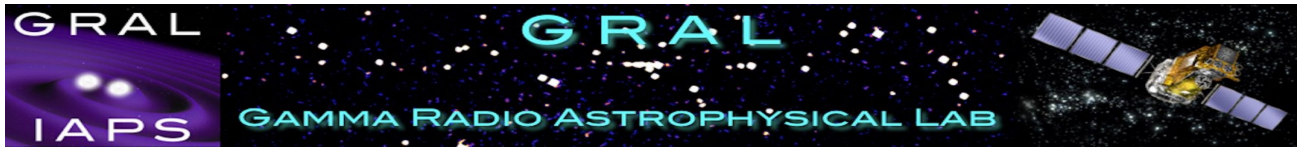
RICAP-22 Roma International Conference on AstroParticle Physics

Sep 6 – 9, 2022
Physics Department, University "La Sapienza", Roma, Italy
Europe/Rome timezone

Extragalactic sources: phenomenology and open questions

Francesca Panessa



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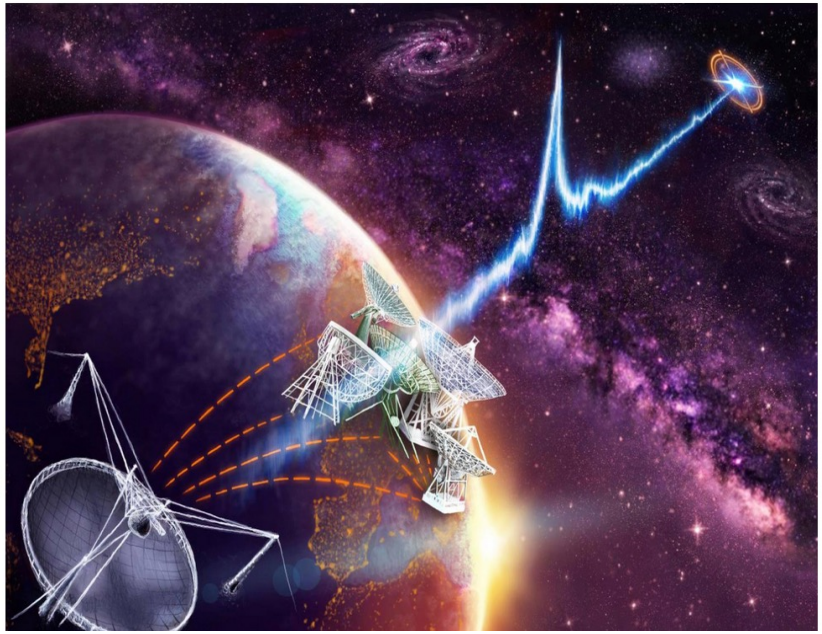
The GRAL

The Gamma-Radio group at IAPS has a long sought experience in High Energy Astrophysics and it has been involved in the design, realisation, calibration, management and science exploitation of instruments on board of astronomical satellites and stratospheric balloons. Recently, we are also acquiring expertise in Radio Astronomy. Our group is deeply involved in the investigation of Galactic and Extra-galactic astrophysics, including multi-frequency follow-up of the new transients, such as gravitational waves, neutrinos and fast radio bursts.



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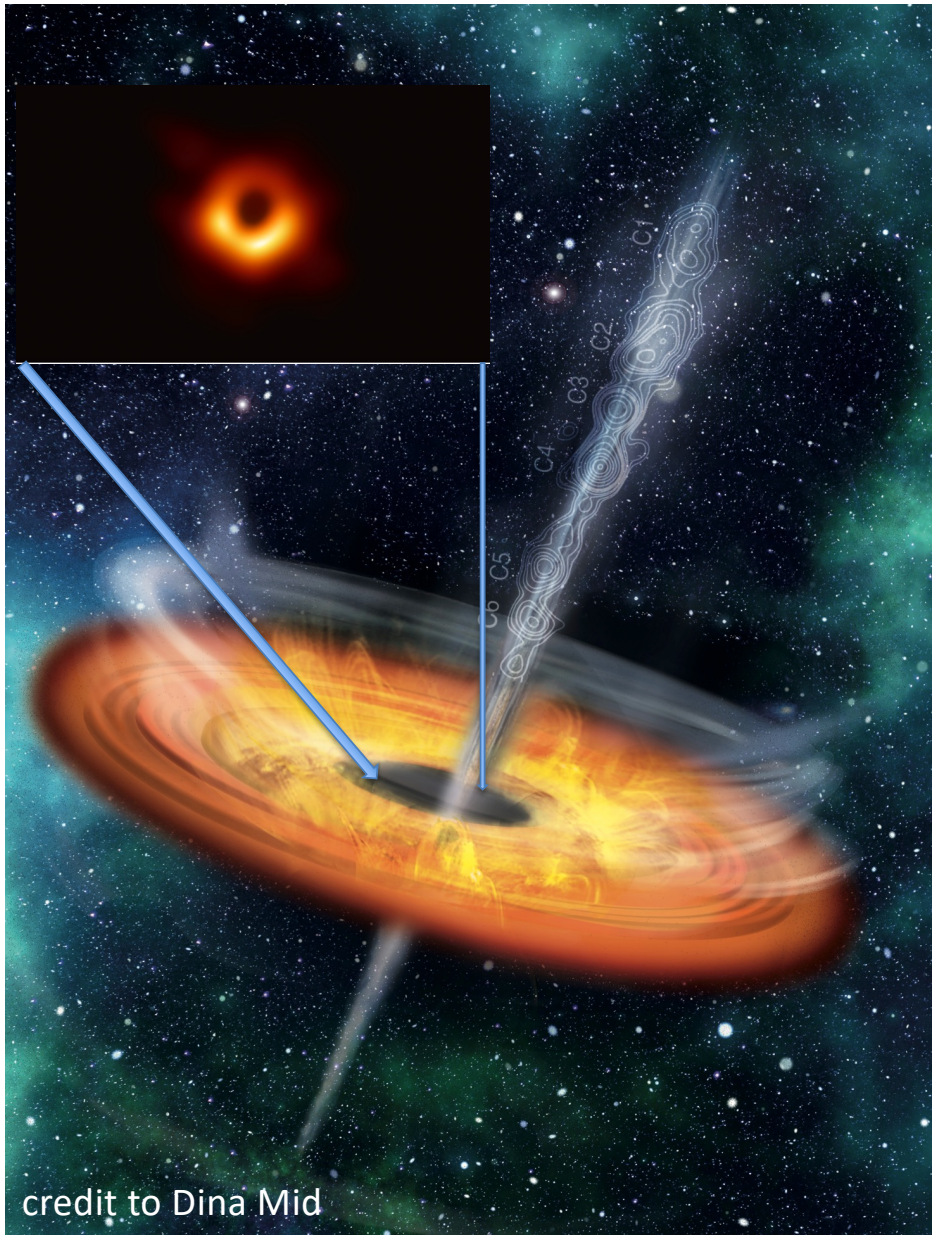
GRAL research group:

`http://gral.iaps.inaf.it/`



AGN PHYSICS and FEEDBACK

MAIN PLAYERs:

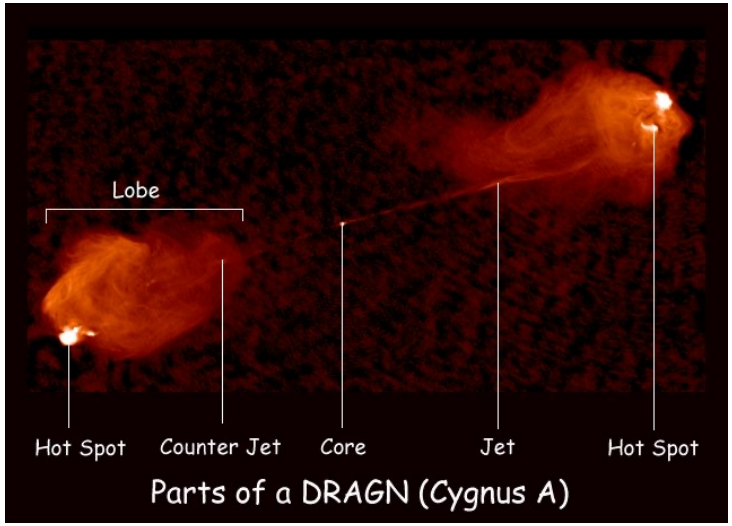
- Accretion disc
- Hot corona
- Wind
- Jet
- Star-formation

AGN: WITH JETS, WITHOUT JETS

With jet:

✓ Large scale radio lobes

✓ Compact luminous cores often with apparent luminal motions

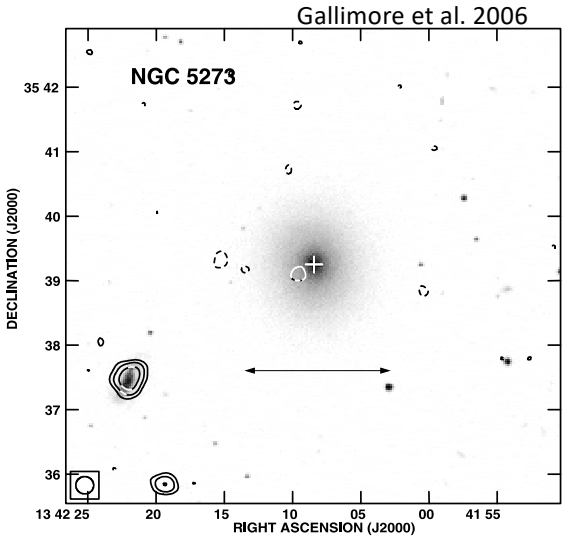


Radio Loud

Without jet:

✓ Faint radio sources

✓ Emission confined to sub-kpc scale



Radio Quiet

RADIO LOUDNESS R = L(5 GHz) / L(B)

AGN AT HIGH ENERGY

Radio Loud AGN:

→ high fraction of gamma-ray emitting objects

Non-thermal emission:

→ at all wavelengths

→ pronounced variability

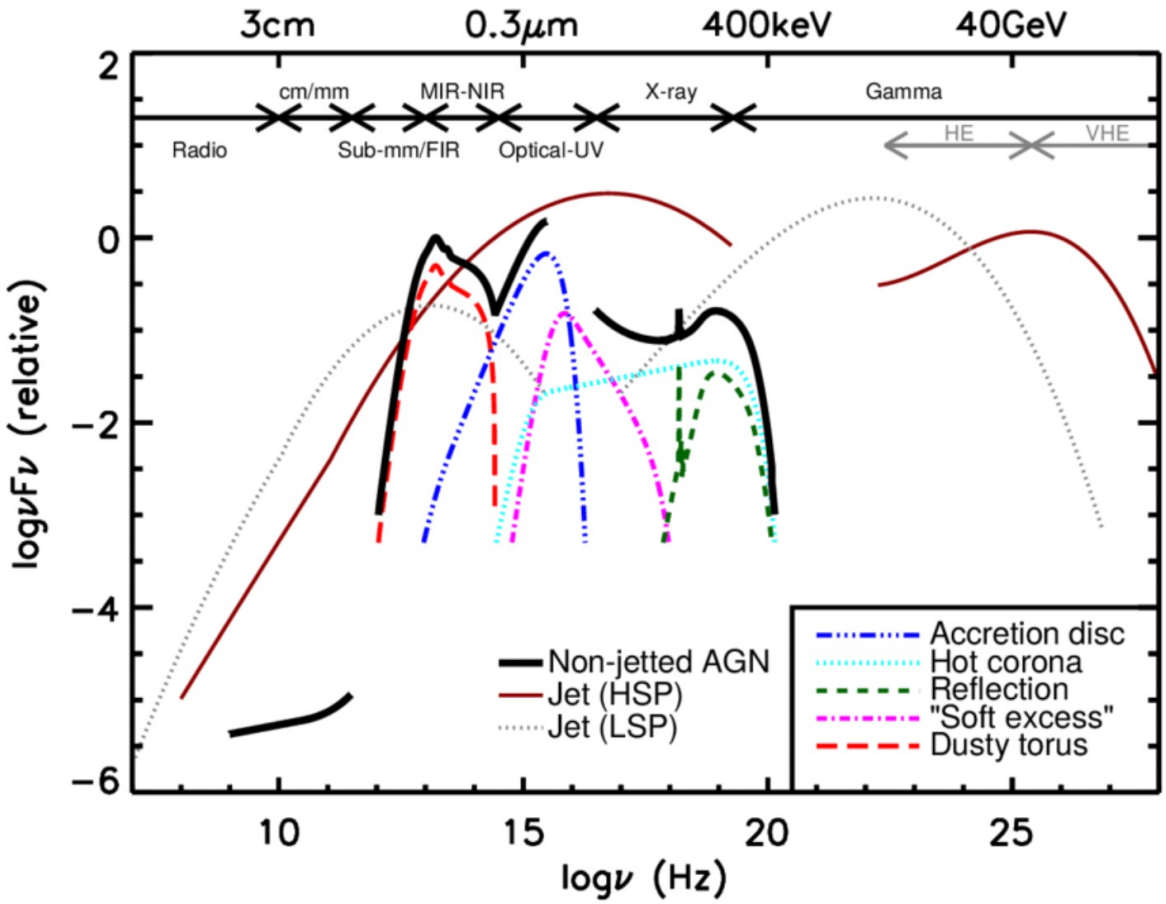
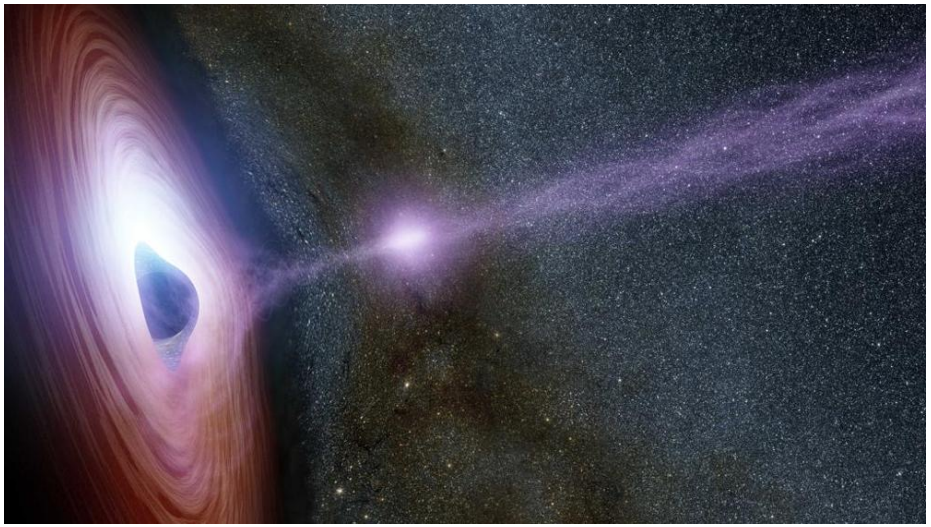


Image credit: C. M. Harrison

AGN AT HIGH ENERGY



Open questions:

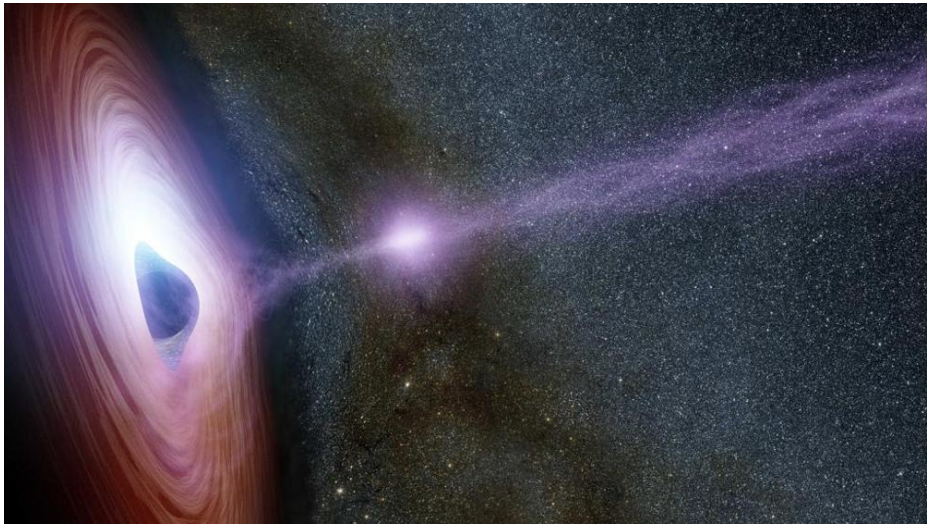
- ✓ Jet-disk coupling
- ✓ Gamma-ray emitting processes
- ✓ Gamma-ray emitting region
- ✓ Seed photon fields
- ✓ Extreme blazars

✓ High energy emission from non-blazars AGN

The gamma-ray production sites for radio galaxies are controversial as relativistic beaming effects should be weaker in these objects

Leptonic compact jet models → standard scenario (Abdo +2009)

