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Research Note

Long-term infrared variation of 3C 279 and 4C 29.45

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Abstract. In this paper, the historical infrared (JHK) data compiled from 22 publications are presented for 3C 279 and 4C 29.45. Relations between color index and magnitude and between color-color indices are discussed. (J-K) is found closely correlated with (J-H) while (J-H) is almost not correlated with (H-K), which is perhaps due to two facts of (1) (J-K) shows wider distribution than (J-H) and (H-K) and (2) the spectrum deviates from the power law. For color-magnitude relation, there is a correlation of color index increasing with the magnitude for 3C 279 suggesting that the spectrum flattens when the source brightens. But an opposite tendency is also noted between (H-K) and J when J is fainter than 14 magnitude, which suggests that the near-IR spectrum of 3C 279 consists of, at least, two components. No similar result is found for 4C 29.45. The largest amplitude infrared variation is smaller than but comparable with the largest amplitude optical variation for the two objects.

Key words: galaxies: quasars: individual: 3C 279 – galaxies: quasars: individual: 4C 29.45

1. Introduction

Blazars are AGNs characterized by compact radio core, high and variable radio and optical polarization, superluminal radio components. The continuum emissions are rapidly variable at all frequencies with amplitude of variability increasing with frequency (see Kollgaard 1994, Urry & Padovani 1995 and Scarp & Falomo 1997). Blazars include BL Lac objects, optically violently variable quasars (OVVs), highly polarized quasars (HPQs), flat spectrum radio quasars (FSRQs), and core dominated quasars (CDQ). All those objects are basically the same thing (Fugmann 1989; Impey et al. 1991; Valtaoja et al. 1992; Will et al. 1992; Scarpa & Falomo 1997).

3C 279 (PKS 1253-055, 4C-05.55) and 4C 29.45 (QSO 1156+295, Ton 599) are blazars. These two objects have some interesting observation properties. They are QSOs showing properties similar to those of a BL Lacertae object: Large amplitude variation and high and variable polarization. 4C 29.45 is classified as a BL Lac object (see Fan et al. 1993 and references therein), but its line spectrum looks like that of a normal QSOs when the continuum is faint (B $\sim$ 18) (Wills et al. 1983). 3C 279 occupies the same place as radio selected BL Lacertae objects (RBLs) in the polarization-Doppler factor diagram and is more like an RBL than a QSO (Fan 1998).

Before γ-ray observations were available, Impey & Neugebauer (1988) found that the infrared emission (1–100 μm) dominates the bolometric luminosities of blazars. The infrared emission is also an important component for the luminosity even when the γ-ray emissions is included (von Montigny 1995). The high energetic γ-ray emission mechanism is still an open problem (see Fan et al. 1998a, and references therein). Recently, Xie et al. (1997) found that the high energy γ-rays are correlated with the near-IR emissions suggesting that the soft photons scattered to the γ-rays region are from the dust. So, study of the infrared will throw some lights on the understanding of the emission mechanisms in AGNs, particularly temporal correlation.

Blazars have been observed in the infrared region for more than 20 years, but there are no available long-term infrared variations in the literature for all these objects. In this paper, we present the long-term infrared (J,H, and K bands) light curves for 3C 279 and 4C 29.45 and discuss the variation properties in these wavebands. The paper has been arranged as follows: In Sect. 2, we present the literature for the data and the light curves; in Sect. 3, we discuss them and give a brief conclusion.

2. Near-infrared light curves

2.1. Data

Infrared observations are available since the 1960s. Here we have compiled the data from 22 publications listed in Table 1, which gives the observers in Column 1. and the telescope(s) used in Column 2.

2.2. Light curves

The flux density in the literature has been convected back to magnitude using the original conversion. No dereddening correction was done for the two high Galactic latitude ($b^{II} = 57^\circ.1$ for 3C 279, $b^{II} = 80^\circ$ for 4C 29.45) objects. The measurements were not always made in three bands, generally, there are more measurements in H and K than in J. The light curves are shown in Fig. 1a–c, and Fig. 2a–c for 3C 279 and 4C 29.45, respec-

