GRACE

Giant RAdio galaxies and their duty CyclE

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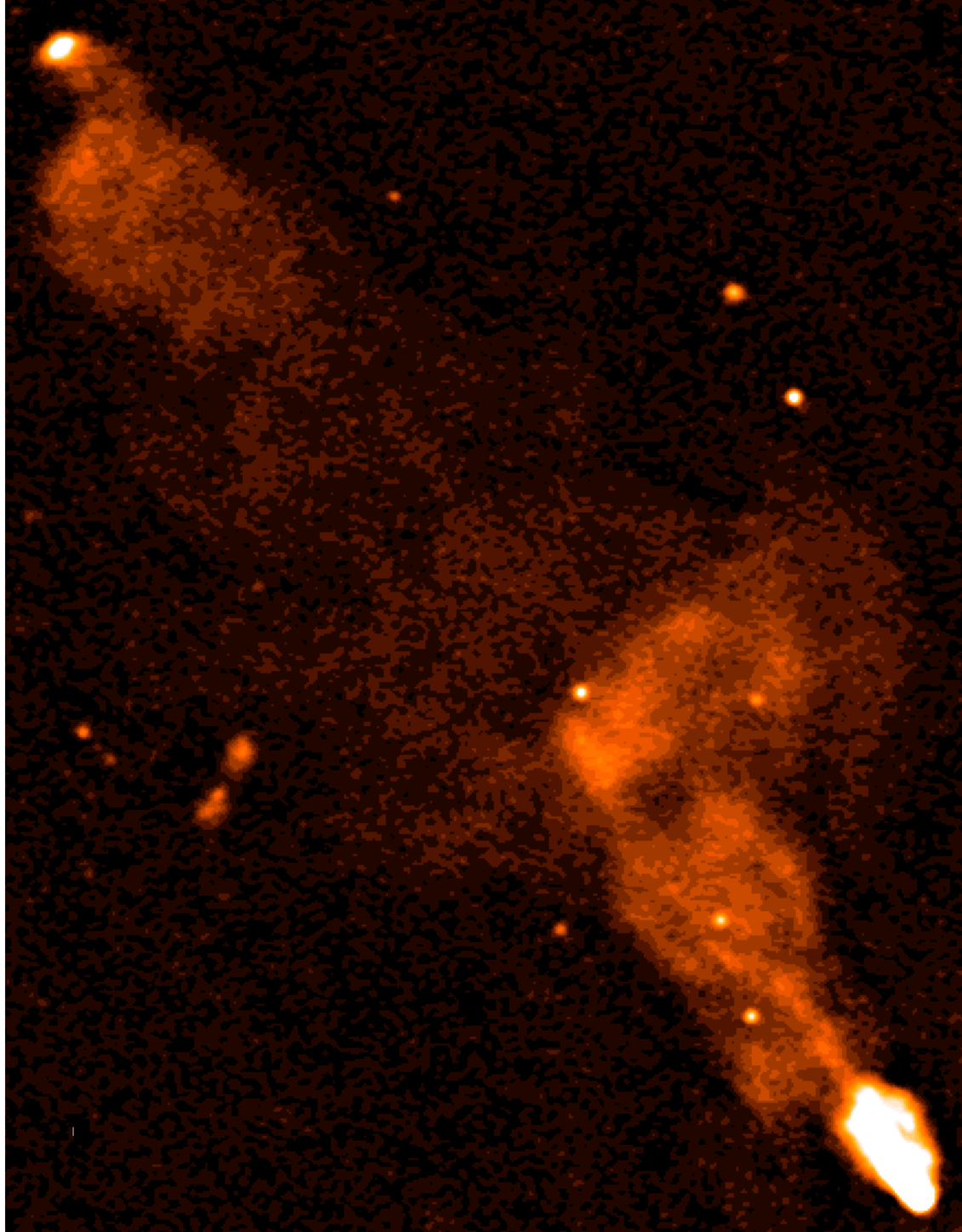


THE GAMMA-RAY SKY

keV *MeV* *GeV*

Swift/BAT
(15 keV - 150 keV)

INTEGRAL/IBIS
(15 keV - 10 MeV)

Fermi/LAT
(20 Mev – 300 Gev)

