Optical and Infrared Flux Variability of the FSRQ 3C 454.3

Li Zhou[a], Guangyang Xu, Lisa Wang, Jiufu Chen, and Xiaopan Li

School of Physics and Information Engineering, Zhaotong University, Zhaotong 657000, China.

[a]Zhou20081983@163.com

Keywords: Periodic light change; Color change; Band light change; Time delay

Abstract: Based on the introduction of the flat-spectrum radio quasar 3C 454.3, the optical and infrared data are collected, and the historical light curve, color index change and time delay are analyzed according to the data. The results are as follows: (1) The light curve indicates that the target's optical activity is intense and unstable, and may have periodic components of 79.89 days and 53.26 days in the optical B-band. (2) Color index analysis shows that there are many correlations between color index and brightness. (3) The DCF method indicates that there is no significant time delay in the optical changes of the target optical and infrared bands.

1. Introduction

The blazar object is one of the frontiers of astronomical research. It is the most active species in the active galactic nucleus and the most extreme subclass. The blazar object is a very high-quality energy source. According to the observation characteristics, it can be divided into two categories: flat-spectrum radio quasar (FSRQ) and BL Lac object. Due to the unique characteristics of blazar objects with high energy and rapid changes, it is generally believed that there is a relativistic jet in the direction pointing to the earth. Due to its dramatic and rapid light changes, large and variable polarization, unique observational features such as superluminal motion and continuous non-thermal radiation, it has become a focus of astronomical astronomy. Light change is one of the most prominent features of the blazar object. The blazar object is very common in fast short-time standard light. Currently, short-time standard light changes are found in the radio, optical, infrared, X-ray and Y-ray bands [1].

The flat-spectrum radio quasar 3C 454.3 is a blazar object that has been widely studied and studied. At present, scientists have discovered that celestial body 3C 454.3 can observe light changes in multiple wavelengths such as radio, optics, X-ray and gamma ray, and since 2000, it has entered a brighter state, which is more active than before. severe. In 2008, it was found that the source exhibited a very sharp burst of flow in the gamma ray energy segment and the optical band, and it was found that the gamma ray light changed into the pre-infrared J-band light change in this explosion for about 2 days [2]. Yuan et al. used power spectrum method to find that the long-term polarization of 3C 454.3 has periodic changes of 17.9 years, 6.9 years and 3.9 years, and pointed out that there may be correlation between spectral index and average degree of polarization [3]. Dong et al. used the structure function method and the discrete correlation function method to analyze the optical curve of 3C 454.3 in the infrared band and found that the source may have a periodic optical change of 192d, and explained the appearance of periodic light changes [4]. Gu et al. found a strong correlation between the gamma ray band of 3C 454.3 and the flow variation of the radio band, and pointed out that the latter lags the former [5]. Liu et al. used the structure function and discrete correlation function method to analyze the 3C 454.3 Fermi/LAT gamma band flow light curve and found a number of characteristic light-changing time scales, and pointed out that 3C 454.3 light energy light change may have double Cyclic phenomena, the correlation between optical and radio current changes are also very obvious [6].

It can be seen from the above analysis that domestic researchers are very intensive in the study of the flat-spectrum radio quasar 3C 454.3, and are concentrated in the optical, infrared and high-energy gamma ray bands. This paper focuses on the optical infrared optical properties of 3C 454.3, focusing on its periodic optical changes, color changes and time delays of light changes in each band.

2. Observations and Light Curves

Since November 2011, the SMARTS telescope has observed the optical bands (B, V, R, J, K) of the flat-spectrum radio quasar 3C 454.3, and collected 3C 454.3 from November 2010 to 2014. In July of the year, 3457 data points, including 714 data points in the B-band, 685 data points in the V-band, 698 in the R-band, 684 in the J-band, and 676 in the K-band. In order to more intuitively find out the optical-relationship relationship of the flat-field radio quasar 3C 454.3 in five bands, the B, V, R, J, K-band optical curves of the flat-spectrum radio quasar 3C 454.3 are given. Figure 1 is the historical light curve of the 3B 454.3 (B, V, R, J, K) bands from November 2010 to July 2014. The abscissa is the approximate Julian day (day), and the ordinate is the brightness (star, etc.).

