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Testing the mechanisms for optical micro-variability of powerful active galactic nuclei

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Abstract. We present the first results of a new type of observational programme being carried out using the 2.34m Vainu Bappu Telescope at Kavalur. This programme involves intra-night optical monitoring of radio quiet but optically luminous quasars. This experiment is expected to provide a fairly straight-forward test of the two major mechanisms that have been proposed so far to explain the phenomenon of optical micro-variability of powerful AGN, which has been established during the past 4 years. The two categories of mechanisms involve (i) shocks moving in the relativistic jets and (ii) random hot spots occurring on the quasar accretion disks. Our optical monitoring of the 7 radio-quiet quasars, so far, has not revealed any clear event of intra-night variability. Positive detection of such a variability would provide a strong support to the model invoking accretion disks, while a clear absence of such events would strongly favour the models relying on shocks propagating down the relativistic jets.

Key words : differential photometry—AGN—QSOs

1. Introduction

It has been long recognized that the optical intensities of many, if not all quasars vary significantly on time scales of months to years. But, in general, large variations are seen only in the case of radio-loud quasars (RLQs), particularly those emitting strong radio emission from the nuclear region of size < 1 pc. Recently it has been emphasized that the main difference between the spectral energy distributions of RLQs and the (far more common) radio quiet quasars (RQQs) is chiefly confined to the radio band (Antonucci 1993). The cause of this major difference is now believed to be the existence of a pair of relativistic jets ejected by RLQs. RQQs, somehow, fail to produce such jets.

It is now widely believed that the rapid radio as well as optical variability on timescales of > 1 month can be observed whenever a localized (shocked) region of increased emissivity forms and propagates down the relativistic jet, thereby appearing Doppler boosted to an observer. Those RLQs showing a pronounced variability in radio, optical and other wavebands are variously referred to as blazars or optically-violent-variables (OVVs).

2. Radio/optical micro-variability

During the past 3-4 years systematic monitoring programmes for RLQs have established a new phenomenon manifesting as flux variations to ~ 10% level at centimetre wavelengths on day-like time scales (e.g. Witzel 1990; Quirrenbach *et al.* 1991) and at the level of a few percent, or more, in the optical on hour-like time scales (e.g. Miller *et al.* 1992; Wagner 1992). Interestingly, the micro-variability has only been demonstrated for blazars and is, in fact, found to be fairly common for them. Although relativistic beaming of the shocked regions moving with the jets could again be invoked to explain the micro-variability, the bulk Lorentz factors required for the jets would be very large (~100, for the radio micro-variability). Another possible cause for the micro-variability is the occurrence of small swings in the jet direction, which are inferred from the parsec-scale resolution radio VLBI maps of the quasar cores (Gopal-Krishna & Wiita 1992; Camenzind & Krockenberger 1992).

3. Radio/optical micro-variability as a propagation effect

Conceivably, the micro-variability could even be externally imposed, when the relativistically propagating shocked region within the jet is gravitationally microlensed by compact object(s) located, say, within an intervening galaxy. This phenomenon of superluminal microlensing can also provide a fairly natural explanation for the observed (albeit, puzzling) preference for day-like timescales of the radio micro-variability (Gopal-Krishna & Subramanian 1991; Subramanian & Gopal-Krishna 1991).

An essential feature of all the mechanisms mentioned so far are relativistic jets. Essentially, this is also needed in the models incorporating plasma processes, both incoherent (Krishan & Wiita 1993) and coherent (Baker *et al.* 1988; Krishan & Wiita 1990).

4. A new type of model for the optical micro-variability

While the micro-variability is now known to be a common attribute of RLQs (specifically, blazars/OVVs), time scales as short as 1 hour have been demonstrated only at optical and UV wavelengths (Miller *et al.* 1992; Edelson *et al.* 1991). Unlike the radio emission, optical/UV/X-rays can even escape out of the vicinity of the central engine. This has led to a new type of interpretation for the optical/UV/X-ray micro-variability. In this new scheme, transient hot spots are postulated to occur on the accretion disk rotating around a supermassive black hole, which is now thought to reside at every quasar nucleus and power its activity. Such an explanations for the micro-variability (Wiita *et al.* 1991; Abramowicz *et al.* 1991; Zhang & Bao 1991; Chakrabarti & Wiita 1993) may offer a viable alternative to the above described models in which relativistic jets play the central role.

5. An observational test of the proposed major mechanisms

In order to conceive of a reliable observational test between the two competing classes of theoretical explanations (jet, or accretion-disk based), it may be recalled that the phenomenon of optical micro-variability has so far been well demonstrated only in the case of blazars (whose emission is dominated by relativistic jets). If significant optical fluctuations on hour-like time scale could also be detected in RQQs, for which there is no evidence for relativistic jets, then the model invoking hot spots on the accretion disk would be clearly supported. On the other hand, if a persistent search fails to detect such fluctuations in the RQQs, the jet-based models would be strongly favoured.

This straight-forward observational test employing RQQs was proposed and initiated recently (Gopal-Krishna, Wiita & Altieri 1993) and is now being carried out by us in an extensive manner at Kavalur using the 2.34m Vainu Bappu Telescope (Gopal-Krishna, Sagar & Wiita 1993).

