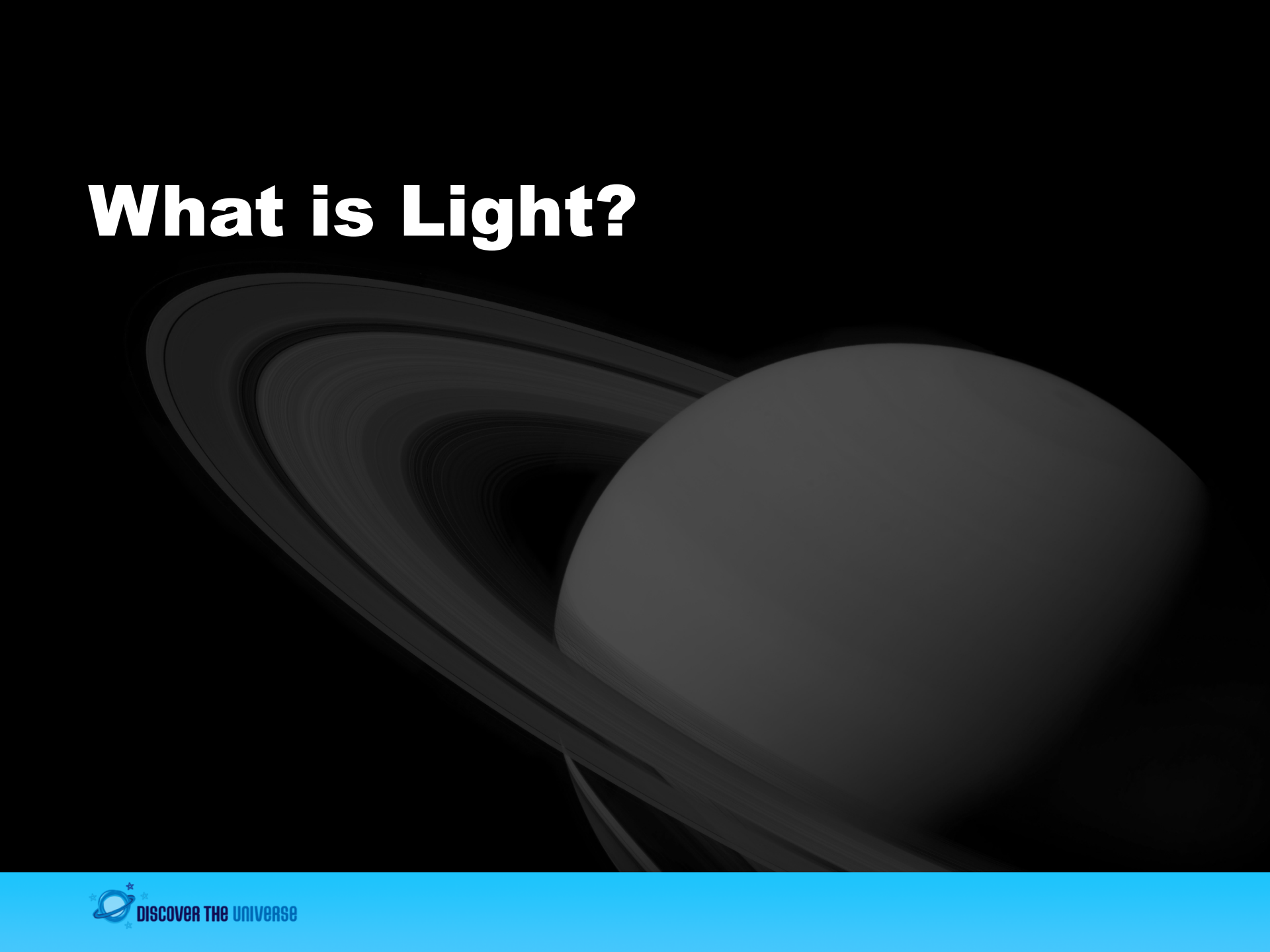
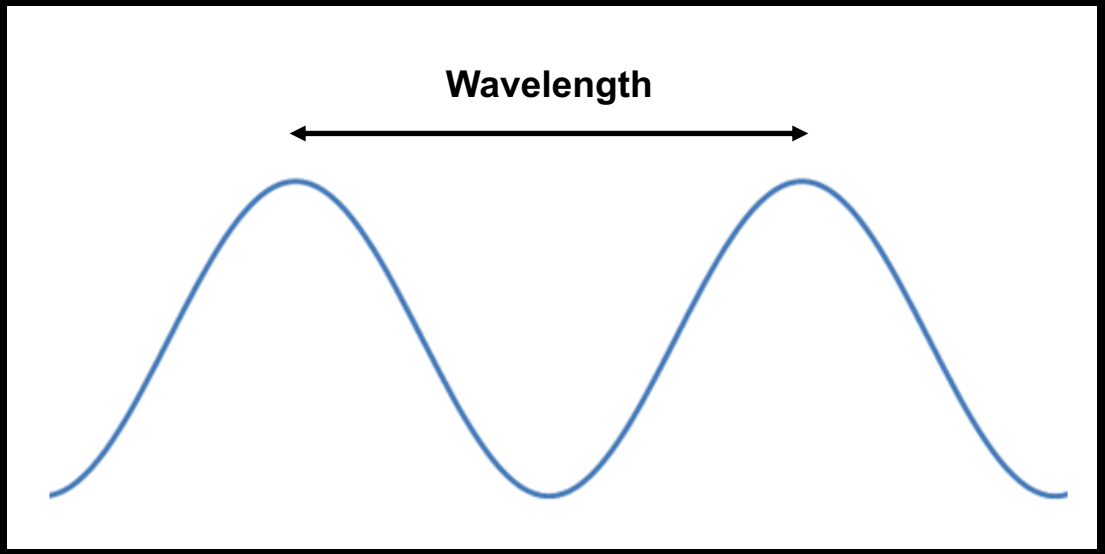
Light – Cosmic Messenger

What is Light?



What is Light?

★Light is an electromagnetic wave…



★ AND a particle (photon).

Speed of Light

★In vacuum, light travels at 300,000 km/s.

★According to Einstein's theory of relativity, nothing can travel faster.

★The speed of light is used to calculate distances in astronomy:

- One light-year is the distance traveled by light in one year.

Telescope = Time Travel Machine

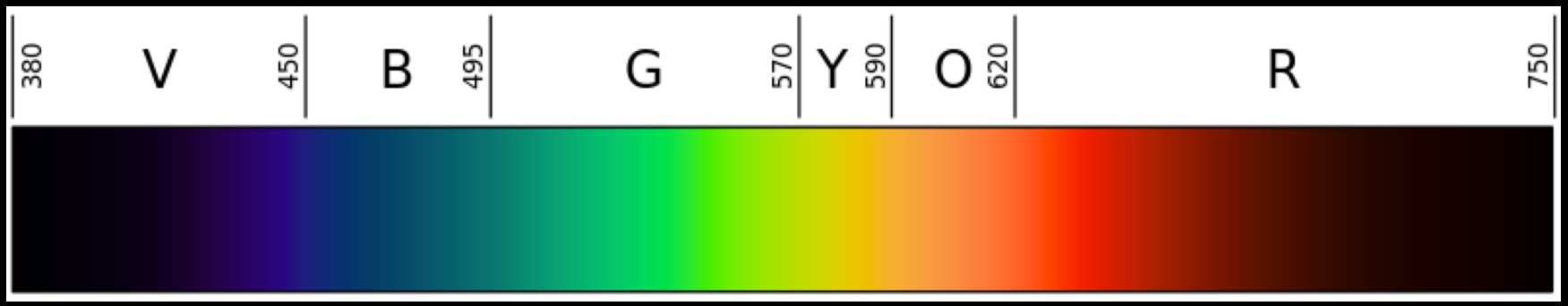
Light is fast but not infinitely fast.

When we look at a star 100 light-years away, we see it the way it was 100 years ago.

Some galaxies in this image are billions of light-years away…

Visible Light

Our eyes perceive different wavelengths of light as different colours. We can see light with wavelengths between 400nm and 700 nm.



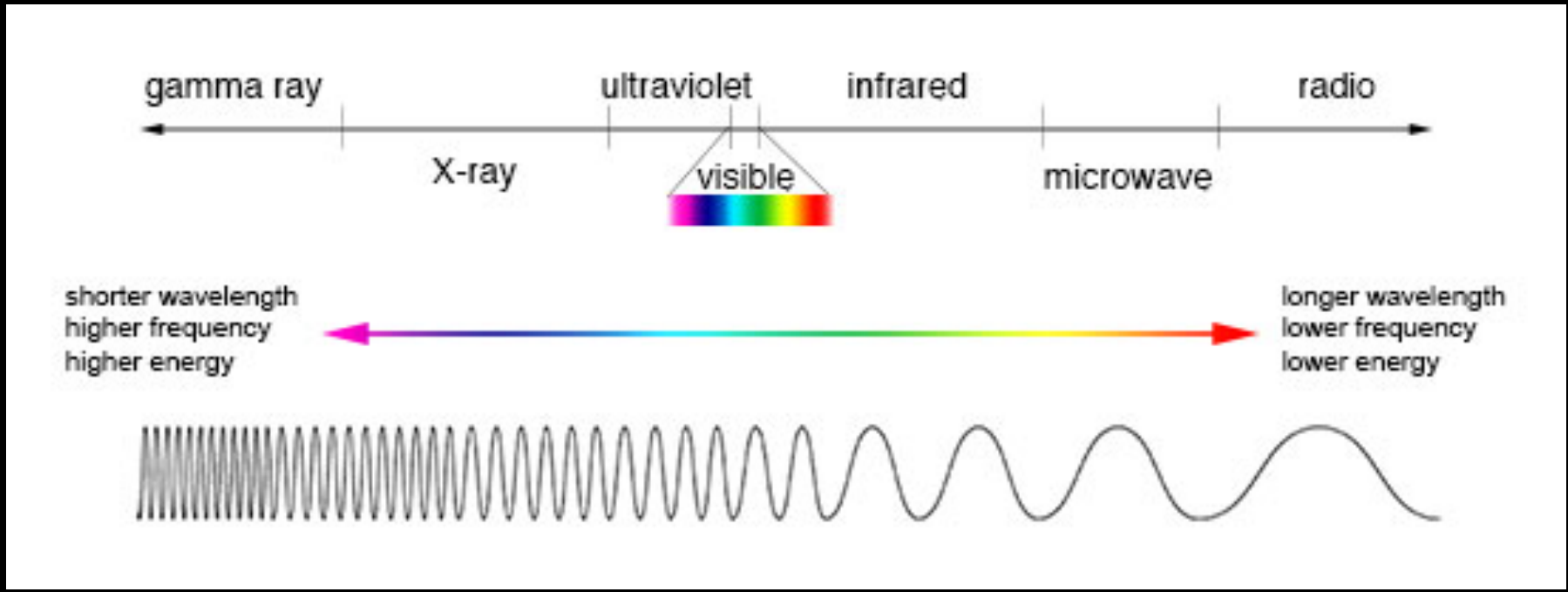
1 nm = 1 nanometre = 10^{-9} m = one millionth of 1 mm

Visible Light

White light is composed of all colours in the visible spectrum.

Electromagnetic Spectrum

Visible light is only a tiny part of the entire electromagnetic spectrum.



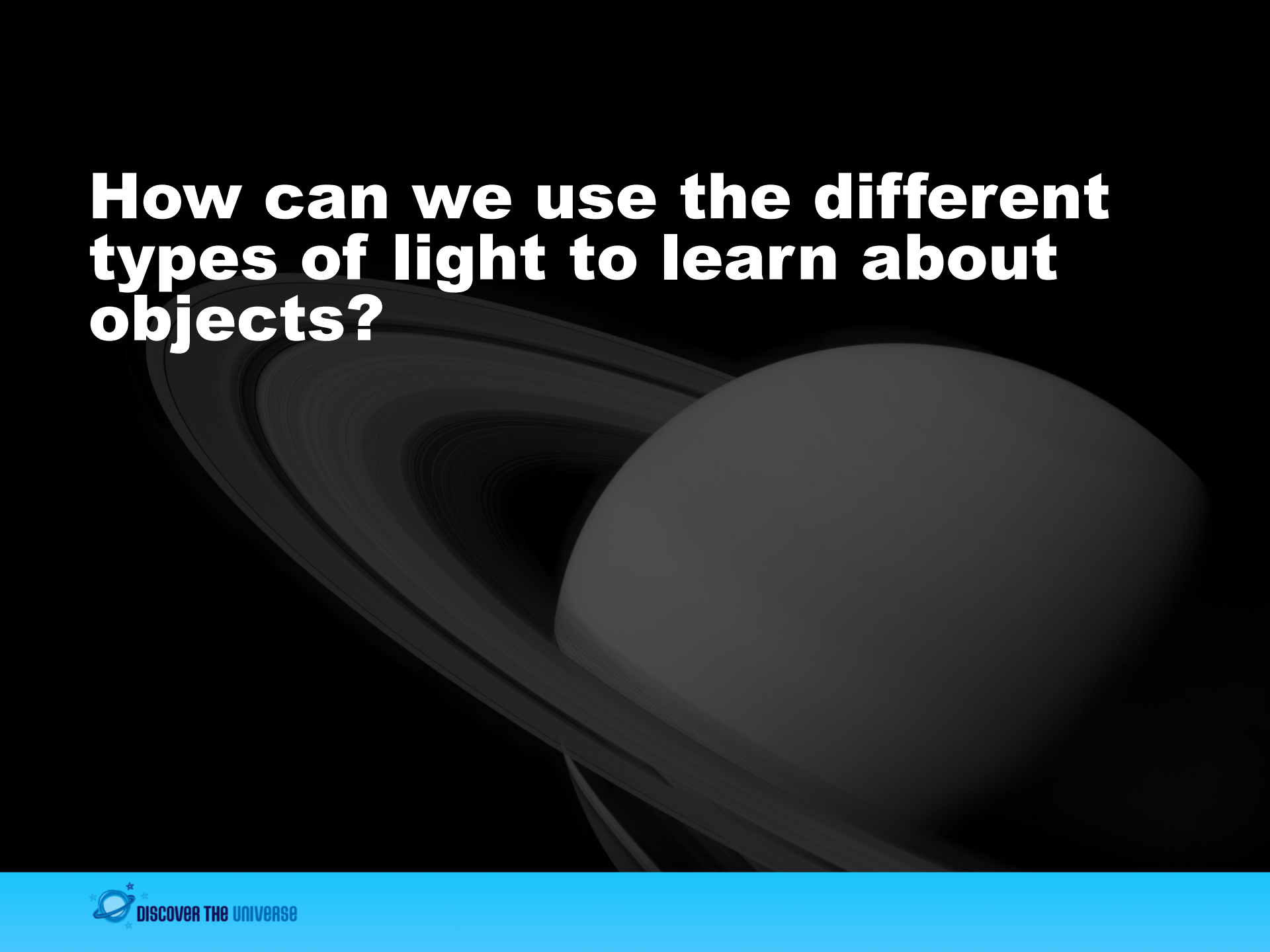
Electromagnetic Spectrum

- ★Gamma rays
- ★X-rays
- ★Ultraviolet
- ★Infrared
- ★Microwaves
- ★Radio waves

« Colours » which we can't see.

