HQ CAR IS A NEW W VIR TYPE STAR

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ABSTRACT. HQ Car is listed as an δ Cep star (DCEP) in the GCVS. High-resolution spectra of HQ Car showed the presence of the Balmer and He I 5876Å emissions. The light curve shows steeper rise than decline, and there is evidence for the presence of a bump in the descending branch around the phase of 0.4. From considerations of the period, spectral type, presence of the bump, Helium and Balmer emissions we conclude that HQ Car belongs to the W Vir class of Type II Cepheids.

Key words: W Vir type Cepheids – stars: individual: HQ Car

1. Introduction

The type II Cepheids are low-mass, high-luminosity pulsators, with periods from 1 to 40 days. These evolved stars have a He core surrounded by an outer H shell. Type II Cepheids are population II stars and are thus old, typically metal-poor, and low mass objects.

Type II Cepheids are divided into three subclasses: BL Her, W Vir, and RV Tau. All three classes are characterized by the presence of Balmer emission, especially Hα, during some parts of their pulsation cycle. Evolutionary scheme of these classes is suggested by Gingold (1985). In this scheme the BL Her stars are evolving from horizontal branch towards the lower asymptotic giant branch (AGB). However, the W Vir variables exhibit a blueshift from the AGB. The RV Tau stars stars exhibit a blueshift in the post-AGB phase. Now there is a consensus that Type II Cepheids are fundamental pulsators with masses below 0.8 $M_{\odot}$.

W Vir stars are typically 1.5 magnitudes fainter than their related Type I stars and have a mass of less than 1 solar mass, so that they are clearly at a different evolutionary stage. They also have a distinctive light curve with a variation of 0.3 to 1.2 magnitude and a bump on the decline branch.

The reliable identification of field type II Cepheids is important for several reasons. Achieving a firm understanding of the population to which they belong is hampered by our inability to reliably identify individual stars in the field. This limits our understanding of their origin and evolution. In turn, any potential application of these stars as tracers of older populations and possibly the structure of the halo is compromised.

Various observable parameters which have been proposed to distinguish between type I and type II Cepheids include the form of the light curve, the stability of the pulsation, spectral features, metallicity, space motions, and location.

Schmidt et al. (2004) obtained Hα line profiles of Cepheids with periods longer than 8 days. The authors found that emission in Hα was a good discriminator between population I and II Cepheids.

The light curves of those monoperiodic Population II pulsators are not like those of classical Cepheids, at least regarding the usually steeper rising branch as compared to the slower brightness decline. The shorter-period W Vir stars, with say 8 to about 12 days period, can have rather smooth sinusoidal light curves, i.e. light curves, which are much more harmonic than, for example, classical Cepheids with comparable periods. On the other hand, the longer-period representers often show a well expressed secondary bump on the descending branch; that bump can be so strong that there is almost a plateau formed after the peak brightness, or the secondary maximum can even dominate over the peak light after the steep rising branch of the light curve. Spectroscopic variability is reminiscent of radial pulsations with pulsation-velocity amplitudes between 10 and 50 km/s. The velocity curves can be discontinuous, Balmer lines can pick up emission components, and metal lines can double, all indicating the propagation of strong shocks in the atmospheres of the corresponding W Vir stars.

2. The photometry

To study a behavior of the period change of HQ Car, the photometric observations were taken from ASAS (Pojmanski, 2002), VizieR On-line Data Catalog (Berdnikov, 2008) and paper (Madore, 1975). We have determined 34 times of maxima from the individual

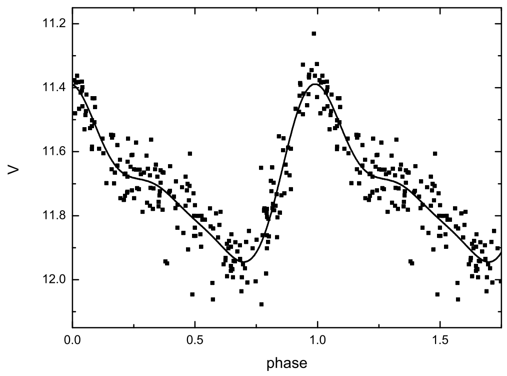

Figure 1: Light curve of HQ Car using ASAS photometry from JD2444500 through 2445168.

