The extended gas origin and kinematics in the fading AGN host galaxies

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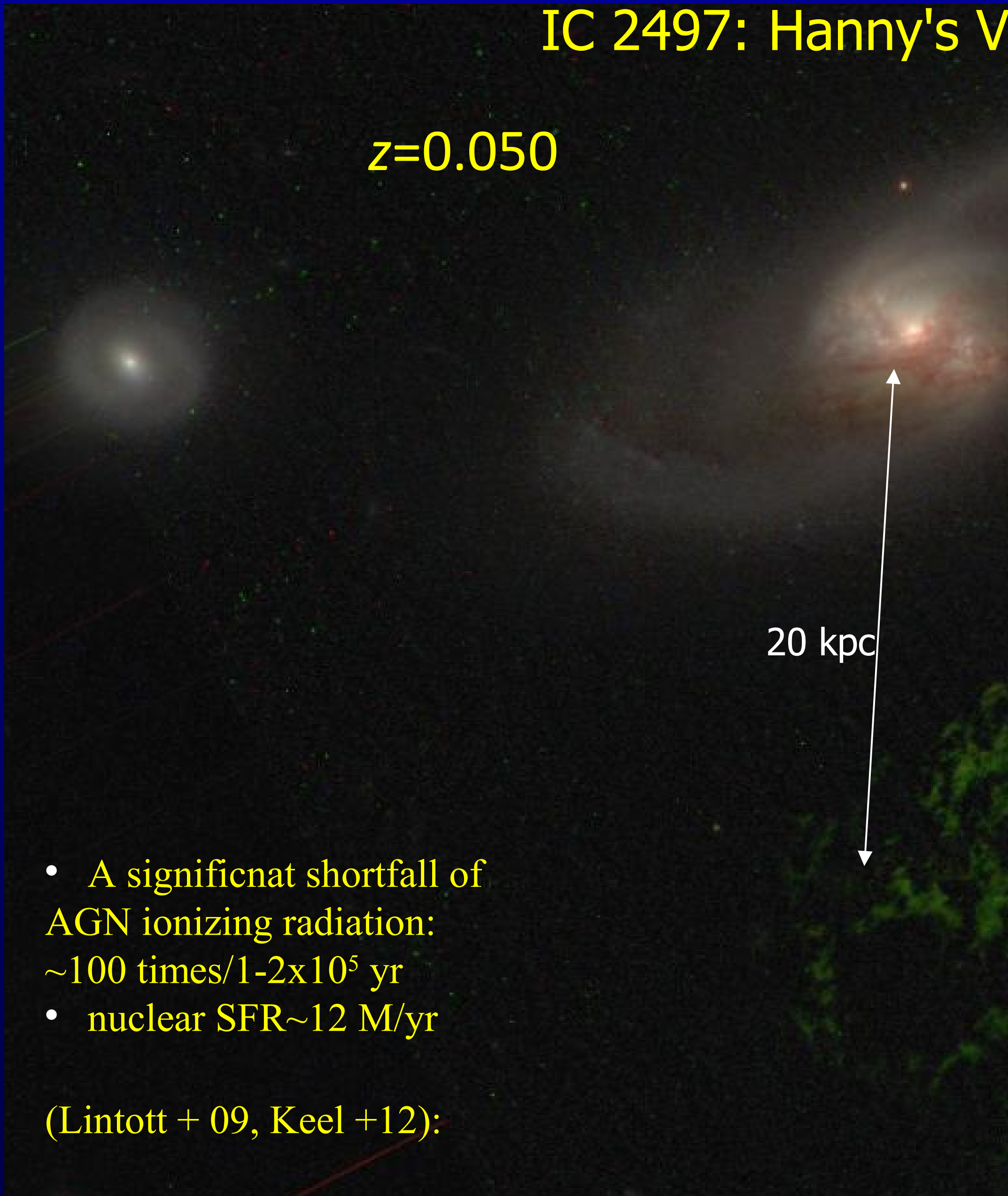
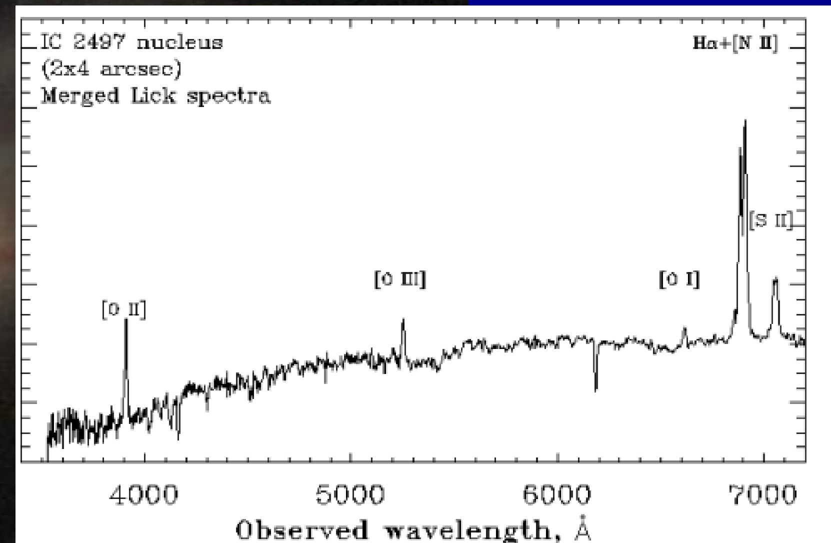
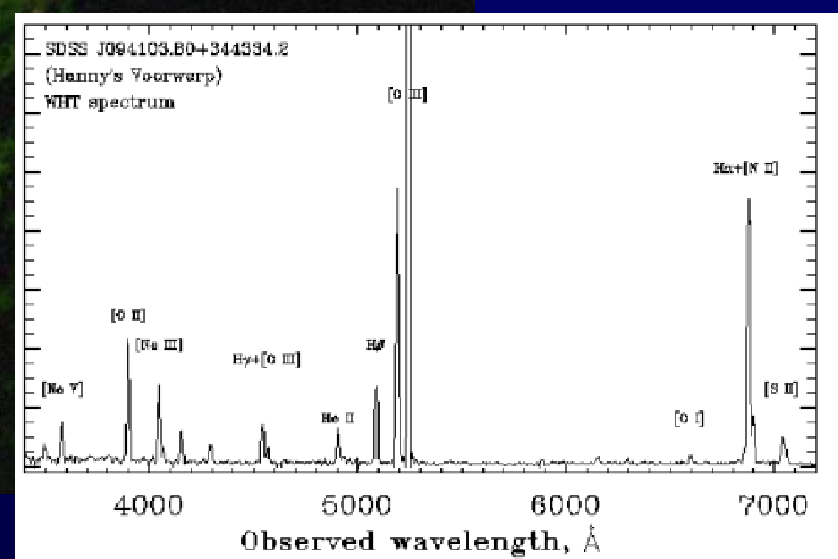
(9) University of California

IC 2497: Hanny's Voorwerp:

z=0.050



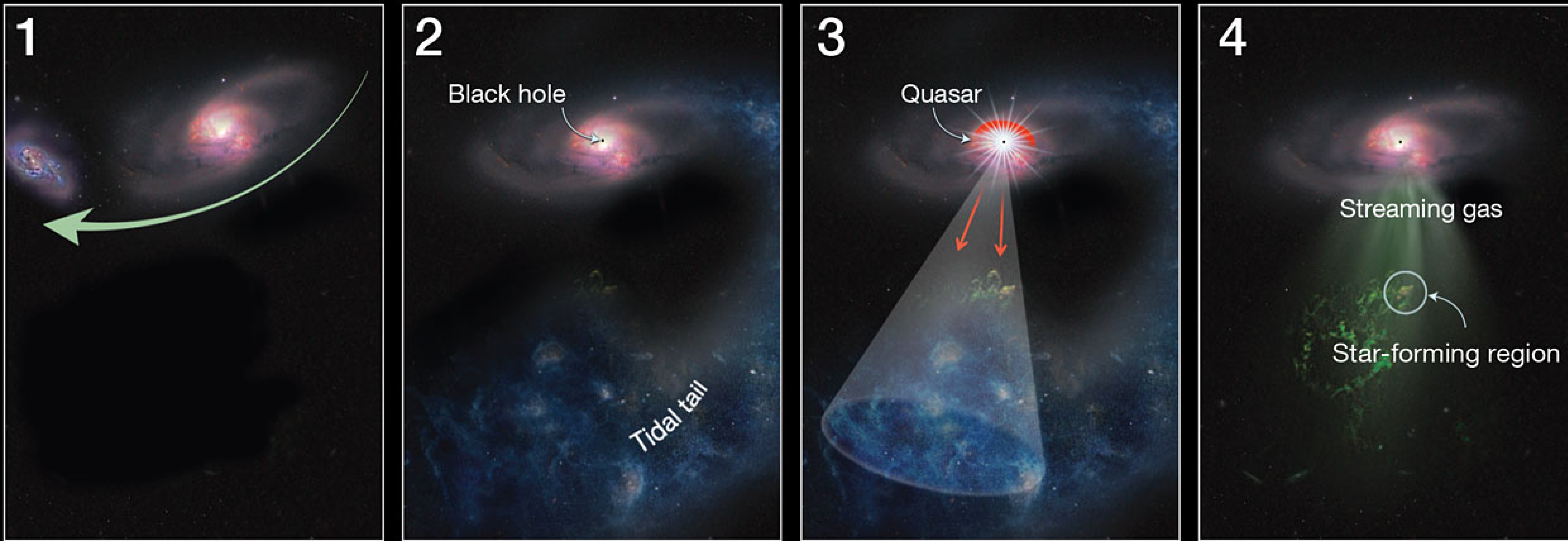




- A significnat shortfall of AGN ionizing radiation: ~100 times/1-2x10^5 yr
- nuclear SFR~12 M/yr

