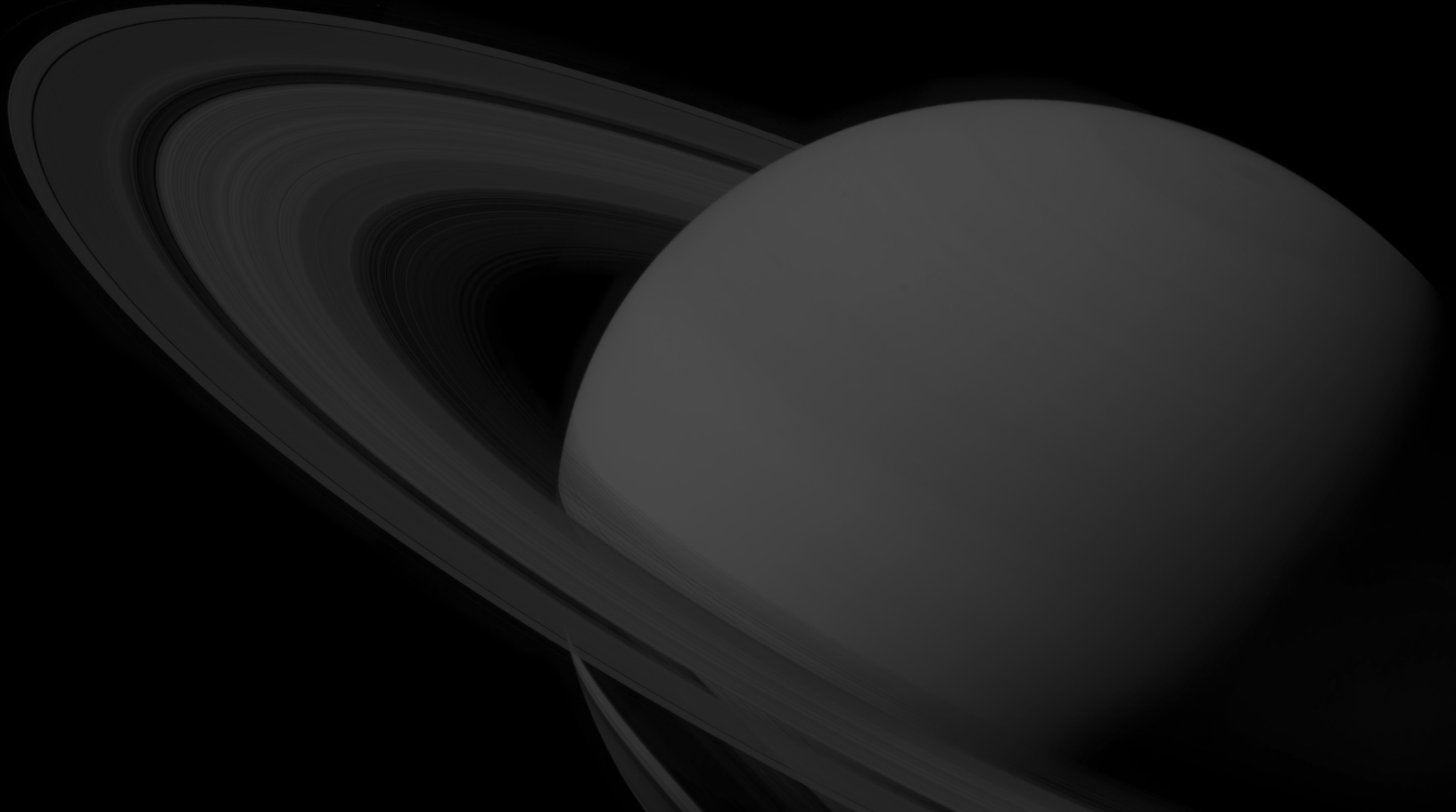


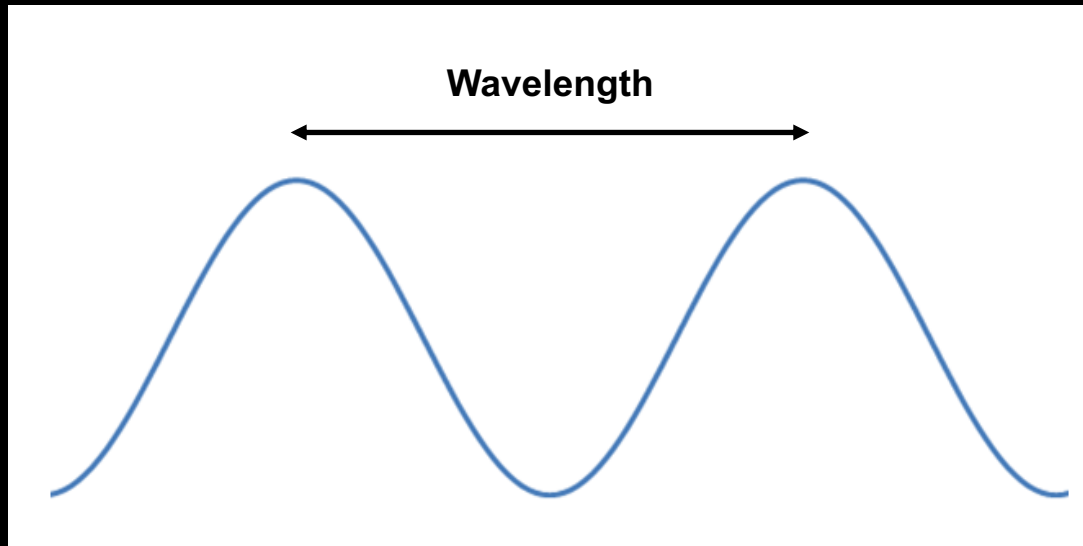
Light – Cosmic Messenger

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.

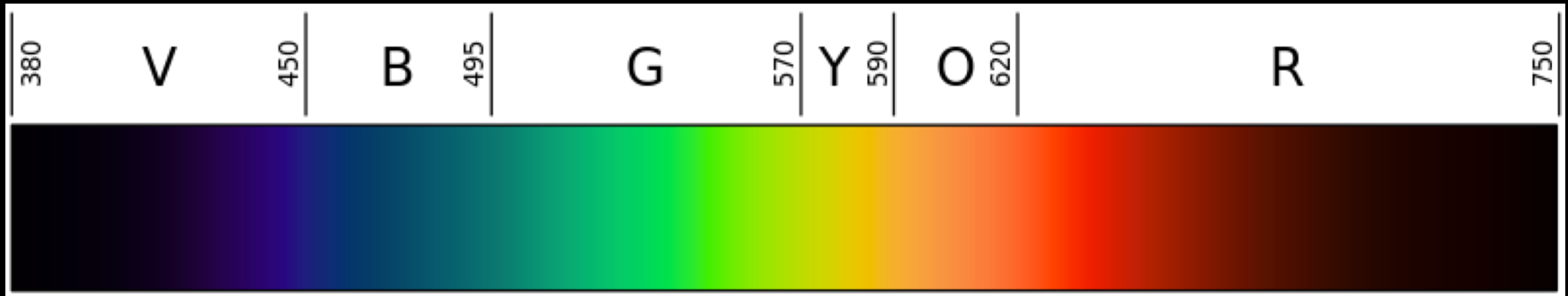
When we look at a star 100 light-years away, we see it the way it was 100 years ago.

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

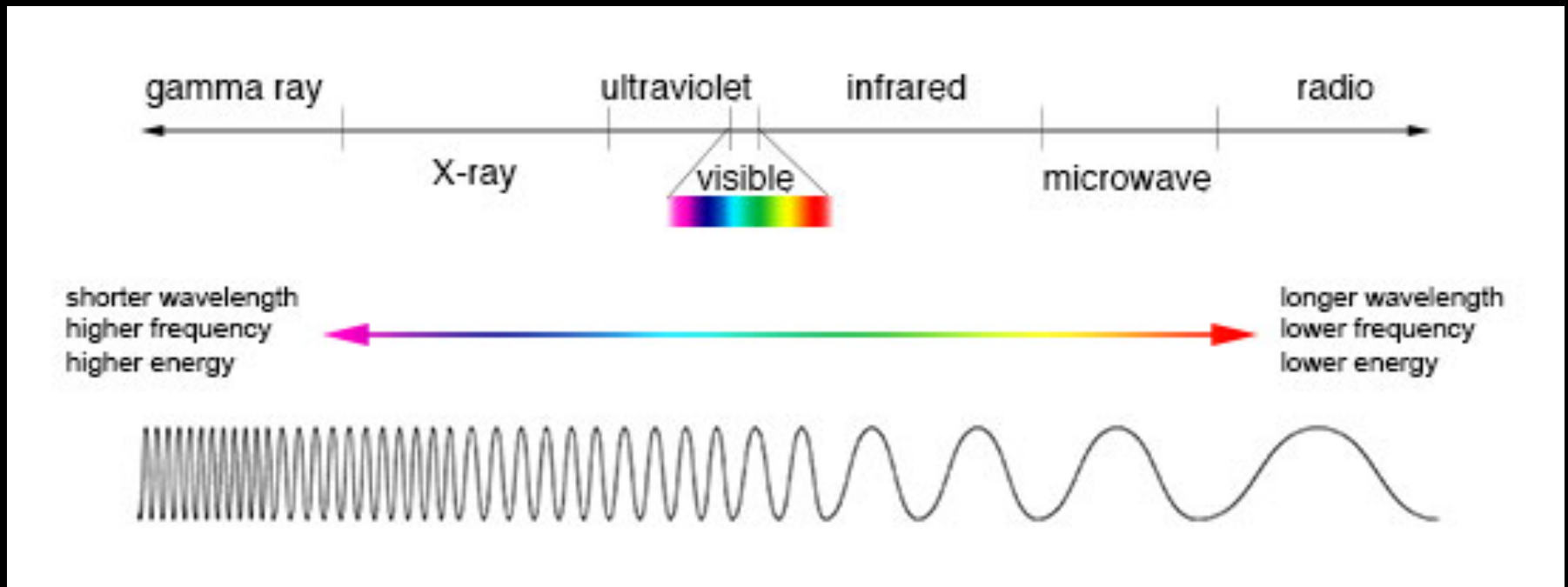
Visible Light

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?

