PHY 114

Quantum Physics

Lecture 1-B

Birth of Planck's Constant $\hbar$

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Motivation:

Why did Blackbody Radiation intensity distribution cause a crisis ?

All bodies radiate EM waves at finite temperature .

An object at thermal equilibrium radiates as much as it absorbs. .

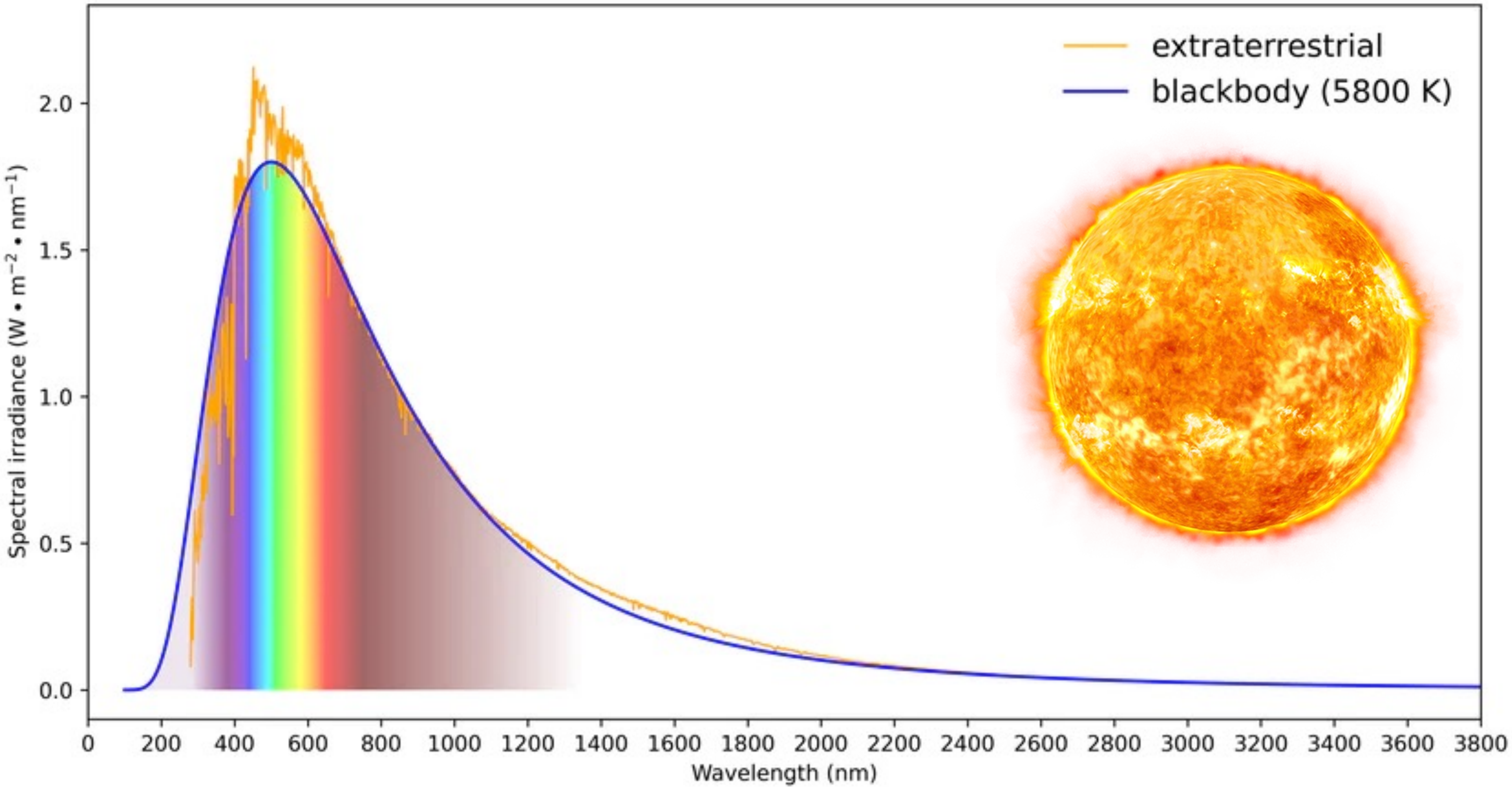
***Radiance R** is the power radiated per unit area. It depends on the temperature T, and the nature of the radiating surface.*

***Black Body** : Absorbs all radiation incident on it. It is a perfect emitter as well as absorber.*

Total radiance $R = \int R(\lambda) d\lambda$

Spectral Radiancy

Solar Spectrum



How do you realize a black body in the Laboratory ?

