Light - ASTR - Lecture notes 1

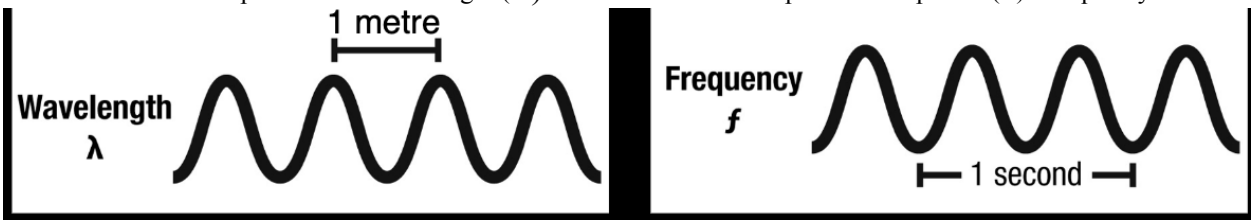
Exploring the Night Sky (University of Victoria)

Nature of Light and Atomic Spectra

Light "Waves"

- We visualize waves based on water waves – alternating peaks and troughs in the medium

The distance between peaks is the wavelength (λ) and the time between peaks is the period (T). Frequency is f=1/T

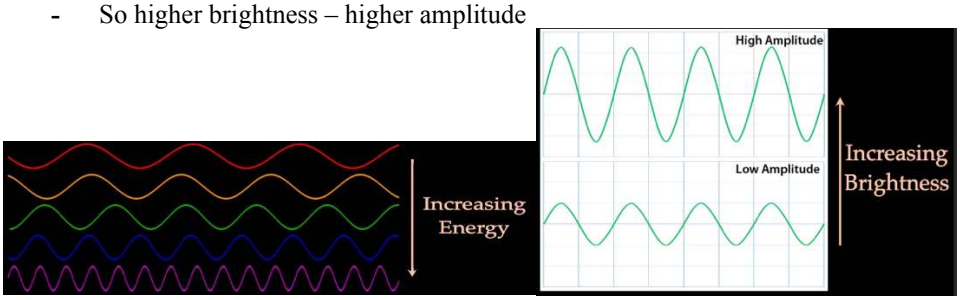


Wavelength and Frequency

- The frequency (f) and wavelength are not independent of each other
- The SPEED of the wave is fixed by the medium in which it travels. Light travels at the speed of light: c =2.9979 x 10^8 m/s

Energy of a Wave

- The energy contained in the wave depends on two things: amplitude and frequency
- Faster a wave oscillates – higher energy wave
- We experience amplitude as brightness
- So higher brightness – higher amplitude



Waves

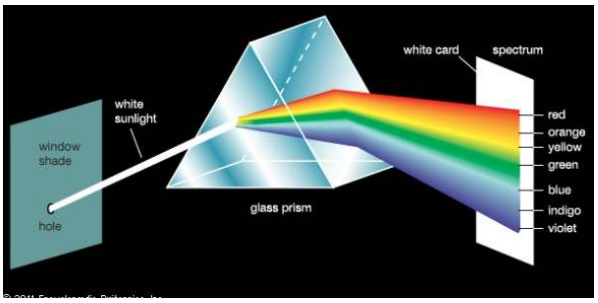
- Technically, a wave is a propagation of energy that experiences interference / diffraction
- This is when two sources of waves combine to either amplify or cancel out their amplitude

Light Waves

- We say that light is a wave because of this – it carries energy and it undergoes interference
- There should be only 2 columns of light if light doesn't interfere – two lines representing slit regions. Interference creates more coloumns!

