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Research Note

Optical microvariability and radio quiet QSOs

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Abstract. We report the first search for intra-night optical variability in radio quiet, but optically bright and luminous, quasi-stellar objects, using two southern QSOs. Our limited data show no evidence for microvariability. Such observations, when carried out on a more intensive scale and expanded to larger numbers of sources, would provide a means of discriminating among various theoretical mechanisms proposed for the origin of optical intra-night variability in active galactic nuclei.

Key words: galaxies: active – galaxies: nuclei of – photometry – quasars: general – quasars: individual 0530 – 379; 0540 – 389

1. Introduction

In recent years a number of flat spectrum radio sources have been reported to show optical flux variations of at least a few percent over the course of several hours (e.g. Miller et al. 1989; Carini et al. 1991; Wagner et al. 1990). Recently it has been shown that such variations can also occur during relatively quiescent phases of a blazar (Miller et al. 1992). The phenomenon of optical microvariability for blazars, all of which are radio-loud, thus appears to be well established. At centimeter wavelengths rapid flux variations have also been recorded for several blazars (e.g. Quirrenbach et al. 1989; Wagner et al. 1990), with an indication of preferred day-like timescales (Heeschen 1984; Quirrenbach et al. 1989). In at least one case, 0716+714, the characteristic timescales for optical and radio variability appear to change simultaneously (Quirrenbach et al. 1991).

The theoretical explanations of intra-night variability fall broadly into extrinsic and intrinsic categories. Among the former are superluminal microlensing (Gopal-Krishna & Subramanian 1991) and refractive interstellar scintillations, although the latter seems to be inconsistent with the observed simultaneity of the variations over a large range of radio frequencies (Qian et al. 1991). Intrinsic explanations include a relativistic shock propagating down a jet and interacting with irregularities in the flow (Qian et al. 1991; Marscher et al. 1992) or relativistic shocks with a modest flutter in direction (Gopal-Krishna & Wiita 1992). A related model involves non-axisymmetric bubbles carried outward in relativistic magnetized jets (Camenzind & Krockenberger 1992). Another family of intrinsic explanations invoke numerous flares on the surface of the accretion disk believed to surround the central engine (e.g. Wiita et al. 1992; Mangalam & Wiita 1993); a similar model has been proposed to explain rapid X-ray variations of blazars (e.g. Abramowicz et al. 1991; Zhang & Bao 1991).

Since, unlike blazars, radio-quiet AGN are not believed to eject relativistic jets (e.g. Antonucci et al. 1990; Terlevich et al. 1987), any evidence for microvariability in such objects would provide substantial support for the hot-spot on accretion disk models. Nearly all sources searched for intra-night variability in the optical or radio are core dominated radio sources which were known to vary by large amounts over longer time scales. A few Seyfert galaxies have been monitored using CCD detectors as N-star photometers, but with negative results; these, however, could easily be due to the short durations of the observations (Miller, private communication 1992). Claims for optical microvariability in the Seyferts NGC 4151 (Lyutyi et al. 1989) and NGC 7469 (Dultzin-Hacyan et al. 1992) have been made, but the former is already known to have a mini-blazar type nucleus (Wilson & Ulvestad 1982), and the latter also has a compact non-thermal radio source

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Table 1. Separations of comparison stars from QSOs

Q 0530−379			Q 0540−389		
Star	Separation (″)	PA (°)	Star	Separation (″)	PA (°)
A	24	103	A	56	297
B	52	67	B	126	79
C	71	343	C	160	124
D	57	174	D	92	173
E	94	230	E	110	190

at its nucleus (Ulvestad et al. 1981); further, these measurements have not employed the most modern instrumentation and are prone to systematic errors due to contamination from the circumnuclear emission. Hence, the most secure test of the accretion disk model would come from optical monitoring of radio-quiet, but optically powerful (and hence, pointlike) QSOs, using wide-field CCD arrays which would encompass several suitable comparison stars on each frame.

Here we present preliminary results from such a program: observations have been made of the cosmologically distant bright quasars 0530−37 (z = 0.29) and 0540−38 (z = 0.83). These objects were selected because they are relatively bright, have good comparison stars within their CCD frames, and could be tracked for several hours at low airmass on the nights the observations were made. Neither of these sources has been detected in either the Parkes (Bolton & Shimmins 1973) or Molonglo (Large et al. 1981) radio surveys, which are complete to 0.22 Jy at 2.7 GHz and 1 Jy at 408 MHz, respectively. A recent search for radio emission in these QSOs using the VLA[1] at 1.4 GHz has also been negative down to a limit of 3–4 mJy, so it is fair to say that these QSOs are indeed radio quiet.

