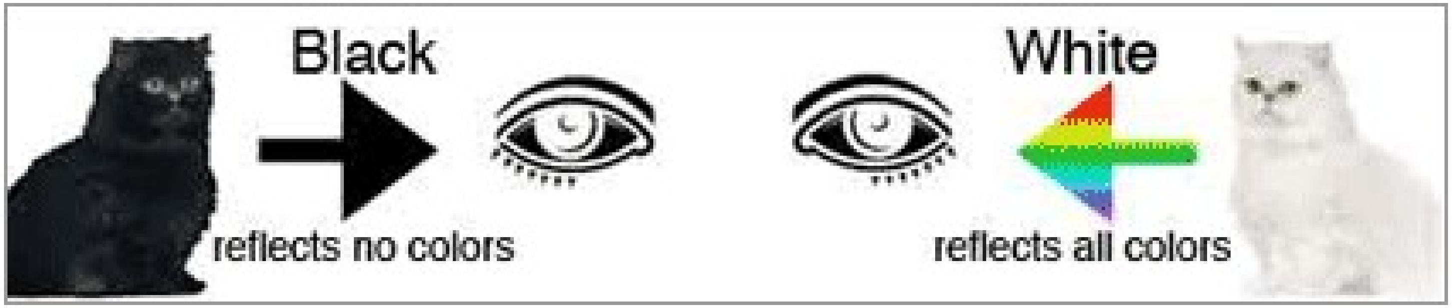
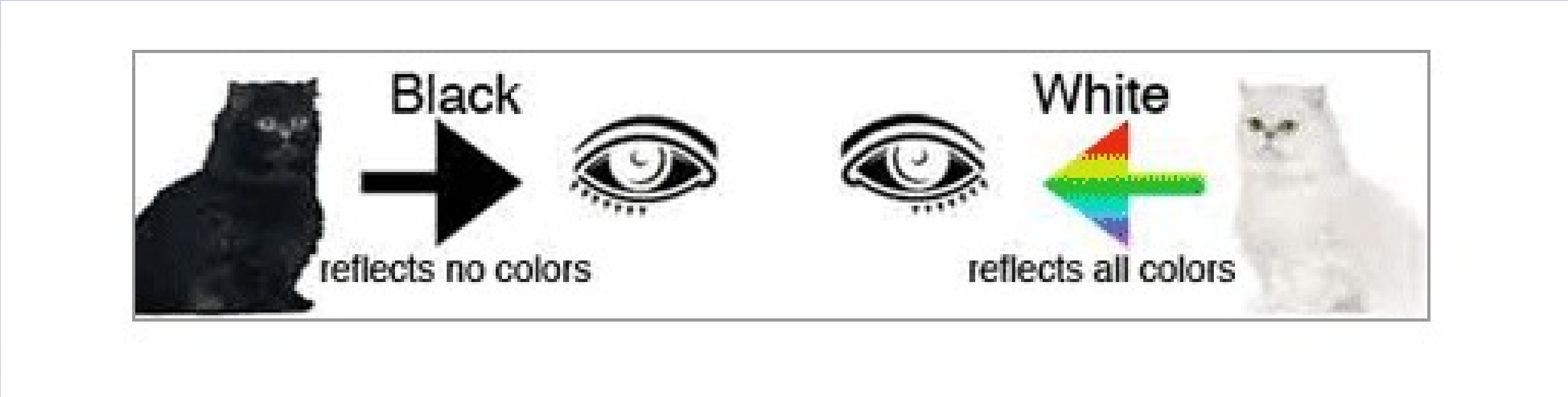

Black
reflects no colors
White
reflects all colors

Cuerpo Negro



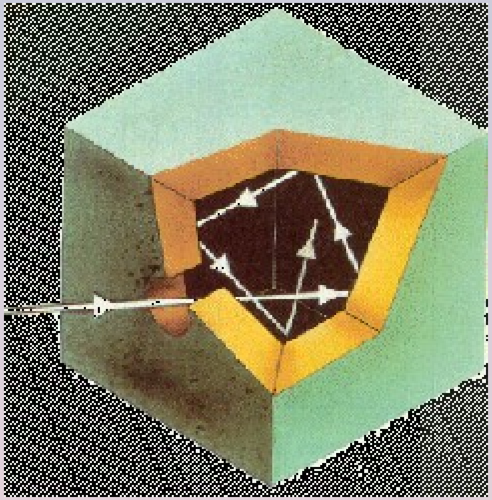
Un cuerpo negro es un objeto teórico (ideal) que **absorbe** toda la luz y toda la energía radiante que incide sobre él. Nada de la radiación incidente se refleja o pasa a través del cuerpo negro. El cuerpo negro emite radiación y constituye un sistema físico idealizado para el estudio de la emisión de la REM.

Cuerpo Negro

Se estudia la radiación proveniente de un agujero pequeño en una cámara aislada.

La cavidad irradia energía como un CN. La luz emitida depende de la $T_{interior}$, produciendo el espectro de emisión de un CN.

La luz que entra por el orificio incide sobre la pared más alejada, donde parte de ella es absorbida y otra reflejada en un ángulo aleatorio y vuelve a incidir ... Luego de muchas reflexiones, toda la energía incidente ha sido absorbida.



Color y temperatura

The connection between the color of light emitted by a hot object and its temperature was first noticed in 1792 by the English maker of fine porcelain Thomas Wedgewood. All of his ovens became red-hot at the same temperature, independent of their size, shape, and construction. Subsequent investigations by many physicists revealed that any object with a temperature above absolute zero emits light of all wavelengths with varying degrees of efficiency; an *ideal emitter* is an object that absorbs *all* of the light energy incident upon it and reradiates this energy with the characteristic spectrum shown in Fig. 8. Because an ideal emitter reflects no light, it is known as a **blackbody**, and the radiation it emits is called **blackbody radiation**. Stars and planets are blackbodies, at least to a rough first approximation.

