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APASS COLORS FOR 112 SHORT-PERIOD W UMa BINARY CANDIDATES

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The period distribution of the overcontact binary star systems with convective envelopes, the W UMa binaries, shows a peak at about 0.27 days and a short-period limit at about 0.2 days (Rucinski, 2007). No satisfactory explanation for the short-period limit is yet known, and there is great interest in the discovery and characterization of systems near the limit. Recently, Lohr et al. (2013) published a list of 143 candidate W UMa systems with periods less than 0.23 days discovered in a search of data gathered by the SuperWASP project (Pollacco et al., 2006).

The AAVSO Photometric All-Sky Survey (Henden et al., 2012; hereafter, APASS) is an all-sky survey in five passbands (Johnson B,V and Sloan g',r',i') that covers the 10th-17th magnitude range, making it a complementary source of information for extrasolar planet surveys like SuperWASP and the Kepler mission (Borucki et al., 2010). APASS provides magnitudes and colors with a precision of 0.02 mag to about V=14 for well-sampled observations at a single epoch, with the usual exponential scatter at fainter magnitudes and a precision of about 0.1 mag at V=16.5.

Synoptic surveys like SuperWASP are effective at discovering variable stars, but unfiltered or single-filter observations are ineffective at distinguishing different types of variable stars whose light curve shapes are very similar. For example, in the period range where W UMa systems are found, the light curves of pulsating variables such as δ Scuti stars can be indistiguishable from low-inclination W UMa system light curves. Color information, however, can resolve the identification problem because pulsating stars are of earlier spectral types than the W UMa systems.

With this capability in mind, the APASS database was searched for the 143 sytems in Lohr et al. (2013), and 112 of them were found to have at least two nights of observations. For those systems, the $B-V$ color was measured at each epoch of APASS observation, and then means were formed for all observations of a given star. The larger of the standard deviation of the mean of the $B-V$ values or 0.02 mag (usually for objects with only two APASS observations) was taken as the error in $B-V$.

W UMa systems are known to follow a period-color relation (Terrell, Gross & Cooney, 2012; hereafter, TGC) and this relation can be used to distinguish W UMa systems from pulsating stars. Figure 1 shows the period-color relation for systems from TGC with periods less than 0.3 days (black circles) and the systems from Lohr et al. (2013) that have APASS data (red squares). The short-period blue envelope (SPBE) from Rucinski

(1998) is shown as a solid curve. The dashed curve is a modified SPBE computed as the Rucinski SPBE minus 0.18 mag in $B-V$ to match the bluest systems from TGC that are known to be W UMa systems. Systems significantly below this curve can be ruled out as W UMa systems.

