

# Summary Notes - Topic 5: Solar System Observation



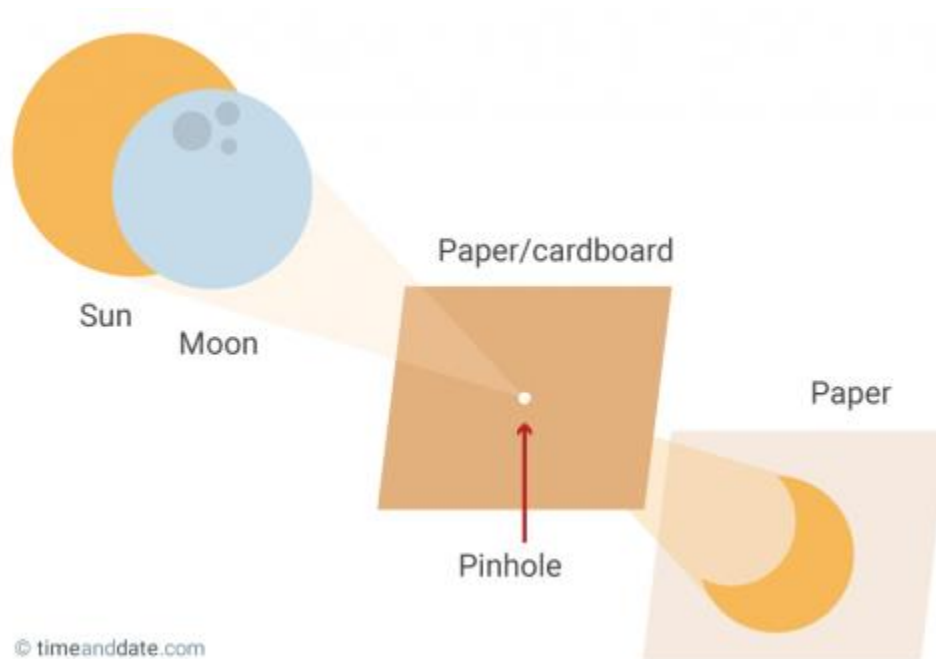
## 5.1 Observing the Sun Safely Using Pinhole Projection

- The Sun is extremely bright, and looking at it directly can cause **permanent eye damage**, even with sunglasses.
- **YOU MUST NOT EVER LOOK DIRECTLY AT THE SUN ESPECIALLY WHEN LINING UP YOUR PINHOLE PROJECTOR**

### Using Pinhole Projection Method:

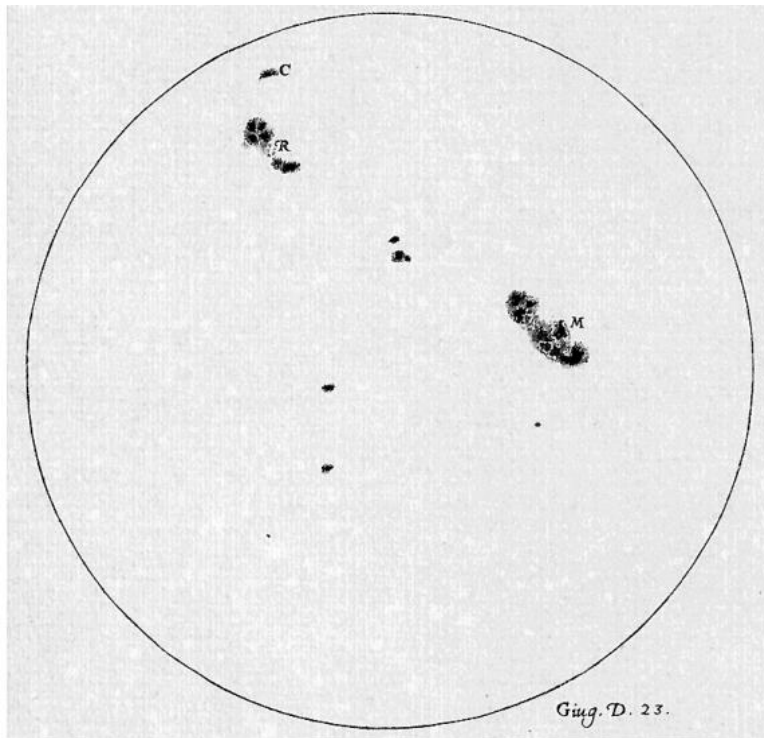
1. Take a piece of **cardboard or thick paper** and make a small hole in it.
2. Hold it up to allow sunlight to pass through the hole onto a **flat white surface** (like another piece of paper or a wall).
3. The small, projected image of the Sun can be safely observed.

This method allows you to **track sunspots and solar movement**.



