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# HIGH VELOCITY CLOUDS. REVIEW OF OBSERVATIONAL PROPERTIES

(Invited Paper)

I.F. Mirabel

Department of Physics
Faculty of Natural Sciences
University of Puerto Rico

RESUMEN

Se presenta una síntesis de las propiedades observacionales de las nubes de hidrógeno neutro de alta velocidad ($|V| > 80$ km s$^{-1}$). Relevamientos recientes con alta sensitividad confirman la tendencia del gas con alta velocidad a acumularse en bandas estrechas que se extienden varios grados a lo largo del cielo. Existe una preponderancia de movimientos de acercamiento con una clara asimetría entre los hemisferios galácticos para los objetos con velocidades extremas ($V < -200$ km s$^{-1}$). Los modelos que proponen el disco galáctico como fuente última del gas de alta velocidad encuentran dificultades graves cuando intentan explicar los fenómenos. La mayor parte del gas con alta velocidad es el resultado de fuerzas de marea entre la Galaxia y las Nubes de Magallanes. La distribución en gran escala y las propiedades estructurales del gas con velocidad extrema indican que la Corriente Magallánica se ha esparcido en una amplia región del hemisferio sur galáctico. El influjo de gas observado implica una adquisición de materia por la Galaxia de 1 $M_{\odot}$ año$^{-1}$.

ABSTRACT

A review is given of the observational properties of neutral hydrogen high velocity clouds ($|V| >$ 80 kms s$^{-1}$). Recent high sensitivity surveys confirm the tendency of high velocity gas to cluster along narrow bands extending several degrees across the sky. There is a preponderance of inward motions with a clear asymmetry between the galactic hemispheres for the features with extreme velocities ($V < -200$ km s$^{-1}$). The galactic fountain models for the origin of this high velocity gas are faced with serious difficulties in explaining the phenomena. The bulk of the observed high velocity gas is the result of tidal interactions between the Galaxy and Magellanic Clouds. The large scale distribution and structural properties of the gas with extreme velocities indicate that the northern section of the Magellanic Stream has scattered throughout the southern galactic hemisphere. The observed influx of gas implies an actual increase of mass of the Galaxy of 1$M_{\odot}$ yr$^{-1}$.

*Key words:* GALAXIES-MILKY WAY – GALAXIES-MAGELLANIC CLOUDS – GALAXIES-INTERGALACTIC MEDIUM

## I. INTRODUCTION

The major part of the neutral hydrogen within the ılactic system is confined to a disk-shaped region with a ıickness of a few hundred parsecs. Knowing that the ılactic disk is fairly flat, and smoothly rotating, one can redict at what velocities the HI emission is expected.

The objects known as high velocity clouds (HVCs) are ɜutral hydrogen features showing properties not readily ‹plained by simple models of galactic structure. They :e found at high galactic latitudes having anomalous ıdial velocities. Since their discovery, nearly two ɜcades ago, their nature and origin has been a subject of ɔntroversy. The main reason being that the HVCs, until ow, can be studied only by means of the 21-cm line nission of neutral hydrogen.

In the present review we discuss the neutral hydrogen ata which are not related to the galactic disk. We ɔnfine ourselves to velocities in excess of the arbitrary ılue of 80 km s$^{-1}$. Since at lower latitudes ($|b| < 20^{\circ}$) ıe high velocity gas is mixed together with the outer spiral structure, we will concentrate on features which clearly do not belong to the spiral arms.

Several authors have reviewed the properties of HVCs in the past. In this paper we give an overview adding the results of recent high sensitivity surveys. A preliminary report of Arecibo observations with high angular and velocity resolution of a sample of HVCs with extreme negative velocities is presented.

## II. SURVEYS OF HIGH VELOCITY CLOUDS

Early surveys with moderate resolution and sensitivity had shown that the brighter HVCs appear as small clouds embedded in elongated areas of low intensity emission at similar velocities. The brighter condensations had been found in the second galactic quadrant at positive latitudes, the majority having negative velocities. Reviews of the early surveys have been given by Davies (1975*a*) and Verschuur (1975).

More recently, when cooled receivers came into operation, large sections of the northern sky were resurveyed by Hulbosch (1978) and Giovanelli (1980) with detection limits of $2 \times 10^{18}$ atoms $cm^{-2}$, an order of magnitude fainter than typical detection limits in previous observations. Furthermore, smaller selected areas of the sky were surveyed by Wright (1974), Davies (1975*b*), Cohen and Davies (1975), Mirabel and Cohen (1979), and Mirabel (1981). The sky south of $\delta = -37°$ has been surveyed by Mathewson *et al.* (1974) and completely mapped for the region around the Magellanic Clouds (Mathewson 1976). For the remaining part of the sky below $\delta = -37°$ only incomplete data are available and the need for high sensitivity observations in the southern hemisphere is relevant for our understanding of the HVC phenomena.

The available data on HVCs with LSR velocities greater than $|V| = 80$ km $s^{-1}$ are summarized in Figure 1. Data were taken from Hulbosch (1968, 1973), Meng and Kraus (1970), van Kuilenberg (1972), Wannier and Wrixon (1972), Mathewson (1976), Hulbosch (1978), Giovanelli (1980, for detections labeled q = 1), Mirabel and Cohen (1979), and Mirabel (1981). When known, the halfpower sizes of the features are indicated. Small circles represent detections in single positions. When compared with the distribution of HVCs as known some years ago (Davies 1975), the most striking feature in Figure 1 is that the southern galactic hemisphere is full of HVCs, sometimes extending to very high negative velocities ($V < -200$ km $s^{-1}$). Furthermore, several new HVCs were discovered in the northern galactic hemisphere in the region $20° < \ell < 70°, 0° < b < 40°$. Early observations had shown that the distribution of HVCs is uneven with a general tendency to cluster along narrow bands covering several degrees in the sky. As shown in Figure 1, more recent high sensitivity surveys confirm this tendency.

