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Quasi-simultaneous two band optical micro-variability of luminous radio-quiet QSOs

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A B S T R A C T

We report the first results of quasi-simultaneous two passband optical monitoring of six quasi-stellar objects to search for micro-variability. We carried out photometric monitoring of these sources in an alternating sequence of R and V passbands, for five radio-quiet quasi-stellar objects (RQQSOs), 0748 + 291, 0824 + 098, 0832 + 251, 1101 + 319, 1225 + 317 and one radio-loud quasi-stellar object (RLQSO), 1410 + 429. No micro-variability was detected in any of the RQQSOs, but convincing micro-variability was detected in the RLQSO on two successive nights it was observed. Using the compiled data of optical micro-variability of RQQSOs till date, we got the duty cycle for micro-variability in RQQSOs is ~10%. The present investigation indicates that micro-variability is not a persistent property of RQQSOs but an occasional incident.

1. Introduction

There are two major classes of quasars. The majority of these ~85–90% belong to the radio-quiet class and are thus known as radio-quiet quasars (RQQSOs) and the remaining ~10–15% are in the radio-loud class and are known as radio-loud quasars (RLQSOs). RQQSOs and RLQSOs show, similar optical characteristics, but in RQQSOs the ratio of radio (at frequency $\nu = 5$ GHz) to optical flux densities (at wavelength $\lambda = 4400$ Å), $R \leqslant 10$ (Kellermann et al., 1989), and the radio to X-ray fluxes are one to several orders of magnitude lower than those of the RLQSOs (Terashima and Wilson, 2003).

Flux variability is a common property of active galactic nuclei (AGNs) and a small subset of radio-loud AGNs show variability on diverse time scales ranging from a few minutes to several years at almost all wavelengths of the EM spectrum, with the emission being strongly polarized. Such AGNs are called blazars, and their radiation at all wavelengths is predominantly non-thermal. Significant variability in brightness over a few minutes to several hours (less than a day) is commonly known as micro-variability, intra-night variability or intra-day variability. Optical micro-variability in blazars have been reported on several occasions in the last two decades using CCD detectors, and is now a well established property of blazars. The first pioneering papers in the field of blazar optical micro-variability using CCD detectors include: Miller et al. (1989), Carini et al. (1990, 1991, 1992), Carini and Miller (1992) and Heidt and Wagner (1996). It is believed that the micro-variability in blazars is a consequence of relativistic beaming by jets (Bregman, 1991). The beaming can amplify intrinsic variations which may or may not originate within the jet. It is also well accepted that many other radio-loud AGNs (non-blazars) also exhibit micro-variability (Jang and Miller, 1995, 1997; de Diego et al., 1998; Romero et al., 1999; Stalin et al., 2004, 2005).

After about one and a half decades of work, detections of micro-variability in radio-quiet AGNs have been elusive and little is known about their micro-variability. In a recent paper, Carini

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et al. (2007) compiled the micro-variability results for 117 radio-quiet AGNs to date, and in most of the cases the detected micro-variability is not convincing. Clear detection of micro-variability in a few radio-quiet QSOs have been reported in some recent papers (Gopal-Krishna et al., 2003; Stalin et al., 2004, 2005; Gupta and Joshi, 2005). Gupta and Joshi (2005) compiled the micro-variability data for different classes of AGNs and have done statistical analysis of micro-variability behavior by dividing the sample into three classes viz. radio-loud AGNs (blazars), radio-loud AGNs (non-blazars) and radio-quiet AGNs. They found, generally ≈10% and 35–40% radio-quiet AGNs and radio-loud AGNs (non-blazars) respectively show micro-variability. For any blazar, if observed continuously for less than 6 h and more than 6 h, the chances of detection of micro-variability are ≈60–65% and 80–85%, respectively. They also found that the maximum amplitudes of variations are about 10%, 50% and 100% for radio-quiet AGNs, radio-loud AGNs (non-blazars) and blazars, respectively.

So far, for optical micro-variability studies of RQQSOs and RLQSOs, several groups have observed sources continuously in only one optical band (Gupta and Joshi, 2005; Carini et al., 2007 and references therein), and clear detections in a few cases of micro-variability in RQQSOs suggest micro-variation may be caused by a faint jet (Gopal-Krishna et al., 2000; Falcke et al., 1996b; Ulvestad et al., 2005) or optical flares above an accretion disk and/or accretion disk instabilities (Wiita et al., 1992). In the present work, a sample of five RQQSOs and one RLQSO are considered for study. These five RQQSOs have shown optical micro-variability on some occasions in their earlier observations. However, to investigate whether micro-variability is a persistent property of RQQSOs or it is only occasional events, we monitored these sources again. We also included a new radio-loud QSO to search for optical micro-variability. Here we are reporting the quasi-simultaneous continuous observations of these sources in two optical bands (V and R) in an alternating sequence for these sources for the first time. In addition to looking for micro-variability in two optical bands, our observations also give additional information of micro-variation in V–R color.

Section 2 presents our sample selection criterion; in Section 3, we report the observations and data analysis technique; in Section 4, the results of the present work are presented and in Section 5 our conclusions are given.

2. Sample selection criterion

In the present study, we have selected five RQQSOs and one RLQSO from the recent catalog of active galactic nuclei and quasars of Veron-Cetty and Veron (2006). The detailed information and observation log of the QSOs are given in Table 1.Using the standard cosmological model, we have used the well known relation by Weinberg (1972) for calculating the absolute magnitude of the QSOs (M_V),

$$m_v - M_V = 25 - 5\log H_0\ (\mathrm{km\ s^{-1}\ Mpc^{-1}}) + 5\log cz\ (\mathrm{km\ s^{-1}}) + 1.086(1-q_0)z \quad (1)$$

where m_v, z are, respectively, the apparent magnitude and redshift of the QSOs, and c is the speed of light. We have used the Hubble constant $H_0 = 70\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$ and $q_0 = 0.5$.

