

AST-191 Special Topics: “Radiative Processes in Astrophysics”

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Fall 2024 semester:

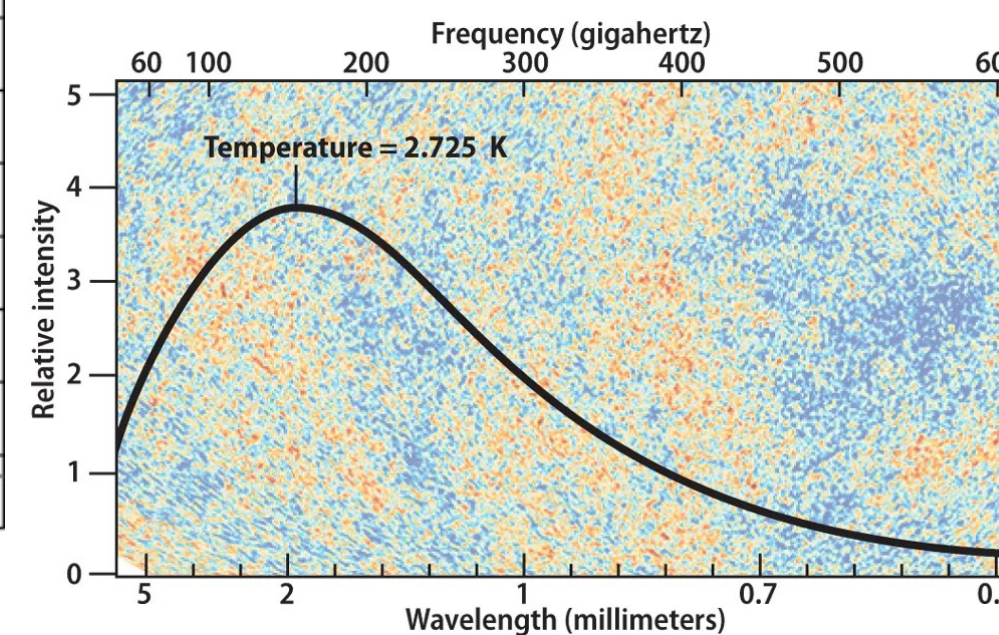
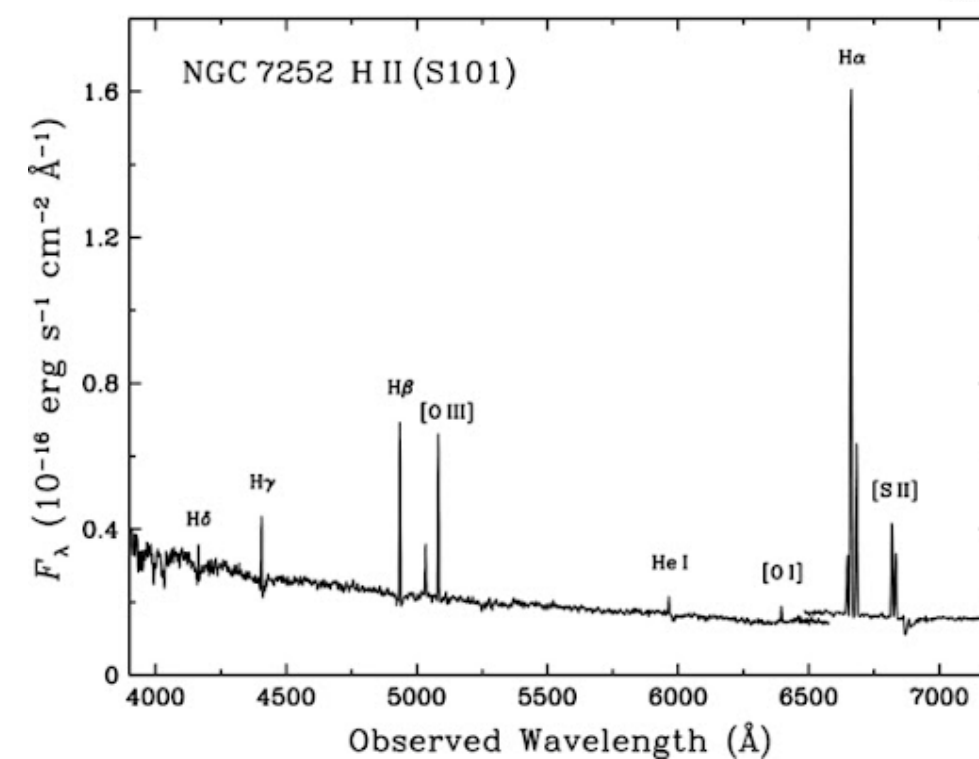
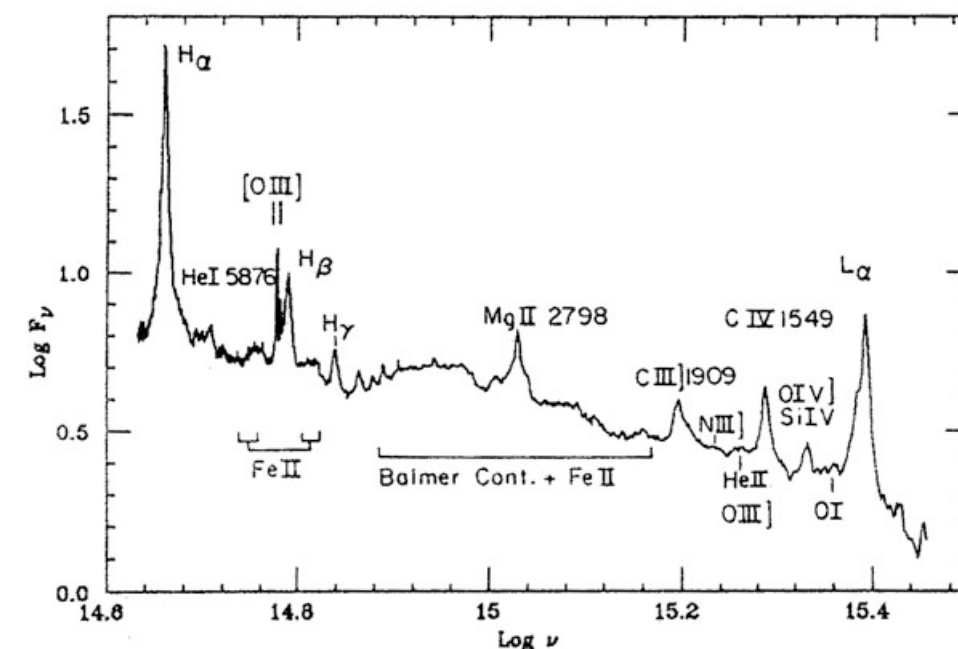
Mon-Wed
9:00-10:15am
CLIC 204

Recommended textbook:

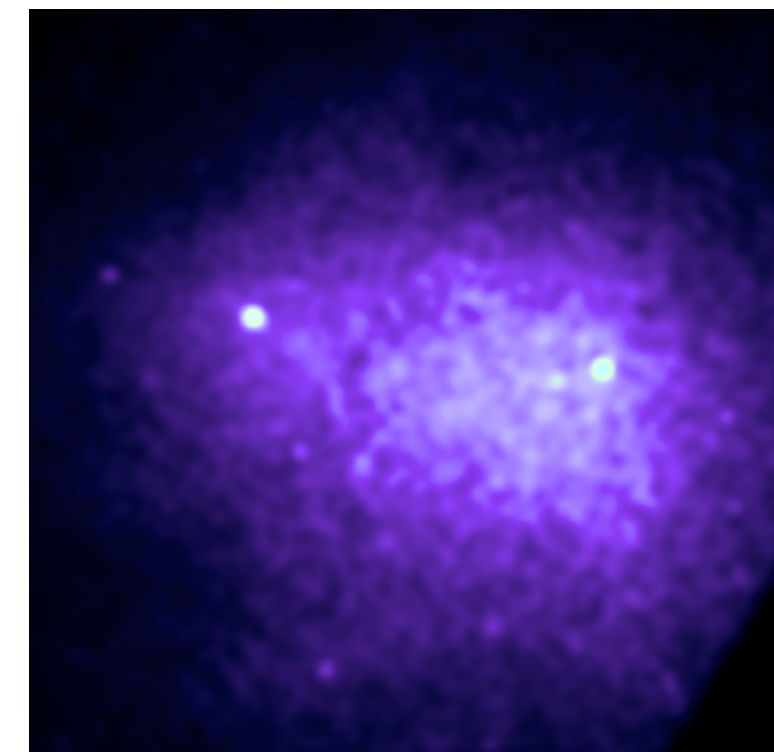
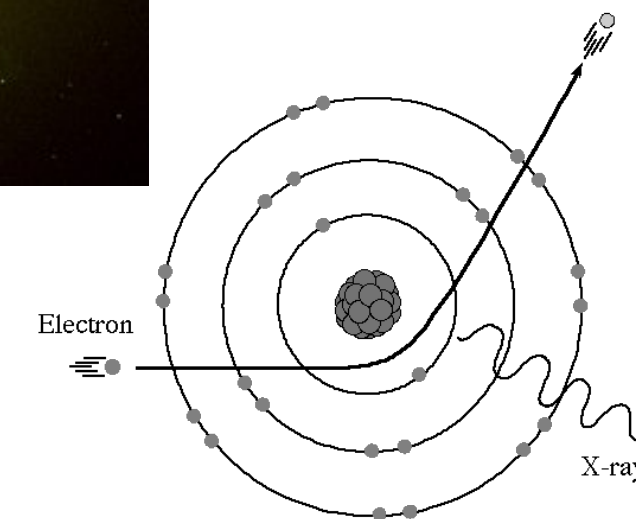
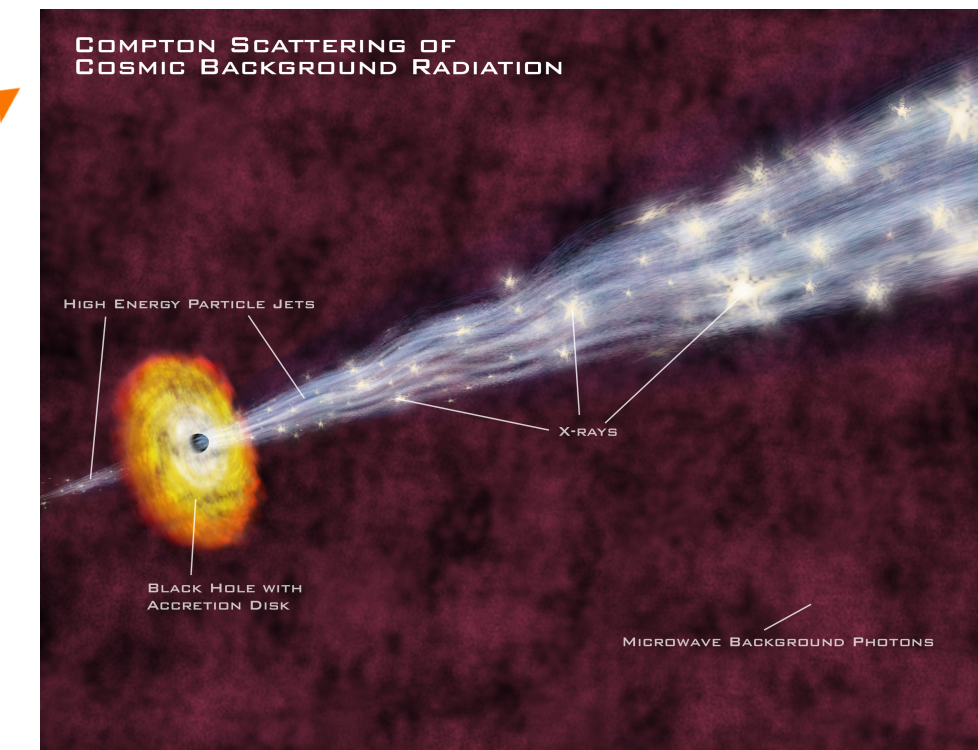
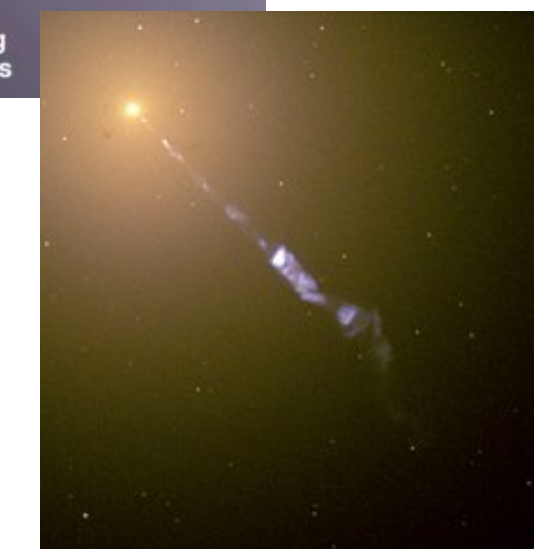
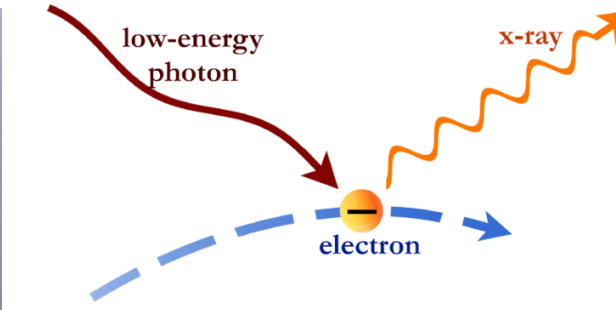
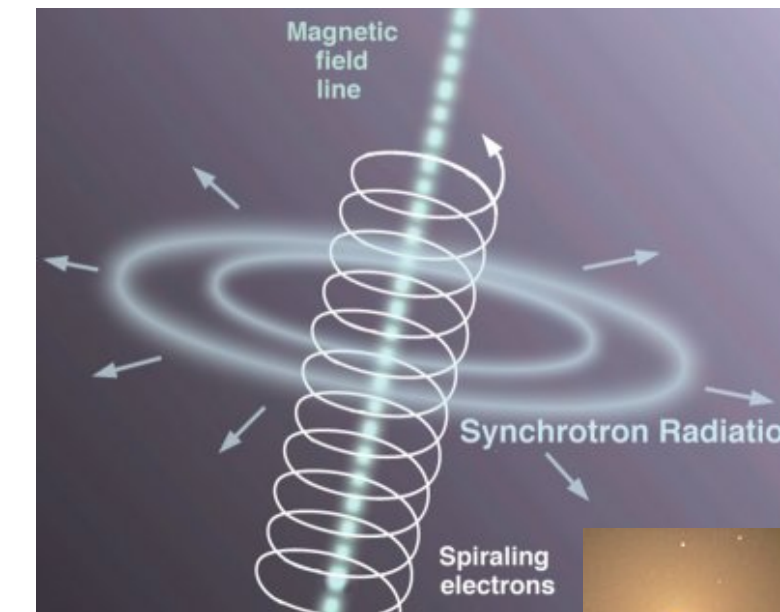
“Radiative Processes in Astrophysics”
by Rybicki & Lightman

COVERED TOPICS:

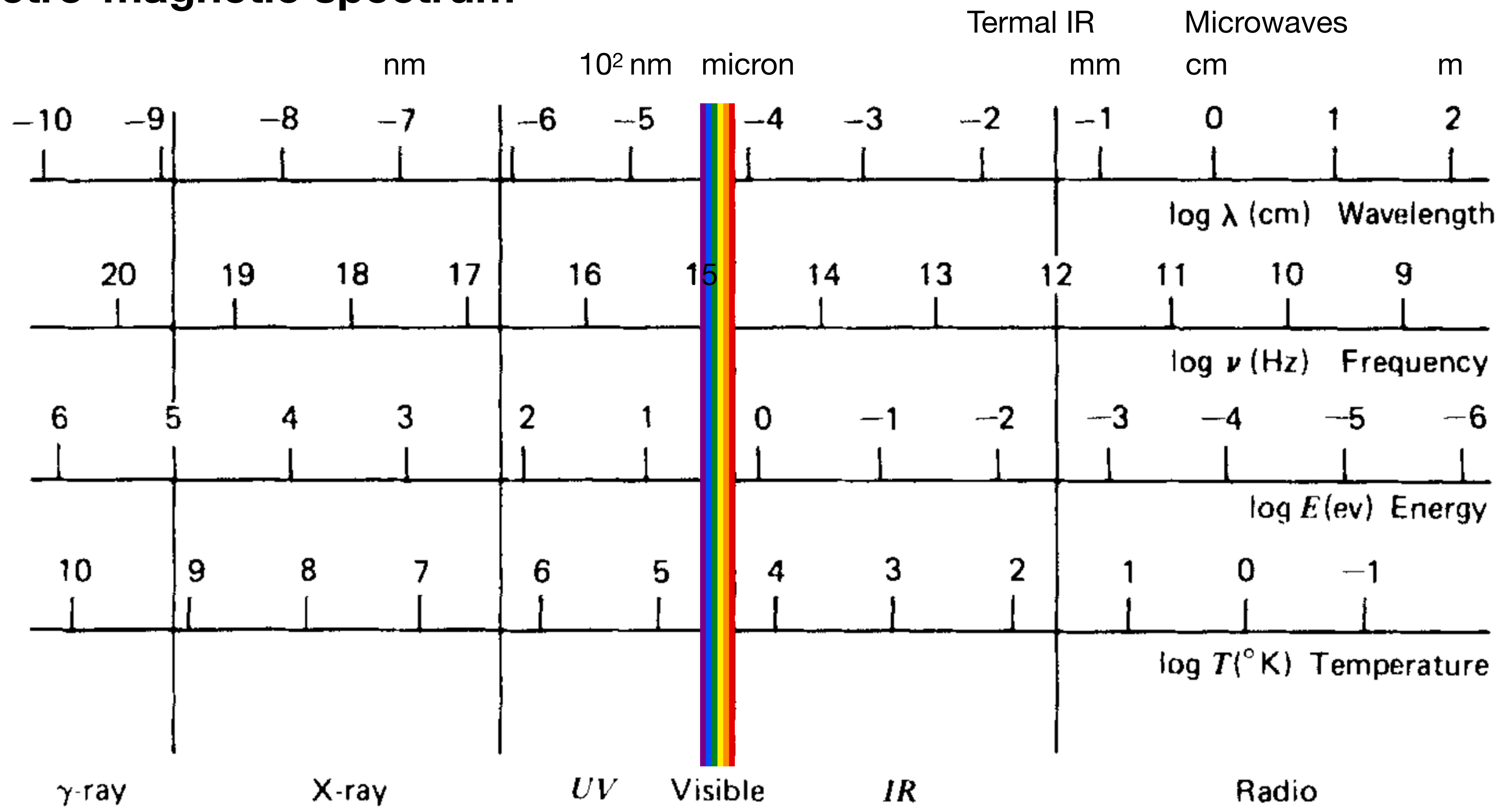
- Fundamentals of Radiative Transfer
- Radiation from Moving Charges
- Bremsstrahlung
- Synchrotron Radiation
- Compton scattering
- Plasma Effects
- Atomic Structure
- Radiative Transitions
- Molecular Structure