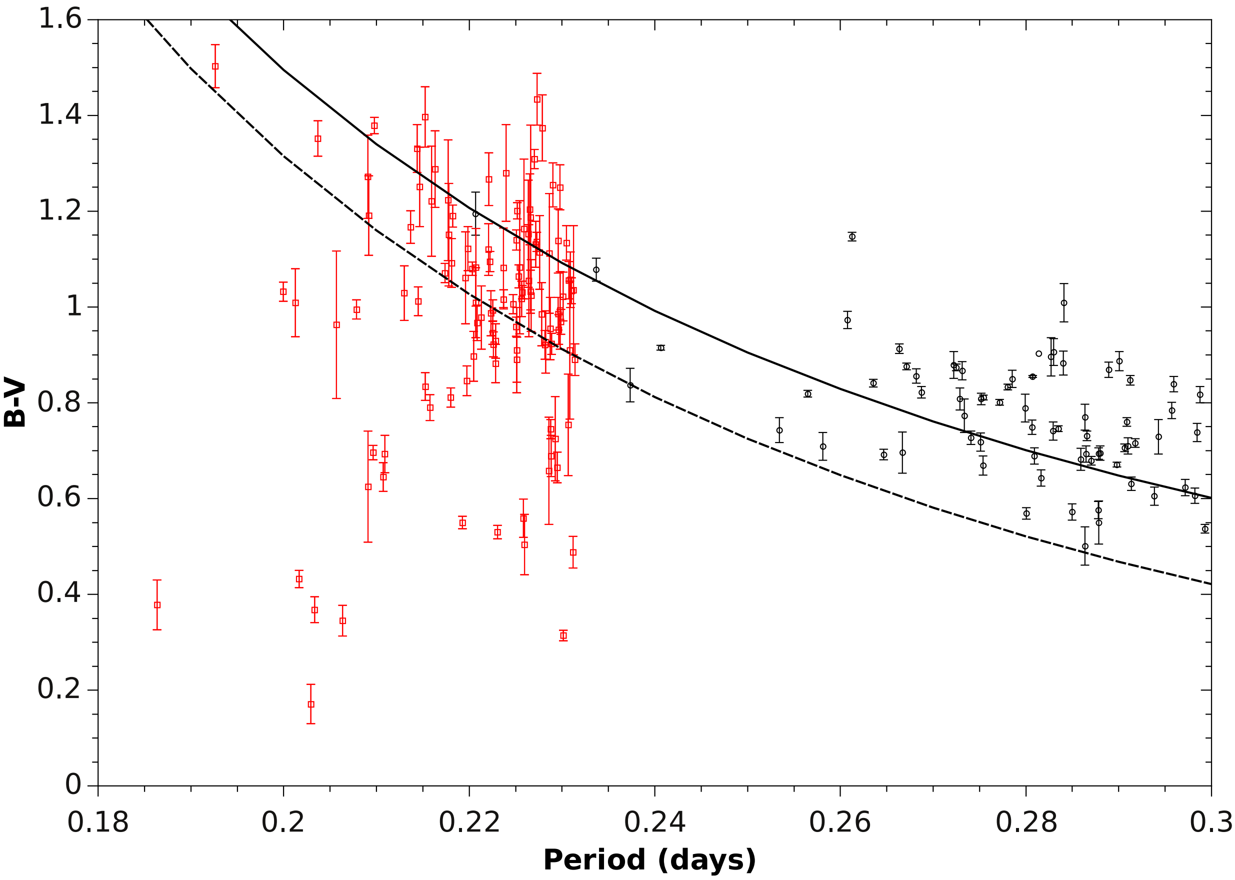

Figure 1. The period-color diagram for W UMa systems (black circles) from Terrell, Gross, and Cooney (2012) and the candidate W UMa systems (red squares) with APASS observations. The upper curve (solid) is the short-period blue envelope (SPBE) from Rucinski (1998) and the lower curve (dashed) is the Rucinski SPBE lowered by 0.18 mag in $B-V$ to include the bluest W UMa systems from Terrell, Gross, & Cooney (2102).

Interstellar reddening can, of course, affect the location of a given object in the period-color diagram. An estimate of the maximum reddening can be determined with the NASA/IPAC Infrared Science Archive's Galactic Dust Redddening and Extinction tool at `http://irsa.ipac.caltech.edu/applications/DUST/` which uses the Schlafly and Finkbeiner (2011) reddening measurements.

Based on the location of an object in the period-color diagram and the error in the $B-V$ color, we can classify the object as unlikely, possibly, or likely to be a W UMa system. For the systems defined as unlikely to be W UMa systems, the APASS $B-V$ is the reddest intrinsic color that the object can have, since dereddening will only make the derived intrinsic color bluer. If the object is lower than the modified SPBE by three times its standard deviation in $B-V$, it is placed in the group of objects unlikely to be W UMa systems. Table 1 gives the APASS $B-V$, the color excess $E(B-V)$, and the unreddened $B-V$ for these systems.

Table 1. APASS Observations of Objects Unlikely to be W UMa Systems.

