Summary:

- EM Spectrum
- Spectra
- Blackbodies + Wien's Law
- Spectroscopy
- Spectral Types
- Luminosity and the inverse square law
- Variation in Luminosity

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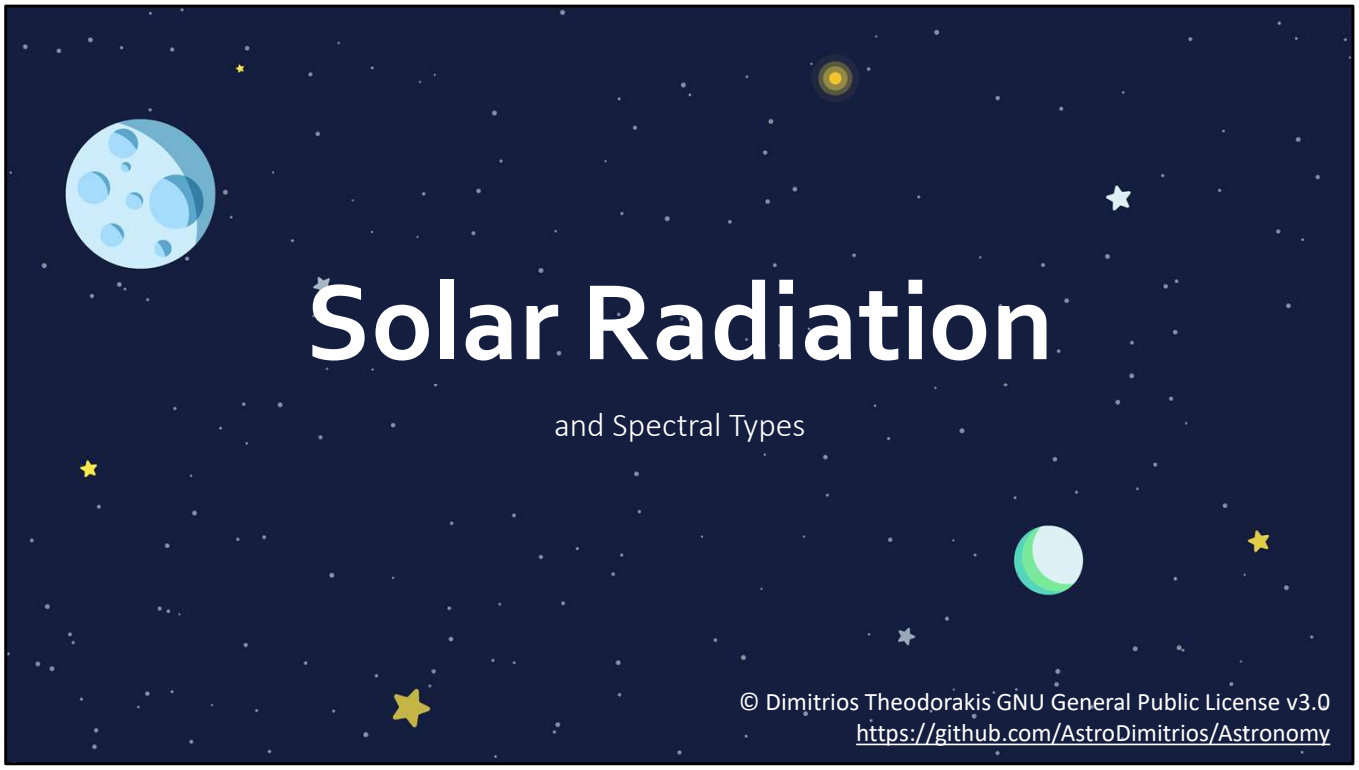
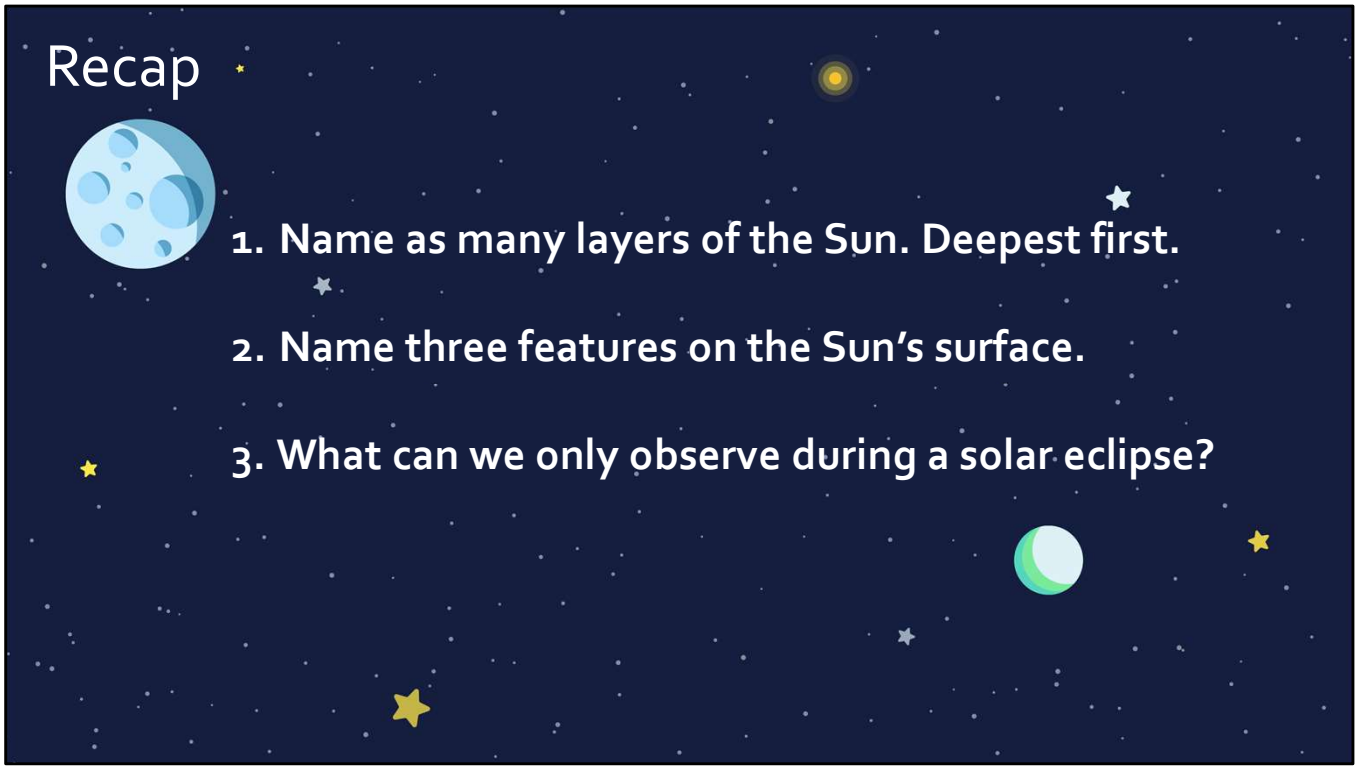
https://github.com/AstroDimitrios/Astronomy

SUMMARY
Strong theory focus.
Little math although Wien's law, and the luminosity-brightness relationship are given.

