RevMexAA (Serie de Conferencias), **11**, 65–66 (2001)

THE COLLISIONS OF HVCS WITH A MAGNETIZED GASEOUS GALACTIC DISK

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RESUMEN

ABSTRACT

We discuss 2-D MHD numerical simulations for the interaction of high-velocity clouds with a magnetized Galactic disk. The initial magnetic field is oriented parallel to the disk, and we consider two different field topologies: parallel and perpendicular to the plane of motion of the clouds. The impinging clouds move in oblique trajectories and fall toward the plane with different initial velocities. The B-field lines are distorted and compressed during the collision, preventing the cloud from penetrating into the disk. The perturbation creates a complex, turbulent, pattern of MHD waves that induce oscillations on both sides of the plane, and can trigger the Parker instability. The field efficiently transmits the perturbation over a large volume, while acting like a shield that inhibits the mass exchange between halo and disk. For non-magnetized disk cases, the shocked layer generates a tail that oscillates, creating vorticity and turbulent flows along its trajectory.

Key Words: **HIGH-VELOCITY CLOUDS — INTERSTELLAR MATTER — MAGNETOHYDRODYNAMICS**

1. INTRODUCTION

There is evidence for possible collisions between HVCs and gaseous disks, both in our Galaxy and in external galaxies: in the anticenter region (Mirabel 1981; Mirabel & Morras 1990; Morras et al. 1998), in the direction of the Draco Nebula (Kalberla et al. 1984; Herbstmeier et al. 1996), in M101 (van der Hulst & Sancisi 1988), and in NGC 4631 (Rand & Stone 1996). These observations support the idea that HVC-galaxy interactions could have a significant influence on the structure of the interstellar medium, and may trigger the formation of clouds and stars (Franco 1986; Franco et al. 1988; Alfaro et al. 1991; Comerón & Torra 1992; Lepine & Duvert 1994; Cabrera-Caño et al. 1995), as well as the Parker instability (Franco et al. 1995; Santillán et al. 1998).

Previous 2-D and 3-D numerical simulations for collisions with non-magnetic, or mildly magnetic, disks (e.g., Tenorio-Tagle et al. 1986, 1987; Franco et al. 1988; Comerón & Torra 1992; Lepine & Duvert 1994; Rand & Stone 1996), indicate that fast HVCs can drill a hole through the whole disk, and an efficient mass exchange can result from the interaction of the HVC system with the disk. The resulting interstellar structures have sizes of several hundreds of parsecs, similar to those ascribed to superbubbles from OB associations. However, these interactions can have a radically different outcome in a thicker and more magnetized disk than assumed by these previous works (Cox 1990 and Franco et al. 1995). An extended gas layer with a magnetic field drastically alters the results obtained previously with purely hydrodynamic models. The details of these new models are discussed in Santillán et al. (1999) and Kim et al. (2000). Here we summarize the main results.

2. MAGNETIZED DISK MODELS

The magnetic disk model is plane-parallel. Thermal and magnetic pressure provide the support of the initial magnetohydrostatic equilibrium, but our model does not include cosmic-ray pressure. The density distribution adequately describes the observed gas z-structure in the solar vicinity (Boulares & Cox 1990; hearafter BC). The functional form for the gravitational acceleration g is taken from Martos (1993), and provides a good fit to the data of Bienaymé, Robin & Crézé (1987). The midplane values are taken from BC: gas density $\rho_0 = 2.24 \times 10^{-24}$ g cm^{-3}, total pressure $p(0) = 2.7 \times 10^{-12}$ dyn cm^{-2}, magnetic field strength of $B(0) = 5\ \mu$G, and effective disk temperature of $T_{eff}(0) = 10,900$ K. For simplicity, the model we adopt, which we may call a "warm" magnetic disk model, is defined by $T_{eff}(z) = T_{eff}(0)$ (independent of z). Thus, the implicit sound speed of this warm model is similar to the observed dispersion of the main H I cloud component, ~ 8 km s^{-1}.

