

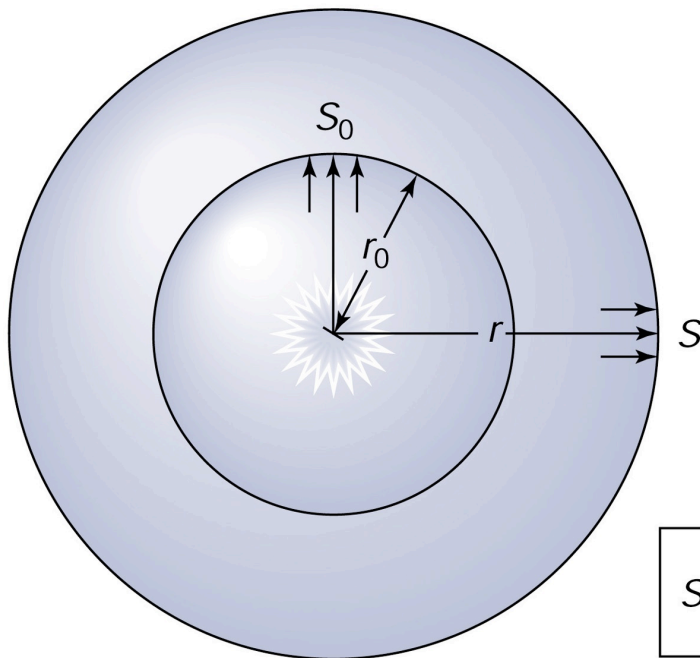
Lecture 12: Planets & radiation

Flux and the ‘inverse-square’ law

Radiation **flux** is the amount of energy passing through an area perpendicular to the radiation beam per unit time.

Units: Joules per second per square meter = $\text{J s}^{-1} \text{m}^{-2}$
= Watts per sq. meter = W m^{-2}

(Because $1 \text{ J s}^{-1} = 1 \text{ W}$, by definition)



Flux, S , from a star drops off with increasing distance. In fact, it decreases with the square of the radial distance, r , from the star, as $S \propto 1/r^2$.

$$S = S_0 \left(\frac{r_0}{r} \right)^2$$

e.g., Sun's flux at the planet Mars

Earth	Distance from Sun = 1 A.U.	Solar flux = 1370 Wm ⁻²
Mars	Distance from Sun = 1.5 A.U.	Solar flux = 608.9 Wm ⁻²

Reduced
by a factor
of $1/(1.5)^2$
= 2.25
compared to
Earth

Radiation Recap - 1

1. Electromagnetic radiation:

- propagates through space at speed of light, c
- has a characteristic **wavelength** (λ) and **frequency** (ν)
- useful to talk about two parts of the spectrum:
SW: shortwave (mostly visible; also UV, near-IR) from Sun
LW: longwave (mostly infrared) from planet

2. Radiation and matter interact in 4 ways:

- Radiation can be:
 - absorbed**
 - transmitted**
 - reflected (or scattered)**
- All matter emits radiation
 - emission by matter**

Radiation Primer - 2

3a. **Absorption** of radiation causes matter to warm up (or gain heat)

3b. **Emission** of radiation causes matter to cool down (or lose heat)

Radiation Primer - 3

4. Temperature of matter is crucial because both the **wavelength** and the **total energy** of radiation emitted by matter depend upon its temperature.

4a. Hotter matter emits **shorter** wavelengths [Wien's Law]

