Mon. Not. R. Astron. Soc. **322**, 689–694 (2001)

Nuclear spectra of polar-ring galaxies

V. P. Reshetnikov,[1★] M. Faúndez-Abans[2★] and M. de Oliveira-Abans[2★]

[1]*Astronomical Institute of St. Petersburg State University, 198904 St. Petersburg, Russia*
[2]*MCT/Laboratório Nacional de Astrofísica, Caixa Postal 21, CEP:37.504-364, Itajubá, MG, Brazil*

Accepted 2000 September 17. Received 2000 October 9; in original form 2000 March 21

ABSTRACT

We report the results of spectroscopic observations of eight southern polar-ring galaxies (PRGs), in the wavelength range 5900–7300 Å. We find that five out of eight galaxies contain LINERs or Sy nuclei. Taking into consideration all PRGs with available spectral data, we estimate that about half of all PRGs and PRG candidates have either LINER or Seyfert nuclei. The observed widths of the [N II]λ6583 line in the nuclei of early-type PRGs follow the linewidth–absolute luminosity relation for normal E/S0 galaxies. We found that one of the observed galaxies – ESO 576-G69 – is a new kinematically-confirmed polar-ring galaxy with a spiral host.

Key words: galaxies: active – galaxies: kinematics and dynamics – galaxies: peculiar.

1 INTRODUCTION

Polar-ring galaxies (PRGs) are rare relics of galaxy interactions. The Polar-Ring Galaxy Catalogue (PRC, Whitmore et al. 1990) contains only about 100 PRGs and PRG candidates in the northern and southern hemispheres. At present, at least half of all northern PRGs and candidates have been investigated; southern objects have been studied less extensively (except for a few well-known examples, e.g. NGC 4650A).

The main aim of the present work is to collect new observational data on southern hemisphere PRGs in order to enlarge the available information about this specific type of extragalactic object. We discuss nuclear spectra of eight PRGs and candidates of the PRC.

Throughout this work the value $H_0 = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ is adopted.

2 OBSERVATIONS AND DATA REDUCTION

The observations were performed with the 1.6-m telescope at the Observatório do Pico dos Dias (OPD, Brazil) in 1997 May, equipped with a Cassegrain spectrograph and CCD-05-20-0-202 detector #48 (thick, front-illuminated and coated for the UV) with $770 \times 1152\,\mathrm{pixel}^2$, 22.5 μm each, $6.6e^-$ readout noise, and $3.3e^-\,\mathrm{ADU}^{-1}$ gain. A grating of $900\,\mathrm{line\,mm^{-1}}$ was centred at 665 nm, with a dispersion of $1.15\,\text{Å}\,\mathrm{pixel}^{-1}$ and resolution of 1.1 pixels (FWHM). The slit size was $3 \times 52\,\mathrm{arcsec}^2$. The configuration yielded a scale factor of $0.235\,\mathrm{arcsec\,pixel}^{-1}$ and a spectral coverage of 5900–7300 Å. The seeing during the observations was <2 arcsec. The spectra were taken with the slit along the major axes of the central galaxies (except for AM 1837-631). In general three 20-min exposures were taken and co-added for each object, except for AM 1934-563 of which only one 20-min spectrum was obtained. A log of the observations is given in Table 1.

The reductions were carried out with standard techniques using IRAF and ESO-MIDAS packages. This includes bias subtraction, flat-field correction, cosmic rays removal, sky subtraction and wavelength calibration.

★ E-mail: resh@astro.spbu.ru (VPR); mfaundez@lna.br (MF); mabans@lna.br (MO)

3 RESULTS

The nuclear Hα spectra of all galaxies are presented in Fig. 1. The results of our measurements of the nuclear emission-line properties within $3 \times 0.7\,\mathrm{arcsec}^2$ (three pixels along the slit) are summarized in Table 2. Positions of the nuclei were determined as the location of the maximum intensity in the continuum. The listed uncertainties in the derived parameters are internal measurement errors as found from averaging the data from different emission lines (for the heliocentric velocities) and from different pixels along the slit. The observed FWHM were corrected for the instrumental profile.

Subsequently, we comment on the individual galaxies.