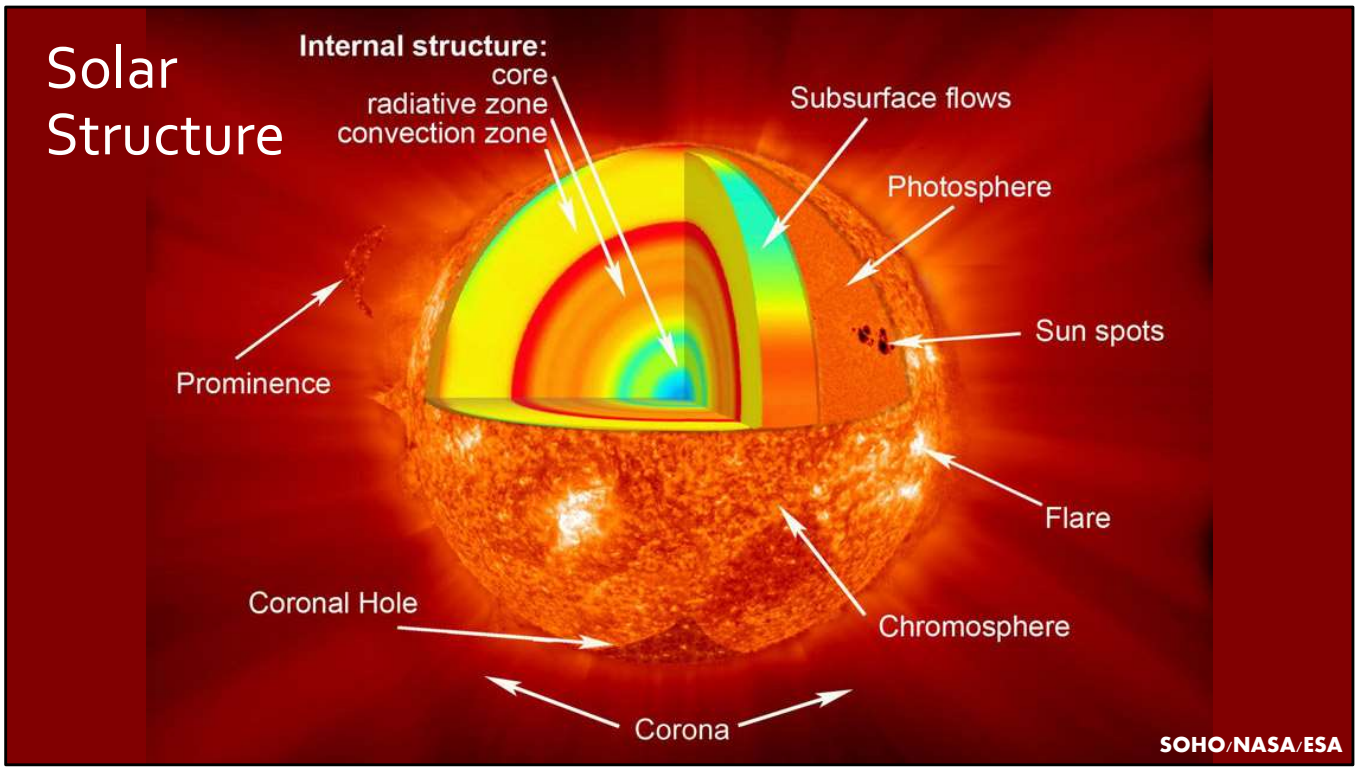


TITLE
Use this slide to briefly introduce the topic of today's lesson.



RECAP
Spend 4-5 minutes recapping the last lesson (Solar Structure). Have students answer the questions in TPS format.

1. Answers on next slide
2. Answers on next slide
3. The Corona



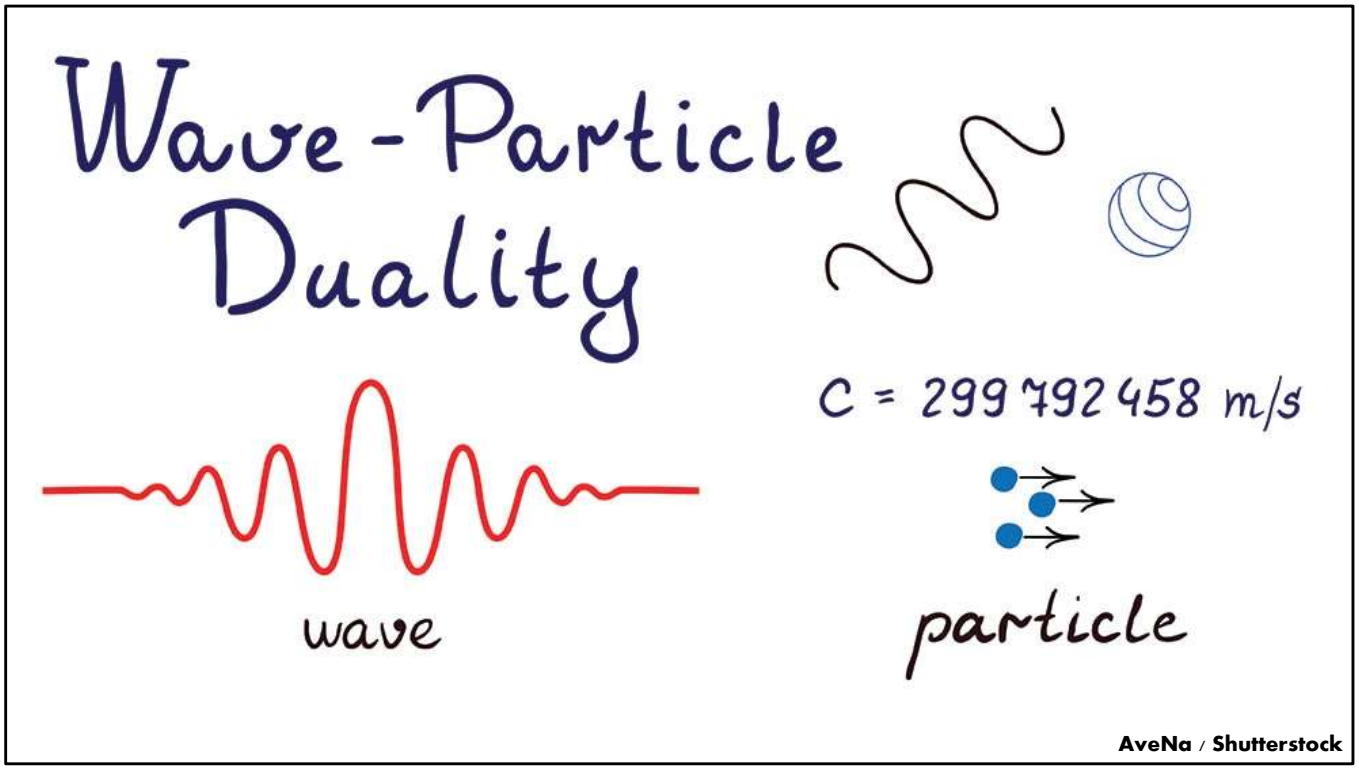
PRESENTATION NOTES

- Students should remember the granular surface structure
- Quick recap

SCIENCE NOTES

- Photosphere is where light comes from
- Chromosphere is the layer of the atmosphere above the photosphere
- Subsurface flows of gas away from the equator to the poles (diff rotation from last lessons)

Image from UCAR: https://scied.ucar.edu/sun-features-regions



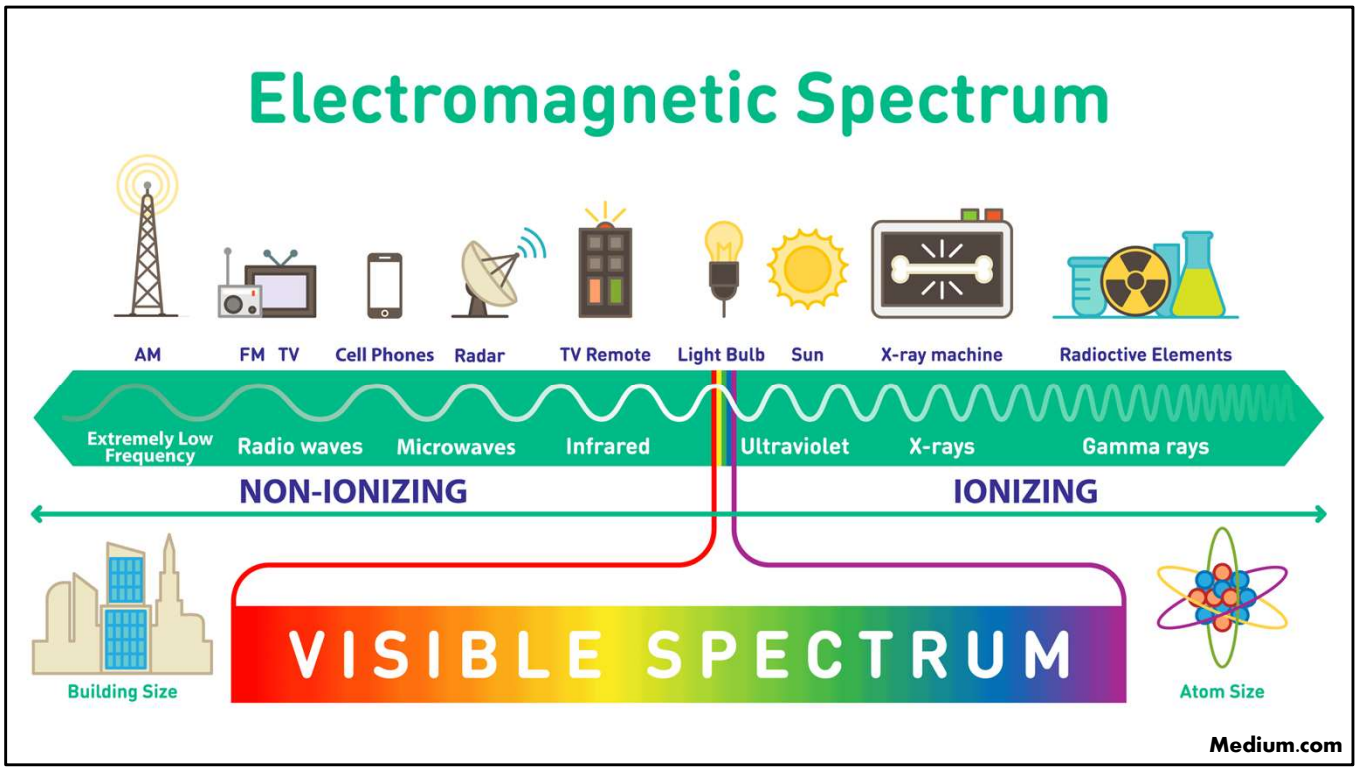
PRESENTATION NOTES

- Very quick slide – what do you know about light?
- Maybe ask the question before showing this slide

SCIENCE NOTES

- Particle of light is a photon

Image from: https://www.azoquantum.com/Article.aspx?ArticleID=146



PRESENTATION NOTES

- Recap the EM spectrum
- Can students remember the wavelengths for visible light?