SuperWASP ID	Period (d)	Obs.	$B-V$	E($B-V$)	Unreddened $B-V$
J115605.88-091300.5	0.21091	5	0.693±0.039	0.030±0.003	0.663±0.039
J201208.72+083509.8	0.21577	5	0.790±0.027	0.156±0.004	0.634±0.027
J204843.90-350912.7	0.22883	4	0.689±0.043	0.054±0.001	0.634±0.043
J111931.48-395048.2	0.22949	2	0.665±0.032	0.106±0.001	0.559±0.032
J084925.17-151516.5	0.19996	2	1.032±0.020	0.065±0.004	0.968±0.020
J151652.90+004835.8	0.21073	4	0.645±0.030	0.043±0.001	0.603±0.030
J144331.57-421626.8	0.21526	3	0.834±0.029	0.102±0.005	0.731±0.029
J060334.52-283427.1	0.20635	5	0.345±0.032	0.029±0.001	0.315±0.032
J161858.05+261303.5	0.22878	2	0.745±0.020	0.047±0.001	0.698±0.020
J231839.72+352848.2	0.20126	4	1.009±0.071	0.077±0.002	0.932±0.071
J201816.85+112452.8	0.18636	5	0.378±0.052	0.174±0.006	0.204±0.052
J092339.29-412648.9	0.20293	3	0.171±0.041	0.287±0.004	−0.116±0.041
J194726.58-243941.0	0.20334	2	0.368±0.027	0.086±0.002	0.282±0.027
J133105.91+121538.0	0.21801	2	0.811±0.020	0.022±0.000	0.789±0.020
J061011.73-345809.0	0.23014	2	0.314±0.020	0.040±0.000	0.274±0.020
J142312.63-222425.1	0.20964	3	0.696±0.020	0.098±0.002	0.598±0.020
J121359.79-414742.7	0.21927	3	0.550±0.020	0.137±0.007	0.413±0.021
J075149.14+362250.9	0.23119	7	0.488±0.033	0.043±0.001	0.445±0.033
J024148.62+372848.3	0.21975	2	0.846±0.031	0.050±0.001	0.796±0.031
J214046.44+130716.6	0.22596	4	0.504±0.063	0.144±0.005	0.359±0.063
J235935.22+362001.5	0.20167	6	0.432±0.020	0.116±0.002	0.316±0.020
J050128.17-041206.9	0.22584	5	0.559±0.040	0.042±0.001	0.517±0.040
J210423.94+073104.8	0.20909	2	0.625±0.116	0.061±0.002	0.564±0.116
J162117.36+441254.2	0.20785	2	0.995±0.020	0.009±0.001	0.986±0.020
J070953.45+364417.3	0.22305	2	0.530±0.020	0.050±0.000	0.480±0.020

On the other end of the color range, there are objects redder than the SPBE and these are the systems likely to be W UMa systems. Since these objects might be intrinsically bluer because of reddening, we compare their de-reddened $B-V$ with the modified SPBE. If the object is higher than the SPBE in the period-color diagram by more than three times its standard deviation in de-reddened $B-V$, it is placed in the group of objects likely to be W UMa systems, because even with the maximum amount of reddening, they cannot fall below the modified SPBE. Table 2 gives the color data on these systems.

For the remaining systems, the errors in their $B-V$ values are too large to firmly place them in the likely or unlikely W UMa groups. These systems are grouped together as possible W UMa systems, and future observations will have to be made to determine their character. Table 3 lists the color data on these systems. Figure 2 shows the unlikely (black circles), likely (red squares) and possible (green triangles) W UMa systems in the period-color diagram. Note that the upper-leftmost object is BX Trianguli, the W UMa system with the shortest known period (Dimitrov & Kjurkchieva, 2010).

Table 2. APASS Observations of Objects Likely to be W UMa Systems.

SuperWASP ID	Period (d)	Obs.	$B-V$	E($B-V$)	Unreddened $B-V$
J212813.35-520029.1	0.23048	2	1.134±0.036	0.017±0.001	1.117±0.036
J041655.13-492709.8	0.23102	3	1.034±0.027	0.013±0.001	1.021±0.027
J222302.02+195031.8	0.22518	2	1.201±0.020	0.037±0.001	1.164±0.020
J211359.46+122712.4	0.22211	6	1.267±0.055	0.061±0.002	1.206±0.055
J055215.51-551950.8	0.22728	2	1.136±0.020	0.097±0.004	1.039±0.020
J115557.62+072009.1	0.22702	2	1.309±0.020	0.013±0.000	1.295±0.020
J093443.60+420831.9	0.22224	6	1.095±0.021	0.012±0.001	1.083±0.021
J120110.98-220210.8	0.22717	3	1.131±0.048	0.043±0.003	1.088±0.048
J114929.22-423049.0	0.22731	4	1.434±0.054	0.152±0.003	1.282±0.054
J161335.80-284722.2	0.22978	8	1.250±0.047	0.186±0.007	1.064±0.048
J180947.64+490255.0	0.22788	4	1.374±0.069	0.048±0.002	1.326±0.069
J164349.61+325637.8	0.22509	2	1.140±0.021	0.029±0.001	1.110±0.021
J221117.26-150216.6	0.21525	9	1.397±0.063	0.026±0.001	1.372±0.063
J102328.57-153951.7	0.20978	3	1.379±0.020	0.069±0.002	1.310±0.020
J224747.20-351849.3	0.21822	2	1.190±0.023	0.012±0.001	1.177±0.023
J150957.56-115308.4	0.22902	7	1.255±0.046	0.087±0.001	1.168±0.046

