1996MNRAS.281.1267S

Mon. Not. R. Astron. Soc. **281,** 1267–1276 (1996)

Intranight optical monitoring of optically selected bright quasars

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Accepted 1996 March 4. Received 1996 February 2; in original form 1995 October 12

ABSTRACT

As part of an ongoing programme to search for intranight optical variations, we report results for six radio-quiet and one radio-moderate, but all optically bright and luminous, quasi-stellar objects (QSOs), using the 2.34-m Vainu Bappu Telescope. Moderately strong evidence is found for the microvariability of the radio-quiet QSOs 0946 + 301 and 1444 + 408 and weaker evidence is found for the QSO 0117 + 213. We also draw attention to a few 'spikes' (on time-scales of ≤ 10 min) seen in the optical output of the radio-quiet QSOs 0117 + 213, 0946 + 301 and 1630 + 377. Additional observations of these and other QSOs could provide a powerful means of discriminating among the various theoretical mechanisms proposed for the energy source and, in particular, the origin of optical microvariability in active galactic nuclei (AGN). Finally, by comparing the present observations with those made by us ~ 1 yr earlier, long-term variability (5 to 15 per cent) is detected for four of the QSOs in our sample.

Key words: galaxies: active – galaxies: photometry – quasars: general.

1 INTRODUCTION

Although intranight flux variations are a well-known characteristic of optically violently variable quasars and BL Lacertae objects (e.g. Carini 1990; Heidt & Wagner 1996) and have recently been shown to be common among flat spectrum radio-loud quasars (Jang & Miller 1995, 1996), the occurrence of such rapid variations is not yet fully established for radio-quiet quasars (RQQSOs). Positive detections of intranight variability in bona fide RQQSOs can provide important clues on the physical emission processes occurring on the innermost scales of these powerful AGN (Gopal-Krishna, Sagar & Wiita 1993b, hereafter Paper I; 1995, Paper II).

In order to bridge this important observational gap, we have been carrying out a systematic programme of monitoring a set of optically bright ($V \sim 16$ mag) and intrinsically luminous ($M_V \leq -25$ mag) RQQSOs using the 2.34-m Vainu Bappu Telescope (VBT) located at Kavalur in southern India. The observational strategy consists of using a CCD camera as an N-star photometer, which allows detection of fluctuations of 1–2 per cent on time-scales of less than about 1 h (thereby providing clear evidence of any microvariability that may be present). In Papers I and II, we have reported the observations for 10 QSOs, including one radio-moderate and nine RQQSOs. Our data revealed microvariability for the radio-moderate QSO 0838 + 359, and provided strong indications of microvariability for two RQQSOs, namely, 0946 + 301 and 1049 – 006. Our radio-quiet objects are effectively 'radio-silent', with $R \ll 1$, where R is the ratio of radio (5-GHz) to optical (440-nm) flux densities. Evidence for intranight variability in three of 19 RQQSOs has recently been presented by Jang & Miller (1995, 1996). In this paper, we report new observations carried out during 1993–95 which cover six RQQSOs (including two new ones) and the radio-moderate QSO 0838 + 359. The main objective is to build a sample of RQQSOs which are good candidates for microvariability, so that by monitoring them intensively the question of the presence of RQQSO microvariability can be settled.

2 OBSERVATIONS AND DATA REDUCTION

The QSOs in the present programme were chosen from the lists of Hewitt & Burbidge (1993) and Véron-Cetty & Véron (1993) following the criteria outlined in Paper II, which ensure that the selected objects are bona fide optically luminous QSOs of the radio-quiet class, with extremely weak radio emission (flux densities < 1 mJy at 6 cm, Keller-

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★E-mail: sagar@iiap.ernet.in (RS); krishna@gmrt.ernet.in (G-K); wiita@chara.gsu.edu (PJW) mann et al. 1994; but see below for 0836 + 359); and are apparently bright enough ($V \approx 16$ mag) to yield a signal-to-noise ratio of 50–100 within ≤ 10 min exposure time. An additional requirement imposed was the presence of at least two to three suitable comparison stars on the CCD frame containing the QSO. In that the probability of observing intranight variability in blazars rises dramatically if the source is observed for more than 3 or 4 h (Carini 1990; Noble 1995) we attempted to follow each source for at least 4 h during the portion of the night where it was close to the meridian.

At the time of these observations the reflectivity of the primary mirror of the VBT had become quite poor, necessitating the relatively lengthy exposures (compared to say, the recent results of Noble & Miller 1994; Noble 1995; or Jang & Miller 1995) to obtain an adequate signal-to-noise (S/N) ratio. The larger plate scales of the VBT also mean that our images occupy a larger number of pixels than do those of the above authors and thereby include more noise. Further, most of the observations were made on nights with relatively high sky-brightness.

Basic information about the seven QSOs and the dates of the observations analysed herein are provided in Table 1. A Hubble constant $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$ are assumed for computing M_V. Although each QSO was monitored primarily in the *R* photometric passband, at least one exposure was taken in each of the *B* and *V* bands, in order to determine the colours of the QSOs relative to those of their comparison stars. The detector used was a blue coated Astromed GEC P8603 CCD chip mounted at the f/3.23 prime focus of the VBT. This chip has 385 × 578 pixels of 22 microns square, corresponding to a 0.64 arcsec^2 area on the sky, so that the total area covered by a CCD frame is about 4×6 arcmin^2. The readout noise was about 8 electron pixel^{-1}, and the electron ADU^{-1} was 4. Bias and dark frames were taken intermittently. In order to be able to detect small fluctuations reliably we carried out differential photometry, generally ensuring that the locations of the QSO and comparison stars did not change by more than a few pixels from exposure to exposure. This largely obviated the need to flat-field the frames, which would have introduced additional noise.

