HIGH-VELOCITY CLOUDS

B.P. WAKKER
University of Illinois, Department of Astronomy, Urbana USA

INTRODUCTION

This contribution describes high-velocity clouds (HVCs), neutral hydrogen moving with velocities inexplicable by differential galactic rotation. They have been invoked as evidence for infall of gas to the Galaxy, as manifestations of a galactic fountain, as energy source for the formation of supershells, etc. It is becoming clear that a single model will not suffice to explain all HVCs. A better understanding is mainly hampered by the fact that the distance remains unknown. Many aspects to the study of HVCs will be discussed here.

1) Section 2 gives a historical overview of surveys and then describes some of the results of the latest surveys.
2) Section 3 discusses some attempts at distance determination.
3) Studies at high angular and velocity resolution are described in Sect. 4.
4) The appearance of HVCs at other wavelengths should give a better handle on their structure and environment. Unfortunately, only a very limited number of such detections exists (Sect. 5).
5) After knowing the observational facts, an interpretation is in order.
   In Sect. 6 an overview of various propositions is given.
   In Sect. 7 summarizes the conclusions and outlines outstanding problems.

SURVEYS FOR HIGH-VELOCITY NEUTRAL HYDROGEN

High-velocity gas was originally found by Muller *et al.* (1963). Surveys following this detection were at first fairly coarse and insensitive. Several of the brighter clouds were found: HVC 40-15+100 (Smith 1963), complexes A and C (Hulsbosch & Raimond, 1966) the "South Pole complex" (Dieter 1964), clouds M, AC I, AC II, AC III (Mathewson *et al.* 1966). All these detections revealed only gas at negative velocities relative to the LSR, which gave rise to the notion that HVCs have negative velocities and therefore must be falling into the Galaxy. After these initial surveys, ever more complete surveys were done: van Kuilenburg (1970, 1972) found the first few HVCs at positive velocity; the large and relatively sensitive survey by Meng

H. Bloemen (ed.), The Interstellar Disk-Halo Connection in Galaxies, 27–40.

& Kraus (1970) showed many negative-velocity HVCs; and Wannier *et al.* (1972) detected a large number of faint positive-velocity clouds.

Another paradigm that formed after the initial surveys was that HVCs are at high galactic latitude. However, Hulsbosch (1975) already described a cloud in the plane, HVC 131+1−200, which deviates by at least 70 km s^{-1} from galactic rotation and is one of the brightest HVCs. It was ignored in most further studies.

The "South Pole Complex" was eventually shown to be part of the Magellanic Stream (mapped by Mathewson *et al.* 1974). Most probably this is a tidal tail between the Magellanic Clouds and the Galaxy (Murai & Fujimoto 1980).

The first era of HVC surveys culminated in the study of Giovanelli *et al.* (1973) who mapped the three northern complexes A, M and C on a fully sampled grid with 10′ and 1.37 km s^{-1} resolution and 0.5 K rms. Even now this survey is unsurpassed in completeness for these three complexes. Structural features ranged in size from 10′ to 60°.

In the following years many clouds were observed with higher resolution or improved coverage. Wright (1974) discovered a very-high-velocity cloud (VHVC, having $v_{lsr} < -200$ km s^{-1}) . Many others were subsequently found (most notably HVC 110−7−465 and HVC 114−10−440, Hulsbosch 1978) and it became clear that many small VHVCs exist at southern galactic latitudes.

Giovanelli (1980) presented maps of AC I, II and III and of a stream from $(l,b)=(140°,-5°)$ to $(l,b)=(180°,-20°)$. Cohen (1981) studied HVC 160−50−110, which is a 10° long filament, coinciding with a similarly structured filament at −10 km s^{-1}. He also showed that a small cloud near $(l,b)=(165°,-45°)$ was the brightest spot in a complex with velocities up to −340 km s^{-1} (Cohen 1982). Mirabel & Morras (1984) made a sensitive survey around the galactic center. They found many small clouds at high negative velocities scattered on the sky. Together with the Anticenter clouds these clouds may provide evidence for an inflow of material toward the Galaxy.

