GRACE

Giant RAdio galaxies and their duty CyclE

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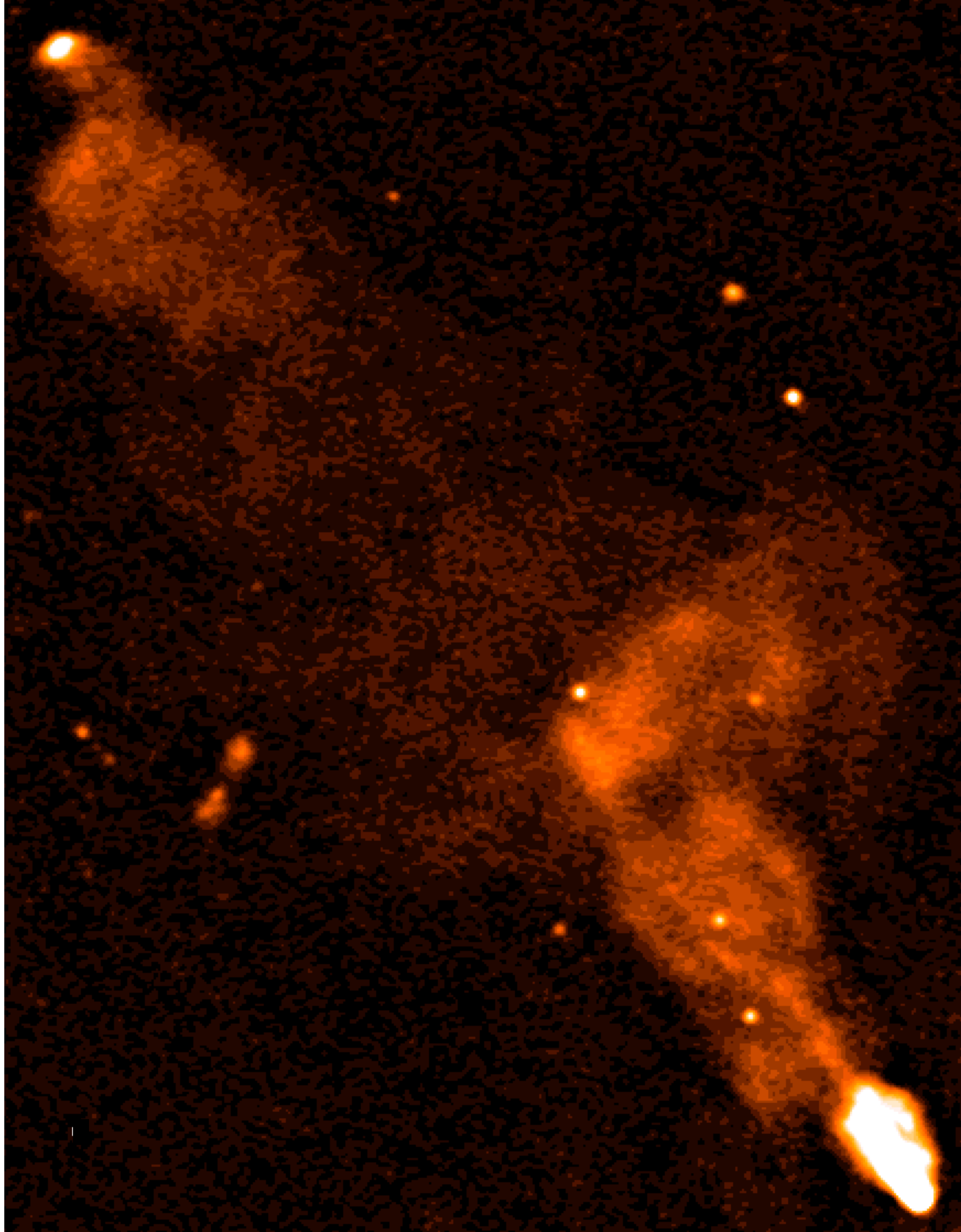
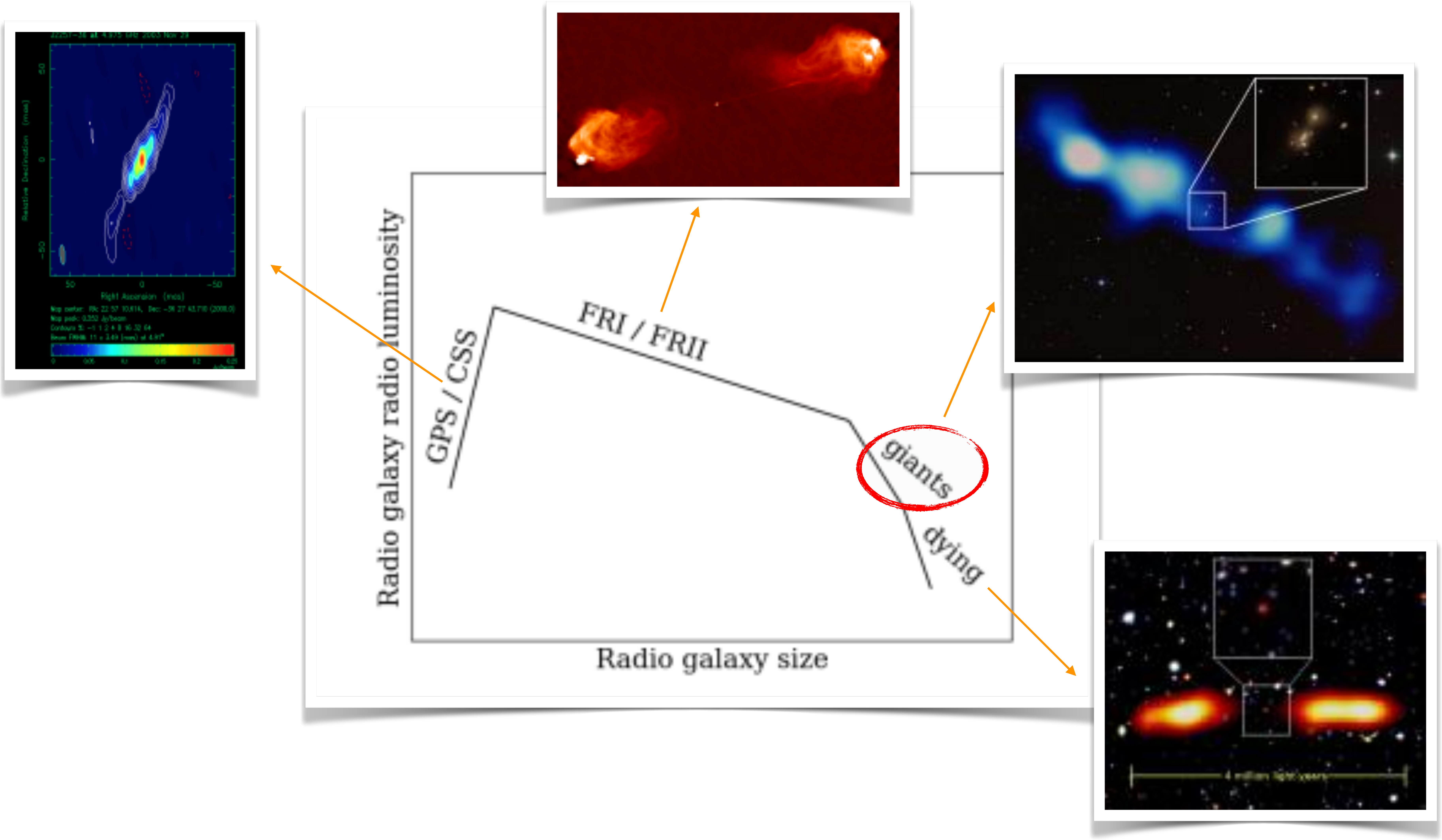
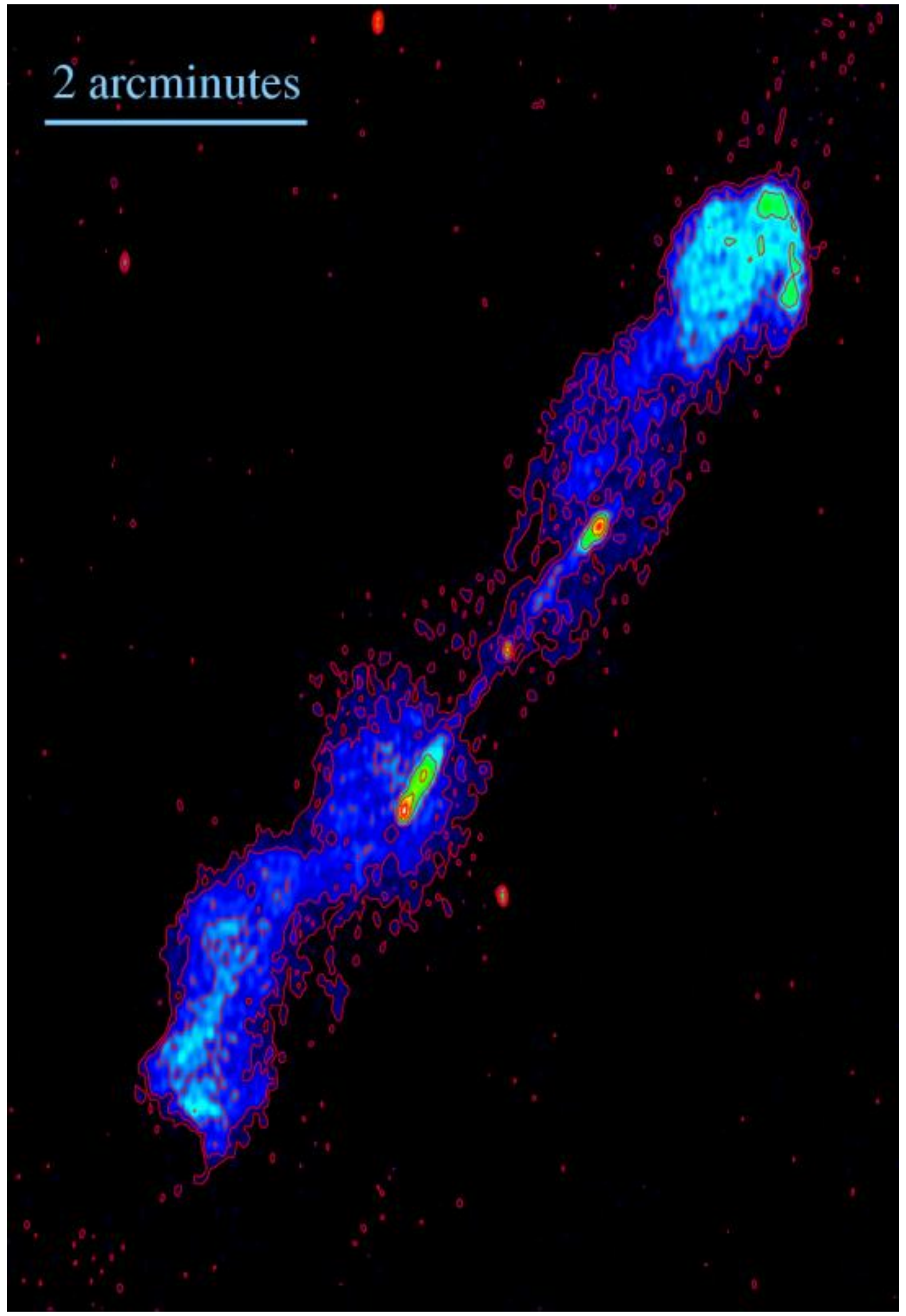


