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GAMMA LOUD NLS1S: A LOW SCALE VERSION OF FSRQS?

C. Boisson[1]

Abstract.
The detection of several variable radio-loud narrow-line Seyfert 1 (NLS1) galaxies by Fermi hints at the existence of a rare, new class of gamma-ray emitting active galactic nuclei with low black hole masses. Like flat spectrum radio quasars (FSRQs), their gamma-ray emission is thought to be produced via the external Compton mechanism whereby relativistic jet electrons upscatter a photon field external to the jet, e.g. from the accretion disc, broad line region (BLR) and dusty torus, to higher energies. In this respect, jetted NLS1s seem to be situated between blazars (dominated by non-thermal emission) and Seyferts (accretion disc dominated). In this presentation, we compare the physical properties of the central engines of gamma-loud jetted NLSy1s and the higher disk luminosity FSRQS via multi-component radiative modeling of the observed multi-wavelength radiation Spectral Energy Distribution.

Keywords: Seyfert, blazar, jets, gamma-ray, models

1 Introduction

Blazars are a peculiar class of radio-loud active galactic nuclei (AGN) with jets of relativistic magnetized plasma ejected from the neighborhood of an accreting black-hole, viewed close to the line of sight. The majority of γ-ray emitting AGNs discovered by the *Fermi Gamma-Ray Space Telescope* (Fermi) are blazars (Acero et al. 2015), evenly distributed between flat-spectrum radio quasars and BL Lacertae objects. The spectral energy distribution (SED) of BL Lacs, from radio frequencies up to gamma-rays, is jet dominated, exhibiting a double humped synchrotron and inverse Compton spectrum, the two bumps being roughly equal in luminosity, that can be accurately described by a simple one-zone leptonic Synchrotron Self-Compton (SSC) emission model. In contrast, the FSRQ have GeV Compton humps that are considerably more luminous than their synchrotron emission humps and features a more complex emission spectrum that requires radiation from external photon fields such as the AGN components (accretion disc, corona and broad-line region), and/or the dusty torus to be accounted for.

This differences can be understood in the nature of the accretion flow. BL Lacs have low accretion rates so the accretion flow is in the hot, advection dominated state with little intrinsic UV emission and hence a very weak or absent BLR, while FSRQs accrete at higher rates and have standard disks (Fig. 1). Both BL Lacs and FSRQs are associated with large mass ($M_{BH} \sim 10^8$ $M_\odot$) black holes hosted by elliptical galaxies. BL Lacs and FSRQ form the so-called blazar sequence of increasing accretion power onto the most massive BHs (Ghisellini et al. 2017).

A very small number of γ-ray emitting AGN, detected by Fermi, are optically classified as narrow-line Seyfert 1s. NLS1s are a subclass of AGN characterised in the optical by narrow permitted emission lines (Hβ FWHM ≤ 2000 km s^{-1}), weak forbidden [OIII] lines ([OIII]λ 5007/H$\beta \leq 3$), and strong iron emission lines (Osterbrock & Pogge 1985).

These are similar to the standard blazars in that their Fermi γ-ray emission is dominated by a relativistic jet aligned close to the line of sight, but distinctly different in that this is powered by accretion onto a black hole of much lower mass. They tend to have higher accretion rates relative to their Eddington limit than typical Seyfert 1 (Foschini 2011). The discovery of narrow-line Seyfert 1s as a class of γ-ray emitting AGN is intriguing, since they generally reside in gaz rich disk galaxies (Crenshaw et al. 2003) and are not known as strong radio

