Astron. Astrophys. 338, 200–208 (1998)

ASTRONOMY AND ASTROPHYSICS

Westerbork HI observations of two High-Velocity Clouds

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Received 22 January 1998 / Accepted 18 February 1998

Abstract. Westerbork HI synthesis observations are presented for the directions of the stars 4 Lac and HD 135485. Interstellar absorption lines at high velocities had been reported in the UV spectrum of 4 Lac, setting an upper limit of 1.2 kpc on the distance of the associated, small HI cloud (Bates et al. 1990, 1991). The Westerbork observations show that this cloud ($l = 100^{\rm o}$, $b = -7^{\rm o}$, $v_{\rm LSR} = +100$ km s^{-1}), which must have a high velocity relative to the surrounding disk gas, consists of two small condensations; the observations provide constraints on their mass and density, and indicate that the metallicity of this cloud is close to solar. For HD 135485, Albert et al. (1993) had found high-velocity absorption lines in optical spectra, but later reports indicate that these lines are probably circumstellar. The Westerbork observations around HD 135485 show that the HI found here is part of a larger HVC complex, Complex L, described by Wakker & van Woerden (1991). For both objects, the Westerbork results are compared with Jodrell Bank single-dish observations.

Key words: ISM: clouds – Radio lines: ISM – ISM: individual objects: HVC 100–7+100, HVC 347+35–112

1. Introduction

1.1. *Definition and properties of High-Velocity Clouds; outline of this paper*

High-Velocity Clouds (HVCs) are concentrations of atomic hydrogen gas whose velocities are incompatible with simple models of differential rotation in the Galactic Disk. In practice, HVCs are generally defined in terms of a lower limit on the absolute value of the LSR velocity, e.g. 80 km s^{-1} (at $|b| > 10^{\rm o}$). Sizes vary from a few arcminutes to more than 10 degrees; column densities range up to 10^{20} atoms cm^{-2}. For reviews of the subject see Wakker (1991) and Wakker & van Woerden (1997).

In view of their anomalous velocities, HVCs probably lie outside the Galactic Disk, in the Halo. However, even 30 years after their first discovery (Muller et al. 1963), the origins of most HVCs remain unknown. The most likely origins appear to be: infall of debris from tidal interactions between the Galaxy and the Magellanic Clouds, and circulation of gas between the Disk and the Halo, driven by violent events in the Disk (Wakker & van Woerden 1997).

A key problem in the investigation of origins is the lack of information about the distances of HVCs, and thus about their precise locations within the Milky Way. Upper and lower limits to HVC distances may, in principle, be derived from the presence or absence of absorption by metal ions at the HVC's velocity in spectra of stars at various distances. In most HVCs investigated, metal ions have indeed been found present through their absorption in the spectra of extragalactic background probes (Schwarz et al. 1995, Wakker & van Woerden 1997). However, so far only few solid distances are available (Wakker & van Woerden 1997).

For two smaller clouds, which we name HVC 100–7+100 and HVC 347+35–112, upper distance limits were reported several years ago, although for the latter cloud the limit is no longer valid (see below). For these two clouds, we have used the Westerbork Synthesis Radio Telescope in the 21-cm HI line, in order to determine their small-scale structure and measure their physical properties. Together with single-dish observations obtained at Jodrell Bank, the Westerbork maps further provide improved HI column densities on the lines of sight to the stars, and hence (for HVC 100–7+100) improved metal ion abundances.

In the remainder of this section, we summarize previous information on HVC 100–7+100 and HVC 347+35–112. Sect. 2 describes the Westerbork observations and their reduction. Sect. 3 discusses the results. Sect. 4 gives conclusions.

1.2. *HVC 100–7+100*

Bates et al. (1990) found interstellar absorption lines of several ions (AlII, FeII, MgI, MgII, OI) at $v_{\rm LSR} \approx +100$ km s^{-1} in IUE spectra of the star 4 Lac (= HD 212593), which lies at 1.2 kpc distance in $l = 99.90^{\rm o}$, $b = -6.71^{\rm o}$. (Ultraviolet and visual absorption at $v_{\rm LSR} \approx +80$ km s^{-1} had earlier been found in several stars over a region of 40 by 30 degrees (Bates et al. 1983), and a possible association with the Radio Loops II and III suggested.) At Jodrell Bank, 21-cm HI emission at $v_{\rm LSR} = +100$ km s^{-1} was found on the position of 4 Lac (with $T_{\rm b} \approx 0.10$ K and FWHM ≈ 20 km s^{-1}), but not at neighbouring

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positions, suggesting that the absorbing cloud was quite small (Bates et al. 1991). Van Woerden (1993) noted that this cloud, to be called HVC 100–7+100, had not been detected in the Dwingeloo survey of Hulsbosch & Wakker (1988). Assuming a distance of D kpc for the cloud, he derived limits of $0.35D^2$ and $80D^2M_\odot$ for its HI mass; the lower value followed from the Jodrell Bank observation, assuming the cloud to be small and centred on the star; the higher value was valid if the cloud was located at $l = 99.50^o$, $b = -6.50^o$, and had the largest brightness and size consistent both with the Jodrell Bank observation and with the non-detection at the four surrounding Dwingeloo grid points.

The star 4 Lac sets an upper limit of 1.2 kpc on the distance of this HVC, and hence of 140 pc on its distance from the Galactic plane (van Woerden 1993). This places HVC 100–7+100 *within* the generally assumed boundaries of the Galactic HI layer. On the other hand, since in this direction differential Galactic rotation leads to negative velocities, this HVC must have a velocity of at least 100 km s^{-1} with respect to its surroundings. These facts made this HVC a very unusual one. We undertook Westerbork observations in order to derive its size, structure, mass and further physical properties.

