Physics of Planetary Systems — Exercises — Set 11

Problem 11.1 *(2 points)*

Consider a lens at a distance of 2 kpc and a source at a distance of 10 kpc. Calculate the magnification and duration of a microlensing event where the lens passes at a closest distance of 0.01 milliarcseconds from the source for the following lenses:

(a) a Sun-like star,
(b) a Jupiter-mass planet, and
(c) an Earth-mass planet.

Hint: Assume a projected velocity of 200 $\frac{km}{s}$.

Problem 11.2 *(2 points)*

Imagine you measure the arrival times of pulses from a pulsar (with $\mathscr{M}_* = 1.4\ \mathscr{M}_\odot$) and you note that the times deviate periodically (with a period $P = 1$ yr) by up to ± 1 ms from those expected for constant intervals.

(a) What is the minimum mass of a possible companion that could cause this deviation (assume a circular orbit).
(b) What is the expected maximum deviation of the arrival times of the pulses from those of a planetless but otherwise equal pulsar?

Problem 11.3 *(1 point)*

Estimate the critical planet mass below which the timescale for type-II migration is as short as the gas accretion timescale.

Bonus problem 11.4 *(3 extra points)*

As you know, a sufficiently massive planet opens a gap in a surrounding gas disk. This happens if the orbiting planet removes gas along its orbit faster than the viscous accretion brings new material into the gap.

Derive an alternative gap opening criterion based on the following assumptions. Imagine a gas disk with a planet trying to eat a gap with a width of (twice) the planet's Hill radius. Assume that the gas is refilling the gap "behind" the planet at the radial gas drift speed of a viscous accretion disk, v_r. Estimate the minimum planetary mass needed in order to create a gap that is still open when the planet reaches the same region of the gas disk again. How massive has the planet got to be to successfully clear a gap?

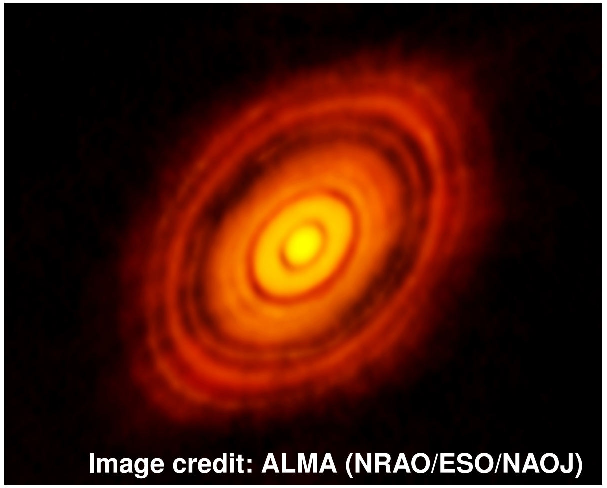

Figure 1: Annular gaps in the famous protoplanetary disk around HL Tau.

Distributed: 20 June 2025, results due: 27 June 2025