

New measurements of gas metallicity in polar-ring galaxies

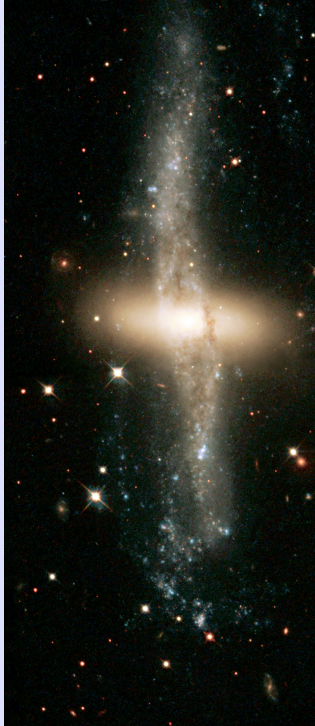
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Special Astrophysical Observatory of Russian Academy of Sciences



MULTI-SPIN GALAXIES @ SAO RAS

SEPTEMBER 26, 2016



Polar-ring galaxies (PRGs)

PRGs - the most famous sort of multi-spin galaxies: an external discs or rings rotating at the plane nearly perpendicular to the host galaxy (usually ETG).

- The story of PRGs studies has begun from the discovery of NGC 2685 by Sandage (1961). Surprisingly, Józsa et al. (2009) found that NGC 2685 is not a classical PRG.
- 0.5% of all S0 galaxies are PRG (5% after correction for selection effects) (Whitmore et al. 1990)
- Several hundreds PRG candidates are known. Most of them are from two catalogues: Whitmore et al. (1990) and Moiseev et al. (2011)
- Despite the large amount of known PRGs, they are still relatively poor studied

NGC 2685

Image from Sandage (1961)



SDSS-image



PRGs formation scenarios

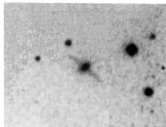
- Merging of two galaxies (Bekki 1997; Bournaud & Combes 2003)
- Gas accretion from the companion (Reshetnikov & Sotnikova 1997)
- Cold accretion of pristine gas along filament (Maccio et al 2006; Brook et al. 2008).

Polar Ring Galaxies Catalogue

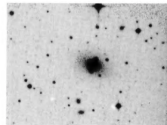
157 galaxies included in the catalogue



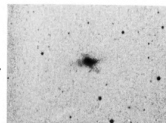
A-1 A0136-0801



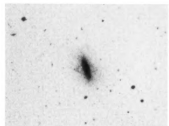
A-4 UGC 7576



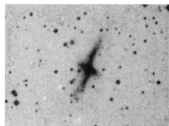
B-19 AM 2020-504



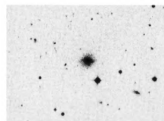
B-22 A 2329-4102



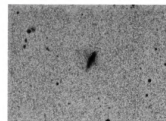
A-2 ESO 415-G26



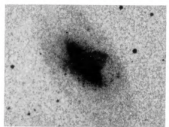
A-5 NGC 4650A



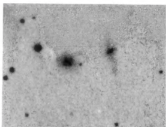
B-20 A 2135-2132



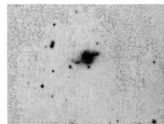
B-23 A 2330-3751



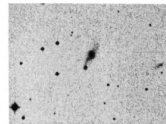
A-3 NGC 2685



A-6 UGC 9796



B-21 ESO 603-G21



B-24 A 2333-1637

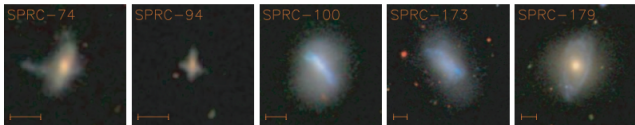
SDSS-based Polar Ring Catalogue

275 galaxies included in the catalogue

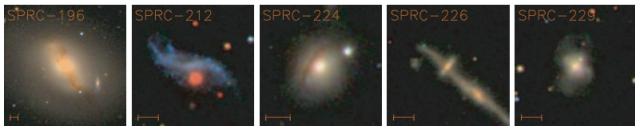
Best candidates (70):



