Astrophysics with a 12-inch telescope: Observations of V404 Cygni During its 2015 Outburst Suggest a Highly Energetic Jet-base

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1. Introduction

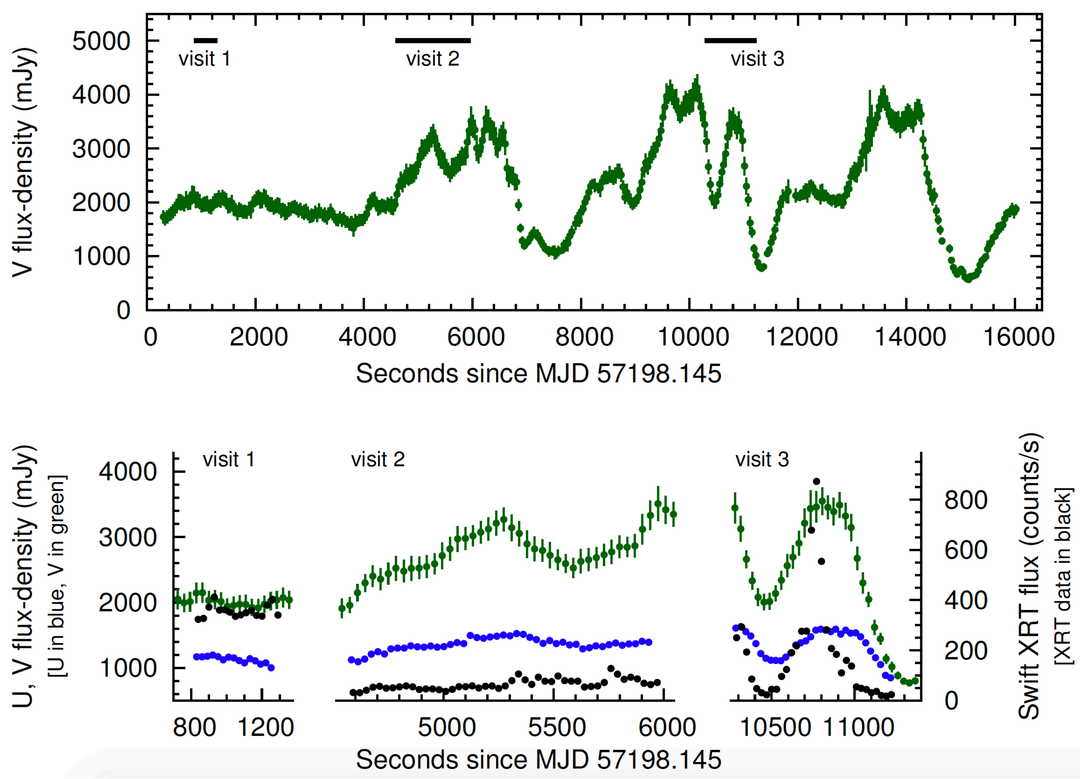
We present results of V-, R_C-, and I_C-band optical photometry of the black hole X-ray binary system V404 Cygni obtained using Wheaton College Observatory's (WCO) 0.3m telescope, along with strictly simultaneous INTEGRAL and Swift observations, on 2015 June 25 and June 27. These observations were made when V404 Cygni was going through an epoch of violent activity in all wavelengths ranging from radio to gamma-rays.

2. Observations

- **Equipment:** 12" SCT + SBIG STT-8300M @ -20C, with Johnson-Cousins V, R_C, I_c filters.
- **Observers:**
  - John Scarpaci (class of 2018) & DM.
  - Nightlong imaging + often using a hair-dryer to get rid of condensation on the scope from time to time!

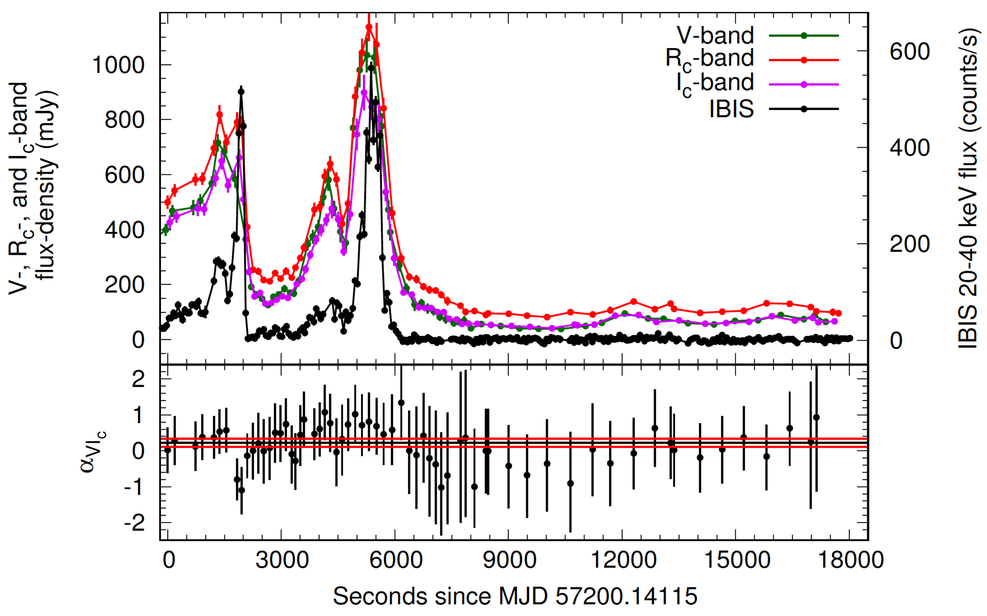

John Scarpaci taking sky flats on 2015 June 25.

