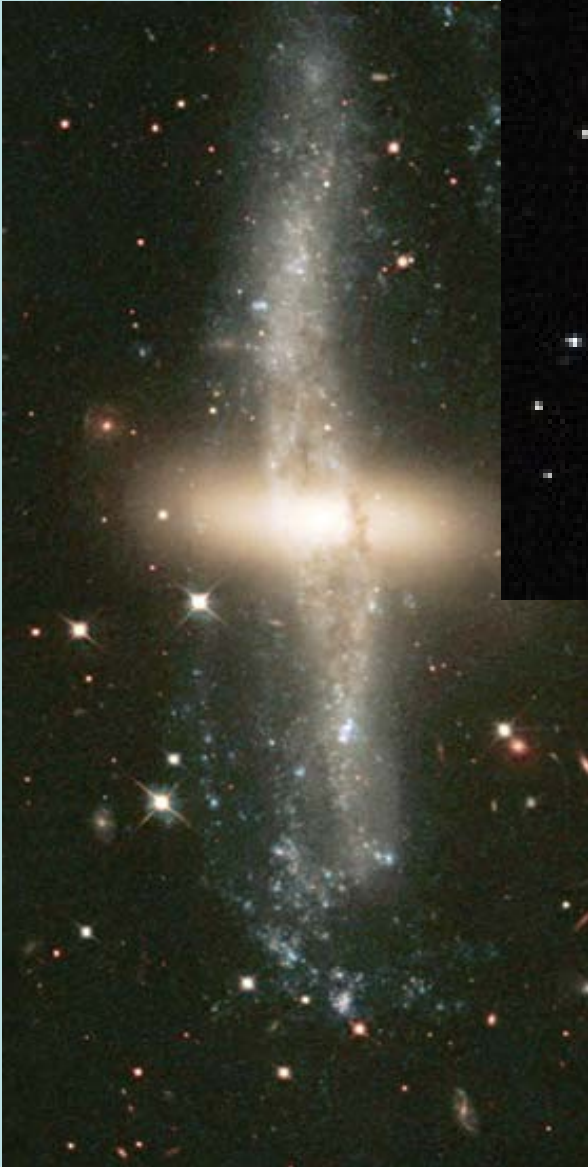# Studying of Candidates to Polar-ring Galaxies by the Methods of 2D-spectroscopy
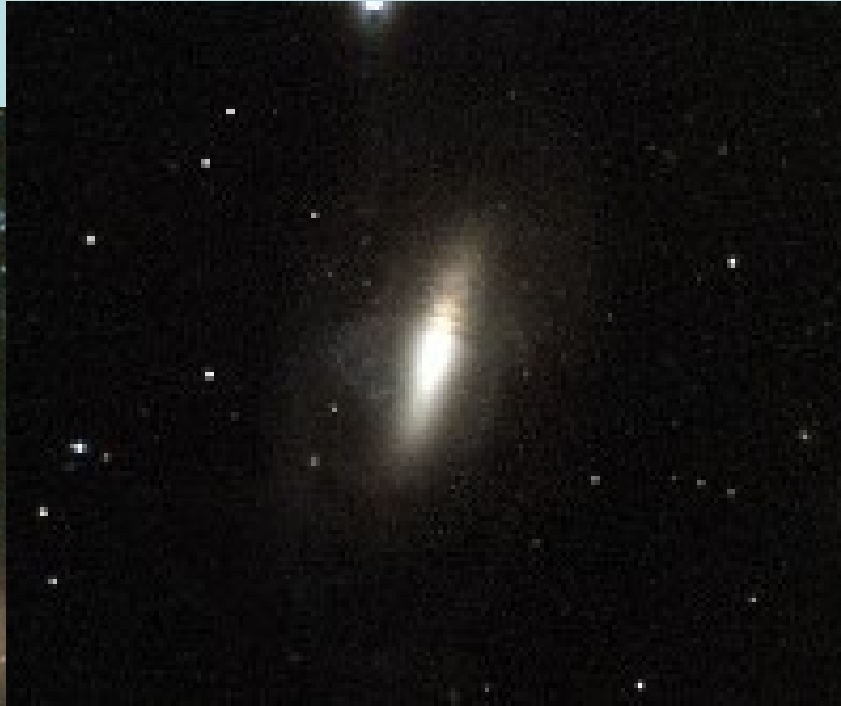
O. Merkulova, G. Karataeva, L. Shalyapina, V. Yakovleva (Saint-Petersburg State University)

# Polar-ring galaxies

NGC 4650A

NGC 2685

NGC 660

Polar-ring galaxies

NGC 4650A

◆ the rare class of dynamically
  peculiar systems where the rings of
  gas, dust and stars aligned roughly
  perpendicular to the major axis
  of the main galaxy

◆ Whitmore et al. (1990): «Catalog
  of polar-ring galaxies, candidates
  and related objects» (PRC)

Polar-ring galaxies are the rare class of dynamically peculiar systems where the rings of gas, dust and stars aligned roughly perpendicular to the major axis of the main galaxy.
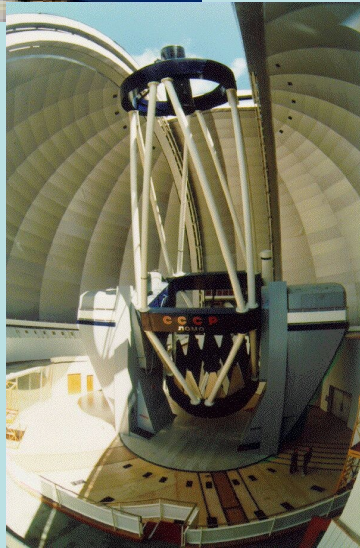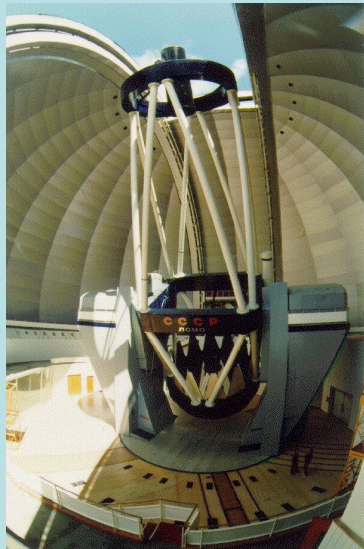

NGC 4650A

Observations:
(*6-m telescope of SAO RAS*)
− integral field (3D) spectroscopy
(Interferometer Fabry-Perot (Hα),
Multi Pupil Fiber Spectrograph
("green" and "red")),
− high resolution long-slit
spectroscopy ("green" and "red")
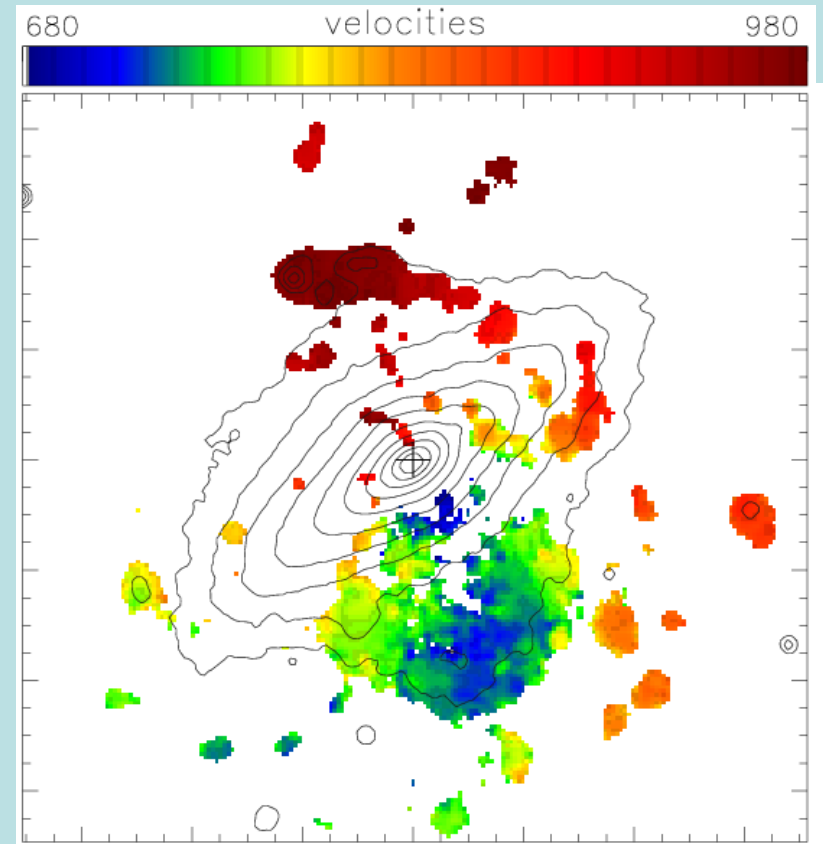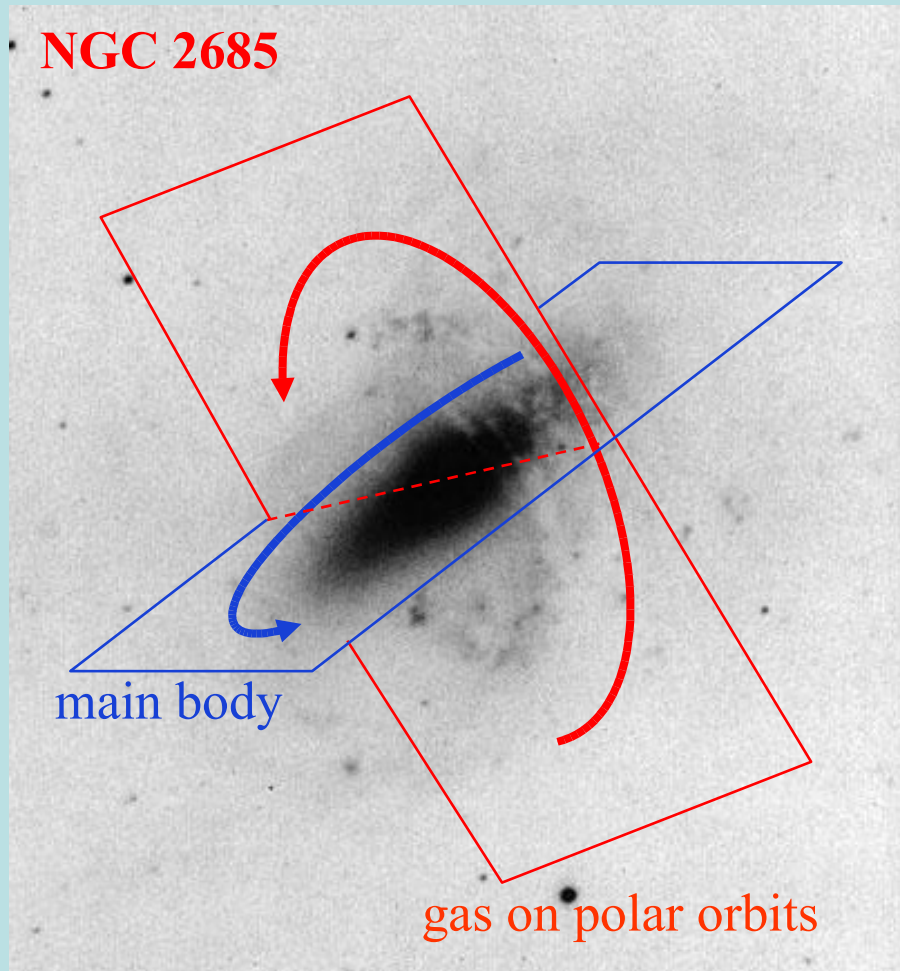
Observations:

(*6-m telescope of SAO RAS*)
− integral field (2D) spectroscopy
(Interferometer Fabry-Perot (Hα),
Multi Pupil Fiber Spectrograph
("green" and "red")),
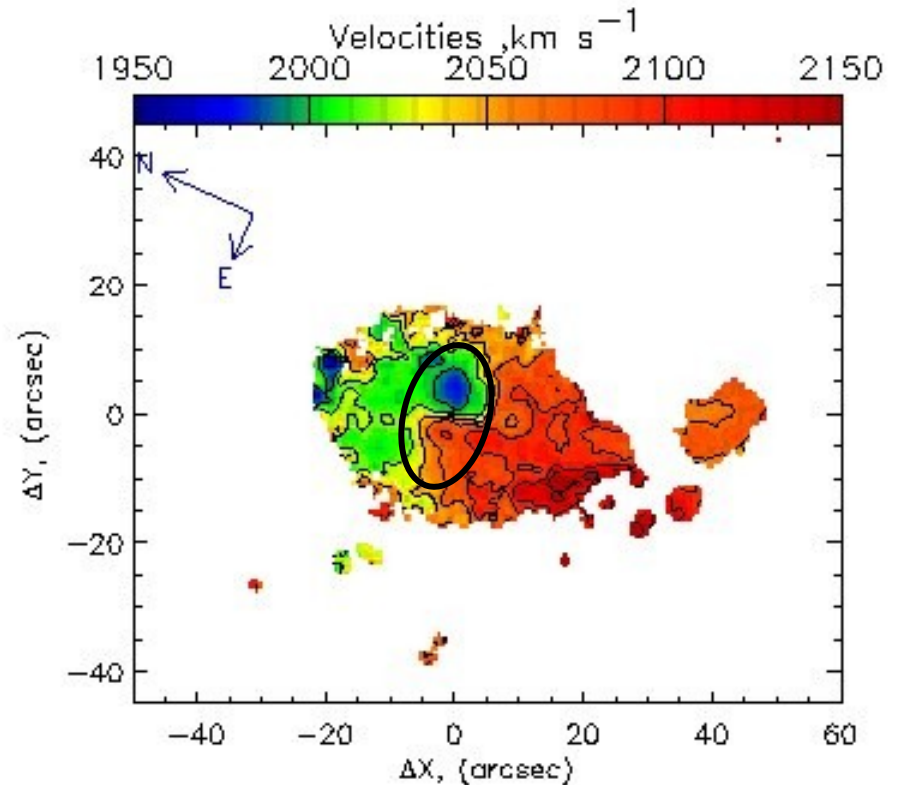− high resolution long-slit
spectroscopy ("green" and "red")

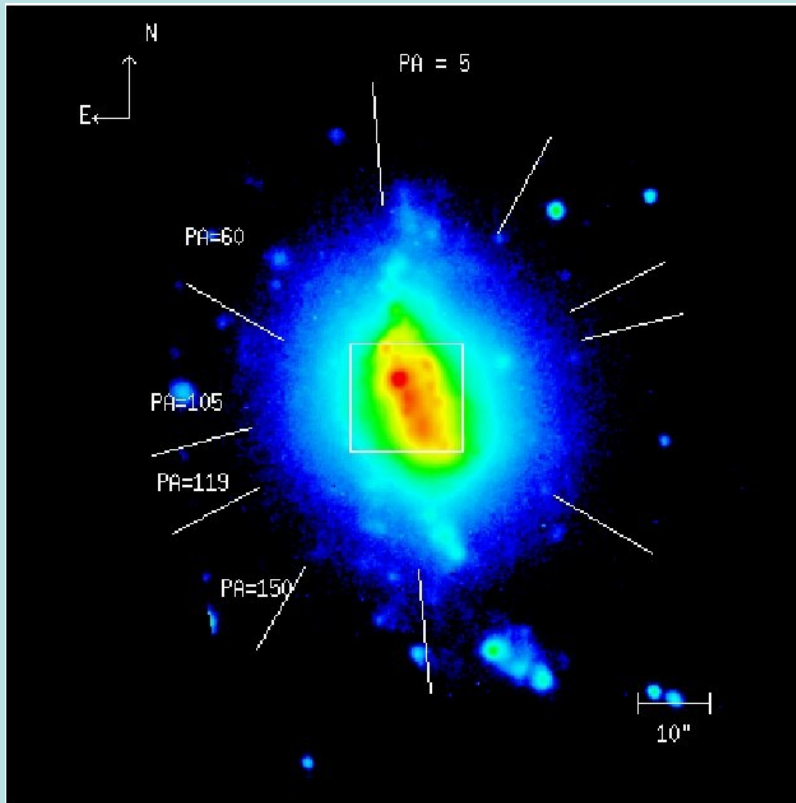# NGC 2685 – the prototype of polar-ring galaxies

NGC 2685

main body

gas on polar orbits

Candidates from the list
by *Whitmore et al. (1990)*

680   velocities   980
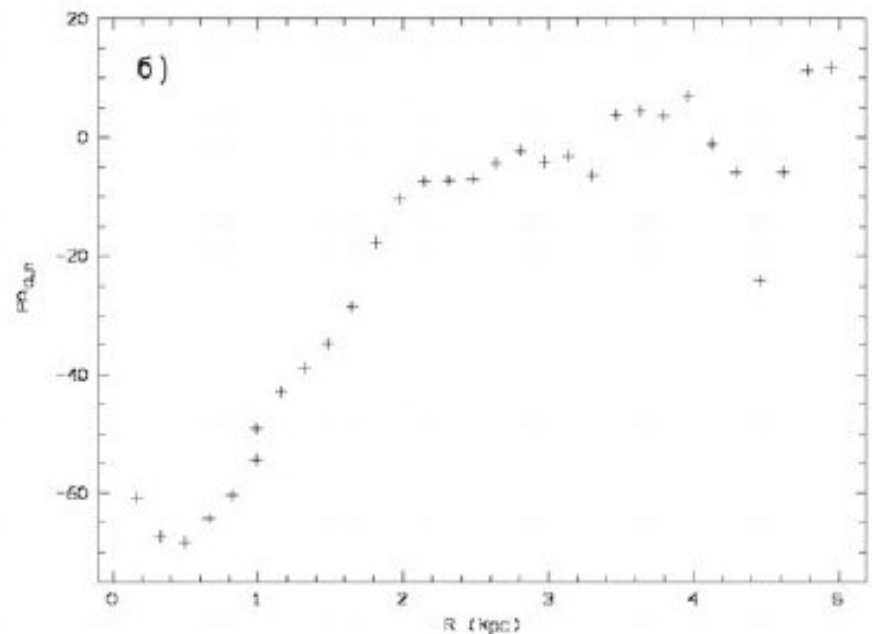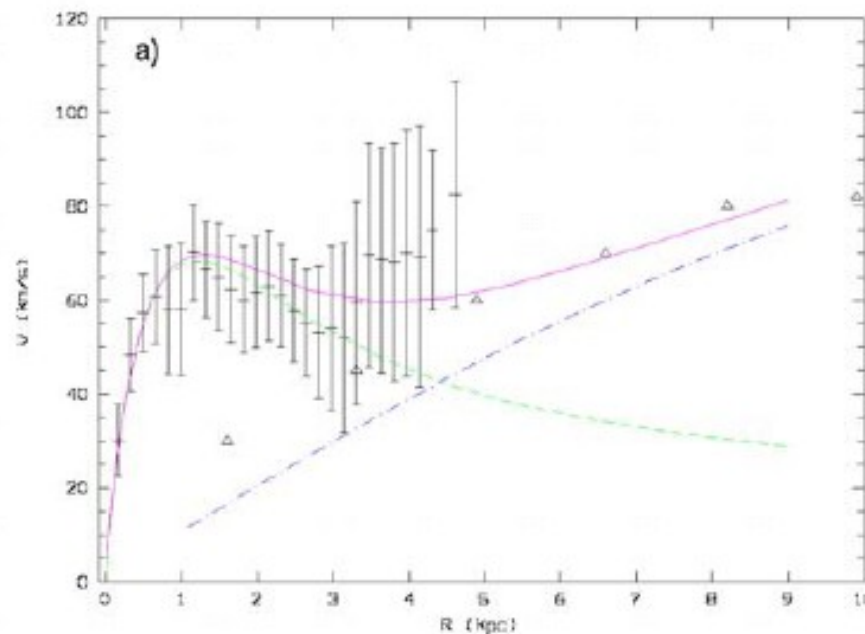
Hagen-Thorn et al. (2005)

NGC 7468 – the galaxy with inner polar disk

The galaxy has multinuclear structure and regions of brightness excess along the major axis of the galaxy (the putative polar ring).
Our Hα velocity field revealed the existence of **the inner polar disk**!

Shalyapina et al. (2004)

(a) Rotation curves. 1: resulting curve; 2: disk component; 3: halo; 4: our data; 5: the data from Richter et al. (1990). (b) The change in the location of the dynamic axis with radius.

The two ways of the observed structures formation are available:

− *the central collision* of NGC 7468 with a gas-rich dwarf galaxy and their subsequent *merging* seem to be responsible for the formation of the inner polar disk, and the features along major axis are either tidal structures or weakly developed spiral arms;

− the galaxy has *triaxial Stackel potential* (de Zeeuw, Franx, 1989), the outer brightness excess may belong to the polar ring formed after the interaction with the companion observed in HI map (D = 45.5 kpc).

NGC 7465 − the galaxy with inner polar disk
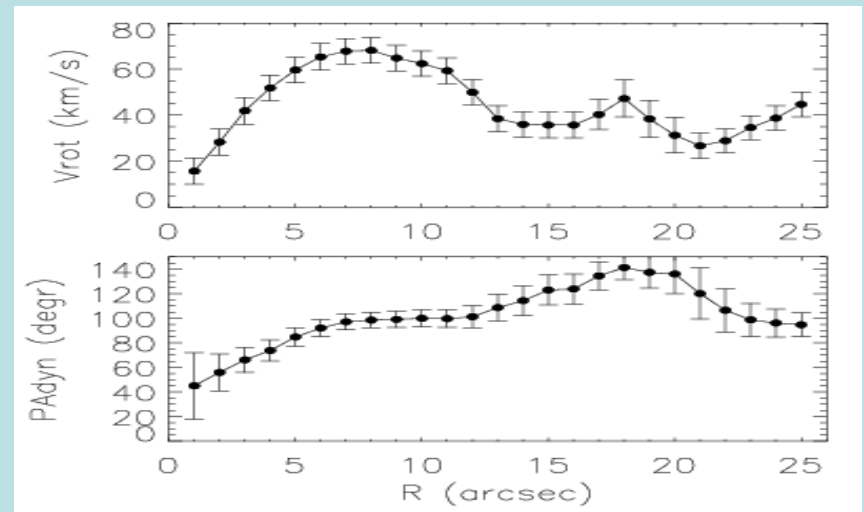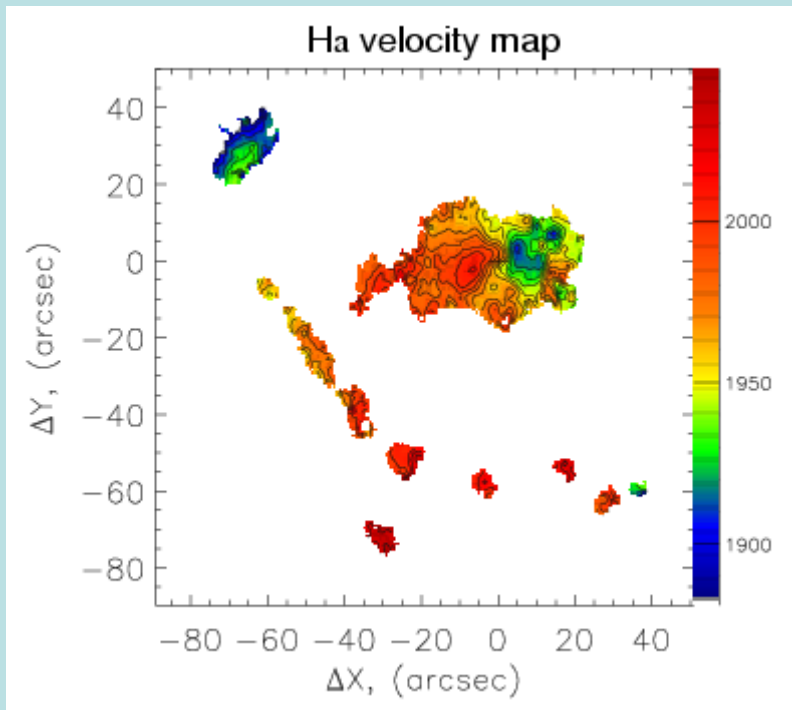

Deep R-image with Hα-isophotes overlapped
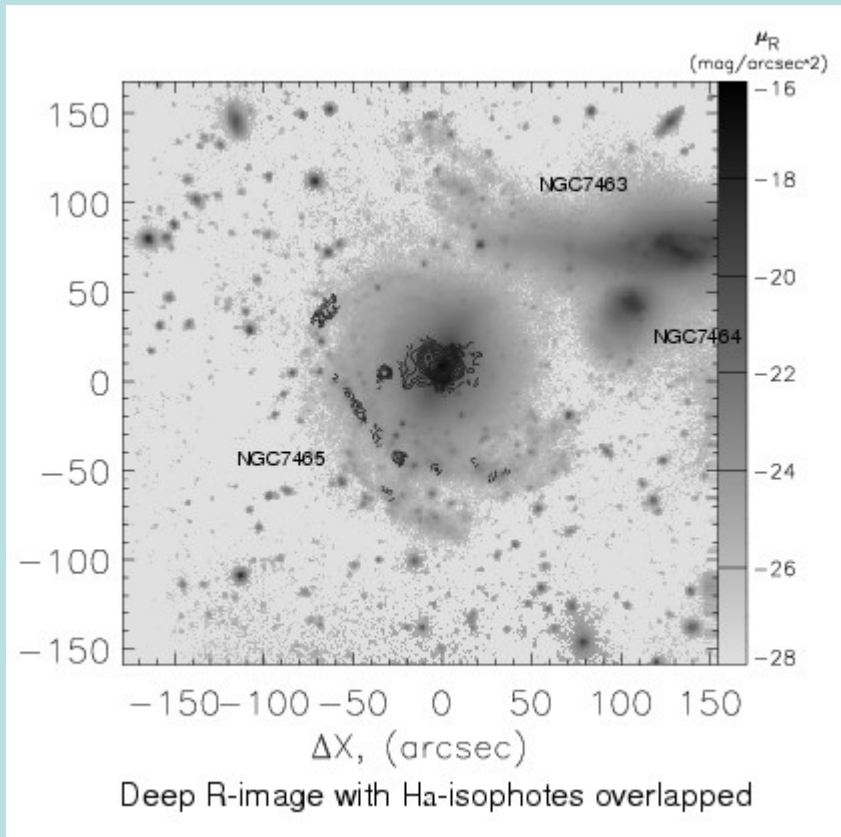
NGC 7465 − a member of the compact group of peculiar galaxies NGC 7465/64/63.

