AGNs that transitioned to radio-loud state

UMK

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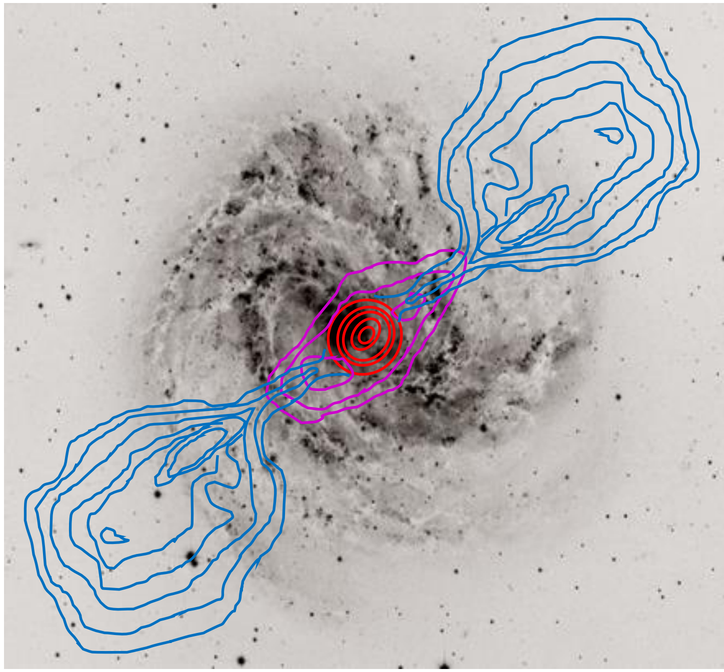
The life cycle of radio galaxy



GPS (< 1 kpc) => CSS (< 15 kpc) => FRI/FRII (> 15 kpc)

Many of radio-loud AGNs may undergo short episodes of activity (accretion) – 10^4-10^5 years.

Reynolds & Begelman 1997, O'Dea & Baum 1997, Czerny+2009, Kunert-Bajraszewska+2010, Sadler+2014, Callingham+2017

<u>Long-term studies of AGN evolution:</u>
Readhead+ 1994, Fanti+ 1995; Taylor+ 1996, O'Dea & Baum 1997, Snellen+ 2000, Marecki+ 2003, Gugliucci+ 2005, Kunert-Bajraszewska+ 2010, An & Baan 2012, Dallacasa+ 2013

An excess of compact sources – explanations:

Frustration scenario –
dense environment in the host galaxy preventing the source to develop above a certain size.

A short time scale episodic activity -
e.g. the radiation pressure instabilities in an accretion disk make the radio sources transient on timescales $<10^4-10^5$ yr.

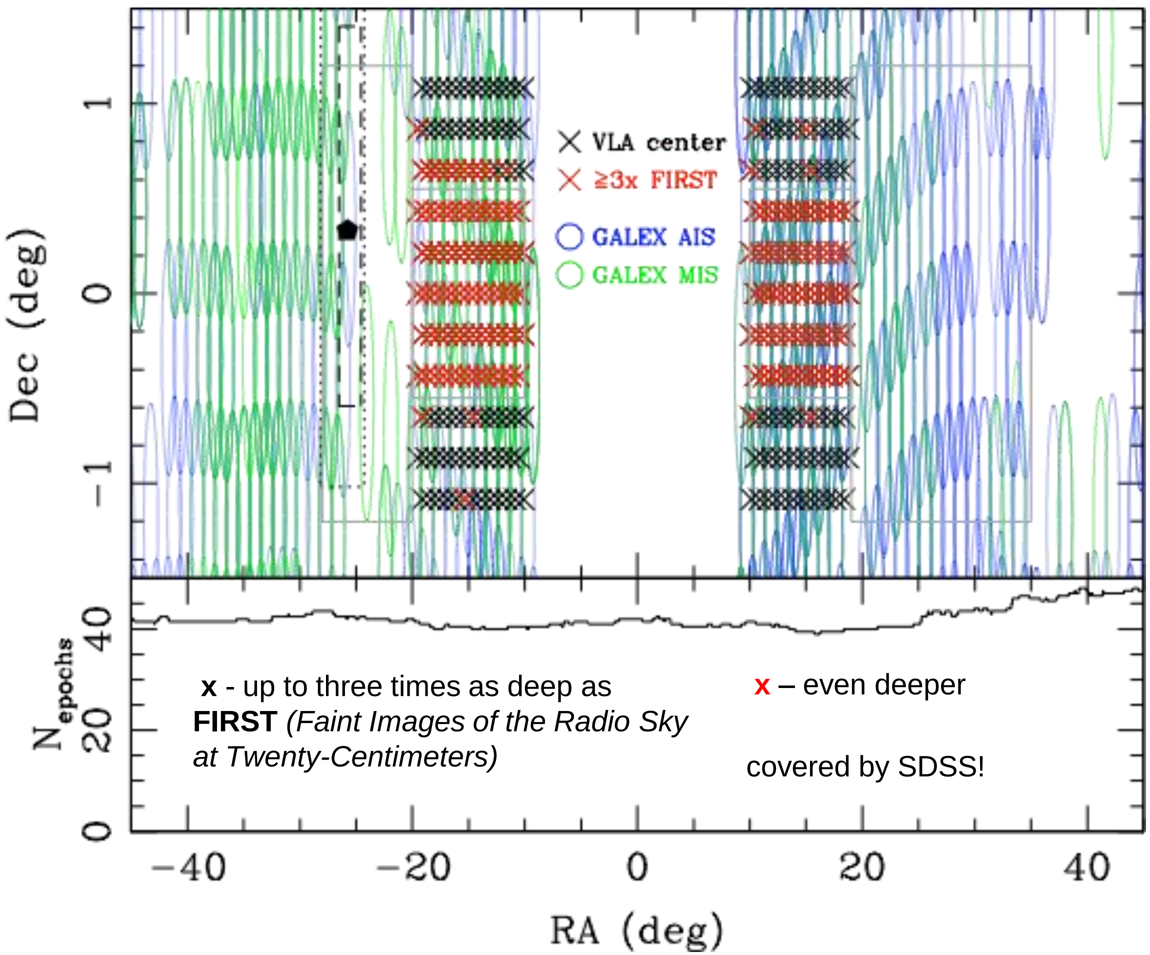
Newly discovered transient sources on decadal timescales that are likely associated with renewed AGN activity:

Kunert-Bajraszewska+2020 CNSS survey
Wołowska +2021

Nyland+2020 VLASS survey

The Caltech-NRAO Stripe 82 Survey (CNSS)