GIANT RADIO GALAXIES



GIANT RADIO GALAXIES

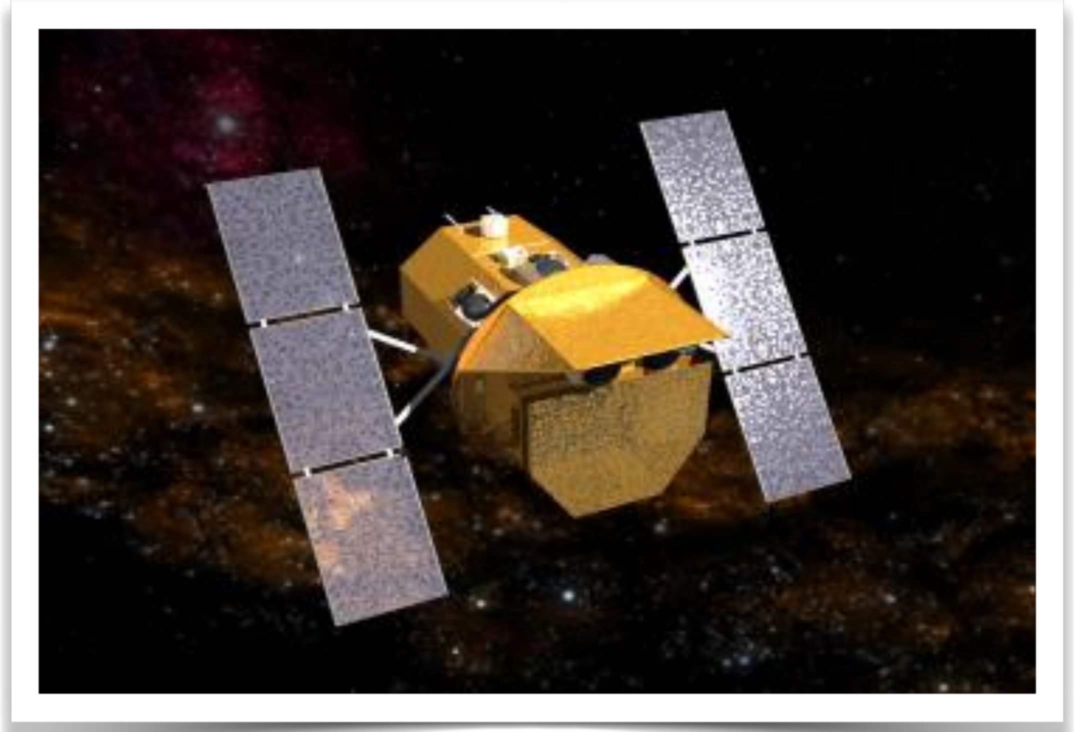
- GRG are the largest single-entities in the Universe (>0.7 Mpc)
- Low surface brightness, complex morphology, difficult to discover
- In radio surveys, only 1-6% of objects are GRG (~500 GRG known to date)
- Size due to environment, or high jet power, or long activity time?



B1545-321 (ATCA, 13cm)

THE SOFT GAMMA-RAY SKY

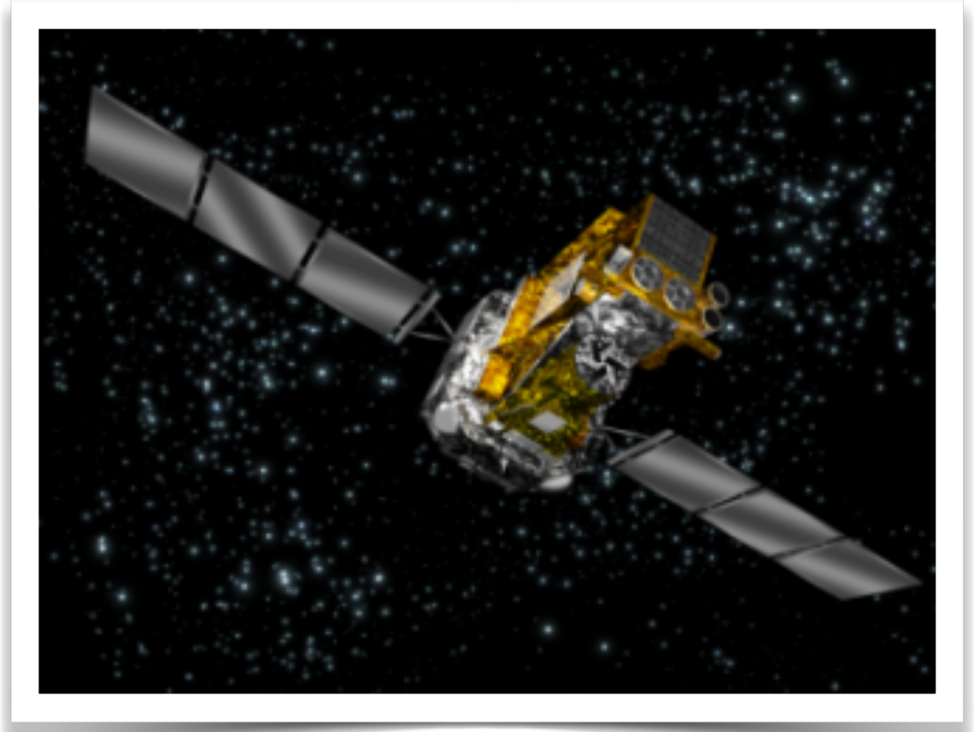
Space-based observatories scanning the soft gamma-ray sky since 2002…



Swift/BAT

(15 keV - 150 keV)

Baumgartner et al. 2013



INTEGRAL/IBIS

(15 keV - 10 MeV)

Bird et al. 2010

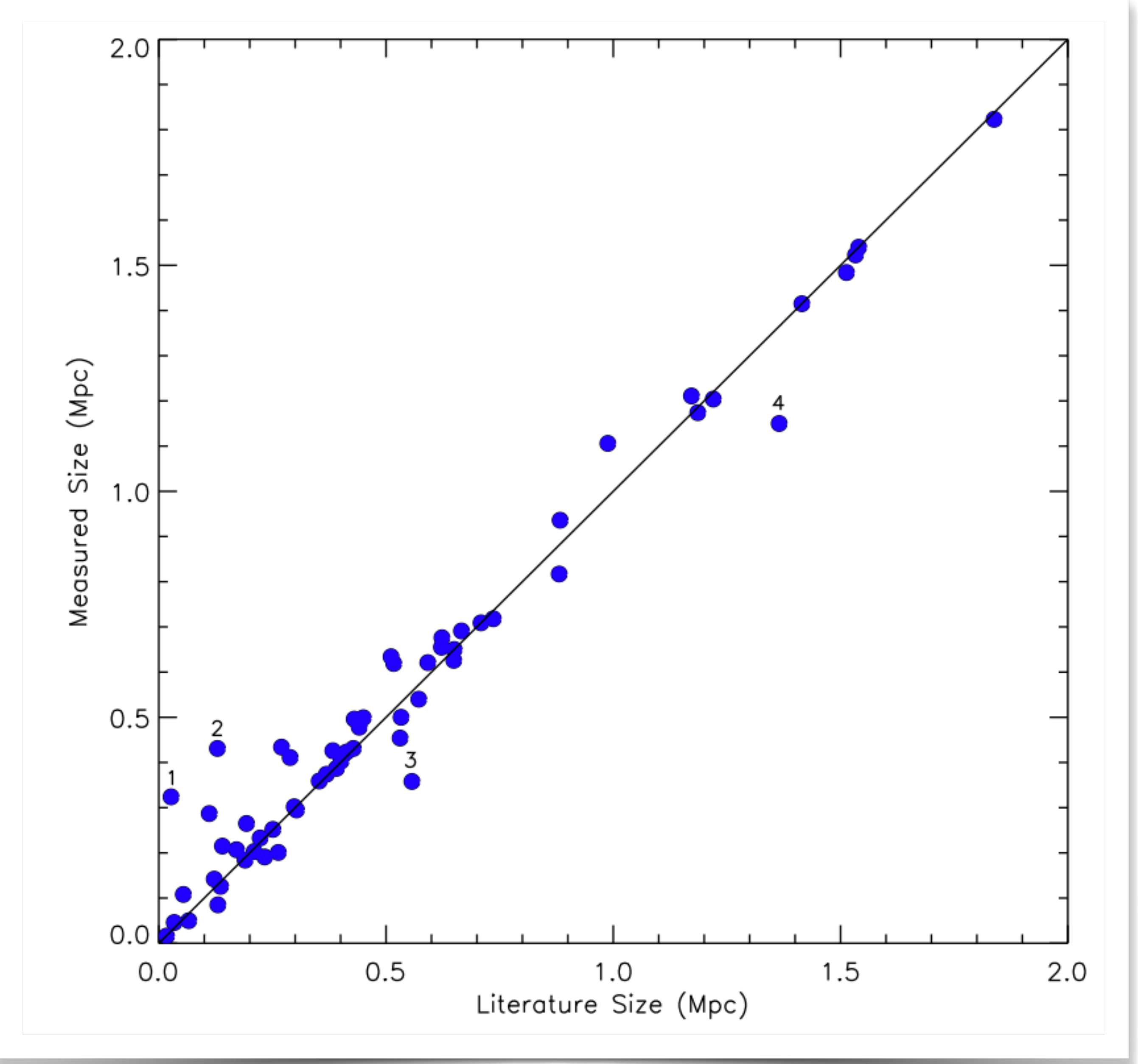
Malizia et al. 2012

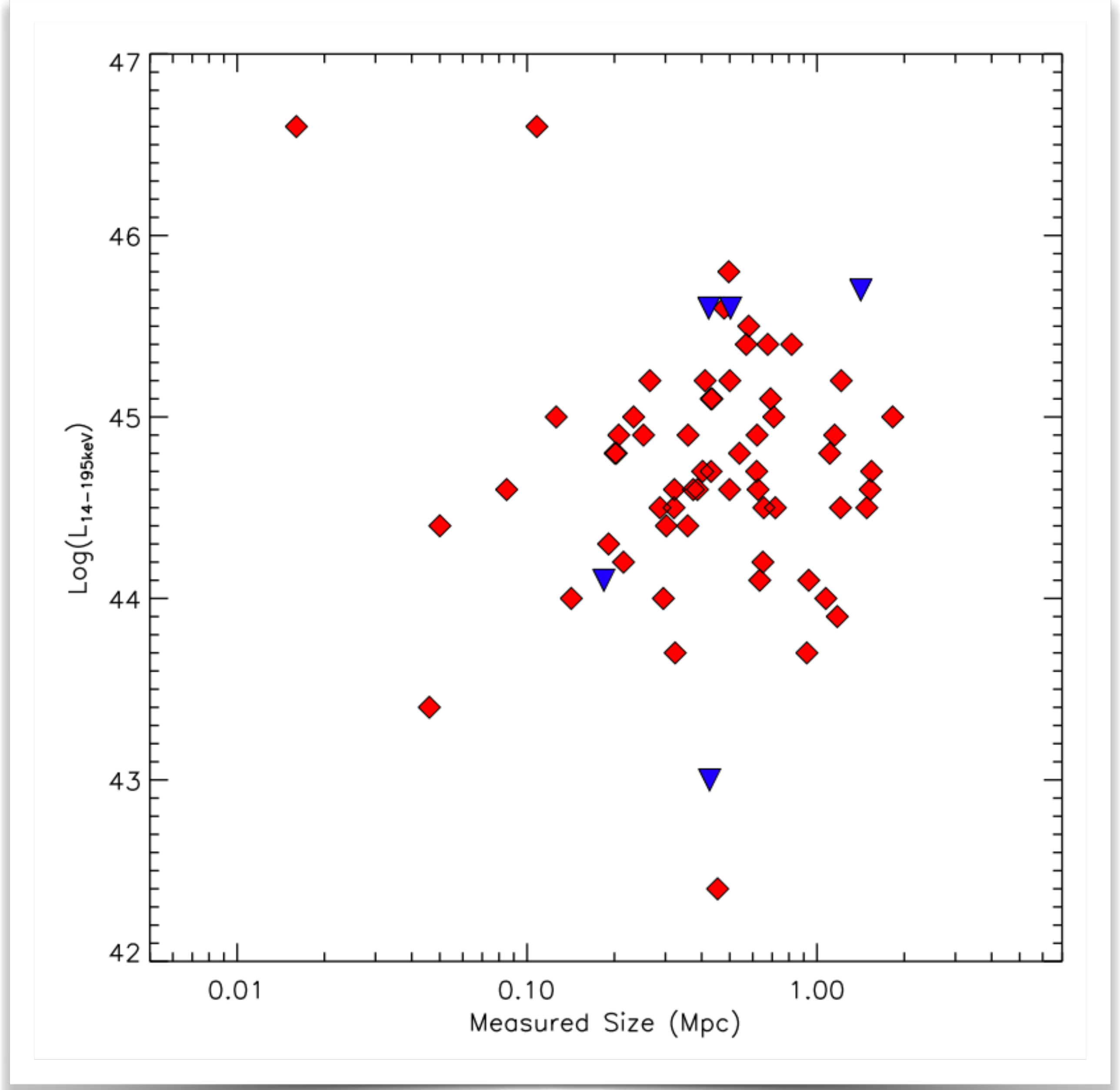
…most extensive list of soft gamma-ray selected AGN

