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High energy emission component and population of gamma-ray emitting radio galaxies

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Fukazawa et al. 2022, ApJ 931m 131

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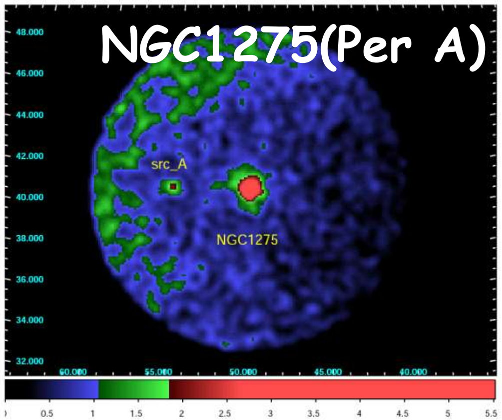
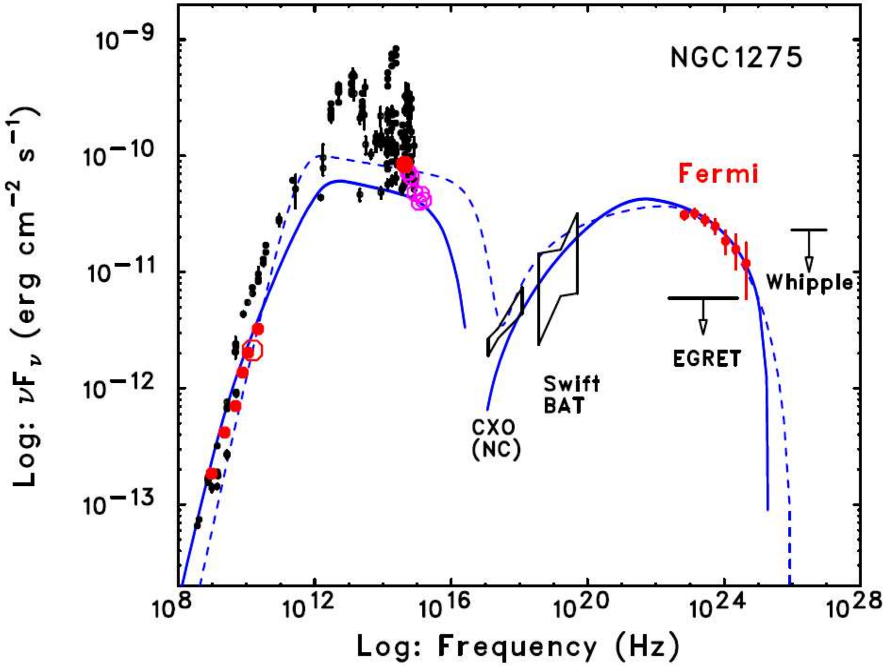
Radio galaxies established as a gamma-ray source
thought to be a parent population of blazars
more numerous than blazars

Open Questions for GeV-loud radio galaxies …

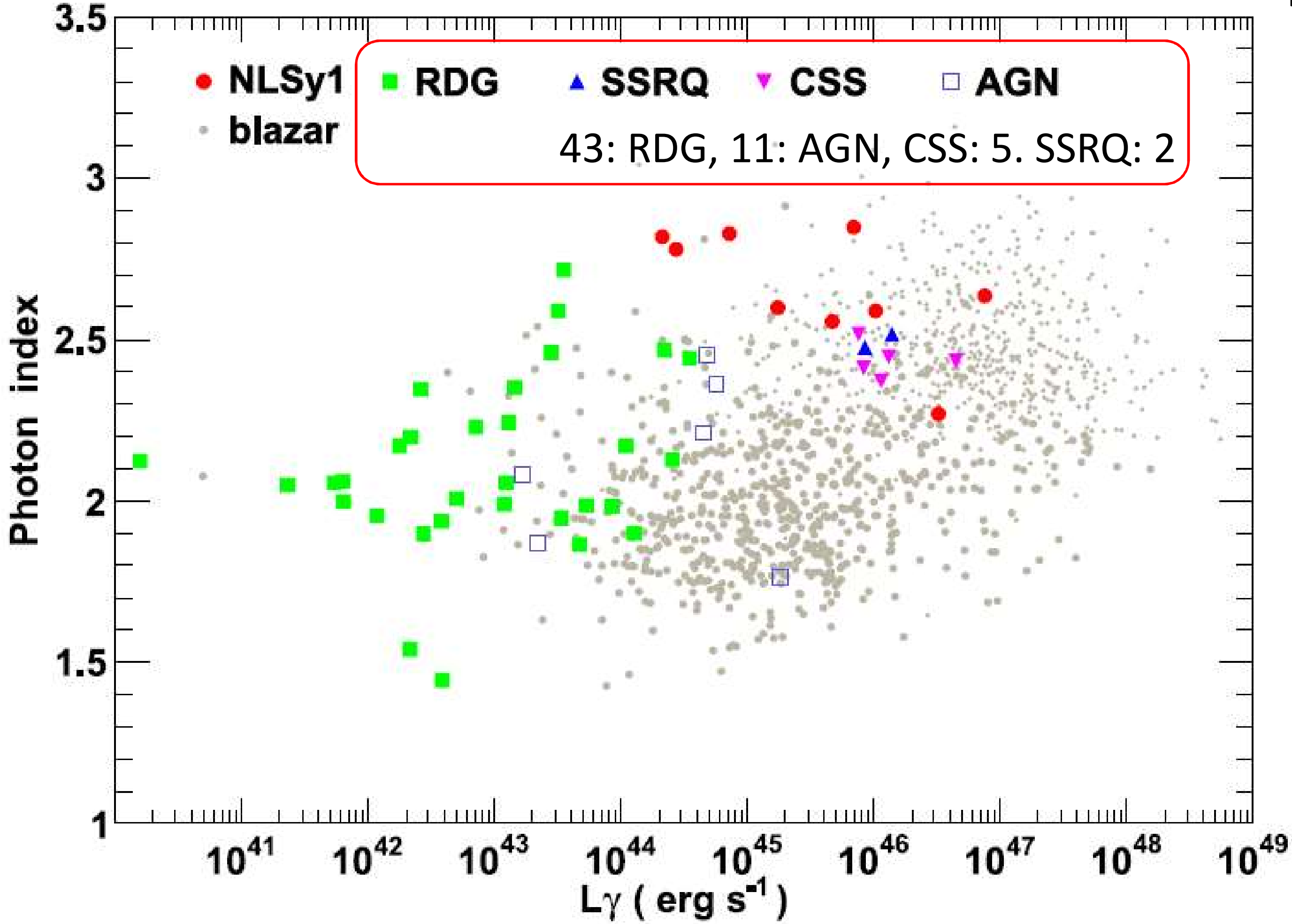
- Luminosity Function (LF) ?
- Contribution to Extragalactic gamma-ray bgd ?
- How about SED is from X-ray to gamma-ray ?
- Population ?
    - FR-I rich ? FR-II rich ?
    - GeV-loud vs GeV-quiet ?
    - Relation with Blazars ?





