DESTRUCTION OF THE INTERSTELLAR CLOUDS BY THE SHOCK WAVES

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ABSTRACT. We study the influence of the interstellar cloud structure irregularity on the dynamics of its destruction by a supernova shock wave. It is shown that irregular clouds are destroyed twice quickly as the spherical ones. Subject to that the fragments of the clouds sustain high-density and do not mix with the intercloud gas.

Key words: interstellar medium, shock wave, cloud destruction.

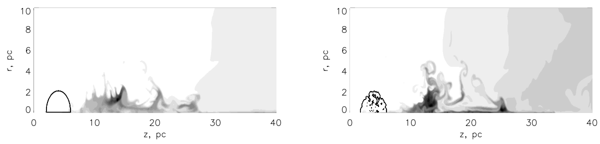

Figure 1: Density distribution after the interaction with the shock wave (left panel – spherical cloud, right – irregular cloud).

1. Introduction

The issue of the interaction of the shock waves with the interstellar clouds is one of the fundamental ones in the space gas dynamics. Usually the phase homogeneity of the medium is implicitly assumed in ISM dynamic processes considerations. However, recently there were performed several studies, where the effects of the multiphase ISM are explicitly taken into account. The system of the clouds is treated in several ways: a) a dynamically constant background (Hartquist et al 1986, Shchekinov 1996, Lizano et al 1996), b) as a dynamically independent component described as a set of the point objects (Cowie et al 1981), c) as an independent gas dynamic subsystem (Kamaya & Shchekinov 1997). In all cases the functions describing the exchange of the mass, the momentum and the energy between the phases are based on the simplified estimates of the dynamic destruction efficacy of the clouds, or on the calculations of the spherically symmetric vapour of the clouds by the heat transfer from the surrounding hot gas. We study destruction dynamics of the clouds by a shock wave from the point of view of chaotic movements excited in it and in terms of the conversion efficacy of a part of the shock wave energy to the kinetic energy of the fragments of a cloud. We especially pay attention to the influence of the cloud surface structure irregularity on the dynamics of destruction.

2. Description of the model

We consider the dynamics of the spherical and quasispherical clouds after the interaction with shock wave. Initially the clouds are in dynamic equilibrium with the background gas. In our main model, we study the temperature of the intercloud medium – $T_i = 10^4$ K, the density $n_i = 0.1$ cm^{-3}; in the cloud at undisturbed state $T_c = 10^3$ K, $n_c = 1$ cm^{-3}. We examine two cases for cloud: cloud with spherical surface of the radius $a_0 = 2.5$ pc and quasispherical cloud with irregular surface and average radius a_0. In the calculations we neglect gravity, the effects of the heat conduction and radiation losses taking the ideal gas state equation with a factor of an adiabatic $\gamma = 5/3$.

The calculations were conducted on a fixed cylindrical grid $[z, r] = 1200 \times 200$ of cells with a spatial resolution of 0.05 pc that corresponds to the physical size of the entire computational zone 60 pc $\times$ 10 pc. The detailed desription of the model can be found in (Matvienko & Shchekinov 2007).

3. Results

Fig. 2 shows with the mosaics the distribution of the cloud density contrasts by the mass depending on time; it is shown with the shades of the gray tones the mass of the calculated cells with a density contrast (with respect to the background value) at a given interval with

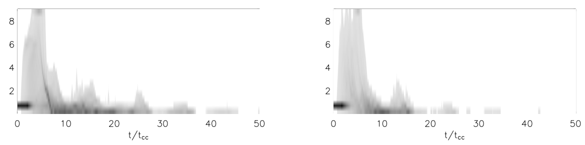

Figure 2: Histograms of the density distribution (left panel – spherical cloud, right – irregular cloud).

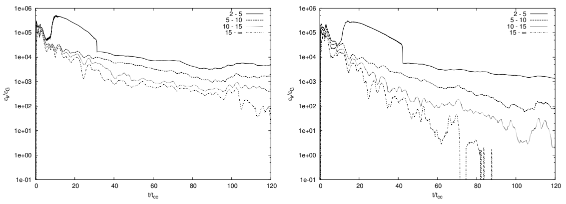

Figure 3: Average kinetic energy of the cloud fragments to the original gravitational energy per unit of volume (left – spherical cloud, right – irregular cloud).

darker areas corresponding to the larger mass involved in the computational zones. It should be noted that a cloud with an irregular border shows faster evolution, it overcomes a smaller number of oscillations of the cells number with the high contrast of the density and it disappears.

Fig. 3 shows the ratio of kinetic energy per unit of volume of the cloud fragments chaotic motions (for the spherical and quasispherical cases) with different values of the density contrasts to the original gravitational energy per unit of volume of the spherical cloud.

Another quanity characterized the random motions of cloud fragments is the velocity autocorrelation function. Fig. 4 shows the autocorrelation functions for several time moments. The autocorrelation function for velocities of the chaotic motions shows the coherence of the motions in z direction and in perpendicular direction to it. The autocorrelation function for velocities of the chaotic motions shows the coherence of the motions in direction of the initial blast spread and in perpendicular direction to it.

4. Conclusions

In this paper we examined the dynamics of destruction of the interstellar clouds with an irregular border. We have shown that:

- The destruction of the clouds with irregular shape by the shock waves is more effective - such clouds are destroyed with the time twice less than the time of a spherical cloud.
- The proportion of the energy of a shock wave that falls on the cloud and converts to the kinetic energy of the chaotic movements of the fragments in case of the irregular cloud is half times more. Stimulation of the starburst by the action of the shock waves on the clouds is difficult, particularly if we take into consideration that fact that the real clouds have irregular shape.
- The autocorrelation function for velocities of the chaotic motions shows the coherence of the motions in direction of the initial blast spread and in perpendicular direction to it.

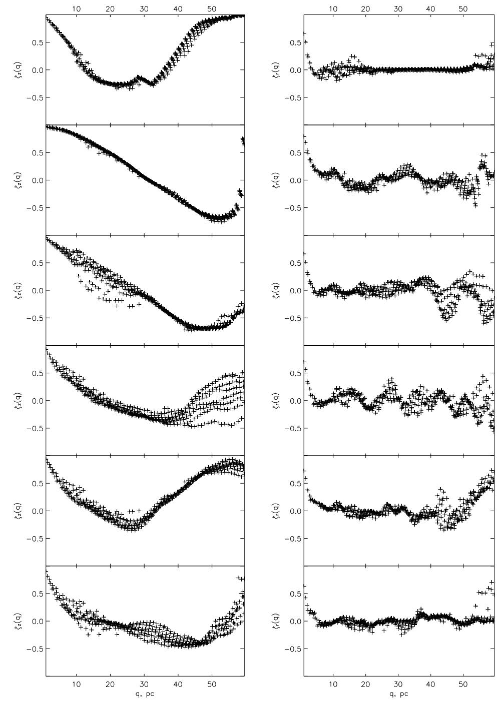

Figure 4: The velocity correlation functions in z (left column) and r (right column) directions for several time moments.

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