Space Exploration

Unit E (pp. 366-475)

Early Views About the Cosmos (1.1)

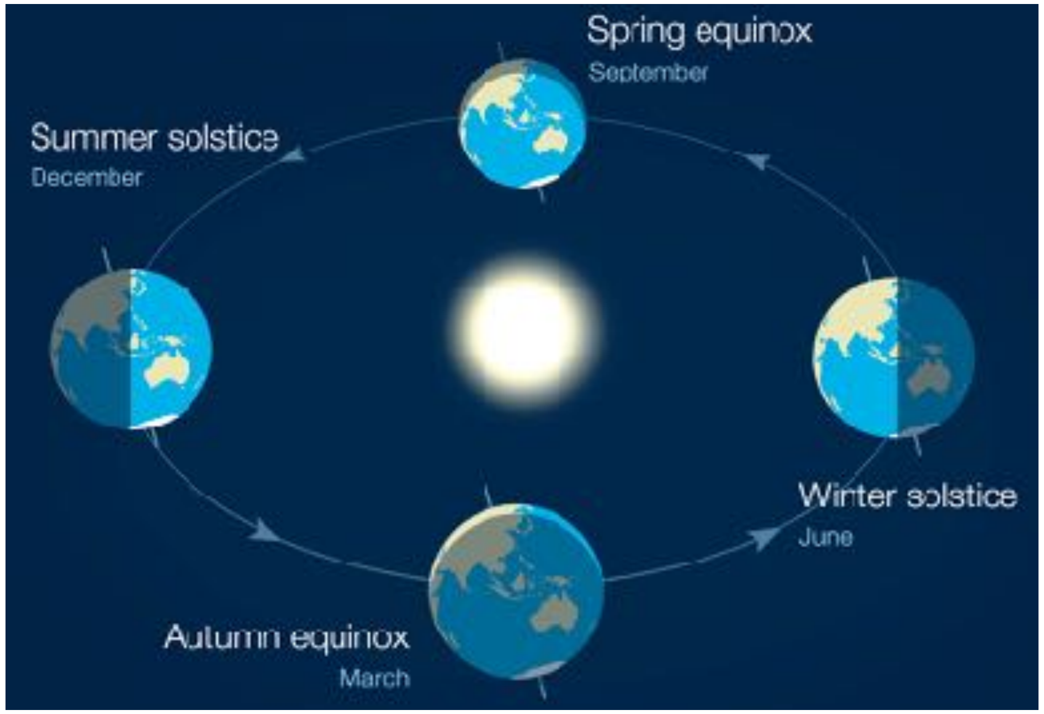
- Objects in the sky have fascinated humans for thousands of years. For example:
    - First Nations peoples of the Pacific Northwest thought the night sky was a pattern on a great blanket overhead. They believed it was held up by a spinning "world pole" which rested on the chest of a woman named Stone Ribs.
    - The ancient Mayans built an elevated observatory (El Caracol) at Chichen Itza to make naked eye observations of the heavens including the position of Venus and solar/lunar eclipses.
    - The ancient Egyptian often lined up the entrances to their monuments with certain stars and/or the sun. For example, the axis of Abu Simbel was positioned by the ancient architects in such a way that on October 22 and February 22 the rays of the sun would penetrate deep into the sanctuary to illuminate a sculpture of Pharaoh Ramses II along with the sun gods Re-Horakhte and Amon-Re. These dates are Ramses' birthday and coronation day, respectively.
    - Dating back 5000 years, England's Stonehenge was designed to track the position of the sun throughout the year. Especially important days include the summer and winter solstice and the spring and fall equinox.

- As mentioned, dates of particular importance ancient astronomical calendars with the solstices and the equinoxes.

    - **Solstice:** A day of year where the "sun stops". This is either the longest day of the year (ie. the summer solstice on or near June 21) or the shortest day of the year (ie. the winter solstice on or near December 21). These dates coincident with the first day of summer and the first day of winter respectively.

    - **Equinox:** A day of year where there is "equal night". This is either on the first day of spring (ie. the spring equinox on or near March 21) or the first day of fall (ie. the fall equinox on or near September 21).

- The main pyramid at Chichen Itza (El Castillo) was designed to be a calendar using these dates. The four sided pyramid has staircases on each face, each with 91 steps. Combined with the platform at the top, this totals the 365 days of the solar year. As well, shadows cast during the equinoxes creates a golden serpent gliding down the pyramid. This signalled the best time of the year for the Mayans to plant their most important crop (ie. corn).



- Modern theories of **astronomy** (ie. the scientific study of celestial objects and phenomena that originate outside the Earth's atmosphere) began, like so many other branches of the science, with the ancient Greeks.

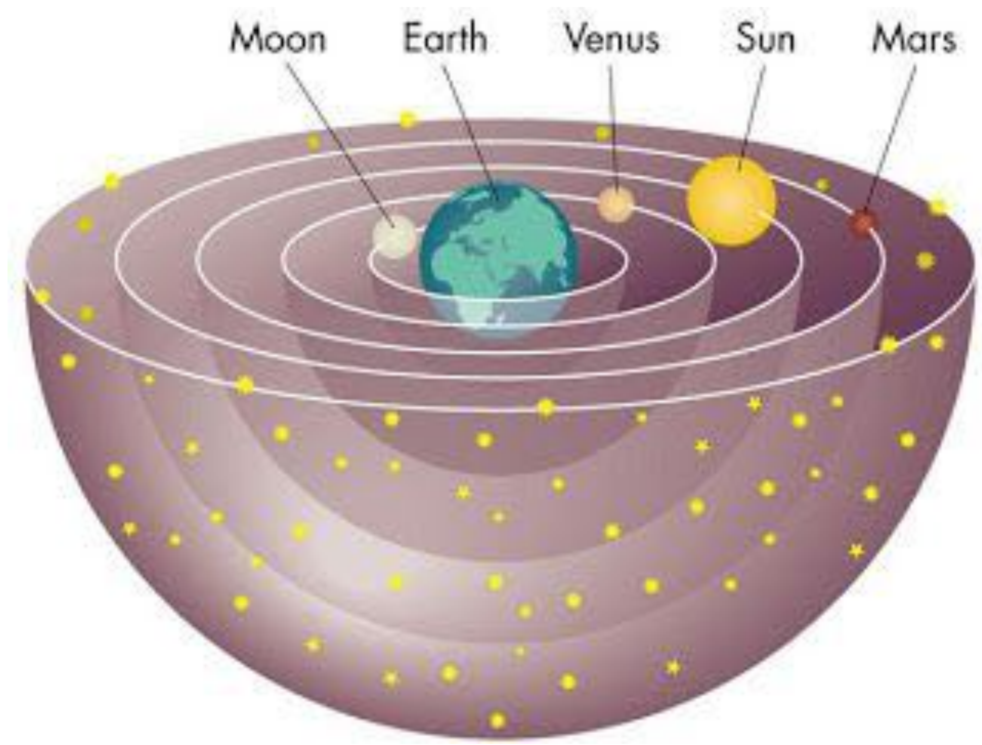
    - Remember when **Aristotle** proposed the theory that all matter was made up of earth, air, water and fire? Well his massive influence set back astronomy for centuries when he proposed the **geocentric** model of the universe.

        - The Earth was at the centre of the universe.

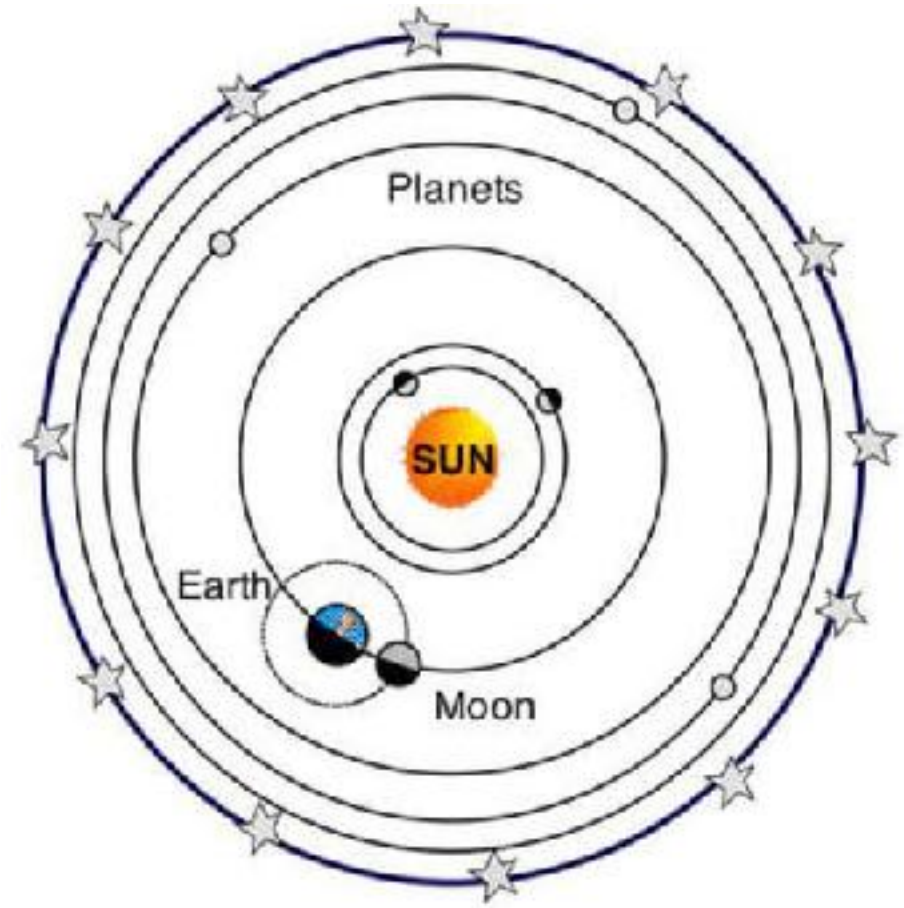
        - The Sun and planets revolved around the earth.

        - Distance stars were fixed to an outer "celestial" sphere.

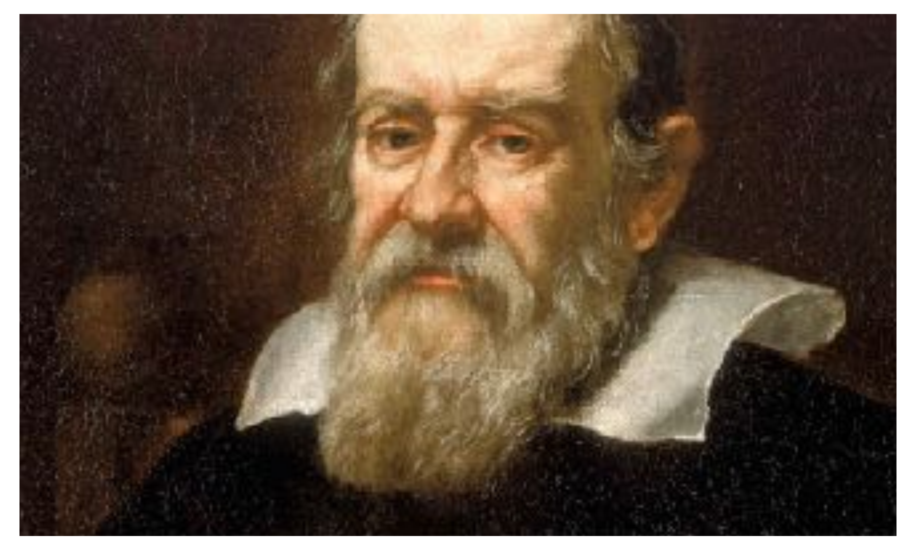
- Reinforced by Roman scientist **Ptolemy**, this theory would remain largely unchallenged for alsmot 2000 years.



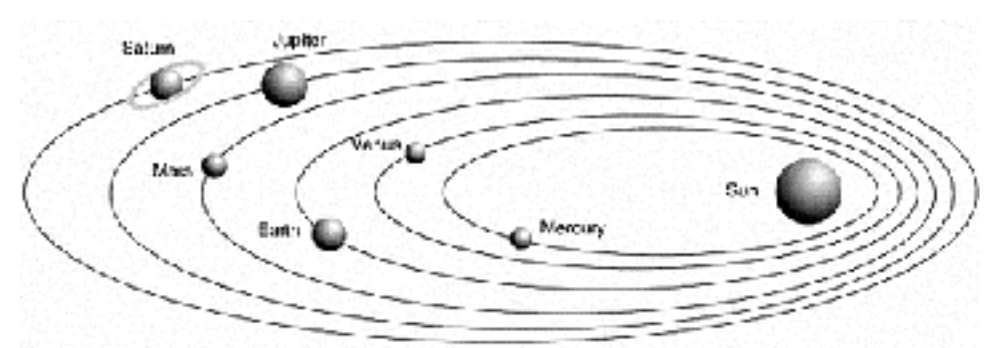
- In 1530, German astronomer ***Nicolaus Copernicus*** proposed that the Sun was at the centre and that Earth and the other planets revolved in circular orbits around it in his **heliocentric** model. Technically **Aristarchus of Samos** had proposed this theory less than a hundred years after Aristotle but was largely ignored. Remember Democritus?



- The invention of the telescope in 1608 allowed Italian scientist **Galileo Galilei** to confirm Copernicus' findings. He also discovered rings around Saturn, moons around Jupiter, spots on the Sun and was the first person to observe Neptune (although he didn't know it was a planet). What he did get for his efforts? For crimes of heresy, he was put under house arrest for the rest of his life. This sentence wasn't officially acknowledged as an "error" by the Catholic church until 1992.



- At roughly the time, German mathematician **Johannes Kepler** discovered that planetary orbits were **ellipses**, not circles as proposed by Copernicus. Kepler's calculations were based on largely on the observations made by Danish astronomer ***Tycho Brahe***.



Discovery Through Technology (1.2)

- As we discussed in the previous section, ancient cultures such as the Egyptians and the Mayans were able to understand the sky and its mysteries.

- How were they able to do this? With the right tools, of course:

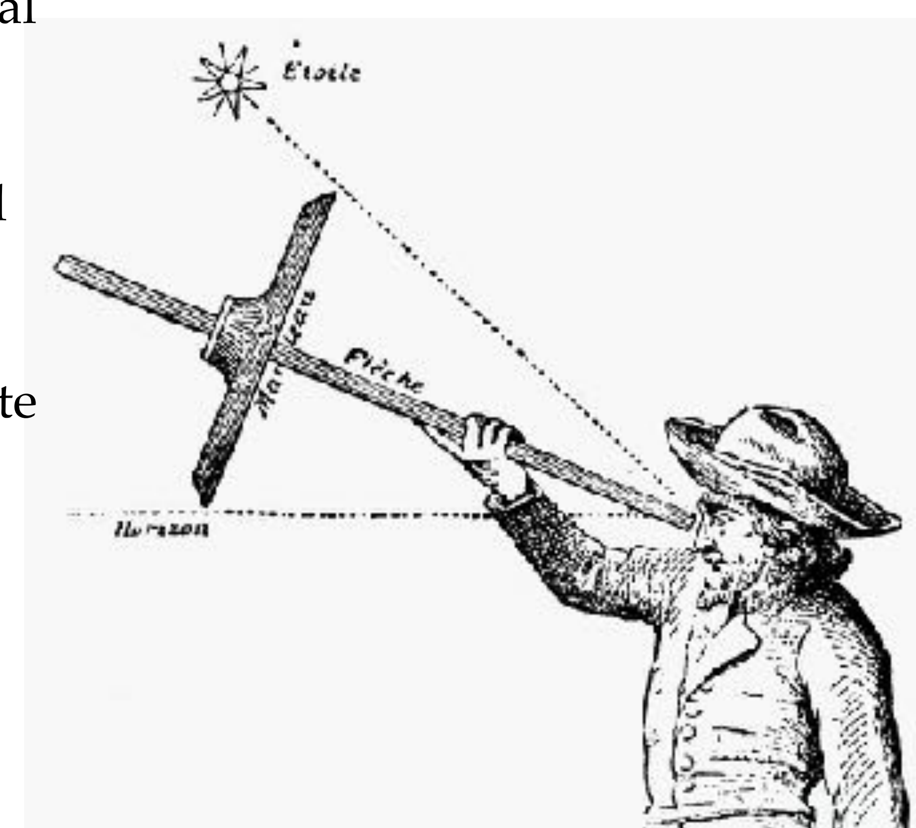
  - **Sundials:** Have been used for more than 7000 years to measure the passage of time based on the position of the sun in the sky.

  - **Merkhet:** Invented by the Egyptians to chart astronomical positions and predict the movement of stars.

  - **Quadrant:** Also invented by the Egyptians and was used to measure a star's height above the horizon.

  - **Astrolabes:** Invented by the Arabians, they made accurate star charts for ship navigators at night.

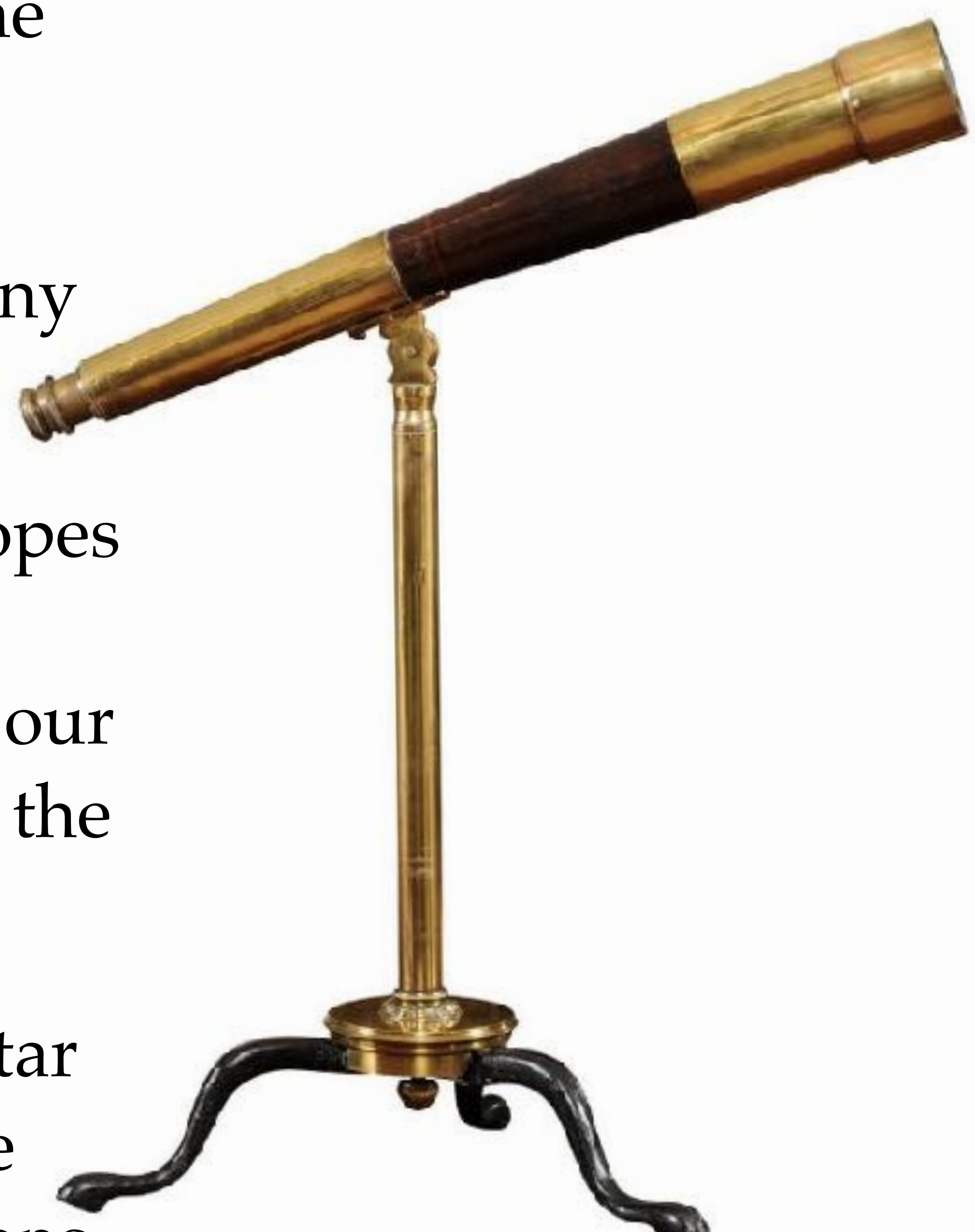
  - **Cross-Staff:** Designed to measure the angle between the Moon and any given star.