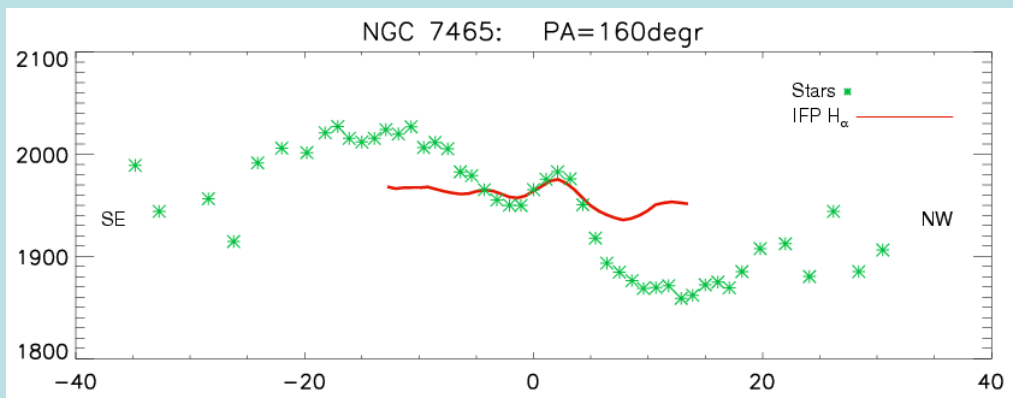- Distance to the group: $D = 31.7$ Mpc ($H_0 = 72$ km/s/Mpc);
- Scale: $1'' = 0.15$ kpc.

Li & Seaquist (1994):
a HI ring at $r \approx 80''$ is polar?

One of the spiral arms of NGC 7465 forms a **bridge** to 7464/63.
A chain of radiating in line *Hα knots* located to the SE from the center of NGC 7465 falls on **spiral arms** of the galaxy.
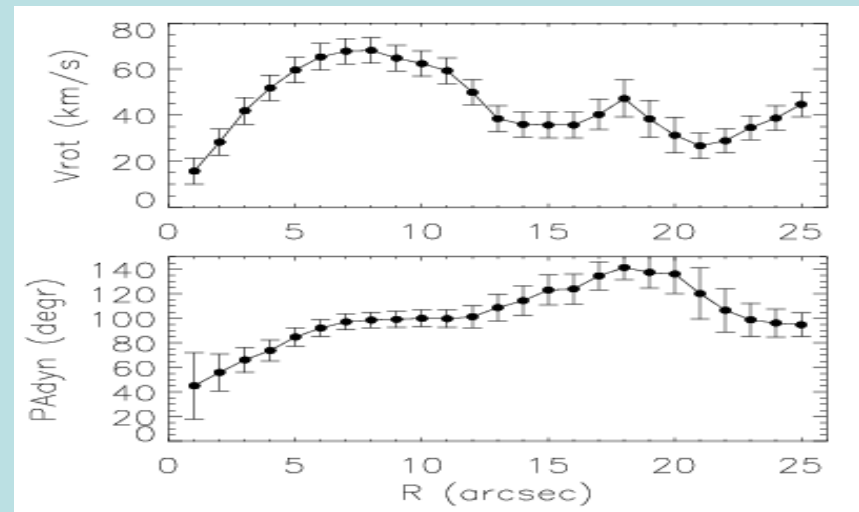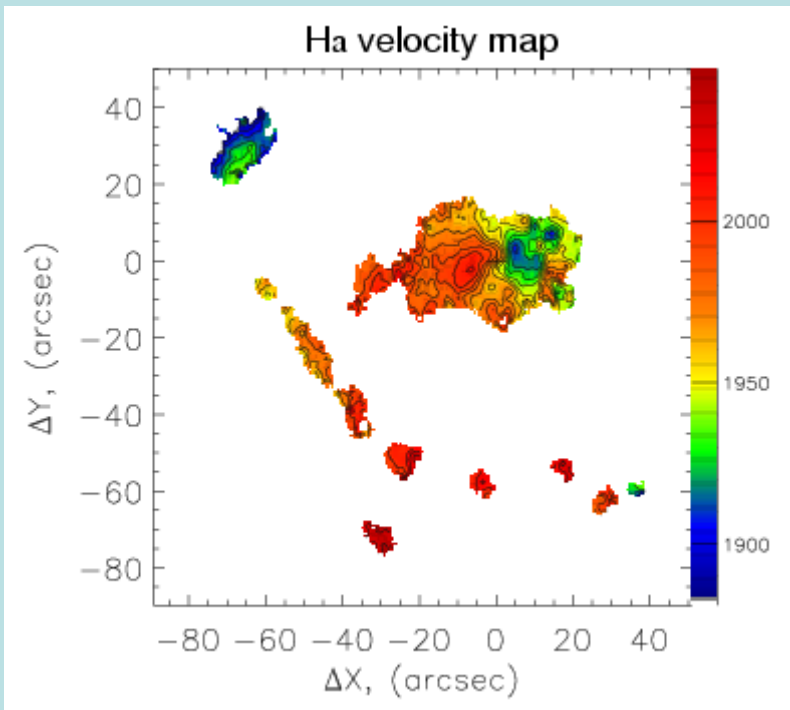
Ha velocity map

The turning of the dynamical axis of the gaseous component.

NGC 7465:   PA=160degr

|r| < 4": line-of sight velocities of stars and gas coincide

|r| ≥ 4": stars rotate around the minor axis of the galaxy

NGC 7465 − the galaxy with *inner polar disk*?

(*poster Karataeva et al.*)

Ha velocity map
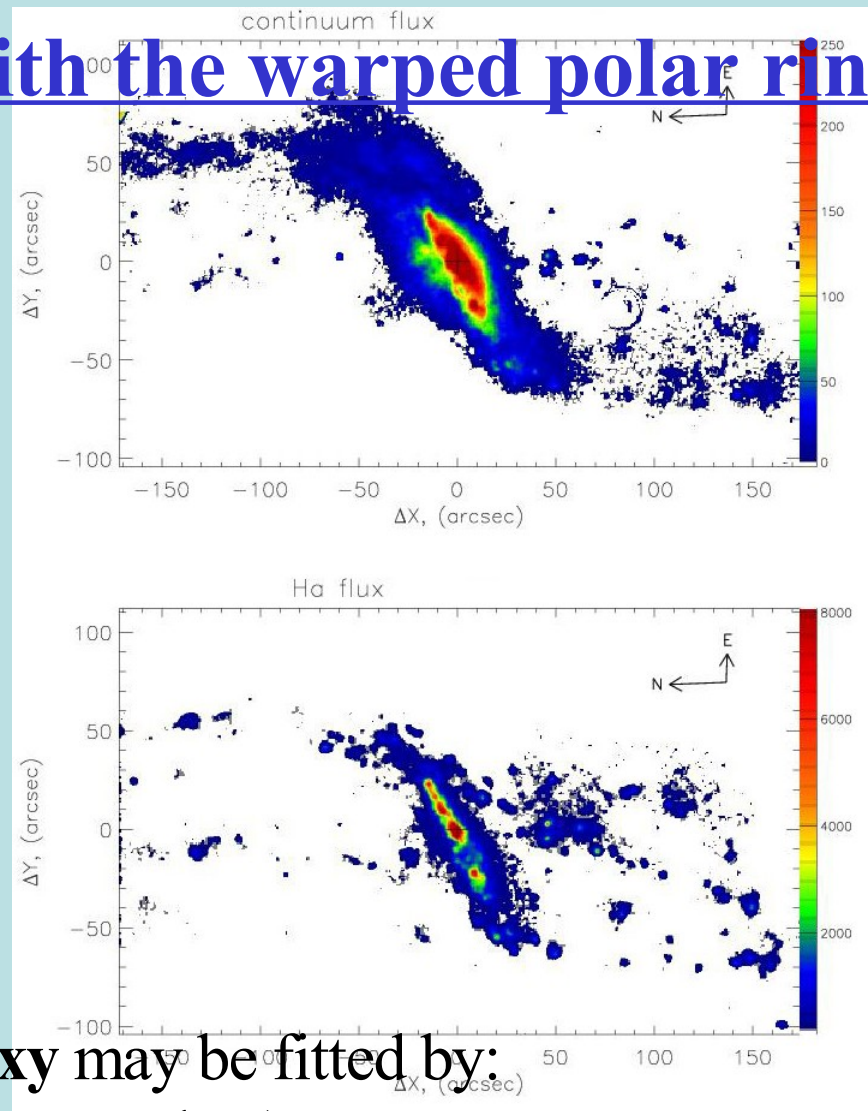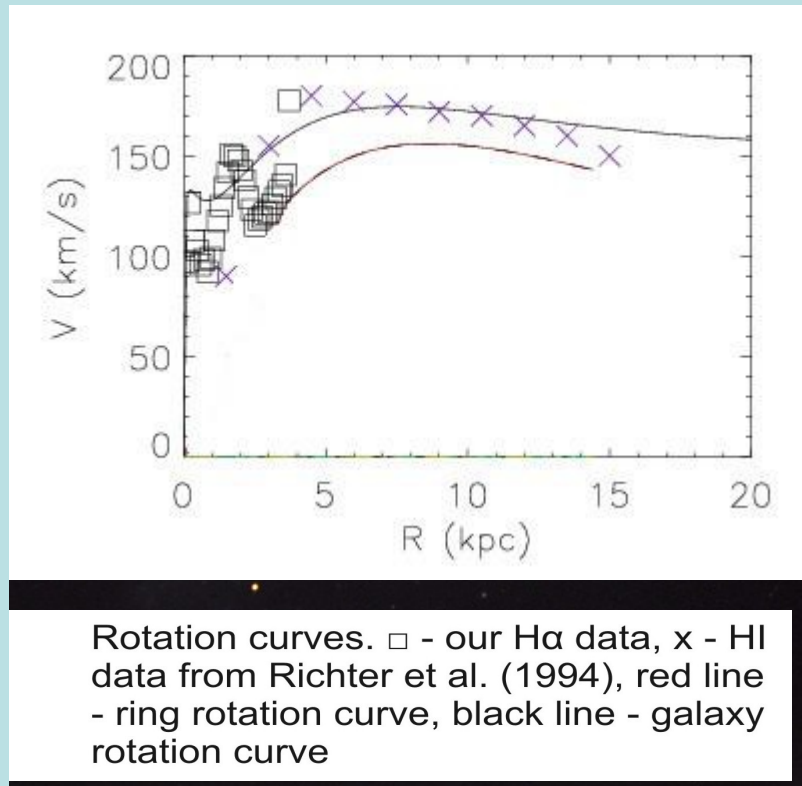
The turning of the dynamical axis of the gaseous component.

In continuum: r ≤ 7″: PA ~120°, i ~0°;
            r > 7 ″: PA ~155°, i ~40°;
In Hα: r ≤ 5-7″: PA_{dyn} ~50°, i_{dyn} ~50°;
       r > 7″: PA_{dyn} ~110°, i_{dyn} ~60°.

NGC 7465 − the galaxy with ***inner polar disk***?

(poster Karataeva et al.)

NGC 660 – the galaxy with the warped polar ring

Rotation curves. □ - our Hα data, x - HI data from Richter et al. (1994), red line - ring rotation curve, black line - galaxy rotation curve

The rotation curve of **the host galaxy** may be fitted by:
- bulge ($r_e = 0.8$ kpc), • disk (h = 2.8 kpc),
- halo (r = 0.01 Msun/pc^3, $R_c = 6.5$ kpc).