Light – Cosmic Messenger

Infrared



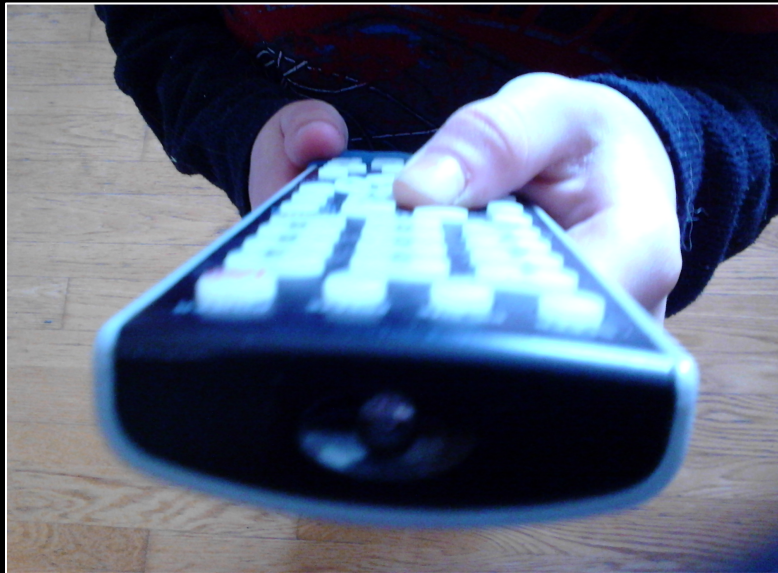
Light – Cosmic Messenger

Infrared

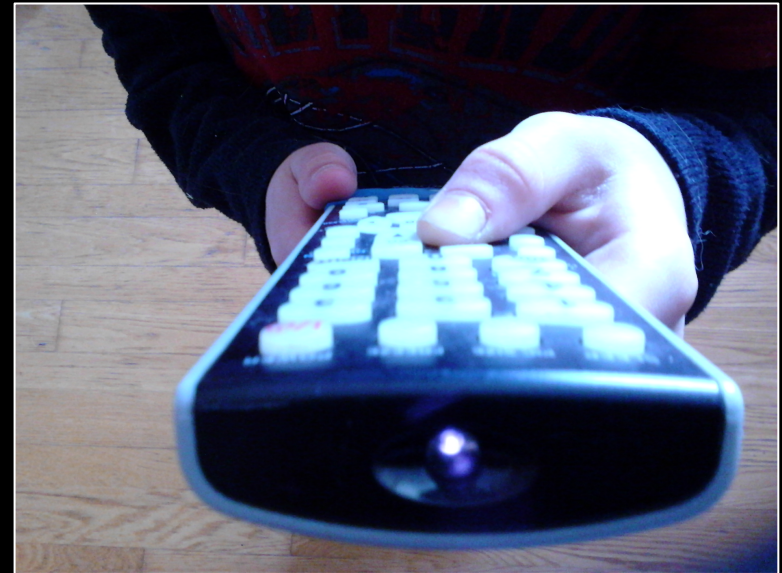


Infrared - Experiment

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



With the eye



Through a camera

Infrared - Experiment

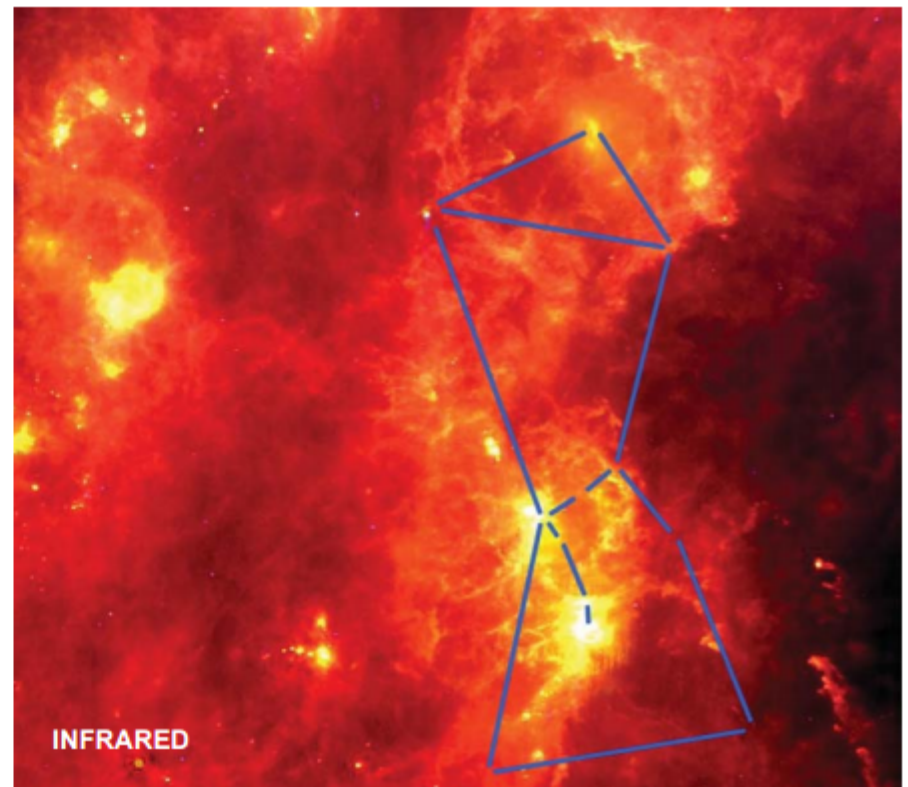
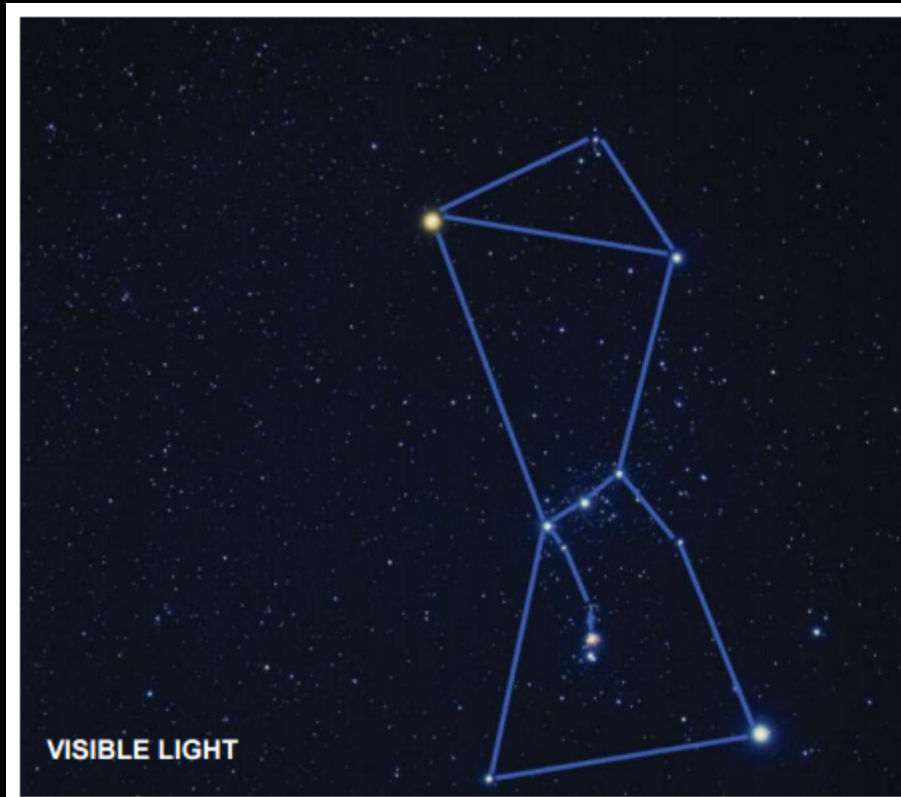
You can try it in class or with a group.

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.

Light – Cosmic Messenger

The Sky in Infrared



Light – Cosmic Messenger

Ultraviolet



Light – Cosmic Messenger

Sun in Visible Light and UV – Helioviewer.org

The screenshot displays the Helioviewer.org web interface. At the top left, the logo "Helioviewer.org" is visible. The main area shows two side-by-side solar images. The left image is a white-light image of the Sun, showing dark sunspots. The right image is a UV image of the Sun, showing bright, active regions. The interface includes a sidebar on the left with the following sections:

- Observation Date:** Date: 2017/09/05 03:15:10 UTC, Jump: 1 Day.
- Images:** HMI Int, 2017/09/05 03:14:50 UTC. Settings include Opacity, Observatory: SDO, Instrument: HMI, Measurement: continuum, and Difference: No difference ima.
- Features and Events:** HEK, 2017/09/05 03:15:10 UTC. Includes checkboxes for "check all" and "check none", and a list of features: Active Regions (10), NOAA SWPC Observer (5), SPoCA (5), Coronal Cavities, Coronal Dimmings, Coronal Holes (3), SPoCA (3), Coronal Jets, and CMEs (0).

At the top right, there are navigation controls and coordinates: x: 2469 " y: 1118 ". A "Data Sources" panel is visible on the right side of the interface.

Sun in Visible Light and UV – Helioviewer.org

Helioviewer.org x: 2120 " y: 19 "

Observation Date ?

Date: UTC NEWEST

Jump:

Images + Add Layer ?

AIA 171 2017/09/05 03:14:57 UTC

Opacity:

Observatory:

Instrument:

Measurement:

Difference:

HMI Int 2017/09/05 03:14:50 UTC

Opacity:

Observatory:

Instrument:

Measurement:

Difference:

Features and Events ?

HEK 2017/09/05 03:15:10 UTC

check all check none

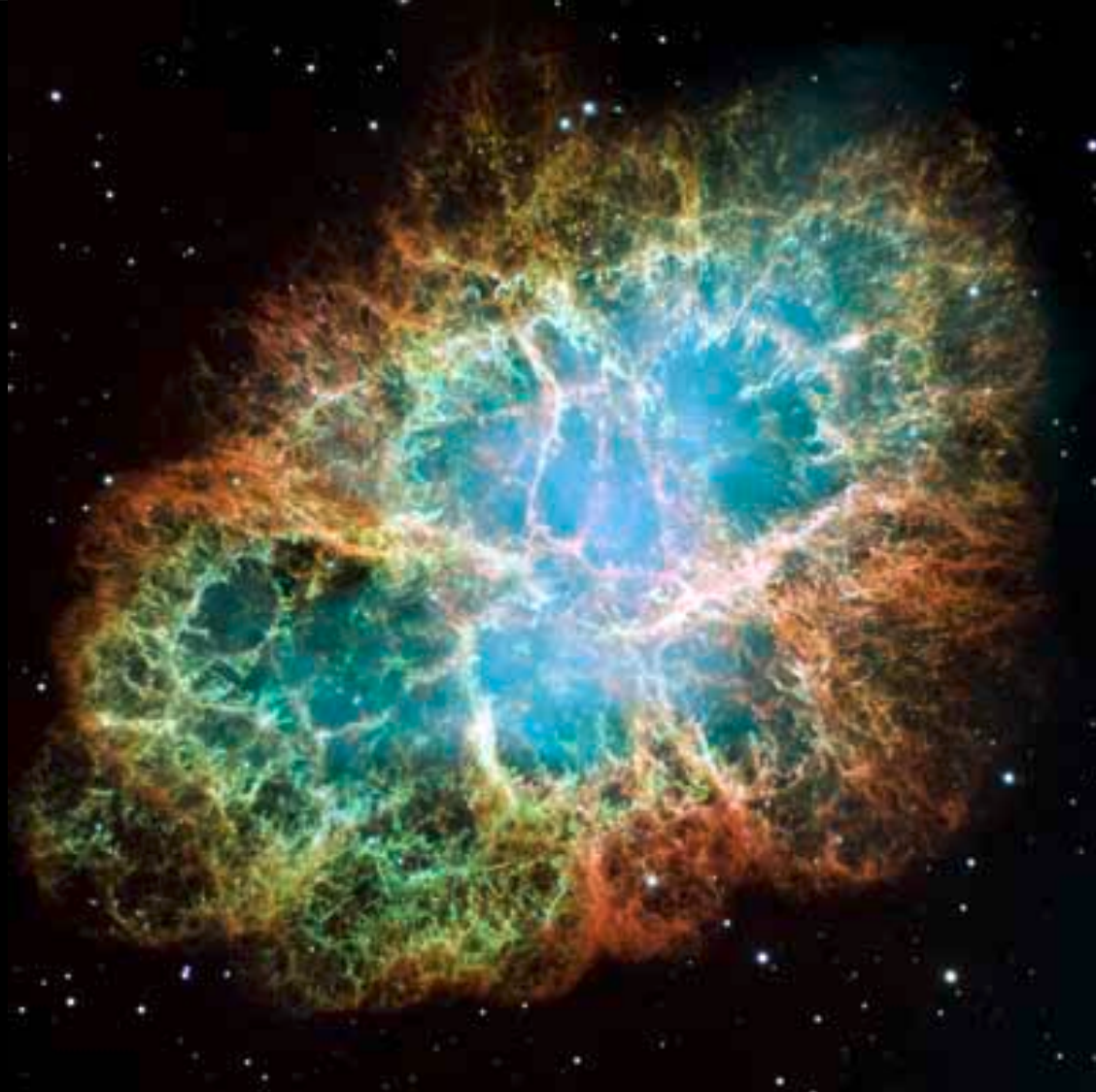
Active Regions (10)

