Special Session Sp3 “3D view on interacting and post-interacting galaxies from clusters to voids”

Counter-rotating stellar population in disc galaxies

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Outline:

- Introduction
- Spectral decomposition
  - Technique basics
  - IC 719
  - NGC 448
- Dynamical evolution of counter-rotating discs

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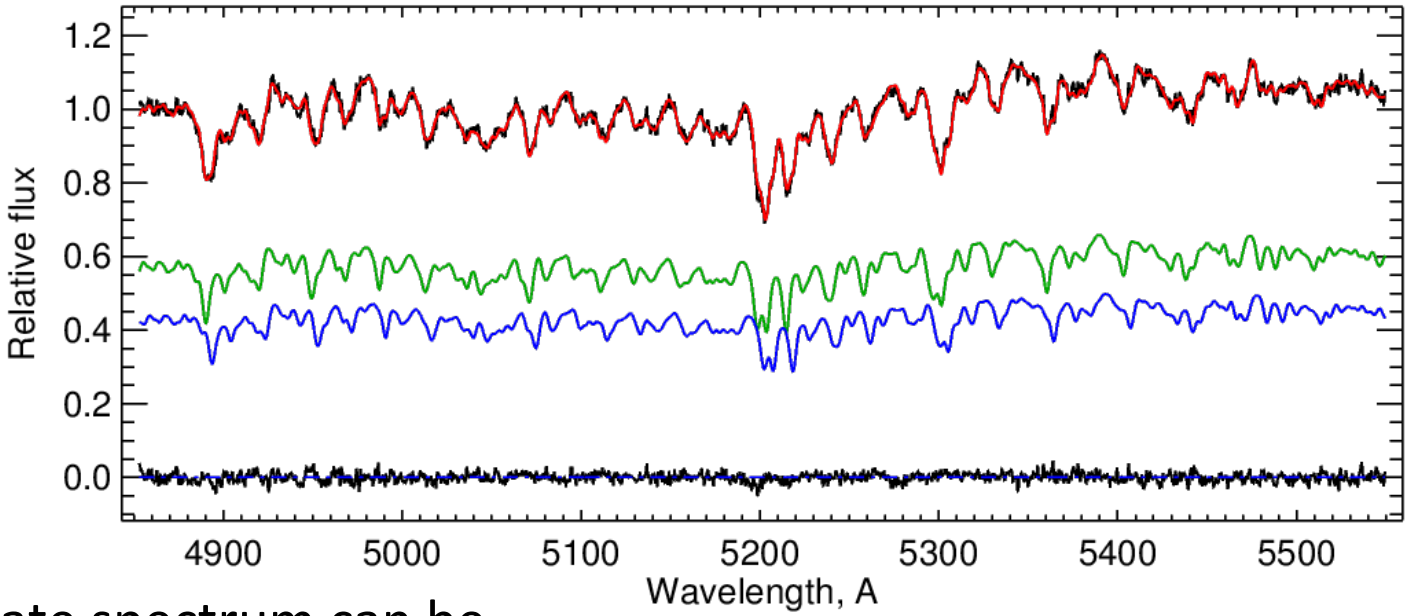
Spectral decomposition: basics

- Based on full spectral fitting techniques
- Main formula: $S_{models} = W_1(L(v_1,\sigma_1) * T_1) + W_2(L(v_2,\sigma_2) * T_2)$



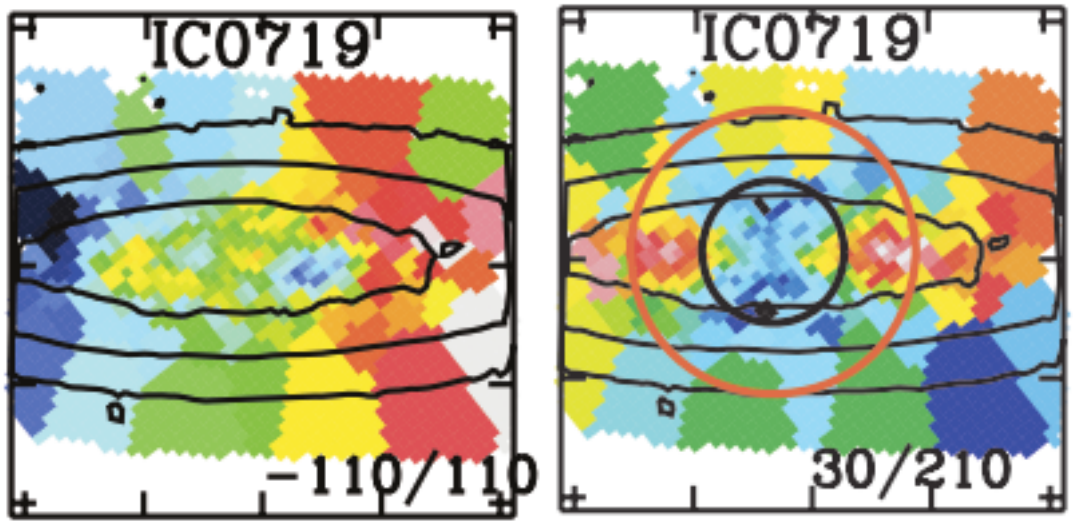
- Template spectrum can be
  - linear combination of stellar spectra (*Coccato et al 2011,2013; Johnston et al. 2013* – heritage from pPXF code Cappellari & Emsellem 2004)
  - SSP model for given SFH (*our work*, heritage from NBursts code Chilingarian et al. 2007)

