

Photometric characteristics of polar-ring galaxies

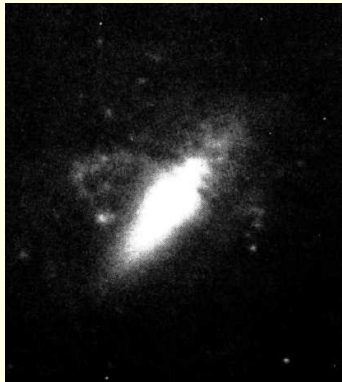
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- Some history of surface photometry of PRGs
- Central galaxies
- Polar structures
- Polar rings vs. polar bulges

History of PRGs photometry

Burbidge & Burbidge (1959): first description of NGC 2685

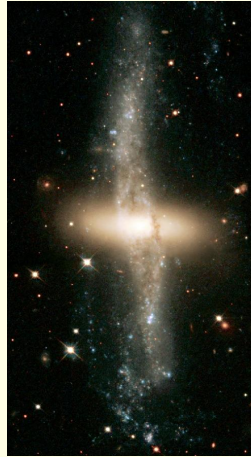
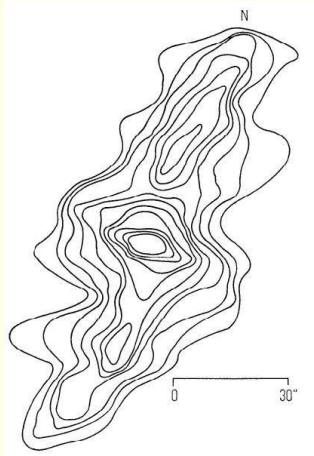


there is a spiral structure which has the appearance of being wrapped around the main body and which apparently has an axis of symmetry *along* the major axis of the galaxy.

Knots or condensations can be seen on the most prominent loop of the spiral, on the west side of the main body, and also on the opposite side. Where the the loops pass in front of the main body, they appear dark, indicating the presence of dust.

History of PRGs photometry

Sersic (1967): photographic isophotes of NGC 4650A



The nuclear region of the main body has emission in H -alpha, while the southern extension of the filament shows a marked blue condensation near its end.

History of PRGs photometry

Sersic & Aguero (1972): photographic photometry of NGC 4650A

Photometric information on G5.

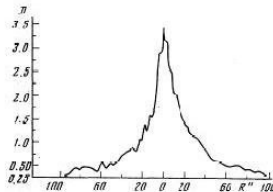
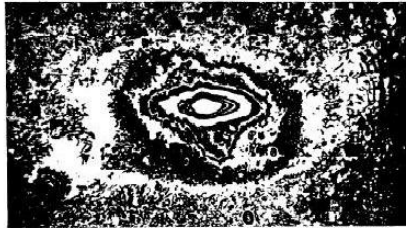
| | P | V | C | C' | P_s | V_s |
|------------------|-------|-------|-------|-------|-------|-------|
| Total | 14.33 | 13.61 | 0.72 | 0.47 | 14.78 | 13.05 |
| Filament (North) | 16.33 | 16.17 | 0.16 | -0.09 | 15.47 | 13.59 |
| Central body | 14.98 | 14.05 | 0.93 | 0.68 | 14.25 | 12.81 |
| Filament (South) | 15.97 | 16.07 | -0.10 | -0.35 | 15.35 | 13.85 |

P, V = photographic and photovisual magnitudes, C, C' = observed and corrected colours, P_s, V_s = surface brightnesses.

The most striking feature we observe in this table is the great difference in colour between the central region ($C' = 0.68$ characteristic of early spirals) and the S and N extensions of the filament ($C' = -0.09$ and -0.35 respectively).

History of PRGs photometry

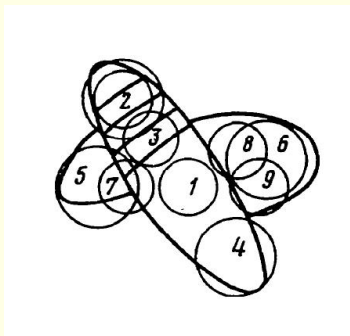
Gorbatskii & Korovyakovskii (1979): possible explosion in NGC 2685



Various distinctive features of the intricate structure observed in the galaxy NGC 2685 may have been caused by an explosion in its central region.

