An introduction to Light

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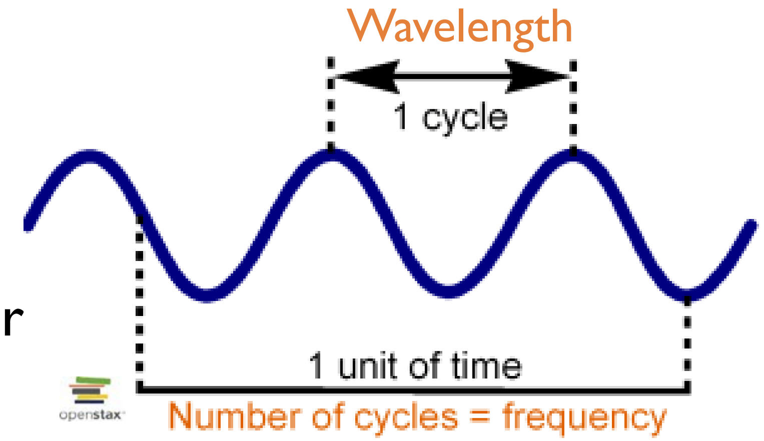
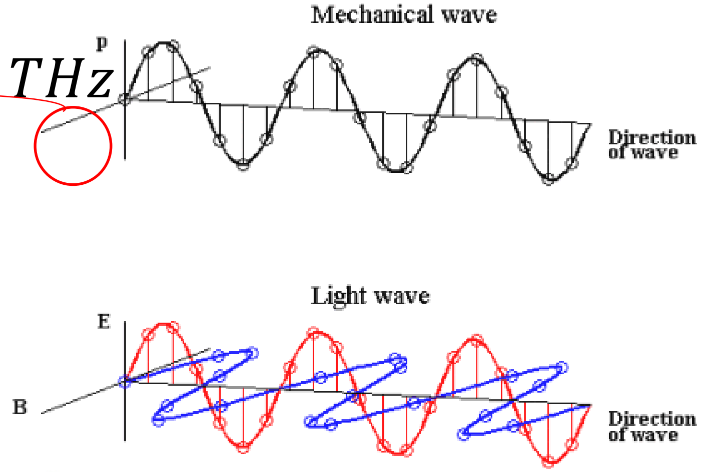
Light is a **wave**



- Light as a *Wave*
  - Described by laws of electromagnetism, linking electric & magnetic fields (along with electric charges and cur
  - Light waves are often referred to as "radiation"
  - Light waves travel (in a vacuum) at the "speed of light", $c = 2.998 \times 10^8\ m/s = \lambda f\ = \text{(wavelength)} * \text{(frequency)}$
    - e.g. Yellow light has a wavelength of roughly 500 nm,

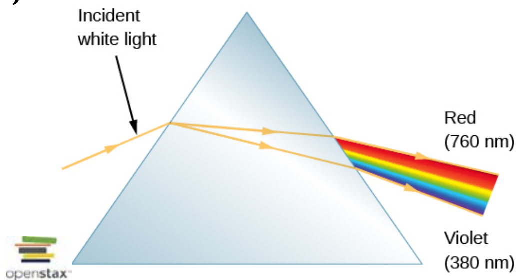
$$\text{so } f_{\text{yellow}} = \frac{c}{\lambda} = \frac{2.998\times10^8\ m/s}{500\ nm} \frac{(1\ nm)}{(10^{-9}\ m)} \approx 6 \times 10^{14}\ \frac{1}{s} = 600\ THz$$



    - e.g. Typical FM radio has roughly 100 MHz frequency,

$$\text{so } \lambda_{\text{FM}} = \frac{c}{f} = \frac{2.998\times10^8\ m/s}{10^8\ Hz} = 2.998\ m$$

  - Light you are used to seeing, e.g. from the Sun or a light bulb, is actually composed of several wavelengths



