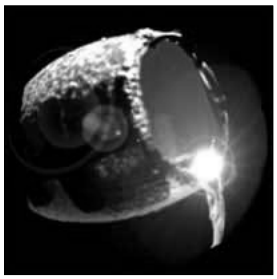
Atoms and Starlight

- Why do the stars shine?
  - planets shine by reflected sunlight—but what generates the Sun's light?
- What does starlight tell us about the stars?
  - their temperature
  - their chemical composition
  - their motion towards or away from us
  - sometimes, their age

Generating light

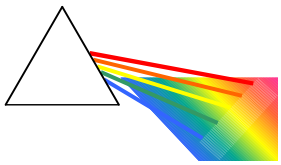
- What everyday objects emit light?
  - hot solid objects (molten metal, electric bar fire, tungsten filament lamp)
  - electrical discharge in gas (neon lights, aurora, lightning)



Measuring light

- Two issues:
  - intensity
    - how bright is the source?
  - wavelength
    - what colour is the light?
- Use prism or grating to spread light into a spectrum

➔ our basic information: intensity ***as function of wavelength***



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Light and atoms

- Light is an electromagnetic wave
  - wavelengths range from fm (gamma rays) to m (radio)
    - atmosphere transparent only to optical, some infra-red, and radio
    - depend on satellites to observe x-rays, UV, sub-millimetre
- Light is made of particles
  - called ***photons***
    - each carries energy hc/λ, where h is Planck's constant, c is speed of light, λ is wavelength
    - this picture of light is vital in understanding how light and atoms interact

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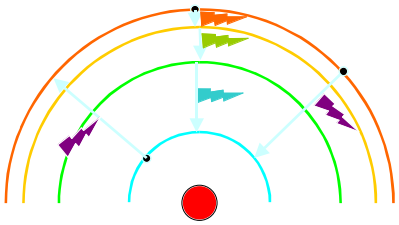
Atoms and light

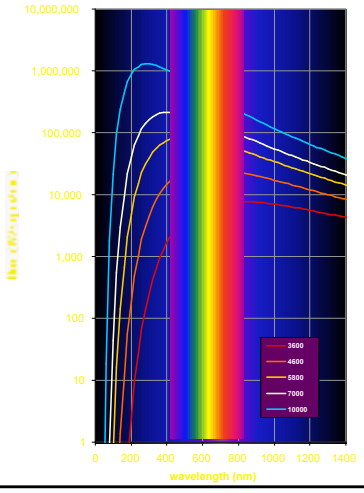
- Electrons in atoms occupy certain fixed energy levels (orbitals)
  - basis of chemistry
  - moving electron to higher level requires energy; moving to lower level releases energy
  - absorption or emission of photons of light of specific wavelength (energy)



➔ ***these patterns of emission or absorption provide a "fingerprint" for any element***

Blackbody radiation

- Light from hot solid objects is not made up of emission lines
  - collisions between atoms and photons of light change photon energies
  - result is continuous spectrum
  - if object has no intrinsic colour (blackbody) spectrum depends only on its temperature
  - hotter = **bluer** and **brighter**

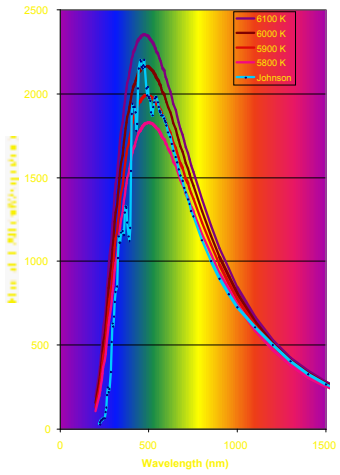


The Sun's spectrum

- Basically continuous, but with dark absorption lines
  - is the Sun solid?
    - no, because we know its rotation period varies with latitude
    - the Sun is a **dense** gas (about 1.3 times as dense as water)
  - does the Sun have an atmosphere?
    - yes, of cooler gas, to create absorption lines
- Colour of Sun tells us its temperature
  - so do absorption lines, because strength of lines for given element depends on temperature (though position does not)
- Lines tell us about chemical composition
  - as well as temperature and density

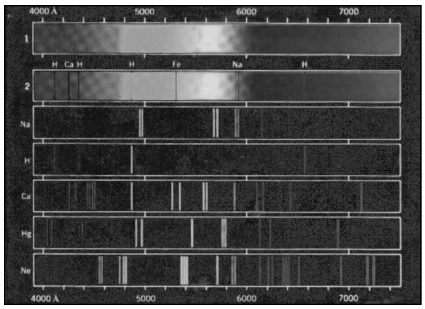
How hot is the Sun?

