The (sub-) mm and γ-rays connection in blazars

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Planck

- launched in August 2009
- all-sky survey in 6 months
- 9 months catalog of compact sources (ERCSC) at 9 frequencies: 30, 44, 70, 100, 143, 217, 353, 545, 860 GHz
Planck Early Results 15: Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources


Observatories involved: APEX, ATCA, Effelsberg, IRAM, Medicina, Metsahovi, MRO, OVRO, RATAN, VLA, KVA, Xinglong, SWIFT, Fermi/LAT

Simultaneous Planck, Swift, and Fermi observations of X-ray and \(\gamma\)-ray selected blazars

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A&A accepted, arXiv:1108.1114
Planck Early Results 15: Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources


A&A accepted, arXiv:1101.2047

\[ \alpha_{\text{LF}} (\leq 70 \text{ GHz}) \]
\[ \alpha_{\text{HF}} (> 70 \text{ GHz}) \]
A flat $\alpha_{\text{HF}}$ has two possible explanations:

- either the total HF spectra are defined by several underlying components or,

- the energy spectrum of the electron population is much harder than generally assumed ($s \approx 1.5$)

Planck Early Results

Ackermann + 2010
Simultaneous Planck, Swift, and Fermi observations of X-ray and $\gamma$-ray selected blazars

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A&A accepted, arXiv:1108.1114
• Simple SSC models cannot explain the SED of many blazars

• No obvious correlation of the type predicted by the blazar-sequence was found.
mm and γ-ray connection

- From the Metsahovi QSO monitoring program, we select the 45 best sampled light curves.

- We decompose the 37 GHz Metsahovi light curves into individual exponential flares as in Valtaoja et al. (1999)

- Each of the individual outburst corresponds to the ejection of a new component into the jet (Savolainen et al. 2002).

mm and γ-ray flares

mm and γ-ray flares
mm and γ-ray flares

mm flare onset ≈ e-folding time

mm-γ-rays delay

The average delay from a mm-flare onset \((S_{\text{max}}/e)\) to the peak of the most intense γ-rays is,

\[
t_{0}^{\text{mm}} - t_{\text{peak}}^{\text{LAT}} \sim -70 \text{ days}
\]

in the source frame,

\[
t_{0}^{\text{mm}} - t_{\text{peak}}^{\text{LAT}} \sim -30 \text{ days}
\]
The location of the $\gamma$-rays zone

We convert the observed delay into linear distances by

$$\Delta \tau = \frac{\beta_{app} c (t_{0}^{mm} - t_{\text{peak}}^{\text{mm}})}{\sin \theta (1 + z)}$$

$$< R_\gamma > \sim 7 \text{ pc}$$

Well agreement with the average distance derived by Pushkarev et al. (2010)

**OJ 287 :** $R_\gamma > 14 \text{ pc}$  
(Agudo et al. 2010)

**3C 279 :** $R_\gamma \sim 10^5 R_\odot$  
(Fermi-LAT collaboration. 2010)

<table>
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<th>alias</th>
<th>phase</th>
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The $\gamma$-ray emission site

$EC$ [Accretion-disk, BLR]

$SSC$ [jet]

$EC$ [Torus]

$7 \text{pc} \sim 1.5 \times 10^5 R_G$

(assuming $M_{BH} = 5 \times 10^8 M_\odot$)
The strongest γ-ray flares occur after the mm flare onset and are produced at \( <R_γ> = 7 \) pc from the radio-core.

The source of seed photons could be either the jet itself \( (SSC \ fails \ to \ reproduce \ the \ observed \ γ-rays, \ Lindfors \ et \ al. \ 2006) \) or the dusty torus \( (\ few \ detections, \ Turler \ et \ al. \ 2006, \ Malmrose \ et \ al. \ 2011). \)

Soft-photon field from BLR unlikely...?
is Jet Influencing BLR?
The Telescopes

**3C 390.3**
- Optical monitoring
  - *(Shapovalova et al. 2001; 2010)*
- Radio monitoring

**3C 120**
- Optical monitoring
  - 2002–2008
  - *(Doroshenko et al. 2009)*
- Radio monitoring
  - 2001–2008

**Very Long Baseline Array**
- 11 ± 1 telescopes
The case of 3C 390.3 (FR II)

Linear fits to component separations yield epochs of ejection from the core $D$ and passages through the stationary region $S1$.

Is Jet Influencing BLR?

The flaring optical-continuum in 3C390.3 is associated with the stationary component located in the jet ~0.4 pc from the core.

The case of 3C 120 (FR I)
Is Jet Influencing BLR?

Is Jet Influencing BLR?

3C120: The same relation between optical flares and passages of new jet components through a stationary region located at about 1.3 pc from the core.

The source of variable optical-continuum
Dusty torus

Radio-core

Outflowing BLR

Stationary feature

Non-thermal optical continuum

Broad-line emission

flux

time

Dusty torus
is Jet Influencing BLR?

The **flaring** component of the **optical-continuum** in 3C 390.3 and 3C 120 is associated with the stationary region located **in the jet**.

Since the strength of Hβ and continuum emission is correlated in 3C 390.3 and 3C 120 then a significant amount of **broad-line emission** is **driven** by continuum radiation from the **jet**.

Thus, BLR is complex and **NOT** completely virialized.

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Implications of an outflowing BLR

- **AGN models**: BLR is complex and may have other components (e.g., inflows, outflows).

- **BH mass**: Estimates using reverberation mapping relations (assume BLR is virialized).

- **γ-rays**: Outflowing BLR may serve as a source of seed photons for inverse Compton scattering? (Leon-Tavares et al. 2011, A&A, 532, 146)
The γ-ray emission site
Work in progress: Spectroscopic monitoring

Monitoring a sample of bright gamma-ray blazars with prominent broad-line emission
**Summary II**

- The strongest γ-ray flares occur after the mm flare onset and are produced at $<R_\gamma> = 7$ pc from the radio-core.

- The source of seed photons could be either the jet *itself*, *dusty torus* or....

- An outflowing BLR might be an alternative source of BLR seed photons to produce γ-rays, even at distances of several parsecs from the BH.