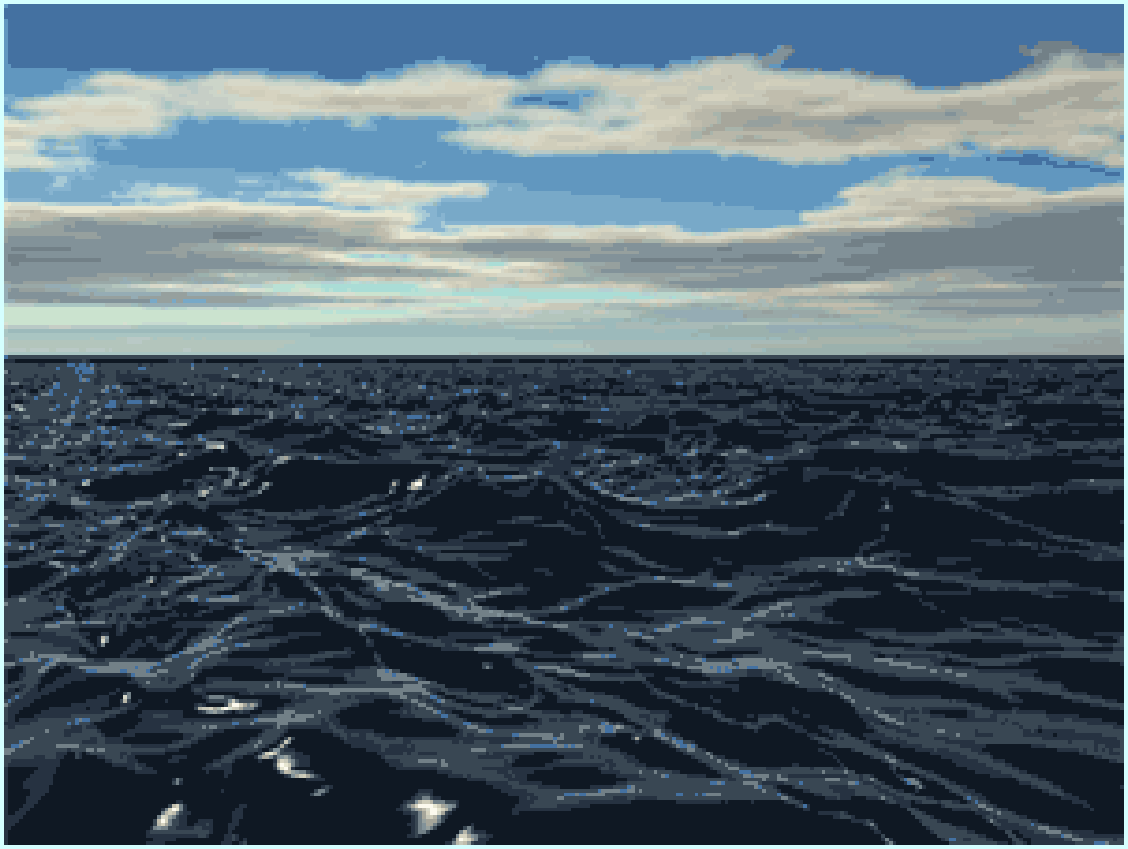
Light!

We experience WAVE PHENOMENA every day.

Ocean Waves



Most WAVE PHENOMENA are a disturbance

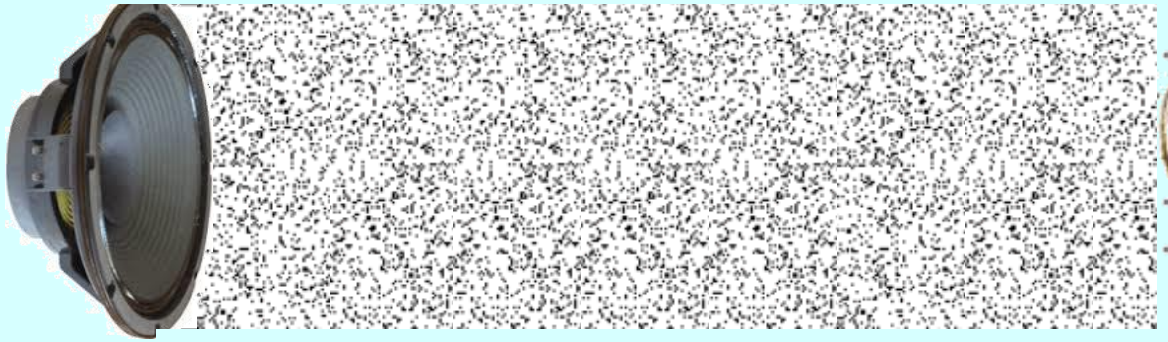
We experience WAVE PHENOMENA every day.

Ocean Waves

Sound Waves

SOUND needs something to travel in: air or water

Sound is a disturbance



Energy is transferred to the ear

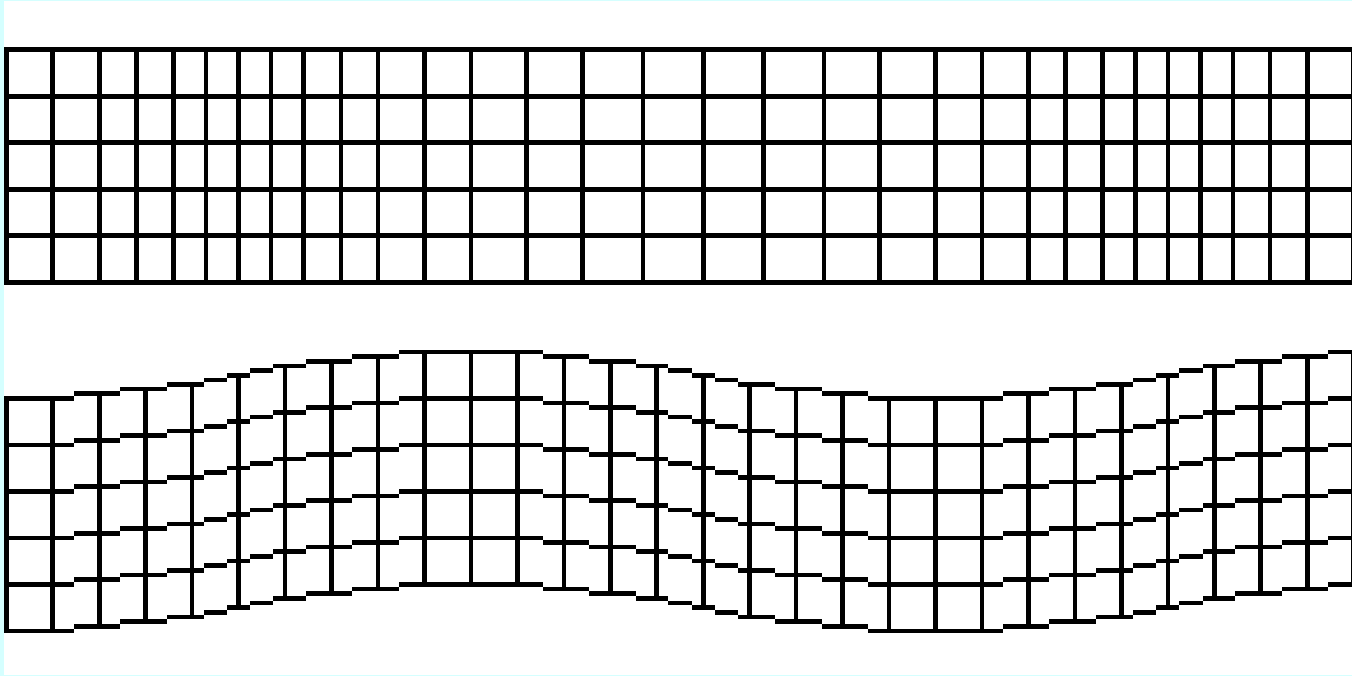
The compression can be represented as a wavelength

We experience WAVE PHENOMENA every day.

Ocean Waves

Sound Waves

Earthquakes



EARTHQUAKES are a disturbance

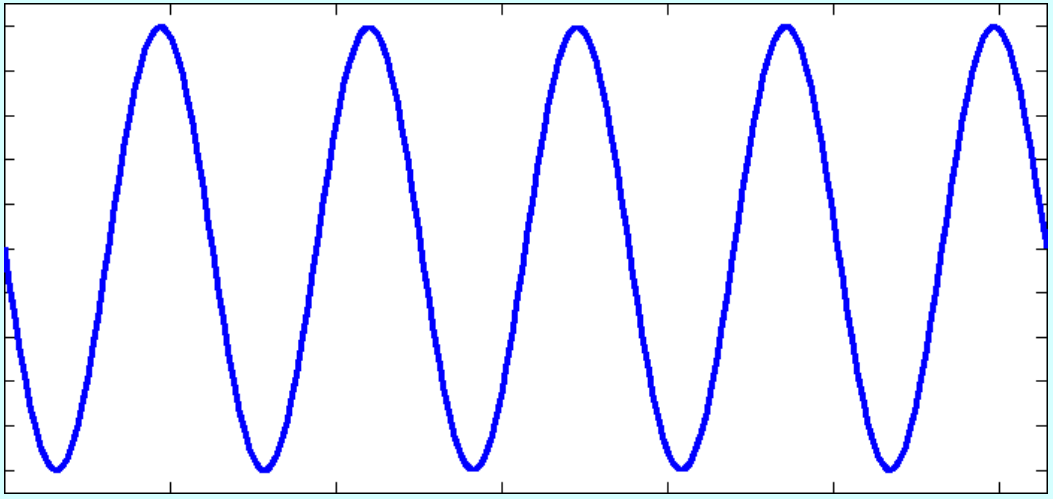
We experience WAVE PHENOMENA every day.

Ocean Waves

Sound Waves

Earthquakes

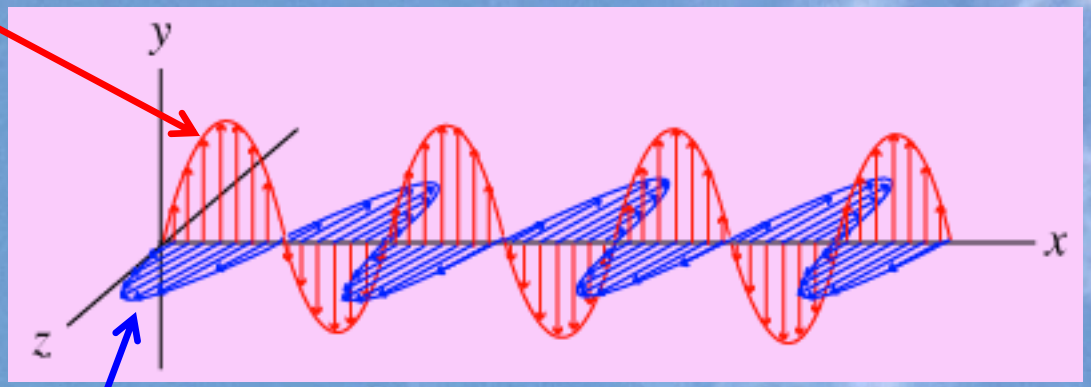
Light Waves



but LIGHT needs NOTHING to travel in

Light is made of electric and magnetic waves.

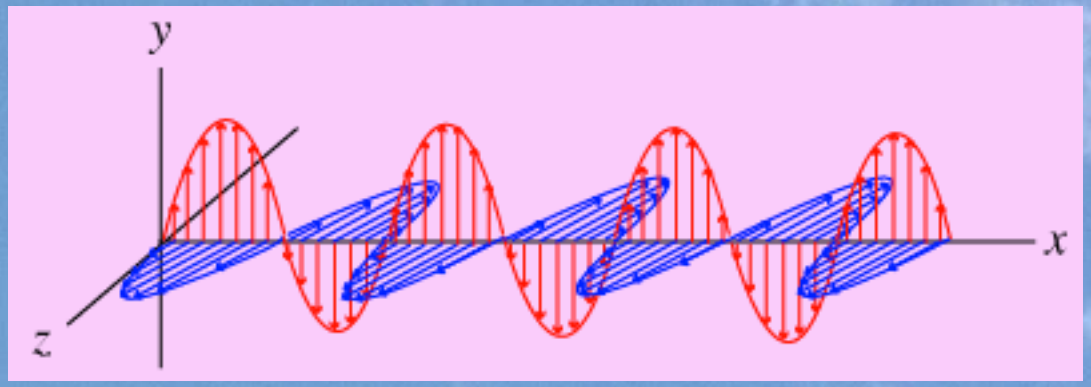
Electric wave



Magnetic wave

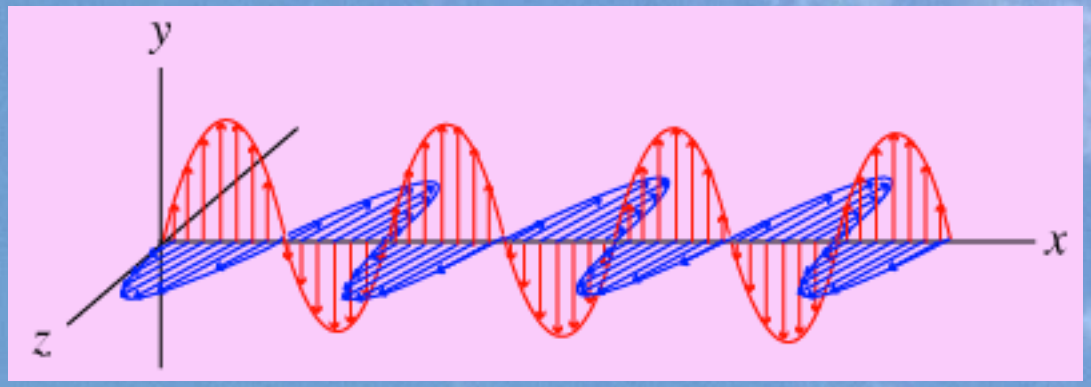
But sometimes, it behaves as if it were a compact particle,

like a billiard ball.



