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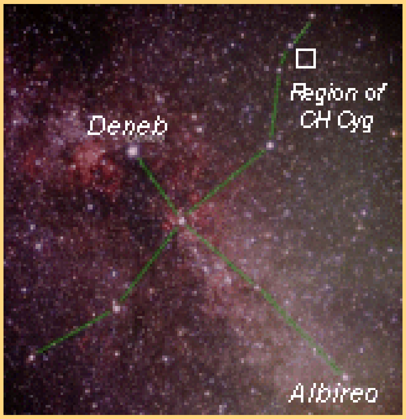
# Variable Star Of The Month

## August, 2000: CH Cygni

## CH Cygni




The variable star CH Cygni lies in the constellation Cygnus just under the western wingtip of the swan.

The symbiotic variable star CH Cygni is a rewarding star to observe and a puzzling one to study due to its erratic light variations and peculiar spectra. This month, observers in the northern latitudes are best situated to find CH Cyg flying high in the constellation Cygnus just under the western wingtip of the Swan, two degrees south-southwest of Iota Cygni. The American Association of Variable Star Observers has recorded the brightness of CH Cyg from as bright as magnitude 5.6, when it can be seen with the naked eye, to as faint as 10.5 in 1997, when it became a challenge for binoculars. For the past decade or so, it has stayed around the faint end of this range, but this unpredictable star often rises or fades sharply in just a month or two providing a treat to watchful observers.

## History of Symbiotic Stars

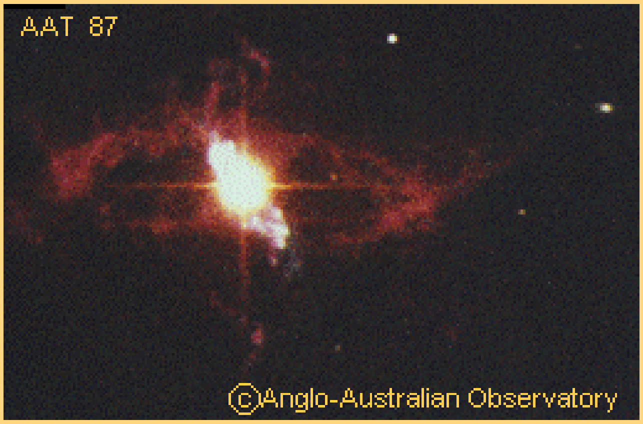
In 1912, Mrs. W.P. Fleming published an exceptional paper entitled, “Stars Having Peculiar Spectra”. One of her discoveries was that certain long period variables showed uncharacteristic emission lines and unusually small ranges in brightness. These peculiar stars later emerged in the work of Miss A. Cannon, an extraordinary woman who devised the familiar spectral classification scheme O, B, A, F, G, K, M. Cannon noted that some M type stars, like Z And and CI Cyg, showed bright HI and HeII emission lines, usually associated with hotter stars. The spectra of these peculiar stars were rediscovered and studied by Paul Merrill and M.L. Humason in 1932. In certain spectra, they found the unusual case of a TiO absorption band, common to cool (M-type) stars, co-existing with highly ionized helium emission lines, common to hot stars. The interesting combination of spectral lines prompted Merrill and Humason to search for more stars with similar spectra. Over a dozen *stars with combination spectra* had been discovered by 1941 when Merrill coined the phrase *symbiotic stars* to describe objects that show evidence for cool M-type photospheric absorption lines *and* very high temperature emission lines (Kenyon, 1988).

**Annie Jump Cannon (1863-1941): Theorist of Star Spectra**

During a time when women won only grudging acceptance in science, Annie Jump Cannon created a theoretical yet simple spectral classification scheme (O, B, A, F, G, K, M) that constitutes the spectral classification structure of modern astrophysics.

## The Class of Symbiotics

How can one star exhibit a spectral profile that exhibits features from two very different types of stars? The generally accepted answer is simply that a symbiotic system **is** two very different stars, stars that are close enough to each other to form an interacting binary system. Paul Merrill borrowed the term "symbiosis" from biology, where it signifies the co-existence of different types of organisms to their mutual advantage. The astronomical analogy is appropriate since a symbiotic star system is usually comprised of two very different types of stars - a cool red giant star and a hot compact object (probably a white dwarf)- existing together by exchanging mass in their evolutionary stages. These stars are embedded in a gas shell, or nebula. The source of the nebulosity is the red giant star, which loses considerable amounts of mass either through a stellar wind or through pulsation. Moreover, symbiotic stars can be divided into two main types: those with dust emission and those without it. Some of those with dust emission also have radio emission (CH Cyg is an example).




