Migration

1) Gas drag. Using the minimum mass solar nebula for the gaseous component, and the sub-Keplerian orbital velocity given by D’Angelo et al. (for $\eta$, the fractional slowing of the gas), find what the stopping time of a 1 meter planetesimal is at 1 AU (using Epstein drag). On what timescale would the semimajor axis change by order itself ($\tau = a/(da/dt)$)? (2 points)

2) Type I. Draw in pictures the gas flow around a protoplanet which is migrating in the type I regime. Show the gas’s streamlines on all sides around the planet, and comment on why the migration direction is hard to predict from a local analysis. (1 point)

3) Type III. Explain in drawings of horseshoe orbits why this type of migration, with gas able to reach the partially-cleared horseshoe region, can be a run-away process. (1 point)