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SPECTROSCOPICAL STUDY OF FAINT SOUTHERN CEPHEIDS WITH SOUTHERN AFRICAN LARGE TELESCOPE (SALT). FIRST RESULTS.

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ABSTRACT. First Cepheids observations using echelle-spectrograph HRS fed by Southern African Large Telescope (SALT) were realized during 2016. All spectra have been obtained in the medium resoltion mode (R≈31000–41000) wth high S/N ratio near 50–220. All data were processed using package developed by authors based on the standard system of astronomical data reduction MIDAS. Using new echelle data we found the atmosphere parameters and chemical composition for 30 faint Cepheids of southern hemisphere, where for the most of theses stars these results we obtained for the first time. 28 stars are Cepheids after the first-dredge up stage, while ASAS 075842-25336.1 and ASAS 1131714-6605.0 having remarkable Li I 6707.8 Å absorption line and anomalous CNO and Na content could be consider as first crossing of the Cepheids instability strip.

Keywords: Stars: Cepheids: atmosphere parameters; Cepheids: chemical composition

1. Introduction

The abundance gradient for the Galaxy as observational characteristic of the galactic disk is the most input parameter in any theory of galactic chemical evolution. Many questions concerning the present-day abundance distribution in the galactic disk, its spatial properties and evolution with time remain to be answered. To answer these questions it would be reasonably to use the Cepheids as the quite suitable probes of metallicity in the Galactic disc.

According to results of investigations for iron, for example, its abundance gradient displays a multimodal structure: a rather flat part in vicinity of the Sun, a small gradient in the outer part of the disk (here the distribution shows some scatter and all the stars are metal-deficient comparing to the stars from the solar vicinity), and a quite large negative gradient in the inner part of the disk in the range from 4 to 7 kpc, but it with a very small number of investigated stars, and poorer statistics.

Even though elemental abundance increases towards the galactic center, there are arise two questions: 1) what is the real behavior of the abundance distributions within the inner parts (less than 7 kpc) of the galactic disk; 2) what is the real one for the galactocentric distances more than 10 kpc?

Therefore, the main objective of our program is to observe additional Cepheids situated closer to the galactic center and situated too much far away from it in order to:
1) Constrain the metallicity distribution and its gradient in these regions;
2) Find the properties of the abundance distribution at galactocentric distances of less than 7 kpc and more than 10 kpc.
3) To extract the possible objects belonging to the Population II.

To realize this program we have used Southern African Large Telescope (SALT). Our observational

Table 1: List of investigated Cepheids.