The seeing was typically 2 arcsec, adequate to provide accurate relative magnitudes for point-like objects. The procedure for data reduction including the differential photometry using the DAOPHOT software package has been described in Paper II, together with the details of photometric error estimation. The position offsets of the best comparison stars from the respective QSOs, as well as their relative colours, are given in Table 2. The rather small colour differences indicate that any effects on the differential photometry of the convolution of the filter with the spectral differences between the QSO and the comparison stars will be negligible (Carini 1990; Paper I). For each frame three or four comparison stars were reduced in a manner identical to that of the QSO, except for a couple of cases where only two suitable stars were on the frame. It may be further noted that for all five QSOs common

Table 1. Monitoring of QSOs.

QSO	z	m_V	M_V	Dates of Observations	Microvariable
0117+213	1.493	16.1	−29.6	12, 13 Nov 93	Possible
0838+359^a	1.775	16.00	−30.1	12,13 Nov 93; 18 Dec 93	Yes^b
0946+301^a	1.216	16.38	−28.6	11 Jan 95	Probable
1049−006^a	0.357	16.04	−25.8	10,11 March 94	Probable^b
1206+459^a	1.158	16.07	−28.8	19,20 Feb 94; 6,7,11 Mar 94; 30,31 Mar 95	No
1444+408	0.267	15.7	−25.4	23 Apr 93; 9 Apr 94	Probable
1630+377^a	1.466	16.07	−29.5	4,5 May 94; 4 June 94	Possible

Notes: ^{a}additional data is in Paper II; ^{b}but no positive evidence in this new data.

Table 2. Comparison stars.

QSO	Star 1				Star 2				Star 3			
	Δr(″)	PA(°)	B−V	V−R	Δr(″)	PA(°)	B−V	V−R	Δr(″)	PA(°)	B−V	V−R
0117+213	70	8	0.44	0.14	71	269	0.22	0.00	140	293	0.28	0.05
0838+359	135	293	0.61	0.19	180	52	0.12	−0.04	170	85	0.32	0.05
0946+301	46	166	0.23	0.02	84	259	0.46	0.14	201	324	...	...
1049−006	235	110	0.43	0.02	101	146	0.37	0.09	90	182	0.19	0.09
1206+459	271	255	...	0.05	158	238	0.33	0.10	...	...	...	...
1444+408	260	120	...	0.23	282	129	...	0.23	180	157	...	0.24
1630+377	124	68	...	0.03	124	36	...	0.06	107	152	...	0.00

Note: the columns headed $B - V$ and $V - R$ refer to the differences of the colour indices of the stars from those of the corresponding RQQSO.

to Paper II the comparison stars have been defined identically.

3 DIFFERENTIAL LIGHT CURVES (DLCs)

3.1 Intranight variability

The plots of differential magnitudes versus time for the seven QSOs are shown in Figures 1–7. We adopt the statistical criterion of Kestevan, Bridle & Brandie (1976): if $P(\chi^2) > 0.999$ we can absolutely claim to have seen variability, but we consider a source with $P(\chi^2) < 0.995$ to be formally non-variable. A piece of compelling evidence for intranight variability for either a QSO or a star would be provided by correlated variations (both in time and amplitude) seen on different DLCs involving that particular object. We now discuss the results for each of the QSOs.

3.1.1 0117 + 213

This is a RQQSO newly included in our programme. The DLCs are displayed in Fig. 1. The only statistically significant variations detected over the course of entire nights for the QSO are with respect to star 2 ($P_{Q-2} > 0.999$ on both nights); however, the difference between star 2 and star 1 is nearly as significant ($p_{1\text{-}2} > 0.98$ on both nights), and we can attribute this result to the relative brightness and possible low-level variation of star 2.

Examination of the DLCs does show possible small 'flares' by the QSO at both 17.0 UT and 19.3 UT on 1993 November 12 and again around 18.0 UT on November 13; at these times no variations between the check stars are seen. However, none of these apparently correlated changes is greater than 2.5σ and each is seen at only one point in the light curves. Therefore we consider this data to provide merely a hint of microvariability and suggest that additional careful monitoring of this RQQSO be undertaken in the future.

3.1.2 0838 + 359

As mentioned in Paper II, this is the only QSO in our sample which is not strictly radio-quiet (~ 6 mJy at 1.4 and 8 GHz). Its radio-to-optical flux densities ratio, $R \approx 5$, which is below the limiting vlaue of 10 usually considered to be the borderline between the radio-loud and radio-quiet quasar populations (Kellermann et al. 1989). Thus, while on this basis it may be formally classified as radio-quiet, the detected flat-spectrum radio core is probably manifesting the relativistic jet phenomenon. It may be recalled that out of the seven QSOs discussed in Paper II, this was the only case for which intranight variability could be clearly established, although the fully RQQSOs, 1206 + 459, 1049 − 006