History of PRGs photometry

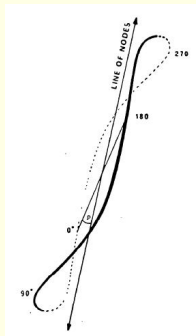
Hagen-Thorn et al. (1979): polarimetry of NGC 2685 (V-band)



Polarimetric observations of the peculiar galaxy NGC 2685 are reported. Fields including the dark bands exhibit $\approx 2\%$ polarization in a direction matching the position angle of the bands. This polarization probably arises from the same mechanism as the interstellar polarization in our Galaxy.

History of PRGs photometry

Laustsen & West (1980): geometrical model of NGC 4650A

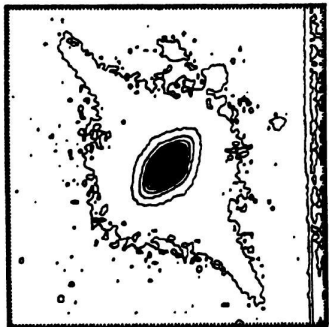


It is interpreted as a prolate, elliptical galaxy surrounded by a warped ring of H II regions, dust and stars.

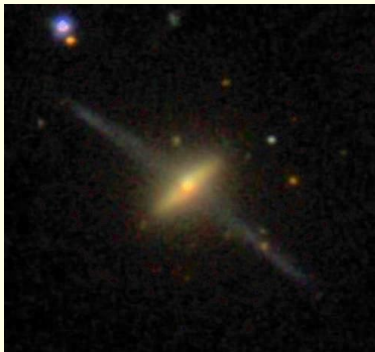
The observed configuration may be the result of interaction with the nearby galaxy, NGC 4650.

History of PRGs photometry

Mould et al. (1982): first CCD photometry of PRG (UGC 7576)
(1.5 hours exposure!)



A contour map of the red image of UGC 7576

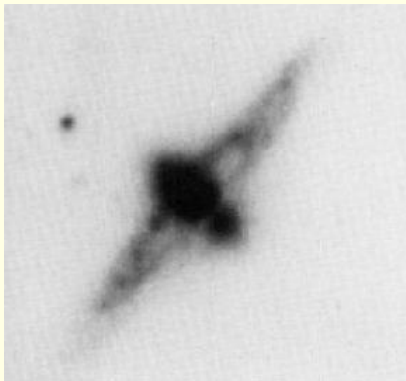


SDSS

Optical photometry of UGC 7576 supports the view that this system consists of an edge-on disk galaxy with a prominent bulge aligned almost orthogonally to a low surface brightness disk.

History of PRGs photometry

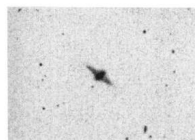
Schweizer et al. (1983): photographic photometry of A 0136-0801



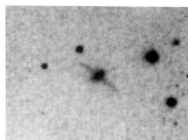
We first present a detailed optical study of A0136 – 0801, a $16\frac{1}{2}$ -mag “spindle” galaxy girdled by a ring of gas, dust, and young stars. The spindle is a normal S0 disk seen nearly edge-on, as shown by its photometric profile and fast rotation ($v_{\text{rot}}/\sigma_v = 2.2$); a prolate structure seems to be ruled out. The surrounding ring runs over the poles of this S0 disk

History of PRGs photometry

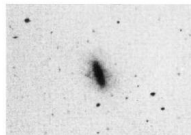
Whitmore et al. (1990): catalog of PRGs and CCD photometry of 12 galaxies



