The Fermi-LAT view of misaligned Active Galactic Nuclei after 10 years

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on behalf of the Fermi-LAT collaboration

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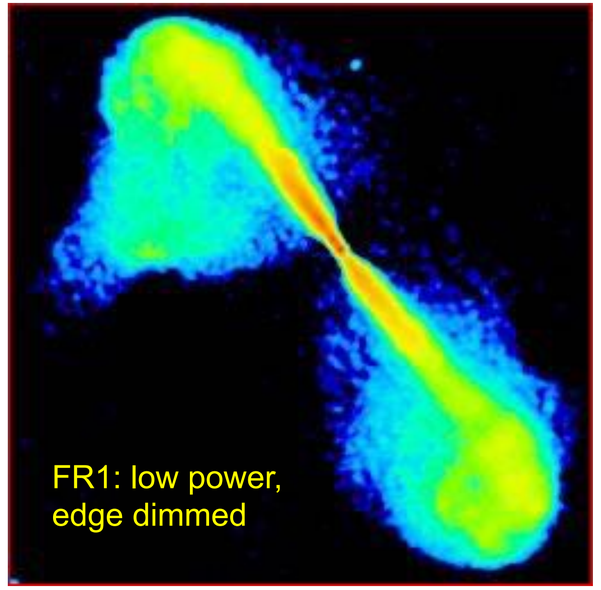
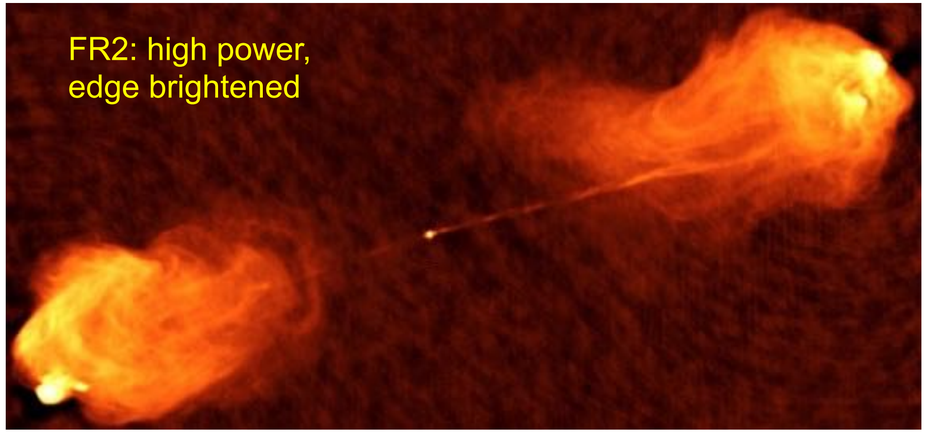
“Misaligned” AGN

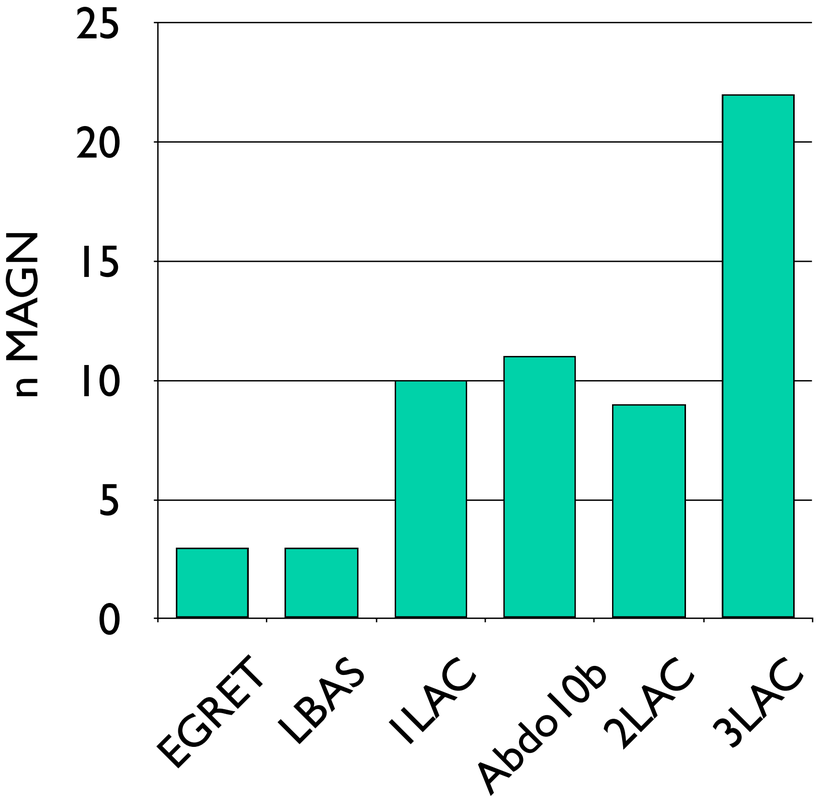
- Blazars dominate the LAT sky, but they are actually a minority of the sources in the Universe, for simple geometrical reasons
- Most radio loud AGNs are misaligned (“off-axis”), with **extended steep spectrum lobes extending to 100’s kpc scales**
- Unlike in blazars, the cores are not boosted and their emission is then negligible in comparison to that of the extended lobes
- Radio luminosity $\boldsymbol{L_r}$ in GHz domain range: $\mathbf{10^{22}\text{-}10^{29}\ W\ Hz^{-1}}$
  - At lower L_r end (with brighter central regions): FR1 type
  - At higher L_r end (with brighter outer rims): FR2 type
- All complicated by internal (**bends, interactions, ageing**) and observational (**viewing angle, angular distance, sky position**) effects





