Light and Astronomy

The Message of Starlight

Location & Motion
Luminosity & Temperature
Composition of the Light Source
Composition of any Intervening Medium
Rotation & Surface Motions
Electric & Magnetic Fields

Basic "Eyeball" Measurements of Light

Direction: "From where?"
Brightness: "How much?" "Is it constant?"
Color: "What kind?"
....and also Polarization

The Nature of Light

The Basic Behavior of Light

Light Travels in Straight Lines
(The Inverse-Square Law)

Light Carries Energy and Momentum
(Light heats or cools and exerts forces)

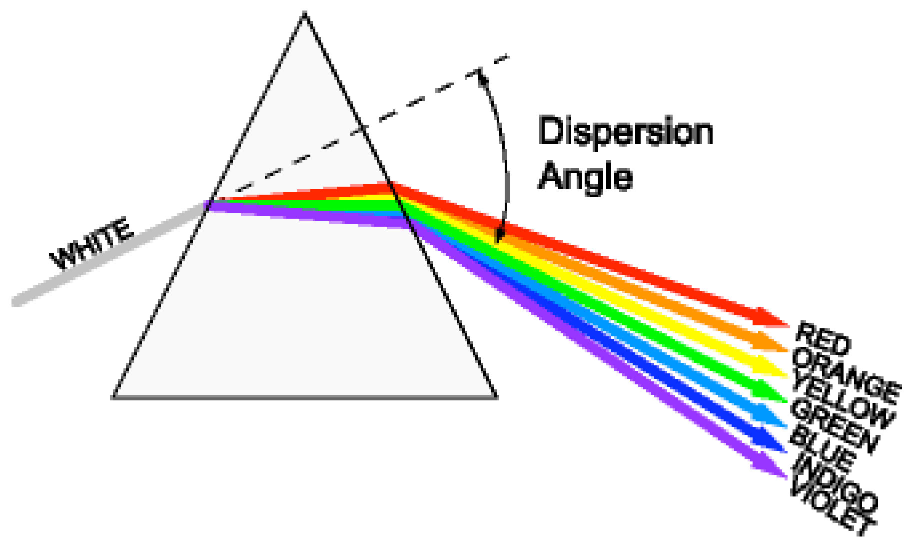
Light Travels at a Finite Speed
(c = 300,000 km/s)

Some Forms of Light are Invisible to the Eye
("Electromagnetic Radiation")

Digression: Aristotle (again) and the Classical View of light
light = φυσ   photons = φωτονι