4th Fermi Catalog (4FGL-DR2): Misaligned AGN (61 galaxies)

From 4LAC paper

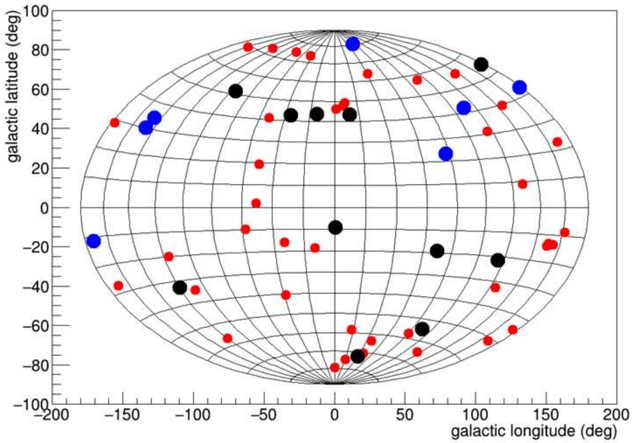


X-ray data

We searched for X-ray data with a priority order of XMM-Newton, Chandra, Swift, RASS. 8 bright objects are from Fukazawa+15 Suzaku results..

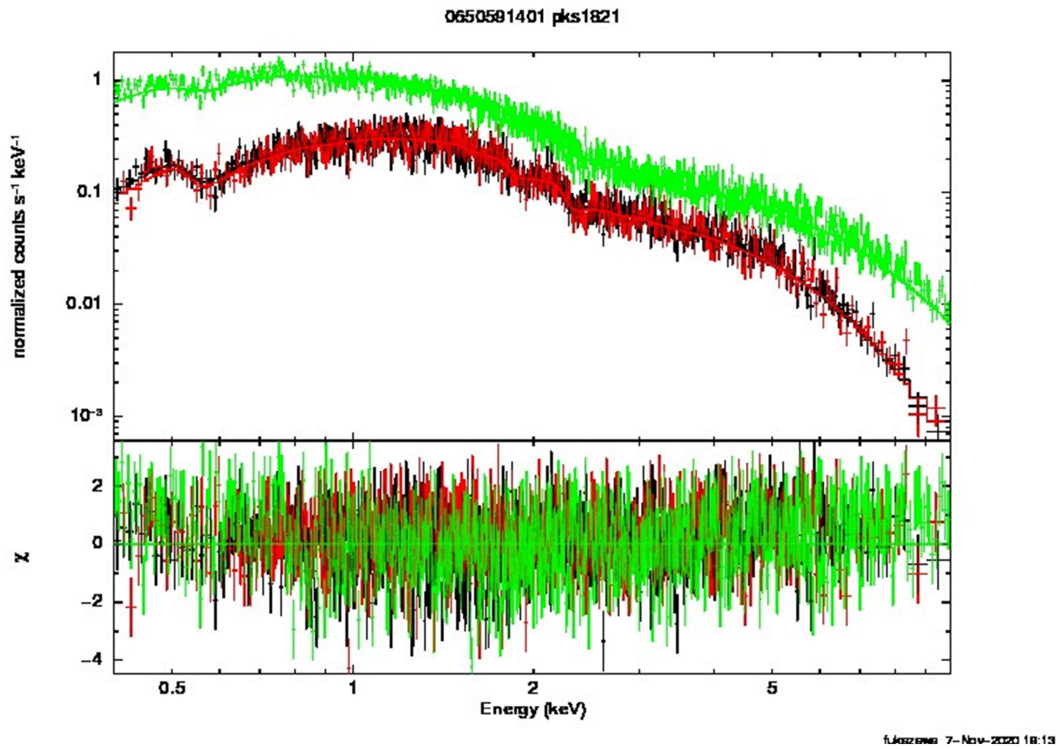
XMM-Newton	20
Chandra	14
Swift	9
NuSTAR	1
RASS	5
XMM slew	1
Suzaku	7
No X-ray data	4

RDG
AGN
CSS/SSRQ



Fitted with powerlaw to obain a photon index and flux.

