OPTICAL AND RADIO OBSERVATIONS OF BL Lac OBJECTS:

LONG TERM TRENDS AND VLBI IMAGING

Enrico Massaro and Franco Mantovani

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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.

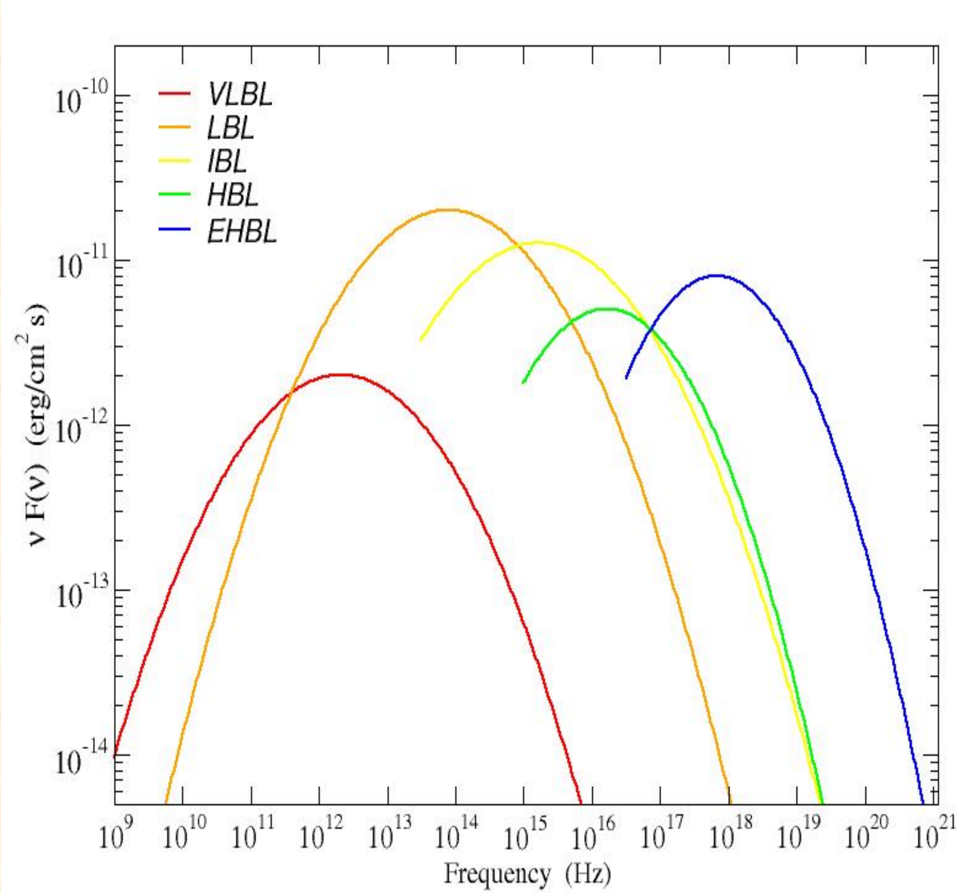
More "classes" have been defined:

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 ν) plot:

$$S(\nu) = A\,(\nu/\nu_o)^{-[a + b\,Log(\nu/\nu_o)]}$$

or the combined law:

$$S(\nu) = A\,(\nu/\nu_o)^{-[a + b\,Log(1+ (\nu/\nu_1))]}$$

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 lenght 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 < a few light yr