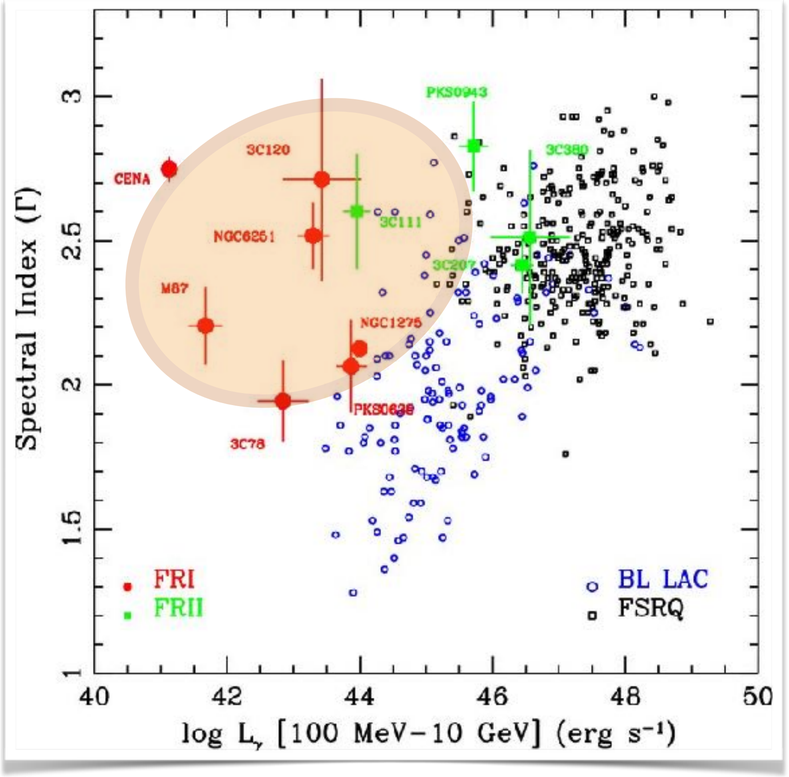
Gamma-ray history

- EGRET: 2 radio galaxies; GLAST (pre-launch): predictions
- Abdo et al. (2010b, “the LAT MAGN paper”): 11 misaligned AGN studied with 15 months of data
- In 3LAC: 22 MAGNs, of which 11 FR1, 3 FR2, 8 SSRQ
  - broad range of luminosity, photon index, variability
  - some famous sources: CenA, M87, 3C84, 3C 120



Why are γ-ray MAGN interesting?

- Largely uncharted territory
- Different regions and mechanisms of emission
  - lobes: IC/CMB, particle energy distribution
  - jets: transverse structures, spine/sheath interplay
- Still unconstrained contribution to diffuse background

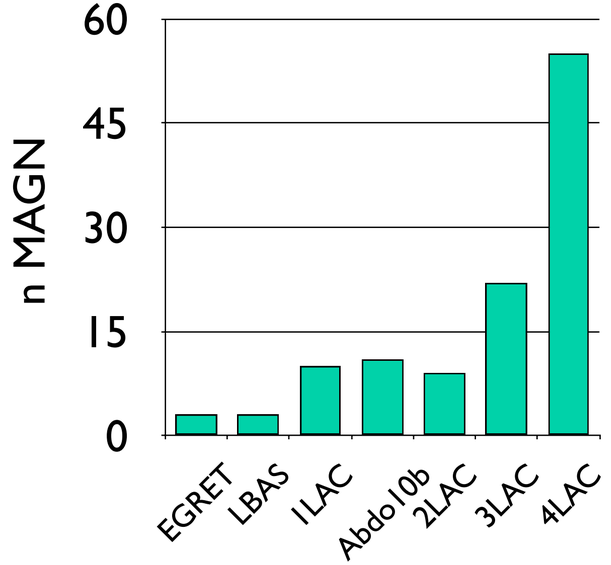


Abdo et al. (2010b)

4FGL census

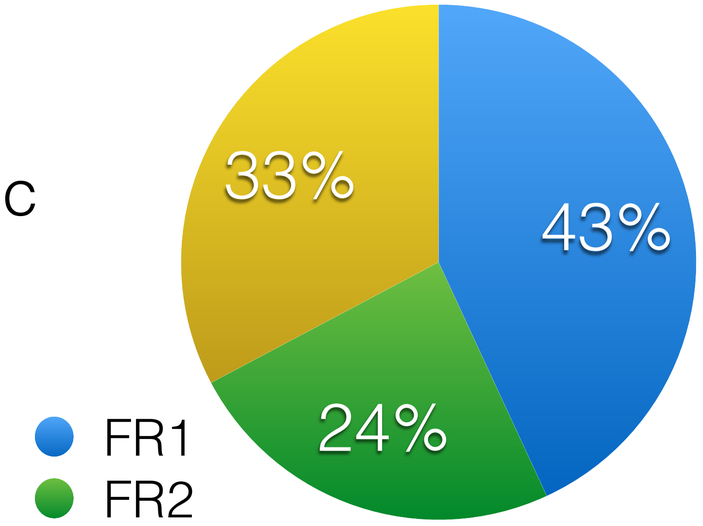
~60 misaligned AGN in 4FGL/4LAC-DR2

Factor ~3x increase with respect to 3LAC



- 4LAC-DR2 classification:
  - 44 radio galaxies
  - 2 steep spectrum radio quasars
  - 5 compact steep spectrum sources
  - 11 “agn(*)”

