

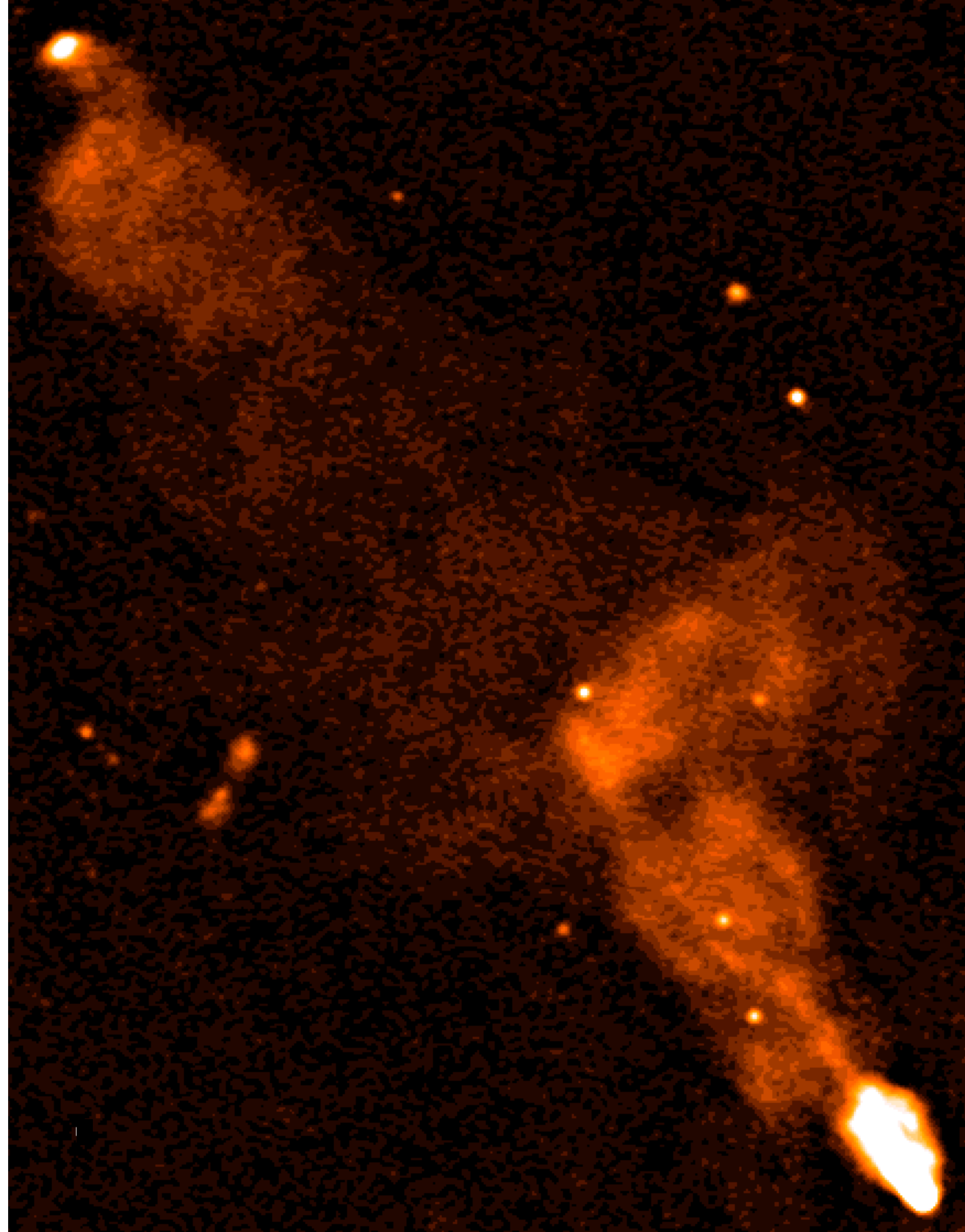
GRACE

Giant **RA**dio galaxies and their duty **Cycle**

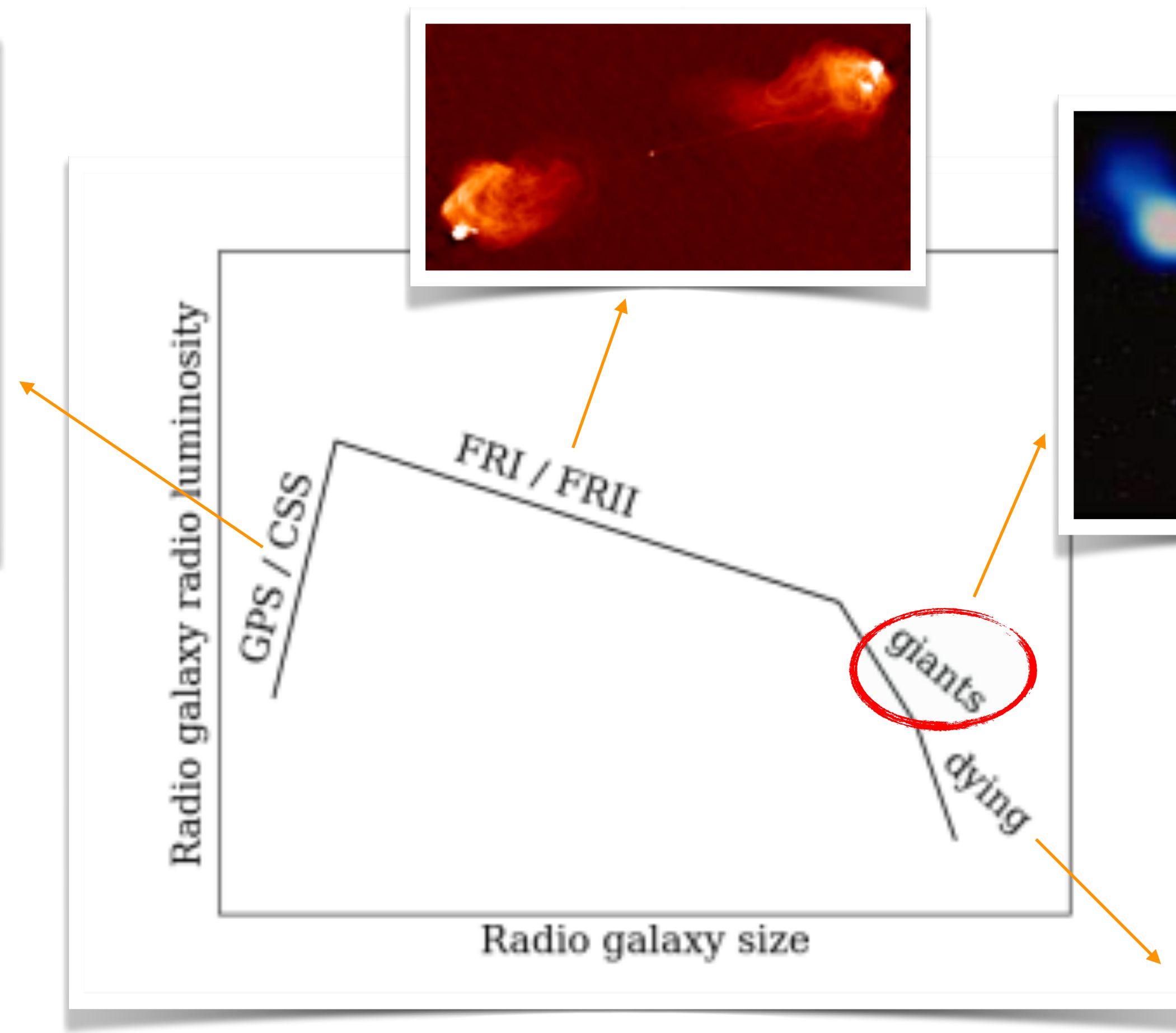
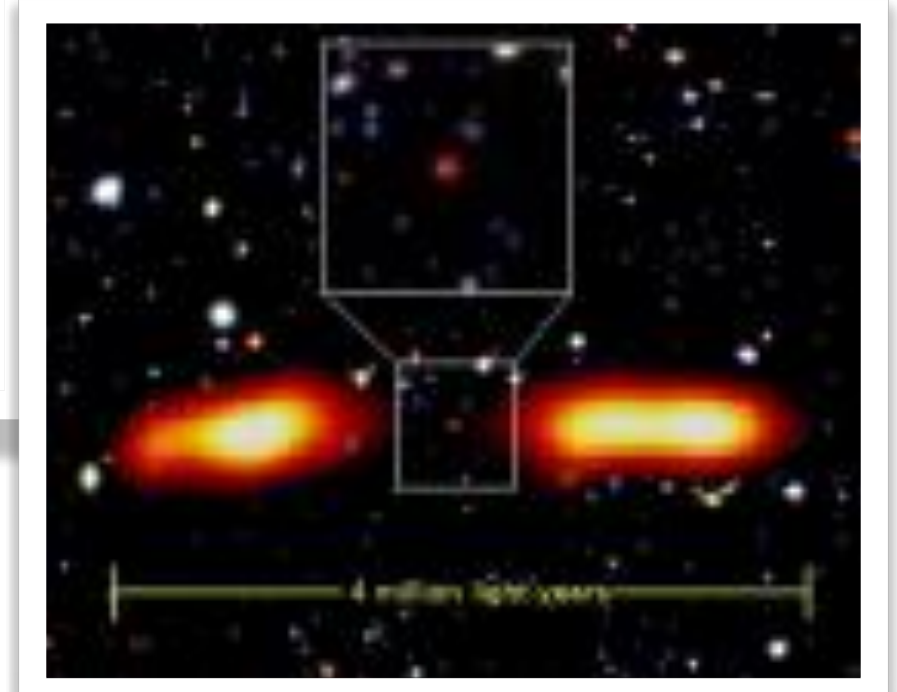
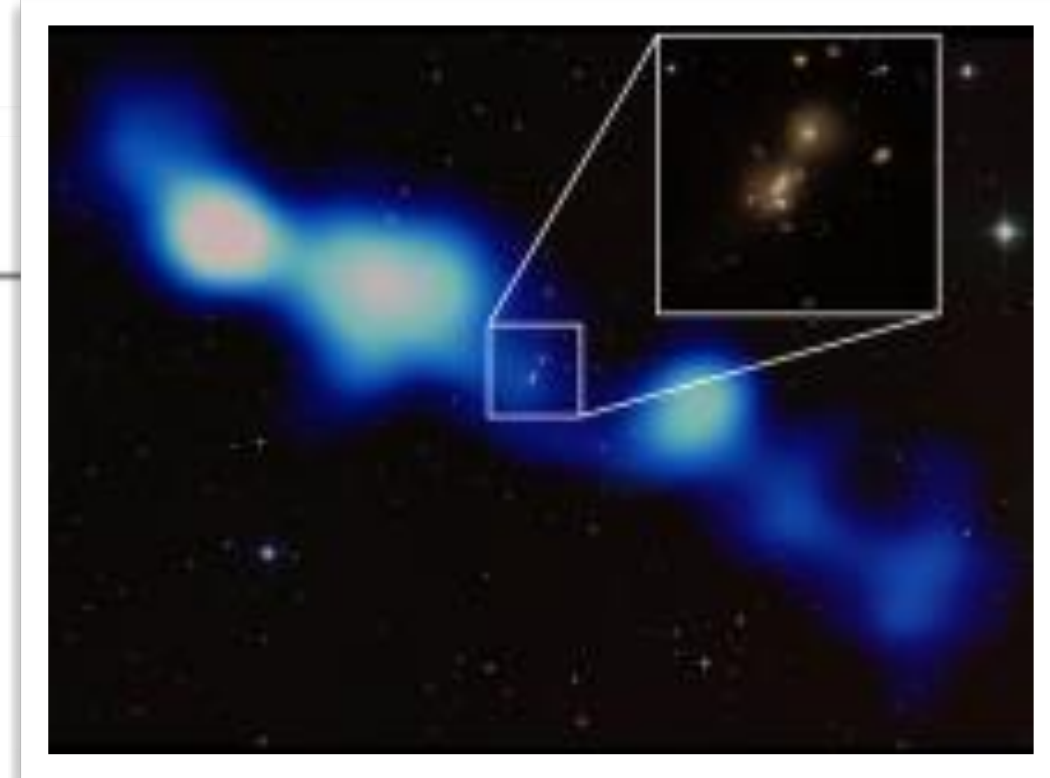
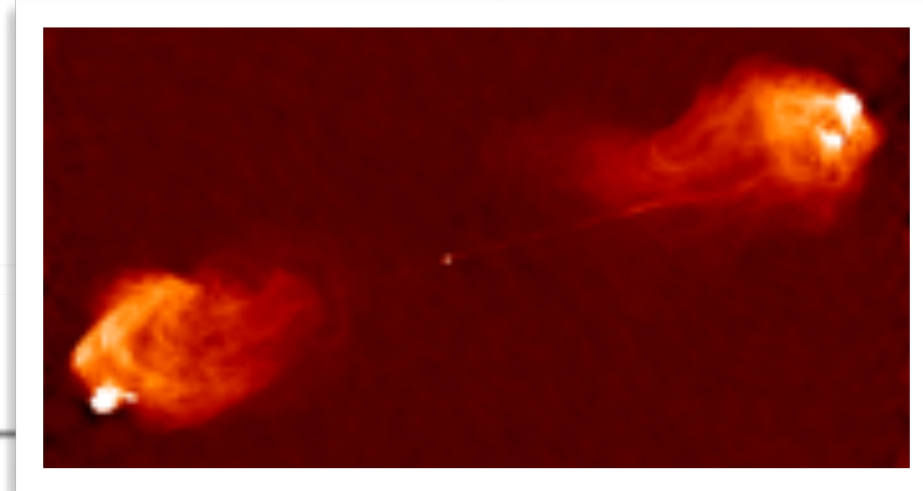
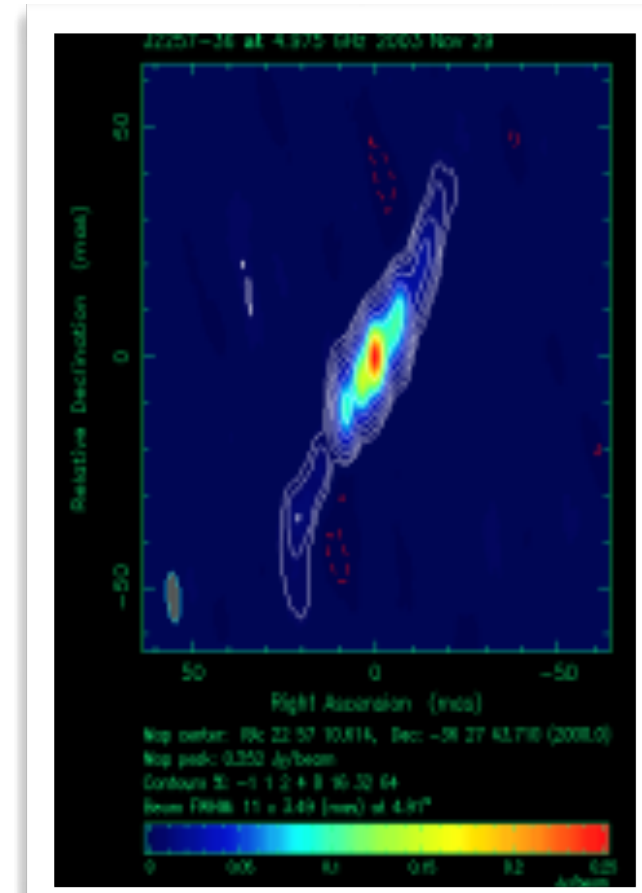
Gabriele Bruni, INAF-IAPS



