ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **127,** 397-408 (1998)

An H I line search for optically identified dwarf galaxy candidates in the M 81 group

W. van Driel [1], **R.C. Kraan-Korteweg** [2], **B. Binggeli** [3], **and W.K. Huchtmeier** [4]

[1] Nançay Radio Observatory, USN, Observatoire de Paris, 5 Place Jules Janssen, F-92195 Meudon Cedex, France
[2] DAEC, Observatoire de Paris, 5 Place Jules Janssen, F-92195 Meudon Cedex, France
[3] Astronomical Institute, University of Basel, Venusstrasse 7, CH-4102 Binningen, Switzerland
[4] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

Received October 14, 1996; accepted May 22, 1997

Abstract. Sensitive 21 cm H I line observations were performed for 23 dwarf members and possible members of the nearby M 81 group of galaxies, including five objects of a clustering of extremely low-surface brightness objects of unknown nature. With the Nançay decimetric radio telescope the radial velocity range of -529 to 1826 km s^{-1} was searched to an rms noise of $\sim 2-4$ mJy. Only three objects were detected. However, their high radial velocities (between 600 and 1150 km s^{-1}) show them to lie behind the M 81 group. These three objects, classified as dS0: (UGC 4998) and Im (Kar 1N and UGC 5658), have H I masses of 0.4, 1.6 and 2.0 $10^8\mathcal{M}_\odot$, for the assumed distance of 4 Mpc, and H I mass-to-blue light ratios of 0.04, 0.73 and 0.18 $\mathcal{M}_\odot/L_{\odot,\mathrm{B}}$, respectively.

Considering that half of the observed objects are classified as irregular dwarfs, hence expected to be relatively gas-rich, the resulting detection rate of about 1/3 is quite low. However, the mean redshift and velocity dispersion of the M 81 group ($<V>= 101$ km s^{-1}, $\sigma = 114$ km s^{-1}) suggest that the H I emission of low velocity H I-rich members of the M 81 group may still remain hidden within the strong Galactic H I emission (typically $-150 \lesssim V \lesssim 115$ km s^{-1}) or, for the 6 dwarf candidates in the immediate vicinity of M 81, overshadowed by the very extended H I envelope encompassing M 81, M 82, NGC 3077, and NGC 2976 ($-280 \lesssim V \lesssim 355$ km s^{-1}).

Key words: galaxies: distances and redshifts — galaxies: irregular — galaxies: ISM — radio lines: galaxies — galaxies: clusters of: M 81 group

Send offprint requests to: W. van Driel, e-mail: vandriel@mesioq.obspm.fr

1. Introduction

Dwarf galaxies provide important clues to the origin and evolution of structure in the Universe. Being low-mass objects, dwarfs are most vulnerable to interactions with the environment. They are hence ideal test particles to study evolutionary processes in different galaxy environments and, furthermore, to map the gravitational potential of galactic halos, groups and clusters.

Studies of dwarf galaxies have concentrated on the Local Group, and on clusters such as Virgo and Fornax. Local Group dwarfs can be studied in great detail, but there are only a few of them. The clusters, albeit rich in dwarfs, are relatively distant. Here, the M 81 group provides the ideal probe: it has about three times the dwarf content of the Local Group but is at only about a quarter of the Virgo cluster distance.

An extensive survey of M 81 group dwarfs has been carried out by Börngen et al. (1982), resulting in a list of dwarf members to a limiting absolute magnitude of ≈ -11, for the adopted distance of 4 Mpc to the group. They furthermore report the clustering of a number of unusual, very low-surface brightness about 7° southeast of M 81. Although classified as dwarf members of the M 81 group (Börngen et al. 1984), the nature of these objects is uncertain. Are these remarkable objects dwarfs at the extreme faint end of the luminosity function? And if true, do they contain any gas and might thus be the lowest H I-mass objects yet observed?

The goal of the survey presented here is to determine the H I properties of the dwarfs of the M 81 group. Dwarf galaxies in groups and in the field generally are irregulars (Binggeli et al. 1990) – hence gas-rich. We therefore searched at Nançay for 21 cm H I line emission in 23 candidate dwarf galaxy members of the M 81 group with considerably lower rms noise than previously obtained.

Table 1. Members and possible members (P) of the M 81 group of galaxies

		Ident.	R.A. (h m s)	Dec. (° ′ ″)	Type	Diam (′)	B_T (mag)	V_{hel} (km/s)	H I	Nançay
	1.	Ho II	08 13 53.5	70 52 13	Im	7.9	10.2	157±1	det	
	2.	Kar 52	08 18 43.0	71 11 25	Im	1.3	14.2	114±6	det	
	3.	DDO 53	08 29 33.3	66 21 08	Im	1.5	13.6	19±10	det	
	4.	UGC 4483	08 32 07.0	69 57 16	Im	1.1	13.9	156±5	det	
	6.	UGC 4998	09 20 52.9	68 35 53	dS0:	1.6	13.9		no det	*
	7.	Ho I	09 36 00.9	71 24 55	Im	3.6	12.2	136±3	det	
P	8.	Kar 1N	09 41 00.0	69 37 00	Im	1.2?	15.5			*
	9.	N 2976	09 43 11.5	68 08 45	Sd	5.9	10.9	3±5	det	
	10.	Kar 2N	09 43 42.0	69 30 00	dE?		15.9		no det	*
	11.	Kar 59	09 46 40.0	72 17 41	Im	0.3	17.1		no det	*
	12.	Kar 3N	09 49 42.0	69 12 00	Im	0.5	17.1	−40±60	no det	*
	13.	M 81	09 51 27.3	69 18 08	Sb	26.9	7.9	−34±4	det	
	14.	M 82	09 51 43.6	69 55 00	Amorph	11.2	9.3	203±4	det	
	15.	A952+69	09 53 27.0	69 31 18	Im		14.3			*
	16.	Kar 61	09 53 01.0	68 49 48	dE,N	1.2	13.8			*
	17.	Ho IX	09 53 28.0	69 16 53	Im	2.5	13.5	46±6	det	
	18.	NGC 3077	09 59 21.9	68 58 33	Amorph	5.4	10.6	14±4	det	
	19.	Garland	09 59 54.0	68 55 30	Im			50		*
	20.	Kar 5N	10 00 42.0	68 30 00	dE:		18.1		no det	*
	21.	DDO 71	10 01 18.0	66 47 53	dE,N	0.9	14.6		no det	*
P	22.	UGC 5423	10 01 25.3	70 36 27	BCD	0.9	13.8	349±5	det	
	23.	Kar 64	10 03 07.2	68 04 20	dE,N	1.8	14.9		no det	*
	24.	DDO 78	10 22 48.0	67 54 40	dE	2.0	14.3		no det	*
P	25.	UGC 5658	10 23 52.6	71 29 34	Im	1.0	15.0		no det	*
	26.	IC 2574	10 24 41.3	68 40 18	Sm	13.2	11.0	47±3	det	
	27.	DDO 82	10 26 48.0	70 52 33	Sm/BCD:	3.2	11.8	40	no det	*
	28.	Kar 6N	10 31 00.0	66 16 00	dE		16.0		no det	*
P	29.	Anon 1	10 45 30.0	65 02 00	?		17.4			
P	30.	UGCA 220	10 46 04.0	64 59 00	Im:	1.7	16.9		no det	*
P	31.	DDO 87	10 46 17.0	65 47 40	Im:	2.4	14.9	338±5	det	
P	32.	Anon 2	10 46 48.0	65 00 00	?		16.3			
P	33.	Kar 7N	10 47 06.0	65 22 00	?		16.2		no det	*
P	34.	Anon 3	10 47 12.0	65 00 00	?		16.5			
P	35.	Anon 4	10 47 18.0	65 00 00	?		16.5			
	36.	Kar 73	10 49 30.0	69 48 55	Im	0.6	14.9	115	no det	*
P	37.	Anon 5	10 50 30.0	65 31 00	?		15.5			*
P	38.	Anon 6	10 50 54.0	65 17 00	?		16.1			*
P	39.	Kar 8N	10 51 06.0	65 28 00	?		15.4			*
P	40.	Anon 7	10 51 18.0	65 33 00	?		15.8			*
	41.	Kar 74	10 59 05.2	70 32 01	dE/Im:	1.0	15.2		no det	*

Note: Column 1: P denotes a possible group member; Column 10: indicates objects previously observed in H I and status, i.e. detection or no detection; Column 11: * marks dwarfs observed in present survey (see Table 2).