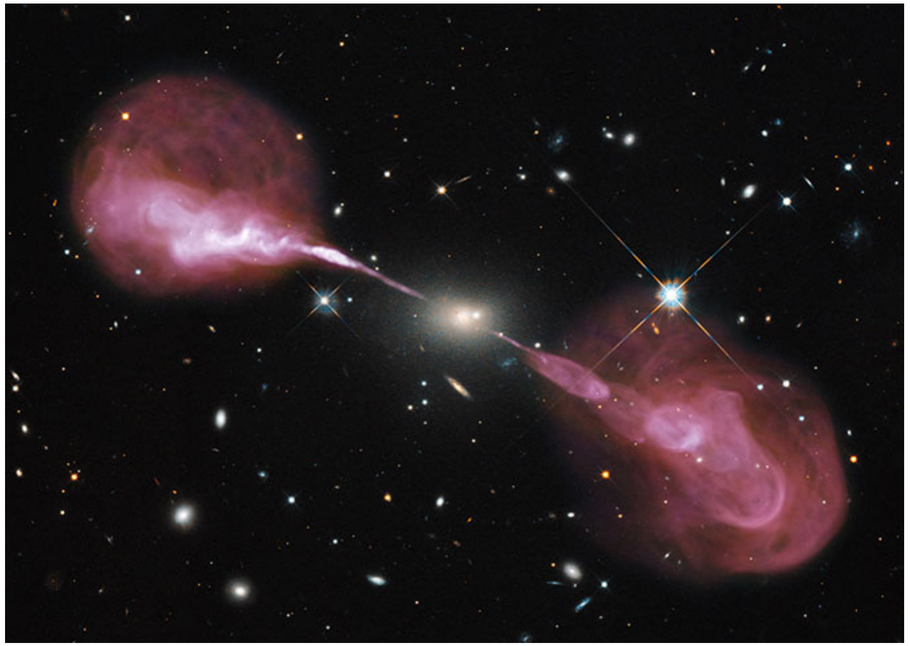
Baumgartner et al. 2013

Bird et al. 2010
Malizia et al. 2012

Ajello et al. 2020

…most extensive list of soft gamma-ray selected AGN

THE RADIO GALAXIES FRACTION



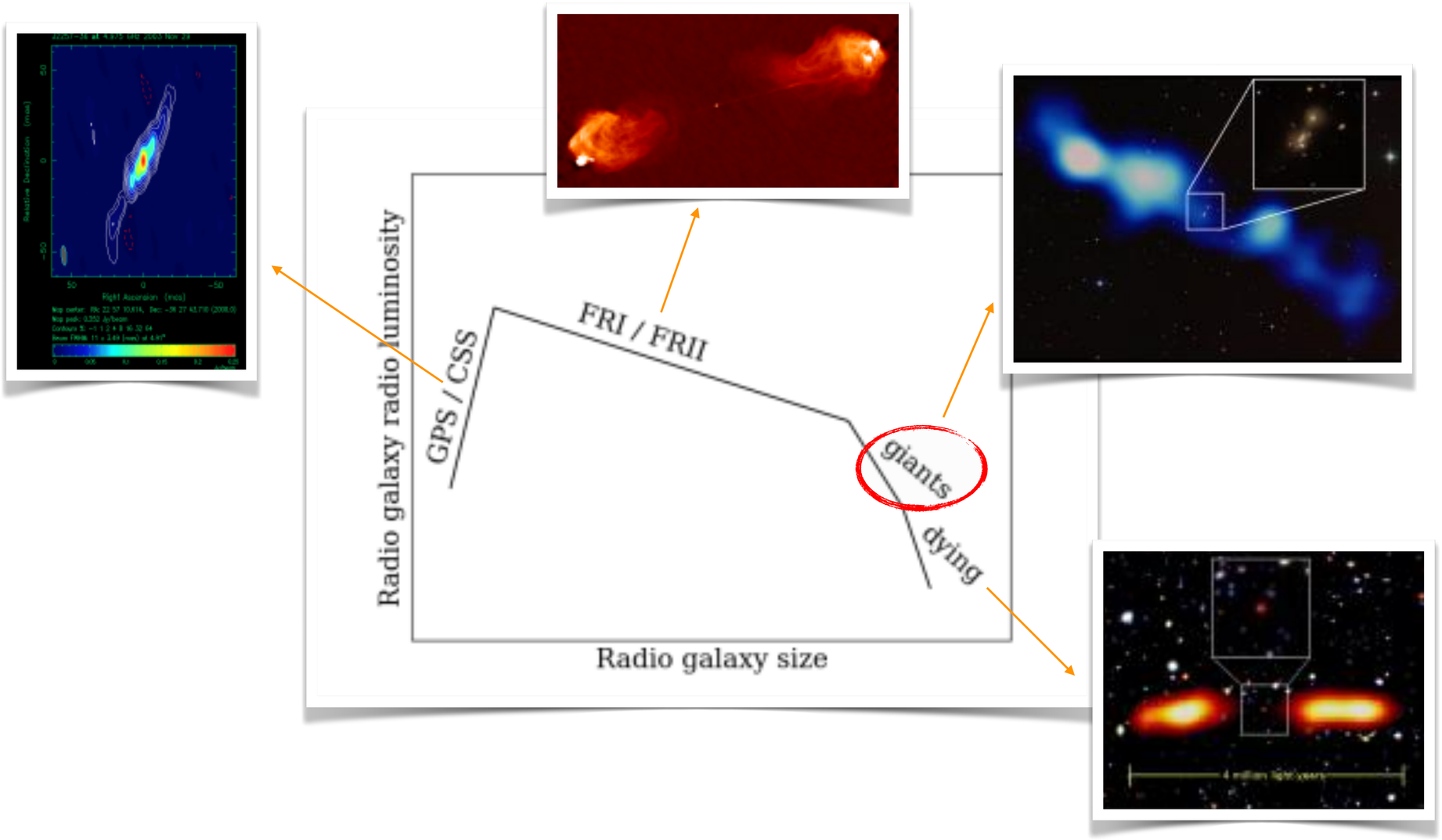
Radio galaxies, recognised through their core, jets, and lobes radio morphology, constitute only a small fraction of high-energy AGN

8% in the INTEGRAL/IBIS AGN sample

1% in the Fermi/LAT AGN sample

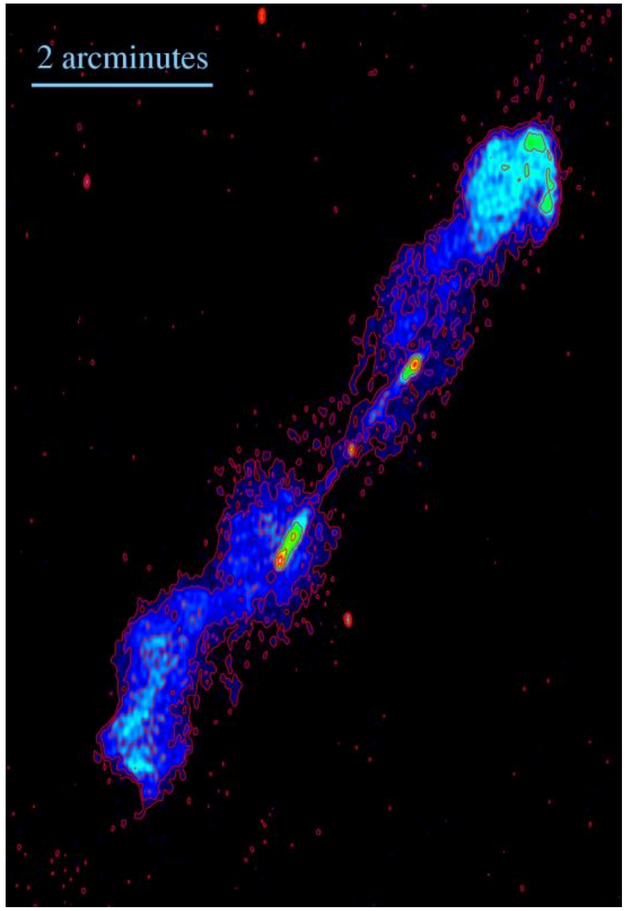
Despite their rarity, they offer the unique possibility to study at the same time jets and accretion processes, and their connections

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?

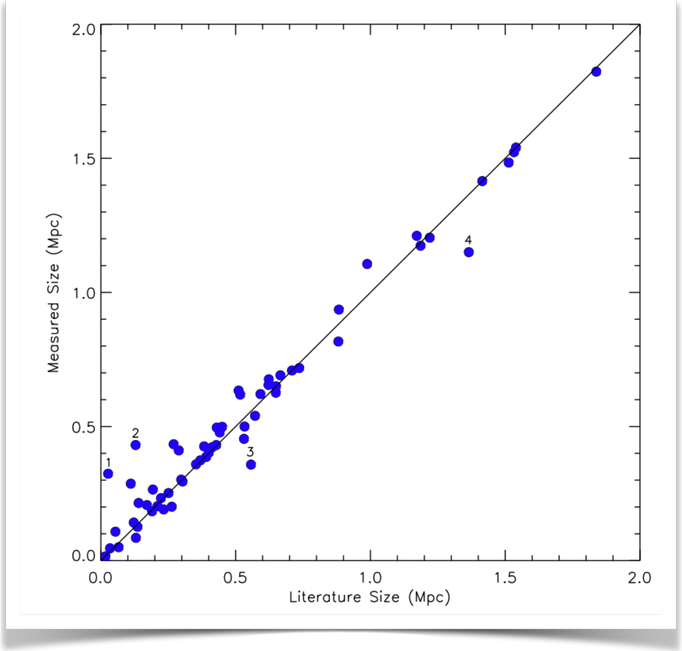


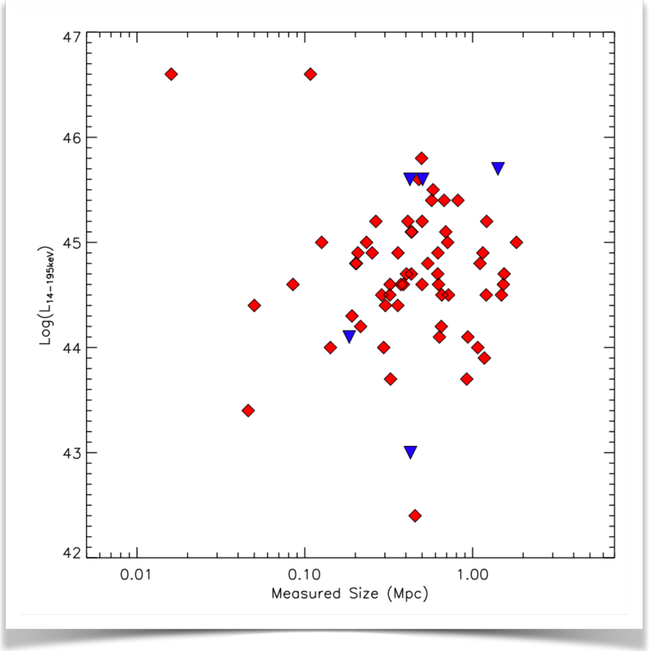
B1545-321 (ATCA, 13cm)