PKS 1821--327

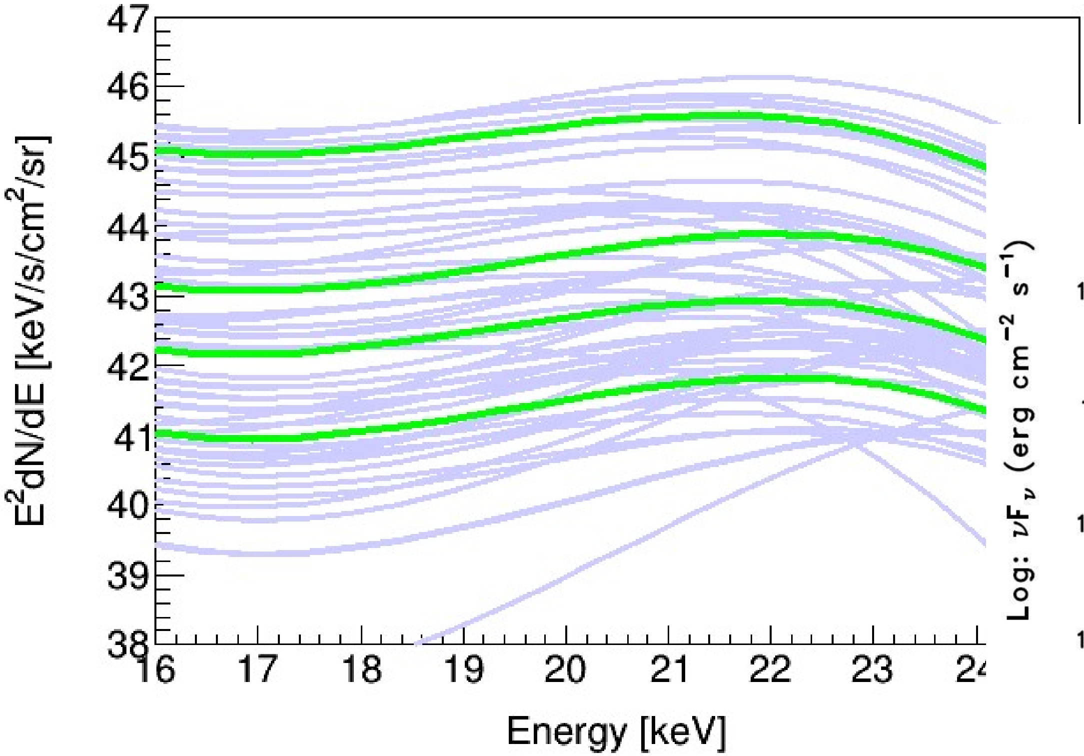


SED analysis from X-ray to GeV gamma-ray

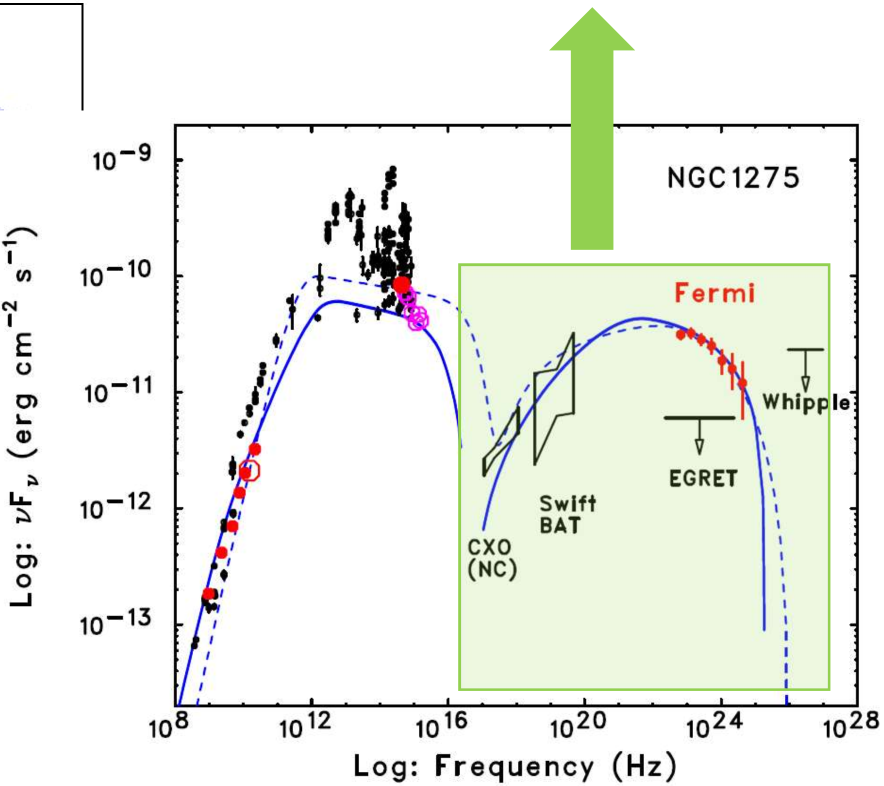
Fitted X-ray and gamma-ray spectra with 4-th polynomial function.

Plot of obtained SED curves for each galaxy

Average SEDs of 4 luminosity regimes



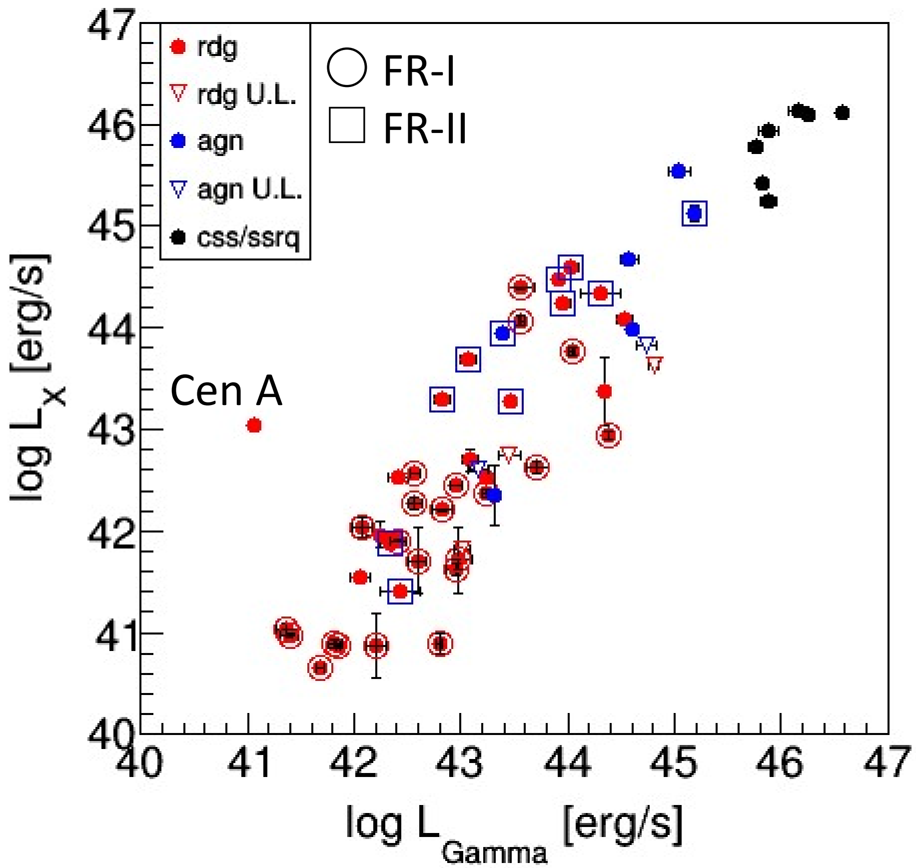
High energy (H.E.) emission
Jet, disk/corona



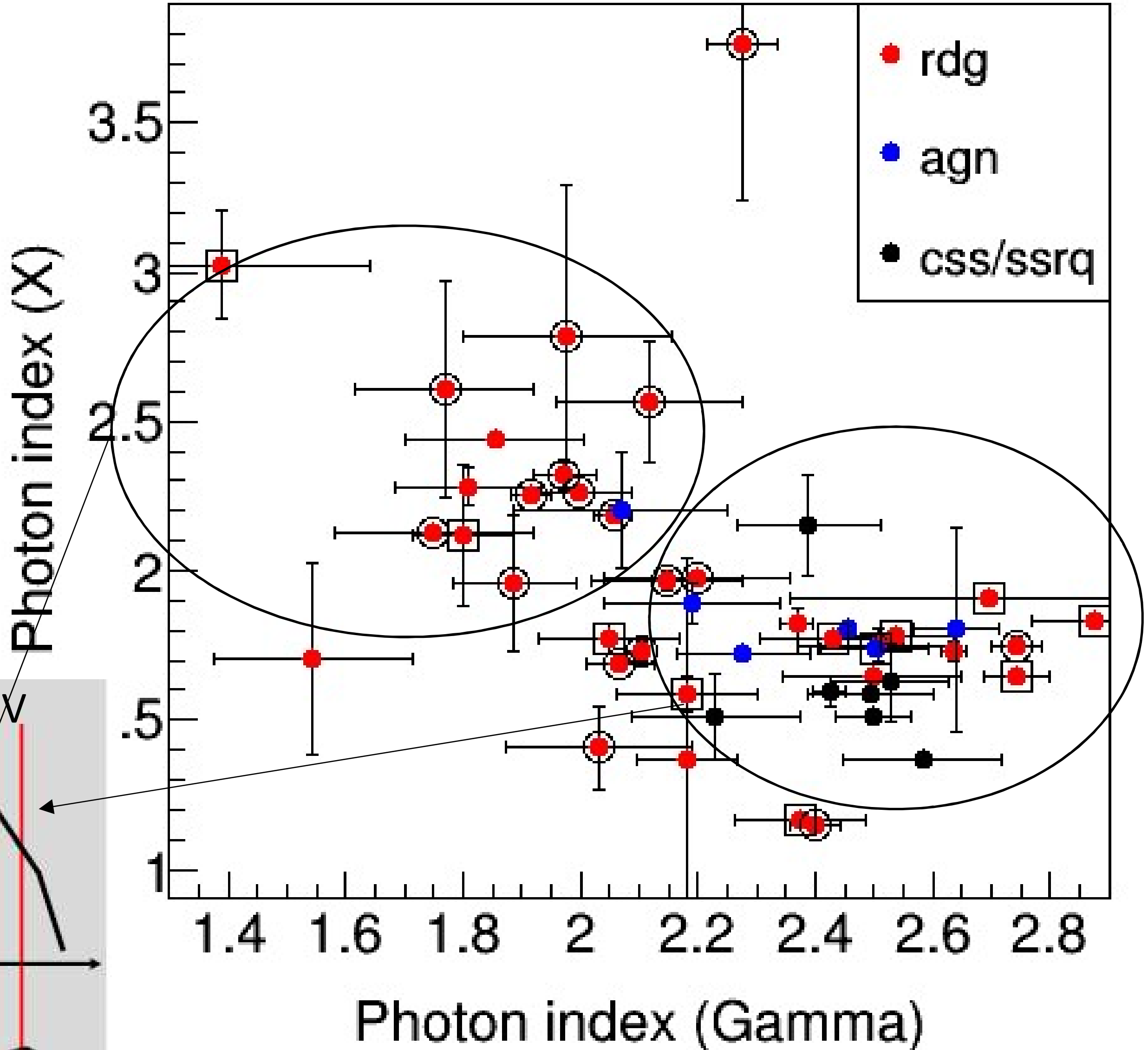
Correlation of luminosity between X-ray and GeV.

