Large-scale disks of ionized gas in lenticular galaxies: imprints of external accretion.

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VOLGA

View On the Life of GAlaxies

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Gas contents in S0 galaxies: evolution of views

Gas-poor galaxies:
"...they show no trace of gas or anything of the sort.." (Baade, 1975)

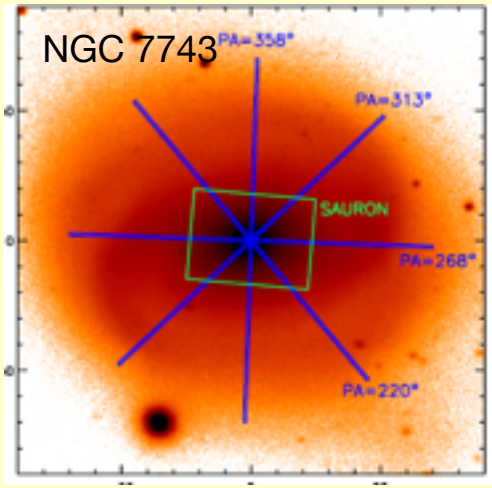
Ionized gas in the central kiloparsec:
"...24±8 % of the gas discs in S0 counter-rotate" Kuijken & Merrifield, 96

Cold gas, HI environment, multi-spin structures:
- S0s are the central components of polar ring systems:
  Polar Ring Catalogue (Whitmore, 90, 91)
(SDSS-based Polar Ring Catalogue (Moiseev+ 11
- CO emission is detected from 78% of the sample (Welch & Sage, 03)
- molecular gas discs in ETG (Davies +13) ← M. Bureau talk on Tuesday!
- 36% of fast-rotating ETG in ATLAS^{3D} sample have their ionized gas kinematically misaligned with respect to the stars (Davies+ 11)

Large-scale ionized gas discs also exist in S0 !

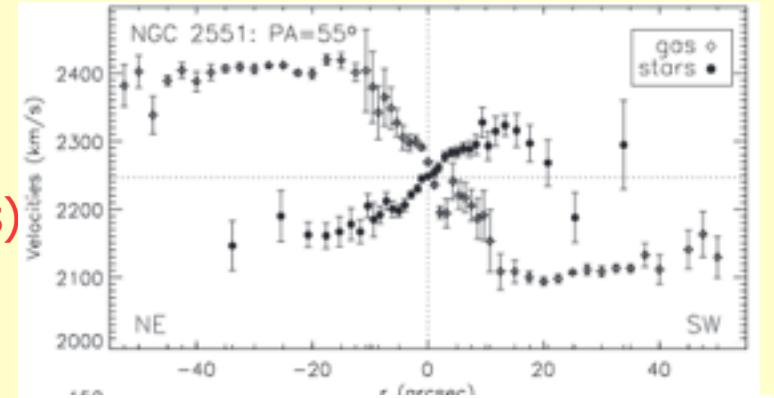
Gas contents in S0 galaxies: large-scale discs

An inclined gaseous structure in NGC 7743
(Katkov, Moiseev & Silchenko 2011)
r(disc)~6 kpc, Δi=34º or 77º



Counter-rotating discs: (see review by Corsini 14):
NGC 4546 (Bettoni + 91)
NGC 2551, NGC 5631 (Sil'chenko + 09)
NGC 4550 (Coccato+13, Johnston +13)

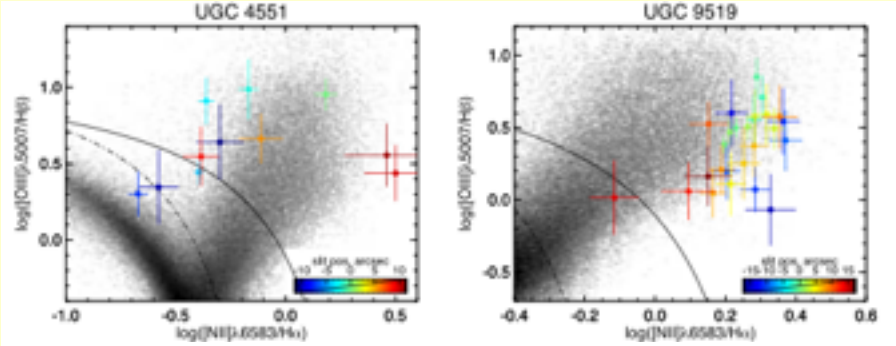
New statistics (6-m BTA and SALT 10-m telescopes)
extended ionized-gas discs are found in
58-72% of the isolated S0 (Katkov + 14, 15)



Sil'chenko, Moiseev & Afanasiev (2009)

Gas ionization (Sil'chenko+09, Katkov+14)
[NII]/Ha>1:
- shock ionization of accreted matter?
- AGB stars?
- a specific regime of star formation?

← G.M. Gomes talk!



Katkov, Sil'chenko & Afanasiev (2014)

Why large-scale 2D kinematic maps are important?

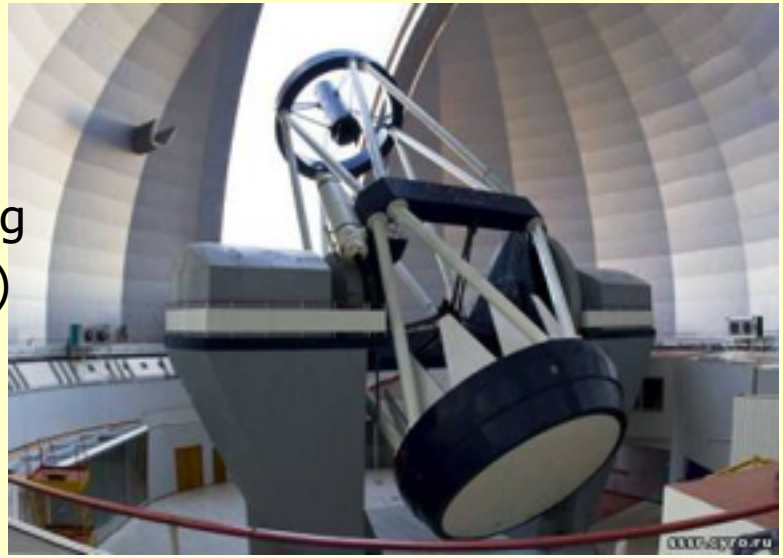
1) Long-slit cross-sections are insufficient in a complex kinematical picture
2) Gas/stars kinematic misalignment changes with radius (warped structures, etc)
3) To choose between minor/major merging and accretion scenarios

We need:
- Large FOV=1-4 arcmin (D_{25} at d=12-40 kpc)
- High sensitivity for low-brightness emission features

The main sample: 63 galaxies possesses extended [OIII]5007 emission and/or evidences for HI 21 cm structures in ATLAS 3D data (Serra +12)
+ some well-known objects from the literature
+ long-slit data taken at the SAO RAS 6-m and SAAO SALT 10-m telescopes

