Formation of collapsing cores in subcritical magnetic clouds: three-dimensional MHD simulations with ambipolar diffusion

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We have performed fully three-dimensional magnetohydrodynamic simulations of collapsing core formation in molecular clouds with subcritical mass-to-flux ratio, including ambipolar diffusion[1]. Some of our major findings are as follows.

- Core formation in subcritical clouds is generally slow. The core develops gradually over an ambipolar diffusion time. When the initial mass-to-flux ratio is 0.5 times a critical value, the formation time is about 3×10^7 years for an initial midplane number density 10^4 cm^{-3}.
- The core formation time is shortened by strong velocity fluctuations. When the average strength of the velocity fluctuation is 3 times the sound speed, the formation time is about 5×10^6 years for the same cloud described above.
- The core formation time scales as $t_{core} \propto 1/\sqrt{\rho_{peak}}$, where ρ_{peak} is the value of the density peak during the first compression in the time evolution of the maximum density.
- In the case of a highly subcritical cloud, the core formation time does not strongly depend on the initial mass-to-flux ratio even when there is strong velocity fluctuation.
- Once a core forms, the density, velocity, and magnetic field structure of the core do not strongly depend on the initial strength of the velocity fluctuation. The infall velocities are subsonic and the magnetic field lines show weak hourglass shapes.

Figure 1 shows a close-up view of a core that is obtained in this simulation. The iso-surface contour shows the logarithmic density and the lines represent the magnetic field. The core is located in a filamentary structure that was induced by the initial velocity fluctuation. The magnetic field lines show an hourglass shaped structure because of the infall motion into the center of the core.

Figure 2 shows the core formation time as a function of ρ_{peak}, where ρ_{peak} is defined as the value of the density peak during the first compression in the time evolution of the maximum density on $z=0$. It shows that the core formation time is shorter when the density peak ρ_{peak} is greater, and indicates that it is nearly proportional to $1/\sqrt{\rho_{peak}}$. The density dependence is similar to that derived in quasistatically contracting magnetically supported cores, assuming a force balance of the magnetic force and gravity in the core.

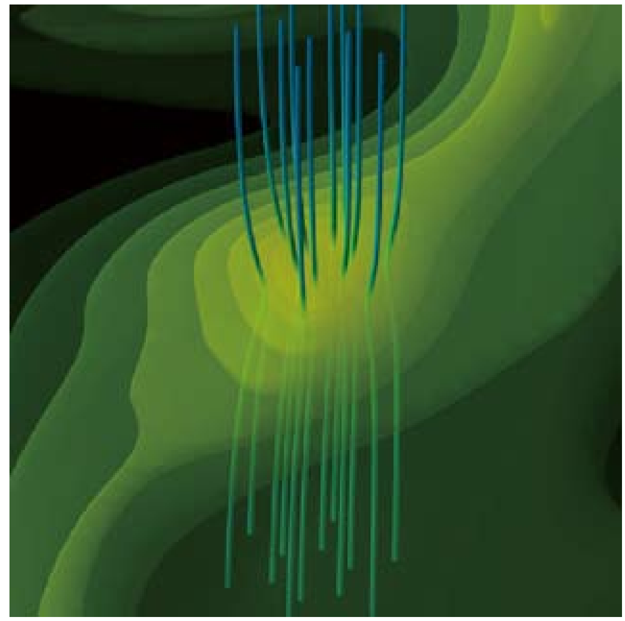

Figure 1: Isosurface of the logarithmic density, and the magnetic field lines near a core. The spatial scale is ~ 0.5pc.

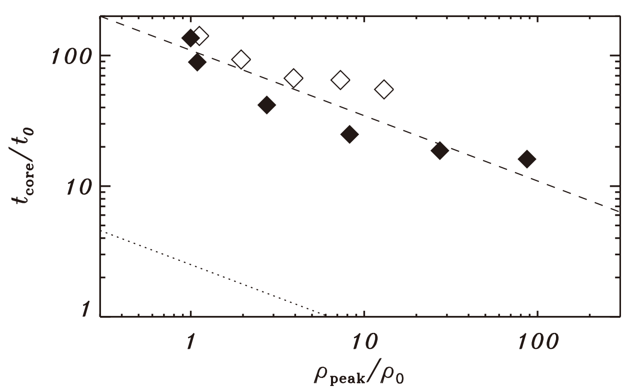

Figure 2: Core formation time as a function of the density peak during the rst compression in its time evolution ($t_0 \simeq 2.5\times10^5$ year, $\rho_0 \simeq 4\times10^{20}$ g cm^{-3}). The filled and open squares represent the results for the initial k^{-4} and k^0 spectra, respectively. The dashed line shows that the core formation time is nearly proportional to $1/\sqrt{\rho_{peak}}$. The dotted line represents the free fall time of gas with density ρ_{peak} for comparison.

Reference

[1] Kudoh, T., Basu, S.: 2011, *ApJ*, **728**, 123.