X-ray L iroughly correlates with GeV L.

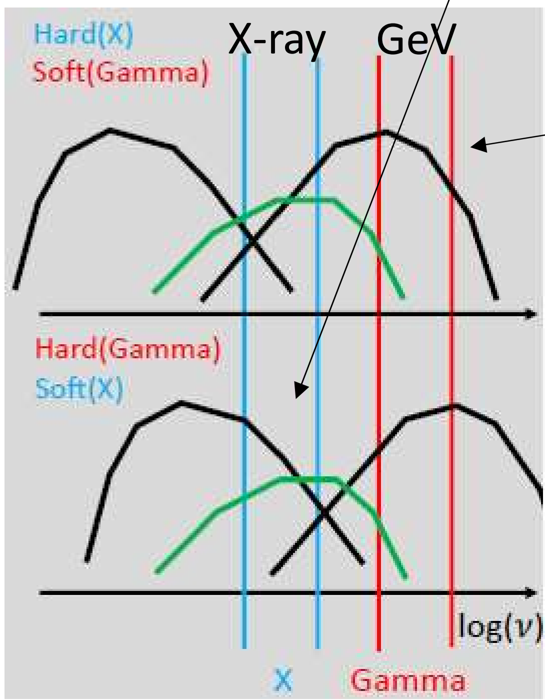
FR-II is not always bright.
CSS/SSRQ are the brightest in both X-ray and GeV.



Correlation of photon index between X-ray and GeV

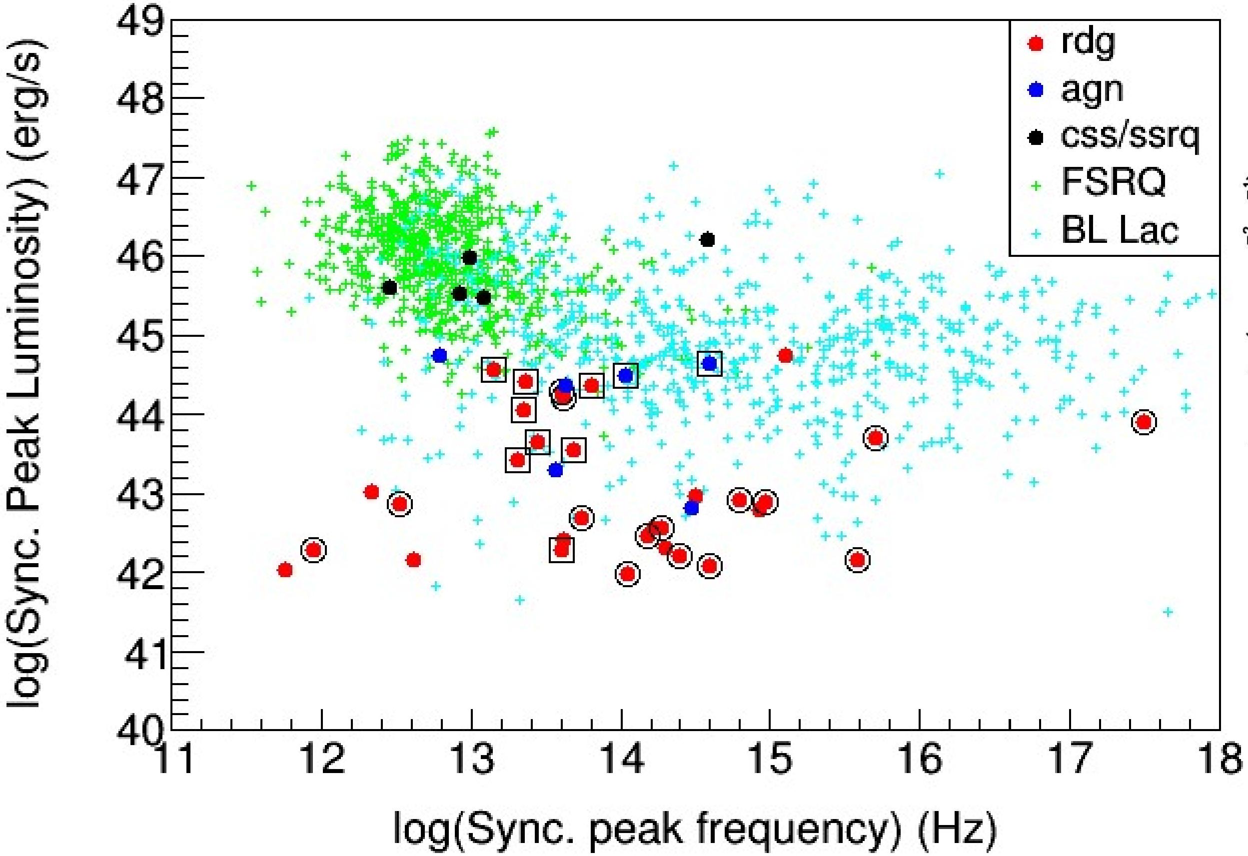


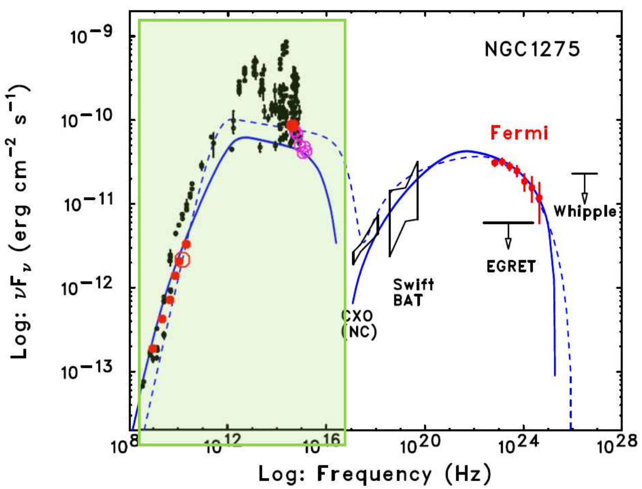
SED



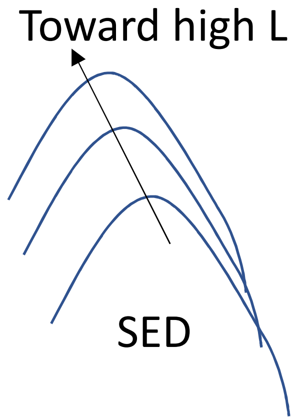
Synchrotron Peak (from 4LAC(-DR2)

Note that SED in IR, Opt, and X-ray could be contaminated by non-jet emissions.