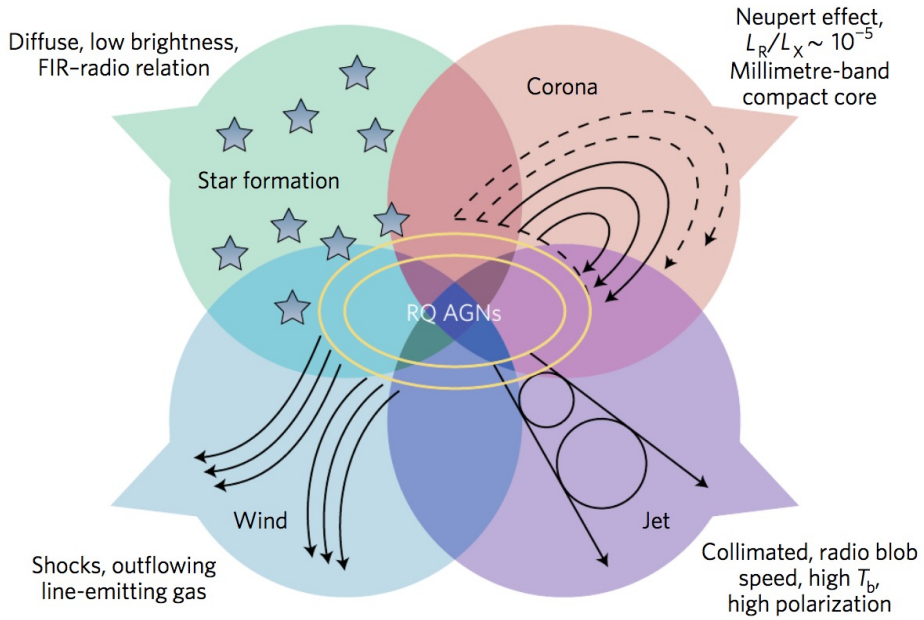
AGN AT HIGH ENERGY: NON BLAZARS



Alternative models:

- ✓ hadronic jets (Reynoso et al. 2011)
- ✓ large-scale jets (Hardcastle & Croston 2011)
- ✓ hybrid jets (Fraija & Marinelli 2016)
- ✓ black-hole (BH) magnetospheres (Kisaka et al. 2020)
- ✓ magnetically arrested accretion disk (MAD) (Kimura & Toma 2020)

AGN AT HIGH ENERGY: RADIO QUIET



GeV gamma-ray detections reported from **radio-quiet AGN:**

→Starburst vs AGN
→Non-thermal activity in accretion flows

Wojaczyński et al. 2015; Abdollahi et al. 2020

Panessa, Baldi, Laor, Padovani, Behar & McHardy 2019, Nature Astronomy Review

AGN AT HIGH ENERGY

4th Fermi catalogue:
98% blazars
(Ajello et al. 2020)

Non-blazars AGN:

41 Radio Galaxies
9 Narrow Line Seyfert 1
5 Compact Steep Spectrum RG
2 Steep Spectrum RG
1 Seyfert type 1
11 AGN

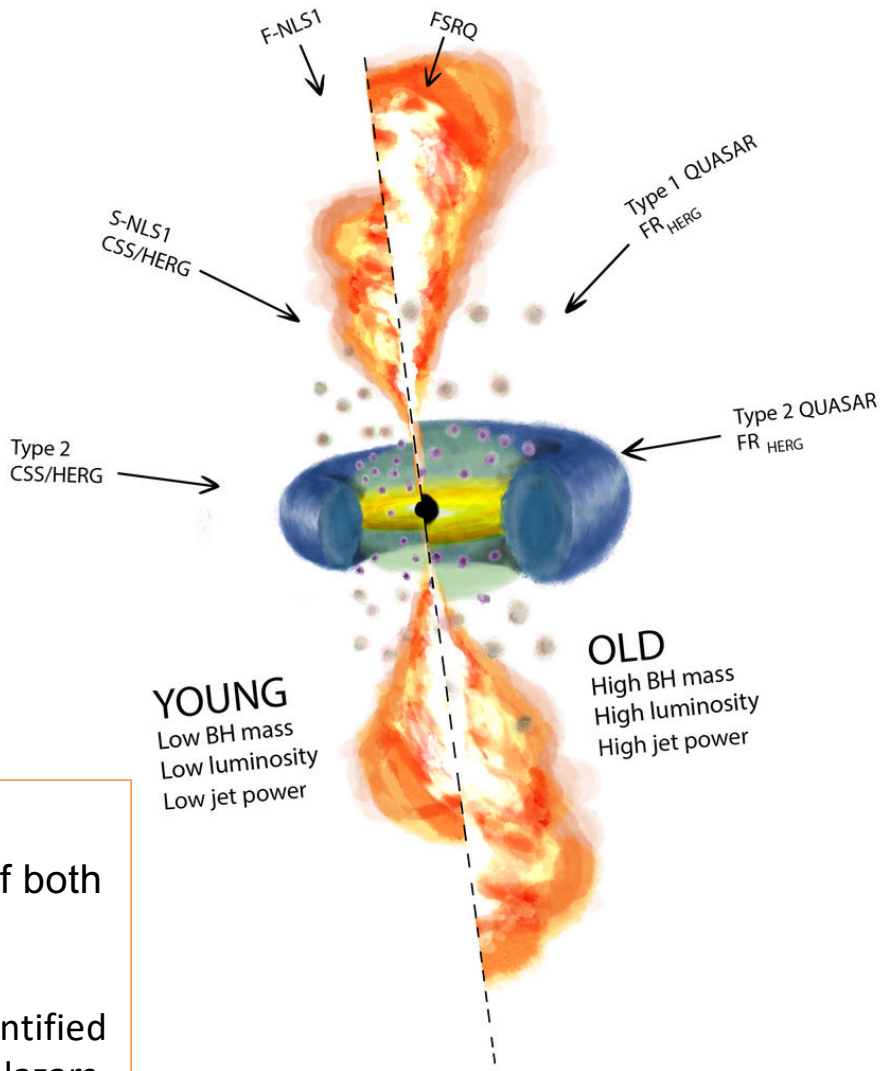


Image credit: Berton et al. 2017

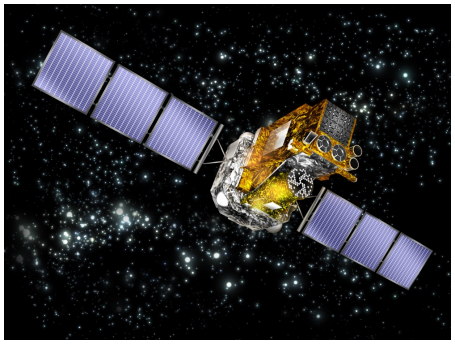
RELEVANCE

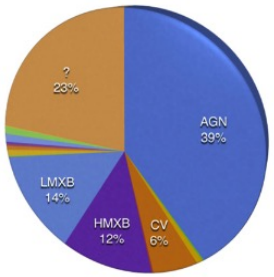
The spectral energy distribution shows signatures of both accretion and jet related emission:

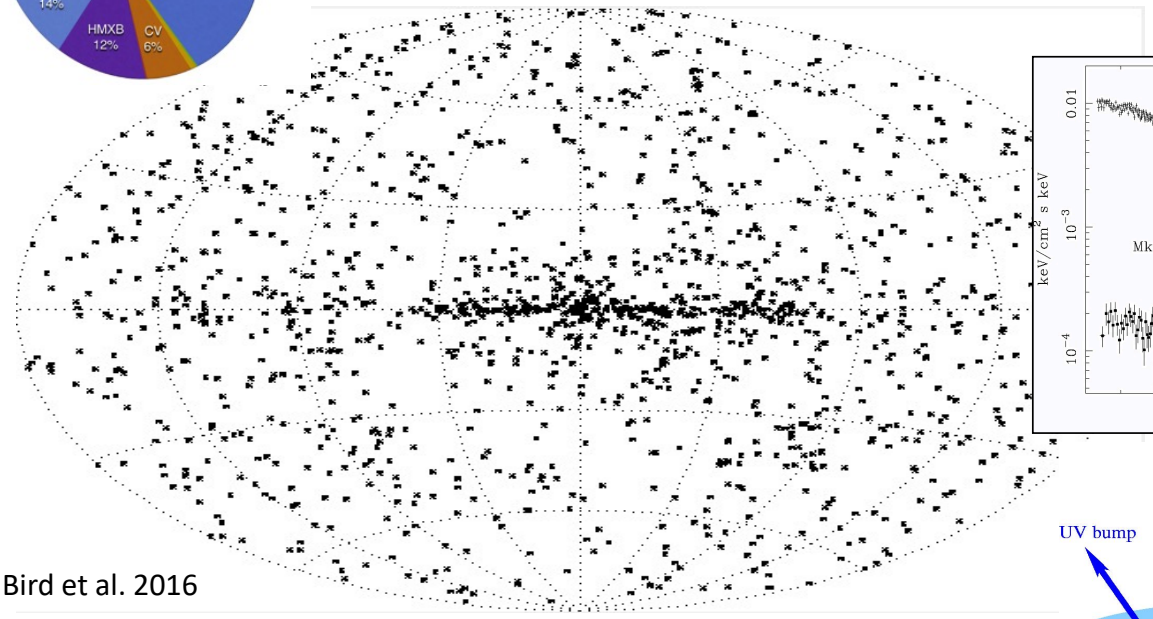
→ jet progressive misalignment

→ misaligned blazar can also be found among still unidentified γ-ray AGN or between objects wrongly classified as blazars

