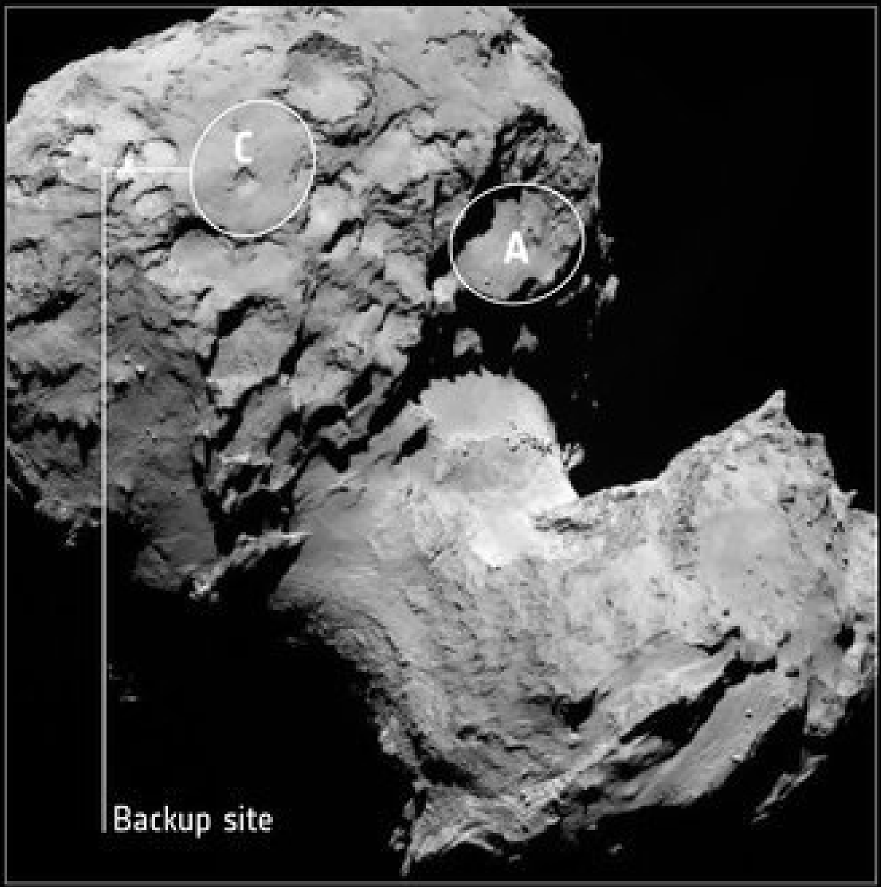
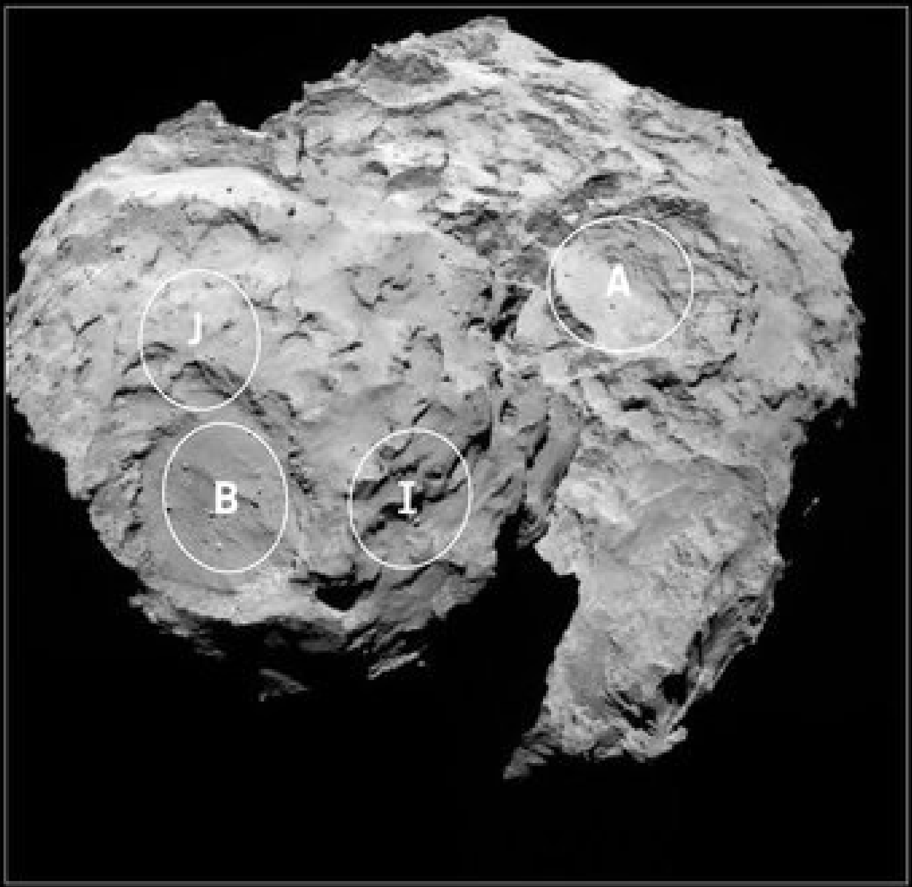
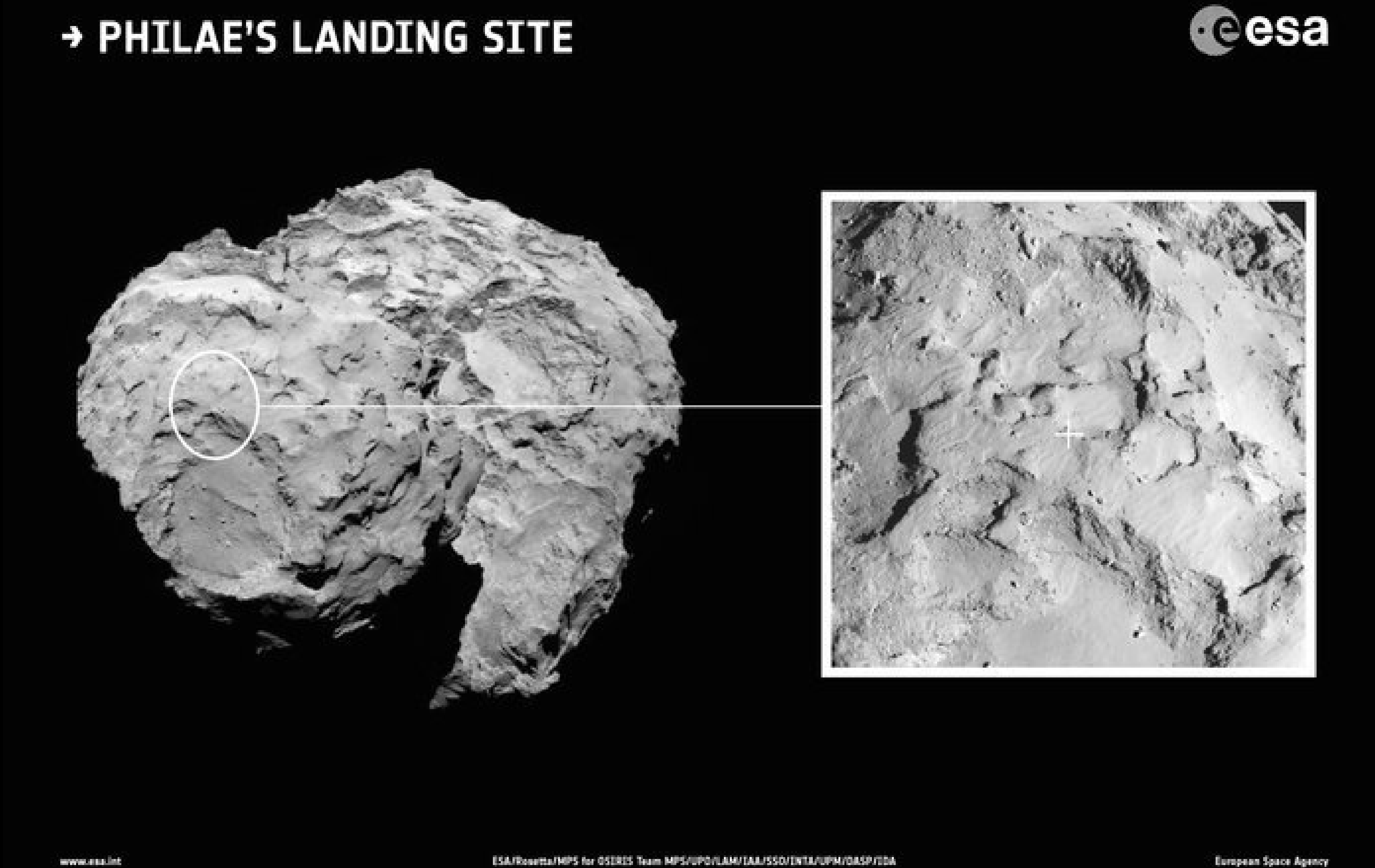
Update: Rosetta picks landing spot





Credits: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Update: Rosetta picks landing spot



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Update: Rosetta picks landing spot

