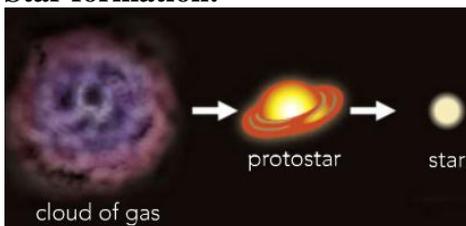


### Topic 3 – Waves and the Universe

- **THE UNIVERSE**
- **Early astronomers:**
- Using only the naked eye, early astronomers believed that stars were fixed, all the same distance very far away from the Earth
- Using a telescope, Galileo Galilei noted that stars were other suns and that each star was a different distance away from the Earth
- **Modern day:**
- As technology improved, telescopes with greater magnifications (i.e that could zoom further) were invented
- Building on Galileo's discoveries, we now know that...:
  - The Solar System contains 8 planets orbiting round one star (the Sun), in addition to some dwarf planets (e.g Pluto), many moons and several smaller bodies (e.g asteroids)
  - Millions of stars make up our galaxy - the Milky Way (The Solar System is just a small part of the Milky Way galaxy)
  - The Milky Way is just one of billions of other galaxies (some of the nebulae seen from Earth are these other galaxies) that together make up the Universe
  - In other words...:
    - Galaxies are made up of lots of stars
    - The Universe is made up of all the galaxies
- **EXPLORING THE UNIVERSE**
- Early telescopes let people see objects that emitted visible light
- The invention of photography allowed detailed pictures to be taken of even faint objects (by pointing the telescope at a fixed point for hours)
- As already mentioned in earlier topics, most objects give out energy in all parts of the electromagnetic spectrum
- →Modern telescopes can be designed to detect almost any part of the spectrum, showing us things that can't be detected using visible light
  - E.g the Hubble Space Telescope has been in orbit around the Earth since 1990, and can detect UV, visible light and IR
- **Telescopes in space:**
- It is important for telescopes to be located outside the Earth's atmosphere:
  - 1. Outside the atmosphere, light waves from space are not reflected or refracted by clouds and dust or even by movements of air in the atmosphere → clearer and brighter image
  - 2. Some wavelengths of electromagnetic radiation (particularly UV, IR and x-rays) are absorbed by the atmosphere...:
    - →Telescopes detecting these types of radiation have to be located outside the Earth's atmosphere
    - If these telescopes were put on Earth they would not detect anything
- **ALIEN LIFE? – LOOKING FOR LIFE BEYOND EARTH**
- The Earth is hospitable to life mainly because of the presence of water, oxygen in the atmosphere and its optimum distance from the Sun (→ideal temperature)
- →When looking for life, scientists look for planets that have these characteristics (i.e they look for planets that are similar to Earth)

- **Investigating the Solar System:**
- 3 ways to explore space:
  - Telescopes
  - Space probes – these take photos from space
  - Space landers – these land and sample rocks and soil
- Much of the research into forms of life in our Solar System has been done on Mars because:
  - 1. Space probes orbiting Mars have photographed channels that were probably created millions/billions of years ago by flowing water
    - All life as we know it depends on liquid water
    - →evidence that there was water suggests that a long time ago there may have been life on Mars
  - 2. Mars is a similar distance away from the Sun as the Earth (→its temperatures may be hospitable to life)
- Missions to Mars:
  - 1. Rovers on Mars that took photos of the soil found no evidence of life
  - 2. Viking landers in 1976 did experiments on the soil, looking for chemical changes that could have been caused by living organisms. Despite some positive results, scientists concluded there was no evidence of life
  - 3. The Phoenix lander discovered frozen water in the Martian soil in 2008 (still no direct evidence of life on Mars at present, though)
- **Beyond the Solar System:**
- Scientists have discovered planets orbiting other stars (in a similar way that planets orbit the Sun in our Solar System), but they are too far away...
  - Telescopes can't produce clear images
  - Space landers or space probes would take too long to get there (also, the mission would be too expensive)
- However, scientists can sometimes find out information about the gases in the atmosphere of far away planets
- The Earth's atmosphere is hospitable to life because of its high content of oxygen in its atmosphere (released by photosynthesising plants)
- →Presence of oxygen in the atmosphere of another planet could be evidence that life may exist on that planet
- **Searching for Intelligent Life (SETI):**
- SETI analyse radio waves coming from space, looking for signals possibly produced by 'intelligent' beings. No messages have been detected so far
- This is different from other projects (e.g space probes, landers) which are just looking for 'life' – i.e respiring microorganisms or plants
- **LIFE CYCLES OF STARS**
- **Star formation:**



- Nebula stage:
  - Stars form when a nebula (cloud of dust and gases – mainly hydrogen) is pulled together by gravity