RADIO COUNTERPARTS

- Cross-correlation with NVSS, FIRST, and SUMSS
- Visual inspection of 1000 images, searching for extended structures…
- …and measuring the largest angular size, and linear size in Mpc

67 radio galaxies with double morphology
31 RG with size >0.5 Mpc
15 GRGs >0.7 Mpc (22%)



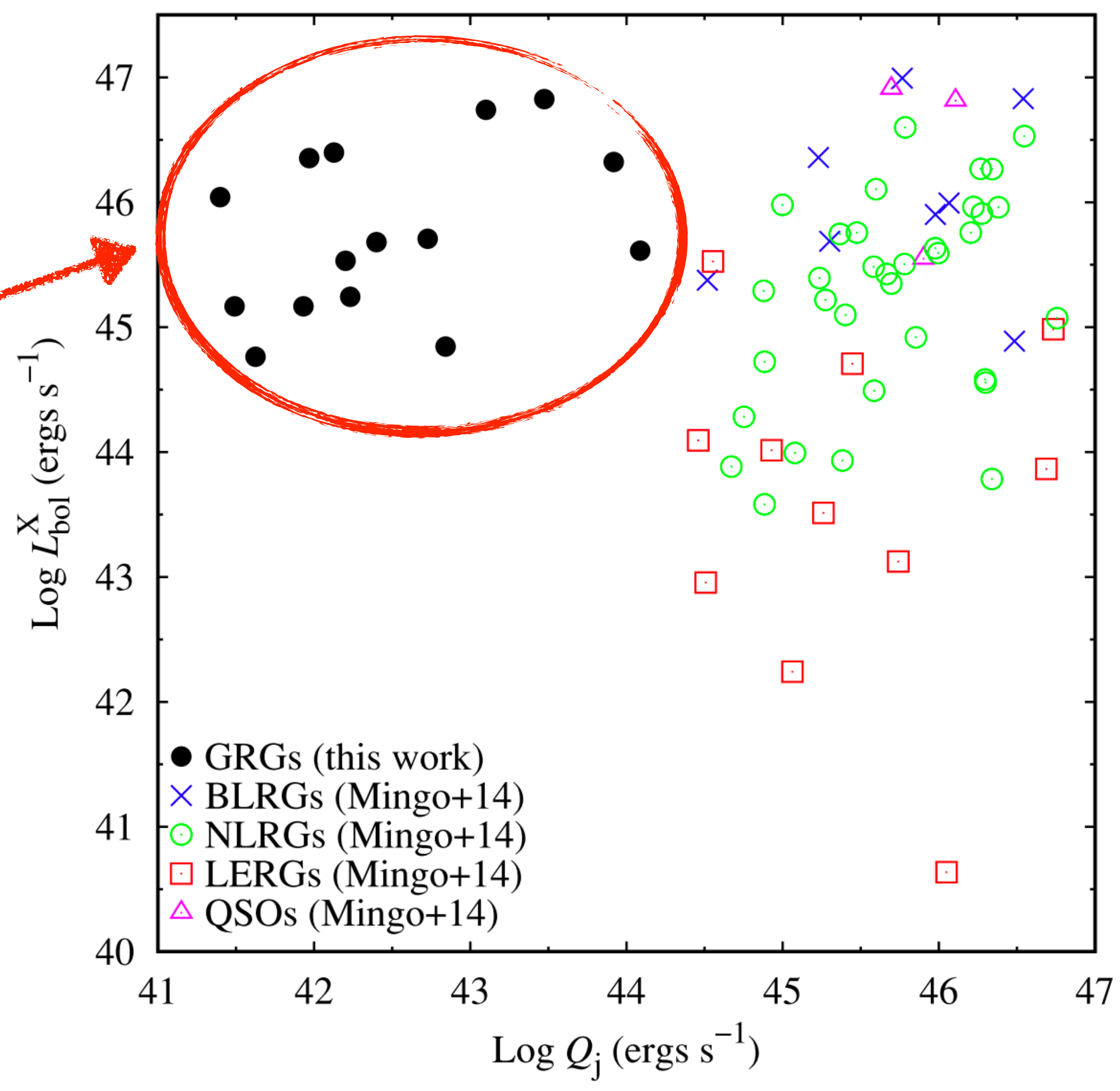


Bassani et al. 2016

SIGNS OF RESTARTING ACTIVITY

- Correlation between the X-ray luminosity and the radio core luminosity, consistent with that expected for AGN powered by efficient accretion.
- Luminosity of the radio lobes and the estimated jet power are relatively low compared with the nuclear X-ray emission.
- either the nucleus is more powerful than in the past, consistent with a restarting central engine, or giant lobes are dimmer due to expansion losses.

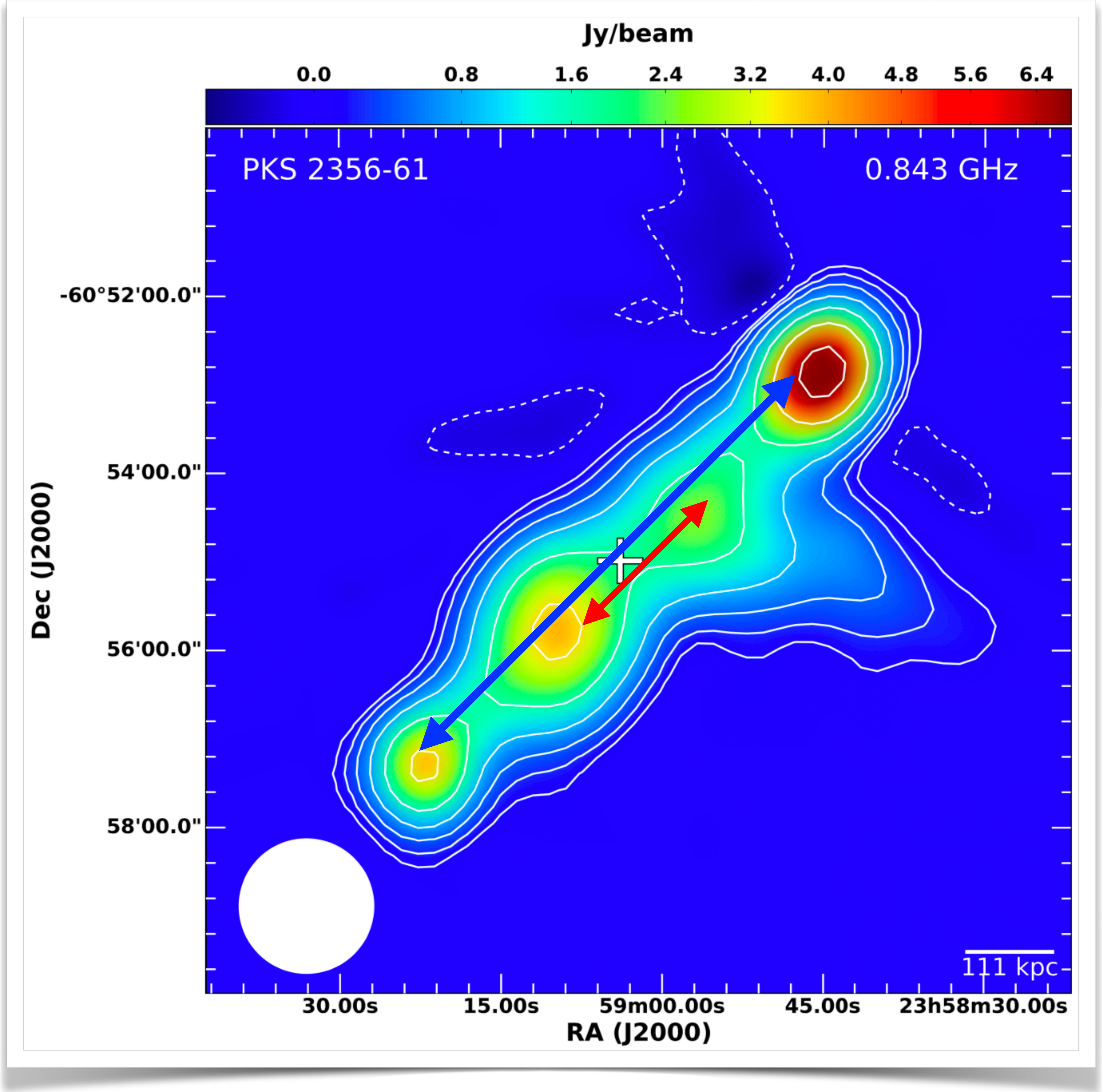
X−ray−derived bolometric luminosity vs. jet power