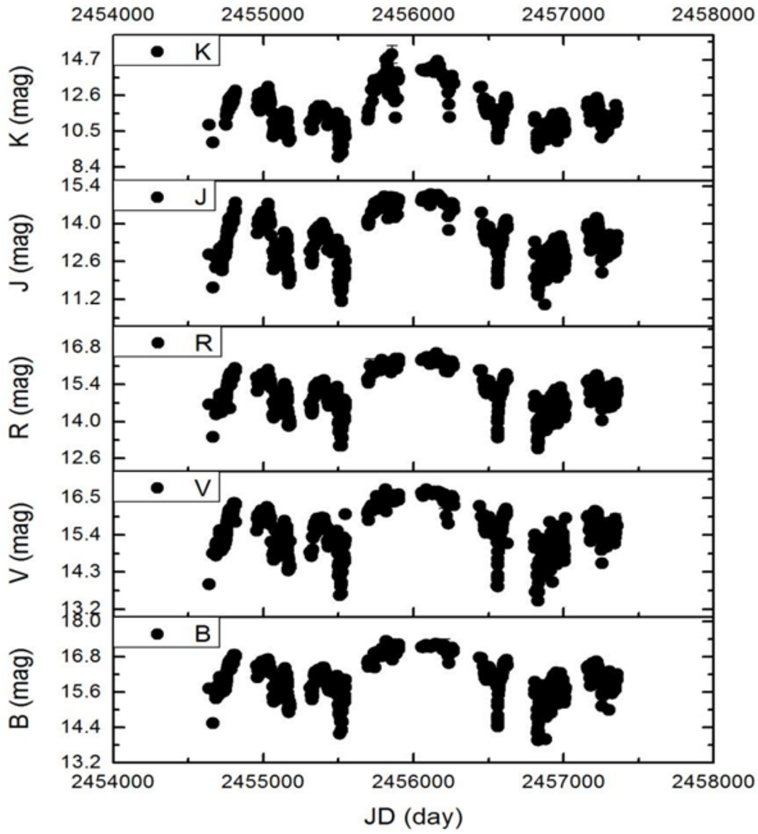

Fig. 1 B, V, R, J, K band light curve of 3C 454.3

It can be seen from the observation data and the light curve that the B-band and the V-band are the darkest on September 12, 2011. At this time, the star value is 17.337 stars and 16.756 stars, which is the brightest on July 23, 2014. The star value is 13.964 stars and 13.448 stars. The outbreak lasted for 941 days, and the optical variation range reached 3.373 stars and 3.308 stars, respectively. The average value was 16.076 stars and 15.511 stars, and the standard deviations were 0.637 and 0.661, respectively. The J-band reached its darkest on June 5, 2012. At this time, the star was 15.092 stars, and it was the brightest on August 8, 2014. At this time, the star value was 11.012 stars, which lasted for 793 days. The light amplitude is 4.08 stars, the average value is 13.381 stars, and the standard deviation is 0.864. The K-band reached its brightest on November 1, 2010. At this time, the star value was 6.017 stars, and it reached the darkest after 352 days. At this time, the star value was 15.017 stars. It can be seen that the light change of the flat-spectrum radio quasar is intense and unstable.

In order to further analyze the change of celestial brightness, the B-band star is selected as the abscissa, and the stars of the four bands V, R, J, and K are the ordinate, as shown in Figure 2. It can be seen from the above figure that as the equivalent value of the B-band star increases, the equivalent values of the V, R, J, and K bands also increase, showing a positive correlation, and the brightness is gradually darkened. As the B-band star value decreases, the corresponding star values of V, R, J, and K gradually decrease, and the brightness becomes brighter. The linear regression equation with the B-band as the abscissa and the V-band as the ordinate on the ordinate is: V=(0.87±0.02)+(1.32±0.37), the correlation coefficient is 0.81, and the confidence probability is:0. It can be seen from the correlation coefficient of 0.81 that the brightness of the star of the B-band and the V-band has a strong correlation, that is, as the brightness of the B-band is gradually darkened, the brightness of the V-band is gradually darkened.