Improvements in the sensitivity of radio receivers led to a survey by Giovanelli (1980) with the Green Bank 300-ft telescope. He found 800 HVC detections in 6000 spectra and thus estimated that they cover about 10% of the sky. His data allowed to make scatter diagrams of longitude against velocity, from which he showed that the distributions with respect to position, velocity and structure are very asymmetric: large and bright negative-velocity clouds occur mainly in the first two quadrants, while smaller and fainter positive-velocity clouds are seen in the third and fourth quadrants. Further, in the first two quadrants and the Anticenter region there is a population of clouds at very high negative velocities, well-separated in velocity from other HVCs. The separation suggests that these VHVCs have a different origin. The major drawbacks of this survey were the incomplete sky coverage and the fact that the beam was small compared to the grid.

The latest surveys repair these shortcomings. Hulsbosch & Wakker (1988) surveyed the whole sky north of declination −18° on a 1°×1° grid in galactic coordinates with the 25-m Dwingeloo telescope (35.′2 beam). The detection limit was 0.05 K (about $2 \cdot 10^{18}$ cm^{-2}). Bajaja *et al.* (1985) used the 25-m telescope at Villa Elisa (Argentina) to make a survey on a 2°×2° grid with detection limit

0.08 K south of −10°. In these surveys a large number of small clouds was discovered and previously-known objects were shown to be much more extended. Also, HVC 165−45−280 and the AC clouds were shown to be connected.

An analysis of the statistical properties of the combined new surveys is given by Wakker (1990a). The latitude distribution of the HVCs shows that they are not limited to high b, but that there is a concentration toward low b. Further, negative velocities are not as predominant as was apparent from the first surveys. This impression was created by their lower sensitivity and the fact that most of the, generally fainter, positive-velocity clouds are in the southern sky. However, the total amount and the sky coverage of high-velocity gas at negative velocities still is greater than that at positive velocities.

At the survey limit of 0.05 K, 11% of the sky is covered by gas having $|v_{lsr}| < 100\,\mathrm{km\,s^{-1}}$, an increase of a factor two over earlier surveys (detection limits ~0.2 K) (Wakker 1990a). Using ultra-violet absorption lines and assuming an element abundance one can probe much lower hydrogen column densities than in the 21-cm line. For instance, the Si II λ1260 line allows to detect material where $N_{HI} = 2{\cdot}10^{17}\,\mathrm{cm^{-2}}$. An extrapolation of the relation between sky coverage and detection limit down to this limit leads to the prediction that at that level between 30 and 60% of the sky should b covered by gas having $v_{lsr} < -100\,\mathrm{km\,s^{-1}}$. However, the sample of Danly (1989) contains 19 stars with D>1.5 kpc, in none of which absorption at $v_{lsr} < -100\,\mathrm{km\,s^{-1}}$ is detected. Unless the HVCs have low heavy element abundances this implies that, statistically, they are farther away than 1.5 kpc.

Wakker & van Woerden (1990) used the surveys to construct the first homogeneous catalogue of HVCs. This includes all known clouds and lists their properties. Ten different populations (groups of clouds occupying certain regions in l-b-v_{lsr} space) are defined, each of which may have different physical properties, origin and relation to the Galaxy. Figure 1 shows the l-v_{lsr} distribution of the catalogued clouds, with different symbols indicating different populations.

The catalogue was also used to construct the $\log N(>S)$ and $\log N(>\Omega)$ distributions of HVCs. The slopes of these relations can be explained if the HVCs have a mass spectrum $n(M)dM = N_\circ\ M^{-3/2}dM$, are related to the Galaxy and visible throughout it (Wakker & van Woerden 1990). The slope of this mass spectrum is similar to that found for H I in the disk (−1.87, Dickey & Garwood 1989) and molecular clouds (−1.6, Scoville & Sanders 1987).

DISTANCE DETERMINATIONS

The main problem in the study of high-velocity gas is the impossibility to use the velocity to determine a distance. The only practical method known is to search for interstellar absorption lines at the velocity of the HVC in spectra of probe stars with known distance (e.g. van Woerden *et al.* 1989).

