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

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

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

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

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

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

The value of σ is

$$\sigma = \frac{2\pi^5\left(1.3806488\times10^{-23}\right)^4}{15\left(6.62606957\times10^{-34}\right)^3\left(2.99792458\times10^8\right)^2} \tag{4}$$

$$= 5.670373\times10^{-8}\ \mathrm{W\ m^{-2}K^{-4}} \tag{5}$$

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

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

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