2. The M 81 group

The M 81 group of galaxies is the most nearby rich concentration of dwarf galaxies beyond the Local Group. For our study of possible dwarf members of the M 81 group of galaxies, we used the optically selected catalog of 41 members and possible members (dwarfs or otherwise) compiled by Binggeli (1993). These data represent a compilation of various publications, databases and private communications. Binggeli's catalog is strongly based on the 2 m Tautenberg Schmidt survey by Börngen & Karachentseva (1982), the photometric work by Börngen et al. (1982), and the photographic atlas of Karachentseva et al. (1985a) obtained with the 6 m SAO telescope. Note that we rejected object No. 5 (Kar 54 = UGC 5954, at $\alpha = 09^{h}17^{m}.6$, $\delta = 75°57'$) due to its high redshift of 659 km s^{-1}, which was unknown in 1993. We also rectified the identification of Ho IX, erroneously named Ho IV in Binggeli (1993).

The basic optical data of these objects are listed in Table 1. Binggeli's numbering was retained throughout

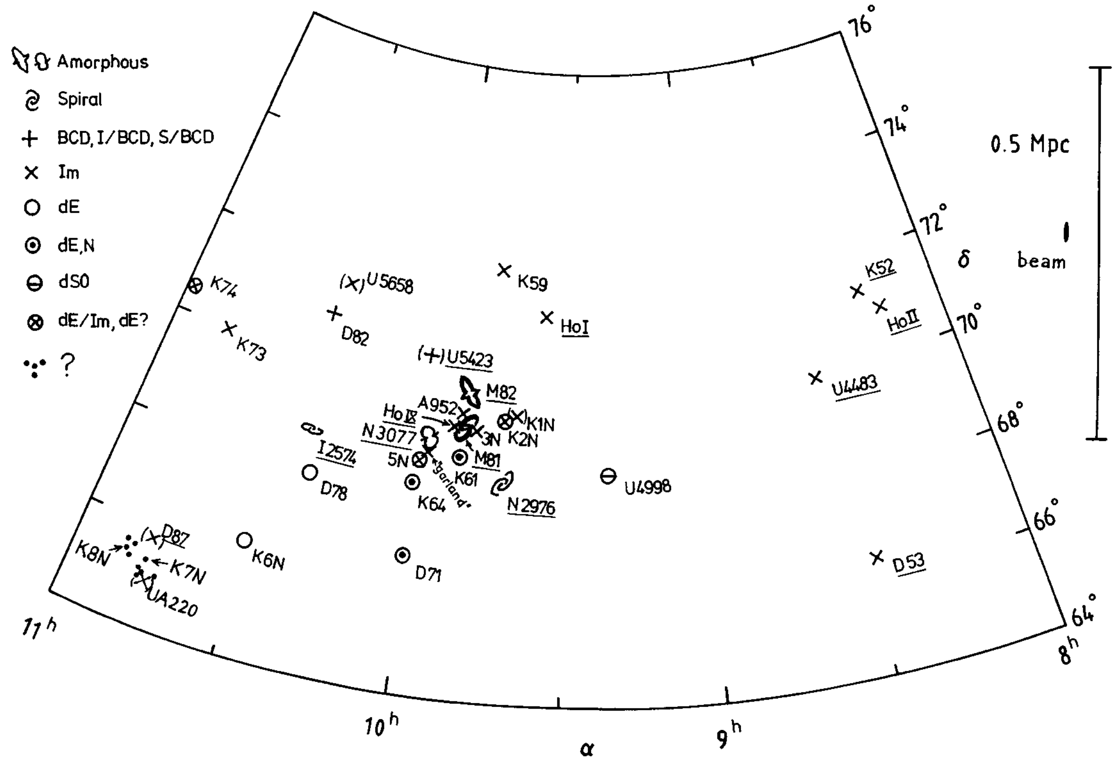

Fig. 1. Distribution on the plane of the sky of all 40 members and possible members of the M 81 group of galaxies listed in Table 1, within the boundaries of the Schmidt survey of Börngen & Karachentseva (1982). The morphological type of each galaxy has been indicated. Uncertain group members are put in parentheses, the latter also include the clustering of low-surface brightness objects of unknown nature in the SE corner. The names of galaxies previously detected in H I have been underlined. The linear scale bar of 0.5 Mpc is based on the assumed distance of 4 Mpc. Also shown is the HPBW of the Nançay radio telescope

this paper. The coordinates were taken from NED and are for the epoch 1950.0. All velocities are heliocentric and calculated according to the conventional optical definition ($v = c\Delta\lambda/\lambda_0$). Heliocentric velocities are from de Vaucouleurs et al. (1990, RC3), except for the following objects: No. 1 Holmberg II (Strauss et al. 1992), No. 12 Kar 3N (Tikhonov & Karachentsev 1993), No. 19 Garland (Karachentseva et al. 1985b), No. 22 UGC 5423 (Schneider et al. 1992) and No. 36 Kar 73 (Tikhonov & Karachentsev 1993); note that the heliocentric velocity of 180 km/s listed for No. 27, DDO 82, in the RC3 is incorrect (see Sect. 4.1).

The distribution on the sky of all 40 members and possible members of the group listed in Table 1 is shown in Fig. 1, where the morphological type of each object has been indicated. We have adopted a distance of 4 Mpc for the M 81 group. This is significantly smaller than the value of 5.5 Mpc given in the RSA (Sandage & Tammann 1987), but is in good accord with more recent work (Karachentsev 1996, cf. his Table 1).

The M 81 group, like others, shows a clear morphological segregation: most early-type dwarfs are found in a dense core around M 81, while the dwarf irregulars are spread out over the entire survey area.

The M 81 group is more compact than the Local Group, and the core galaxies are known to be strongly interacting, as shown by the large, dynamically complex H I cloud embedding M 81, M 82, NGC 3077, and NGC 2976 (van der Hulst 1977; Appleton et al. 1981, recent VLA results in Yun et al. 1994, and also the dynamical analysis by Karachentsev 1996). Because of this, and the lack of radial velocities, it is impossible to determine which dwarf belongs to which specific large galaxy.

The M 81 group may well be more dynamically evolved than the Local Group, having already released its formerly bound dwarfs through dynamical friction. On the other hand, the Garland system is a knotty dwarf irregular that apparently formed only recently from a tidal tail, a system that is likely to have been born free. A peculiar case is that of the clustering of low-surface brightness objects (Kar 7N, Kar 8N, and Anon 1 to 7 in Table 1) noted by Börngen et al. (1984). It is not clear whether these are of an extragalactic nature; they may be Galactic cirrus clouds; the M 81 group is an area of the sky rife with potential for confusion between Galactic and extragalactic objects (cirrus, HVCs, tidal tails).

3. H I line observations of M 81 group dwarfs

Of the 40 objects listed in Table 1, only 13 have previously been detected in the 21 cm H I line (see also Table 3). Four galaxies (Kar 1N, A952+69, Kar 61, and Garland), as well as 8 of the peculiar low-surface brightness objects first noted by Börngen et al. (1984) have never before been observed in the 21 cm line. These 4 galaxies, as well as the four brightest objects of unknown nature, i.e. Kar 8N, and Anon 5, 6 and 7, were selected for our deep H I search.