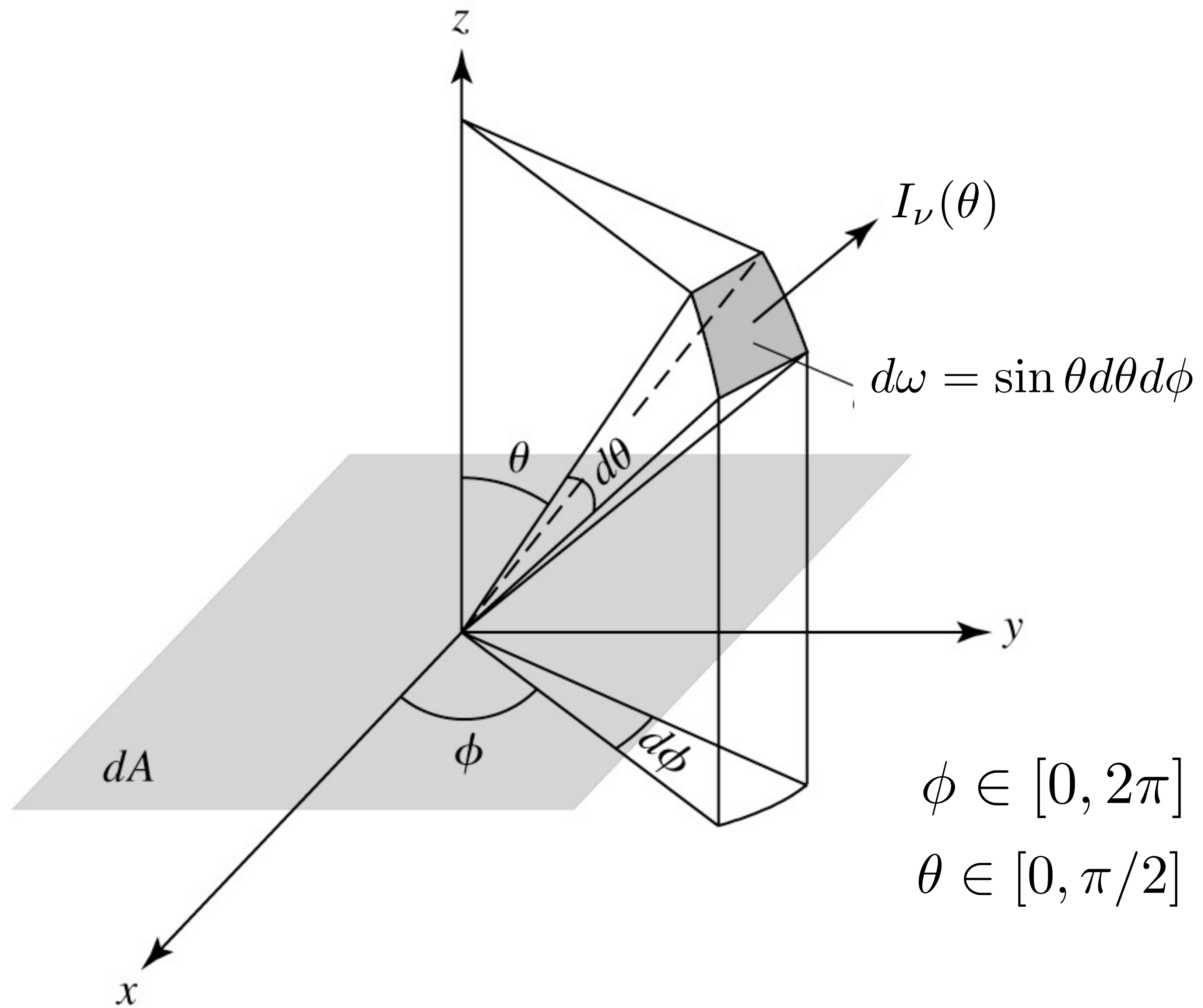


$\lambda\nu = c$	$E = h\nu = hc/\lambda$	$P = E/c$	$\omega = 2\pi\nu$	$P = \hbar K$	$m - m_0 = -2.5 \log(F/F_0)$	$L = \frac{dE}{dt}$
FLUX $F_\nu = dE/dAdtd\nu$		TOTAL FLUX $F = \int F_\nu d\nu$		INVERSE SQUARE LAW $F = L/4\pi r^2$		
BRIGHTNESS OR SPECIFIC INTENSITY $I_\nu = \frac{dE}{dAd\Omega dt d\nu}$ $\left[\frac{\text{erg}}{\text{cm}^2 \text{ster Hz}}\right]$		$F_\nu = \int I_\nu \cos\theta d\Omega$ $\left[\frac{\text{erg}}{\text{cm}^2 \text{Hz}}\right]$		$F = \int I_\nu d\Omega$ $\left[\frac{\text{erg}}{\text{cm}^2}\right]$		
ENERGY DENSITY $u_\nu = \frac{1}{c} \int I_\nu d\Omega = \frac{4\pi}{c} J_\nu$		$J_\nu = \frac{1}{4\pi} \int I_\nu d\Omega$		$u = \int u_\nu d\nu = \frac{4\pi}{c} \int J_\nu d\nu$		
RADIATION PRESSURE (ISOTROPIC) $P_\nu = \frac{2}{c} \int I_\nu \cos^2\theta d\Omega$		$P = \frac{2}{c} \int J_\nu d\nu \int \cos^2\theta d\Omega$		$P = \frac{1}{3} u$		
CONSTANCY OF I_ν IN FREE SPACE $dE_1 = I_\nu dA_1 dt d\nu_1$ $dA_1 d\nu_1 = dA_2 d\nu_2$ $dE_1 = dE_2 \Rightarrow I_\nu = I_\nu'$ $I_\nu = \text{CONST.}$		$\frac{dI_\nu}{ds} = 0$				
UNIFORMLY BRIGHT SPHERE $\theta_c = \sin^{-1}(R/r)$		 $F = \int I \cos\theta d\Omega = \pi B \int_0^{\theta_c} \sin\theta \cos\theta d\theta$ $\Rightarrow F = \pi B (1 - \cos^2\theta_c) = \pi B \sin^2\theta_c$		$F = \pi B \left(\frac{R}{r}\right)^2$ $F = \pi B$ $I(\theta) = \begin{cases} B & \theta < \theta_c \\ 0 & \theta > \theta_c \end{cases}$		
RADIATIVE TRANSFER		EMISSION COEFFICIENT $j_\nu = \frac{dE}{dV dt d\nu d\Omega}$		$dI_\nu = j_\nu ds$ $\frac{dI_\nu}{ds} = j_\nu \neq 0$		ISOTROPIC EMITTER $j_\nu = \frac{1}{4\pi} P_\nu = \frac{c\nu P}{4\pi E_\nu}$ $P = \frac{\text{power}}{V \text{ Hz}}$
ABSORPTION $dI_\nu = -\alpha_\nu I_\nu ds = -n\sigma_\nu I_\nu ds$		$\alpha_\nu = n\sigma_\nu = \kappa_\nu$ $\alpha_\nu [\text{cm}^{-1}]$		$\sigma_\nu [\text{cm}^2]$ $\kappa_\nu [\text{cm}^2 \text{g}^{-1}]$ OPACITY		
RADIATIVE TRANSFER $\frac{dI_\nu}{ds} = -\alpha_\nu I_\nu + j_\nu$		EMISSION ONLY $\frac{dI_\nu}{ds} = j_\nu$ $I_\nu(s) = I_\nu(s_0) + \int_{s_0}^s j_\nu(s') ds'$		ABSORPTION ONLY $I_\nu(s) = I_\nu(s_0) e^{-\int_{s_0}^s \alpha_\nu(s') ds'}$ $I_\nu = 0$		
OPTICAL DEPTH $d\tau_\nu = \alpha_\nu ds$ $\tau_\nu(s) = \int_{s_0}^s \alpha_\nu(s') ds'$		OPTICALLY THICK $\tau_\nu \gg 1$ $\frac{dI_\nu}{ds} = -I_\nu + S_\nu$		SOURCE FUNCTION $S_\nu = \frac{j_\nu}{\alpha_\nu}$ $\text{As } \tau_\nu \rightarrow \infty, I_\nu \rightarrow S_\nu$		

