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V-BAND OBSERVATIONS OF V4641 SAGITTARII

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In this note we report high time resolution V Johnson photometry of the microquasar V4641 Sgr (SAX J1819.3–2525 = XTE J1819–254). This source was discovered as an X-ray transient by BeppoSAX and RossiXTE satellites (In't Zand et al. 1999; Markwardt et al. 1999). On 1999 September, a very fast transient optical and X-ray outburst was observed, reaching up to $V \simeq 8\overset{\mathrm{m}}{.}8$ and 12 Crab units (Stubbings 1999; Smith et al. 1999). Rapid X-ray variability, by a factor of 4 on time scales of minutes, was observed at the time of the outburst (Wijnands & van der Klis 2000). Collimated radio ejecta were also detected on this occasion with possible superluminal velocities (Hjellming et al. 2000). All this evidence suggests the presence of a compact object, most probably a black hole. The spectral type of the mass donor and its distance have been estimated from optical observations as A2V and $D = 6100$ pc, respectively (Orosz et al. 2000). This distance value is significantly far away than the nearby ~ 0.5 kpc independently obtained from the radio data (Hjellming et al. 2000), based on the inferred proper motion of the ejecta and other assumptions. Recent photometric and spectroscopic work by Chaty et al. (2001a,b) give support to the optical estimates, with these basic parameters being constrained to be most likely B3-A2 V and $4 < D < 8$ kpc. If the high distance values are correct, V4641 Sgr should be considered a High Mass X-ray Binary (HMXRB) microquasar instead of a low mass system.

The previous optical photometric observations indicated variability on time scales of days and months (see e.g. Kato et al. 1999). The present note is mainly an attempt to explore the V4641 Sgr variability on much shorter time scales, i.e. from a few minutes to a few hours.

Our differential photometry observations were obtained with the 1.23-m telescope of the Centro Astronómico Hispano Alemán (CAHA) observatory, in Almería (Spain). We observed on three nights during the period 23–29 June 2000. Several filters were used, but only the V-band observations with wider time coverage are discussed here. The total number of V-band CCD frames processed was 117. The exposure times were of 30 s, with a readout time of 30 s since we used only a small part of the SITe#2b-17 chip. Only three suitable comparison stars could be found in the CCD frame being non-saturated, isolated enough and with brightness similar to the target source. We finally selected two of them whose magnitude differences remained well constant mostly within $\pm 0\overset{\mathrm{m}}{.}012$, $\pm 0\overset{\mathrm{m}}{.}020$, and

Table 1: V-band observations of V4641 Sgr

Julian Day	V	N_V
2451719.525	14.0	18
2451719.569	14.0	
2451723.475	14.0	25
2451723.571	14.0	
2451724.423	13.8	74
2451724.574	13.9	

$\pm0\overset{m}{.}015$, for the nights 23/24, 27/28, and 28/29 June, respectively. These differences are plotted in Fig. 1 and they are indicative of the quality of the different nights for differential photometry at the high air mass of the source.

Since we devoted most of our telescope time to V4641 Sgr, only one or two standard stars from the list of Landolt (1992) could be observed each night. Approximate photometric zero points were thus estimated using average extinction coefficients suitable for the CAHA site. In this way we derived V magnitudes for the comparison stars in the field, that we adopted in order to express the differential photometric results in an absolute scale. The absolute calibration achieved is believed to be accurate at the $\pm0\overset{m}{.}1$ level. This procedure is useful to provide an idea of the source real brightness and, of course, it does not change the relative variations seen in the data. In Table 1, the resulting Johnson V magnitudes (rounded to $0\overset{m}{.}1$) are given for the beginning and the end of the night, and the N_V value refers to the number of exposures obtained for the corresponding night.

The brightness of V4641 Sgr during our run was in the range $V = 13.8$–14.0, i.e., considerably fainter than the values reported during the 1999 September outburst (Stubbings 1999). Our magnitudes are close to the faintest observed in the last year (see Kato et al. 1999; Chaty et al. 2001a,b).

In the X-ray domain, the quick-look results provided by the ASM/RXTE team indicated very low X-ray activity during the time of our Calar Alto observations, with the source being practically undetected at their beginning. Only on JD 2451723, the ASM flux increased to ~ 4 counts s^{-1}, thus suggesting a moderate enhancement of X-ray activity. Unfortunately, there is no ASM data for the last night of the CAHA run.

We attempted to search for variability over time scales of minutes to hours. The shortest time resolution achieved in our runs was about 1.5 minutes (100 s) and the observed behaviour of the source is presented in Fig. 2.

We did not detect variability, with amplitude higher than $0\overset{m}{.}02$, on the shortest (few minute) time scales. In contrast, variability is certainly present on time scales of hours. In the lower panel, a brightness decrease of about $0\overset{m}{.}1$ during 3.5 h is clearly visible. During this interval, the differences between the comparison stars remained constant practically within $\pm0\overset{m}{.}015$ (see Fig. 1). Therefore, the observed trend is fully reliable. A similar behaviour is also present in simultaneous I band data not included in this paper. Weak traces of a similar hour variability can be seen as well in the first night (upper panel in Fig. 2).