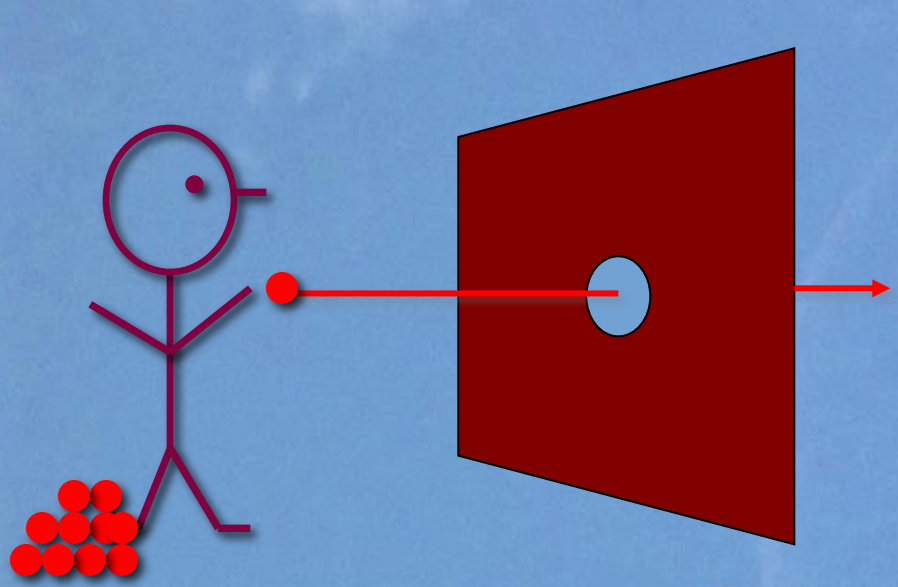
But sometimes, it behaves as if it were a WAVE.

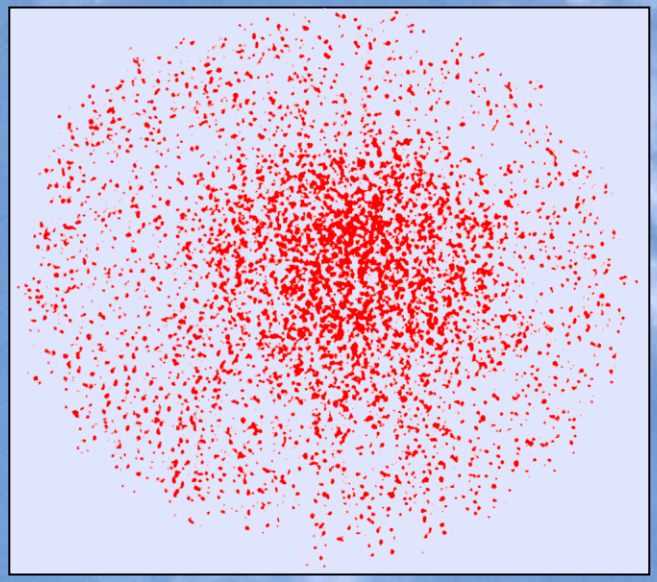
This is called the WAVE-PARTICLE DUALITY of light



Here is how we know……..

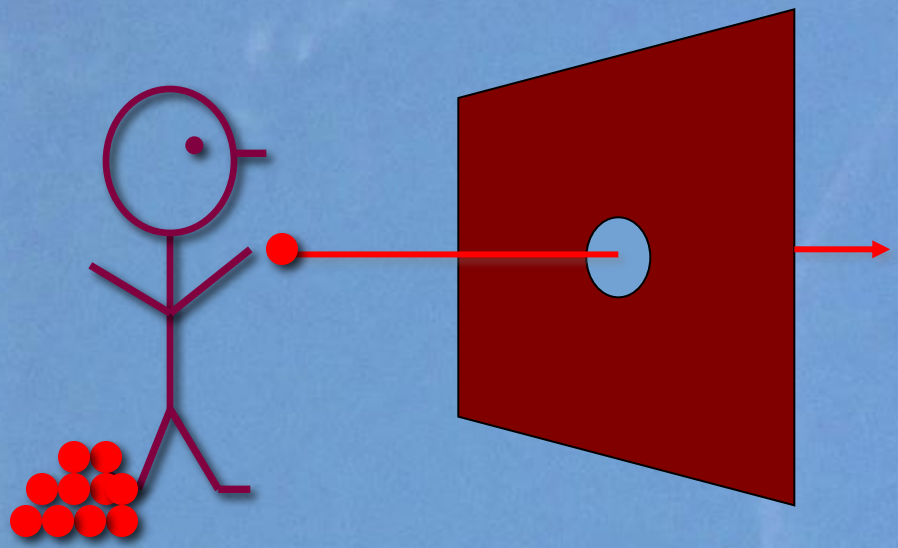
We know this because particles act differently than waves.

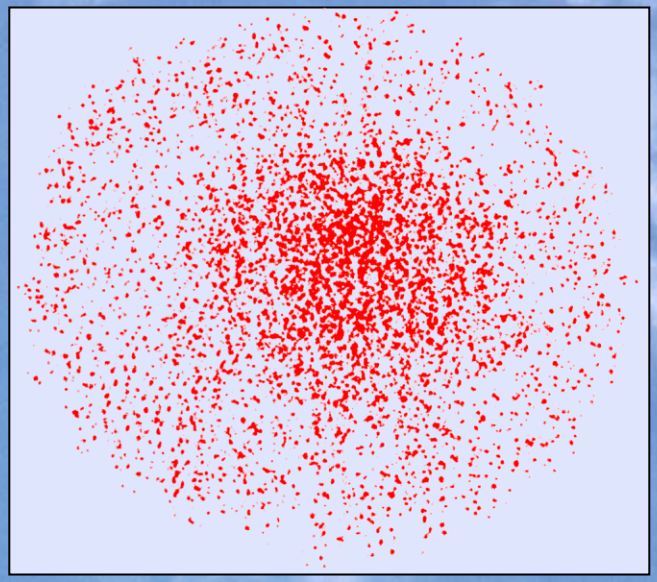




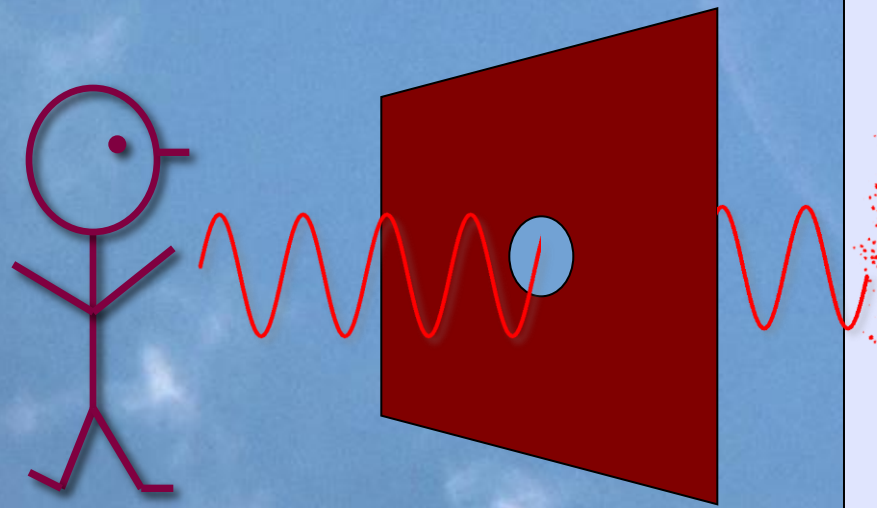
particles act like this when going through a hole

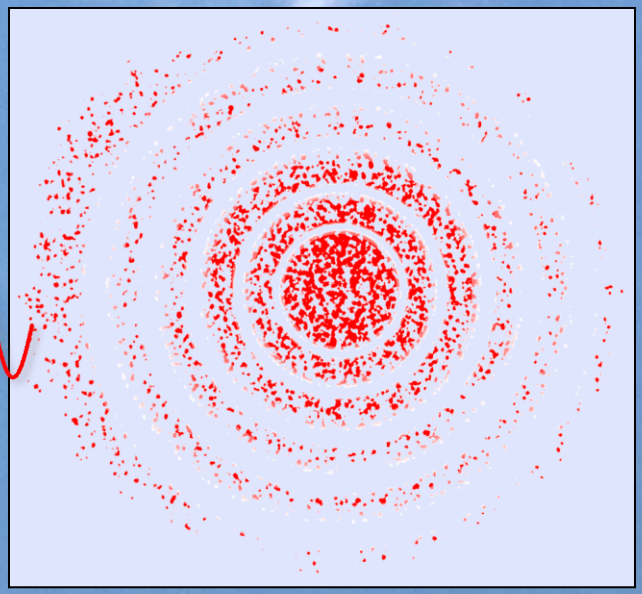
We know this because particles act differently than waves.





PARTICLES act like this when going through a hole

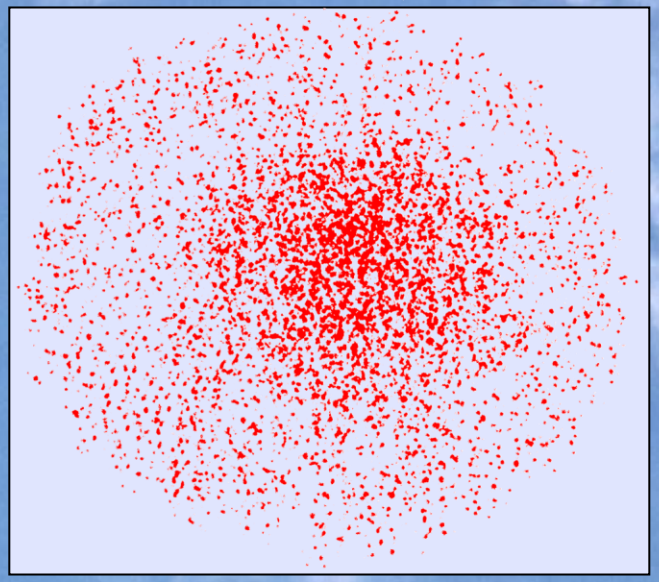




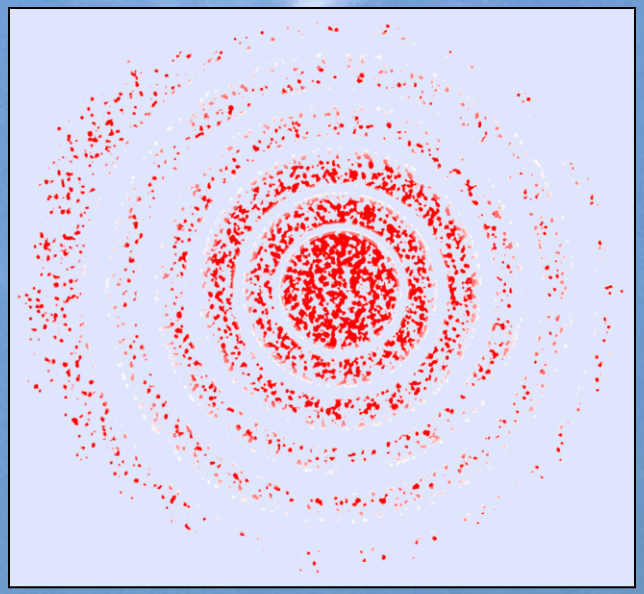
WAVES act like this when going through a hole

Light acts always as ONE or the OTHER, not both at a time.