Credits: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Astronomy 103

Copernican Revolution Wrap-up

Light and Matter

Please read Chapter 2

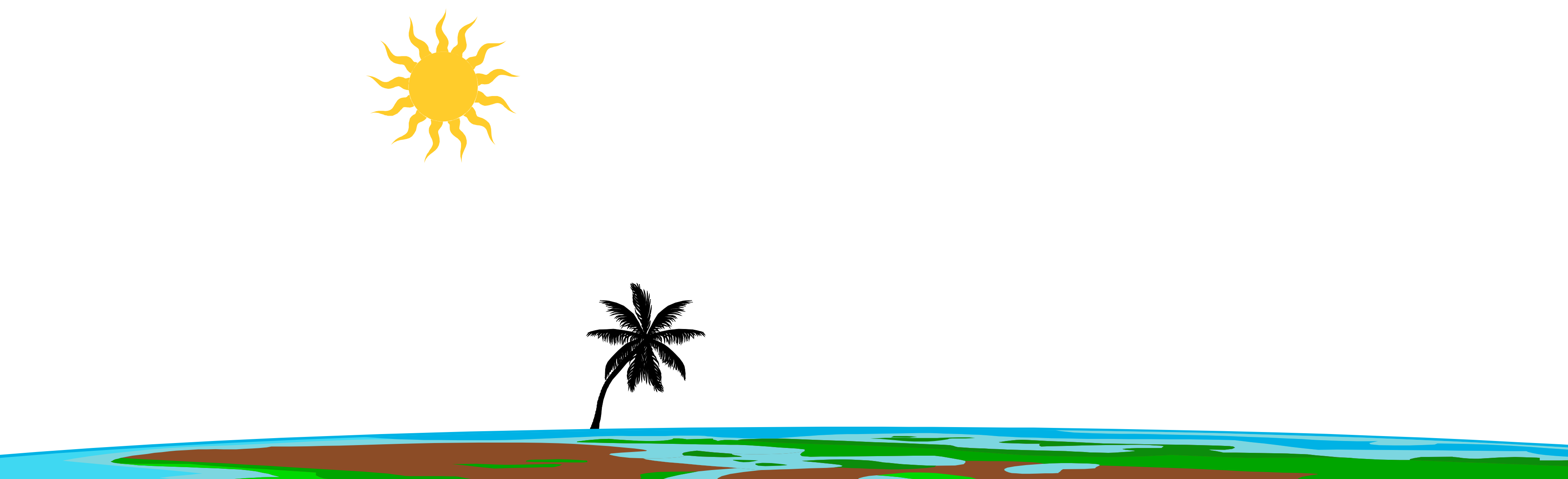
Concepts of Space and Time

PRE-GREEK

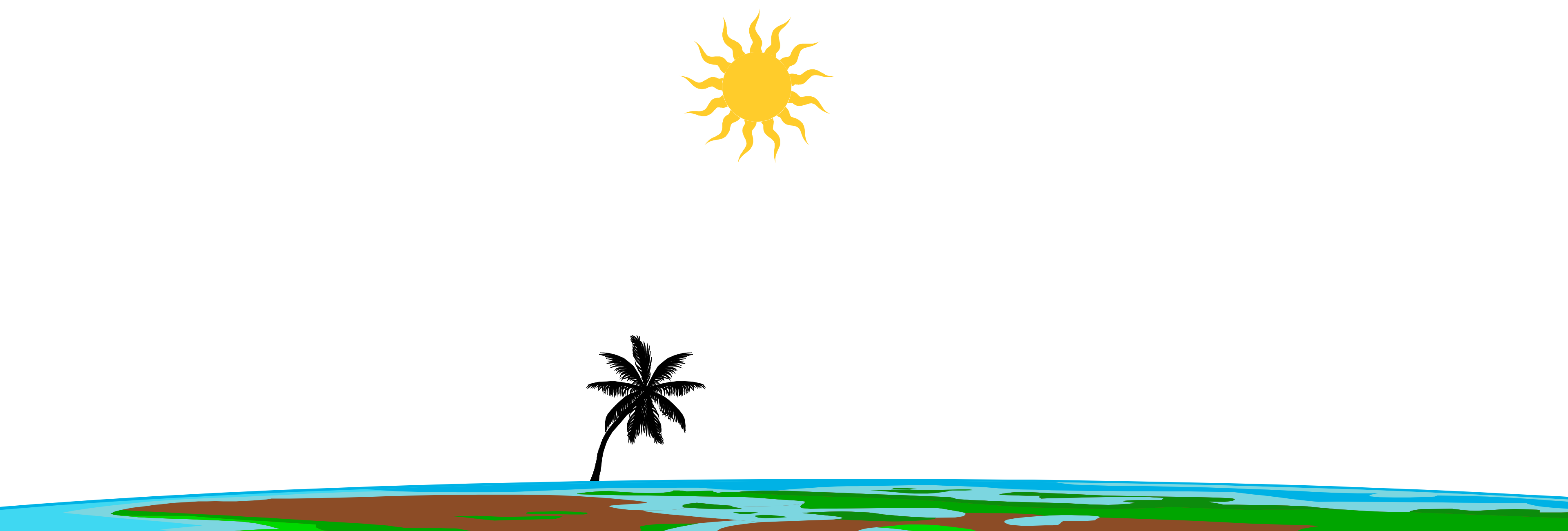
- The Earth is flat
- There is a preferred direction (up)
- The Earth is at rest. Space is absolute – there is an unmoving place from which positions and velocities can be measured
- Time is absolute:
  You know what it means for two events to occur at the same time
- Space is flat

Pre-Greek

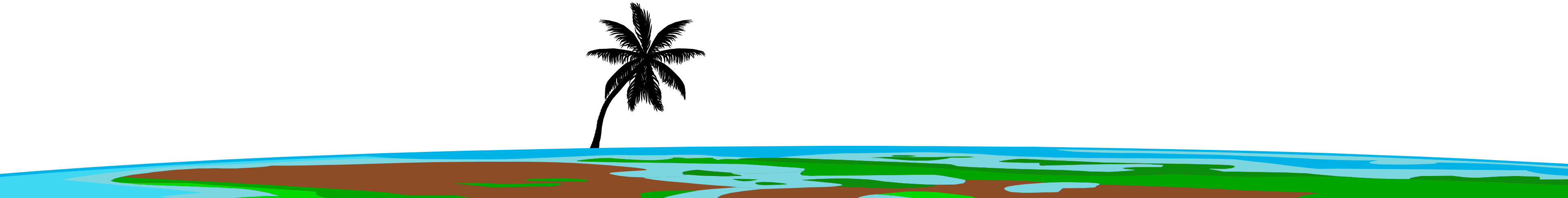
Pre-Greek



Pre-Greek

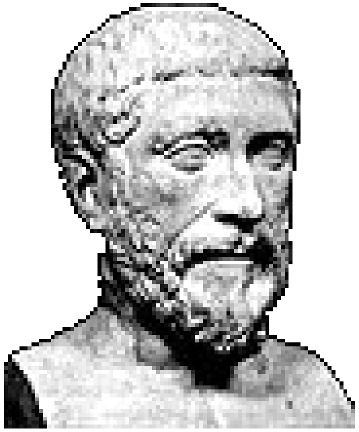


Pre-Greek



Pre-Greek

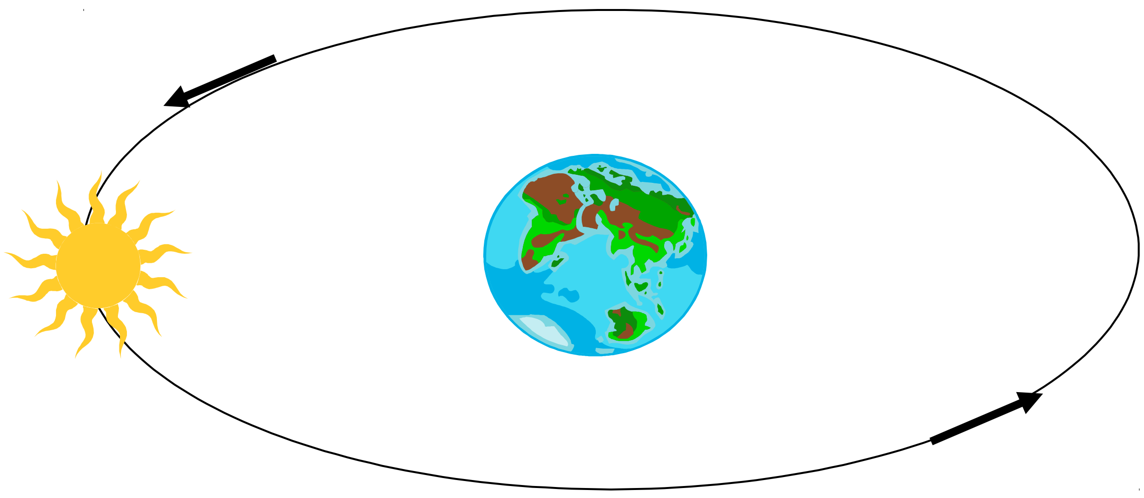
Concepts of Space and Time



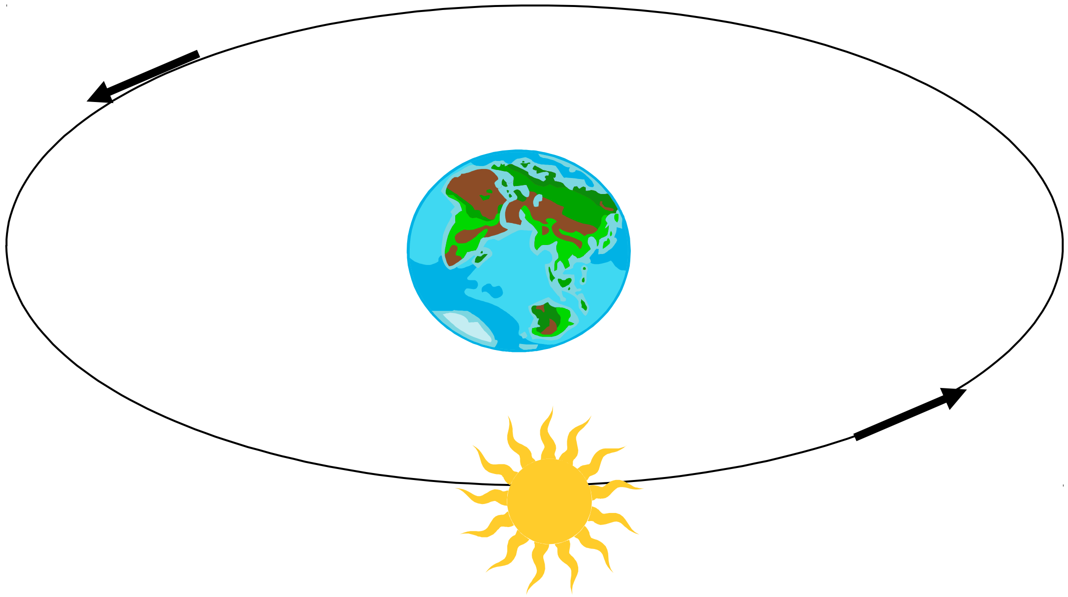
GREEK:

- The Earth is curved
- Up depends on where you are
- The Earth is at rest. Space is absolute – there is an unmoving place from which positions and velocities can be measured
- Time is absolute:
  You know what it means for two events to occur
  at the same time
- Space is flat

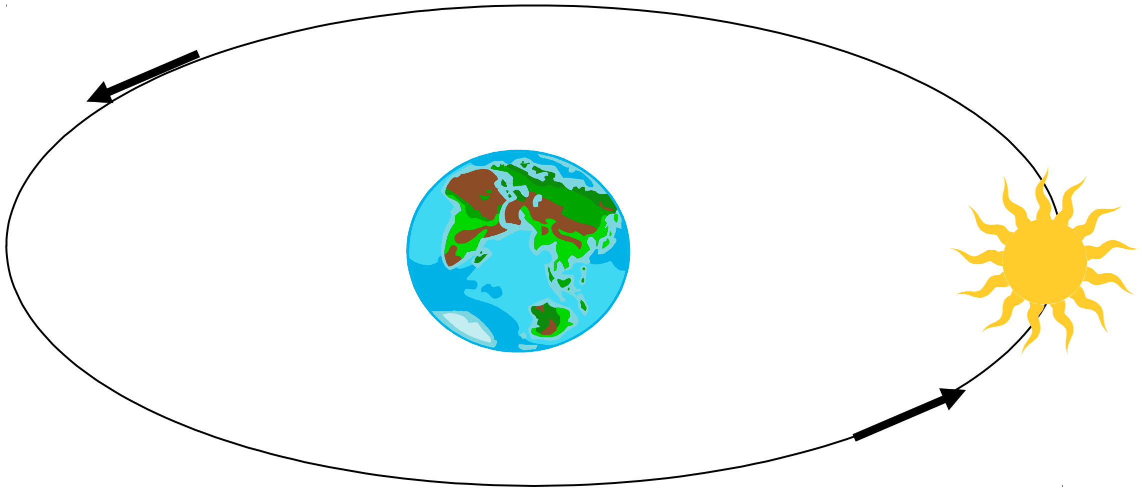
Greek



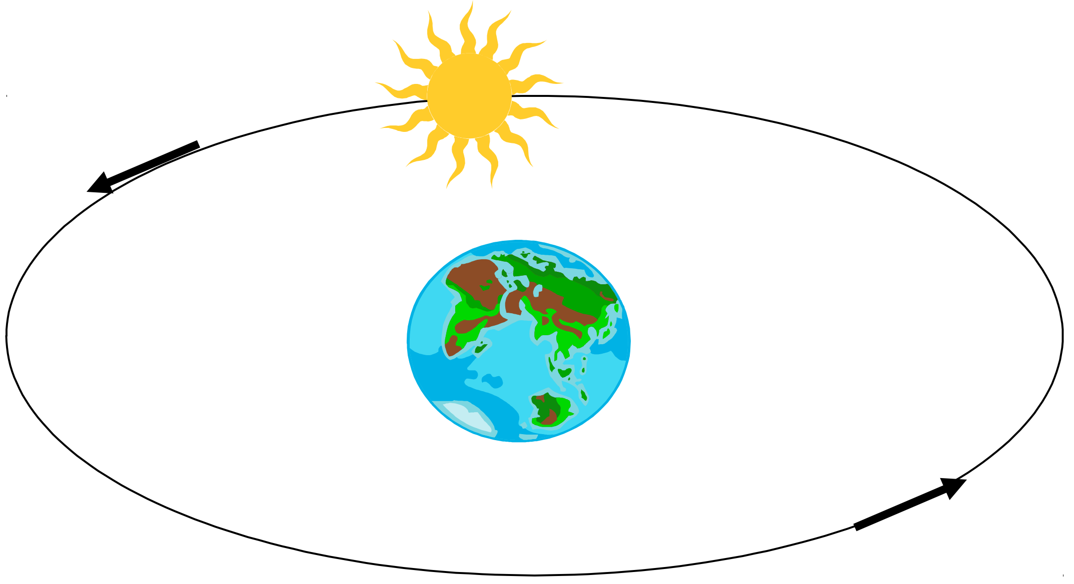
Greek

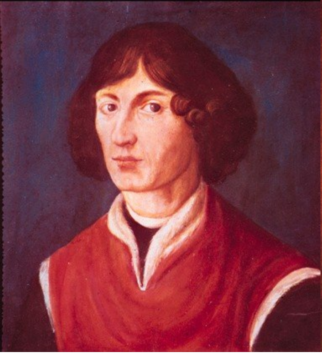
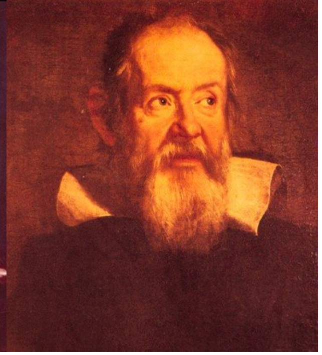