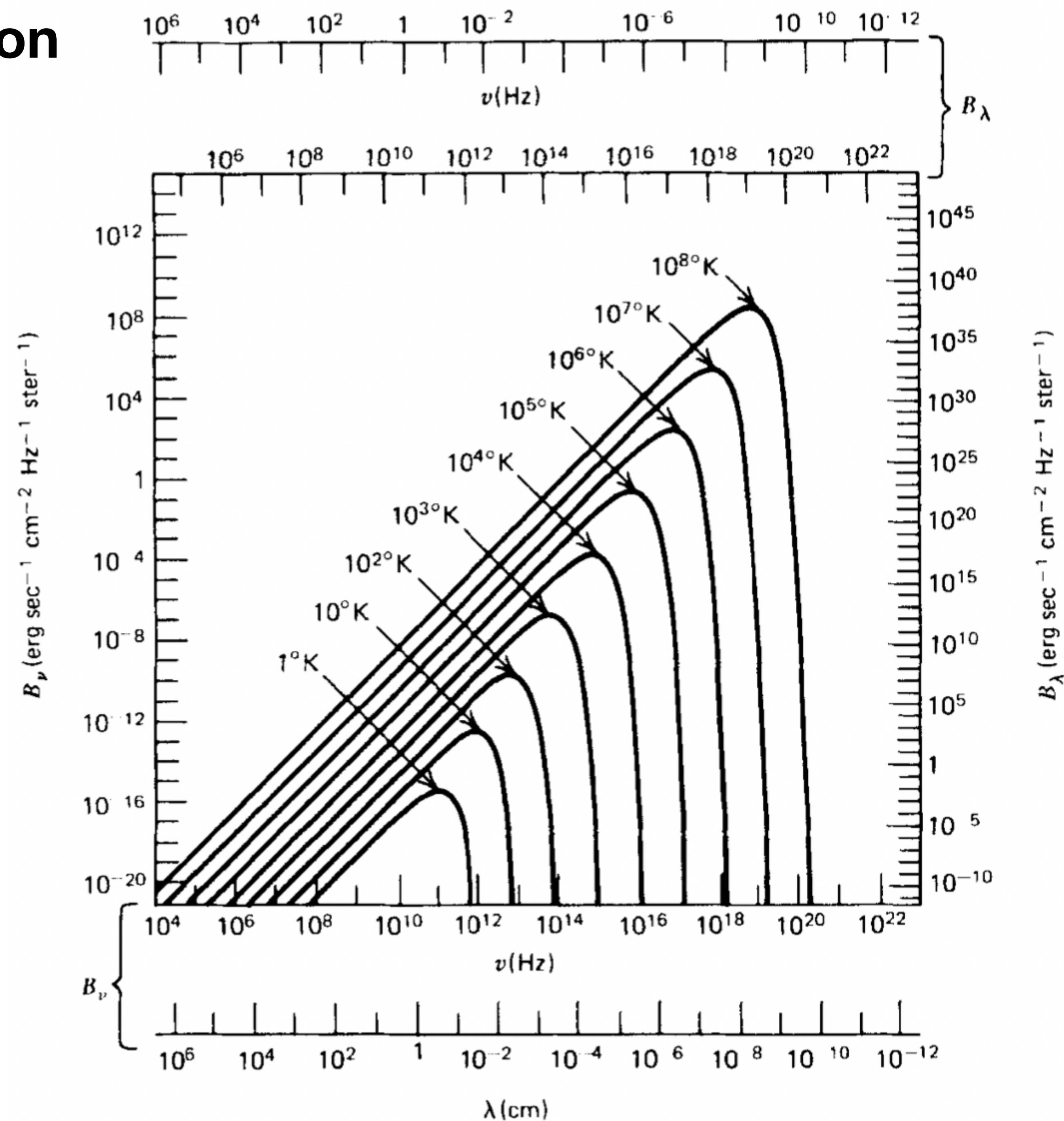


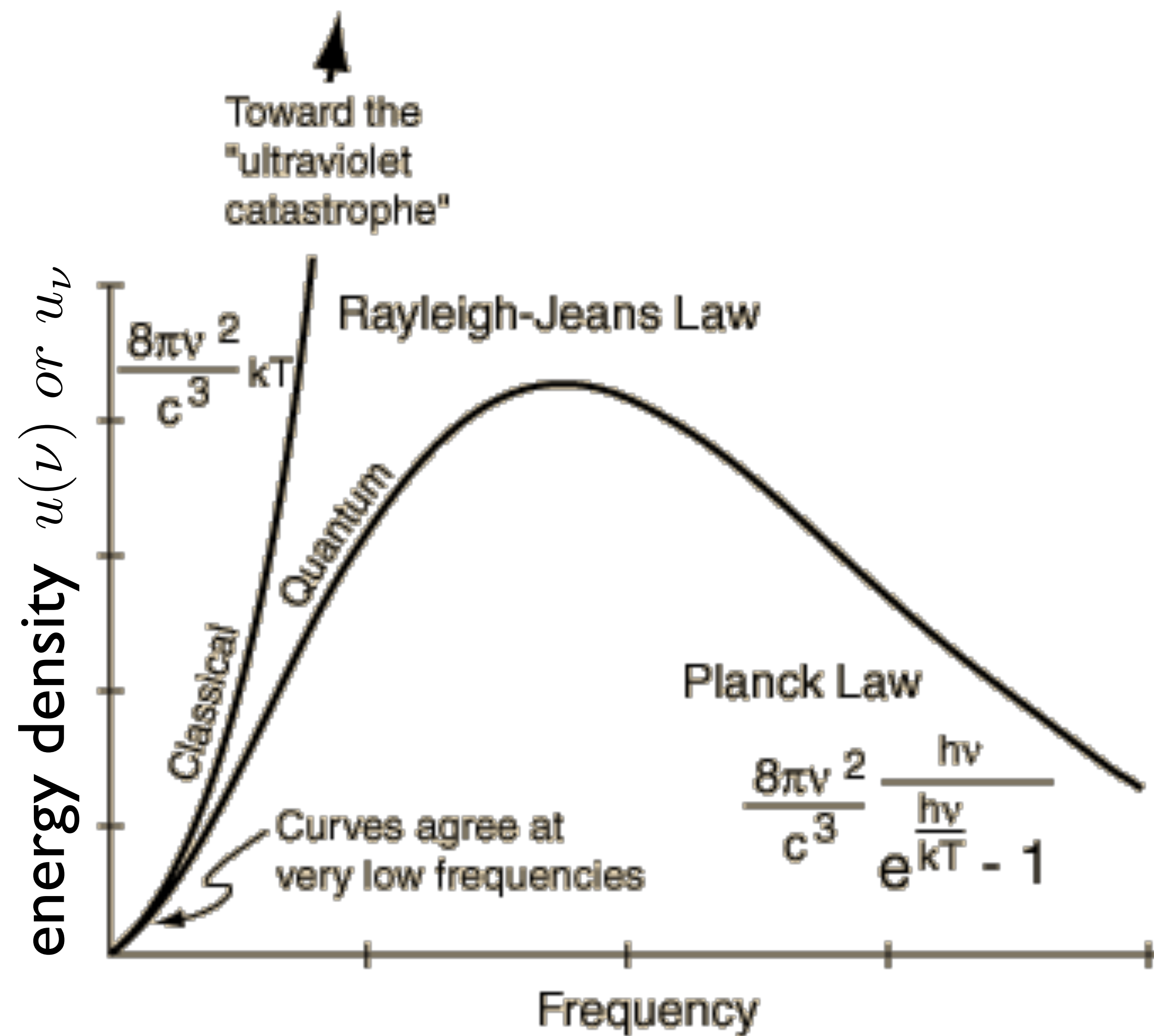
Electro-magnetic spectrum





Blackbody radiation (Plank's law)





