RevMexAA (Serie de Conferencias), **3**, 101–104 (1995)

NUMERICAL SIMULATIONS OF THE STABILITY OF A THICK GASEOUS DISK WITH MAGNETIC FIELD

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RESUMEN

Se estudia la respuesta a perturbaciones de un disco galáctico gaseoso grueso, con campo magnético y rayos cósmicos. Se exploran diferentes modelos para la capa de gas en equilibrio hidrostático con el campo gravitacional local. Las perturbaciones simulan eventos de gran amplitud, tales como el impacto de nubes masivas con el disco galáctico. Presentamos resultados preliminares para una serie de experimentos sobre la estabilidad del disco con y sin campo magnético.

ABSTRACT

We study the response to perturbations of a thick galactic disk of gas, with a magnetic field and cosmic rays. Different models for the layer in hydrostatic equilibrium with the local gravitational field are explored. The perturbations simulate large amplitude events, such as the impact of massive clouds with the galactic disk. We present preliminary results for a series of experiments on the stability of the layer with and without magnetic fields.

Key words: **MAGNETIC FIELDS — MHD**

1. MOTIVATION

The thick layer of gas is expected to respond to perturbations in a highly non-linear fashion. The layer has different modes of oscillations whose coupling may result in complex velocity fields, as observed in the interstellar medium. In the presence of the magnetic field, the distortion of the field lines, due to events such as cloud-disk collisions, may lead to the onset of instabilities (Franco, Santillán, & Martos 1995). In particular, the Parker instability can result in the formation of large gaseous structures which eventually become large molecular cloud complexes (Parker 1966; Matsumoto et al. 1988). The motivation of the present set of experiments is to study the formation of structures as different perturbations evolve throughout the gaseous disk. This is a continuation of the work reported by Martos & Cox (1994) and Franco et al. (1995)

2. MODEL

The condition for hydrostatic equilibrium in the disk, if all quantities depend only on the height z, depends on the total pressure distribution. This can be written as weight of a column density of gas, $P(z) = -\int_z^b \rho K_z \, dz$, where $\rho(z) = 1.27 m_H n(z)$ and $K_z(z)$ represent the density of interstellar matter and gravitational acceleration in the z direction, respectively. To calculate this integral, we use the expressions for the number density and $K_z(z)$ given by Martos & Cox (1994) and the outer boundary condition $P(b) = 0$ is adopted at $b = 5$ kpc. We model the disk including two pressure terms: the first component represents both the thermal and cosmic ray contributions $P_t = n(z)kT_{eff}$ (the effective temperature T_{eff} is held constant and independent of z) and a magnetic term $P_b = B(z)^2/8\pi$. The extra condition $P(z) = P_b(z) + n(z)kT_{eff}$ applied to midplane gives $T_{eff} = 10\,900$ K.

Perturbations are imposed assuming quasi-isothermality ($\gamma = 1.01$) and flux freezing. The magnitude of the magnetic field $B(z = 0)$ is taken as $5\mu G$, which gives the correct P_b in the midplane. The problem is initiated with the usual geometry of magnetic field lines parallel to the Galactic midplane. Self-gravity in the perturbed gas is neglected.