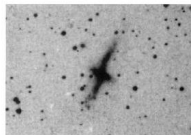
A-1 A0136-0801



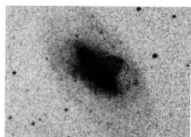
A-4 UGC 7576



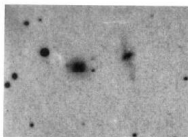
A-2 ESO 415-G26



A-5 NGC 4650A



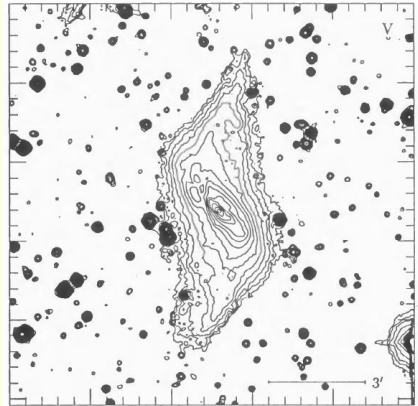
A-3 NGC 2685



A-6 UGC 9796

History of PRGs photometry

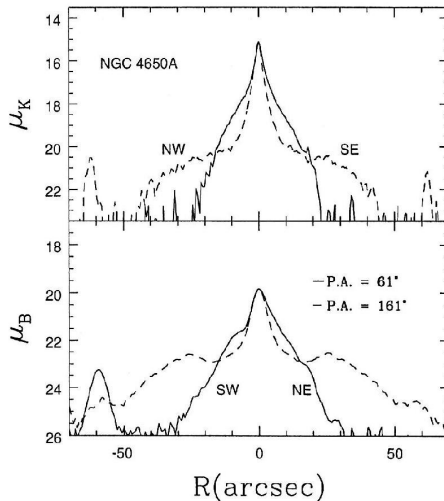
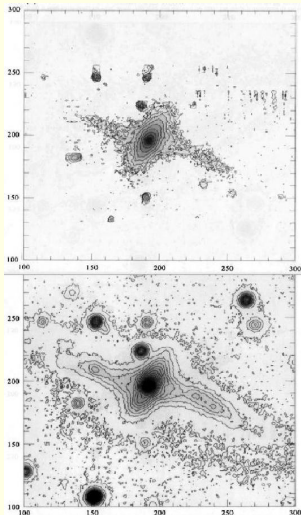
van Driel et al. (1995): surface photometry of NGC 660 with spiral host



It has been morphologically classified as SBa, but our data show it has the global characteristics of a later-type (Sc?), gas-rich disk. The disk and the polar ring both have an exponential luminosity profile, with scale lengths of 1.3 and 3.9 kpc, respectively. The polar ring is blue ($V-I \sim 1.0$), indicating a stellar population age of a few billion years, according to our stellar population synthesis model and the nucleus is red ($V-I \sim 1.8$).

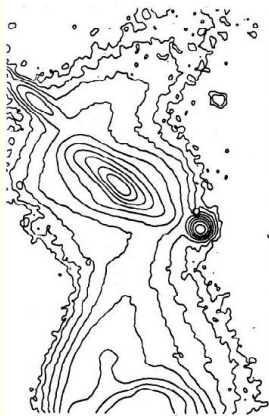
History of PRGs photometry

Arnaboldi et al. (1995): first NIR photometry (5 PRGs)



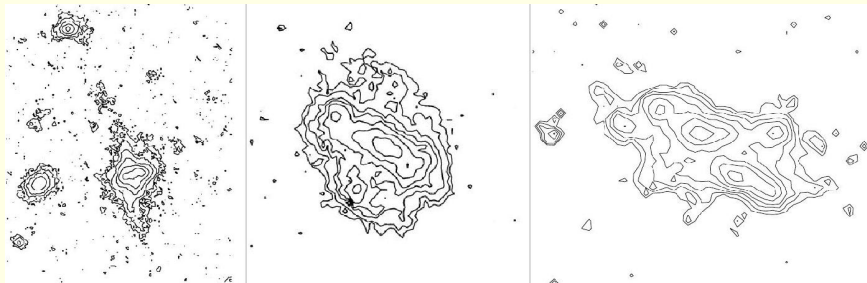
History of PRGs photometry

Reshetnikov et al. (1996): first photometric study of two possibly forming PRGs with spiral hosts (NGC 3808B and NGC 6286)