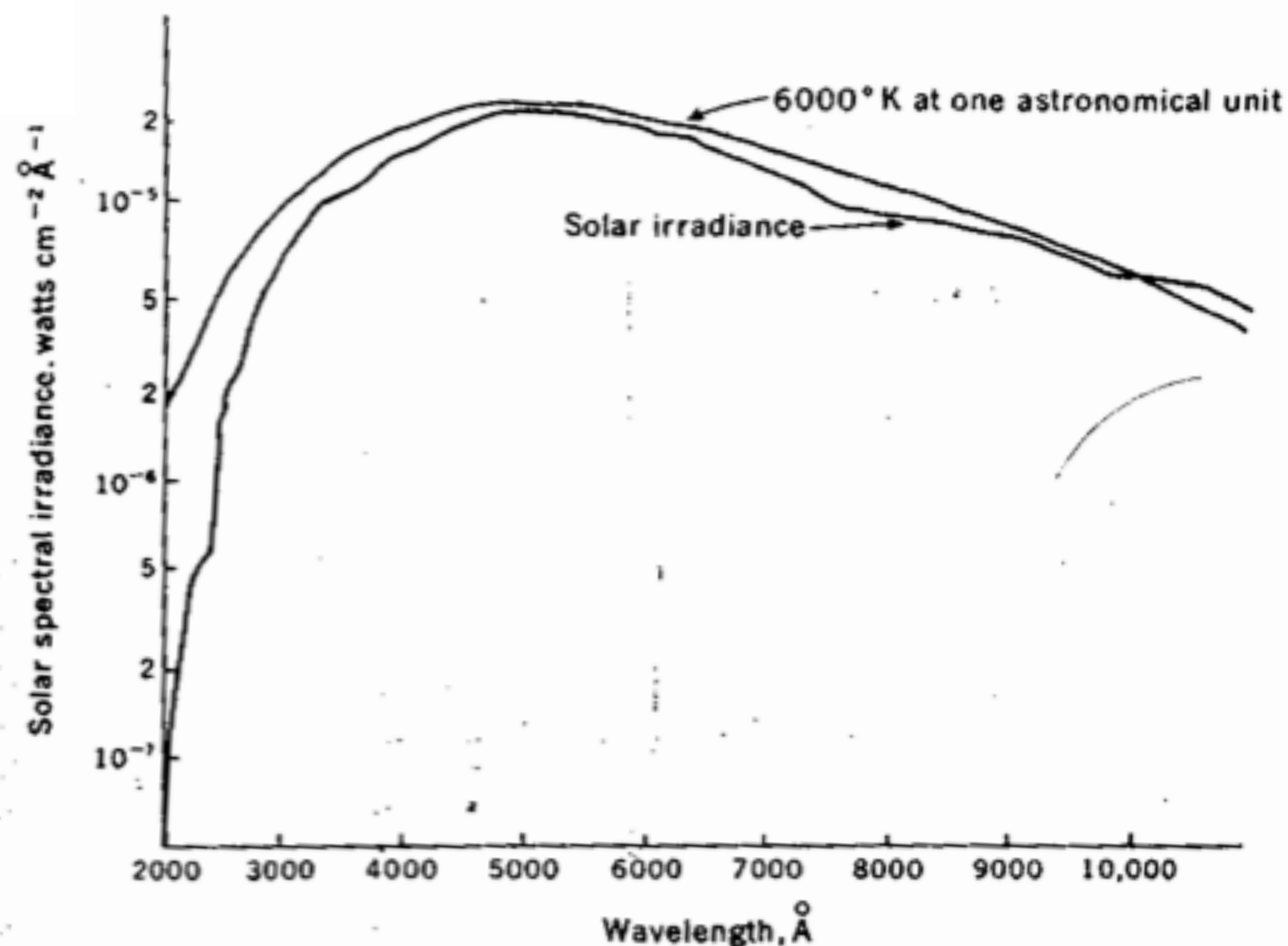
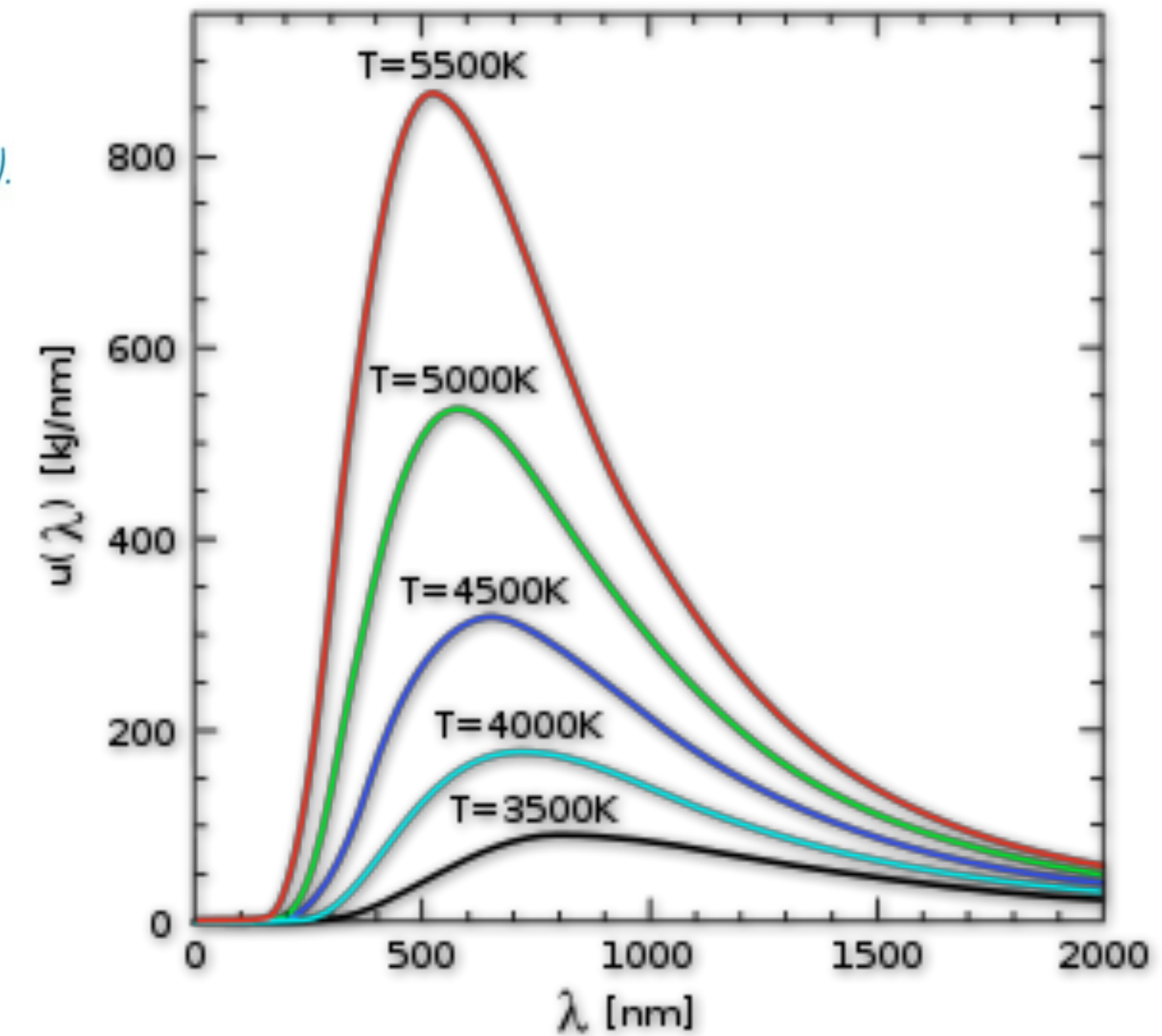
