NEAR-INFRARED PHOTOMETRY OF BLAZARS

C. Chapuis\textsuperscript{1,2}, S. Corbel\textsuperscript{1}, P. Durouchoux\textsuperscript{1}, T. N. Gautier\textsuperscript{3}, and W. Mahoney\textsuperscript{3}

\textsuperscript{1) Service d’Astrophysique DAPNIA, CEA Saclay F-91191 Gif sur Yvette cedex 
2) Département de physique, Université de Versailles, F-78035 Versailles cedex 3) Jet Propulsion Laboratory 169-327, 4800 Oak Grove Dr., Pasadena, CA 91109}

ABSTRACT

The rapid variability of blazars in almost all wavelengths is now well established. Two days of observations were conducted at the Palomar Observatory during the nights of 25 and 26 February 1997 with the 5-meter Hale telescope, in order to search for rapid variability in the near-infrared (NIR) bands J, H, K\textsubscript{s} for a selection of eight blazars. With the possible exception of 1156+295 (4C 29.45), no intraday or day-to-day variability was observed during these two nights. However, for these eight blazars, we have measured the NIR $\nu F_\nu$ luminosities and spectral indices. It has recently been reported that the $\gamma$-ray emission is better correlated with the near-infrared luminosity than with the X-ray luminosity (Xie et al. 1997). This correlation is suggested as a general property of blazars because hot dust is the main source of soft photons which are scattered off the relativistic jets of electrons to produce the gamma rays by inverse Compton scattering. We thus used this relationship to estimate the $\gamma$-ray luminosity.

KEYWORDS: AGN, blazar, near infrared, observations

1. INTRODUCTION

1.1 The blazar properties

The discovery that blazars (i.e., optically violently variable quasars and BL Lac objects) and flat radio-spectrum quasars emit most of their power in high-energy gamma rays (Fichtel, et al. 1994) probably represents one of the most surprising results from the Compton Gamma-Ray Observatory (CGRO). Their luminosity above 100 MeV in some cases exceeds $10^{48}$ ergs s\textsuperscript{-1} (assuming isotropic emission) and can be larger (by a factor of 10-100) than the luminosity in the rest of the electromagnetic spectrum. Moreover, the $\gamma$-ray emission can be strongly variable on time-scales as short as days, indicating that the emission region is extremely compact (Kniffen et al. 1993). Blazars have smooth, rapidly variable, polarized continuum emission from radio through UV/X-ray wavelengths. All have compact flat-spectrum radio cores and many exhibit superluminal motions.
1.2 The origin of gamma rays in blazars

A variety of theoretical models have been recently proposed to explain the origin of the \( \gamma \)-ray emission of blazars. Most models describing the high-energy emission involve beaming from a jet of highly relativistic particles and include:

1. Synchrotron self-Compton. The \( \gamma \)-ray spectrum is the high-energy extension of the inverse-Compton radiation responsible of the X-ray radiation (Maraschi et al. 1992), i.e., the scattering of synchrotron radiation by relativistic electrons gives rise to a higher frequency flux, which can be scattered a second time and so on.

2. Inverse Compton scattering of accretion-disk photons by relativistic nonthermal electrons in the jet (Dermer et al. 1992).

3. Inverse Compton scattering of ambient soft X-rays by relativistic pairs accelerated \textit{in situ} by shock fronts in a relativistic jet (Blandford & Levinson 1995).

4. Synchrotron emission by ultrarelativistic electrons and positrons (Ghisellini et al. 1993).

Various relations between the emission at different wavelengths are implied by these models and can be used to observationally distinguish among a variety of emission mechanisms.

1.3. The infrared and near-infrared luminosities

A strong correlation between \( \gamma \)-ray and near-infrared luminosities was recently reported for a sample of blazars and it was suggested that this relation might be a common property of these objects (Xie et al. 1997). For that reason, the authors conclude that hot dust is likely to be the main source of the soft photons (near-infrared) which are continuously injected within the knot and then produce \( \gamma \)-ray flares by inverse Compton scattering on relativistic electrons. Given this correlation, it is easy to use the near-infrared luminosities to deduce the \( \gamma \)-ray fluxes, and then, the total emitted fluxes.

2. OBSERVATIONS

We observed eight blazars with the 5-meter Hale telescope on Mt. Palomar during the nights of 25 and 26 February 1997, using the Cassegrain Infrared Camera, an instrument based on a 256 \times 256-pixel InSb array with the J (1.25 \( \mu \)m), H (1.65 \( \mu \)m) and Ks (2.15 \( \mu \)m) filters and a field-of-view of 32 arcsec.

The reduction of data was done under IRAF and included subtraction of the dark noise, flat field corrections, and combination of images to remove bad pixels, cosmic rays, and the sky. Then aperture photometry for each object was performed using nearby faint standards for calibration. The apparent magnitudes are summarized in Table 1 and plotted in Figure 1.