History of PRGs photometry

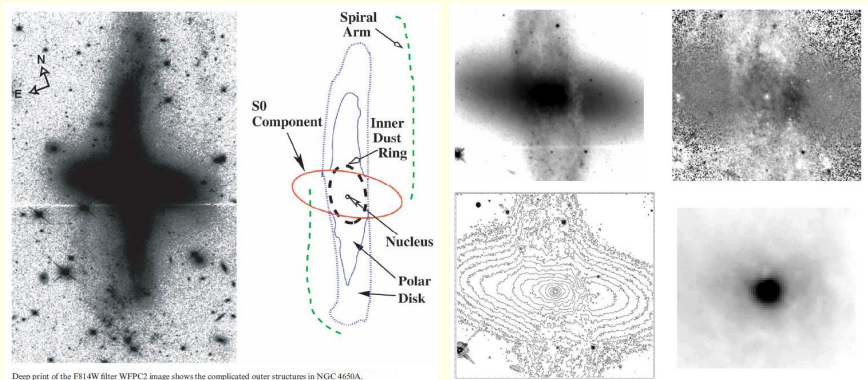
Reshetnikov (1997), Reshetnikov & Dettmar (2007): photometry of 3 candidates for distant ($z \sim 1$) PRGs (HDF-N, HUDF)



Diameters of host galaxies $\sim 1''$ or ~ 10 kpc

History of PRGs photometry

Gallagher et al. (2002): first HST observations of PRG (NGC 4650A)

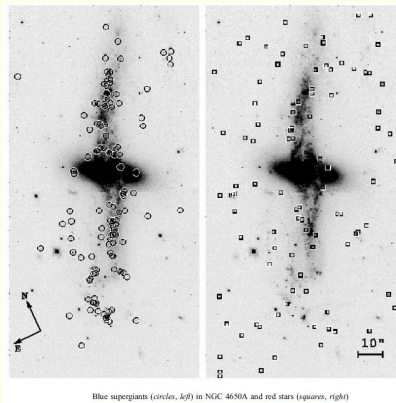


In regions that appear free of dust obscuration, the S0 component shows a surprisingly constant optical color: $(B-I)_0 = 2.0$.

The absence of a large-scale radial color gradient across the S0 component implies that the stellar content is unusually well mixed, perhaps as a result of the merger that could have formed the polar disk.

History of PRGs photometry

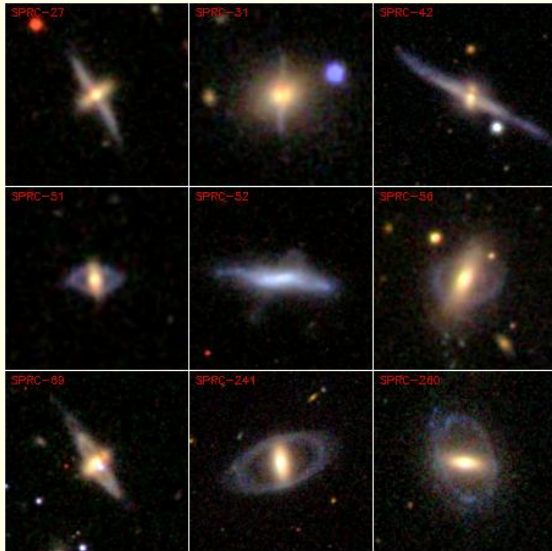
Karataeva et al. (2004): stellar photometry of NGC 2685, NGC 4650A and NGC 660 (2 papers)



The stellar features in the CM diagrams are best represented by isochrones with metallicity $Z = 0.008$. The process of star formation in the polar rings of both galaxies was continuous, and the age of the youngest detected stars is about 9 Myr for NGC 2685 and 6.5 Myr for NGC 4650A.