3.1 ESO 503-G17 (B-12)

This is a relatively isolated and distant galaxy. No significant companions are listed in the NASA/IPAC Extragalactic Database (NED) within 30 arcmin (~1 Mpc at the distance of ESO 503-G17). It is marked in the PRC as one of the best polar-ring candidates. Van Driel et al. (2000) estimated $\mathrm{M_{H\,I}} = 6.2 \times 10^9\,\mathrm{M_\odot}$. Our derived heliocentric velocity, $10\,465 \pm 35\,\mathrm{km\,s^{-1}}$, is comparable to the optical value of Jarvis & Sackett of $10\,313\,\mathrm{km\,s^{-1}}$ listed by Richter, Sackett & Sparke (1994) and that of van Driel et al. (2000) of $v_{H\,I} = 10\,481\,\mathrm{km\,s^{-1}}$ ($\Delta v_{50} = 377\,\mathrm{km\,s^{-1}}$).

Emission lines of Hα, [N II] and [S II] are very notable in the nucleus of the galaxy. The small $I(\mathrm{H}\alpha)/I([\mathrm{N\,II}])$ ratio and relatively strong [S II] lines allow us to classify the nucleus as a LINER (low-ionization nuclear emission region).

3.2 Abell 1631-14 (B-13)

This galaxy is a member of cluster Abell 1631 (Taniguchi et al. 1986). It has no published redshift. Sackett & Jarvis (private communication, as quoted in van Driel et al. 2000) measured $v_{\mathrm{opt}} = 16\,300\,\mathrm{km\,s^{-1}}$, but this measurement is not confirmed (Sackett, private communication). Nevertheless the good quality of our spectra indicates that our significantly lower heliocentric velocity of $12\,771 \pm 39\,\mathrm{km\,s^{-1}}$ should be correct.

The spatial profiles of the emission lines of Hα and [N II] demonstrate fast rotation of the gas within ± 1 arcsec (0.8 kpc) from the galaxy nucleus (with $V_{\max} \geqslant 170\,\mathrm{km\,s^{-1}}$). The observed inner gradient of the rotation curve is about $250\,\mathrm{km\,s^{-1}\,kpc^{-1}}$. Using the correlation between the inner gradient and the bulge-to-disc luminosity ratio (B/D) from Márquez & Moles (1999), we obtain $B/D \sim 0.16$ for Abell 1631-14 in the B-band. This value is common for Sbc galaxies (Simien & de Vaucouleurs 1986).

The spectral properties are common for H II region-like nuclei.

Table 1. Log of observations.

Galaxy	PRC number	Date	Exposure (min)
ESO 503-G17	B-12	10 May 1997	20+20+20
Abell 1631-14	B-13	10 May 1997	20+20+20
NGC 5122	B-16	06 May 1997	20+20+20
AM 1934-563	B-18	06 May 1997	20
ESO 500-G41	C-33	11 May 1997	20+20+20
ESO 576-G69	C-46	11 May 1997	20+20+20
ESO 232-G4	C-52	10 May 1997	20+20+20
AM 1837-631	D-29	11 May 1997	20+20+20

3.3 NGC 5122 (B-16)

NGC 5122 is a relatively nearby and well-known polar-ring galaxy. The H I velocity field indicates that the gas in the ring rotates around the major axis of the central galaxy, while stellar absorption-line spectra show rotation of the central galaxy around its minor axis (Cox 1996). The mass of H I associated with NGC 5122 is $\sim 2 \times 10^{9}\,\mathrm{M_{\odot}}$ (Cox 1996; Huchtmeier 1997). The galaxy has a nearby gas-rich companion (MCG -02-34-45) (Cox 1996). Our emission-line heliocentric velocity ($2818 \pm 10\,\mathrm{km\,s^{-1}}$) is in agreement with H I measurements: $2855\,\mathrm{km\,s^{-1}}$ (Cox 1996), $2842 \pm 10\,\mathrm{km\,s^{-1}}$ (Huchtmeier 1997).

The emission-line properties are typical for LINER nuclei (e.g. Veilleux & Osterbrock 1987).

3.4 AM 1934-563 (B-18)

This is a member of a triple system. Our systemic velocity ($11\,613 \pm 54\,\mathrm{km\,s^{-1}}$) is close to the velocity of $11\,556 \pm 48\,\mathrm{km\,s^{-1}}$ quoted by Fisher et al. (1995).