The rotation curve of **the polar ring** goes lower →
→ the nonspherical potential.

continuum flux with contours of model rings

velocity field with contours of model rings
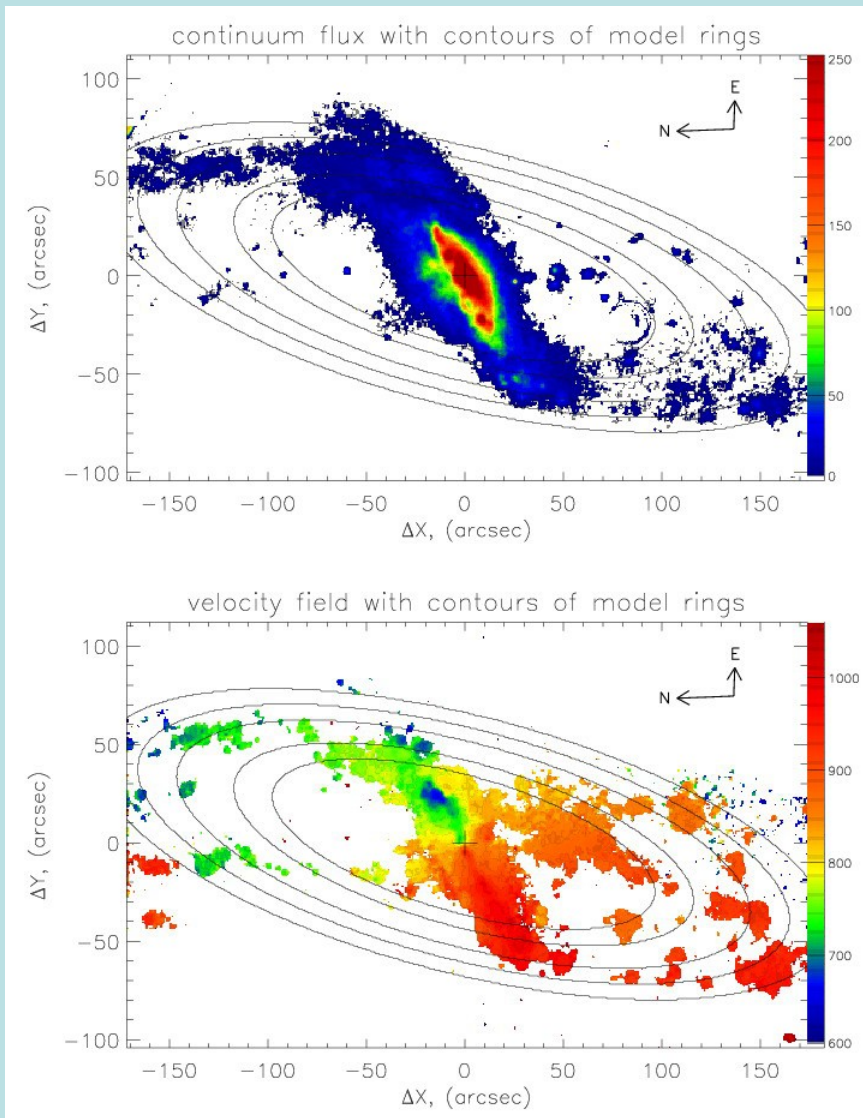
The model of *the warped polar ring*: the angle between the plane of the inner ring and of the outer ring is ~30°; the mass of the rings varies from 6.8×10^8 M_{Sun} to 1.2×10^{10} M_{Sun}.

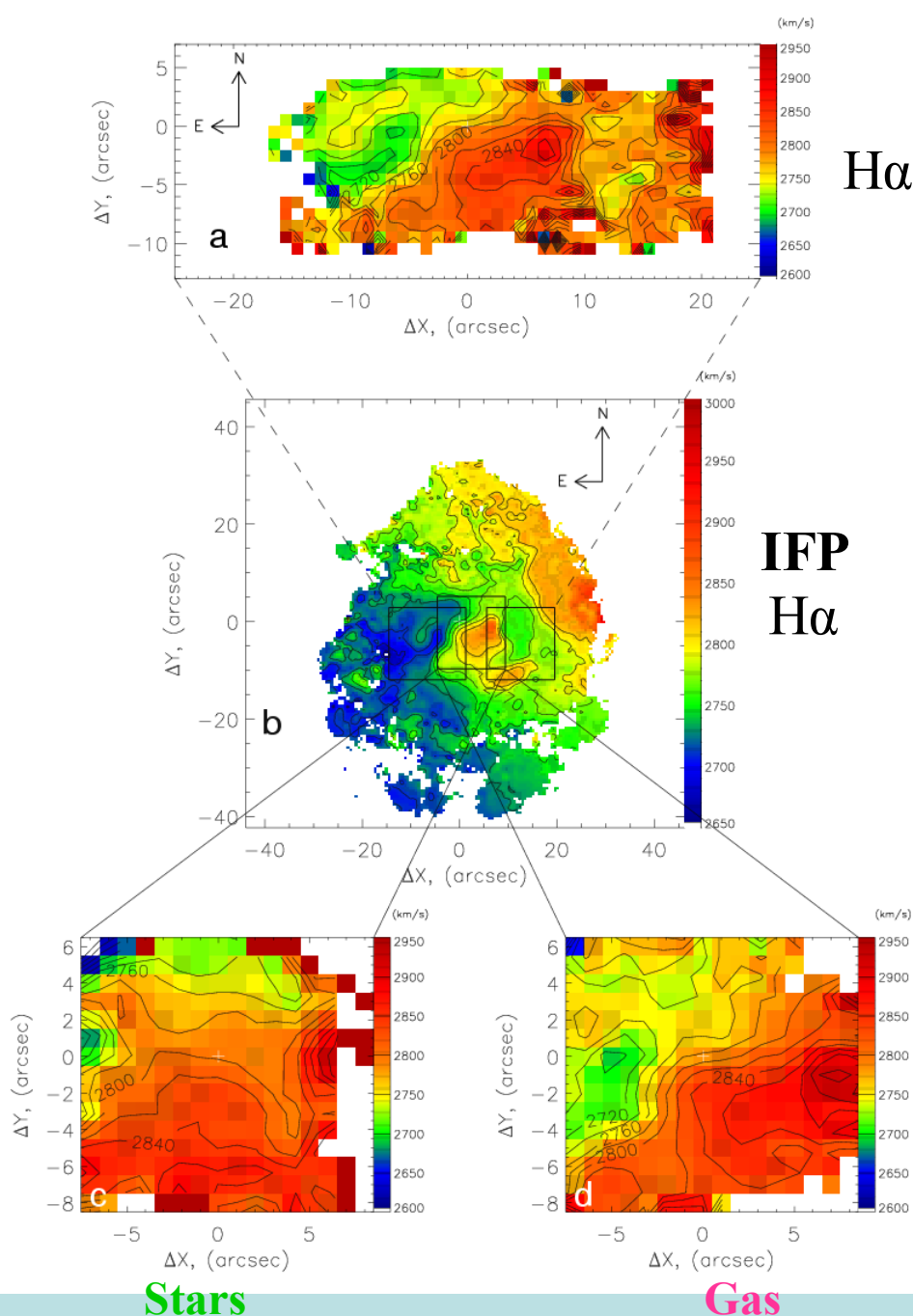The ring is quite heavy to stabilize by self-gravity.

UGC 5600 – the galaxy with the warped polar ring
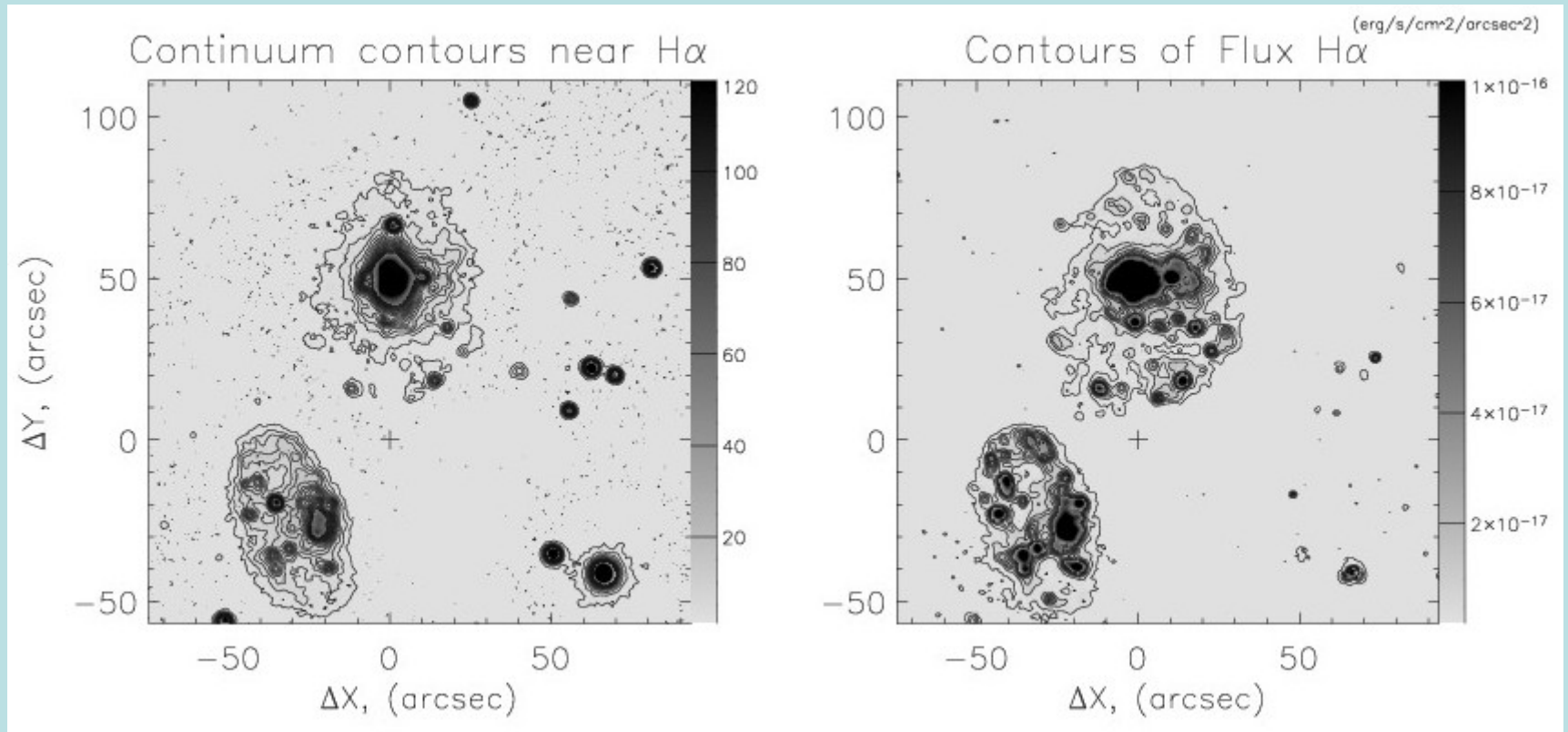
UGC 5600 is the member of the pair of galaxies VV 330.
Complex structure of the galaxy which is different for stellar and
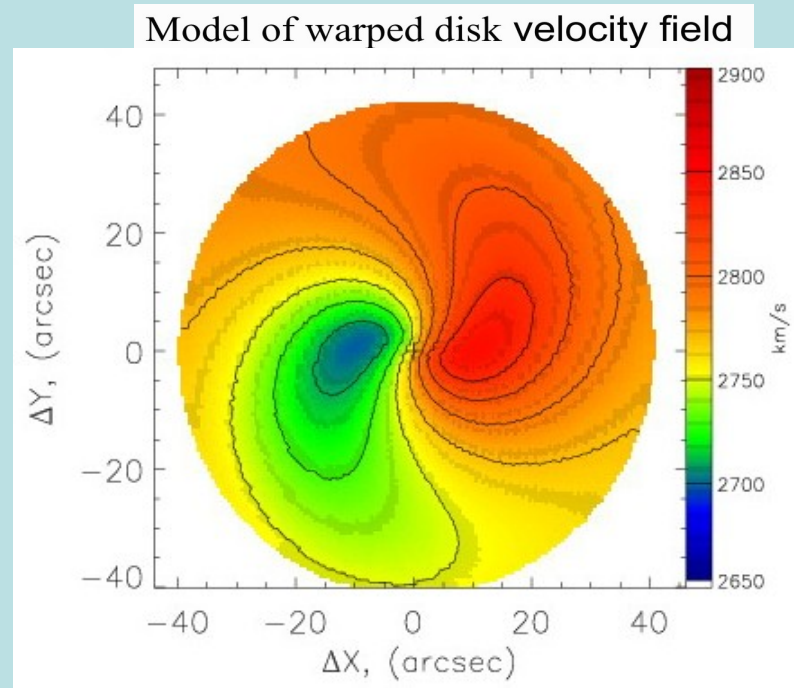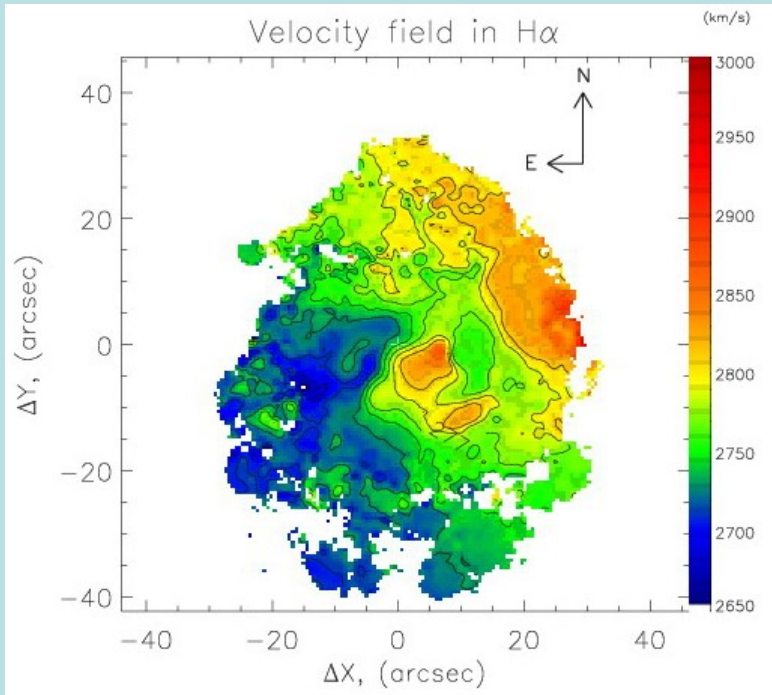gaseous components is observed.