Greek



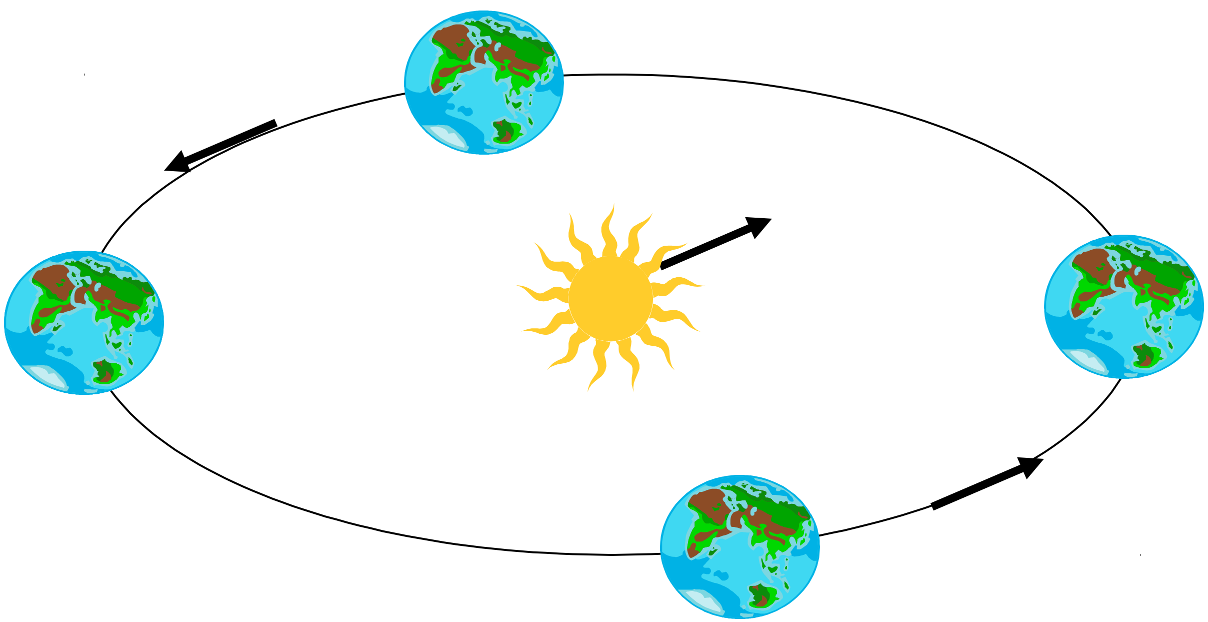
Greek



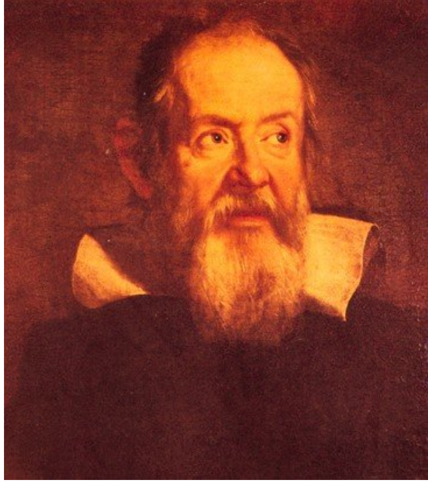



Galilean


IOANNIS KEPPLERI
Mathematici Cæsarei
hanc imaginem
ARGENTORATENSI BIBLIOTHECÆ
Consecr.
MATTHIAS BERNEGGERUS
Kal. Ianuar. Anno Chr.
M DC XXVII

Concepts of Space and Time



GALILEAN
Meaning of the Copernican Revolution

- The Earth is curved
- Up depends on where you are
- The Earth is moving – we no longer have an absolute, unmoving reference point
- Time is absolute:
  You know what it means for two events to occur at the same time
- Space is flat

It will take another 200 years before these last two assumptions are modified – more on that later!

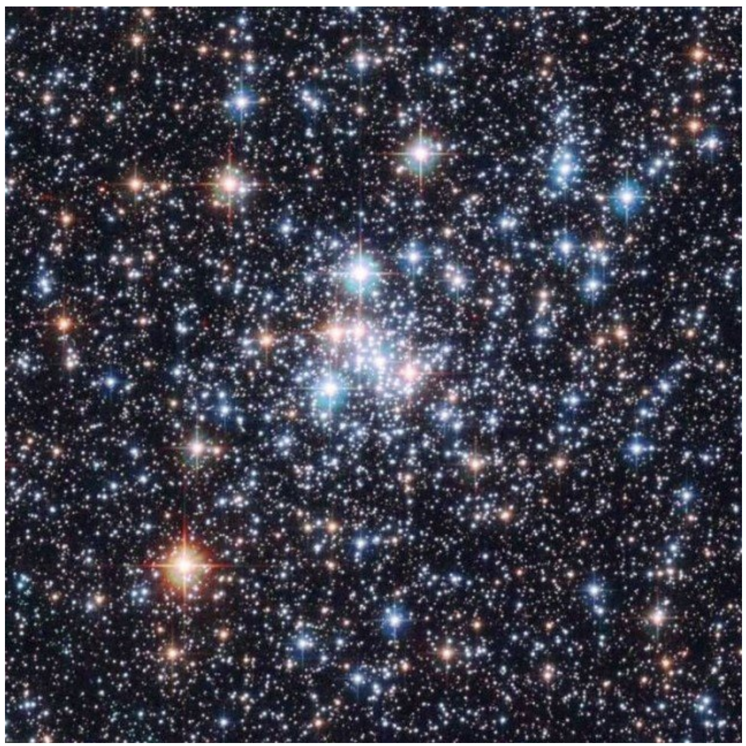
Light and Matter

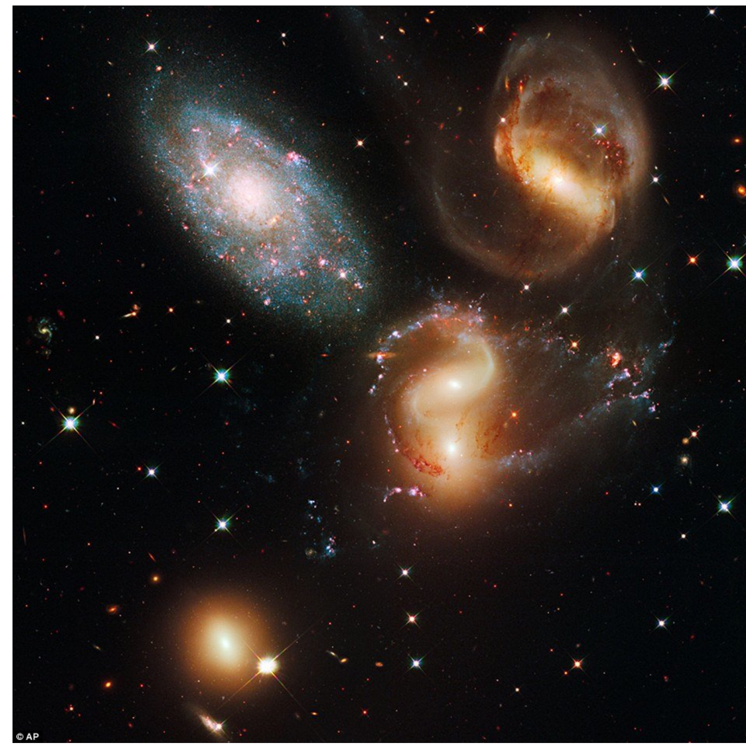
Please read chapter 2

Today we will cover sections 2.1 to 2.3

Everything* we know about the universe outside our solar system comes from light

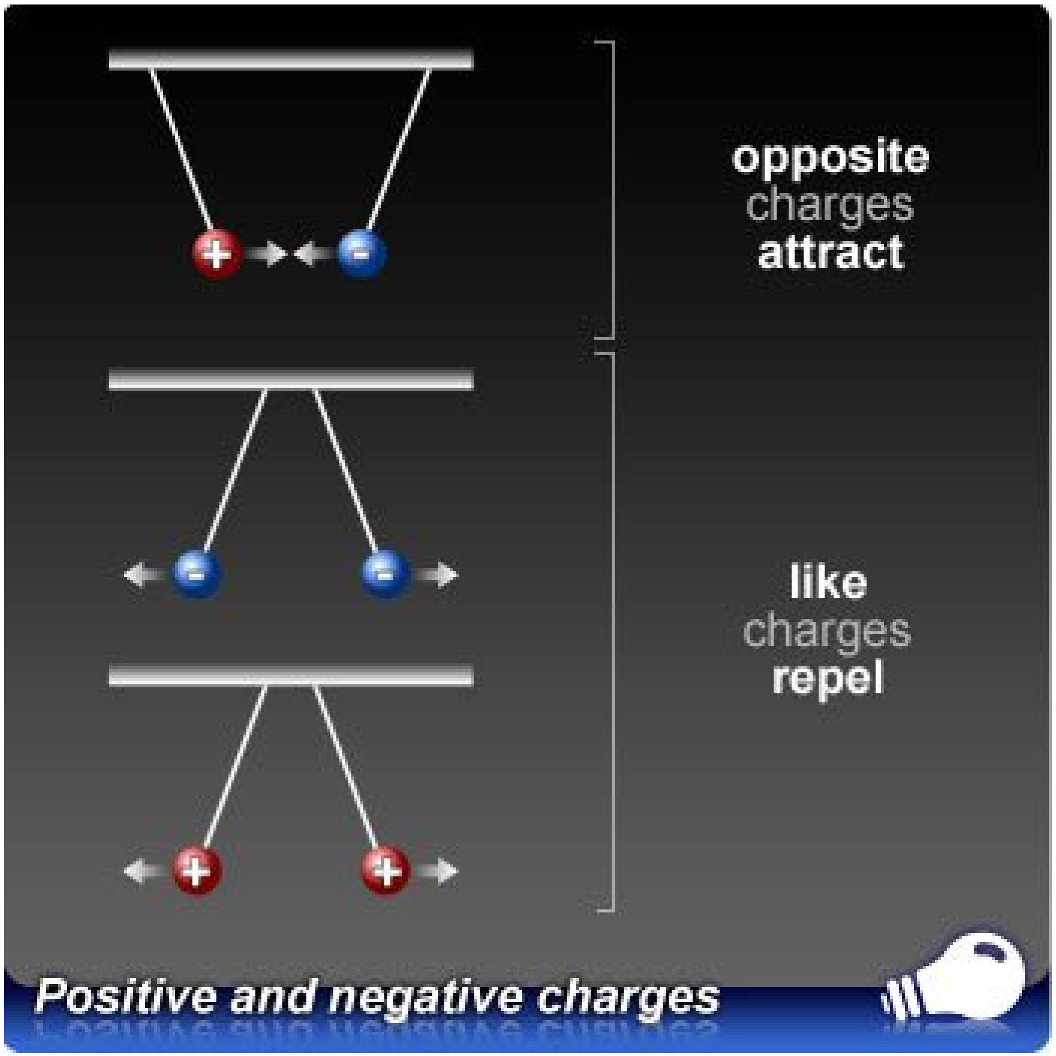
We can’t put stars and galaxies in lab and do experiments on them – we can only look at the light they emit





*Almost. There are also some charged particles, and soon we may detect **gravitational radiation** that isn’t light.