1.3. HVC 347+35–112

CaII K-line absorption was observed by Albert et al. (1989, 1993) at LSR velocities of -98 and -127 km s^{-1} in the star HD 135485 ($l = 347.31^o$, $b = +35.46^o$, distance 2.4 kpc, z height $+1.4$ kpc), but not in three neighbouring stars: HD 135230 ($D = 200$ pc), HD 135681 ($D = 170$ pc), and HD 138485 ($D = 300$ pc). Van Woerden (1993) noted that the position of HD 135485 and both absorption velocities lie within the ranges covered by HVC Complex L (Wakker & van Woerden 1991), which consists of several small clouds, together covering only 22 square degrees, and with l, b, $v_{\rm LSR}$ averages 346^o, $+34^o$, -112 km s^{-1}. At an assumed distance of 1 kpc this HVC complex would have a mass of $300M_\odot$. In what follows, we use the star's position in naming the HI observed in the field around HD 135485: HVC 347+35–112.

The distance bracket $0.3 < D < 2.4$ kpc suggested by Albert et al. (1989) prompted us to obtain Westerbork observations in the direction of HD 135485, and derive the small-scale structure, HI column density and Ca$^+$ abundance of this HVC. Meanwhile, Albert et al. (1993) noted that ultraviolet spectra of this star are complex, revealing possible stellar wind features and suggesting that the optical absorption lines found might be attributable to circumstellar, rather than interstellar, material. After the present study had been essentially completed, analysis of the ultraviolet spectrum of HD 135485 led Danly et al. (1995) to the firm conclusion that the high-velocity CaII absorptions must be circumstellar. We discuss the consequences of this in Sect. 3.2.

2. Observations and reduction

2.1. The observations

The HI synthesis measurements were obtained with the Westerbork Synthesis Radio Telescope (WSRT); this instrument consists of 10 fixed and 4 movable parabolic dishes of 25 metres diameter, together spanning a baseline of 2.8 km. A $12^{\rm h}$ integration produces a map of a field as large as the primary beam (FWHM of $36'$). In such a map each source produces grating responses in form of ellipses, with diameters of $20'$ in right ascension and $20'(\sin\delta)^{-1}$ in declination, and multiples thereof. Doubling the integration time, with the movable telescopes moved to different positions, results in doubling of the diameters of the grating responses. We used $2 \times 12^{\rm h}$ integrations; therefore the smallest grating responses had radii of $20'$ and $20'(\sin\delta)^{-1}$ in α and δ, respectively. This can cause confusion problems for extended objects; see Sect. 3.2.

Another shortcoming of synthesis observations in general is the lack of short-spacing information; the shortest spacing available to us was 36 meters. As a result, very large structures (e.g. a constant background across the primary beam) are not detectable.

The parameters of our observations are summarized in Table 1.

2.2. Calibration of the data

The data were calibrated by observing standard point sources, before and after each $12^{\rm h}$ integration, for 30 minutes on each of two frequencies, shifted 2 MHz (i.e., 422 km s^{-1}) on either side from the central frequency used on the HVC field. The shift is necessary to avoid Galactic absorption effects in the calibrator observations.

From the observations of the calibrators we derived gain and phase corrections, making use of "redundancy" (Wieringa 1992), and moreover using the self-cal method (Noordam & de Bruyn 1982). The averages of gains and phase corrections from all four calibration observations were applied to the data, for each velocity.

2.3. Additional smoothing

Since the signals were very weak, we used only baselines up to 1440 meters, giving basic angular resolutions of $24''$ by $24''(\sin\delta)^{-1}$. In order to improve the signal/noise ratio, we performed additional smoothing in right ascension and declination, resulting in synthesized beams as given in Table 1. Also, we performed box smoothing in velocity over seven channels, resulting in a velocity resolution of 7.6 km s^{-1}.

2.4. Cleaning of the maps

The grating responses at $20'$ distance (Sect. 2.1) can result in confusion problems for extended structures. The first object, HVC 100–7+100, turned out to be so small that the grating responses cause no problems, although the missing short spacings

Table 1. Observational parameters of WSRT HI obervations of HVC 100–7+100 and HVC 347+35–112

	HVC 100–7+100		HVC 347+35–112	
Observing date	1992 Sept. 3/4 and 7/8		1992 Sept. 4 and 8	
Total observing time	$2 \times 12^{\rm h}$		$2 \times 9^{\rm h}$	
Spacings	36 m (171λ), 72 m (341λ)...to 1440 m (6820λ)			
Grating ellipse				
Radius in α	$20.2'$		$20.2'$	
Radius in δ	$26.3'$		$79.8'$	
Phase and Pointing centres				
$\alpha(1950)$	$22^{\rm h}22^{\rm m}32^{\rm s}$		$15^{\rm h}12^{\rm m}58.45^{\rm s}$	
$\delta(1950)$	$+49^{\rm o}15'0''$		$-14^{\rm o}30'30.02''$	
$l(1950)$	$99.92^{\rm o}$		$347.31^{\rm o}$	
$b(1950)$	$-6.69^{\rm o}$		$+35.46^{\rm o}$	
Primary beam HPBW	$36'$			
Spectrometer				
Number of channels	256		256	
$v_{\rm LSR}$	-70 km s^{-1} to $+194$ km s^{-1}		-172 km s^{-1} to $+92$ km s^{-1}	
Channel separation	1.03 km s^{-1}		1.03 km s^{-1}	
Resolution				
Velocity resolution	2.06 km s^{-1}	7.6 km s^{-1}	2.06 km s^{-1}	7.6 km s^{-1}
Synthesized beam ($\Delta\alpha\cos\delta \times \Delta\delta$)	$107'' \times 140''$	$302'' \times 396''$	$23'' \times 155''$	$210'' \times 880''$
Grid separation	$40'' \times 40''$	$80'' \times 80''$	$10'' \times 40''$	$80'' \times 80''$
$T_{\rm b}$ for 1 mJy beam^{-1}	0.040 K	0.0051 K	0.170 K	0.0033 K
Sensitivity (RMS noise)				
[mJy beam^{-1}]	8	6	5	6
[K]	0.3	0.03	0.9	0.02

can still distort our observations. However, for HVC 347+35–112 the grating responses give serious problems. Moreover, since this object is at negative declination, only part of the required $12^{\rm h}$ hour-angle coverage could be obtained. This results in a synthesized antenna beam (or point spread function) with strong (positive or negative) side-lobes, as shown in the first panel of Fig. 4. Striking are the butterfly-like near side-lobes and the x-shaped "spokes" at greater angular distance.