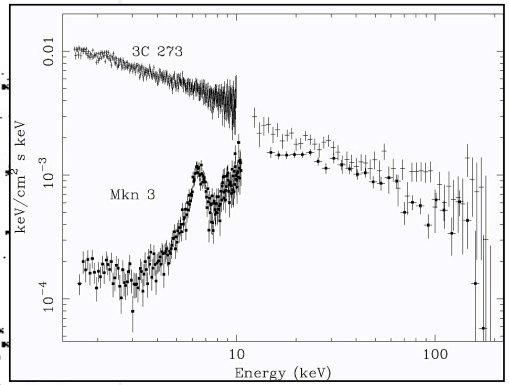
INTEGRAL hard X-ray sky

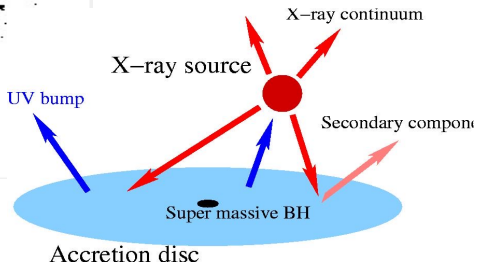






Bird et al. 2016

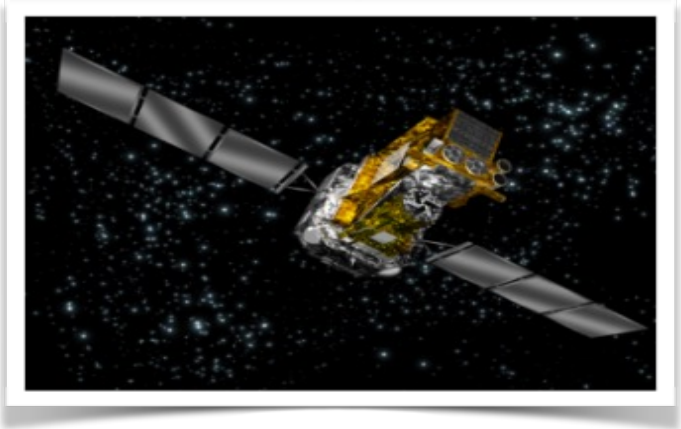




→ unbiased view of AGN accretion disc/corona system

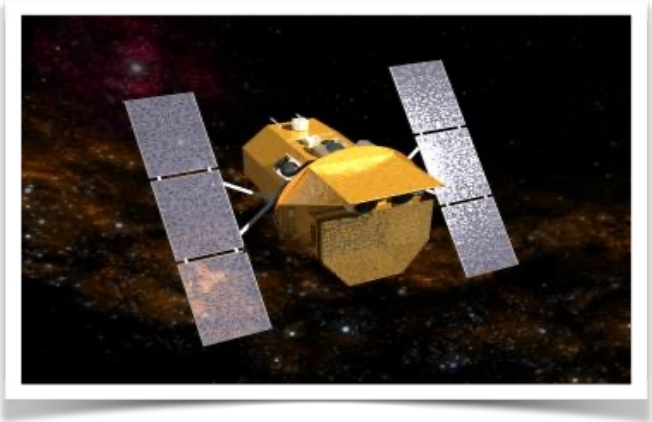
RADIO GALAXIES: an HARD X-RAY SAMPLE

Starting Point: the **INTEGRAL AGN** (Malizia et al. 2012) and **SWIFT/BAT** AGN from 70 month catalogue by Baumgartner et al. (2013)



Swift/BAT

14-195 keV



INTEGRAL/IBIS

15 keV – 10 MeV

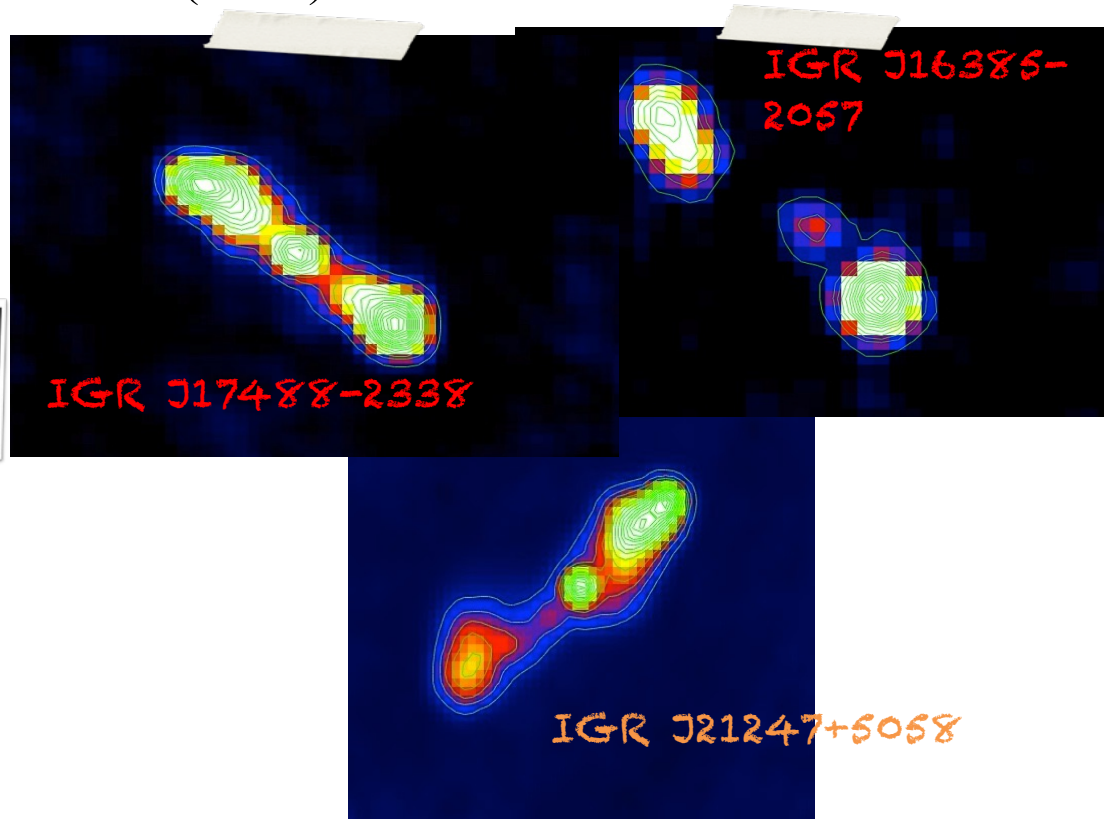
RADIO GALAXIES: an HARD X-RAY SAMPLE

Starting Point: the **INTEGRAL AGN** (Malizia et al. 2012) and **SWIFT/BAT** AGN from 70 month catalogue by Baumgartner et al. (2013)

