Astronomy 405: Homework #9 (Planetary Atmospheres)

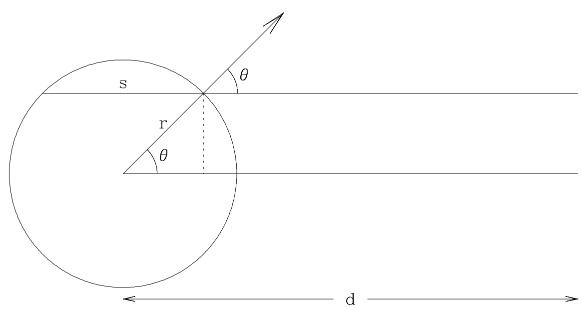
1. Consider a rapidly rotating planet with an atmosphere in monochromatic radiative equilibrium and local thermodynamic equilibrium (LTE). The planet is located at a heliocentric distance $r_\odot = 2$ AU; its Bond albedo $A_b = 0.3$ and emissivity $\epsilon = 0.9$ at all wavelengths. Calculate the equilibrium temperature. Why is the effective temperature equivalent to this value? For which planets in the solar system is this not the case, and why? (5 pts)

2. (a) Consider an optically thick ($\tau \gg 1$) cloud at a geocentric distance d. The cloud emits thermal radiation. Express the observed intensity, I_ν, from the center of this cloud, as a brightness, $B_\nu(T)$. (5 pts)

   (b) The brightness temperature, T_b, is the temperature of a blackbody which has the same brightness at this frequency. Derive the relationship between T_b, τ, and T using the Rayleigh-Jeans approximation. Under what conditions does this condition hold? (5 pts)

   (c) Approximate the cloud as a sphere. Define θ as the angle between the line of sight and the normal to the surface. Determine the center-to-limb variation in the observed intensity. (5 pts)

   Use the following diagram to set up problems 3(c) and 4(c). Think qualitatively about what you would expect to happen for optically thick and thin clouds, and then perform appropriate calculations.



3. (a) Consider an optically thin ($\tau \ll 1$) cloud at a geocentric distance d. The cloud emits thermal radiation. Express the observed intensity, I_ν, from the center of this cloud, as a brightness, $B_\nu(T)$. (5 pts)

   (b) The brightness temperature, T_b, is the temperature of a blackbody which has the same brightness at this frequency. Derive the relationship between T_b, τ, and T using the Rayleigh-Jeans approximation. Under what conditions does this condition hold? (5 pts)

   (c) Approximate the cloud as a sphere. Define θ as the angle between the line of sight and the normal to the surface. Determine the center-to-limb variation in the observed intensity. (5 pts)

4. If you were to observe Jupiter's thermal emission at radio wavelengths, where one probes down to well below the planet's tropopause, would you expect limb brightening, darkening or no change in intensity when you scan the planet from the center to the limb? Explain your reasoning. (8 pts)

   Note that for a line of sight which makes an angle θ to the normal to the surface (extending to the right in the figure), the radial distance z along a path length s is