

New polar ring galaxies catalogue.

Alexei Moiseev⁽¹⁾, Ksenia Smirnova⁽²⁾, Aleksandrina Smirnova⁽¹⁾
Vladimir Reshetnikov⁽³⁾ & Francoise Combes⁽⁴⁾

(1) Special Astrophysical Observatory RAS, Russia

(2) Ural State University, Russia

(3) St. Petersburg State University, Russia

(4) Observatoire de Paris, LERMA & CNRS, France

A photographic atlas of 157 polar ring galaxies, Whitmore et al (1990):

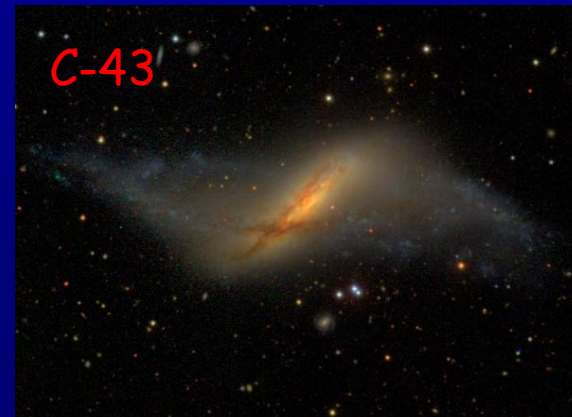
PRC-A (6 galaxies):
Kinematically confirmed



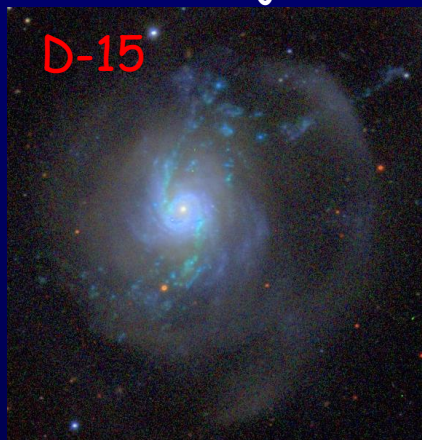
PRC-B (27 galaxies)
Good candidates



PRC-B (73 galaxies)
Possible candidates



PRC-D (51 galaxies)
Related objects



- Studying a role of merging and interactions in galaxy evolution (disc and bulge formation, starformation, etc.)
- Implication for dark matter contents: $M/L > 20-50$
- Probe to the 3D shapes of dark matter halo
- "Cold" gas accretion for galaxies masses assembly?

Formation of polar rings: simulations

1) The major merging scenario:

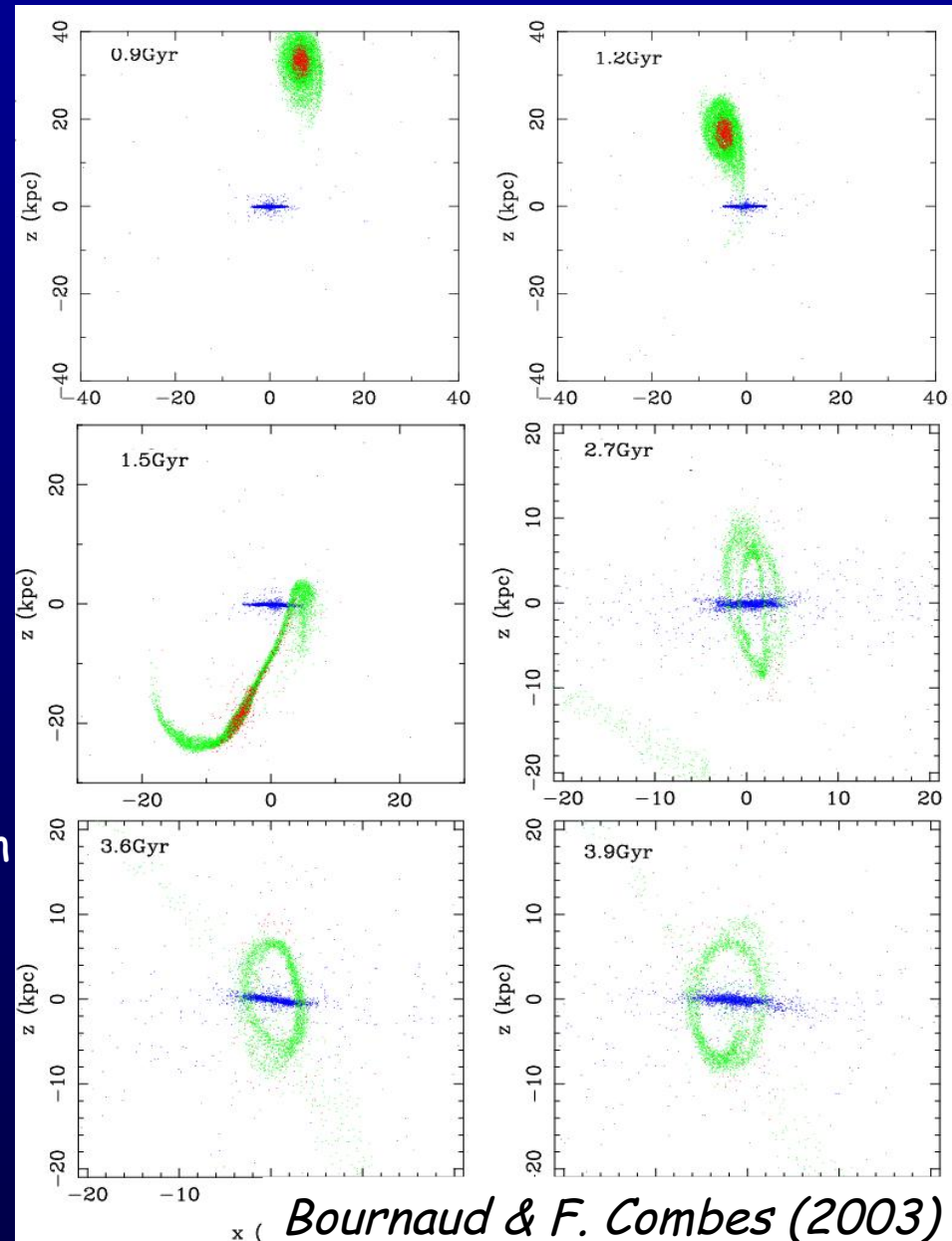
- A head-on collision between two orthogonal spiral galaxies (Bekki, 1998; Bournaud & Combes, 2003)

2) The accretion scenario:

- Tidal accretion of the polar material from a gas-rich donor galaxy (Schweizer et al. 1983; Reshetnikov & Sotnikova 1997)

- the disruption of a small companion on a polar orbit

- accretion of gas infalling from extragalactic cosmic filaments (Maccio et al., 2006)



20 years looking in Polar Rings Catalogue...

see Combes (2005), Iodice et al. (2003), Sparke (2002) ...