Data Sources

Earth Scale

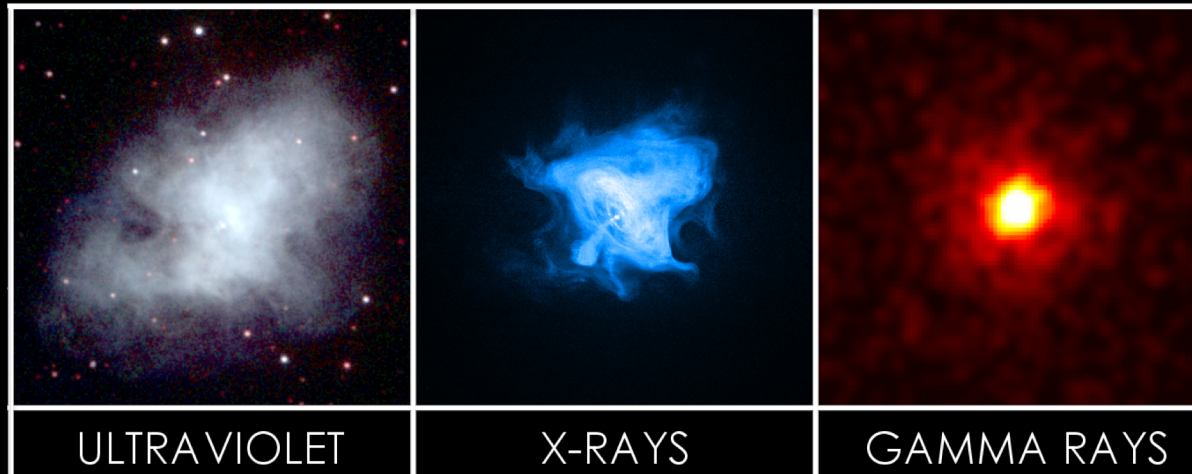
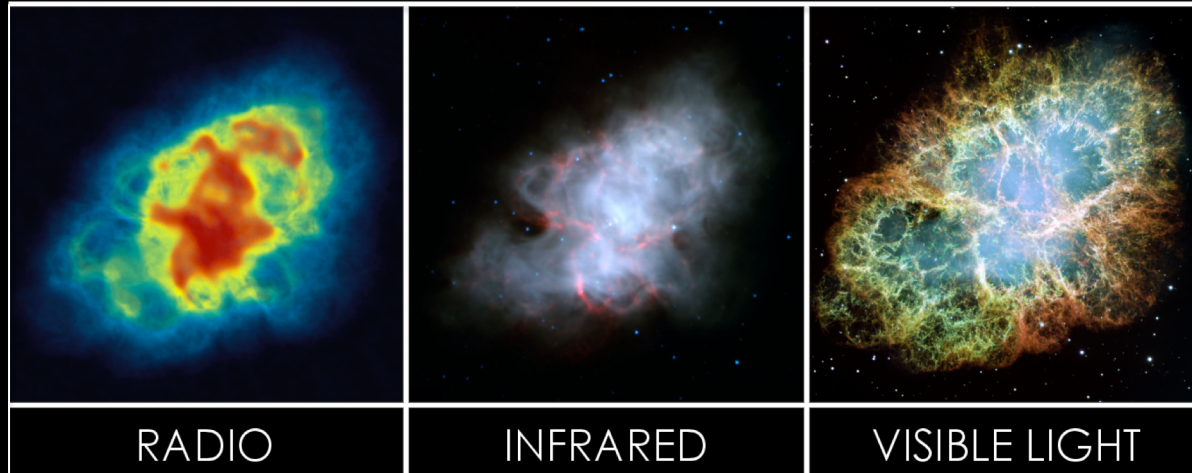
Light – Cosmic Messenger

Crab Nebula – M1



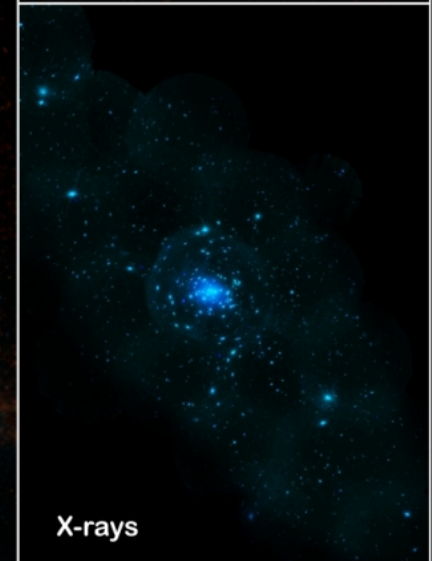
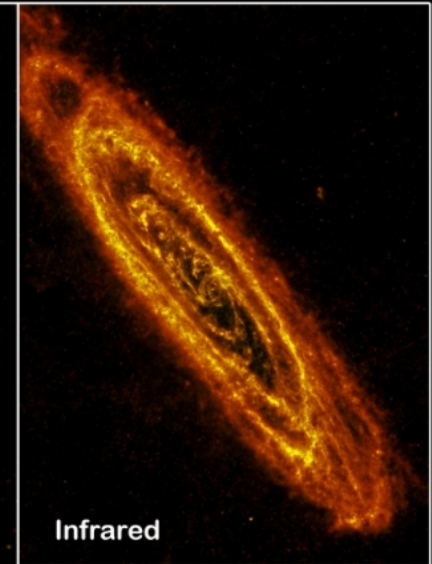
Light – Cosmic Messenger

