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V-Band Photometry in V404 Cygni

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Abstract

Here I present the results of my photometry on the V-band emissions of the low-mass X-Ray binary system V404 Cygni using the Las Cumbres Observatory Global Telescope Network 1m instrument in Texas during the Summer 2015 outburst. This was done to attempt to ascertain whether the system had returned to quiescence or not at the time of observation.

Introduction

A binary system of stars consists of two stars orbiting around their common centre of mass. There are many different types of binary systems, one of which is the low mass X-ray binary system. The two stars this contains are an accretor, which grows by accumulating matter (a black hole candidate or neutron star), and a donor star (a low-mass late type star – late type stars are cooler than our Sun). Periodic outbursts of X-rays occur as mass is transferred from the donor to the accretor.

V404 Cygni, a low mass X-ray binary system in the constellation Cygnus, was first observed going into outburst in 1938[1], and has since gone into outburst at least three more times. The other confirmed outbursts occurred in 1956[2] , 1989[3] and most recently June 2015. This system is also known as a nova because of these outbursts, as well as being considered a soft X-ray transient due to the short X-ray bursts it emits. The black hole candidate in V404 Cygni has an estimated mass of ~10-15 times that of the Sun while its donor star is thought to be about two-thirds the mass of the Sun[4].

On June 15 2015 the Swift satellite, operated by NASA, detected activity in the area of V404 Cygni[5] and on June 17 the ESA INTEGRAL gamma-ray observatory started making observations[6]. Observers worldwide monitored the system in all wavelengths of light[7], including optical (visible light). Using the McDonald Telescope, located in the McDonald Observatory in Texas, I made observations of V404 Cygni and used differential photometry, a process of comparing the brightness of a particular object to others in the same image, to measure its magnitude. This allowed me to compare the magnitude of V404 Cygni at that time to the quiescent average magnitude (its average magnitude when not in outburst). I used the difference between those values to infer what state the system was in at the time of measurement.

Method

The data presented here were obtained using the McDonald 1m Telescope. On August 12, I took five exposures of 60 seconds duration using the Bessel-V filter on the SciCam Spectral instrument fitted with a Fairchild CCD-486. The featured image is a greyscale composite image comprised of my five 60 second exposures. Other exposures of 10, 20 and 45 seconds duration were taken – however, the other exposures were too short to be of any scientific value.

I also attempted to take exposures with the Faulkes Telescope North, a remote-controlled 2m f/10 Ritchey-Chrétien telescope based at the Haleakala Observatory in Hawaii, on July 15, 16 and 29 and August 11. However, automated overrides and poor weather prevented the intended exposures being taken. Both the McDonald Telescope and the Faulkes Telescope North are owned and operated by the Las Cumbres Observatory Global Telescope Network (LCOGTN). My observing time was allocated to me by the Faulkes Telescope Project, a UK-based charitable foundation supporting enquiry-based science education in second-level schools and an educational partner of LCOGTN.

The five 60 second exposures were combined using the imcomb tool in the IRAF (Image Reduction and Analysis Facility) software system to form a 300-second exposure of V404 Cygni. This collated image was then reduced using standard APT (Aperture Photometry Tool) routines and an instrumental magnitude for V404 Cygni was obtained. In order to save observing time, I checked to see whether the stars in the field surrounding V404 Cygni had been previously calibrated during the 1989 outburst, which would allow me to record a magnitude for V404 Cygni using previously established photometric standards. I found that sufficient stars had been suitably measured[8] prior to my observations, which meant I didn't have to perform additional measurements myself, saving time. The specific stars I used were the C1 and C4 stars referred to by Udalski and Kaluzny.

Results

I used the calibrated stars in the field surrounding V404 Cygni in order to correct the instrumental magnitude recorded during my observations (instrumental magnitude varies according to the equipment used for observation). I found a difference in the magnitude of V404 Cygni in the V-band (a band of visible light with a mean wavelength of 540nm). I found the corrected magnitude of V404 Cygni to be 17.24, with the usual quiescent magnitude in the V-Band ranging between 18.3-18.4[9].

Analysis

From the data presented above, there is evidence to suggest that V404 Cygni had not yet reached total quiescence at the time of my observations. However, there is a noticeable decline in magnitude from the maximum values recorded during the peak of the outbursts, 12.1[10]. The most obvious thing to note here is that my observations were quite limited in scope due to restrictions on observation time and therefore they were not as comprehensive as I would have liked. My other exposures were too short as I had no precedent with which to estimate appropriate exposure values. The unavailability of the Faulkes Telescope North due to unforeseen circumstances compounded the issue. My observations were also limited to only one band of the optical spectrum. The variation in magnitude observed is consistent with continuing activity in V404 Cygni on the scale of 300 second intervals. Although my data were limited, the difference of over one magnitude suggests that V404 Cygni had yet to return to total quiescence at the time of measurement.

Conclusions and Further Work

Further observations would have been needed to confirm that the increased magnitude observed was indeed an indicator of persisting outburst activity in V404 Cygni. Exposures of different durations would reveal variations on other short time-scales. Exposures in other bands would also help to provide further proof over the optical range. From the limited observations I have conducted, there is evidence to suggest that V404 Cygni had not reached total quiescence at the time of my observations. This finding was also corroborated by the findings of University College Dublin[11] at the Irish National Astronomy Meeting 2015 where I discussed my results with Prof. Hanlon.

This work was presented in poster format at the Irish National Astronomy Meeting 2015 and the Young Scientists Journal 2015 conference, where it was awarded 3rd place overall.

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