Four objects (Holmberg I, Kar 52 (= M 81 dwarf A), Kar 73 and Kar 3N) were mapped in H I with the VLA (Westpfahl & Prugniel 1994). The first two look like rather face-on incomplete rings with evidence for slow rotation, while the latter two resemble discs with a central hole seen edge-on and complex or confused velocity fields without clear signs of systematic rotation in the dwarf systems. No H I profile parameters are given in this reference – note, that neither Kar 73 nor Kar 3N has been reported as detected in any single-dish study, including ours.

Fifteen of these galaxies have previously been searched for with the 90 m Green Bank (Schneider et al. 1992) and the 100 m Effelsberg dish (Huchtmeier & Skillman 1994, 1997), with an rms noise varying from 7 to 15 mJy, and 4 with an rms noise of 18 mJy only for earlier work by Fisher & Tully (1981) at Green Bank and Effelsberg. We reobserved these galaxies at Nançay with considerably higher sensitivity (2 – 4 mJy rms).

The total sample of 23 dwarf galaxy candidates selected for observation in H I at Nançay are marked in the last column of Table 1. The searches for 21 cm H I line emission were made with the Nançay decimetric radio telescope in the period December 1995 – September 1996. The telescope is a meridian transit-type instrument, which permits the tracking of such high-declination galaxies for about 3 hours per day. The telescope has the equivalent collecting surface of a 94 m diameter round dish, but its HPBW is about $4' \times 22'$ ($\Delta\alpha \times \Delta\delta$), due to its elongated geometry. Most objects were observed for about 4 hours each, while the 3 low-surface brightness Anonymous objects were observed for about 8 hours each. It should be noted that the telescope is somewhat less sensitive at high declinations, like those observed for the present survey ($65° - 72°$), then at lower declinations, due to its geometry.

The 1024 channel correlator set-up used permitted an H I line search in both H and V polarisation in the radial velocity range of -529 to 1826 km s^{-1}, with a 190 km s^{-1} overlap between the filter banks, from 548 to 747 km s^{-1}, at a resolution of about 6 km s^{-1}.

After averaging the individual spectra, the data was smoothed to a velocity resolution of 12.7 km s^{-1}, and third-order baselines were fit. For the conversion of antenna temperature to flux density in mJy we used the standard declination-dependent calibration relation established by the Nançay staff through regular monitoring of strong continuum sources, and our observations of a sample strong late-type galaxies (Matthews et al. 1997) observed earlier at Nançay as well as with other telescopes.

4. Results

The resulting H I spectra of all 23 M 81 group candidate dwarf galaxy members are shown in Fig. 2.

The optical centre positions to which the telescope was pointed, the rms noise of the spectra at 12.7 km s^{-1} resolution, as well as derived H I line properties are listed in Table 2. Upper limits to the H I line flux are 3σ values for an assumed line width of 50 km s^{-1}. The last two columns indicate the velocity range within which the strong Galactic H I line signal prevents detection of external galaxies (typically $-150 \lesssim V \lesssim 115$ km s^{-1}), or the strong emission of the interconnected H I distribution around the galaxies M 81, M 82, NGC 3077 and possibly NGC 2976 obliterates the lower flux emission of the 6 dwarf candidates in that vicinity, i.e. a detection of Kar 2N, Kar 3N, A952+69, Kar 61, Garland and Kar 5N in the velocity range –280 km s^{-1} to +355 km s^{-1} (cf. van der Hulst 1977; Appleton et al. 1985, and Yun et al. 1994 for detailed H I maps of this complex region).

4.1. Notes to individual galaxies

In the search for objects that may possibly have confused the 4 H I line spectra in which the profile of an external galaxy was detected (i.e., of UGC 4998, Kar 1N, Kar 59 and UGC 5658) we queried the NED database in an area of $6' \times 33'$ ($\Delta\alpha \times \Delta\delta$), i.e. 1.5 times the HPBW in both R.A. and Dec.

No. 6 = U 4998 A photograph is displayed in the photographic atlas of Karachentseva et al. 1985a (forthwith KKB85), obtained with the 6 m SAO telescope, who suggest a dE7 classification. The structural parameters from photometry based on scans of plates from the 2 m Tautenburg Schmidt telescope and the above KKB85 atlas are given in Karachentseva et al. (1987), henceforth KKRBF87. The Nançay observations reveal a clear detection at 631 km s^{-1}. The earlier H I observations by Fisher & Tully (1981, henceforth FT81) were not sensitive enough and the signal discovered here is outside the velocity range covered in the Green Bank 90-m H I survey of Schneider al. (1992) (henceforth STMM92). Within the search area no other galaxies are known, only a radio source (87GB 092050.8+68181) at 17$'$.7 distance. The detection at Nançay at 631 km s^{-1} hence suggests that this dwarf candidate is not a member of the M 81 group but lies behind the M 81 group.

No. 8 = Kar 1N = Mailyan 45 The positional agreement – later confirmed by Madore et al. (1994) – and