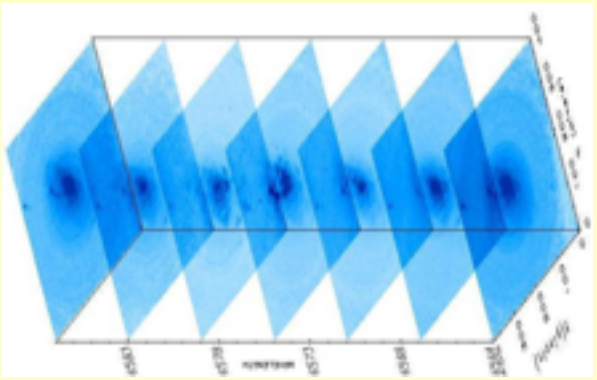
→ ~20 candidates with extended [OIII] or [NII] emissions proposed for 3D spectroscopic observations with the scanning Fabry-Perot interferometer

Observations: SAO RAS 6-m telescope



Multi-mode SCORPIO-2 focal reducer with a scanning Fabry-Perot interferometer (Afanasiev & Moiseev 11)
Emission lines : [NII]6583, [OIII]5007, Hα

Field of view: 6.1 x 6.1 arcmin
Spatial sampling: 0.70 arcsec/px
Vel. Resolution (FWHM): 70-120 km/s



Additional data:
Long-slit spectroscopy (6-m BTA, 10-m SALT):
stellar kinematics, age/metallicity

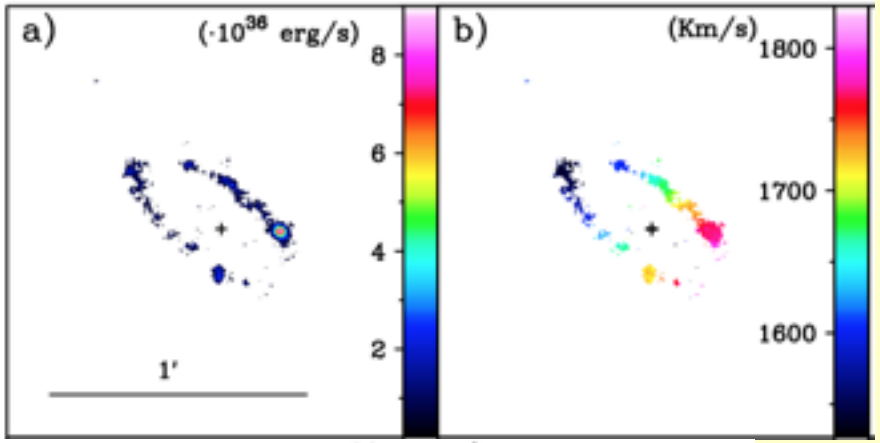
Available IFU maps: ATLAS3D, CALIFA, MPFS/6-m telescope

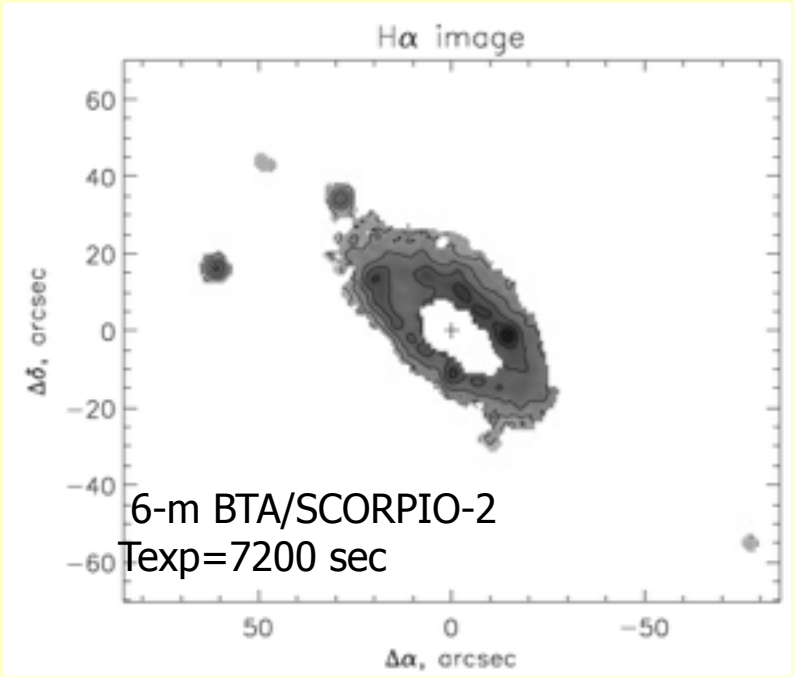
Large FOV & Deep data

Hα kinematics of S⁴G spiral galaxies-II. Data descript

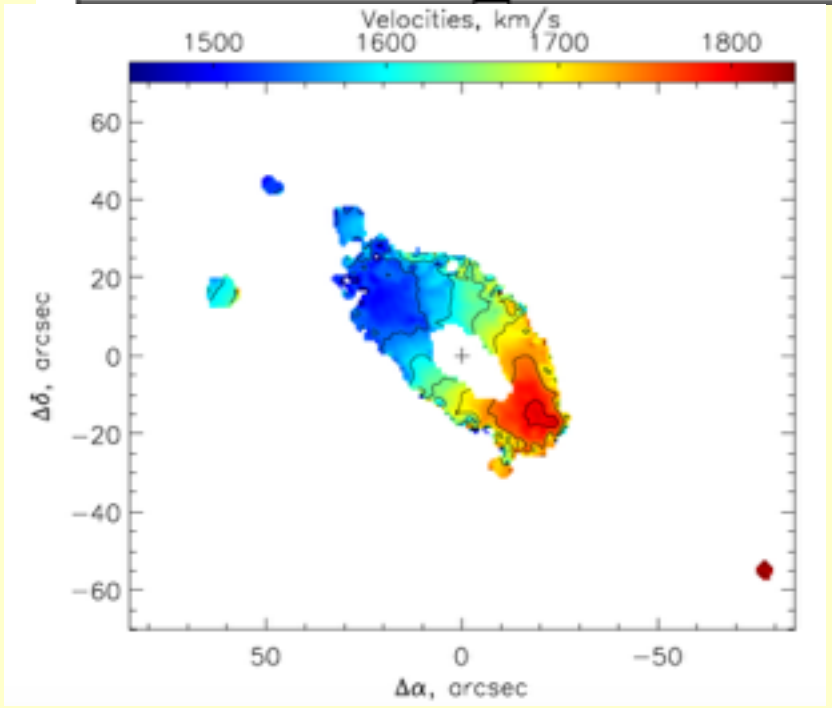
S4G: Erroz-Ferrer + 15
4.2-m WHT/GHaFaS
Texp=8160 sec