- The biggest breakthrough came with the invention of the **telescope** in 1608 by Hans Lippershey (not Galileo as many have claimed).

- Over the last 500 years, telescopes have become more and more powerful. This has expanded our knowledge and boundaries of the known universe.

- Our Sun is only one average star in a small corner of an average galaxy that is one among billions of others throughout the universe.



- As the size of the known universe is so immense, using standard units of measurement, such as kilometres, becomes impractical.

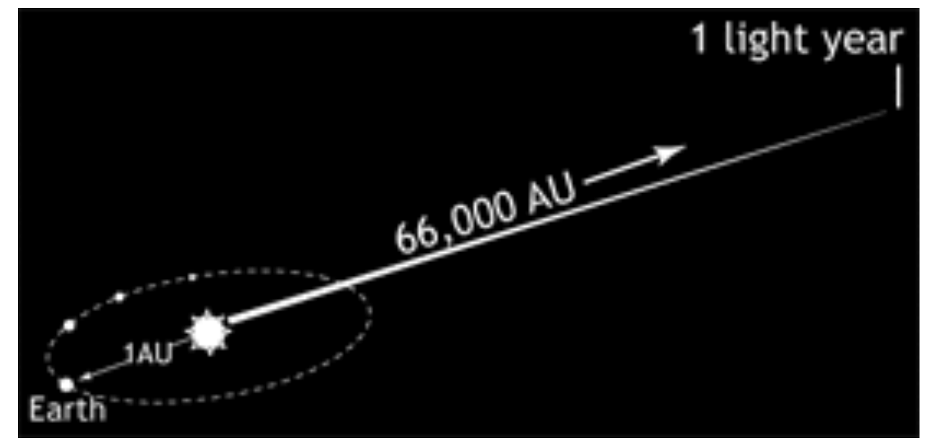
- Due to this, astronomers devised two new units of measure:

    - **Astronomical unit (AU):** Is equal to the average distance from the centre of the Earth to the centre of Sun (roughly 150 million km). This can be used for measuring “local” distances such as planets in our solar system.

    - **Light-year:** Is equal to the distance that light travels in one year (roughly 9.5 trillion km or 66 000 AU). This is used to measure the vast distances beyond the solar system.

- To put things into perspective as far as measurements go:

    - The closest star to our Sun is Proxima Centuri is 40.14 trillion km / 268 700 AU / 4.2 light years aways.

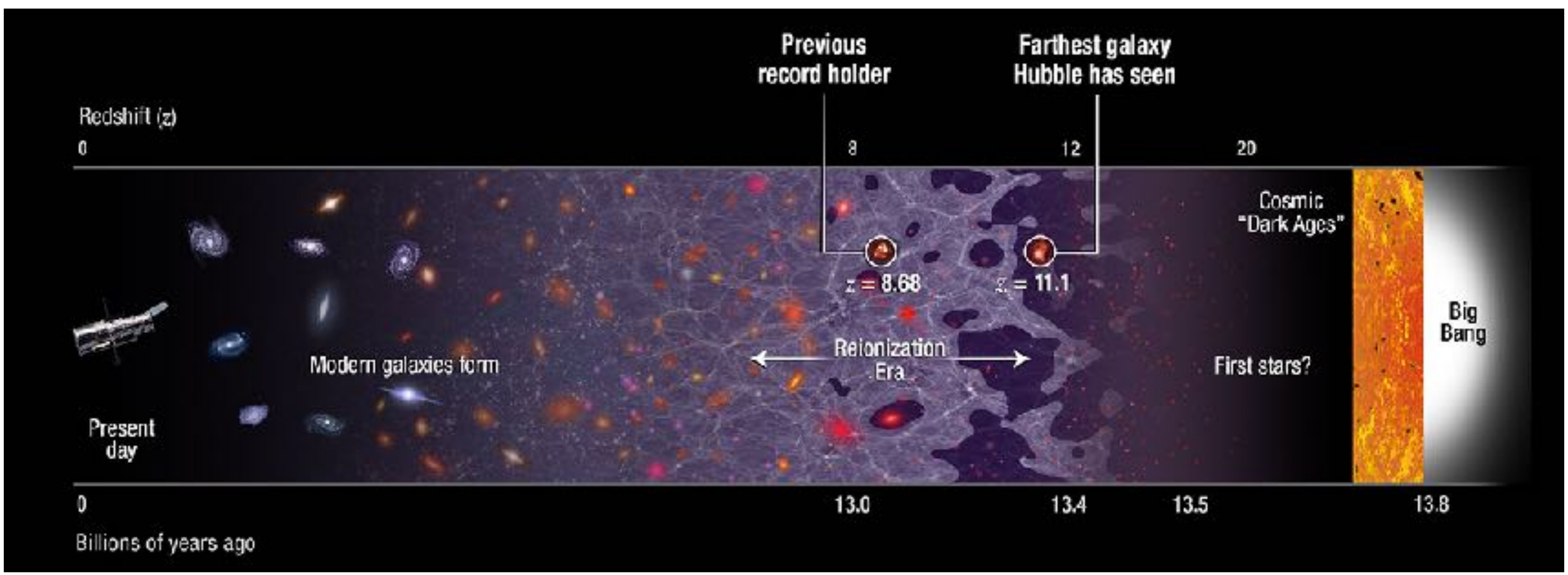


- The deeper into the universe we look, the further back in time we go.

- For example, GN-z11 is a galaxy found in the constellation Ursa Major (ie. the Big Dipper). It's currently most distant known galaxy in the observable universe at a distance of approximately 13.2 billion light-years.

- This also makes this the oldest galaxy known, as it has taken 13.2 billion years for the light reflecting off the galaxy to enter telescopes on Earth. What we currently see GN-z11 looking like is what it actually looked like only 400 million years after the Big Bang (ie. the creation of the universe).

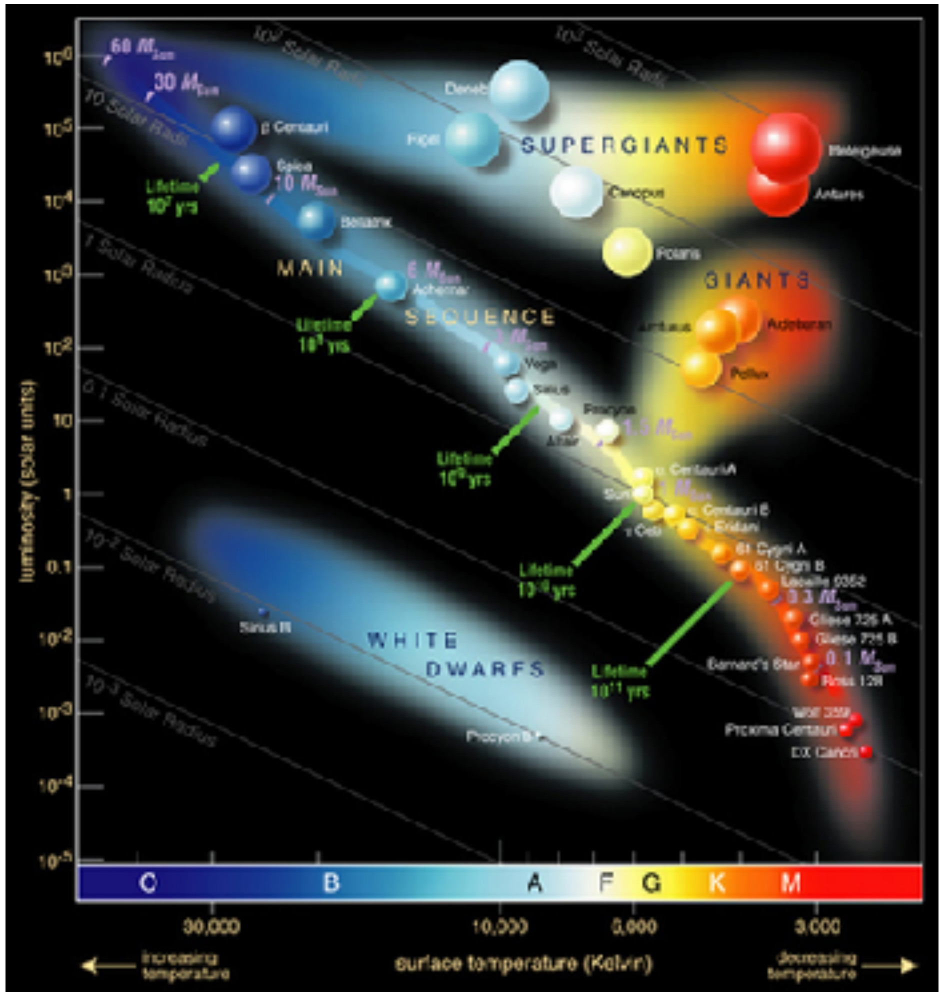
- Mind blown…



- ***Homework:*** Complete questions 1 & 3-9 on p. 376 and questions 1, 3-4 & 7-8 on p. 383 in the textbook.

The Distribution of Matter in Space (1.3)

- One of the most common features in the universe are **stars**.
- These are hot, glowing balls of mainly hydrogen gas that give off tremendous light energy
- It is estimated there are 1 billion trillion (ie. 1 000 000 000 000 000 000 000) stars in the universe.
- They vary greatly in size and color (ie. temperature) because they form are born then change over very long periods of time and eventually die.
- As discovered by scientists Hertzsprung and Russell in the 1910, there's a direct relationship between a star's temperature and brightness. the hottest/brightest stars tend to be blue ones, while the coldest/dimmest star tend to be red ones. They plotted this graphical information on their now famous H-R diagram.



- Stars running the down the middle of the H-R diagram are called **main sequence** stars and represent ones that are "living out their lives" by fused hydrogen into helium. We'll discuss the ones in the top right and bottom left shortly…

- Stars form in regions of space which contain huge amounts of **interstellar matter** (ie. gas and dust particles) called **nebulae**.

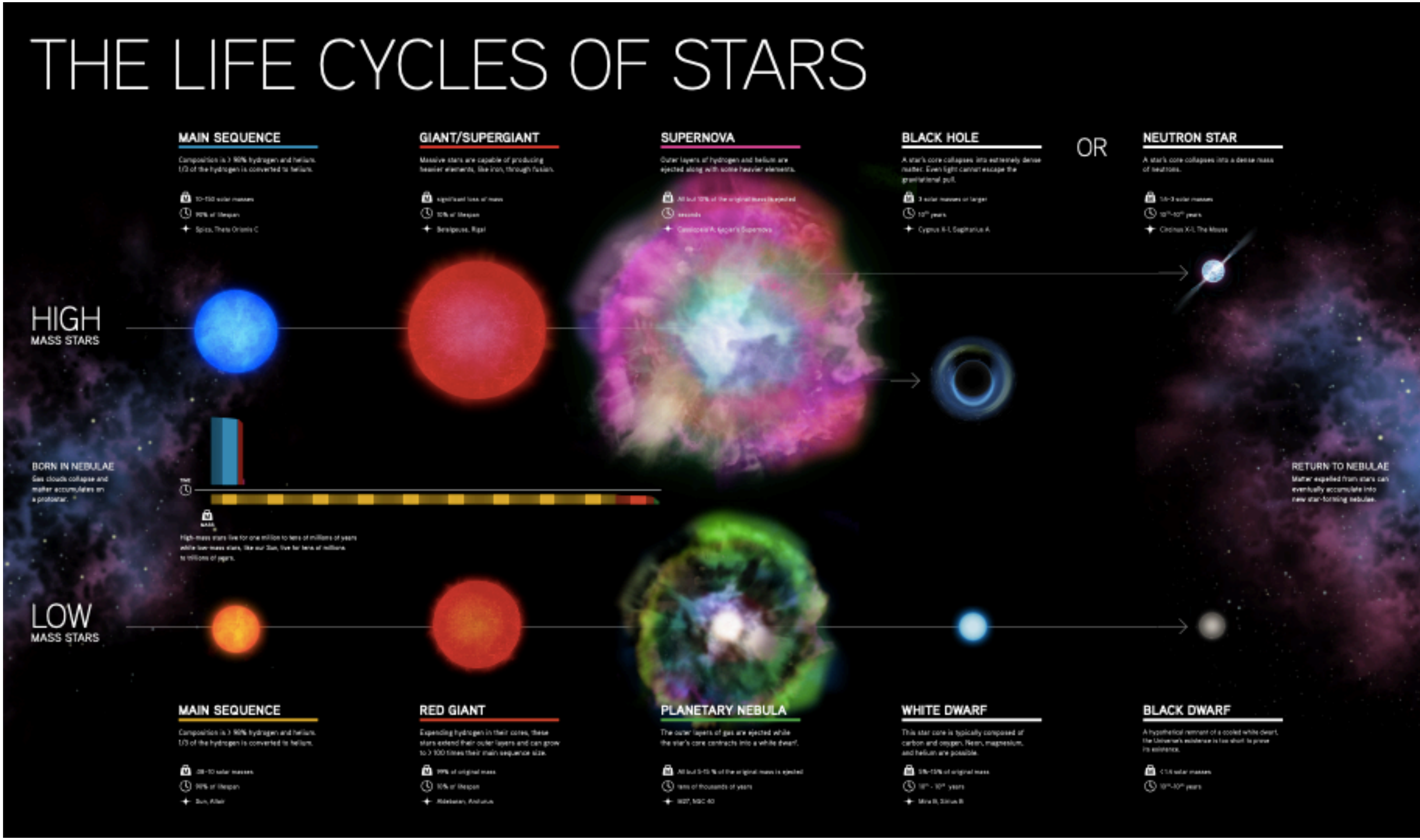
- Gravity acting between the atoms of interstellar matter can cause a small area of a nebula to start collapsing into rotating clouds.

- As more material is drawn into the spinning ball, its mass and temperature increase. It causes it to glow and forms a **protostar**.

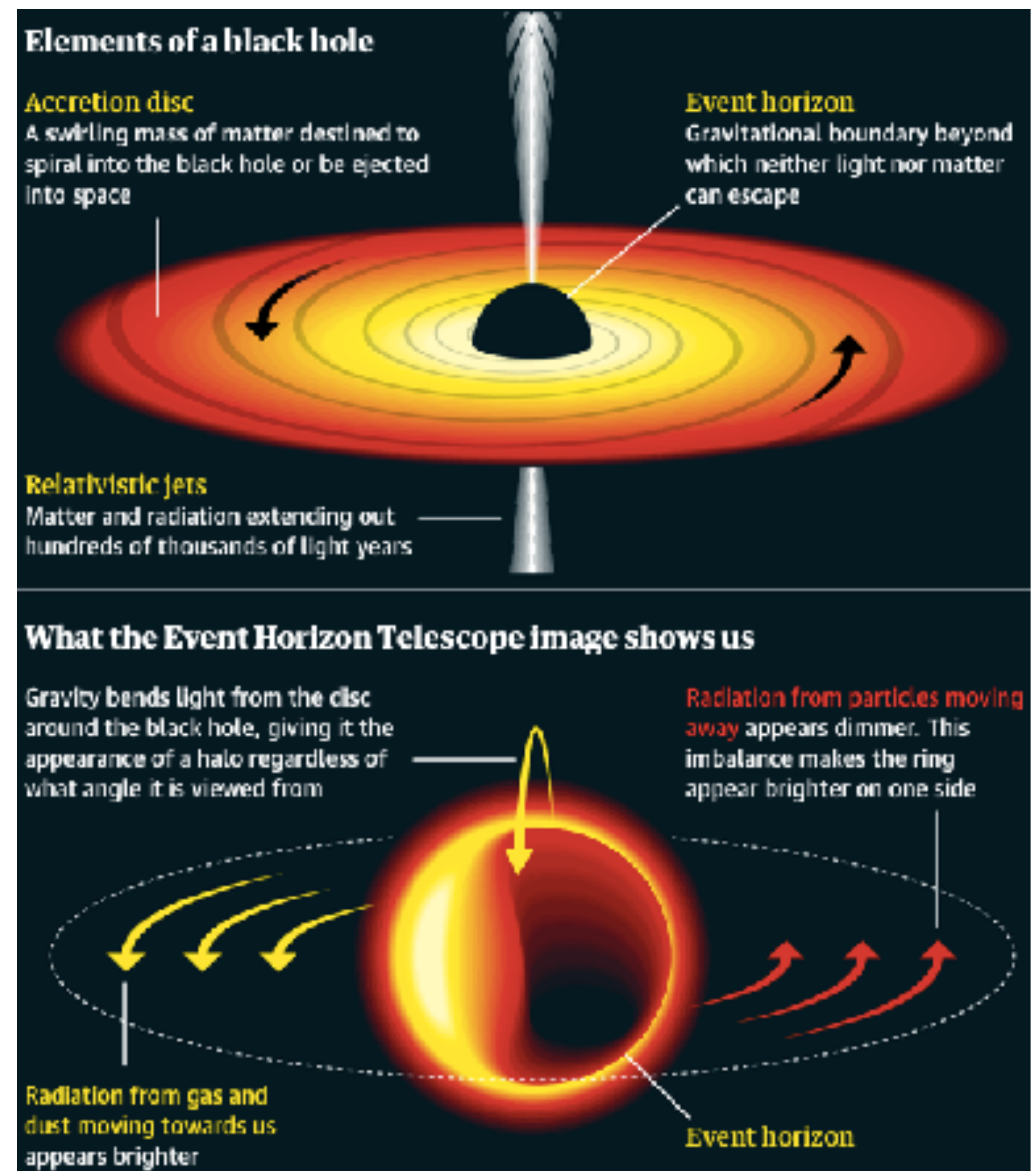
- If the protostar's core reaches 10 million degrees celsius, it causes hydrogen fusion into helium. This releases huge quantities of energy and radiation and a star is born!

