

New Elements for Double- and Multimode High-Amplitude Delta Scuti Variables

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#	Name	Other	Coord (J2000)	Type	Max	Min	System	Period	Epoch (JD)	type	Sp	Comment	L.Curve	Find.Chart	Data
1		TYC 2420 00093 1	06 12 13.90, +31 48 24.4	HADS(B)	12.89	13.20	WASP	(see Comments)	(see Comments)	max		Comm. 1	1.PNG	chart1.PNG	1SWASP_data_1.txt
2		TYC 7805 00075 1	14 28 21.58, -38 12 14.5	HADS	9.89	10.09	WASP	(see Comments)	(see Comments)	max		Comm. 2	2.PNG	chart2.PNG	1SWASP_data_2.txt ASAS 142822-3812.3
3		TYC 8699 00544 1	15 23 15.43, -56 03 43.2	HADS(B)	11.22	11.57	V	(see Comments)	(see Comments)	max		Comm. 3	3.PNG	chart3.PNG	ASAS 152315-5603.7
4		GSC 3881-00874	16 29 40.31, +57 20 33.3	HADS(B)	13.24	13.48	WASP	(see Comments)	(see Comments)	max		Comm. 4	4.PNG	chart4.PNG	1SWASP_data_4.txt CSS_data_4.txt
5	NSV 09856	GSC 7378-01754, HV 10309	17 56 00.20, -30 42 46.6	HADS(B)	12.10	12.50	V	(see Comments)	(see Comments)	max		Comm. 5	5.PNG		ASAS 175600-3042.8
6		GSC 6905-01641	20 10 22.51, -23 10 59.7	HADS(B)	14.84	15.29	CV	(see Comments)	(see Comments)	max		Comm. 6	6.PNG	chart6.PNG	CSS_SSS_data_6.txt
7		TYC 2706 01244 1	21 12 53.68, +33 17 34.3	HADS(B)	10.47	10.69	WASP	(see Comments)	(see Comments)	max		Comm. 7	7.PNG	chart7.PNG	1SWASP_data_7.txt NSVS 8673444 NSVS 8691341

Comments:

1. The variability of GSC 2420-00093 was discovered by Pribik & Brat (2009). The variable was classified as a HADS(B) variable, pulsating in the fundamental and first overtone modes with one additional frequency. Pribik & Brat give the following light elements:

HJD(max) 2454758.4180 + 0.07105196×E (fundamental mode period);

HJD(max) 2454758.4072 + 0.05503008×E (first overtone period);

HJD(max) 2454758.4170 + 0.04250400×E (additional period).

I re-analyzed 1SWASP data and confirm the HADS(B) nature of this variable as well as two of the three periods (the fundamental and first-overtone ones). It is actually a triple-mode HADS(B) star, pulsating in the fundamental, first, and second overtone modes. The additional period suggested by Pribik & Brat (2009) is a one-day alias of the real second overtone period (see the Table). Confidently identified are also frequencies related to interactions between the three main modes: $f_1 - f_0$, $f_2 - f_0$, $f_1 + f_0$, $f_2 + f_0$. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, WASP mag	Period, days	Epoch, HJD
f_0	14.07349	0.079	0.0710556	2454100.533
f_1	18.17151	0.027	0.0550312	2454100.525
f_2	22.52663	0.016	0.0443919	2454100.5395
$f_1 - f_0$	4.09803	0.009	0.24402(0)	2454100.523
$f_2 - f_0$	8.45316	0.005	0.118299	2454100.576
$f_1 + f_0$	32.24496	0.005	0.0310126	2454100.5255
$f_2 + f_0$	36.6001	0.004	0.0273223	2454100.508

$P_1/P_0 = 0.7745$, $P_2/P_1 = 0.8067$. $B-V = 0.010$ (Tycho2), $J-K = 0.248$ (2MASS). In our Galaxy, this is the fourth case of a triple-mode HADS(B) star, along with the previously known DO CMi (Wils et al. 2008), V829 Aql (Handler et al. 1998), and the newly discovered TYC 3144-595-1 (Ulusoy et al. 2013).

2. The variability of TYC 7805 00075 1 was discovered by Pojmanski (2002). The ASAS-3 catalog lists the variable as a DSCT star with the elements HJD(max) 2451903.31 + 0.166993×E. I reinvestigated the star using the currently available 1SWASP and ASAS-3 data. I confirm the delta Scuti nature and the fundamental period of this variable. A secondary wave (possibly nonradial) is superimposed on the fundamental pulsation. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, mag	Period, days	Epoch, HJD
f_1	5.988124	0.081 (WASP), 0.078 (V, ASAS)	0.1669972	2455200.003

f_2	9.69979	0.007 (WASP), 0.007 (V, ASAS)	0.103095	2455200.067
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The period ratio is: $P_2/P_1 = 0.6173$. f_2 is possibly a nonradial pulsation; its identification with the second overtone mode is not excluded. Also not excluded are other weak pulsations, with the periods of 0.0997346 days, 0.1822313 days, 0.0995966 days and small amplitudes. $B-V = 0.411$ (Tycho2), $J-K = 0.174$ (2MASS). From the ASAS-3 data, the variability range is $9^m.66 - 9^m.89$ (V). The WASP data from different time intervals exhibit considerable differences of the mean brightness; my analysis was based on one of them, JD2454148–2454274.