Crab Nebula – M1



Light – Cosmic Messenger

Andromeda Galaxy



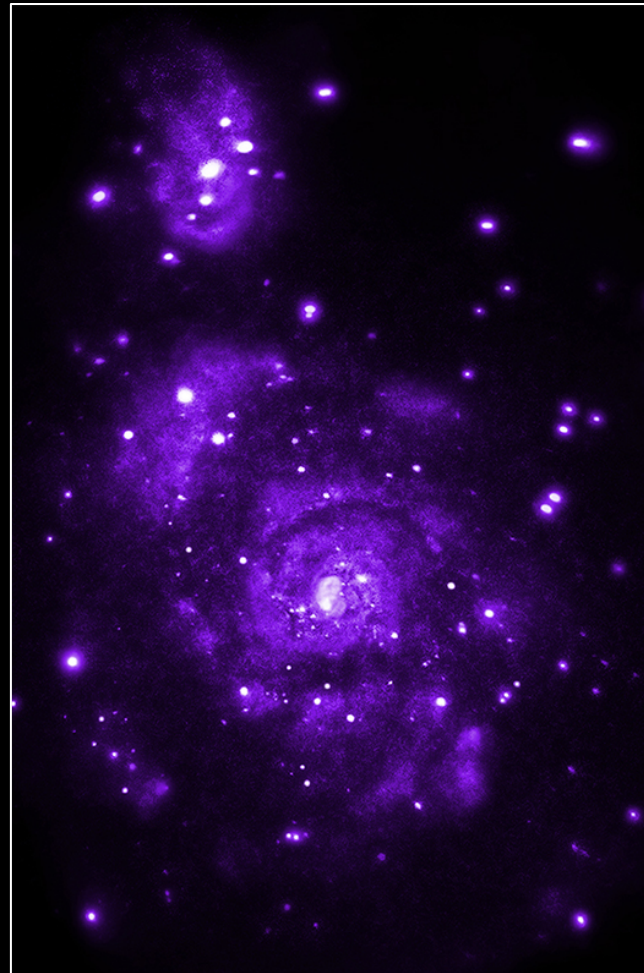
Light – Cosmic Messenger

M51 – Whirlpool Galaxy

Visible light

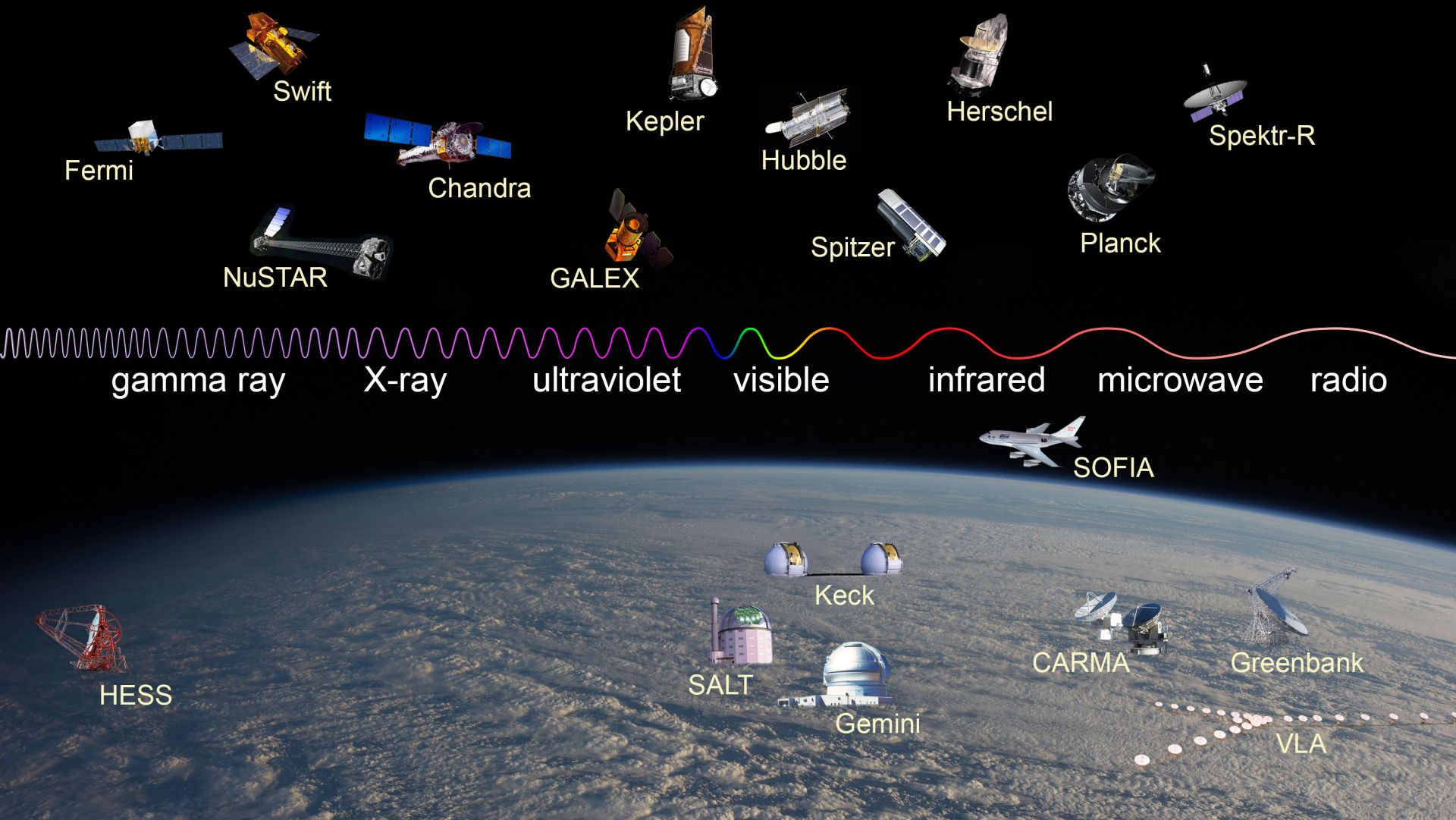


X-rays

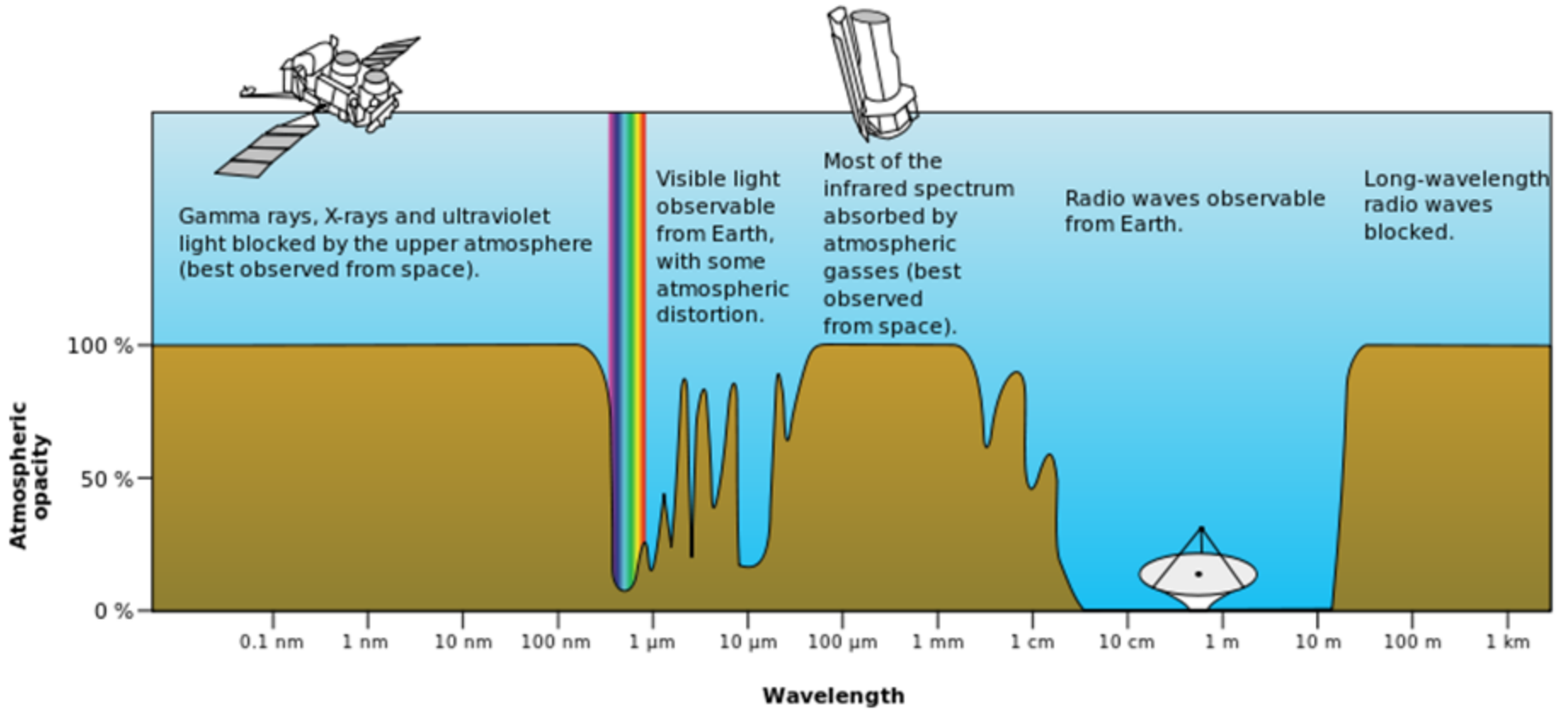


Light – Cosmic Messenger

Telescopes Across the Spectrum



Atmosphere Opacity

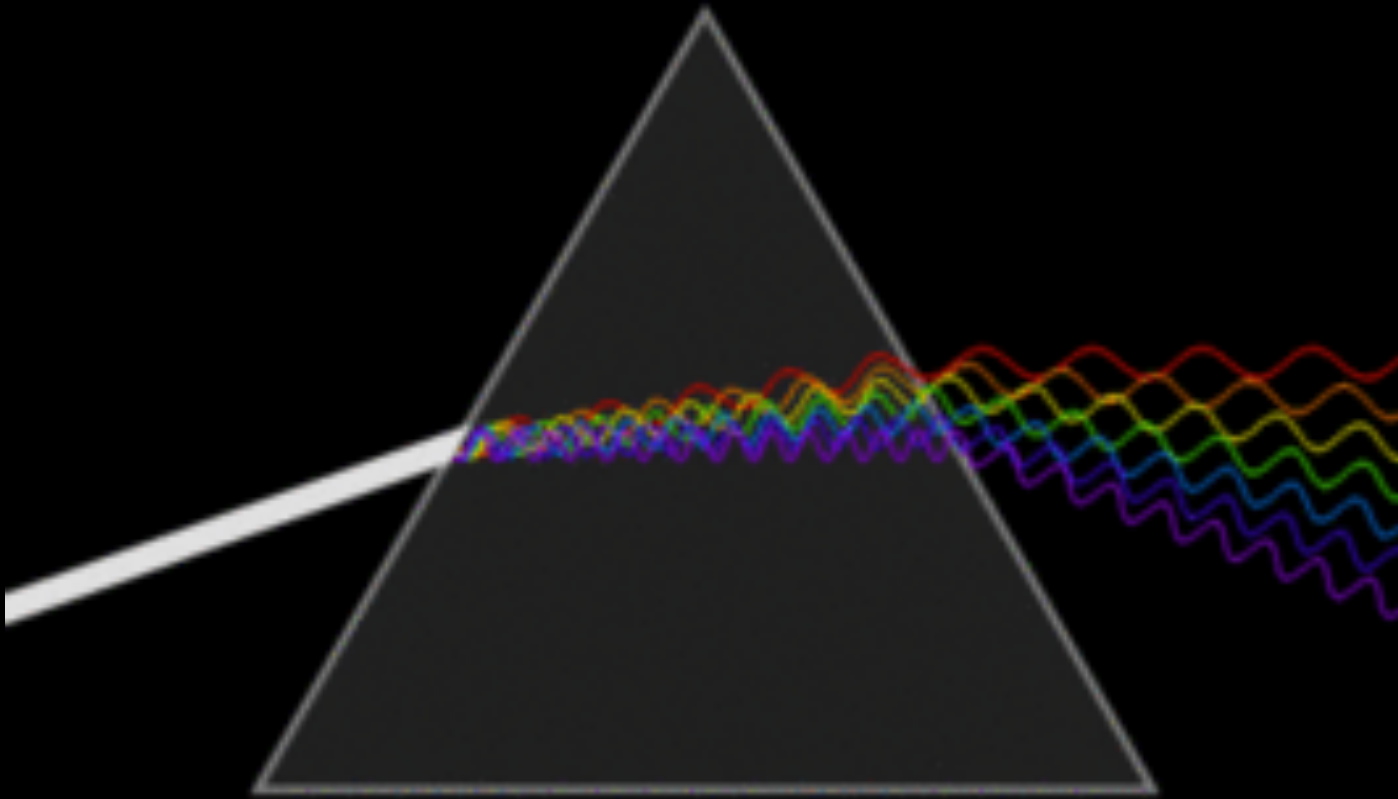


Spectroscopy: the Art of Decoding Light



Light – Cosmic Messenger

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)