UGC 5600
velocity fields

Hα

IFP
Hα

Stars

Gas

Three kinematic subsystems:

❖ **stellar disk;**

❖ **"inner gaseous ring",** the angle between ring and disk ~80°;

❖ **outer gaseous disk,** stellar and outer gaseous disks are noncoplanar

*Shalyapina et al. (2007)*

Velocity field in Hα (km/s)

Model of warped disk velocity field

Three kinematic subsystems: *a stellar disk*, an "*inner gas ring*" turned with respect to the disk through ~80°, and an *outer gaseous disk*. The stellar and outer gaseous disks are noncoplanar.

Possible scenario is considered: the gas was striped from the companion and large-scale velocity field is represented by the kinematic model of a warped disk; this disk is a polar; its existence is possible if it is massless and gravitates in the triaxial potential (Schwarz, 1985; Sparke, 1986).
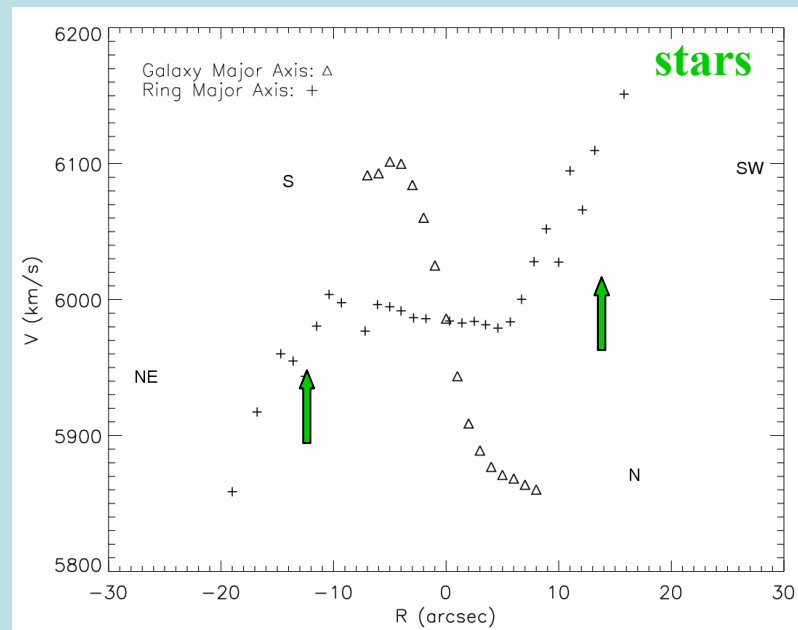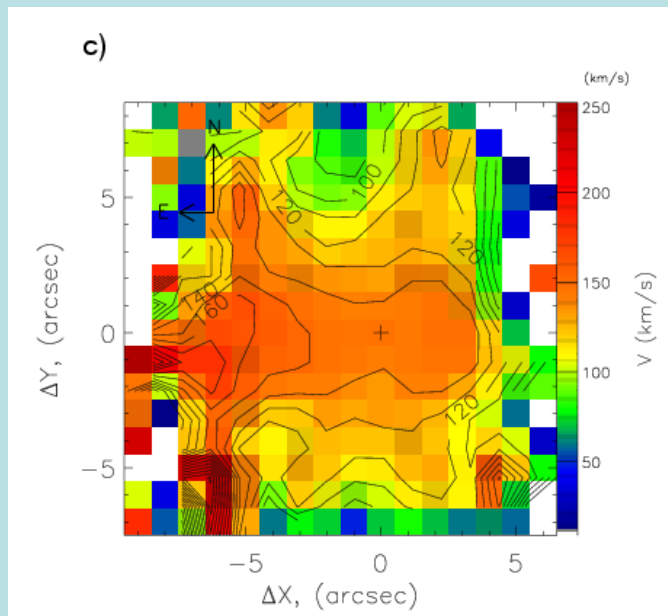
UGC 5119 – the galaxy with the stellar polar ring
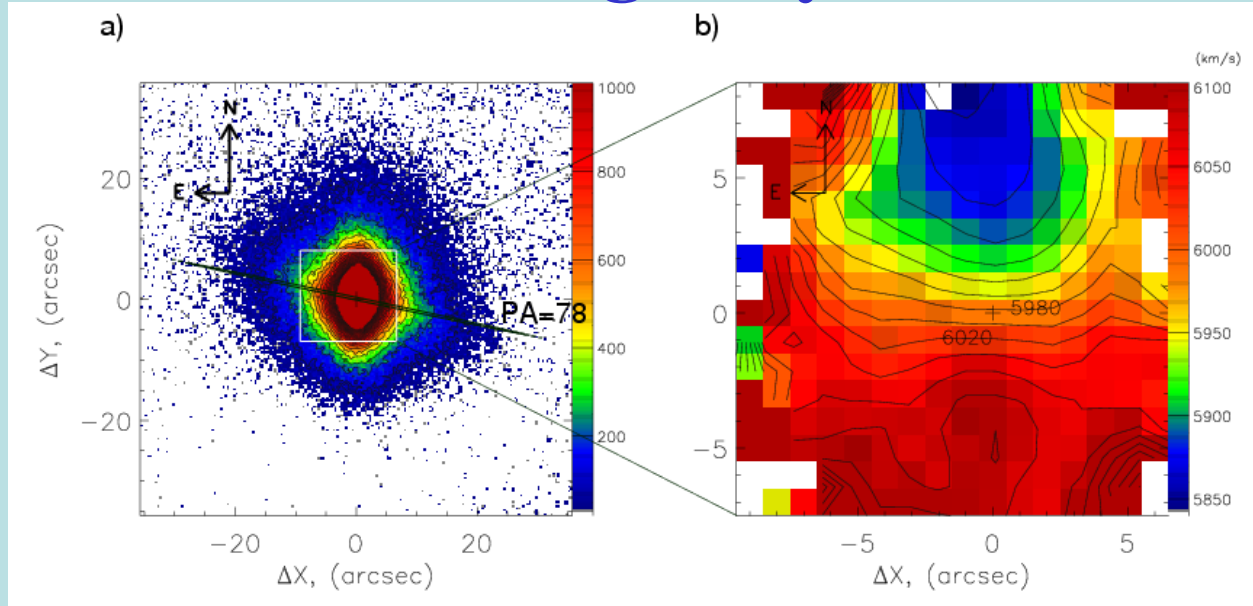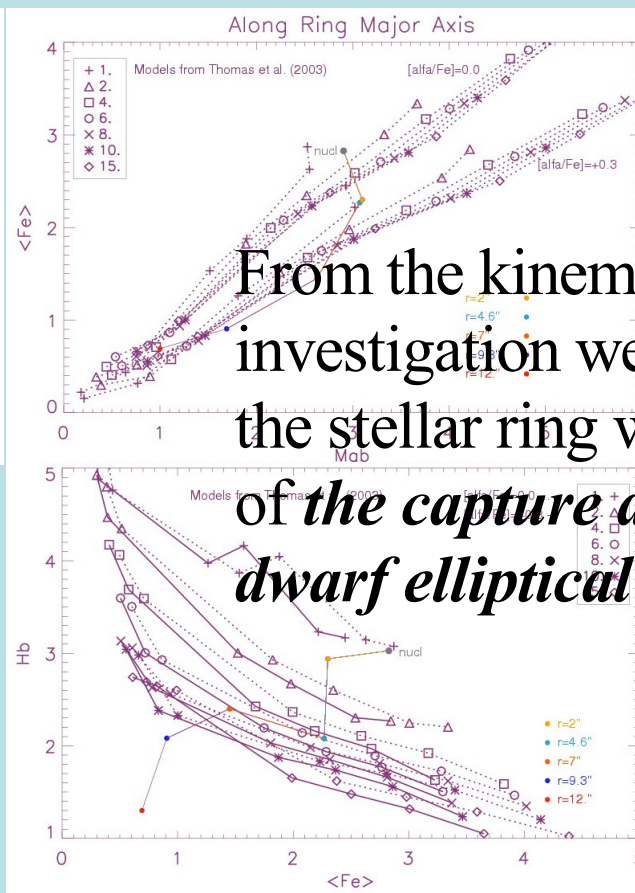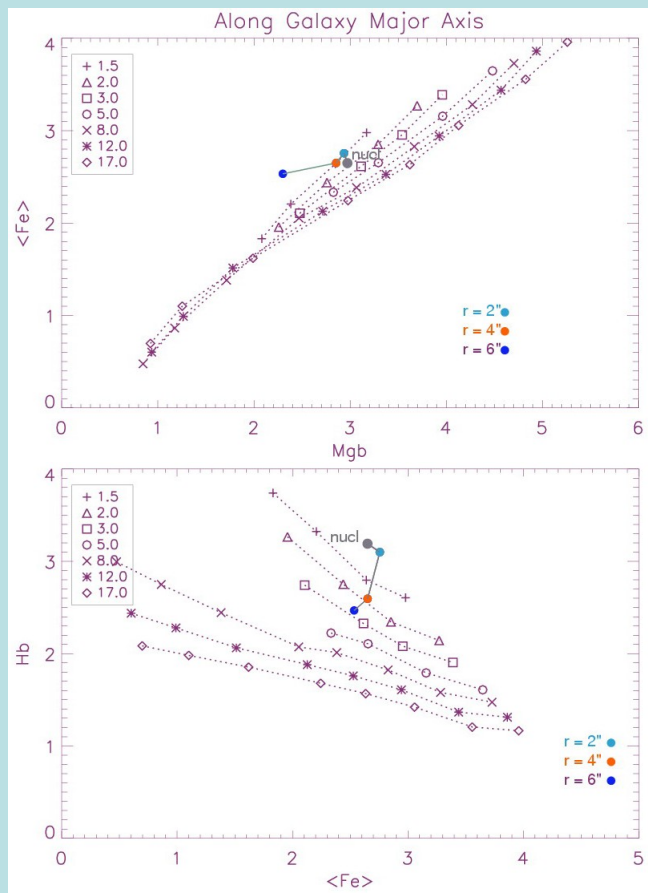

rapidly rotating *disk*

velocity gradient along the major axis of ring

stellar polar ring?

From the kinematics and chemistry investigation we may suppose that the stellar ring was formed in result of ***the capture and disruption of dwarf elliptical galaxy-companion***.