(Lintott + 09, Keel +12):

Hanny's Voorwerp: a space oddity

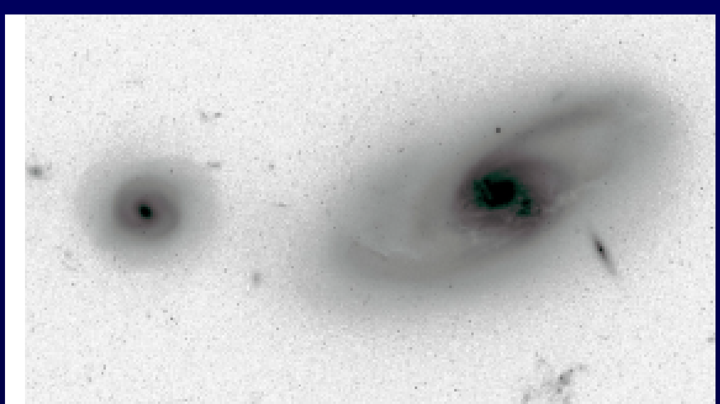


1. Spiral galaxy IC 2497 gravitationally interacts with a bypassing galaxy

2. A large tidal tail of gas is pulled out of the spiral galaxy

3. Engorged with gas, a black hole at the centre of IC 2497 "turns on" as a quasar and emits a powerful cone of light, which ionises a portion of the tidal tail, creating Hanny's Voorwerp

4. Gas streaming out from the galaxy centre impacts the tidal tail and triggers star formation

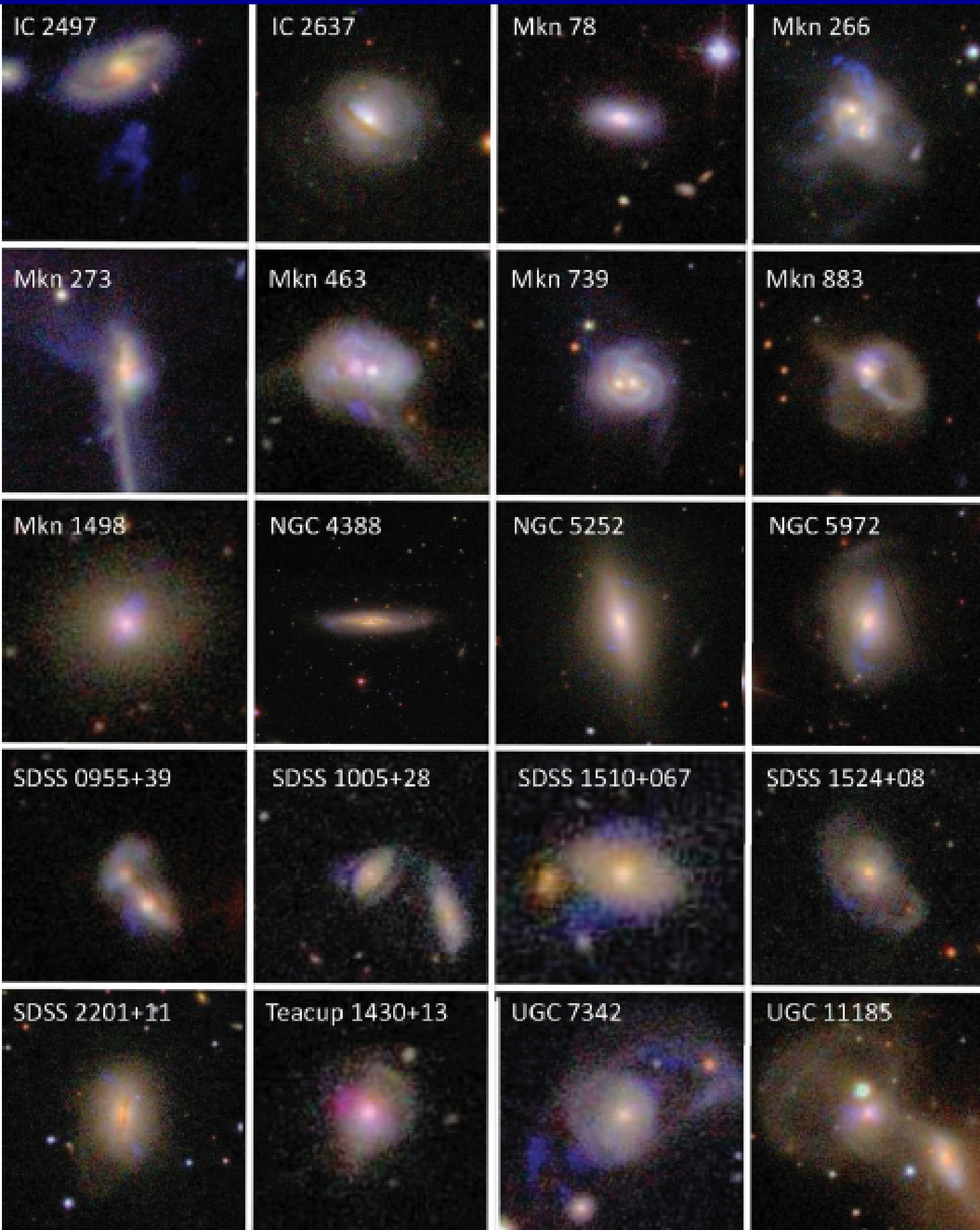


Keel +12:

The companion galaxy has a small Vsys difference from the main galaxy (24 km/s), BUT:

- it seems undisturbed
- too low mass and lumonisity (5.5 times smaller than IC2497) to product ~9x10^{9} M_o HI tidal structure (Jozsa +09) .

New Galaxy Zoo survey (Keel+2012):



A sample of 18116 “potential AGN”, z<0.1

→ 49 galaxies for follow up spectroscopic confirmation (2.1-m KPNO, 3-m Lick)

→ 19 confirmed systems with AGN-ionized gas detected more than 10 kpc from the nucleus

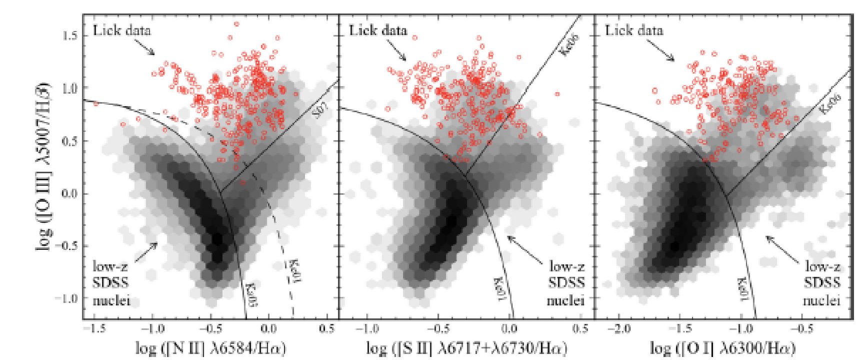
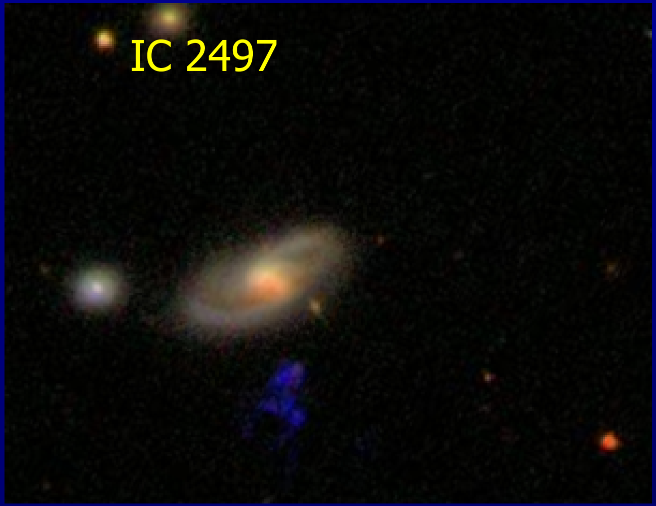
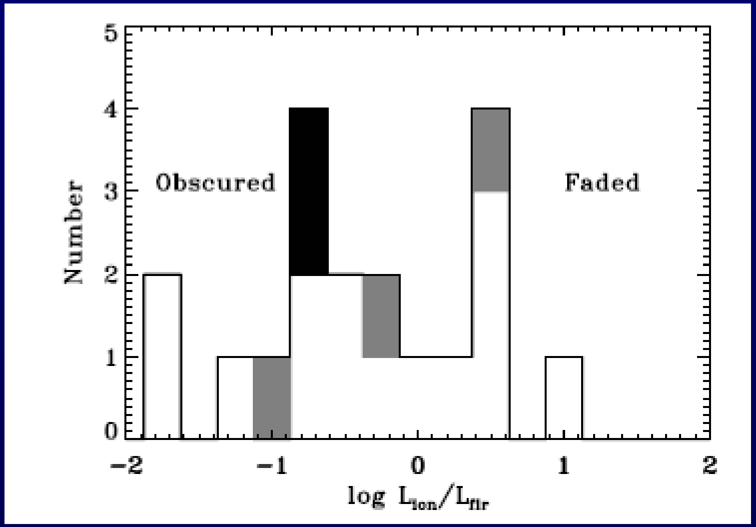


