The brightness and colors of stars

Blackbody

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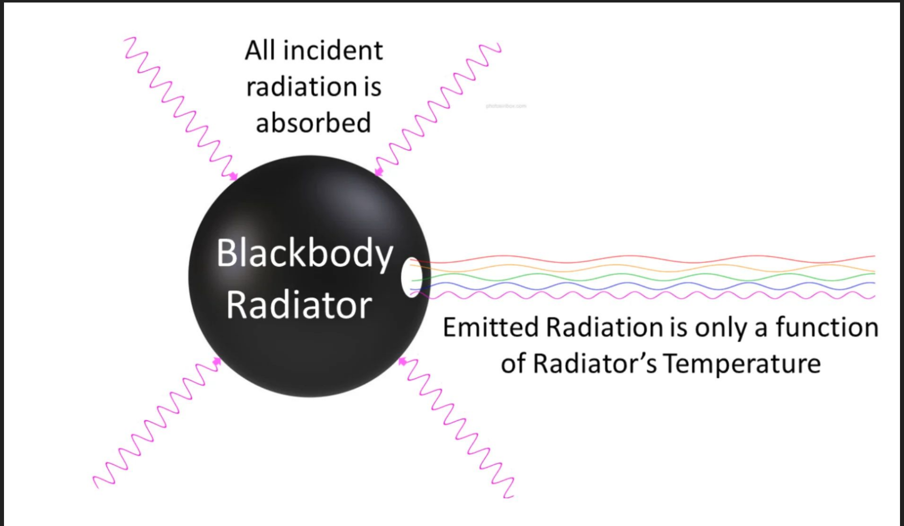
- Absorbs all incoming radiation, reflects none
- The energy they emit is called blackbody radiation
- All objects emit light, due to their temperature
- Why the name blackbody?
- What are examples of blackbodies?



Blackbody radiation

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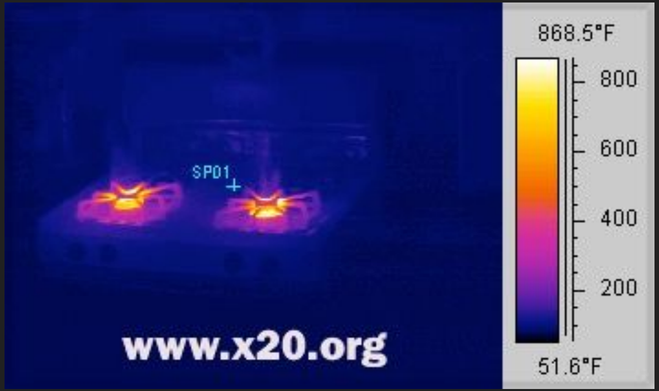
- The amount of light emitted at each wavelength depends only on the blackbody's temperature
- Hotter blackbodies are brighter (more intense) and bluer (shorter wavelengths).



