On the origin of massive stars: discs and outflows in the early phases of massive star formation

Matthias Gonzalez*[1], Raphaël Mignon-Risse[2], and Benoit Commerçon[3]

[1]Astrophysique Interactions Multi-échelles – CEA, CNRS : UMR7158, Université Sorbonne Paris Cité – France

[2]AstroParticule et Cosmologie – Commissariat à l'énergie atomique et aux énergies alternatives : DRF/IRFU, Institut National de Physique Nucléaire et de Physique des Particules du CNRS, Observatoire de Paris, Centre National de la Recherche Scientifique : UMR$_7$164, $Universit\acute{e}ParisCit\acute{e} : UMR_7164 - -France$

[3]Centre de Recherche Astrophysique de Lyon – École Normale Supérieure - Lyon, Université Claude Bernard Lyon 1, Institut national des sciences de lÚnivers, Centre National de la Recherche Scientifique : UMR5574, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut National des Sciences de l'Univers – France

Résumé

Massive star formation remains one of the most challenging problems in astrophysics, as illustrated by the fundamental issues of the radiative pressure barrier and the initial fragmentation. The wide variety of physical processes involved, in particular the protostellar radiative feedback, increase the complexity of massive star formation in comparison with its low-mass counterpart.
We aim to study the details of mass accretion and ejection in the vicinity of massive star forming cores using high-resolution (5 AU) numerical simulations. We use state-of-the-art three-dimensional adaptive-mesh-refinement models of massive dense core collapse, which integrate the equations of (resistive) grey radiation magnetohydrodynamics, and include sink particle evolution. For the first time, we include both protostellar radiative feedback via pre-main-sequence evolutionary tracks and magnetic ambipolar diffusion. We investigate the mechanisms at the origin of outflows (radiative force versus magnetic acceleration) and the properties of the disc forming around massive protostars depending on the physics included: hydrodynamics, magnetic fields under the ideal approximation (perfect coupling), and ambipolar diffusion (resistive case).

We find that magnetic processes dominate the early evolution of massive protostellar systems (up to 20 solar masses) and shapes the accretion and ejection as well as the disc formation (Commerçon+22). Magneto-centrifugal processes are the main driver of the outflow. Then, the disc properties heavily depend on the physics included. In particular, the disc formed in the ideal and resistive runs show opposite properties in terms of plasma beta; that is, the ratio of thermal-to-magnetic pressures and of magnetic field topology. While the disc in the ideal case is dominated by the magnetic pressure and the toroidal magnetic fields, the

*Intervenant

one formed in the resistive runs is dominated by the thermal pressure and essentially has a vertical magnetic field in the inner regions (R $<$ 100–200 AU).
To build upon these results, we then present simulations of more realistic environmental conditions including turbulence, and better numerical treatment of the star irradiation. They are the first RMHD simulations of massive star formation including the newly-implemented hybrid radiative transfer method (Mignon-Risse+20) and non-ideal MHD (ambipolar diffusion). We identify the magnetic or radiative origin of massive protostellar outflows and compare their properties (e.g., opening angle) with observational constraints (Mignon-Risse+21b). With initial turbulence, we investigate the regulating mechanism of disk formation and the dependence of stellar multiplicity on the environment (Mignon-Risse+21a). Finally, we address the question of the disk-outflow-magnetic fields alignment.