

# THREE CEPHEIDS IN GALACTIC OPEN CLUSTERS: CHEMICAL COMPOSITION AND EVOLUTION

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**ABSTRACT.** Three classical Cepheids in galactic open clusters (CF Cas, DL Cas and WZ Sgr) were investigated, using high-resolution CCD spectra. Their  $T_{eff}$  and  $E_{B-V}$  estimations have a good agreement with photometrically determined ones. CF Cas and DL Cas have metallicity values, close to those of the Sun, whereas WZ Sgr has overabundant metallicity content with  $Z=0.029$ . Chemical abundance data show that they are the post first dredge-up stars. C and O content and ages have a good agreement with the theoretically predicted values. All these objects have a good fit with the PL relation for galactic Cepheids.

**Key words:** Stars: abundances ; stars: Cepheids in open clusters; stars: individual: CF Cas, DL Cas, WZ Sgr.

## 1. Introduction

Since until now classical Cepheids in galactic open clusters are the calibration objects for "period – luminosity" relation, it would be important to determine spectroscopically their atmospheric parameters and metallicity. It is very appreciably for the faint Cepheids, for which  $T_{eff}$  and metallicity values estimated till recently using multicolour photometries data. In our work we represent the results of investigations for three Cepheids in galactic open clusters: CF Cas (NGC 7790), DL Cas (NGC 129) and WZ Sgr (C1814-191). Thus, there was set the problems:

- 1) To obtain the high-resolution CCD – spectra in different phases of light curve for each Cepheid.
- 2) Using the new method of effective temperature determination, based on the ratio of the spectral line depths (Kovtyukh & Gorlova 2000), to obtain the  $T_{eff}$  estimates for these stars.
- 3) To compare our mean  $T_{eff}$  estimations with ones, obtained from UBV– photometry and to specify the colour excess values.
- 4) On the base of equivalent widths data of Fe I and Fe II lines to determine the gravities and turbulent velocities for these Cepheids, using the atmosphere

Table 1: Program stars spectra

Star	Period (days)	V (mag)	(B-V) (mag)	Number of spectra	Region (Å)
CF Cas	4.88	11.126	1.232	6	5500–7200
DL Cas	8.00	8.964	1.206	12	5500–7200
WZ Sgr	21.85	8.030	1.485	10	5500–7200

V and (B-V) data from Berdnikov (1987)

models from Kurucz (1992) grid and WIDTH 9 code.

5) To calculate the elemental abundance for these Cepheids, drawing the main attention for carbon and oxygen content.

6) To compare our C and O abundance results with theoretically predicted ones from Schaller et al.(1992) evolutionary models grid.

7) To estimate the evolutionary masses and ages for these Cepheids and to determine their evolutionary status.

## 2. The observations and analysis

All spectra was obtained using échelle spectrograph Sandiford, fed by 2.1–m Struve reflector, McDonald Observatory. The resolving power  $R = 60000$ ,  $S/N \approx 100$ . The information concerning the program stars and their CCD spectra is given in Table 1.

Using the IRAF procedure we extracted échelle orders from CCD frames, made dark and cosmic ray hit subtraction, and wavelength calibration. The continuum level drawing, wavelength calibration, equivalent width measurements, – were made using the IBM/PC compatible DECH 20 package (Galazutdinov, 1992).

The atmospheric parameters:

- 1)  $T_{eff}$  were found using the ratio of the depths of spectral lines by the method of Kovtyukh & Gorlova (2000) with an accuracy of  $\pm 10$ –30 K.
- 2) The surface gravities were determined by forcing the Fe I and Fe II to produce the same abundance (within an accuracy of about  $\pm 0.20$  dex).
- 3)  $V_t$  were obtained by forcing the abundances from the Fe II lines to be independent of the equivalent widths (with an accuracy of about  $\pm 0.30$  km s<sup>-1</sup>).