- ◆ A host galaxy like S0 or E, the polar component is like spirals or irregular galaxies (gas-rich and bluer)
- ◆ Not only narrow annuli, but also extended disc-like rings
- ◆ Warped and inclined rings

Only 20 large-scale polar rings + 6 inner rings were kinematically confirmed from the Whitmore et al. list:

- HI maps (Cox et al; Sparke et al.)
- optical-long slit spectroscopy (Reshetnikov et al)
- optical 3D spectroscopy (Spalyapina et al, Brosch et al)

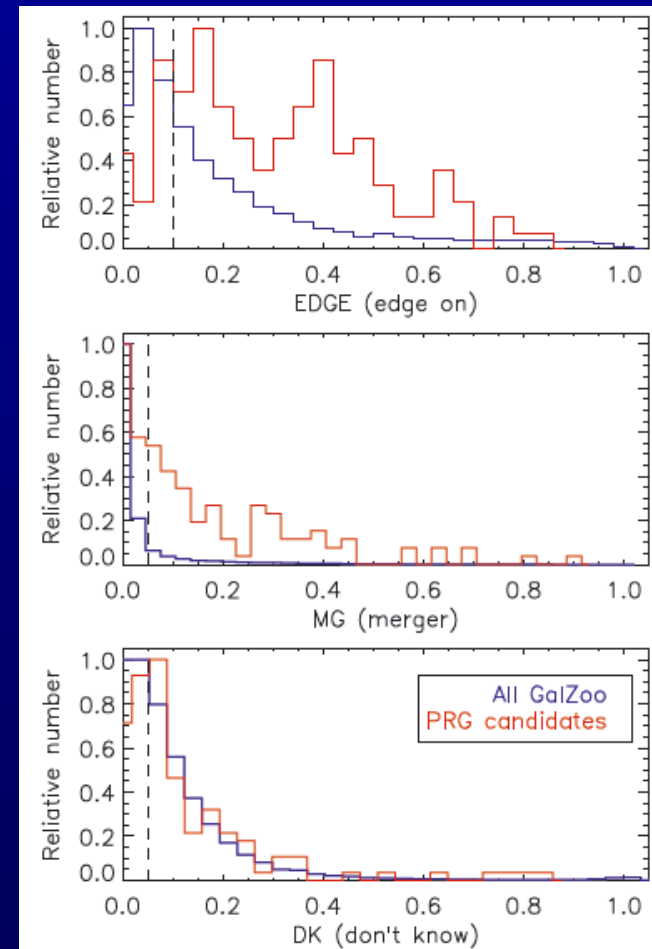
SDSS-based Polar Ring Catalogue (=SPRC)

Results of original Galaxy Zoo project:

- GalZoo ring galaxies internet-forum
- Visual inspection of 41958 SDSS DR7 images preliminary selected using Galaxy Zoo simple classification from Lintott, et al (2011)

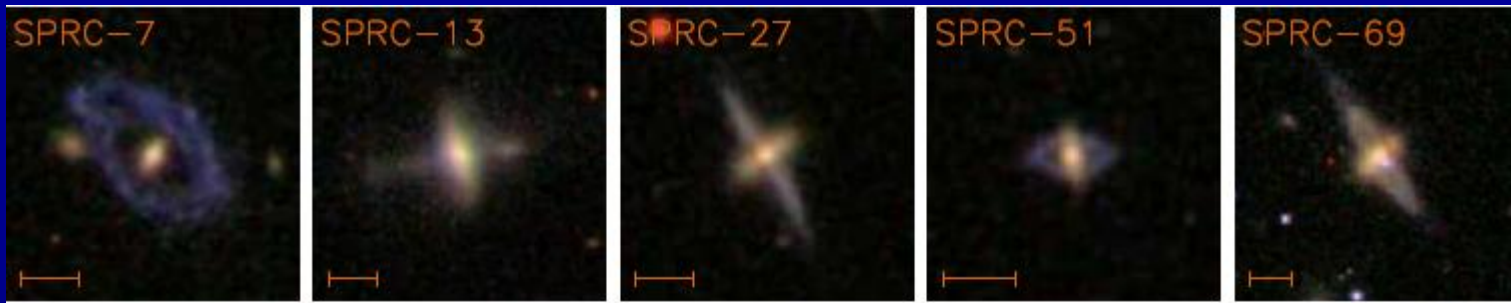
Class	Button	Description
1	●	Elliptical galaxy
2	⌚	Clockwise/Z-wise spiral galaxy
3	⌚	Anti-clockwise/S-wise spiral galaxy
4	⦿	Spiral galaxy other (eg. edge on)
5	✦	Star or Don't Know (eg. artefact)
6	☾	Merger

Table 1. Galaxy Zoo classification categories showing schematic symbols

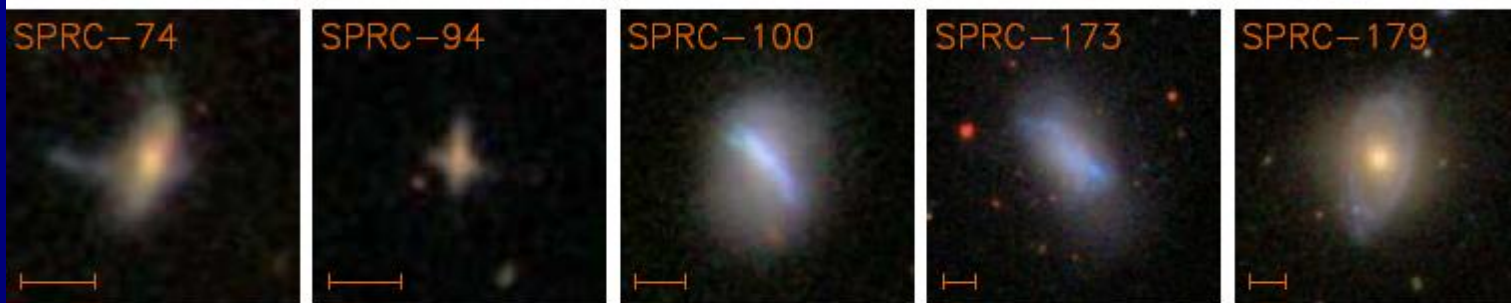


Moiseev et al (2011, MNRAS, 418, 244):
 275 candidates
 14 already have kinematic confirmation