The host galaxy is expected to contribute less than 10% to the total flux of the luminous QSOs. The host galaxy is also expected to be encompassed within the aperture radius ~6 arcsec used for photometry. For a lower ratio of AGNs to galactic light, false indications of variability produced by seeing variations that include different amounts of host galactic light within the photometric aperture become very probable (Cellone et al., 2000). Carini et al. (1991) investigated whether a conspicuous galaxy component produces variations, due to variation in atmospheric seeing or transparency, which are not intrinsic to the source. They showed that, even for sources with significant underlying galaxy components, any spurious variations introduced by fluctuations in atmospheric seeing or transparency are typically smaller than the observational uncertainties. To further reduce this effect, we have selected sources which are optically bright (brighter than $M_V < -24.9$ mag) (except one RQQSO namely Ton 52 which has $M_V = -24.3$ mag), so that the fluctuations due to the underlying galaxy are minimal; however the modest optical luminosity ($M_V \approx -24.9$ mag) lies close to the critical value below which the sources are classified as Seyfert galaxies (Miller et al., 1990).

3. Observations and data reductions

The photometric observations of the five radio-quiet QSOs and one radio-loud QSO were carried out in the V and R passbands of the optical filter system of Bessell (1990) using a Loral Lick 3 CCD detector (2048 pixels × 2048 pixels) mounted at the f/9 Cassegrain focus of the 2.16 m R-C system optical telescope at the National Astronomical Observatories, Xinglong Station, in China. Observations were carried out using BFOSC (Bao Faint Object Spectrograph and Camera) in an alternating sequence of V and R passbands. The pixel size of the CCD detector is 15 μm × 15 μm and each pixel of the CCD projected on the sky corresponds to 0.305 arcsec in both dimensions. The entire CCD chip covers ~10.41 × 10.41 arcmin^2 of the sky. Read out noise and gain of the CCD detector were 1.67 electrons and 4 electrons/ADU, respectively. Throughout the observing run, the typical seeing was ~2.0 arcsec ranging from 1.5 to 2.5 arcsec. Several bias frames

Table 1

Complete log of V and R bands observations of five RQQSOs and one RLQSO[c]

IAU name[a]	Other name	$\alpha_{2000.0}$	$\delta_{2000.0}$	z	V	M_V	R[b]	Date of observation	Data points × Exposure time (V) (s)	Data points × Exposure time (R) (s)
0748 + 294	Q J0751 + 2919	07 51 12.3	+29 19 38	0.912	16.21	−27.2	0.21	12.03.2007	44 × 120	44 × 80
0824 + 098	1WGA J0827.6 + 0942	08 27 40.1	+09 42 10.0	0.260	15.5	−24.9	3.2	11.03.2007	40 × 90	40 × 60
0832 + 251	PG 0832 + 251	08 35 35.9	+24 59 41.0	0.331	16.1	−24.9	1.26	10.03.2007	38 × 120	39 × 80
1101 + 319	Ton 52	11 04 07.0	+31 41 11	0.440	17.30	−24.3	<0.39	11.03.2007	22 × 150	22 × 100
1225 + 317	b2 1225 + 317	12 28 24.8	+31 28 38	2.219	15.87	−30.2	...	10.03.2007	44 × 120	44 × 80
1410 + 429	RXS J14119 + 4239	14 11 59.7	+42 39 50.0	0.888	17.37	−26.0	>155	11.03.2007	18 × 150	18 × 100
1410 + 429	RXS J14119 + 4239	14 11 59.7	+42 39 50.0	0.888	17.37	−26.0	>155	12.03.2007	20 × 250	20 × 150

[a] Based on coordinates defined for 1950.0 epoch.
[b] The value of R for RQQSOs were taken from Carini et al. (2007).
[c] Other parameters of QSOs were taken from the Veron-Cetty and Veron (2006).

Table 2
Coordinates and apparent magnitudes of comparison stars in the field of observed RQQSOs and RLQSO

IAU name	Star number	$\alpha_{2000.0}$	$\delta_{2000.0}$	B (mag)	V (mag)	R (mag)	Remarks
0748 + 291	1	07 51 09.7	+29 21 05.9		14.6 ± 0.5		
	2	07 51 02.6	+29 19 23.9	16.5		15.0	
	3	07 51 09.2	+29 16 19.9	17.0		15.5	
	4	07 50 59.0	+29 16 49.8		15.3 ± 0.6		
0824 + 098	1	08 27 44.3	+09 45 05.3	17.3		15.7	
	2						Not detected in USNO and GSC 2.2
	3	08 27 34.6	+09 39 24.6	16.1		15.0	
	4	08 27 23.5	+09 41 17.5		15.1 ± 0.6		
0832 + 251	1	08 35 24.0	+25 01 04.6	16.8		15.1	
	2	08 35 12.0	+24 57 12.3		15.4 ± 0.6		
	3	08 35 44.1	+25 02 52.1		15.2 ± 0.6		
	4	08 35 47.3	+24 57 19.3	16.9		15.4	
1101 + 319	1	11 04 21.2	+31 47 58.2	17.4		16.7	
	2						Not detected in USNO and GSC 2.2
	3	11 04 14.1	+31 44 09.1	18.5		15.9	
	4	11 03 59.5	+31 47 20.7	16.7		15.4	
1225 + 317	1	12 28 11.0	+31 27 18.9		14.6 ± 0.6		
	2	12 28 30.6	+31 26 33.5	16.7		15.6	
	3	12 28 18.7	+31 25 19.7		15.3 ± 0.6		
	4	12 27 55.2	+31 31 53.3		15.3 ± 0.6		
1410 + 429	1	14 11 38.8	+42 44 08.3		14.8 ± 0.6		
	2	14 11 29.9	+42 43 32.5		14.6 ± 0.6		
	3	14 11 46.4	+42 43 28.5	17.5		16.0	
	4	14 11 54.0	+42 41 22.3		15.0 ± 0.6		

