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An HI survey of polar ring galaxies

II. The Effelsberg sample*

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Abstract. We present the results of a neutral hydrogen survey conducted with the 100-m radiotelescope at Effelsberg of 44 northern objects in the polar-ring galaxy atlas of Whitmore et al.(1990). These observations were performed to complement the Green Bank observations of polar-ring galaxies (Paper I). We detected 29 of these above our detection limit of a few mJy. The relative content of neutral hydrogen (M_{HI}/L_B) of the early-type galaxies (E, S0) in this sample is significantly higher than for galaxies of the same morphological types from comparison samples, i.e. for elliptical galaxies $M_{HI}/L_B = 0.17 \pm 0.09$ and for S0 galaxies M_{HI}/L_B=0.75±0.13 which is about 6 times the mean value from the comparison samples for the same morphological types.

Key words: galaxies: distances and redshifts; elliptical and lenticular; ISM; peculiar – radio lines: galaxies

1. Introduction

A quick look at the photographic atlas of polar-ring galaxies by Whitmore et al. (1990; PRC hereafter) reveals a series of peculiar objects. Polar-ring galaxies (PRG) often consist of early-type galaxies surrounded by a ring-like structure of gas, dust, and stars in a plane orthogonal to the central galaxy. Many of the PRC galaxies have been described as blue "post-eruptive" (CGCG) [1]with plumes and jets. A number of these galaxies are to be found in catalogs of special objects like the MCG, Arps catalogs of peculiar galaxies and have nearby companions. Interaction and merger processes are likely to be responsible for such phenomena where gas and dust settles on early-type galaxies. A few data on HI-rich PRGs are found in the literature (e.g. Sackett 1991).

The intention of this series of papers is to get a more homogeneous and sensitive set of HI data of galaxies in the PRC. These observations with the 100-m radiotelescope at Effelsberg complement the 140 ft observations at Green Bank (Richter et al. 1994; Paper I) in order to get a larger data base for a global study of PRGs. A certain overlap of the observing list was chosen deliberately in order to look for structural changes in global profiles as a function of beam size. For more detailed studies of the PRG phenomenon observations with high spatial resolution will be needed. For further discussions of the phenomena of polar-ring galaxies we refer to PGC and Paper I. A great majority of the galaxies in the PRC are classified as PRGs or possible PRGs. Only a smaller part are described as objects possibly related with PRGs. Throughout this paper we will use a value of 75 km s^{-1} Mpc^{-1} for the Hubble constant, the same as in Paper I.

2. HI-observations

Observations were performed in severel sessions in 1992/93 with the 100m radiotelescope at Effelsberg which has a half-power-beamwidth of 9.3 ' at a wavelength of 21 cm. A two channel cooled HEMT receiver was followed by a 1024 autocorrelator which was split into four banks of 256 channels each. A total bandwidth of 12.5 MHz yielded a channel separation of 10.3 km s^{-1}, which corresponds to a resolution of 12.8 km s^{-1} or to 20.6 $km\ s^{-1}$ after Hanning smoothing. The system temperature was around 30K. Observations were performed in the total power mode integrating 5 min on an empty (comparison) field ahead of the source followed by a 5 min integration on the source. Source and reference observations were combined to produce the profile. In cases when the radial velocity of the source was not known the four channels of the autocorrelator were used with a frequency separation of 10 MHz each in order to cover a wide search region in radial velocity (i.e. from -400 to 8800 km s^{-1}) and sufficient overlay between these channels. Position checks and calibration measurements were done by observing well-known radio continuum sources. Regular system checks were performed every few hours by observing well-known line sources.

HI profiles of the detected galaxies are given in Fig. 1.

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* Table 2 is available only in electronic form at the CDS via anonymous ftp (130.79.128.5)