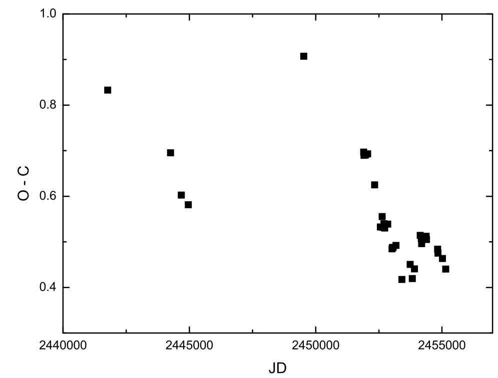

Figure 2: O–C diagram of HQ Car.

light curves. For calculation O–C diagram and phases of spectra we have used the elements of GSVS (Samus et al., 2011): HJDmax = 2420326.03 + 14.0722 E, and elements, which were calculated from ASAS date, respectively: HJDmax = 2452784.603 + 14.06378 E.

In Fig. 1, we have plotted the photometric phase curve of HQ Car based on the data obtained during the ASAS project (Pojmanski, 2002). It has been known for many years that there is a tendency for type II Cepheids to exhibit more scatter in their light curves than is the case for classical Cepheids.

In Fig. 2 we plot O–C, the difference between the fitted dates of maximum and dates calculated from a mean period versus the Julian Date. O–C diagram of HQ Car is typical for W Vir type stars.

3. The spectral observations

HQ Car was observed using the echelle spectrographs on the 4 m telescopes at the Cerro Tololo Inter-American Observatory (CTIO). Long red cameras were used with the 31.6 lines mm^{--1} echelle gratings. Second-order blue light was blocked using GG495 filters. The wavelength coverage was 5500–8000 ÅÅ. A 1.0" slit provided a spectral resolution of 28 000 (2 pixels per resolution element) and a dispersion of 0.07 pixel at 5800 Å. The signal-to-noise ratio S/N=57 per pixel in the order containing Hα (see Yong et al. 2006).

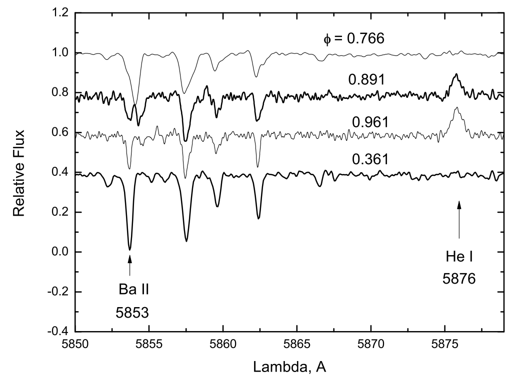

Figure 3: The behavior of the 5876 Å He I line profile.

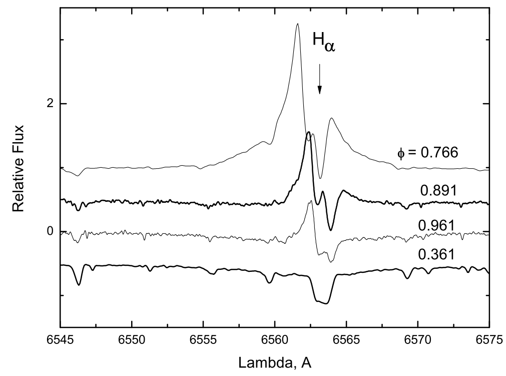

Figure 4: Hα profile variation.

One spectrum was obtained using the 2.2m MPG telescope and FEROS spectrograph at ESO La Silla. The spectrum cover a continuous wavelength range from 4000 to 7850 Å with a resolving power of about 48 000. Typical maximum S/N values (per pixel) for the spectra are in excess of 150 (see Luck et al 2011).

