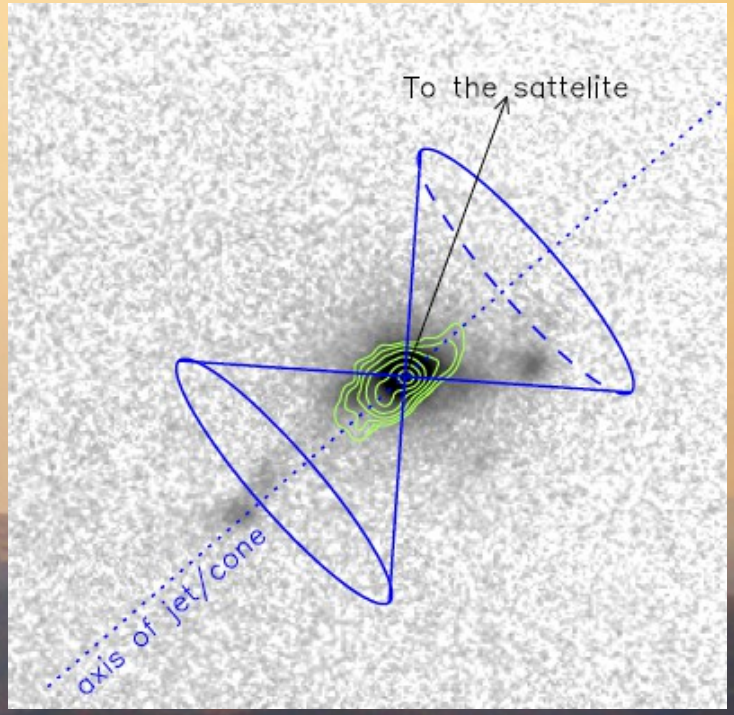
Radio-jets and ionization cones in Seyfert galaxies

Alexei Moiseev
Special Astrophysical Observatory, Russian Academy of Sciences




W. Keel
(Alabama Uni)


A. Smirnova

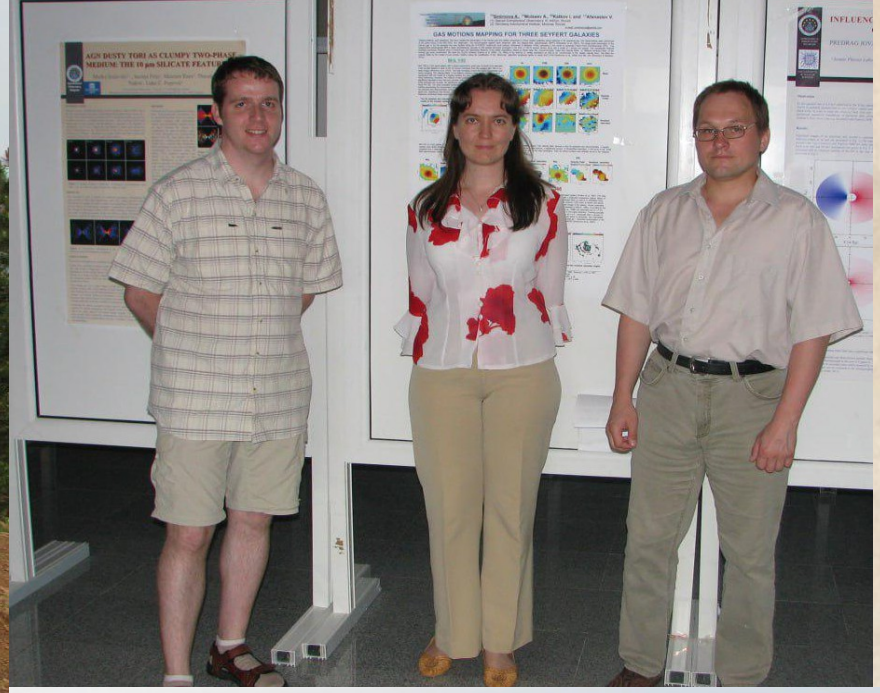

D. Oparin


R. Uklein


A. Ikhsanova
(Padova Uni)


S. Dodonov


Victor Afanasiev



From 8th SCSLSA, Divčibare, 2011

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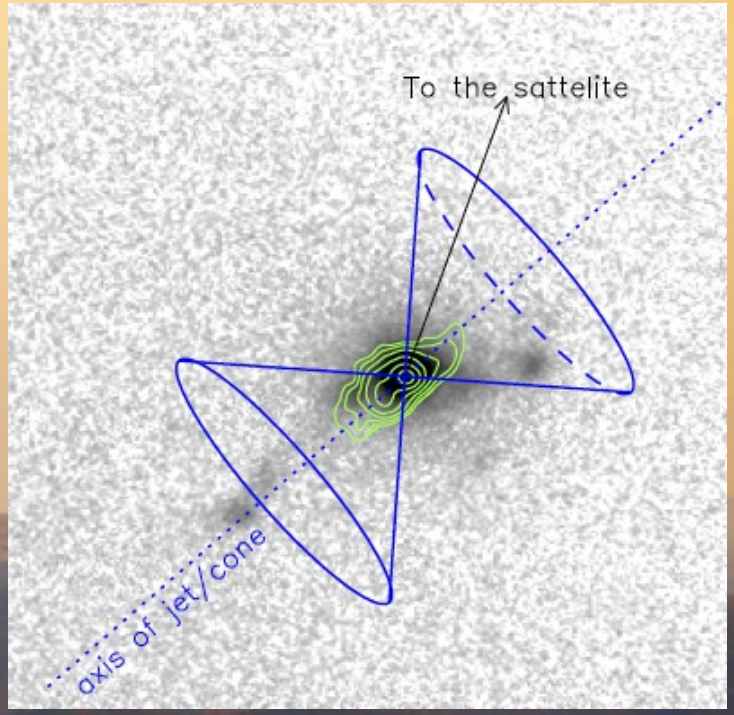


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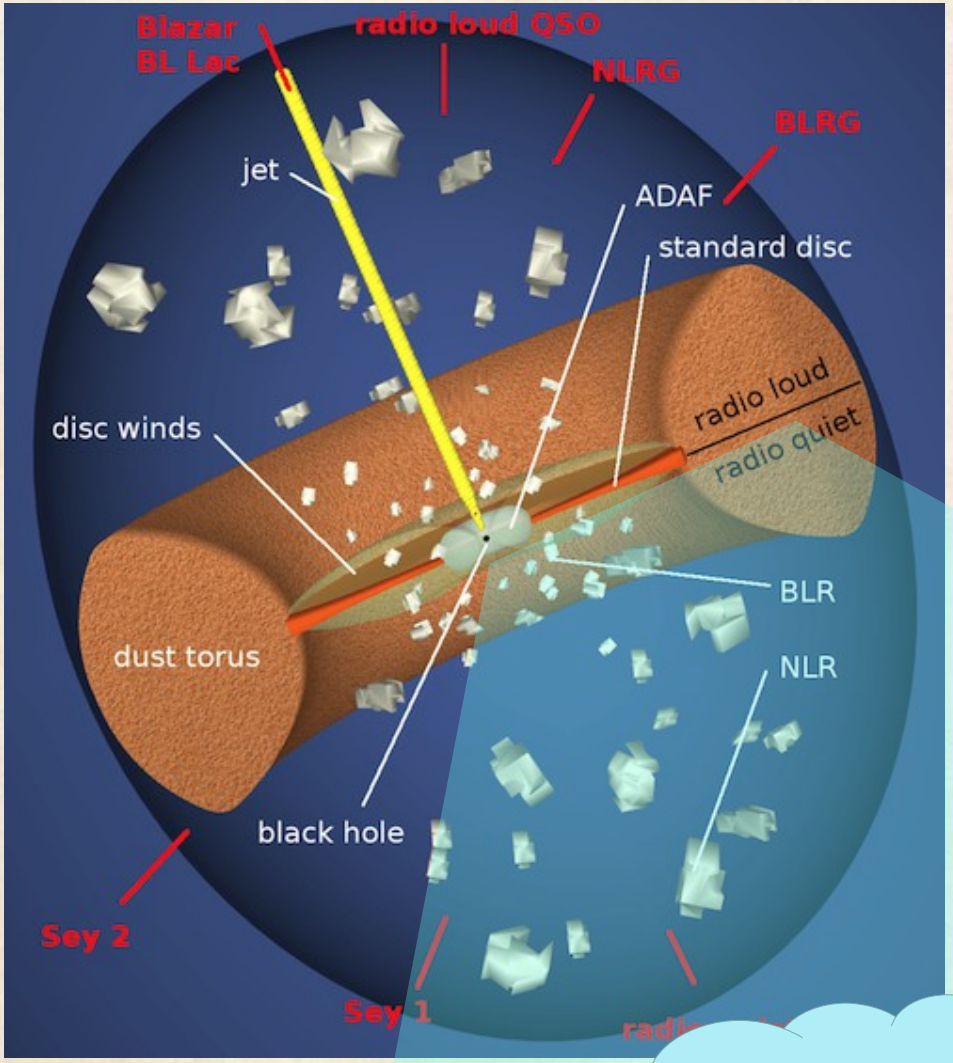
Radiative-mode (cone) and kinetic mode (radio jet)



The different modes of the nuclear activity fuelled by different accretion mechanism and likely characterised by different time scales:

- Jet-mode: advection-dominated accretion flow (ADAF) inside a truncated disk
- Radiative-mode: standard disk accretion

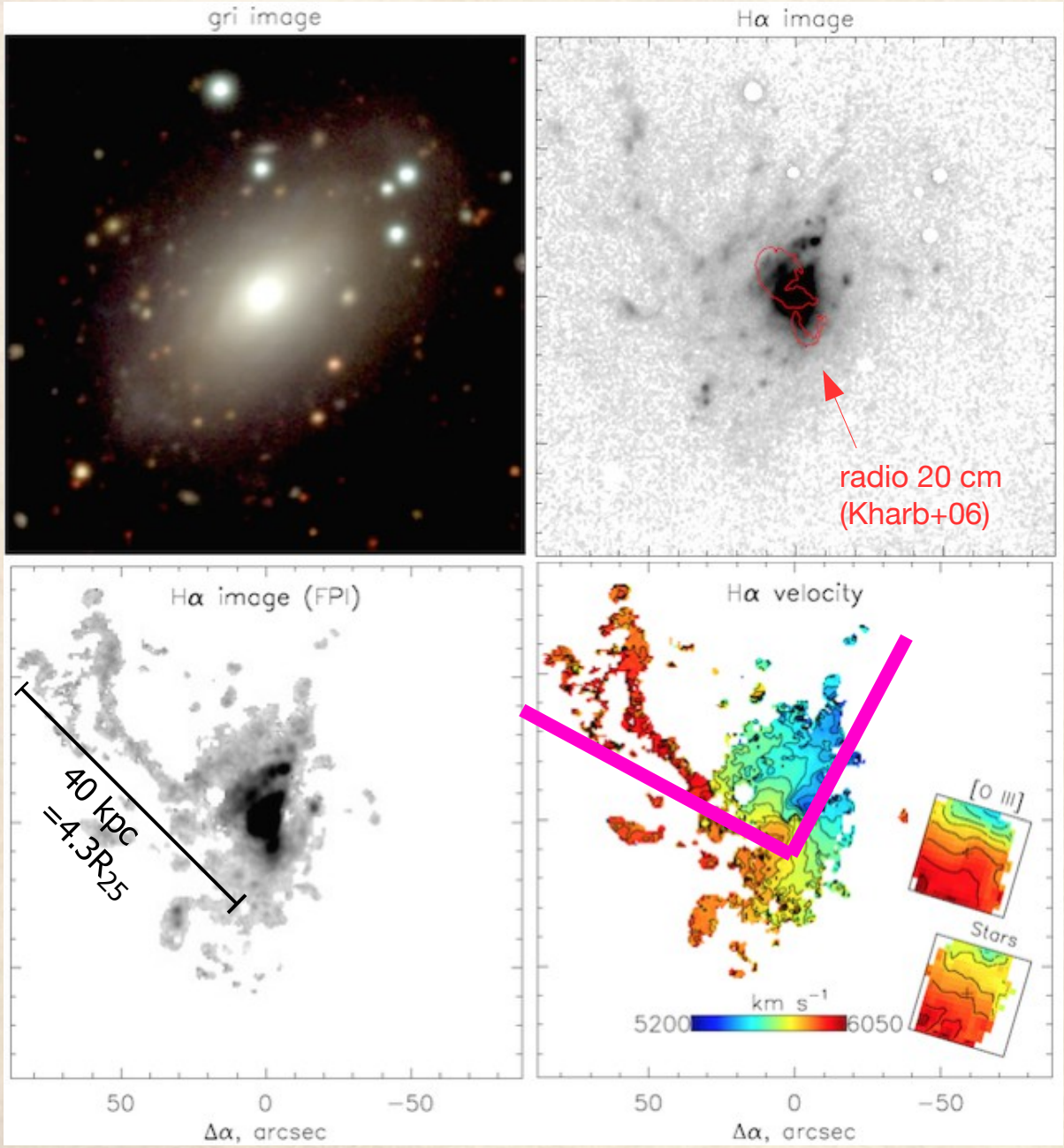
(Best +2005, Morganti 2017)

