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The infrared peak of the blazar spectral energy distribution and the monitoring from Antarctica

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Abstract. Blazars are a class of Active Galactic Nuclei (AGN) with a highly luminous and rapidly variable non-thermal emission. Their overall Spectral Energy Distribution (SED) is a smooth and featureless continuum with a typical two bump structure due to synchrotron and inverse Compton radiation. The energy budget of blazar is dominated by infrared emission from 1 μm to 100 μm. The low frequency peaked blazar (LBL) and intermediate blazar, typically emit from 1/3 to 2/3 of the total luminosity in this range. We report some simulations of the SED of two intermediate objects, ON 231 and BL Lac. Using the available multiwavelength data, during some phases of variability a relevant peak of mid infrared emission was predicted, but there was always a large gap of observation between the radio and near-IR/optical bands, for any blazar, to really constraint the model. We remark that a moderate-size telescope like IRAIT, placed in the Antarctica plateau, might give just a unique way to perform a mid-IR monitoring of the southern blazars variability, also as a secondary program. This could be crucial to constraint the global energetics and models, and might allow to obtain decisive mid-IR fluxes during the multiwavelength observing campaigns.

Key words. Active Galactic Nuclei – BL Lacertae objects: general – radiation mechanisms: non-thermal – Infrared: photometry – Infrared: galaxies

1. The Spectral Energy Distribution of Blazars

The thermal radiation from hot dust may account for the infrared emission in most radio-quiet Active Galactic Nuclei (AGN). In the Seyfert galaxies the far-IR radiation is representative of a circumnuclear enhanced star formation, doing massive starburst. On the contrary for blazar, the emission through IR wavebands is mainly non-thermal. Blazars are radio-loud with a smooth IR-optical-UV continuum spectra emitted by a compact nucleus, showing high optical polarization and non-thermal emission over the whole electromagnetic spectrum, with high and rapid variations

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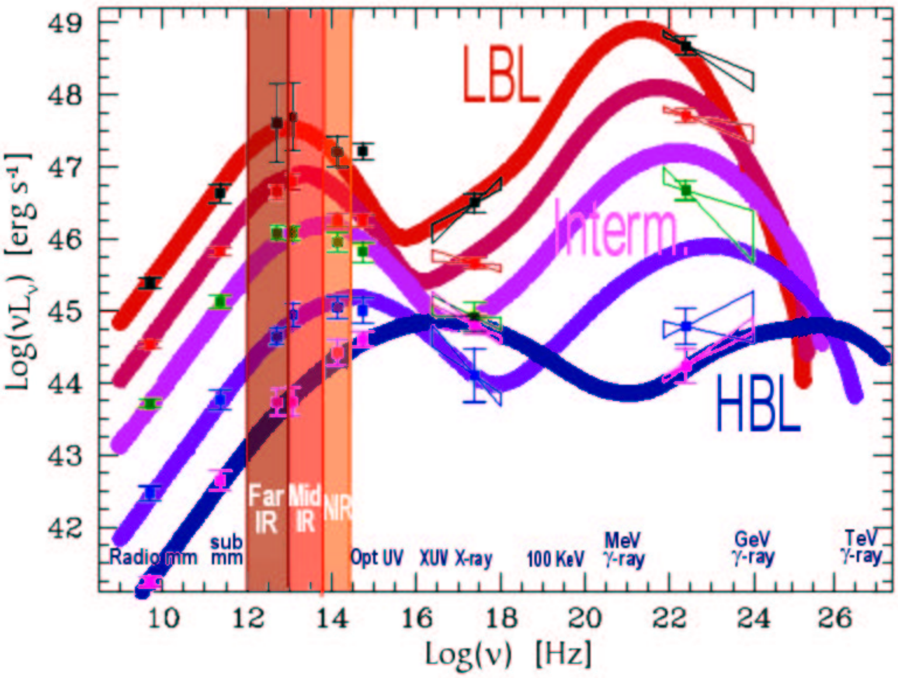

Fig. 1. The average overall spectral energy distributions (SEDs) from different samples of blazars, binned according to radio luminosity. This SEDs clearly show the typical two-bump structure due to synchrotron and IC emission. All the LBL and intermediate blazar in quiescent phase, have the synchrotron peak in infrared bands. Adapted from Fossati et al. (1998).

