Light is a Transverse Wave

- No Medium Required! (Michelson-Morley Expt.)

Electric Field

Magnetic Field
Supernumerary Rainbows
Water waves interfere

So do light waves!

Young Proved Light is Wave
Double Slit Expt. (1801)
Waves of Light

Light has wave-like properties, such as *diffraction.*

(Diffraction = bending around an opening)
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).

Visible Light observable from Earth, with some atmospheric distortion.

Most of the Infrared spectrum absorbed by atmospheric gases (best observed from space).

Radio Waves observable from Earth.

Long-wavelength Radio Waves blocked.
Spitzer Infrared Telescope

Gamma Ray Observatory

Chandra X-ray Observatory

Hubble Space Telescope (optical & ultraviolet)
Orion Nebula --- star-forming region

optical

infrared

WFPC2

NICMOS
Blackbody Radiation

An ideal “blackbody” absorbs all light incident upon it. Its glowing walls then radiate this light away.

Light is emitted by this blackbody can be studied.
Using Light to Measure Temperature

Red Hot  Orange Hot  Yellow Hot
The portion of light we detect from a star/blackbody depends on several factors that have nothing to do with the star!

-- The area of our detector
-- The wavelengths to which it is sensitive (visible? IR? just green?)
-- The fraction of the star’s area whose light we receive.
-- The angle of our detector with respect to the incoming light.
We need a way to translate the light we observe to the object’s intrinsic properties. So we consider:

- only light falling on 1 square meter in one second
- only a specific wavelength range: $[\lambda, \lambda + d\lambda]$
- only light entering a given solid angle: $d\Omega$

We then can measure energy received as:

Joules per second per m$^2$ per unit wavelength per unit solid angle.

Watts/m$^2$/nm/stereadian.

That’s: $B_\lambda(T)$
Catastrophe!!!

Classical physics was used to predict the amount of light produced by a blackbody at various wavelengths. These predictions were utterly wrong!

Since the discrepancy was greatest at UV wavelengths, this problem was called the: "ultraviolet catastrophe."
Quantum Physics

Stephan-Boltzman Law and Wien’s Law are in fact, aspects of a deeper reality, discovered by Max Planck in 1901.

Planck tried to explain blackbody radiation anyway he could.

He postulated that energy came only in discrete units:

\[ E = h \nu \]

Where \( h = 6.67 \times 10^{-34} \text{ J s} \) became known as Planck’s constant.

This guess allowed him to derive the dependence of the light from the BB on Temperature and wavelength. He found...
If you ask: “at which wavelength does this function reach a maximum?” \( \lambda_{\text{MAX}} \), you find:

\[
B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{e^{hc/\lambda kT}}{e^{hc/\lambda kT} - 1}.
\]

\( B_\lambda(T) \) is the intensity of light at each specific wavelength (\( \lambda \)) produced by a blackbody of temperature T.

“Planck function”

If you ask: “at which wavelength does this function reach a maximum?” \( \lambda_{\text{MAX}} \), you find:

\[
\lambda_{\text{MAX}} T = 0.002897755 \text{ m K}.
\]

If you ask: “What is the total energy output, at all wavelengths for a given temperature” you get:

\[
L = 4\pi R^2 \sigma T_e^4.
\]