First Precision Photometric Observations and Analyses of the Totally Eclipsing, Solar Type Binary V573 Pegasi

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Abstract. CCD VR_cI_c light curves of V573 Peg were taken 26 and 27 September and 2, 4, and 6 October, 2017, at the Dark Sky Observatory in North Carolina with the 0.81-m reflector of Appalachian State University. Five times of minimum light were calculated, two primary and three secondary eclipses, from our present observations. The following quadratic ephemeris was determined from all available times of minimum light: JD Hel MinI = 2456876.4958 (2) d + 0.41744860 (8) × E –2.74 (12) × 10^{-10} × E^2, where the parentheses hold the ± error in the last two digits of the preceding value. A 14-year period study (covered by 24 times of minimum light) reveals a decreasing orbital period with high confidence, possibly due to magnetic braking. The mass ratio is found to be somewhat extreme, $M_2/M_1 = 0.2629 \pm 0.0006$ ($M_1/M_2 = 3.8$). Its Roche Lobe fill-out is ~25%. The solution had no need of spots. The component temperature difference is about 130 K, with the less massive component as the hotter one, so it is a W-type W UMa Binary. The inclination is $80.4 \pm 0.1°$. Our secondary eclipse shows a time of constant light with an eclipse duration of 24 minutes. More information is given in the following report.

1. Introduction

Studies of solar-type eclipsing binaries continue to yield important information on their evolution and nature of orbits. These investigations possibly link detached configurations to semidetached V1010 Oph types (Angione and Sievers 2013) and Algol types to contact binaries, to overcontact binaries, and to red novae (Tylenda and Kamiński 2016) and fast rotating A-type (Guinan and Bradstreet 1988) and FK Comae single stars. Many O–C plots of these binaries are found to be sinusoidal indicating the presence of an orbiting third body. A parabolic O–C plot indicates a continuously decreasing (decaying) or increasing orbital period. V573 Pegasi is a binary in the later case in a near extreme mass ratio configuration with a decaying orbital period.

2. History and observations

The variable was discovered by Maciejewski *et al.* (2004) in a list of 28 new variable stars (SAVS 231034+314253). Their light curve is shown as Figure 1.

They give a V-magnitude of 12.34, an amplitude of V = 0.51 mag, and the ephemeris:

$$\text{JD Hel MinI} = 2452885.2469 + 0.417461\,(3)\,\text{d} \times \text{E}, \quad (1)$$

was given as well as an EW designation. This variable was listed in "A Catalog of 1022 Bright Contact Binary Stars" (Gettel *et al.* 2006). Timings of minimum light have been given by Gürol *et al.* (2007), Paschke (2009), Nelson (2009), Gökay *et al.* (2012), Demircan *et al.* (2012), and Hübscher (2014). The system was listed in "The 80th Name-List of Variable Stars" (Kazarovets *et al.* 2013).

This system was observed as a part of our professional collaborative studies of interacting binaries at Pisgah Astronomical Research Institute from data taken from Dark Sky Observatory (DSO) observations. The observations were taken by D. Caton. Reduction and analyses were done by Ron Samec. Our 2017 VR_cI_c light curves were taken at Dark Sky Observatory 26 and 27 September and 2, 4, and 6 October 2017 with a thermoelectrically cooled (–35° C) 2KX2K FLI camera and VR_cI_c filters. Individual observations included 328 in V, 338 in R_c, and 348 in I_c. The probable error of a single observation was 7 mmag in R_c and I_c, as well as 8 mmag in V. The nightly Comparison—Check star values stayed constant throughout the observing run with a precision of 3 mmag in V and R_c, and 3.5 mmag in I_c. Exposure times varied from 25-30s in V and 25s in R_c and I_c. To produce the images, nightly images were calibrated with 25 bias frames, at least five flat frames in each filter, and ten 300-second dark frames.

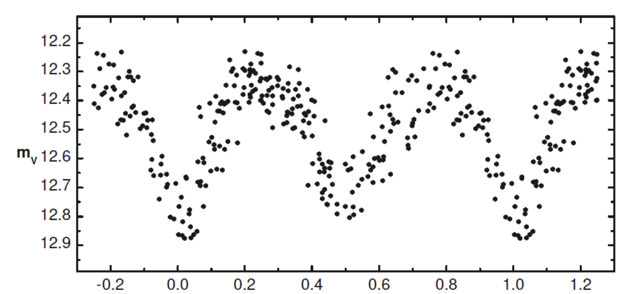

Figure 1. SAVS discovery light curve of SAVS 231034+314253 (V573 Peg). From Maciejewski *et al.* (2004).

The VR_cI_c observations are given in Table 1 as HJD vs Magnitude. Figures 2a and b show two sample light curves taken September 27 and October 2, 2017.

3. Finding chart

The finding chart, given here for future observers, is shown as Figure 3. The coordinates and magnitudes of the variable star, comparison star, and check star are given in Table 2.

4. Period Study

Five mean times (from VR_cI_c data) of minimum light were calculated from our present observations, three primary and two secondary eclipses:

HJD Min I = 2456876.49380 ± 0.0006, 2458023.6420 ± 0.0011, 2458028.65221 ± 0.0021

HJD Min II = 2458022.5991 ± 0.0011, 2458023.8510 ± 0.0010, 2458028.86081 ± 0.0005.

A least squares minimization method (Mikulášek *et al.* 2014) was used to determine the minima for each curve. VR_cI_c results were averaged to determine each time of minimum light. All minima were weighted as 1.0 in the period study.

In addition, nineteen times of minimum light were collected from literature and listed in Table 3. A weighted least squares program was used to determine linear and quadratic ephemerides from these data:

$$\text{Min I} = \text{JD Hel } 2456876.4944\,(11) + 0.41745021\,(25)\,\text{d} \times E \quad (2)$$

$$\text{Min I} = \text{JD Hel } 2456876.4958\,(3) + 0.41744860\,(12)\,\text{d} \times E - [2.7\,(2) \times 10^{-10}] \times E^2 \quad (3)$$

The residuals from the linear term of Equation 3 is shown with the quadratic fit in Figure 4.