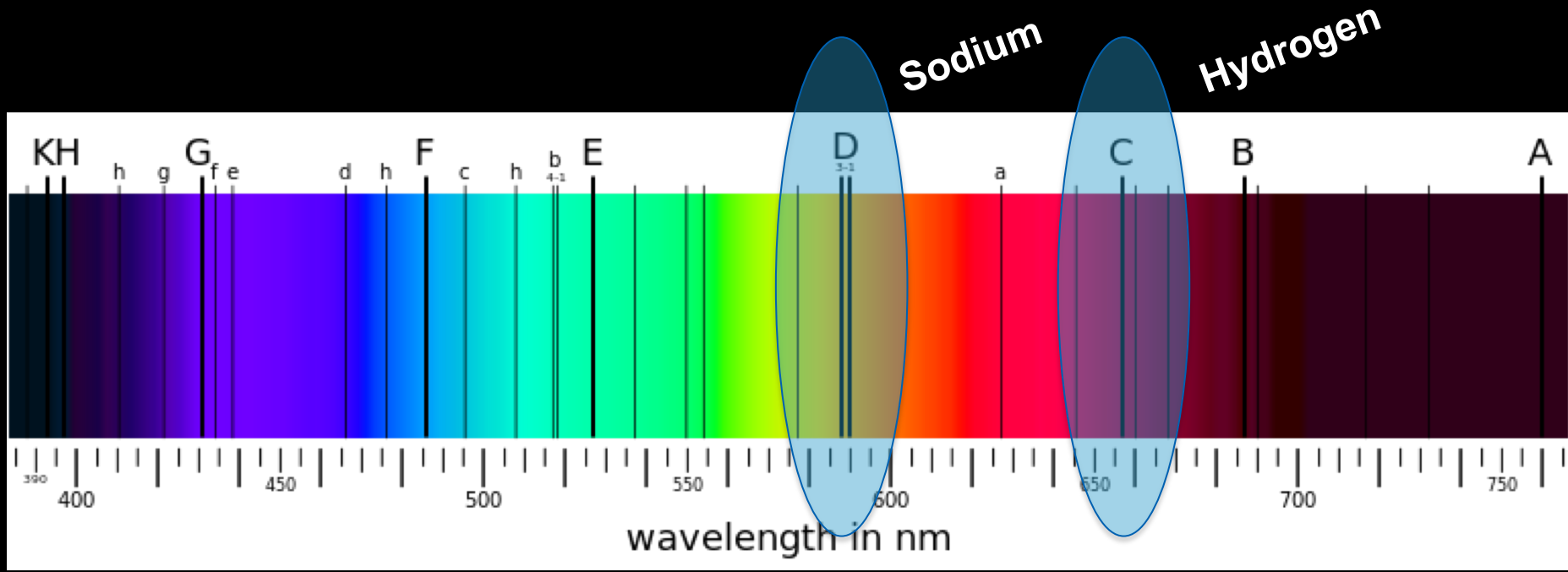
most used in astronomy

Composition of Objects



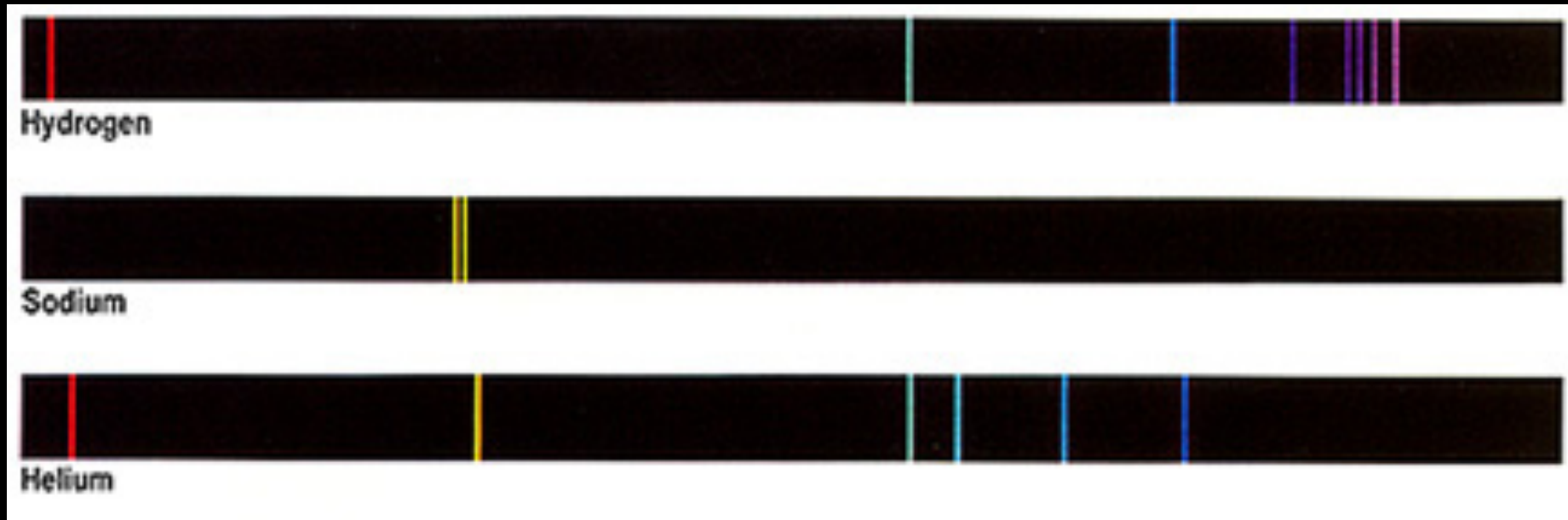
Light – Cosmic Messenger

Solar Spectrum



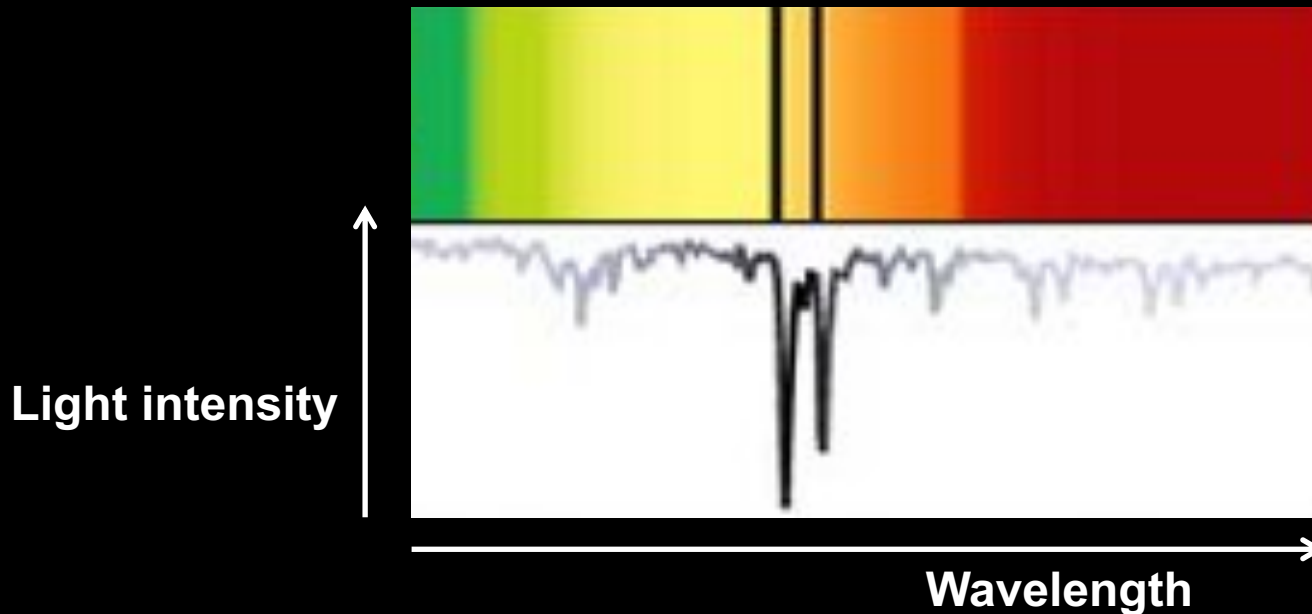
Spectrum Analysis

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

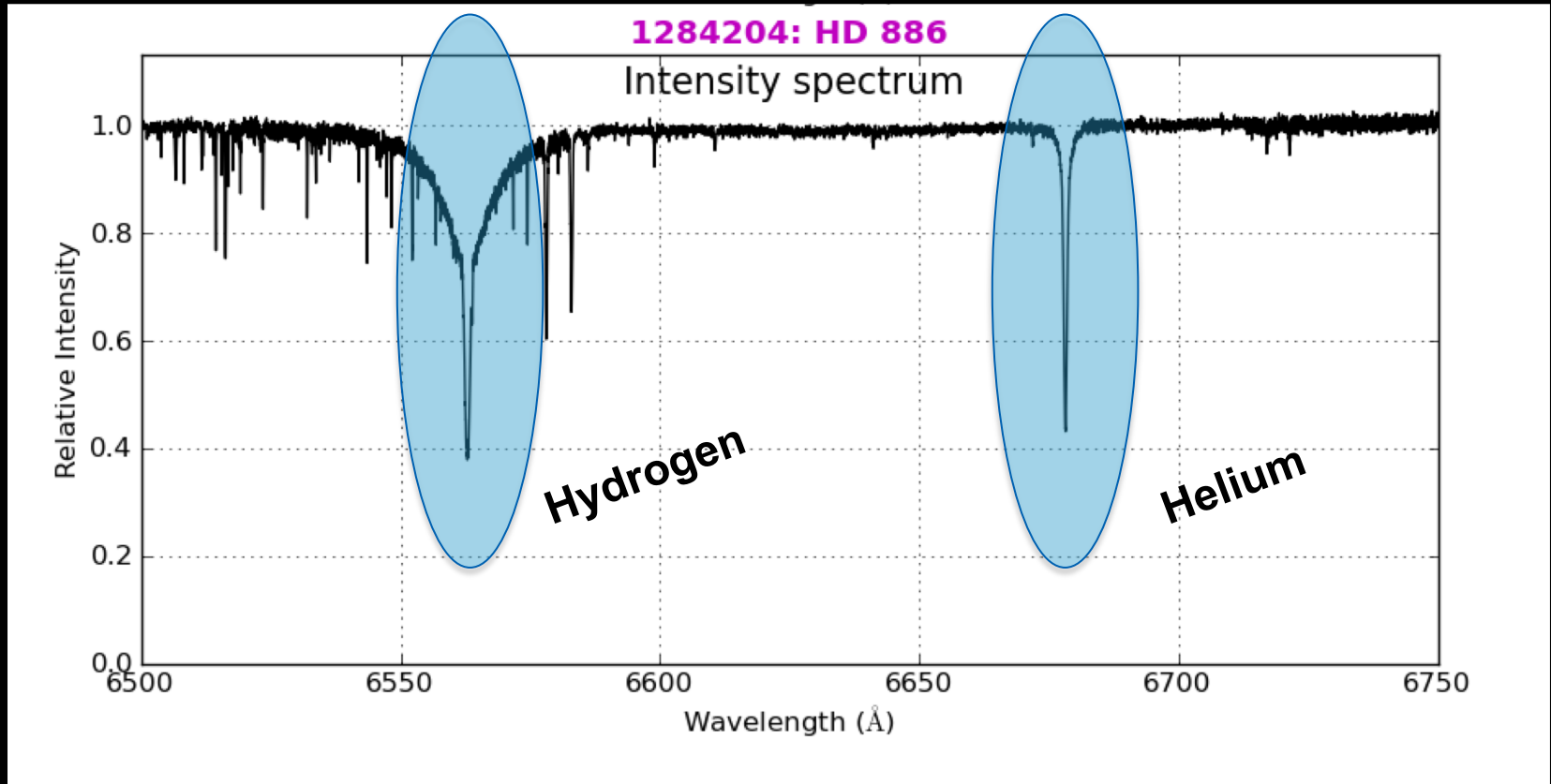


Spectrum Analysis

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

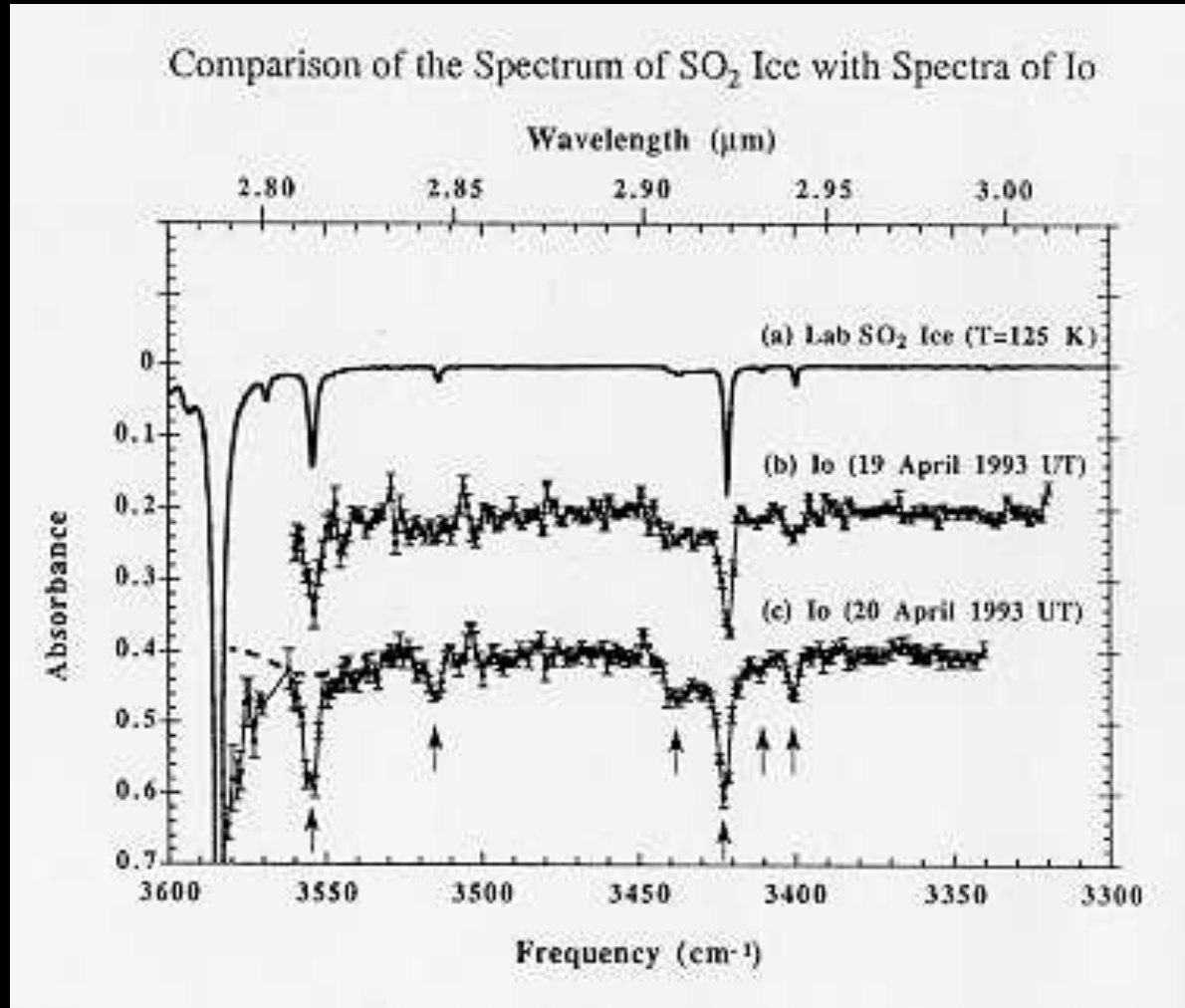


Spectrum Analysis



Data from the Canada-France-Hawaii Telescope

Composition of Io, moon of Jupiter



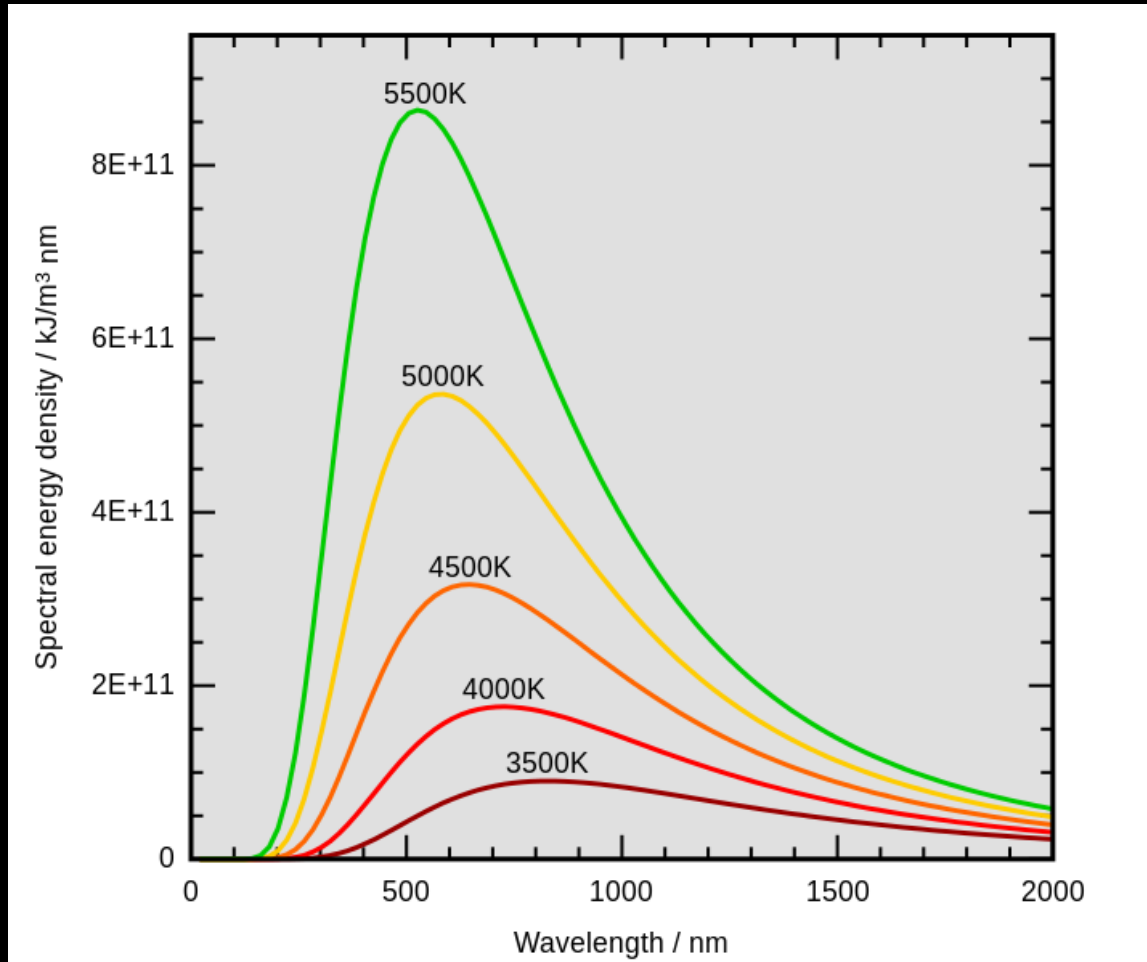
Temperature of Objects