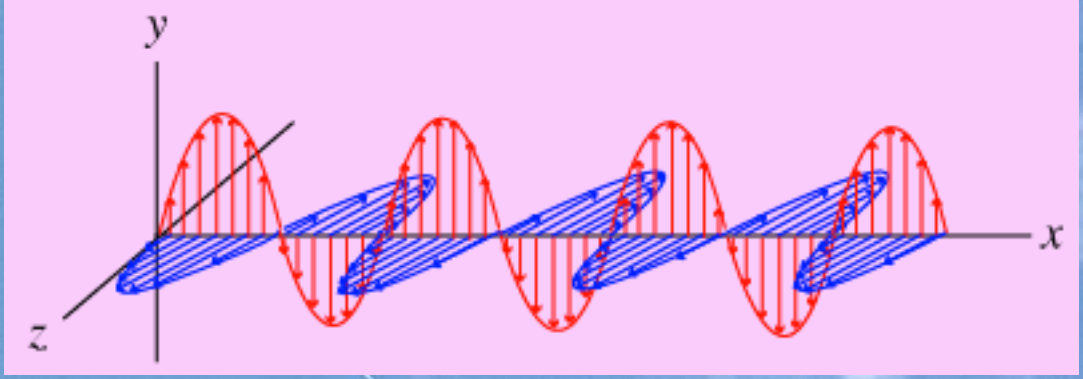
PARTICLES act like this when going through a hole



WAVES act like this when going through a hole



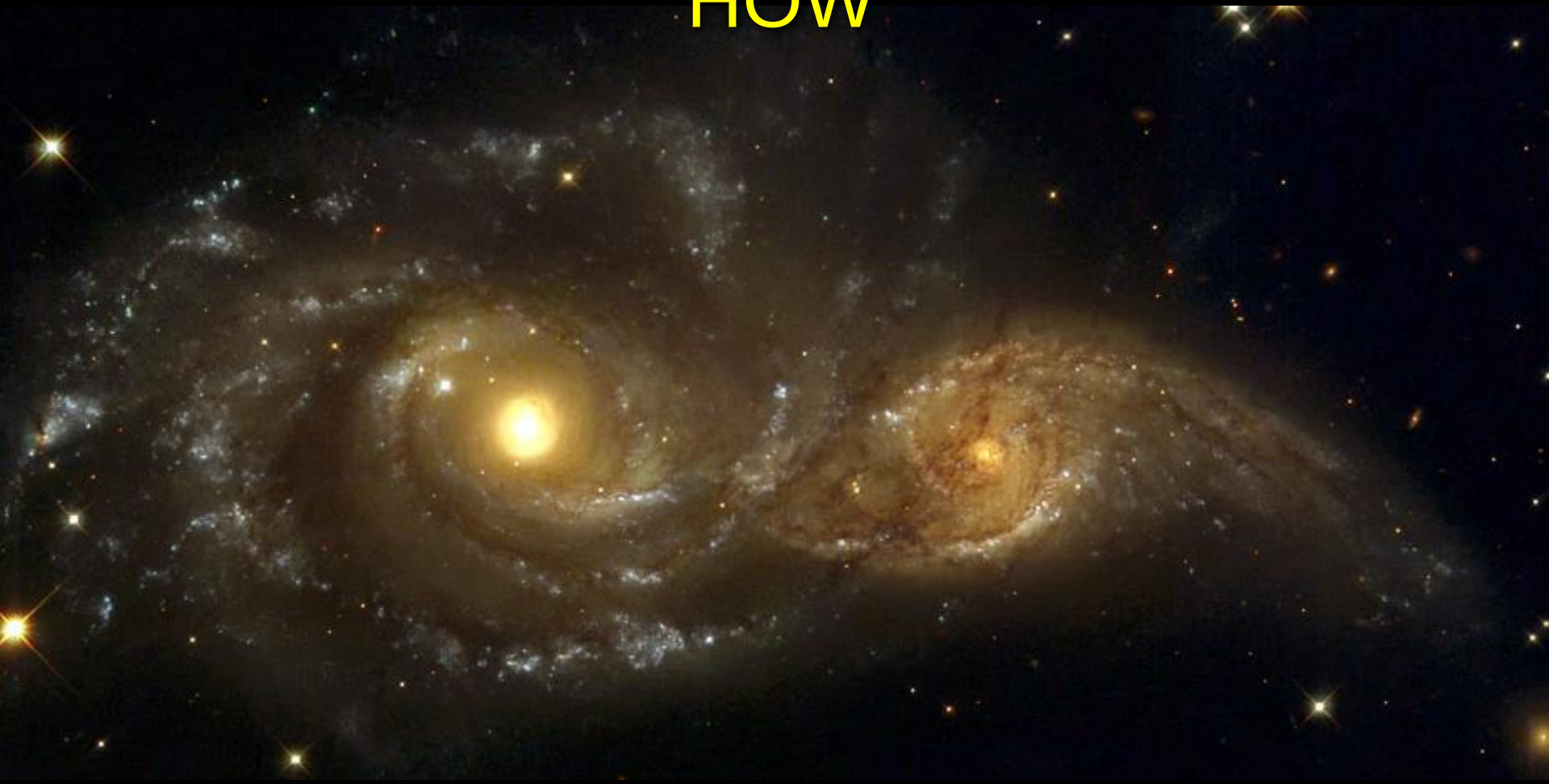
When we refer to a "piece" of light, we call it a PHOTON.



LIGHT does not need anything to travel through.

LIGHT can travel through empty space. And although we understand how light works, we don't know why Nature works this way!

We know the WHAT, and we know the HOW

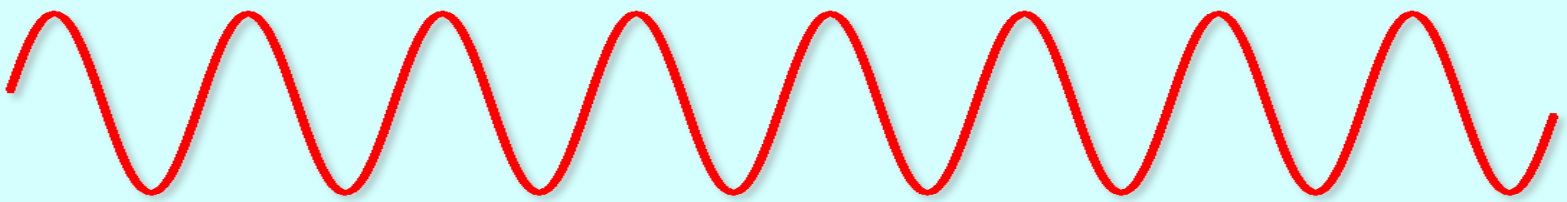


But we don’t know the WHY.

Light has the basic characteristics and properties of all waves.

Characteristics:

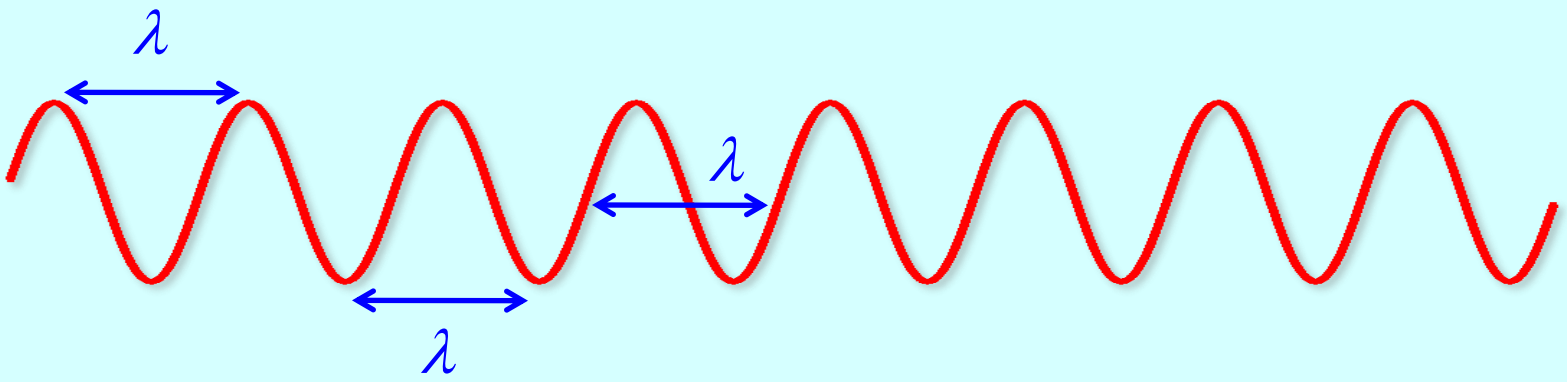
- wavelength
- frequency
- speed



Light has the basic characteristics and properties of all waves.

Characteristics:

- wavelength λ
- frequency
- speed



Light has the basic characteristics and properties of all waves.

Characteristics:

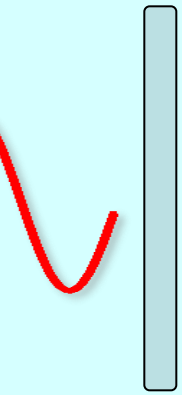
wavelength λ

→ frequency f

speed

8 wavelengths in 2 seconds make a frequency:

f = 4 per sec



Light has the basic characteristics and properties of all waves.

Characteristics:

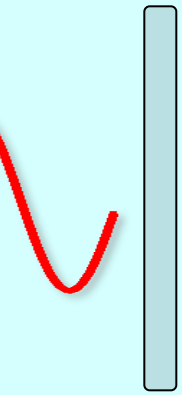
wavelength λ

frequency f

→ speed c

$\lambda \times f = c$

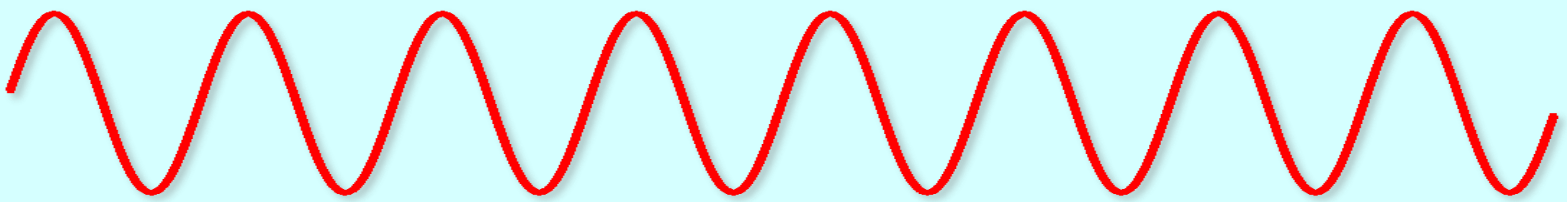
$c = 3 \times 10^5$ km/s



Light has the basic characteristics and properties of all waves.

Properties:

- reflection
- refraction
- interference
- diffraction



Light has the basic characteristics and properties of all waves.

Properties:

reflection →

Light travelling from the mountains bounces off the surface of water (i.e. reflects) and creates an image of the mountain on the water

Light has the basic characteristics and properties of all waves.

Properties:

reflection

refraction →

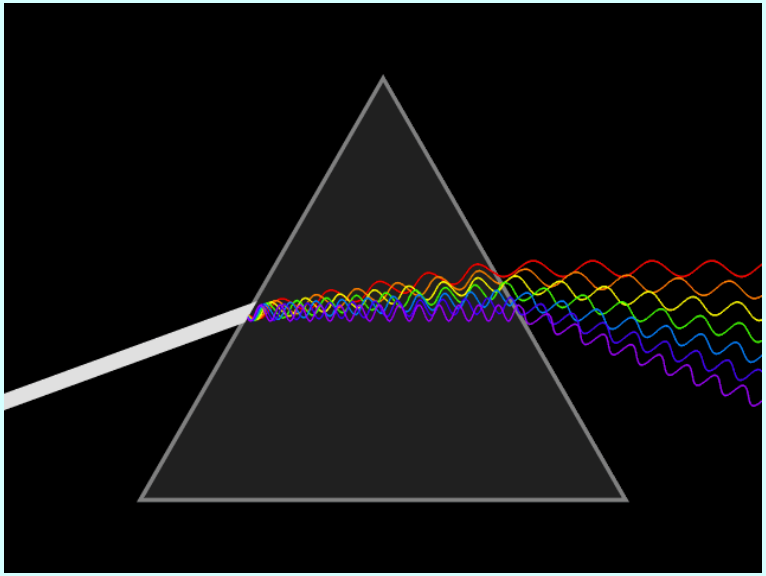
Light travelling from the part of the pencil under water refracts (i.e. changes direction) when passing from water to air (i.e. changes medium), producing an image of a bent pencil to an observer located outside the water

Light has the basic characteristics and properties of all waves.