NGC 4324

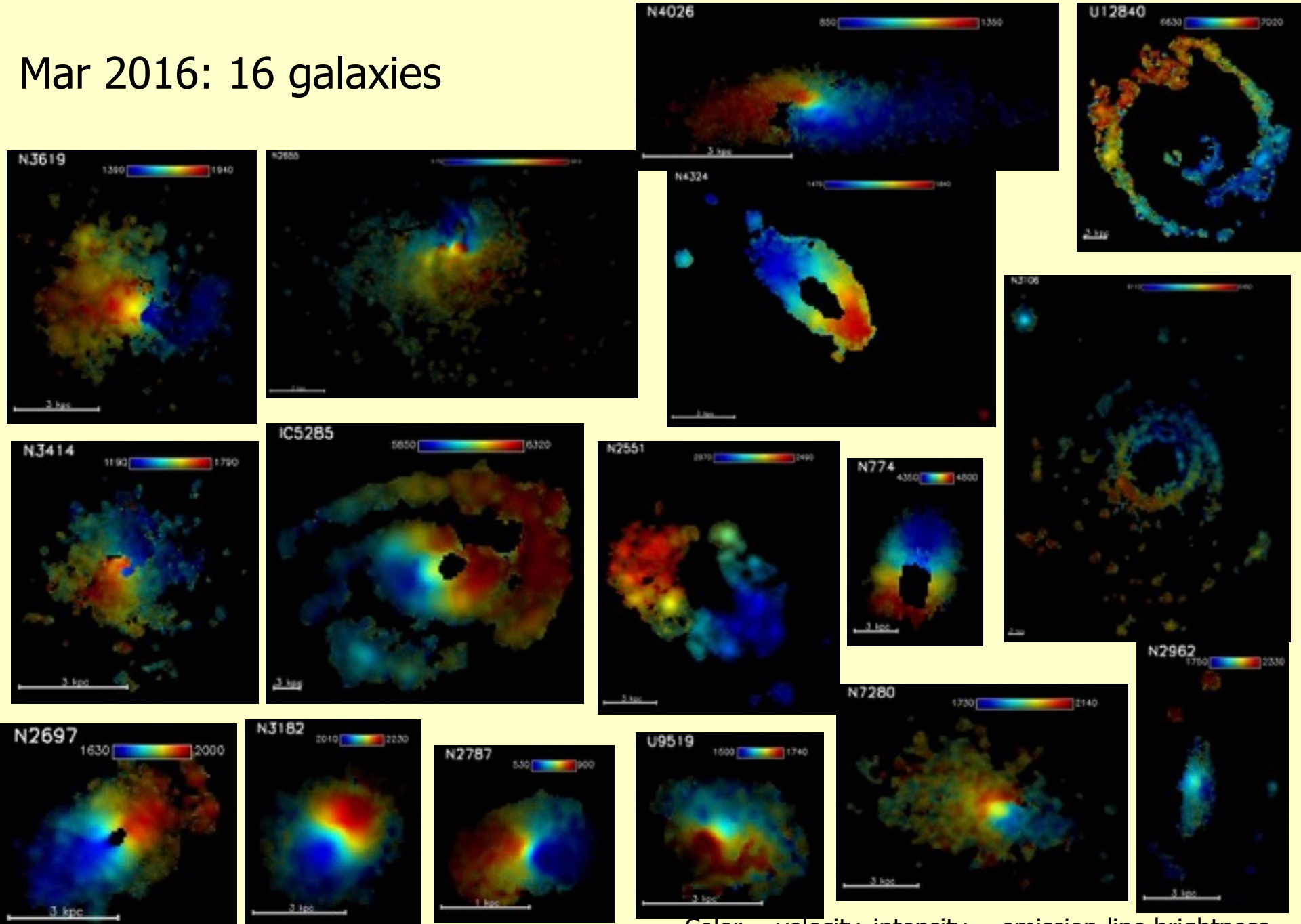




6-m BTA/SCORPIO-2
Texp=7200 sec

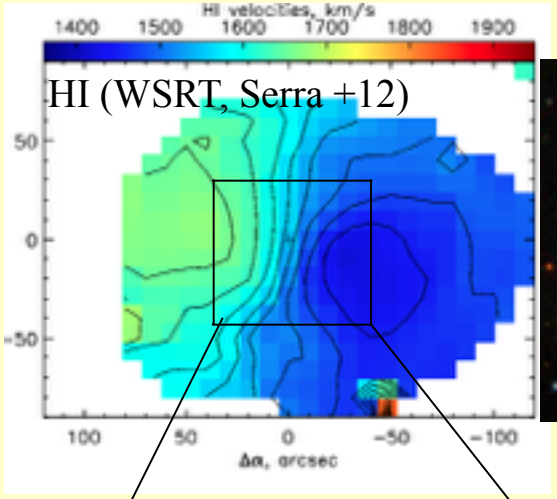


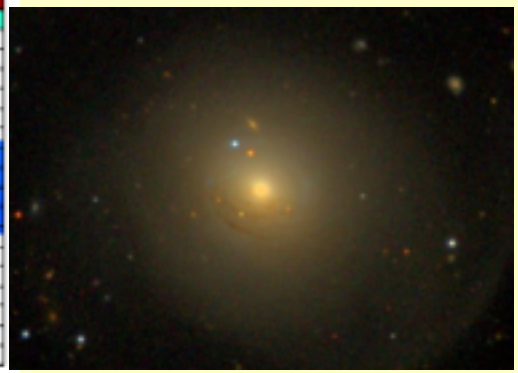
Mar 2016: 16 galaxies

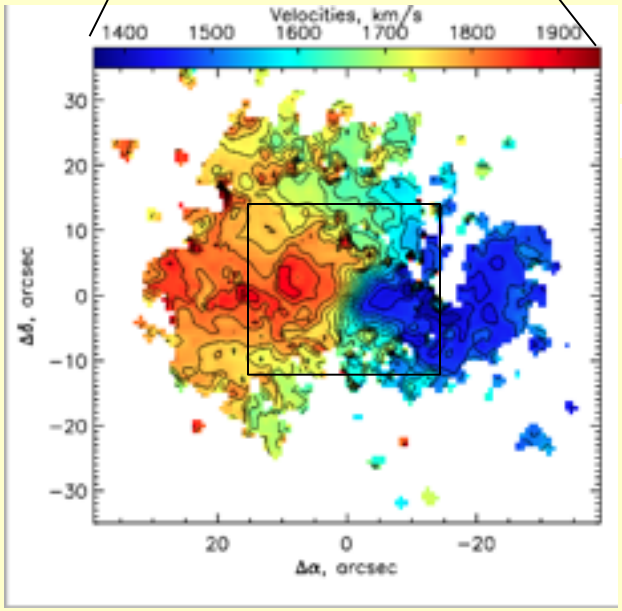


Color = velocity, intensity = emission-line brightness

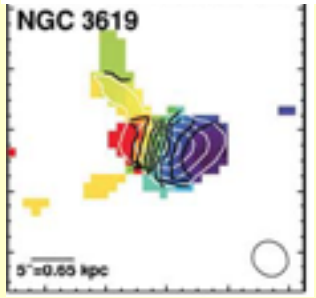
NGC 3619, S0/a: different gas spices on the different scales

