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Optical photometry of the low mass X-ray binary V404 Cyg during ourburst

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Abstract: We report on the early optical follow-up of the system using the 0.40 m f/8 robotic telescope at the University of Athens. We present the R-band light-curve (LC) for the period MJD 57189.29-57199.60 and the preliminary results of optical timing analysis. Additionally, we perform correlation tests for simultaneous X-ray and optical observations of the system.

1 Introduction

V404 Cyg is a black hole LMXB (for a review on LMXB, see *Fender & Belloni, 2012, Science, 337, 540*) that has been first detected in X-rays during the outburst of 1989 (*Makino, 1989, IAU Circ., 7482*). Since then it remained in quiescence, until June 15 18:32 UT, when the *Swift*/BAT triggered due to the strong X-ray activity of V404 Cyg (Barthelmy et al. GCN #17929. This marked the onset of a new outburst. Here, we present results of the optical photometry of V404 Cyg that started a few hours after the *Swift*/BAt trigger (MJD 57189.2907) and stopped at MJD-57199.60. We also discuss the results of a preliminary timing analysis that we performed on the R-band light curve (LC).

2 Results

R-band and X-ray light curves: Figure 1 (left panel) shows the R-band light curve for the period MJD 57189.2907-57199.60. Various vertical lines are over-plotted marking the dates where radio and mm observations were performed. A zoom in the individual nights of optical observations are presented the middle and right panels of Fig. 1. On June, 24 the R-band flux remains approximately constant at ~ 60 mJy and shows short-time, low-amplitude variability; similar to X-ray flickering. On June 25, 2015 the optical light curve is strongly variable. It exhibits large amplitude flares with $\Delta m \sim 1 - 1.5$. Short-time variability is also present, but it shuts down during the decay phase of large optical flares (this behaviour has been also reported by Hynes et al. #ATel 7767). The striking difference in the temporal behaviour may be associated with differences in the production site or/and emission mechanism. Simultaneous (over a ~ 2 ks interval) optical and X-ray light curves are presented in the left and middle panels of Fig. 2. The data are strongly correlated; see right panel in Fig. 2. The results of a Spearman's correlation test are summarized in the figure caption.
Timing analysis: Figure 3 summarizes the results of a preliminary timing analysis of the optical data. We find no indications of a single periodicity when using the full R-band light curve. Yet, many individual peaks are detected on the periodogram. During smaller time intervals, varying from hours to days, periodic behavior was detected. For example the second day of the outburst a $\sim$1.68 hour periodic modulation was detected (ATEL #7650).
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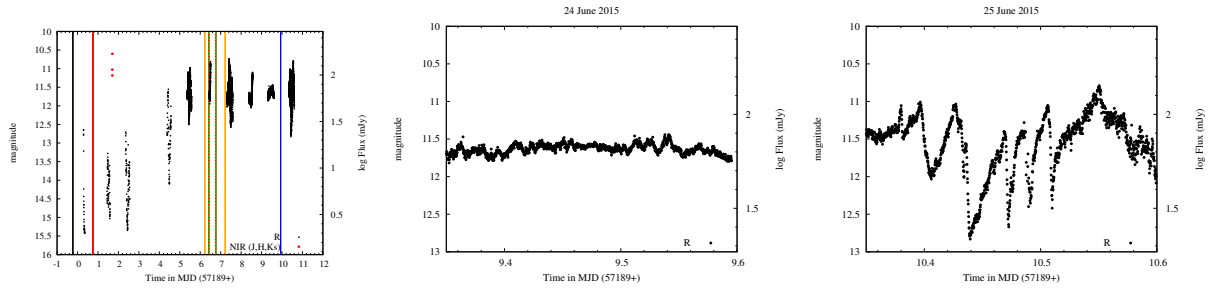

Figure 1: **Left panel:** R-band light curve (black points). The coloured vertical lines denote times of radio and mm observations with: SMA (red solid) at 230 GHz (ATels #7661, #7708), Waseda University Nasu radio telescope (orange solid) at 1.4 GHz (ATel #7701), VLA (dashed green) at 5.25 GHz, 7.45 GHz, 20.8 GHz and 25.9 GHz (ATel #7708), and RATAN-600 (solid blue) at 2.3, 4.6, 8.2, 11.2 and 21.7 GHz (ATel #7716). The black vertical line marks the trigger-time of Swift/BAT (GCN #17929). NIR measurements at filters J, H and Ks are also overplotted (data taken from Garner et al. ATel #7663). **Middle and right panels:** R-band light curves obtained in two successive nights (June 24 and 25 2015).

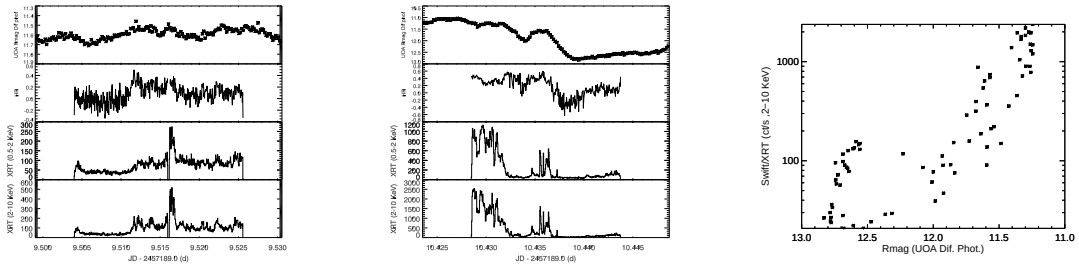

Figure 2: **Left and middle panels:** Simultaneous R-band (top sub-panel) and Swift/XRT X-ray light curves at (0.5-2) keV (third panel) and (2-10) keV (fourth sub-panel), for the ninth and the tenth day of the outburst. The hardness ratio defined as $(C_{i+1} - C_i)/(C_{i+1} + C_i)$ where C_i is the count rate in two consecutive energy bands. Simultaneous observations span over a periods between 500 and 2000 s. **Right panel:** A preliminary analysis shows a significant correlation between the optical and X-ray bands. The Spearman's correlation coefficient is $\rho = 0.85$, and the probability of a correlation by chance is less than 10^{-24}.

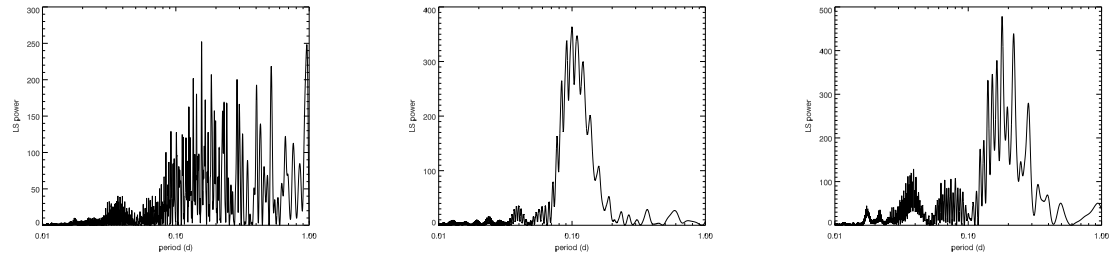

Figure 3: Lomb-Scargle periodograms for the full R-band light curve (left panel) and for two time intervals, i.e. MJD 57193.5-57195.5 (middle panel) and 57197.5-57199.5 (right panel).