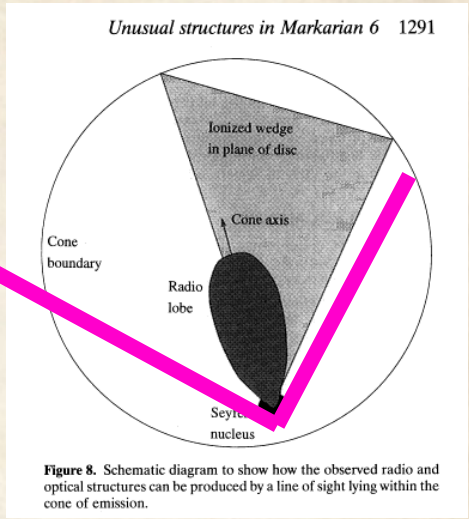
Extended Emission-Line Region (Wilson 1996)

EELR

Cone as `an experimental fact'!
EELRs: 1-50 kpc (the host galaxy disk and even beyond)

Mrk 6: deep and 3D data





(Kukula +96)

A radiation of the Seyfert nucleus collimated in a broad cone allows us to see a part (?) of an off-plane gaseous structure orbiting around Mrk 6

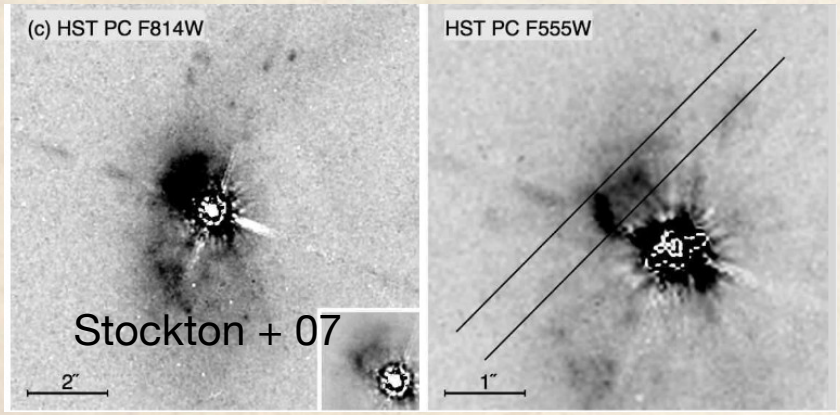
Smirnova et al. 2018

Extended emission-line regions in different AGN modes

Radio-loud AGN (QSO, radio galaxies):

- Jet-clouds interaction, outflows..
- **Large** velocity gradient
- **High** velocity dispersion

(Stockton + 06)

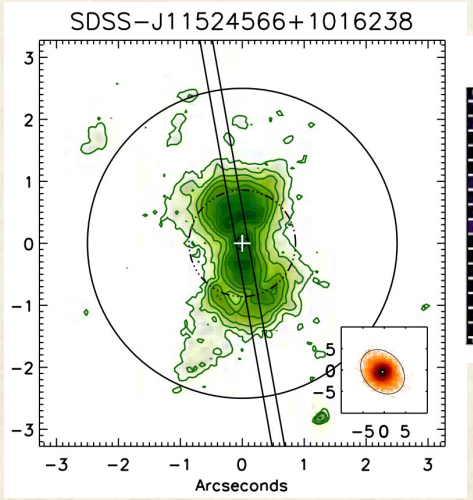


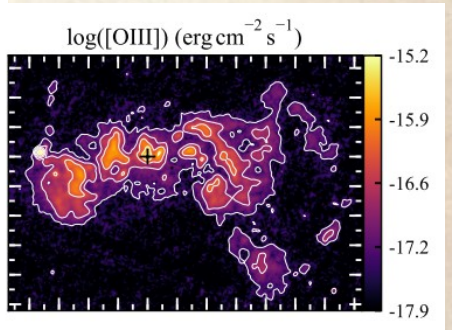
Radio-quiet AGN (Seyferts):

- AGN ionization cones
- **Circular** rotation pattern
- **Low** velocity dispersion

(Unger+87, Wilson+96)

Storchi-Bergmann +18

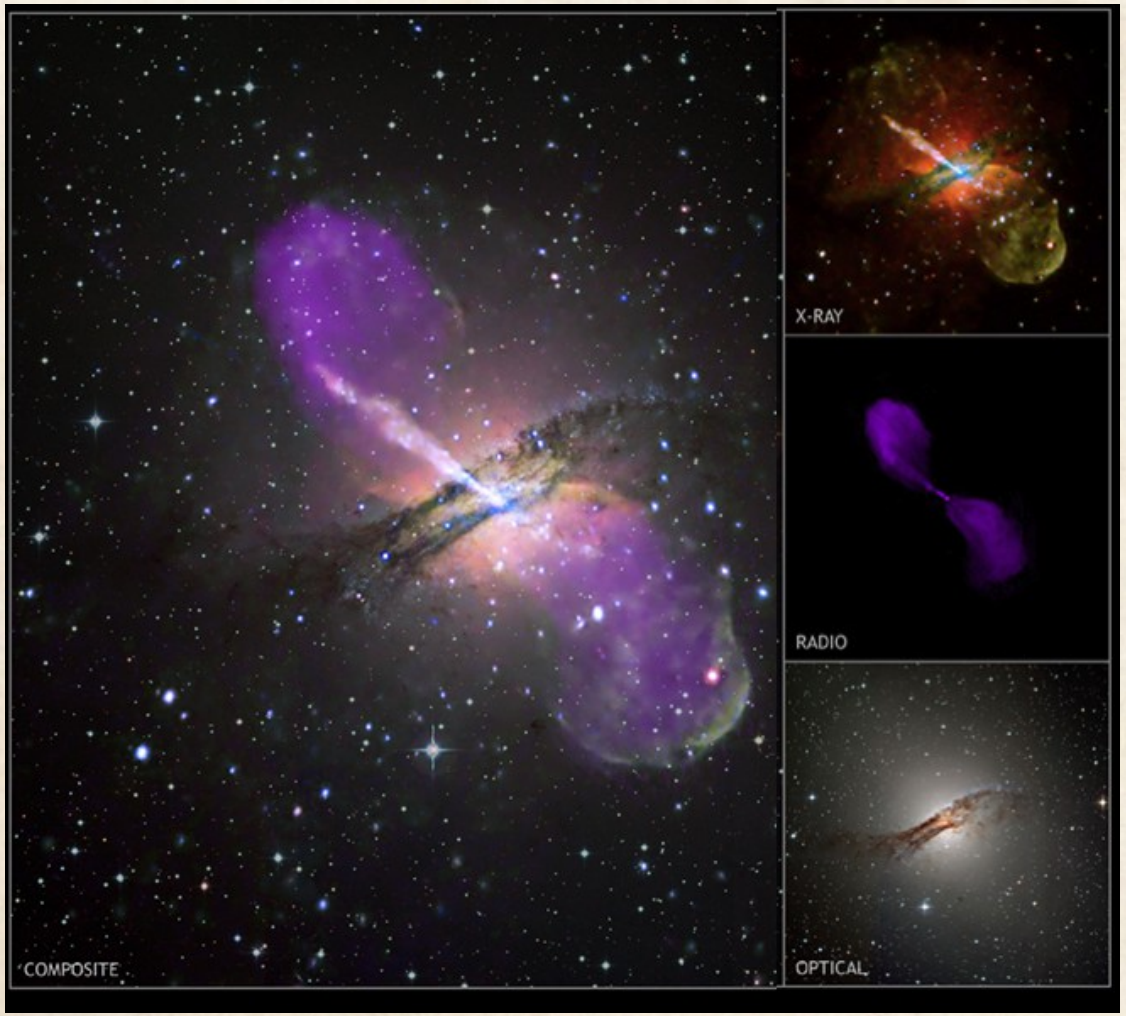




Fischer + 18

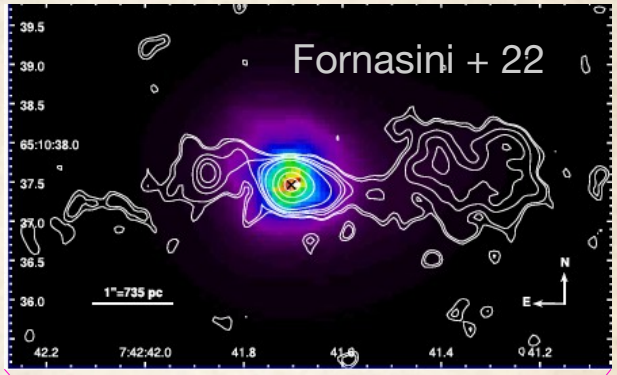
Kinetic (radio jet) vs radiative modes in observations

