MHD INSTABILITIES AND FRAGMENTATION OF MOLECULAR CLOUDS

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The properties of the interstellar magnetic clouds, their hierarchy, turbulence and their origin in a processes of the rising of MHD-instabilities are discussed.

1. Observations. The observational characteristics of basic molecular cloud structures in the interstellar medium of Galaxy are given in Table 1 (see Scalo 1985; Goldsmith 1987; Dudorov 1990). The exponents q_σ, κ, q_ω of scaling relations between the velocity dispersion and cloud dimension ($s \sim R^{q_\sigma}$), between the magnetic field and the density ($B \sim n^{\kappa}$) and between the angular velocity and cloud dimension ($\omega \sim R^{-q_\omega}$) for every hierarchical level are presented also in the Table. Besides that the Table display the values of the ratio of magnetic energy to a module of gravitational one, ϵ_m and of plasmic beta $\beta = 8\pi P/B^2$, where P - gas pressure.

2. MHD turbulence. Observational parameters of scaling relations agree with theoretical ideas of the development of turbulence in magnetized conductive medium (Vainshtein 1983). In a strong magnetic field (levels 1,2) the turbulence can be regarded as a two-dimensional one with the index q_σ=0.75-1.0 being dependent on the compressibility of the medium. In this case the strength of magnetic field does not depend on the density.

The turbulence of molecular and protostellar clouds (levels 3,4) is three-dimensional one. Magnetic field is not active in this case, its strength depend on the density. The weakening of the magnetic field influence on the turbulence correlate with the decreasing of spectral index q_σ along the hierarchical sequence. Note, that the index of Kolmogorov turbulence q_σ=1/3 and passive Kraichnan MHD turbulence is characterized by index q_σ=0.25.

The index q_σ=0.5 can be explained by the intermittent compressible turbulence of the conductive medium in variable magnetic field. This value is appeared also in a picture of magnetogravitational turbulence (Falgarone and Puget 1986).

3. MHD gravitational instabilities. The discussion of the last point shows, that hierarchical levels may correspond to real turbulent structures of interstellar magnetic clouds.

Superclouds (SC) are represented frequently by shells,

E. Falgarone et al. (eds.), Fragmentation of Molecular Clouds and Star Formation, 402–404.

Table 1
Characteristics of interstellar magnetic clouds

Hierarchy	SC Super-cloud	MCC Molecul. cloud complex	MC Molecul. cloud	PC Proto-stellar cloud	References W-warm C-cold
T (K)	100	15-40 10	15-40 8-40	30-100 10	W C
n (cm-3)	1	100-300 1E2-1E3	1E2-1E3 1E3-1E4	1E3-1E5 1E4-1E6	W C
M (Mo)	1E7-3E7	8E4-2E6 1E3-2E4	1E3-1E5 20-500	10-1E3 0.3-20	W C
R (pc)	0.5E3-2E3	30-80 3-20	3-30 0.2-4	0.5-3 0.05-0.5	W C
σ (km/s)	10-20	6-15 1-3	4-12 0.5-1.5	1.5-3 0.2-0.4	W C
q_σ	1	0.7-1 0.6-0.7	0.4-0.6 0.3-0.4	0.2-0.4 0.2-0.3	W C
q_ω	0	0	0.3	0.4	W, C
k	0	1/3-1/2	1/2-2/3	1/2-2/3	W, C
ϵ_m	1	1	1/2	<1	W, C
β	<<1	<1	1	>1	W, C

Note to table: 1E4=1*10^4 and so on.

envelopes of superbubbles, clumps of spiral arms and other two-dimensional structures, oriented along a force line of galactic magnetic field. The basic dimension of supercloud is comparable with length of unstable disturbances in MHD shock wave and with the radius of superbubbles (≈1 kpc). The masses of superclouds may be limited by gravitational instability in the magnetic sheets. In this case mass $M=\rho\lambda_{cr}\lambda_j H$, wher the magnetic critical length λ_{cr}=2-4 kpc, Jeans lengs λ_j=0.2-0.4kpc, the magnetic pressure scale H=200-400pc. Some superclouds may be formed by Parkers instability. When β=2,

$\gamma=1.4$, the ratio of cosmic ray and magnetic pressure $P_{cr}/P_m=0.2$, then the unstable wavelength $\lambda_p=10H$.

The Supercloud may contain several complexes of molecular clouds (CMC), each of those may contain many molecular clouds (MC). The complexes of molecular clouds are observed often as a filamental or cilindrical structures. They may be a consequence of formation of magnetic flux tubes by channel gravitational instability in superclouds after their relaxation (Oganesyan 1960).

The formation of small scale turbulent magnetic field in turbulized gas of molecular clouds may lead to decrease of total pressure (Kleeorin et. al. 1990) and therefore to formation of long magnetic flux tubes with radius of crossection, $\lambda=H_\rho=100$pc. This MHD instability has the maximum increment, when $H_\rho \ll H_B$, where H_ρ and H_B are homogenity scales of the density and the magnetic field.

The molecular clouds may be formed by gravitational division of magnetic cilinders orin a process of gravitational relaxation due to the magnetic ambipolar diffusion. The ambipolar diffusion in quasistatic regime leads to the temporal collapse of molecular clouds and subsequent fragmentation in protocluster clouds with mass M=500-1000 Mo (Dudorov 1990).

The magnetic braking of rotation is very efficient in the case hierarchical levels 1,2 (c.f. Table 1). In course of the evolution of molecular and protocluster clouds the angular velocity rise upto 10-50 of its initial values.

Fagmentation of magnetostatic protocluster clouds may be induced by thermal, ionizational, resistive instabilities, leading to formation of protostellar clouds. The last stage of fragmentation of collapsing protostellar clouds may be induced by anomal ambipolar diffusion, when the magnetic protostars are formed with masses M>0.1-0.3 Mo, and with the ratio $\epsilon_m=0.1-0.3$. If the gas clouds are ionized by XR, UV the masses of protostars may be as large as several tenth of solar masses. Cosmic rays allow the formation of protostars with the masses more than 10 Mo.

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