RADIO MORPHOLOGY

search for a

double lobe morphology



GIANT RADIO GALAXIES STATISTICS

60% → LAS > 0.4 Mpc
22% → LAS > 0.7 Mpc

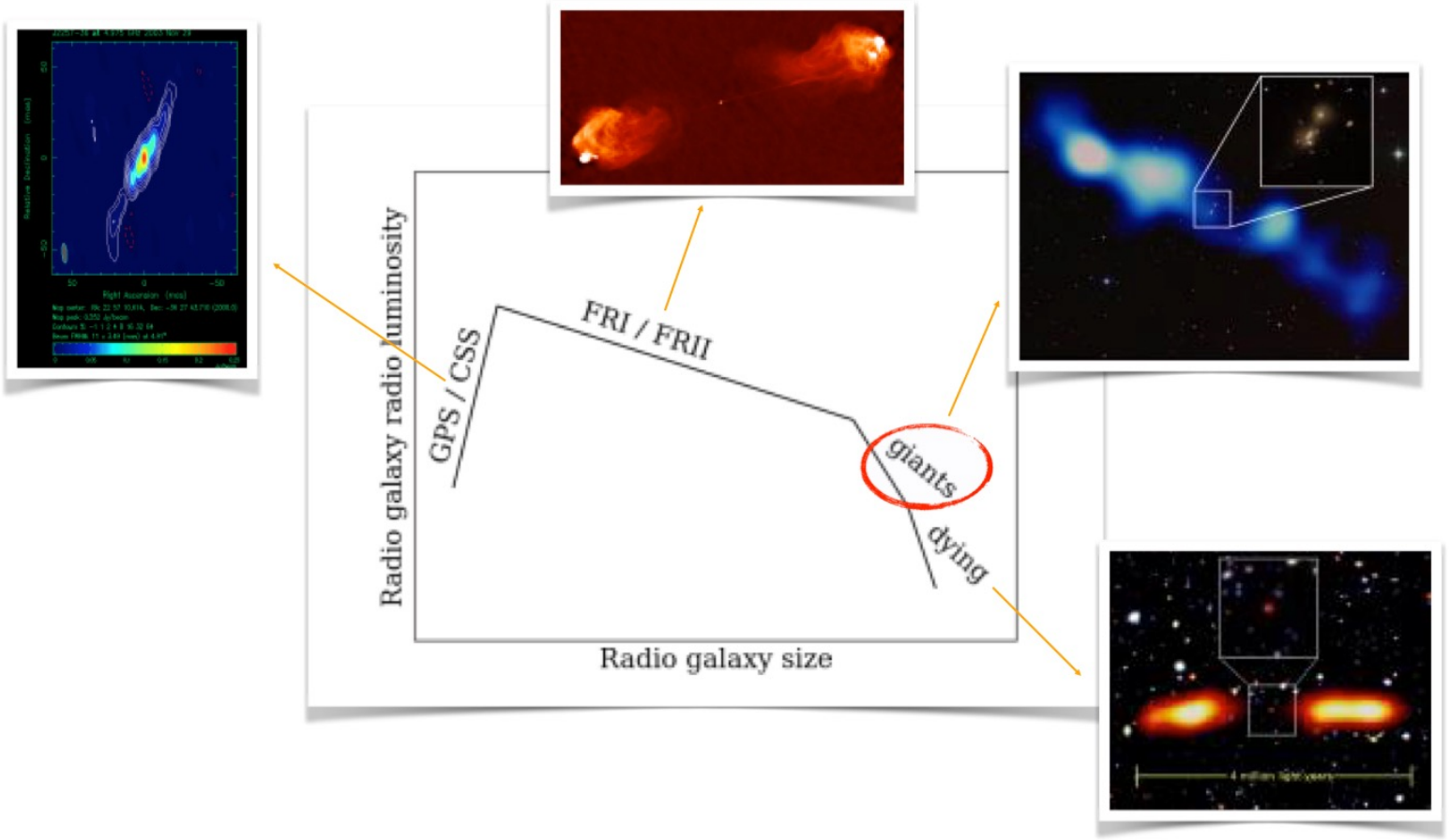
Bassani et al. 2016

Typical percentage in radio selected sample are:

- ✓ 6% in 3CR catalogue (Ishwara-Chandra & Saika 1999)
- ✓ 1% for z<0.2 ~3500 NVSS, SUMSS & WENSs images (Andernach et al. 2014)
- ✓ 5.6% among 672 FRII with known z (Nilsson 1998)
- ✓ 5.5% among 401 FR II in the SDSS sample (Kozile-Wierzbowska & Stasinska 2011)
- ✓ 2% among 46 HEG in the sample (Buttiglione et al. 2010)

1-6% in radio versus 20% in soft gamma

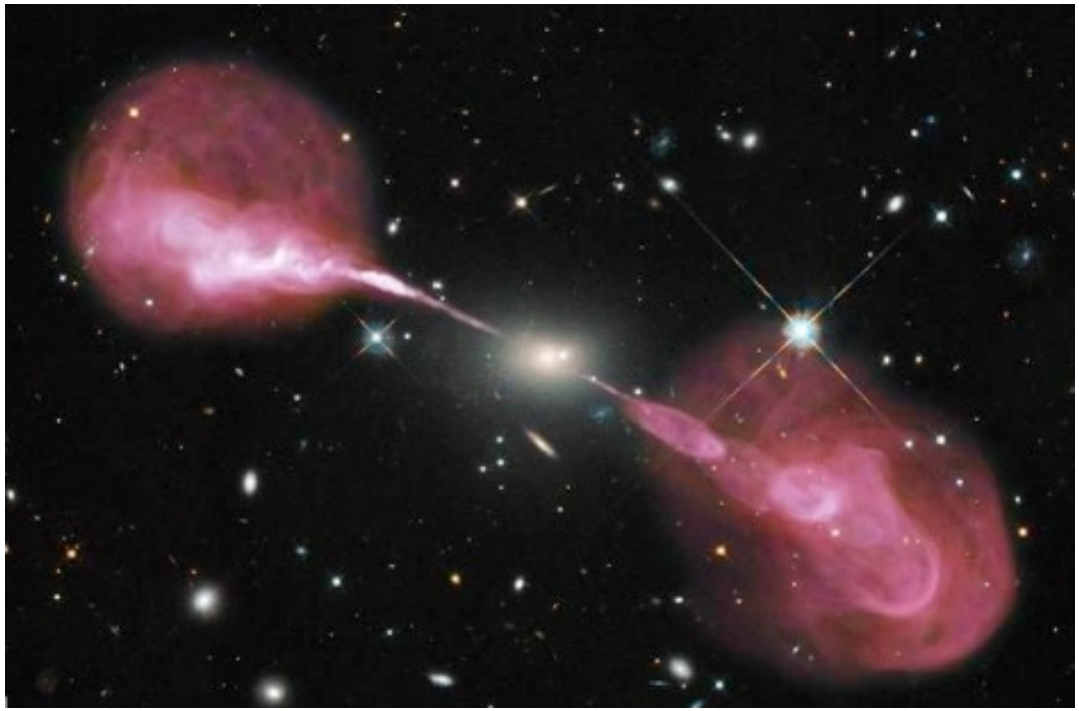
LIFE of a RADIO GALAXY: jet activity duty cycle



GIANT RADIO GALAXIES

Sizes > 0.7 Mpc → largest and most energetics single entities in the universe

✓ ideal targets to study the duty cycle of radio activity



Large Fraction of restarting activity!!

What's new?

LOFAR

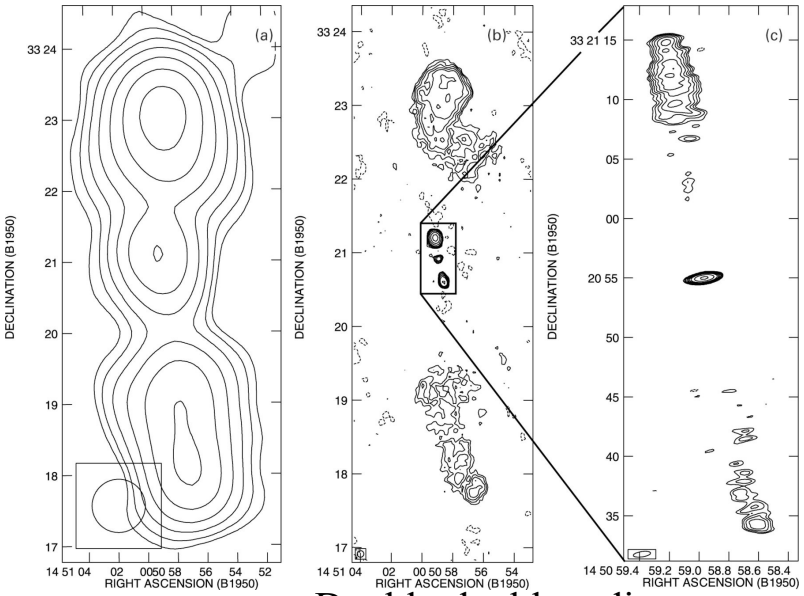
Molina et al. 2014, 2015, Bassani et al. 2016, Panessa et al. 2016, Hernandez-Garcia et al. 2017,2018, Ursini et al. 2018, Bruni et al. 2019, 2020, 2021

AGN RESTARTING ACTIVITY

Schoenmakers et al. 2000

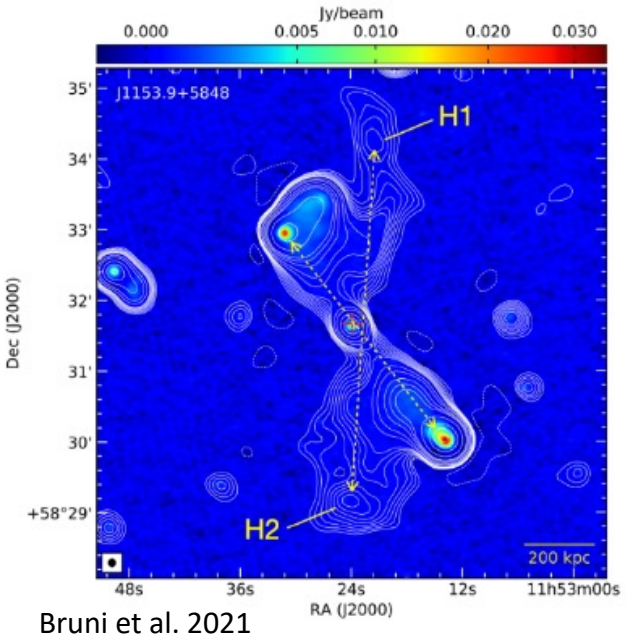
AGN ARCHEOLOGY!