Stripe 82 - 270 deg^2 of sky on the celestial equator

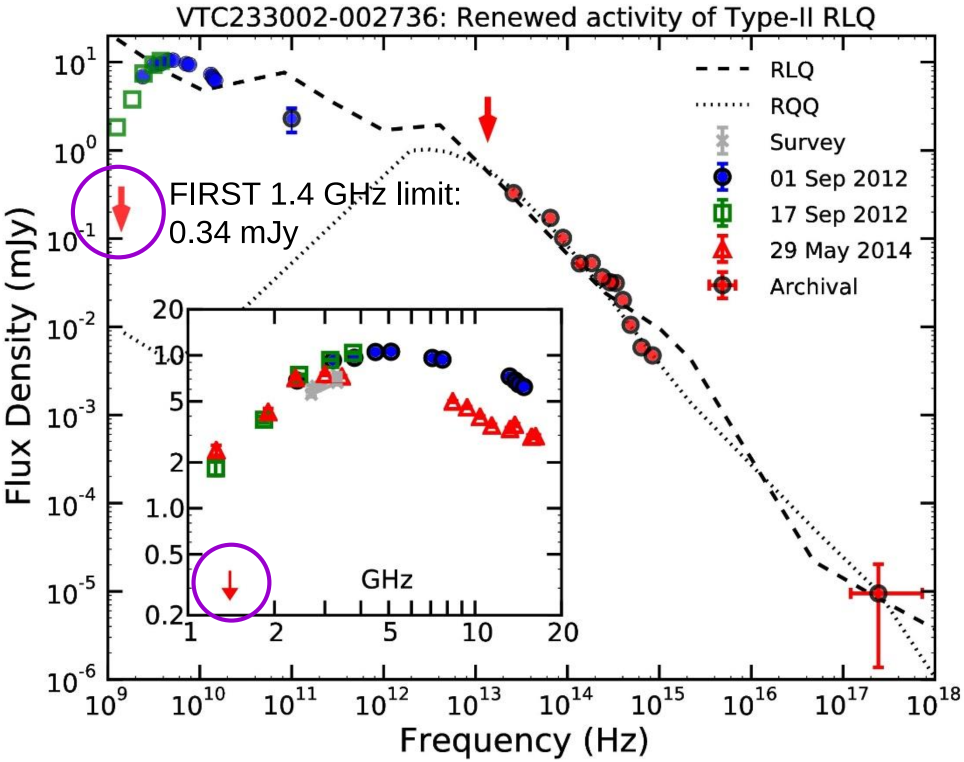


- **VLA, 2–4 GHz**, A and B conf.
  5 epochs (2012–2015)
  ~80 uJy (RMS) per epoch
  PI: Gregg Hallinan
- Over 140 transient phenomena discovered in pilot survey, e.g. binary stars, stellar outbursts and AGN shocks.
- 12 AGN outbursts that cannot be explained by shocks, not present in any radio catalogue --> **new sample!**

Mooley+2016, 2019

The first discovered source

Initial pilot survey of a 50 deg^2 region of Stripe 82.



Mooley+2016

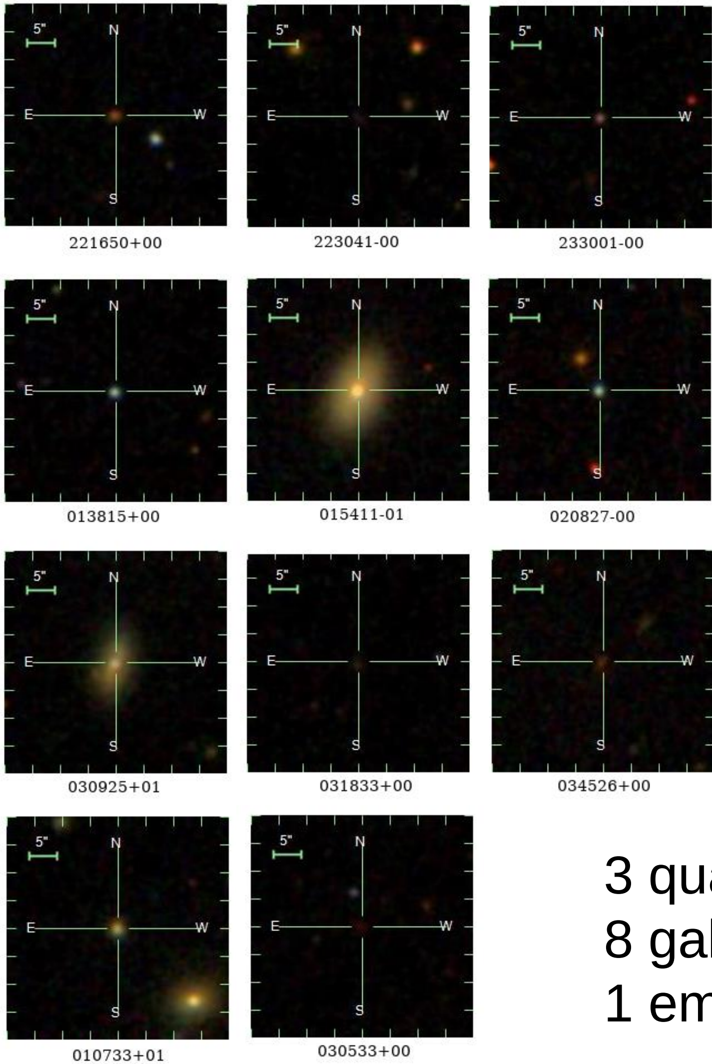
- A type-II quasar which increased its flux density about ten times at 1.4 GHz over a 15 yr period – not present in FIRST.
- Transition from radio-quiet to radio-loud phase.
- GPS spectrum indicative of a young jet.
- **Conclusion** - renewed jet-activity caused by the enhanced accretion process.

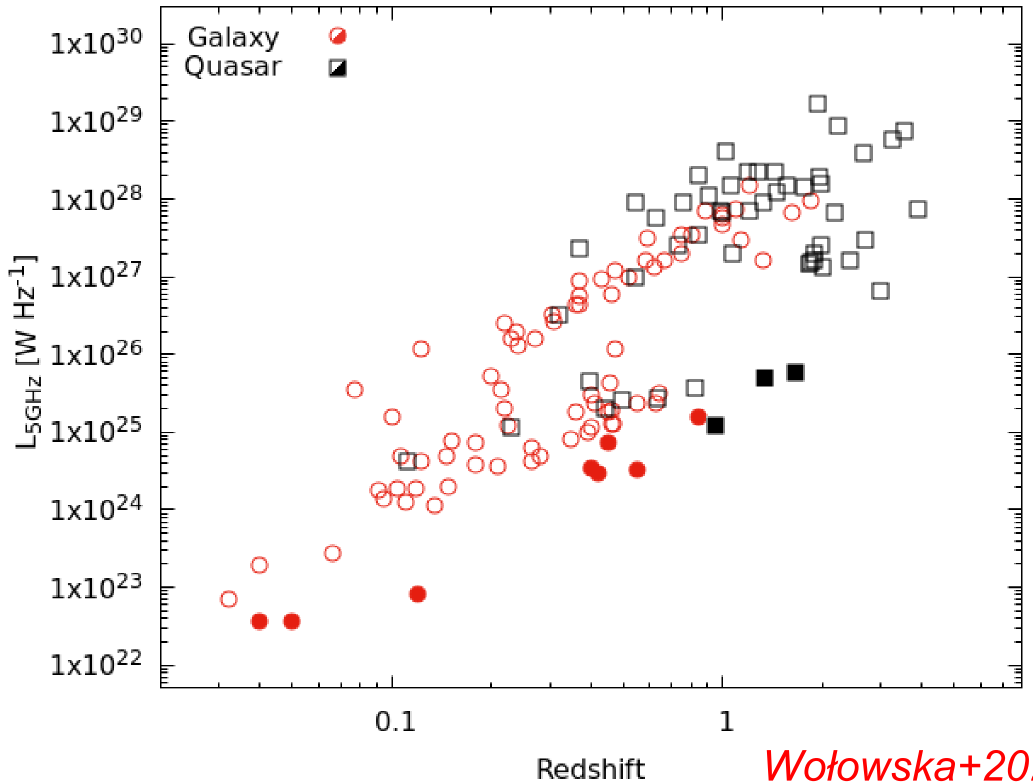
Another 11 such sources found in the whole Stripe 82 → **detection rate:** 1source per 20 deg^2.