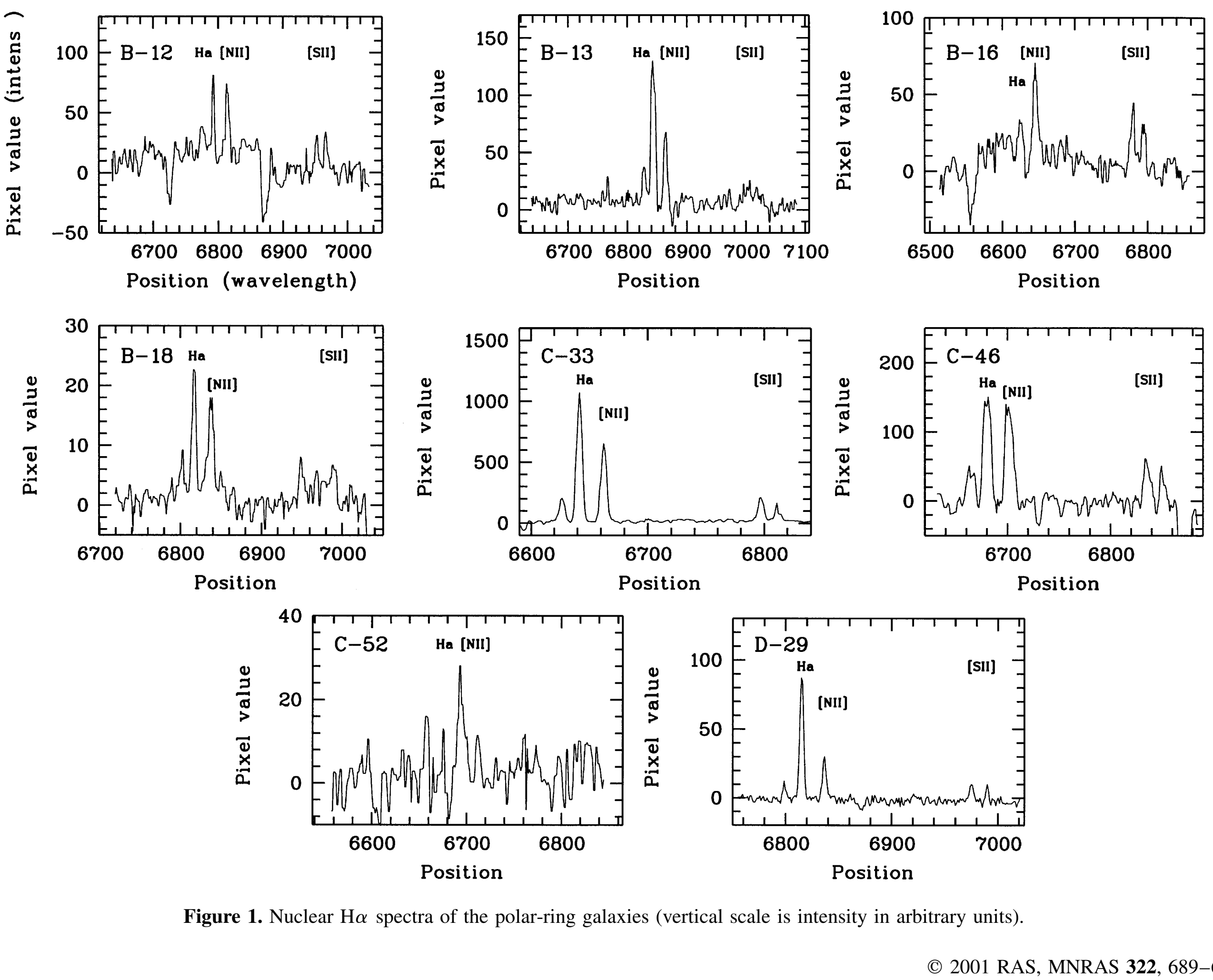

Figure 1. Nuclear Hα spectra of the polar-ring galaxies (vertical scale is intensity in arbitrary units).

Table 2. PRGs characteristics.