## Using a Telescope or Binoculars

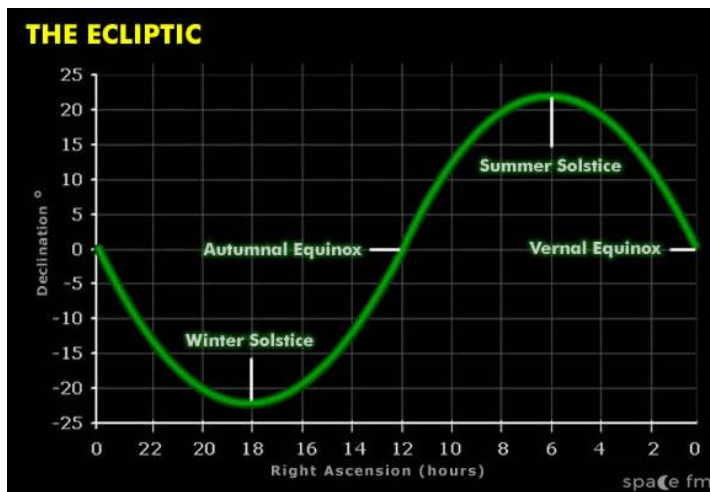
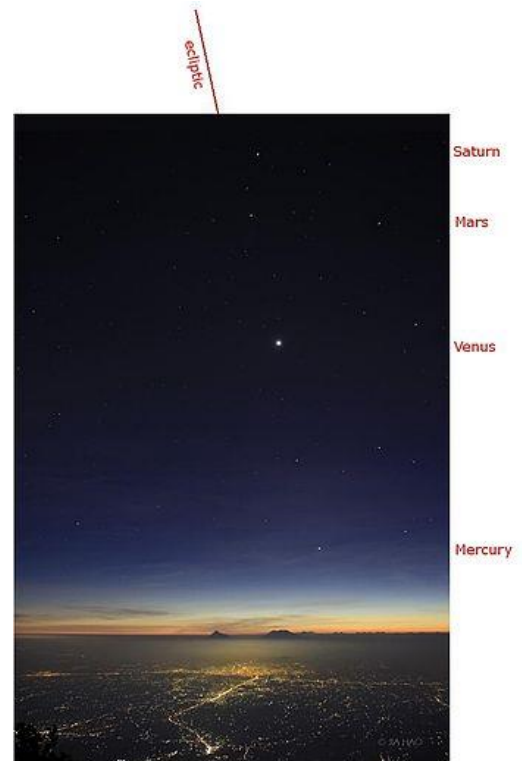
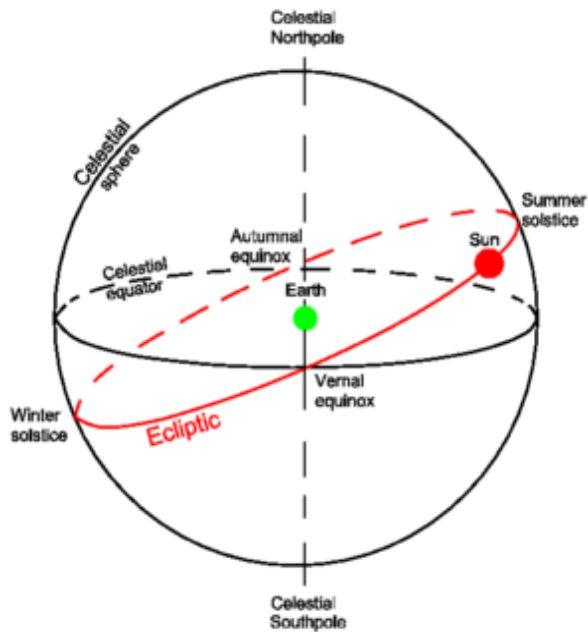
- The safest practical way to see the Sun is by eyepiece projection or use of a certified filter.
- Line up your telescope with the Sun, but instead of looking through the eyepiece, hold a sheet of white paper behind the eyepiece.
- You'll see a solar image projected onto the paper. Experiment with the paper to get a sharp viewing contrast. You should be able to see the largest sunspots with this method.
- You can safely observe a TOTALLY eclipsed Sun with the naked eye, but you will need a pinhole camera, an appropriate type of welder's glass, or special Mylar glasses to safely observe the beginning and ending of a full or partial eclipse.



Galileo Galilei (left) and sunspot drawings (above) from The Galileo Project.  
<http://es.rice.edu/ES/humsoc/Galileo/>

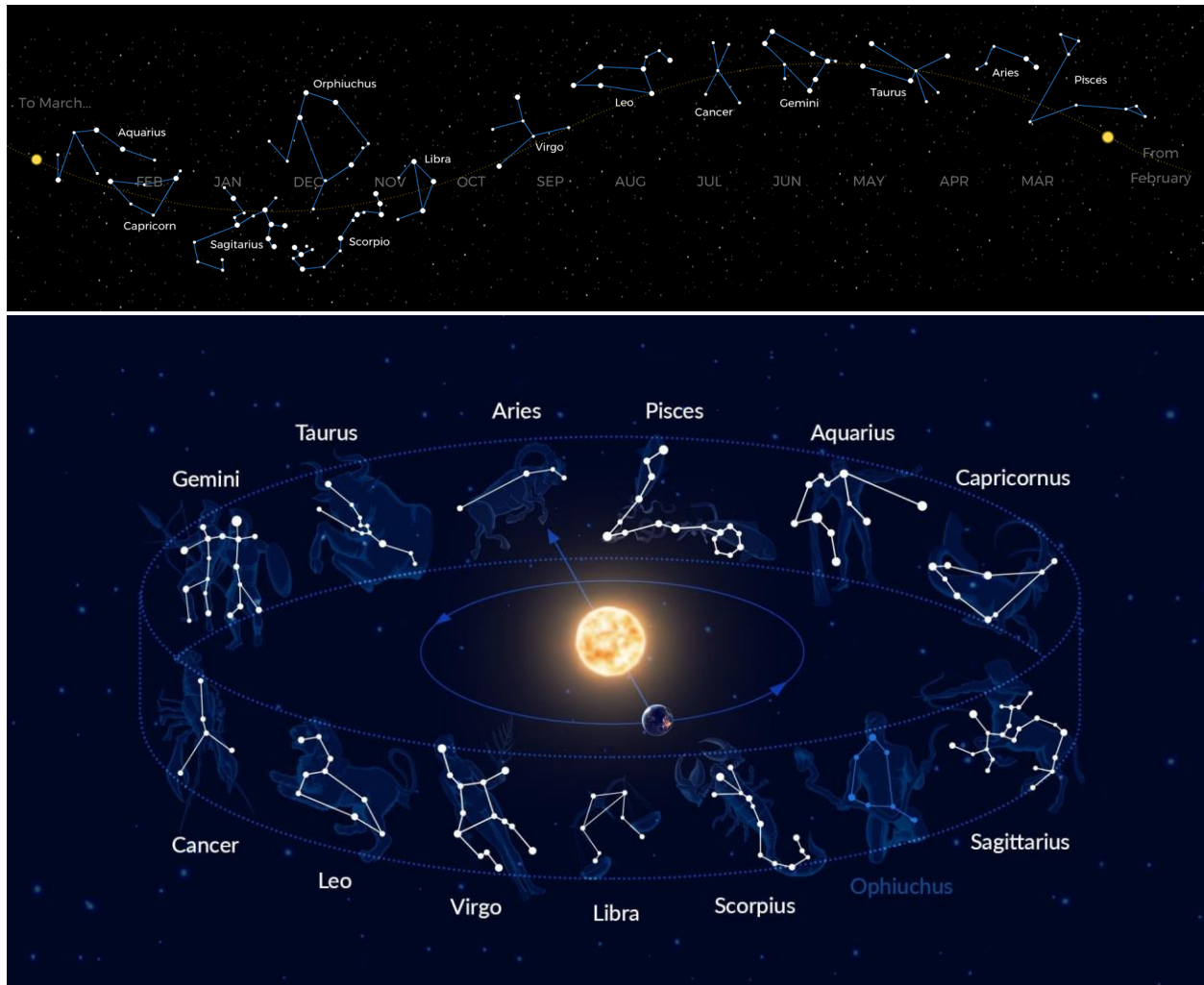
## 5.2 The Sun's Annual Path - The Ecliptic