SCIENCE NOTES

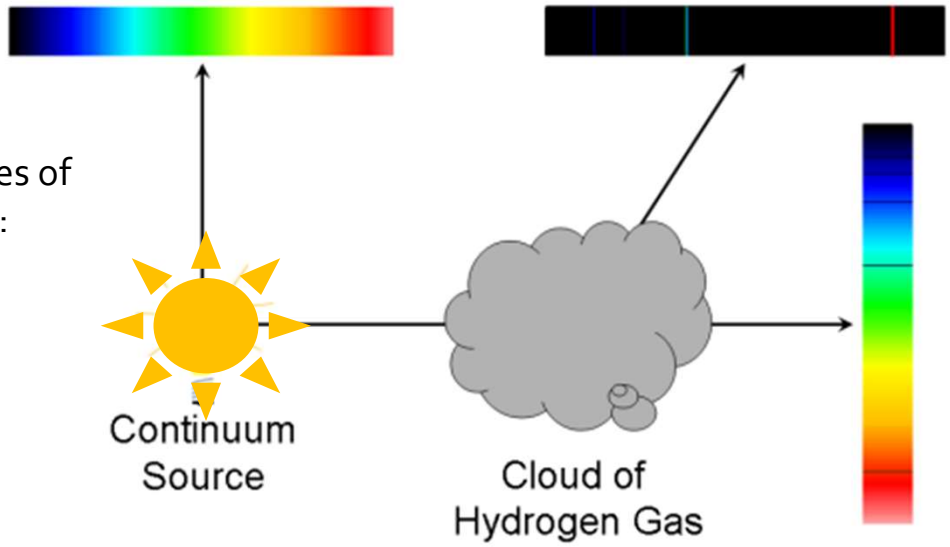
- Ionising – Can damage DNA UV and higher frequencies only (so not 5G!)

Image from: https://medium.com/@tajamulfayaz621/electromagnetic-spectrum-b80002a65665

Spectra

There are three types of spectra shown here:

- Continuous
- Emission
- Absorption



R Pogge

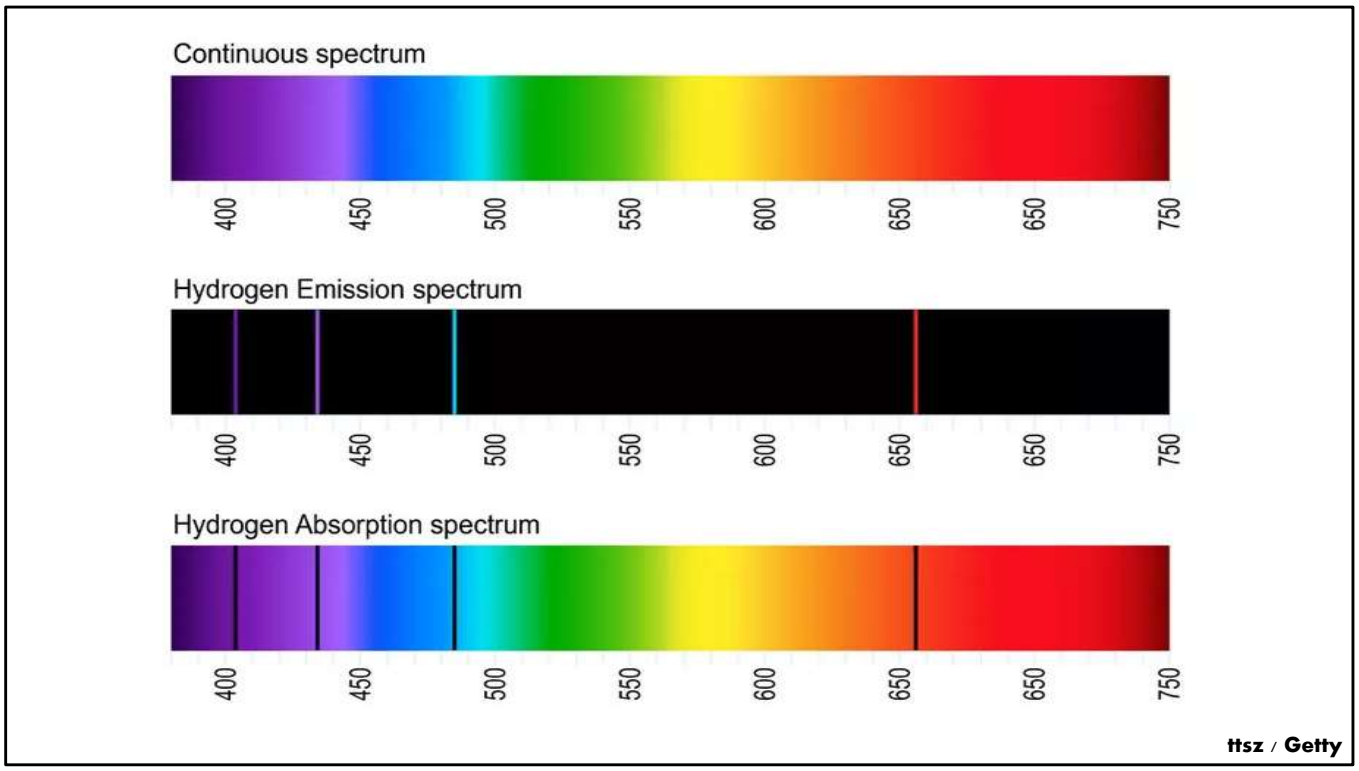
PRESENTATION NOTES

- It is important that students understand the difference between the three types of spectra!
- We often as astronomers look at clouds of Hydrogen gas.

SCIENCE NOTES

- The three types are listed clockwise starting top right with the continuous spectrum.

Image from: http://www.astronomy.ohio-state.edu/~thompson/161/spectra.html
http://www.astronomy.ohio-state.edu/~pogge/Ast162/copyright.html



PRESENTATION NOTES

- Don't labour on this – just an example.

SCIENCE NOTES

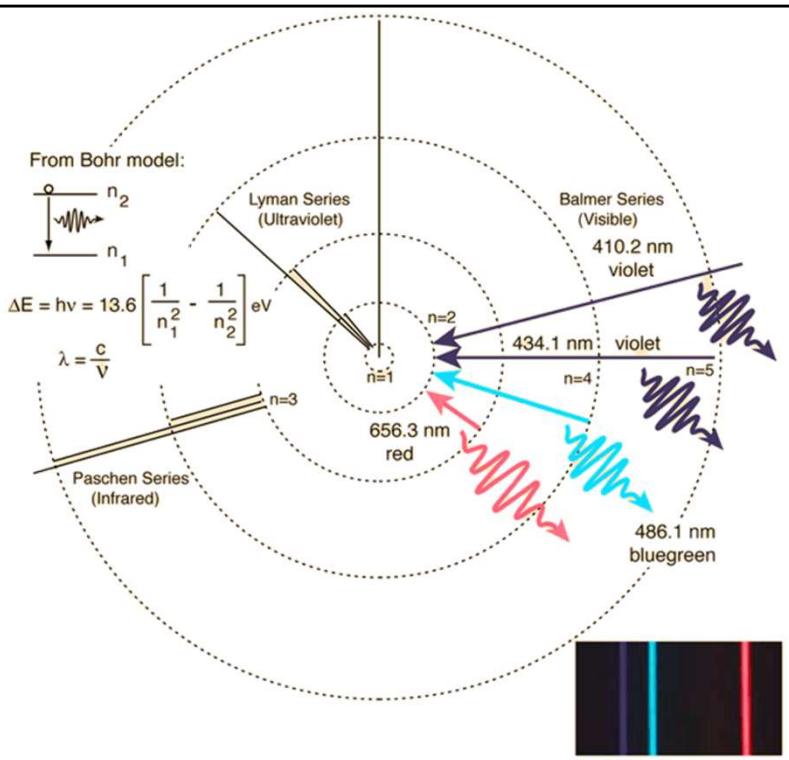
- The two purple lines are hard to see being on the edge of visible/UV.
- The main emission line is the red H-alpha line which we try to image on its own when searching for Hydrogen.
- The blue line is the H-beta emission line

Image from: https://www.thoughtco.com/definition-of-balmer-series-604381

Spectra

This shows the energy levels of Hydrogen.

The Balmer Series on the right is the visible light emission.



R Nave

PRESENTATION NOTES

- Depending on the level of your students skip.
- Focus on the right hand side since it links to the previous slide.