- Depending on the mass of the star formed, it lives the remainder of its life (ie. *main sequence*) and death in one of two main ways:

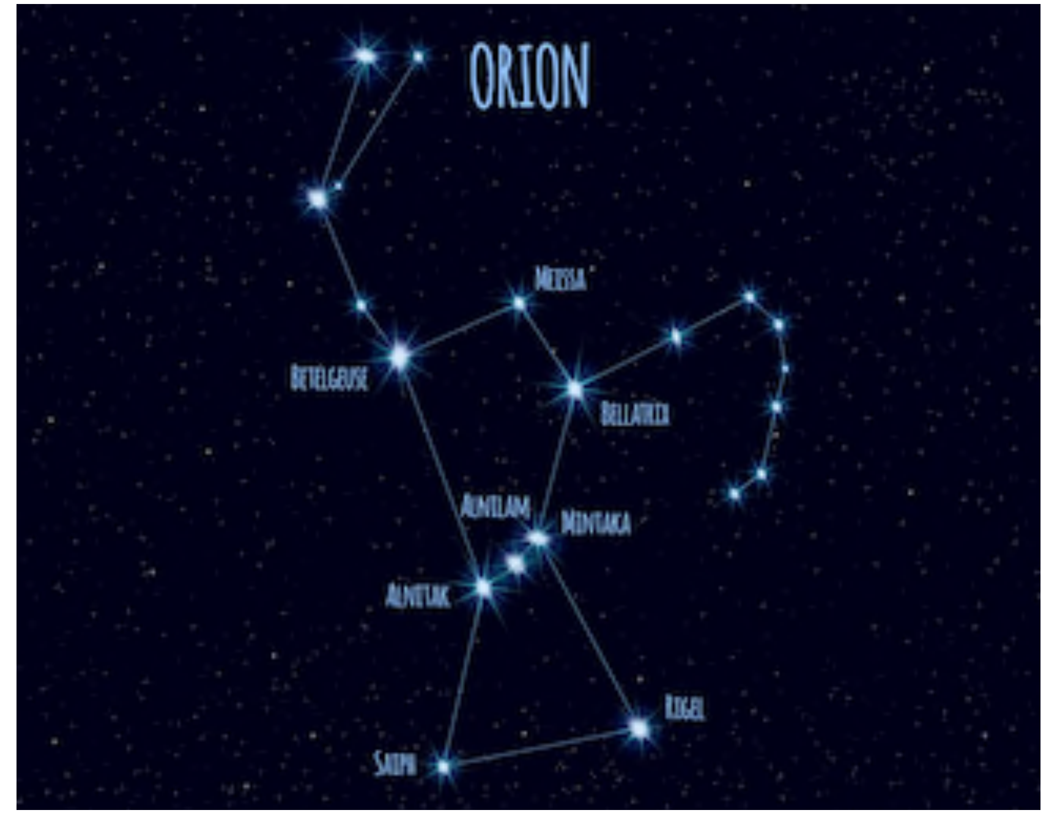
Sun-like Main Sequence Stars	Massive Main Sequence Stars
Red Giant: As the star begins to run out of fuel in its core, it expands out.	**Red Supergiant:** As the star begins to run out of fuel in its core, it expands out.
Planetary Nebula: This type of nebula is consists of an expanding, glowing shell of ionized gas that is ejected from the red giant near the end of its existence.	**Supernova:** Once the star is completely out of fuel it shrinks back in on itself. It causes massive shock wave or explosion. If the supernova doesn't destroy the star two outcomes are possible.
White Dwarf: Once the star is completely out of fuel it shrinks back in on itself to a size much smaller than when it was in the main sequence of its lifespan.	**Neutron Star:** This highly dense tiny star that may only be 20 km in diameter. The gravity here would be 2 billion times stronger than on Earth and a teaspoon of the star would weigh roughly a billion tons.
Black Dwarf: Eventually the star cools down enough to stop glowing and "dies". This process takes so long that there may not yet be any of these stars in the universe.	**Black Hole:** These are reserved for only the largest massive stars. Gravity here is so strong that not even light can escape.

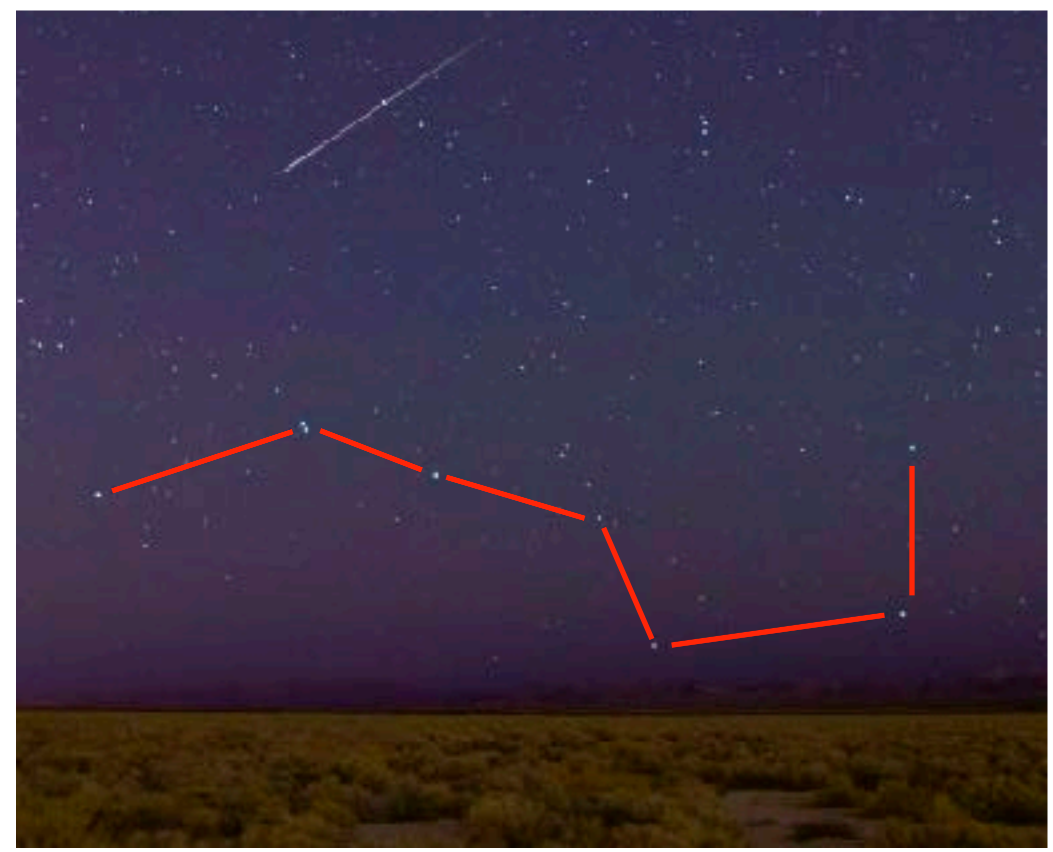

THE LIFE CYCLES OF STARS
MAIN SEQUENCE
Composition is > 90% hydrogen and helium. 1/3 of the hydrogen is converted to helium.
GIANT/SUPERGIANT
Massive stars are capable of producing heavier elements, like iron, through fusion.
SUPERNOVA
Outer layers of hydrogen and helium are ejected along with some heavier elements.
BLACK HOLE
A star's core collapses into extremely dense matter. Even light cannot escape the gravitational pull.
OR
NEUTRON STAR
A star's core collapses into a dense mass of neutrons.
HIGH
MASS STARS
BORN IN NEBULAE
RETURN TO NEBULAE
LOW
MASS STARS
MAIN SEQUENCE
Composition is > 90% hydrogen and helium. 1/3 of the hydrogen is converted to helium.
RED GIANT
Expending hydrogen in their cores, these stars extend their outer layers and can grow to > 100 times their main sequence size.
PLANETARY NEBULA
The outer layers of gas are ejected while the star's core contracts into a white dwarf.
WHITE DWARF
This star core is typically composed of carbon and oxygen. Neon, magnesium, and helium are possible.
BLACK DWARF

- In 2019, scientists announced that the first photographic evidence of a black hole had been obtained.
- Located in galaxy M87, 53.5 million light years from Earth, this black hole's event horizon shows light bending in a perfect loop around it.
- This means that if you could stand there you would be able to see the back of your own head.
- In order to get the image, the Event Horizon Telescope relied on a technique called interferometry (which we will discuss later in the unit).

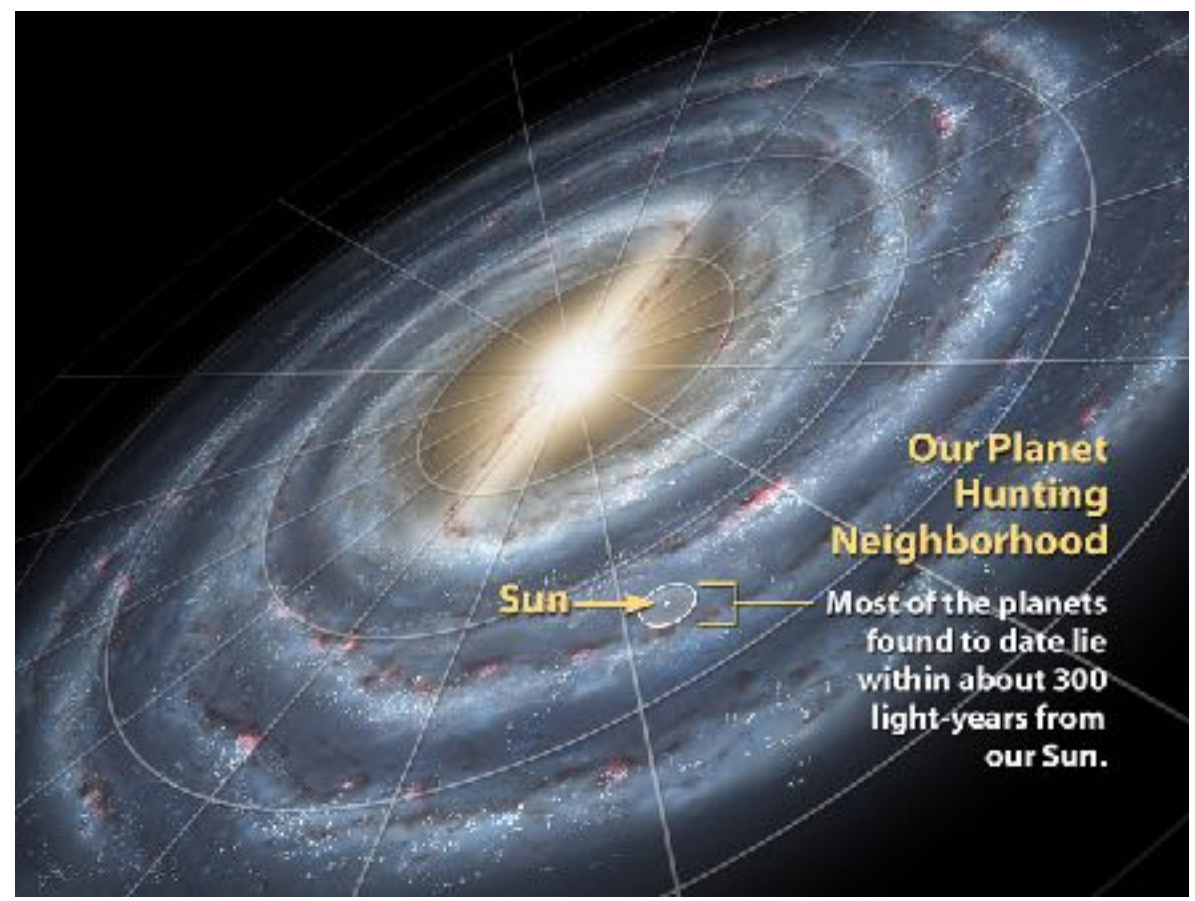


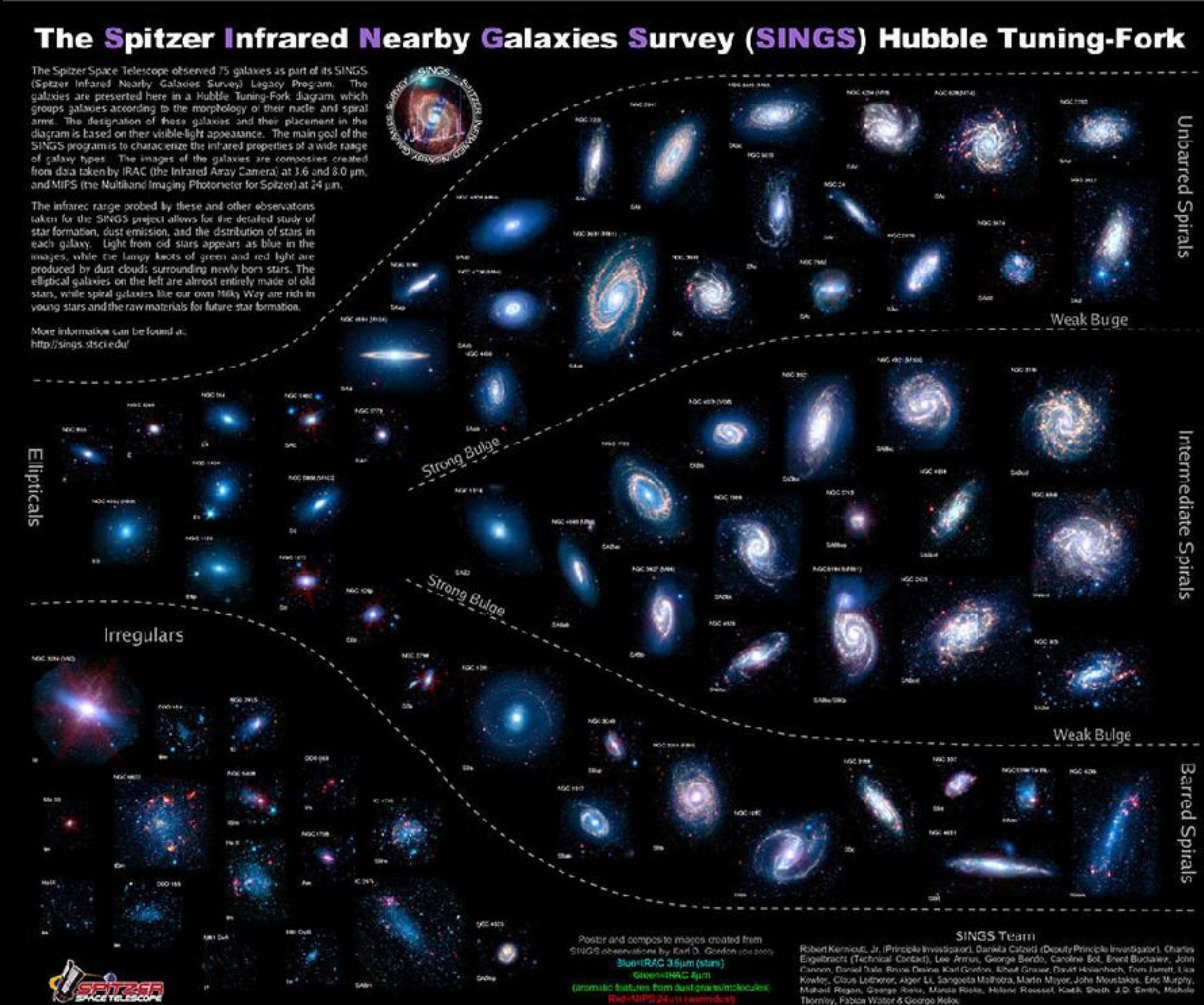
- **Constellations** are groupings of stars we see as patterns in the night sky.
- There are 88 officially recognized by the International Astronomical Union. These include:
    - Orion
    - Ursa Major ("The Great Bear")
    - Scorpio
- There are unofficially recognized star groupings which are called **asterisms**. The most famous is the "Big Dipper" which consists of seven stars in the Ursa Major constellation. Can you spot it in the picture to the right?





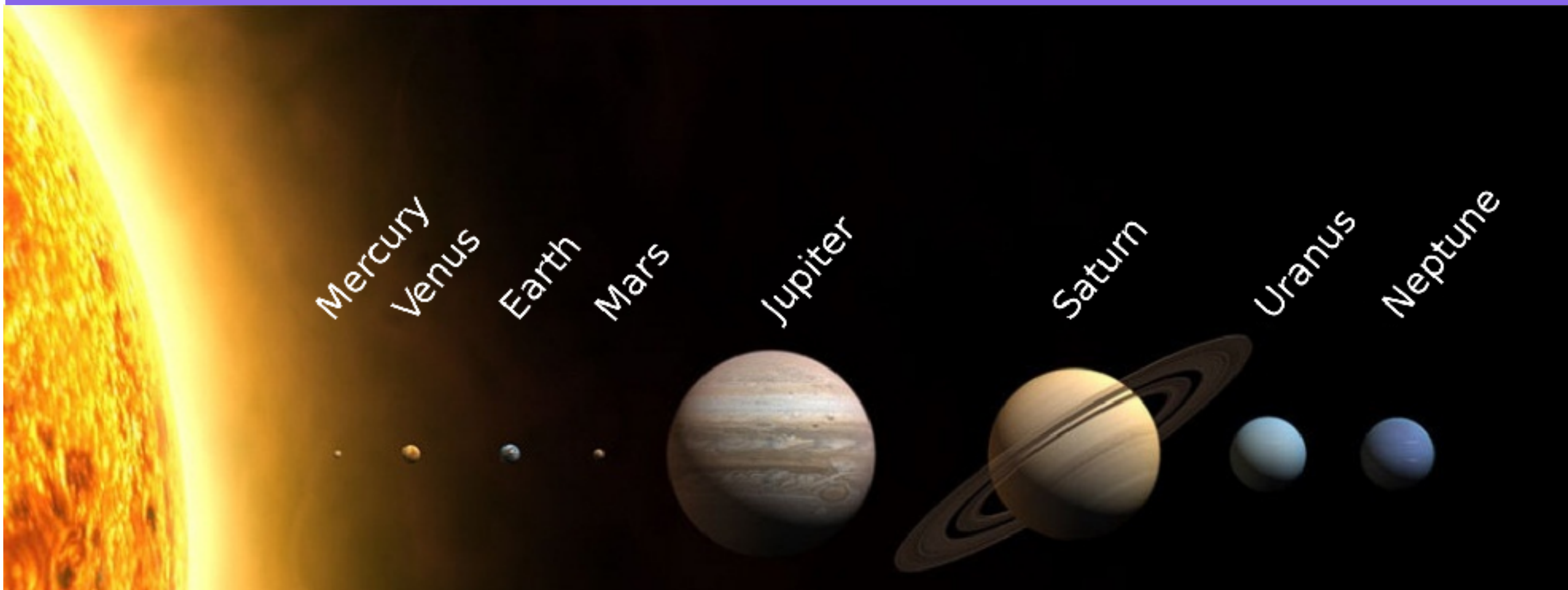
- Put enough stars together in close proximity and what do you get?
- A **galaxy** is a grouping of million or billions of stars. Like stars galaxies come in many shapes and sizes.
- The six main type of galaxies are spiral, barred spiral, lenticular, peculiar, elliptical and irregular.
- It's estimated there is anywhere from 100 to 200 billion galaxies in the universe.
- We are located in the spiral **Milky Way** galaxy that has between 100-400 billion stars.




