ASTR705 ISM
HW #6
Due Friday, 3/24

1) a) (2pt) Suppose dust produces extinction $A(\lambda) \propto \lambda^{-1}$. What would be the value of R_V?
   b) (2 pt) If the extinction instead varied as $A(\lambda) \propto \lambda^{-\beta}$, what value of β is needed for $R_V = 3.1$?
   c) (1 pt) From what you know about high-R_V environments, for what environment may $\beta = 0.5$ be appropriate?

2) Let's create an extinction curve model! How hard can it be? Use this paper: https://iopscience.iop.org/article/10.1086/426679/pdf as a guide. Extinction curves are generally referenced to the NIR filters J, H, or K, or to the visible filter V. We will be using the K filter as a reference.

   First we need some data to work with. Go to IPAC's Gator catalog service (http://irsa.ipac.caltech.edu/applications/Gator/). Select "Spitzer Space Telescope", then "GLIMPSE I Catalog." Pick a small region of space to search away from the Galactic plane. You may want to avoid large star forming regions, or not. My web site can help you identify a field if you do want to avoid certain regions: astro.phys.wvu.edu/wise/ . You want at least 10^4 stars, preferably more since not all of these will have all the required photometry values.

   The default column setting will get you all the magnitudes you need, from 2MASS (JHK) and GLIMPSE (2.6, 4.5, 5.8, and 8.0 μm). (Yes, we will be working in magnitudes!) Note that 2MASS K in the table is actually the K_s band.

   a) (2 pt) Prove analytically that Equation 1 of the paper is correct.

   b) (6 pt) The slope of $\lambda - K$ versus $J - K$ color-color diagram is the color excess ratio $E_{\lambda-K}/E_{J-K}$. Derive values for the color excess at all wavelengths possible. Ideally, we would only use one type of star with a relatively uniform absolute magnitude (K giants, or red clump stars, used in above paper). This ensures that you are sampling uniformly across the disk, and that the different color excess values you are measuring are not intrinsic to the star. We can hopefully forget about this complication here, but this depends a little on the field you chose. You may have to do a simple $J - K$ color cut as in Figure 3, if your fits are really ugly. Or some wavelengths may just not be usable.

   c) (2 pt) Use Equation 1 from the paper to derive A_λ/A_K. Assume $A_J/A_K = 2.5$.

   d) (2 pt) Plot A_λ/A_K versus wavelength. This is the extinction curve! You did it!!!

   e) (2 pt) Compare your plot to Figure 6 of the paper. Is your result what you expected? Is there anything you can say about your field to explain the discrepancies (lots of extinction, etc)?

3) Spinning dust!
(a) (3 pt) Equate the rotational energy of a spinning dust grain to the kinetic energy to derive the angular frequency of the spinning grain. Your final expression should only depend on the grain temperature, the grain radius, and the grain density. Assume spherical grains.
(b) (2 pt) What grain sizes may be responsible for the 30 GHz anomalous microwave emission? Assume the grain density $s = 2000\,\mathrm{kg\,m^{-3}}$, and $T_d = 50$ K.

4) A while back my group observed a source we call "DB015." This object is at a distance (from the Sun) of about 15 kpc. The IRAS flux densities are 1.171, 2.885, 36.08, 78.48 Jy at 12, 25, 60, and 100 μm ($1\,\mathrm{Jy} = 10^{-26}\,\mathrm{W\,m^{-2}\,Hz^{-1}}$). We have two more data points from the Herschel Space Observatory at 250, 350, and 500 μm of 70, 50, and 20 Jy.
a) (2 pt) *Very roughly* estimate the dust temperature from Wien's Law.
b) (2 pt) Determine the dust mass for DB015, using any "reasonable" assumptions. Assume a distance of 20 kpc.