SCIENCE NOTES

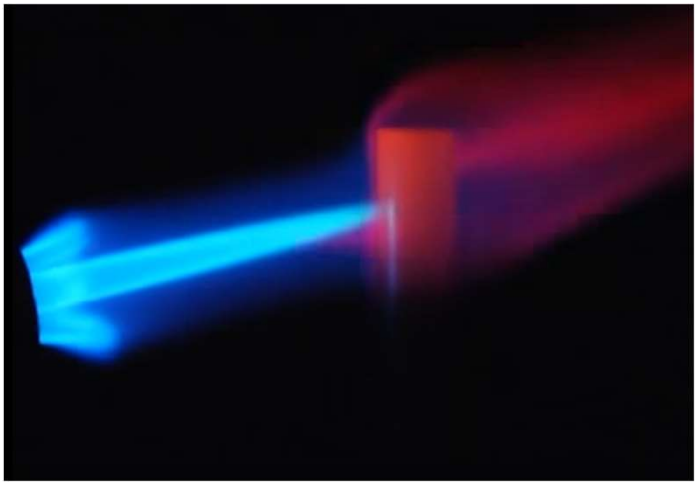
- Electrons can only occupy certain energy levels! This is due to the quantisation of energy.
- The equation on the left is how to calculate the energy from a transition from the energy level n1 to n2.

Image from: http://hyperphysics.phy-astr.gsu.edu/hbase/hyde.html#c4

Generating Light

Light can be generated by:

- Charges that are accelerating
- Heating an object up (Thermal Radiation)
- Fusion



R Pogge

PRESENTATION NOTES

- We are focusing on Thermal Radiation.
- Load the video and narrate- it shows an IR camera and what happens in visible if you heat a metal rod with a blowtorch.
- https://www.youtube.com/watch?v=sUp_WZKZID4

SCIENCE NOTES

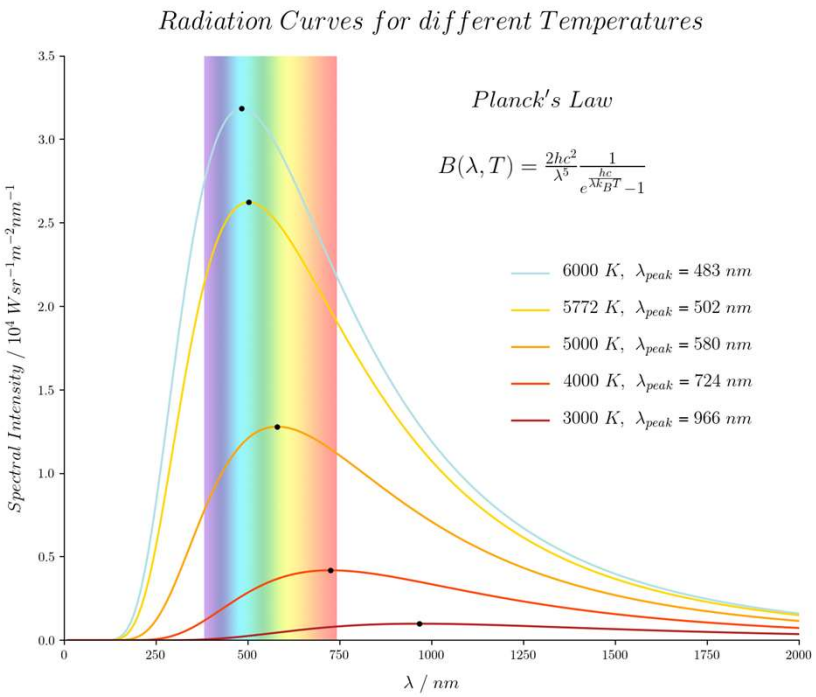
- The orangey flame is due to the surface of the metal reacting with the air around it.

Image from video: https://www.youtube.com/watch?v=sUp_WZKZID4

Blackbody Radiation

A blackbody absorbs all incident radiation and emits all radiation perfectly.

No real object is a perfect blackbody.



PRESENTATION NOTES

- The second tallest curve is for our Sun.
- We approximate the Sun as a blackbody to do calculations.
- If we get the spectrum of a star and fit a curve to it we can get the surface temp (more later).

SCIENCE NOTES

- Our Sun has a peak in the blue/green wavelengths but it emits more yellows/reds since it doesn't tail off very fast (whereas the blue side it drops fast).
- So overall our Sun looks yellow.
- The intensity of each wavelength is given in Watts per steradian (a 3D solid angle) per metre squared per nanometre.

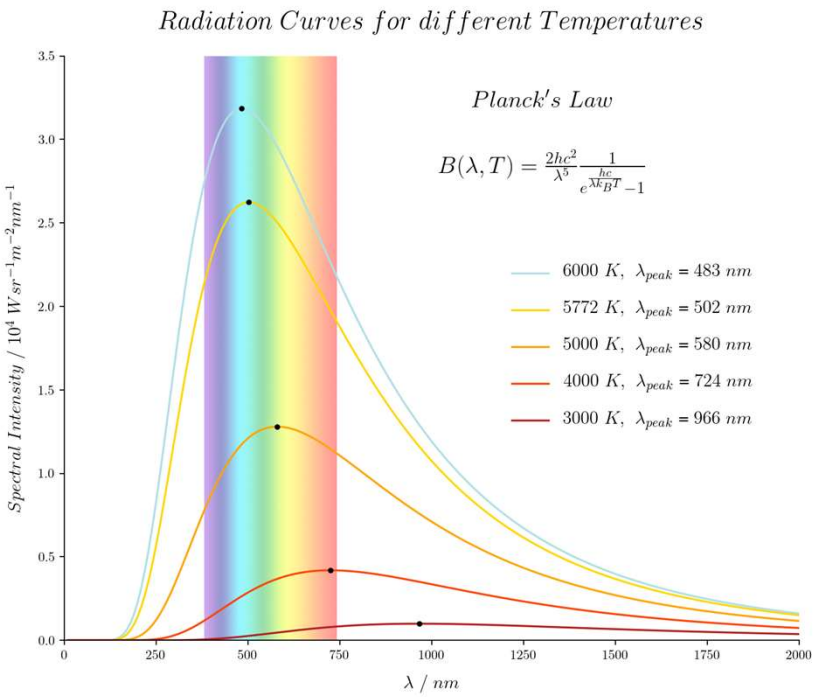
Image by Dimitrios Theodorakis

Wien's Law

A hotter object emits more high energy radiation.

$$\lambda_{peak} = \frac{b}{T}$$

We can find the wavelength the object emits most using Wien's Law.



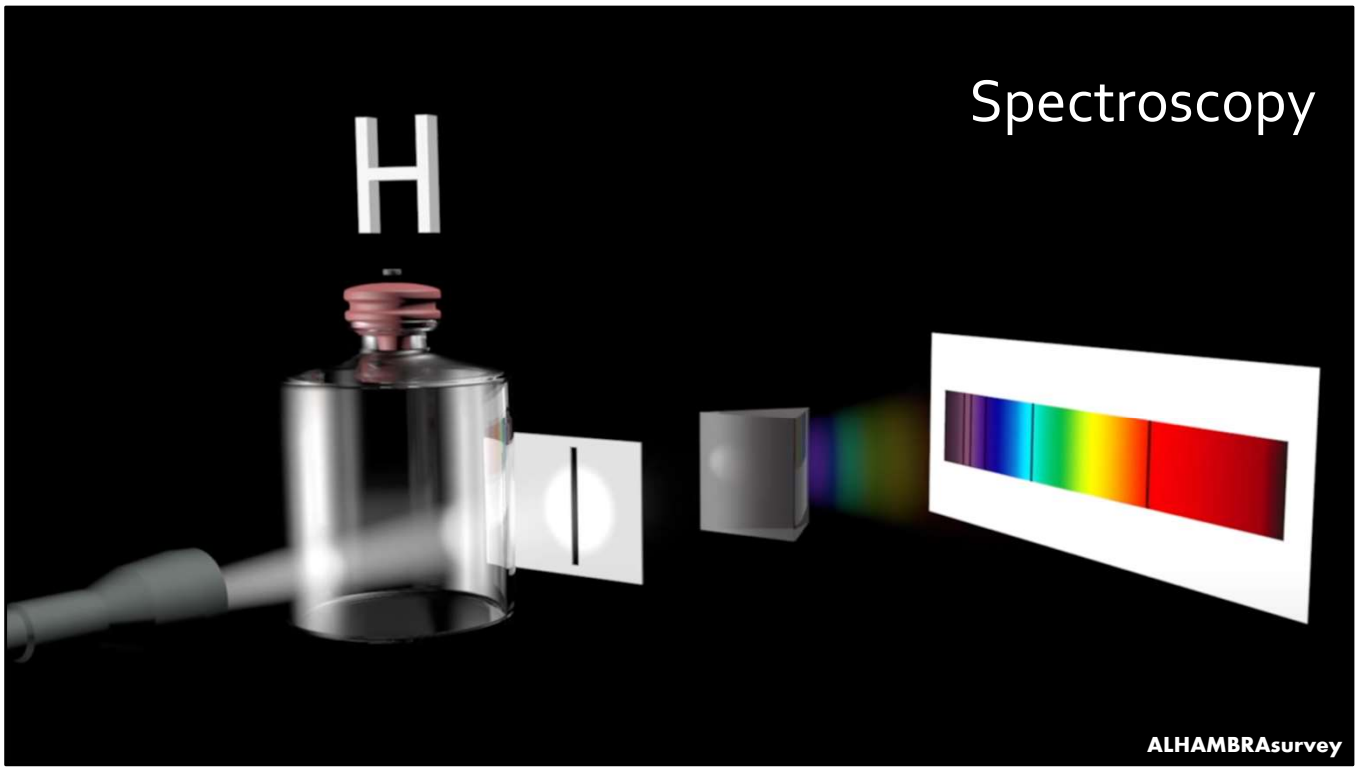
PRESENTATION NOTES

- The hotter an object is the further left towards higher energy wavelengths we shift.
- So Hotter = Higher Energy, glows whiter.