The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork
The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 µm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 µm.
The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.
More information can be found at: http://sings.stsci.edu/
Unbarred Spirals
Weak Bulge
Strong Bulge
Intermediate Spirals
Ellipticals
Strong Bulge
Irregulars
Weak Bulge
Barred Spirals
Poster and composite images created from SINGS observations by Karl D. Gordon
Blue=IRAC 3.6µm (stars)
Green=IRAC 8µm
(aromatic features from dust grains/molecules)
Red=MIPS 24µm (warm dust)
SINGS Team
Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Fabian Walter & George Helou
SPITZER SPACE TELESCOPE

- ***Homework:*** Complete questions 1-3 & 6-10 on p. 391 in the textbook.

Our Solar Neighbourhood (1.4)

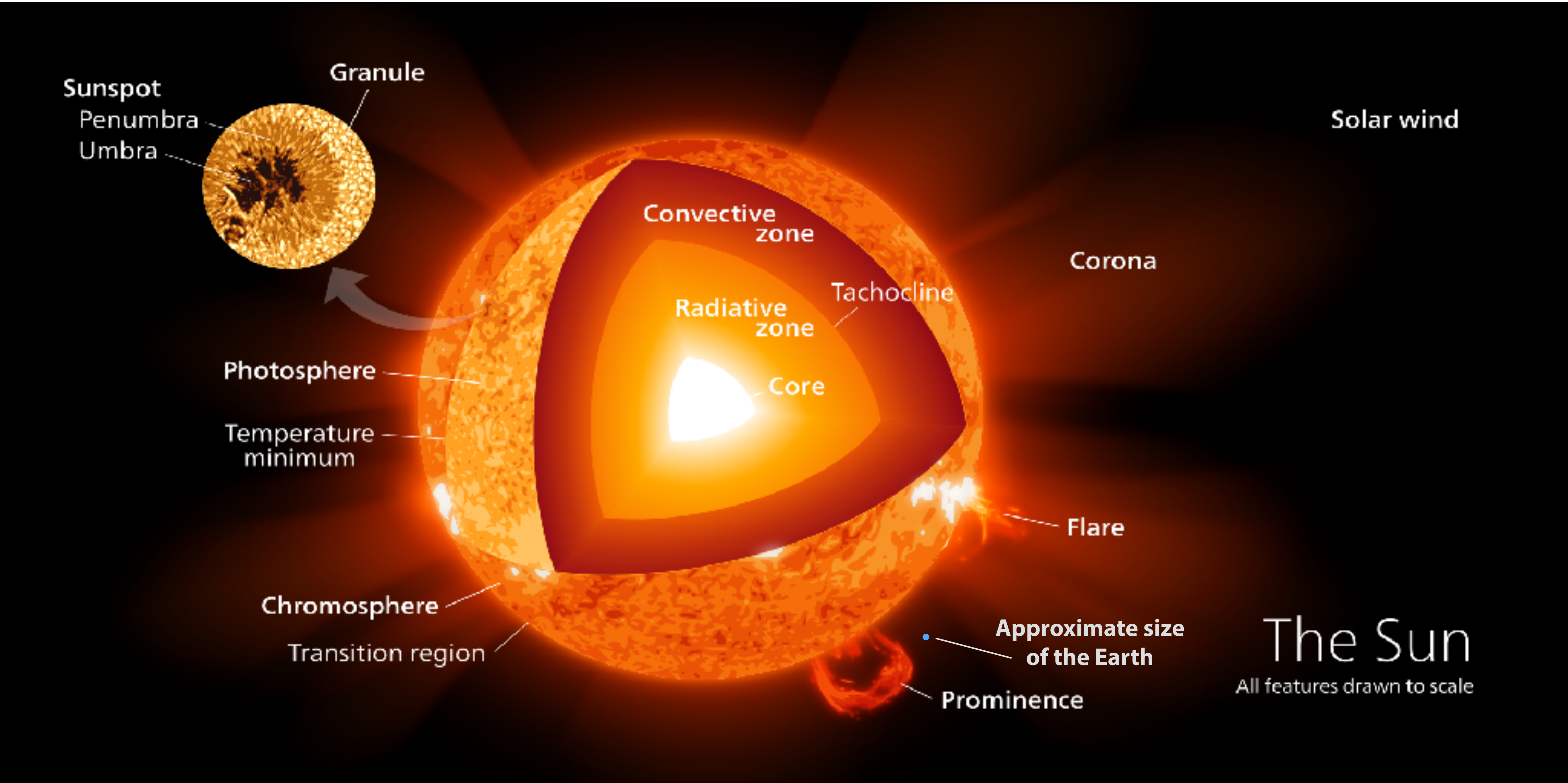


- Our tiny section of the Milky Way is known as the ***solar system.***
- As mentioned earlier in the unit, our solar system has a star sitting in the middle of it (ie. the **Sun**).
- The Sun accounts for 99.86% of the total mass of the solar system.

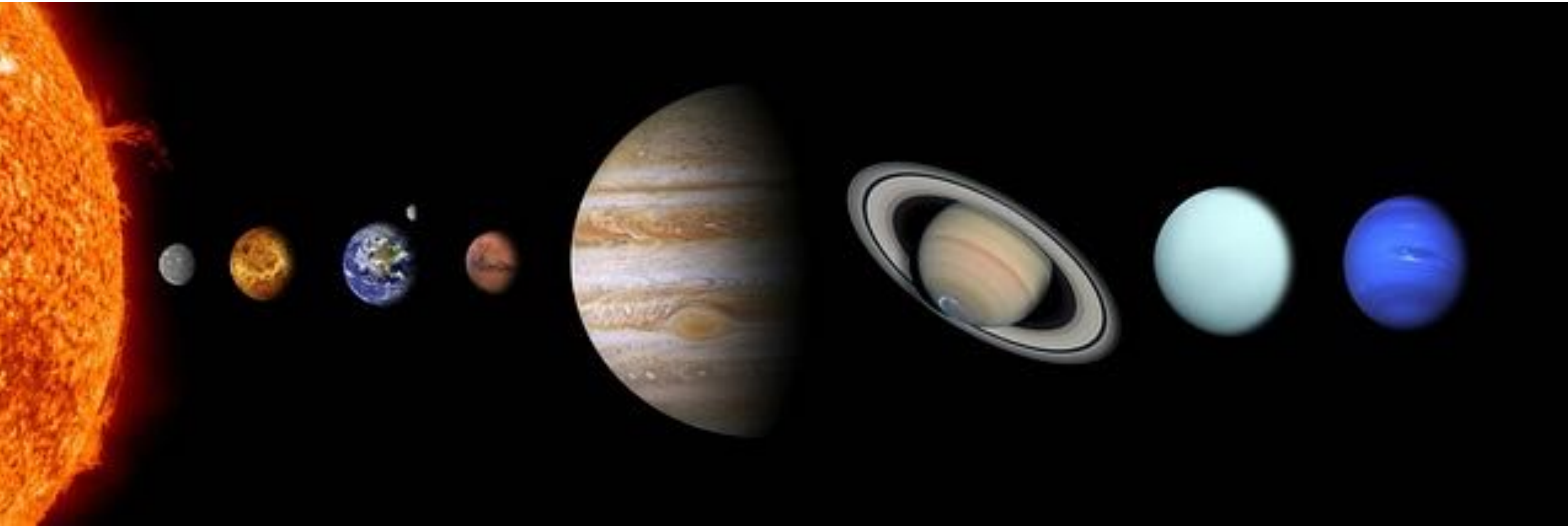
- *The Sun* produces energy in its core by fusing hydrogen into helium. This converts roughly 4 million tons of matter into energy every second. This energy over thousands of years will eventually work it's way to the sun's surface

- These charged sub-atomic particles of energy eventually leave the sun to form what is called the **solar wind**. When it reaches the Earth, it is deflected by our planet's magnetic field at an average speed of 400 km/s.

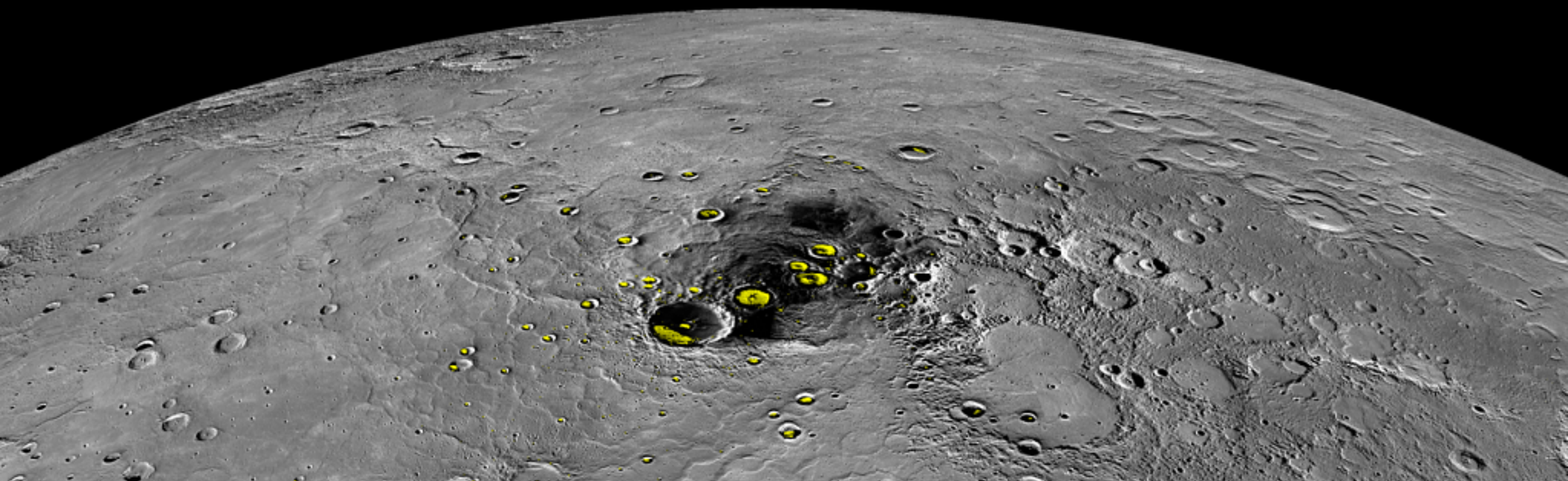
- As energy leaves the core and moves toward the sun's surface, it creates huge moving columns of charged plasma. This causes the sun to emit large magnetic fields. As we learned in the last unit, magnetic fields create electrical fields. When electrical fields in the sun short circuit you get what is called a **solar flare**. These can have major impacts on electronic technologies if and when they reach the Earth.



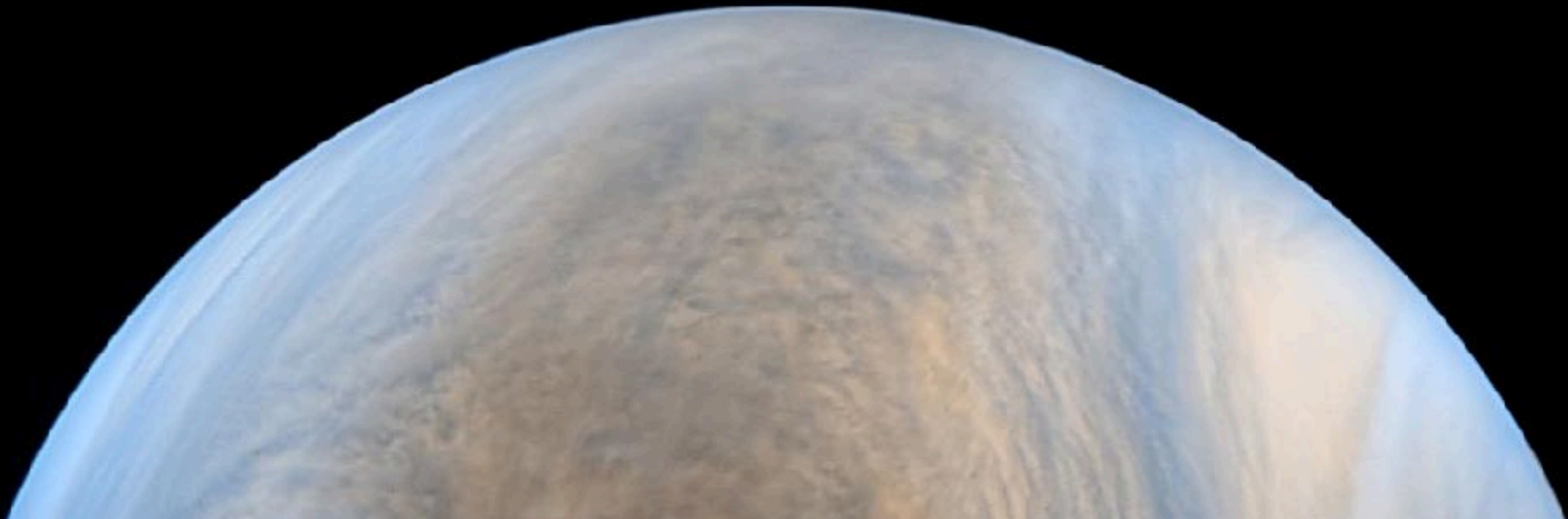
- Moving away from the Sun, the solar system has 8 planets.
- A **planet** is a celestial body that orbits a star and has sufficient mass for its self-gravity to obtain a nearly round shape and has “cleared the neighbourhood” around its orbit.
- The four closest to the Sun are smaller in size and are known as the **terrestrials**. These include Mercury (smallest), Venus, Earth and Mars.
- The four furthest from the Sun are larger in size and are known as **gas giants**. These include Jupiter (largest), Saturn, Uranus and Neptune.



- *Mercury*
  - Distance from the Sun: 58 000 000 km or 0.39 AU
  - Composition: Solid silicate crust and mantle overlying a solid, iron sulfide outer core layer, a deeper liquid core layer, and a solid inner core. Almost no atmosphere.
  - Number of Moons: 0
  - Period of Rotation & Revolution: 59 days & 88 days
  - Surface Temperature: Up to 427^{o}C during the day and down to -173^{o}C at night
  - Probes: Mariner 10 (1974-75), Messenger (2011-2015) & BepiColombo (2025)
  - Interesting Trivia: Despite it's proximity to the Sun there are pockets of frozen water in deep craters near its north pole region (shown below in yellow). It has the most elliptical orbit of any planet in the solar system. Craters here are named after artists (ie. musicians, novelists, painters).



- *Venus*
  - Distance from the Sun: 107 700 000 km or 0.72 AU
  - Composition: Rocky mantle and crust and a central iron core. A thick atmosphere comprised of mainly carbon dioxide.
  - Number of Moons: 0
  - Period of Rotation & Revolution: 243 days & 225 days (ie. this means a day on Venus lasts longer than a year)
  - Surface Temperature: Up to 450^{o}C because of an out of control greenhouse effect
  - Probes: Venera 1-16 (1961-1983), Mariner 2 (1962), Vega 1-2 (1985), Pioneer Venus Project (1978-1992), Magellan (1990-1994), Venus Express (2006-2014) & Atasuki (2015-)
  - Interesting Trivia: It's the third brightest object in the sky (after the Sun and the Moon). Acid deposition is norm on Venus as sulphuric acid rain is common.



- *Earth*
  - Distance from the Sun: 149 600 000 km or 1.00 AU
  - Composition: A rocky crust and mantle that surrounds a liquid outer core and a nickel-iron inner core. The atmosphere comprised of mainly nitrogen and oxygen.
  - Number of Moons: 1
  - Period of Rotation & Revolution: 23.93 hours & 365.25 days
  - Surface Temperature: An average of 14^{o}C, but ranges from -88^{o}C to 58^{o}C.
  - Interesting Trivia: It’s the largest of the inner terrestrial planets. Earth is the only planet not named after a god.

- *Mars*
  - Distance from the Sun: 227 390 000 km or 1.52 AU
  - Composition: It’s the “Red Planet” because of a thick layer of iron oxide dust on the surface. It’s rocky mantle surrounds a solid core of iron, nickel and sulfur. A thin atmosphere comprised of mainly carbon dioxide.
  - Number of Moons: 2 (Phobos and Deimos)
  - Period of Rotation & Revolution: 24.6 hours & 607 days
  - Surface Temperature: -125^{o}C to 20^{o}C
  - Probes: Mars has seen dozens of space probes over the years including Mariner 3-9 (1964-1971), Viking 1-2 (1976), Mars Pathfinder (1996), Mars Exploration Rover (2004), Mars Science Laboratory (2012) & InSight (2018)
  - Interesting Trivia: Home to the largest volcano in the solar system, Olympus Mons. It has a diameter the size of Arizona and is 25 km high with a crater at the top in excessive of 80 km wide.

- *Jupiter*

  - Distance from the Sun: 778 392 000 km or 5.27 AU

  - Composition: A thick atmosphere hundreds of kilometres thicks comprised of mainly hydrogen and helium. Whether the planet has a core at large is still up for scientific update but some scientists agree that its interior is made of liquid hydrogen metal.

