Photometry and Light Curve Modeling of HO Piscium and V535 Pegasi

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Received July 17, 2018; revised October 29, November 12, 2018; accepted November 12, 2018

Abstract In this article we will present the photometric study of the overcontact binaries HO Psc and V535 Peg. The data were acquired with the 304-mm telescope of RIAAM Observatory, and after the data reduction and photometry, the main parameters of the systems such as temperatures, inclination, and mass ratio were found using modeling in PHOEBE software.

1. Introduction

Studies of eclipsing binary stars are currently of interest because of testing models and understanding their various intrinsic properties (Terrell 2006). HO Psc (Martignoni 2006) and V535 Peg (Geske *et al.* 2006) are also overcontact eclipsing binaries, so they share a common envelope of material. W UMa system light curves usually have equal depth of primary and secondary minima, that is because both components have almost equal temperature. In W UMa variables, usually the components are so close that gravitational effects causes deformations of components. Information on these stars can be seen in Figure 1 and Table 1.

2. Observation and data reduction

We used the Research Institute for Astronomy and Astrophysics of Maragheh (RIAAM) observatory equipment which include a 304.8mm schmidt-cassegrain telescope and a SBIG STX-16803 CCD. The data were captured from July 2016 to October 2017 in BVR filters. The telescope was guided with a DMK31AU03 CCD mounted on a small telescope with focal length of 1000 mm. We also used 2 × 2 binning, and the CCD's temperature was fixed on –35° C with 75% of cooling fan power. The IRAF package was used for reducing the bias and dark frames and also dividing the flat field frame, which we captured in twilight from sky horizon at opposite direction of the sunrise. The reduced data were used for aperture photometry, so the photometry files were made in columns of HJD, object magnitude, and check star magnitude for each filter.

All of the magnitude points of the check star were subtracted from the average of them in order to find the variation range of the magnitude in observing time, and then they were subtracted from the object's magnitude (as seen in Tables 6 and 7). The HJD were converted to orbital phase using Equation 1 and the light curves have been plotted as seen in Figures 2 and 3.

$$\text{Phase} = \text{decimal}[(\text{HJD}_0 - \text{Epoch}) / \text{period}] \qquad (1)$$

The data of period of 0.4 to 0.6 and 0.9 to 1.1 for each minima were exported to an ASCII file in HJD and magnitude columns in order to calculate the minima time. The table curve software was used for peak fitting the data and calculating the minima time and error as seen in Table 2, and the O–C diagrams were plotted (Figure 4).

The data for HO Psc and V535 Peg are given in Tables 6 and 7, respectively, at the end of this article.

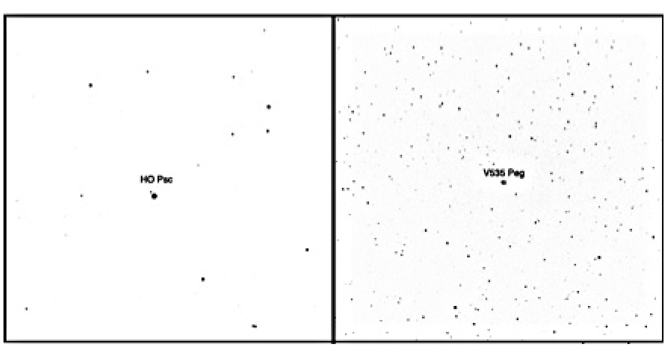

Figure 1. Field of view of the objects, left: HO Psc, right: V535 Peg.

3. Light curve modelling

In order to find the physical parameters of the systems we tried to achieve the best fitted model using the PHOEBE software (Prša and Zwitter 2005) , which uses the Wilson-Devinney code (WD; Wilson and Devinney 1971). The data were imported as an ASCII file with columns of phase and magnitude of the objects. The initial values of the temperatures of the systems were used considering their color indexes. As we have close binaries, the difference between the surface temperatures of the components was almost equal.

The next important parameter in PHOEBE is the mass ratio (q) of the systems. We tried about 20 steps for initial value of the mass ratio from 0.4 to 3, and considering the shape of the synthetic light curve and the chi^2 value, q = 0.9 for HO Psc and q = 0.6 for V535 Peg were used.

The limb darkening values have been added from the van Hamme (1993) table with logarithmic law for the stars with

Table 1. Objects.

Object	*R.A. (2000)* *h m s*	*Dec. (2000)* *deg ' "*	*Magnitude (simbad)* *B*	*V*	*J*	*H*	*K*
HO Psc	01 30 16.466	+13 33 25.08	11.0	11.50	9.659	9.29	9.215
V535 Peg	22 36 16.7640	+33 18 56.761	11.18	10.851	9.157	8.793	8.694

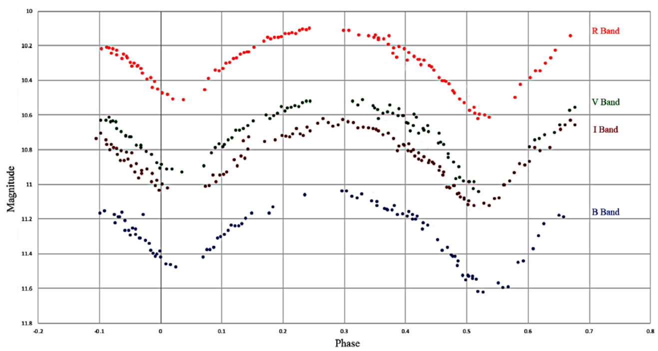

Figure 2. V535 Peg BVRI light curve.