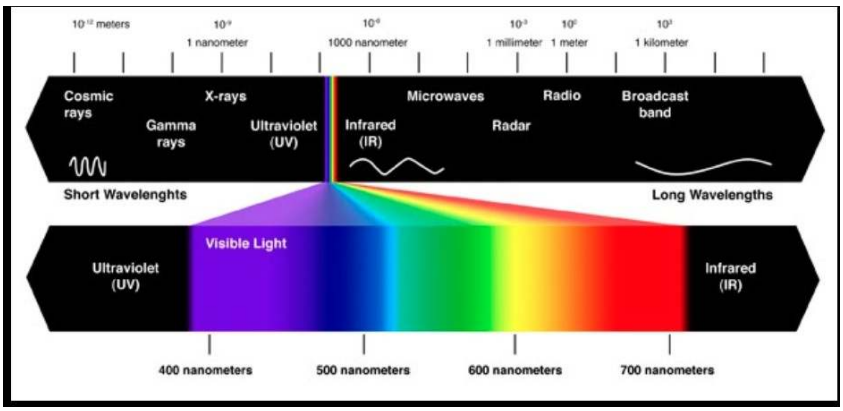
Experiencing Light

- Colour is simply the word we use to describe our experience of light
- All colours combined produces "white" light
- The "white" light produced by the Sun can be separated out into the separate colours using a prism or diffraction grating.
- But there is much more that we can't see



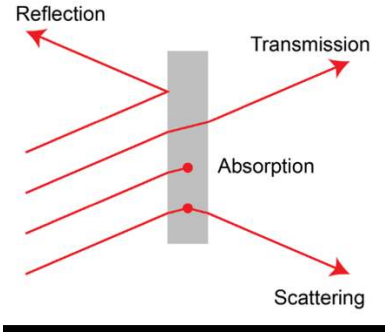
Spectrum

- The wavelength of visible light is just 400-700 nm (1nm = 1/ Billion m).

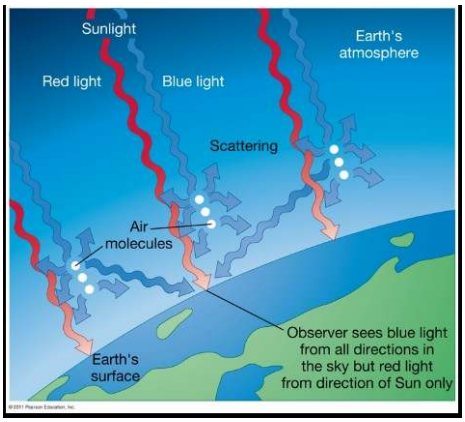


Transmission of Light

- When light strikes a material, it can do one or four things
- The relative % of each of these determines how we experience that object
- High reflectivity, low scattering = mirror
- High absorption = dark material
- High transmission, low scattering = transparent.

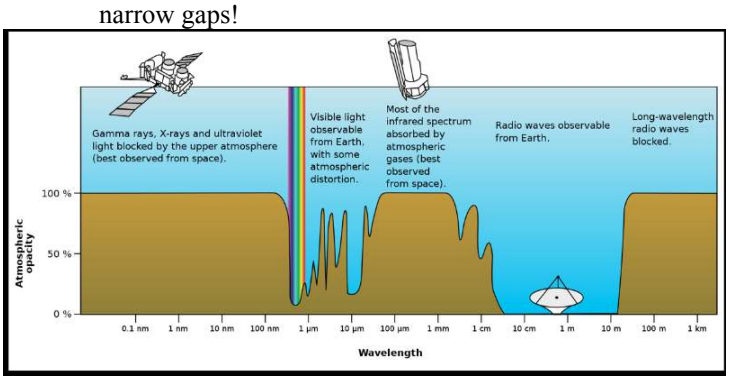


- Every material behaves differently for each frequency / colour of light. This explains why we see the colours and opacities that we do. For example, the atmosphere scatters blue light more than red light, which explains why the sky looks blue.



Transmission of Light

- For other colours / frequencies, our atmosphere behaves very differently
- This has a huge effect on astronomy: we can only make Earth based telescopes that see light within those narrow gaps!



Sources of Light

- All light is produced by the motion of charged particles (electrons & protons). When a charged particle accelerates / changes state, it emits/ absorbs light
- Changes of state occur in two primary ways: collisions and excitations

Thermal Light

Thermal motion

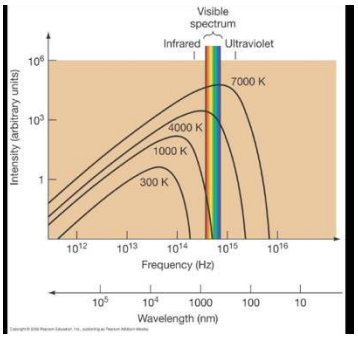
- Temperature measures the average speed of particles – faster speed, higher temperatures
- Even in solids, the particles can vibrate at higher speeds
- Higher speed collisions result in higher energy light emitted, which is higher frequency of light