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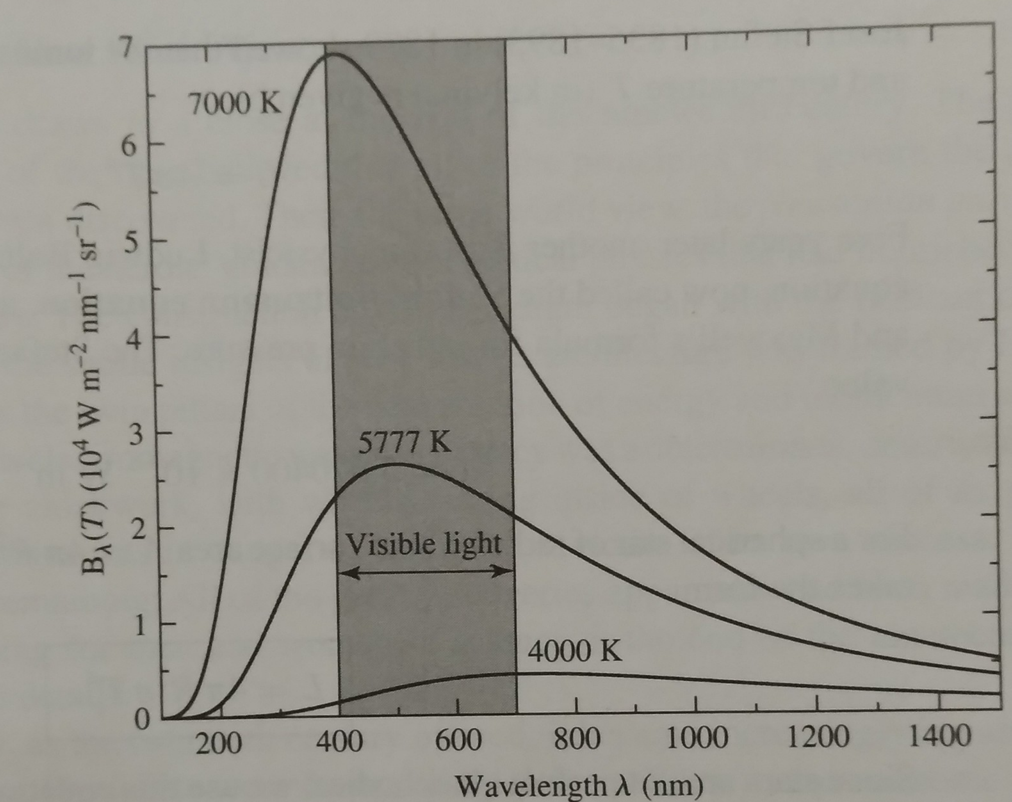
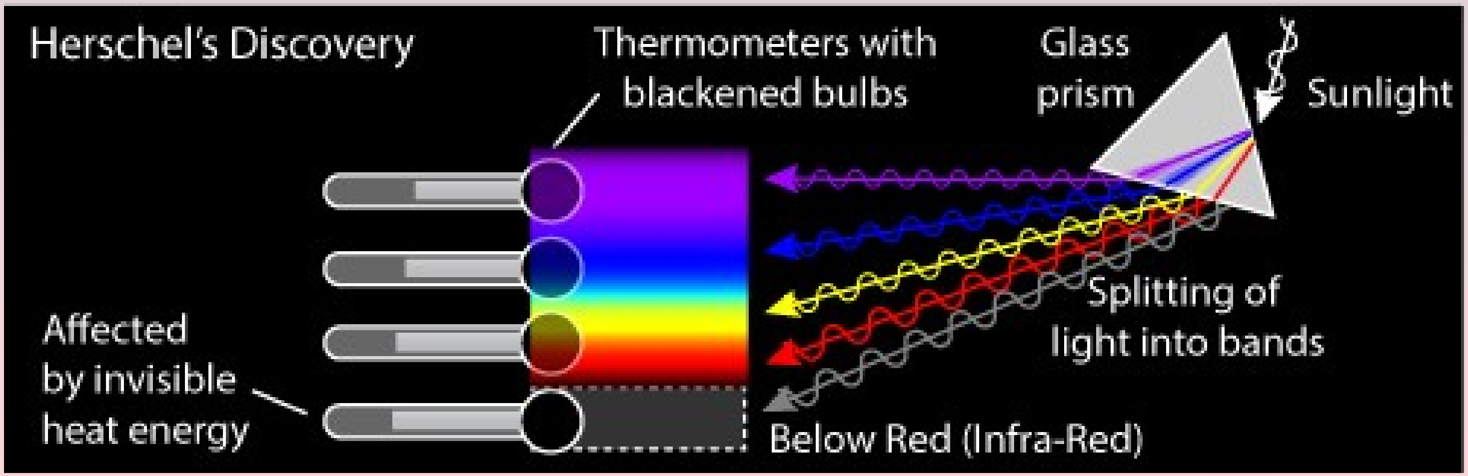
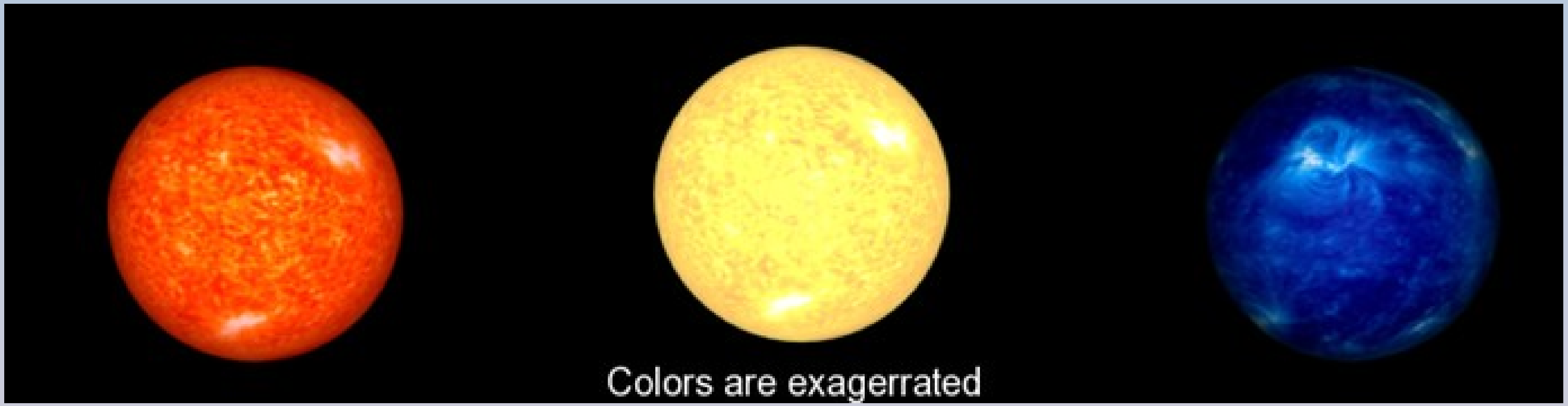


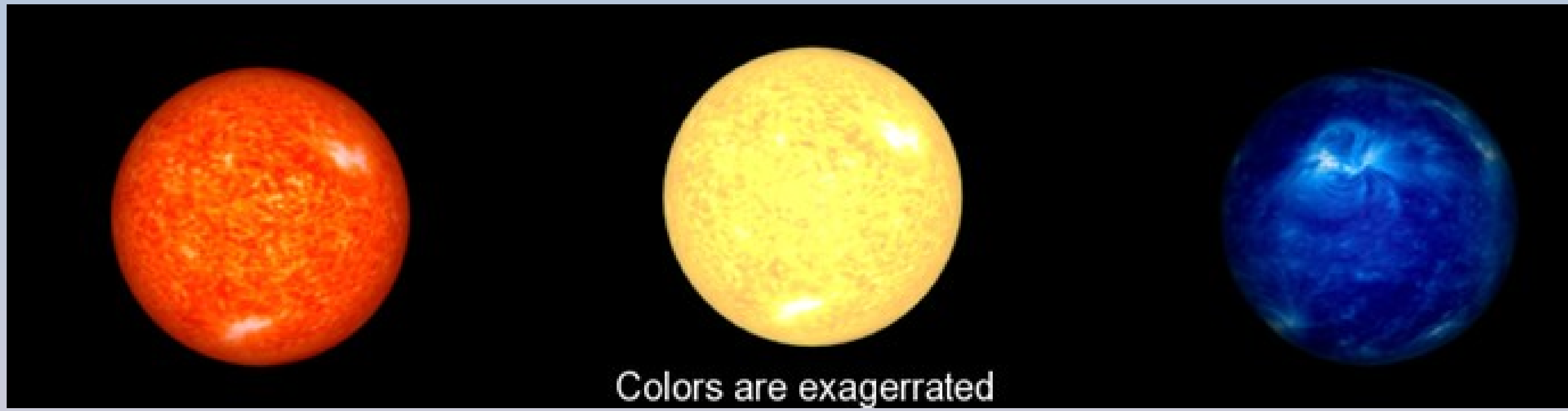
FIGURE 3.8 Blackbody spectrum [Planck function $B_\lambda(T)$].