- The **ecliptic** is the imaginary line on the sky which marks the path of the Sun through the sky in the day.
- This motion is due to **Earth's orbit around the Sun**.
- The ecliptic is tilted **23.5°** relative to the celestial equator due to **Earth's axial tilt**.
- The planets also travel along this ecliptic.
- The ecliptic is the starting point for the celestial coordinate system for all other stellar objects.

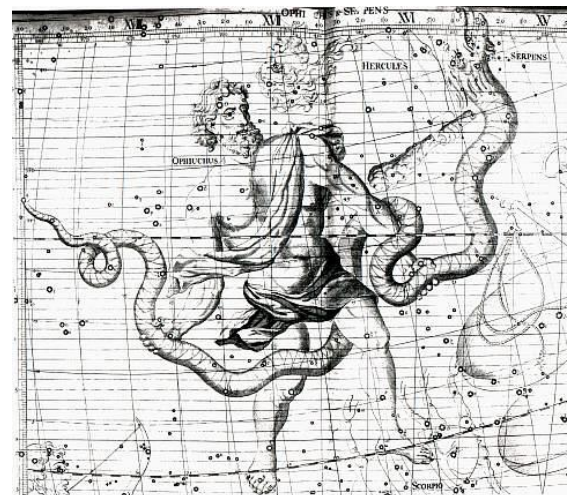


Motion of the Sun along the ecliptic.

## 5.4 The Zodiacal Band

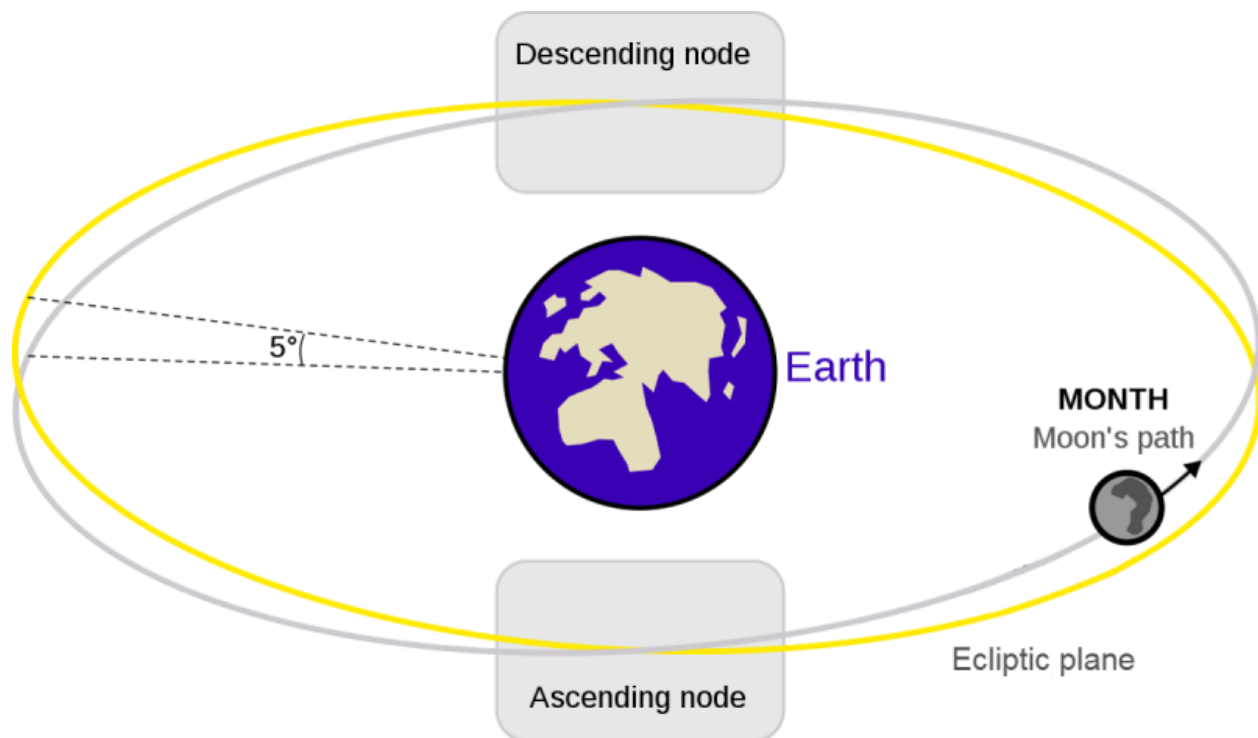


- All constellations of the **zodiac** are found along the ecliptic.
- There are **13** zodiacal constellations, the 12 astrological signs and Ophiuchus (the Serpent-bearer) which is only partially located along the ecliptic (between Scorpius and Sagittarius)



