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Scientific Report

The goal of this project was to determine the distance to high velocity gas clouds. These clouds are believed to lie in the halo of the galaxy, but this is a matter of controversy. The technique that we used was to look for the effect of absorption by these clouds against the light of stars at various distances along the line of sight to these clouds. This was done in the ultraviolet using the International Ultraviolet Explorer. Absorption at the velocity of the clouds was not found in any of the stars, which have kiloparsec distances. We conclude that the vertical distance to these clouds is at least 1.5 kpc, putting them firmly in the halo of the galaxy.

For a more detailed report, see the enclosed journal article, which is published in Astronomy and Astrophysics.

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Determinations of the Distance to the complex C of High-Velocity Halo Clouds *

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Abstract. High resolution IUE spectra of sdB and HBB stars in the direction of the neutral high-velocity gas Complex C have been obtained. Their interstellar absorption line profiles are compared with Effelsberg HI 21-cm profiles. Since the distances to the stars are known from spectroscopic investigations, firm lower limits can be derived for the distance of the gas at about -110 km s^{-1} of Complex C I and C III. With additinal results from the literature we conclude that Complex C is at a z-distance definitely larger than 1.5 kpc.

Key words: interstellar medium: clouds, structure – galaxy: halo, structure – ultraviolet: interstellar

1. Introduction

Neutral clouds at high galactic latitudes showing large radial velocities were discovered in HI 21-cm observations by Muller et al. (1963). These clouds were thought to be in the halo of the Milky Way while falling toward the disk. Since then it has become clear that a substantial fraction of both the northern sky (Giovanelli 1980, Hulsbosch & Wakker 1988) and the southern sky (Bajaja et al. 1985) shows such high-velocity gas. For reasons mostly based on the interpretation limits of the 21-cm data, clouds with LSR radial velocities $v_{rad} > 100$ km s^{-1} are called high-velocity clouds (HVCs), while clouds with $50 < v_{rad} < 100$ km s^{-1} are called intermediate-velocity clouds (IVCs). HVCs are easy to spot in all directions of the sky and thus also in the disk of the Milky Way, whereas clouds at smaller velocities cannot be recognised well because of the possible presence (in the same direction) of gas in the disk at similar velocities. However, the separation between the two categories is artificial. A discussion of selection effects in the observations of halo clouds can be found in de Boer (1989). In the present paper we will use the word HVC for all clouds whose velocities cannot be understood with simple models for galactic rotation.

The distances of the HVCs are still largely unknown, in spite of substantial efforts to pin them down. The method to determine such distances involves finding stars with known distances in the direction of the clouds, observing them at high spectral resolution, and searching the data for absorption lines from the interstellar gas at the velocity of the cloud as known from HI 21-cm observations. If a resonance line shows up in absorption one can determine the column density of the respective species. If this column density is in agreement with the one known from HI (allowing for the intrinsic abundance difference between these elements) the star is behind the cloud. If there is no or very little absorption found and the calculated column density or its upper limit is well below the column density expected for the cloud, then the cloud is behind the star. The method works well and has been successful in the direction of several nearby lower-velocity clouds (see e.g. Hobbs et al. 1986; Lilienthal & de Boer 1990, and refs. there). It is clear that it is most advantageous to have several stars spread in distance in almost the same direction to determine the distance of the gas cloud in a meaningful way.

Toward HVCs the method has had little succes. One problem is to find a sufficient number of stars to employ the method, either using the lines of CaII or NaI in the visual or lines in the UV.

For studies in the visual, York et al. (1986) have proposed to use RR Lyr type stars and measure the CaII lines. The luminosities of these stars are known and thus their distances easy to calculate, but most RR Lyr stars are rather faint for spectroscopy. Songaila et al. (1988) used such and other stars to try to find the distance to the northern-sky gas Complex C (see map in Wakker 1991), but the interpretation of their CaII spectra appears to be troubled (Lilienthal et al. 1990). A-type stars were used by Lilienthal et al. (1990) to measure the NaI lines. Here the limitation is that only few such stars are known at large distances. Albert (1983) measured the CaII lines in stars with early type spectra which, if they are on or above the main sequence, are rather luminous and at large dis-

*Based on observations obtained with the International Ultraviolet Explorer (operated jointly by the NASA, ESA and SERC) at the VILSPA station

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Table 1. Data for the programme stars and the IUE spectra

Star	RA,DEC (1950)[a]	V (mag)	Sp.Type	T (K)	d (kpc)	IUE-LWP image	exposure time (min)	remarks on spectrum
PG 0009+036	00 09 53.9 +03 37 50.4	13.1	B	15000	7.3	19503	343	low signal
PG 1510+635	15 10 15.5 +63 33 02.4	14.1	HBB	13750	4.1	17862	860	low signal
PG 1519+640	15 19 42.2 +64 02 49.3	12.4	sdB	27000	0.6	18878	383	
PG 1536+690	15 36 35.8 +69 01 54.0	14.1	He-sdO	63000	2.0	11655	360	no signal
						11950	422	no signal
PG 1619+522	16 19 22.6 +52 13 14 [a]	13.2	sdB	31000	0.8	11390	368	
						11398	320	
PG 1648+536	16 48 52.4 +53 36 36.7	14.0	sdB	30000	1.2	17868	360	
						17872	870	
						20826	390	
PG 1705+537	17 05 09.1 +53 39 24.9	13.0	HBB	17000	2.4	17903	342	
						20835	382	

V, Sp.Type, T, and d are from Moehler et al. 1990a, 1990b, Dreizler et al. 1990, Theissen 1991, and Schmidt et al. 1992
[a] Positions have been determined astrometric, see text, except the one for PG 1619+522.
Finding charts for the stars can be found in Green et al. (1986)

tances. She used close lines of sight, found always the gas near 0 km s^{-1} LSR and only in a few cases Ca absorption at velocities near –50 km s^{-1}. With extragalactic objects as background light sources only few significant results are known. Morton & Blades (1986) review Ca data on 24 such sight lines of which 2 show gas at $v_{rad} > 50$ km s^{-1}. These velocities are compatible with galactic corotation in the directions to those sources. Also the quasar PKS 0837–120 shows high velocity Ca absorption at +105 km s^{-1} (Robertson et al. 1991). Those studies show that HVCs do contain Ca indeed. In general, the interstellar absorption lines in the visual have small optical depth and the detection of low column density clouds, such as the HVCs, is not a simple matter.