Figure 4. Summary BPT diagrams for the Lick spectra, where we measured the requisite red emission lines. Circles indicate points along the slit for extended clouds classified as AGN-ionized and the host nuclei. Grey-scale background shows the density of points from all low-redshift SDSS galactic nuclei, as in

Energy budget in external clouds

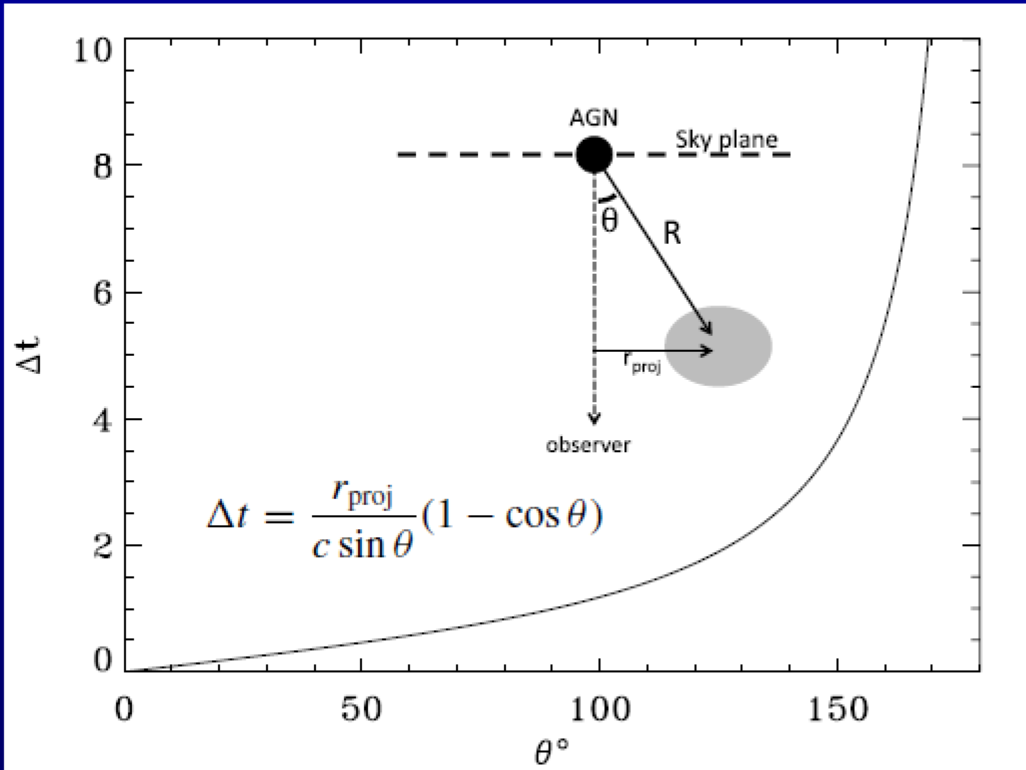




R=10-37 kpc
14/20 — mergers and interacting systems (Keel + 12)
20/20 — including tidal features (Keel + 14)

Gas photoonized(AGN) rather than shocks (jet):
- Te=10 000-20 000 K
- the shock velocities ~400 km/s are needed to produce observed [Ne V] and He II emission

In 7 galaxies:
L(ion)/L(FIR)>1



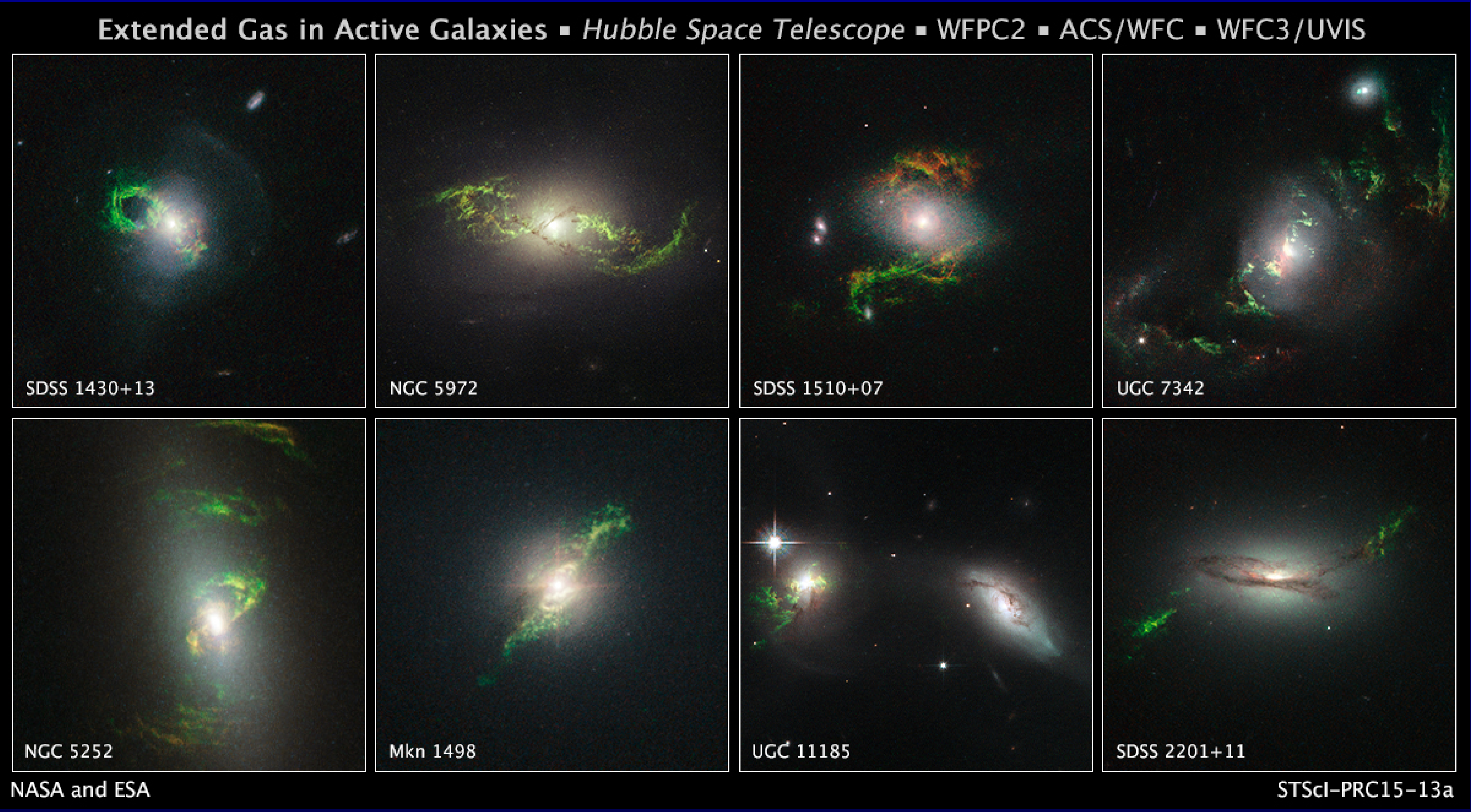
Characteristic time scales:
T(fade)= (20 — 200)x10^3 yr
Dynamical times:
r=40 kpc: ~ 1 Gyr
r=0.5 kpc: ~10 Myr

Galaxy	AGN type	z
Mkn 1498	Sy 1.9	0.0547
NGC 5252	Sy 1.5	0.0228
NGC 5972	Sy 2	0.0297
SDSS 1510+07	Sy 2	0.0458
SDSS 2201+11	Sy 2	0.0296
Teacup AGN	Sy 2	0.0852
UGC 7342	Sy 2	0.0477
UGC 11185	Sy 2	0.0412

The main aim: detalied model of interaction + spatial orientation of gas clouds

- HST: imaging and long-slit spectroscopy
- Ground-based long-slit spectroscopy: ionization state, chemical abundance
- 3D spectroscopy: ionized gas kinematics
- X-ray, HI ?

HST/WFC3, ACS: continuum vs [OIII]

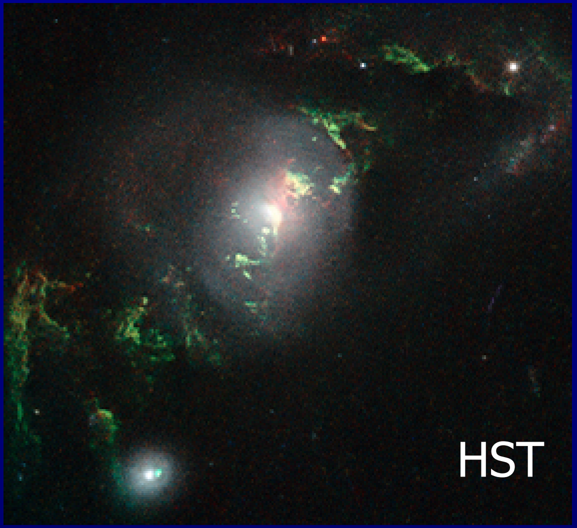


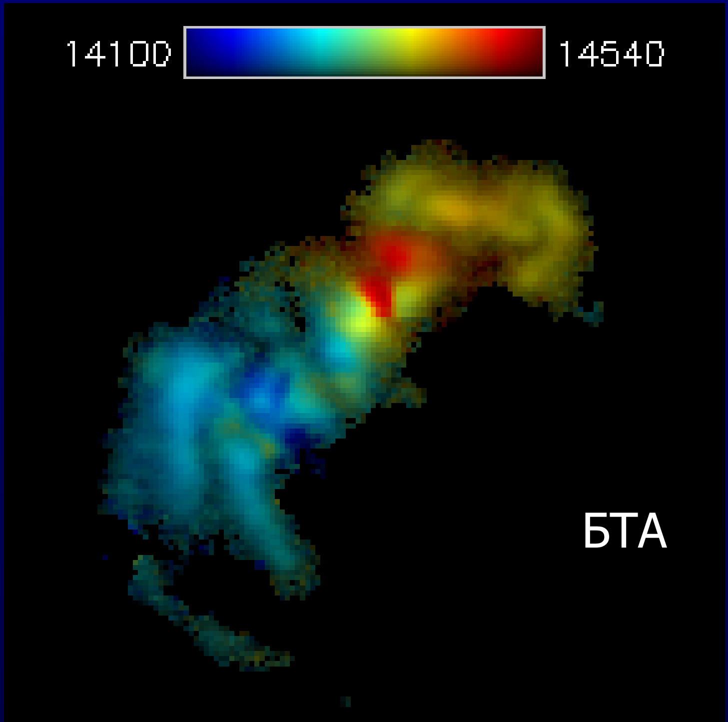
News Release Number: STScI-2015-13

6-m telescope BTA: scanning Fabry-Perot interferometer (FPI)