RADIO COUNTERPARTS

- Cross-correlation Swift/BAT+Integral/IBIS ⊗ 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%)

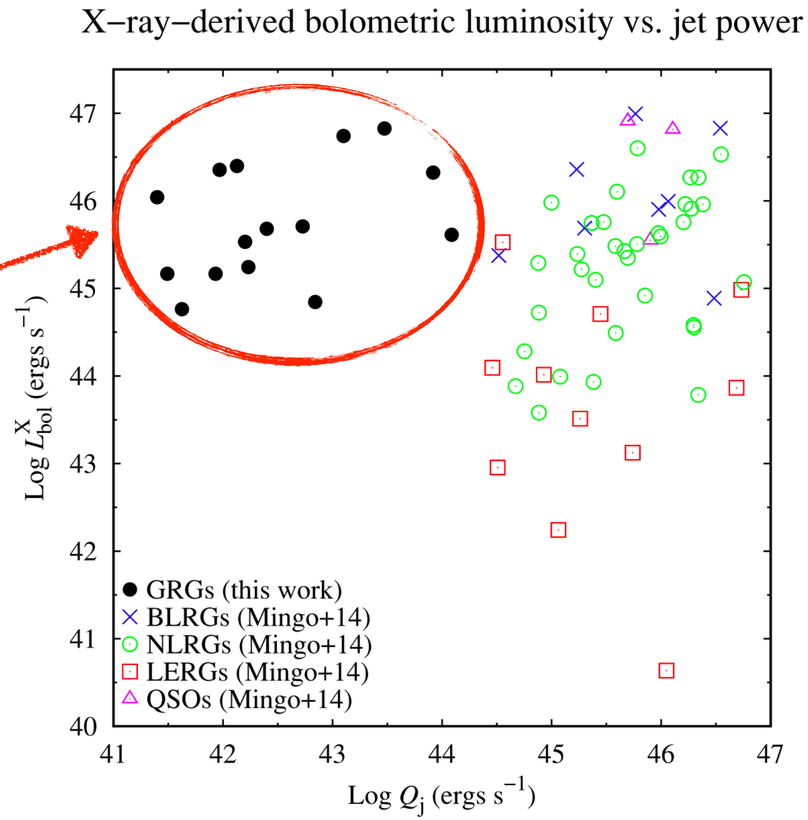




Bassani et al. 2016

SIGNS OF RESTARTING ACTIVITY

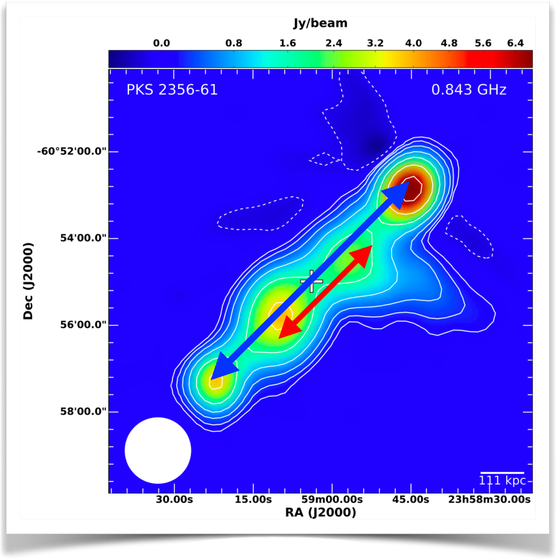
- Correlation between the X-ray luminosity and the radio core luminosity, consistent with that expected for AGN powered by efficient accretion.
- Luminosity of the radio lobes and the estimated jet power are relatively low compared with the nuclear X-ray emission.
- either the nucleus is more powerful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



