A multi-wavelength approach to current blazar issues

Simultaneous *Planck, Swift, and Fermi* observations of X-ray and γ-ray selected blazars


- **Large number of sources:** 175 blazars observed by Swift when they were in the FOV of Planck: ~160 Swift ToOs

- **Truly simultaneous** Planck Swift Fermi + ground based telescopes

- **Multi-selection approach.** Four flux-limited samples.
  - Soft X-ray (RASS, sample)
  - Hard X-ray (Swift-BAT sample)
  - γ-ray (Fermi sample)
  - Radio (100 brightest northern sources)

- **Fermi-LAT integrations:**
  - simultaneous (~1 week),
  - 2 months,
  - 27 months
S5 0716+714

IBL/ISP

S5 0716+714
Summary of $\gamma$-ray detections (TS > 25) in 27 month Fermi-LAT data.

<table>
<thead>
<tr>
<th>Sample</th>
<th>No. of detected sources</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSRQs</td>
<td>BL Lacs</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td>Fermi-LAT</td>
<td>28 (100%)</td>
<td>14 (100%)</td>
<td>8 (100%)</td>
<td></td>
</tr>
<tr>
<td>Swift-BAT</td>
<td>17 (63%)</td>
<td>7 (100%)</td>
<td>3 (50%)</td>
<td></td>
</tr>
<tr>
<td>Rosat/RASS</td>
<td>6 (53%)</td>
<td>14 (88%)</td>
<td>2 (17%)</td>
<td></td>
</tr>
<tr>
<td>Radio</td>
<td>42 (72%)</td>
<td>16 (100%)</td>
<td>9 (64%)</td>
<td></td>
</tr>
</tbody>
</table>
The synchrotron/invC peak frequencies $\nu_{\text{peak}}$ and intensities $\nu_{\text{peak}} f(\nu_{\text{peak}})$

Measured using 3rd degree polynomial functions
\[ \langle \nu_{\text{peak}}^S \rangle = 10^{13.1 \pm 0.1} \text{ Hz} \]
The Compton dominance
The graph shows the normalized fraction of FSRQs and BL Lacs in the RASS sample. The x-axis represents the logarithm of the Compton Dominance, and the y-axis represents the normalized fraction. Two categories are distinguished by the logarithm of the peak frequency: 

- \( \log(v_{\text{peak}}^S) < 14.0 \)
- \( \log(v_{\text{peak}}^S) > 14.0 \)
Fig. 10. The SED of the blazar PKS0003-066 as an example of estimation of the upper limits on $v_{\text{peak}}^{\text{IC}}$ and on $F(v_{\text{peak}}^{\text{IC}})$ combining the X-ray data with the 27 month Fermi-LAT upper limits.
Most (radio selected) FSRQs have Compton Dominance $\sim 1$ ($\log(\text{CD}) = 0$)
A simplified view of blazars: clearing the fog around long-standing selection effects

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Based on

- **beaming** (of FR I + FR II radio galaxies, unified schemes)
- **light dilution** (non-thermal jet + accretion + host galaxy)
- **minimal physical assumptions** for the non-thermal/jet emission
Monte Carlo Simulations: The ingredients

- Luminosity function + Evolution estimated from WMAP blazars
- Unified schemes
- Non-thermal component: SSC with single distribution of electron peak energies and Doppler factors. No dependence on luminosity or redshift
- Thermal component + broad lines from SDSS template
- EW distribution from radio quiet QSOs (estimated from SDSS spectra)
- Disk to jet power ratio estimated from the SED a large number of blazars
- Host Galaxy: Giant elliptical

Figure 4. The distribution of the Lorentz factors of the electrons radiating at the peak of the synchrotron SED used for the simulation, which also assumes a magnetic field of B=0.15 Gauss and a gaussian distribution of Doppler factors with $\langle \delta \rangle = 15$. 
Blazar classification

A simulated source is classified as FSRQ, BL Lac or radio galaxy on the basis of the balance of Thermal, Blue-bump/broad-lines, non-thermal/jet radiation and host galaxy in the optical band (3800-8000 Å in the observer frame)

- **FSRQ** if the rest-frame EW (Non-thermal + Blue bump) of any line in the optical band is > 5 Å
- **BL-Lac** if the observed EW (Non-thermal + Blue bump) of any line in the optical band (observer frame) is < 5 Å
- **Radio Galaxy** if only absorption features form the host galaxy are in the optical band and Ca H&K break > 0.4

Redshift of BL Lacs is assumed to be **not measurable** if the EW of the brightest line in the optical band is < 2 Å
<table>
<thead>
<tr>
<th>Category</th>
<th>FR I/LERGs</th>
<th>FR II/HERGs</th>
<th>Viewing angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong jet dilution (ew &lt; 5 Å, CaH&amp;K &lt; 0.4)</td>
<td>BL Lac</td>
<td>BL Lac</td>
<td>θ &lt; θ_{blazar}</td>
</tr>
<tr>
<td>Weak jet dilution</td>
<td>Radio galaxy</td>
<td>FSRQ</td>
<td>θ &lt; θ_{blazar}</td>
</tr>
<tr>
<td>Misdirected Jet</td>
<td>Radio galaxy</td>
<td>Radio galaxy</td>
<td>θ &gt; θ_{blazar}</td>
</tr>
</tbody>
</table>
Figure 6. Top panel: the redshift distribution of the WMAP5 FSRQs (solid histogram) compared to that of FSRQs in a simulation of a radio survey (dashed histogram). Bottom panel: the redshift distribution of the WMAP5 BL Lacs (solid histogram) compared to that of BL Lacs in a simulation of a radio survey (dashed histogram)
The different synchrotron peak energy distributions in BL Lacs and FSRQs is NOT due to cooling or other physical reason, but to selection effects!
BL Lacertae objects beyond redshift 1.3 - UV-to-NIR photometry and photometric redshift for Fermi/LAT blazars

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The discovery of high power – high synchrotron peak blazars

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Main Conclusions

- A lot of progress has been made recently on blazar research thanks to the availability of multi-frequency data from several facilities (Planck, Swift, Fermi, TeV/Cherenkov telescopes, other ground based observatories, etc.)
- The distributions of several blazar key physical parameters have been measured and correlations have been investigated.
- The Compton dominance of (radio selected) blazars peaks at values close to 1 and it extends to values as large as 100 or more.
- Selection effects play a major role in the composition of blazar samples and cause large biases in the estimation of several parameters.
- Simple SSC one-zone models are not consistent with the SED of LBL blazars, but might be consistent with the SED of HSP objects.
- Simulations show that all blazar properties can be interpreted within a very simple scenario where classification in different subclasses and their peculiar evolution is the result of the combination of different components and to selection effects.
- High redshift HSP objects have been discovered, these objects are “forbidden in the Blazar sequence scenario”.
- Some distant (up to ~1.6-1.8) HSP blazars detected in the 10-100 GeV band implying that many sources of this type could be detected in future VHE experiments, particularly the CTA.