This period study covers a time interval of over 14 years and shows an orbital period that is decreasing (at the 13-sigma level). A possible cause of this effect is magnetic braking that occurs as plasma winds leave the system on stiff, but rotating and spreading, dipole magnetic field lines. This causes a continuous angular momentum loss. This scenario is typical for overcontact binaries which eventually coalesce, albeit, in a catastrophic way, producing red novae (Tylenda and Kamiński 2016). The residuals from the linear term of Equation 3 is shown with the quadratic fit in Figure 4. Both the linear and quadratic O–C residuals are given in Table 3.

5. Light curve characteristics

The VR_c and I_c curves and $V–R_c$, $V–I_c$ color curves are shown in Figures 5a and b. These are phased with Equation 2. Light curve amplitudes and the differences in magnitudes at various quadratures are given in Table 4. The curves are of good precision, averaging somewhat better than 1% photometric precision. The amplitude of the light curve varies from

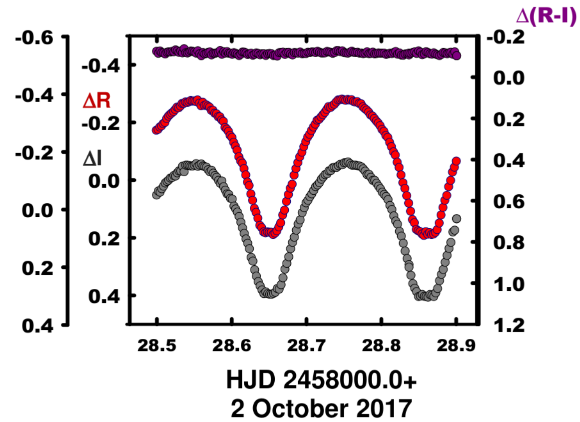

Figure 2a. V573 Peg. Observations taken 2 October 2017.

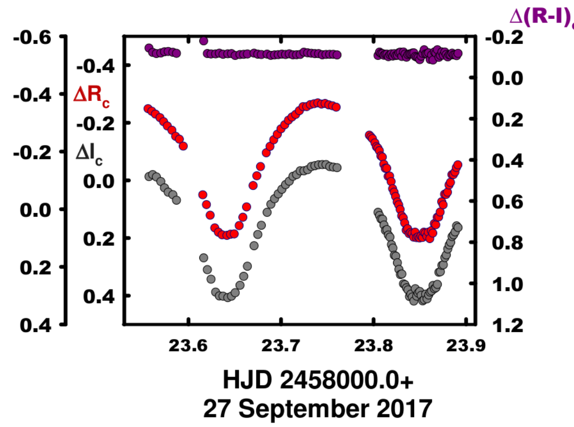

Figure 2b. V573 Peg. Observations taken 27 September 2017.

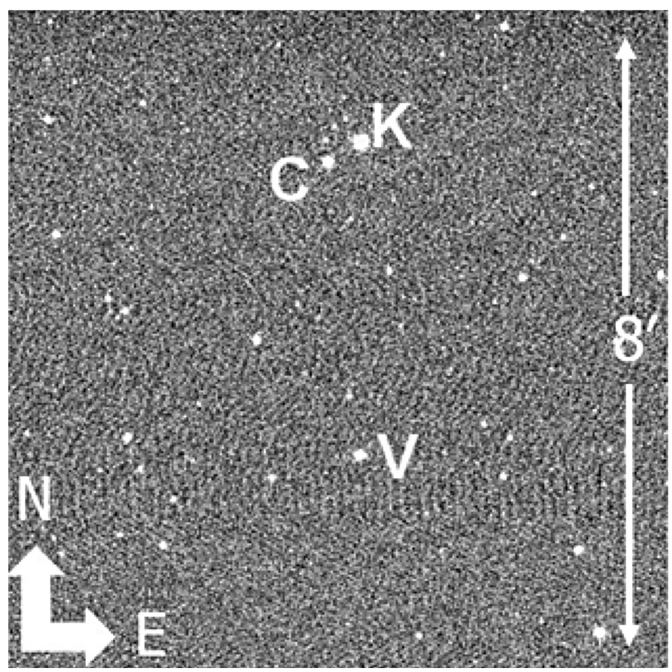

Figure 3. Finding chart, V573 Peg (V), Comparison (C), and Check (K).

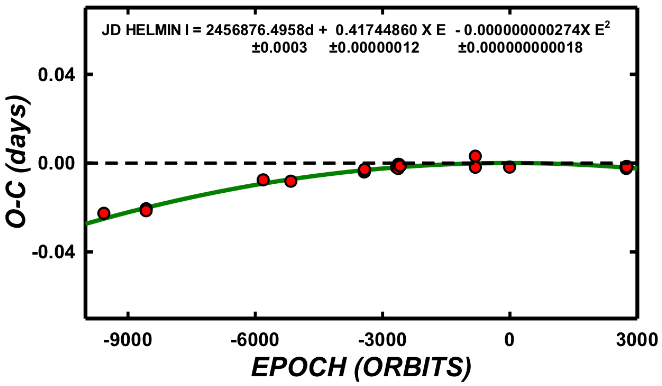

Figure 4. The residuals from the quadratic term of Equation 3 in the period study of V573 Peg.

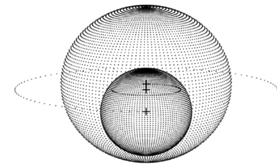

Figure 6a. V573 Peg, geometrical representation at phase 0.00.

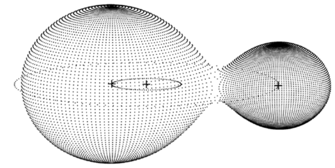

Figure 6b. V573 Peg, geometrical representation at phase 0.25.

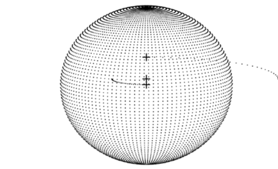

Figure 6c. V573 Peg, geometrical representation at phase 0.50.

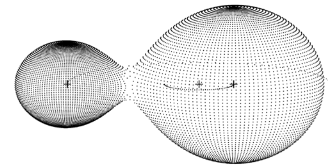

Figure 6d. V573 Peg, geometrical representation at phase 0.75.