→ Duty cycle of jet activity

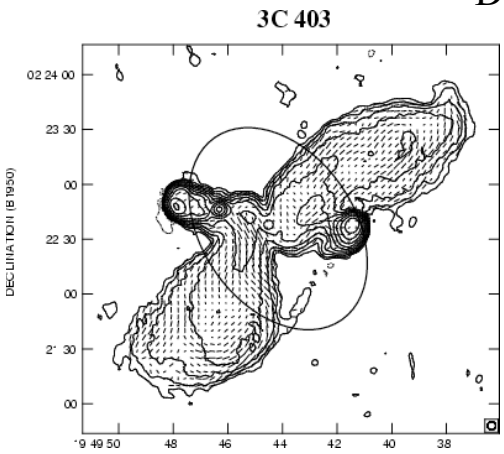


Double-double radio-sources

X-shaped radio-sources



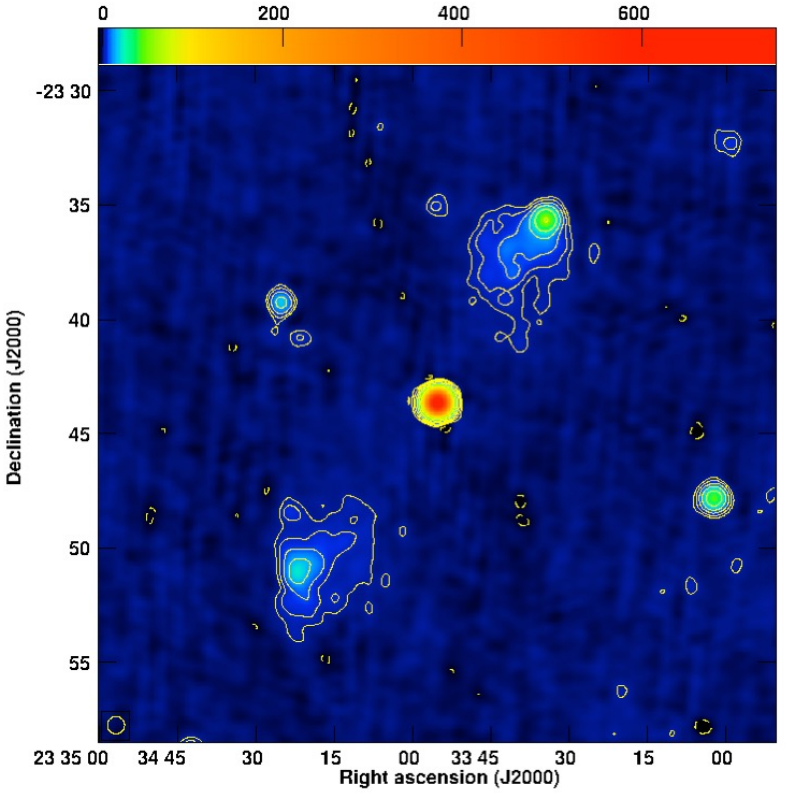
Bruni et al. 2021

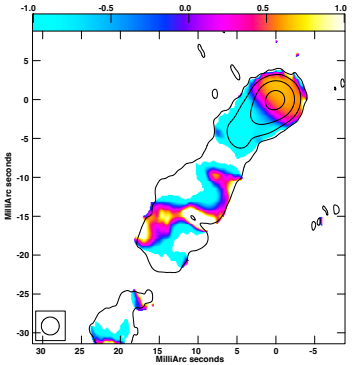


Dennett-Thorpe et al. 2002

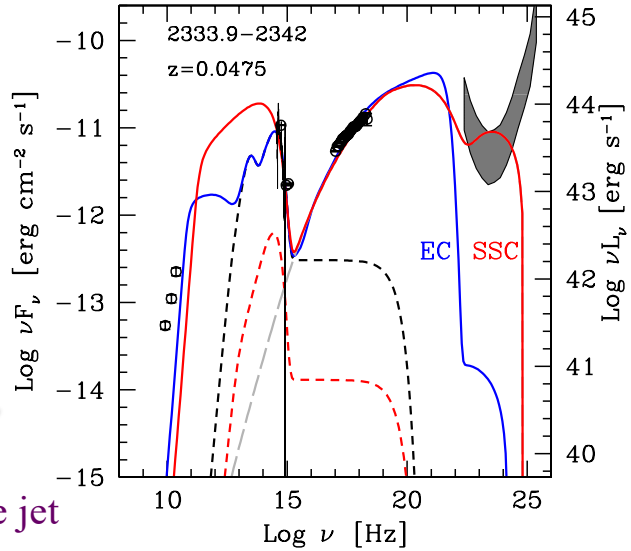
THE REACTIVATING NUCLEUS OF PBC J2333.9-2343

from giant radio galaxy to blazar!





→ small angle!