Radiation : emission or transmission of energy (not necessarily dangerous!)

How can we use the different types of light to learn about objects?

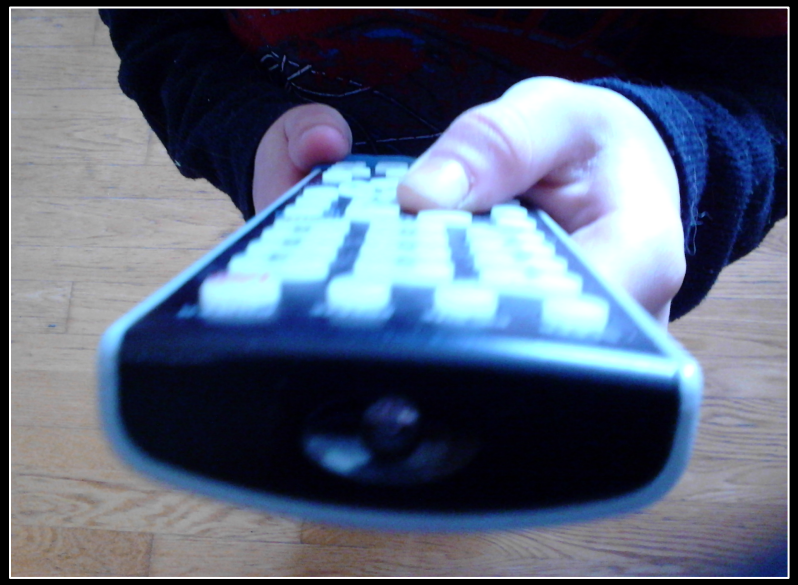


Infrared

Infrared

Infrared - Experiment

Digital cameras are sensitive to infrared light and can detect the signal emitted by remote controls.



With the eye

Through a camera

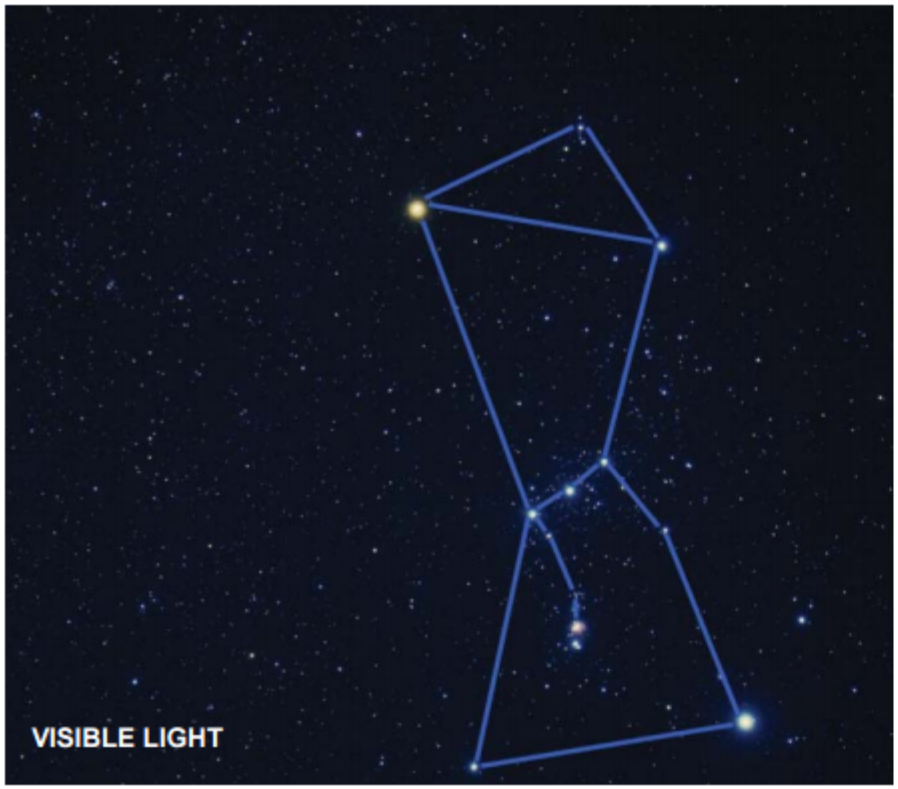
Infrared - Experiment

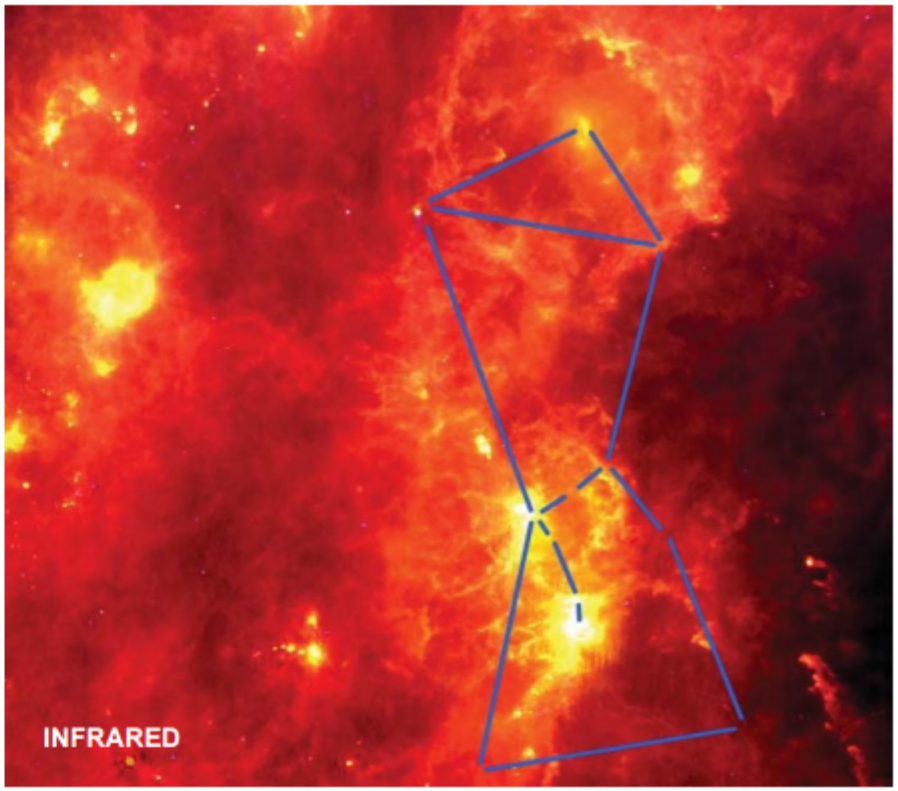
You can try it in class or with a group.

For once, ask your students to take out their cellphones, iPod or other electronic device with a camera!

The signal might not be very strong: ask the students to get closer to the remote control and to be directly in line with the infrared LED.