in a typical flare-like behavior. Their overall Spectral Energy Distribution (SED) exhibit a typical two-bump structure where the lower frequency broad component is peaked either in the IR/optical (low frequency peaked blazar LBL) or in the UV/X-ray bands (high frequency peaked HBL blazars) (e.g. Padovani & Giommi 1995). This bump is believed to be produced by synchrotron radiation, while the higher frequency broad component should be to inverse Compton (IC) scattering of soft photons. Synchrotron radiation and IC scattering are usually interpreted as due to diffusive shock acceleration of relativistic leptons within a plasma jet. The emitted anisotropic radiation is thus enhanced in luminosity and photon density by the Doppler boosting caused by the relativistic bulk motion of the plasma near our sight line. In the standard "monster" model of AGNs, the central engine is a supermassive black hole of 10^6-10^9 $M_\odot$, surrounded by an accretion disk and fast moving clouds (e.g. Urry & Padovani 1995; Ulrich et al. 1997). The shift in peak frequency of the SEDs from the LBL to the HBL subclasses could be caused by different beaming factors and by intrinsic physical parameters (Fig. 1). The SEDs are variable in time and the ratio of intensities in the synchrotron component and the IC component (Compton dominance) is variable, especially when a flare occurs, taking away the SED from its low luminosity state to the high.

2. Blazar SED models and the infrared data

Here we report two examples of SEDs fitted with a pure Synchrotron Self-Compton (SSC) model (IC scattering of the relativistic electrons over the same population of photons produced by the synchrotron emis-

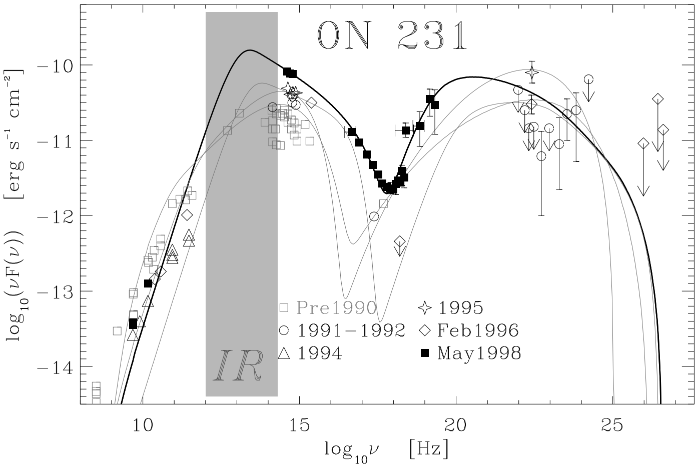

Fig. 2. Attempts to fit quasi-simultaneous multiwavelength data in the SED of the intermediate blazar ON 231 (W Com, z=0.102). We applied a time-dependent model, with a single flaring blob and a pure Synchrotron Self-Compton (SSC) emission. A relevant mid infrared synchrotron peak was predicted by the simulated SED of May 1998 (dark line), corresponding to the phase of a concave X-ray spectrum. We can clearly see that in the mid and far infrared no data were available to constraint the SEDs and the global energetics during the different phases of the broadband variability.

sion) for the intermediate blazars ON 231 (W Com, B2 1219+28) and BL Lac (S4 2200+42, OY 401). We used a single homogenous flaring blob of electron plasma for the high energy emission, with a time dependent kinetic equation. Due to the variability of the SEDs we have to take simultaneous data when available. From the simulations in Fig. 2 and Fig. 3, appear that the synchrotron bump peaks in the mid infrared bands, (for the darkest black fit line). This dark line correspond to a phase of detected concave X-ray spectrum for both the objects (a typical signature of intermediate blazars). Only old IRAS data are available in mid and far infrared, not useful for our multiwavelength analysis.

For the LBL the energy budget is indeed dominated by the IR emission from 1 to 100 μm: typically from 1/3 to 2/3 of the total luminosity is emitted in this range (Impey & Neugebauer 1988, hereinafter IN88) . The synchrotron bump of LBL and intermediate blazar, peaks often at IR wavelength and most of the energy is produced at this break frequency. Future infrared and sub-mm observations will be crucial to constraint blazar global energetics, acceleration-emission models and the physical parameters. Actually there is a gap between the radio and near-IR/optical observations for all the objects of this class of AGNs. Mid-IR observations could be very important in the multiwavelength campaigns and variability monitoring, setting decisive data for the estimation of the bolometric energy. The second (IC) peak of the SEDs at MeV-GeV energies, is accessible only from space, and any γ-ray mission actually observe this frequency range, so the energetics could be only estimated constraining the first (synchrotron) bump with infrared observations. When the next generation of GeV γ-ray satellites (AGILE, GLAST) will be available, with a mid-IR blazar variability monitoring will be possible to search for correlation in the flux at the synchrotron and IC peak frequencies. The first really simultaneous broadband multiwavelength observations using