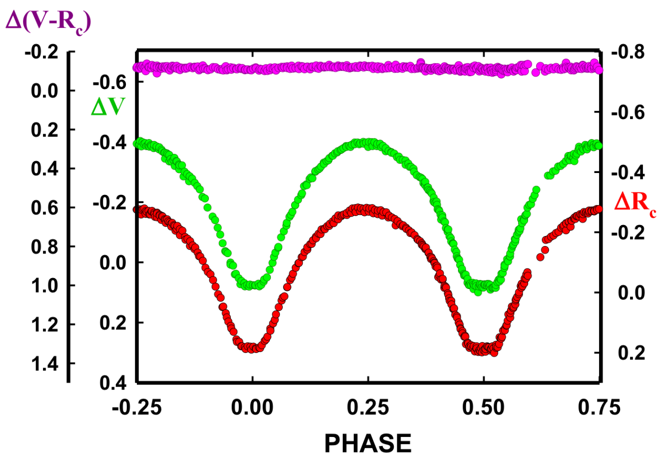

Figure 5a. VR_c magnitude light curves of V573 Peg phased by Equation 2.

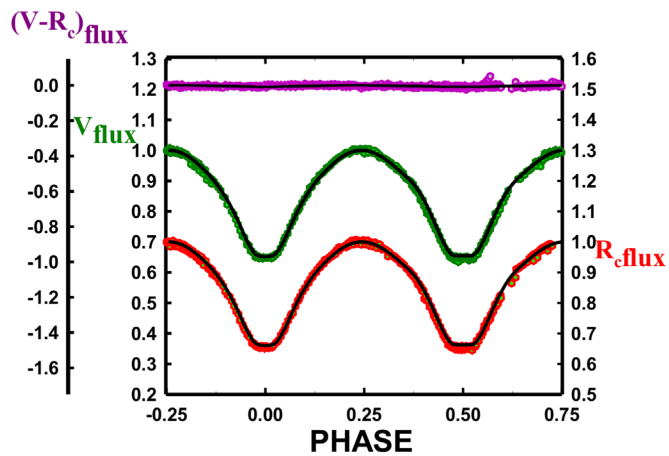

Figure 7a. V573 Peg, V, R_c normalized fluxes overlaid by our solution.

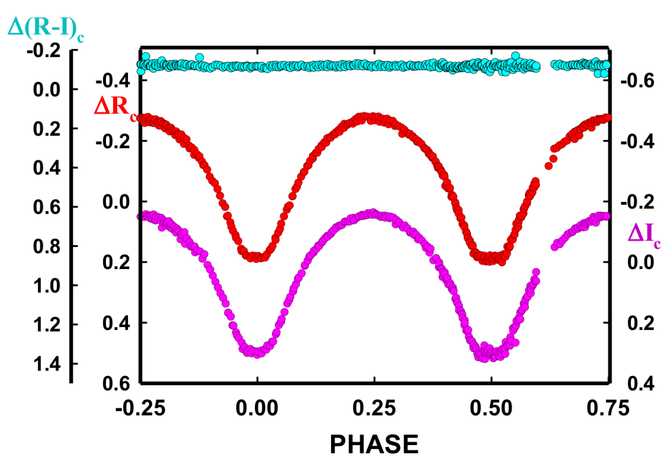

Figure 5b. R_cI_c magnitude light curves of V573 Peg phased by Equation 2.

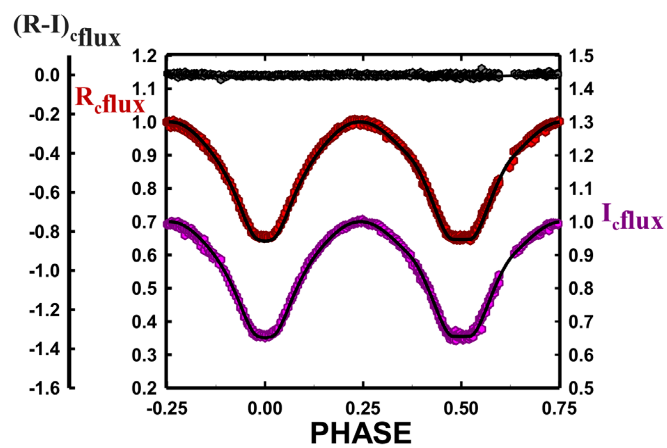

Figure 7b. V573 Peg, R_c, I_c normalized fluxes overlaid by our solution.

0.47–0.46 mag in V to I_c. The O'Connell effect, an indicator of spot activity, averages less than the noise level, 0.002–0.004 mag, not necessarily indicating the presence of star spots. The differences in minima are negligible, 0.005–0.008 mag, indicating overcontact light curves in thermal contact. A time of constant light, a total eclipse, occurs at our secondary minima.

6. Temperature

The 2MASS J–K equals 0.314 ± 0.049 for the binary. The APASS B–V equals 0.59. These correspond to a ~F7 ± 2V spectral type, which yields a temperature of 6250 K ± 300 K. Fast rotating binary stars of this type are noted for having convective atmospheres, so the binary is of solar type.

7. Light curve solution

The VR_cI_c curves were pre-modeled with BINARY MAKER 3.0 (Bradstreet and Steelman 2002). Fits were determined in VR_cI_c filter bands which were very stable. The solution was that of an overcontact eclipsing binary. The parameters were then averaged and input into a three-color simultaneous light curve calculation using the Wilson-Devinney Program (Wilson and Devinney 1971; Wilson 1990, 1994; Van Hamme and Wilson 1998). The computation was computed in Mode 3 and converged to a solution. Convective parameters, g = 0.32, A = 0.5 were used.

An eclipse duration of ~24 minutes was determined for our secondary eclipse (phase 0.5) and the light curve solution. The less massive component is the hottest, making the system a W-type W UMa contact binary. Since the eclipses were total, the mass ratio, q, is well determined with a fill-out of 24.5 (1)%. The light curve solution is given in Table 5. The Roche Lobe representation at quarter orbital phases is shown in Figures 6a, b, c, and d and the normalized fluxes overlaid by our solution of V573 Peg in VR_cI_c are shown in Figures 7a and b.

8. Discussion

V573 Peg is an overcontact W U Ma binary. The system has a rather extreme mass ratio of ~0.26, and a component temperature difference of ~130 K. No spots were needed in the modeling. The Roche Lobe fill-out of the binary is ~24.5% with an inclination of ~80 degrees. Its photometric spectral type indicates a surface temperature of ~6250 K for the primary component, making it a solar type binary. Such a main sequence star would have a mass of ~1.25 $M_{\odot}$ and the secondary (from the mass ratio) would have a mass of ~0.33 $M_{\odot}$, making it very much undersized. The W-type configuration is thought to be due to a surface saturated with solar phenomena on the primary component, suppressing its temperature. The secondary component has a temperature of ~6379 K.