Ultraviolet absorption lines generaly have a larger optical depth. Danly (1989) and Danly et al. (1992) surveyed many lines of sight to blue stars at high galactic latitudes using IUE spectra. She and her collaborators, using the slightly less sensitive SiII absorption lines (see Sec. 4), found evidence for a distance of 1 to 2 kpc for intermediate-velocitiy gas clouds between +50 and –80 km s^{-1}. No gas at larger velocities was seen in absorption in spectra of stars out to $z = 1.5$ kpc. These distance values depend critically on the distances assumed by Danly et al. for the stars; they were based on MK classifications but luminosities are notoriously inaccurate for giants and supergiants. IUE spectra of Magellanic Cloud stars showed (Savage & de Boer 1979, 1981) that two well defined clouds exist at +60 and +130 km s^{-1} with a metal abundance not much below solar on that line of sight. Their distance is >1 kpc and obviously <50 kpc. It has been suggested that these HVCs might belong to the LMC. The spatial extent on the sky as seen in HI 21-cm emission, however, makes clear that they belong to the halo of the Milky Way (de Boer et al. 1990).

In this paper we report on the ultraviolet interstellar spectroscopy toward blue subluminous stars at high galactic latitudes we carried out over the past years. The stars are of sdB and HBB type and have the advantage that luminosities and distances can reliably be derived from photometry and spectroscopy with Balmer-profile fitting methods. This has been done for the present purpose for a large number of these stars (de Boer et al. 1988, Moehler et al. 1990b, Dreizler et al. 1990, Theissen 1991, Schmidt et al. 1992). From this data stars were selected (see Table 1) in the direction of known HVCs to be observed with the International Ultraviolet Explorer (IUE) satellite (Boggess et al. 1978) at high dispersion. For 4 lines of sight we have determined significant upper limits to the absorption by HVCs while for 1 line of sight clouds have possibly been detected. These results are compared with new HI 21-cm profiles obtained with the 100 m Effelsberg Radiotelescope. Section 2 and 3 describe the observations and the data reduction. Section 4 gives the analysis of the data followed by a presentation of the results in Section 5.

2. Observations of absorption lines with the IUE

The spectra have been obtained with the IUE between 1986 and 1991 with the long wavelength prime (LWP) camera. There are several reasons for the choice of this wavelength range. The stars used are of sdB or HBB type, which means that their absolute visual magnitude is between about +2.5 and +0.5 mag. Their effective temperature ensures that the UV absolute magnitude (between 250 and 300 nm) of these types of stars is roughly equal at about +1 mag. However, their short wavelength continua are not blue enough to compensate for the more limited sensitivity of the IUE short wavelength spectrographic camera with respect to the long wavelength range. Also, in the short range one expects many stellar spectral lines as well, making the recognition of the weak interstellar lines more difficult. Another reason to use the long wavelength range for our observations is that several interstellar absorption lines with normally large optical depth are found there (see Sec. 4), in particular the doublet of MgII near 280 nm as well as lines of FeII near 260 and 238 nm. Absorption structure in one of these lines can possibly be confirmed by absorption in the others.

The observations have been performed in the blind-offset mode. Positions for the stars were determined by M. Geffert in Bonn using new refractor plates (from the Observatory Hoher

List of the Sternwarte Bonn) or through measurements on the Palomar Sky survey prints. They have an accuracy of about 1"; note that the positions in the Palomar-Green survey (Green et al. 1986) may show errors of over 10". The data for the stars and for the IUE spectra are given in Table 1.

The spectra were extracted from the IUE images at the VILSPA and GSFC observatories. They were further processed on the VAX network of the Astronomical Institutes of the University of Bonn. This included selecting the relevant portions of the spectra, smoothing with a running triangular filter with FWHM of 20 $\mathrm{km\,s^{-1}}$, and transforming the wavelength scale into a velocity scale based on the laboratory wavelength of the absorption line. The zero point of the velocity scale is known to about 10 $\mathrm{km\,s^{-1}}$ but shifts may be present if the star was not centered in the IUE aperture. The gas in the solar vicinity, which in almost all directions shows up in 21 cm and in absorption, normally is at 0 $\mathrm{km\,s^{-1}}$ LSR. For the analysis here we assumed that the main emission peak in the HI 21-cm profiles represents the same gas as that giving the deepest absorption near 0 $\mathrm{km\,s^{-1}}$. Thus small shifts are needed to align the IUE spectra to the 21-cm profiles, which can be understood as due to residual inaccuracies in the positions of the stars. The relevant unshifted spectra are plotted in Fig. 1.

Table 2. Results from the HI 21-cm profiles

Star	v_- $\mathrm{km\,s^{-1}}$	v_+ $\mathrm{km\,s^{-1}}$	N(H) 10^{18} $\mathrm{cm^{-2}}$
PG 0009+036	−70	−25	18
	−25	+50	312
PG 1510+635	−165	−80	11
	−80	−40	13
	−40	+40	103
PG 1519+640	−195	−145	8
	−145	−80	30
	−80	+60	142
PG 1536+690	−210	−100	19
	−100	−35	124
	−35	+ 50	166
PG 1619+522	−140	−50	17
	−50	+50	190
PG 1648+536	−180	−100	30
	−100	−40	15
	−40	+35	394
PG 1705+537	−160	−85	12
	−85	−30	26
	−30	+35	142

3. Observations of HI emission lines at Effelsberg

The HI 21-cm surveys of high- and intermediate-velocity gas at high galactic latitudes had been carried out with 25 m radiodishes giving 15' resolution on a course grid (see Hulsbosch & Wakker 1988). Since for a proper interpretation of the IUE data one has to have HI profiles for the exact positions of the stars observed, measurements of the HI 21-cm emission line have been performed with the 100 m Effelsberg Radiotelescope. The beam has a FWHM of 9' and the velocity interval observed runs from −380 to +280 $\mathrm{km\,s^{-1}}$ at 1.3 $\mathrm{km\,s^{-1}}$ resolution. One set of measurements dates from 1987, a second set was obtained in the fall of 1991. The data were reduced in the usual way and the relevant ones are shown in Fig.2.