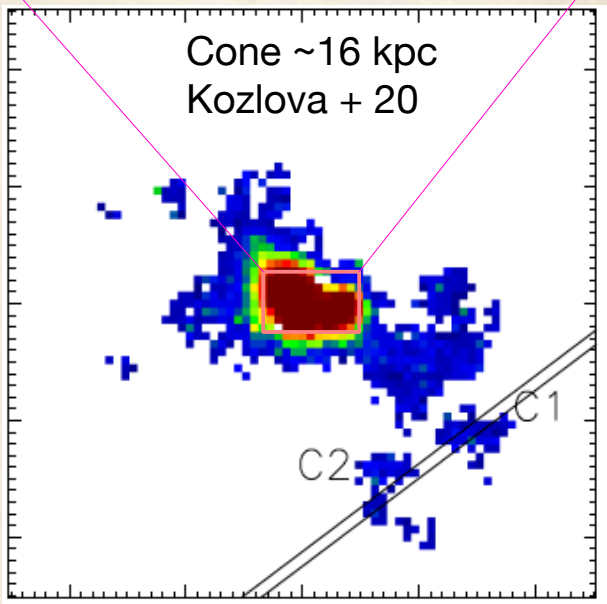
Cen A (NGC 5128)



https://chandra.harvard.edu/photo/2008/cena/more.html

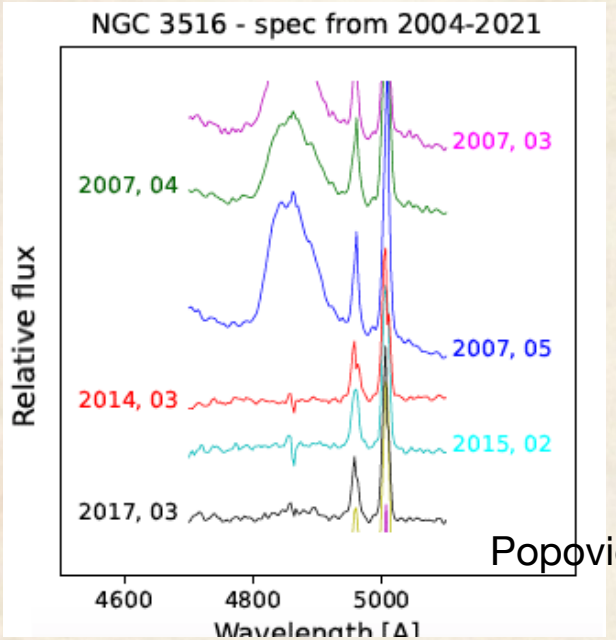
Mrk 78: ~2 kpc jet+outflow





AGN Archaeology

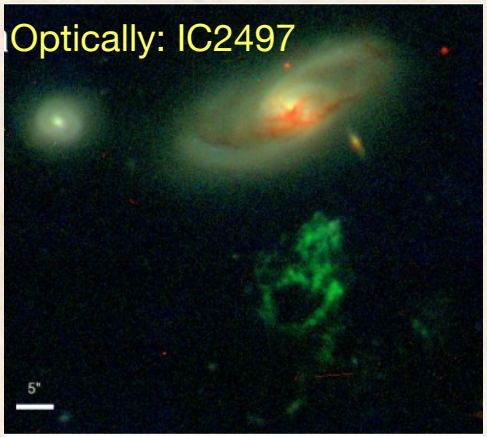
- Changing-look AGNs



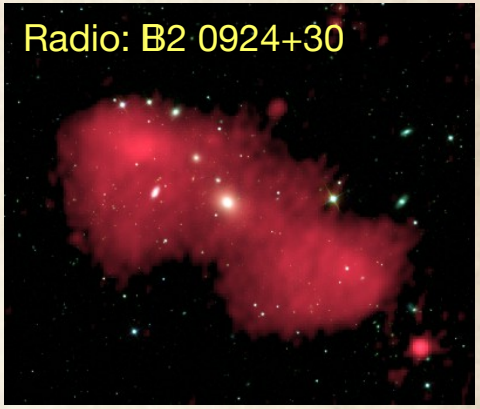
t~10 yr

Popovic + 23

- "AGN remnants"



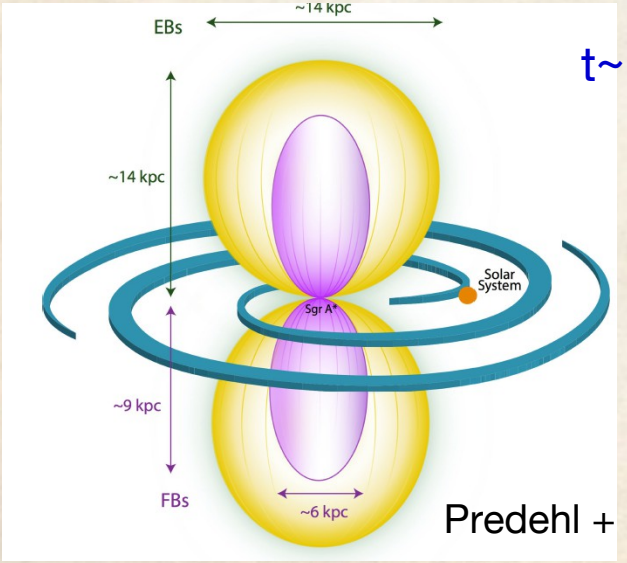
t~0.1 Myr



t~50 Myr

Morganti 2017

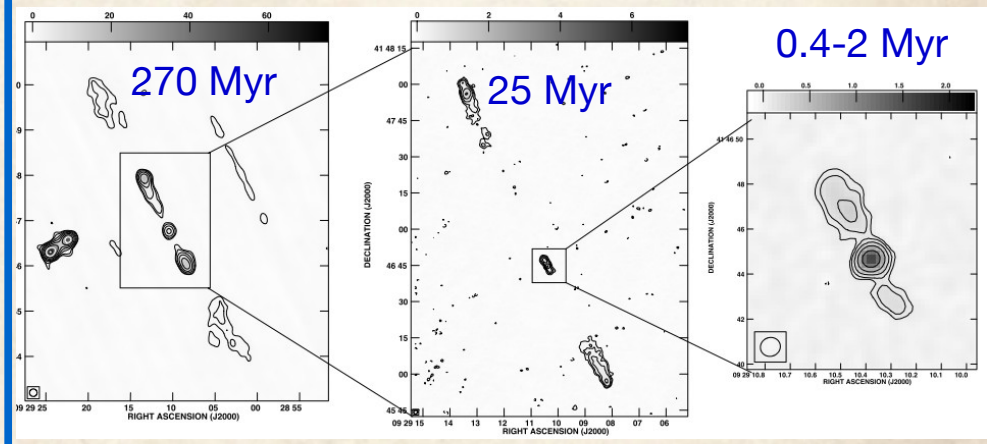
- MW: Fermi & eROSITA bubbles



t~1-3 Myr

Predehl + 2020

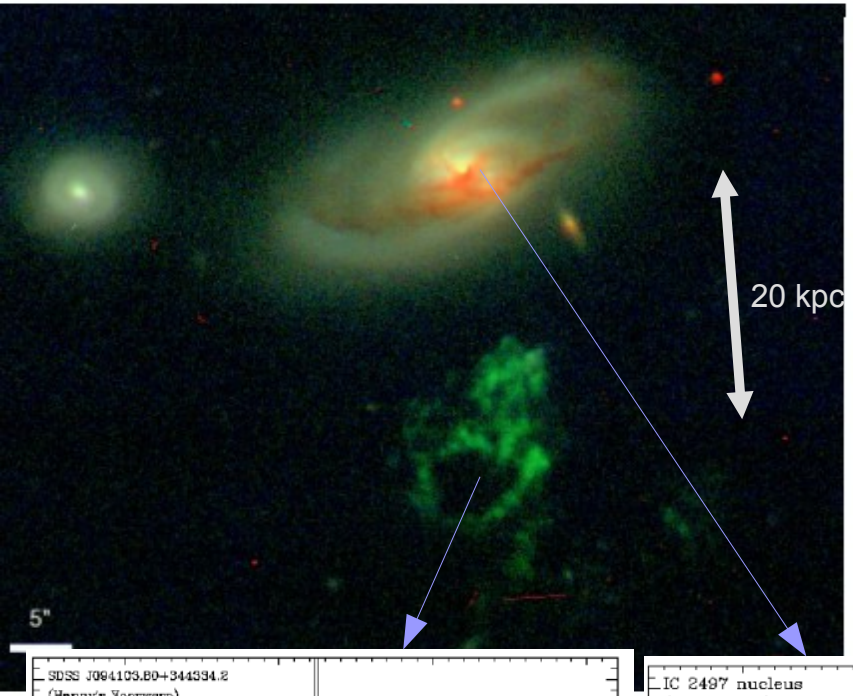
- Radio galaxies with multi phases activity

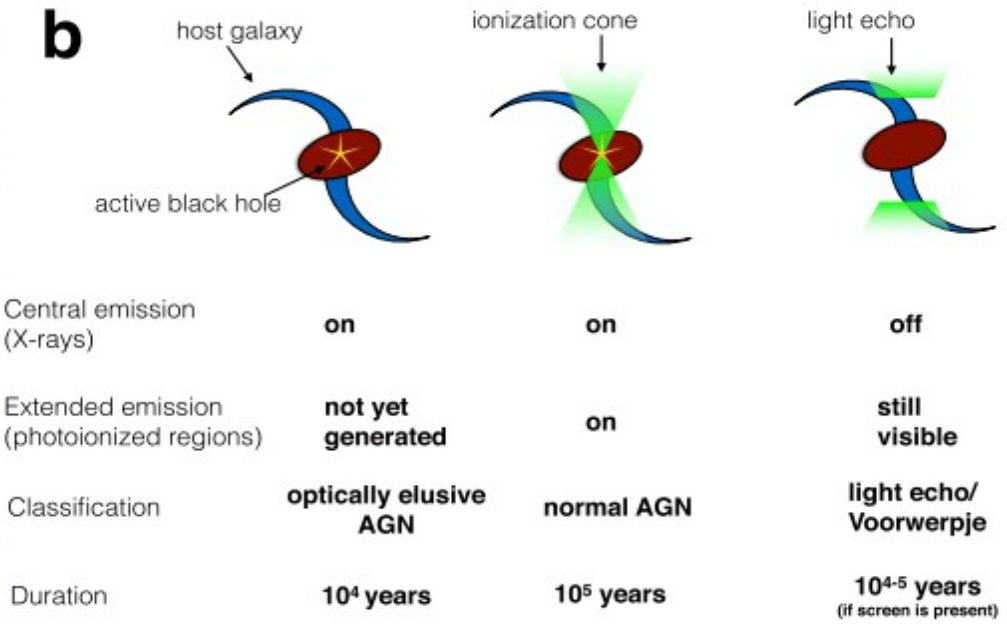


Brocksopp + 2007

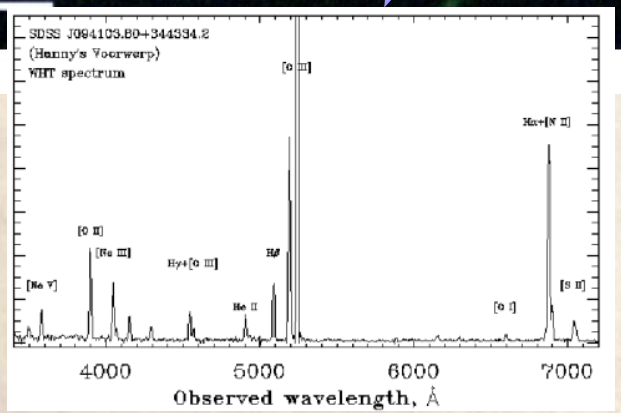
"Hanny's Voorwerp" (IC 2497)

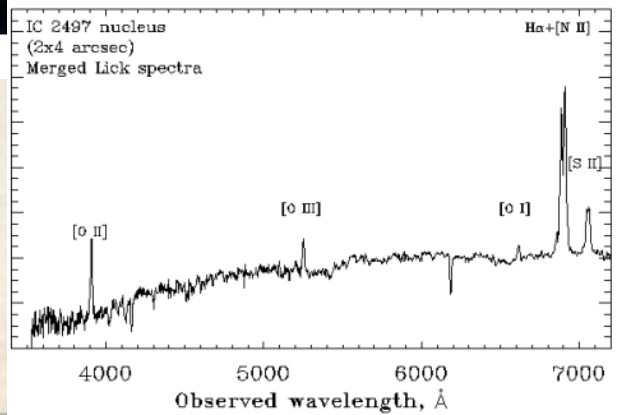
AGN archaeology – R. Morganti - Nature Astronomy Review