9. Conclusion

The period study of this overcontact W UMa binary has a 14-year duration. The orbital period is found to be increasing at about the 13-sigma level. The system is of solar type and this is hinted at by the fact that the smaller component is the hotter one. This "W-type" phenomena is probably due to spots saturating the primary component with its deep convective envelope. The strong period decrease is probably due to magnetic braking. If this is the case, the system will slowly coalesce over time with the mass ratio becoming more extreme, as it loses angular momentum. In time, if this continues, one would expect that the binary will become a rather normal, fast rotating, single ~F2V type field star after a red nova coalescence event and some mass loss (Tylenda and Kamiński 2016).

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Table 1. V573 Peg observations, ΔV, ΔR_c, and ΔI_c, variable star minus comparison star.

Δ*V*	*HJD 2458000+*	Δ*V*	*HJD 2458000+*	Δ*V*	*HJD 2458000+*	Δ*V*	*HJD 2458000+*	Δ*V*	*HJD 2458000+*
–0.365	22.5156	–0.385	23.7271	–0.391	23.7350	–0.190	23.8924	0.070	28.6446
–0.350	22.5224	–0.382	23.7311	–0.391	23.7390	–0.192	23.8940	0.077	28.6472
–0.323	22.5285	–0.391	23.7350	–0.393	23.7430	–0.210	23.8956	0.075	28.6497
–0.316	22.5321	–0.391	23.7390	–0.382	23.7470	–0.222	23.8972	0.077	28.6523
–0.310	22.5356	–0.393	23.7430	–0.385	23.7510	–0.240	23.8988	0.077	28.6548
–0.280	22.5425	–0.382	23.7470	–0.385	23.7549	–0.287	28.5012	0.072	28.6574
–0.258	22.5458	–0.385	23.7510	–0.381	23.7589	–0.287	28.5035	0.076	28.6599
–0.239	22.5491	–0.385	23.7549	–0.368	23.7629	–0.301	28.5058	0.058	28.6625
–0.199	22.5541	–0.381	23.7589	–0.262	23.7969	–0.303	28.5081	0.051	28.6650
–0.175	22.5574	–0.368	23.7629	–0.255	23.7985	–0.317	28.5104	0.026	28.6676
–0.141	22.5606	–0.262	23.7969	–0.247	23.8001	–0.319	28.5127	0.003	28.6701
–0.108	22.5670	–0.255	23.7985	–0.236	23.8028	–0.326	28.5150	–0.031	28.6727
–0.062	22.5712	–0.247	23.8001	–0.227	23.8044	–0.335	28.5173	–0.047	28.6752
–0.012	22.5754	–0.236	23.8028	–0.202	23.8060	–0.344	28.5196	–0.082	28.6778
0.045	22.5813	–0.227	23.8044	–0.196	23.8076	–0.351	28.5219	–0.102	28.6803
0.076	22.5855	–0.202	23.8060	–0.190	23.8092	–0.347	28.5242	–0.130	28.6829
0.090	22.5897	–0.196	23.8076	–0.173	23.8108	–0.354	28.5265	–0.150	28.6854
0.073	22.5957	–0.190	23.8092	–0.157	23.8124	–0.373	28.5287	–0.167	28.6880
0.074	22.5999	–0.173	23.8108	–0.148	23.8140	–0.367	28.5310	–0.189	28.6905
0.082	22.6041	–0.157	23.8124	–0.135	23.8156	–0.374	28.5333	–0.207	28.6931
0.083	22.6095	–0.148	23.8140	–0.113	23.8172	–0.379	28.5356	–0.222	28.6960
0.055	22.6137	–0.135	23.8156	–0.100	23.8188	–0.382	28.5379	–0.252	28.6985
0.013	22.6179	–0.113	23.8172	–0.085	23.8204	–0.392	28.5402	–0.255	28.7010
–0.028	22.6229	–0.100	23.8188	–0.068	23.8220	–0.381	28.5425	–0.276	28.7036
–0.076	22.6271	–0.085	23.8204	–0.061	23.8236	–0.388	28.5448	–0.278	28.7061
–0.103	22.6313	–0.068	23.8220	–0.041	23.8252	–0.386	28.5471	–0.302	28.7087