Collaborators: F. Panessa, E. Chiaraluce, A. Bazzano, P. Ubertini (INAF-IAPS)
L. Bassani, A. Malizia, M. Molina, F. Ursini (INAF-OAS)
D. Dallacasa, T. Venturi, M. Giroletti, M. Brienza (INAF-IRA)
L. Saripalli (RRI, India), L. Hernandez-Garcia (U. Valparaiso)

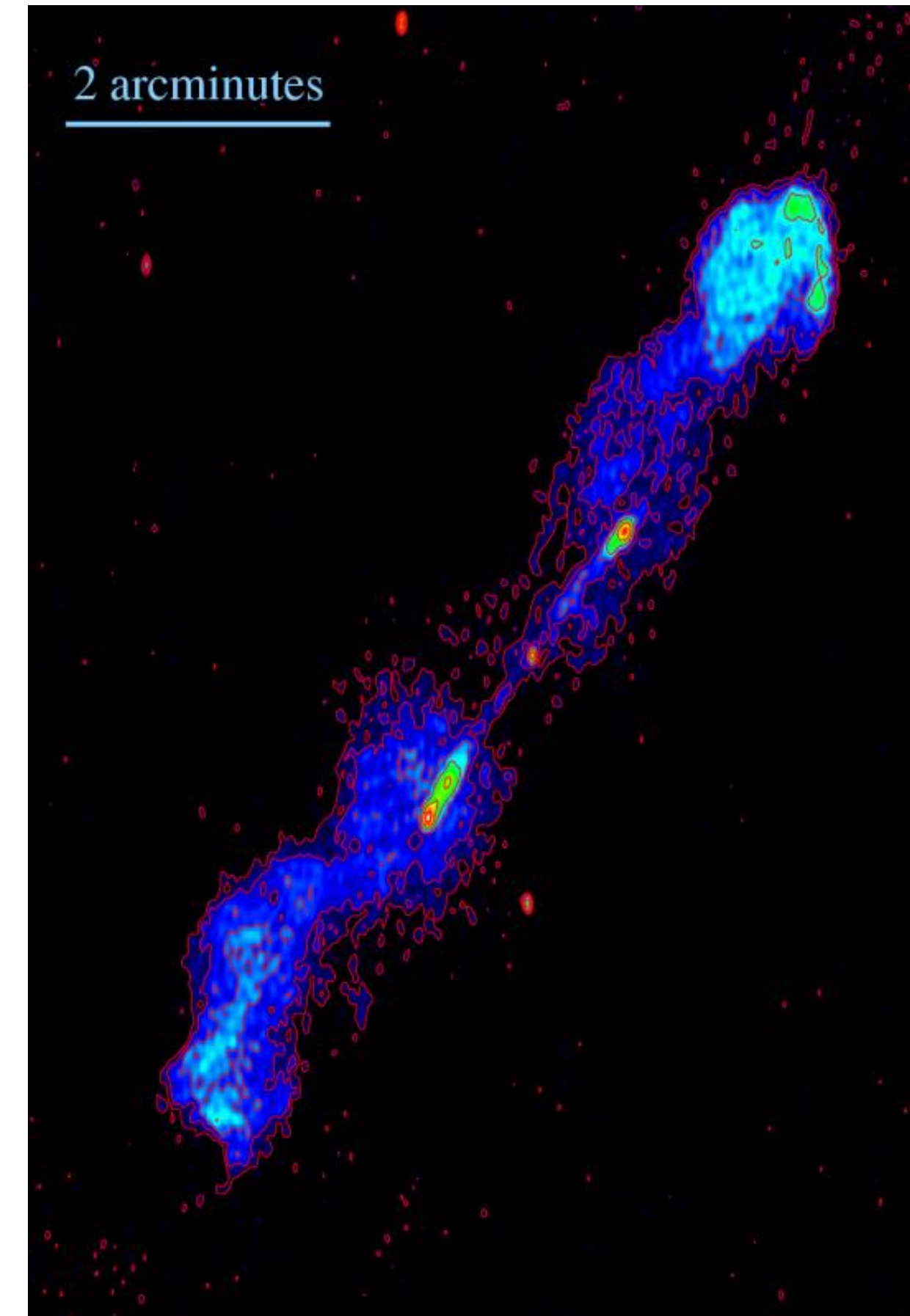


GIANT RADIO GALAXIES



GIANT RADIO GALAXIES

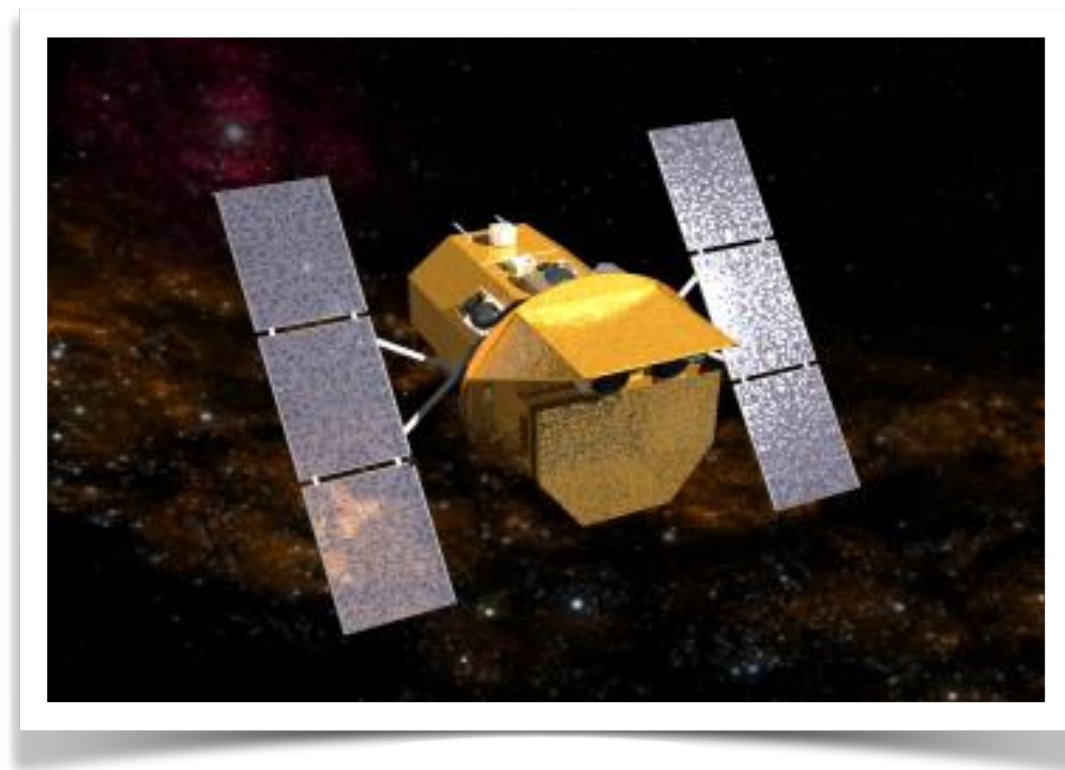
- GRG are the largest single-entities in the Universe (>0.7 Mpc)
- Low surface brightness, complex morphology, difficult to discover
- In radio surveys, only 1-6% of objects are GRG (~ 500 GRG known to date)
- Size due to environment, or high jet power, or long activity time?



B1545-321 (ATCA, 13cm)

THE SOFT GAMMA-RAY SKY

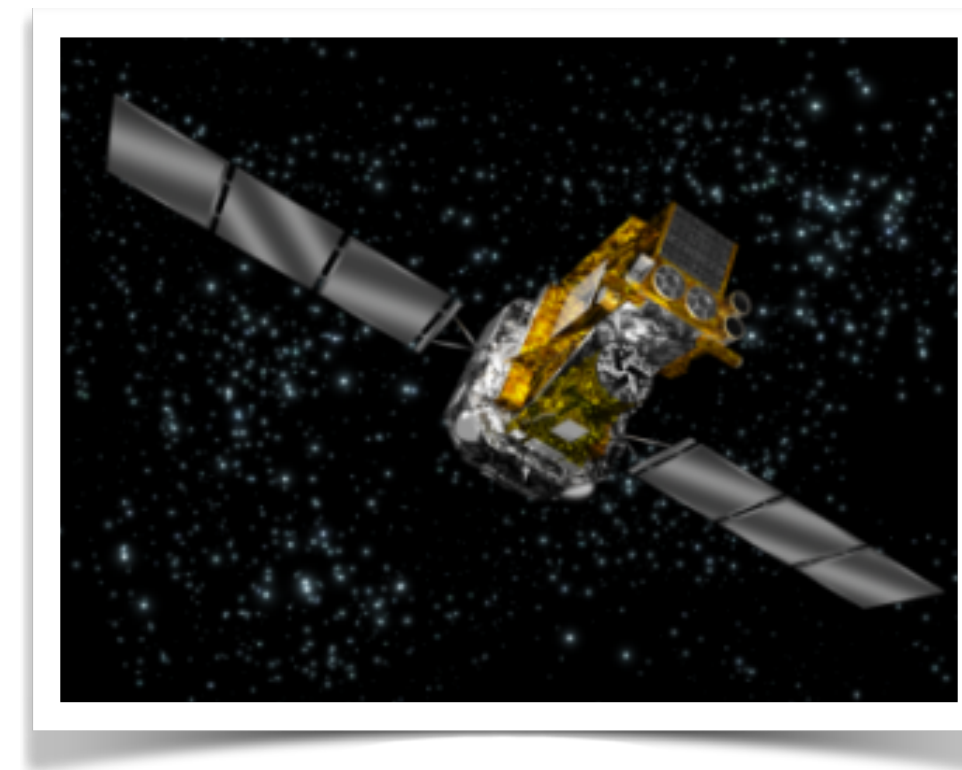
Space-based observatories scanning the soft gamma-ray sky since 2002...



Swift/BAT
(15 keV - 150 keV)



Baumgartner et al. 2013



INTEGRAL/IBIS
(15 keV - 10 MeV)