Final sample: **12 radio transients undetected in the FIRST survey (~ 1992), but discovered in CNSS to have brightened dramatically in the past <20 years.**

Kunert-Bajraszewska+2020, Wołowska+2021

The sample





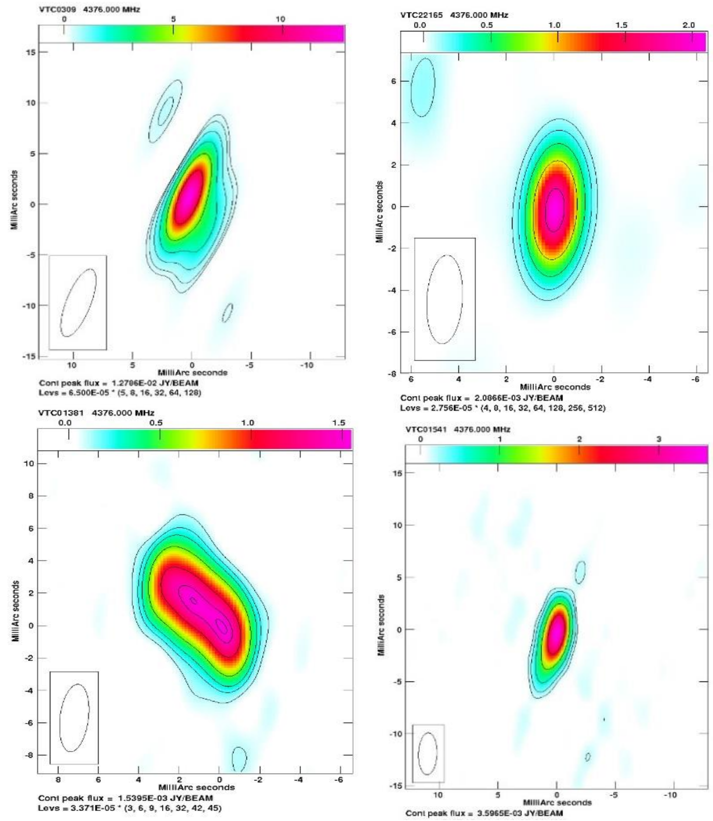
Wołowska+2021

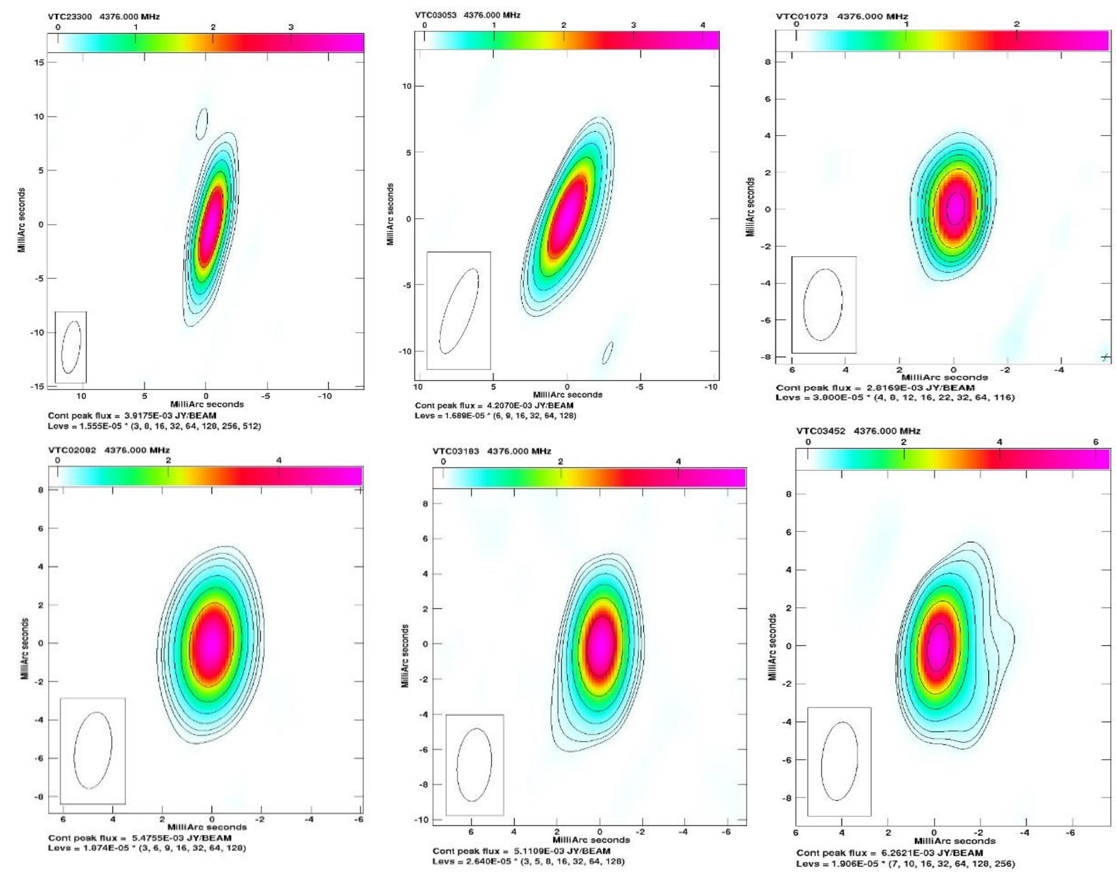
3 quasars with z>0.9
8 galaxies
1 empty field

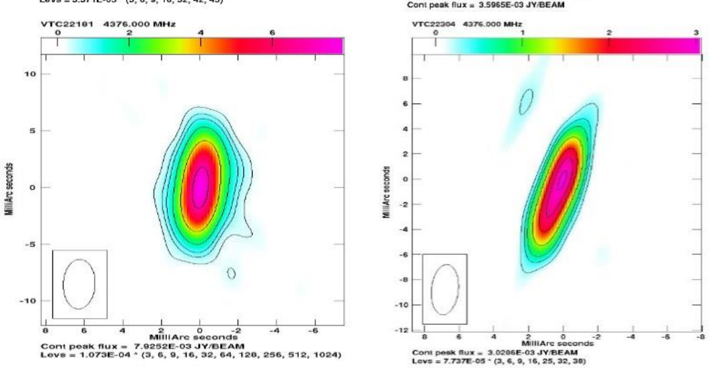
Luminosity range:
log [L_{5GHz}/ W Hz-1] : **22.6 – 25.7**

The follow up multi-epoch and multi-frequency study:
VLBA, VLA, GMRT, Chandra, XMM-Newton, SALT and SDSS.