The method CLEAN (Högbom 1974, Schwarz 1978) was used to remove side-lobe effects as much as possible. For HVC 100–7+100 cleaning is straightforward; but for HVC 347+35–112, where the u v plane is not fully sampled, cleaning can give ambiguous results. In order to set additional constraints, we chose two regions (see Fig. 1) where cleaning was allowed to put δ-functions. The cleaned channel maps for the appropriate velocities are displayed in Figs. 2 and 4 for the two objects. The first two panels give the synthesized antenna-pattern and the continuum map, respectively; the third panel shows the distribution of HI column density in the HVC (Sect. 2.5).

2.5. Total HI

The HI column density (sometimes called "total HI") in the HVC was derived by adding those parts of the CLEANed data cube which show significant radiation (above 3σ); for this a 3-D CLEAN was used, with a 3-D Gaussian restoration beam. The intensities $S_{\rm b}$ given in mJy beam^{-1} were scaled into brightness temperatures $T_{\rm b}$ [K] using:

$$T_{\rm b} = \frac{c^2}{2k\nu^2}\frac{S_{\rm b}}{\Omega_{\rm b}} = \frac{605.7{\rm K}\ S_{\rm b}[{\rm mJy}]}{b_x b_y[{\rm arcsec}^2]}\left(\frac{\nu_0}{\nu}\right)^2 \quad (1)$$

where c: velocity of light, k: Boltzmann's constant, ν: frequency of observation, ν_0: frequency of 21-cm line, $S_{\rm b}$: flux density per synthesized beam, $\Omega_{\rm b}$: beam solid angle, b_x and b_y: FWHM of synthesized clean beam (assumed to be Gaussian) in right ascension and declination. The values b_x and b_y are listed in Table 1. The column density $N_{\rm HI}$ is then:

$$N_{\rm HI} = 1.823 \times 10^{18}{\rm cm}^{-2} \sum T_{\rm b}\Delta v[{\rm K\ km\,s^{-1}}]. \quad (2)$$

The resulting maps are shown in the top-right panels of Figs 2 and 4. The maps are based on the WSRT observations only, and are not corrected for the missing short spacings, nor for the sensitivity differences in the primary beam. These corrections are applied in the later stages of the reduction: Sects. 2.6 and 2.7.

2.6. 21-cm line spectra

From the 3-D cleaned data cube we have determined HI-line spectra for specific areas of sky, by plotting the brightness tem-

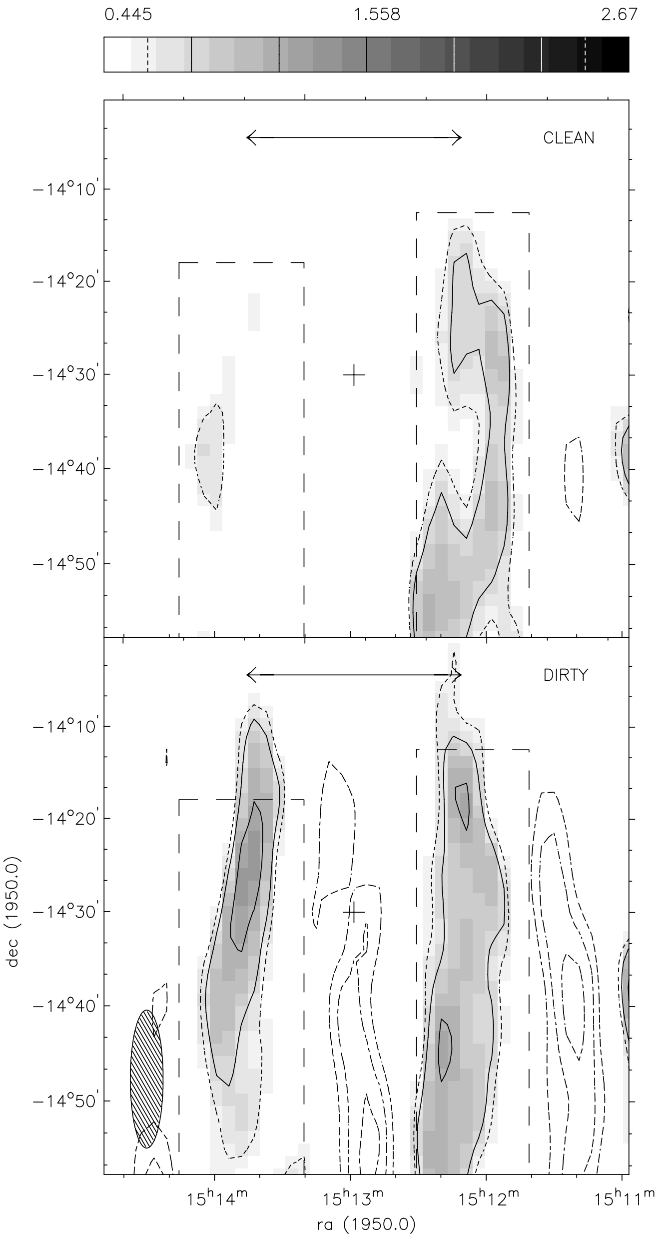

Fig. 1. Example of cleaning. The grating ring responses at a distance indicated by the horizontal arrow can give ambiguities. CLEAN can further have problems with the strong negative sidelobes (30%); in order to avoid such problems, two boxes around the strongest two positive features were defined, in which searching by CLEAN was allowed.

peratures averaged over such areas as a function of radial velocity. In Fig. 3a and b we consider the following spectra, all calculated for the position of the star 4 Lac:

1. The spectrum measured at Westerbork, within the synthesized beam resulting from the smoothing operations described above (and corrected for the sensitivity differences within this synthesized beam).
2. The spectrum measured with the 76-meter single dish at Jodrell Bank (beam: FWHM = 12 arcmin) by Bates et al. (1991).
3. The Westerbork spectrum averaged over the Jodrell Bank beam (assumed to be Gaussian, with 12 arcmin FWHM).
4. A combination: Spectrum 1 + Spectrum 2 – Spectrum 3, as discussed in Sect. 2.7.