### a) *Nearby and distant populations of HVCs*

Although it is not possible to determine the distance to the HVCs, the analysis of the data can clarify the following more general question. Do all HVCs represent a local phenomenon in the solar neighborhood, or are there some subgroups located at large distances, such as the outskirts of the Galaxy, or the immediate intergalactic space?

The analysis of the contribution of the galactic rotation to the velocity distribution of the gas with anomalous velocities provides insight into this question. The distribution of LSR velocities as a function of galactic longitude is plotted in Figure 2*a*. This plot shows that LSR velocities are a strong function of galactic longitude. Most HVCs have negative velocities in the first and second quadrant, and positive velocities in the third and fourth quadrants. This fact is in favor of a distribution in which a large subsample of HVCs is at large distances from the Sun. If all the HVCs were a local phenomenon taking part of the local rotational velocity about the galactic center, one would expect very small changes in the radial velocity distribution of HVCs across the sky.

In spite of the generally strong dependence of LSR velocities with galactic longitudes shown in Figure 2*a*, there is an extended population of HVCs between $\ell = 20°$ and $\ell = 200°$ with radial velocities in the range $-150 < V < -80$ km $s^{-1}$. The mean LSR velocity in this band is independent of galactic longitude, which is an indication of a subgroup of relatively nearby HVCs. The differences in the structural properties between the distant and nearby populations will be discussed later.

### b) *The preponderance of inward motions*

One of the most striking properties of the HVCs shown in Figure 1 and Figure 2*a* is that except for some weak complexes, the majority have negative velocities, suggesting a systematic inward motion of matter towards the galactic disk. Figure 2*a* shows that all the HV gas for $0° < \ell < 230°$ with $|V| > 150$ km $s^{-1}$ have negative velocities. After subtraction of the LSR component the majority of this gas has negative galactocentric components. It has been argued that this preponderance of negative velocities may be a selection effect, due to the motion of the LSR and the incompleteness of surveys in the southern sky. However, the line of sight component of the solar motion in both the galactic center and anticenter directions is small, and all features in both regions with $|V| > 150$ km $s^{-1}$ have similar extreme inward motions. This fact is a strong indication that a subgroup of HVCs represents a flow of infalling matter towards the galactic disk.

### c) *The hemispheric asymmetry. A probe of the net inflow of matter towards the galactic disk*

Striking asymmetries between the northern and southern galactic hemispheres have been noted by Giovanelli (1980). Figures 2*b* and 2*c* are similar to Figure 2*a*, except that they show the longitude-velocity distribution for each galactic hemisphere separately. Most features with $V < -200$ km $s^{-1}$ are located in the southern hemisphere. The few points at $b > 0°$ with $V < -200$ km $s^{-1}$ are near the galactic equator at $b < 8°$.

This clear hemispheric asymmetry for the large inward motions provides a test for the theories on the origin of the infalling matter. Bregman (1980) has proposed a galactic fountain model for the HVCs. Supernova-heated gas rises up and outward in a hot, dynamic corona. Coronal gas is subject to thermal instabilities and neutral gas condensed from the corona falls ballistically towards its point of origin. Although Bregman's model reproduces the large observed inward motions, the hemispheric asymmetry of the infalling gas

