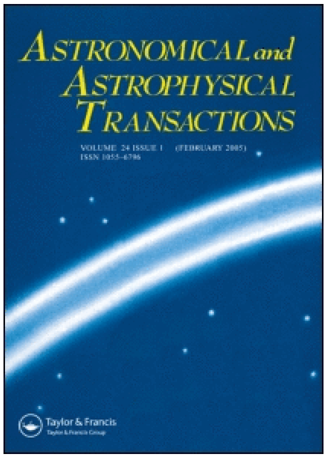

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DESTRUCTION OF INTERSTELLAR CLOUDS BY SHOCK WAVES

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We describe briefly the results of two-dimensional simulations of the interaction between a steady planar shock wave and a non-magnetized interstellar cloud. We address particularly the question of how the efficiency of destruction depends on the initial shape of the cloud. For this purpose we consider two cases: a spherical cloud, and a cloud of equal mass and density but with irregular ('fractal') surface. We argue that the 'fractal' clouds lose their integrity faster than spherical clouds do.

Keywords: Interstellar clouds; Shock waves; Two-dimensional simulations

1 INTRODUCTION

Mass exchange between different phases of the interstellar medium (ISM) has a great importance on its global dynamics and star formation activity in galaxies. Shock waves from supernovae explosions, stellar winds and H II fronts striking interstellar clouds are the most efficient engine which carries out such an exchange. Since the pioneering paper by Woodward (1976), many numerical simulations have been performed with an increasing accuracy and resolution in order to understand better the dynamics of cloud destruction by shock waves and dynamic structures accompanying this process. Cloud motion itself through a tenuous intercloud medium can result also in disruption of the cloud and transfer of its mass to the intercloud gas. The most comprehensive study of these processes has been given by Klein *et al.* (1994), MacLow *et al.* (1994) and Gregori *et al.* (1999).

The key questions being addressed in these simulations are as follows. Is a cloud subject to a shock or moving through a diffuse medium destroyed or shrunk? What fraction of cloud mass is transfered to the surrounding gas? The degree of cloud disruption depends on many factors. In particular, it is found that a magnetic field stabilizes clouds against disintegration (MacLow *et al.*, 1994; Gregori *et al.*, 1999). One of the factors which may play a crucial role in the outcome of the interaction of clouds with shock waves and gas flows is the cloud shape. Any deviation from a sphere increases the cloud surface area and therefore enhances the effects of pressure variations on its dynamics. It is not obvious from first principles, however, whether such an enhancement will increase or decrease the degree of the

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disruption. From one side, an increase in surface area enlarges the force from external pressure and can stimulate shrinking. On the other side, however, it enhances proportionally the effects of Kelvin–Helmholtz and Rayleigh–Taylor instabilities, which are the dominant disruptive mechanisms. In this communication we describe briefly the results of numerical simulations of the interaction of a shock wave with a cloud of irregular form in two-dimensional geometry. In Section 2 we describe the model accepted, the results are briefly outlined in Section 3, and in Section 3 we give our conclusions.

2 MODEL

In our model a homogeneous cloud of density $\rho = 1.66 \times 10^{-24}\,\mathrm{cm}^{-3}$ and mass $M_c = 0.73 M_\odot$ (the corresponding radius for a spherical cloud is $a = 2\,\mathrm{pc}$) is immersed under pressure equilibrium in a homogeneous intercloud medium with a temperature $T = 10^4\,\mathrm{K}$ and density $\rho = 1.66 \times 10^{-25}\,\mathrm{g\,cm}^{-3}$. At the initial time $t = 0$, a planar shock wave (assumed to be from a distant supernova) encounters the cloud. In this contribution we report the results for the initial Mach number of the shock: $\mathcal{M}_0 = 28.7$. However, for strong shocks the results seem to be invariant with respect to the low scaling described by Klein *et al.* (1994). In the model shown here the flow in the intercloud medium behind the shock corresponds to an adiabatic shock from a supernova (so that the shock velocity varies corresponding to a planar geometry as $v_s \propto t^{-1/3}$); that is, hydrodynamic variables are not kept constant. This assumption leads to a lowering of the degree of cloud destruction. The computational zone is a cylinder with 1200 grids in the z direction, and 200 radial grid points. The cloud is placed at $z_0 = 4\,\mathrm{pc}$ from the origin, so that the Mach number is about $\mathcal{M} = 20$ when the shock encounters the cloud. We consider two types of clouds:

(i) a spherical cloud;
(ii) a cloud with irregular boundary (a 'fractal' cloud).

In the latter case the boundary was generated in a random process with a one-dimensional curvature in the interval $\kappa = 0.33$–$20\,\mathrm{pc}^{-1}$. Numerical simulations were performed using the ZEUS2D code (Stone and Norman, 1992) at http://zeus.nsca.uiuc.edu.

