MHD model of nonaxisymmetric accretion from an envelope to a protoplanetary disk

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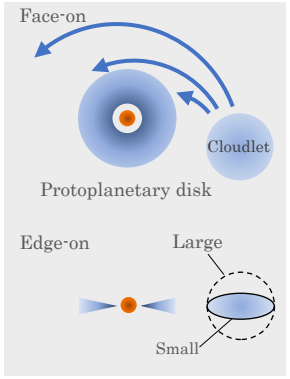
Abstract:

Recent observations suggest that disks encounter molecular cloudlets and receive additional mass and angular momentum during their evolution. We performed 3D MHD simulations of the interaction between a disk and a magnetized cloudlet.
We find that magnetic fields not only extract angular momentum of the cloudlet but also accelerate a part of it to form a spiral structure as seen in RU Lup depending on the cloudlet size relative to disk thickness.

Cloudlet capture scenario with a protoplanetary disk



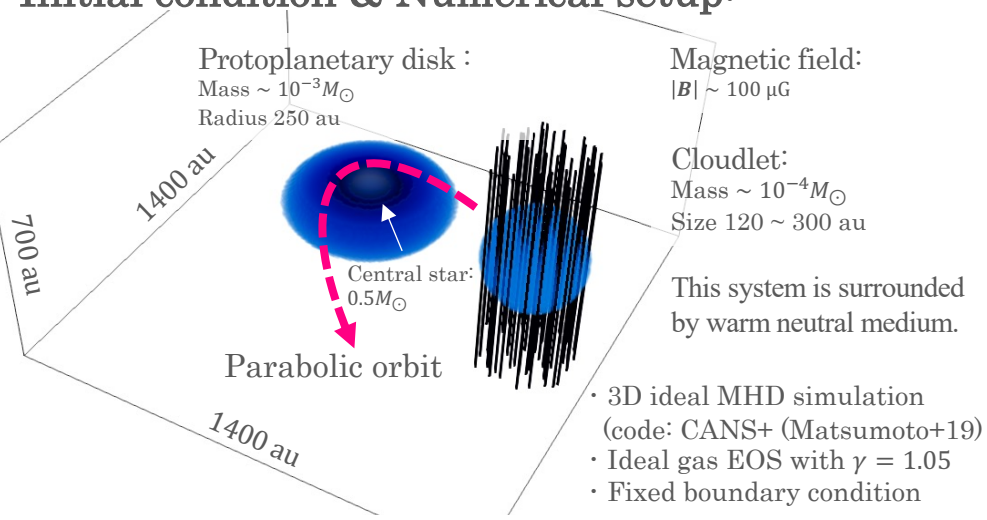
Accretion process is asymmetric:

- Some Class I & II sources show asymmetric features. (Sakai+16; Ginski+21).
- Cloudlet capture models for asymmetric accretion (Dullemond+19; Küffmeier+20) do not take account of magnetic fields for simplicity.

We constructed an MHD model and investigated

Q: How does magnetic field affect the cloudlet accretion process ?

Initial condition & Numerical setup:



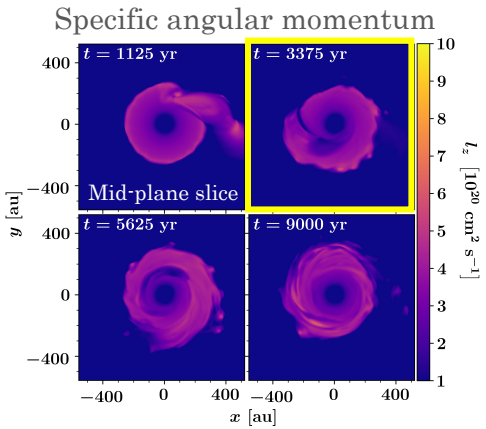
Magnetic field:
$|\boldsymbol{B}|$ ~ 100 μG