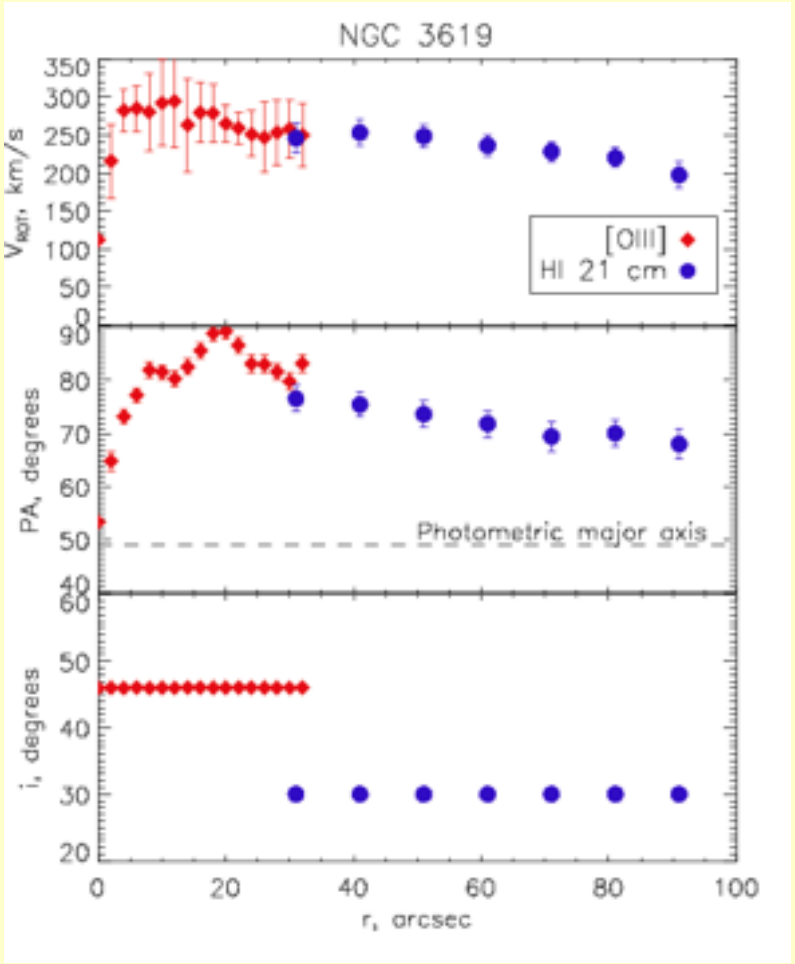






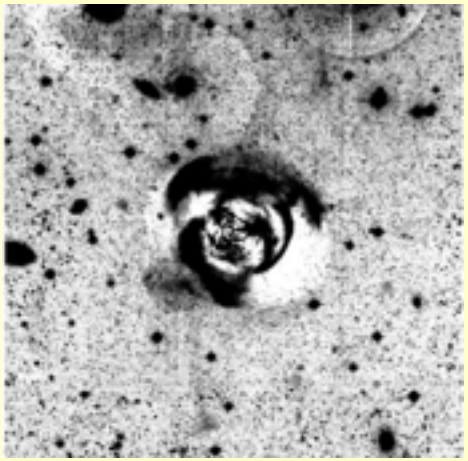
CO(CARMA, Alatalo +13)

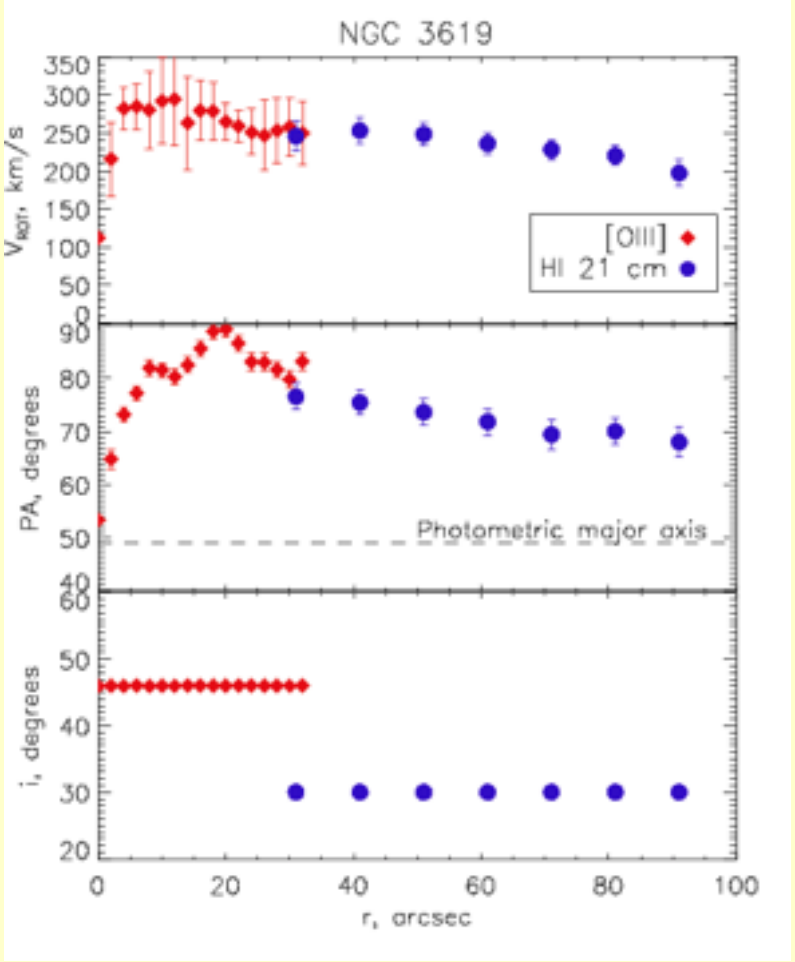




Warped HII+HI disk unsettled to the stellar one

NGC 3619: MEGACAM deep images (Duc et al. 2015)