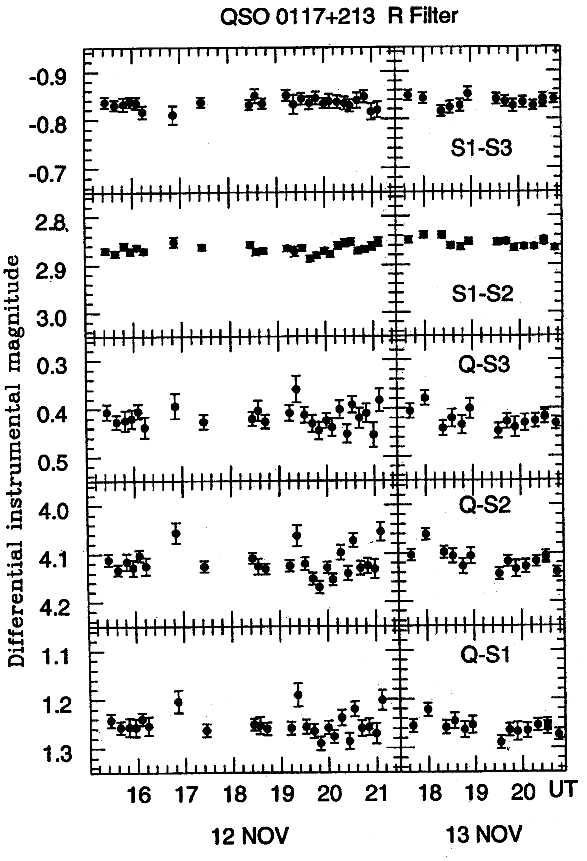


Figure 1. *R*-band observations for the QSO 0117 + 213. Starting from the bottom panel, differential light curves are presented for the QSO with respect to stars 1, 2, and 3; similar curves are also given for the differences between stars 1 and 2 and stars 1 and 3.

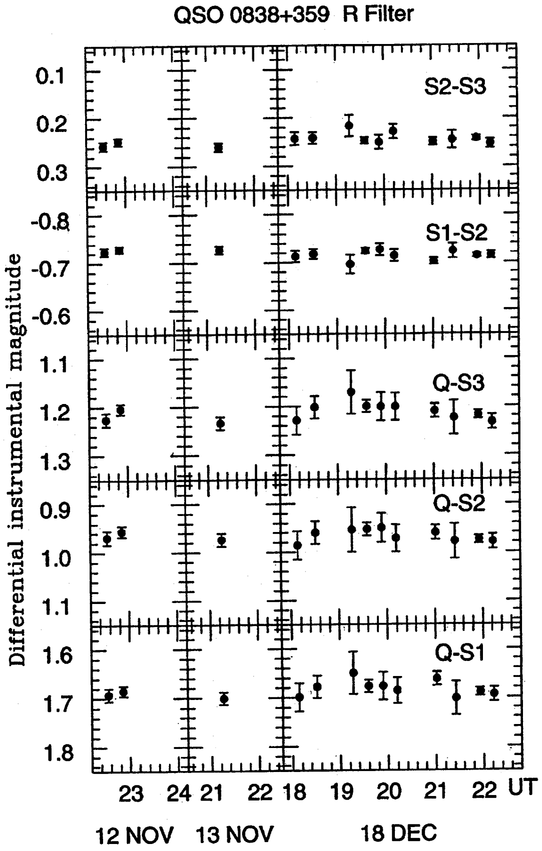


Figure 2. Differential light curves for QSO 0838 + 359 as in Fig. 1, except that the upper panel is for the difference between stars 2 and 3.

and 0946 + 301 each provided increasingly convincing evidence for this phenomenon.

Although the present observations of 0838 + 359 span five weeks in 1993, good temporal coverage is available only for the night of December 18 (Fig. 2), but the S/N ratio was worse than usual that night. This data set provides no evidence for intranight variation. We note that the QSO flux remained essentially constant over the period 1993 November 12–December 18.

3.1.3 0946 + 301

Our new observations of this RQQSO were made on one night, 1995 January 11, and the DLCs are displayed in Fig. 3. Our earlier observations (Paper II) indicated a high probability of microvariability having been detected for this QSO thanks to correlated changes in the DLCs, although the variation was not considered to be absolutely secure by our strict criterion. Again, in our present data no formally significant variations of the QSO with respect to the comparison stars were detected, with $P_{Q-3} = 0.9524$ the largest probability of microvariation; however, this time $P_{1-2} = 0.992$ and $P_{1-3} > 0.99999$. Unfortunately, all of the comparison stars are significantly brighter than the QSO, so that the error bars for the QSO/star comparisons are significantly greater than those for the star/star checks, and either small stellar fluctuations or small underestimates of the sizes of these errors could explain these results.

Nonetheless, examination of the DLCs between 19.6 and 20.0 UT do seem to show that the QSO underwent a correlated rise and fall of ~0.03 mag while no clear star/star fluctuations occurred. Another roughly 2σ variation in the form of a single spike at 22.8 UT is also seen for the QSO in comparison with each star. Having seen correlated changes in the DLCs on both (widely separated) epochs that we observed this RQQSO makes it an excellent microvariability candidate.