Ever since HVCs were discoverd, probe stars have been observed but no convincing detection exists. In recent years much progress has been made, including the proof of the existence of heavy elements in at least a few HVCs (Songaila 1981,

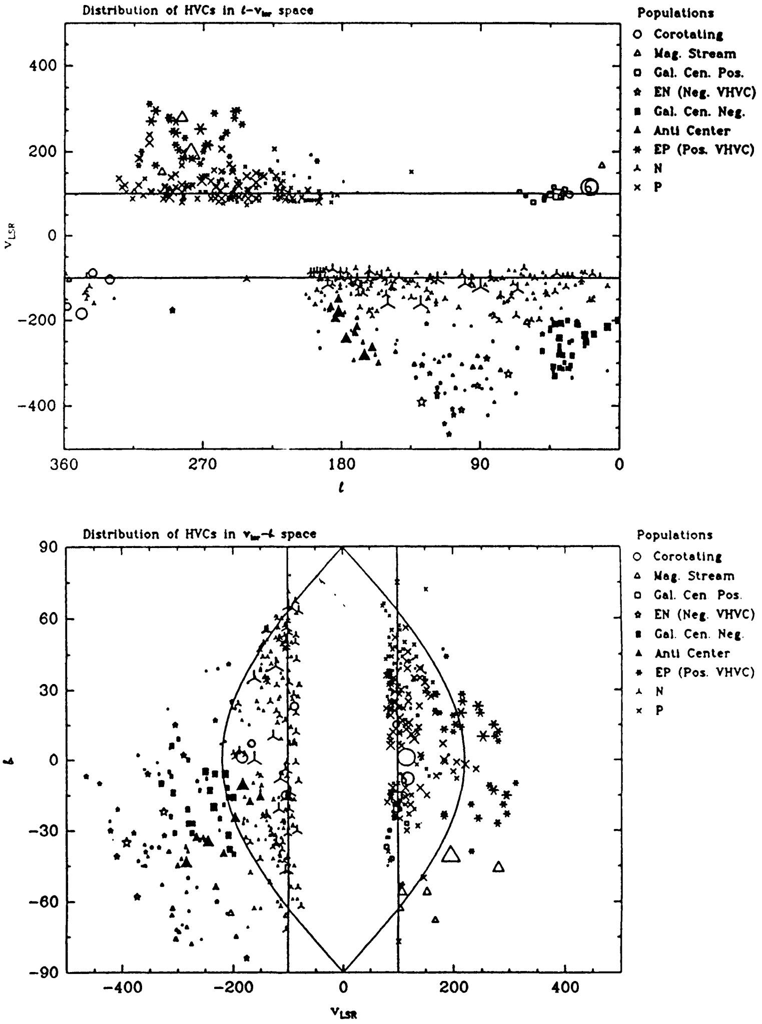

Fig. 1. Longitude-velocity and velocity-latitude distribution of HVCs in the catalogue of Wakker & van Woerden (1990).

West *et al.* 1985, Robertson *et al.* 1990). Songaila *et al.* (1988) claimed the detection of a line due to complex C in the spectrum of the star BT Dra, but Lilienthal *et al.* (1990) have shown that this line is likely to be stellar. In complex A two horizontal-branch stars have been observed and one in complex C, all lacking interstellar absorption at the HVC velocity (Pettini priv. comm., Schwarz *et al.* 1990).

As an extragalactic object projected against complex A does show a (faint) absorption (Schwarz *et al.* 1990), this would imply a distance larger than 5 kpc, but alternative explanations for the non-detections cannot be excluded at present.

FINE STRUCTURE

Up to the study of Giovanelli *et al.* (1973), HVCs were always observed with telescopes with half-degree beams. The cloud parameters they found at 10′ resolution were different from those previously known. Column densities went up, estimated sizes decreased. Linewidths, which used to be of the order of 20 km s^{-1} appeared to be around 8 km s^{-1}.