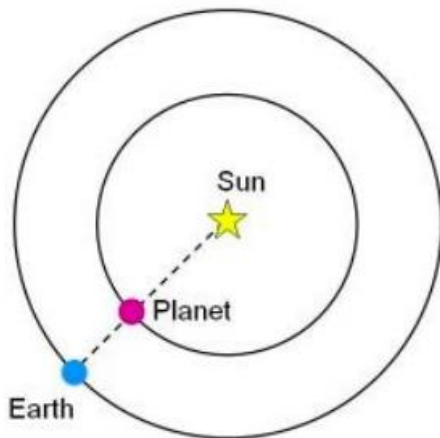
## 5.3 Motion of the Moon and Eclipses

- The moon is close to the ecliptic but slightly tilts (approx.  $5^\circ$ ) which is why we don't have monthly eclipses.
- When the moon crosses (twice every orbit) we call these nodes. The ascending node is when the moon crosses the ecliptic from the south side to north side and the descending the converse.
- The moon crosses the ecliptic twice a month, but only if the moon is full or new will this transit lead to eclipses.

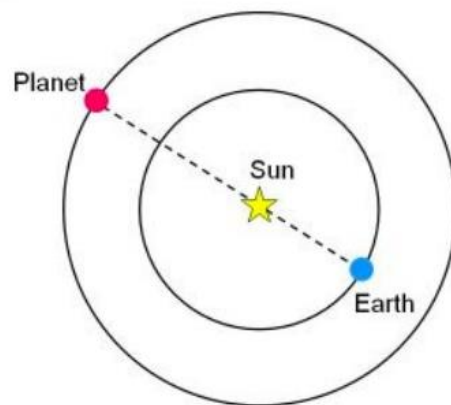


## 5.8 Key Astronomical Terms

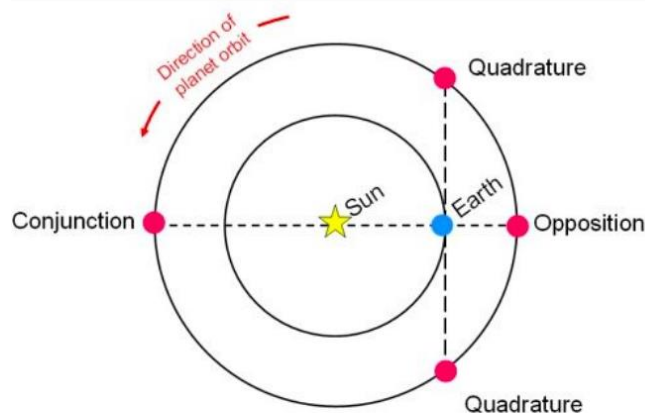
- **Conjunction:** When two celestial objects appear **close together** in the sky.
  - **Inferior Conjunction:** When an inner planet (Mercury or Venus) is between Earth and the Sun.
  - **Superior Conjunction:** When an inner planet is on the opposite side of the Sun from Earth.
- **Opposition:** When a planet is directly **opposite the Sun** in the sky (best time for observation).
- **Elongation:** The angle between a planet and the Sun as seen from Earth.
- **Transit:** When a planet passes **directly in front of the Sun** from Earth's perspective (e.g., Mercury or Venus transits).
- **Occultation:** When one celestial object passes **in front of another**, blocking its view (e.g., Moon occulting a star).



A **planet** at inferior conjunction, on a line between the Earth and the Sun.



A **planet** at **superior conjunction** lies along the same line as the Earth and the **Sun**, but on the opposite side of the Sun from the Earth.



A **Solar** System body at opposition, on the opposite side of the Earth from the **Sun**.

## 5.3 Planetary Motion on the Ecliptic

- Since the planets are in approximately the same plane as the Earth, the ecliptic serves as a good guide for finding the “Naked-Eye Planets” in the Sky. (They will be within 7 ° of that line)
- The planets can be distinguished from the stars because their position changes slightly against the background stars from one night to the next and their brightness varies in a regular cycle over a period of time.
- Stars are so distant that they appear as points of light in the night sky, and they appear to **scintillate** because of turbulence in the Earth's atmosphere. Even in the largest Earthbound telescopes, a star appears as little more than a point of light.
- The naked eye planets, on the other hand, are close enough to the Earth to form a sizeable (relatively) disk in the night sky and consequently, when they are well above the horizon, the planets shine with a more steady light than the stars.
- Planets shine by reflecting a proportion of the sunlight they receive back out into space. The proportion of sunlight they reflect (known as the albedo) depends upon the planet's size, cloud cover and the reflectivity of the features on its surface.
- The brightness of a planet to the naked eye depends on; its distance from the Sun, its apparent size (i.e. its angular size when seen from the Earth) and the relative positions of the planet and the Earth in their orbits.
- The period of time during which any given planet can be seen is known as an **apparition**.
- The length of a planet's apparition depends upon its orbital period (i.e. the time it takes the planet to orbit the Sun) and its position in relation to the Sun and the Earth at any given time.
- Apparitions can last from just a few weeks (in the case of Mercury) to almost two years (for Mars) although a planet is normally seen at its best for only a part of this time.