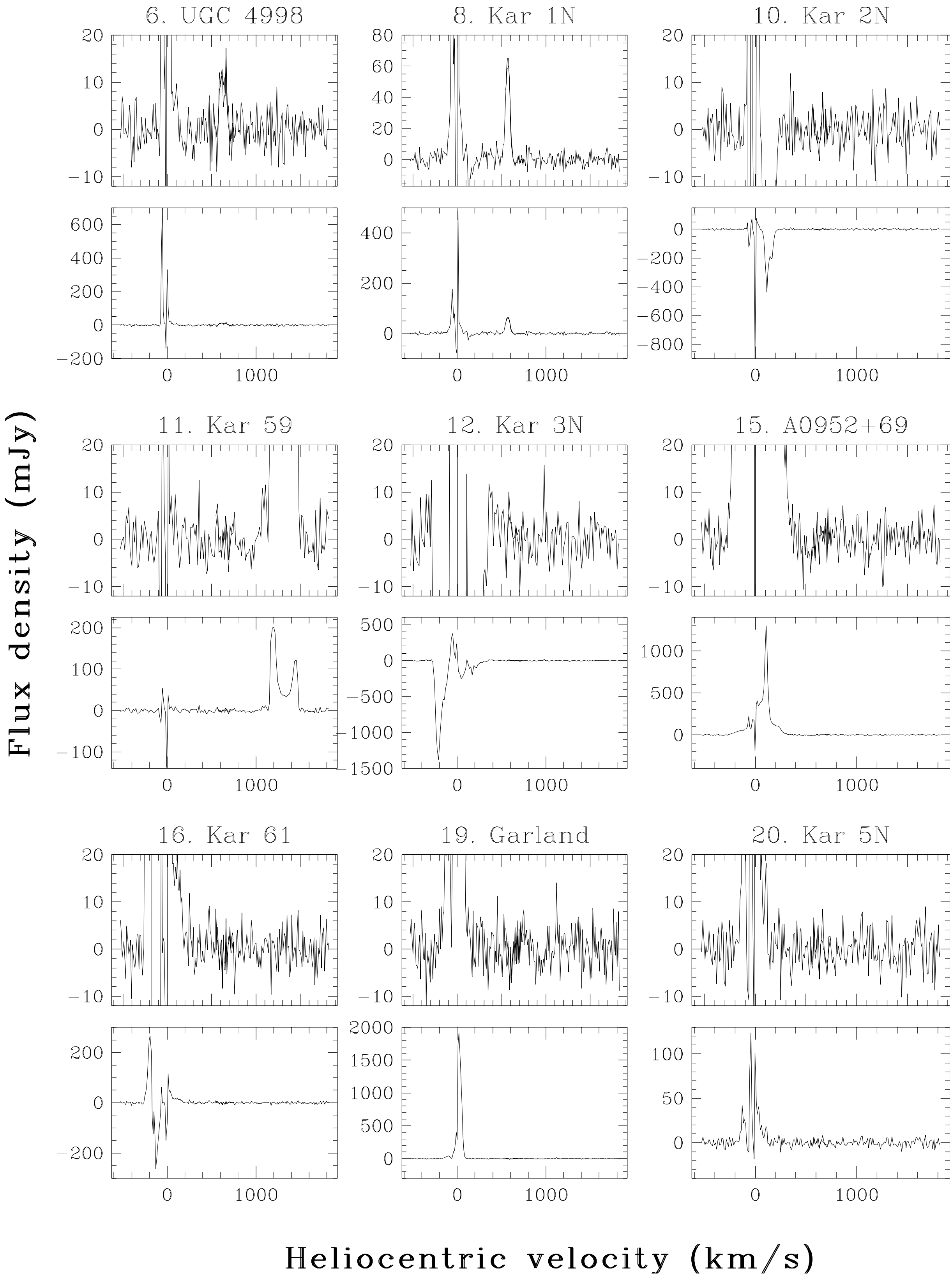

Fig. 2. 21 cm H I line spectra of all 23 candidate dwarf galaxy members of the M 81 group observed. Velocity resolution is 12.7 $\mathrm{km\,s^{-1}}$. For each object two panels are shown, with the upper displaying a small range in flux density to reveal faint features, and the lower giving the full intensity range to demarcate the Galactic H I features (typically at $-150 \lesssim V \lesssim 115$ $\mathrm{km\,s^{-1}}$) as well as confusion in the H I complex surrounding M 81, in the range -280 $\mathrm{km\,s^{-1}}$ to $+355$ $\mathrm{km\,s^{-1}}$, cf. Yun et al. 1994). Radial velocities are according to the radio convention