[1] LUTH, Observatoire de Paris, site de Meudon, France

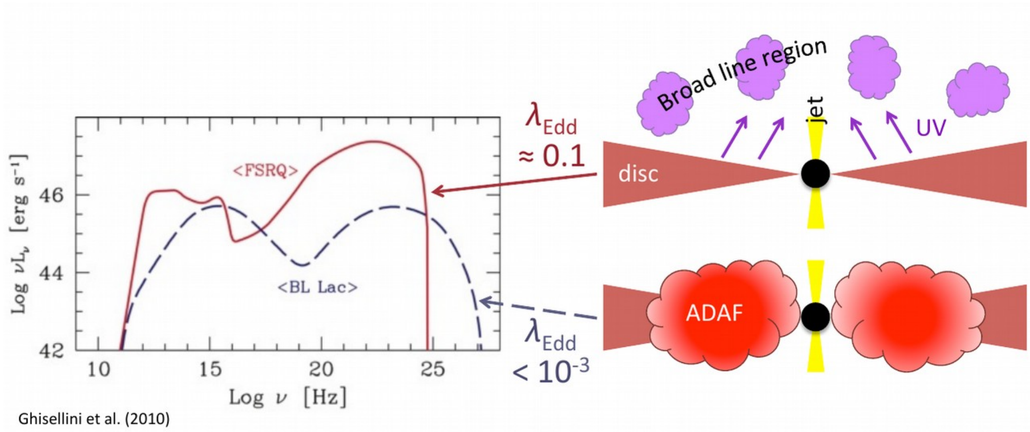

Fig. 1. Blazars SED, courtesy of D. Kynoch

emitters, but evidence has been collected that a few % (Komossa et al. 2006) of NLS1s are radio loud and show a flat radio spectrum.

This recent detection of narrow-line Seyfert 1 galaxies by Fermi suggests the existence of a rare, new class of γ-ray emitting active galactic nuclei. We started a detailed modeling of those γ-NLS1s to investigate whether γ-NLS1s represent the low-mass, low-power tail of FSRQs in the blazar sequence, or whether they constitute a genuinely new class of their own.

In the following we give a summary of a preliminary study on NLS1s detected by Fermi in both quiescent and flaring states in the GeV domain. We apply a multi-component radiative model that considers both the emission from the relativistic jet and the external photon fields (torus, disc, corona, and BLR) and discussed results in line with FSRQs.

2 Multi-component model

To model the NLS1 SED, we apply a multi-component code, described in Arrieta-Lobo et al. (2017). This code is based on a stationary homogeneous one-zone blob in jet SSC model with additional external photon fields from the dusty torus (a simple black body, Dermer & Menon (2009)), the accretion disc (a multi-temperature black body,Dermer & Menon (2009)), the X-ray corona (a simple power law with an exponential cut-off at 150 keV (Ghisellini & Tavecchio 2009) and the BLR.

Accretion disc and corona photons will ionize the BLR, which is considered as a spherical shell of width $\triangle$R expanding between an inner and an outer radius. The illuminating continuum is modelled as combination of a UV bump with an X-ray power law. The density of the BLR has a power law shape within $\triangle$R, with an index ξ fixed to $\xi = 2$ that implies that most of the ionization takes place close to the inner edge of the BLR. The BLR reprocesses disk radiation into emision lines. Thus, the BLR will emit a spectrum of monochromatic emission lines (see Cerruti et al. (2013) for more details).

The direct radiation from the components are scaled by the black hole accretion rate and black hole mass. Compton up-scattered components depend on opacities of the different photon fields. The radius of the torus and of the BLR scale with the disc luminosity, which depends on the black hole mass M_{BH} and the radiative efficiency (see for instance Ghisellini & Tavecchio (2009)), reducing the number of free parameters of the model. Parameters and model constraints are given in Fig. 2 (left).

Note that the luminosity of the external inverse compton (EIC) components is strongly dependent on the distance between the blob and the black hole

2.1 Application to NLS1s

For each source we assemble two different multi-wavelength datasets with respect to Fermi gamma-ray flux level, one representing the quiescent/average state and one for a flaring state.

