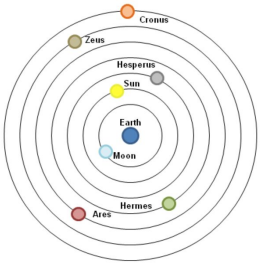
U2 The Solar System

**Intro:**

Geocentric Model: Earth is at the center of the solar system
Heliocentric Model: Sun is at the center of the solar system

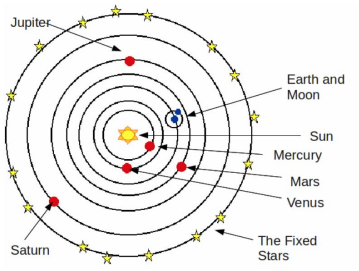
**The Pioneers and their Model:**

Pythagorus/Plato:




- One of the earliest models of solar system was developed 530 BC by Pythagorus: pictured Earth as stationary object in space, surrounded by a sphere which contained everything else -> objects inside sphere rotated slowly east at speed depending upon how far they were from Earth
    - Plato tried his hand in model -> what he produced was no better

Aristarchus:




- He experimented with placing sun in the centre ->satisfied that the geometry seemed to work and seemed to predict events in the solar system he moved on to other topics of interest and never promoted his model

Ptolemy:

- Extremely religious and sucked up to every authority figure in the Catholic church
    - He put the Earth back in centre -> even though the idea is not scientifically valid it was supported for 1,400 as it was promoted by Catholic Church

Copernicus:

- Polish scientist who also put the sun in the centre of system and had earth rotate about the sun and revolve on an axis once per day
    - His friends published the book but stated contents were handy for calculating planetary position but should not be taken as anything representing reality to avoid the Church attacking and disseminate the hypothesis

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Tycho Brahe:

- Witnessed a supernova (thought it was a very bright star)
- He also noticed how the star's light could be seen during the day and appeared in the same spot no matter what
- He built the world's first observatory
- He did not believe Copernicus's model but did agree that he had succeeded in removing some of Ptolemy's problems

Johannes Kepler:

- Worked with Tycho
- Plantes been pushed into their orbits by the sun
- Force was strongest near the sun
- He assumed force had to be magnetic but had no proof
- He reduced to speculations that planets were moving in their orbits by magnetic angels
- Developed 3 laws:
    1. First law defines the construction of an ellipse because he realized that planets did not move in perfectly circular paths -> sun focal point and others hypothetical point in space -> sum of distances of any point on the ellipse form 2 foci is a cotant which means that the Earth- sun distance is constantly changing as planet goes around orbit
        - Perihelion: point of nearest approach of a planet to the sun
        - Aphelion: point of greatest separation

Galileo Galilei:

- He was first to observe plants through a telescope
    - What he saw convinced him that Copernicus was right
- Did not invent telescope but improved it by polishing lenses
- He used his 8 power instrument to observe the Moon and sunspots
    - He also saw 4 satellites orbiting around Jupiter
    - He was told to stop teaching Copernicus's theories so he did but he still argued about it -> encouraging his Pope friend to publish a book -> but the Inquisition charged him of heresy

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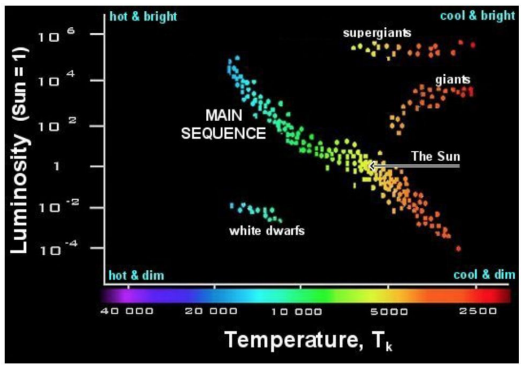
## Chapter 4
## A Star Called Sun

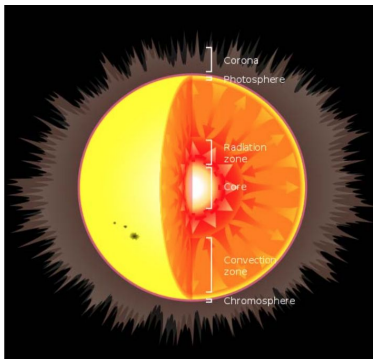
Hertzsprung-Russell Diagram




**The Anatomy of the Sun:**

- Sun is made up of gas that becomes denser as you move toward the centre

- Photosphere (visible outer layer of a star): represents depth within that gas at which we can see no deeper toward the core
- Atmosphere changes from transparent to opaque so it appears as well defined boundaries even though it is not
- Size of the sun is the size of the region surrounded by photosphere