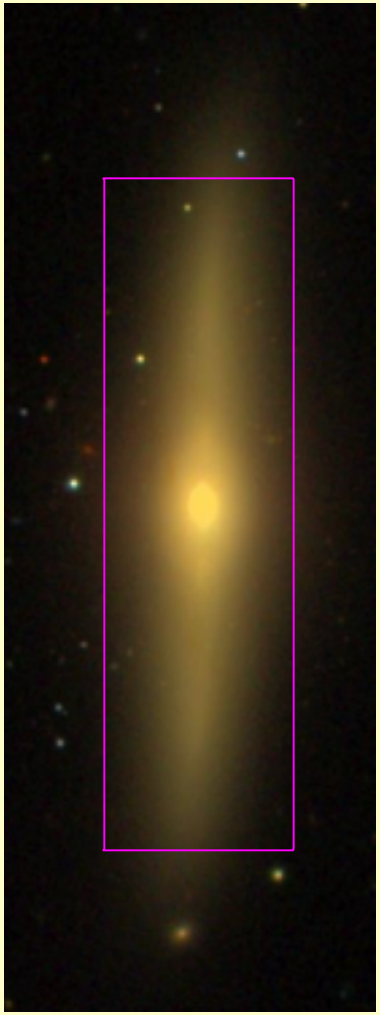


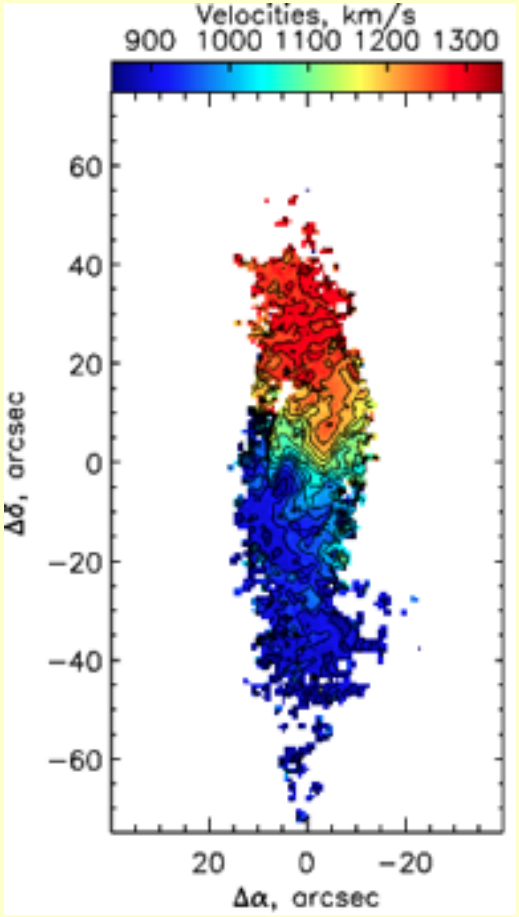


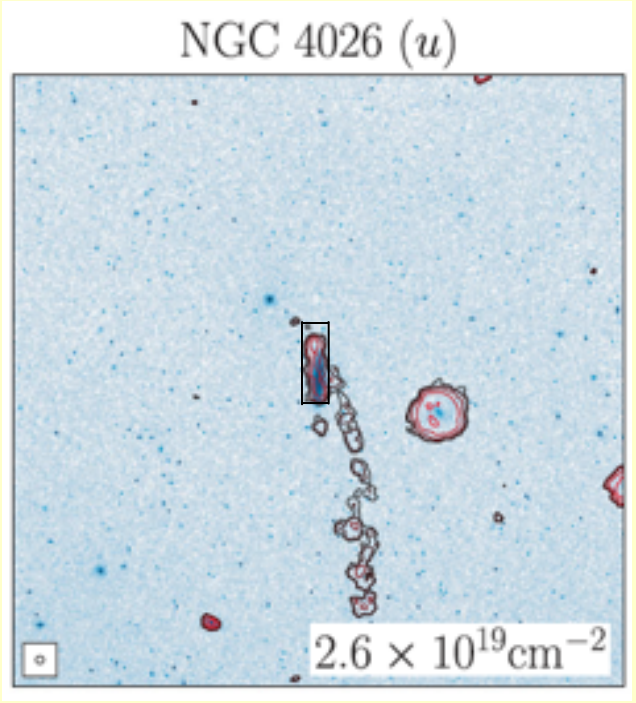
Duc et al 2015:
"presence of radial structures, formed during a previous or late independent accretion event..."

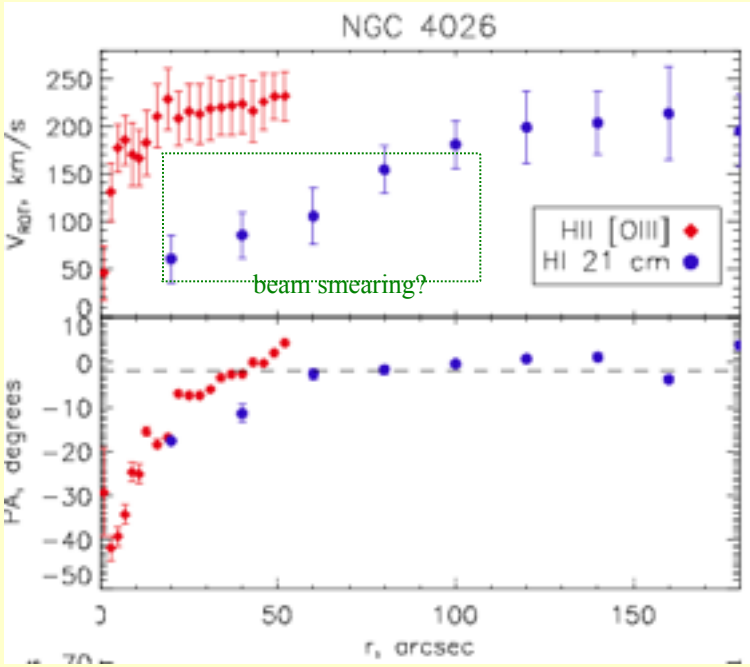
The gas comes from a reservoir unrelated with previous minor merging event in this rich group of galaxies

NGC 4026, S0: inner warp





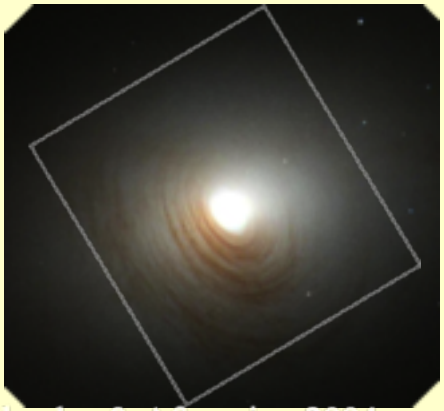


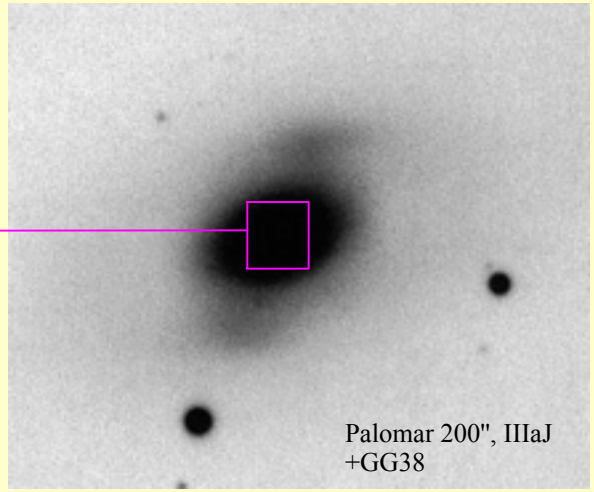


Warped inner disc: result of secondary accretion event!

Ursa Major group/cluster member.