IC 719

Global Parameters of the Galaxies

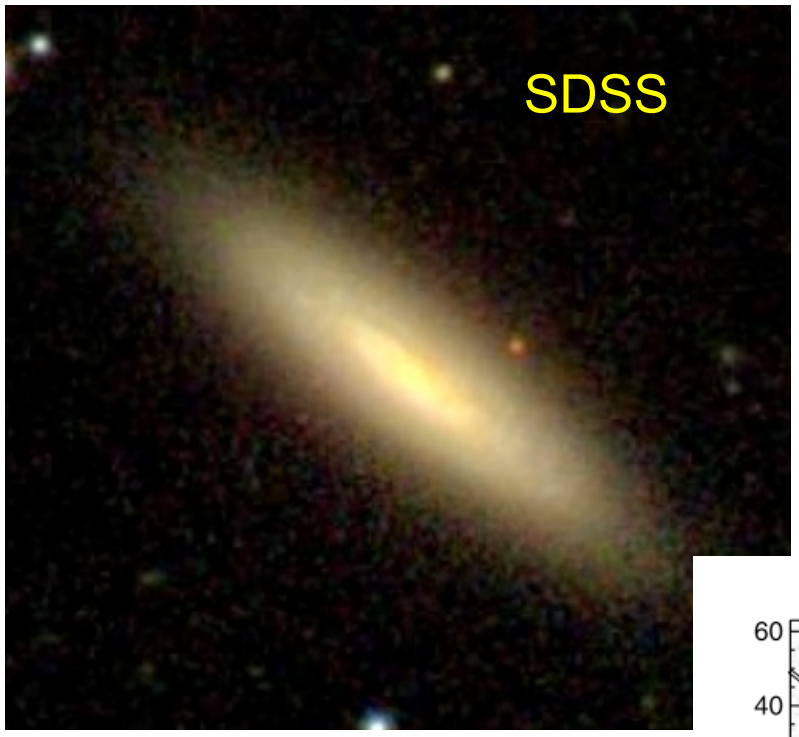
Galaxy	IC 719
Type (NED[a])	S0?
R_{25}, kpc (NED+RC3[b])	5.5
B_T^0 (LEDA[c])	13.66
M_B (LEDA)	−18.6
M_K (ATLAS-3D)	−22.7
V_r (NED)	1860 km s^{-1}
Distance, Mpc (ATLAS-3D)	29.4
Inclination (LEDA)	90°
$PA_{\rm phot}$ (LEDA)	52°
$V_{\rm rot} \sin i$, km s^{-1}, (LEDA, H I)	114.4 ± 6.6
σ_*, km s^{-1}, (LEDA)	121
$M_{\rm H\,I}$, 10^9 $M_\odot$[d]	0.54
$M_{\rm H_2}$, 10^8 $M_\odot$[e]	1.8

- Non-regular rotator
- 2sigma peaks



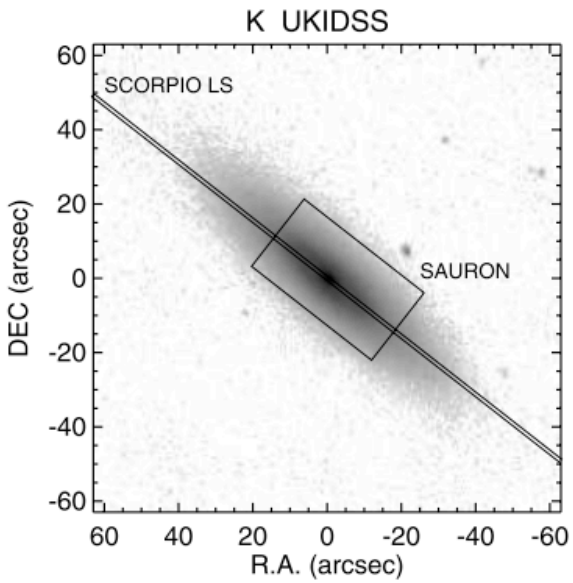
Krajnovic et al. (2011)

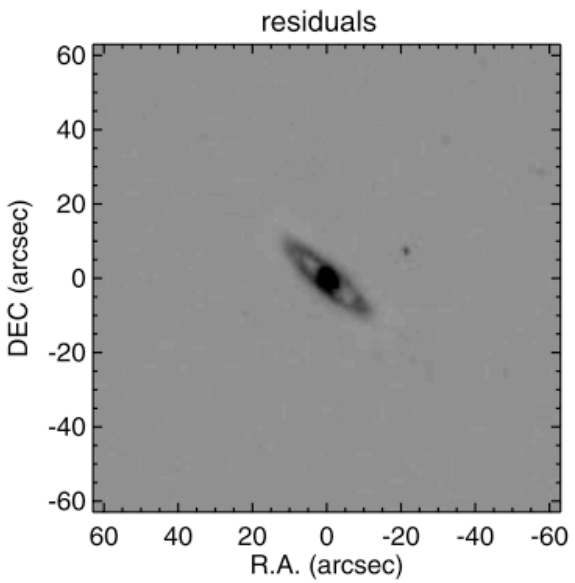
IC 719



- 1” long-slit mode
- 4300-7300 AA
- Sp. Resolution~3.5 A
- σ_{inst}~90 km/s
- T_{exp}~2.5^h