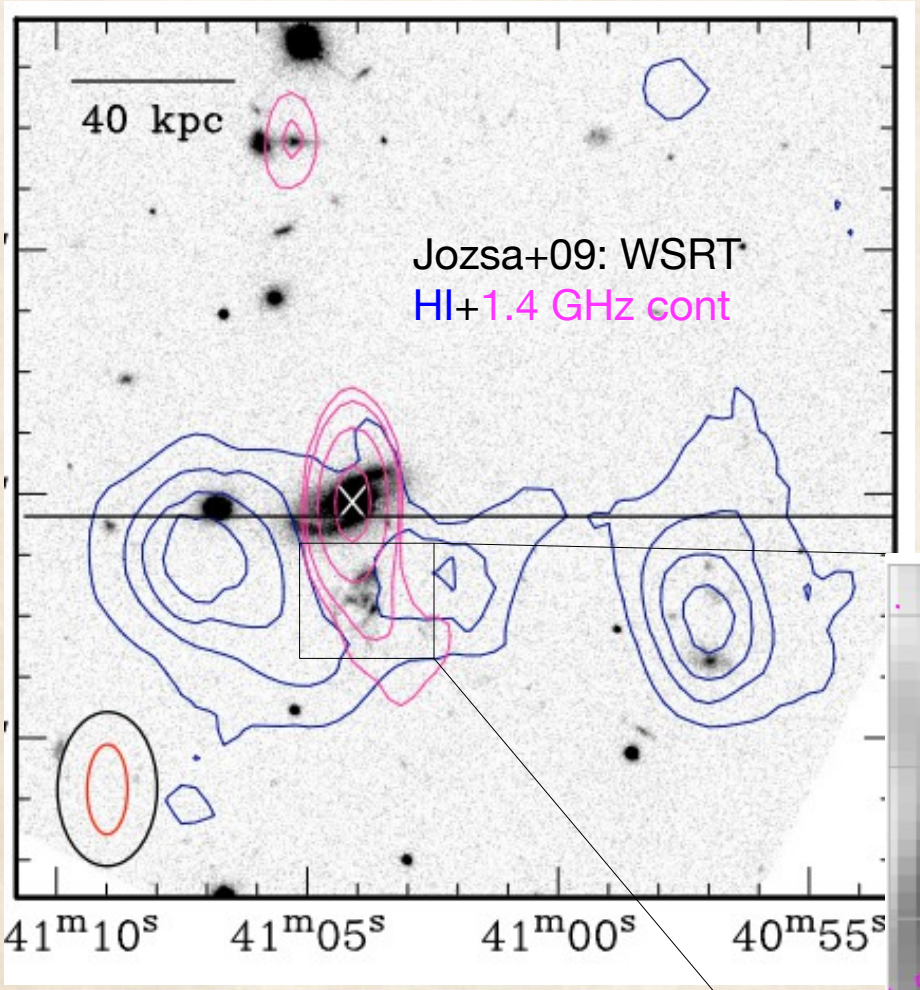
Central emission (X-rays)	**on**	**on**	**off**
Extended emission (photoionized regions)	**not yet generated**	**on**	**still visible**
Classification	**optically elusive AGN**	**normal AGN**	**light echo/ Voorwerpje**
Duration	**10^4 years**	**10^5 years**	**10^{4-5} years** (if screen is present)





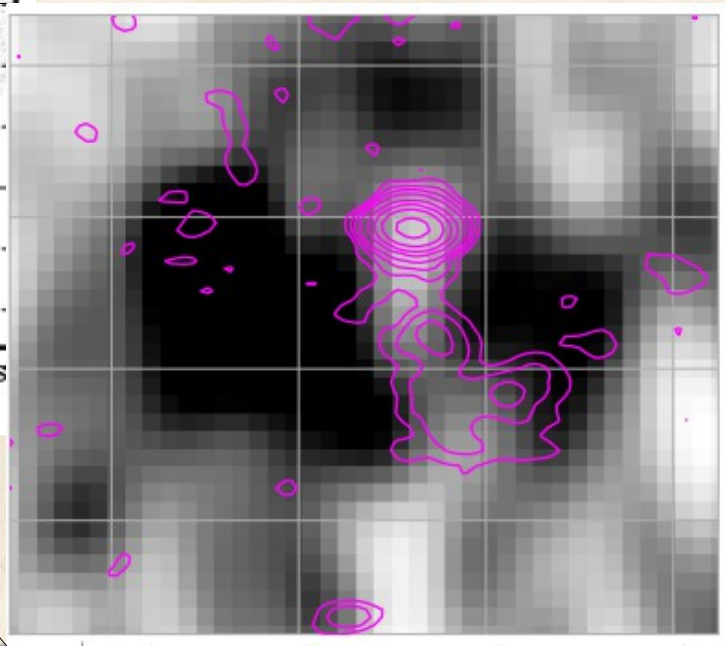
- A significant shortfall of AGN ionizing radiation: ~100 times/1-2x10^5 yr
- (Lintott + 09, Keel +12)

Relic jet activity in "Hanny's Voorwerp" (Smith + 2022)



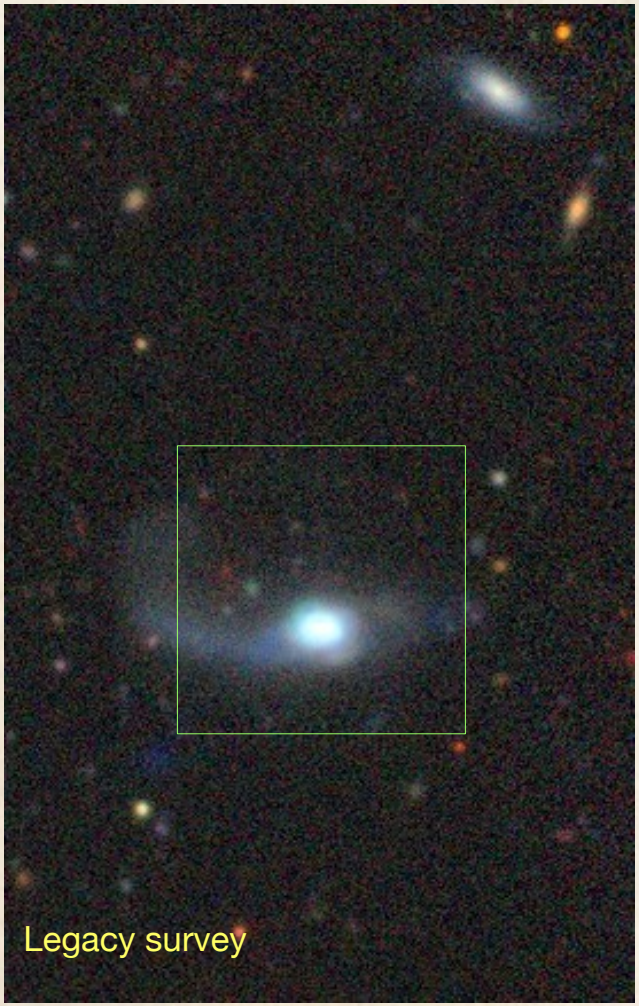
Proposed scenario of HV evolution:

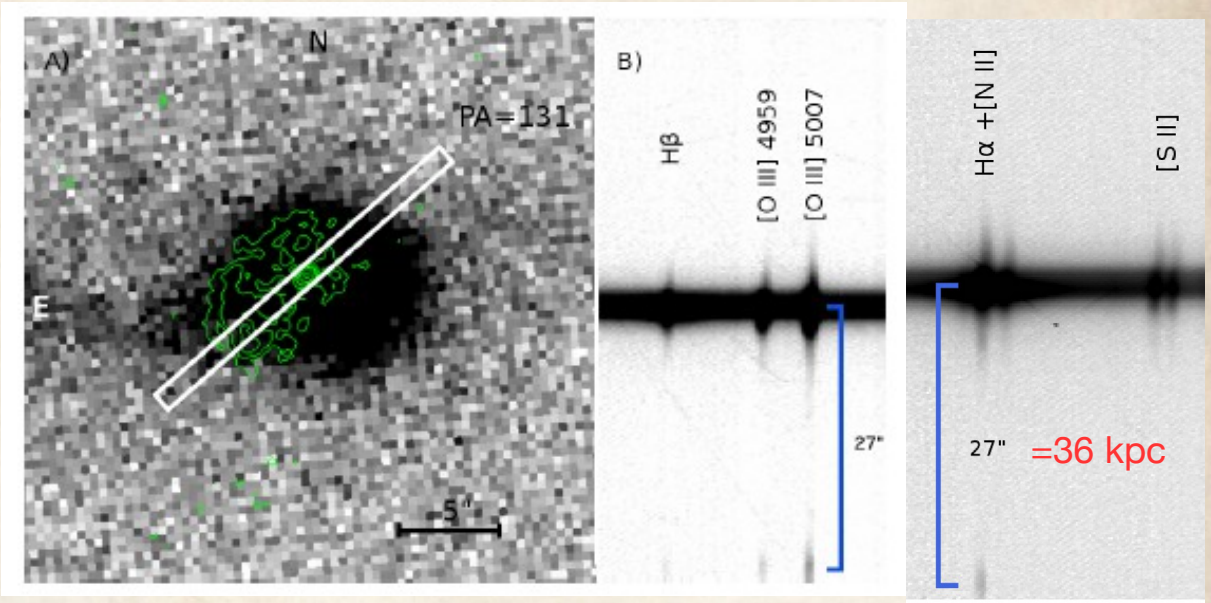
- tidal encounter left the HI clouds
- radio outburst ~ 100 Myr ago radio jet punched a hole in the HI gas
- recently (~0.1 Myr ago) – a radiative-efficient AGN outburst illuminates the gas and created HV



LOFAR 150 MHz+HI:

Mrk 783: NLSy1 with 14 кпк radio structure





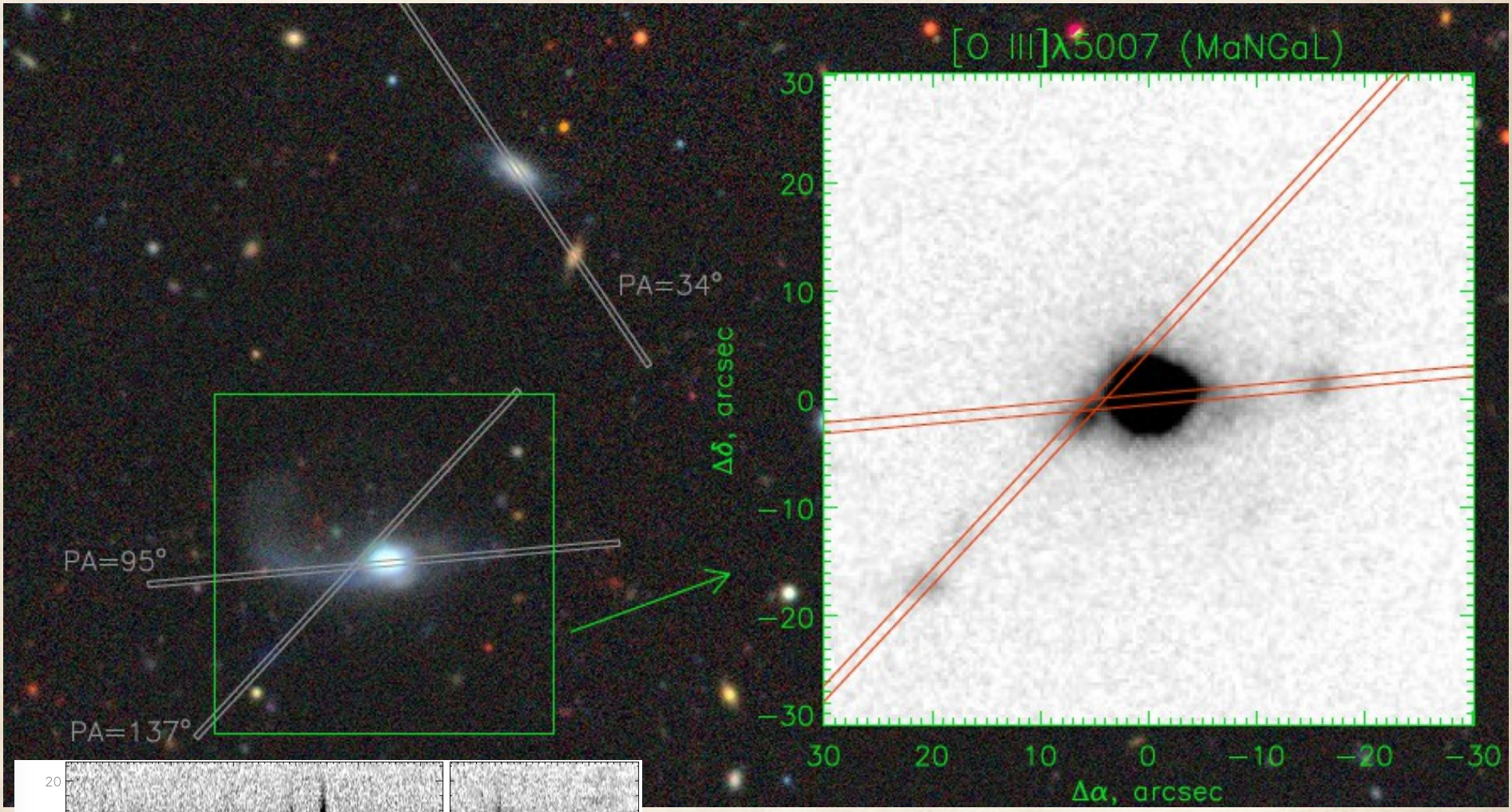
Congiu + 17a,b

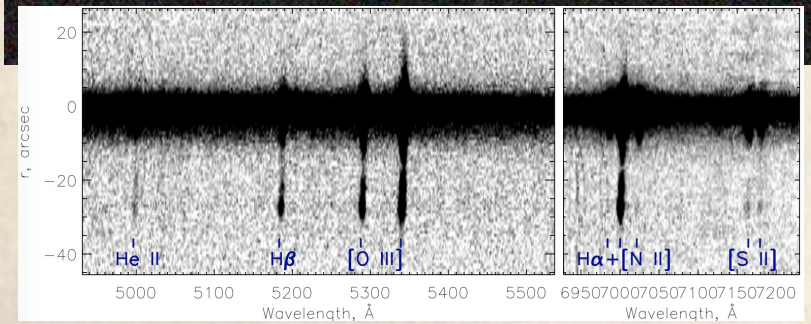
The galaxy is one of the few NLS1 showing such an extended radio emission at $z < 0.1$

R=L(5GHz)/L(B)~10, between radio-quiet and radio-loud AGN

The extended emission might be a relic of radio-loud cycle?

Mrk 783: 2.5 and 6-m telescopes

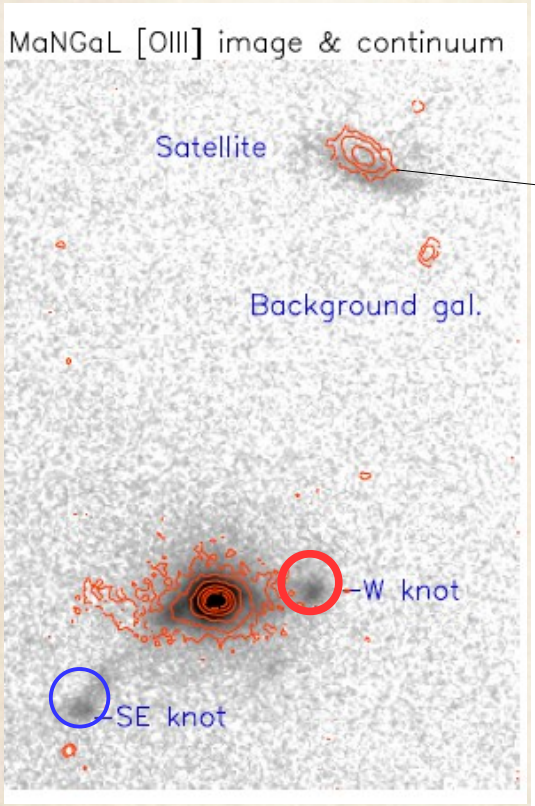


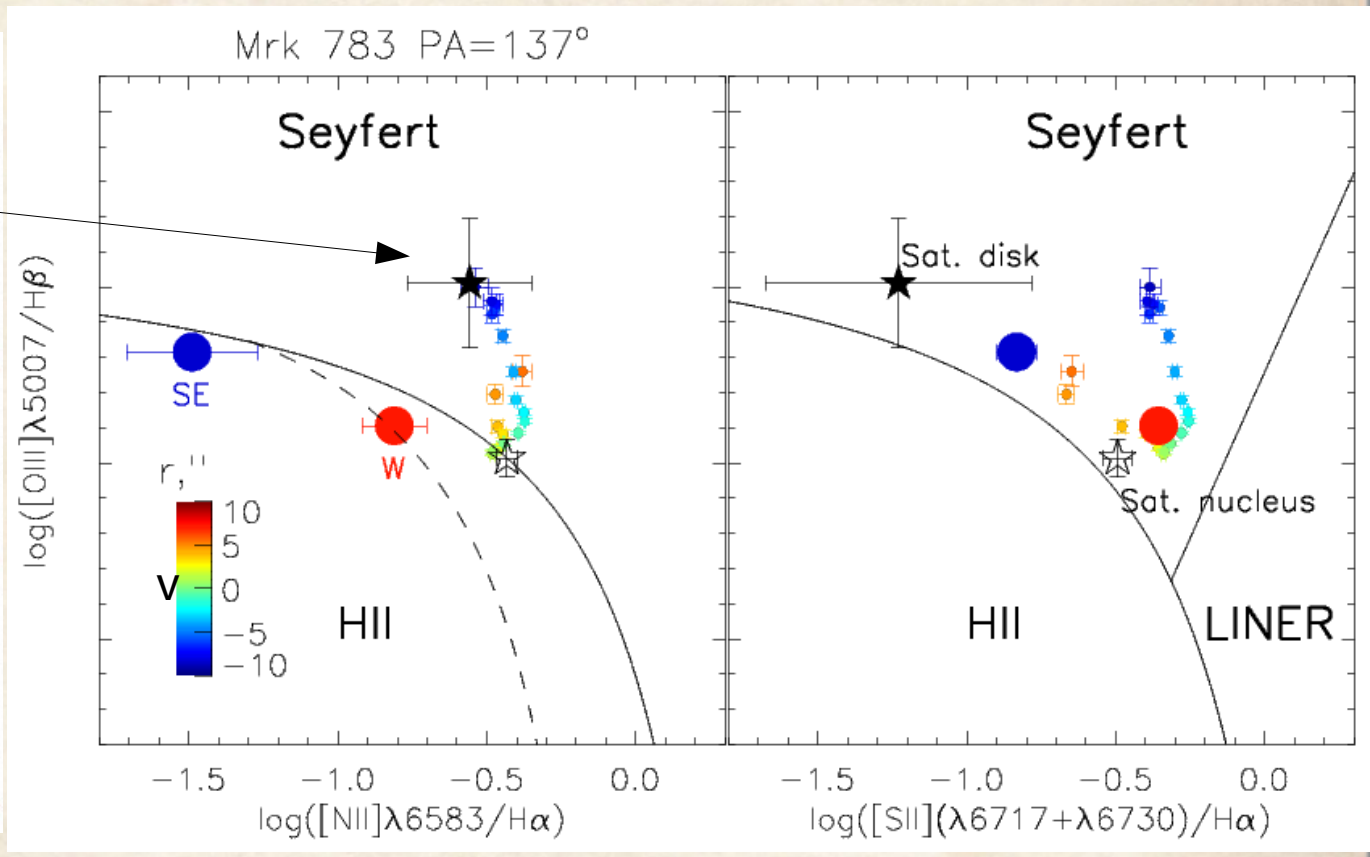


HeII/Hβ= 0.2-0.3

=> poster by A. Smirnova et al.

Mrk 783: gas ionization



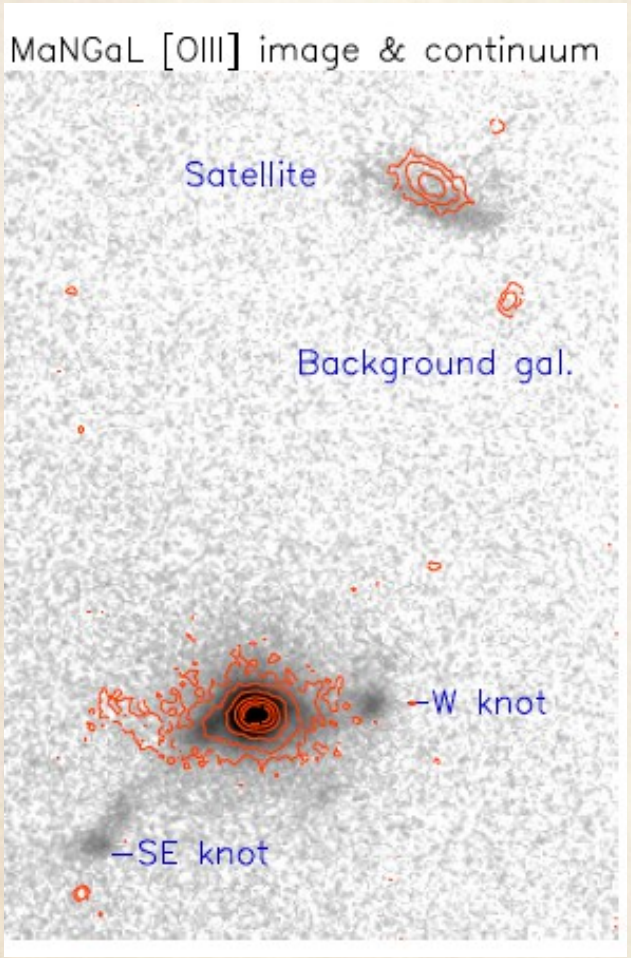


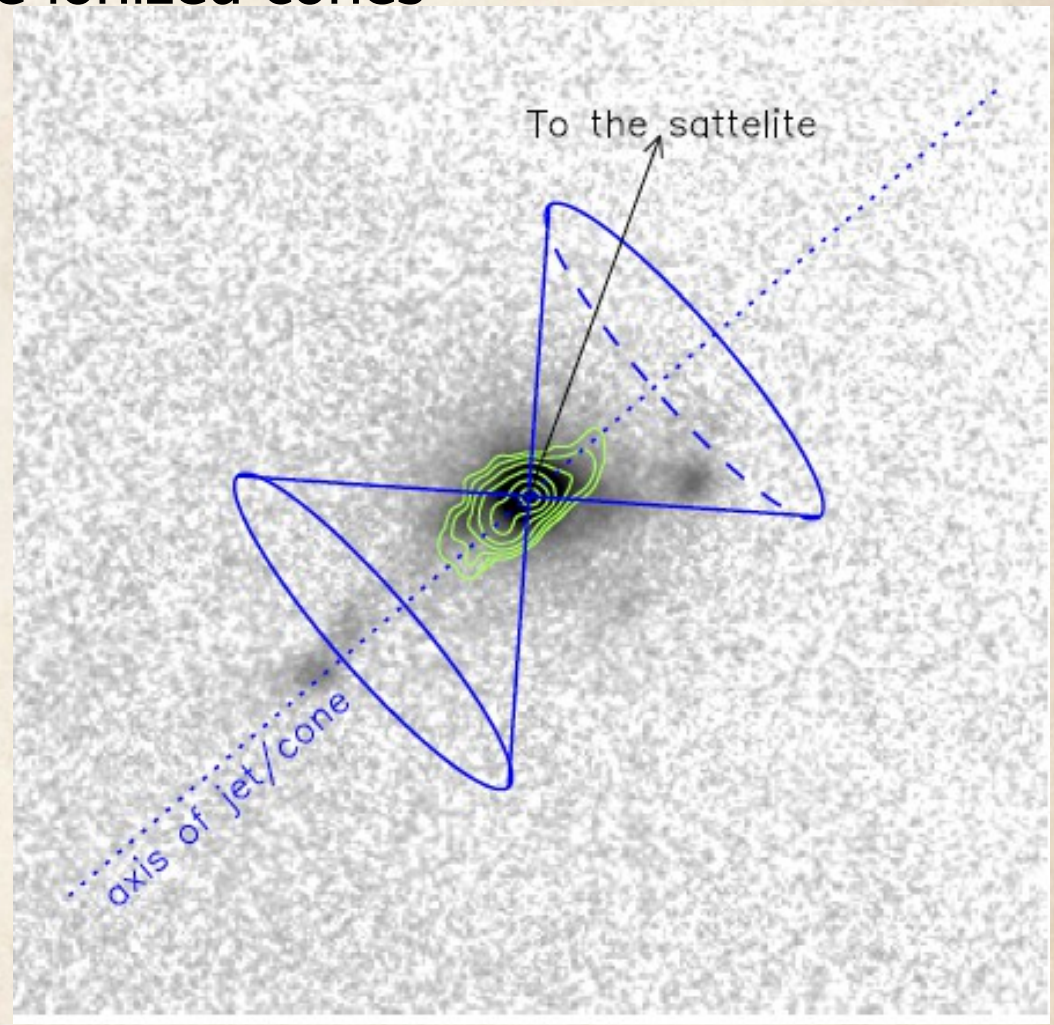
The same state of gas ionization both along the radio jet, and in tidal structures outside it, including the outskirts of the satellite gaseous disk (~90 kpc!)

