δ SCUTI COMPONENTS IN ECLIPSING BINARY SYSTEMS

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Introduction

δ Sct stars are remarkable objects for asteroseismology because of their pulsation characteristics and positions in the Hertzprung-Russell (H-R) diagram. It is known that about 70% of stars are binaries or in multiple systems [1,2,3]. Therefore it is possible to find δ Sct variables as members of binary systems. Particularly, existence of a pulsating star in an eclipsing binary system makes this variable more valuable. This kind of systems exhibits both eclipse and pulsation features. Utilizing these features of eclipsing binaries with a pulsation component, the accurate fundamental parameters of binary components (e.g. mass, radius) can be derived by modeling their light and radial velocity curves in addition to pulsation frequency analysis. Thus, the stellar structure and evolutionary status can be examined and understood in a great detail. Therefore, in this study we focus on δ Sct components of eclipsing binaries. The spectroscopic analysis of 6 δ Sct stars in eclipsing binary systems and the revised list of this kind of objects are presented in the study.

Spectroscopic Analysis

The spectral analysis of 6 eclipsing binaries with a δ Sct component were performed. The spectra of systems were taken with a single order coudé spectrograph attached to the 2 meter telescope which is at the Ondrejov observatory (Czech Republic). The resolving power of the instrument is about 25000 at Hγ wavelength. Our observations were taken in 4272-4506 wavelength region which covers Hγ and metal lines of Ti, Mg and Fe. For each star, we obtained two spectra approximately at 0.5 orbital phase to decrease the light contributions of secondary components in the spectra. Thus only the spectra of primary pulsating components were tried to be obtained. The S/N ratios of taken spectra vary between ~40 and 120.

The spectral classifications of primary components were derived. Before the spectral analysis, initial atmospheric parameters (effective temperature T_{eff}, surface gravity logg) were derived from the de-reddened indices of Johnson, 2MASS and Strömgren photometric systems by using the methods of [4], [5] and [6], respectively. The spectroscopic T_{eff} and logg values were obtained by the analysis of Hγ line using the method described in [7]. These parameters were fixed in the metallicity analysis and the metallicity of primary components were determined by using the spectroscopy made easy (SME) code [8]. In the spectral analysis, plane-parallel, LTE synthetic models were generated by ATLAS9 code [9]. The line list was taken from the Vienna Atomic line database (VALD) [10]. The obtained parameters of stars are given in Table 1.

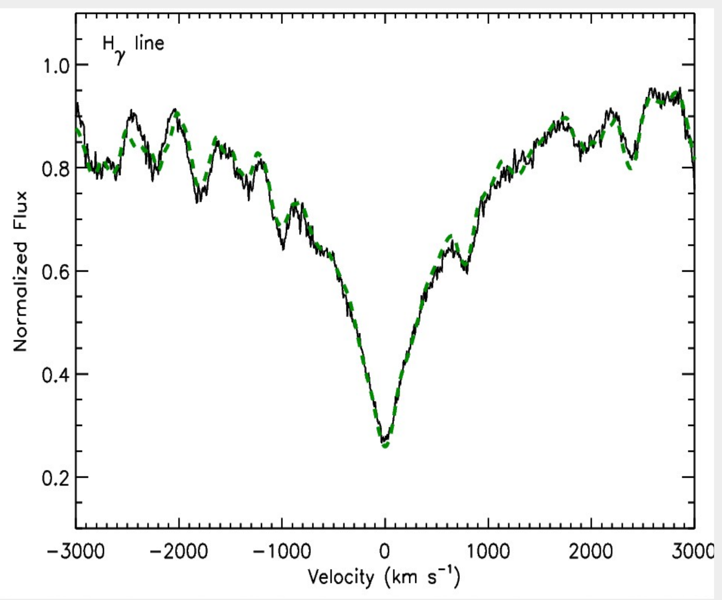

Figure 1. Comparison of the theoretical (dashed-line) and observed Hγ line spectra (solid line) of HL Dra.