–0.155	22.6365	–0.061	23.8236	–0.019	23.8269	–0.389	28.5494	–0.307	28.7112
–0.338	22.6766	–0.041	23.8252	–0.009	23.8285	–0.384	28.5517	–0.317	28.7138
–0.335	22.6808	–0.019	23.8269	0.010	23.8301	–0.392	28.5540	–0.330	28.7163
–0.383	22.6850	–0.009	23.8285	0.028	23.8317	–0.385	28.5563	–0.335	28.7189
–0.376	22.6918	0.010	23.8301	0.040	23.8335	–0.395	28.5586	–0.345	28.7214
–0.374	22.6922	0.028	23.8317	0.042	23.8351	–0.385	28.5609	–0.353	28.7240
–0.395	22.6964	0.040	23.8335	0.069	23.8367	–0.389	28.5632	–0.361	28.7265
–0.386	22.7022	0.042	23.8351	0.077	23.8383	–0.384	28.5655	–0.368	28.7291
–0.402	22.7064	0.069	23.8367	0.077	23.8398	–0.374	28.5678	–0.372	28.7316
–0.383	22.7148	0.077	23.8383	0.069	23.8414	–0.373	28.5700	–0.378	28.7341
–0.343	23.5637	0.077	23.8398	0.078	23.8430	–0.363	28.5723	–0.382	28.7367
–0.334	23.5676	0.069	23.8414	0.080	23.8446	–0.361	28.5746	–0.386	28.7392
–0.319	23.5725	0.078	23.8430	0.101	23.8462	–0.356	28.5769	–0.390	28.7418
–0.308	23.5765	0.080	23.8446	0.076	23.8478	–0.333	28.5792	–0.397	28.7443
–0.284	23.5804	0.101	23.8462	0.074	23.8494	–0.346	28.5815	–0.397	28.7469
–0.268	23.5854	0.076	23.8478	0.085	23.8510	–0.334	28.5838	–0.395	28.7494
–0.033	23.6188	0.074	23.8494	0.075	23.8526	–0.321	28.5861	–0.399	28.7520
0.009	23.6228	0.085	23.8510	0.078	23.8542	–0.321	28.5884	–0.397	28.7545
0.041	23.6267	0.075	23.8526	0.073	23.8558	–0.300	28.5907	–0.399	28.7571
0.074	23.6317	0.078	23.8542	0.092	23.8574	–0.292	28.5930	–0.398	28.7596
0.081	23.6357	0.073	23.8558	0.086	23.8590	–0.285	28.5953	–0.398	28.7621
0.082	23.6396	0.092	23.8574	0.084	23.8606	–0.277	28.5976	–0.392	28.7647
0.078	23.6448	0.086	23.8590	0.086	23.8622	–0.263	28.5999	–0.393	28.7672
0.081	23.6488	0.084	23.8606	0.067	23.8637	–0.252	28.6022	–0.386	28.7698
0.065	23.6527	0.086	23.8622	0.065	23.8653	–0.241	28.6045	–0.378	28.7723
–0.017	23.6620	0.067	23.8637	0.059	23.8669	–0.216	28.6068	–0.369	28.7749
–0.050	23.6660	0.065	23.8653	0.037	23.8685	–0.211	28.6091	–0.363	28.7774
–0.121	23.6732	0.059	23.8669	0.009	23.8701	–0.181	28.6114	–0.360	28.7800
–0.157	23.6772	0.037	23.8685	–0.002	23.8733	–0.151	28.6160	–0.348	28.7825
–0.189	23.6811	0.009	23.8701	–0.018	23.8749	–0.139	28.6183	–0.339	28.7851
–0.228	23.6873	–0.002	23.8733	–0.044	23.8765	–0.114	28.6206	–0.339	28.7876
–0.258	23.6913	–0.018	23.8749	–0.058	23.8781	–0.091	28.6229	–0.337	28.7902
–0.281	23.6953	–0.044	23.8765	–0.067	23.8797	–0.062	28.6251	–0.327	28.7927
–0.300	23.6993	–0.058	23.8781	–0.090	23.8813	–0.036	28.6274	–0.316	28.7952
–0.311	23.7032	–0.067	23.8797	–0.107	23.8829	–0.029	28.6297	–0.300	28.7978
–0.326	23.7072	–0.090	23.8813	–0.112	23.8844	0.002	28.6321	–0.288	28.8003
–0.338	23.7112	–0.107	23.8829	–0.129	23.8860	0.012	28.6345	–0.282	28.8029
–0.353	23.7152	–0.112	23.8844	–0.143	23.8876	0.039	28.6370	–0.276	28.8054
–0.364	23.7191	–0.129	23.8860	–0.156	23.8892	0.054	28.6396		
–0.374	23.7231	–0.143	23.8876	–0.181	23.8908	0.063	28.6421		