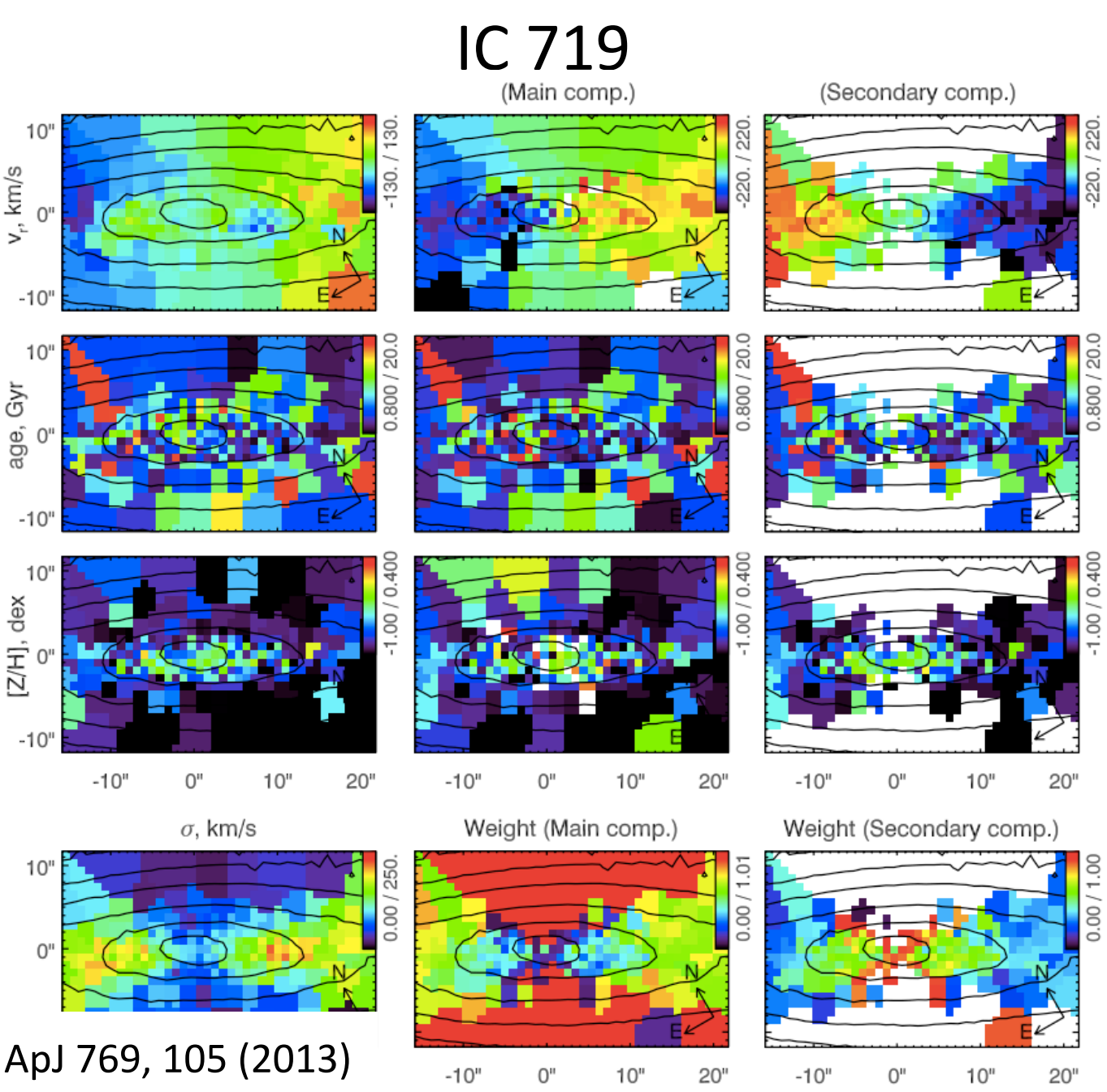
Atlas3D data with SAURON spectrograph





Katkov et al. ApJ 769, 105 (2013)

SAURON
IFU data



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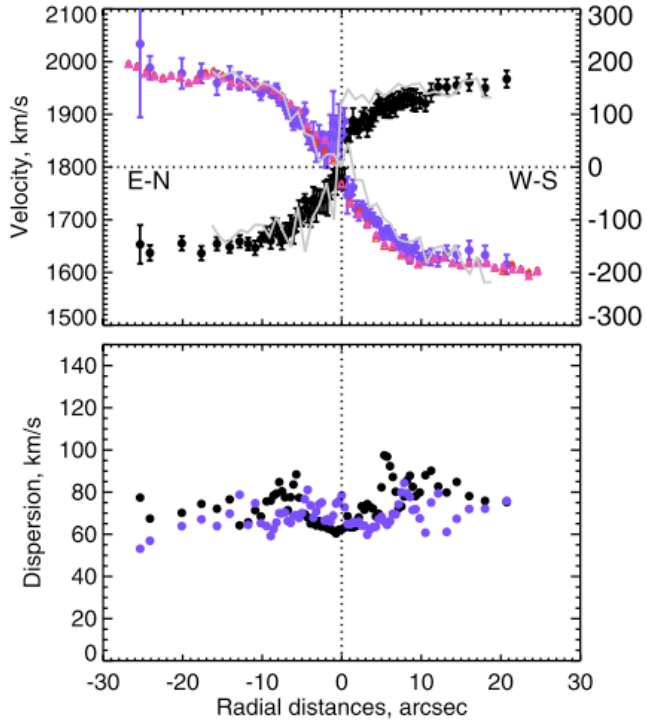
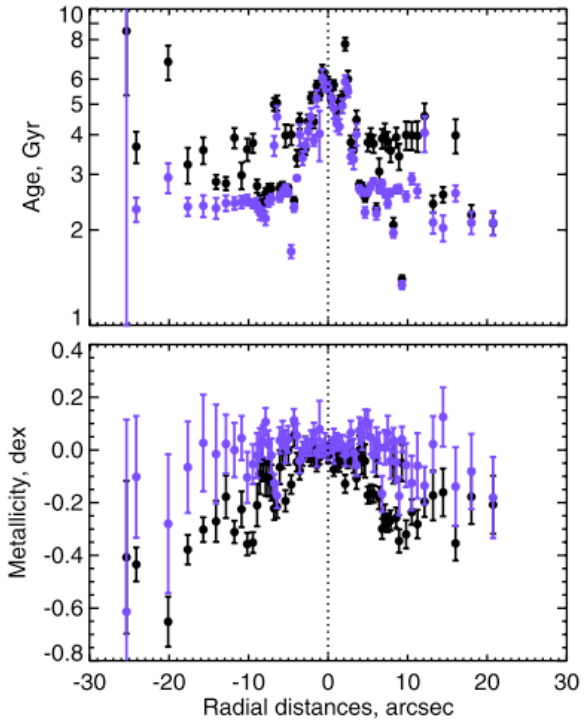
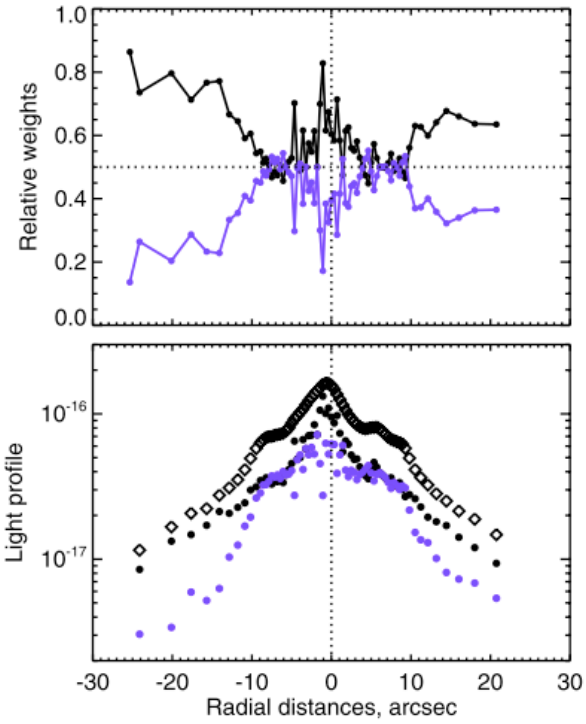




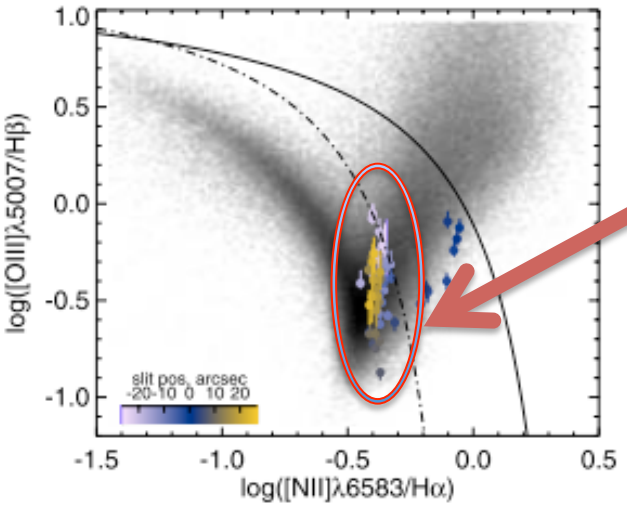


Secondary counter-rotating component is younger and more metall-reach.