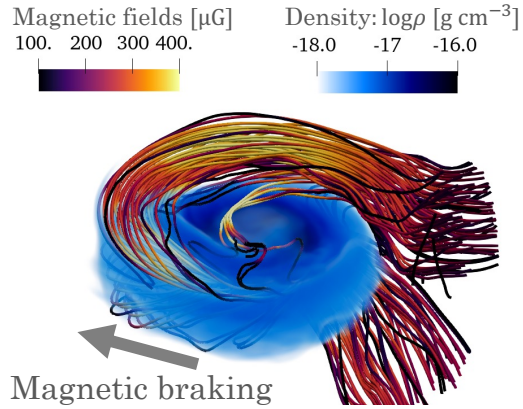
Cloudlet:
Mass ~ $10^{-4}M_\odot$
Size 120 ~ 300 au

This system is surrounded by warm neutral medium.

- 3D ideal MHD simulation (code: CANS+ (Matsumoto+19)
- Ideal gas EOS with $\gamma = 1.05$
- Fixed boundary condition

Small cloudlet model ~ disk thickness:





Angular momentum loss due to magnetic braking

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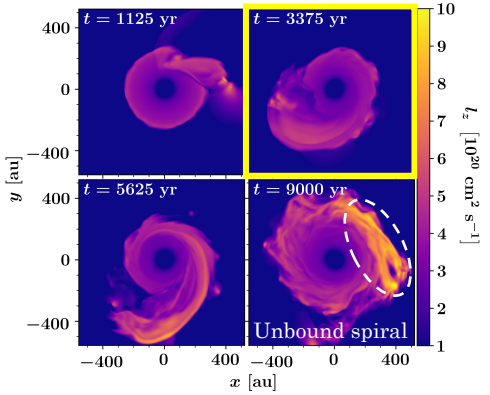
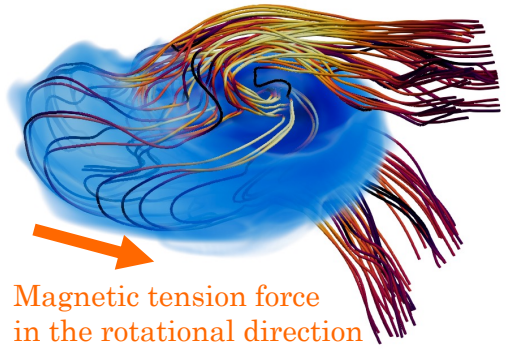
Most of cloudlet accretes onto the disk.

Large cloudlet model > 2 × disk thickness:





Magnetic tension accelerates a part of the cloudlet.

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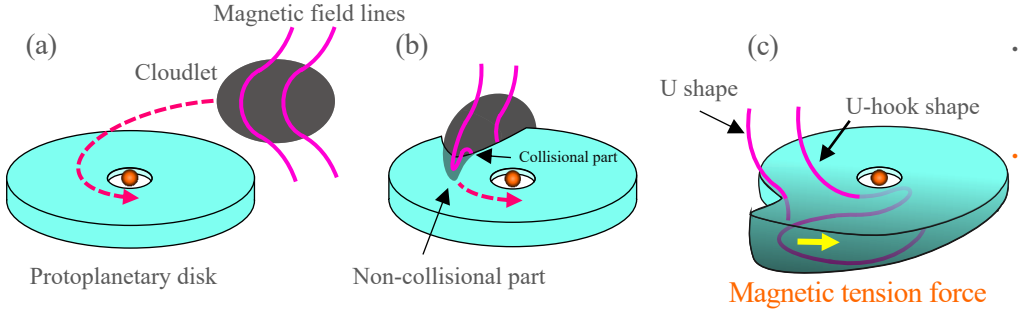
Unbound spiral structure such as RU Lup (Huang+20) is formed.

Summary: How does magnetic tension force affect the cloudlet accretion ?



- We modeled magnetized cloudlet accretion onto a protoplanetary disk.
- Magnetic fields accelerate a part of cloudlet if the cloudlet is larger than the disk thickness.