Color y temperatura

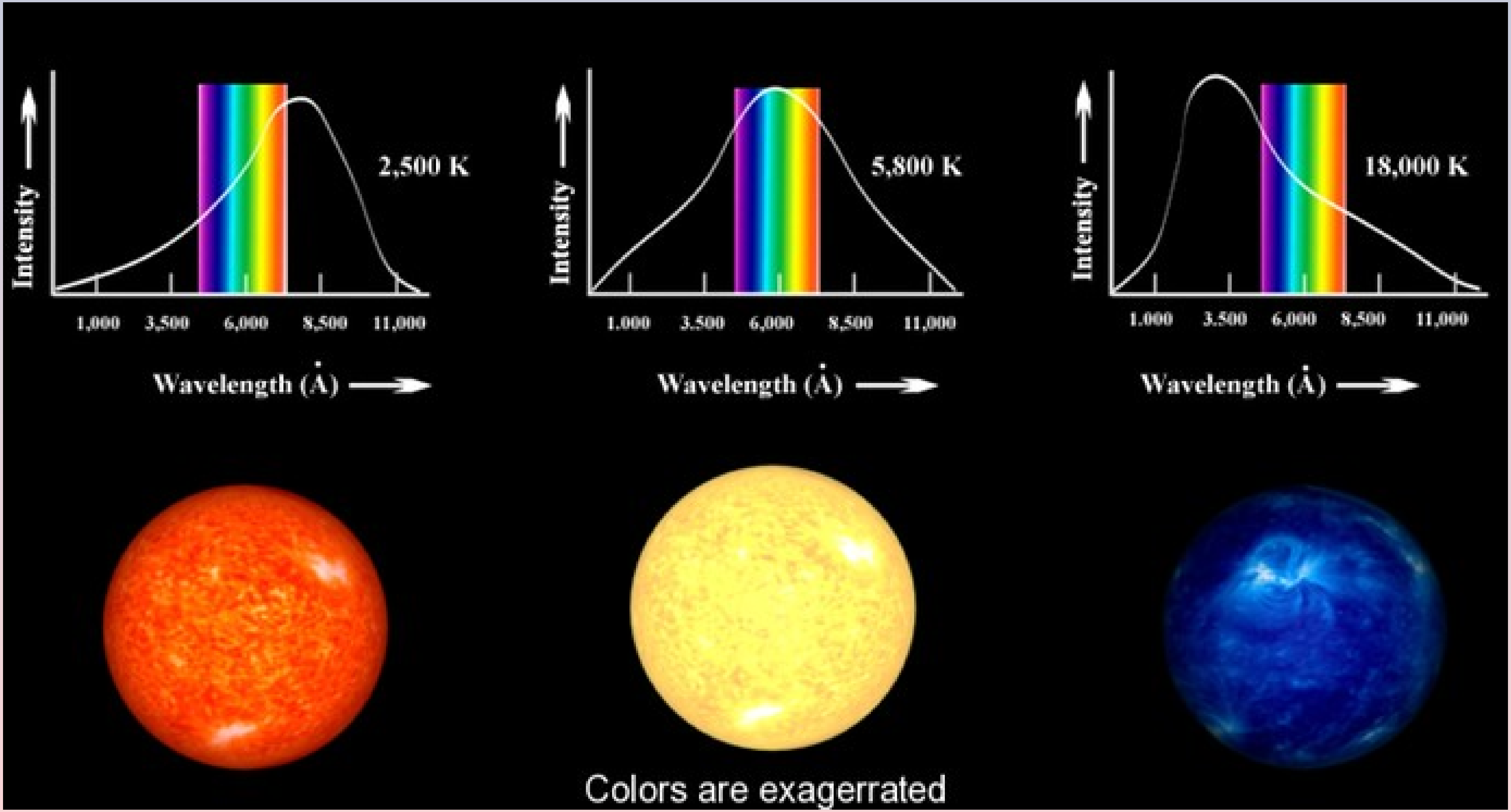
The connection between the color of light emitted by a hot object and its temperature was first noticed in 1792 by the English maker of fine porcelain Thomas Wedgewood. All of his ovens became red-hot at the same temperature, independent of their size, shape, and construction. Subsequent investigations by many physicists revealed that any object with a temperature above absolute zero emits light of all wavelengths with varying degrees of efficiency; an *ideal emitter* is an object that absorbs *all* of the light energy incident upon it and reradiates this energy with the characteristic spectrum shown in Fig. 8. Because an ideal emitter reflects no light, it is known as a **blackbody**, and the radiation it emits is called **blackbody radiation**. Stars and planets are blackbodies, at least to a rough first approximation.



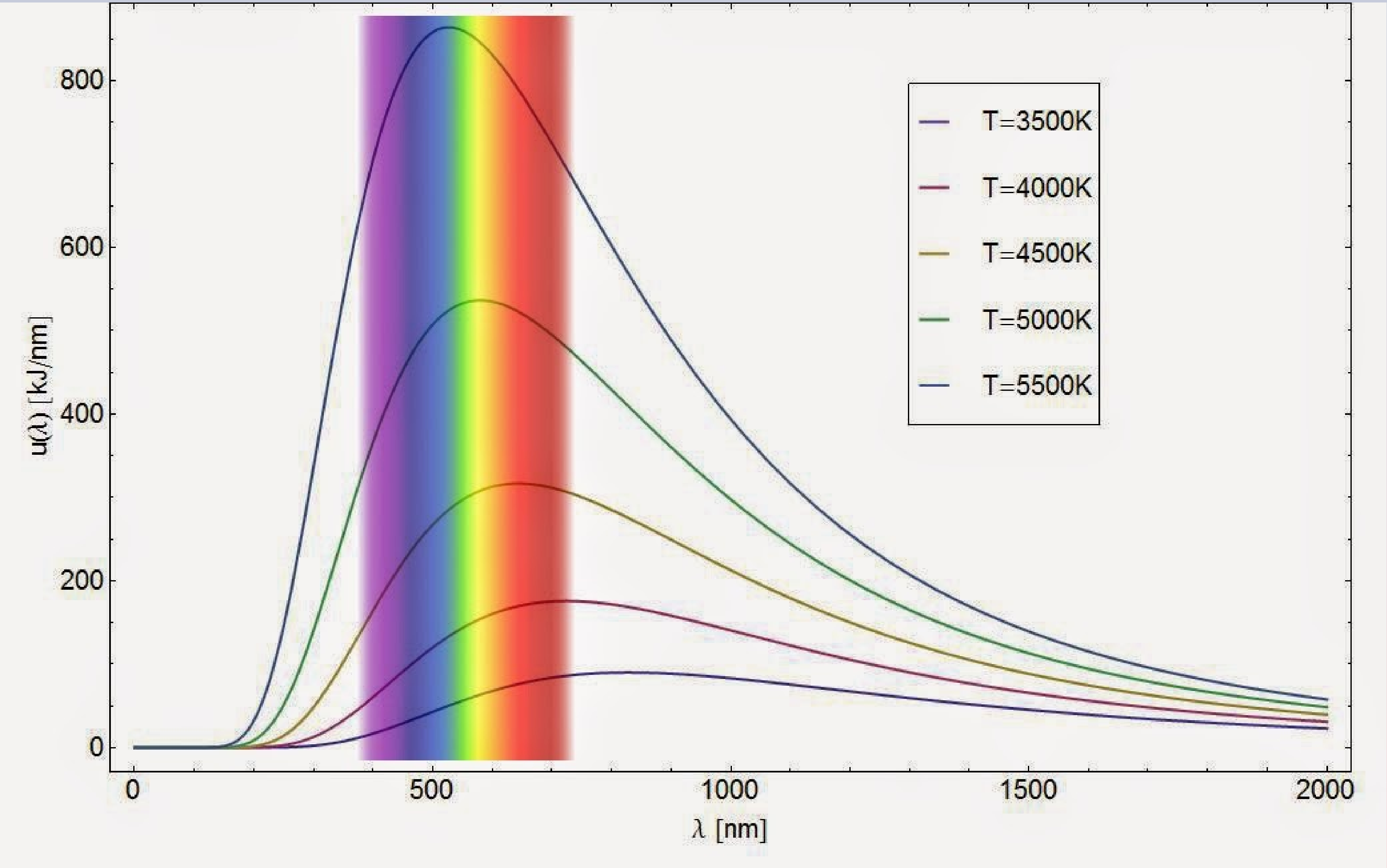

Colors are exagerrated



B – V	T (K) ± 5%
–0.30	(40000)
–0.20	23000
–0.10	16000
0.00	12000
+0.10	11100
+0.20	9500
+0.30	8100
+0.40	7200
+0.50	6500
+0.60	5900
+0.70	5400
+0.80	5000
+0.90	4600
+1.00	4300
+1.10	4050
+1.20	3800
+1.30	3600
+1.40	3400
+1.50	3200
+1.60	3100

