Extended gaseous discs in early-type galaxies: 3D spectroscopy of the ionized gas.

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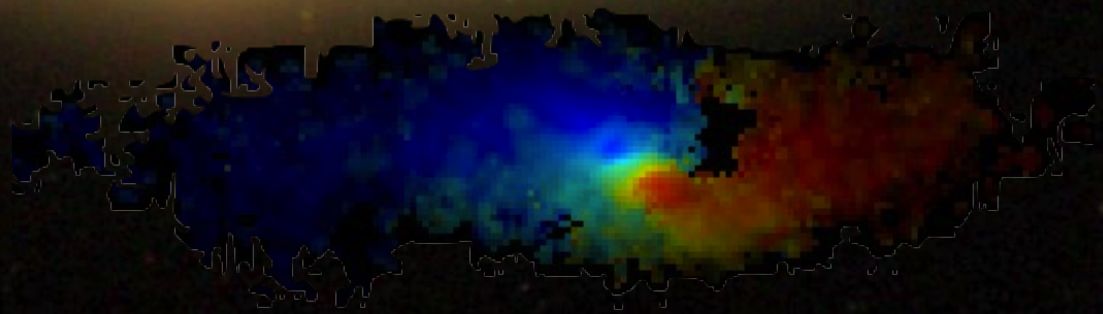


VOLGA

View On the Life of GAlaxies

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 galaxies counter-rotate .."
(Kuijken & Merrifield 1996)

Cold gas, HI environment, multi-spin structures:
- S0s are the central components of polar ring systems:
  Polar Ring Catalogue (Whitmore, 1990, 1991)
  SDSS-based Polar Ring Catalogue (Moiseev et al, 2011)
- *CO emission is detected from 78% of the sample* (Welch & Sage, 2003)
- molecular gas discs in ETG (Davies et al., 2013)
- 36% of fast-rotating ETG in ATLAS 3D *sample have their ionized gas*
- *kinematically misaligned with respect to the stars* (Davies et al., 2011)

Large-scale ionized gas discs also exist in S0 !

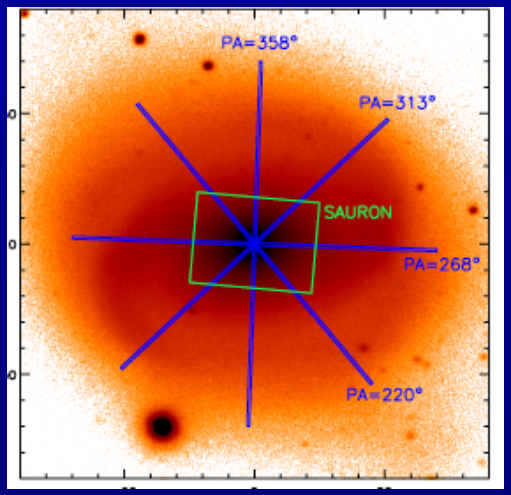
Gas contents in S0 galaxies: large-scale discs

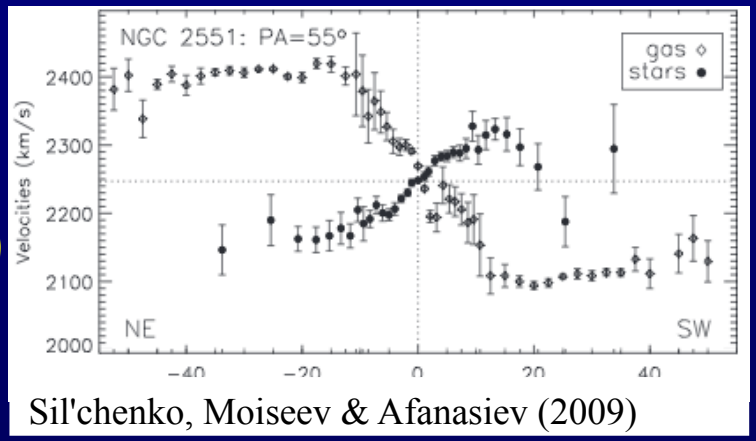
An inclined gaseous structure in NGC 7743
(Katkov, Moiseev & Silchenko 2011)
r(disc)~6 kpc, Δi=34° or 77°

Counter-rotating discs:
(see review by Corsini 2014):
NGC 4546 (Bettoni + 91)
NGC 2551, NGC 5631 (Sil'chenko + 09)
NGC 4550 (Coccato+13, Johnston +13)

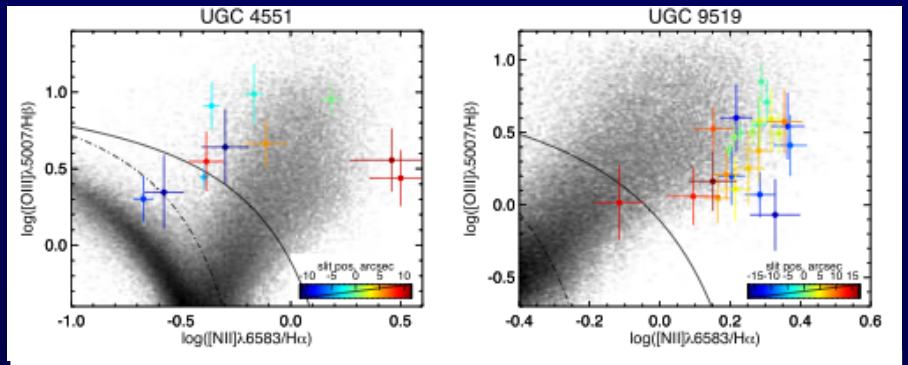
New statistic (6-m and SALT 10-m telescopes)
extended ionized-gas discs are found in
58-72% of the isolated S0 (Katkov + 14, 15)

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





Sil'chenko, Moiseev & Afanasiev (2009)



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

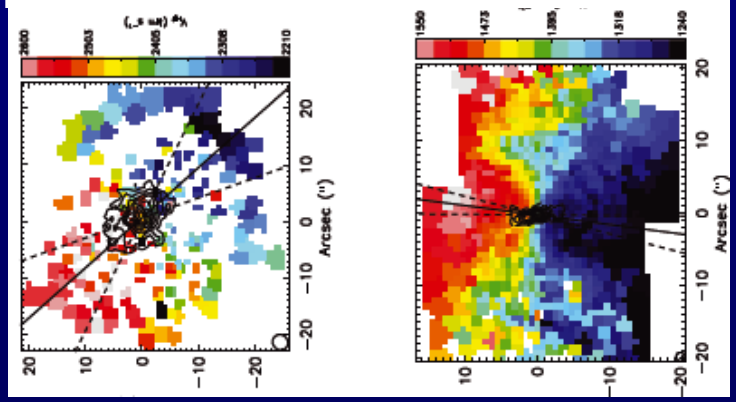
2) Gas/stars kinematic misalignment changes with radius (warped structures, etc)

3) To choose between minor/major merging and accretion scenarios

ATLAS^{3D} volume-limited sample:
260 early-types galaxies,
maps in 33''x41'' field (r<2-3 kpc)

And Paolo Serra yesterday talk!