VLBA studies (4.5 and 7.5 GHz)

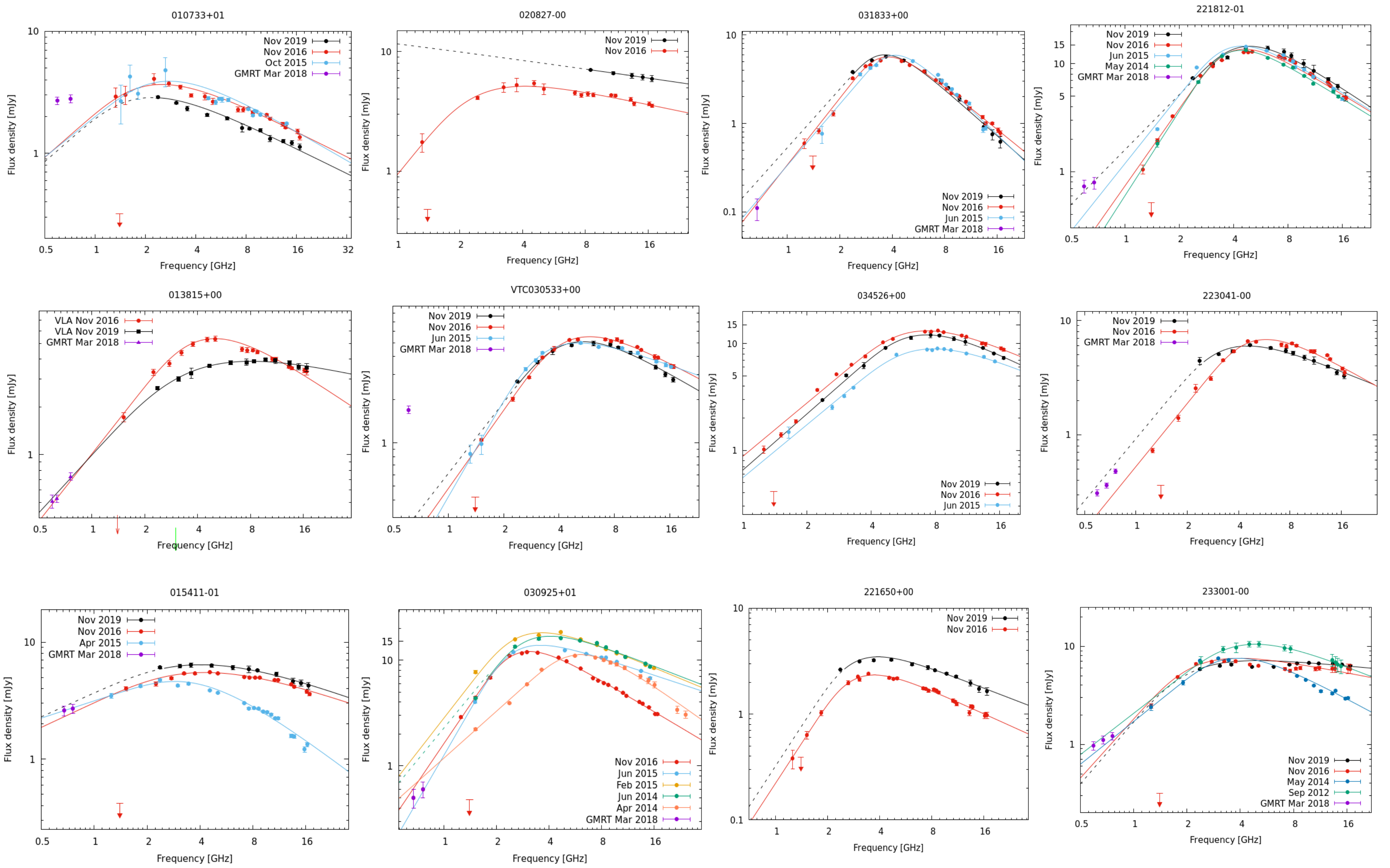




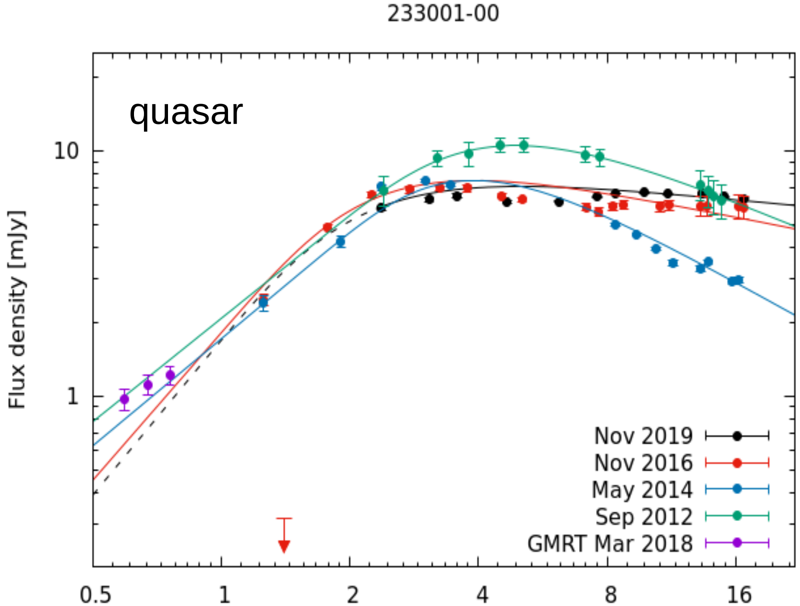


- Compact or slightly resolved structures.
- Small jets visible in some of them.
- Estimated linear sizes: 0.4 – 67 pc.

