
Astronomy Picture of the Day
http://antwrp.gsfc.nasa.gov/apod/astropix.html
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Announcements

If you can't see your clicker scores in UNM Learn then you still need to register your clicker.

If you can't see your Homework 1 scores in Learn then you might have messed up your Banner ID in Smartworks

Last day to drop without a grade (with refund) is Sept 9. If you are not in Smartworks and using a clicker by then you will be dropped.

HW #2 is Due on Thursday (September 8) as usual. Chris will be in RH111 on that day.

Exam #1 is on Tuesday (September 13)

Escape Velocity

Velocity needed to completely escape the gravity of a planet.
The stronger the gravity, the higher the escape velocity.
Examples:

Earth	11.2 km/s
Jupiter	60 km/s
Deimos (moon of Mars)	7 m/s = 15 miles/hour

Consider Helium Gas at room temperature (300 K)

$E = kT = 4.1 \times 10^{-14}$ erg

$E = 0.5\, m\, v^2 = 4.1 \times 10^{-14}$ erg

so $v = 1$ km/sec on average, but sometimes more

Clicker Question:

Suppose Matt weighs 120 lbs on his bathroom scale on Earth, how much will his scale read if he standing on a platform 6400 km high (1 Earth radius above sea-level)?

A: 12 lbs

B: 30 lbs

C: 60 lbs

D: 120 lbs

E: 240 lbs

Electromagnetic Radiation

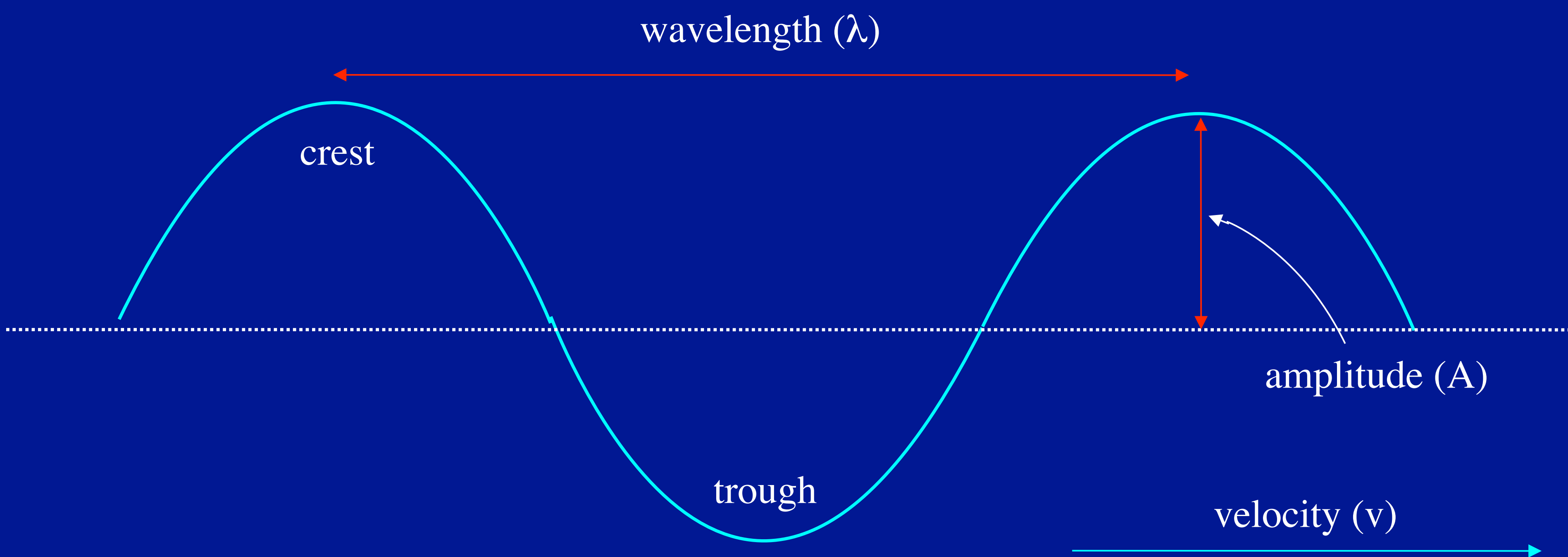
(How we get most of our information about the cosmos)

Examples of electromagnetic radiation:

Light
Infrared
Ultraviolet
Microwaves
AM radio
FM radio
TV signals
Cell phone signals
X-rays

Radiation travels as waves.
Waves carry information and energy.

Properties of a wave



λ is a distance, so its units are m, cm, or mm, etc.

Period (T): time between crest (or trough) passages

Also, $v = \lambda \nu$

Frequency (ν): rate of passage of crests (or troughs), $\nu = \frac{1}{T}$
(units: Hertz or cycles/sec)

$E = h\nu$

Demo: making waves - wave table

Demo: slinky waves

Radiation travels as Electromagnetic waves.

That is, waves of electric and magnetic fields traveling together.

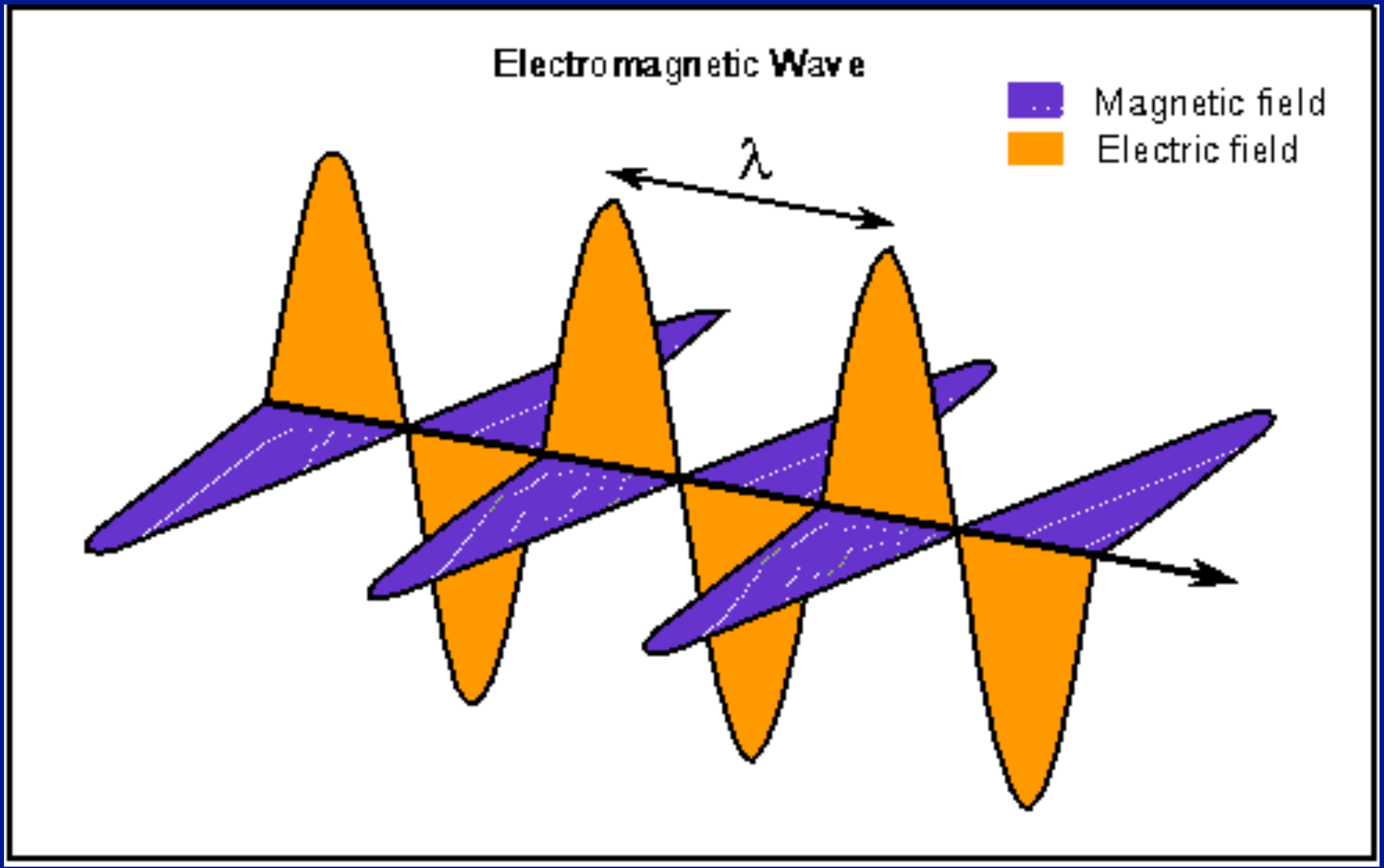
Examples of objects with magnetic fields:

a magnet
the Earth
Clusters of galaxies

Examples of objects with electric fields:

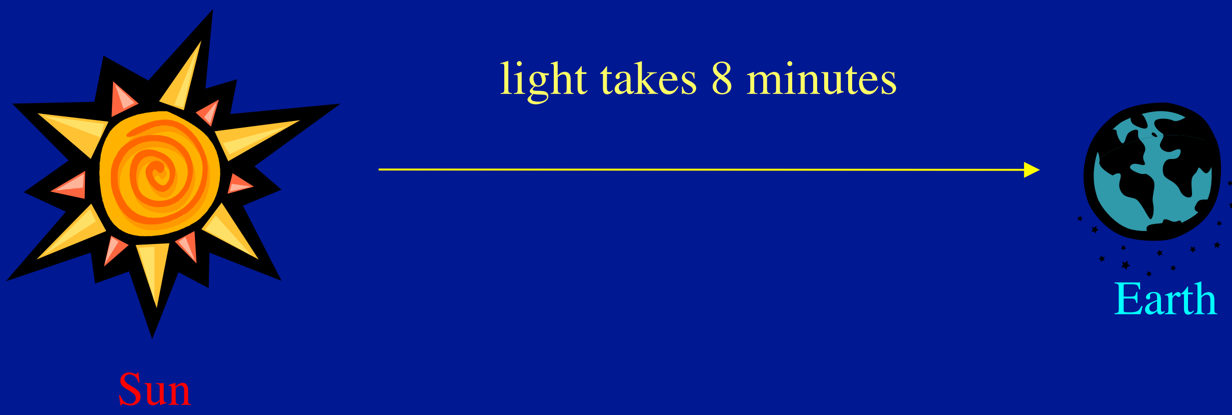
Power lines, electric motors, …
Protons (+)
Electrons (-)
} "charged" particles that make up atoms.

