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

In-Class Problems 16 [23 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. **Planetary Transits: [10 pts]** A small planet is transiting a large star, whose surface brightness is approximately given by a linear limb-darkening law, $I_0 = 1 - u(\mu - 1)$. Sketch the system's transit light curve:
   (a) ... in the limit of no limb darkening ($u \approx 0$, e.g., far into the IR)
   (b) ... for moderate limb darkening ($u \approx 0.5$, e.g., for visible light)
   (c) ... for strong limb darkening ($u \approx 1$, e.g. near-UV)

2. **Chromospheric Emission** of a Sun-like star [15 pts].
   (a) Draw a rough sketch of a simple three-layer stellar atmosphere model, temperatures T_D in the deep interior, T_P in the photosphere (which has optical depth $\tau_{\lambda,P}$), and T_C in the chromosphere (which has optical depth $\tau_{\lambda,C} < \tau_{\lambda,P}$). [3 pts]
   (b) Derive an expression for the intensity of radiation, $I_{\lambda,1}$, that emerges from the photosphere layer (i.e., ignore the chromosphere layer for now), in terms of T_D, T_P, and $\tau_{\lambda,P}$. [2 pts]
   (c) Derive an expression for the intensity of radiation, $I_{\lambda,2}$, that emerges from the chromosphere layer (i.e., from the entire star), in terms of $I_{\lambda,1}$ and other relevant, given quantities. [2 pts]
   (d) Consider a narrow line at $\lambda_0 = 1\,\mu$m in the star's spectrum. Assume:
      i. T_D=6000 K, T_P=5800 K, and T_C=10000 K;
      ii. $\tau_{\lambda,P}$ and $\tau_{\lambda,C}$ are zero outside of the line, but are 0.4 and 0.01, respectively, in the deepest part of the center of the line.

      Calculate the intensity of emitted radiation (i) far from the line, and (ii) in the center of the line. [5 pts]
   (e) How would your answer above change without the chromosphere layer? [3 pts]