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THE 1989 OUTBURST OF V404 CYGNI: A VERY UNUSUAL X-RAY NOVA

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ABSTRACT

On May 22, 1989 the Japanese Ginga Team discovered a new X-ray source that was cataloged as GS 2023+338. This source was subsequently identified as coincident in position with a previously known nova cataloged as V404 Cygni. Its last recorded outburst was in 1938 when it rose to about 12th mag. Spectroscopic data were obtained and confirmed the nature of the outburst Additional ground based data were obtained by us at CTIO and the VLA. The X-ray behavior of this object has been reported to be very unusual and it reached a peak of about 17 crab about one week after discovery. Since then it has varied widely in magnitude at all wavelengths at which it has been studied. We present a brief summary of the observations that have been obtained up to the time of the meeting and shortly thereafter.

INTRODUCTION

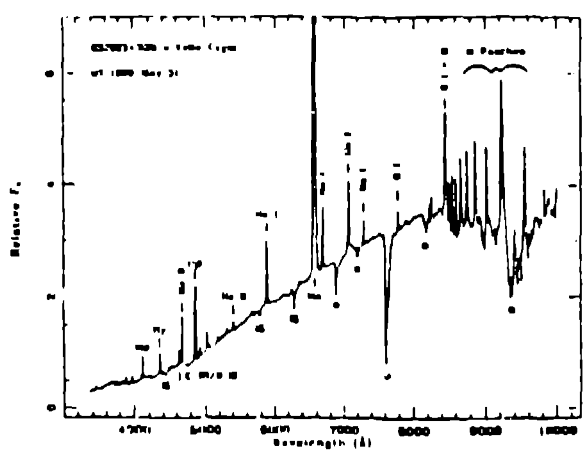
Low mass X-ray binaries (LMXRB) are cataclysmic variables in which the compact object is either a neutron star or a black hole. One of the principal differences between these objects and other classes of cataclysmic variables is that they emit a significant fraction of their radiative energy at X-ray wavelengths rather than in the UV or optical. Reviews of the properties of these objects can be found in Bradt and McClintock (1983) and Mason (1988) and references therein. Many of these objects show steady emission at X-ray wavelengths while others show transient X-ray outbursts and have been called X-ray Novae. One such outburst, A0620-00 or V616 Mon, occurred in 1975 and lasted for more than 9 months. This system was recently shown to contain a black hole by McClintock and Remillard (1986). In addition to the X-ray outburst, this object was also found to show an optical brightening which confirmed the detection of the source. There have been other X-ray novae since that time but not all of them have occurred in LMXRB's.

Just as for classical novae, the discovery of another X-ray nova can be an exciting event as one observes the outburst and identifies the optical counterpart. Once an optical identification has been made, observations can proceed in other regions of the spectrum such as UV, IR, and radio. All of the data that one gathers on such an outburst can provide information on gas-dynamics under some of the most extreme conditions observable in astronomy. Many of these systems exhibit features characteristic of accretion disks, gas flows, strong magnetic fields, and nuclear burning.

Therefore, when it was announced that the **Ginga** all-sky monitor had discovered a bright transient X-ray source (Makino *et al.* 1989 IAUC No. 4782), there was an immediate attempt by some of us to identify the optical object. Unfortunately, as was discovered later, the position of the object actually lay outside the initial X-ray error box. However, Marsden noticed that there was an object listed in Duerbeck (1987) that lay very close to the boundary and Wagner, Starrfield, and Cassatella (1989, IAUC 4783) were able to confirm that this was, indeed, the object. One of the more interesting facets of the discovery was that most of the real-time communications between the above investigators were done by using the SPAN network as the observations were being performed. In addition, the discovery that V404 Cyg had brightened was done, photometrically, with the FES detector on the IUE Satellite at VILSPA. Confirmation spectra were obtained at the Perkins 1.8-m Telescope of the Ohio Wesleyan and Ohio State Universities at the Lowell Observatory. It was a truly transatlantic and transpacific discovery. In the next section we describe the initial observations and in Section III we present a discussion and summary.

OBSERVATIONS

After the original X-ray discovery by **GINGA** and the optical spectroscopic and photometric confirmation that V404 Cyg was the object in outburst (see above), it was monitored for the next few weeks in all of the available wavelength regimes from γ-rays to radio. The spectroscopic data obtained on May 27.4 showed a very reddened continuum with superposed emission lines (Figure 1). Other characteristics of this X-ray nova in outburst were strong emission from both the Balmer and Paschen series



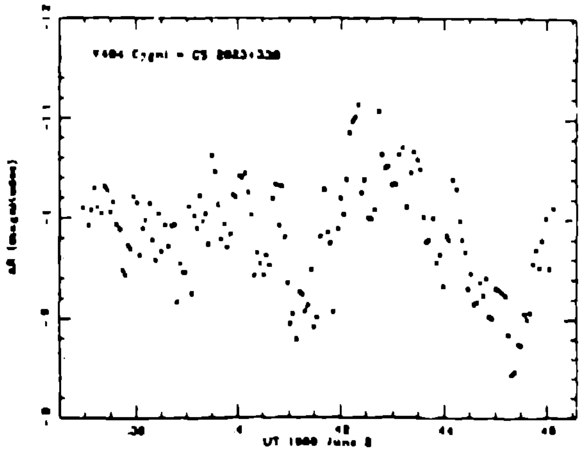
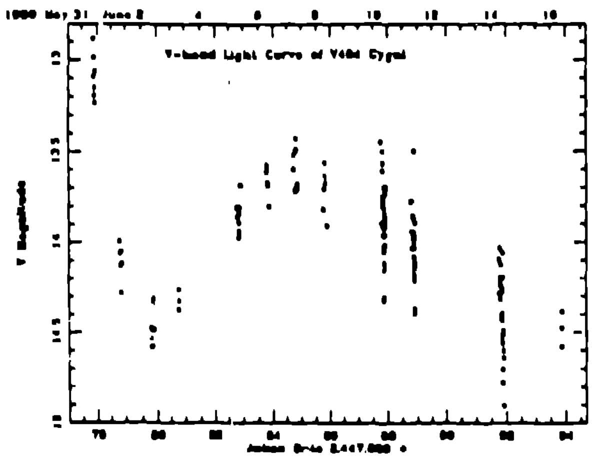