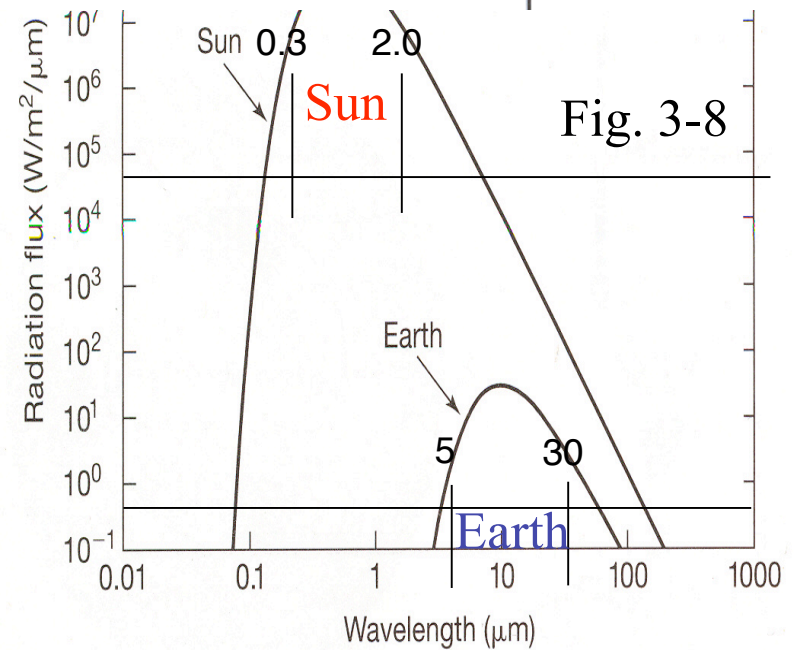
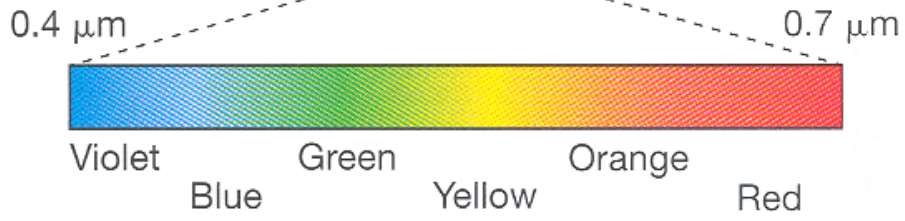
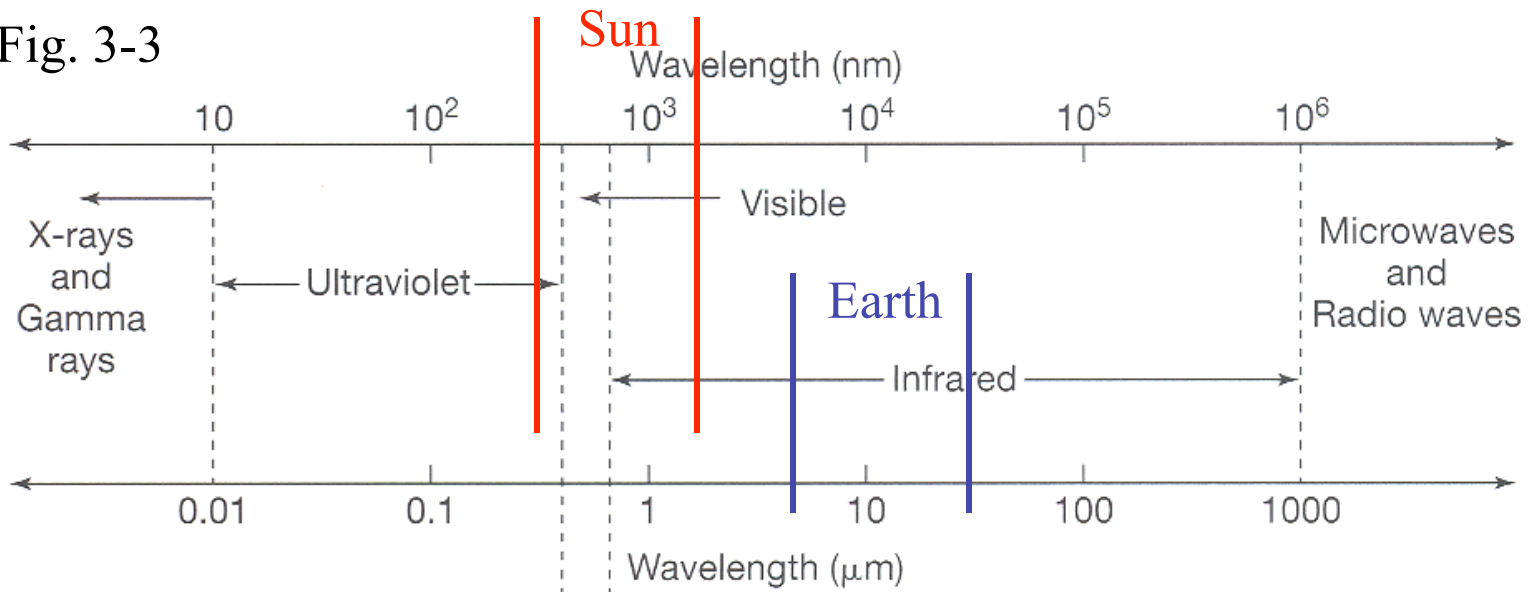
- **Sun**: “SW” [ultraviolet (UV), visible, near-infrared]

- **Earth**: “LW” [infrared (IR)]

ground, ocean, atmosphere, clouds, etc
also, moon and other planets

4b. Hotter objects emit **more total energy**. [Stefan-Boltzmann Law]

Fig. 3-3



Radiation vs Wavelength

Stefan-Boltzmann Law

Hotter objects emit **more total energy**:

$$\text{Stephan-Boltzmann Law: } F = \sigma T^4$$

$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

= a constant of nature

T is temp in Kelvin, the absolute temperature scale

$$T(\text{K}) = T(\text{C}) + 273.15$$

Applies to an ideal material known as a "blackbody".

