Gamma-ray emitting Narrow Line Seyfert 1 galaxies

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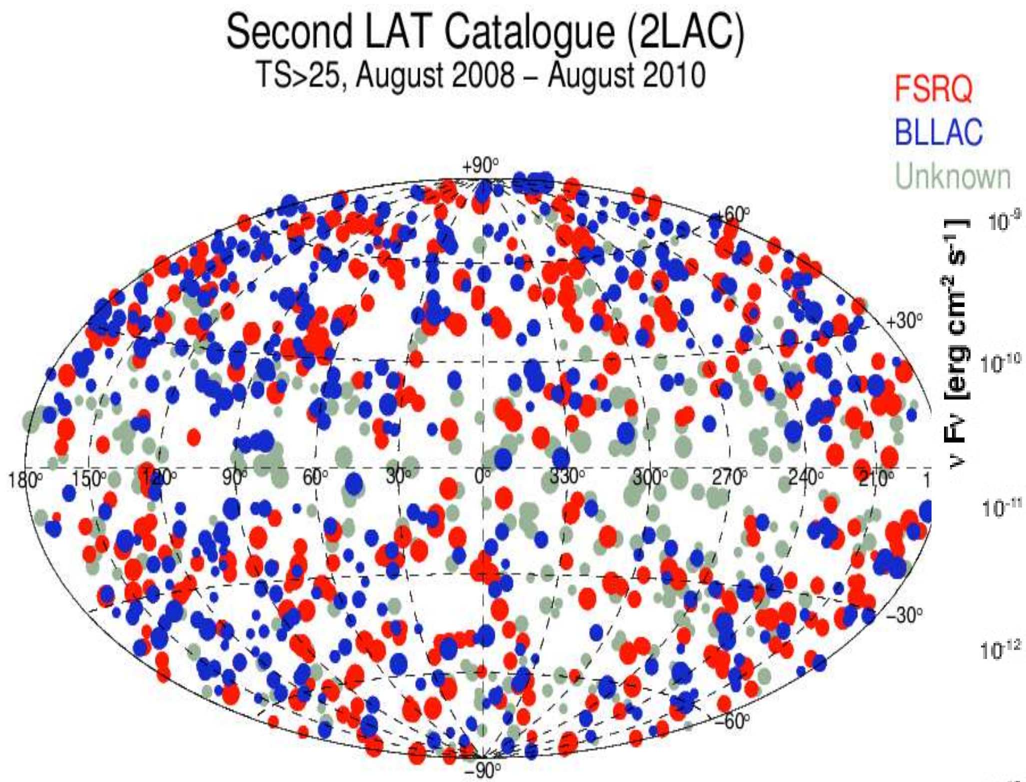
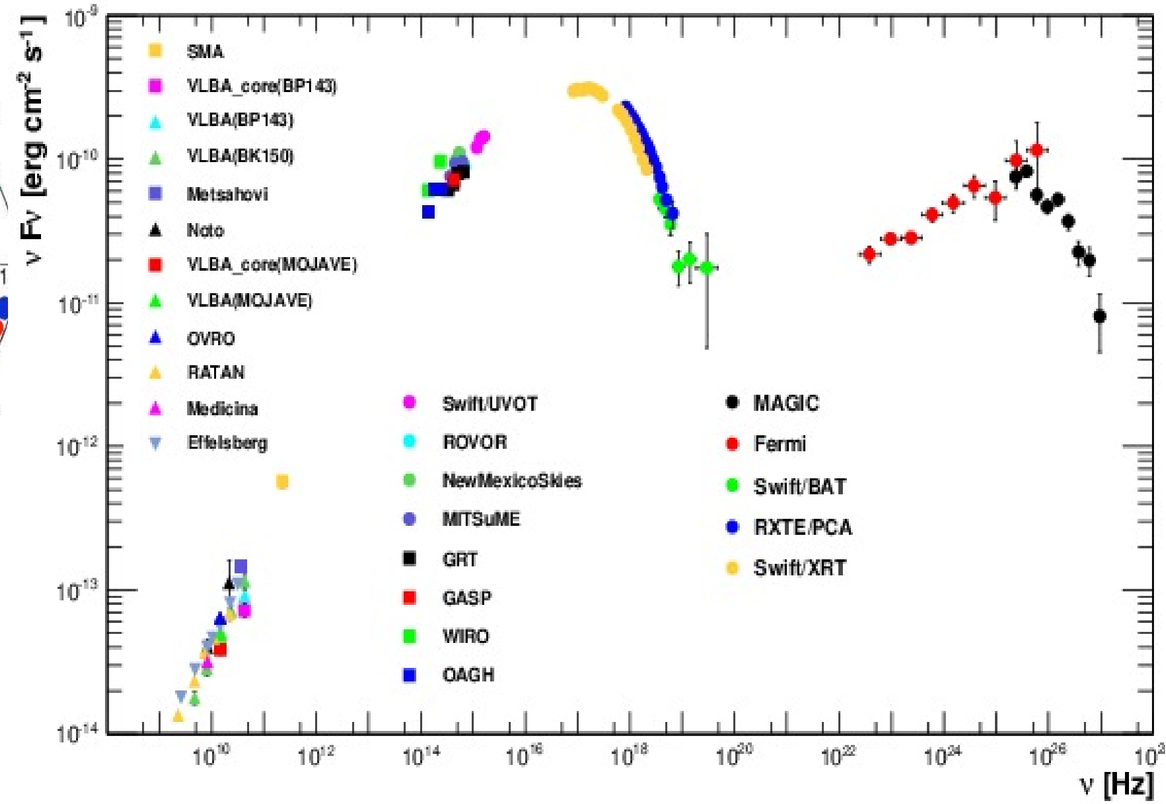
Extragalactic *Fermi* sources dominated by blazars - > non-thermal processes