The adopted warm disk model is Parker unstable (Martos & Cox 1994) and, from a linear stability analysis for the ondular mode, we have found that the minimum growth time and the corresponding wavelength are 60 Myr and 3 kpc, respectively (Kim et al. 2000). The simulations are performed with the MHD code ZEUS-3D; the effects of self–gravity and differential rotation of the Galaxy are not included in our simulations. Our frame of reference is one in which the Galactic gas is at rest, and the origin of our 2D Cartesian grid is the local neighborhood. The coordinates $(x,\ z)$ represent distances along and perpendicular to the midplane, respectively. The grid resolution is the 200×200 zones, the physical intervals of the simulations presented here are 3 kpc × 3 kpc (the z-axis runs from -1.5 kpc to $+1.5$ kpc). In this work, all infalling clouds were given the same dimensions, 210 × 105 pc, and we have set the initial density of the clouds to n=1 cm^{-3}, the mass and energy densities of the models were 5.0×10^{-25} g cm^{-3} and 2.5×10^{-11} erg cm^{-3}. We positioned the cloud centers at several selected heights, from 350 pc to 4050 pc, and made a series of runs with different incoming velocities and incident angles. The velocity range spanned was from 0 to 200 km s^{-1} (i.e., from free-fall to nearly the largest observed approaching velocity), and the angles were varied from 0° to 60° with the vertical (z) axis. The results are discussed in Santillan et al. (1999) and we are now working magnetic field topologies that are not parallel to the plane of the disk.

REFERENCES

Alfaro, E. J., Cabrera-Caño, J. & Delgado, A. J. 1991, ApJ, 378, 106

Boulares A., & Cox, D. P. 1990, ApJ, 365, 544 (BC)

Bienayme, O., Robin, A. C., & Crézé, M. 1987, A&A 180, 94

Cabrera-Caño, J. Moreno, E. Franco, J. & Alfaro, E. 1995, ApJ, 448, 149

Comerón, F. & Torra, J. 1992, A&A, 261, 94

Cox, D. P. 1990, in Interstellar Disk–Halo Conection in Galaxies, ed. H. Bloemen (Kluwer), 143.

Franco, J. 1986, RevMexAA, 12, 287

Franco, J., Tenorio-Tagle, G., Bodenheimer, P., Różyczka, M. & Mirabel, I. F. 1988, ApJ, 333, 826

Herbstmeier, U., et al., 1996, ApJS, 117, 497

Kalberla, P. W. M., Herbstmeier, U. & Mebold, U. 1984, in Local Interstellar Medium, eds. Y. Kondo, F. Bruhweiler & B. Savage, NASA-CP2345

Kim, J, Franco, J., Hong, S. S., Santillán, A., & Martos, M.A. 2000, ApJ531, 873

Lepine, J. R. D. & Duvert, G. 1994, A&A, 286, 60

Martos, M. A. 1993, Ph.D. Thesis, UW-Madison

Martos, M. A., & Cox, D.P. 1994, in Numerical Simulations in Astrophysics, ed. J. Franco, S. Lizano, L. Aguilar & A. Daltabuit (Cambridge: Cambridge University Press), p. 229.

Mirabel, I. F. 1981, ApJ, 247, 97

Mirabel, I. F. & Morras, R. 1990, ApJ, 356, 130

Morras, R., Bajaja, E. & Arnal, E. M. 1998, A&A, 334, 659

Rand, R. & Stone, J. M. 1996, AJ, 111 190

Santillán, A., Franco, J., Martos, M. A., & Kim, J. 1999, ApJ515, 657

Tenorio-Tagle, G., Bodenheimer, P., Różyczka, M. & Franco, J. 1986, A&A, 170, 107

Tenorio-Tagle, G., Franco, J., Bodenheimer, P. & Różyczka, M. 1987, A&A, 179, 219

van der Hulst, T. & Sancisi, R. 1988, AJ, 95, 1354