Blackbody spectrum

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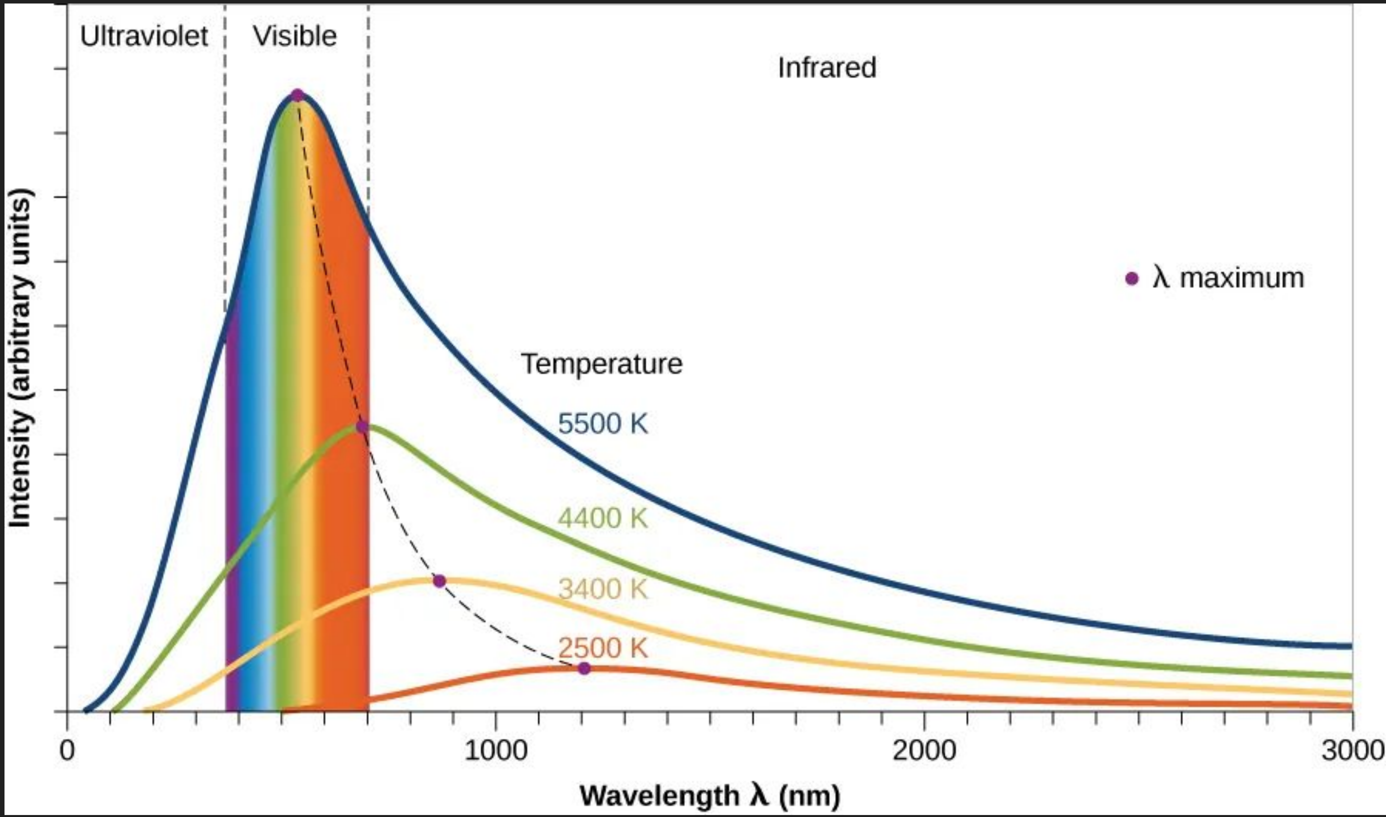

Blackbody spectrum

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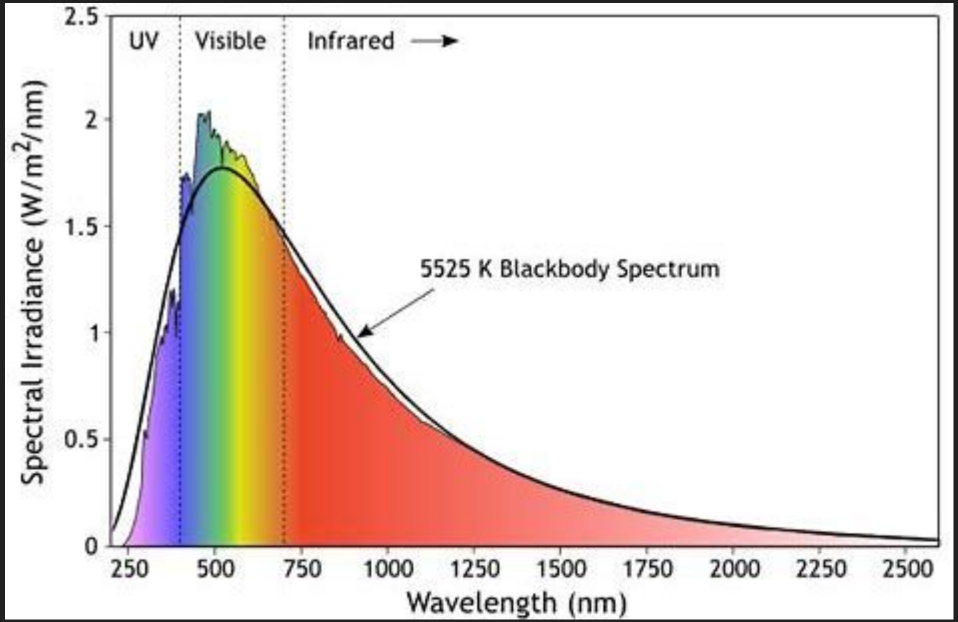
- The Sun resembles a blackbody with temperature ~5500 K
- Why is the Sun's spectrum slightly different?