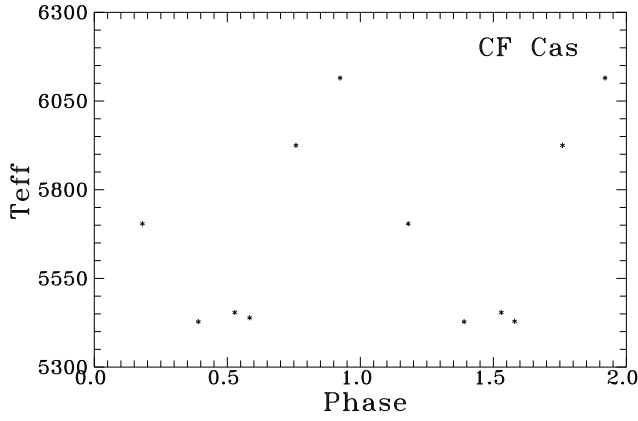


Figure 1: CF Cas effective temperature variation through the pulsation cycle.

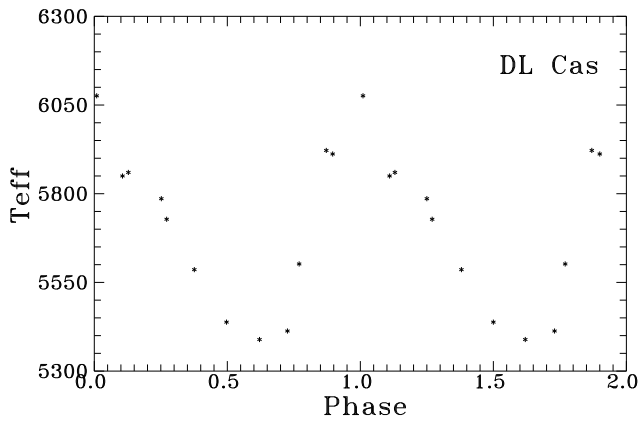


Figure 2: DL Cas effective temperature variation through the pulsation cycle.

Moreover, we have estimated the corresponding  $T_{eff}$  values for this Cepheids using  $BVRI$  photometry data, Bessel, Castelli & Plez (1998) (BCP) calibrations and Grey (1992) relationship:

$$\log T_{eff} = 3.988 - 0.881(B - V) + 2.142(B - V)^2 - 3.614(B - V)^3 + 3.2637(B - V)^4 - 1.4727(B - V)^5 + 0.2600(B - V)^6 \quad (1)$$

All these data and colour-excesses estimates, determined by us and another authors are given in Table 2. In the Figures 1, 2 and 3 we displays the  $T_{eff}$  variations through the pulsation cycles for the investigated Cepheids.

The analysis of chemical composition was carried out using of Kurucz's WIDTH 9 code. Atmosphere models were interpolated from the Kurucz (1992) grid. All the oscillator strengths were so-called "solar"  $\log gf$  values (Kovtyukh & Andrievsky 1999), derived using unblended solar lines. All the data of Cepheids chemical composition are given in Table 3.

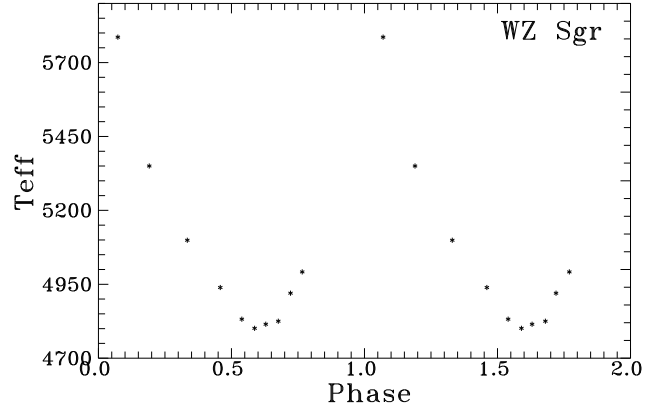


Figure 3: WZ Sgr effective temperature variation through the pulsation cycle.

Table 3: Average abundances for Cepheids.