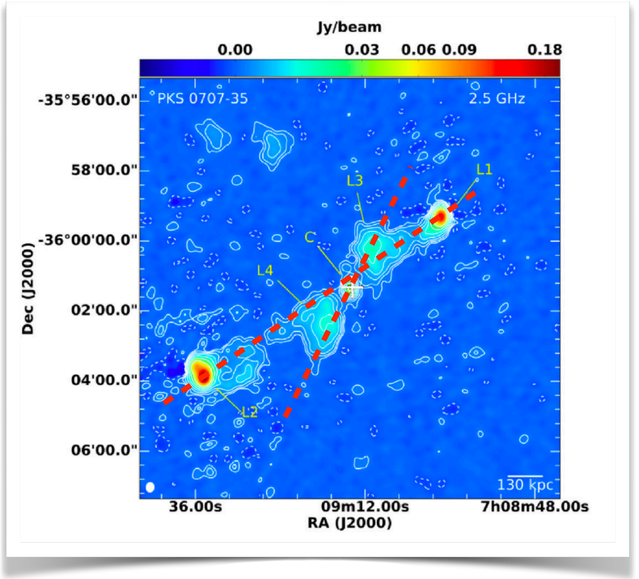
Ursini et al. 2018

SIGNS OF RESTARTING ACTIVITY

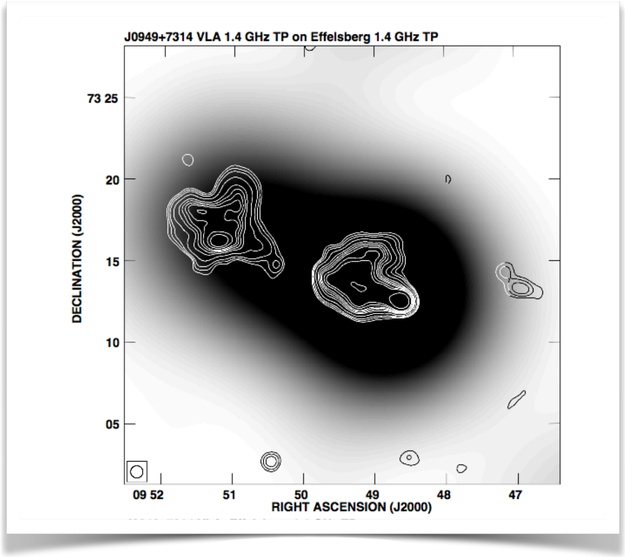
Double-Double



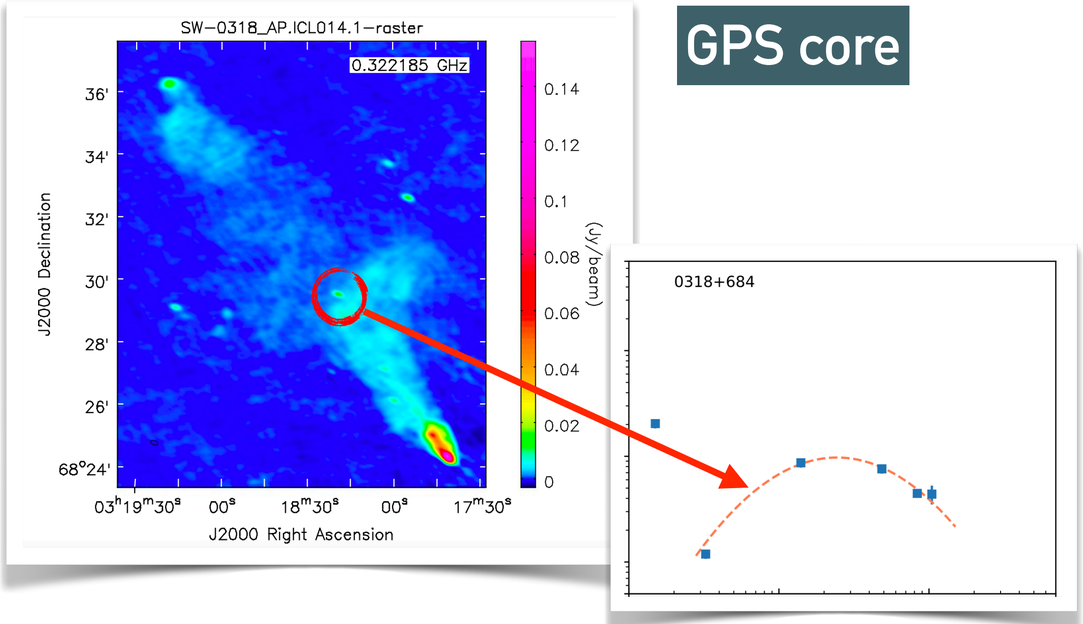
X-shaped



Radio cocoon



GPS core



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)*

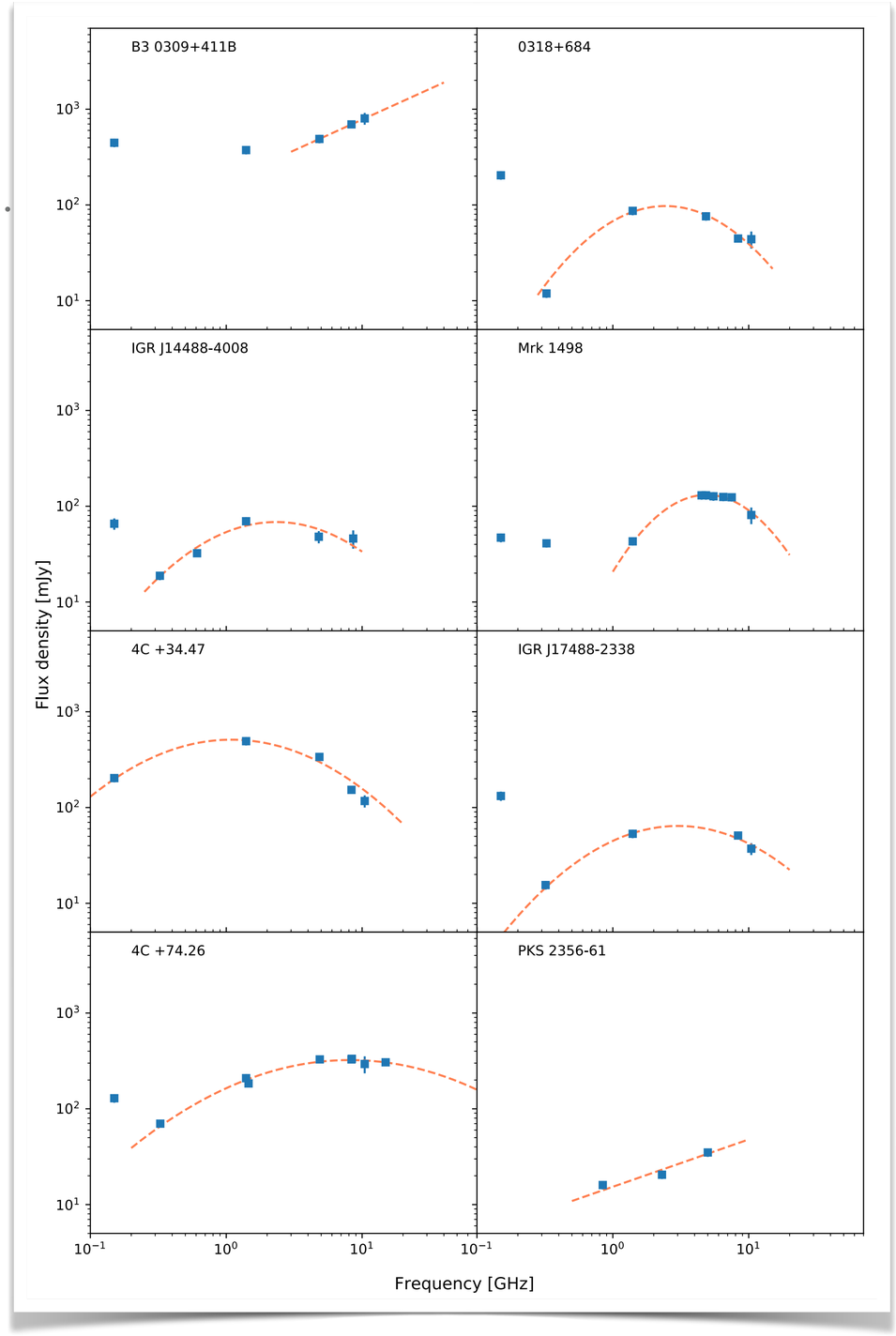
- *TGSS images at 150 MHz (25x25 arcsec resolution, 12/15)*
- *LoTSS DR2 images at 150 MHz (6x6 arcsec resolution, 5/15)*

