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A Visual Method of Time Scale Determination using a PC for Radio Sources

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Abstract. Variability is one of the extremely observational properties. In the radio bands, variability is caused by the shock in the jet. In this case, emissions increase rapidly following an exponential curve, and then decrease rapidly also in an exponential curve. The variability time scale is important with regard to the physics carrying on in the jet. However, it is not easy to fit the light curve. In this paper, we proposed a method of light curve fitting on a PC machine, in which the theoretical exponential light curve is adopted to the observations using the least regression method. Using this method, anybody can fit the light curve and get the time scale by moving and clicking the mouse. We also used this method to some light curves obtained from the archive and compared our results with those in the literature.

Key words. AGNs–quasars–general-jets.

1. Introduction

Blazars are an extreme subclass of AGNs with luminous and rapid variable emissions through the whole electromagnetic spectrum, high and variable polarization and high energetic emissions even up to TeV (see Fan *et al.* 2009a, 2009b; Abdo *et al.* 2010). All those properties are associated with a relativistic beaming effect. Very rapid variabilities are detected at all wavebands, short time scales vary from 30 s from H0323+022 in X-ray bands (Feigelson *et al.* 1996) to 3.3 min from 3C 273 in the optical band (Fan *et al.* 2011). Rapid variation in radio bands was also detected by many authors. If the time scale indicates the size of the emission region, then the rapid variability suggests a brightness temperature,

$$T_{\mathrm{b,var}}(K) = 4.05 \times 10^{17}\mathrm{h}^{-2}\Delta S_{\max}\left(\frac{\lambda}{\tau_{\mathrm{obs}}}\right)^2 \times \left[\int_1^{1+z} \frac{1}{\sqrt{\Omega_M x^3 + 1 - \Omega_M}}\mathrm{d}x\right]^2.$$

Here, λ is the observed wavelength in meters, z is the red shift, $\Delta S_{\max}$ is the maximum amplitude of the outburst in Jy, τ_{obs} is the observed variability time scale in days, $\Omega_\Lambda \simeq 0.7$, $\Omega_M \simeq 0.3$ and $\Omega_K \simeq 0.0$ are adopted from the Λ-CDM model (Pedro & Priyamvada 2007).

It is clear that if we can get the time scale at a certain radio waveband, we can calculate the brightness temperature, and finally estimate the Doppler factor, which is an important factor for AGNs. In this work, we carry out a visual method to get the time scale for exponential flares as proposed by Lähteenmäki & Valtaoja (1999).

2. Method and results

A data file of light curves consists of an array of pairs $A = \{(t_i, x_i), 1 \le i \le n\}$, which are ordered by the first coordinate t_i increasingly. The following method is to propose a way to fit a portion of the array using an exponential curve visually and interactively: (1) To plot all of the pairs in A and two vertical lines $t = t_a$ and $t = t_b$ on a window; (2) To deal with the mouse events so that we can drag the lines $t = t_a$ and $t = t_b$ to change their positions by moving mouse; (3) To take all the pairs in A that satisfy the condition $t_a \le t_i \le t_b$, denote those pairs by B; (4) To fit the data in B by a formula $x = x_0\, e^{\frac{t_0 - t}{\tau}}$ and plot it, where t_0, τ and x_0 are the times that correspond to peak flux density, the rising time scale, and peak flux density for the fitting curve. Then we get the fitting result τ which can be used to calculate the brightness temperature as we did in our previous work (Fan *et al.* 2009a, 2009b).

The brightness temperature higher than 10^{12} K can be explained to the effect of beaming effect $T_B = T_B^{in}\delta^3$ for general consideration, or $T_B^{in}\delta^5$ as proposed by Qian *et al.* (1991).

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