Scottish physicist James Clerk Maxwell showed in 1865 that waves of electric and magnetic fields travel together => traveling "electromagnetic" waves.



The speed of all electromagnetic waves is the <u>speed of light</u>.

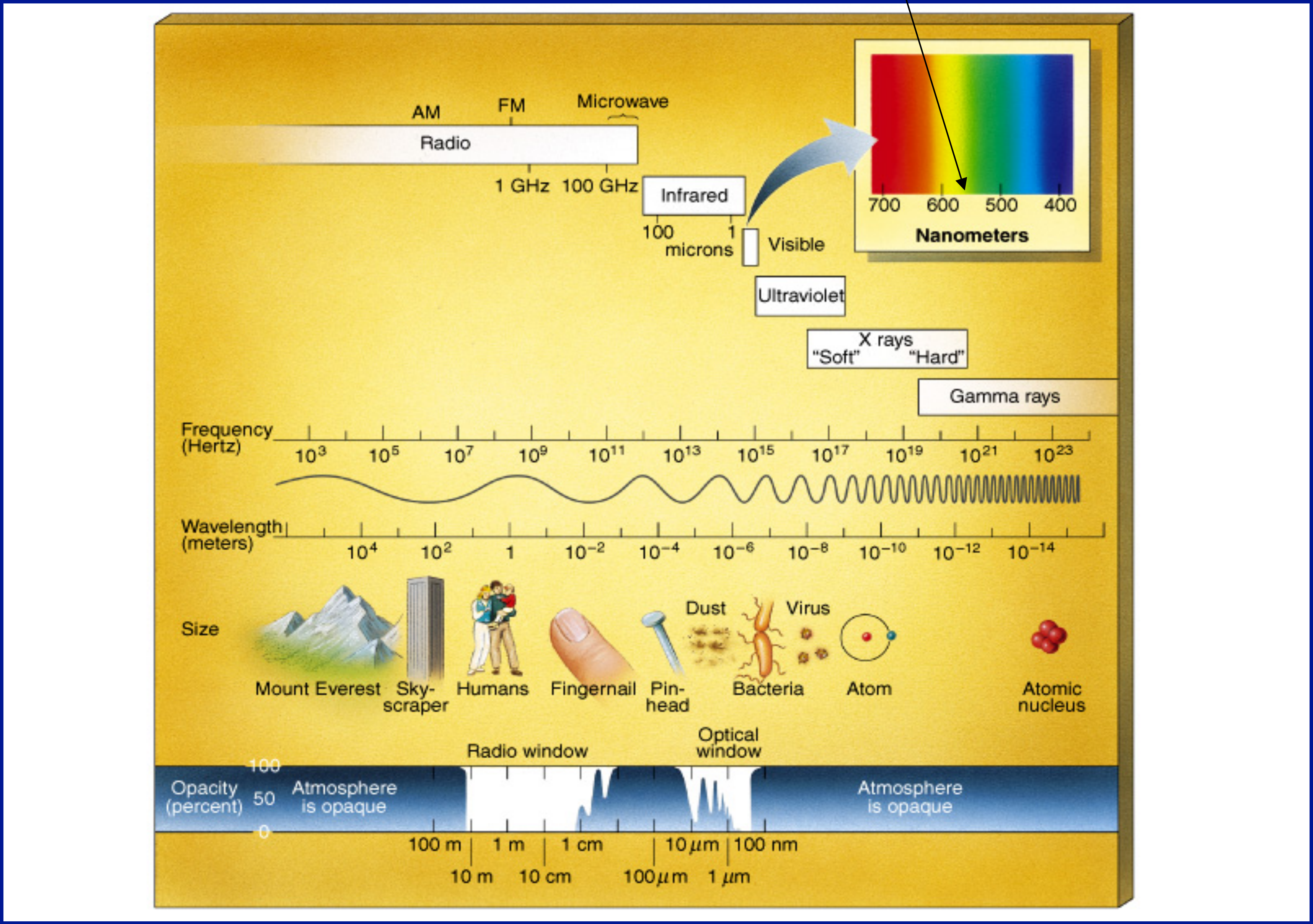
$c = 3 \times 10^{8}$ m / s
or $c = 3 \times 10^{10}$ cm / s
or $c = 3 \times 10^{5}$ km / s



$c = \lambda \nu$ or, bigger λ means smaller ν

The Electromagnetic Spectrum

1 nm = 10^{-9} m , 1 Angstrom = 10^{-10} m



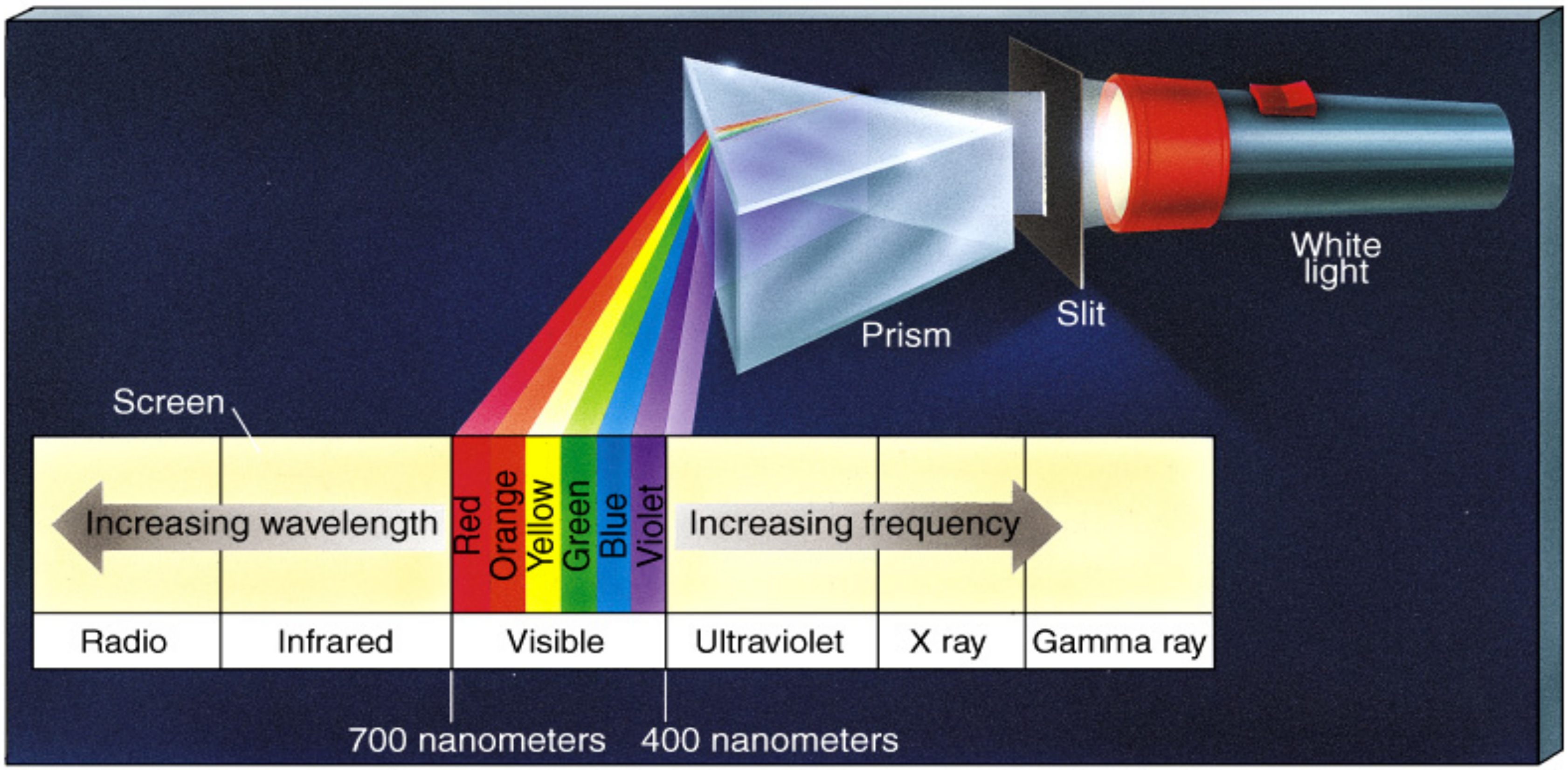
$$c = \lambda \nu$$

A Spectrum

Demo: white light and a prism

Refraction of light

All waves bend when they pass through materials of different densities. When you bend light, bending angle depends on wavelength, or color.