3.1.4 1049 – 006

Exceptionally good coverage is available for this RQQSO on both nights; no intranight variability is noticeable (Fig. 4). Recall that this source exhibited possible microvariability in our earlier V band measurements of 1993 February 26 (Paper II). The sharp feature seen on the DLC on 1994 March 10 at 16.3 UT is clearly associated with star 1, which

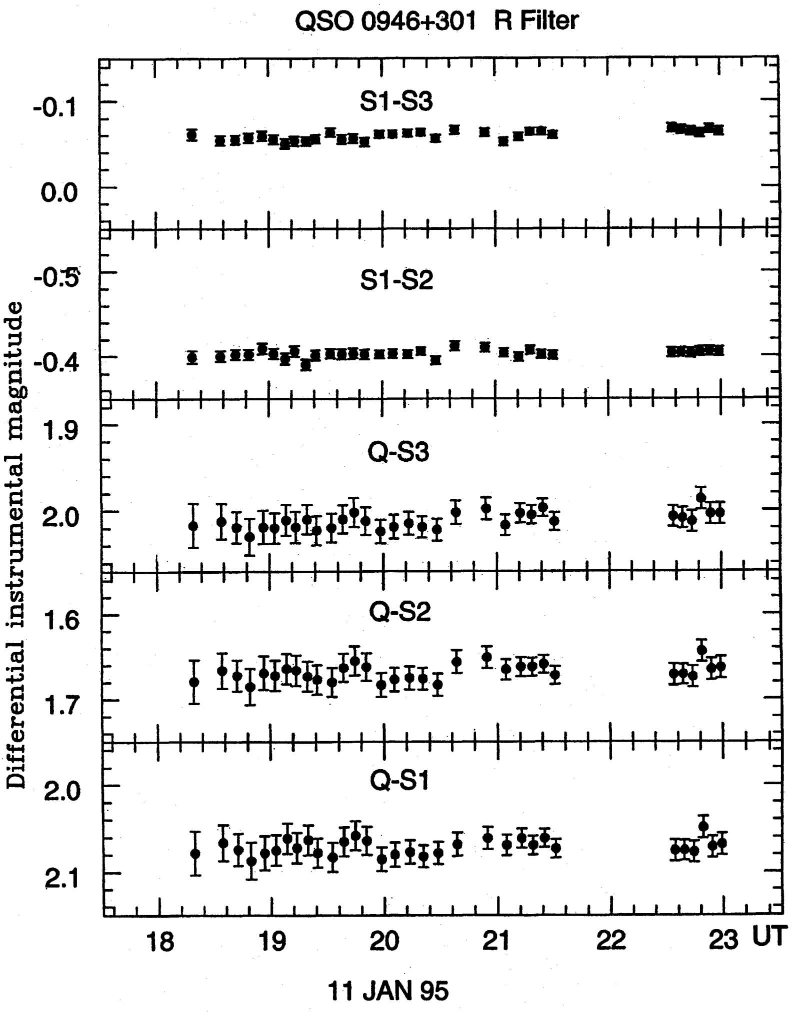


Figure 3. Differential light curves for QSO 0946 + 301 as in Fig.1.

may be showing, in addition, a steady positive gradient in brightness, subsequent to the short dip of ≈ 0.1 mag.

3.1.5 1206 + 459

Of the seven nights' data acquired for this RQQSO since that published in Paper II, fairly good temporal coverage along with a good S/N ratio is available only for 1994 February 19 and 20 (Fig. 5). The data for the two other nights during which we had extensive coverage, 1994 March 6 and 7, are noisier owing to a cloudy sky; also, on those nights star 1 was at the edge of the CCD frame and therefore was excluded from the analysis. The DLCs for 1995 March 30 and 31 are not presented here as both the data quality and temporal coverage are poor. However, we have used the data for the study of long-term variability in the object. No significant variability is found for the QSO in these seven nights of observations. Hints of intranight variability were found for this source in both of our earlier observations of it (Papers I and II), but never was a statistically significant fluctuation claimed.

However, two kinds of variations associated with star 2 are evident in our new data. First, a large spike (depression) of greater than 0.2 mag is seen near 23.4 UT on February 20. Secondly, its mean level shows a change of about 0.03 mag between February 19 and 20, and these types of variability deserve further study.

3.1.6 1444 + 408

This RQQSO is newly included in our programme. The measurements reported here refer to two epochs roughly a year apart (Fig. 6). On the first occasion, the QSO flux relative to all three comparison stars appears to drop within ~ 0.5 h from a maximum near 21.8 UT by 0.04 mag to a steady level. Formal significance of this variation is large, with $P > 0.99999$ for the QSO compared to each of the three stars. However, we note that only 10 data points were collected that night, and that the formal significance of the variation of star 2 with respect to star 3 also exceeds 0.9999 (while those for 1 against 2 and 1 against 3 are not significant). Since the first point seems to contribute much of the variation and the last point is significantly noisier, we have also computed χ^2 probabilities with both these data points excluded. The variation of the QSO with respect to each of the three stars remains significant at a level exceeding

