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SHORT-TERM OPTICAL VARIABILITY IN BROAD ABSORPTION LINE QSOs

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ABSTRACT

We present the first results from a pilot program to monitor the short-term optical variability in broad absorption line system QSOs. Intranight optical variations of ∼5% were detected on timescales of ∼1 hr in QSOs 0846+156 and 0856+172. Further, the mean magnitude level decreased in the two objects by ∼0.05 and ∼0.15 mag, respectively, during the period of our observations. The observed light curves are quite similar to those previously seen in the flat-spectrum radio-loud sources, especially the BL Lacertae objects, and can provide important constraints for the origin of microvariability and also a possible evolutionary link between the radio-loud and the radio-quiet QSOs.

Subject headings: galaxies: photometry — quasars: absorption lines — quasars: general — quasars: individual (0846+156, 0856+172)

1. INTRODUCTION

Intraday flux variations are a well-known characteristic common to BL Lacertae objects, optically violently variable quasars, and flat-spectrum radio-loud quasars (Wagner & Witzel 1995). Theoretical explanations for these variations invoke relativistic shocks propagating down a jet and interacting with irregularities in the flow (Qian et al. 1991; Marscher, Gear, & Travis 1992), or numerous flares or hotspots on the surface of the accretion disk believed to surround the central engine (Mangalam & Wiita 1993). Rapid variations in radio-quiet quasars were not established until searches for optical intranight variabilities pioneered by Gopal-Krishna, Sagar, & Wiita (1993) in an effort to constrain both the models for the origin of the variability and also the nature of the nuclear energy source in AGNs. Clear detections of low-amplitude optical microvariability were reported for a sample of bright radio-quiet QSOs (Gopal-Krishna, Sagar, & Wiita 1995; Sagar, Gopal-Krishna, & Wiita 1996), favoring their origin in accretion disks around central massive black holes.

We have begun a complementary program to study the intranight optical variability in QSOs with broad absorption lines (BAL) to probe the influence of the BAL phenomena in the microvariabilty within the systems. Since the BAL systems belong primarily to the sample of radio-quiet QSOs, and form a minor subset of it, a similarity in their short-term light curves would reflect their origin from the same parent population. However, departures in their microvariability behavior from those of the parent population would be suggestive of a possible link to the BAL phenomena and its origin.

In this Letter we present the results of our monitoring study for two BAL QSOs 0846+156 and 0856+172 chosen for our pilot program, using the 2.3 m Vainu Bappu Telescope.

Section 2 presents the observations, and the results are described in § 3. Section 4 discusses our results.

2. OBSERVATIONS AND ANALYSIS

The BAL QSOs in the present study were chosen from the Hewitt & Burbidge (1987) catalog. The observations were carried out at the Vainu Bappu Observatory, Kavalur, using a Tek 1024 × 1024 CCD detector at the prime focus of the 2.3 m Vainu Bappu Telescope (VBT). Each CCD pixel corresponds to 0.6 × 0.6 arcsec^2, and the total sky area covered by the detector is about 10 × 10 arcmin^2. The EPADU for the system is 5.6, and the read noise is about 12 electrons.

We report here the observations of QSO 0846+156 (z = 2.928; V = 18.3) and QSO 0856+172 (z = 2.311; V = 19.0), observed on 1997 February 3 and 4. Both objects were observed in the V band. Several exposures, each of 600 s integration time, were obtained for both of the objects over a total period of ≥2 hr. The sky conditions were nonphotometric on both of the nights, and the seeing ∼ 2″–2.″5. The data were reduced using the IRAF software package. All frames were bias subtracted using a mean bias value. Flat-field correction was applied using a median twilight sky flat. Aperture photometry of all the stars in the field was performed using concentric apertures of diameter 4″, 6″, 8″, 12″, 14″, and 18″ centered on the object. Sky background was subtracted using values measured in an annulus of 3″ at a radius of 10″ from the center. Based on a growth curve for the brighter stars in the frame, the 14″ aperture was chosen. Differential magnitudes were obtained following the method of Howell, Mitchell, & Warnock (1988) and Howell (1992), choosing a bright star in the field as the comparison and a nearby check star with magnitude similar to that of the QSO. Because the QSO and the check star are faint, the magnitude measured from the 14″ aperture is severely affected by the background and read noise. Hence, we use the magnitude from the 4″ aperture, correcting for the photons from the source outside this aperture (up to 14″) using a correction factor estimated based on the brighter stars.