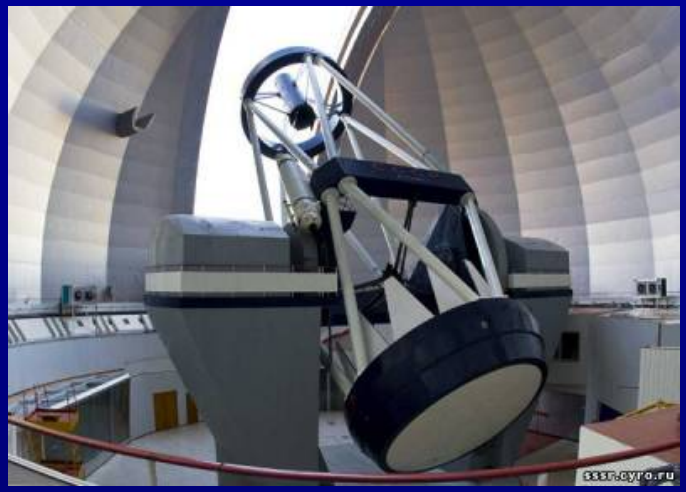
SAURON Hβ velocity fields (Davies +11)



The main sample: 63 galaxies possesses extended [OIII]5007 emission and/or evidences for HI 21 cm structures (Serra et al, 2012) in ATLAS 3D data
+ some well-known objects from the literature
+ our long-slit observations at the SAO RAS 6-m and SALT 10-m telescopes

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

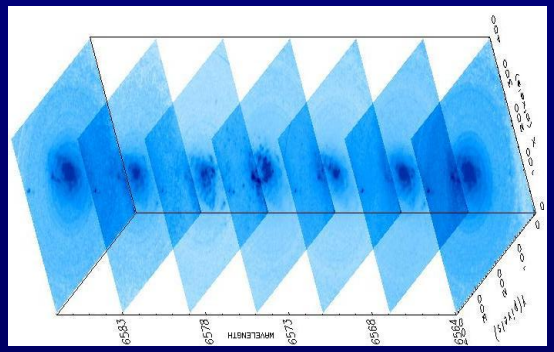
Observations: SAO RAS 6-m telescope



Multi-mode SCORPIO-2 focal reducer with a scanning Fabry-Perot interferometer (Afanasiev & Moiseev,2011)

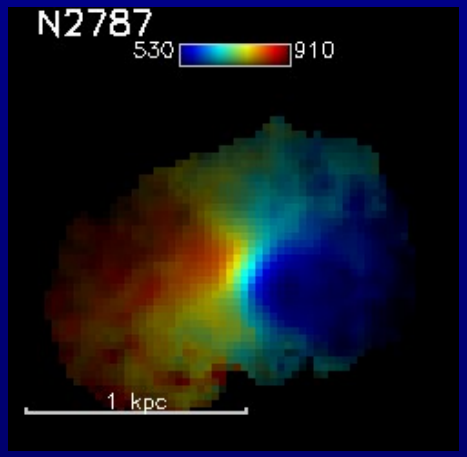
Forbidden emission lines : [NII]6583, [OIII]5007

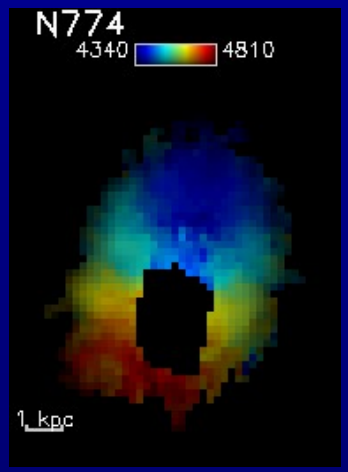
Field of view: 6.1 x 6.1 arcmin
Spatial sampling: 0.70 arcsec/px
Spectral resolution: 1.7-2 A (78-120 km/s)

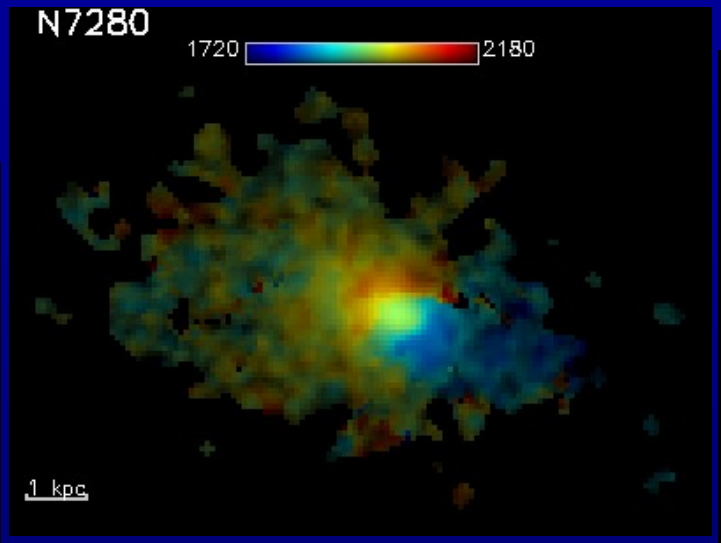


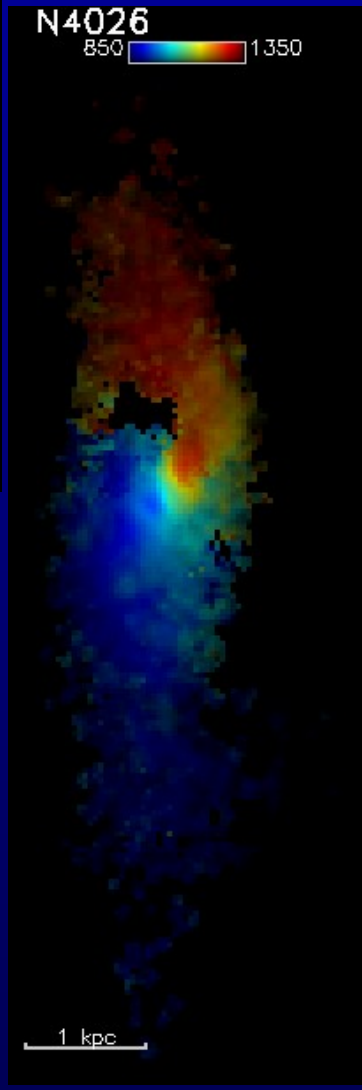
SCORPIO-2 long-slit spectroscopy: stellar kinematics, age/metallicity
Available IFU maps: SAURON (ATLAS3D), PMAS/PPAK (CALIFA),