Dynamically cold gas (σ<50 km/s)

HeII 4686/Hβ~0.25 => illumination by AGN radiation

Mrk 783: orientation of the ionized cones

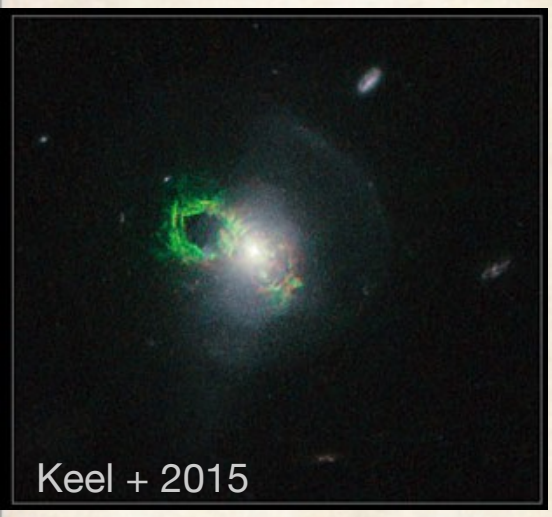




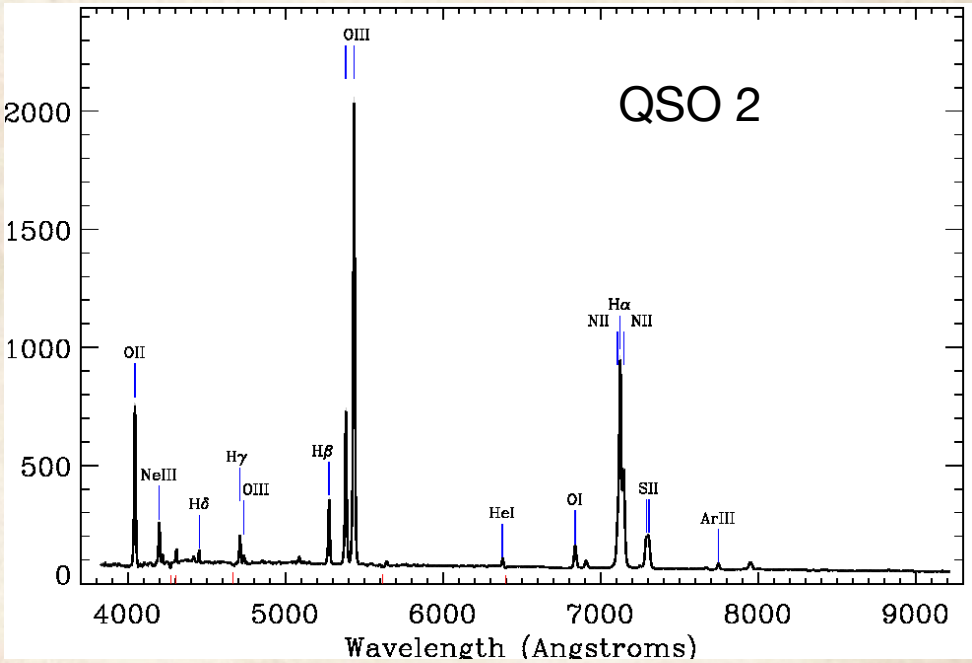
Looks like the Hanny's Voorwerp (old large radio-jet, emission nebulae outside the stellar tidal tail) but in “active” stage of a radiative mode

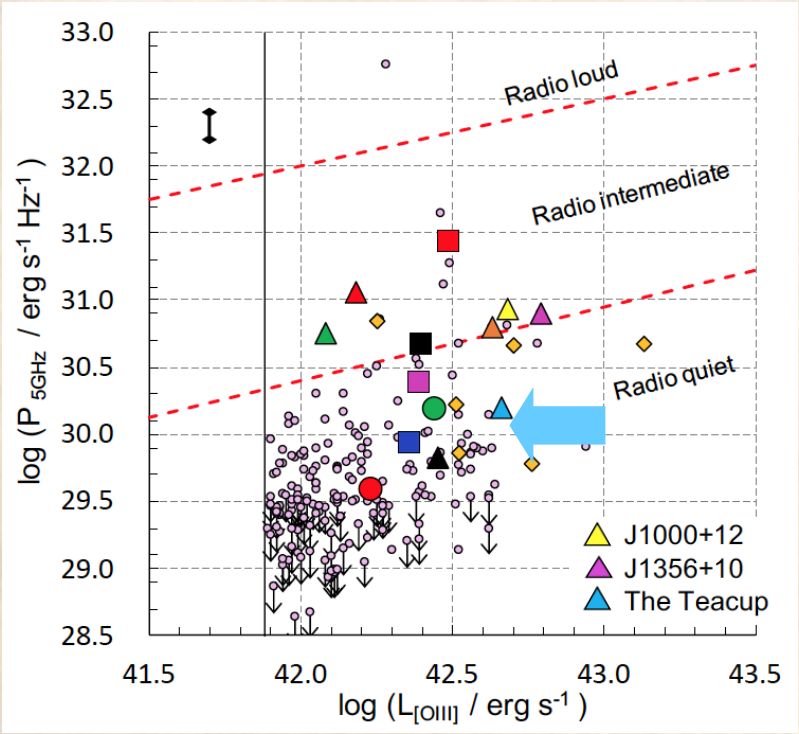
L(AGN)=L(cloud ionization)

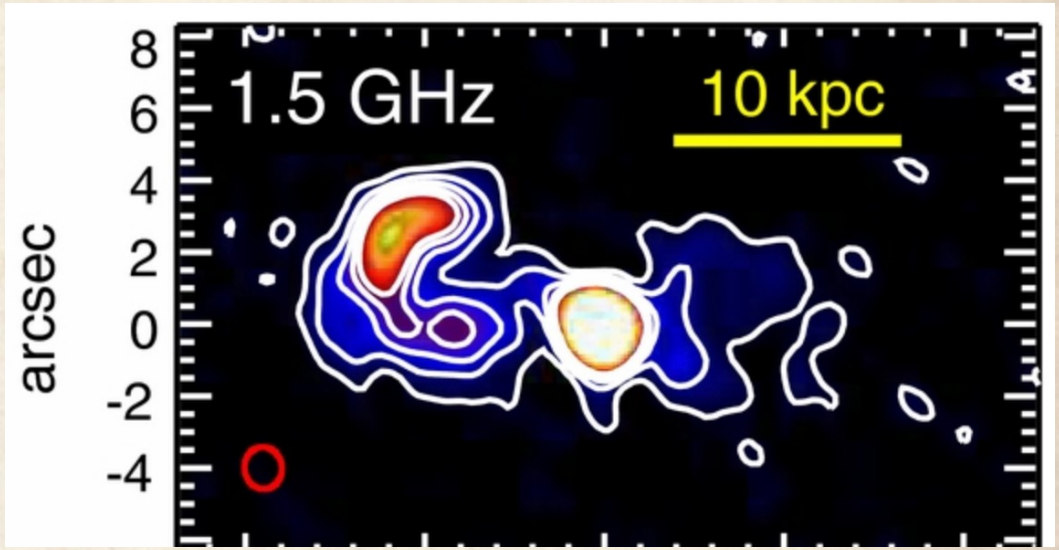
SDSS J143029.88+133912.0 (Teacup AGN)



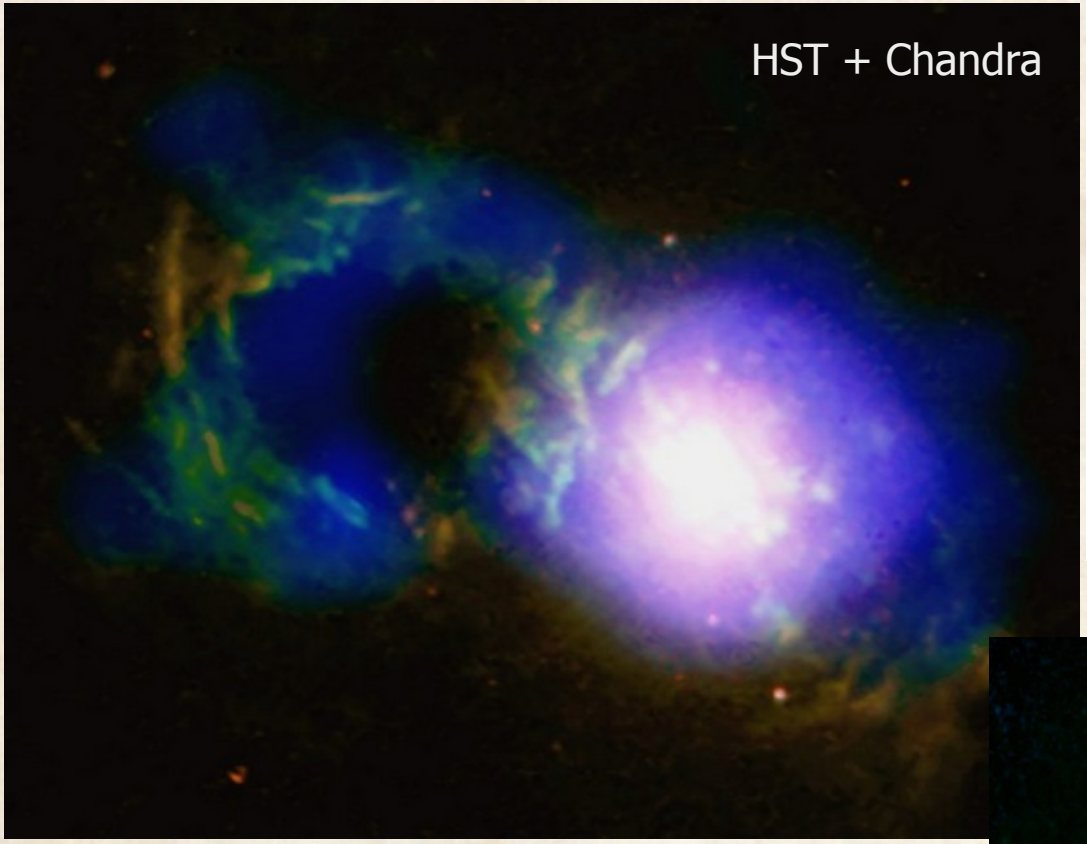
m(r)=15.4 mag
z=0.085
D=360 Mpc
1.6 kpc/''







Harrison et al (2015)