Since a synthesis telescope is insensitive to extended sources of radiation, an averaged Westerbork spectrum may contain less flux than the corresponding single-dish spectrum (see Sect. 3.1).

2.7. Estimate of the column density $N_{\rm HI}$ at the position of the star

The column densities given by Eq. 2 had to be corrected for the primary beam (Sect. 2.6) and for the effects of the missing short spacings. The usual method for the latter correction is to process a series of single-dish maps (obtained from a raster of spectra around the field centre of the synthesis map), in order to extract the missing $u\,v$-data (zero spacing and short spacings). This method requires a considerable amount of single-dish data, and moreover has some fundamental drawbacks (Schwarz & Wakker 1991). Since we were interested mainly in $N_{\rm HI}$ at the star's position, $N^*_{\rm HI}$, we could use a simpler approach, described by Schwarz et al. (1995). In short this method consists of observing the HI spectrum at the position of the star with a large single-dish telescope (Spectrum 2 in Sect. 2.6); then subtracting from this the spectrum of the fine-structure, found from the synthesis observations and smoothed with the single-dish beam (Spectrum 3); and finally adding the unsmoothed synthesis spectrum (Spectrum 1). The resulting Spectrum 4 (≡ Sp. 1 + Sp. 2 –Sp. 3) is a good approximation of the true spectrum at the star's position.

2.8. Derived physical parameters

If the distance D is known, the mass $M_{\rm HI}$ of atomic hydrogen in the object can be derived from the column-density (or "total hydrogen") map:

$$\begin{aligned} M_{\rm HI} &= m_{\rm HI} D^2 \int\limits_{\rm HVC\ Area} N_{\rm HI}(\alpha,\delta){\rm d}\alpha{\rm d}\delta \qquad (3)\\ &= 0.188\times10^{-6} M_\odot\,(D[{\rm kpc}])^2 \sum_i N^{(18)}_{{\rm HI}i}\Delta\alpha['']\Delta\delta[''] \end{aligned}$$

where $m_{\rm HI}$ is the mass of the hydrogen atom, and $N^{(18)}_{{\rm HI}_i}$ is the column density at position i in units of $10^{18}{\rm cm}^{-2}$.

The density $n_{\rm HI}$ can be derived if we can make an estimate of the line-of-sight dimension of the cloud, L. The usual assumption is made that L is similar to the smallest dimension of the cloud across the sky, $\beta_{\rm min}$; this assumption holds for spheres and for filamentary objects, but not for "pancakes". Then:

$$\begin{aligned} n_{\rm HI} &\equiv N_{\rm HI}/L \qquad (4)\\ &= 66{\rm cm}^{-3} N^{(18)}_{\rm HI}\frac{1}{D[{\rm kpc}]}\frac{1}{\beta_{\rm min}['']} \end{aligned}$$

