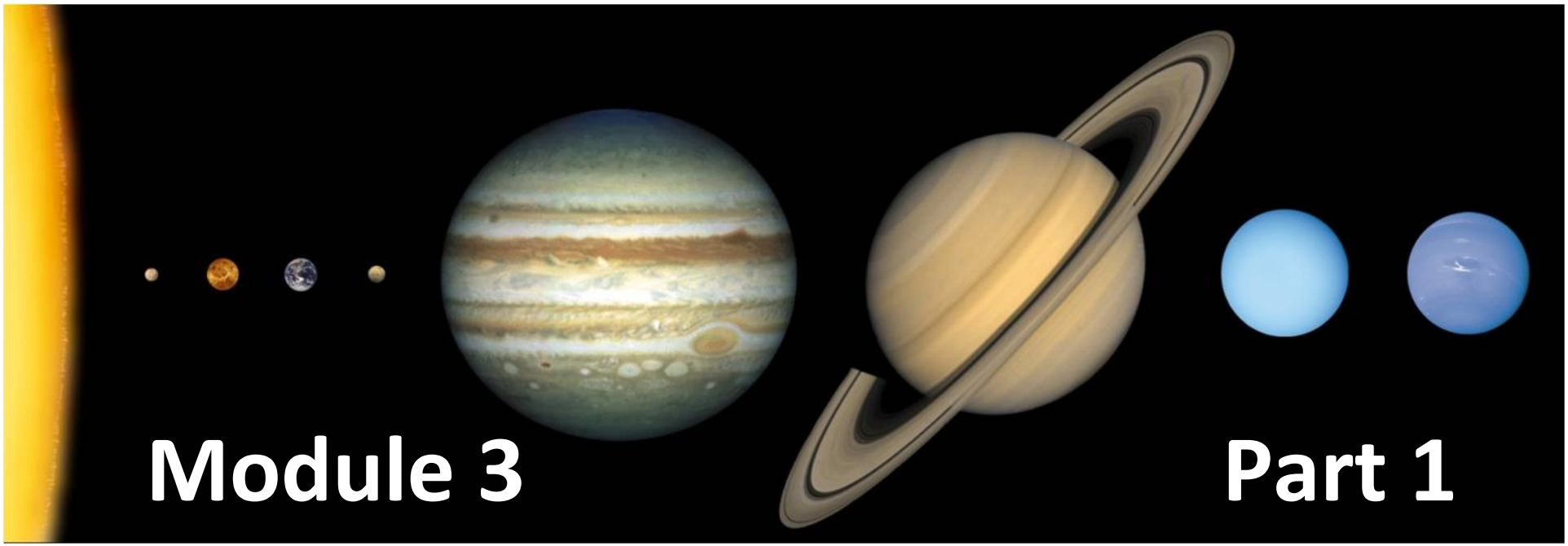
Earth Sciences 2150 – Fall 2022

Solar System and Planetary Science



Historical and Modern Observations of the Solar System: The Early Days

EASC 2150: The Solar System
The Plan for Today (Part 1)

A history of our understanding of the heavens, and overview of our Solar System

- The long human interest in the heavens (often for the wrong reasons) and what we have learned – and where the terminology we use comes from.
- The ways in which we are able to gain information about the Solar System and try to understand it….this is a very general introduction, with more details to follow.
- A quick overview of the components that make up the Solar System, and the emphasis that we'll place on each.
- We will progressively introduce the "Big Picture"

Human Observation of the Solar System and Heavens

- Looking at the skies is an ancient human activity; possibly older than agriculture (and linked to it).

- Our ancestors were limited to what they could see without aids.

- The Sun is visible because of the light it emits. Other objects in our solar system are visible because they reflect sunlight. Stars twinkle. We could always see them and wonder what they were, and found connections with seasons.

Many different computer software packages are available to help explore the skies. This stuff was recorded thousands of years ago, although we do not many records from those times…..

• The oldest known ***written records*** of organized astronomical observation come from the Sumerian civilization (~3,000 BCE) in the Middle East. Sumeria was ultimately incorporated into the Babylonian Empire, which continued making astronomical observations. But why did they have this interest in stargazing?

Astronomy slowly grew from the less scientific ideas of astrology: the prediction of future events by observing celestial events.

- Sumerian baked clay tablets such as this one recording observations of the planet Venus exist from as early as 3,200 BCE. A lunar calendar exists from the same period.

- Later Babylonian tablets still in existence include star catalogues from the 8th century BCE and "astronomical diaries" from the 7th century to the 1st century BCE. These diaries represent the earliest real 'astrological' records.

• Stone circles with supposed astronomical significance are found in many places in the world. Stonehenge dates from **~3,000 BCE** but other similar features (usually made from wood and not as well preserved) were built elsewhere in Europe as long ago as **5,000 BCE**.

How it works

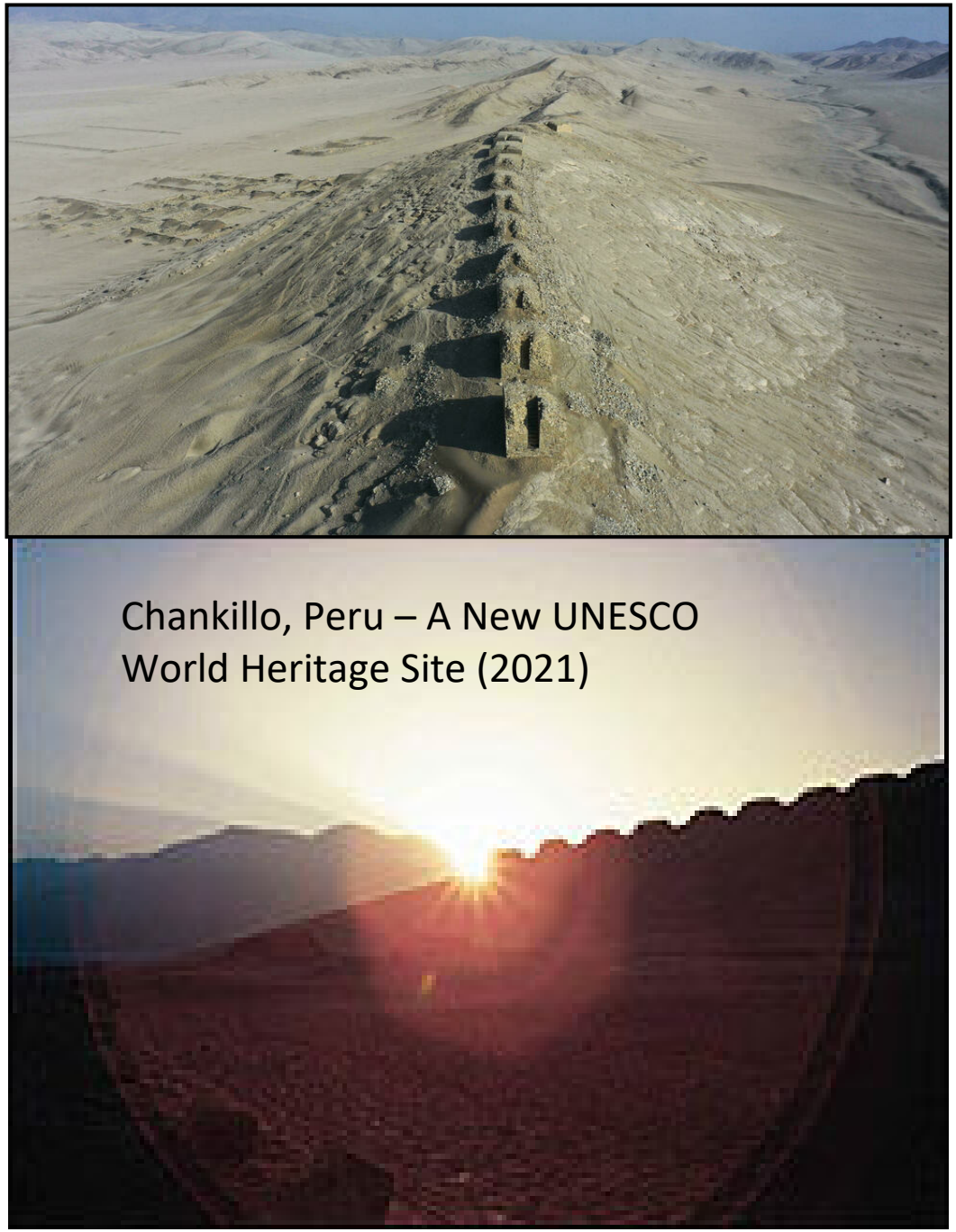
- In fact, policing the crowds who come to the site in June has become a major challenge……

- At each summer solstice, spring equinox etc. the sun rises through the opening in a different standing stone. Some modern Britons still gather at Stonehenge on June 21st.

• Medicine Wheels are possibly equivalent structures built by the plains Indians of western North America using small stones. This one, the Bighorn Medicine Wheel in Montana, is only a **few hundred years old**. The oldest wheel known, which is in Majorville, Alberta, dates from the same period as Stonehenge (i.e. **~3,000 BCE**). They are commonly aligned with astronomical parameters.

What was the Purpose of these Structures?

- The various circles appear to be a form of calendar, converting astronomical observations of the Sun into dates for the start of spring planting, fall harvest *etc.*
- The direction defined by the centre and one of surrounding stones is the direction from which the sun rises at the summer solstice.
- The directions defined by the centre and the other stones gives directions from which the Sun rises on the first day of Spring etc.
- These dates had practical significance for planting and harvesting crops as well as religious significance (e.g. rebirth of the world in spring).
- Fundamentally, these are **calendars**…..although it's possible that some also might have seen the occasional grisly sacrifice……pure speculation.



Chankillo, Peru – A New UNESCO World Heritage Site (2021)

- The 'Medicine Wheels' are not definitively seen as observatories. The oldest astronomical observatory in the Americas is in Peru, on a mountain ridge.

- Like the structures at Stonehenge, those at the site (~ 4th century BCE) site discovered near Lima, Peru, align with the directions of sunrise and sunset at the time of the summer and winter solstices. But they are now slightly inaccurate. Why?

- In addition to ‘routine’ observations there are reports of unusual events.

- Like a meteorite that landed near the town of Ensisheim, Germany in 1492. There were other reports of suddenly bright stars, perhaps like the Star of Bethlehem. Reports are hard to verify.

Practical versus Theoretical Astronomy

- In the Babylonian Empire (the first empire large enough to have government bureaucrats) an accurate calendar was essential for business, administration, as well as agriculture.

- Astronomy had a **purely practical aspect** to the Babylonians. There is no evidence that they were interested in gaining a scientific understanding of what they observed.

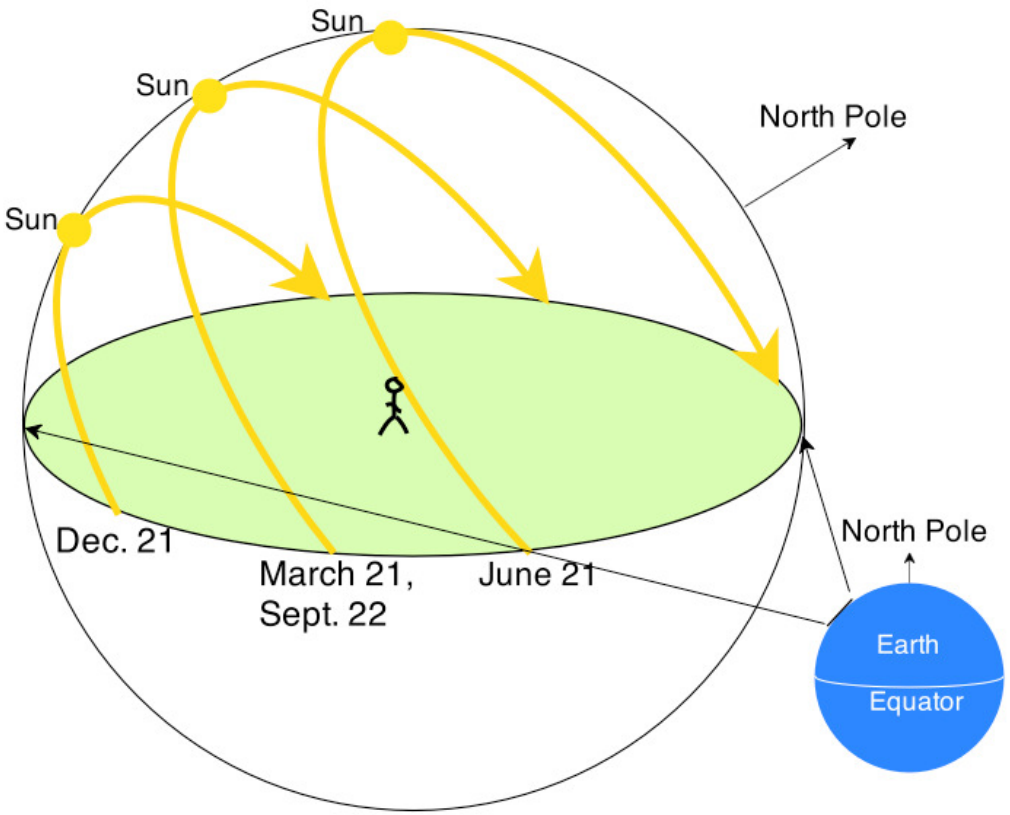
- Similarly, the standing stones, the Medicine Wheels and comparable structures all appear to have been designed to act as calendars rather than to understand motions of the heavenly bodies. Tracking time and seasons, mostly…..

- Nevertheless, observations made from these early structures indicated **COMPLEXITY**. What did it all mean?

Things that ancient astrologers or thinkers could readily observe on a recurring basis

- The daily motion of the sun through the sky.
- The changes in sunrise, sunset, day length and the position of the sun in the sky with the passing of seasons.
- The path of the Moon through the sky and the phases of the Moon, defining the concept of months (although Lunar Months are not the same as Calendar Months).
- The stars, and their patterns – which remain fixed, even though the individual constellations move with night, day and the seasons.
- Some peculiar stars that appear to 'wander' through the stars in a rather predictable (but unusual) pattern.
- Interesting but scary events like solar and lunar eclipses.

