OPTICAL AND RADIO OBSERVATIONS OF BL Lac OBJECTS: LONG TERM TRENDS AND VLBI IMAGING

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**BL Lac Properties:**
a BLAZAR subclass (BL Lac + FSRQ)

- Strong non-thermal emission over the entire e.m. spectrum (γ-ray sources in the EGRET catalog)
- Featureless optical spectrum
- Variability on all time scales: from minutes to about one century ......
- High (and variable) linear polarisation
Spectral Energy Distribution (SED)

- The typical SED of a BL Lac object shows two broad peaks:
  - the peak at LOW frequencies is explained by synchrotron radiation and that at HIGH frequencies by Inverse Compton emission.
BL Lac classification

Padovani & Giommi (1995) introduced two BL Lac classes based on the frequency of the Synchrotron peak:

- **LBL** or Low energy peaked BL
- **HBL** or High energy peaked BL.

More “classes” have been defined:

- **VLBL**: Very LBL
- **IBL**: Intermediate BL
- **EHBL**: Extreme HBL

The peak frequency varies with the source brightness.
A simple spectral law

- In LBL objects synchrotron emission extends from radio to optical frequencies.
- A simple parametrisation for the synchrotron spectrum is a parabola in a \((\log S - \log \nu)\) plot:

\[
S(\nu) = A \left(\frac{\nu}{\nu_0}\right)^{-[a + b \log(\nu/\nu_0)]}
\]

or the combined law:

\[
S(\nu) = A \left(\frac{\nu}{\nu_0}\right)^{-[a + b \log(1 + (\nu/\nu_1))]}\]

The parameter \(b\) describe the spectral curvature.
SEDs of LBL objects
Variability

- BL Lac objects show large variations on a very broad range of time scales: from minutes (microvariability) to many years.
- Rapid variations are explained by relativistics perturbations moving down a jet, closely aligned to the line of sight (Doppler beaming factor \( D > 10 \))
- The origin of long-term variations is unclear and can be associated with modifications of the source structure detectable with VLBI experiments
Long-term optical variability

• Historic light curves show brightness trends over time scales > 10-20 yr
• In some cases (e.g. OJ 287) a periodicity of a few years has been found, although not safely established
• Typical length scales ($R < c\Delta t$) may be of the order of about a few pc, corresponding to mas angular distances, well resolved in VLBI images
Origin of long-term trends

Geomteric effects in the source may be very important:

• change of the jet direction (precession ...)
• binary BH system (mergers ?)
• interaction with circumnuclear matter
It is very useful to search for correlations between long-term radio-optical trends and changes in the inner jet structure with VLBI imaging.

Redshift limit: $z < 0.3$, minimum detectable size $< \text{a few light yr}$
• Many BL Lac objects have been imaged with VLBI: they show one sided jets, superluminal motion and linear polarisation (e.g. The 1 Jy BL Lac sample, Gabuzda, Pushkarev & Cawthorne 2000).

• These structural features, however, were not related to long-term optical trends (many sources at \( z > 0.3 \)).

• Optical monitoring is available only for few BL Lac objects.

• Savolainen et al. (2002) found for several sources a correlation between the occurrence of flares at 22 and 43 GHz and the appearence of new VLBI component in the jet.
An open problem:

One or two emission components?
VLBI images can help to distinguish different types of variability

Optical flare  Radio-optical flare
• Some examples ......
The historic optical light curve of OQ 530
photometric B band (z = 0.15)
**OQ 530: radio and optical light curves**  

- **Optical data**: Perugia and Roma (10 year monitoring)

- **Radio data from**:
  - Terasranta et al. (1998)
  - Venturi et al. (2001)
  - Robson et al. (2001)

- **5 GHz light curves from VLBI images**:
  - core (filled squares)
  - jet (open squares)
OQ 530

The historic optical light curve of OJ 287
photometric $R_C$ band

($z = 0.3$)
RRFID 8 GHz images of OJ 287
(Tateyama & Kingham 2004)

Fig. 4.—Helical curves superposed on the VLBA maps of Fig. 1. The solid line represents the best helical model to describe the radio features.

Is the change of the jet direction related to the optical brightening trend after 1997?

Geodetic (snapshots) images are very useful. Deeper observations are also important to study in more detail these changes.
ON 231 – historic light curve
(see the poster by Mantovani et al.)

$z = 0.10$
ON 231: The giant flare and decay
ON 231 – Image and spectral index map
$S5\ 1803+784$

$(z = 0.68, \ 1\ \text{mas} \rightarrow 20\ \text{light year})$
The $D$ vs $\beta_{\text{app}}$ relation

Two families of curves:
$\Gamma = 5, 8, 10$
$\theta = 2^\circ, 5^\circ, 10^\circ, 15^\circ$

A change of $\theta$ ($\Gamma$ constant) can imply an increase of $\beta_{\text{app}}$ and a decrease of $D$
Next 10 years will be very important for BLAZAR multifrequency observations

- Coordinated observations between space and ground based instruments will be very useful to understand the nature of the power output of BL Lac objects and Blazars in general.
Future IR, X and γ-ray space missions: Planck, Swift, AGILE, GLAST
• Thousands of γ-ray sources are expected to be discovered by GLAST, many of which will be BL Lac objects
• γ-ray emission can be variable on a wide range of time scales
• An accurate study of the brightest sources is relevant to understand the physics of BL Lac objects
• It is important to select a sample of targets to be monitored in the radio, IR and optical bands
• VLBI imaging of this selected sample can provide useful data on the sources’ structure and evolution

• >>>>>> a  Key  Project in connection with the scientific teams of these space observatories will be important