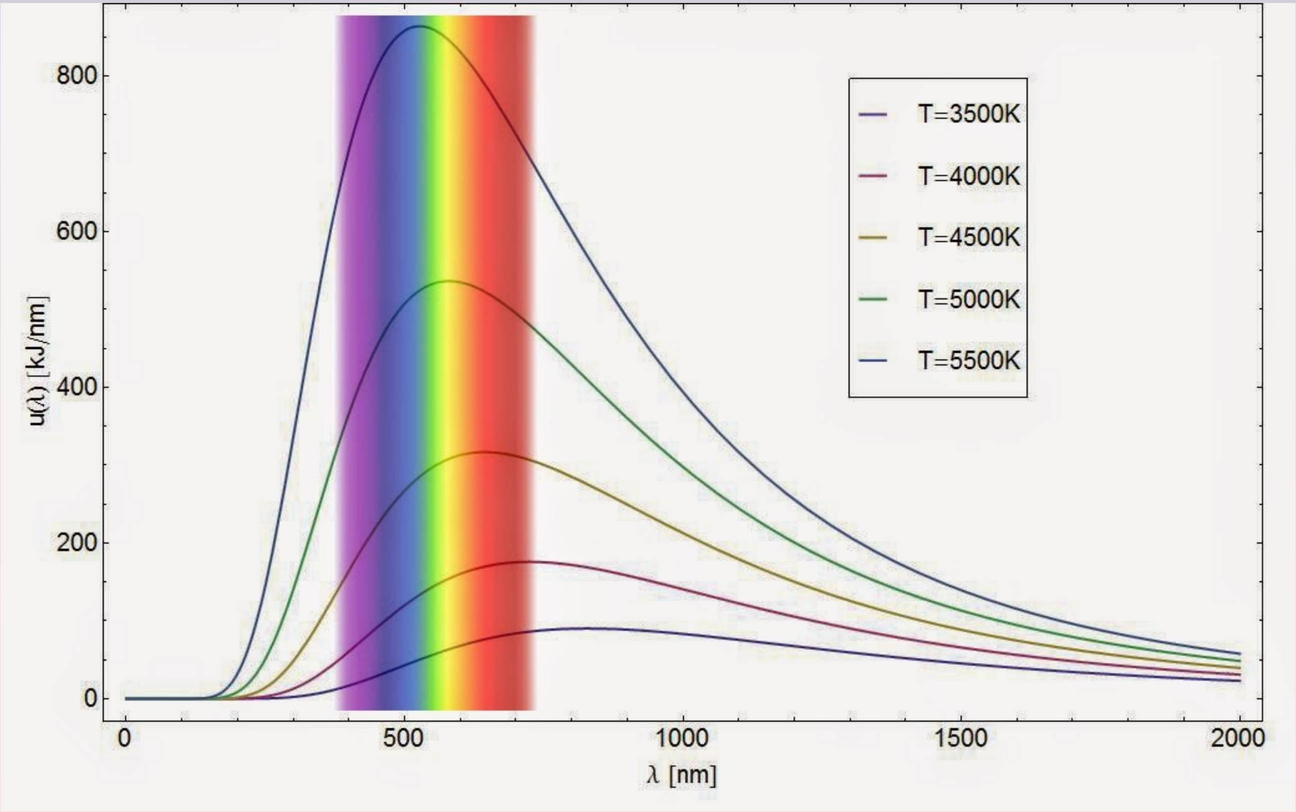

Intensity
2,500 K
1,000
3,500
6,000
8,500
11,000
Wavelength (Å)
Intensity
5,800 K
1,000
3,500
6,000
8,500
11,000
Wavelength (Å)
Intensity
18,000 K
1,000
3,500
6,000
8,500
11,000
Wavelength (Å)
Colors are exagerrated

¿Cómo explicar esto?



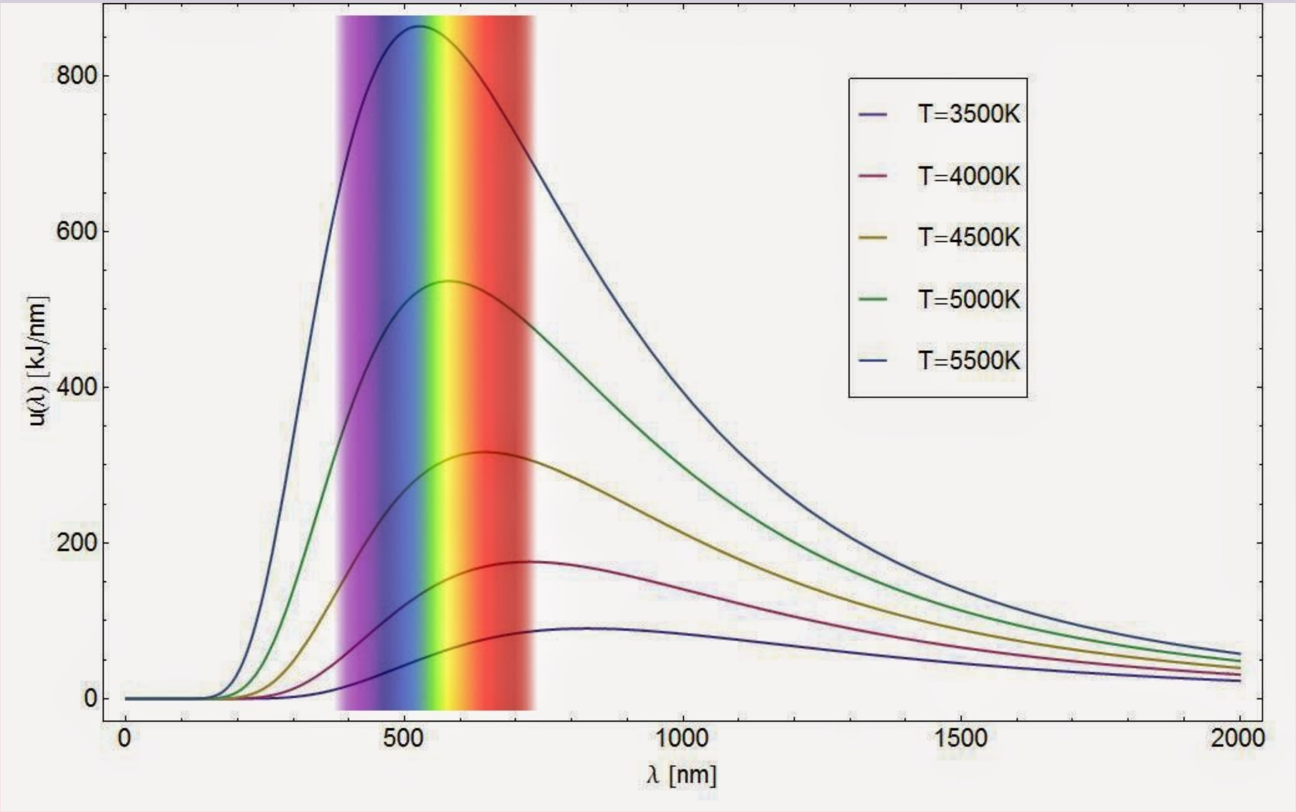
Ley de desplazamiento de Wien

$$\boxed{\lambda_{\max} T = 0.002897755 \text{ m K.}}$$



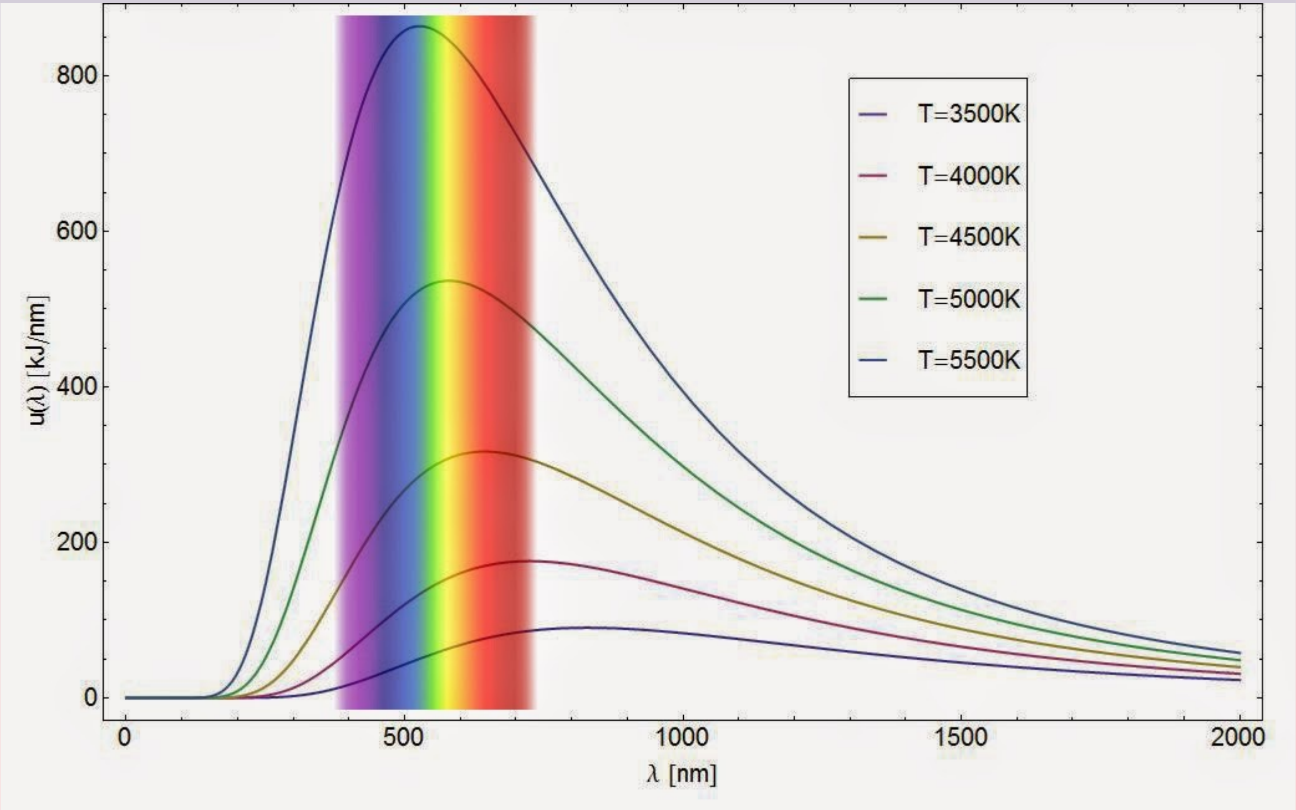
Ley de Rayleigh-Jeans (altas λ) ("catástrofe en el UV")