SCIENCE NOTES

- $b \approx 2898$ µm·K, b is Wien's displacement constant
- Planck's law gives the spectral intensity (brightness B) for each wavelength and was used to construct this figure.

Image by Dimitrios Theodorakis



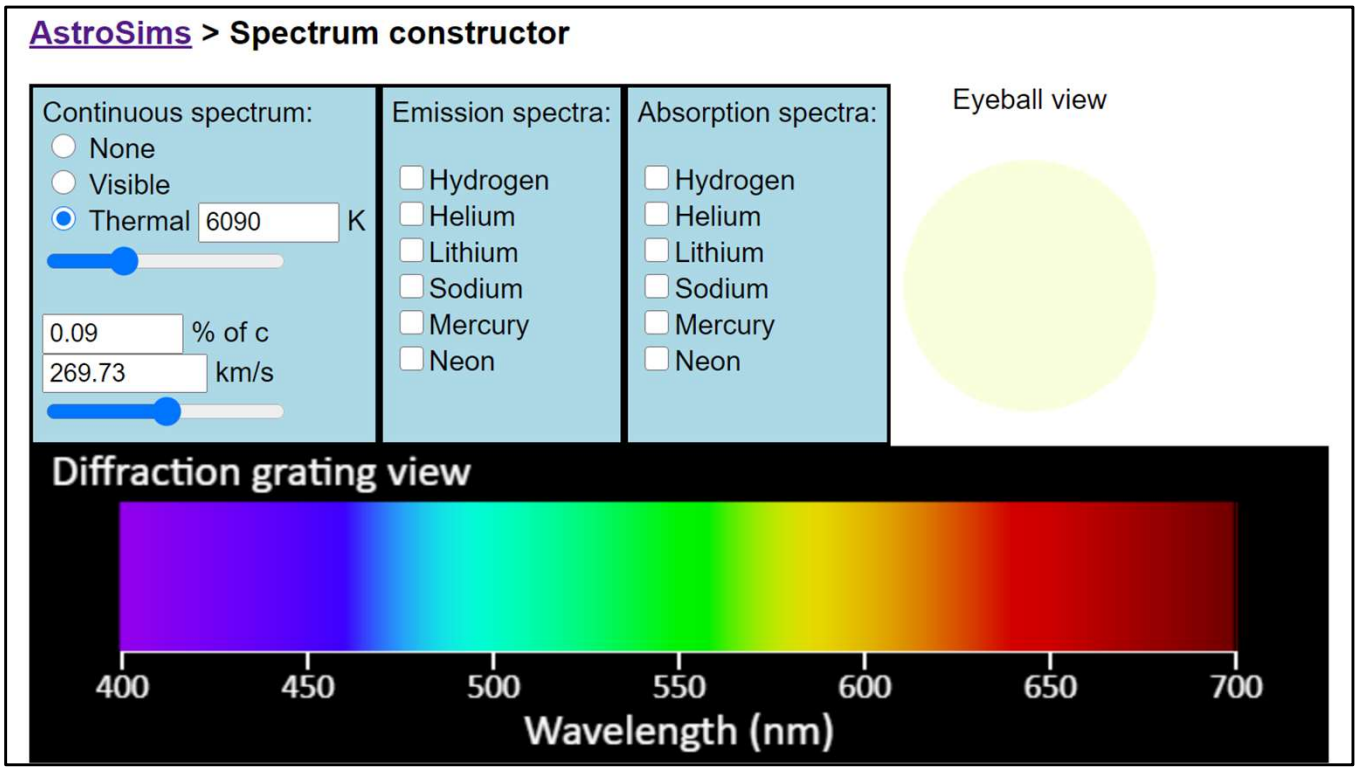
PRESENTATION NOTES

- The video is really short (1 min) if you want to watch it and has a bit of history at the start.
- Explain the process of spectroscopy – most students will be familiar with prisms.
- Some spectrometers have diffraction gratings.

SCIENCE NOTES

- $b \approx 2898$ µm·K, b is Wien's displacement constant.
- The absorption spectrum for Hydrogen is shown.
- In large spectrometers a plate is placed on the telescope where a camera would normally go. The plate has holes in over the positions of stars and optical fibres go in the holes and feed starlight down the a cooled spectrometer in another room (see SDSS plates).

Image from: https://www.youtube.com/watch?app=desktop&v=g_M4cgdjjrI



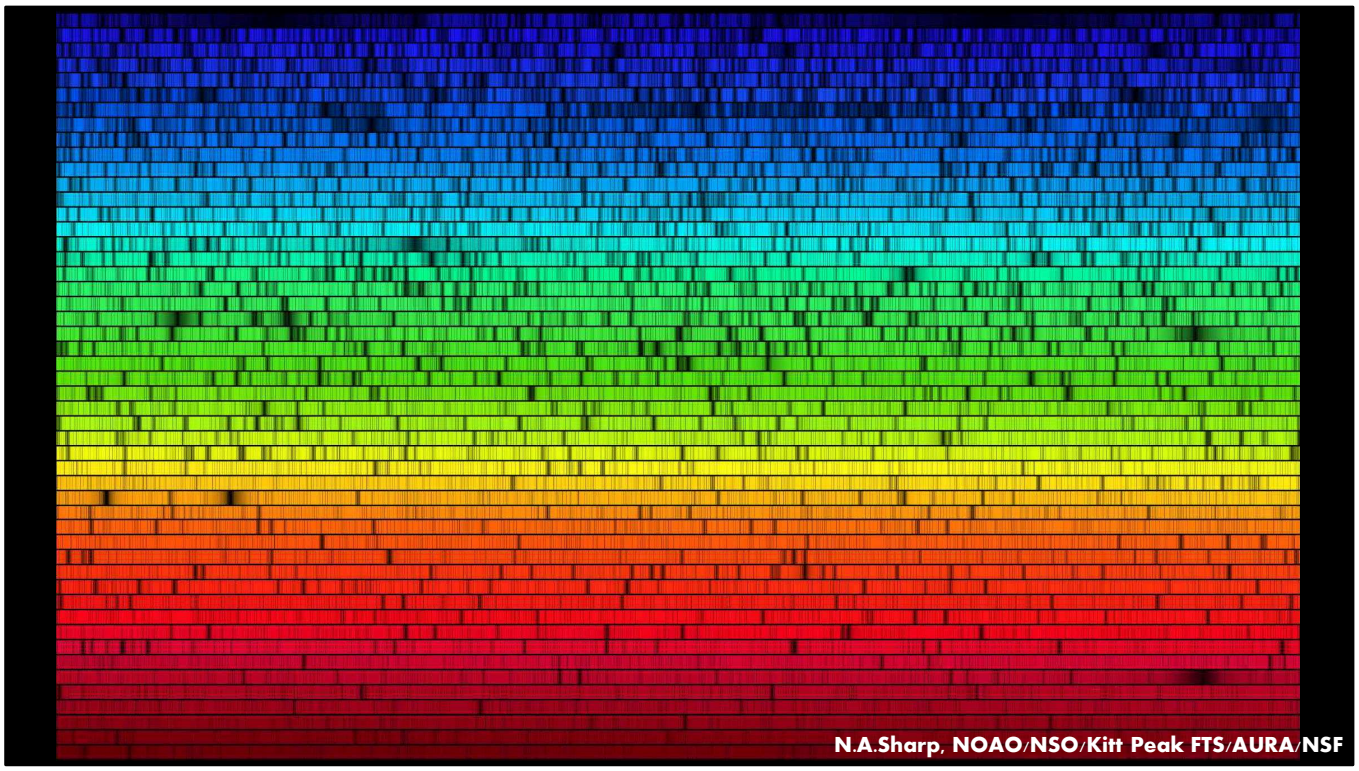
PRESENTATION NOTES

- https://foothillastrosims.github.io/Spectrum-Constructor/
- Use the simulation to demonstrate how the spectra we get from the telescope (below the continuum - not shown on this slide) changes when the temp of the star changes using the thermal slider.
- Then add in some absorption spectra – start with Hydrogen.