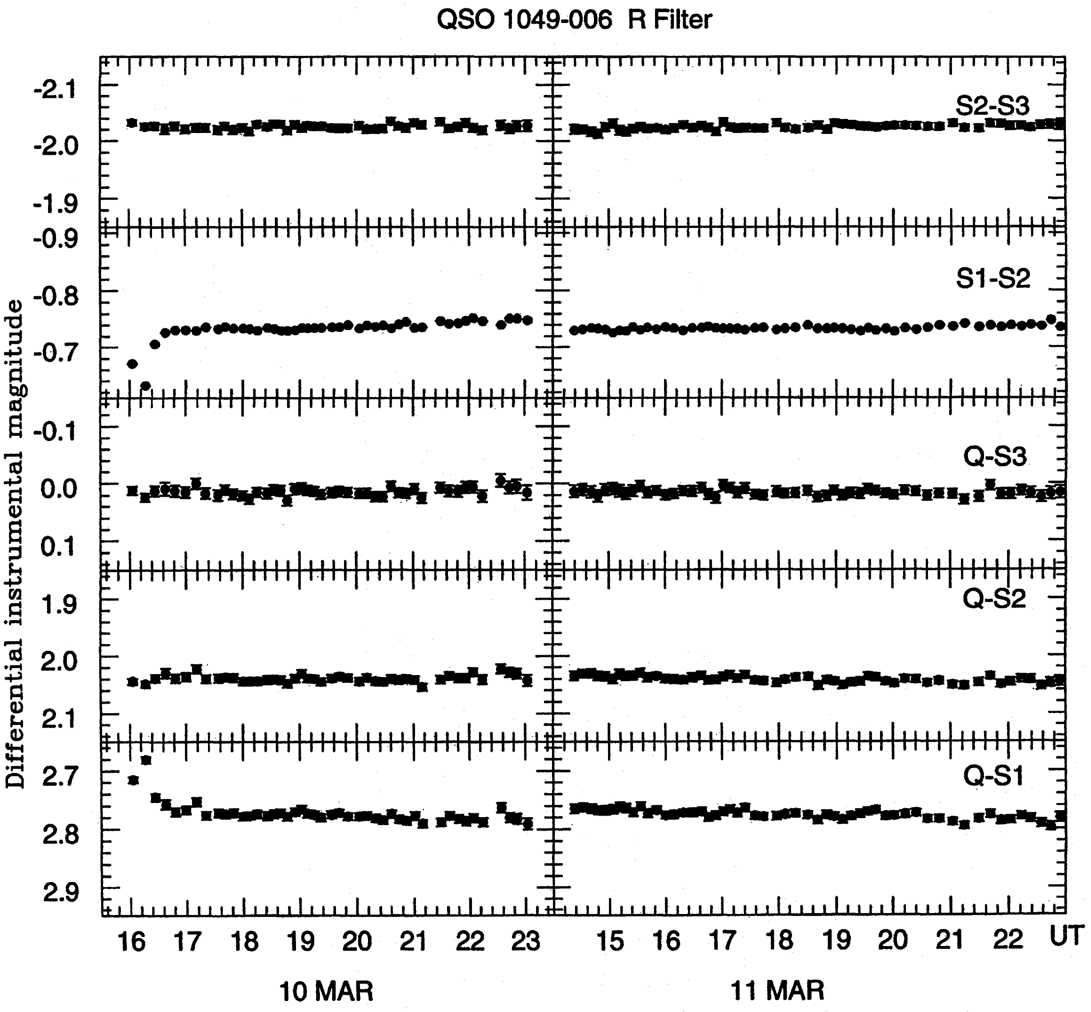


Figure 4. Differential light curves for QSO 1049 – 006 as in Fig. 2.

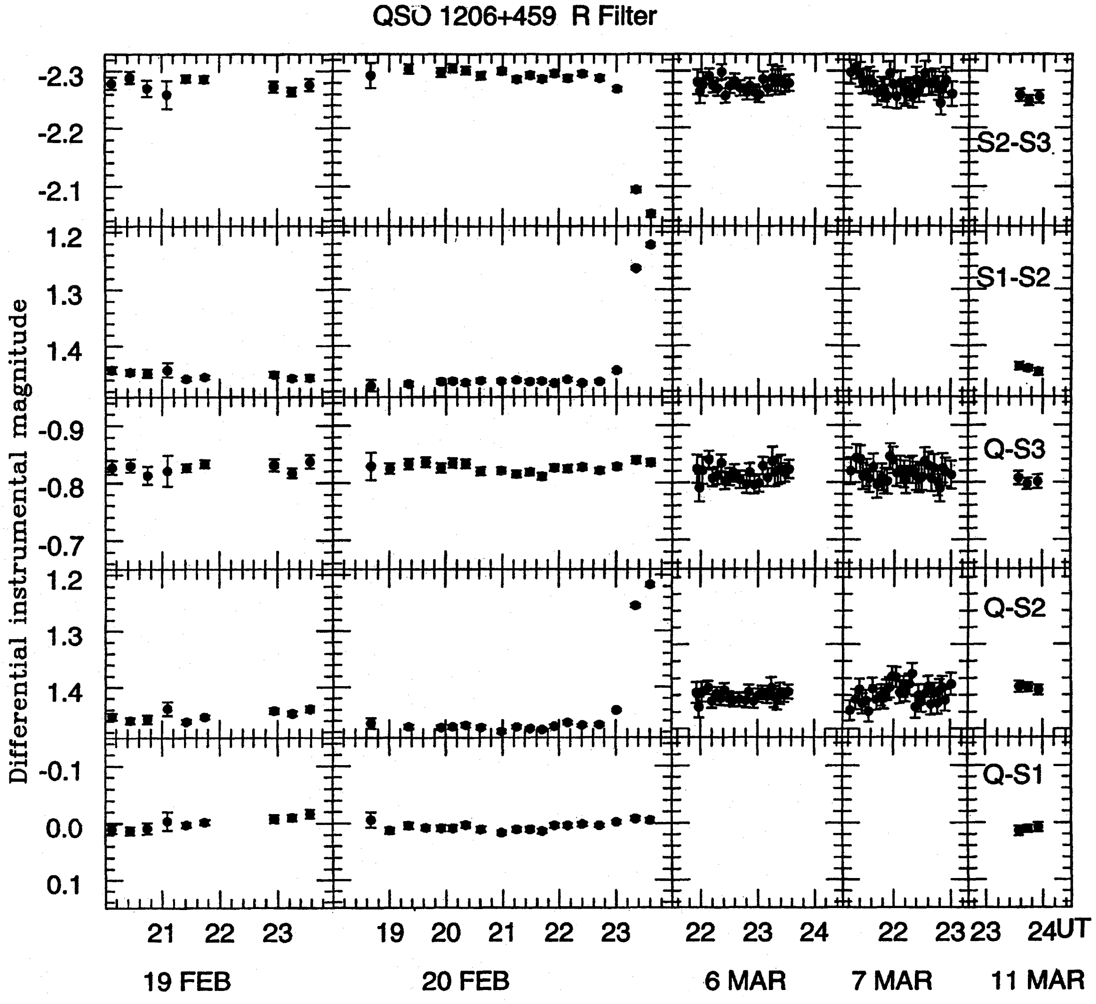


Figure 5. Differential light curves for QSO 1206 + 459 as in Fig. 2.