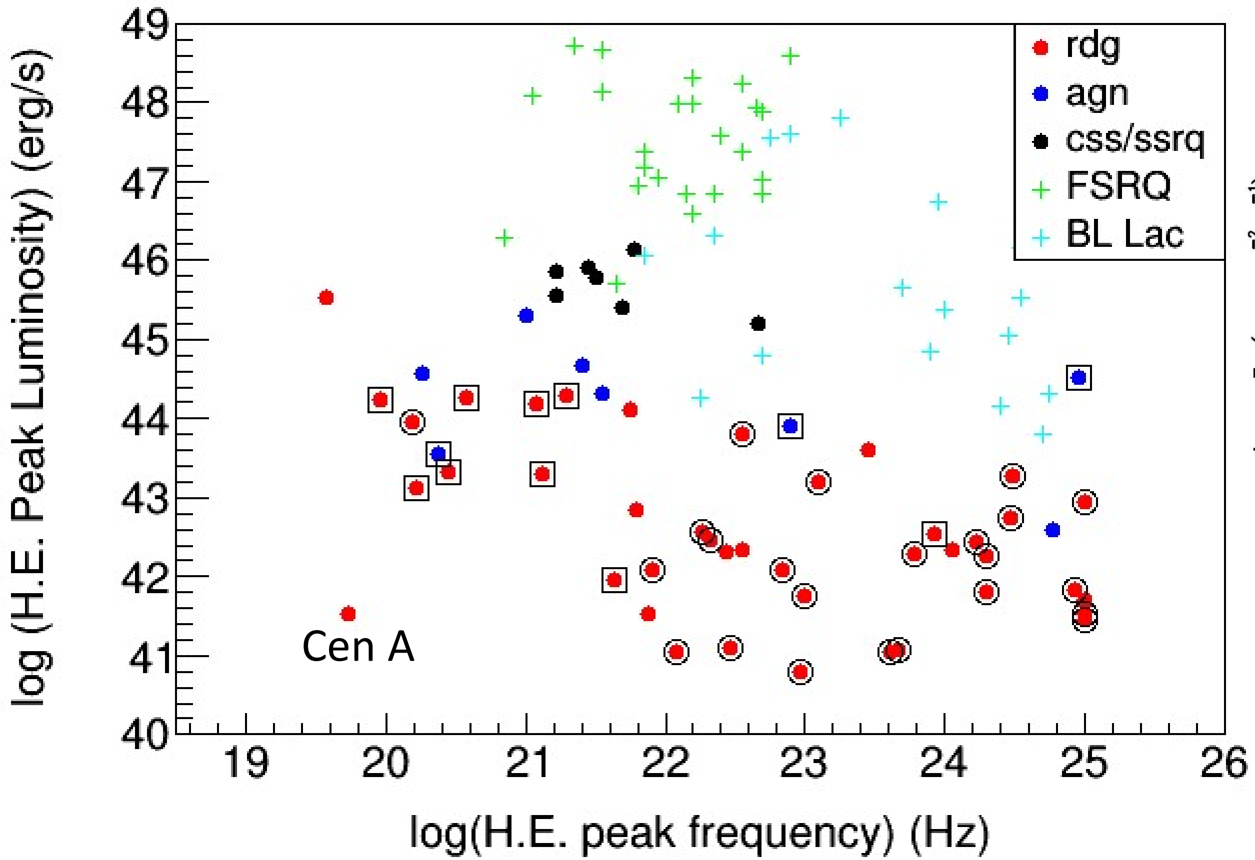


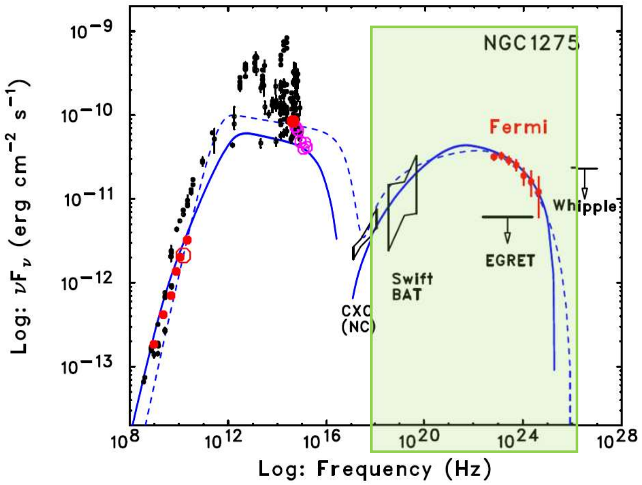


H.E. component peak (from SED fit)



Wide dist. of peak frequency, and blazar-like seq. is seen.

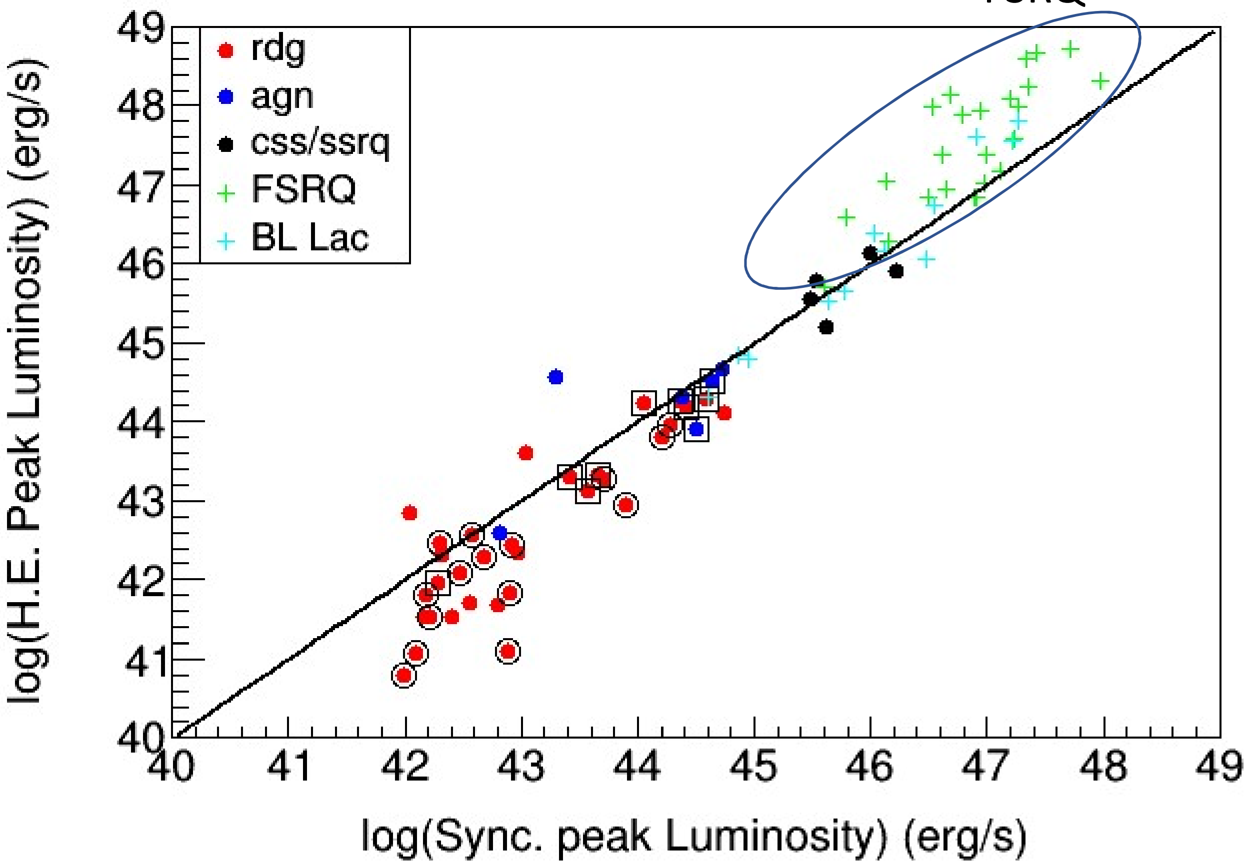




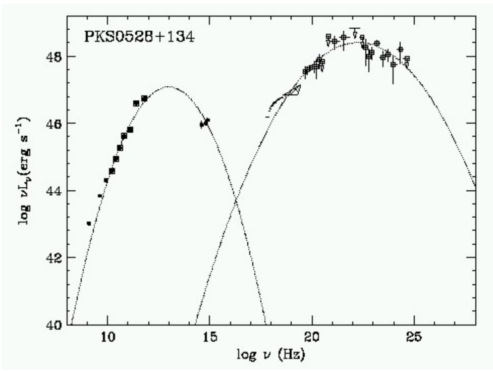
Correlation of luminosity between Sync-peak and H.E. peak.