Clicker Question:

Compared to ultraviolet radiation, infrared radiation has greater:

A: energy

B: amplitude

C: frequency

D: wavelength

Clicker Question:

The energy of a photon is proportional to its:

A: period

B: velocity

C: frequency

D: wavelength

Clicker Question:

A star much colder than the sun would appear:

A: red

B: yellow

C: blue

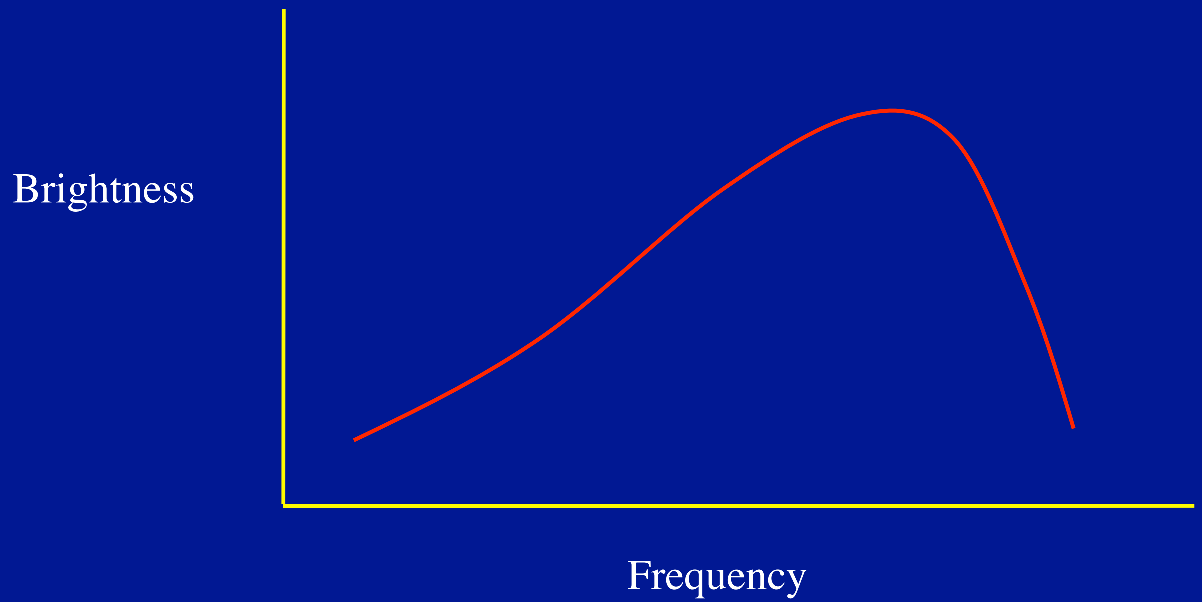
D: smaller

E: larger

We form a "spectrum" by spreading out radiation according to its wavelength (e.g. using a prism for light).

What does the spectrum of an astronomical object's radiation look like?

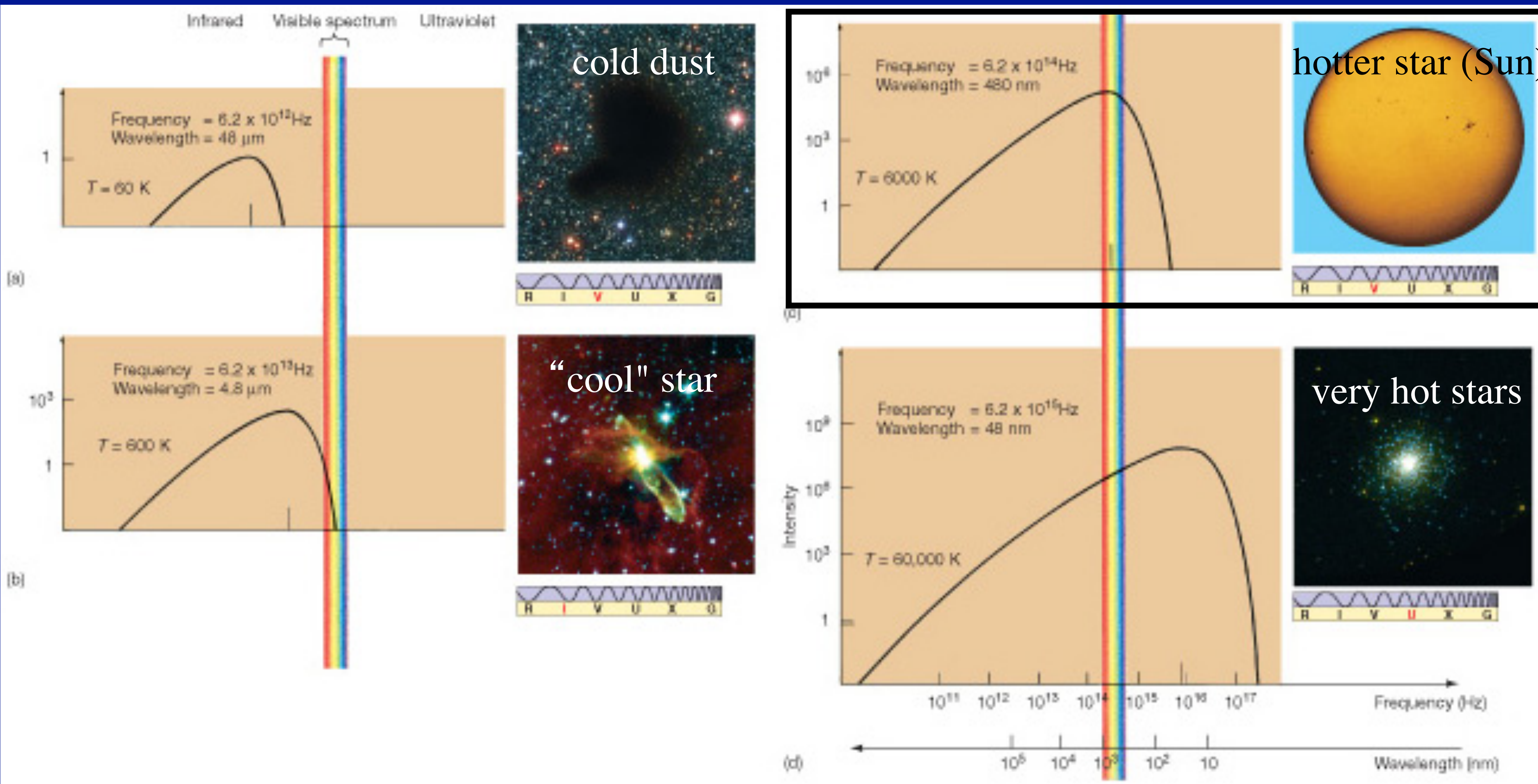
Many objects (e.g. stars) have roughly a "Black-body" spectrum:



- Asymmetric shape
- Broad range of wavelengths or frequencies
- Has a peak

also known as the Planck spectrum or Planck curve.

Approximate black-body spectra of astronomical objects demonstrate Wien's Law and Stefan's Law



frequency increases,
wavelength decreases →

Laws Associated with the Black-body Spectrum

Wien's Law:

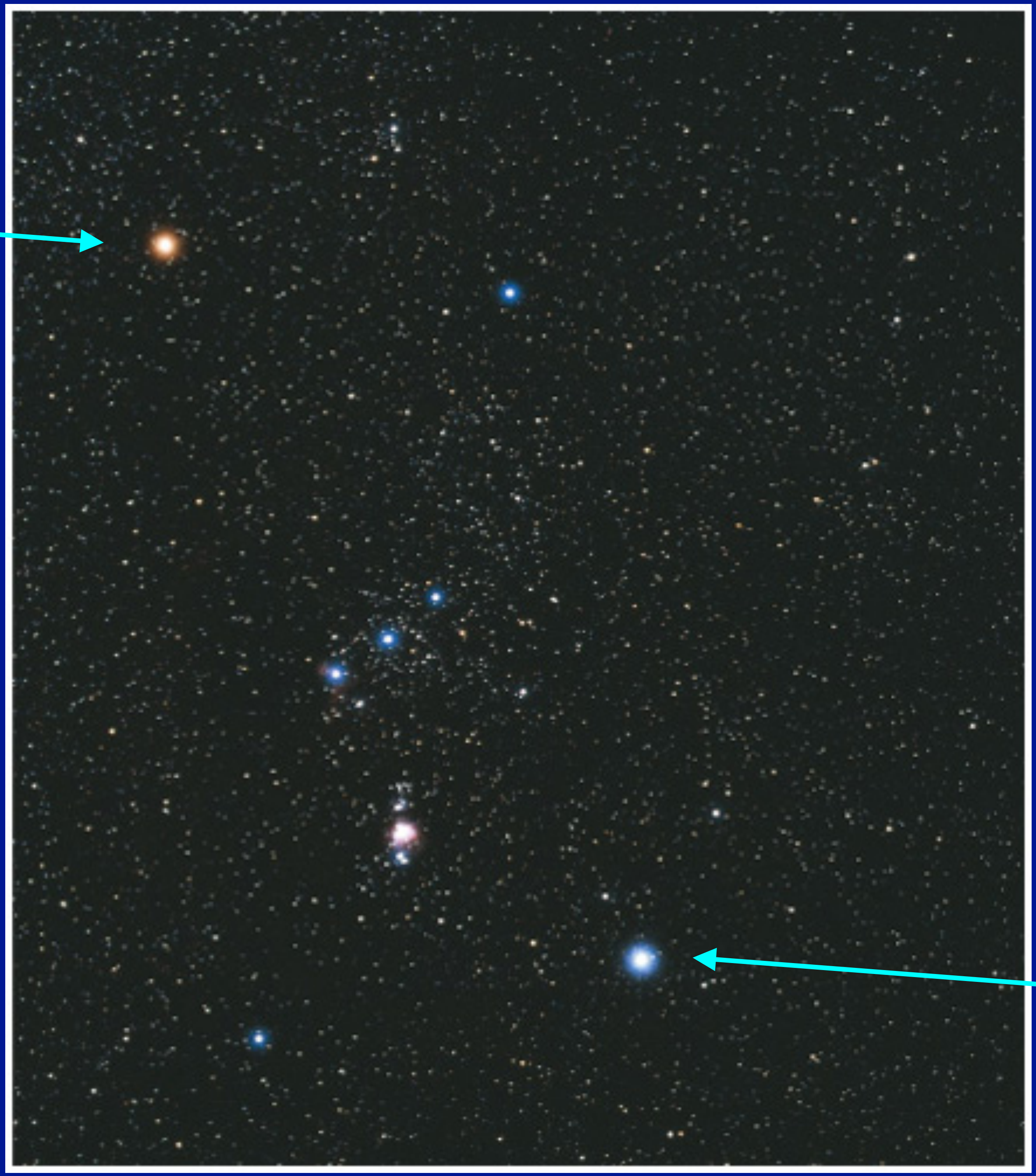
$$\lambda_{\text{max energy}} \;\alpha\; \frac{1}{T}$$

