Exploring the Disk-Jet Connection in Gamma-Ray Selected Blazar AGN

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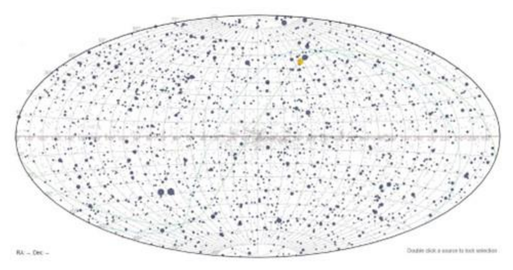
We explore the disk-jet relationship in a sample of gamma-ray selected Blazar AGN. Our focus is on FSRQs for which the big blue bump and broad-line region (BLR) are well contrasted with the underlying synchrotron continuum.

Gamma-ray emission is believed to emanate from Compton scattering of lower energy photons from either the accretion disk and its associated BLR and/or torus (EC) or from the synchrotron radiation field itself (SSC).

The EC scenario is likely predominant in the most luminous objects. As proxies for the disk power, we use BLR measurements – Balmer lines or rest-frame UV lines depending on source redshift – as well as blue-bump continuum fluxes.

We present the results of cross-correlation analyses between these accretion-disk emission proxies and the gamma-ray (>100-MeV) light curves obtained by the Fermi Gamma-Ray Space Telescope, typically with ~weekly sampling.

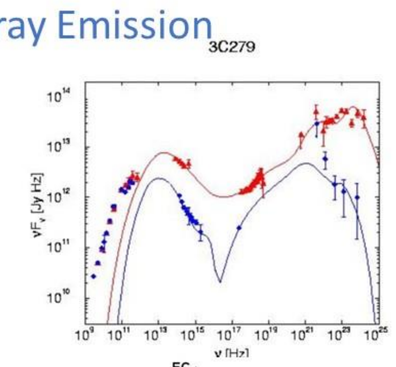
Jet-dominated (Blazar) AGN and gamma-ray Emission



The γ-rays sky at high-galactic latitudes is dominated by Blazar AGN, ~3500 cataloged. The γ-ray emission is indicative of strongly beamed and highly aligned objects and is a proxy for the jet power.

Subclasses are the BL Lac objects and FSRQs. The latter have the highest luminosities, steep spectra and the blue-bump and BLR are prominent. This work focuses on FSRQs.

The external-Compton or EC mechanism is believed to be predominant in high-luminosity objects given their large Compton ratios and multi-component Compton-hump SED structures sometimes exhibited.



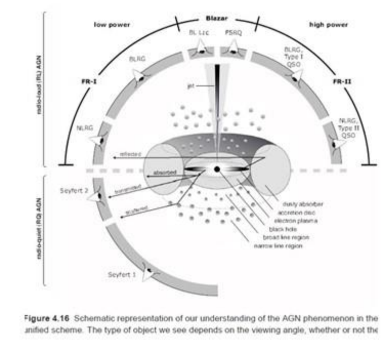
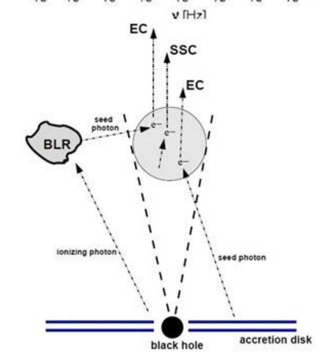


Figure 4.16 Schematic representation of our understanding of the AGN phenomenon in the unified scheme. The type of object we see depends on the viewing angle, whether or not the