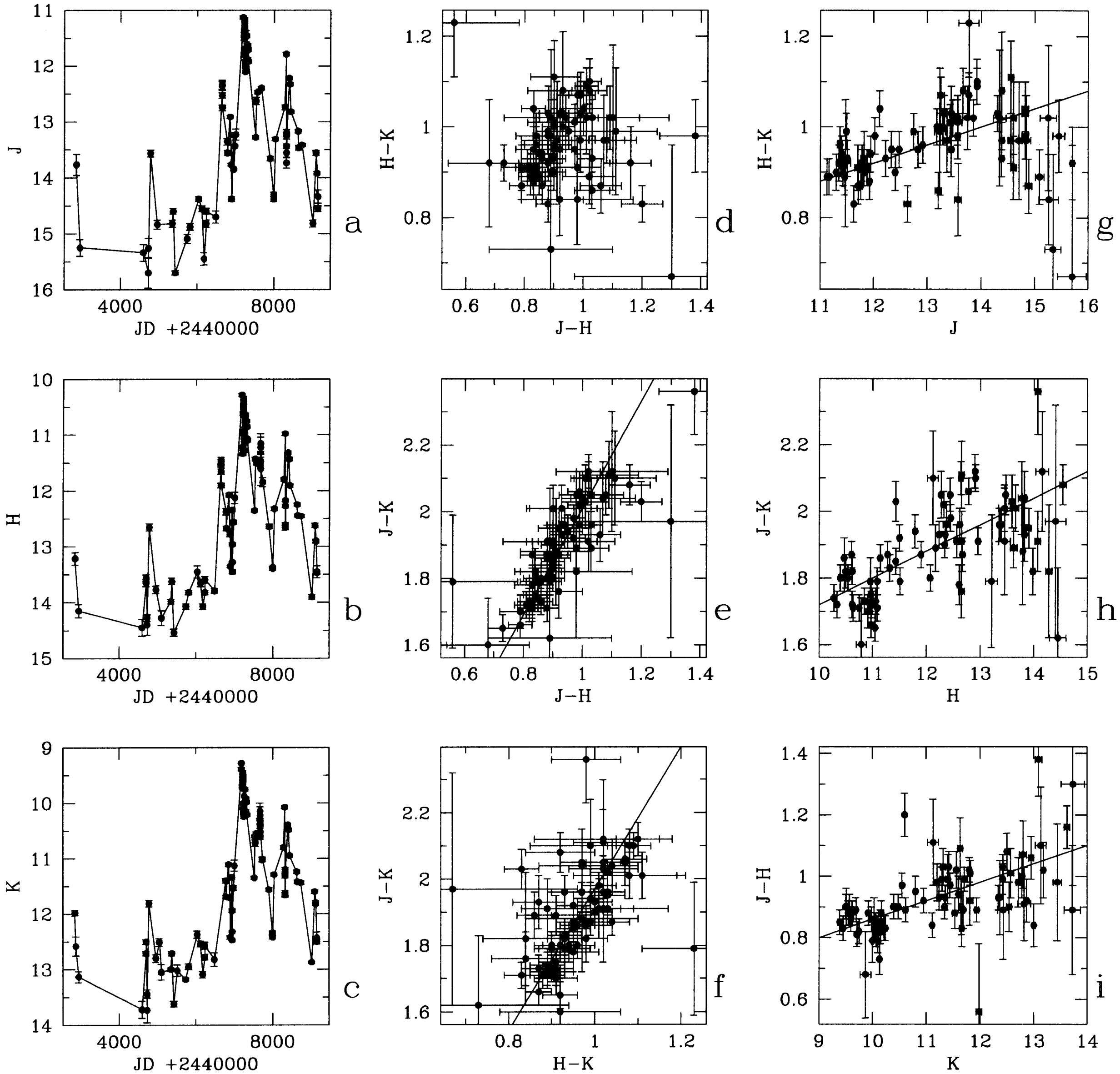

Fig. 1a–i. Light curves and color index properties for 3C 279. **a** J light curve; **b** H light curve; **c** K light curve; **d** J-H vs. H-K; **e** J-K vs. J-H; **f** J-K vs. H-K; **g** H-K vs. J; **h** J-K vs. H; **i** J-H vs. K

tively. In the literature, some measurements from 3C 279 have relatively large uncertainties(one point from Neugebauer et al. (1979), one from Lepine et al. (1985), and one from Impey et al. (1984) for instance). Figs. 1a–c show that there is good overall agreement in the flux variation. The largest amplitude variations are ΔJ = 4.57, ΔH = 4.26, and ΔK = 4.45 for 3C 279 and ΔJ = 3.47, ΔH = 3.82, and ΔK = 3.97 for 4C 29.45. Now, we will analyse the correlation between color indexes and that between color index and magnitude.