Compton dominance of RGs is similar to or less than that of BL Lac.

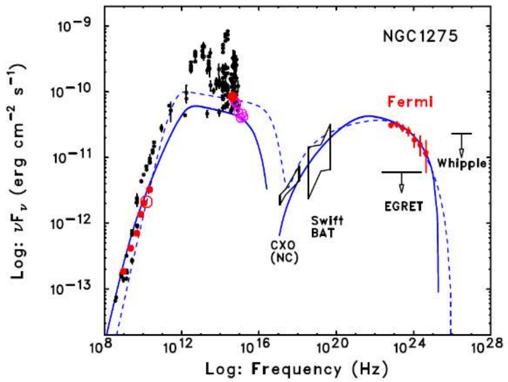
FSRQ



FSRQ



Radio Galaxy



Population (1)

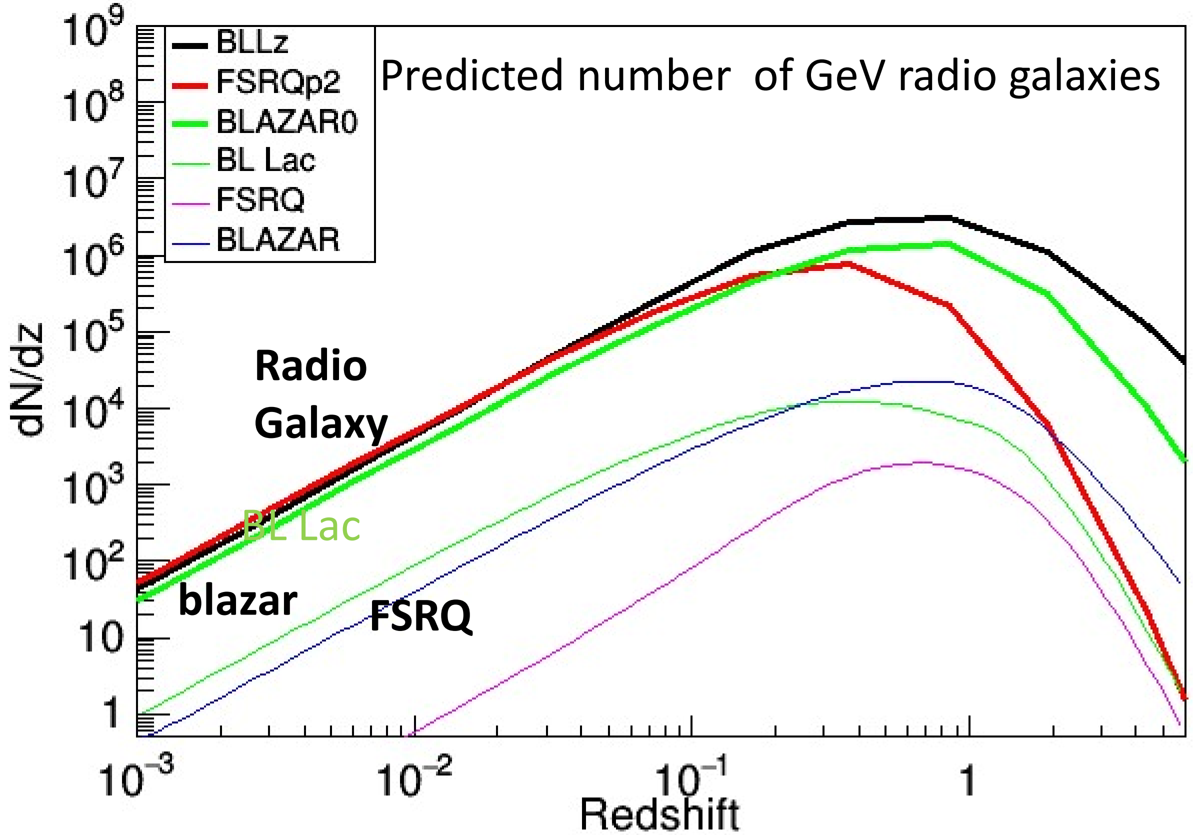
GeV radio galaxies are 10—30 times as numerous as blazars.

←→ Viewing angle of blazars is 0-10deg.

Only 10% of 2 Jy flux-limited radio-sample RG (Mingo+14) are detected in GeV.

Considering a beaming effect, only a small fraction of RGs with a viewing angle <24deg are seen in GeV ? (Inoue 11), consistent with less soft X-ray absorption of GeV RG

(Kayanoki+22)



Population (2)