The Composition of Light

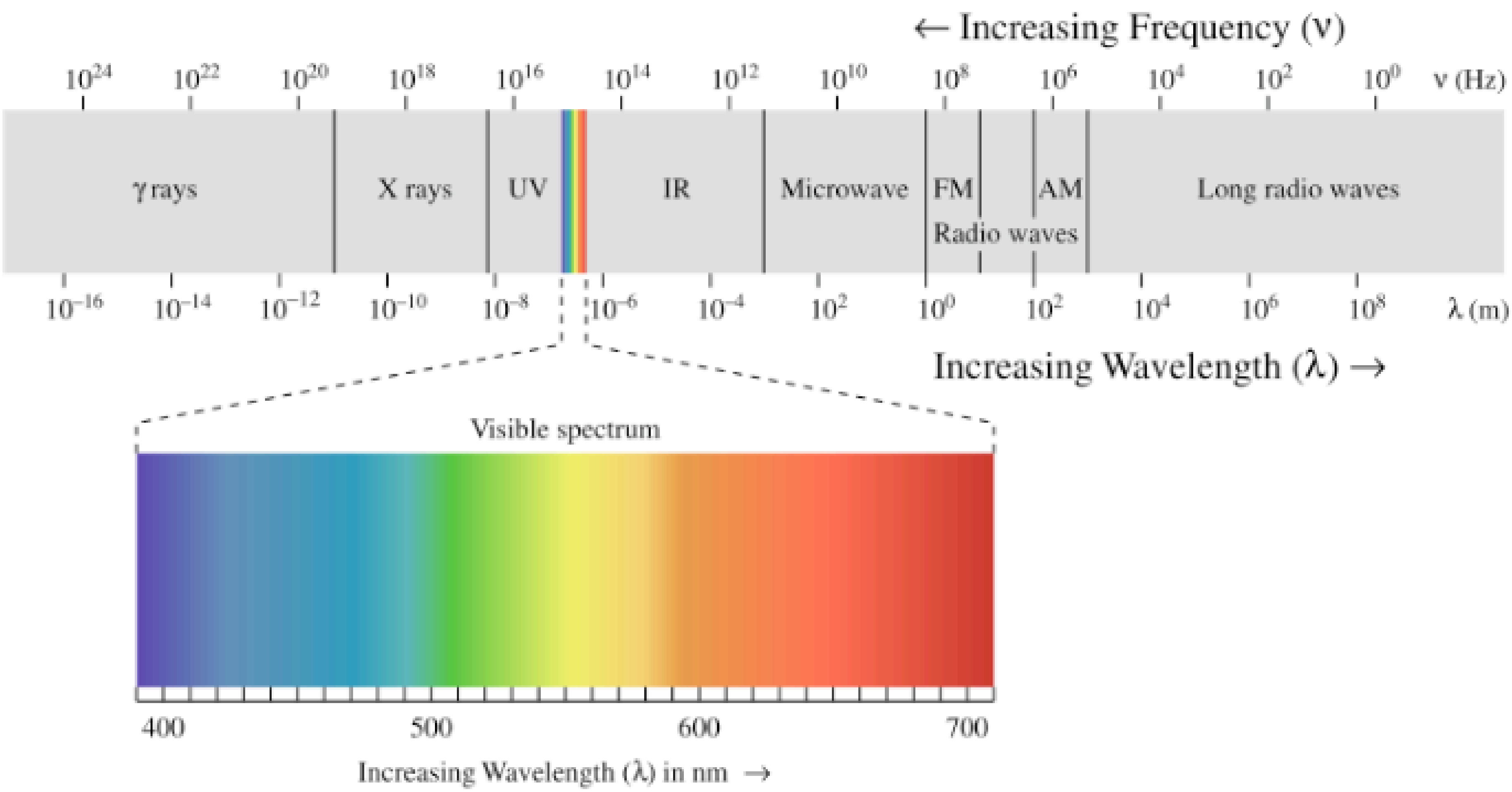
(Newton and Others)



Light exhibits wavelike properties

Each "color" corresponds to a measurable wavelength, λ , and frequency, ν. (They are related by $\lambda\nu = c$.)

The Electromagnetic Spectrum



For <u>any</u> kind of a wave $\lambda\nu = c$ *where c is the wave's speed.*

A Surprising Property of Light

The Measured Speed of Light (in a vacuum) is independent of the relative motions of the source and the observer.
(c = 300,000 km/s, **always**)

Einstein's Special Theory of Relativity (1905) is a consequence:

Predicted (and Observed) Phenomena:
Time Dilation,
Relativistic Mass Variation,
The Lorentz-Fitzgerald Contraction,
and Mass-Energy equivalence.

$$E = mc^2$$

(Probably the most famous equation in the world.)
....with lots of consequences:

Another Surprising Property of Light

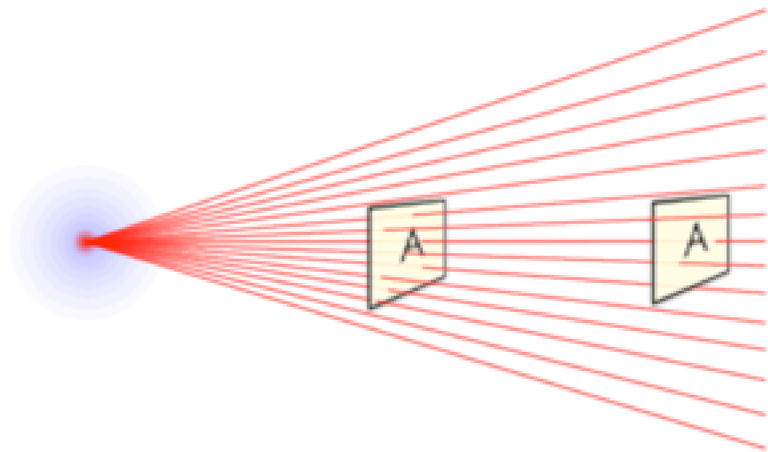
Light Exhibits the Properties of <u>both</u> Waves and Particles
("Photons" and "Electromagnetic Waves")