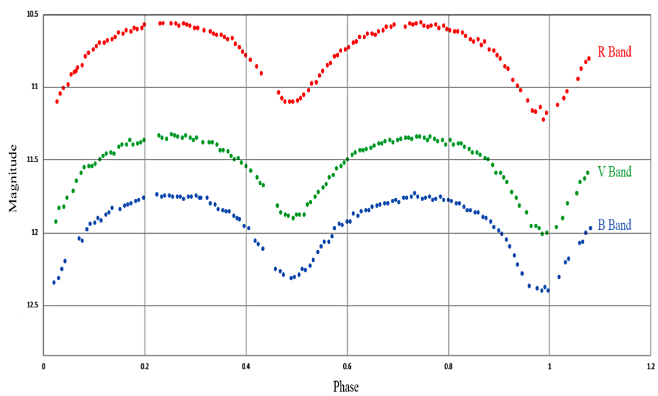

Figure 3. HO Psc BVR light curve.

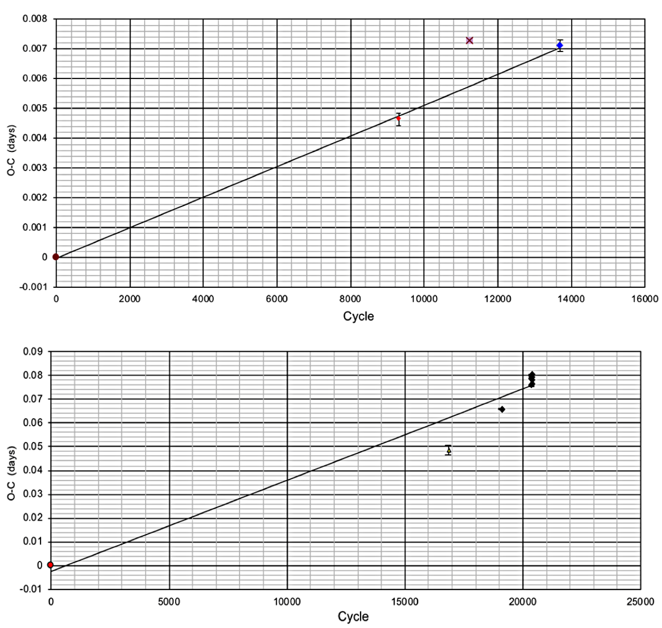

Figure 4. O–C diagrams for HO Psc (upper plot) and V535 Peg (lower plot).

$T_{eff} < 9000$ with convective layer (Al-Naimiy 1978). The gravity darkening values were also used from the table of Lucy (1967). After that, we tried to achieve the best physical parameters of inclination and temperature. With a lot of iterations, we used the calculation of PHOEBE to get the best fitted model considering the chi^2 without spot as seen in Table 3. In both systems' light curves, a difference in the magnitude was seen in the out-of-eclipse region that is known as the O'Connell effect (O'Connell

Table 2. Observed minima.

Object	*Primary Minima*	*rms Error*	*Secondary Minima*	*rms Error*
HO Psc	2457702.4888	$4.1e^{-5}$	2457702.3262	$0.9e^{-5}$
V535 Peg	2458035.3140	$6.32e^{-5}$	2458035.4725	$1.83e^{-5}$
	2458038.2224	$1.22e^{-5}$	2458038.383	$3.91e^{-5}$
	2458039.189	$2.94e^{-5}$	2458039.349	$1.39e^{-5}$

Table 3. Physical parameters.

Parameter	*HO Psc*	*V535 Peg*	*Error*
Period (days)	0.324747736	0.323003849	—
New epoch	2457702.4872	2458039.18664	—
Ω_1	3.35	2.85	0.03
Ω_2	3.35	2.85	0.03
q_{ptm}	0.90	0.58	0.01
Inclination	75.14°	72.56°	0.1
Limb Darkening (linear)	x1 = 0.68 y1 = 0.18	x1 = 0.67 y1 = 0.21	—
Limb Darkening (non-linear)	x2 = 0.68 y2 = 0.18	x2 = 0.67 y2 = 0.20	—
Gravity Darkening	g1 = 0.5	g1 = 0.32	—
	g2 = 0.82	g2 = 0.32	—
T_{eff1}	6674 K	6730 K	12
T_{eff2}	6228 K	6509 K	20
L_1 ($L_\odot$)	4.38	4.88	—
L_2 ($L_\odot$)	3.24	2.514	—
R_1 ($R_\odot$)	1.57	1.63	—
R_2 ($R_\odot$)	1.50	1.25	—
M_{bol1}	3.14	3.02	—
M_{bol2}	3.53	3.74	—
SMA	5.86	2.60	—

Table 4. HO Psc spot parameters.

