INTERACTION OF HVCS WITH THE OUTSKIRTS OF
GALACTIC DISKS: TURBULENCE

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Abstract. There exist many physical processes that may contribute to
the driving of turbulence in galactic disks. Some of them could drive
turbulence even in the absence of star formation. For example, hydro-
dynamic (HD) or magnetohydrodynamic (MHD) instabilities, frequent
mergers of small satellite clumps, ram pressure, or infalling gas clouds.
In this work we present numerical simulations to study the interaction
of compact high velocity clouds (CHVC) with the outskirts of mag-
etized gaseous disks. With our numerical simulations we show that
the rain of small HVCs onto the disk is a potential source of random
motions in the outer parts of H\textsubscript{i} disks.

1 Introduction

There is solid evidence that, in most spiral galaxies, the linewiths of H\textsubscript{i} emission
line, σ, vary radially from \sim 12 to 15 km s\(^{-1}\) in the central parts to a very constant
value between 6 to 8 km s\(^{-1}\) in the outer parts \cite{Dib et al. 2006}. Our main goal
is to assess how much of the velocity dispersion observed in extended H\textsubscript{i} galactic
disks is due to the impact of HVCs and intermediate velocity clouds (IVCs). Strong
evidence for the presence of continuing gaseous infall to the Galactic disk and
external galaxies has been compiled in \cite{Beckman et al. 2003}. Not all the accreting
material should have an extragalactic origin. \cite{Booth & Theuns 2007} showed that
the Galactic fountain can efficiently cycle matter from the center of the Galaxy to
its outskirts at a rate of \sim 0.5 M\(_{\odot}\) yr\(^{-1}\).

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2 Numerical Model and Results

The simulations were performed with the MHD code ZEUS–3D (Stone & Norman 1992a, 1992b) and the MHD–TVD code (Kim et al. 1999). Our local frame of reference is rotating with the disk, at a distance $R_0 \approx 20$ kpc from the galactic center. We have run two-dimensional (2D) and three-dimensional (3D) simulations. The coordinates $(x,y)$ correspond to the horizontal (planar) direction and $z$ to the perpendicular direction. The boundary conditions are periodic in the $x$–axis and $y$–axis, and outflow in the $z$–axis. The evolution was computed in the quasi–isothermal regime ($\gamma=1.01$), ignoring gas self–gravity and differential rotation. In the 2D simulations, the magnetic field has only one component along the $y$–axis and is initially stratified in the $z$–direction, $B_y(z)$. The ISM is initially in magnetohydrostatic equilibrium. The resolution of the domain for our 2D simulations was of $1024 \times 1024$ zones, and $128 \times 128 \times 256$ zones for the 3D case.

All infalling clouds have the same physical characteristics, initial radius $R_{cl} = 50$ pc and internal density $n_{cl} = 0.1$ cm$^{-3}$. The accretion mass rate due to the accreting clouds is 0.5 $M_\odot$ yr$^{-1}$. The CHVCs are injected at $z_{cl} = \pm 2$ kpc, i.e., the injection occurs in both caps of the disk, with a vertical velocity $v_{cl} = 100$ km s$^{-1}$. The case where the injection occurs only along one side was discussed in Santillán et al. (2007).

The 2D evolution of the ISM in the outskirts of a Galactic disk is shown in Figure 1. The disk suffers the continuous bombardment of CHVCs during 2 Gyr. The impact of each cloud produces a strong galactic shock directed downward and a reverse shock that penetrates into the cloud (Santillán et al. 1999). When two shocks that moves in opposite directions collide, most of the kinetic motion, which ultimately contributes to the gas velocity dispersion, is dissipated. The steady-state vertical velocity dispersion is close to transonic as long as the injection velocity of the clouds is $> 50$ km s$^{-1}$. In the vertical direction, accelerated gas due to incident clouds are decelerated by the external gravitational potential and falls back to the disk. Again, this falling material may collide with ascending gas, leading to energy dissipation and momentum cancellation.

Although the details differ, the basic gasdynamic phenomena described above and density contrasts and magnitude of the velocity dispersion are quite similar in the 3D simulations. The clouds loss its identity because they sweep up interstellar gas as they travel through the dense disk. In order to visualize their effect on the disk, Figure 2 shows the density distribution across the equatorial plane ($z = 0$) of the disk. We see the presence of elongated regions of higher density that resemble filaments and other more rounded regions of $\sim 300$ pc size, which can be interpreted as holes. The appearance of the density resembles that found in simulations of supernova–driven turbulence.

The inclusion of cooling and diffuse UV heating will result in a larger dynamical range in density. Nevertheless, we expect that the result that the velocity dispersion of the warm phase is transonic is a very general rule independent on these additional ingredients. The most sensitive parameter in our simulations is the internal density of the clouds. If this density is below a certain critical value,
Fig. 1. Evolution of the gas in the outer parts of the galactic disks. The sequence shows the density (*color logarithmic scale*) and velocity field (*arrows*) at two selected times (0.1 and 2 Gyr).

Clouds are destroyed in the upper halo and then the disk at $z \simeq 0$ cannot feel that the accretion is clumpy. In that case, the response of the disk is similar to the ram pressure exerted by a smooth wind. In order to circumvent this limitation, we plan to simulate the accretion of clouds with an astrophysically motivated spectrum of masses and of sizes, so that they may have different internal densities.
The Role of Disk–Halo Interaction in Galaxy Evolution: Outflow vs Infall?

3 Discussion and conclusions

The final fate of HI gas filaments in the galactic halos is accretion onto the disk. It is important to have a view of the response of the gaseous disk to accretion even if, surely, this is not the sole mechanism for driving turbulent motions in the outer parts of galactic disks. Our simulations suggest that for mass accretion rates consistent with current empirical determinations, the rain of CHVC onto the galactic disks can maintain transonic turbulent motions in the warm phase. In a forthcoming paper, we will report the evolution and amplification of the magnetic field and vorticity, and compare the distributions of surface density and velocity dispersion of our patch of the disk with observations.

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