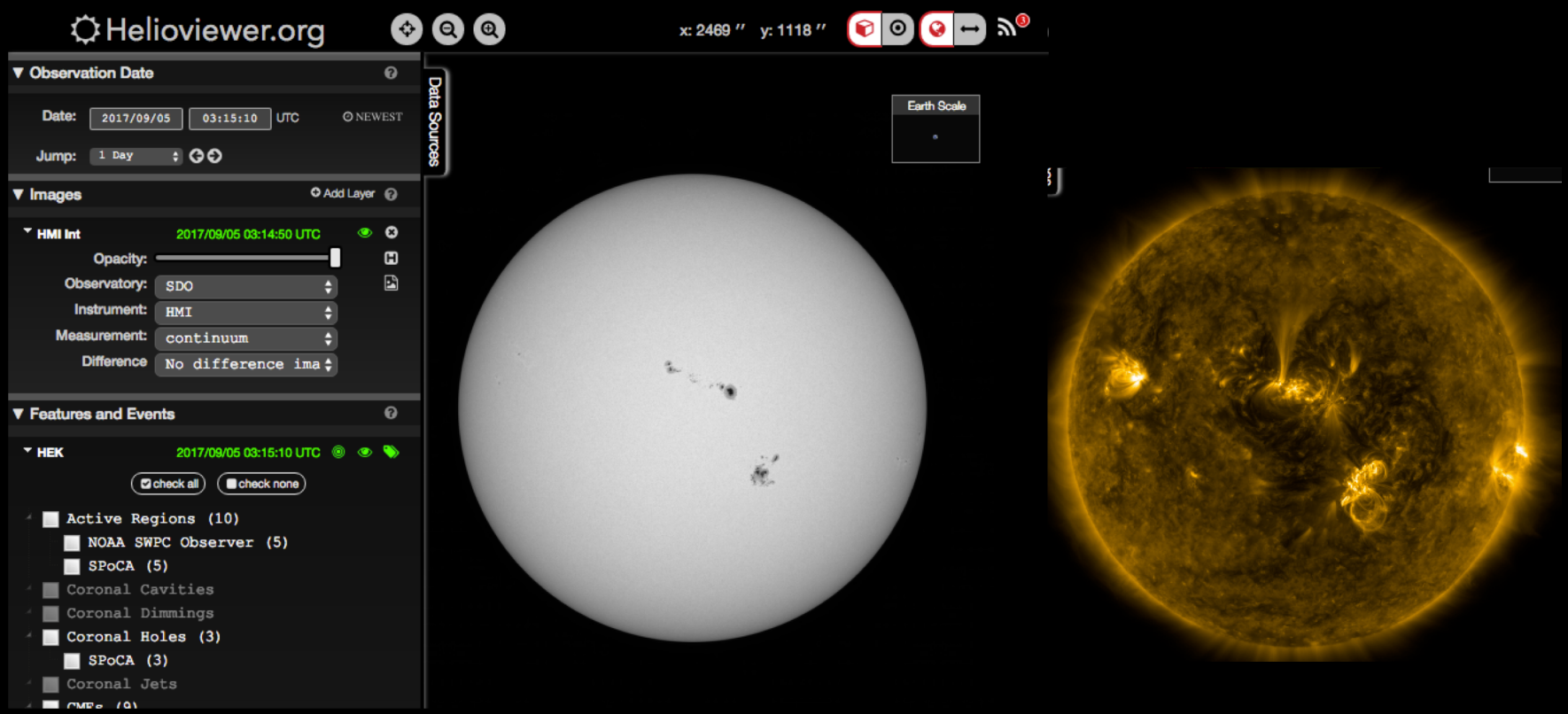
The Sky in Infrared



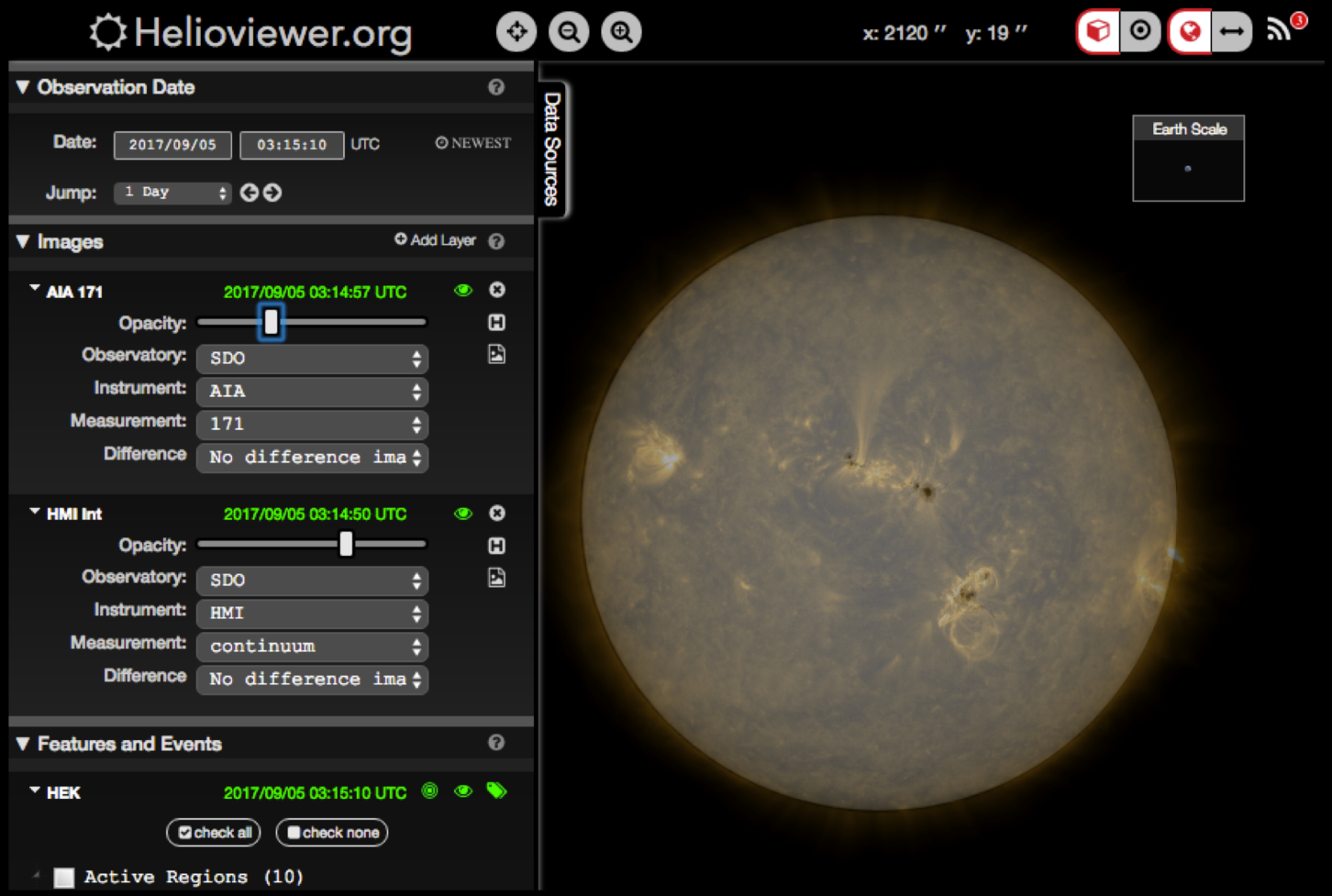


Ultraviolet

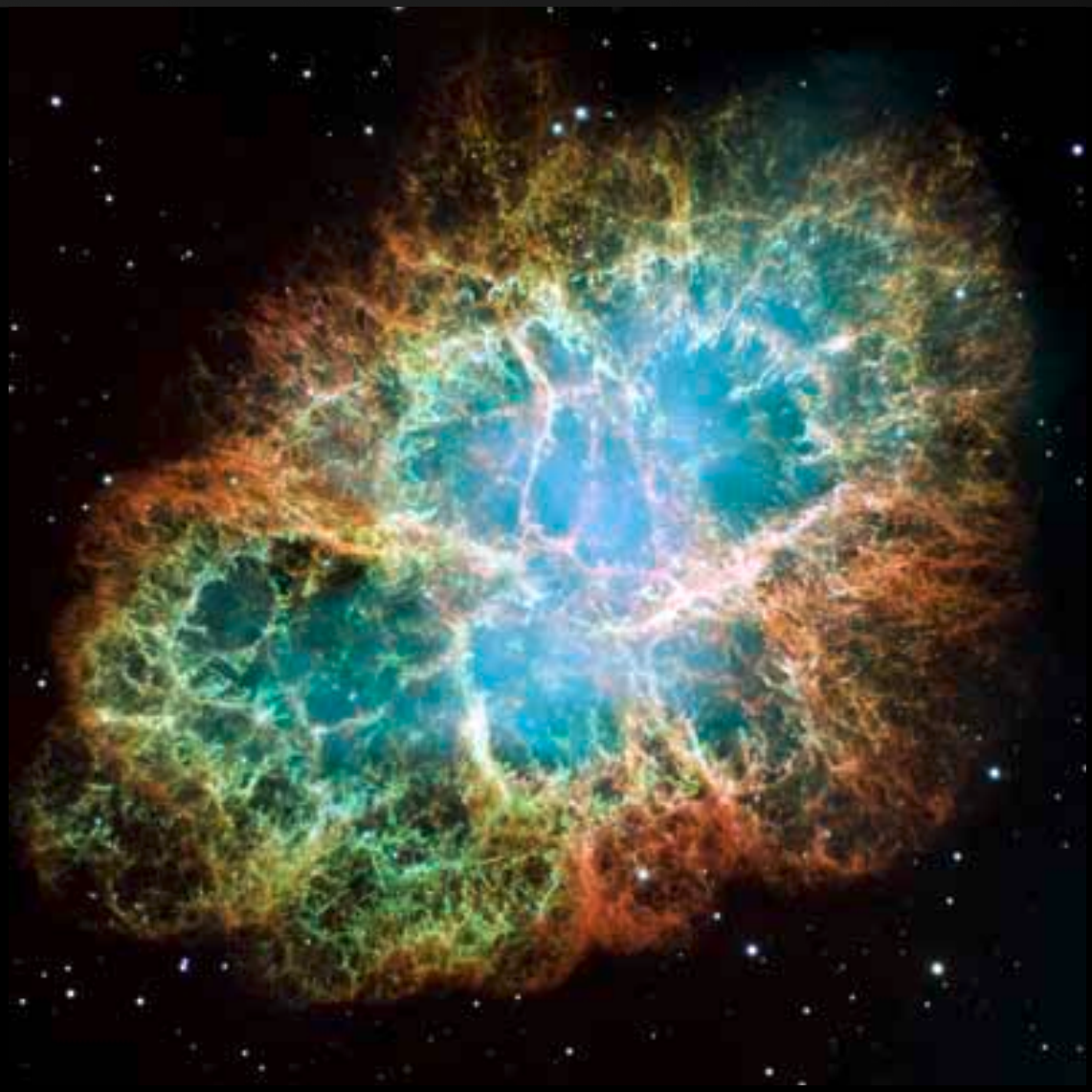
Sun in Visible Light and UV – Helioviewer.org



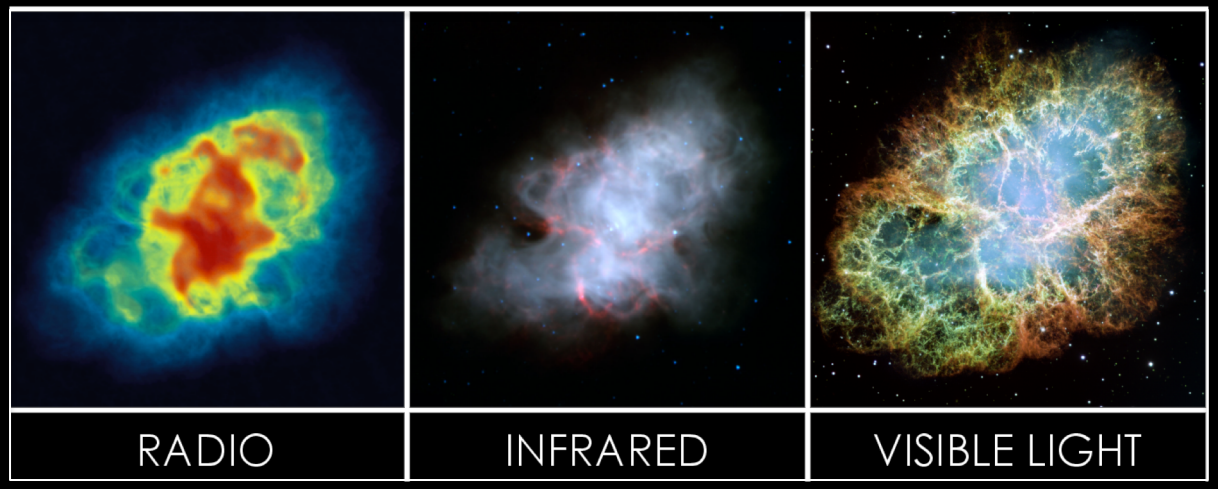
Sun in Visible Light and UV – Helioviewer.org

