

# *The Blazar Times*

A Research Newsletter Dedicated to the BL Lac and Blazar Phenomena

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### *Journal Abstracts*

#### **The Effects of Periodically Gapped Time Series on Cross-Correlation Lag Determinations**

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The three bright TeV blazars Mrk 421, Mrk 501 and PKS 2155–404 are highly variable in synchrotron X-ray emission. In particular, these sources may exhibit variable time lags between flux variations at different X-ray energy bands. However, there are a number of issues that may significantly bias lag determinations. Edelson et al. (2001) recently proposed that the lags on timescales of hours, discovered by ASCA and BeppoSAX, could be an artifact of periodic gaps in the light curves introduced by the Earth occultation every  $\sim 1.6$  hr. Using Monte Carlo simulations, in this paper we show that the lags over timescales of hours can not be the spurious result of periodic gaps, while periodic gaps indeed introduces uncertainty larger than what present in the evenly sampled data. The results also show that time lag estimates can be substantially improved by using evenly sampled light curves with large lag to bin-size ratio. Furthermore, we consider an XMM-Newton observation without interruptions and re-sample the light curves using the BeppoSAX observing windows, and then repeat the same cross correlation function (CCF) analysis on both the real and fake data. The results also show that periodic gaps in the light curves do not significantly distort the CCF characters, and indeed the CCF peak ranges of the real and fake data overlap. Therefore, the lags discovered by ASCA and BeppoSAX are not due to periodic gaps in the light curves.

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For preprints via ftp or WWW: <http://arXiv.org/abs/astro-ph/0401287>

#### **Modeling the TeV Gamma-Ray Spectra of Two Low-Redshift Active Galactic Nuclei: Markarian 501 and Markarian 421**

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We discuss the results of modeling the TeV -ray spectra of two active galactic nuclei, Mrk 501 and Mrk 421, that have almost the same redshifts:  $z = 0.031$  and  $0.034$ , respectively. The effect of intergalactic -ray absorption is treated as an uncertainty in the measurement of the intrinsic spectrum. Although the objects differ, we obtain satisfactory fits for both of them in a synchrotron self-Compton scenario. Compared to previous models, our fits are characterized by higher values of the Doppler factor ( $\delta \geq 50$ ) and an electron injection spectrum extending to higher energies ( $\gamma_{max} \geq 1.5 \times 10^5$ ). In the case of Mrk 421, the observed difference in spectral slope in X-rays and TeV -rays between the high and low states can be explained as a variation of a single parameter the maximum energy  $\gamma_{max}mc^2$  at which electrons are injected.

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## M87 as a Misaligned Synchrotron-Proton Blazar

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The giant radio galaxy M87 is usually classified as a Fanaroff-Riley class I source, suggesting that M87 is a mis-aligned BL Lac object. Its unresolved nuclear region emits strong non-thermal emission from radio to X-rays which has been interpreted as synchrotron radiation. In an earlier paper we predicted M87 as a source of detectable gamma ray emission in the context of the hadronic Synchrotron-Proton Blazar (SPB) model. The subsequent tentative detection of TeV energy photons by the HEGRA-telescope array would, if confirmed, make it the first radio galaxy to be detected at TeV-energies. We discuss the emission from the unresolved nuclear region of M87 in the context of the SPB model, and give examples of possible model representations of its non-simultaneous spectral energy distribution. The low-energy component can be explained as synchrotron radiation by a primary relativistic electron population that is injected together with energetic protons into a highly magnetized emission region. We find that the  $\gamma$ -ray power output is dominated either by  $\mu^\pm/\pi^\pm$  synchrotron or proton synchrotron radiation depending on whether the primary electron synchrotron component peaks at low or high energies, respectively. The predicted  $\gamma$ -ray luminosity peaks at  $\sim 100$  GeV at a level comparable to that of the low-energy hump, and this makes M87 a promising candidate source for the newly-commissioned high-sensitivity low-threshold Cherenkov telescopes H.E.S.S., VERITAS, MAGIC and CANGAROO III. Because of its proximity, the high-energy spectrum of M87 is unaffected by absorption in the cosmic infrared (IR) background radiation field, and could therefore serve as a template spectrum for the corresponding class of blazar if corrected for mis-alignment effects. This could significantly push efforts to constrain the cosmic IR radiation field through observation of more distant TeV-blazars, and could have a strong impact on blazar emission models. If M87 is a mis-aligned BL-Lac object and produces TeV-photons as recently detected by the HEGRA-array, in the context of the SPB model it must also be an efficient proton accelerator.

