MAGNETIC FLUX DISSIPATION DURING THE CONTRACTION OF A MAGNETIC PROTOSTELLAR GAS CLOUD

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The role of the magnetic field and the possibility of its leakage during the contraction of an interstellar cloud need more studies both quantitatively and qualitatively.

Because the physics of the interstellar cloud collapse is relatively complicated, we studied the hydromagnetics of a self-gravitating magnetic cloud neglecting both the chemistry and rotation. An adiabatic relation is used for the temperature variation. A hydromagnetic computer code has been constructed in order to follow numerically the collapse of an axially symmetric (2D) magnetized cloud. The method of explicit donor-cell was applied to the hydromagnetic equations with a moving grid of cylindrical coordinates. This ensures mass and momentum conservation and allows the grid to follow the collapse of the fluid near the center of the grid. The cloud is assumed to be axisymmetric and initially uniform. The contraction has been studied for densities in the range of $10\ cm^{-3} \lesssim n \lesssim 10^{13}\ cm^{-3}$. The ion density has been calculated by the relation $x_i \propto n^{-1}$.

We have carried out nine numerical models. The first four models were developed assuming that the magnetic field is frozen in the cloud. The rest of the models were devoted to study magnetic flux dissipation.

In case of frozen in magnetic field, the central magnetic field increases according to the relation $B \sim \rho^k$, $k \lesssim 1/2$, in agreement with Scott and Black(1980). The contraction was followed up to density increase by about five orders of magnitude. All the models predict flattening.

Comparison of the magnetic flux to mass ratio of different objects reveals that there are about three orders of magnitude difference between a molecular cloud and a magnetic star, El-Nawawy and Aiad(1986) and Nakano(1983). The magnetic flux dissipation through Joule heating was studied in five models (5-9), in order to explain the difference in the mass flux ratio between a molecular cloud and the sun.

The results indicate that the magnetic flux dissipation

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by Joule heating starts at densities $n \gtrsim 5\times10^{10}$ cm^{-3}. The magnetic flux dissipation is sensitive to both the ion density and the magnetic field strength and its gradient. At densities $n \gtrsim 10^{13}$ cm^{-3},the central magnetic flux has decreased by more than three orders of magnitude;thus explaining how the magnetic flux can decrease to stellar values. The resulting magnetic flux dissipation in our study represents only the contribution of ions. Therefore our results represent the maximum values for the magnetic flux dissipation. At densities $n \gtrsim 5\times10^{10}$ cm^{-3}, the electrons in addition to ions increase the magnetic flux dissipation. At lower densities($n \lesssim 5\times10^{10}$ cm^{-3}), $n_i/n_e \lesssim 100$ as given by Nakano(1984). In this case,the electron conductivity opposes the magnetic flux dissipation. Hence the minimum density for the begining of magnetic flux dissipation cannot become earlier than 5×10^{10} cm^{-3}.

Due to magnetic flux dissipation,the magnetic field tends to increase isotropically especially at higher densities. In addition,the pressure increases with temperature according to an adiabatic relation. Therefore as long as the magnetic dissipation becomes effective,and the pressure increases,the core of the evolved protostellar cloud tends to be spherical and magnetically isotropic,especially in clouds of initially small magnetic to gravitational energy ratio. This can explain why the observed new-born stars are approximately spherical while the dense dark clouds are mostly flattened.

Up to densities 5×10^{10} cm^{-3},one may expect that the magnetic field effectively transfers the angular momentum from a contracting cloud.

For more details see El-Nawawy(1985).

References

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