Astronomy beyond the visible

Beatriz García, Ricardo Moreno, Josep Corominas

International Astronomical Union
ITeDA and Universidad Tecnológica Nacional, Argentina
Colegio Retamar, Madrid, Spain
Escola Pia, Sitges, Spain

Goals

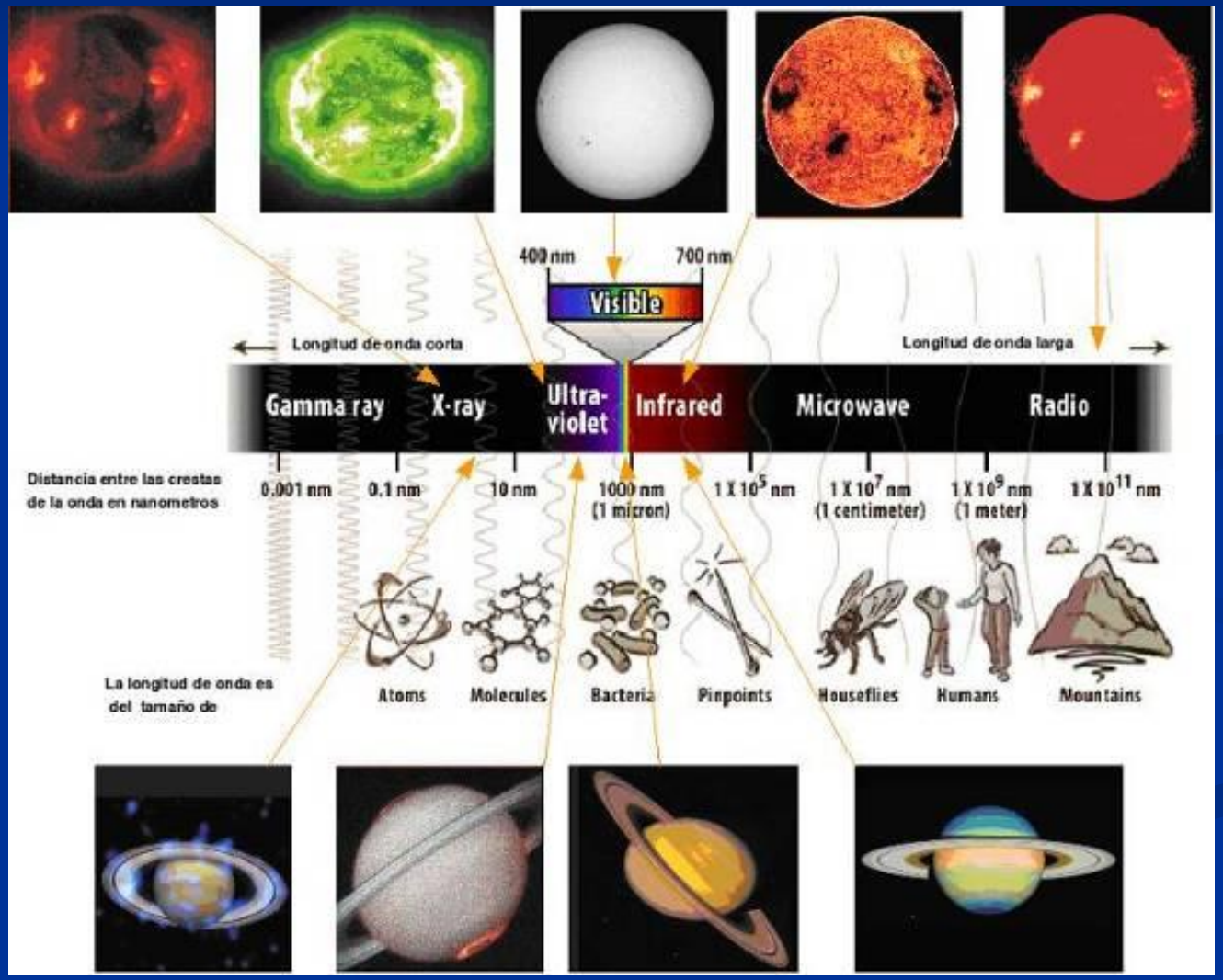
- Show phenomena beyond the visible, e.g. the electromagnetic energy emitted by celestial bodies, but undetectable by the human eye.
- Perform several simple experiments for determining the existence of emission in the wavelength regions of radio waves, infrared, ultraviolet, microwave and X-ray.

Presentation

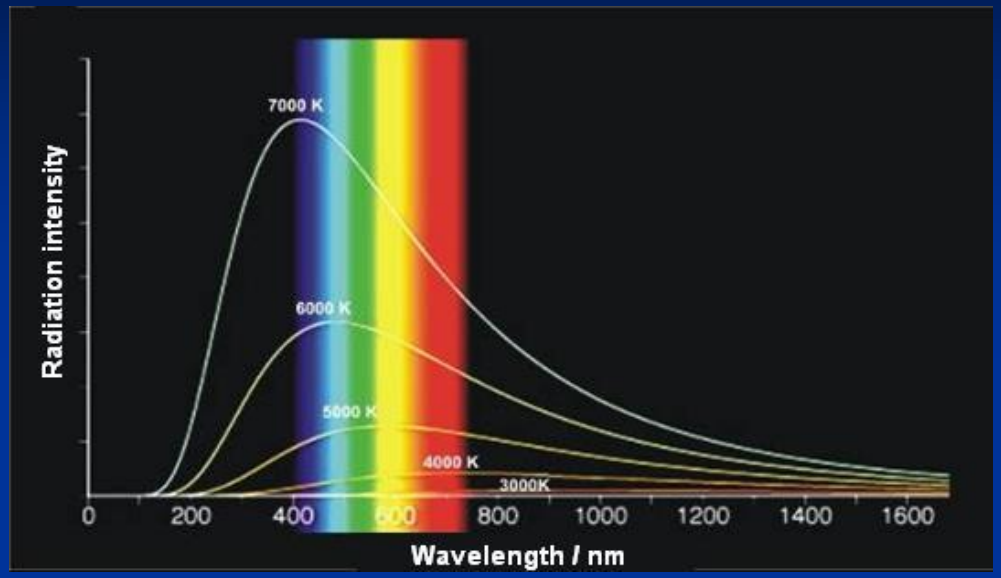
- For centuries, the universe had been studied only with the light detected by the human eye.
- There is information that comes electromagnetic waves of other wavelengths that our eyes cannot see.
- Astronomers observe today in the radio, microwave, infrared, ultraviolet, X-rays and gamma rays as well as in visible rays.

Electromagnetic Spectrum

All wavelengths of electromagnetic radiation.



Blackbody Radiation



Any "black body" when heated emits light at many wavelengths.