2.3. Correlation

Because of the uncertainties in the considered data, straight-line fitting with the uncertainties in both coordinates considered is used to deal with the data.

$$y(x) = a + bx$$

In principle, a and b can be determined by minimizing the χ^2 merit function, i.e. Eq. (15.3.2) in the book by Press et al. (1992)

$$\chi^2(a,b) = \sum_{i=1}^{n} (y_i - a - bx_i)^2 w_i$$

where σ_{y_i} and σ_{x_i} are the x and y uncertainties for the ith point and $\frac{1}{w_i} = \sigma_{y_i}^2 + b^2\sigma_{x_i}^2$. Unfortunately, the occurrence of b in the denominator of the above χ^2 merit function results in the equation for $\frac{\partial\chi^2}{\partial b} = 0$ being nonlinear, which makes the task of fitting very complex, although we can get a formula for a from $\frac{\partial\chi^2}{\partial a} = 0$,

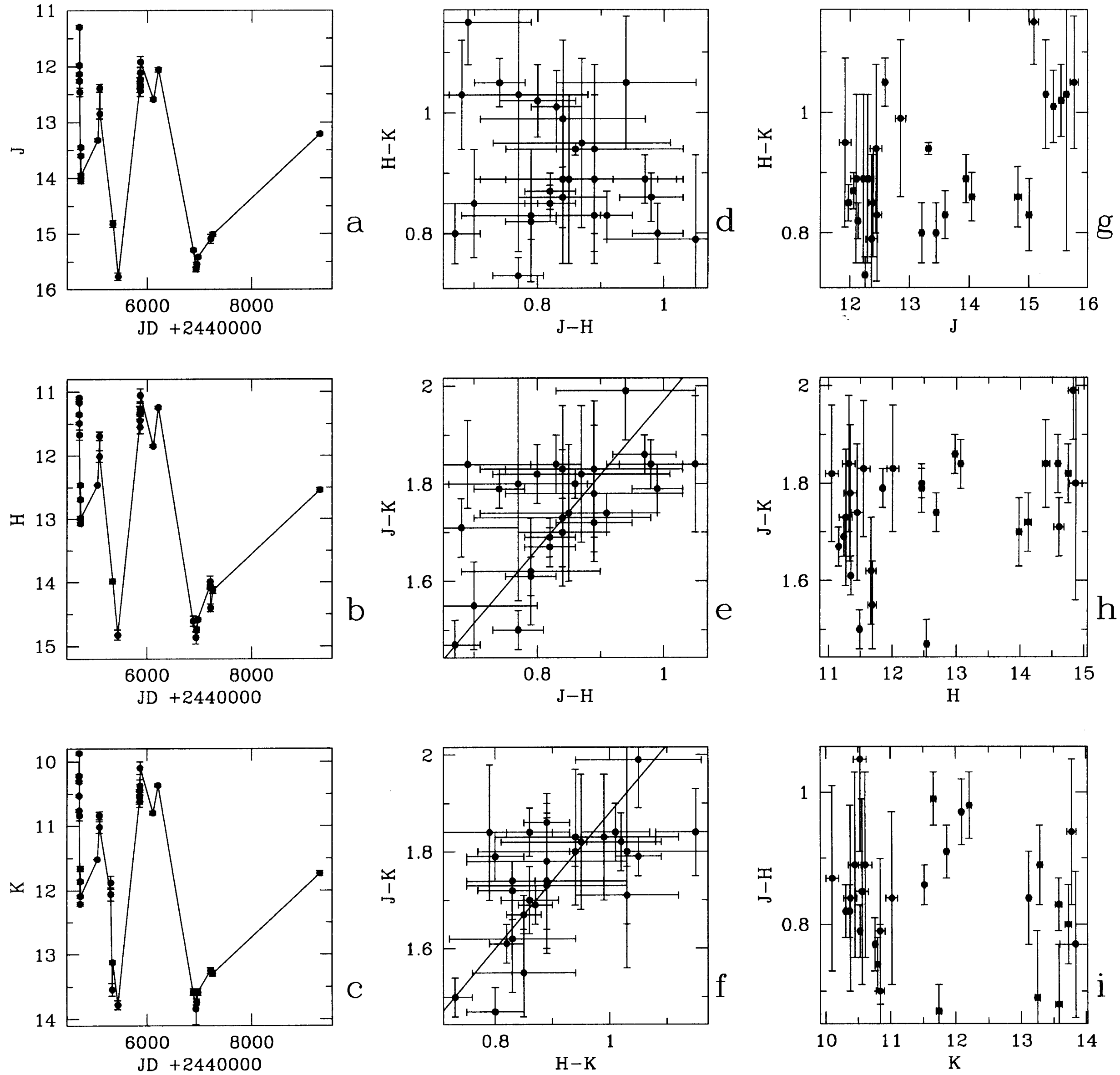

Fig. 2a–i. Light curves and color index properties for 4C 29.45. **a** J light curve; **b** H light curve; **c** K light curve; **d** J-H vs. H-K; **e** J-K vs. J-H; **f** J-K vs. H-K; **g** H-K vs. J; **h** J-K vs. H; **i** J-H vs. K