Evolving spectra – VLA and GMRT observations

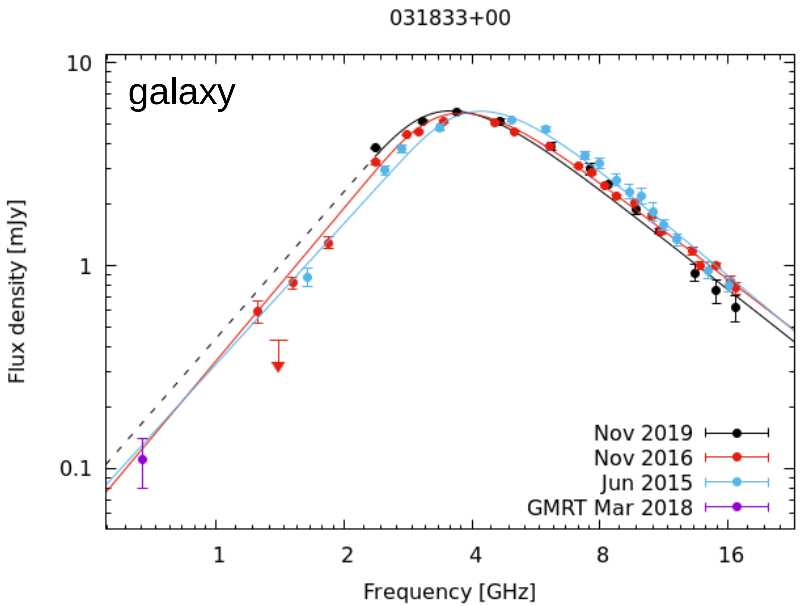


Evolving spectra – VLA and GMRT observations



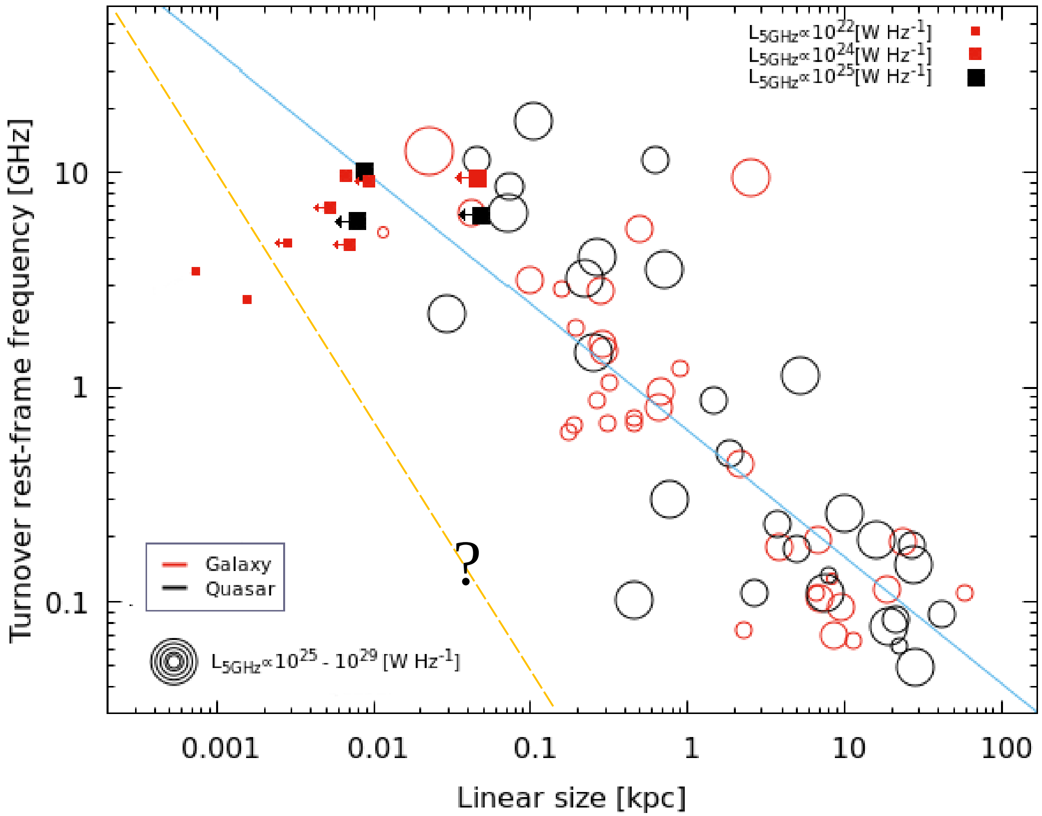
Obs epoch	S_p [mJy]	ν_p [GHz]	ν_p (1+z) [GHz]	α_{thin}	α_{thick}
Sep 2012	10.39±0.07	4.39±0.05	11.63	-0.74±0.07	1.45 ±0.25
May 2014	7.55±0.21	3.82±0.15	10.12	-0.98±0.06	1.45*
Nov 2016	6.60±0.15	2.40±0.19	6.36	-0.35±0.05	1.85 ±0.22
Nov 2019	5.60±0.22	2.20±0.16	5.83	-0.17±0.03	1.85*

- Spectra peaking at a few GHz.
- GPS quasars transform into flat–spectrum objects.
- GPS galaxies keep the convex shape of the spectrum.
- Our sources do not exceed the SSA limit of optically thick index = 2.5, however several of them are close to it.



Obs epoch	S_p [mJy]	ν_p [GHz]	ν_p (1+z) [GHz]	α_{thin}	α_{thick}
Jun 2015	5.77±0.23	4.25±0.10	5.95	-1.75±0.12	2.30 ±0.09
Nov 2016	5.65±0.09	3.70±0.05	5.18	-1.60±0.04	2.50 ±0.07
Nov 2019	5.80±0.13	3.55±0.08	4.97	-1.65±0.07	2.40*