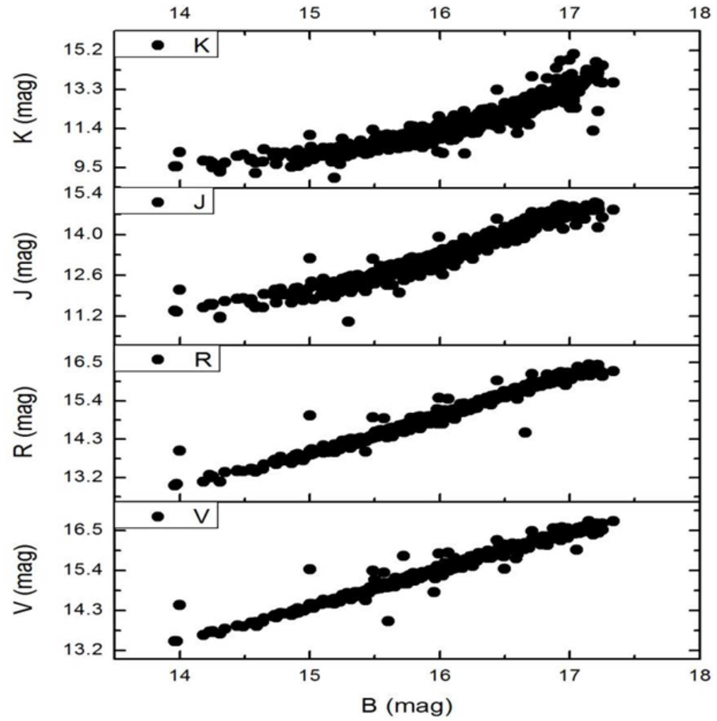

Fig. 2 B-band brightness variation and brightness variation of V, R, J, and K bands

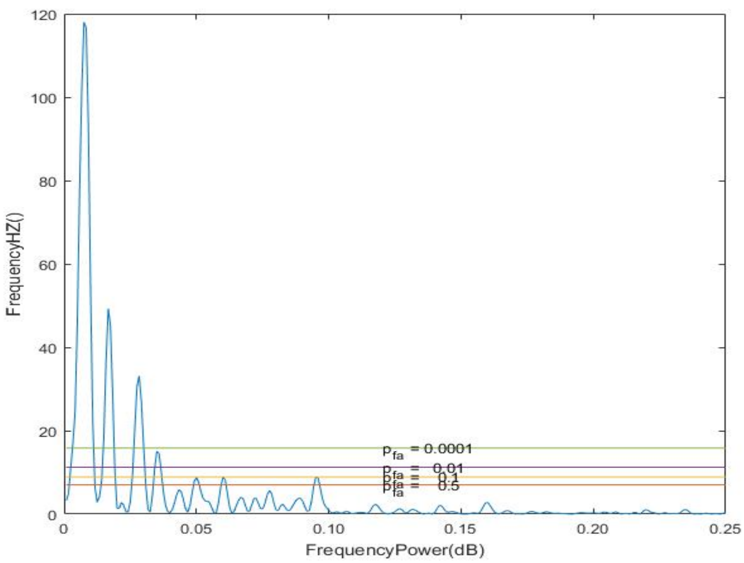

Fig. 3 Period diagram of the optical B-band light curve of the flat spectrum radio quasar 3C 454.3

3. Flux Variability

3.1 Periodic Variability

In order to better analyze the periodic variation of the 3C 454.3 star of the flat-spectrum radio quasar, the Lomb-scared periodogram method is used to study the dramatic light changes on the 3C