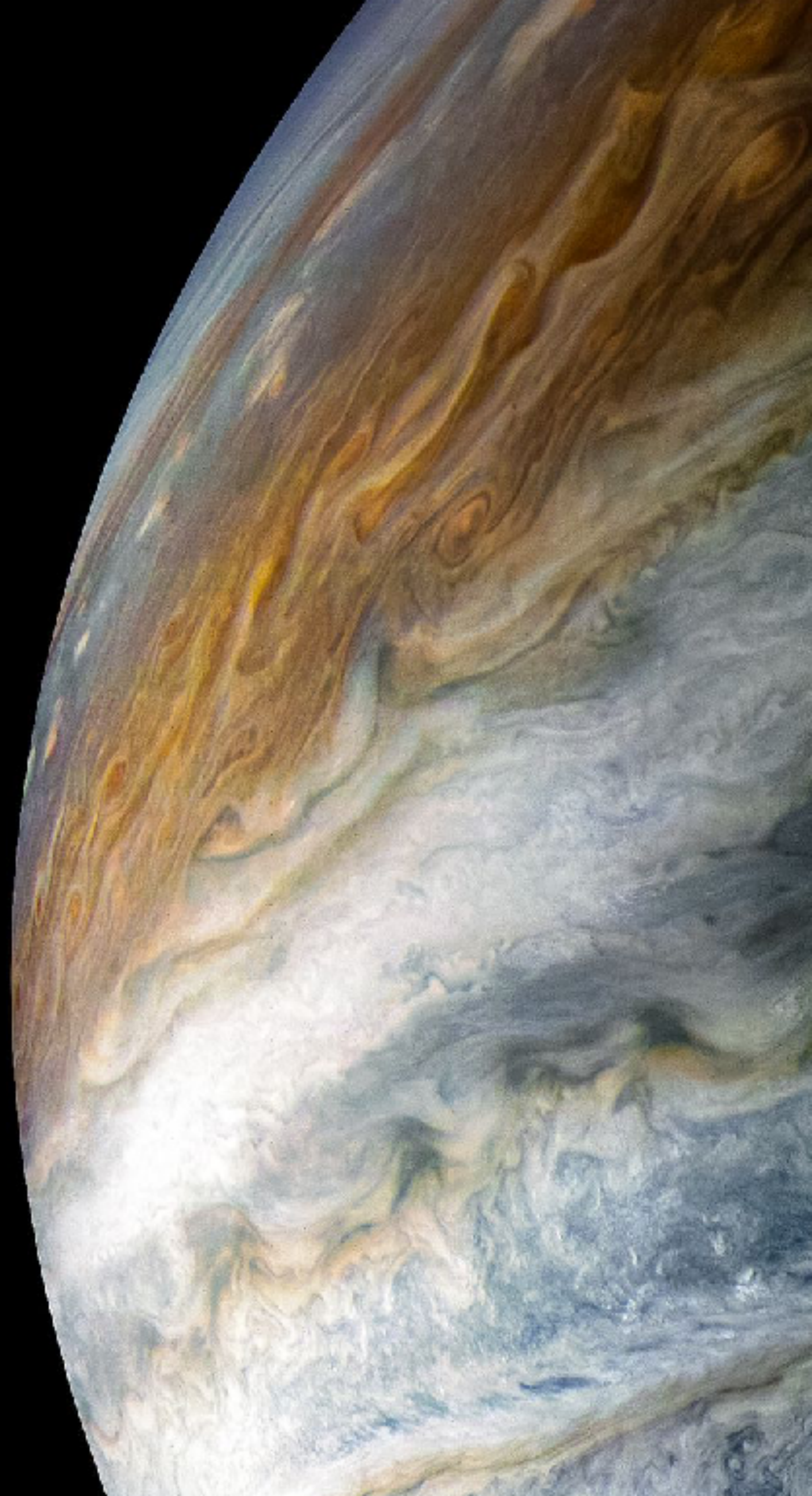
  - Number of Moons: 79 [including Io, Ganymede (the largest in the solar system), Callisto and Europa]

  - Period of Rotation & Revolution: 9.85 hours & 11.9 years

  - Surface Temperature: -145^{o}C at the top of the cloud layer

  - Probes: Pioneer 10-11 (1973-1974), Voyager 1-2 (1979), Cassini (2000), New Horizons (2007), Galileo (1995-2003) Juno (2016-2021) & Jupiter Icy Moon Explorer (2030)

  - Interesting Trivia: Jupiter's "Great Red Spot" is actually an incredibly large hurricane with wind speeds of up to 500 km. It has been raging over the planet for at least 300 years (when humans first "spotted" it). As well, while not as pronounced as those on Saturn, Jupiter does have a series of thin rings surrounding it.



- *Saturn*

  - Distance from the Sun: 1 427 184 000 km or 9.54 AU

  - Composition: A thick atmosphere comprised of mainly hydrogen and helium. The composition of the core is still uncertain but some scientists think it is made of liquid hydrogen metal.

  - Number of Moons: 62 [including Titan (second largest in the solar system), Rhea, Iapetus & Enceladus]

  - Period of Rotation & Revolution: 10.38 hours & 29.5 years

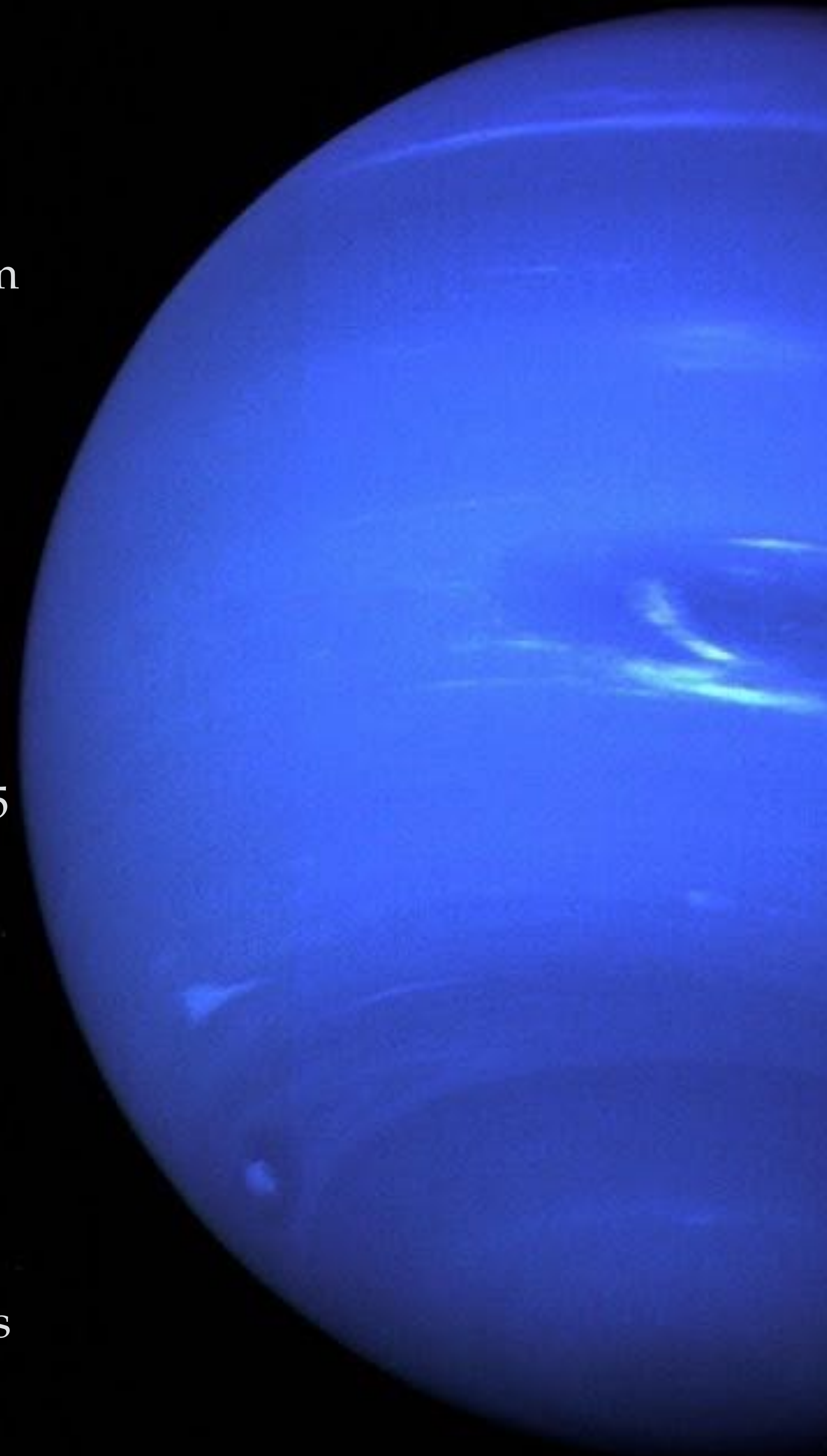
  - Surface Temperature: -178^{o}C at the top of the cloud layer

  - Probes: Pioneer 11 (1979), Voyager 1 (1980), Voyager II (1981) & Cassini-Huygens (2004-2017)

  - Interesting Trivia: Saturn is the least dense planet in the solar system. Saturn's moon Titan is the first celestial body other than Earth to have liquid oceans on its surface. Unlike Earth, these oceans are not made of water but methane.

- ***Uranus***
    - Distance from the Sun: 2 870 824 000 km or 19.19 AU
    - Composition: An atmosphere of hydrogen, helium and methane surrounds the planet. The surface is a frozen ocean of water, ammonia and methane. The core is comprised of iron and magnesium silicate.
    - Number of Moons: 27 (including Miranda, Ariel, Umbriel, Titania and Oberon)
    - Period of Rotation & Revolution: 17.4 hours & 84 years
    - Surface Temperature: -220^{o}C at the top of the cloud layer (coldest in the solar system)
    - Probes: Voyager 2 (1986)
    - Interesting Trivia: Uranus has an axis tilt of roughly 98 degrees. This means that it's rotation, ring systems and moons are all flipped sideways. Uranus' moons are named after characters in Shakespearian plays.

- *Neptune*
  - Distance from the Sun: 4 496 976 000 km or 30.06 AU
  - Composition: An atmosphere of hydrogen, helium and methane surrounds the planet. The surface is a frozen ocean of water, ammonia and methane. The core is comprised of iron and magnesium silicate.
  - Number of Moons: 14 (including Triton, Proteus, Galatea and Larissa)
  - Period of Rotation & Revolution: 16.2 hours & 165 years
  - Surface Temperature: -200^{o}C at the top of the cloud layer
  - Probes: Voyager 2 (1989)
  - Interesting Trivia: Like all the other giant gases, Neptune has a ring system. However, it resembles Jupiter’s more than it does Saturn’s and was discovered until 1984.

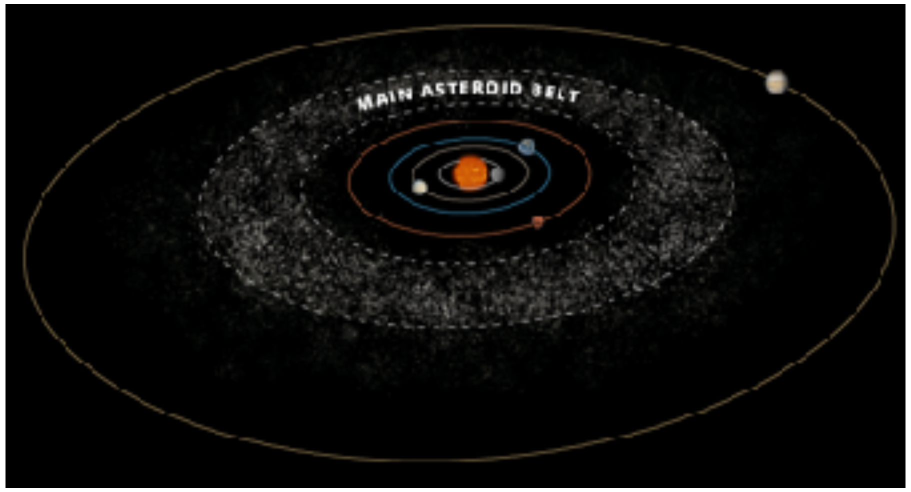


- Other than the Sun and the 8 planets, there are many other objects in the solar system:

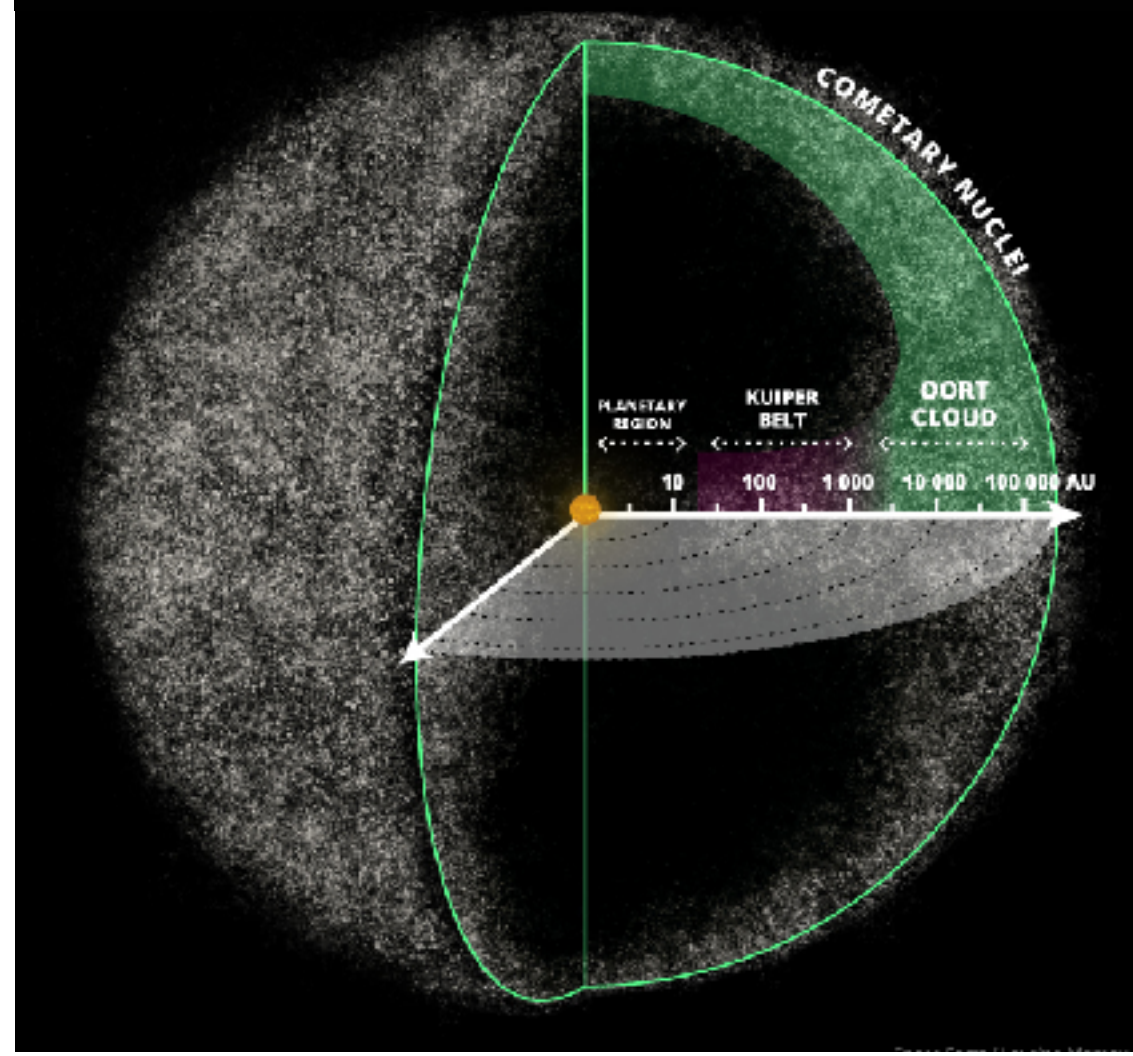
    - ***Asteroids:*** Small rocky objects that orbit around the Sun mainly between the inner terrestrial planets and the outer giant gases.

    - ***Meteoroids:*** Small rocky objects that flying through space with no particular path. If one enters the Earth's atmosphere it's then called a **meteor**. If a meteor survives atmospheric entry and lands we can it a **meteorite**.

    - ***Comets:*** Small objects made up of dust and ice. They are generally found in the outer solar system. However, some work their way into the inner solar system and get caught into very elliptical orbits around the Sun. Their characteristic brightly glowing long tails only appear when they interact with solar winds as they close in to the centre of the solar system. Possibly the most famous of these objects is Halley's comet which is visible from Earth every 76 years. It's scheduled for its next return visit in 2062.



- What about the solar system past Neptune’s orbit?
    - The **Kuiper belt** is a region similar to the asteroid belt, but is far larger. It is 20 times as wide extending from 30 AU to 50 AU away from the sun. It consists mainly of small icy bodies from when the Solar System formed. It’s home to three officially recognized **dwarf planets**: Haumea, Makemake and **Pluto** (which lost it’s planetary status in 2006),
    - The **Oort cloud** is an extended shell of icy objects that exist in the outermost reaches of the solar system (up to 200 000 AU or 3.2 light years from the sun). It’s roughly spherical and is thought to be the origin of most of the long-period comets that have been observed.
- *So just how do you put this all into perspective?*



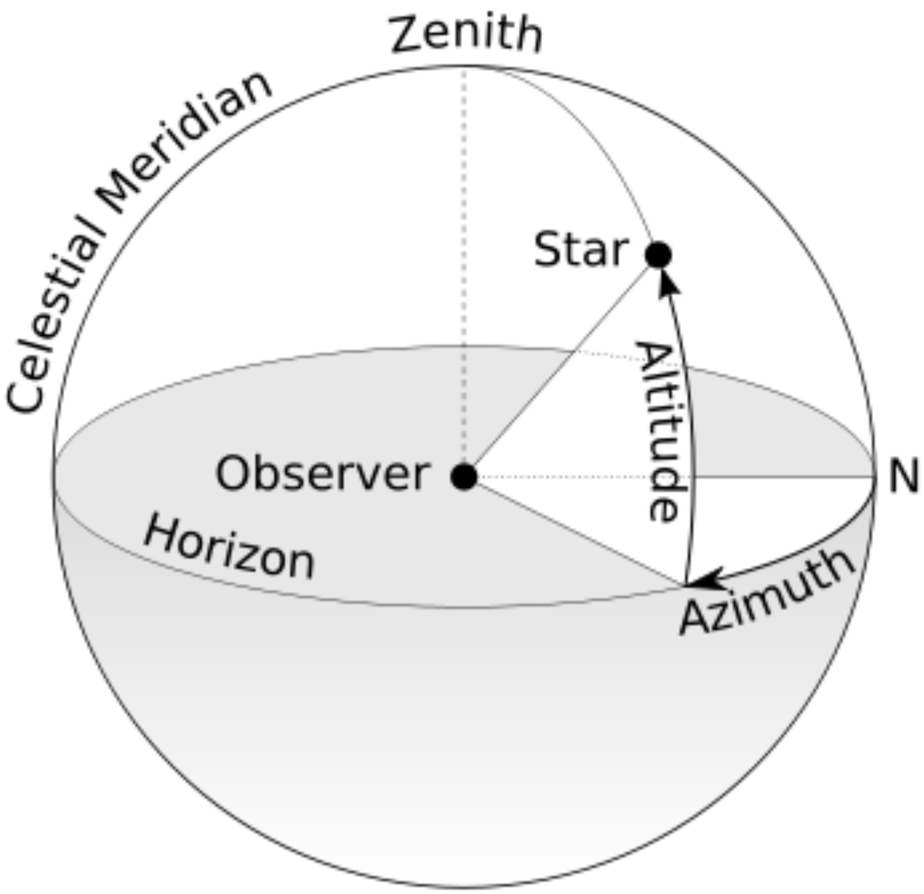
- ***In-Class Activity/ Homework:*** Complete the "Solar System" worksheet and answer questions 1-6 on p. 400 in the textbook.