The Peak Frequency - Linear Size Relationship



Wołowska+2021

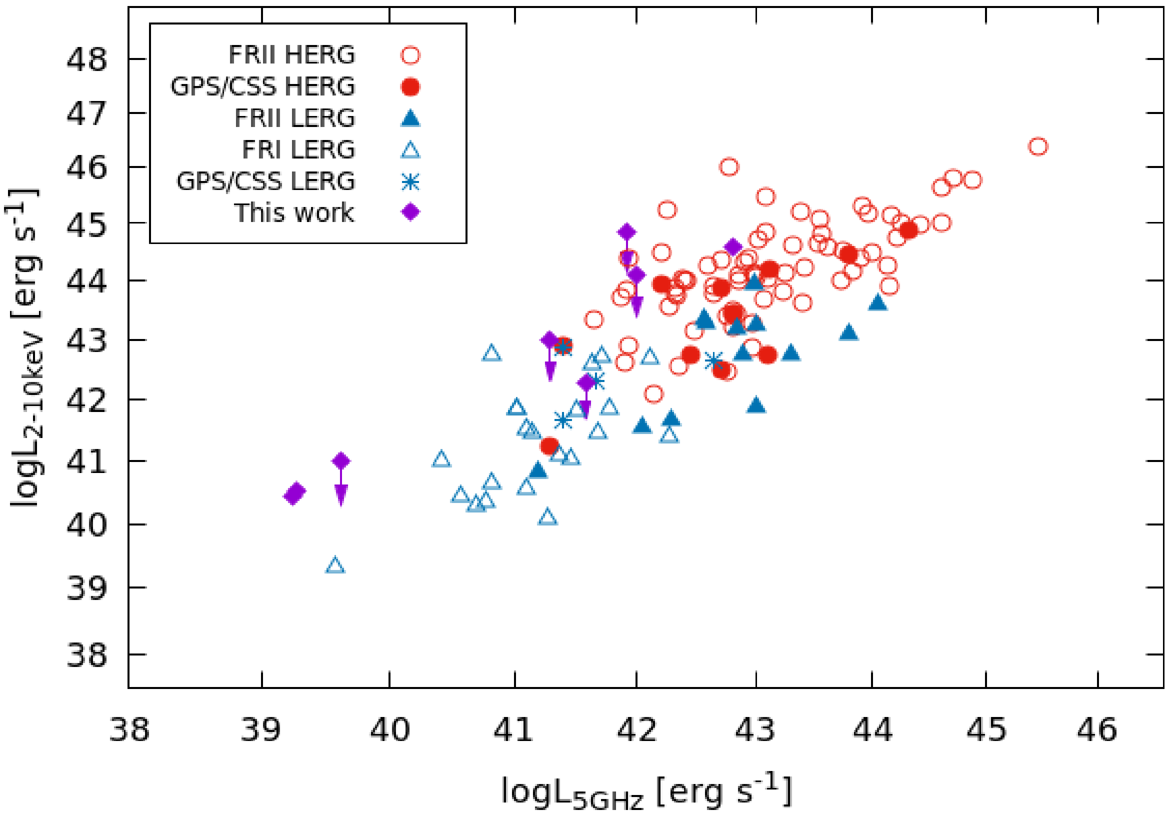
Filled squares: our 12 transient sources
Empty circles: sources from: O'Dea 1998, Snellen+ 1998, de Vries+ 1997, Stanghellini+ 1998, Fanti+ 1990.

Radio properties of our sources:

- weak radio objects;
- very compact; arrows indicate linear size upper limit;
- placed at the upper-left part of the plane → early life stage;
- some of them show slight discrepancy from the established relation (Orienti & Dallacasa 2014) suggesting remaining compact for a longer period of time.

X-ray properties

XMM-Newton/Chandra observations

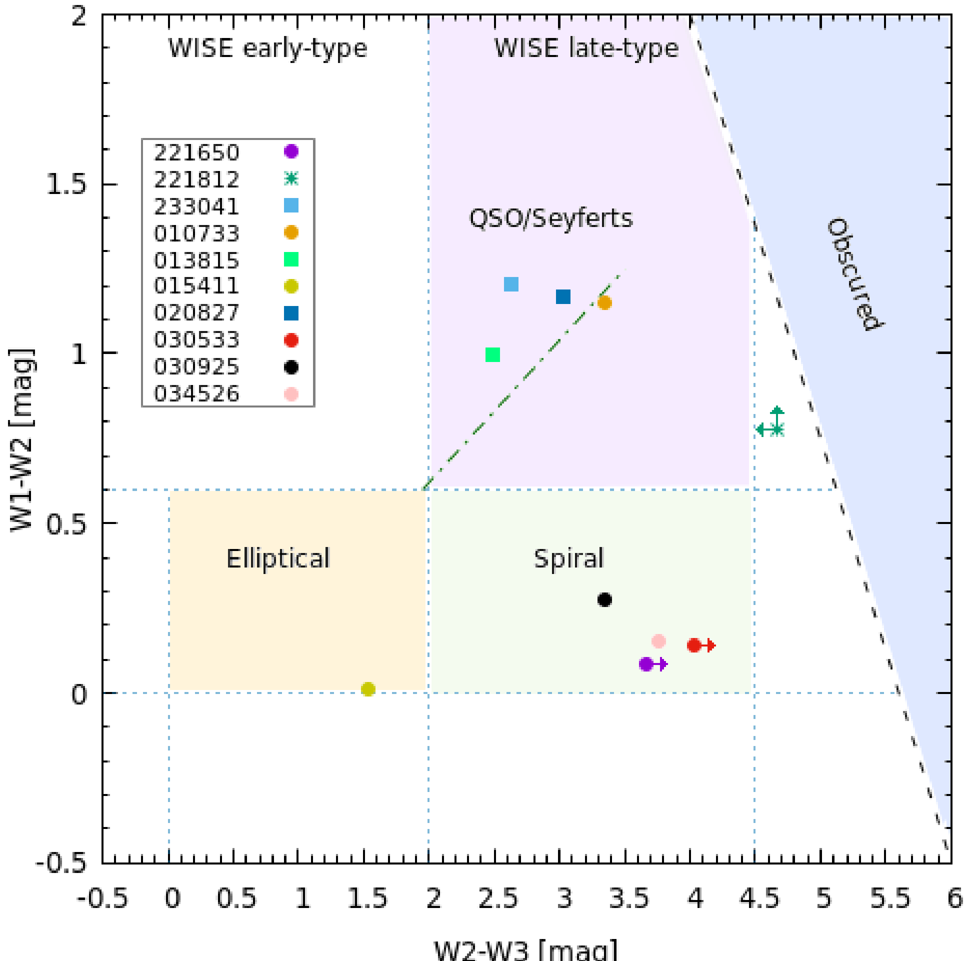


Wołowska+2021

- Nine sources observed between 2016 and 2018 withXMM-Newton and Chandra.
- 3 detections.
- Upper limits for other sources.

- Wide luminosity range: $40 < \log_{10}[L_X/\mathrm{erg\ s^{-1}}] < 45$; the lower values are consistent with inefficient accretion mode.
- Location of the sources on the radio/X-ray luminosity plane provides a preliminary classification (2 galaxies classified as LERGs and one quasar classified as HERG).

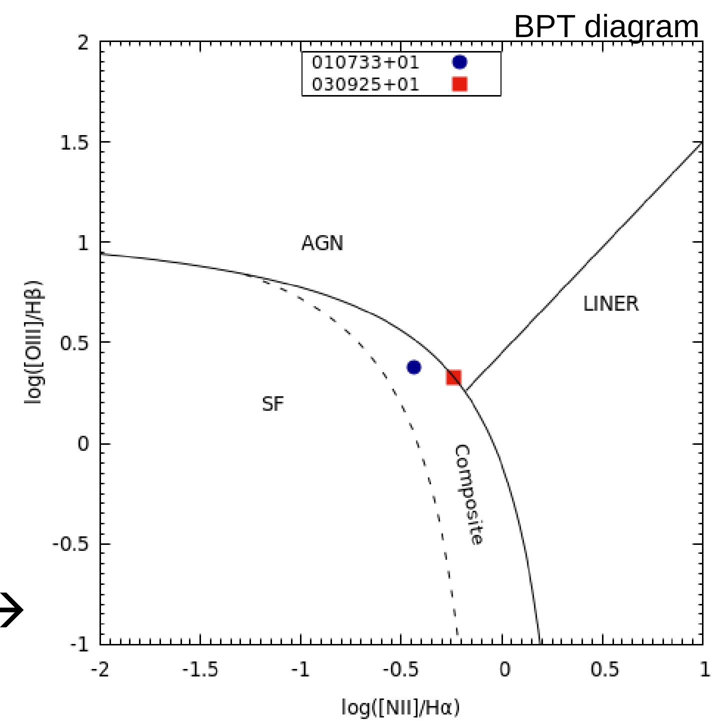
IR emission *(WISE data)*



Wołowska+2021

Divisions for different group of sources based on:
Wright+2010,Massaro+ 2012, Sadler+2014,Lonsdale+ 2015.