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

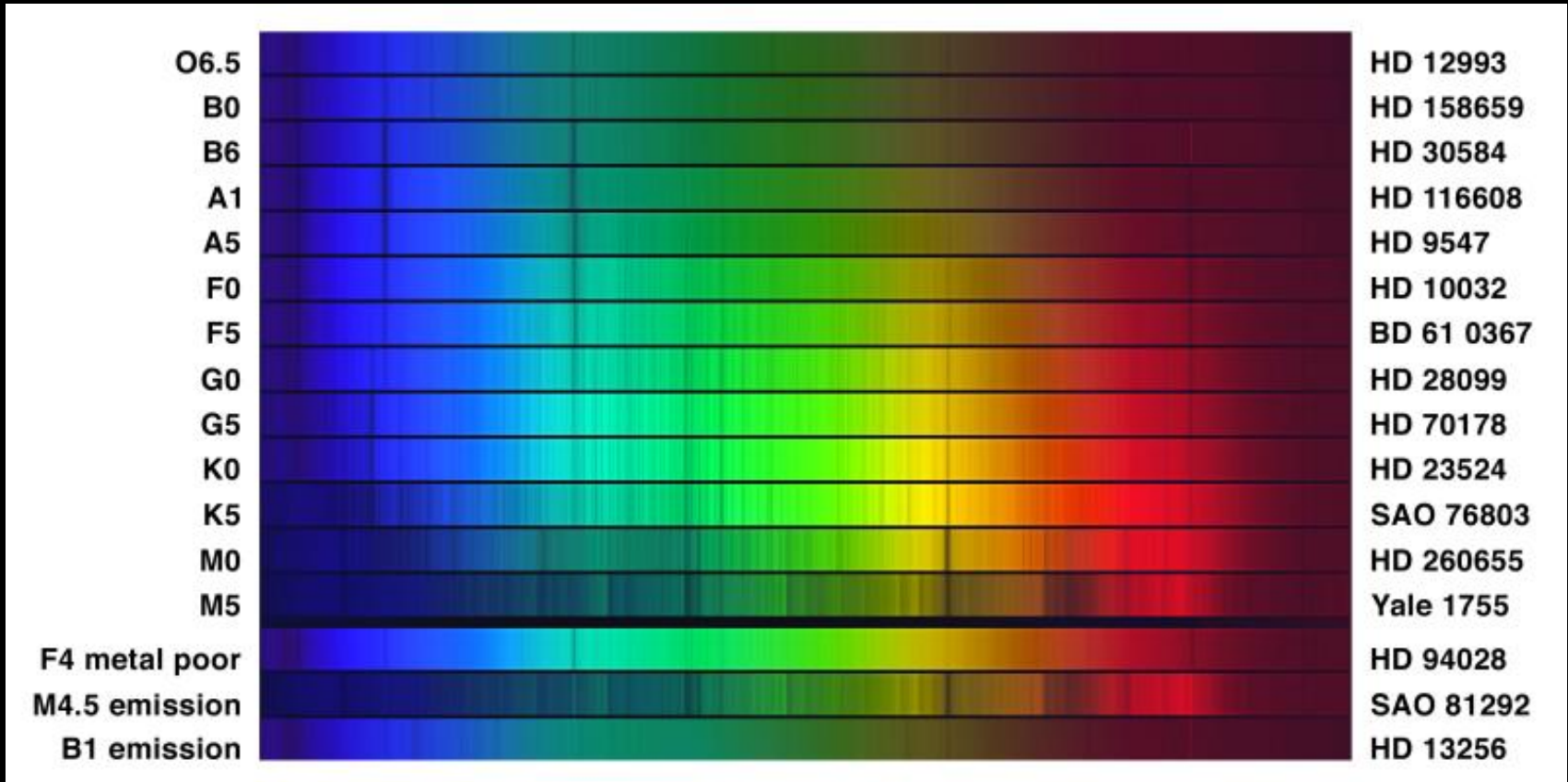
The colours of the stars give us clues about their temperatures: blue is hotter than red.



hot star (30 000°)

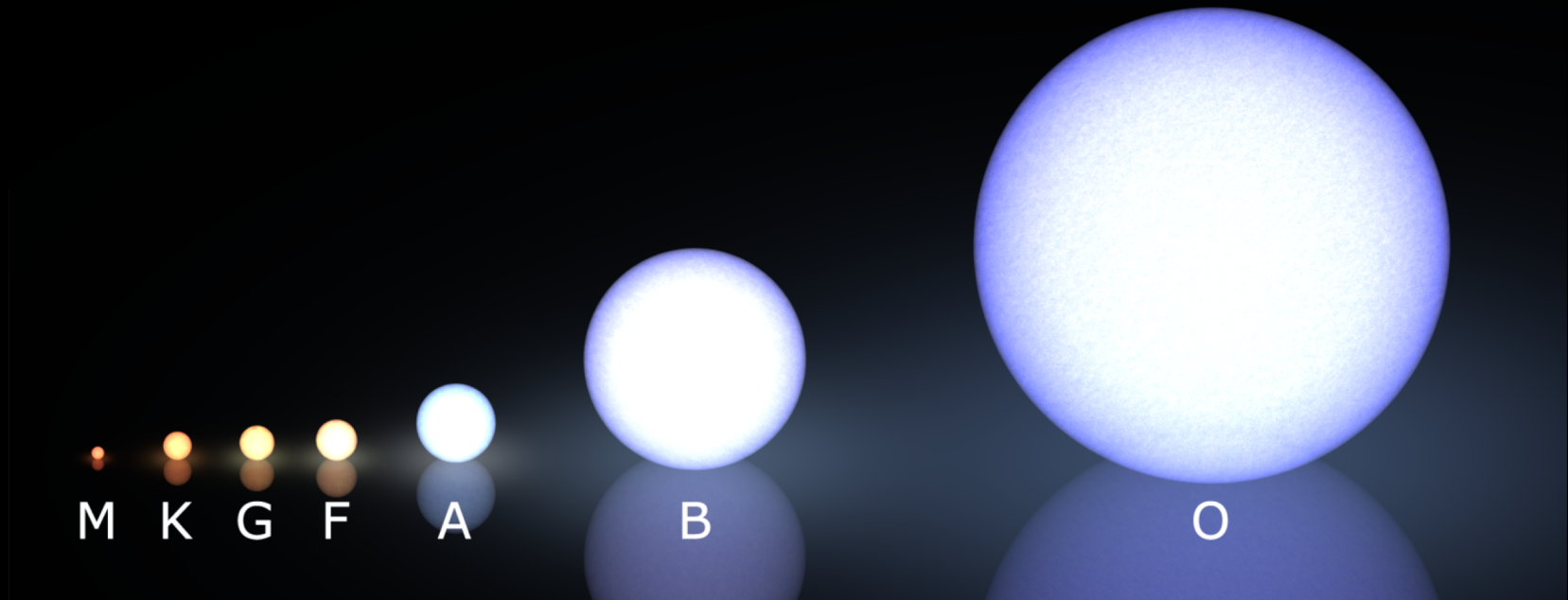
'cool' star (3500 °)

Star Spectra



Light – Cosmic Messenger

Star Spectra

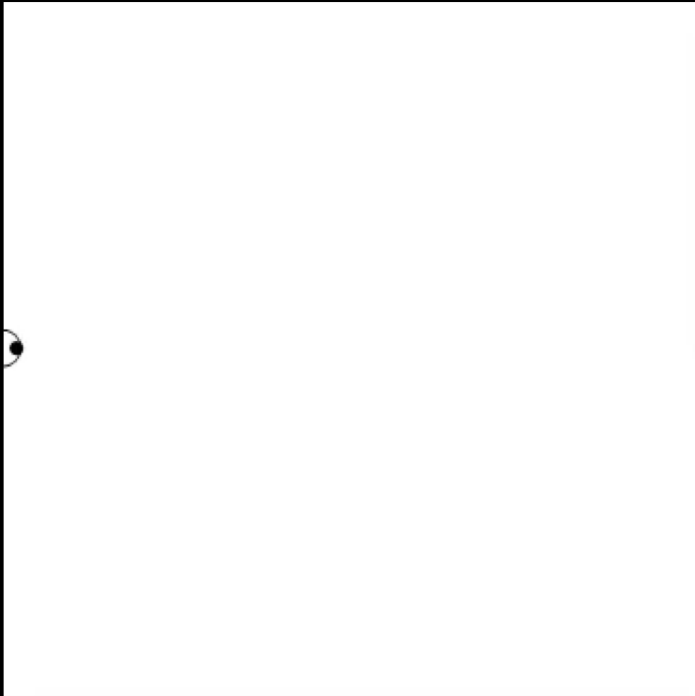


Speed of Objects



Doppler Effect

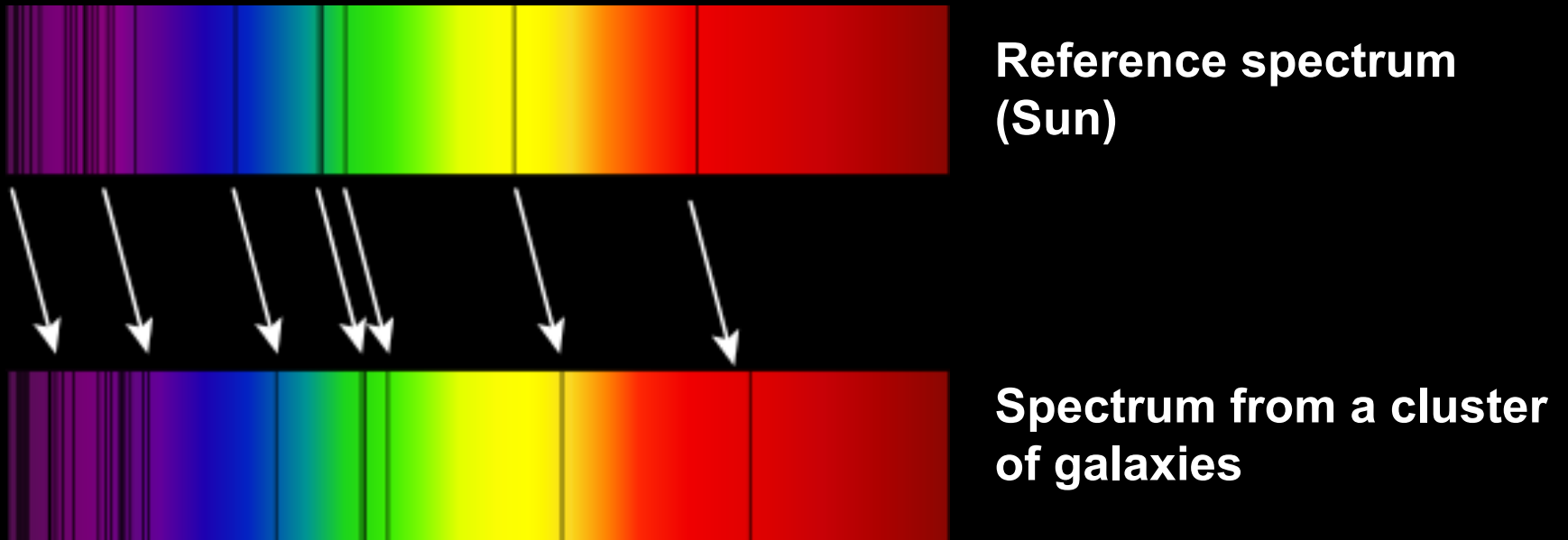
The speed of an object can be determined from its spectrum using the Doppler effect.



- ★ 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).



