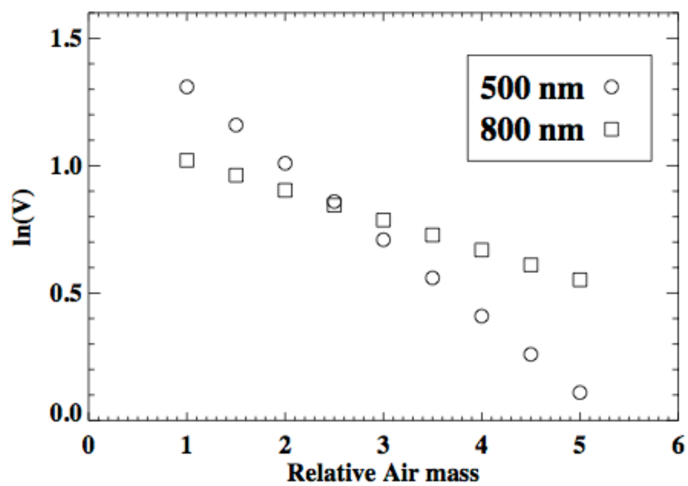
AT622/Spring 2015
Homework 3
Due Friday March 13, 2015 4pm

1) Beer's Law states that, at a particular wavelength, $I = I_0 \exp(-\tau/\mu)$, which represents the extinction of light traversing a layer with zenith extinction optical depth τ at a zenith angle θ such that $\mu = \cos(\theta)$. Starting with $dI = -I\,\beta_e\,ds$ (which is based on laboratory observations), derive Beer's law (also known as the Beer-Lambert-Bouger law).

2) The plot below shows observations of a "sun photometer"; this instrument is like a telescope pointed right at the sun. It typically records a voltage V that is proportional to the incoming solar intensity at a particular wavelength. The plot shows ln(V) as a function of the relative air mass, $1/\cos(\theta)$, for two wavelengths.



a. Please estimate the total atmospheric optical depth at each wavelength.
b. The total optical depth includes contributions from ozone absorption, molecular Rayleigh scattering and aerosol. Assuming that ozone absorption is negligible at these wavelengths, calculate the optical depth due to aerosol alone, using the approximation that the molecular Rayleigh scattering OD is approximately $0.00877\ \lambda^{-4.05}$ at standard atmospheric pressure (1013 hPa), where λ is given in μm. (assume we're at atmospheric pressure).
c. The *Angstrom exponent* α presumes that the aerosol optical depth for a given species follows a power law:

$$\tau_{aer} = C\lambda^{-\alpha}$$

Smaller particles typically have α greater than 1.5, while larger particles typically have α less than 1. (Notice that pure Rayleigh scattering has $\alpha \sim 4$). Based on your results from part b, calculate the Angstrom exponent and determine if these are smaller or larger particles.

3. Petty Problem 7.6

4. Petty Problem 7.7, and calculate the altitude of peak O_2 absorption when the sun is at a zenith angle of 45 degrees.

5. Petty problem 7.9

6. A 1 km thick cloud has a (vertically constant) cloud water content of 0.1 g/m^3. If the effective radius is 8 μm, what is the (zenith) optical depth of the cloud? What is the number density of the cloud droplets (in drops per m^3)? How thin would the cloud need to be (in meters) to have a zenith transmittance of 50%, assuming the same number density and effective radius?