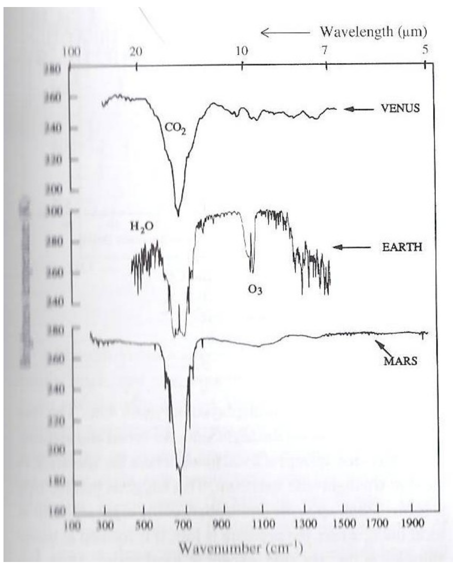
EART164 Homework #4 Due Wednesday 1st May 2013

Show all your working for full credit

1. a) Explain in words why heat transfer occurs by convection deep in an atmosphere and radiation at shallower depths [2]

b) The column density of Titan's atmosphere is about ten times that of the Earth, but the compositions are similar. Would you expect the radiative time constant of Titan's atmosphere to be longer or shorter than that of the Earth? Explain your answer. [3]

c) In the figure below, explain the shape of the CO_2 and O_3 features of Earth's spectrum [3] [8 total]



2. The warming effect of dust.

a) In the absence of dust, the temperature at 15 km height on Mar is about 180 K. When dust is present, it is more like 230K. What is the implied optical depth (from the top of the atmosphere to this height)? [1]

b) Taking d=10 km, ρ_s=2000 kg m^{-3} and the dust grain radius =1 micron, what is the ratio (mass of dust in a 1 m^3 volume: mass of gas in a 1m^3 volume)? You may take the atmospheric density at 15 km to be 0.003 kg m^{-3}. [2]

c) How does the absorption coefficient α of this dust compare with typical gas absorption coefficients? [1]

d) What do your results to b) and c) imply about the relative influences of dust and gas on the temperature of the Martian atmosphere? [2] [6 total]

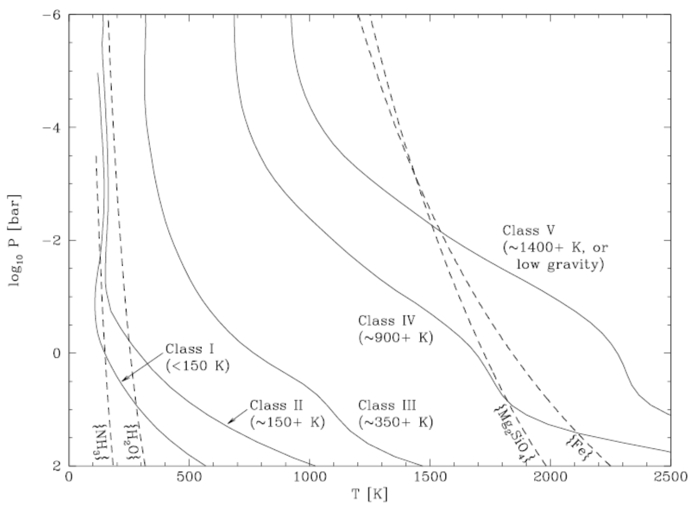
3. We saw in the notes that the radiative heat flux F can be written

$$F = \frac{c}{\rho} T^3 \frac{dT}{dz}$$

Where c is a constant (units W kg m^{-4} K^{-4}), ρ is the density and T is the temperature. In a steady-state atmosphere, we can assume that F is constant and is equal to the incoming solar flux absorbed.

a) Using the chain rule and assuming hydrostatic equilibrium, derive an expression for dP/dT where P is pressure, and hence find an expression for how T varies with pressure if T=T_0 at P=P_0. [5]

b) Taking T_0 to be the temperature at the top of the atmosphere and making use of the class notes, write down an expression relating F to T_0. [1]



c) The figure above (from Week 3) shows that for Class III exoplanets T=600 K at 0.1 bar and that T_0=300 K (when the pressure P_0 is approximately zero). Taking g=25 ms^{-2} and Stefan's constant to be 5.7×10^{-8} in SI units, use your results above to find the value of c [2].

d) For this same value of c, what would you predict the temperature to be at 100 bar? Why do you think your prediction does not agree with what is shown on the figure? [3] [11 total]