Light and the electric force



Charged particles create an **electrical** force, just as **massive** particles create a **gravitational** force.

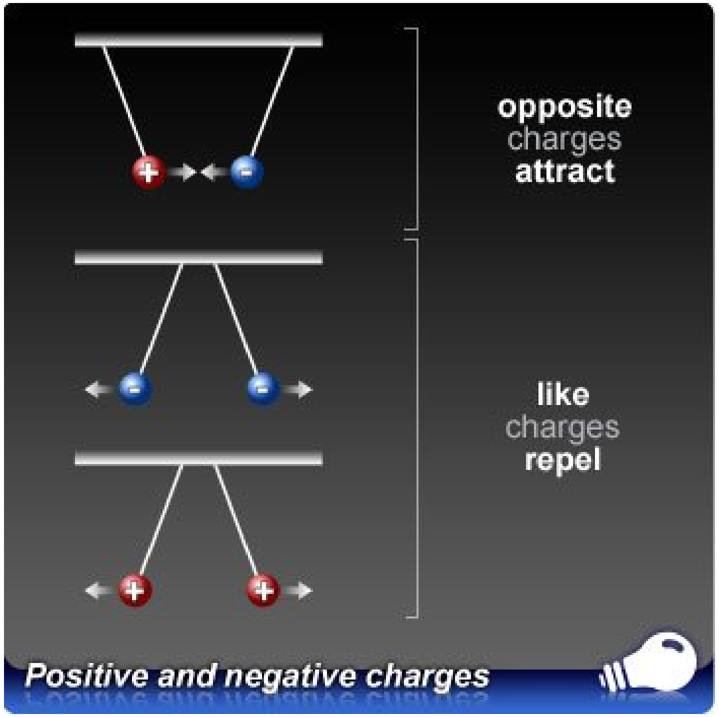
Light and the electric force

To understand light and how it is produced, we first need to review some facts about the electric force

Charges can be positive or negative

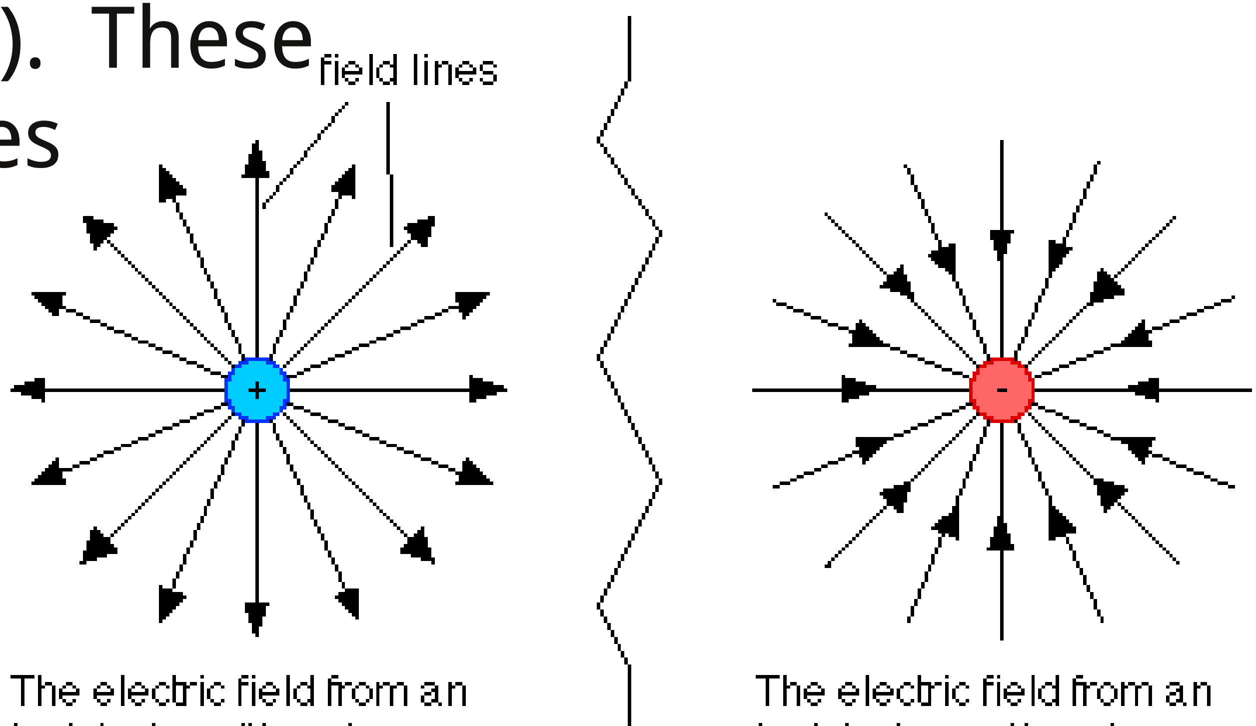
Particles or larger objects with the same charges (two positively charged particles or two negatively charged particles) repel each other

Particles with opposite charges (one positive and one negative) attract each other



Electric forces and electric fields

The electric force is caused by the electric field – imagine it as a bunch of outward pointing lines from a positive charge (and inward for negative charge). These electric field lines stretch out to infinity, but weaken as they go outward.

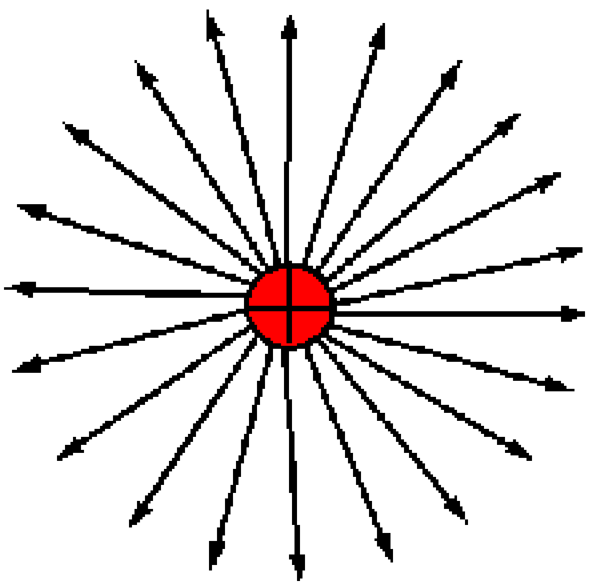


The electric field from an isolated positive charge

The electric field from an isolated negative charge

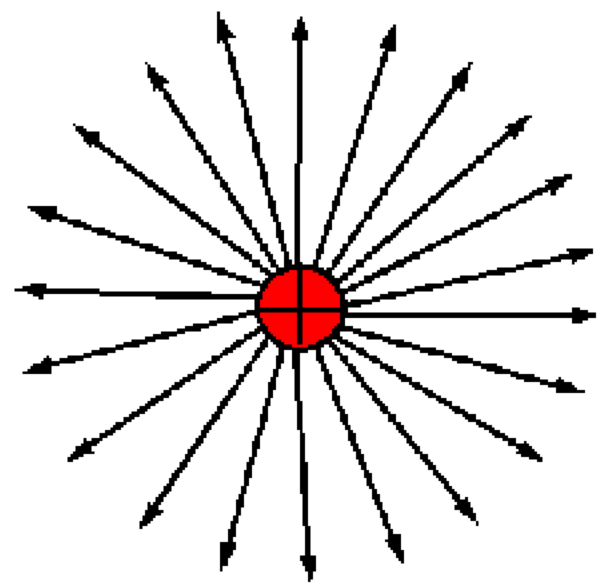
What does this have to do with light?

When a charge changes its position, its field changes, and the information that the particle has moved is transmitted by the electric field.



What does this have to do with light?

When a charge changes its position, its field changes, and the information that the particle has moved is transmitted by the electric field.



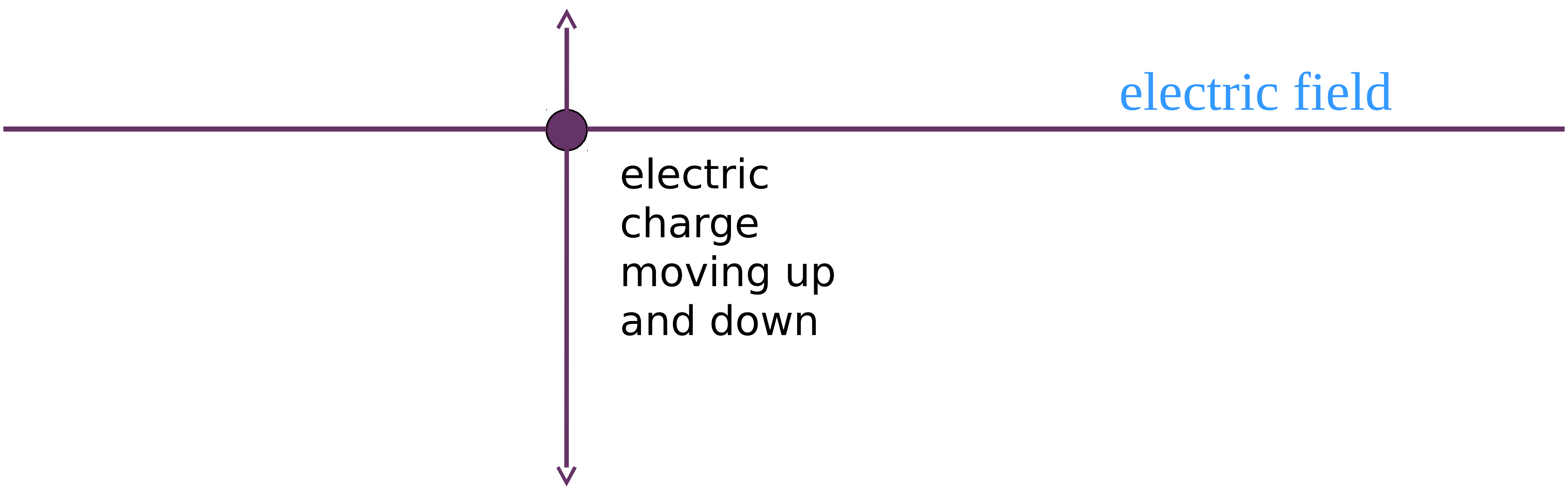
But the information that the particle has moved is not communicated instantaneously:

There is a maximum speed of information in our universe.

This information moves at a speed of 300,000 km/s, **the speed of light**, or the maximum speed in the universe

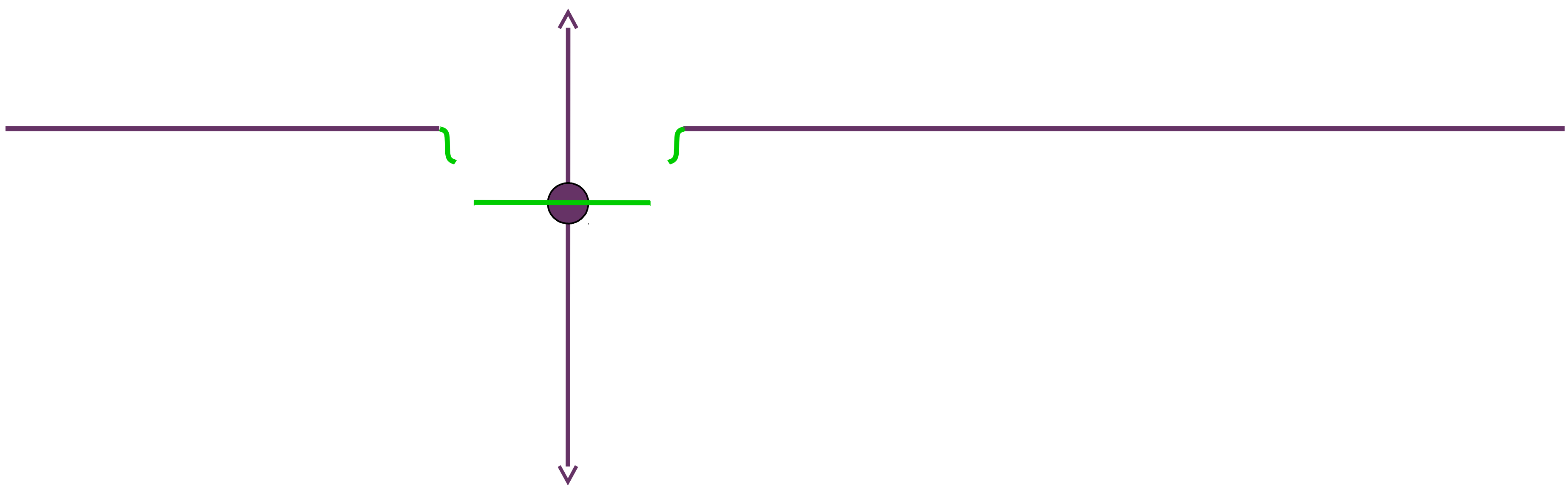
This speed limit means that light travels in a <u>wave</u>

When a charge moves, the information that it is at a new position travels outward at 300,000 km/s.



