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THE SYMBIOTIC STAR CI CYGNI

JANET AKYÜZ MATTEI
AAVSO
187 Concord Avenue
Cambridge, MA 02138

Abstract

The spectroscopic and optical characteristics of symbiotic stars are summarized. Long-term visual (AAVSO) and photographic behavior of the symbiotic star, CI Cygni, is discussed. The visual and the three color (blue, red, and yellow) photographic light curves are all in phase. They are suggestive of both eclipsing binary and eruptive type variations, with eclipses occuring 855 days apart, and eruptions occuring directly after each eclipse. The eruptions may be phase dependent.

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Symbiotic stars are a group of rare and interesting variables, generally believed to be interactive close binary systems made up of a late type giant and a hot star, imbedded in a tenuous, highly excited nebulosity. Spectroscopically, in the visual region of the electromagnetic spectrum, they display a hybrid spectrum composed of low-temperature absorption lines, particularly those of TiO, Ca I, and Ca II, contributed by the cool star, and of high-temperature emission lines of He II, O III, or more highly ionized atoms, contributed by the excited nebula (Boyarchuk 1975).

In the near and far ultraviolet regions, as measured by the International Ultraviolet Explorer (IUE) satellite, the spectrum is characterized by high excitation emission lines that are superimposed on a continuum between 1200 and 3200 Å (Michalitsianos 1981). The spectrum is "dominated by strong allowed, and semiforbidden lines of a variety of ions ranging from neutral to simply ionized [elements] ... such as O I, C II, and Mg II, to highly ionized ones like He II, N IV, N V, C IV, O IV, Ne V, and Mg V" (Kafatos 1981).

The x-ray survey of about 30 symbiotics with the High Energy Astronomical Observatory (HEAO-2 - Einstein Observatory) satellite indicated that about 10 to 15% of these stars are sources of extremely soft x-rays. The proximity of the system and the occurence of a slow nova-like outburst determined the x-ray detection (Allen 1981).

The infrared observations between 2.3 and 23 microns have shown that the infrared emission varies from star to star, with some symbiotics, like AG Peg, showing no infrared excess, some, like CH Cyg, showing moderate, and others, like V1016 Cyg and HM Sge, showing extreme and variable infrared excess (Bopp 1981).

In their optical behavior, these stars are generally characterized by their semi-periodic, nova-like outbursts of up to 3 magnitudes in amplitude. The prototype of the class is Z Andromedae.

CI Cygni, at position $\alpha = 19^h\ 48^m\ 21^s$, $\delta = +35^\circ\ 33'.4$ (1950), was discovered by Miss Annie J. Cannon on Harvard spectrum plates in 1922. Her examination of 300 photographic plates taken from 1890 to 1920 suggested an irregular light variability. Later study of Harvard plates by Naomi K. Greenstein (1937) for the interval between 1890 and 1936 revealed that although for the most part CI Cygni varies irregularly between photographic magnitudes 12 and 13, there is some suggestion of a periodicity of 900 days, between successive minima. A "remarkable rise" was noted on August 1, 1911, when the star brightened from 12.1 to 10.7 mpg. This significant outburst lasted 200 days. The features of the light curve together with spectral peculiarities led Greenstein to suggest a close resemblance between CI Cygni and Z Andromedae.

The photographic light variation of CI Cygni has also been studied by W. Miller (1967) at Fordham University, D. Hoffleit (1968) at Maria Mitchell Observatory, B. Whitney (Hoffleit 1968) at the University of Oklahoma, and E. Splittgerber (1975) at Sonneberg Observatory.

Fordham plates for the years 1940 to 1955 indicate a rough periodicity of 900 days between successive minima, with no nova-like outbursts. Later observations by B. Whitney for the years 1945 to 1960 reveal a periodic light variation of about 855 days, and a light curve suggestive of an eclipsing binary (Hoffleit 1968), satisfying the elements (Kukarkin et al. 1969):

$$JD_{(Min)} = 2411902 + 855.25\ E. \qquad (1)$$

Hoffleit's study of Maria Mitchell Observatory plates from 1916 to 1967 provide a good composite light curve fitted to the 855 day period. However, a departure from this mean curve was another spectacular, almost nova-like outburst in May, 1937, when the brightness reached 10.2 mpg.