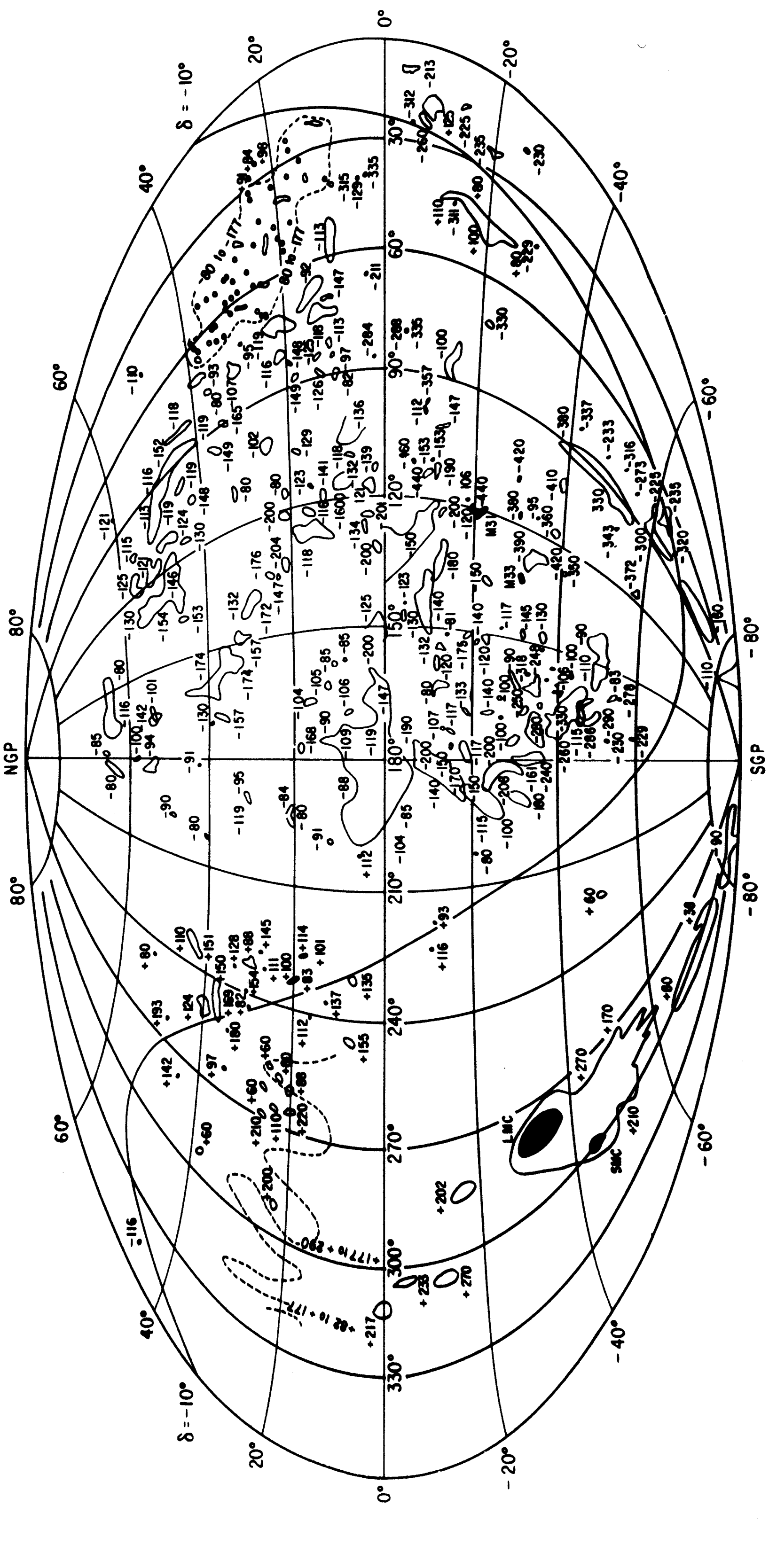


Fig. 1. The distribution of HVCs in galactic coordinates. Each cloud is labeled with its mean velocity relative to the LSR. The Large and Small Magellanic Clouds as well as M31 and M33 are plotted. The $\delta = -10°$ line is indicated. Data have been taken from the sources mentioned in the text.

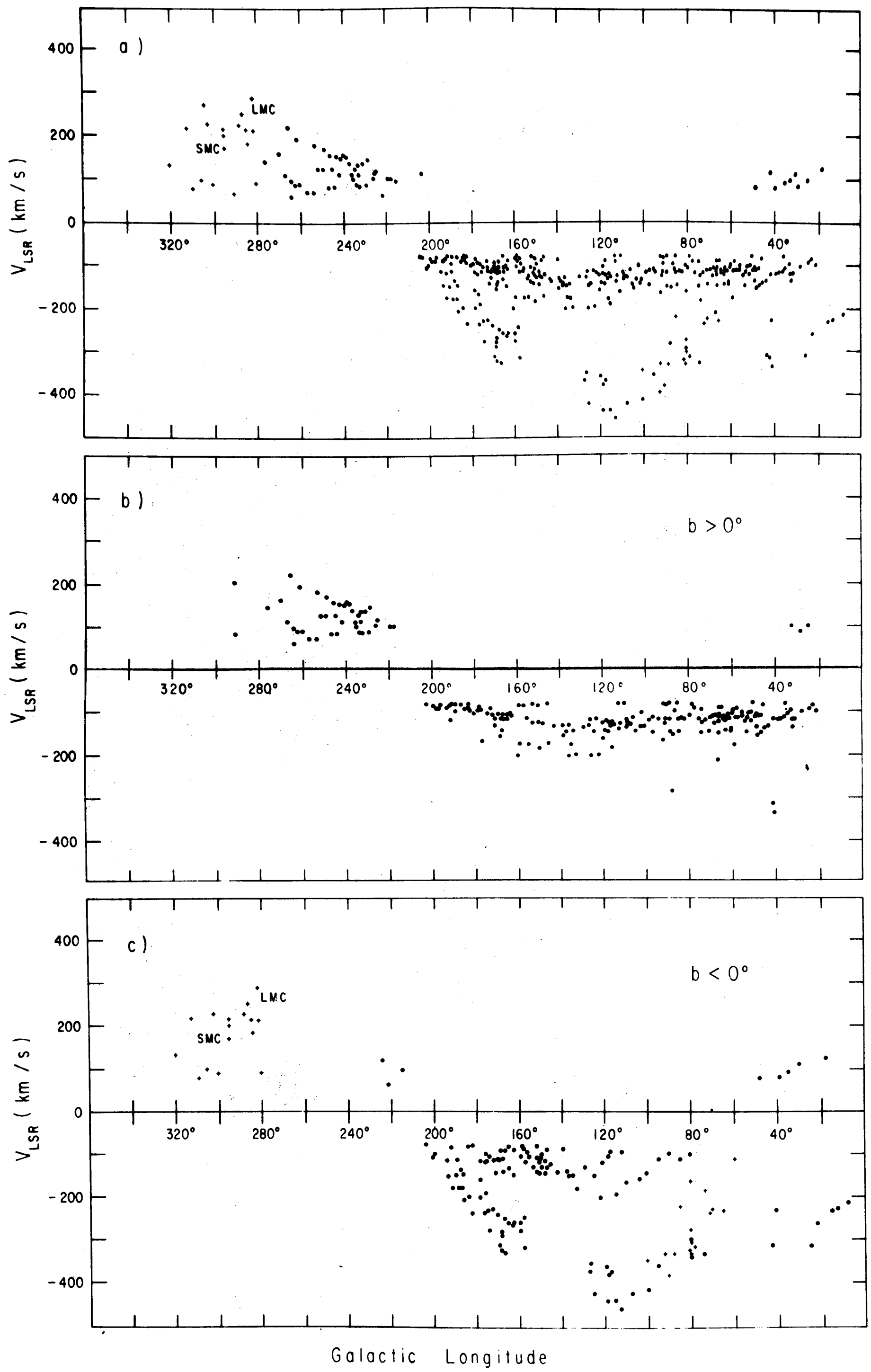


Fig. 2. *a)* LSR velocity plotted versus galactic longitude, for the clouds shown in Figure 1. Features of the Magellanic Stream are indicated with crosses. *b)* Same as above but for the southern galactic hemisphere only. *c)* Same as above but for the southern galactic hemisphere only.

is difficult to understand if the ultimate source of this material is the galactic disk. Moreover, the Magellanic Stream is left as a phenomenon of a different nature and origin.