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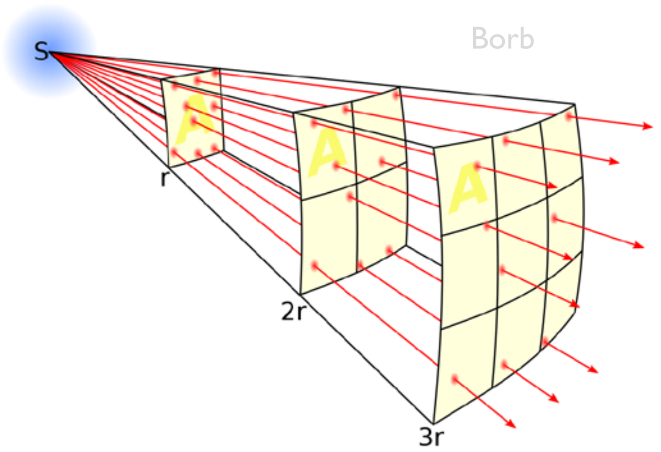
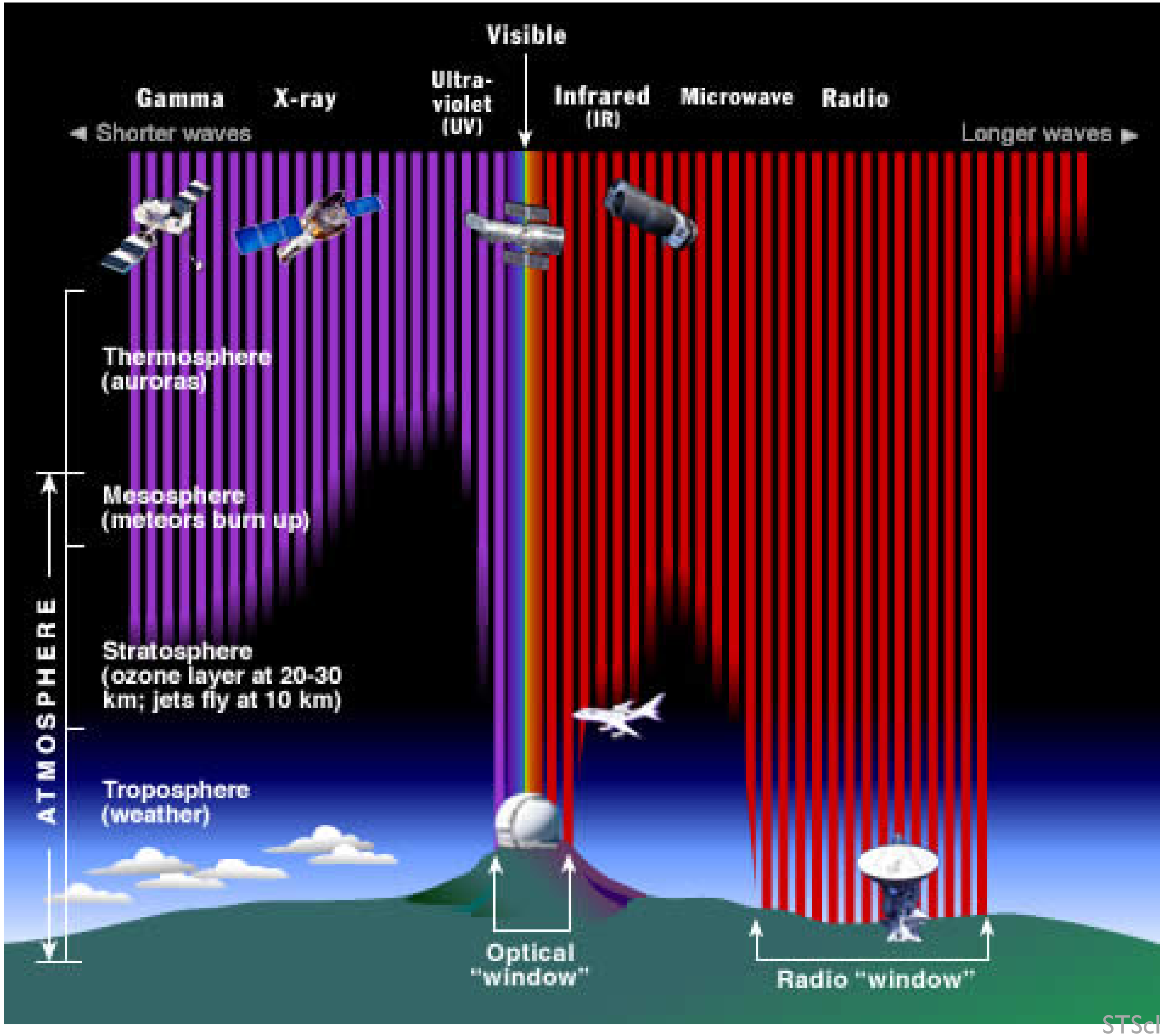
Light is a **particle**

- Light as a *particle*
  - One unit is a photon, which is a packet of electromagnetic energy
  - One photon carries energy $E = hf$, where h is a constant (Planck's constant)
  - A brighter object is generating a lot more photons
    - For example, a 60W light bulb is generating ~10^{20} photons per second
  - The closer a light detector (e.g. your eye) is to the light source, the more photons it will intercept
    - This is the "inverse square law":
      - The number of photons of a given energy per area per time, which is the intensity I, decreases as the distance squared d^2 from a light source
      - $\frac{I_1}{I_2} = \frac{d_2^2}{d_1^2}$
    - Cutting the distance to the source in half results in 4x the detected intensity.
      Cutting the distance in 1/4 results in 16x the intensity



Light comes in many wavelengths

- Radio, microwave, red, x-rays, … are all light
- λ spans a huge range:
  - γ-ray: $\lambda < 0.01$ nm
  - Radio: $\lambda >$ m
- All wavelengths play provide valuable information in astronomy. For example:
  - γ-rays from radioactive decay provide signatures of element-formation
  - X-rays are the natural λ of explosions on neutron stars
  - Infrared is main λ from warm solar system objects
  - Radio is emitted from neutron stars