Nucleus: $T=1 \times 10^9$ yr, [Fe/H]=0.0-0.25, [α/Fe]=0.0

R = 4″: $T=2 \times 10^9$ yr, [Fe/H]= 0.0-0.25, [α/Fe]=0.0

R = 5″: $T=6 \times 10^9$ yr, [Fe/H]=-0.33, [α/Fe]=0.0

R=6″: $T=3 \times 10^9$ yr, [Fe/H]=0.0, [α/Fe]<0.0

R=9″: $T=17 \times 10^9$ yr, [Fe/H]=-1.5, [α/Fe]=+0.3

Lick indices =>
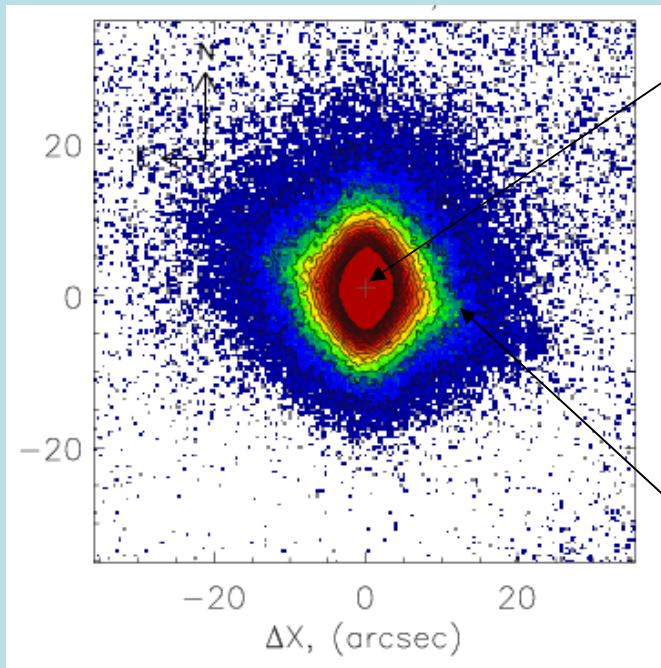
Circumnuclear region: *young stellar population, high metallicity* ([Mg/Fe] = 0.0, T~1-2 Gyr, [Z/H]~+0.67)

Ring: *old stellar population, low metal abundance* ([Mg/Fe] = +0.3, T~15 Gyr, [Z/H]~-1.0)
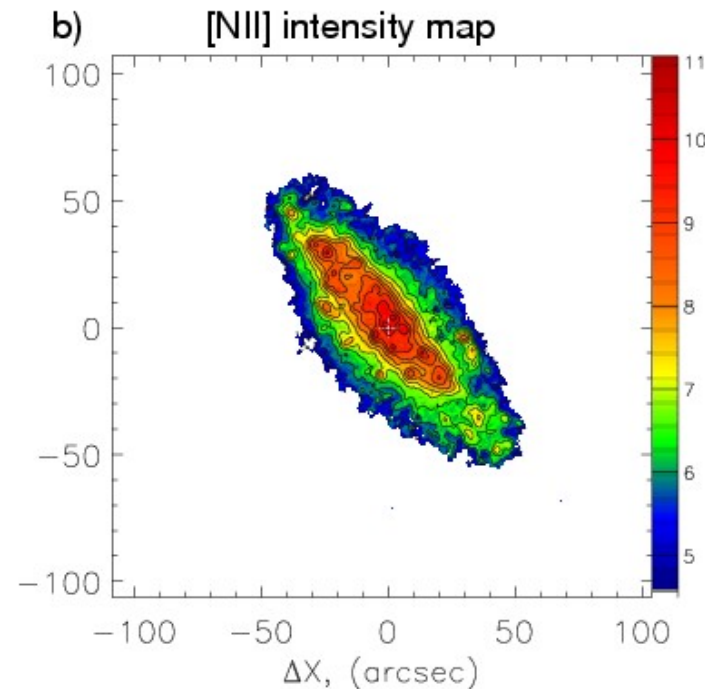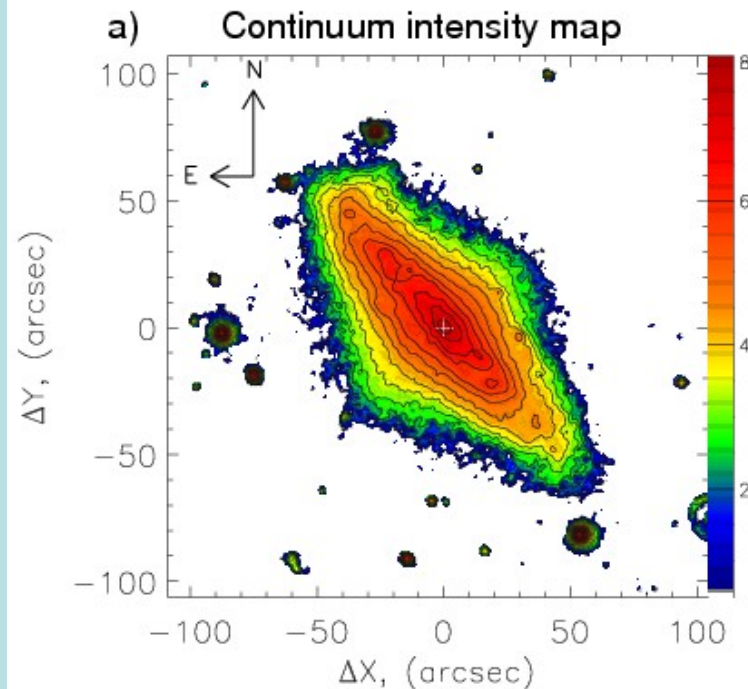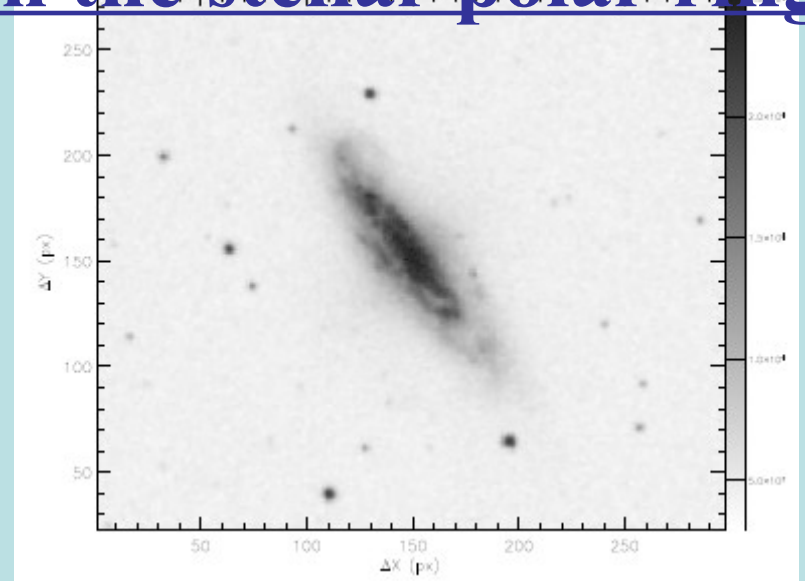
UGC 5119 − elliptical galaxy with the rapidly rotating *disk component* in central region and the *stellar* (probably polar) *ring*
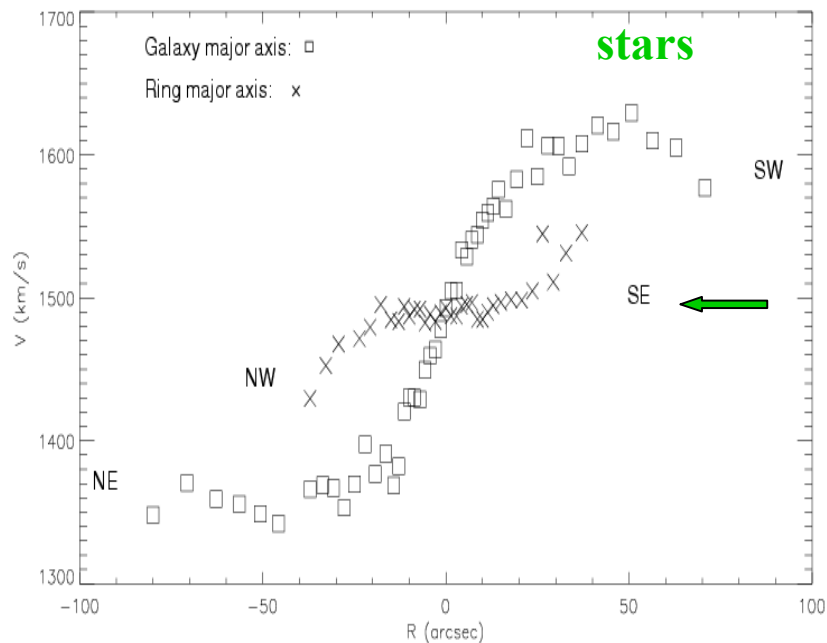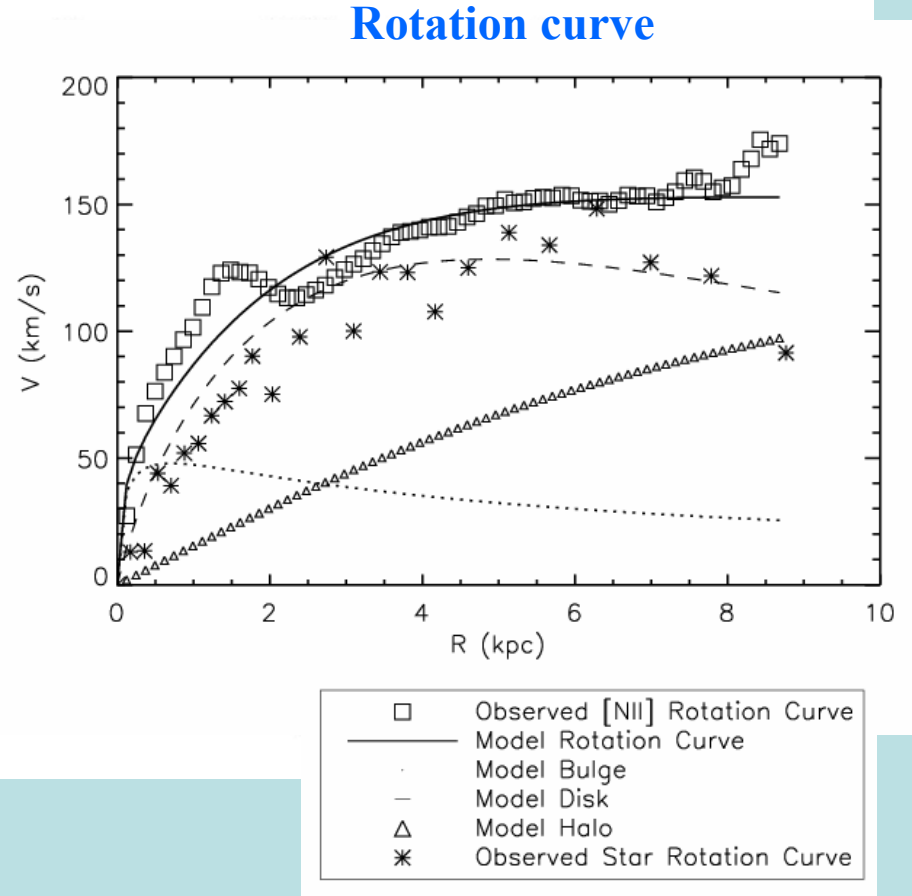
Merkulova et al. (2008)
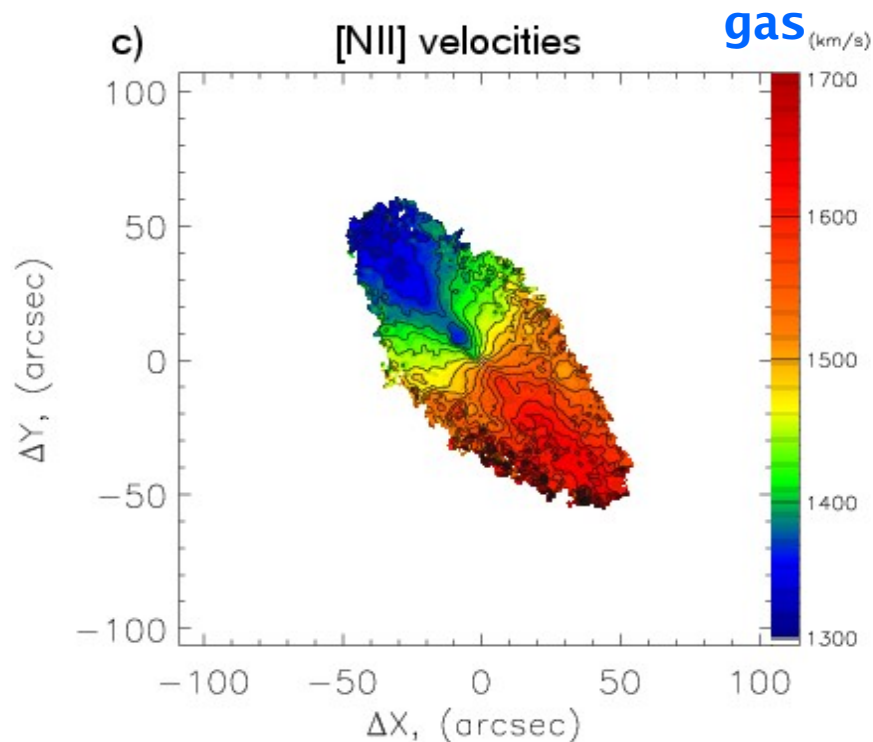
spiral galaxy + **diffuse extensions along minor axis**

