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

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

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

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

The value of σ is

$$\begin{aligned}\sigma &= \frac{2\pi^{5}\left(1.3806488\times10^{-23}\right)^{4}}{15\left(6.62606957\times10^{-34}\right)^{3}\left(2.99792458\times10^{8}\right)^{2}} && (4)\\ &= 5.670373\times10^{-8}\text{ W m}^{-2}\text{K}^{-4} && (5)\end{aligned}$$

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

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

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