Two spectra were obtained with the High Accuracy Radial velocity Planet Searcher (HARPS; Mayor et al. 2003) spectrograph mounted at the 3.6 m telescope at the La Silla ESO observatory. HARPS is a fibre-fed, cross-dispersed echelle spectrograph, which provides a resolution R=115.000 with a fixed format covering the 3800–6900 ÅÅ spectral range. The HARPS pipeline delivers science-quality products. In particular, master calibrations are created (master-bias and master-flat

Table 1: O-C residuals for HQ Car

JD	O–C	JD	O–C	JD	O–C
2441769.712	0.83295	24452657.356	0.53173	24453908.499	0.44057
2444258.555	0.69534	24452699.686	0.53979	24454134.693	0.51439
2444679.419	0.60282	24452713.687	0.53473	24454176.811	0.50738
2444960.560	0.58129	24452727.699	0.53045	24454190.726	0.49621
2449524.539	0.90719	24452854.469	0.53899	24454373.890	0.51223
2451899.783	0.69701	24453022.573	0.48481	24454387.864	0.50525
2451913.753	0.68974	24453036.682	0.48743	24454823.804	0.48406
2451970.056	0.69075	24453064.831	0.48776	24454837.755	0.47545
2452054.520	0.69294	24453177.471	0.49219	24455020.527	0.46361
2452335.006	0.62486	24453415.646	0.41740	24455146.849	0.44031
2452558.865	0.53275	24453739.773	0.45055		
2452629.546	0.55549	24453823.769	0.41948		

fields), and data are bias subtracted and divided by the flat field by using the calibrations closest in time to the science observations. Spectral orders are located and extracted, and the wavelength solution obtained using a Thorium-Argon calibration lamp is then applied.

Table 2 contains details concerning our program Cepheid observations.

4. Emission features in spectra of HQ Car

Fig. 3 give the picture of the He I 5875 line variation. As expected, this line appears as a quite strong emission on phase about 1.0, when the shock wave front passes through the photosphere, and then fades away towards the phase 0.3. Since the radiation in 5876 He I line is caused by the electron captures by ionized helium, the gas producing He line emission should be located behind the shock-wave front.

Emission in the hydrogen lines has been noted and detaily examined by many authors. Our Fig. 4 shows the behaviour of the profiles of Hα line. Qualitatively, the behaviour of the Hα profile is similar to that reported by Lebre & Gillet (1992) for W Vir (P = 17.277 d, see also Luck et al. 2011). As it was mentioned above, these authors assumed that this emission component is a single one at all the phases but distorted by two narrow absorptions.

HQ Car with an estimated $|z|$ of 0.3 kpc was listed as a type II Cepheid by Harris (1985).

3. Conclusion

Founded that HQ Car is a type II Cepheid according to the distance from the Galactic plane (Harris 1985), light curve, He I 5876 Å and Balmer lines emission.

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Table 2: Spectral observations of HQ Car

JD	phase	Remarks
2450834.86370	0.361	CTIO
2455284.65800	0.766	FEROS
2456411.53798	0.891	HARPS
2456412.51417	0.961	HARPS

For HARPS spectra:
JDmax=2452784.603+14.06378

References

Berdnikov L.N.: 2008, **VizieR On-line Data Catalog**, UBVRIc-observations

Galazutdinov G.A.: 1992, *Preprint SAO RAS*, **92**, 2

Gingold R.A.: 1985, *Mem.Soc.Astr. Italy*, **56**, 169

Harris H.C.: 1985, *AJ*, **90**, 756

Lébre A. & Gillet D.: 1992, *A&A*, **255**, 221

Luck R.E., Andrievsky S.M., Kovtyukh V.V., Gieren W., Graczyk D.: 2011, *AnJ*, **142**, 51

Mayor M., Pepe F., Queloz D. et al.: 2003, *Messenger*, **114**, 20

Pojmanski G.: 2002, *Acta Astronomica*, **52**, 397

Madore B.F.: 1975, *ApJSS*, **29**, 219

Samus N.N., Durlevich O.V., Kazarovets E.V., Kireeva N.N., Pastukhova E.N., Zharova A.V. et al.: 2011, *General Catalogue of Variable Stars* (GCVS database, Version 2011Jan)

Schmidt E.G., Johnston D., Lee K.M., Langan S., Newman P.R., Snedden S.A.: 2004, *AJ*, **128**, 2988

Yong D., Carney B.W., de Almeida M.L.T., Pohl B.L.: 2006, *AnJ*, **131**, 2256