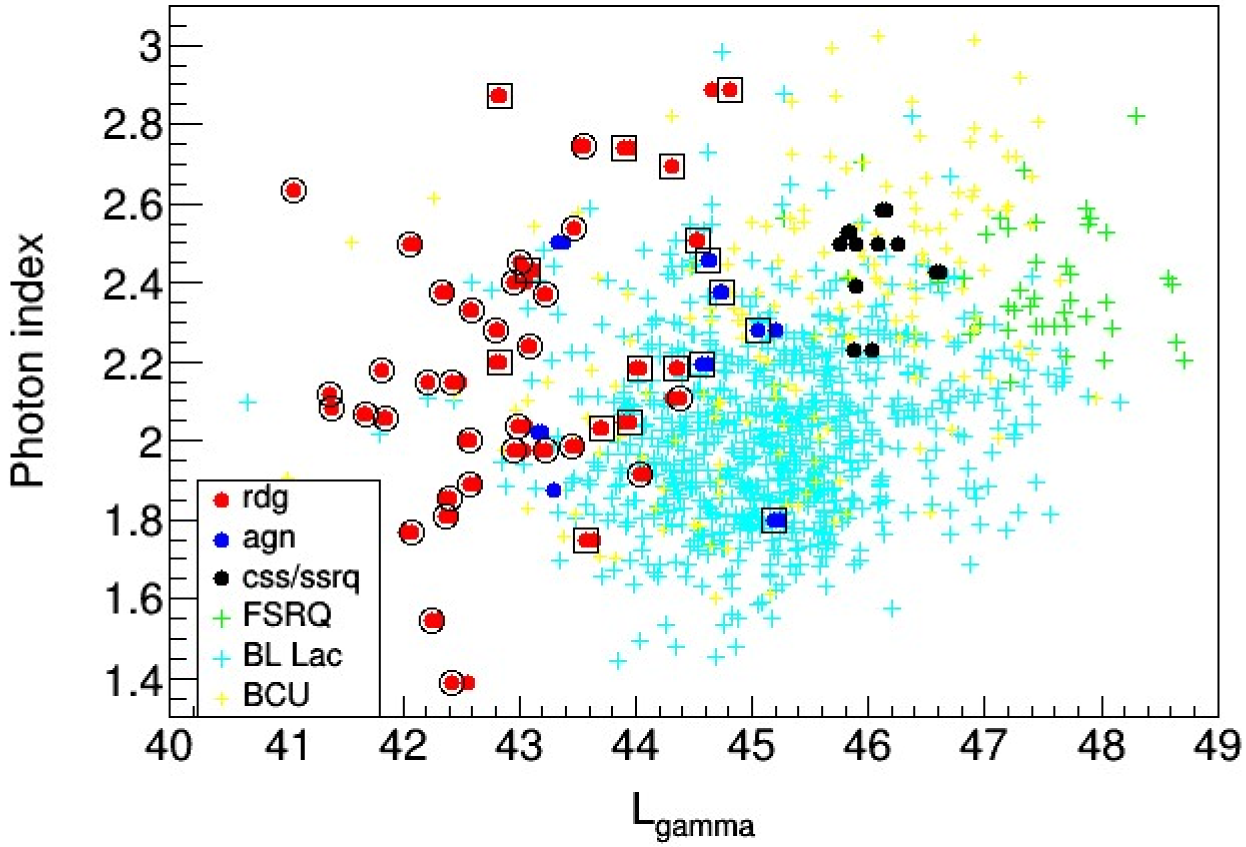
FR-I / FR-II ←→ BL Lac / FSRQ

Blazar seq of H.E. emission component is common.

No FR-II with as large Compton dominance can be due to difference of

“. beaming pattern between external Compton and SSC (Finke+13).

Some FR-Iis may correspond to BL Lac (LBL)?



Population (3)

35 FR-I vs 17 FR-II in GeV …… **FR-Iis are lacking.**

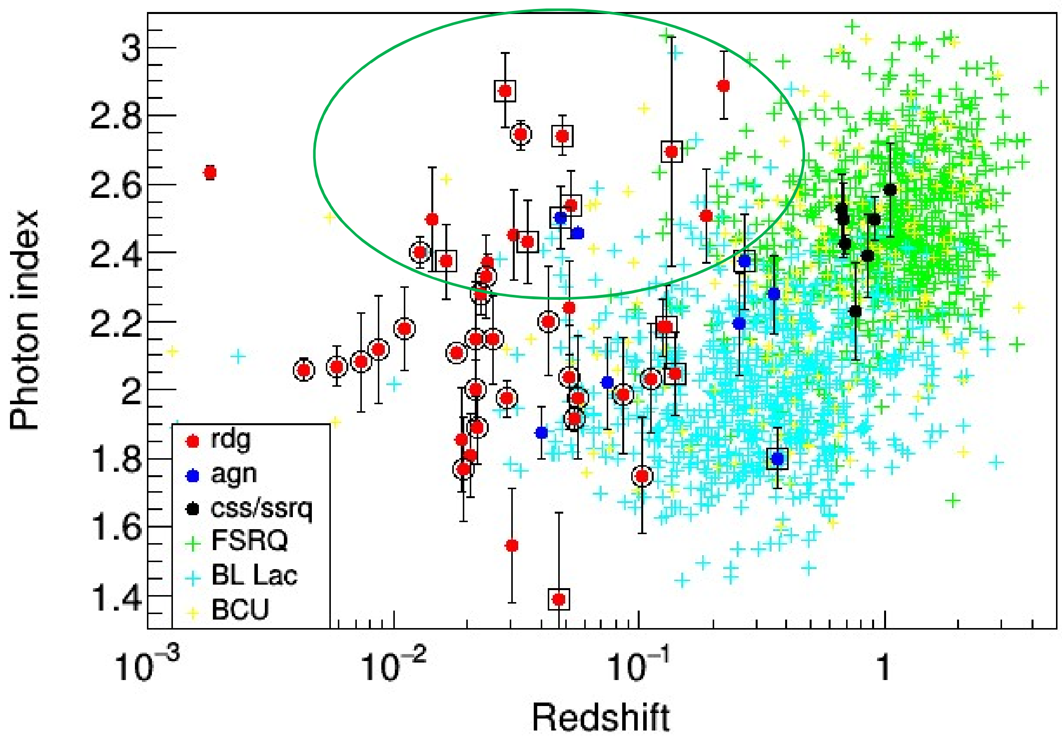
6 FR-I vs 33 FR-II in radio flux-limited (Dicken+18).

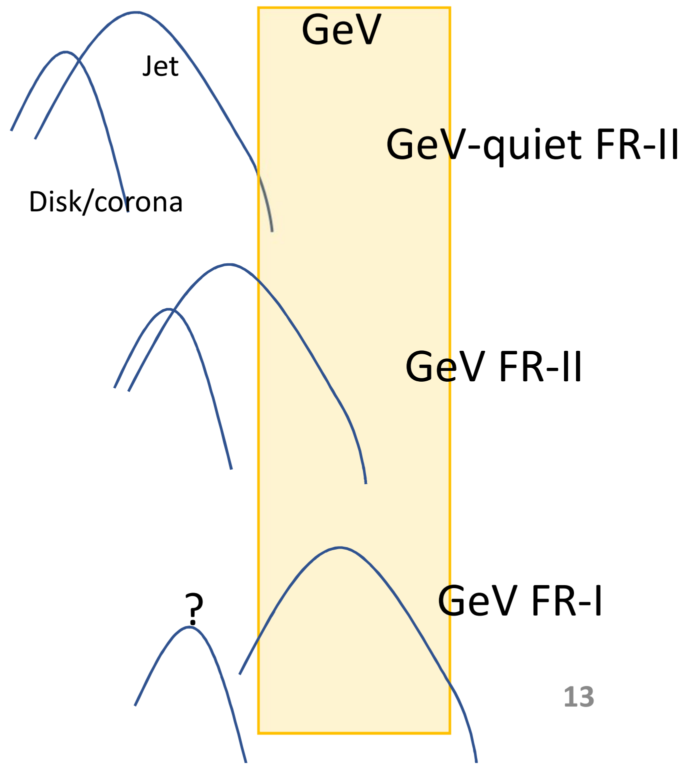
80% of X-ray RGs are FR-II (80%) (Rusinek+20).

H.E. component peak freq. is lower for FR-II. -→ soft GeV spectrum

SED of many FR-II could not reach GeV.

Beaming is more significant for FR-II while FR-I is less due to structured jet.