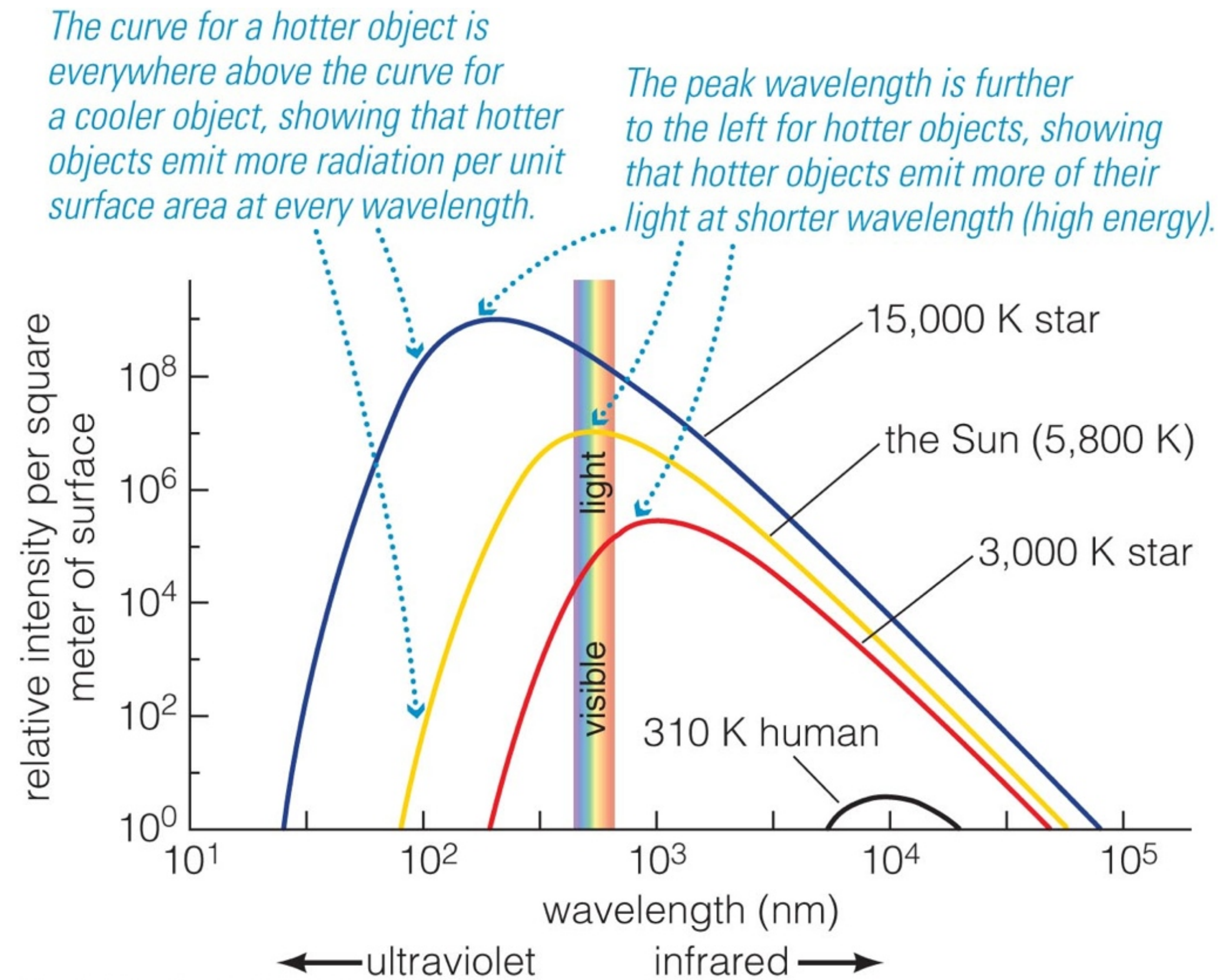
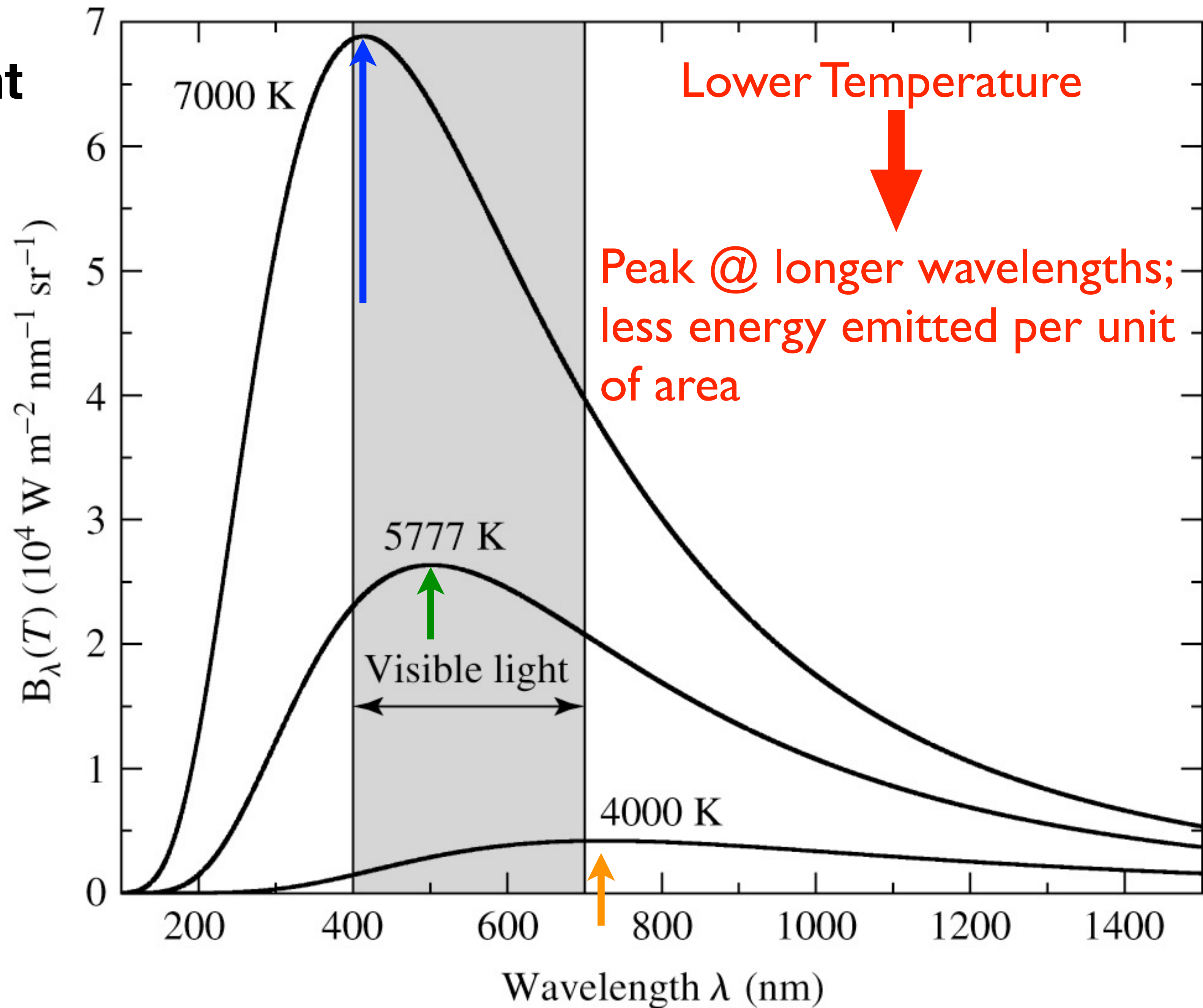


