Multi mission-multi frequency
Observations of Blazars

Paolo Giommi
ASI
Blazars

- AGN
- Highly variable at all frequencies
- Highly polarized
- Radio core dominance
- Superluminal speeds

Observed at a small angle to the jet and therefore rare AGN: 5-8% of all AGN (but only at optical or X-ray frequencies!)

Blazars are the dominant population of extragalactic point sources at

- Gamma-ray
- TeV
- Microwave frequencies
Two types of Blazars:

**BL Lacs**: no strong lines; no strong cosmological evolution

**FSRQs**: strong and broad emission lines; strong cosmological evolution
The overall Spectral Energy Distribution (SED) of a typical Blazar: 3C 279
Third EGRET Catalog

E > 100 MeV

- Red: Active Galactic Nuclei
- Green: Unidentified EGRET Sources
- Pink: Pulsars
- Yellow: LMC
- Blue: Solar Flare
BeppoSAX Blazars
Observations Statistics

116 pointings of 60 BL Lacs for a total exposure of ~3.5Ms
83 pointings of 49 Radio Loud QSOs, exposure of ~3.3Ms

About 15% of the full BeppoSAX scientific program.
BeppoSAX spectral fits

Fig. 4. Spectral energy distributions of a typical LBL object (PG 1418+546, $\nu_{peak} \approx 0.4$ eV $\approx 8 \times 10^{13}$Hz) for which the X-ray emission is dominated by the flat inverse Compton radiation and of an Intermediate BL Lac (ON 231, $\nu_{peak} \approx 1$ eV $\approx 2 \times 10^{14}$Hz) where the simultaneous optical and BeppoSAX observations (Tagliaferri et al. 2000) clearly show that the transition between the synchrotron and inverse Compton emission occurs in the soft X-ray band.

Fig. 5. Spectral energy distributions of HBLs where the X-ray emission is completely dominated by synchrotron radiation. In the case of PKS 2155−304 $\nu_{peak}$ is at $\approx 50$ eV $\approx 10^{16}$ Hz while for the extreme HBL 1H 1430+423 $\nu_{peak}$ is above 10 keV.
BeppoSAX NFI data: BL Lacertae
# A Catalog of 157 X-ray Spectra and 84 SEDs of Blazars observed with BeppoSAX

P. Giommi, M. Capalbi, M.T. Fiocchi, E. Merola, M. Perri, S. Piranomonte, S. Rebecchi and E. Massaro

Proceedings of the workshop

**Blazar Astrophysics with BeppoSAX and other Observatories**

- [Abstract](#)
- [Full paper (gzipped postscript)](#)

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**Available parameters**
- Name
- RA
- Dec
- Z
- Vmag
- Radio flux 5.0GHz
- Survey
- Class

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### Subset selection mode: inclusive

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SSC model parameters

1.40
Norm. el. sp. log (cm⁻³)

1.450
el. sp Index 1 n < 3

4.70
el. sp Index 2 n > 3

4.45
el. sp break en. log (eV/cm³)

0.250
mag field B (Gauss)

14.00
Doppler factor \delta

0.0030
Jet radius (pc)

0.031
redshift

Log $\nu_{\text{peak}} = 16.02$ (rest-frame)

$\nu f(\nu)$ (erg cm⁻² s⁻¹)

Log frequency $\nu$ (Hz)

Super-AGILE sensitivity
AGILE-GRID sensitivity

Show instruments limiting sensitivity?
○ none ○ Integral-IBIS ○ AGILE

Get data file? ○ no ○ yes
UHBLs as counterparts of EGRET high lIbIII unidentified sources?

1RXS J 123511.1-14033
UHBLs as counterparts of EGRET high l unidentified sources?

Well, may be not...
UHBLs as counterparts of EGRET high IbIII unidentified sources?