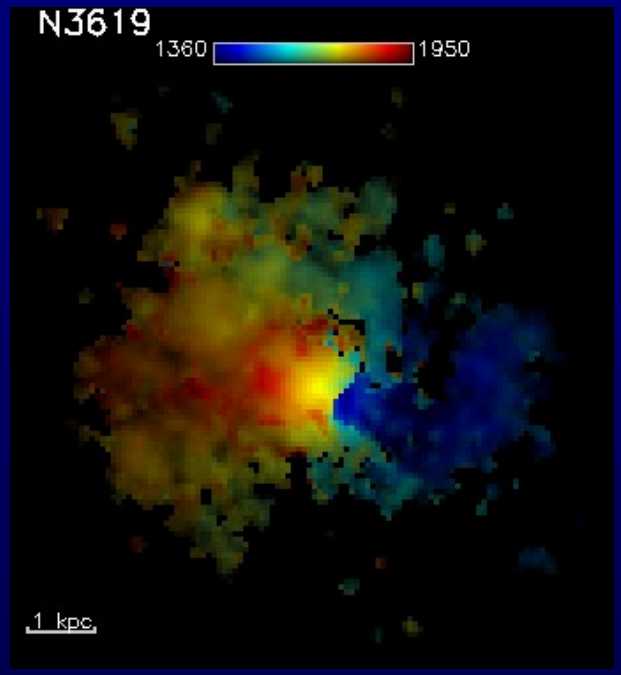
The first results (2014 obs.)

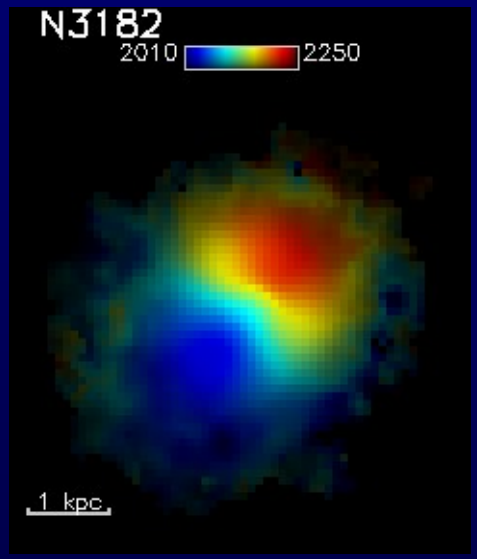






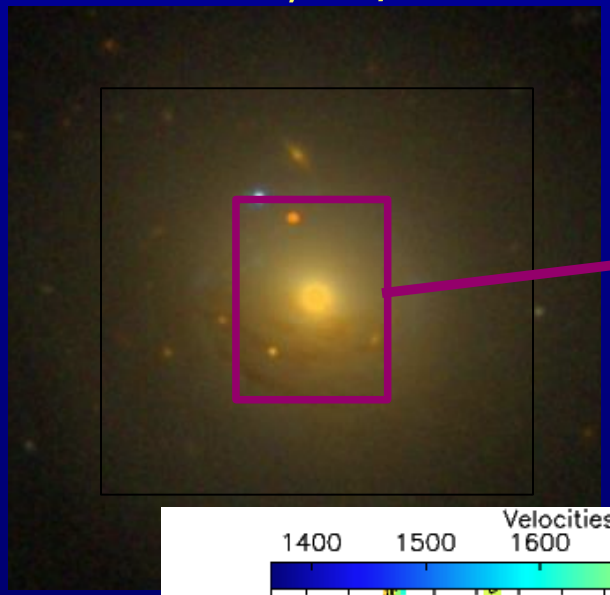




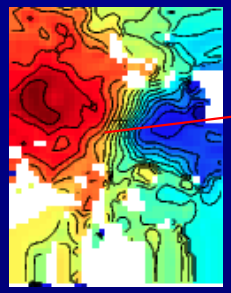


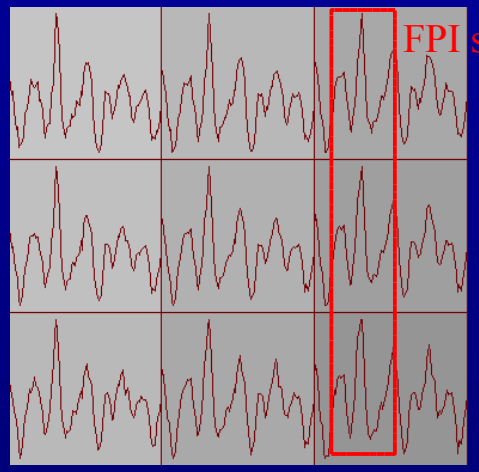
color coding – velocity scale
intensity – emission-lines brightness