SCORPIO-2 (Afanasiev & Moiseev 2011)

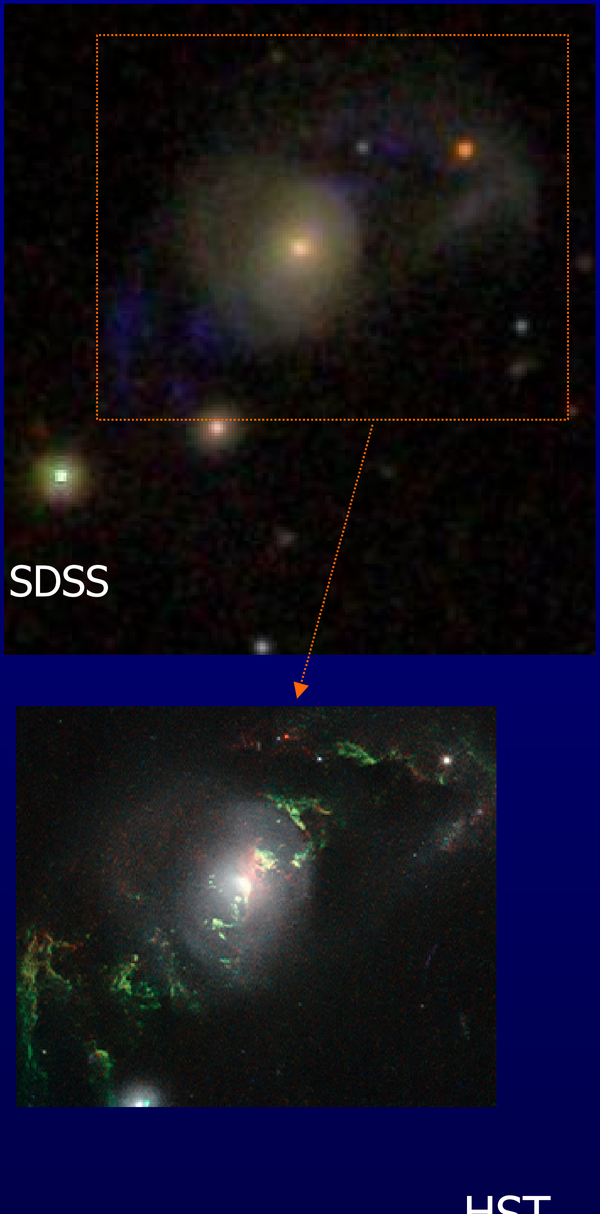
Data cubes in [OIII] 5007
Spectral resolution ~2 Å (120 km/s)
Seeing limited ang. Resolution: 1.5-2 "

