Numerical simulations on effects of magnetic fields in formation processes of molecular clouds

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We investigate effects of magnetic fields on the neutral gas motion in the molecular cloud formation process.

Molecular clouds are considered to be formed by the transition from the thermally stable to unstable phases by compression and the subsequent development of the thermal instability. We study two models by one-dimensional simulations for the one-fluid (neutrals completely coupled with ions and magnetic fields) or two-fluid (neutrals and ions moderately coupled with each other) media. First, in Thermal instability model, we study the development of the initially unstable gas (n = 0.30 /cc, P = 2000 K/cc and v = 0) via the thermal instability. The background magnetic field is assumed to be perpendicular to the simulation system with the strength of 2.6 micro gauss. Next, in Compression and thermal instability model, we take into account the compression process of the initially stable gas (n = 3.5 /cc and P = 2000 K/cc) by a shock (v = 25 km/s) as a trigger for the thermal instability. We assume that the direction of the background magnetic field is perpendicular to the shock normal direction and that the magnetic field intensity is 0.65 micro gauss.

In the Thermal instability model, the neutral gas condenses into clouds without prevention by magnetic fields in the two-fluid medium. The cloud density and formation time are comparable to those in the case without magnetic fields (n = 23 /cc and t = 2.9 Myr in the two-fluid case; n = 24 /cc and t = 2.7 Myr in the case without magnetic fields). In the Compression and thermal instability model, while the cloud formation is prevented by the magnetic pressure in the one-fluid case, a cloud of n ˜10ˆ1 /cc is formed in the two-fluid case within the time scale of ˜10 Myr via gas slipping from magnetic fields. Compared to the cloud formation (n ˜10ˆ2 and t ˜2 Myr) in the case without magnetic fields, however, the cloud formation is suppressed by magnetic fields. Therefore it is suggested that the compression process decreases the effectiveness of the gas slipping from magnetic fields and that the magnetic fields prevent the cloud formation even in the partially ionized medium.

The ineffectiveness of slipping is not drastically improved even in the case with weak magnetic fields (B = 0.081 micro gauss). Although effects of condensation along magnetic fields are also investigated by considering inclination of magnetic fields to a shock, the effect of slipping is little and the neutral gas traces the evolution almost same as in the flux freezing case. It is concluded that magnetic fields have significant influence to the neutral gas motion and regulate the molecular cloud formation even in the partially-ionized interstellar medium.