Structure and Mass of Filamentary Isothermal Cloud Threaded by Lateral Magnetic Field

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Observations of thermal dust emissions with Herschel satellite have revealed that molecular clouds consist of many filaments [1]. That is, the molecular filaments are the building blocks of interstellar clouds. On the other hand, near IR interstellar polarization indicates the filaments are extending in the perpendicular direction to the interstellar magnetic field [2].

Equilibrium solutions of isothermal clouds, in which the gravity is balanced with the Lorentz force, thermal pressure and the external pressure, are obtained with a self-consistent field method [4]. Figure 1 shows typical solutions of cross-cut of these filaments. Top and bottom panels show solutions with low and high center-to-surface density ratios, respectively.

We obtained an empirical relation between the maximum supported mass against the self-gravity, $\lambda_{\rm max}$, and magnetic flux, $\Phi_{\rm cl}$, as,

$$\lambda_{\rm max} \simeq 0.24\,\Phi_{\rm cl}/G^{1/2} + 1.66\,c_s^2/G,$$

where $\Phi_{\rm cl}$, G, and c_s represent, respectively, one-half of the magnetic flux per unit length of the filament, Newton's gravitational constant, and the isothermal sound speed of the filament gas. For $\Phi_{\rm cl} > 3\ {\rm pc}\,\mu{\rm G}\,(c_s/190\ {\rm m\ s^{-1}})^2$, the magnetic force (the Lorentz force) plays more important role than the thermal pressure in determining the equilibria. It is known that axisymmetric isothermal clouds have a maximum mass which is supported against the self-gravity by the magnetic field as $M_{\rm max} \simeq \Phi_{\rm 2D}/2\pi G^{1/2}$, where $\Phi_{\rm 2D}$ represents the magnetic flux threading the cloud. The importance of this article is that structure and the maximum mass of the filaments, which are building blocks of molecular clouds, are firstly determined theoretically.

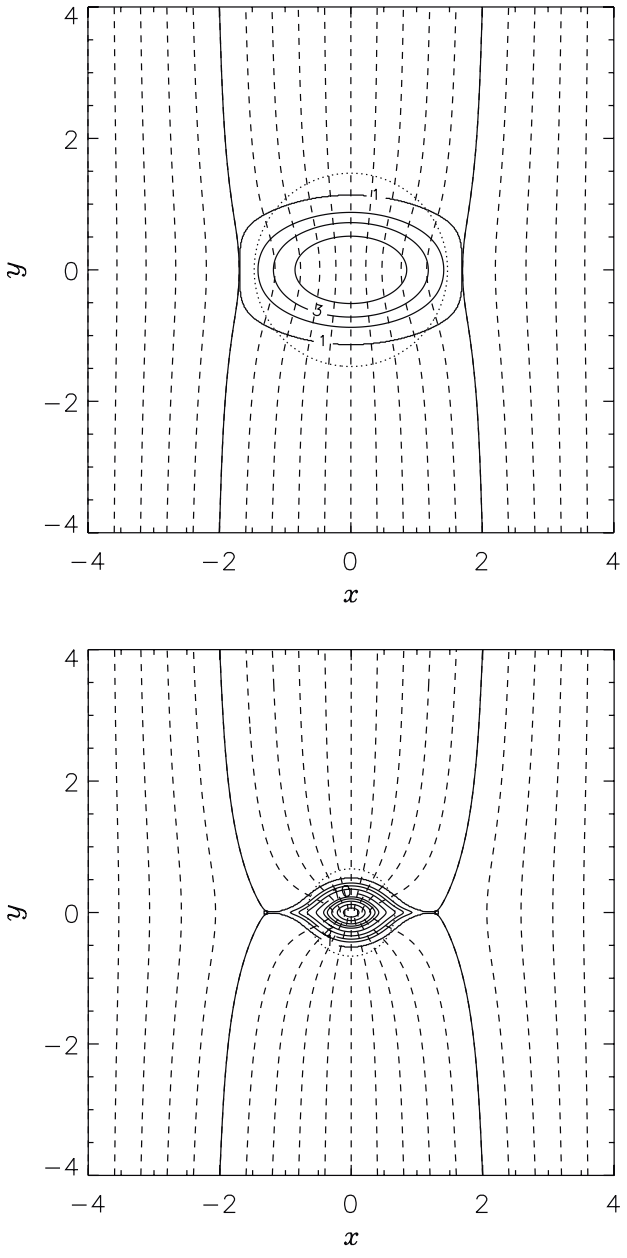

Figure 1: Structure of the isothermal filament laterally threaded by magnetic field. Long dashed lines running vertically represent the magnetic field lines. Closed solid lines are iso-density contours. Contour lines are placed for 1, 2, 3, 5, 10, 20, 30, 50, 100, and 200 times the density at the surface. Non-dimensional initial radius of the filament is taken as $R_0 = 2$ and the plasma beta of the ambient gas outside the filament is taken as $\beta_0 = 1$. We plotted two typical solutions with different center-to-surface density ratios, 10 (upper) and 300 (lower). Vertical and horizontal axes mean nondimensional distances from the center of the filament.

References

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