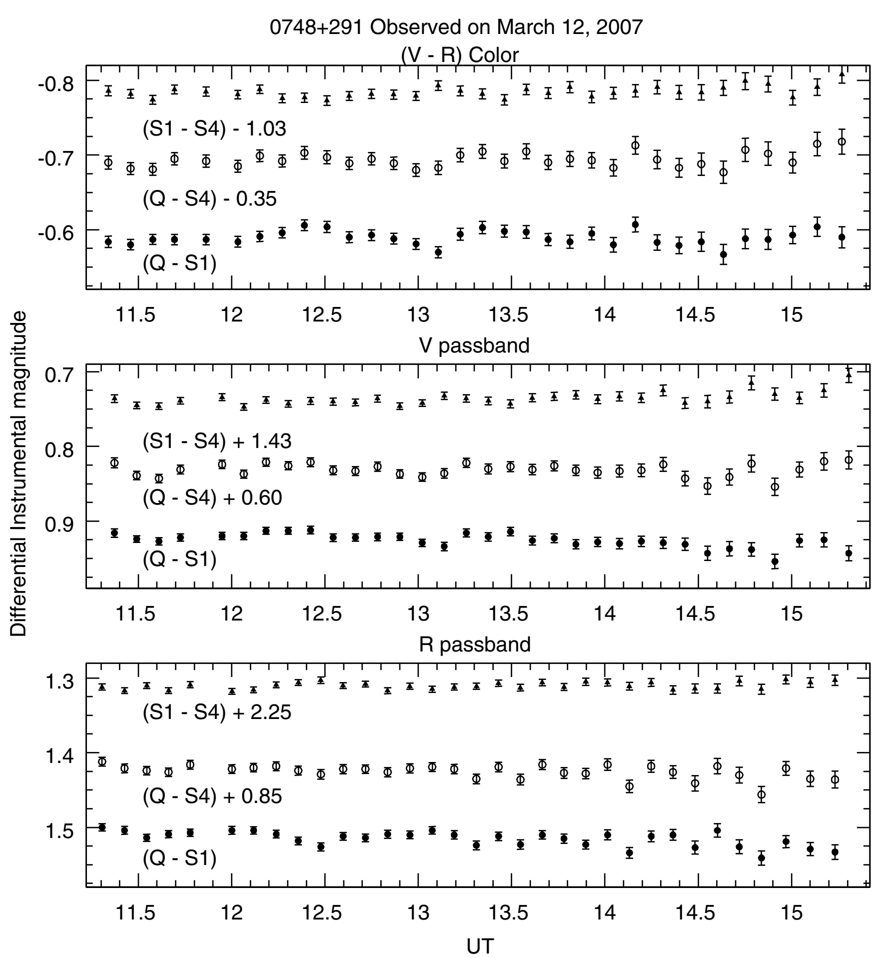

Fig. 1. The V, R and V-R light curves of 0748 + 294 on the night of March 12, 2007. In caption S and Q represent star and QSO, respectively. For clarity, the DLCs are offseted by the amounts marked on the panels.

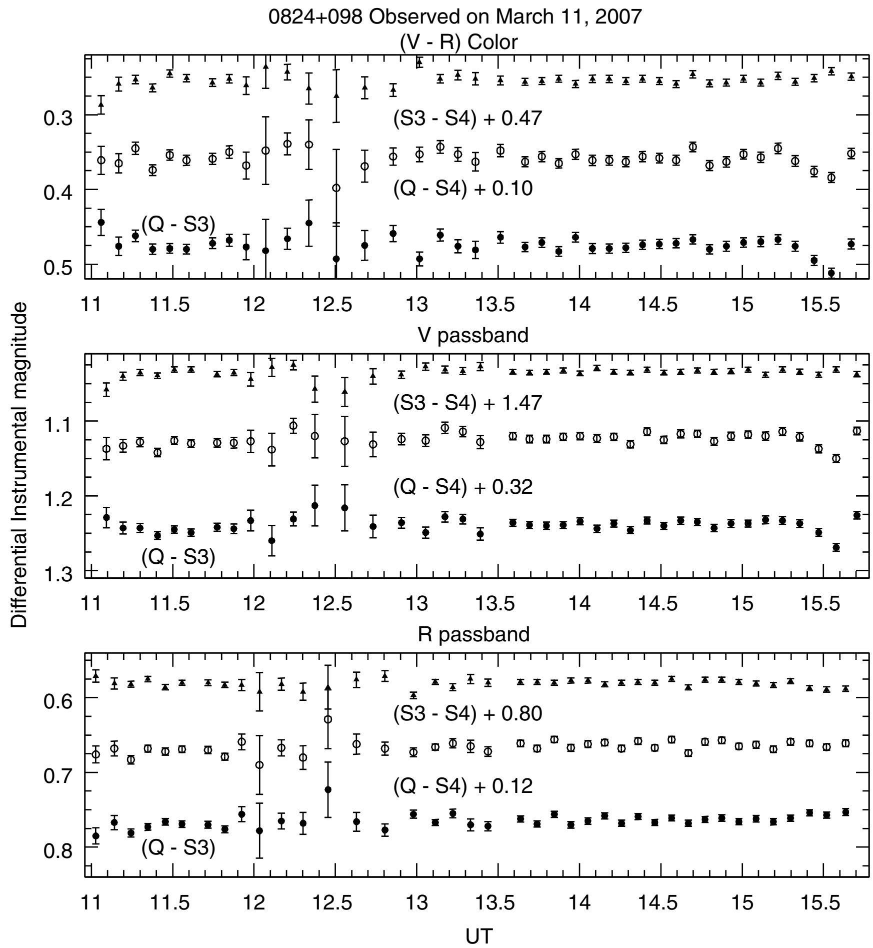

Fig. 2. The V, R and V-R light curves of 0824 + 098 on the night of March 11, 2007. In caption S and Q represent star and QSO, respectively. For clarity, the DLCs are offseted by the amounts marked on the panels.

were taken intermittently in each observing night and twilight sky flats were taken in V and R passbands. The observation log is given in Table 1.