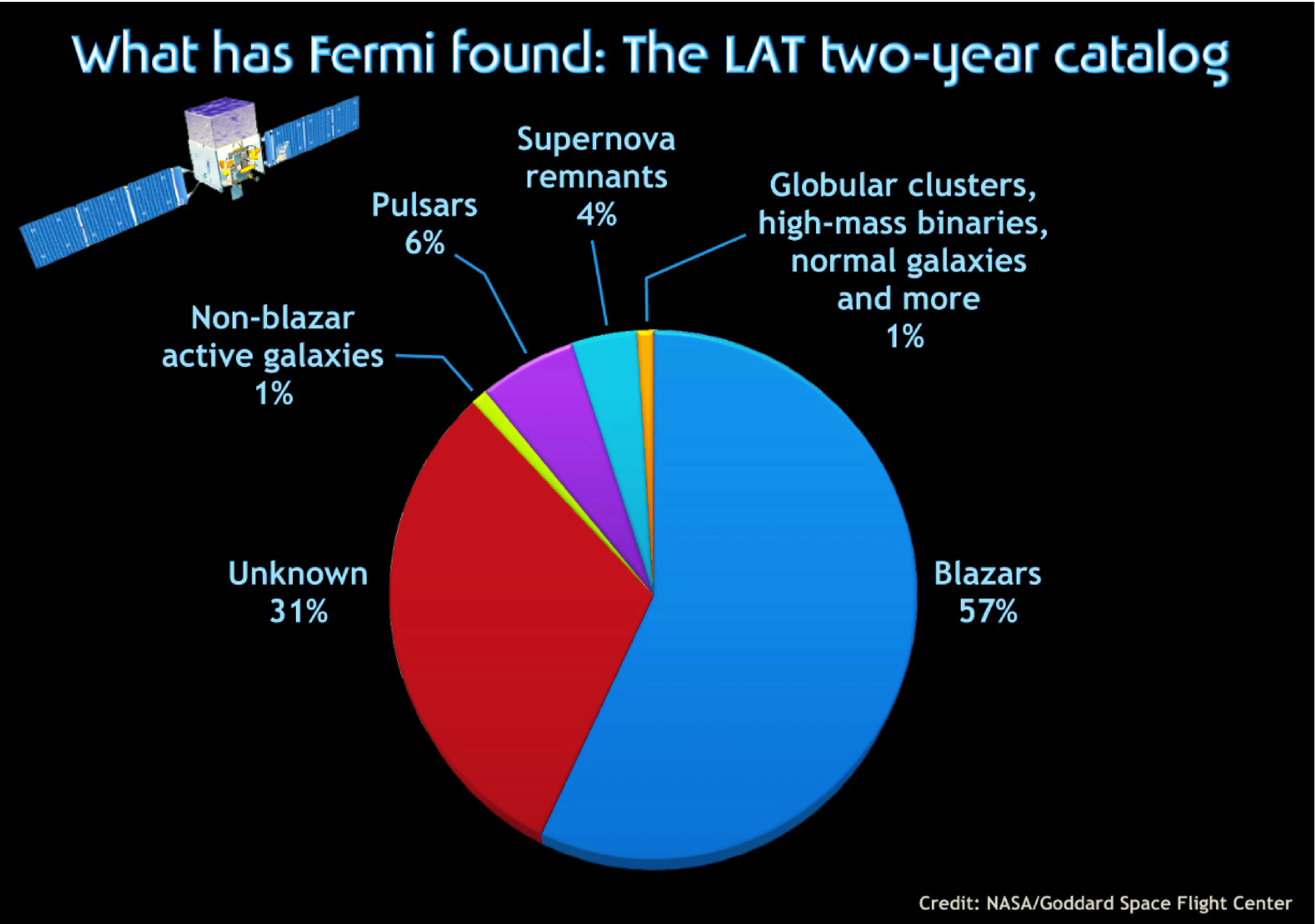


Abdo et al. 2011, ApJ, 736, 131



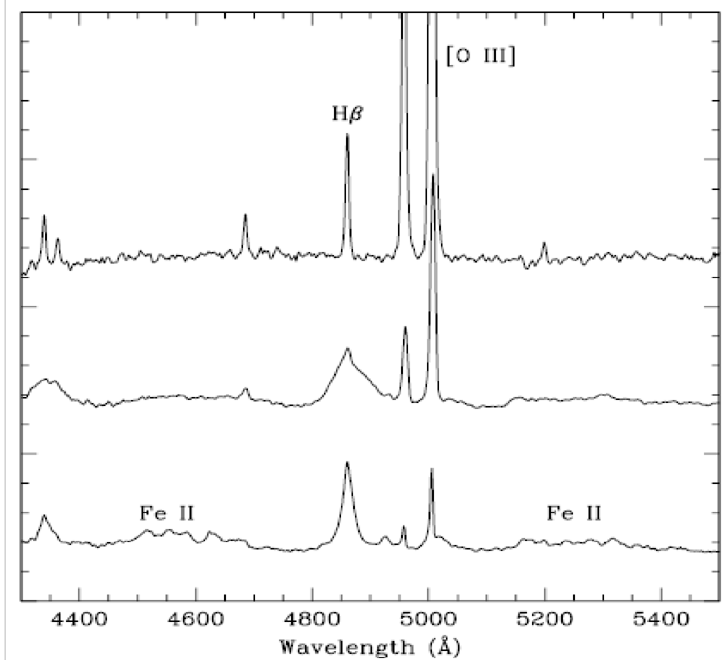
Variety of observations are needed to understand these sources

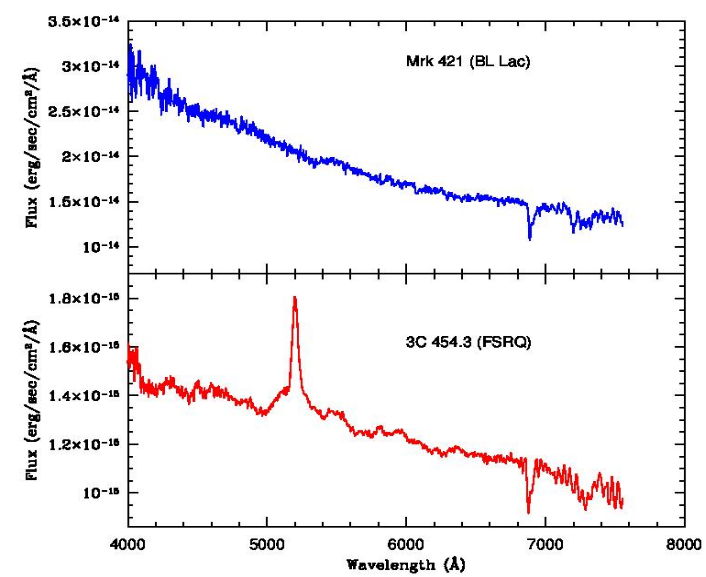
The Gamma-ray sky as seen by Fermi



Narrow Line Seyfert 1 galaxies(1985 - 2008)

- FWHM < 2000 km /sec
- [O III]/Hβ < 3 (Osterbrock & Pogge 1985)
- Have Fe II lines
- Low mass black holes (10^6 – 10^8 M$_\odot$; Decarli et al. 2008)
- Soft X-ray excess & variability
- High accretion rate (0.1 – 1 Eddington; Boroson & Green 1992; Boller et al.1996)
