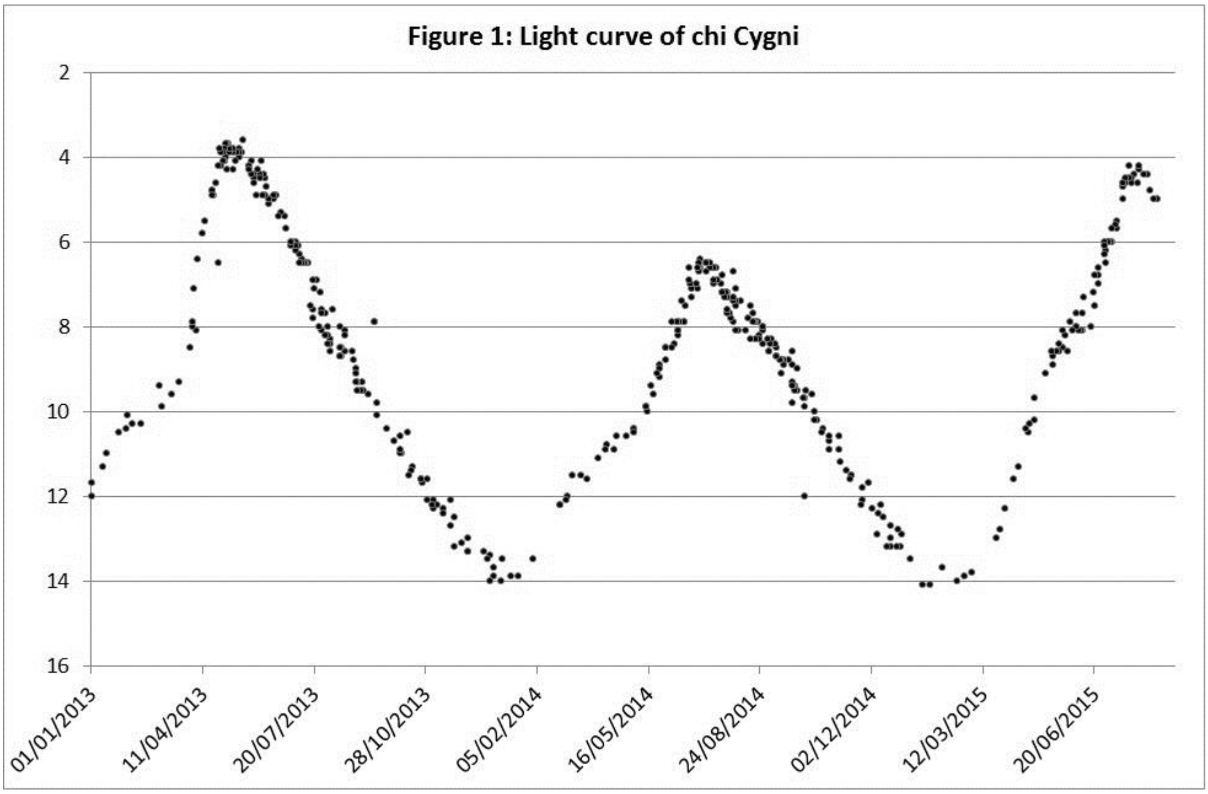
A Low Resolution Spectrum of chi Cygni Shortly After the 2015 Maximum

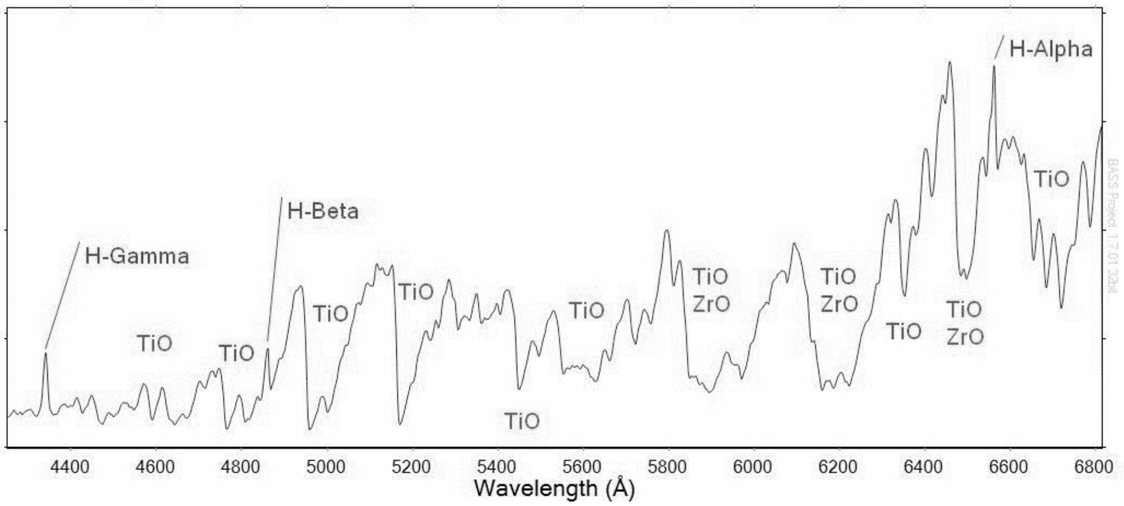
There has been a lot of interest in chi Cygni over the Summer months as it approached maximum brightness in its 408 day cycle (see figure 1 for a light curve from the BAAVSS Online Database[(1)]). This is a fascinating Mira variable with a huge range from about 4th to 14th magnitude. Maximum brightness occurs when the star is at its smallest physical size corresponding to its highest temperature, and as the star expands it cools and fades. Chi Cygni is near the end of its life, on the AGB (Asymptotic Giant Branch) of the Hertzsprung-Russel diagram. Such stars burn hydrogen and helium in shells around an inert core composed of carbon and oxygen.