NGC 3619, S0/a: FPI + SAURON/ATLAS 3D

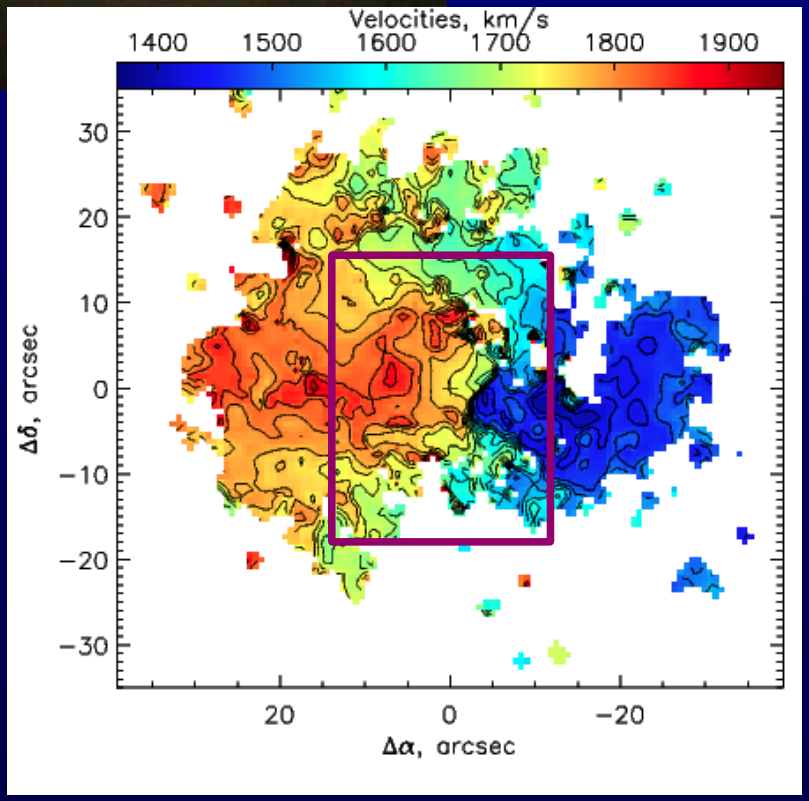


SAURON [OIII]5007

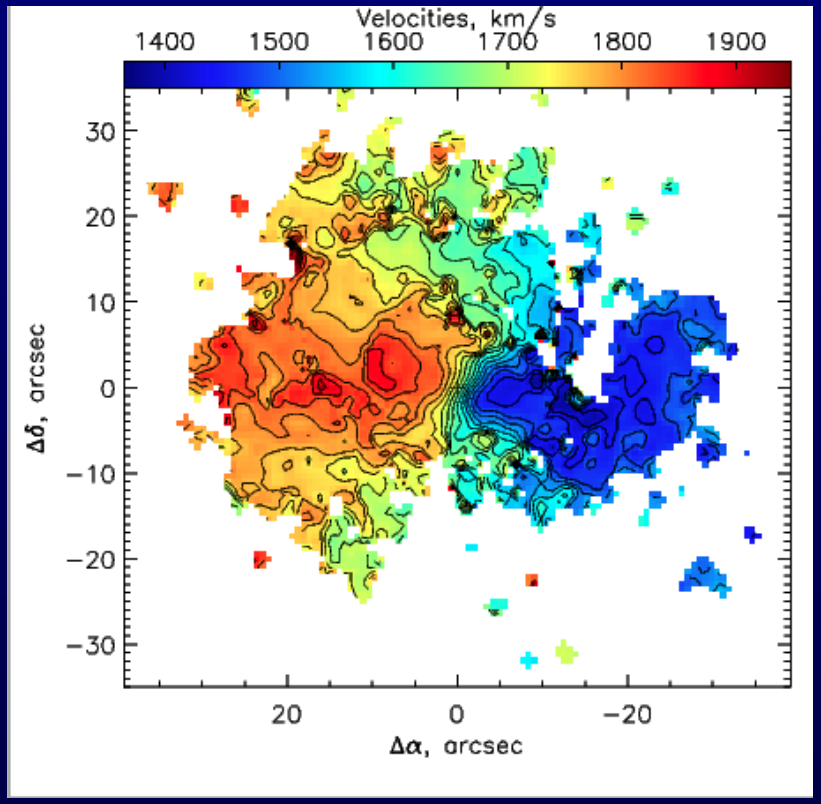




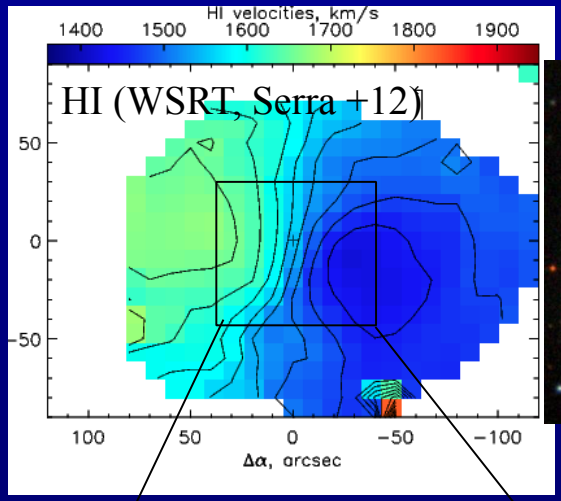
FPI [OIII]5007

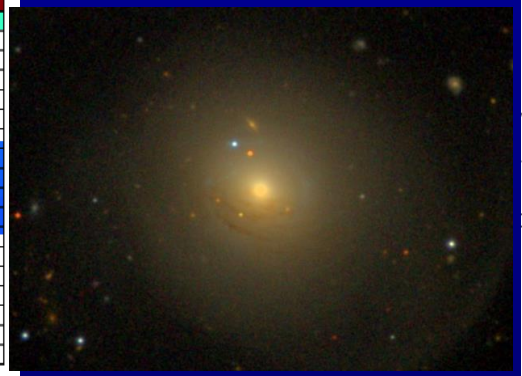


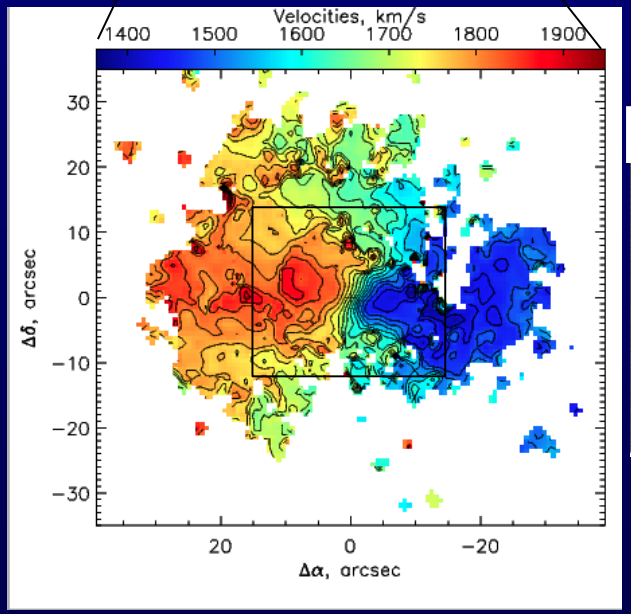
SAURON + FPI combined map:

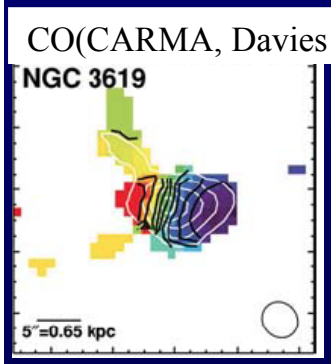


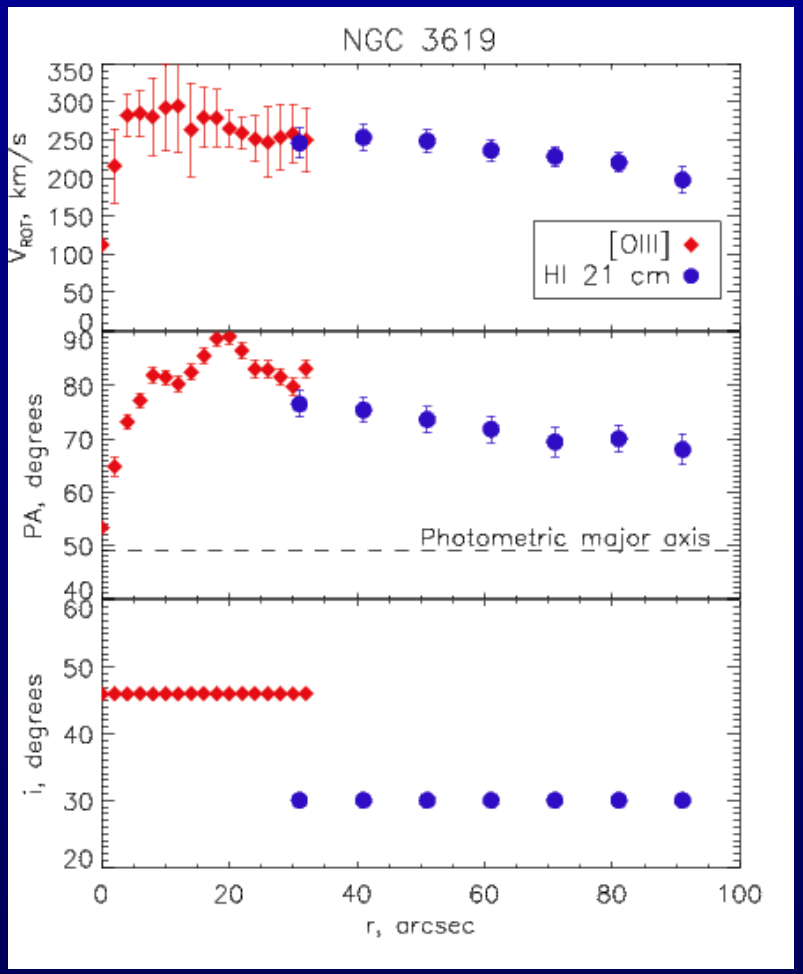
NGC 3619, S0/a: different gas spices on the different scales





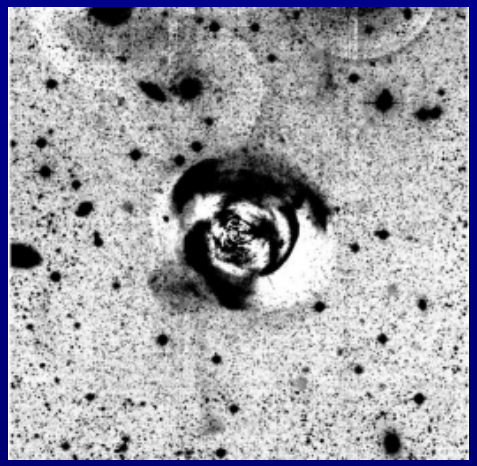


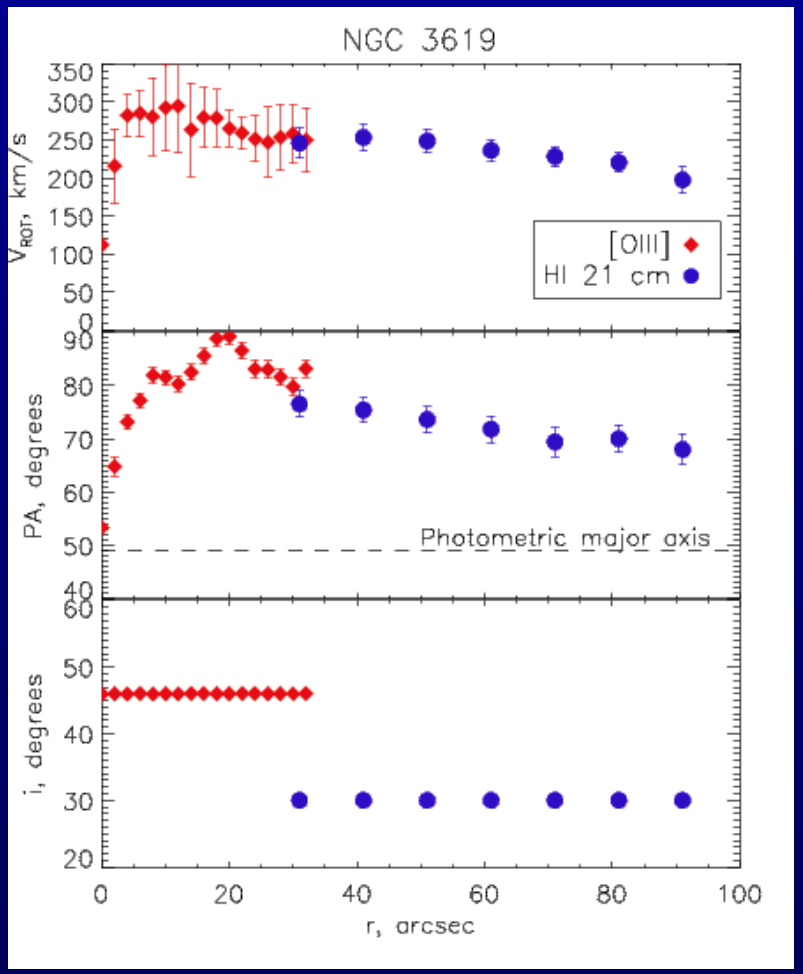




Warped HII+HI disc unsettled to the stellar one!