- Surrounding photosphere is gases called chromosphere (we can see with special instruments as it is transparent to most visible radiation)
- The chromosphere merges to outermost region of the Sun's atmosphere the Corona -> extends millions of Km into space above the photosphere
    - Usually cant see the corona but you can during solar eclipse

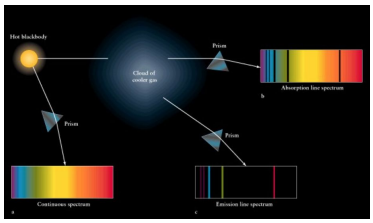
**Distance Measurements inside the Solar System:**

- Distance between Earth and the Sun is about 150  million Km,
    - One astronomical unit (1 AU) = mean average distance between the Sun and Earth
    - Using AU makes discussions and calculations easier

**Chemical Composition:**

Spectroscopy:

- Measurement and analysis of energy spectra to determine the composition of matter
    - Uses spectrometer or a spectrograph which records spectrum of light emitted or absorbed by a given material -> can be used to determine the chemical composition of a substance as particular elements emit unique wavelengths of energy




- Beam of sunlight is made up of mixtures of colors and a glass prism will bend or refract various colours unequally (short wavelengths most refracted)
- W. H. Wollasten passed sunlight through prism and obtained true solar spectrum with red at one end through orange, yellow, green, blue, and violet
    - dark lines were characteristic of particular elements discovered later by other scientists

*10 Most abundant elements in the Sun:*

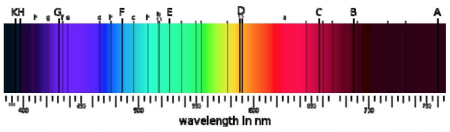


Fig 4.4 Fraunhofer lines in the solar spectrum (Image source: Wikimedia commons)

**Table 4.1: Most abundant elements in the Sun**

| Element | Symbol | % of Total Mass |
|---|---|---|
| Hydrogen | H | 71.0 |
| Helium | He | 27.1 |
| Oxygen | O | 0.97 |
| Carbon | C | 0.40 |
| Nitrogen | N | 0.096 |
| Silicon | Si | 0.099 |
| Magnesium | Mg | 0.076 |
| Neon | Ne | 0.058 |
| Iron | Fe | 0.014 |
| Sulfur | S | 0.040 |

- Sun has the same elements found on earth but in different proportions -> as sun is so hot that all elements are in gaseous state

The Genesis Experiment:

- Sun contains over 99% of the matter that makes up our solar system
- NASA'S Genesis mission set out to capture particles of the solar wind and return them for study on Earth
    - It was launched in an area in space between Earth and the Sun where the gravity of the 2 bodies balanced -> there it collected solar wind particles for more than 2 years
    - However the capsule parachutes containing the samples crashed as the parachutes failed to open
        - But it was possible to separate dirt from the samples
        - Once analyzed it turned out that isotopic composition of oxygen and nitrogen are significantly different to those in most of the solar system objects
            - Unexpected results as the sun's outer layers is expected to have the same composition as the solar nebula from which plants formed
            - There's no answer for it yet

**Sun in Action:**

- Photosphere is in constant state of turmoil
- Chromosphere there are prominences (arcs of gas that begin ong the bright surface and soar to as much as 10,000 Km into the Corona
- Flares are short lived gas eruption that last no more than 20 minutes usually

Magnetic Fields:

- Sun has a magnetic field which has to do with the interaction of the unique properties of matter in the different layers inside the sun
- Giant bar magnetsL north at one end, south at the other and a field surrounding them commonly expressed as lines of different strength and orientation

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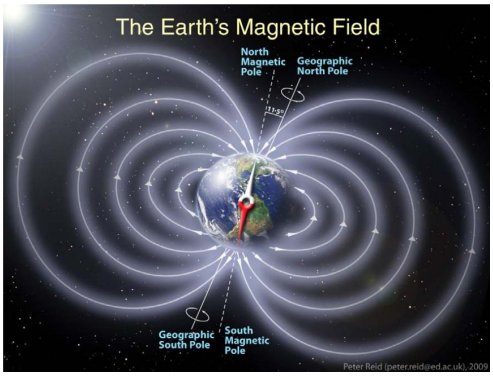
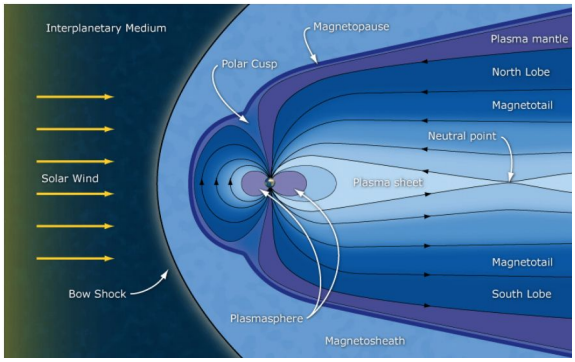