3. RESULTS

3.1. *0846+156*

This source was observed on 1997 February 3 for ∼2 hr, with a signal-to-noise ratio of 50–80. The differential magnitudes with respect to the comparison star (qso-c_1) are shown in Figure 1. Also shown in the figure are the differential magnitudes of the comparison star (c_1) and the check star (c_2). The scatter in the individual measurements shown in the figure was estimated following Howell et al. (1988) and Howell (1992). The QSO light curve reveals a variability that could be periodic. There also appears to be a gradual decline in the mean magnitude level, estimated as a mean line through the observed points, by about 0.05 mag. This trend is not seen in the light

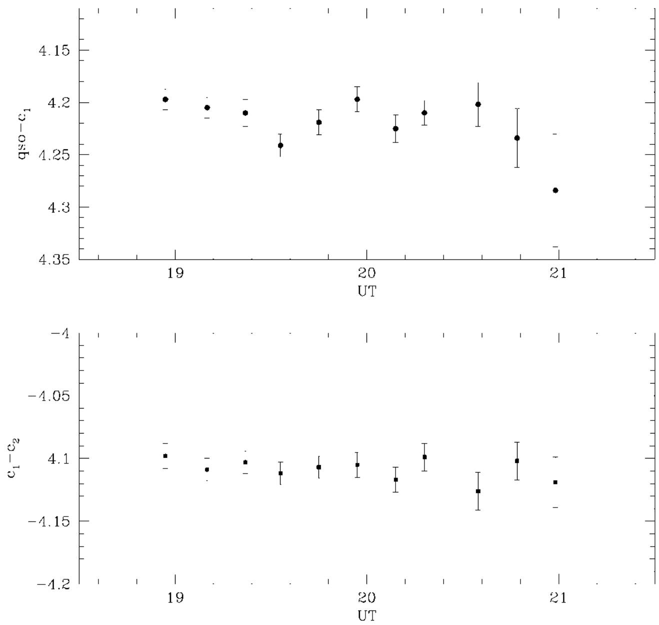

FIG. 1.—*Top*: *V*-band differential light curve for QSO 0846+156 with respect to comparison star (c_1). *Bottom*: Difference between the comparison star (c_1) and the check star (c_2).

curve of the check star, which shows an overall variation of ≤0.01 mag, similar to the scatter in the measurements. We have tested for intrinsic variability in the QSO following the statistical method of Howell et al. (1988) and find intrinsic variability in the source at a 95% confidence level.

3.2. *0856+172*

This source was observed on 1997 February 4, also for nearly 3 hr, with a signal-to-noise ratio of 30–50. In Figure 2 we plot the differential magnitudes, along with the scatter in the individual measurements. This source also reveals a nearly periodic variability with a period ≈40 minutes and a gradual decline in the mean level by 0.15 mag. There is a sudden dip in the light curve by 1 mag at UT 20.5. There is a slow drift in the (c_1-c_2) light curve by 0.04 mag, while no drastic change is seen at UT 20.5. The statistical test indicates intrinsic variability at a 95% confidence level.

4. DISCUSSION

Optical variability in BAL QSOs has been established on timescales of the order of years. In his review paper Turnshek (1988) notes that the optical variability of BAL QSOs differs

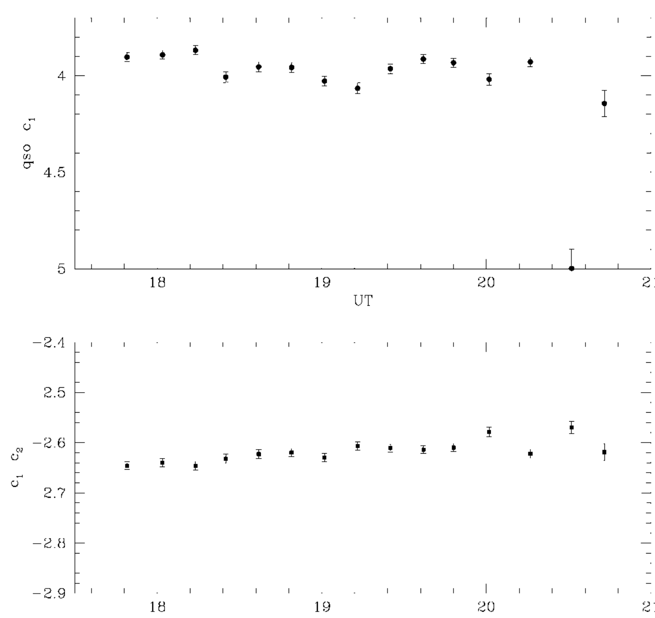

FIG. 2.—Same as Fig. 1, but for QSO 0856+172. *Top*: Note the 1 mag dip around UT 20.5.

markedly from that of the non-BAL radio-quiet sample. Furthermore, on these longer timescales, time variability has been observed in the strength of the BAL features (Turnshek 1988; Barlow et al. 1992; Hamann, Barlow, & Junkkarinen 1997) by as much as a factor of a few over timescales of ∼0.3 yr (Barlow et al. 1992; Hamann et al. 1997). Intranight variability has not been reported since the previous studies were more suited for detecting long-term variations. The observations reported here were specifically designed to look for the shorter timescale microvariability, limited only by the S/N consideration at the VBT.