2025	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
☿ <b>Mercury</b>	Dawn	Dusk	Dusk	Dawn	Dawn	Dusk	Dusk	Dawn	-	Dusk	Dus Daw	Dawn
♀ <b>Venus</b>	Eve	Eve	Dusk	Mor	Mor	Mor	Mor	Mor	Dawn	Dawn	-	-
♂ <b>Mars</b>	AN	Eve	Eve	Eve	Eve	Eve	Eve	Eve	Eve	Dusk	-	-
♃ <b>Jupiter</b>	Eve	Eve	Eve	Eve	Dusk	-	Dawn	Mor	Mor	Mor	Mor	Mor
♄ <b>Saturn</b>	Eve	Dusk	-	Dawn	Mor	Mor	Mor	Mor	AN	Eve	Eve	Eve
♅ <b>Uranus</b>	Eve	Eve	Eve	Dusk	-	Dawn	Mor	Mor	Mor	Mor	AN	Eve
♆ <b>Neptune</b>	Eve	Eve	-	Dawn	Mor	Mor	Mor	Mor	AN	Eve	Eve	Eve

General visibility time of the planets in 2025.

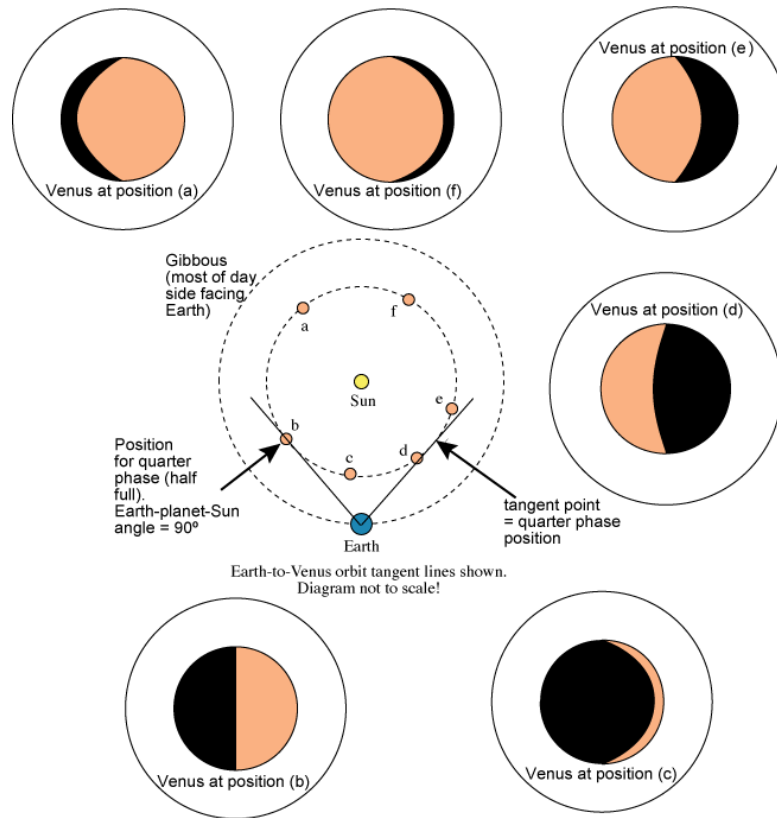
(AN meaning 'All-Night')

## 5.3 The 'Inferior' Planets

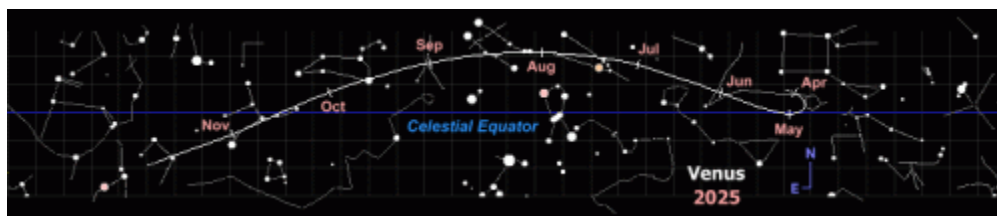
- For Mercury and Venus, this is the period during which the planet is well seen in either the morning sky or the evening sky.



- **Venus** is by far the easiest planet to see with the naked eye. It shines with a brilliant white light, although some claim that it has a slightly bluish tint. It is the brightest planet in the night sky; when visible, it outshines all the other planets - and indeed all the other stars in the night sky - at which time only the Sun and the Moon are brighter.
  - The phases of Venus were first observed telescopically by Galileo in 1610, using one of the world's first telescopes.
- The observation of Venus' Moon-like phases was an important discovery because it provided clear evidence supporting of the 'Copernican' (Heliocentric) system of planetary orbits (more on this later) rather than the 'Ptolemaic' (Geocentric) system.
  - Each apparition lasts for several months, during which time the planet slowly moves away from the Sun, reaches its **greatest elongation** (around 46 degrees away) and then slowly moves back towards the Sun, eventually disappearing into the morning or evening twilight (remaining visible for most of the time).
  - At greatest elongation, Venus rises/sets some 3 hours before/after the Sun.
  - Venus has a small orbital inclination, meaning its orbit is tilted only about  $3.4^\circ$  relative to the ecliptic. This is a relatively slight tilt, contributing to its nearly circular orbit, and means that **transits** of Venus are rare.