Information Encoded in Light

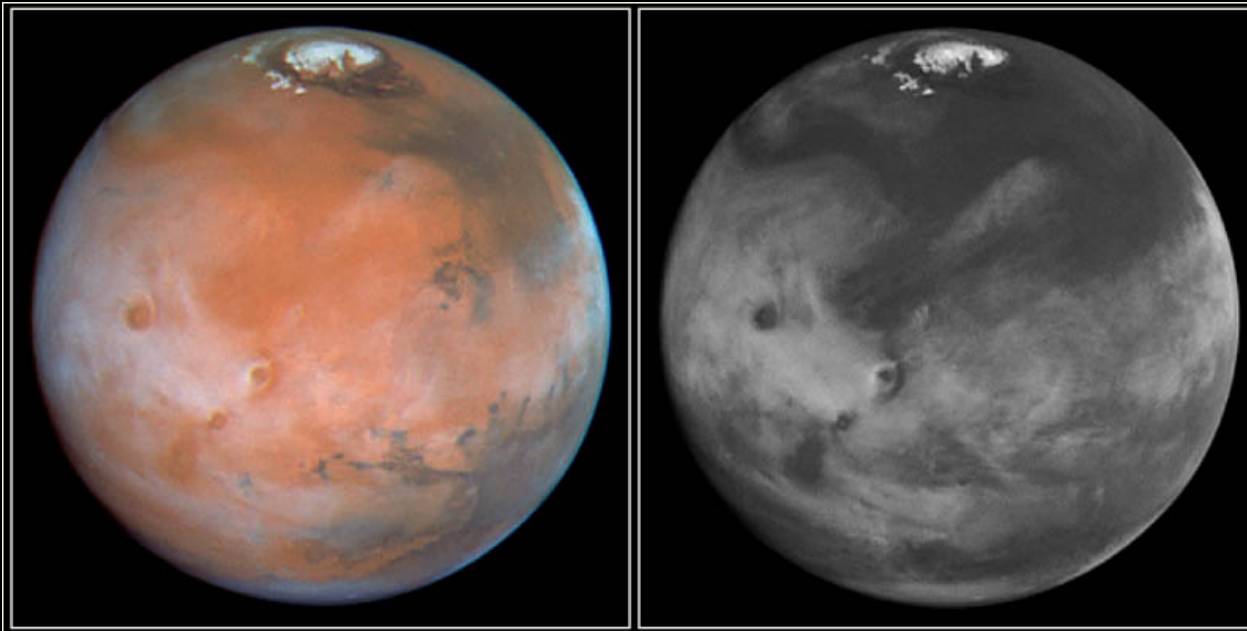
- ★ **type of object** → **spectrum type**
(absorption/emission) and images at multiple wavelengths
- ★ **temperature** → **spectrum or dominant colour**
- ★ **composition** → **spectral lines**
- ★ **speed** → **Doppler effect on spectral lines**
- ★ **and more** (rotation, presence of exoplanets around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

How do scientists get the nice astronomy pictures?