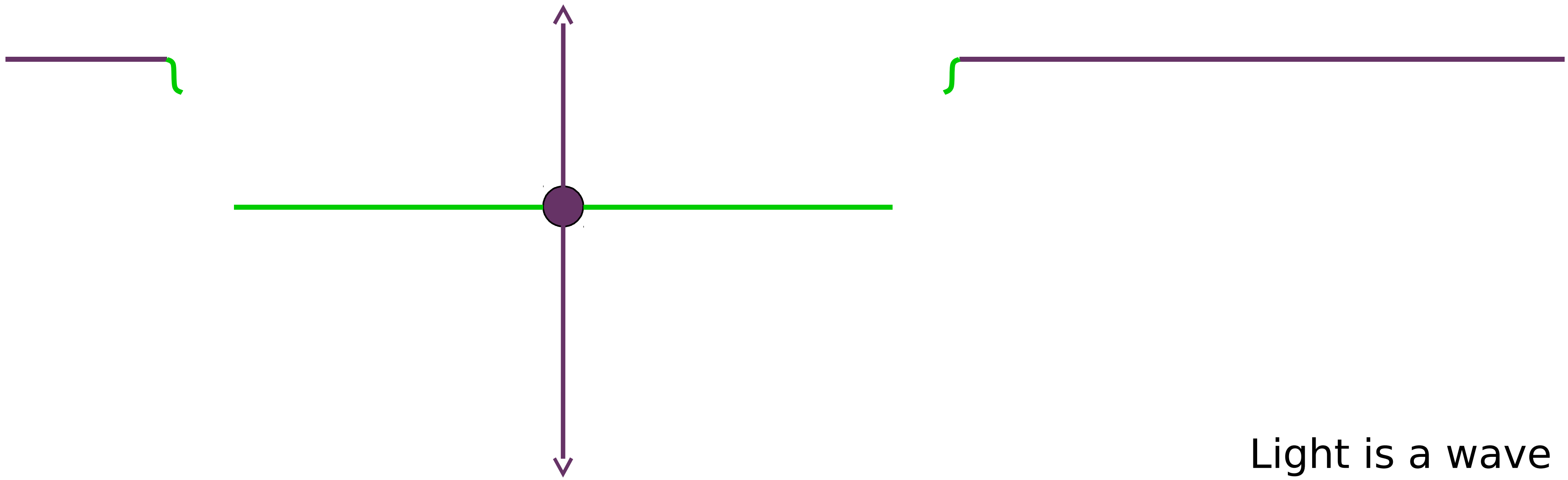
Light is a wave in the electric field

After 1 second, the electric field has changed only within a distance 1 light-second from the charge (about the distance from the Earth to the Moon).



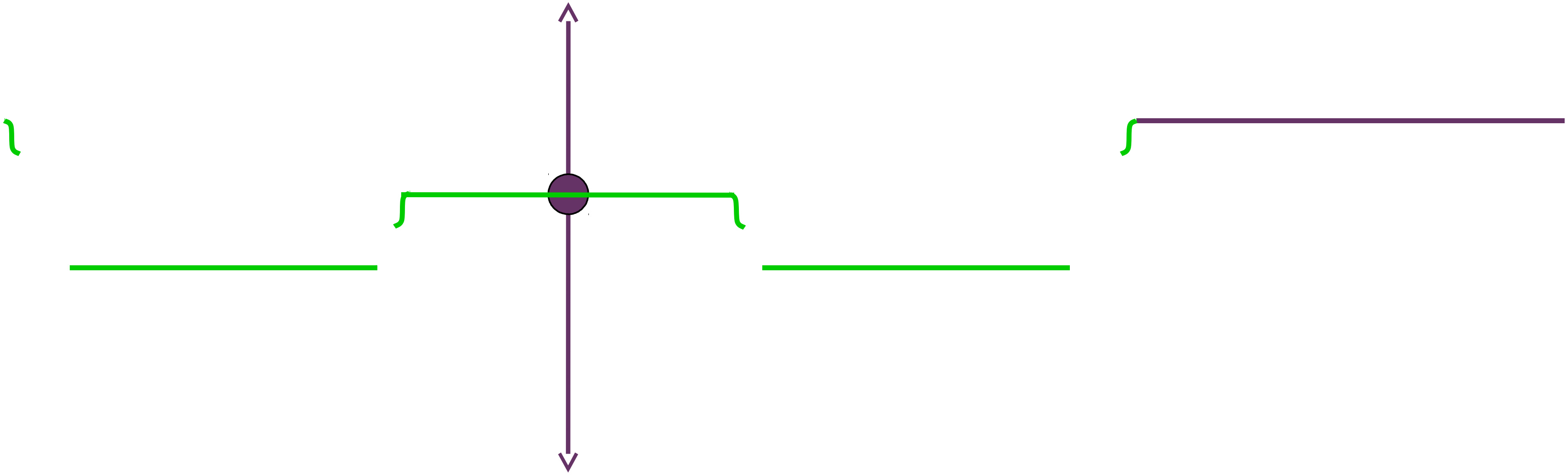
Light is a wave in the electric field

After 2 seconds, the electric field has changed within a distance 2 light-seconds from the charge.



Light is a wave in the electric field

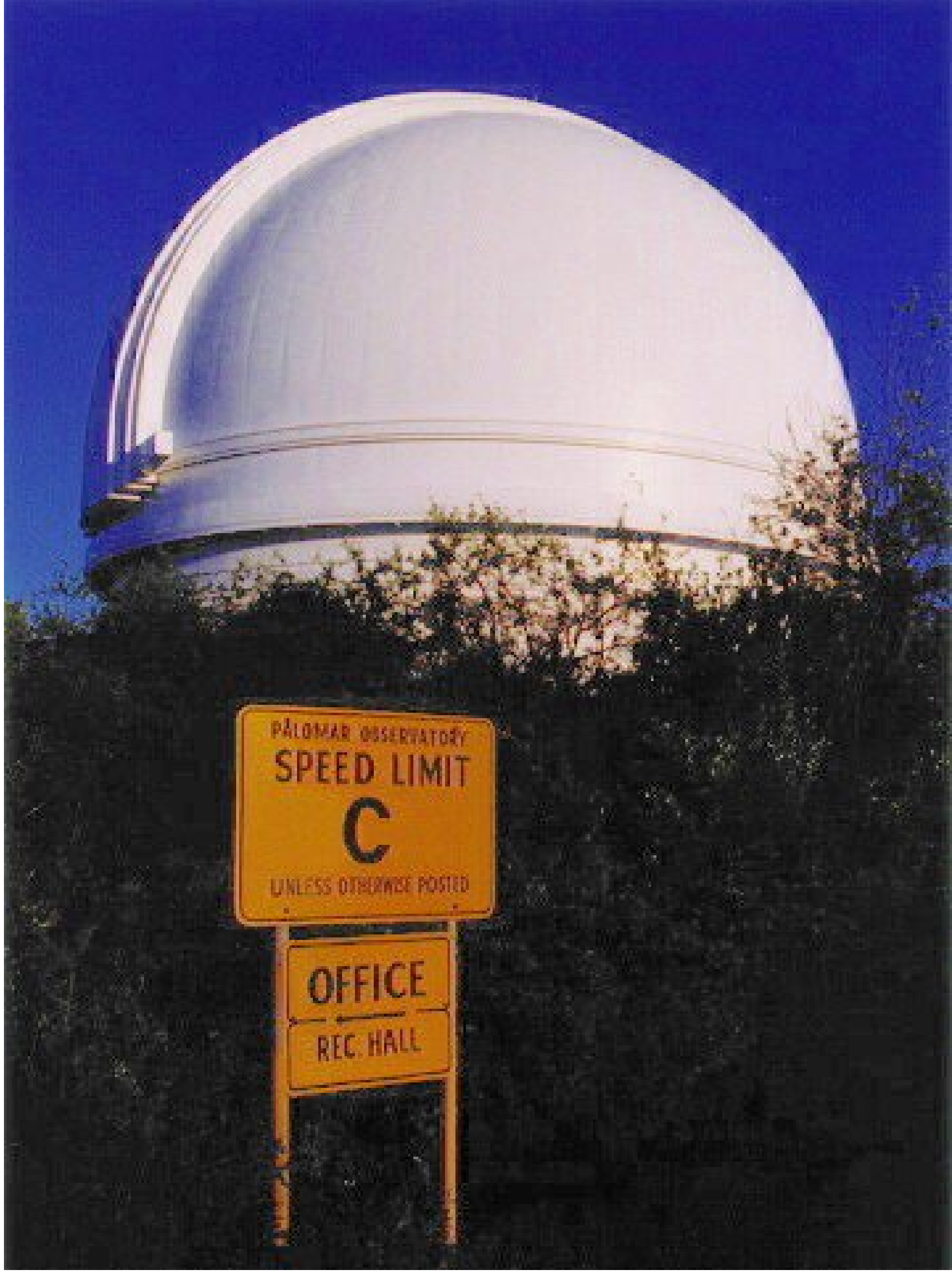
After 3 seconds, the electric field has changed within a distance 3 light-seconds from the charge.



Light is a wave in the electric field

This charge moving up and down creates a wave in the electric field that moves at 300,000 km/s.