The Magellanic Clouds are located in the southern galactic hemisphere, and it seems more natural to consider the gas with extreme velocities observed in this hemisphere as a net inflow of matter towards the Galaxy. The connection between the Magellanic Stream and the Magellanic Clouds has established beyond doubt the extragalactic origin of the stream of HVCs in the southern galactic pole. All current models of this feature consider it as material within the Milky Way-Magellanic Clouds System falling towards the galactic disk. The distribution of the HV gas with large negative velocities shown in Figures 1 and 2*c* suggests that clouds with the same origin have scattered throughout the southern galactic hemisphere.

The net mass of gas streaming towards the Milky Way depends on unknown factors, such as the distance to the clouds and the thickness of the gas along the line of sight. If we assume that this gas is located at an average distance of 30 kpc, inside a layer of thickness 10 kpc, with an average space velocity of 200 km $s^{-1}$, then assuming that ten per cent of the sky is populated with $5 \times 10^{18}$ atoms $cm^{-2}$, we obtain a flux of 1 $M_{\odot}$ $yr^{-1}$.

## III. STUDIES OF THE FINE STRUCTURE IN HVCs

Does the phenomenological diversity of HVCs represent different steps involved in a unique evolutionary process? Or, alternatively, are the structural differences between HVCs an indication of diverse origins of the phenomena? Studies of the fine structure in HVCs can provide further insight into explaining their origin.

Surveys over large sections of the sky outline the large scale properties of the gas with anomalous velocities, but provide limited information on small scale properties such as cloud sizes, intrinsic velocity widths and velocity gradients.

Early surveys of HVCs showed that they have sizes of a few degrees and velocity widths at half intensity of 20 to 40 km $s^{-1}$. Observations with higher resolution in angle and velocity showed that this is an oversimplified picture (Giovanelli *et al.* 1973; Davies *et al.* 1976; Cram and Giovanelli 1976; Giovanelli and Haynes 1976; Schwarz *et al.* 1976; Cohen and Mirabel 1979; Mirabel, Cohen and Davies 1979).

In the following sections we summarize published high resolution observations, as well as preliminary results on features with extreme velocities obtained with the 305-m radiotelescope of NAIC[1] by the author in collaboration with R. Giovanelli.

1. The Arecibo Observatory is part of the NAIC, which is operated by Cornell University under contract with the National Science Foundation.

### a) *Fine structure in nearby HVCs*

The brighter HVCs located in the northern galactic hemisphere show a complex structure. They consist of narrow filaments with exceedingly clumpy concentrations of HI (Giovanelli *et al.* 1973), having dimensions of $\sim 5'$ or less (Schwarz *et al.* 1976). The gas shows an uneven density distribution, sometimes with the presence of rather steep edges with conspicuous erratic changes in velocity of $\sim$ 18 km $s^{-1}$ between adjacent clouds. Oort and Hulbosch (1978) have argued that this is infalling gas in the nearby galactic halo at distances between 2 and 3 kpc. The observed properties of the gas, such as its steep edges and erratic velocity jumps have been produced by collisions with the observed irregular structures located $\sim$ 2 kpc above the galactic plane.

Another indication that these clouds must be located in the nearby galactic halo is provided by their LSR velocity distribution as a function of galactic longitude. They are found between $\ell = 90^{\circ}$ and $\ell = 160^{\circ}$ at $b > 0^{\circ}$. Figure 2*b* shows that they belong to the population of clouds with mean LSR velocities that are independent of galactic longitude.

One of the most striking properties of the northern HVCs is the clear-cut spectral division between broad line profiles seen throughout the clouds, and the narrow line components seen only in the bright condensations (Cram and Giovanelli 1976). The broad components have typical velocity half widths of 25 km $s^{-1}$, whereas the narrow components have velocity widths of $\sim$ 7 km $s^{-1}$. The existence of sharp velocity components in the northern HVCs was interpreted by Giovanelli and Haynes (1977) as evidence of the interaction between galactic and intergalactic material postulated by Oort (1970), with shock waves leading to strong compression and hence forming dense cores.

Giovanelli and Haynes (1976) and Cohen and Ruelas-Mayorga (1980) have studied in detail a few positive velocity clouds. They find that the morphology of the positive velocity features is similar in most respects to that of the nearby HVCs with negative velocities.

### b) *Fine structure in the Magellanic Stream*

The Magellanic Stream is the narrow band of HVCs extending along a great circle from the Magellanic Clouds past the South Galactic Pole towards $\ell = 90^{\circ}$, $b = -35^{\circ}$ (Figure 1). Mathewson *et al.* (1977) showed that it is composed of six large discrete clouds.

There is a systematic radial velocity variation with angular distance along the Stream.

Current models locate the H I within the Milky Way-Magellanic Clouds System and consider it as material that is being captured by the Galaxy.

Mirabel, Cohen, and Davies (1979) published detailed maps of several regions in the northern part of the Magellanic Stream. With a $12'$ angular and 1.8 km $s^{-1}$

velocity resolution they found a narrow filamentary structure running parallel to the main direction of the Stream. The clouds have typical angular sizes of 0°.4 × 0°.6, typical masses of 15 $D^2$ $M_\odot$, (where D is distance in kpc) and are preferentially oriented along the filaments. The mean velocity differences between the clouds increase towards the tip of the Stream.