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

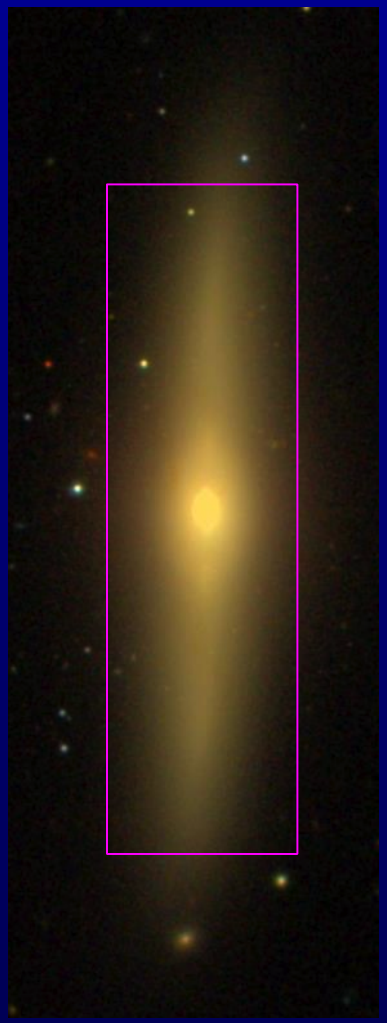


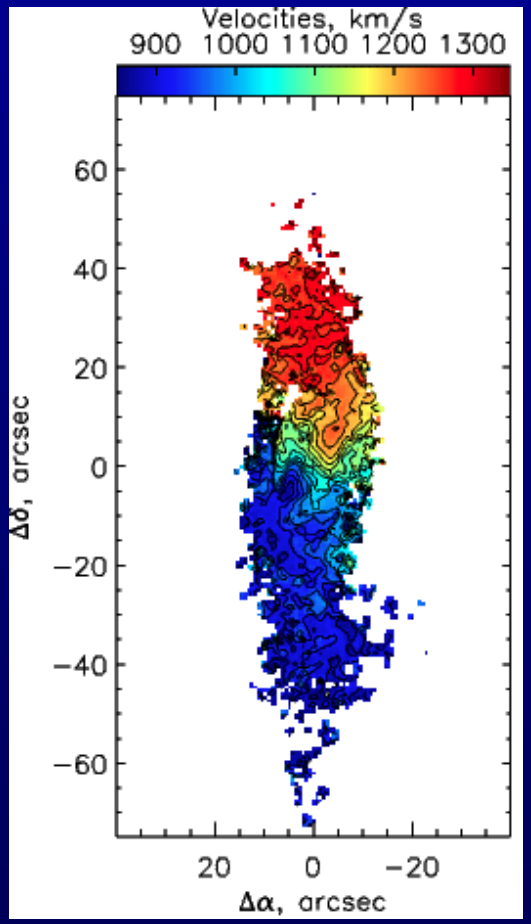


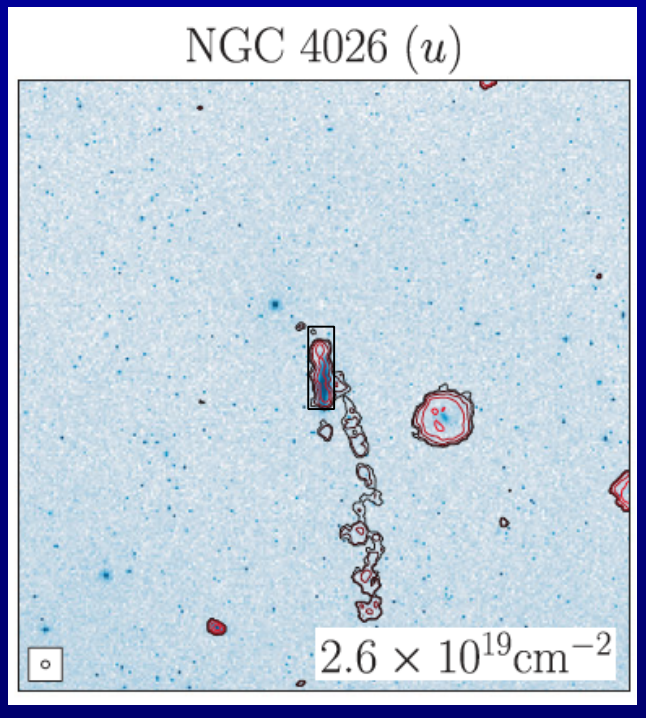
Duc et al:
"presence of radial structures, formed during a previous or late independent accretion event..."

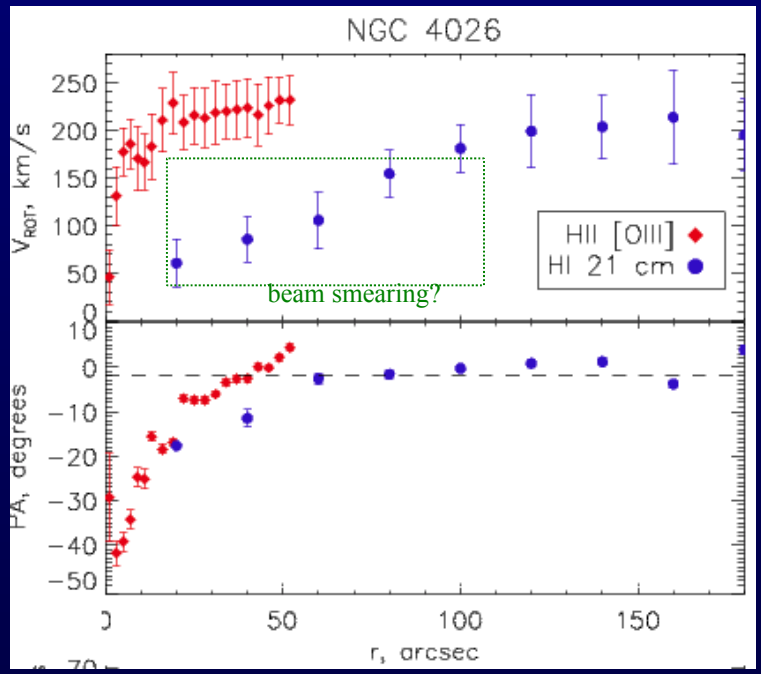
Our conclusion:
The gas comes from a reservoir unrelated with previous minor merging event in this rich group of galaxies