- Dynamic system sometimes the sun's magnetic generators become confused and very unstable which results in the sudden switch of the poles -> occurs very irregularly on earth but almost every 11 years on the sun
- Right now we are emerging from solar maximum and precious time the sun did a flip was in Feb 2001 ( the last solar max was around April 2014 and the current cycle is predicted to be unusually weak and long)
- The clearest manifestation of switch time for the sun is development of a great number of sunspots -> region of the sun's photosphere marked by lower average temperature appearing black
    - First described by Galileo as black spots on the Sun's surface
- During intense flares corresponding intense magnetic storms occur on Earth
    - 2 obvious effects on earth as a result of matter being carried into earth's upper atmosphere by solar wind:
        1. Interference to complete breakdown of power grids and systems carrying telemetric signals
        2. Visual spectacular northern lights

<u>Solar Wind:</u>

- Made up of charged particles sent out from the sun at all times in all directions
- Made up of plasma (ionized gas made up of a mixture of electrons and protons)
- These little particles escape because of their high kinetic energy
- During periods of solar flares stream of solar wind is devastating as far away as the earth
    - Telsat 401 satellite was killed by one of these solar wind storms

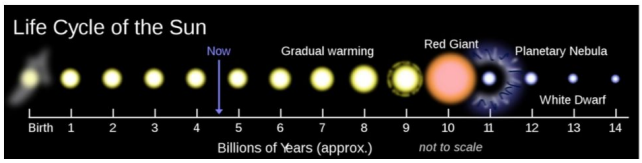



- Without earth's magnetic field we would never exist as the bombardment of cosmic particles would be so great as to destroy cells
- The magnetic field volume around a body lie earth called the magnetosphere

- This reaction protects most of the earth's surface from solar wind but not the poles -> on the earth's magnetic poles the solar particles interact with molecules of gas in the upper atmosphere resulting in the emission of a light photon -> aurora (aurora borealis in the north and in the south aurora australis)

**Life and Death of the Sun:**

- UV rays are good for sterilization but the main cause of skin cancer
- Ozone in our atmosphere greatly attenuates that radiation -> we are losing large amounts of that ozone




- At 4.6 billion years along the sun is halfway through its life cycle so nuclear fusion reactions in its core have fused hydrogen into helium yielding great amounts of energy
- Sun has grown 30% brighter -> diameter grew proportionately
    - As the last of inner H fuel is consumed in about 5 billion years from now the sun will expand into a red giant -> bringin radius past present position of Earth
    - Sun will blow off its outer envelope into space leaving its core to cool and become white dwarf and ultimately a black dwarf when it stops glowing
    - However the sun may never reach this as it is assumed that the Andromeda and Milky Way are due to merge in 3 billion years

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## Chapter 5
## Geometry of the Solar System

**Tools and Trade:**

Optical Telescope:

- Gather up light and allows you to examine and image at a focal position
- Even the best optics have limited resolution because of the wave nature of light
- The twinkling of stars come from the turbulence in the air that makes up the atmosphere
    - Atmosphere acts as a huge distorting lense
- To see the stars clearly you need to find a system that compensates for the motion of atmosphere or move the telescope outside the atmosphere
- 2 basic Types:
    1. Refractors: collect light by means of glass lens
    2. Reflectors: collect light with curved mirror
    - The actual magnification is done by the eyepiece/ocular
    - World's largest optical telescopes are the two Keck telescopes mounted on Mauna Kea in Hawaii -> Keck observed the transit of a massive planet in front of its parent star confirming for the first time that stars other than the sun have planets
- The Canada France Hawaii Telescope on Muana Kea Hawaii do the job for Canada
    - A picture taken shows the Lagoon Nebula -> home to a cluster of very young stars, developing among globules and pillars of gas -> red color depicts hydrogen and the green oxygen

- Hubble Space Telescope:
    - Mirrors mounted inside a hollow tube -> fitted while signal detectors and operates 24 hours/day
    - Launched in 1990 and has had 5 service calls -> each increasing the power by 10 x
    - Wide field camera (see 3 types of light), cosmic origin spectrograph (breaks light into its component colours)

Non Optical Telescope:

- Sometimes called invisible astronomy when using these telescopes
- collect s radio waves -> dished have been built to collect every other energy range possible
- Most rockets satellites and space probes carry one or more types of non-optical telescopes
    - To be able to insert a satellite into orbit need a rocket that will deliver orbital velocity -> just enough velocity to place the satellite in a position that exactly balances gravity's pull on the satellite with the inertia of the satellite's motion
        - Orbital velocity depends on the altitude of satellites above earth (nearer to earth higher orbital velocity)
        - Geostationary satellite: stays right over geostationary orbit -> with a velocity that makes one revolution of Earth every 24 hours

**Classifications of Planets:** *Order of Planets from Sun:* Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune

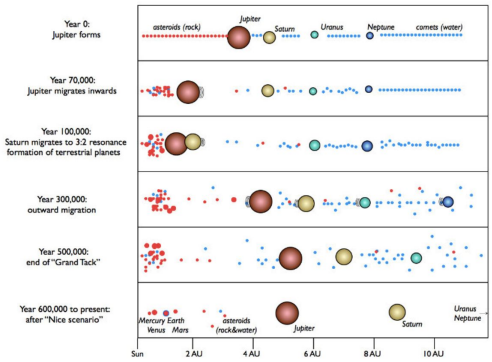
Asteroids: Dense objects orbiting the Sun - much smaller than planets
Comets: Icy objects orbiting in highly eccentric patterns

- Traditionally objects of the Solar system were divided into plants and their satellites, asteroids, and comets
    - 4 planets closest to the sun are dense and mostly made or rock and metal, fairly small; call them terrestrial planets (Mercury Venus Earth and Mars -> Earth and Mars have satellites)
    - Farther away 4 very large planets termed as jovian planets or gas giants (Jupiter, Saturn, Uranus, and Neptune) -> huge low density composed mostly of hydrogen and helium and surrounded by rings and many satellites
    - Between terrestrial and jovian planets there is a band of asteroids making up asteroid belt -> largest is Ceres (spherical and may have ocean and atmosphere)
    - Pluto: out past gas giants -> discovered in 1930 -> too small and too dense, different orit style so it is not classified as a planet
    - Kuiper belt is past pluto -> thick band of icy bodies -> Eris and Sedna are larger objects in this area
    - Oort Cloud -> outer limits of the solar system -> icy beld of bodies
- A planet is a celestial body that: (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune)
    - Orbit around the sun
    - Sufficient mass for self gravity to overcome rigid body forces so that it assumes a nearly round shape
    - Cleared the neighborhood around its orbit
- A dwarf planet is a celestial body that's: (Ceres, Pluto, Eris, and two that were added later: Haumea and Makemake)
    - In orbit around sun

    - Has sufficient mass for itself gravity to overcome rigid body forces so that it assumes a nearly round shape
    - Not cleared the neighbourhood around its orbit
    - Not a satellite
- Everything else except satellites orbiting the sun is a small solar system bodies
- Also all planets located toward the outer regions of the solar system would be called plutoids

**Planetary Reshuffle:**

Grand Tack:

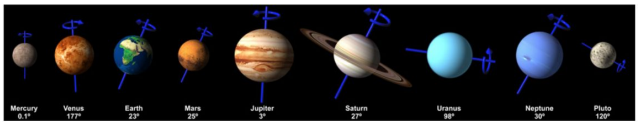



- The big four planets assemble very quickly from the dun but after a couple million years they started interaction with one another and pushed them out into different positions
    - Nice Model: Uranus and Neptune pushed out
- Terrestrial planets are much smaller because Jupiter initially migrates inward being pulled in toward the sun and it pushed rocky planetesimals inward and creates a mini disk where terrestrial planets were formed -> Jupiter than gets caught by saturn and they both swing around and move back out into their current positions -> Grand Tack Model
- Jupiter grows to become large really quickly -> all Grand Tack Action takes place within 5 million years and the nice model covers the next 500 million years

The Late Heavy Bombardment:

- Moon and Mercury have craters that were made around the end of the planetary reshuffle -> evidence that small orbiting bodies had their orbits disturbed when gas giants were being pushed out -> small bodies began to fall toward the sun and most likely impacted terrestrial planets
- In Greenland and Northern Canada unusual abundance of particular isotope of tungsten that could be extraterrestrial in origin fits with late bombardment story

**Obliquity of Planets:**




- Obliquity: angle between its equatorial plane and orbital plane
- Mercury's obliquity is pretty close to zero but all the others vary greatly -> during the planet shuffle the few large collisions of the large protoplanets and planetesimals knocked planets askew -> Venus is rotating bottoms up