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## The Gamma-ray Bright BL Lac Object RX J1211+2242

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RX J1211+2242 is an optically faint ( $B \simeq 19.2$  mag) but X-ray bright ( $f_{2-10\text{keV}} = 5 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ ) AGN, which has been shown to be a BL Lac object at redshift  $z = 0.455$ . The *ROSAT* X-ray, Calar Alto optical, and NVSS radio data suggest that the peak of the synchrotron emission of this object is at energies as high as several keV. *BeppoSAX* observations have been carried out simultaneously with optical observations in order to extend the coverage to higher energies. The new data indeed indicate a turn-over in the 2 – 10 keV energy region. We propose that RX J1211+2242 is the counterpart of the unidentified EGRET source 3EG J1212+2304, making it a gamma-ray emitter with properties similar to, for example, Markarian 501 in its bright state, though being at a much larger distance.

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## Radio-Optical Flux Behavior and Spectral Energy Distribution of the Intermediate Blazar GC 0109+224

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About twenty years of radio observations in five bands (from 4.8 to 37 GHz) of the BL Lac object GC 0109+224 (S2 0109+22, RGB J0112+227), are presented and analysed together with the optical data. Over the past ten years this blazar has exhibited enhanced activity. There is only weak correlation between radio and optical flares delays, usually protracted on longer timescales in the radio with respect to the optical. In some cases no radio flare counterpart was observed for the optical outbursts. The radio variability, characterised by peaks superposition, shows hints of some characteristic timescales (around the 3-4 years), and a fluctuation mode between the flickering and the shot noise. The reconstructed spectral energy distribution, poorly monitored at high energies, is preliminarily parameterised with a synchrotron-self Compton description. The smooth synchrotron continuum, peaked in the near-IR-optical bands, strengthens the hypothesis that this source could be an intermediate blazar. Moreover the intense flux in millimetre bands, and the optical and X-ray brightness, might suggest a possible detectable gamma-ray emission.

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*Preprint:* astro-ph/0401271

## Evolution of BL Lacertae Host Galaxies

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We present and discuss deep, high-resolution I-band images of 24 BL Lac objects between  $z = 0.3$  and 1.3 taken with the Nordic Optical Telescope (NOT) and the ESO-NTT and VLT telescopes. In addition, new redshifts for the BL Lac objects PKS 0406+121, PKS 0426-380 and PKS 1519-273 are reported.

In 17/24 (71%) of the BL Lac objects, we detected an underlying nebulosity, in 11/17 for the first time. We assigned the underlying nebulosity to the BL Lac host galaxy in 11 cases spanning the redshift range  $z = 0.3-1$ . The remaining 6 BL Lac objects have either intervening galaxies (S4 0218+35, PKS 0426-380), no redshift (MH 2133-449) or are

probably misidentified (Q 0230+3429, B2 0937+26, MS 2347.4+1924).

Restricting ourselves to the 11 BL Lac objects ( $\langle z \rangle = 0.6$ ), where a core and host galaxy was detected, we find that their host galaxies are luminous ( $M_I = -25.2 \pm 0.8$ ) and large ( $r_e = 10.5 \pm 7$  kpc). They are on average about 0.6 mag brighter than BL Lac host galaxies at  $z \sim 0.3$  indicative of evolution, whereas their half-light radii are similar.

By combining our data with literature data at low-redshift and applying evolutionary models to them, we show that the properties of the host galaxies of BL Lac objects up to  $z \sim 1$  are compatible with passively evolving elliptical galaxies formed at a redshift of  $z \sim 2$  (13 Gyrs ago in our adopted cosmology).

Our results, however, are affected by an unavoidable luminosity bias and need to be confirmed. Future prospects are described. If they could be confirmed, host galaxies of low-luminosity radio-loud AGN (BL Lac/FR I) have very similar properties to the hosts of radio-quiet QSOs and high-luminosity radio-loud AGN (radio-loud QSO/FR II) over a wide redshift range. This supports the picture of the "Grand Unification" in which AGN activity is a transient phenomenon in galaxy evolution.

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## A Multifrequency Analysis of Radio Variability of Blazars

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We have carried out a multifrequency analysis of the radio variability of blazars, exploiting the data obtained during the extensive monitoring programs carried out at the University of Michigan Radio Astronomy Observatory (UMRAO, at 4.8, 8, and 14.5 GHz) and at the Metsähovi Radio Observatory (22 and 37 GHz). Two different techniques detect, in the Metsähovi light curves, evidences of periodicity at both frequencies for 5 sources (0224 + 671, 0945 + 408, 1226 + 023, 2200 + 420, and 2251 + 158). For the last three sources consistent periods are found also at the three UMRAO frequencies and the Scargle (1982) method yields an extremely low false-alarm probability. On the other hand, the 22 and 37 GHz periodicities of 0224+671 and 0945+408 (which were less extensively monitored at Metsähovi and for which we get a significant false-alarm probability) are not confirmed by the UMRAO database, where some indications of ill-defined periods about a factor of two longer are retrieved. We have also investigated the variability index, the structure function, and the distribution of intensity variations of the most extensively monitored sources. We find a statistically significant difference in the distribution of the variability index for BL Lac objects compared to flat-spectrum radio quasars (FSRQs), in the sense that the former objects are more variable. For both populations the variability index steadily increases with increasing frequency. The distribution of intensity variations also broadens with increasing frequency, and approaches a log-normal shape at the highest frequencies. We find that variability enhances by 20–30% the high frequency counts of extragalactic radio-sources at bright flux densities, such as those of the WMAP and PLANCK surveys. In all objects with detected periodicity we find evidence for the existence of impulsive signals superimposed on the periodic component.