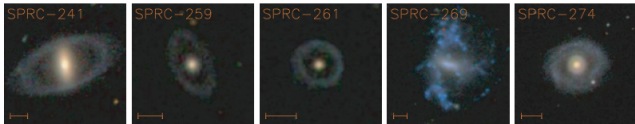
Good candidates (115):



Related objects (53):



Possible face-on rings (37):



Gas metallicity in SPRC galaxies

- Gas metallicity estimation in polar rings are important for testing their formation scenarios: low metallicity expected in case of the cold accretion of pristine gas along a filament
- Only a few metallicity estimates are published to date
- Unfortunately, some of them are very uncertain:
 - poor quality of the UGC7576 spectra ($S/N(H\alpha) \sim 1-1.5$) in Spavone et al. (2011)
 - unrealistic physical parameters estimates (e.g., Balmer decrement $H\alpha/H\beta = 2.24$ for UGC 9796 in Spavone et al., 2011; $H\alpha/H\beta = 0.74$ for VGC31b in Spavone & Iodice, 2013)

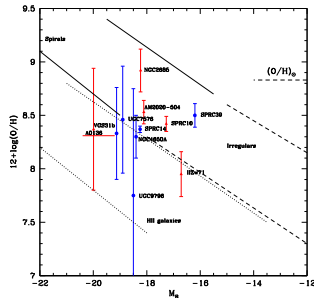
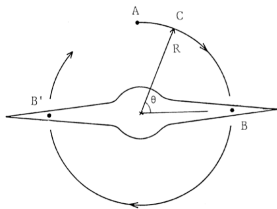


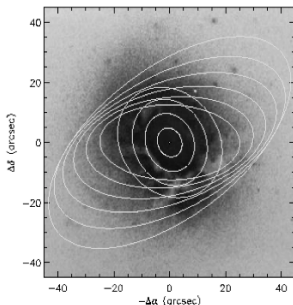
Figure 9. Oxygen abundance versus absolute blue magnitude for A0136-0801 (from this work) and for other PRGs: VGC31b (Spavone & Iodice 2013), NGC4650A (Spavone et al. 2010), IIZw71 (Pérez-Montero et al. 2009), NGC2685 (Eskridge & Pogge 1997), AM2020-504 (Freitas-Lemes et al. 2012), UGC7576 and UGC9796 (Spavone et al. 2011), SPRC10-14-39 (Moiseev, Egotov & Smirnova 2014). Blue circles represent wide PRGs, while red triangles are for narrow PRGs. The sample of late-type disc galaxies are by Kobulnicky & Zaritsky (1999): spirals are in the region marked with continuous lines, irregulars are between dashed lines and HI galaxies are between dotted lines. The horizontal dashed line indicates the solar oxygen abundance.

Shock waves in multi-spin galaxies?

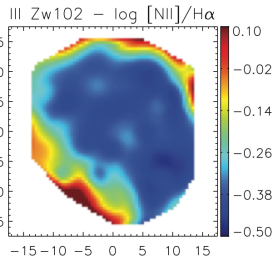


Wakamatsu, *AJ*, 105, 1745 (1993)

- Shocks can be generated when gas on polar orbits crosses the potential well of a stellar disc (like in spiral waves).
- Observational signs for and against this hypothesis are exist.



García-Lorenzo et al., *ApJ*, 677, 201 (2008)



Shocks are observed in the multi-spin galaxies that reveal gas motions in significantly inclined planes:

NGC 3248, UGC 4551, UGC 9519:

Katkov et al., MNRAS, 438, 2798 (2014)

NGC 7743: *Katkov et al., ApJ*, 740, 83 (2011)

NGC 5631: *Sil'chenko et al., ApJ*, 694, 1550 (2009)

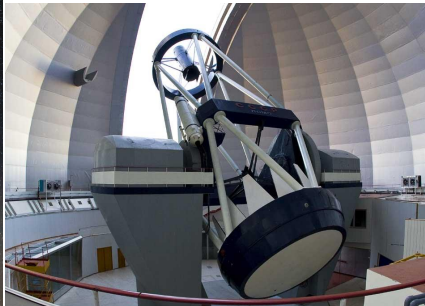
This topic is almost not studied in classical PRGs.