For all lines of sight the HI profiles have been analysed. The column density for the local gas and for any existing higher velocity gas has been calculated and is given in Table 2.

4. Analysis of the IUE spectra

The IUE spectra of such faint stars are of modest signal and only stronger absorption structures can be recognised. In addition, the detection limit is not uniform due to the echelle nature of the spectra. However, several absorption lines from FeII and a pair of lines from MgII (in two adjacent orders the pair is present) can be used to identify the weakest absorption structures. A measure of the expected optical depth is obtained from the product of the abundance A of the species and the transition strength parameter $f\lambda$. The product $Af\lambda$ is proportional to the familiar $Nf\lambda$ in the expression for the optical depth of an absorption line. Assuming solar abundances for the elements in the gas outside the Milky Way disk one can calculate relative expected optical depths, as given in Table 3.

There are two factors which influence the detectability of the absorption lines. The obvious one is that the ions may be present in the gas with an abundance different from solar. The element may be depleted due to locking into dust, which results in a correction factor D for gas with little extinction as taken from de Boer et al. (1987). Its effect is shown in Table 3. Alternatively, the abundance of the elements may be lower in general in halo gas but if the factor is the same for all elements it does not affect the sequence in $Af\lambda$ of the Mg and Fe lines. The second factor affecting the detectability is the location of the absorption line in the echelle order in the spectrum. If the line is near the peak of the response R, one has a good signal; if the line is more to the side in the echelle order then R is smaller than 1 and the detectability is reduced. Table 3 gives also estimates of R for all of the lines studied. The sensitivity of the SiII line in the IUE short wavelength range (used by Danly et al.) is a factor of 2 less than that of the strong MgII line. Table 3 shows in addition the sensitivity of the CaII K line.

For each spectrum one can determine the upper limit for the detection of an absorption line. These values differ from line to line (location in the spectrum) and from spectrum to spectrum (exposure level). The upper limits have been calculated from the noise structure in the spectra locally and represent the equivalent width which should have been visible had it been present. It is a somewhat subjective value but we have never set it on the small side. Since the absorption lines studied have different f-values, the upper limits lead to different upper limits for column densities of gas (always assuming that the gas is optically thin, linear portion of the curve of growth). The final value for the upper limit to a column density is equal to the strictest one from the lines of the same species. These values are given in Table 4, including the one for the possible detection of high-velocity gas toward one of the stars.

In order to compare the column densities or the respective upper limits of MgII and FeII with those of HI, we have to compensate for the relative abundance of the elements. We will use in the analysis for both elements the solar abundance values (as given in de Boer et al. 1987). Also indicated in Table 2 is the effect of the use of abundances reduced by depletion

Table 3. Relative optical depth factors for the absorption lines studied

Ion	λ (nm)	log A[a]	log $f\lambda$[b]	log $Af\lambda$	log D[c]	log $ADf\lambda$	R[d]	log $ADf\lambda R$.
MgII	279.553	7.5	2.23	9.73	-0.3	9.4	0.5	9.1
MgII	280.270	7.5	1.93	9.43	-0.3	9.1	0.4	8.7
MgI	285.281	4.5[e]	2.72	8.22	-0.3	7.9	1.0	7.9
FeII	259.940	7.5	1.76	9.26	-1.4	7.9	1.0	7.9
FeII	258.588	7.5	1.22	8.72	-1.4	7.3	0.6	7.0
FeII	238.204	7.5	1.86	9.36	-1.4	8.0	1.0	8.0
FeII	234.350	7.5	1.41	8.91	-1.4	7.5	0.2	6.6
CaII[f]	393.366	6.3	2.40	8.70	-2.5	6.2	-	5.9
SiII[f]	126.042	7.5	2.10	9.60	-0.5	9.1	-	8.8

[a]) Solar abundances taken from de Boer et al. 1987; scale [H]= 12.0

[b]) $f\lambda$-values from the compilation of Morton 1991; with λ in nm

[c]) Depletion factor for gas with little extinction, from de Boer et al. 1987

[d]) Relative response factor in IUE echelle spectra at the position of the line

[e]) Under the assumption n(MgII)/n(MgI) = 1000

[f]) Included for comparison; last column assuming response R as for MgII

Table 4. Results from the IUE spectra

Star	v_- km s^{-1}	v_+ km s^{-1}	log W_λ/λ MgII 279.5	FeII 259.9	log N MgII	FeII	log N(H)[b] from MgII	log N(H) from HI
PG 1519+640	−195	−145	<−5.3	<−5.1	<11.5	<12.1	<16.0	18.9
	−145	−80	<−5.3	<−5.3	<11.5	<12.0	<16.0	19.5
	−80	+60	−3.5	−3.7	a	a		
PG 1619+522	−140	−50	<−4.8	<−4.7	<12.0	<12.8	<16.5	19.2
	−50	+50	−4.0	−4.0	a	a		
PG 1648+536	−180	−120	−4.2	<−4.5	13.2	<13.0	17.7	19.5
	−120	−60	−4.3	−4.2	13.0	14.1	17.5	19.1
	−60	+35	−3.5	−3.8	a	a		
PG 1705+537	−160	−85	<−5.0	−	<11.8	−	<16.3	19.1
	−85	+35	−4.0	−	a	−		

[a] For gas at local galactic velocities column densities cannot be determined because of saturated absorption

[b] N(H) from MgII assuming solar abundance for Mg

as found in gas in the Milky Way disk with little extinction. It is clear that the FeII observations are rendered insignificant when depletion is taken into account. The IUE spectra give as most significant upper limit (or detection) the column density derived from the MgII lines.