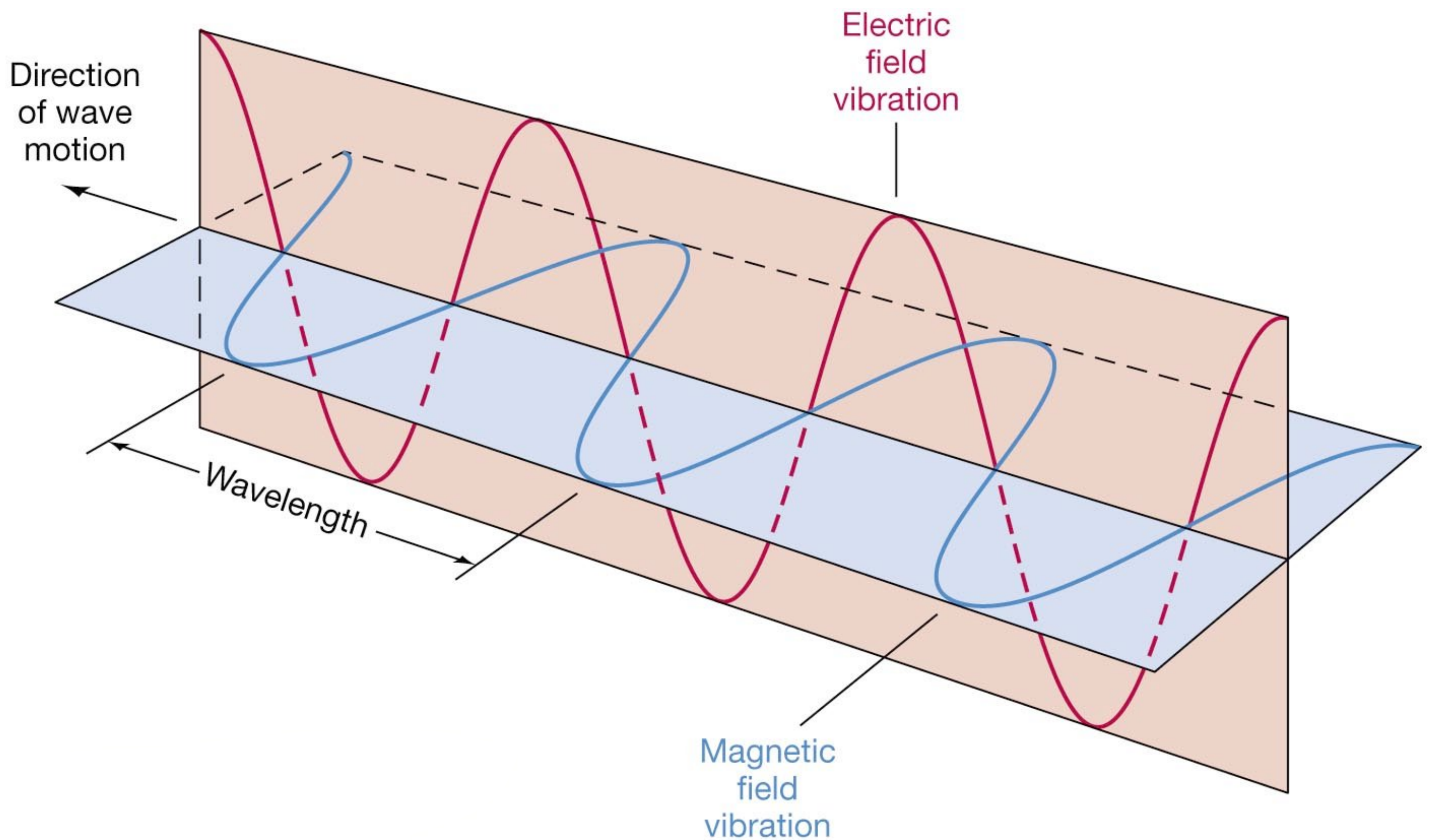
This wave in the electric field is what we call light, and the speed at which it travels is called the speed of light. We always use the letter c for the speed of light.



$$E=mc^2$$

speed of light

This is not quite the whole story. A changing electric field turns out to produce a **magnetic field**, so the wave is really a wave in both the electric field and magnetic field. But it is the electric field that we see:



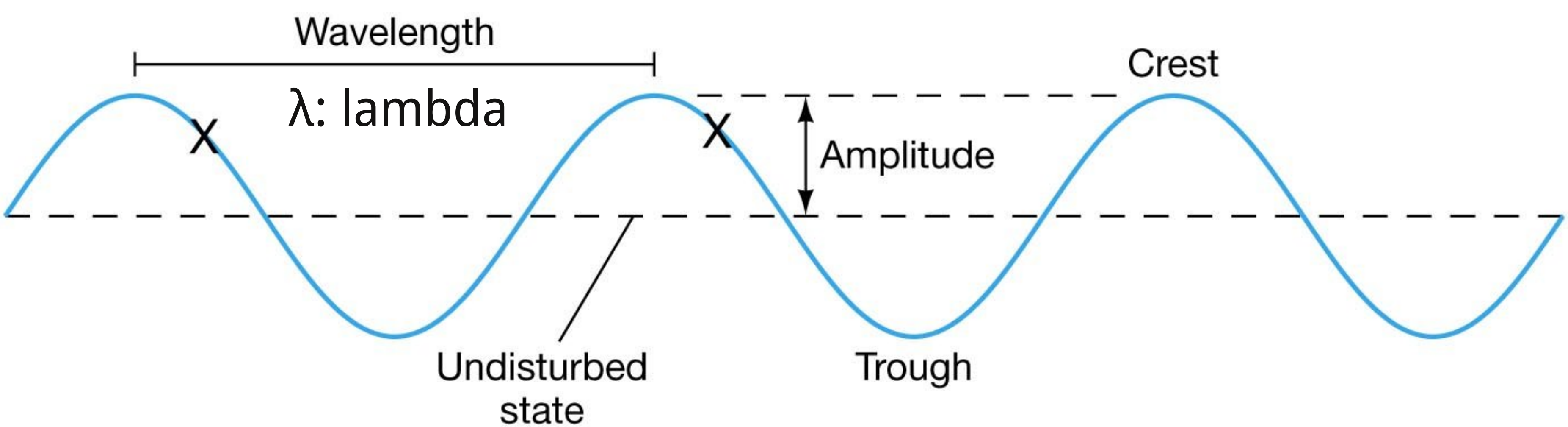
So light is also called electromagnetic radiation

Light characteristics

So light is a wave. There are two important characteristics about waves:

Frequency – number of waves that pass a point per second – units of Hertz or Hz

Wavelength – distance between wave crests



All electromagnetic radiation (light) is defined by its wavelength (or frequency).

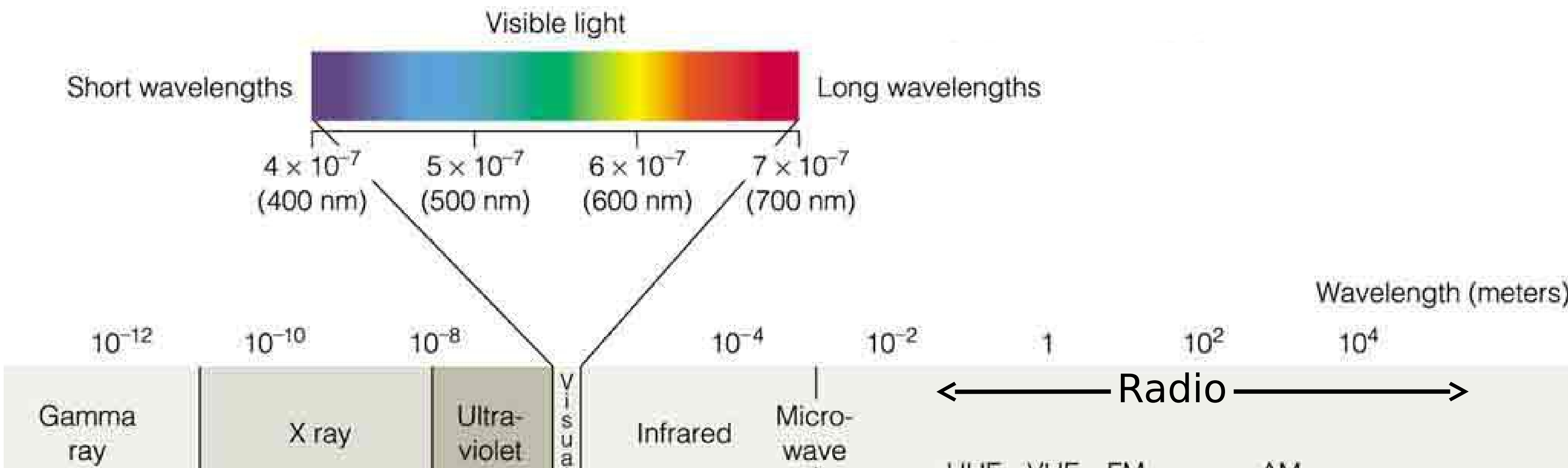
For visible light the longest wavelength is red and the shortest is violet.

A prism can break up light into its colors, which are defined by wavelength – discovered by Newton.

The complete spectrum of light

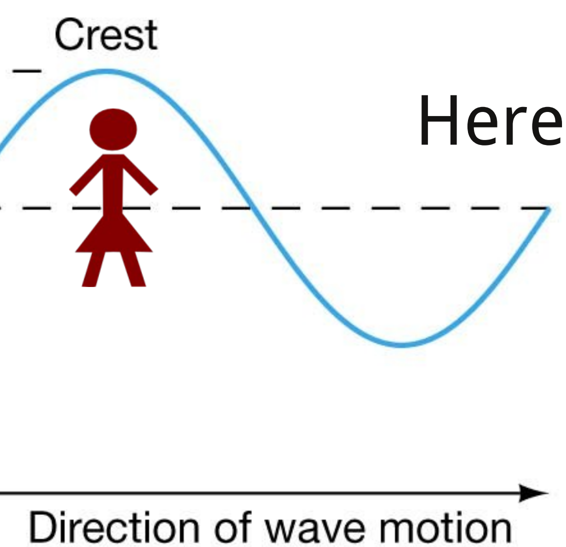
But visible light is only a narrow part of the full spectrum of electromagnetic radiation.

- Visible wavelengths have wavelengths between 400 nm (violet) and 700 nm (red)
  1 nm = 1 nanometer = 10-9 m.
- There is stuff at longer and shorter wavelengths.



Relation between frequency and wavelength

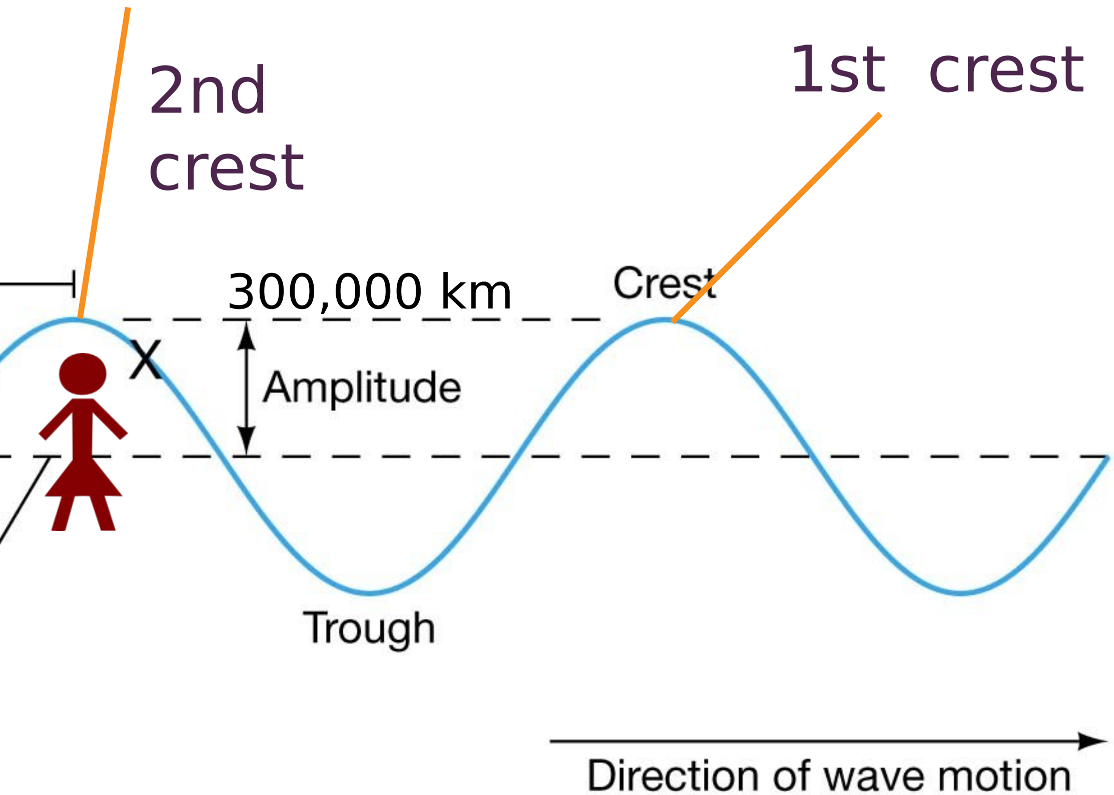
This is a distance = speed x time problem.
Look again at a wave moving by you, with one crest passing you each second, for a slow frequency of 1 crest per second or 1 Hz.
In the second between crests the first crest has moved away at the speed of light.



Here is the first crest passing you.

The second crest is now passing you. The first crest has moved one second at the speed of light, so it is 300,000 km away from the second crest

This means that the distance between crests is 300,000 km. This is the wavelength of the wave.



Relation between frequency and wavelength

This is a very long radio wave with wavelength λ = 300,000 km, nearly the distance to the Moon.