Ursini et al. 2018

SIGNS OF RESTARTING ACTIVITY

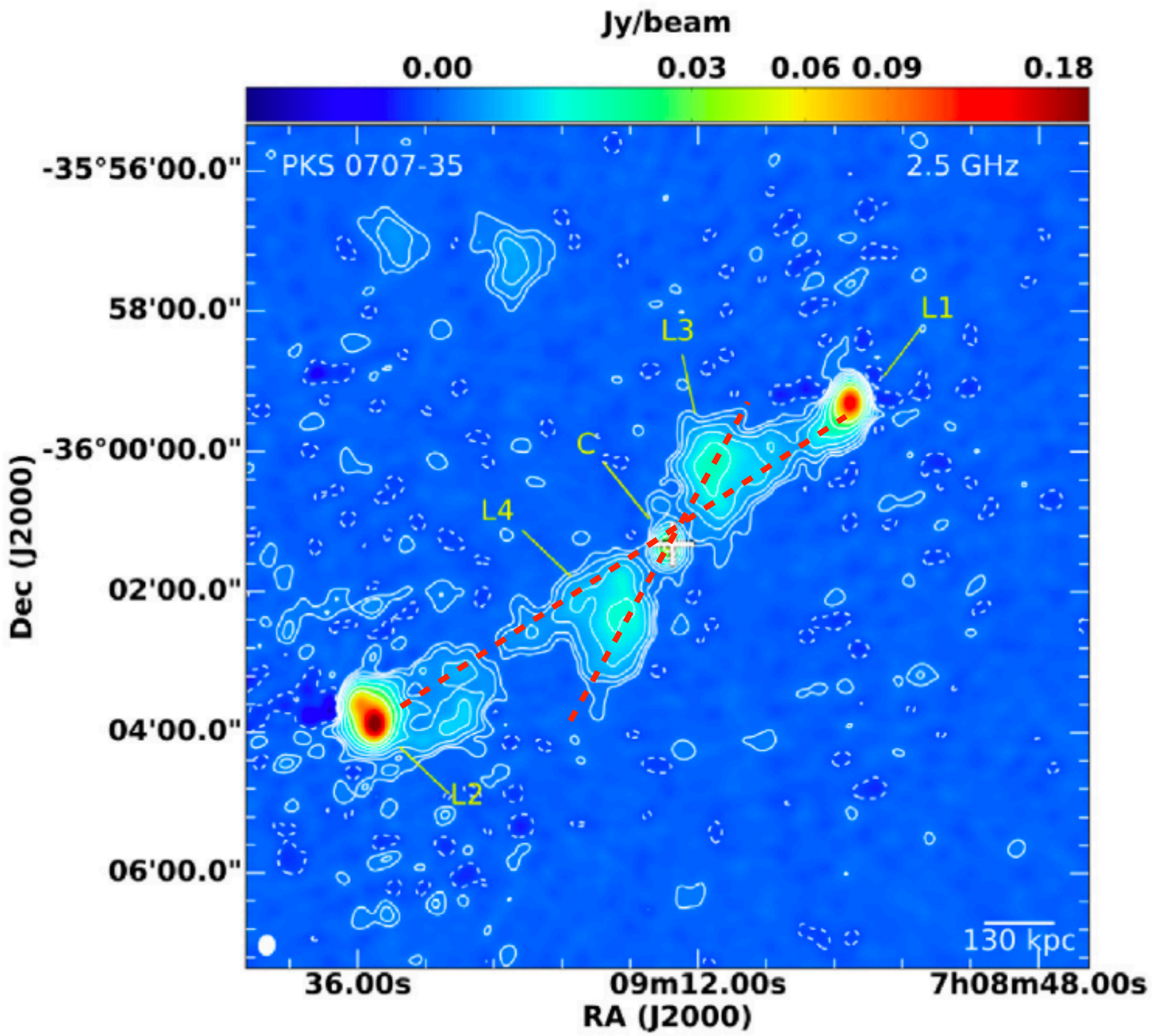
Double-Double RG

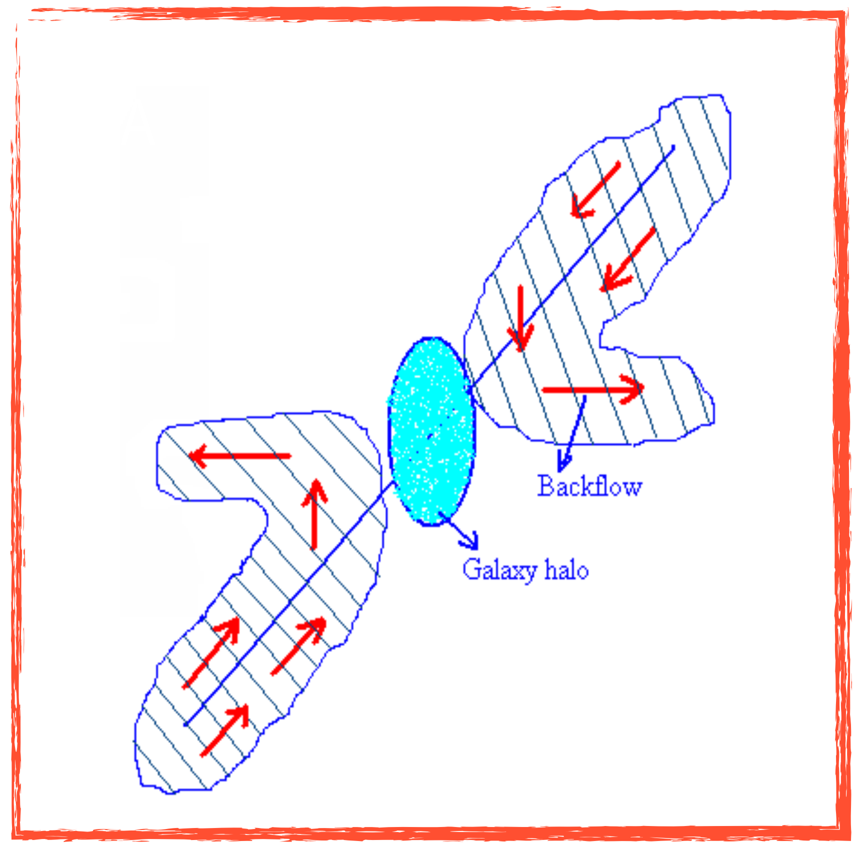


SUMSS
Bruni et al. 2020
Subrahmayan et al. 1996

SIGNS OF RESTARTING ACTIVITY

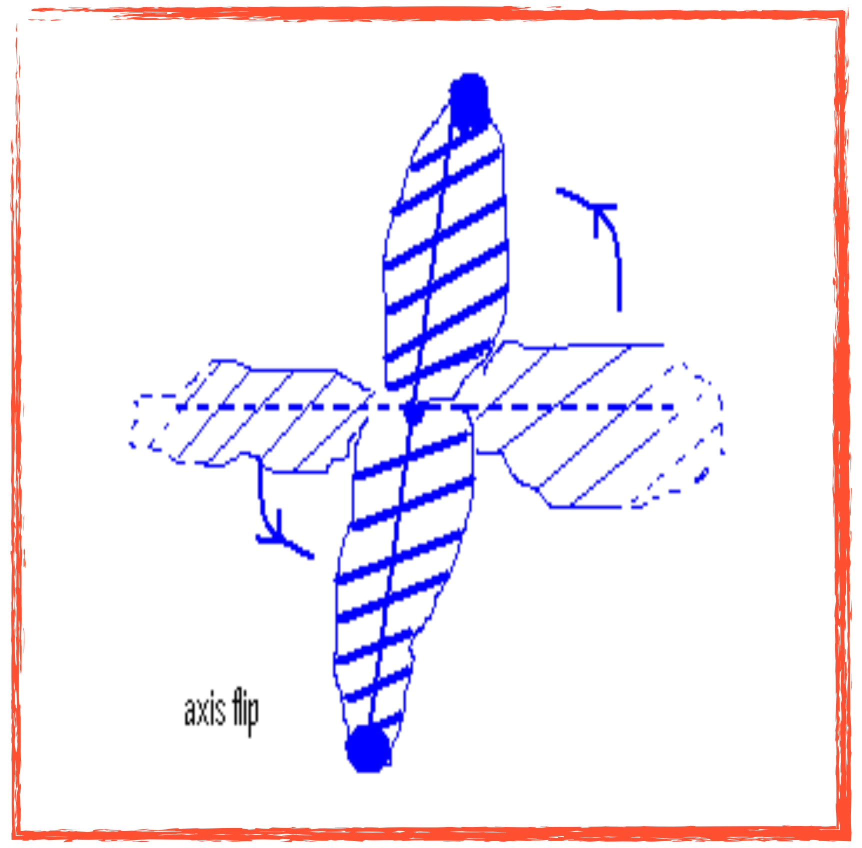
X-shaped RG





Backflow model

Lobe material back flowing towards core, deflected by thermal gas halo.



Jet reorientation

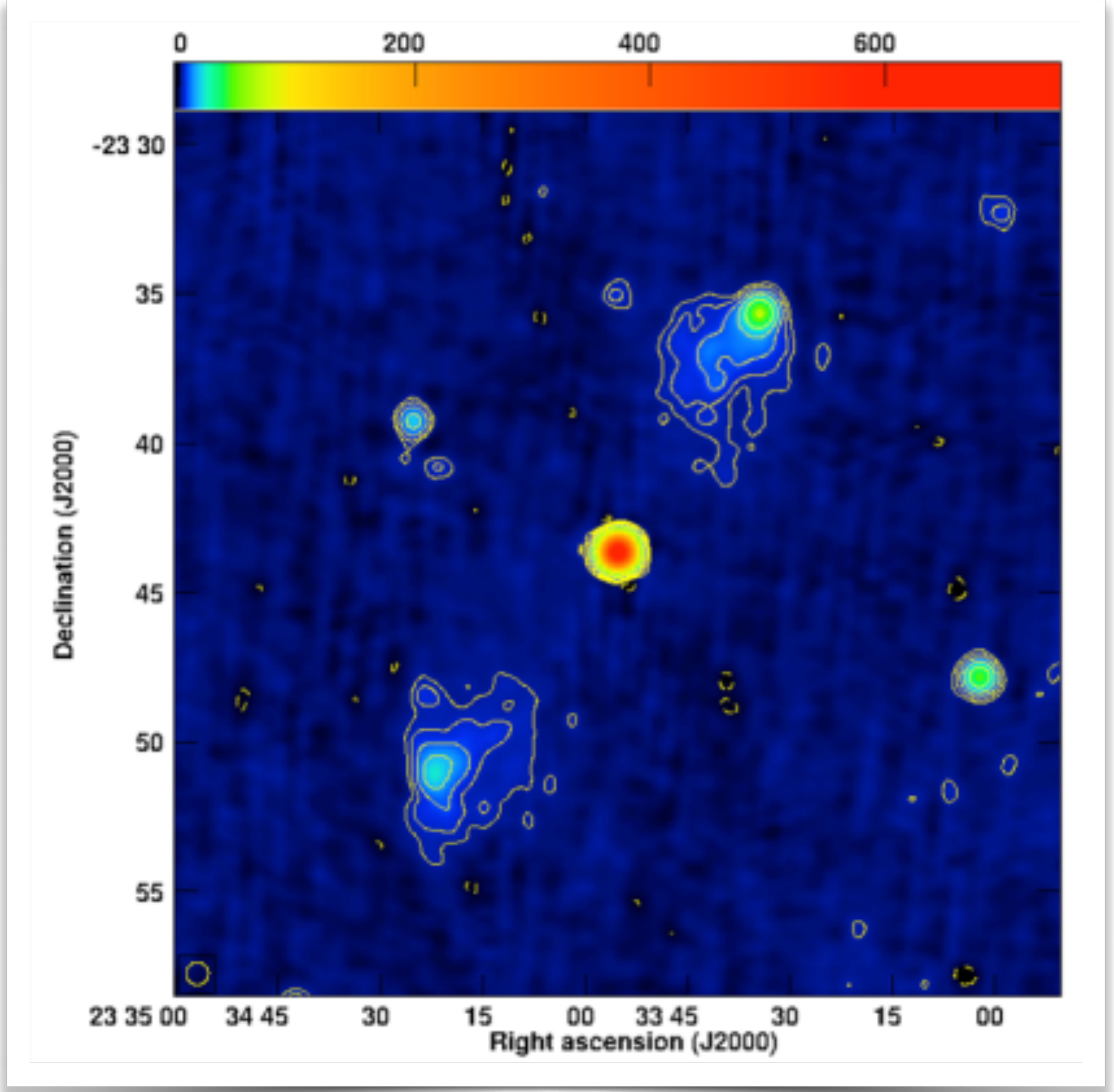
Jet axis flips over a large angle, producing new lobes.