- Spiral host, often with bars (Crenshaw et al. 2003; Deo et al. 2006)
- Generally high star formation activity (Sani et al. 2010)





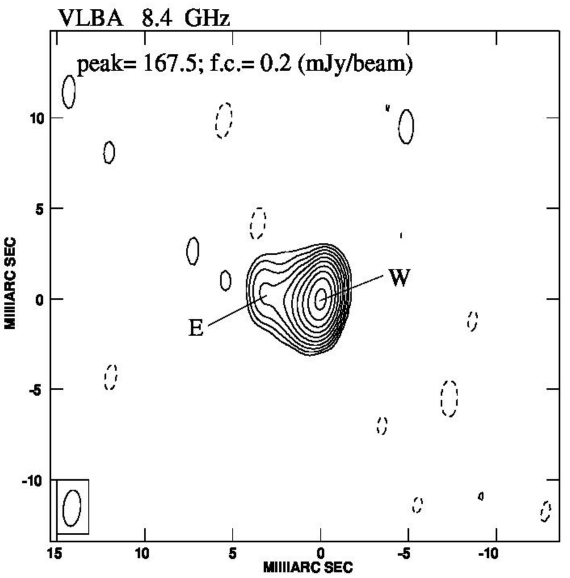
- R-parameter: often used as a proxy for jet production
- Radio-loud ($R > 10$, AGN with higher BH mass, $>10^8$ M, low accretion rates, have relativistic jets)
- Radio-quiet ($R < 10$, AGN with low BH mass, $10^6 – 10^8$ M, high accretion, do not have relativistic jets)
- NLSy1 galaxies (radio quiet, have low BH mass and high accretion rates)