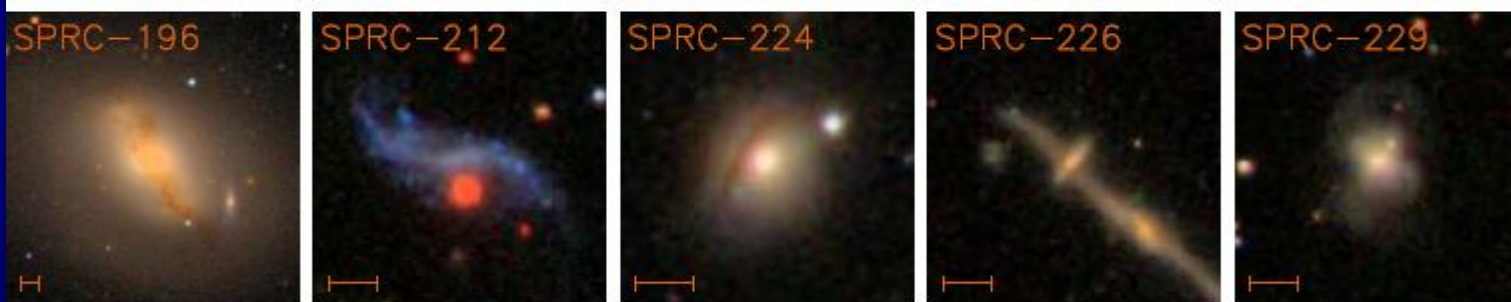
$EDGE \geq 0.1, MG \geq 0.05, DK \geq 0.05$



The BEST
Candidates
(70)



GOOD
Candidates
(115)



RELATED
Objects
(53)



FACE ON
Rings
(37)

New catalogue — SPRC: 275 candidates (185 — “the best” + “good”)

SDSS-based Polar Ring Catalogue

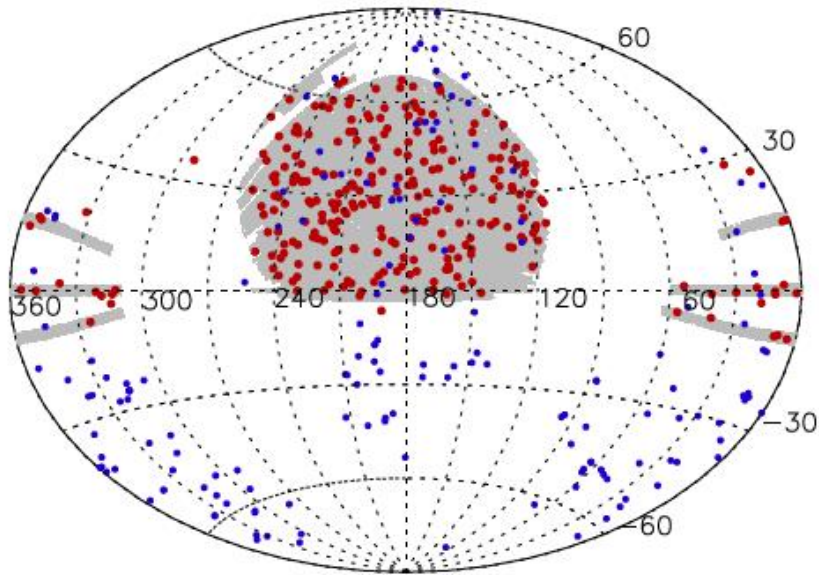


Figure 2. Apparent distribution of PRG candidates in the sky in equatorial coordinates. The gray shaded area marks the Galaxy Zoo region. Blue dots are the objects from Whitmore et al. (1990), red dots are the galaxies from the new catalogue.