Fig. 1-5 Comparison of the visible solar energy-distribution curve with that from a blackbody at 6000°K. The overall resemblance is good, although the sun is quite deficient in the ultraviolet. (D. P. Le Galley and A. Rosen (eds.), "Space Physics," p. 111, John Wiley & Sons, Inc., New York, 1964.)



Wien's displacement law

Wien's displacement law



Color temperature T_c

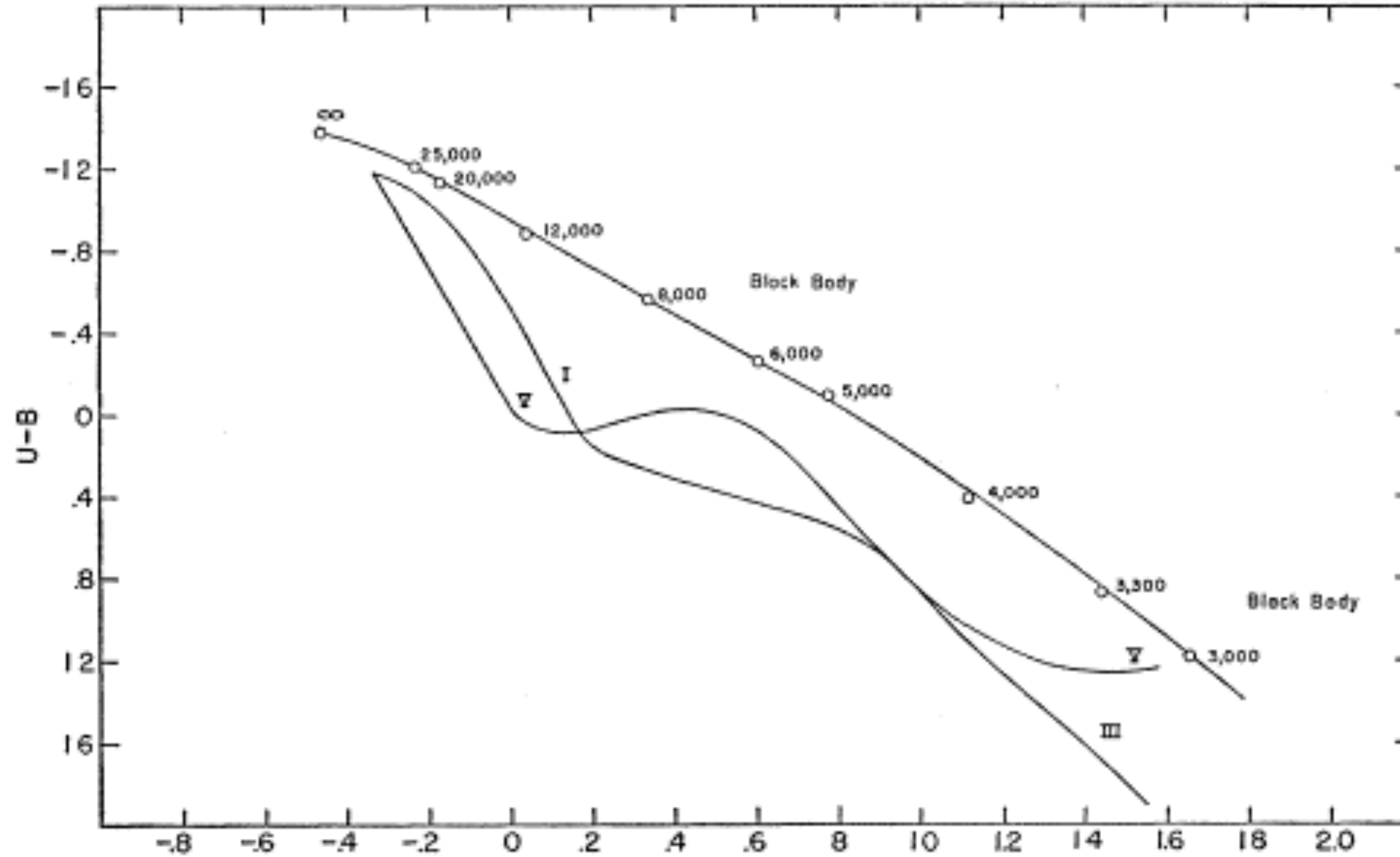
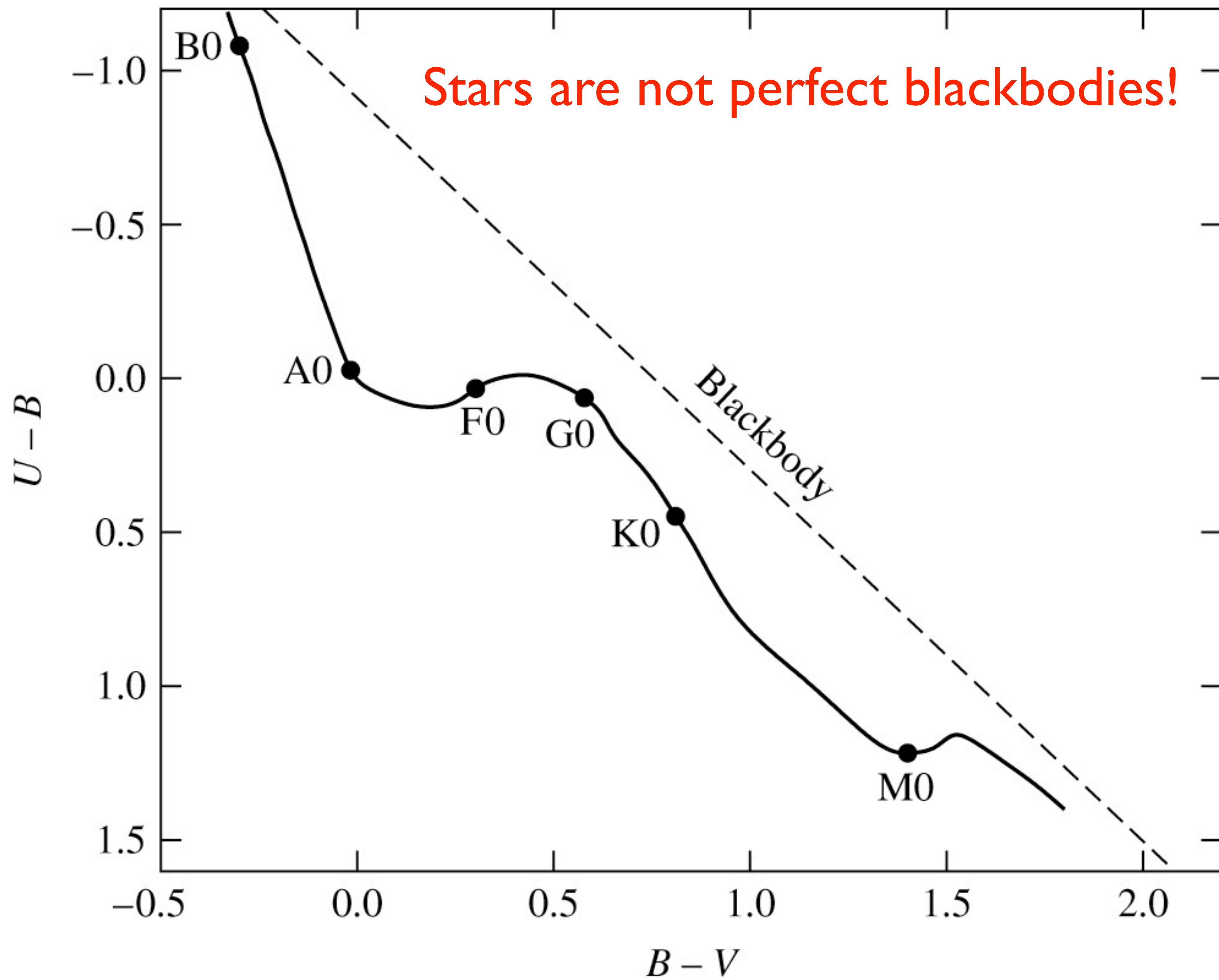
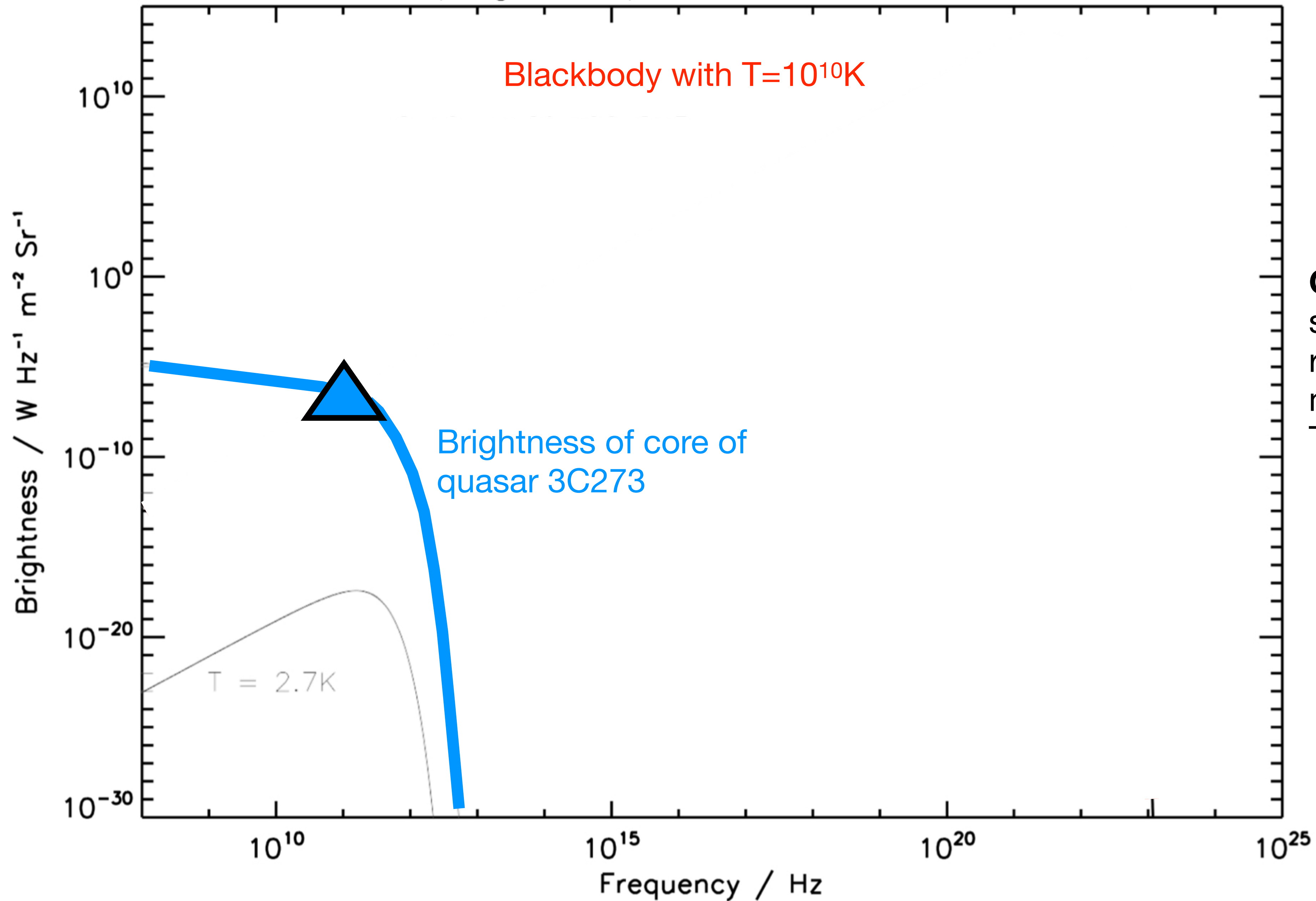


FIG. 1.—The $U - B$, $B - V$ relation for black bodies. The plotted points are taken from the last two columns of Table 2. The standard Johnson relations for stars of luminosity classes I–V are also shown.



Equivalent (brightness) temperature of a radiosource



CAREFUL! If the emitted spectrum is not blackbody radiation, then temperature measurements of T_b , T_c , or T_{eff} are wrong.