Cram & Giovanelli (1976) analyzed 300-ft spectra of positions in complexes A, C and M and found a two-component structure; one component with mean widths of 23 km s^{-1} and another with mean widths 7 km s^{-1}. The presence of two components correlates with cloud morphology: narrower lines are seen in the bright concentrations. The same two-component structure was subsequently also found in positive-velocity HVCs (Giovanelli & Haynes 1976, Cohen & Ruelas Mayorga 1980, Morras & Bajaja 1983). These observations were interpreted as evidence for two thermally stable phases in the clouds. The warm component has a temperature of order 10^4 K, giving rise to the broad lines. The cool component was supposed to have a temperature around 100 K, though the linewidths corresponded to a temperature of order 1000 K. Therefore the existence of fine structure in concentrations on scales smaller than the resolution of the telescopes used was predicted.

Aperture synthesis observations of high-velocity clouds were first carried out with the Westerbork telescope by Schwarz *et al.* (1976), who studied part of A 0 at 2′ resolution. Much fine structure was found, with sizes of order 5′ and peak brightness temperatures rising from the 2.2 K observed with a 35′ beam to 25 K. A breakthrough was the Westerbork study by Schwarz & Oort (1981), who mapped A I at 1′ and 2 km s^{-1} resolution. Their analysis confirmed the prediction that the brighter cores seen at 10′ resolution consist of many smaller concentrations, with sizes down to a few arcmin. The distribution of linewidths was very broad, with a modus at 5 km s^{-1}. Column densities were up to a few 10^{20} cm^{-2} and estimated volume densities varied between 25/ D_{kpc} and 100/ D_{kpc} cm^{-3} (with D_{kpc} the cloud distance in kpc). A remarkable feature was the fact that only 20% of the flux observed with a single-dish telescope is recovered in the WSRT maps. This indicates that the broad component indeed consists of warm gas and is not completely due to velocity crowding and beam smearing.

Since this study a large number of fields has been observed at Westerbork, i.a. five in the classical complexes A, M and HVC 131+1−200, and two VHVCs. A full description of these data is presented by Wakker (1990b) and Wakker & Schwarz (1990). Generally, the properties found by Schwarz & Oort are also found for these fields. In three fields 25% of the single-dish flux is recovered, while in the other three (including the two VHVCs) this is 40%. Estimates of the pressure show that it is likely that the hotter gaseous envelope is in equilibrium with the small cores. A

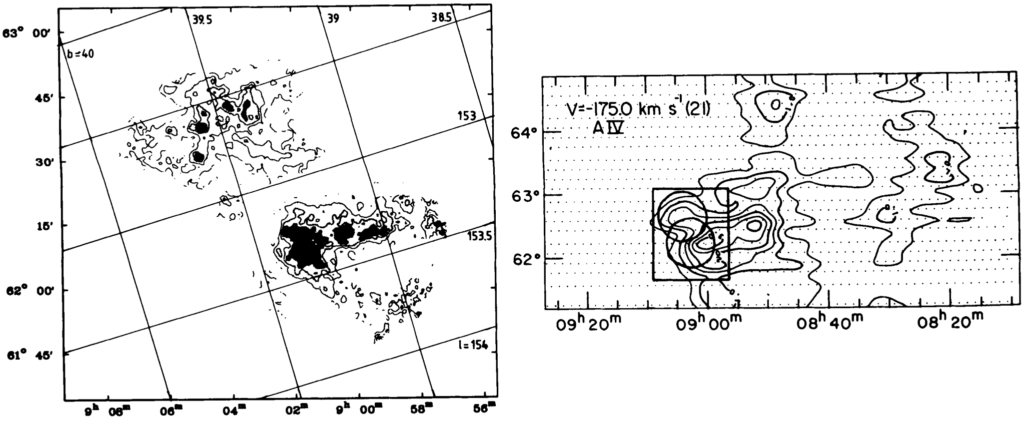

Fig. 2. Cloud A IV as observed with the Westerbork telescope.

comparison of timescales reveals that the fine structure within a cloud must evolve much faster than the whole cloud, so that different dynamical processes play a role to determine structure on different scales.