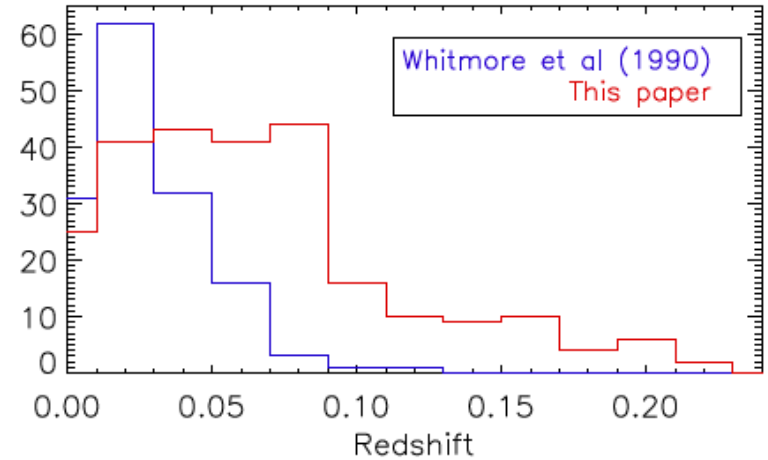
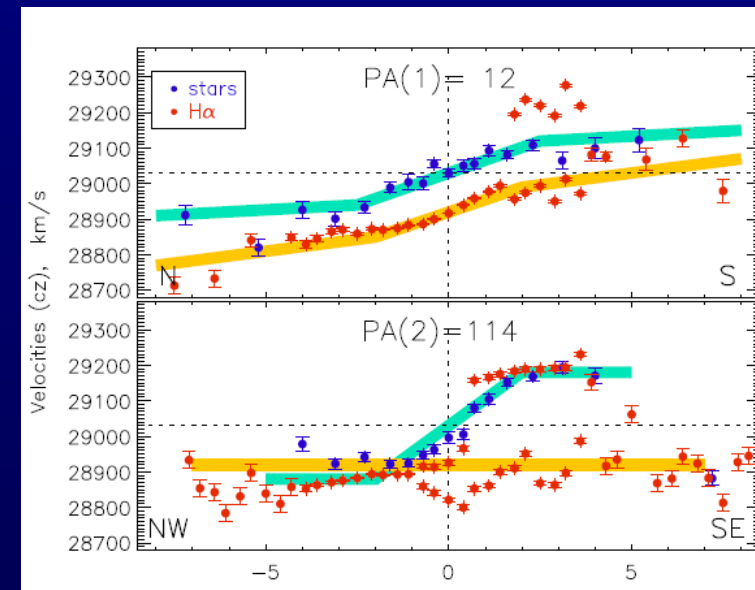
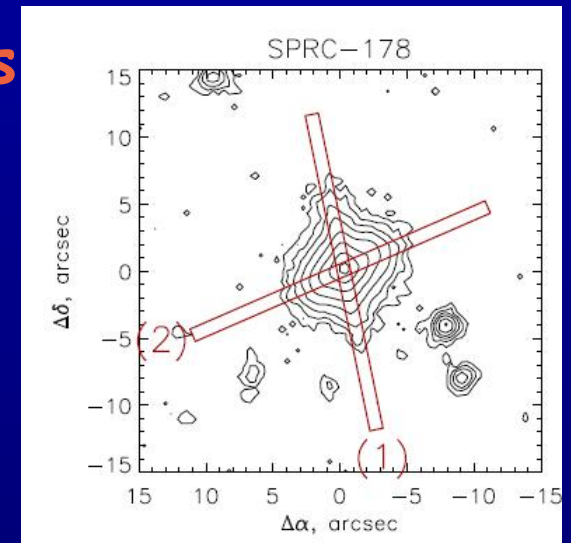
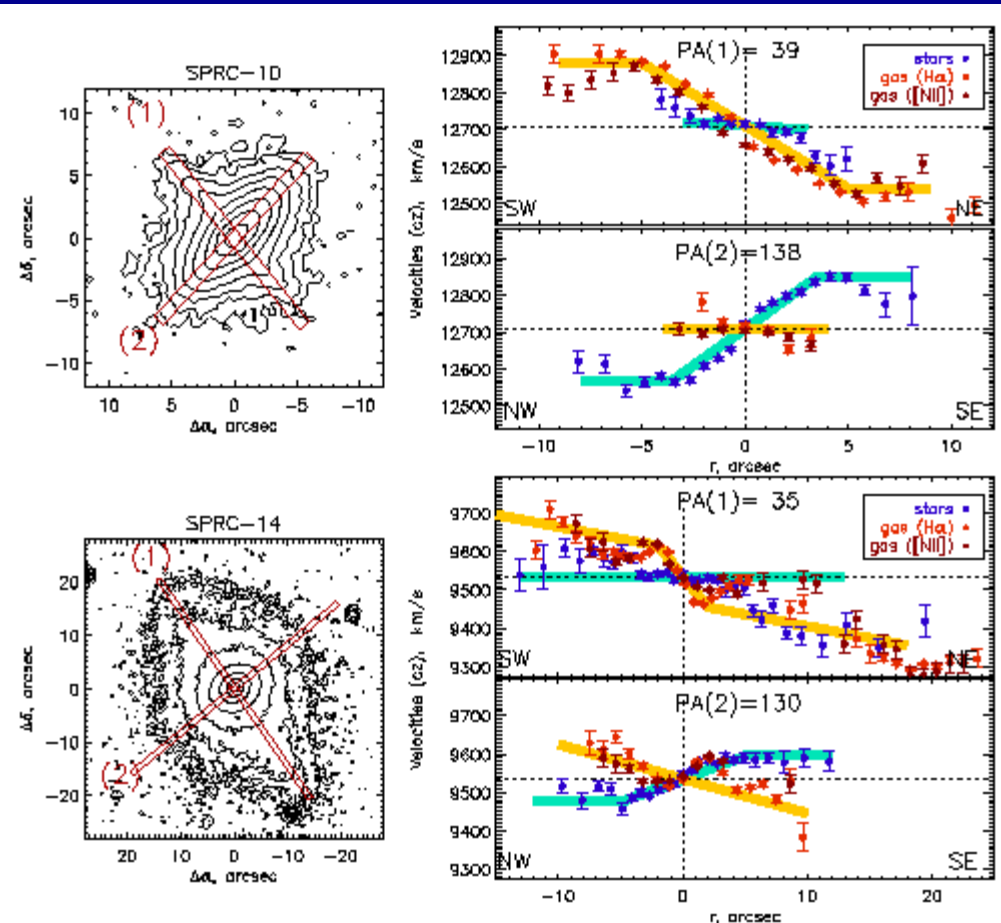