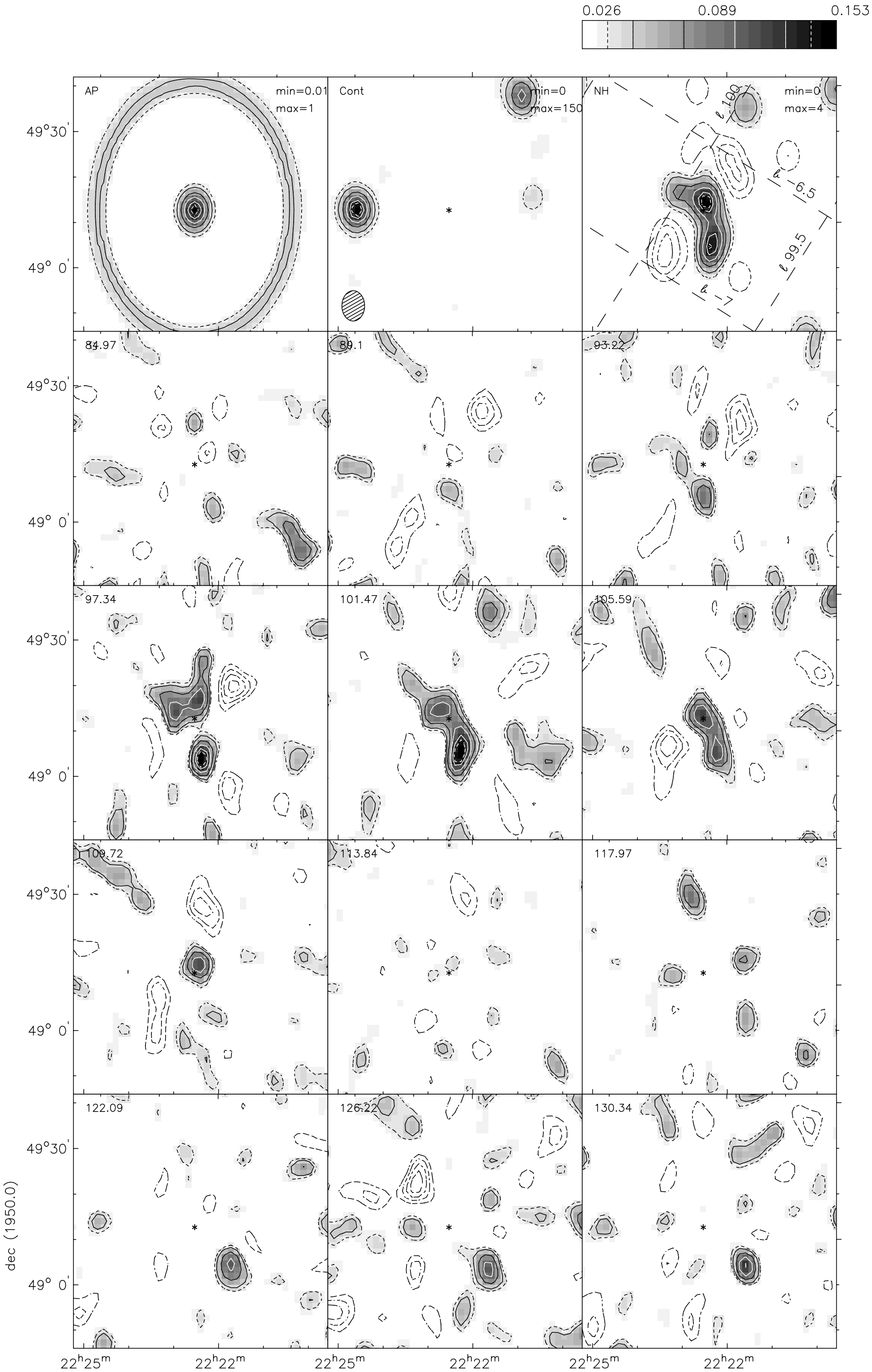

Fig. 2. Maps of HVC 100–7+100. The top-left panel shows the synthesized beam, with maximum 1. The top-middle panel shows the continuum; the two background sources have fluxes of 155 and 100 mJy, respectively. The top-right panel gives the HI column densities (or "total hydrogen"); contour values, in units of 10^{18} atoms cm^{-2}, are -0.66, -0.33, $+0.33$ (dashed), $+0.66$, $+1.33$, $+2.0$, $+2.67$, $+3.33$. The remaining panels show monochromatic brightness distributions, at velocities spaced by 4.13 km s^{-1} from $+85.0$ to $+130.3$ km s^{-1}, as given in the top-left corner of each panel; brightness temperatures are shown in gray-scale, identified by scale-bar at top-right, and by contours, with values 0.038 K (dashed), 0.051 K, 0.077 K, 0.102 K, 0.128 K and 0.140 K (dashed). Velocity resolution: 7.6 km s^{-1}; angular resolution: $302'' \times 396''$ (FWHM), shown by hatched ellipse in continuum panel. The position of the star 4 Lac is marked by an asterisk.

3. Results and discussion

3.1. HVC 100–7+100

The channel maps (Fig. 2; resolution 5.0×6.6 arcmin) show the monochromatic brightness distributions of this object at velocities between $+86$ and $+130$ km s^{-1}. In calculating column densities $N_{\rm HI}$, we have integrated from $+93$ to $+112$ km s^{-1}, thus excluding the marginal feature around $v_{LSR} = +124$ km s^{-1}. The resulting column-density map (top-right panel of Fig. 2) only shows two small condensations, lying close together. In

Table 2. HI spectrum parameters at the star's position

Object	HVC 100–7+100	HVC 347+35–112
Star	4 Lac	HD 135485
WSRT-results		
$N_{\rm HI}[10^{18}{\rm cm}^{-2}]$	3.1 ± 0.2	-
$T_{\rm b}$(max) [K]	0.12	-
$v_{\rm LSR}$ [km s^{-1}]	106 ± 0.4	-
Δv(FWHM) [km s^{-1}]	12.9 ± 0.4	-
Best estimate (WSRT combined with single dish)		
$N^*_{\rm H}$ [10^{18} cm^{-2}]	5.0	5.1
$T^*_{\rm b}$(max) [K]	0.16	0.08

Table 3. Physical properties of concentrations in HVC 100–7+100

Object	HVC 100–7+100
Position centre	
α	$22^{\rm h}22^{\rm m}32^{\rm s}$
δ	$+49^{\rm o}15'$
Distance, upper limit [kpc]	1.2
Distance, assumed [kpc]	D
Linear dimension [pc]	$< 1.5D$
Estimated mass [M$_\odot$]	$0.3D^2$
number density [cm^{-3}]	$> 1D^{-1}$

principle, we cannot exclude the possibility that HVC 100–7+100 might have an extended component, to which the synthesis instrument would not be sensitive. Comparison (Fig. 3a) of the spectrum obtained with the Jodrell Bank 76-meter single-dish telescope (Bates et al. 1991) and that measured at Westerbork, convolved to the beam of the single dish, suggests indeed that the synthesis observation does not fully recover the total flux (cf. Sect. 2.6). However, the Jodrell Bank map obtained by de Vries et al. (1997) shows no trace of any extended feature, and its morphology agrees fully with the Westerbork map. Hence, we assume that the Westerbork map in Fig. 2 is a fair approximation of the true column-density distribution in HVC 100–7+100.

Our results confirm that HVC 100–7+100 is quite small, as suspected already by Bates et al. (1991). The Westerbork map shows that the cloud consists of two condensations; both have peak column densities of order 5×10^{18} atoms cm^{-2} and velocity widths of order 15 km s^{-1}. At a distance of order 0.6 kpc (i.e., half the distance of the star 4 Lac), the angular diameters of about 5 arcmin correspond to about 1 pc. The HI masses in both condensations then are of order $0.10 M_\odot$, and their average densities of order 2 atoms cm^{-3}. The total mass of both condensations together could at most be about $1 M_\odot$, if they are at the same distance as 4 Lac: 1.2 kpc. Table 3 summarizes the estimated properties of these condensations.