SCIENCE NOTES

- When more than one element is present causing dips in the spectra we compare the dips to known reference spectra to see if they match what we should see if there was only one element present.

Image from: https://foothillastrosims.github.io/Spectrum-Constructor/



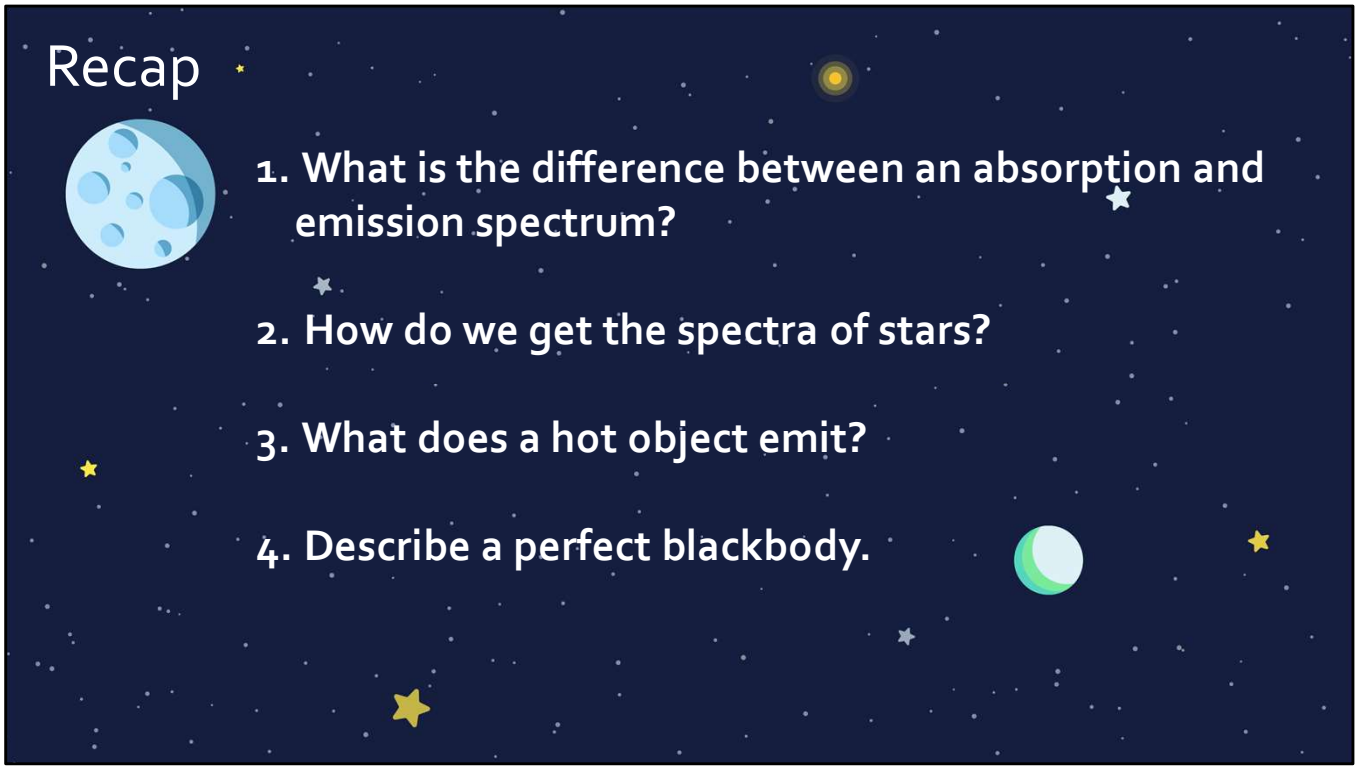
PRESENTATION NOTES

- Spectrum of the Sun
- "The first evidence of helium was observed on August 18, **1868**, as a bright yellow line with a wavelength of 587.49 nanometres in the spectrum of the chromosphere of the Sun. The line was detected by French astronomer Jules Janssen during a total solar eclipse in Guntur, India." Wikipedia - Helium

SCIENCE NOTES

- See the link below for more info.

Image from: https://www.cfa.harvard.edu/ssp/stars_planets/solarspectrum.html
N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF



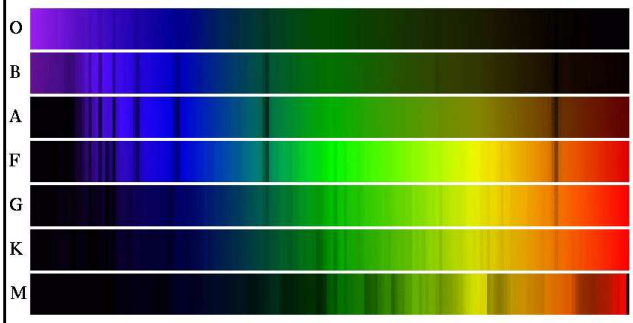
RECAP
Spend 4-5 minutes recapping. Have students answer the questions in TPS format.

1. Emission is black with coloured lines showing wavelengths that are emitted. Absorption is rainbow with black lines where wavelengths are absorbed.
2. Using spectrometers attached to telescopes (or in another room so they can be cooled and light is fed via optical fibres)
3. EM Radiation! The hotter the higher energy – we emit IR at body temp
4. An object which absorbs all incident radiation and emits all wavelengths

Spectral Type

OBAFGKMLTY

Orion **B**attles **a**cross **F**ar **G**alaxies **K**illing **M**artians



Class	Temperature	Apparent color	Hydrogen lines	Other noted spectral features
O	≥ 30,000 K	blue	Weak	ionized helium lines
B	10,000–30,000 K	blue white	Medium	neutral helium
A	7,500–10,000 K	white to blue white	Strong	ionized calcium (weak)
F	6,000–7,500 K	white	Medium	ionized calcium (weak)
G	5,200–6,000 K	yellowish white	Weak	ionized calcium (medium)
K	3,700–5,200 K	yellow orange	Very weak	ionized calcium (strong)
M	≤ 3,700 K	orange red	Very weak	Titanium oxide lines

writescience

PRESENTATION NOTES

- The left hand side is presented again later so focus on the order OBAFGKMLTY and the right hand side.
- We normally ignore LTY.

SCIENCE NOTES

- LTY are dwarf stars, Y can be colder than the human body and were discovered for the first time by the WISE spacecraft.

Image from: https://writescience.wordpress.com/tag/spectra/

Mnemonic Contest

OBAFGKMLTY

Orion **B**attles **a**cross **F**ar **G**alaxies **K**illing **M**artians

Come up with a mnemonic to remember the sequence of spectral classes

- Must be in English
- Must be suitable for work
- Extra points for the whole sequence (with LTY)

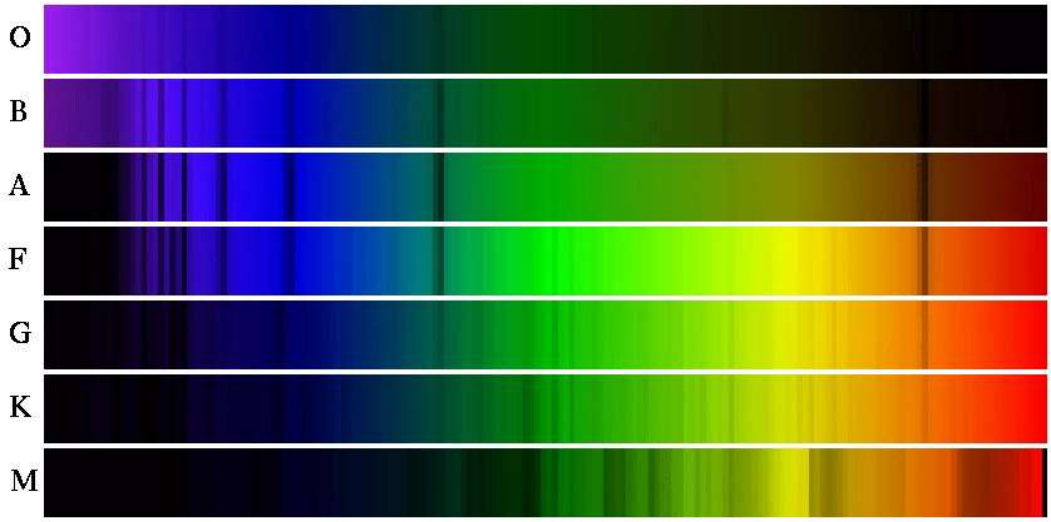
Prizes for best entries

PRESENTATION NOTES

- Other mnemonics: Oil, butter and fat gonna kill me
- Only brilliant astronomers find gorilla killing meteors
- Stolen from: http://www.astro.sunysb.edu/fwalter/AST101/mnemonic.html