Name	Type	M_B^a	Heliocentric velocity (km s^{-1})	Emission lines parameters	Type of nucleus
ESO 503-G17 (B–12)	S0:[b]	–19.4	10465 ± 35	I(Hα)/I([N II]6583) = 0.7: W(Hα) = 1.2 Å W([N II]6583) = 1.7 Å W([S II]6716+31) = 1.7: Å W([O I]6300) = 0.4: Å FWHM([N II]6583) = 320 ± 50 km s^{-1}	LINER
Abell 1631-14 (B–13)	Sbc:	–20.1:	12771 ± 39	I(Hα)/I([N II]6583) = 2.7 ± 0.3 I([O I]6300)/I(Hα) ⩽ 0.05 W(Hα) = 24.8 ± 1.4 Å W([N II]6583) = 9.2 ± 0.6 Å FWHM([Hα) = 340 ± 50 km s^{-1}	H II
NGC 5122 (B–16)	S0	–18.3	2818 ± 10	I(Hα)/I([N II]6583) = 0.5: I([O I]6300)/I(Hα) = 0.2: W(Hα) = 0.6 ± 0.3 Å W([N II]6583) = 1.2 ± 0.2 Å W([S II]6716+31) = 1.15: Å FWHM([N II]6583) = 410 ± 40 km s^{-1}	LINER
AM 1934-563 (B–18)	Sbc:	–20.1	11613 ± 54	I(Hα)/I([N II]6583) = 1.2 ± 0.3 I([O I]6300)/I(Hα)⩽0.1 W(Hα) = 10.2 ± 0.9 Å W([N II]6583) = 8.8 ± 1.3 Å FWHM([Hα) = 300 ± 20 km s^{-1} FWHM([N II]6583) = 330 ± 20 km s^{-1}	Sy 2/LINER:
ESO 500-G41 (C–33)	Sab	–19.4	3574 ± 11	I(Hα)/I([N II]6583) = 1.7 ± 0.1 W(Hα) = 20.0 ± 1.7 Å W([N II]6583) = 11.5 ± 0.5 Å W([S II]6716+31) = 4.0 ± 0.3 Å FWHM([Hα) = 250 ± 25 km s^{-1} FWHM([N II]6583) = 260 ± 25 km s^{-1}	H II
ESO 576-G69 (C–46)	Sbc:	–19.5	5339 ± 10	I(Hα)/I([N II]6583) = 1.1 ± 0.1 W(Hα) = 4.0 ± 0.2 Å W([N II]6583) = 3.3 ± 0.1 Å W([S II]6716+31) = 1.8 ± 0.1 Å FWHM([Hα) = 410 ± 20 km s^{-1} FWHM([N II]6583) = 440 ± 10 km s^{-1}	Sy 2/LINER
ESO 232-G4 (C–52)	S0/a	–19.8	5083 ± 57	I(Hα)/I([N II]6583) = 0.1: W([N II]6583) = 1.4 Å FWHM([N II]6583) = 370 ± 50 km s^{-1}	LINER:
AM 1837-631 (D–29)	S_{pec}	–20.9	11508 ± 21	I(Hα)/I([N II]6583) = 3.3 ± 0.4 W(Hα) = 27.7 ± 1.2 Å W([N II]6583) = 8.6 ± 0.9 Å W([S II]6716+31) = 6.8 ± 0.6 Å FWHM([Hα) = 180 ± 20 km s^{-1} FWHM([N II]6583) = 180 ± 20 km s^{-1}	H II

[a] From NED photometry and $H_0 = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.
[b] Values marked ‘:’ are uncertain.

The spatial profile of the Hα and [N II] emissions indicate fast rotation of the gas within ±2 arcsec (1.5 kpc) from the nucleus (Fig. 2). The observed inner gradient of the rotation curve is about 310 km s^{-1} kpc^{-1} from which we obtain $B/D \sim 0.2$ for AM 1934-563 in the B-band, a common value for Sbc galaxies (Simien & de Vaucouleurs 1986).

The nucleus shows signs of Sy 2 or LINER activity.