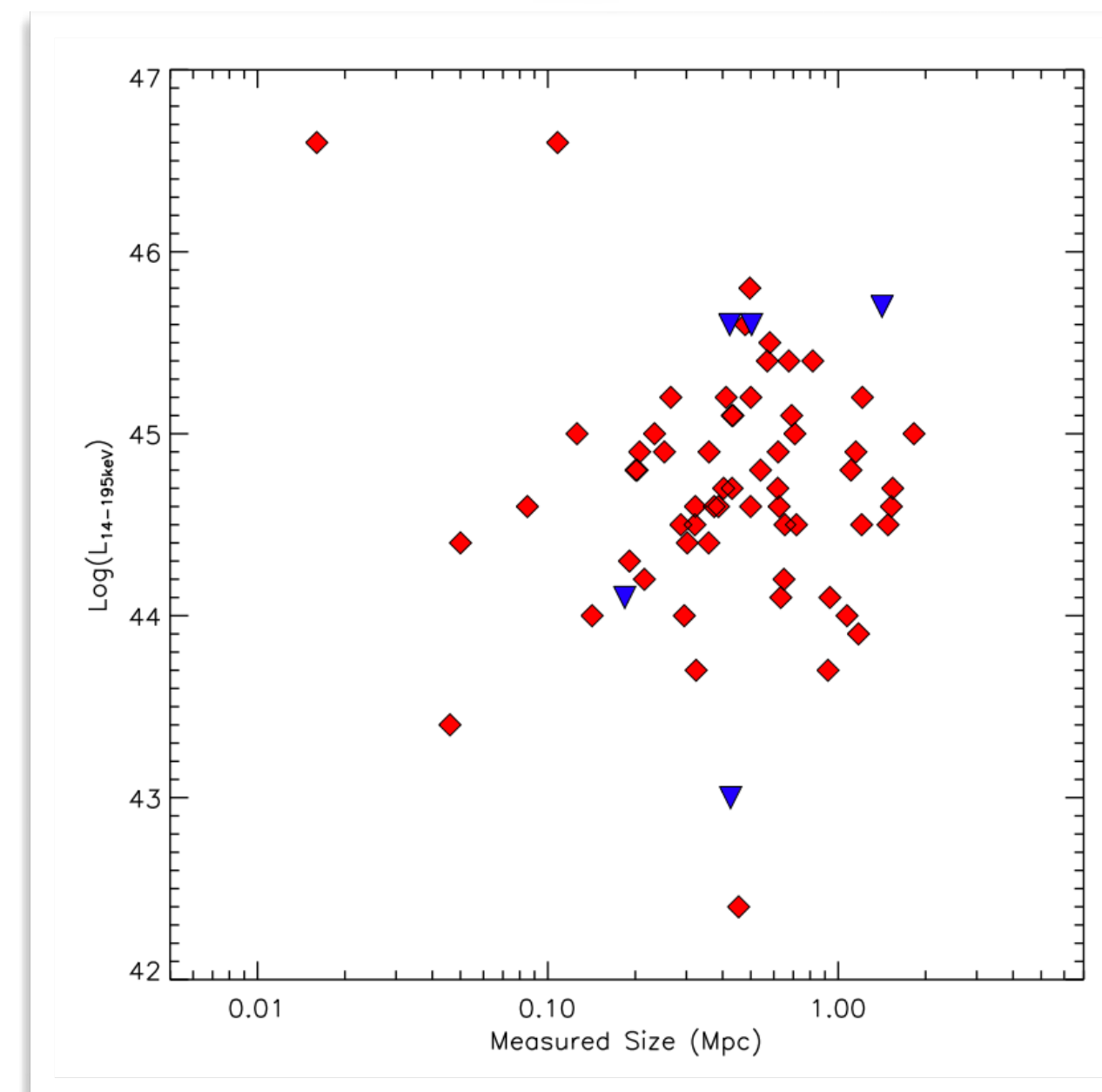
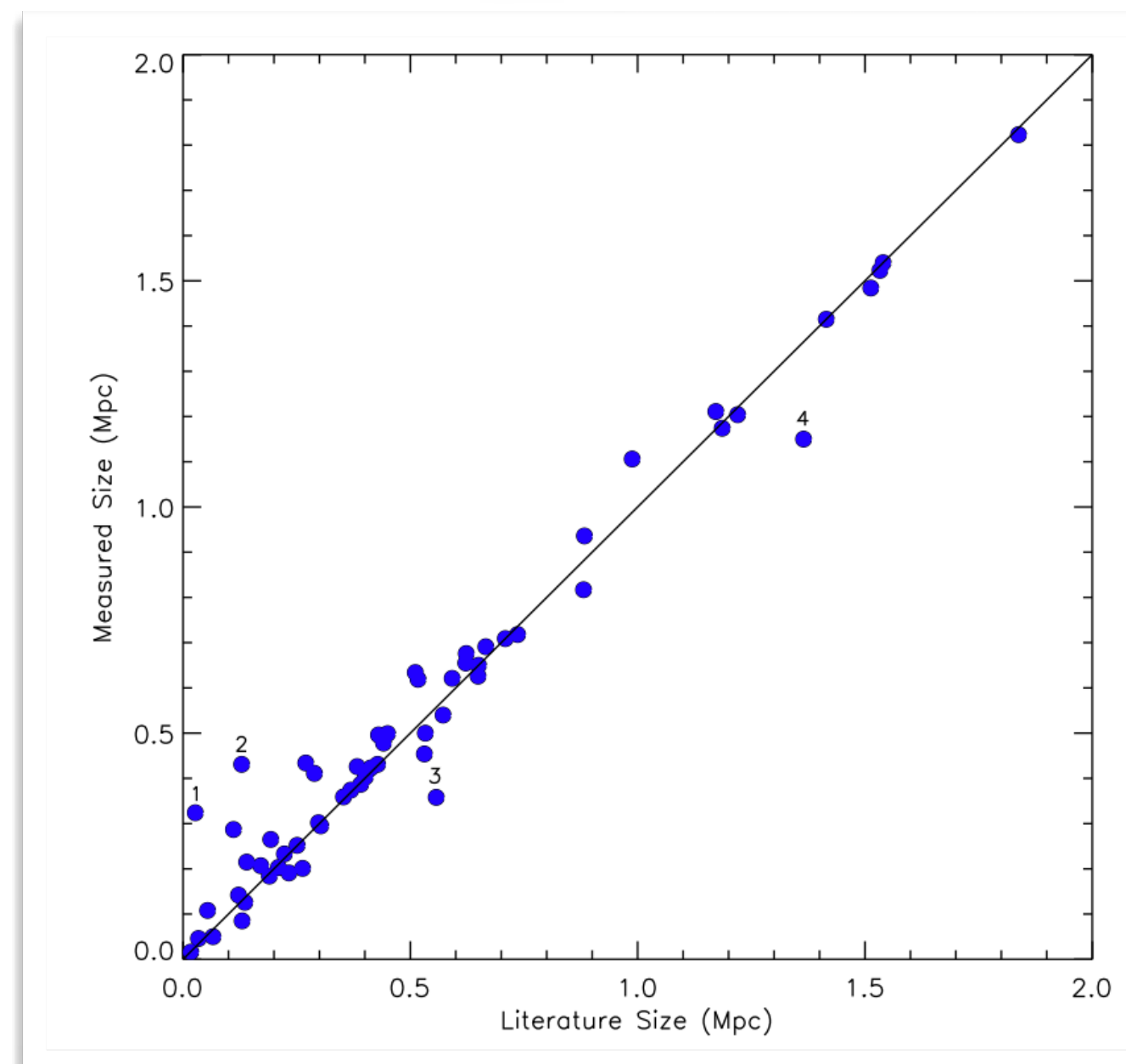
Bird et al. 2010
Malizia et al. 2012

...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

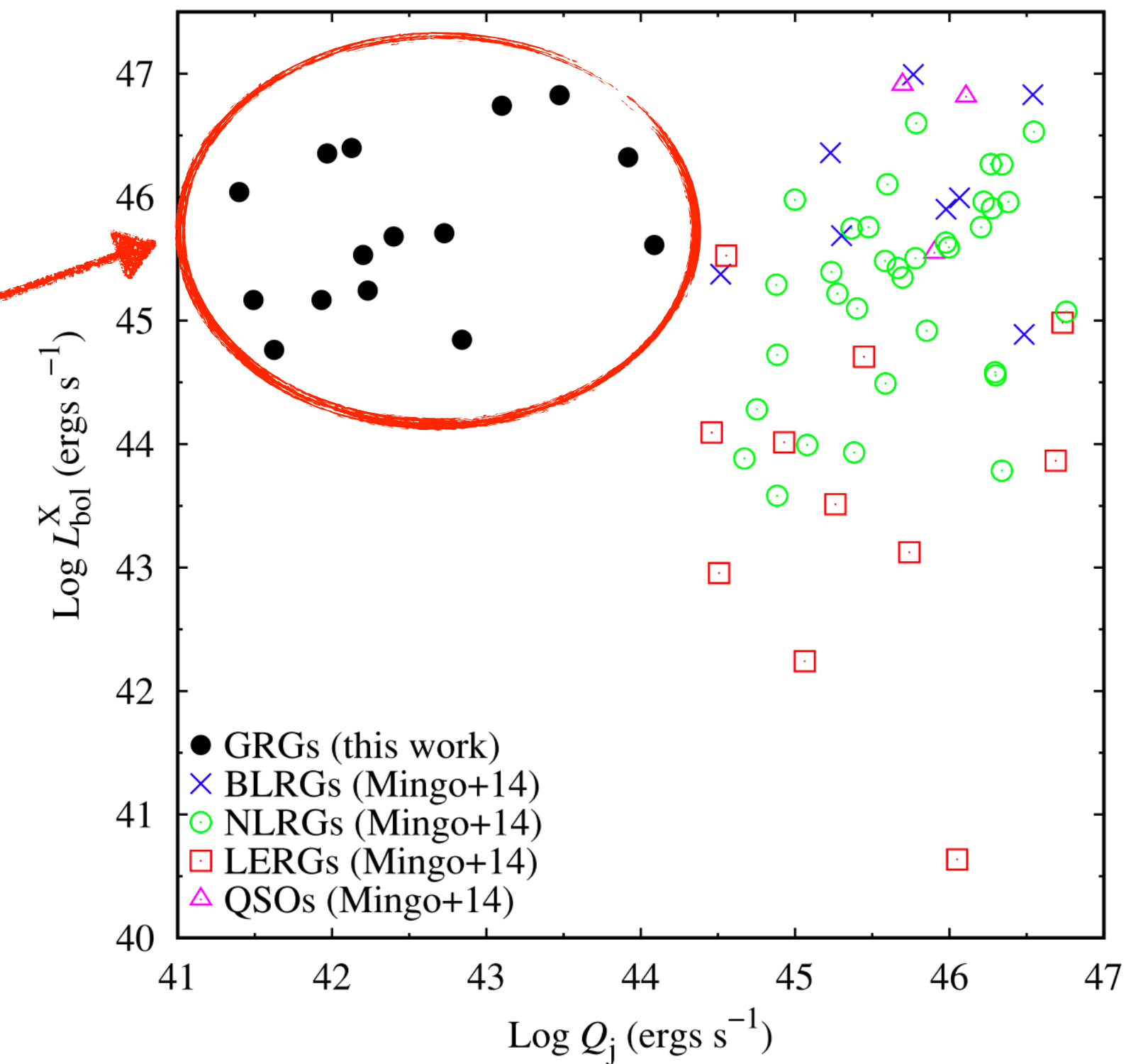
67 radio galaxies with double morphology
31 RG with size >0.5 Mpc
15 GRGs >0.7 Mpc (22%)



SIGNS OF RESTARTING ACTIVITY

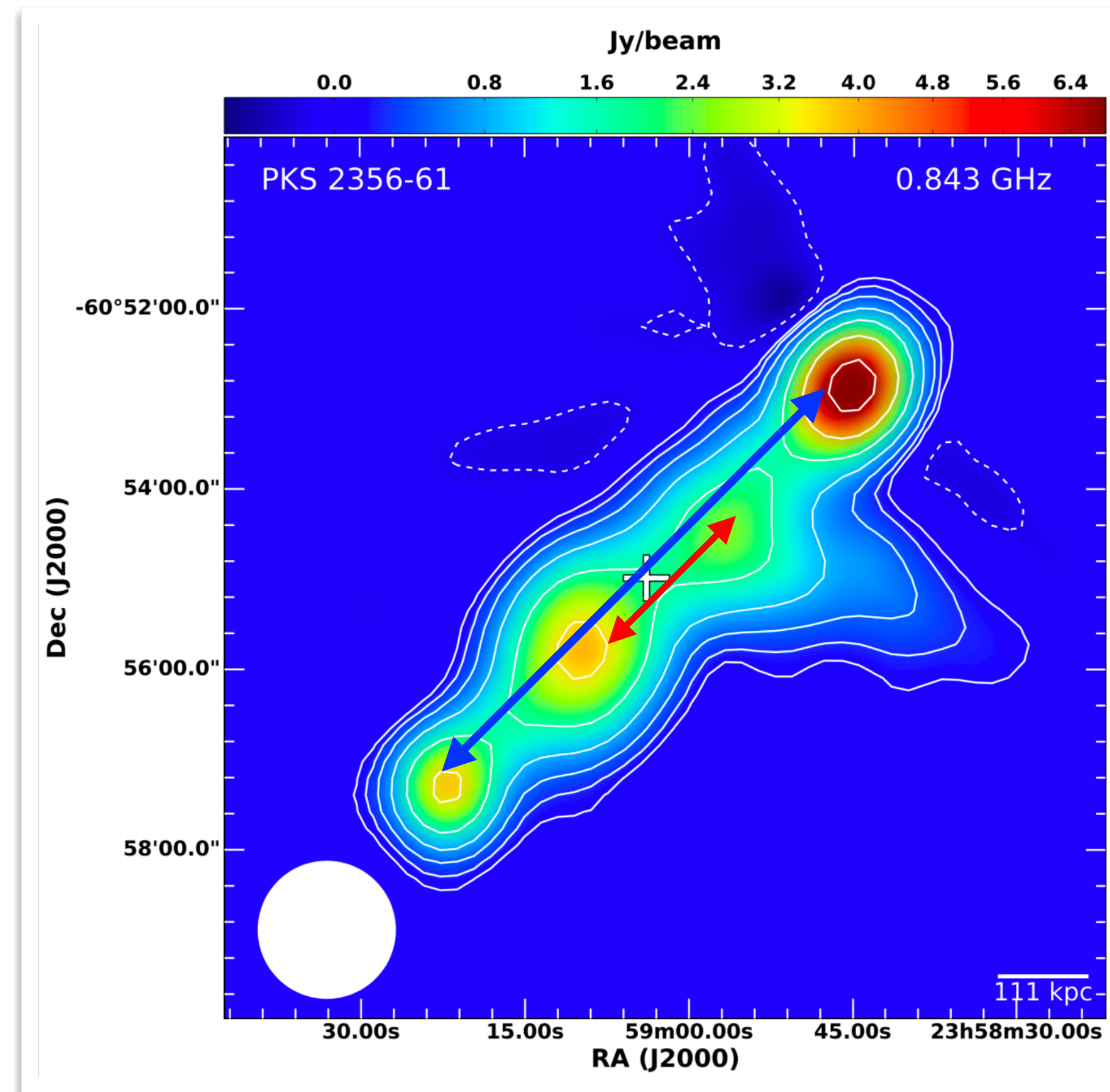
- Correlation between the X-ray luminosity and the radio core luminosity, consistent with that expected for AGN powered by efficient accretion.
- Luminosity of the radio lobes and the estimated jet power are **relatively low** compared with the nuclear X-ray emission.
- either the nucleus is more powerful 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