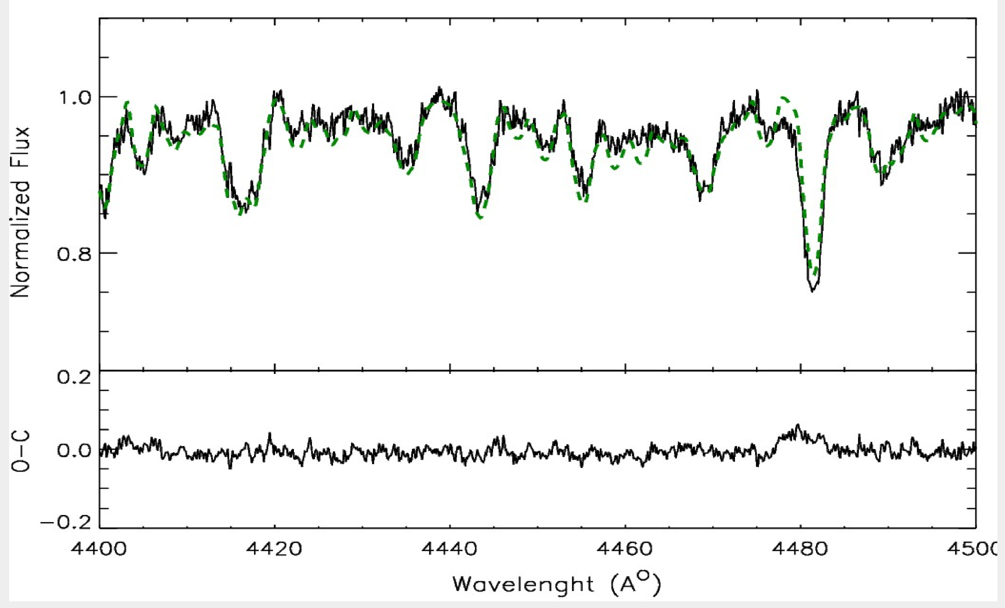

Figure 2. Comparison of the theoretical (dashed-line) and observed spectra (solid line) of HL Dra (upper panel) and difference between them (lower panel).

Table 1. The derived parameters of δ Sct components.

Name	V [mag]	E(B-V) [mag]	Sp type [Simbad]	Sp type [this study]	T_{eff} av* [K]	T_{eff} H line [K]	logg [dex]	Vsini [km/s]	[m/H] [dex]
HL Dra	7.36	0.019	A5	A6IV	7750	7800±200	3.8^a	107±10	-0.121±0.170
HZ Dra	8.14	0.011	A0	A8/A7V	7600	7700±200	4.0^b	120±10	-0.086±0.170
XX Cep	9.18	0.016	A7V	A7V	7300	8200±300	4.1±0.3	54±5	0.594±0.170
TZ Dra	9.32		A7V	A7V		7800±200	4.0^b	86±8	-0.008±0.160
CL Lyn	9.77	0.128	A5	A8IV	7600	7600±300	4.0^b	75±3	-0.160±0.170
UW Cyg	10.86		A5	A7/A6IV		7800±350	4.0^b	45±10	**

* Average value of T_{eff} calculated by photometric indices ** [m/H] parameter could not be derived because of low S/N ratio. [a] logg value taken from uvbyβ calculation. [b] assumed, because hydrogen lines are insensitive to logg when T_{eff} value of a star is lower than the 8000 K [11] [12].

δ Sct Components in Eclipsing Binaries

The revised list of eclipsing binaries with δ Sct components was obtained by searching the literature. Thus the parameters of 96 eclipsing binary systems with δ Sct components were gathered. The list also contains the our analyzed stars which are given in Table 1. The T_{eff}, logg, masses (M), radii (R), luminosities (L), bolometric magnitudes (M_{bol}), semi-major axes (a), filling factors (f), projected rotational velocities (Vsini), pulsation amplitudes and periods of pulsating primary components and parallaxes, orbital inclinations (i), mass ratios (q) of binary systems were collected in addition to visual magnitudes (V), spectral types and eclipsing binary types.

The spectral types of stars were found between A0 and F5, while they are mostly clustered at about A7. 62 of all stars are semi-detached systems, while 18 and 16 of them are detached and unclassified types of eclipsing binaries. δ Sct type pulsating components in eclipsing binary systems mainly pulsate in periods between ~0.016 and 0.147 d^{-1}, with approximately 20 mmag average amplitude. The average pulsation periods for semi-detached and detached systems were obtained to be 0.049 and 0.095 d^{-1}, respectively. T_{eff}, logg and Vsini ranges of δ Sct components in eclipsing binaries were illustrated in Figure 3. Both photometric and spectroscopic T_{eff} and logg values almost have same ranges which are in 6750-9660 K and 3.40-4.38 dex, respectively. The Vsini values of these δ Sct components were also obtained between 12 and 130 km/s. Additionally, the M and R parameters were found in ranges of 1.46-3.30 and 1.57-4.24, respectively.