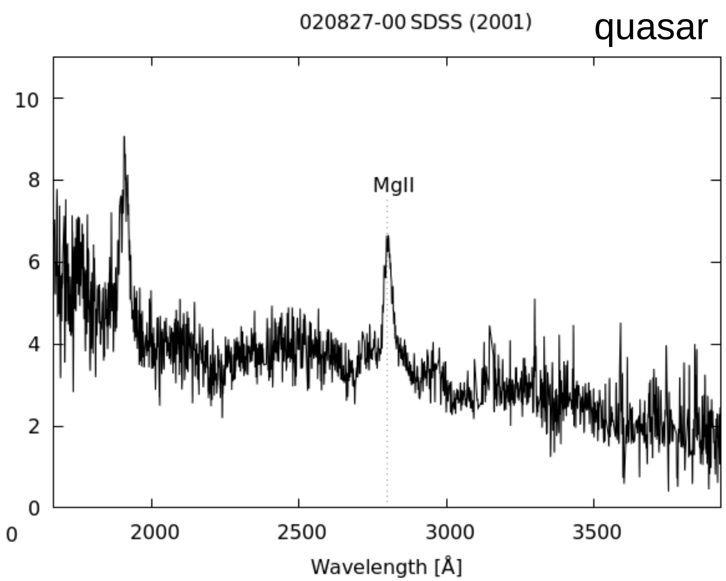
- Objects with W2-W3 > 2 are thought to have gas- and dust- rich environments (Chandola+2020).
- Majority of the host galaxies of our sources are spirals or other dusty, late-type galaxies with some ongoing star-formation.

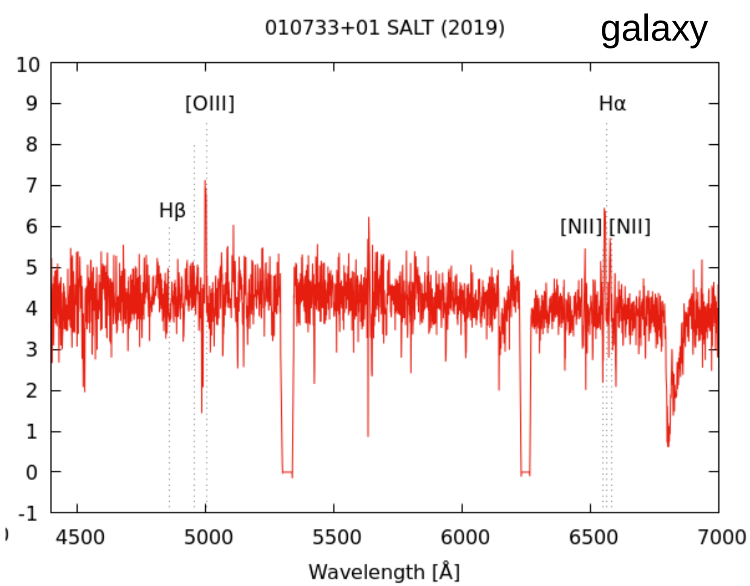


In agreement with optical classification →

Optical spectra and properties

SDSS, Keck and SALT data





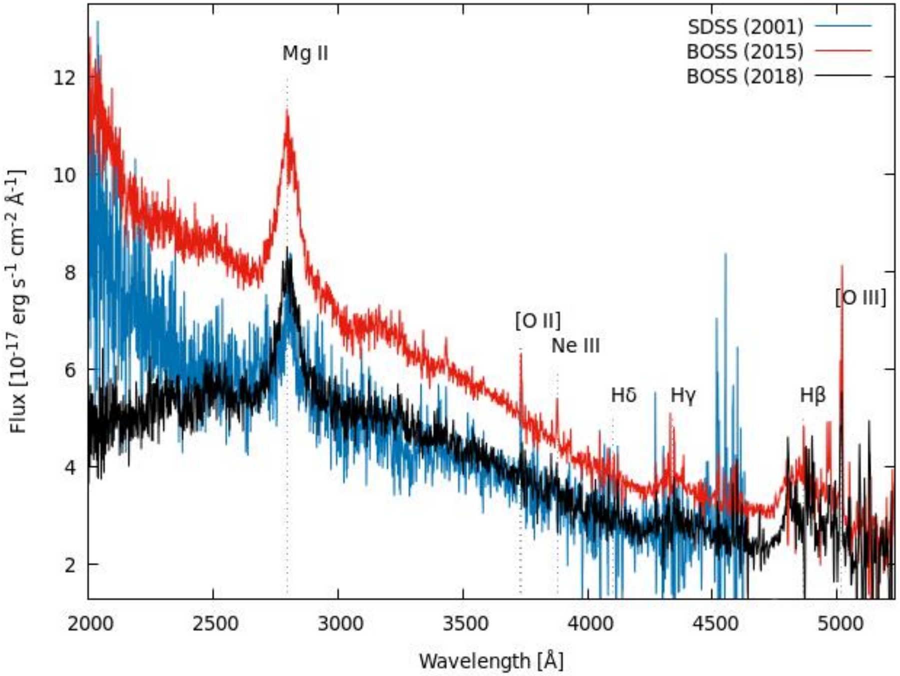
Wołowska+2021

- spectra available for 6 out of 12 objects;
- strong broad MgII line typical of unobscured AGN - quasars;
- many narrow emission lines typical for obscured AGN – galaxies;
- wide range of bolometric luminosities, black hole masses and jet powers, suggesting that young AGNs belong to several different sub-classes of objects;

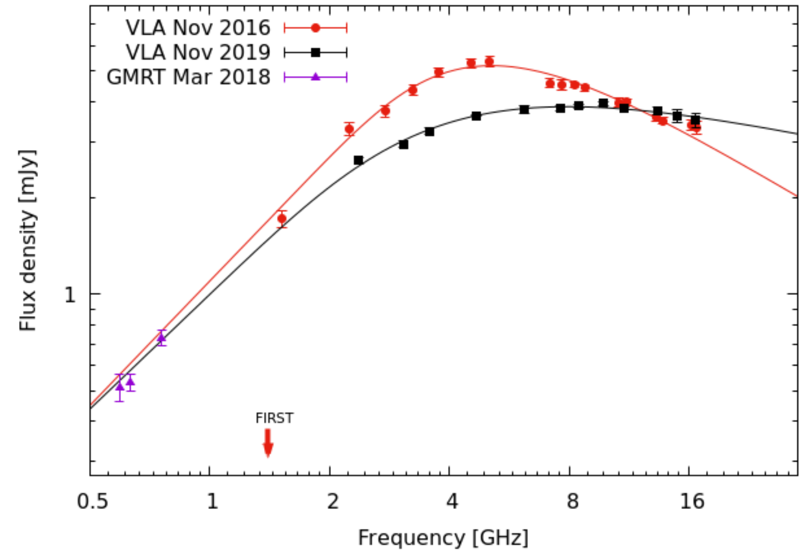
Black hole mass: $6.8 < \log M_{BH} < 9.4$
Bolometric luminosity: $42.7 < \log L_{bol} < 45.7$
Jet power: $40.1 < \log P_j < 44.8$

