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The formation of protostars and protoplanetary disks with all the three non-ideal MHD effects

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It has been recognized that non-ideal MHD effects (Ohmic diffusion, Hall effect, ambipolar diffusion) play a crucial role for the protostar and circumstellar disk formation and evolution. In this talk, I will report the results of the first three-dimensional MHD simulations incorporating all the three non-ideal MHD effects as well as radiation transfer.

We found that the Hall effect notably changes the magnetic torque in the envelope around the disk, and strengthens and weakens the magnetic braking in molecular cloud cores having parallel and anti-parallel magnetic field with respect to the core angular momentum, respectively. This causes the bimodal evolution of the disk size in the early disk evolutionary phase (fig. 1), which is actually suggested by the recent disk observation of Class 0 YSOs. Ohmic and ambipolar diffusion decouple the gas and the magnetic field, and significantly reduces the magnetic torque in the disk, which enables the formation of the circumstellar disk.

Furthermore, we also found that non-ideal effects imprint the observable characteristic velocity structures around the circumstellar disk. Hall effect forms a counter-rotating envelope around the disk. Our simulations show that counter rotating envelope has the size of 100-1000 AU and several recent ALMA observations actually infer such structures. On the other hand, ambipolar diffusion causes the significant ion-neutral drift around the circumstellar disks. Our simulations show that the drift velocity of ion could become 100-1000 m/s which can be observable with ALMA. We suggest that the magnetic field strength is qualitatively measured from the ion-neutral drift velocity.

References

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