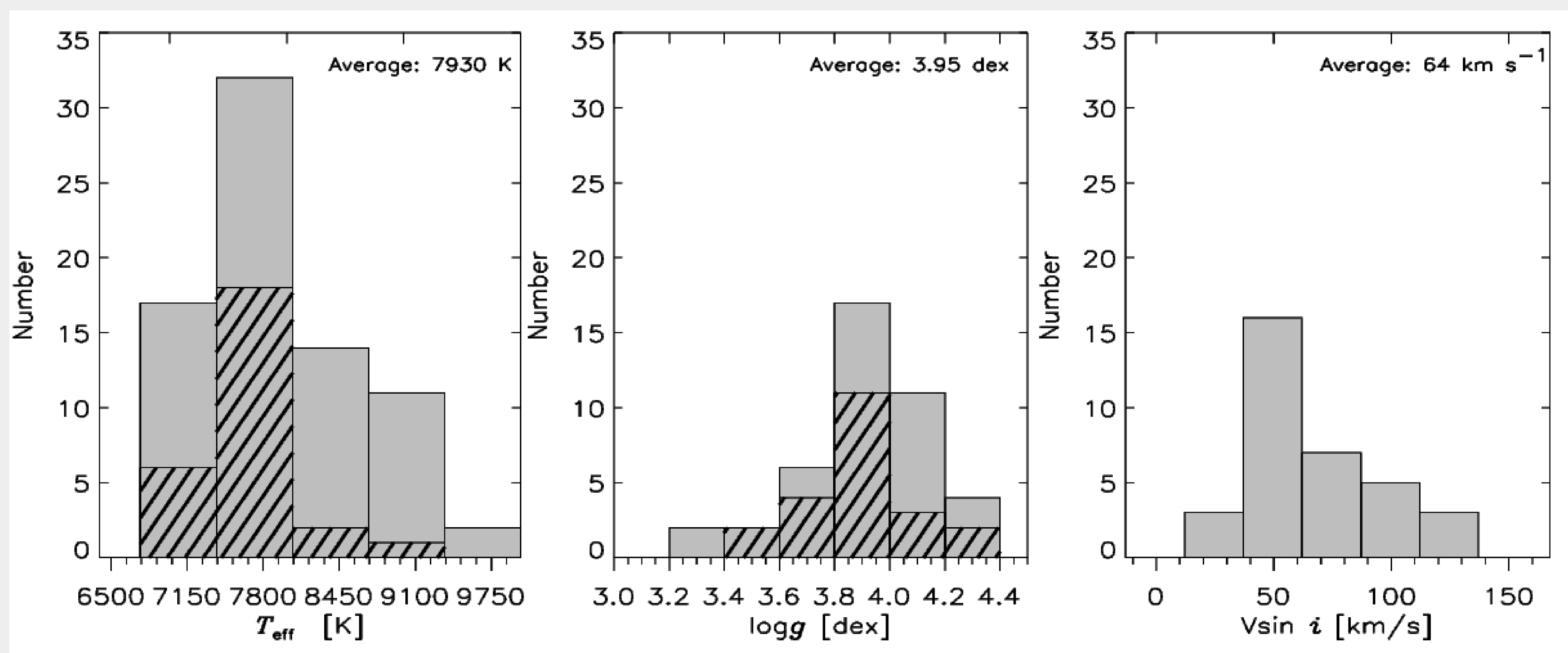

Figure 3. The distributions of T_{eff}, logg, and Vsini values of the eclipsing binary stars with a δ Sct component. The gray histograms show the distribution of whole sample, while slanted lines represent distributions of the stars that have accurate T_{eff} and logg values.

