission information, simulations, explanations
- planetaria
  - Greenwich Observatory or a mobile planetarium
- National schools observatory
- David Sang (ed, 2011) *Teaching secondary physics* ASE / Hodder
- *Practical Physics Astronomy* webpages