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OPTICAL VARIABILITY OF THE RADIO SOURCE J1128+5925. II. CONFIRMATION OF ITS OPTICAL QUIETNESS

Jianghua Wu, Xu Zhou, Jun Ma, Zhenyu Wu, Wei Zhang, Zhaoji Jiang, and Jiansheng Chen
National Astronomical Observatories, Chinese Academy of Sciences, 20A Datun Road, Chaoyang District, Beijing 100012, China; jhwu@bao.ac.cn
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ABSTRACT

The source J1128+5925 was recently found to show strong intraday variability at radio wavelengths and its radio variability may come from interstellar scintillation. In the optical, the object was quiet in our 2007 monitoring session. Here, we report the results of our new optical monitoring of this source in 2008. In addition to confirming our 2007 results that the object did not display any clear variation on timescales from hour–day to month, we provide evidence that the object does not vary on timescale of one year, and it is probably intrinsically quiet in optical domain. Its very different behaviors in optical and radio regimes can be naturally explained if its strong radio variability comes from interstellar scintillation.

Key words: galaxies: active – quasars: individual (J1128+5925)

1. INTRODUCTION

Blazars are believed to be those active galactic nuclei (AGNs) with their relativistic jets pointed basically to our line of sight (LOS; Antonucci 1993; Urry & Padovani 1995). Because of the beaming and relativistic effects in the jet, blazars show strongest and fastest variability among all AGNs, and this variability shows up across the entire electromagnetic spectrum. The monitoring of blazars simultaneously at multiwavelength can reveal their spectral energy distributions (SEDs), and is crucial to constrain their emission and variation mechanisms (e.g., Wagner et al. 1996; Ghisellini et al. 1997; Tagliaferri et al. 2003; Böttcher & Reimer 2004; Böttcher et al. 2007, 2008). Based on the strength of their emission lines, blazars are currently separated into BL Lacertae objects and flat-spectrum radio quasars (e.g., Marchã et al. 1996; Landt et al. 2004).

Recently, the flat-spectrum radio quasar J1128+5925 was found to show strong intraday variability (IDV) at centimeter wavelengths, and its IDV timescale displayed an annual modulation (Gabányi et al. 2007). Therefore, its radio IDV may come from interstellar scintillation (ISS; for a review of various variation mechanisms see Wagner & Witzel 1995). In order to open a new window to investigate the variability of this object, we made the first optical monitoring of J1128+5925 in 2007 May. We found that the object showed only trivial variability on an internight timescale and did not present any clear intranight variability (Wu et al. 2008, hereafter Paper I).

However, our 2007 monitoring session was not long enough to determine whether the object was just quiet at that period of time or is intrinsically quiet in the optical regime. In order to resolve this ambiguity, we carried out a new monitoring program on this object in 2008. Here, we present our observations, data reduction procedure, and the results in the next sections. Discussions on the variation mechanisms are given at the end.

2. OBSERVATIONS AND DATA REDUCTIONS

The monitoring was performed with a 60/90 cm f/3 Schmidt telescope at Xinglong Station, National Astronomical Observatories of China. The telescope is equipped with a 4096 × 4096 E2V CCD, which has a pixel size of 12 μm and a spatial resolution of 1″.3 pixel^{-1}. When used for blazar monitoring, only the central 512 × 512 pixels are read out as a frame. Each such frame has a field of view (FOV) of about 11′ × 11′. Our monitoring was made in the Cousins *R*-band, and covered the period from 2008 April 22 to June 4. The exposure times are mostly 480 s and can be as short as 120 s, depending on weather and moon phase.

The data reduction procedures include bias subtraction, flat-fielding, extraction of instrumental aperture magnitude, and flux calibration. We used differential photometry. For each frame, the instrumental magnitudes of the blazar and four comparison stars (see Figure 1) were extracted at first. The radii of the aperture and the sky annuli were adopted as 3, 7, and 10 pixels, respectively. Then the brightness of the blazar was measured relative to the average brightness of the three reference stars 1, 2, and 3. Star 4 acted as a check star, which has an apparently similar brightness as the blazar (for a reasonable selection of reference and check stars, see Howell et al. 1988). Its brightness was also measured relative to the average brightness of the three reference stars, so as to verify the stable fluxes of the four comparison stars and to verify the accuracy of our measurements. This definition of reference and check stars is different from that in Paper I. In Paper I, the check star was among the reference stars. When the brightness of check star was measured relative to the average of all reference stars, it was actually measured relative partly to itself and would result in an underestimated "variation" of the check star. This is unreasonable and was rejected in this paper.[1]

3. RESULTS

Figure 2 shows the intranight light curves of J1128+5925 on seven nights with intensive monitoring. Also shown are those of star 4, the check star. Except for the first panel (JD 2,454,579), where the light curves have relatively large errors, all other panels have light curves close to horizontal straight lines and do not demonstrate any clear variation.