From Westerbork maps of about 1 arcmin resolution, Wakker & Schwarz (1991) have found small-scale structure of similar angular sizes (1 - 5 arcmin) in several major HVCs. However, those HVCs are certain or likely to have distances of at least several kpc, hence their condensations have linear sizes of

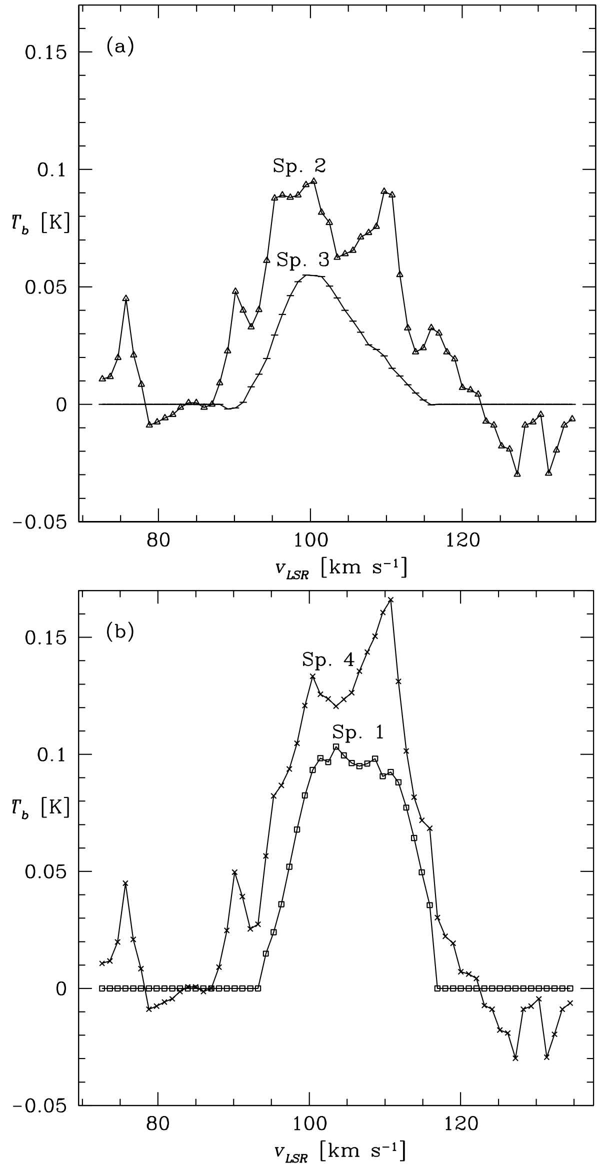

Fig. 3a and b. HI spectra of HVC 100–7+100 at the position of the star 4 Lac (see also text of Sect. 2.6 and Sect. 2.7). **a** Spectrum 3: WSRT data, averaged over Jodrell Bank beam (12 arcmin FWHM). Spectrum 2: Jodrell Bank spectrum (Bates et al., 1991). **b** Spectrum 1: WSRT data, smoothed to a resolution of 5.0×6.6 arcmin. Spectrum 4: Best estimate of spectrum at star position, obtained as Spectrum 1 + Spectrum 2 – Spectrum 3.

several pc; their HI column densities exceed those in HVC 100–7+100 by one or two orders of magnitude, and the masses of those condensations are much greater: of order $10^3 M_\odot$. Hence, the condensations found here appear to be of a different nature.

The parameters of the Westerbork spectrum are listed in Table 2. Combination of Westerbork and Jodrell Bank data, as described in Sect. 2.7, yields the estimated spectrum (Spectrum 4) shown in Fig. 3b; its parameters are also given in Table 2. The best estimate for the HI column density in the direction of the star 4 Lac is 5×10^{18} atoms cm^{-2}. The angle subtended by the star is, of course, only a small fraction of a second of arc. In