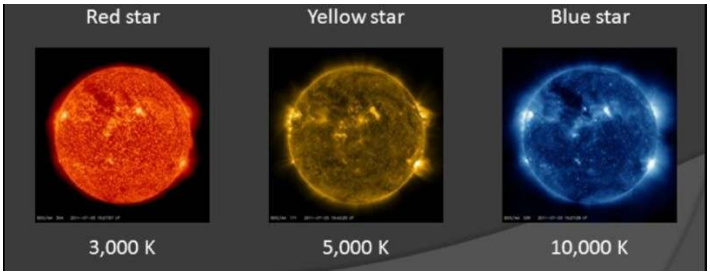
Thermal Light

- Infrared light is lower frequency than visible light. Thus, things that emit infrared light are actually relatively cold!
- Visible light is higher frequency, so things that emit visible light are actually quite hot!

Blackbody Radiation

- We call this type of light: blackbody radiation. This is because this type of light is just as easily absorbed as it is emitted – and "black" things absorb.
- A range of frequencies are emitted
- The peak frequency corresponds directly to temperature of the object.

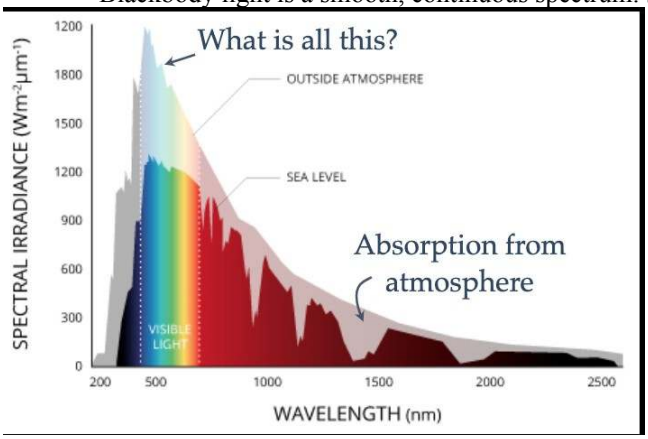




- Star colour indicates temperature, but blackbody radiation of planets, asteroids, and nebula all indicate temperature too.

Sun through our atmosphere

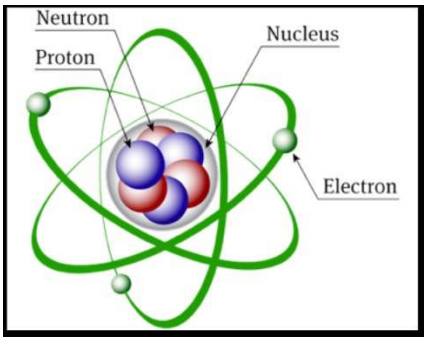
- Due to the opaqueness of our atmosphere, we don't see all the Sun's light
- Blackbody light is a smooth, continuous spectrum. So what are the jagged parts?



Atomic Light

Atoms

- A common understanding of atoms is given by the Bohr Model
- In the Bohr Model, protons and neutrons bind together tightly in the nucleus, while electrons orbit around
- This model is actually an analogy to orbits in our solar system

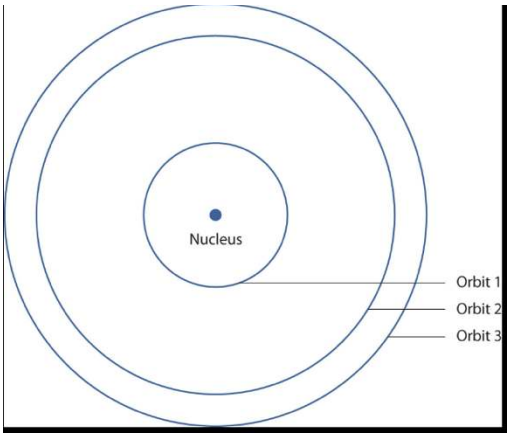


Atoms

- The Bohr Model was sufficient enough to explain the periodic table of elements
- The number of protons (+ charge) in the nucleus determines the element number
- Each electron orbital can only hold a max number of electrons: 2, 8, 8, 16, 16, 32, 32…

Electron Orbits

- Electrons are arranged into orbitals based on the symmetries studied in Quantum Mechanics
- The orbits are not equally spaced, and the higher the # of protons in the nucleus , the closer the orbits are to the nucleus.
- Protons attract electrons