Saripalli et al. 2008

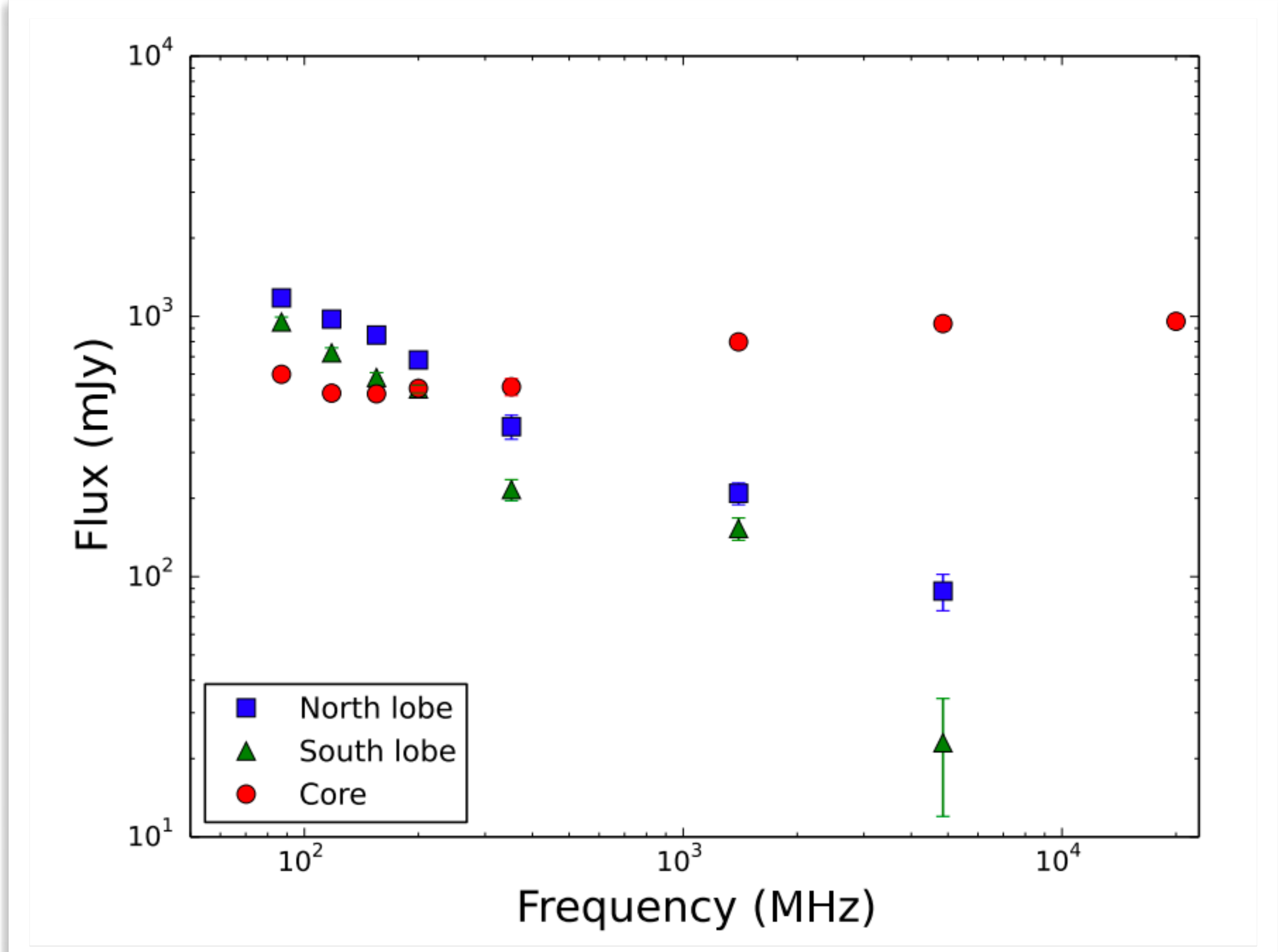
SIGNS OF RESTARTING ACTIVITY

Blazar-like core!