3.5 ESO 500-G41 (C-33)

ESO 500-G41 is a Sab galaxy with inner and outer rings (Buta 1995). Our systemic velocity (3574 ± 11 km s^{-1}) is in agreement with optical measurements by Fisher et al. (1995) (3532 ± 20 km s^{-1}), Fairall et al. (1992) (3541 ± 29 km s^{-1}) and with H I data of Huchtmeier (1997) (3570 ± 12 km s^{-1}) and van Driel et al. (2000) (3560 km s^{-1}). The total H I mass is (1.4–2.4) × $10^9\,M_\odot$ (Huchtmeier 1997; van Driel et al. 2000). The central velocity gradient (⩾400 km s^{-1} kpc^{-1}; see Fig. 2) is consistent with a ~Sb galaxy (Márquez & Moles 1999).

The nuclear properties are common for H II regions.

3.6 ESO 576-G69 (C-46)

The peculiar galaxy ESO 576-G69 has a long tidal tail and possibly a ring around the major axis. The quasar PKS 1327-206 lies 38 arcsec SE of the galaxy (e.g. Kunth & Bergeron 1984). Our optical heliocentric velocity – 5339 ± 10 km s^{-1} – is consistent with measurements by Kunth & Bergeron (1984)

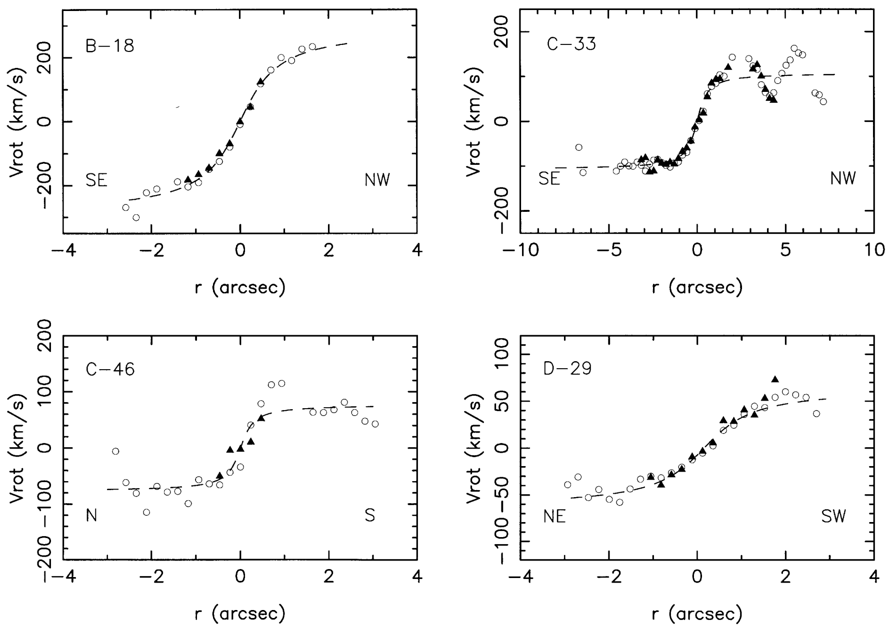

Figure 2. Central position–velocity plots of polar-ring galaxies (circles – Hα measurements, triangles – [N II]λ6583). The dashed lines represent arctangent fits.

Table 3. Kinematical parameters of PRGs.

Galaxy	$V^a_{\max}$ (km s^{-1})	r^a_t ($''$)	$V^b_{\max,c}$ (km s^{-1})	$R_{\rm opt}$ (kpc)	$M_{\rm tot}$ (M$_\odot$)	$M_{\rm tot}/L_B$ (M$_\odot$/L$_{\odot,B}$)	M(H I)/L_B (M$_\odot$/L$_{\odot,B}$)
AM 1934-563	292	0.65	309	13	2.9×10^{11}	17	
ESO 500-G41	108	0.44	172	5.1	3.5×10^{10}	4	0.2:[c]
ESO 576-G69	77	0.22	84	6.4	1.0×10^{10}	1	0.5
AM 1837-631	64	0.84	100:	15	3.5×10^{10}	1	

[a] Arctangent fit.
[b] Corrected for inclination.
[c] Values marked ':' are uncertain.