Observations: SCORPIO-2 at 6-m telescope

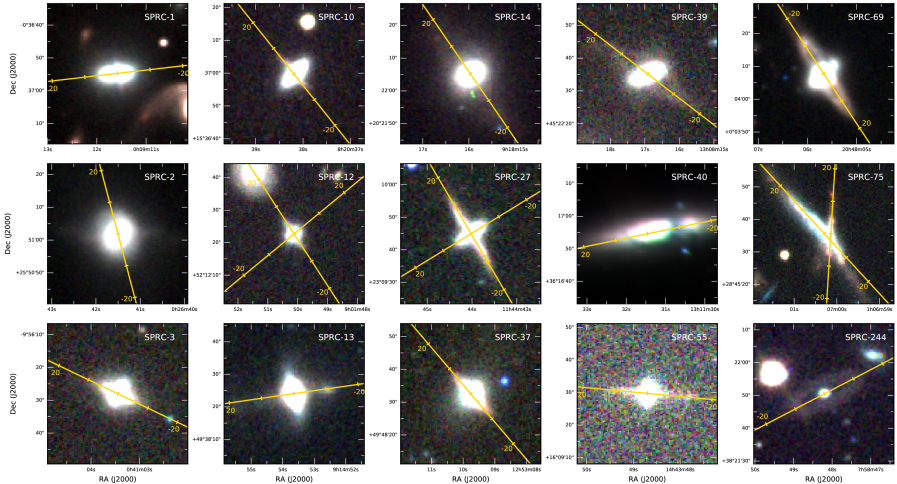


SCORPIO-2 (Spectral Camera with Optical Reducer for
Photometric and Interferometric Observations -2)
Afanasiev & Moiseev, Balt.Astron., 20, 363 (2011)

Parameters in long-slit mode:
Spectral range: 3600-10000 Å
Field of view: $6.1' \times 6.1'$
Spectral resolution: $R=500-4000$

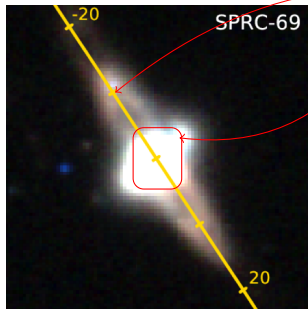


Observations: sample of SPRC galaxies



First results for SPRC-10, SPRC-14 and SPRC-39 were published in
Moiseev, Egorov & Smirnova, ASP Conf. Ser., 486, 71 (2014)

Observations: data analysis



① Reduced long-slit spectrum



② 1D-spectra of polar disc and of the area of its overlap with the host galaxy



③ Stellar population modelling



④ Emission spectra of each component

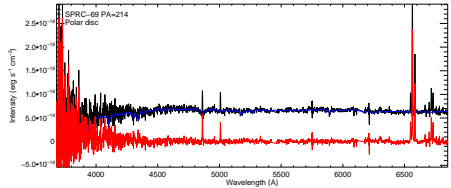
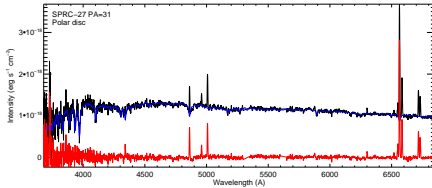
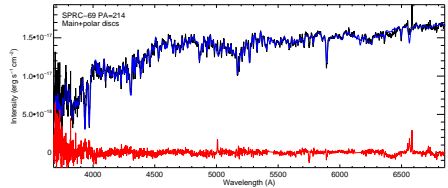
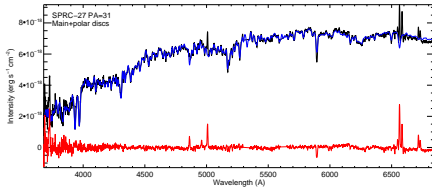