SIGNS OF RESTARTING ACTIVITY

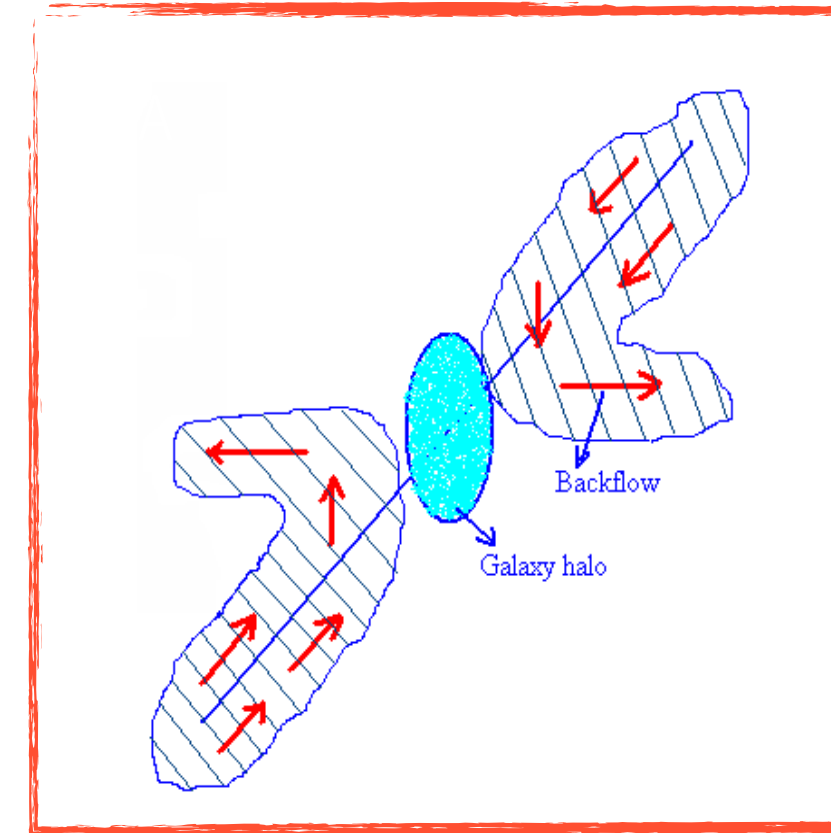
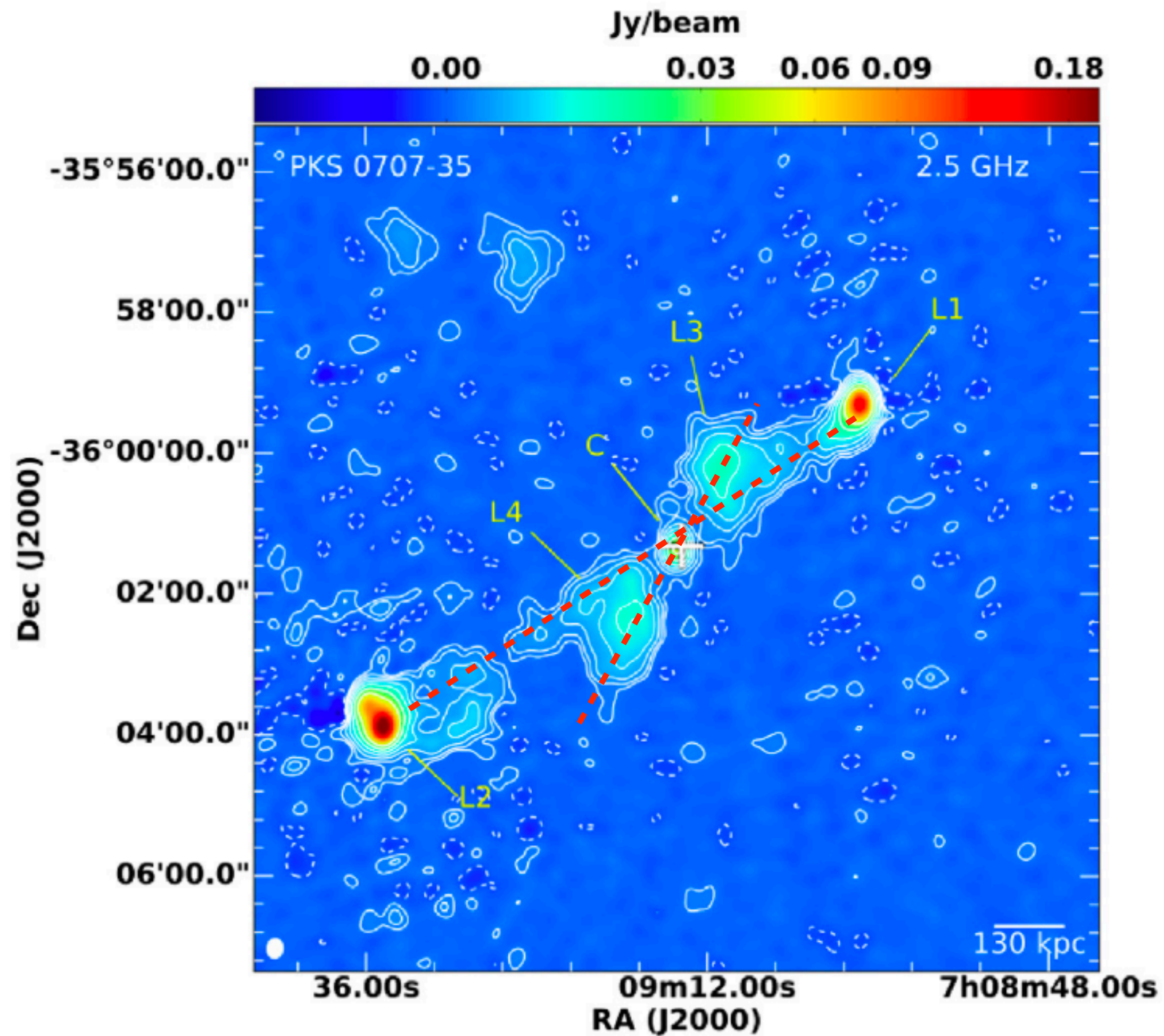
Double-Double RG



SUMSS
Bruni et al. 2020
Subrahmayan et al. 1996

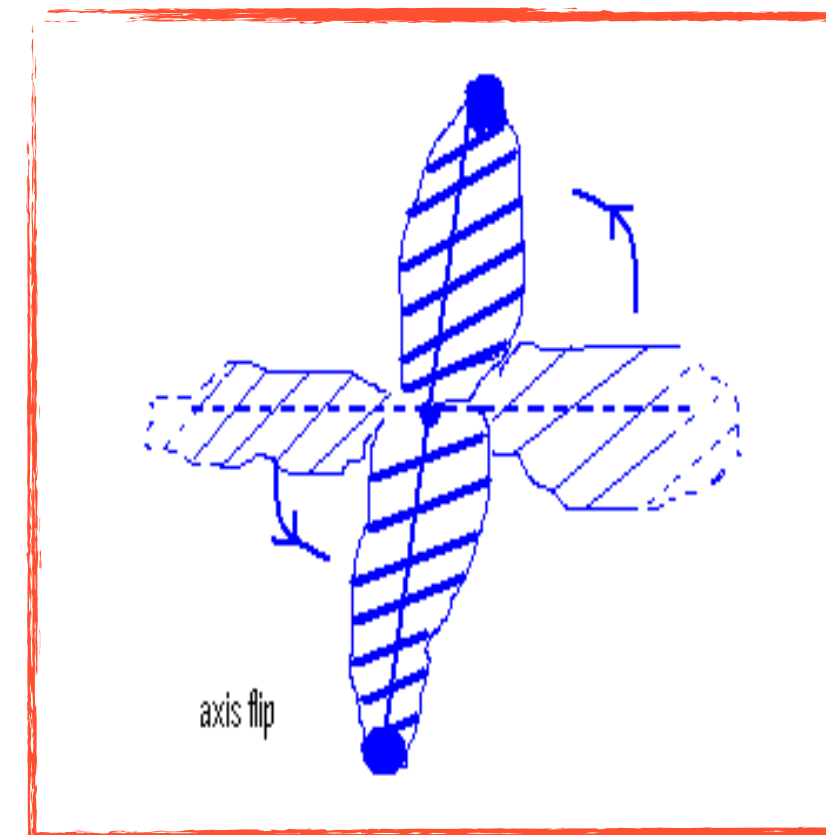
SIGNS OF RESTARTING ACTIVITY

X-shaped RG



Backflow model

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



Jet reorientation

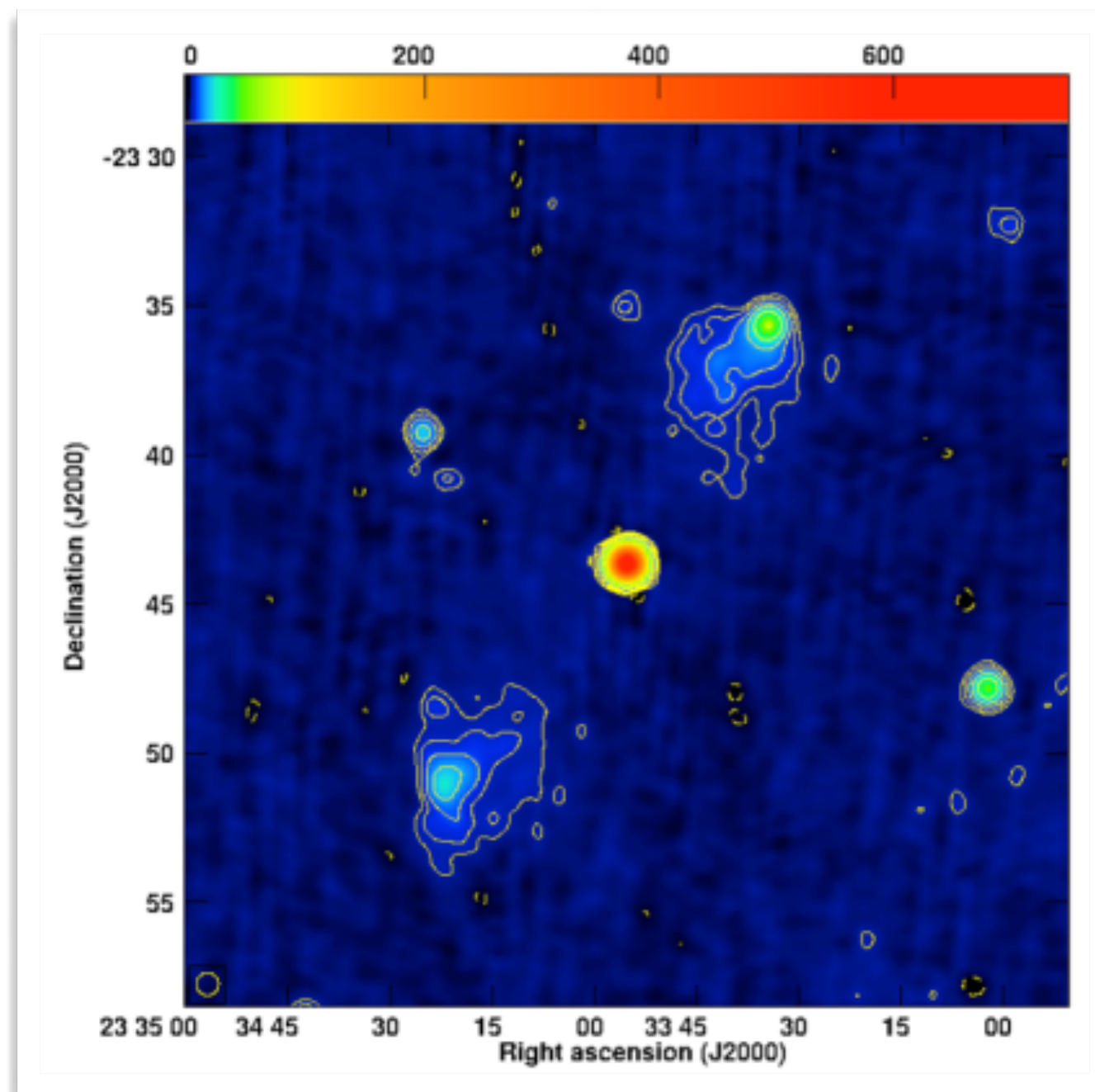
Jet axis flips over a large angle, producing new lobes.