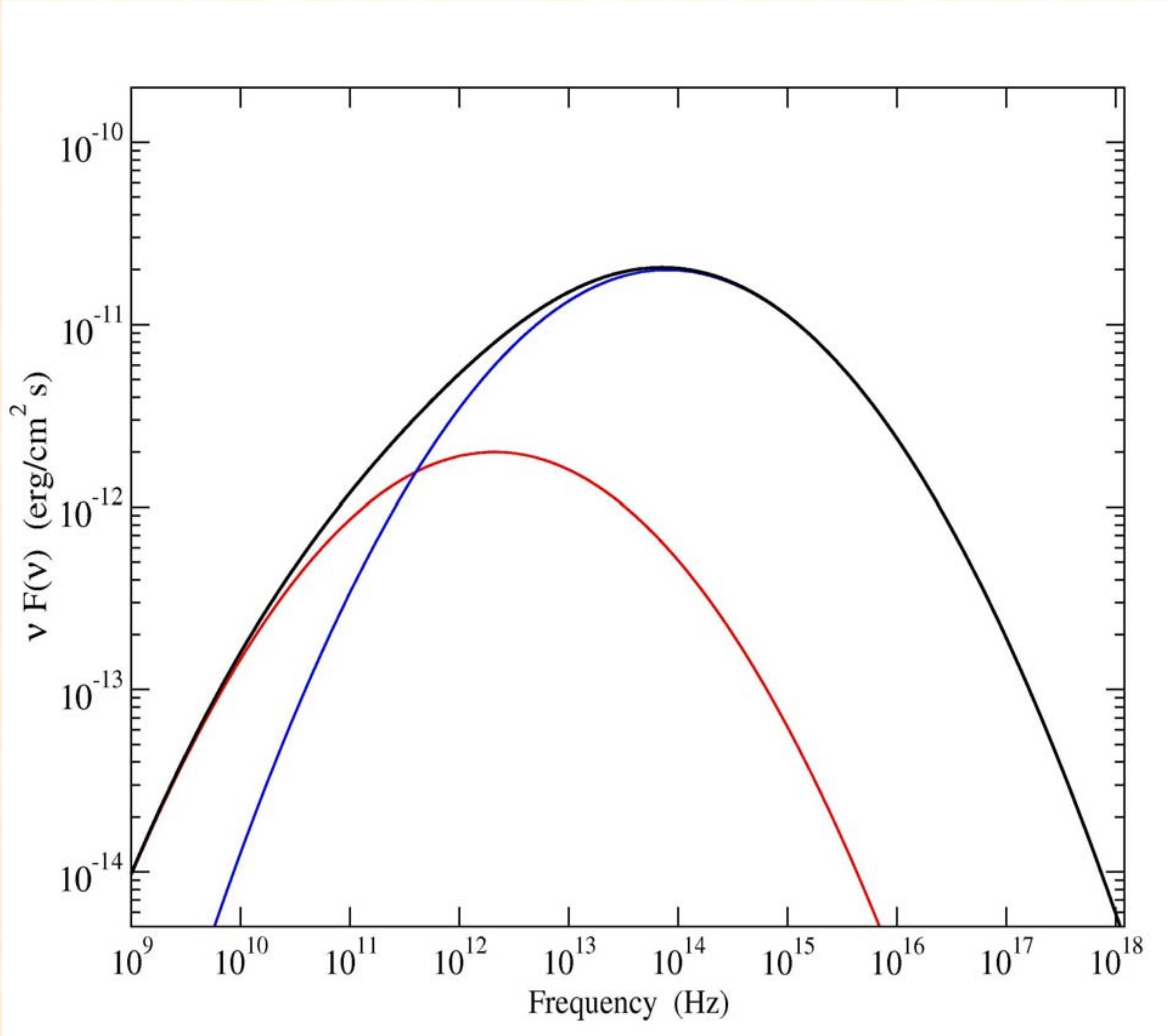
- Many BL Lac objects have been imaged with VLBI: they show one sided jets, superluminal motion and linear polarisation (e.g. The 1 Jy BL Lac sample, Gabuzda, Pushkarev & Cawthorne 2000).

- 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.