- Radio morphology classification:
  - 25 FR1
  - 14 FR2
  - 2 hybrid
  - 2 compact symmetric objects
  - 5 CSS quasars
  - 14 unknown



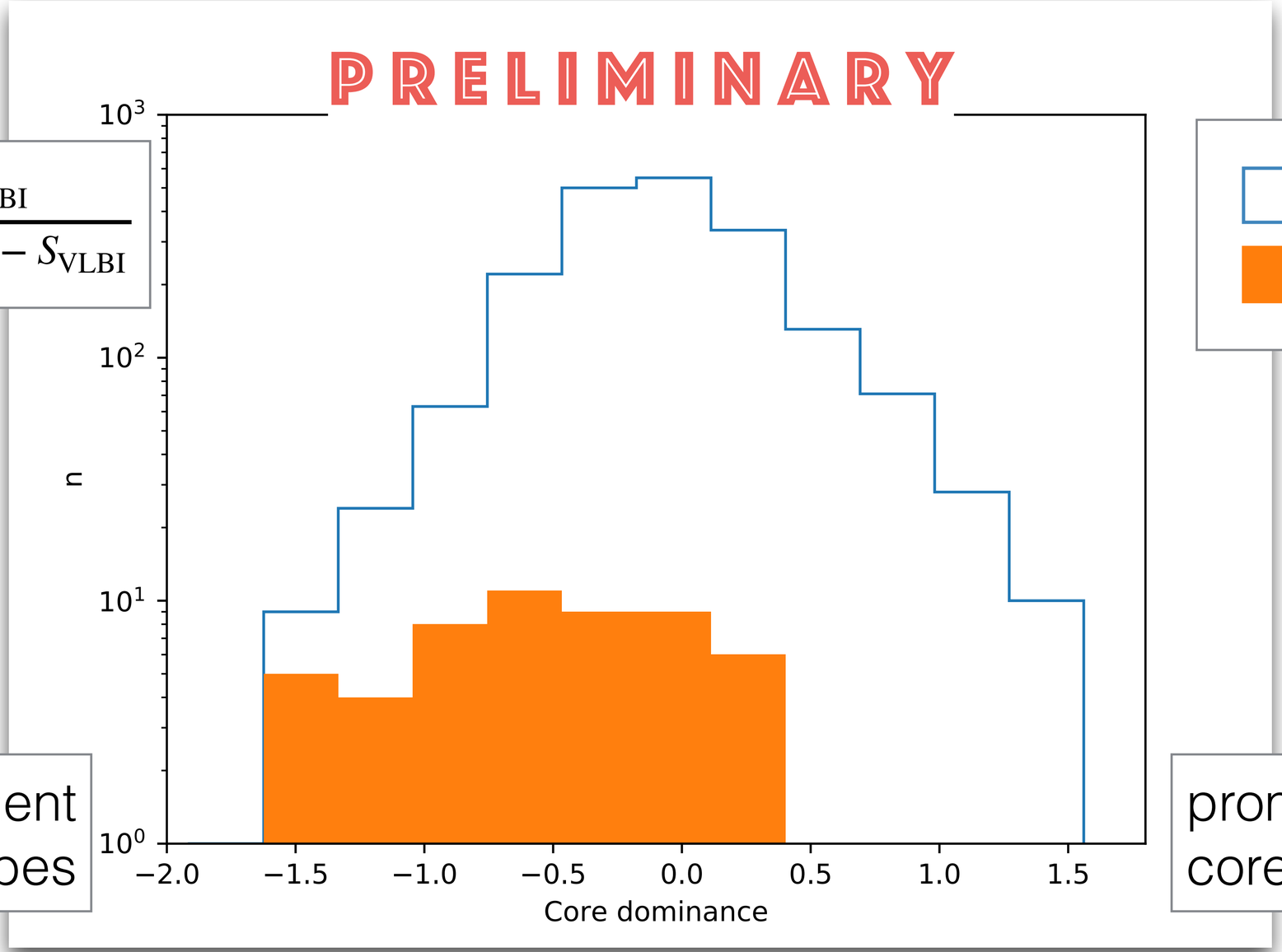
(*) transitional/variable/complex sources, or simply without sufficient information to establish blazar nature

Current analysis

- Collection of various literature samples (historical, selected at low frequency, eg 3C, more recent, selected on morphology, eg FRICAT/FRIICAT, etc)
- Thorough check of images and MWL data to clean sample, assign morphology, estimate LAS (largest angular size)
- Collection of core flux densities (from VLBI) and total flux density (from single dish, checking for extended emission on a source-by-source basis)
  - extended to whole 4LAC for reference
- Determine distance dependent properties (luminosity, size)
- Plots, statistics, in comparison to blazars