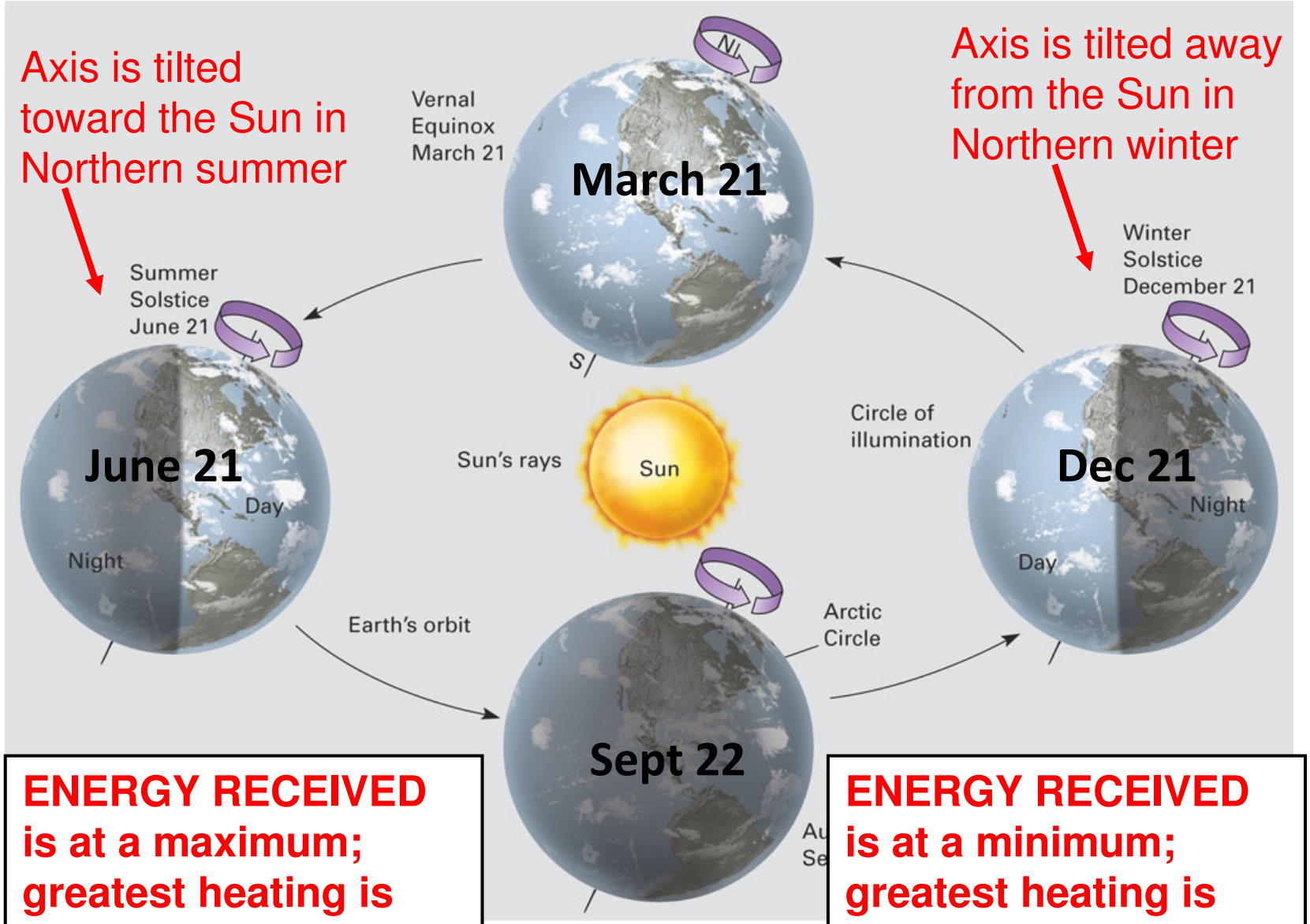
The Sun's Path



An observer in the northern hemisphere sees the Sun travel on daily paths through the sky that vary as shown here. These paths define summer and winter solstices, and the two equinoxes.

- The Sun follows a daily path through the sky, appearing over the horizon approximately in the east and disappearing below the horizon approximately in the west.
- The Sun's daily path through the sky changes over the course of a year, being highest above the horizon in summer and lowest in winter.
- The length of the day changes with the seasons and is only rarely the same length as the night.

Seasons result from the tilting of the Earth's rotation axis; either the north or south is tilted towards the sun.



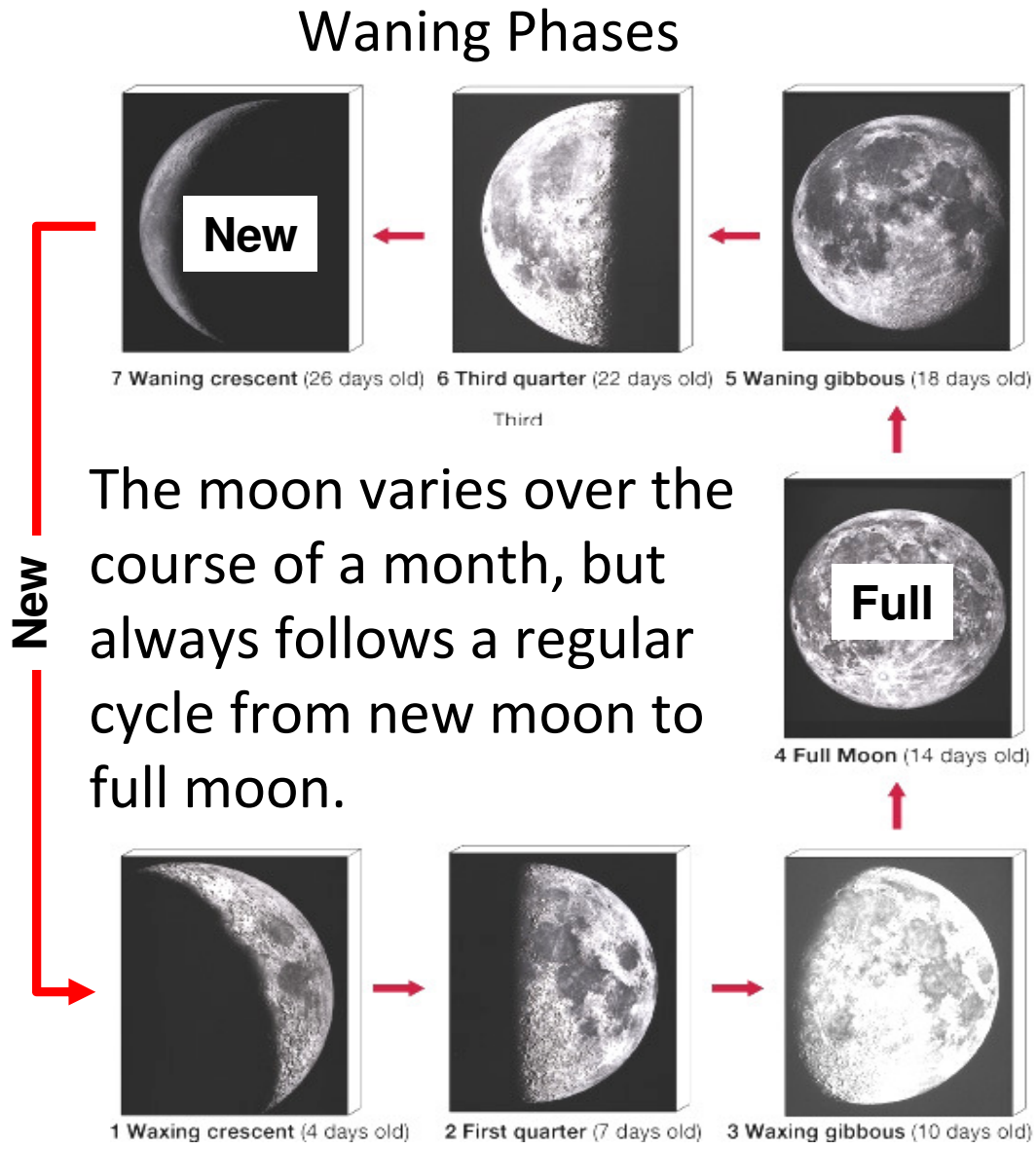
ENERGY RECEIVED is at a maximum; greatest heating is North of the equator.

ENERGY RECEIVED is at a minimum; greatest heating is South of the equator.

Understanding the Solar Calendar – A Matter of Surviving and Food Supplies

- The quest to understand the seasons and develop a calendar is probably one of the first aspects of astronomy that we developed. It is the origin of many ‘festivals’.
- The winter solstice is a time of celebration (Christmas) as it means that spring will come again. It predates Christianity.
- The Spring equinox (vernal) is a time to start planting crops in the northern hemisphere; the Fall equinox (autumnal) marks the beginning of harvest time.
- We think of these patterns as **permanent**, but over time there is a wobble in Earth’s rotation – it ‘precesses’. There will come a time when June, July and August correspond with the northern winter. Calendars shift in deep time.

Phases of the Moon

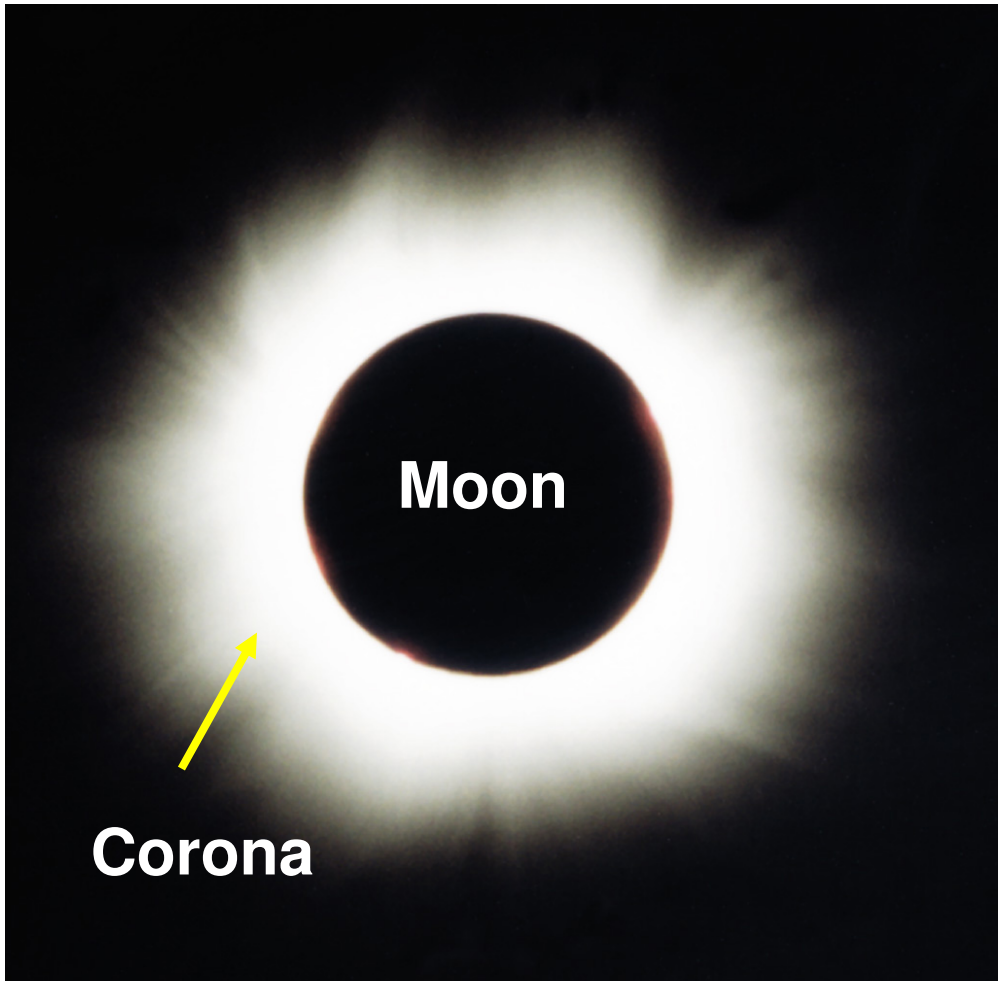


The moon varies over the course of a month, but always follows a regular cycle from new moon to full moon.

- Like the Sun, the Moon follows an E-to-W path through the sky on a daily basis and is higher or lower in the sky with the seasons.
- A full moon appears on the eastern horizon at dusk.
- Waxing (growing) phases are at variable distances through their E-W transit at dusk.
- Waning (shrinking) phases appear on the eastern horizon part-way through the night.

Solar Eclipses – Total and Partial

- Occasionally there is a partial or total **eclipse of the Sun**.
- These eclipses occur **only** when there is a new moon.
- **But there isn't a solar eclipse every time there is a new moon, and they are seen only in certain places.**
- **Eclipses were always seen as malevolent events – certainly very scary events for early peoples.**
- Can we predict them ?



Total solar eclipse – here we see the solar corona (atmosphere), which is normally invisible to us.

Lunar Eclipses – Total and Partial

- More often, we see a **lunar eclipse** in which the Moon. becomes darkened briefly. We don't always notice them.
- Lunar eclipses happen **only when there is a full moon**
- But there isn't a lunar eclipse **every time** there is a full moon. Could they also be predicted on a regular cycle?

• This sequence of images taken during a lunar eclipse shows the full moon being progressively cast into shadow. These were scary in their own way – such as 'blood moons'

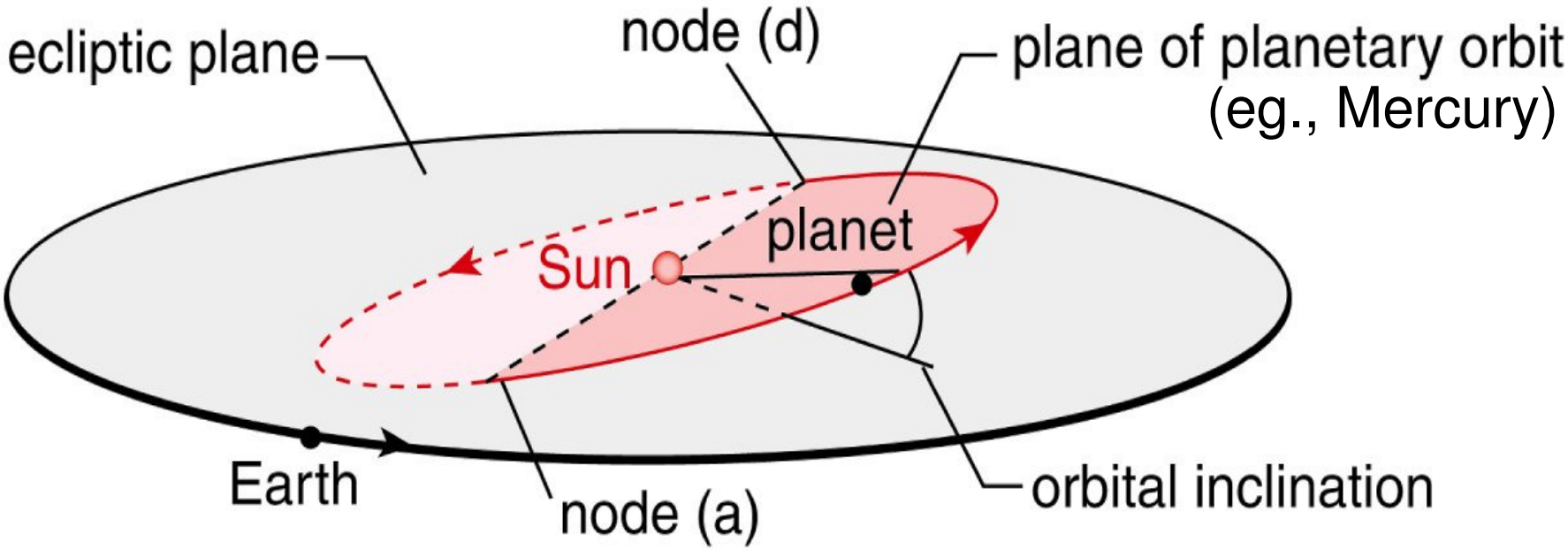
- There was a blood moon eclipse on May 26, 2021. I think it was cloudy in St. John's.