3 RESULTS AND CONCLUSIONS

Figures 1(a) and (b) show the density contours for the spherical and 'fractal' clouds respectively at time $t = 5 \times 10^{13}$ s. It is seen that fragments and filaments of the 'fractal' cloud are spread mostly in the radial direction, while the spherical cloud is rather stretched in z axis. This is mainly because, when the shock engulfs the irregular boundary of the 'fractal' cloud, it drives into the cloud multiple intersecting shocks and a strongly fluctuating pressure inside. This circumstance enhances the degree of disruption of the 'fractal' cloud. It can also be seen that the flux rope is less pronounced in the back side of the 'fractal' cloud; this is due to defocusing of the intracloud shock.

In Fig. 2 the time evolutions of the density distributions for both a spherical and a 'fractal' cloud are shown, where all the cells have a density contrast larger than 2. The initial state corresponds to the peak at density contrast $\delta = 10$. The disturbance from the shock generates multiple fragments and filaments of low density, and dense cores. For the 'fractal' cloud the number of low-density cells ($\delta < 6$) grows more rapidly and, after $t \approx 5 \times 10^{13}$ s, most material has a density contrast $\delta < 10$. After $t \approx 10^{14}$ s, a substantial fraction of fragments is

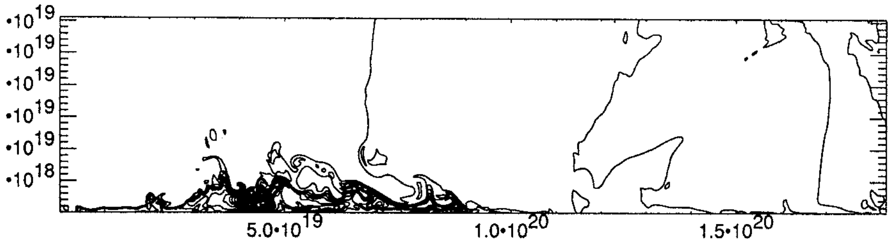

FIGURE 1 Time evolution of the density distribution for a spherical cloud: the density contrast (x axis) is given with respect to the intercloud medium, the time (y axis) is in seconds, and the vertical axis shows the number of grid cells with density contrast in a given interval.

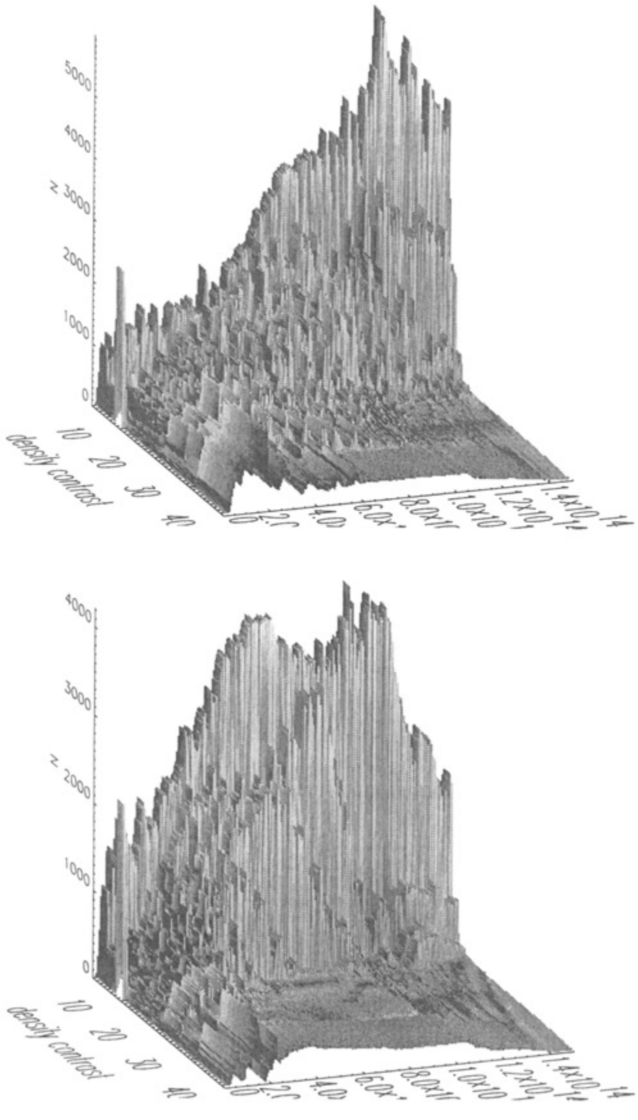

FIGURE 2 Density contours at time 5×10^{13} s for (a) the spherical and (b) the 'fractal' clouds.

brought into regions with density contrast lesser than 2 and is mixed with the ambient post-shock gas. Contrarily, in the spherical cloud, dense cores (with contrast $\delta > 10$) survive up to $t \approx 1.4 \times 10^{14}$ s, and a smaller amount of cells is transferred into rare regions with contrast $\delta < 2$. Thus, clouds with an irregular surface seem to be destroyed by shock waves more efficiently. A more detailed analysis will be given elsewhere.

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