NGC 2787: inner polar/inclined disc in quite isolated galaxy

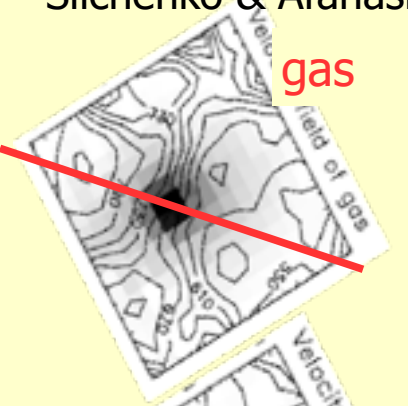


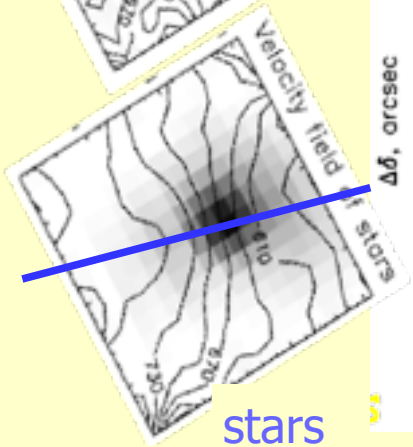


Silchenko & Afanasiev 04

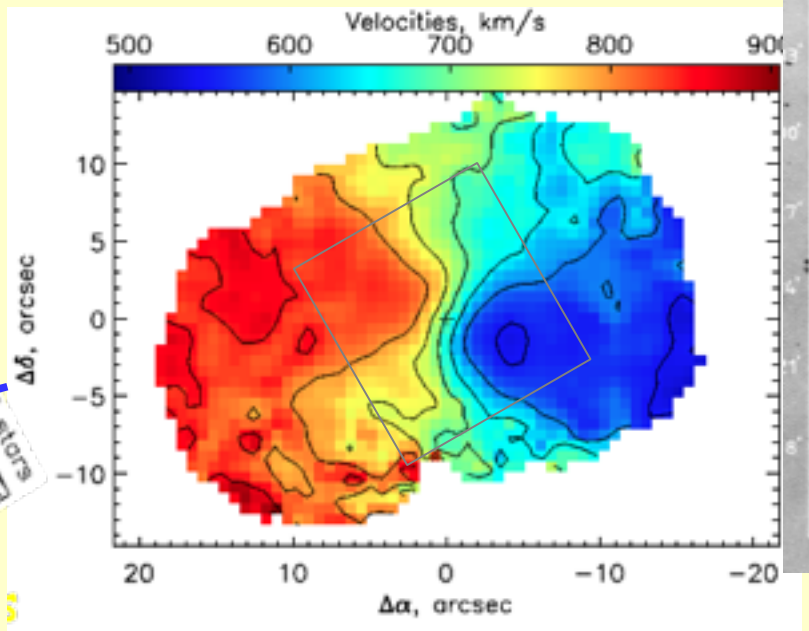
Inner gaseous disc with dust lanes is inclined to the main stellar disc:
Δi=32º or 76º (Moiseev 2012)
But nearly orthogonal to the bar!

gas

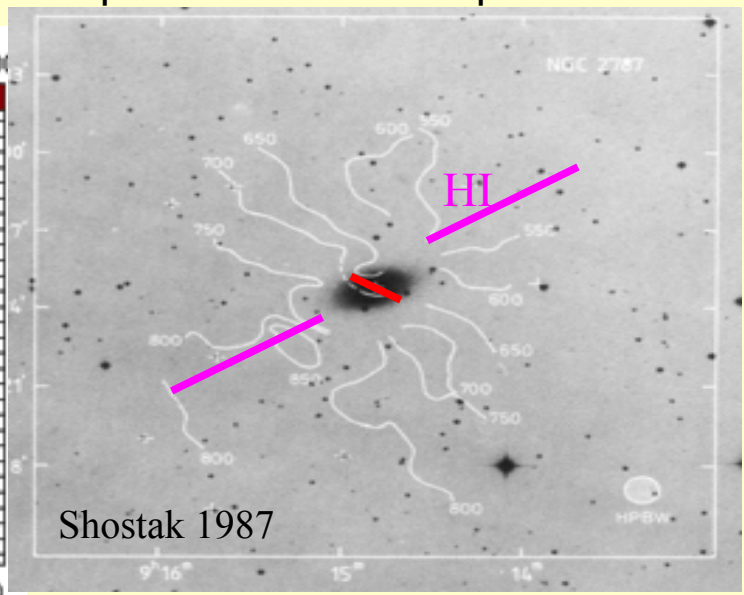




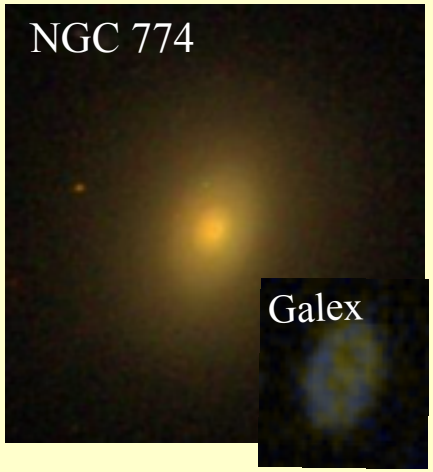
stars

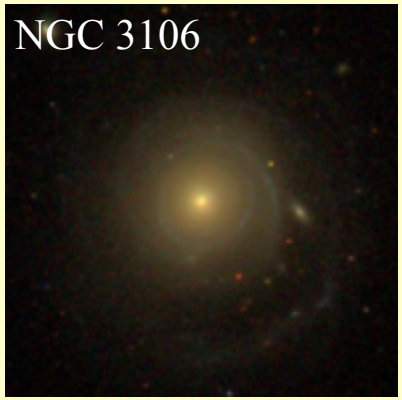


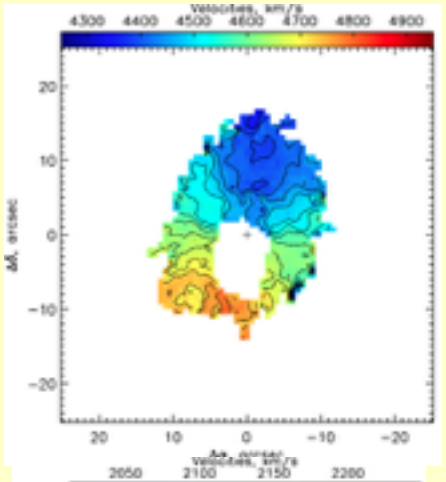
The outer HI is quite regular and decoupled from the inner polar disc