- These are associated with eclipses, and form when the the light from the Sun has to pass through the atmosphere to reach the Moon.

Causes of Solar Variations and Eclipses

- We now understand these effects well, but there were many steps in reaching this point – challenges were related to the prevailing concept that WE are the centre of the Universe, which of course is not true.
- The Sun rises and sets because of Earth's rotation; the variations through the year are due to inclination of the Earth's rotation axis, which changes the apparent path.
- The phases of the Moon record changes in the degree of lunar illumination from our viewpoint, as the Moon orbits around us. **The dark side of the Moon is NOT always dark!**
- Eclipses occur when the Moon's shadow moves across the Earth, or the Earth's shadow moves across the Moon.
- **All these result from orbital motions in the Solar System.**

Then Came the Concept of the Ecliptic Plane

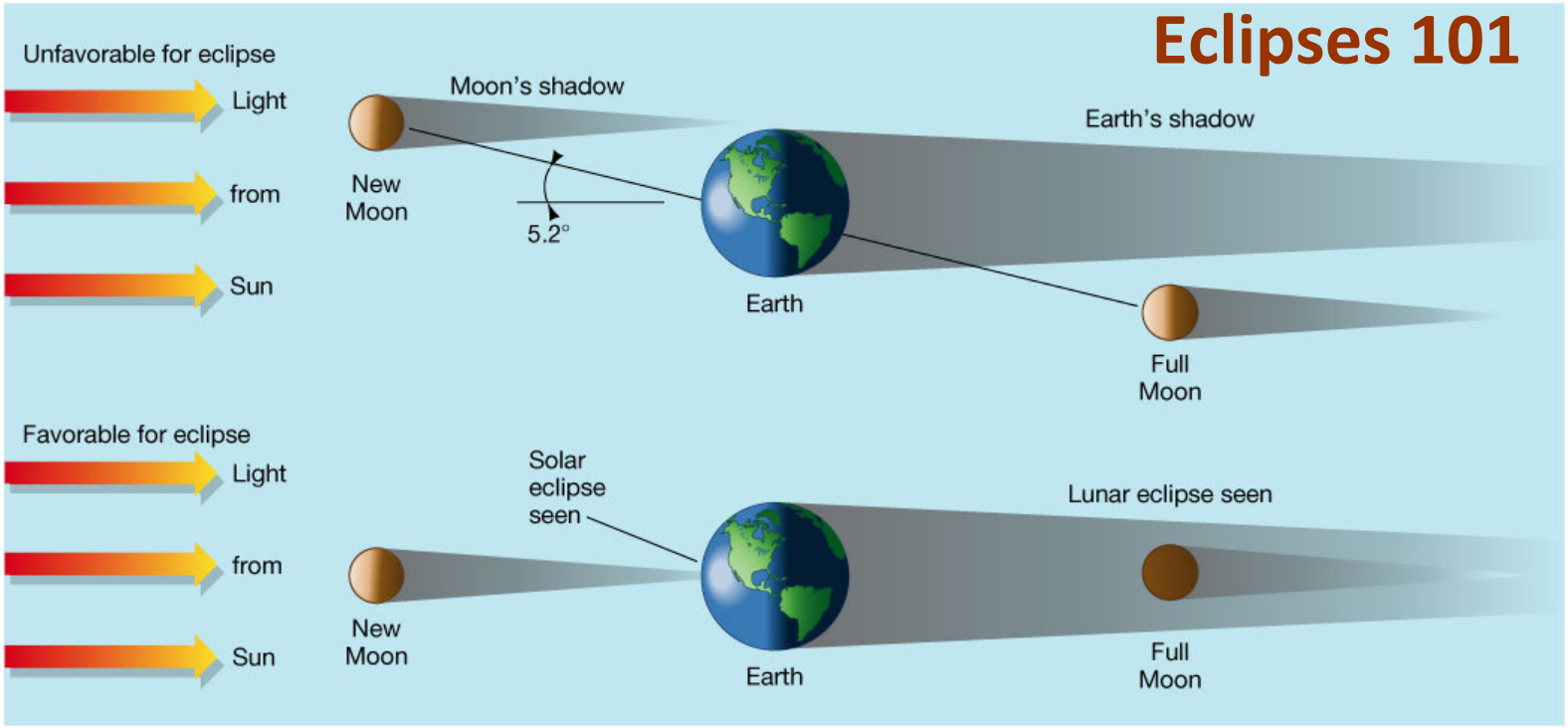


• The 'ecliptic plane' is defined by the Earth's orbit around the sun. It is called this because ***eclipses can only occur in this plane – this allows the moon to come between us and the sun.*** Not all planets orbit in the ecliptic plane, but most are close to it. A 'node' is a crossing point on the plane.

Why the prediction of eclipses is tricky

- Much effort went into the prediction of eclipses by early astronomers, but not always for reasons of science!
- Eclipses do not occur on a monthly basis whenever there is a new moon. They ***only*** can occur when the Moon crosses the ecliptic plane…….
- This is because the Moon's orbit around us is not precisely in the same plane as our orbit around the Sun (the ecliptic). A solar eclipse requires that the Moon be at a 'node' at the same time as a new moon (between us and the Sun).
- With a knowledge of these motions, eclipses can be predicted, and this is easily done with computers. The ancients managed fairly well, but did so from careful study of historical records. Eclipses show defined periodicity….

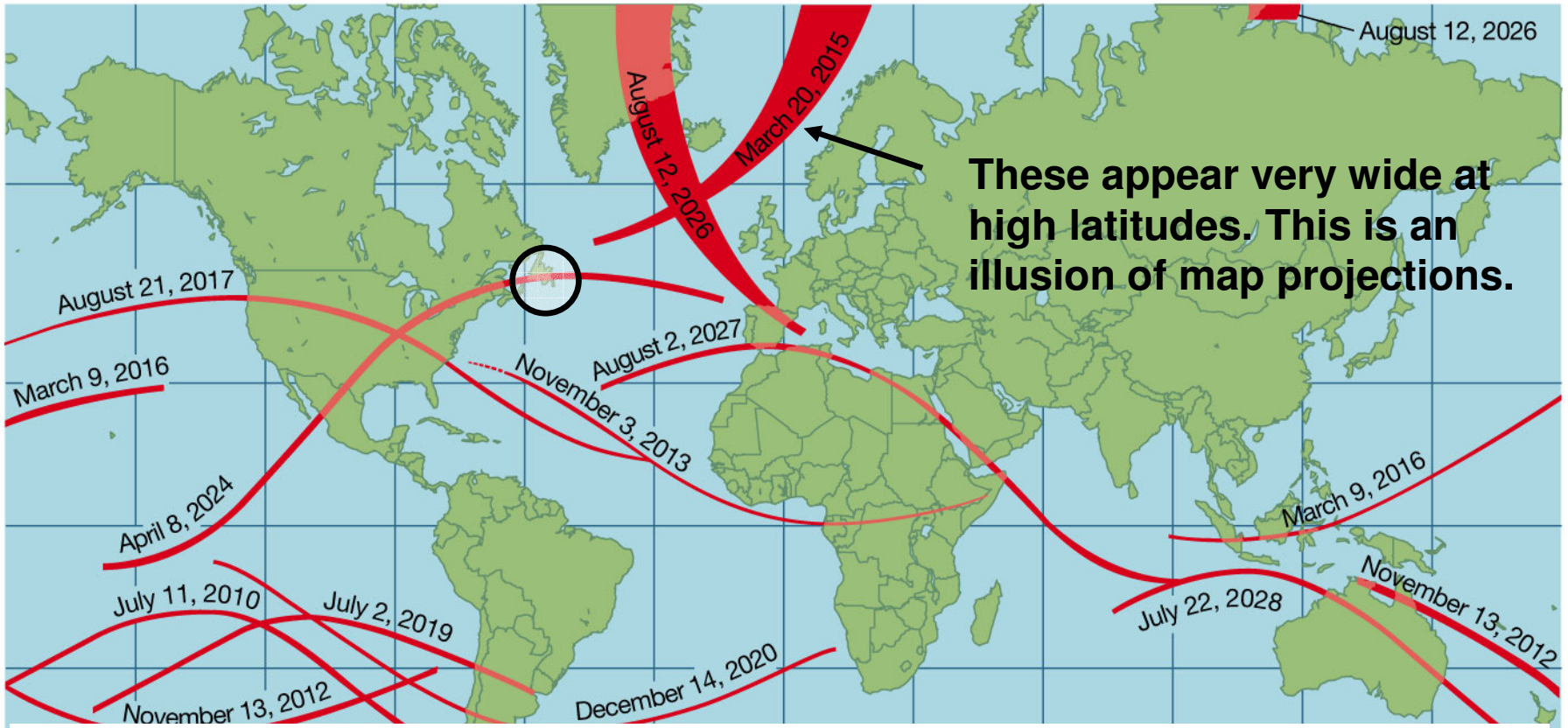
Eclipses 101



(a)

- The upper panel shows what happens most of the time; the Moon is **out of the ecliptic**, so its shadow does not touch Earth, and our shadow does not touch the Moon.
- Only when the Moon ***is in the ecliptic plane can an eclipse occur*** – note that only the tip of the Moon's shadow touches the Earth, but our shadow affects the entire Moon. Only a narrow band on Earth will experience a 'total eclipse'.

The tracks of eclipses – shadow paths



- The Moon's shadow is much too small for it to block the sun everywhere on Earth, so the 'path of totality' is narrow. In April 2024 (if it's clear) there will be a total eclipse of the sun here. The width of the track also depends on the distance between Earth and Moon, which is not constant.