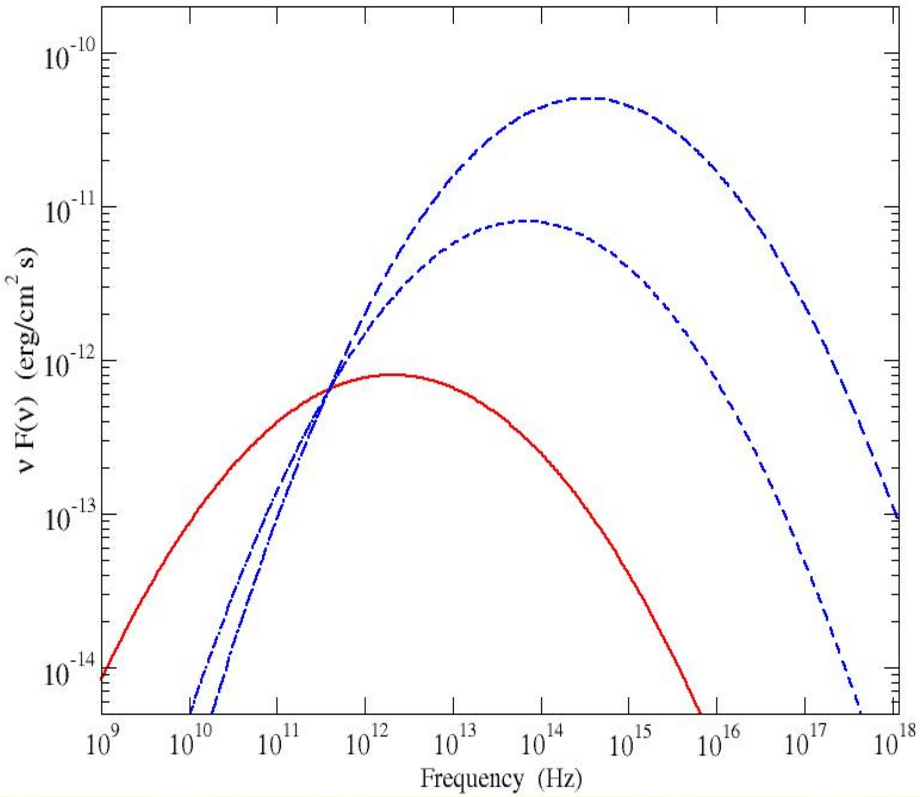
- Savolainen et al. (2002) found for several sources a correlation between the occurrence of flares at 22 and 43 GHz and the appearence of new VLBI component in the jet

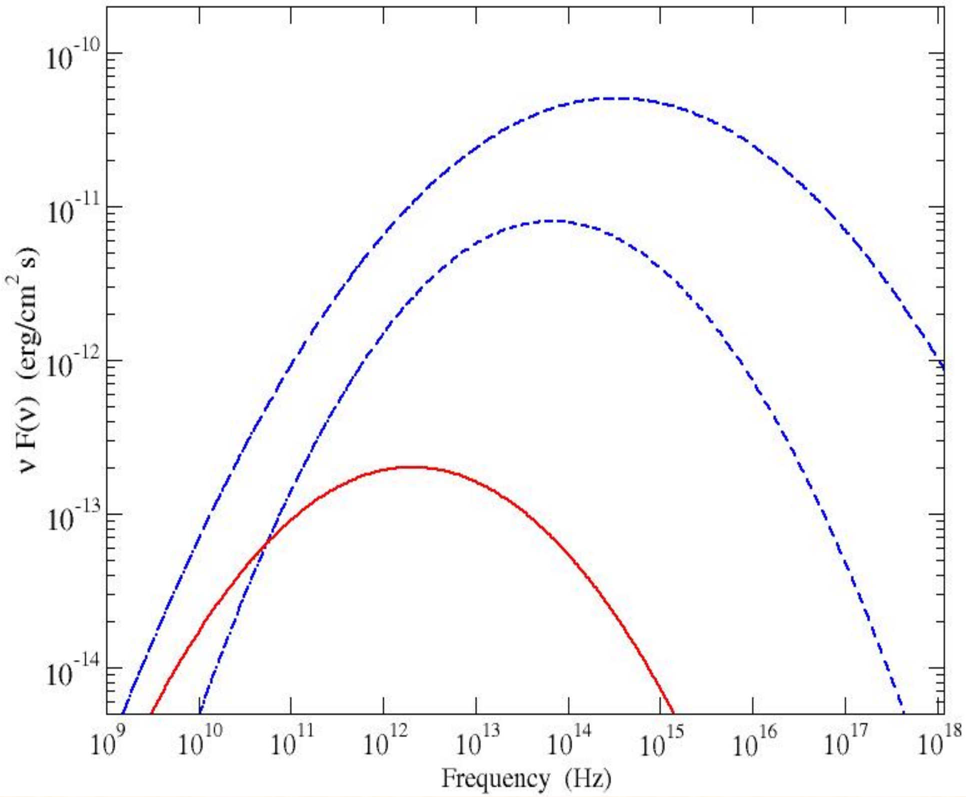
An open problem:
One or two emission components ?