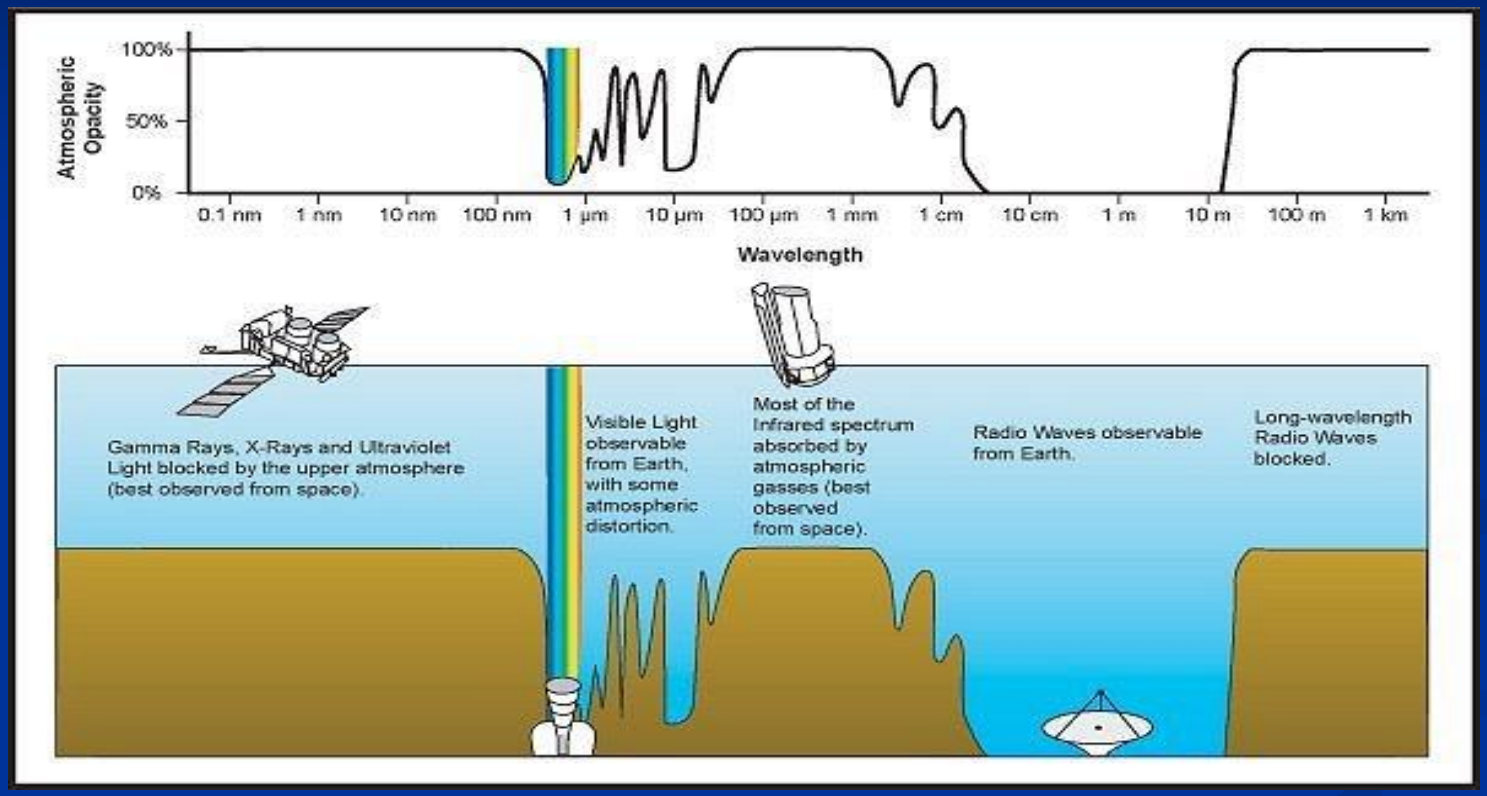
There is λ_{max} at which the intensity of radiation is maximum. This λ_{max} depends on the temperatura T:

$$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T} \quad (m)$$

Wien's Law

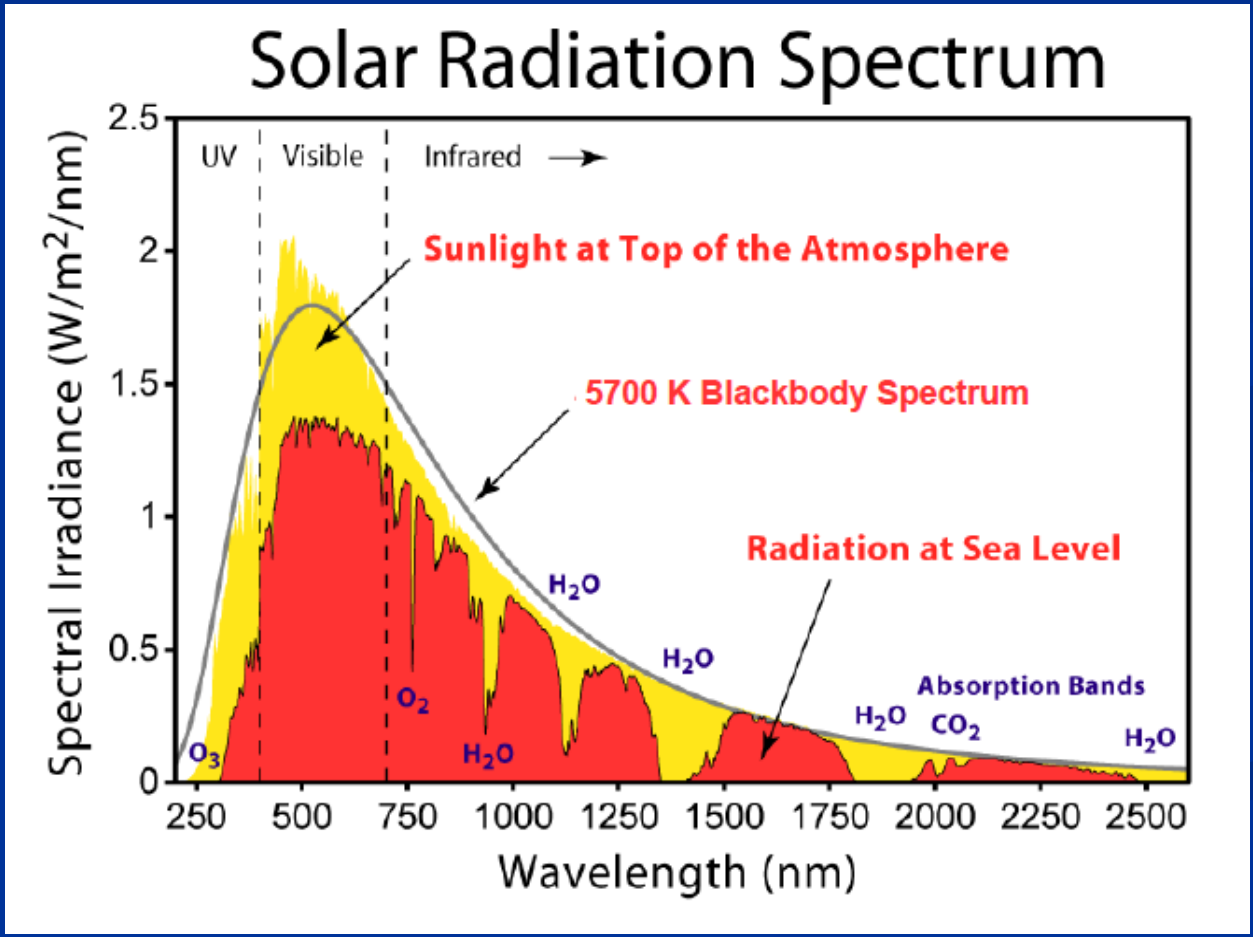
By studying the radiation of a distant object, we can measure its temperature without having to go there. This applies for the stars, which are almost black bodies

Solar radiaton
Windows for different energy regions



The Earth's atmosphere is opaque to most wavelengths of radiation. We can detect the hight energies from space and low energies require special detectors.

When the solar electomagnetic energy goes through the atmosphere, the "black body" radiation change, but the λ_{max} at which the irradiance is máximum remains almost without change

