Problem Set 1

1 Cyclotron

Suppose you have a (non-relativistic) electron spinning circles in a magnetic field.

1.1 Show that the frequency of oscillation does not depend on the velocity of the electron.

1.2 In what waveband would an electron spiralling in the Earth's magnetic field emit?

2 Brightnesses, Magnitudes, and Photons

In the old days, astronomers classified the brightness of celestial objects using the magnitude system, which roughly corresponded to the sensitivity of the human eye. Today we continue to use this ancient system because... well, I don't know, but we do. The magnitude of an object in a given filter i is

$$m_i = 2.5 \log_{10}(F_i/F_{0,i}) + m_{0,i} \qquad (1)$$

where F_i is the observed flux integrated over a given filter

$$F_i = \int_0^\infty F_\nu(\nu)\phi(\nu) \ d\nu \qquad (2)$$

where $\phi(\nu)$ is the filter transmission function (a number between 0 and 1). The magnitude system is calibrated by specifying $F_{0,i}$ and $m_{0,i}$ which may be done in a number of ways. A common system is Vega-magnitudes, in which the star Vega is defined to have $m \approx 0$ in all bands.

2.1

Grab the filter transmission functions and the spectrum of Vega (bessel_V.dat and vega_spectrum.dat in the github repository, noting that the Vega spectrum is given as F_λ, with units ergs s^{-1} cm^{-2} Å^{-1}). numerically integrate the apparent V-band magnitude of Vega to determine how many photons the world's largest ground-based optical telescope (Keck, with a mirror diameter of 10m) would collect per second from Vega.

2.2

Use the fact that Vega is about 8 pc away, and has a diameter of approximately 2.5 $R_\odot$, to determine the specific intensity of Vega in cgs units, assuming Vega appears as a uniform disk on the sky.

2.3

If we were twice as close to Vega (say, 4 pc), figure how many photons per second Keck would receive in V band, and re-determine the specific intensity of Vega. Are the scalings of photons per second and specific intensity with distance consistent with one another? How so?

3   Dust Bowl

Dust particles are about 100 microns in diameter. In the years of the Dust Bowl in the 1930s, it was not uncommon for dust clouds to completely obscure the Sun. According to Wikipedia:

> On April 14, 1935, known as "Black Sunday", 20 of the worst "black blizzards" occurred across the entire sweep of the Great Plains, from Canada south to Texas. The dust storms caused extensive damage and turned the day to night; witnesses reported they could not see five feet in front of them at certain points.

3.1

Using this observation, estimate the number density of dust particles in the air. We'll do a more sophisticated treatment of dust grains later in the class, but for now, assume these dust grains to be perfectly opaque, and large enough to be treated geometrically (without diffraction, etc.).

3.2

If these clouds extended half a mile into the air, how much topsoil was lost to each one of these clouds?