

STEFAN-BOLTZMANN CONSTANT: LUMINOSITY OF A STAR AS A BLACKBODY

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Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 3, Problem 3.14.

The blackbody radiation rate in terms of wavelength is

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

B_λ is the rate at which a blackbody at temperature T radiates in watts per unit area, per unit wavelength band, per steradian. The amount of radiation emitted in a wavelength span $[\lambda, \lambda + d\lambda]$ is therefore $B_\lambda d\lambda$. As we saw earlier, the total rate of emission of energy per unit area, integrated over all wavelengths and over solid angle is

$$j = \frac{2\pi^5 k_B^4}{15h^3 c^2} T^4 \quad (2)$$

The constant multiplying T^4 is the Stefan-Boltzmann constant, defined as

$$\sigma \equiv \frac{2\pi^5 k_B^4}{15h^3 c^2} \quad (3)$$

The value of σ is

$$\sigma = \frac{2\pi^5 (1.3806488 \times 10^{-23})^4}{15 (6.62606957 \times 10^{-34})^3 (2.99792458 \times 10^8)^2} \quad (4)$$

$$= 5.670373 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \quad (5)$$

This value agrees with the currently accepted value of the constant.

If the star radiates uniformly over its entire surface, then the luminosity of the star is j times the surface area, so

$$L = 4\pi R^2 j = \frac{8\pi^6 R^2 k_B^4}{15h^3 c^2} T^4 = 4\pi R^2 \sigma T^4 \quad (6)$$

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