Core dominance

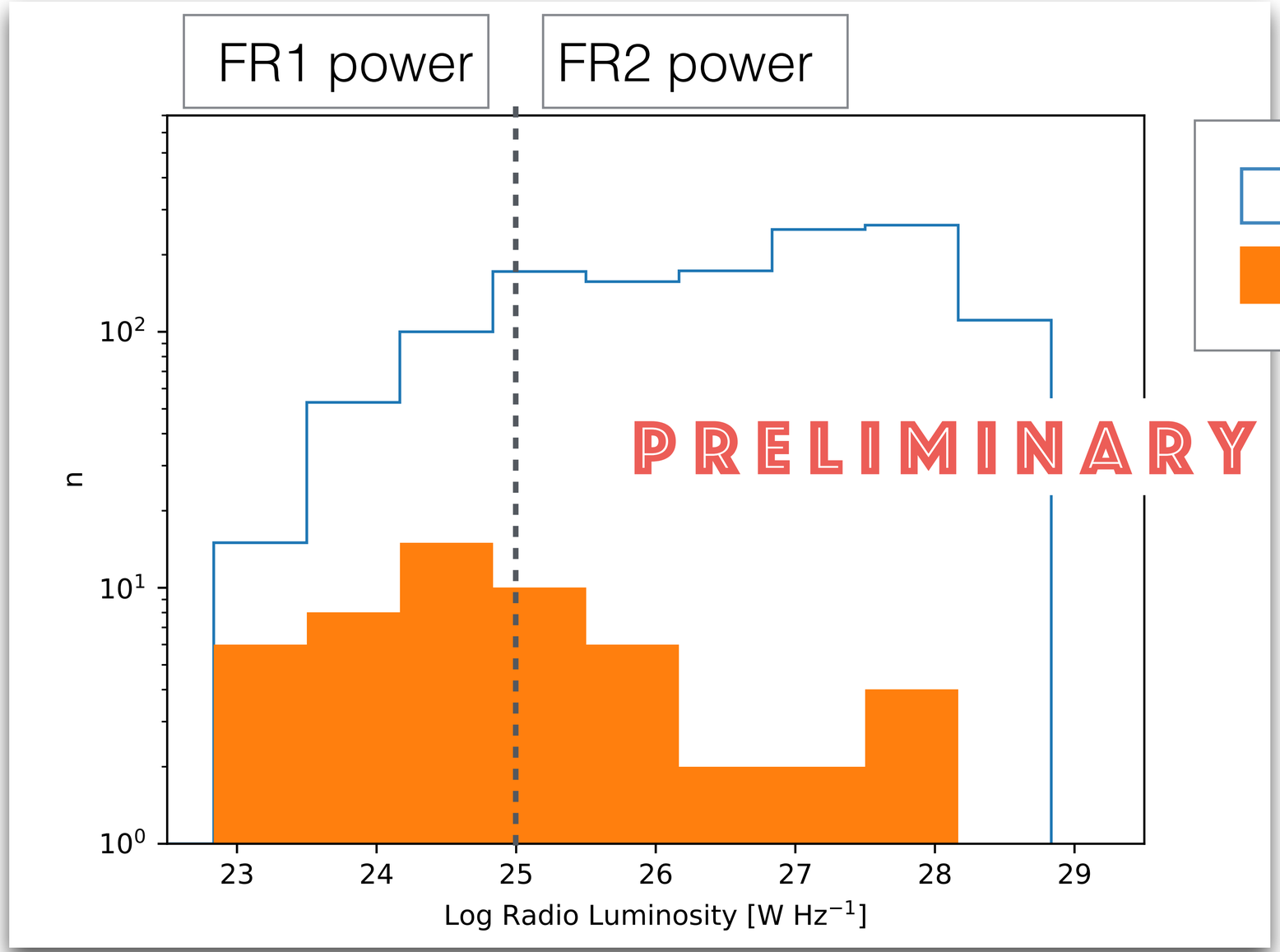
$$CD = \log \frac{S_{\mathrm{VLBI}}}{S_{\text{single dish}} - S_{\mathrm{VLBI}}}$$