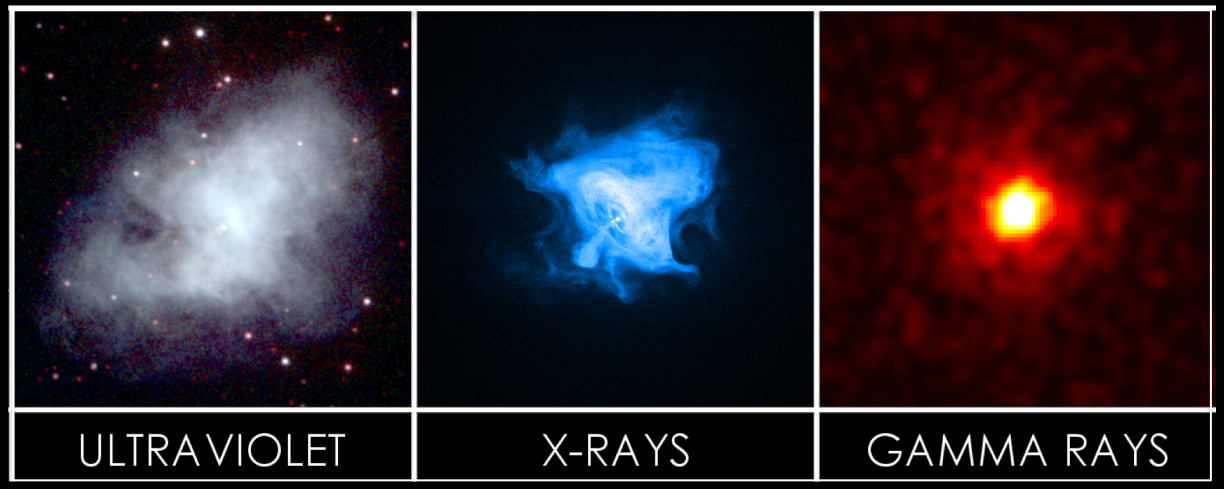


Crab Nebula – M1

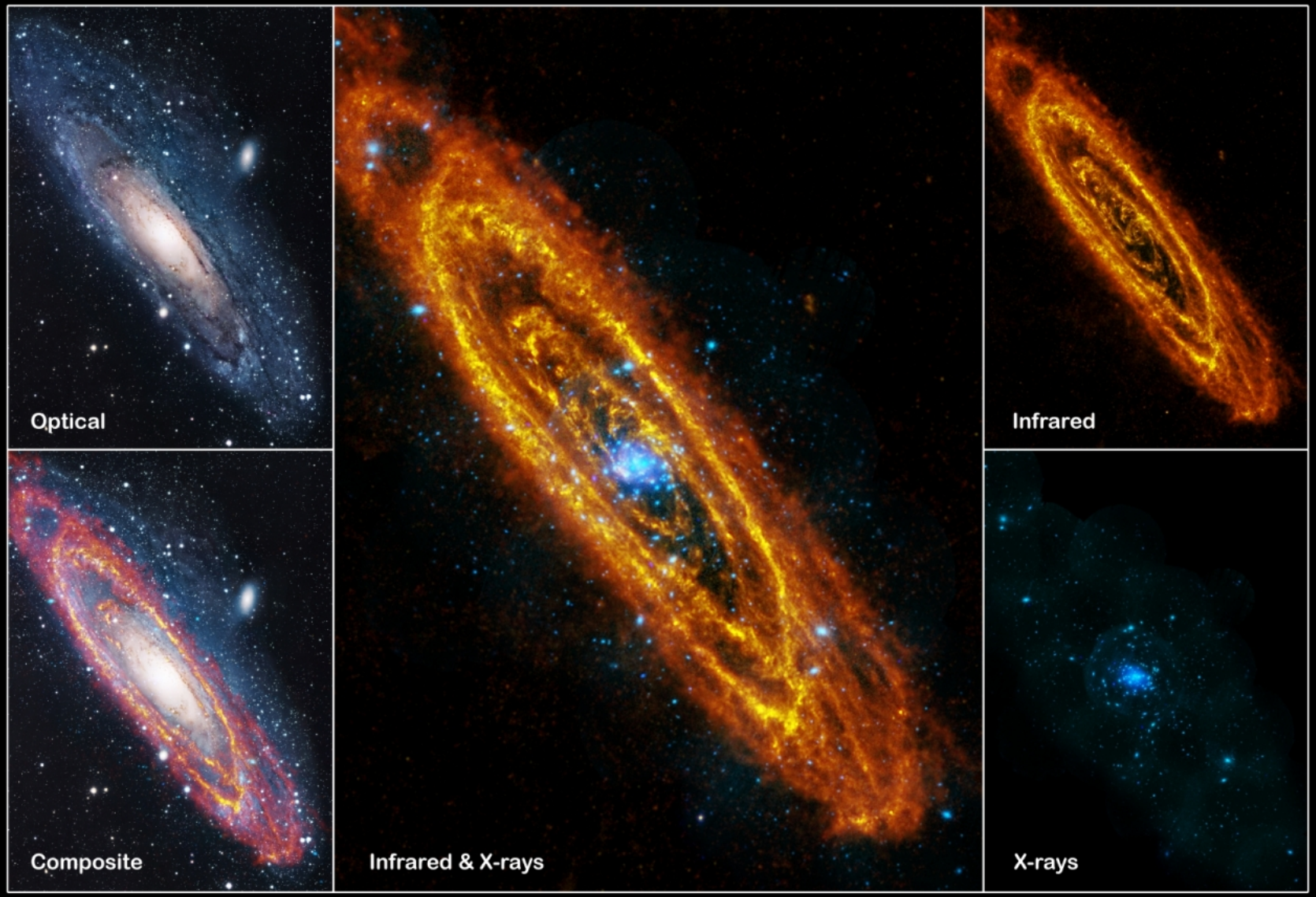


Crab Nebula – M1





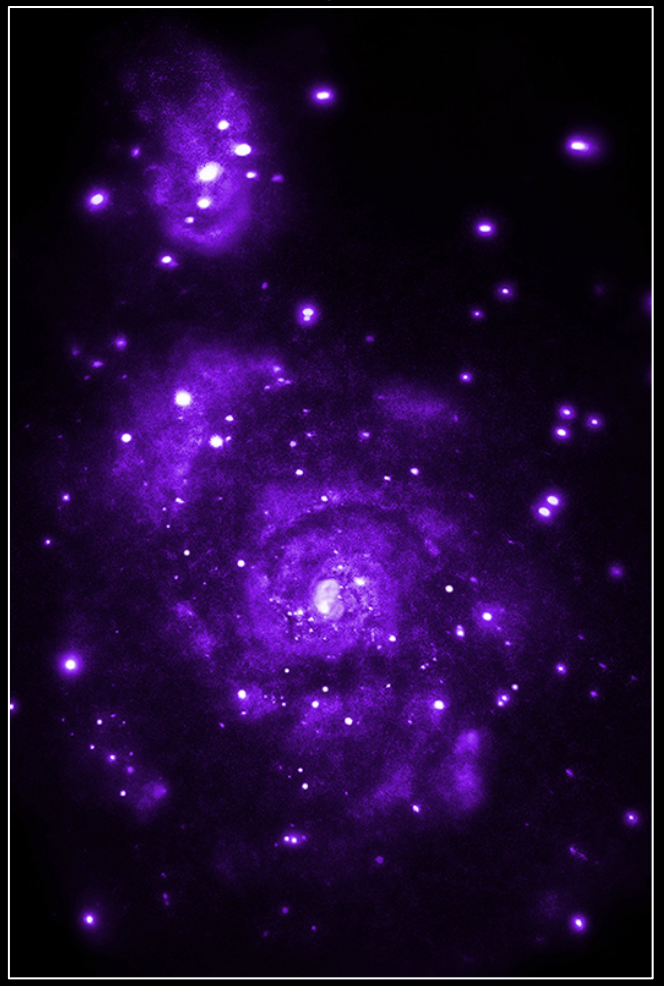
Andromeda Galaxy



M51 – Whirlpool Galaxy

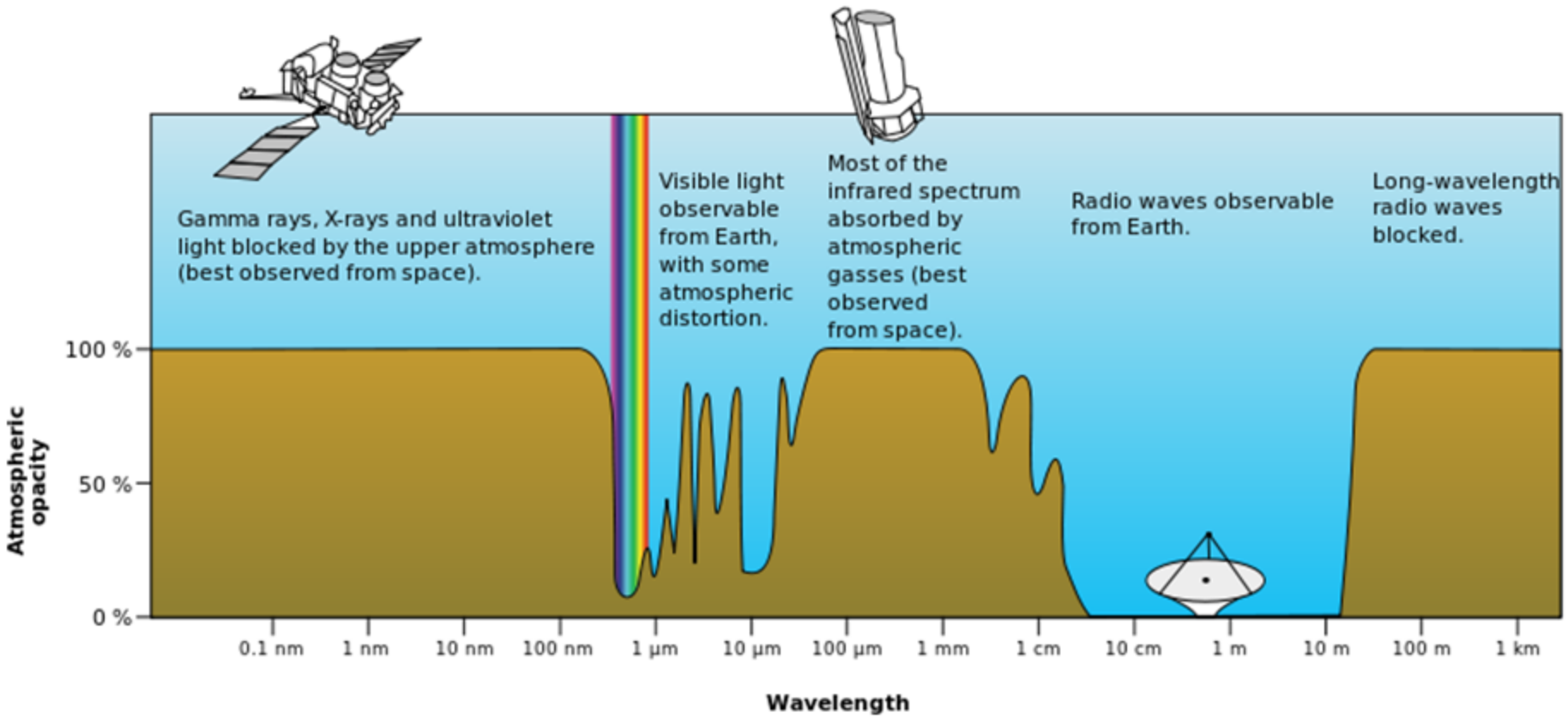
Visible light

X-rays

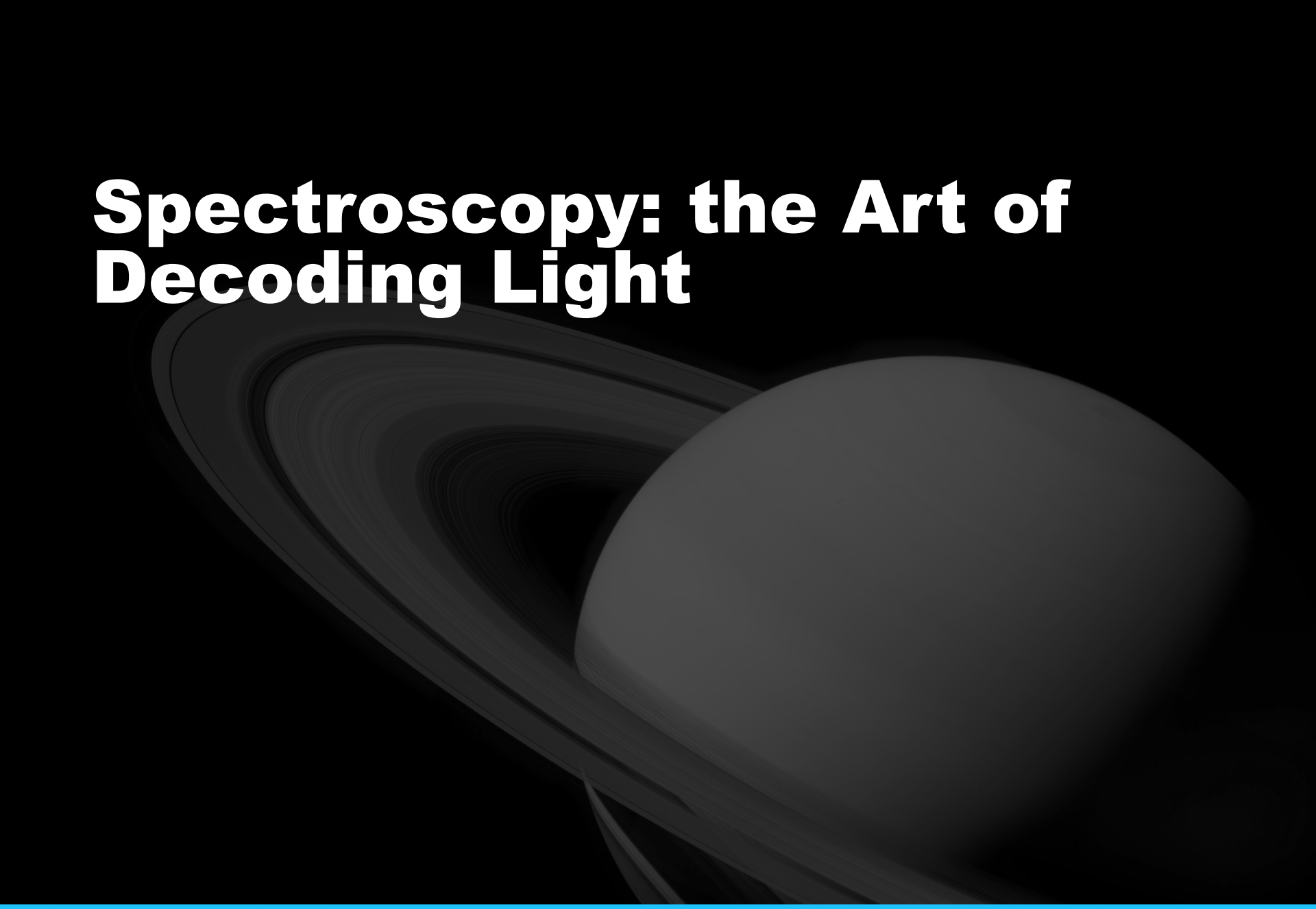


Telescopes Across the Spectrum

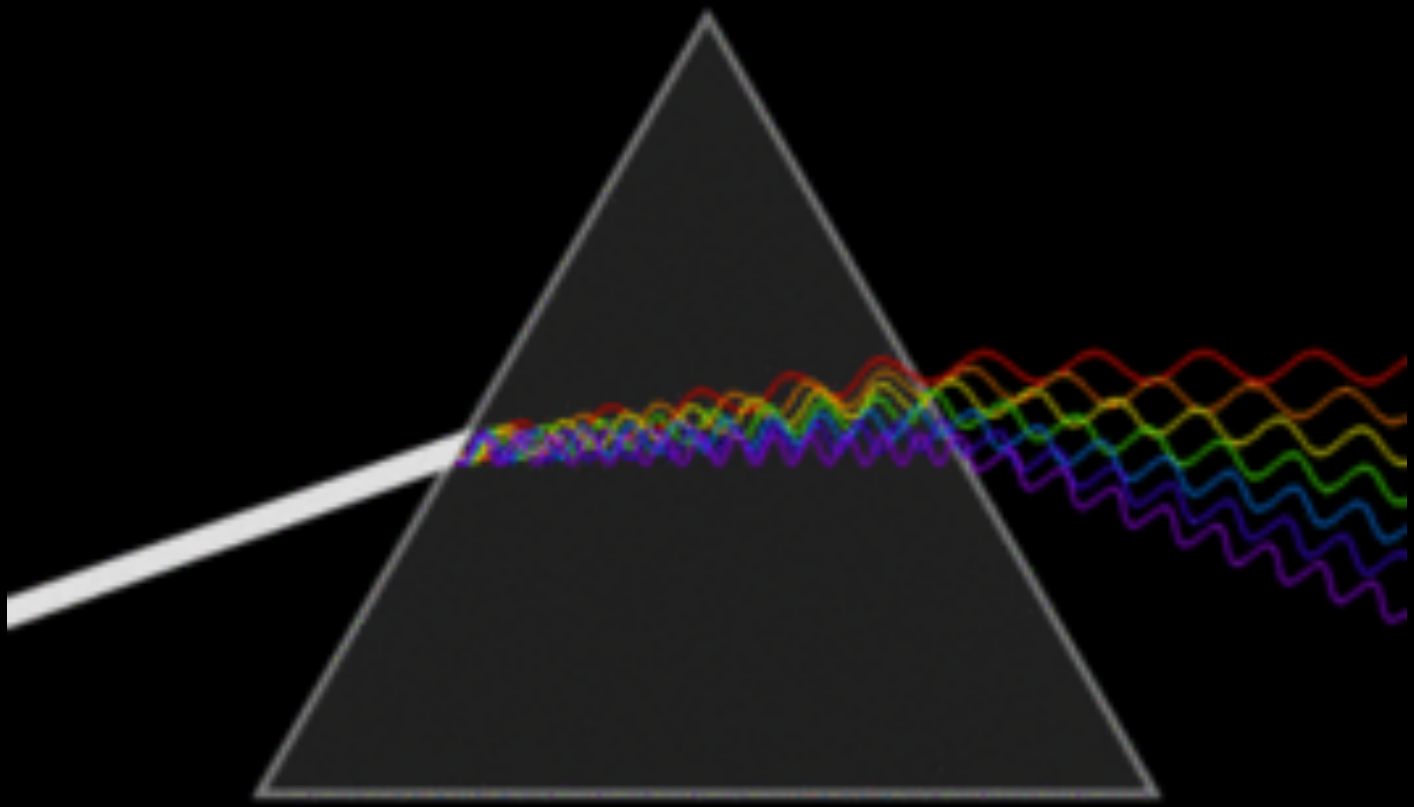
Atmosphere Opacity



Spectroscopy: the Art of Decoding Light



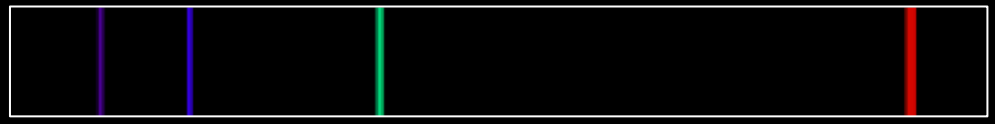
Spectroscopy



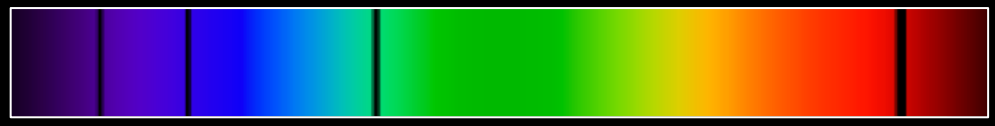
Types of Spectrum

Continuous spectrum (created by a hot object)