Density contrasts can be as high as 4 on scales of 4′. For absorption-line studies this implies there is considerable uncertainty in the derivation of abundances. A small feature in the line of sight to a halo star may provide a strong absorption component, but go undetected in a single-dish beam due to beam-dilution effects. Alternatively, a cloud seen in H I but not in absorption could in fact lie in front of the probe star, but be patchy so that most of the gas lies just off the line of sight to the star

At each position in the WSRT data cubes a gaussian fit was made to the spectrum. Usually only one component is present, but profiles with two or three components are common. From the fits one obtains the velocity field of the cloud and the linewidths of its profiles. There is much velocity structure, with both smooth gradients and erratic jumps occurring often, just as is observed on large scales in the survey data (see figures in Wakker 1990a and 1990b). The origin of this structure is not understood, but it probably is a mixture of a number of different causes, like projection effects, macro-turbulent motions, and motions guided by an embedding medium or magnetic fields.

The linewidths are generally rather small and have a broad distribution with modus at 3–6 $\mathrm{km\,s^{-1}}$ FWHM. The kinetic temperature of the gas is likely below a few 100 K. The measured peak brightness temperatures provide a lower limit of 30 K.

STUDIES OTHER THAN IN 21-CM EMISSION

To determine the gas temperature directly emission-absorption observations have often been tried. These studies are difficult because few bright continuum sources are projected against HVC emission bright enough to expect a detectable line. Further, such observations require a small beam, so that most single-dish telescopes are not useful. Payne *et al.* (1980) failed to find absorptions using the Arecibo telescope. An exhaustive study of all bright continuum sources visible from Arecibo by Colgan *et al.* (1990) also gave negative results only. However, the limits that they can derive for the temperature are not very stringent. Wakker *et al.* (1990) describe the only known detection, obtained with the Westerbork telescope HVC 131+1−200. The spin temperature of this object is shown to be ~50 K.

Observations of HVCs at other wavelengths have often been attempted, with very little success. On the POSS plates no enhanced emission or extinction can be discerned. Kutyrev (1985), Reynolds (1987) and Kutyrev & Reynolds (1989) have searched for Hα and Hβ emission from some of the brighter clouds. No clear-cut result was obtained in these studies, although there is one possible detection. Because of the extremely low signal-to-noise ratio and because the method of observation is beset with difficulties, progress is slow.

A search for 100 μm emission, using IRAS data (Wakker & Boulanger 1985) showed that the amount of far-infrared radiation from clouds M I and A III is less than expected. The non-detection is interpreted as: 1) the amount of dust in these two HVCs is at least a factor three below the minimum amount found in low-velocity neutral hydrogen or 2) the dust is very cool, which implies a minimum cloud distance of 10 kpc.

CO observations have often been tried, although the negative results were never published. Some integrations of many hours still showed no emission at the HVC velocity. However, assuming a "normal" ratio of H I to H_2 and of H_2 to CO, no strong lines are to be expected.

INTERPRETATIONS

The paper by Oort (1966) already brings forward most of the interpretations for HVCs. He discusses the following set:

a) they are parts of nearby supernova shells,
b) they are condensations formed in a gaseous corona of high temperature,
c) they have been ejected from the galactic nucleus,
d) they have been ejected as cool clouds from the galactic disk,
e) they are intergalactic gas accreted by the Galaxy,
f) they are gas clouds in the Local group (i.e. independent galaxies or small satellites of the Milky Way).

In later work a few other alternatives have been proposed:

g) they are high-z spiral arms,

h) they are connected with distant globular clusters and nearby dwarf galaxies in the Local Group,

i) they were drawn out from the Magellanic Clouds on a previous passage of these galaxies, just as the Magellanic Stream was drawn out during the last passage.

To assess the implications of the survey data for these explanations, modeling is necessary. Ballistic models have been constructed (Wakker & Bregman 1990) that are based on the scheme described below.

1) Choose a galactic potential.
2) Inject clouds into this potential according to some prescription. A prescription consists of specifying position, velocity and mass at the time of formation.
3) Follow the clouds in their orbit until they either disperse or are destroyed.
4) Determine at the end of the calculation the observables longitude, latitude, velocity relative to the LSR, flux, area and brightness temperature.