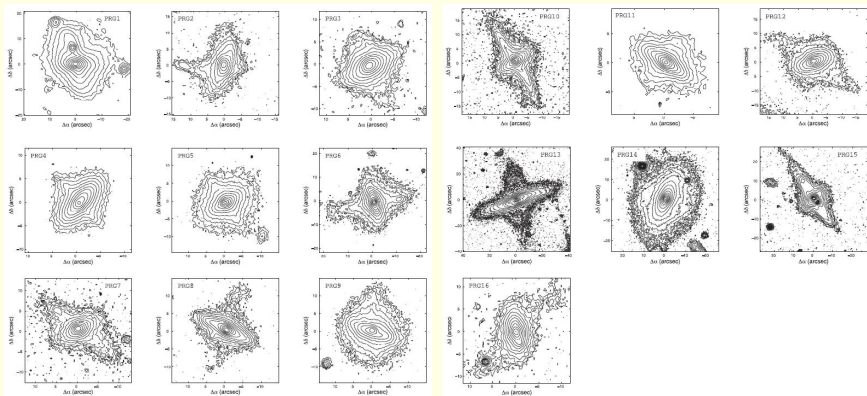
History of PRGs photometry

Moiseev et al. (2011): SDSS-based catalogue of PRGs (SPRC)



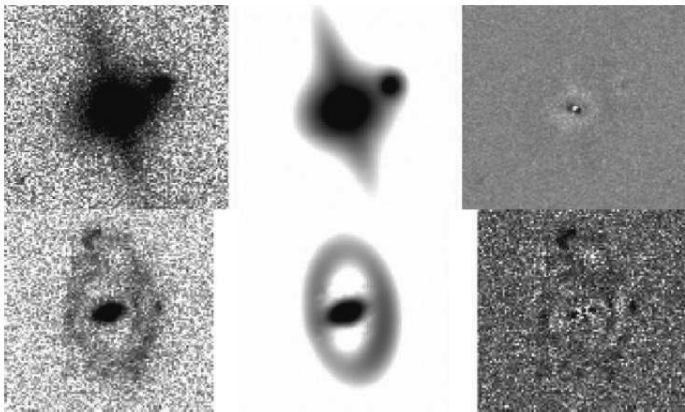
History of PRGs photometry

Finkelman et al. (2012): photometry of 16 galaxies from the SPRC (u and r filters)



History of PRGs photometry

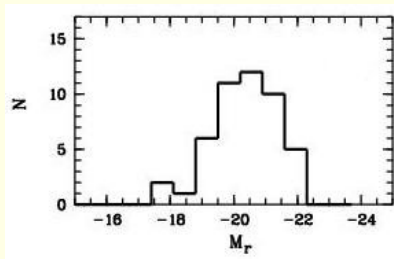
Reshetnikov & Combes (2015): 2D decomposition of 50 PRGs from the SDSS



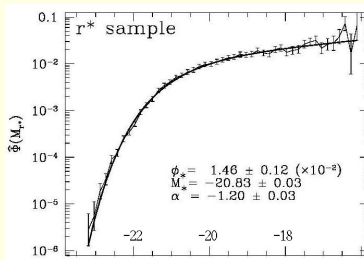
Examples of the PRGs images modelling: SPRC-58 (top), SPRC-7 (bottom). From left to right: original SDSS r -band image, 2D model, and residual image.

Host galaxies of PRGs

- Host galaxies of PRGs look mostly like **early-type galaxies** but $\sim 1/3$ (??) can be spirals
- HGs are **not bright, not dwarf** ($\sim L^*$ galaxies)



R&C (2015)



Blanton et al. (2001)

Host galaxies of PRGs

– Optical colors

Finkelman et al. (2012)
(16 galaxies)

$$\langle u - r \rangle = +2.48 \pm 0.23$$

Fukugita et al. (2007)

$$+2.50 \pm 0.18 \quad (\text{E})$$

$$+2.39 \pm 0.22 \quad (\text{SO})$$

R&C (2015) (50 galaxies):

$$\langle g - r \rangle = +0.74 \pm 0.16$$

$$\langle r - i \rangle = +0.41 \pm 0.09$$

Fukugita et al. (2007)
for SO:

$$+0.74 \pm 0.07$$

$$+0.38 \pm 0.04$$

Host galaxies of PRGs

– NIR colors

Iodice et al. (2002) (5 galaxies, JHK filters):

In all PRGs of our sample, the host galaxy has on average bluer colors than the typical values for early-type galaxies. They are more similar to the colors of spiral and dwarf galaxies, with the exception of AM 2020-504.