⑤ Ionization conditions and gas metallicity

Koleva et al., A&A 501, 1269 (2009)

Koleva et al., MNRAS, 385, 1998 (2008)

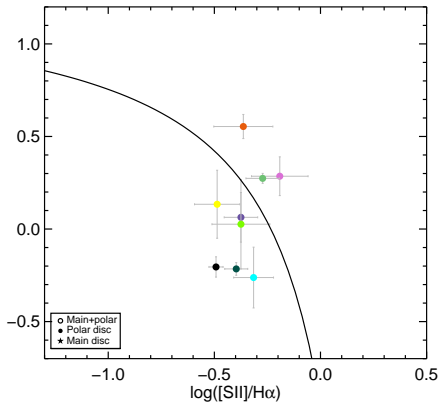
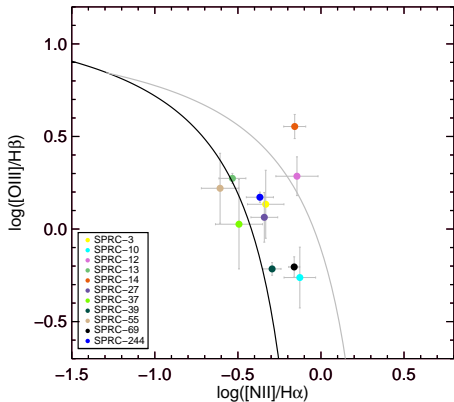
Observations: spectra examples



Observed spectrum; SSP model; Emission spectrum

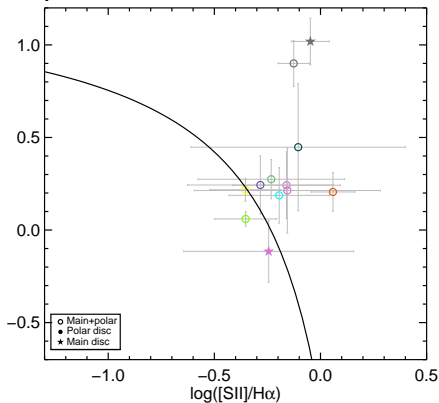
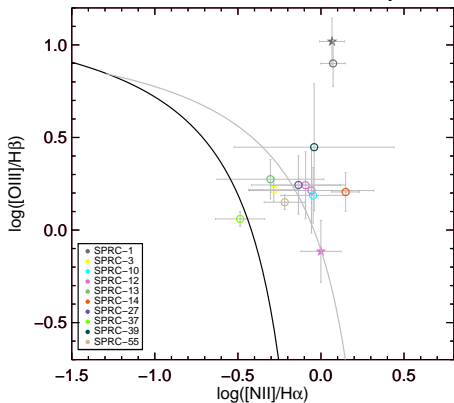
Ionization conditions in polar rings