Properties:

reflection

refraction →

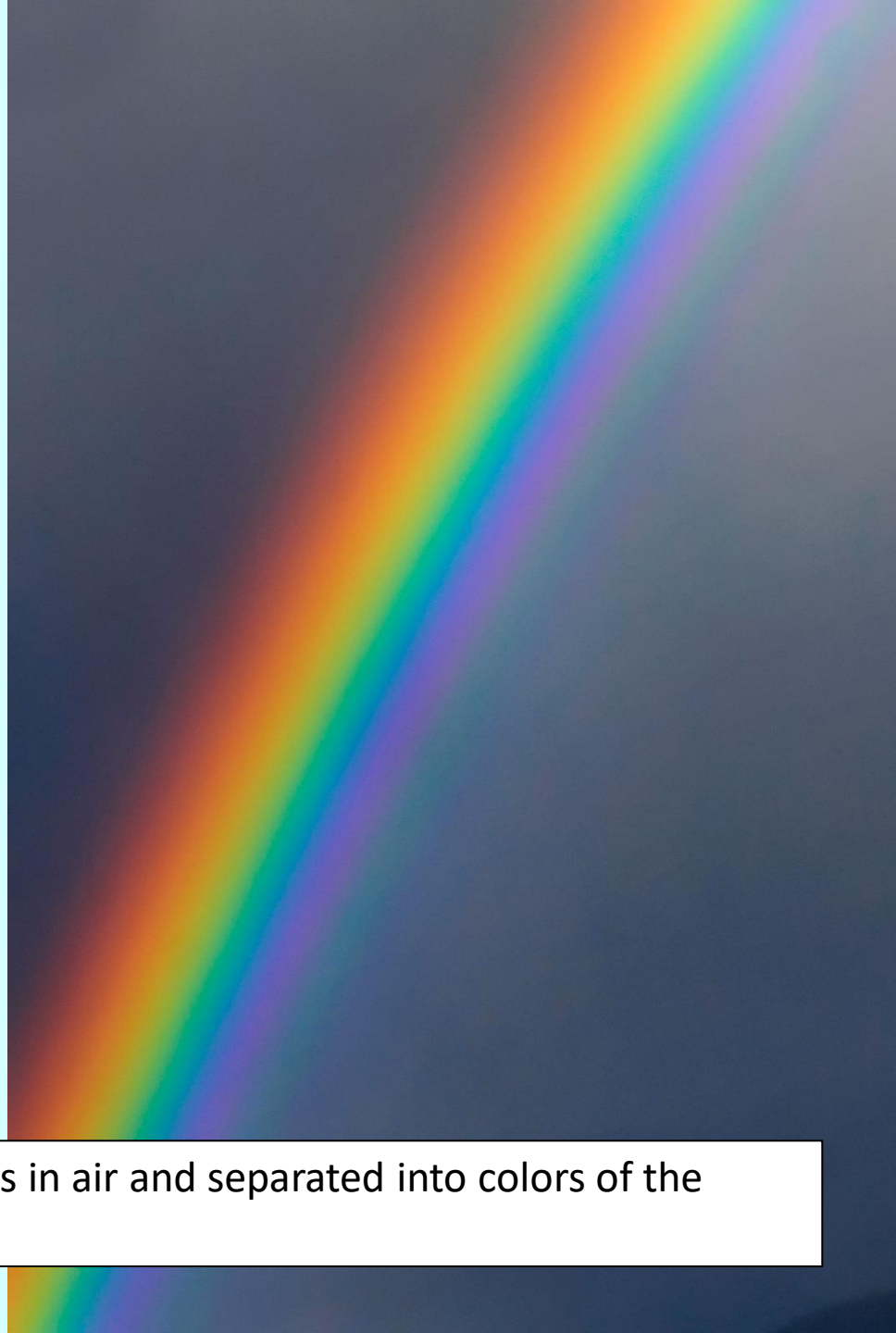


White light travelling through air from the left enters a glass prism, and refracts because it is changing medium. The different constituent colors of white light bend by different angles, and separate into distinguishable colors.

Properties:

reflection

refraction →

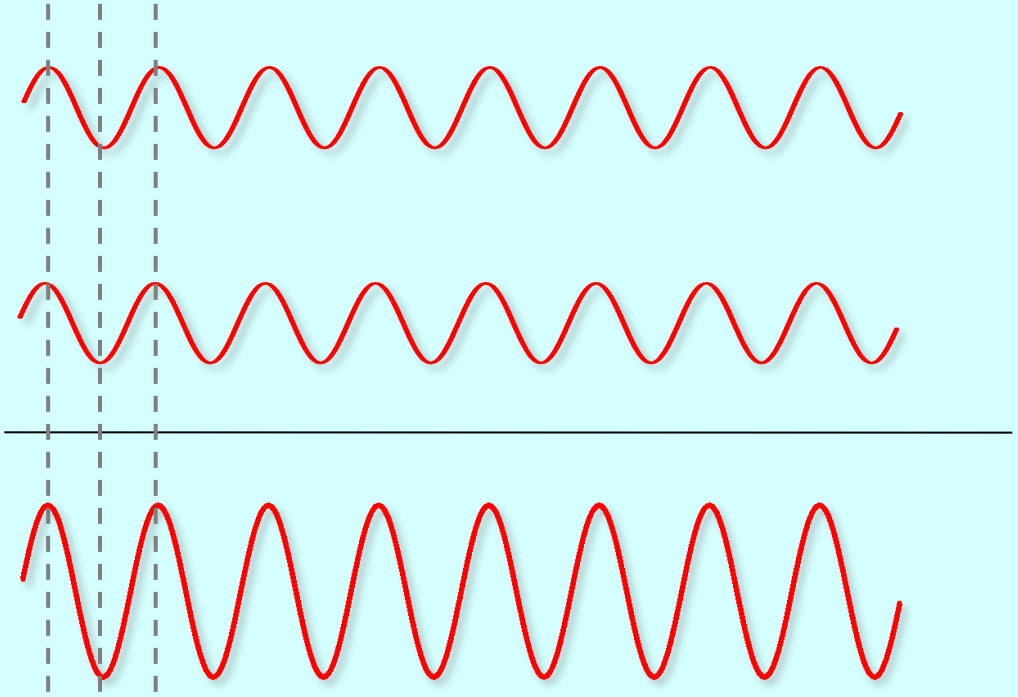


White sunlight is refracted by water particles in air and separated into colors of the rainbow

Light has the basic characteristics and properties of all waves.

Properties:

- reflection
- refraction
- → interference
- diffraction



Two waves superimposed (i.e. placed on top of each other) can interfere to form a resultant wave. If the peaks and troughs of both waves are aligned, the resultant wave exhibits *constructive interference*.

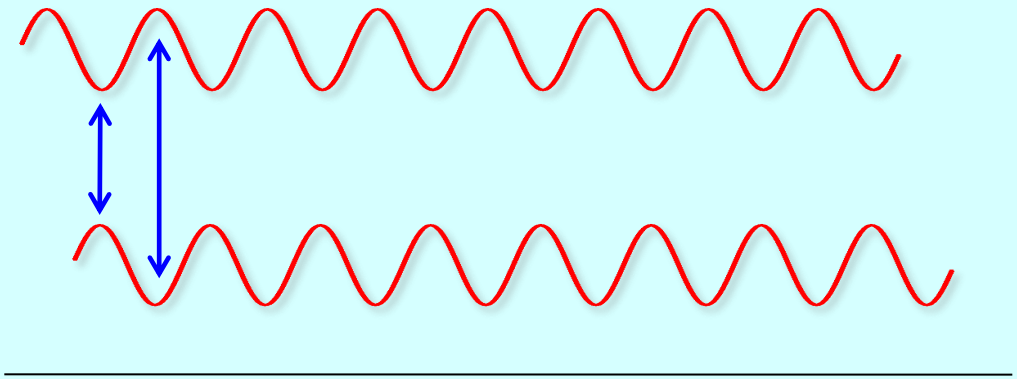
Light has the basic characteristics and properties of all waves.

Properties:

reflection

refraction

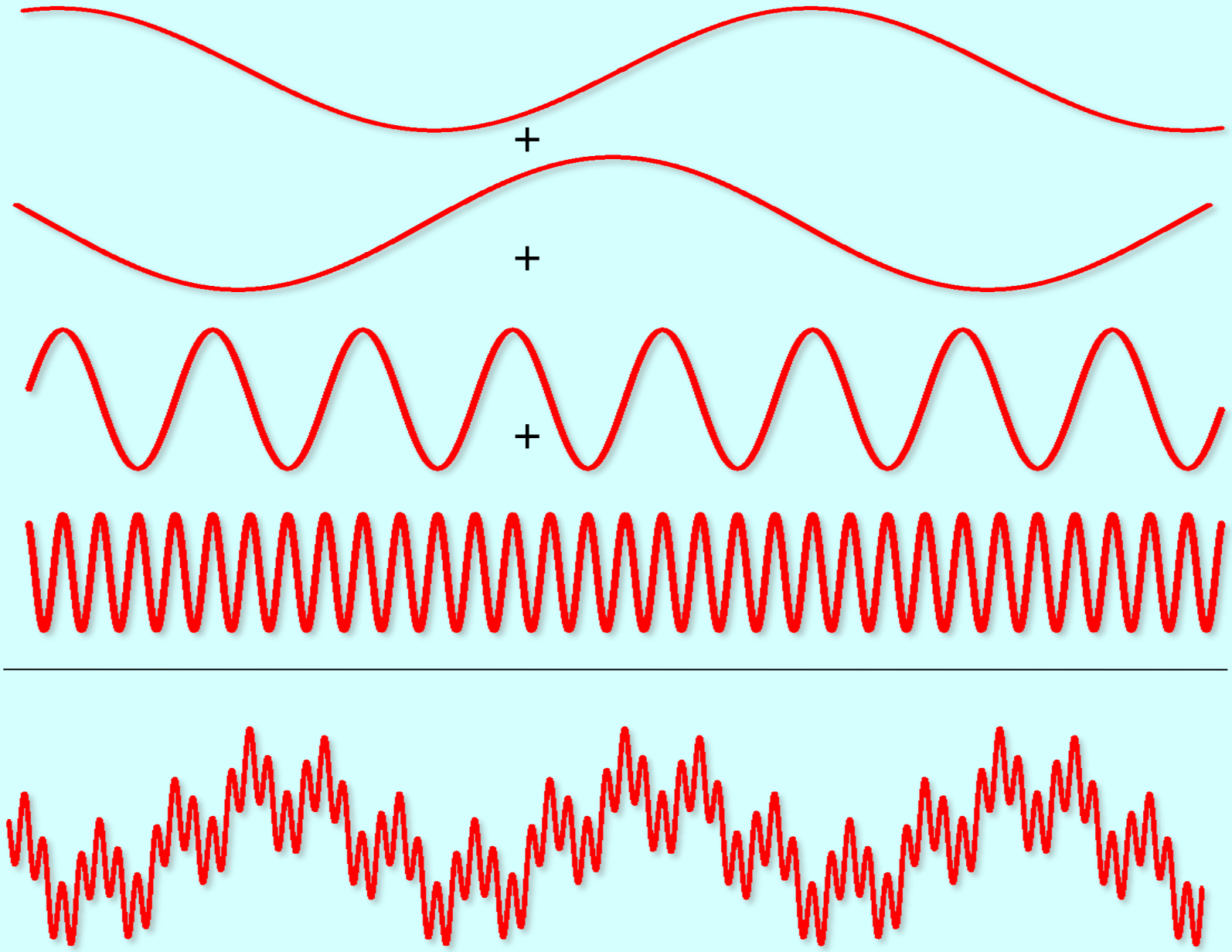
→ interference



No wave, i.e. cancels out completely!

If the peaks of one wave are aligned with the troughs of the other wave, then the resultant wave exhibits *destructive interference*; in case of completely destructive interference, the two original waves completely cancel each other and there is no resultant wave.

or if you have a complicated addition:



Light has the basic characteristics and properties of all waves.