The other two HMXRB microquasars well observed at optical wavelengths are Cyg X-1 and SS 433. Cyg X-1 shows an ellipsoidal modulation in its light curve with amplitude $\Delta V = 0\overset{m}{.}04$, with a difference only of $0\overset{m}{.}02$ between the high and low X-ray states (Brocksopp et al. 1999; Karitskaya & Goranskij 1996). In contrast, SS 433 shows different classes

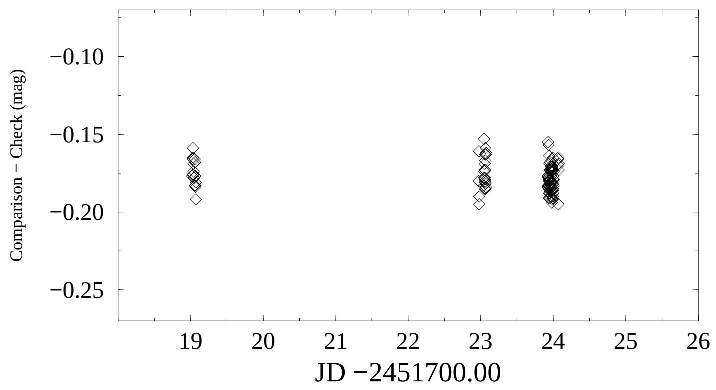

Figure 1. V magnitude differences between comparison and check star in the V4641 Sgr frames for the three different nights of observation

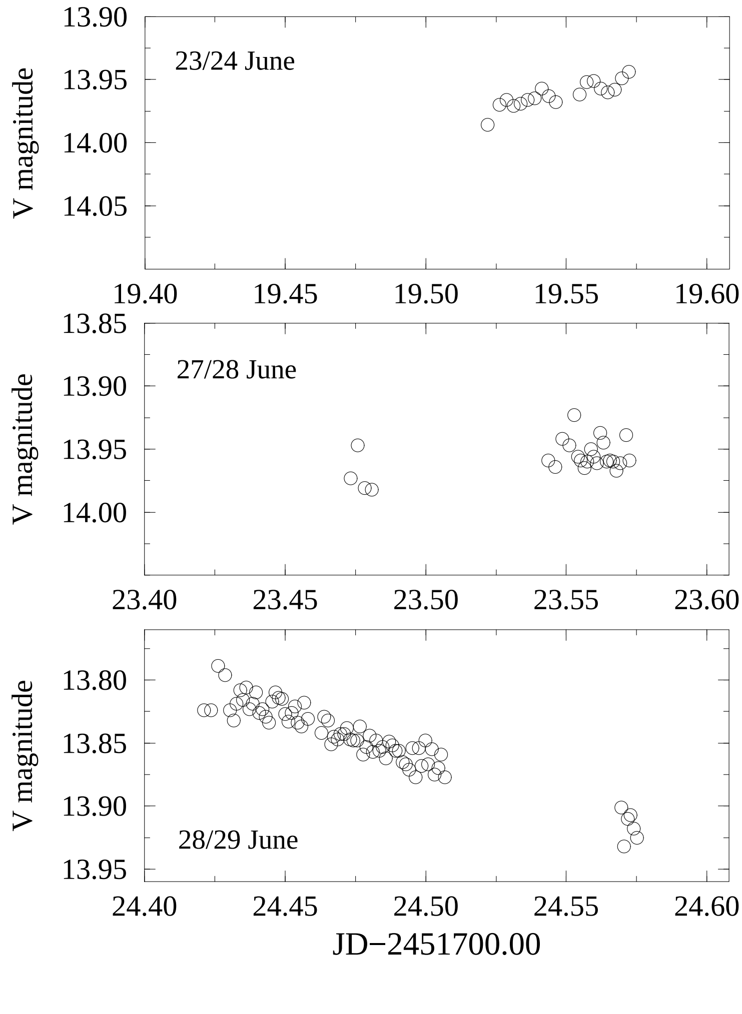

Figure 2. The Johnson V band observations of V4641 Sgr during June 2000. Short term variability, on time scale of minutes, is not visible. However, we do see during the last night a decrease in brightness of $\sim 0\overset{m}{.}1$ over a time scale of about 3 hours. A similar variability probably occurred during the first night too. In all these three panels, the Y axis interval corresponds to $0\overset{m}{.}25$, and the X axis size expands over 5 hours (= 0.208 days)

of optical variability identified by their corresponding time scales $\Delta\tau$ (see e.g. Zwitter et al. 1991): class (a) with $\Delta\tau > 6$ h; class (b) with $\Delta\tau \approx 1$ h; class (c) with $\Delta\tau \approx 10$ min. For classes (b) and (c), the amplitude does not exceed typically $0\overset{\mathrm{m}}{.}1$. The detected variations of V4641 Sgr are reminiscent, both in time scale and amplitude, of the SS 433 class (b) variability, which according to Zwitter et al. (1991) should be interpreted as originating in an extended corona surrounding the jets. However, with the present observations we cannot rule out alternative possibilities for the observed trend, such as being part of an ellipsoidal modulation or due to orbital and precessional motion (class a). The ellipsoidal modulation possibility is certainly a serious explanation to be considered, specially taking into account the evidence pointed out by Orosz et al. (2000) based on photographic archive data.

On the other hand, class (c) variability in SS 433 is probably connected with the jets. The fact that we do not see this kind of short term variations in V4641 Sgr is consistent with the radio quiet state of the source during the CAHA run. Although simultaneous radio monitoring from the Green Bank Interferometer (GBI) is not available, the GBI flux densities at cm wavelengths two months before our observations were already consistent with zero.

In any case, further extended photometric monitoring of V4641 Sgr would be advisable to better constrain the physical properties of this new microquasar not yet well studied.

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