RESULTS FROM OUR CAMPAIGN

GPS fraction

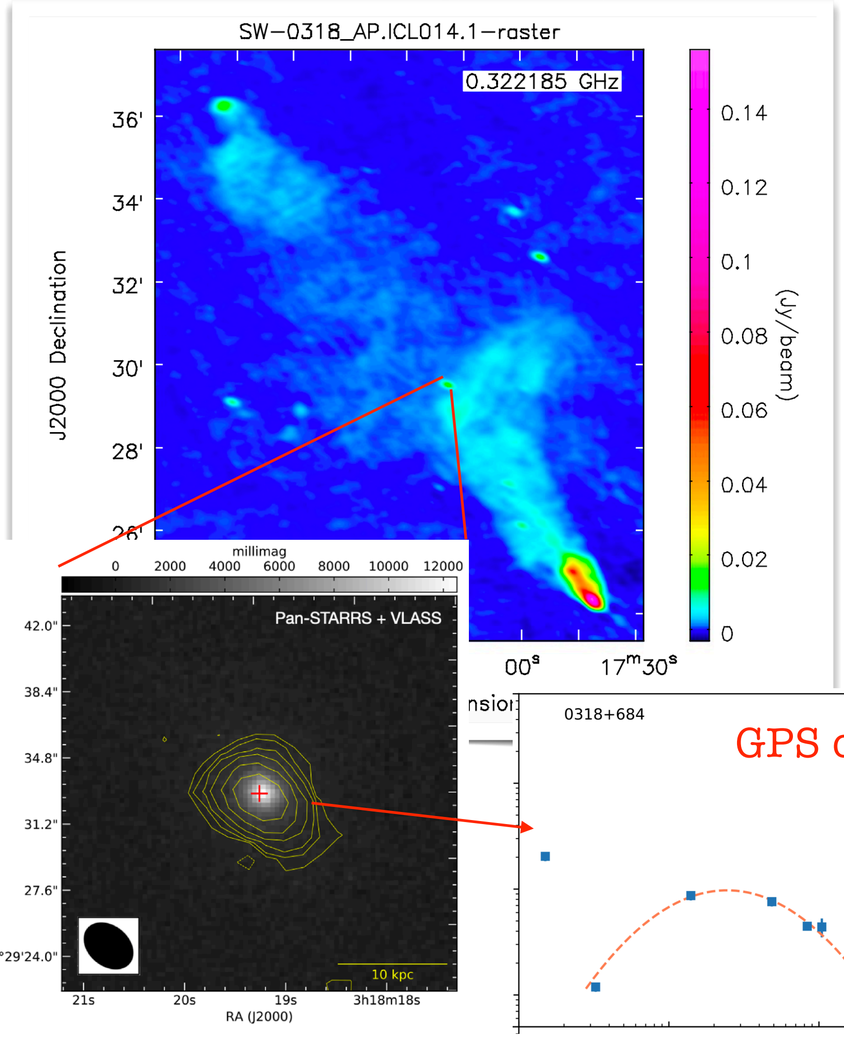
- Collecting data from archive in the MHz-GHz range for all sources
- A GPS fraction of 61(+30 -21)% is found
- Cores are often young radio sources