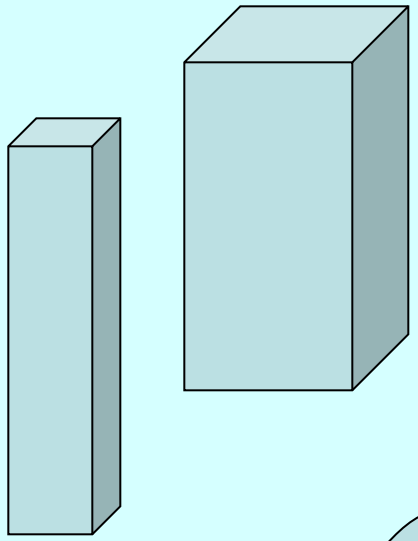
Properties:

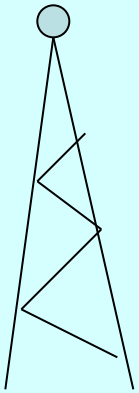
→ reflection

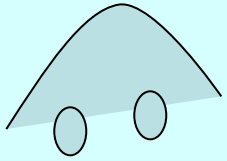
refraction

→ interference

e.g. Radio waves transmitted from a station tower







Light has the basic characteristics and properties of all waves.

Properties:

- reflection
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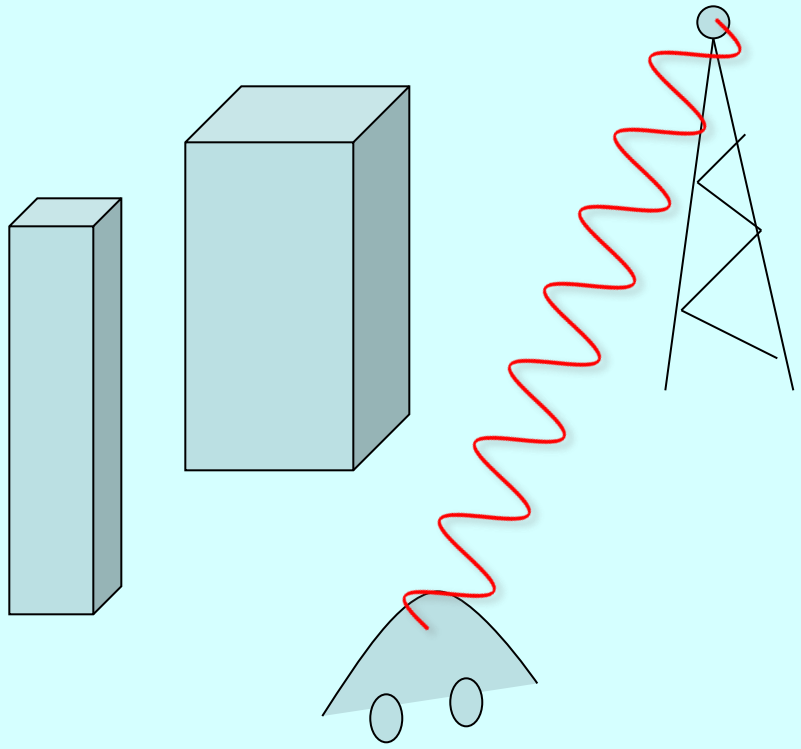

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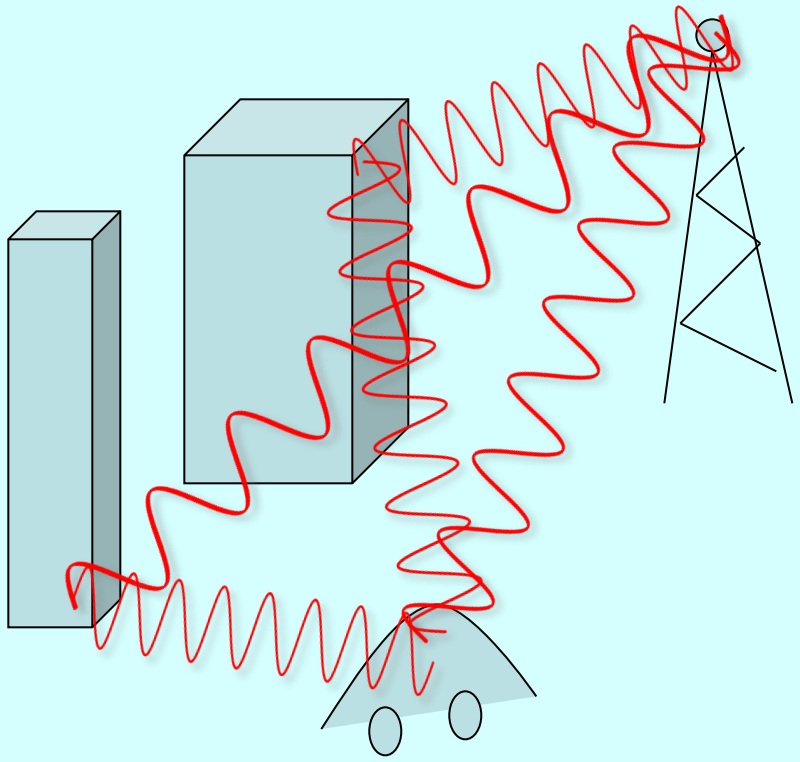
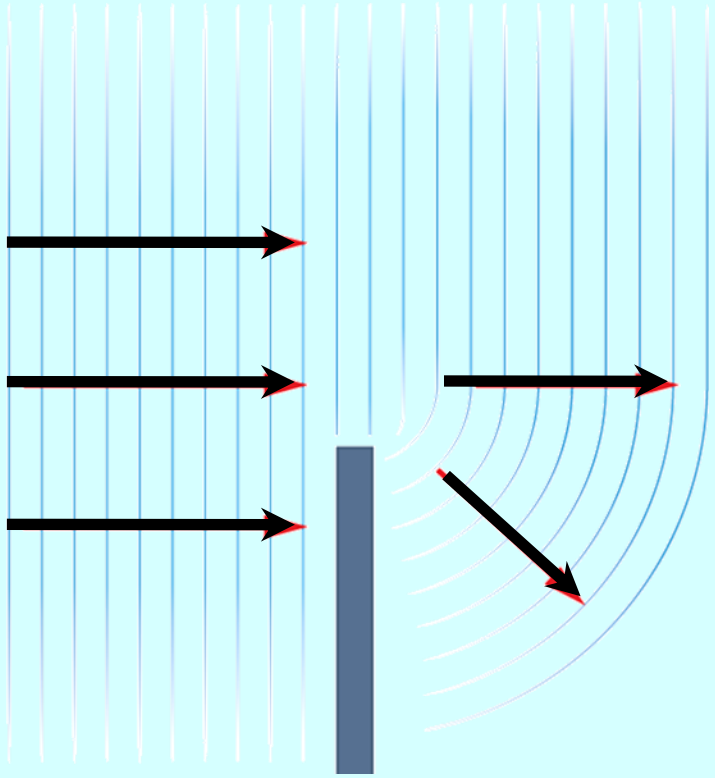
e.g. Radio waves transmitted from a station tower



Light has the basic characteristics and properties of all waves.

Properties:

- reflection
- refraction
- interference
- difraction →

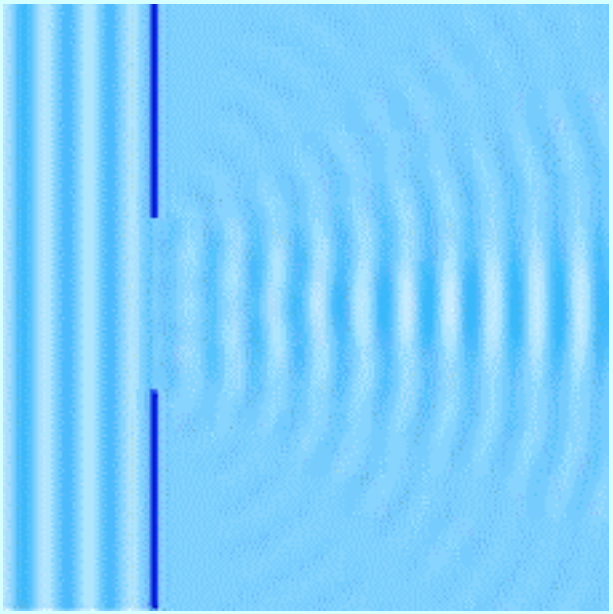


waves bend around barriers

Light has the basic characteristics and properties of all waves.

Properties:

- reflection
- refraction
- interference
- difraction →



waves bend around barriers

Light has the basic characteristics and properties of all waves.

Properties:

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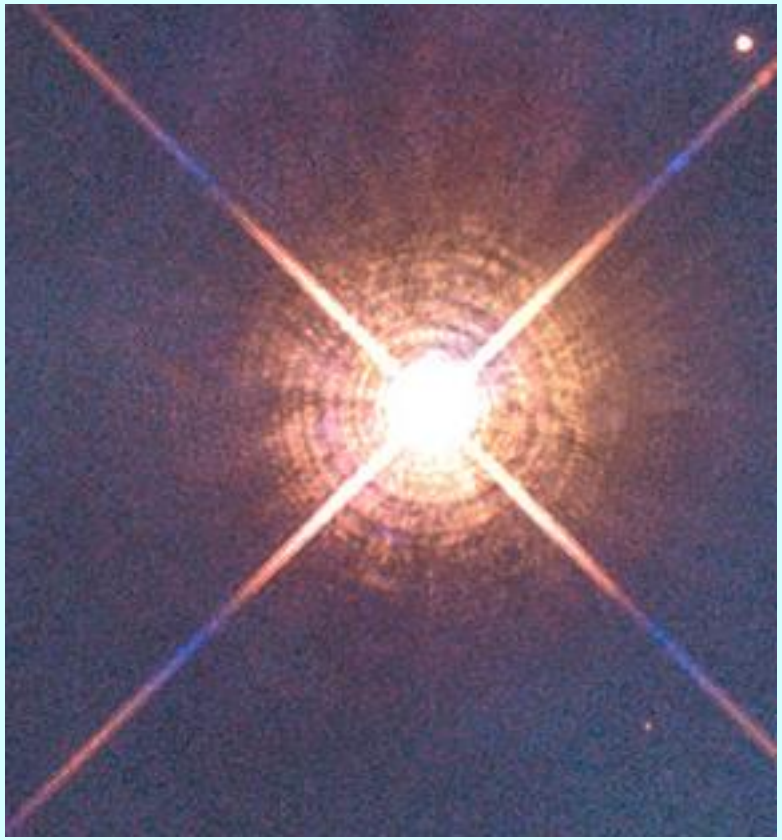
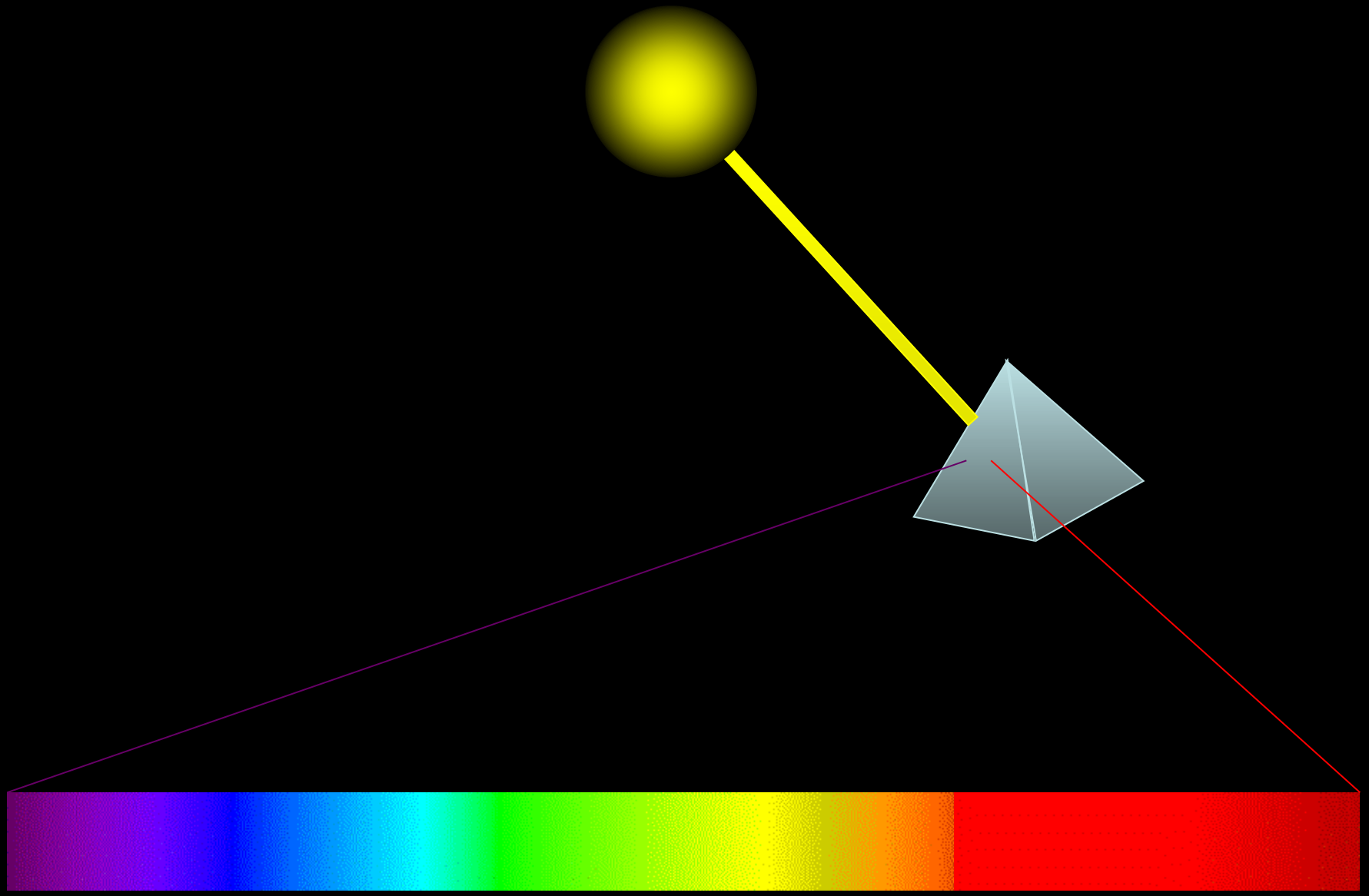
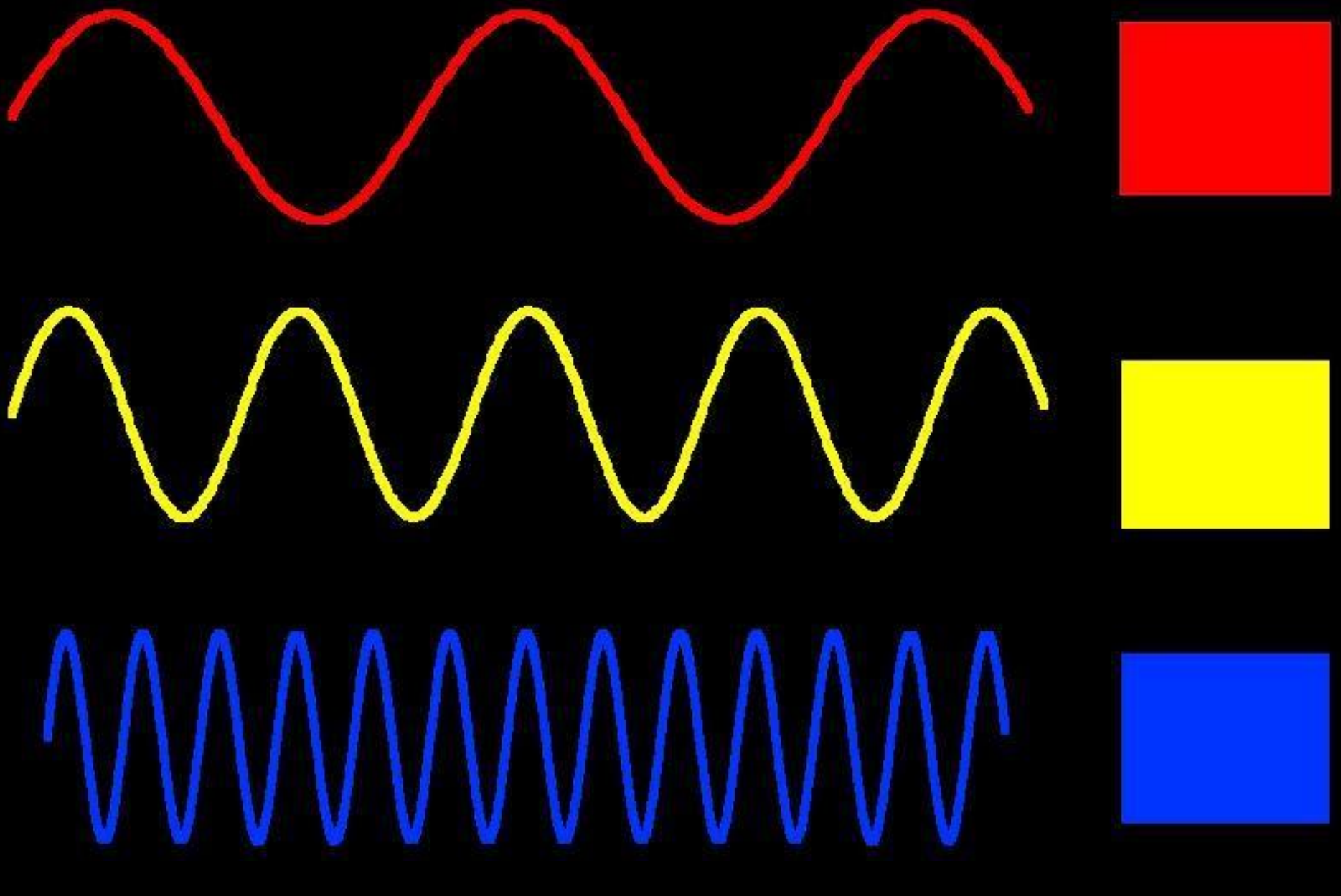


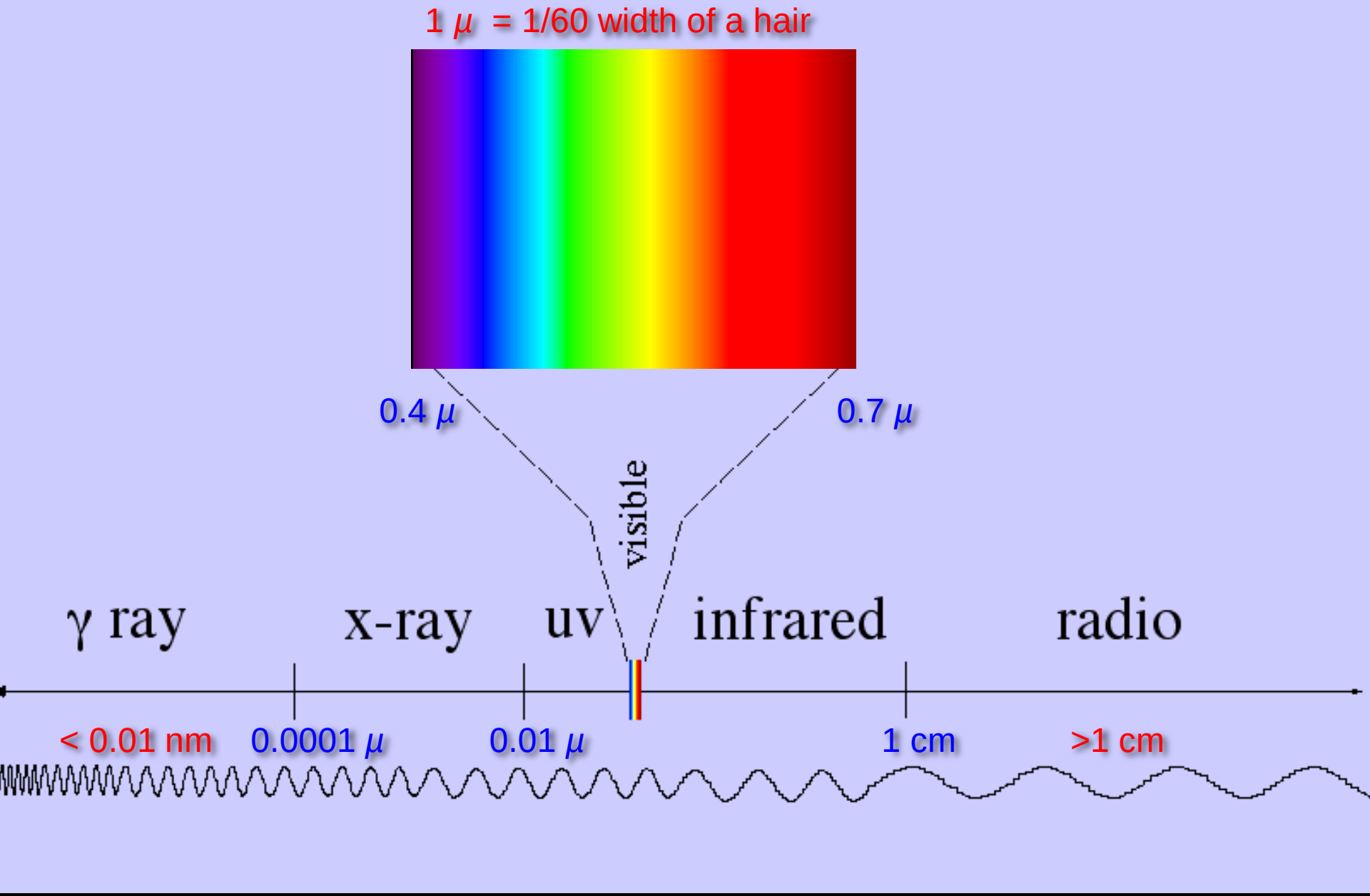
a diffraction pattern

Light passing through a telescope lens diffracts and produces an image with diffused rings



Electromagnetic Spectrum = RAINBOW





Electromagnetic Spectrum = LIGHT

LIGHT WAVES HAVE ENERGY!

0.4 μ

0.7 μ

visible

γ ray x-ray uv infrared radio

HIGH ENERGY

SHORT wavelength

Electromagnetic Spectrum = LIGHT

LIGHT WAVES HAVE ENERGY!

0.4 μ

0.7 μ

visible

γ ray | x-ray | uv | infrared | radio

HIGH ENERGY

LOW ENERGY

SHORT wavelength

LONG wavelength

Electromagnetic Spectrum = LIGHT

visible light

how bees see the world:

visible light

uv light

visible light

how snakes see the world:

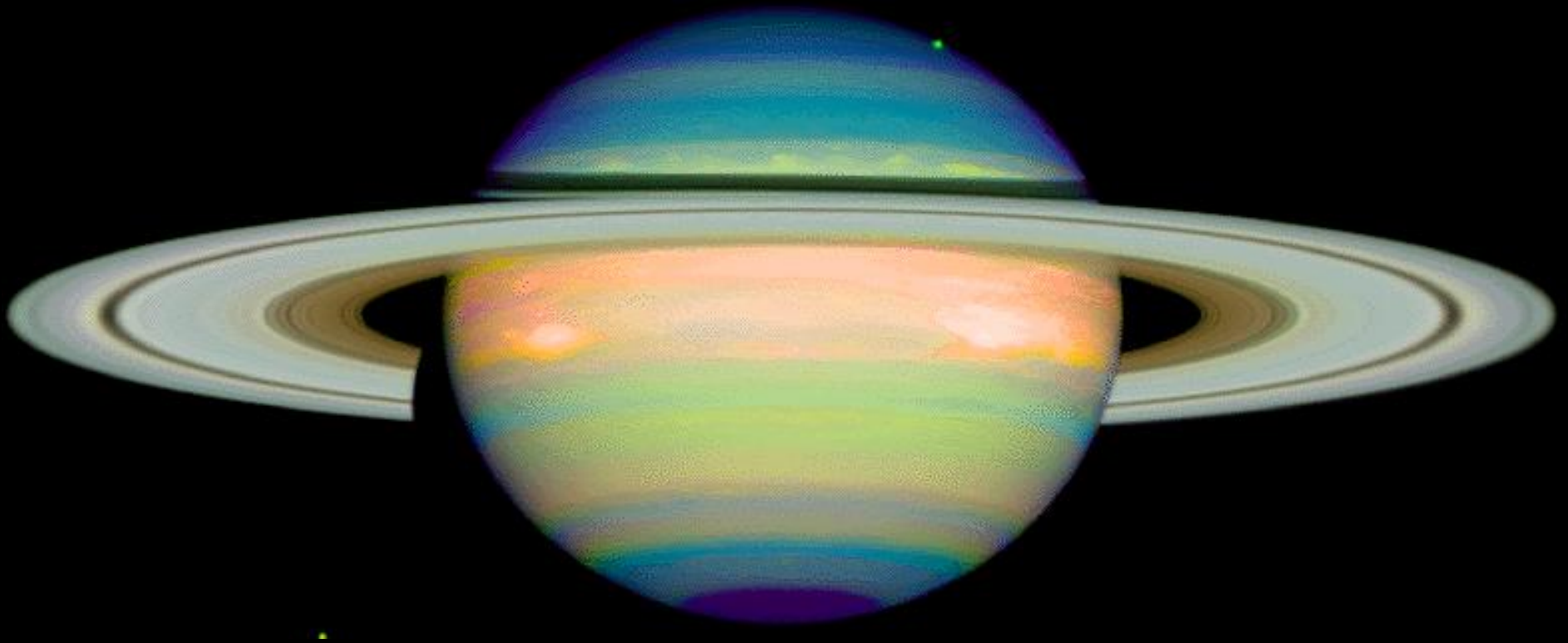
visible light

infrared light

A human in dim visible light

A human in INFRARED light

Saturn in visible light



Saturn in INFRARED light

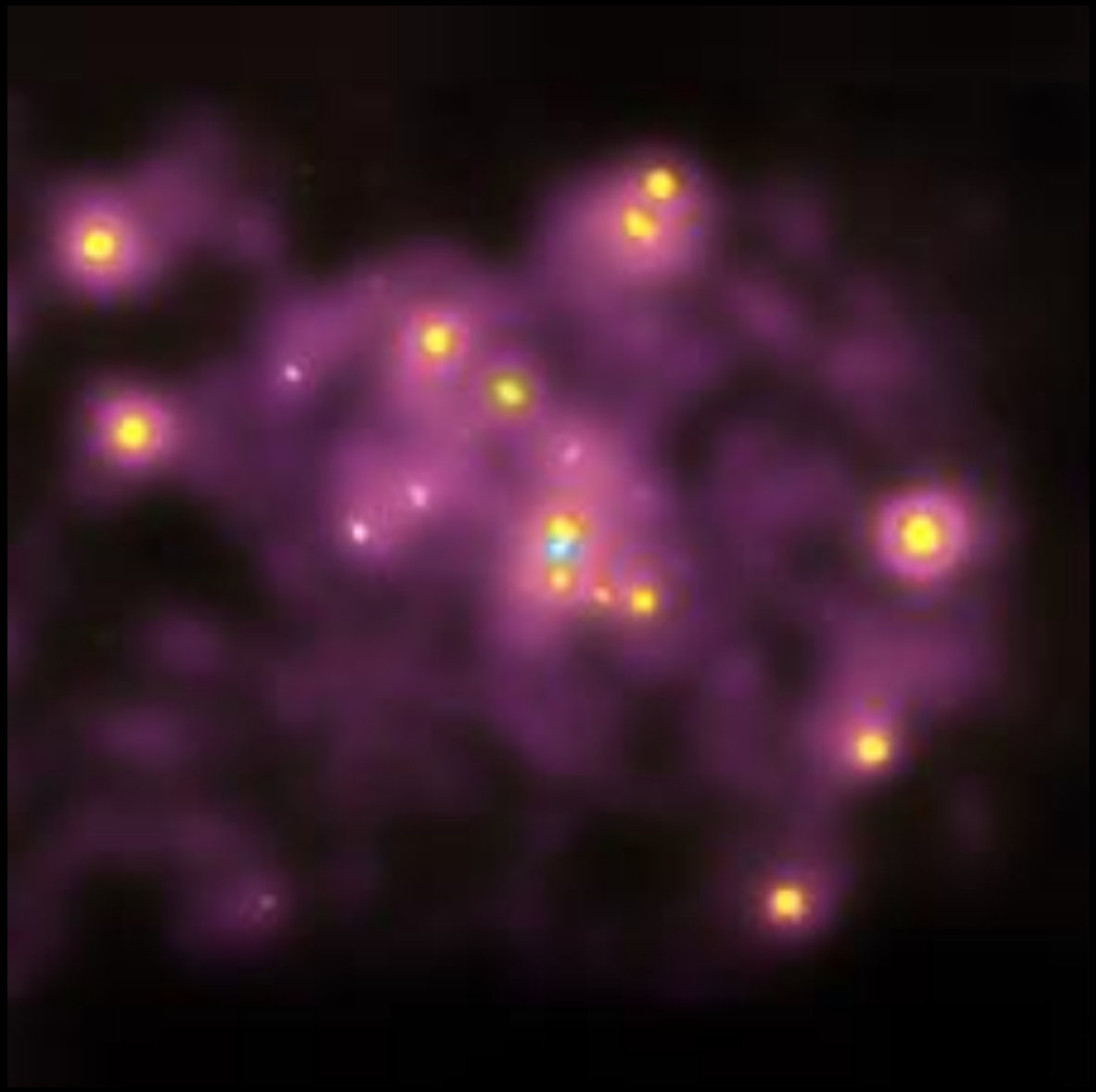
M51 galaxy in VISIBLE light

M51 galaxy in UV light

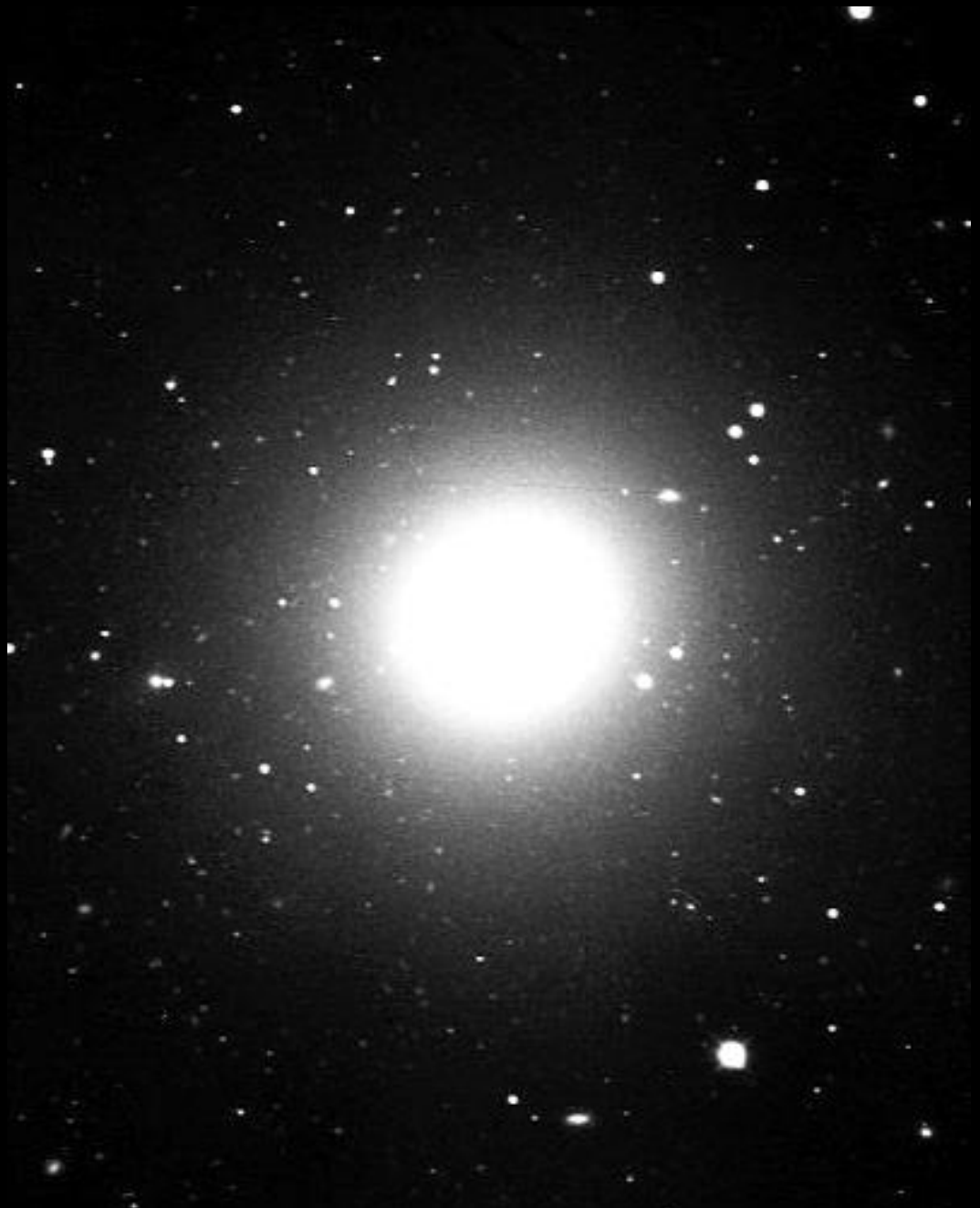
M51 galaxy in X-RAY light

Andromdea Galaxy in visible light (color)

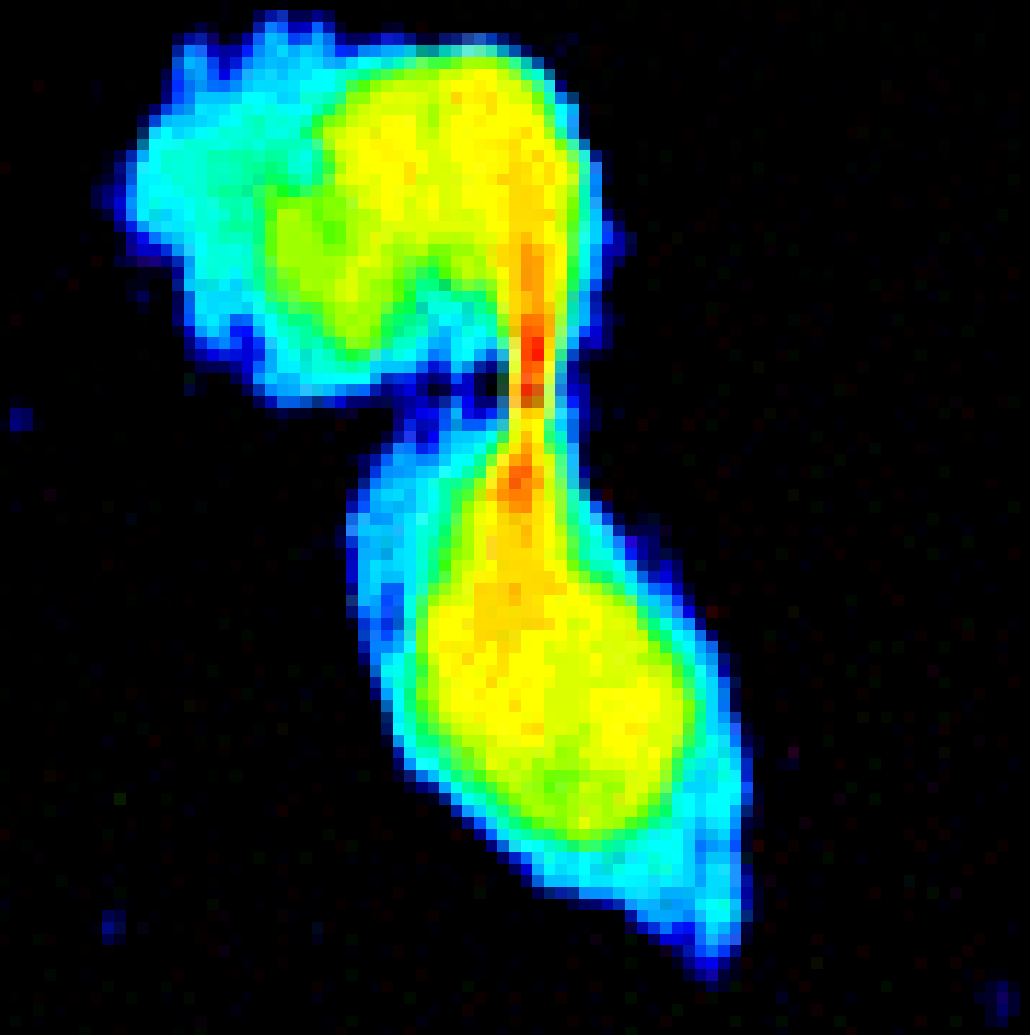
Andromdea Galaxy in visible light (color)