But a few days later...
SHBL J044127.4+150456

$\log \nu_{\text{peak}} = 20.59$ (rest-frame)

![Graph showing the relationship between log frequency $\nu$ and log intensity $\nu f(\nu)$ with two sensitivity curves: Super-AGILE and AGILE-GRID.](image)
A detailed analysis of all BeppoSAX observations of MKN 421
Massaro, Perri, Giommi, Nesci, 2003 A&A in press
MKN421 in a bright state: the BeppoSAX observation of May 2000
BeppoSAX spectral fits: main results

In HBL Objects, where the synchrotron component dominates the γ-ray spectrum, the logarithmic parabola model describes the data significantly better than other models.

This is interpreted as evidence of intrinsic curvature in the particle spectrum rather than cooling.

Such a curvature can be obtained in simple statistical acceleration processes where the probability for a particle to increase its energy is a decreasing function of energy itself.
5. Statistical particle acceleration and log-parabolic spectra

5.1. Energy distribution of accelerated particles

The energy spectrum of accelerated particles by some statistical process, like a shock wave, is usually written as a power law

\[ N(\gamma) = N_0 (\gamma/\gamma_0)^{-s} , \]  

where \( N(\gamma) \) is the number of particles having a Lorentz factor greater than \( \gamma \) and \( s \) is the spectral index given by:

\[ s = -\frac{\log p}{\log \epsilon} , \]  

where \( p \) is the probability that a particle is subject to the acceleration step \( i \) in which it has an energy gain equal to \( \epsilon \) assumed both independent of energy:

\[ \gamma_i = \epsilon \gamma_{i-1} \]  

and

\[ N_i = p N_{i-1} = N_0 \, p^i . \]  

A log-parabolic energy spectrum follows when the condition that \( p \) is independent of energy is released and one assumes that it can be described by a power relation as:

\[ p_i = g/\gamma_i^q , \]  

where \( g \) and \( q \) are constant; in particular, for \( q > 0 \) the probability for a particle to be accelerated is lower and lower when its energy decreases. Such a situation can be realized, for instance, if particles are confined by a magnetic field with confinement efficiency decreasing for an increasing gyration radius. After simple calculations one finds instead of Eq.(9):

\[ N_i = N_0 \frac{g^i}{\prod_{j=0}^{i-1} \gamma_j^q} . \]  

Using Eq.(8) one can write this product as:

\[ \prod_{j=0}^{i-1} \gamma_j^q = \gamma_0^i \prod_{j=1}^{i-1} \epsilon_j^q = \gamma_0^i (\epsilon_q^q)^{i(i-1)/2} , \]  

where \( \gamma_0 \) is the initial Lorentz factor of the particles; inserting this result into Eq.(11) we obtain:

\[ N_i = N_0 \left( \frac{g}{\gamma_0^q} \right)^i (\epsilon_q^q)^{i(i-1)/2} . \]  

Finally, combining this equation with Eq.(8) one can obtain the integral energy distribution of the accelerated particles:

\[ N(\gamma) = N_0 (\gamma/\gamma_0)^{-s + r \log (\gamma/\gamma_0)} , \]  

with

\[ s = -\frac{\log (g/\gamma_0)}{\log \epsilon} - \frac{q}{2} . \]
The Cosmic Energy Density Spectrum

Energy Density [nW/m² sr]

Frequency [Hz]

CMB
CIB
COB
Stars/AGN?
Big Bang
CXB
AGN
WMAP bright foreground source catalog

208 bright sources, of which

- 140 FSRQs
- 23 BL Lacs
- 13 Radio galaxies
- 5 Steep Spectrum QSOs
- 2 starburst galaxies
- 2 planetary nebule
- 17 unidentified
- 6 without radio counterpart (probably spurious)

The vast majority of bright WMAP foreground sources are Blazars
Radio Galaxy PKS 0518-45

Radio Galaxy 3C 111

Fiocchi, Grandi et al. in preparation
Boomerang 90 GHz CMB MAP
De Bernardis et al. 2000
[Giommi & Colafrancesco 2003]
[Giommi & Colafrancesco 2003]
The Blazar LogN-LogS

\[ C_{t, \text{Blazar}} = \int_{S_{\text{min}}}^{S_{\text{max}}} dS \frac{dN}{dS} S^2 \]
Blazar Surveys
“Classical Approach”