Conclusion

The revised list of eclipsing binary stars with a δ Sct component and the analysis of 6 of this type of stars are presented. Consequently we found that:

- T_{eff} value of primary component is generally fixed in the light curve analysis. Therefore, its wrong value changes all results (e. g., mass, radius). When we compared T_{eff} obtained by us with values in the literature, we noticed that if T_{eff} are not determined using a spectral analysis or a spectral classification, T_{eff} values used in light curve analysis differ by about 1500 K from our results.
- The spectral type range of δ Sct components of eclipsing binaries is almost same with spectral type range of single δ Sct stars.
- Pulsation periods of δ Sct stars in eclipsing binaries are between ~0.016 and 0.147 d^{-1}, while single δ Sct stars' periods range from ~0.016 to 0.288 d^{-1} [13]. This result shows that the single δ Sct stars pulsate in longer periods.

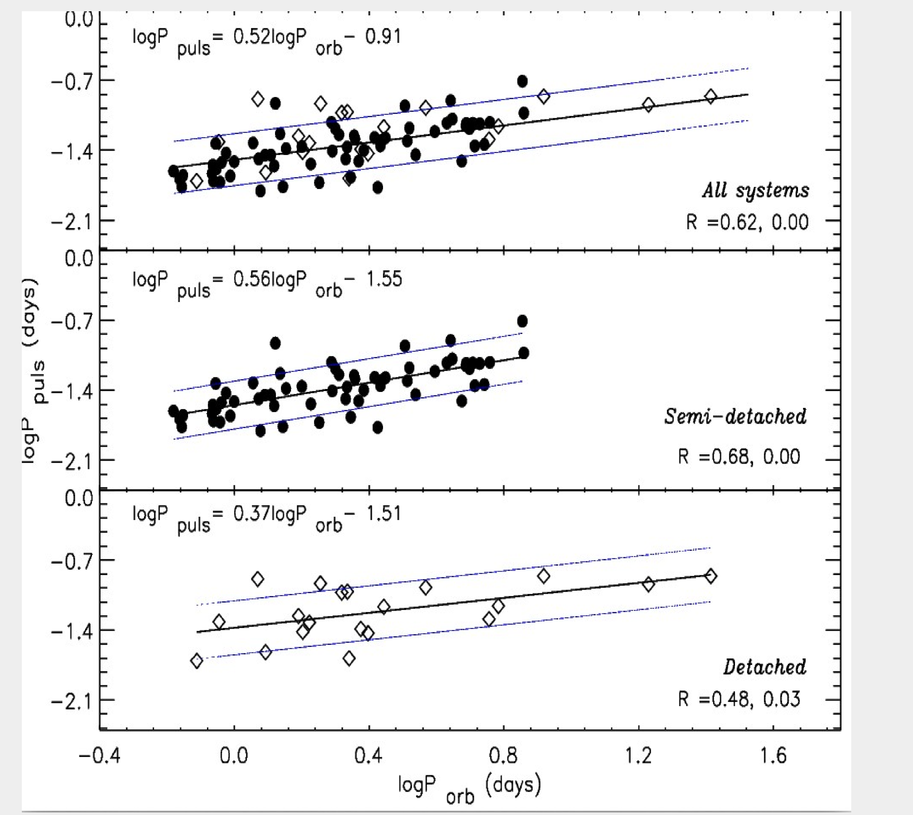

Figure 4. The relations between P_{puls} and P_{orb} for detached (lower panel), semi-detached (middle panel) and all systems (upper panel). The blue dotted lines represent the 1-σ levels. The equations given in each panel were obtained from the correlations. The R constant gives the strength of correlation (first number) and the deviation amount of points from the correlation (second number).

- We found that amplitudes of single δ Sct stars (~2-250 mmag) [13] are mostly higher than amplitudes of δ Sct stars in eclipsing binaries (~3-60 mmag) (High amplitude δ Sct stars (HADS) were omitted).
- The average period of detached systems (~0.095 d^{-1}) is longer than the average period of semi-detached systems (~0.045d^{-1}). This and above item show us effects of he secondary component and tidal distortion on pulsation.
- The range and average values of Vsini of δ Sct stars in eclipsing binaries are from 12 to 130 km/s and ~64 km/s, respectively, while these values are between 12 and 285 km/s and ~90 km/s for single δ Sct stars [13]. The single δ Sct stars rotate faster than δ Sct components in eclipsing binaries.