Spectral Type

OBAFGKMLTY



writescience

PRESENTATION NOTES

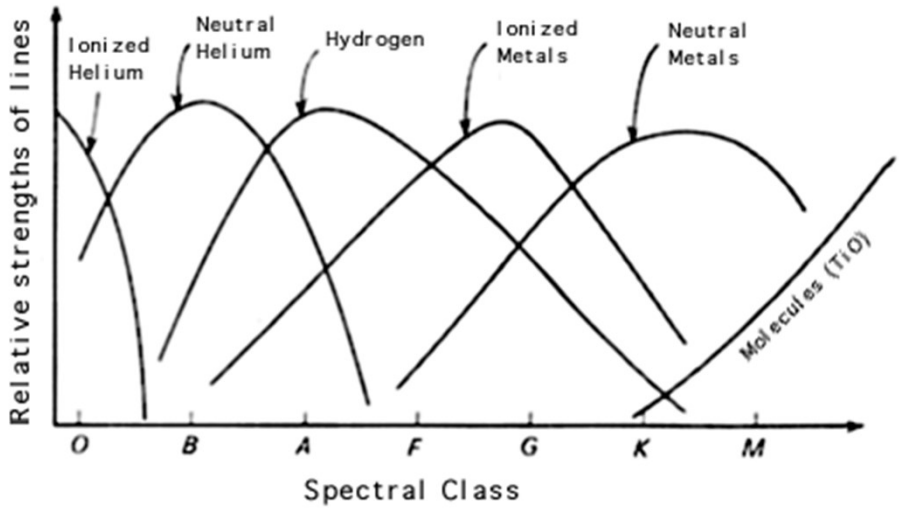
- You can clearly see that going M to O (increasing Temp) you shift towards blue which are lower wavelengths with more energy.

SCIENCE NOTES

- The Sun is a G2V star. 2 means it is on the hotter end of the G type stars. V means it is on the main sequence (main part of its life).

Image from: https://writescience.wordpress.com/tag/spectra/

Spectral Type



P Crowther

PRESENTATION NOTES

- A little deep for most but this helps explain that KM stars are cold enough for molecules to form/stay as molecules.
- In the hotter stars you can only have elements.
- Too hot and you end up ionising elements like H and He.

SCIENCE NOTES

- Molecules can't survive the high temperatures in hotter stars so those lines disappear from stars in the OBAFG(K) classes.

Image from: http://www.star.ucl.ac.uk/~pac/spectral_classification.html

Luminosity

$$L = A\sigma T^4$$

Luminosity, L is measured in Watts (W). Think of it as the Power of the star.

A is the surface area of the star in m^2
σ is the Stefan-Boltzmann Constant, 5.67 $Wm^{-2}K^{-4}$
T is the temperature in Kelvin (K)

PRESENTATION NOTES

- Students in the UK will have come across Power so frame it as Luminosity is the Power of the star.

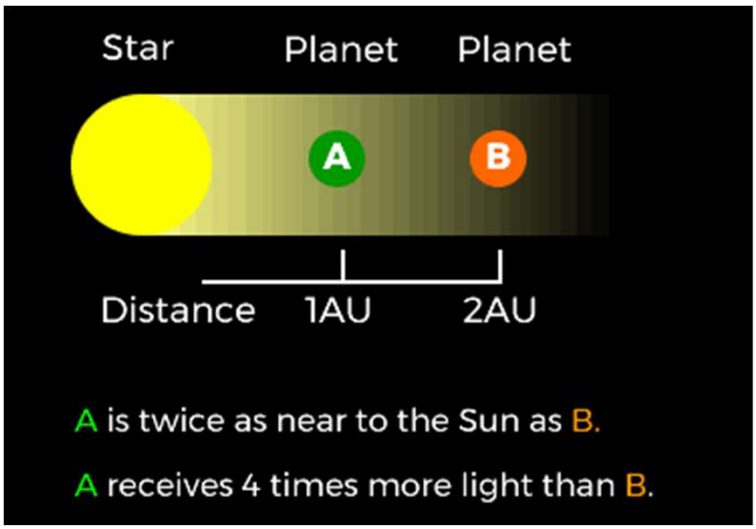
SCIENCE NOTES

- This is the Stefan-Boltzmann equation and is missing a term called the emissivity. We have assumed it is 1 which means our star is a perfect blackbody: https://en.wikipedia.org/wiki/Stefan%E2%80%93Boltzmann_law
- The luminosity of the Sun is 3.83×10^{26} W if we ignore neutrinos.

Inverse-square law

The further away from a light emitting object the less light you receive.

If you double the distance you receive four times less light.



space.fm

PRESENTATION NOTES

- Link to gravitational field strength.

SCIENCE NOTES

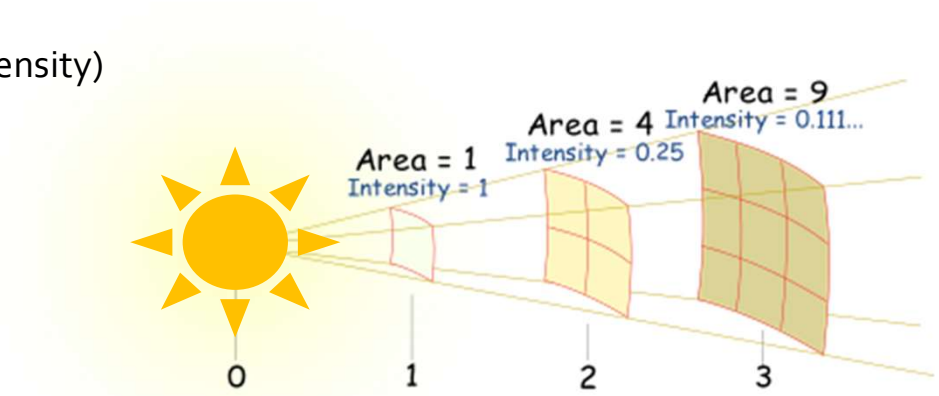
- Here AU is the astronomical unit. The Earth is 1 AU from the Sun so A might be Earth!

Image from:
https://www.space.fm/astronomy/planetarysystems/gravityandinverse.html

Inverse-square law

The brightness (intensity) of light is given by:

$$b = \frac{L}{4\pi d^2}$$



It has units of Wm^{-2}.
d is the distance you are from the star.

mathsisfun

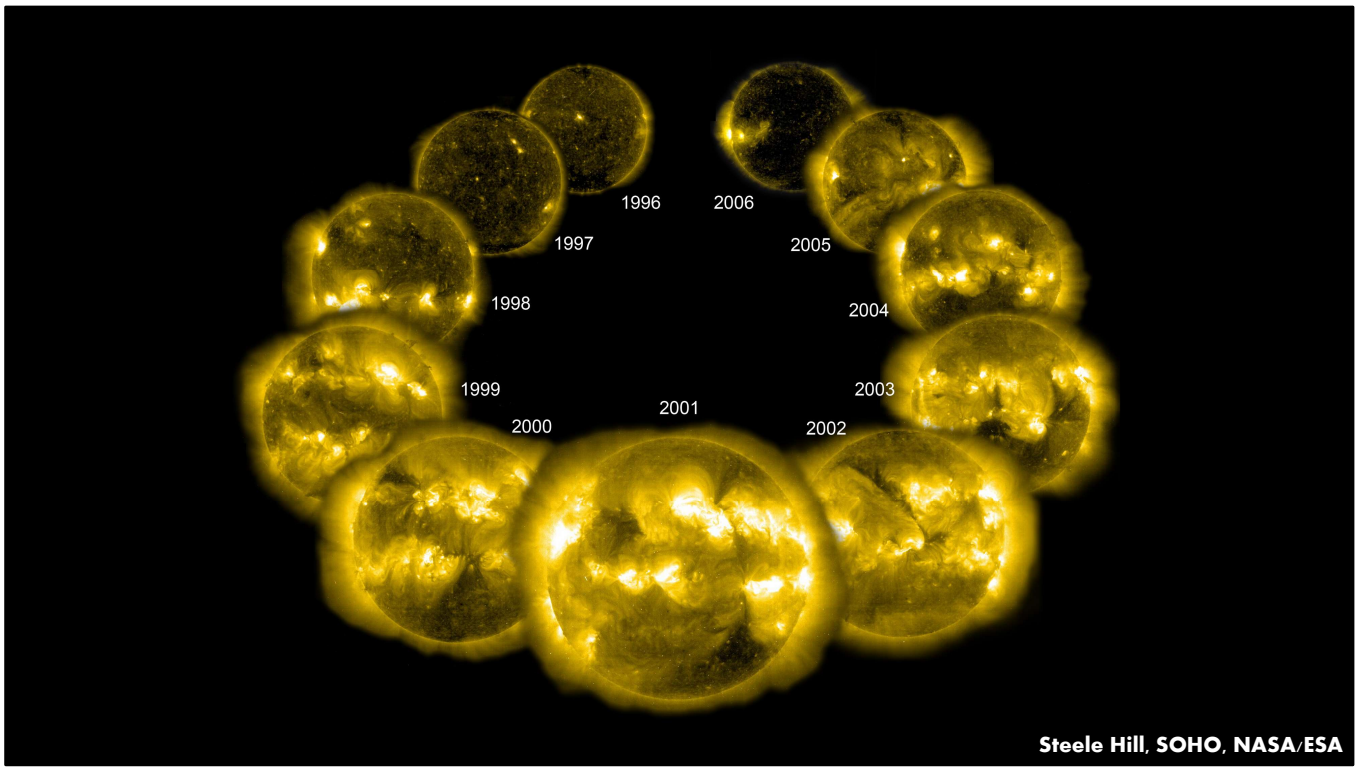
PRESENTATION NOTES

- Intensity and brightness are interchangeable.