A quantitative assessment was performed on whether or not the object was variable on these seven nights. As in Jang & Miller (1997), Stalin et al. (2006), Hu et al. (2006), and Paper I, a parameter C is defined as $C = \sigma_B/\sigma_S$, where σ_B is the standard

[1] The conclusion that J1128+5925 did not vary on all nights in Figure 3 of Paper I is still viable because the quietness of this object was justified by even a higher-than-actual standard (σ_B was slightly underestimated) on these nights.

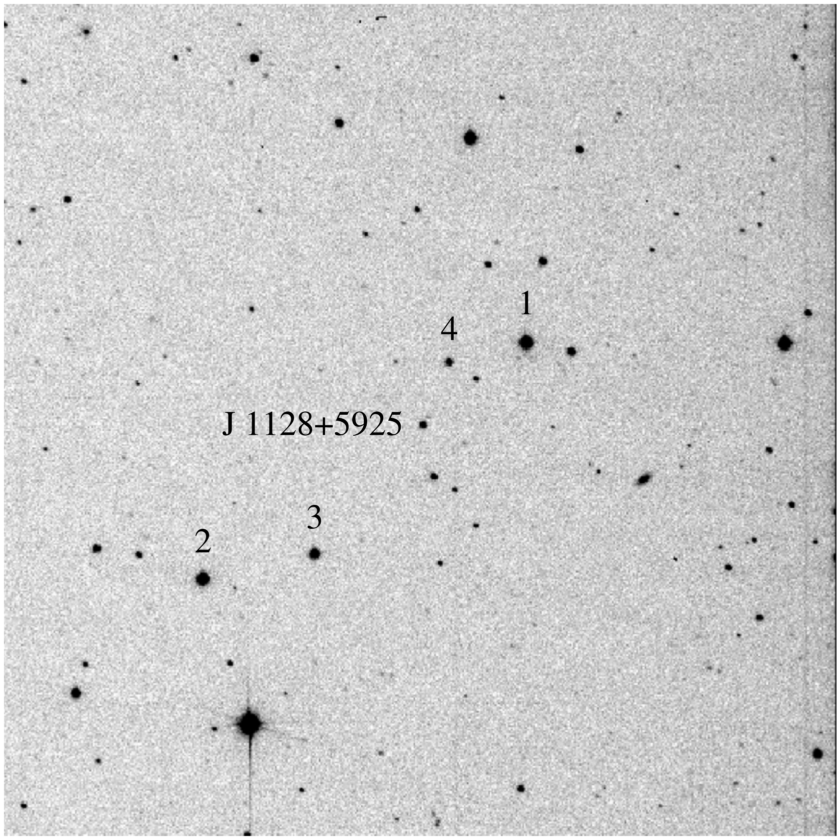

Figure 1. Finding chart of J1128+5925. The blazar and four comparison stars are labeled. Up is north; left is east.

Table 1
Statistics on Seven Intranight Light Curves

Julian Date	*N*	Duration (hr)	*C*	Var?
2,454,579	17	2.23	1.11	N
2,454,580	21	2.88	1.83	N
2,454,582	9	1.15	0.65	N
2,454,587	8	1.02	1.29	N
2,454,611	10	1.32	1.54	N
2,454,612	10	1.58	1.69	N
2,454,622	11	1.13	1.33	N

deviation of the magnitudes of the blazar and σ_S is that of the check star. When $C \geqslant 2.576$, the object can be claimed to be variable at the 99% confidence level. Table 1 lists the results. All *C*s are less than 2.0, implying that J1128+5925 was not variable on these nights.

The light curve of the whole monitoring period is shown in Figure 3 (left). Across the period of 44 days, the nightly average brightness of the blazar, as indicated by the open circles and the dashed line, was quite stable at $dR \sim 2.46$, and had an amplitude of 0.04 mag and an rms of 0.01 mag. When we take into account the probability that the peak around JDs 2,454,584 and 2,454,585 and the trough from JDs 2,454,589 to 2,454,597 might be biased by very few observations on these nights, the amplitude and rms may be even smaller. This is to say, the object was quiet on a timescale of about one month.