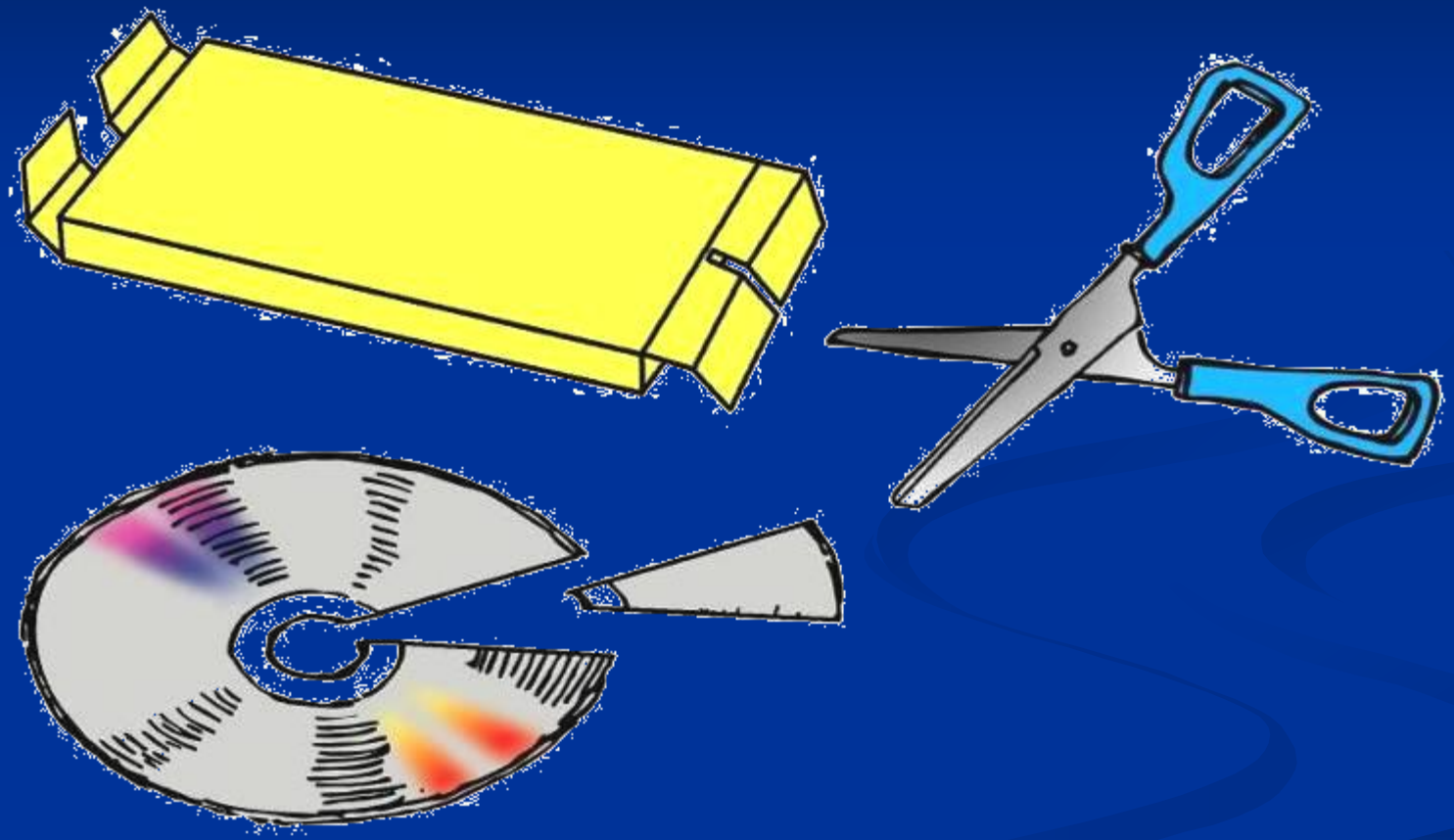


We know that there is λ_{max} at which the irradiance or emission is maximum depends on the temperature T, but it does not need to be in a visible region of the spectrum

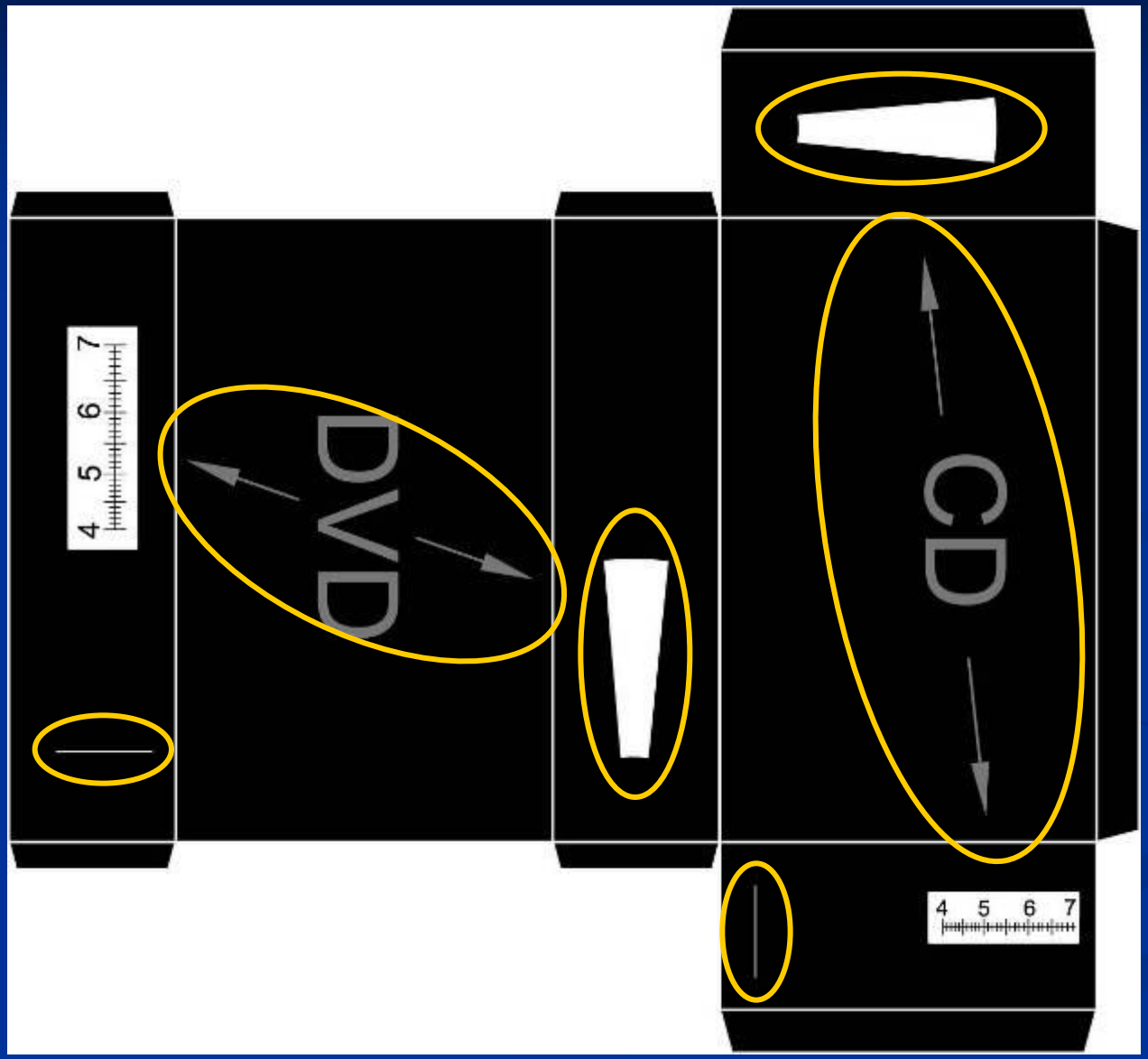
For example, the human body has a temperature of T = 273+37 = 310 K. Then, emits the maximun in $\lambda_{máx}$ = 9300 nm.

The night vision devices uses this $\lambda_{máx}$.

Activity 1: Building a spectrometer



Activity 1: Building a spectrometer



Depending what you use, a DVD part or a CD one, you cut the matching portions the template.

Activity 1: Building a spectrometer

Remove the metal layer of the CD using tape or scratching it.

NB! The coating will not peel off white or commercial CDs.

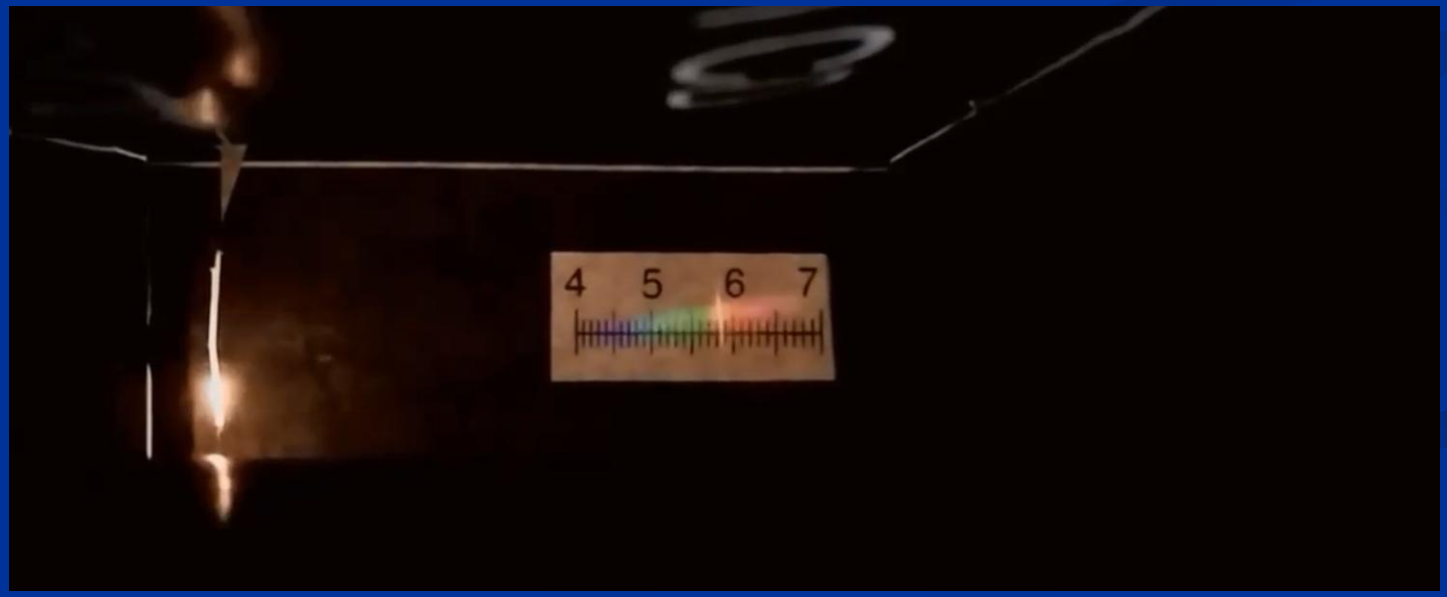
Activity 1: Building a spectrometer

The black surface folded on the inside.