[1] *Catalogue of Galaxies and Clusters of Galaxies*, Zwicky et al. 1961

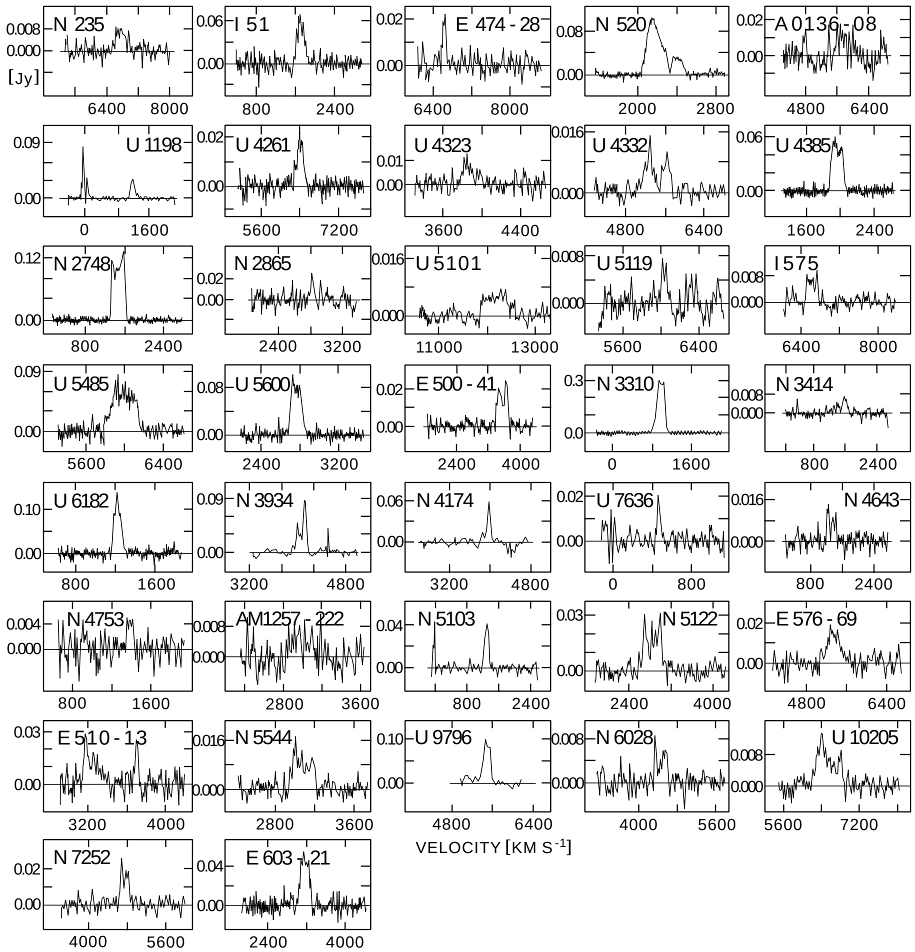

Fig. 1. HI-profiles of polar-ring galaxies observed with the 100-m Effelsberg radio telescope with a half power beam width of 9.3'.

3. The data

In Table 1 we present the optical data of the galaxies in our source list in order of their Right Ascension: the PRC no. and the galaxy name (columns 1 and 2), the morphological type (column 3), the 1950.0 coordinates (column 4), the heliocentric optical radial velocity (column 5), the total blue apparent magnitude (column 6), and the major axis diameter (D_{25}) in arc min (column 7). Optical data are from the RC3 [2] , the PRC, the UGC [3], in this order of preference. The following HI-data are presented in columns 8 to 11 of Table 1: the total line flux in Jy km s^{-1} (column 8), the maximum intensity (S_{max}) and the rms error in mJy (column 9), the heliocentric radial velocity of the HI-line (mean of the two midline velocities at a level of 25% and 20% of the peak) and its error (column 10), and the observed line width at a level of 20% of the line peak in column 11. Confusion by nearby galaxies is indicated in the footnotes of Table 1.

Global parameters of the galaxies have been derived following the formulae given by Huchtmeier and Richter (1988 (**HR1**from hereon)) and by Richter et al. 1994.

[2] *Third Reference Catalogue of Bright Galaxies*, de Vaucouleurs et al. 1991

[3] *Uppsala General Catalog of Galaxies*, Nilson 1973

In Table 2 (only available in electronic form) we present derived quantities for the unconfused 38 galaxies from Paper 1 and Paper 2: the PRC no. and the galaxy name (column 1 and 2), the morphological type (column 3), the blue luminosity (column 4), the total HI-mass (column 5) and the relative HI-content M_{HI}/L_B (column 6).