Element	CF Cas		DL Cas		WZ Sgr	
	[El/H]	$\sigma$	[El/H]	$\sigma$	[El/H]	$\sigma$
C I	-0.19	0.09	-0.31	0.12	+0.03	0.12
O I	+0.06	0.32	-0.01	0.12	+0.13	0.25
Na I	+0.09	0.08	+0.11	0.04	+0.39	0.09
Mg I	-0.21	0.12	+0.11	0.08	+0.01	-
Al I	+0.10	0.00	+0.14	0.16	+0.28	0.17
Si I	+0.01	0.10	+0.02	0.09	+0.28	0.17
Si II	+0.12	0.18	+0.09	0.16	-	-
S I	+0.10	0.19	+0.21	0.29	+0.51	0.24
Ca I	-0.01	0.19	+0.01	0.16	+0.19	0.25
Sc I	+0.16	0.18	-	-	+0.24	-
Sc II	-0.18	0.19	-0.16	0.28	-0.00	-
Ti I	+0.00	0.15	+0.06	0.14	+0.24	0.18
Ti II	-0.02	0.05	-0.22	0.13	+0.16	0.17
V I	-0.04	0.13	+0.02	0.09	+0.20	0.09
V II	-0.19	0.10	-0.19	0.13	+0.04	0.09
Cr I	+0.04	0.16	+0.05	0.08	+0.19	0.21
Cr II	+0.22	0.12	+0.23	0.14	+0.20	-
Mn I	-0.01	0.06	-0.14	0.11	+0.15	0.05
Fe I	-0.01	0.09	-0.01	0.15	+0.17	0.09
Fe II	+0.01	0.10	-0.01	0.14	+0.19	0.08
Co I	-0.15	0.10	-0.04	0.21	+0.12	0.09
Ni I	-0.03	0.10	+0.00	0.11	+0.21	0.09
Cu I	-0.11	0.16	-0.19	-	+0.13	0.18
Zn I	+0.25	0.19	+0.47	0.28	+0.35	-
Y I	-	-	-	-	+0.56	-
Y II	+0.11	0.07	+0.21	0.23	+0.30	0.08
Zr II	-0.19	0.11	+0.16	0.35	-0.08	0.05
La II	+0.14	0.09	+0.16	0.35	+0.24	0.04
Ce II	-0.17	0.13	+0.09	0.26	-0.08	0.08
Nd II	+0.04	0.20	+0.12	0.17	+0.18	0.20
Eu II	+0.06	0.06	+0.11	0.15	+0.15	0.15
Gd II	-0.02	0.15	-0.05	-	+0.08	0.08

Table 2: Atmosphere parameters, colour indices and colour excesses

Star	Our estimations			$E_{B-V}$		Gray		BCP	
	$T_{eff}$	$\log g$	$V_t$	$E_{B-V}$	Other authors	$(B-V)_0$	$T_{eff}$	$(B-V)_0$	$T_{eff}$
CF Cas	5636	1.7	3.8	0.55	0.55 (1)	0.682	5650	0.685	5635
DL Cas	5715	1.7	4.4	0.55	0.50 (2)	0.656	5702	0.660	5725
WZ Sgr	5036	0.7	4.2	0.57	0.56 (3)	0.920	5023	1.030	5025

(1) – Matthews et al. (1995); (2) – Gieren et al. (1994); (3) – Turner et al. (1993)

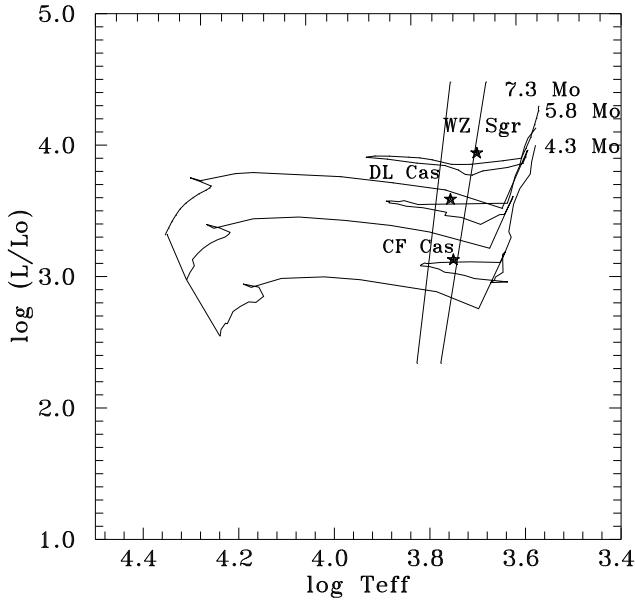


Figure 4: The HR diagram for CF Cas, DL Cas and WZ Sgr. The instability strip edges for fundamental mode pulsation were derived using relations from Chiosi et al. (1992)

Since carbon and oxygen are the best indicators of the evolutionary state of yellow supergiants, it would be interesting to compare our observational data with the theoretically predicted ones from Schaller et al. (1992) evolutionary models grid. All these results are given in Table 4.