The gamma-ray radiation is explained by a combination of EIC emission from jet electrons on the photon field from the accretion disc and (dominantly) the BLR. For each studied NLS1s, the characteristics of the

Component	Parameter	Value
Black Hole	Mass	$M_{BH} \sim 10^7 - 10^9$ M$_\odot$
Emission region	Distance	$R_{src} < R_\gamma < R_{out}^{BLR}$]
Torus	Temperature	$T_{IR} \sim 1200$ K-1300 K
	Distance	$R_{IR} = 3.5 \times 10^{18} \sqrt{\frac{L_D}{10^{45}}} \left(\frac{T_{IR}}{10^3}\right)^{-2.6}$ cm
	Covering factor	$\tau_{IR} \sim 0.1 - 0.3$
Big Blue Bump	Inner radius	$R_{IN} = 3R_S$
	Outer radius	$R_{OUT} = 500R_S$
	Accretion efficiency	$\eta_{Edd} = \frac{1}{12}$
	Eddington ratio	$l_{Edd} \sim 0.5 - 1.0$
Corona	Inner radius	$R_{IN} = 3R_S$
	Outer radius	$R_{OUT} = 60R_S$
	Reprocessing factor	$\tau_X \sim 0.01 - 0.5$
Broad Line Region	Distance	$R_{BLR} \simeq 10^{17} L_{disk,45}^{1/2}$ cm
	Width	$\Delta R = 3\, R_{BLR}$
	Density profile	$\zeta = -2$
	BLR optical depth	$\tau_{BLR} \sim 10^{-4} - 0.1$

	1H 0323+342	
	Quiescent	Flare
δ	9	11
K [1/cm^3]	6.5×10^6	8×10^6
R_{src} [cm]	1.15×10^{15}	1.15×10^{15}
B [G]	2.6	2.6
$n1$	2.2	2.2
$n2$	4.2	3.4
R_γ [R_G]	3×10^3	3×10^3
l_{Edd}	~ 0.76	
$\dot{m}$ [$M_\odot$ yr^{-1}]	~ 0.43	
L_{Disc} [erg s^{-1}]	2×10^{45}	
u_e/u_b	5.66	9.63
n_e [1/cm^3]	1.85×10^6	3.16×10^6

Fig. 2. Left: Model constraints. **Right:** 1H0323+342 - all quantities are input parameters to the model but the last four that are derived from the input parameters.

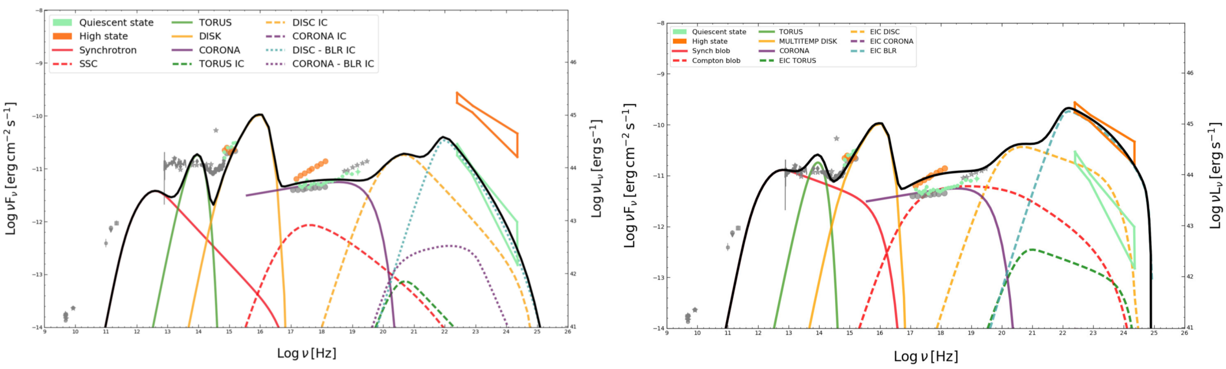

Fig. 3. Left: 1H 0323+342 quiescent state. **Right:** 1H 0323+342 flaring state.

external photon fields are kept constant between different states, to reduce the number of free parameters of the model. All variations are explained by changes in the electron population in the compact relativistic jet.