Now suppose that in 1 second, 100 crests pass you (frequency $f = 100$ Hz).

Then the time between crests is 1/100 s and the wavelength is λ = 300,000 km/s x 1/100 s = 3,000 km.

A higher frequency (faster, more energetic electron) gives a shorter wavelength.

In general, for a frequency of f crests per second, you can see that the time between crests is $T = 1/f$.

The distance between crests is then given by distance = speed x time: i.e. $\lambda = c\,T$ or

$$\lambda = \frac{c}{f}$$

We can also reverse the relation to solve for the frequency

$$f = \frac{c}{\lambda}$$

Which of the following waves has the **highest frequency**?

A A radio wave with λ=21 cm

B X-rays with $\lambda=10^{-10}$ m

C Visible red light with λ=700 nm

D Infrared radiation with $\lambda=10^{-6}$ m

Which of the following waves has the **highest frequency**?

A — A radio wave with λ=21 cm

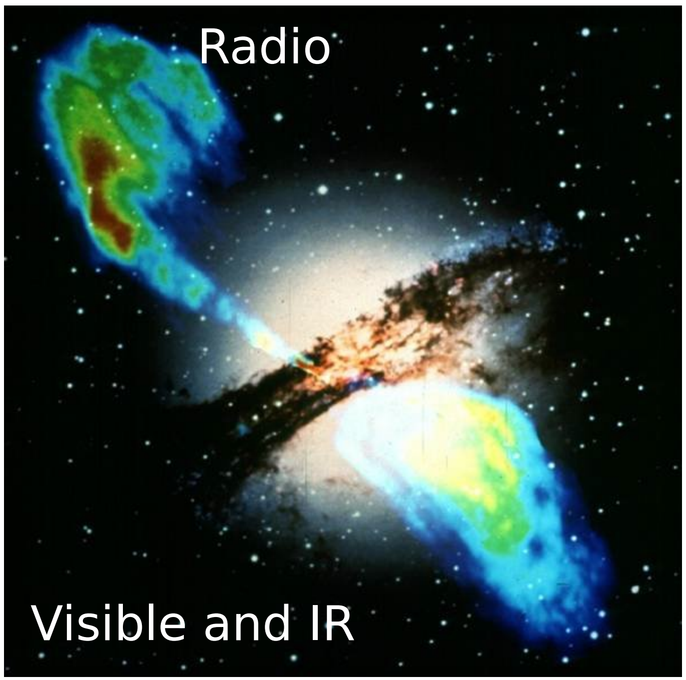
B — X-rays with λ=10^{-10} m

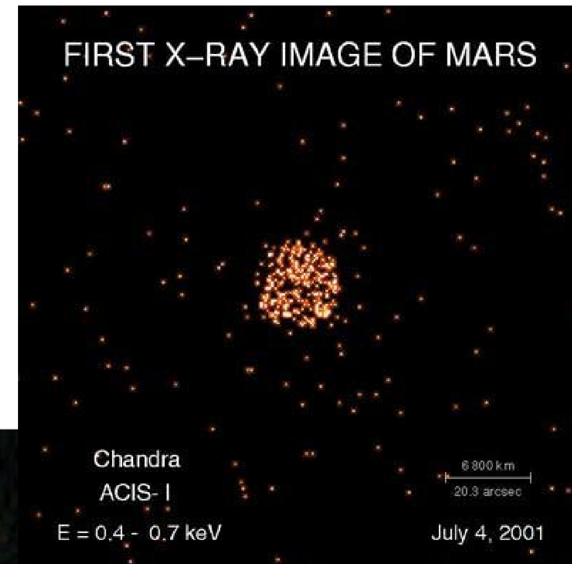
shortest wavelength = highest frequency

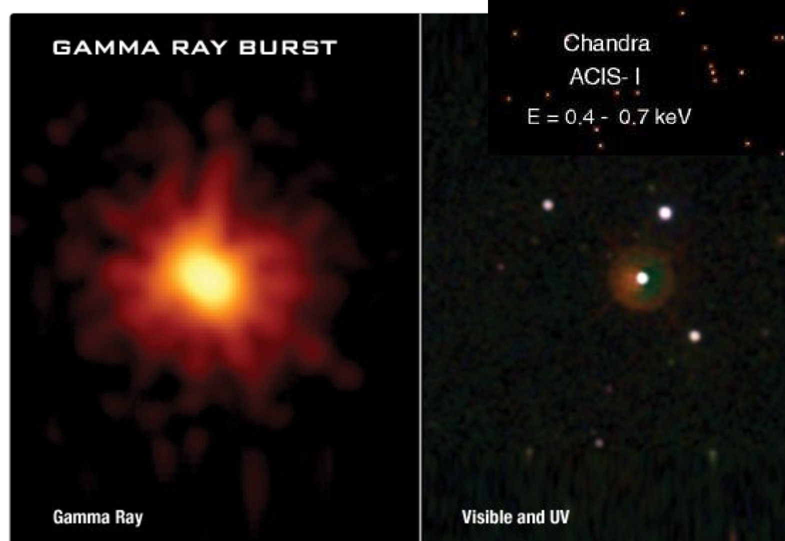
C — Visible red light with λ=700 nm

D — Infrared radiation with λ=10^{-6} m

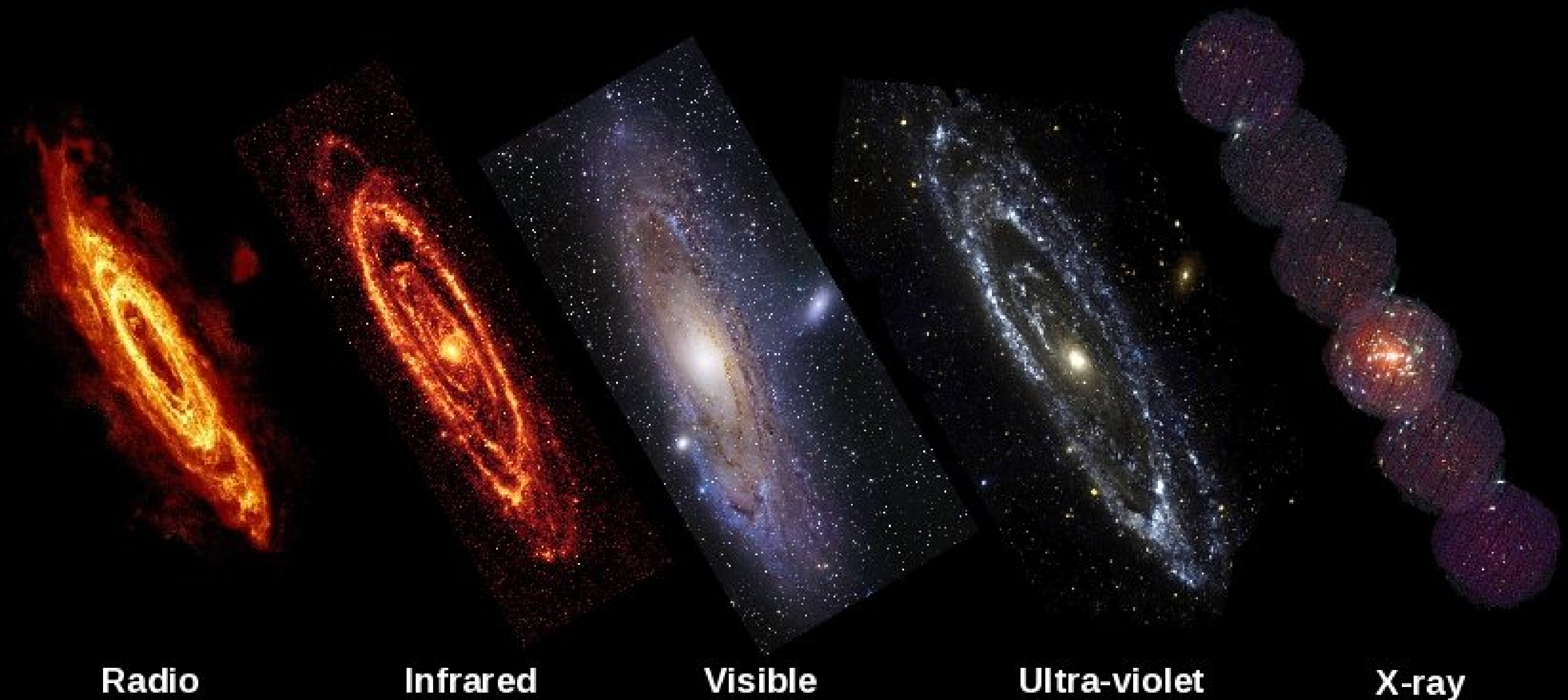
Astronomical objects produce radiation from the full electromagnetic spectrum, from very high frequency gamma rays to very low frequency radio waves – so astronomers observe at all wavelengths