As a comparison, the light curve of our 2007 monitoring session, which covered a period of 25 days, is also displayed in Figure 3 (right). The magnitudes were recalibrated by using the new definition of comparison stars described in Section 2. The average brightness is $dR \sim 2.45$, the same as in 2008. This similarity is unlikely by chance, because our 2007 and 2008 monitoring sessions lasted for close to and more than a month, respectively. Therefore, the object may not vary on a timescale of one year.

4. CONCLUSIONS AND DISCUSSIONS

We conducted a new optical monitoring program on radio source J1128+5925 in the Cousins *R*-band from 2008 April 22 to June 4. The results show that the object still did not demonstrate any clear variability on timescales from hour–day to month, which confirmed our 2007 monitoring results in Paper I. Furthermore, the object had similar brightness in 2008 as in 2007, suggesting that it may not vary even on a timescale of one year. Being quiet on such a long timescale, the object was unlikely just in a quiescent state at optical wavelength in our two monitoring sessions. It may be intrinsically quiet in optical domain.

In Paper I, we proposed simultaneous radio and optical observations on this source in order to verify the extrinsic origin of its radio IDV. Now our new optical observations reinforced its optical quietness. In radio, there were respectively about three days of observations on this source in 2008 April and June, and it still illustrated strong IDV phenomena (T. Krichbaum 2008, private communication), as in Gabányi et al. (2007). Because of the very limited time coverage by both optical and radio observations, a correlation analysis was impractical. In fact, the very different behaviors in optical and radio regimes ruled out the probability of correlated optical and radio variations in J1128+5925.

The origin of the IDV in radio sources is still a subject of much debate. If the origin is intrinsic, the short timescale would require a very small emission region and hence an extremely high apparent brightness temperature of 10^{16}–10^{21} K, which is