**Symbiotic Star System R Aquarii**

The two stars, a variable giant and a white dwarf companion create both a nebula and a jet
Credit: Anglo-Australian Observatory

The spectra obtained from symbiotic stars are signatures of the components in the systems. The high-excitation emission lines (noted earlier by Fleming and Cannon) arise in the nebula by radiation from the hot component, which is accreting mass from the cool component. There are also lower-excitation lines like FeII, which do not arise in the shell, but in those regions of the cool component's atmosphere that are turned towards the hot star. Finally, the late type absorption lines (TiO, CaI, CaII, etc.) seen in the spectra come from the cool red giant star.

Each component of the symbiotic system contributes to the light variability, and the following five effects may be seen together:

1. Variability in the transparency and the excitation of the gas shell.
2. Variability of the hot component, probably because of irregularities in the mass-accretion and energy-release rates.
3. Long-period or Mira-type changes in the cool component (pulsations).
4. In a few cases, eclipses.
5. Rotational changes in magnitude due to differing surface brightness (starspots)

(Hoffmeister *et al.* 1984)

A symbiotic star exhibiting all five of these light variations produces a complex light curve that is difficult to interpret. Most symbiotic systems typically have periodic photometric variations with amplitudes ~ .5-1.0 mag and periods of 100-2000 days. These brightness changes usually are interpreted in terms of orbital motion in the binary system, either as a result of an eclipse of the hot component by the giant, or because the hot star illuminates the facing hemisphere of its giant companion. In addition to periodic light variations, symbiotic stars display irregular eruptions with amplitudes 2-7 magnitudes (Kenyon 1988).

Symbiotic stars are a diverse class of stars that probably represent a number of different evolutionary stages in binary systems. Today there are about 150 symbiotics known, of which Z And is a prototype of the class and CH Cyg is extremely unique.

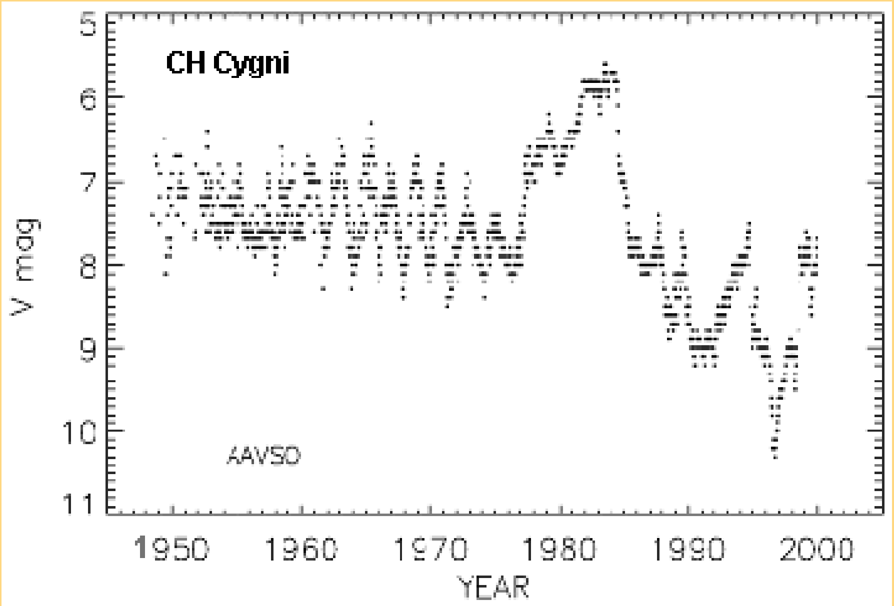
## CH Cygni A Distinctive Symbiotic

CH Cygni was first thought to be a red semiregular in Sergei Gaposchkin's 1952 study of Harvard patrol plates. Much like a semiregular variable, CH Cygni had an M6-M7 spectrum, 90-100 day period, and about one-magnitude amplitude. This classification seemed to fit most of the facts until 1976 when the star began to behave differently. A hot blue continuum appeared in the spectrum, and CH Cygni grew brighter than it had ever before been seen. Rapid fluctuations were also observed, especially in ultraviolet light. CH Cygni was then identified as a *symbiotic system* by Deutsch (1964), who noticed the composite nature of its spectra: a hot blue continuum and emission lines of H, He, [FeII], and CaII combined with a late type spectrum. CH Cygni is now recognized as the brightest of the *symbiotic* stars. It consists of an M giant (semiregular) and an active hot component, possibly a white dwarf. These stars are imbedded in a dusty nebulosity. CH Cygni is a good target for astronomical research since it is relatively close to the Earth. The Hipparcos satellite recently determined that the distance to CH Cygni is 268 +/- 61 pc (ESA 1997).