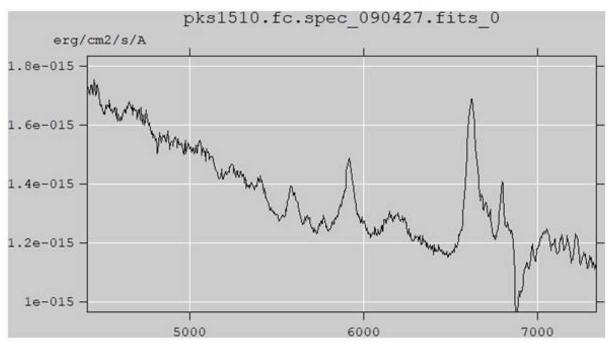
Sample Selection and Data Description

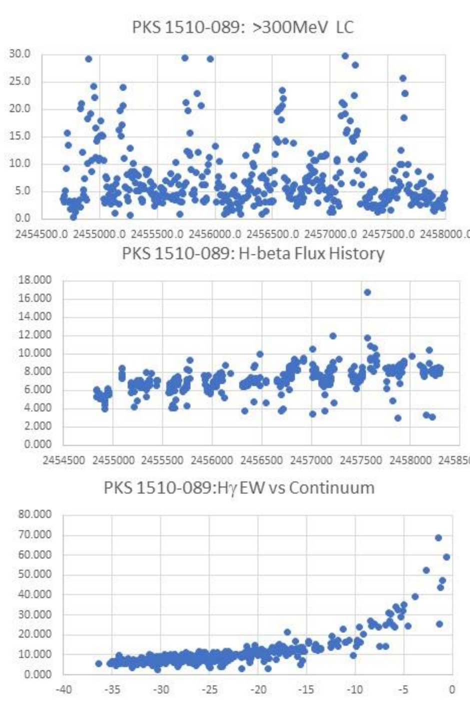
- All data used are in the public domain and were obtained from the website of the Fermi Science support Center <https://fermi.gsfc.nasa.gov/ssc/>.
- The source sample characteristic were gamma-ray-bright, FSRQ Blazars with high-variance flux histories.
- They were included in the Steward Observatory photometric-spectral-spectral-polarimetric data as described in Smith et al. 2009 <arXiv:0912.3621> and 2011:<arXiv:1110.6040>
- The Spectral coverage, ~4000-7000A, included at least one prominent AGN broad line, notably CIV, C III, Mg II, Hγ, Hβ
- γ-ray light curves, *E>300 MeV*, were sampled with 1-week binning

Source ID	Redshift	BLR Lines Assessed:
3C 273	0.158	Hγ,Hβ
3C 279	0.538	MgII
3C454.3	0.859	MgII
4C +01.02	2.099	CIV, CIII
4C +14.23	1.038	MgII
4C +28.07	1.207	CIII, MgII
BZU J0742+5444	0.723	MgII
CTA102	1.037	MgII, CII]
PKS 0454-234	1.003	MgII, CII]
PKS 0736+01	0.191	Hδ,Hγ,Hβ
PKS 1222+216	0.435	Hγ,Hβ
PKS 1244-255	0.638	Hδ,Hγ,MgII
PKS 1502+106	1.839	CIV
PKS 1510-089	0.360	Hγ,Hβ
PMN J2345-1555	0.621	MgII
S3 0827+24	0.939	MgII

Data Examples:

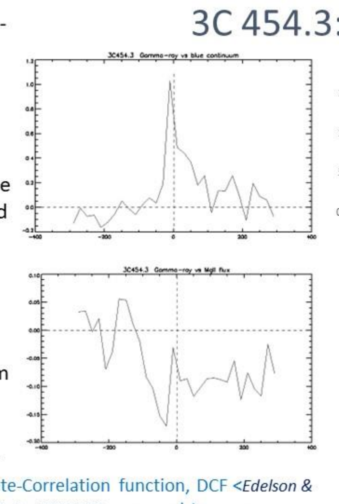
Sample spectrum below, in this case PKS 1510-089, plotted in the source frame and not reddening corrected. Coverage spans about 4000Å - 7000Å At redshift of z=0.191 the Balmer lines, δ, γ and β are seen is [O III]. On the right-hand panels the γ-ray and Hβ flux histories, spanning about 10 years are shown. The Hγ EW is also plotted against the continuum flux for the full data set.



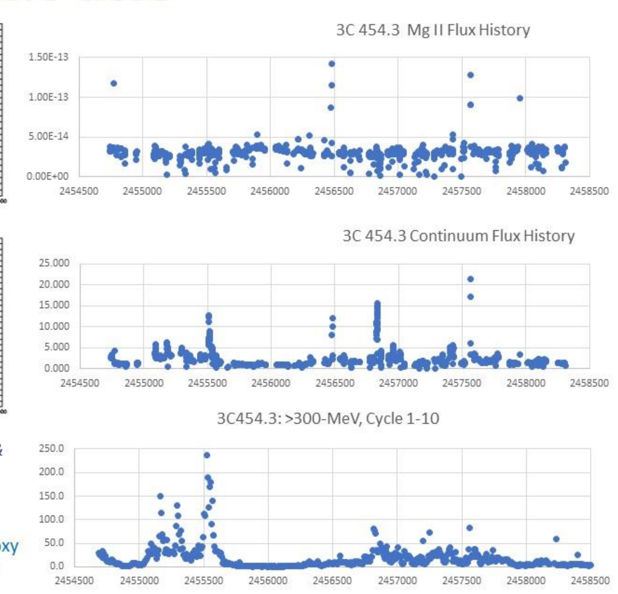


3C 454.3: z=0.858

This is a prolific gamma-ray source with on of the highest variance statistics among the ~3500 Fermi Blazars. The Mg II (2800Å, source frame) broad line was extracted and fitted (EW and net Flux) for 725 epochs over 2008-218. While a correlation, consistent with zero lag, is seen between the continuum and the γ-ray intensity the line flux is not significantly correlated.