$$B_\lambda(T) \simeq \frac{2ckT}{\lambda^4},$$



Ley de Wien (bajas λ)

$$B_\lambda(T) \simeq a\lambda^{-5} e^{-b/\lambda T},$$



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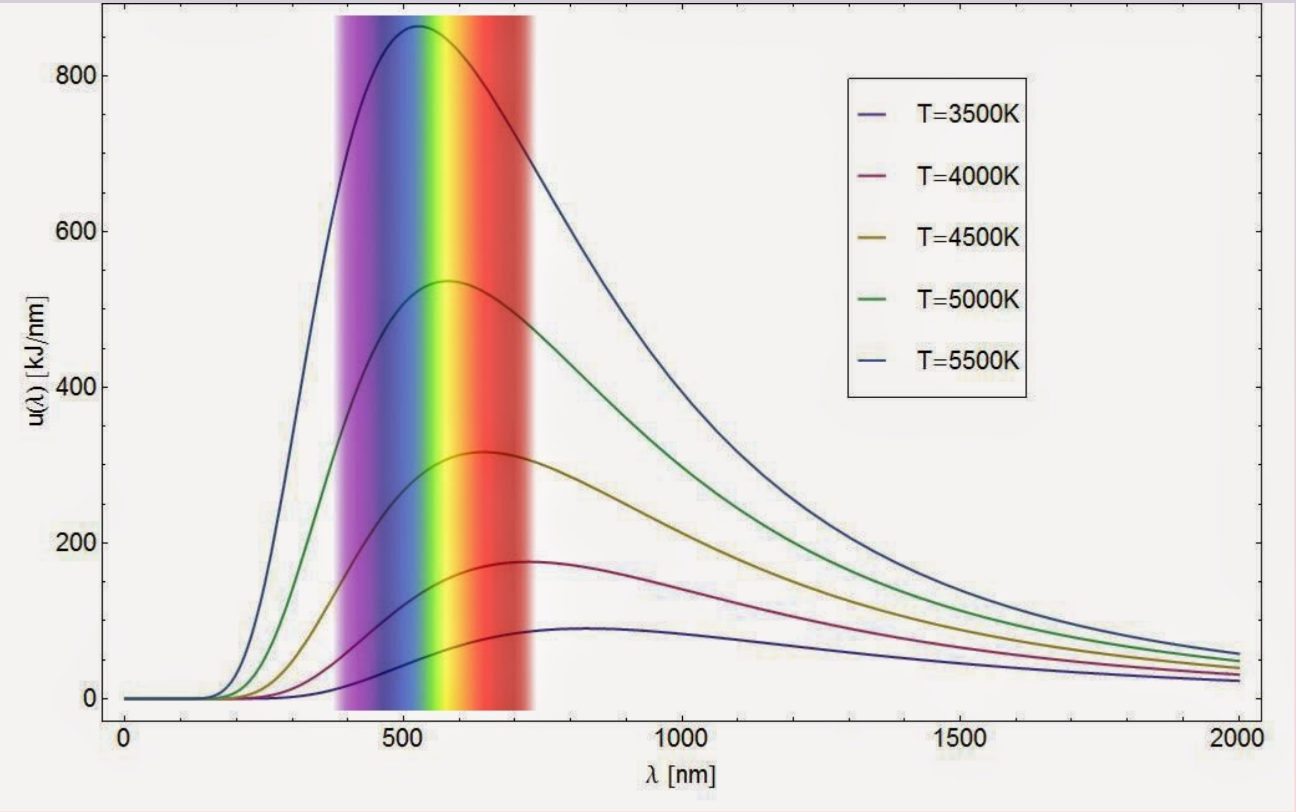
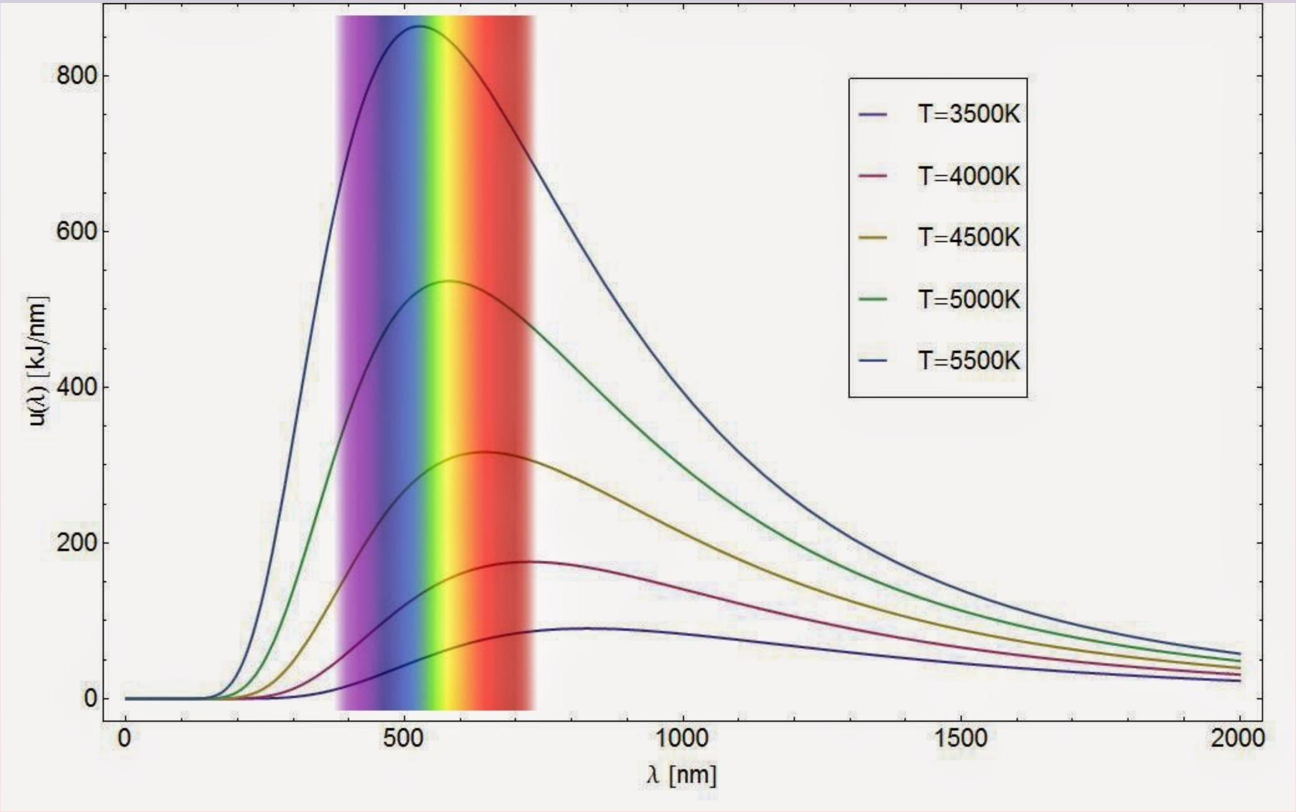
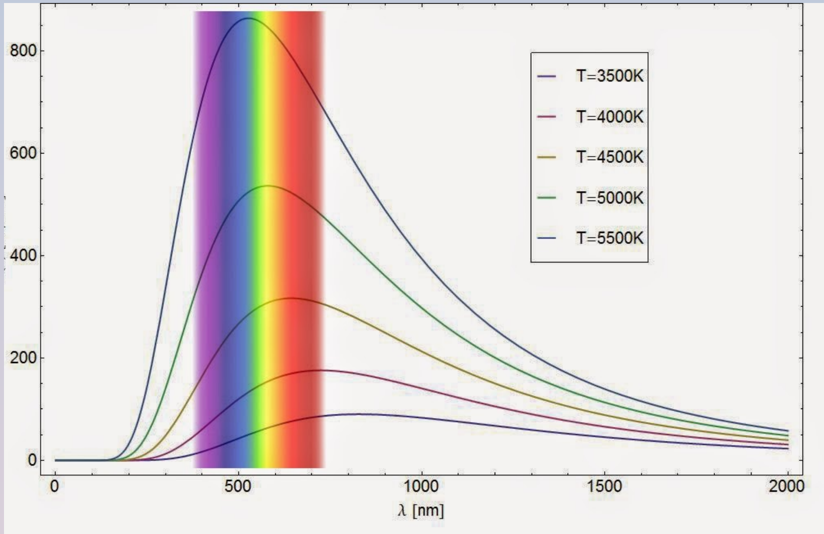