(5396 ± 90 km s^{-1}) and by Moran, Halpern & Helfand (1996) (5366 km s^{-1}). The H I velocity measured by Huchtmeier (1997) (5365 ± 25 km s^{-1}) and by Carilli & van Gorkom (1992) (5370 ± 5 km s^{-1}) also agree with our measurement. The total H I mass is 5.3×10^9 M$_\odot$ (Huchtmeier 1997). The central velocity gradient (~330 km s^{-1} kpc^{-1}; see Fig. 2) corresponds to an Sbc galaxy (Márquez & Moles 1999).

The galaxy has Sy 2 or a LINER nucleus.

3.7 ESO 232-G4 (C-52)

This is a possible candidate for a polar-ring galaxy (PRC). It is listed in the Catalogue of Ringed Galaxies (Buta 1995) as an S0/a type. Fairall (1984) listed a heliocentric velocity of the galaxy – 5600 ± 200 km s^{-1} – which differs significantly from our value (5083 ± 57 km s^{-1}). Our measurement is based on faint emissions of Hα, [N II] and the absorption blend of Ca I + Fe I (λ6495).

The nucleus is classified preliminarily as a LINER (this conclusion must be confirmed by observations with a better signal-to-noise ratio).

3.8 AM 1837-631 (D-29)

This peculiar object is similar to NGC 2685 (PRC) in that it presents 'helical' dust lanes covering the eastern half of the galaxy (sic). The galaxy has no published redshift. Our derived value – $11\,508 \pm 21$ km s^{-1} – suggests that the galaxy can belong to a nearby cluster of galaxies (Pavo II) with $V_{\rm hel} \sim 10\,750$ km s^{-1} (Lucey & Carter 1988). Fig. 2 shows the central ($\leqslant$2 kpc) rotation curve with a slit orientation at ~45° to the major axis.

The emission-line properties are typical for H II type nuclei.

4 KINEMATICAL PROPERTIES OF POLAR-RING CANDIDATES

In Fig. 2 emission-line rotation curves (RC) of the central regions of four polar-ring candidates are presented. Dashed lines show a simple arctangent fit of the form $V_{\rm rot}(r) = (2/\pi)V_{\max}\tan^{-1}(r/r_{\rm t})$ to each of the observed curves, where $V_{\max}$ is the asymptotic maximum value of the RC and $r_{\rm t}$ is a 'turnover' radius. It should be noted that $V_{\max}$ is a fit parameter and not the true value of the maximum rotational velocity. According to Willick (1999), the arctangent fit is useful for determining the amplitude of the RC.

The general kinematical properties of the four polar-ring candidates for which the velocity profiles were measured are summarized in Table 3. The second and third columns of Table 3 list the arctangent fit parameters $V_{\max}$ and $r_{\rm t}$. The fourth column gives the maximum rotation velocity corrected for the inclination of the galaxy: $V_{\max,c} = V_{\max}/\sin i$, where the inclination i is estimated from the apparent axial ratio. In the fifth column we present optical radii of the galaxies (measured from the DSS – Digitized Sky Survey – images), and the sixth column lists our estimate of the total galaxy mass within the optical radius under the assumption of a spherical mass distribution. The last two columns contain the ratio of mass to observed luminosity and the relative H I content, respectively. As can be seen from Table 3, polar-ring candidates show characteristics which are quite common for typical spiral galaxies (the comparatively large value of M_{tot}/L_B for AM 1934-563 may be partially explained by its almost edge-on orientation; the magnitude corrected to a face-on orientation may be as much as ~1 mag brighter).

In Fig. 3 we compare the Tully–Fisher relation for normal spiral galaxies (Broeils 1992) to that of our spiral polar-ring candidates. For the latter we used maximum rotation velocities corrected for inclination and absolute luminosities (de Vaucouleurs et al. 1991). As can be seen, two galaxies (AM 1934-563 and ESO 500-G41) follow the relation for normal spirals, while two others (ESO 576-G69 and AM 1837-631) have too large luminosities (for fixed V_{max}) or too small rotation velocities for their luminosity. Probably both of these possible reasons can contribute to the observed deviations, as galaxy interactions and mergers can enhance optical luminosities as well as disturb emission-line velocity fields in the involved galaxies.