PBC J2333.9-2343



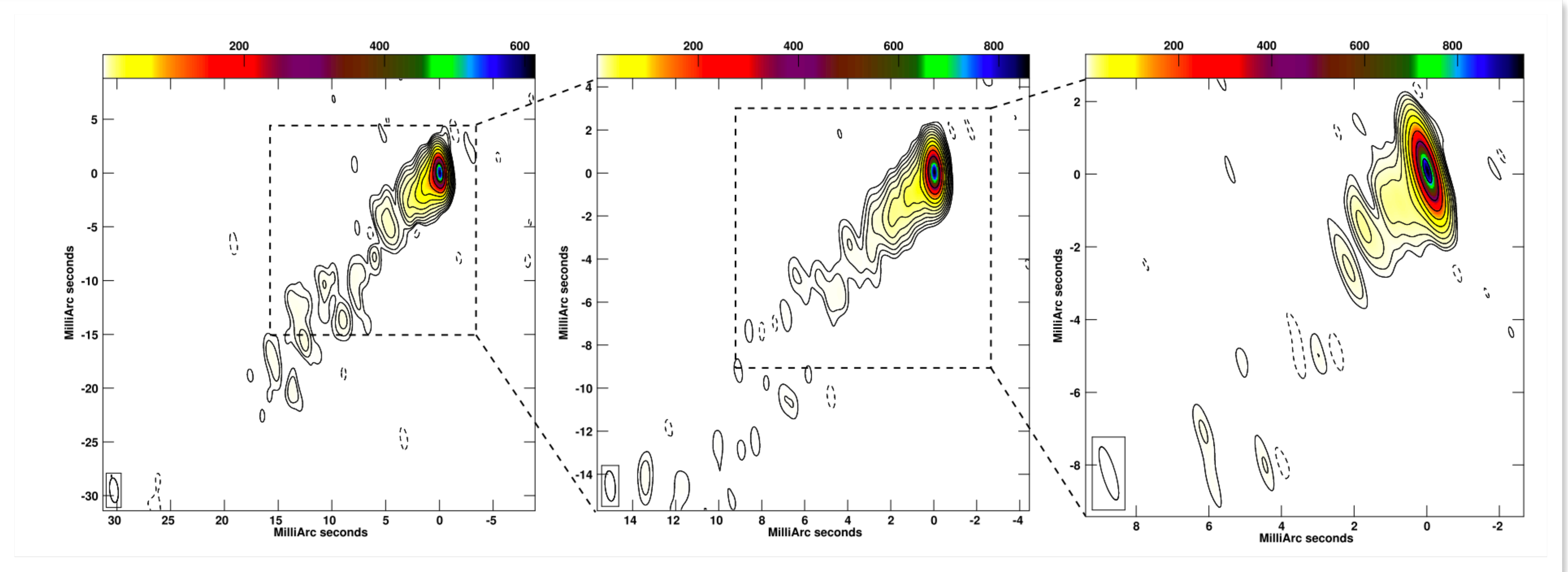
NVSS



Radio SED from literature

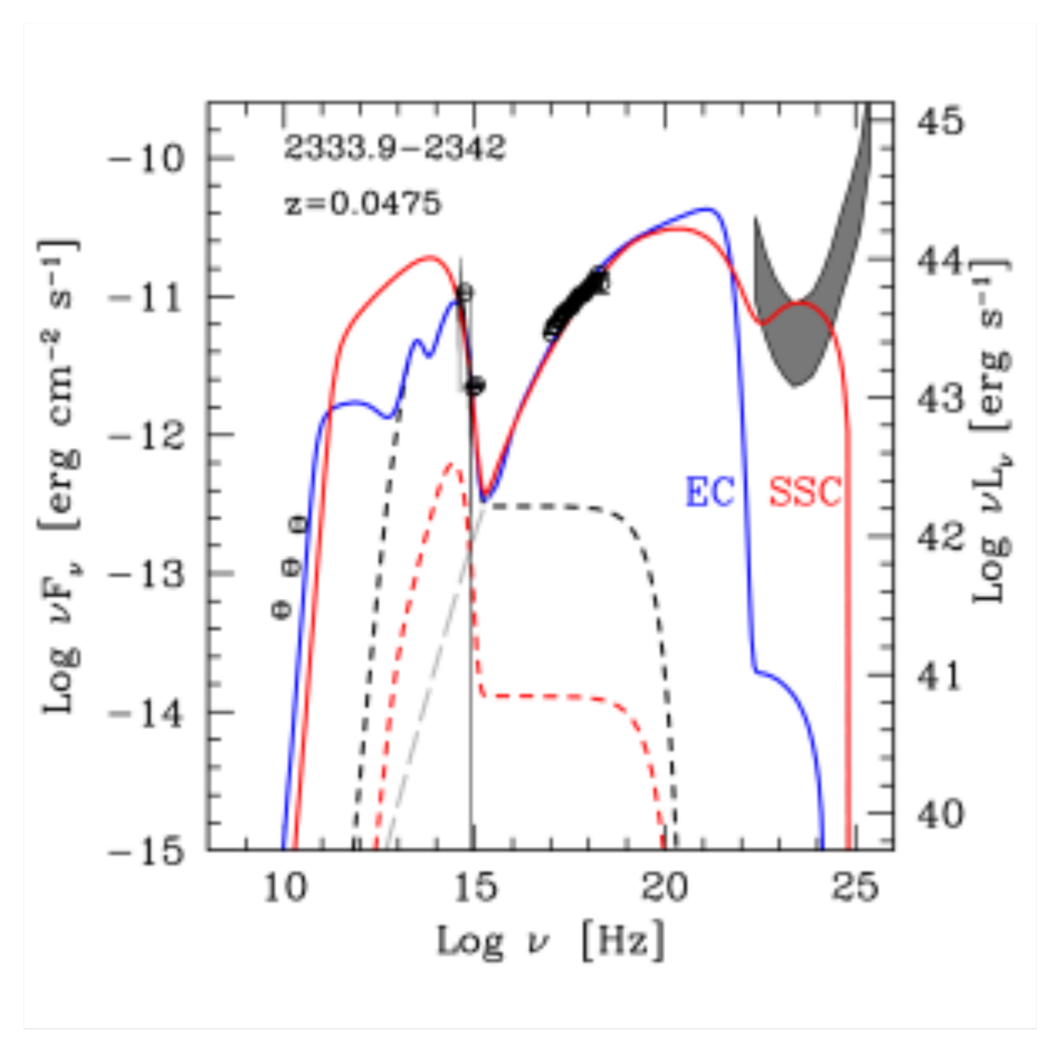
Hernandez-Garcia et al. 2017

SIGNS OF RESTARTING ACTIVITY

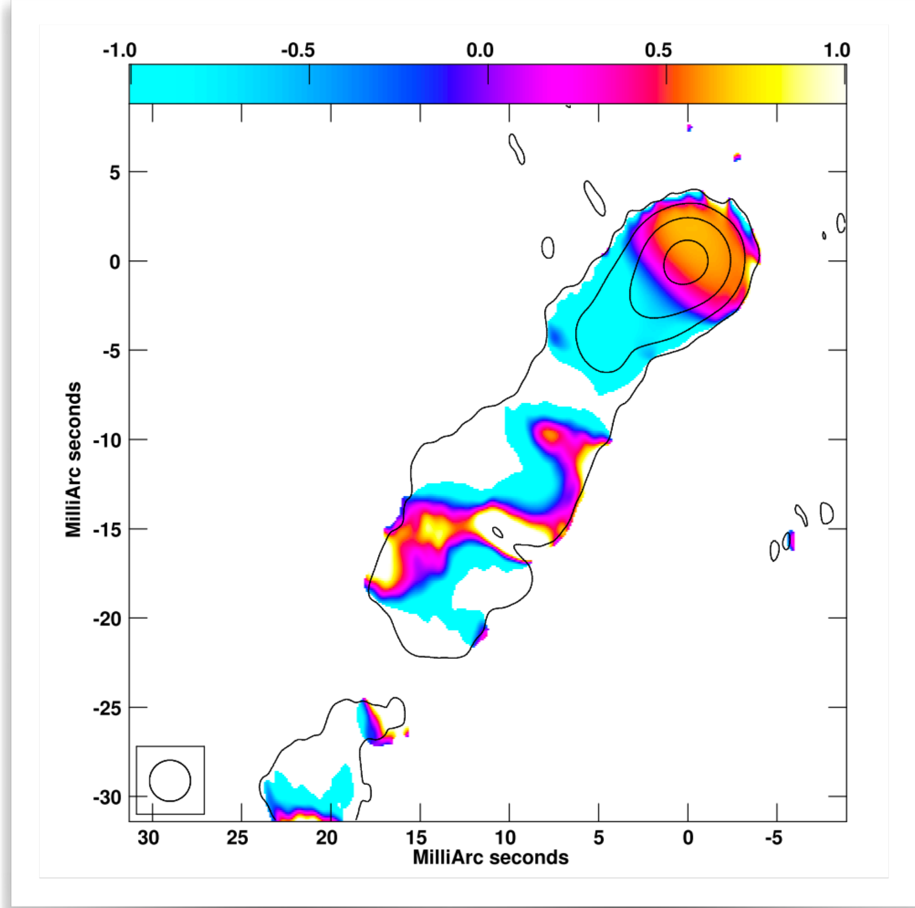


VLBA

8, 15, 22 GHz



…inner jet axis towards line of sight



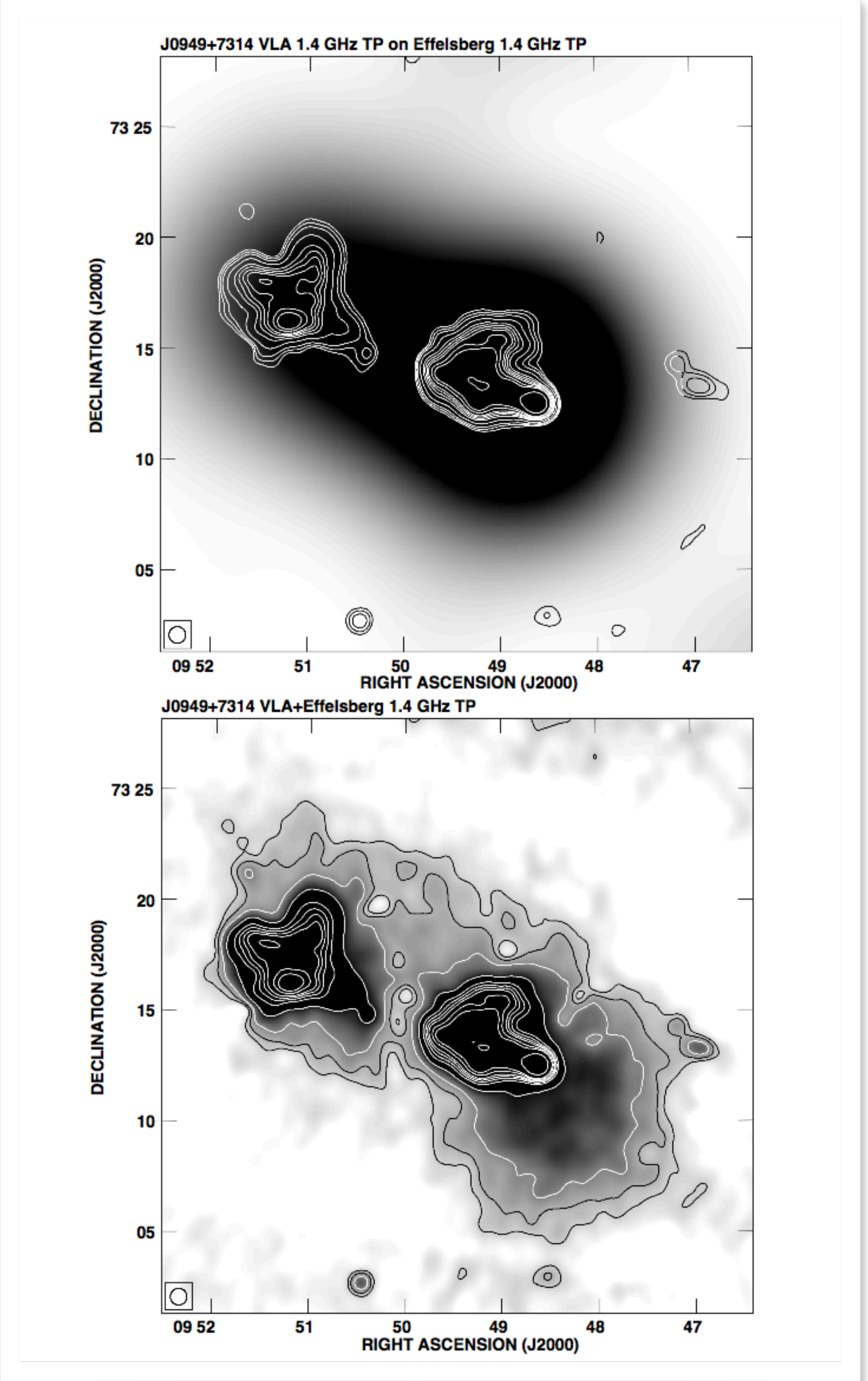
Hernandez-Garcia et al. 2017

SIGNS OF RESTARTING ACTIVITY

Radio cocoon

Weak extended emission with large angular size (639 kpc, >200 My in age) within which a compact edge-brightened double-lobed source (36 kpc, >33 My in age) is embedded.

4C 73.08



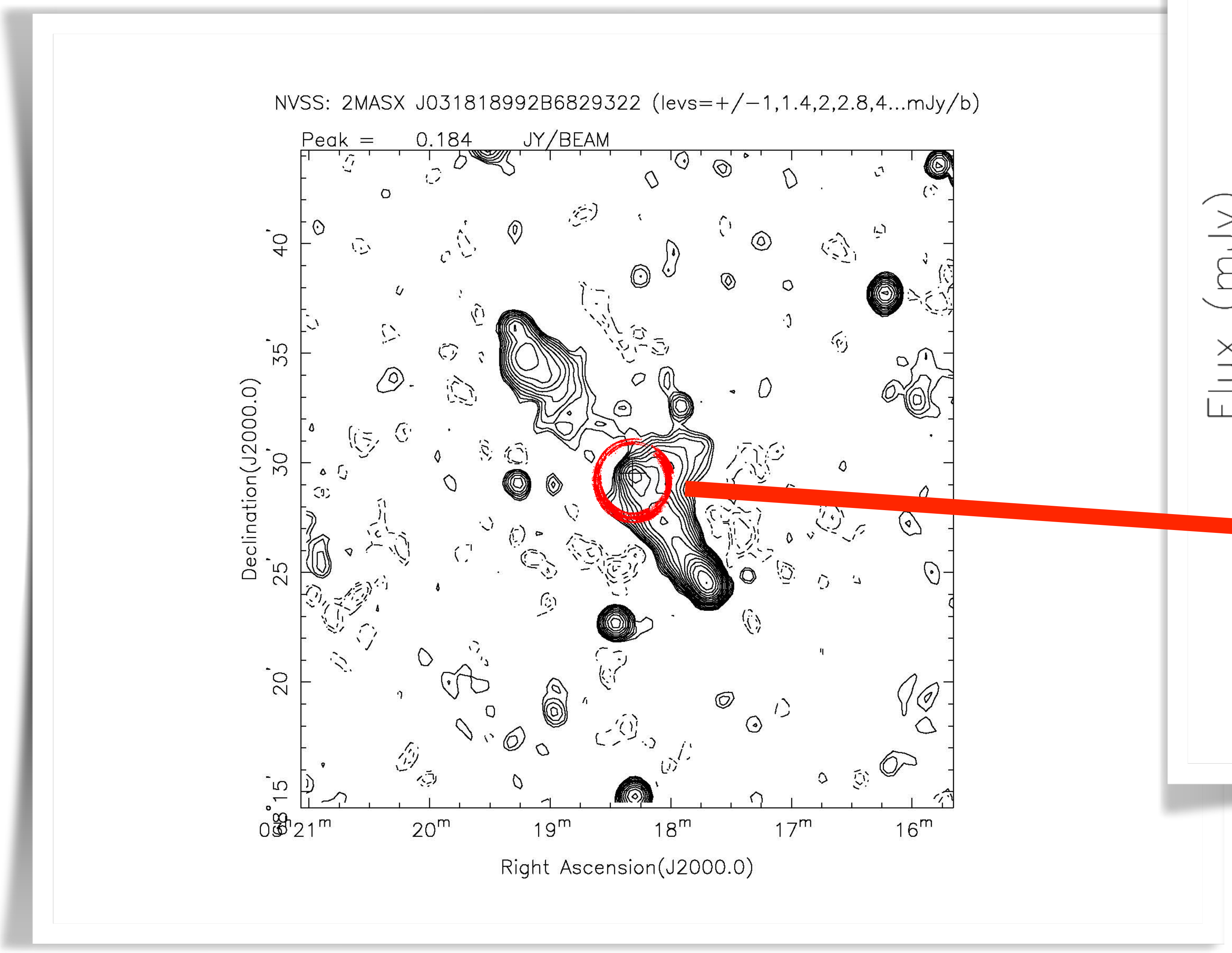
1.4 GHz: NVSS+Effelsberg
Wezgoviec et al. 2016