0.9999, but no interstar variation probability then exceeds 0.89. The 1994 data was too sparse to allow investigation of intranight fluctuations.

Thus, this RQQSO is very likely an intranight variable and a good candidate for future monitoring.

3.1.7 1630 + 377

Fairly dense temporal coverage is available for this RQQSO on all the three nights it was observed in 1994 (Fig. 7). Its flux level remained essentially steady for nearly all observations, though a significant variation of star 2 can be discerned on June 4, as was also the case for our 1993 measurements.

Two possible events of flickering of the RQQSO are present in the DLCs of May 4; these lead to tremendous formal probabilities of variation, with $P > 0.99999$ for the QSO against each of the stars, while the maximum interstar variation was between 2 and 3 ($P = 0.80$). The first event is an apparent brightening at 18.1 UT, and is marginally significant at the 1.7–2.3σ level (the range arises from different stars being compared to the QSO). A major *drop* in the RQQSO emission appears at 19.7 UT, and this is extremely significant, at the 8.1–9.0σ level. Unfortunately, after this data was taken the filter was changed to blue and subsequently to visual, which resulted in the large gaps in the light curves (Fig. 6), and the lack of possible confirming data points. If real, such a drop might be evidence for an eclipse of some hot portion of an accretion disc (e.g. Mangalam & Wiita 1993). No fluctuation at either time is evident on the DLCs involving the three comparison stars. We note that upon removing those two points from the analysis, all χ^2 probabilities drop below 0.77. Since only one point is involved in each case, the reality of the sharp drop in intensity thus remains uncertain, despite its large formal statistical significance. This object is clearly also worthy of additional intensive monitoring.

3.2 Long-term variability

Our new observations allow us to examine the long-term behaviour of five QSOs which are common to this work and Paper II (0838 + 359, 0946 + 301, 1049 − 006, 1206 + 459 and 1630 + 377). The DLCs reported in Paper II refer to the

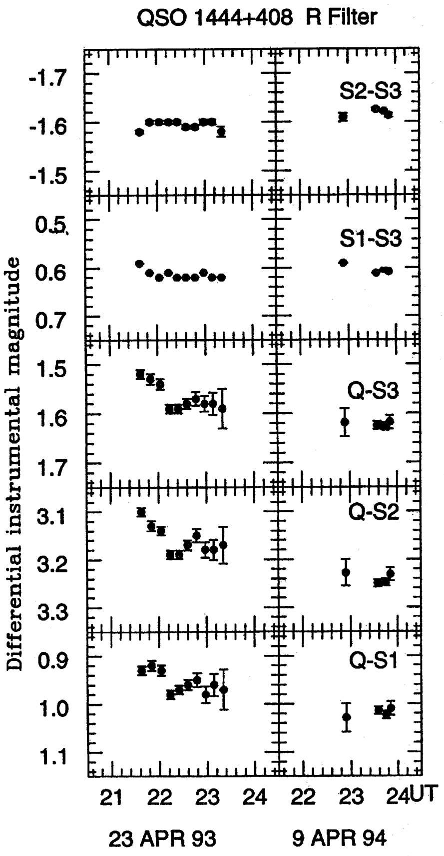


Figure 6. Differential light curves for QSO 1444 + 408 as in Fig. 2, except that the second panel is for the difference between stars 1 and 3.

epochs 1993 January, May, April, April and May, respectively. The corresponding epochs for the observations reported here are: 1993 December, 1995 January, 1994 March, 1994 February and 1994 May, respectively. In addition, we now have data for 1444 + 408 in both 1993 April and 1994 April. Thus, our observations typically cover approximately one-year baselines (in the observer's frame) in each case except for 0946 + 301 and 1206 + 459 where the baselines are 1.75 and 1.9 yr long, respectively. All the comparisons are restricted to the R-band (although we primarily used the V-band for the first-epoch observations of 0838 + 359 and 1049 − 006, a few exposures of them were taken in the R-band as well). Note that for all epochs, we have adhered to the same definition of comparison stars.