BL Lacs

- 1 Jy, radio flux limited, 5GHz (34 objects)
- EMSS, X-ray flux limited (41 objects)
- IPC Slew Survey, X-ray (51)

Flat spectrum Radio Quasars

- 2 Jy, radio flux limited, 2.7 GHz (52 objects)
Blazar Surveys
Recent multi-frequency BL Lac samples

- **DXRBS Deep X-ray Radio Blazar Survey**
  Radio (BG6, PMN) $S_{5\text{GHz}} > 50\text{ mJy}$, X-ray (ROSAT WGACAT) $S_{(0.1-2.4\text{ keV})} > 2\times10^{-14}\text{ cgs}$
  44 objects $\sim 95\%$ identified

- **RGB RASS-Green Bank**
  Radio (GB6), $S_{5\text{GHz}} > 20\text{ mJy}$, X-ray ROSAT All Sky Survey $S_{(0.1-2.4\text{ keV})} > 3\times10^{-13}\text{ cgs}$
  Optical $m_B < 18\sim 94\%$ identified
  33 objects in complete sample, 127 total

- **REX Radio Emitting X-ray survey**
  X-ray (ROSAT PSPC serendipitous sources) $S_{(0.1-2.4\text{ keV})} > 3\times10^{-14}\text{ cgs}$,
  Radio (NVSS) $S_{1.4\text{GHz}} > 5\text{ mJy}$
  72 objects, 30\% identified,
  sub-sample of 55 objects ($S_{(0.1-2.4\text{ keV})} > 4\times10^{-13}\text{ cgs}$) $\sim 90\%$ identified

- **Sedentary multi-frequency survey (extreme HBLs only)**
  X-ray RASS ($S_{(0.1-2.4\text{ keV})} > 10^{-12}\text{ cgs}$), radio NVSS ($S_{1.4\text{GHz}} > 3.5\text{ mJy}$),
  optical APM/COSMOS/GSC2
  153 objects, 100\% identified
Blazar Surveys
Recent multi-frequency BL Lac samples
Continued..

- **CLASS Cosmic Lens All Sky Survey**
  Radio (GB6,NVSS) $f_{5\text{GHz}} > 30$ mJy, Optical $R < 1.75$, $\alpha_{\text{radio}} < 0.5$
  47 objects ~ 70% identified

- **FIRST Flat Spectrum sample**
  Radio (FIRST), $f_{1.4\text{GHz}} > 35$ mJy, GB6 $f_{5\text{GHz}} > 20$ mJy, optical $B < 19$
  $\alpha_{\text{radio}} < 0.5$ 87 sources ~84% identified

- **RASS-ASDC 1Jy sample**
  Radio (NVSS) $f_{1.4\text{GHz}} > 1000$ mJy, X-ray RASS ($f_{(0.1-2.4\text{keV})} > 8 \times 10^{-14}$ cgs),
  25 objects , 93% identified
The ASDC catalog of known Blazars

(updated to September 2003)

(1250 objects)

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The broad-band color-color plane
The ASDC Blazar candidate sample

Cross-correlation between NVSS and RASS radio and X-ray surveys. Optical magnitudes from GSC2 (assuming Jmag < 19.5 when no counterpart is found in GSC2)

Over 7400 objects (500 of which are included in the catalog of known Blazars).
A subsample of about 450 objects for which Sloan survey data are available is being used to estimate the quality of the sample.

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A subsample of about 450 objects for which Sloan survey data are available is being used to estimate the quality of the sample.

\[ \Delta_{r-x} < 2.5 \sigma_{r-x} \text{ and } < 0.8 \text{ arcmin} \]
\[ \alpha_{ox} \text{ and } \alpha_{ro} \text{ within Blazar area} \]
Blazars candidate sample