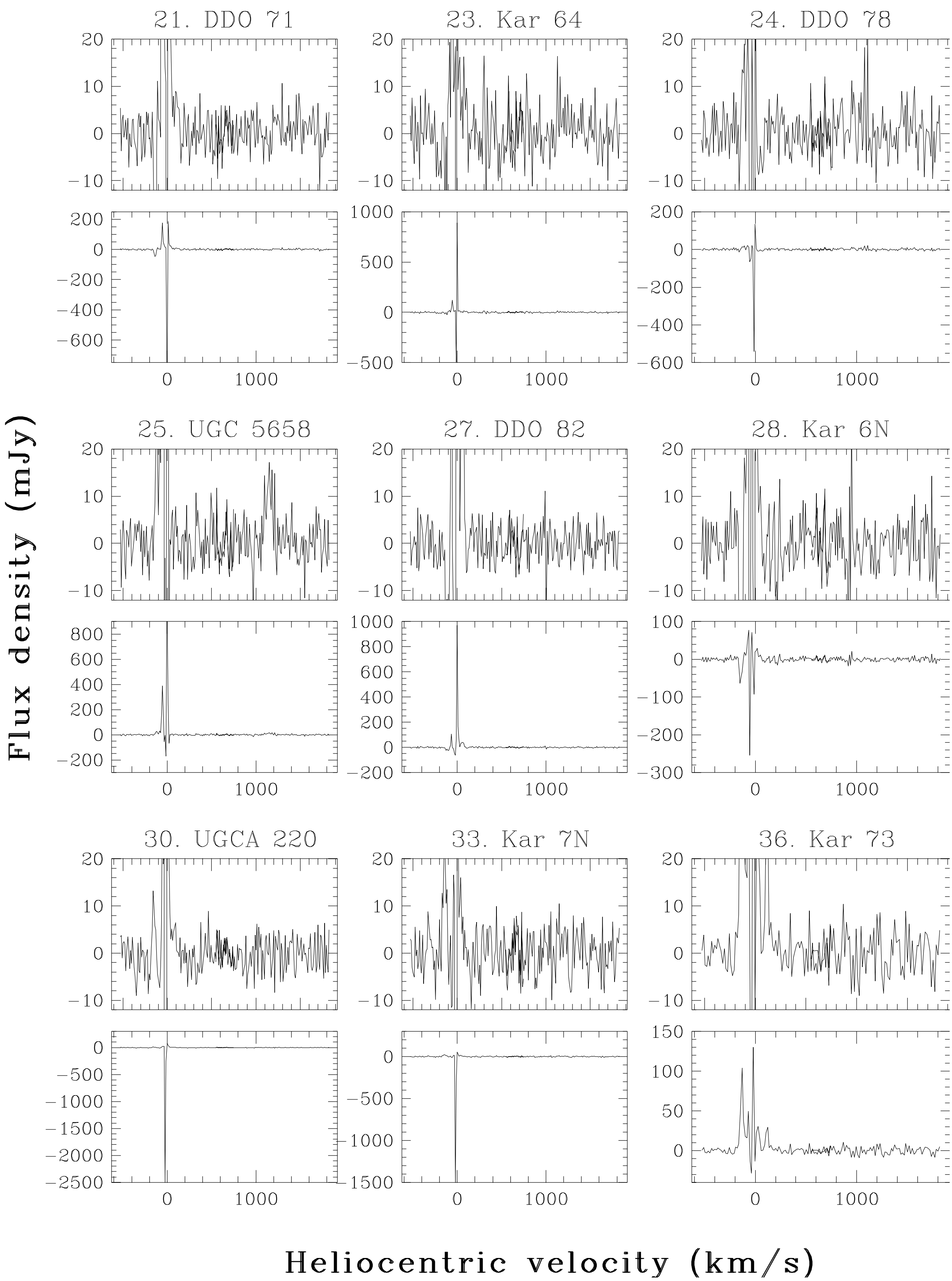

Fig. 2. continued

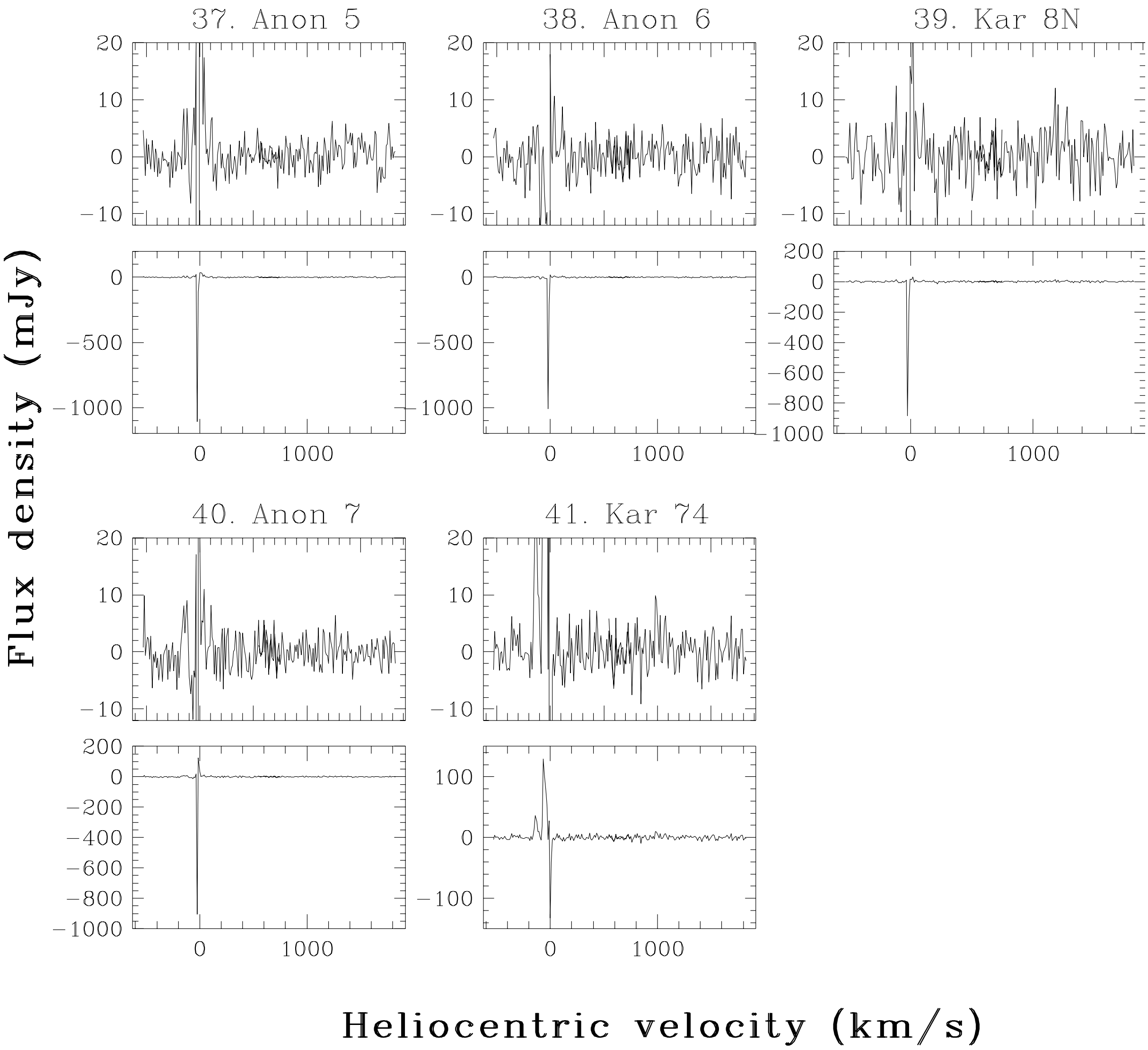

Fig. 2. continued

corresponding dimensions suggest this galaxy to be the dwarf Mailyan 45 discovered earlier (cf. Mailyan Dwarf Galaxy Catalog, Mailyan 1973). A photograph and isodensity map is given in KKB85 who suggest that this very elongated object might be interacting with the intergalactic medium, as its light distribution is noticeably lopsided. The Nançay observations find a clear detection at 569 km s^{-1}. No objects which might cause confusion were found in NED, only a radio source (87GB 094123.3+692131) at 15$'$.7 distance, and a faint 60 μm source (IRAS F09413+6914) at a distance of 22$'$.2. This irregular galaxy is thus more distant than the M 81 group.

No. 10 = Kar 2N Photograph in KKB85. No structural details can be seen. Note the strong negative (residual) emission between 0 and 200 km s^{-1} in the spectrum given in Fig. 2. This emission is due to the higher velocity gas of the western part of M 81 entering through the sidelobes of the Nançay radio telescope. If this object were to have some gas in this velocity range it would not be detectable with these observations.

No. 11 = Kar 59 Photograph of this very faint low-surface brightness object is given in KKB85, its structural parameters in KKRBF87. Our H I spectrum shows higher noise in the 170 to 250 km s^{-1} range, due to interference in the H polarization during these observations; but the other data (V polarization) do not show a detection in this velocity range either. The strong, double-horned profile visible in the spectrum at 1323 km s^{-1} is due to NGC 2985, a 11.2 mag Sab spiral at 13$'$.5 distance ($\alpha = 09^{\rm h}45^{\rm m}52^{\rm s}.6$, $\delta = 72°30'45''$), just outside the area searched in NED (in which no objects were found). For an H I line profile of NGC 2985, see Oosterloo & Shostak (1993). KKRBF87 classify this object as a dwarf spheroidal rather than an irregular which might explain the non-detection in H I.

Table 2. Nançay H I observations of the 23 possible dwarf galaxy members of the M 81-group

Ident.	R.A. (h m s)	Dec. (° ′ ″)	Type	B_T (mag)	V_{opt} (km/s)	rms (mJy)	V_{HI} (km/s)	$\int S dV$ (Jy km/s)	ΔV_{50} (km/s)	ΔV_{20} (km/s)	Conf. range (km/s)	
6. U 4998	09 20 53	68 35 53	dS0:	13.9		3.1	632	0.67	89	105	–90	140
8. Kar 1N	09 41 00	69 37 00	Im	15.5		3.5	570	3.05	56	81	–120	75
10. Kar 2N	09 43 42	69 30 00	dE?	15.9		3.5		<0.52			–115	250
11. Kar 59	09 46 40	72 17 41	Im	17.1		4.0	(1322	27.7	311	326)	–110	100
12. Kar 3N	09 49 42	69 12 00	Im	17.1	–40	4.0		<0.60			–280	290
15. A952+69	09 53 27	69 31 18	Im	14.3		3.1		<0.47			–270	355
16. Kar 61	09 53 01	68 49 48	dE,N	13.8		3.4		<0.50			–260	190
19. Garland	09 59 54	68 55 30	Im		50	3.8		<0.58			–170	75
20. Kar 5N	10 00 42	68 30 00	dE:	18.1		3.6		<0.54			–195	130
21. DDO 71	10 01 18	66 47 53	dE,N	14.6	–126	3.4		<0.50			–160	150
23. Kar 64	10 03 07	68 04 20	dE,N	14.9		4.3:		<0.65			–115	130
24. DDO 78	10 22 48	67 54 40	dE	14.3		4.9		<0.74			–145	90
25. U 5658	10 23 53	71 29 34	Im	15.0		4.0	1159	1.20	127	203:	–155	35
27. DDO 82	10 26 48	70 52 33	Sm	11.8	40	3.4		<0.50			–135	100
28. Kar 6N	10 31 00	66 16 00	dE	16.0		4.4:		<0.79			–170	65
30. UA 220	10 46 04	64 59 00	Im:	16.9		3.1		<0.47			–180	115
33. Kar 7N	10 47 06	65 22 00	?	16.2		4.3		<0.65			–175	75
36. Kar 73	10 49 30	69 48 55	Im	14.9	115	4.3		<0.65			–165	165
37. Anon 5	10 50 30	65 31 00	?	15.5		2.3		<0.34			–100	80
38. Anon 6	10 50 54	65 17 00	?	16.1		2.8		<0.41			–55	50
39. Kar 8N	10 51 06	65 28 00	?	15.4		3.6		<0.54			–50	45
40. Anon 7	10 51 18	65 33 00	?	15.8		2.2		<0.32			–165	70
41. Kar 74	10 59 05	70 32 01	dE/Im:	15.2		3.1		<0.47			–165	60

Note: The strong "Kar 59" detection is due to the nearby spiral NGC 2985.

No. 12 = Kar 3N The photograph by KKB85 and Tikhonov & Karachentsev (1993) shows resolution into blue stars. The latter determined a photometric distance of 2.8 Mpc from the brightest stars. KKB85 consider it to form one tidally-disrupted object together with two small fragments about $1' - 2'$ north of it. Kar 3N might well be H I-rich, but this irregular dwarf lies within the extended H I envelope of M 81 (cf. Yun et al. 1994) and any emission from the dwarf within $-270 \lesssim V \lesssim 355$ km s^{-1} will be lost in the strong and broad emission from M 81 itself (cf. Fig. 2). VLA H I imaging (Westpfahl & Puche 1994) shows a structure like an edge-on disc with a central hole; the velocity field shows systematic rotation, but it is not clear if this is due to the local M 81 arm or to internal motions in Kar 3N.

No. 15 = A952+69 The photograph in KKB85 shows a very low-surface brightness object with clumpiness indicative of star formation. It was resolved into stars with the 6m telescope by Efremov et al. (1986). Again the non-detection of this Im galaxy with the Nançay radio telescope does not necessarily imply this galaxy to be gas-poor. VLA synthesis observations in D-array by Yun et al. (1994) in an area of 1.5 □° around the galaxy M 81 reveals a concentration of H I at the position of this irrregular galaxy (their concentration II), suggestive of an H I mass of $\mathcal{M}_{HI}$= 3.0 10^8 $\mathcal{M}_\odot$ (at the adopted distance of 4 Mpc to the M 81 group). The mean velocity of this gas clump is about 100 km s^{-1} with a width of about 30 km s^{-1} (see also van der Hulst 1977; Appleton et al. 1981). With the single dish observation obtained here this signal cannot be resolved from the much stronger emission of M 81.

