

Problem set 5

Ge/Ay 133

Due November 10

More MMSN

Scattering of planetesimals in the outer solar system caused the orbits of Saturn, Uranus, and Neptune to expand. Using adiabatic theory, one can show that the eccentricities of the KBOs grow as they are pushed outward so that the final eccentricity is related to the initial eccentricity and beginning and ending semimajor axes of Neptune as:

$$e_{\text{KBO final}}^2 \approx (1/3) \ln(a_{\text{Neptune final}}/a_{\text{Neptune initial}}) + e_{\text{KBO initial}}^2.$$

- a. How much did Neptune's orbit have to expand to account for Plutinos with eccentricities as high as 0.34?
- b. Using conservation of angular momentum, estimate to order of magnitude precision the amount of mass that Neptune needs to have scattered inward to account for this motion.
- c. Make a hand waving argument about the movement of the other giant planets, and estimate how much their orbits expanded or contracted.
- d. Assuming the starting orbital positions you calculated above, make a plot of the surface density in this minimum mass solar nebula. Be sure to use the original masses of the planets (as calculated in Problem Set 2).
- e. Discuss timescales for the formation of Uranus and Neptune in your new minimum mass solar nebula. Are there still problems?
- f. If you extrapolate your new MMSN, how much mass resides in the 10 AU region beyond Neptune. How does this compare to the mass of the present-day Kuiper belt? How does this compare with the mass that you calculated that Neptune need have scattered? Comments?