SCORPIO long-slit data

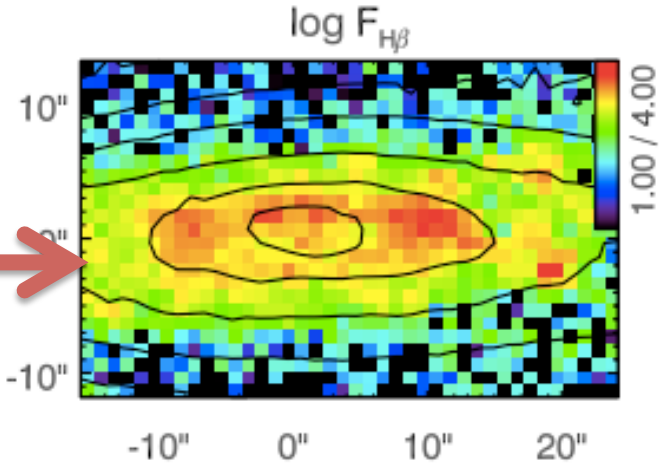
Katkov et al. ApJ 769, 105 (2013)

IC 719

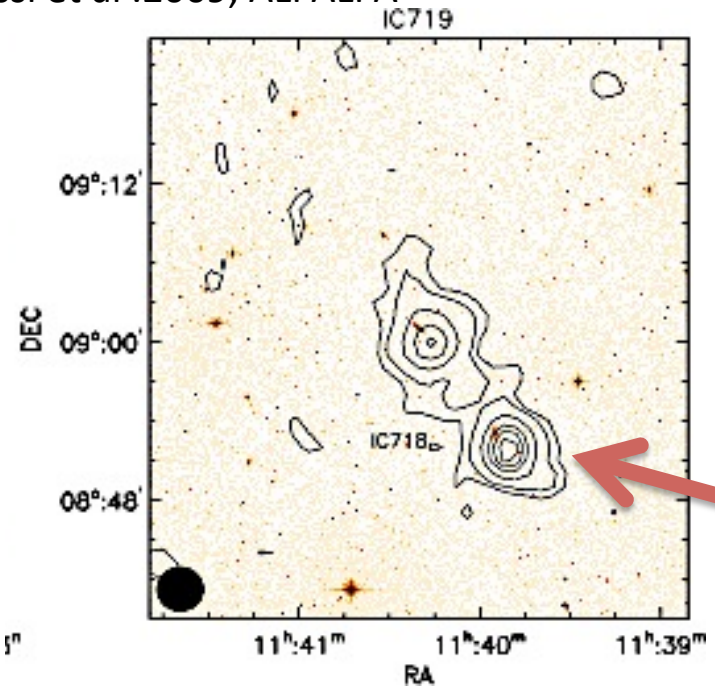


Grossi et al .2009, ALFALFA

Star-forming ring



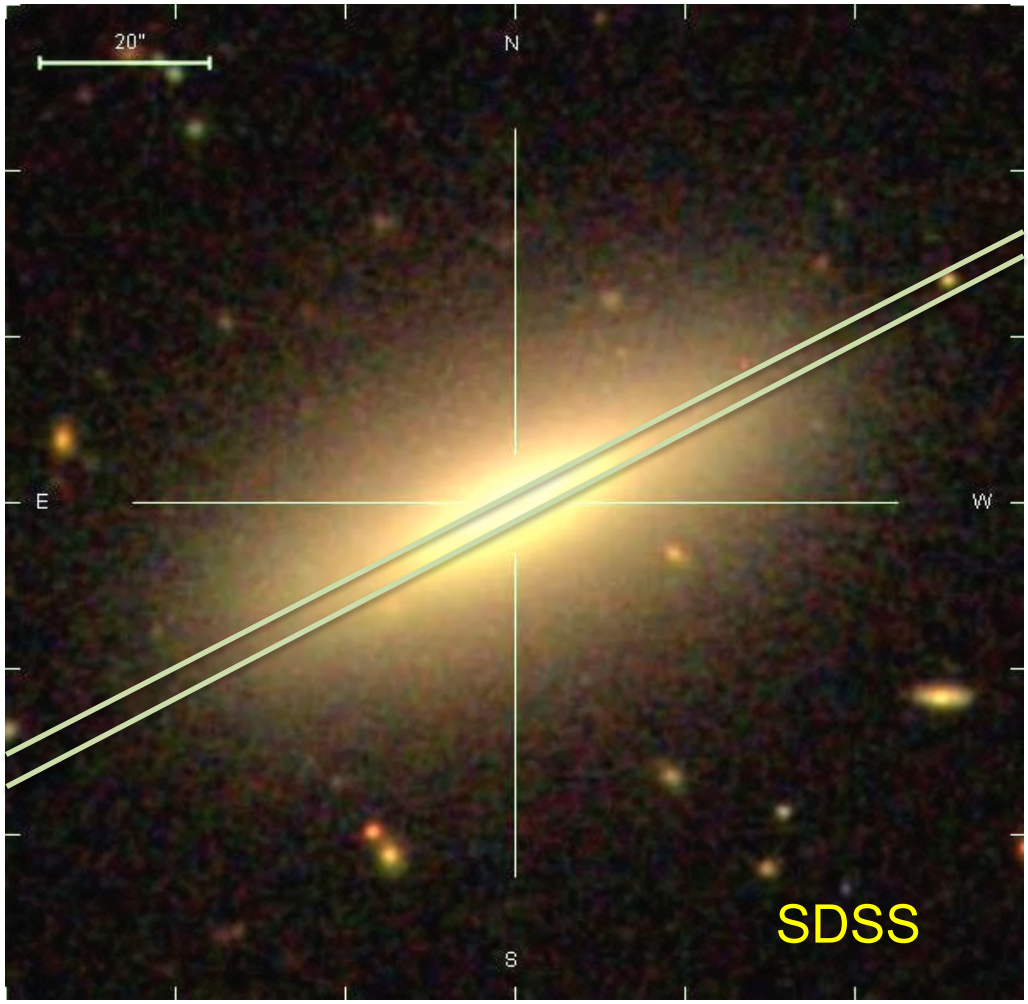
$Z_{main} < Z_{gas} < Z_{second}$



Accretion history consist of two accretion events

IC718 – gas reach dwarf satellite which can be source of external materials with decoupled angular momentum.