There are two lines of MgII in the spectra and the pair shows up in each of two adjacent orders in the echelle spectrum. However, the 279.55 nm line in one order and the 280.27 nm line in the other order are of little use because they are very close to the edge, have very low signal there, and cover only a small velocity range. This means that effectively each of the lines from the doublet is available only once. For some of the stars more than one spectrum is available. The Mg profiles from these can be added to improve the signal to noise ratio. This has been done and the result is shown in Fig. 2 and the upper limits from these sums are given in Table 4.

As a last possibility to improve the detection limit for absorption one can add different absorption spectra from the same ion. Here it is important to add lines with essentially the same $f\lambda$-value, otherwise the continuum of the spectrum of the weaker line will make absorption by the stronger line more shallow and thus reduce its contrast with respect to the continuum. In the case of our lines this procedure may be usefull for the FeII lines at 259.94 and 238.20 nm, although the overall noise in the spectrum is larger near the latter line. Summing the two MgII lines will help only marginally due to the fact that the $f\lambda$-values differ by a factor 2.

A final statement has to be made on the strength of an aborption line based on a given column density of HI. The strength of a line will depend on the velocity spread in the absorbing gas, characterised by the so-called b-value in the theory of the curve of growth. Starting with N(HI) = 10^{19} cm^{-2} and assuming a (depleted) Mg abundance of −4.8 one would expect log N(MgII) =14.2. Such a column density produces an amount of absorption of log W_λ/λ = −4.9, −4 or −2 for values of b of 1, 7 or 100 km s^{-1} respectively. Given the spectral reso-

Table 5. Distance determinations of high-velocity clouds

Cloud	l	b	v_{rad}(21 cm) km s^{-1}	significant objects	z-distance of cloud (kpc)	reference
North Pole	42	+79	−70	M 3:vZ 1128	<10	de Boer & Savage 1984
	153	+80	−40	HZ 25	<3.3	Danly et al. 1992
Complex C I	59	+41	−80	M 13:B 29	<4	de Boer & Savage 1983
	80	+44	−.−	PG 1619+522	−.−	this paper
	81	+40	−105	PG 1648+536	>0.8	this paper
	81	+37	−110	PG 1705+537	>1.4	this paper
	86	+44	−110	HD 146813	>1.6	Danly et al. 1992
Complex C III	100	+47	−115	PG 1519+640	>0.5	this paper
	113	+50	−140	HD 121800	>1.7	Danly et al. 1992
Southern sky	270	−32	+60	LMC stars	1 to 25	Savage & de Boer 1981 and
Clouds	270	−32	+130	,,	,,	de Boer et al. 1990

Literature data are restricted to HVCs for which $|b| > 20^0$ and having z-distance limits > 1 kpc

lution of the IUE spectrograph, the interstellar line will in the first two cases have the instrumental width, while for the high b-value case it will be present as a wide absorption line. The intrinsically narrow absorption lines will thus be spread into the shape of the instrumental profile thereby becoming much shallower than they were. These aspects influence the lower limits to the column densities to be derived from the spectra. Wakker & Schwarz (1991) have shown that the velocity width of the 21-cm profiles of the HVCs is in the intermediate velocity range.

5. Results

The observed stars can be put together in 3 groups on the sky. These are a) stars in the direction of Complex C I (PG 1619+522, PG 1648+536, PG 1705+537) with fair spectra; b) stars in the direction of Complex C III (PG 1510+635, PG 1519+640) of which only the latter star gave good spectra; and c) a star in the direction of the Magellanic Stream Cloud V (PG 0009+036) giving a very poor spectrum. Because the PG 0009+036 spectrum is of too low signal we will not discuss this direction further.

In the direction of Complex C III a quite good spectrum is available for PG 1519+640. Local gas is well visible (the MgI line), as well as an absorption extending to about −50 km s^{-1} suggesting a separate cloud. No absorption is seen at the velocity of the HI cloud present near −115 km s^{-1}. The upper limit for the absorption at this velocity is given in Table 4. The IUE spectrum of PG 1510+635 has, in spite of the 2 shift ESA-NASA exposure, a too weak spectral continuum to discern absorption structure. Moreover, the 21-cm profile (which became available much later than the IUE spectrum) shows little gas and only weak high-velocity gas emission near −115 and −60 km s^{-1}. From the lines of sight observed in the direction of Complex C III we conclude that the HVC at -115 km s^{-1} is clearly behind the star, the star PG 1519+640 being at a distance of 0.65 kpc.

In the direction of Complex C I, which has velocities near −100 km s^{-1}, three stars were observed, of which the IUE spectrum of PG 1705+537 is of poor quality. Toward PG 1619+522, which is just off the edge of Complex C (see Fig. 3) two spectra are available. In the summed spectra absorption by local gas is seen but no absorption near high velocities; relevant column densities and upper limits are given in Table 4. The HI profile shows no HVC either. Toward PG 1648+536 three spectra were obtained, of which one is from a 2 shift ESA-NASA exposure. The total available data allow rather accurate determinations of equivalent widths. The local gas has a width in absorption similar to that in 21-cm emission. The high-velocity emission near −150 km s^{-1} (which has a structure as if there are two clouds) does not have a clear counterpart in absorption. However, in the IUE spectra there seems to be absorption near 100 km s^{-1}. If the spectra were to be shifted by +30 km s^{-1}, the dip in a MgII profiles falls right near the 21-cm emission structure. Yet, there is no good reason to apply such a large shift to the IUE spectra.

