Solar Energy: The Sun to Earth Transaction

Learning objectives:

1) To calculate the energy received by the Earth from the Sun
2) To compare the energy received by Earth from the Sun, with the energy usage by humankind

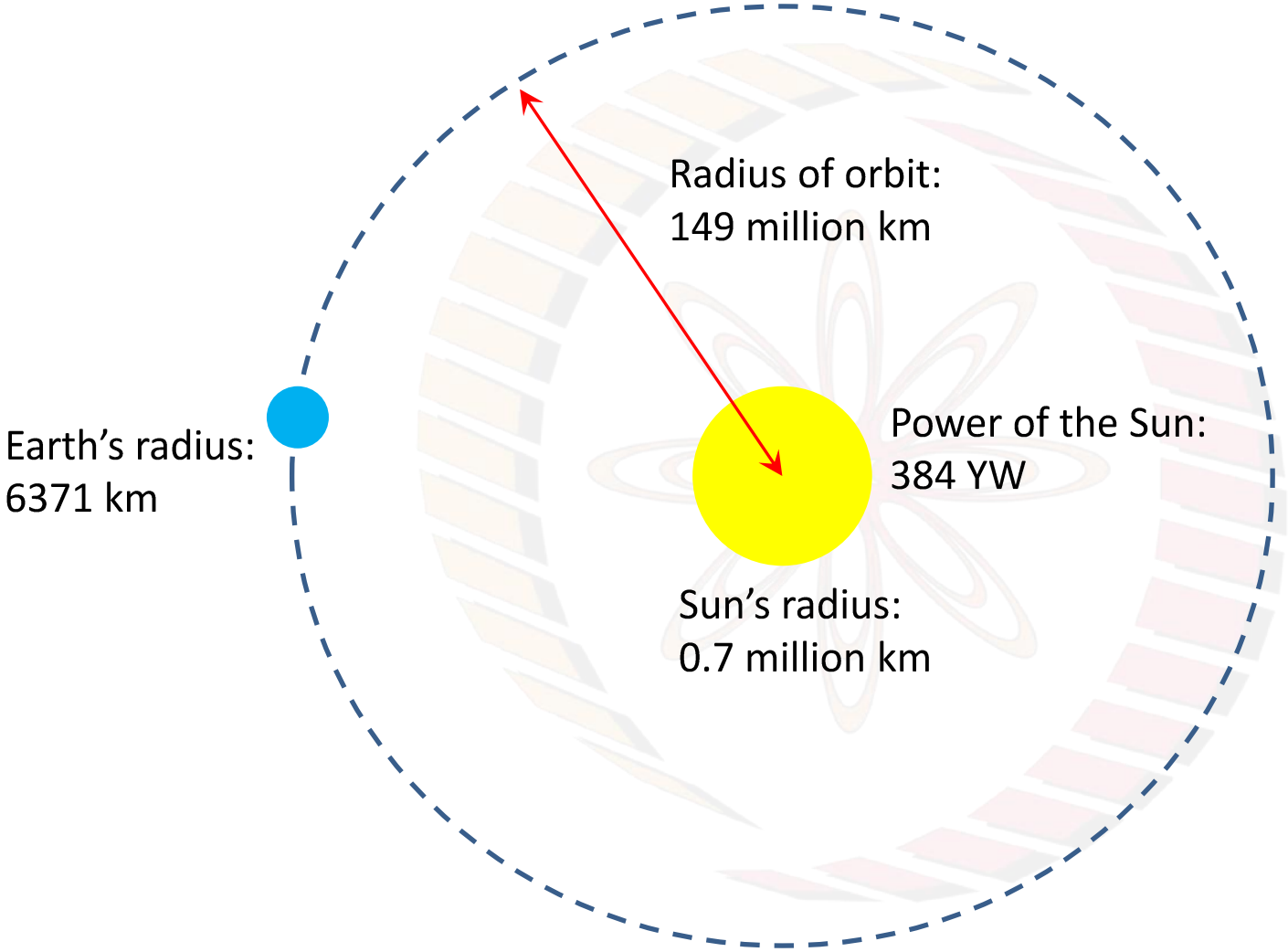
Surface of the Sun ~ 5500 ^{o}C

Core of the Sun, several million ^{o}C

Sun gives out 384 Yotta Watts

$= 384 \times 10^{24}$ W

$= 3.84 \times 10^{26}$ W

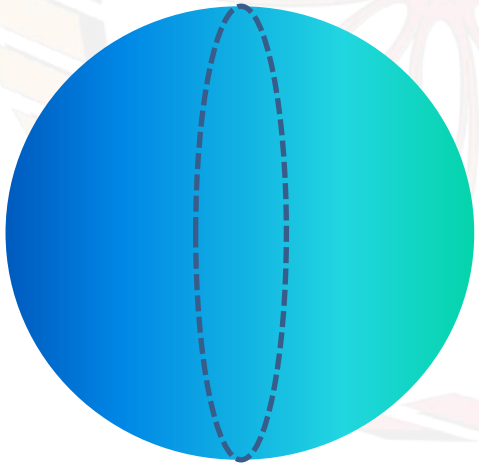

Radius of orbit:
149 million km
Earth’s radius:
6371 km
Power of the Sun:
384 YW
Sun’s radius:
0.7 million km

Intensity of Sun's radiation at Earth's orbit:

$$= \frac{3.84 \times 10^{26}}{4 \times 3.14 \times (1.49 \times 10^{11})^2} = 1377 \text{ W/m}^2$$

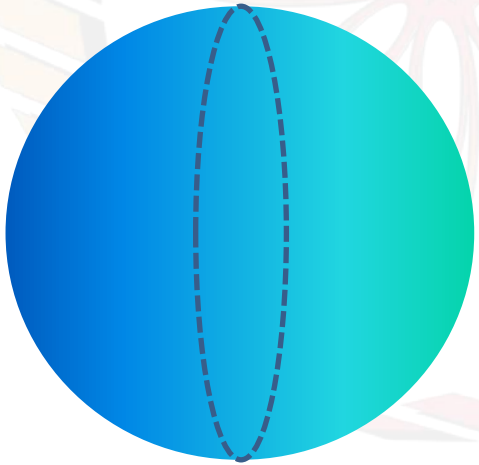
Area of Earth's disc:

$= \quad 3.14 \text{ X } (6.371 \text{ X } 10^{6})^{2} \quad = 1.27 \text{ X } 10^{14} \text{ m}^{2}$



Power received from the Sun, by Earth:

$= 1.27 \text{ X } 10^{14} \text{ X } 1377 = 1.755 \text{ X } 10^{17} \text{ W or J/s}$



Energy received from the Sun, by Earth each year:

$$= 1.755 \text{ X } 10^{17} \text{ X } 60 \text{ X } 60 \text{ X } 24 \text{ X } 365$$

$$= 5.5 \text{ X } 10^{24} \text{ J}$$

= 5.5 million Exa Joules per year

Humankind uses:

= 500 Exa Joules per year

Earth receives from the Sun:

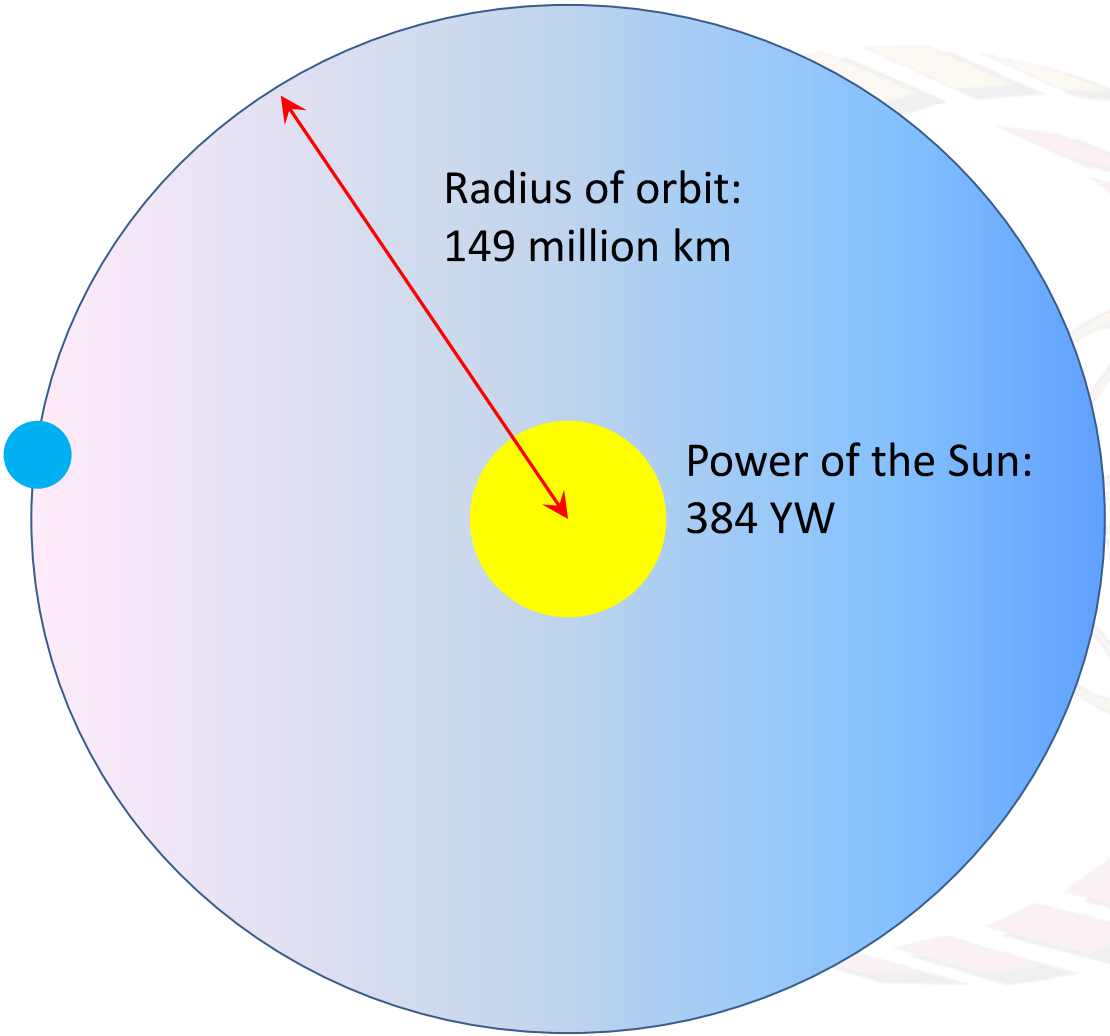
5.5 million Exa Joules per year

This is received in :

$500 / 5.5 \times 10^{6} = 9 \times 10^{-5}$ years = 0.033 days = 0.79 hours

Since 30% of the incident energy is reflected back, on the surface of the Earth, the energy used by humankind each year is received in :