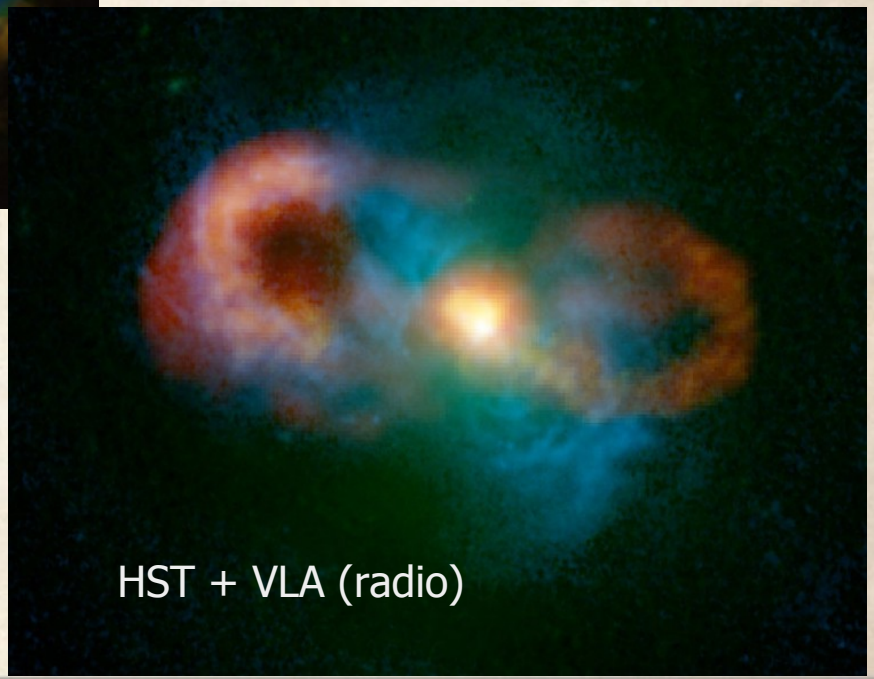
WIKIPEDIA
The Free Encyclopedia

Teacup galaxy

Article Talk

From Wikipedia, the free encyclopedia

The **Teacup galaxy**,[3] also known as the **Teacup AGN**[2] or SDSS J1430+1339 is a low redshift type 2 quasar,[4] showing an extended loop of ionized gas resembling a handle of a teacup, which was discovered by volunteers of the Galaxy Zoo project and labeled as a Voorwerpje.[5]

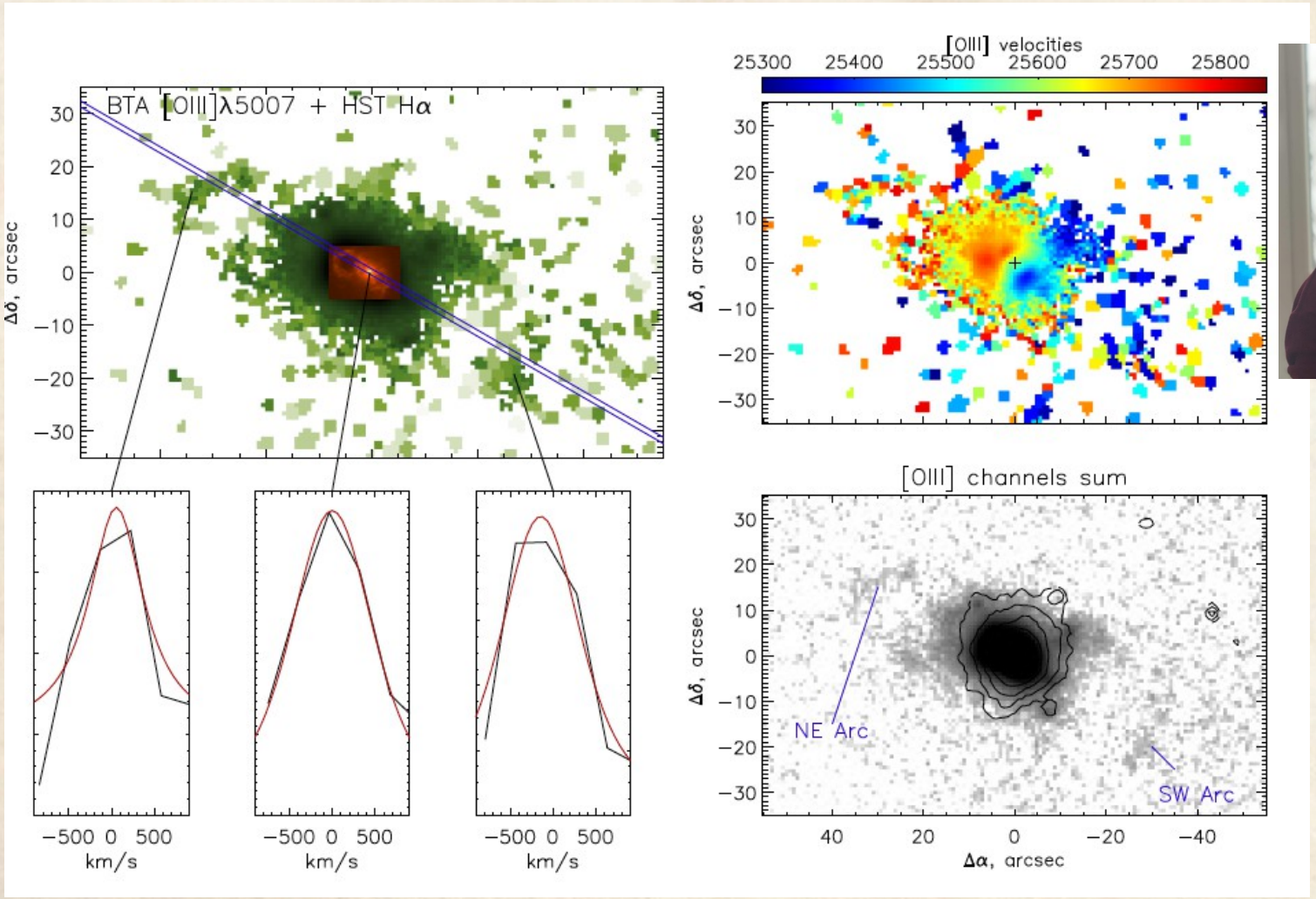


A 100 kpc nebula (Villar-Martin et al 2018)

"The giant nebula is among the largest known around active galaxies at any z."

Moiseev & Ikhsanova (2023)

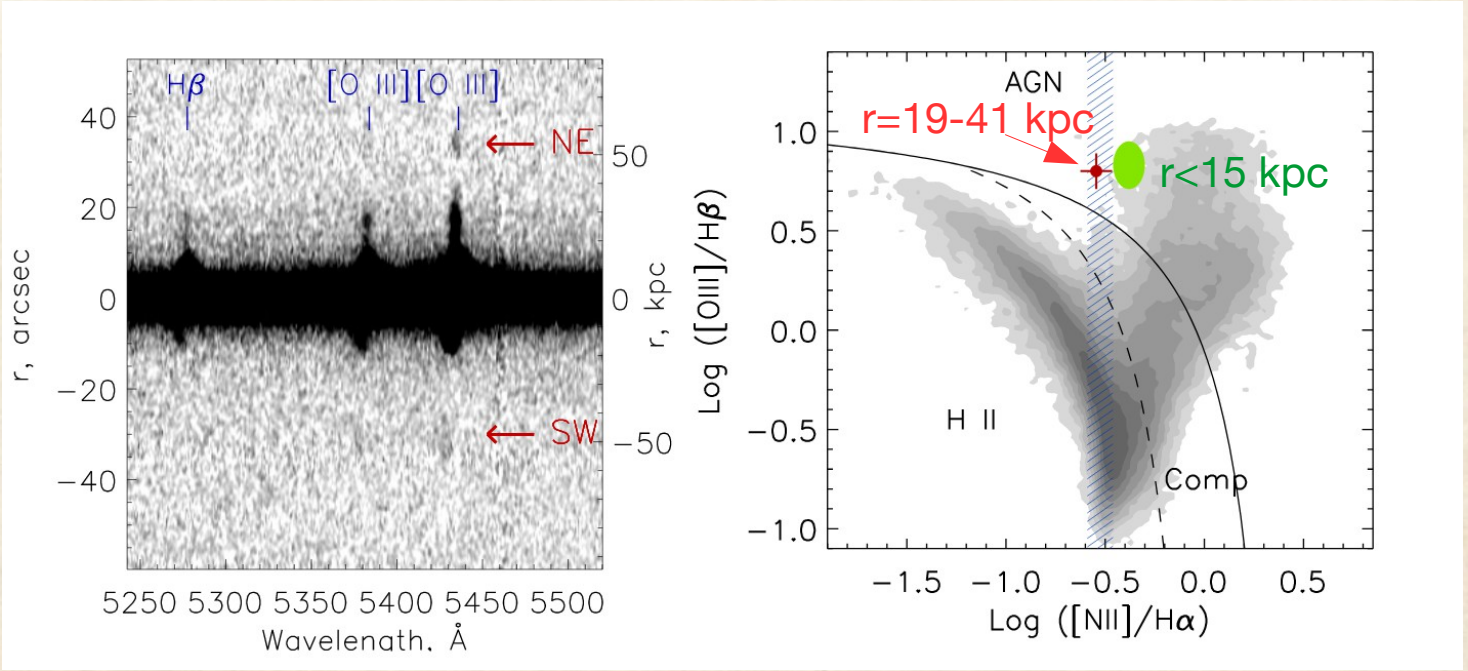
6-m/SCORPIO-2: the first [OIII] image of the external arcs



