Physics of Planetary Systems — Exercises — Set 10

Problem 10.1 *(2 points)*

The planet candidate Beta Pictoris b, at 19.3 pc distance from the Sun, could be directly imaged at only three times the diffraction limit (at 2.2 μm, corresponding to the Ks band) at the VLT, using the instrument NaCo. Suppose next generation adaptive optics instruments will allow a comparable performance for the much larger ELT (39 m in diameter), allowing a detection at the same "number" of diffraction limits). How close, in astronomical units, could a planet be detected next to Beta Pic and how much closer is this in comparison to the currently used 8.2 m VLT?

Problem 10.2 *(2 points)*

A laser for producing an artificial guide star is mounted on the tube of a 4 m diameter telescope. Calculate the diameter, in arcseconds, of the artificial guide star that is produced in the sodium layer. Assume a height to the center of the mesospheric sodium layer of 90 km and a full-width at half maximum of 11.5 km for the layer.

Problem 10.3 *(2 points)*

It is usually assumed that gravity dominates the dynamics of planetesimals bigger than $1km$. Check this with a direct estimate. To this end, calculate the gas drag force on a planetesimal of radius s (in the solar nebula at 1au from the Sun, gas density $\rho_{gas} \sim 10^{-9}\mathrm{gcm}^{-3}$) and then the gravitational force between two planetesimals of size s during their close encounter. At which size are both forces equal? Why is the result far from the expected $1km$?

Problem 10.4 *(1 point)*

Estimate the planetesimal radius s, starting from which gravity becomes important, with a quite different method. It is known that, if two planetesimals collide and destroy each other, the resulting fragments will have typical relative velocities $\sim 10ms^{-1}$. However, the debris cloud might immediately reassemble by mutual gravity. What is the minimum radius s that makes such rebounds possible?

Distributed: 13 June 2025, results due: 20 June 2025