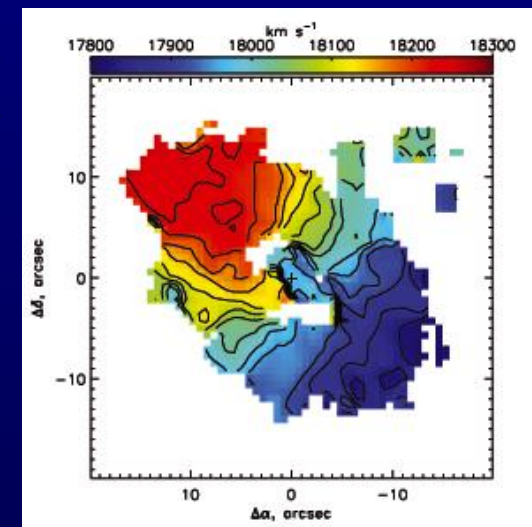
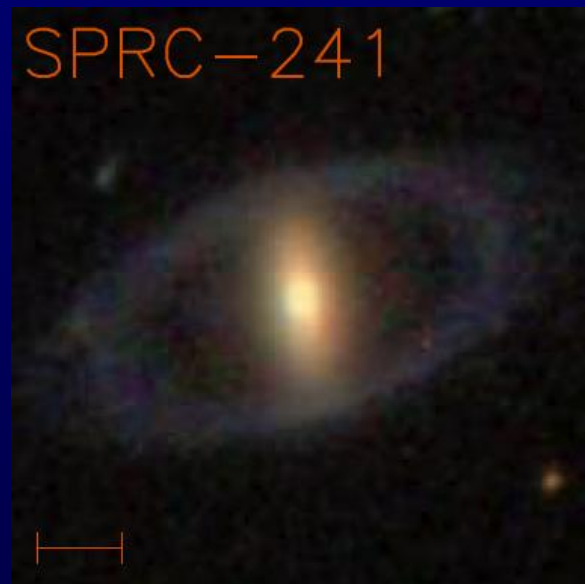
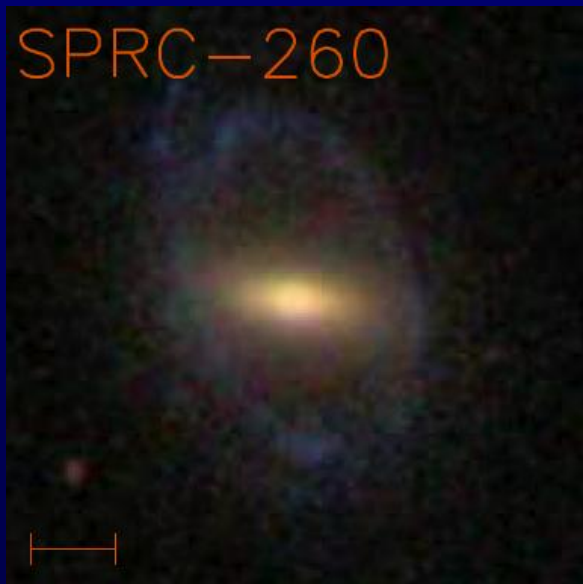
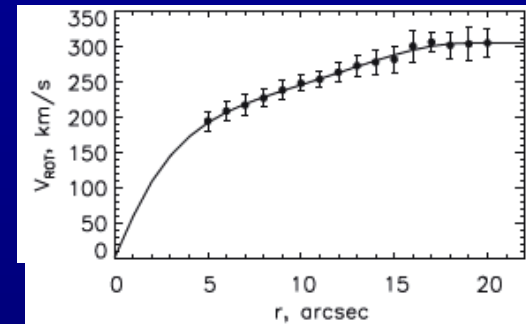
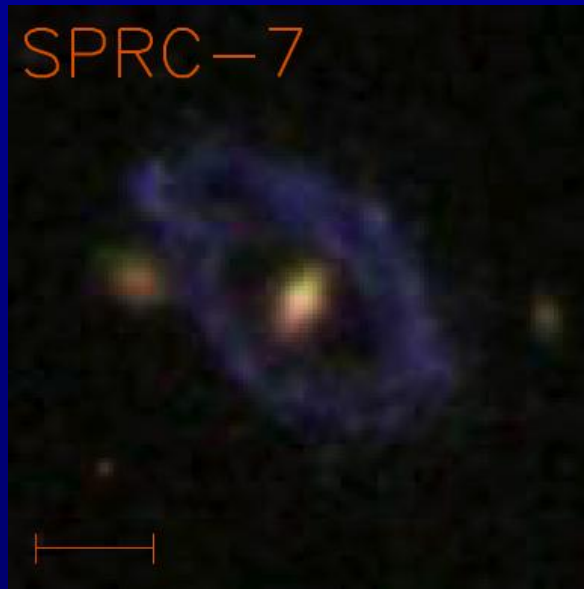
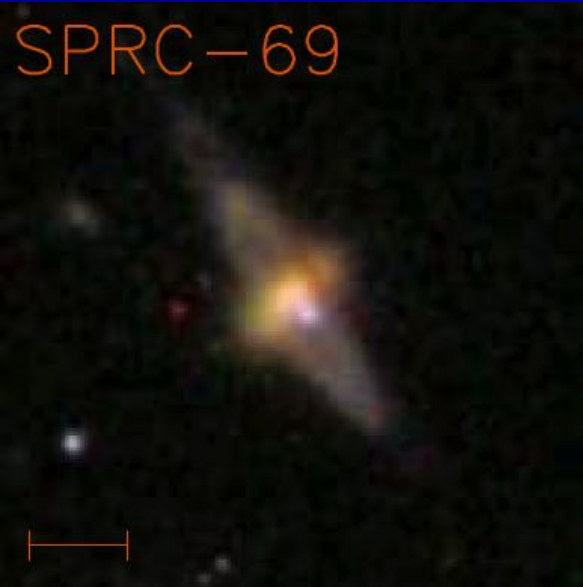
Figure 7. Histograms of the distribution of PRG candidates by redshift for the Whitmore et al. (1990) catalogue and the new list.

SAO RAS 6-m telescope observations



In references: 5 confirmed polar rings (including SPRC-7 observed at the 6 m telescope
 2010: 5 confirmed polar rings, 1 case of overlap
 2011: + 4 confirmed polar rings

"The best" objects with known gas/stars kinematics



What is the true shape of dark matter halo?

Theory and simulations:

A flattening should be depend from the origin

(Combes, 2005):

Accretion: $c/a < 1$

Merging: $c/a \approx 1$

Triaxial CDM halo: $c/a = 0.5 - 0.7$

Observations:

T-F relation (Iodice et al 2003; Reshetnikov 2004):

flattened halo along polar plane

Iodice et al (2009): new dynamical model for NGC4450A

constrains very flat halo with $c/a = 0.3$

Strongly tilted rings would survive preferentially in roundest halos:

NGC 2685 (Josza et al, 2009),

NGC 3718 (Sparke et al, 2009),

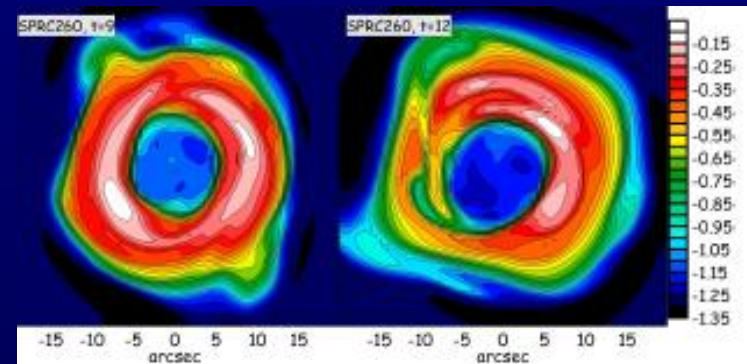
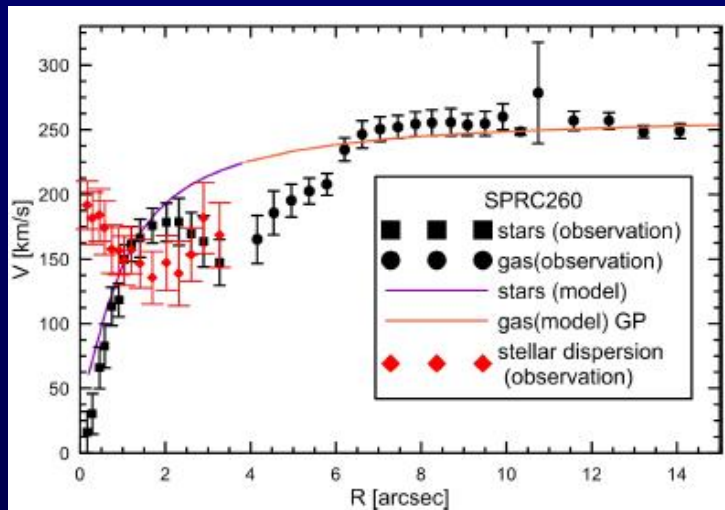
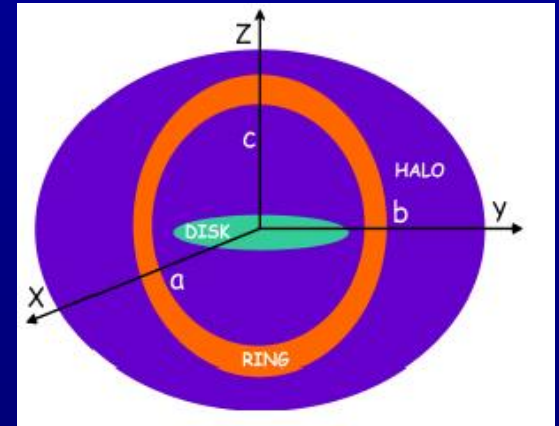
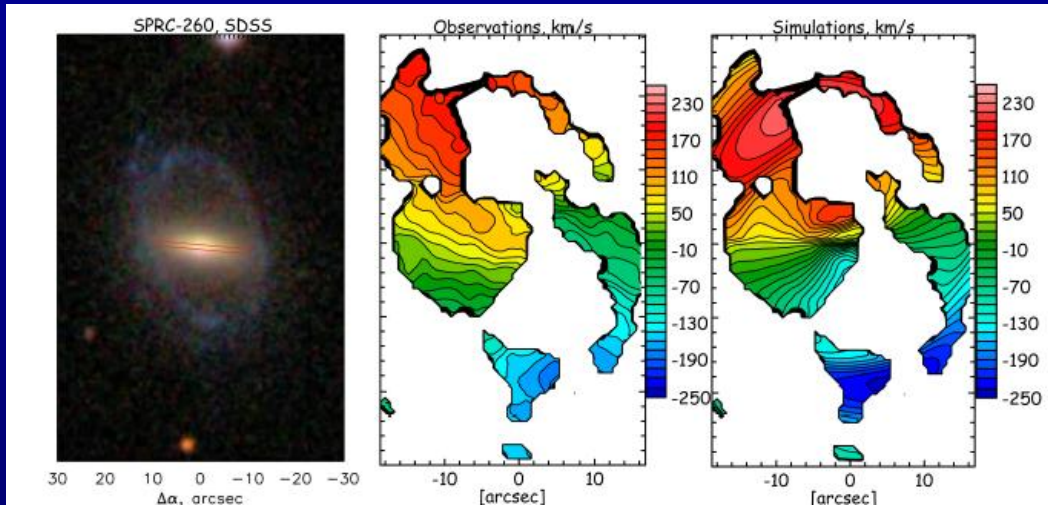
NGC 4753 (Steiman-Cameron, 1993)



Iodice et al (2009)

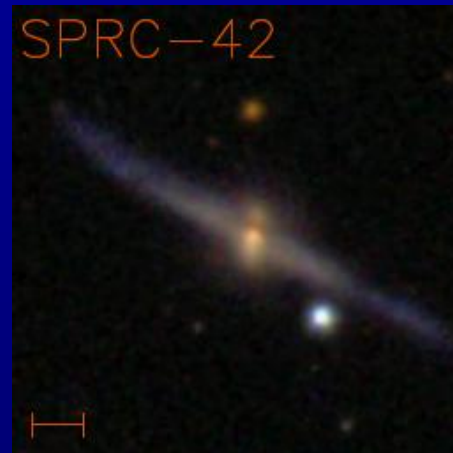
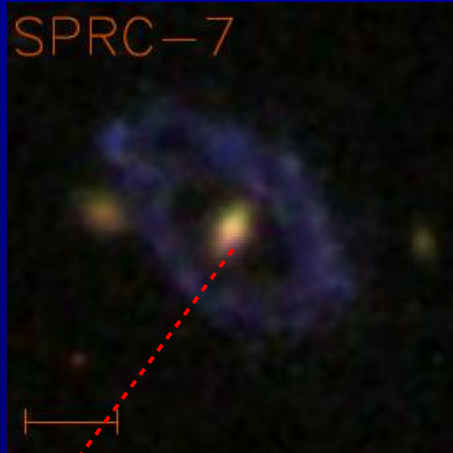
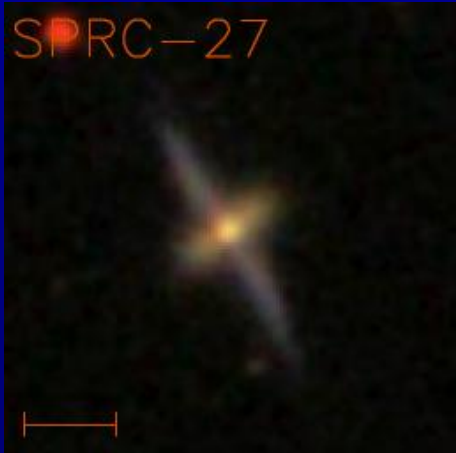
We need more spatial resolved 2D kinematics + detailed modeling of the 3D gravitational potential distribution

3D dark halo shape: simulations vs. observations:

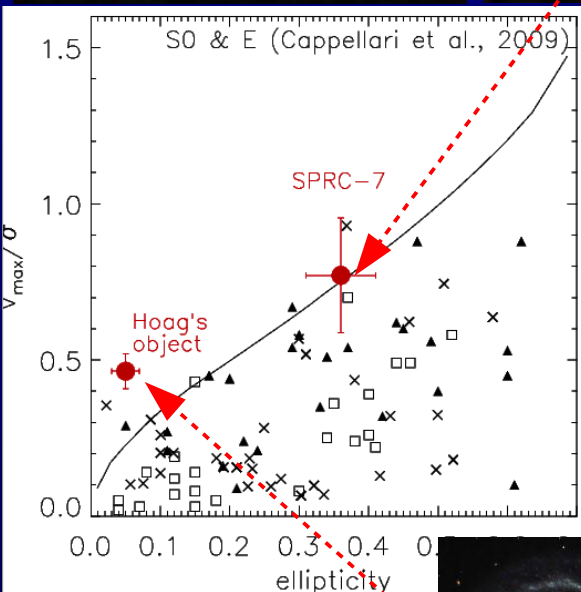


- 1) Slightly triaxial halo ($c/b=0.95$ $a/b=1.1$)
 - 2) Evolved spiral structure in the polar ring
- (Khoperskov et al, poster on the SpS 3)