Stars, Constellations, Planets and the Ecliptic

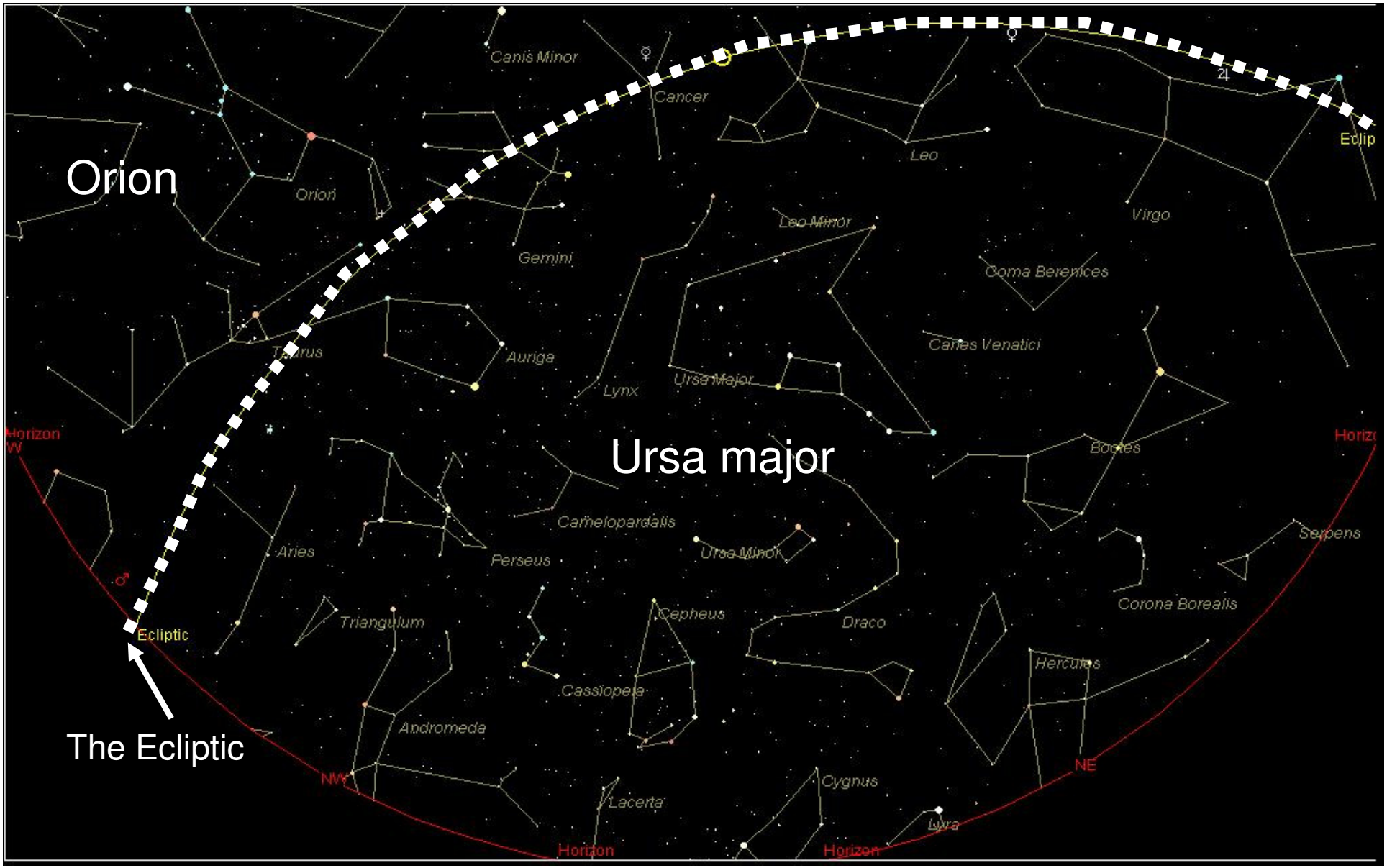


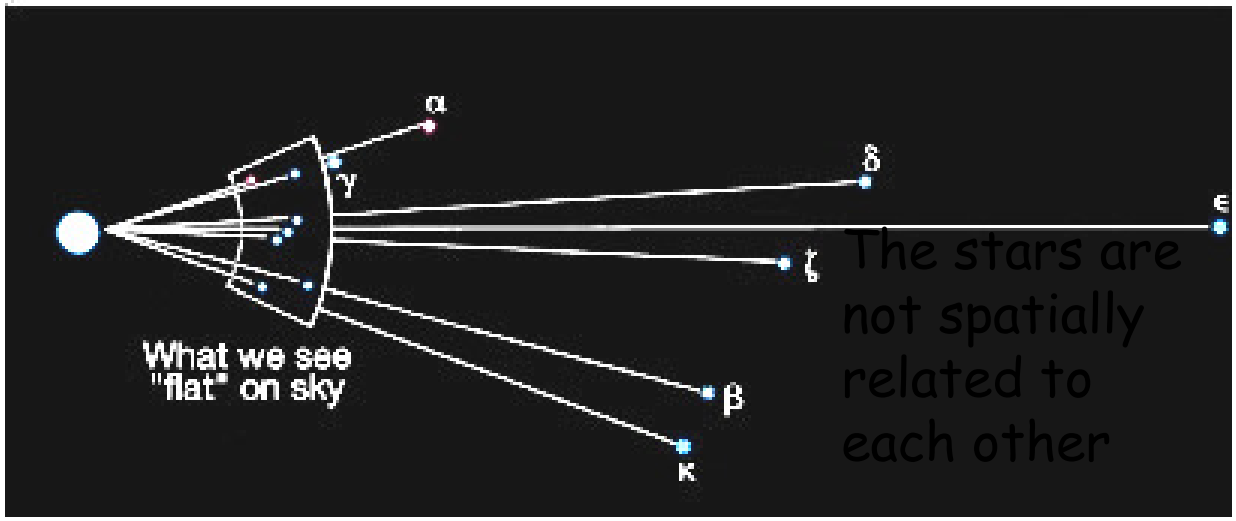
Image produced by Sky Chart – The Most Familiar Constellations

The Stars – Rather Different Behaviour

- The stars pass across the night sky from E to W on a daily basis just as do the Sun and Moon.
- The patterns of stars (called **the constellations**) appear fixed as they move across the sky.
- But unlike the Sun and Moon, specific constellations are visible from a particular location on Earth *only* during certain times of the year. Some are only visible from one hemisphere – e.g., the Southern Cross.
- However, the constellations always return to their same locations at the same time from one year to another. So they are **very** predictable.
- Some very useful stars (e.g. Polaris) are fixed, at least with reference to *our* history. We navigate by them. But, again – things changes over time.

Pattern of stars in the constellation Orion

Fanciful interpretation of the pattern



- The sky is divided into 88 **constellations**.

The Constellations are groupings of stars that form what we humans interpret as patterns.

The individual stars of any constellation often exist at very different distances from Earth. Their patterns are accidental and would look quite different if viewed from another location in the galaxy.

Constellations – Fanciful but Useful

• Even though constellations are essentially random configurations of stars to which humans have assigned significance, constellations do play one important role in astronomy – they are the basis of 'heavenly geography'

• They divide the visible sky into regions and so provide useful quick references for locations of objects in the sky.

• **Some Examples:**

• The meteor shower that appears every year in late July and early August known as the ***Perseids*** is centred in the region of the sky containing the constellation ***Perseus*****.**

• The ***Orion Nebula*** – a region of stellar formation – sits within the constellation ***Orion*****.**

The Planets – The Wandering Stars

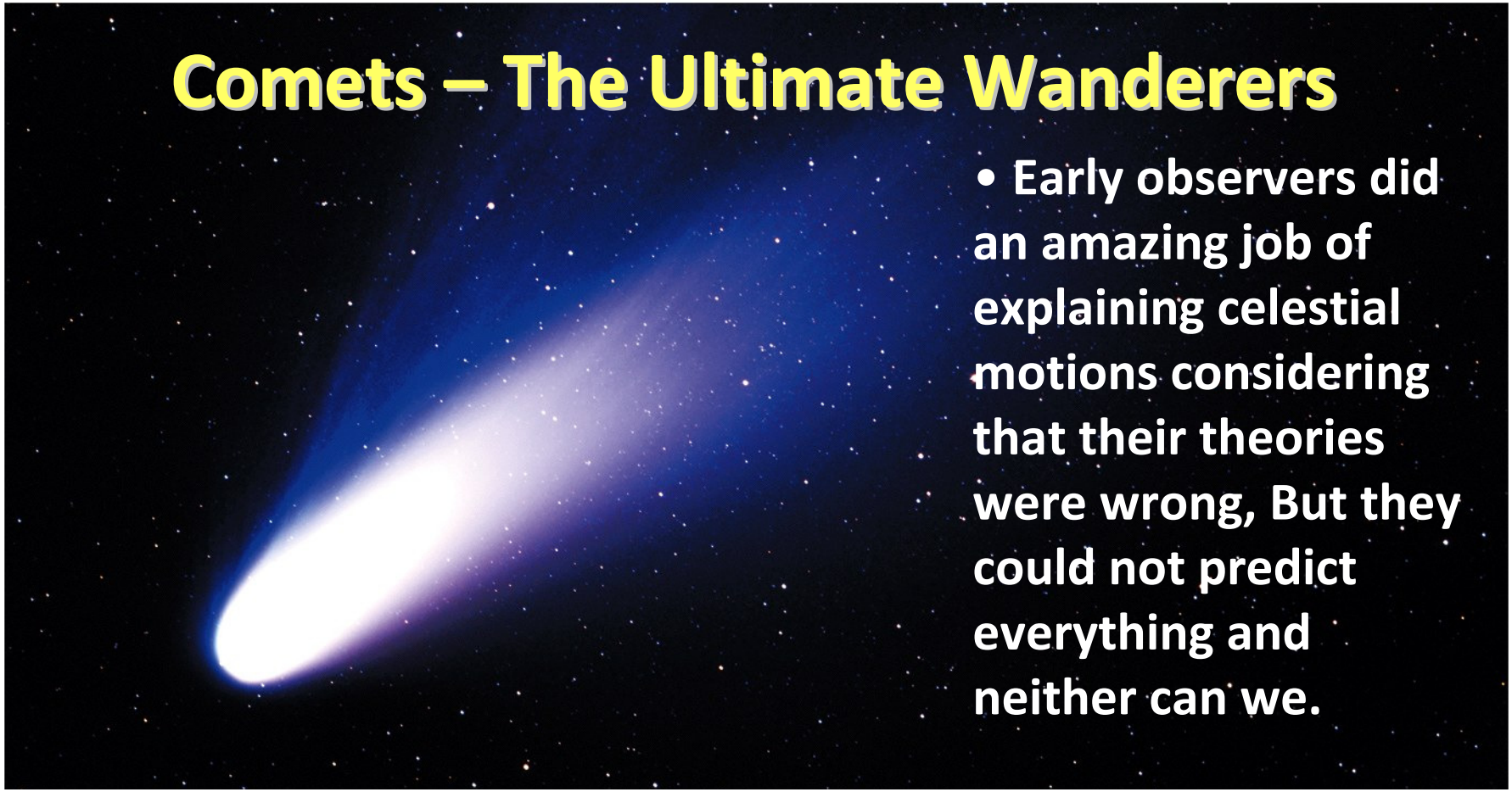
- Planets are different. *Over the course of one night*, planets move from E to W along with the stars.
- *Over the course of many nights*, a planet doesn't stay fixed relative to the stars but (*usually*) appears to travel slowly from **W to E through the fixed patterns of stars**. All move through the same general 'sky track' – the Ecliptic plane.
- This motion relative to the pattern of the stars is the origin of the word **planets**, which comes from the ancient Greek word for "travelers" or "wanderers".
- Five planets are visible with the naked eye and were known to the ancient astronomers: **Mercury, Venus, Mars, Jupiter** and **Saturn**.
- The **Sun** and **Moon** also move against the background of stars, and so these were also considered as planets by the ancient astronomers.

The Zodiac and the Ecliptic

- The Sun, the Moon and the planets all appear to travel across the sky in approximately the same path or 'plane', which is known as the **plane of the ecliptic**. Eclipses will always be in this plane.
- As planets travel along the ecliptic they appear to move from W to E against a background of 12 specific constellations known as the **zodiac**, which have supposed astrological significance.
- These constellations are the ones we are most familiar with, and the 'signs of the Zodiac' are the constellations where the Sun would sit with respect to at a time of the year. However, you can't see the sun and stars together.
- For example, I'm a **PISCES**, born on March 3rd. What sign are you? And does it really make any difference?

Celestial Motions – What Do They Mean?

- We now understand all this, but it caused problems in the past – again, because of our Earth-centred view.
- The movement of the stars is clearly due to the Earth's rotation, but the ancients thought of them as a distant rotating 'Celestial Sphere'. Similarly, the planets were assumed to move around the Earth in some defined fashion on 'spheres', so that they moved through the 'backdrop' of the Celestial Sphere, because they were **inside** it.
- However, at certain times, planets appeared to 'backtrack' ("retrograde motion") – they would go from West to East for a while, and then head off West again. Pretty strange.
- This particular type of behaviour was very difficult to explain, but an explanation ***was*** developed –it did give a ***mostly*** consistent answer, but it was actually wrong.

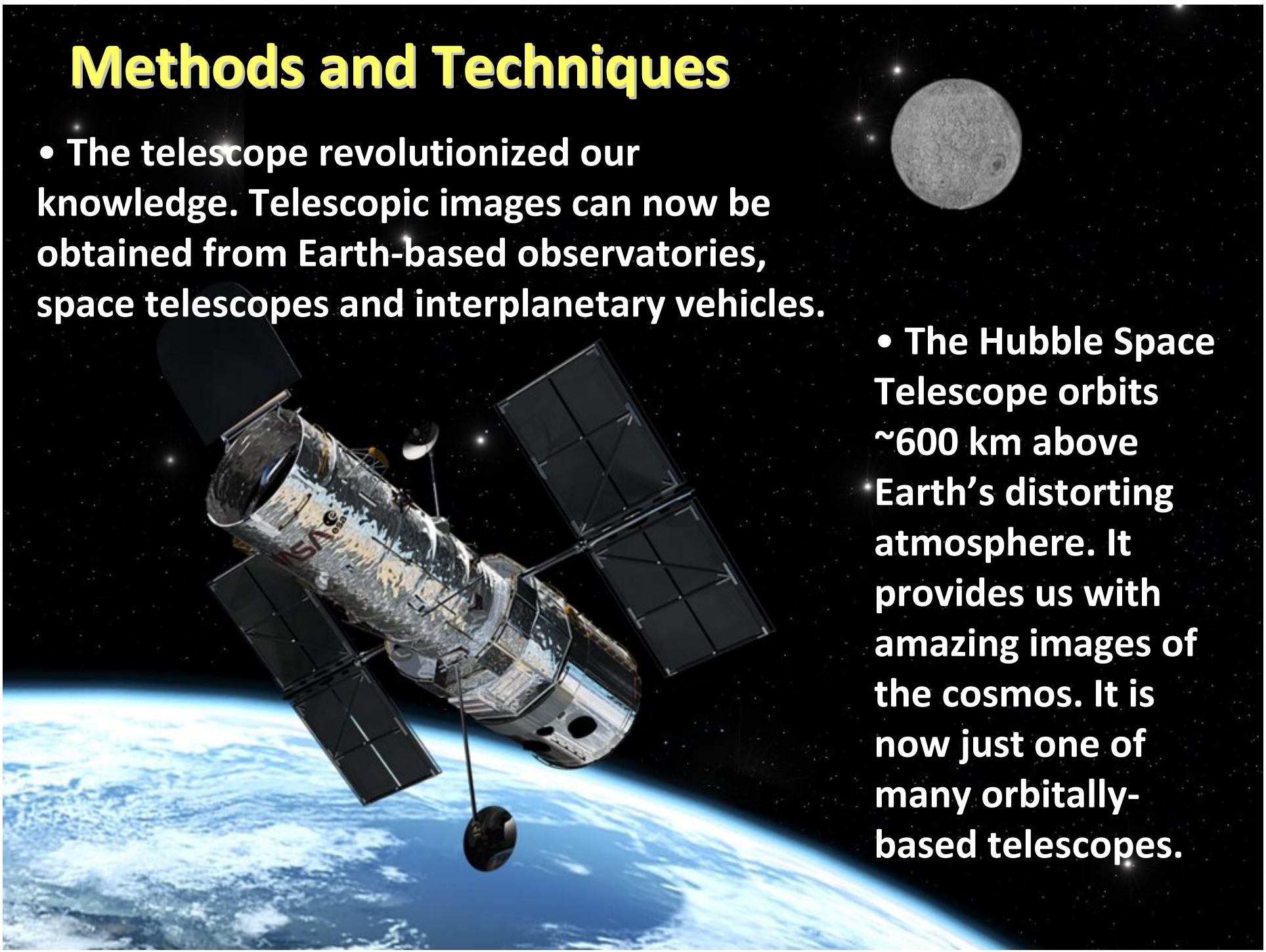


- Other things observed for centuries seemed not to have patterns – like comets, for example. Their appearance and locations were not really predictable, and some would be seen only by one generation of observers. The same applies to Supernovae – suddenly bright stars. What are these ?

- We are in a very different era of exploration and science, but we still have only actually visited one other world.