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

(Massaro et al. A&A 2004)

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

- Radio data from:

  Terasranta et al. (1998)

  Venturi et al. (2001)

  Robson et al. (2001)

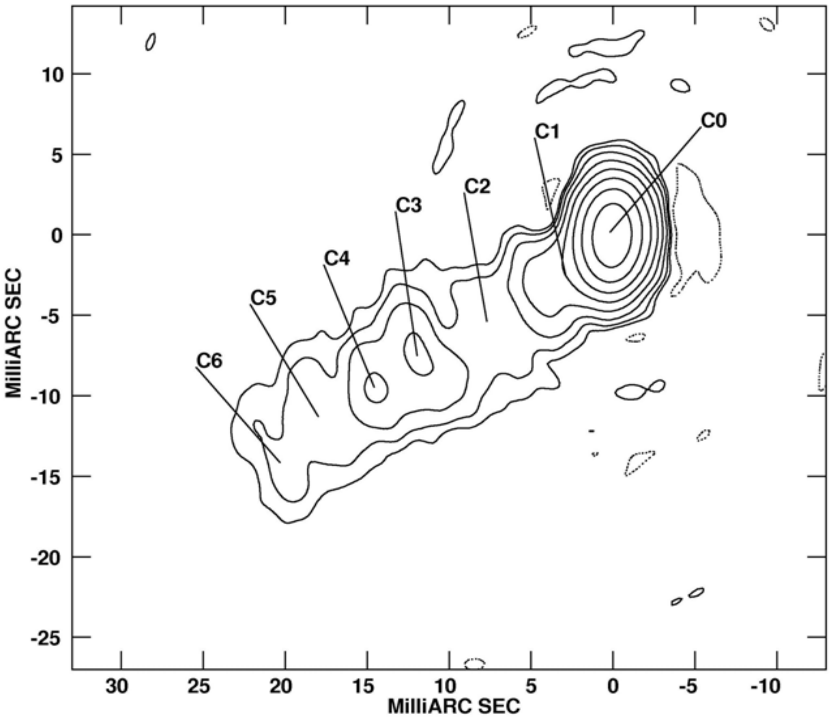
- 5 GHz light curves from VLBI images:

  core (filled squares)

  jet (open squares)

OQ 530

(Massaro et al. A&A 2004)



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)