- Compare its spectrum with blackbody
  - similar shape
  - temperature ~5800 K (same overall area, i.e. same total power output) — ~6000 K (most similar shape)
  - note that this is only its **surface** temperature



What is the Sun made of?

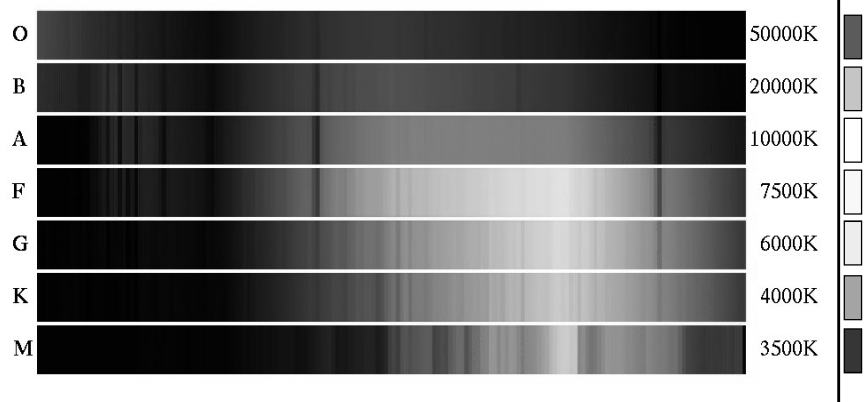
- Most of the lines are metals (Ca, Fe, Mg, etc.)
  - is the Sun's composition similar to the Earth?
  - No!
    - hydrogen and helium form strong lines only at very high temperature
    - the Sun is in fact 73% H, 25% He, 2% everything else (Cecilia Payne, 1924)



Other stars

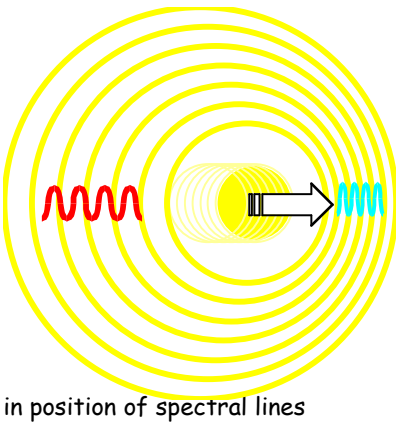
- Different colours suggest different temperatures
  - line strengths agree
  - classification system based on line patterns
    - hottest stars have strong helium lines
    - hot stars have hydrogen
    - sun-like stars have ionised metals
    - cooler stars have neutral metals
    - very cool stars have molecules
- Is Sun's composition typical?
  - all stars have similar amounts of hydrogen and helium
  - amount of "heavy" elements varies from much less (down to <0.01%) to a little more
  - remember this is **surface** composition

The spectral sequence



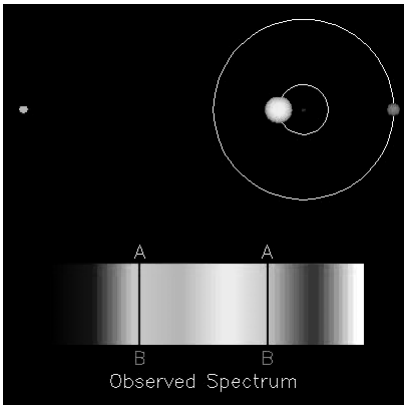
The Doppler shift

- If a light source moves
  - away from us:
    - peaks of light wave arrive further apart
    - light is redshifted
  - towards us:
    - peaks of wave arrive closer together
    - light is blueshifted
- This is the Doppler shift
  - same effect with sound
    - e.g. ambulance siren
  - in astronomy observe change in position of spectral lines



Moving stars

- Doppler shift can help us measure the motion of stars
  - in binary systems
  - in their orbits around the Galactic centre
  - in other galaxies
- It can also provide evidence for planets around other stars
- and tell us about the history and fate of the universe



R. Pogge, Ohio State

What have we learned?

- The colour of a star tells us its temperature
  - blue stars are hot (>10000 K)
  - red stars are cool (~3000 K)
- The spectral lines confirm its temperature and tell us about its composition
  - all stars are mainly hydrogen and helium
  - everything else typically ~1-2% or less
- The positions of spectral lines tell us about motion
  - redder than expected: moving away from us
  - bluer than expected: moving towards us
- If we know colour (i.e. temperature) and luminosity, we can deduce size
  - from form of blackbody radiation

What do we now know about relatively nearby stars?

- distance (parallax)
- brightness (from measured brightness and distance)
- surface temperature (from spectrum)
- size (from spectrum and brightness)
- composition (from spectrum)
- mass (if suitable binary)

➔ So we can now look at
- what kinds of stars exist
- how stars are born, live, and die
- what this has to do with our existence on Earth

...starting next lecture!