(wavelength at which most energy is radiated is longer for cooler objects)

Stefan's Law:

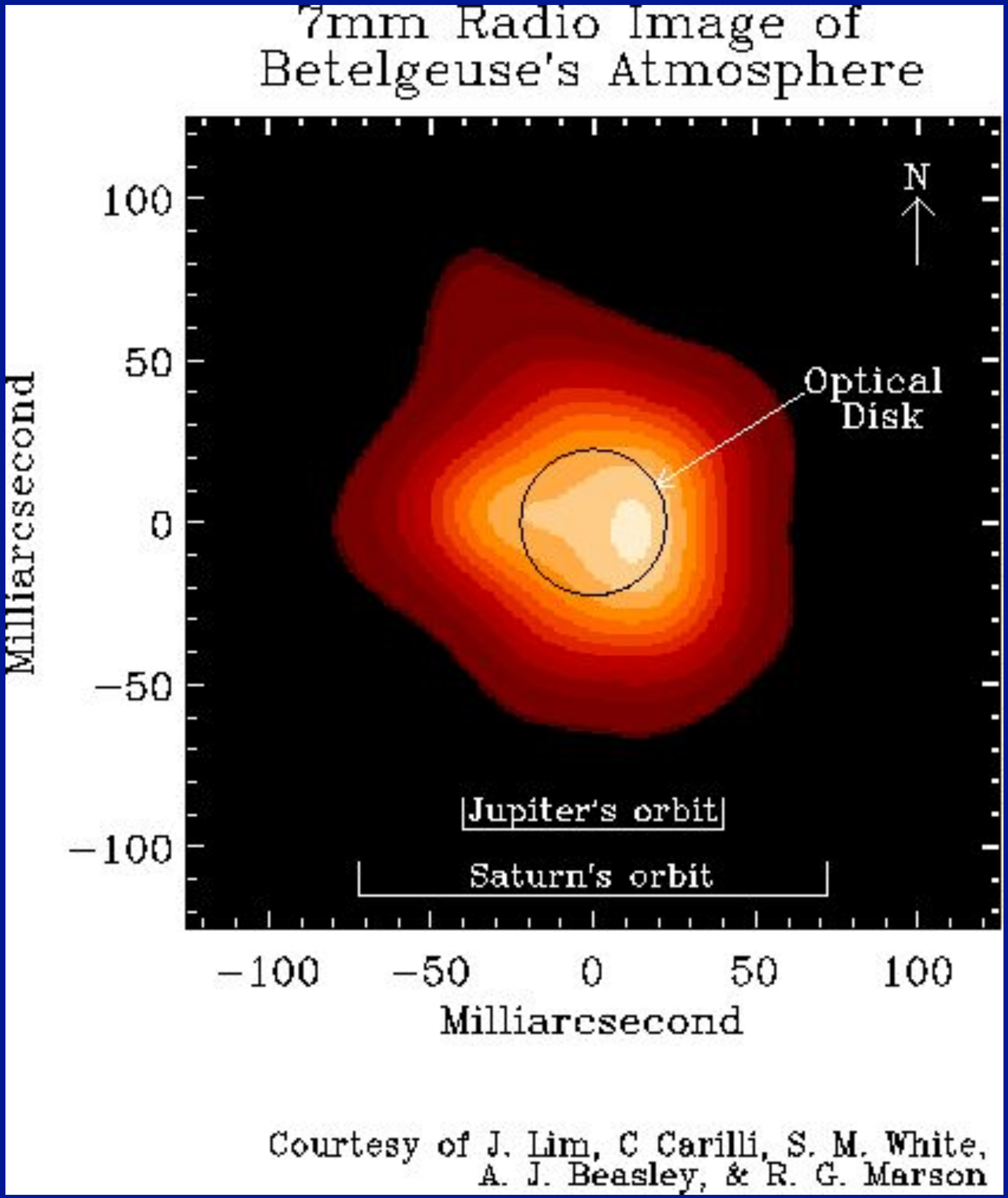
Energy radiated per cm^2 of area on surface every second α T^4
(T = temperature at surface)

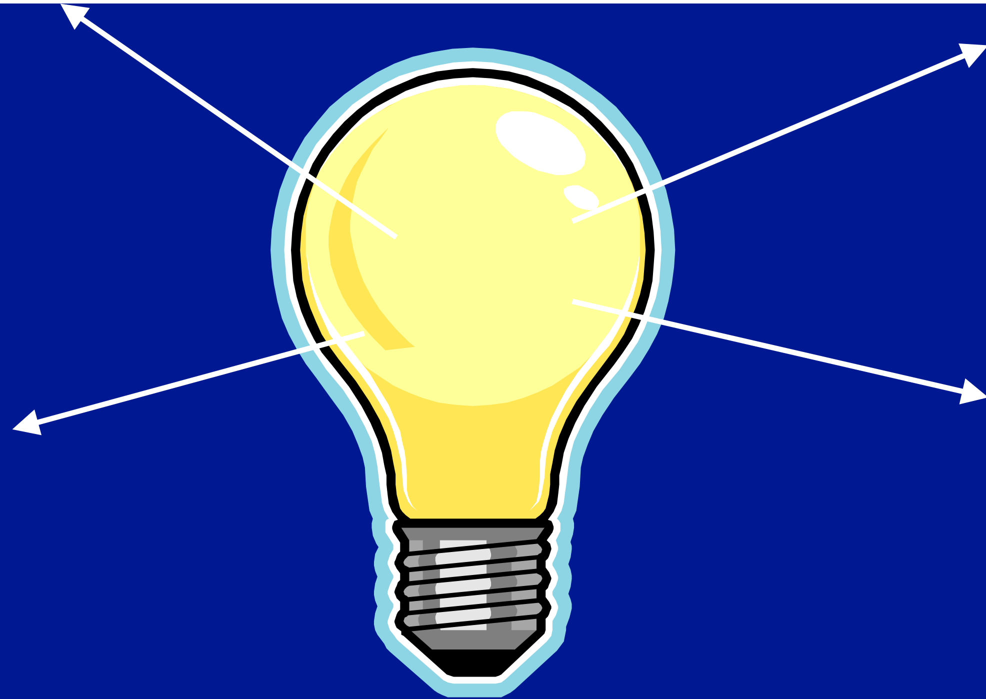
Betelgeuse



Rigel

Betelgeuse


7mm Radio Image of
Betelgeuse's Atmosphere
100
50
0
−50
−100
Milliarcsecond
N
Optical
Disk
Jupiter's orbit
Saturn's orbit
−100
−50
0
50
100
Milliarcsecond
Courtesy of J. Lim, C Carilli, S. M. White,
A. J. Beasley, & R. G. Marson

