Spectral changes in AC Herculis during its rise to a maximum in 2014 July

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Four low resolution (R~1000) spectra were obtained of the RV Tauri-type variable AC Her during its rise from a deep minimum in July 2014. These show changes in spectral type and Balmer line equivalent width as the star brightened, consistent with previous observations.

AC Herculis

AC Her was first reported as a variable by Dorothy Applegate in a Harvard College Observatory *Circular* in 1921.[1] B. P. Gerasimovic, in a similar publication in 1929,[2] listed AC Her as one of 'twelve undoubted RV Tauri variables'.

RV Tauri stars are luminous pulsating variables, located between the Cepheids and long period variables on the Hertzsprung–Russell diagram, which show two unequal minima per cycle. According to the *General Catalogue of Variable Stars* (GCVS),[3] AC Her is a RVA variable with a period between successive primary minima of 75.5 days and V magnitude between 6.85 and 9.0. RVA variables are RV Tauri stars that do not vary in mean magnitude. The quoted period contains two pulsation cycles, sometimes of similar amplitude and sometimes of significantly different amplitudes. Alternate minima which are on average the deepest are referred to as primary minima and the following maxima are primary maxima.

Historical spectroscopic observations of AC Her

W. F. Waterfield, in a Harvard College Observatory *Bulletin* in 1927,[4] reported that the spectral type of AC Her had been found to be variable by Margaret Walton and subsequently observed by Annie Cannon to be F8 at maximum, passing through G0 and G5 as it faded to K5 at minimum. A series of studies of AC Her over the next 65 years reported the spectral type as varying from anywhere between F1 and F4 at maximum to between K0 and K5 at minimum.[5–11] In some cases classification of the spectrum depended on which part of the spectrum was used and as a result the spectrum was described as Fp (p= peculiar).

These stars have vast extended atmospheres which experience shock waves during the pulsation cycle so the normal rules for classifying steady main sequence stars do not apply. Noting the strength of CH and CN bands in its spectrum, L. Rosino[6] identified it as a carbon star. A list of published spectral classifications for AC Her can be found in the *Catalogue of Stellar Spectral Classifications* maintained by Brian Skiff.[12] A recent classification by L. Tomasella *et al*.[13] is F4Ibpvar. The spectral type currently listed in the *GCVS* is F2pIb-K4e(C0,0).

Due to the limited spectral sensitivity of the blue photographic plates used, many of the classifications prior to the use of CCDs were made using spectral lines at wavelengths shorter than 5000Å. In that range the Hδ, Hγ and Hβ lines were generally found to be in absorption, or in emission for only a short part of the pulsation cycle. When the Hα wavelength was recorded, however, that line was found to be in emission throughout the cycle although varying greatly in strength.

New spectroscopic observations

On 2014 July 8 John Toone informed me that AC Her had passed through a deep primary minimum at mv= 8.7 two nights before. I recorded four spectra of AC Her on July 9, 15, 21 and 25 as it rose to a primary maximum at mv= 7.2 on July 21 and remained at that magnitude for at least 9 days.

The equipment used was a Celestron 280mm SCT with a LISA spectrograph and SXVR-H694 CCD camera. The spectra have a

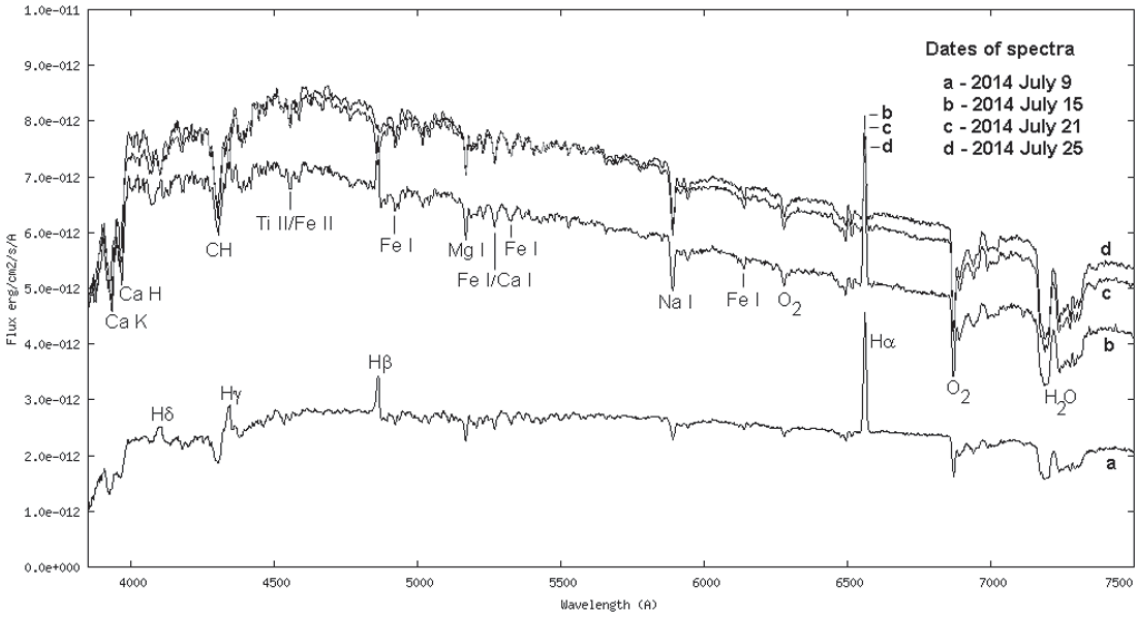

Figure 1. Composite plot of flux calibrated spectra of AC Her indicating some prominent spectral features.

