

Six New ZZ Ceti Stars from the SPY and the HQS Surveys

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Abstract. We report on the discovery of six new ZZ Ceti stars. They were selected as candidates based on preparatory photometric observations of objects from the Hamburg Quasar Survey (HQS), and based on the spectra of the Supernova Ia Progenitor Survey (SPY). Time-series photometry of 19 candidate stars was carried out at the Nordic Optical Telescope (NOT) at Roque de Los Muchachos Observatory, Spain. The new variables are relatively bright, $15.4 < B < 16.6$. Among them is WD 1150–153, which is the third ZZ Ceti star that shows photospheric CaII in its spectrum.

1. Target Selection

We selected candidate ZZ Ceti stars based on temperatures that we derived from photometric data or spectra of the candidate objects, similar to the selection that is described in Voss et al. (2006).

About half of the targets are objects that are listed in the catalogue of Homeier (2001) as probable white dwarfs in the HQS (Hagen et al. 1995) survey. To derive accurate temperatures for these objects, we conducted photometric follow-up observations of about 300 of these probable white dwarfs, using the four channel CCD camera BUSCA at the Calar Alto 2.2 m telescope. The other half of the targets was selected based on the high resolution spectra that were obtained at the ESO VLT with the UVES spectrograph for the SPY project (Napiwotzki et al. 2003).

We derived temperatures and gravities by fitting the photometry or the spectra with synthetic photometry or synthetic spectra that we determined from Koester WD model atmospheres. The resulting atmospheric parameters are listed in Table 1. The typical uncertainties are about 0.07 dex and 250 K for the SPY data, or 0.25 dex and 500 K for the BUSCA-derived parameters. Further

Table 1. Properties of the observed ZZ Ceti candidate stars. Objects with parameters from BUSCA photometry are listed in the upper part of the table, those with parameters from SPY spectroscopy are given in the lower part. The last column gives the type of the objects, where NOV x describes an object for which no variations with an amplitude higher than x mma were present. hDAV and cDAV refers to ZZ Ceti stars on the hot side and on the cool side of the instability strip, respectively.

Object	RA	(J2000)	DE	B	T_{eff}	$\log g$	type
				(mag)	(K)		
HS 0210+3302	02 13 06.2	+33 16 10		15.8	11924	7.39	hDAV
HS 0213+0359	02 15 36.7	+04 13 38		16.6	13035	8.01	NOV2
WD 0235+069	02 38 33.1	+07 08 10		16.6	10950	7.75	cDAV
HS 0733+4119	07 37 07.9	+41 12 28		15.9	11162	7.72 ¹	cDAV
HS 1246+1232	12 49 02.3	+12 16 14		15.5	12590	8.55	NOV1
HS 1701+5039	17 02 19.0	+50 34 59		16.4	11586	8.05	NOV2
HS 1951+7147	19 50 45.6	+71 55 39		16.8	11789	8.40	NOV2
HS 2217+2454	22 20 15.7	+25 09 09		16.1	11731	7.74	NOV3
HS 2304+2809	23 06 36.1	+28 25 30		16.3	12122	8.02	NOV3
HS 2351+3554	23 53 55.0	+36 11 27		16.6	11325	7.58	NOV2
WD 0344+073	03 46 51.4	+07 28 02		16.2	10470	7.77	NOV2
HE 0344-1207	03 47 06.7	-11 58 09		15.8	11466	8.28	cDAV
HS 0401+1454	04 04 35.0	+15 02 27		16.2	12375	8.10	NOV2
WD 0710+216	07 13 21.6	+21 34 07		15.3	10222	7.97	NOV1
WD 1150-153	11 53 15.4	-15 36 36		16.0	12453	8.03	hDAV
HS 1308+1646	13 11 06.1	+16 31 03		15.5	10957	8.33	NOV1
HS 1641+1124	16 43 54.1	+11 18 50		16.1	12209	7.96	NOV1
WD 1959+059	20 02 12.9	+06 07 35		16.4	11033	8.23	cDAV
WD 2333-049	23 35 54.0	-04 42 15		15.7	10506	8.00	NOV2

¹ Homeier et al. (1998) give $T_{\text{eff}} = 11420$ K, $\log g = 7.63$ for HS 0733+4119

details of the photometric observations and of the data analysis can be found in Voss et al. (2006).

2. Time Series Observations and Reduction

Two runs of time series observations, with seven useful nights in total, were carried out at the 2.5 m Nordic Optical Telescope (NOT) at the Roque de los Muchachos Observatory, Spain, with the instrument ALFOSC. This camera was used in a multi-window fast-readout mode, with integration times between 30 s and 50 s, depending on the target magnitude. The observations were made through a sky contrast filter (NOT # 92) with a bandwidth of 2750 Å, centred on 5500 Å. We observed all but one of the variables for at least two hours, distributed over two adjacent nights.