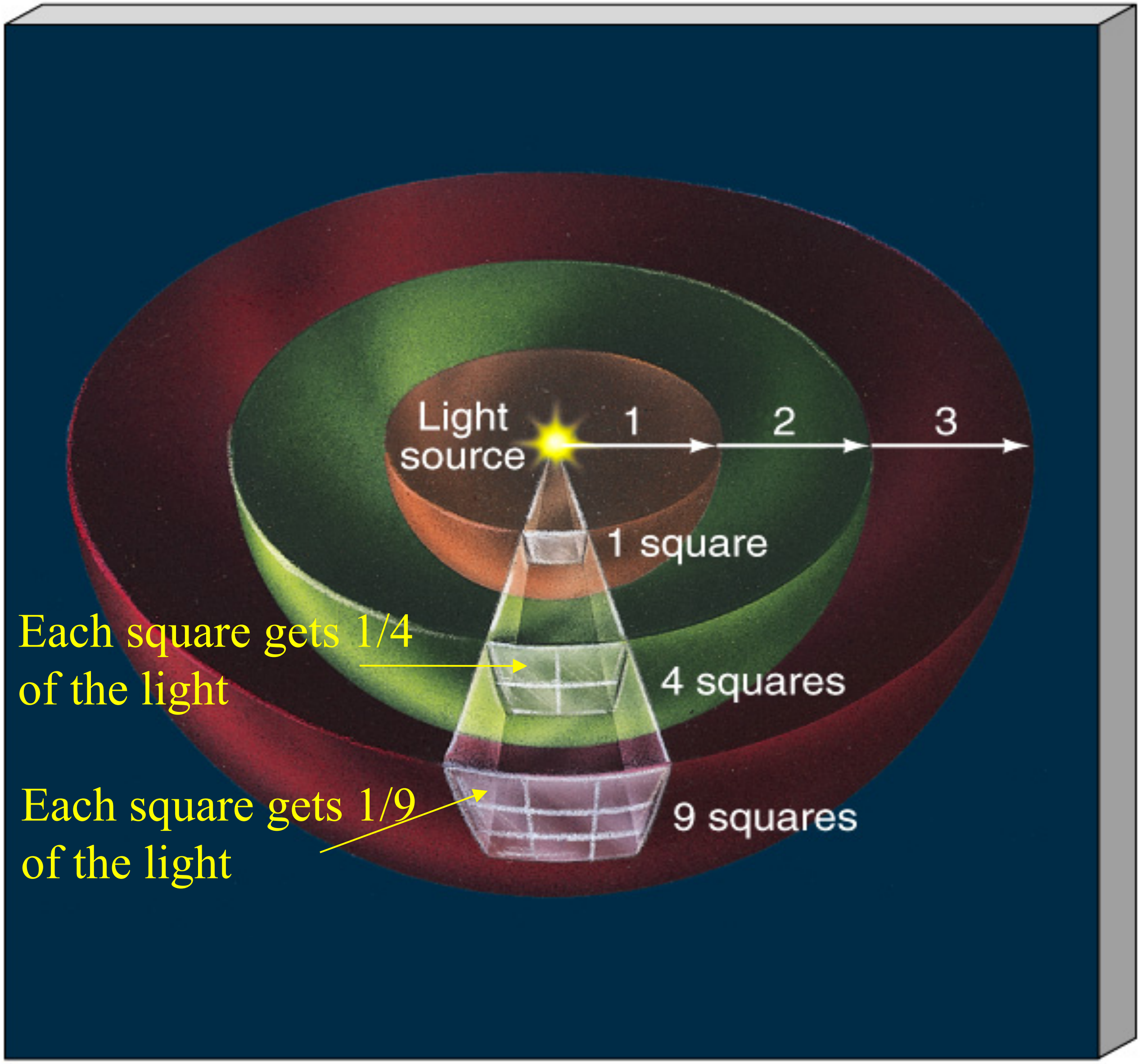


The total energy radiated from entire surface every second is called the luminosity. Thus

Luminosity = (energy radiated per cm^2 per sec) x (area of surface in cm^2)

For a sphere, area of surface is $4\pi R^2$, where R is the sphere's radius.

The "Inverse-Square" Law Applies to Radiation

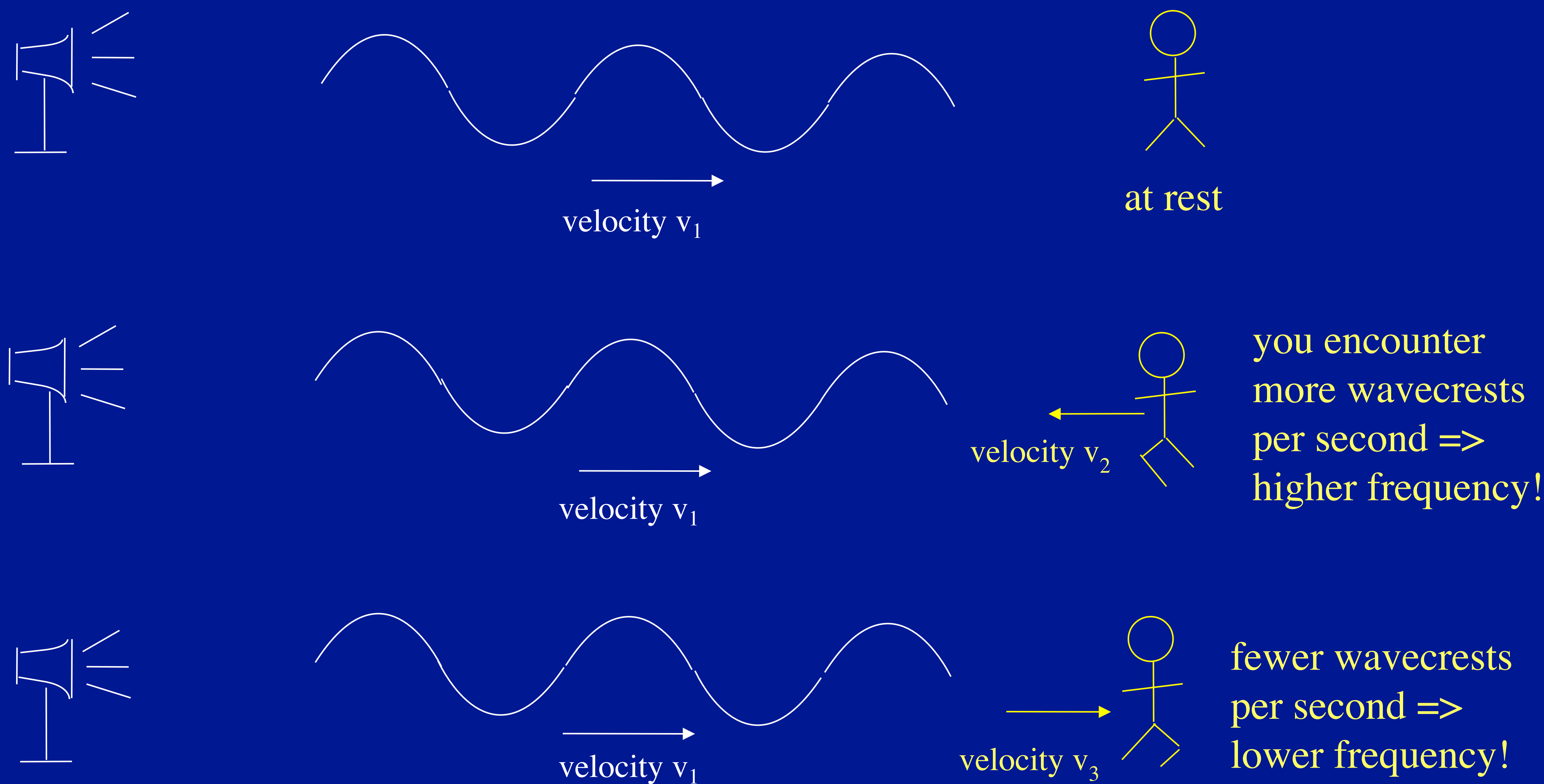


apparent brightness $\alpha \ \frac{1}{D^2}$

D is the distance between source and observer.

The Doppler Effect

Applies to all kinds of waves, not just radiation.