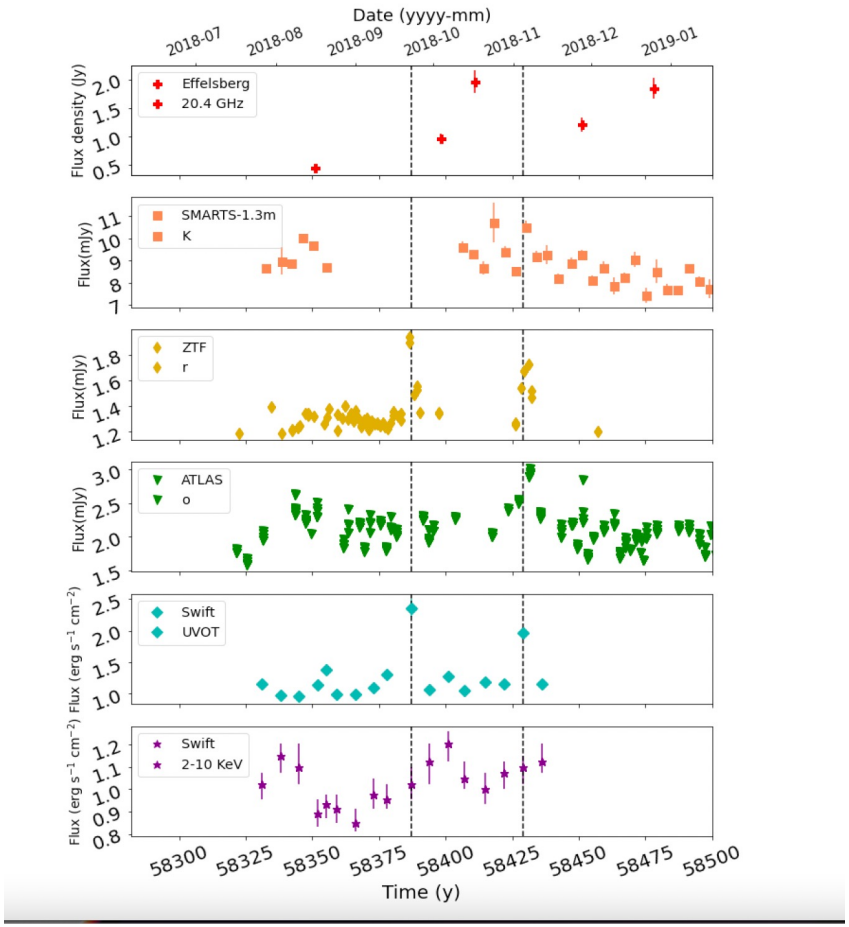


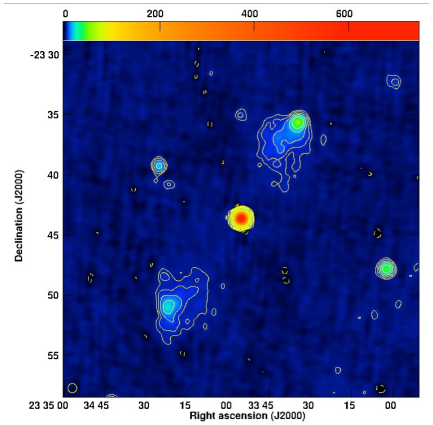
Hernandez-Garcia et al. 2017

→ X-rays produced by the jet

THE REACTIVATING NUCLEUS OF PBC J2333.9-2343

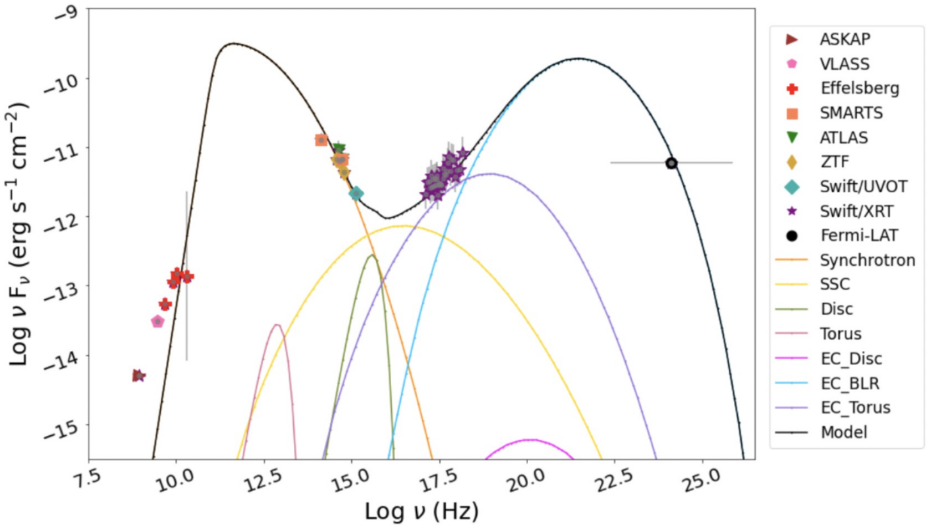
from giant radio galaxy to blazar!





→ Confirmed small angle!

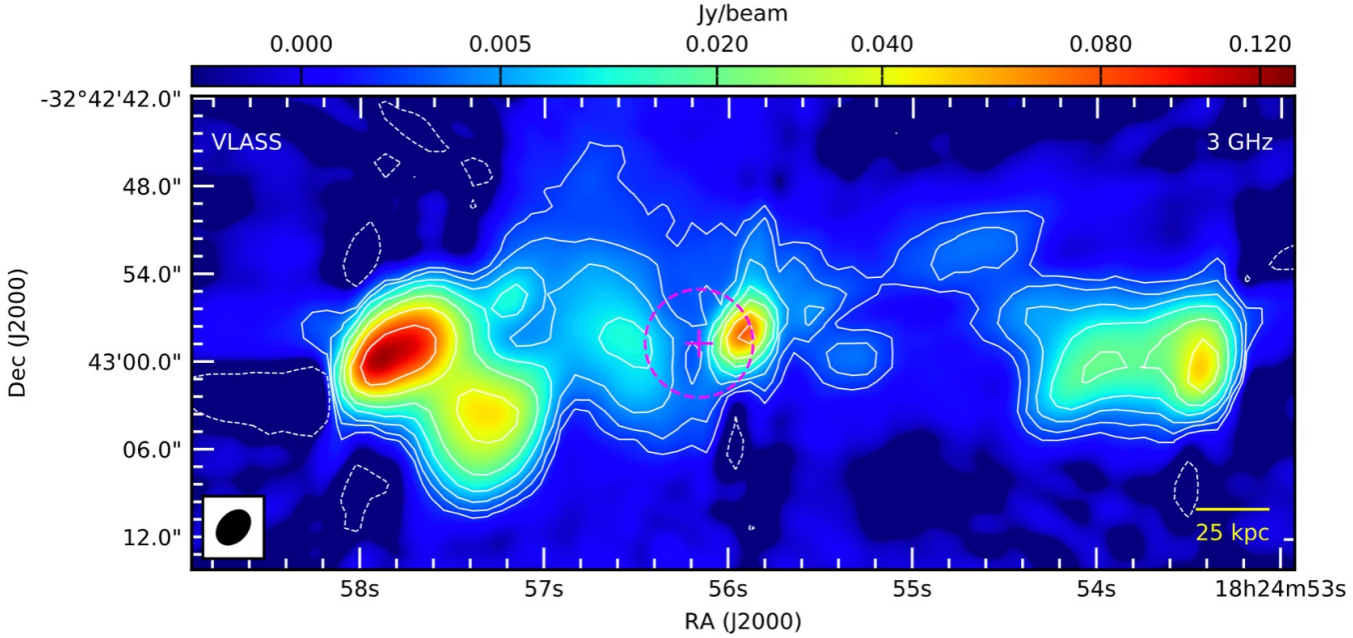
→ Single-zone leptonic mode



Hernandez-Garcia et al. in preparation

A NEW GeV EMITTING FRII

VLASS and RACS surveys to probe radio galaxy candidates among Fermi/LAT AGN



A new FRII galaxy detected both in hard X-rays and gamma-rays:

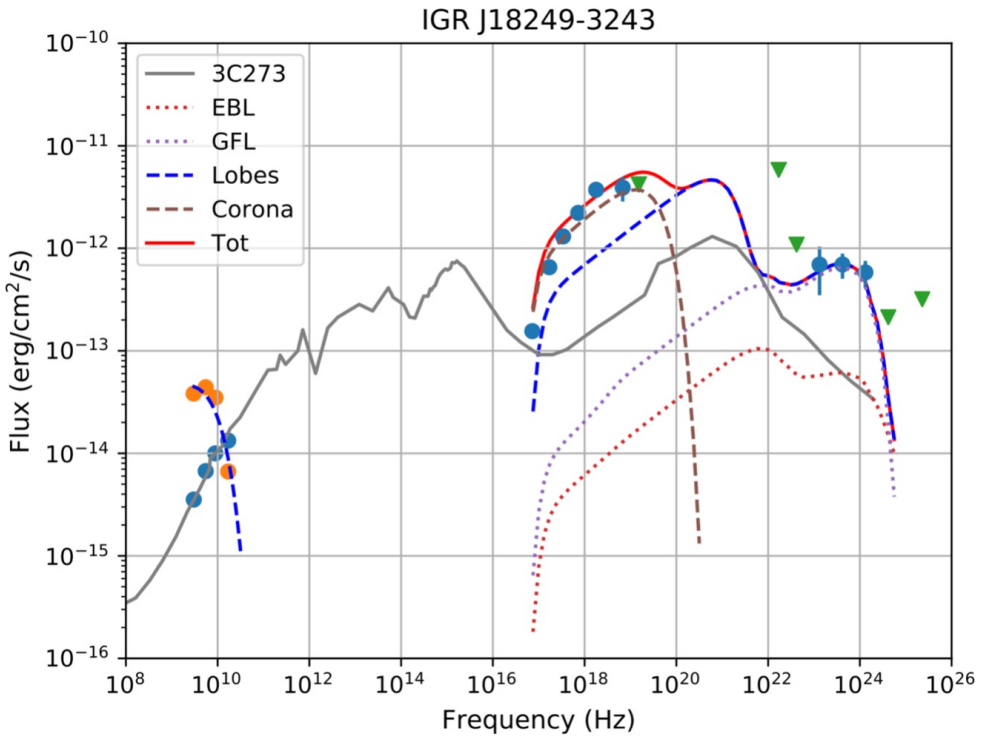
→ GeV emission is x10 larger than what expected from the AGN core

Bruni et al. 2022, MNRAS, 513, 886

A NEW GeV EMITTING FRII

the commonly invoked inner-jet contribution is not sufficient to account for the observed gamma-ray flux for this source

Broad-band SED modelling suggests a substantial lobes contribution via IC of the radio-emitting electrons off the ambient photon fields