NGC 4026, S0: inner warp





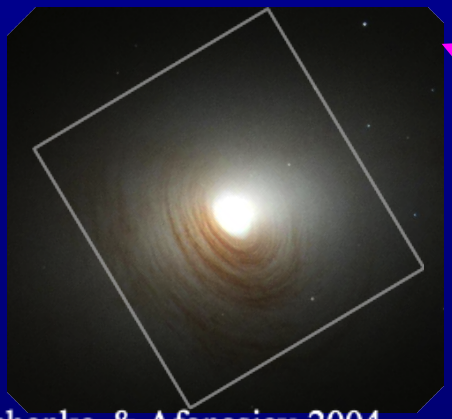




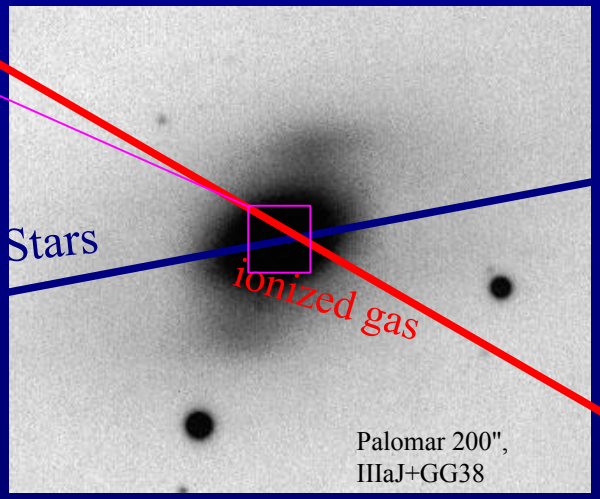
Warped inner disc: result of secondary accretion event!

Ursa Major group/cluster member.

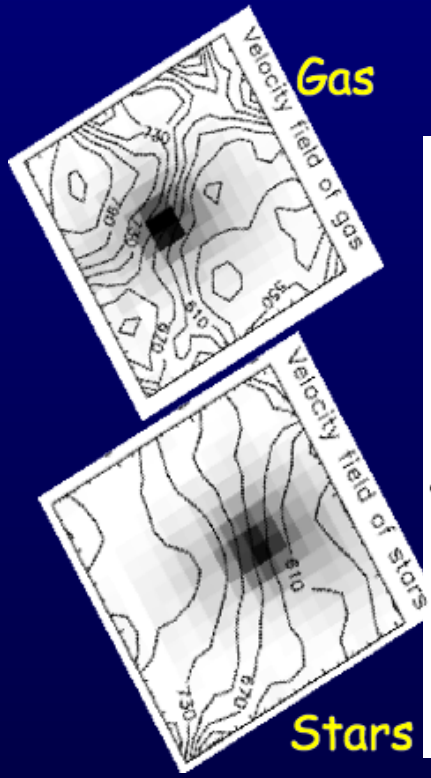
NGC 2787: inner polar/inclined disc in quite isolated galaxy

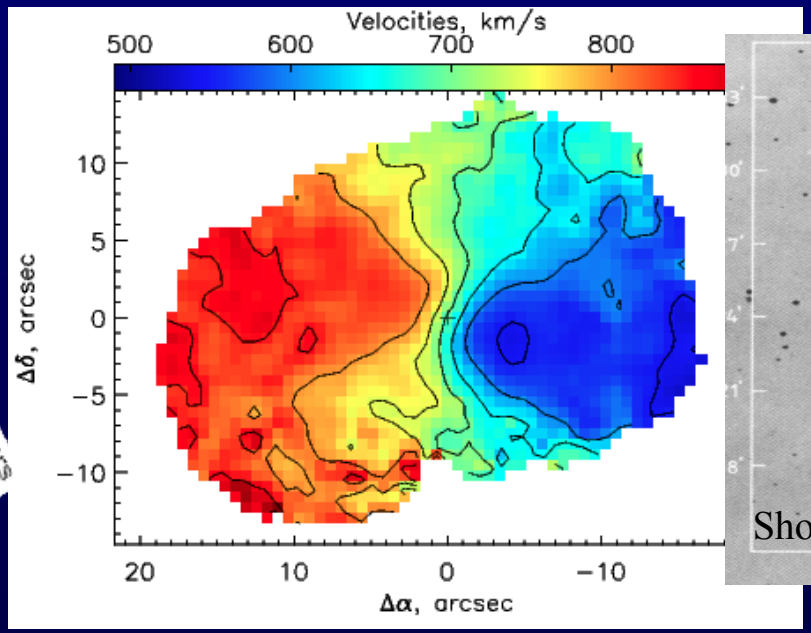


Sil'chenko & Afanasiev 2004

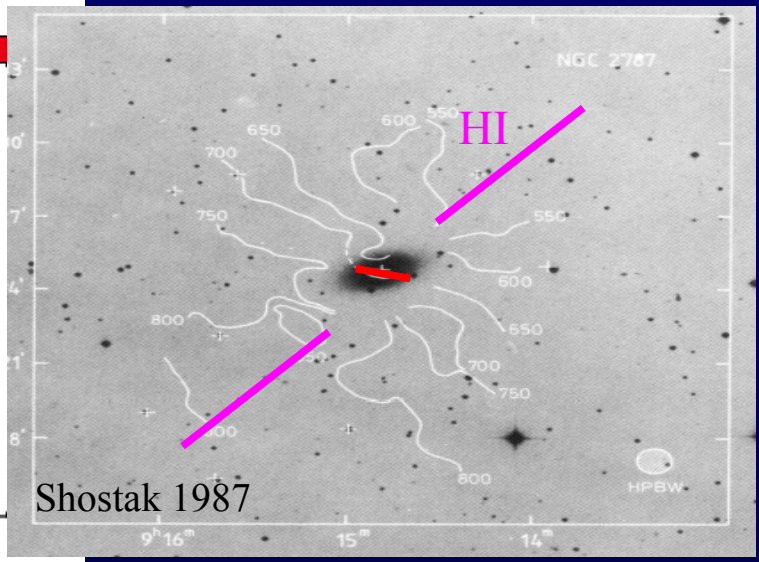


Inner gaseous disc with dust lanes is inclined to the main stellar disc:
Δi=32° or 76° (Moiseev 2012)
But nearly orthogonal to the bar!