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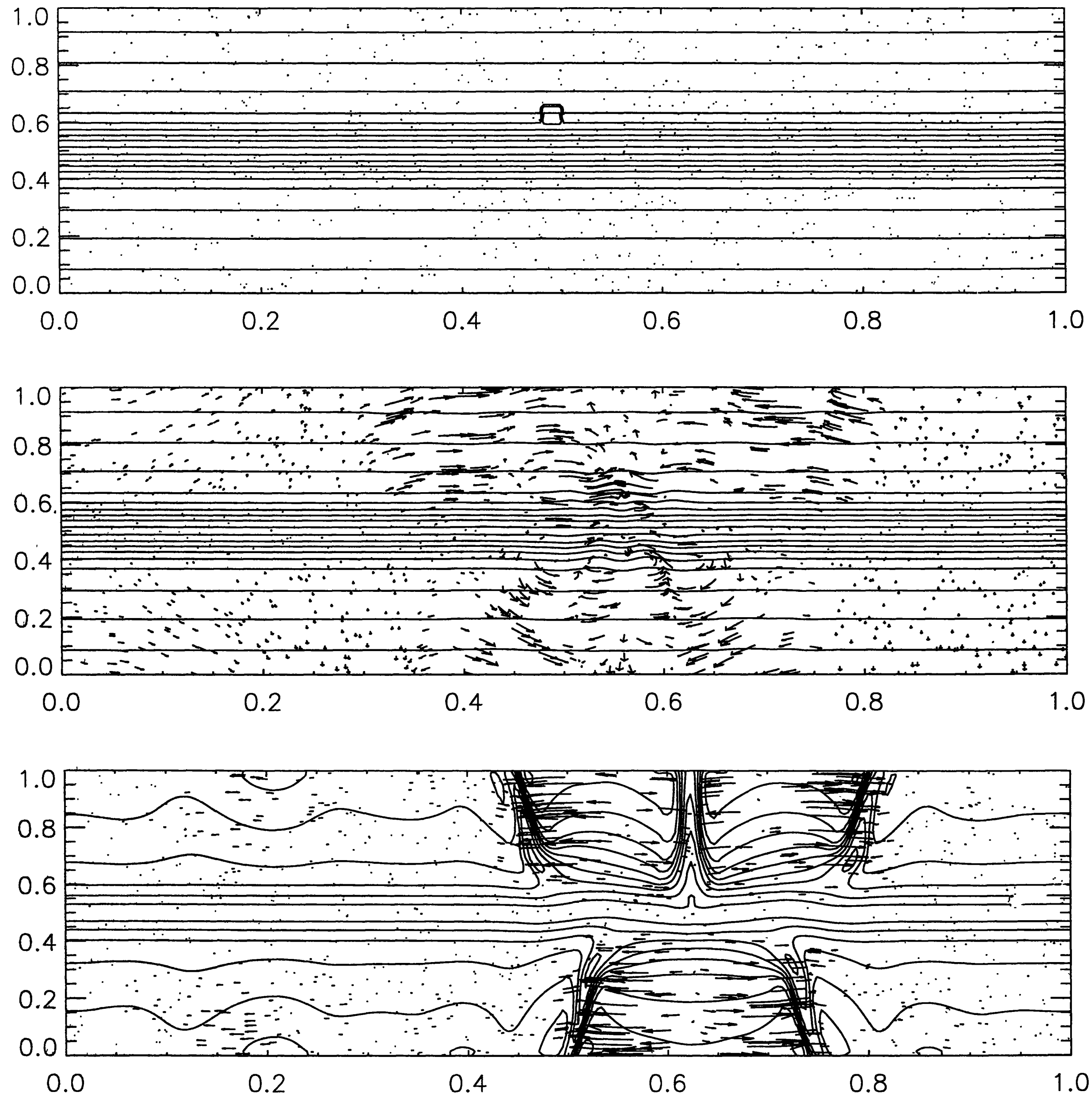

Fig. 1. Model of the perturbations produced by an infalling cloud in a gaseous disk without a magnetic field (Model I). The sequence shows isodensity contours and the velocity fields, indicated by arrows, at three selected times: $t = 0$, 2.9×10^8, and 3.8×10^8 yr. The maximum velocity values are 0, 2, and 3 km s^{-1}, respectively. The horizontal axis has a total length of 24 kpc and the vertical axis, with midplane at the center, ranges from -1.5 to 1.5 kpc.

3. RESULTS

Figures 1 and 2 show the temporal evolution of the two models. We consider a region with dimensions 24 kpc in X and 3 kpc in Z. The calculations were performed on a grid of 256×64 cells. The figures show isodensity contours, with the velocity field indicated by arrows. Model I is without a magnetic field, while Model II is with a magnetic field. Both models include an initial density perturbation of 3 times the unperturbed value in a region of size 500×250 pc, situated at a height of 400 pc above the plane of the disk.

