CONTEMPORANEOUS MULTIWAVEBAND OBSERVATIONS OF BLAZARS

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October 28, 1993

Abstract. We have observed a number of blazars at wavebands ranging from radio to γ-ray. We find bright γ-ray emission to be associated with strong synchrotron flares observed at lower frequencies. The X-ray flux and entire radio spectrum of 4C 39.25 have each increased in strength by 30% over a 2-year period, in agreement with the prediction of the bent relativistic jet model.

Key words: quasars, BL Lac objects, γ rays, multifrequency observations

1. Introduction

While much has already been learned about the nonthermal emitting regions in radio-loud, highly variable quasars and BL Lac objects (collectively referred to as "blazars"), we are still ignorant concerning many of the most important aspects of these sources. Multiwaveband observations of flares in blazars currently hold the greatest promise for exploring the region where the relativistic plasma is generated and the jet formed, focused, and accelerated. The timescales of variability can be as short as a few days, which indicates that the flares originate deep within the jet, perhaps near its base. By measuring time delays of variations in brightness as a function of frequency, it is potentially possible to determine the geometry of the inner jet as well as infer the steepness of gradients in magnetic field, relativistic electron density, and bulk Lorentz factor of the jet flow (e.g., Marscher 1993).

The most exciting recent development is the detection of strong, highly variable γ-ray emission from about 40 blazars (see Kurfess *et al.* and Thompson *et al.*, these proceedings). The apparent γ-ray luminosity is typically 1–2 orders of magnitude greater than that observed at other wavebands. Therefore, unless the γ-ray emission is more highly beamed than that at lower frequencies, most of the nonthermal energy emerges as very high energy photons during the γ-ray high states. Variability on timescales as short as a few days is observed, which indicates that the γ rays are produced in the inner jet. Understanding the γ-ray emission mechanism is therefore crucial to the exploration of the energetics and structure of the innermost regions of blazars.

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T. J.-L. Courvoisier and A. Blecha: Multi-Wavelength Continuum Emission of AGN, 155–158.

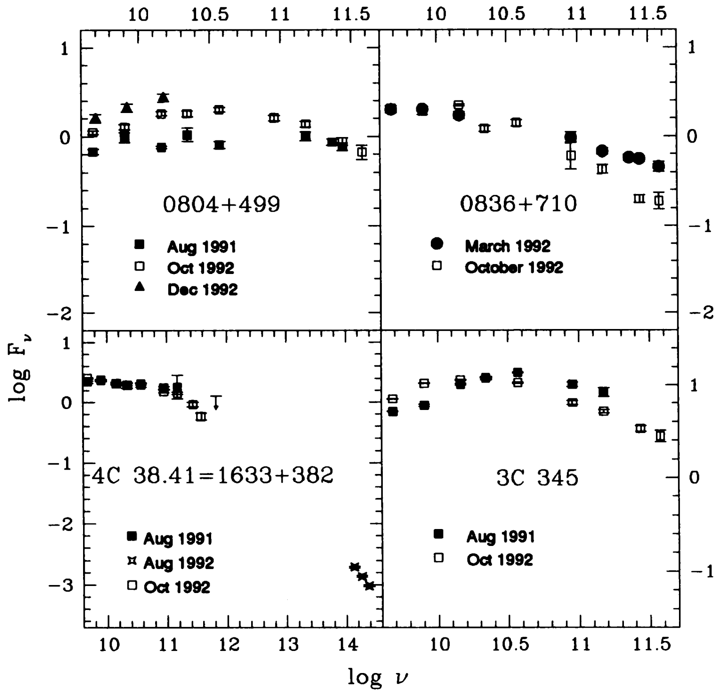

Fig. 1. Simultaneous radio to submillimeter spectra of four blazars. Epochs of measured strong γ-ray emission are: 0804+499 and 0836+710 — Jan & Mar 1992; 4C 38.41 (note different frequency scale) and 3C 345 — Sept 1991. From Bloom *et al.* (1994).

2. Relation between γ-ray and Lower Frequency Emission

We are in the midst of studies involving contemporaneous multiwaveband observations of blazars, consisting of VLBI, radio–submm, IR (for a few sources), X-ray, and γ-ray observations, in many case at multiple epochs. Instruments used include the VLBA and VLBI network, the U. Michigan and Metsähovi radio antennas, IRAM, the JCMT, UKIRT, ROSAT, and CGRO (mainly the EGRET detector). There are many collaborators, the most important for the work discussed here being H. D. and M. F. Aller, H. Teräsranta, E. Valtaoja, and S. D. Hunter.

Early results for γ-ray bright quasars are shown in Fig. 1. In all cases except 4C 38.41 (for which the data are rather sparse), *periods of high γ-ray flux are contemporaneous with enhanced levels of synchrotron emission* (see also Reich *et al.* 1994).