prominent lobes

prominent cores

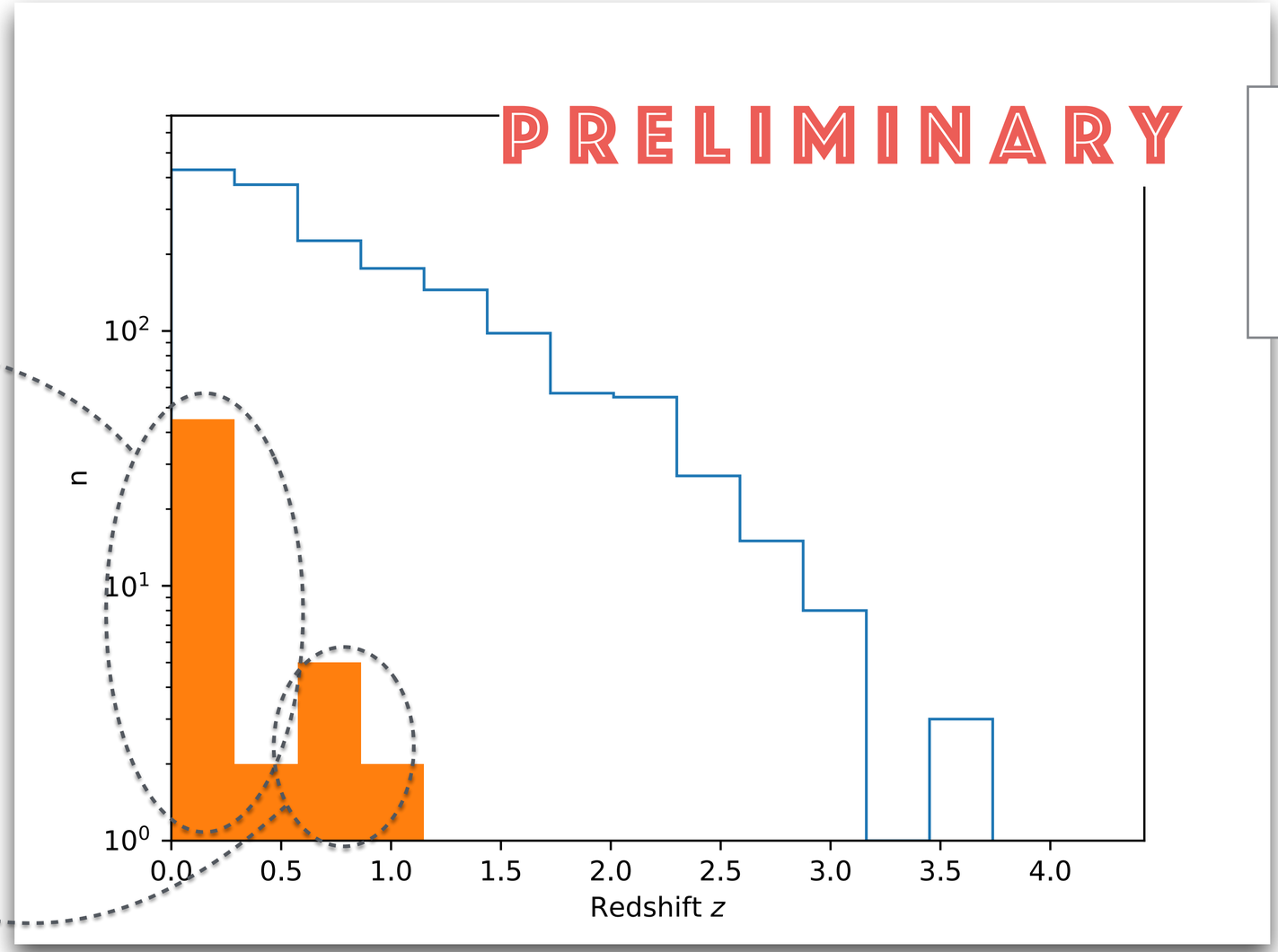
Total radio luminosity



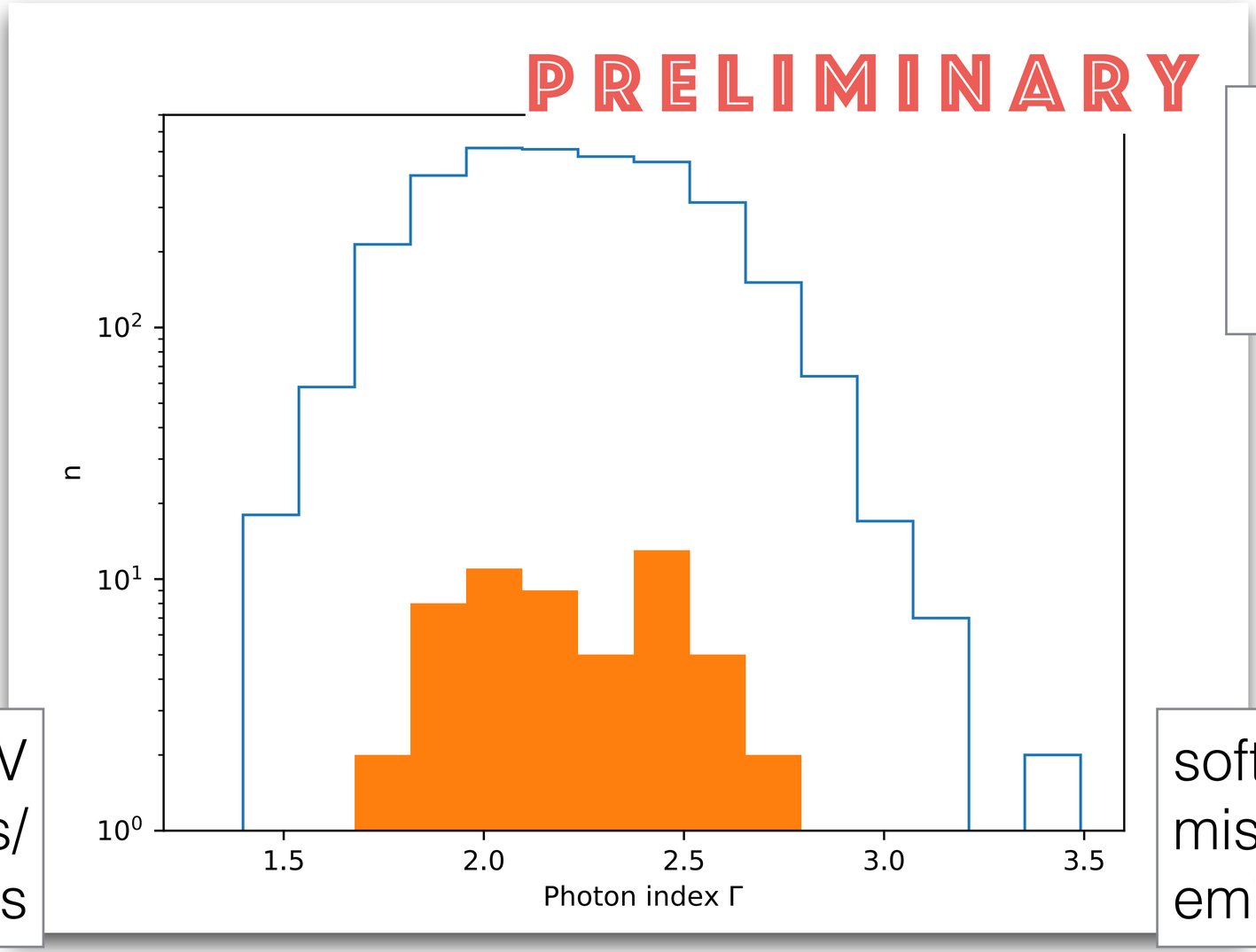
Redshift

dominant host galaxy

mainly QSOs



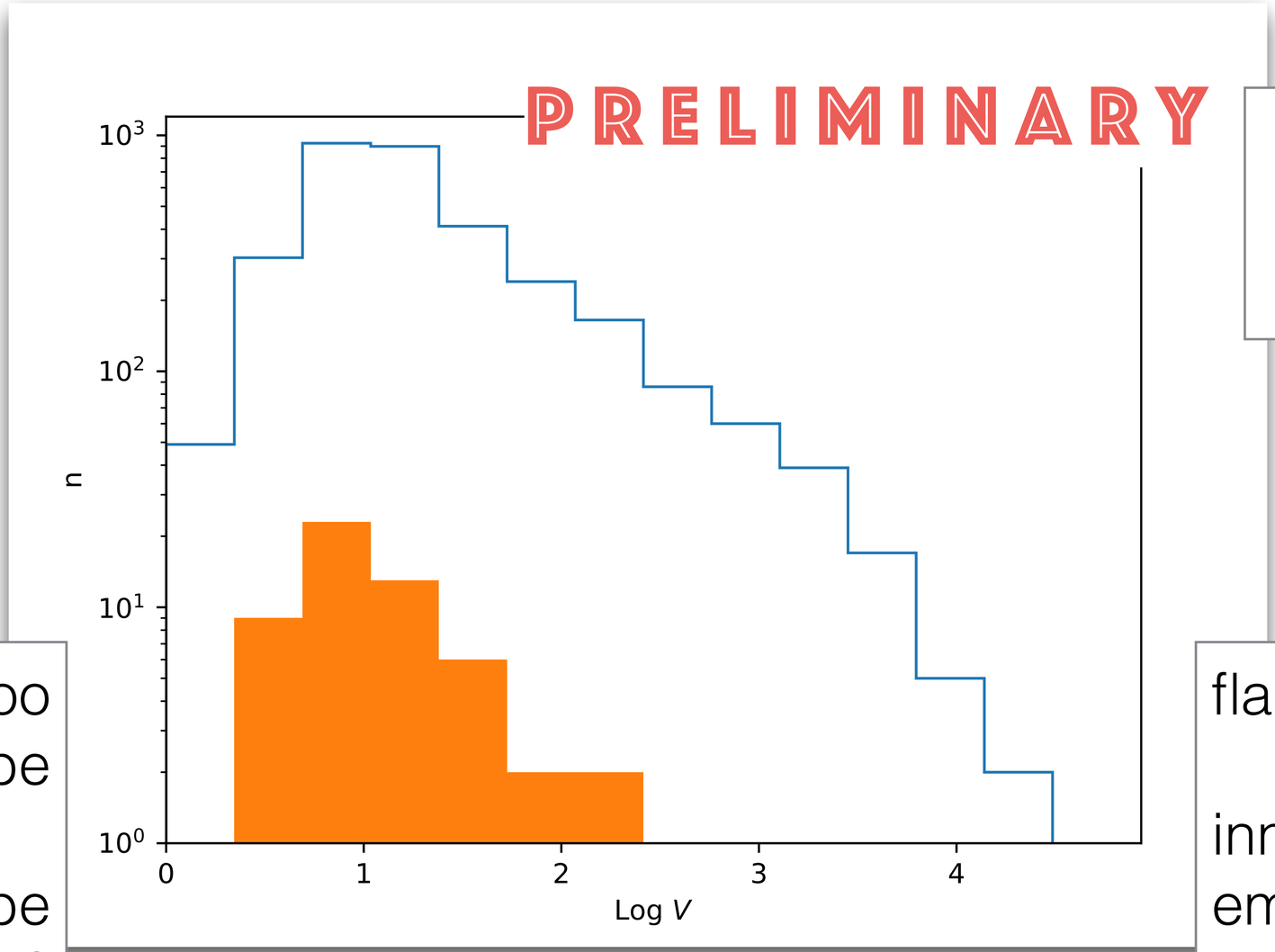
Photon index



hard - TeV sources/ candidates

soft: large misalignment, lobe emission?

Variability index



steady, or just too faint to probe

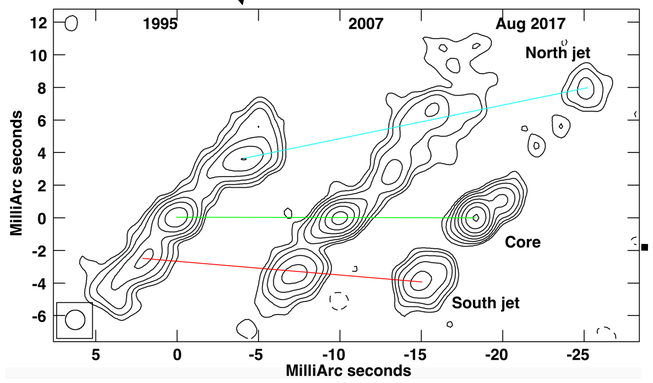
FR1 types, lobe emission?