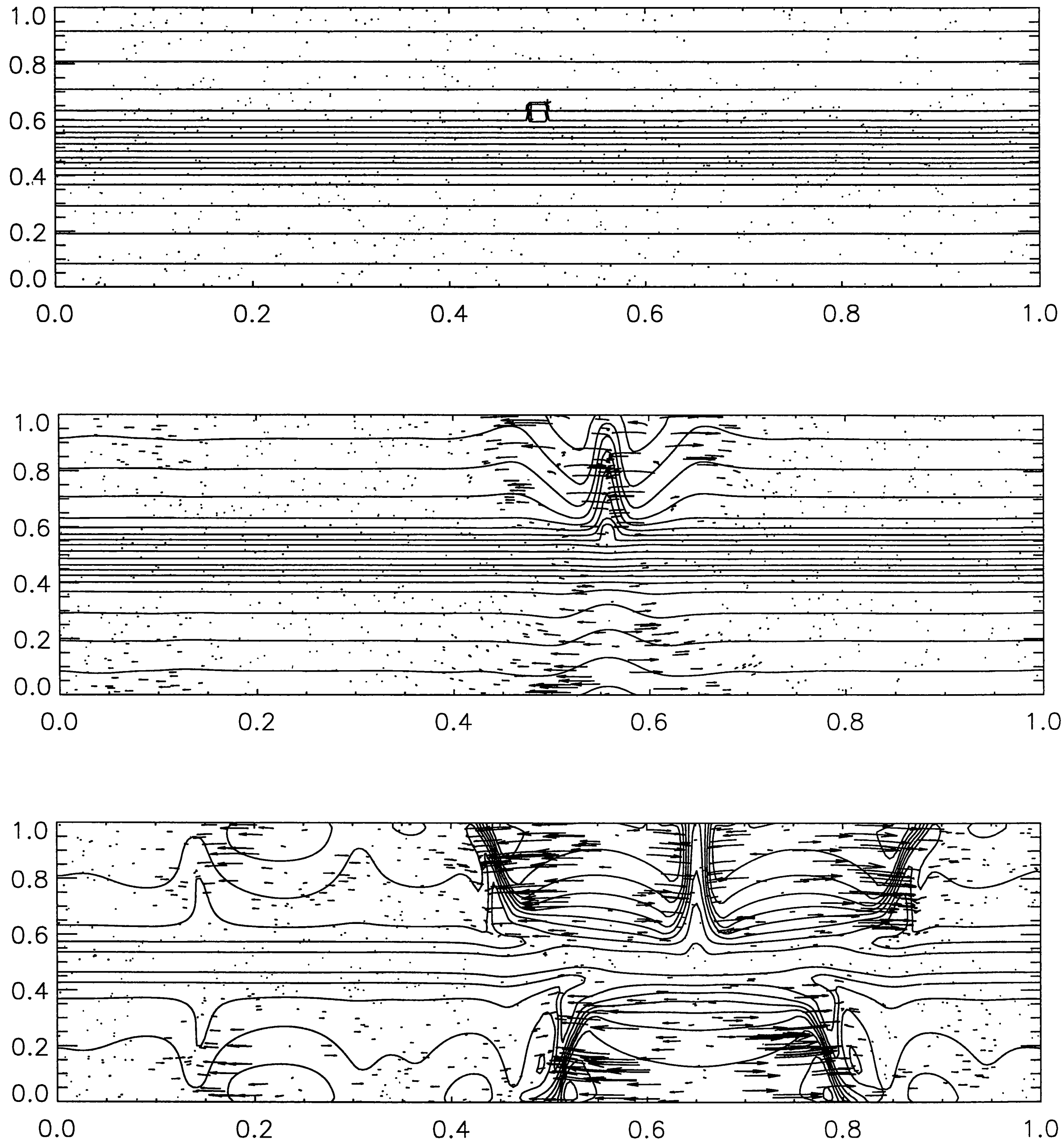

Fig. 2. Model of the perturbations produced by an infalling cloud in a magnetized gaseous disk (Model II). The sequence shows isodensity contours and the velocity fields, indicated by arrows, at three selected times: $t = 0$, 2.9×10^8, and 3.8×10^8 yr. The maximum velocity values are 0, 10, and 55 km s^{-1}, respectively. The vertical and horizontal axis are as in Figure 1.

The numerical simulations were performed with the Cray Y-MP of the supercomputer Center at UNAM-México, with the code Zeus, developed by M. Norman, D. Clarke, J. Stone and associated groups at NCSA-Illinois (Stone & Norman 1992a, 1992b). This work has been partially supported by DGAPA-UNAM through the grant IN105894, by a R&D grant from Cray Research Inc. and CONACYT grant 400354-5-4843E.

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