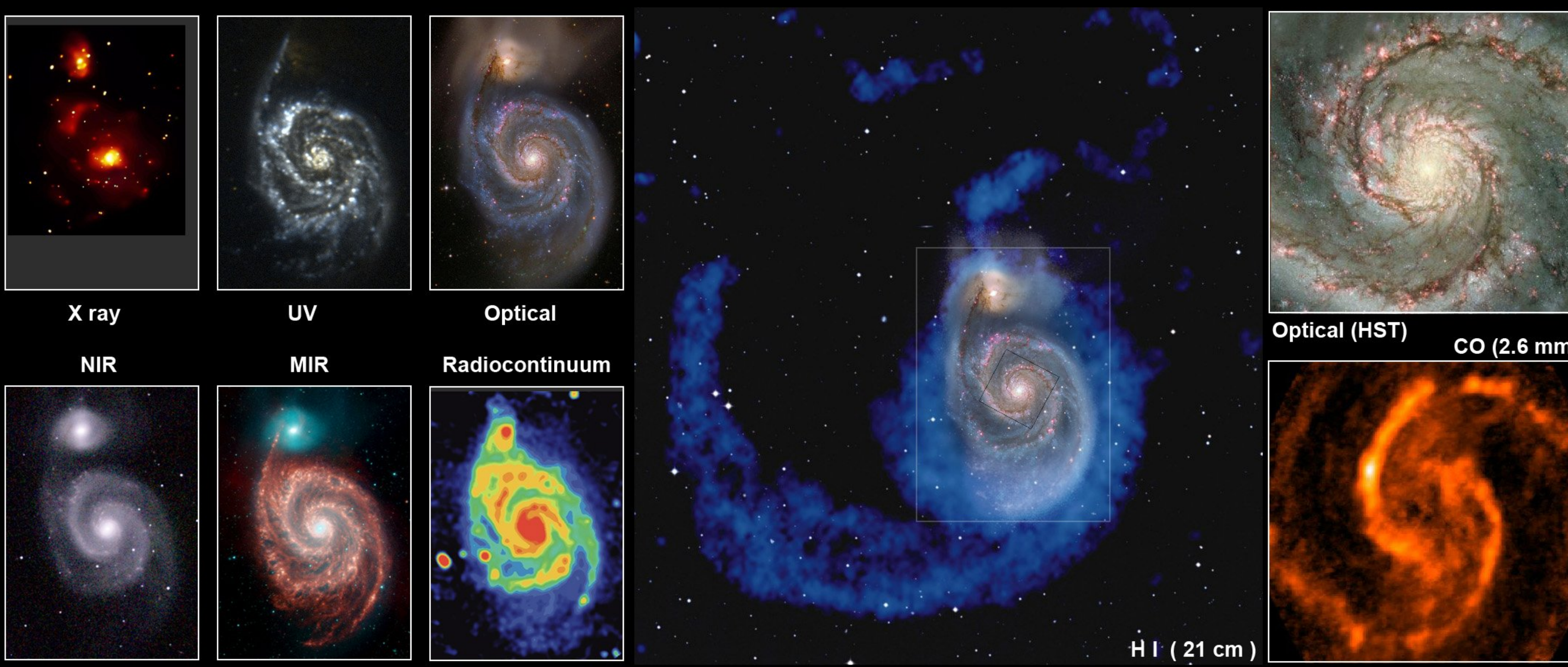


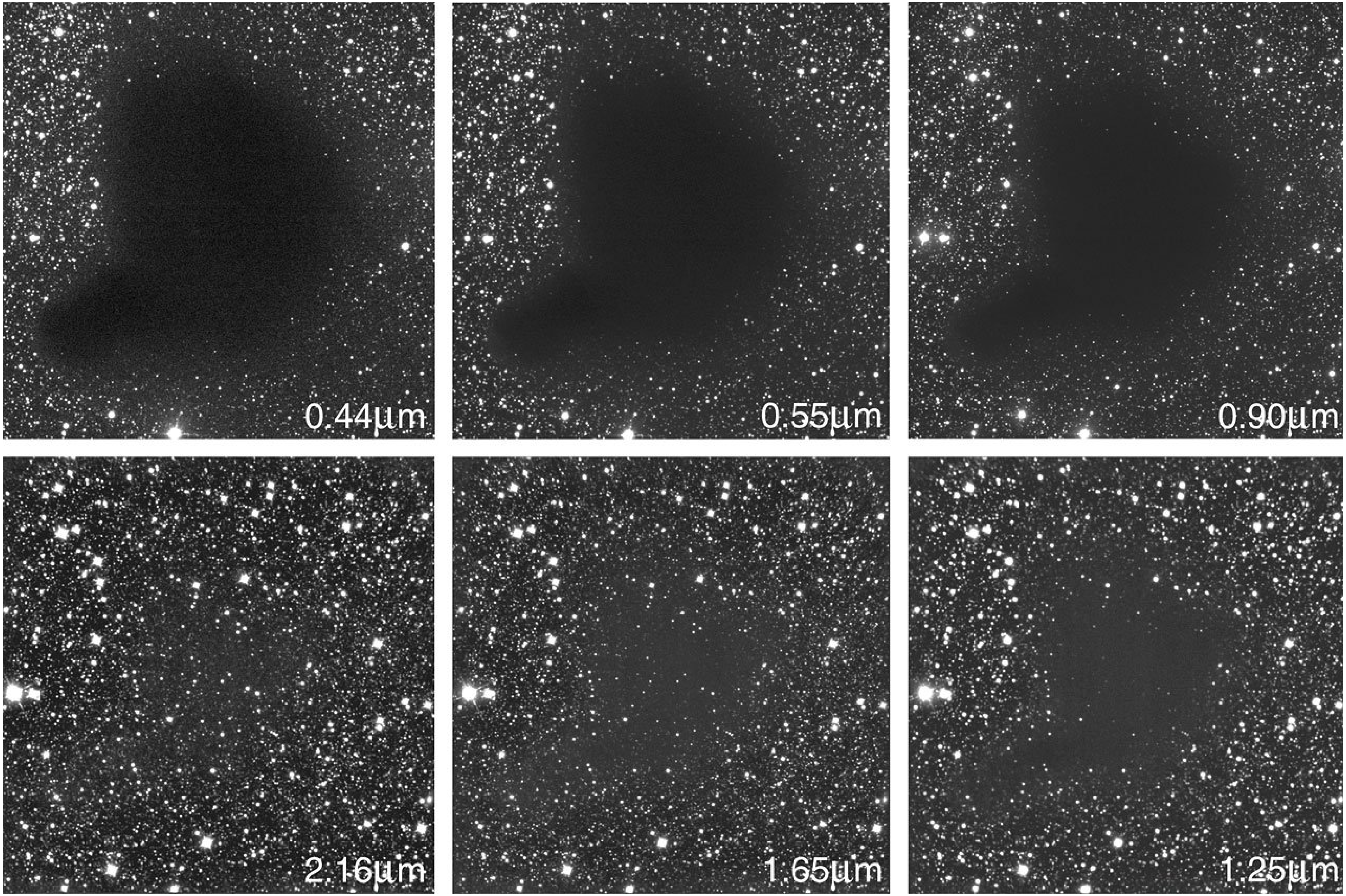


Astronomy across the spectrum



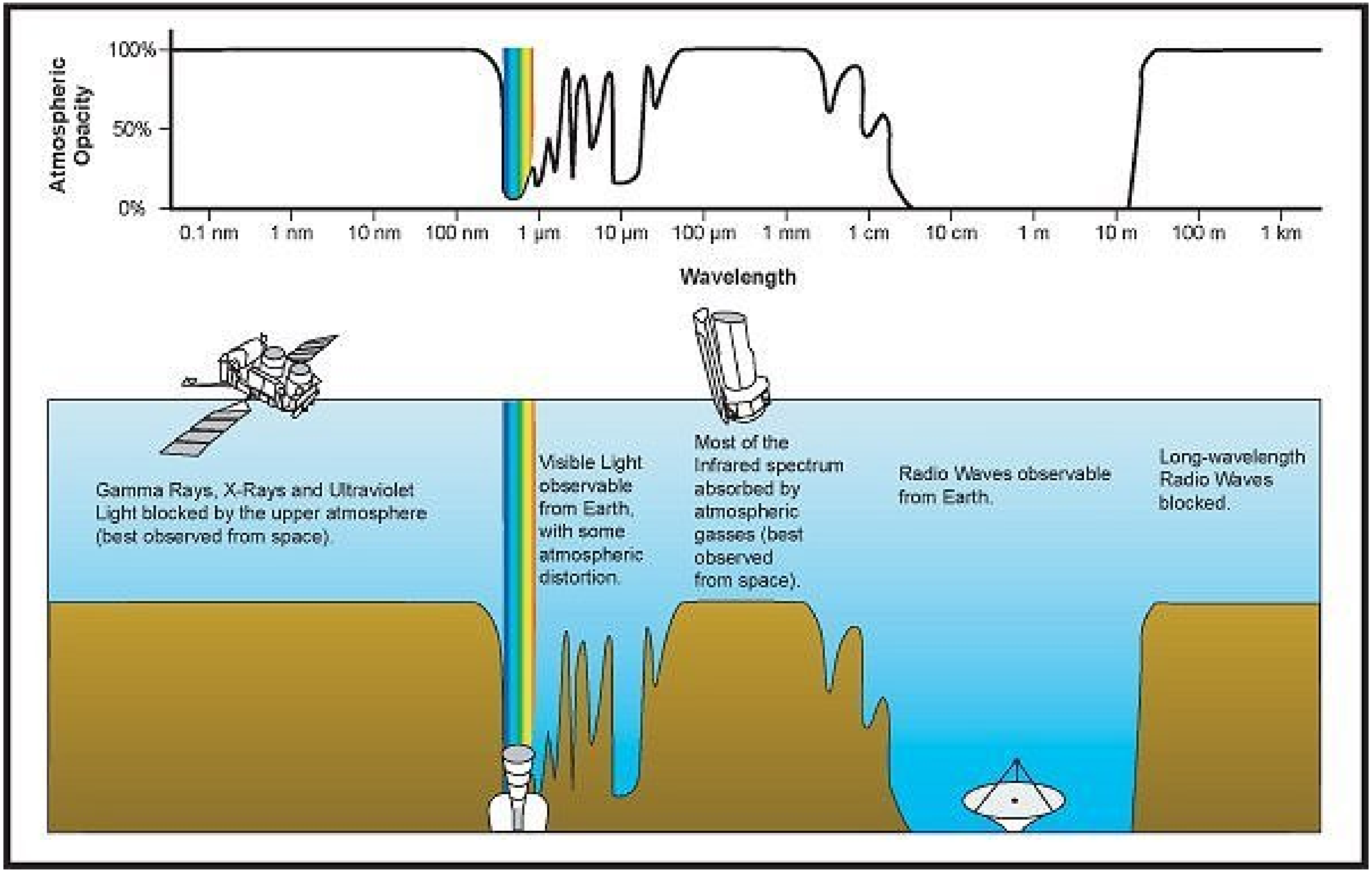
Astronomy across the spectrum



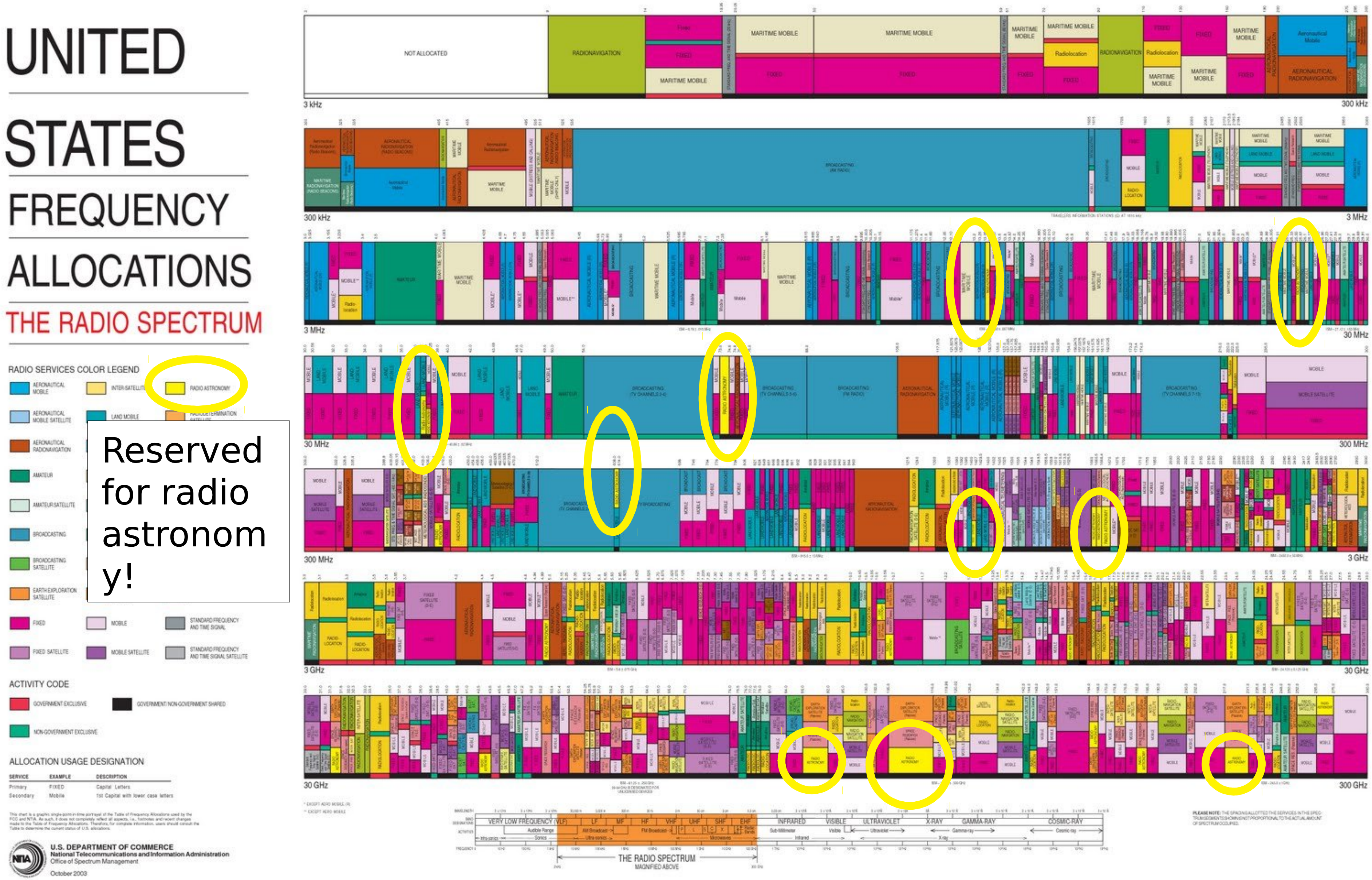


Bok Globule B68 – Source: ESO

Why send telescopes into space?



The radio spectrum is crowded!



Reserved for radio astronomy!

Astronomy across the spectrum

Pillar in NGC 2174 ▪ *Hubble Space Telescope*

Visible ▪ WFPC2 ▪ 2001

Infrared ▪ WFC3/IR ▪ 2014

Astronomy across the spectrum

Source: http://christensenastroimages.com/

Astronomy across the spectrum