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How Does a Protostar Form by Magnetized Gravitational Collapse?

Star formation through the dynamical magnetized collapse remains an active area of astrophysical research. We carry out a comprehensive exploration on the magnetized gravitational collapse of a non-rotating self-gravitating initially spherically symmetric prestellar cloud core using two-dimensional nonideal magnetohydrodynamic simulations incorporating ambipolar diffusion and Ohmic dissipation. Our study encompasses a broader range of equations of state (EOSs) in the form of $P(\rho) \propto \rho^{\Gamma}$, with the aim of constraining the choice of EOSs for allowing star formation. Our results reveal that the collapse with a Γ no stiffer than $4/3$, complemented by magnetized virial theorem, allows the dynamical contraction of the prestellar core to happen continuously where a central point mass forms and steadily builds up its mass from the infalling envelope, with a mass accretion rate of the order of $c_{\rm s}^3/G$. The choice of an isothermal EOS most naturally facilitates the collapse as a magnetic analog of the inside-out collapse. In addition to that, our study exhibits that the nonisothermal magnetized collapse models with a Γ no stiffer than 4/3 qualitatively demonstrate similar infall features to those of an isothermal EOS. Furthermore, the collapse models with a Γ stiffer than 4/3 fail to ensure the sufficient cooling to allow the direct mass growth of the central point mass, thus delaying the infall. Our work can offer deeper insights in understanding the significance of EOSs on the magnetized gravitational collapse, enabling star formation.

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