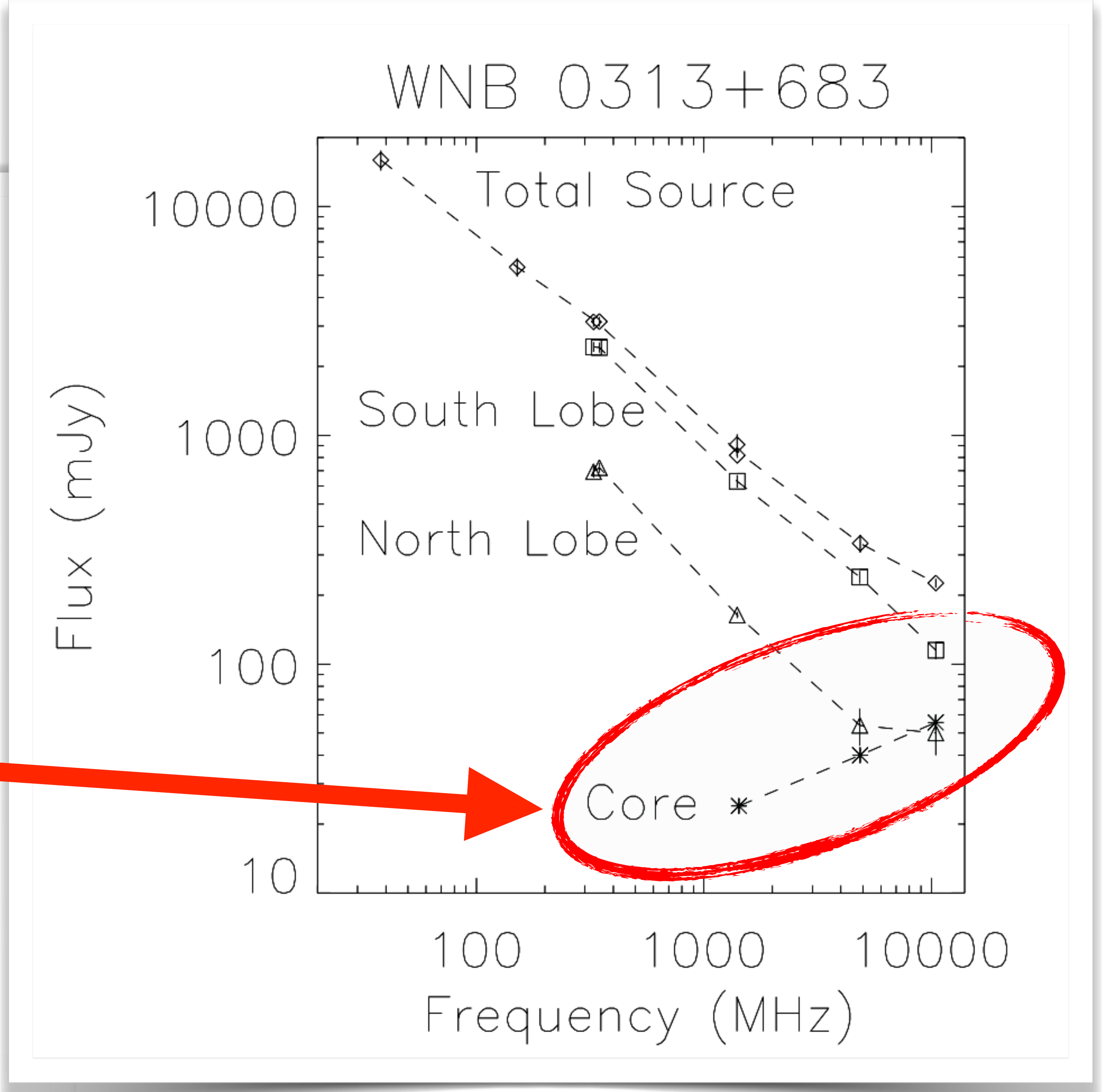
SIGNS OF RESTARTING ACTIVITY

GPS-like core

WNB 0313+683

Inverted spectrum from the core, new episode of radio activity?





Schoenmakers et al. 1998

SIGNS OF RESTARTING ACTIVITY

- 6/15 GRG present signs of restarting activity from the literature (~40%)
- Radio campaign to check the remaining objects via:

- *Single dish (Effelsberg) photometry to test presence of GPS cores (10/15)*
- *GMRT (MHz-range) observations to study morphology (4/15)*

+

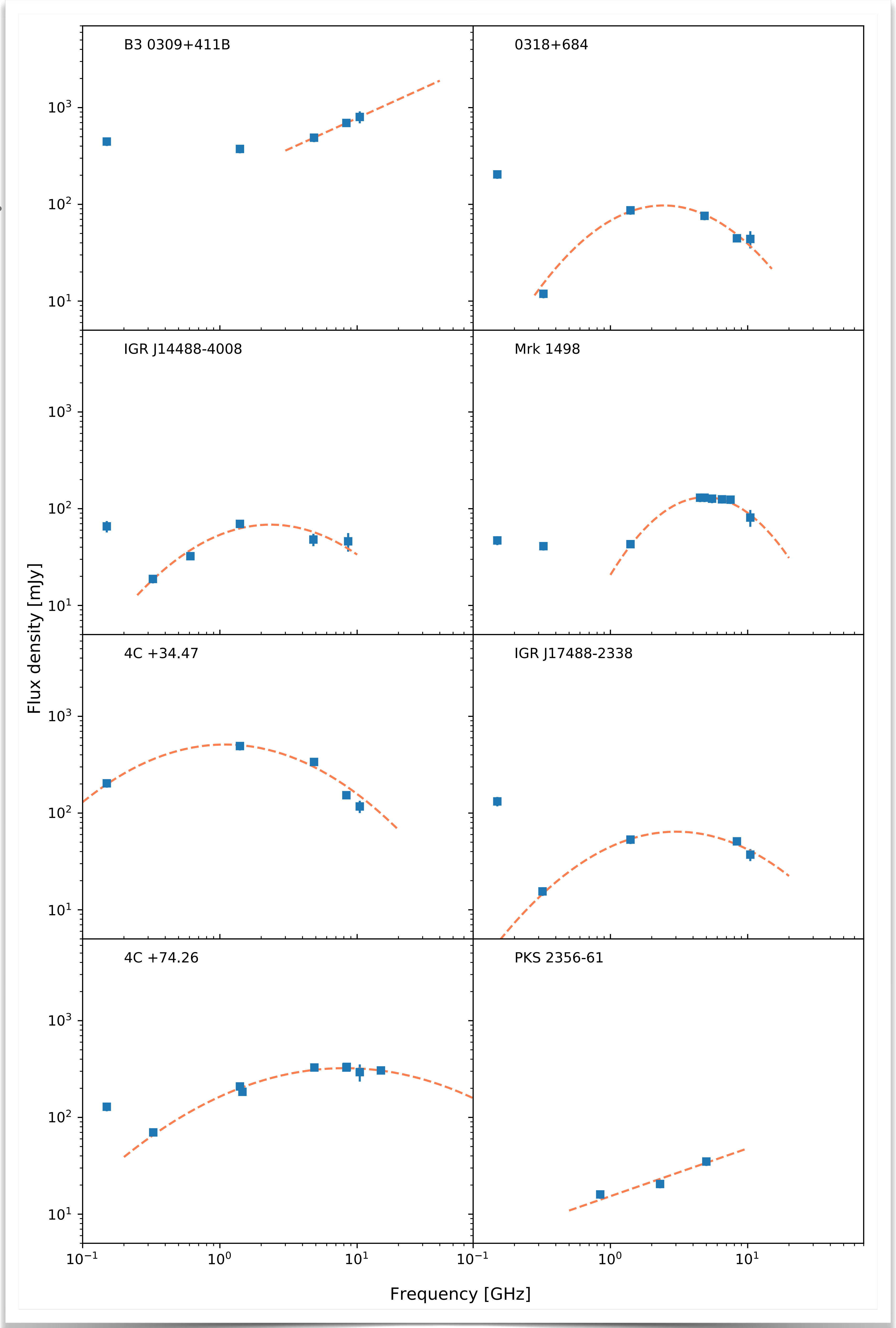
- *TGSS images at 150 MHz (25x25 arcsec resolution, 12/15)*
- *LoTSS DR2 images at 150 MHz (6x6 arcsec resolution, 5/15)*

RESULTS FROM OUR CAMPAIGN

GPS fraction

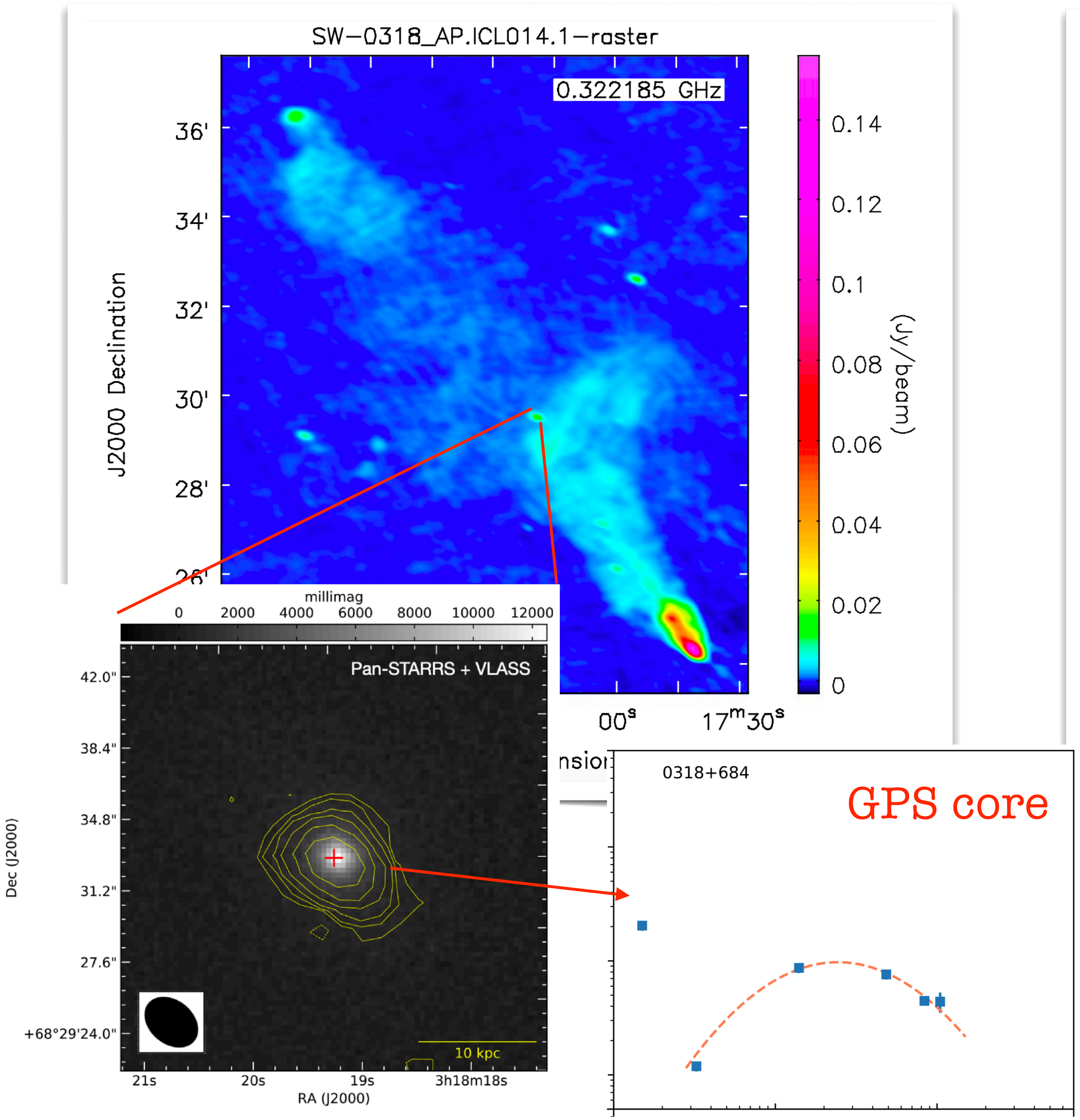
- ➤ Collecting data from archive in the MHz-GHz range for all sources
- ➤ A GPS fraction of 61(+30 -21)% is found
- ➤ Cores are often young radio sources