Optical spectra and properties

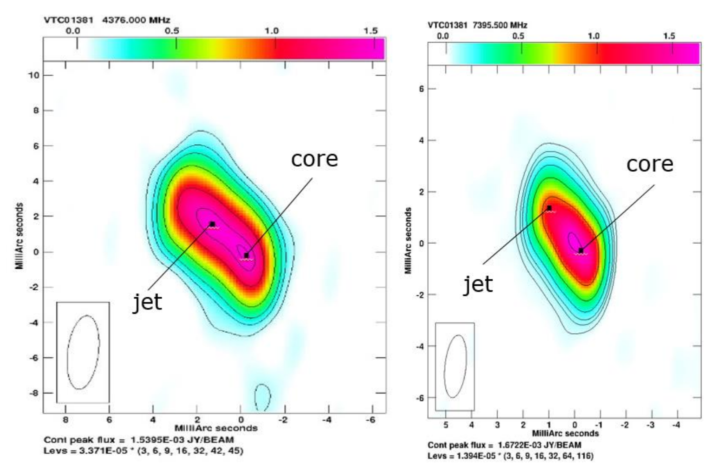
SDSS, Keck and SALT data



quasar 013815 at z=0.94

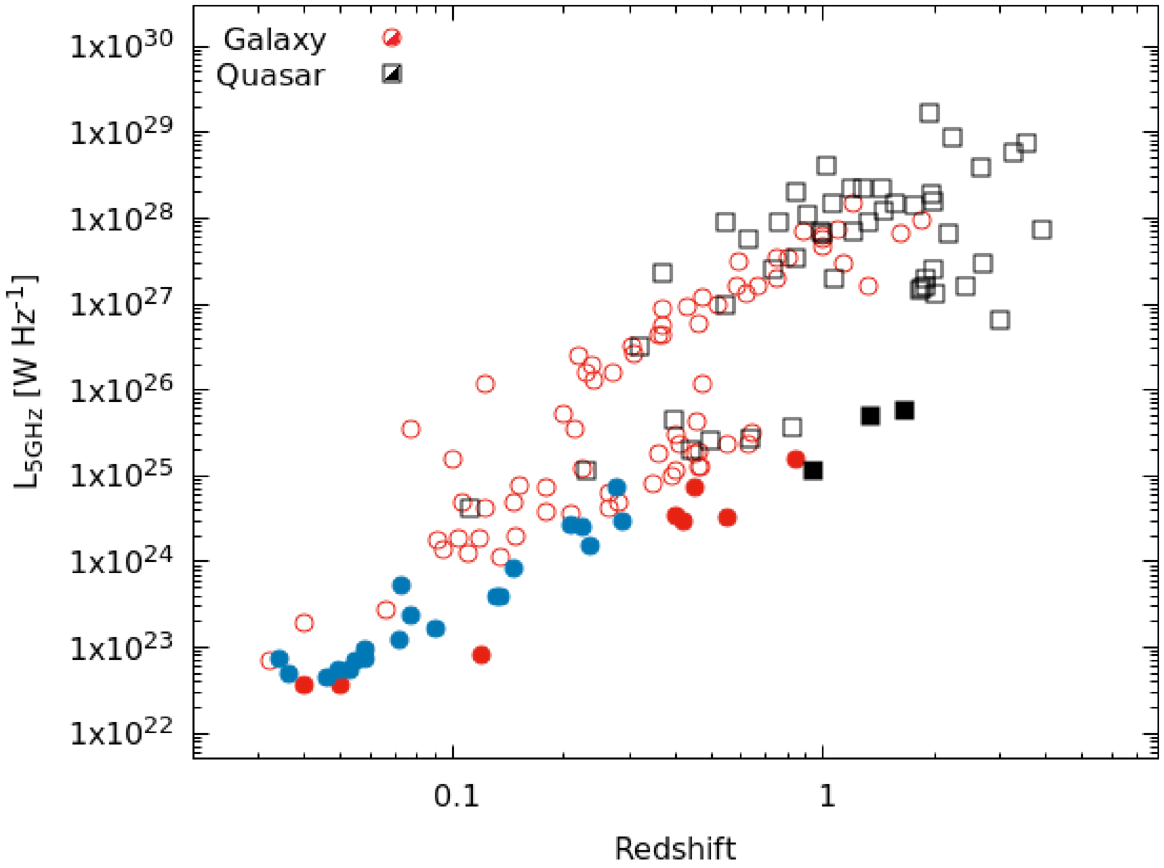


Kunert-Bajraszewska+2020



- Discovered as a radio source on 12.12.2013.
- Transition to the radio-loud mode coincides with changes of its UV–optical continuum and the low ionization Mg II broadline.
- It went through the short gigahertz-peaked spectrum phase at the beginning of its activity.

Future studies



○ □ - previous sample found in the literature

● ■ - new transients from CNSS

● - new VLASS galaxies

VLA Sky Survey (VLASS) epoch 1 observations;

point-like sources that were >8 mJy and absent in the NVSS (<2.5 mJy at 1.4 GHz);

coincident within 2 arcsec with the nuclei nearby galaxies having r<20 mag based on visual inspection of a Pan-STARRS optical images;

Final sample:

24 newly-born candidates for short-lived radio AGN, undetected in the NVSS survey (~1995), but discovered in VLASS to have brightened in the past ~25 years.

Summary

- The discovered radio sources might have transitioned from a radio-quiet to radio-loud state either as a result of the increase in radio power or its ignition.

- They have been classified as GPS sources based on their radio properties.

- Over time, GPS sources transform into flat-spectrum objects while galaxies keep the convex shape of the spectrum. We conclude thus that many of the young quasars can be hidden in the flat-spectrum quasars population.

- The placement of the sources on the turnover frequency vs. linear size plane indicates that they are in early life stage. Some of the sources show slight discrepancy from the established elation suggesting their slower growth in size.

- WISE infrared colors imply that the majority of the host galaxies of our sources are spirals or other dusty, late-type galaxies with some ongoing star-formation.

- The X-ray luminosities and physical parameters of the sources, suggesting that they belong to several different subclasses of objects. Changes in the accretion disk happen on the much shorter timescales than the lifetime of the newborn radio source.


Thank you!