The gradient of radial velocities of ionized gas along minor axis
(Reshetnikov & Combes, 1994)

a) Continuum intensity map

b) [NII] intensity map

c) [NII] velocities   gas (km/s)

Rotation curve

□ Observed [NII] Rotation Curve
— Model Rotation Curve
·   Model Bulge
— Model Disk
△ Model Halo
∗ Observed Star Rotation Curve
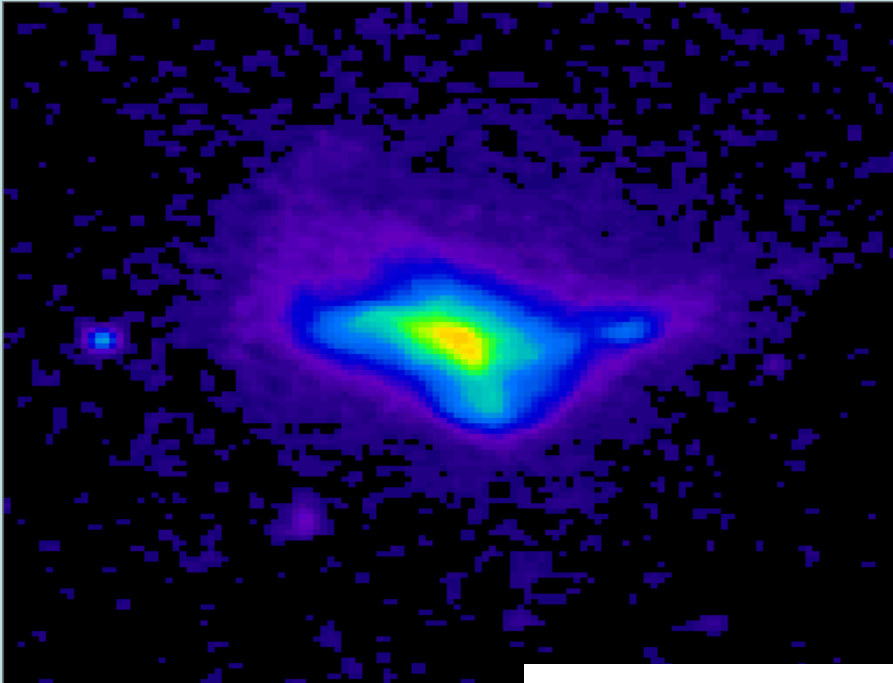
stars

Galaxy major axis: □
Ring major axis: ✕

velocity gradient along the major axis of the ring (at $|R| \geq 20''$)

stellar polar ring?

Merkulova et al. (2009)

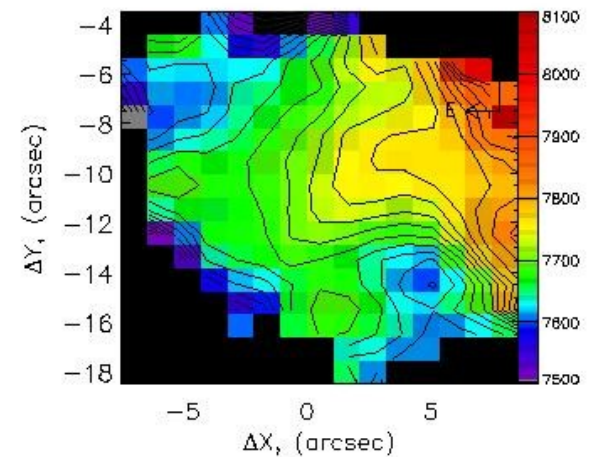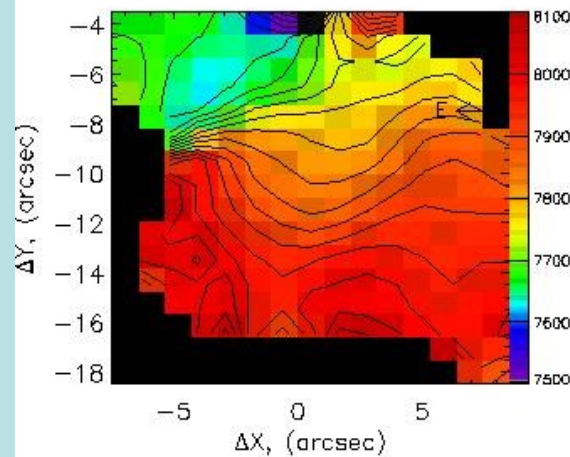# UGC 4892 − interacting galaxies

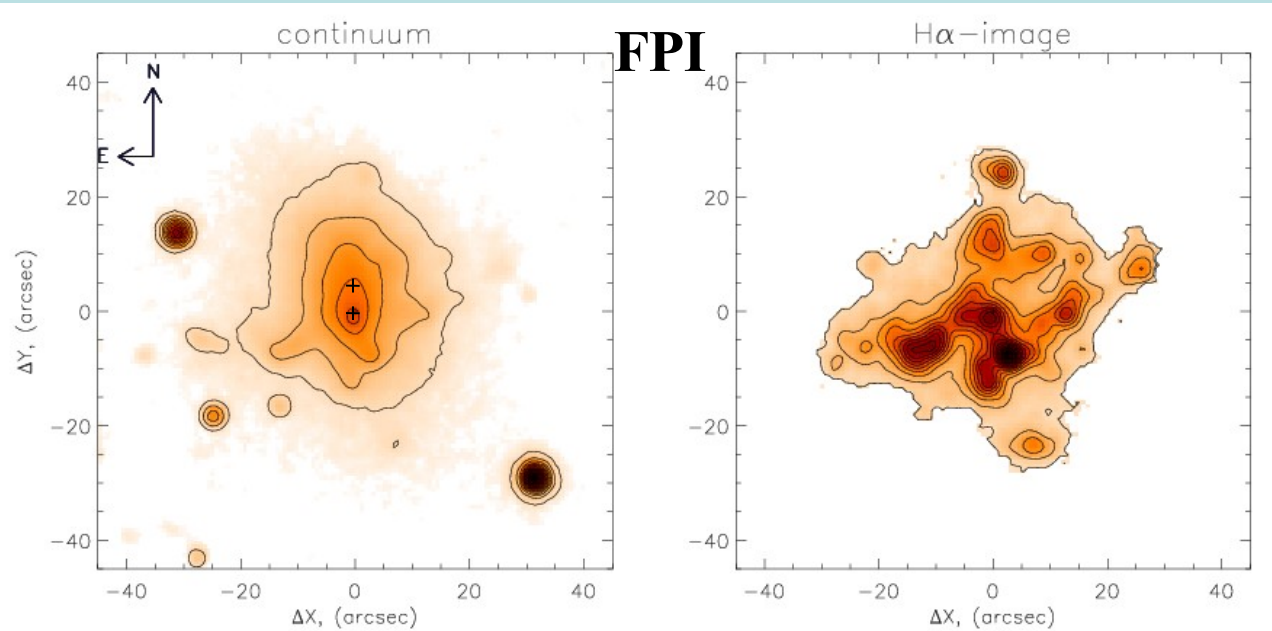
VV593 – group "Nests"

Sbc
V_{sys} **= 7708 km/s**
M_B **= -20^m.7**

Hagen-Thorn et al. (2003)

MPFS

UGC 4385 − interacting galaxies

FPI

continuum

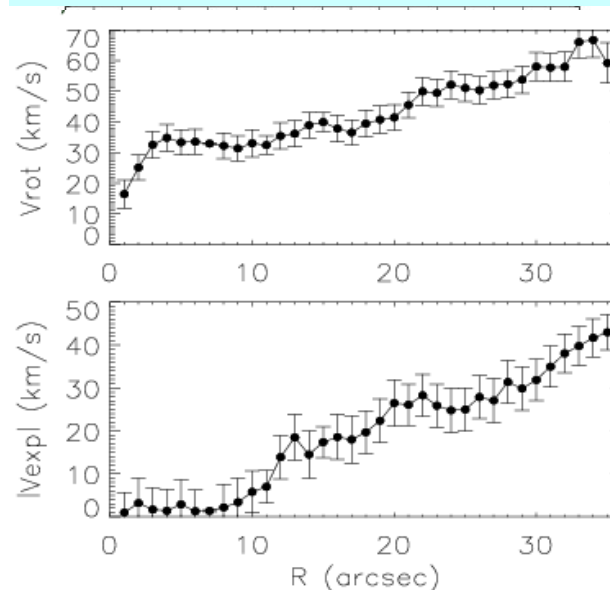Hα−image

A pair of galaxies:

− *spiral galaxy*

− *collision ring galaxy*

Merkulova et al. (2009)

Hα Velocities, km s^{-1}
1860   2063
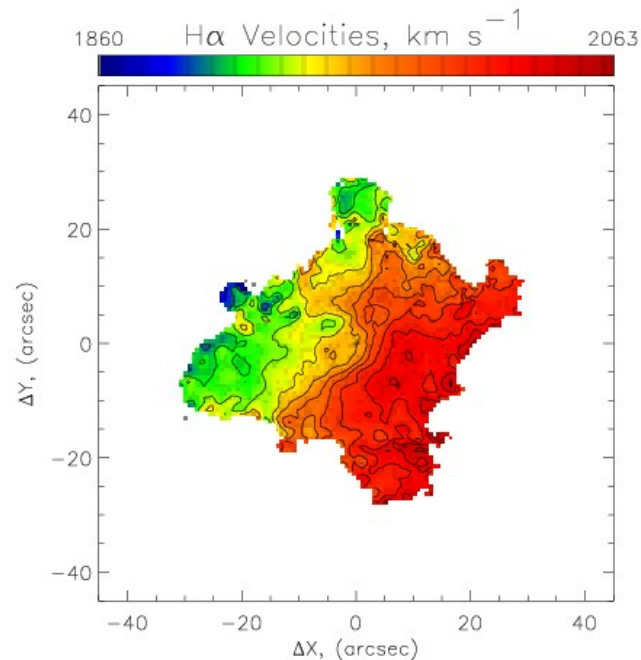
rotation curve of ring/disk

r ≥ 10″:
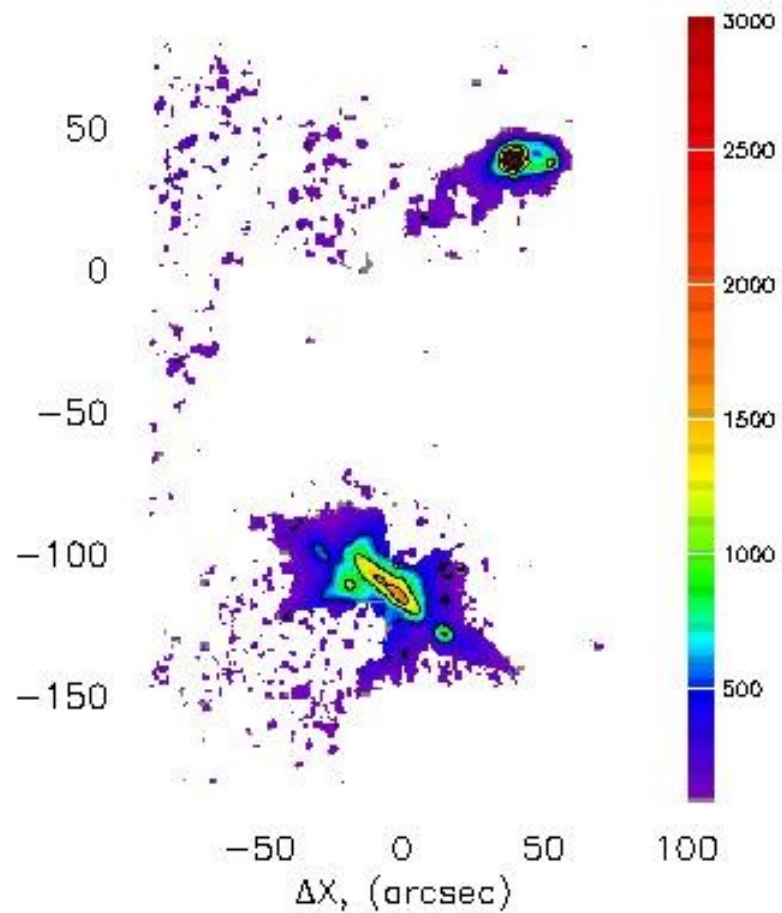V$_{exp}$ ↑ **up to 40 km/s**
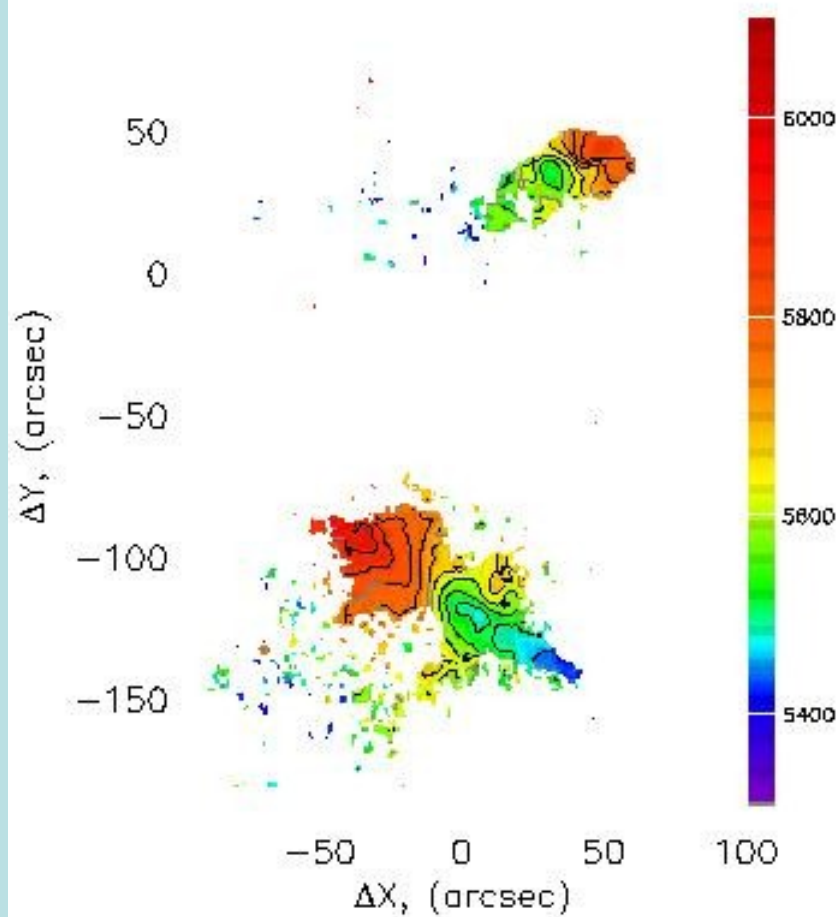**at r = 35″**