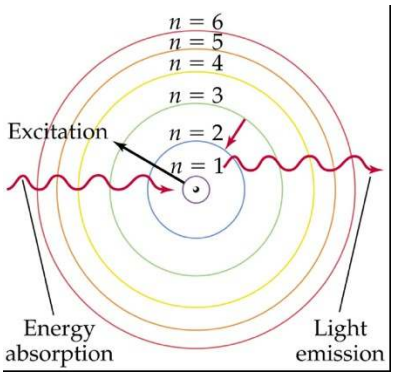


Cold Atoms

- For cold atoms, all the electrons fill up the orbitals as close to the nucleus as possible
- This is commonly shown in orbital diagrams as the ground state
- Even if there are no electrons in the orbital, however, the orbital still exists as an empty space

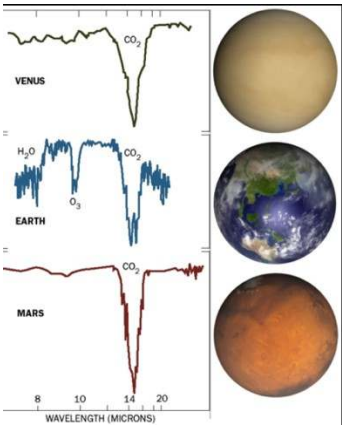
Atomic Spectra

- The energy needed for electrons to move between orbitals depends on the orbital number (n).
- When the light of the exact right frequency (energy) hits the atom, the electron can absorb it to boost to a higher orbital
- The electron can't absorb partial energies, only the EXACT energy needed to excite
- After a short period of time, the electron always de-excites down to lower orbitals, releasing the energy in a random direction
- It doesn't have to drop to the original orbital. It can take any downward path!



Atmosphere of Planets

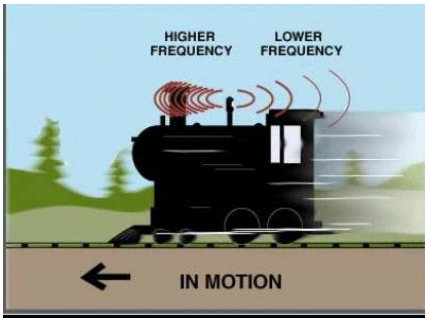
- We can tell the atmosphere of a planet by looking at its emission / absorption spectrum!
- Blackbody light produces absorption lines. See visible emission lines from Sun's light interacting with atmosphere
- We don't even have to visit the planets to know a lot about them.



The Doppler Effect

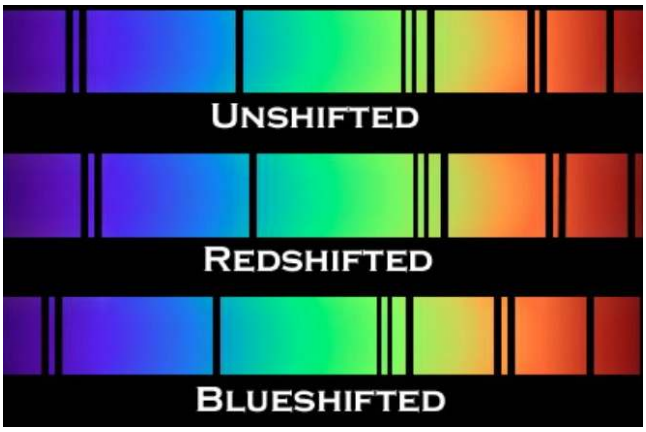
Doppler Effect

- Waves experience a shift in their frequency / wavelength when emitted by a moving object
- Frequency increases and wavelength decreases in direction of motion, and vice-versa for direction away from motion.



Doppler Shifted Spectra

- When looking at absorption or emission spectra, the lines are shifted based on the doppler effect
- Things that are moving away from us are "red shifted" to a lower frequency
- Things that are moving towards us are "blue shifted" to a higher frequency



Measuring Radial Speed

- We can measure the angular velocity of objects by looking how they move in the sky.
- Doppler shifts of blackbody spectra would just look like a higher/lower temperature object.
- Because atomic spectra occur at characteristic frequencies, we can use this to determine the radial speed (towards/away)