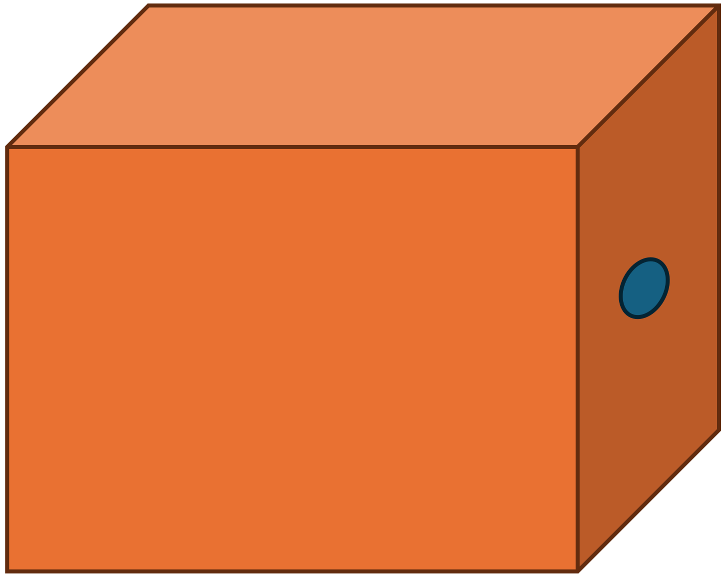
1860 : Kirchoff's Cavity

A <u>cavity</u> in thermal equilibrium is a black body.

James Jeans showed an empty metal cube with a small hole is a good approximation to black body radiation.

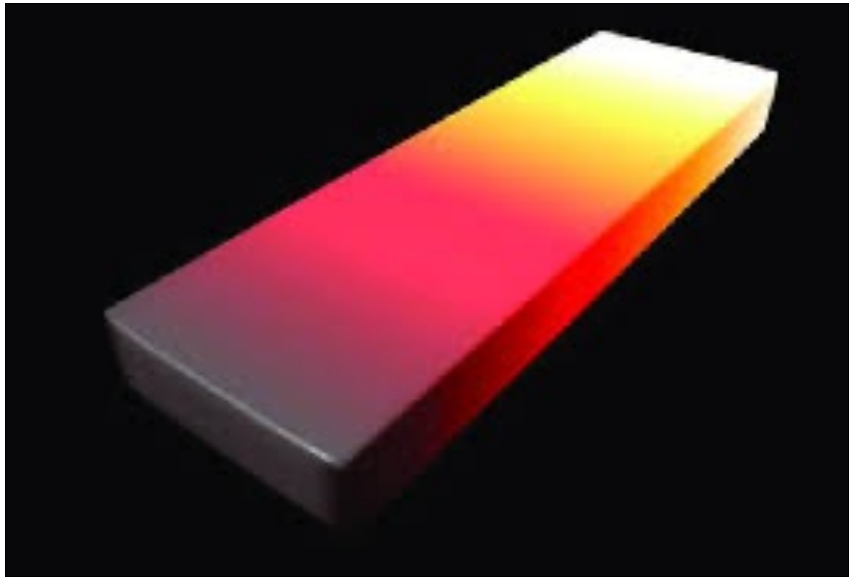
$$R(\lambda) = \frac{c}{4}\,u(\lambda) \qquad\qquad R(\nu) = \frac{c}{4}\,u(\nu)$$