$$a = \frac{\sum_i w_i(y_i - bx_i)}{\sum_i w_i}$$

By minimizing the χ^2 merit function with respect to b and using the equation for a at each stage to ensure that the minimum with respect to b is also minimized with respect to a, we can get a and b, but finding the uncertainties, σ_a and σ_b, in a and b is more complicated (see Press et al. 1992). So, in the present paper, we only estimated the regression parameters a and b without considering the corresponding uncertainties in a and b.

2.3.1. Color-color relation

The data discussed here and in the following section are given simultaneously in the original literature except for a few several-day-averaged points of 3C 279. From the simultaneous observations, we can get that the averaged color indices are: (J-H) = 0.93±0.12, (J-K) = 1.89±0.14, and (H-K) = 0.95±0.09 for 3C 279; (J-H) = 0.84±0.09, (J-K) = 1.74±0.13, and (H-K) = 0.91±0.09 for 4C 29.45. When the straight-line fitting is used to the color indices, (J-K) is found associated with both (J-H) and (H-K) while there is almost no correlation between (J-H) and (H-K) as found in RBLs (Fan & Lin 1999). For 3C 279, (J-K) = 1.6(J-H) + 0.41 with the correlation coefficient $r = 0.876$ and the probability p of the relation happening by chance almost zero, (J-K) = 2.14(H-K) - 0.17 with $r = 0.72$ and p is almost zero; For 4C 29.45 (J-K) = 1.52(H-K) + 0.45 with $r = 0.62$ and $p = 4.2 \times 10^{-4}$, (J-K) = 1.4(H-K) + 0.48 with $r = 0.705$ and $p = 3. \times 10^{-5}$. They are shown in Fig. 1d–f and Fig. 2d–f.

Table 1. Literature and telescopes for the data

Observer(s)	Telescope(s)
Brown et al. (1989b)	UKIRT 3.8m
Garcia-Lario et a l(1989)	TCS 1.5m
Gear et al. (1985,1986a)	UKIRT 3.8m
Glassgold et al. (1983)	UKIRT 3.8m
	Palomer Mt. 5m
Holmes et al. (1984)	UKIRT 3.8m
Impey et al. (1984)	UKIRT 3.8m
Kidger & Casares (1989)	TCS 1.5m
Kidger et al. (1992)	TCS 1.5m
Landau et al. (1986)	UKIRT 3.8m; Hale 5m &
	Mount Lemnon 1.5m
Lepine et al. (1985)	ESO 3.6m
Litchfield et al. (1994)	ESO 2.2m
Maraschi et al. (1994)	Sutherland 1.9m
Mead et al. (1990)	UKIRT 3.8m
Neugebauer et al. (1979)	Hale 5.0m
O'Dell et al. (1978)	UM/UCSD 1.5m
Rieke et al. (1977)	UOA 90inch & 61 inch
Roelling et al. (1986)	UKIRT 3.8m
Sitko et al. (1982)	UM/UCSD 1.5m
Sitko & Sitko (1991)	KPNO 1.3m & 1.5m
Smith et al. (1987)	KPNO 2.1m
Takalo et al. (1992)	TCS 1.5m

2.3.2. Color-magnitude relation

In AGNs, it is common for the continuum spectrum to change with the brightness of the source, generally, the spectrum flattens when the source brightens but an opposite behaviour is found in some RBLs (see Fan & Lin 1999, and references therein). But for the spectral index versus flux density correlation, there is a statistic bias (e.g. Massaro & Trevese 1996). To avoid this bias, we discuss the relation between the magnitude in one band and the color index obtained in two other bands. Used the straight-line-fittin, following relations are found for 3C 279: (H-K) = 0.04J + 0.44 with $r = 0.53$ and $p = 5.0 \times 10^{-7}$, (J-K) = 0.08H + 0.92 with $r = 0.72$ and p is near 0.0, (J-H) = 0.06K + 0.26 with $r = 0.72$ and $p = 2.0 \times 10^{-10}$. No similar result is found for 4C 29.45 (see Fig. 1g–i, Fig. 2g–i).