This makes chi Cygni not just a fascinating star for visual and CCD observers, but also an excellent target for spectroscopy. I obtained a low resolution spectrum of chi Cygni at 22:25 UT on 15th August 2015 (see figure 2). About 20 minutes earlier, at 22:04 UT, Gary Poyner observed the star estimating it at magnitude 5.0 (BAAVSS Online Database [(1)]).

Typically a low resolution spectrum will show course detail over a wide range of wavelengths, while a high resolution spectrum will show great detail over just a small range of wavelengths. This spectrum covers about 2500 Angstroms with a resolution of 18 Angstroms at H-alpha, meaning details with a wavelength smaller than 18 Angstroms will not be reliably detectable. Note that 1 Angstrom is 10^{-10} metres.

Figure 2: Low Resolution Spectrum of chi Cygni on 15th August 2015



The technical details of the spectrum are as follows. It was a 450 second exposure, composed of 15x30 second sub-exposures. The spectroscope was an LHIRES III(6) with a 150 l/mm grating and a 23 µm slit. The imaging camera was a Starlight Xpress SXVR-H694 and the telescope a 10" F8 Ritchey-Chretien. I used a spectrum of the star HD 190603 obtained at 22:40 UT along with a standard spectrum of this star from the Miles spectral library (copy in ISIS(4)) to correct for instrumental and atmospheric response. The spectrum processing was performed using ISIS(4), with the presentation created using BASS(5).

Chi Cygni is a cool red giant with a temperature of around 3000K and spectral class S. While the spectrum of hotter stars are often a good approximation of a black body curve, this is not so for cool stars. The temperature is sufficiently low that molecules form in the star's atmosphere. Due to the many rotational and vibration states that molecules can take, they tend to form bands of absorption where many individual spectral lines overlap and merge. This results in large deep absorption bands in the spectra of cool stars, usually due to the presence of TiO (Titanium Oxide). In S class stars there are also absorption bands due to ZrO (Zirconium Oxide). In the spectrum of chi Cygni the majority of the absorption is due to TiO, with a few ZrO absorption features superimposed. The TiO and ZrO absorption bands were identified using Richard Walker's Spectroscopy Atlas(3).

Of particular interest in the spectrum of 15th August are the hydrogen Balmer emission lines of H-alpha, H-beta and H-gamma. Most stars do not show emission lines in their spectra. In the case of chi Cygni, the emission lines are due to a radiative hypersonic shock wave passing through the star(2). The shock wave emerges from the star's photosphere once per cycle at around maximum light, which judging by the light curve was within a week or two of when this spectrum was taken.

I would recommend anyone with low resolution spectroscopy capability to monitor chi Cygni over the coming months while it is within easy reach of amateur equipment. Observers with a "Star Analyser"(7) may find they can even follow it down to minimum brightness, although this would be quite a challenge. It would certainly be interesting to observe how the spectrum changes over its pulsation cycle, and in particular the strength of the hydrogen emission lines.

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References

1 - BAAVSS Online Database: http://britastro.org/vssdb/

2 - "Shock-Induced Polarized Hydrogen Emission Lines in the Mira star omicron Ceti", N. Fabas, A. Lèbre, and D. Gille, Astronomy & Astrophysics (30 September 2011): http://arxiv.org/pdf/1109.6500v1.pdf

3 - Spectroscopic Atlas for Amater Astronomers, version 5.0, Richard Walker: http://www.ursusmajor.ch/downloads/spectroscopic-atlas-5_0-english.pdf

4 - ISIS: http://www.astrosurf.com/buil/isis/isis_en.htm

5 - BASS (Yahoo group for obtaining the software and support): https://uk.groups.yahoo.com/neo/groups/astrobodger/info

6 – The LHIRES III is a spectroscope manufactured by Shelyak Instruments: http://www.shelyak.com

7 – The Star Analyser is a transmission diffraction grating mounted in a standard 1¼" thread cell to fit into a camera filter wheel or eyepiece.