Table continued on following pages

Table 1. V573 Peg observations, ΔV, ΔR_c, and ΔI_c, variable star minus comparison star, cont.

ΔR_c	HJD 2458000+	ΔR_c	HJD 2458000+	ΔR_c	HJD 2458000+	ΔR_c	HJD 2458000+	ΔR_c	HJD 2458000+
–0.248	22.5129	–0.141	23.6921	0.049	23.8783	0.132	28.6349	–0.148	28.8085
–0.222	22.5195	–0.160	23.6960	0.041	23.8799	0.157	28.6375	–0.131	28.8110
–0.219	22.5256	–0.179	23.7000	0.016	23.8815	0.165	28.6400	–0.116	28.8135
–0.210	22.5292	–0.193	23.7040	0.007	23.8831	0.180	28.6426	–0.098	28.8161
–0.196	22.5327	–0.209	23.7080	–0.020	23.8847	0.183	28.6451	–0.087	28.8186
–0.173	22.5398	–0.220	23.7119	–0.020	23.8863	0.180	28.6477	–0.062	28.8212
–0.162	22.5431	–0.229	23.7159	–0.029	23.8879	0.181	28.6502	–0.044	28.8237
–0.143	22.5464	–0.242	23.7199	–0.045	23.8895	0.181	28.6528	–0.018	28.8263
–0.110	22.5514	–0.256	23.7239	–0.054	23.8911	0.189	28.6553	0.009	28.8288
–0.096	22.5547	–0.256	23.7278	–0.173	28.4993	0.184	28.6579	0.029	28.8314
–0.050	22.5579	–0.263	23.7318	–0.176	28.5016	0.176	28.6604	0.054	28.8339
–0.021	22.5636	–0.266	23.7358	–0.184	28.5039	0.162	28.6630	0.080	28.8365
0.021	22.5678	–0.265	23.7438	–0.188	28.5062	0.148	28.6655	0.108	28.8390
0.055	22.5720	–0.267	23.7477	–0.196	28.5085	0.121	28.6681	0.137	28.8415
0.120	22.5779	–0.262	23.7517	–0.200	28.5108	0.104	28.6706	0.148	28.8441
0.145	22.5821	–0.259	23.7557	–0.214	28.5131	0.074	28.6732	0.171	28.8466
0.179	22.5863	–0.254	23.7597	–0.222	28.5154	0.050	28.6757	0.176	28.8492
0.187	22.5923	–0.157	23.7955	–0.228	28.5177	0.028	28.6783	0.179	28.8517
0.187	22.5965	–0.151	23.7972	–0.233	28.5200	0.014	28.6808	0.187	28.8543
0.189	22.6007	–0.145	23.7988	–0.238	28.5223	–0.017	28.6834	0.192	28.8568
0.188	22.6060	–0.130	23.8015	–0.245	28.5246	–0.040	28.6859	0.179	28.8594
0.185	22.6102	–0.117	23.8031	–0.253	28.5269	–0.061	28.6885	0.188	28.8619
0.153	22.6144	–0.112	23.8047	–0.251	28.5292	–0.081	28.6910	0.182	28.8645
0.111	22.6194	–0.103	23.8063	–0.257	28.5315	–0.097	28.6939	0.189	28.8670
0.061	22.6236	–0.085	23.8079	–0.266	28.5337	–0.116	28.6964	0.187	28.8696
0.027	22.6278	–0.081	23.8095	–0.266	28.5360	–0.133	28.6990	0.181	28.8721
–0.015	22.6331	–0.056	23.8111	–0.271	28.5383	–0.149	28.7015	0.172	28.8746
–0.058	22.6373	–0.042	23.8127	–0.269	28.5406	–0.159	28.7041	0.149	28.8772
–0.116	22.6501	–0.042	23.8143	–0.272	28.5429	–0.172	28.7066	0.121	28.8797
–0.140	22.6543	–0.014	23.8158	–0.276	28.5452	–0.184	28.7092	0.095	28.8823
–0.205	22.6732	–0.015	23.8174	–0.274	28.5475	–0.194	28.7117	0.070	28.8848
–0.217	22.6774	0.004	23.8190	–0.275	28.5498	–0.208	28.7143	0.053	28.8874
–0.243	22.6816	0.029	23.8206	–0.273	28.5521	–0.211	28.7168	0.023	28.8899
–0.243	22.6883	0.041	23.8222	–0.278	28.5544	–0.219	28.7194	0.001	28.8925
–0.261	22.6930	0.056	23.8238	–0.267	28.5567	–0.227	28.7219	–0.028	28.8950
–0.270	22.6988	0.075	23.8256	–0.258	28.5590	–0.235	28.7244	–0.045	28.8976
–0.276	22.7030	0.085	23.8272	–0.270	28.5613	–0.245	28.7270	–0.066	28.9001
–0.258	22.7072	0.101	23.8288	–0.259	28.5636	–0.255	28.7295	–0.217	30.6022
–0.260	22.7114	0.123	23.8304	–0.261	28.5659	–0.252	28.7321	–0.229	30.6048
–0.258	22.7156	0.130	23.8321	–0.257	28.5682	–0.258	28.7346	–0.234	30.6073
–0.250	22.7198	0.148	23.8337	–0.253	28.5704	–0.263	28.7372	–0.237	30.6099
–0.249	23.5564	0.173	23.8353	–0.242	28.5727	–0.271	28.7397	–0.248	30.6124
–0.240	23.5604	0.168	23.8369	–0.242	28.5750	–0.278	28.7423	–0.253	30.6149
–0.230	23.5644	0.185	23.8385	–0.232	28.5773	–0.279	28.7448	–0.259	30.6175
–0.218	23.5693	0.181	23.8401	–0.230	28.5796	–0.281	28.7473	–0.259	30.6200
–0.204	23.5732	0.185	23.8417	–0.220	28.5819	–0.279	28.7499	–0.263	30.6225
–0.189	23.5772	0.197	23.8433	–0.220	28.5842	–0.277	28.7524	–0.267	30.6251
–0.174	23.5822	0.180	23.8449	–0.209	28.5865	–0.280	28.7550	–0.271	30.6276
–0.153	23.5862	0.199	23.8465	–0.204	28.5888	–0.278	28.7575	–0.268	30.6302
–0.143	23.5902	0.196	23.8481	–0.183	28.5911	–0.279	28.7601	–0.273	30.6328
–0.119	23.5944	0.200	23.8497	–0.177	28.5934	–0.273	28.7626	–0.273	30.6353
0.050	23.6155	0.193	23.8513	–0.169	28.5957	–0.271	28.7652	–0.270	30.6379
0.084	23.6195	0.198	23.8529	–0.155	28.5980	–0.272	28.7677	–0.276	30.6404
0.121	23.6235	0.180	23.8544	–0.148	28.6003	–0.266	28.7703	–0.269	30.6429
0.165	23.6285	0.183	23.8560	–0.131	28.6026	–0.265	28.7728	–0.270	30.6455
0.180	23.6324	0.194	23.8576	–0.118	28.6049	–0.254	28.7753	–0.268	30.6480
0.189	23.6364	0.180	23.8592	–0.104	28.6072	–0.248	28.7779	–0.264	30.6506
0.191	23.6416	0.202	23.8608	–0.081	28.6095	–0.243	28.7804	–0.264	30.6531
0.187	23.6455	0.175	23.8624	–0.067	28.6118	–0.236	28.7830	–0.254	30.6556
0.186	23.6495	0.183	23.8640	–0.059	28.6141	–0.226	28.7855	–0.251	30.6582
0.157	23.6548	0.150	23.8656	–0.040	28.6164	–0.222	28.7881	–0.240	30.6607
0.128	23.6588	0.154	23.8672	–0.018	28.6187	–0.214	28.7906	–0.235	30.6633
0.092	23.6628	0.128	23.8688	0.007	28.6210	–0.205	28.7932	–0.227	30.6658
0.018	23.6699	0.127	23.8704	0.019	28.6233	–0.198	28.7957	–0.222	30.6683
–0.016	23.6739	0.110	23.8720	0.048	28.6256	–0.189	28.7983	–0.210	30.6709
–0.048	23.6779	0.074	23.8736	0.070	28.6279	–0.176	28.8008		
–0.096	23.6841	0.085	23.8752	0.098	28.6302	–0.169	28.8034		
–0.118	23.6881	0.048	23.8767	0.112	28.6325	–0.155	28.8059		

Table continued on following pages

Table 1. V573 Peg observations, ΔV, ΔR_c, and ΔI_c, variable star minus comparison star, cont.

