

ASTRO 342 – FALL 2006

Building a Solar System Project **Exercise 2: Atmospheres, Surfaces and Interiors** **DUE Wed., Nov. 29**

It's time to explore the structure of the planets and moons in your solar system in more detail. We'll do this by applying some of what we've been learning about planetary atmospheres, surfaces and interiors.

0. Before starting with new things, let's complete some unfinished business from Exercise 1. Make a line graph with the star at radius 0.0, and each planet marked at a distance equal to its orbital semi-major axis. Draw a circle for each planet at the appropriate location. Make the circle big for a giant planet and small for others. For small planets put an I (for ice) or an R (for rocky) within the circle, depending on which is the dominant constituent (see below). Draw an axis through each circle at an angle from the vertical equal to the obliquity. Put moons next to their parent planets, with a dot for an asteroidal moon and a small circle for larger moons. Attach names as appropriate. These diagrams will allow different groups to quickly compare their solar systems.
1. We need to start with the **interiors** and the **bulk composition and structure** of each planet. Specifically, for each planet, We'd like you to suggest a bulk internal composition based on the following considerations:
 - distance from the central 'Sun' and comparison to our solar system. For example, it appears that most of the molecules that can condense into ices were swept out of the inner solar system before they could be accreted by the terrestrial planets, yet plenty were available for the outer planets. Thus, it seems unlikely that T-planets located within 3 au (the "ice-line") of the 'Sun' have thick mantles of liquid water or solid ices. It also seems unlikely that a bare rocky T-planet would be found in the outer solar system, unless it had been thrown out there after formation, via interactions with other planets.
 - planetary mass. E.g., in the outer solar system, big protoplanets will be able to accrete more H and He, and thus, will more likely evolve to become gas giants rather than ice balls. Of course, the proto-planetary disk probably got less dense with distance from the star, which would make it more difficult to form a big protoplanet, and there would be less material to accrete, at very large distances.
 - Extra-solar systems with their 'hot Jupiters' provide exceptions to some of these generalizations, though we don't quite understand all the whys and wherefores. If you want to deviate from solar system norms you might explain how your system is like some of the known extra-solar systems.

In any case, most of your planets will probably be differentiated into distinct layers. For this project, the T-planets may have only 2 significant layers: 1. A heavy iron-type element core, and 2. A silicate like mantle. There may be more layers in gas giant planets, as in our solar system. Ice planets may have 2 primary layers – rocky core and ice mantle – though under the right circumstances there could be a liquid ocean in the outer mantle. Figure it out for each of your planets and moons. (Asteroidal moons can be assumed to consist of a single layer of iron or silicate-rich minerals, though this is not true in the largest asteroids of our solar system.)

Specifically, you need to assign a mass to each layer of each planet, figure out whether the layer is solid, liquid or gas, estimate an appropriate density, and compute the thickness of each layer. Then you can compute the radius and mean density of the each world. Table 6.1 from the text gives useful density information, and the Planetary Scientist's Companion gives even more. Note: solids are not highly compressible, so their density in an interior is not hugely greater than their density at the surface. Gas and liquid densities can be estimated from the ideal gas law, with the appropriate mean molecular weight. The phase graphs in chapter 6 of the text will help you to determine whether a layer is in a solid, liquid or gaseous state. How do your final radii and mean densities compare to any estimates you might have made in Exercise 1? *Give your results in a table*, and add interior schematics if you like.

2. **Surfaces.** Discuss the likely nature of each surface, e.g., are they gas, liquid or solid, and why do you think so? Compute the surface gravity of each planet and moon. Using the example in the notes, estimate the maximum height of a mountain on each world with a solid surface. Given that Earth and Venus still have volcanism, but the smaller T. planets don't, do your T-planets?

One complication to consider – without a massive Jupiter in the middle of the planetary system, residual planetesimals would not have been scattered out in the first billion years. While there would have been less “late heavy bombardment,” there could much more ongoing bombardment, and cratering would not be a simple indication of old surfaces.

3. **Atmospheres.** Which of your planets or moons are unlikely to have an atmosphere? Justify this conclusion by estimating the escape time for the most abundant molecules.

For each of your T-planets that are massive to retain an atmosphere, assume that the mass of the atmosphere is equal to the mass of Venus' atmosphere times the ratio of your planet's mass to Venus' mass (M_p/M_v). Assume that the composition of these T-planet atmospheres is like that of Mars (as a first approximation).

- Compute the stellar insolation (incoming flux) at the top of the atmosphere.
- Find the surface temperature assuming zero albedo and that the planet radiates thermally from its whole surface if it has a massive atmosphere like Venus, or from one hemisphere if it is a low mass T-Planet, with a thin atmosphere.
- Compute the atmospheric scale height.

- Compute the atmospheric surface density using the atmospheric mass and the volume derived from the scale height times the planetary surface area.
- Use the ideal gas law to compute the surface pressure. Compare to Earth.
- Given the surface temperature and pressure estimate whether it is possible to have liquid water on the surface.
- Now estimate the likelihood of clouds or icy surfaces from your derived surface conditions. From this make a better, non-zero estimate of the mean albedo. Redo the previous steps with this improved albedo.

Extra Credit. Do the above atmospheric analysis for any ice worlds that are massive enough to retain an atmosphere. Be careful to consider what molecules may be frozen on the surface, versus those that will still be in the gas phase.

4. At this stage of the project do you want to add or drop a planet or planets? If you want to add planets, then redo the above analysis for the new planet(s). Do you want to change any fundamental characteristic of one or more of your planets? If so, and if the change is relevant to the above analysis, redo the analysis.