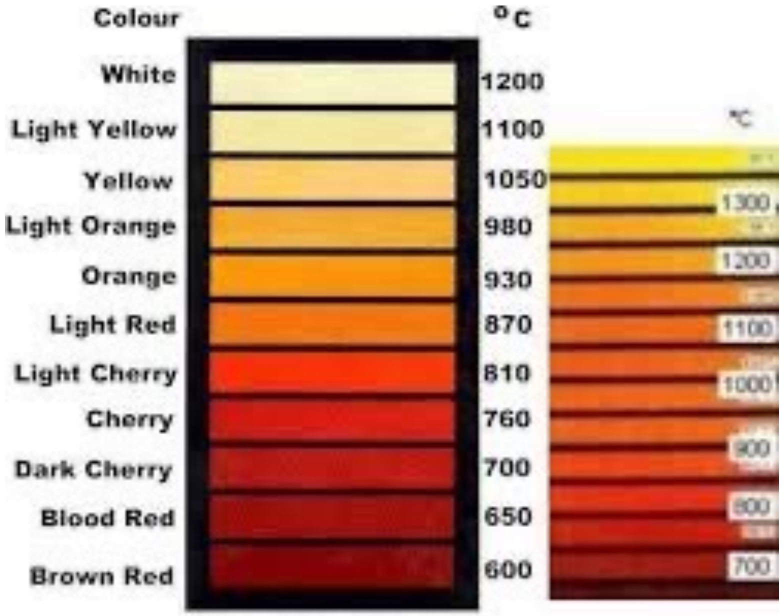
Spectral energy density

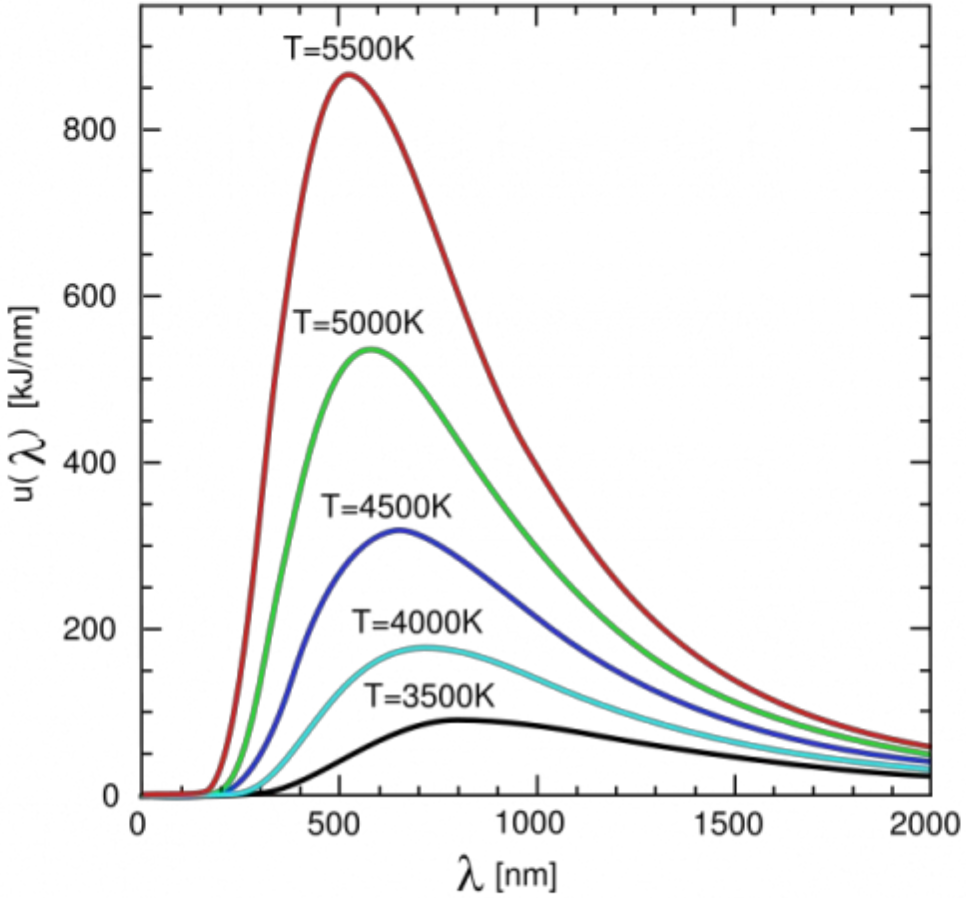


Jeans Cube

Colour Temperature and Spectral Energy Density







T ↑ R ↑

$$R = \sigma T^4$$

T ↑ λ_{max} ↓

$$T\lambda_{max} = constant$$

Prediction of Classical vs Planck for $u(\nu)$?

We know ***Maxwell's EM Theory*** *&* ***Boltzmann's Classical Thermodynamics*****.**

Calculate the number density of oscillators in a cavity, and multiply the average energy of each oscillator.