No. 16 = Kar 61 = A0961+68 = Mailyan 47 A photograph is given in Bertola & Maffei (1974), an isodensity map in KKB85, the luminosity profile and structural parameters in KKBRF87. This is a typical example of a low-surface brightness dwarf spheroidal system and the non-detection at Nançay is not surprising. However, the analysis by Appleton et al. suggest that this dwarf spheroidal is associated with a clump of H I gas of the order of $\mathcal{M}_{HI}$= 2.6 10^7 $\mathcal{M}_\odot$ with a mean velocity of about $V_{hel} = -87$ km s^{-1}and a linewidth of ∼35 km s^{-1}. This clump is visible in the more detailed H I map by Yun et al. (1994), but it looks more like the end of a spiral arm than a distinct H I concentration. In either case, the expected signal would not be sufficiently strong to stand out over the M 81 – M 82 – NGC3077 H I complex (cf. also Fig. 3).

No. 19 = Garland Deep photographs, spectra and a detailed discussion of this dwarf irregular are presented in Karachentseva et al. (1985b). The total extent of the object is about $6' \times 4'$ and its centre lies about 4$'$.5 from that of NGC 3077, which has an about 55 km s^{-1} lower redshift. It shows various knots of star formation and lies in the extension of the H I bridge connecting NGC 3077 to M 81. Garland may be at an intermediate stage in the conversion of a tidal tail or bar into an ordinary dwarf galaxy as a result of the interaction between M 81 and NGC 3077. Its internal motions are of order 55 km s^{-1} and its dynamical age is estimated to be about 10^8 years only. The H I distribution within NGC 3077 shows an extension to the SE. This might be associated with Garland. The signal in our spectrum primarily originates from NGC 3077 ($V = 14$ km s^{-1}, $\Delta V = 93$ km s^{-1}).

No. 20 = Kar 5N The faintest object in our sample (m_B= 18.1). It is round and without structural details (cf. KKB85). It is outside the H I complex around M 81, hence any gas emission could only reside within the narrow velocity range of the Galactic gas.

No. 21 = DDO 71 = Kar 63 = UGC 5428 = Mailyan 49 The photograph in KKB85 finds DDO 71 to be a circular, structureless, very low-surface brightness object. It was not detected in the earlier H I work by FT81 with rms noise of 18 mJy, or at Green Bank (STMM92) with an rms of 8.5 mJy. It is not found in co-added IRAS data either (Melisse & Israel 1994). Based on its optical radial velocity ($V = -126$ km s^{-1}) and the Galactic gas emission as seen in the spectrum, its H I emission – if present – should have been measurable.

No. 23 = Kar 64 = UGC 5442 = Mailyan 50 A photograph and isodensity map are given in KKB85. Not detected previously by STMM92.

No. 24 = DDO 78 The photograph in KKB85 shows a circular, very low-surface brightness object. Not detected by FT81.

No. 25 = U 5658 = Mailyan 53 The overexposed photograph in KKB85 shows a high-surface brightness object with a regular elliptical outline, partially resolved into knots surrounded by diffuse material. This low flux object was not detected in the earlier less sensitive H I surveys (FT81 & STMM92). The NED search finds two galaxies in the 1.5 times the HPBW area, but they do not appear to be related to our H I line detection: CGCG 333 – 030, a 15.7 mag object of unknown morphological type and redshift, at 8'.9 distance ($\alpha = 10^h24^m24^s$, $\delta = 71°21'00''$), and UGC 5645, a 16th mag SBb spiral at a redshift of 10 490 km s^{-1}, at 11'.2 distance ($\alpha = 10^h23^m16^s.1$, $\delta = 71°40'25''$).

No. 27 = DDO 82 = UGC 5692 The photograph in KKB85 shows a dwarf spiral galaxy with a very distorted spiral structure. Its optical spectrum shows bright Hα and [SII] lines (Karachentsev & Karachentseva 1984) yielding a recesson velocity of $V = 40$ km s^{-1}. Note, that the radial velocity of 180 km s^{-1}listed in the NED database and elsewhere is wrong, since the solar motion has been corrected for twice (Karachentsev et al. 1994). A distance of 4.5: Mpc was derived from photometry of its brightest stars (Karachentsev et al. 1994). Its morphology, the distance and its detection at 60 and 100 μm in co-added IRAS data (Melisse & Israel 1994) strongly suggest this galaxy to be H I-rich. But it was not detected in the present Nançay survey, nor in the earlier surveys (FT81, STMM92), nor in a short Westerbork interferometer observation (Kamphuis et al. 1996). This can only be explained, if the gas is at the same velocity as the optically obtained velocity ($V = 40$ km s^{-1}) rendering detection impossible due to Galactic H I emission.

No. 28 = Kar 6N The photograph and isodensity map in KKB85 show it to be a low-surface brightness object with an axial ratio of 0.5, hardly any luminosity gradient and no structural detail.

No. 30 = UGCA 220 = Mailyan 58 The KKB85 photograph reveals a diffuse, lumpy object with patches of different surface brightness suggestive of star formation and presence of H I gas. This galaxy was not detected at Nançay, nor earlier by FT81. It may be part of the clustering of peculiar low-surface brightness objects, 5 of which were included in our present observing program.

No. 33 = Kar 7N The KKB85 photograph shows a diffuse, patchy faint object. Belongs to the group of unusual objects discovered by Börngen et al. (1984).

No. 36 = Kar 73 Photographs in KKB85 and Tikhonov & Karachentsev (1993) find this galaxy to be resolved into separate knots (stars and H II regions?) superimposed on a diffuse, very low-surface brightness background. Tikhonov & Karachentsev determine a photometric distance of 4.0 Mpc from the brightest stars. VLA H I imaging (Westpfahl & Puche 1994) shows a structure resembling an edge-on disc with a central hole; the velocity field is too complex to discern systematic rotation.

No. 37 = Anon 5 Belongs to the group of peculiar objects. Photograph in Börngen et al. (1984).

No. 38 = Anon 6 Belongs to the group of peculiar objects. Photograph in Börngen et al. (1984).

No. 39 = Kar 8N Diffuse, patchy object of large angular size, at the detection limit of the 6m photograph in KKB85. Belongs to the group of unusual objects reported by Börngen et al. (1984).

No. 40 = Anon 7 Belongs to the group of peculiar objects. Photograph in Börngen et al. (1984).

No. 41 = Kar 74 The photograph (cf. KKB85) shows a featureless object of regular elliptical shape.

5. Discussion

5.1. HI line detections

We have observed 23 dwarf galaxy candidate members of the M 81 group of galaxies, including 5 peculiar objects of unknown nature. Of the 18 with given morphology, half are early types (dE or dS0: and one dE/Im:), and half are late types (Im or Sm). The latter 9 objects should in principle be gas-rich, hence detectable at Nançay with the sensitivity obtained here.