Describing the Position of Objects in Space (1.5)

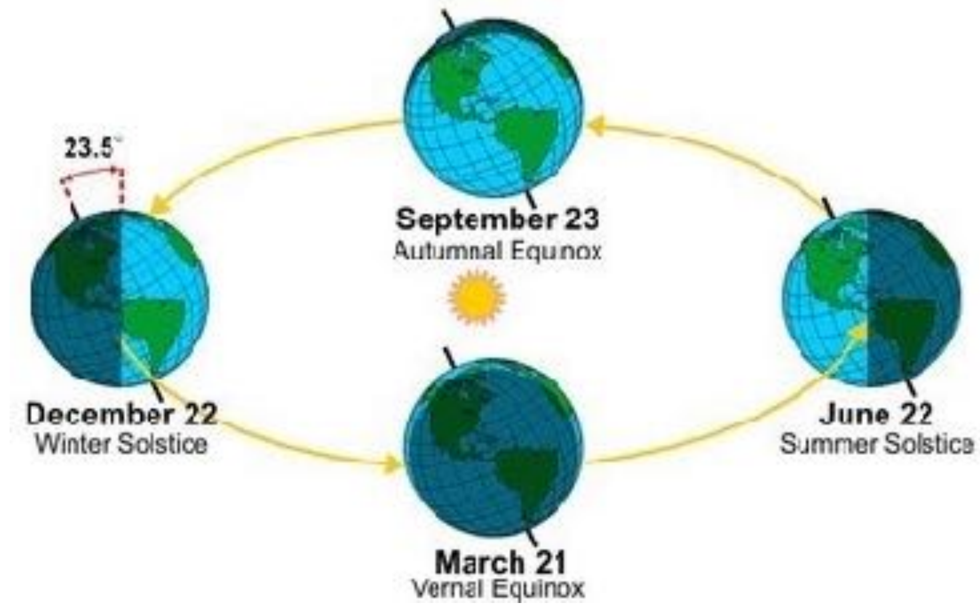
- So you think you've discovered a new celestial object in the sky. How do you tell people where to find it?

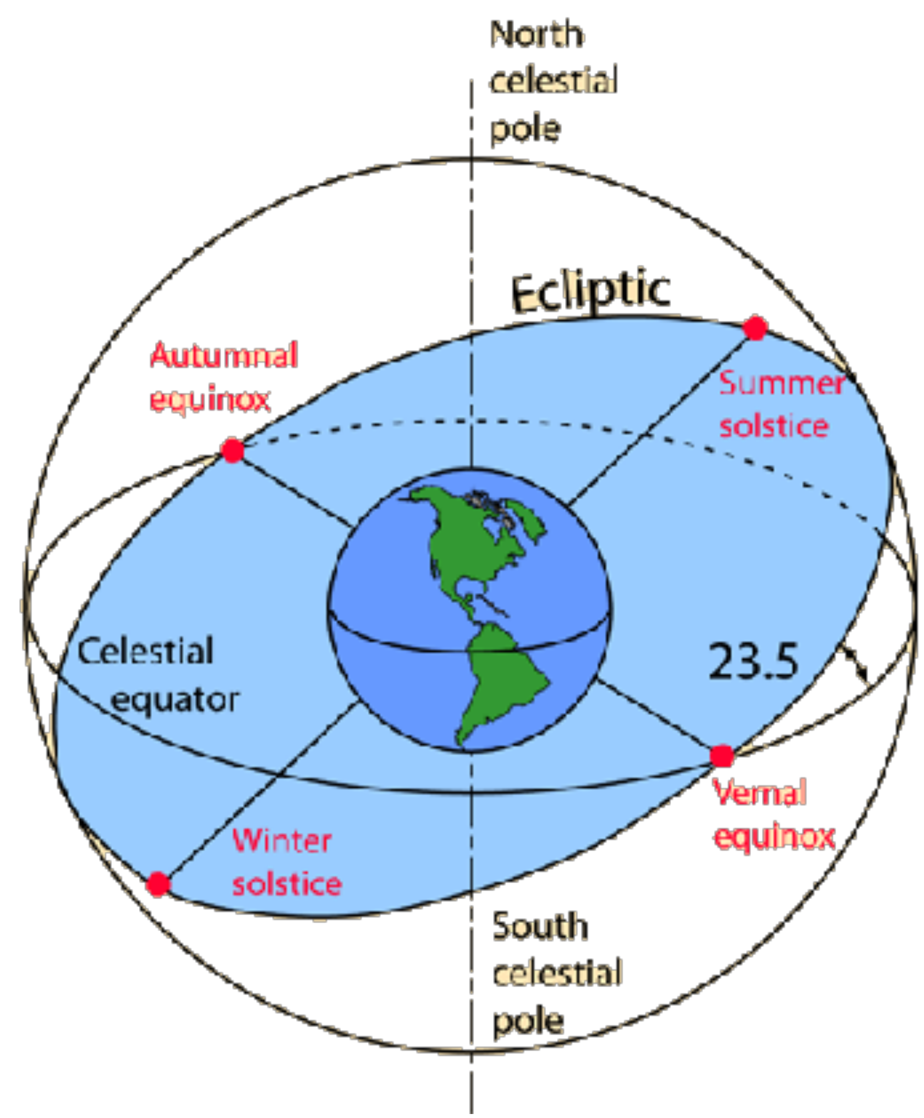
- First you provide the **azimuth**. Using compass north as 0 degrees and going clockwise, this tells you which direction to point.

- Second you provide the **altitude**. This is how high in the sky it is from 0 degrees (the horizon) to 90 degrees (the **zenith** which directly overhead). This is what tools like a quadrant, astrolabe or cross-staff do.



- The azimuth of sunrise and sunset, as well as the altitude of the sun changes in the sky throughout the year.
- This is because the Earth's axis is slightly tilted.
- During the summer the northern hemisphere, the sun's path through the sky (ie. **ecliptic**) is higher than it is during the winter.
- The ecliptic at its highest on the date of the summer solstice (ie. the longest day of the year) and at it's lowest on the date of the winter solstice (ie. the shortest day of the year).
- The exact opposite is true in the southern hemisphere (ie. our summer is their winter)





- ***In-Class Activity/ Homework:*** Complete questions 1-4 on page 405 & questions 2-4, 6-9, 11, 13-14, 16 & 18 on pages 406-407 in your textbook in preparation for the 1.1-1.5 quiz next class.

Getting There: Technologies in Space Transport (2.1)

- In order for humanity to explore space, we needed to solve the following problems:
  - How to go fast enough to break free of Earth's gravity.
  - How to leave Earth's orbit altogether.
  - How to keep equipment operating in the extreme environment of space.
  - How to transport people into and out of space.
  - How to communicate with equipment and people in space.

- The development of the technologies that would eventually lead to space travel occurred very quickly:
    - In 1903, Konstantin E. Tsiokovsky publishes the "rocket equation". This concerns relationships between rocket speed and mass.
    - In 1926, Robert Goddard successfully launches the first liquid-fuelled rocket.
    - During World War II, Hermann Oberth developed theories on how to use a rocket to escape Earth's gravity. He also helped the Nazis build V-2 rockets.
    - In 1957, the Soviets launched the first satellite into orbit (ie. *Sputnik I*). The American followed a year later with *Explorer 1***.**
    - In 1961, Yuri Gagarin becomes the first human in space.
    - In 1962, the first Canadian telecommunications satellite is launched (*Alouette 1*).
    - In 1969, Neil Armstrong steps foot onto the moon.
    - In 1970, the first probe to land on other planet, *Venera 7* ,touches down on Venus.

- In 1981, the first Space Shuttle mission launches.
- In 1986, the Space Shuttle *Challenger* explodes shortly after launch killing all seven crew members.
- In 1998, the International Space Station (ISS) is put into orbit.
- In 2001, the first space tourist pays $20 million to ride on a Soyuz spacecraft.
- In 2003, the Space Shuttle *Columbia* burns upon re-entry into the Earth's atmosphere.
- In 2008, private company SpaceX launches Falcon 1.
- In 2011, the Space Shuttle program is ended.
- In 2012, *Voyager I* becomes the first first man-made probe to enter interstellar space.

- **Rocketery** is much pretty at the heart of all of these milestones. So how do rockets work?
    - A rocket is divided into three parts:
        - The structural/mechanical elements (ie. engines, storage tanks and the outer casing)
        - The fuel (ie. liquid oxygen and hydrogen)
        - The payload (ie. what the rocket is carrying into space)
    - Sir Isaac Newton's 3rd Law of Motion states that for every reaction, there's an equal and opposite reaction.
    - *Essentially a rocket is a mass engine* (start the video at 12:17). When fuel is consumed and expelled in one direction, the rocket is propelled in the other direction (ie. skywards).

- ***Homework:*** Complete questions 1, 3-4 & 6 on page 417 of your textbook.

Surviving There: Technologies for Living in Space (2.2)

- Getting to space is only the first step. Once people get into space, there are a series of challenges awaiting them:
    - Physical Environment
        - How do we recycle water?
        - How do we generate electricity?
        - What do we do with waste?
        - How do we keep the temperature constant?
        - How do we produce oxygen?
    - Physiological
        - What is the effect of of no gravity or ***microgravity*** (ie. when gravitational forces are weaker than on earth) on the body?
        - What are the psychological challenges of extended isolation and confined living spaces?

- NASA has announced that it's working to establish a permanent human presence on the Moon within the next decade to uncover new scientific discoveries and lay the foundation for private companies to build a lunar economy.
- From there, they have their eyes on Mars. *What would be the challenges of such a mission?*
- ***Homework:*** Complete questions 1-2, 6 & 8 on p. 425 of your textbook for next class.

Using Space Technology to Meet Human Needs on Earth (2.3)

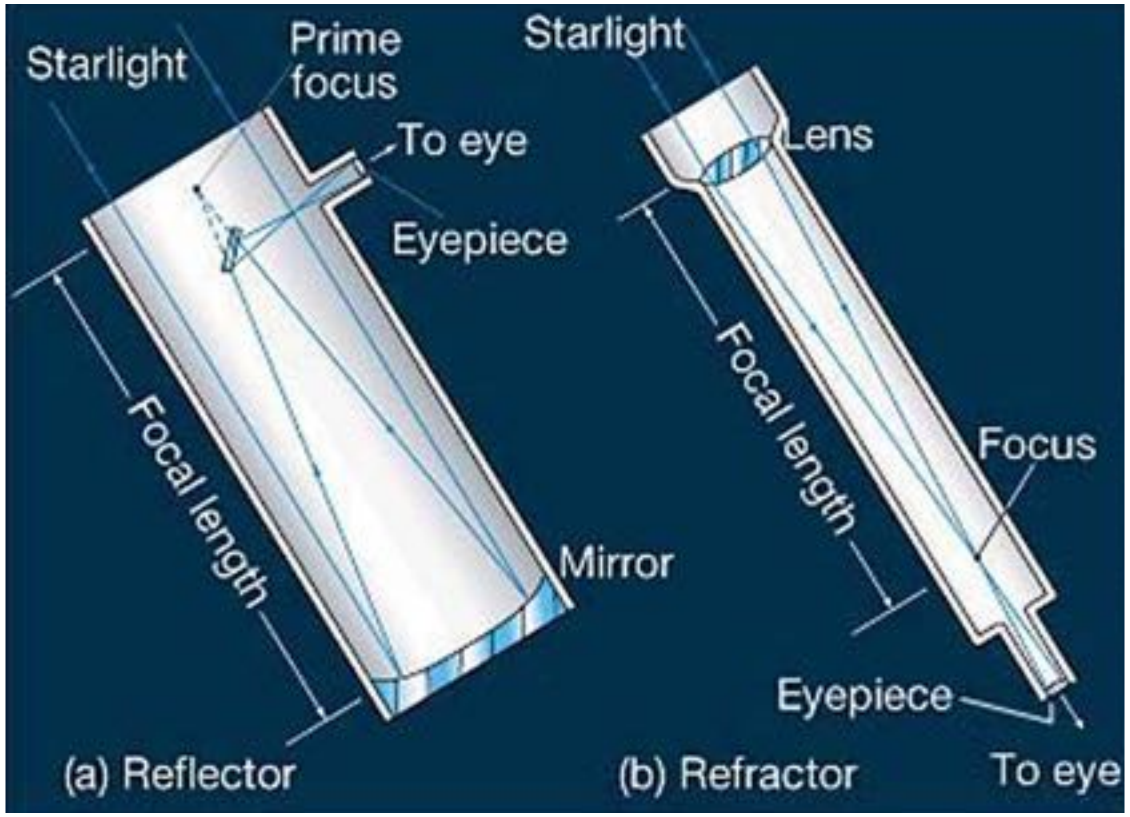
- Since being launched for the first time in 1957, artificial ***satellites*** have become a major part of our lives:
    - Communication (ie. phones, TV, internet, business/finance)
    - Observation and Research (ie. Google Earth, as well as monitoring various things from weather to forest fires to climate change)
    - Navigation (ie. GPS)
    - Astronomy (ie. telescopes in orbit such as Hubble)
- Some satellites are designed to always be above one position on earth. These are named **geosynchronous satellites** (ie. global positioning satellites).

- *Development of technologies to get us to and from space have also lead to many areas of innovation and development on planet Earth.*
    - Microelectronics
    - Smoke stack scrubbers
    - Virtual reality software
    - Food preservation techniques
    - Improved helmets, golf balls and shoe design
    - Voice control systems
    - Improved tire rubber
    - Robotics

- ***Homework:*** Complete questions 1-3 & 8 on p. 432 and questions of your textbook for next class.

Using Technology to See the Visible (3.1)

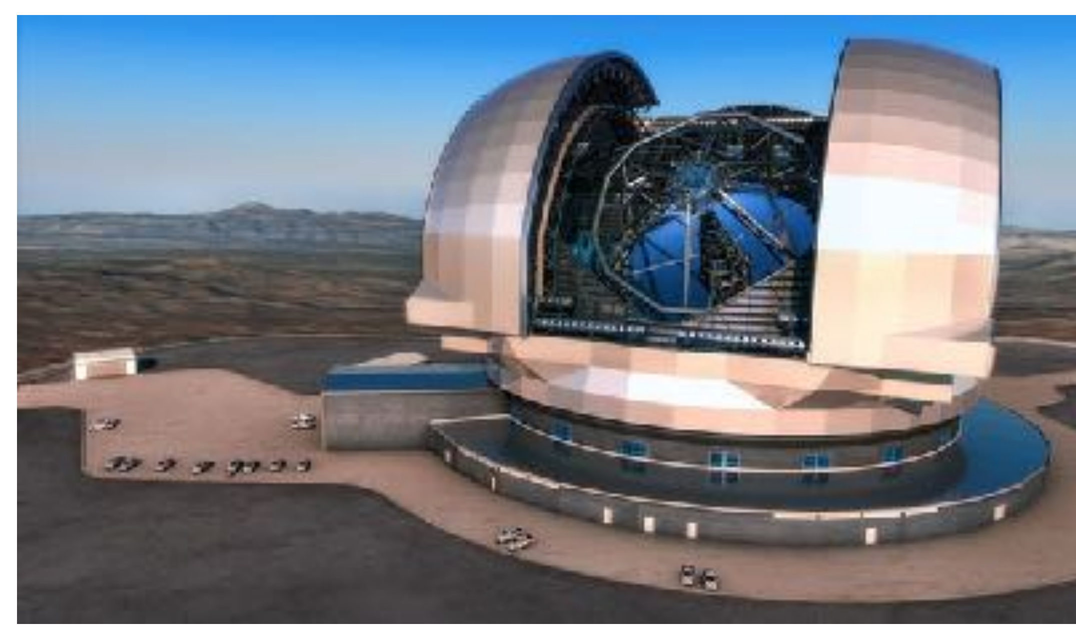
- ***Optical telescopes*** are able to view visible objects in the night sky and are divided into two main categories:
    - **Refracting Telescopes:** This was the type of telescope used by Galileo. It uses two lenses to gather and focus starlight. This are limited to a lens size of 1 metre.
    - **Reflecting Telescopes:** Uses larger polished mirrors coated with thin metal rather than lenses. By segmenting the mirrors, this telescopes can be greatly increased in size. This greatly increases their light-gathering ability and resolving power (ie. the ability to distinguish details in an object).



- The resolution of telescopes can be improved further when two or more of them are used together in an array. This process is known as **interferometry**.

- For example, there are two massive reflecting telescopes on the top of Mauna Kea on the big island of Hawaii called Keck I and Keck II. Each one has a 10 metre segmented mirror (ie. comprised of 36 pieces) and they are located only 85 metres apart.

- Planned for completion in 2025 is the ELT (Extremely Large Telescope) in the Atacama Desert of northern Chile. It will have a diameter of 39.3 metre and will be comprised of almost 800 segments. When complete, it will produce images 15 times sharper as compared to the world’s most famous telescope - Hubble.



- **Hubble Space Telescope** has made more than 1.3 million observations since its mission began in 1990. This includes looking at objects more than 13.4 billion light years from Earth.

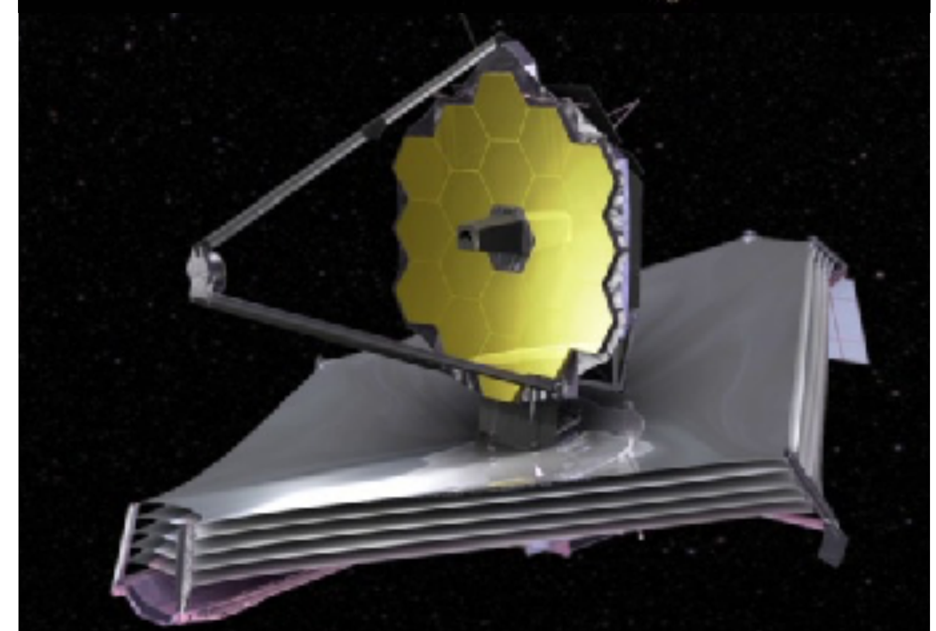
- Hubble's primary mirror is 2.4 metres in diameter and the telescope itself is roughly the length of a large school bus.

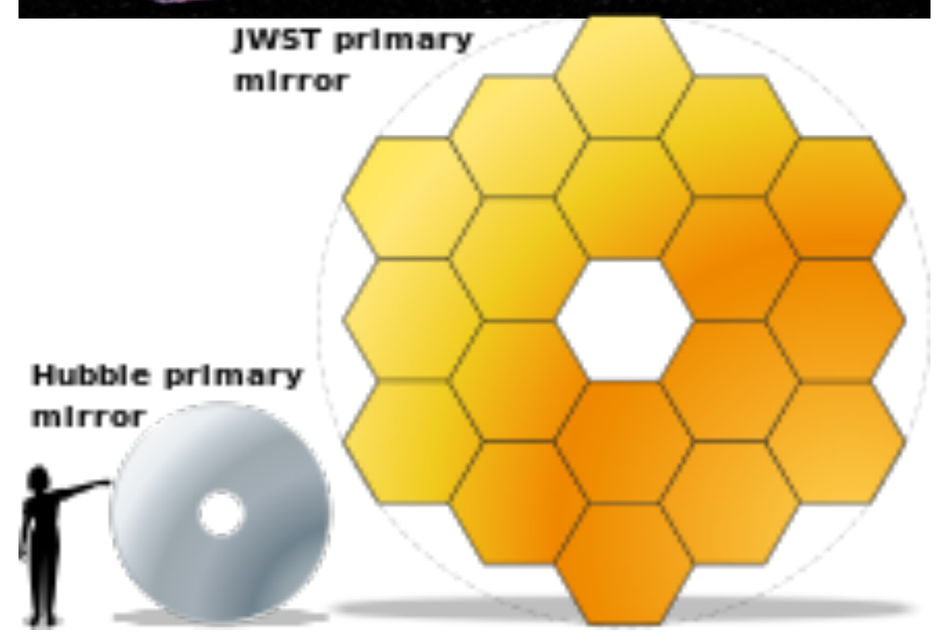
- Due to the combination of superior optics and with no atmosphere to interfere with the light reaching it, Hubble could spot a night light on the surface of the Moon from Earth.