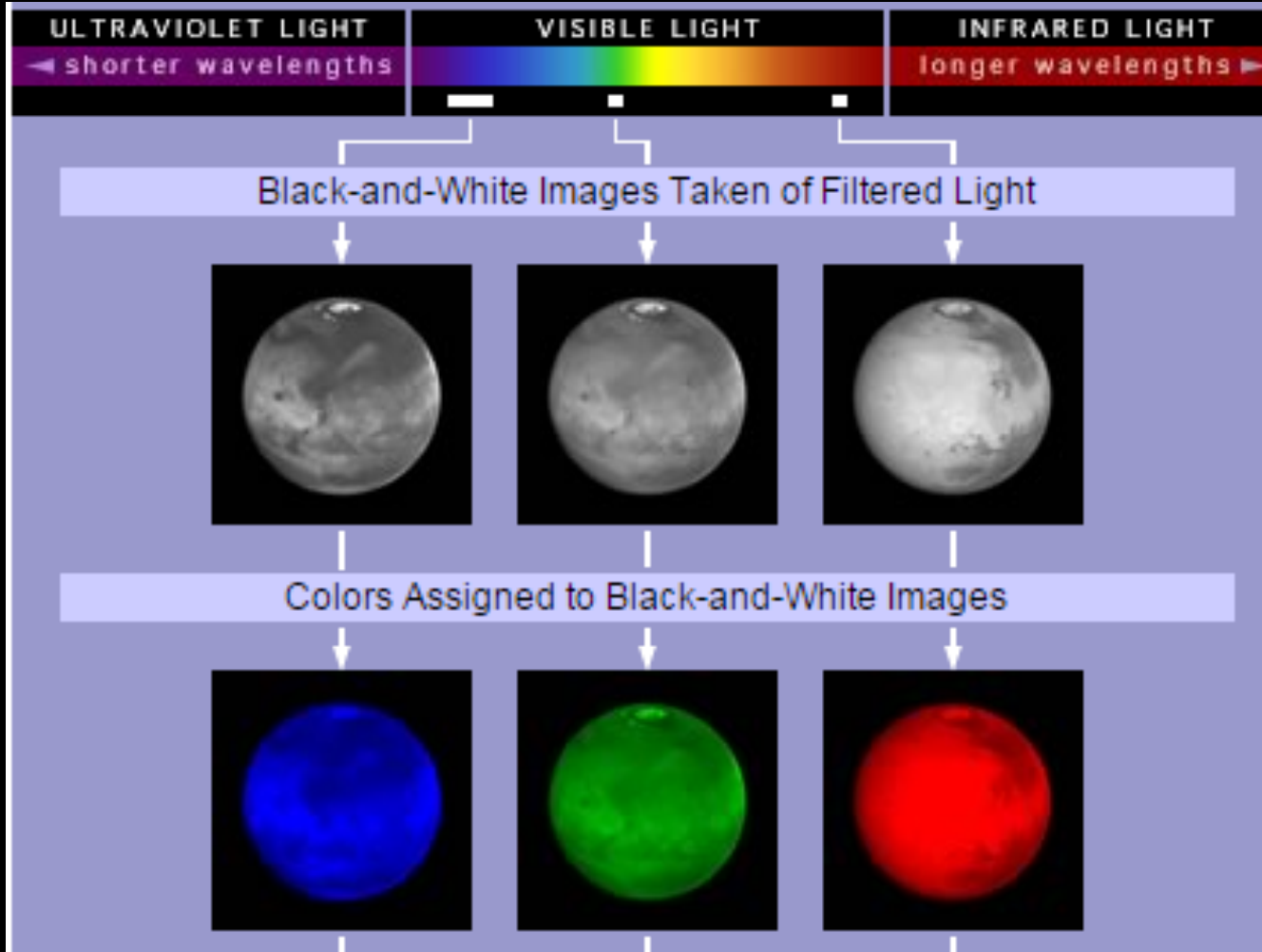
Colour Images

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

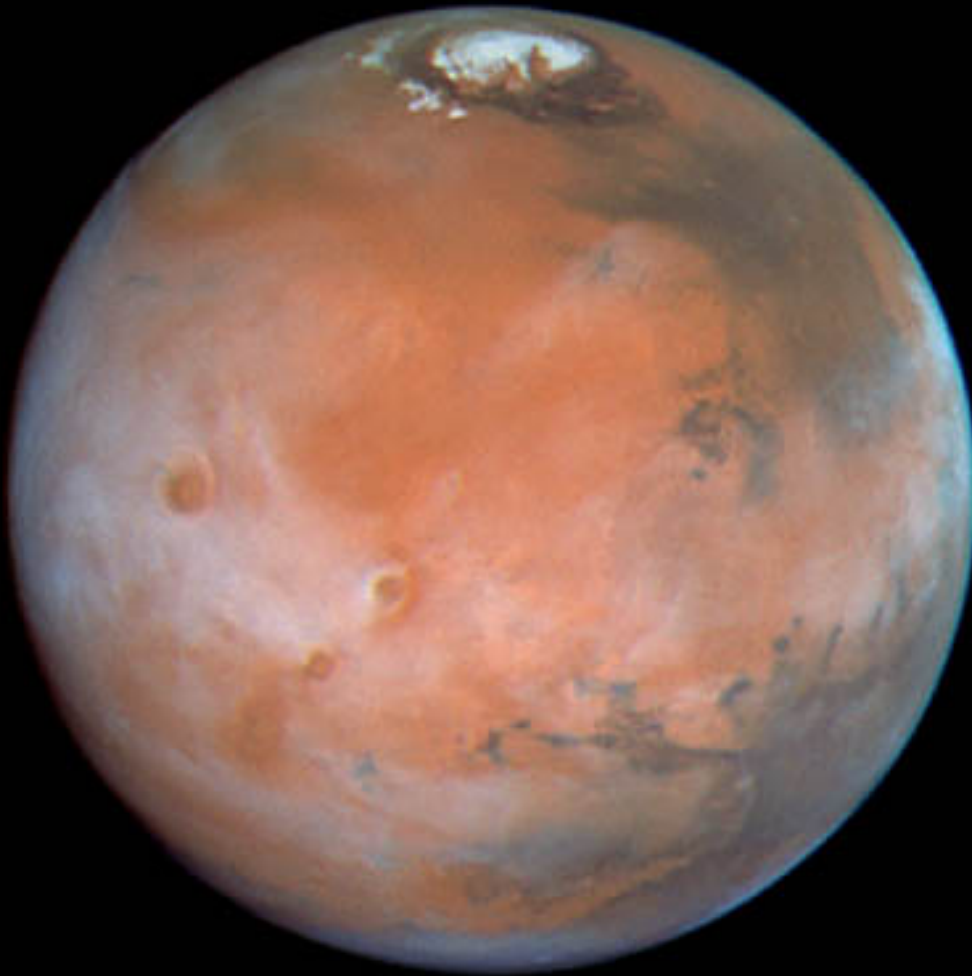
Colour Images



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

Light – Cosmic Messenger

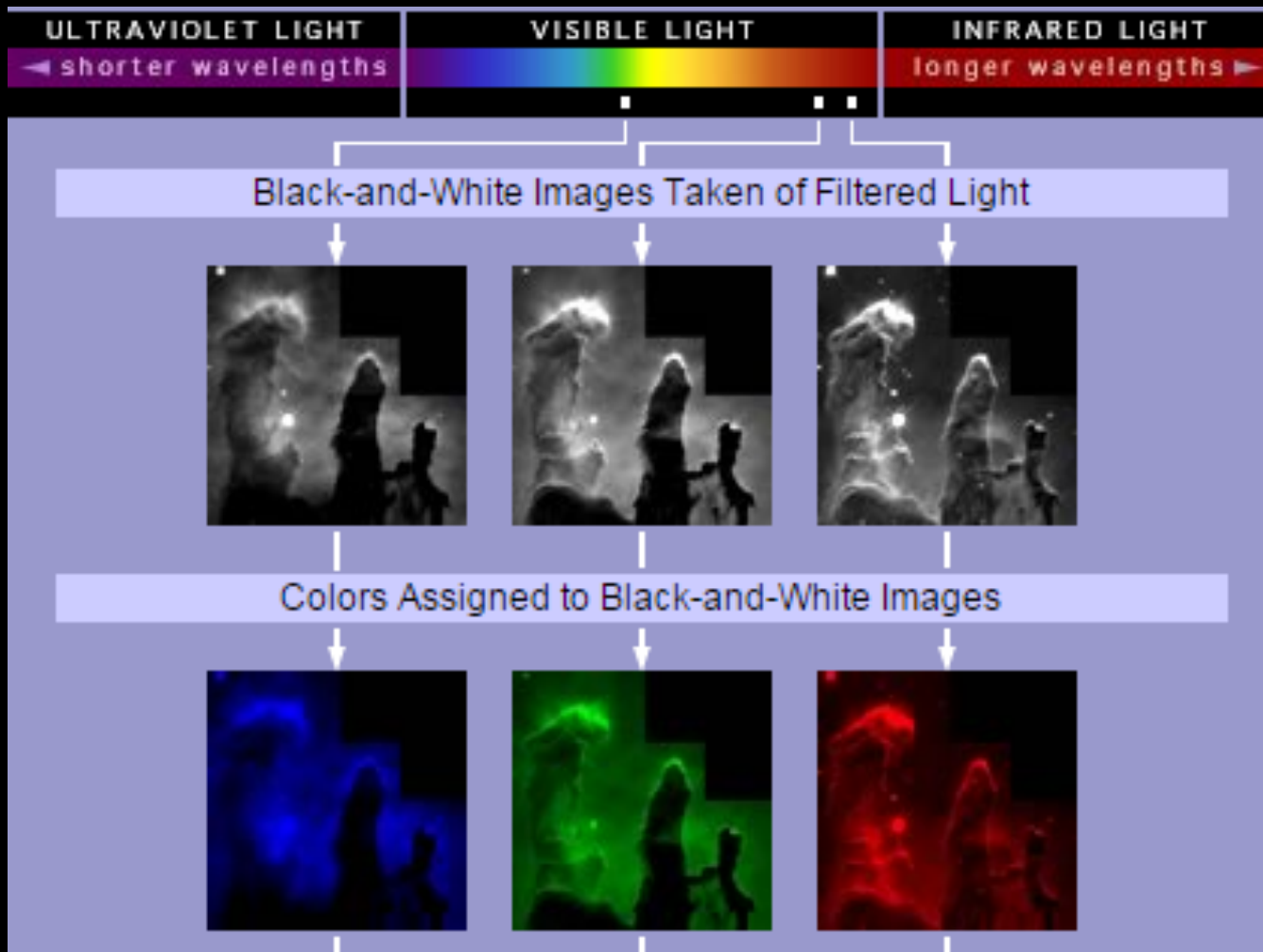
Colour Images



**Visible light image,
natural colours**

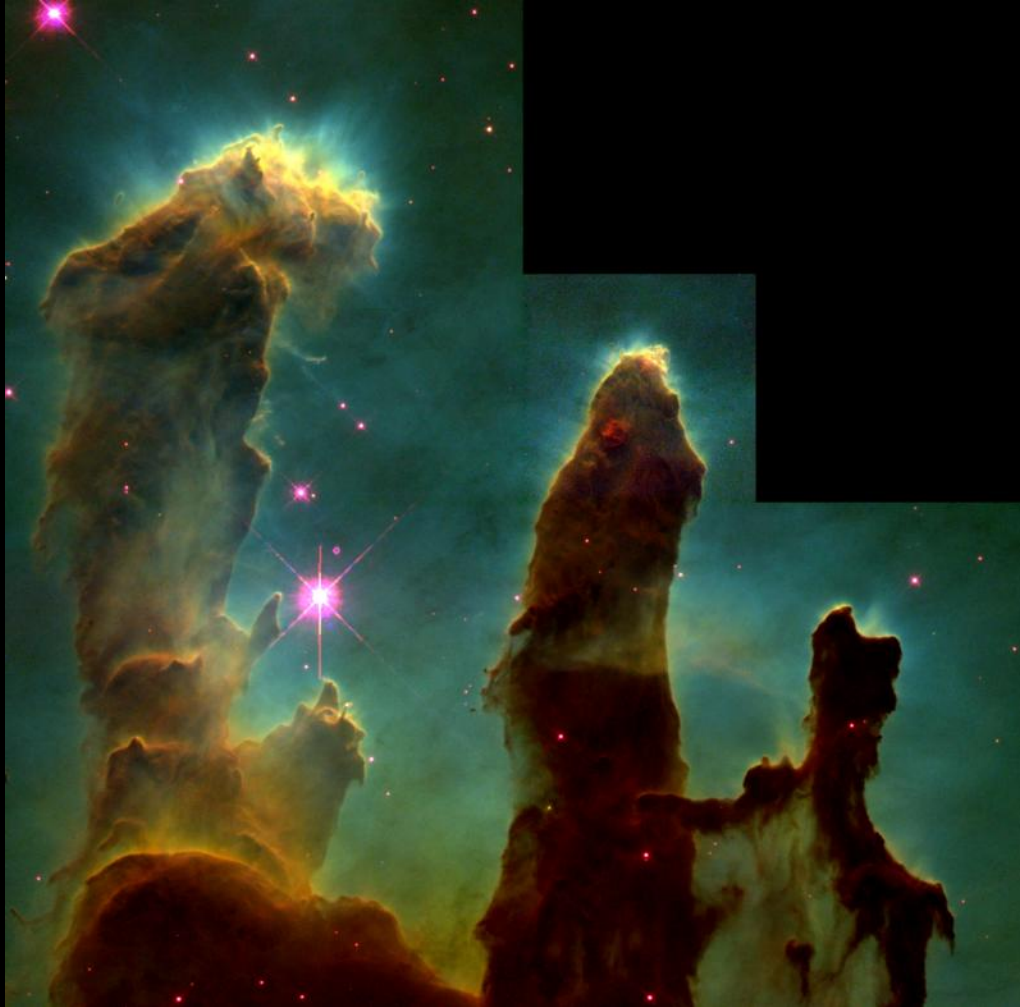
Light – Cosmic Messenger

Colour Images



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

Colour Images

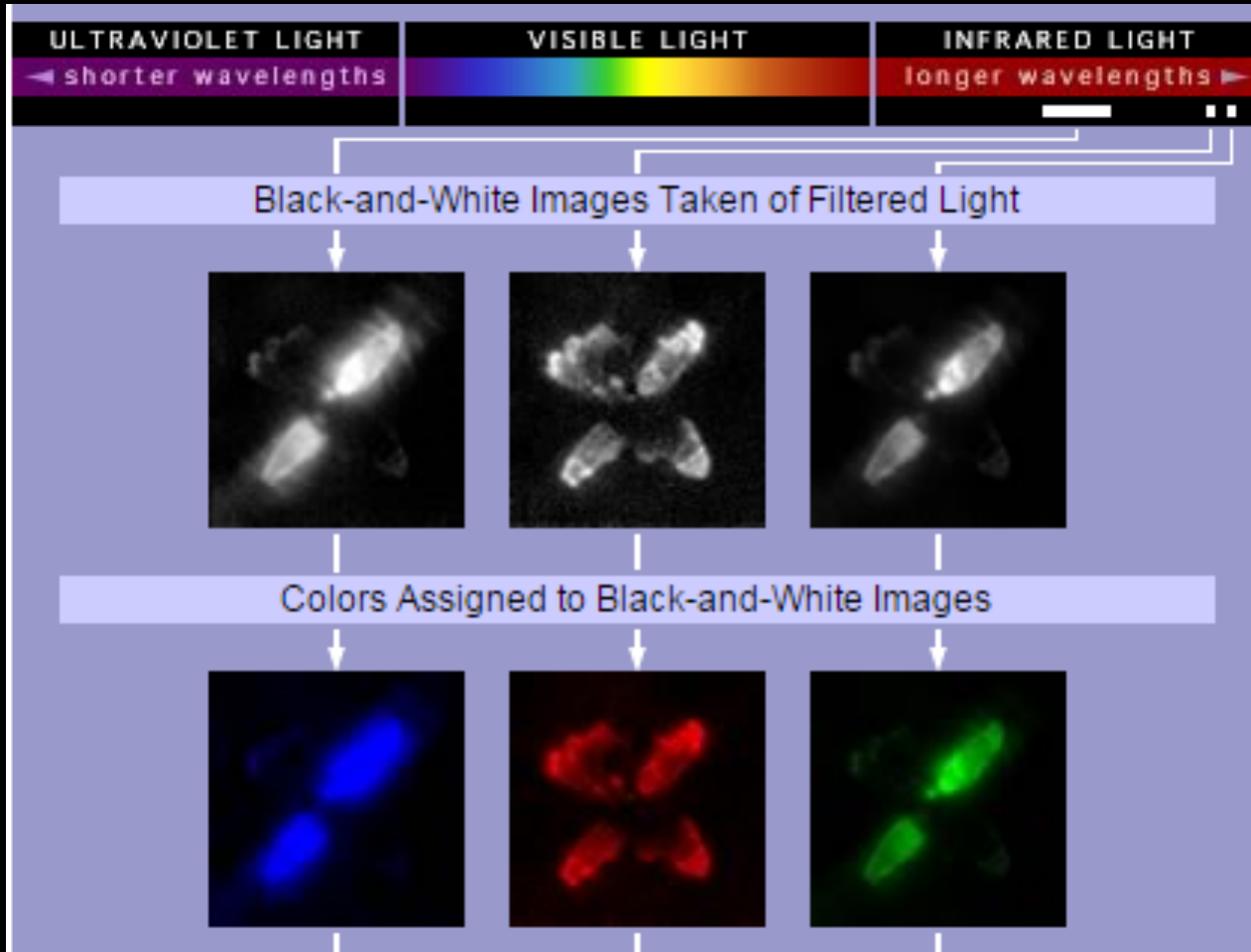


**Visible light image,
false colours**

**Blue-green: hydrogen
and oxygen**

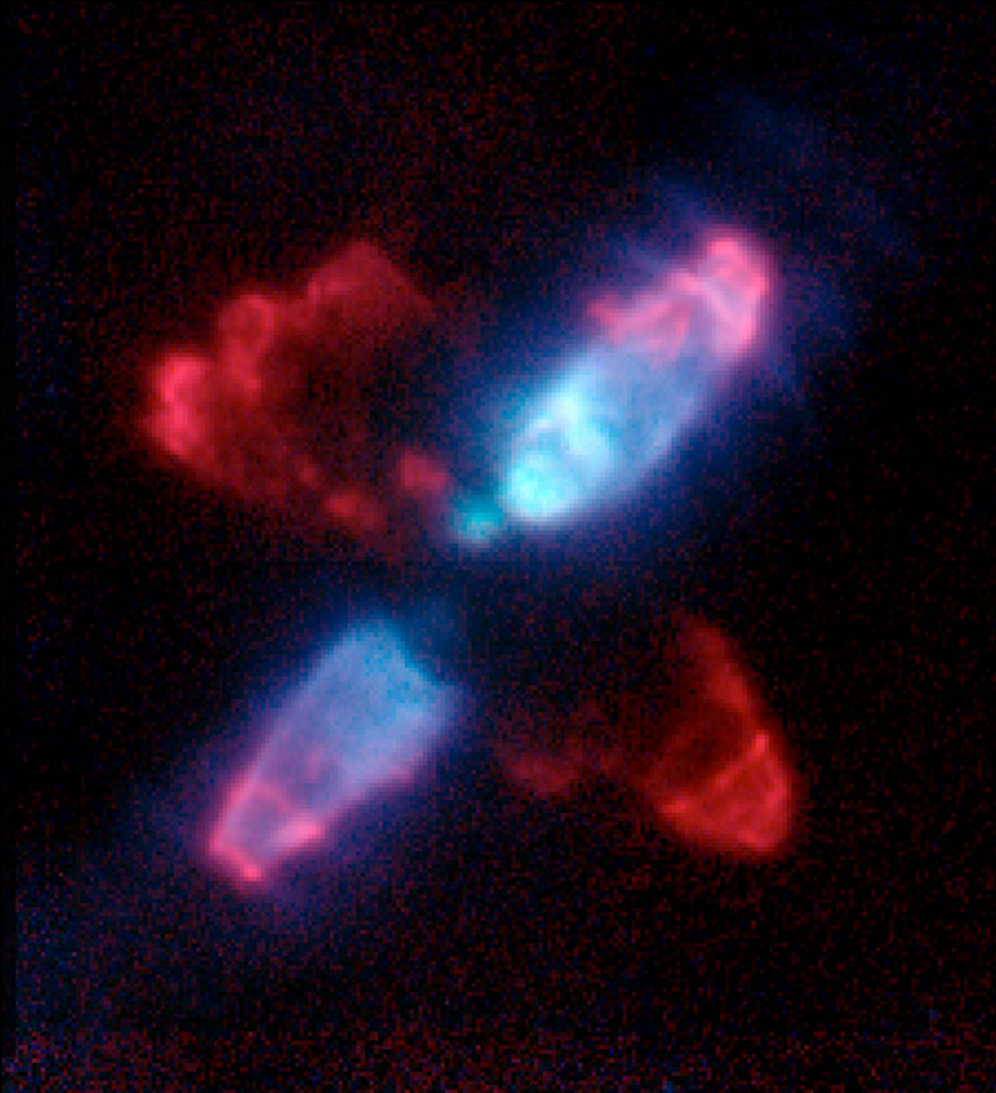
Red: sulfur

Colour Images



Three images taken in the infrared with different colours assigned to black-and-white 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)

Light – Cosmic Messenger

Thank you!