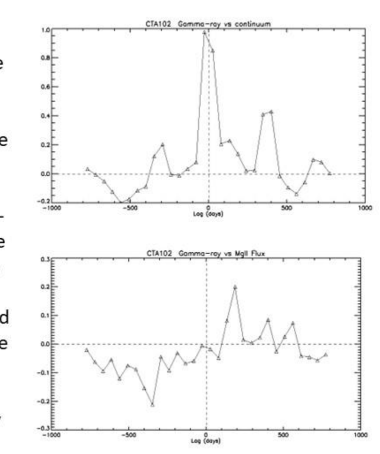


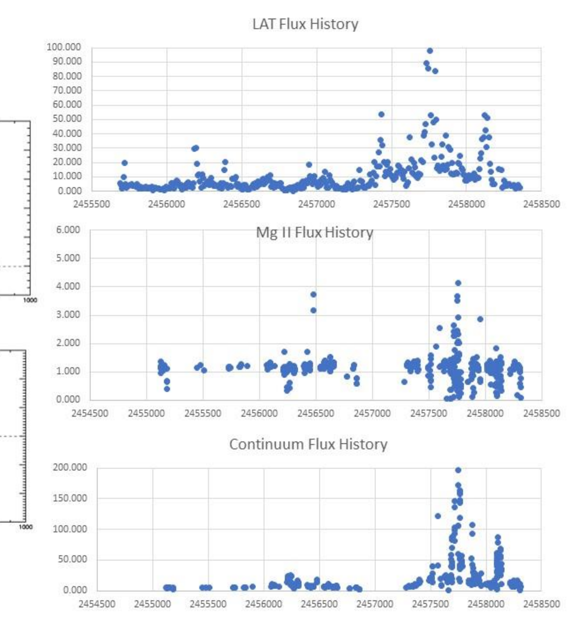
The discrete-Correlation function, DCF <*Edelson & Krolik, 1988, ApJ 333,646*> was used to assess possible correlated behavior between the accretion disk – a proxy for which is the BLR emission line intensities – and the γ-rays as a proxy for the jet power. Uncertainties were computed following Peterson, et al 1998, PASP 110, 660.



CTA 102

CTA 102 is a consistently bright γ-ray source with a high variance and prolific flaring. At redshift z=1.03 the 2800A Mg II feature is accessible from the ground and strongly detected and variable (EW~-5Å to ~ -30Å). Here as you can see the blue continuum is strongly correlated with the γ-rays (the γ-ray lag of <~30 days suggested here is statistically consistent with 0 days) , but the line flux seems uncorrelated.