INFERENCE: NLSy1 galaxies are radio-quiet AGN, and the young BH undergoing rapid growth via high accretion rate CANNOT produce relativistic jets

- Show radio-loud/radio-quiet dichotomy
- 7% are radio-loud compared to 15% in quasars

Narrow Line Seyfert 1 galaxies (2008 – Present)

- Radio spectra (blazars)
- Radio structure (blazars)
- Superluminal motion (blazars)
- Black hole mass (low v/s high)
- Host galaxies(spirals v/s ellipticals)

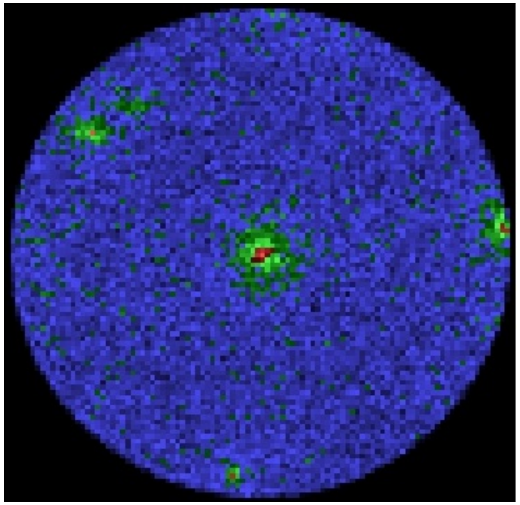


SBS 0846+513 (D'Ammando et al. 2012, MNRAS)

As of now 6 high confidence detections by *Fermi*

Strong optical polarization -> 18% (Ikejiri et al. 2011)

Confirms that these sources do have relativistic jets similar to blazars (Elliptical – Jet paradigm)


PMN J0948+0022

Key Questions:

1. What is their intra-night optical variability nature ?

2. How do their γ-ray spectra look like (FSRQs v/s BL Lacs) ?

3. What is the nature of their broad band SED (FSRQ type v/s BL Lac type)

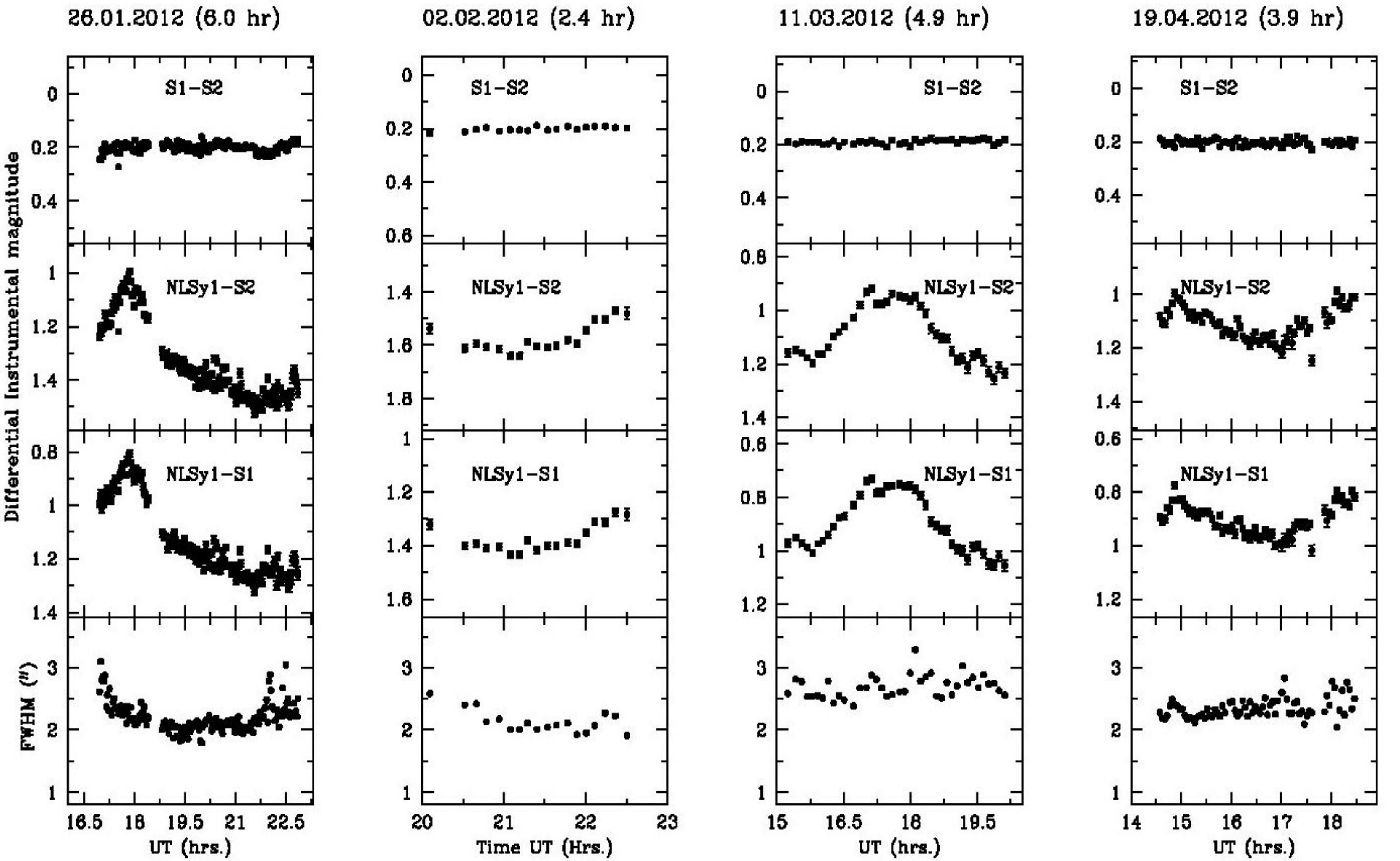
1. What is their intra-night optical variability nature ?