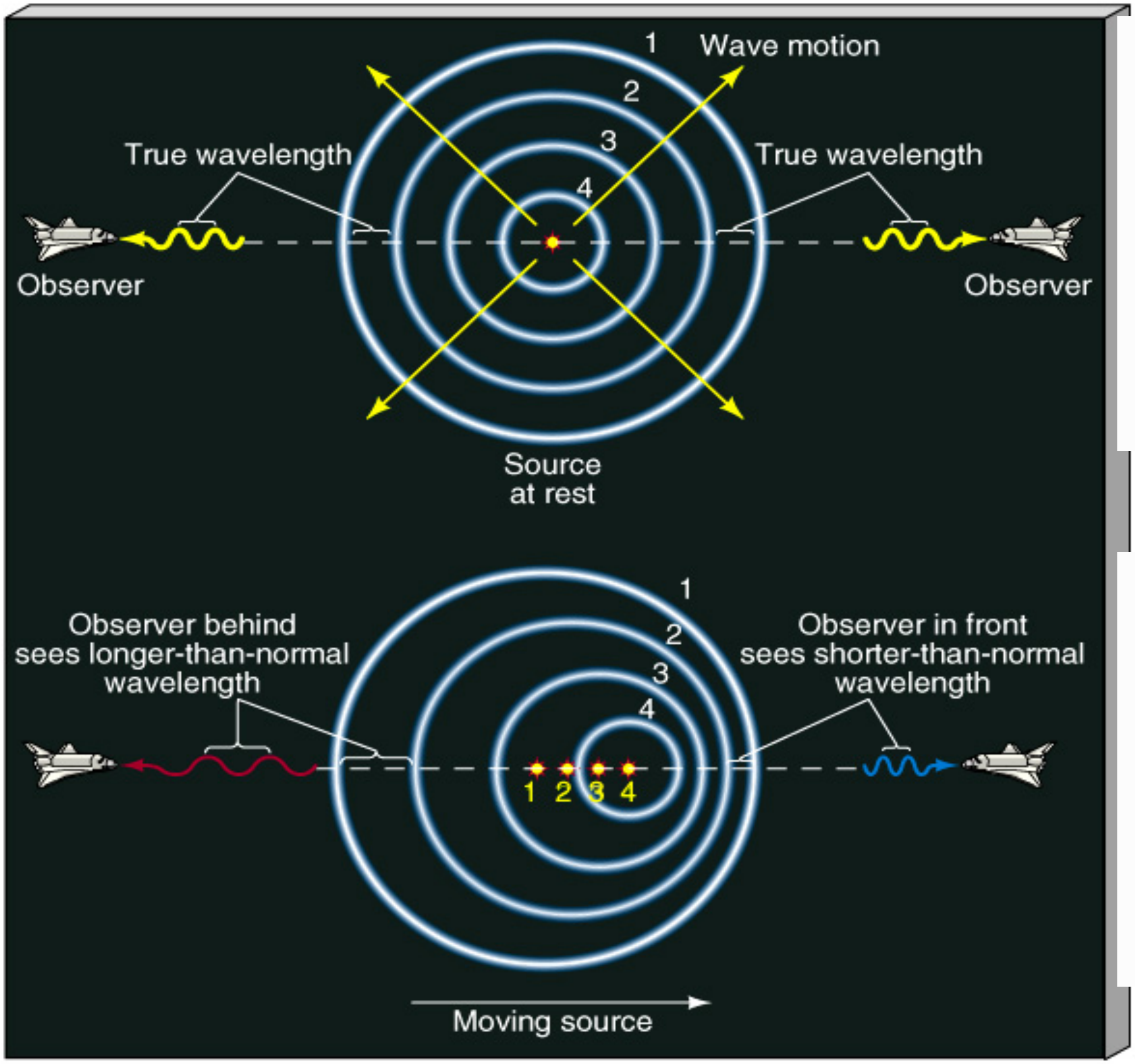


Doppler Effect

Demo: buzzer on a moving arm

Demo: The Doppler Ball

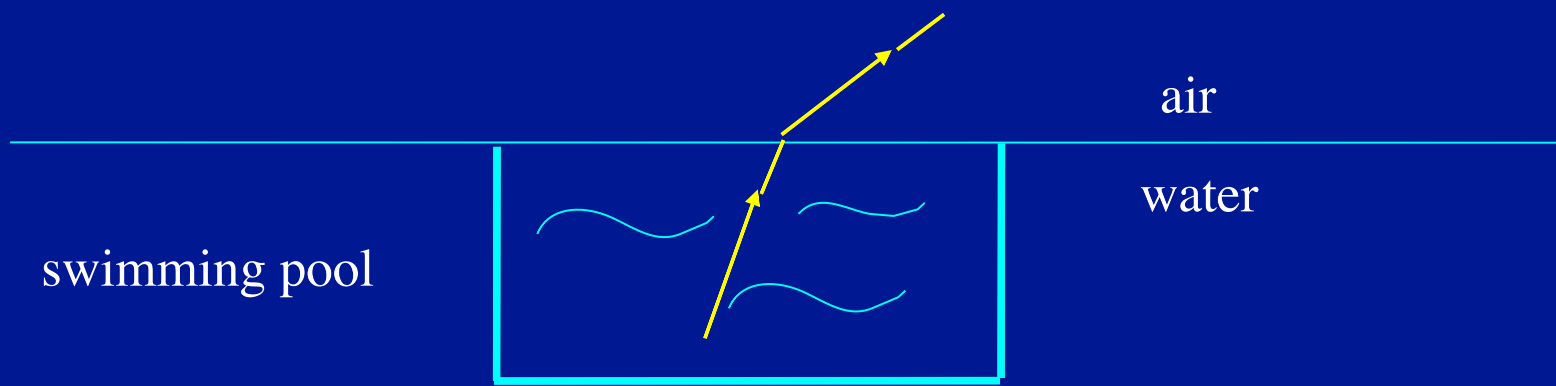
The frequency or wavelength of a wave depends on the relative motion of the source and the observer.

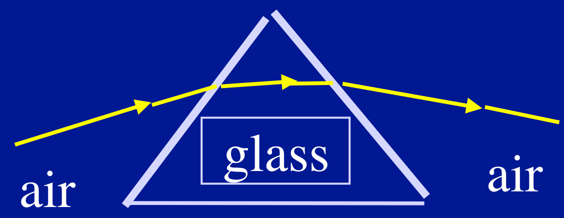


Things that waves do

1. Refraction

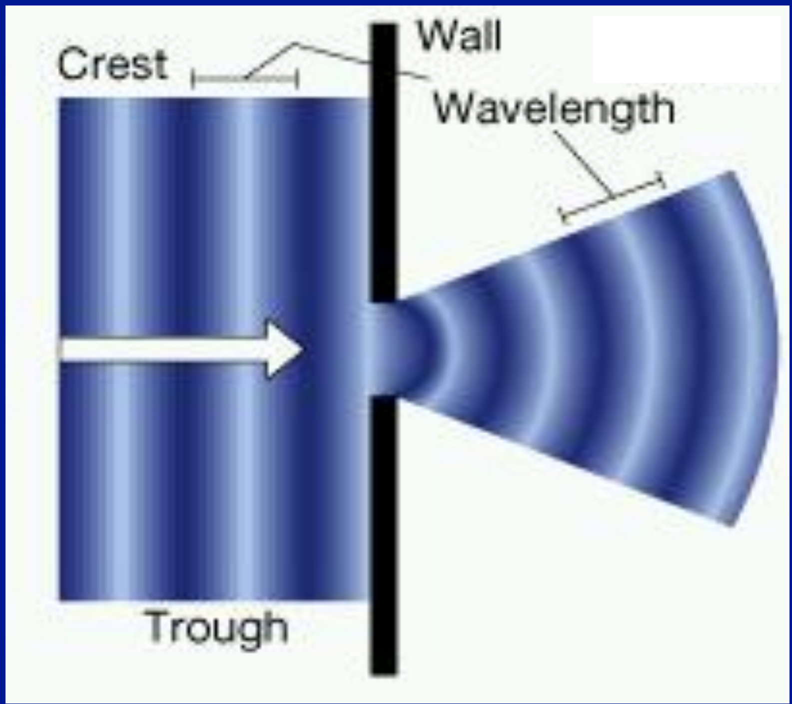
Waves bend when they pass through material of different densities.





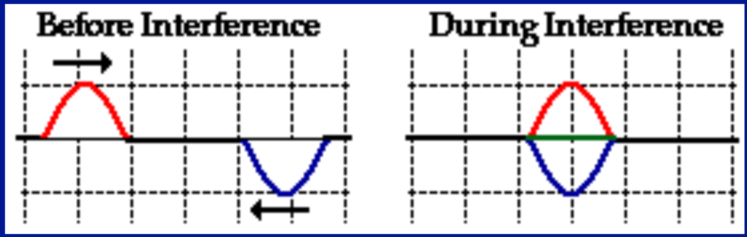
2. Diffraction

Waves bend when they go through a narrow gap or around a corner.

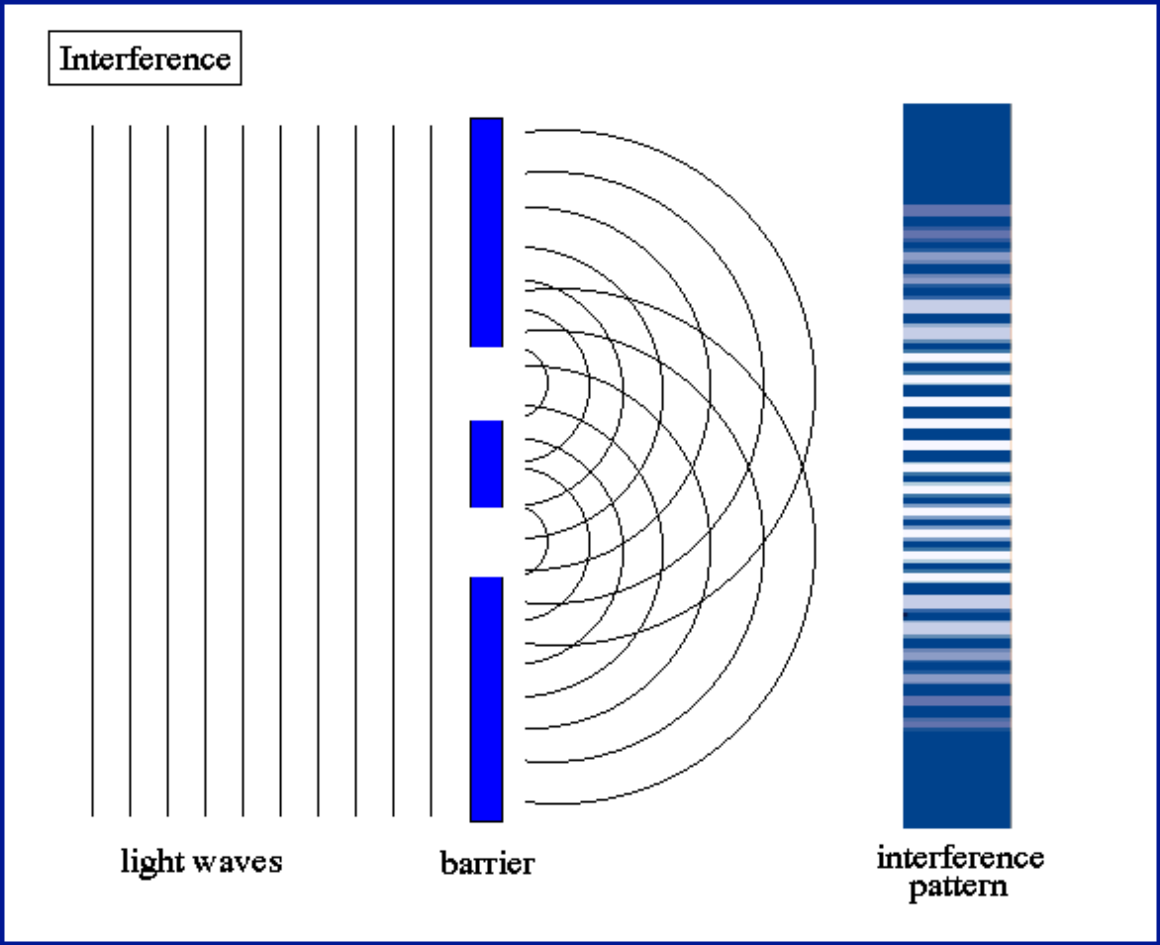


3. Interference

Waves can interfere with each other



Demo:
LASER fringes



Clicker Question:

Compared to blue light, red light travels:

A: faster

B: slower

C: at the same speed

Clicker Question:

Which of the following is not an electromagnetic wave:

A: radio waves

B: visible light

C: X-rays

D: sound waves

E: gamma-rays

Clicker Question:

If a star is moving rapidly towards Earth then its spectrum will be:

A: the same as if it were at rest

B: shifted to the blue

C: shifted to the red

D: much brighter than if it were at rest

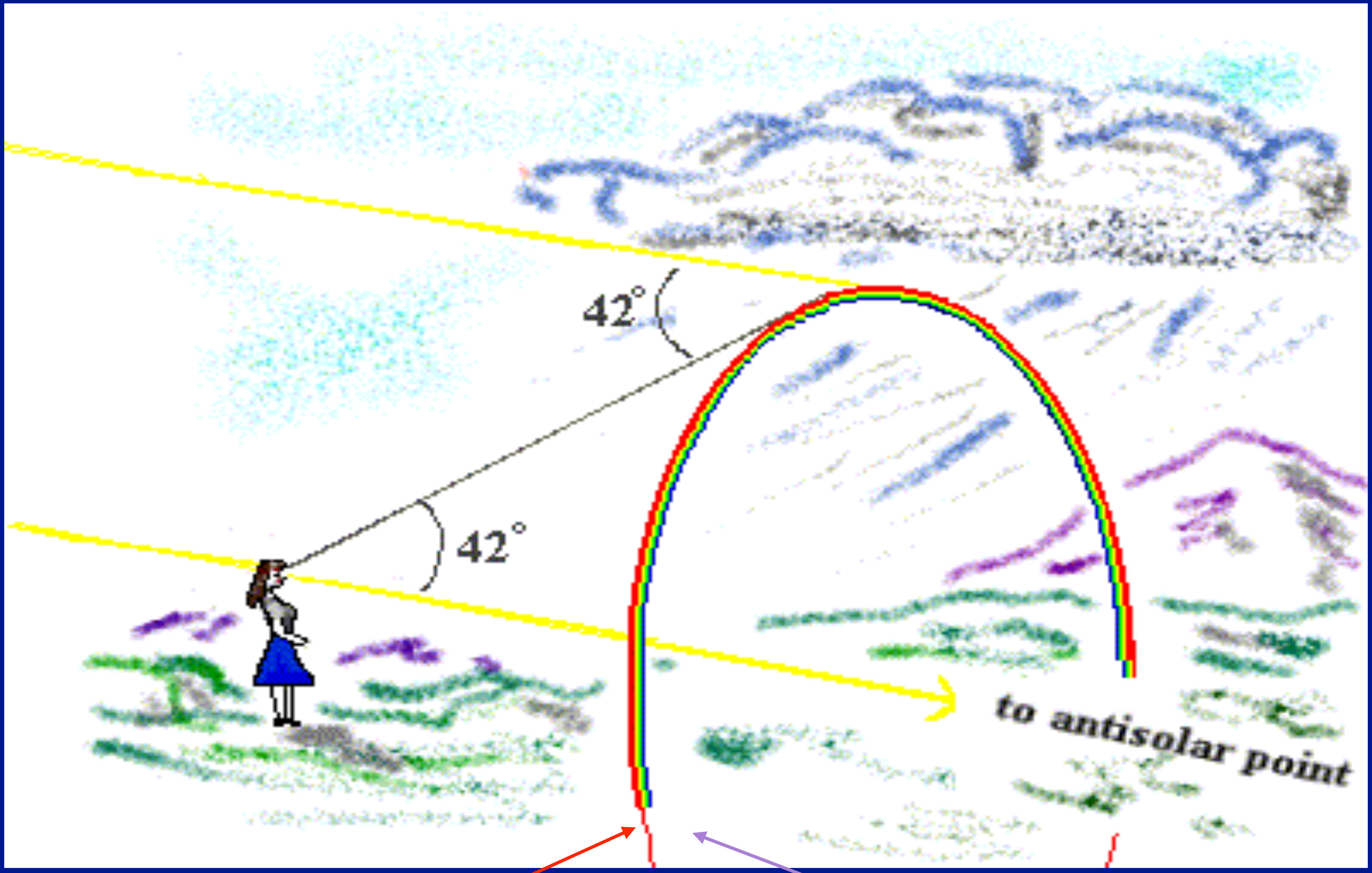