ΔI_c	*HJD 2458000+*	ΔI_c	*HJD 2458000+*	ΔI_c	*HJD 2458000+*	ΔI_c	*HJD 2458000+*	ΔI_c	*HJD 2458000+*
–0.124	22.5137	–0.133	23.7208	0.064	23.8913	0.296	28.6507	0.042	28.8191
–0.113	22.5204	–0.133	23.7248	–0.048	28.4997	0.296	28.6532	0.053	28.8216
–0.096	22.5265	–0.137	23.7288	–0.062	28.5020	0.293	28.6558	0.078	28.8242
–0.089	22.5300	–0.148	23.7328	–0.058	28.5043	0.289	28.6583	0.094	28.8267
–0.074	22.5336	–0.151	23.7367	–0.070	28.5066	0.276	28.6609	0.119	28.8293
–0.046	22.5406	–0.154	23.7407	–0.079	28.5089	0.278	28.6634	0.146	28.8318
–0.030	22.5439	–0.155	23.7447	–0.090	28.5112	0.263	28.6660	0.172	28.8344
–0.005	22.5472	–0.155	23.7487	–0.095	28.5135	0.239	28.6685	0.193	28.8369
0.018	22.5522	–0.148	23.7527	–0.100	28.5158	0.209	28.6711	0.202	28.8369
0.050	22.5555	–0.146	23.7566	–0.107	28.5181	0.189	28.6736	0.230	28.8395
0.061	22.5588	–0.144	23.7606	–0.109	28.5204	0.166	28.6762	0.259	28.8420
0.085	22.5646	0.011	23.8049	–0.116	28.5227	0.138	28.6787	0.275	28.8446
0.135	22.5688	0.022	23.8065	–0.114	28.5250	0.116	28.6813	0.287	28.8471
0.174	22.5730	0.034	23.8081	–0.125	28.5273	0.098	28.6838	0.304	28.8497
0.248	22.5789	0.035	23.8097	–0.132	28.5296	0.074	28.6864	0.302	28.8522
0.285	22.5831	0.055	23.8113	–0.132	28.5319	0.052	28.6889	0.297	28.8547
0.315	22.5873	0.074	23.8129	–0.148	28.5342	0.038	28.6915	0.303	28.8573
0.321	22.5933	0.071	23.8145	–0.129	28.5364	0.013	28.6943	0.304	28.8598
0.308	22.5975	0.090	23.8161	–0.152	28.5387	–0.004	28.6969	0.306	28.8624
0.313	22.6017	0.097	23.8177	–0.152	28.5410	–0.021	28.6994	0.297	28.8649
0.314	22.6071	0.123	23.8193	–0.151	28.5433	–0.030	28.7020	0.300	28.8675
0.304	22.6113	0.135	23.8209	–0.149	28.5456	–0.042	28.7045	0.304	28.8700
0.277	22.6155	0.160	23.8225	–0.149	28.5479	–0.052	28.7071	0.291	28.8726
0.267	22.6205	0.163	23.8241	–0.152	28.5502	–0.064	28.7096	0.276	28.8751
0.190	22.6247	0.186	23.8258	–0.157	28.5525	–0.077	28.7122	0.249	28.8777
0.150	22.6289	0.209	23.8274	–0.148	28.5548	–0.083	28.7147	0.227	28.8802
0.104	22.6341	0.227	23.8290	–0.152	28.5571	–0.091	28.7173	0.210	28.8827
0.065	22.6383	0.225	23.8306	–0.156	28.5594	–0.103	28.7198	0.185	28.8853
–0.115	22.6826	0.259	23.8324	–0.149	28.5617	–0.111	28.7224	0.161	28.8878
–0.137	22.6894	0.262	23.8340	–0.147	28.5640	–0.119	28.7249	0.137	28.8904
–0.143	22.7124	0.273	23.8356	–0.145	28.5663	–0.122	28.7275	0.116	28.8929
–0.137	22.7166	0.280	23.8372	–0.136	28.5686	–0.132	28.7300	0.080	28.8955
–0.113	23.5574	0.303	23.8388	–0.129	28.5709	–0.133	28.7325	0.074	28.8980
–0.120	23.5614	0.295	23.8403	–0.134	28.5731	–0.143	28.7351	0.034	28.9006
–0.112	23.5654	0.305	23.8419	–0.124	28.5754	–0.145	28.7376	–0.098	30.6027
–0.096	23.5702	0.319	23.8435	–0.116	28.5777	–0.144	28.7402	–0.110	30.6052
–0.074	23.5742	0.276	23.8451	–0.110	28.5800	–0.150	28.7427	–0.114	30.6078
–0.059	23.5782	0.302	23.8467	–0.099	28.5823	–0.155	28.7453	–0.121	30.6103
–0.050	23.5832	0.291	23.8483	–0.089	28.5846	–0.153	28.7478	–0.127	30.6129
–0.031	23.5871	0.286	23.8499	–0.097	28.5869	–0.160	28.7504	–0.129	30.6154
–0.025	23.5953	0.299	23.8515	–0.077	28.5892	–0.160	28.7529	–0.135	30.6179
0.169	23.6165	0.318	23.8531	–0.065	28.5915	–0.163	28.7555	–0.139	30.6205
0.210	23.6205	0.314	23.8547	–0.052	28.5938	–0.157	28.7580	–0.144	30.6230
0.243	23.6244	0.295	23.8563	–0.050	28.5961	–0.152	28.7605	–0.144	30.6256
0.288	23.6294	0.311	23.8579	–0.037	28.5984	–0.152	28.7631	–0.147	30.6281
0.301	23.6334	0.298	23.8595	–0.034	28.6007	–0.152	28.7656	–0.151	30.6307
0.302	23.6374	0.288	23.8611	–0.010	28.6030	–0.150	28.7682	–0.151	30.6332
0.307	23.6425	0.284	23.8627	0.011	28.6076	–0.149	28.7707	–0.148	30.6358
0.302	23.6465	0.265	23.8642	0.026	28.6099	–0.146	28.7733	–0.148	30.6383
0.290	23.6505	0.276	23.8658	0.046	28.6122	–0.139	28.7758	–0.150	30.6409
0.264	23.6557	0.272	23.8674	0.066	28.6145	–0.131	28.7784	–0.153	30.6434
0.233	23.6597	0.261	23.8690	0.085	28.6168	–0.119	28.7809	–0.141	30.6459
0.198	23.6637	0.219	23.8706	0.104	28.6191	–0.120	28.7835	–0.137	30.6485
0.127	23.6709	0.217	23.8722	0.119	28.6214	–0.110	28.7860	–0.140	30.6510
0.088	23.6749	0.195	23.8738	0.138	28.6237	–0.099	28.7886	–0.135	30.6536
0.056	23.6788	0.193	23.8754	0.168	28.6260	–0.099	28.7911	–0.128	30.6561
0.011	23.6850	0.168	23.8770	0.181	28.6283	–0.089	28.7936	–0.129	30.6587
–0.017	23.6890	0.159	23.8786	0.211	28.6306	–0.079	28.7962	–0.115	30.6612
–0.036	23.6930	0.138	23.8802	0.233	28.6329	–0.070	28.7987	–0.108	30.6637
–0.053	23.6970	0.124	23.8818	0.252	28.6354	–0.058	28.8013	–0.100	30.6663
–0.069	23.7010	0.115	23.8833	0.267	28.6380	–0.050	28.8038	–0.104	30.6688
–0.085	23.7049	0.095	23.8849	0.281	28.6405	–0.043	28.8064	–0.092	30.6713
–0.097	23.7089	0.089	23.8865	0.294	28.6430	–0.012	28.8115		
–0.114	23.7129	0.079	23.8881	0.288	28.6456	0.002	28.8140		
–0.120	23.7169	0.058	23.8897	0.294	28.6481	0.024	28.8166		

Table 2. Information on the stars used in this study.