- RQQs 17%
- LDQs 12%
- CDQs 20%
- BL Lacs 70% (Stalin et al. 2005)

- 3 objects monitored over 10 nights in 2012 (more observations are made during 2014/2015)
- 130 cm in Devasthal, ARIES was used
- INOV noticed with amplitudes > 3%
- DC ~85%
- Mini-flares in time scales as short as 12 min

Vaidehi S. Paliya, C. S. Stalin et al. 2013a, MNRAS, 428, 2450

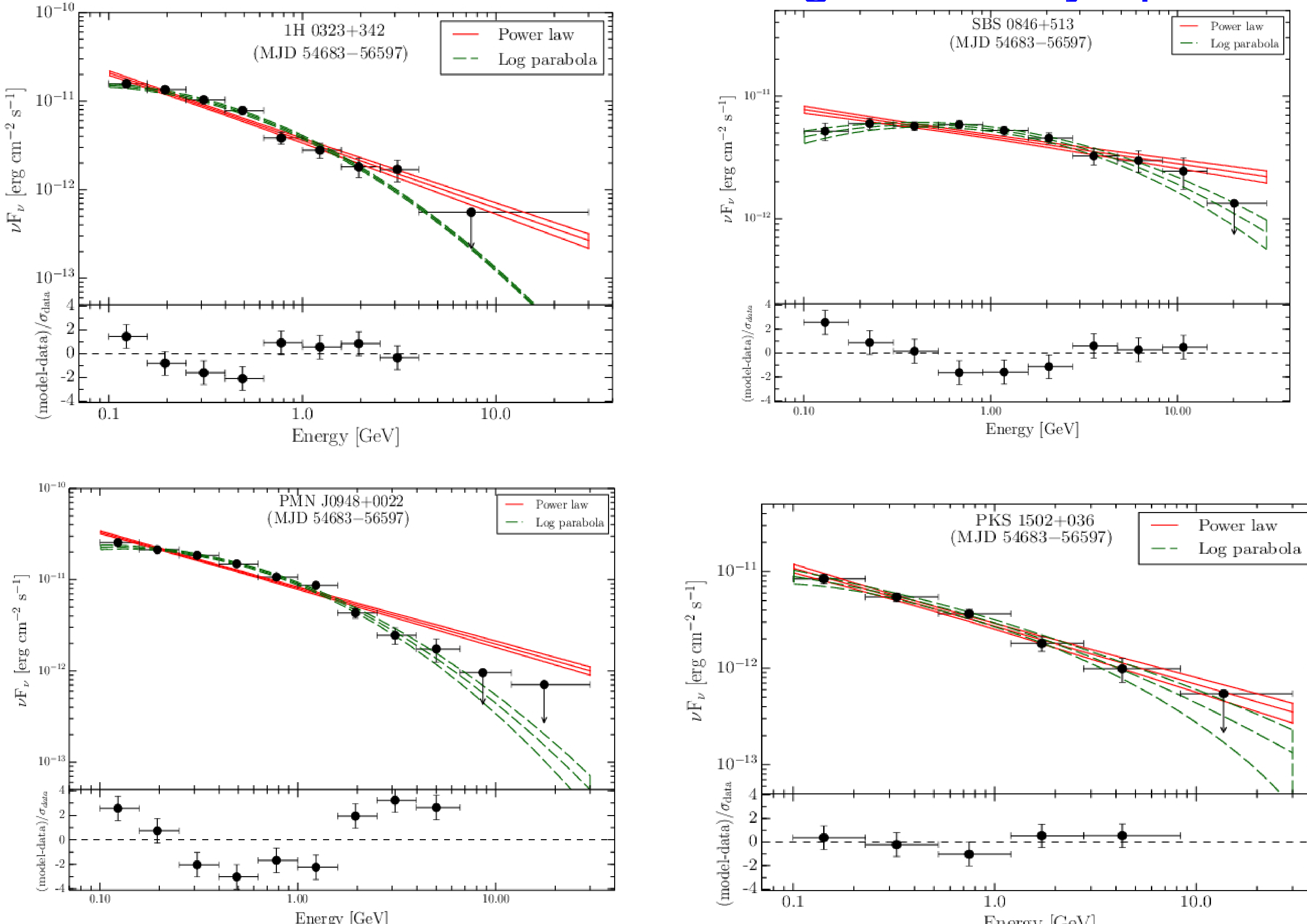