NGC 448

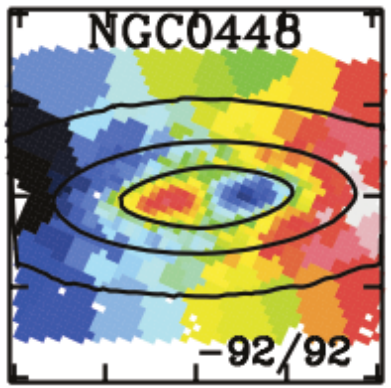


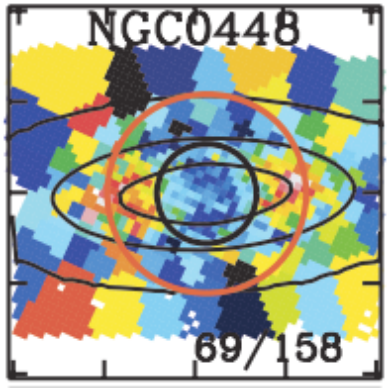
- 1” long-slit mode
- 4800-5550 AA
- Sp. Resolution~2.3 A
- σ_{inst}~60 km/s
- T_{exp}~3^h

Atlas3D data with SAURON spectrograph

Krajnovic et al. (2011)

- regular rotator
- 2sigma peaks

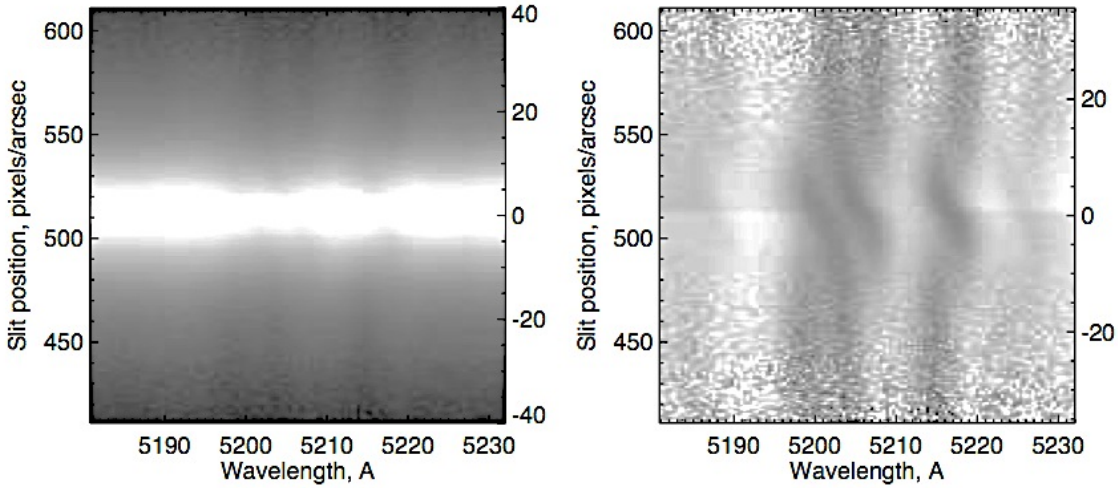