We constructed median bias, and median flat field images in the V and R passbands for each night which were used for bias and flat field corrections. Image processing or pre processing (bias subtraction, flat-fielding and cosmic rays removal) were done using standard routines in IRAF[1] (Image Reduction and Analysis Facility) software. Photometric reduction (instrumental magnitude of the QSOs and local comparison stars in the QSOs fields) of the data were performed by aperture photometric technique using DAOPHOT II (Dominian Astronomical Observatory Photometry) software (Stetson, 1987). Aperture photometry was carried out with four concentric apertures of radii of ≈1, 2, 3, and 4 times of the FWHM of stars in the image frames. The data reduced with different aperture radii were found to be in good agreement. However, it was noticed that the best signal to noise ratio (S/N) was obtained with an aperture radius of ≈3× the typical FWHM. In each QSO field, we selected four comparison stars and finally used the two best non-variable stars for analysis purposes (constructing differential instrumental magnitude light curves). The coordinates and B and R magnitude of the four comparison stars in each QSO field are given in Table 2, which are taken from the USNO (United States Naval Observatory) catalog (Monet et al., 2003). The coordinates and V magnitude of comparison stars were taken from STScI (Space Telescope Science Institute) GSC 2.2 (Guide Star Catalog Version 2.2), if stars were not available in the USNO catalog. The positional accuracy in GSC 2.2 is 0.3 arcsec.

In the present work, in general, we have got the photometric error in each data point is less than 0.01 magnitude (∼ better than 1%). If we take 3σ detection of micro-variability as genuine micro-variability then any variation in magnitude or color is more than 0.03 magnitude (∼ more than 3%) should be clearly visible. Observations presented here have maximum exposure time of 250 s in V band followed by 150 s in R band. After including the readout time of the CCD detector, we repeat our observations in V or R band maximum after ∼10 min. So, the data presented here is sensitive for the minimum time scale of 10 min and any detected variability with time scale more than 10 min should be clearly visible.

4. Results

Differential Light Curves (DLCs) of the five RQQSOs and the RLQSO, are plotted in Figs. 1–6. From bottom to top, the panels show the differential instrumental magnitudes of the QSO and two comparison stars in the R band, V band and V-R color. In the figures Q and S represent the QSO and the comparison star, respectively. For generating V-R light curves, we have taken an average time for each set of alternate image frames and the R band

[1] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy Inc., under cooperative agreement with the National Science Foundation.

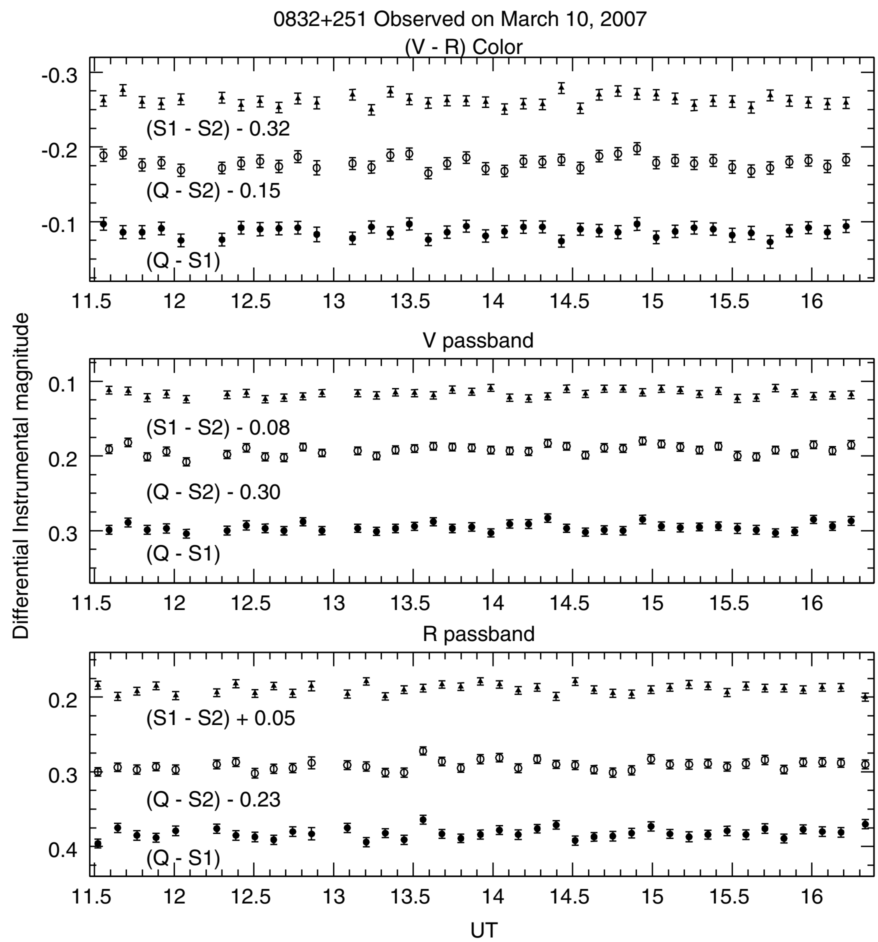

Fig. 3. The V, R and V-R light curves of 0832 + 251 on the night of March 10, 2007. In caption S and Q represent star and QSO, respectively. For clarity, the DLCs are offseted by the amounts marked on the panels.

differential magnitude is subtracted from the corresponding V band differential magnitude. We use offsets to plot the lights curves for clarity in the figures.

