Abstract of Doctoral Dissertation

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Massive core/star formation triggered by cloud-cloud collision: Effects of magnetic fields and collision speeds
（分子雲衝突によって引き起こされる大質量コアおよび大質量星形成：磁場と衝突速度の影響）

Massive stars are important in astrophysics, since they strongly impact the interstellar medium and evolution of galaxies. Despite their importance, their formation process is not well understood. Cloud-cloud collision is proposed as a strong candidate for massive star formation. We study the effect of magnetic field and collision speed on massive star formation triggered by cloud-cloud collision. We describe our study in two parts as follows.

In the first part, we study the effect of magnetic field by performing magnetohydrodynamic simulations with sub-parsec resolution (0.015 pc) that can resolve the molecular cores. Initial clouds with the typical gas density of the molecular clouds are immersed in various uniform magnetic fields of three different directions, parallel, normal, and oblique to collision axis. The turbulent magnetic fields are generated in the clouds by the internal turbulent gas motion before the collision to be consistent with the observation by Crutcher et al. (2010) if the uniform magnetic field strength is 4.0 μG. The collision speed of 10 km s^{-1} is adopted, which is much larger than the sound speeds and the Alfvén speeds of gas in the clouds. We identify gas clumps with gas densities greater than 5×10^{-20} g cm^{-3} as the dense cores and trace them throughout the simulations to investigate their mass evolution. We analyze their gravitational boundness for judging massive star formation. We show that a greater number of massive cores greater than 10 $M_{\odot}$ and massive, gravitationally bound cores are mostly formed in the strong magnetic field (4.0 μG) models than the weak magnetic field (0.1 μG) models and isolated, non-colliding cloud models. This is partly because the strong magnetic field suppresses the spatial shifts of the shocked layer that can be caused by the nonlinear thin shell instability in no magnetic field case. The spatial shifts promote the formation of low-mass dense cores in the weak magnetic field models. The numerical results of massive core formation in the strong magnetic field models with magnetic field directions show that the magnetic field direction is not so important for the massive core numbers, although detailed structures of shocked gas region and spatial distribution of dense cores depend on the magnetic field direction. We discuss the implications of our numerical results on massive star formation.

In the second part, we study the effect of collision speed on massive core formation. We assume two combinations of colliding clouds, Small (7 pc) and Medium (14 pc) clouds, and Small and Large (20 pc) clouds, and collision speeds in the range between 10 and 40 km s^{-1}. The clouds are initially immersed in a uniform magnetic field of 4 μG, and turbulence is generated in them, as in the first part. In the collision of Small and Medium clouds with 20 km s^{-1}, massive bound cores are hard to form than the 10 km s^{-1} case. In the collision of Small and Large clouds, a greater number of massive bound cores form than that in Small and Medium clouds with 20 km s^{-1}. These results indicate that longer duration of the collision in this model than that in Small and Medium clouds can explain such massive bound core formation by mass growth due to gas accretion to the dense cores. In the same colliding clouds with higher collision speeds, 30 and 40 km s^{-1}, massive bound core formation is more suppressed with increasing collision speed. Our numerical results show that the collision speed controls massive dense core formation and an upper limit of collision speed for massive bound core formation exists. This upper limit increases with sizes of colliding clouds. We discuss a relation between collision speed and column density of magnetized, colliding clouds for massive bound core formation and the observed relation by Enokiya, Torii, and Fukui (2021) about the collision speeds and number of massive stars in observed colliding clouds.

Finally, we discuss future works based on this study.