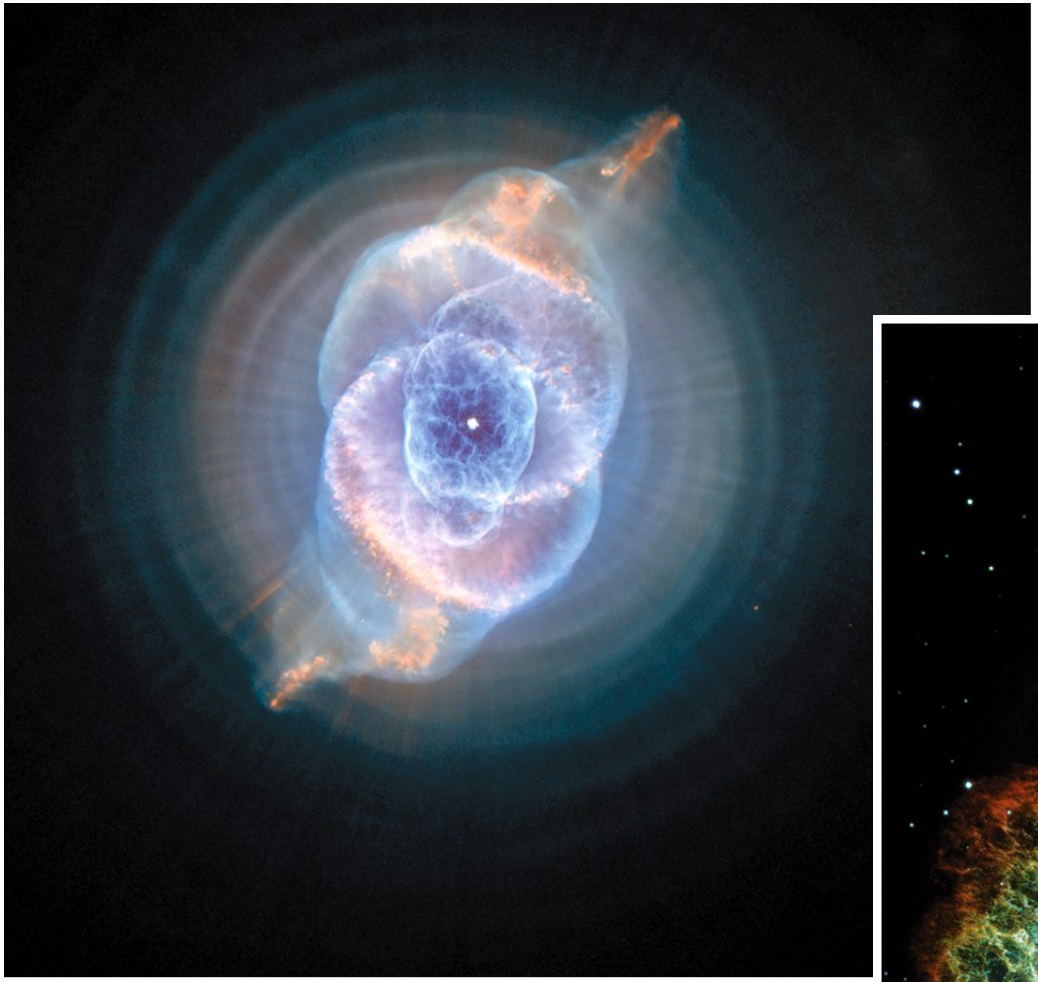
Methods and Techniques

- The telescope revolutionized our knowledge. Telescopic images can now be obtained from Earth-based observatories, space telescopes and interplanetary vehicles.



- The Hubble Space Telescope orbits ~600 km above Earth's distorting atmosphere. It provides us with amazing images of the cosmos. It is now just one of many orbitally-based telescopes.

Cat's Eye Nebula



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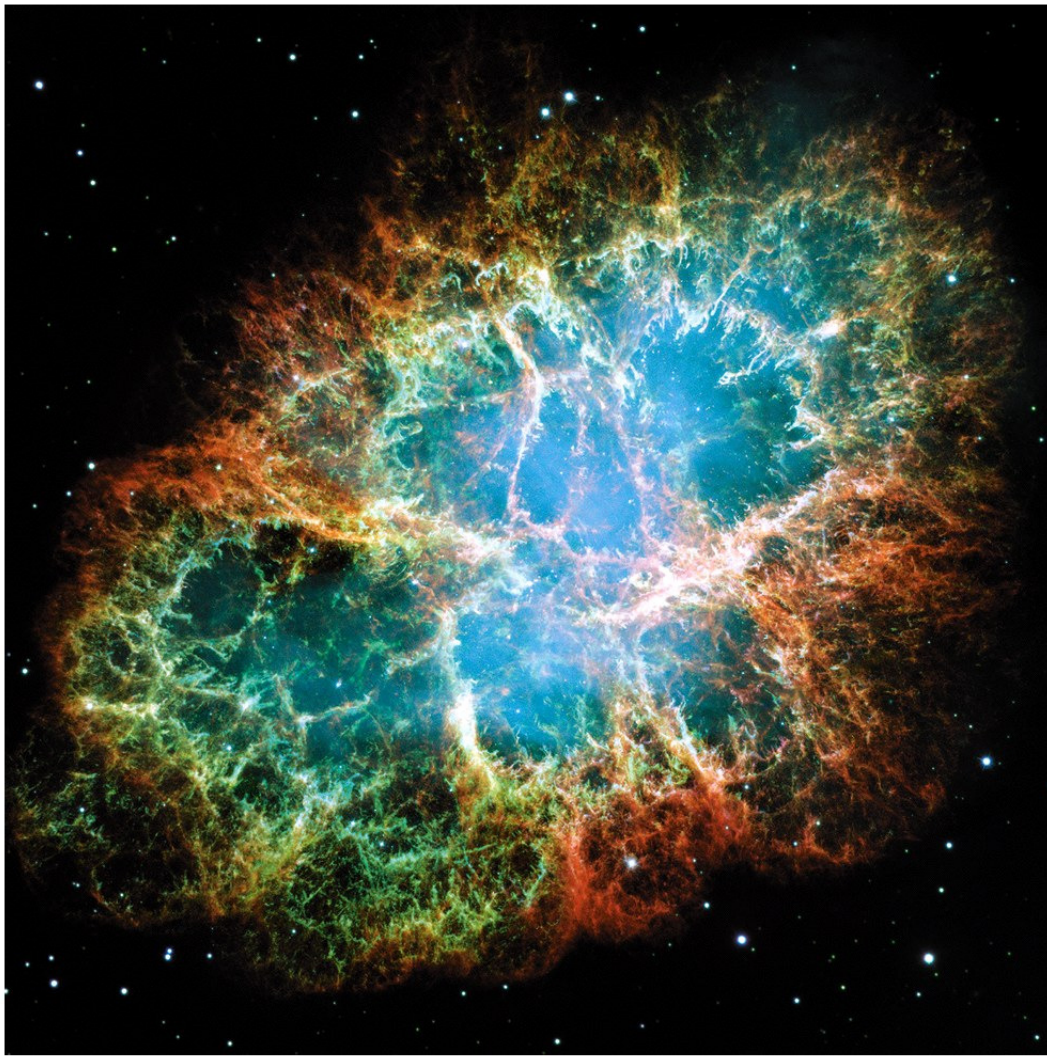
NASA/NG Image Collection

Crab Nebula

Hubble Images



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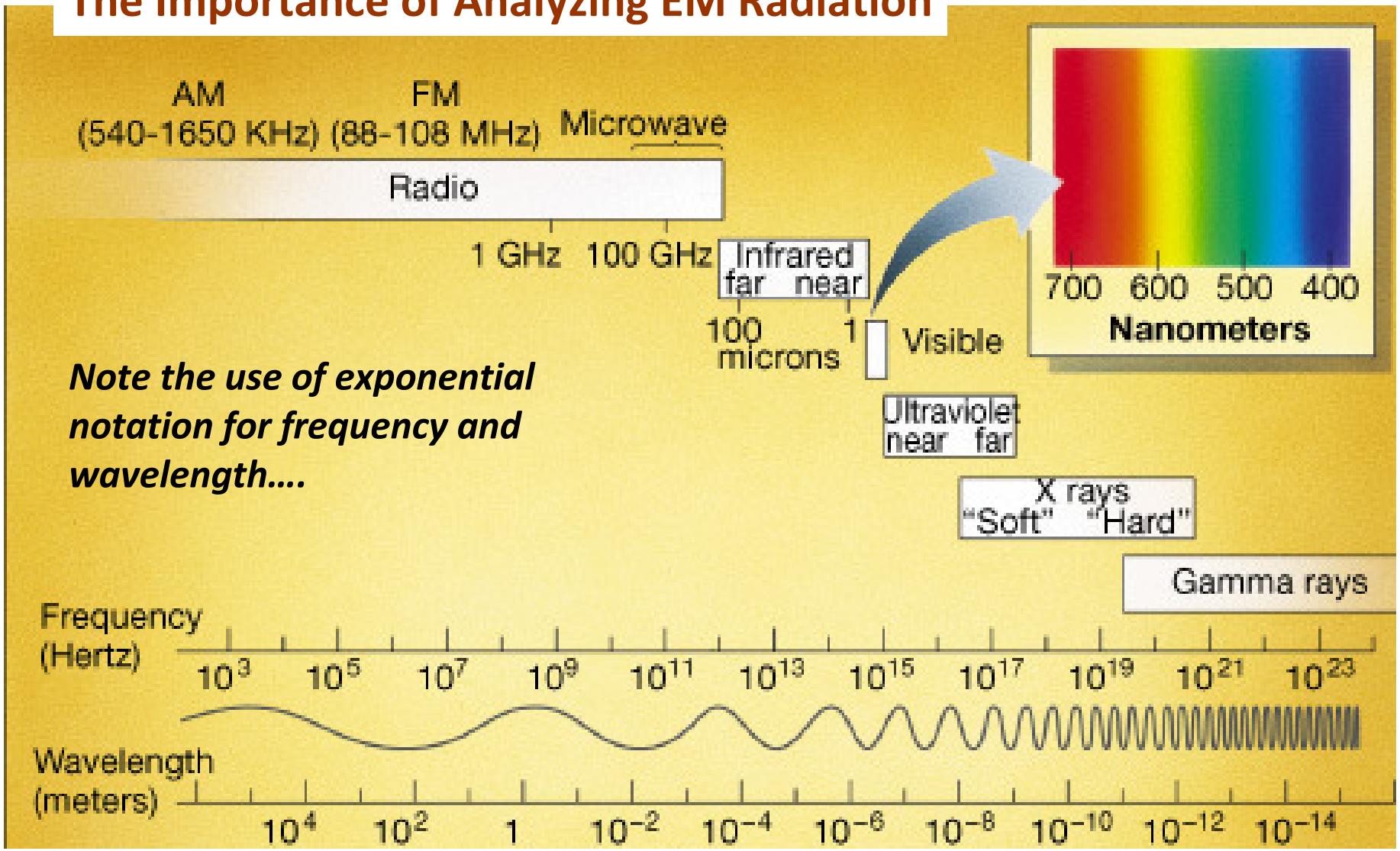
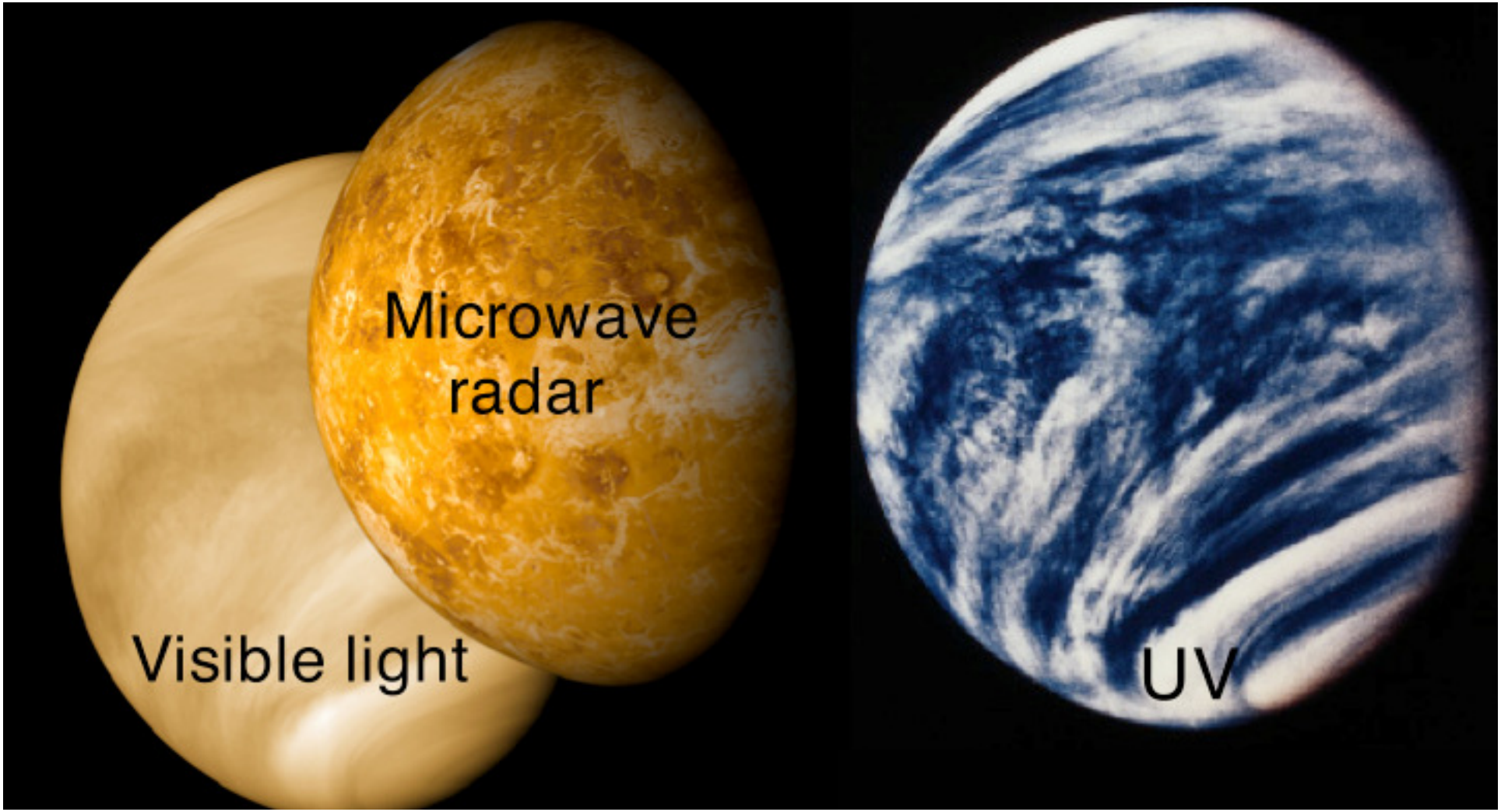
The Importance of Analyzing EM Radiation