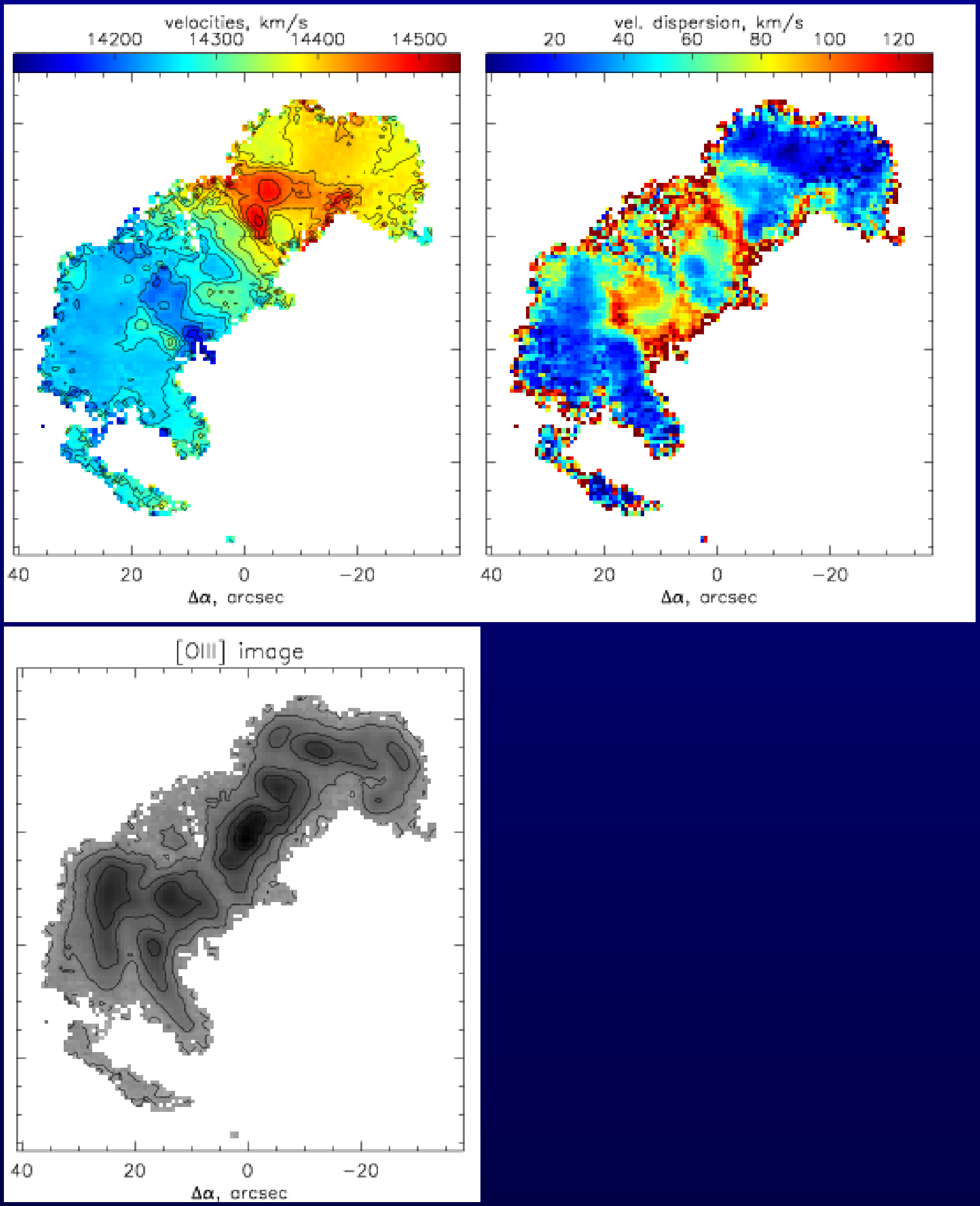




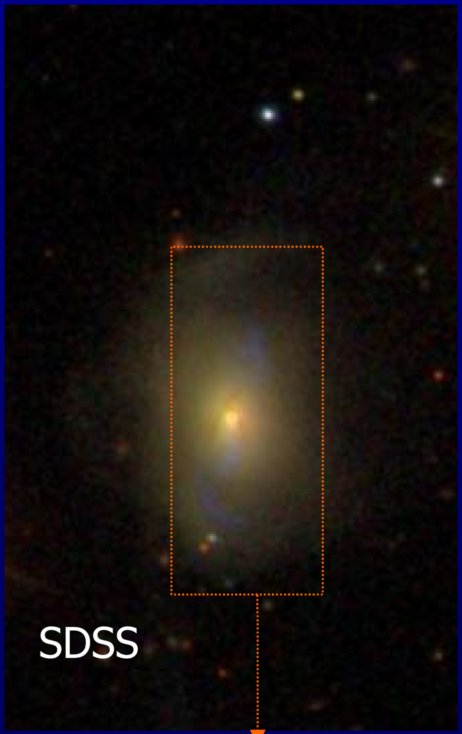
http://www.sao.ru

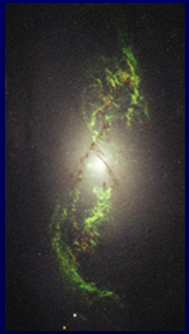
UGC 7342

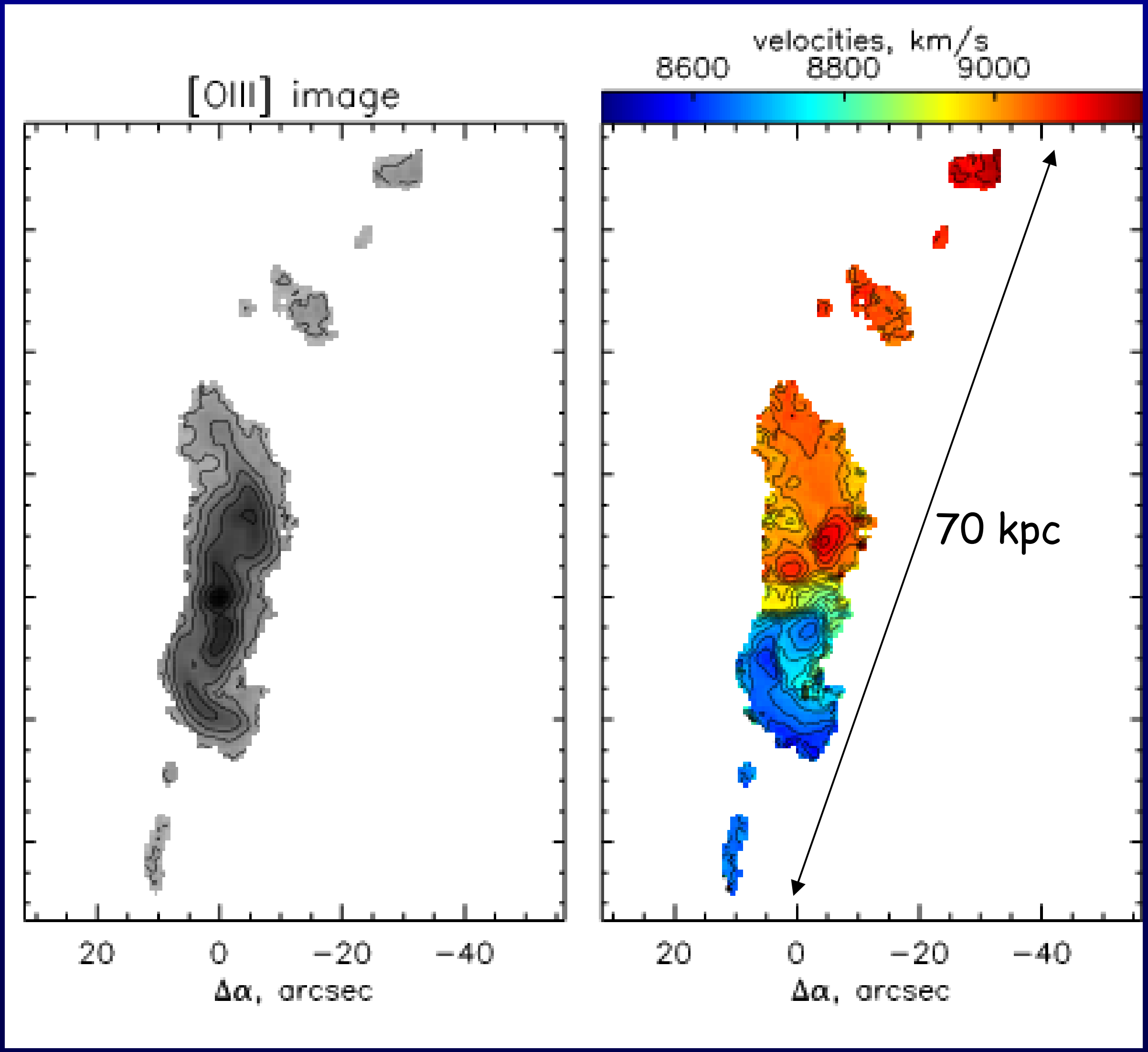

SDSS
HST


velocities, km/s
14200
14300
14400
14500
vel. dispersion, km/s
20
40
60
80
100
120
40
20
0
−20
Δα, arcsec
[OIII] image

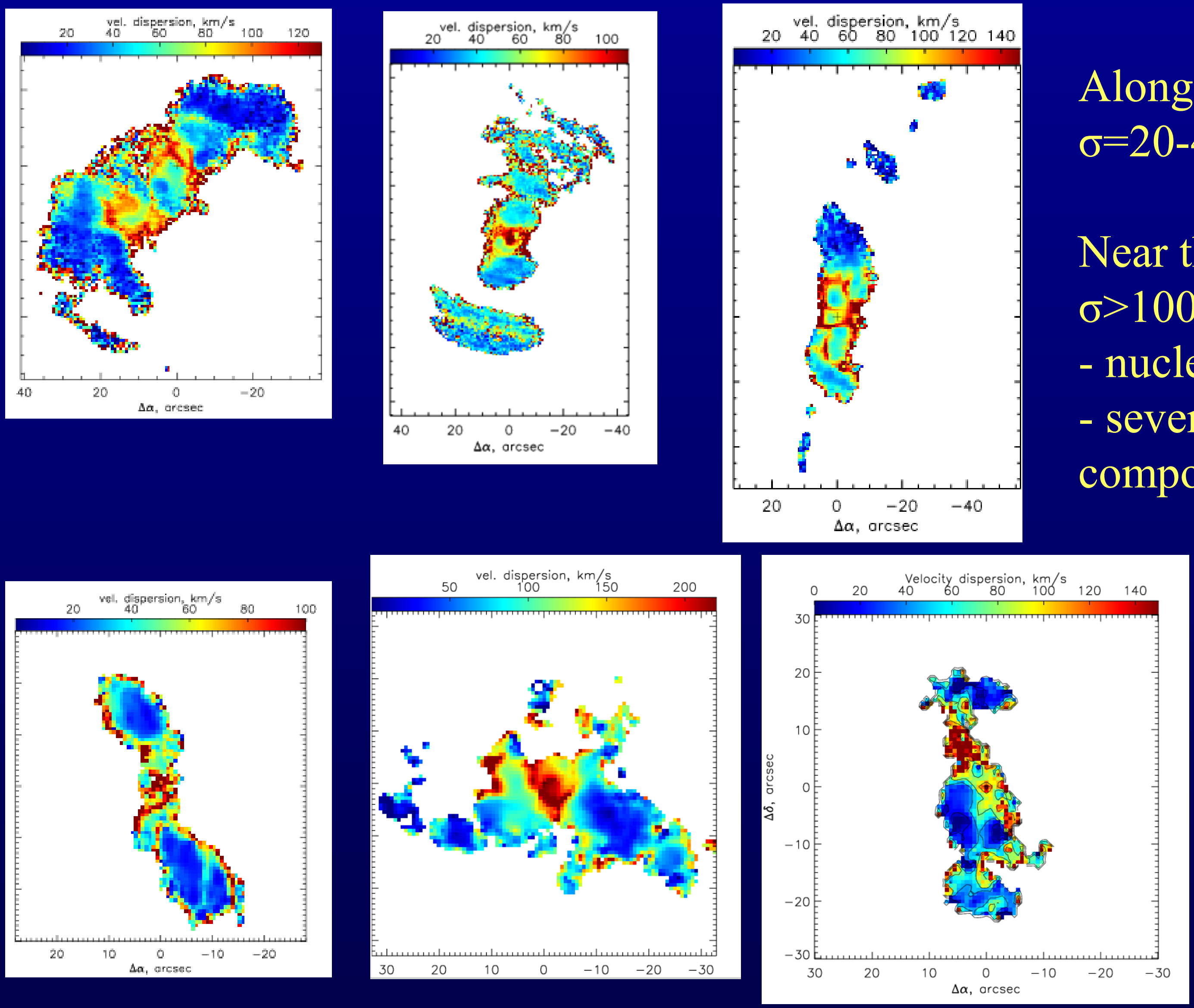
NGC 5972: the distant filaments







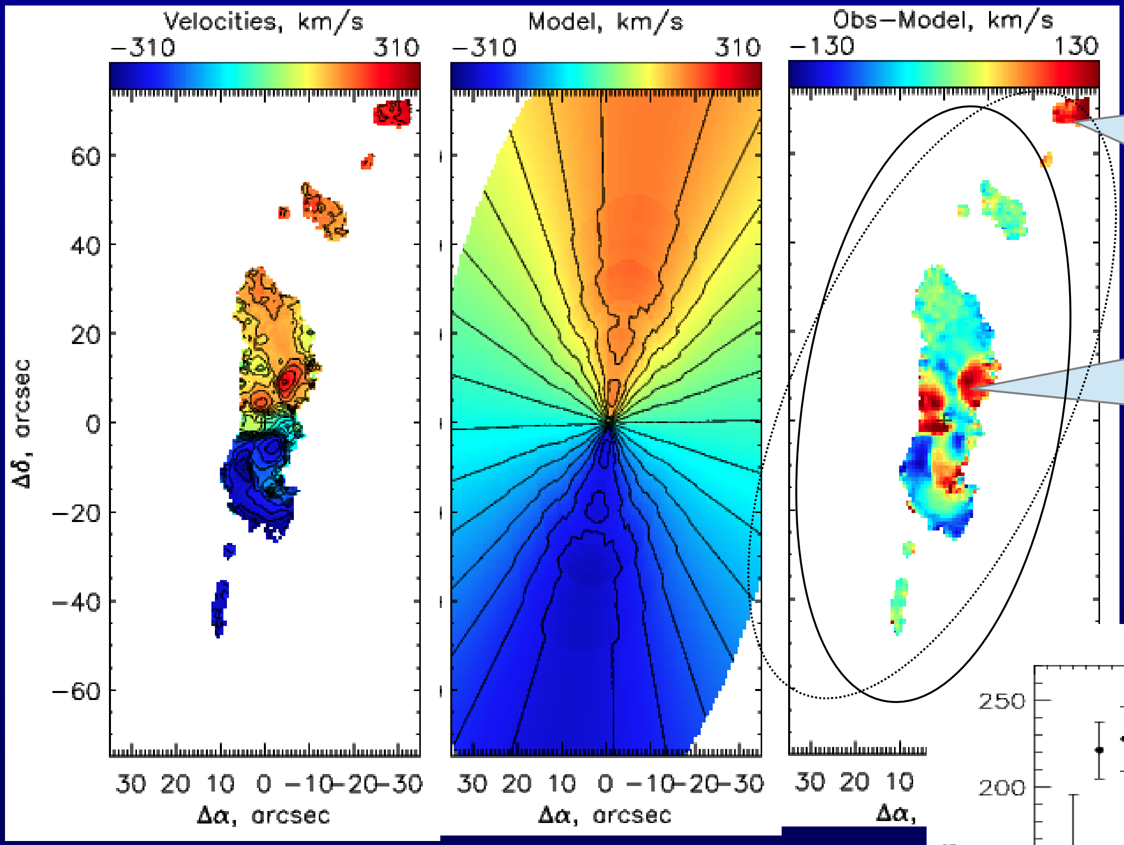
Rotation-supported kinematics: low gas velocity dispersion