Object	Type	P (d)	R_G (kpc)	[Fe/H]	[C/H]	[N/H]	[O/H]	[Na/H]	[Mg/H]	[Al/H]
V1048 Cen	DCEP	1.300	7.44	–0.09	–0.35	+0.38	–0.35	+0.15	–0.12	+0.10
ASAS 114920-6600.6	DCEPS(B)	1.960	7.32	–0.04	–0.20	+0.34	+0.52	+0.12	–0.21	+0.15
ASAS 072424-0751.3	DCEPS	2.071	9.76	–0.19	–0.43	+0.22	-	+0.25	+0.18	+0.02
ASAS 073200-2529.3	DCEPS	2.421	9.25	–0.20	–0.47	+0.14	+0.05	+0.11	–0.20	–0.04
ASAS 174603-3528.1	DCEPS	2.573	6.02	+0.11	+0.04	+0.60	-	+0.41	–0.15	+0.43
ASAS 183652-0907.1	DCEP	2.590	6.55	+0.14	–0.21	+0.42	–0.15	+0.45	+0.16	+0.33
BD-10 4739	DCEP	3.058	6.63	+0.04	–0.24	+0.28	–0.29	+0.30	–0.18	+0.25
104130-5956.9	DCEPS	3.081	7.56	+0.00	–0.26	+0.39	+0.15	+0.18	–0.06	+0.18
V720 Car	DCEP	3.081	7.56	–0.03	–0.27	+0.36	–0.28	+0.17	–0.06	+0.13
ASAS 065851-1344.2	DCEPS	3.280	11.55	–0.29	–0.59	+0.18	–0.35	+0.06	–0.24	–0.09
FZ Car	DCEP	3.578	7.64	+0.05	–0.21	+0.51	–0.28	+0.29	+0.01	+0.21
HD 317966	DCEP	3.720	6.90	+0.08	–0.15	+0.64	–0.23	+0.40	+0.10	+0.23
ASAS 100814-5856.6	DCEPS	3.767	7.78	–0.07	–0.36	+0.24	–0.35	+0.11	+0.02	+0.16
HD 160473	DCEP	3.780	6.81	+0.04	–0.20	+0.51	–0.11	+0.23	+0.10	+0.21
V701 Car	DCEP	4.090	7.71	–0.01	–0.21	+0.51	-	+0.43	+0.00	+0.22
V690 Car	DCEP	4.150	7.85	+0.12	–0.18	+0.46	–0.04	+0.38	+0.04	+0.32
V1210 Cen	DCEP	4.320	6.88	+0.08	–0.08	+0.16	–0.25	+0.15	+0.39	+0.32
GI Car	DCEP	4.431	7.48	–0.04	–0.33	+0.34	–0.31	+0.18	–0.09	+0.13
CC Car	DCEP	4.760	7.76	+0.09	–0.17	+0.47	–0.28	+0.30	–0.06	+0.33
ASAS 182714-1507.1	DCEP	5.550	6.02	+0.32	–0.01	+0.90	–0.26	+0.67	+0.23	+0.58
ASAS 123617-6317.6	DCEPS	6.166	6.86	+0.09	–0.21	+0.47	-	+0.34	+0.22	+0.32
RS Nor	DCEP	6.198	6.26	+0.15	–0.11	+0.60	+0.32	+0.54	+0.11	+0.37
ASAS 070832-1454.5	DCEPS	6.388	9.58	–0.06	–0.38	+0.26	–0.52	+0.15	–0.26	+0.11
ASAS 092758-5218.9	DCEP	7.640	8.33	+0.05	–0.19	+0.35	-	+0.35	+0.22	+0.26
ASAS 093942-4931.5	DCEPS	7.754	8.08	–0.01	–0.24	+0.43	–0.28	+0.18	–0.00	+0.18
VX Cru	DCEP	12.213	6.78	+0.24	–0.03	+0.67	–0.09	+0.68	+0.25	+0.46
ASAS 083611-3903.7	DCEP	12.960	8.39	–0.08	–0.37	+0.13	–0.09	+0.10	–0.03	+0.08
VW Cen	DCEP	15.036	6.28	+0.38	+0.15	+0.74	–0.19	+0.67	+0.18	+0.53
ASAS 075842-2536.1	DCEPS(B)	0.580	9.03	–0.17	–0.30	–0.14	–0.06	–0.14	–0.46	+0.06
ASAS 131714-6605.0	DCEPS	1.290	6.85	+0.05	–0.17	+0.68	+0.01	+0.36	–0.05	+0.40

list contains 168 Cepheids located at galactocentric distances smaller than 7 kpc and more than 10 kpc (Mel'nik et al., 2015). They are to be bright enough to be accessible with SALT.

2. Observations, data reducing and objects selection

All observations have been **taken** using 11m SALT (Southern African Large Telescope) equipped by HRS (High Resolution Spectrograph). HRS is a dual-beam (3700-5500 & 5500-8900 ÅÅ) fiber-fed, white-pupil, echelle-spectrograph, employing VHP gratings as cross dispersers. We obtained even one spectrum for each Cepheid using *medium mode* spectral resolution (R = 40000), mean S/N = 100 and more, and it could be enough to resolve our observational tasks. These spectra will be used to obtain the atmosphere parameters and chemical composition of these unexplored yellow supergiants. The data were reduced using the *échelle* package which consist of huge amount of basic procedures for echelle data reduction. *FEROS* is another package and it was developed for the reduction of of echelle data from Fiber-fed Extended Range Optical Spectrograph (FEROS). FEROS looks very similar to HRS and both instruments have very close type of echelle data.

DECH30 package (Galazutdinov, 2007) allows to measure the line depths and radial velocities using spectra in FITS format. Lines depths were used to determine the effective temperature (a method based on the spectroscopic criteria, Kovtyukh, 2007).

78 objects with magnitude $10^m \leq V \leq 12.^m5$ have been selected from GCVS, ASAS and 2MASS catalogues. At now we have the results for spectra of 30 Cepheids. All these data are given in Table 1.