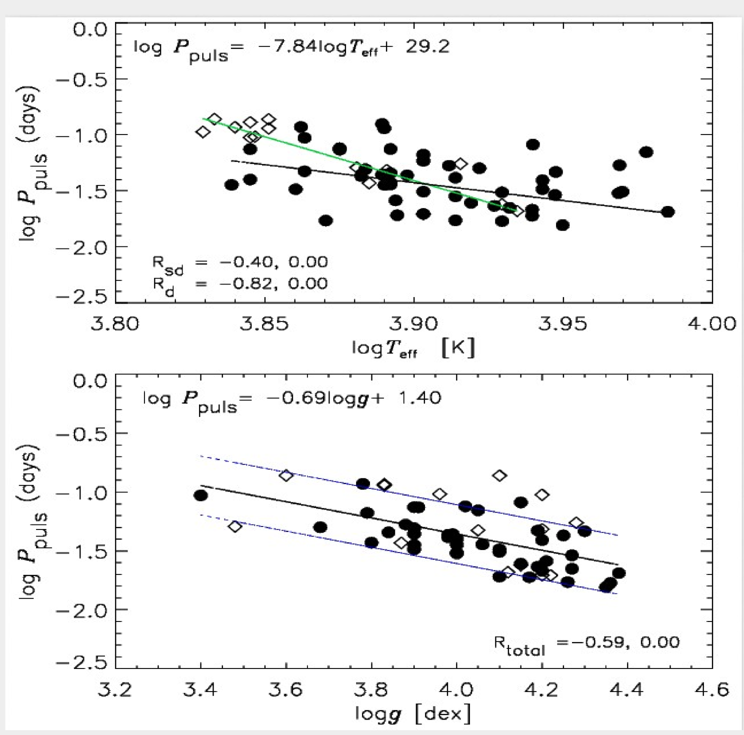

Figure 5. The T_{eff} - $\log P_{puls}$ (upper panel) and log g - $\log P_{puls}$ (lower panel) relations. Green dotted line in upper panel illustrates the correlation for detached systems, while black line shows semi-detached systems' correlation. The equations in upper and lower panels are given for detached and all systems' correlations, respectively. The blue lines, symbols and R constant are same as in Fig.4.

- Positive correlations between pulsation (P_{puls}) and orbital (P_{orb}) periods were found for detached and semi-detached systems as shown in Figure 4.
- We found that the pulsation amplitude also increases with the growing P_{orb}.
- Significant relations between T_{eff}, logg and P_{puls} were obtained as shown in Figure 5. These relations were also found for single δ Sct stars [14] [15].
- A positive correlation between radii and P_{puls} and a negative correlation between masses and P_{puls} of stars were obtained.
- Mass ratios (q) of binaries and P_{puls} relation was examined and it turned out that while q has not effect on P_{puls} in semi-detached systems, it affects P_{puls} of detached systems.
- The Vsini and P_{puls} relation was found as shown in Figure 6. According to relation P_{puls} decreases with increasing Vsini in detached systems. The same relation was examined for single δ Sct stars by [16]. However, they found an opposite relation.

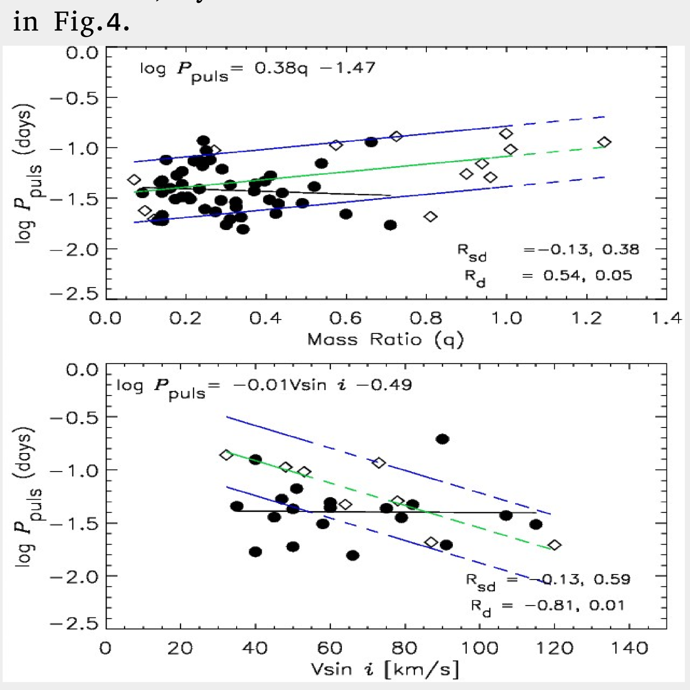

Figure 6. The q - $\log P_{puls}$ (upper panel) and Vsini– $\log P_{puls}$ (lower panel) relations. Green lines illustrate the correlations for detached systems, while black lines show semi-detached systems' correlations. The equations in each panel were derived from the correlations of detached systems. The blue dotted lines, symbols and R constant are same as in Fig. 4.