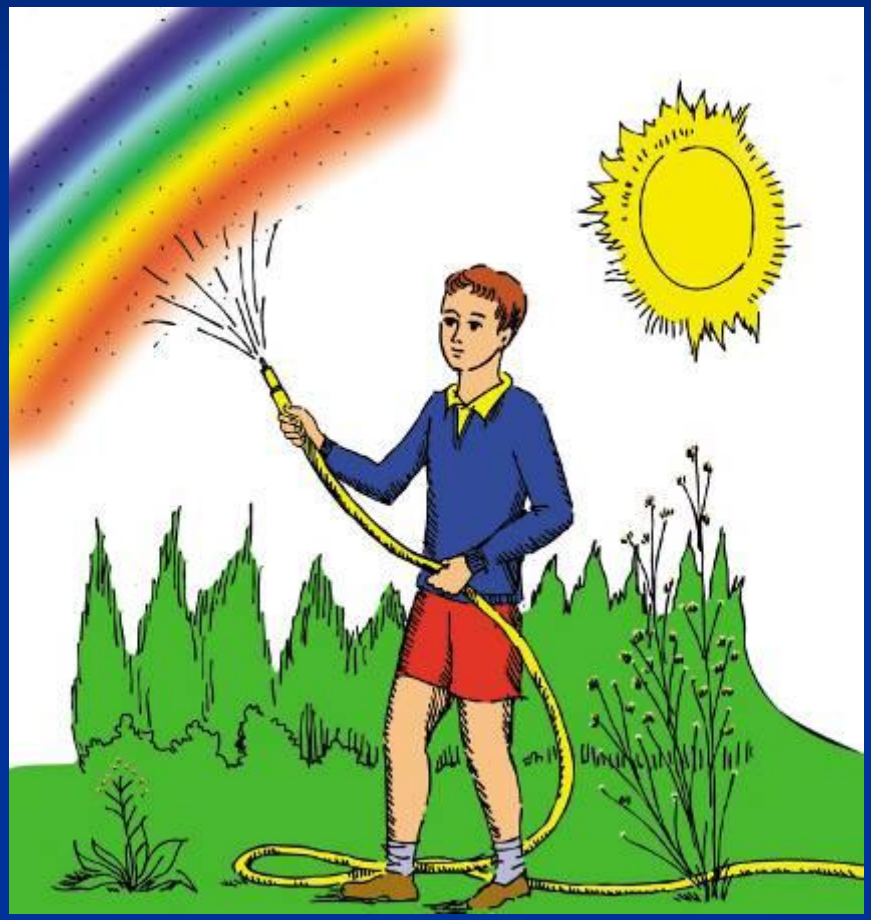
Compare the spectra from filament lamps, fluorescent lamps and streetlights.

Activity 2: Sodium lines visualization

Spectroscopy allows us to know the chemical composition of stars and exoplanets by studying the spectra that come to us. Let's see an example using a candle where we will impregnate the wick with a little common salt (Na Cl) to see the Sodium emission line that corresponds to a wavelength of 589.



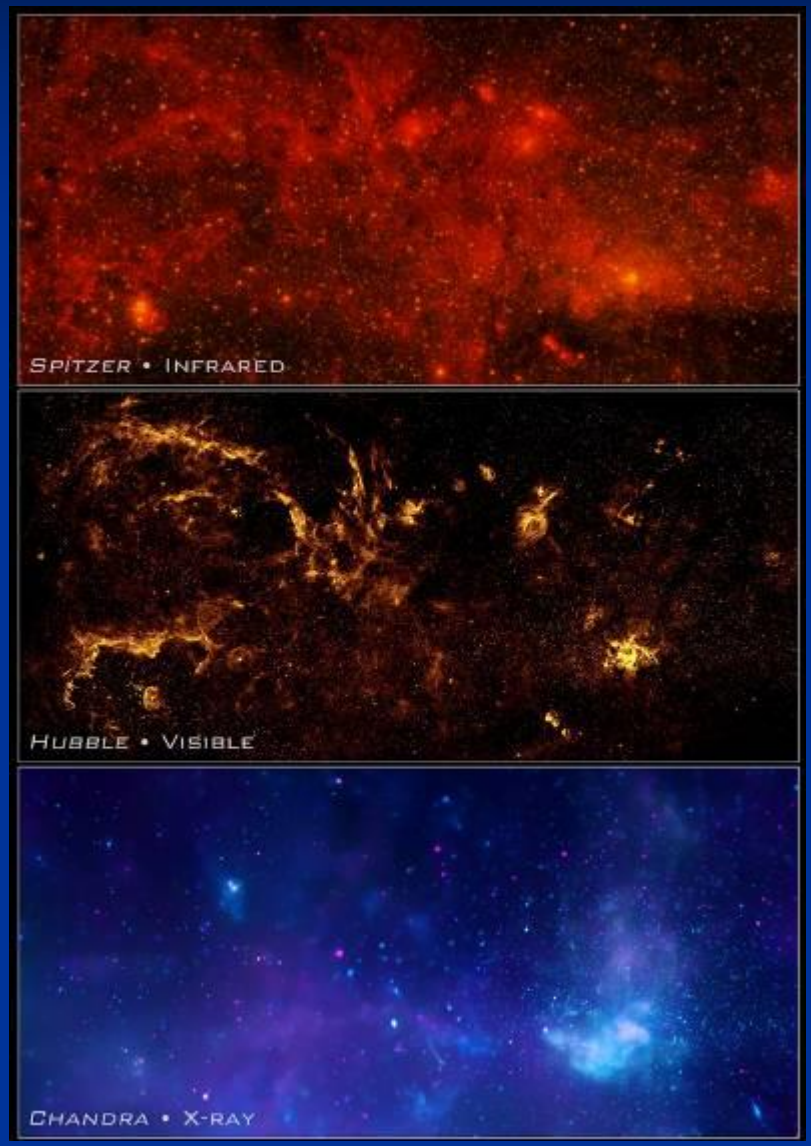
Activity 3: Decomposing sunlight with water drops



Children can split the sunlight and make a rainbow.

They need a hose with a fine spray. They must have their back to the Sun.