3. Atmosphere parameters and chemical composition

3.1. Methods

The effective temperatures T_{eff} were determined by a method based on the depth ratios of selected pairs of spectral lines most sensitive to the temperature. Several spectroscopic criteria (Kovtyukh, 2007) were used in this case. This method provide an internal accuracy of 10 – 30 K for T_{eff} (the error of the mean). The microturbulent velocity V_t was determined from the condition for the Fe I abundance derived from a set of lines being independent of their equivalent widths. The surface gravity $\log g$ was determined from the ionization equilibrium condition for Fe I and Fe II atoms.

When estimating the atmospheric parameters and chemical abundances, we used the VALD oscillator strengths (Kupka et al., 1999) and model atmospheres from Castelli & Kurucz (2004).

3.2. RS Nor as a testing object

We used RS Nor as a testing object **since** its atmosphere parameters and chemical composition were determined earlier by Luck (2014). Our carbon and oxygen abundances estimations are close to ones from Luck (2014) paper, thereas sodium and iron show some less values ([Na/H] = +0.77 and [Fe/H] = +0.23 from Luck paper). All our data are given in Table 1.

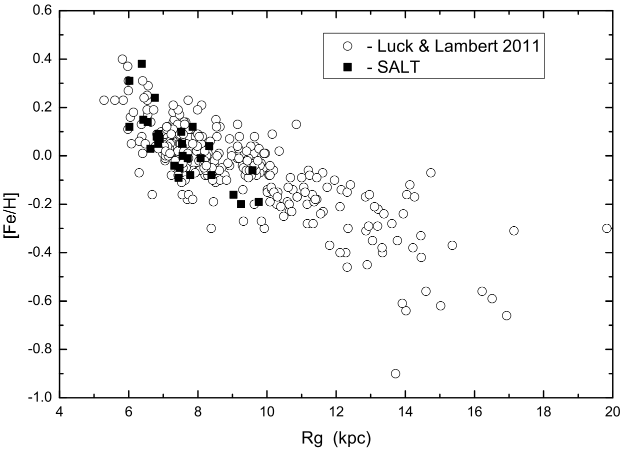

Figure 1: Metallicity gradient of Galaxy according to Cepheids [Fe/H] values. Open circles – Luck & Lambert (2011), filled squares – SALT data.

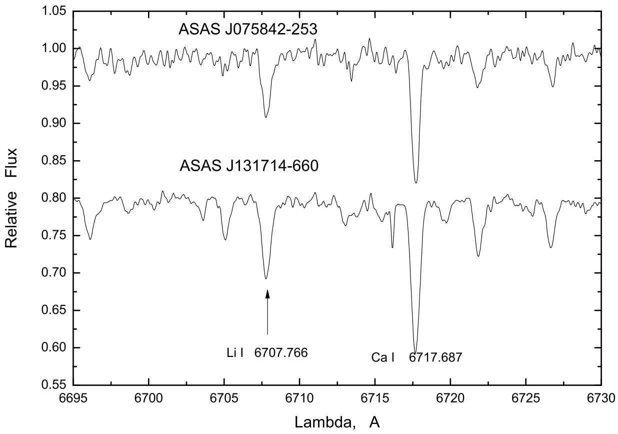

Figure 2: Spectral region around the 6707.8 Å Li I line in the spectra of ASAS 075842-2536.1 and ASAS 131714-6605.0.

4. Conclusions

Our analysis of the available spectra **results** to the following conclusions:

1. As seen from Table 1 all objects have metallicity values within the ranges of –0.3 – +0.4 dex that is an evidence of their belonging to Population I.

2. Our [Fe/H] estimates for these Cepheids are in good agreement with Luck & Lambert (2011) data for iron abundance gradient of Galaxy.

3. CNO- elements abundances in the whole show the typical values for yellow supergiants after first dredge-up stage. Carbon is in deficient, excepting ASAS 174603-3528.1, ASAS 182714-1507.1 and VW Cen. These Cepheids have metallicity overabundance and their [C/Fe] relation give the deficient too. Nitrogen demoinstrates overbundance except of case for ASAS 075842-2536.1. There are significant discrepancies of oxygen from the solar value.

4. Sodium is in overabundace, exept ASAS 075842-2536.1. Magnesium abundance shows discrepances and aluminium content is overabundant in most cases except for ASAS 073200-2529.3 and ASAS 065851-1344.2

5. Objects ASAS 075842-2536.1 and ASAS 131714-6605.0 have remarkable absorption line of lithium 6707.8 Å (see Figure 2), and anomalous CNO and Na content. Quite probably these stars are Cepheids, first time crossing the Cepheids instability strip (CIS).

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