Table 3. APASS Observations of Possible W UMa Systems.

SuperWASP ID	Period (d)	Obs.	$B-V$	E($B-V$)	Unreddened $B-V$
J215826.52+253437.4	0.22261	13	0.922±0.026	0.054±0.001	0.867±0.026
J162841.41-334419.8	0.20369	3	1.352±0.037	0.509±0.013	0.843±0.039
J210318.76+021002.2	0.22859	4	0.658±0.112	0.077±0.003	0.581±0.112
J151144.56+165426.4	0.21986	2	1.122±0.046	0.027±0.001	1.095±0.046
J015100.23-100524.2	0.21450	3	1.012±0.030	0.028±0.001	0.984±0.030
J101618.12-085531.0	0.21466	3	1.251±0.083	0.040±0.000	1.211±0.083
J092754.99-391053.4	0.22534	3	1.064±0.024	0.273±0.006	0.792±0.025
J041120.40-230232.3	0.21632	4	1.288±0.080	0.038±0.001	1.250±0.080
J095706.80-201408.7	0.22759	3	1.114±0.077	0.035±0.000	1.079±0.077
J153951.12+105420.7	0.22072	2	1.083±0.081	0.041±0.001	1.042±0.081
J062634.80-385650.1	0.22369	2	1.082±0.083	0.098±0.001	0.984±0.083
J201808.68-231443.0	0.22781	3	0.985±0.066	0.067±0.001	0.918±0.066
J051459.80-021923.6	0.23090	6	1.057±0.058	0.164±0.028	0.893±0.064
J160156.04+202821.6	0.22653	2	1.204±0.074	0.048±0.003	1.156±0.074
J235333.60+455245.8	0.23074	3	1.056±0.039	0.111±0.004	0.945±0.039
J011732.10+525204.9	0.22397	2	1.280±0.101	0.411±0.010	0.869±0.101
J232610.13-294146.6	0.23012	9	1.022±0.051	0.020±0.000	1.002±0.051
J034439.97+030425.5	0.22988	5	0.969±0.026	0.188±0.009	0.780±0.028
J044132.96+440613.7	0.22815	2	1.785±0.101	0.937±0.008	0.848±0.101
J031700.67+190839.6	0.22565	3	1.017±0.037	0.129±0.002	0.888±0.037
J030749.87-365201.7	0.22667	2	1.024±0.075	0.018±0.001	1.005±0.075
J211625.31+251755.4	0.21739	2	1.071±0.020	0.102±0.004	0.969±0.020
J042200.64-450312.5	0.21810	4	1.092±0.051	0.017±0.001	1.076±0.051
J022050.85+332047.6	0.19263	6	1.503±0.045	0.067±0.001	1.437±0.045