NGC 6286 − galaxy with the superwind
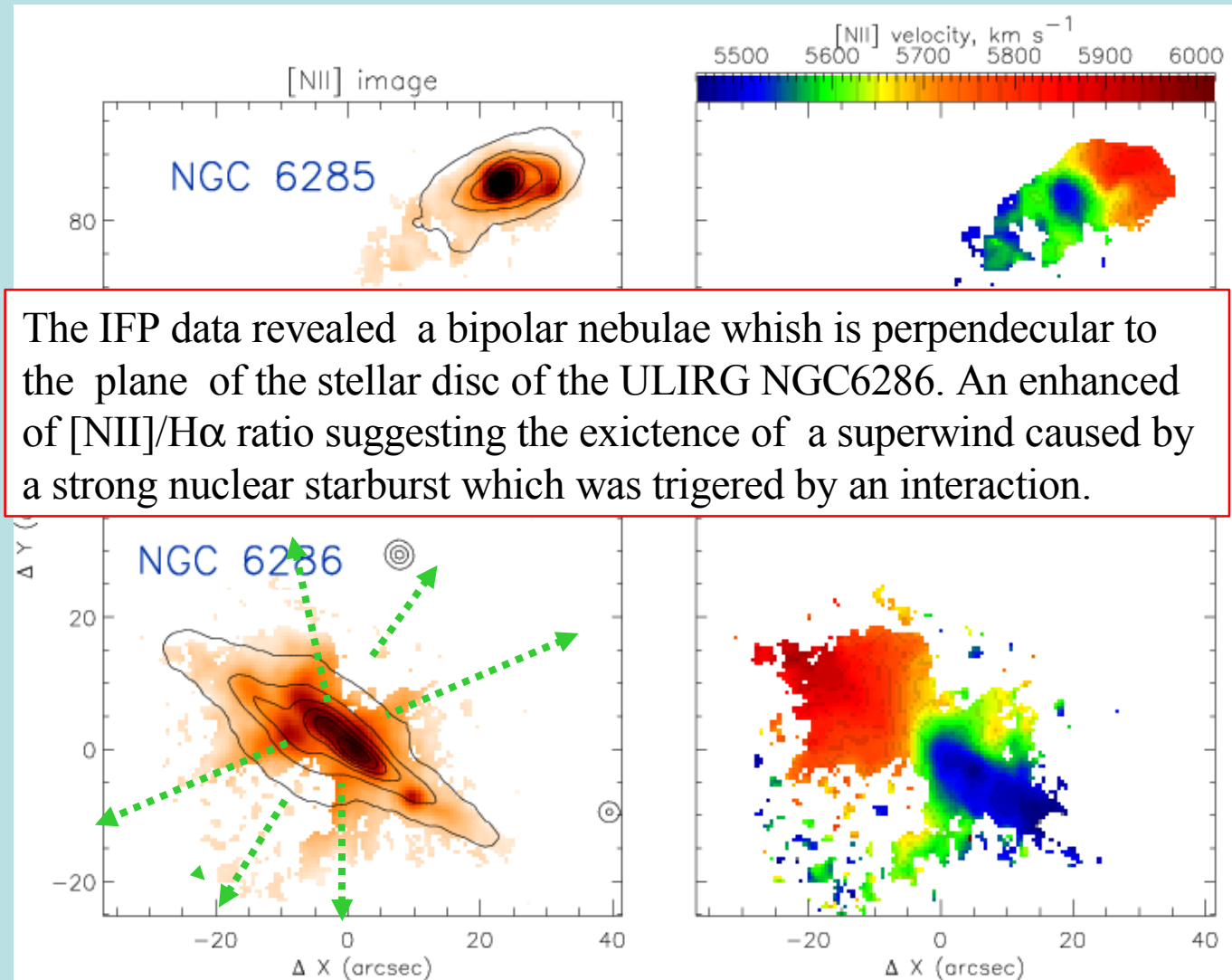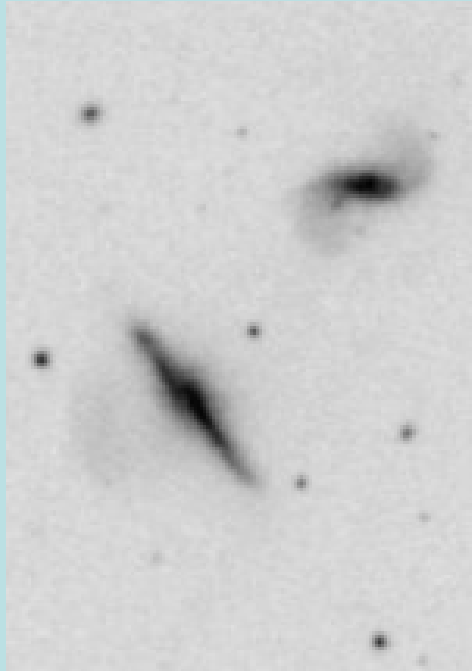
The IFP data revealed a bipolar nebulae whish is perpendecular to the plane of the stellar disc of the ULIRG NGC6286. An enhanced of [NII]/Hα ratio suggesting the exictence of a superwind caused by a strong nuclear starburst which was trigered by an interaction.
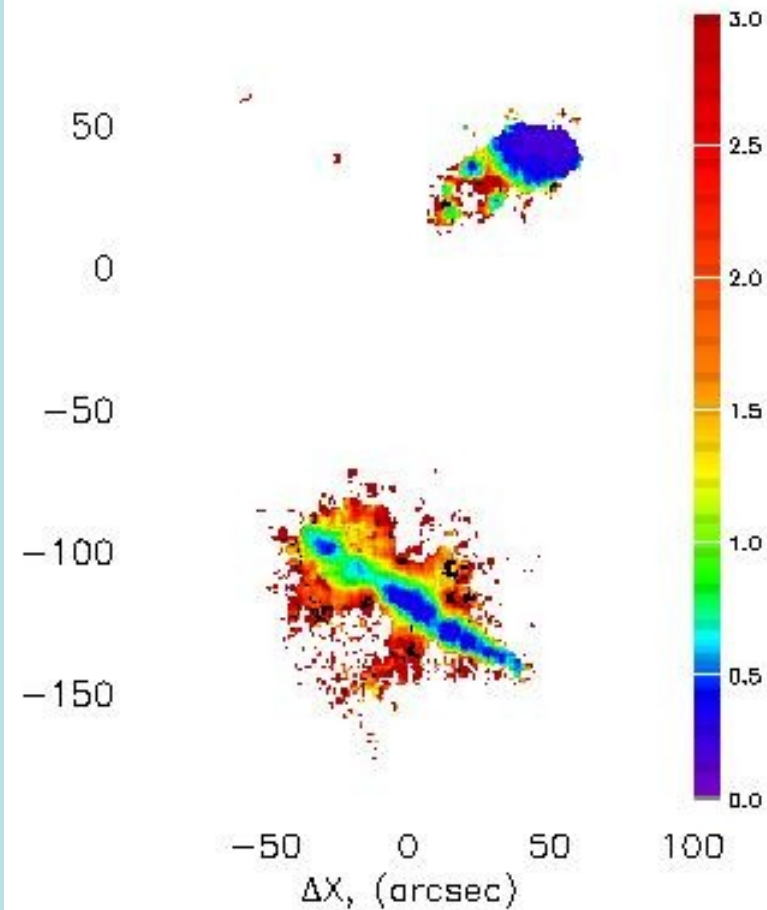
Shalyapina et al. (2004)
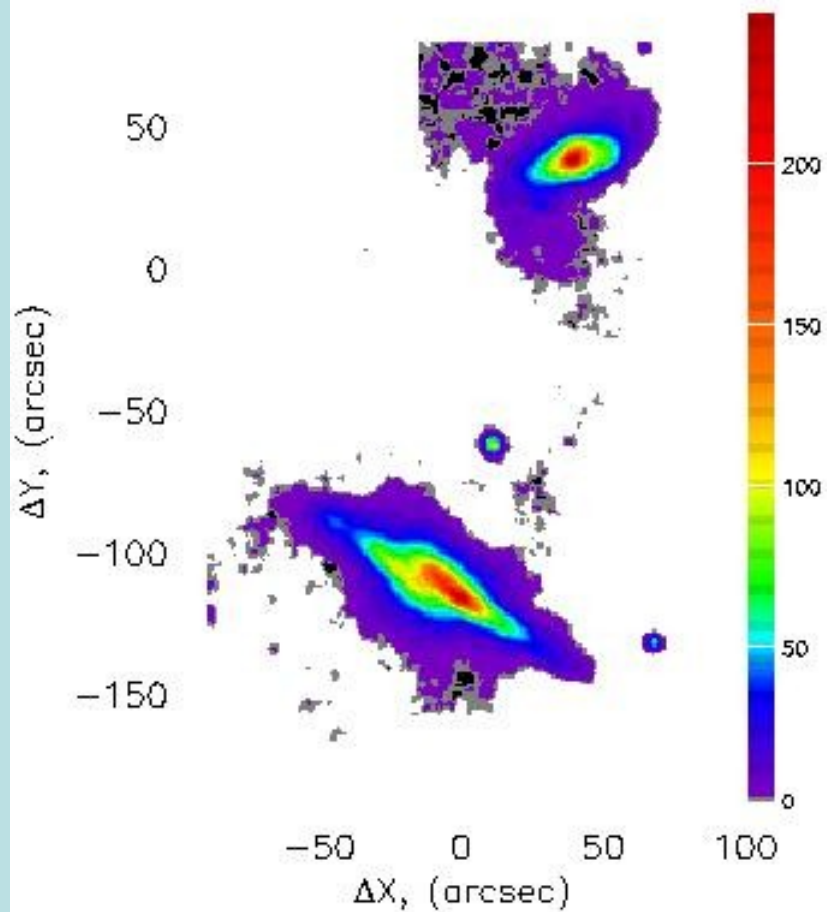
Continuum image

[NII] image

[NII] velocity field   **[NII]/Hα**

Conclusions:

The detailed analysis of the data allowed us to conclude that investigated objects have **complicated multicomponent structure** among which we can distinguish *galaxies with classical polar rings, with circumnuclear polar disks, galaxies with warped gaseous disks and rings* and even *with stellar polar rings*.

Considered objects are in the different environment: some of them are isolated objects, others are the members of the groups but all of them have **peculiar structure** or in *the morphology* or in *the kinematics* or in *both*.

The modern methods of galaxies investigation **allow to get more information** which is necessary for the understanding of *galaxies evolution* on the whole.