More recently, in collaboration with R. Giovanelli, we have carried out finer observations in the northern tip of the Magellanic Stream using the 305-m radiotelescope of the Arecibo Observatory. The observations where done with an angular resolution of 3'.3 and a velocity resolution of 3 km $s^{-1}$. Figure 3 shows position-velocity maps along directions perpendicular to the main extension of the Stream. The maps reveal the existence of turbulent motions with velocity differences of 25 to 35 km $s^{-1}$ between adjacent clouds. Condensation smaller than 5' with hydrogen masses as small as 0.8 $D^2$ $M_\odot$ are present in the Stream. The velocity halfwidths are typically 20-25 km $s^{-1}$ and no narrow velocity features were detected. The narrowest velocity component we have found has a width of 20 km $s^{-1}$. The Arecibo observations show that the velocity gradients and broad emission profiles present in the Stream when observed with smaller telescopes are due to the blending of emission from different filaments and clouds within the telescope beam, rather than to intrinsic rotation within the filaments and clouds.

The velocity dispersion between clouds inside the narrow filaments, as well as the velocity widths of the clouds, imply positive energy if the only mass is the observed HI. Assuming free expansion, our observational results imply an expansion age of 4 × $10^5$ D years (where D is the distance in kpc). The tidal model (Davies and Wright 1977) and the turbulent wake model (Mathewson *et al.* 1977) for the origin of the Stream establish that the northern tip is located at D < 50 kpc and originated ∿3 × $10^8$ years ago. The expansion age of the Stream, as stated by our high resolution observations, falls at least a factor of ten short of the age predicted by current models.

There are several reasons to believe that the northern section of the Magellanic Stream is breaking apart and will scatter along a large area of the southern galactic hemisphere. The results of our high resolution observations indicate that the filaments in the tip are disintegrating. Mathewson *et al.* (1977) have reported a progressive decrease of surface densities as well as an increase of turbulent motions from the Magellanic Clouds towards the tip of the Stream. The general distribution of clouds with V < −200 km $s^{-1}$ in the southern galactic hemisphere described in section II, suggests the possibility that clouds with the same origin have scattered throughout a large section of the sky.

The tidal model proposed by Davies and Wright (1977) can account qualitatively for the morphology of the Stream and the progressive increase of velocity

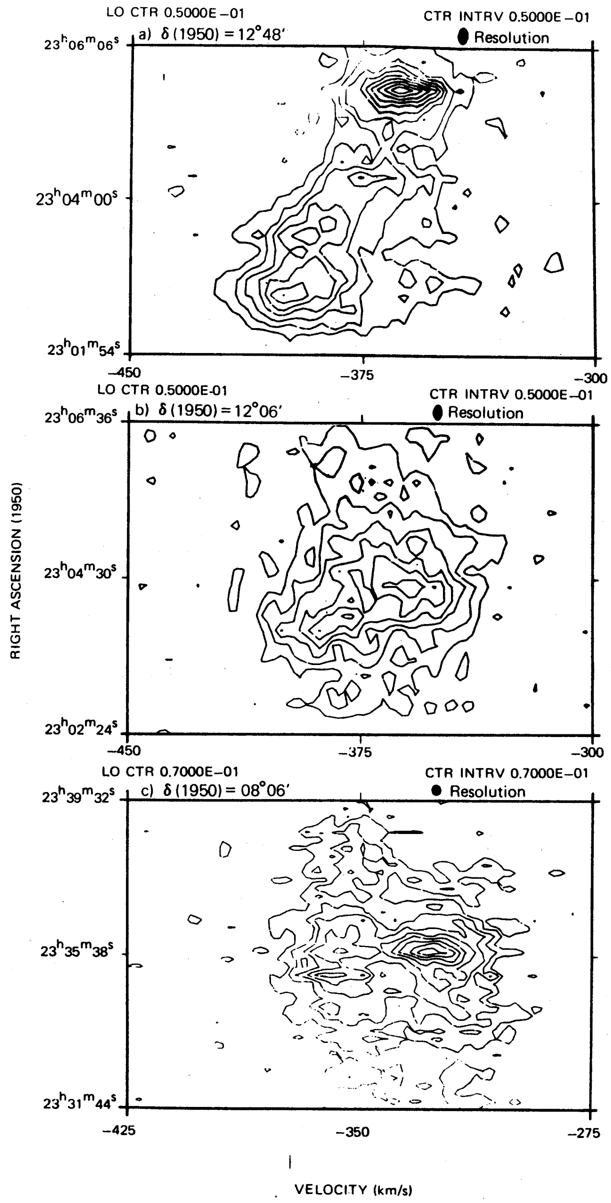


Fig. 3. Position-velocity maps of the Magellanic Stream. Observations were done with the 305-m radiotelescope of the Arecibo Observatory. Angular resolution is 3'.3 and velocity resolution is 3 km $s^{-1}$. Lower contours and contour intervals are indicated at the top of each map. *a)* Map for δ = 12°48'. *b)* Map for δ = 12°06'. *c)* Map for δ = 8°06'.

differences between adjacent clouds towards the tip of the Stream. The tidal forces of the Galaxy stretch the gas producing the observed narrow filaments running parallel to the main direction of the Stream. Since this model locates the head of the Stream at a distance of ∿ 10 kpc from the galactic center, the larger velocity differences between adjacent clouds in this region is a

›nsequence of the stronger tidal forces from the alaxy.