3. Discussion

Blazars are variable at all wavelengths. Infrared observations have been available for more than 20 years, but no long-term variation is available for AGNs except for the works of Neugebeuer et al. (1979) and Litchfield et al. (1994), in which they presented infrared observations of about 8-year for some selected objects. Recently, we found that variations in the optical and infrared closely associated for PKS 0735+178 (Lin & Fan 1998) and OJ287 (Fan et al. 1998c) indicating these two bands coming from the same mechanism. But, it is reasonable that other nonvariable or slowly varying near-IR component, such as the stars in the parent galaxy, is present in the spectrum of AGNs. In this sense, when the source is bright, the spectrum is observed to steepen when the source dims, as expected from a synchrotron component which experiences radiative energy losses, but when the source dims further, because of the presence of the underlying near-IR emission, the spectrum will flatten with the source getting faint as pointed out by Brown et al. (1989). Because the underlying near-IR emission affects J more serious than other two bands, we would expect that there is a clear tendency of spectral flattening with J when J is fainter than a certain magnitude.

3C 279 is a well known OVV with a large optical variation of $\Delta B \geq 6.70$ mag (Eachus & Liller 1975) and a highly optical polarization of $P_{opt} = 43.3 \pm 1.3\%$ (see Scarpa & Falomo 1997). It has shown a violent optical brightness increase of 2.0 mag during an interval of 24 hours (Webb et al. 1990). The largest amplitude optical variation is greater than the largest amplitude infrared variation. The straight-line fitting gives a very significant linear correlation between (H-K) and J, but Fig. 1g indicates that (H-K) decreases with J when J is fainter than 14 mag, indicating the spectrum flattens when the source dims, but this tendency does not show up obviously in Fig. 1h or Fig. 1i. The difference between the fitting and the plot is from the faint J points with large error bars, which play a less important role on the fitting. If we remove the two points with large error bar at the bottom right corner, the tendency is not very clear. Nevertheless, it is worthy of notice and being discussed with more data. If this tendency is real, it is perhaps from the affection of the underlying galaxy as discussed above. The near-IR spectrum of 3C 279 consists of at least two components. The underlying galaxy affects J more serious than H or K, so the tendency appeared in Fig. 1g does not show up clearly in Fig. 1h or 1i.

4C 29.45 also shows large amplitude variation ($\Delta m = 5.0$, Branly et al. 1996), high and variable polarizations ($P_{IR} = 28.06\%$, P_{opt}=28%, Holmes et al. 1984; Mead et al. 1990). The largest amplitude variations in the infrared are smaller than, but comparable with, those in the optical band. The infrared light curves show two one-year-separating-double-peaked outbursts with an interval of 3.2 years. During the simultaneous infrared observations, 4C 29.45 showed no significant spectral changes when the source was relative bright ($\alpha = -0.98 \pm 0.18$ when the source dimmed by $\sim$ 0.9 mag from K = 9.87 to 10.76 during April 5–8, 1981). But the spectral index obtained at the end of April ($\alpha = -1.39 \pm 0.08$) showed spectral steepening when the source was about 2.5 magnitude fainter than it was on April 5 (Glassgold et al. 1983). There are no continuous observations between them. From the compiled long-term data, this association is complex and some data (Smith et al. 1987) have relatively large uncertainties, $\sigma = 0^m.1$, (see Fig. 2g–i). From the data, we found that the largest variation in J is smaller than that in K. The reason is that there are fewer points in J than H and K in the literature. Besides, a weak correlation of (J-K) increasing with H ($p \sim 0.5\%$) can be obtained. For this object, the data are sparse, its variability properties should be discussed with more observations.

For the color indices, there are correlations between (J-K) and (H-K) and (J-H) as well, but there is almost no correlation between (J-H) and (H-K). We think the reasons are perhaps due to the facts that (1) (J-K) has wider distribution than (J-H) and (H-K) so that (J-H) and (H-K) concentrate in a narrow region diluting the correlation, and (2) the spectrum deviates from the power law (Fan et al. 1998d).

We have both compiled the infrared light curves for 3C 279 and 4C 29.45, and investigated the largest amplitude variation, color-color relation and color-magnitude relations. The largest variation in the infrared is smaller than that in the optical band, (J-K) is strongly associated with (J-H) for the two objects while a color-magnitude relation is only found for 3C 279, the (H-K)-J plot suggests that the spectrum of 3C 279 consists of at least two components. No similar results are found for 4C 29.45.

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