¿Cómo explicar esto?
¡Función/Ley de Planck!

$$B_\lambda(T) = \frac{a/\lambda^5}{e^{b/\lambda T} - 1},$$

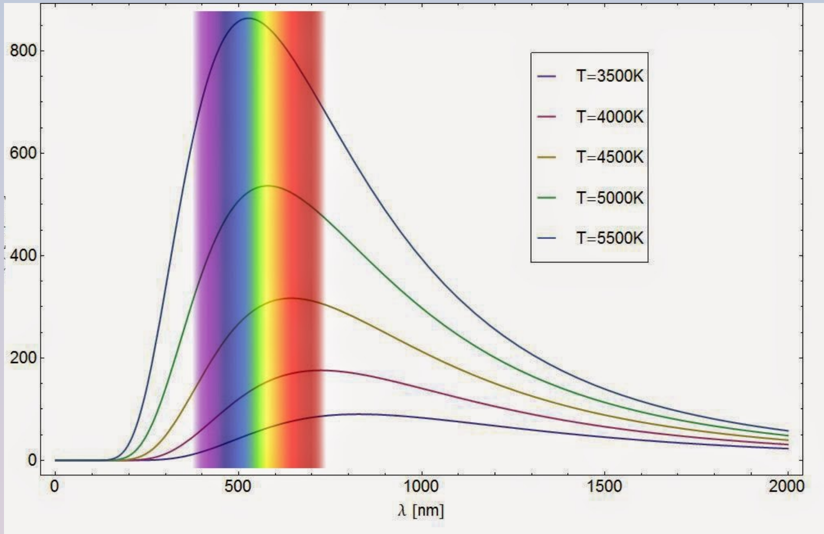


Función/Ley de Planck



$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\,\frac{1}{(e^{hc/k\lambda T} - 1)}$$

Función/Ley de Planck



$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

$B_\lambda(T)$ o $B(\lambda,T)$ representa la cantidad de energía emitida por unidad de superficie del cuerpo negro, dentro de la unidad de ángulo sólido, en la unidad de tiempo y por unidad de longitud de onda. Esto es la **intensidad específica monocromática** del cuerpo negro.

Distribución espectral
Cuerpo Negro

https://phet.colorado.edu/sims/html/blackbody-spectrum/latest/blackbody-spectrum_en.html

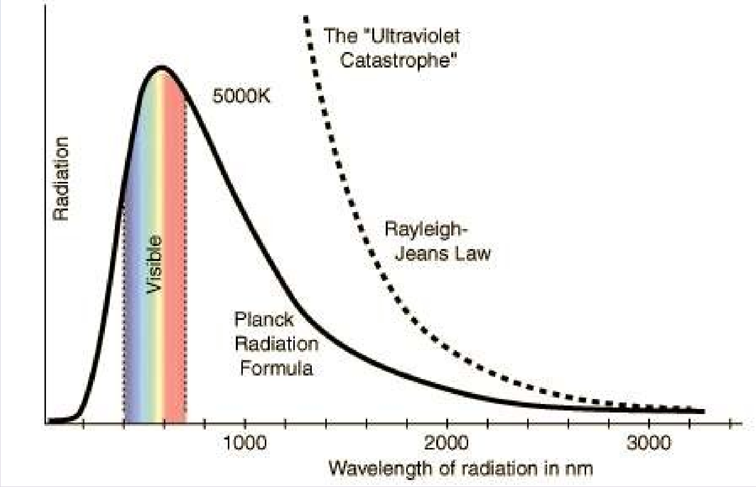
https://www.spectralcalc.com/blackbody_calculator/blackbody.php

Recordemos:

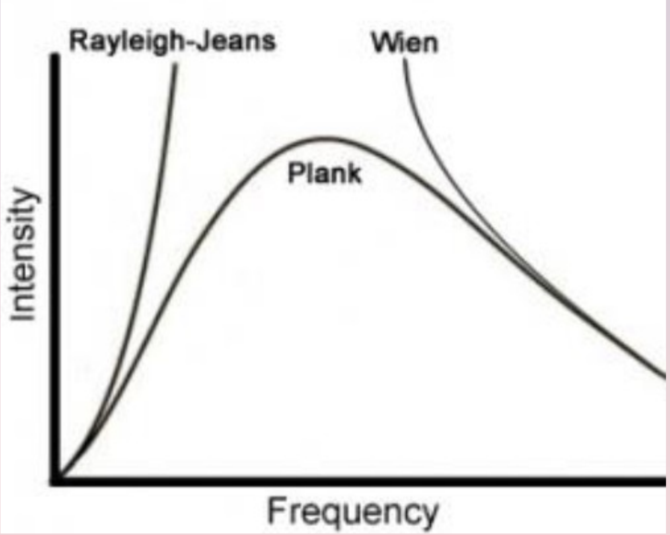
1 micrómetro = 10^{-6} m
1 nm = 10^{-9} m
1 A = 10^{-10} m
(1 nm = 10 A; 1 A = 0.0001 μ)

Función/Ley de Planck

…



$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

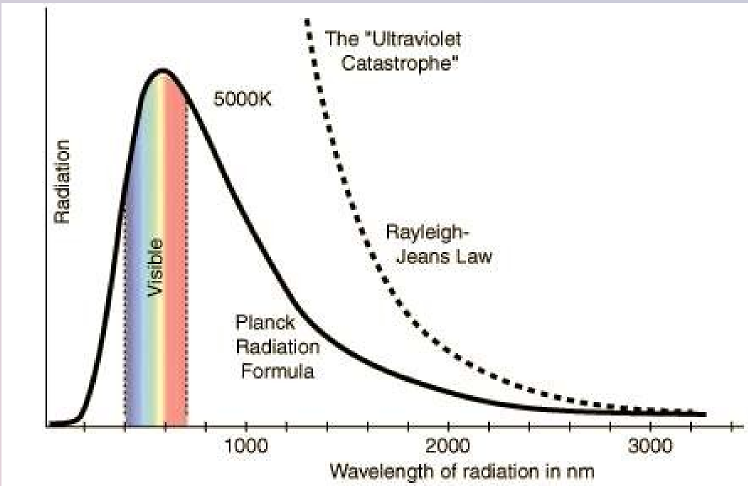


Función distribución:

$$B_\lambda(T) d\lambda = B_\nu(T) d\nu$$

Función/Ley de Planck

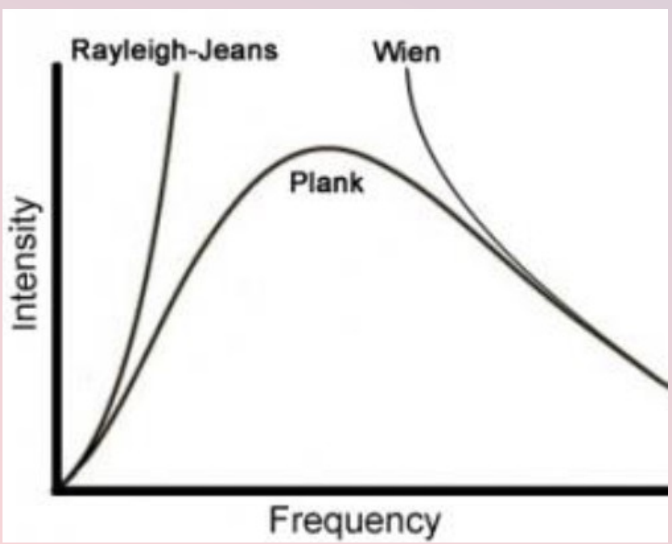
...