Saripalli et al. 2008

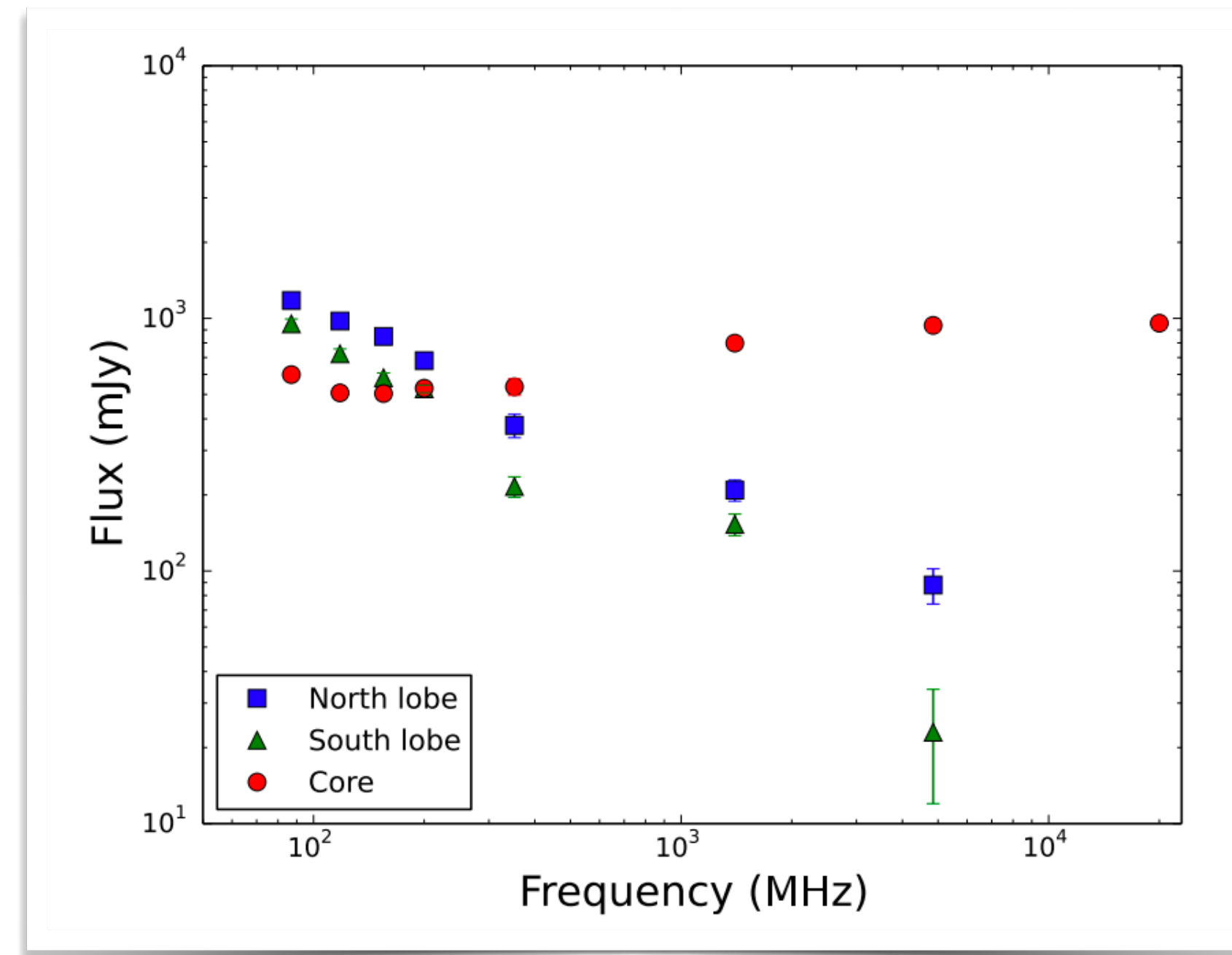
SIGNS OF RESTARTING ACTIVITY

Blazar-like core!