SCIENCE NOTES

- The denominator is the surface area of a sphere since light is radiated spherically in all directions from the Sun and other stars.
- The brightness or solar radiation at Earth is ~ 1,400 Wm^{-2}.
- On Mars this value is ~715 Wm^{-2} (max values taken).

Image from: https://www.mathsisfun.com/physics/radiation.html



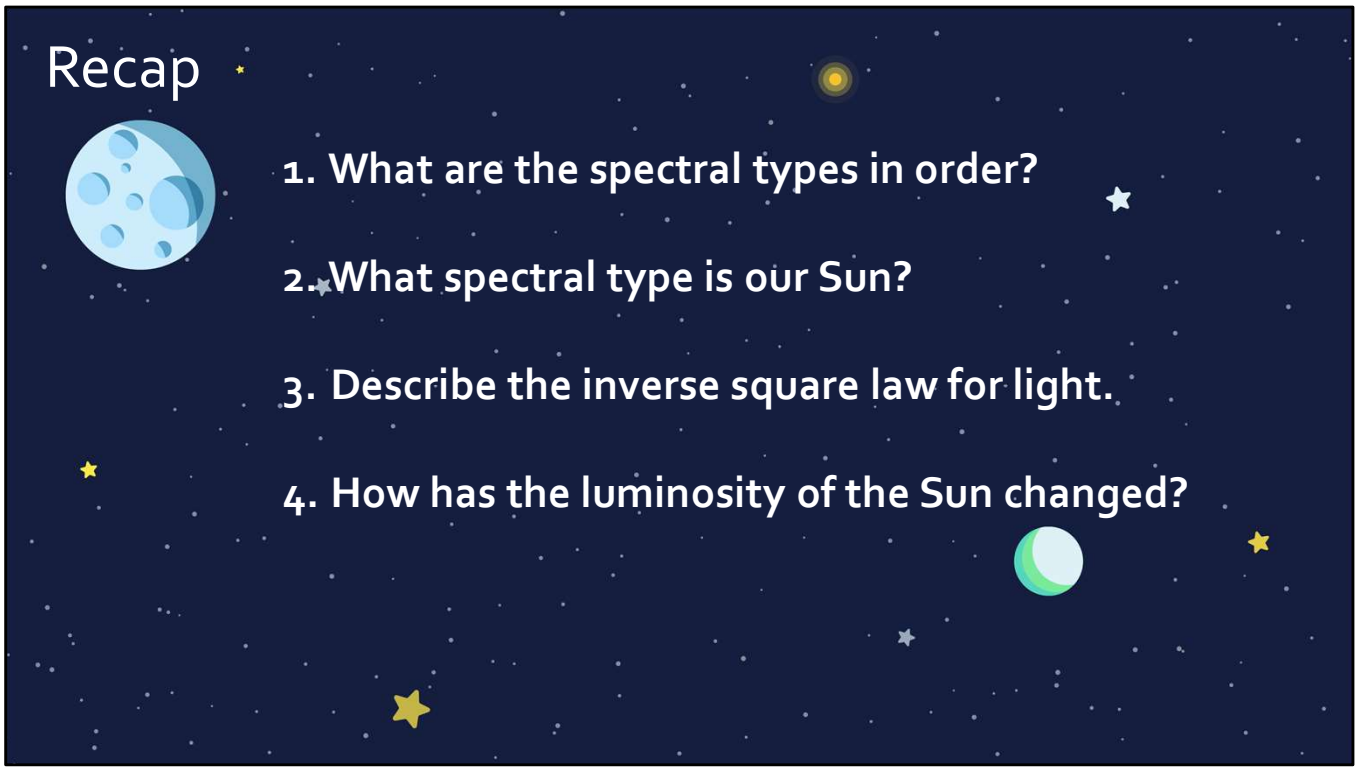
PRESENTATION NOTES

- Link to what students already know about the solar cycle. Question them:
- What wavelength is this?
- What do the bright spots show?
- How long is the solar cycle?

SCIENCE NOTES

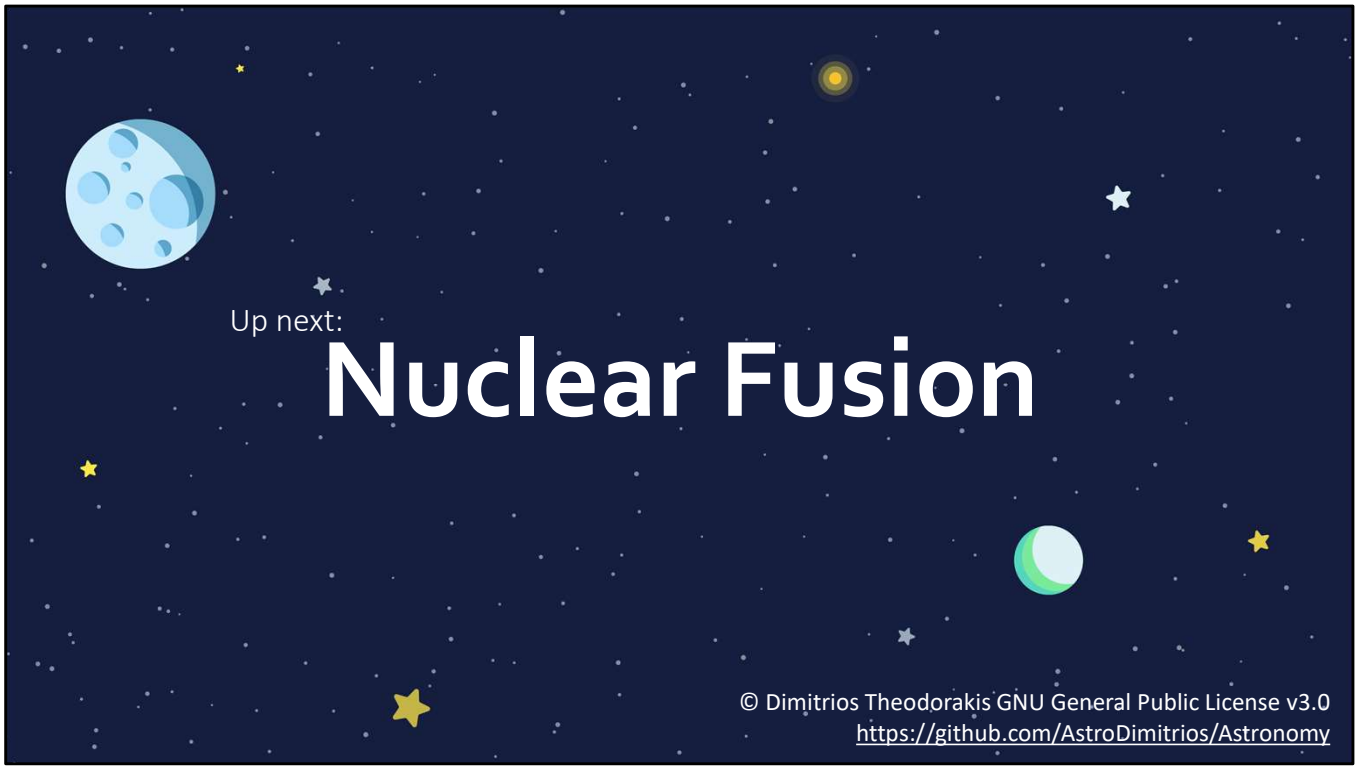
- Total Solar Irradiance (TSI) varies by ~0.1 % during a solar cycle
- Over the Sun's lifetime it's power has increased by 30 %
- "This is an inevitable evolution which comes about because, as the billions of years roll by, the Sun is burning up the hydrogen in its core. The helium "ashes" left behind are denser than hydrogen, so the hydrogen/helium mix in the Sun's core is very slowly becoming denser, thus raising the pressure. This causes the nuclear reactions to run a little hotter. The Sun brightens." - https://faculty.wcas.northwestern.edu/~infocom/The%20Website/evolution.html

Image from:
https://www.nasa.gov/mission_pages/Glory/solar_irradiance/total_solar_irradiance.html



RECAP
Spend 4-5 minutes recapping the last lesson. Have students answer the questions in TPS format.

1. OBAFGKM(LTY)
2. G2V lower number is hotter in the class, V for typical main sequence
3. Doubling the distance from the light source decreases the brightness by a factor of 4
4. Increased by 30 % over its liftetime



PRESENTATION NOTES

- The next PPT is on Nuclear Fusion