– B/D ratio

Reshetnikov et al. (1994), 5 galaxies, B-band:

$$\langle B/D \rangle = 0.32 \pm 0.33$$

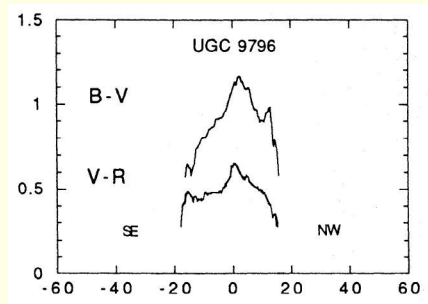
Iodice et al. (2002a,b), 5 galaxies, K-band:

$$\langle B/D \rangle = 0.32 \pm 0.24$$

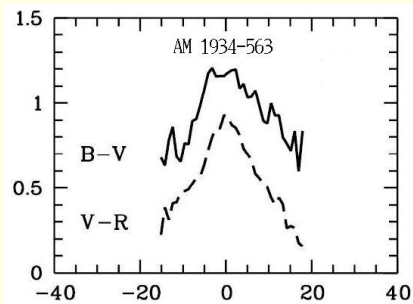
Host galaxies of PRGs

– Radial gradients

Strong color gradients between the central region of the HG and its outer parts (optics and NIR)



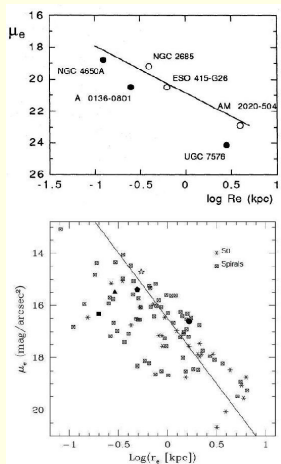
RHY (1994)



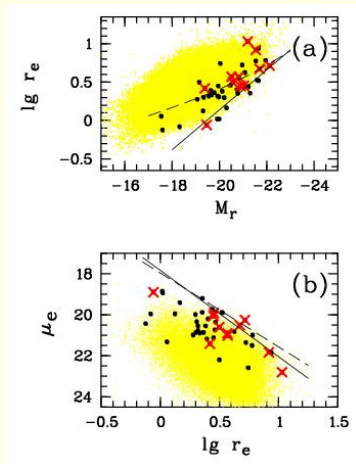
RBCFO (2006)

Host galaxies of PRGs

– Photometric scaling relations



RHY(1994) B
Iodice et al. (2002) K

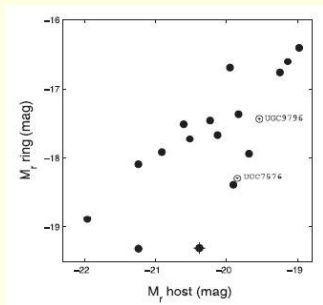


R&C (2015) r

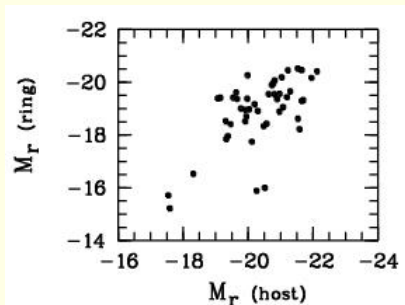
⊥ Polar structures

– Luminosities

R&C (2015): $\langle M_r \rangle = -18.9 \pm 1.3$ (50 galaxies)
 $\langle L_{pol}/L_{host} \rangle = 0.38 \pm 0.31$



Finkelman et al. (2012)



R&C (2015)