On Sonneberg photographic plates from 1956 to 1974, CI Cygni varies between 12.0 and 12.8 mpg, with the exception of two small-scale rises to about 11.5 and 11.8 mpg in 1962, and 1967, respectively (Splittgerber 1975).

CI Cygni was introduced to the AAVSO by Dr. Dorrit Hoffleit at the time of its 1971 outburst (Hoffleit 1971). AAVSO data prior to this date were contributed by AAVSO member, Wayne M. Lowder.

The AAVSO optical light curve shows that CI Cygni varies between visual magnitudes 9.0 and 11.6. The behavior is suggestive of both an eruptive and an eclipsing binary type of star. The eclipses satisfy the elements given in Equation (1). The duration of the eclipses ranges from 100 to 200 days. The amplitude of the eclipses varies, ranging from 2.5 magnitudes to 0.3 mv. The recovery from eclipse is accompanied by an eruption, suggesting the possibility of a phase dependence of the eruptions. The decrease in brightness after an eruption is gradual, and continues until the next eclipse.

Beginning in April, 1975, and prior to the predicted eclipse in October, 1975, CI Cygni brightened from magnitude 11.5 to 8.9 in 100 days. It stayed at maximum for 30 days, then had a deep eclipse at the predicted time. This brightening appears to be similar to those reported by Greenstein and Hoffleit.

I have examined 190 Maria Mitchell Observatory (blue, IIa-O) and 103 Harvard College Observatory Damon (blue, IIa-O; yellow, IIa-D; red, 103a-F) photographic plates taken between 1967 and 1981. I used the photographic sequence of Hoffleit (1968) for the blue plates, the AAVSO visual sequence for the yellow plates, and my adjusted sequence for the red plates.

Figure 1 is the visual (AAVSO) and photographic light curve of CI Cygni from 1967 to 1981. The three-color light curve is in phase with the visual. The highest amplitude in light variation is in the blue. The color index is largest during eclipses and smallest when the system undergoes an outburst.

CI Cygni appears bright on most of the red photographic plates taken out of eclipse. However, a significant decrease in brightness is observed on those red plates taken during the eclipses of 1968, 1973, and 1975. This decrease may be due to the eclipse of a dust shell or accretion disk around the hot component.

The late-type component of the system may be an M5 giant (Boyarchuk 1975), as indicated by the strengths of the TiO and Ca I absorption spectral lines. The hot companion may be an A - F main sequence star surrounded by an accretion disk, as indicated by the ultraviolet spectra (Stencil et al. 1981). The accretion of mass from the late type star onto the hot main sequence component is suggested to be the mechanism that gives rise to the outbursts (Bath 1981).

Since the recovery from the shallow eclipse in 1980, CI Cygni has been fluctuating quasi-periodically, a behavior that is unprecedented since 1971. Stencil (1981) reports that IUE spectra obtained in August, 1981, show the lines of Mg II to be five times stronger than in April, 1981, and for the first time, highly ionized forbidden lines of Mg V have appeared in the spectrum. These features suggest the presence of a tenuous, highly excited nebulosity. Is the system getting ready for another outburst? This interesting variable deserves continuous close monitoring. Longterm UBV photoelectric photometry of CI Cygni, particularly during eclipses, would be of significant value in understanding the changes occuring in the system.

I thank Jacque Kloss, Acting Curator of Harvard College Observatory Plate Stacks, for allowing me to use the Harvard Damon Plates and Dr. Emilia Belserene, Director of Maria Mitchell Observatory (MMO) for allowing me to examine the extensive photographic plate collection at MMO and for her assistance in providing the comparison star sequences. We are delighted that Dr. Dorrit Hoffleit introduced this interesting variable to AAVSO. I am indebted to the dedicated observers of AAVSO for their close monitoring of CI Cygni, which made it possible to determine its optical behavior since 1971.