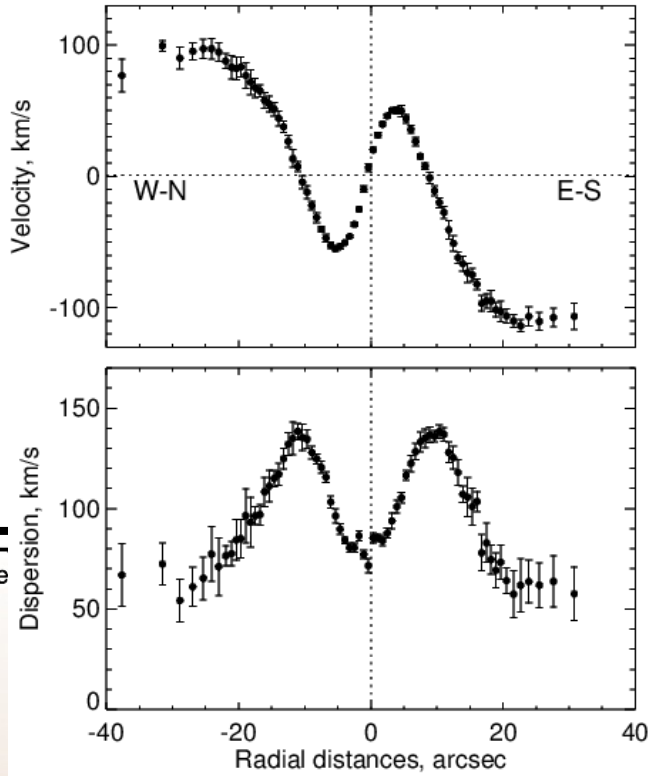


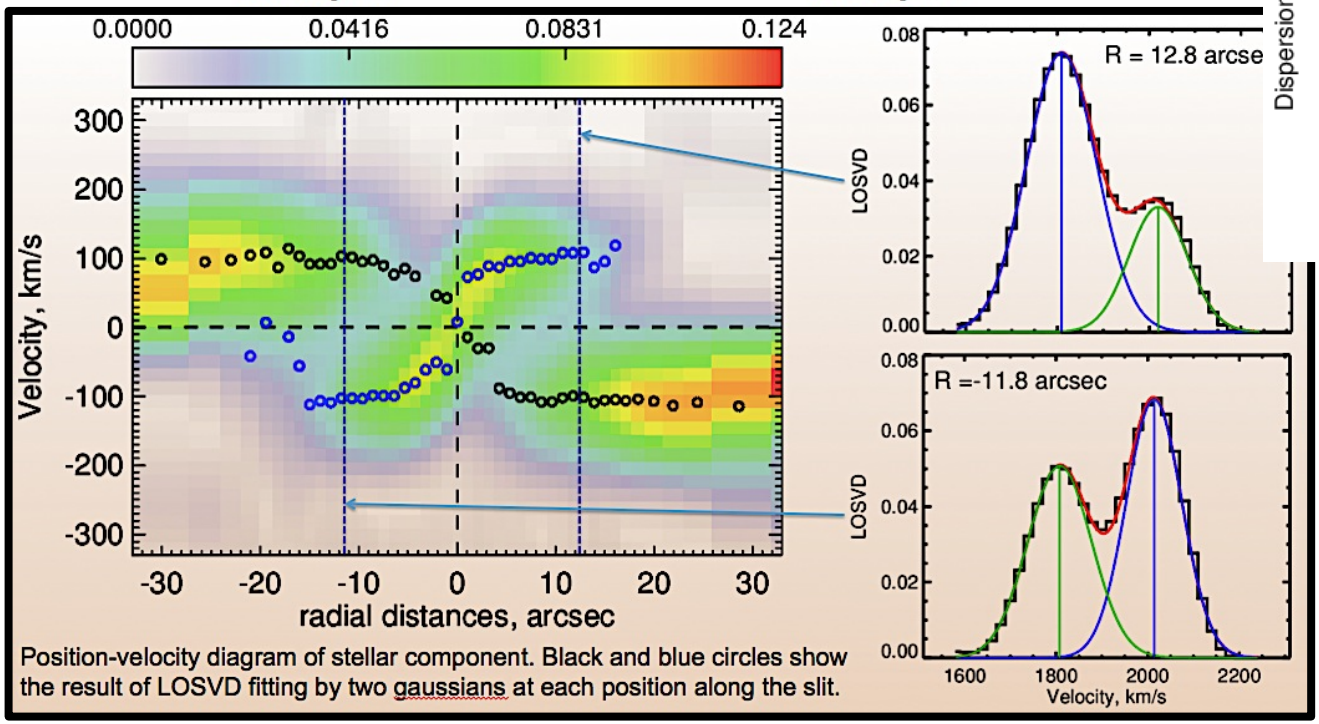
M_B=-19.2^m

NGC 448

SCORPIO long-slit data





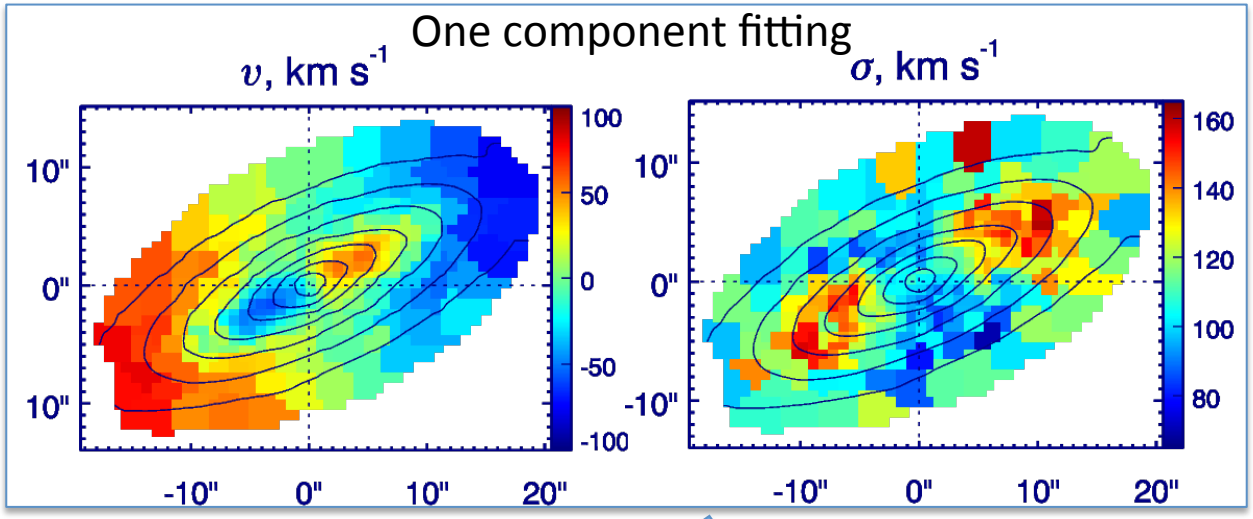


Position-velocity diagram of stellar component. Black and blue circles show the result of LOSVD fitting by two gaussians at each position along the slit.