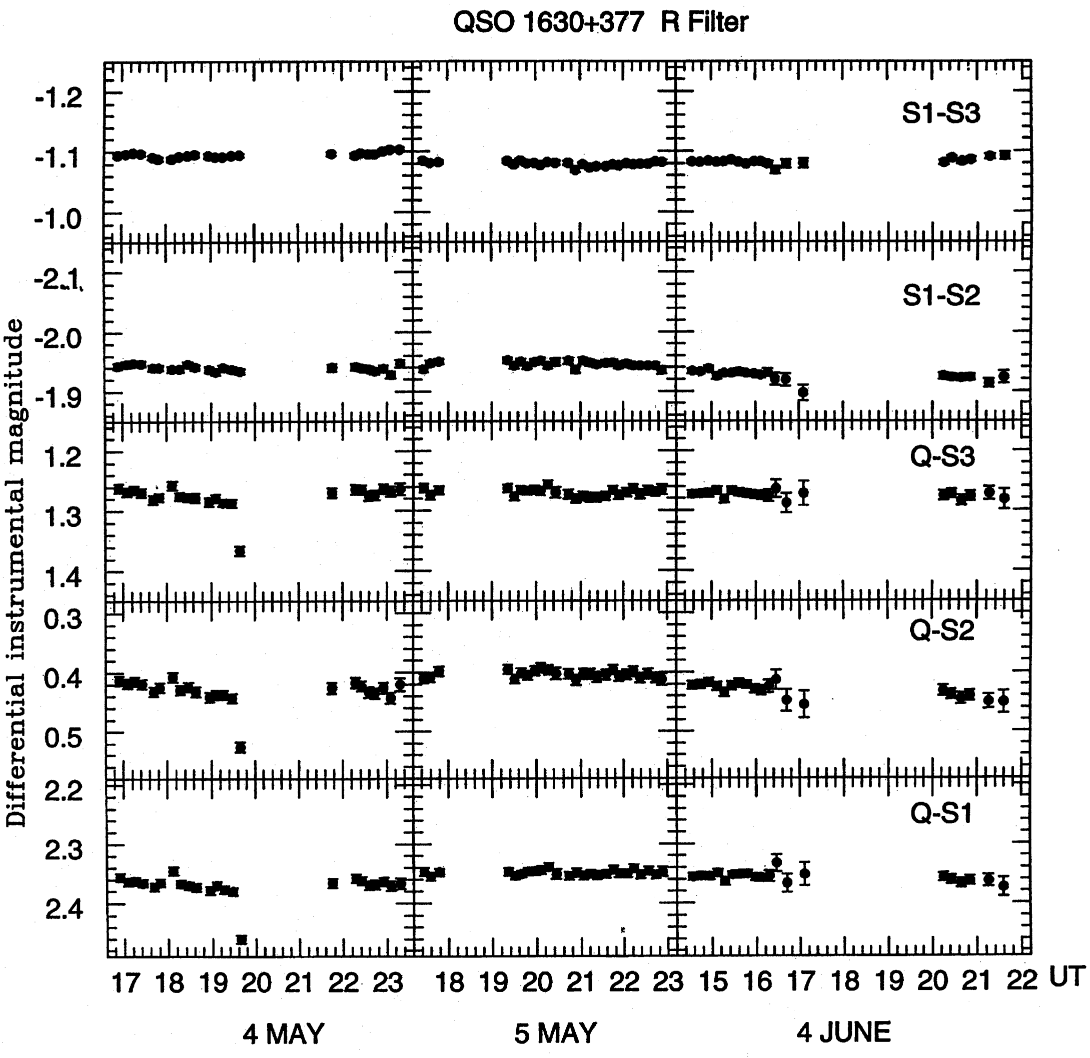
Table 3 gives the differences in the average magnitudes between the different epochs for the QSOs, as well as for their comparison stars. While hardly any changes are found for all of the comparison stars as well as for the QSOs 0946 + 301 and 1206 + 459, significant brightening has occurred in the cases of the QSOs 0838 + 359 ($\delta m = 0.05 \pm 0.02$), 1049 − 006 ($\delta m = 0.16 \pm 0.02$), and 1630 + 377 ($\delta m = 0.08 \pm 0.02$), while 1444 + 408 had dimmed ($\delta m = -0.07 \pm 0.02$). Interestingly, the variability of the flat-spectrum radio-moderate quasar 0838 + 359 on the time-scale of ~ 1 yr is *not greater* than that exhibited by the three radio-quiet quasars.

4 DISCUSSION AND CONCLUSIONS

As discussed in Papers I and II, intranight optical variability can be a key observable to address the basic issue of the energy source in QSOs (see also Gopal-Krishna, Sagar & Wiita 1993a). In Paper II we presented a strong hint for such microvariability events in two radio-quiet QSOs, namely, 0946 + 301 and 1049 − 006, and some less significant evidence for 1206 + 459. In the present set of observations, somewhat less persuasive, yet statistically significant microvariability is noticed in the RQQSO 1444 + 408. Possible intranight variability was found in two other RQQSOs, 0117 + 213 and 0946 + 301 (for a second time). Very rapid fluctuations have apparently been detected for the RQQSO 1630 + 377 as well. Together, these six radio-quiet quasars form a promising set of candidates for intensive optical monitoring, in order to fully establish these results and to determine the frequency of microvariability events in RQQSOs. Since most of these objects lie at $z \simeq 1$, the R-band observations actually refer to the blue region in the source frame, and therefore less dilution from the underlying galaxy is expected.

The only other attempt to detect intraday variability for RQQSOs of which we are aware has been conducted by Jang & Miller (1995, 1996). They report detections of microvariability in II Zw 175 (= 2214 + 13) (1995) and in Ton 951 (= 0844 + 34) and Ton 1057 (= 0923 + 20) (1996); these three sources were among a total of 19 RQQSOs they monitored for between one and five nights (typically three) and they found no evidence for microvariability in the other 16. We note that each of the three objects for which good evidence for rapid changes was found is at low redshift ($z < 0.2$), though they all are valid QSOs, with $M_B < -23$ (e.g., Kellermann et al. 1989). The Jang & Miller RQQSO sample was defined by them by requiring $R < 1$, and includes four objects that are better classified as Seyfert galaxies, so the percentage of actual RQQSOs evincing rapid changes may be understated by them. It is also worth pointing out that the most luminous of the RQQSOs for which they found any hints of intranight variation was Ton 1057, with $M_B = -24.3$, but only two of their sample of 19 RQQSOs had $M_B < -25$ and only 7 had $M_B < -24$.