SuperWASP ID	Period (d)	Obs.	$B-V$	E($B-V$)	Unreddened $B-V$
J212009.70-185220.8	0.21780	3	1.151±0.107	0.037±0.001	1.114±0.107
J004050.63+071613.9	0.22927	5	0.725±0.088	0.034±0.002	0.691±0.088
J084408.68-040640.1	0.21773	2	1.223±0.126	0.014±0.000	1.209±0.126
J004545.23-244516.2	0.22034	2	1.080±0.020	0.017±0.001	1.063±0.020
J061850.43+220511.9	0.21439	5	1.331±0.050	0.746±0.031	0.585±0.059
J231943.31+134121.4	0.23084	2	0.910±0.144	0.049±0.002	0.862±0.144
J010642.20-330857.9	0.22208	9	1.120±0.054	0.022±0.002	1.098±0.054
J000205.32+381321.5	0.20908	4	1.272±0.087	0.088±0.002	1.183±0.087
J050904.45-074144.4	0.22958	4	0.986±0.034	0.077±0.002	0.909±0.034
J104942.44+141021.5	0.22980	3	0.993±0.081	0.028±0.002	0.964±0.081
J123148.12-020602.3	0.22661	2	1.032±0.045	0.020±0.001	1.012±0.045
J010340.37-172138.8	0.22824	3	0.927±0.065	0.015±0.000	0.912±0.065
J233120.96-145814.2	0.21594	3	1.221±0.115	0.025±0.000	1.197±0.115
J200756.54-163408.0	0.22253	2	0.946±0.024	0.124±0.002	0.822±0.024
J173003.21+344509.4	0.22371	2	1.016±0.020	0.026±0.001	0.990±0.020
J040615.79-425002.3	0.22234	4	0.987±0.047	0.009±0.000	0.978±0.047
J172717.97+431624.0	0.22507	2	0.959±0.020	0.014±0.001	0.946±0.020
J195730.89+000705.1	0.22643	3	1.055±0.117	0.171±0.002	0.884±0.117
J025054.80+012357.5	0.23067	6	0.754±0.106	0.046±0.002	0.708±0.106
J221058.82+251123.4	0.21300	8	1.029±0.057	0.067±0.003	0.961±0.057
J134430.51-270302.8	0.22965	3	0.953±0.031	0.051±0.000	0.902±0.031
J200059.78+054408.9	0.20569	4	0.963±0.154	0.103±0.006	0.860±0.154
J130920.49-340919.9	0.22284	5	0.882±0.040	0.058±0.001	0.825±0.040
J135403.76-462948.7	0.22873	3	0.955±0.065	0.094±0.003	0.861±0.065
J140533.33+114639.1	0.22512	3	0.910±0.089	0.020±0.000	0.890±0.089
J183738.17+402427.2	0.22131	2	0.978±0.066	0.062±0.002	0.916±0.066
J052036.84+030402.1	0.23140	4	0.890±0.033	0.103±0.006	0.787±0.034
J121906.35-240056.9	0.22637	3	1.153±0.112	0.083±0.002	1.070±0.112
J115326.51+060756.0	0.22864	3	1.112±0.125	0.010±0.001	1.103±0.125
J234401.81-212229.1	0.21368	5	1.167±0.034	0.019±0.000	1.148±0.034
J231505.30-010617.0	0.22959	6	1.138±0.067	0.035±0.001	1.103±0.067
J074658.62+224448.5	0.22085	2	0.967±0.037	0.039±0.001	0.927±0.037
J003033.05+574347.6	0.22662	6	1.187±0.193	0.412±0.009	0.775±0.193
J214510.25-494401.1	0.22816	2	0.921±0.030	0.019±0.001	0.902±0.030
J104125.56-145842.3	0.22572	2	1.031±0.020	0.041±0.002	0.990±0.020
J075102.16+342405.3	0.20917	3	1.191±0.083	0.040±0.001	1.151±0.083
J052825.85+093943.7	0.22070	2	1.009±0.073	0.276±0.013	0.733±0.074
J193537.06-401409.1	0.22590	3	1.163±0.146	0.105±0.002	1.058±0.146
J220734.47+265528.6	0.23124	10	1.035±0.135	0.064±0.001	0.971±0.135
J090758.16-153811.8	0.22888	4	0.923±0.022	0.064±0.001	0.858±0.022
J151146.20-354721.9	0.22254	3	0.993±0.022	0.130±0.007	0.863±0.023
J130111.22+420214.0	0.22544	2	1.083±0.139	0.015±0.000	1.068±0.139
J220235.74+311909.7	0.22048	14	0.897±0.052	0.085±0.002	0.812±0.052
J025959.18-395812.3	0.22285	4	0.929±0.036	0.015±0.001	0.914±0.036
J222514.69+361643.0	0.22473	2	1.006±0.020	0.089±0.001	0.917±0.020
J132308.74+424613.3	0.22513	2	0.890±0.047	0.014±0.001	0.876±0.047
J160202.07+121213.5	0.21960	3	1.061±0.096	0.044±0.001	1.017±0.096