Along filaments:
σ=20-40 km/s

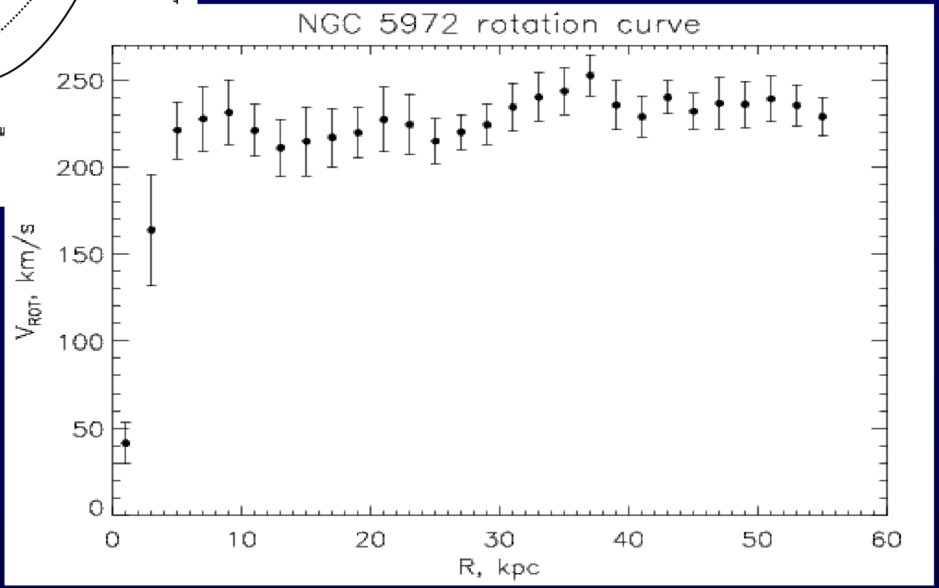
Near the AGN
σ>100 km/s:
- nuclear jet/outflow
- several line-of-sight components

Rotation-supported kinematics: gas follows circular orbits



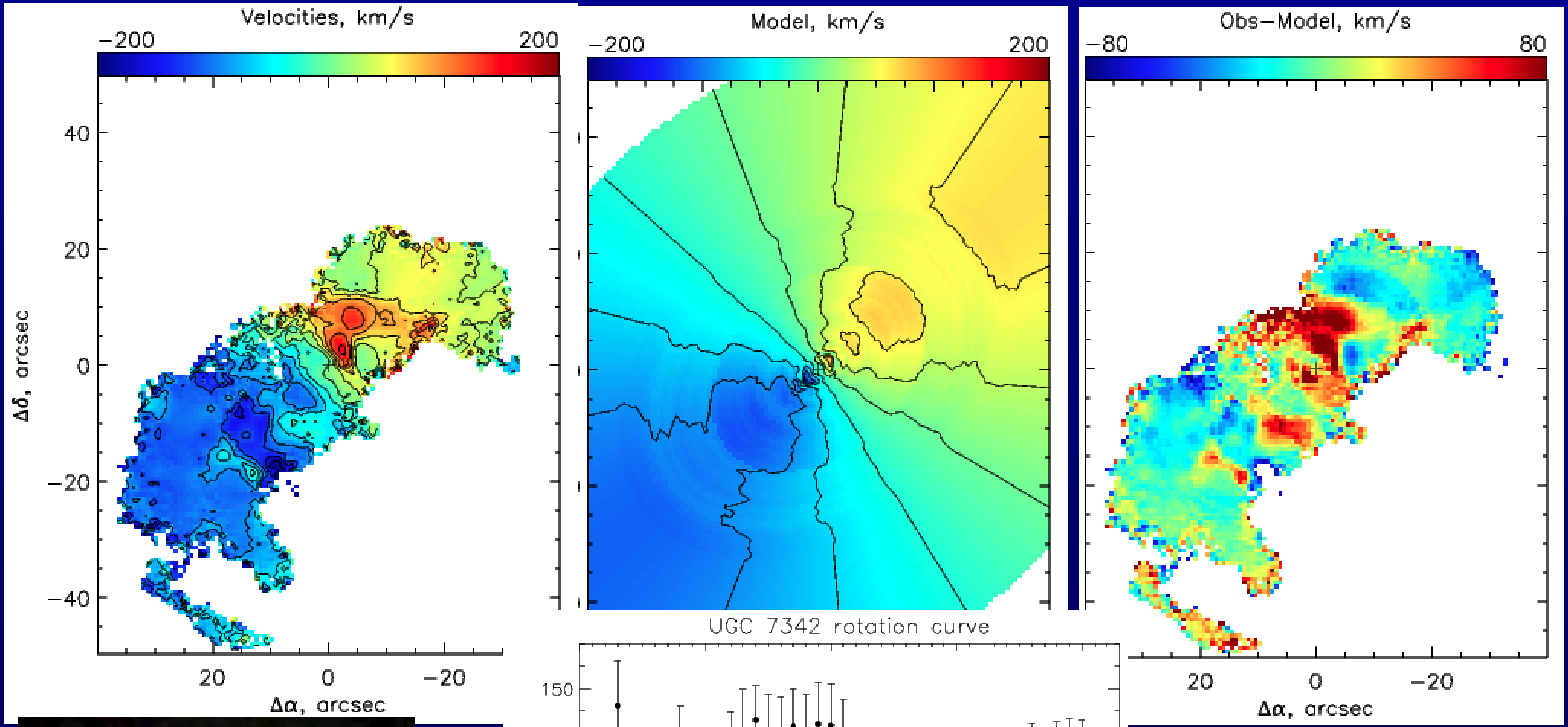
Vres=+80 km/s
or~20 km/s
for modest warp ΔPA=15-20°

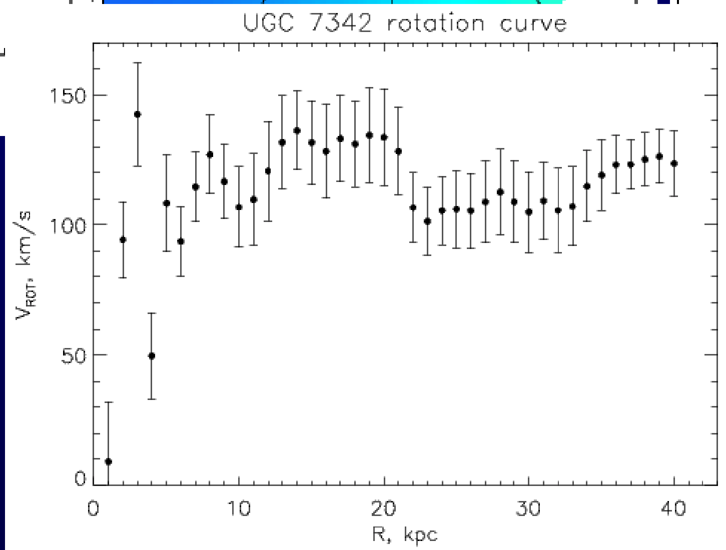
Near the nucleus:
Vres=±150 km/s
(outflow?)



Residual velocities from tiilted-rings model of circular rotating disc
Vres=±10-20 km/s