PBC J2333.9-2343

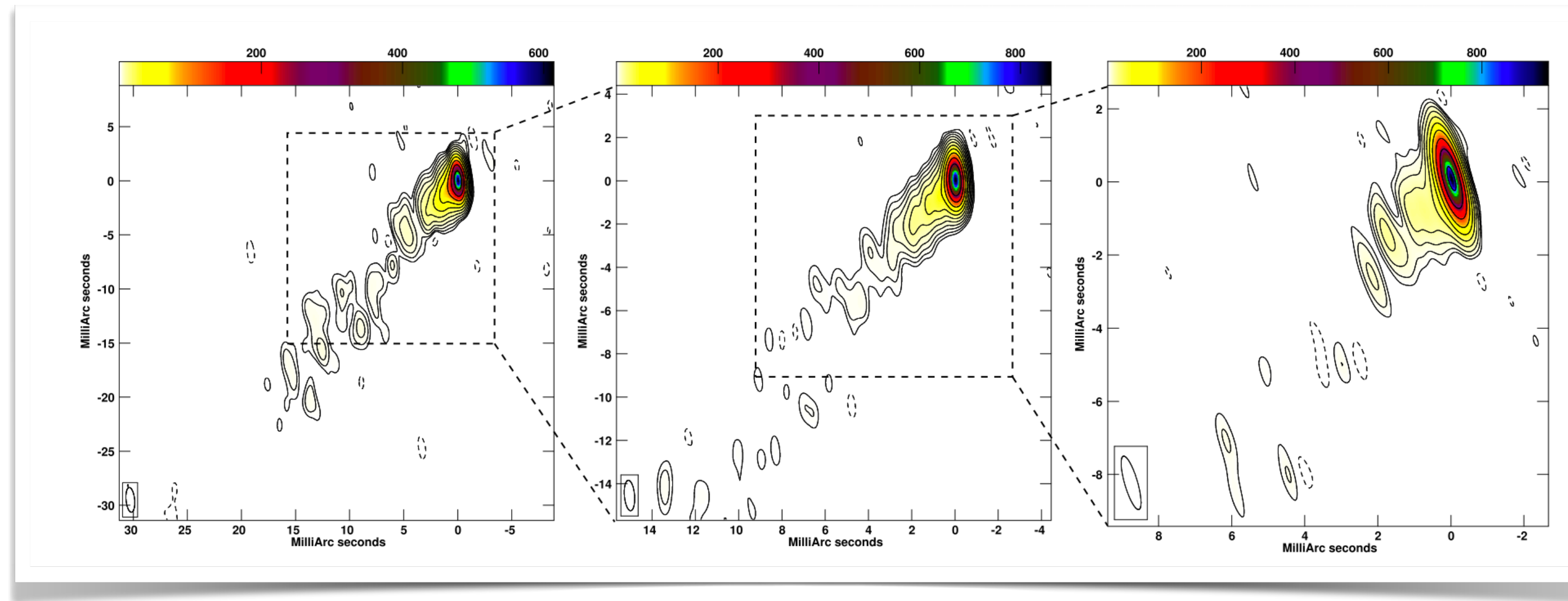


NVSS



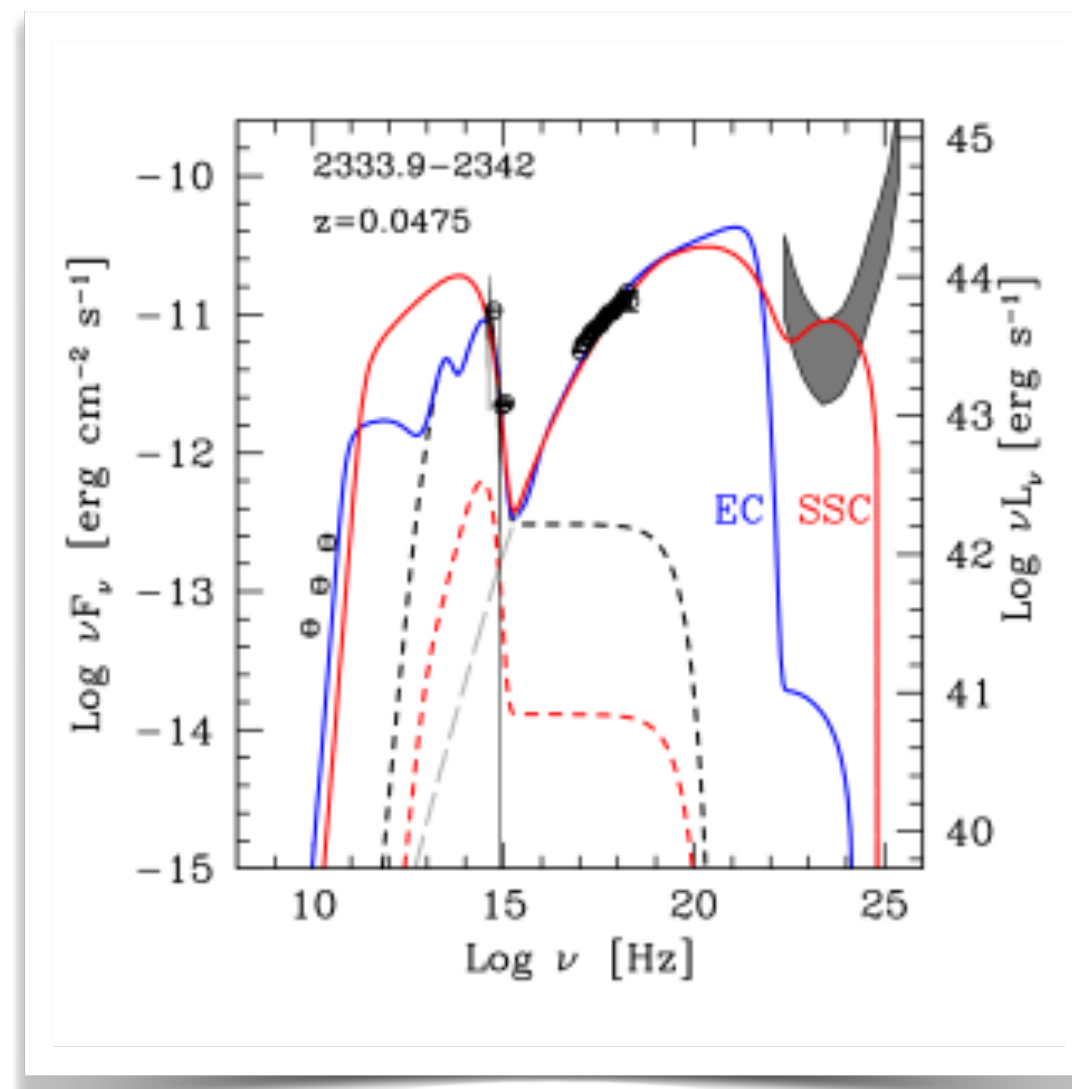
Radio SED from literature

SIGNS OF RESTARTING ACTIVITY

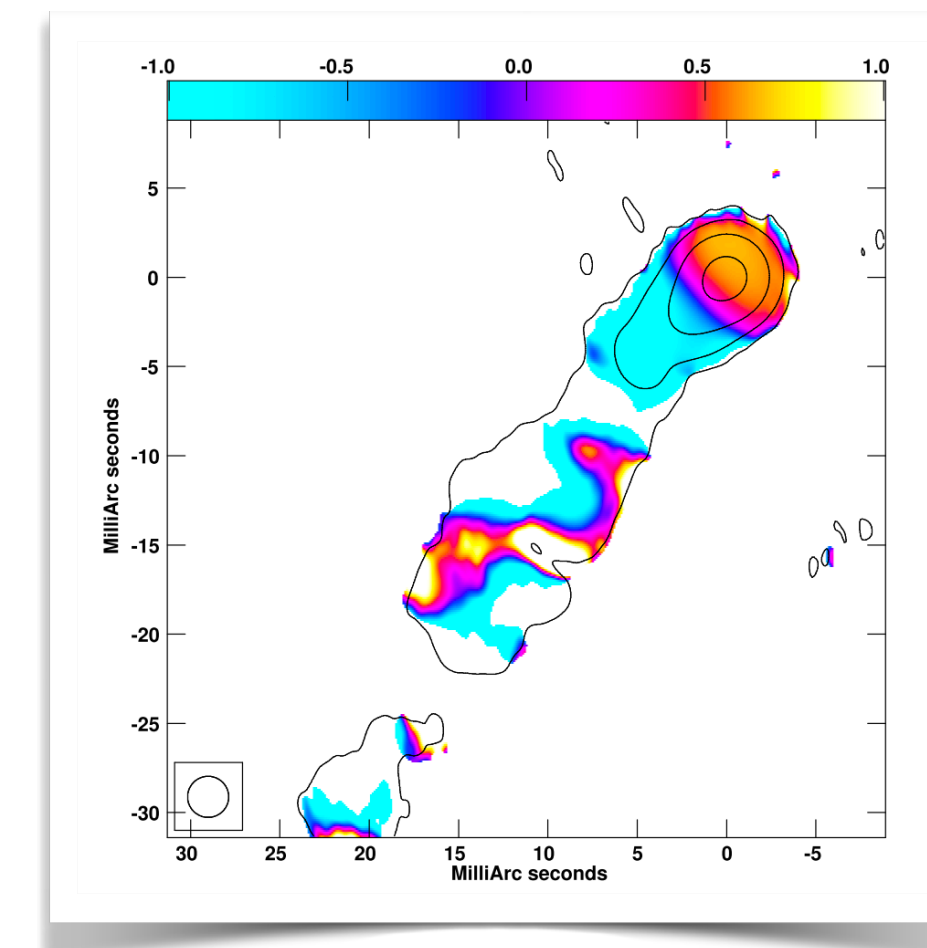


VLBA

8, 15, 22 GHz



...inner jet axis towards line of sight

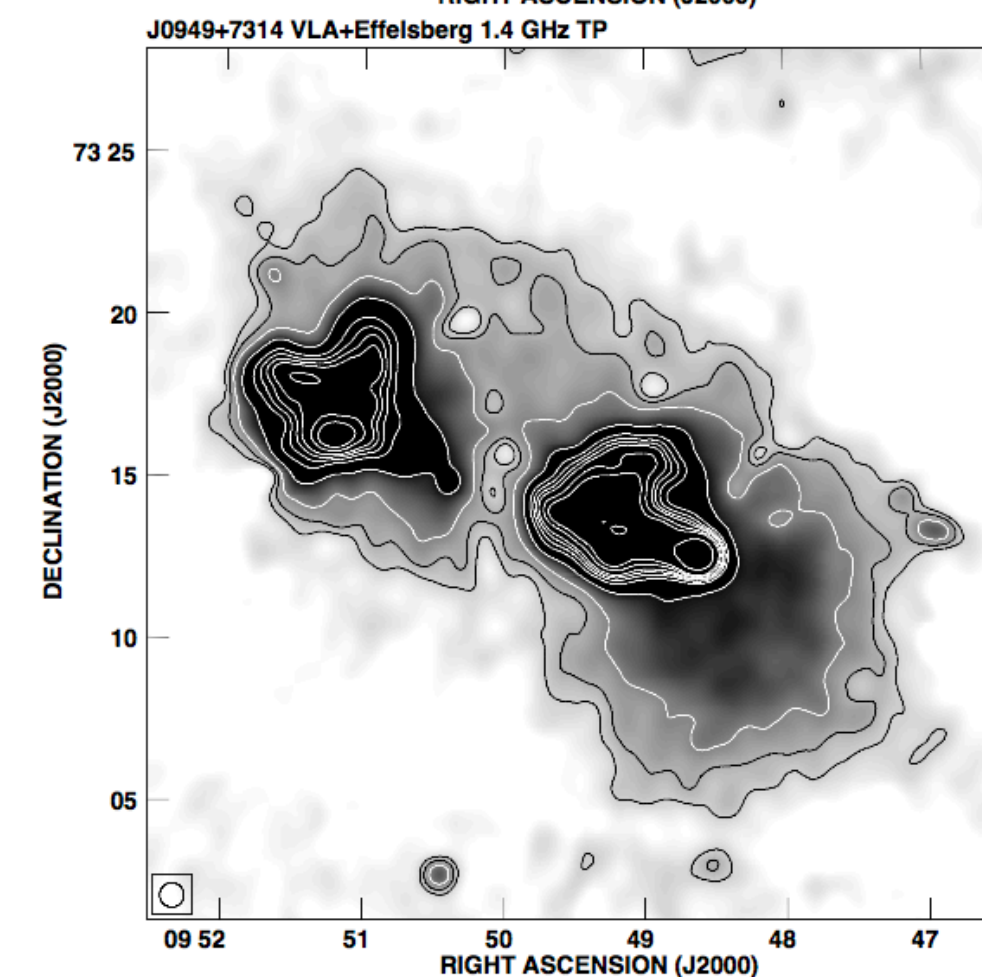
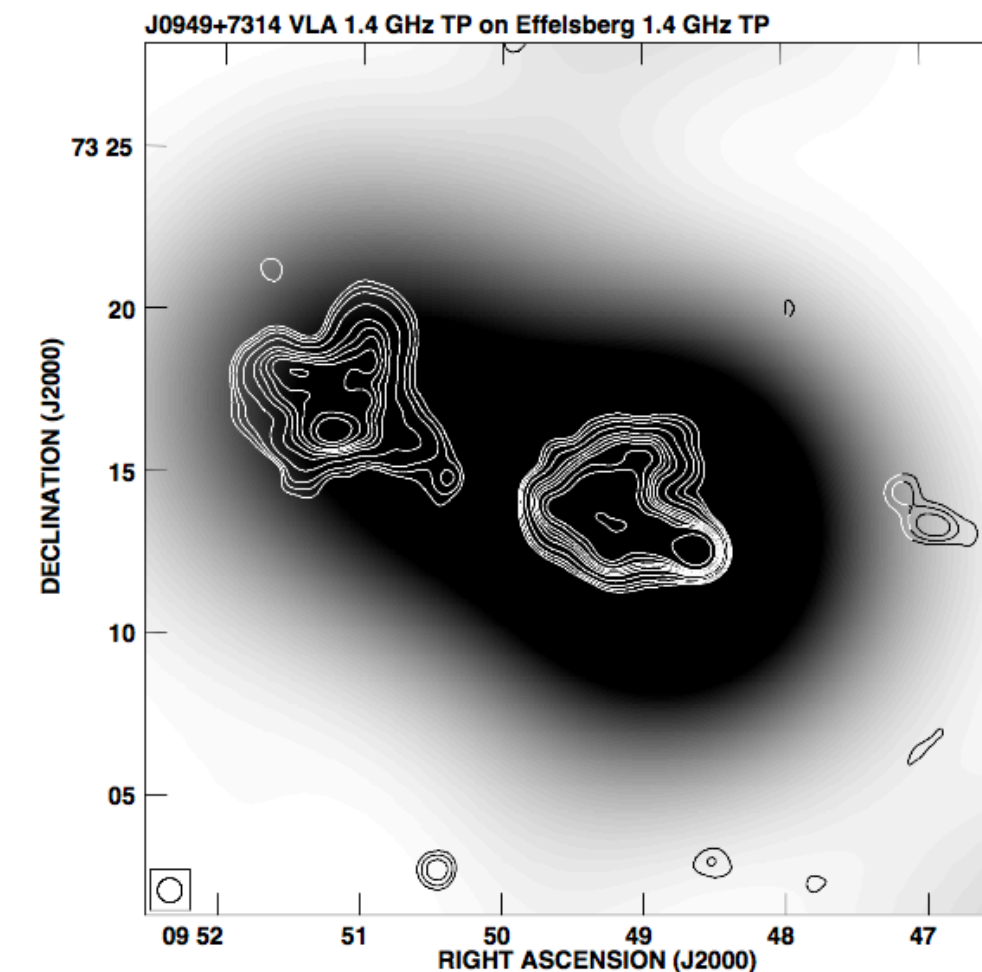


SIGNS OF RESTARTING ACTIVITY

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



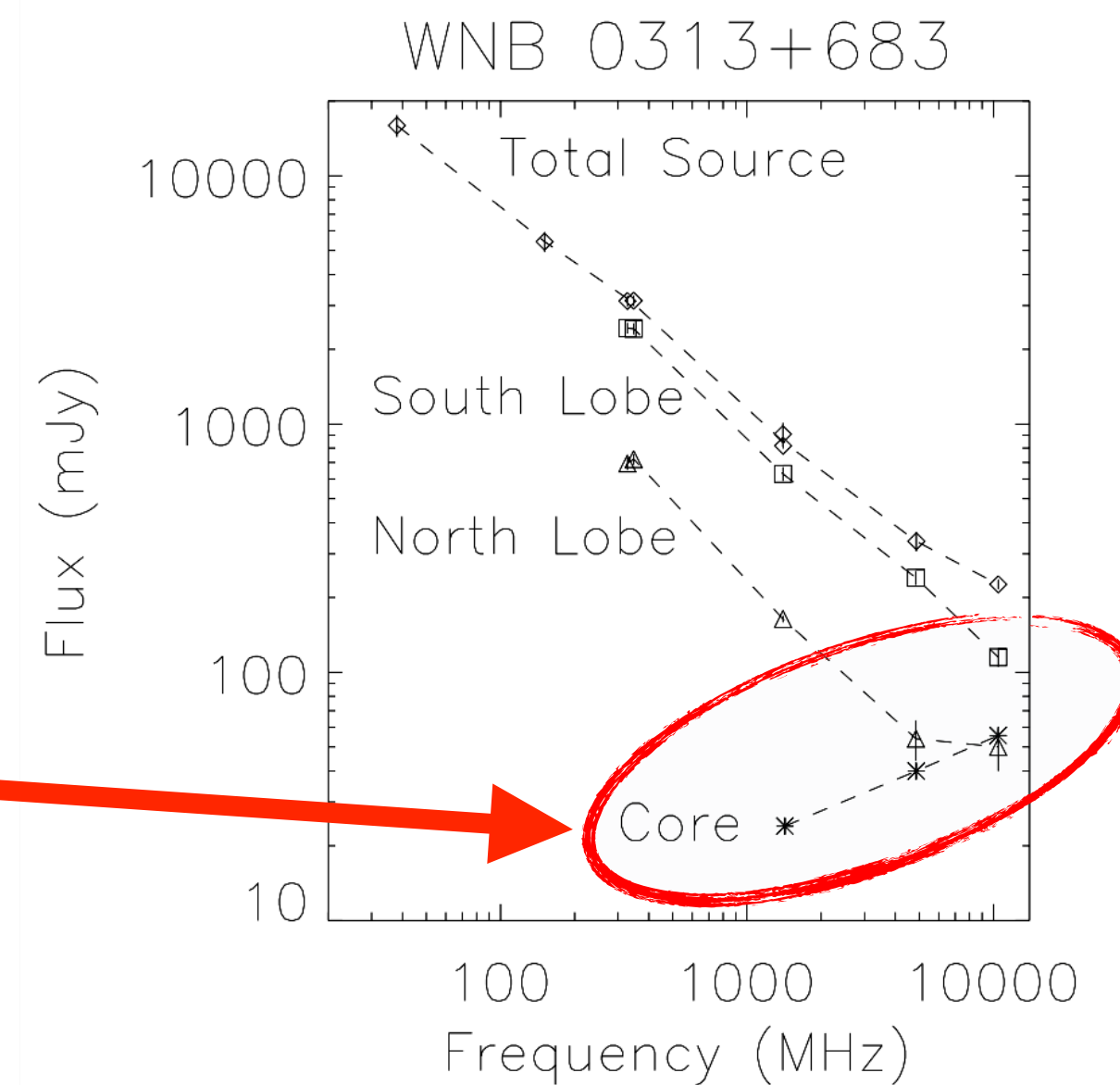
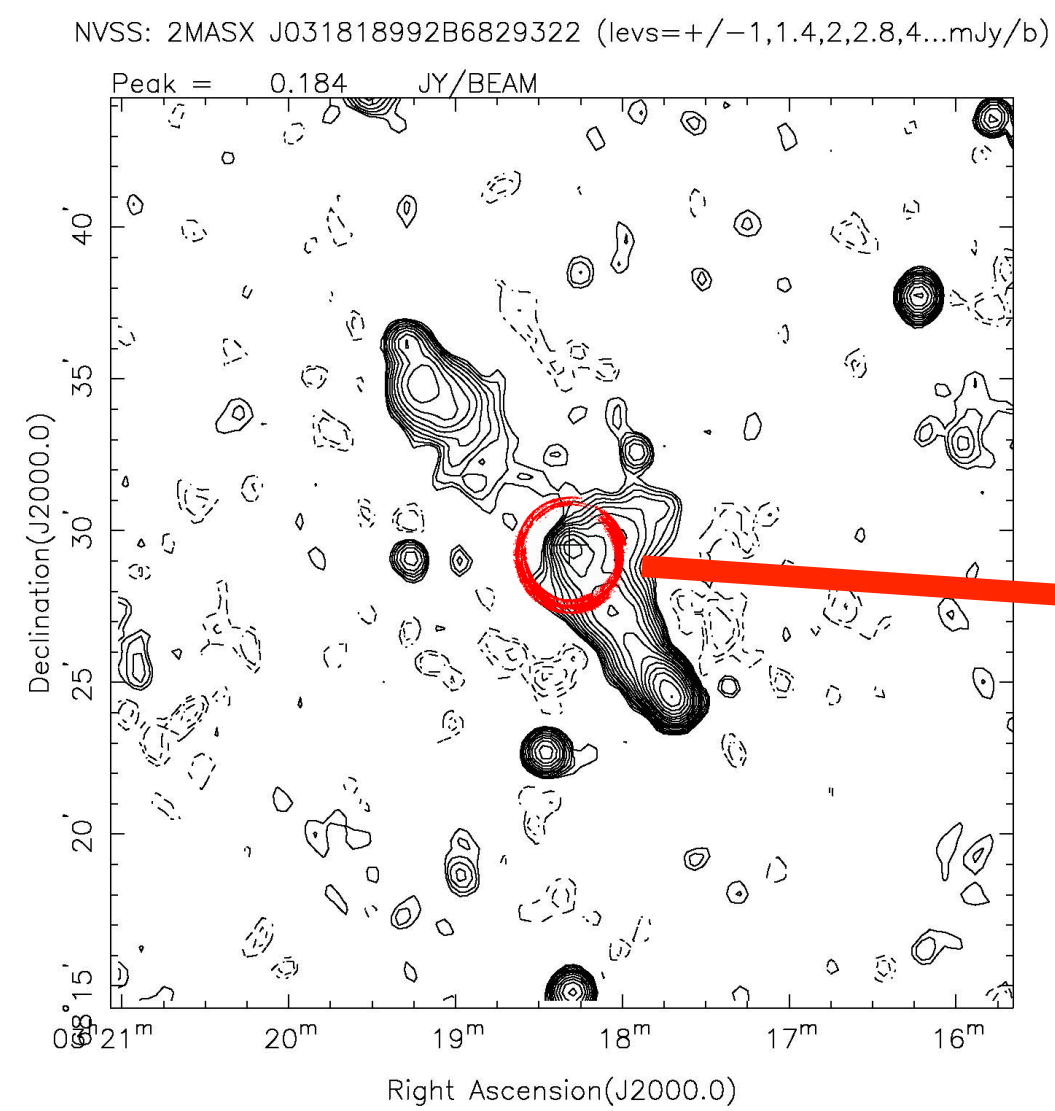
1.4 GHz: NVSS+Effelsberg
Wezgowiec et al. 2016

