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Slowing down runaway giant planets accretion during disk dissipation

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Abstract

Gas giant planets acquire massive gaseous envelopes during the lifetime of protoplanetary disks. Different studies based on hydrodynamical 3D models [1, 7, 3, 5] report accretion rates of the order of 10^{-2} Earth masses per year for Jupiter mass planets in the runaway regime. No mechanism that can halt such rapid accretion is revealed by those studies and explaining the different masses of giant planets remain difficult to understand unless we consider that their completion coincided with the dissipation of the protostellar disk.

In this work we investigate the influence of disk dissipation on the envelope's accretion of a Jupiter mass planet. We use 3D hydrodynamical simulations that include radiative transfer and model disk's dissipation by reducing the gas density outside of the planetary Hill's sphere.

In order to obtain sufficient resolution in the planetary neighborood (about 10 Jupiter radii) we use the FARGOCA code [6] and a prescription of non-uniform grid [2, 4], which gives near-uniform cells inside the Hill sphere of the planet and larger cells farther out.

Realistic dissipation timescales (of the order of 10^5 yr, [8]) considered for photoevaporation can not be numerically investigated in 3D simulations, and some simplifications must be introduced. We use a snapshot approach covering different photoevaporation phases until the gas is almost completely removed.

Precisely an evaporation phase is characterised by the rapid reduction of the gas density ($1-2$ planet's orbits) until a suited value is reached. We then stop the gas evaporation and continue the numerical simulation letting the system relax to the new configuration until a quasi-steady state is reached (~ 10 orbits). For each evaporation phase we measure the planet's accretion rate. By combining the sequence of measured accretion rates we can trace the planetary mass evolution during disk's evaporation.

We also investigate the characteristisc of the gas flow in the planet vicinity and show that the planet form a circumplanetary hot envelope cooling very slowly (the radiative diffusion timescale is if the order of $\sim 10^4$ orbits) even when the disk has dissipated $\simeq 70\%$ of its mass. This result suggests that the cooling of the gas envelope, necessary for the formation of a circumplanetary disk, is most probably a post-disk process.

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