Andromdea Galaxy in X-RAY light

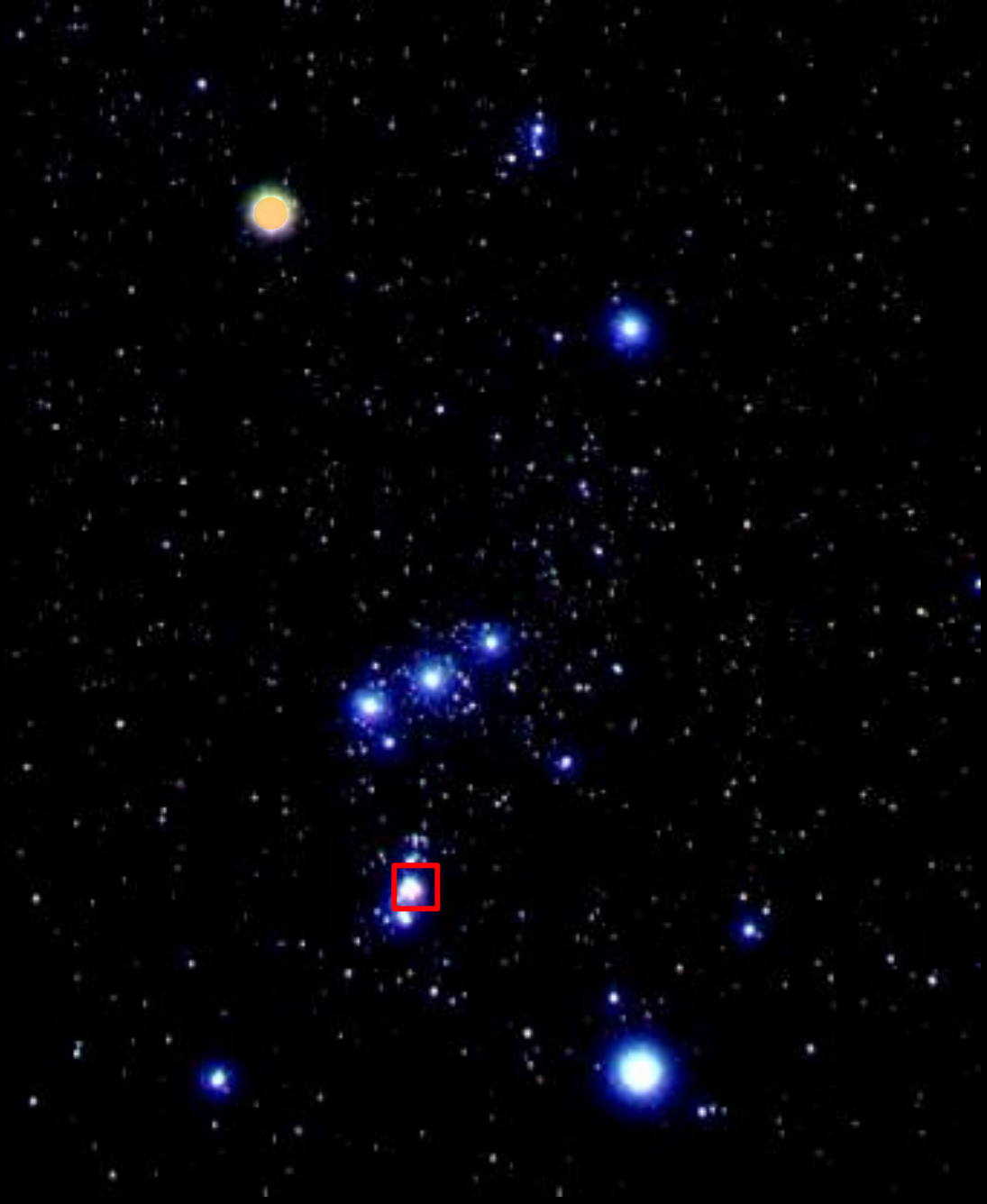


Galaxy M84 in visible light (b&w)



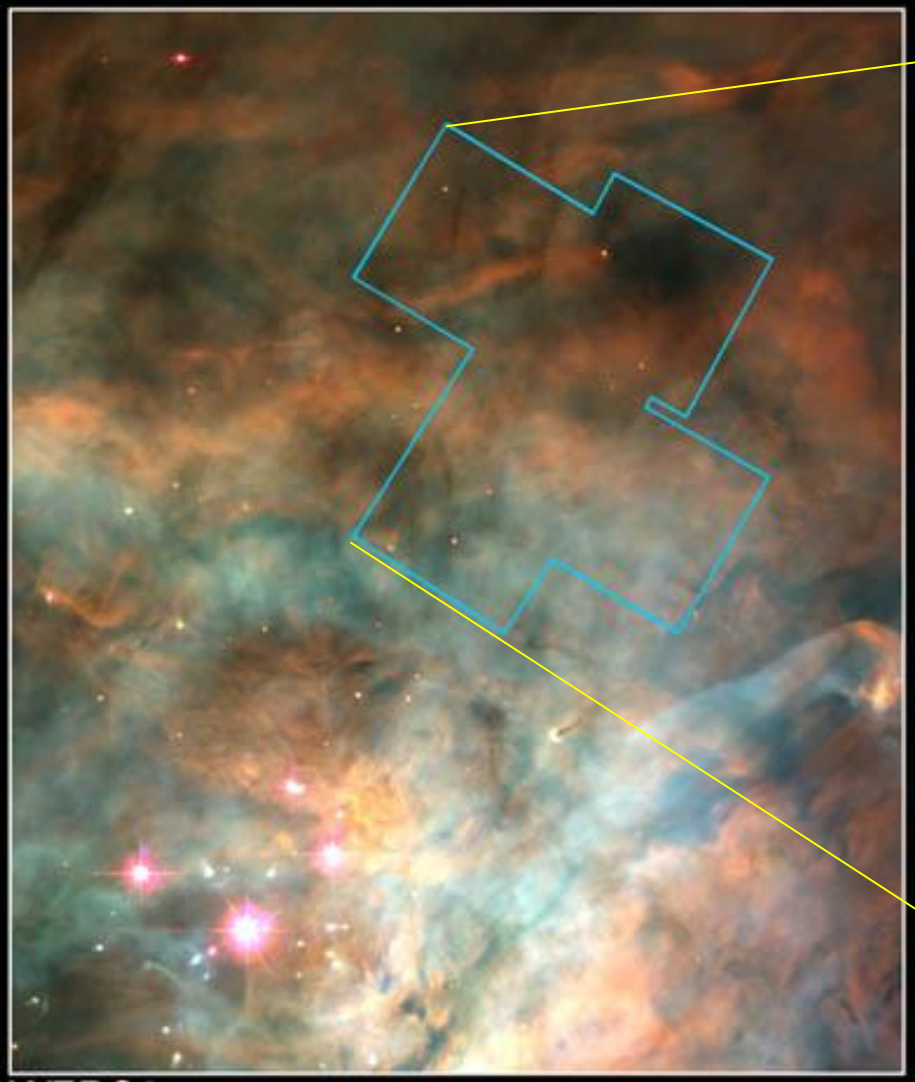
Galaxy M84 in RADIO light

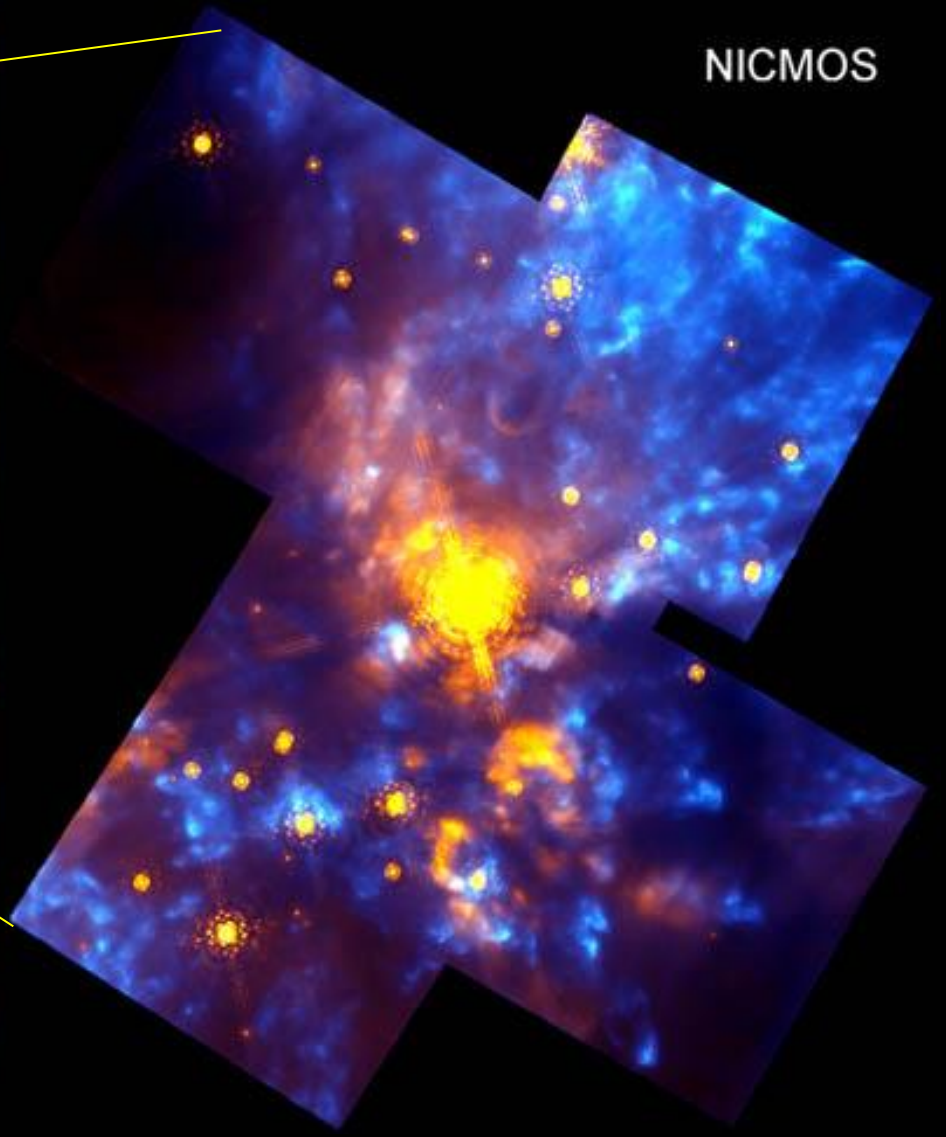
Great Nebula in Orion in visible light (true color)



Great Nebula in Orion in visible light (true color)

Great Nebula in Orion in visible light (true color)





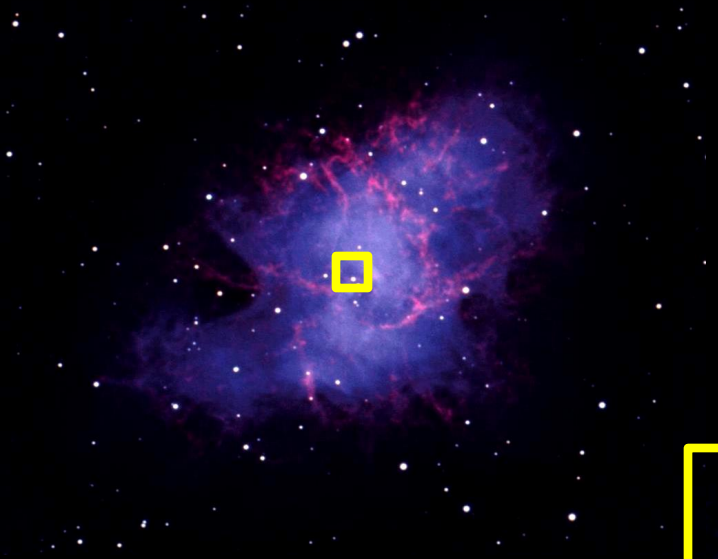
Great Nebula in Orion in visible light (color) from HST

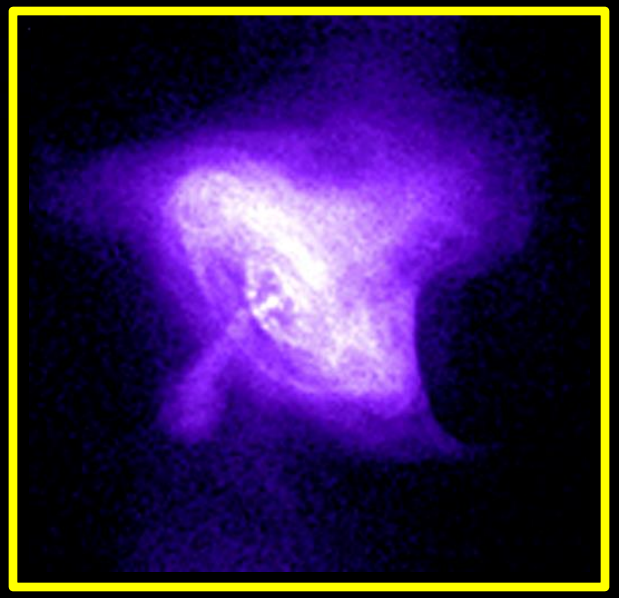
Great Nebula in Orion in INFRARED light rom HST

Crab Nebula in visible light

Crab Nebula in visible light

Crab Nebula in visible light





Crab Nebula in very short x-rays