$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{(e^{hc/k\lambda T} - 1)}$$

Función distribución:

$$B_\lambda(T)d\lambda = B_\nu(T)d\nu$$



$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT} - 1}$$

Función/Ley de Planck
Función distribución

$$B_\lambda(T)d\lambda = B_\nu(T)d\nu$$

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT}-1}$$

Aproximaciones a la Ley de Planck

Ley de Rayleigh-Jeans (altas λ =>): $\nu h \ll kT$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

Aproximaciones a la Ley de Planck

Ley de Rayleigh-Jeans (altas λ =>): $\nu h \ll kT$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

$$\boxed{B_\lambda(T) = (\frac{2c}{\lambda^4})kT}$$

Aproximaciones a la Ley de Planck

Ley de Wien (bajas λ=>): $\nu h >> kT$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

Aproximaciones a la Ley de Planck

Ley de Wien (bajas λ=>): $\nu h >> kT$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

$$\boxed{B(\lambda, T) = C_1 \lambda^{-5} e^{-C_2/\lambda T}}$$

Aproximaciones a la Ley de Planck

Ley de Rayleigh-Jeans (altas λ =>): $\nu h << kT$

$$B_\lambda(T) = (\frac{2c}{\lambda^4})kT$$

Ley de Wien (bajas λ=>): $\nu h >> kT$

$$B(\lambda,T) = C_1\lambda^{-5}e^{-C_2/\lambda T}$$

Leyes de Wien

…

- 1º Ley: $$\lambda_{max} T = C$$

- 2º Ley: $$\int_0^\infty B_\nu(T) d\nu = \frac{\sigma}{\pi} T^4 = \alpha \lambda_{max}^{-4}$$

Leyes de Wien

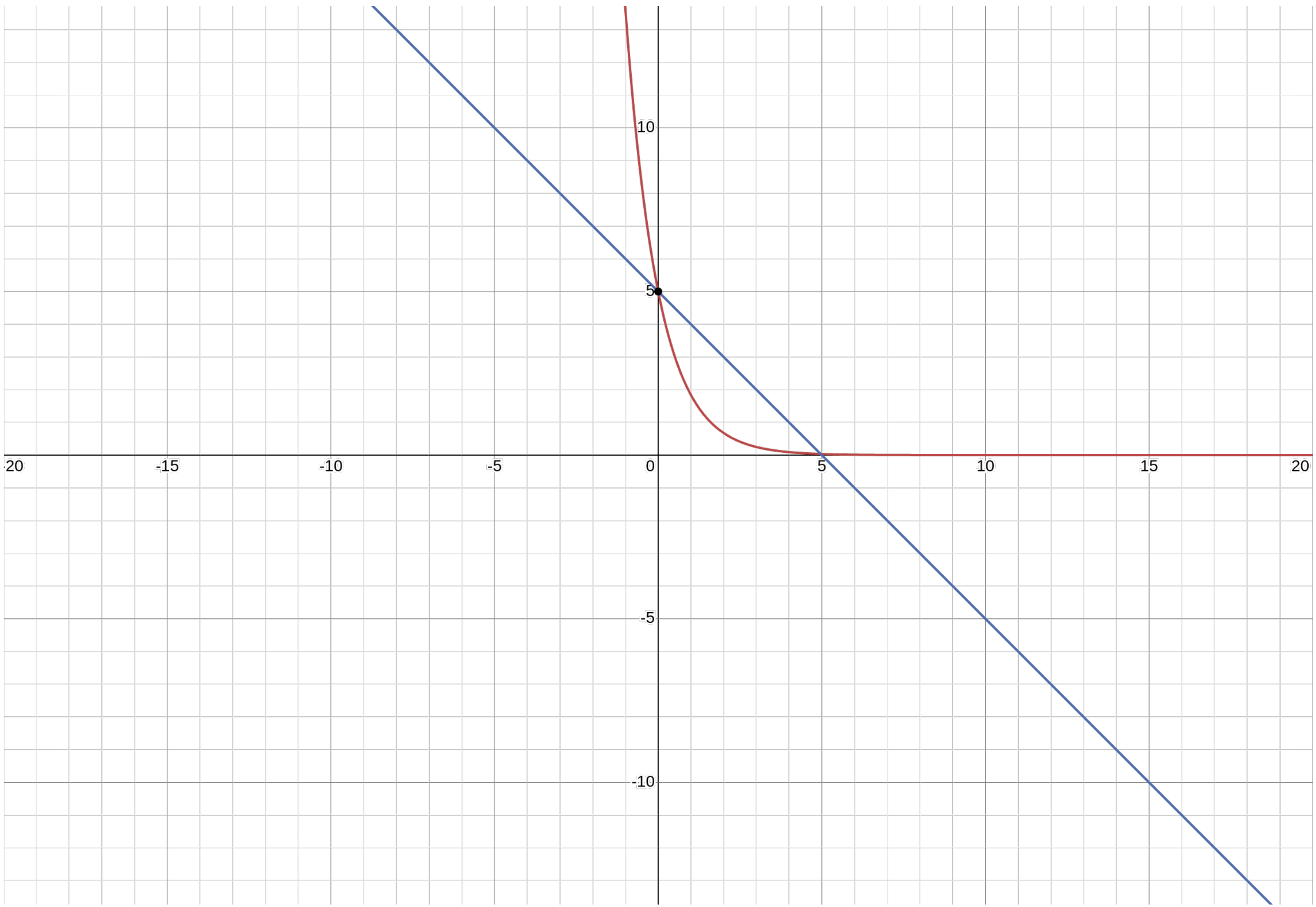
...

- 1º Ley: $\boxed{\lambda_{max} T = C}$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

Dibujar cada lado de la ecuación. La solución es el valor x del punto de la intersección.

$x \approx 0, 4.96511423$



Leyes de Wien

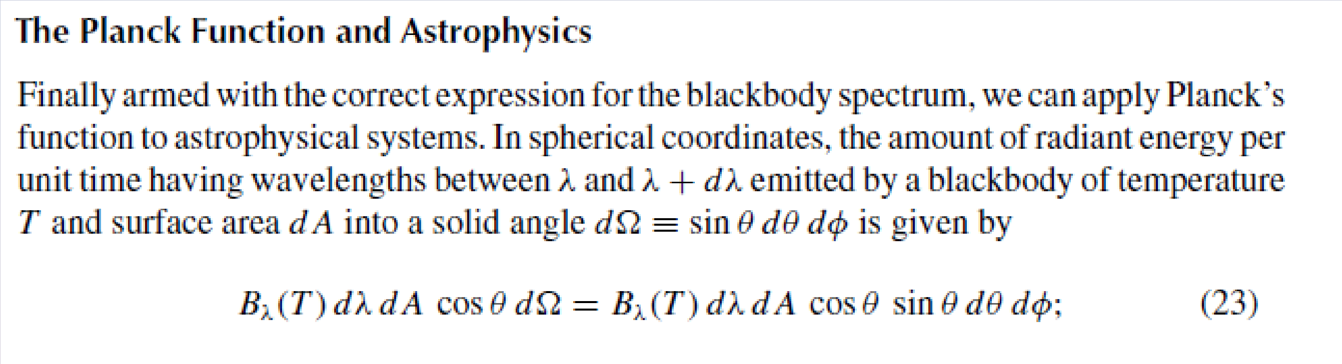
…

- 1º Ley: $\boxed{\lambda_{max} T = C}$

- 2º Ley: $\boxed{\int_0^\infty B_\nu(T)\, d\nu \;=\; \frac{\sigma}{\pi} T^4 \;=\; \alpha \lambda_{max}^{-4}}$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{(e^{hc/k\lambda T} - 1)}$$