E: much fainter than if it were at rest

Rainbows

Rainbows

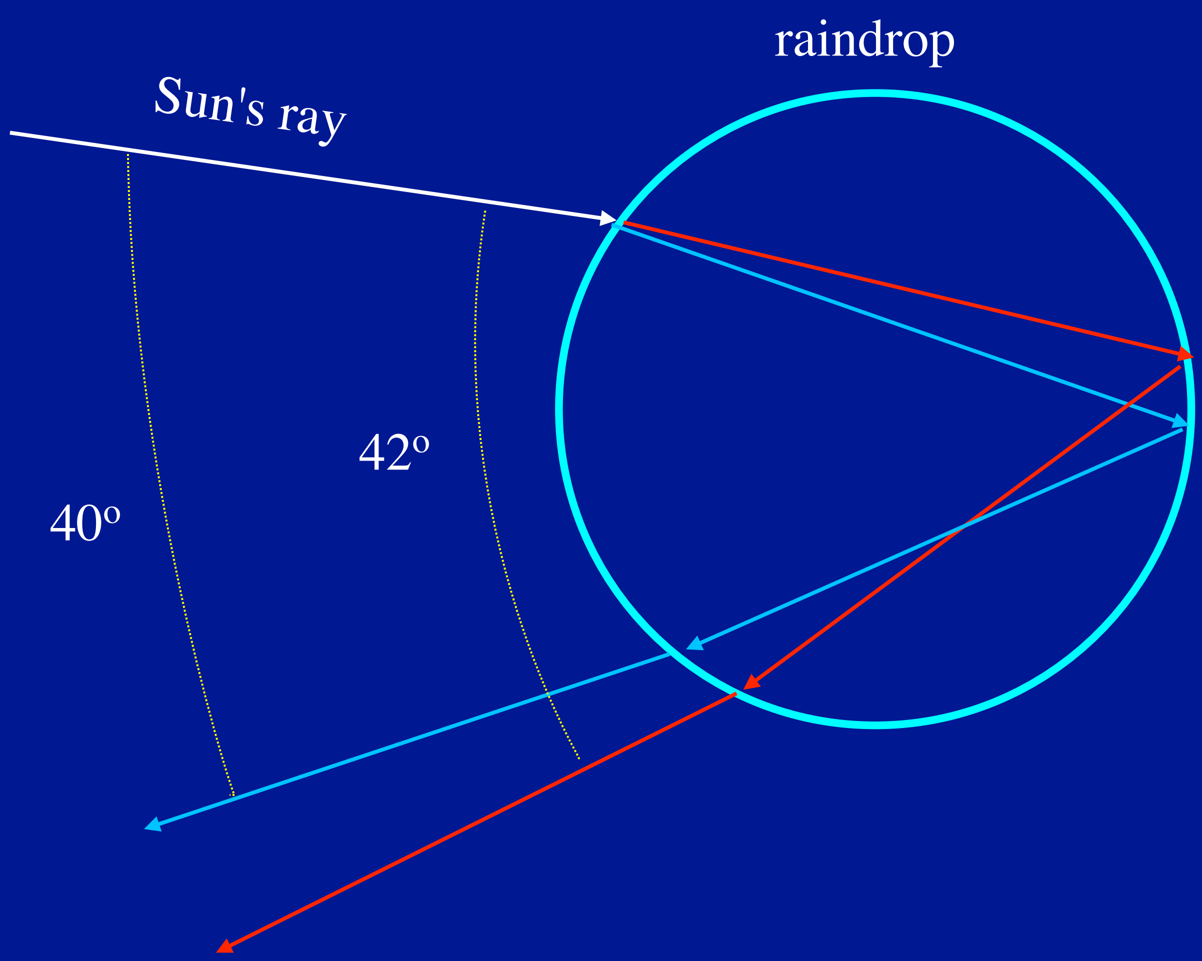
Rainbows

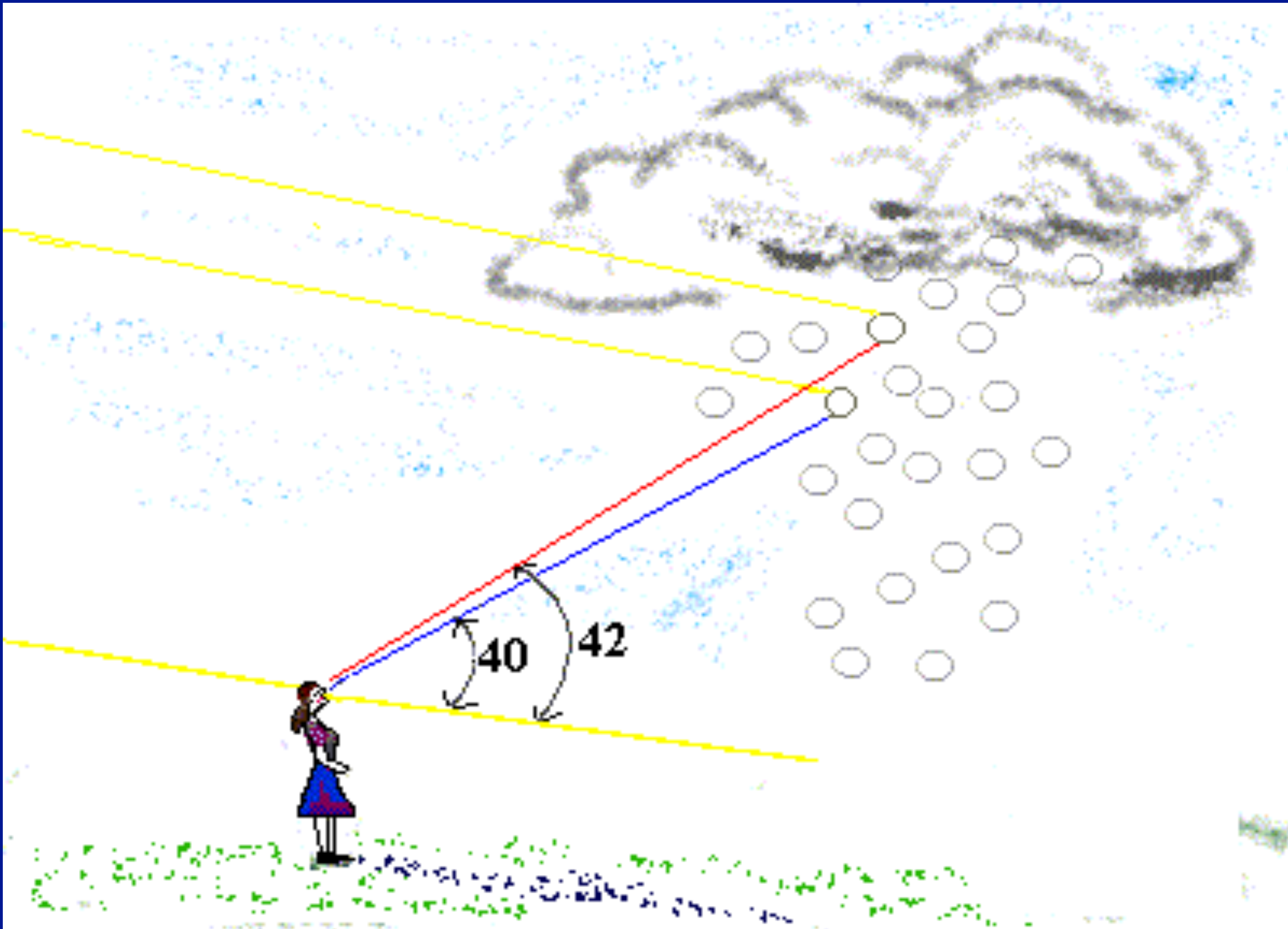
Rainbows



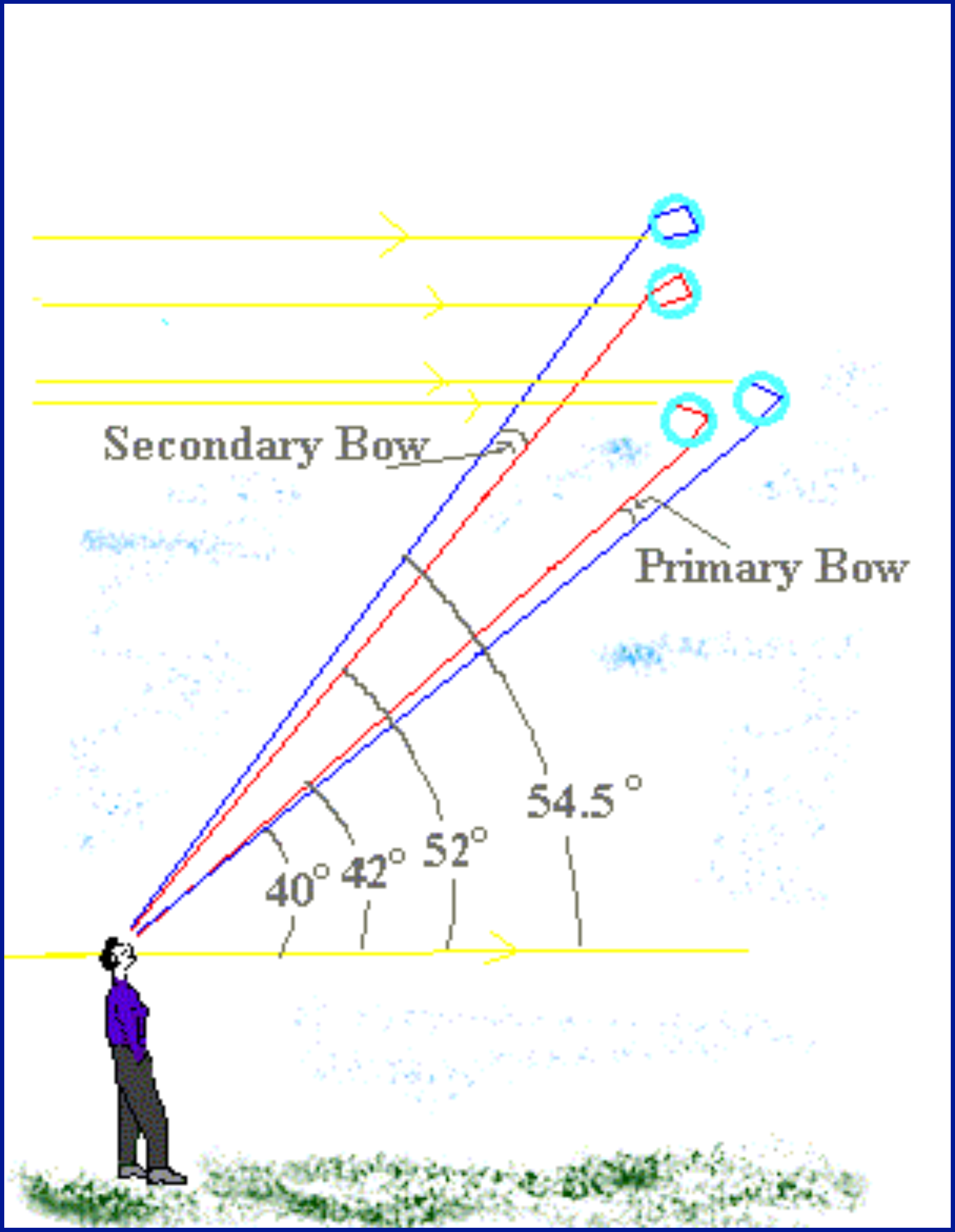
rred orange yellow green blue violet

What's happening in the cloud?



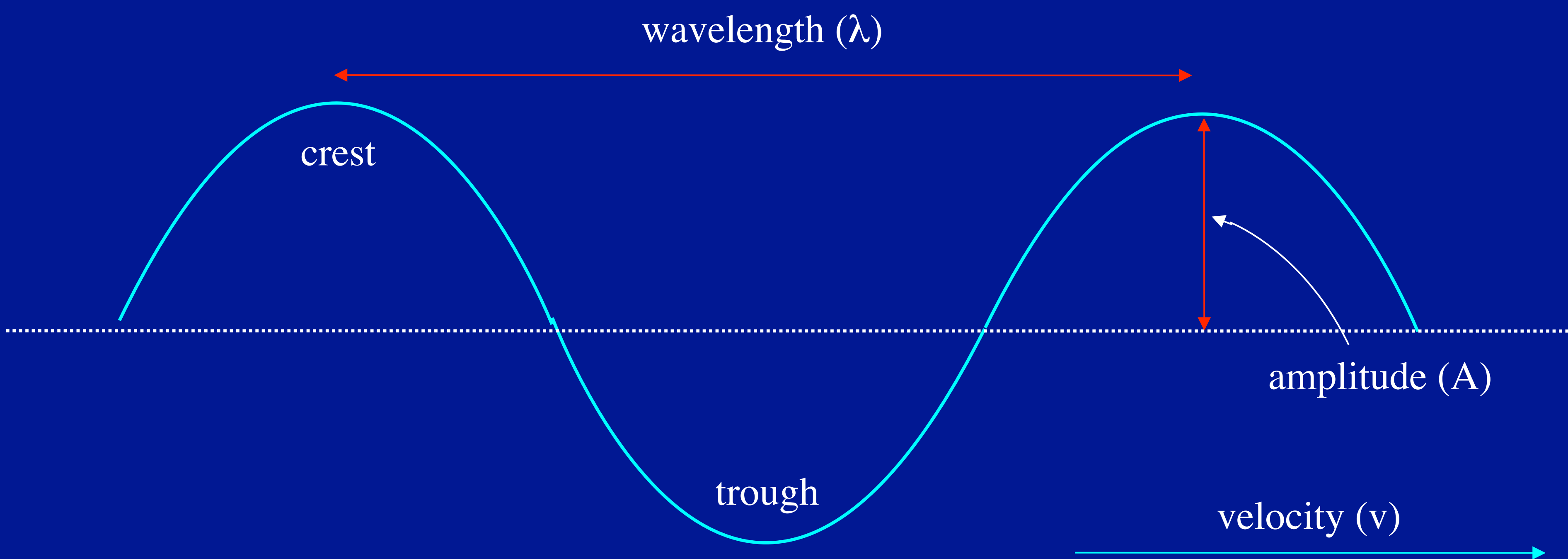

40
42

Double Rainbows



Radiation travels as waves.
Waves carry information and energy.

Properties of a wave



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