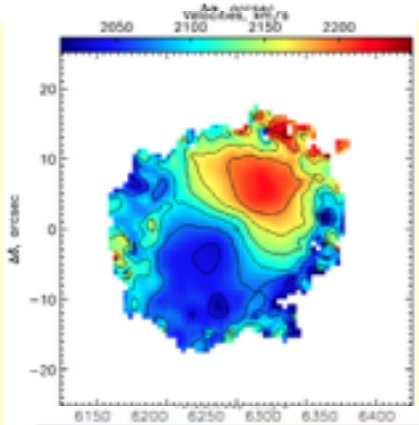


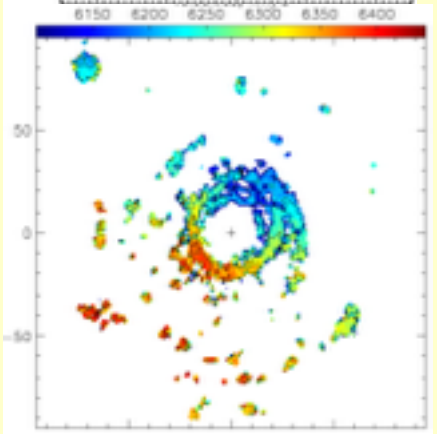
UV/Ha starforming rings: NGC 774, NGC 3106, NGC 3182











A good agreement between gas rotation PA, photometric PA and stellar rotation

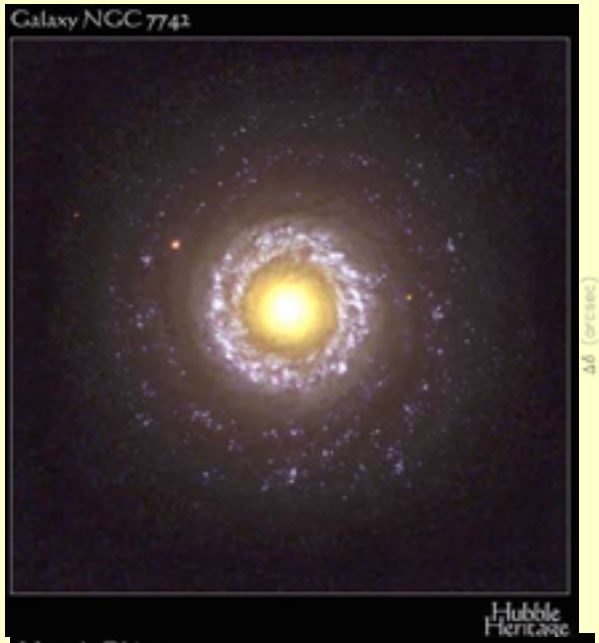
→ settled gaseous rings

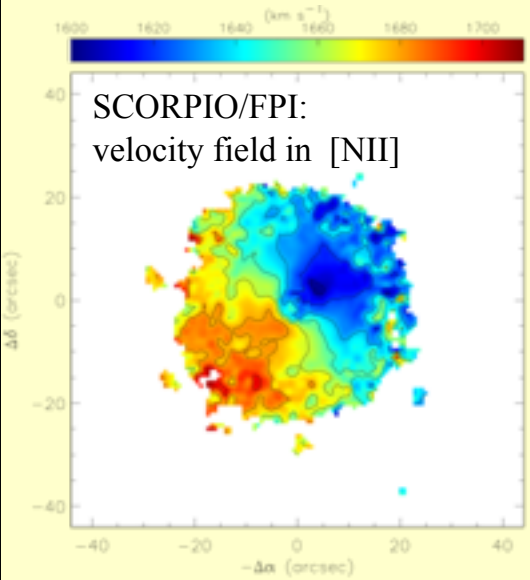
← F. Combes talk!

How did they form?

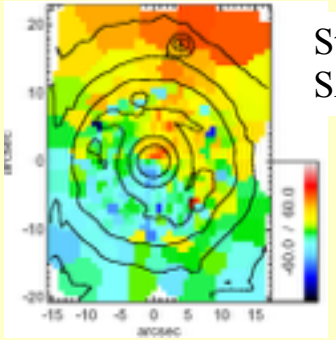
Formation scenario:	Counter argument:
ILR/UHR resonances	bar is absent while SF rings are too young.
Colliding rings	pure circular gas rotation, without expansion motions
Polar rings	gas is settled to the disk

Accretion/merger origin of rings in unbarred galaxies

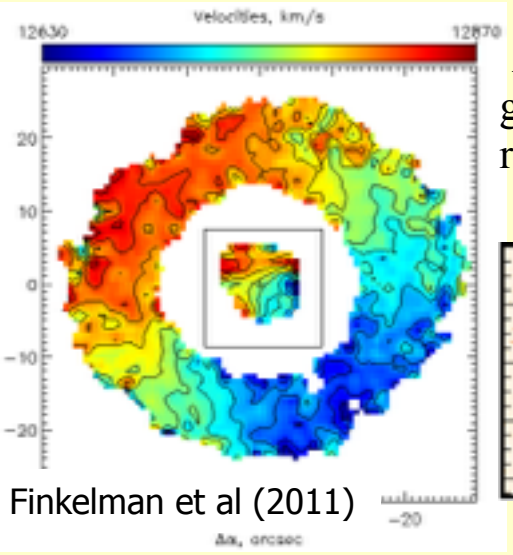




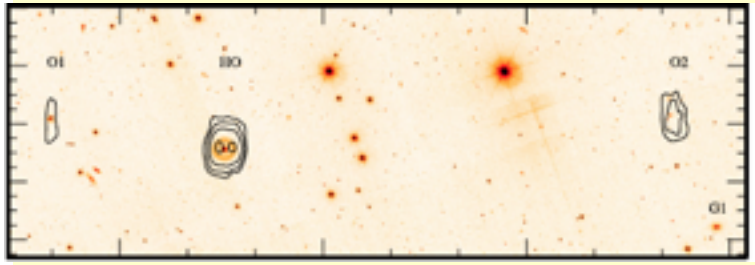
Sil'chenko & Moiseev 06
Mazzuka + 06:
the ring might be produced as resonance features by tidally induced oval distortions of the global stellar disks.



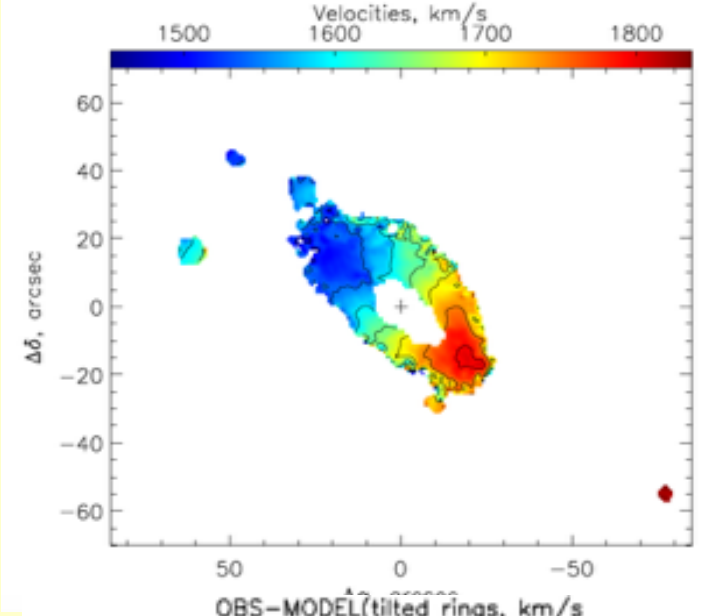
Stellar kinematics:
SAURON (Fathi 04)