Intranight optical variability



Vaidehi S. Paliya, C. S. Stalin et al. 2013, MNRAS, 428, 2450

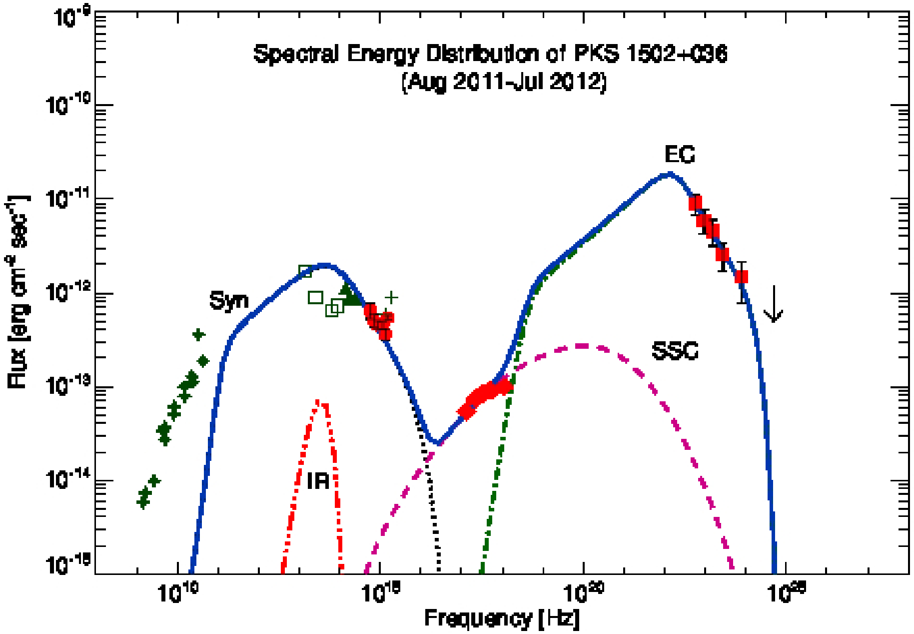
Their INOV nature are similar to blazars (FSRQ v/s BL Lacs)

2. What is the shape of their gamma-ray spectra



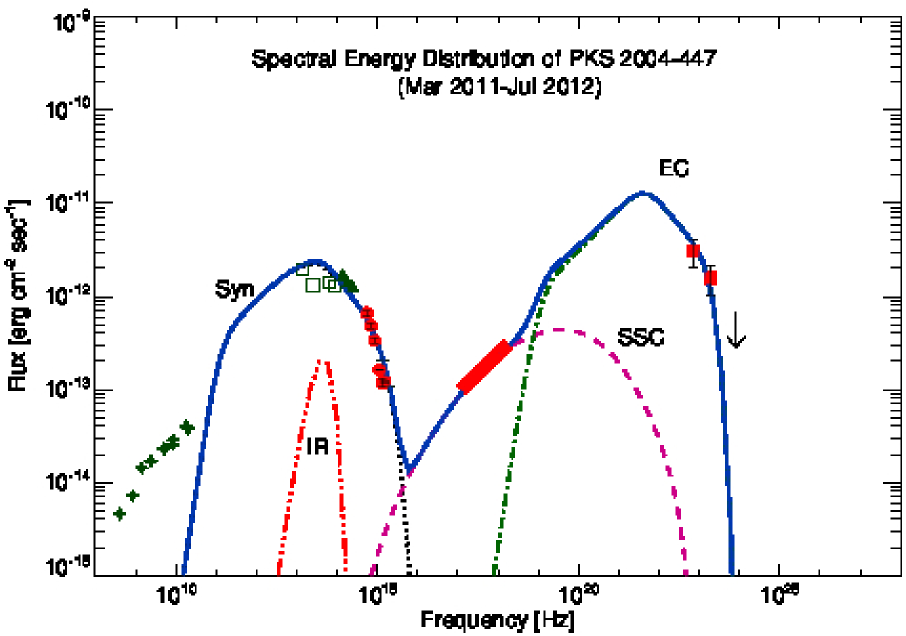
V. S. Paliya & C. S. Stalin, C. D. Ravi Kumar 2015, AJ, 149, 41

How is their broad band spectral energy distribution ?