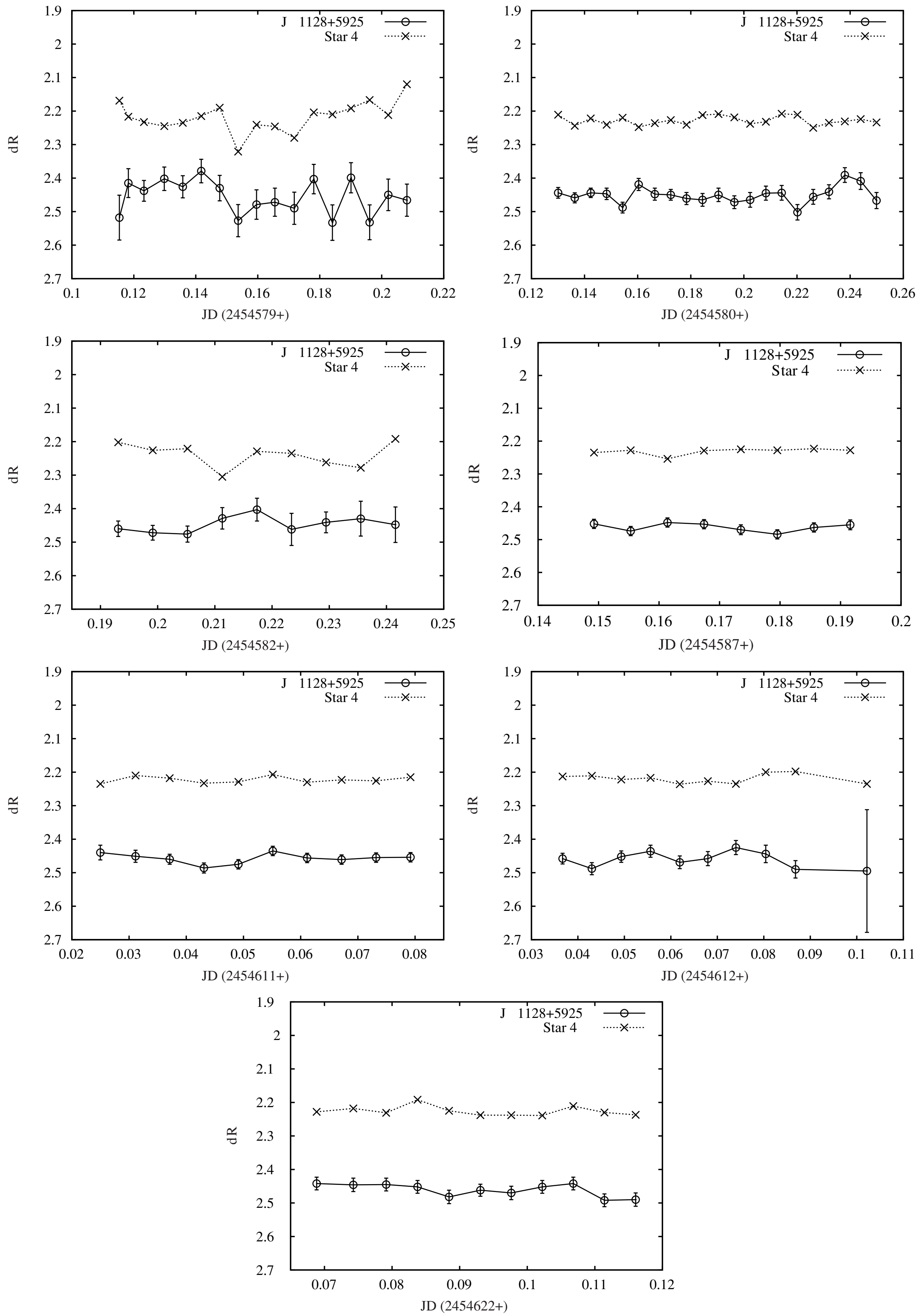

Figure 2. Intranight light curves on seven nights with intensive monitoring. The open circles and solid lines show the light curves of the blazar, while the crosses and dotted lines show the light curves of star 4.

far beyond the inverse Compton limit of $\sim 10^{12}$ K (Kellermann & Pauliny-Toth 1969). Then high Doppler factors up to 40–100 are required to reconcile this contradiction (e.g., Peng et al. 2000, and references therein). Extrinsic origins, such as ISS, can also result in IDV in radio sources (Rickett 1990). Indeed, strong IDV can be convincingly explained in terms of ISS in some blazars,

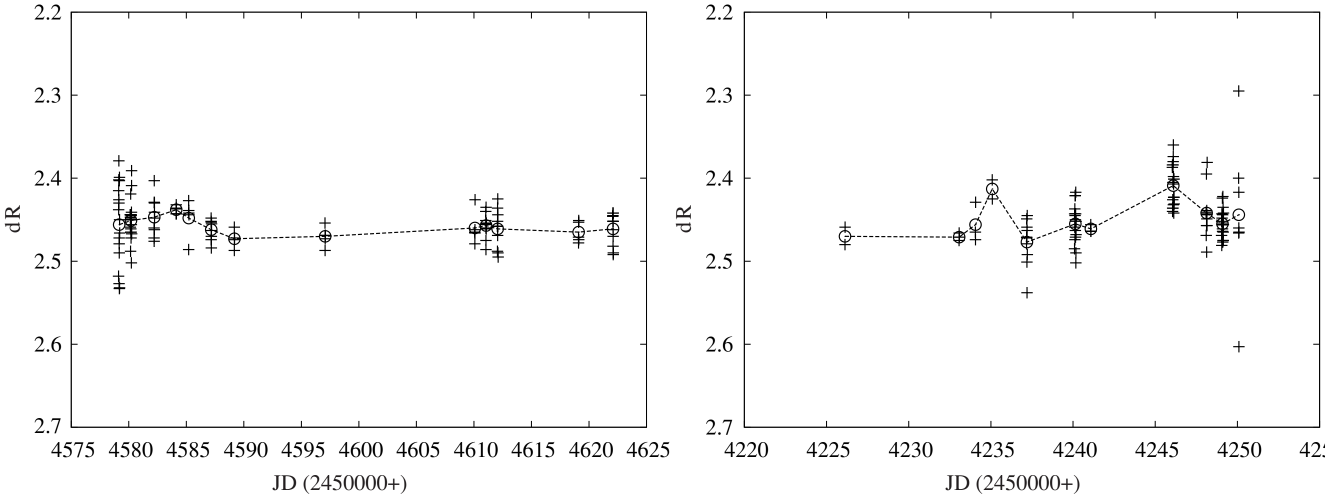

Figure 3. Light curves of all nights in 2008 (left) and 2007 (right). The plus symbols are individual measurements, while the open circles and dashed lines mark the nightly average light curves.

such as J1819+3845 (Dennett-Thorpe & de Bruyn 2002, 2003) and PKS 1257–326 (Bignall et al. 2003). However, some other blazars, such as S5 0716+714, show correlated IDVs in radio and optical regimes (Quirrenbach et al. 1991; Wagner et al. 1996). This is taken as strong evidence for the intrinsic origin of IDV, because the ISS cannot result in variability in optical regime (Wagner & Witzel 1995). J1128+5925 demonstrates strong IDV at radio wavelengths but is very quiet in optical domain. This can be naturally explained if the strong IDV comes from ISS, which was suggested by Gabányi et al. (2007).

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