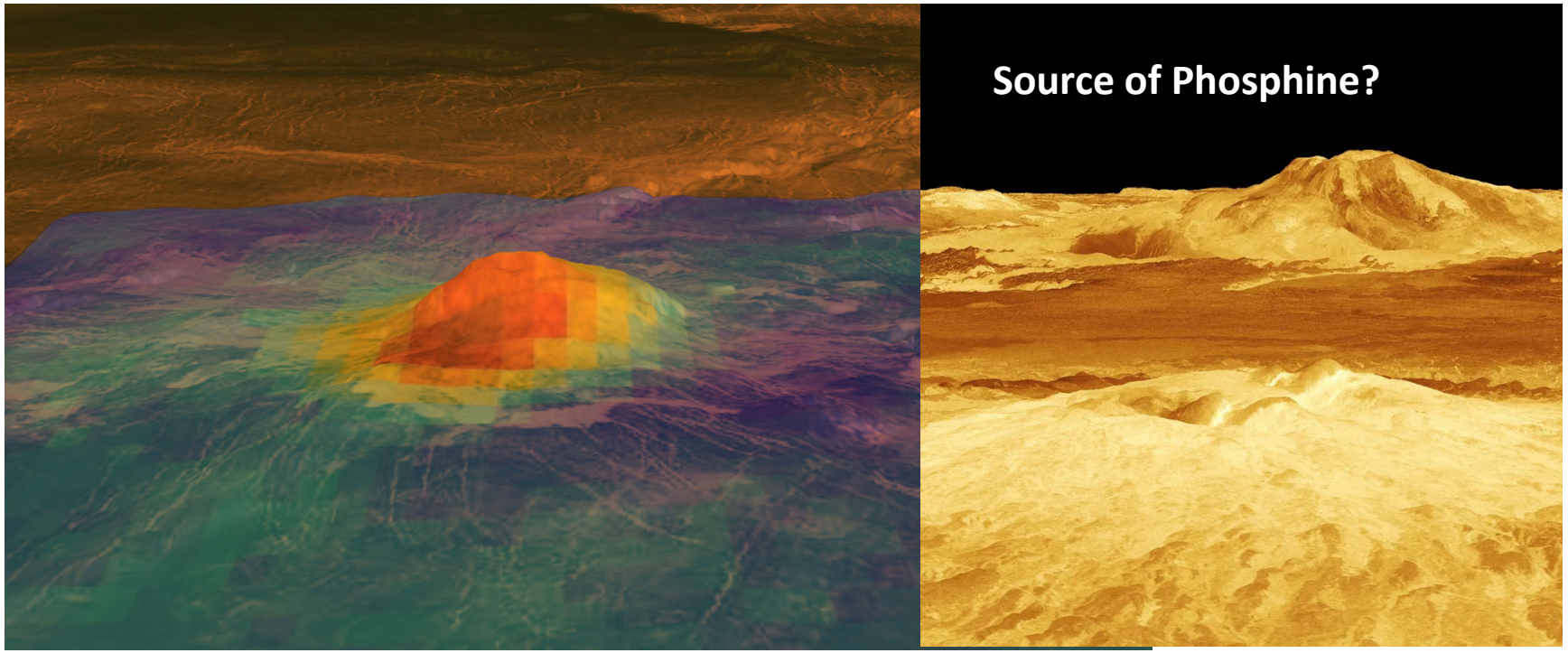
Note the use of exponential notation for frequency and wavelength….

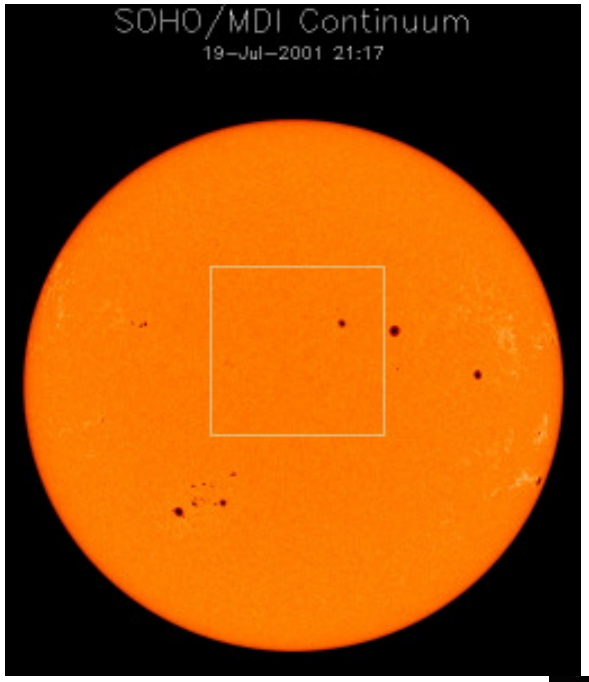
Our eyes respond only to visible light but telescopes can use other parts of the electromagnetic spectrum as well. These provide very different information and images. **Spectroscopy** is critical!



Venus is a mystery, and visible telescopy told us next to nothing. Its surface is obscured by clouds. Using UV gives a different picture of the clouds, although we don't fully understand it. But by using longer wavelength RADAR methods we can get information about surface features. But not with the same resolution and accuracy.

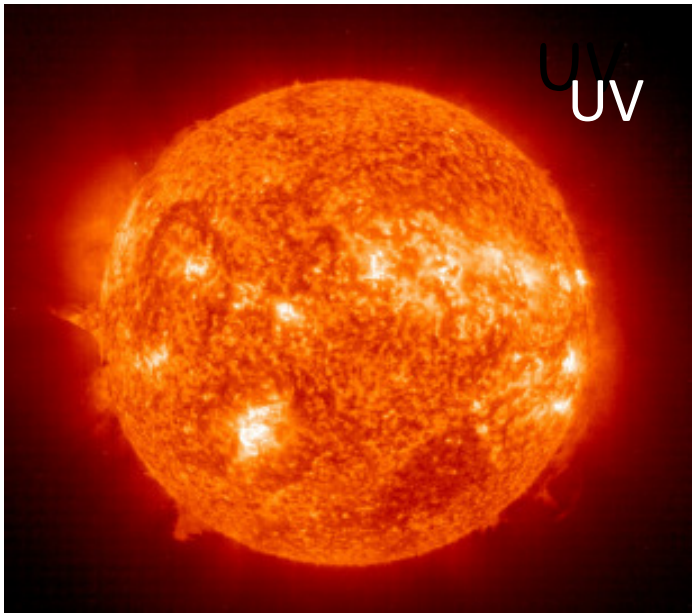
- **Venusian volcanoes – a simple radar image (yellow is false colour) of a large area. The other shot is a 3D image of topography (exaggerated) showing spectral data. The volcano is different to areas around it, suggesting that it is geologically young……..**

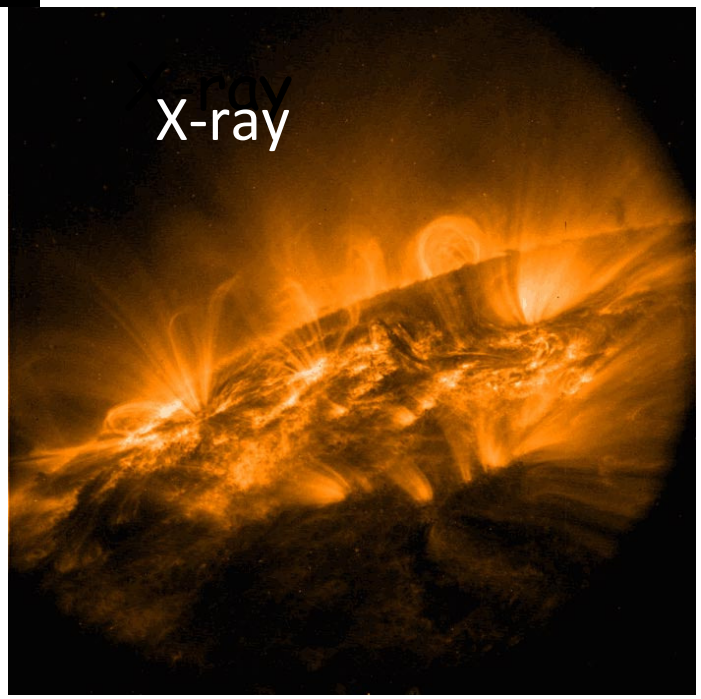




Visible Light

The Sun as seen in different parts of the E-M spectrum





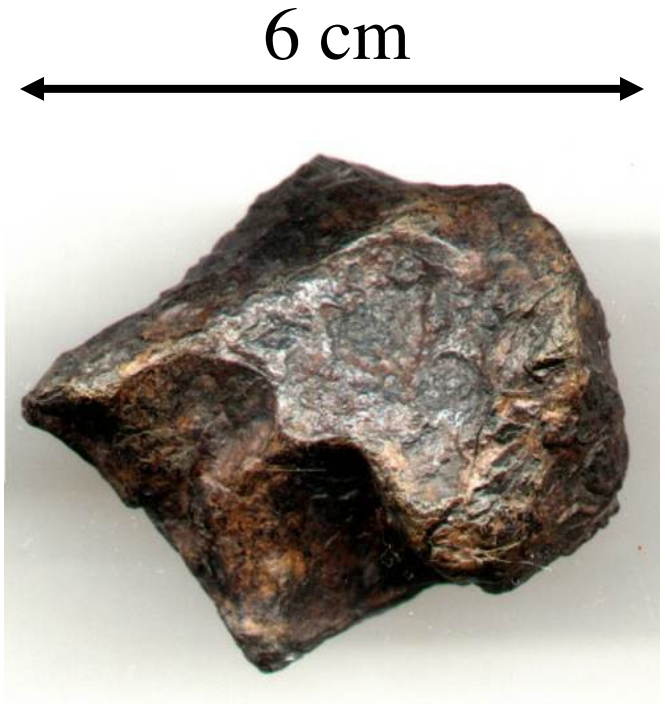
- In all three cases shown here, the energy is generated by the Sun, but the spectral balance is varied on the surface. Sunspots are more energetic regions.

Remote Sensing Methods and their Power

- Remote sensing techniques have given us amazing insight into other planets, and the development of these methods for space exploration has in turn led to new views of the Earth from satellite observation. Space science benefits us!
- Laser altimetry provides images of the surface of the Moon and Mars that give incredible topographic resolution, so that we can interpret surface features.
- Infrared methods give us information about the absorption of solar energy and re-radiation – these provide proxy information about minerals and composition.
- Measurements of gravity and magnetic fields give us information about the internal structure of other planets and bodies.

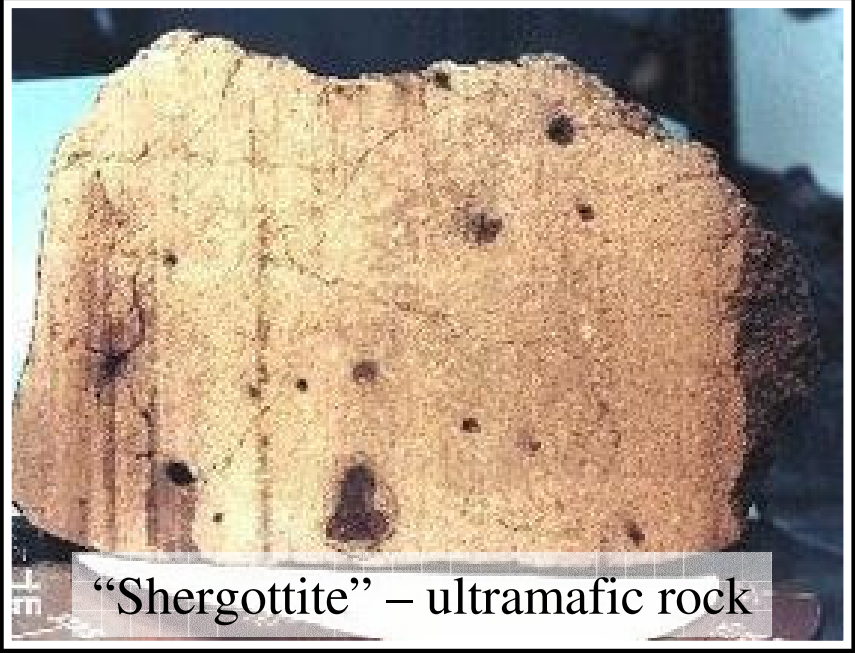
Direct samples of material from elsewhere in the Solar System arrive on Earth as rare meteorites.

The Barringer crater of Arizona formed ~50,000 years ago as a result of the Canyon Diablo meteorite colliding with Earth.



This is a fragment of the Canyon Diablo meteorite. The whole thing was probably ~100 m in diameter. Most of it was vapourized – no iron ore!