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)*



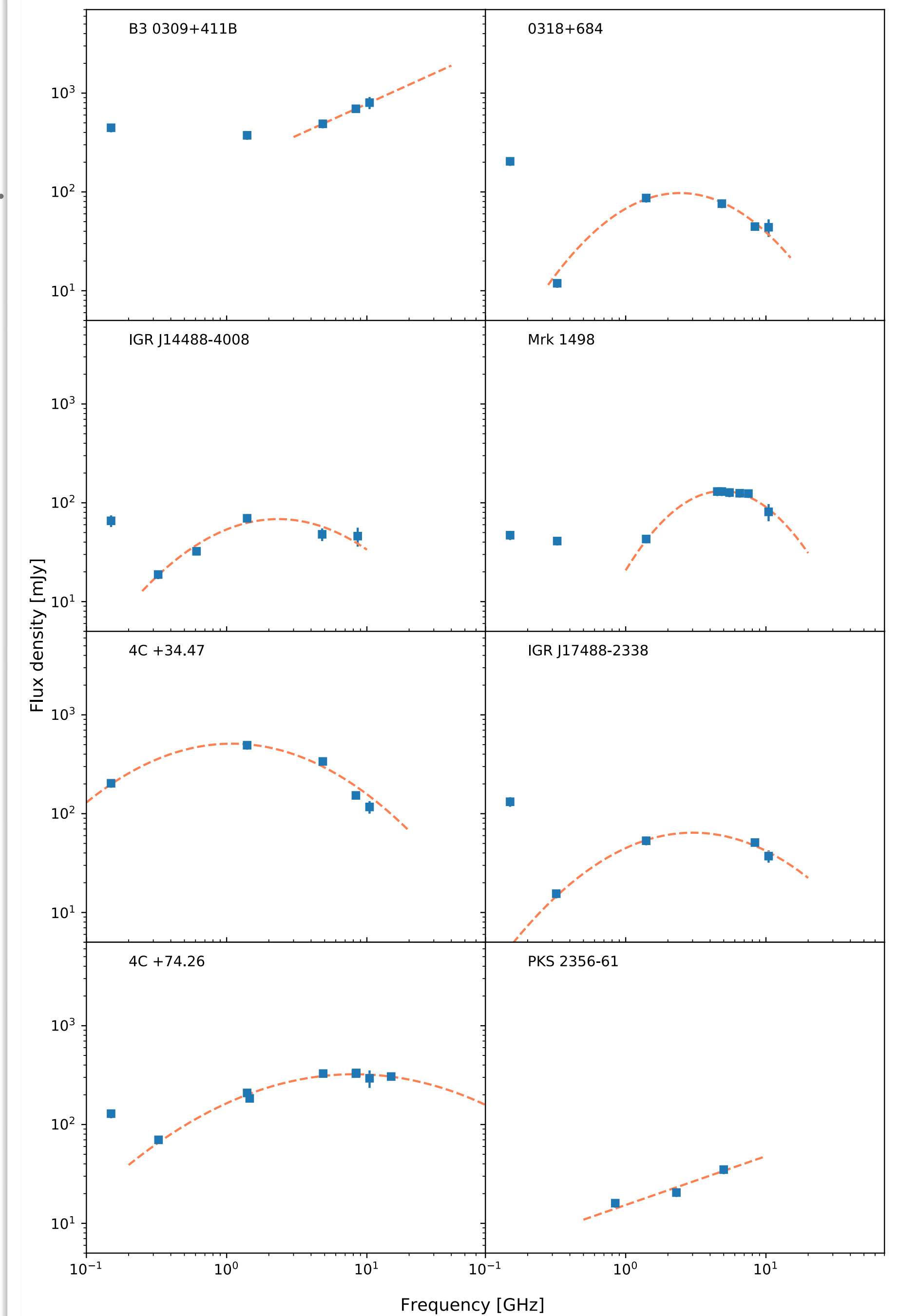
- *TGSS images at 150 MHz (25x25 arcsec resolution, 12/15)*
- *LoTSS DR2 images at 150 MHz (6x6 arcsec resolution, 5/15)*

RESULTS FROM OUR CAMPAIGN

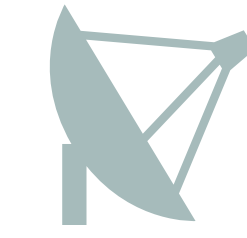
GPS fraction

- 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

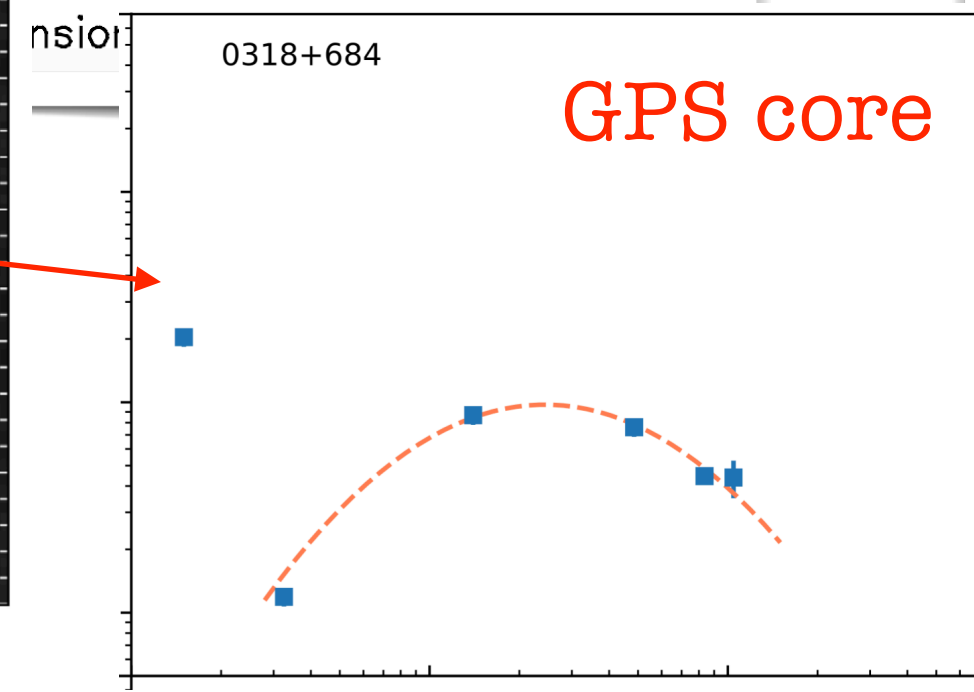
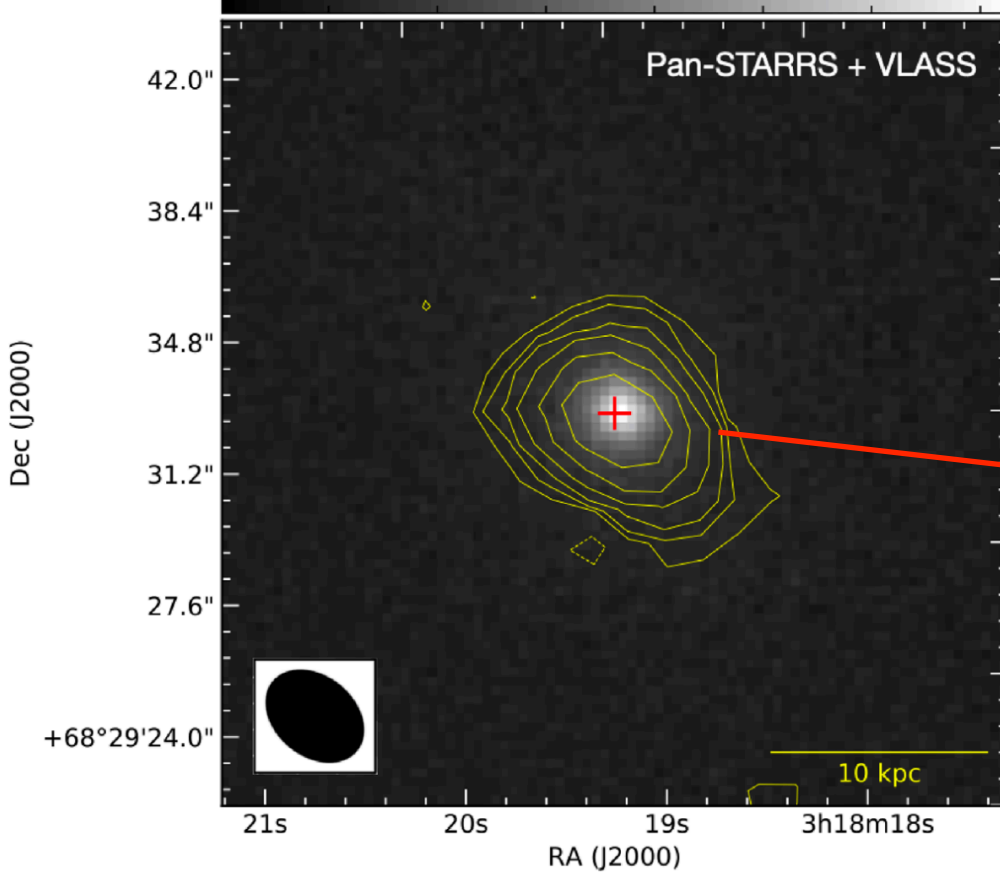
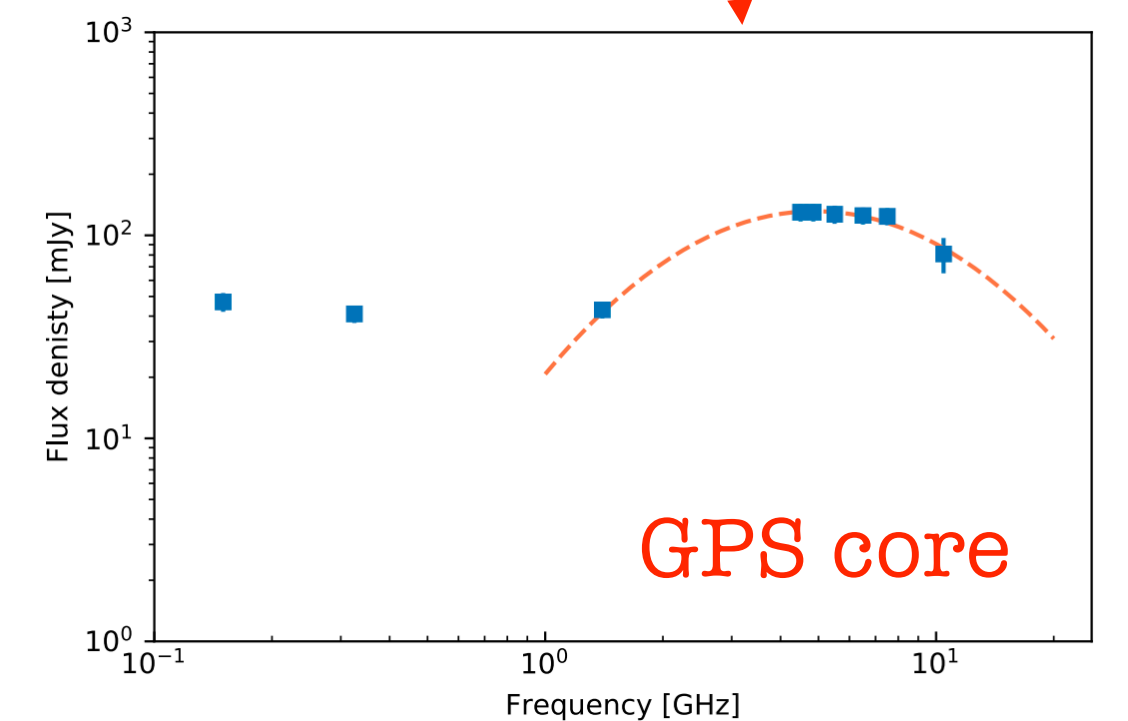
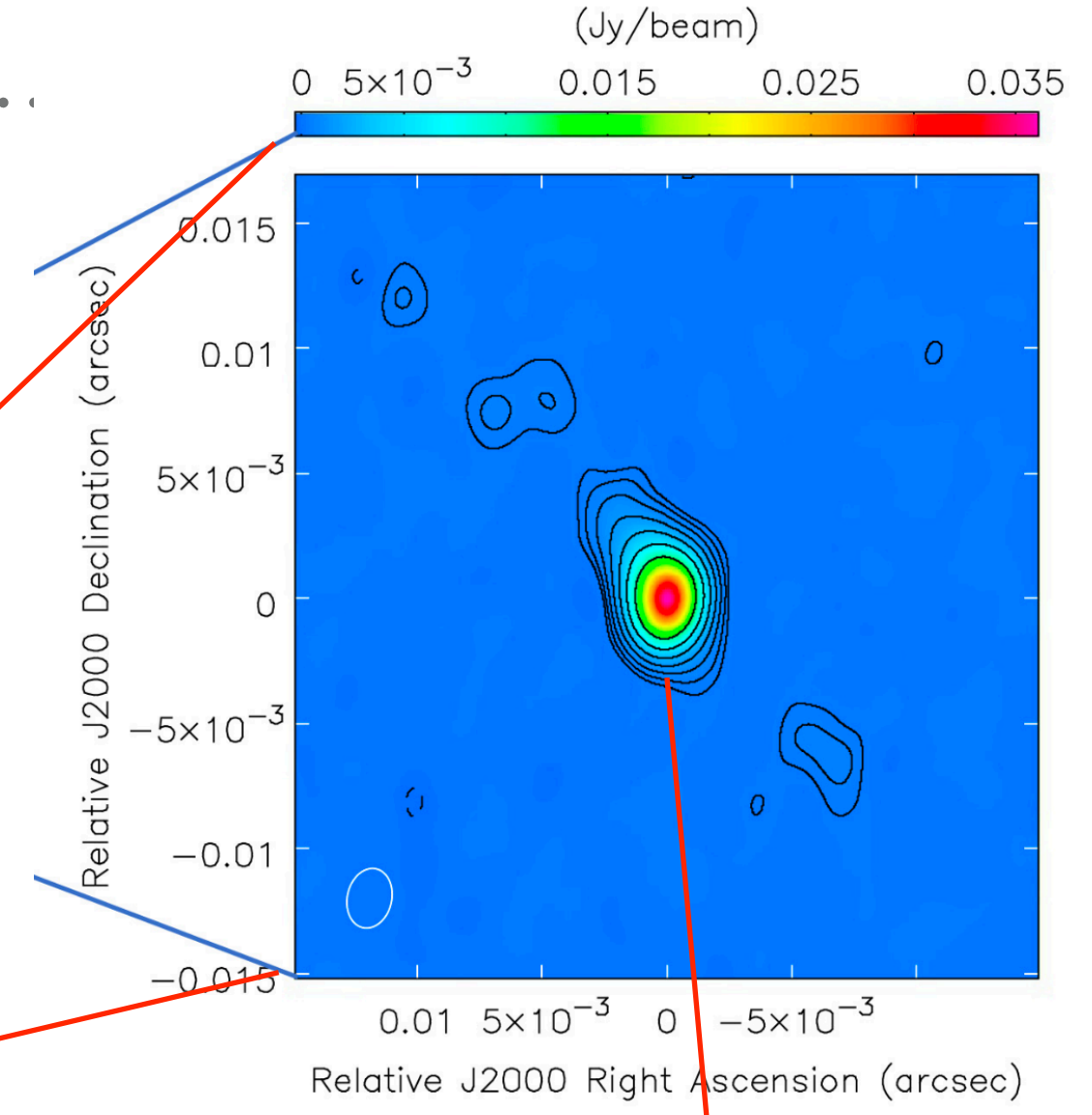
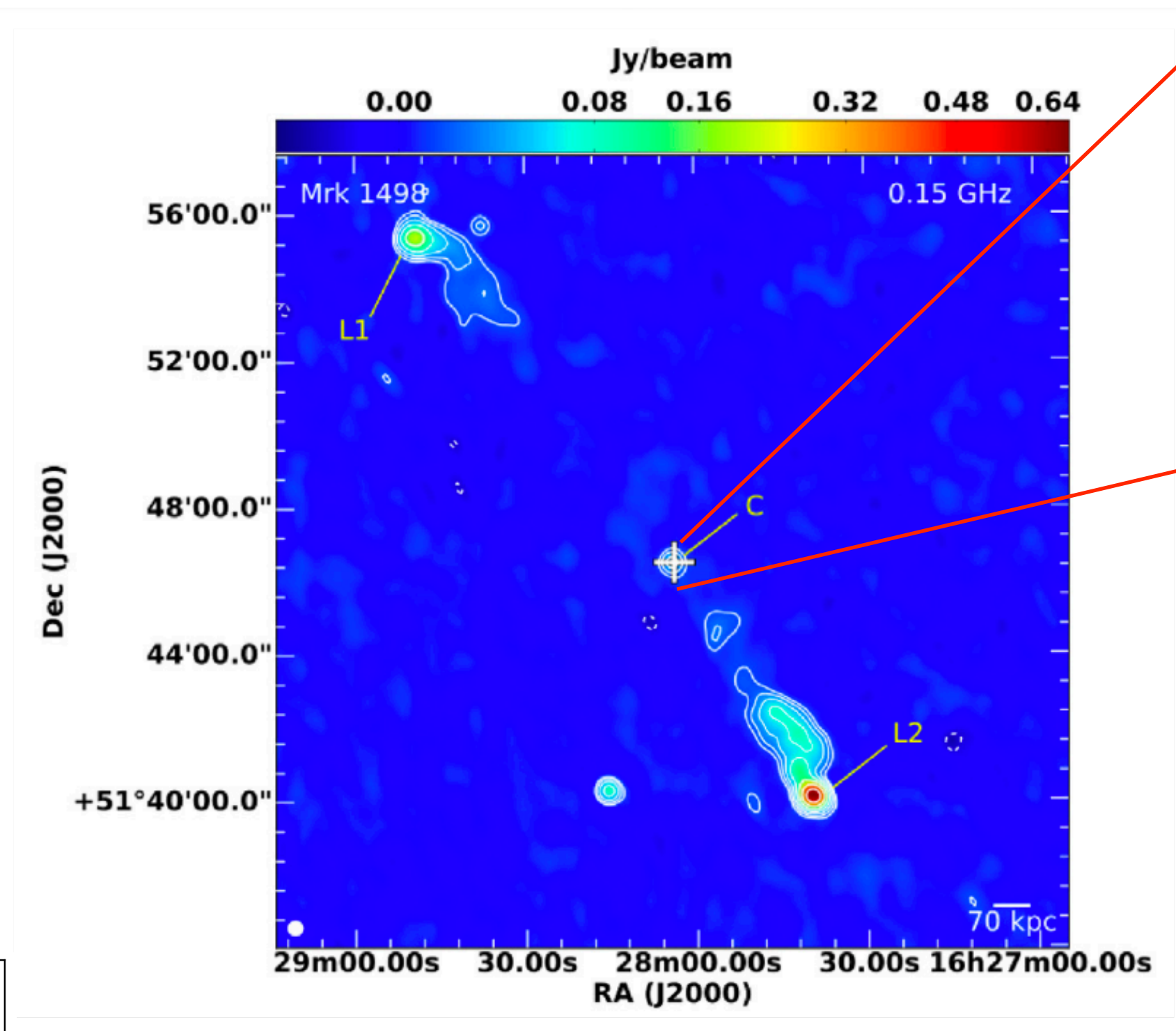
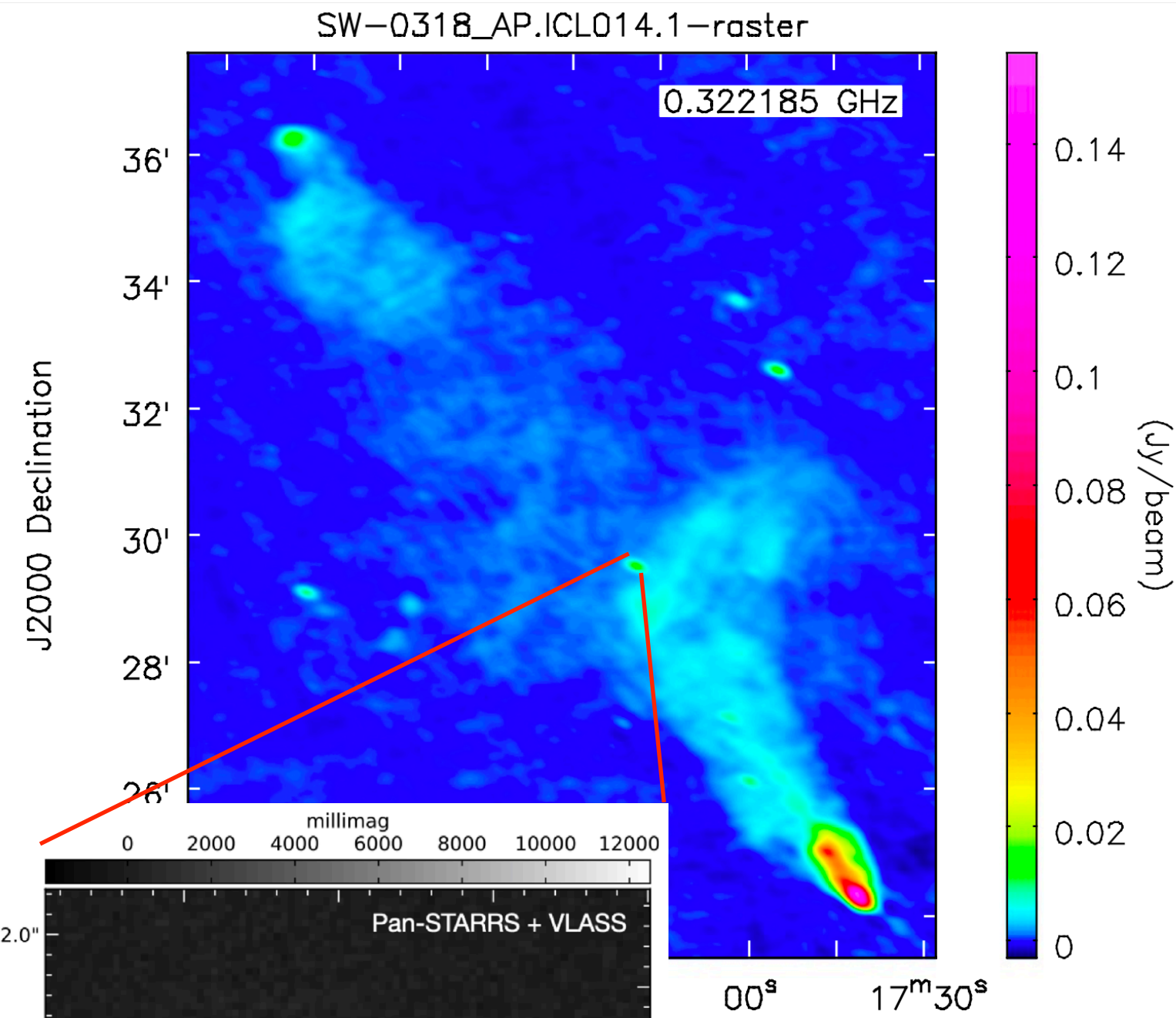