Emission spectrum (created by something that emits energy, like hot gas)



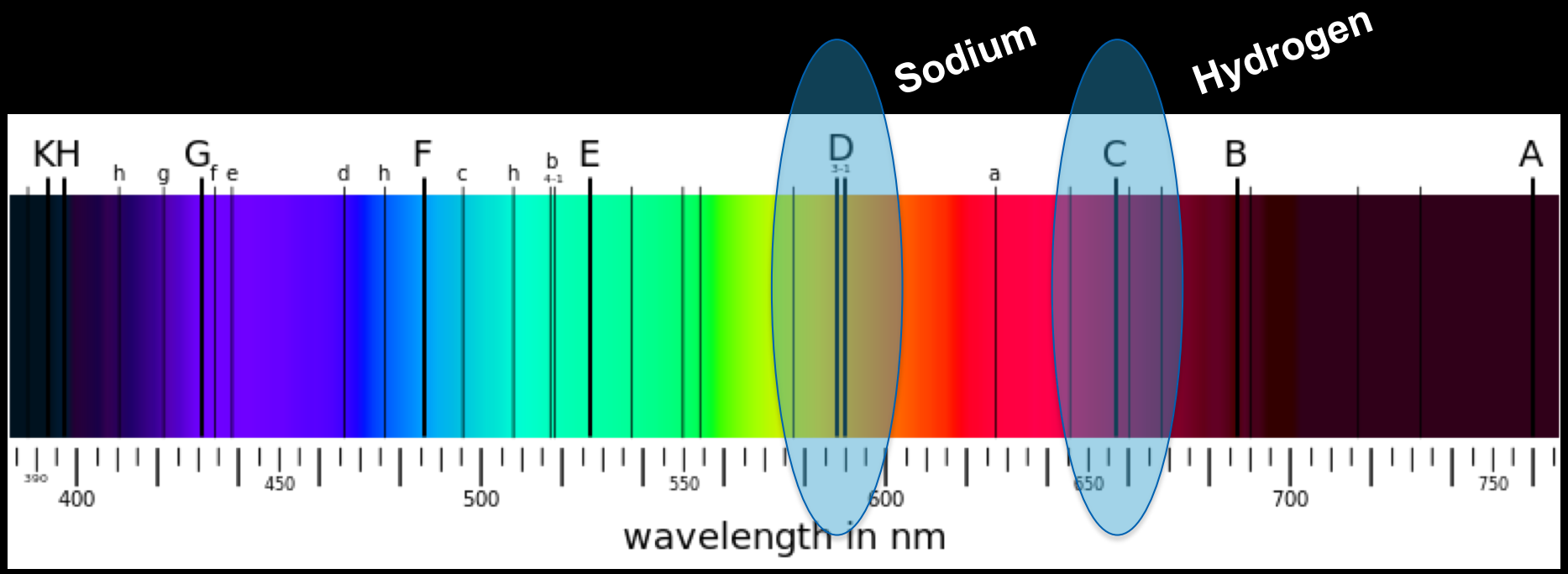
Absorption spectrum (something absorbs the energy at specific wavelength)



most used in astronomy

Composition of Objects

Solar Spectrum

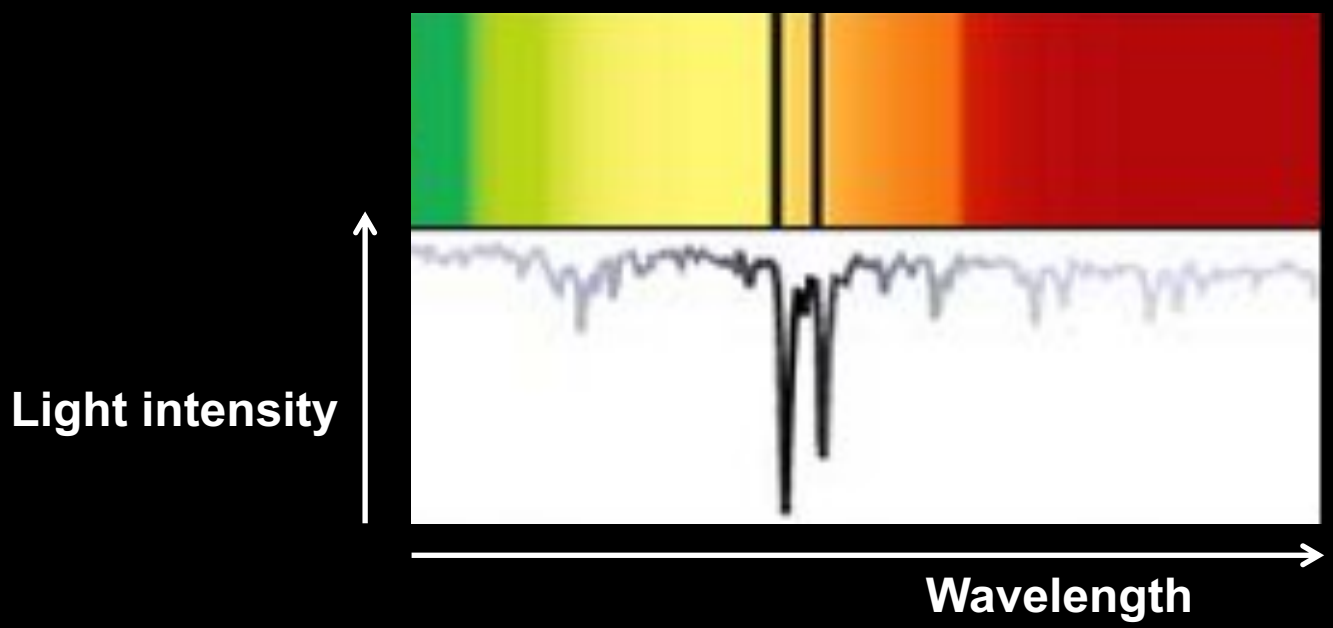


Spectrum Analysis

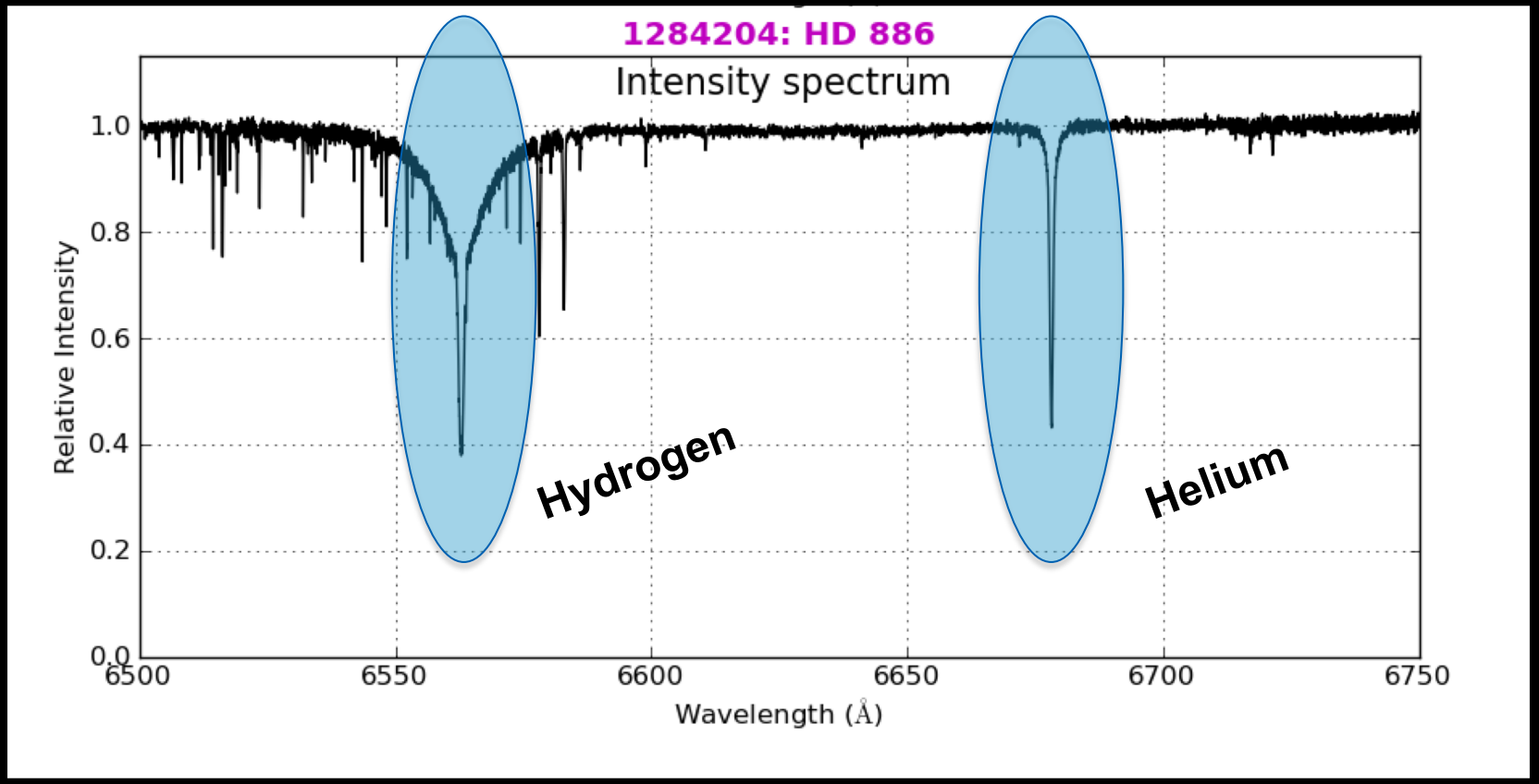
Each element or molecule has its own spectrum, like a fingerprint allowing the identification in objects.

Spectrum Analysis

Instead of looking at the spectrum directly, astronomers use a graph showing the intensity of the light as a function of the wavelength (colour).