Intranight variability is clearly detected in both of the BAL QSOs presented here. 0846+156 shows variability with a maximum peak-to-peak variation of 5%, which could be periodic, while 0856+172 shows periodic variability on a timescale of 40 minutes with a maximum peak-to-peak variation of 9%. Further, both objects show a gradual decline in their mean level by ∼0.05 and ∼0.15 mag, respectively, during the period of our observations (2–3 hr). The magnitudes of microvariability observed in these two objects are slightly more than reported for the non-BAL radio-quiet sample of Gopal-Krishna et al. (1995) and Sagar et al. (1996), which show variability of the order 3%–5%. The radio-quiet sample also does not show any gradual rise/decline of the magnitude levels as seen here.

The C IV BAL troughs fall within the *V* band in 0846+156, while they fall outside the *V* band in 0856+172, ruling out the possibility of the observed light-curve variations being caused by variations in the strength of the BAL features. This result is similar to the conclusion of Barlow et al. (1992), who found that the variation in the absorption equivalent widths in CSO 203 are not a result of the changes in the broadband fluxes that are ≤10%. The light-curve variations observed in the two objects presented here are continuum variations, as in the case of both the radio-quiet and the radio-loud objects.

The observed variability may be directly linked with the BAL phenomena, or the choice of the BAL QSO sample produces a selection of objects more conducive for time variability studies. In the former case, in which the variability is caused by the BAL phenomena, it is unclear how the absorbing clouds typically at a distance of ∼1 pc from the central continuum source could produce variability on such a short timescale. Neither a smoothly flowing BAL wind (Hamann, Korista, & Morris 1993) or clumpy BAL clouds (Turnshek 1988) or stellar contrails from evolved stars in the nucleus (Scoville & Norman 1995) can easily account for the observed microvariability. A more likely possibility appears to be that the intrinsic optical microvariability in the BAL and the non-BAL radio-quiet QSOs is of the same origin, but their observability is more optimized in the case of the BAL systems. Such a scenario would, in principle, arise if the BAL clouds participate in supersonic outflows from the polar regions of a black hole plus accretion disk system and are closely aligned to the line of sight to the observer. In such a case, the disk and all the associated variability phenomena on its surface, such as flares, hot spots, etc., would be seen face on. Thus the BALs select the most advantageous orientation for viewing the variability phenomena and can explain the observed difference in the microvariability with respect to the parent radio-quiet population as an "orientation effect."

A most intriguing aspect of the present study appears to be the similarity in the observed light curves with those of the BL Lacertae objects (Miller & Carini 1991; Wagner et al. 1991; Carini 1991; Wagner & Witzel 1995), which are flat-spectrum radio-loud sources. The BL Lac objects show a similar decline in the mean light curve, with a suggestion of microvariability similar to those observed here for the BAL QSOs. For example, in the data presented by Carini (1991), OJ 287 faded in brightness by ∼0.08 mag in ∼3.7 hr on one occasion, in addition to rapid variability. In addition to rapid variations, decline in the magnitude by ∼0.1 mag has been detected in both BL Lac and OQ 530 (Miller & Carini 1991). Recently Becker et al. (1997) have detected a flat-spectrum radio-loud BAL QSO along with two other low-ionization BAL quasars from a radio-selected quasar sample. The studies of the properties of the three objects suggest a trend of increasing radio luminosity with the amount of absorption to the quasar, leading them to suggest their objects could be transition objects evolving from radio-loud to radio-quiet BAL systems as the QSO emerges from an enshrouding material. These findings seem to favor the orientation effect as an explanation for the observed differences in the light curves of the BAL QSOs and non-BAL QSOs.

The detection of microvariability in radio-quiet non-BAL QSOs and the detection of flat-spectrum radio-loud BAL QSOs, together with the results presented here, open the possibility that the BAL QSO systems are a direct link between the radio-loud BL Lac objects and the radio-quiet QSO samples.

Krishan & Wiita (1994) have considered detailed physics of a variety of plasma mechanisms that could give rise to variability in AGNs from timescales of hours to years. These fall broadly under MHD fluctuations, flares, and plasma-modulated electromagnetic wave instabilities. Of these, the last class appears to be best suited to describe the short-timescale variations seen here.

More observations of a larger sample are required to be able to detect similarities/dissimilarities among the different class of objects and also ascertain the nature of the observed microvariabilities.

5. SUMMARY

We present the first results from a pilot program to monitor the short-term optical variability in BAL QSO systems. Intranight optical variations of ∼5%–9% were detected on timescales of ∼1 hr in QSOs 0846+156 and 0856+172. Further, the mean magnitude level decreased in the two objects by ∼0.05 and ∼0.15 mag, respectively, during the period of our observations. The observed light curves are quite similar to those previously seen in the flat-spectrum radio-loud sources, especially the BL Lacertae objects. QSO 0856+172 showed a sudden dip in the light curve by ∼1 mag.

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