However, in the present survey only 3 objects were detected in the H I line. The strong signal in the spectrum of No. 11 (Kar 59) at 1323 km s^{-1} originates from a nearby bright spiral. None of the 3 detected dwarfs seem to be a member of the M 81 group of galaxies, however, as their redshifts of 632, 570 and 1159 km s^{-1} clearly show them to be behind the group. If we calculate distances directly from their recession velocites corrected to the LSR following the precepts given in Sandage & Tammann (1987), and

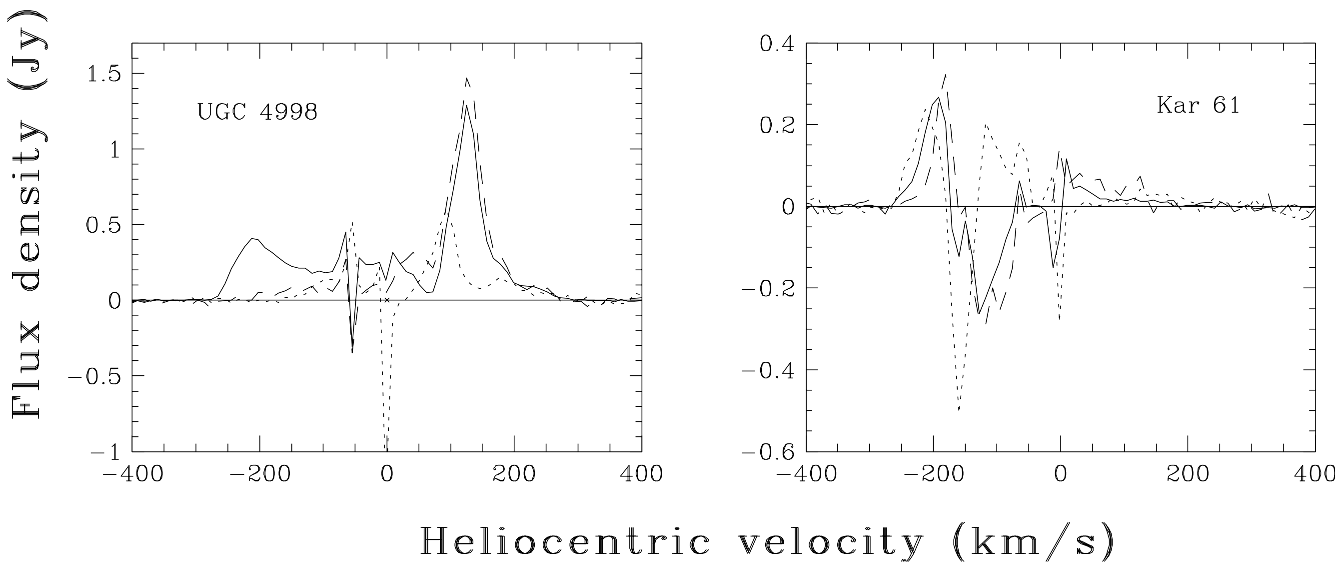

Fig. 3. A comparison of spectra obtained exactly at the optical centre of the two objects (No. 15, A952+69 and No. 16, Kar 61) with offsets of one beam width (4′) due East and West. The fact that the line profiles are so similar makes it impossible to disentangle the expected much fainter contribution of the dwarf from the signal which is due to the Galaxy and the M 81 complex

a Hubble constant of $H_0 = 50$ km s^{-1} Mpc^{-1}, the galaxies UGC 4998, Kar 1N and UGC 5658 are at distances of 15.9, 14.7 and 26.6 Mpc and have H I masses of 0.4, 1.6 and $2.0 \cdot 10^8 \mathcal{M}_\odot$. The resulting H I mass-to-blue light ratios are 0.04, 0.73 and 0.18 $\mathcal{M}_\odot/L_{\odot,\mathrm{B}}$, respectively.

The profile of Kar 1N is narrow ($\Delta V_{50} = 61$ km s^{-1}) and clearly Gaussian shaped, that of UGC 4998 is a bit broader (89 km s^{-1}) and more flat-topped, while that of UGC 5658 ($\Delta V_{50} = 127$ km s^{-1}) least resembles a typical dwarf line profile.

The two detected objects classified as magellanic irregulars (Kar 1N and UGC 5658) have quite discrepant $\mathcal{M}_{\mathrm{HI}}/L_{\mathrm{B}}$ ratios (0.73 and 0.18 $\mathcal{M}_\odot/L_{\odot,\mathrm{B}}$) for their similar morphological type. In particular, the $\mathcal{M}_{\mathrm{HI}}/L_{\mathrm{B}}$ ratio of 0.18 for UGC 5658 seems very low for an irregular dwarf, whereas the extremely low $\mathcal{M}_{\mathrm{HI}}/L_{\mathrm{B}}$ ratio of 0.04 $\mathcal{M}_\odot/L_{\odot,\mathrm{B}}$ for the dS0: galaxy UGC 4998 seems quite consistent with the upper limit of about 0.15 found for morphologically pure lenticulars (Knapp et al. 1989).

For comparison, the global optical and H I line properties of all 11 previously detected M 81-group dwarf galaxies are given Table 3. The values are taken from the Huchtmeier & Richter (1989) and Schmidt & Boller (1992) compilations, with the exception of the integrated fluxes for the systems M 81, M 82, and NGC 3077 interconnected in H I, as well as Ho IX, which are adopted from the VLA synthesis analysis by Yun et al. (1994).

5.2. The non-detections and confusion problems

The average 3σ upper limit of 10.5 mJy and an assumed line width of 50 km s^{-1}imply an upper limit of 0.52 Jy km s^{-1} to the H I line flux for the objects not detected in our survey. This implies an upper mass limit of 2.4 10^6 $\mathcal{M}_\odot$ (and even less for the "anonymous" low-surface brightness objects of unknown nature) at the adopted distance of 4 Mpc to the M 81 group, and upper limits to the $\mathcal{M}_{\mathrm{HI}}/L_{\mathrm{B}}$ ratios of 0.08 and 0.5 $\mathcal{M}_\odot/L_{\odot,\mathrm{B}}$ for a 15$^{\mathrm{th}}$, respectively a 17$^{\mathrm{th}}$ magnitude galaxy.

However, the non-detections are unlikely due to a lack of gas in these dwarfs. Inherent to H I line searches for nearby objects is always the problem of confusion by or with strong Galactic H I lines, i.e. emission lines of external galaxies being lost among strong Galactic lines, or being interpreted as part of the Galactic emission (see, e.g., the case of the discovery of Dwingeloo 1 by Kraan-Korteweg et al. 1994). We have noted the velocity ranges dominated by Galactic confusion for each object in Table 2, i.e., the range in which we estimate that the profile of a typical dwarf with a peak intensity of 10 mJy would not be recognized as such. The average range is about −150 to 115 km s^{-1} with about ±50 km s^{-1} for the 2 narrowest profiles. As the mean velocity of the 18 members of the M 81 group with known redshifts listed in Table 1 is $< V > = 101$ km s^{-1}, with a dispersion of $\sigma =$ 114 km s^{-1}, this means that, statistically speaking, more than half of them would be lost among strong Galactic H I lines if they were all gas-rich. In fact, 5 of the galaxies observed at Nançay have known optical redshifts (see Table 2), which *all* fall within the velocity range obscured by Galactic H I.

In the central part of this group, i.e. in an area of about 1.5 □° around the galaxy M 81, the confusion problem is even worse. Here, M 81, M 82, NGC 3077, and –

Table 3. Members of the M 81 group detected previously in H I

	Ident.	R.A. (h m s)	Dec. (° ′ ″)	Type	Diam (′)	B_T (mag)	V_{hel} (km/s)	$\int S dV$ (Jy km/s)	ΔV_{20} (km/s)	$\mathcal{M}_{HI}/L_B$ ($\mathcal{M}_\odot/L_{\odot,B}$)
1.	Ho II	08 13 53.5	70 52 13	Im	7.9	10.2	158	359.7	79	0.59
2.	Kar 52	08 18 43.0	71 11 25	Im	1.3	14.2	114	3.7	38	0.25
3.	DDO 53	08 29 33.3	66 21 08	Im	1.5	13.6	19	23.7	46:	0.89
4.	UGC 4483	08 32 07.0	69 57 16	Im	1.1	13.9	157	3.1	70	0.16
7.	Ho I	09 36 00.9	71 24 55	IABm	3.6	12.2	136	49.0	45	0.50
9.	NGC 2976	09 43 11.5	68 08 45	SAcp	5.9	10.9	3	63.6	159	0.20
13.	M 81	09 51 27.3	69 18 08	Sb	26.9	7.9	–34	859.9	464	0.19
14.	M 82	09 51 43.6	69 55 00	Amorph	11.2	9.3	203	245.2	290	0.20
17.	Ho IX	09 53 28.0	69 16 53	Im	2.5	13.5	46	94.8	120:	3.63
18.	NGC 3077	09 59 21.9	68 58 33	Am	5.4	10.6	14	212.5	93	0.57
22.	UGC 5423	10 01 25.3	70 36 27	BCD	0.9	13.8	343	2.3	80	0.11
26.	IC 2574	10 24 41.3	68 40 18	Sm	13.2	11.0	47	442.5	126	1.52
31.	DDO 87	10 46 17.0	65 47 40	Im:	2.4	14.9	338	18.9	80	2.35

according to Appleton et al. (1981, their Fig. 2) – also NGC 2976 are embedded in a common, very extended H I cloud with H I bridges connecting the major galaxies, and distinct H I clumps, some of which coincide with optically identified dwarfs.