CH Cygni is a unique symbiotic star. The onset of symbiotic activity in 1963, after a long period of quiescence is challenging to interpret. CH Cyg is probably an eclipsing star system (Skopal *et al.* 1996). Radio jets have been detected in CH Cygni (Taylor *et al*. 1986). And Hinkle *et al*. (1993) suggested the presence of a third body in the system, possibly a low-mass main sequence star.

## The Light Curve

CH Cygni's light curve shows many interesting features that indicate its complex structure. Prior to 1976, fairly periodic light variations were the strongest feature in the curve, varying on timescales from one to three years. Then, in 1976, a significant change in the behavior of CH Cygni was detected. CH Cyg erupted considerably, and after a brief fading, brightened to 5.6, a magnitude visible to the unaided eye. During this ten-year outburst, CH Cygni was said to be in a "blue outburst" state. This great outburst ended in 1986 with the emission of bipolar radio jets and a decline of about 2.5 visual magnitudes (Taylor *et al.* 1986). Since 1986, the star has continued to show an overall decline in magnitude, reaching an all time faint magnitude of 10.5 in 1997. However the decline has not been smooth. There are semi-periodic oscillations with each minimum becoming fainter than the last. Since 1997, CH Cygni has been varying from 7.7 to 9.1. Recently it has been slowly fading, and it was around 9.1 in July. It will be interesting to see if it will continue the pattern and fade to a fainter minimum than that seen in 1997.

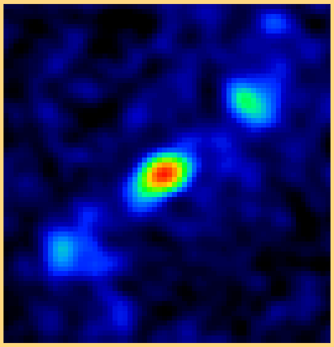



**AAVSO light curve (10-day means of observations) of CH Cygni from 1948 to 2000.**

The eruptions of CH Cygni are unpredictable and last from several months to several years. During an outburst four things happen. The system brightens strongly in the UV and usually also in visible light. The hot component contributes more light thus making the system bluer overall. The hot star, or its accretion disk, begins to flicker on various timescales as small as minutes (Karovska et al. 1993). Finally, strong, variable emission lines appear in the spectrum (Isles, 1995).

Due to the devotion and dedication of AAVSO observers, a well-determined light curve can be produced for CH Cygni. Karovska and Mattei (1992) use this data to determine periods of light variation in this symbiotic system. They found several periods of which 100 days, 155 days, and about one year may be due to the pulsations of the M-giant, visible in the light curve; the periods of about 2 years and 17 years may reflect the orbital motion of the components of the system.

## Radio Jet Formation



A VLA image of the symbiotic star CH Cygni in 1986, two years after a major nova-like outburst. The two blobs seen in the image are material ejected in the initial outburst.
*Credits: VLA, Stellar Radio Astronomy Group at Jodrell Bank University.*

Tuning in to CH Cygni at different wavelengths is important, especially in the radio region where there is evidence of radio jets. Radio emission was first detected in the symbiotic system of CH Cygni in 1984 (Taylor *et. al.* 1986). CH Cygni was further investigated in 1996 (Karovska *et al.*) at which time the radio source was resolved and a jet-like structure determined. The physical mechanisms of jet formation in symbiotic systems are still unknown, however, one possibility is that the radio jet is ejected from the accretion disc around the hot companion. In order to better understand this phenomenon, studies have been conducted on those symbiotics that contain radio jets. CH Cyg is an optimal target because it is a close system.

In the midst of the most prominent CH Cyg outburst, observed between 1977 and 1986, a powerful jet formed. The 1984 jet was first detected by the Very Large Array (VLA) radio telescope.

Observations carried out in 1984 and 1985 detected a strong radio outburst occurring shortly after the onset of the visual decline in brightness. High- resolution radio maps revealed jet-like structures exhibiting significant changes over the next two to three months. In 1996, CH Cyg again faded, only this time more dramatically and approached a much fainter magnitude than before, providing a good opportunity to search for jet structures again. Alerted to this rapid decline in brightness by AAVSO observers in the summer of 1996, Karovska *et al.* (1998) started to monitor this system using the VLA in the autumn of 1996. In addition to flux measurements, a high angular resolution radio map resulted, indicating that the radio source is resolved. In particular, the image shows a significant North-South elongation, suggesting a possible jet. Further research is needed to better understand how the radio jets are formed.

## Models of CH Cygni

CH Cygni has been described as a unique and distinctive symbiotic system with a light curve that evades simple explanation. The following section describes three different models of CH Cygni that have recently been proposed to explain this unpredictable star.