Here it may be recalled that several authors have found an abrupt change in radio properties of QSOs near $M_B = -24.5$; QSOs fainter than this limit are rarely radio-loud (e.g., Peacock, Miller & Longair 1986; Miller, Peacock & Mead 1990; Padovani 1993; Della Ceca et al. 1994; Schmidt et al. 1995). It is very possible that most fainter QSOs, with $M_B > -24.5$, are associated with spiral galaxies and are high-luminosity analogues of radio-quiet Seyfert galaxies, while the more luminous ones are hosted by ellipticals. Our set of RQQSOs, all of which are intrinsically very luminous, with $M_B \sim -28$ in most cases, but always < -25, clearly belong to the latter category and yet, essentially all of them are radio-silent with $R \leq 0.25$ (Kellermann et al. 1994) and therefore unlikely to eject jets. Quite plausibly, they are a different population from the (fainter) QSOs observed by Jang & Miller (1995, 1996). A very interesting result of the Jang & Miller work is that in the course of monitoring 11 radio-loud AGN (three of which are Seyferts), typically for somewhat less time than for their RQQSOs, they nonetheless detected intraday variability in 9 of them. While there is



Fgiure 7. Differential light curves for QSO 1630 + 377 as in Fig. 1.

certainly not yet enough data to draw strong conclusions, it does seem that microvariability, similarly to extreme optical variability, is correlated with strong radio emission. This indicates that shock-in-jet models (e.g., Hughes, Aller & Aller 1991; Marscher, Gear & Travis 1992) have an important (if perhaps not exclusive) role to play.

The levels of long-term variability (~ 1 yr) detected in our repeated observations of several sources (~ 0.1 mag) are typical for all QSOs (e.g., Smith et al. 1988; Hook et al. 1994). The recent survey of ~ 300 optically selected quasars using data collected over 16 yr (Hook et al. 1994) indicates that the most luminous QSOs tend to be less variable than less luminous ones (root-mean-square ~ 0.1 mag at $M_B = -28$, but ~ 0.25 mag at $M_B = -23$). This trend has long been seen for radio-selected QSOs (e.g. Angione 1973), and our very sparse data is consistent with it, in that the least luminous QSO for which we have widely separated data (1049 − 006) showed the largest variation over the course of a year.

Equally interesting is the question of whether RQQSOs show optical flickering on a time-scale of ≤ 10 min. Only a few preliminary hints of such events can be found in the present data for the three sources 0117 + 213, 0946 + 301, and 1630 + 377 (Section 3.1). A careful search for such spikes would require an even more dense temporal coverage, and therefore require a larger telescope to achieve similar S/N ratios for shorter exposures. Doing so would be important, since one would then be sampling time-scales approaching the light-crossing time for the Schwarzschild radius of a 10^8 $M_\odot$ black hole. On the assumption (discussed in some detail in Paper II, and further supported by the lack of optical polarization; e.g., Impey & Tapia 1990; Wills 1991), that radio-quiet QSOs lack relativistic jets, such short time-scales are unlikely to arise from relativistic time compression, nor could they be because of external effects such as superluminal microlensing (cf. Gopal-Krishna & Subramanian 1991) and must therefore be intrinsic to the QSO. Plausible theoretical scenarios would then invoke accretion disc flares (e.g., Zhang & Bao 1991; Wiita et al. 1992; Chakrabarti & Wiita 1993; Mangalam & Wiita 1993) and coherent radiation processes (e.g., Benford 1992; Krishan & Wiita 1990, 1994; Lesch & Pohl 1992).

Table 3. Long-term variability in QSOs.

QSO	Date	Epoch	Q-S1 (mag)	Q-S2 (mag)	Q-S3 (mag)	S1-S2 (mag)	S1-S3 (mag)	S2-S3 (mag)
0838+359	24-1-93	1	1.73	1.01	1.27	−0.71	...	0.25
	18-12-93	2	1.68	0.96	1.21	−0.72	...	0.24
	δ		0.05	0.05	0.06	0.01	...	0.01
0946+301	17-5-93	1	2.08	1.66	2.02	−0.42	−0.06	...
	11-1-95	2	2.07	1.67	2.02	−0.40	−0.06	...
	δ		0.01	-0.01	0.00	−0.02	0.00	...
1049−006	22-4-93	1	2.93	2.20	...	−0.73	...	...
	11-3-94	2	2.78	2.04	...	−0.73	...	...
	δ		0.15	0.16	...	0.01	...	...
1206+459	23-4-93	1	−0.01	1.44	...	1.45	...	...
	20-2-94	2	0.00	1.44	...	1.45	...	...
	30-3-95	3	−0.01	1.43	...	1.44	...	...
	δ		0.01	0.01	...	0.01	...	...
1444+408	23-4-93	1	0.96	3.16	1.57	0.61	...	−1.60
	09-4-94	2	1.02	3.24	1.62	0.60	...	−1.62
	δ		−0.06	−0.08	−0.06	0.01	...	0.02
1630+377	17-5-93	1	2.44	0.51	1.35	−1.93	−1.09	...
	4-5-94	2	2.37	0.42	1.27	−1.94	−1.09	...
	δ		0.07	0.09	0.08	0.01	0.00	...

ACKNOWLEDGMENTS

We thank the VBT TAC for the generous allocation of observing time, and M. Jang and H. R. Miller for discussions and unpublished data. This work was supported in part by NASA and the Chancellor's Initiative Fund at Georgia State University.

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