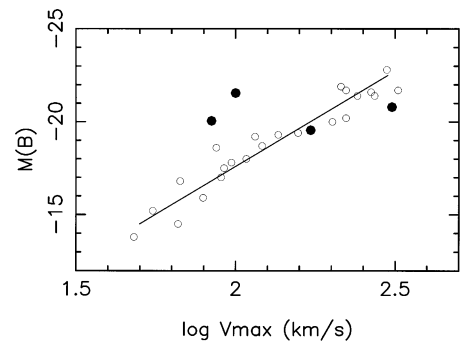

Figure 3. Tully–Fisher relation for normal spiral galaxies (Broeils 1992) (open circles, solid line) compared to the luminosity–rotation velocity relation for the polar-ring candidates (filled circles).

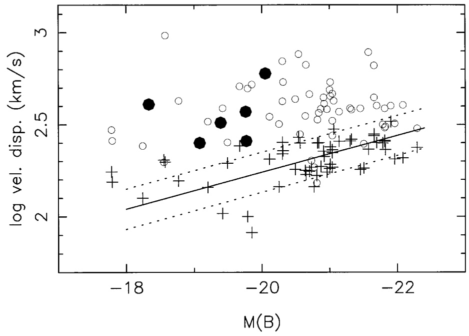

Figure 4. Plot of central stellar velocity dispersion versus absolute magnitude in the *B* passband for E/S0 galaxies from Phillips et al. (1986) (crosses). The solid line represents the $L \propto \sigma^4$ relation and the dotted lines show the $\pm 1\sigma$ dispersion about this relation. The dependence of the nuclear line width (FWHM of [N II]λ6583) versus absolute magnitude for the same galaxies is shown by open circles. Filled circles show characteristics of our E/S0 polar-ring galaxies.

In Fig. 4 we plot the nuclear stellar velocity dispersion (σ) and the nuclear linewidth (FWHM) of [N II]λ6583, indicating the velocity dispersion of the interstellar gas, as a function of the total blue absolute magnitude for the sample of elliptical and S0 galaxies observed by Phillips et al. (1986) (redshifts, apparent magnitudes and velocity dispersions are taken from NED and LEDA (Lyon-Meudon Extragalactic Database) data bases). As one can see, the increase of the central velocity dispersion of the gas with *M*(*B*) is similar to that observed for the stars, although with a larger dispersion and a notable systematic shift. The mean ratio of FWHM([N II]) to σ is 2.08 ± 0.14 (rms). In Fig. 4 the polar-ring galaxies ESO 503-G17, NGC 5122, ESO 232-G4 (present paper), IC 1689 (Hagen-Thorn & Reshetnikov 1997), UGC 4323 and NGC 4753 (Reshetnikov & Combes 1994) are located in the same region as normal early-type galaxies.

The peculiar spiral galaxy ESO 576-G69 (C-46) is the most interesting object in our sample. As shown by Carilli & van Gorkom (1992), an asymmetric ring-like structure surrounding the galaxy along the minor axis (probably a polar ring) rotates around the major axis of ESO 576-G69 with $V_{max} \sim 100\,\mathrm{km\,s^{-1}}$. Our kinematical observations show that the main body of the galaxy, on the other hand, rotates around the minor axis. Therefore, ESO 576-G69 can be classified as a *kinematically-confirmed spiral polar-ring galaxy*. This kind of extragalactic object is extremely rare (e.g. UGC 4385 – Reshetnikov & Combes 1994; NGC 660 – van Driel et al. 1995).

5 DISCUSSION

Our results provide new data on nuclear properties of PRGs. A first look at Table 2 shows that active nuclei are overpresented in the sample, where they represent ~60 per cent (5/8). Because of the small sample size, this conclusion is not statistically significant. However, considering all 16 objects from Reshetnikov & Combes (1994) as well as the data on NGC 2685 (Willner et al. 1985), NGC 660 (van Driel et al. 1995), and IC 1689 (Hagen-Thorn & Reshetnikov 1997), the sample of PRGs and candidates with nuclear spectra increases to 27 galaxies. Of these at least 14 (52 per cent) have LINER or Seyfert nuclei. Considered separately, and according to the original papers, Seyfert nuclei are found in 3–6 objects (the first number refers to confident classifications and the second one includes uncertain classifications) or 12.5–25 per cent, respectively, and LINERs in a total of 8–11 objects (counted as above) or 33–41 per cent. Therefore, the fraction of active nuclei is high among PRGs and candidates.