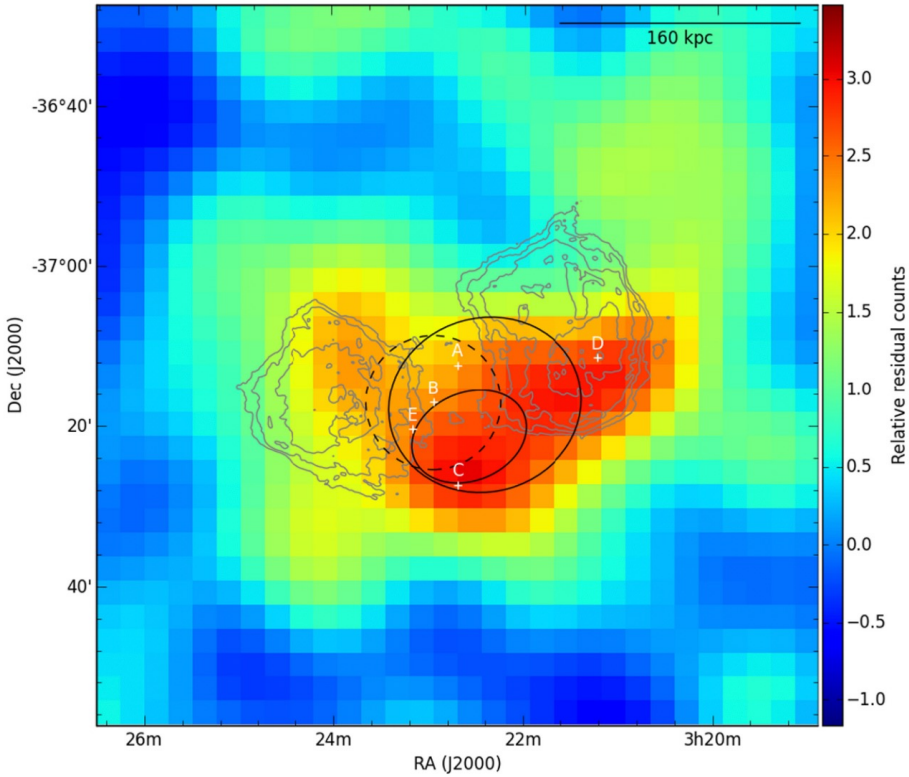


Bruni et al. 2022, MNRAS, 513, 886

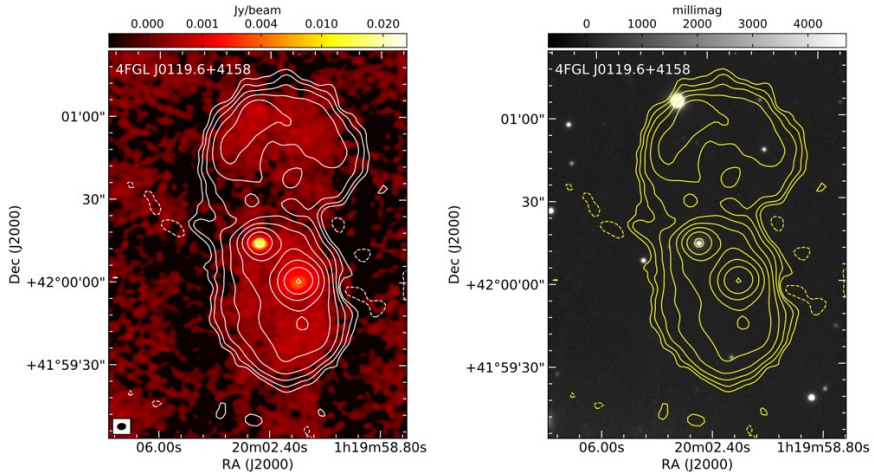
GeV EMISSION FROM THE RADIO LOBES

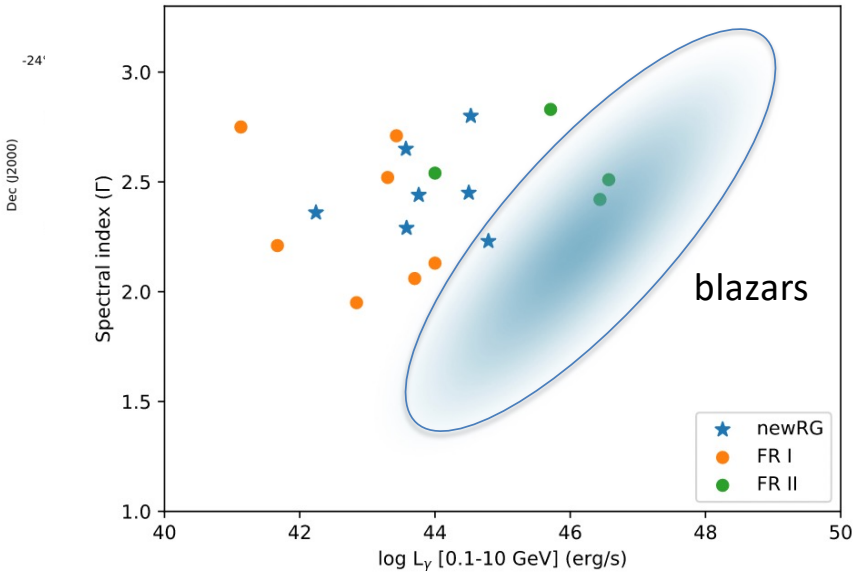
The γ-ray emission from the lobes in two nearby and very extended sources: Centaurus A and Fornax A
(Abdo et al 2010; Ackermann et al 2016)

Inverse Compton of the radio emitting electrons on the ambient optical radiation field can be sufficient to account for the GeV emission in a set of four radio galaxies
(Persic & Rephaeli 2019, 2020)



FORNAX A; Ackermann et al. 2016





EMERGING POPULATION of HIGH ENERGY RADIO GALAXIES

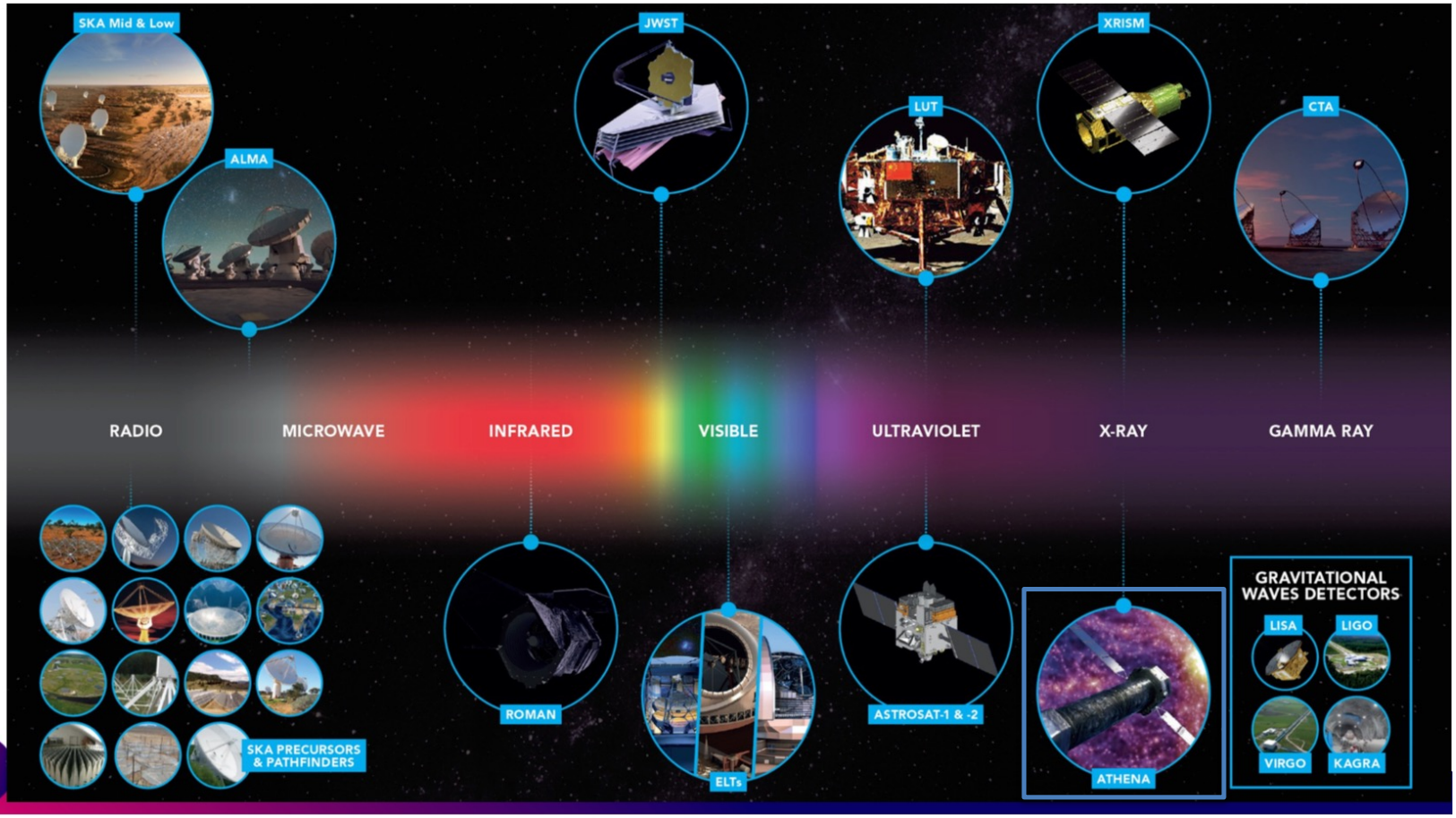
→ 4 more objects with a double-lobed morphology and Fermi/LAT detections

An emerging population of GeV-emitting radio galaxies might be found in the near future with the advent of LOFAR, SKA, as counterparts of the high-energy sky

Bruni et al. 2022, MNRAS, 513, 886

RADIO & HIGH ENERGY SINERGY

21st Century Astronomy



Thank you