Polar component

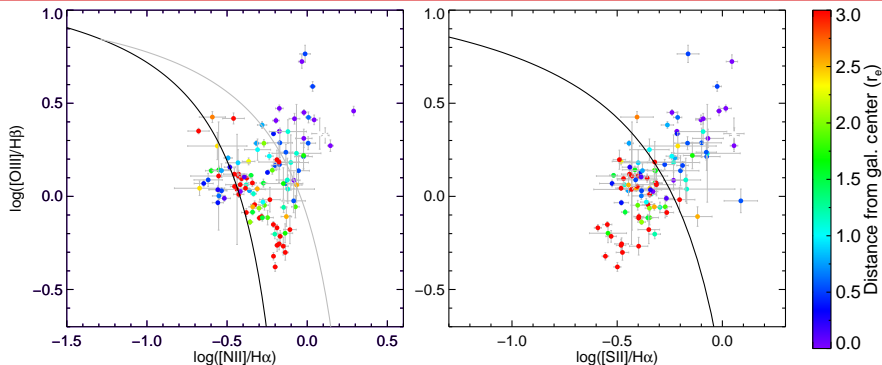


Ionization conditions in polar rings

Main+polar components



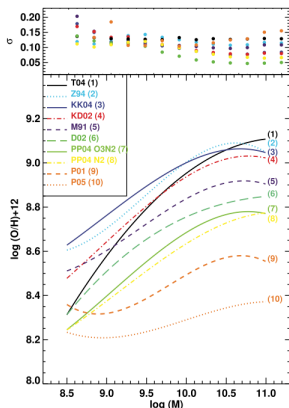
Ionization conditions in polar rings



- Shocks are observed close to the host galaxy, while its contribution is significantly lower in the outer regions of polar disc. Freitas-Lemes et al. (2012) obtained the same result for AM 2020-504 galaxy. These findings are consistent with the Wakamatsu (1993) hypothesis.
- Because of the shocks, we should use empirical methods for metallicity estimation near the host galaxy with a caution. But such methods should work in the outer regions of polar rings.

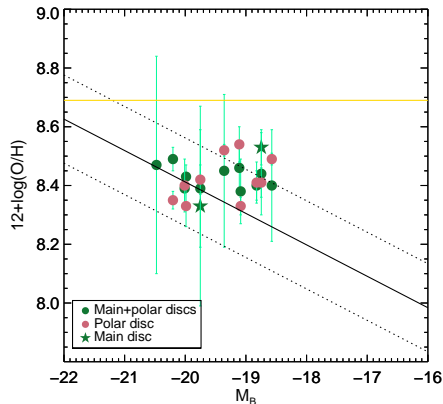
Gas metallicity estimations: methods

- The well-known problem of the discrepancy (up to 0.5 dex) between the different metallicity calibrators is still unresolved.
- We used two empirical methods for the analysis:
 - O3N2 *Marino et al., A&A, 559, A114 (2013)*
 - izi *Blanc et al., AJ, 798, 99 (2015)*

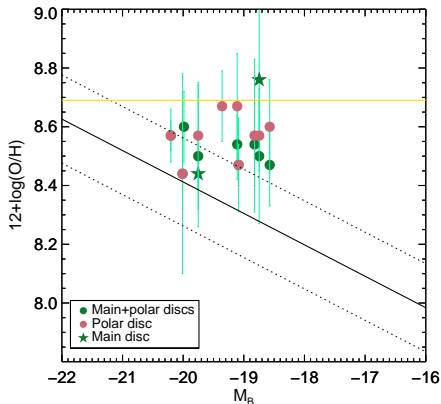


Gas metallicity in SPRC galaxies

O3N2-method (Marino et al., 2013)



izi (Blanc et al., 2014)



Metallicity-luminosity relation from Berg et al. (2012) and the estimates for different components of the studied SPRC galaxies .

Gas metallicity in SPRC galaxies

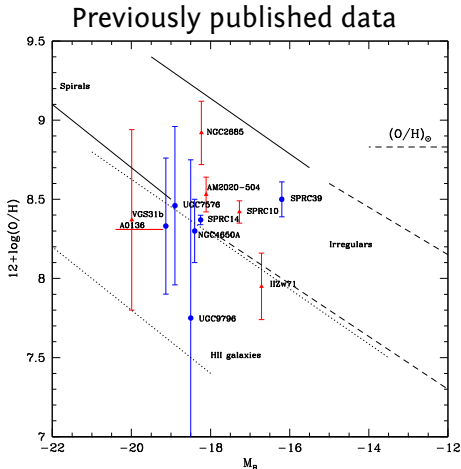


Figure 9. Oxygen abundance versus absolute blue magnitude for A0136-0801 (from this work) and for other PRGs: VGS31b (Spavone & Iodice 2013), NGC4650A (Spavone et al. 2010), IZw71 (Pérez-Montero et al. 2009), NGC2685 (Eskridge & Pogge 1997), AM2020-504 (Freitas-Lemes et al. 2012), UGC7576 and UGC9796 (Spavone et al. 2011), SPRC10-14-39 (Moiseev, Egorov & Smirnova 2014). Blue circles represent wide PRGs, while red triangles are for narrow PRGs. The sample of late-type disc galaxies are by Kobulnicky & Zaritsky (1999): spirals are in the region marked with continuous lines, irregulars are between dashed lines and H II galaxies are between dotted lines. The horizontal dashed line indicates the solar oxygen abundance.