Wien’s Law

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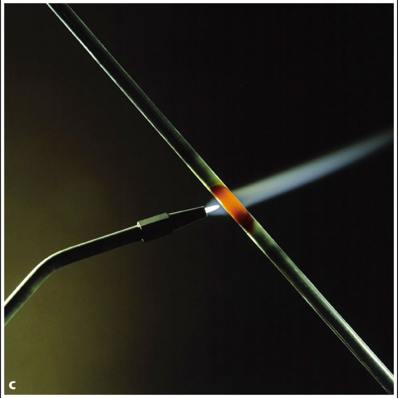
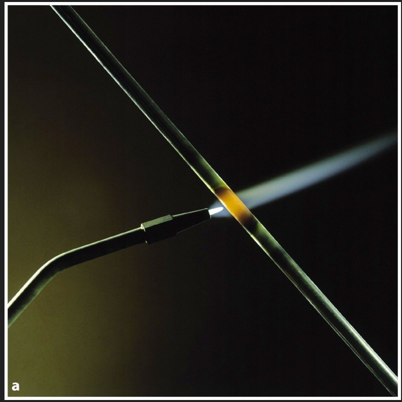
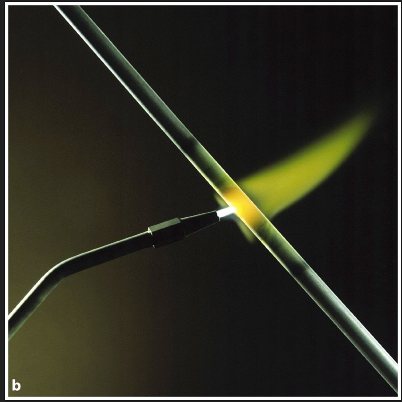
- The hotter an objects, the stronger it emits at shorter (bluer) wavelengths
- The peak wavelength of thermal emission is inversely proportional to its temperature in Kelvin







Wien's Law

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- Peak wavelength of blackbody radiation depends on blackbody temperature
  - Hotter objects are bluer
- Wavelength, λ (m)
- Temperature (K)
  - Temperature can never reach 0 K
  - All objects have a defined peak wavelength of thermal emission

$$\lambda_{\text{peak}} = \frac{2.898 \times 10^{-3}\ \text{m K}}{T}$$

Luminosity of a blackbody

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- Luminosity (total brightness) depends on blackbody temperature
  - Hotter objects are brighter
- Luminosity (Watts)
- Area (m^2)
- Temperature (K)
  - Temperature can never reach 0 K
  - All objects emit thermal radiation
- Heating up an object to double its temperature will make it 16 times brighter!

$$L = \sigma A T^4$$

$$\sigma_{\mathrm{SB}} = 5.67 \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{4}}$$

