Birth of magnetized low-mass protostars and circumstellar disks

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The formation of protostars and circumstellar disks during a gravitational collapse is profoundly influenced by magnetic fields that regulate angular momentum transport. Using the highest-resolution three-dimensional radiative magnetohydrodynamic (MHD) simulations to date, including ambipolar diffusion, we model the collapse of a dense cloud core down to stellar densities, resolving both the nascent protostar and circumstellar disk with unprecedented detail. The simulations were carried out using the `RAMSES` astrophysical code.
Our results reveal that the initial magnetic field strength in the protostar aligns with observations of young stellar objects, which broadly report ∼kG values. However, as the protostar accretes substantial angular momentum, its surface layers reach breakup rotational velocities, leading to the formation of a rapidly expanding circumstellar disk. These findings provide important insights into two long-standing problems in star formation: the angular momentum problem (how collapsing gas sheds enough angular momentum to form stars) and the magnetic flux problem (how excess magnetic flux is expelled during the collapse). By bridging high-resolution simulations with observational constraints, our work advances our understanding of protostellar formation in magnetized environments.