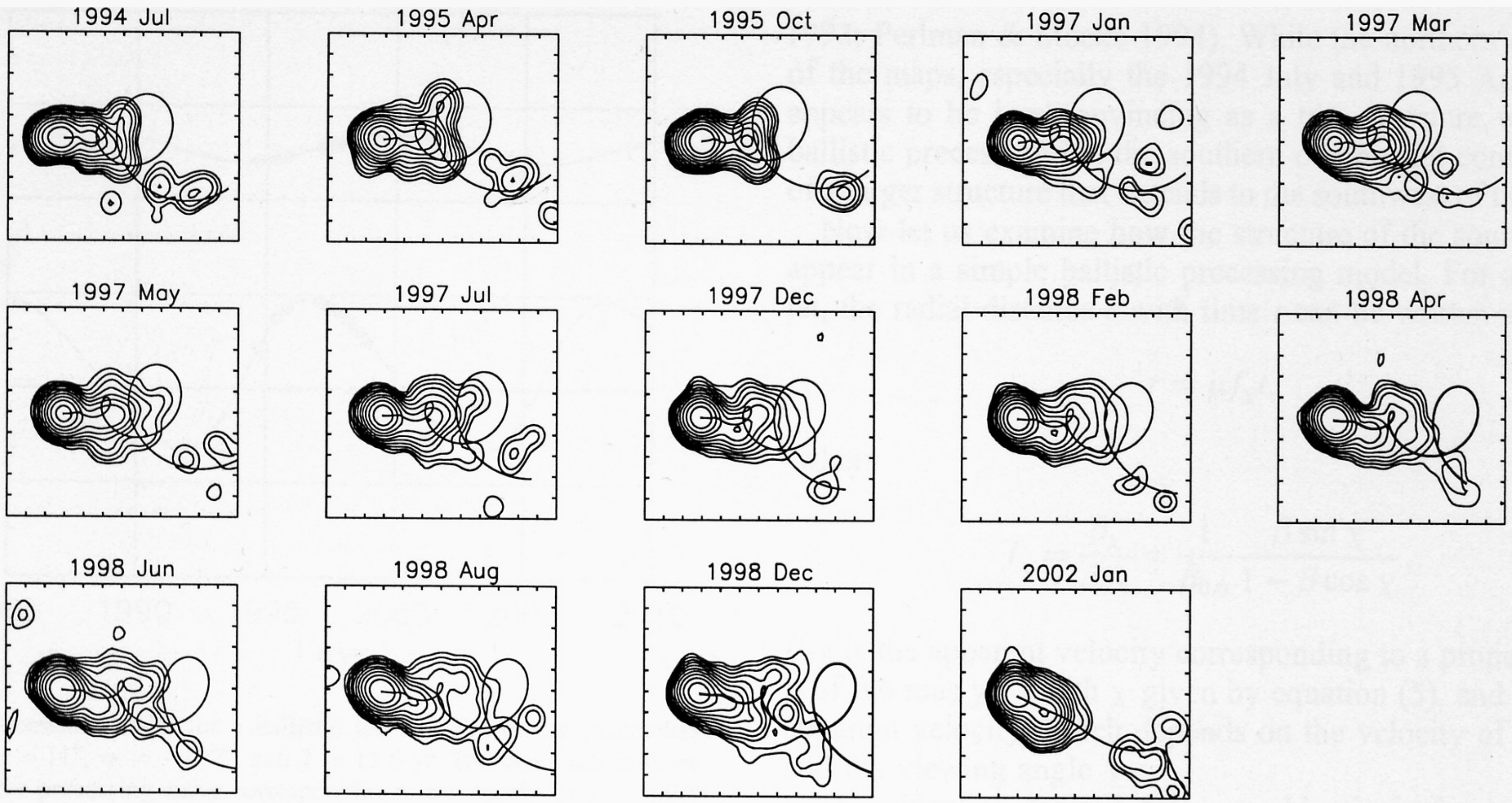


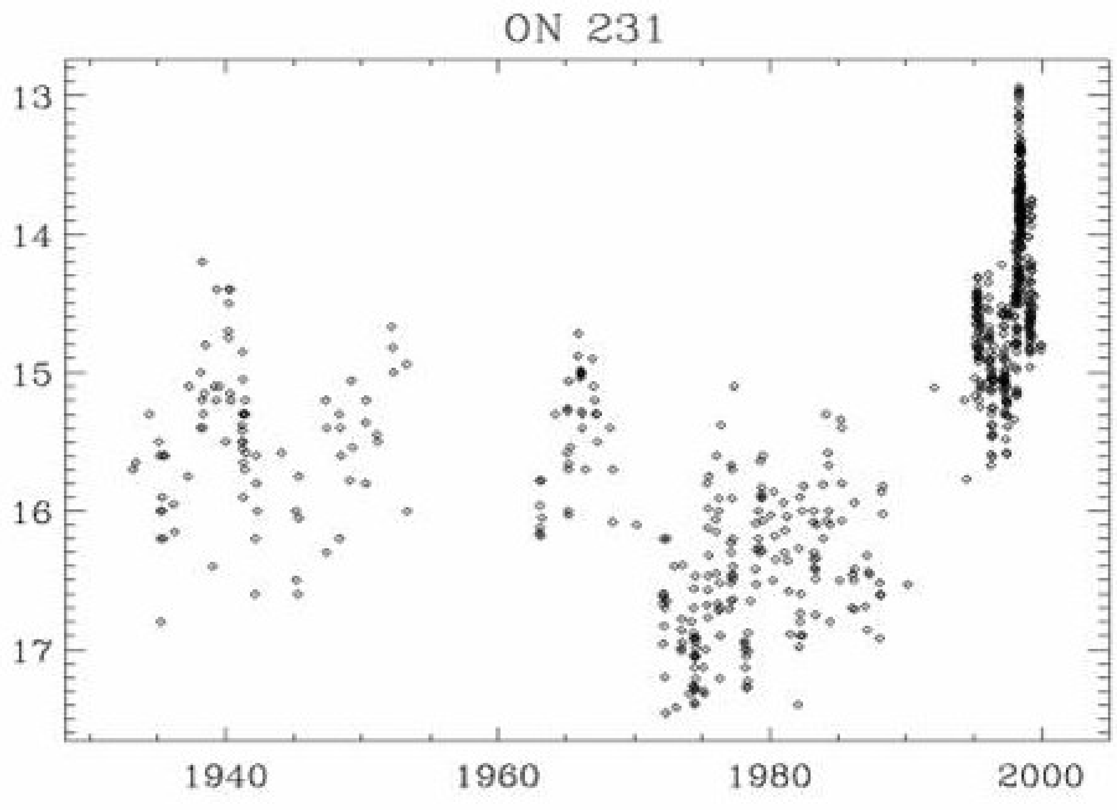
FIG. 4.—Helical curves superposed on the VLBA maps of Fig. 1. The solid line represents the best helical model to describe the radio features.