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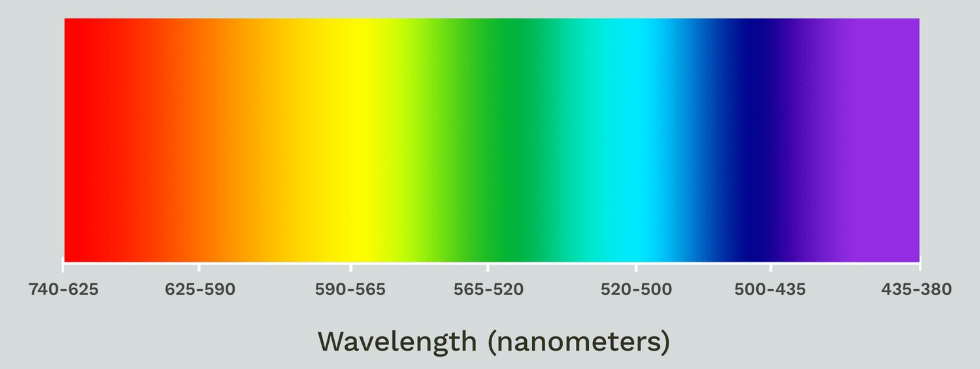
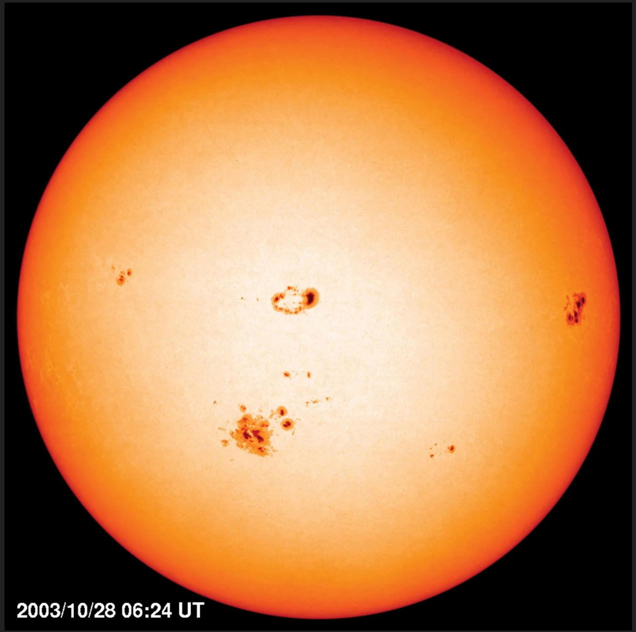
[results]

Wien's Law: the Sun

- Sun's surface temperature is 5800 K
- λ_{peak} = 2.898E-3 /5800
- λ_{peak} = 5E-6
- λ_{peak} = 500 nm
- Near the middle of the optical spectrum
- Green?





Wien's Law: humans

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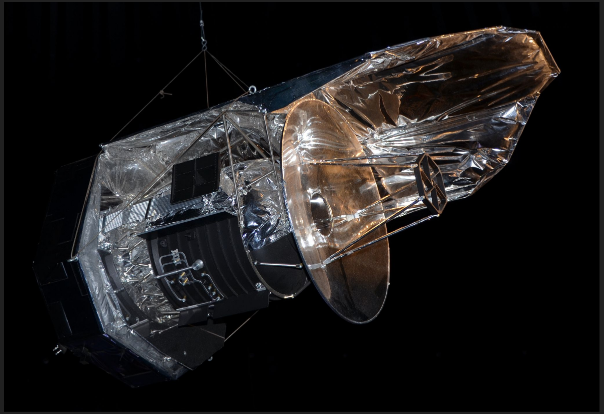
- Body temperature: 310 K
- λ_{peak} = 2.898E-3 /310
- λ_{peak} = 1E-5
- λ_{peak} = 10 μm
- Infrared