Bruni et al. 2019

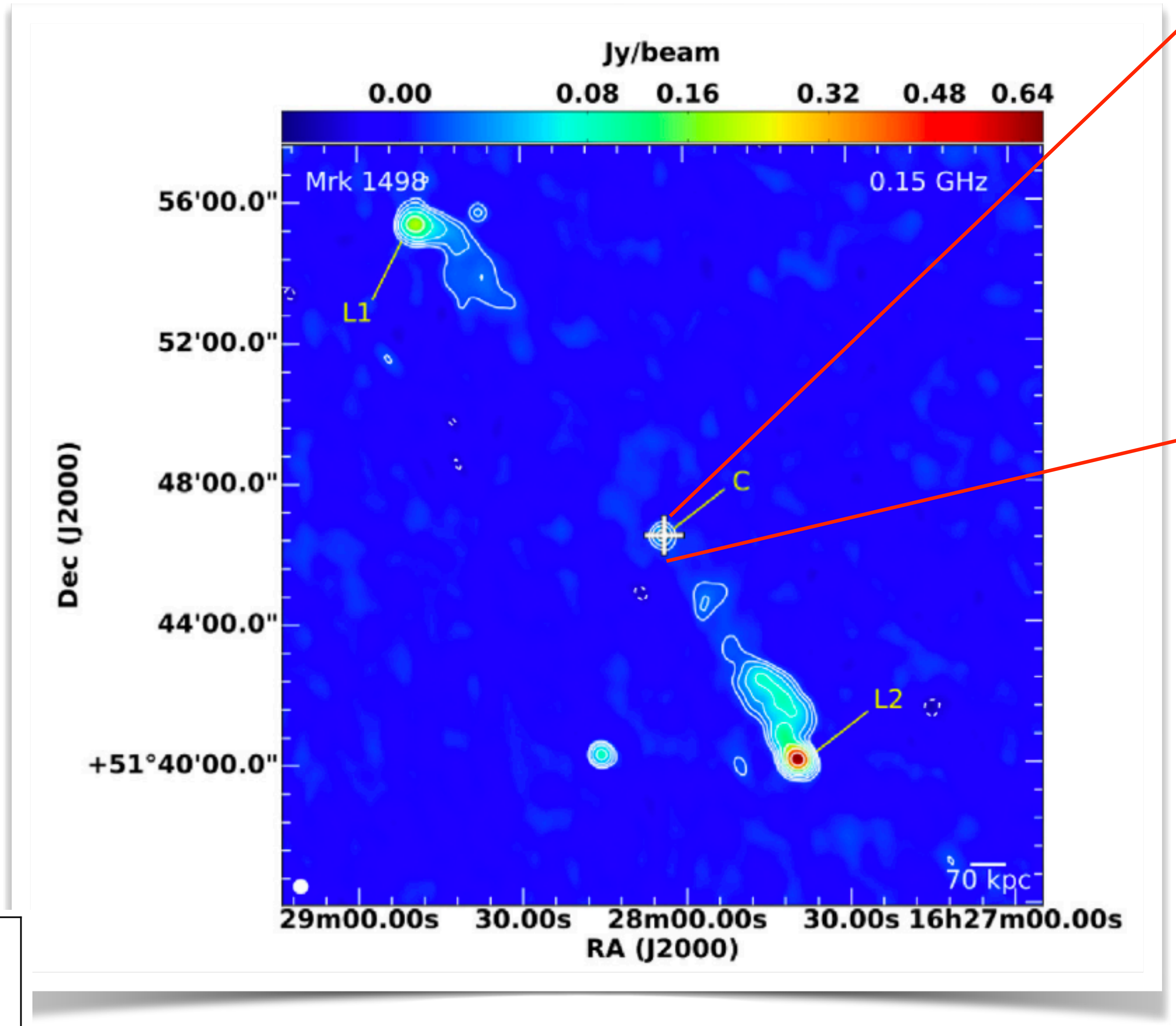


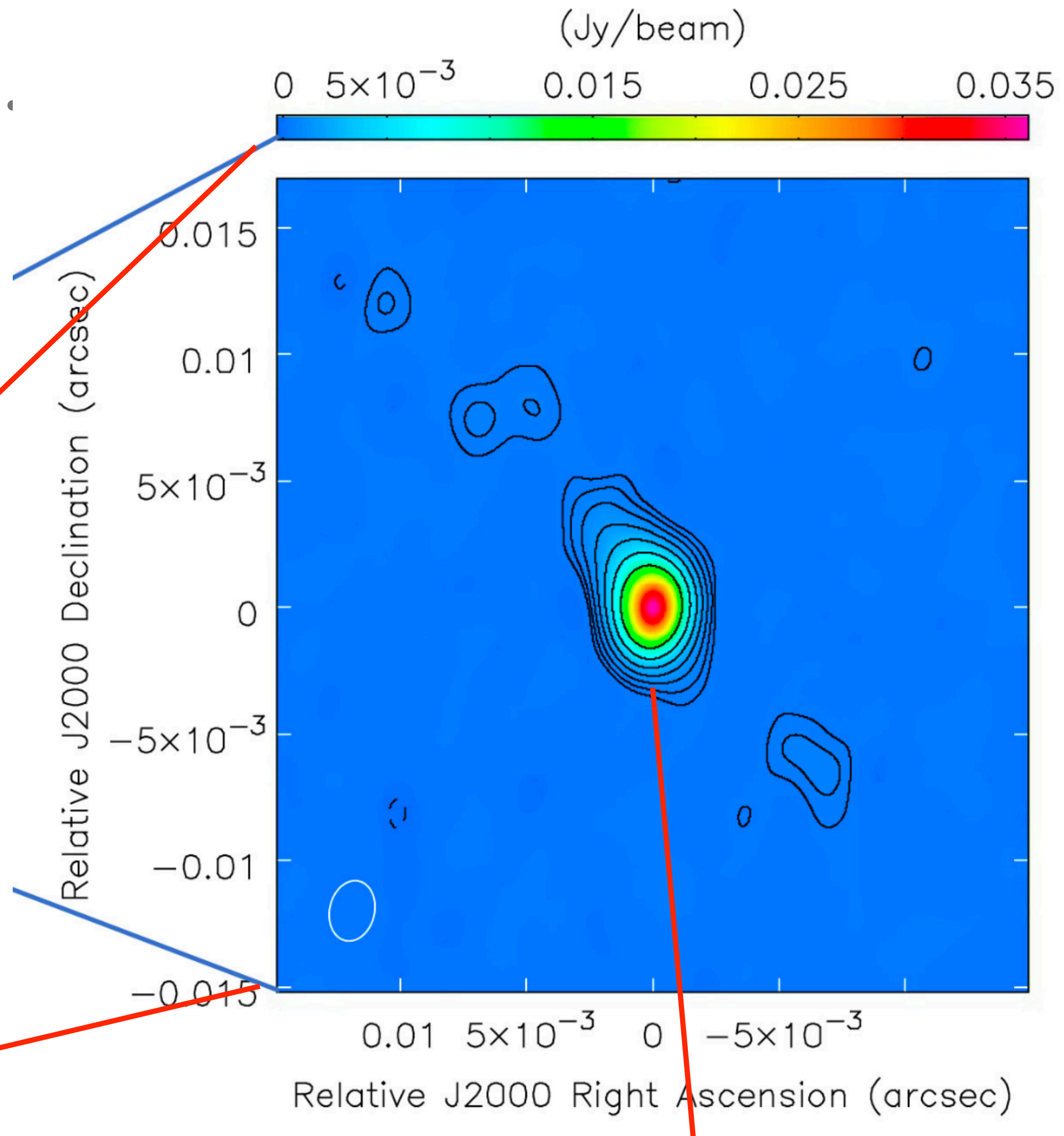
RESULTS FROM OUR CAMPAIGN

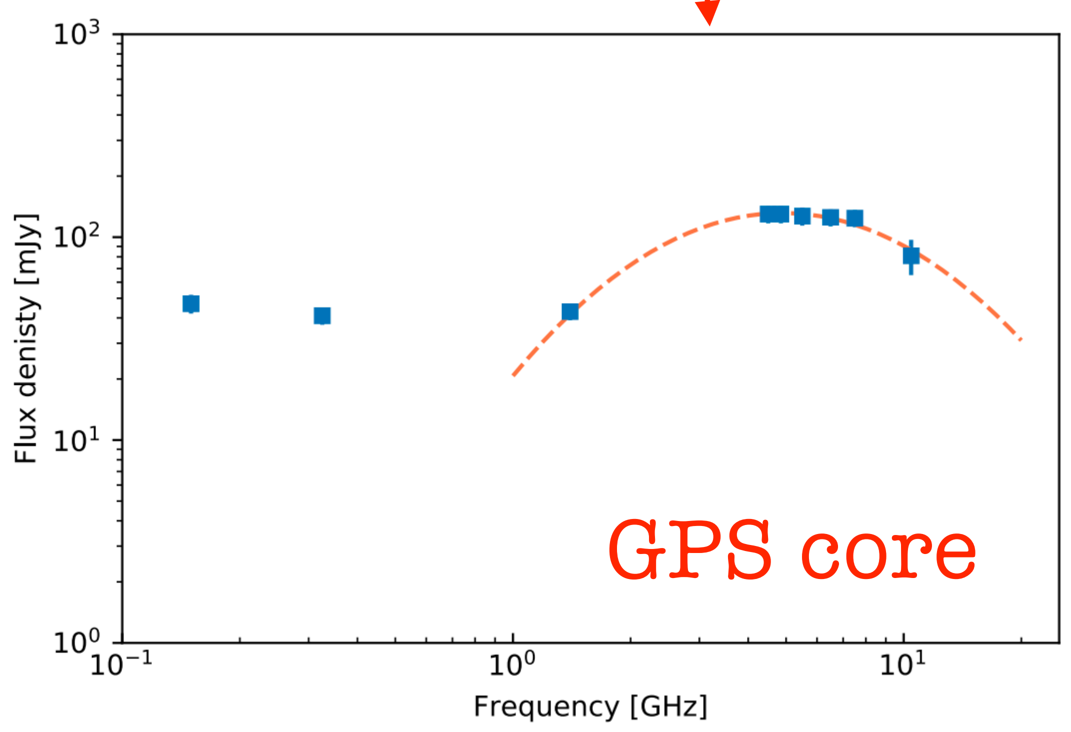
SW-0318+68



Mrk 1498







Bruni et al. 2020
Hernandez-Garcia et al. 2019

RESULTS FROM OUR CAMPAIGN

Name	z	Notes
B3 0309+411B	0.134	Restarting (Bruni+19, GPS component)
LCF 2001 J0318+684	0.090	Restarting (Schoenmakers+1998; Bruni+19)
PKS 0707-35	0.111	Restarting (Saripalli+13)
4C 73.08	0.058	Restarting (Wezgoviec et al. 2016)
B2 1144+35B	0.063	Restarting (Schoenmakers+99; Giovannini+07)
NVSS J143649-161339	0.144	-
IGR J14488	0.123	Restarting (Bruni+19, GPS component)
4C +63.22	0.204	-
WN1626+5153 (Mrk1498)	0.055	Restarting (Bruni+19, GPS component)
4C +34.47	0.206	Restarting (Bruni+19, CSS component)
IGR J17488	0.24	Restarting (Bruni+19, GPS component)
4C +74.26	0.104	Restarting (Pearson+92; Bruni+19)
PKS 2331-240	0.048	Restarting (Hernandez-Garcia+17)
PKS 2014-55	0.060	Restarting (Saripalli+08)
PKS 2356-61	0.096	Restarting (Bruni+19, GPS component)

6 restarting from the literature + 7 from present work = 13/15

Bruni et al. 2020

CONCLUSIONS

- We selected a GRG sample starting from INTEGRAL+Swift soft gamma-ray catalogues
- GRG fraction among soft gamma-ray selected RG is four times larger than in radio-selected samples
- Almost all GRGs show signs of restarting activity: ~60% have a GPS core, ~40% restarting morphology
- Bias due to high-energy selection? Duty cycle?

FUTURE

- Comparison sample study ongoing to exclude (or understand) selection effects
- EVN large program ongoing + complementary LBA and eMerlin observations.
- Synchrotron aging study for a pilot sample of 3 sources ongoing (GMRT+VLA)

http://gral.iaps.inaf.it