4. Discussion

The large overlap of 26 galaxies between the present work and Paper I was planned to check for consistency and to have a first check for HI extent or confusion by observations with different beam sizes. By comparing the HI data from Paper I with the present results we find good agreement for a large number of galaxies in HI-flux, velocity and line width. In a number of cases where the galaxies have been detected by one telescope only this is a question of sensitivity (e.g. C-60, D-25, D-28, D-43). Some of the discrepencies in HI-flux could be due to the noise (i.e. sensitivity) in one of the measurements (e.g. C-12, C-25, C-29, C-35). A few cases need some more discussion:

NGC 442 - comparable noise for the observations from both telescopes, 100-m RT - no detection, GB 140" a weak 2 sigma profile, may not be a safe detection;

UGC 4323 - agreement between both profiles rather poor;

Table 1. Optical and HI data

PRC no.	Galaxy name	type	Position(1950) h m s o ' "	optical velocity $km\,s^{-1}$	m_{BT}	D_{25} '	$HI\,flux$ Jy $km\,s^{-1}$	S_{max} mJy	HI velocity $km\,s^{-1}$	linewidth dv_{20} $km\,s^{-1}$
D-02	NGC 235	S0	00 40 24 -23 48 55	6664±21	14.24	1.32	2.4	9±2.2	6765±26	303
B-01	IC 51	E/S0	00 43 54 -13 42 57	1666		1.35	9.4	70±6	1728±5	216
D-03	E 474-28	Sbc	00 45 07 -23 04 12	6800	14.91	0.73	3	24±3	6635±20	135
C-09	NGC 442	S0	01 12 05 -01 17 48	5620±50	13.98	0.98		±3		
D-44	NGC 520	S0	01 22 00 03 31 54	2224	12.05	6.8	21.3	10.6±5.2	2189±5	450
A-01	A0136-0801	S0	01 36 26 -08 01 19	5523	15.82		3	18±6	5670±27	310
C-12	UGC 1198	E	01 40 58 85 00 38	1207	14.40	1.0	3.6	32±2.4	1152±25	152
C-24	UGC 4261	S.	08 07 40 36 58 38	6421	14.07	0.91	3	21±3	6404±18	239
C-25	UGC 4323	E	08 15 36 67 08 22	3943±106	13.90	1.58	0.9	11±4.4	4037±30	250
C-26	UGC 4332	S.	08 16 43 21 16 23	5505±94	14.21	1.32	4.3	±1.8	5412±30	620
C-27	UGC 4385	I	08 21 04 14 54 54		14.33	0.87	7.4	62±4	1968±5	177
C-28	NGC 2748	Sbc	09 08 02 76 40 53	1456±58	11.69	3.02	54	140±13	1478±2	140
D-12	UGC 4892	Sbc	09 13 32 45 54 34		14.86			±3		
C-29	NGC 2865	E	09 21 15 -22 56 54	2611±13	12.18	2.45	1.7	26±7	2850±20	159
C-30	UGC 5101	S.	09 32 05 61 34 33	11945±35	14.72			±2.2		
B-10	UGC 5119	S0	09 34 08 38 19 01	5982±38	14.48	0.1	7	34±5	5856±4	353
C-32	IC 575	Sa	09 52 04 -06 51 28		14.5	4.07	1.6	9.5±4	6639±40	273
D-14	UGC 5485	Sab	10 07 40 65 31 23		15.1		16.2	85±3.9	5990±5	331
B-11	UGC 5600	S0	10 19 17 78 52 52	2823		1.41	11.1	101±7.8	2769±2	156
C-33	E 500-41	Sab	10 24 35 -23 50 03		14.22	1.07	5	24±4.4	3570±12	332
D-15	NGC 3310	Sbc	10 35 40 53 45 46	1018±12	10.95	3.09	54.4	300±6.2	983±3	234
C-35	NGC 3414	S0	10 48 32 28 14 28	1434±27	11.86	3.55	1.2	6±1.8	1526±25	322
D-16	NGC 3406	S0/a	10 48 45 51 17 15	7139	13.7			±6.9		
C-37	UGC 6182	Sc	11 05 08 53 53 16	1255	14.07	0.93	10.7	135±8.7	1230±5	114
C-38	NGC 3934	S0/a	11 49 36 17 07 00	3626±56	14.28	1.07	15.9	85±5.7	3702±8	317
C-39	NGC 4174	Sb	12 09 55 29 25 38	3980±32	13.81	0.83	9.4	63±3.8	3936±9	262
D-21	UGC 7636	Im	12 27 28 08 12 24		14.71	1.10	0.63	21±3.6	475±10	47
D-22	NGC 4643	SB0	12 40 47 02 15 06	1399±58	11.54	3.09	2.3	13±2.3	1325±20	274
D-23	NGC 4753	S0	12 49 49 -00 55 40	1237±38	10.71	6.02	0.55	8±2.1	1396±10	91
D-24	AM1257-22	E	12 57 41 -22 25 36		13.53	1.1	1	11±3	2806±30	390
D-25	UGC 8387	Im	13 18 17 34 24 04	6892±25	14.32	1.55		±2.4		
C-44	NGC 5103	Sab	13 18 18 43 20 45	1283±50	13.36	1.44	3.5	37±3	1288±10	141
B-16	NGC 5122	Sc	13 21 37 -01 23 29	2939			5.4	21±4	2842±10	386
C-46	E 576-69	Sa	13 27 22 -20 40 36		14.6	0.9	4.6	19±4.2	5365 ±25	464
D-43	E 510-13	Sa	13 52 15 -26 32 18	3559±77	12.89	1.95	3.1	28±3	3452±10	571
D-46	NGC 5544	S0	14 14 56 36 48 11	3121±29		0.98	2.2	18±2.2	3078±12	234
A-06	UGC 9796	S0	15 14 00 43 22 00		16.04	1.38	7.3	43±3.6	5480±6	214
C-49	NGC 6028	S0	15 59 16 19 29 48	4480±67	14.21	1.32	1.1	8±1.8	4474±25	293
C-50	UGC 10205	Sa	16 04 40 30 14 06	6605±58	13.82	1.44	3.9	13±1.6	6560±35	595
D-28	NGC 6240	S0/a	16 50 28 02 29 03	7351±44	13.17	2.14		±4.9		
C-51	NGC 6285	S0	16 57 47 59 03 00		14.48	1.32		±2.8		
C-60	E 464-31	S0	21 15 25 -27 33 36		15.02	0.65		±4.2		
D-35	NGC 7252	S0	22 17 58 -24 55 48	4760±25	12.47	1.95	3.8	26±4.8	4750±15	223
B-21	E 603-21	Sbc	22 48 41 -20 30 42		15.5	0.83	17.2	54.6±3.5	3449±10	355