6. The basic observational strategy

Our basic sample consists of ~20 apparently bright (V ~16 mag) as well as intrinsically luminous ($M_V < -26$ mag) quasars which are confirmed to be radio quiet down to the milli-Jansky level and are, moreover, surrounded by a minimum of 3 comparison stars having intensities and colours comparable to those of the RQQ. Thus, the CCD detector is used as a N-star photometer, so that any fluctuation of the RQQ would be treated as confirmed only provided it is found to occur relative to at least 2 or 3 comparison stars registered on the same CCD frame. This way, fluctuations down to ~ 2-3% level can be reliably detected.

7. The first results

Up to now, we have monitored 7 RQQs from our sample, in the V-band, each for a period ranging between 4 to 8 hours. Figure 1 shows the observed light curves for two of the monitored RQQs (Q1206+459 & Q1352+011); the intensities are in fact plotted relative to the comparison stars that were also being recorded simultaneously, within the CCD frame containing the RQQ. The details of the results are provided by Gopal-Krishna, Wiita & Altieri (1993) and Gopal-Krishna, Sagar & Wiita (1993). For both of these RQQs, low-amplitude intra-night variations may have been detected, but the significance level is < 2 sigma and therefore no positive detection can be claimed. A more dense time coverage (with

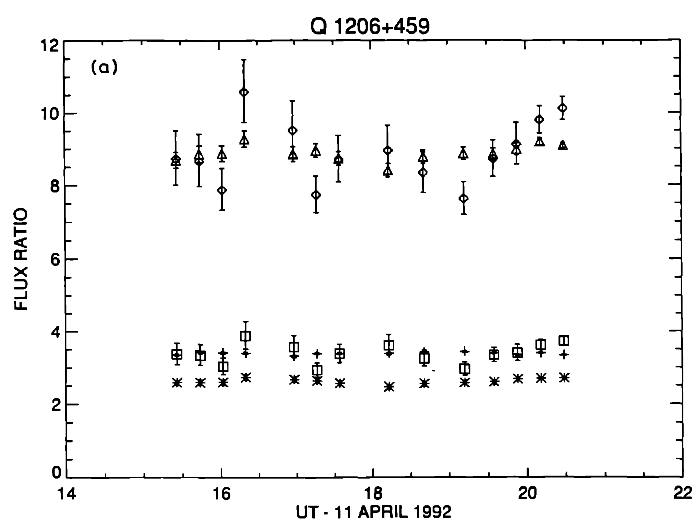

Figure 1(a). Flux ratios for Q1206+459 and three comparison stars, 1, 2 and 3. The symbols correspond to : $1/Q$ +; $Q/2$ *; $Q/3$ ◇; 1/2 Δ and 2/3 □. Note that the error bars are often significantly smaller than the size of the symbols. Also note that at some times the + symbols (and their associated tiny errors) lie within the □ symbols in this figure.

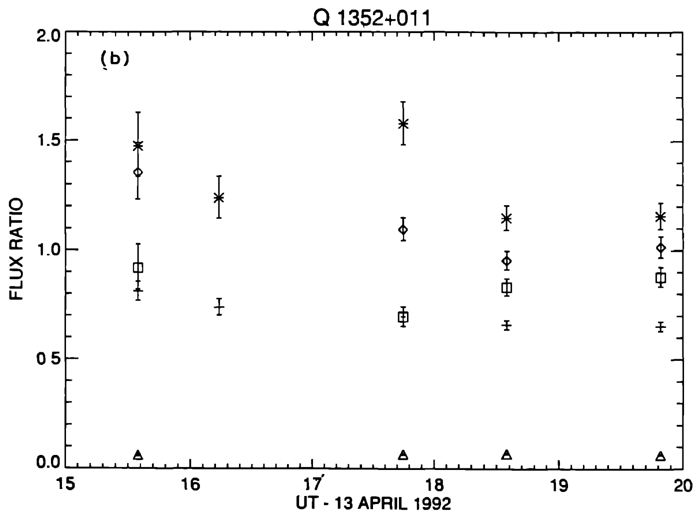

Figure 1(b) Flux ratios for Q1352+011 and three comparison stars, 1, 2 and 3. Symbols are : 10 × (*Q*/1) +; 2/*Q* *; *Q*/3 ◇; 3/1 Δ and 2/3 □.

a minimum of 2 data points/hour) would be needed and this will be the objective for our forthcoming observing runs at Kavalur. It is worth stressing here that the nature of this experiment is such that a null result is as interesting and physically meaningful as a positive detection of micro-variability.

8. Conclusions

Neither of the 7 RQQs monitored so far by us in the optical has shown a clear event of micro-variability. Thus, the observations up to this point provide no clear evidence in favour of the hot-spots-on-accretion disk model for the optical micro-variability. Nonetheless, even the hints of intra-night variations present in some of these observations of the RQQs reinforce the need to pursue these pioneering observations vigorously, as they offer a simple and fairly direct means of discriminating between the two main mechanisms proposed for the phenomenon of optical/UV/X-ray micro-variability.

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