GeV gamma-ray luminosity function of radio galaxies

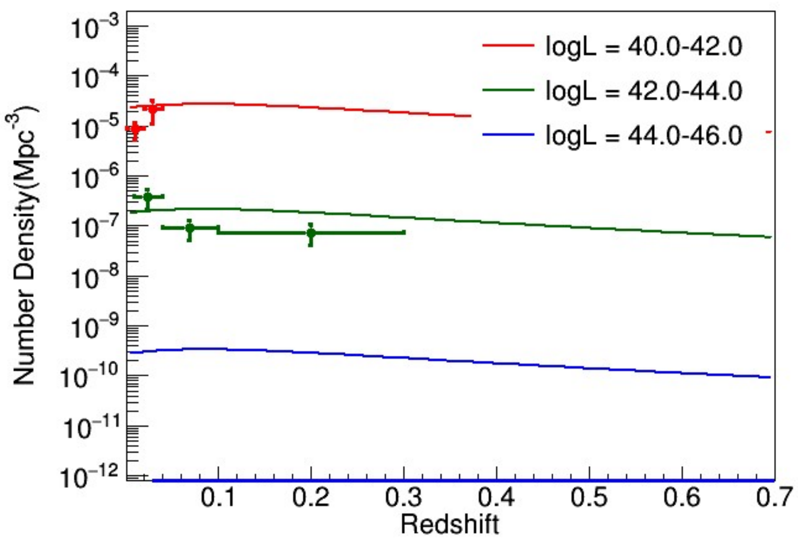
Negative evolution in nearby universe

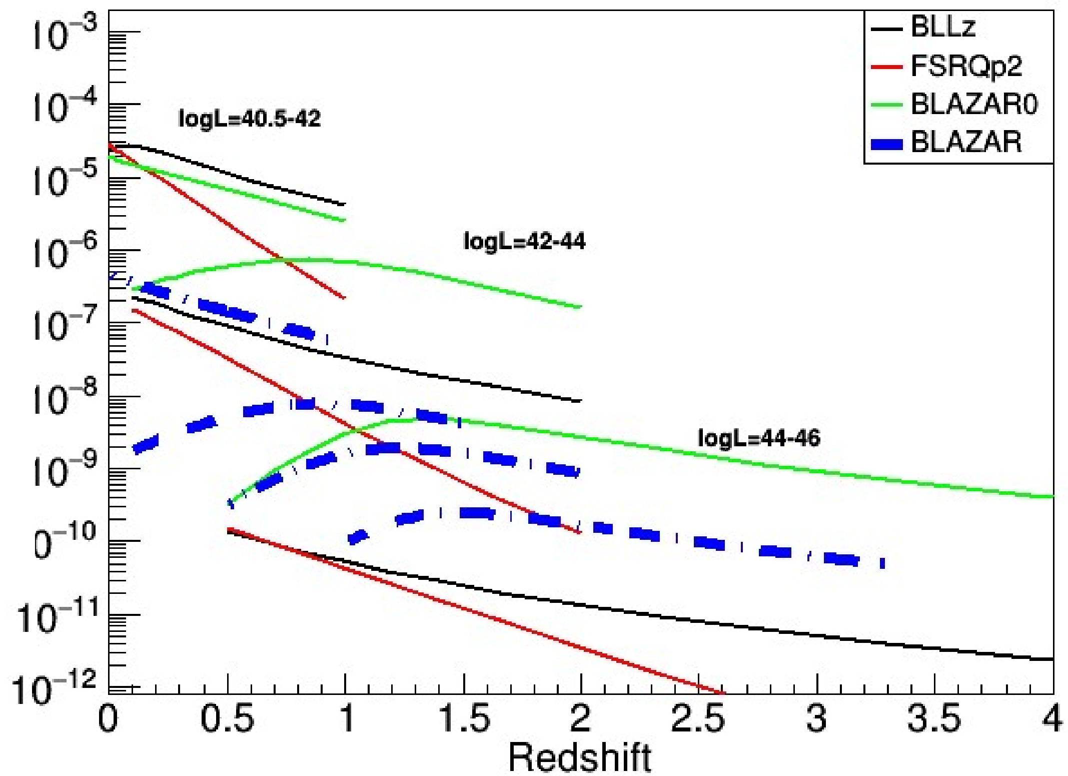
Many low-power gamma-ray L galaxies exit in low-z.

FR-0s (Paluya+21)

Parent population of elliptical-like blazars ? (Itoh+20)

Emission other than the core jet; (e.g. Cen-A kpc jet by HESS)

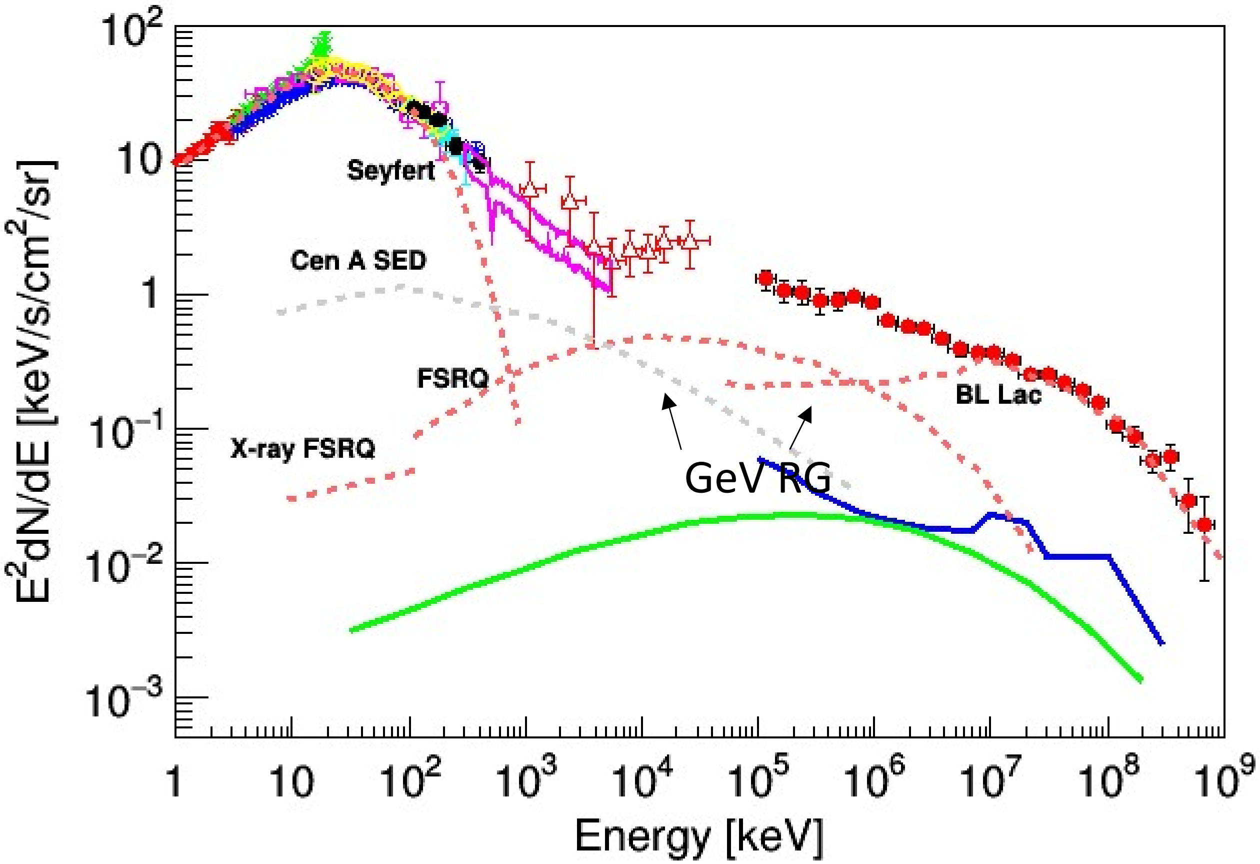




Contribution of GeV-loud RG to the EGB

1-10% contribution of GeV-loud RG.

Many GeV-quiet FR-II RGs could contribute to the MeV EGB.



Conclusion

GeV-loud RG has a blazar-like Sequence on H.E. SED.

GeV-loud RG is a small part of radio-loud RG; only beamed ones are seen in GeV.

FR-I/II vs BL Lac/FSRQ correspondence is consistent with our results.

FR-II is lacking in GeV; H.E. SED peak freq. is lower.
Many GeV-undetected FR-Iis are there.

Possible significant contribution to MeV gamma-ray background

GeV-loud RG has a negative evolution in nearby universe.