Cloud evolution is modelled in a very simple way: they are assumed to be pressure-confined throughout their lifetime and therefore always keep the same size. Only when clouds hit the gaseous disk are they assumed to be destroyed. At formation a mass is given to each cloud, chosen from a power-law spectrum ($n(M)dM = N_\circ\ M^\alpha dM$, $\alpha = -1.5$ from the survey data). Assuming the same average density for all clouds makes it possible to calculate the cloud radius. Together with the distance this gives the cloud flux, brightness temperature and area. Fitting the predicted $\log N(>S)$ and $\log N(>\Omega)$ relations to the data sets the scale of the model and allows to determine the total mass in high-velocity gas.

The main problem with these ballistic models is that the clouds are modeled as particles and that gas dynamics (e.g. drag forces) is ignored. However, the consistency of the predicted and observed sky and velocity distributions can be checked.

Below, each of the possible explanations is discussed in more detail.

a) The hypothesis that HVCs are nearby supernova remnants was already rejected by Oort because of their sky distribution, the fact that if they are shells only one side is visible, and the indication of lower distance limits of at least 500 pc. Over the years these arguments have only been strengthened.

b) The idea that hot gas in a galactic corona condenses to form cool H I clouds that fall back to the disk has gained popularity over the years. The circulation of gas implied in this model is known as the "galactic fountain" (Shapiro & Field 1976). Oort (1966) originally argued that if there is pressure equilibrium between the hot and the cool gas, friction would quickly slow down the clouds. However, later he argued (Oort 1978) that a strong argument in favor of the fountain model is the observed fine structure. The random velocity jumps combined with the presence of a warm and a cold gas phase are easy to understand within this model. Nevertheless, more theoretical work is needed, aiming at predicting the ratio between ionized and neutral material, and the kind of structure that can be expected.

Bregman (1980) found that the fountain model gives a good approximation when applied to predict the sky and velocity distributions of the HVCs with $|v_{lsr}| < 200\,\mathrm{km\,s^{-1}}$. The ballistic models of Wakker & Bregman (1990) fairly well reproduce the observed distributions (Fig. 3a). However, it is very difficult to produce

HVCs with $b > 45°$. Also, the VHVCs and the Anticenter complexes remain unexplained. The flow implied is $5\,M_\odot\,yr^{-1}$.

c) Ejection from the galactic nucleus does not seem to be a viable theory. The distribution of velocities on the sky is incompatible with this model (Oort 1966).

d) Oort (1966) calculated that it is possible that gas which was expelled from the galactic disk 70 Myr ago now appears near the Sun at a high negative velocity. Such gas could have been accelerated by the cumulative effect of many supernovae. However, to achieve the observed amount an excessive number is needed. Wakker & Bregman (1990) calculated a similar model under the name "cannonball" model. They show that the predicted velocities and latitudes are generally too low. Only some HVCs near the plane could originate this way.

e) If intergalactic gas clouds are falling into the Galaxy, they would be accelerated to the escape velocity (of the order of $450\,km\,s^{-1}$) of the Galaxy if there is no braking. When Oort (1966) first discussed this possibility, VHVCs were undiscovered and the highest known velocity was $200\,km\,s^{-1}$. He therefore argued that considerable deceleration must have occurred. With the discovery of VHVCs there is no need to assume deceleration and the hypothesis becomes more likely.

f) An explanation in terms of gas clouds moving around in the Local Group was also suggested by Oort (1966). He rejected this on the basis of 1) the large angular size of some clouds, 2) the structural similarity between HVCs and IVCs, some of which were shown to be nearby, 3) the preponderance of high negative velocities. Giovanelli (1977) argued that 4) the narrowness of the lines observed in most HVCs can not be reconciled with very large distances, as the velocity dispersions would be too low for the large masses implied. Currently the third argument can not be maintained, and for the VHVCs Oort's objections 1) and 2) are not valid: VHVCs are generally small, and Cohen & Mirabel (1979) and Wakker & Schwarz (1990) show that two VHVCs have a structure different from most other HVCs.