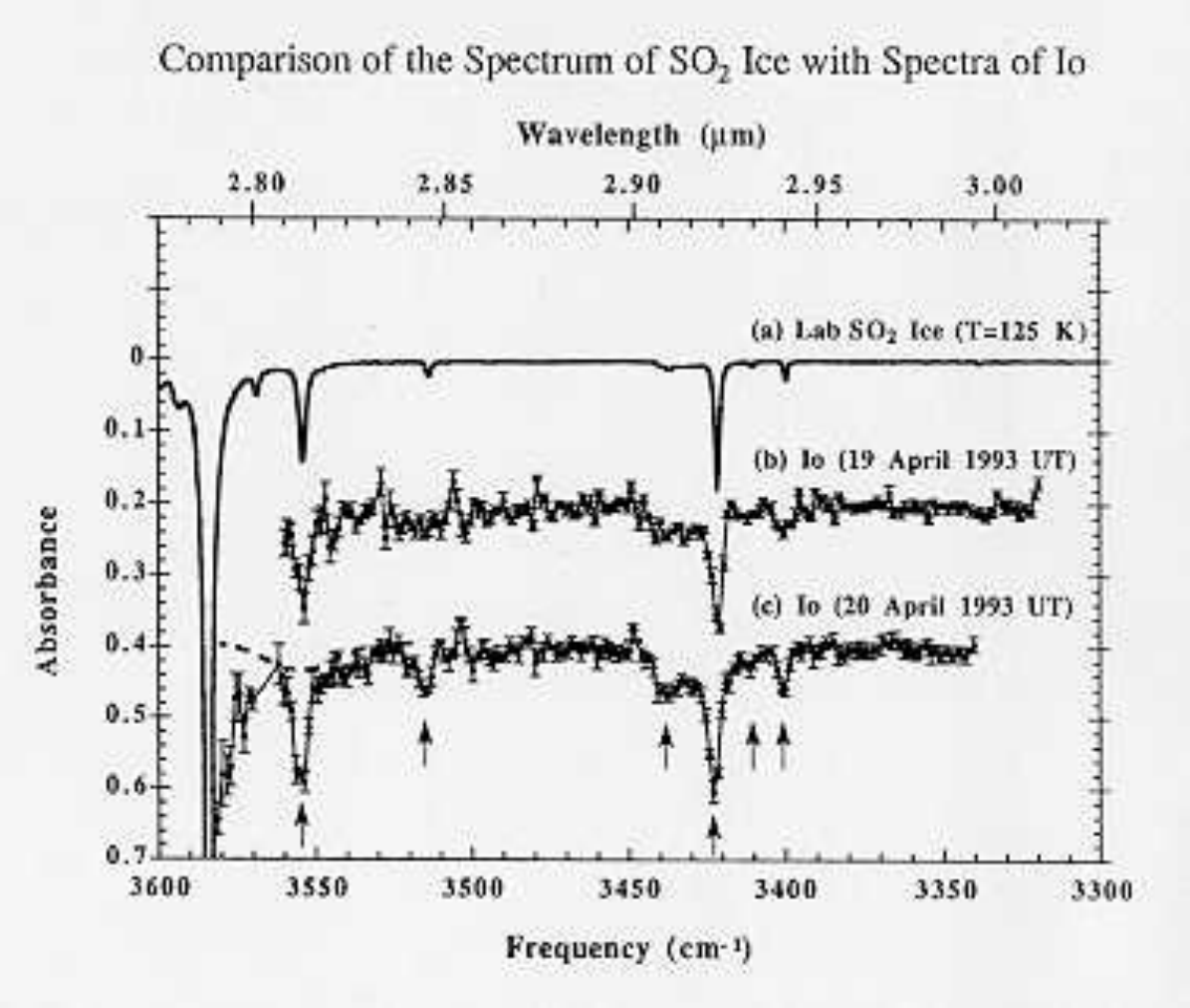


Spectrum Analysis



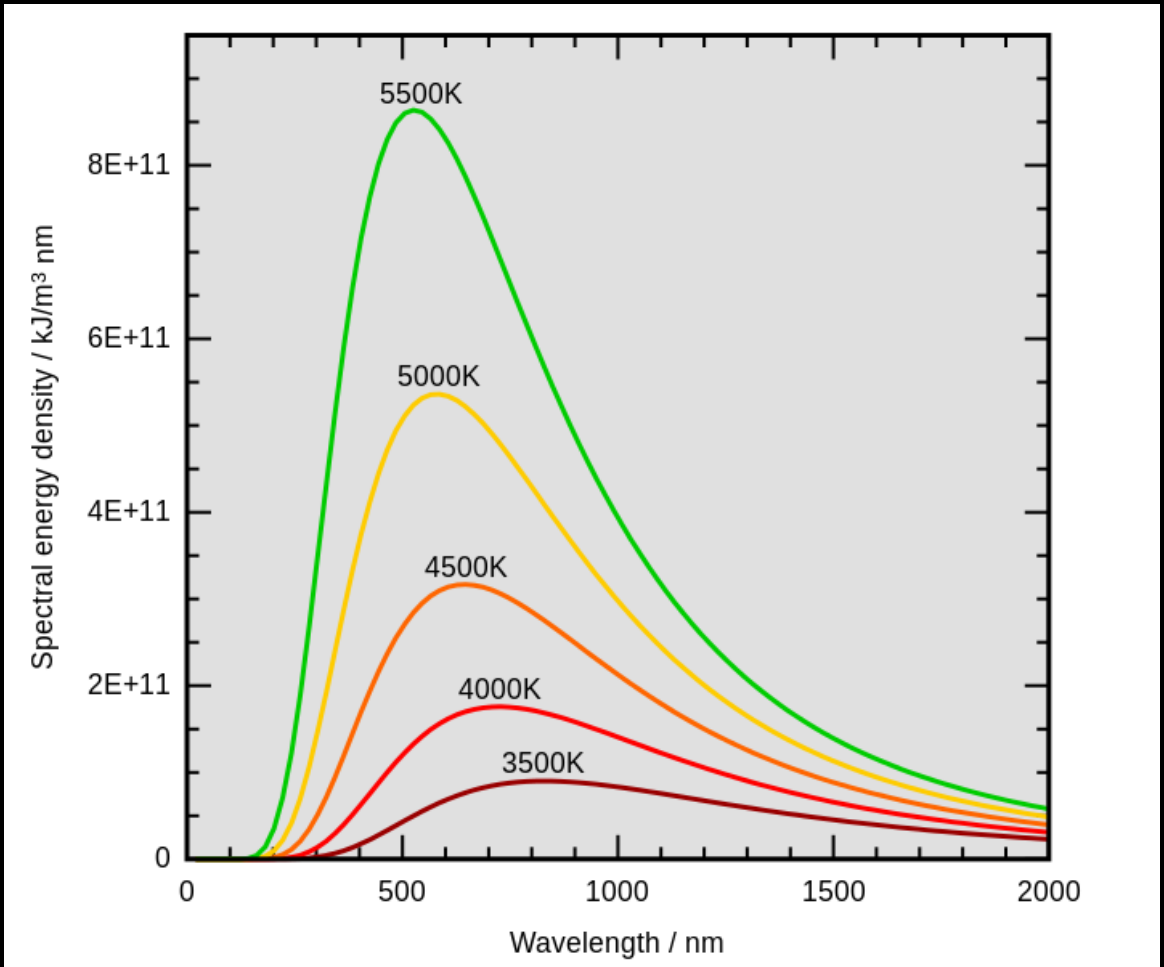
Data from the Canada-France-Hawaii Telescope

Composition of Io, moon of Jupiter



Temperature of Objects

Temperature of an Object



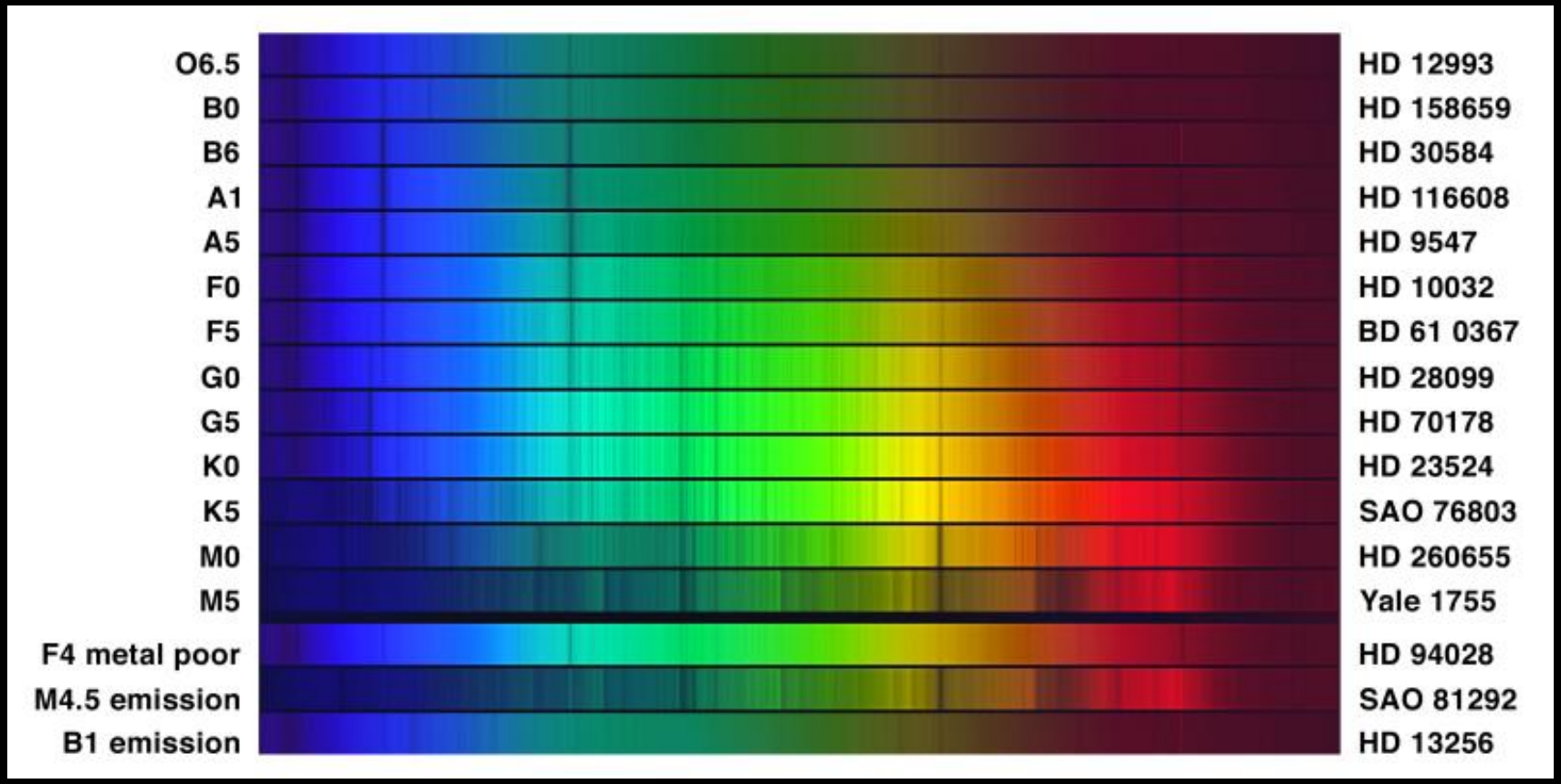
The hotter the object, the more light it emits.

The hotter the object, the shorter the wavelength of the peak radiation (blue, UV…)

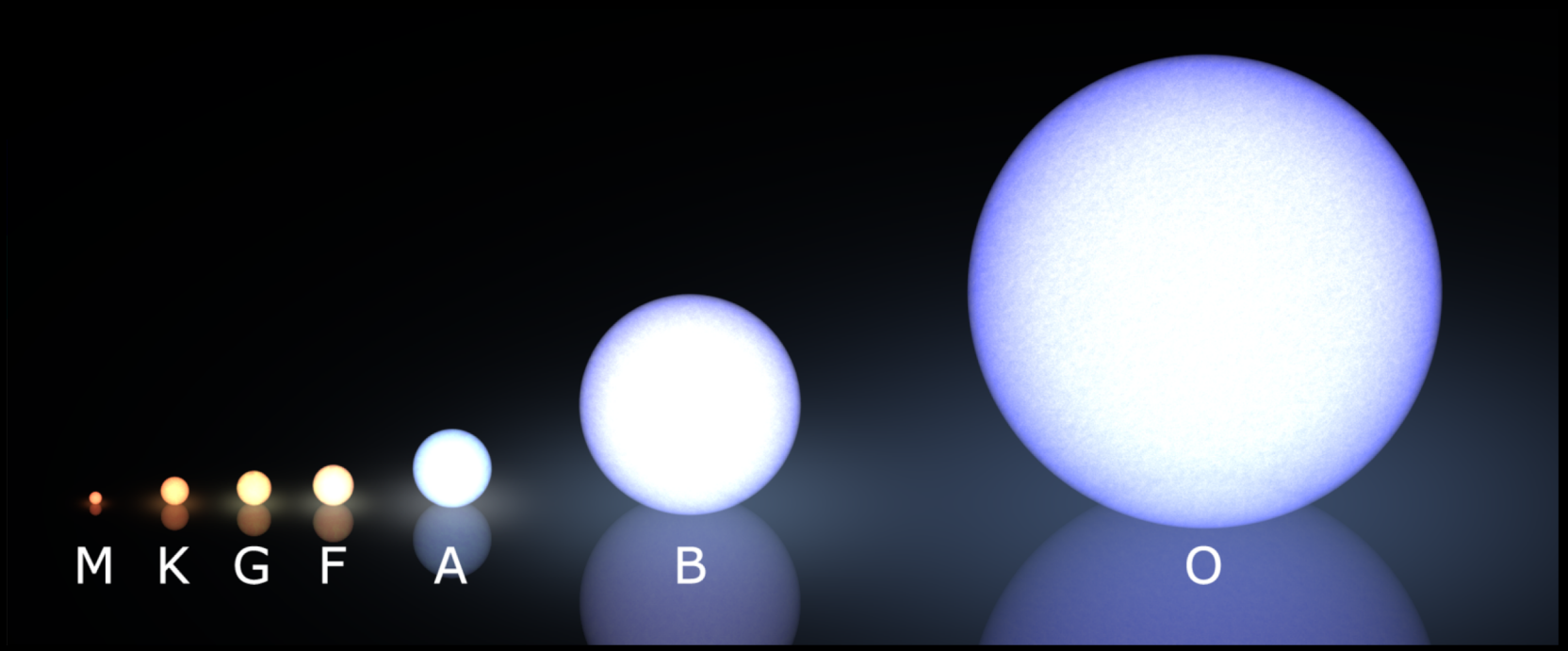
Temperature of an Object

The colours of the stars give us clues about their temperatures: blue is hotter than red.

Star Spectra



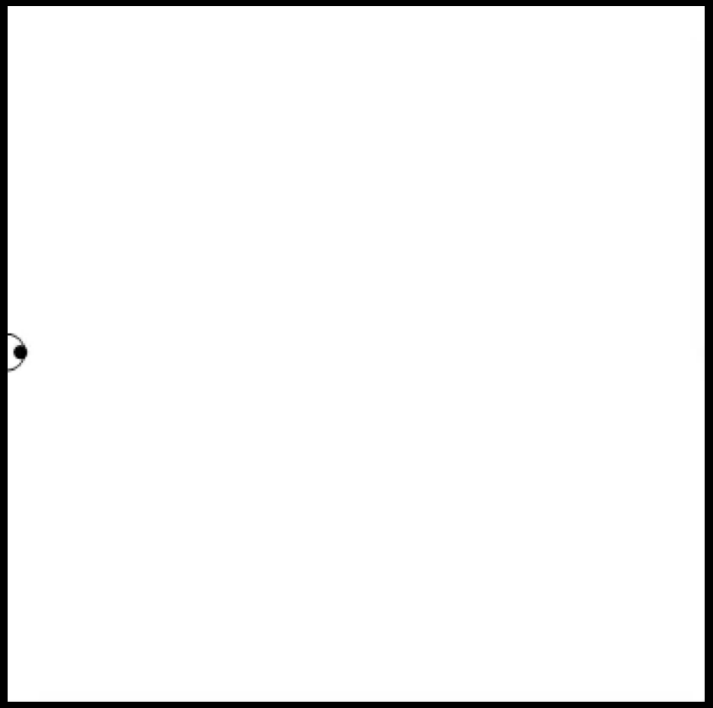
Star Spectra



Speed of Objects

Doppler Effect

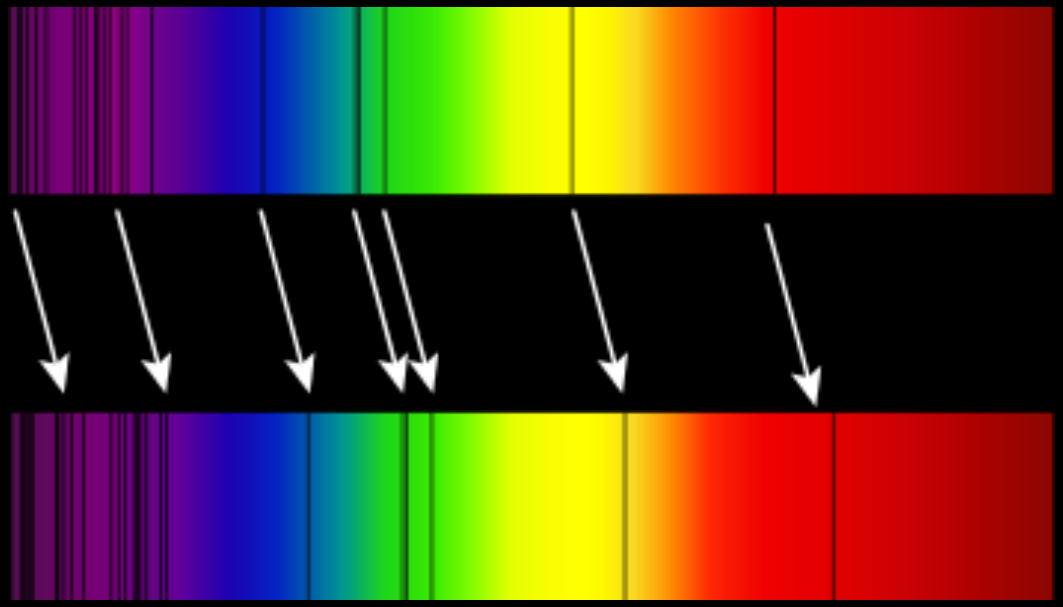
The speed of an object can be determined from its spectrum using the Doppler effect.