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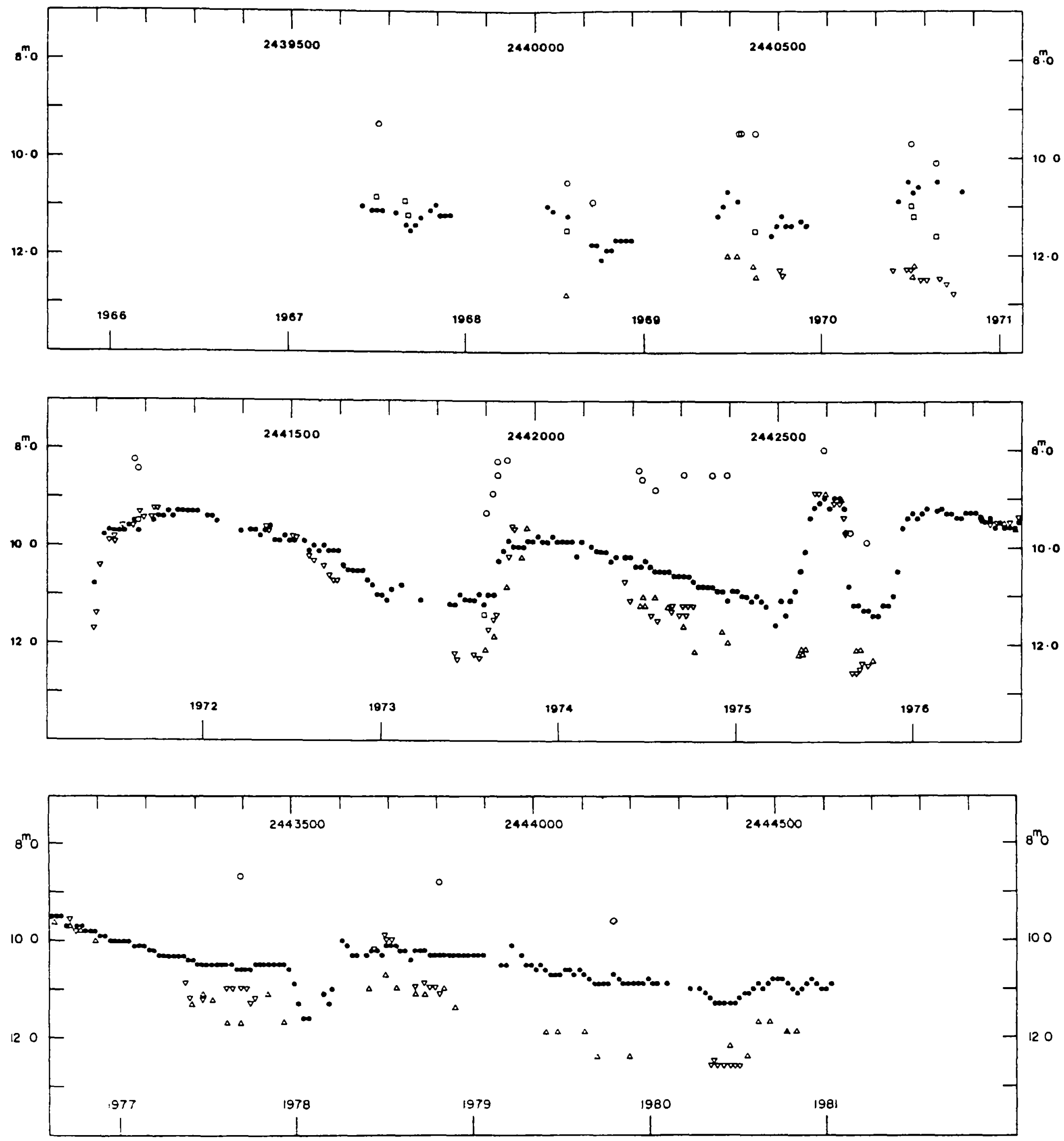

Figure 1. The visual (AAVSO) and photographic light curve of CI Cygni. ●: 10-day means of AAVSO observations; ○: photographic (red) Harvard College Observatory (HCO); Δ: photographic (blue) HCO; ∇: photographic (blue) Maria Mitchell Observatory; □: photographic (yellow) HCO.