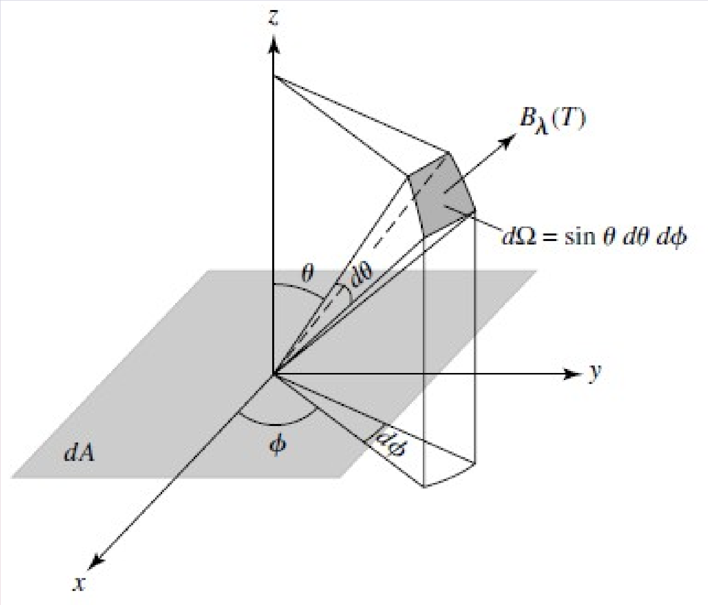
Unidades de la Función de Planck



The Planck Function and Astrophysics

Finally armed with the correct expression for the blackbody spectrum, we can apply Planck's function to astrophysical systems. In spherical coordinates, the amount of radiant energy per unit time having wavelengths between λ and $\lambda + d\lambda$ emitted by a blackbody of temperature T and surface area dA into a solid angle $d\Omega \equiv \sin\theta \, d\theta \, d\phi$ is given by

$$B_\lambda(T)\, d\lambda \, dA \, \cos\theta \, d\Omega = B_\lambda(T)\, d\lambda \, dA \, \cos\theta \, \sin\theta \, d\theta \, d\phi; \qquad (23)$$



Unidades B (λ,T): W m^{-2} sr^{-1} A^{-1}

Ley de Stefan-Boltzmann

- Vimos que (en isotropía):

$$R = \pi \, I$$

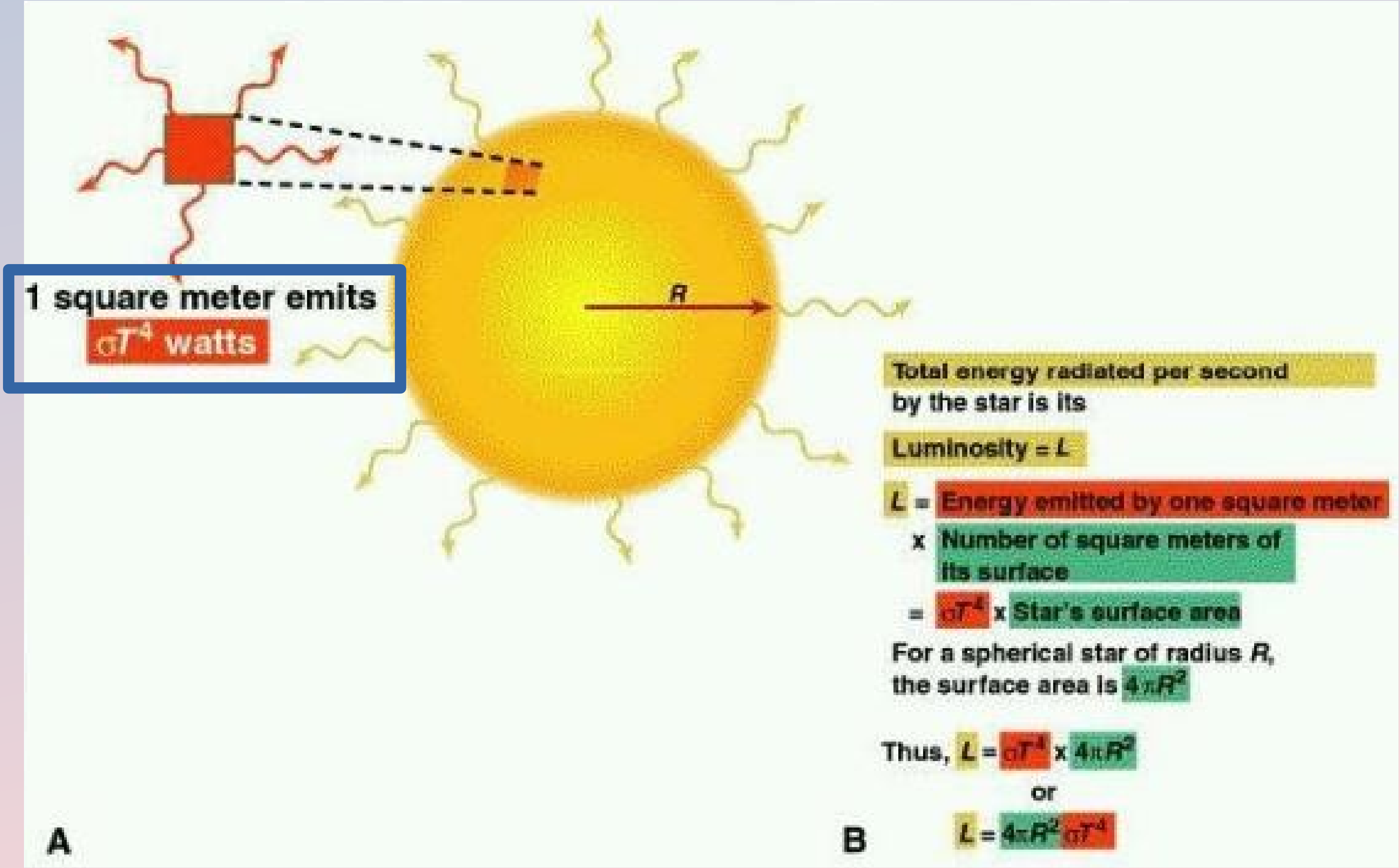
- Si la fuente irradia como un CN:

$$I(\lambda,T) = B(\lambda,T)$$

- Integrando sobre todas las λ: (...)

$$\boxed{\mathbf{R_{CN} = \sigma \; T^4}}$$

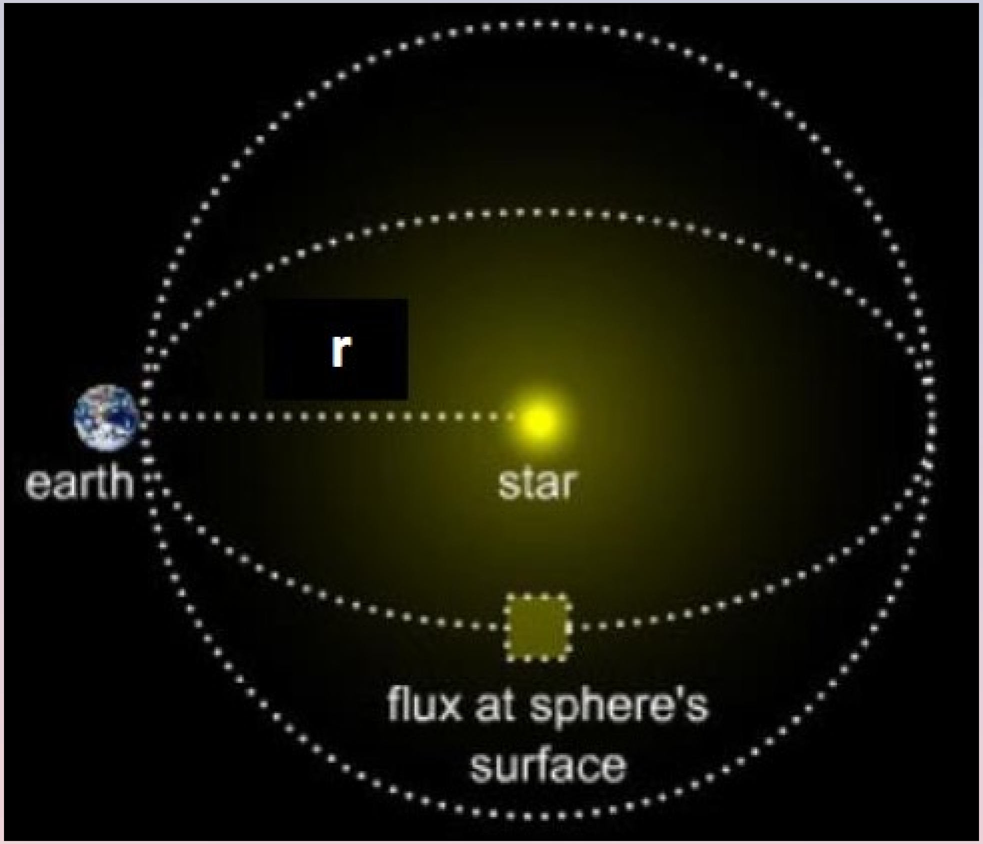
Ley de Stefan-Boltzmann
Luminosidad (L)



Flujo recibido

Si no hay absorción:

$$\boxed{L=4\pi R^2\sigma T^4 = 4\pi r^2 F}$$



Temperatura Efectiva

$$L = 4\pi R^2 \sigma T_{eff}^4$$

Temperatura de Brillo (determinada λ)
Temperatura de Color (reproduce (B-V))