- ★If the object is moving towards us, its light is shifted towards shorter wavelengths (blue).
- ★If the object is moving away from us, its light is shifted towards longer wavelengths (red).

Doppler Effect

Specifically, the spectral lines are either shifted towards the red (moving away) or towards the blue (moving towards us).



Reference spectrum (Sun)

Spectrum from a cluster of galaxies

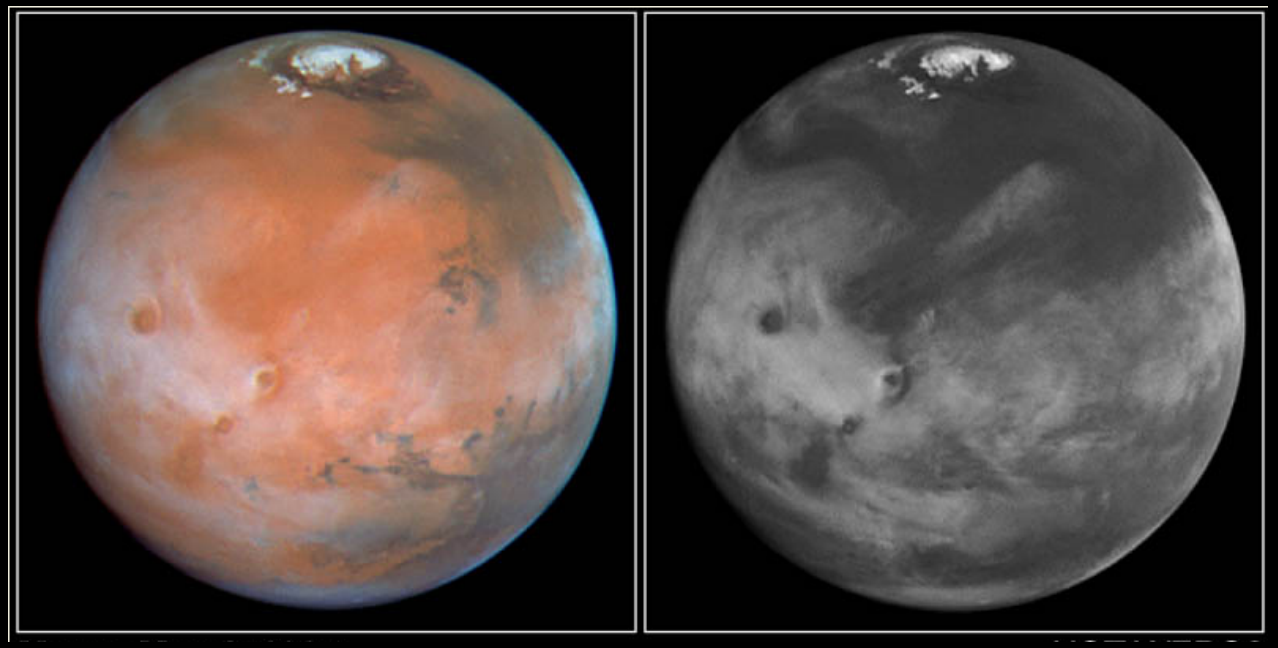
Information Encoded in Light

- ★type of object → spectrum type (absorption/emission) and images at multiple wavelengths
- ★temperature → spectrum or dominant colour
- ★composition → spectral lines
- ★speed → Doppler effect on spectral lines
- ★and more (rotation, presence of exoplanets around a star…)

How do scientists get the nice astronomy pictures?

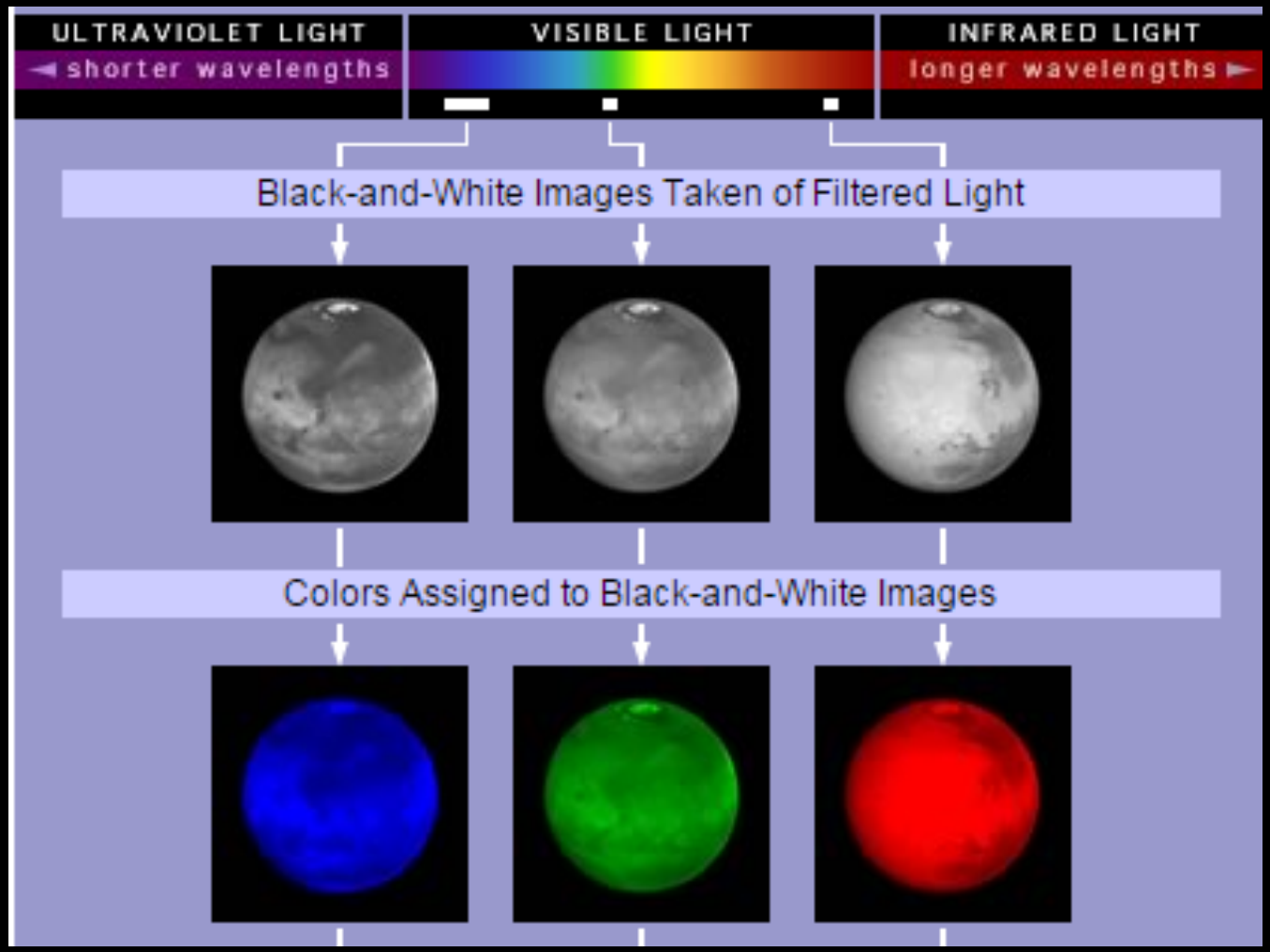
Colour Images

Sensitive cameras on telescopes capture images in black and white. How do we get nice colour pictures?



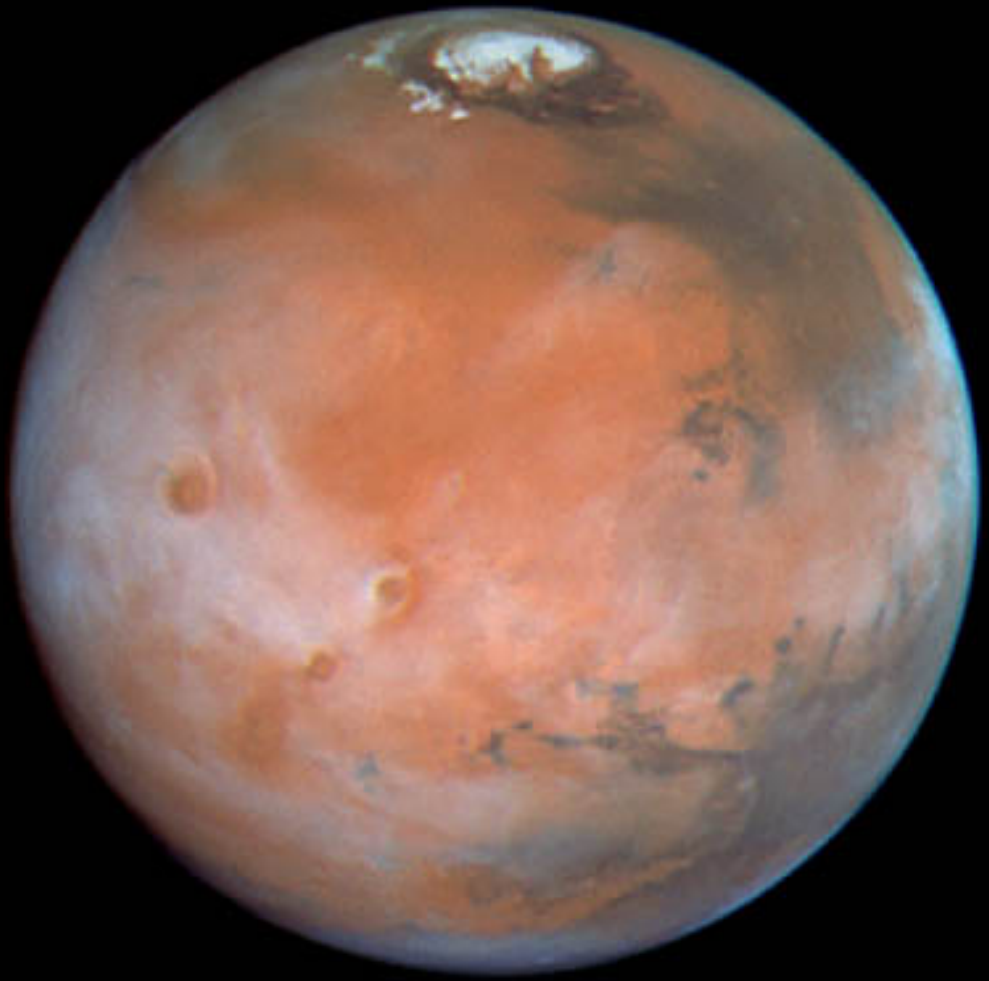
Mars, as seen by the Hubble Space Telescope

