Problem set 4

Ge/Ay 133

Due 03 November 2011

1 Gaps and migration

(a) Large planets open gaps in disks and then become tied to the evolution of the disk. Thus, if the disk is evolving on the viscous timescale, the planet will also migrate on the viscous timescale. Based on the viscous disk evolution timescale discussed in class, write an approximate expression for the speed of the migration for a giant planet which has formed a gap.
(b) Assume that every planetary system forms planets at 5 AU and then these planets migrate inwards on the viscous timescale. Then, at some random time, the gas in the disk instantly disappears (halting migration). If this happens in a huge set of planetary systems, what distribution of semi-major axes might you expect to observe in planetary systems? (You can try your own simulation, or else create a sketch of what you think it will look like.)
(c) Compare this predicted distribution to that of extrasolar planets. Be sure to consider the (severe) biases in the discoveries of extrasolar planets. You can make your own up-to-date plot of the semi-major axis distribution, and many other correlations, starting at the link:

`http://exoplanets.org/plot`

(d) In what ways is the process suggested in part (a) realistic? In what ways is it not?

2 Stop That Planet

The distribution of extra-solar planets has a pile-up at small distances. In this problem, you're going to brainstorm about possible explanations for this pile-up. (Note that this is still an unsolved problem, so don't be afraid to speculate!)
(a) Magnetic fields may clear out the inner region of the disk, opening up a space between the disk and the star. The argument goes that the disk truncates where the rotation of the stellar magnetic fields (which equals the rotation of the star) is equal to the Keplarian rotation speed of the disk. Interior to this region, the magnetic fields drag the disk (or at least the ions in the disk) along at super-Keplarian speeds and they simply accrete inwards. T Tauri stars seem to rotate at 10% of the breakup speed (the speed at which the outer layers are essentially in orbit). What is the truncation radius for the disk in this case? How does this compare with the locations of extrasolar planets?
(b) Can you think of any other way to clear out the inner region of a disk?
(c) Supppose the inner region of the disk is cleared out to the truncation radius. Now consider the migration processes described in Ward 1997:

`http://www.gps.caltech.edu/classes/ge133/reading/ward_migration.pdf`

(and also discussed in Armitage). Would you expect that migration will stop when the planet reaches an inner clearing in the disk? Explain your answer.