Magical Messenger Meteorites from Mars



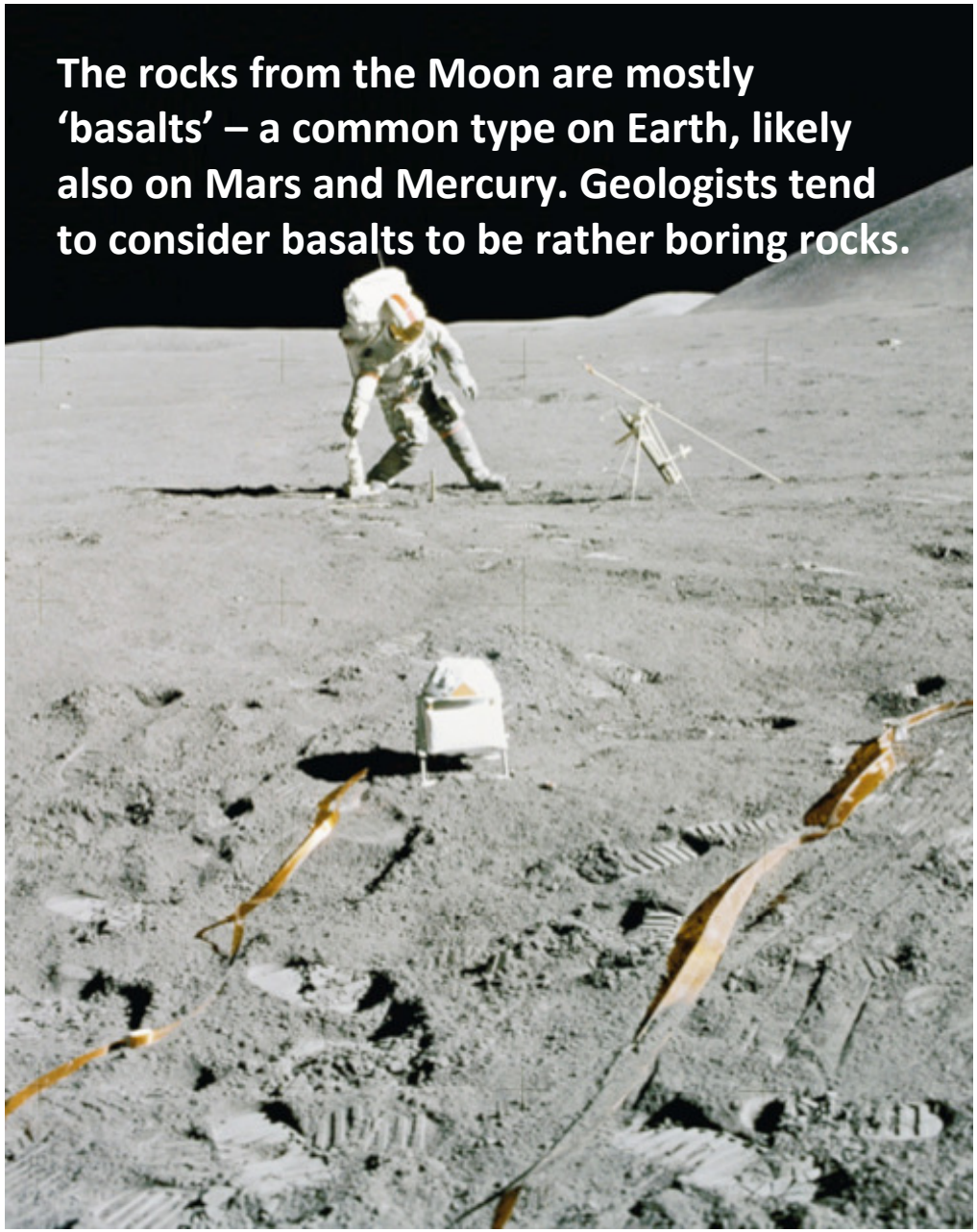
- Most meteorites are 'space garbage' left over from the early solar system. But a few actually seem to have been blasted off Mars or the Moon by impacts, and then eventually made landfall on Earth. What a lucky coincidence! There are over 100 known or suspected from Mars.

The origins are confirmed because isotopic ratios in gases match Mars.

Direct Sampling

• American astronauts visited the Moon between 1969 and 1972 as part of NASA's Apollo program. They returned to Earth with ~380 kg of rock samples. These have been used to measure composition and age of the Lunar surface.

• This image shows an astronaut deploying seismic sensors for moonquakes.
• Samples have also been 'returned' from comets.



- **For some, the absence of green cheese was a major disappointment.**

- **Lunar rocks are essentially identical to things we find on the Earth, although they contain almost no water in comparison. The light areas on the moon are made of anorthosite (mostly plagioclase feldspar) which occurs in Labrador. Dark areas are mostly basalt (volcanic). Remember!**

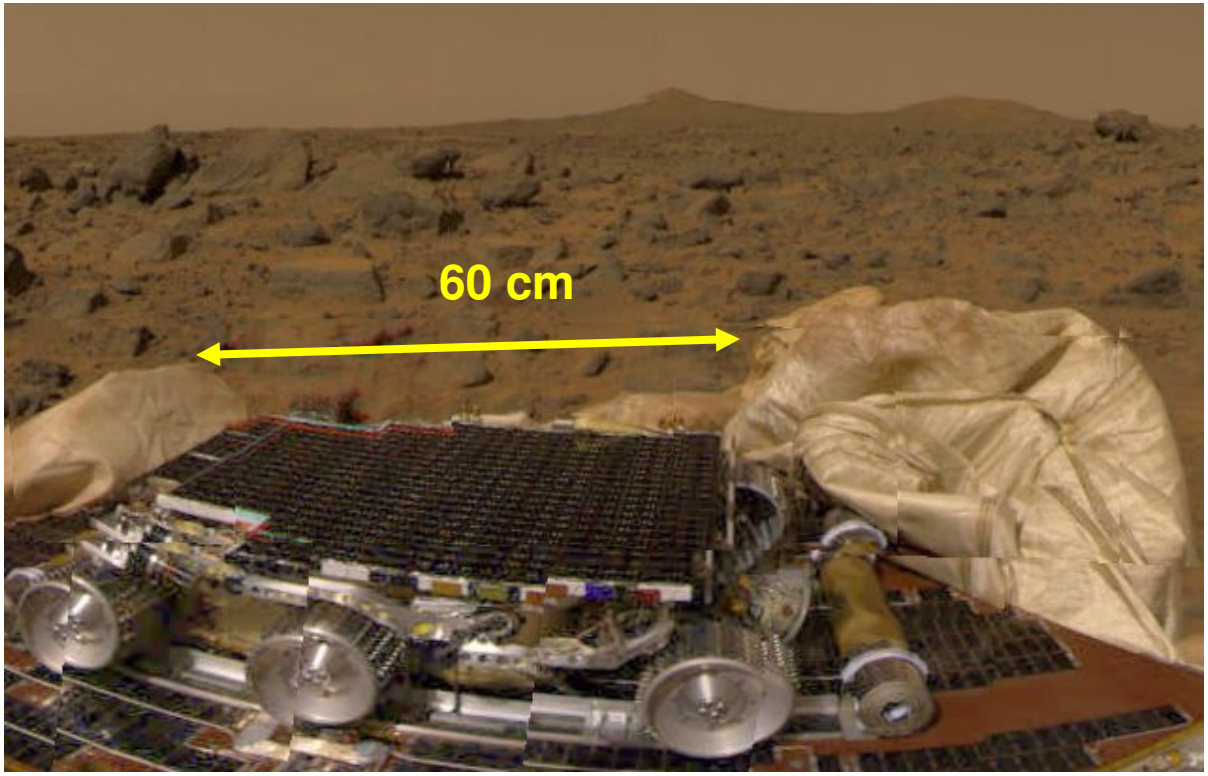
Robotic Exploration of the Planets

- Back in the the 1970s, everyone thought we'd be visiting the Moon regularly and soon be on other planets…….I certainly thought this way.
- **However, it is much more affordable and safer to use robotic space probes for exploration.**
- The development of this technology had important impacts on science – things we now take for granted.
- A series of important missions have explored the inner planets, especially Mars, and also have ventured into the outer solar system. The Voyager missions took advantage of an unusual planetary alignment….
- This continues to be the main focus in space science, but in the end there is no substitute for 'being there'.
- Will it ever happen? I certainly hope so.

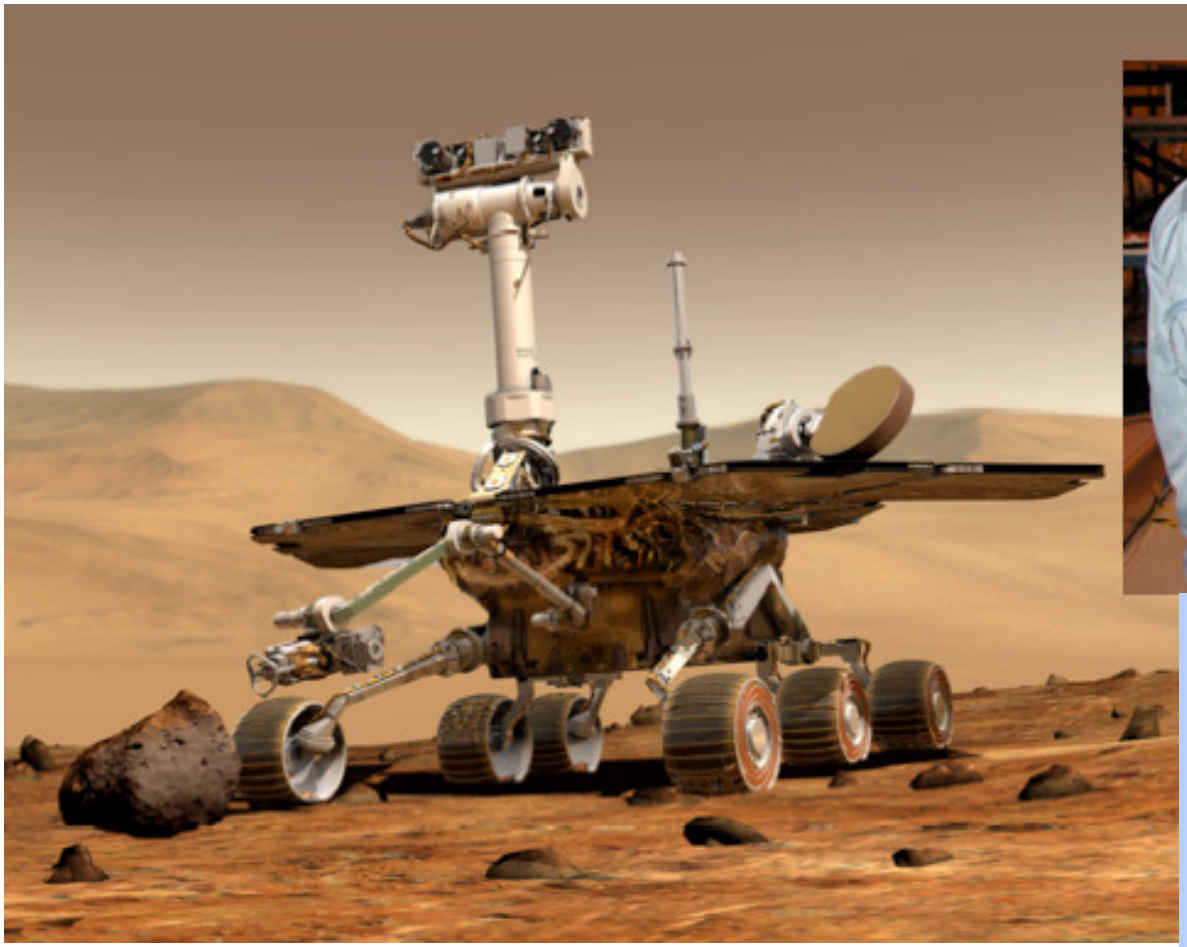
Mars Desert Research Station, operated by the Mars Society in Utah.

Others also think so. There are geologists who are crazy enough to put on spacesuits and pretend to do field work in the desert, as a proxy for Mars.

- Remote sampling and analysis of other planets, moons, asteroids and comets is possible via robotic missions such as *Curiosity, Mars Rovers, Deep Impact and Phoenix*. Samples were returned from comets.



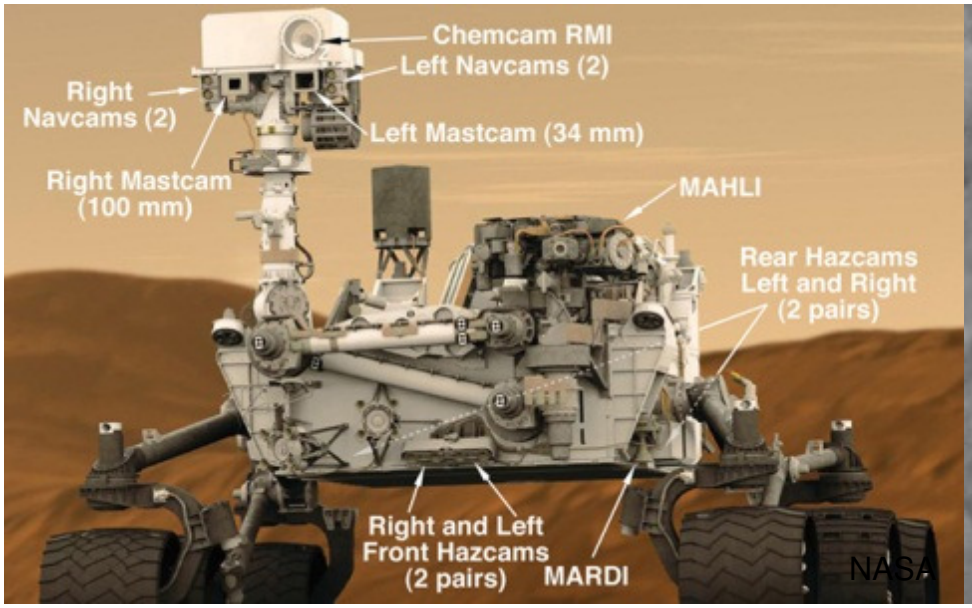
Sojourner robotic rover (aka Mars Pathfinder rover) landed on Mars in July, 1997.

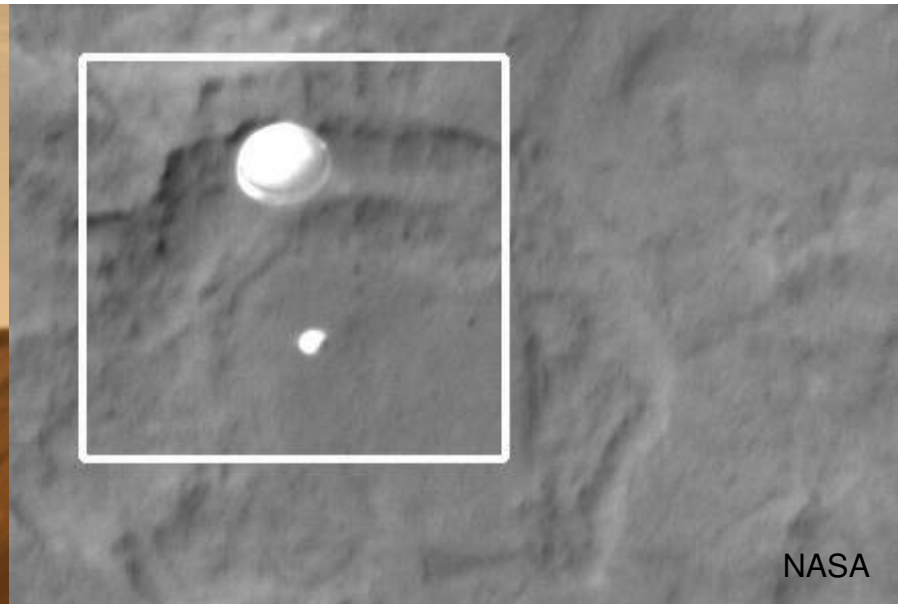


Images from NASA
http://marsrovers.jpl.nasa.gov/
gallery/spacecraft/images/

- **NASA's twin robotic Mars Exploration Rovers, *Spirit* and *Opportunity*, landed on Mars January 4 and 25, 2004 in search of answers about the history of water on Mars. They were part of NASA's Mars Exploration Program, a long-term program of robotic exploration of Mars. The results have been totally amazing.**