3. Results from First Night (2015 June 25)



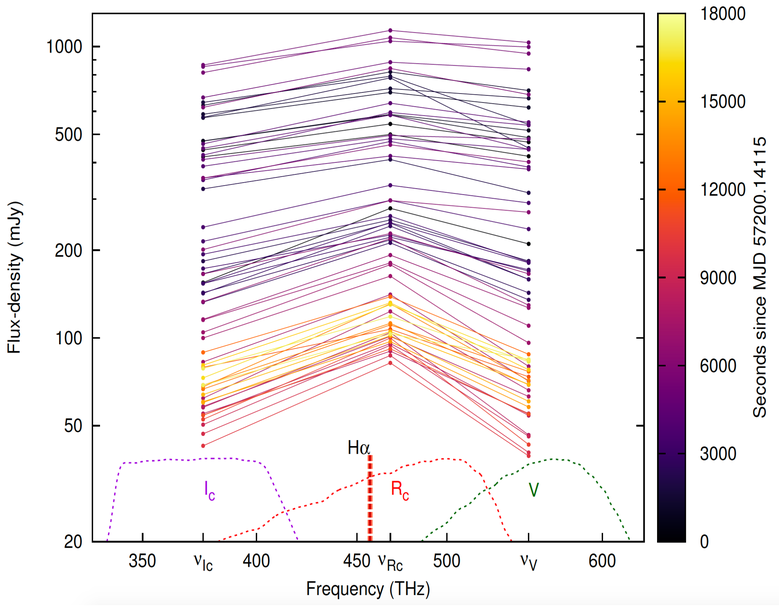
Dereddened V-band light curve obtained by the WCO 0.3m telescope on MJD 57198 (June 25) is shown in green in both the top and bottom panels. V-band flux variations of ~9x in less than 15 minutes were observed. While the top panel shows the V-band light curve for the entire night, the bottom 3 subpanels zoom in to show the Swift/UVOT U-band (in blue) and Swift/XRT (in black) light curves as well. Timing analysis shows no detectable lead or lag between any of these light curves.

4. Results from Second Night (2015 June 27)



Top panel: Dereddened, interloper-subtracted V-band (green), R_C-band (red), and I_C-band (purple) light curves obtained on MJD 57200. The INTEGRAL/IBIS 20–40 keV hard X-ray light curve is shown in black. Note the remarkable similarity in the morphology of the optical and the hard X-ray light curves. The simultaneous INTEGRAL/IBIS 20--40 keV hard X-ray light curve correlates very strongly with the optical light curve, with no detectable delay between the optical bands as well as between the optical and hard X-rays. *Bottom panel:* Evolution of the power law slope V-I_C connecting V- and I_C-bands. There is no significant spectral evolution between the V and I_C bands. The best-fit value of V-I_C spectral slope is 0.22±0.11, and is indicated by the solid black line and the red dotted lines flanking it. In a jet scenario this would imply that the optically-thick to optically-thin break is at frequencies higher than that of the V-band.

5. Evolution of the SED during the second night



The location of rest frame Hα emission as well as the V, R_C, and I_C filter transmission curves are shown near the bottom by dashed lines in this figure.

This log-log plot clearly shows that the optical SED during highest overall fluxes is quite flat whereas at low overall brightnesses of V404 Cyg the V and I_C fluxes drop significantly more than the R_C flux, creating a peak in the SED near the R_C-band.

This excess in the R_C-band, especially prominent at low brightness, is most likely due to Hα emission from a quasi-spherical nebula surrounding the source (Munoz-Darias+2016, Rahoui+2017).

6. Conclusions

- The multiwavelength variability timescale favors a compact emission region, most likely originating in a jet outflow.
- The slope of the dereddened spectral energy distribution was roughly flat between the V- and I_C-bands even though both the optical and the X-ray flux varied by >25x during the run, ruling out an irradiation origin and favoring a jet origin for the observed optical emission.
- Our observations further suggest that the optically-thick to optically-thin jet synchrotron break was at a frequency larger than that of the V-band, which is quite extreme for X-ray binaries.
- We conclude that the optical emission originated very close to the base of the jet. Our data, in conjunction with contemporaneous data at other wavelengths presented by other groups, strongly suggest that the jet-base was extremely compact and energetic during this phase of the outburst.

References

- **Scarpaci & Maitra, 2015, ATel, 7721.**
- **Scarpaci et al., 2015, ATel, 7737.**
- **Munoz-Darias et al., 2016, Nature, 534, 75.**
- **Rahoui et al., 2017, MNRAS, 465, 4468.**
- **Maitra et al., 2017, ApJ, 851, 148.**

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