3. The variability of TYC 8699 00544 1 was discovered by Pojmanski (2002). The ASAS-3 catalog lists the variable as a DSCT star with the elements HJD(max) 2451920.154 + 0.126749×E. I reinvestigated the star using the currently available ASAS-3 data. It is actually a high-amplitude double-mode Delta Scuti star. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, V mag	Period, days	Epoch, HJD
f_0	7.889752	0.107	0.1267467	2453600.5683
f_1	10.238370	0.030	0.0976718	2453600.577

The period ratio of the first overtone and fundamental modes is $P_1 / P_0 = 0.7706$. $B-V = 0.397$ (Tycho2), $J-K = 0.224$ (2MASS).

4. The variability of GSC 3881-00874 was reported in 2012 by P. Wils in the [VSX database](#) (BPS BS 16084-151) according to 1SWASP data (Butters et al. 2010). The star was classified by the discoverer as a DSCT star with the light elements: HJD(max) 2454286.400 + 0.061144×E. I reinvestigated the star using the currently available 1SWASP data. It is actually a high-amplitude double-mode Delta Scuti star. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, WASP mag	Period, days	Epoch, HJD
f_0	16.355196	0.072	0.06114265	2454450.5110
f_1	21.05112	0.020	0.0475034	2454450.5245
$f_1 + f_0$	37.40625	0.006	0.0267335	2454450.5172
f_N	16.46578	0.005	0.0607320	2454450.5493

The period ratio of the first overtone and fundamental modes is $P_1 / P_0 = 0.7769$. $J-K = 0.156$ (2MASS). From the CSS data, the variability range is $13^m.09 - 13^m.25$ (CV).

5. The delta Scuti nature of NSV 09856 = HV 10309 was reported by Kazarovets & Pastukhova (2013) according to ASAS-3 data. Their light elements are: HJD(max) 2453581.7052 + 0.1184880×E. I re-analyzed the ASAS-3 data. It is actually a triple-mode HADS(B) star, pulsating in the fundamental, first-overtone, and second-overtone modes. In our Galaxy, it is the fifth case of a triple-mode HADS(B) star. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, V mag	Period, days	Epoch, HJD
f_0	8.439673	0.090	0.1184880	2453581.7052
f_1	10.95611	0.066	0.0912733	2453581.7065
f_2	13.65426	0.027	0.0732372	2453581.7080
$f_1 - f_0$	2.516521	0.024	0.397374	2453581.715
$f_1 + f_0$	19.39582	0.018	0.0515575	2453581.7497

$P_1 / f_0 = 0.7703$; $P_2 / f_1 = 0.8024$; $P_2 / f_0 = 0.6181$. $J-K = 0.239$ (2MASS).

6. The variability of GSC 6905-01641 was reported by Keller et al. (2008, SEKBO 112944.737). The variable was classified as a possible RR Lyrae star (RR:) without light elements. According to the Siding Springs Survey data (Drake et al. 2009), it is a double-mode HADS star. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, CV mag	Period, days	Epoch, HJD
f_0	14.53469	0.147	0.0688009	2455000.5337
f_1	18.76433	0.039	0.0532926	2455000.5470

The period ratio is $P_1 / P_0 = 0.7746$. $J-K = 0.121$ (2MASS).

7. The variability of TYC 2706 01244 1 was reported in 2011 by Gregor Srdoc in the [VSX database](#) (VSX J211253.6+331734), according to 1SWASP data (Butters et al. 2010). The star was classified by the discoverer as a HADS star with the light elements: HJD(max) 2454318.4732 + 0.08785×E. I re-analyzed 1SWASP and NSVS data and found out that the variable was actually a double-mode HADS star. The light elements are:

Mode	Frequency, c/d	Semi-amplitude, mag	Period, days	Epoch, HJD
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f_2	11.38334	0.060 (WASP), 0.052 (R, NSVS)	0.0878477	2454340.557
f_1	9.49652	0.040 (WASP), 0.044 (R, NSVS)	0.105302	2454340.558
$f_2 + f_1$	20.8798	0.009 (WASP)	0.0478932	2454340.5460
$f_2 - f_1$	1.8882	0.004 (WASP)	0.5296	2454340.53
$2f_2 + f_1$	32.2630	0.004 (WASP)	0.0309953	2454340.5152
$f_2 + 2f_1$	30.3759	0.002 (WASP)	0.0329208	2454340.5115

The period ratio is $P_2 / P_1 = 0.8342$. Radial pulsations in the second and third overtones are not excluded. $B-V = 0.402$ (Tycho2), $J-K = 0.210$ (2MASS).

Remarks:

I present an investigation of seven high-amplitude Delta Scuti variables.

I re-analysed all observations available for these stars from the [SuperWASP](#) (Butters et al. 2010), [ASAS-3](#) (Pojmanski 2002), [ROTSE-I/NSVS](#) (Woźniak et al. 2004) and [Catalina Surveys](#) (Drake et al. 2009) online public archives using the period-search software developed by Dr. V.P. Goranskij for Windows environment. According to these data, the variables are double- or multimode high-amplitude Delta Scuti stars.

The period ratios P_1/P_0 and P_2/P_1 are typical for radially pulsating high-amplitude double-mode and multi-mode Delta Scuti stars (Petersen & Christensen-Dalsgaard 1996). In one case, we possibly encounter nonradial pulsations (or F and 2O modes), and one case possibly corresponds to pulsations in the second and third overtone modes. In certain cases, multiple frequencies or frequencies related to interactions between the two main modes were found (see the Comments).

The coordinates were drawn either from the Tycho-2 or from the 2MASS catalogs.

The SuperWASP observations are available as FITS tables, which were converted into ASCII tables using the [OMC2ASCII program](#) as described by Sokolovsky (2007).

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