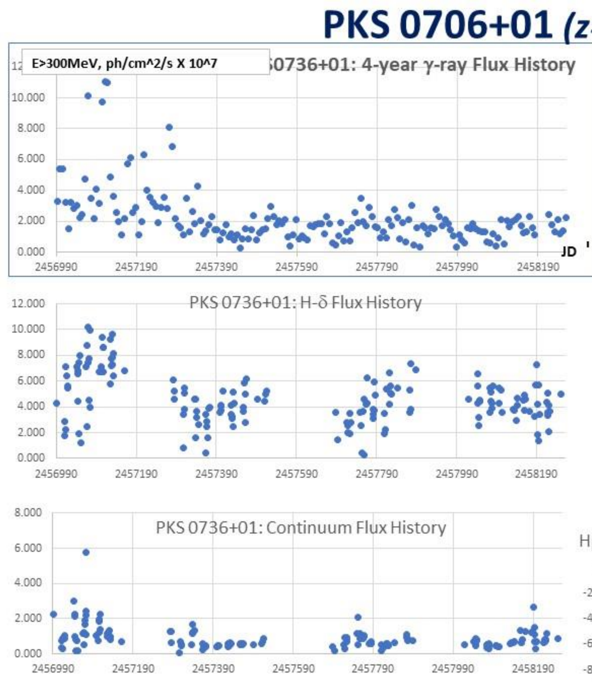




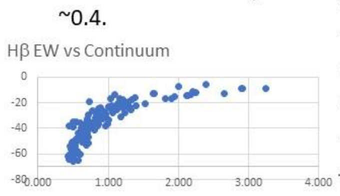
Summary of Results

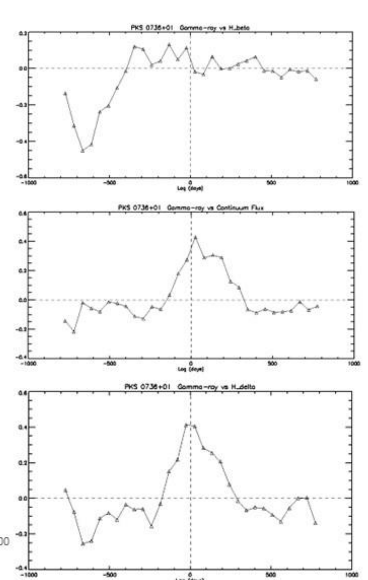
Source ID	Redshift	BLR Lines Assessed:	Results: γ-ray to Continuum	γ-ray to BLR	Comments
3C 273	0.158	Hγ,Hβ	Null	Null	
3C 279	0.538	MgII	Null	Null	
3C454.3	0.859	MgII	Null	Null	
4C +01.02	2.099	CIV, CIII			PKS 1016+013
4C +14.23	1.038	MgII	correlated, zero lag	correlated, zero lag	
4C +28.07	1.207	CIII, MgII	correlated, <50-day lag	correlated, <50-day lag	possible non-zero lags in
BZU J0742+5444	0.723	MgII	correlated, zero lag	Null	
CTA102	1.037	MgII, CII]	correlated, zero lag	Null	
PKS 0454-234	1.003	MgII, CII]	Null	Null	
PKS 0736+01	0.191	Hδ,Hγ,Hβ	correlated, zero lag	δ,γ ~zero lag,β Null	H-γ most interesting case
PKS 1222+216	0.435	Hγ,Hβ	correlated, zero lag	marginal lag	
PKS 1244-255	0.638	Hδ,Hγ,MgII	weakly correlated?		signifacance?
PKS 1502+106	1.839	CIV	Null	Null	no CIV - continuum lag
PKS 1510-089	0.360	Hγ,Hβ	Null	β Null, γ ~zero lag	
PMN J2345-1555	0.621	MgII	Null	Null	
S3 0827+24	0.939	MgII	uncorrelated	uncorrelate	OJ 248

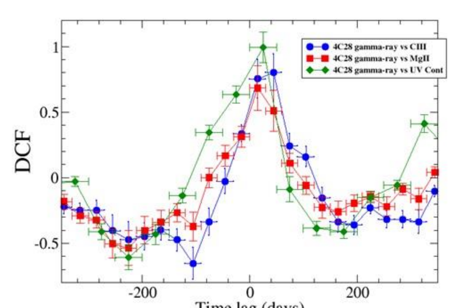
PKS 0706+01 *(z=0.189)*

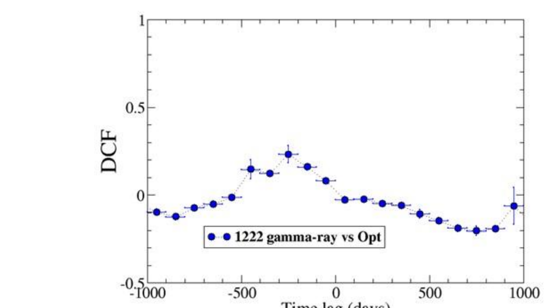


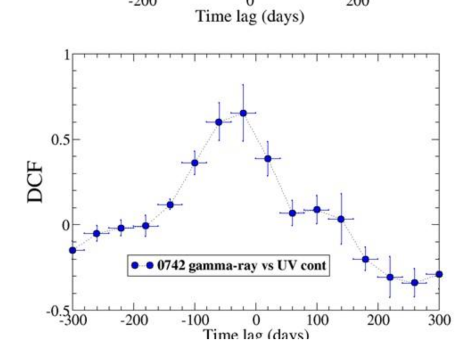
The Balmer lines, δ γ β, are all measured at this redshift. While Hβ is variable and correlated with the continuum it is uncorrelated with the γ-rays. The continuum and both Hδ and Hγ (not shown) are possibly correlated at zero lag but at a level of only ~0.4.











Our analysis when error-propagation is considered suggests a strong correlation with no time lag shorter than 50 days (time binning for the DCF analysis) for 4C+28.07. A mildly strong correlation is also seen for BZU 0742+5444. There is a hint of a very weak correlation for gamma-ray – continuum and Balmer variations for PKS 1222+216.

Summary and Conclusions

- The UV-optical continuum is often correlated with the gamma rays consistent with zero lag.
- The BLR lines are most often uncorrelated. There are several suggestive cases, notably 4C+28.07 and PKS 1222+216
- This suggests that the UV continuum – γ-ray correlation is not due to the disk (i.e., the big-blue-bump component) but is likely synchrotron
- The EC could be dominated by the torus? Or the γ-ray production occurs further downstream in the jet – i.e., well beyond the scale of the BLR and any correlations get smeared out?
  - Note that following a different approach – utilizing sub-parsec scale jet dynamics and overall radio luminosity as a proxy for jet power and the instantaneous BLR luminosity for a large sample <Rajguru & Chatterjee 2022 <arXiv:2209.12264v1> find discernable correlation, but redshift biases are noted.