– Colors

Finkelman et al. (2012)
(16 galaxies)

$$\langle u - r \rangle = +1.91 \pm 0.32$$

Fukugita et al. (2007)

$$+1.93 \pm 0.31 \quad (\text{Sb})$$

$$+1.89 \pm 0.28 \quad (\text{Sc})$$

R&C (2015) (50 galaxies):

$$\langle g - r \rangle = +0.61 \pm 0.25$$

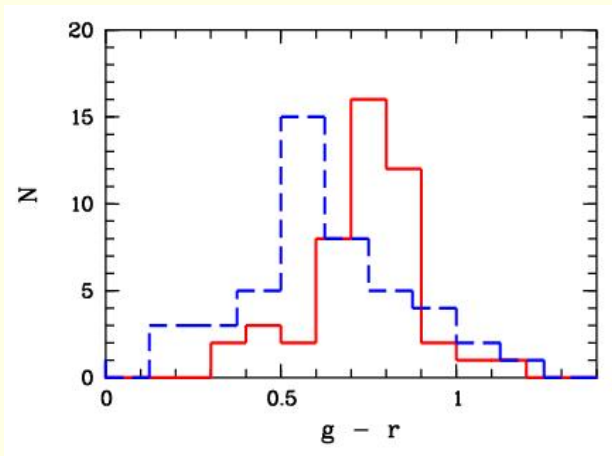
$$\langle r - i \rangle = +0.33 \pm 0.22$$

Fukugita et al. (2007)
for Sb:

$$+0.60 \pm 0.13$$

$$+0.31 \pm 0.09$$

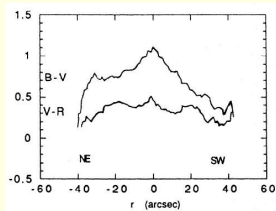
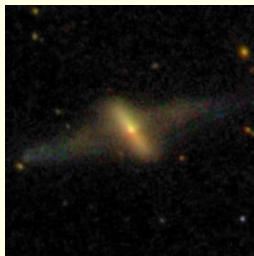
⊥ Polar structures



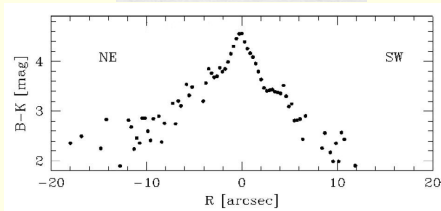
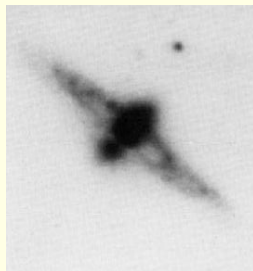
R&C (2015)

⊥ Polar structures

– Radial gradients (UGC 9796 and A 0136-801)



RHY (1994)

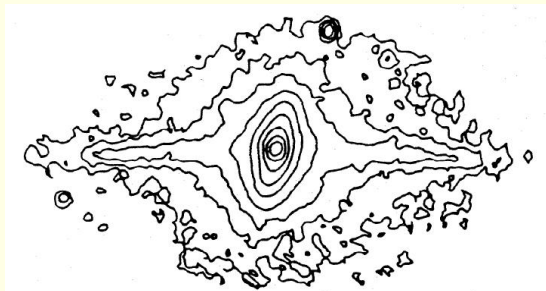


Spavone et al. (2015)

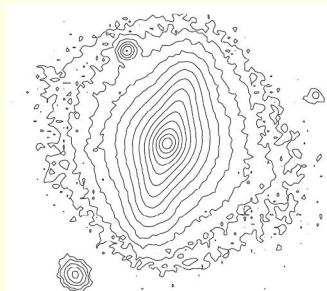
Outer structures

Outer halos – ?

Relics of tidal interactions – ?