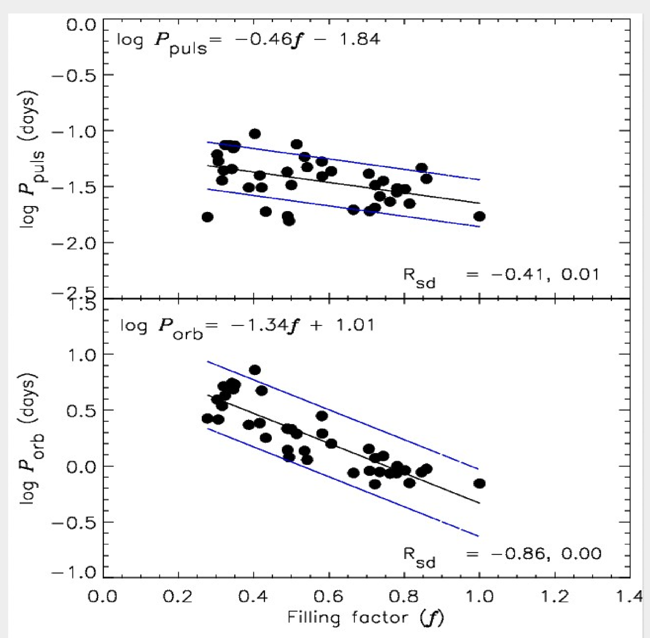

Figure 7. The relation between f and $\log P_{puls}$ for semi-detached systems. The equations in the panels were derived from the correlations for semi-detached systems. The blue dotted lines and R constant is same as in Fig. 4.

Relation between filling factor (f) and P_{puls} was examined. According to [17] there should be a direct correlation between f and P_{puls}. However, it was not found but a negative correlation was obtained, besides we showed that P_{orb} has more effect on the pulsation than f. These correlations are all shown in the Figure 7.

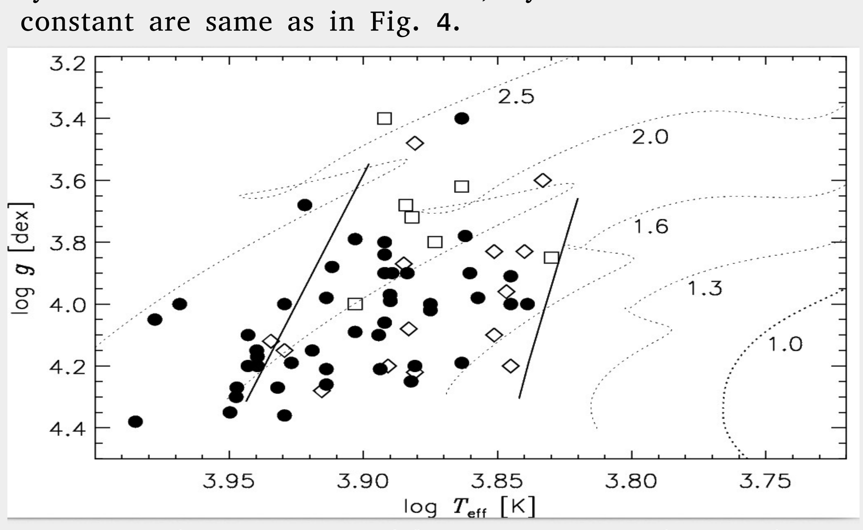

Figure 8. The positions of δ Sct stars in eclipsing binary systems. The symbols are same as in Fig. 4 and squares represent unclassified eclipsing binaries. Solid lines show the theoretical instability strips of δ Scuti stars [18].

The positions of δ Sct stars in eclipsing binary systems were examined as well. As shown in Figure 8, δ Sct stars are mostly located on their own instability strips. The stars beyond the blue edge have the parameters which were determined from light curve analysis and were not reliable.

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