54.3 B-band, as shown in Figure 3. It can be seen from the above figure that the main peak power in the B-band is 118.00 dB, and the corresponding period is about T1 = 53.26 days, and its frequency is 0.017HZ, and the strongest signal appears at this position. The secondary peak power is 46.06dB, the corresponding period is about T2 = 79.89 days, its frequency is 0.0125HZ, the third peak power is 36.73dB, and the corresponding period is about T3 = 25.23 days, and its frequency is 0.0396HZ. The results show that 3C 454.3 may have a photoperiod component of T2 = 79.89 days and T1 = 53.26 days. This component may be true for T2 = 79.89 days, or it may be due to 53.26 days of signal superposition or due to noise interference, or it may be due to insufficient duration of the data sample. It can be seen from the above analysis that the flat-spectrum radio quasar 3C 454.3 may have periodic components of 79.89 days and 53.26 days in the optical B-band.

3.2 Color index Variability

In order to study the optical characteristics of the flat-spectrum radio quasar 3C 454.3 more thoroughly, the color index will be analyzed [6]. In this paper, we take the correlation coefficient greater than 0.2, and the confidence probability is less than 0.01, indicating that there is significant positive between the color index and the flow rate. Correlation, that is, the color characteristic of BWB (bluer-when-brighter) exists between the two [7], the correlation coefficient is less than 0.2 and the confidence probability is less than 0.01, indicating that there is a significant negative correlation between the color index and the flow, that is, RWB exists between the two. The color characteristics of (redder-when-brighter), in addition, indicate that there is no correlation between the two. Take B as the abscissa (unit: star, etc.) with BV as the ordinate (unit: star, etc.) where its slope is: 0.01±0.00, the intercept is: 0.45±0.07, and thus its linear regression equation is: BV= (0.01±0.00) + (0.45±0.07) B, correlation coefficient r=0.07, confidence probability is p=0.05. It can be seen that there is no obvious correlation between the B-band and the color index. The correlation coefficient between J-band and color index obtained by linear regression is -0.50, and the confidence probability is P=0, indicating that they are negatively correlated. The relationship between visible color index and flow is very complicated, some cases are negatively correlated, and some cases are not correlated. At the same time, the increase or decrease of the flow rate will also have different color changes, and it also reflects the difference in the time when the flow rate of each band reaches the peak value.

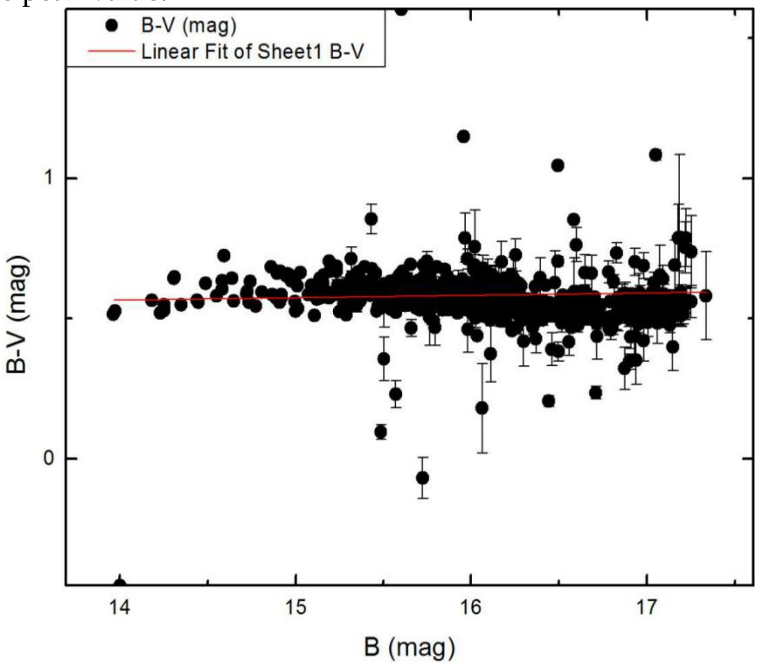

Fig. 4 3C 454.3 Linear regression of B-band brightness variation and color index change

3.3 Time lag

Edelson and Krolik proposed the Discrete Correlation Function (DCF) method, which is the result of real light curve analysis [8], without linear interpolation, no artificial data insertion, DCF method is to study the time delay originally introduced One method is generally used to calculate the time delay. This method is applied to calculate the time delay.