Wavelike Phenomena: Diffraction, Interference, Doppler Effect
Brightness or Intensity = Wave Amplitude,
Color = Frequency ν or Wavelength λ
(Recollect: $\lambda\nu = c$)
Polarization = Oscillation Direction

Particle-like Phenomena: Vacuum propagation, discreteness
Brightness or Intensity = Photon Numbers,
Color = Photon Energy ($E = h\nu$)
Polarization = Photon Spin
...leading to the realization that "obvious" particles (like rocks) can also display wavelike properties:
Welcome to the Weird World of Quantum Mechanics!

Useful Phenomenon:
The Inverse-Square Law for Light*

$$F = L/4\pi d^2$$



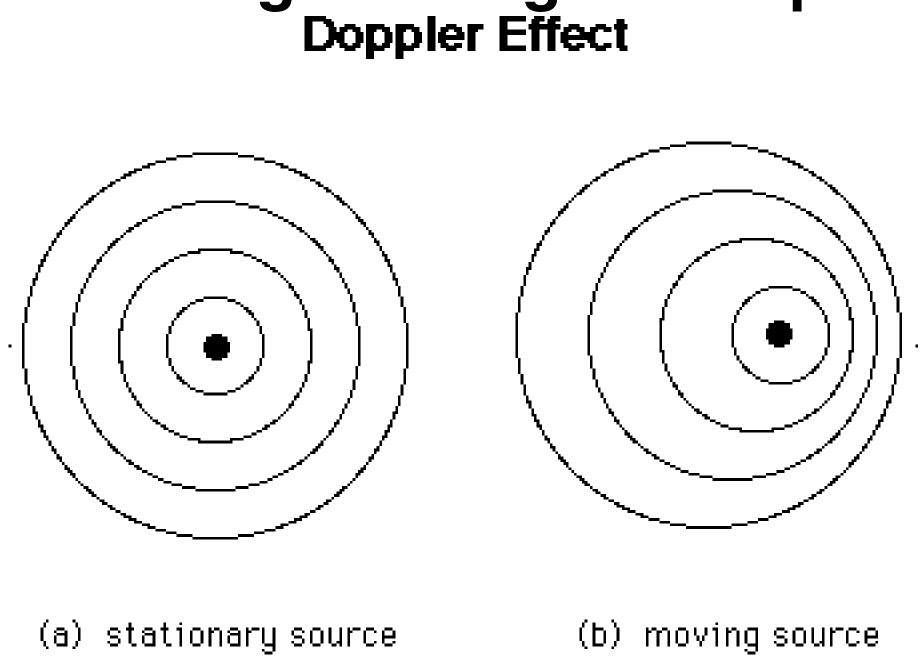
The apparent brightness (F) is proportional to the luminosity (L) of the source and inversely proportional to the square of the distance from the source (d)

*Johannes Kepler, *The Optical Part of Astronomy* (1604)

Useful Phenomenon: The Doppler Effect

A wave originating in a receding source will appear to be of longer wavelength or lower frequency. (*i.e.*, redder)

A wave originating in an approaching source will appear to be of shorter wavelength or higher frequency.(i.e., bluer)



Note: The source is moving to the right in the second figure.

The Doppler Formula

The fractional shift in wavelength is equal to the radial velocity divided by the wave velocity

$$\Delta\lambda/\lambda_o = (\lambda - \lambda_o)/\lambda_o = +v_{radial}/c$$

where λ_o is the emitted wavelength, λ the observed wavelength

A radial velocity is the rate at which an object's distance changes. It's positive if the source is receding and negative if it's approaching

The Doppler Formula for frequency looks *almost* the same:

$$\Delta\nu/\nu_o = (\nu - \nu_o)/\nu_o = -v_{radial}/c$$

......but note the minus sign.

Since $\lambda\nu = c$, an upward shift in frequency is the same as a downward shift in wavelength, and *vice versa*.