- Hubble has no thrusters. To change angles, it uses Newton's third law by spinning its wheels in the opposite direction. It turns at about the speed of a minute hand on a clock, taking 15 minutes to turn 90 degrees.

- There are already plans for Hubble's big brother - **JWST (James Webb Space Telescope)**. It's set to launch in 2021 and will have a segmented mirror of 6.5 metre in diameter and will be placed in a much higher orbit than Hubble (ie. 1.5 million km compared to 550 km).

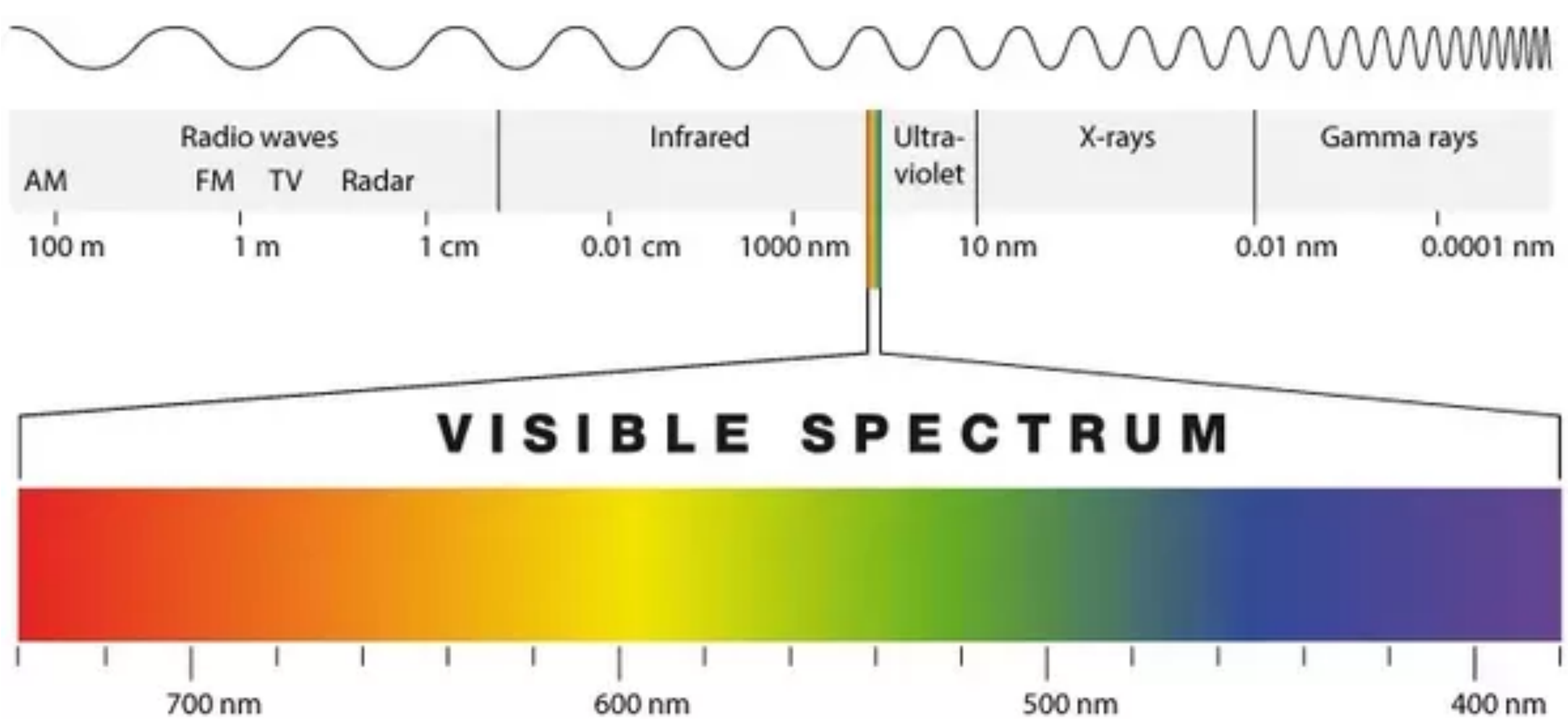
- *Homework:* Complete questions 1-9 on page 439 of the textbook.





Using Technology to See Beyond the Visible (3.2)

- Optical telescopes are only able to see visible light.
- However, this is only a small portion of the entire **electromagnetic spectrum** which covers the whole range of **electromagnetic energy** sources including radio waves, infrared (heat) waves and X-rays for example.
- All types of electromagnetic energy travel at the speed of light (ie. 300 000 km/s) and are differentiated from each other by their various wavelengths.



- It’s for this reason that scientists has developed telescopes that “look” at electromagnetic waves other than visible light. For example, JWST will be able to see infrared waves.

- Another example are **radio telescopes**. They have several advantages over their optical cousins:

    - They can used to collect data regardless of weather or time of day.

    - They are not distorted by the atmosphere.

    - They are not blinded by bright celestials objects which might prevent us from seeing other dimmer objects nearby.

- Due to the fact that radio waves are the longest electromagnetic waves, these telescopes must be huge in order to detect them. For example, the largest one in the world in China has a diameter of over half a kilometre.

- Like optical telescopes, radio telescopes can be combined into huge array to increase their resolving power (ie. interferometry).
- Unlike optical telescopes arrays that must be put close together, radio telescope arrays are more accurate the further apart the telescopes are. For example, the Very Large Array in Socorro, New Mexico uses over 2 dozen 25 metre telescopes ranged in a Y pattern that covers a distance of 61 km. This is equivalent to using a single refracting telescope with a mirror diameter of 27 km!

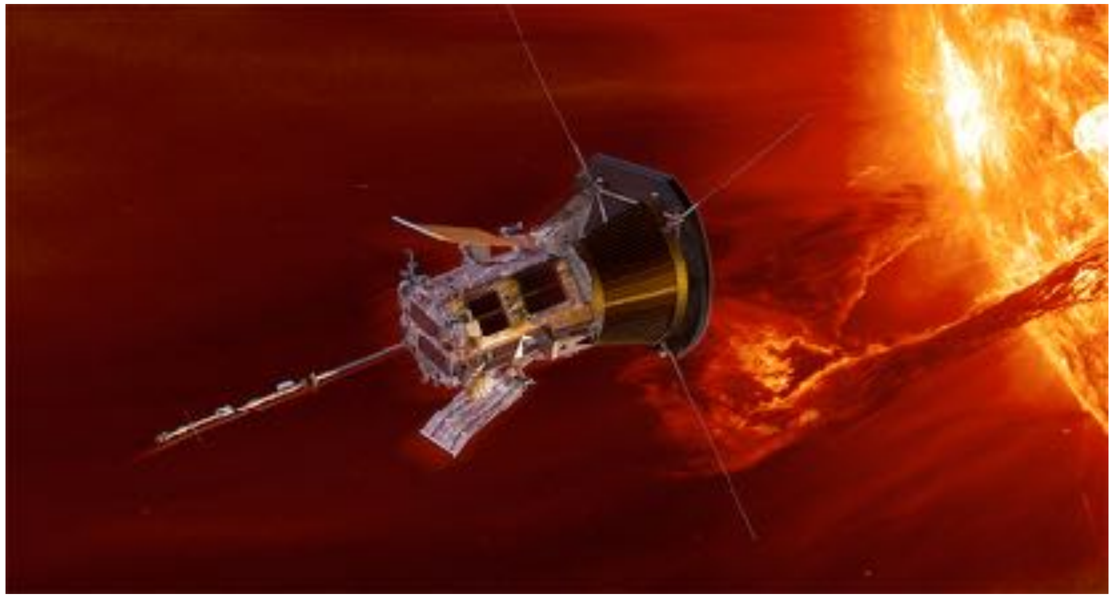
- As mentioned earlier in the unit, scientists have used unmanned **space probes** to explore many areas of our solar system.

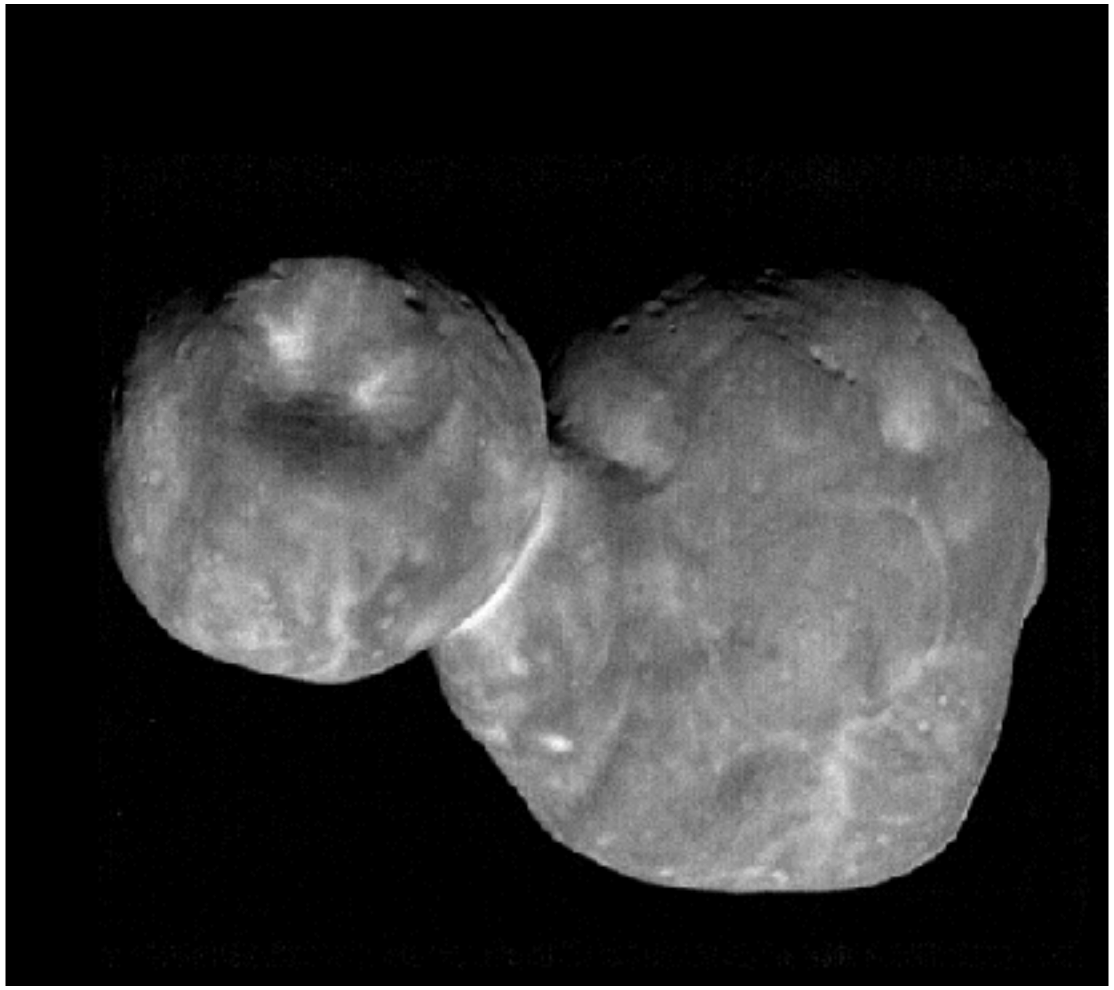
- Some of the latest include:

  - The Parker Solar Probe: Launched in 2018, it will enter the Sun's corona. NASA has equipped it with a state-of-the-art heat shield and other crucial cooling systems. The result is that this spacecraft will stay at room temperature in in an area so close to the Sun that temperatures reach above 1.5 million degree Celsius.

  - New Horizons: After being launched in 2006 and rendezvousing with Pluto in 2015, it did a flyby of the Kuiper belt object "Ultima Thule" in 2019. It also confirmed the existence of a hydrogen wall at the outer edge of our solar system. This "wall" was first detected in 1992 by the two Voyager probes that were launched in the 1977.

- ***Homework:*** Complete questions 1-5 & 7 on page 445 of your textbook.





Using Technology to Interpret Space (3.3)

- When astronomers look at star, they can using basic geometric principle of **triangulation** to calculate their distances from the Earth (ie. the same principle used by GPS).

- Here's how triangulation works:

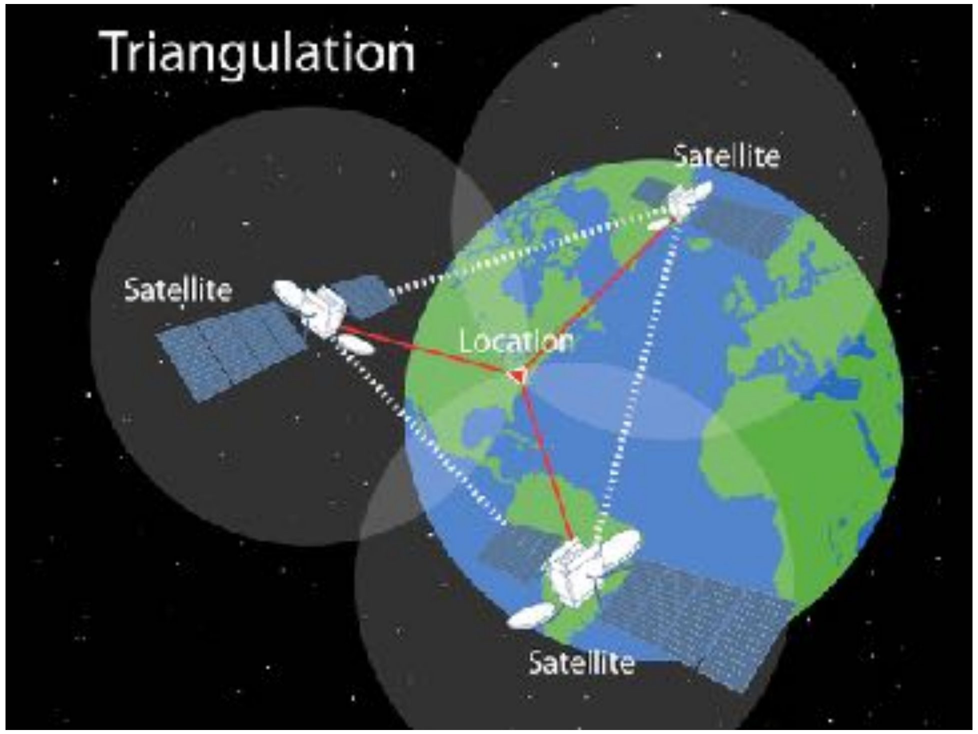
    - First you need a known base line measurement between two viewing positions of an object.

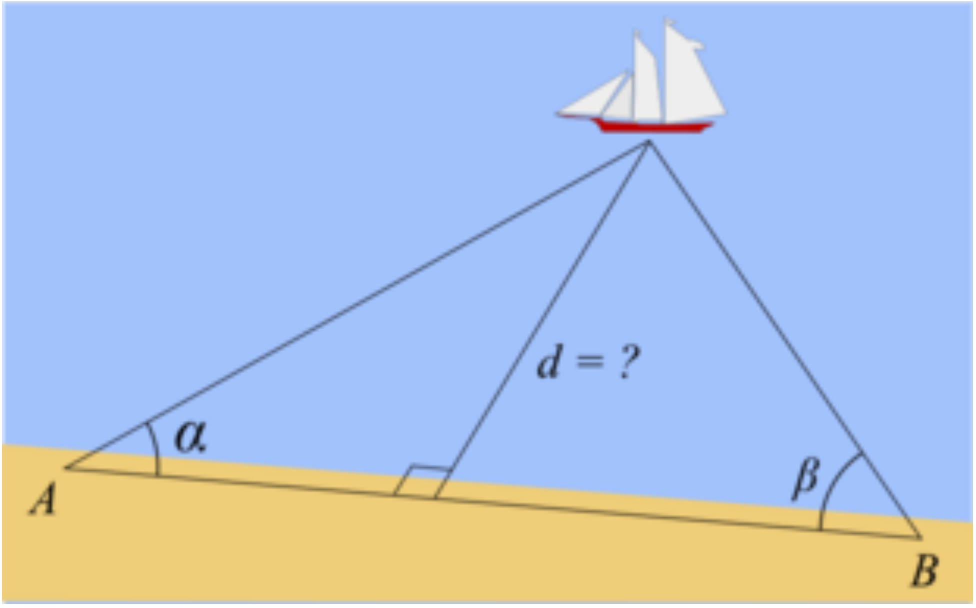
    - From each viewing position, measure the angle of the sight line to the object.

    - Now that you the two angles and the base line distance, you can use math to solve the rest (ie. the distance to the object).

- When attempting these types of calculations with stars that are extremely long distances from the Earth, the longer the baseline is the more accurate the math will be.

- How can we achieve this?