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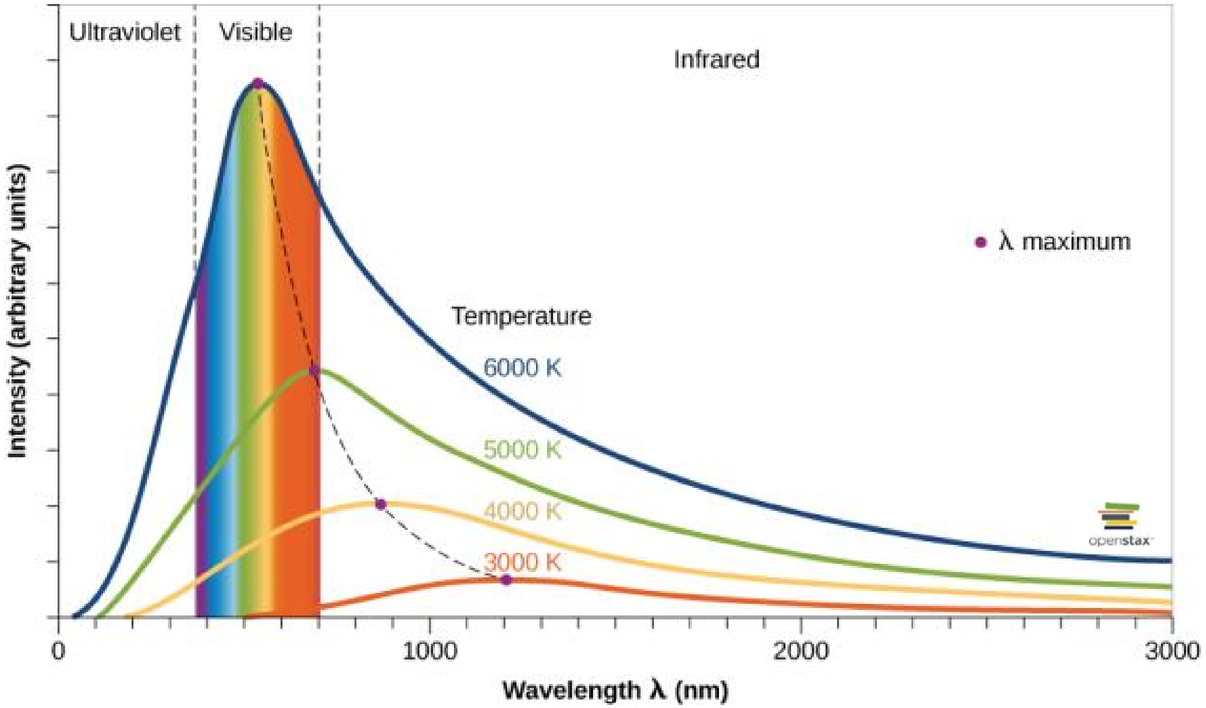
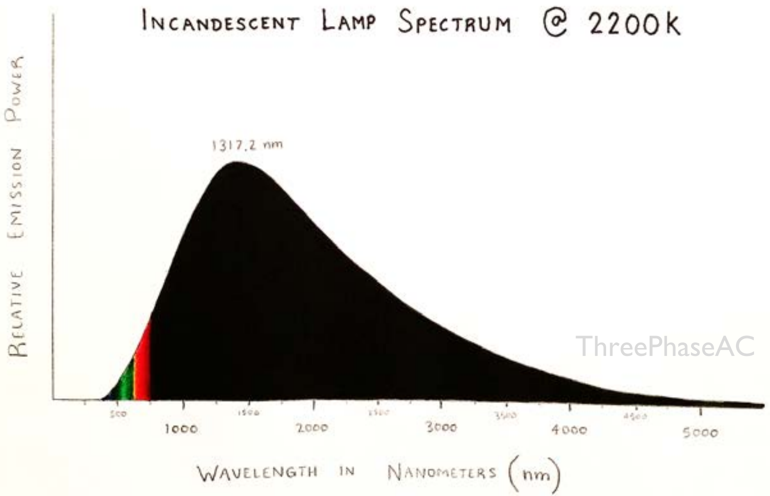
Warm objects emit a range of wavelengths

- "Warm" means essentially everything.
- How warm it is (i.e. the temperature) determines the intensity of light emitted at each wavelength
- We often assume objects are a "blackbody", which just means that all light is absorbed (like a purely black object) and re-emitted
- The wavelength with the highest intensity, the "peak" or maximum wavelength, is directly related to the temperature:
  - $\lambda_{\max} = \frac{2.9\times10^6\ nm}{T\ [K]}$, where $T\ [K]$ is temperature in Kelvin.
  - This is known as Wien's Law.
  - An incandescent bulb has $\lambda_{\max}\sim1300\ nm$
    So, $T_{\text{bulb}} \approx (2.9 \times 10^6\ nm)/(1300\ nm) = 2200\ K$
  - ~3500 F





The amount of light from a warm object depends on T

- By approximating a star as a blackbody, determine the **effective temperature**:

$$T_{\text{eff}} = \left(\frac{F}{\sigma_{SB}}\right)^{1/4}$$

Stefan-Boltzmann constant

- Meaning

$$L = (\text{Area} * \text{Flux}) = 4\pi R^2 \sigma_{SB} T_{\text{eff}}^4$$

- A greater L for the same λ_{peak} means a larger R