$$= 0.79/0.70 \sim \textbf{1 hour}$$



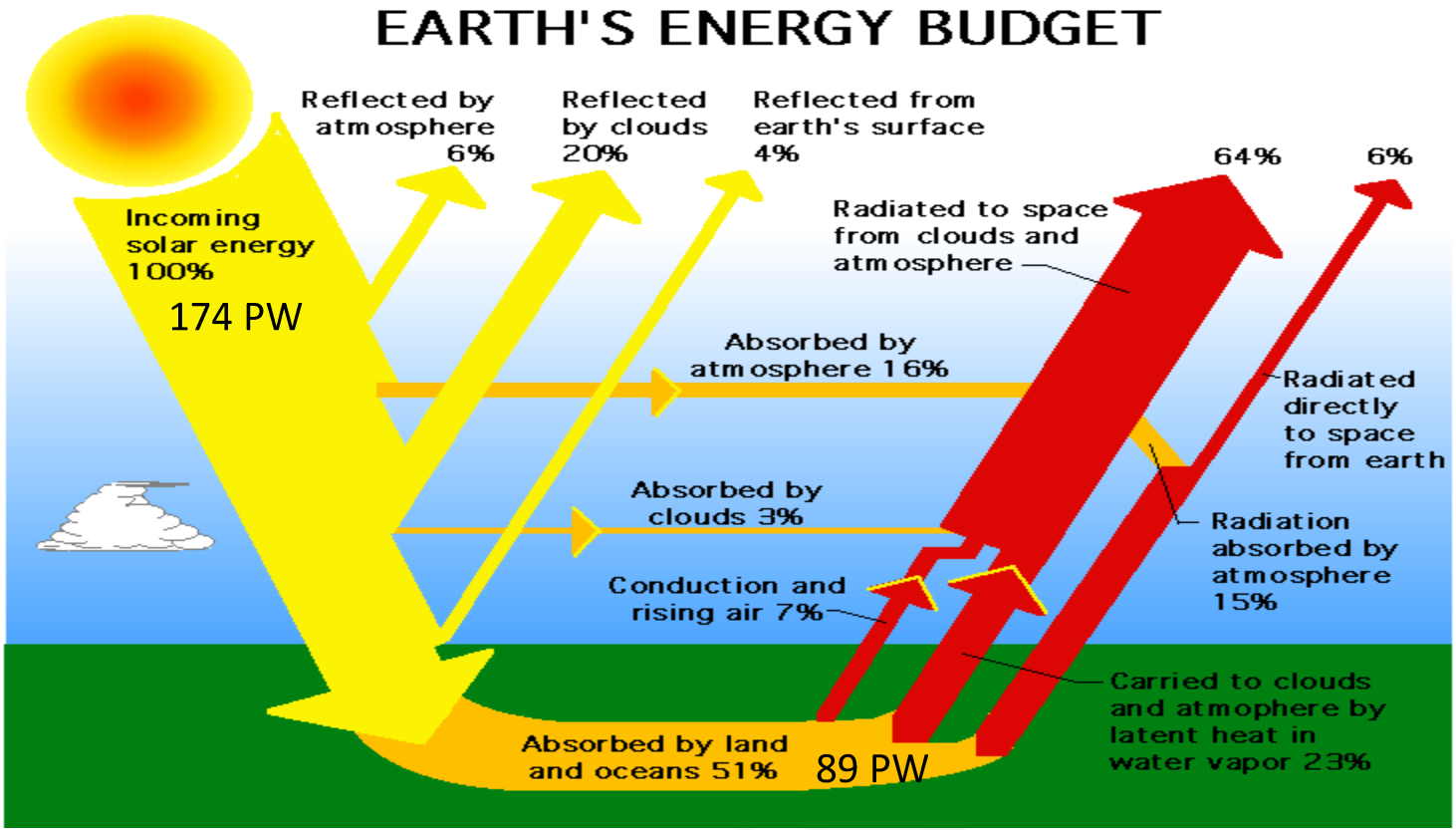
Dyson Sphere:
Freeman Dyson (1960)

Kardashev Scale (1964)
Type 1: All energy reaching planet
Type 2: All energy of Star
Type 3: All energy of Galaxy