New examples of extended massive rings

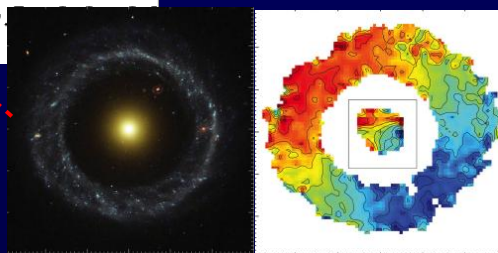


NGC 4650A - a local analogue (Spavone+ 2010)



- Discs rather than rings...
- How did they acquire a mass equal with their hosts?
- Fast rotation of central galaxies contradicts with a major merging scenario

Cold gas accretion along misalignment filaments?

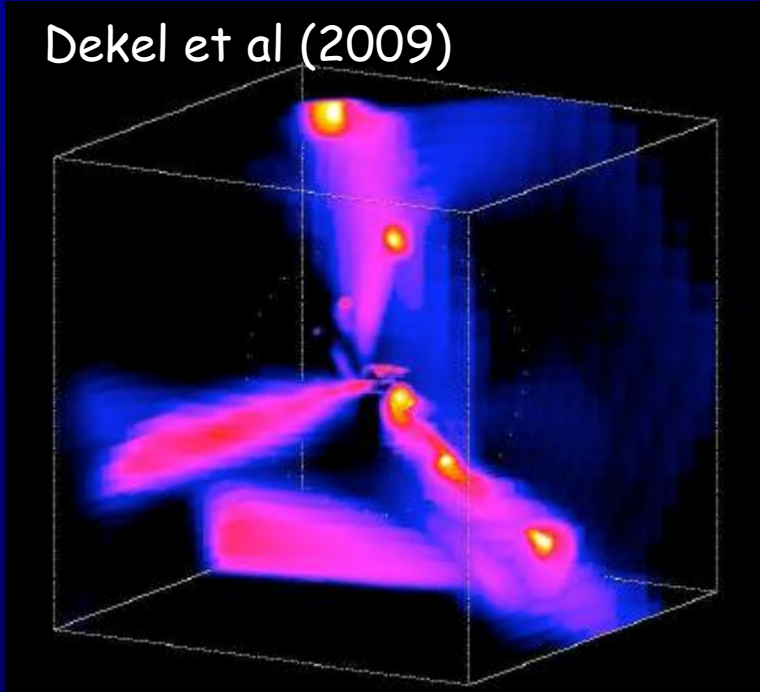


Hoag object (my talk on SpS 3)

Gas accretion from cosmic filaments

Macci et al (2006):
gas infalling from cosmic filaments, with inclined angular momentum

Dekel et al (2009)



Brook et al (2008) :
Simulated object similar with NGC 4650A

Iodice et al (2010): low metallicity ($Z=0.2 Z_{\text{sun}}$) in the polar disk of NGC 4650
implies a cold accretion scenario?