Rotation-supported kinematics: UGC 7342





Differentially precessing discs of accreted matter

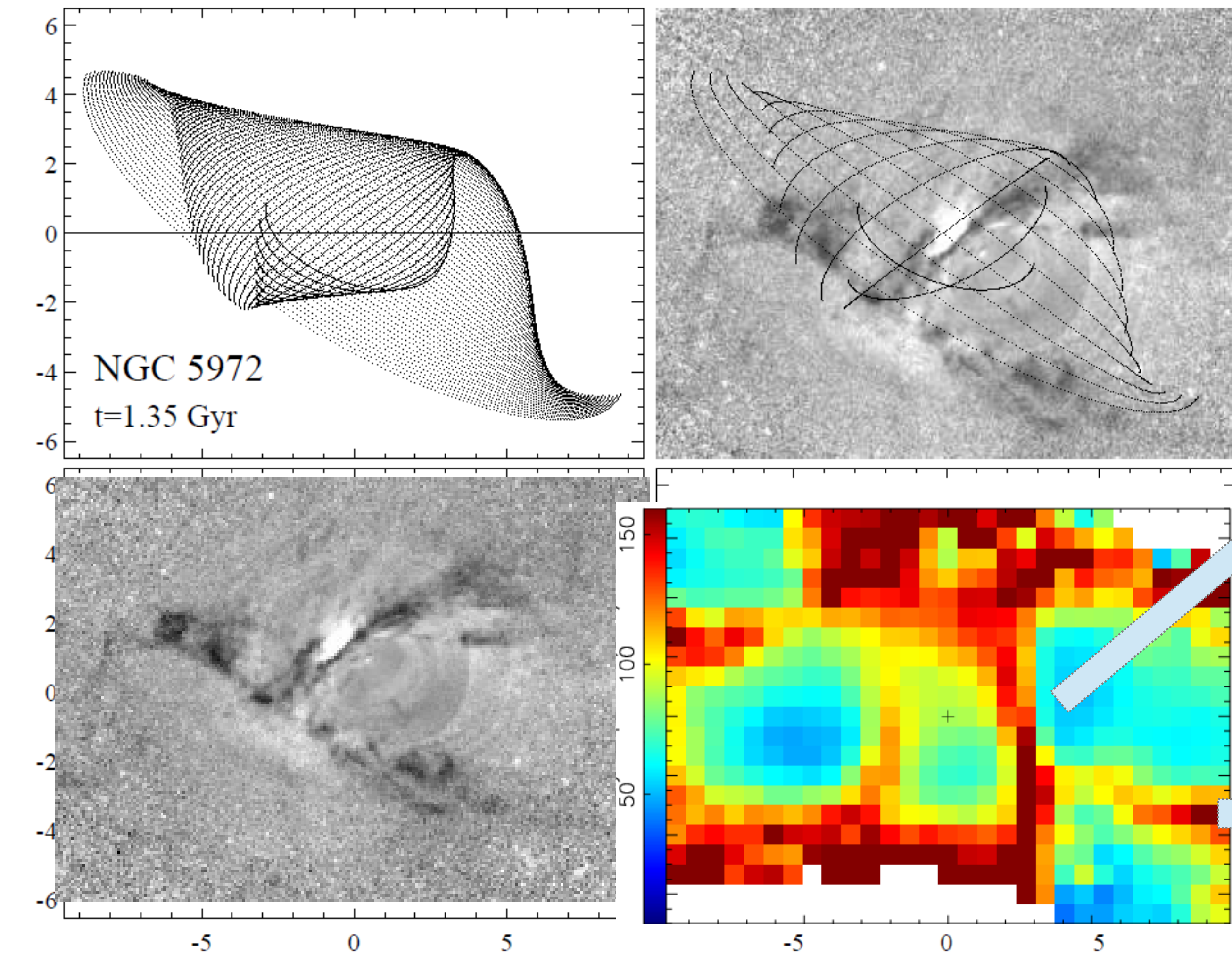
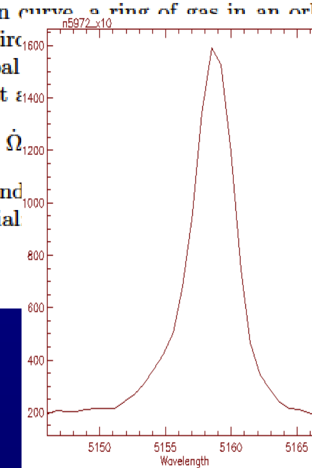


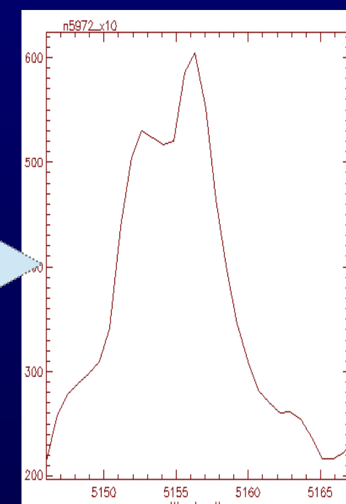
Fig. 8.— Schematic precessing-disk model for dust in NGC 5972. These are edge-on views at a time 1.35 Gyr after introduction of an annulus of material inclined by $i = 33°$ to the principal plane of the host galaxy, a timestep which captures three important dust locations in the images. In comparison to images of NGC

by Steiman-Cameron et al. (1992). Using their scale-free logarithmic potential model with a flat rotation curve, a ring of gas in an orbit of radius r at circ… on i to the principal … well, will precess at a …

$\dot{\Omega}$ … (1)

where η depend… tri-axial) potential … (2).





SUMMARY

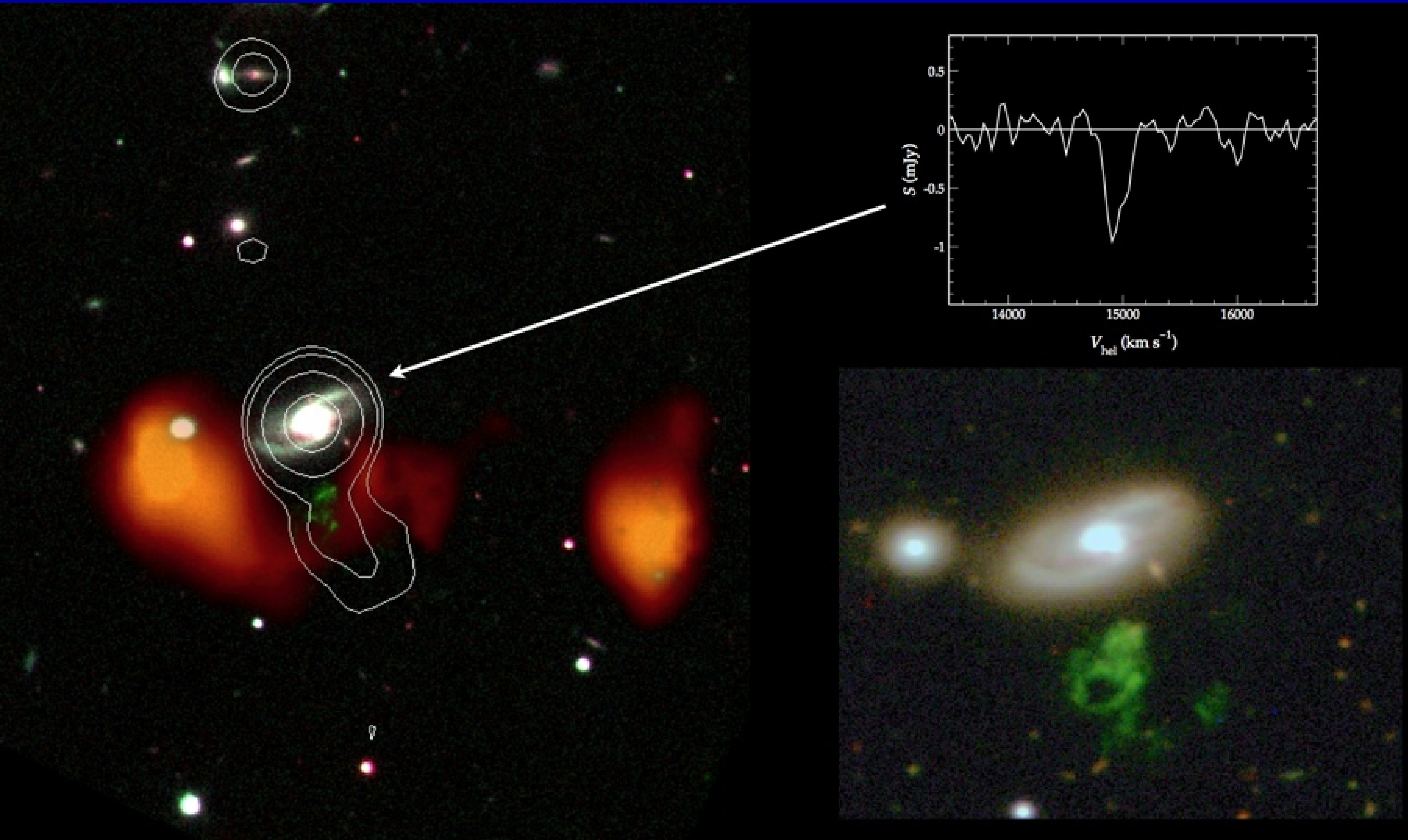
The [OIII] emission line kinematics on the distances 10-40 kpc from the nucleus was studied in the sample of galaxies identified fading nuclear activity (on 50-100 000 yr time scale). In contrast to clouds near radio-loud AGN, our 3D spectroscopic with scanning FPI has shown:

- The considered structures are dominated by circular rotation:
  - Low velocity dispersion (except some circumnuclear regions with AGN)
  - Velocities in a good agreement with a mean rotation curve
- However, the rotation plane is not always match with host galaxies stellar discs:
  - extrenal warps
  - inner warp (1.5-2.5 Gyr time scale)

The observed picture is consistent with a tidal origin for the extended gas in most systems

THANK YOU FOR YOUR ATTENTION!