Star	Name	R.A. (2000) h m s	Dec. (2000) ° ′ ″	V	J–K
V	V573 Peg GSC 2751-1007 SAVS 231034+314253 CRTS J231034.2+314254 NSVS 9014625 3UC167-320333	23 10 34.2395	31 42 53.744[1]	12.59[2]	0.314 ± 0.049[2]
C	GSC 2751-01803 3UC244-290293	23 10 32.1420	31 46 54.821[1]	12.55[2]	0.48[2]
K (Check)	GSC 2751-0129 3UC167-320353	23 10 34.2599	31 47 10.500[3]	11.263[2]	0.277 ± 0.046[2]

[1] UCAC-3 (USNO 2012). [2] 2Mass (Skrutskie et al. *2006). [3] TYCHO (Høg, E.,* et al. *2000).*

Table 3. O–C Residuals for V573 Peg.

	Epoch 2400000+	Cycles	Linear Residuals	Quadratic Residuals	Reference
1	52885.2469	–9561.0	–0.0060	0.0022	VSX
2	53300.4014	–8566.5	–0.0057	–0.0008	Gürol *et al.* 2007
3	53301.2365	–8564.5	–0.0055	–0.0007	Gürol *et al.* 2007
4	53301.4443	–8564.0	–0.0064	–0.0016	Gürol *et al.* 2007
5	54452.3640	–5807.0	0.0030	0.0015	Paschke 2009
6	54723.7050	–5157.0	0.0014	–0.0011	Nelson 2008
7	55445.4778	–3428.0	0.0028	–0.0010	Gökay *et al.* 2012
8	55448.4001	–3421.0	0.0029	–0.0008	Gökay *et al.* 2012
9	55449.4447	–3418.5	0.0039	0.0001	Gökay *et al.* 2012
10	55764.4106	–2664.0	0.0036	–0.0002	Demircan *et al.* 2012
11	55778.3963	–2630.5	0.0047	0.0009	Demircan *et al.* 2012
12	55781.5255	–2623.0	0.0030	–0.0007	Demircan *et al.* 2012
13	55783.4059	–2618.5	0.0049	0.0011	Demircan *et al.* 2012
14	55790.5024	–2601.5	0.0048	0.0010	Demircan *et al.* 2012
15	55799.2681	–2580.5	0.0040	0.0002	Demircan *et al.* 2012
16	55799.4769	–2580.0	0.0041	0.0003	Demircan *et al.* 2012
17	56539.4090	–807.5	0.0057	0.0031	Hübscher 2014
18	56539.6127	–807.0	0.0007	–0.0019	Hübscher 2014
19	56876.4938	0.0	–0.0006	–0.0020	Hübscher 2014
20	58022.5991	2745.5	–0.0048	0.0003	This paper
21	58023.6420	2748.0	–0.0056	–0.0005	This paper
22	58023.8510	2748.5	–0.0053	–0.0002	This paper
23	58028.6522	2760.0	–0.0047	0.0004	This paper
24	58028.8608	2760.5	–0.0049	0.0002	This paper

Calculated from the light curve data given in the reference.
The quadratic ephemeris yields a $\dot{P} = -4.79 \times 10^{-7}$ d/yr.

Table 4. Averaged light curve characteristics of V573 Peg.

Filter	Phase	Magnitude Min. I	Phase	Magnitude Max. I
	0.0		0.25	
V		0.075 ± 0.002		–0.393 ± 0.007
Rc		0.184 ± 0.005		–0.274 ± 0.007
Ic		0.298 ± 0.006		–0.157 ± 0.004

Filter	Phase	Magnitude Min. II	Phase	Magnitude Max. II
	0.5		0.75	
V		0.080 ± 0.009		–0.392 ± 0.006
Rc		0.192 ± 0.007		–0.271 ± 0.006
Ic		0.303 ± 0.009		–0.153 ± 0.018

Filter	Min. I – Max. I	Max. I – Max. II	Min. I – Min. II
V	0.468 ± 0.009	–0.002 ± 0.013	–0.005 ± 0.011
Rc	0.458 ± 0.011	–0.004 ± 0.013	–0.008 ± 0.011
Ic	0.455 ± 0.010	–0.004 ± 0.022	–0.005 ± 0.015

Filter	Max. II – Max. I	Filter	Min. II – Max. I
V	0.002 ± 0.013	V	0.472 ± 0.016
Rc	0.004 ± 0.013	Rc	0.463 ± 0.013
Ic	0.004 ± 0.022	Ic	0.456 ± 0.013

Table 5. VR_cI_c solution parameters for V573 Peg.

Parameter	Overcontact Solution	Parameter	Overcontact Solution
l_V, l_{Rc}, l_{Ic} (nm)	440, 550, 640, 790	$q(m_2/m_1)$	0.2629 ± 0.0003
$x_{bol1,2}$, $y_{bol1,}2$	0.640 0 .640, 0.232, 0.232	Fill–outs: $F_1 = F_2$ (%)	24.5 ± 1.0
$x_{1Ic,2Ic}$, $y_{1Ic,2I}c$	0.569, 0.569, 0.271, 0.271	$L_1/(L_1+L_2)_{Ic}$	0.7554 ± 0.0003
$x_{1Rc,2Rc}$, $y_{1Rc,2Rc}$	0.652, 0.652, 0. 278, 0.278	$L_1/(L_1+L_2)_{Rc}$	0.7531 ± 0.0003
$x_{1V,2V}$, $y_{1V,2V}$	0.725, 0.725, 0.266, 0. 266	$L_1/(L_1+L_2)_V$	0.7023 ± 0.0003
g_1 , g_2	0.320, 0.320	JD_o (days)	2458028.65131 ± 0.00006
A1 , A_2	0.5, 0.5	Period (days)	0.417454 ± 0.000007
Inclination (°)	80.43 ± 0.06	r_1, r_2 (pole)	0.4751 ± 0.0003, 0.2613 ± 0.0006
T_1, T_2 (K)	6250, 6379 ± 1	r_1, r_2 (side)	0.5152 ± 0.0005, 0.2733 ± 0.0008
$\Omega_1 = \Omega_2$ pot	2.3421 ± 0.0005	r_1, r_2 (back)	0.5426 ± 0.0006, 0.3146 ± 0.0016