As seen from Tables 3 and 4, all these Cepheids are the post first dredge-up yellow supergiants. Therefore their evolutionary masses can be determined from the mass–luminosity relation with overshooting (Antonello & Morelli 1996):

$$\log(L/L_{\odot}) = 3.52\log(M/M_{\odot}) + 0.9; \quad (2)$$

The final results, including our ages estimation from Schaller et al. (1992) evolutionary models grid, are given in Table 5.

In the Figures 4 and 5 we represent the positions of our investigated Cepheids on the HR and PL diagrams, respectively.

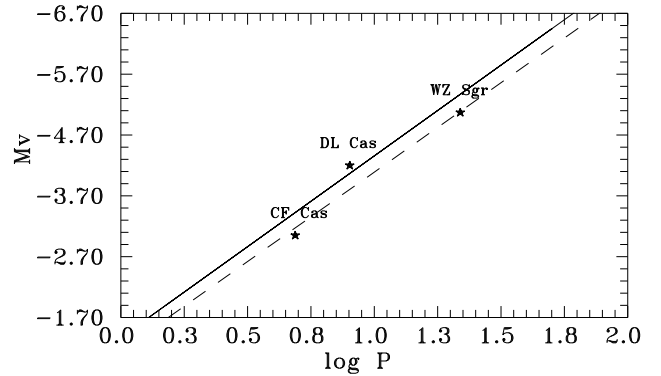


Figure 5: Positions of CF Cas, DL Cas and WZ Sgr on PL diagram. Solid line, – PL relation from Gieren, Barnes & Moffit (1993), dashed, – the same from Turner (1992)

### 3. Conclusions

1) The mean effective temperatures of CF Cas, DL Cas and WZ Sgr, obtained by using of the spectroscopical criterion have a good agreement with ones, determined photometrically.

2) Our colour excesses for CF Cas and WZ Sgr are in good agreement with the estimates of other authors, while for DL Cas it has a slightly more value.

3) CF Cas and DL Cas have metallicity values, close to those of the Sun, whereas WZ Sgr has overabundant metallicity content with  $Z = 0.029$ .

4) Chemical abundance data for all these Cepheids show that they are the post first dredge-up stars. Their carbon and oxygen content have a good agreement with the theoretically predicted ones.

5) Both positions of CF Cas and DL Cas on the HR diagram corresponds to their third crossing of Cepheids instability strip. Position of WZ Sgr is not clear and it might be connected with uncertainty in the distance determination. Moreover, WZ Sgr located near the red edge of the instability strip.

6) The ages of these Cepheids have a good agreement with ones, determined for their open clusters. Their positions on the PL diagram have a good fit with the "period–luminosity" relation for galactic Cepheids.

Table 4: Metallicities and C and O abundances

Star	[Fe/H]	Z	Carbon				Oxygen	
			Carbon		Oxygen			
			Predicted	Observed	Predicted	Observed		
CF Cas	0.00	0.020	-0.175	-0.19±0.09	-0.030	+0.06±0.32		
DL Cas	-0.01	0.020	-0.174	-0.31±0.12	-0.032	-0.01±0.12		
WZ Sgr	+0.18	0.029	-0.181	+0.03±0.12	-0.036	+0.13±0.25		
WZ Sgr ([El/Fe])			-0.181	-0.15±0.12	-0.036	-0.05±0.25		

Table 5: Luminosities, distances, radii, evolutionary masses and ages

Star	$M_V$	d (pc)	$\log(L/L_\odot)$	$R/R_\odot$	$M_{ev}$	$\log t$	$\log t$ (Other authors)
CF Cas	-3.05	3130	3.13	40.6	4.3	8.14	8.0 – 8.1 (1)
DL Cas	-4.20	2034	3.59	66.0	5.8	7.78	7.6 (2)
WZ Sgr	-5.07	1787	3.94	122.9	7.3	7.66	7.3 (3)

(1) – Matthews et al. (1995); (2) – Gieren et al. (1994); (3) – Turner et al. (1993)

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