Colour Images



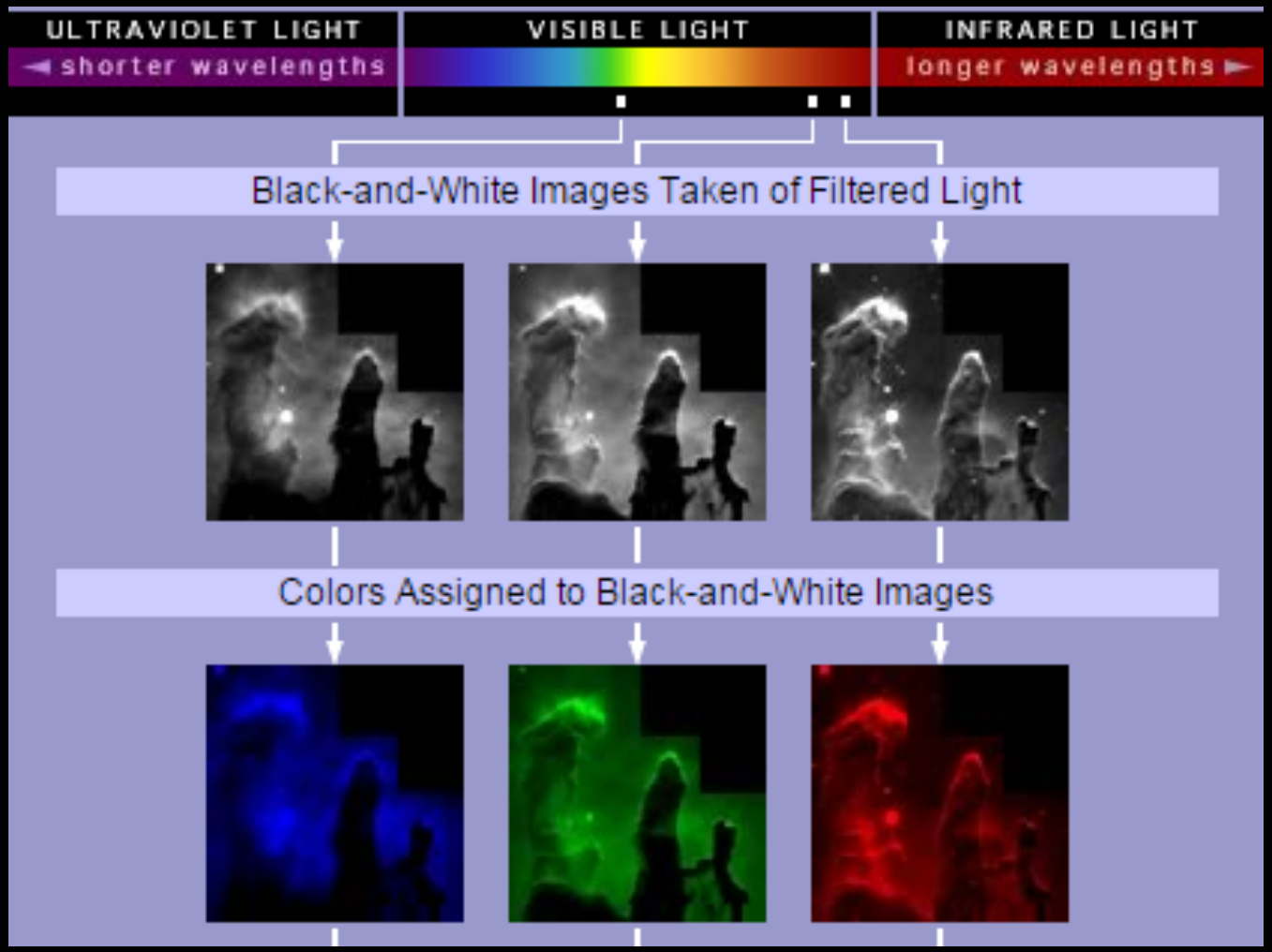
We need three images, each taken through a different filter. Then we colour the images and recombine them.

Colour Images



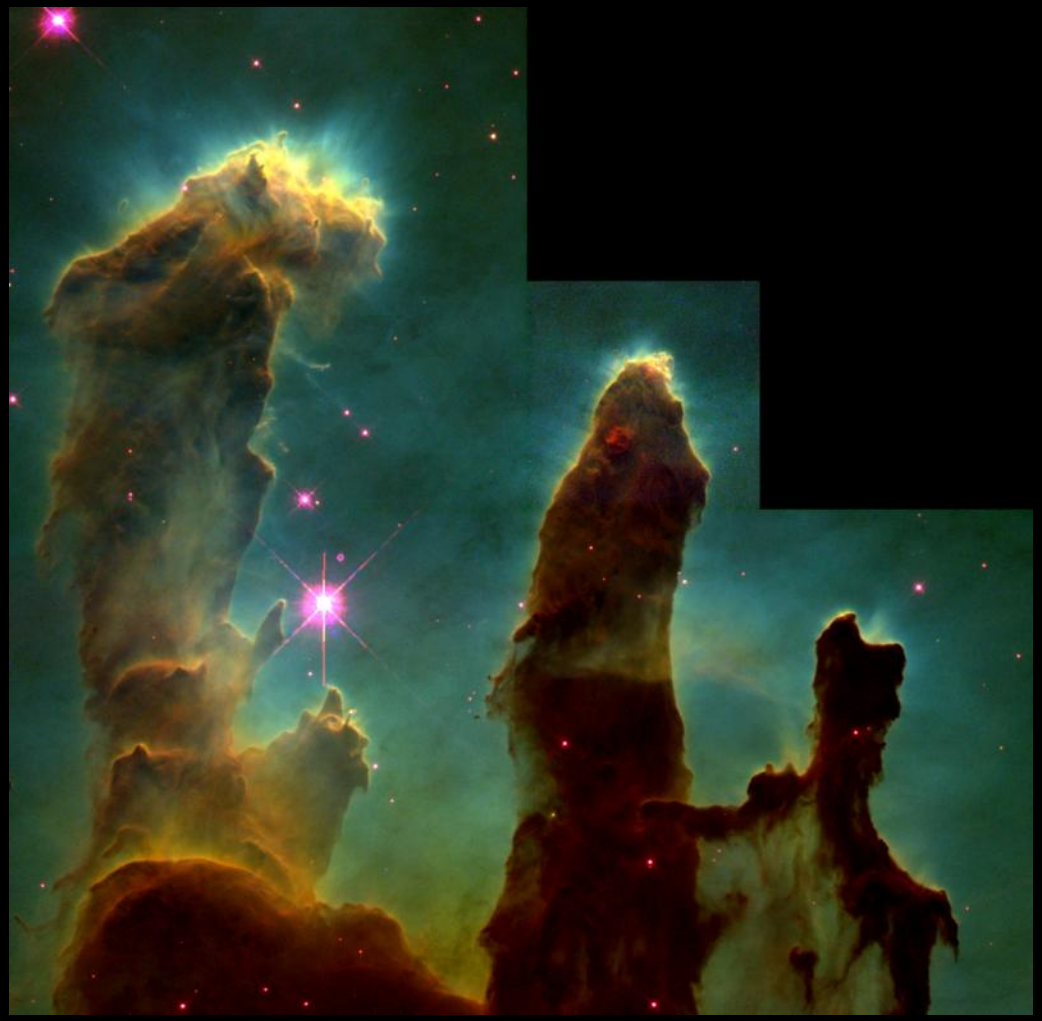
Visible light image, natural colours

Colour Images



Sometimes, we assign colours to precise wavelengths (here, light emitted by specific elements)

Colour Images

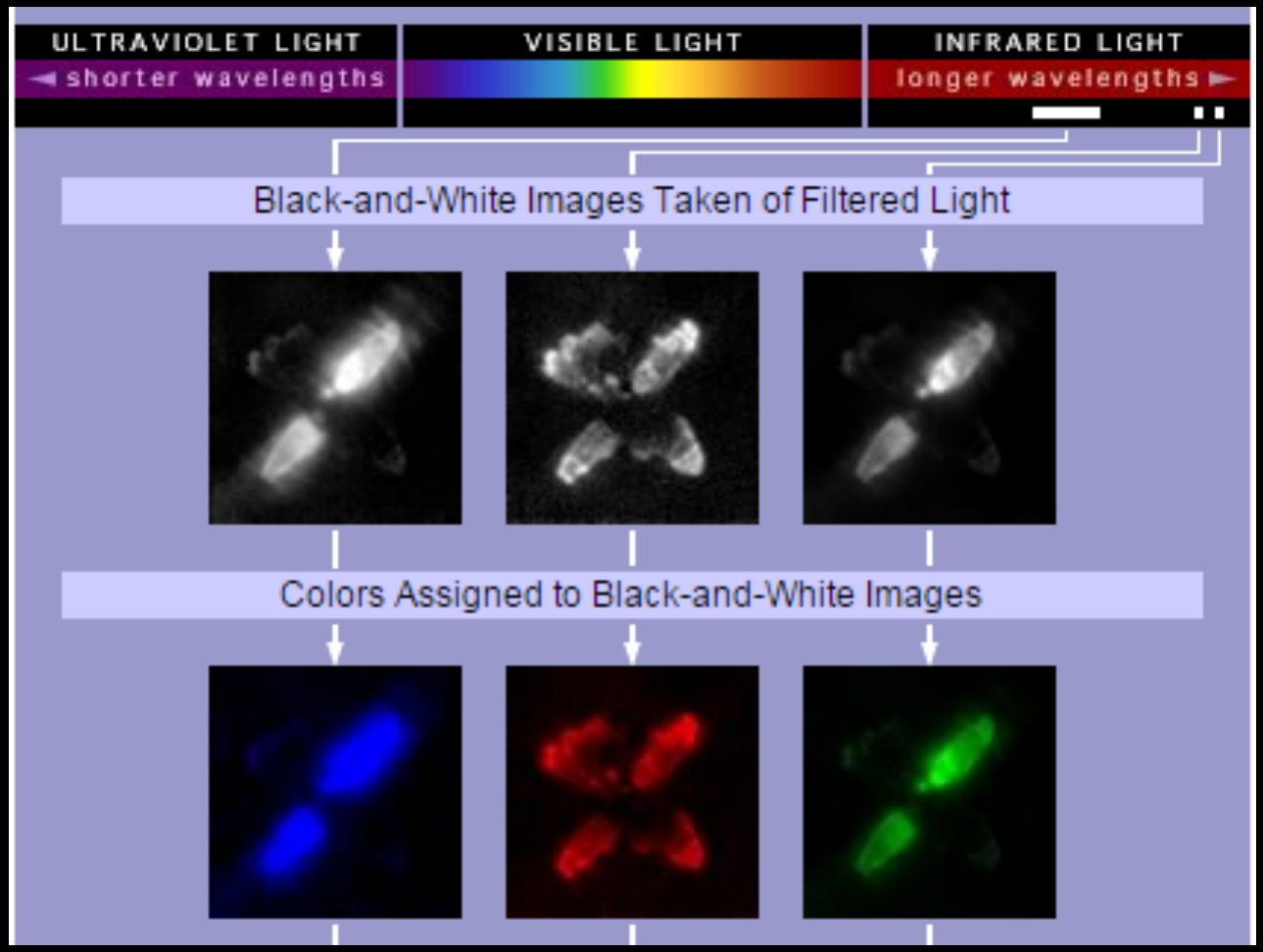


Visible light image, false colours

Blue-green: hydrogen and oxygen

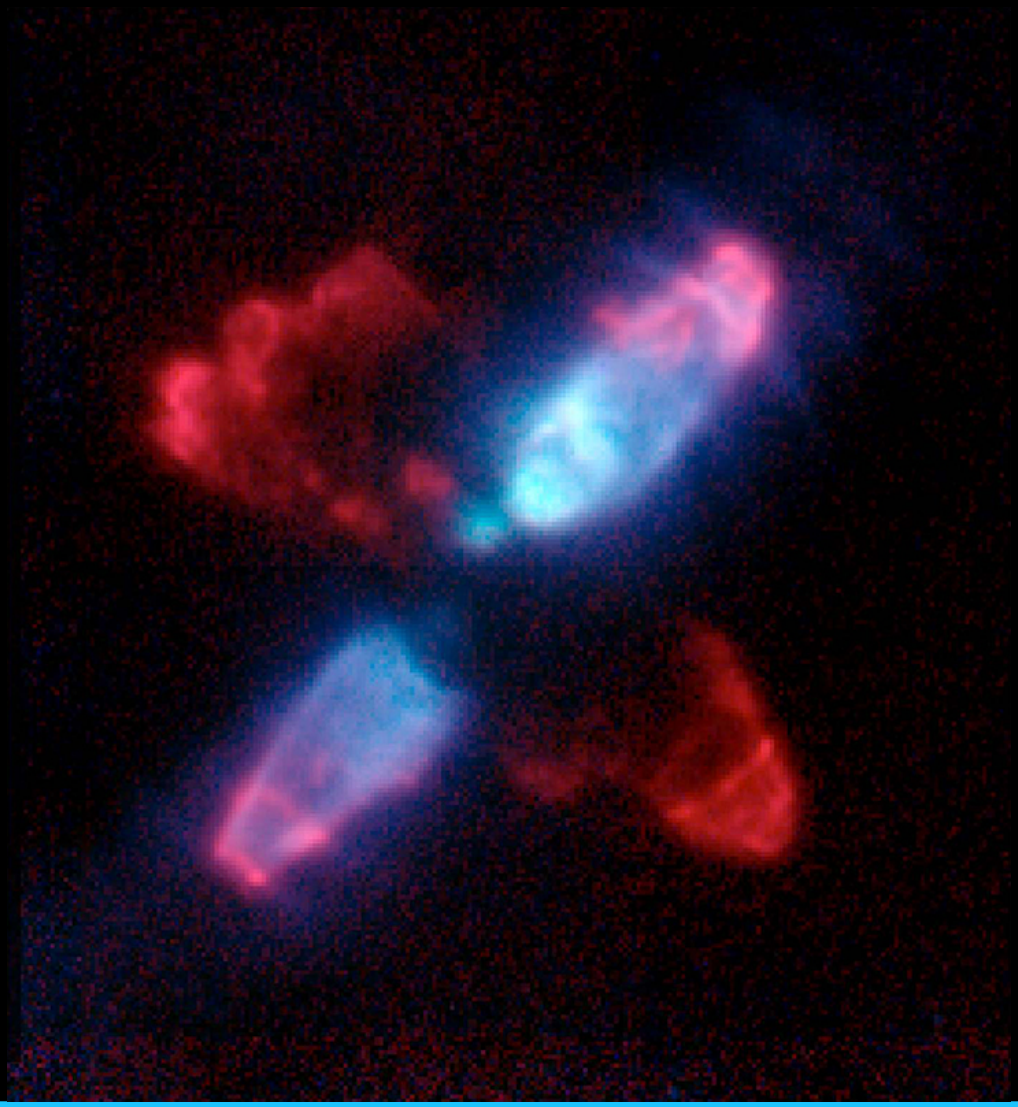
Red: sulfur

Colour Images



Three images taken in the infrared with different colours assigned to black-and-while images.

Colour Images



Infrared image, false colours

Green and blue: light reflected of the dust surrounding the star

Red: hydrogen cloud

Resources

★ HubbleSite pages on creating colour images, with interactive animations.

★ Multi-wavelength images from the Chandra telescope (the tabs under the pictures allow you to change wavelength)

★ Our educational module The Solar Cycle (using UV and visible images of the Sun in HelioViewer)

★ Activities on light, selected by Science in School (European magazine)

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Thank you!