PRGs hosting AGNs are predominantly S0 galaxies. It would be interesting to compare the number of $S0_{(Sey)}$ and $S0_{(LINERS)}$ to the number of ordinary S0. This requires good morphological classifications of our PRGs and candidates, but such comparison is presently impossible since the available data is neither good nor abundant enough for the classification. Moreover, most PRG candidates are very peculiar and faint. More detailed and precise statistics can only be done when we have a sample of PRGs at least twice as large as presently available, together with good optical images.

PRGs are very heterogeneous objects regarding both morphology and environment. However, they have one particular feature in common: the existence of two large-scale strongly inclined kinematic subsystems. Such complicated internal kinematics are considered usually as a consequence of relatively long-lasting galaxy interactions, accompanied by mass transfer from one galaxy to another (ranging from gas accretion to complete merging). One can speculate that such interactions are favourable for the formation of non-thermal nuclear activity. Owing to the limited size of our sample this conclusion must, however, remain tentative for the time being.

ACKNOWLEDGMENTS

We have used the Lyon-Meudon Extragalactic Database (LEDA) supplied by the LEDA team at the CRAL-Observatoire de Lyon (France) and 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. This research has made use of NASA's Astrophysical Data System Abstract Service (ADS), and of the Digitized Sky Survey (DSS), which was produced at the Space Telescope Institute under US Government grant NAG W-2166. VR acknowledges support from the Russian Foundation for Basic Research (98-02-18178) and the 'Integration' programme (*N* 578). This work was partially supported by the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) grant CEX 1864/95 and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil. We would like to thank the referee, Dr Willem van Driel, and Dr Albert Bruch for a critical reading of the manuscript and for their suggestions of improvements on its original form. This paper was based on observations made at the Observatório do Pico dos Dias, operated by the Laboratório Nacional de Astrofísica, Brazil.

REFERENCES

Broeils A. H., 1992, PhD thesis, Groningen
Buta R., 1995, ApJS, 96, 39
Carilli C. L., van Gorkom J. H., 1992, ApJ, 399, 37
Cox A. L., 1996, PhD thesis, Univ. Wisconsin-Madison
de Vaucouleurs G., de Vaucouleurs A., Corwin H. G., Jr, Buta R. J., Paturel G., Fouqué P., 1991, Third Reference Catalogue of Bright Galaxies. Springer-Verlag, Berlin
Fairall A. P., 1984, MNRAS, 210, 69
Fairall A. P. et al., 1992, AJ, 103, 11
Fisher K. B., Huchra J. P., Strauss M. A., Davis M., Yahil A., Schlegel D., 1995, ApJS, 100, 69
Hagen-Thorn V. A., Reshetnikov V. P., 1997, A&A, 319, 430
Huchtmeier W. K., 1997, A&A, 319, 401
Kunth D., Bergeron J., 1984, MNRAS, 210, 873
Lucey J. R., Carter D., 1988, MNRAS, 235, 1177
Márquez I., Moles M., 1999, A&A, 344, 421
Moran E. C., Halpern J. P., Helfand D. J., 1996, ApJS, 106, 341
Phillips M. M., Jenkins C. R., Dopita M. A., Sadler E. M., Binette L., 1986, AJ, 91, 1062
Reshetnikov V. P., Combes F., 1994, A&A, 291, 57
Richter O.-G., Sackett P. D., Sparke L. S., 1994, AJ, 107, 99
Simien F., de Vaucouleurs G., 1986, ApJ, 302, 564
Taniguchi Y., Shibata K., Wakamatsu K., 1986, AS&S, 118, 529
van Driel W. et al., 1995, AJ, 109, 942
van Driel W., Arnaboldi M., Combes F., Sparke L. S., 2000, A&AS, 141, 385
Veilleux S., Osterbrock D. E., 1987, ApJS, 63, 295
Whitmore B. C., Lucas R. A., McElroy D. B., Steinman-Cameron T. Y., Sackett P. D., Olling R. P., 1990, AJ, 100, 1489 (PRC)
Willick J. A., 1999, ApJ, 516, 47
Willner S. P., Elvis M., Fabbiano G., Lawrence A., Ward M. J., 1985, ApJ, 299, 443

This paper has been typeset from a TEX/LATEX file prepared by the author.