Physics of Planetary Systems — Exercises — Set 7

Problem 7.1 *(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 mesospheric sodium layer.

Hint: for the sodium layer, assume a height to the center of 90 km and a full-width at half maximum of 11.5 km.

Problem 7.2 *(1 point)*

The planet candidate β 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 β Pic and how much closer is this in comparison to the currently used 8.2 m VLT?

Problem 7.3 *(2 points)*

Consider vertical settling and grain growth in a protoplanetary disk. Given a mass coagulation rate $\dot{m} \propto \sigma \rho_{\rm gas} \dot{z}$ (where $m = 4/3 \times \pi \rho s^3$ and $\sigma \propto s^2$) and a Gaussian vertical gas density distribution $\rho_{\rm gas} \propto \exp(-z^2)$, show that a grain's final radius (as it arrives in the disk's mid-plane) is independent from its (small) initial radius.

Bonus problem 7.4 *(2 extra points)*

Perform a direct estimate of the final radius in Problem 7.3.

Problem 7.5 *(1 point)*

Estimate the altitude from which you should drop an object (on Earth) so that it hits the ground at 1 cm/s, a velocity typical for grain–grain collisions in protoplanetary disks.

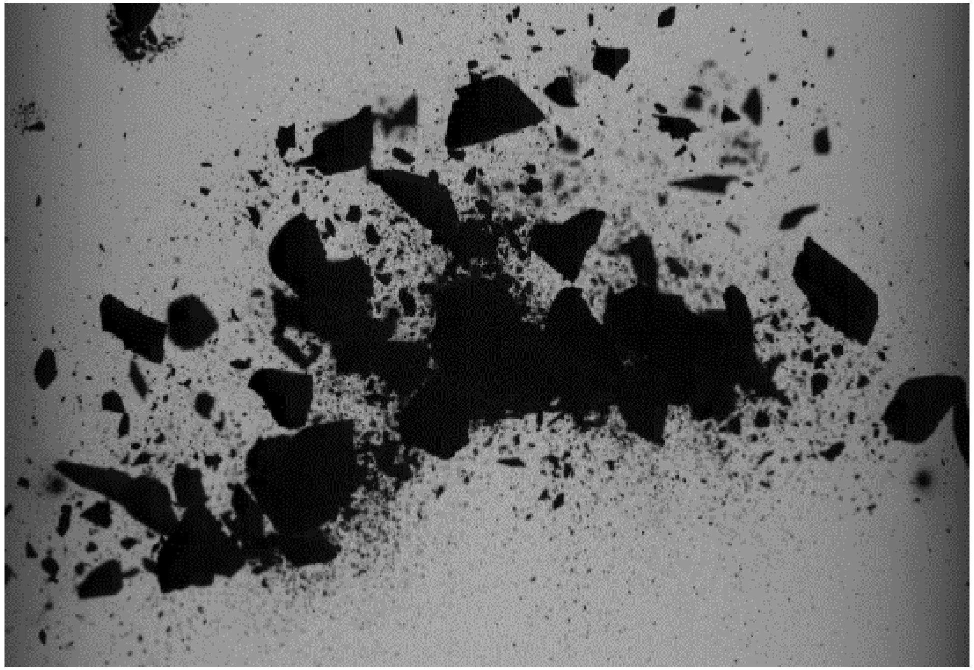

Figure 1: Snapshot of a cloud of fragments produced in a (high-velocity) collision experiment set up in a laboratory at Braunschweig University. (Blum, IGeP/TU Braunschweig)

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