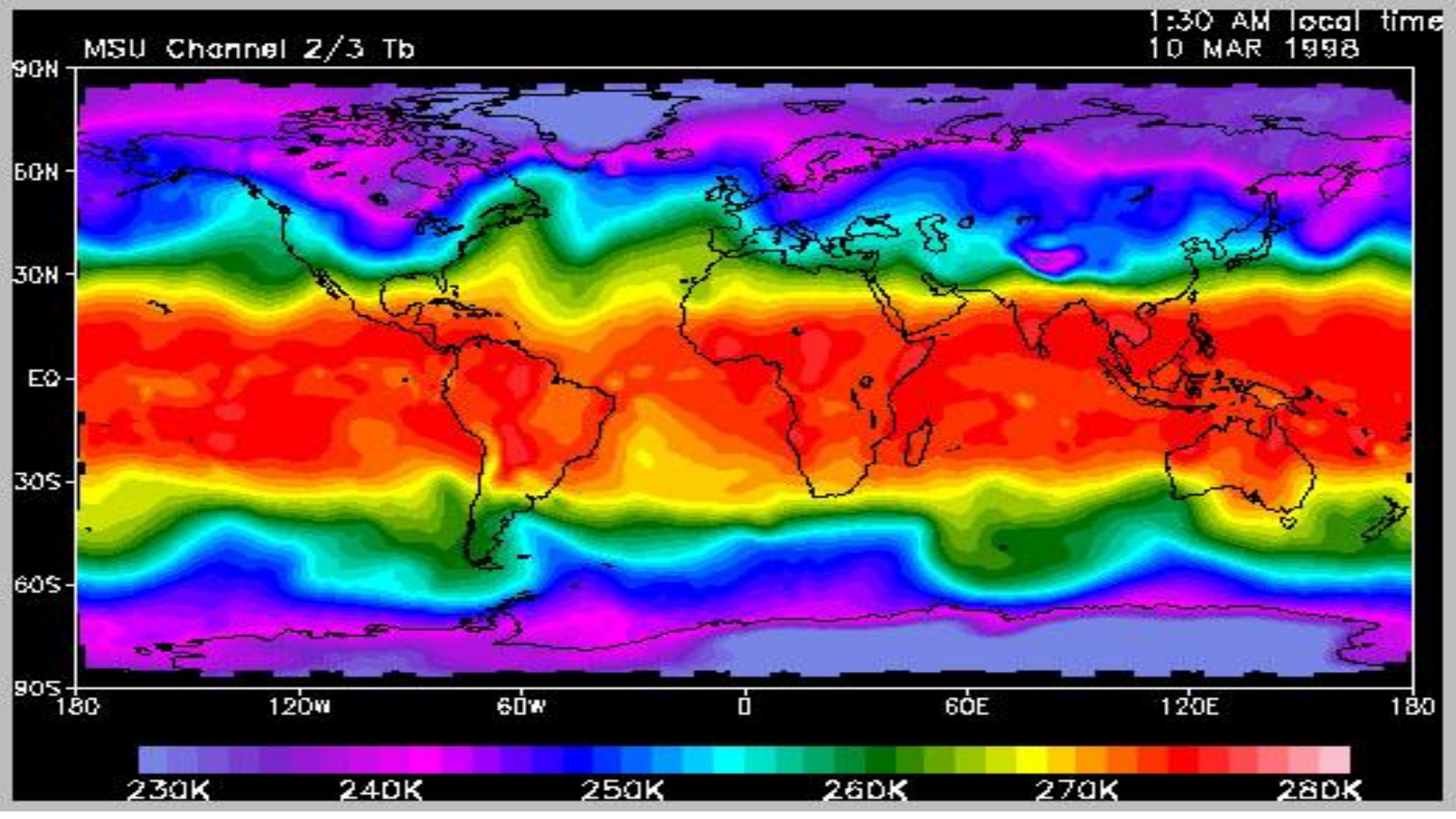
Conclusions:

1) Earth receives nearly 5.5 million exa joules of energy from the Sun each year
2) The entire energy used by humankind each year, is received on the surface of the earth, from the sun, each hour!