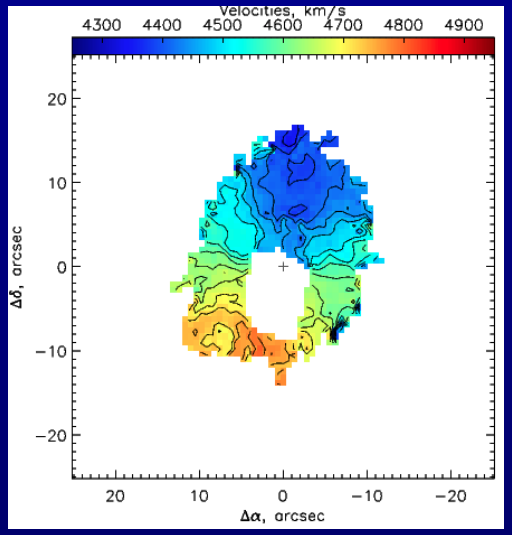


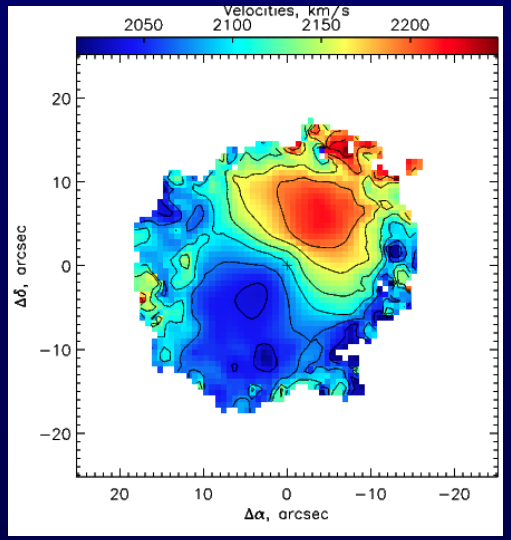


The outer HI is quite regular and decoupled from the inner polar disc



UV rings: NGC 774 and NGC3182



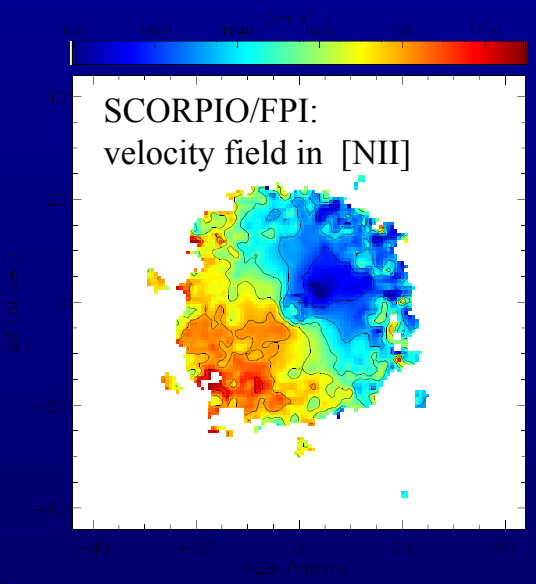


In both galaxies we observe a good agreement between gas rotation PA, photometric PA and stellar rotation → settled gaseous rings

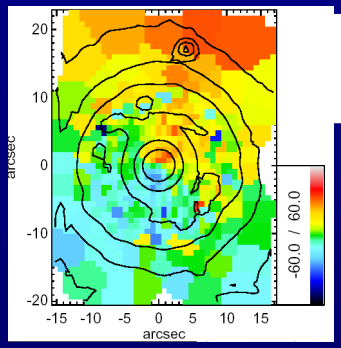
BUT how did they form?

Ring formation scenario	**Arguments against**
ILR/UHR resonances	Bar is absent, while SF rings are too young.
Colliding rings	No expansion velocities and companions
Polar rings	Gas is settled

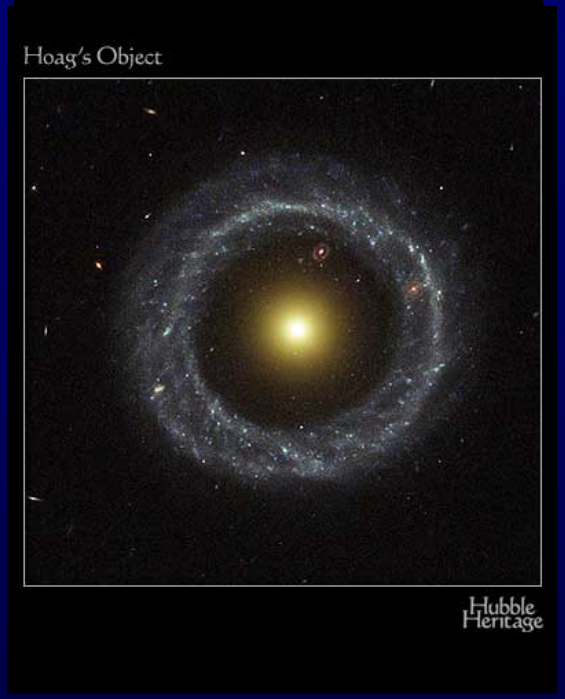
Accretion/merger origin of rings in unbarred galaxies

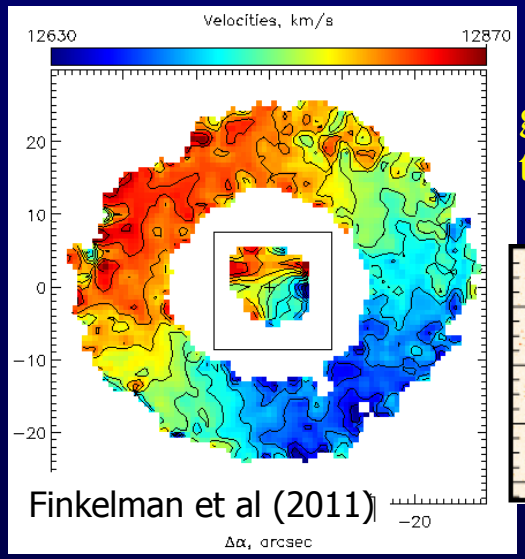


Sil'chenko& Moiseev (2006):
the ring might be produced as resonance features by tidally induced oval distortions of the global stellar disks.



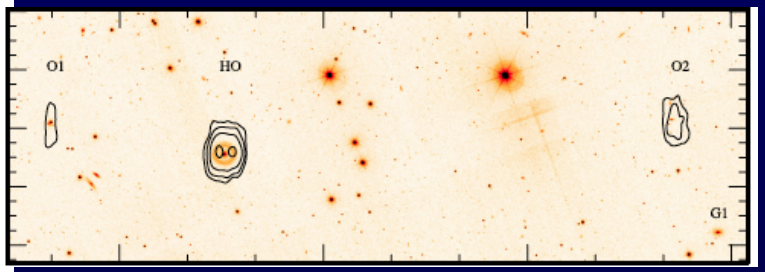
Stellar kinematics:
SAURON (Fathi,2004)





Finkelman et al (2011)

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



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

- Analysis of these data together with available archival information on the central regions and on the external HI gas behaviours provides evidences for gas accretion from outside in the most of the observed objects.

- The degree of gas/stars misalignment can significantly vary with radii on a scale of a few kpc

- Gas accretion footprints are present in different environments: from rich groups (NGC 4026, NGC 3619) to quite isolated galaxies (NGC 2787)

Thanks for your attention!