NGC 235 - NGC 275A (S0, 6772 $km\,s^{-1}$) at 0.3'
UGC 1198 - VII Zw 3 'eruptive galaxy' compact bar (jet) crossing major axis
UGC 4892 - 'eruptive sytem', chaotic jet
NGC 2865 - Leda 0092253 (Sd) at 5.2'
IC 575 - MCG 1-25-57 (Sc) at 2', MCG 1-25-59 at 4', IC 574 (E) at 6'
UGC 5485 - two short jets from main body, MCG 11-13-5 (Sc) at 3.2', and MCG 11-13-4 at 4.1'
UGC 5600 - VV 330, interactive with UGC 5609 (S0/a, 2773 $km\,s^{-1}$)
NGC 3414 - double system in contact, UGC 5958 (Sbc, 1182 $km\,s^{-1}$) at 7.6', UGC 5963 (S0/a, 1251 $km\,s^{-1}$) at 8.5'
NGC 3406 - double system in contact, NGC 3410 (Sdm, 7105 $km\,s^{-1}$) at 1.8'
NGC 3934 - UGC 6839 (Sc, 3736 $km\,s{-}1$) at at 3.5'
NGC 4174 - NGC 4139 (E/S0, 3808 $km\,s^{-1}$) at 2.5', NGC 4173 (Sdm, 1105 $km\,s^{-1}$) at 3.5', NGC 4175 (Sc, 3938 $km\,s^{-1}$) at 3.2'
UGC 7636 - UGC 7629 = NGC 4472 (E,) at 5.4'
AM 1257-22 -
UGC 8387 - Arp 193, I Zw 56, strongly peculiar eruptive
E 576-69 - E 576-70 (Sa) at 6'
NGC 5544 - Arp 199 = VV 220, NGC 5545 at 0.6'
UGC 9796 - 2 Zw 73, probably superimp. comp. at 1.5' in group of 5, MCG 7-31-49 (Sb, 5515 $km\,s^{-1}$) at 3-4'
NGC 6028 - I Zw 133, comp. (E/S0) at 7.6'
NGC 6240 - strongly peculiar jet and loop, comp. at 2.9' and 4.3'
NGC 6285 - NGC 6286 (Sa, 5595 $km\,s^{-1}$) at 1.5', UGC 10641 (Scd, 5314 $km\,s^{-1}$)
E 464-31 - E 464-31A at 0.1'
E 603-21 - E 603-20 (Sdm, 3171 $km\,s^{-1}$) at 5'