Bruni et al. 2019

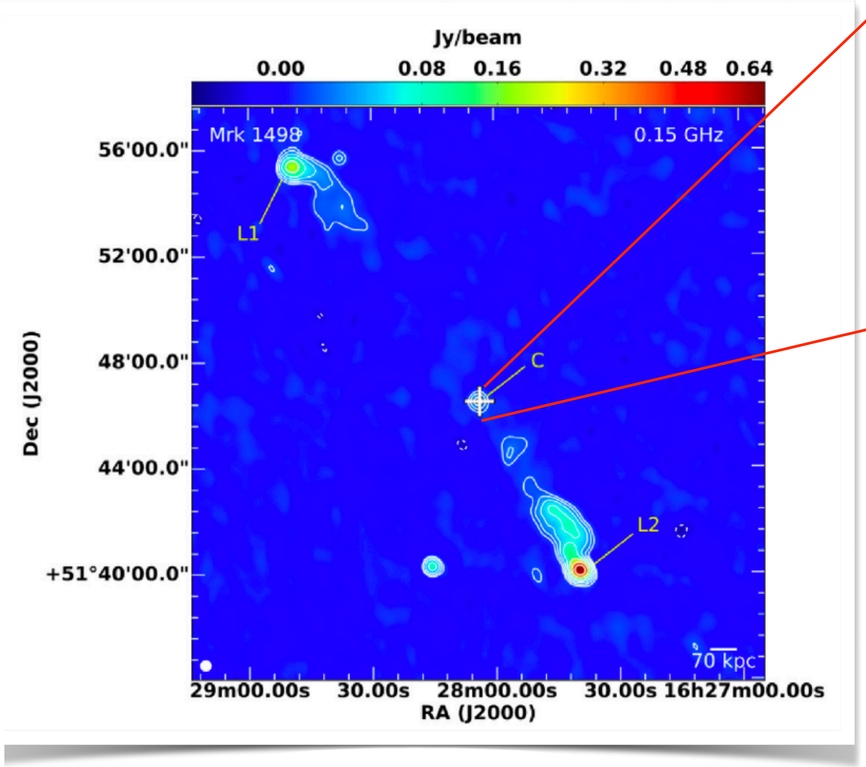


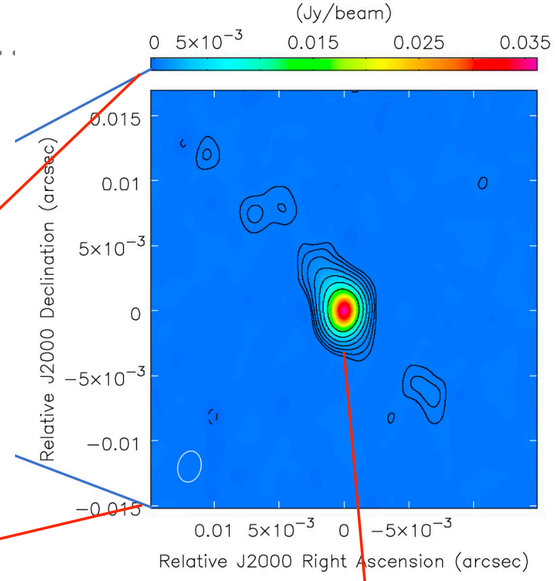
RESULTS FROM OUR CAMPAIGN

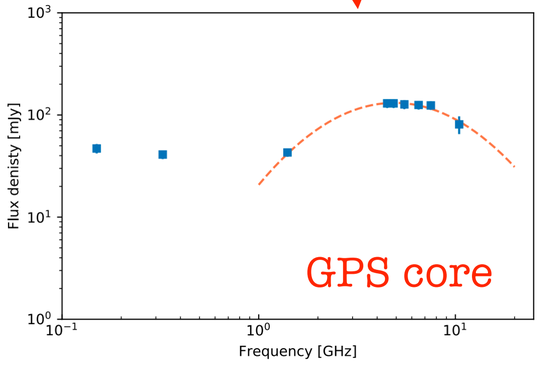
SW-0318+68



Mrk 1498







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

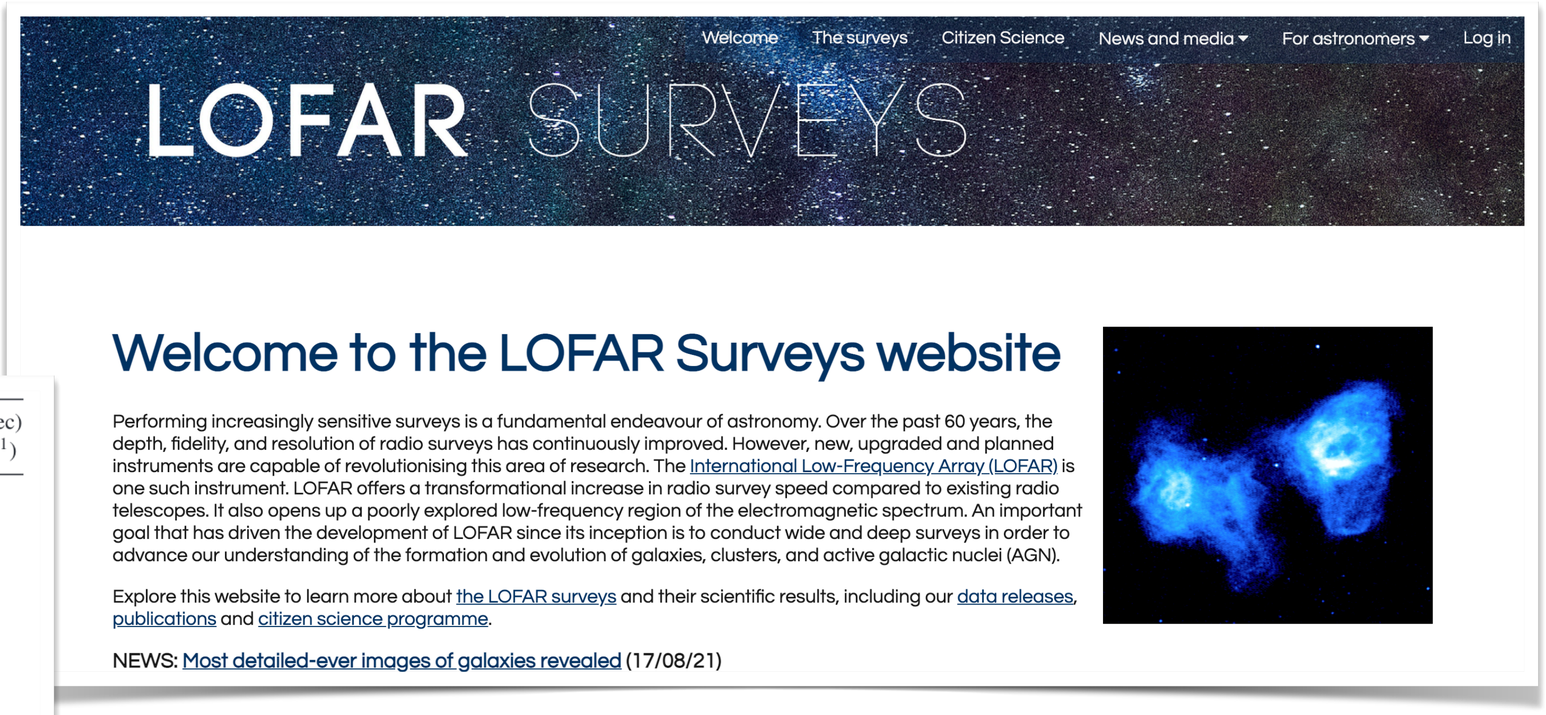
RESULTS FROM OUR CAMPAIGN

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

THE LOFAR VIEW

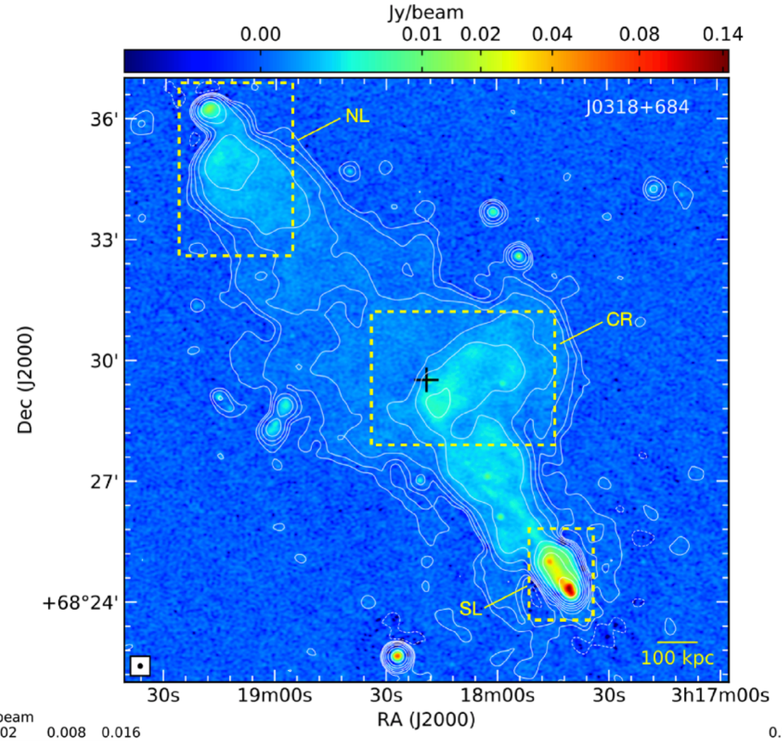


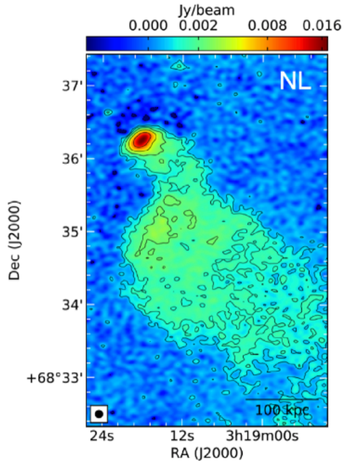
Source	rms (6 arcsec) (μJy beam^{-1})	rms (20 arcsec) (μJy beam^{-1})
J0318+684	220	360
J0801.7+4764	130	420
B2 1144+35B	90	180
J1153.9+5848	100	160
J1238.4+5349	90	240
J1503.7+6850	150	390
4C +63.22	120	360
Mrk 1498	110	220
4C +34.47	230	760

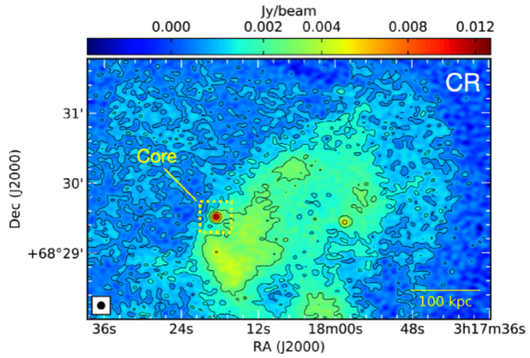
- 9 HX-GRG observed by LoTSS DR2 survey (150 MHz, Shimwell in prep.)
- Angular resolution 6 arcsec (more details) 20 arcsec (recover diffuse emission)
- RMS of a few hundreds uJy/beam

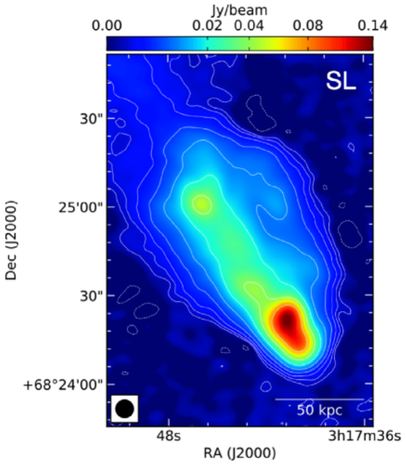
THE LOFAR VIEW

- Linear extension >10 arcmin
- Off-axis diffuse emission recovered at 20 arcsec resolution by LOFAR
- Lobes substructure revealed at 6 arcsec