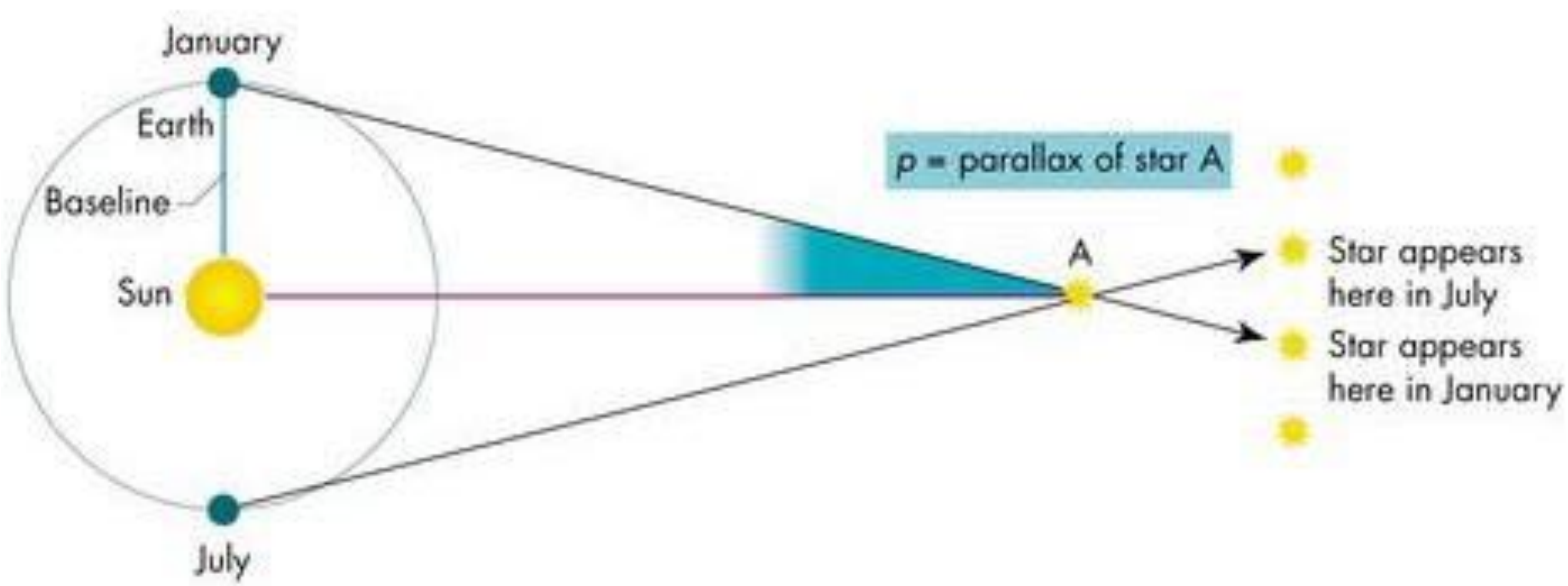


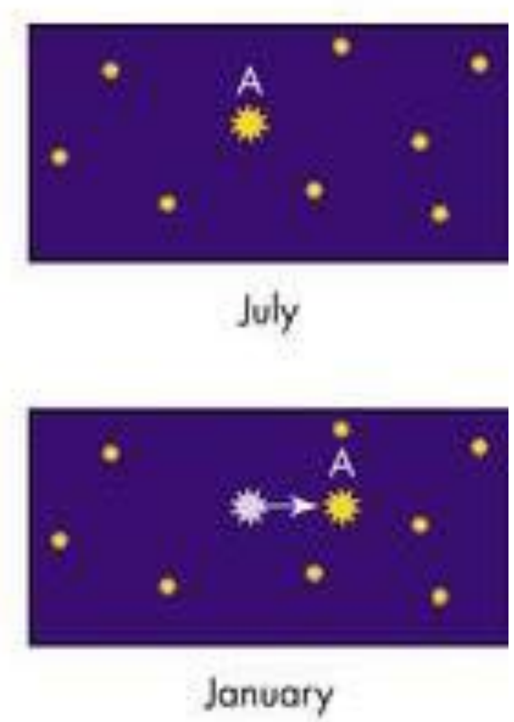


- We use the Earth's orbit to create the baseline.

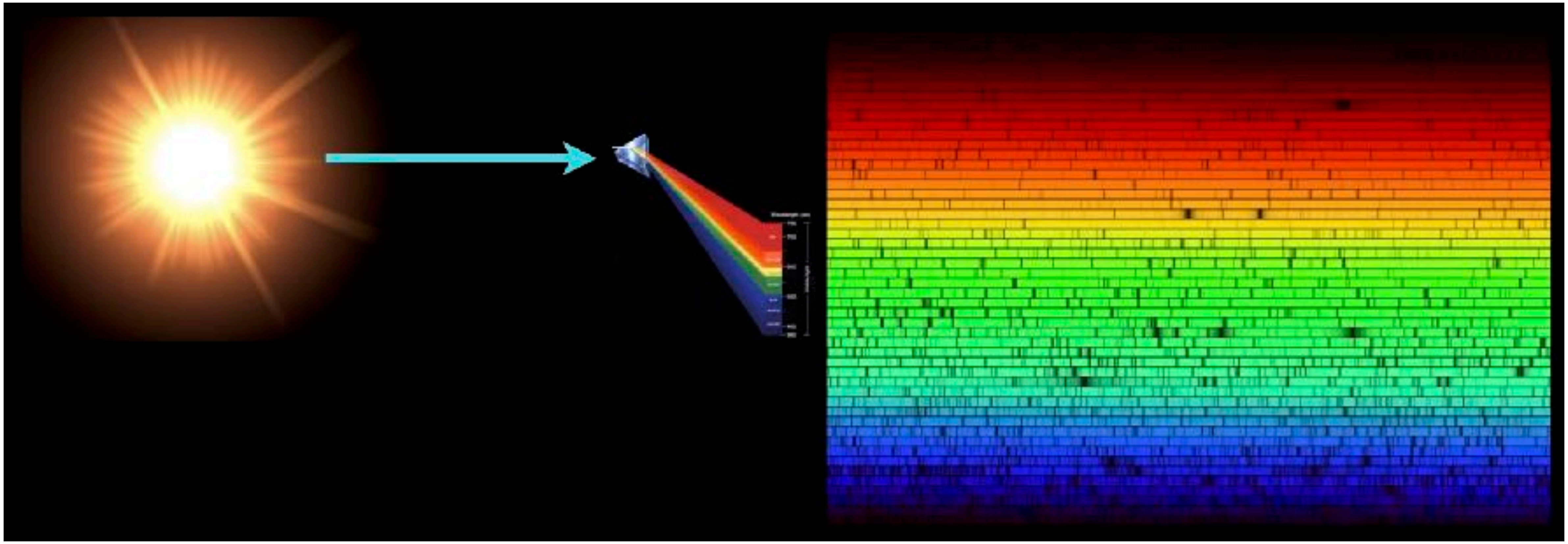
- If we look at the same star from the same telescope on two days that are half a year apart from one another, our baseline becomes 2 AU.

- From of these two positions, the star appears to shift position in the sky. This is known as **parallax** and it's what astronomers use to calculate the angles to use when triangulating the star's distance from the Earth

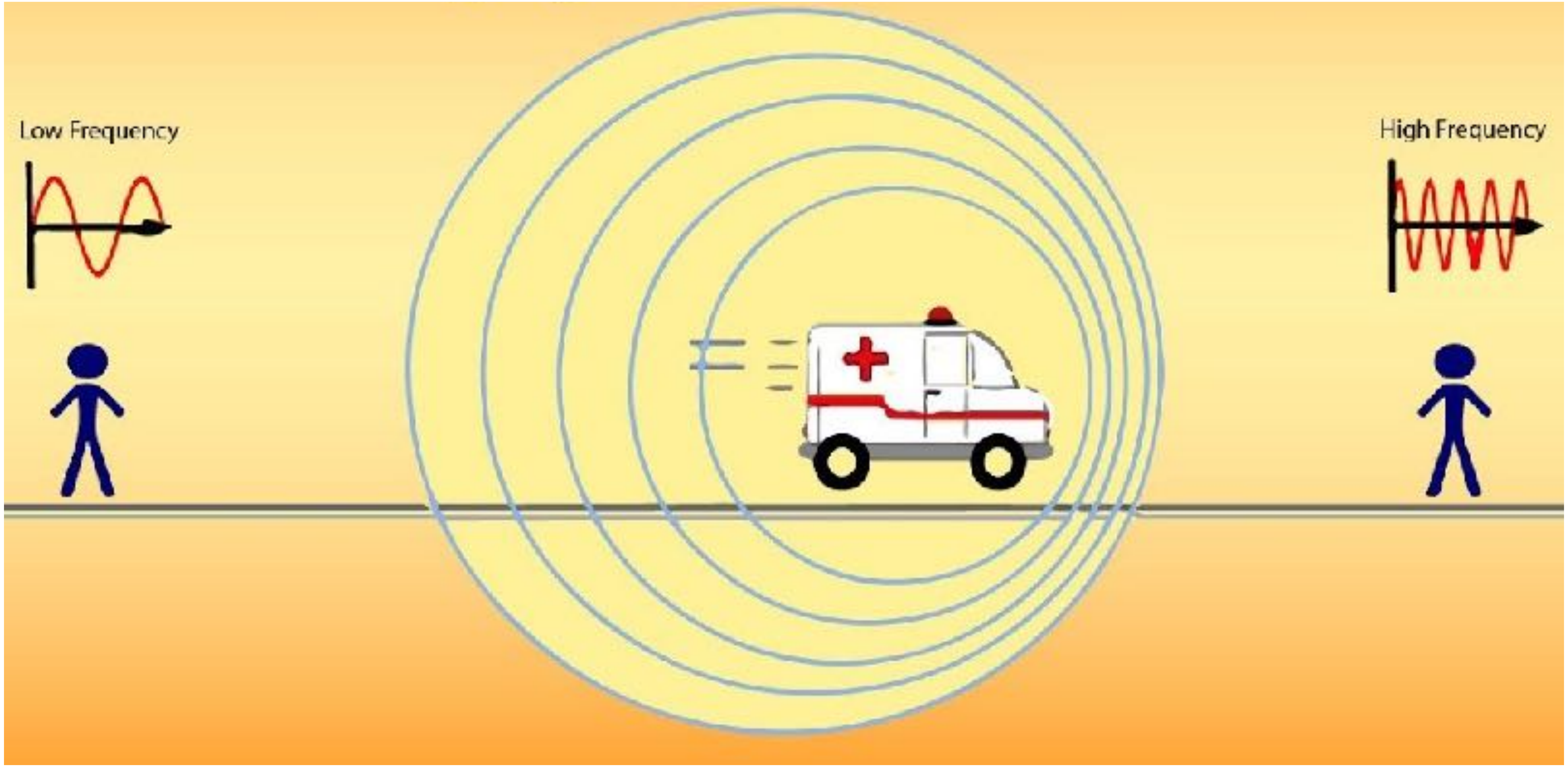




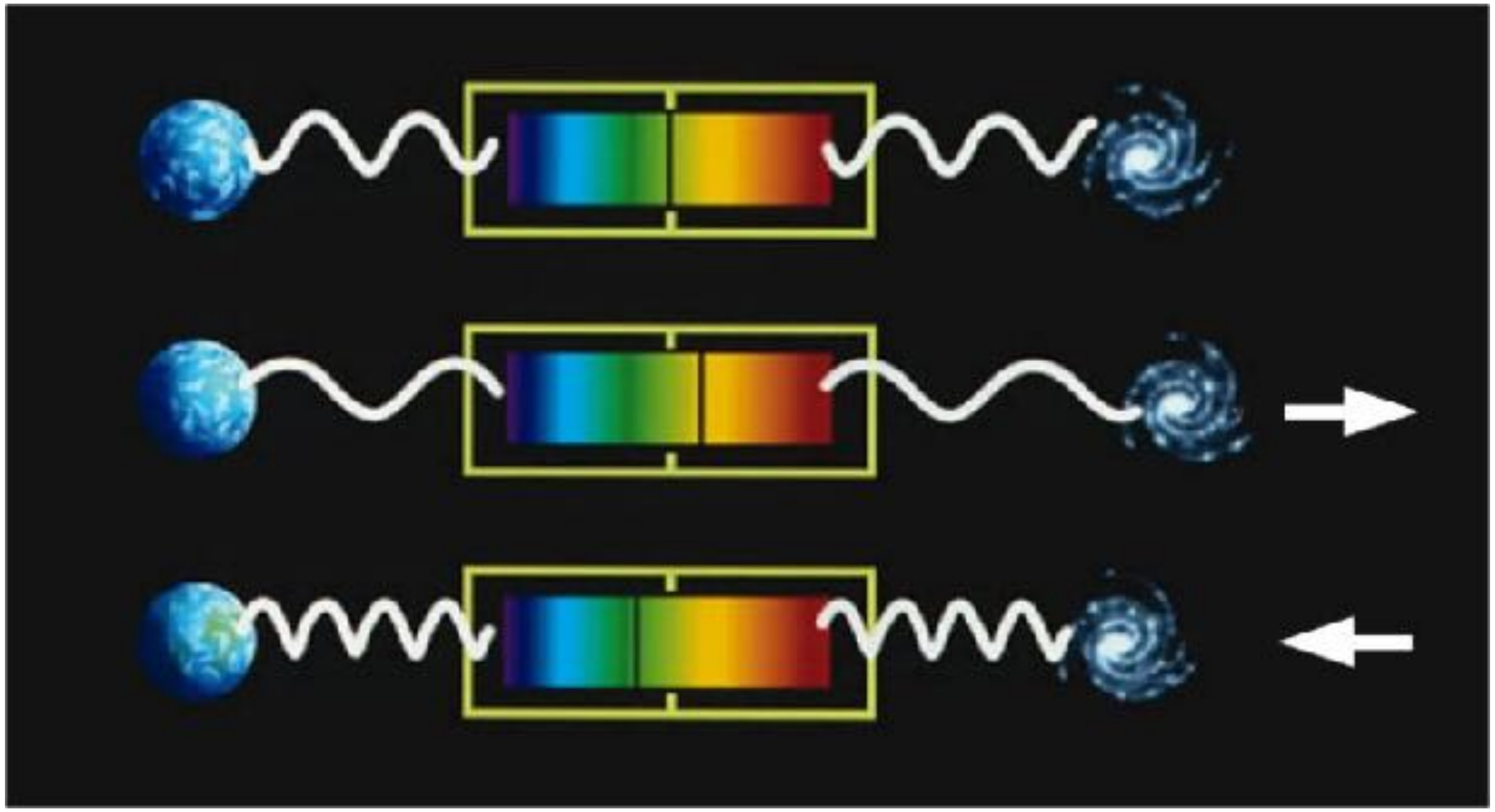
- Astronomers can take this a step further. Once they know the star's distance from the Earth, they can also determine its composition.
- They use an instrument called a **spectroscope** to do so. It measures the wavelengths of light that different elements absorb and emit (ie. reflect). Astronomers compare the spectrum emitted by a star with known spectra produced by elements to determine what the star is made of.



- Astronomer can also spectroscopy to determine a star's direction of motion.
- You may be familiar with the **Doppler effect**. When a vehicle approaches you the sound waves are compressed in front of it causing the pitch to rise (ie. higher pitch sounds are created through shorter wavelengths). When it passes, the wavelengths behind the vehicle are no longer squeezed and the pitch decreases.



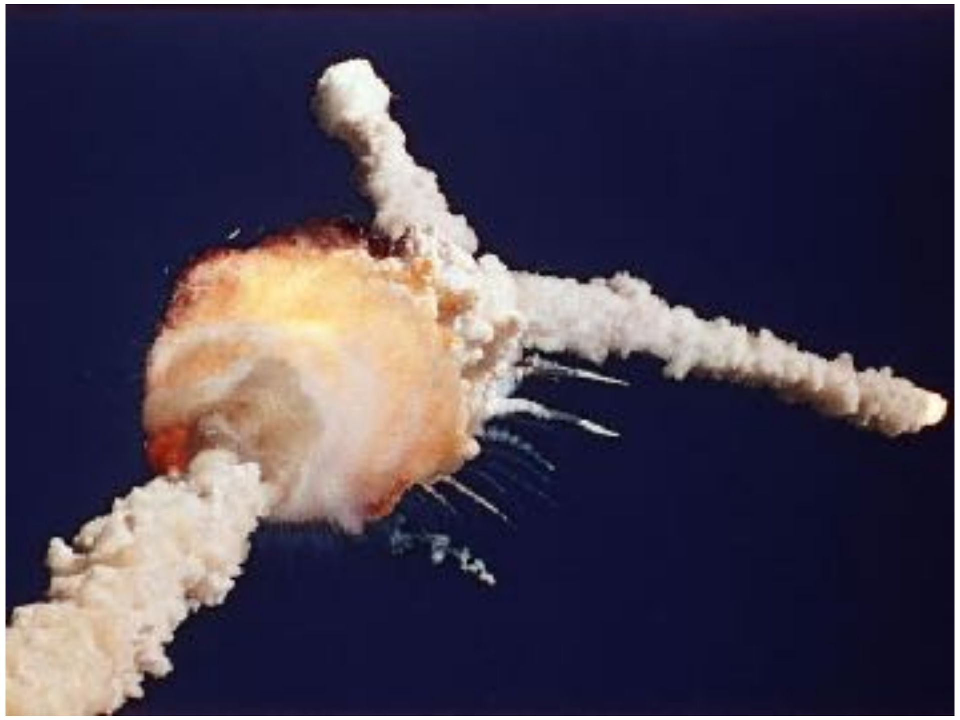
- Light does the same thing:
    - When it moves towards you it become compressed or **blue-shifted** (ie. blue represents the shortest waves of visible light).
    - When it moves away from you it become stretched or **red-shifted** (ie. red represents the longest waves of visible light).
- A spectroscope is sensitive enough to pick up these "shifts" and can therefore determine if the star that's emitting the light is moving toward or away from us. If there is no shift, the star is said to be stationary.



- ***In-Class Activity/ Homework:*** Complete questions 1-7 on page 454 and questions 1-9 on page 455 of your textbook in preparation for your upcoming Topic 2.1-3.3 quiz.

The Risks and Dangers of Space Exploration (4.1)

- *How many people have died in space?*
- The 1986 *Challenger* and the 2003 *Columbia* Space Shuttle disasters are stark reminders about the dangers of space travel.
- Exposure to cosmic radiation is also another concern for astronauts. Outside the safety of the Earth's magnetic field, these particles from the Sun and other sources in the Milky Way can kill cells in vital organs and damage bone marrow. This can lead to increased risks of cancer.
- Another issue about human's presence in space is **space junk**. This refers to all the pieces of debris that have fallen off rockets, satellites, space shuttles and space stations and remain floating in space.



Canadian Contributions to Space Exploration and Observation (4.2)

- Canadians have had a long and proud tradition in space exploration:
    - In 1972, researchers from the University of Toronto found the first physical evidence of a black hole (ie. Cygnus X-1).
    - The Canadarm was a remote-controlled robotic arm developed for NASA's space shuttle problem. From 1981-2011, it was used on 90 space missions. It helped capture and deploy satellites, dock space shuttles and even built the ISS. The Canadarm2 has been a permanent fixture on the ISS since 2001.
    - Only a few Canadians have ever been in space, starting with Marc Garneau in 1984. In 1992, Roberta Bondar became the first Canadian female in space. Chris Hadfield conducted the first Canadian spacewalk in 2001. He then proceeded to spend 5 months on the ISS in 2012-2013.
    - The University of Guelph leads the world in research for building greenhouses in space using hydroponics. Scientists are testing small hydroponic crops of lettuce, radish, tomato and cucumber in Nunavut where there is very little sunlight.
    - Many craters on Mars are named after places in Canada - Banff, Okotoks, Nipigon, Penticton, Inuvik and Gander to name a few.

Issue Related to Space Exploration (4.3)

- **Political Issues**
  - Who owns space?
  - Who has a right to the resources in space?
  - Who will determine how space will be used?
  - Who owns the ISS and who has assess to it?
- **Ethical Issues**
  - It is right to spend money on space over other humanitarian issues?
  - Do we have a right to materials in space to meet our needs?
  - How do we ensure space exploration benefits all humanity, not just a few nations?
- **Environmental Issues**
  - Who is responsible for protecting the “environment” of space?
  - Who is responsible for cleaning up space junk?

- ***Homework:*** Complete the questions 1-7 on p. 469 of the textbook.

- ***In-Class Activity/ Homework:*** Complete the unit outcomes and review booklet in preparation for your upcoming electrical principles and technologies unit exam.