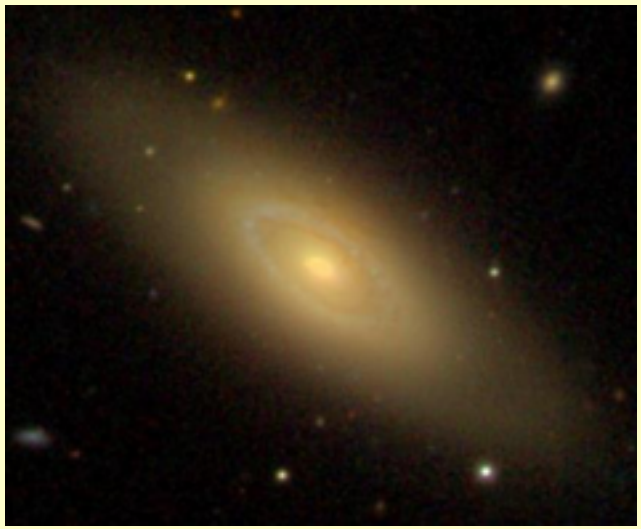


A prolonged 'cold' accretion of primordial gas from the intergalactic medium formed the ring (cf. HI data in Brosch et al, 2013)

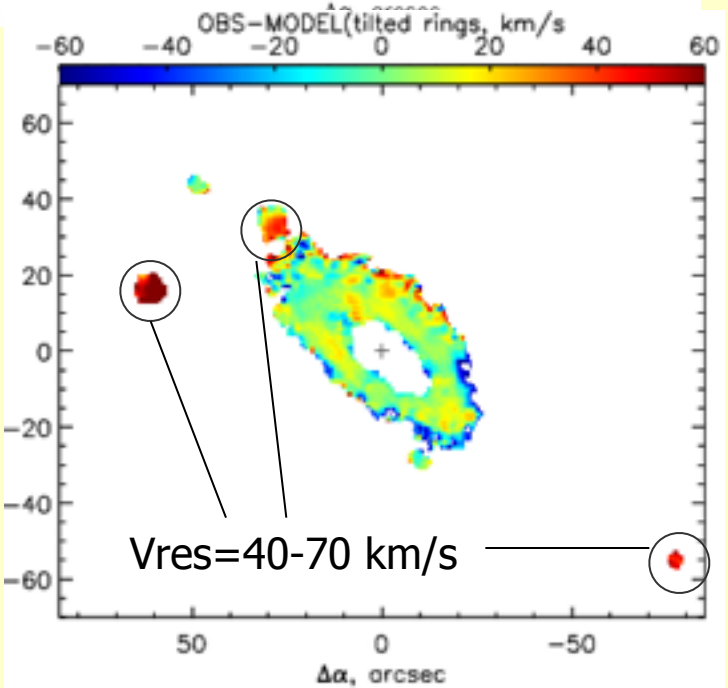


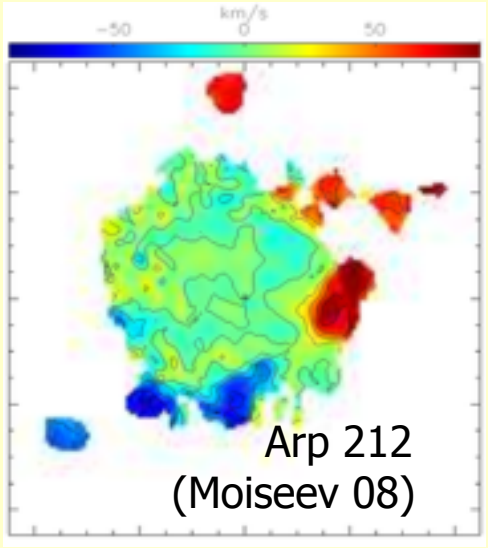
NGC 4324: imprints of accretion origin of SF ring!

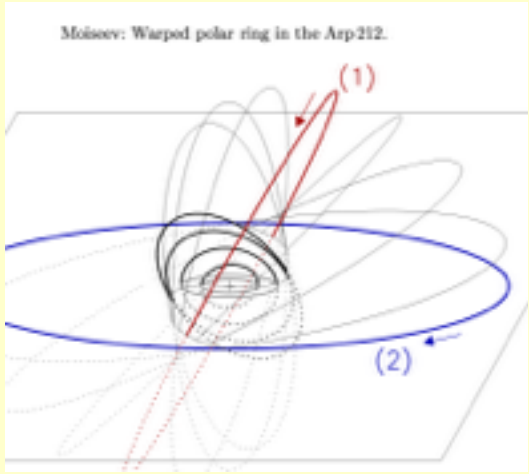




SF ring ~5 kpc in size + external off-plane knots seems like a warped structure in Arp 212:







Warped/inclined/polar/counter-rotating gas : 9/16

N 2551 - counter-rotation to stars
N 2655 - polar/inclined
N 2787 - polar/inclined
N 2962 - inner polar
N 4026 - polar to warped
N 3414 - polar to warped
N 3619 - warped
N 7280 - Inner polar, outer counterrotation
U 9519 - two components, warp/polar

Accretion rings (?) in non-barred galaxies: 4/16

N 774, N 3106, N 3182, N 4324

An external origin: 81±15%

Coplanar gas in all radii: 3/16

IC5285, UGC 12840, N 2697

SUMMARY

We have presented the first results of the survey of large-scale kinematics of the ionized gas in gas-rich S0 galaxies using the scanning FPI at the SAO RAS 6-m telescope:

- Our data together with available archival information on the central regions and on the external HI gas provides evidences for gas accretion in the most of the observed lenticular galaxies.
- The degree of gas/stars misalignment can significantly vary with radii on a scale of a few kpc (inclined, strong warped disks, etc.)
- Gas accretion imprints are presented in different environments: from rich groups to quite isolated galaxies.
- An accretion origin of coplanar star forming rings in non-barred galaxies: numerical simulations are welcome!

Thank you for your attention!

MULTI-SPIN GALAXIES 2016

http://www.sao.ru/hq/multispin16

NIZHNY ARKHYZ (RUSSIA), 26-30 SEPTEMBER 2016

Invited speakers:

- Belokurov Vasily
- Bettoni Daniela
- Bizyaev Dmitry
- Bouche Nicolas
- Brosch Noah
- Duc Pierre-Alain
- Jozsa Gyula
- Karachentsev Igor
- Khoperskov Sergey
- Kroupa Pavel
- Mapelli Michela
- Pizzella Alessandro
- Reshetnikov Vladimir
- Steinmetz Matthias
- Walcher Jacob