6. Discussion

The column density of MgII detected in the −150 km s^{-1} range toward PG 1648+536 is, using solar Mg abundance, almost 2 orders of magnitude smaller than the HI column density from emission. If Mg were depleted by a factor of 6 (which is the average value for galactic gas with stronger extinction) the difference in column density from Mg and from HI itself would be a factor of 10. We therefore conclude that the 21 cm HVC is not detected in absorption and thus lies behind PG 1648+536.

From the data presented two firm lower limits for the distance to HVCs have been derived. These are 0.65 kpc in the direction of Complex C III (PG 1519+640) and 1.2 kpc in the direction of Complex C I (PG 1648+536) while the 2 kpc line of sight to PG 1705+537 gives less certain results.

Results of an earlier attempt to derive the distance to Complex C of HVCs have been published by Songaila et al (1988). However, as mentioned before, their interpretation is troubled due to the presence of stellar lines in the spectra (Lilienthal et al. 1991). Moreover, HI 21-cm profiles obtained recently with Effelsberg in the exact direction of the three RR Lyr stars of Songaila et al. show that there is no high-velocity gas visible in emission in those directions (Lilienthal, priv. comm.). So even if their optical spectra had been of very high quality it is rather unlikely that the CaII K absorption from the HVC would have been visible.

The difficulty with these programmes of interstellar absorption line measurements without prior knowledge of HI profiles in the exact direction of the programme stars is that one does not know if HVCs are present at all. The use of maps such as those of Hulsbosch & Wakker (1988), which all by itself are very good, does not give sufficient information to guarantee that the stars are indeed located in the very direction of high-velocity gas. It is also known by now that HVCs may be very filamentary (Wakker & Schwarz 1991) so 21-cm survey measurements may not be good enough to prove the existence of high-velocity gas on the line of sight.

Let us now summarise the earlier attempts to find distances for HVCs. The determinations which are of relevance are collected in Table 5. There are now several results in the general direction of Complex C. If all of that gas is equally far away our most significant lower limit puts it beyond 1.2 kpc while the spectra of B 29 in M 13 lead to an upper limit of 6 kpc. Including the literature data for Complex C one can therefore conclude that it is at a z-distance of between 1.5 and 4 kpc (Table 5). For Chain A there is the small lower limit of 0.2 kpc from Lilienthal et al. (1990). The HVCs seen in the southern sky with the help of IUE spectra of LMC stars have a z-distance of more than 1 and less than 25 kpc. Overlooking all data it is clear that more and better distance determinations are badly needed.

Wakker & Bregman (1922) have investigated the possible locations of the HVCs in relation with various models for the origin of the gas. Of these models the galactic fountain seems to be able to explain most of the observations of HI at 21 cm (Bregman 1980, Kaelble et al. 1985; Wakker & Bregman 1992). In that scenario most of the clouds are expected at distances beyond 5 kpc. Our present measurements and those from the literature all indicate large distances to the HVCs placing that gas well into the halo of the Milky Way.

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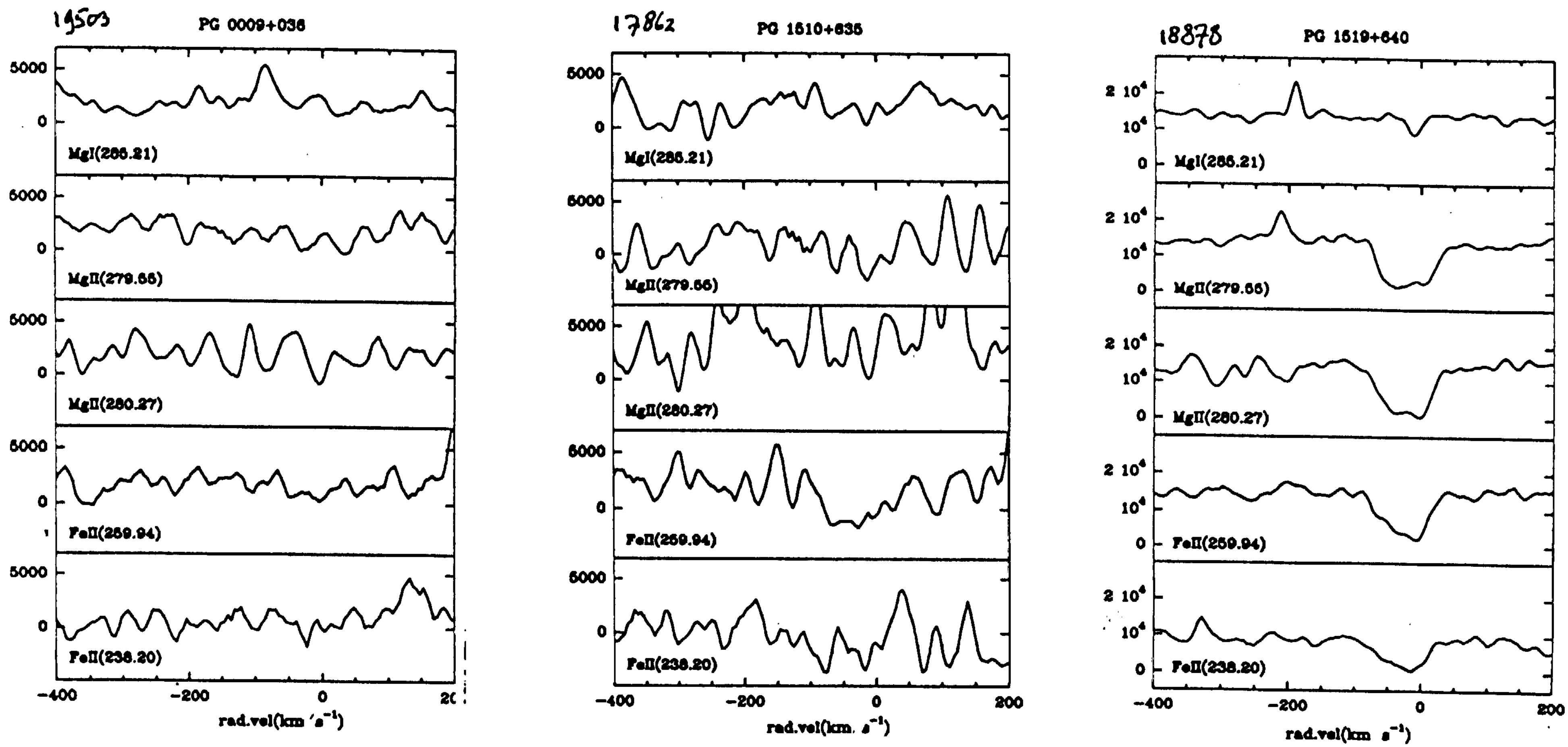
Fig. 1. The interstellar absorption lines of MgI (285.28), MgII (279.55), MgII (280.77), FeII (259.94), and FeII (238.20) from the IUE spectra (number given) to the stars indicated at the top are shown. The spectra are given in velocity space (LSR) but a small velocity offset may still be present (see text). Intensities are in arbitrary units. Not all observed spectra are displayed (Table 1). For some lines of sight the sum of several spectra is given in Fig.2