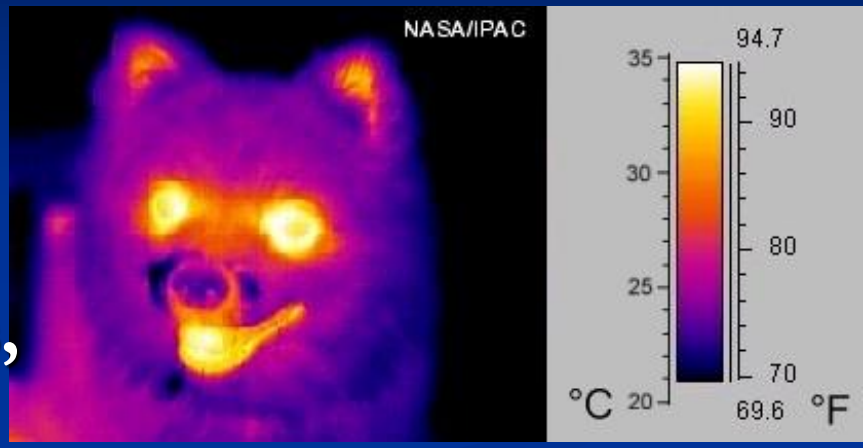
Other regions of the spectrum

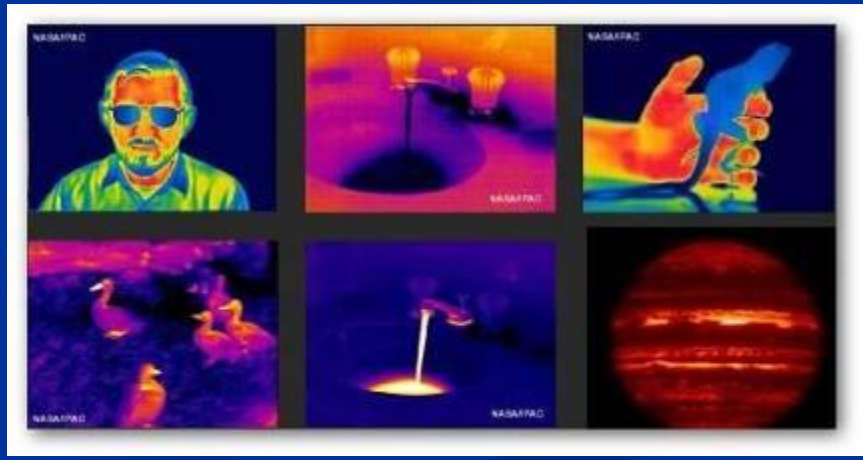


- There is a matter with a temperature much lower than that of the stars, for example, clouds of interstellar matter.
- They do not emit visible radiation, but emit infrared radiation, microwaves and radio waves.
- The type of radiation is associated with the processes that are occurring inside the object. E.g., details in the centre of our galaxy ...

The infrared radiaton

- William Herschel discovered the infrared using the prism and thermometers.
- It is a property of warm bodies, even those not hot enough to emit visible light.
- To highlight this radiation we establish an equivalence between temperature and colour.

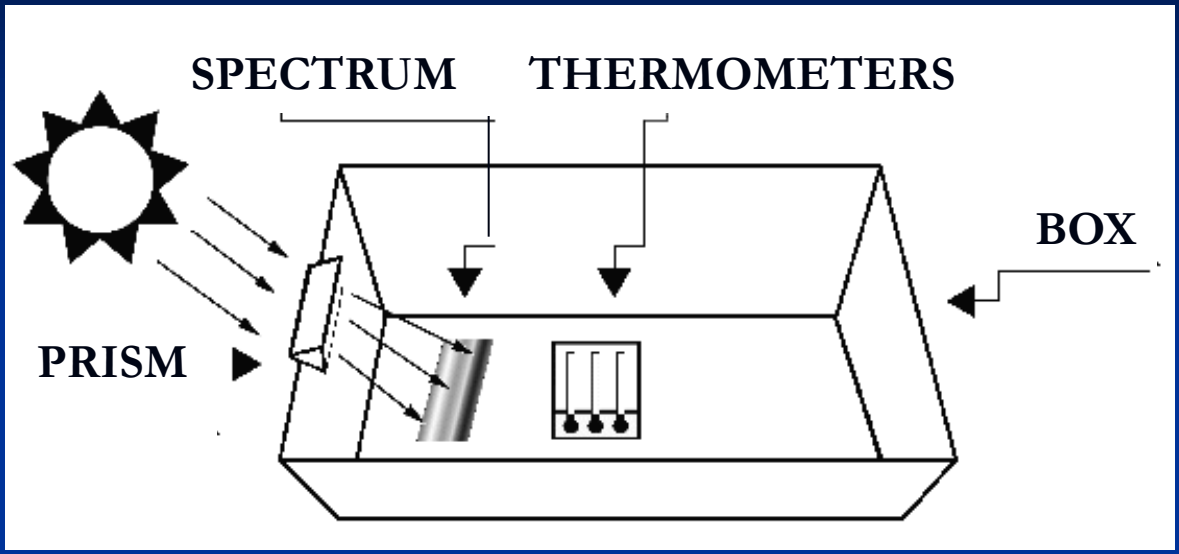


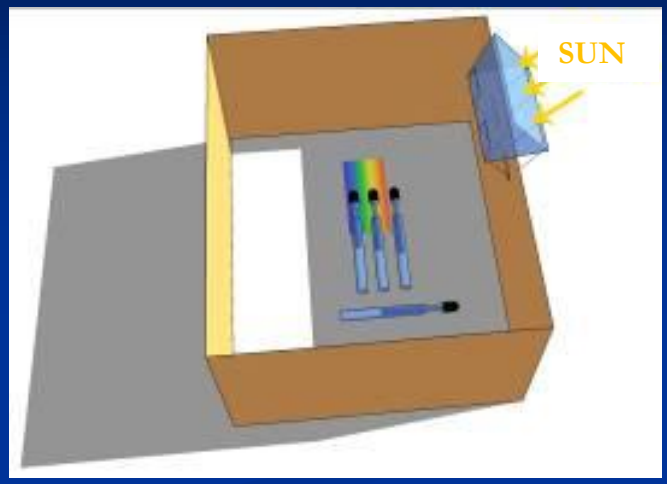


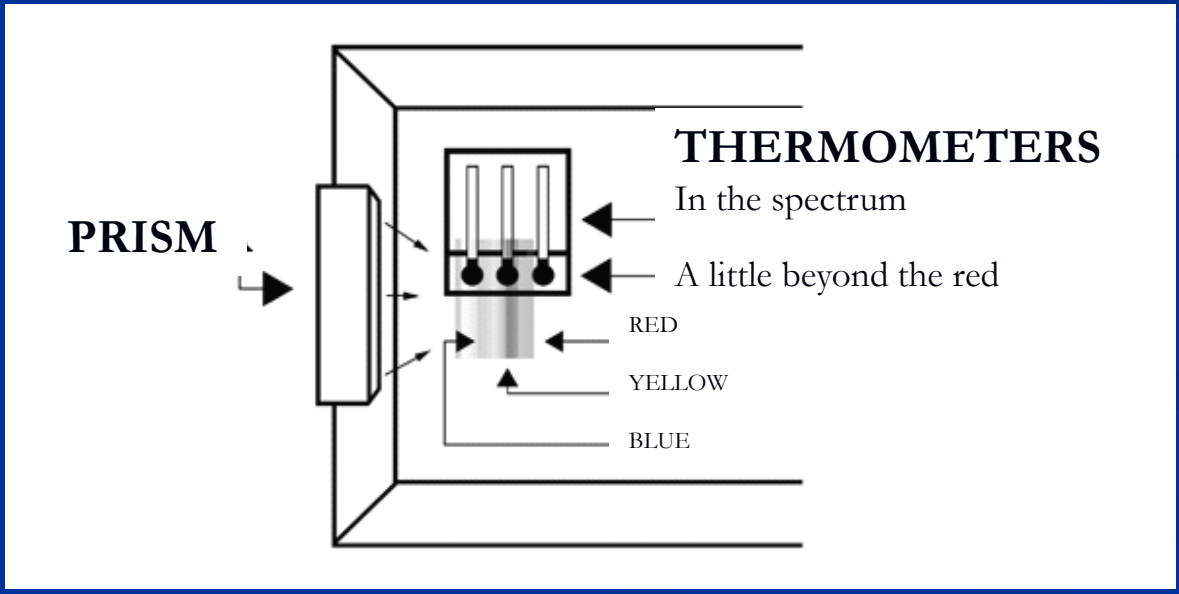
Activity 4: Herschel Experiment

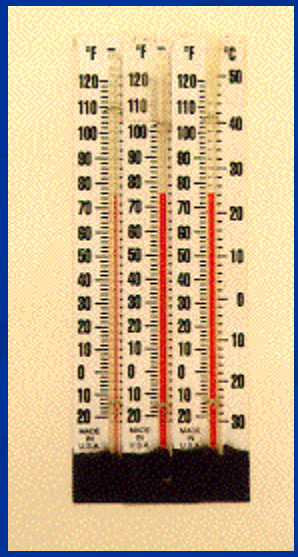
- In 1800, Herschel discovered the infrared in sunlight.