### c) *Fine structure in clouds with very high negative velocities*

In section II we mentioned the existence of a idespread population of HVCs in the southern galactic ›misphere with velocities more negative than –200 km $^{1}$. Reduction of the velocities to the GSR, yields sidual velocities of up to –200 km s$^{-1}$ for these atures. Cohen and Mirabel (1979) and Wright (1979) ıve published maps for a few of these clouds. More cently, Giovanelli and I have mapped a sample of atures with large inward motions using the 305-m diotelescope at Arecibo.

Figure 4 shows position-velocity maps for features in ıe anticenter complex of HVCs obtained with the )5-m radiotelescope. Figure 4*a* presents the feature beled ACI by Hulbosch (1975) at constant declination. he feature with a LSR velocity of –190 km s$^{-1}$ shows velocity gradient of 20 km s$^{-1}$ per degree. A weak ‹tension from ACI towards lower velocities is an dication of a possible physical link between ACI and ıe feature at V = –130 km s$^{-1}$. A strong perturbation . the contours of the low velocity gas is present in this gion of the sky. Figures 4*b* and 4*c* show position- ›locity maps for the anticenter feature labeled AC III y Hulbosch (1975). Velocity gradients of 20 km s$^{-1}$ ›r degree are present in this feature. No narrow velocity nission has been detected in the anticenter complex. he narrowest velocity component we have found has a ılfwidth of 20 km s$^{-1}$.

Figure 5 shows Arecibo position-velocity maps across ther clouds with extreme velocities. Figures 5*a* and 5*b* ıow maps in a HVC complex discovered by van uilenberg (1972). Several condensations are present in igure 5*a*. A velocity variation of 36 km s$^{-1}$ is found ›ross these clouds. Figure 5*b* shows a cut in a condensa- on within the same complex. A velocity variation of 20 m s$^{-1}$ is found across it. This is equivalent to a ıriation of 60 km s$^{-1}$ per degree. Figure 5*c* shows a osition velocity map of Shostak's (1977) cloud. The ›ndensation exhibits a velocity variation of 22 km s$^{-1}$ ›ross 10′ which represents a gradient of 130 km s$^{-1}$ per egree.

The Arecibo observations have shown that the objects ith extreme negative velocities exhibit systematic ›locity patterns. Their morphology does not show the eep edges seen in the northern HVCs. Velocity ıriations of $\sim$ 20 km s$^{-1}$ are common within the ›ndensations. Fine velocity structure in the emission rofiles is not a widespread phenomenon.

Narrow emission with halfpower velocity widths of ‹ 7 km s$^{-1}$ have been found until now only in four louds with extreme velocities (Cohen and Mirabel 1979; 'right 1979; Mirabel 1981). All four show smooth column density and velocity maps with no evidence for interaction with galactic material. Cohen and Mirabel (1979) have pointed out that some other mechanism different from that proposed by Giovanelli and Haynes (1977) is required to trigger the collapse of the condensa- tions in these clouds. The bright condensations with narrow velocity emission are thought to be thermal instabilities which have condensed out of their envelope material. Evidence for rapid rotation and collapse in the cooler condensations of HVCs has been suggested (Cohen and Mirabel 1979; Cohen and Ruelas-Mayorga 1980), but needs to be confirmed by observations at high angular and velocity resolution.

## V. CONCLUSIONS

Recent high sensitivity surveys confirm the tendency of high velocity clouds (HVCs) to cluster along narrow bands extending several degrees across the sky. The most striking feature is the discovery of a population of clouds with LSR velocities more negative than –200 km s$^{-1}$ down to –460 km s$^{-1}$. The distribution of objects with $V < -200$ km s$^{-1}$ shows a clear hemispheric asymmetry, most of it being spread in the southern galactic hemisphere between $\ell = 0°$ and $\ell = 180°$.

There is a preponderance of negative radial velocities which implies a general inflow of HI towards the galactic disk. In the galactic center and anticenter regions similar extreme inward motions are found.

The contribution of the galactic rotation to the velocity distribution of the gas provides evidence for the existence of two large subsamples of HVCs: a) a sub- group of relatively nearby features in the local galactic halo; b) a subgroup of HVCs at large distances from the Sun, located in the intergalactic space, within the Milky Way-Magellanic Clouds System and the outskirts of the Galaxy.

Galactic fountain models for the origin of the HVCs as proposed by Bregman (1980) are confronted with grave difficulties when trying to explain the properties of the gas with extreme velocities ($V < -200$ km s$^{-1}$).

The reviewer supports a scenario in which most of the observed HV gas is the result of tidal interactions between the Galaxy and the Magellanic Clouds. Davies (1975) showed that much of the HV gas at low latitudes ($|b| < 20°$) is part of the outer spiral structure of the Galaxy. The bulk of the extended low latitude gas originated in the Galaxy and was pulled out of the plane by the tidal interactions during a close approach of the Magellanic Clouds.

The remaining gas at high latitudes, or having extreme velocities, originated in the tidal disruption of the Magellanic Clouds by the Galaxy. Clearly the Magellanic Stream is material falling towards the Galaxy which has been removed from the Magellanic System. The HI condensations and filaments in the faint, northern