4.1. Micro-variability and variability amplitude

Using the aperture photometry of the QSO and two comparison stars in the QSO field, we determined the differential instrumental magnitudes V, R and V–R; of the QSO – comparison star A, QSO – comparison star B and comparison star A – comparison star B. We determined the respective observational scatter from; QSO – comparison star A σ (QSO – Star A), QSO – comparison star B σ (QSO – Star B) and comparison star A – comparison star B σ (Star A – Star B). The variability of the target QSO is quantified by the variability parameter, C, introduced by Romero et al. (1999); this variability parameter is expressed as the average of C_1 and C_2

$$C_1 = \frac{\sigma(QSO - \text{Star A})}{\sigma(\text{Star A} - \text{Star B})} \quad \text{and} \quad C_2 = \frac{\sigma(QSO - \text{Star B})}{\sigma(\text{Star A} - \text{Star B})} \tag{2}$$

If $C > 2.57$, the confidence level of variability is 99%, and we follow most previous authors in adopting this conservative criterion. The value of C by using both comparison stars for all of the five radio-quiet QSOs and one radio-loud QSO for different observing nights are reported in Table 3.

We use the intra-day variability amplitude defined by Heidt and Wagner (1996)

$$A = 100 \times \sqrt{(A_{max} - A_{min})^2 - 2\sigma^2}\% \tag{3}$$

where A_{max} and A_{min} are the maximum and minimum in the differential light curve and σ the measurement errors. The measured amplitudes are reported in Table 3.

4.2. Notes on individual sources

0748 + 291 (QJ 0751 + 2991)

This RQQSO, reported as the brightest new QSO in the first bright QSO survey (Gregg et al., 1996), has been monitored to search for micro-variability in optical bands on several occasions (Gopal-Krishna et al., 2000; Stalin et al., 2004; Gupta and Joshi, 2005). In one night of observations, Gopal-Krishna et al. (2000) reported detection of spikes (brightness excursions of only a single point). Stalin et al. (2004) did not find any micro-variability in the source in their six nights of observations spread over more than three years, but long-term variations are clearly seen in their observations. Gupta and Joshi (2005) reported the clear detection of micro-variation in the source of their monitoring of the source continuously for eight hours in the V-passband in one night. We observed the source during the night of March 12, 2007. DLCs are plotted in Fig. 1. By using our micro-variability detection test given in Eq. (2), we found the values of C in V, R and (V–R) are 1.0, 1.9, and 1.2, respectively. These values of C show that this RQQSO did not show any genuine micro-variation in V, R and V-R observations.

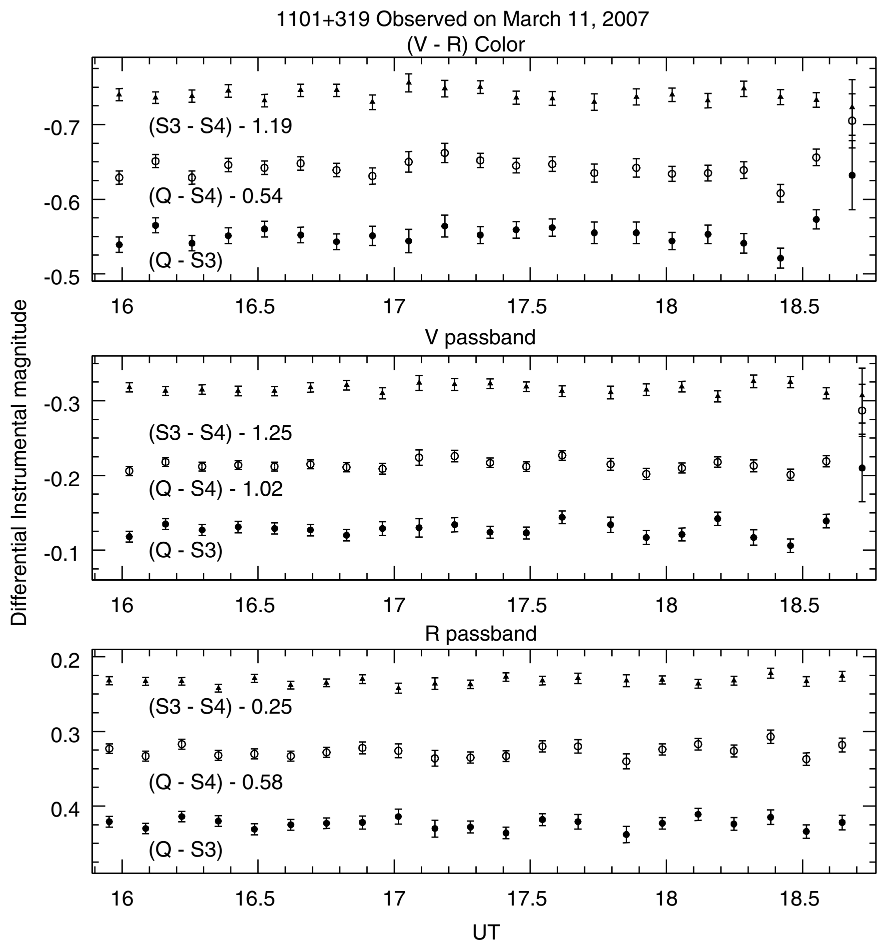

Fig. 4. The V, R and V-R light curves of 1101 + 319 on the night of March 11, 2007. In caption S and Q represent star and QSO, respectively. For clarity, the DLCs are offseted by the amounts marked on the panels.

0824 + 098 (1WGA J0827.6 + 0942)

This RQQSO has been monitored to search for micro-variability in the optical R band on two occasions (Gopal-Krishna et al., 2000; Stalin et al., 2005). Stalin et al. (2005) found 2.2% micro-variation in the source in 8.2 h of continuous monitoring over one night (December 27, 1998). In 3.3 h of observations in one night (February 15, 1999), Gopal-Krishna et al. (2000) reported detection of one spike.We observed the source during the night of March 11, 2007. DLCs are plotted in Fig. 2. We found that the values of C in V, R and (V-R) are 1.2, 1.7 and 1.2, respectively. These values of C show that this RQQSO did not show any genuine micro-variation in V, R and V-R. At the end of the light curve in the V band, the source appeared to become ~0.05 mag fainter and came back to its the normal magnitude in ~20 min. This nominal variation in the V band is also transmitted in the V-R color and made a change of ~0.05 mag in the same duration of observations. Confirmation of such events require further monitoring of the source for longer durations with similar or better S/N.