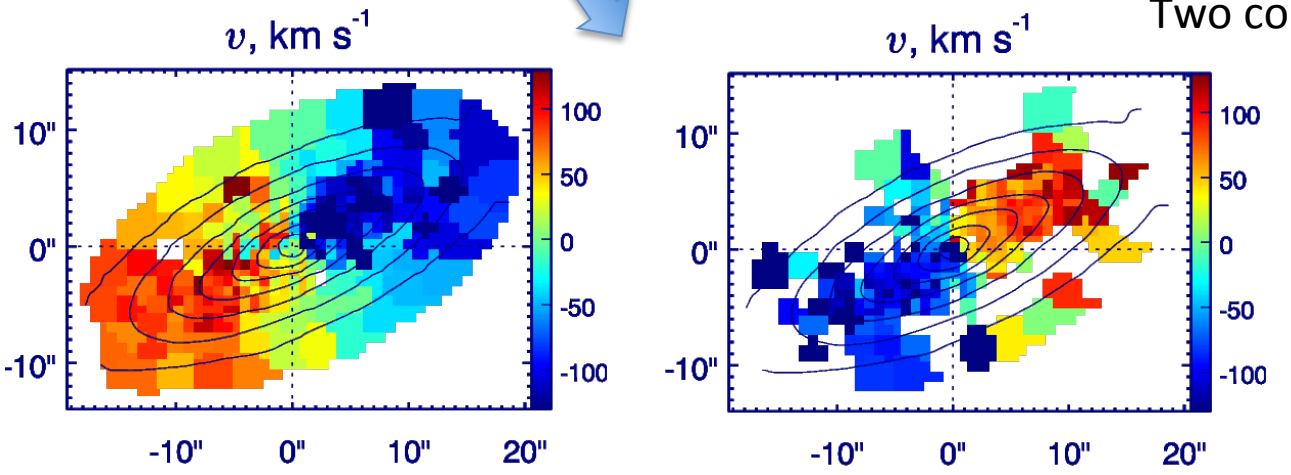
Katkov et al. in prep

NGC 448

SCORPIO long-slit data

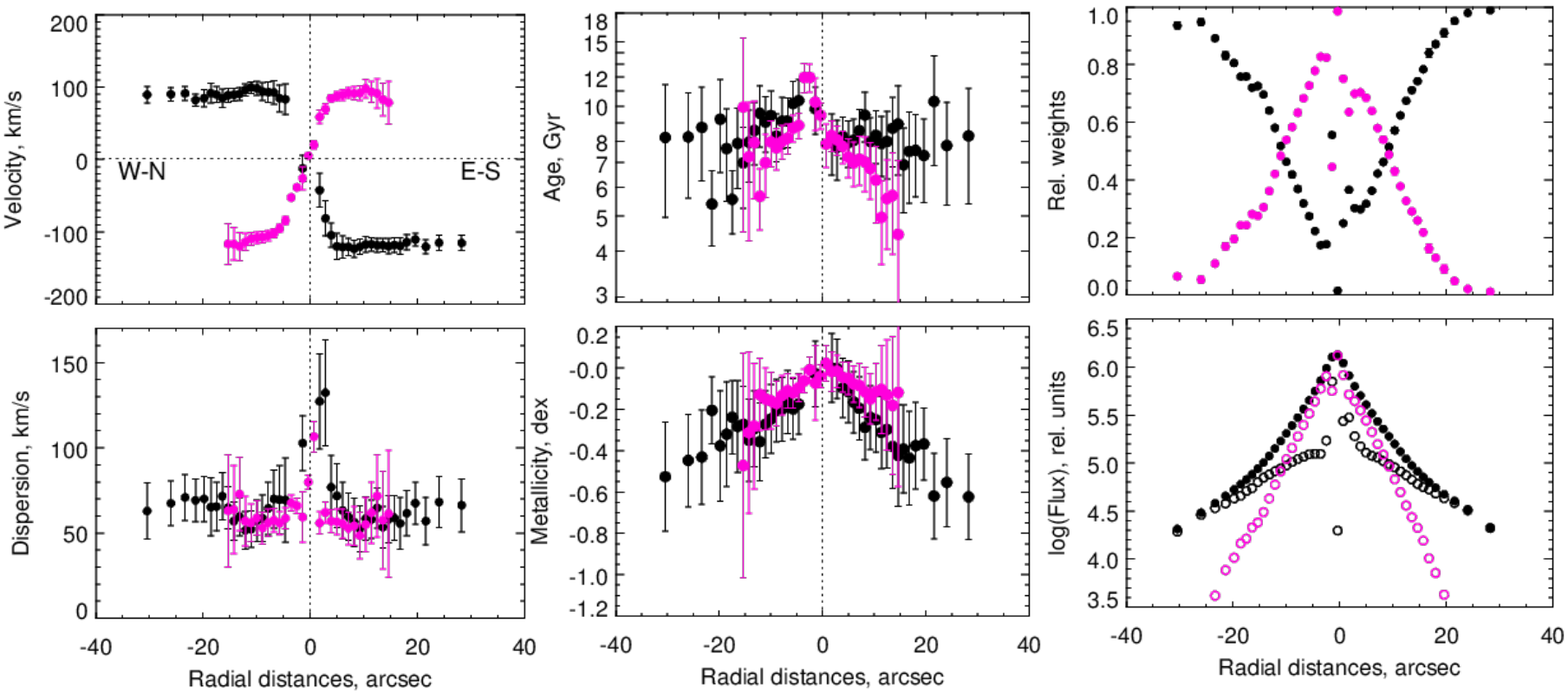


Decomposition of SAURON data is more complicated due to lower spectral resolution. In order to stabilize solution we fixed velocity dispersion on 70 km/s.



Katkov et al. in prep

NGC 448



- The comparable ages in the center exclude the formation of counter-rotating component in situ in the galaxy. Probably the merger event took place in the early epoch.

- Negative age gradient supports inside-out scenario of subsequent formation of outskirts of counter-rotating disc.

Katkov et al. in prep

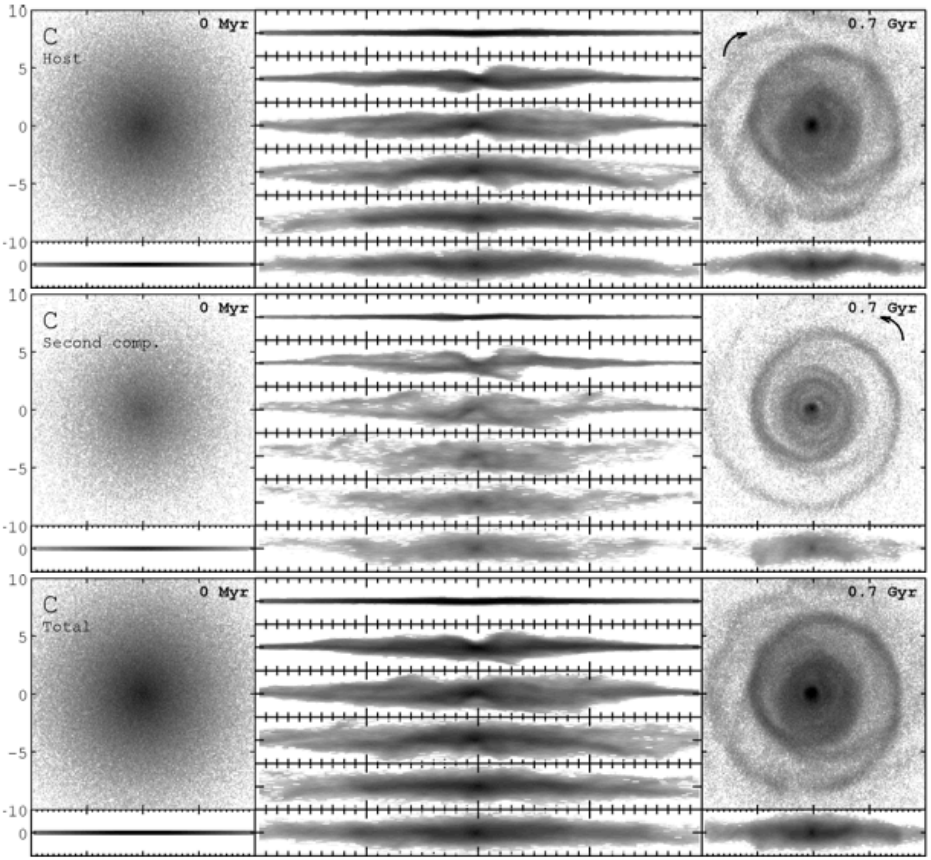
Dynamical evolution of counter-rotating discs