Three infall-type models are described by Wakker & Bregman (1990): The Pure Infall model, in which objects continuously flows in from intergalactic space; the Local Group model, in which clouds are assumed to have the velocity distribution of nearby ($D<300\,kpc$) dwarf galaxies; and the Circular Motion model, in which clouds can remain in orbit around the Galaxy for 10 Gyr. In each of these models VHVCs are predicted to occur. No model gives a fully satisfactory fit to the sky and velocity distributions, however. It is possible to reproduce the Anticenter complexes only if one of the more massive clouds happens to be at the proper place at the present time. Also, the observed North-South asymmetry is never reproduced. Therefore, the limit that can be put on the amount of material falling in from the Local Group is $0.1\,M_\odot\,yr^{-1}$.

A simple model in which the Magellanic Stream is seen as the source of HVCs (Fig. 3b) is able to reproduce the North-South asymmetry very easily. This model is too simplistic to provide a proper fit, but indicates that a connection with the Stream is likely. This explanation was put forward also by Giovanelli (1981), because VHVCs are not exclusively seen toward the central regions of the Local Group, their velocity distribution does not match that of the galaxies, and the

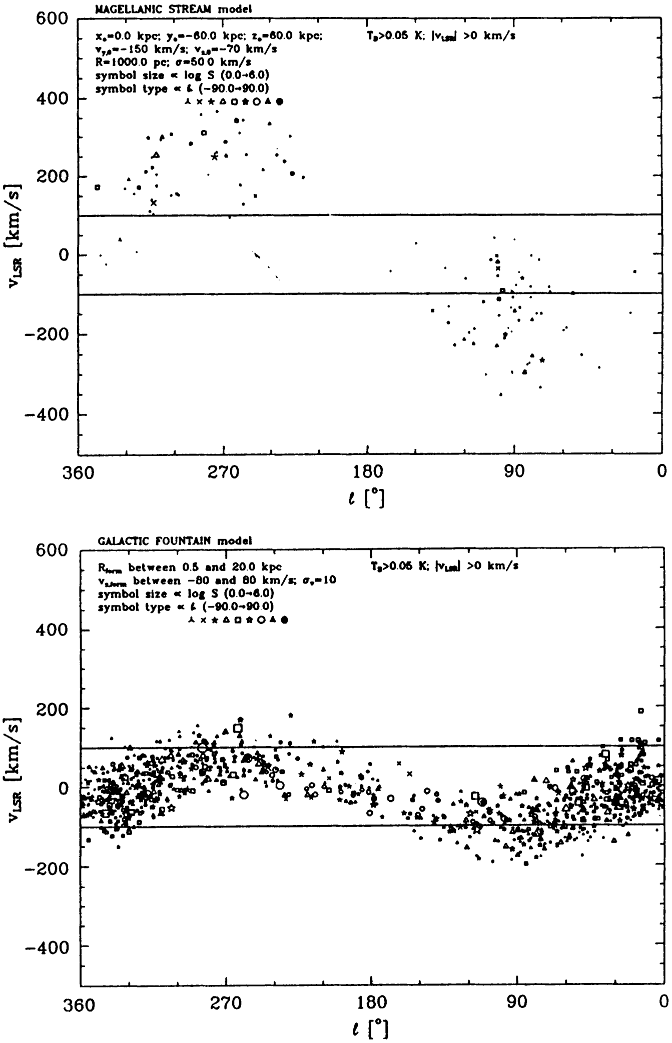

Fig. 3. Model predictions for the longitude-velocity distribution for the galactic fountain model and the one in which Magellanic Stream is the origin of the VHVCs.

internal motions imply instability, which is hard to accept if they are long-lived objects.

g) For the Outer Arm, Habing (1966) and Kepner (1970) made it likely that it is a spiral arm going up to very large heights above the disk. Davies (1972) and Verschuur (1973, 1975) suggested a similar explanation for the complexes A, C and M as relatively nearby high-z extensions of spiral arms. The deviating velocities are explained as due to instabilities (Davies 1972) or acceleration imparted by an intergalactic wind (Oort & Hulsbosch 1978). The positive-velocity HVCs were not properly included in this model. The "streams" of clouds that were defined are not confirmed by the later surveys.