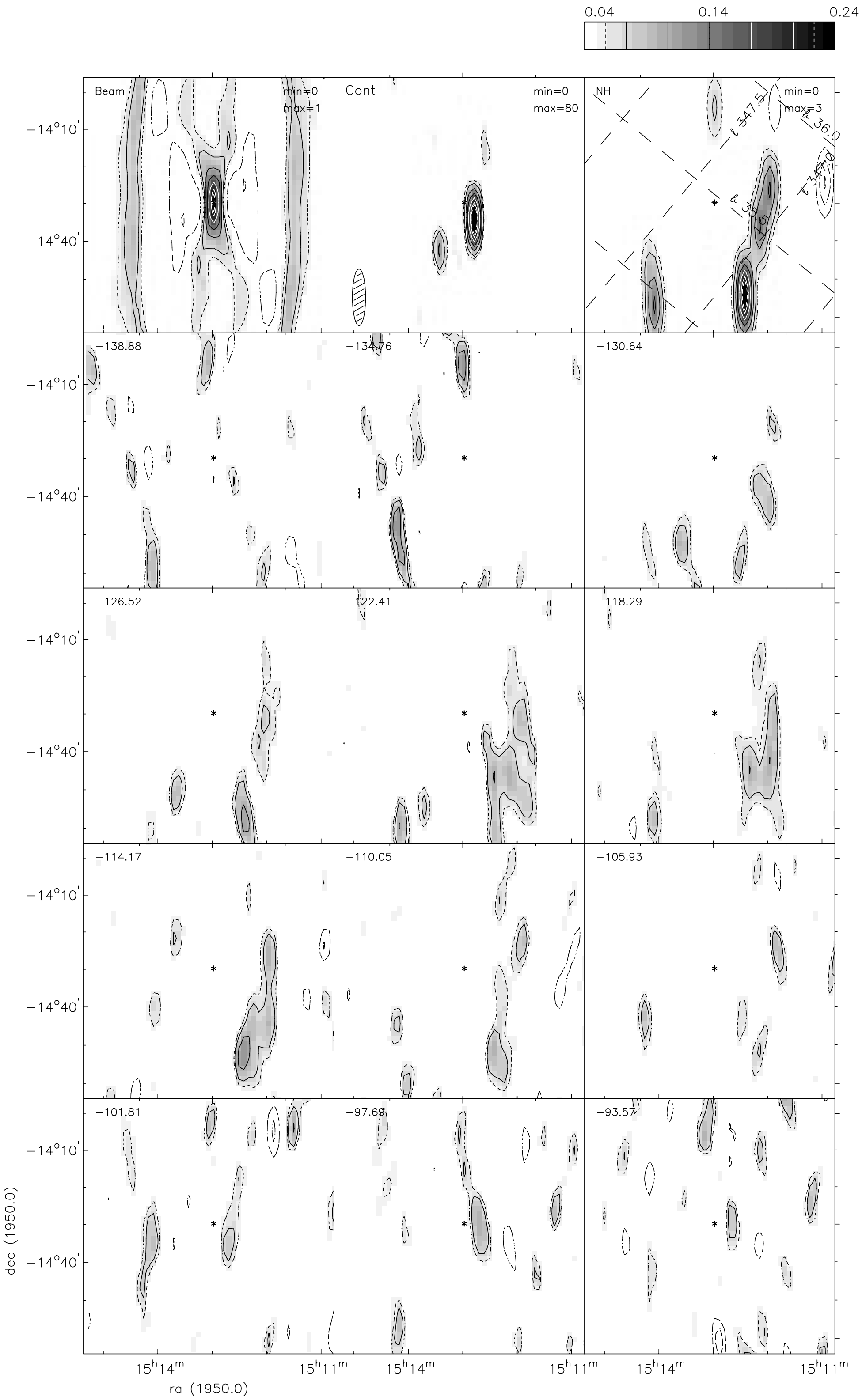

Fig. 4. Maps of HVC 347+35–112. The top-left panel shows the synthesized beam, with maximum 1; negative contours are dashed. The top-middle panel shows the continuum; units mJy/beam. The top-right panel gives the HI column densities (or "total hydrogen"); contour values, in units of 10^{18} atoms cm^{-2}, are -0.75, -0.50, -0.25, $+0.25$ (dashed), $+0.50$, $+1.0$, $+1.5$, $+2.0$, $+2.5$, $+2.75$ (dashed). The remaining panels show monochromatic brightness distributions, at velocities spaced by 4.12 km s^{-1} from -138.9 to -93.6 km s^{-1}, as given in the top-left corner of each panel; brightness temperatures shown in gray-scale, identified by scale-bar at top-right, and by contours, with values 0.057 K (dashed), 0.073 K, 0.107 K, 0.140 K, 0.173 K, 0.207 K and 0.223 K (dashed). Velocity resolution: 7.6 km s^{-1}; angular resolution: $210'' \times 880''$ (FWHM), shown by hatched ellipse in continuum panel. The position of the star HD 135485 is marked by an asterisk.

view of the noise in the spectra of Fig. 3a and b, and the possible presence of unresolved small-scale structures, we must consider the value of $N_{\rm HI}$ uncertain by a factor of 2. Using the column densities of Fe II, Mg I, Mg II, O I and Al II measured by Bates et al. (1990) with IUE, we derive the ion abundances listed in Table 4. While the uncertainties of these values are considerable (factors 2 - 6), together they suggest that the metallicity of HVC 100–7+100 is close to the cosmic value.

Table 4. Abundances in HVC 100–7+100

Ion	$\log N_{\rm ion}$	$\log(N_{\rm ion}/N_{\rm HI})$	$\log(A/A_{\rm cosmic})$
HI	18.7 ± 0.3		
FeII	13.6 ± 0.1	-5.1 ± 0.3	-0.5 ± 0.3
MgI	11.7 ± 0.1	-7.0 ± 0.3	
MgII	14.5 ± 0.5	-4.2 ± 0.6	$+0.3 \pm 0.6$
OI	15.3 ± 0.7	-3.4 ± 0.8	-0.2 ± 0.8
HII	12.8 ± 0.4	-5.9 ± 0.5	-0.3 ± 0.5
Average			-0.2 ± 0.4

The small mass of the cloud, and its position with respect to the star, might suggest a possible circumstellar origin. However, the HVC's velocity of $+100$ km s^{-1} is very different from that of the star (4 Lac = HR 8541), $v_{\rm LSR} = -26$ km s^{-1} (Hoffleit 1962). If the HVC were part of an expanding shell around 4 Lac, one would also expect absorption at large negative velocities, around -150 km s^{-1}. Our data do not include such velocities. However, the Leiden-Dwingeloo Survey by Hartmann & Burton (1997) shows intense emission at these velocities over a large region of sky, undoubtedly to be identified with the well-known Outer Arm; a possible shell at -150 km s^{-1} would be confused with this emission. The observed absorption at high *positive* velocities is inconsistent with an expanding-shell hypothesis.

Another possible origin might lie in a supernova explosion. We have searched the Green (1996) catalogue for supernova remnants (SNRs) in the neighbourhood. In order to produce an absorbing cloud at $+100$ km s^{-1}, the SNR would have to have a shorter distance than 4 Lac. Unfortunately, for most SNRs listed by Green no distance estimate is available. However, *none* of Green's SNRs lies closer than seven times its own diameter to the line of sight to 4 Lac. Moreover, a velocity of $+100$ km s^{-1} would be quite high for a *neutral* portion of an SNR. We note, in particular, that no SNRs are known in the Lacerta association around $l = 97^{\rm o}$, $b = -17^{\rm o}$. Also, no pulsar is known to have originated there (Blaauw, private communication). Thus, it seems unlikely that HVC 100–7+100 could be explained as part of the debris of a supernova. The origin of this cloud thus remains a puzzle.