See the last results in Keel et al. 2015, AJ, 149, 155



WSRT (Garrett et al. 2009): $9x10^9$ M_o H I arc

[O/H] measurements (long-slit data)

Galaxy	Location	[O III]/Hβ	[N II]/Hα	[S II]/Hα	[O I]/Hα	Abund1
NGC 5972	Nucleus	10.2	0.94	0.60	0.075	8.69
BTA	8-22″ N	10.87	1.01	0.59	0.119	8.69
	46-55″ N	13.38	0.77	...	...	8.70
	2-11″ S	9.28	0.99	0.55	0.095	8.66
	16-22″ S	12.77	0.79	0.47	0.052	8.71
UGC 7342	Nucleus	10.85	0.73	0.62	0.083	8.63
BTA	8-16″ NW	14.45	0.26	0.27	0.055	8.54
	18-26″ NW	15.91	0.45	0.31	0.108	8.68
	11-21″ SE	12.30	0.25	0.29	0.039	8.48
	23-30″ SE	13.6	0.26	0.31	0.069	8.48
SDSS 2201	Nucleus	2.67	1.34	0.83	0.133	8.67
BTA	14-20″ S	9.04	0.42	0.27	0.049	8.52
	10-19″ N	12.22	0.38	0.26	0.048	8.52
UGC 11185	Nucleus	9.32	1.66	0.80	0.170	8.78
BTA	4-7″ E	9.56	1.45	0.75	...	8.77
	5-14″ W	5.95	1.41	0.83	0.115	8.72
Mkn 1498	Nucleus	4.95	1.33	0.22	0.07	8.67
2012 data	cloud	16.35	0.19	0.20	0.06	8.57
NGC 5972	Nucleus	3.40	0.92	0.49	0.07	8.57
2012 data	cloud	11.3	1.04	0.61	0.12	8.72
SDSS 2201	Nucleus	7.28	1.61	1.02	0.17	8.77
2012 data	cloud	13.4	0.53	0.35	0.07	8.59
Teacup	Nucleus	10.57	0.31	0.15	0.15	8.44
2012 data	cloud	10.73	0.45	0.36	0.11	8.52
UGC 11185	Nucleus	11.82	1.71	0.88	0.19	8.89
2012 data	cloud	10.78	1.46	0.72	0.07	8.80

the nucleus

the filaments

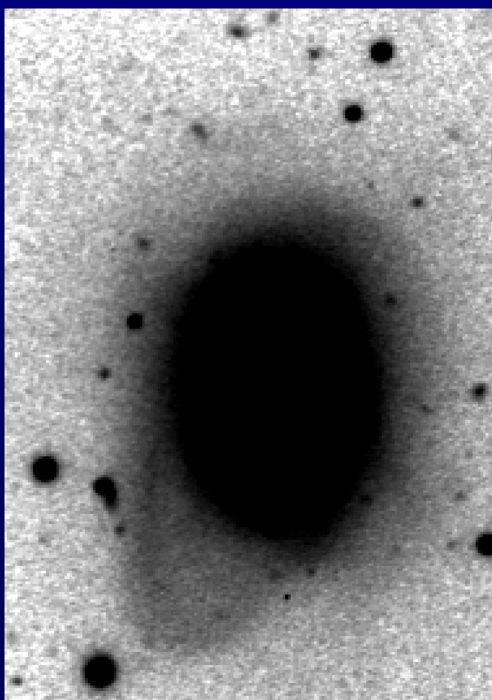
Model grids: Storchi-Bergmann et al 1998

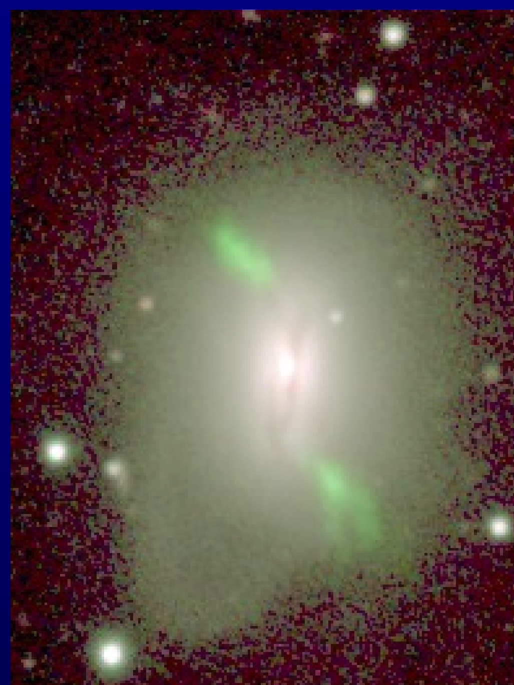
Z=0.5-0.8 Z(sun).

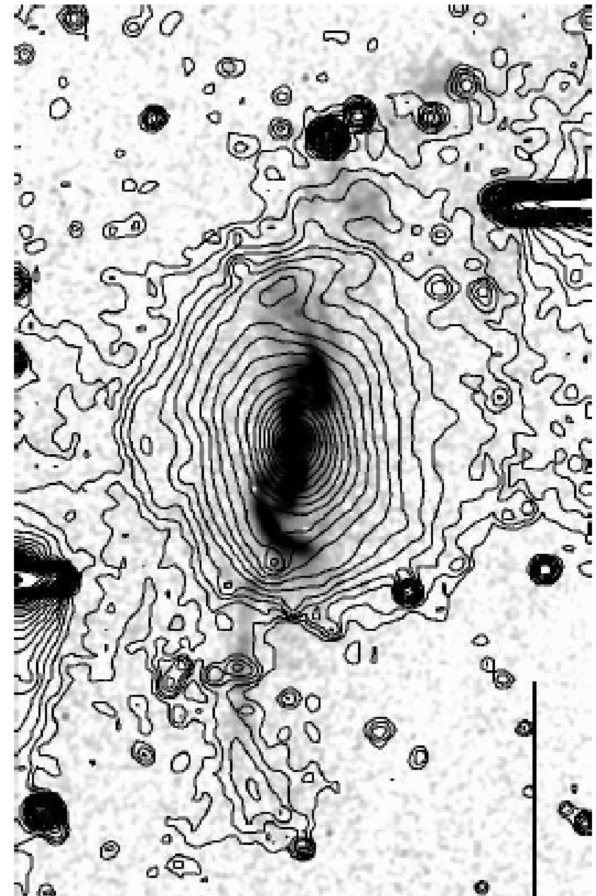
In the most of galaxies a mettaliciti in nucleus is larger on 0.1-0.2 dex than [O/H] in external filaments

Tidal structures: gas vs. stars

SDSS 2201+11 (6-m telescope)



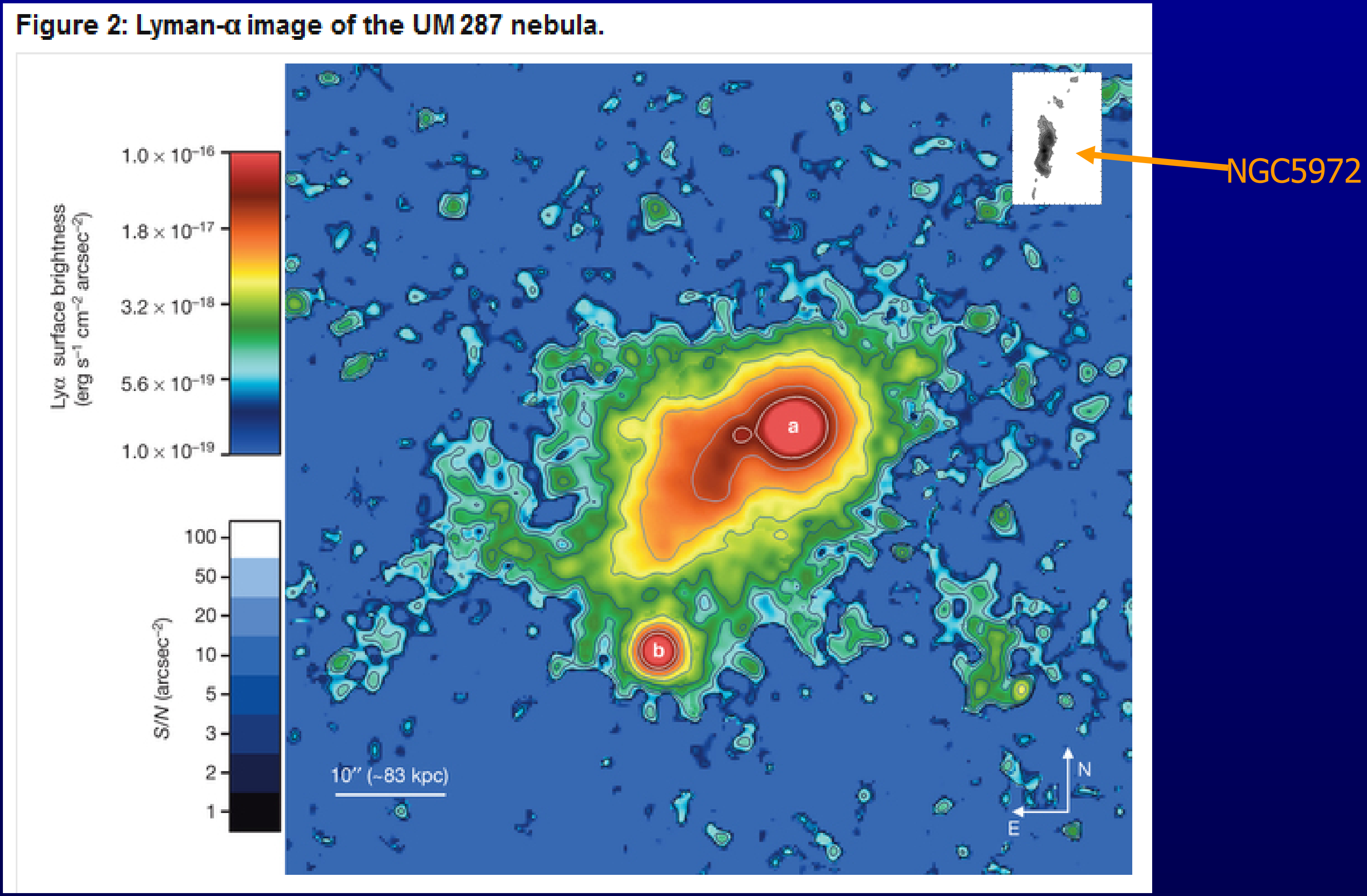




NGC 5972 (KPNO 2.1m)
V+[OIII] contours

Fig. 11.— Stellar and gas tails in NGC 5972, from data with the KPNO 2.1m telescope. Contours

High-z counterparts?



Cantalupo et al. 2014, Nature:
Lyman-a structure extends at 290 kpc from z=2.3 QSO