- Venus has a cycle of alternating morning and evening appearances and is popularly named The Morning Star (when seen in the Eastern sky before sunrise - see photo) and The Evening Star (when seen in the Western sky after sunset).
- **Mercury** is generally more difficult to spot than the other bright planets, mainly because, from the vantage point of the Earth, Mercury never appears very far from the Sun (between 17 and 28 degrees away, the variation being due to its highly eccentric orbit). Consequently, on most occasions it can only be seen with the naked-eye when it is low down in twilight, either shortly after sunset or before sunrise.
- Mercury needs to be viewed near **maximum elongation**. Certified filters must **always** be used due to its proximity to the Sun.
- Because Mercury and Venus are closer to the Sun than we are (i.e., their orbits are inside the Earth's orbit), they are never visible at around midnight (or opposite the Sun)

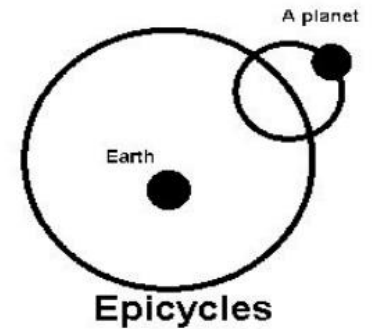


## 5.3 The 'Superior' Planets

- At midnight you are pointed directly away from the Sun so you see solar system objects above the horizon that are further out from the Sun than we are. (Note that this is true for latitudes sufficiently far from the poles---if you are close enough to the poles, then the Sun can be visible at midnight)
- For **Mars** and beyond, an apparition is measured from the time the planet becomes visible in the dawn sky (rising shortly before the Sun) to the time it disappears into the dusk sky (setting shortly after the Sun).
- **Mars** is easily recognised since it has the most distinctive coloration of all the naked eye planets. Although it is popularly called '*The Red Planet*', it rarely appears red to the naked eye; in fact, it varies from pale orange-yellow to orange-red, depending upon its distance from the Earth and therefore, its brightness.
- Because of its eccentric orbit, Mars' distance from the Earth varies considerably from one *opposition* to the next, which typically take place about every 2 years and 7 weeks
- Because they mostly occur around dawn and dusk, a conjunction can be difficult to observe (depending on the observer's latitude and the local season).
- Jupiter appears bright white and is a very obvious sight in the night sky. Like Venus, it can be seen in twilight, and it always shines brighter than the brightest star in the night sky - Sirius (magnitude -1.4). Viewed from the Earth, Jupiter is seen to move through about one zodiac constellation (ca. 30 °) each year.
- Steadily-held, good quality binoculars or a small telescope will show Jupiter as a small white disk; its four brightest natural satellites (moons) - Ganymede (magnitude +4.6 at opposition), Io (+5.0), Europa (+5.3) and Callisto (+5.6) - can also be seen close by, changing their positions from one night to the next.
- Ordinarily the planets ``wander" eastward among the stars (though staying close to the ecliptic)

## 5.5 Retrograde Motion of Planets

- The image shows 29 overlaid images of the planet Mars taken in 2003.



- Ancient Astronomers even as early as Ptolemy were aware of this odd “wobble” in planetary motion.
- Ptolemy believed that each planet moved in its own **epicycle** around Earth (remember that Earth is the centre of the Universe at this point)
- Galileo, Copernicus and Newton disputed this idea as notions of gravitation developed.

### What is actually happening?

- All planets orbit the Sun in the same direction (prograde motion) but at different speeds.
- Apparent **retrograde motion** occurs when a planet appears to **move backward** (westward) for a short period before resuming normal eastward motion.
- This happens because Earth **overtakes** an outer planet in its orbit (or an inner planet overtakes Earth in the case of Mercury and Venus).
- **Superior Planets:** (Mars, Jupiter, etc.): Retrograde motion happens when the planet and Earth are at opposition.
- **Inferior Planets:** (Mercury, Venus): Retrograde motion occurs when the planet is at inferior conjunction.