2. Observations and results

A total of three nights of observations at the European Southern Observatory at La Silla were carried out at V band, using the Thomson 1024 × 1024 pxl CCD on the 3.6 m New Technology Telescope (24/25 December 1991) for both objects and the GEC 587 × 385 CCD on the 0.9 m Dutch Telescope (19/20 and 20/21 December 1991) for 0530−37 alone. The two CCD arrays have pixel sizes of close to $0\farcs4 \times 0\farcs4$ which was adequate for the seeing conditions, which ranged from $1\farcs0$–$1\farcs5$. The array sizes for the two telescopes were approximately $7' \times 7'$ (NTT) and $2\farcm4 \times 3\farcm7$ (Dutch). Since the QSOs 0530−37 and 0540−38 have visual magnitudes of 16.7 and 17.2, respectively (Hewitt & Burbidge 1987; Véron-Cetty & Véron 1989), it was possible to obtain signal to noise ratios of about 100 with exposures of 2 min with the NTT and 30 min with the Dutch Telescope.

The individual CCD frames were reduced using the standard MIDAS software procedure by subtracting the zero-exposure frames and by flat-fielding using the median averaged sky exposures. The flux densities were obtained by integrating the counts within a 9″ circular aperture and subtracting the base level derived from the surrounding annulus. In all cases, 3–5 comparison stars with magnitudes similar to those of the respective quasars were found within ~2′ radii around the quasars, and their flux densities were measured following procedures identical to those observed for the QSOs. The separations and position angles of the stars relative to the QSOs, based on the finding charts given in Osmer & Smith (1980), are given in Table 1.

Figures 1 and 2 illustrate several flux density ratios for QQ 0530−37 and 0540−38, respectively. Conservative error bars (taking into account our lack of knowledge of the differential colors of the stars and QSO) are also plotted for 0530−37; for 0540−38, they are slightly smaller than the symbols on the graph. It is clear that there is no strong evidence for intra-night variability of either QSO down to the level of 2–3% rms. The only hint of microvariability occurs for Q 0530−37 towards the end of the second night, when the observing conditions were found to be worsening due to clouds. A detailed examination of the data indicates that star D near Q 0540−38 seems to have varied by ≈2% during the night of 24/25 December.

In order to check the "radio quietness" of the two QSOs, we arranged to have snap-shots taken at the VLA in May 1992 at 1465 MHz. The data were calibrated employing the source 0537−44, taking it to have a flux density of 4.0 Jy at 1465 MHz, and maps were made using the standard AIPS package. The radio emitter detected nearest to Q 0530−37 is a double source containing 155 ± 6 mJy and centered $2\farcm3$ from the position of the QSO at PA 200°, as shown in the self-calibrated map (Fig. 3). Similarly, the source detected nearest to Q 0540−38 is unresolved, containing 75±6 mJy centered at $6\farcm8$ and PA 148° from the QSO. Any emission from the position of the QSOs is less than the 3σ noise level of ~3 mJy.

[1] The Very Large Array is a facility of the National Radio Astronomy Observatory, which is operated by Associated Universities Inc., under contract with the National Science Foundation.

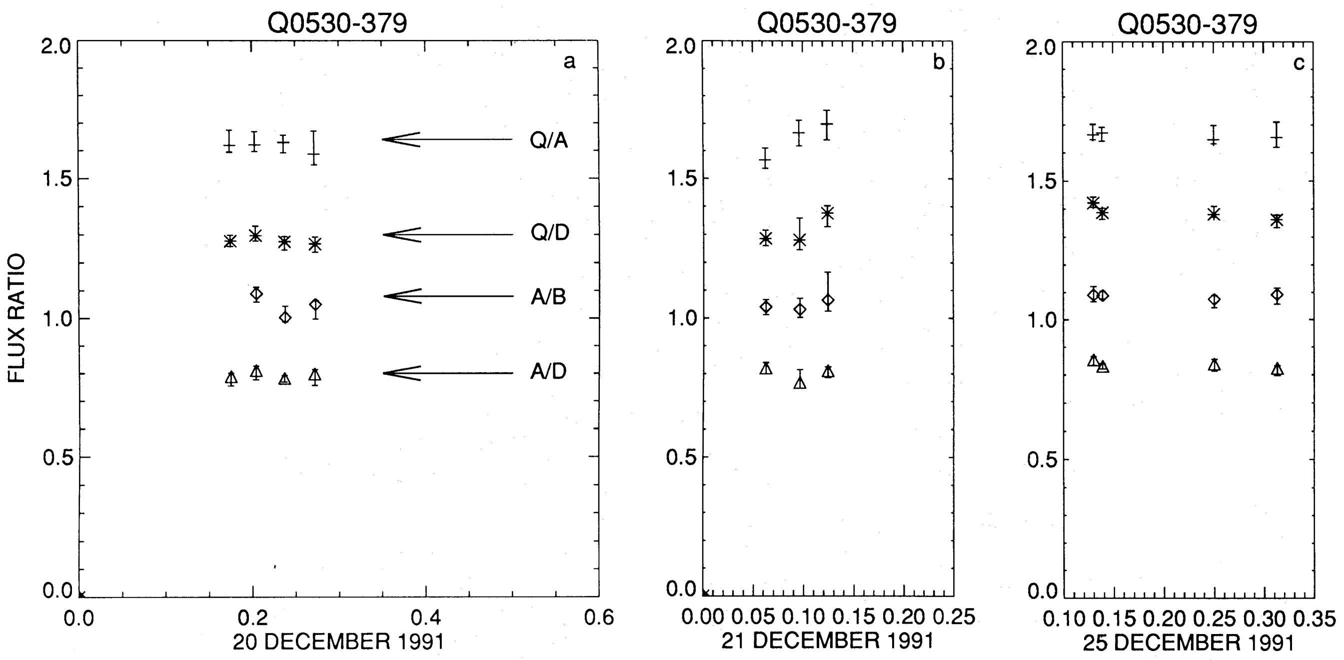

Fig. 1a–c. Flux ratios for Q 0530 – 379 and three comparison stars, A, B, and D on **a** 20 December 1991, **b** 21 December 1991, and **c** 25 December 1991