Gas metallicity in SPRC galaxies

Our estimates (O3N2) + previously published data

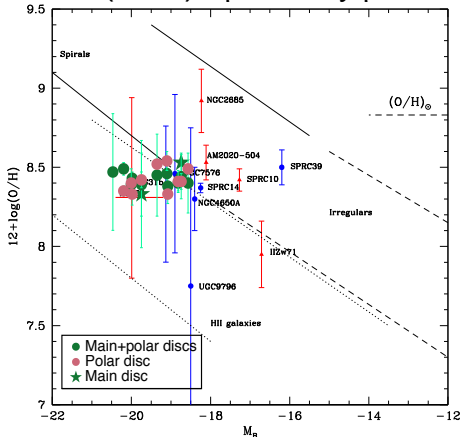


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Spavone et al., MNRAS, 450, 998 (2015); Moiseev & Egorov (in preparation)

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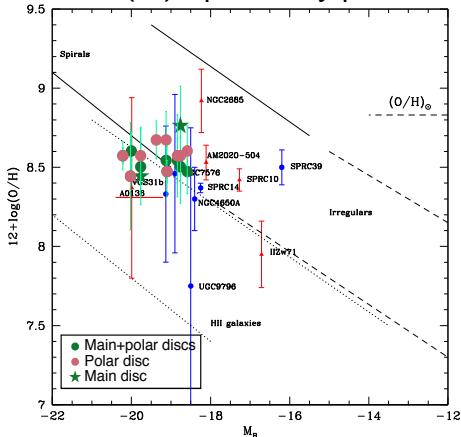
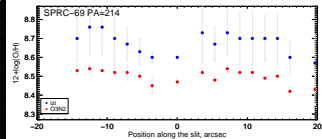
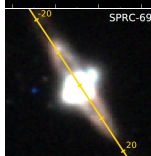
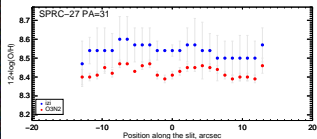
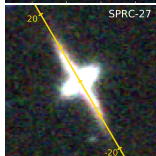
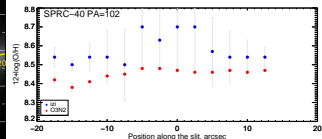
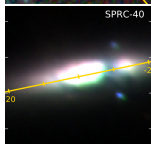
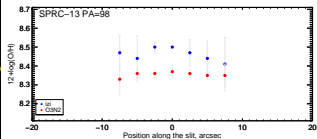
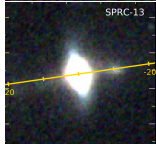
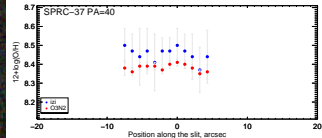
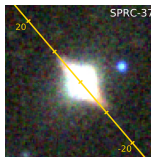
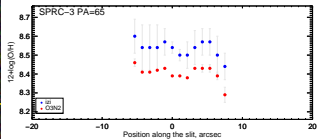
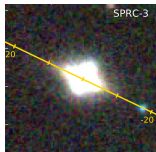


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Spavone et al., MNRAS, 450, 998 (2015); Moiseev & Egorov (in preparation)

No metallicity gradient in SPRC galaxies



Conclusions

- The sample of 15 polar-ring galaxies from the SPRC-catalogue is analysed.
- Shocks are observed in polar rings close to the host galaxy. Its contribution is significantly lower in the outer parts of the polar rings.
- Gaseous polar discs of observed galaxies are chemically homogeneous - no significant metallicity gradient is observed.
- Gas metallicity in all observed galaxies are consistent with their luminosity
- Cold accretion scenario is ruled out for considered polar structures.

Thank you for attention!