0832 + 251 (PG 0832 + 251)

This RQQSO was observed in three nights in less than 1 year in a search for micro-variability (Stalin et al., 2005). Micro-variability was detected in the source on one night.We observed the source during the night of March 10, 2007. DLCs are plotted in Fig. 3. We found that the values of C for V, R and V-R are 1.1, 1.0 and 1.1, respectively. These value of C show that this RQQSO did not show any genuine micro-variation in V, R and V-R.

1101 + 319 (Ton 52)

This RQQSO was observed in five nights spread over about 2 years in a search for micro-variability (Stalin et al., 2004; Gupta and Joshi, 2005). Micro-variability was detected in the source on one night and long-term variation was also noticed (Stalin et al., 2004).We observed the source during the night of March 11, 2007. DLCs are plotted in Fig. 4. In the DLCs, the last data point in the V band has a comparatively large error bar. In our variability detection test given by Eq. (2), we omitted this data point and found that the values of C for V, R and (V-R) are 1.3, 1.5 and 1.8, respectively. These values of C show that there was no genuine micro-variation in V, R and V-R for this RQQSO.

1225 + 317 (b2 1225 + 317)

This source has only been monitored for one night in the V passband for 6.2 continuous hours in a search for micro-variability (Gupta and Joshi, 2005). There was a possible detection of micro-variability in the source.We observed the source during the night of March 10, 2007. DLCs are plotted in Fig. 5. We found the values of C in V, R and V-R are 1.4, 1.8 and 2.3, respectively. The value of C shows that this RQQSO did not exhibit any micro-variation in the V, R and V-R color.

1410 + 429 (RXS J14119 + 4239)

This source is the only radio-loud QSO studied in the present work. So far, this source has not been studied to search for optical micro-variability.We observed the source continuously (UT 19.12–21.59 h) and (UT 18.12–21.52 h) during the nights of March 11 and March 12, 2007 respectively. We obtained the DLCs for both nights of observations and are plotted in Fig. 6.

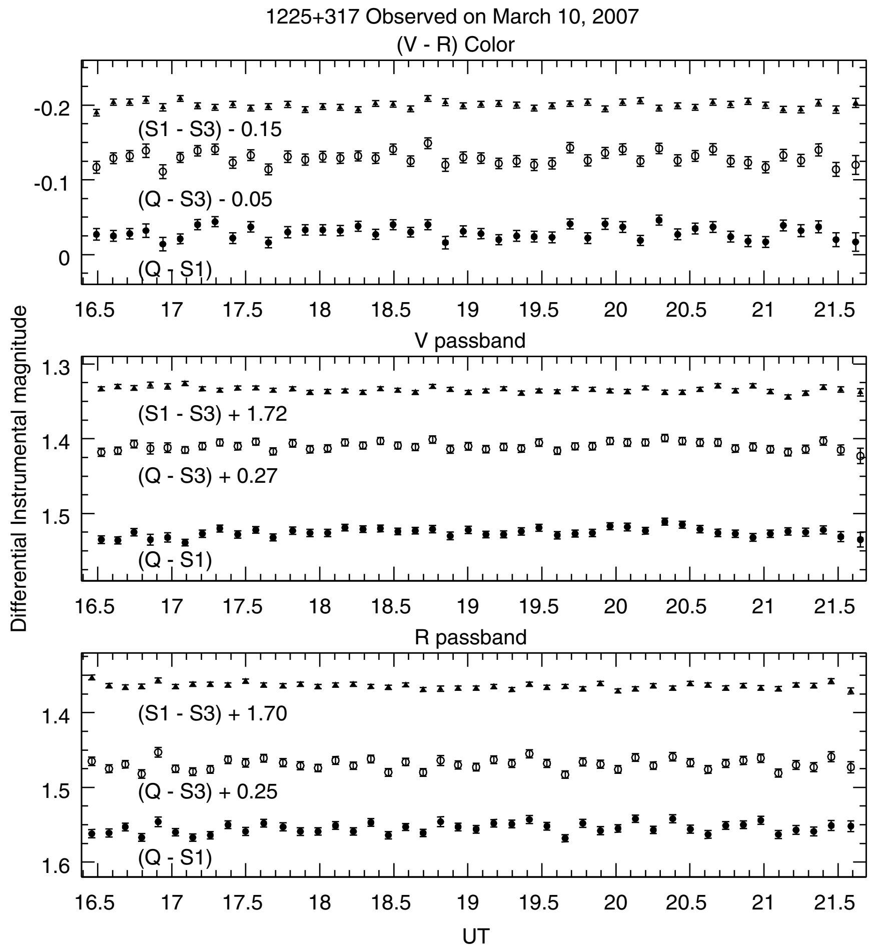

Fig. 5. The V, R and V-R light curves of 1225 + 317 on the nights of March 10, 2007. In caption S and Q represent star and QSO, respectively. For clarity, the DLCs are offseted by the amounts marked on the panels.

We found the values of C in V, R and V-R and they are 3.0, 3.8 and 4.3, respectively, for the March 11 observations. For the observations on March 12, the values of C in V, R and V-R are 2.8, 5.0 and 3.7, respectively. On March 11, one spike was detected in the R band observations which changed the V-R color of the RLQSO. In determination of the values of C, the spike point has been omitted. These values of C show that this RLQSO exhibits clear micro-variation in V, R and V-R on both nights of observation. For the March 11, 2007 observations the amplitudes of variability in V, R and V-R are 4.0%, 3.5% and 6.6%, respectively. For the March 12, 2007 observations the amplitudes of variability in V, R and V-R are 3.9%, 6.5% and 13.7%, respectively. The differential magnitude of the RLQSO shows large error bars because it is ~2.0 mag fainter than both comparison stars.