Figure 1 - Optical spectrum of V404 Cyg obtained by R.M. Wagner on UT 1989 May 31 at the Perkins 1.8-m Telescope using Ohio State University CCD Spectrograph. The spectrum is dominated by strong hydrogen and helium emission lines superposed on a reddened continuum.

Figure 2 - Light curve of V404 Cyg obtained by T.J. Kreidl and S.B. Howell on UT 1989 June 2 at the Perkins Telescope using the Lowell Observatory direct imaging RCA CCD camera. Note the strong flickering on time scales of minutes or shorter



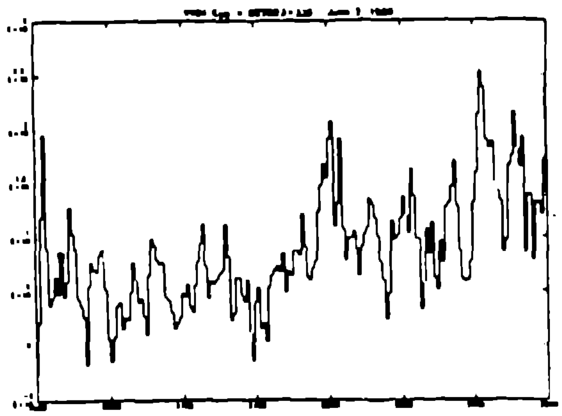


Figure 3 - V-band light curve of V404 Cyg from late May through mid-June recorded by R. Fried using a computer controlled 0.4-m telescope and photoelectric photometry system.

Figure 4 -Optimally extracted IUE spectrum obtained by Angelo Cassatella and Chris Shrader on UT June 2, 1989. It is the result of a combined US1+VILSPA 792 minute exposure. It shows a weak continuum and Mg II in emission. This is the first UV spectrum of an X-ray nova in outburst.

and the neutral helium lines: 5876Å, 6678Å, and 7065Å. In addition, He II 4686Å was comparable in strength to Hβ. Similar features and intensities were seen in A0620-00 some weeks after maximum (Whelan *et al.* 1977). These features remained prominent in the spectrum even as it faded during June and into July.

The optical photometric behavior was also remarkable. As reported by Buie and Bond (1989, IAUC No. 4786) it showed very strong flickering with large excursions on time scales of minutes or shorter. Other photometric data, obtained in early June and reported by Wagner *et al.* (1989, IAUC No. 4797), show large flares (Figure 2) but FFT analyses of the same data also show periodic photometric variations with a 10. ± 0.1min. Unfortunately, no confirmation of this finding has been reported. They hypothesize that this variation could come from rotation of a magnetic compact object. The V-band light curve of V404 Cyg from its discovery through mid-June is shown in Figure 3.

Its behavior in the radio was even more interesting and variations on rapid time scales were also found in this wavelength region by Hjellming and Han (1989, IAUC No. 4796) using the VLA. They reported that "the source fluctuated between 0.05 and 0.15 Jy with systematic variations at all frequencies by amounts varying from 20 to 100 percent on time scales of hours." They also noted that it was not decaying like a normal X-ray nova and its spectral index changed rapidly.

Observations in the IR were reported by Gehrz and his collaborators at the University of Minnesota using the Wyoming Infrared Observatory (IAUC No.'s 4786 and 4816). If one takes their data and assumes that it is being produced by a reddened, very hot object, then it suggests that E(B-V) $\sim$ 1.5 to 2.0. This result explains the failure to detect it below $\sim$ 2600Å in a 792 minute LWP spectrum with the **IUE** Satellite (Figure 4).

One interesting footnote to the discovery of this source is that Szkody has been obtaining magnitudes and colors for all of the "novae" that are presented in the Duerbeck (1987) atlas. In fact, Szkody and Margon (1989, IAUC No. 4794) report a pre-outburst observation of V404 Cyg on April 13, 1989 in which they found it at V=18.3. This is considerably fainter than the peak V of $\sim$ 12 mag reached on May 30th but is brighter than reported as the minimum magnitude in Duerbeck (1987). There may have been some brightening of this star prior to the observed outburst.

Finally, it was reported that V404 Cyg was seen in γ-rays by the Kvant team (Sunyaev *et al.* 1989, IAUC No. 4800). They find a significant detection up to 300 keV. It showed a flat spectrum and was strongly variable.

DISCUSSION

The 1989 outburst of V404 Cyg has turned out to be the most unique of all of the well studied X-ray novae. Neither its optical spectral development nor its radio development resemble any other such outburst. This event underscores the need to follow the outbursts of other "low" amplitude events such as those recorded in Duerbeck (1987). Observations such as those of Szkody and Margon (1989, IAUC No. 4794) demonstrate the importance of studying historical novae at quiescence.

It will be important to follow this outburst down to quiescence and determine the orbital parameters. These observations are in progress. Hopefully, there will be enough information to determine the mass of the compact object and the structure and evolutionary state of the secondary. Calculations of the long term consequences of accretion onto neutron stars should be done in order to try and model these long period events as well as the successful studies of the bursters. We admit, however, that there is no compelling evidence at the present time as to whether or not the compact object in this system is a neutron star or a black hole.

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