h) Lynden-Bell (1976) proposed a connection of HVCs with distant globular clusters and the nearest dwarf galaxies in the Local Group, as some of these are seen projected on top of the large HVCs. However, the map that he used to find these coincidences is wrong and misleading. The idea of an association has stuck, however. Haud (1988) suggested that HVCs form a (broken) polar ring, mainly because the planes defined by the dwarf galaxies and the Magellanic Stream are at a small angle with each other and inclined by almost 90° to the galactic plane. As the northern counterpart of the Magellanic Stream he included complex C and many IVCs. A major problem with this model is that the plane defined by complex C is strongly inclined to that defined by the Magellanic Stream. More work is necessary to see if the new survey data can be reconciled with the polar ring model.

i) Oort & Hulsbosch (1978) considered the possibility that complex A was tidally separated from the Magellanic Clouds during the previous passage of these galaxies past our Galaxy. They rejected the hypothesis because of the very unlikely orbit it would have to follow.

The model calculations of Wakker & Bregman have shown conclusively that the fact that in the the veloicity asymmetry between the eastern and western galactic hemisphere is due to a reflection of the rotation of the LSR around the galactic center. Further, the existence of clouds with $|v_{lsr}| < -200\,\mathrm{km\,s^{-1}}$ near the Anticenter is very hard to reproduce. The North-South asymmetry in the distribution of VHVCs is only found when the Magellanic Stream is the source of the gas. In all infall-type models VHVCs are predicted to occur in large numbers also in the northern hemisphere. To strengthen these conclusions and obtain better fits more work is clearly needed.

It seems very likely that the observed distributions of l, b, v_{lsr}, flux and size can only be reproduced by a combination of two or more models, and hence that there are several sorts of HVCs, with different origins.

CONCLUSIONS

Based on the data and models, the following set of explanations seems the most promising: The Magellanic Stream is a tidal tail drawn out of the Magellanic Clouds by the Galaxy during their last passage (see Murai & Fujimoto 1980). The VHVCs are shreds of the Stream that were disconnected long ago (as proposed by Giovanelli 1981). Other clouds are part of a galactic fountain (Bregman 1980). Complex C is either part of the fountain or a high-z spiral arm (Davies 1972, Verschuur 1973) (these two explanations need not be mutually exclusive). A number of clouds near the galactic anticenter and center probably consist of material streaming toward the Galaxy (Mirabel 1989). The source of this infalling material still remains unclear, as it may be gas coming from nearby intergalactic space, from the Local Group, or even from the Magellanic Stream.

Many problems remain unsolved. The major problem is still that no direct distance determinations are available. To solve this it will be necessary to correlate the whole-sky maps with possible probes, to measure good values of the column density in the direction of the probe using high-resolution data and to obtain high-resolution optical or ultra-violet spectra to search for absorption lines from heavy elements at the HVC velocity.

It would be useful to make in-depth studies of several complexes. Especially a possible connection of the Anticenter complexes with the low-velocity gas in the Taurus Molecular Cloud needs attention. Also, the survey data could be used to unravel the velocity field of complex C. In both cases it will be necessary to include data on intermediate-velocity clouds, as many of these overlap in position with the HVCs (and sometimes even show structural similarities).

To understand the small-scale structures better, hydrodynamical modelling is in order. This should aim at the prediction of observable parameters, like linewidths, temperatures and structure. Such models may then also be used to give constraints on the galactic fountain model, which can provide the initial conditions for these models. Probably it is necessary to include magnetic forces. Therefore, attempts at measuring values of or limits to magnetic field strengths within HVCs are useful.

The ballistic models described by Wakker & Bregman (1990) still need improvements and extensions. A better description of the l-b-v_{lsr} distribution of the VHVCs must be searched for. Further, the influence of drag forces on cloud motion should be studied, and we need an improved description of cloud evolution.

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