	<u>*Classical*</u>	<u>*Planck's Quantum*</u>
Density of Modes:	$g(\nu) = \frac{8\pi}{c^3}\upsilon^2$	$g(\nu) = \frac{8\pi}{c^3}\upsilon^2$
Average Energy :	$\langle\epsilon\rangle = k_B T$	$\langle\epsilon\rangle = \frac{h\nu}{e^{h\upsilon/k_B T} - 1}$
Energy density u_ν *:*	$u_\nu = \frac{8\pi}{c^3}\upsilon^2 k_B T$	$\boxed{u_\nu = \frac{8\pi}{c^3}\upsilon^2 \frac{h\nu}{e^{h\upsilon/k_B T} - 1}}$

Perfect Match with Experiment

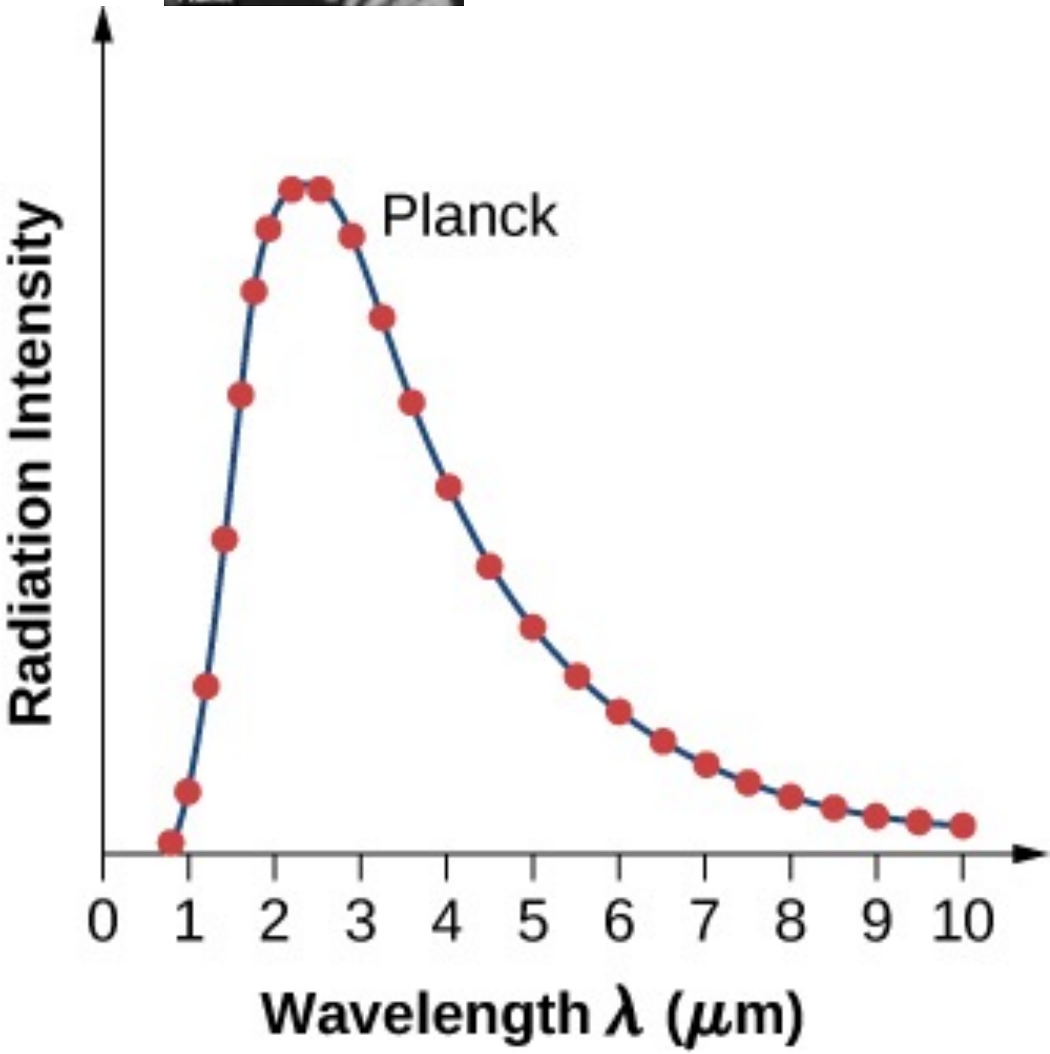
- *Energy of oscillator discrete* $E_n = n\,h\nu$
- *A new universal constant is born* h
- *Indication of a <u>new</u> occupation statistics.*

- *With* h quantum age came into being !

- *But,* h *is quantum of which Physical Quantity ?*

h= 6.62607015×10^{-34} J-s

QUANTUM of ACTION !!



An Act of Desperation...........

"Kurz zusammengefasst, kann ich die ganze Tut nur als einen Akt der Verzweiflung bezeichnen."

"In summary, I can only characterize the entire work as an act of desperation."

- Max Planck in 1931