Alina Ikhsanova with cake and teacup

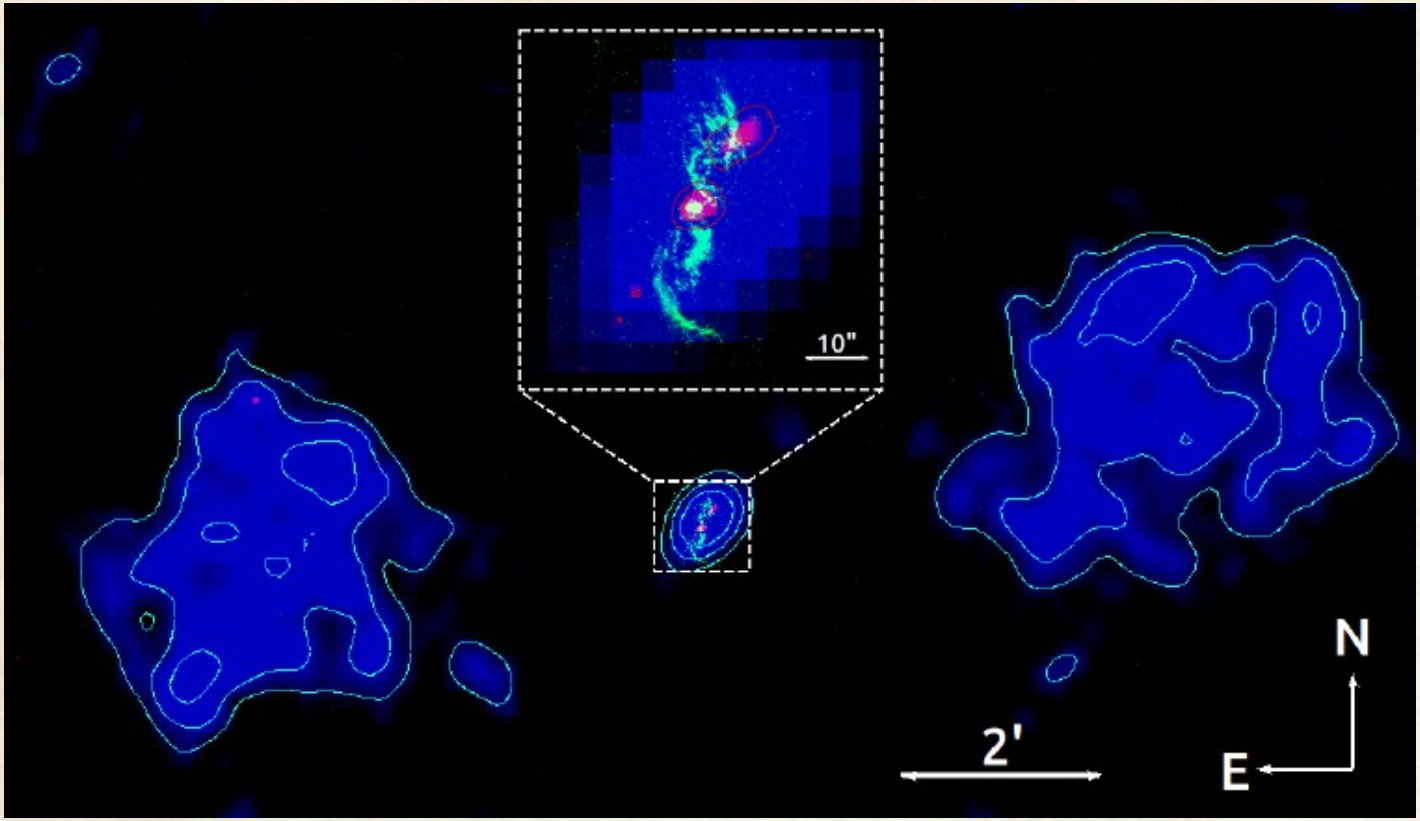
News about Teacup galaxy formation

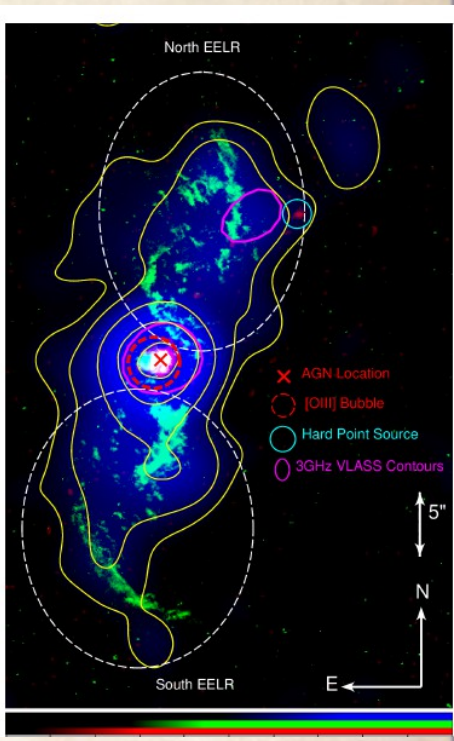
- Stars in the inner r < 5 kpc are significantly younger and metal richer than the outer host galaxy. The starburst age (**t~1 Gyr**) agrees with timescale of the merger event
- The ionized gas velocity field can be described in the term of a circular rotating disk with a flat rotation curve up to distances 50–60 kpc. This disc appears to be significantly inclined or even polar to the stellar host galaxy.
- The deep map of the [O III] emission reveals two symmetric arcs in the external region of the EELR (r = 50-55 kpc). It might be a remnant of the previous AGN outflow (jet-driven + starburst) with the age **t< 0.8 Myr**
- Now AGN radiation dominates in the gas ionization up to 40-50 kpc



Moiseev & Ikhsanova (2023)

NGC5972: radio / EELR misalignment (Harley+ 2208.05915)





Misalignment on multiple spatial scales, including the jets, radio lobes and EELRs, which is not well-explained by the traditional simplistic AGN model.
Ionization cone is perpendicular to the relict (?) radio structure.

Double SMBH?

Summary

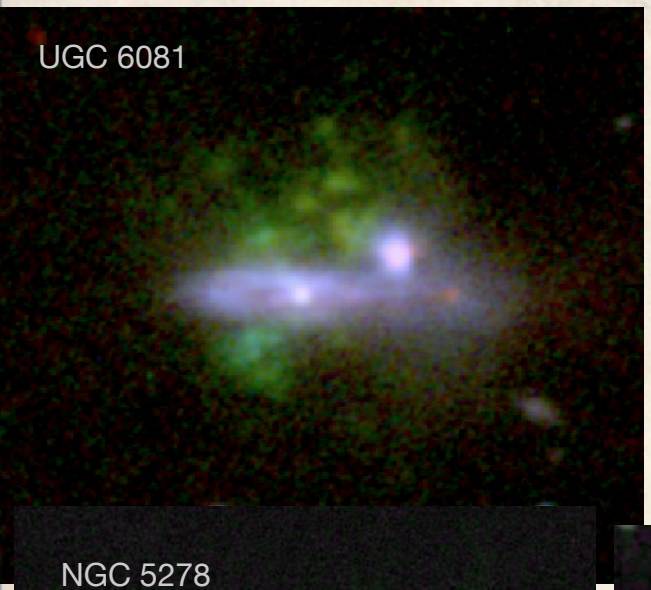
- We can detect ionizing cones in local AGNs up to distances 70-100 kpc, if they are surrounded by a “good screen” (host galaxy ISM, tidal debris, companions, etc)

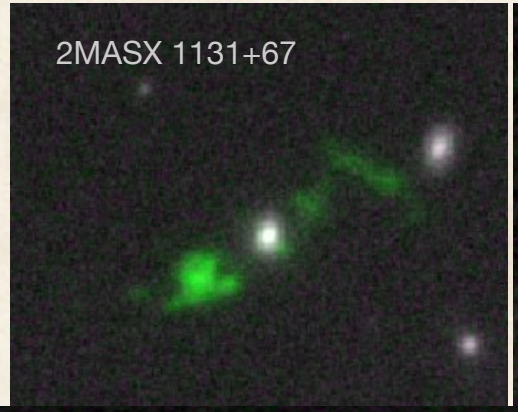
- An `archeology' of nuclear activity (ionization and kinetic output) is possible across the light-travel times ~0.1 Myr in optics and for the times 1 – 200 Myr in radio range

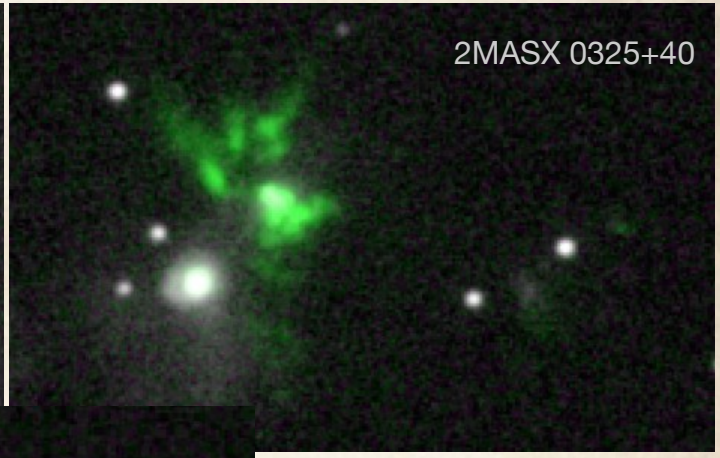
- Switching between kinetic and radiative dominated modes is observed

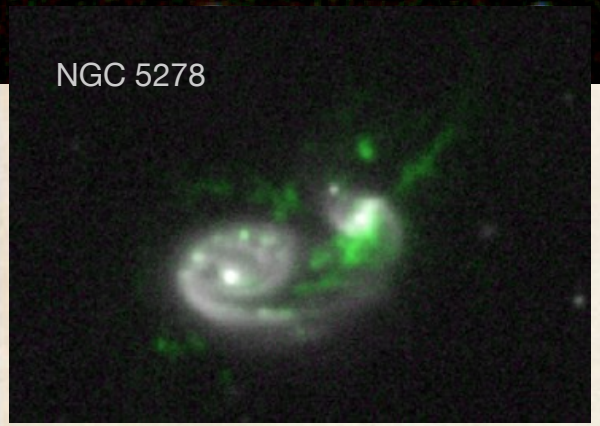
Thanks for your attention!

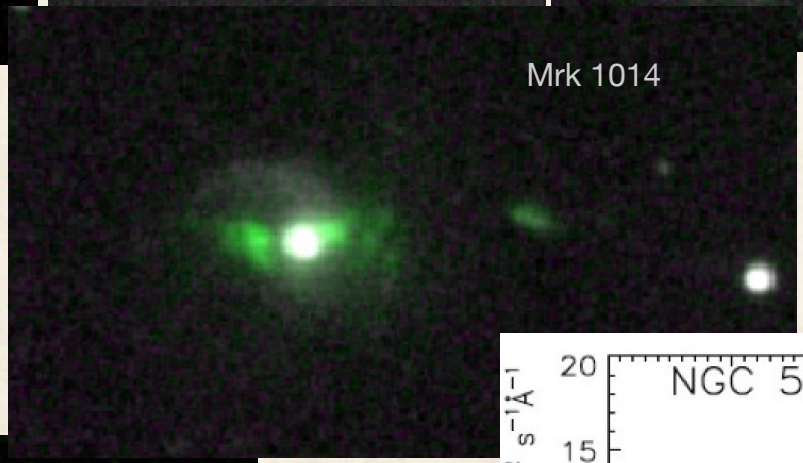
MaNGaL [OIII] maps (2019-2023) , 10 – 75 kpc

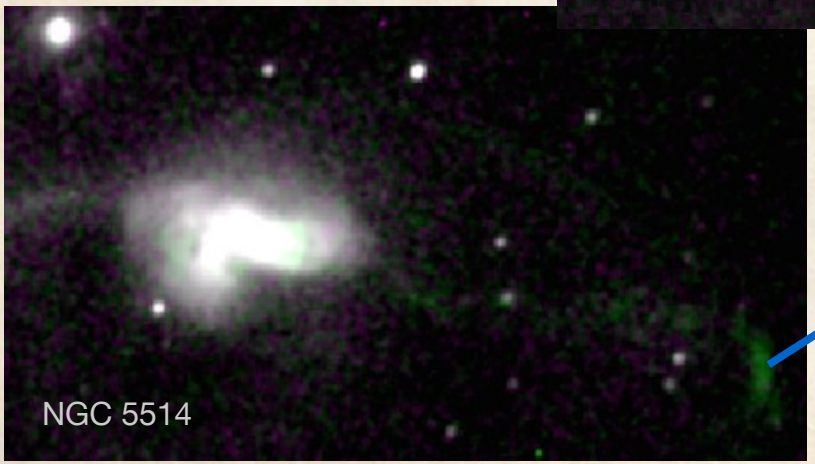


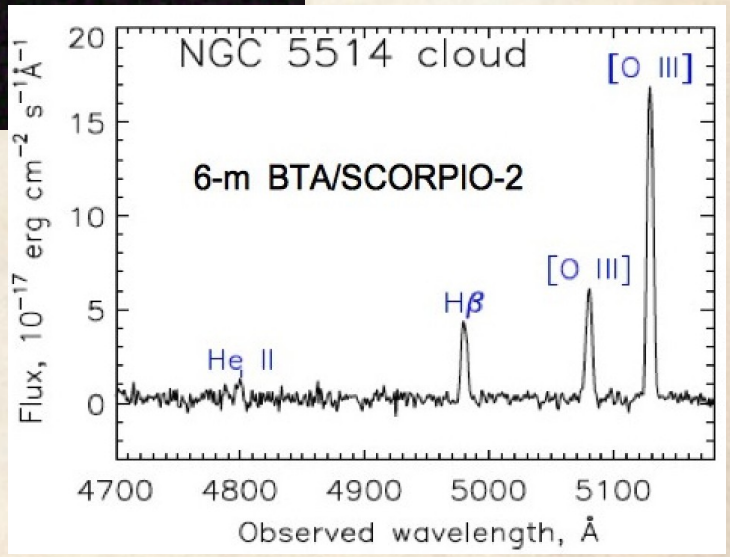












NGC 5514: internal cone and external clouds (75 кпк)