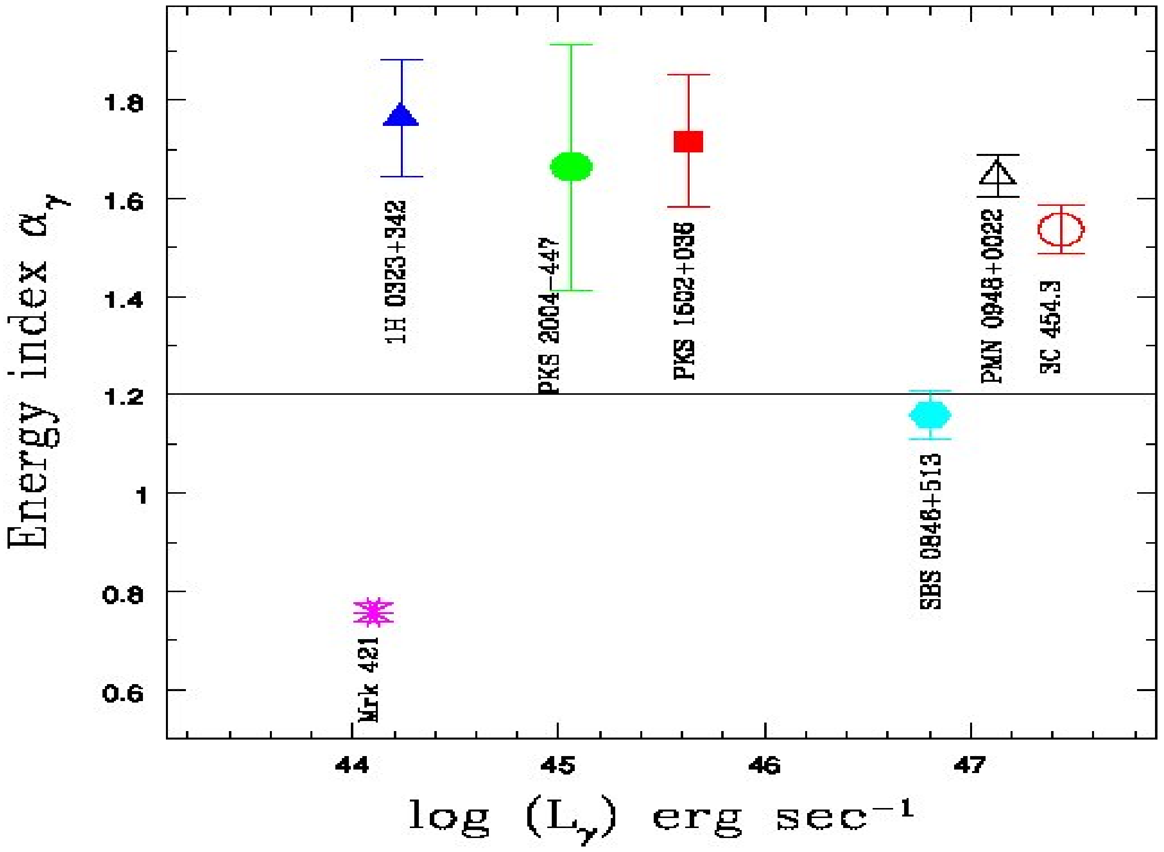
FSRQs: High energy is because of EC, Compton Dominance > 1

BL Lacs: High energy is because of SSC, Compton Dominance < 1



Python- based code has been developed to carryout SED modeling

V. S. Paliya & C. S. Stalin et al. 2013b, ApJ, 768, 52



γ-ray loud NLSy1 galaxies have a wider range of γ-ray luminosities

They have steep γ-ray spectral index more like FSRQs

Conclusions

- Break is seen in the Gamma-ray spectra, similar to FSRQs
- INOV similar to blazars
- SED similar to FSRQs
- Compton Dominance greater than unity; FSRQs
- At-least one source is found to show large polarization

Gamma-ray loud NLSy1 galaxies are low BH mass FSRQs but in a spiral galaxy

They now constitute a third class of gamma-ray emitting AGN

Inference

- Elliptical jet paradigm is an observational bias -> galaxies can have relativistic jets irrespective of their morphological types

