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Effelsberg H I Survey of Compact High-Velocity Clouds

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Abstract. We studied 11 compact high-velocity clouds (CHVCs) in the 21-cm line emission of neutral hydrogen with the 100-m telescope in Effelsberg. We find that most of our CHVCs are not spherically-symmetric as we would expect in case of a non-interacting, intergalactic population. Instead, many CHVCs reveal a complex morphology suggesting that they are disturbed by ram-pressure interaction with an ambient medium. Thus, CHVCs are presumably located in the neighborhood of the Milky Way instead of being spread across the entire Local Group.

1. Introduction

High-velocity clouds (HVCs) were discovered by Muller, Oort, & Raimond (1963) in the 21-cm line emission of neutral atomic hydrogen (H I). HVCs are gas clouds which are characterized by high radial velocities incompatible with a participation in Galactic rotation. Braun & Burton (1999) introduced a subclass of isolated HVCs with small angular sizes of less than 2° FWHM. They compiled a catalog of 66 of these so-called compact high-velocity clouds (CHVCs) from the Leiden/Dwingeloo Survey of Galactic neutral hydrogen (Hartmann & Burton 1997) and proposed that their statistical properties were consistent with a distribution throughout the entire Local Group with distances of the order of 1 Mpc. The typical sizes of CHVCs would then be of the order of 15 kpc with typical H I masses of a few times 10^7 M$_\odot$.

We mapped 11 CHVCs from the Braun & Burton (1999) and de Heij, Braun, & Burton (2002) catalogs in 21-cm line emission with the 100-m telescope in Effelsberg to validate the results of Braun & Burton (1999). The high angular resolution of $9'$ HPBW allows us to extract the H I structure of these 11 CHVCs in much more detail than the previous Leiden/Dwingeloo Survey data. In section 2 we describe the sample selection and data acquisition, section 3 outlines our major results, and section 4 includes the summary and conclusions.

2. Sample selection and data acquisition

The 11 studied CHVCs were selected on the basis of earlier, less sensitive Effelsberg observations by two criteria. They still had to be classified as CHVCs in the improved catalog by de Heij et al. (2002), and the H I peak column density ratio between the Effelsberg data and the Leiden/Dwingeloo Survey had

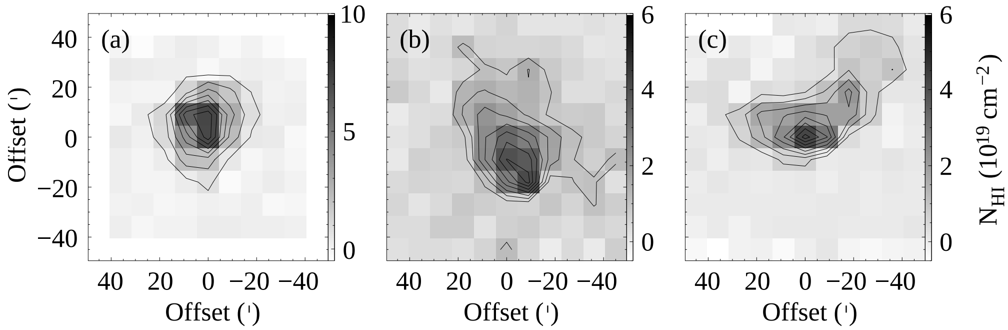

Figure 1. HI Column density maps of (a) spherically-symmetric CHVC 148−82, (b) head-tail CHVC 040+01 and (c) bow-shock shaped CHVC 172−60. Contour levels range from $N_{HI} = 5 \times 10^{18}$ cm^{-2} (1×10^{19} cm^{-2} in (b)) in steps of 5×10^{18} cm^{-2}.

to be $N_E / N_{LDS} \leq 3$ so that only the most compact CHVCs were selected for reinvestigation.

In general, each object was mapped with 11 × 11 spectra on a 9′ grid (beam-by-beam sampling). We reach a sensitivity of $\sigma_{rms} \approx 50$ mK at 2.6 km s^{-1} velocity resolution. These maps allow us to investigate the morphology of our 11 CHVCs and the overall distribution of radial velocities and linewidths of the HI gas. In addition, we observed spectra along an appropriate axis of each CHVC with a longer integration time and a smaller separation of 4.5′ or 6.4′ between the spectra. Along these deep profiles we reach a sensitivity of $\sigma_{rms} \approx 30$ mK, allowing us to obtain the column density profile in more detail.

3. Results

Table 1 summarizes the extracted physical parameters of the observed CHVCs, derived by fitting a Gaussian to the spectral lines. Radial velocities are mainly negative which is simply a selection effect. The mean linewidth of our 11 CHVCs is $\langle \Delta v \rangle = 23 \pm 7$ km s^{-1}, the mean peak brightness temperature is $\langle T_B \rangle = 1.6 \pm 0.8$ K, and the average peak column density is $\langle N_{HI} \rangle = (5.3 \pm 1.6) \times 10^{19}$ cm^{-2}. In some cases, we find evidence for two distinct gas phases in the spectral lines, indicating the existence of a core of cold neutral gas embedded in a diffuse envelope of warm neutral gas.

Among the 11 investigated objects, only CHVC 148−82 appears to be spherically-symmetric (fig. 1 (a)). All other clouds have a more or less complex morphology. 4 CHVCs reveal a head-tail structure which indicates that their envelopes of diffuse, warm gas are stripped off by ram-pressure interaction with an ambient medium. The conception of an interaction process is also supported by the distribution of radial velocities and linewidths across all 4 clouds. Fig. 1 (b) shows CHVC 040+01 as an example for a pronounced head-tail structure.