Wien's Law: Stars

1. Below are four bright stars in the northern sky. Which of them is the hottest?

a. Vega

b. Capella

c. Arcturus

d. Betelgeuse

Wien’s Law: Stars

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a. Vega

9600 K

b. Capella

5300 K

c. Arcturus

4300 K

d. Betelgeuse

3500 K




Flux

- Stars have different temperatures, different intrinsic brightnesses
- Stars are also at different distances
- Define flux as the apparent brightness of an object

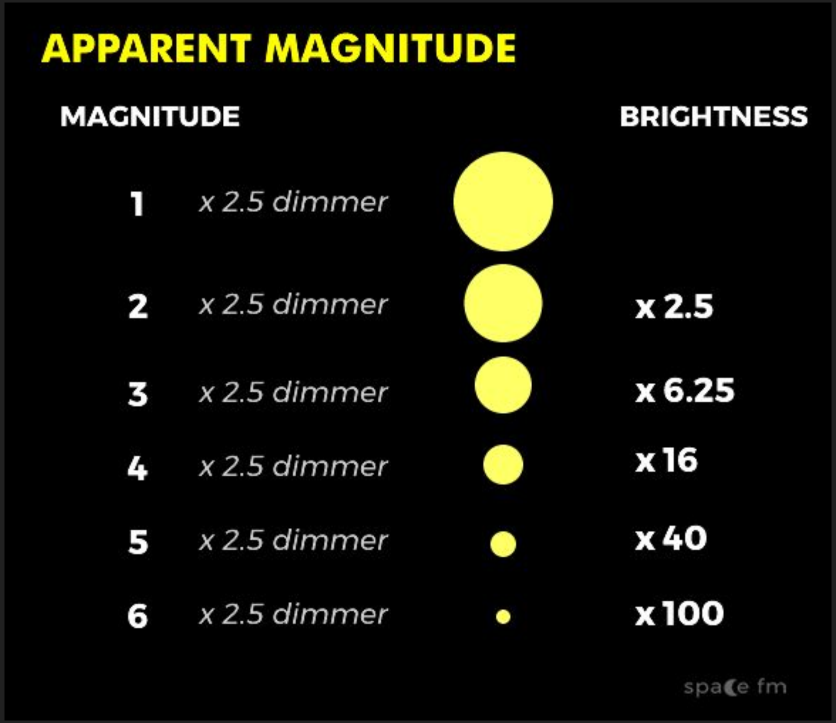
Flux

- Flux depends on intrinsic brightness
- Flux depends on distance
- Luminosity (Watts)
- Distance (m)
- Flux (Watts per meter squared)

$$F = \frac{L}{4\pi d^2}$$

Apparent magnitude scale

- A measure of flux from stars
- Larger magnitude stars are dimmer, smaller (and even negative) magnitude stars are brighter
- A difference in one magnitude is 2.5x difference in brightness
- 5 magnitudes means 100x difference in brightness