Due to the steadyness of the sources, it was possible to fit the energy flux to a power law (defined as \( f(\nu) \propto \nu^{-\alpha} \)) by \( \chi^2 \) minimization, giving the spectral index, \( \alpha \), for each source (Table 1). Finally, we calculated the luminosity, \( L(\nu) = 4\pi d_L^2 \nu f(\nu) \),
FIGURE 1. The mean magnitudes of steady blazars are drawn with diamonds in J, H and Ks bands. For 1156+295 squares (25 February) and diamonds (26 February) are used to show the variation between the two nights. Typical errors range from 0.05 to 0.08 magnitudes. The power law fit is indicated by the dashed lines.

(1) using the luminosity distance, \(d_L\), where \(q_0 = 0.5, H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}\), \(z\) is the redshift, and \(c\) the velocity of light in vacuum:

\[
d_L = \frac{c}{H_0 q_0} (zq_0 - (1 - q_0)(\sqrt{1 + 2q_0z} - 1)) \quad \text{(Weinberg 1972)}
\]

(2) and the K-correction, where \(\alpha\) is the spectral index:

\[
f(\nu) = f_{\text{obs}}(\nu)(1 + z)^{(\alpha - 1)}.
\]

The K-corrected \(L_\nu\) luminosities in the Ks-band (as defined in Dondi & Ghisellini (1995)), calculated from our near-infrared observations, are given in Table 1. For 0716+714, we took the lower limit \(z > 0.3\) of Wagner et al. (1996). All other redshifts were taken from compilations of Ghisellini et al. (1993) and Dondi & Ghisellini (1995).

A strong correlation observed between \(\gamma\)-ray and near-infrared luminosities was shown (Xie et al. 1997) and the authors suggest that it may be a common property of blazars. According to them, inverse Compton scattering of the infrared radiation
| IAU Name      | z      | Apparent Magnitude |   |   |   | T_{IR} | T_{\gamma} |
|--------------|--------|--------------------|---|---|---|------|----------|
| 0446+112     | 1.207  | 17.54(10)          | 16.62(6) | 15.66(5) | 1.6  | 7.3  | 25       |
| 0628+112     | 2.060  | 16.01(5)           | 15.67(5) | 14.77(5) | 1.40 | 53   | 311      |
| 0716+114     | > 0.3  | 11.97(5)           | 11.19(5) | 10.44(5) | 1.90 | > 27 | > 134    |
| 0804+429     | 1.43   | 16.66(5)           | 15.31(5) | 14.27(5) | 0.60 | 9.4  | 35       |
| 0836+710     | 2.172  | 15.64(5)           | 15.05(5) | 14.33(5) | 0.60 | 36   | 191      |
| 1156+295     | 0.729  | 14.03(5)           | 13.18(5) | 13.34(5) | 0.90 | 11   | 43       |
| 1253-055 (3C279) | 0.508 | 14.62(5)           | 13.85(5) | 13.32(5) | 0.80 | 12.6 | 51       |
| 1406-066     | 1.494  | 16.98(5)           | 16.02(5) | 15.26(5) | 1.20 | 14   | 37       |

Table 1. Summary of blazar observations where the columns represent (1) IAU name, (2) redshift, (3-5) J, H, and K_s magnitudes, (6) near-infrared spectral index, and (7-8) K-corrected near-infrared (T_{IR}) and gamma-ray (T_{\gamma}) luminosities in units of 10^{45} erg s^{-1}.

from hot circumnuclear dust by a relativistic electron beam should be responsible for the \(\gamma\)-ray flares. According to Xie, et al. (1997), the near-infrared and \(\gamma\)-ray luminosities of blazars can be related by:

\[
\log T_{\gamma} = 1.26 \log T_{IR} - 11.38
\]

Using this relationship, we then estimated the \(\nu F_\nu\) luminosity in the \(\gamma\)-ray range, using the K-corrected \(\nu L_\nu\) luminosity in the \(K_s\)-band. These results are summarized in Table 1 and their discussion is given in Chapuis et al. (1998).

Acknowledgement: Observations at the Palomar Observatory were made as part of a continuing collaborative agreement between Palomar Observatory and the Jet Propulsion Laboratory. The research described in this paper was carried out in part by the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration.

REFERENCES
Blandford, R.D., & Levinson, A. 1995, ApJ, 441, 79
Chapuis, C., et al. 1998 (in preparation)
Dermer, C., Schlickeiser, R., & Mastichiadis, A. 1992, A&A, 256, L27
Dondi, L., & Ghisellini, G. 1995, MNRAS, 273, 583
Fichtel, C. E., et al. 1994, ApJS, 94, 551
Ghisellini, G., Padovani, P., Celotti, A., & Maraschi, L. 1993, ApJ, 407, 65
Kniffen, D. A., et al. 1993, ApJ, 411, 133
Maraschi, L., Ghisellini, G., & Celotti, A. 1992, ApJ, 397, L5
Wagner, S.J., et al. 1996, AJ, 111, 2187
Weinberg, S. 1972, Gravitation and Cosmology, John Wiley & Sons NY
Xie, G., Zhang, Y., & Fan, J. 1997, ApJ, 477, 114