**Protobinary Evolution Driven by Magnetic Braking**

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**Introduction**

The majority of stars (~75%) reside in binary and multiple systems. The fraction is even higher for young stellar objects, indicating that the formation of multiple system, especially binaries, is a major mode of star formation.

Recent observations of protostellar objects showed a “desert” free of Class 0 binaries with separation between ~150-550AU, which is not present in the Class I or later phases. The inconsistency indicates that binaries may migrate substantially from their birth location.

We focus on one possible mechanism for binary migration: magnetic braking. It is a key factor to understand binary formation and evolution in dense cores that are observed to be strongly magnetized.

Our study addresses the following questions:
- How different magnetic field strengths affect the evolution of binary properties, especially the binary separation and mass ratio?
- How does the misalignment between the magnetic field and rotation axis change the properties?

**Methods**

We use the ENZO code with sink particles. The cloud core is modeled as a singular isothermal sphere with profile $\rho(r)^{-1/2}$, $v_{r}(\theta)^{-1/2} \sin \theta$, $B_{r}(r)^{-1}$. We assume the binary seeds have already formed at the beginning of the calculation.

**Result 1: Equal-Mass Binary**

Fig. 1 compares two extreme cases: the non-magnetic case and the strongest field case (mass-to-flux ratio $\lambda=2$). Both circumstellar disks and circumbinary disk are prominent in the former case, while absent in the latter. The binary separation is also much smaller in the presence of strong magnetic field.

**Migration from Magnetic Braking**

The magnetic field does not act on the stars directly. However, through magnetic braking, it can remove the angular momentum of the infalling material prior to the arrival at the binary seeds. We find that the angular momentum advected in is mainly removed by the magnetic torque rather than gravitational torque.

**Result 2: Unequal-Mass Binary**

The observed distribution of binary mass ratio is roughly flat, yet hydrodynamical simulations tend to over-produce equal-mass binaries by preferential accretion onto the low-mass binary companion. In our study, magnetic braking can suppress the mass ratio growth by removing the angular momentum of the accreting gas.

**Result 3: Effect of Magnetic Field Misalignment**

Numerical calculations have shown that the misalignment between the magnetic field and rotation axis may weaken the magnetic braking and outflows. We find that, for binaries, misalignment tightens the binary orbit, due to faster mass accretion yet slower increase in angular momentum.

**Conclusion**

We found that a magnetic filed of the observed strength can remove, through magnetic braking, most of the angular momentum of the material that reaches the protobinary. Compared with the non-magnetic case: (1) the protobinary orbit becomes much tighter, i.e. inward migration, (2) the mass-ratio does not increase as fast with time for initially unequal mass binaries, (3) field misalignment tightens the binary orbit further.

**Reference**


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