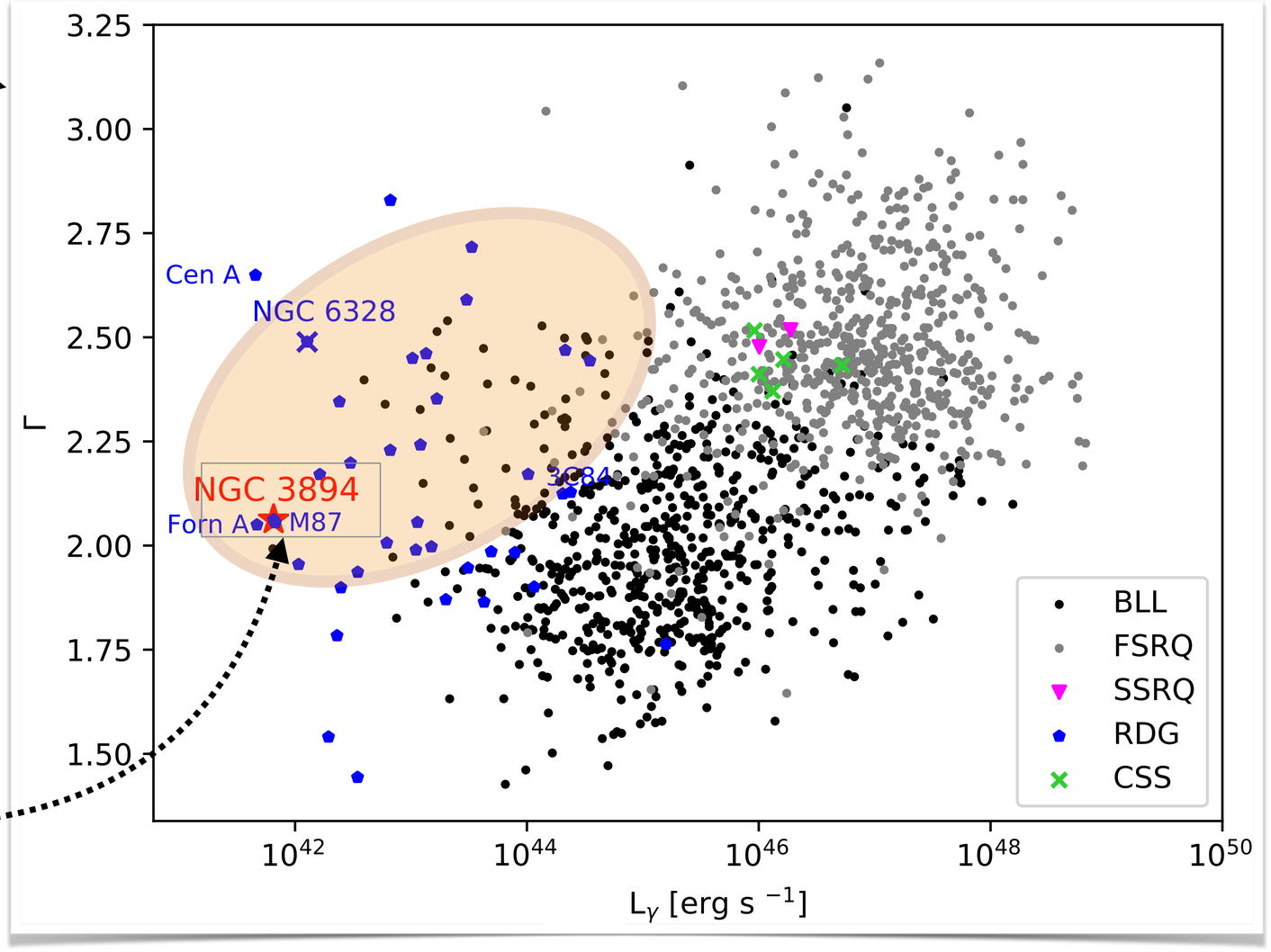
flaring(?)

inner/compact jet emission, small misalignment

Photon index vs luminosity

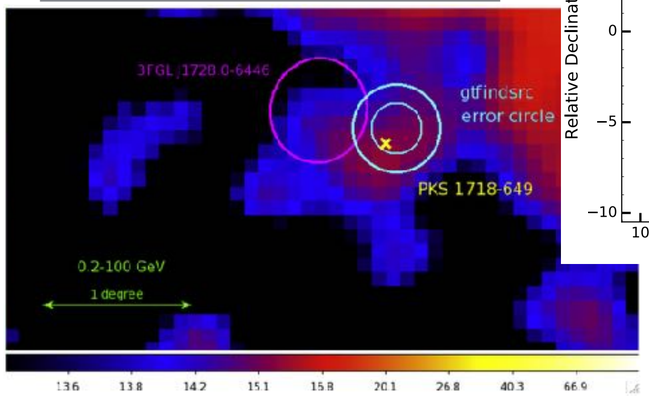
Principe et al. (2020)

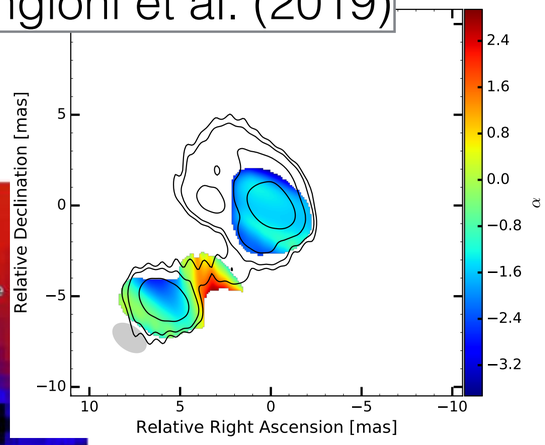


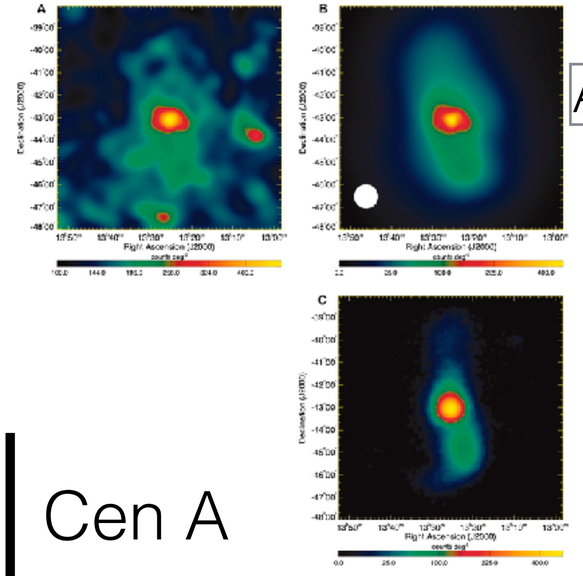


Angioni et al. (2019)