# retrograde motion

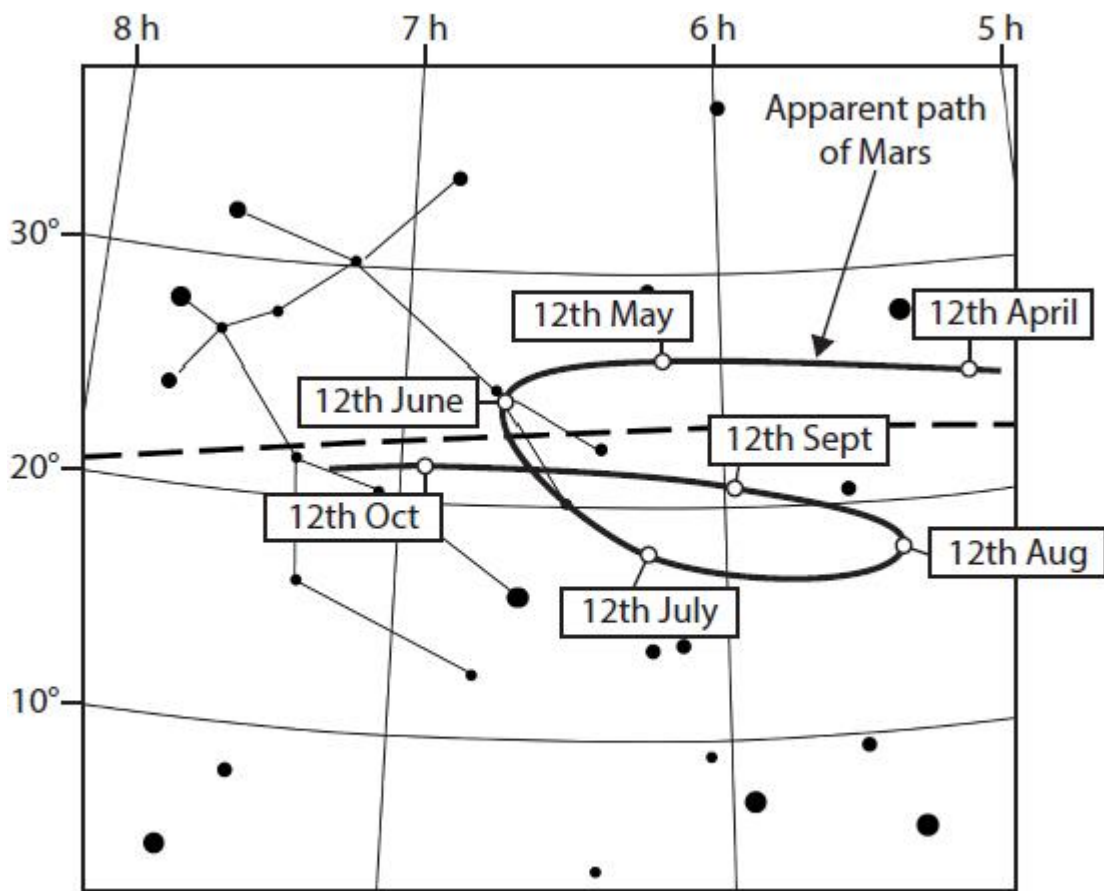
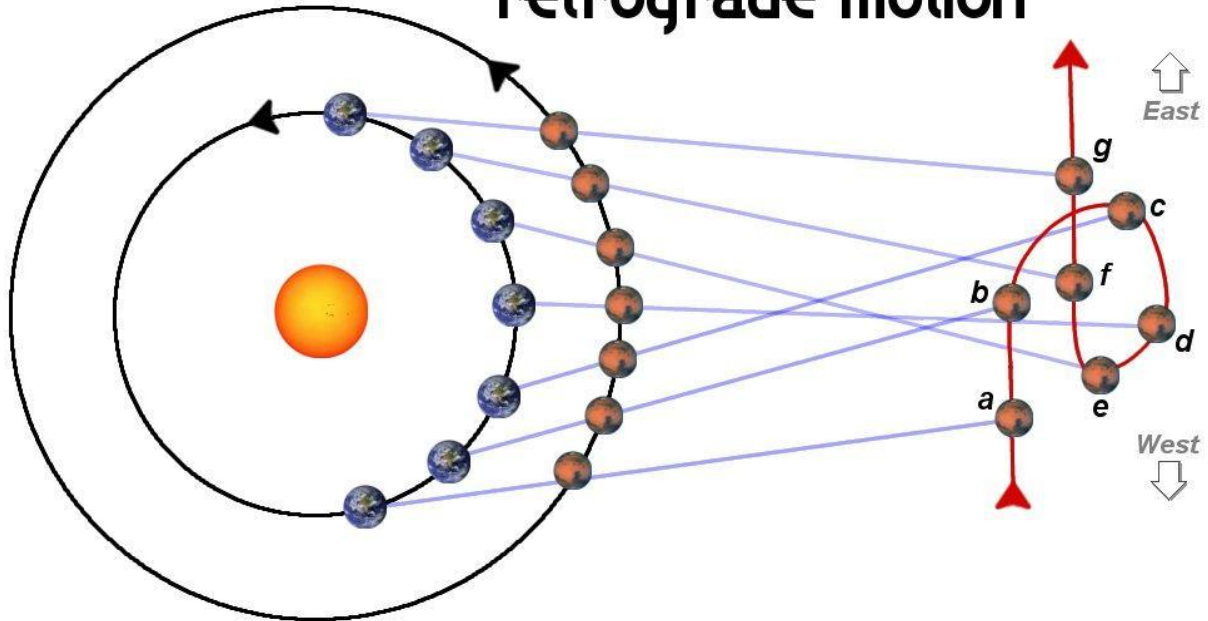
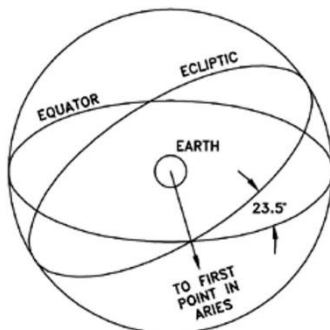
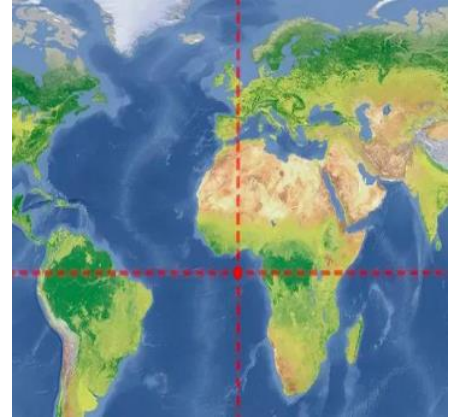


Figure 2

## 5.6 First Point of Aries

- On the Earth's surface we use the Latitude and Longitude grid to locate places.
- In the same way we need a reference grid to navigate the sky, which we call 'The Celestial Sphere'.
- The celestial equivalent of latitude is called **declination** and it is the angle measured above and below the  $0^\circ$  line which is the celestial equator (the projection of Earth's equator into space). It is at  $23.5^\circ$  to the ecliptic.
- Just like with longitude, defining the 'meridian' lines in the sky is a bit more tricky - you just have to choose a zero line. Astronomers chose '**The First Point of Aries**' to define this line.