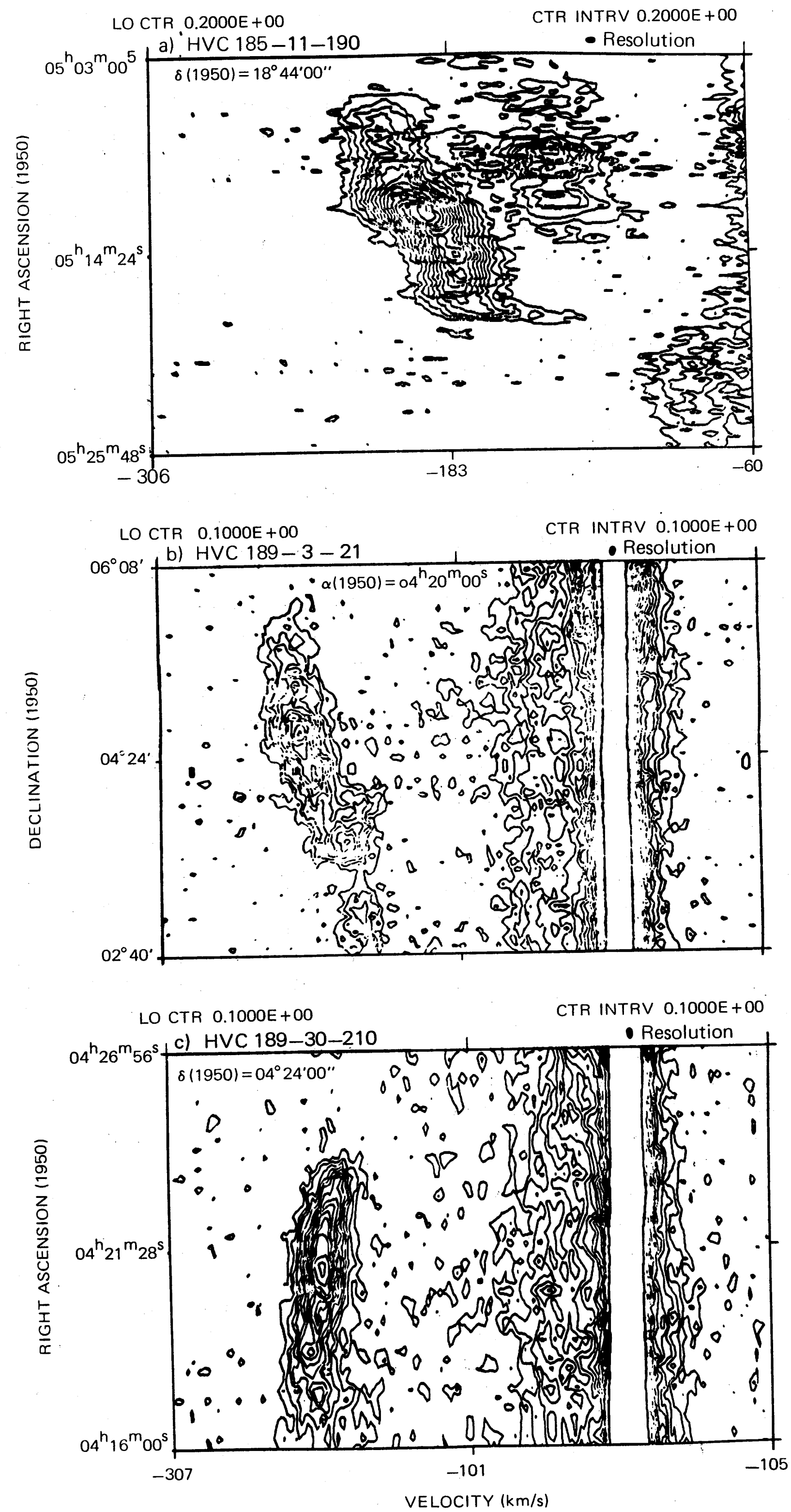


Fig. 4. Position-velocity maps of features in the anticenter complex. Observations were done with the 305-m radiotelescope of th Arecibo Observatory. Angular resolution is 3.′3 and velocity resolution 3 km s$^{-1}$. Lower contours and contour intervals are shown at th top of each map. *a)* Map of ACI for $\delta = 18°44'$. *b)* Map of ACIII for $\alpha = 04^h20^m$. *c)* Map of ACIII for $\delta = 04°24'$.