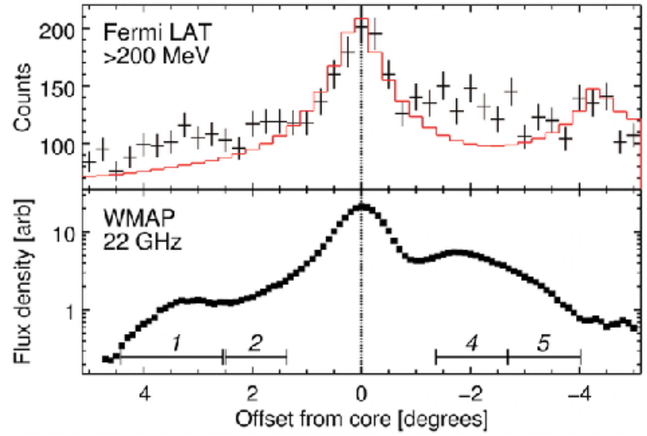
Migliori et al. (2016),







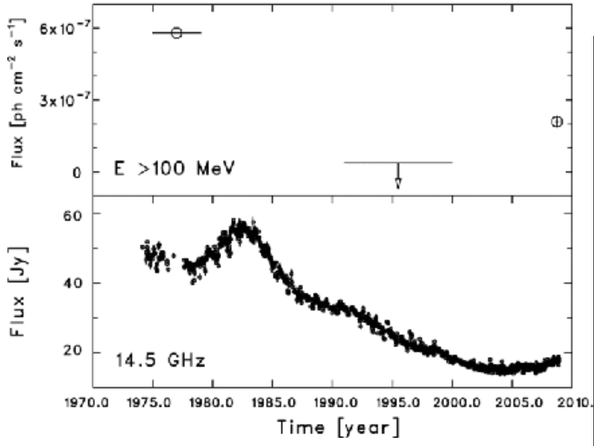
Abdo et al. (2010a)



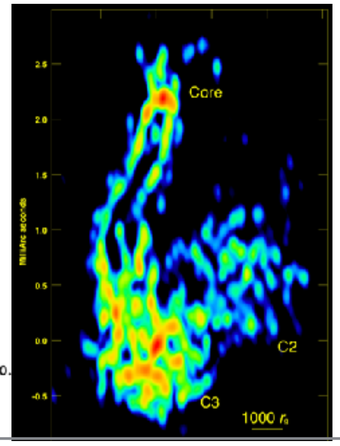
NGC 6328 | Cen A

3C 84 | M87

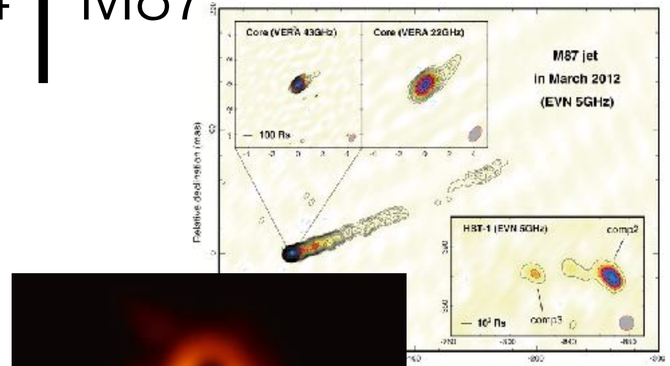
Viewing angle/Photon index

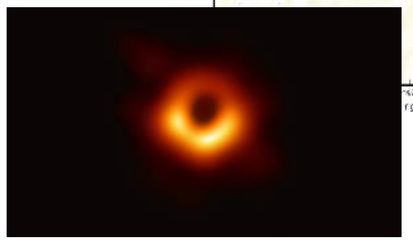


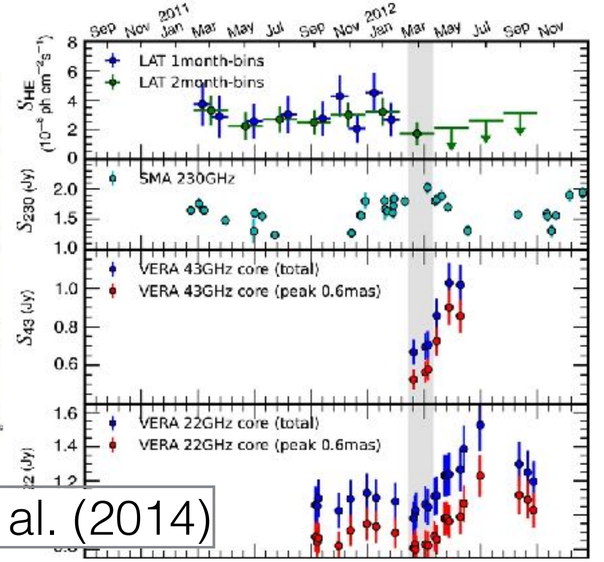
Abdo et al. (2009)



Giovannini et al. (2018)







Hada et al. (2014)

Size, d_L^{-1}

Summary

- Large increase of total number of misaligned AGN
- Heterogeneous class, likely heterogeneous physical properties too (emission regions and processes)
  - challenging to tell apart from blazars
- Including young radio sources (see poster by G. Principe)
- Increase of FR2 fraction?