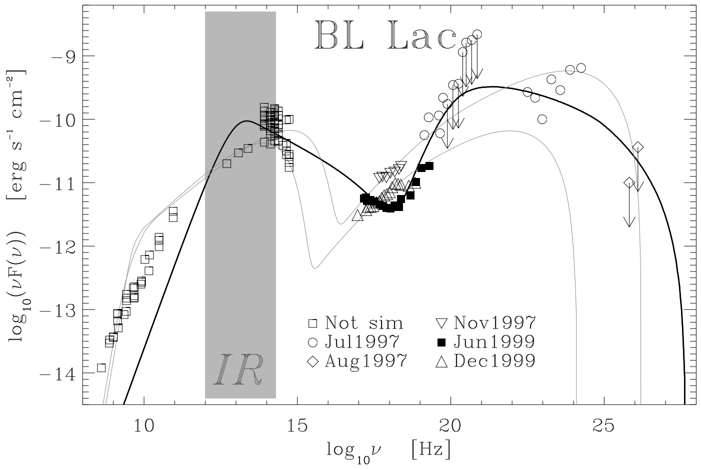

Fig. 3. Attempts to fit, with the same pure SSC model, quasi-simultaneous multiwavelength data in the SED of the eponymous intermediate object BL Lac (z=0.0686). In this blazar also, the mid infrared detections might be crucial to determine the flux values around the synchrotron peak and therefore to constraint the model parameters and the overall energetics during the different variability stages.

also mid and far infrared detections, was made only in May 1996 (by ISO, EUVE, EGRET) and only for the bright southern blazar PKS 2155-304 (Bertone et al. 2000).

Blazars display a direct view of the central engine of the AGNs, then a fundamental issue for the unification schemes was whether or not they showed signs of relevant IR emission, not entirely due to synchrotron radiation, but possibly due to the thermal emission by a dusty and opaque torus around the nucleus, by the host galaxy, or by an IR ambient photon field. Mid-IR data are important to probe the consistence with a smooth synchrotron spectrum powered by the standard monster model of AGN; positive result in this sense have been find for example for 3C 345 by IRAS measures (Soifer et al. 1987). IRAS showed, in the observed sample, that the spectral indices $\alpha_{100/60}$ μm and $\alpha_{60/25}$ μm are often nearly equal but there is a larger spread in the first respect to the second. The infrared emission of blazar with $L > 3 \times 10^{10}$ $L_\odot$ is synchrotron emission and below this bolometric luminosity thermal emission by dust heated by the central engine contribute significantly (IN88).

Mid/far IR variability was found by IRAS for 3C 345, 3C 446, OJ 287, BL Lac. This has larger flux amplitude and shortest times than the variability of radio-quiet quasar and Seyfert galaxies.

3. Mid-infrared observation of southern blazars from Antarctica

First reports and estimations of the sky conditions from the Antarctica plateau (in the Dome C base, at 3200m above s. l., Fig. 4) (Candidi & Lori 2003; Valenziano & Dall'Oglio 1999; Hidas et al. 2000; Busso et al. 2002) point out that are possible stable and high quality observations in the mid-infrared bands, with a broad 2-20 μm atmospheric window and probably with new opened windows between 20 and 40 μm. The low temperature (-50 °C) and the extraordinary low sky background (due to a dry, stable, transparent and cold atmosphere, clear of cloud and aerosols), make of Dome C the darkest and stablest known Earth-based site for this wavelengths.

Moderate size telescopes placed in this site, could carry out a photometric monitoring of the mid-IR variability, and could provide a mid-IR support for the observing multiwavelength campaigns of southern blazars and other AGNs. For one of the first proposed projects, the 0.8 m Cassegrain telescope IRAIT, with a Si:As 256x256 pixel array (2-25 μm) for the imaging (Busso et al. 2002), in background limited performances we derived at 10μm, a preliminary limiting detectable flux density of 20-50 mJy (taken to be a S/N=3), in 10 min. of integration. At 20μm this number should be doubled. From the IRAS flux detections (IN88)(Kim & Sanders 1998; Duc et al. 1997), we have estimated a number of about 40 known southern blazars and 50 known southern ultraluminous IR galaxies (ULIRGs) achievable. This telescope could be the unique way to fill the heavy lack of mid-IR photometric data, not only for blazars but also for other Active Galactic Nuclei (e.g highly obscured AGN, Seyfert galaxies, radiogalaxies and radio-quiet QSO).

Moreover other important extragalactic researches are possible with IRAIT. For example the study of bright nearby galaxies, the search for galaxies behind the obscuring dust of the Zone of Avoidance (the 25% of the sky) with the understanding of the peculiar velocity of the Local Group and the reconstruction of the large-scale local filaments and wall-like structures (Schröder et al. 1999). Or again the identification of the compact galaxies colors at moderate distances and infrared photometric studies of starburst galaxies, ULIRGs and obscured AGN.

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Fig. 4. The two main buildings of the Dome C base under construction, preliminary site testing and a pictorial view of the IRAIT dome.