According to the selection principle of interval $\Delta\tau$, when analyzing the optical B-band and J-band data of 3C 454.3, we will take $\Delta\tau$ =2, with Lag as the abscissa and DCF as the ordinate to draw the B-band and band time delay. As shown in Figure 5.

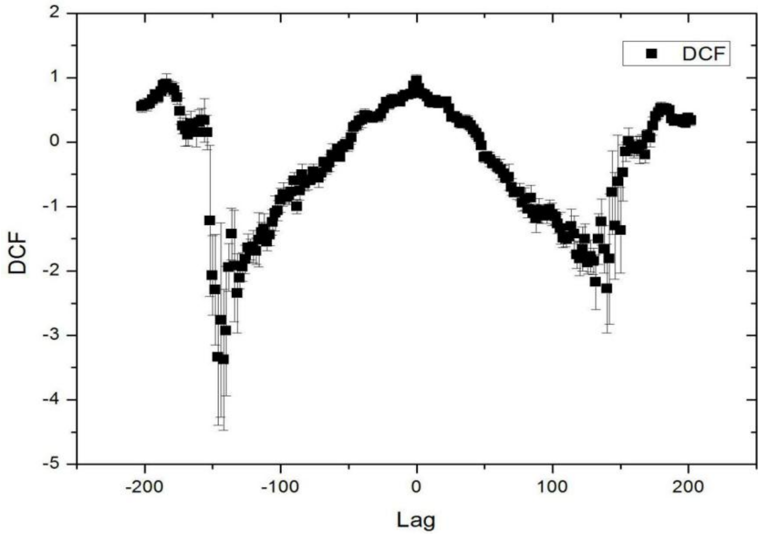

Fig. 5 B-band and J-band time delay plots for 3C 454.3

Since it is within a range $\Delta\tau$, its standard deviation can be expressed as:

$$\sigma(\tau) = \frac{1}{M-1}\left\{\sum\left[UDCF_{ij} - DCF(\tau)\right]^2\right\}^{\frac{1}{2}}$$

On the analysis graph of the discrete correlation function, the larger the peak of the DCF, the stronger the correlation between the two columns of data. If the position of the peak of the DCF is a positive value, it means that the data a lag behind the data b, whereas the data b lags behind the data a. According to the above figure, when the time delay value is 0, the DCF value is 0.9, so the B-band and J-band of 3C 454.3 have a strong positive correlation. It can be seen from the table that DCF formation is near the time delay of 0. The peak value corresponding to the peak value is 0.945, and the corresponding DCF error is 0.095. Therefore, there is no time delay in the B-band and J-band of the flat-spectrum radio quasar 3C 454.3.

4. Summary

Light change is one of the most notable features of the blazar object. The following study is conducted on the time delay of 3C 454.3 from periodic light changes, color changes, and light changes in each band. The light intensity of the flat-field radio quasar 3C 454.3 is very intense and unstable. The linear fitting of the flow changes of the five bands (B, V, R, J, K) indicates that the relationship between the brightness changes of each band is positively correlated. The periodogram of the optical B-band light curve indicates that the optical B-band may have a periodic component. It can be seen from the change of the brightness of the color index and the linear regression line that the relationship between the 3C 454.3 color index and the flow rate is very complicated, and some cases show a negative correlation, and some cases show no correlation. The time delay diagrams of B-band and J-band are made by the Discrete Correlation Function (DCF) method. It can be seen from the figure that the B-band and J-band have strong positive correlation but no time delay.

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