RESULTS FROM OUR CAMPAIGN



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 (Wezgowiec 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

CONCLUSIONS



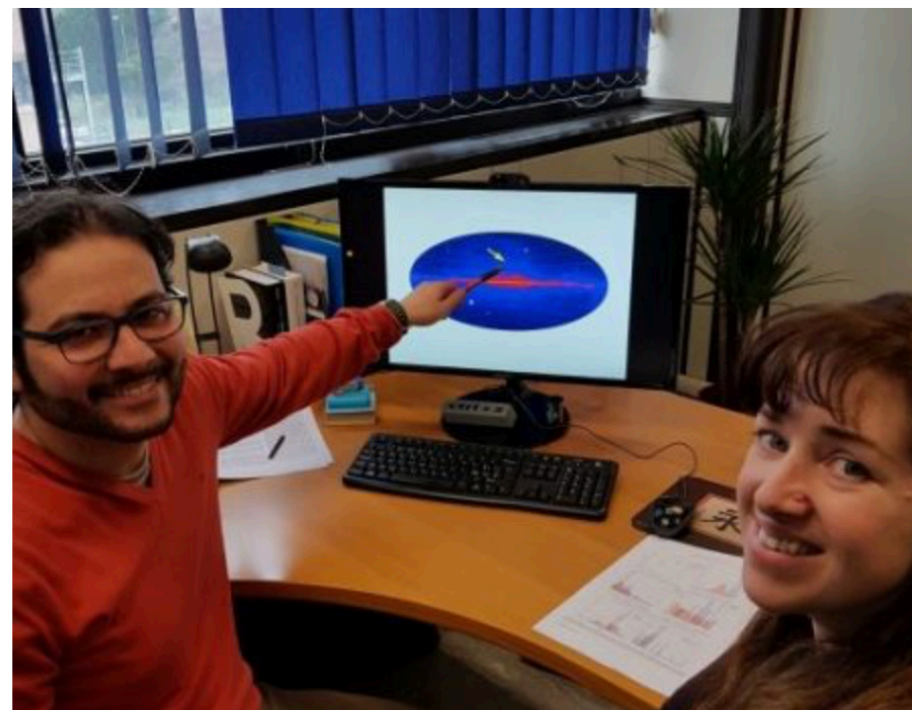
- We selected a GRG sample starting from INTEGRAL+Swift soft gamma-ray catalogues
- GRG fraction among soft gamma-ray selected RG is **four times larger** than in radio-selected samples
- **Almost all GRGs show signs of restarting activity: ~60% have a GPS core, ~40% restarting morphology**
- **Bias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



Home Our Group Research Activities Papers Outreach Links

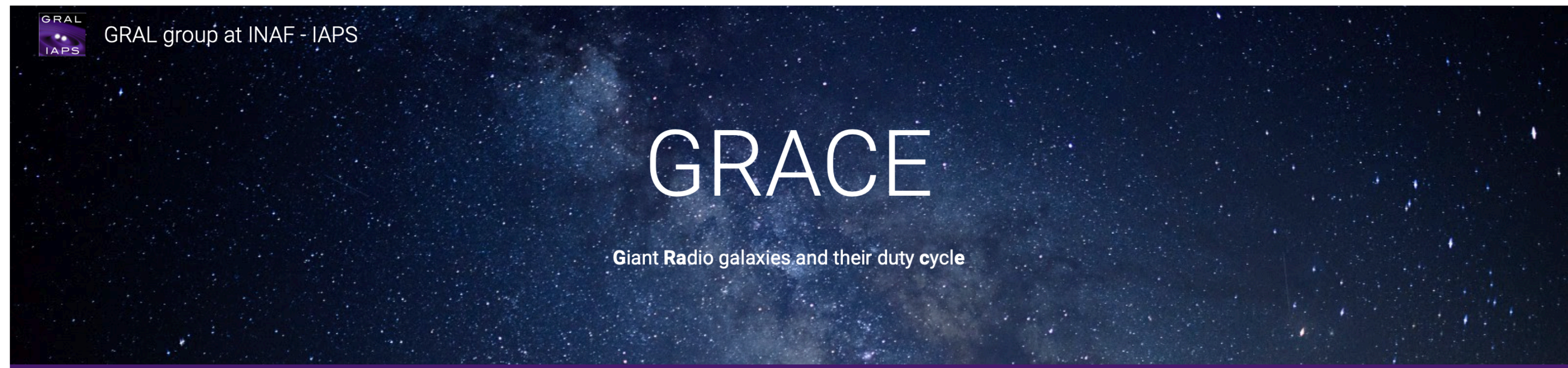


THE GRAL

The Gamma-Radio group at IAPS has a long sought experience in High Energy Astrophysics and it has been involved in the design, management, construction and operation of instruments for satellite missions. Recently, the group has been involved in Radio Frequency Interference (RFI) studies and Extra-Galactic Transients (XGT) and Extreme Multi-Frequency Transients (EMFT) and neutrino detection.

Search

<http://gral.iaps.inaf.it>



GRAL group at INAF - IAPS

GRACE

Giant Radio galaxies and their duty cycle

Giants in the sky

Giant radio galaxies (GRG) are one of the most spectacular manifestation of astrophysical jets, showing plasma ejecta with an extension up to Mpc. However, the conditions allowing such a growth are still unclear, and may be linked to a particularly favourable environment, to peculiar accretion/ejection conditions allowing a very long and continuous radio activity, or to more than one radio cycle. The aim of the GRACE project, carried out by the **GRAL group in Rome**, is to study the radio duty cycle in a sample of giant radio galaxies selected from high energies (hard-X) catalogues produced by the INTEGRAL/IBIS and Swift/BAT space missions.

In this webpage, we collect the information on the GRG sample we are studying since 2016, providing reference works and highlights on our current results.