Weighted differential aperture photometry was carried out using the program RTP (Østensen & Solheim 2000), with an aperture size that was optimised for the highest S/N . The resulting lightcurves and their amplitude spectra are shown in Fig. 1; the pulsation frequencies and amplitudes are listed in Table 2. The noise level in each FT was determined by computing $\langle A \rangle$, the square root of

the average power. It was determined from frequency regions of each FT which exclude the ranges around the peak frequencies.

Table 2. Pulsational properties of the new variables

Object	$\langle A \rangle$ (mma)	Main Amplitudes (mma)	Main Periods (s)
HS 0210+3302	0.64	3.68, 4.74	207.5, 189.4
WD 0235+069	0.38	4.21	1283.7
HE 0344-0712	1.23	18.92, 11.37, 21.14	762.2, 461.0, 392.9
HS 0733+4119	2.30	20.30, 38.73, 19.39	747.4, 656.2, 468.8
WD 1150-153	0.58	4.73, 3.59	249.4, 191.7
WD 1959+059	0.49	5.69	1350.4

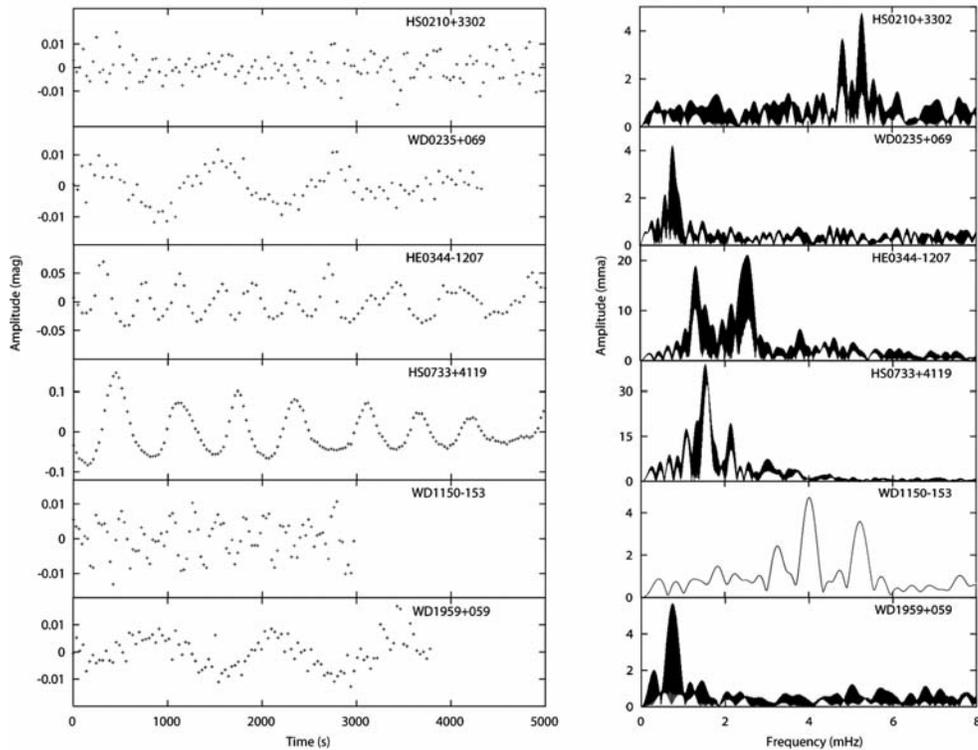


Figure 1. The amplitude spectra and representative parts of the lightcurves of the new variables

These six new variables, and the ten earlier ZZ Ceti detections that were made based on our candidate selection work (Voss et al. 2006; Castanheira et al. 2006; Silvotti et al. 2005), are about two magnitudes brighter than the majority of those that are being discovered among the new white dwarfs detected by the SDSS.

3. WD 1150–153

WD 1150–153 has also been reported as a new ZZ Ceti star by Gianninas, Bergeron, & Fontaine (2006), and is thus a parallel discovery.

This star shows the CaII K line in its spectrum. It is thus a DAZ WD (Koester et al. 2005), and only the third ZZ Ceti DAZ. This is of some interest as it has long been found that the shapes of the H α line cores in the spectra of ZZ Ceti stars are too shallow to be fitted by model spectra of non-rotating model atmospheres (e.g. Koester et al. 1998). Thus, ZZ Ceti stars seem to be relatively fast rotators, but the opposite is found from asteroseismology, where the rotational splitting of pulsation modes provides independent values of the rotation speeds that are close to zero (e.g. Koester et al. 1998; Karl et al. 2005, and references therein). Horizontal surface motions of the ZZ Ceti oscillations have been suggested as an alternative explanation, and recent work by Koester & Kompa (2006) shows that such motions can indeed quantitatively explain the observed line broadening.

WD 1150–153 exhibits a similar effect in the Ca II K line: Berger et al. (2005) have presented the first WD rotation velocities that are derived from the broadening of the CaII line. WD 1150–153 is one of very few objects for which they determine a significant rotation velocity of $9.5 \pm 5.4 \text{ km s}^{-1}$. They suggest, however, that the line profile is probably not caused by rotation but by the same effect that is responsible for the peculiar H α line shapes in the ZZ Ceti stars.

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