Activity 4: Herschel Experiment

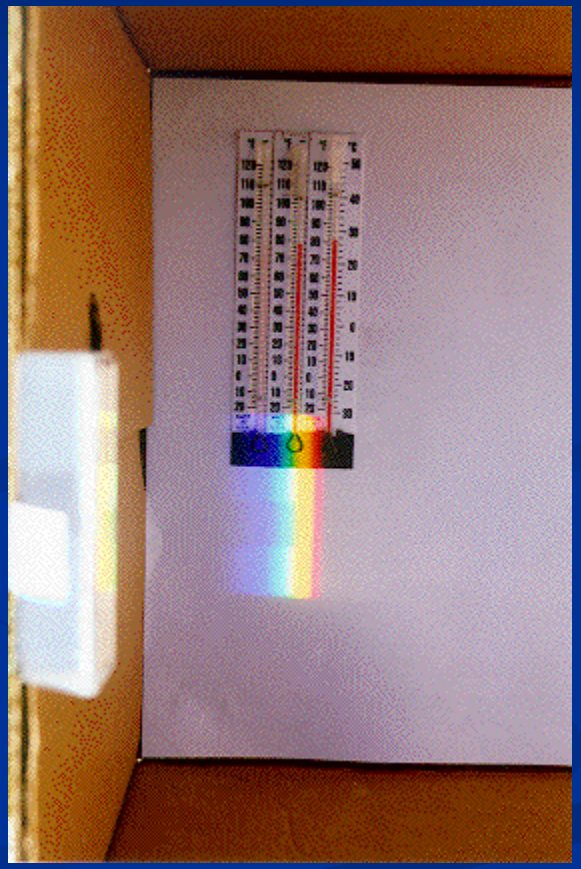








Activity 4: Herschel Experiment



Activity 4: Herschel Experiment

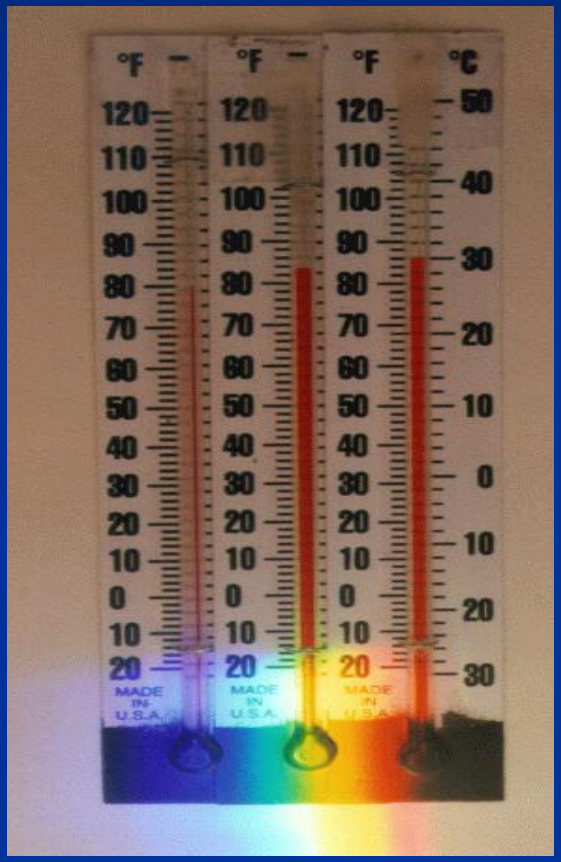


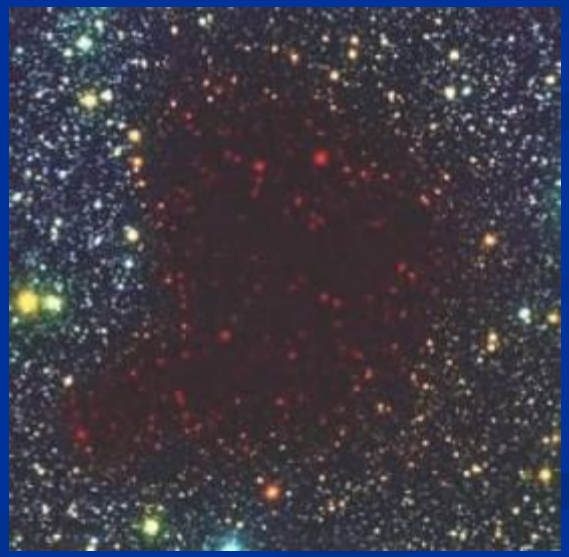
TABLE OF DATA COLLECTION				
	Thermometer No. 1 in the blue	Thermometer No. 2 in the yellow	Thermometer No. 3 beyond the red	Thermometer No. 4 in the shadow
After 1 minute				
After 2 minutes				
After 3 minutes				
After 4 minutes				
After 5 minutes				

Activity 5: IR detection with a phone

- Remote controls emit infrared signals but our eyes cannot see them.
- Many but not all mobile phones cameras are sensitive in IR.

The power of the infrared

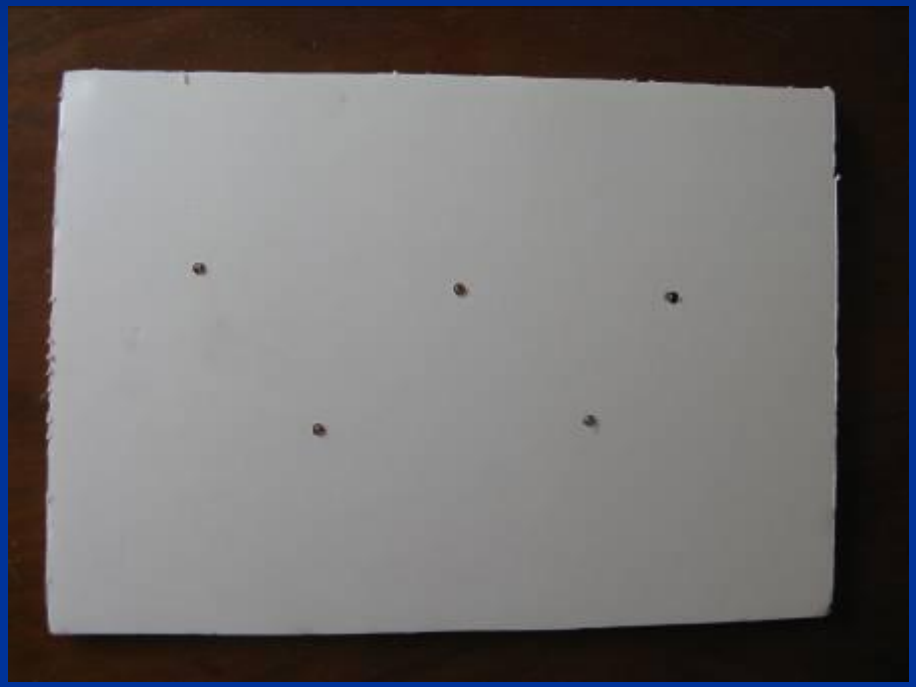
- The interstellar dust absorbs visible light but not infrared so much.

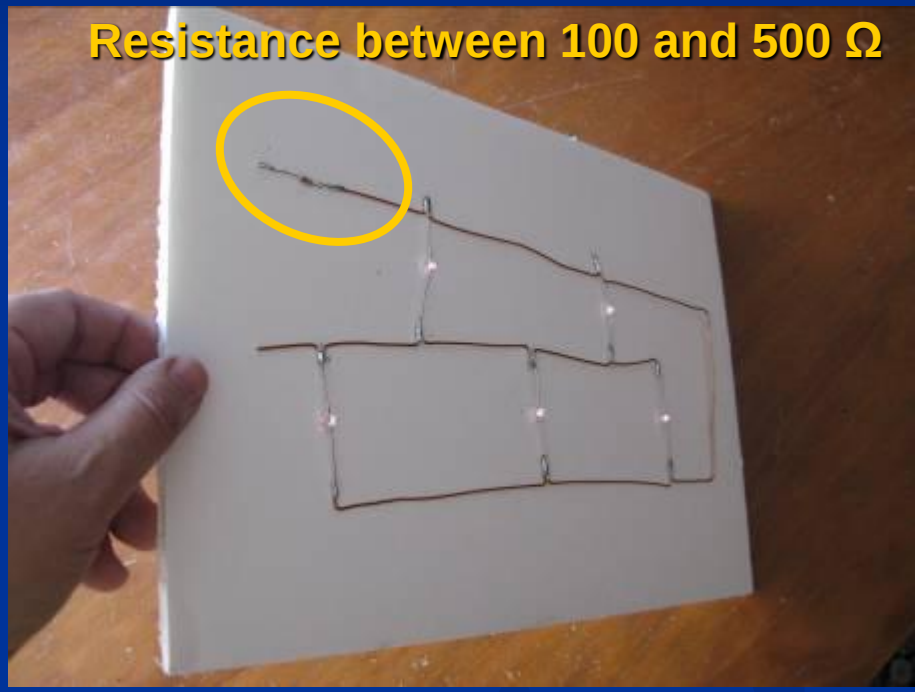


Activity 6: Detection of IR light of a bulb

- Most of the energy emitted by an incandescent bulb is in the visible region, but it also emits infrared that can penetrate some fabrics that cannot be penetrated with visible radiation.
- The same happens with the galactic dust, which can be detected from its infrared emissions, but is opaque in the visible region.

