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Evolution of the Angular Momentum of Molecular Cloud Cores in Magnetized Molecular Filaments

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Star and planet are formed from the molecular cloud core which is a dense region of the molecular cloud. It is crucial to know the physical property of molecular cloud cores because it determines the properties of the star and planet system. The angular momentum of molecular cloud cores plays a key role in the star formation process since it is an important parameter, for example, to determine whether a multiple system is formed or not resulting from the fragmentation of the molecular cloud core[1]. Recent observations show that the molecular cloud cores along the filamentary structure which is a dense elongated structure in the molecular cloud[2]. However, the evolution of the angular momentum of molecular cloud cores formed in magnetized molecular filaments is still unclear.

In this study, we perform 3D magnetohydrodynamics simulations to reveal the effect of the magnetic field on the evolution of the angular momentum of molecular cloud cores formed through filament fragmentation. We implement a Godunov smoothed particle magnetohydrodynamic (GSPM) method[3] in the Framework for Developing Particle Simulator (FDPS) to parallelize the code. In this talk, we show that the angular momentum decreases by 30% and 50% at the mass scale of 1.0 M_{sun} in the case of the initial magnetic field strength of 2uG and 10uG, respectively. By analyzing the torques exerted on fluid elements, we identify the magnetic tension as the dominant process for angular momentum transfer for mass scales < 3.0 M_{sun} for the 10uG case. This critical mass scale can be understood semi-analytically as the timescale of magnetic braking. We show that the anisotropy of the angular momentum transfer due to the presence of a magnetic field changes the resultant angular momentum of the core only by a factor of 2 in the case of 10uG (Fig1). We also find that the distribution of the angle between the rotation axis and the magnetic field does not show strong alignment even just before the first core formation (Fig2). Our results also indicate that the variety of the angular momentum of the cores is inherited from the difference in the phase of the initial turbulent velocity field. The variety could contribute to the diversity in size and other properties of protoplanetary disks recently reported by observations.

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References

[1] Machida, M. N., Inutsuka, S. i., & Matsumoto, T. 2008a, ApJ, 676, 1088
[2] André, P., Men'shchikov, A., Bontemps, S., et al. 2010, A&A, 518, L102
[3] Iwasaki, K., & Inutsuka, S. I. 2011, MNRAS, 418, 1668

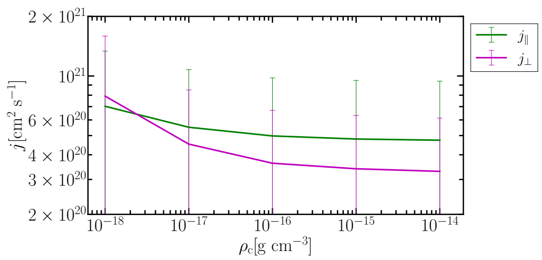

Fig1. Evolution of the angular momentum of the cores with the enclosed mass of 1.0 M_{sun} in the strong magnetic field case. The green and purple solid lines are the specific angular momentum averaged in parallel and perpendicular samples, respectively. The parallel sample is composed of the cores with the angle between their angular momentum and the local magnetic field smaller than 30°. The cores of the perpendicular sample have an angle between their angular momentum and the local magnetic field larger than 60°.

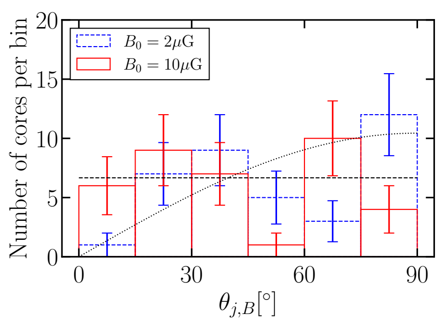

Fig2. Histogram of the angle between the angular momentum vector and the magnetic field of the cores at the final state with 1.0 M_{sun}. The blue dashed and red solid lines represent the weak and strong magnetic field cases, respectively. The black dotted line corresponds to the random distribution in the 3D space, taking into account the effect of the solid angle. The black dashed line represents the random distribution in the 2D plane perpendicular to the filament axis.