4.3. Duty cycle of micro-variability in RQQSOs

Since 1993, there are several attempts to search for optical micro-variability in radio-quiet AGNs by various groups around the globe (e.g. Gupta and Joshi, 2005; Carini et al., 2007 and references therein). But there are only a few occasions on which micro-variability is detected (see the compiled optical micro-variability results in Table 3 of Carini et al., 2007). In last one and half decade observations were carried out in search for optical micro-variability were at non-regular time interval, inconsistent observing time duration for different sources, different selection criterion and different data analysis methods of sources by different groups. Here we have taken the compiled data of RQQSOs (not Seyfert Galaxies) from Table 3 of Carini et al. (2007) and data of the five RQQSOs from the present work to calculate the duty cycle of micro-variability in RQQSOs. Here we defined the duty cycle without weighting the number of hours sources have been observed. If n denotes the total number of occasions on which the optical micro-variability have been detected, and N denotes the total number of occasions on which the sources have been observed in search for micro-variability then the duty cycle DC is defined as

$$DC = \frac{n}{N} \times 100\% \qquad (4)$$

Till date, 70 RQQSOs are observed at 217 occasions in search for optical micro-variability. Optical micro-variability detected in only 17 RQQSOs on 21 occasions in 88 occasions they have been observed. While 53 RQQSOs have never shown optical micro-variability in their observations on 129 occasions. So, the duty cycle of optical micro-variability detection in RQQSOs is only ~10%.

5. Conclusions

To investigate whether micro-variability is a persistent, or only occasional, property of RQQSOs, we have presented new observations of five luminous radio-quiet QSOs and one radio-loud QSO in a search for quasi-simultaneous optical micro-variability in V and R passbands and V-R color for the first time. The RQQSOs studied here have shown optical micro-variability on some occasions of

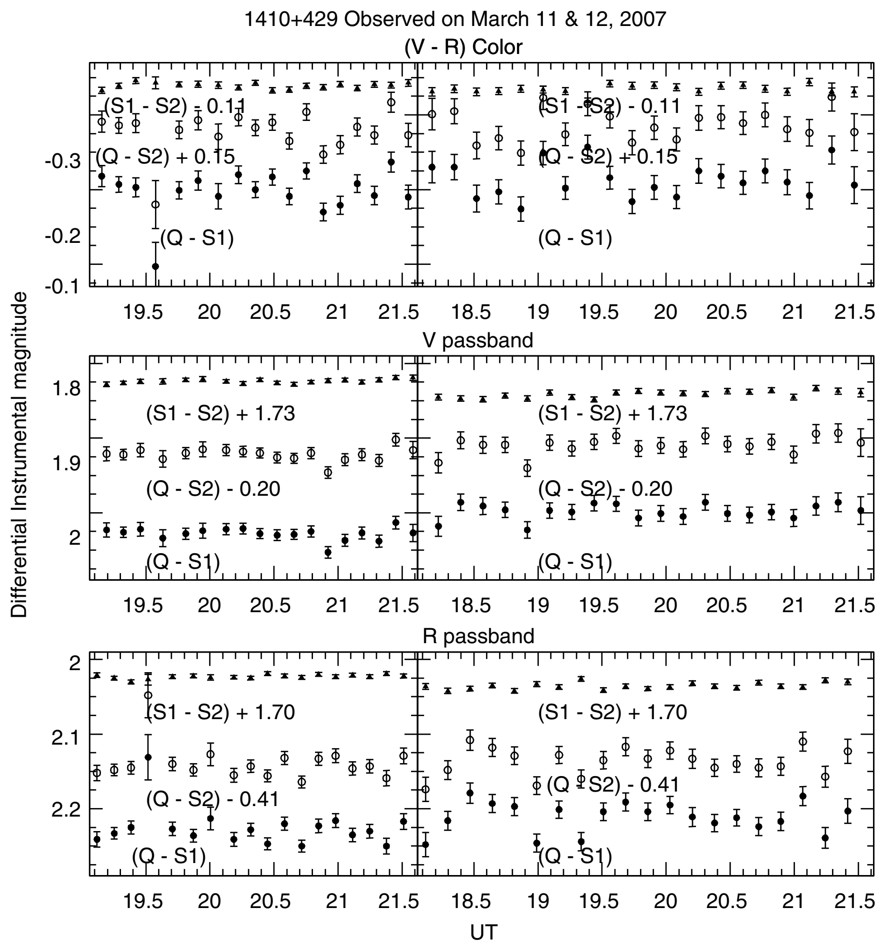

Fig. 6. The V, R and V-R light curves of 1410 + 429 on the nights of March 11 and 12, 2007. In caption S and Q represent star and QSO, respectively. For clarity, the DLCs are offseted by the amounts marked on the panels. One point spike seen in R band QSO observations on March 11, 2007 which has caused one point dip in V-R color is omitted in variability detection test.

Table 3
Results of micro-variability observations of RQQSOs and RLQSO[a]