Seven dwarfs (Kar 2N, Kar 3N, A9562+68, Kar 61, Ho IX, Garland, and Kar 5N) reside in this area where the strong H I emission (within about −280 to +355 km s^{-1}) from the larger interacting galaxies makes the detection of gas-rich dwarfs extremely difficult (local estimates for the confusion range are given for each dwarf candidate in the last column of Table 2). So far, only the dwarf Ho IX has been unambigously associated with H I . None of the 6 dwarfs observed at Nançay were detected. If we regard Fig. 1 of Yun et al. (1994), however, it seems clear that the irregular galaxy A952+69 must be associated with the second H I concentration visible in that image (the first being Ho IX). Appleton et al. (1981) even suggest that the H I concentration in the southern tip of the spiral arm of M 81 visible in H I is due to Kar 61 (No. 16) and that the south eastern extension in the H I distribution of NGC 3077 might be due to the starforming galaxy Garland.

Even with the above indications for gas in three of the central dwarf galaxies, single dish observations cannot resolve these signals from the stronger emission of their dominant companions – or the Galaxy. In case of the two objects with the broadest confusion range in the Nançay beam (No. 15 = A952+69, –270 to +355 km s^{-1}, and No. 16 = Kar 61, –260 to +190 km s^{-1}), we have obtained shorter observations pointed to the galaxy's centre and one HPBW (4′) due East and one due West, in order to verify whether part of the signal could be assigned to the dwarf candidate in question. A comparison of these on and off-source profiles (Fig. 3) confirms the signal to originate from our Galaxy and the H I complex around M 81, as they have about the same velocity extent at and near each galaxy, whose optical diameter is considerably smaller than the beam width.

Not even the detailed H I maps from synthesis observations can resolve these problems. The assignment of individual H I concentrations (or filaments) to optically identified dwarf galaxies remains ambiguous within this highly active region where the gas might have been swept away from the currently visible starforming dwarfs.

Here spectroscopy, in particular the determination of the recession velocities from emission lines in starforming galaxies, might be the only approach to learn more about the kinematics in the M 81 group – not only in the central part of the group, but also within the larger group boundary.

5.3. Conclusion

Three new detections of dwarf candidates in the M 81 group have disproven these objects to be members of the M 81 group. Due to confusion problems the non-detections do not a priori imply that the other observed dwarf candidates are gas-poor, although the high-sensitivity observations clearly demonstrate that they cannot be gas-rich dwarfs just beyond the M 81 group. In order to study the dynamics of the M 81 group in further detail, in particular the behaviour of the dwarfs within the gravitational potential well of the group as such and the massive galaxies within it, spectroscopic observations of the remaining dwarf candidates without velocity information are required.

Acknowledgements. We would like to thank Drs. L. Bottinelli, L. Gouguenheim and G. Theureau for making their flux density calibration data available to us, and V. Etieve for her help with the illustrations. The Nançay Radio Observatory is the Unité Scientifique Nançay of the Observatoire de

Paris, associated as Unité de Service et de Recherche (USR) No. B704 to the French Centre National de Recherche Scientifique (CNRS). The Observatory also gratefully acknowledges the financial support of the Région Centre in France. The research by RCKK is being supported with an EC grant. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

References

Appleton P.N., Davies R.D., Stephenson R.J., 1981, MNRAS 195, 327
Bertola F., Maffei P., 1974, A&A 32, 117
Binggeli B., 1993, Dwarf Galaxies as Bound Companions, Habilitationsschrift, University of Basel, Switzerland
Binggeli B., Tarenghi M., Sandage A., 1990, A&A 228, 42
Börngen F., Karachentseva V.E., 1982, AN 303, 189
Börngen F., Karachentseva V.E., Schmidt R., Richter G.M., Thänert W., 1982, AN 303, 287
Börngen F., Karachentseva V.E., Karachentseva I.D., 1984, AN 305, 53
de Vaucouleurs G., de Vaucouleurs A., Corwin H.C., et al., 1990, Third Reference Catalog of Bright Galaxies. Springer Verlag, New York (RC3)
Efremov Yu.N., Karachentsev I.D., Karachentseva V.E., 1986, Sov. Astron. Lett 12, 181
Fisher J.R., Tully B., 1975, A&A 44, 151 (FT81)
Fisher J.R., Tully B., 1981, ApJS 47, 139
Huchtmeier W.K., Richter O.-G., 1989, A General Catalog of H I Observations of Galaxies. Springer, Berlin
Huchtmeier W.K., Skillman E., 1994, in ESO/OHP Workshop on Dwarf Galaxies, ESO Conf. and Workshop Proc. No. 49, Meylan G. and Prugniel P. (eds.). ESO, Garching, p. 299
Huchtmeier W.K., Skillman D.A., 1997, A&AS (in press)
Kamphuis J.J., Sijbring D., van Albada T.S., 1996, A&AS 116, 15
Karachentsev I., 1996, A&A 305, 33
Karachentsev I.D., Tikhonov N.A., Sazonova L.N., 1994, A&AS 106, 555
Karachentsev I.D., Karachentseva V.E., 1984, Astrofizika 21, 641
Karachentseva V.E., Karachentsev I.D., Börngen F., 1985a, A&AS 60, 213 (KKB85)
Karachentseva V.E., Karachentsev I.D., Börngen F., 1985b, MNRAS 217, 731
Karachentseva V.E., Karachentsev I.D., Richter G.M., et al., 1987, AN 308, 247 (KKRBF87)
Knapp G.R., Guhathakurta P., Kim D.-W., Jura M., 1989, ApJS 70, 329
Kraan-Korteweg R.C., Loan A.J., Burton W.B., et al., 1994, Nat 372, 77
Madore B.F., Sun H., Bennett J.H., et al., 1994, PASP 106, 63
Mailyan N.S., 1973, Astrofizika 9, 33
Matthews L.D., van Driel W., Gallagher J.S. III, 1997, A&A (submitted)
Melisse J.P.M., Israel F.P., 1994, A&AS 103, 391
Oosterloo T., Shostak G.S., 1993, A&AS 99, 379
Sandage A.R., Tammann G.A., 1987, A Revised Shapley-Ames Catalogue of Bright Galaxies, second edition. Carnegie Institution, Washington D.C.
Schmidt K.-H., Boller T., 1992, AN 313, 189
Schneider S.E., Thuan T.X., Mangum J.G., Miller J., 1992, ApJS 81, 5 (STMM92)
Strauss M.A., Huchra J.P., Davis M., et al., 1992, ApJS 83, 29
Tikhonov N.A., Karachentsev I.D., 1993, A&A 275, 39
van der Hulst J.M., 1978, in Structure and Properties of Nearby Galaxies, IAU Symp. No. 77, Berkhuijsen E.M. and Wielebinski R. (eds.). Reidel, Dordrecht & Boston, p. 269
Westpfahl D., Puche D., 1994, in ESO/OHP Workshop on Dwarf Galaxies, ESO Conf. and Workshop Proc. No. 49, Meylan G. and Prugniel P. (eds.). ESO, Garching, p. 295
Yun M.S., Ho P.T.P., Lo K.Y., 1994, Nat 372, 530