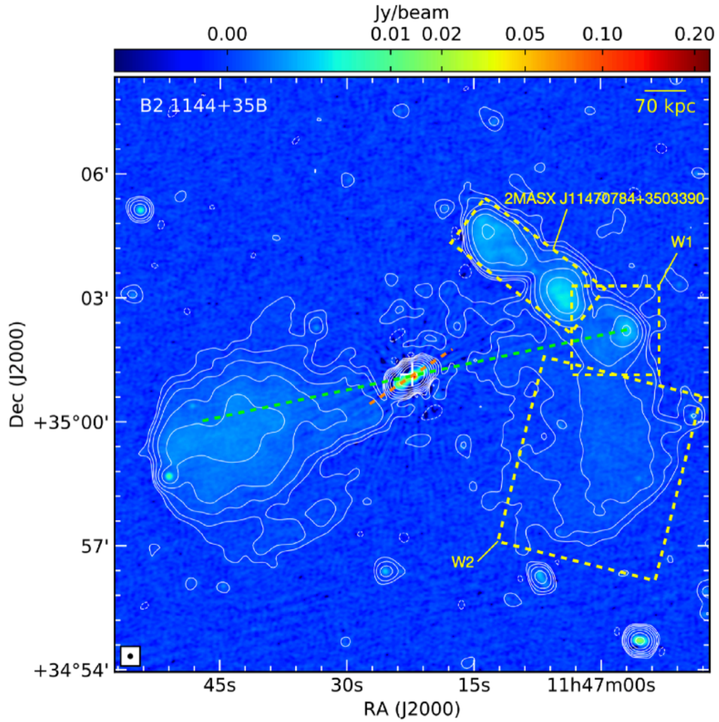


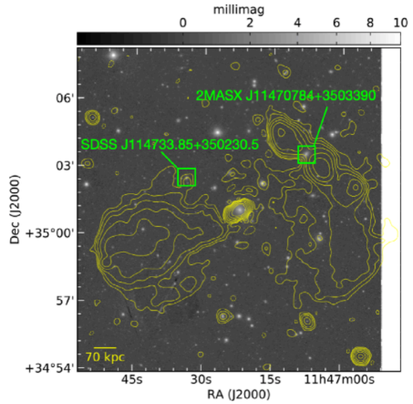


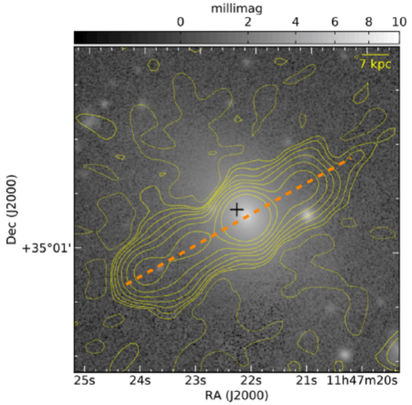
Bruni et al. 2021

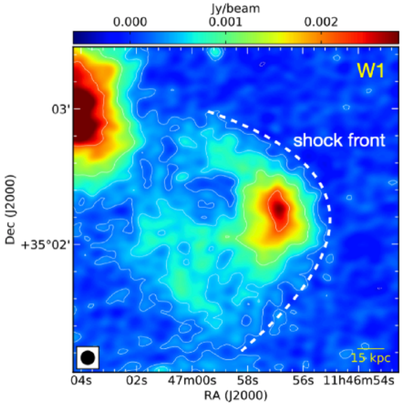
THE LOFAR VIEW

- Faint, diffuse emission on the SW sector restored, possible fat-double classification
- Inner-jet axis differs by ~30 deg from lobes one
- Possible gravitational perturbation by associated cluster, producing jet reorientation on Myr time scale.









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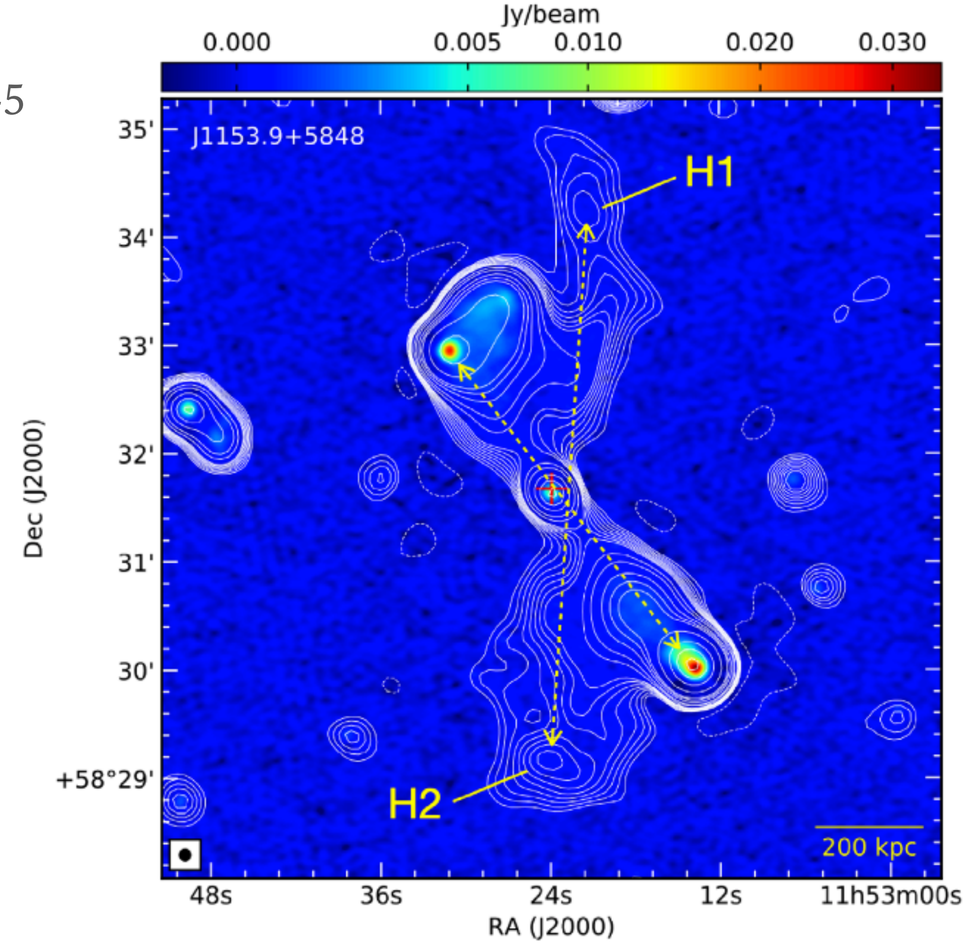
THE LOFAR VIEW

- Discovery of possible relic lobes, on an axis ~45 deg away from the known lobes
- Candidate for jet precession/reorientation