1. ***A Triple Star Model***
   Researchers Hinkle *et al.* (1993) propose that CH Cygni is a non-eclipsing *triple* symbiotic system. This is remarkable because CH Cygni took a long time to reveal its binary nature, and now a triple is suggested. The basis of their research is a 13-year study of precise measurements of radial velocities of high-resolution infrared spectra of the cool component. They conclude that the components of this triple system are: a close interacting binary [(1) an M7 III giant (semiregular) and (2) an accreting white dwarf in a 2.07 year orbit] and circling this symbiotic pair every 14.5 years, is (3) a low mass main sequence star (G-K dwarf).
2. ***An eclipsing model***
   Skopal *et. al.* (1996) show observational evidence of eclipses which strongly suggest that CH Cyg is a triple system consisting of an inner symbiotic binary (red giant and hot companion) with a red giant in a 14.5 year eclipsing orbit. Ultraviolet observations were obtained from the IUE satellite in addition to high-resolution optical spectroscopy which was also used.

   *The inner binary*
   Four well-distinguished minima in the ulraviolet light curve were observed during the lower active phases of CH Cyg: 1967-1970 and 1992-1995. The basic observational results that confirm that these minima are due to eclipses of the hot component by the red giant in the inner binary are as follows:

   . The positions of these minima agree well with times of the inferior spectroscopic conjuctions (with the cool component in front) in the inner binary
   b. The rapid flickering seen in the blue continuum (represents the presence of the hot companion) disappears during these minima
   c. Both the optical and the ultraviolet continua decreased considerably during the minima
   d. The M-giant characteristics dominated the optical spectrum during the minima.
   e. The permitted emission lines (seen from the hot component) decreased in strength while the forbidden emission lines associated with a nebula increased in intensity

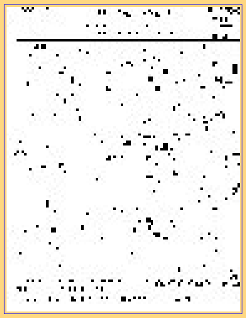
   *Eclipses in the outer binary*

There are two additional minima in the light curve, observed in 1971 and 1985; the latter minimum was well observed at a range of wavelengths. The 1985 minimum is interpreted in terms of the eclipse of the active component by a red giant in a long-period binary. The observations regarding this minimum are widely spread in the literature and are similar to the reasons given above, with the difference that the positions of these minima are nearly identical with the times of spectroscopic conjuction (with the cool component in front) in the outer binary orbit.

These factors taken together lead Skopal *et al*. to conclude that their photometry, ultraviolet, and optical spectroscopy of CH Cyg strongly suggest eclipses of the hot component by a red giant in a short-period (2.07-year) inner binary and the eclipses by a red giant in a long-period (14.5-year) outer binary. These orbital periods agree well with those proposed by Hinkle *et al.* (1993).

3. ***The Resonance Model***
In 1998 the dynamicists Mikkola and Tanikawa proposed a "modified Hinkle model" which explains the sudden onset of symbiotic activity in 1963 that persists until the present. They explain their observations in terms of a model consisting of a close binary that is orbited by a normal white dwarf. The components of the close inner binary are a red giant and a dim star of unknown type, which they predict is probably hard to detect. The idea of this model is that the orbit of the inner binary has a high inclination (more than 40 degrees) with respect to the orbit of the white dwarf. In this kind of system, the inclination and eccentricity cannot remain constant, but cycle with a long period and large amplitude, a phenomenon known as *Kozai Resonance*. This dynamical phenomenon then causes large long-period eccentricity variations in the inner binary. When in the high-eccentricity state, the binary expels gas out of the red giant. Part of this material ends up on the white dwarf, causing the activity. In their model, the eccentricity of the binary was low for a long time and has been growing steadily during this century. This explains the recent onset of symbiotic activity.

## Observe CH Cygni Tonight



Click on image above to get the NEW "c" scale chart for observing CH Cyg.

AAVSO observations have contributed greatly to the understanding of this symbiotic system. However, the nature of CH Cygni is not yet fully understood.

To observe CH Cygni (1921+50), you will need a pair of binoculars or a small telescope since the symbiotic currently shines around 9.0 magnitudes. A new c scale chart for CH Cyg has very recently been updated (July 28, 2000) to account for the recent discovery that, what was previously a 9.4 magnitude comparison star, is actually a variable. It is also possible that this variable is an eclipsing system. When observing CH Cyg do also observe this newly discovered variable. Other charts that are useful when trying to locate CH are: the a scale chart for AF Cyg, and the b scale chart for TZ Cyg. CH Cyg is also in the photoelectric photometry observing program for long period variables of the AAVSO. PEP observations are strongly recommended to observe this system in order to determine its small amplitude variability.

## For More Information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This month's Variable Star of the Month was prepared by Kate Davis, AAVSO Technical Assistant

- Variable Star of the Month Archive