Fig. 2. For those lines of sight where more than one IUE spectrum is available, the spectra can be added to improve the signal to noise ratio. Shown are the interstellar absorption lines of MgII (279.55) and FeII (259.94). At the top of the figure the HI 21-cm emission profile (not available for PG 0009+036) has been added in order to facilitate the comparison between absorption and emission of the interstellar gas. Upper limits for the absorption in relevant velocity ranges are given in Table 4

λ280.2 λ238.2

Fig. 3. The positions of our programme stars and of additional objects in the general direction of Complex C are indicated on the map from Wakker & van Woerden (1991). The map shows contours of brightness temperature (measured with the 25 m dish at Dwingeloo) for gas with velocities <-100 km s^{-1} with the outer contour at 0.04, the heaviest one at 2.0 K. The names of those objects can be found in Table 5, as well as their significance for the determination of the distance limits



19503
PG 0009+036
17862
PG 1510+635
18878
PG 1519+640
MgI(285.21)
MgII(279.55)
MgII(280.27)
FeII(259.94)
FeII(238.20)
5000
0
2 10⁴
10⁴
-400
-200
0
200
rad.vel(km s⁻¹)

Fig 1a

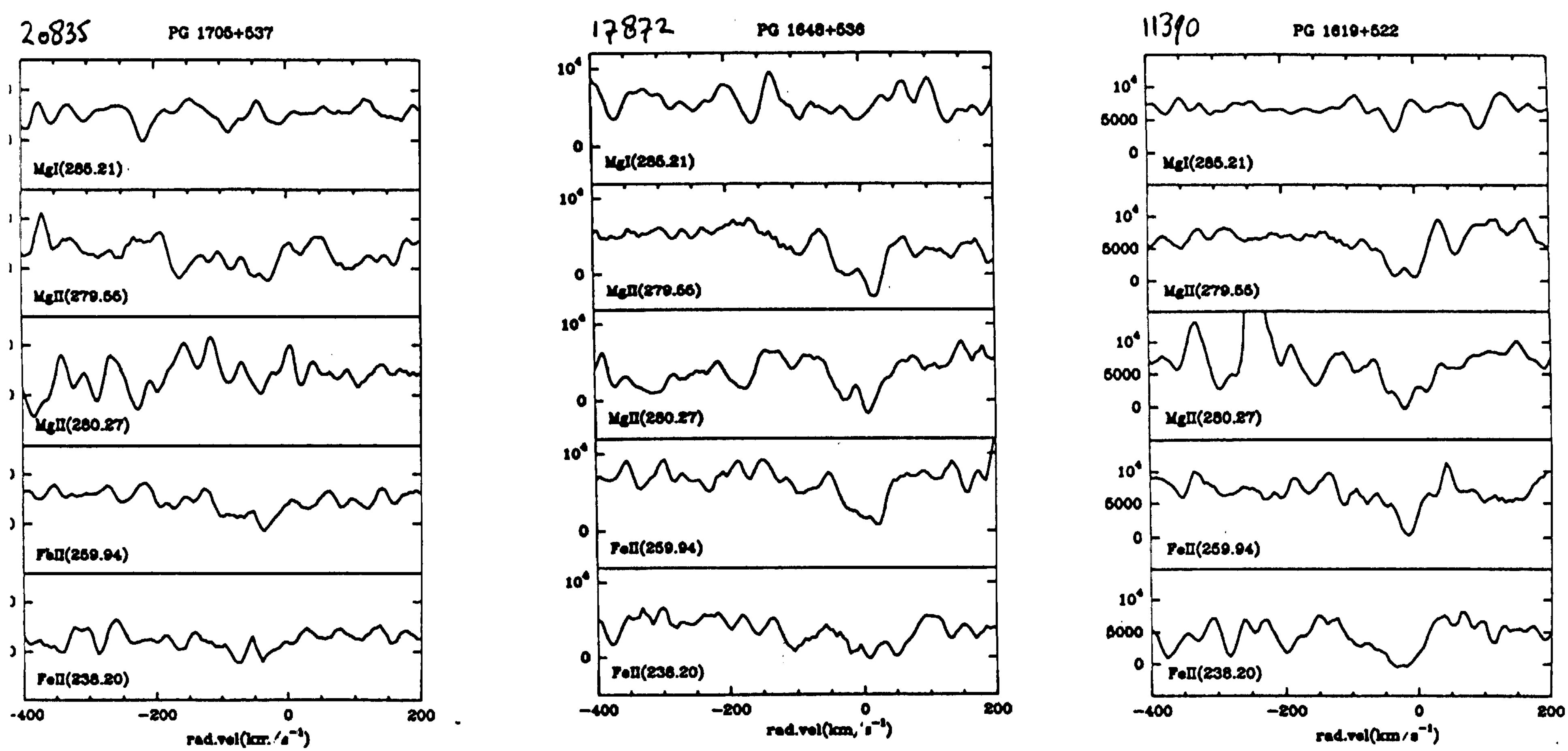

20835
PG 1705+537
17872
PG 1648+536
11390
PG 1619+522
MgI(285.21)
MgII(279.55)
MgII(280.27)
FeII(259.94)
FeII(238.20)
rad.vel(km/s^{-1})