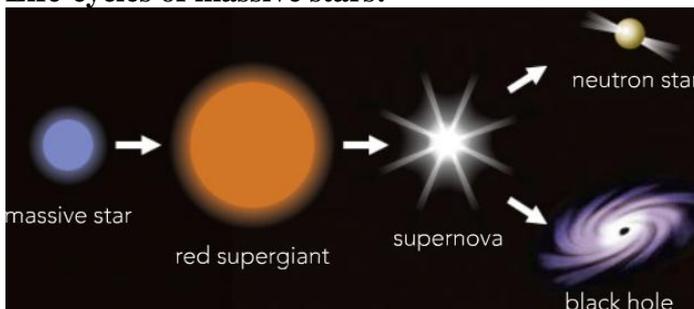
- Protostar stage:
  - The contracting cloud gets more dense and starts to glow
- Main sequence stage:
  - Eventually high temperatures and pressures in the centre of the protostar become high enough to force hydrogen nuclei to fuse together to form helium, releasing lots of energy as electromagnetic radiation
  - The outward pressure from the hot gases balances out the compressing action of gravity
  - →Star enters the stable, 'main sequence' stage of its life cycle

- **Life-cycles of stars like our Sun:**



- Red giant stage:
  - Stars of similar sizes to our Sun remain stable for about 10 billion years
  - After this period, most of the hydrogen has fused with helium
  - →core of the star is no longer hot enough to withstand gravity (i.e outward pressure from hot gases can no longer balance the compressing action of gravity)
  - →the star collapses, and the outer layers form a red giant star (much larger than the original star)
  - Fusion reactions occur in a red giant (which balance compressing action of gravity)→stability is maintained for about a billion years
- White dwarf stage:
  - After about a billion years, red giant throws off a shell of gas
  - The rest of the star is pulled together and collapses to form a white dwarf
  - No fusion reactions happen inside a white dwarf→over about a billion years it gradually cools into a black dwarf

- **Life-cycles of massive stars:**



- Stars with considerably more mass than the Sun are hotter and brighter
- The fusion reactions in a massive star's core happen at a faster rate→stable main sequence is shorter than in smaller stars
- Once hydrogen runs out and the core cools, massive stars become red supergiants
- At the end of the supergiant period, the star rapidly collapses and then explodes, casting off the outer layers of the supergiant
  - This explosion of a red supergiant is known as a supernova
- The next stage in the life-cycle depends on how big the star is...:
  - If the star is really massive then gravity will pull the remains together to form a black hole

- If the remains aren't massive enough to form a black hole, gravity will pull them together to form a small, very dense star called a neutron star
- **THEORIES ABOUT THE UNIVERSE**
- **Red-shift:**
- If a source of light is moving away from us, then its wavelength will be longer and its frequency lower than we expect...i.e its light is shifted towards the red end of the spectrum - this effect is called red-shift...
  - Light from other galaxies is red-shifted→this shows that galaxies are moving away from us
  - →this tells us that the Universe is expanding
- Note: The further away a galaxy is, the faster it is moving away from us
- Astronomers use this information and other data to work out theories that explain the past and present state of the Universe...
- **Big Bang theory:**
- First suggested in the 1930s, this says the whole Universe and all the matter in it started out as a tiny point of concentrated energy about 13.5 billion years ago
- The Universe expanded from this point and is still expanding
- The theory also claims that a huge amount of radiation was left behind after the Big bang
- **Steady State theory:**
- This alternative theory proposed in 1948 suggested that the Universe has always existed and is expanding
- New matter is continuously created within the Universe as it expands
- **Big Bang theory vs Steady State theory:**
- 1. Both theories state that the Universe is expanding, with new matter being created all the time...
  - →The red-shift in the light from other galaxies can be used to support both theories
- 2. The Big Bang theory predicts that the radiation released after the Big Bang should still be detectable as 'cosmic microwave background (CMB) radiation' today...:
  - In 1964, two radio astronomers detected microwave signals coming from all over the sky→supporting the Big Bang theory
  - The Steady State theory cannot explain CMB radiation
- There is more supporting evidence for the Big Bang theory→is accepted by most astronomers today
- **DOPPLER EFFECT**
- A sound with a high frequency has a high pitch
- A sound with a low frequency has a low pitch
- The sound waves in front of a moving vehicle are compressed→frequency is higher→pitch is higher
- The sound waves behind a moving vehicle are stretched→frequency is lower→pitch is lower
- Therefore...
  - As an ambulance comes towards you, you hear a high pitched siren (as sound waves in front have a high frequency)
  - As an ambulance moves away from you, you hear a low pitched siren (as sound waves behind have a low frequency)