Activity 7: Constellation with IR LEDs



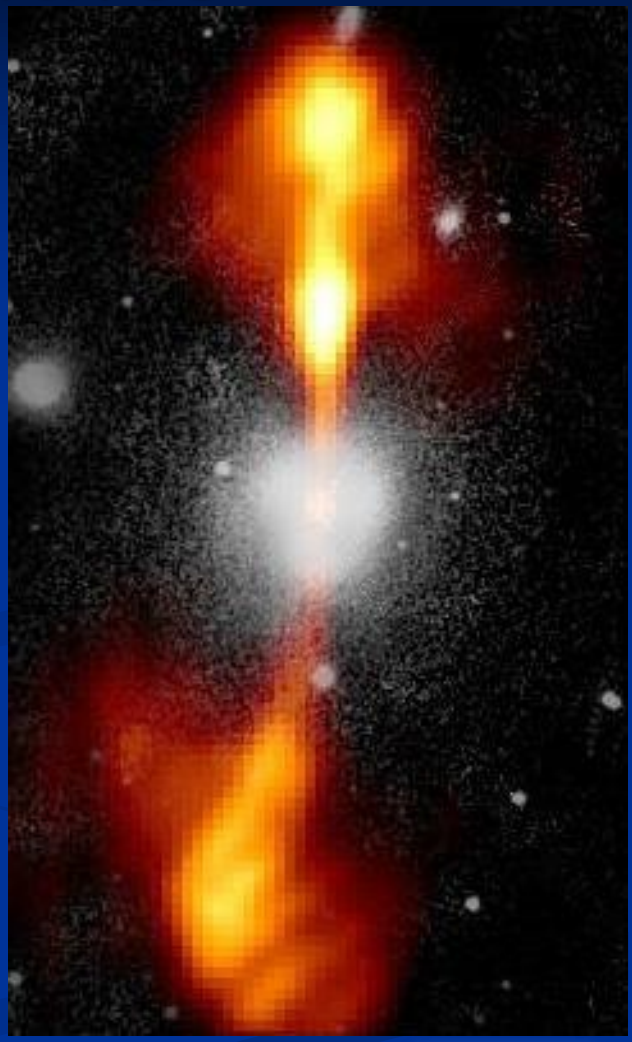


Cassiopeia with IR LEDs.

Activity 8: Constellation with remote controls

Emission of radio waves

- EM radiation with wavelengths from metres to kilometres is called radio waves.
- They are used for commercial stations.
- Radio waves also come from space, and thus provide information that cannot be seen at other wavelengths.



Activity 9: Producing radio waves

ET calls home by producing radio waves

Activity 9: Producing radio waves

Materials needed:

- 2 m of varnished electrical wire*, between 0.2 and 0.5 mm in diameter
- A regular pencil
- A graphite lead pencil (a colored pencil will not work) sharpened at both ends
- A 4.5 V or 9 V battery
- A simple AM radio receiver.

*If varnished electrical wire is not available, it can be substituted with a conventional plastic-coated electrical wire, but only one of the two wires will be used.

Activity 9: Producing radio waves

Procedure:

- Prepare a coil by wrapping the wire around any pencil, so that it has between 50 and 60 turns. You can keep it tightly wound with adhesive tape.
- Scrape off the protective varnish from the ends of the wire and, using a paper clip, secure one end of the wire to the battery (it doesn't matter if it's the positive or negative end).
- Connect the other end of the coil wire to one of the leads of the graphite pencil.
- Turn on the radio to the AM band (not FM).

Activity 9: Producing radio waves

- With the other end of the graphite pencil, we repeatedly touch the other end of the battery and move the dial until we hear the noise picked up by the radio, due to the waves being generated.

Ultraviolet radiation

- UV photons have higher energies than those of visible light. (UV-A black light is used for plant growth)
- UV-C destroys the chemical bonds between organic molecules. At high doses UV can be fatal for life. (UV-C is used for surgical material disinfection)
- UV-C radiation is filtered by atmospheric ozone. The ozone in the atmosphere is formed by the interaction between sunlight and O2, and it filters almost all UV light, allowing only the necessary for the development of life to pass through.

Johann Ritter discovered ultraviolet radiation in 1801

Ultraviolet radiation

- The Sun emits UV radiation, but most of it is filtered by the ozone layer at the top of our atmosphere; the amount that arrives on Earth is beneficial for life.
- This radiation is what makes our skin to tan.
- If the ozone layer decreased in thickness, the Earth would receive higher doses and skin cancers would proliferate.

Ultraviolet light

Andromeda Galaxy in visible light (Hubble)

Andromeda Galaxy in UV light (Swift)

Activity 10: Black Light (UV)

- There is matter that emits light when illuminated with UV. If it is FLUORESCENT, it emits light only while illuminated by UV light.

Marks of tickets or passports

Tonic water, which contains quinine

Activity 11: Phosphorescent and UV light

- There is matter that emits light when illuminated with UV. If it is PHOSPHORECENT, it emits visible light for a while.

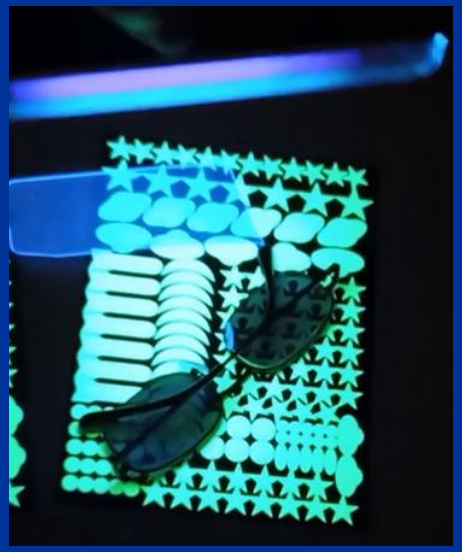
Little stars of decoration

Emergency posters

Activity 12: Filtering UV light

There are materials that filter a lot of UV light, such as glass. Sunglasses should be made of glass, not plastic, to protect the retina, which is epithelial tissue. If they are made of plastic (organic), they must have a UV filter

Glass glasses on phosphorescent material, illuminated with UV light



When you remove the glasses, you can see how they have filtered the UV light

X-rays

- More energetic than UV is the X-ray radiation.
- It is used for radiographs and other medical imaging techniques.

X-rays

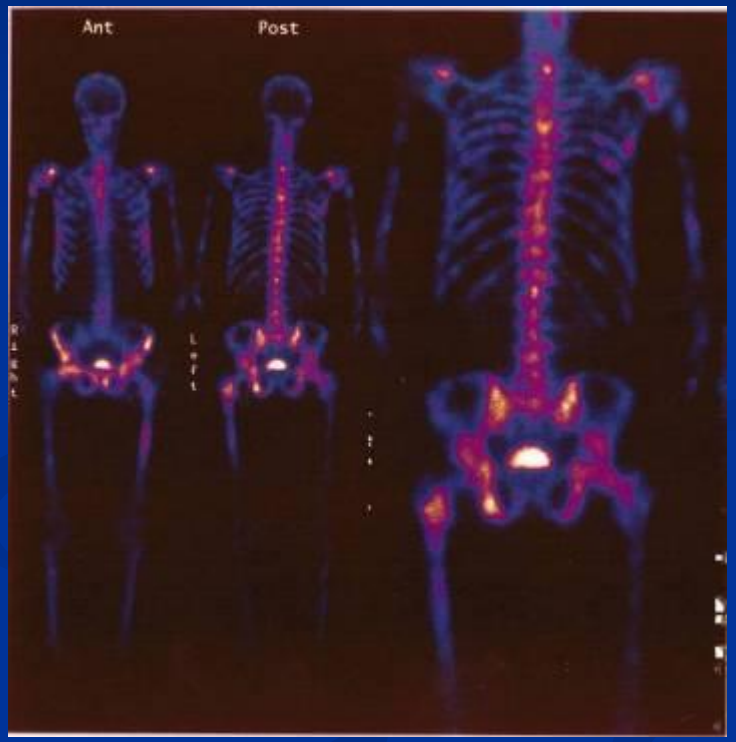
More energetic than UV

- In the cosmos, X-ray radiation is acharacteristic of high-energy events and objects: black holes, star collisions, etc.