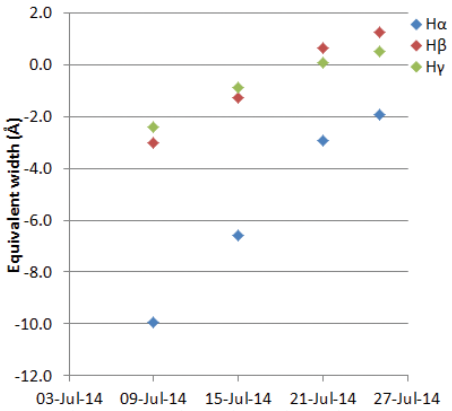

Figure 2. Balmer line equivalent widths.

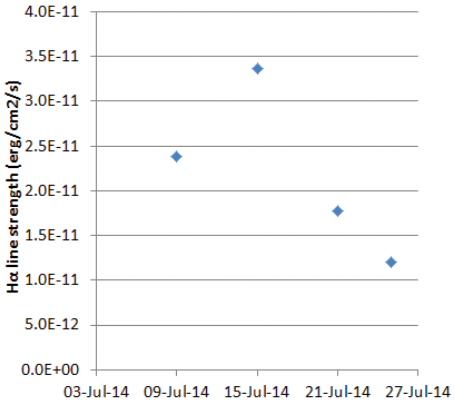

Figure 3. Hα line strength in absolute flux.

Table 1. V magnitudes, Balmer line equivalent widths and Hα line strength for each spectrum

Date (2014)	*JD*	*V mag*	*Hα EW (Å)*	*Hβ EW (Å)*	*Hγ EW (Å)*	*Hα line strength (erg/cm²/s)*
Jul 09	2456848.42370	8.3	−9.94	−3.02	−2.39	2.39E-11
Jul 15	2456854.50010	7.2	−6.60	−1.25	−0.87	3.36E-11
Jul 21	2456860.41910	7.0	−2.93	0.66	0.10	1.77E-11
Jul 25	2456864.44780	7.0	−1.92	1.27	0.51	1.20E-11

resolution of 7Å and an SNR of 200 or greater at 6000Å. All spectra were wavelength calibrated using an internal neon lamp plus Balmer absorption lines in the spectrum of the A0V type star HD171623 located close to AC Her, and were corrected for instrument and atmospheric extinction effects before being flux calibrated using the method I described on the ARAS Forum.[14] This requires knowledge of the V magnitude of the star at the time each spectrum is recorded.

I was able to measure one V magnitude myself before the star became too bright. Thereafter I converted mv magnitude estimates made by Toone to V magnitudes using the following formula which was derived using Toone's visual estimates for Z UMa as described elsewhere:[15]

$$V = mv * 0.846 + 0.935$$

The V magnitudes adopted for flux calibration are listed in Table 1. Based on the uncertainty in the adopted V magnitude, the uncertainty in flux calibration is estimated to be 10%.

Baird & Cardelli[16] measured the reddening of AC Her due to interstellar extinction and found E(B–V)= 0.14. This value was used to correct the spectra for the effect of interstellar extinction and reddening using the formulae for normalised extinction Aλ/Av given by Cardelli *et al.*[17]

A composite plot of the four flux-calibrated and extinction-corrected spectra of AC Her is shown in Figure 1. Prominent features of the spectra are identified. The peak levels of the Hα emission line in spectra b, c and d are marked. Spectra from the Pickles Stellar Spectral Flux Library[18] were used to try to assign an approximate spectral type to each spectrum. As expected from previous comments on the peculiarity of the spectrum of AC Her, this proved to be difficult as none of the spectra matched a specific spectral type from the library well across the whole spectral range. The most that can be said is that, in addition to the increase in flux, there appears to have been a small change in the spectral type from early G to late F as the star brightened. At maximum brightness, while the V magnitude remained constant, the spectrum continued to change as can be seen in the two spectra marked c and d in Figure 1, indicating a slight reddening of the star during this period.

Equivalent widths were measured for the Hα, Hβ and Hγ lines in each spectrum and these are listed in Table 1 and plotted in Figure 2. Hα is in emission (negative equivalent width) in all four spectra, although much reduced in strength at maximum light. The Hβ and Hγ lines are both in emission on July 9 and 15 and absorption on July 21 and 25. This pattern of variation of Balmer line equivalent width is similar to that reported by Mantegazza.[10] The Hα line strength in absolute flux is listed in Table 1 and plotted in Figure 3. This peaked as the star approached maximum brightness then decreased rapidly during the maximum.

These results are broadly consistent with previous spectroscopic observations of AC Her and show that amateur spectroscopy is useful for monitoring the spectral behaviour of bright pulsating variables.

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