The Mars Rover *Curiosity* landed on August 05, 2012

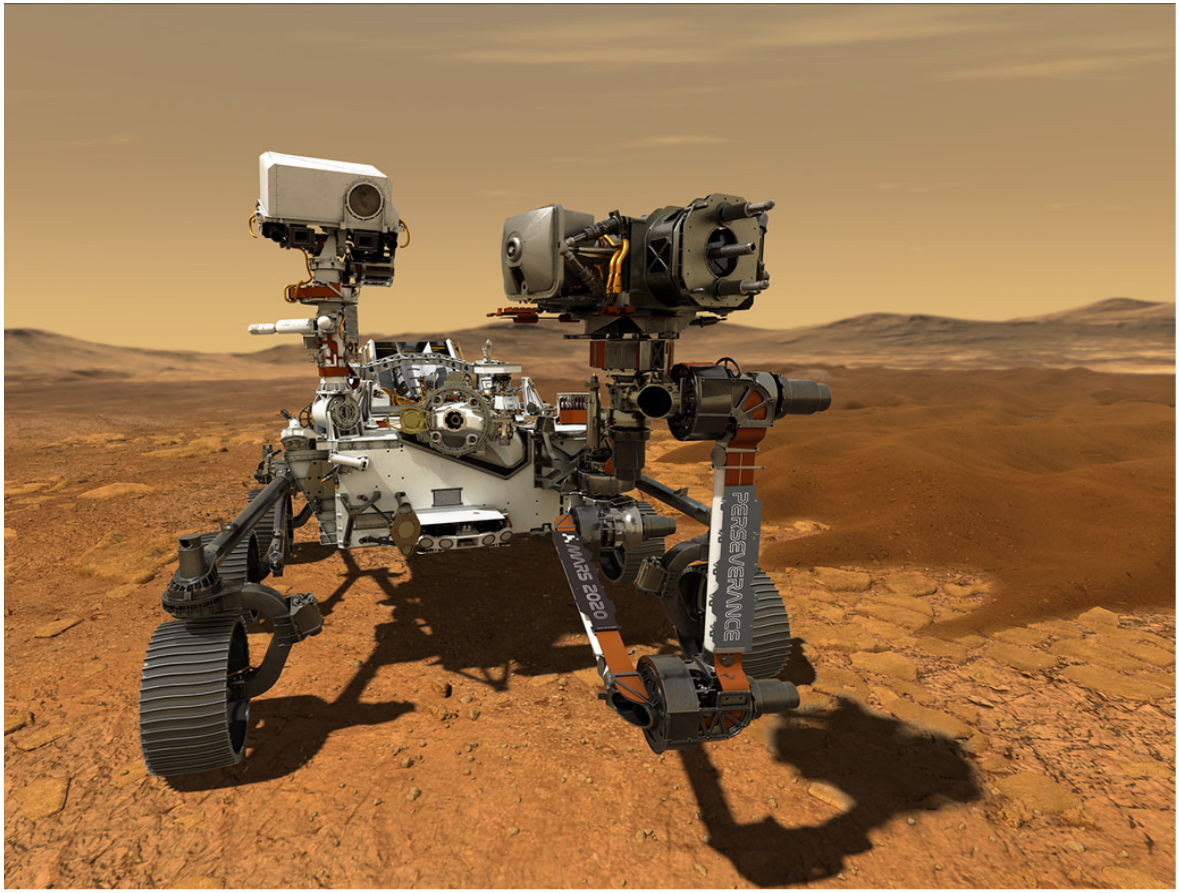




- Curiosity is exploring a specific region that shows evidence for ancient sedimentary rocks (suggesting water in the past).

- Instruments on these rovers allow simple analytical work to identify minerals and rocks, as well as the information from high-resolution digital imagery.
- Mars is a fascinating world, and perhaps the only place we might establish a foothold beyond the Earth.

NASA

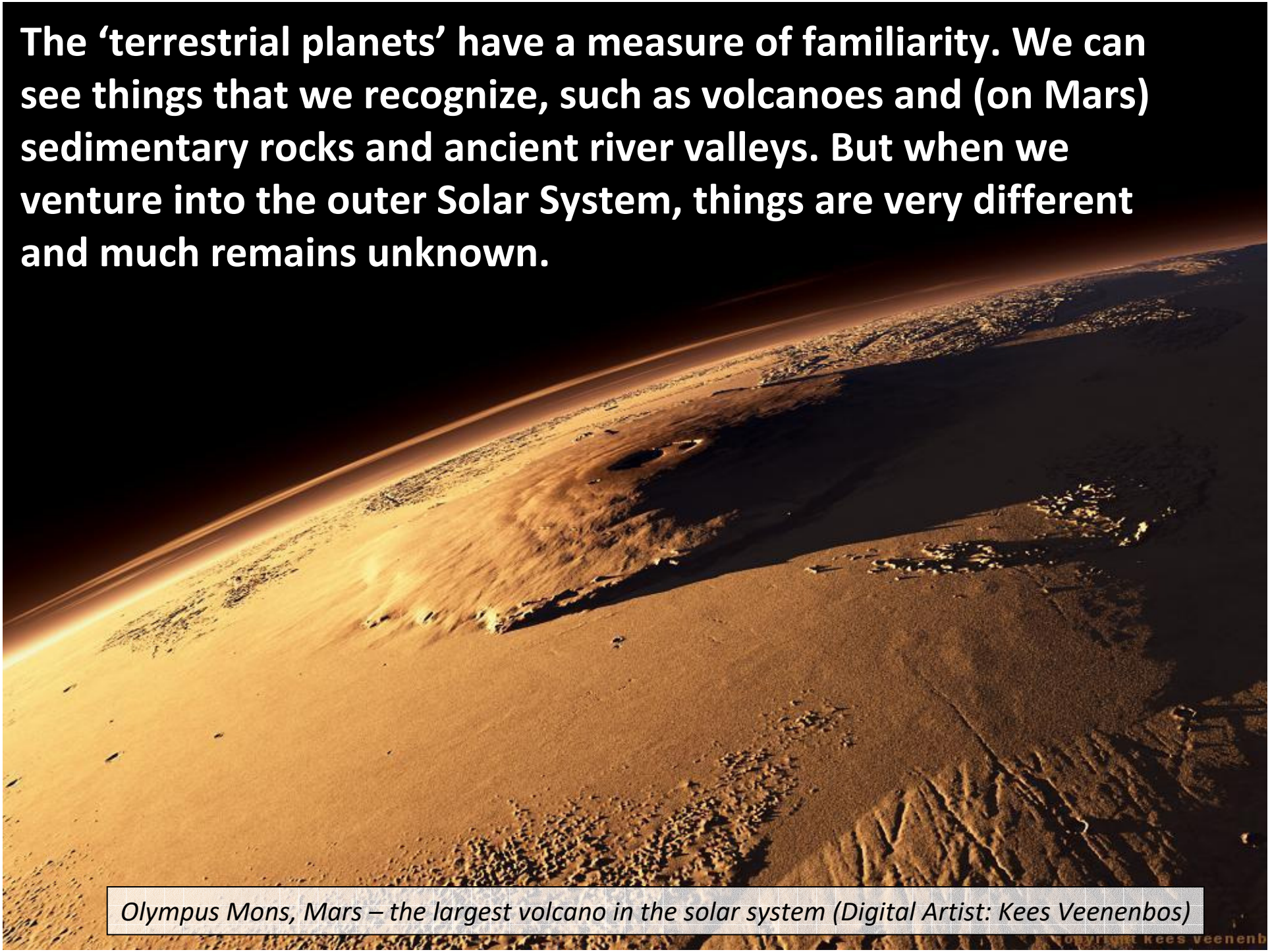


2021: Perseverance and Ingenuity take on a new Mars mission….

Sedimentary rocks on Mars…..

Martian landscape, as imaged by the rover "Opportunity"

The ‘terrestrial planets’ have a measure of familiarity. We can see things that we recognize, such as volcanoes and (on Mars) sedimentary rocks and ancient river valleys. But when we venture into the outer Solar System, things are very different and much remains unknown.



Olympus Mons, Mars – the largest volcano in the solar system (Digital Artist: Kees Veenenbos)

Summary Slides –
Some Key Points from The Class
(Module 3 – Part 1)

- These slides provide a summary of the really important 'take-home' points from this class. However, don't assume that this is the limit on what we expect you to learn from the class, because some of the details in individual topics should also be absorbed. It's a guide to key concepts only.

- You can find information on some (but not) all of the topics discussed in the Seeds and Backman text, specifically in Chapter 2 (User's Guide to the Sky) amd Chapter 3 (Moon Phases, etc.) You might also want to look at Chapter 9 (Origins of stars, etc.) although this is more detailed than the context provided in this course. Stars and stellar evolution are not the main focus of our course.

Observing the Solar System and the Skies

- Watching the skies and trying to understand them is an ancient pursuit of humanity, although our reasons for doing so were not always scientific. Telescopes revolutionized astronomy, but we can see things without them, either because celestial objects emit light or reflect it.
- The Sumerians and the Babylonians were the first to make such observations in the middle East, but their interest was largely for keeping records and calendars. Calendars are based in Astronomy…..
- Other ancient cultures built structures that served as calendars but likely also held spiritual significance. Examples are stone circles, medicine wheels and the observatories of the Inca and Aztec cultures.
- Such things had practical purposes – in agrarian societies, planting and harvesting crops were fundamental to survival. There doesn't seem to be much evidence of real philosophical thought about astronomy as such.
- The ancients would observe some important things – for example, the seasons (defined by the sun's path and the length of the day), the phases of the Moon (defining months), the nightly motion of the stars, and also some rather strange stars that 'wandered' against the stellar background. The latter are the planets. They would also observe lunar and solar eclipses.

Fundamental Observations and Causes

- The sun moves every day from east to west, but its path changes with the season in most places. We know now that the Earth's rotation axis is tilted as it moves around the sun, so northern and southern hemispheres are alternately tilted towards and away from the sun, giving us summer and winter. At the solstices, the Earth is tilted parallel to the Sun.
- The phases of the Moon are due to variation in its angle of illumination and the relative positions of the Earth, Moon and Sun. There is a regular progression from a new Moon (sun is behind the moon) to a full Moon (sun is on the other side of the Earth from the Moon) and back again.
- Eclipses (solar or lunar) are when the Moon's shadow touches the Earth or vice versa. Solar eclipses can only occur when there is a new Moon, and lunar eclipses can only occur when there is a full moon. But eclipses are much rarer than new or full moons, which happen every month. Why is this? The prediction of eclipses was a major goal of early astrologers….
- The 'ecliptic plane' is an important concept. It is an imaginary surface containing the centre of the Sun and the Earth's orbit around it. It is called the ecliptic because this is the plane in which eclipses occur. Most objects in the Solar system also move within the ecliptic plane, but the planet Mercury and the Moon are prominent exceptions.

Eclipses and the Ecliptic

- Eclipses have long been thought to have divine significance, and trying to predict them was a big issue in ancient times. They did a pretty good job considering lack of knowledge about the details.
- Because the moon's orbit around us is inclined with respect to the ecliptic plane, it means that on most full moons and new moons, the moon's shadow misses the Earth, and the Earth's shadow misses the moon. However, the moon's orbit crosses the ecliptic twice a month – at what are called 'nodes'. If a node coincides with a full moon or a new moon, then an eclipse can occur.
- Solar eclipses are only seen within narrow tracks on the surface of the Earth, because the moon's shadow is small. Lunar eclipses can be more widely seen from Earth. The next one in Newfoundland is April 2024.
- The ecliptic plane is important for other reasons. The stars move every night because of the Earth's rotation, but their patterns relative to one another remain fixed. The constellations are our interpretations of the patterns of the stars, and they remain fixed patterns. They have no real meaning but they are useful references for regions of the sky, like nations on a map.
- However, some unusual stars DO MOVE with relation to this background and these are the PLANETS. They also move in the ecliptic plane.

The Causes of Celestial Motions

- For thousands of years it was always assumed that we were the centre of the universe and everything revolved around us. We went to great lengths to find explanations that would keep this premise. Astronomers were naturally reluctant to be burnt at the stake for heresy!
- The motion of the sun every day is due to the Earth's rotation, as is the apparent motion of the distant stars.
- The planets gave the biggest problems. Because they moved with respect to the stars, they were thought to move around the Earth within a wider 'celestial sphere' that contained the stars. But the problem was that sometimes planets appeared to move backwards for a while. This was very hard to explain. Explanations were concocted, and we will talk about some of these in the next class.
- The signs of the Zodiac are simply the constellations that sit along the ecliptic plane as we see it in the sky. They have no significance in terms of personalities or in predicting things, but don't let this stop you reading your horoscope if you enjoy it.
- Although many things in the skies have predictable patterns, some do not. Examples are supernovas (bright new stars) and some comets. Actually many comets are predictable, but their time-scale of recurrence is too long.

Methods and Techniques

- The telescope revolutionized astronomy just as the microscope revolutionized biology.
- In the 21st century, the use of orbital telescopes (e.g., Hubble) has had an enormous impact. Computer technology has vastly improved all telescopes.
- Visible light is only part of the picture. It is part of a wide spectrum of electromagnetic radiation that we can analyse from celestial objects.
- For example, images of Venus and the Sun using visible, UV, X-ray and Radar methods give us very different views. We will talk about “spectroscopy” in more detail later on. It’s important.
- Other types of remote sensing methods from space probes are very important, and these methods are now also widely applied to study the Earth – for example, in assessing climate change and the ozone layer.
- We have direct samples from meteorites and some of these are actually rocks blasted off the surface of Mars and the moon!
- Direct sampling was completed on the Moon during the Apollo era, and samples have been/will be returned by robots from comets and asteroids.
- But since Apollo, much of our effort has gone into robotic exploration – space probes to the outer planets, and the amazing Mars rovers.

Things we will try to explore in this course

- There is a lot of ground to cover, and we can't do everything in as much detail as we would like.
- We will talk about the scale of the Solar System and discuss ideas about how it formed and evolved.
- We will talk about the Sun as the centre of the system.
- We will talk about the individual planets and moons in the system, focusing on what we know, and also what we do not know. We will look at how these data tell us about the origins of the system.
- We will talk at least briefly about fascinating new information concerning exoplanets (planets that orbit other stars). What do these tell us?
- We'll talk about the consequences of impacts as part of the history of the Earth, and also the history of the Earth's biosphere.
- And at the end, we'll talk about the prospects for life elsewhere in the Solar system and in other solar systems that may exist.
- You should not find this course boring unless you find everything boring!