This just means that the emission curve depends only on temperature.

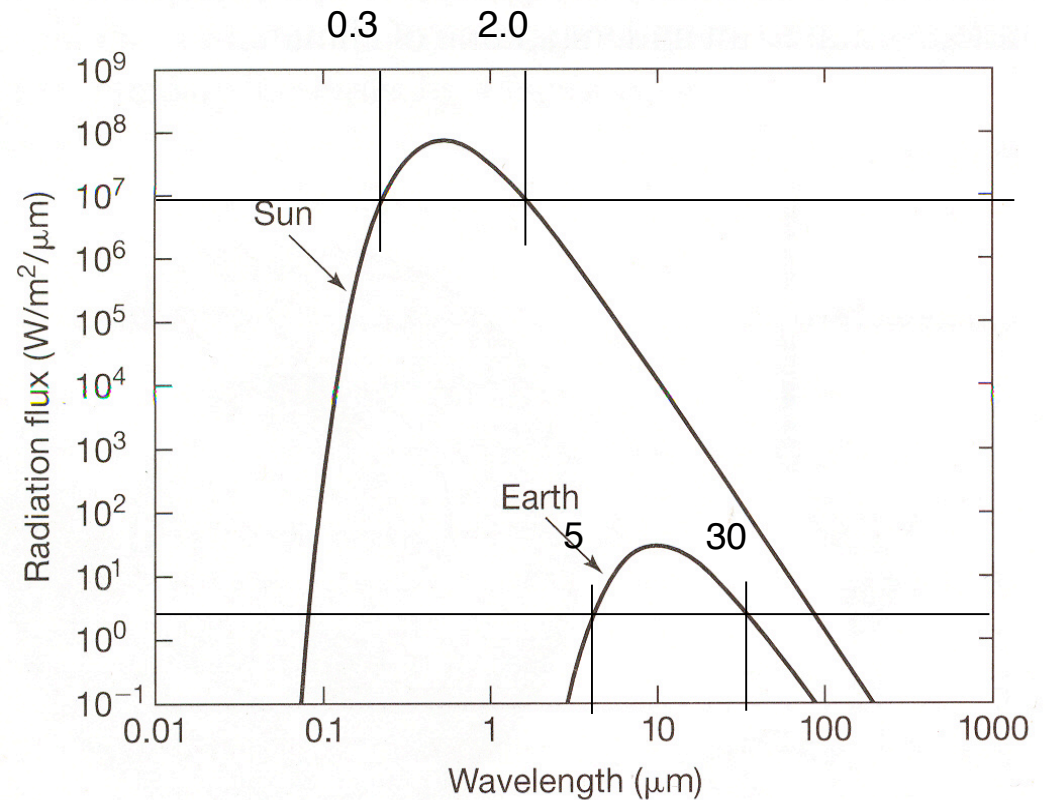


FIGURE 3-8

Blackbody emission curves for the Sun and Earth. The Sun emits more energy at all wavelengths.

Kelvin (absolute) Temperature Scale

$$T(\text{K}) = T(\text{C}) + 273.15$$

Reference Point	Celsius Scale (°C)	Kelvin Scale (K)
water boils (at sea level)	100	373.15
water freezes	0	273.15
Absolute zero	-273.15	0

What is the meaning of "absolute zero" temperature?

Consider...

- Hotter objects emit more total energy
- Can there be a negative temperature on the Kelvin scale?
- What is the meaning of "temperature", anyway?

Kelvin/Boltzmann applications

Stephan-Boltzmann Law: $F = \sigma T^4$

where $\sigma = 5.67 \times 10^{-8}$, F is in W/m^2 , and T is in Kelvin (K)

Kelvin vs. Celsius scale: $T(\text{K}) \approx T(^{\circ}\text{C}) + 273$

Practice:

Qu. 1) The average surface temperature of the Earth is 15°C .
What is this in Kelvin?

Qu. 2) An object warms from 0°C to 10°C .
What is the fractional increase in temperature?
What is the fractional increase in emitted, radiative energy?

Qu. 3) If the Sun's emitting surface layer (the "photosphere") were to warm up by 10%, by how much would the solar flux increase (as a fractional increase)?