We can account for enhanced flaring radiation assuming only parameters linked to the jet/blob vary. The transition from quiescent to flaring states is accounted for by denser emission regions and larger bulk Doppler factors. One example is given in Fig. 2, right for the model parameters and Fig. 3 for the resulting SED model).

Gamma-loud NLS1s can therefore be modelled as FSRQs, underlying the similarities between both types of objects. However NLS1s seem not to simply be low mass FSRQs, as the standard scaling relation between jet and accretion power (as in Ghisellini et al. (2014)) highly overpredicts the jet power deduced for those γ-loud NLS1s.

2.2 Location of the emission region

The detection in the very high energy regime would provide important clues on the location of the emitting region in NLS1s, since their central regions, as for FSRQs, are expected to be highly opaque to gamma rays above few tens of GeV.

In Fig. 4, one can see that when the emitting blob is inside the BLR (at $\sim$3 10^3 R_G), the Fermi-LAT spectrum is due to EIC on BLR lines and one would not expect TeV emission due to absorption in the BLR. Whereas when the emission region is beyond the BLR (at $\sim$3 10^5 R_G), the Fermi-LAT spectrum is due to EIC on dust torus and TeV emission is possible. In that case however one would not expect rapid variability due to the large size of emission region.

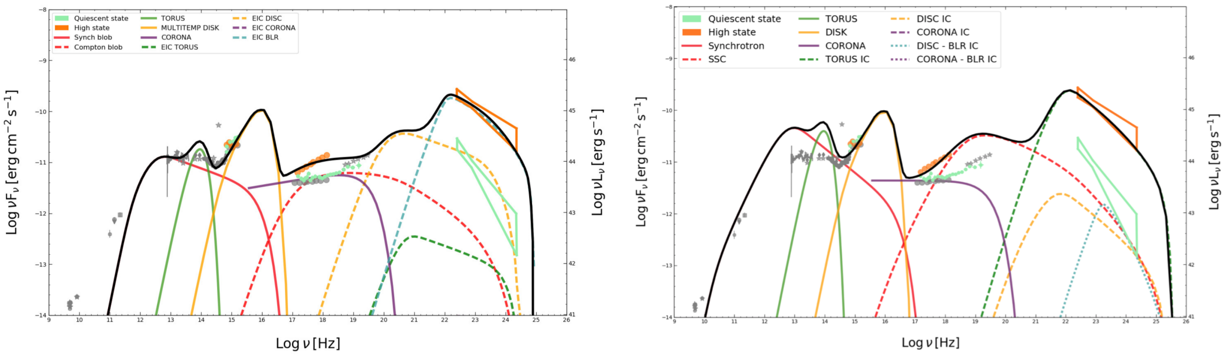

Fig. 4. 1H 0323+342 emission region **Left:** inside the BLR; **Right:** beyond the BLR.

3 Conclusions

NLS1s typically show very strong soft-excess emission, detected above jet emission in the γ-NLS1s. The gamma emission can be accounted for by Compton up-scattering of seed photons external to the jet, as for FSRQs. Changes in jet parameters can explain gamma variability, gamma flares requiring denser emission regions and larger bulk Doppler factors. The external photon fields remain unchanged in that scenario. But γ-NLS1s may not just be low scale version of FSRQs as their jets seem to be underpowered compared with that predicted based on scaling FSRQs. If the the emission region is beyond the BLR, emission in the TeV could be possible but fast variability is then not expected.

The Cherenkov Telescope Array, the next generation of ground-based imaging atmospheric Cherenkov telescope (IACT), with its sensitivity a factor 5 to 20 better with respect to the current IACTs arrays, will give the opportunity to investigate flaring γ-NLS1 galaxies at the highest energies, and thus bring constraints to the models.

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