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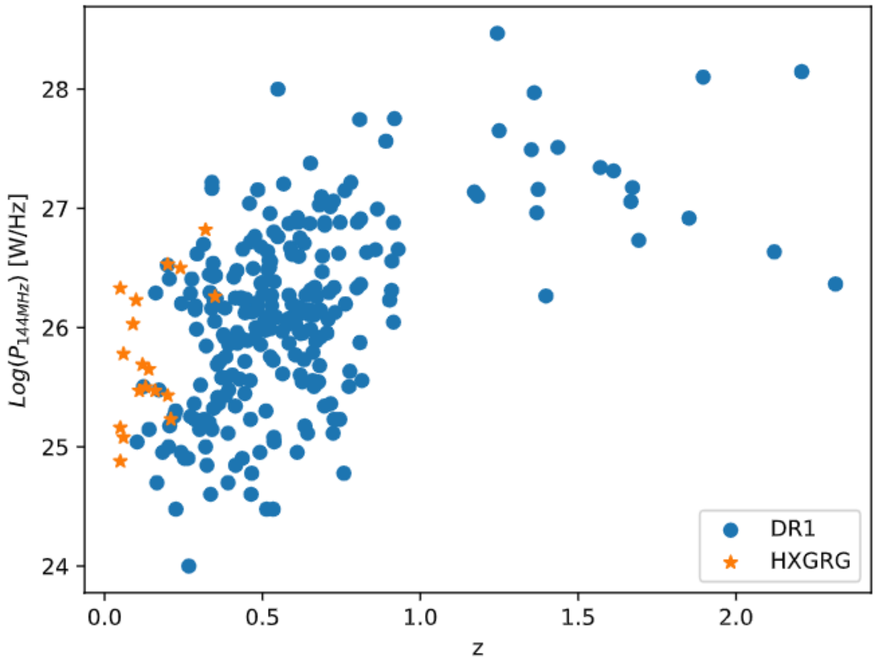
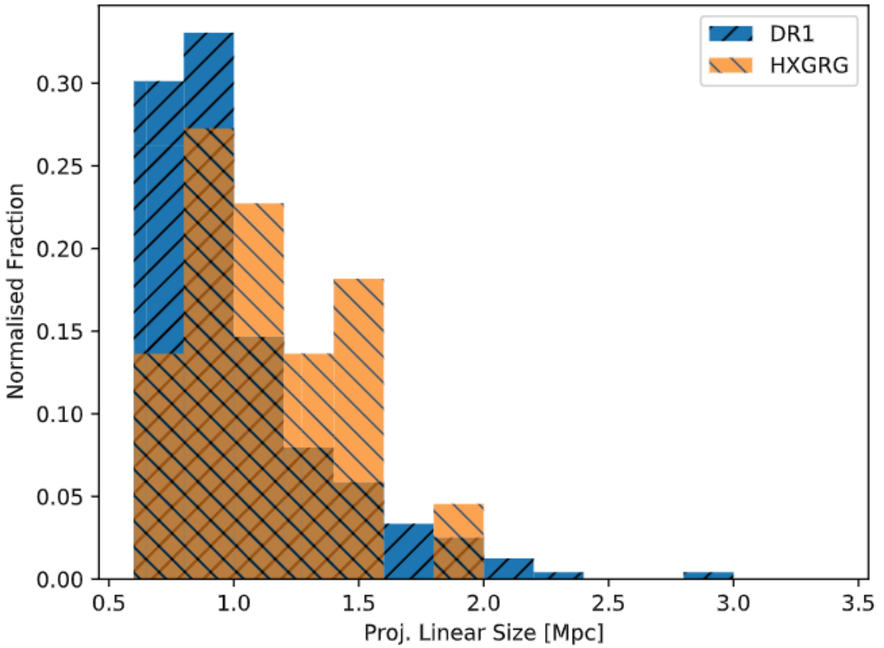
THE LOFAR VIEW





➤ Comparison with LoTSS DR1 GRG reveals slightly larger linear sizes for HXGRG

Bruni et al. 2021

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 PLANS

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

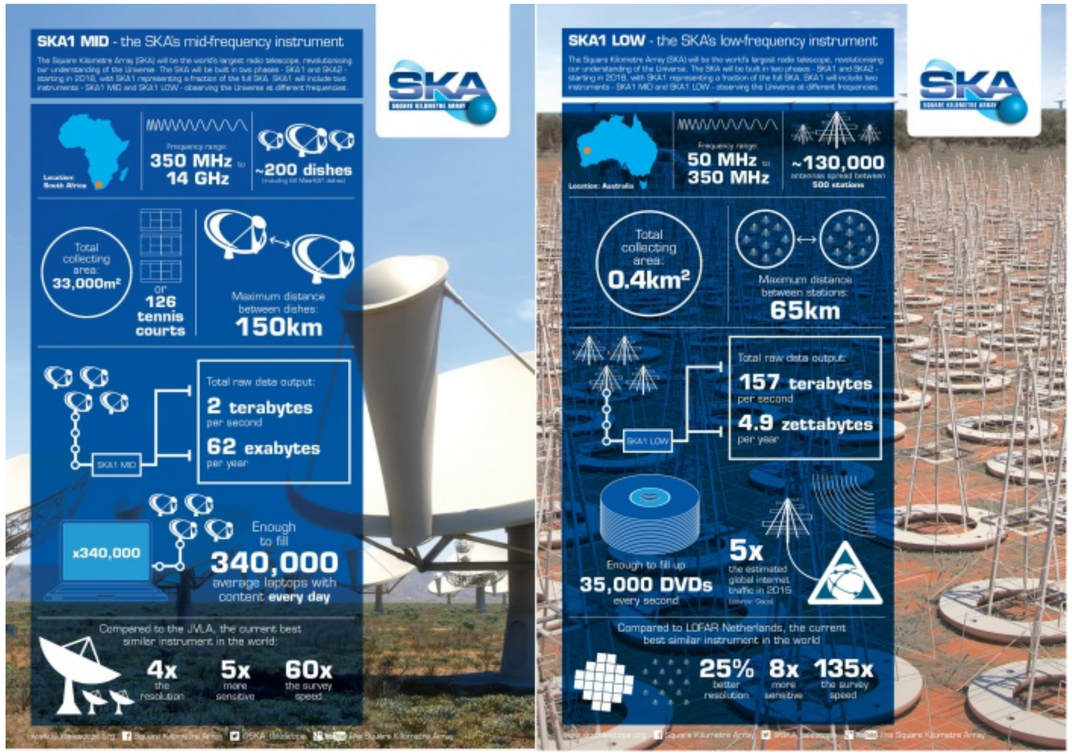
THE FUTURE SKA VIEW

- The study of radio galaxies and their duty cycle needs a rich toolbox: resolution, frequency coverage, sensitivity to emission on different scales, large statistics
- SKA will provide the necessary information to complete our task

SKA-mid

Zoom into core, probing:

- Jet reorientation/precession
- new radio phase spatial scale
- Link between radio phase and accretion



SKA-low

Extended emission:

- Previous radio phases with faint emission
- Impact of giant jets on the IGM/ICM
- Frequency coverage for synchrotron aging: radio duty cycle

Contact us for Master & PhD thesis!

GRAL

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GRAL

GAMMA RADIO ASTROPHYSICAL LAB

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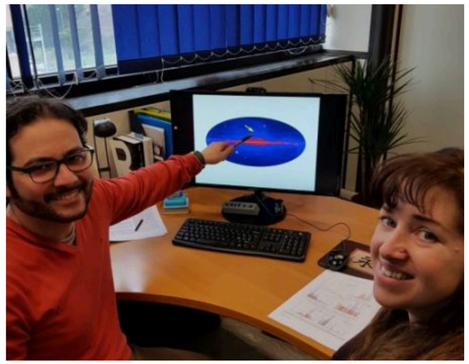

THE GRAL

The Gamma-Radio group at IAPS has a long sought experience in High Energy Astroph… the desi… manage… instrum… satellite… Recently… in Radio… involved… and Extr… multi-fre… transien… neutrino…

Search

Search …

http://gral.iaps.inaf.it

GRAL group at INAF - IAPS

GRACE

Giant **Ra**dio galaxies and their duty **c**ycle

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 allowings 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 continuos 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.

20 years of AGN discoveries with space observations: main results and perspectives on AGN in the high-energy sky

Topics outline:

- Accretion/ejection coupling: jets and outflows launching in the high-accretion regime and its comparison with low-frequency selected AGN samples
- Broad-band studies from Seyfert to Blazars
- The multi-messenger challenge: neutrinos from jets and their EM follow-up
- The gravitational waves sky with the next generation of GW antennas: binary supermassive black holes mergers
- 20 years of AGN with INTEGRAL: heritage and future perspectives