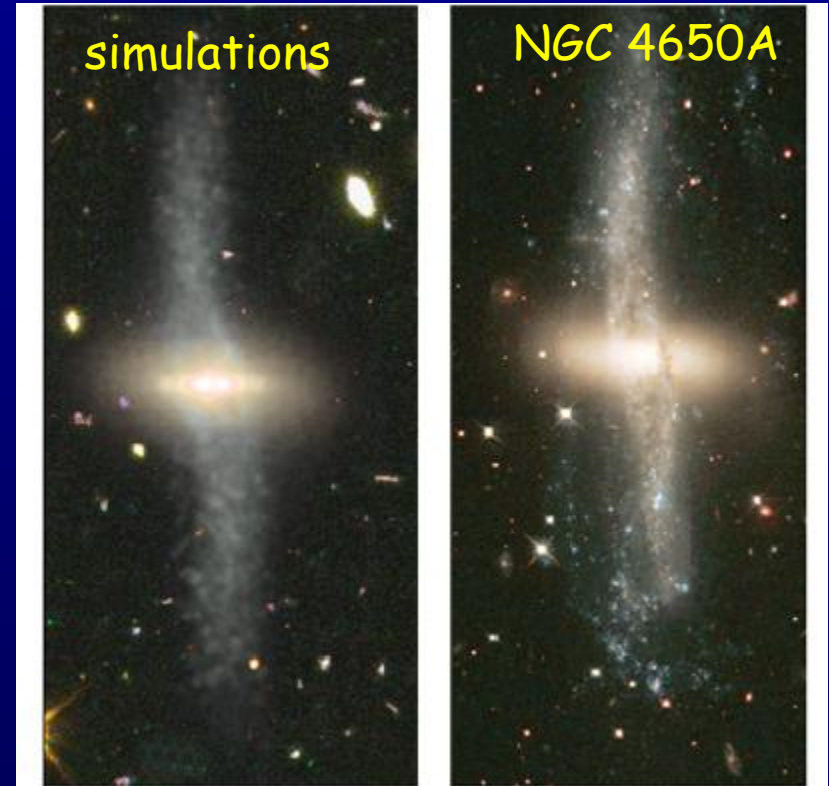


FIG. 3.— The simulated polar disk (left) is imaged by assigning

Molecular gas observations

21 galaxies observed

12 Candidate PRG

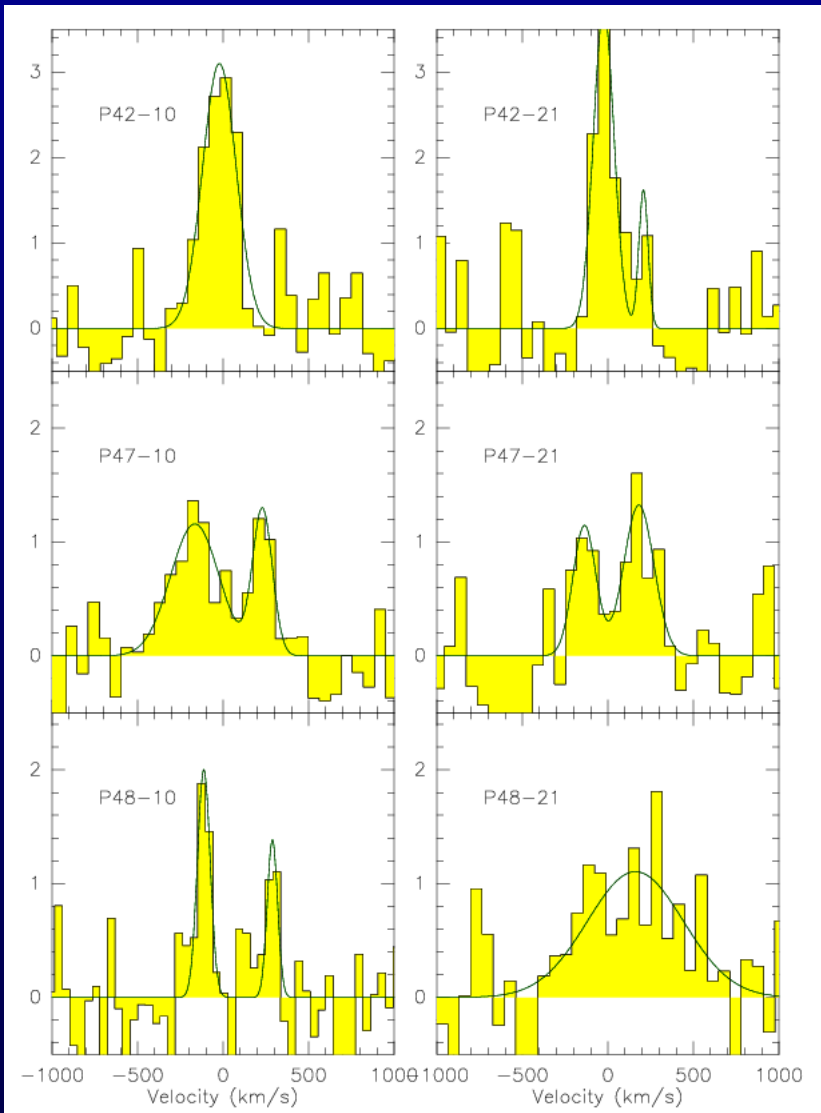
P13 P15 P17 P24 P29 P31

P42 P47 P48 P52 P56 P61

9 Confirmed PRG

PC7 PC10 PC14 PC33 PC39 PC60

PC67 PC69 PC260



Double-horn profiles
→ Rotating disks

Typical masses
 $2 \times 10^9 M_{\odot}$

IRAM-30m



Molecular gas observations

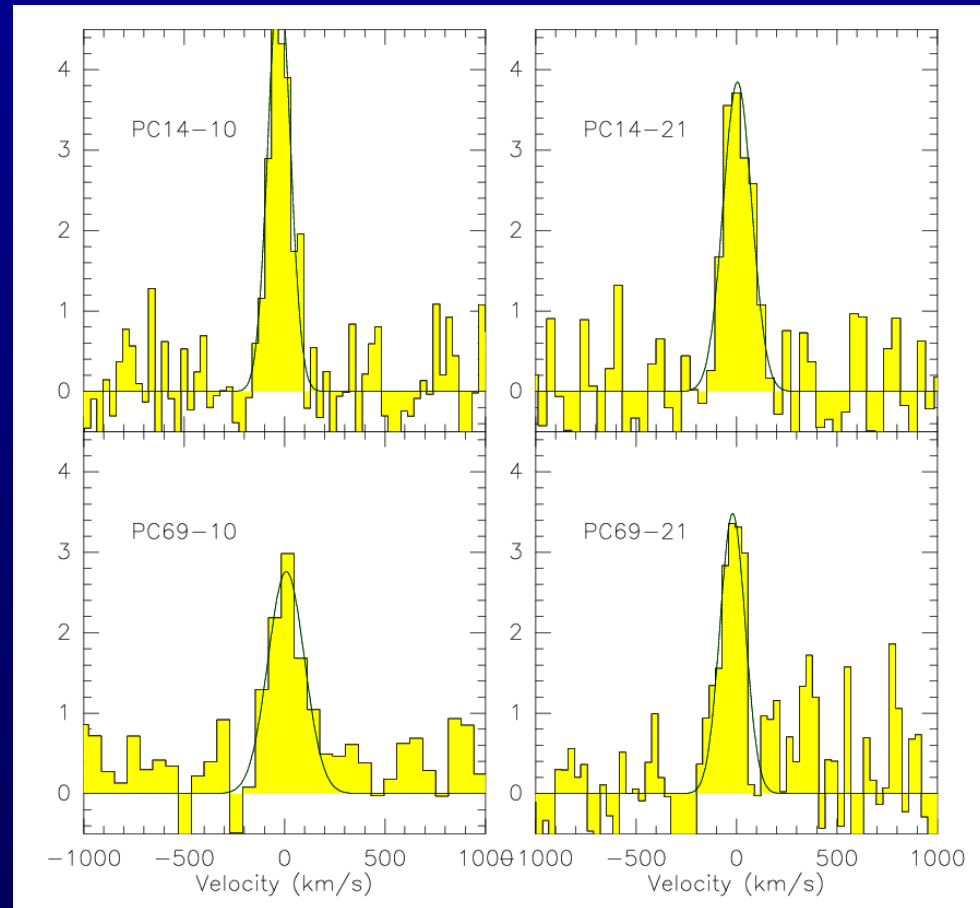
CO(1-0) and CO(2-1)

- Simultaneously observed with IRAM-30m

24% detection rate

- About the same as in ATLAS^{3D} nearby early-types galaxies (22%, Young et al, 2011)

CO(2-1)/CO(1-0) ratio typical of dense galaxy discs or nuclei



Conclusion

Sloan-based Polar Rings Catalogue contains 275 galaxies. It significantly (in 3 times) increases a number of genuine PRG candidates and may serve as a good basis both for the further detailed study of individual galaxies, and for the statistical analysis of PRGs as a separate class of objects.

14 SPRC galaxies already have a kinematic confirmation

The most interesting items related with further studying of SPRC:

- 3D dark halo shape
- Statistic of an external gas accretion, including a cold accretion along filaments

The deep HI observations are strongly needed!

Thank you for your attention!