Date dd.mm.yyyy	QSO	Class	Band	N	Diff. mag QSQ – S_A	Diff. mag QSQ – S_B	Diff. mag S_A – S_B	Variable	*C*	*A*%	Remarks
12.03.2007	0748 + 294	RQQSO	V	33	0.926 ± 0.009	0.232 ± 0.009	−0.694 ± 0.009	NV	1.0		
			R	33	1.515 ± 0.010	0.576 ± 0.009	−0.940 ± 0.005	NV	1.9		
			V-R	33	−0.589 ± 0.009	−0.344 ± 0.010	0.245 ± 0.008	NV	1.2		
11.03.2007	0824 + 098	RQQSO	V	40	1.239 ± 0.010	0.805 ± 0.009	−0.434 ± 0.008	NV	1.2		
			R	40	0.765 ± 0.010	0.546 ± 0.010	−0.219 ± 0.006	NV	1.7		
			V-R	40	0.474 ± 0.012	0.259 ± 0.012	−0.216 ± 0.010	NV	1.2		
10.03.2007	0832 + 251	RQQSO	V	38	0.296 ± 0.005	0.492 ± 0.006	0.197 ± 0.005	NV	1.1		
			R	39	0.382 ± 0.006	0.521 ± 0.006	0.139 ± 0.006	NV	1.0		
			V-R	38	−0.087 ± 0.007	−0.029 ± 0.008	0.058 ± 0.007	NV	1.1		
11.03.2007	1101 + 319	RQQSO	V	20	−0.127 ± 0.009	0.806 ± 0.007	0.933 ± 0.006	NV	1.3		Last V passband point omitted in analysis
			R	21	0.424 ± 0.007	0.907 ± 0.008	0.483 ± 0.005	NV	1.5		
			V-R	20	−0.551 ± 0.012	−0.101 ± 0.012	0.450 ± 0.007	NV	1.8		
10.03.2007	1225 + 317	RQQSO	V	44	1.525 ± 0.006	1.140 ± 0.005	−0.386 ± 0.004	NV	1.4		
			R	44	1.555 ± 0.007	1.219 ± 0.007	−0.336 ± 0.004	NV	1.8		
			V-R	44	−0.029 ± 0.009	−0.079 ± 0.009	−0.050 ± 0.004	NV	2.3		
11.03.2007	1410 + 429	RLQSO	V	18	2.028 ± 0.009	2.122 ± 0.009	0.094 ± 0.003	V	3.0	4.0	One point spike in R passband is removed in analysis
			R	17	2.231 ± 0.012	2.554 ± 0.011	0.323 ± 0.003	V	3.8	3.5	
			V-R	17	−0.203 ± 0.017	−0.433 ± 0.017	−0.229 ± 0.004	V	4.3	6.6	
12.03.2007	1410 + 429	RLQSO	V	20	1.998 ± 0.010	2.110 ± 0.012	0.111 ± 0.004	V	2.8	3.9	
			R	20	2.111 ± 0.021	2.547 ± 0.019	0.336 ± 0.004	V	5.0	6.5	
			V-R	20	−0.213 ± 0.023	−0.437 ± 0.021	−0.224 ± 0.006	V	3.7	13.7	

[a] V and NV in the variable column represent variable and no variable, respectively. N represents the number of data points.

their earlier observations. We found genuine micro-variations in one radio-loud QSO, (1410 + 429) in V, R and V-R on both nights for which the source was observed. Five radio-quiet QSOs, 0748 + 294, 0824 + 098, 0832 + 251, 1101 + 319 and 1225 + 317 did not show any micro-variation in V, R and V-R. Our observations show that micro-variation in RQQSOs is rather rare. Non-detection of micro-variability in any of the RQQSOs in our search is consistent with the other studies (see Table 3 of Carini et al., 2007).

The generally accepted model for micro-variation in radio-loud AGNs is the shock-in-jet model (e.g. Blandford and Königl, 1979; Scheuer and Readhead, 1979; Marscher, 1980, 1992; Hughes et al., 1985; Marscher and Gear, 1985; Valtaoja et al., 1988; Qian et al., 1991), in which the light is seen to fluctuate on time scales of a few minutes to an hour. Other models that can explain the micro-variation in any type of AGNs are optical flares, disturbances or hot spots on the accretion disk surrounding the black hole of the AGNs (e.g. Wiita et al., 1991, 1992; Chakrabati and Wiita, 1993; Mangalam and Wiita, 1993). The micro-variation detected in V, R and V-R of the RLQSO 1410 + 429 can be explained by any of these models.

After intensive searches of micro-variation in RQQSOs over the last one and half decades, the real cause of micro-variation is still not well known. Possible explanations involve either by shock-in-jet or accretion disk based models (Gupta and Joshi, 2005). It is believed that, in radio-quiet AGNs, due to severe inverse-Compton losses, most jets are probably quenched at the incipient stage (Wilson and Colbert, 1995; Blandford, 2000). The weak and rarer evidence of optical micro-variation detection in earlier observations of RQQSOs can be explained with jet models that assume less Doppler boosting than the radio-loud QSOs and much less than the blazars (Gopal-Krishna et al., 2003), which is consistent with unified models of AGNs. VLBA and XMM-Newton studies confirm weak jet emissions in radio and X-ray bands from a few radio-quiet QSOs on some occasions. Some evidence of weak radio jets in a small number of RQQSOs have been reported from deep VLA imaging and related studies (Miller et al., 1993; Kellermann et al., 1994; Falcke et al., 1996a,b). There have been some attempts at VLBA imaging at milliarcsecond resolution of the central engines of 12 radio-quiet QSOs by Blundell and Beasley (1998). They reported eight of these sources show strong evidence of a jet-producing central engine. In another recent paper, Ulvestad et al. (2005) have done deep VLBA imaging of five RQQSOs in which only one source shows a two-sided radio jet and the other four are unresolved. In radio monitoring campaigns with VLBA, relativistic jets were found in the RQQSO PG 1407 + 263 and in Seyfert 1 galaxy III Zw 2 (Blundell et al., 2003; Brunthaler et al., 2005). Gallo (2006) in a recent paper has reported XMM-Newton observations of a RQQSO PG 1407 + 265 in which the X-ray variable emission apparently originates from a combination of jet and accretion disk processes, and where a relativistic X-ray jet only works intermittently.

In a recent paper, Czerny et al. (2008) have done modeling of micro-variability of RQQSOs, using non-simultaneous X-ray and optical data of 10 RQQSOs which have shown optical micro-variability on some occasions. They have discussed that the three possible models for micro-variability in RQQSOs: (i) irradiation of an accretion disc by a variable X-ray flux, (ii) an accretion disc instability, (iii) the presence of weak blazar component, if jet emission is variable. They concluded that the blazar component model is the most promising model to explain the micro-variability in RQQSOs. Future simultaneous multi-color optical and X-ray monitoring observations of a sample of RQQSOs will give insight into the cause of micro-variation in RQQSOs. Micro-variability of RQQSOs is not yet well known and it needs a focused effort which we have plan to do in near future.

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