- **Right ascension** is an astronomical coordinate that specifies an object's position on the celestial sphere, equivalent to longitude on Earth. It is typically expressed in units of time (hours, minutes, and seconds), where 24 hours represents a full  $360^\circ$  circle

- We use is the point at which the Sun crosses the **celestial equator moving from south to north** along the ecliptic (at the vernal Equinox). This point is known as the '**First Point of**

**Aries**' because in 150 B.C. when Ptolemy first mapped the constellations, Aries lay in that position.

- However, although still named the 'First Point of Aries', due to precession, the vernal equinox now lays in the constellation Pisces.
- The First Point of Aries is usually represented by the 'ram's horn' symbol.
- So instead of giving latitude and longitude lines to locate somewhere in the sky, astronomers use **declination** and **right ascension** (or RA and dec for short).

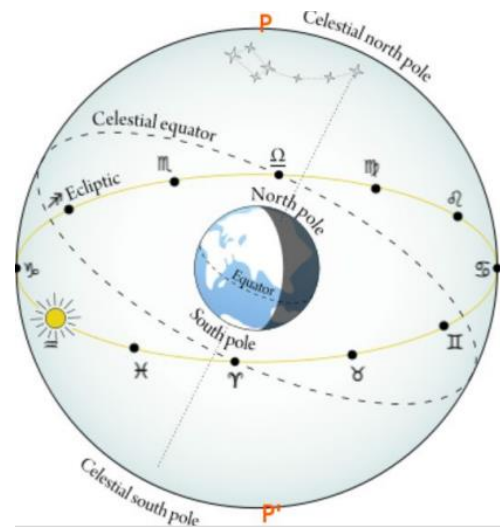


- An example of coordinates in right ascension and declination for **M31 The Andromeda Galaxy: RA 0h 42m 44s | Dec +41° 16' 9"**
- RA is measured in hours, minutes and seconds. (If you lined up a telescope along RA 0h0min0s then 1 hour later the Earth would have turned by 15 ° and your telescope would be looking at RA 1h0min0s).
- Dec is just the angle you would tilt your telescope to above or below the ecliptic. So, to find M31 you could line up with RA 0h0min0s, wait 42min and 44s and tilt your telescope to 41 ° 16' and 9" (16/60 or minutes of arc and 9/3600 or seconds of arc) and, hey presto!



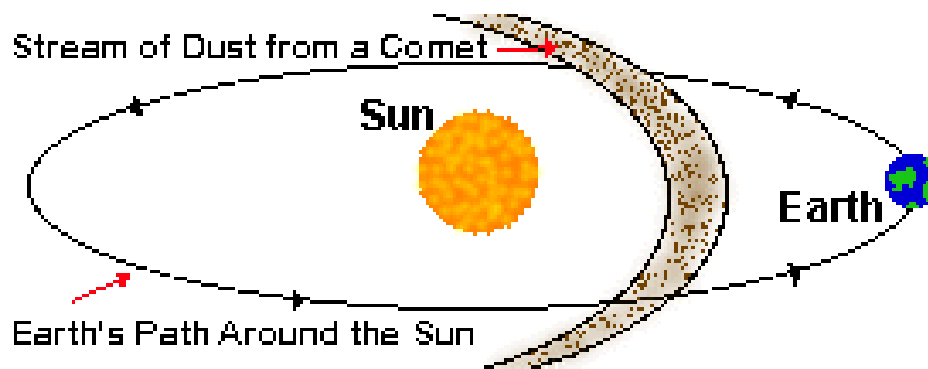
## 5.6 First Point of Libra

- The First Point of Libra on the celestial sphere is **diametrically opposite** the first point of Aries. It is the same as the autumnal equinox. It has right ascension 12h and declination zero. It is the point at which the Sun passes from **north to south of the celestial equator**. (Because of precession, it no longer lies in Libra but in neighbouring Virgo)



## 5.7 Meteors and Meteor Showers

Term	Definition
Meteoroid	A meteoroid is a small piece of space rock, smaller than an asteroid but larger than dust, that orbits in space. Meteoroids are often fragments of asteroids or comets that have broken off.
Meteor	Meteoroids which burn up in the atmosphere of a space body, such as the Earth, prior to impacting on the surface.
Meteorite	Fragments of material that fall from space and impact on other larger space bodies.
Meteor shower	Earth passes through the trail of meteoroid debris left by passing comets. As these meteoroids enter Earth's atmosphere at high speed, they burn up from friction with the air, creating the streaks of light we call meteors or "shooting stars". Because Earth follows a predictable orbit, it encounters these debris trails at the same time each year, resulting in annual meteor showers.
Comet	Frozen masses of gas and dust which have a definite orbit through the solar system.



- A meteor shower is assigned a **radiant**; an apparent point in the sky from which the meteors of a shower seem to originate (imagine a series of roads or train tracks which appear to 'spread out' from a point of convergence on the horizon despite actually being parallel)
- A meteor shower is assigned a **radiant**; an apparent point in the sky from which the meteors of a shower seem to originate (imagine a series of roads or train tracks which appear to 'spread out' from a point of convergence on the horizon despite actually being parallel)
- Finding the radiant point of a meteor shower is one of the **GCSE Astronomy Observational Tasks**, in both Unaided and Aided lists so we need to be able to plan an observation.



- Here is an example of a method you could use to record observations to estimate the radiant point of the Geminid meteor shower which occurs around 14 December every year.
  - First, prepare a recording sheet for your observations - see the next slide for an example.
  - Next, sketch onto it some key stars and constellations that you know you can recognise. (You can use Stellarium to help with this)
  - Record date, time and location
  - Sketch observed meteor trails as they occurred
  - Extend the dotted lines back, with a ruler, to see where they intersect at the estimated radiant.