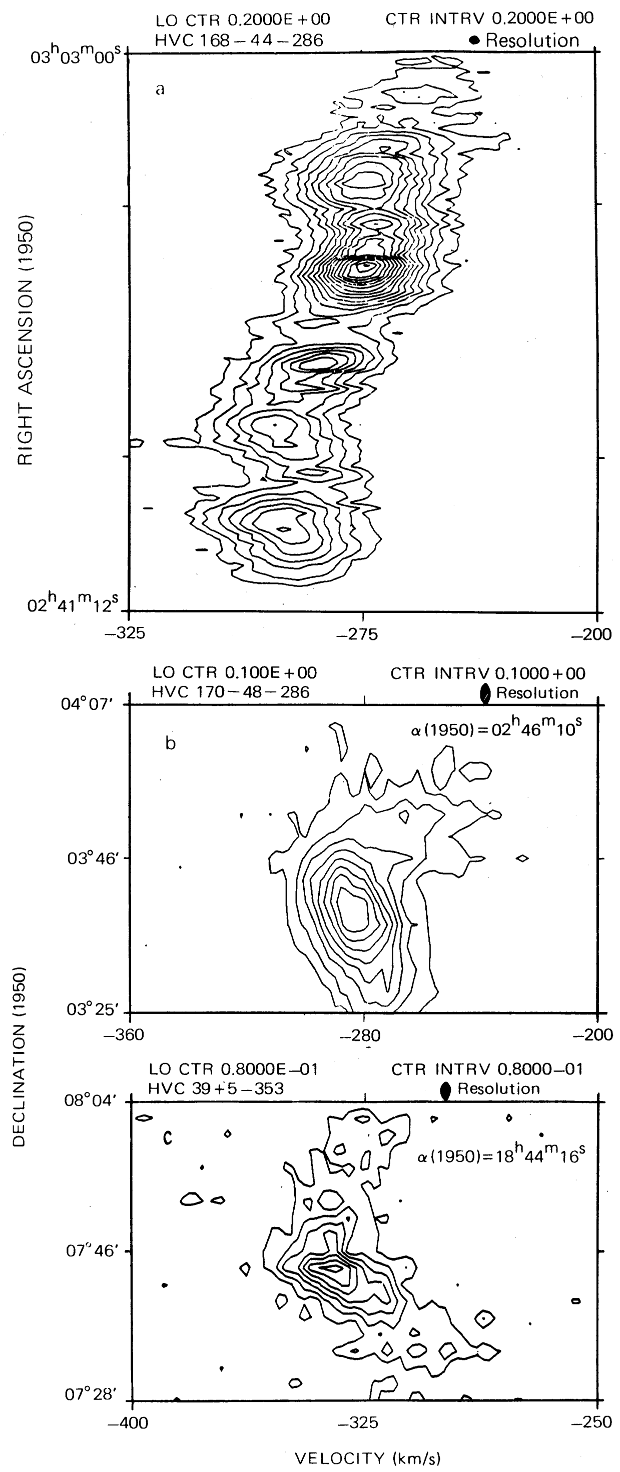


Fig. 5. Position-velocity maps of features with large negative velocities. Observations were done with the 305-m radiotelescope of the Arecibo Observatory. Angular resolution is 3ʹ.3 and velocity resolution 3 km $s^{-1}$. Lower contours and contour intervals are shown at the top of each map. *a)* Map of HVC 168−44−286 for $\delta = 08°54'$. *b)* Map of HVC 170−48−286 for $\alpha = 02^h 46^m$. *c)* Map of HVC 39 + 5−353 for $\alpha = 18^h 44^m 16^s$.

section of the Stream are breaking apart. Velocity differences of 25-35 km $s^{-1}$ are found betweeen adjacent clouds. The expansion age of the filaments falls at least a factor of ten short of the age predicted by current models.

The widespread population of clouds with large inward motions recently found in the southern galactic hemisphere is associated with the Magellanic Stream phenomenon. It has split from the main filaments and scattered throughout a large area of the sky.

These features tend to have elongated shapes with no sign of strong interactions with galactic material. Velocity variations of $\sim$ 20 km $s^{-1}$ within the condensations are common. Their large and small scale structure indicate that they are transient features located in the immediate intergalactic space. Some of the infalling material originated in the vicinity of the Magellanic Clouds has reached the outskirts of the Galaxy. Oort and Hulbosch (1978) interpret the complex of bright clouds in the northern galactic hemisphere (complex A) as infalling gas in the nearby galactic halo. This material may have the same origin as the Magellanic Stream and it is already penetrating the Galactic System, being considerably decelerated as it moves through the halo. The structural properties of the gas in complex A, indicate the occurrence of collisions with galactic H I. Shock waves lead to strong compressions that trigger the collapse of the gas producing the cooler condensations observed throughout the northern HVCs. It is interesting to note that fine velocity structure in the Magellanic Stream and other HVCs with large inward motions is not a widespread phenomenon.

Tidal models can account qualitatively for the elongated structure of HVCs. The large scale distribution in narrow bands and the small scale structure of condensations oriented along narrow filaments can be explained in terms of the effect on the gas by the tidal forces of the Galaxy.

The interpretation supported in this review implies a present flux of HI onto the Galaxy of 1 $M_\odot$ $yr^{-1}$. Such a large influx of matter must be considered in future studies of the large scale structure and evolution of the Galaxy.

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## DISCUSSION

*Peimbert*: ¿Cuál es la masa total de la corriente de Magallanes? ¿Se observa una diferencia entre los perfiles de las NAV (nubes de alta velocidad) que se originan en las Nubes de Magallanes y aquellas que se desprenden de nuestra galaxia?

*Mirabel*: Aproximadamente $5 \times 10^8$ masas solares, dependiendo de las distancias atribuídas por diferentes modelos de distancias. Existe la tendencia a observar estructura fina en velocidad en las NAV que están ubicadas a bajas latitudes galácticas. Ello puede implicar la presencia de elementos pesados en las nubes más cercanas al disco galáctico.

*Campins*: Si se acepta el modelo de de Vaucouleurs y Mattison las nubes también tendrían muy baja metalicidad, ya que serían material primordial.

*Mirabel*: Sí. Sin embargo el interpretar las NAV como materia primordial presentaría serias dificultades para explicar los resultados presentados en mi exposición.

*Morras*: En la sección anterior presenté resultados de una nube de alta velocidad positiva (HVC 287.5 + 22.5 + 240) cuya $V_{gsr}$ es del orden de 20-30 km $s^{-1}$ positiva y la estructura morfológica de los perfiles muestran que es similar a las NAV negativas del hemisferio norte ¿Cómo se explica eso?

*Mirabel*: Que esa estructura tenga una pequeña componente de velocidad positiva de 20 ó 30 km $s^{-1}$ no implica que ese objeto no está cayendo hacia el plano galáctico y que no pueda estar conectado a la estructura espiral exterior de la Galaxia.

*Serrano*: ¿Dentro del esquema propuesto, cómo se explican ahora las nubes de alta velocidad con $b > 0$ y $V_R > 0$?

*Mirabel*: Las nubes de alta velocidad positiva se encuentran en el tercer y cuarto cuadrante galáctico. Un primer grupo de ellas pertenece a la Corriente Magallánica en la sección más próxima a las Nubes de Magallanes y por consiguiente, su distancia es de 30 a 60 kpc. El segundo grupo se encuentra en latitudes galácticas menores que 25° y puede ser interpretado como material conectado a la estructura espiral exterior de la Galaxia.

Igor Félix Mirabel: Departamento de Física, Facultad de Ciencias Naturales, Universidad de Puerto Rico, Río Piedras, Puerto Rico 00931.