Another example for a head-tail CHVC is given in fig. 2 (a). CHVC 017−25 is a relatively compact object, and its slightly asymmetric shape already indicates that gas might have been stripped off the cloud, creating a diffuse, faint

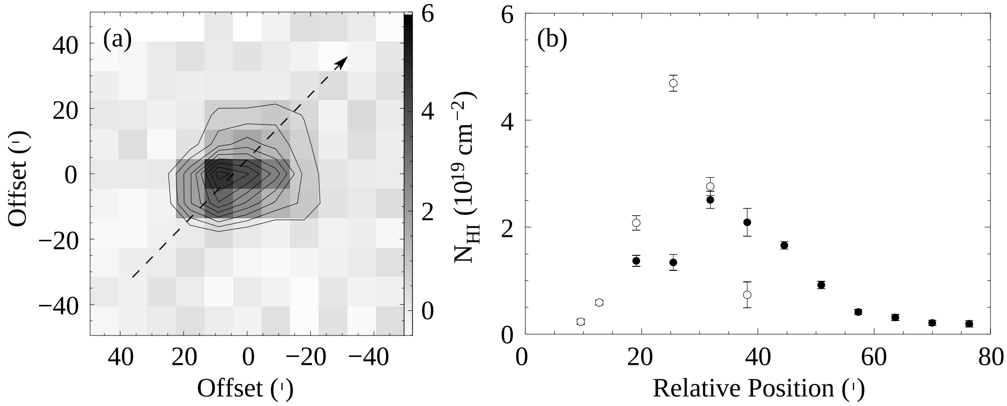

Figure 2. CHVC 017 25. (a) H I column density map. Contours range from $N_{HI} = 5 \; 10^{18}$ cm ^{2} in steps of $5 \; 10^{18}$ cm ^{2}. The dashed arrow marks the position of the deep pro le. (b) H I column density distribution of cold (open circles) and warm (lled circles) neutral medium along the pro le.

tail in north-western direction. Furthermore, CHVC 017 25 shows a clear two-component structure in the H I line pro les. Spectral lines seem to disclose a superposition of a narrow Gaussian component of cold gas and a broad component of warm gas. The cold component shows line widths of about 7 km s ^{1} FWHM, resulting in an upper limit for the gas temperature of roughly 1000 K. The warm component discloses much larger line widths around 20 km s ^{1} FWHM, indicating an upper limit for the gas temperature of about 9000 K. Both gas components can be investigated separately by a Gaussian decomposition of the spectral lines. Fig. 2 (b) shows the distribution of H I column densities of the cold (open circles) and warm (lled circles) gas along the pro le indicated by the dashed arrow in g. 2 (a). One can clearly distinguish a compact cold core surrounded by an extended, di use envelope of warm gas. Furthermore, the cold core and the warm envelope are spatially separated from each other. At the south-eastern edge of the cloud, only the cold gas can be traced while the warm gas forms an extended, faint tail in north-western direction. These results suggest that the di use envelope of warm gas is currently being stripped o the compact cold core of CHVC 017 25 by ram-pressure interaction with an ambient medium.

Two CHVCs from our sample show up with a bow-shock shaped structure which again indicates the existence of an ambient medium. Fig. 1 (c) shows CHVC 172 60 as an example for a bow-shock shaped object. In both CHVCs, radial velocities indicate that the gas is decelerated at the presumable front of the cloud. At the same time, linewidths increase, indicating higher turbulence or heating of the gas. Again, these observations can best be explained by ram-pressure interaction with a medium surrounding the CHVCs.

The remaining 4 CHVCs from our sample reveal an irregular shape. Some of these irregular clouds have large radial velocity gradients, suggesting a rotation. In all cases, the irregular morphology again indicates a disturbance of the objects.

Table 1. Physical parameters of the 11 observed CHVCs. l and b are the Galactic longitude and latitude of the column density maximum, v_{LSR} and v_{GSR} the column density weighted average radial velocities in LSR and GSR frames, v the average linewidth (FWHM), T_B the observed peak brightness temperature, and N_{HI} the HI peak column density.

Name (CHVC l b)	v_{LSR} (km s^{1})	v_{GSR} (km s^{1})	v (km s^{1})	T_B (K)	N_{HI} (10^{19} cm ^{2})
CHVC 016.8 25.2	228	171	14	3.1	5.6
CHVC 032.1 30.7	308	207	30	1.3	6.0
CHVC 039.0 33.2	262	147	22	1.6	8.0
CHVC 039.9+00.6	278	137	32	0.7	4.5
CHVC 050.4 68.4	195	133	27	1.3	4.7
CHVC 147.5 82.3	269	254	22	2.2	8.0
CHVC 157.1+02.9	184	98	22	0.9	3.6
CHVC 172.1 59.6	235	219	28	0.9	4.2
CHVC 218.1+29.0	+145	+27	6	2.8	3.2
CHVC 220.5 88.2	258	263	22	1.0	3.7
CHVC 357.8+12.4	159	167	27	1.5	6.4

4. Summary and conclusions

We showed that 10 of our 11 investigated CHVCs reveal a complex structure and that many of them show signs for ram-pressure interaction with a surrounding medium. This is in opposite to the original idea of CHVCs being the gaseous counterparts of primordial Dark-Matter halos spread across the entire Local Group. Instead, the observed ram-pressure effects and different distance estimates (Westmeier 2003) indicate that CHVCs constitute a circumgalactic population with typical distances of the order of 100 kpc. At such distances, the observed interactions could be caused by an extended Galactic halo gas. Typical HI masses of CHVCs would then be of the order of a few times 10^5 M with typical sizes of about 1 kpc.

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