UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Astrophysics I (ASTR 691) — Prof. Crossfield — Fall 2026

In-Class Problems 18 [12 pts]
You may use your OoMA Sheet, your handwritten notes, and a scientific or graphing calculator – and you may work in a group. As always, be sure to: show your work, circle or highlight your final answer, list units, use the appropriate number of significant figures, and write your name.

1. **Albedos and Temperatures [12 pts]**.

   (a) (3 pts) Assume a planet the size of the Earth, in a 1 AU orbit around a Sun-like star. Plot the planet's expected equilibrium temperature, $T_{\rm eq}$ as a function of Bond albedo A_B, over the full range of $0 \leq A_B \leq 1$.

   (b) (3 pts) Assume the Earth-sized planet above radiates like a simple blackbody (i.e., surface flux given simply by $\pi B_\lambda(T_{\rm eq})$). For the same range of A_B as above, plot the expected wavelength at which the planet's blackbody spectrum would peak. That is: plot $\lambda_{\rm max}$ from Wien's Law as a function of A_B.

   (c) (3 pts) Assume a planet the size of Jupiter, around an M dwarf with radius $R_* = R_\odot/2$ and $T_{\rm eff} = 3800$ K. Further assume that the planet has an Earth-like Bond albedo, and plot the planet's expected equilibrium temperature, $T_{\rm eq}$, as a function of orbital separation, a, from 0.05 AU to 5 AU.

   (d) (3 pts) Assume the Jupiter-sized planet above radiates like a simple blackbody. For the same range of orbital separations a as above, plot the expected wavelength at which the planet's blackbody spectrum would peak (i.e., $\lambda_{\rm max}$ as a function of a).

2. **BONUS/OPTIONAL: A crude Habitable Zone [9 pts]**

   (a) (3 pts) A fairly crude approximation for M, K, and G dwarf stars is

   $$\frac{M_*}{M_\odot} \approx \frac{R_*}{R_\odot} \approx \frac{T_{\rm eff,*}}{T_{\rm eff,\odot}}. \tag{1}$$

   Assuming this relation holds, plot the stellar luminosity ($L_*/L_\odot$) of stars with masses from 0.5–1 $M_\odot$.

   (b) (3 pts) Again assuming the relation above, calculate the semimajor axis (i.e., orbital separation) for a planet with the same albedo and equilibrium temperature as the Earth but orbiting an M dwarf with $M_* = M_\odot/2$.

   (c) (3 pts) For planets with the same albedo as the Earth, but orbiting different types of stars ($0.5 \leq M_*/M_\odot \leq 1$), plot the orbital separation needed to keep the planets at the same $T_{\rm eq}$ as the Earth.