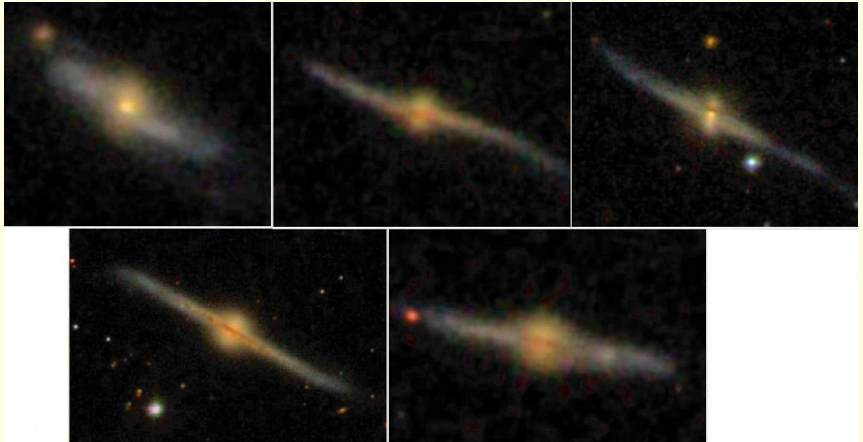
UGC 7576 (V)
RHY (1994)



SPRC-185
Finkelman et al. (2012)

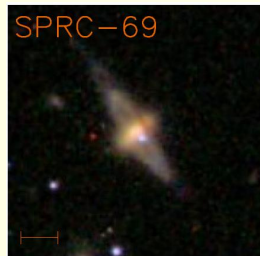
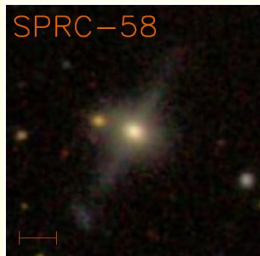
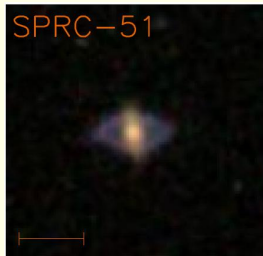
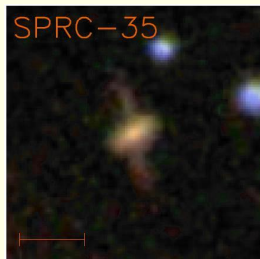
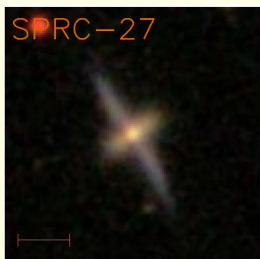
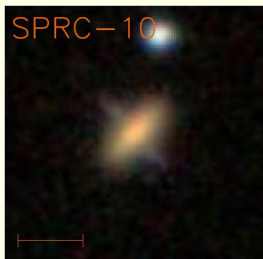
⊥ PRGs vs polar-bulge galaxies

Reshetnikov et al. (2015): polar-bulge galaxies



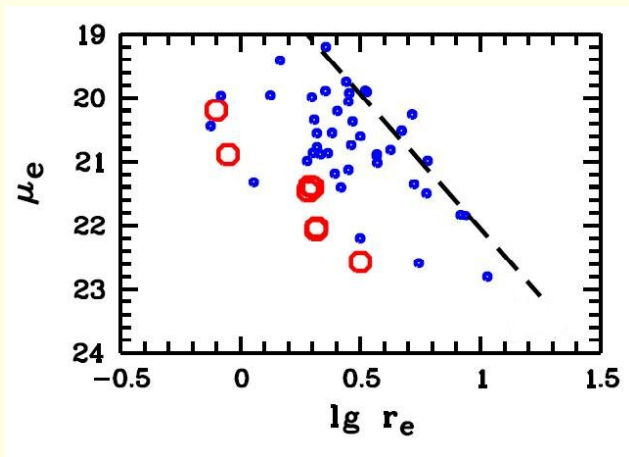
PRGs vs polar-bulge galaxies

Moiseev et al. (2011): 6 galaxies from the SPRC



PRGs vs polar-bulge galaxies

Kormendy relation for the polar bulges (r filter)



Reshetnikov et al. (2015)

└ Conclusions

- A lot of photometric data for a few galaxies
- Limited data for most of other PRGs
- Absence of deep images of PRGs
- PRGs vs polar-bulge galaxies?

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