OJ 287

- According to Tateyama & Kingham (2004) the jet of OJ 287 rotated clockwise of about 30^{o} from 1994 to 2002.
- 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

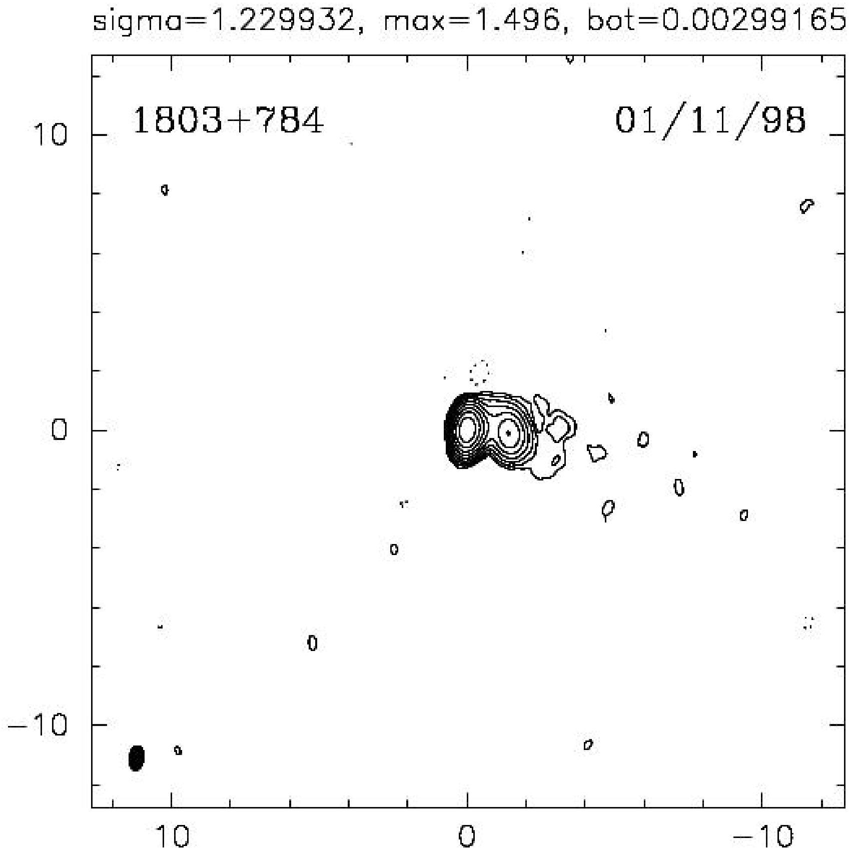


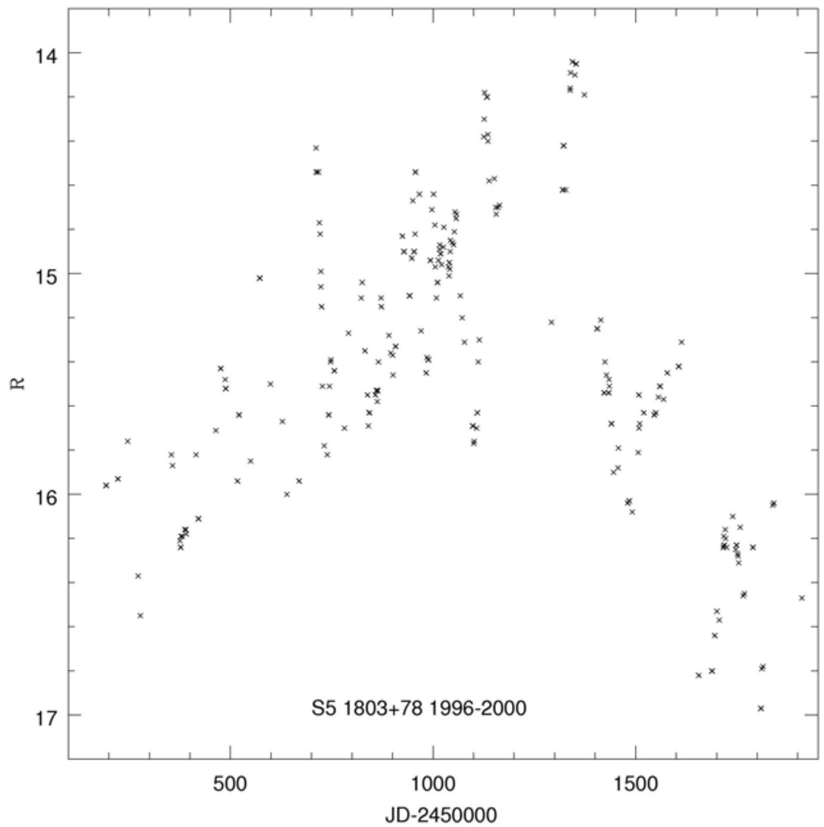
