EART164 Homework #7 Due Wednesday 5th June 2013

Show all your working for full credit

1. Exoplanets.

a) Explain why transits don't directly measure a planet's mass, and give 2 methods which allow the mass of a transiting planet to be determined [3]

b) Explain why radial velocity measurements don't directly yield a planet's mass [1]

c) Slide 2 of Jonathan's presentation shows an apparent positive correlation between semi-major axis and planet mass. Why? (Hint: the data points are mostly from radial velocity surveys). [3]

d) In our notes from Week 5, you are given an expression for the transition between convection and radiation. Write down the critical pressure at which this happens, in terms of g, R_g, C_p, μ, T, T_e and the opacity α. [2]

e) Jonathan's slide 5 shows that this critical pressure is almost independent of T and is about 1 bar. Assuming that T/T_e=1, g=25 ms^{-2}, C_p=10^4 J kg^{-1} K^{-1} and μ=0.002 kg mol^{-1}, find the opacity at this pressure. [2]

f) Jupiter has about 30 zonal bands, while hot Jupiters probably only have a few. Why? [3] [14 total]

2a) The present-day equilibrium temperature of Mars is 217 K and the actual surface temperature is 220 K. Calculate the effective optical depth τ of the Martian atmosphere. [2]

b) If the surface pressure of Mars is 6 mbar and gravity is 3.7 m s^{-2}, what is the column density of the Martian atmosphere? (in kg/m^2). [1]

c) If the solar flux 4 Gyr ago was 70% of its present-day value, what was the equilibrium temperature of Mars? Assume the albedo has not changed. [1]

d) We're going to make the (very simple) assumption that τ is proportional to the column density of CO_2. Making use of the results above, if ancient Mars had a CO_2 pressure of 0.3 bar, what surface temperature would you predict? Is this hot enough to have liquid water at the surface? [4]

e) We can see whether Jeans escape might have removed significant amounts of CO_2. Assuming the exosphere has a temperature of 300 K and the escape velocity of Mars is about 5 km/s, what is the thermal velocity of the molecules, and is Jeans escape likely to be a significant process? [2]

f) The present-day UV flux F_{ext} at Mars is about 5 mWm^{-2} and the CO_2 loss rate as measured by Mars Express is 6 g/s. Assuming that R_{ext}=R, calculate the efficiency factor ε given that the bulk density of Mars is 4 g/cc and it has a radius of 3400 km. [3] [Note that in this example ε is small!]

g) The UV flux over time has decreased according to $F_{ext} = 5\text{mWm}^{-2}\left(\frac{t_{now}}{t}\right)^{5/4}$ where t is time measured from solar system formation and t_{now} is time at the present day (4.5 Gyr). Use this expression to deduce the total amount of energy delivered per unit surface area (in Jm^{-2}) from t=45 Myr to the present day. [3]

h) Using your answers to f) and g), calculate the total mass of CO_2 lost from the Martian atmosphere due to UV. How does this compare to the present-day mass of the Martian atmosphere? Comment on your answer [3] [19 total]