3.2. HVC 347+35–112

Fig. 4 shows channel maps at velocities ranging from -139 to -94 km s^{-1}. Summation of these has yielded the column-density map in the top-right panel of Fig. 4. These maps have angular resolution of 3.5×15 arcmin. The fine-structure information obtained is further limited by the heavy cleaning, necessitated by incomplete $u\,v$-coverage, and by the low brightness temperatures, which remain below 0.2 K. The main concentrations lie at the edge of the primary beam, to the West and SSW of the star; those to the N and SE are marginal. The Jodrell Bank results by de Vries et al. (1997, in preparation), while in fair agreement with the Westerbork map, show weak radiation extending over a degree. The Dwingeloo survey (beam 36 arcmin) by Hulsbosch & Wakker (1988) and that by Bajaja et al. (1985)

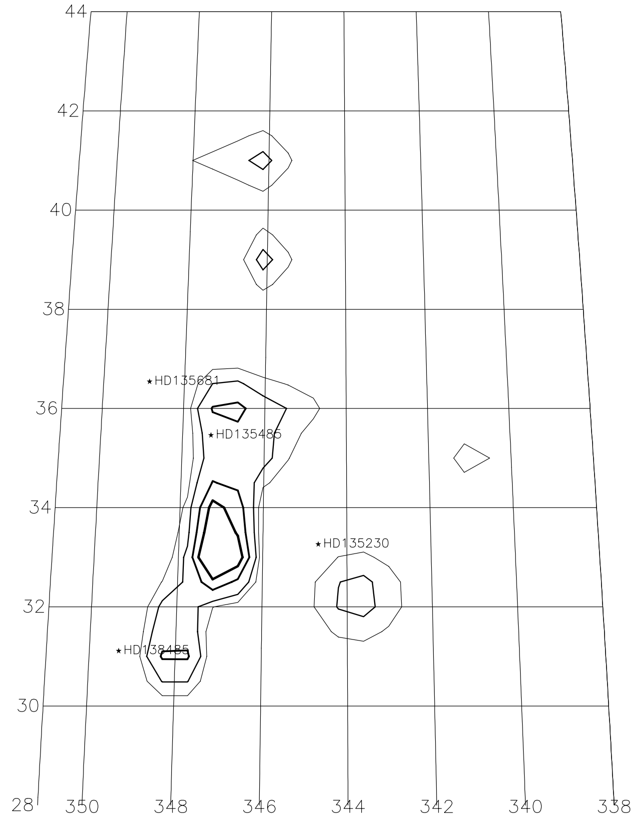

Fig. 5. Overview of HVC #132 (Wakker & van Woerden, 1991) and other clouds belonging to Complex L. Brightness temperatures (contour values: 0.05 K, 0.10 K, 0.20 K and 0.30 K) taken from the survey by Hulsbosch & Wakker (1988; beam $0.6^{\rm o}$ FWHM, grid spacing $1.0^{\rm o}$), except at $l = 344^{\rm o}$, $b = +32^{o}$; that point comes from Bajaja et al. (1985; $0.5^{\rm o}$ beam, $2.0^{\rm o}$ grid). Assuming profile half-widths (FWHM) of 20 km s^{-1}, the corresponding column-density values are: 2, 4, 8 and 12×10^{18} atoms cm^{-2}. The positions of four stars observed by Albert et al. (1993) are marked.

at Villa Elisa (beam 30 arcmin) show emission at similar velocities extending over a larger region. This emission was listed by Wakker & van Woerden (1991) as Complex L, which extends over 22 square degrees and has a mass of $300 D^2 M_\odot$, where D is the distance in kpc. The prominent elongated feature in Fig. 5 is called HVC #132 by Wakker & van Woerden (1991), and is the brightest part of Complex L. While it is not impossible that the gas near HD 135485 seen in Fig. 4 is an isolated, small feature, it appears more likely that it is part of HVC #132.

The distance of these clouds is unknown. While Albert et al. (1989, 1993) had suggested a relationship of the CaII absorptions at velocities of -98 and -127 km s^{-1} in HD 135485 to the high-velocity hydrogen in the region, and van Woerden (1993) had noted that this set an upper limit of 2.4 kpc on the distance of Complex L, IUE spectra by Danly et al. (1995) indicate that the absorptions are circumstellar. Thus, HVC #132 and Complex L may be beyond the star as well as in front.

Since the concentrations seen in Fig. 4 probably extend beyond the primary beam as a large, filamentary structure, and no distance constraints are available, we refrain from estimating their sizes, densities and masses.

As the Westerbork map (Fig. 4) shows no concentration at the position of the star, the best estimate for $N_{\rm HI}$ in the direction of HD 135485 follows directly from the single-dish spectrum at that position: $N_{\rm HI} = 5 \times 10^{18}$ atoms cm^{-2} (Table 2). Because the relationship between the HI structures and the CaII and UV absorptions is now severely in doubt, we cannot give metal ion abundances for Complex L.

4. Conclusions

For HVC 100–7+100, we have a firm upper distance limit of 1.2 kpc. The cloud consists of two small condensations, for which we have given estimates of size, mass and density. Unless the cloud is very nearby, its density is not much higher than the average density in the Galactic Disk. The cloud lies within the Disk, and has a velocity deviating by at least 100 km s^{-1} from its surroundings. However, because it is small (especially if it is much nearer than 1 kpc), it may survive (and already have existed) for millions of years. Its origin remains unclear.

For HVC 347+35–112, no distance constraint is available. This feature appears to be part of an extended, low-density HVC, called Complex L. This object is much smaller and less massive than well-known ones such as Complexes A, C, H and M, and its small-scale structure appears to be less pronounced. In other respects it is not unusual.

Acknowledgements. The Westerbork Radio Observatory is operated by the Netherlands Foundation for Research in Astronomy (NFRA), with financial support from NWO. We thank Prof. A. Blaauw and Prof. R.G. Strom for discussions about supernova remnants and pulsars, and Dr. B.P. Wakker for providing Fig. 5.

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