ON 231:The giant flare and decay

ON 231 – Image and spectral index map

S5 1803+784

(z = 0.68, 1 mas → 20 light year)





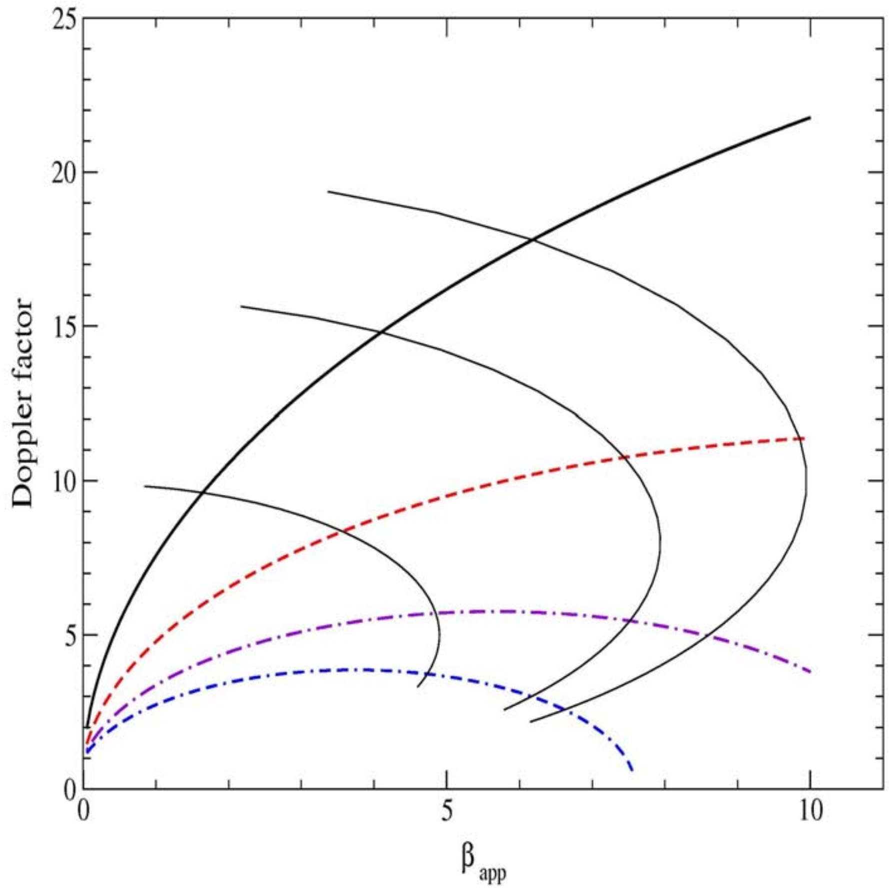
The D *vs* β_{app} *relation*

Two families of curves:

Γ = 5, 8, 10

θ = 2°, 5°, 10°, 15°

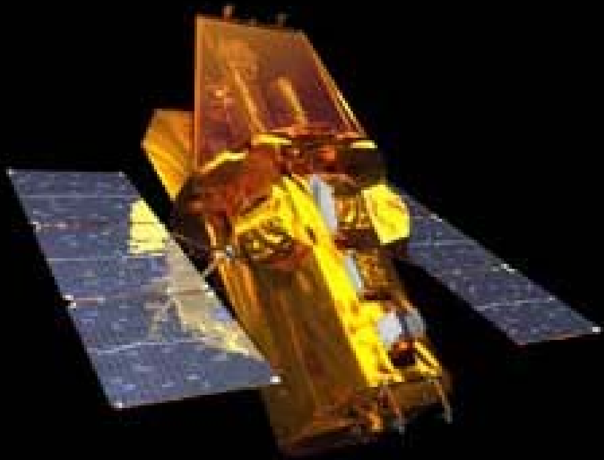
A change of θ (Γ constant) can imply an increase of β_{app} and a decrease of *D*

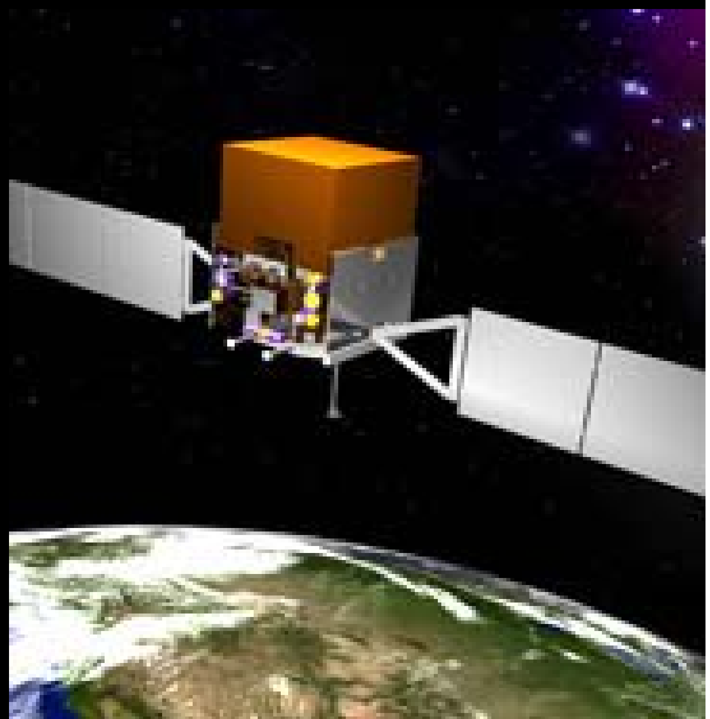


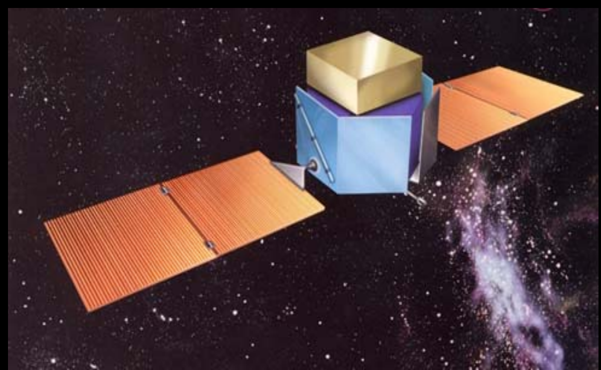
Next 10 years will be very important for BLAZAR multifrequency observations

- 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