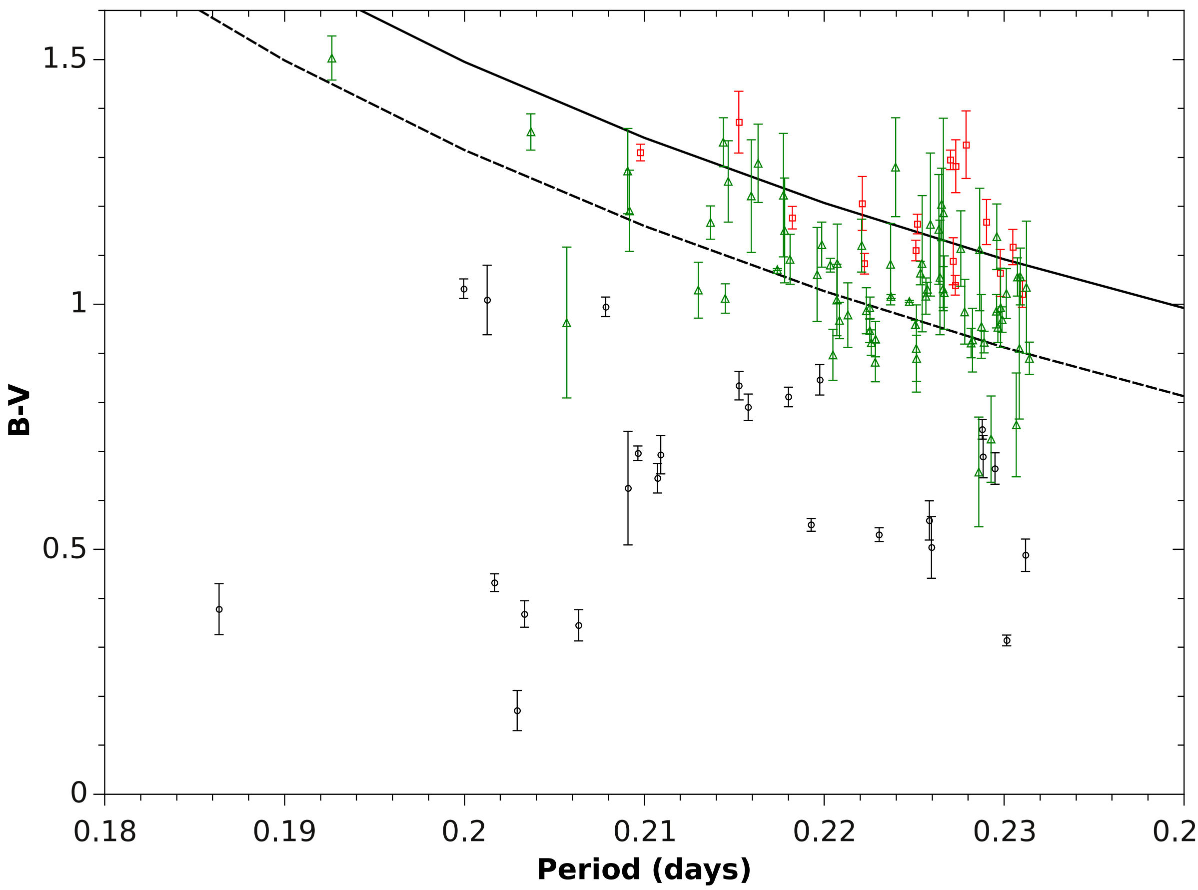

Figure 2. The period-color diagram for objects unlikely to be W UMa systems (black circles) , likely W UMa systems (red squares), and possible W UMa systems (green triangles). The curves are the same as in Figure 1.

In all, 25 objects listed by Lohr et al. (2013) can be ruled out as W UMa systems, while 16 are almost certainly W UMa systems. The remaining 71 could possibly be W UMa systems, and further observations will be needed to characterize them. The 16 likely W UMa systems are good candidates for radial velocity studies to better characterize the properties of overcontact systems near the short-period limit.

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*This version of the paper contains corrections, and differs from the one appeared on-line originally. Date of last modification: Sun Nov 23 06:57:35 CET 2014