IS THE SMALL–AMPLITUDE CEPHEID SZ TAU A POSSIBLE OVERTONE PULSATOR?

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On the base of 8 high-resolution CCD spectra, obtained by the 6-m telescope of SAO RAS (Russia) and 4-m telescope of KPNO (USA), we have determined the mean values of atmospheric parameters for small-amplitude Cepheid SZ Tau. Since SZ Tau is a member of NGC 1647 open cluster and calibrating object for "period – luminosity" relation, it is very important to specify the former [6] supposition that this Cepheid is an overtone pulsator, thereas [5] *HIPPARCOS* data provides fundamental tone for it. The mean $T_{\rm eff}$ and $\log g$ values determined spectroscopically can confirm this fact, in case that if the Turner's distance value for SZ Tau is true. Nevertheless, the chemical composition analysis shows that SZ Tau is the Cepheid in post red supergiant stage. The evolutionary stage of this object is discussed.

INTRODUCTION

The $3^{d}\!.15$ small-amplitude Cepheid (DCEPS) SZ Tau belongs to the galactic NGC 1647 open cluster. A connection between the distance to open cluster and absolute magnitude value for SZ Tau, – 542 ± 4 pc and $-3^{m}\!.09 \pm 0^{m}\!.04$ is considered in [6]. Combination of these data with the different SZ Tau radius values from 34.2 $R_{\odot}$ to 40.42 $R_{\odot}$ [6] has suspected it as overtone pulsator. According to period-luminosity relation for Cepheids open clusters $M_V = -1.15 - 2.94 \log P_0$, derived in [6], this DCEPS is a pulsator in *first* overtone. But for determination of luminosity and distance values, Turner [6] has used photoelectric UBV photometry data. Since the interstellar reddening is very irregular in the cluster area and SZ Tau is a marginal object, Turner's $E_{B-V} = 0^{m}\!.29 \pm 0^{m}\!.01$ value may be mistaken. And this fact, for in turn, has an influence on interpretation of SZ Tau pulsation tone. Nevertheless, [5] using *HIPPARCOS* trigonometric parallax value, estimated the distance to SZ Tau near 321 pc with corresponding values $M_V = -1^{m}\!.94$ and $E_{B-V} = 0^{m}\!.294$, respectively.

Therefore, we have set the following tasks for SZ Tau investigations:

• Using high-resolution spectrograms of this object, to determine its atmosphere parameters. The most interesting are the mean $T_{\rm eff}$ and $\log g$ values.

• To compare these data with those ones, obtained by other authors. To determine the luminosity value and to interpret the pulsation tone.

• To make the analysis of metallicity and CNO–elements abundance, as the key indicators of yellow supergiants evolution.

OBSERVATIONS AND RESULTS

In this work we have used high-resolution spectra of SZ Tau (echelle-spectrometer LYNX, 6-m telescope of SAO RAS; resolving power 24000, S/N $\approx 70-100$; and 4-m telescope KPNO; resolving power 80000, S/N ≈ 110, respectively). The CCD spectra have been reduced using the DECH20 code. In our analysis, we did not use lines with equivalent widths greater than 150 mÅ. The internal accuracy of the equivalent widths is of the order of 5–10%. This estimate is based on the comparison of values derived from the lines present in two overlapping spectral orders.

A modified method of the spectroscopic analysis has been applied for SZ Tau. This method is described in detail by [1]. The principal difference between modified approach and standard technique of the spectroscopic analysis consists in the usage of Fe II lines for microturbulent velocity and gravity determination, instead of Fe I lines that are usually applied for this aim, but more affected by non-LTE effects. The use of Fe II lines, which seems to be free from significal influence of non-LTE effects, allows one to avoid some problems of standard spectroscopic analysis giving physically more acceptable results. Specially developed method of the $T_{\rm eff}$ determination based on the use of different spectroscopic criteria ([2] for yellow supergiants has been used in present study to derive this important atmosphere parameter for SZ Tau. WIDTH 9 code ([4] and Kurucz's grid of atmosphere models were employed to calculate the relative iron and CNO–elements content for this Cepheid. The results of calculations are presented in Table 1.

Table 1: Atmosphere parameters, Fe and CNO content for SZ Tau

Spectrum, No.	Phase (*)	$T_{\rm eff}$	$\log g$	V_t	[Fe/H]	[C/H]	[N/H]	[O/H]
s15907 (SAO)	0.812	6075	2.20	4.70	+0.05	–0.19	+0.59	–0.19
s15908 (SAO)	0.820	6075	2.20	4.70	+0.05			
1 (KPNO)	0.963	6207	2.10	3.60	–0.01	–0.25	+0.51	–0.29
2 (KPNO)	0.279	5994	2.30	3.70	+0.03	–0.25	+0.43	+0.02
3 (KPNO)	0.593	5839	2.00	3.60	+0.04	–0.26	+0.47	–0.05
4 (KPNO)	0.924	6170	2.30	4.30	–0.01	–0.17	+0.42	–0.03
5 (KPNO)	0.237	6037	2.10	3.50	–0.03			
6 (KPNO)	0.549	5811	2.00	4.00	+0.03	–0.29	+0.43	+0.07
Mean		6042	2.15	4.00				

Reference: * – Phases values from [3]

DISCUSSION

Thus, we can conclude that:

1) Using the 8 high-resolution spectra, obtained on the different points of SZ Tau phase curve, we have obtained the mean value of $T_{\rm eff} = 6042$ K. This result has a good agreement with [6] one (6062 K), determined by multicolour photoelectric photometry.

2) Luminosity values, derived from different radius estimates, show that SZ Tau position on the P – L diagram is very vague. If [6] data are true ($M_V = -3.^m09 \pm 0.^m04$), then they really corresponded to pulsation in the *first* overtone. On the contrary, in case of [5] distance value ($M_V = -1.^m94$), SZ Tau pulsates in *fundamental* tone. The same conclusion we can make, estimating the mean $\log g$ value.

3) Abundance analysis shows that SZ Tau has solar metallicity, but CNO–elements content is testified to fact that the DCEPS is the post red giant star and it crossed Cepheids instability strip not for the first time.

4) SZ Tau evolutionary mass values lie in range from 3.7 to 5 $M_\odot$. Comparison with evolutionary tracks for a such mass value with $Z = 0.02$ testifies that the best fit for the cause of second crossing of Cepheids instability strip corresponds to mean radius values 38.6 $R_\odot$ for 5 $M_\odot$ and 27.8 $R_\odot$ for 4 $M_\odot$.

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