Nearly simultaneous multiwaveband spectra of a small number of sources show that the X-ray luminosity is not midway (on a logarithmic scale) between the γ-ray and infrared luminosities. Because of this, the spectra are inconsistent with

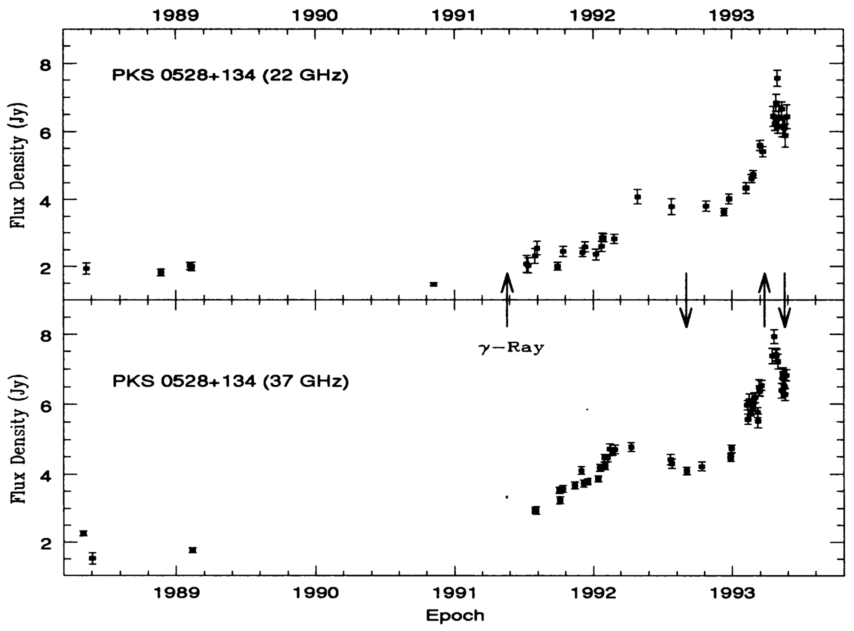

Fig. 2. 22 and 37 GHz light curves of PKS 0528+134. Epochs of CGRO γ-ray observations are indicated by the arrows; up-arrows: very strong detections; down arrows: upper limits to flux, $\sim$ 10 times lower than the strongest detection. From Zhang *et al.* (1994).

second-order (but *are* consistent with first-order) self-Compton emission as the origin of the γ rays (see Bloom and Marscher 1993).

The multiple CGRO observations of PKS 0528+134 provide an opportunity to compare γ-ray and radio emission, since the light curve has been well sampled since mid-1991 at 4.8, 8.0, 14.5, 22, and 37 GHz (Zhang *et al.*, 1994). As shown in Fig. 2, γ-ray high states (Hunter *et al.* 1993; Sreekumar *et al.* 1993) occurred near the beginning of a major high-frequency radio flare in mid-1991, which later propagated to lower frequencies as the outburst became progressively less opaque. The very high γ-ray flux of March 1993 preceded the peak of the strongest 37 GHz flux observed thus far by 25 days, whereas the factor of $\sim$ 10 lower γ-ray flux observed in late May 1993 (Nolan *et al.*, 1993) was measured during the declining phase of the 37 GHz outburst. The source was opaque at this frequency (the turnover frequency increased from 7 to 60 GHz, indicating that the core had become very active after a quiescent period), hence the 37 GHz peak was probably time delayed relative to the optically thin maximum at $\nu \gtrsim 100$ GHz. Nevertheless, these observations show that lags between γ-ray and synchrotron flares can be measured given sufficient time coverage with mm, submm, IR, and optical telescopes during and after (and before, if possible) the CGRO pointings.

It may be that all γ-ray flares are associated with synchrotron outbursts. The converse is not true, however. In the quasar 4C 39.25, the site of the synchrotron flare is a knot in the jet rather than the VLBI core region (Marscher *et al.* 1991; Alberdi *et al.* 1993). Despite a flux density that has risen to over 10 Jy at radio wavelengths, no γ rays were detected by CGRO in September–October 1993 (Mattox, private communication). We tentatively conclude that the synchrotron outburst must be in the core for there to be a γ-ray flare. The above authors model the radio behavior of 4C 39.25 in terms of a bent relativistic jet, with the fractional time rate of increase of flux density being the same at all observed radio frequencies above 4.8 GHz. We find that this extends to the X-ray emission, as predicted by the bent jet model if the X-rays arise from synchrotron self-Compton emission: both the X-ray and radio flux densities increased by 30% between April 1991 and April 1993.

3. Conclusion

The best way to establish and study the connections between γ-ray and X-ray emission and lower frequency synchrotron emission is through simultaneous multi-waveband monitoring. In general, past programs have not had sufficient time coverage to fulfill the promise of this technique. Still, much has been learned. More intensive monitoring is planned during the next few years, which should result in major advances in our knowledge of the physics of blazars.

4. Acknowledgments

This work was supported in part by NSF grant AST-9116525 and by NASA grants NAG5-1637, NAG5-1943, and NAG5-1566 (ROSAT and CGRO Guest Investigator Programs).

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