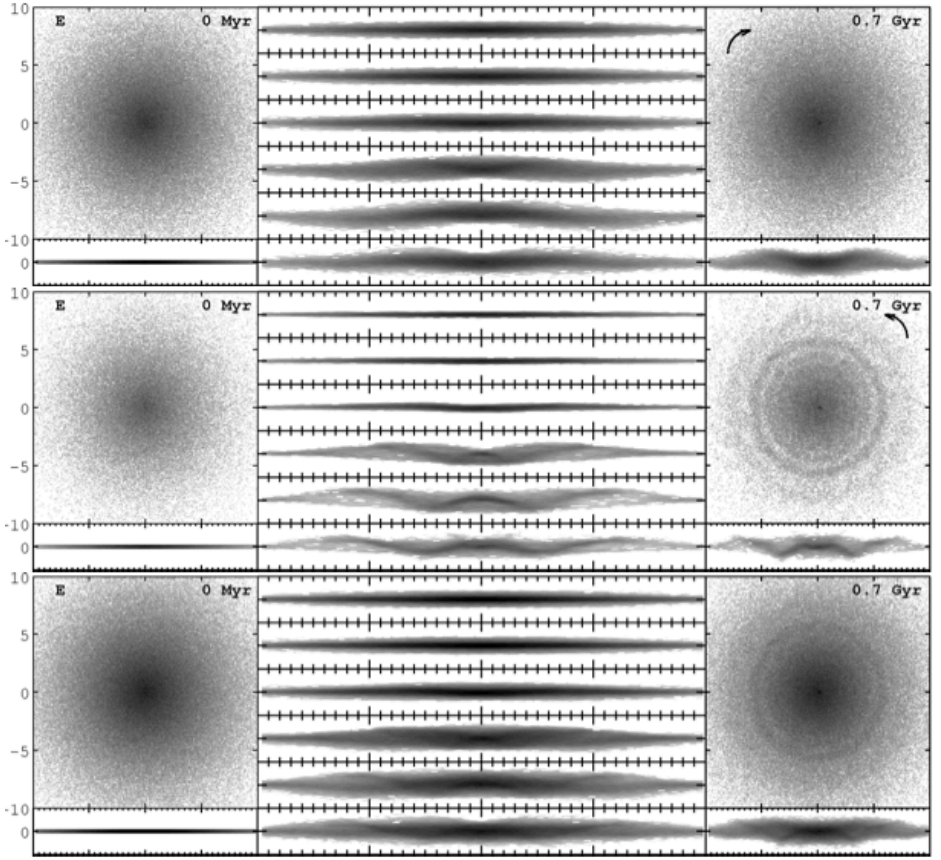
- In collaboration with Sergey Khoperskov (University of Milan,Italy; Institute of Astronomy RAS, Russia)
- Main question: *How dynamical evolution of two gravitationally stable counter-rotating discs is depend on configuration of system?*
- N-body simulations of isolated stellar systems in a fixed potential of DM
- 2-3 10^6 particles
- In various models we vary the parameters of both components: central surface density values, radial scale lengths and central value of the radial velocity dispersion.

Dynamical evolution of counter-rotating discs

Main comp.

CR comp.





Edge-on view

Bending instability

Face-on view

Qeff=0.77

Qeff=1.78

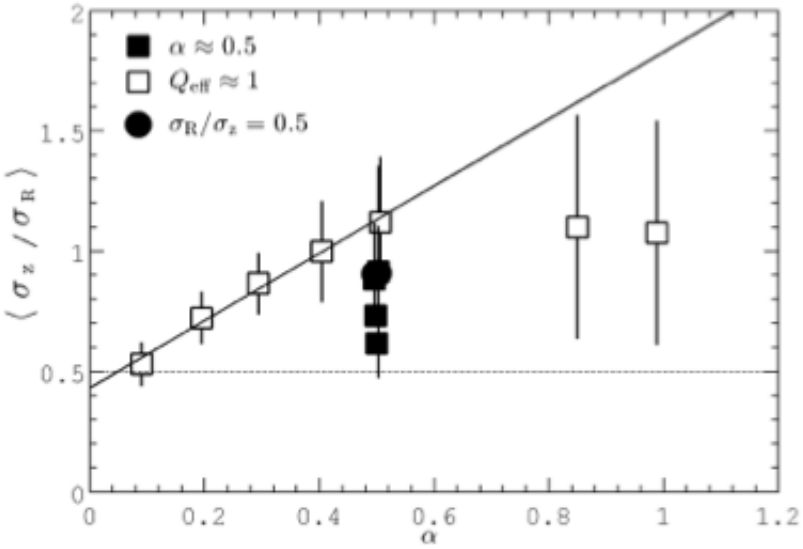
Dynamical evolution of counter-rotating discs

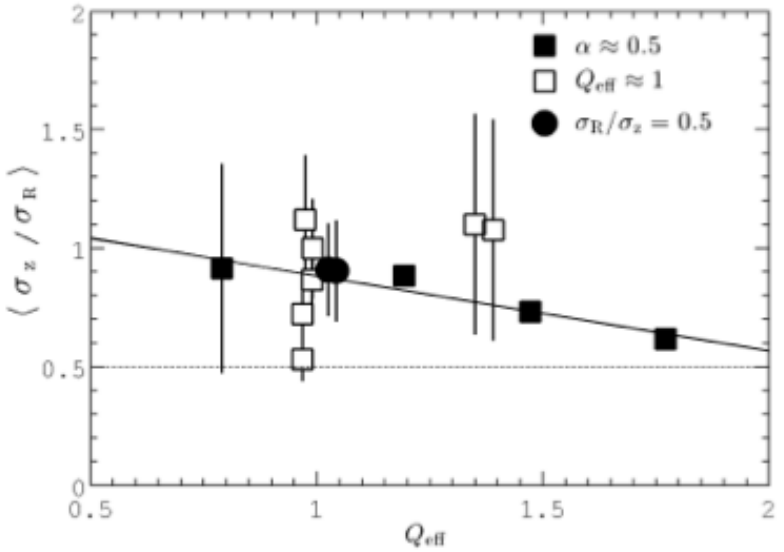
- Strong bending instability provides the strong increases of the vertical to radial velocity dispersion ratio σ_Z/σ_R during short time (few 10^8 yr.).
- Various combinations of the counter-rotating components parameters (disk surface density scale lengths and velocity dispersion scale lengths) gives a radial profile of the σ_Z/σ_R which in the galactic center can be higher than unity!
- Even small undetectable fraction (~5-10%) in mass of CR population can produce valuable increases of σ_Z/σ_R value.
- The bending waves triggered by the counter-rotation can be in principle a mechanism of the vertical disc heating in numerous galaxies.

Summary

- The counter-rotating stellar populations provide possibility to explore the history of accretion processes which is thought to be one of the main galaxy evolution driver
- The detection of counter-rotating galaxies is rare but the phenomena can be much more common.
- High quality spectroscopic data is needed.
  - High S/N is crucial for detection and decomposition of CR
  - High velocity dispersion is important for detection as well as extraction of dynamical structure of CR discs
  - 3D view is important for comprehensive view of knowingly 3D phenomena

Thank for your attention!





$$\alpha \equiv \Sigma_2/\Sigma_1$$

$$\varepsilon \equiv \frac{\int_0^R \pi r \Sigma_2 \left((r\Omega_2)^2 + \sigma_2^2\right) dr}{\int_0^R \pi r \Sigma_1 \left((r\Omega_1)^2 + \sigma_1^2\right) dr} < 1$$