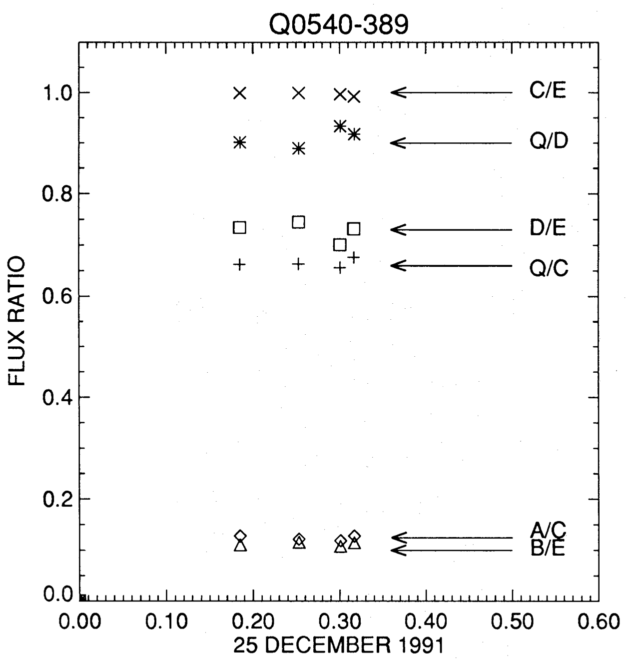

Fig. 2. Flux ratios for Q 0540 – 389 and five comparison stars, A, B, C, D, and E

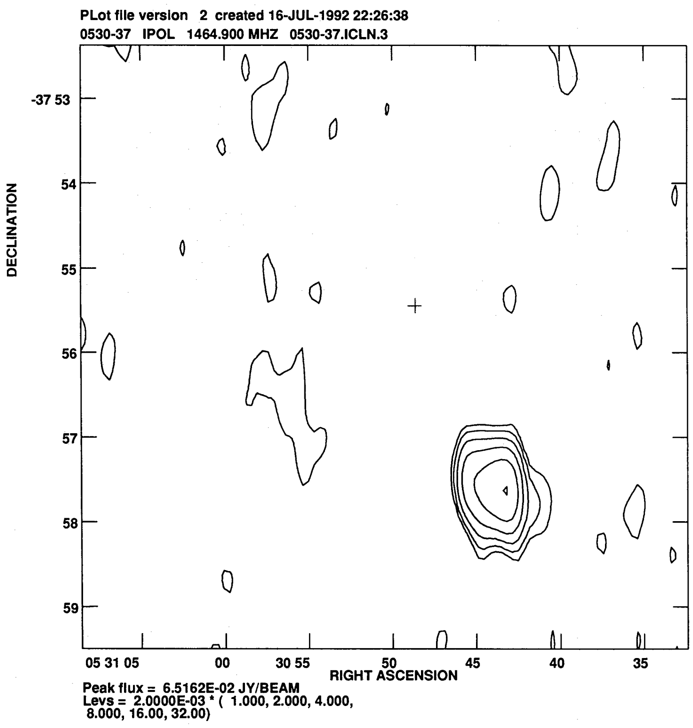

Fig. 3. VLA radio map of the field of Q 0530 – 379 at 1.465 MHz. The half-power beam width is 11″ × 40″ (NS) and the rms noise is ≈ 1 mJy/beam. The position of the QSO is marked with a cross

3. Conclusions

We have begun searching for optical microvariability in radio quiet but optically bright and luminous (Mv < -23) quasi-stellar objects. The two such objects reported on here are among the prime candidates for testing the hypothesis that the origin of microvariability is related to accretion disk fluctuations. If small but significant flux variations are found in radio quiet quasars this would be difficult to explain in jet-based intrinsic or extrinsic models; on the other hand, if a thorough search turns out to be negative, then the accretion disk models would be disfavored. In our limited data, no such fast flux changes were clearly detected down to the 2–3% level. But it should be recalled that even blazars that are definitely microvariable do not show this behavior in every observing run (e.g. Carini 1990). The observations presented here, the first of their type for this class of object, obviously need to be repeated in a more intensive fashion for individual objects and extended to a larger sample of QSOs in order to arrive at definitive conclusions about the underlying physical mechanisms for microvariability. We have begun such a program, which includes more extensive monitoring of several radio quiet quasars using the 2.34 m Vainu Bappu Telescope at Kavalur, India.

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