- The mission of the Chandra Space Telescope is to detect and monitor these kinds of events and objects

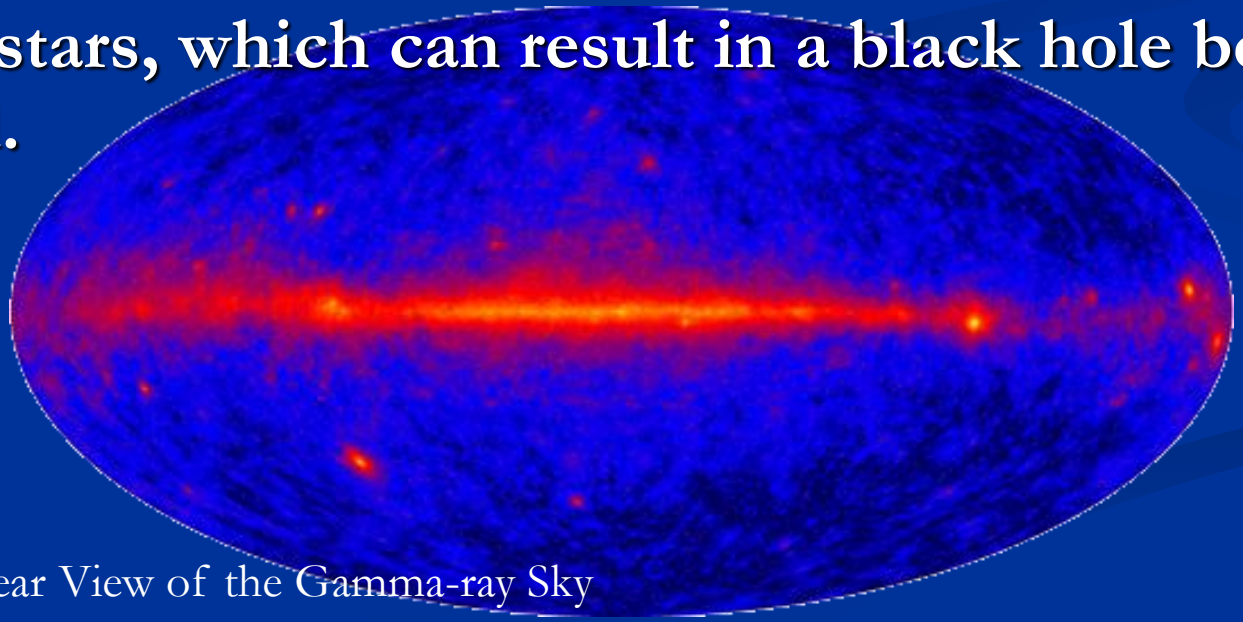
Gamma rays

- It is the most energetic radiation.
- On the Earth these rays are emitted by most of radioactive elements.
- Like X-rays, both are used in medicine, in imaging tests and in therapies to cure diseases like cancer.



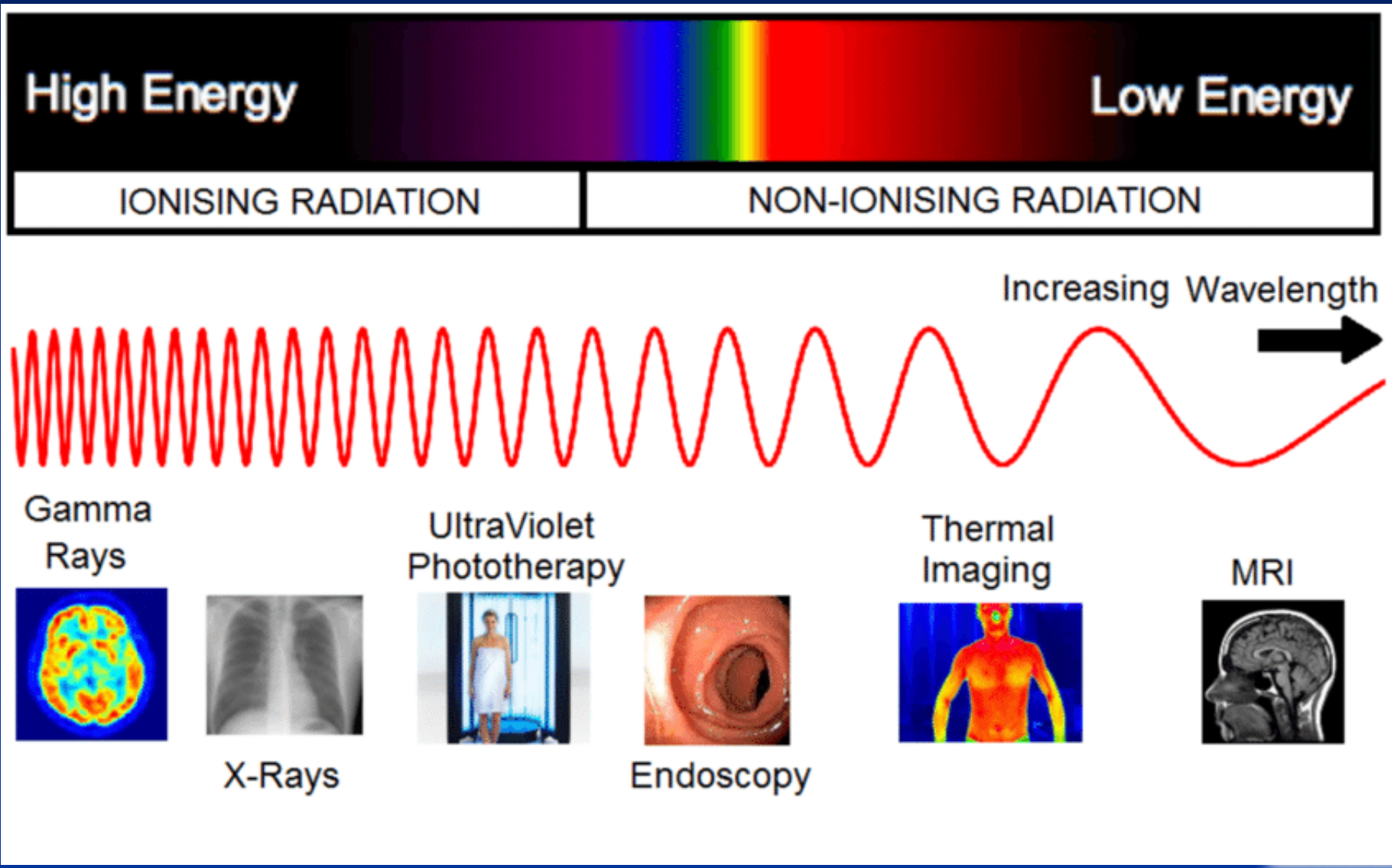
Gamma rays

- The occasional violent eruptions of gamma rays are not unusual in the sky.
- There are different types that last from seconds to hours. One problem is to define their exact location to help identify what objects are producing the radiation.
- Astronomers tend to associate them with the fusion of binary stars, which can result in a black hole being formed.



Fermi's Five-year View of the Gamma-ray Sky

Uses of EM radiation in Medicine



Use of Radio Waves

- Magnetic resonance, diagnosis of soft tissues

MRI Human heart

MRI Normal knee

Use of X-rays

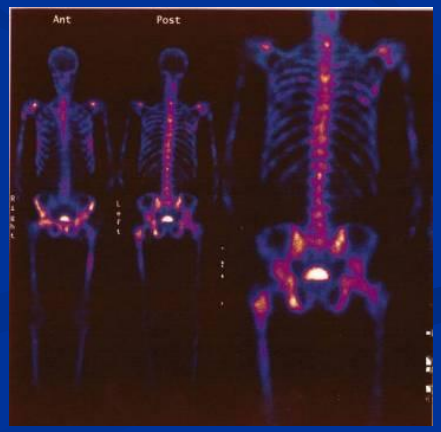
- Radiographs and computed axial tomography (CAT scan)

X-ray

CAT Normal knee

Use of Gamma-rays

- Imaging tests and therapies to cure diseases like cancer. Used in positron emission tomography (PET scan)



Thank you very
much
for your attention!