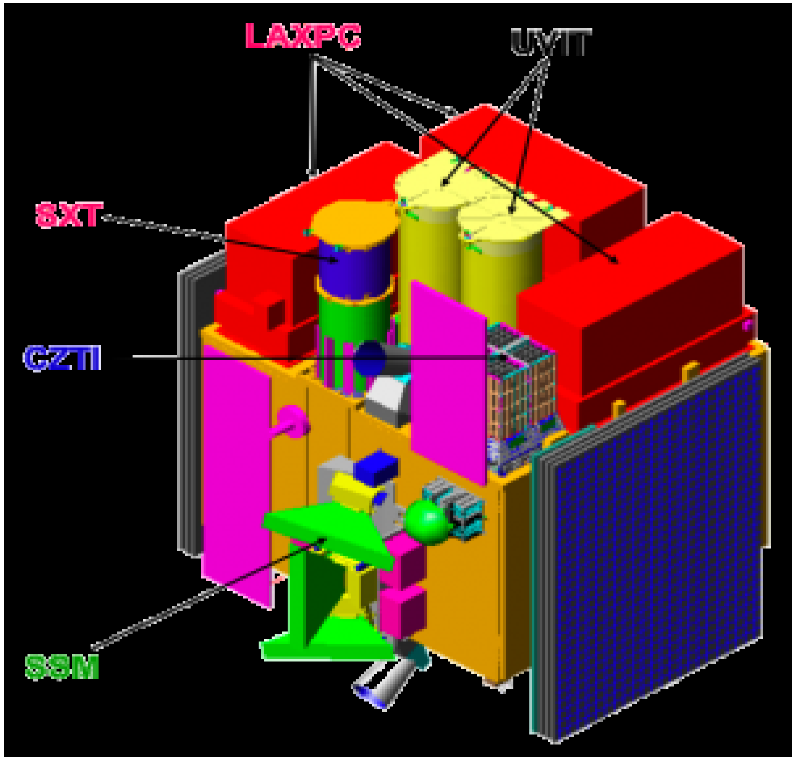
- We are begining to prble a new regime of relativistic jets -> low mass black holes

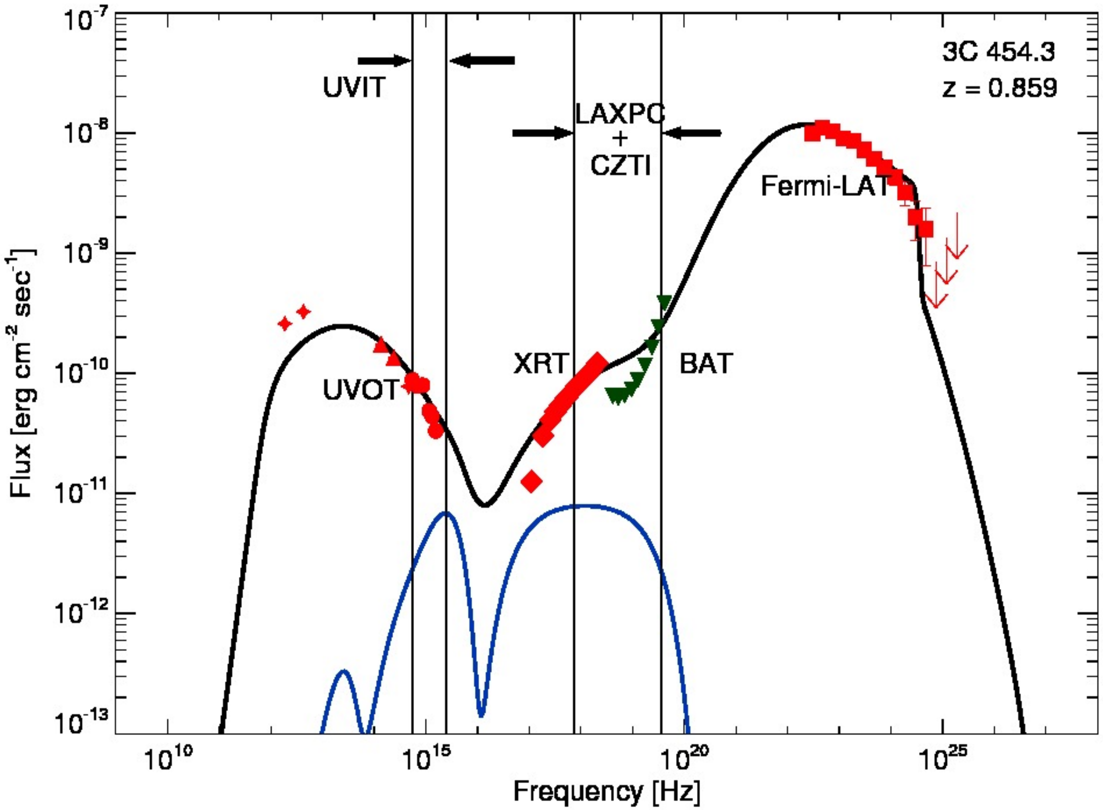
Before *Fermi* / After *Fermi*

AGN properties	Without jets/radio-quiet	With Jets/radio-loud
Galaxy morphology	Spiral / Elliptical	Elliptical **Spiral**
Types	NLSy1s / Sy1 / Sy2	Blazars (FSRQs, BL Lacs) /Radio galaxies **NLSy1s**

The way forward

- Simultaneous multiband observations is the key,
- ASTROSAT is going to play a major role in the coming days





Launched: 28 October 2015