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## A Physical Classification Scheme for Blazars

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Blazars are currently separated into BL Lacertae objects (BL Lacs) and flat spectrum radio quasars (FSRQ) based on the strength of their emission lines. This is done rather arbitrarily by defining a diagonal line in the Ca H&K break value – equivalent width plane, following Marchã et al. We readdress this problem and put the classification scheme for blazars on firm physical grounds. We study  $\sim 100$  blazars and radio galaxies from the Deep X-ray Radio Blazar Survey (DXRBS) and 2 Jy radio survey and find a significant bimodality for the narrow emission line [OIII]  $\lambda 5007$ . This suggests the presence of two physically distinct classes of radio-loud AGN. We show that all radio-loud AGN, blazars and radio galaxies, can be effectively separated into weak- and strong-lined sources using the [OIII]  $\lambda 5007$  – [OII]  $\lambda 3727$  equivalent width plane. This plane allows one to disentangle orientation effects from intrinsic variations in radio-loud AGN. Based on DXRBS, the strongly beamed sources of the new class of weak-lined radio-loud AGN are made up of BL Lacs at the  $\sim 75$  per cent level, whereas those of the strong-lined radio-loud AGN include mostly ( $\sim 97$  per cent) quasars.

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## **Helical Jets in Blazars. Interpretation of the Multifrequency Long-Term Variability of AO 0235+16**

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The long-term variability of the multiwavelength blazar emission can be interpreted in terms of orientation variations of a helical, inhomogeneous, non-thermally emitting jet, possibly caused by the orbital motion of the parent black hole in a binary system (Villata & Raiteri 1999). The helical-jet model is here applied to explain the quasi-periodic radio-optical light curves and the broad-band spectral energy distributions (SEDs) of the BL Lac object AO 0235+16. Through a suitable choice of the model parameters, the helix rotation can well account for the periodicity of the main radio and optical outbursts and for the corresponding SED variability, while the interspersed minor radio events could be interpreted as due either to some local distortions of the helical structure or to other phenomena contributing to the source emission. In particular, the probable existence of flow instabilities provides a viable interpretation for the non-periodic features.

Accepted by A&A

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## **Radio Spectra of a Sample of X-ray Selected BL Lacs**

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We present simultaneous multifrequency radio observations for a complete subsample of 26 XBLs from the *Einstein* Extended Medium-Sensitivity Survey, obtained with the Very Large Array (VLA). Spectra are computed using fluxes at 20, 6 and 3.6 cm. Unlike many radio selected samples, the EMSS did not impose any criterion on the radio spectrum to identify BL Lac objects. It is therefore possible to investigate the intrinsic radio spectral slope distribution and to determine the effect produced by this selection criterion. We find that 15% of the observed objects do not meet the flat-spectrum criterion imposed on some other BL Lac samples. A dataset that includes non-simultaneous data (that are also taken with different VLA configurations) shows an even higher percentage of steep spectrum sources. This effect can be ascribed to a larger fraction of extended flux detected with the more compact VLA configuration. Possible biases introduced by the flat–radio-spectrum criterion in the radio-selected BL Lac samples cannot explain the discrepancies observed in the evolutionary properties of Radio and X-ray selected samples of BL Lacs.

Accepted by A&A

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## *Abstract Guidelines*

Abstracts for “The Blazar Times” are solicited for papers that have been recently accepted for publication by a refereed journal, and for recent Ph.D. theses. Please do not submit an abstract before it has been accepted, nor after it is published. Abstracts from papers which are not refereed (e.g., conference proceedings) are not accepted.

The subject matter should pertain directly to the BL Lac and/or blazar phenomenon in general. Both observational and theoretical abstracts are appropriate. Abstracts from papers dealing with other classes of AGN will generally not be included unless they explicitly discuss their relevance to the blazar phenomenon; however exceptions to this rule will be considered.

A monthly call for abstracts will be issued and abstracts received by the last day of the month will usually appear in the following month’s newsletter. Announcements of general interest to the BL Lac and blazar communities may also be submitted for posting in the newsletter. These might include (but are not restricted to) the following: (i) *Job Openings* directed toward blazar researchers, (ii) announcements of *Upcoming Meetings*, (iii) announcements of *Upcoming Observing Campaigns* for which participation is solicited from the community at large, (iv) reviews of *New Books*, and (v) *General Announcements* that provide or request research-related information.

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