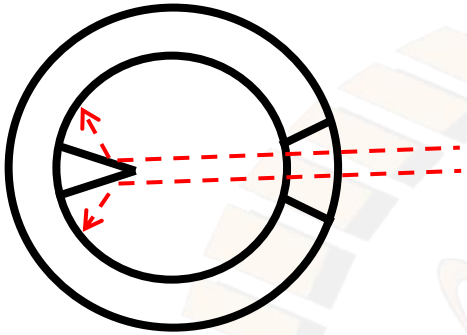
The Solar Budget


EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
174 PW
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmophere by latent heat in water vapor 23%
Absorbed by land and oceans 51%
89 PW

NASA


MSU Channel 2/3 Tb
1:30 AM local time
10 MAR 1998
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
230K
240K
250K
260K
270K
280K

The Solar Spectrum

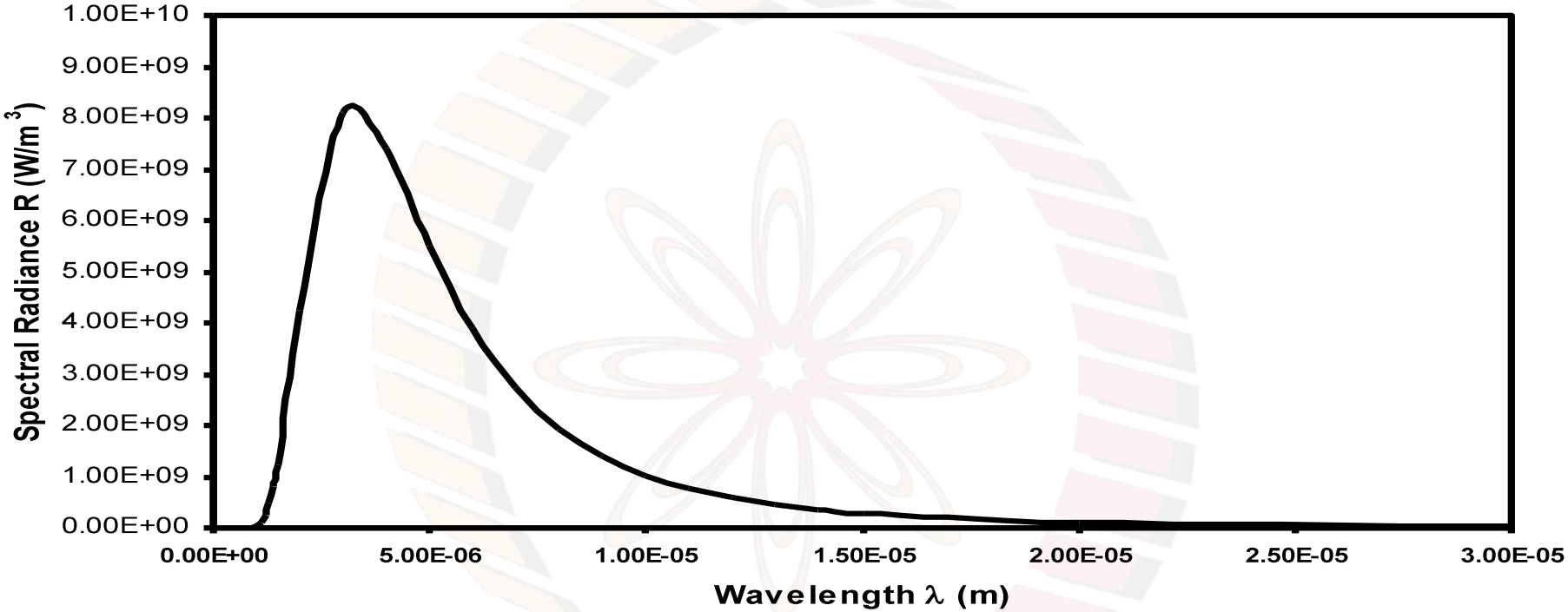


Kirchoff designed a black body in 1859

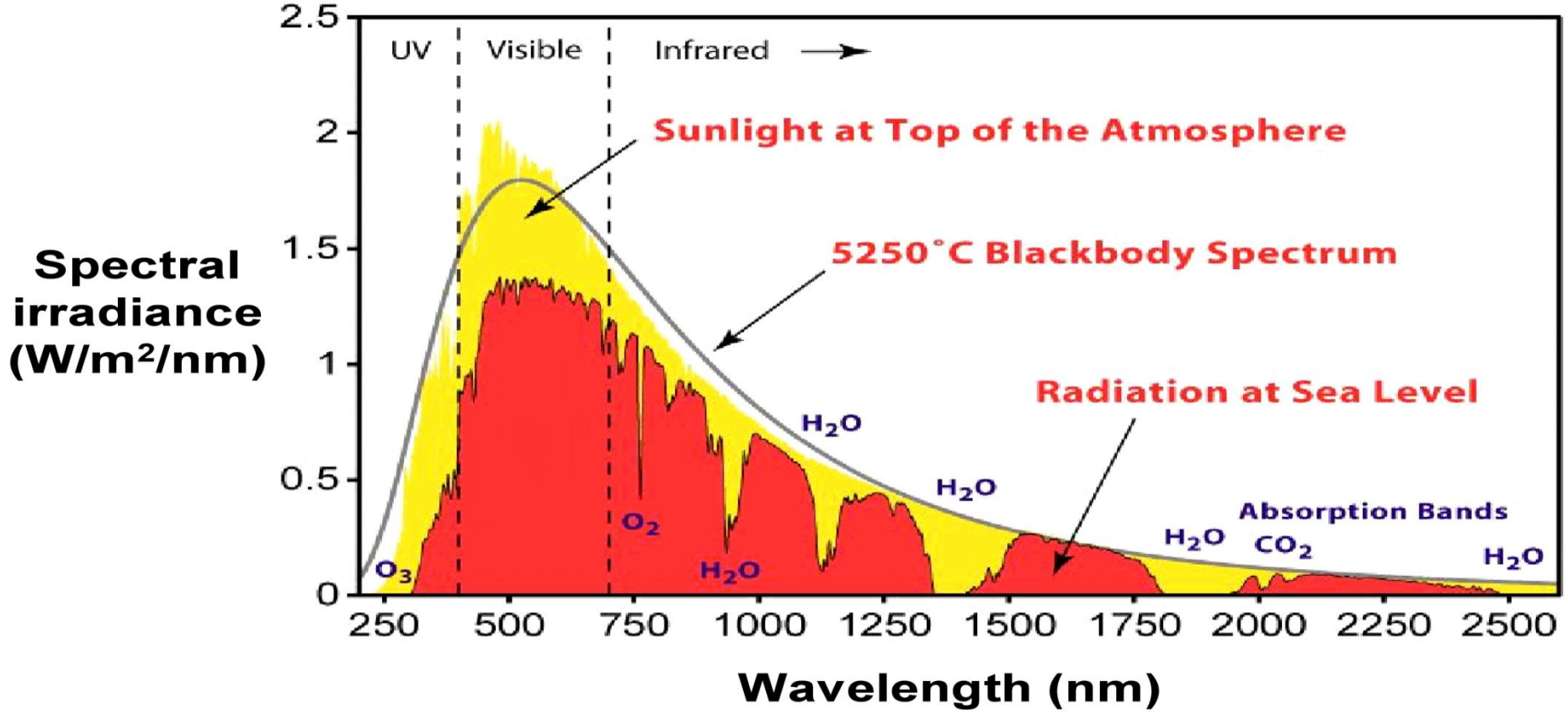
Known properties of black body radiation:

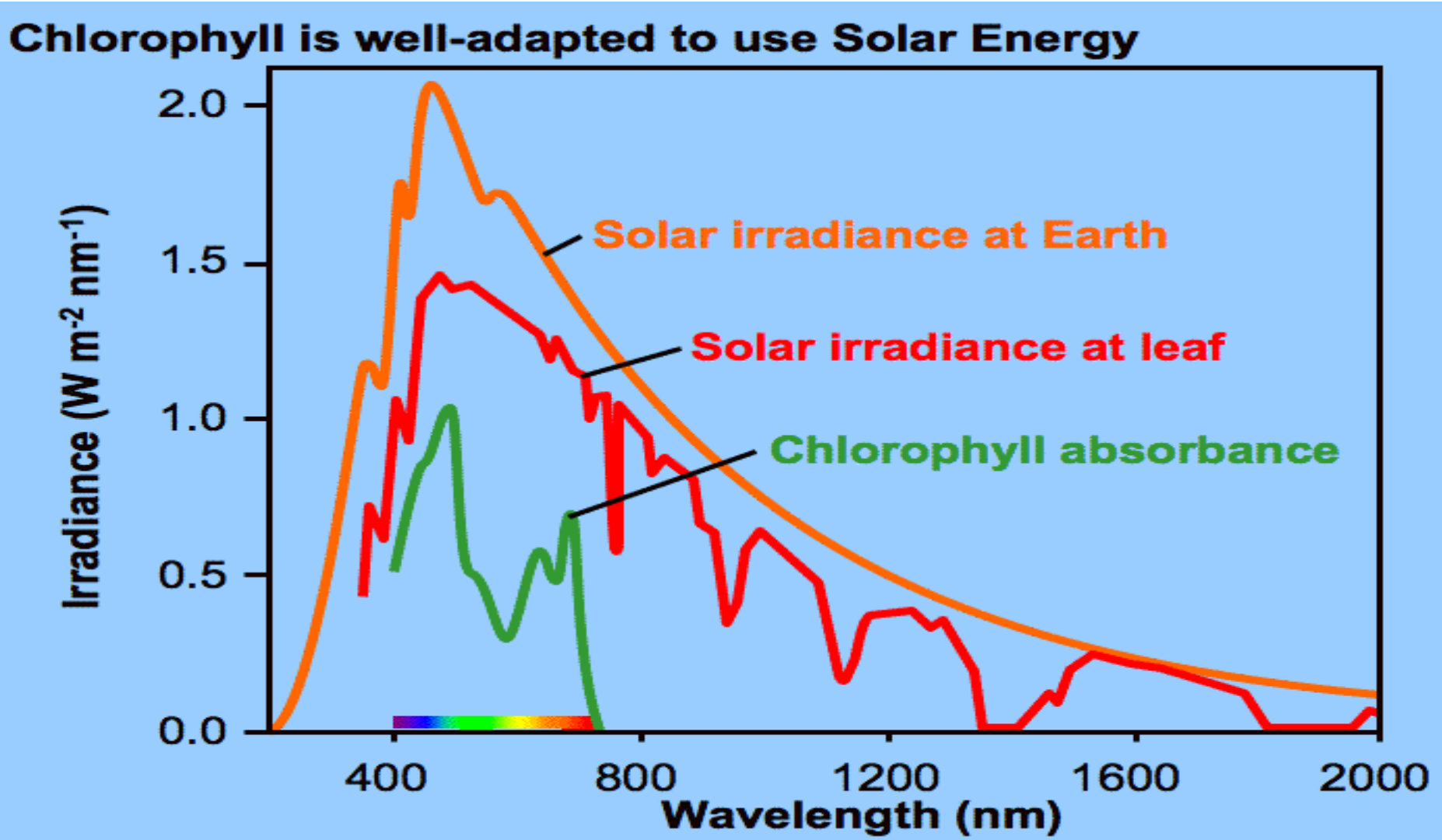
1) As temperature T of the body increases, intensity of the radiation from the body also increases

2) Higher the temperature, lower is the wavelength of the most intense part of the spectrum.



Black body Radiation


Spectral irradiance (W/m²/nm)
2.5
2
1.5
1
0.5
0
UV
Visible
Infrared
Sunlight at Top of the Atmosphere
5250°C Blackbody Spectrum
Radiation at Sea Level
O_3
O_2
H_2O
H_2O
H_2O
H_2O
CO_2
H_2O
Absorption Bands
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)


Chlorophyll is well-adapted to use Solar Energy
Irradiance (W m-2 nm-1)
2.0
1.5
1.0
0.5
0.0
Solar irradiance at Earth
Solar irradiance at leaf
Chlorophyll absorbance
400
800
1200
1600
2000
Wavelength (nm)

Visible Spectrum Wavelength:	400 nm (violet)	to	700 nm (red)
Corresponding band gaps:	3.1 eV	to	1.8 eV