Fig 1b

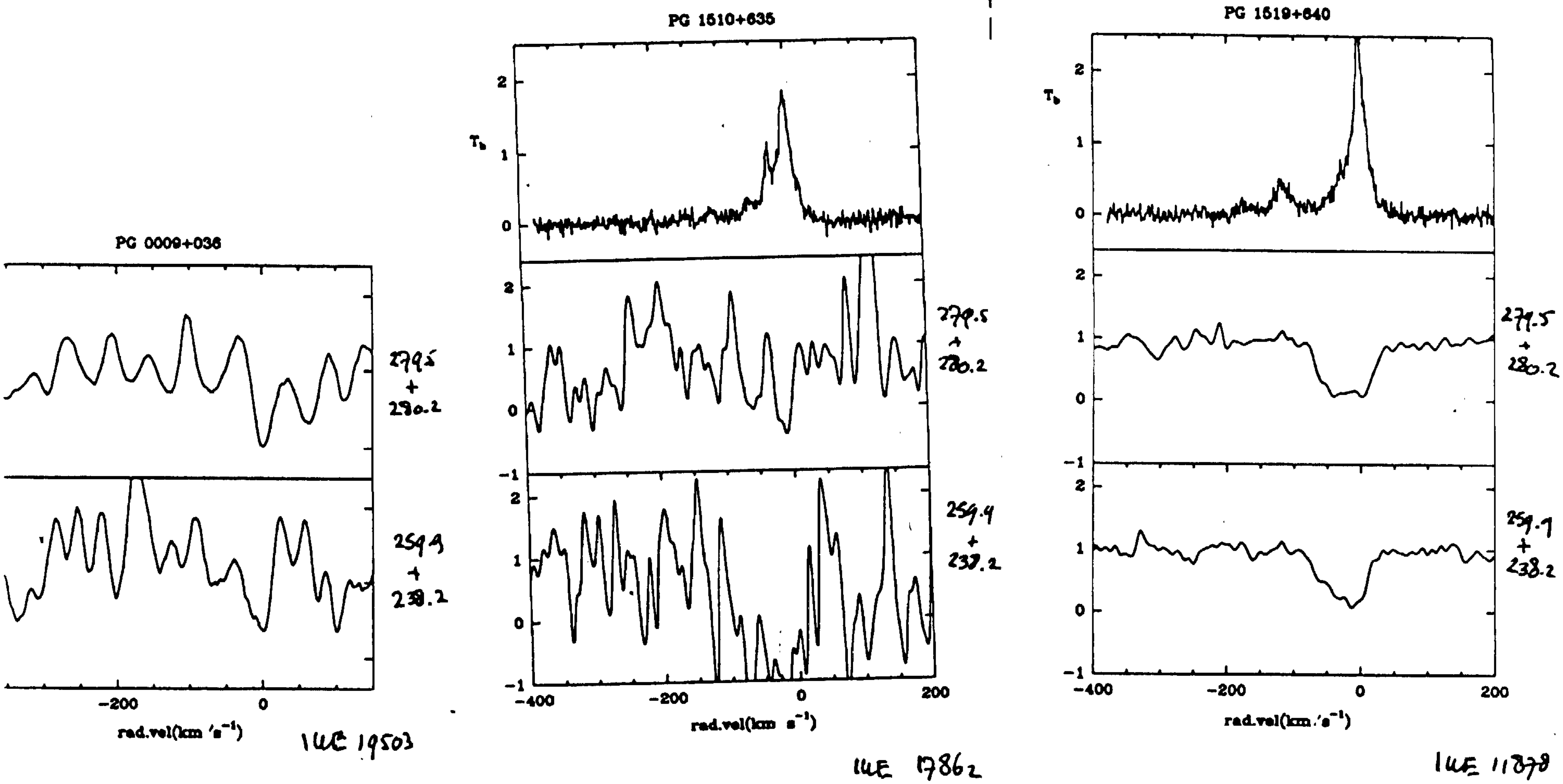

PG 0009+036
PG 1510+635
PG 1519+640
T_b
rad.vel(km 's⁻¹)
rad.vel(km s⁻¹)
279.5 + 280.2
259.4 + 238.2
259.4 + 237.2
259.7 + 238.2
IUE 19503
IUE 17862
IUE 11878