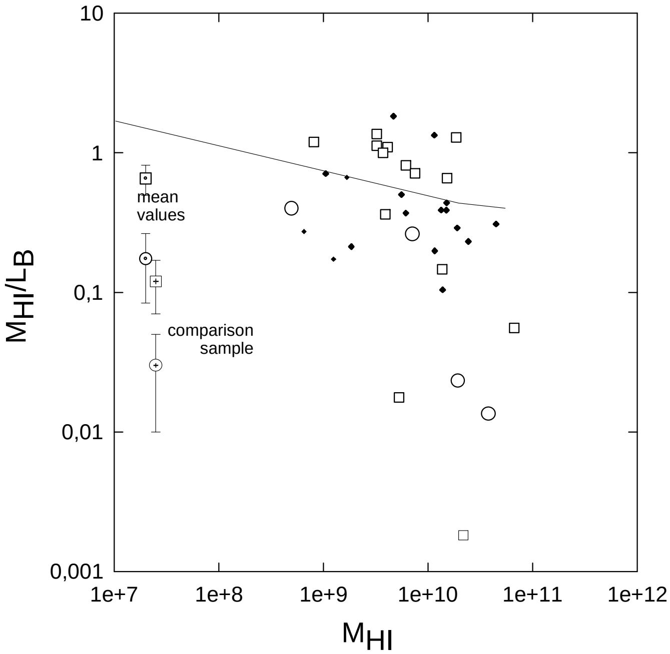

Fig. 2. For the non-confused galaxies (see text) from Paper I and the present work the M_{HI}/L_B values are shown versus blue luminosity L_B. Open circles mark E galaxies, open squares indicate S0 galaxies, a filled square on top is used for all galaxies later than S0/a as their morphological classification becomes uncertain. The solid line is the smoothed average from a complete sample of nearby disk galaxies (HR1). Mean values for E and S0 galaxies (symbols with a dot) are given on the left hand side of the figure as well as the averages from the comparison samples (symbols with a cross at the center).

NGC 2865 - 100-m RT - noisy profile, accept GB 140" profile.

In a number of cases the GB 140" flux is considerably larger than the 100-m RT flux which could be a hint for a larger HI-extent or some confusion (A-06, B-01, C-39, C-44, D-22). A final discussion of all global parameters should be done once the survey of polar ring galaxies is complete (i.e. including results from the southern sky).

At this stage we will discuss the relative HI-content of the galaxies observed in Papers 1 and 2. For this discussion we exclude those galaxies which are (possibly) confused by nearby galaxies. For some of these galaxies we use high-resolution observations by Schechter et al. 1984 (A-04, A-06), Shane 1980 (A-03), van Gorkom et al. 1987 (A-05). There are 33 detections and 4 upper limits in our combined sample. As the few upper limits scatter around the solid line in Fig. 2 we will continue our discussion with the 33 detections only.

In Fig.2 we plot the M_{HI}/L_B values versus blue luminosity in solar units. The solid line in Fig.2 represents the smoothed average relation derived from the sample of nearby galaxies ($v_0 \leq 500 \mathrm{km\,s}^{-1}$, spirals und irregulars exclusively; HR1). In this plot we differentiate between galaxies of type E (4), S0 (13), and S (18); we do not devide type S further due to uncertainties of the classification (e.g. see Table 1). The M_{HI}/L_B values of PRG's classified as spiral galaxies scatter around the relation given by the comparison sample. Part of the increased scatter could be due to greater observational errors due to the larger distances of the PRG sample, part of the scatter could be due to merger events with smaller galaxies which could increase the scatter allowing irregular and dwarf elliptical galaxies as merger victims. The mean M_{HI}/L_B is increasing in this sequence from type E (0.17 ± 0.09) to later-type galaxies. The mean values for type S0 (0.75 ± 0.13) and S (0.48 ± 0.12) agree within their errors if we neglect one HI pour spiral. The M_{HI}/L_B value for E-type PRGs is consistently greater than the correspondent value from a comparison sample of elliptical galaxies from the RSA (Huchtmeier, 1994) 0.030 ± 0.026. The value for S0-type PRGs is consistently greater than the value from the comparison sample (Roberts and Haynes 1994) 0.12 . The relatively high HI-content of the early-type PRGs is in agreement with the assumption that PRGs might be the result of recent merger events with accretion of gas to these early-type galaxies.

5. Conclusions

In this paper we present HI-observations of 44 polar-ring galaxies. For the discussion of the relative HI-content M_{HI}/L_B we used data from Paper I and from the literature. From a total of 35 galaxies we derive that early-type galaxies (E, S0) among the PRGs are significantly HI-rich as compared with well defined comparison samples by a factor of 5 to 6. This is compatible with the assumption that PRGs are the result of recent mergers with gas-rich disk galaxies.

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