Apparent magnitude scale

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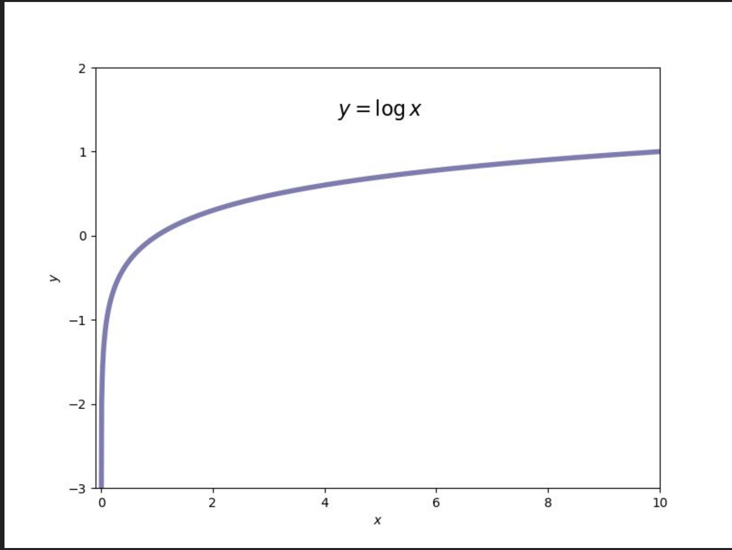
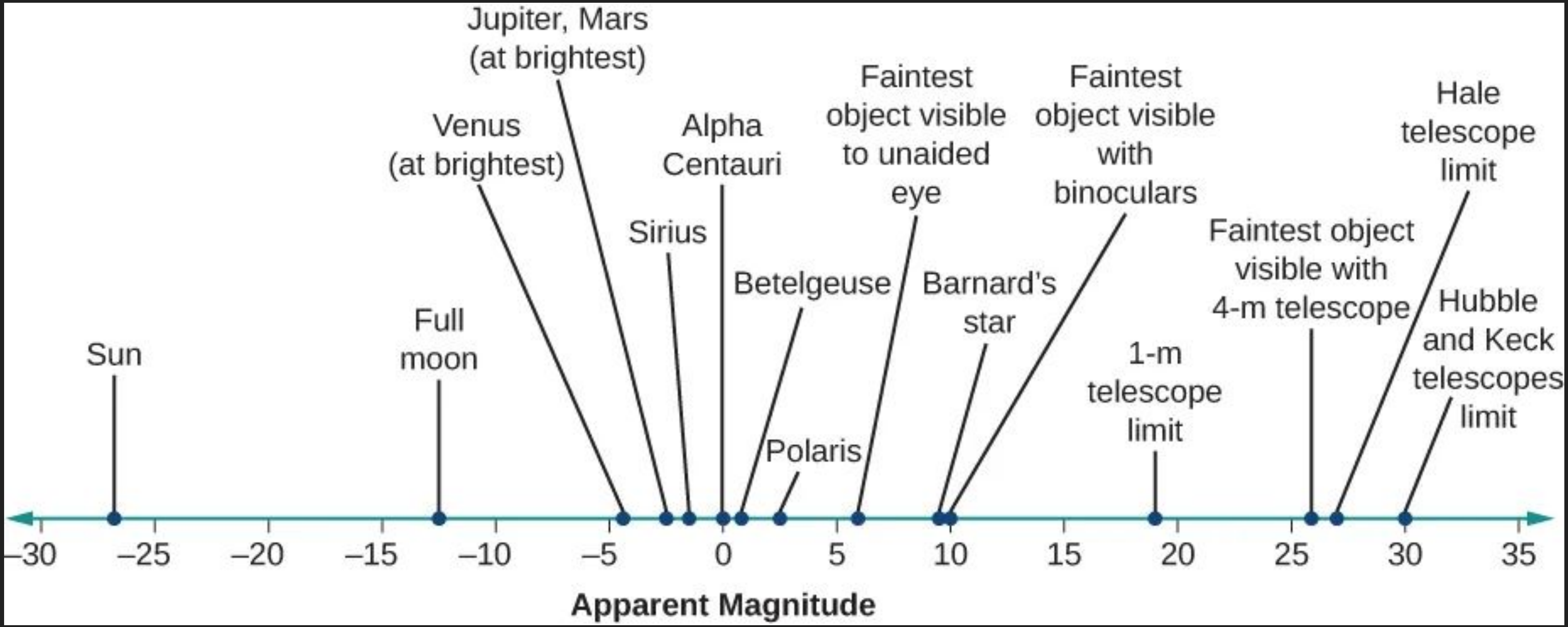
- Magnitude scale measures flux on a logarithmic scale, not linear
- Apparent magnitude m (mags)
- Flux F (Watts per m^2)
- Reference flux F_0, depends on filter

$$m = -2.5 \log \frac{F}{F_0}$$



Apparent magnitudes of common objects



Solar telescope

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Announcements

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- Homework 5 due today

Next time

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- Spectra of stars, from Megan!