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Self-consistent dynamical and thermodynamical evolutions of protoplanetary disks.

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Abstract

Astronomical observations reveal the diversity of protoplanetary disk evolutions. In order to understand the global evolution of these disks from their birth, during the collapse of the molecular cloud, to their evaporation because of the stellar radiation, many processes with different timescales must be coupled: stellar evolution, thermodynamical evolution, photoevaporation, cloud collapse, viscous spreading...

Simulating all these processes simultaneously is beyond the capacity of modern computers. However, by modeling the results of large scale simulations and coupling them with models of viscous evolution, we have designed a one dimension full model of disk evolution.

In order to generate the most realistic protoplanetary disk, we minimize the number of input parameters and try to calculate most of them from self-consistent processes, as early as possible in the history of the disk; starting with the collapse of the molecular cloud that feeds the disk in gas.

We start from the Hueso and Guillot, 2005 [2] model of disk evolution and couple the radiative transfer description of Calvet et al, 1991 [1] allowing us to handle a non-isothermal disk which midplane temperature is defined by an irradiation term form the central star and a viscous heating term depending on the optical depth of the disk. Our new model of the disk photosphere profile allows us to estimate self-consistent photosphere heights and midplane temperatures at the same time.

We then follow the disk evolution using an upgrade of the viscous spreading equation from Lynden-Bell and Pringle, 1981 [3]. In particular, the molecular cloud collapse adds a time varying term to the temporal variation of the surface mass density of the disk, in the same manner that photo-evaporation introduces a density loss term.

The central star itself is modeled using recent stellar evolution code described in Piau et al, 2011 [4].

Using the same temperature model in the vertical direction, we estimate 2D thermal maps of the disk.

We present the diversity of disk evolutions depending on the star properties, and on the initial molecular cloud mass and angular momentum. In particular, we compare our results to observations and see to which extent the diversity of protoplanetary disks is reproduced from their birth to their photoevaporation. A special attention will be dedicated to the influence of the stellar type on the disk evolution in order to identify which stars are more prone to planet formation. This will help targeting future JWST observations.

References

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