Fig 2a

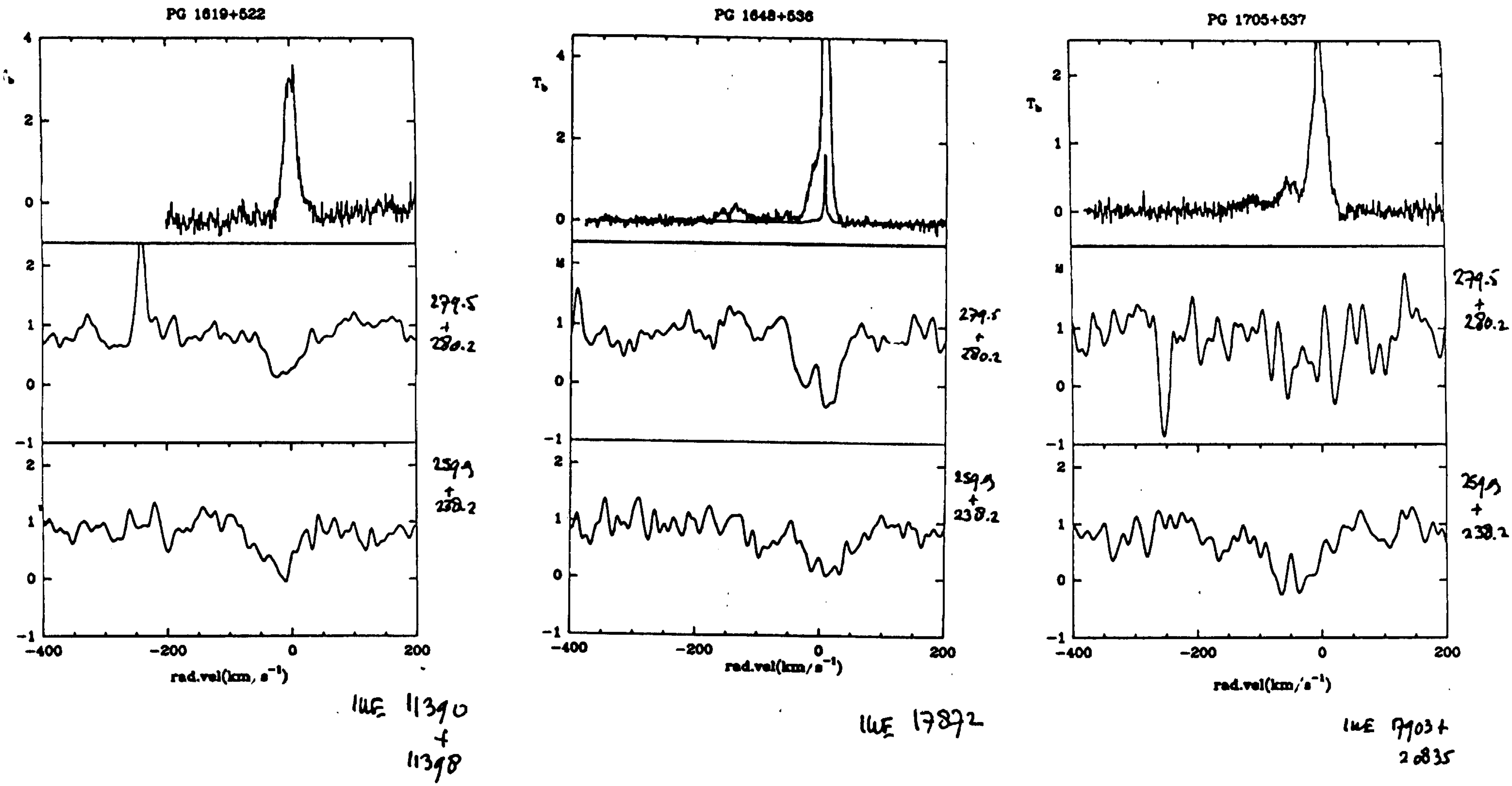

PG 1619+522
PG 1648+536
PG 1705+537
T_b
rad.vel(km, s^{-1})
279.5 + 280.2
259.9 + 238.2
IUE 11390 + 11398
IUE 17872
IUE 7903 + 20835

Fig 2 b

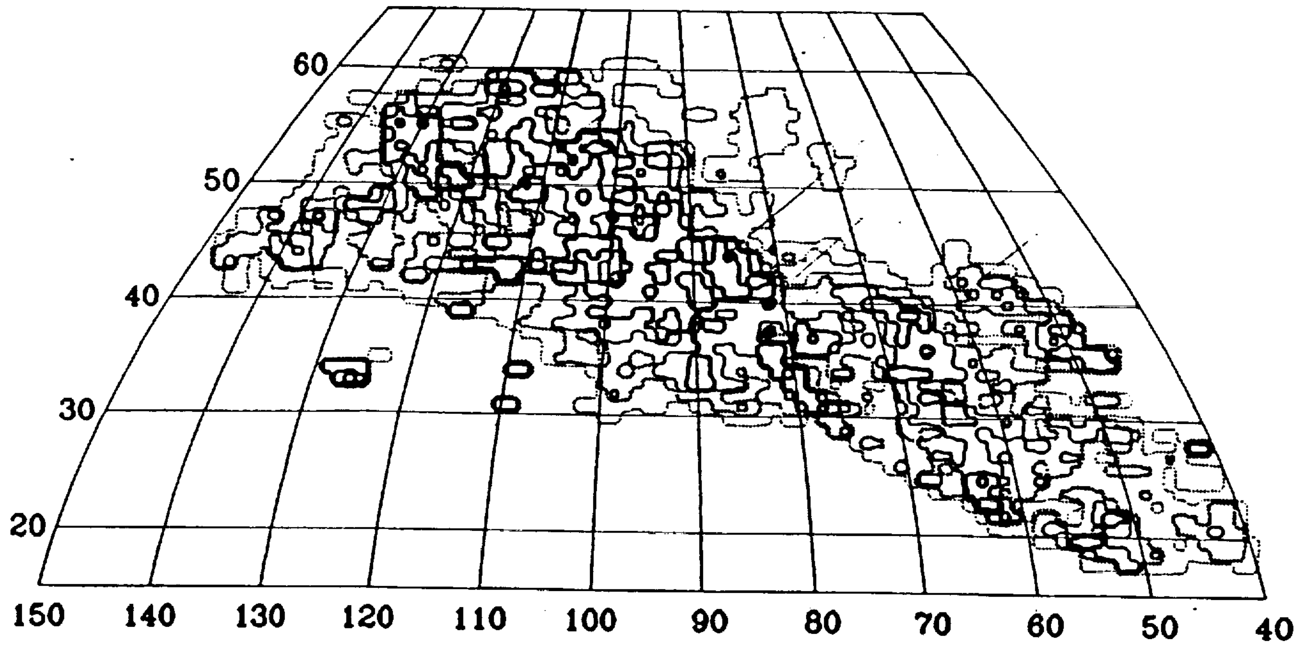


Fig 3