	Colatitude	*Longitude*	*Radius*	*Temperature*
Primary Star	90	90	10	0.9

Table 5. V535 Peg spots parameters.

	Colatitude	*Longitude*	*Radius*	*Temperature*
Primary Star	90	90	20	0.7

1951), so we tried to add a spot (Tables 4 and 5). The fitted models of the systems are shown in Figures 5 and 6.

To test this model, we tried to calculate the luminosities and radii values using the emperical relationship between M_{bol} and T_{eff} given by Reed (1998) for the $T_{eff} < 9141$ as seen in Equation 2 and then, driving luminosity and radius with Equations 3 to 5.

$$BC = -8.499 [\log(T) - 4]4 + 13.421[\log(T) - 4]3 - 8.131[\log(T)- 4]2 - 3.901 [\log(T) - 4] - 0.438 \quad (2)$$

$$M_{bol} = M_v + BC(T_{eff}) \quad (3)$$

$$M_{bol(*)} = M_{bol(sun)} - 2.5 \log(L * / L_{sun}) \quad (4)$$

$$R^2 = L / T_{eff}^4 \quad (5)$$

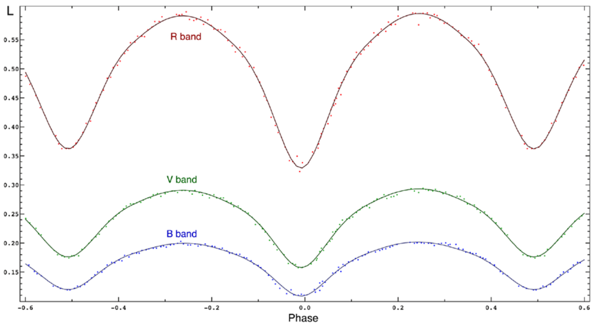

Figure 5. HO Psc fitted model.

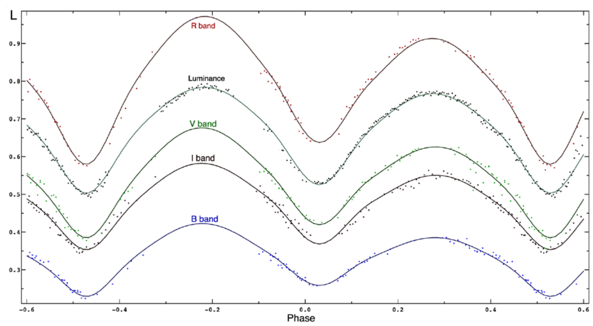

Figure 6. V535 Peg fitted model.

The measured values for radii and luminosities were the same as the values obtained in PHOEBE as seen in Table 3.

We also used the main sequence parameter table of Boyajian *et al.* (2013) for the mass of the components which were well matched with our stars, and considering the mass values we determined the semi-major axis values of the systems.

The 3D shapes of the systems were also drawn using BINARYMAKER software (Bradstreet and Steelman 2002; Figures 7 and 8).

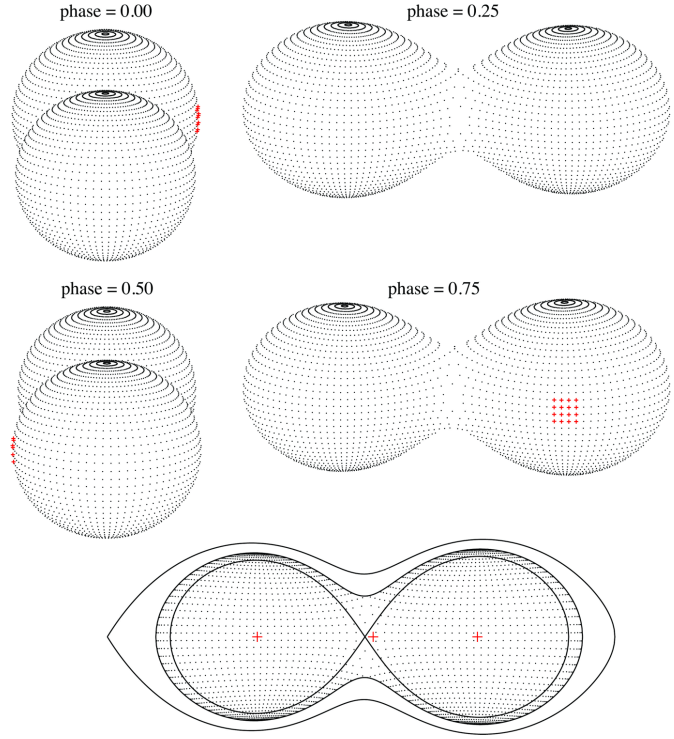

Figure 7. 3D shape of HO Psc.

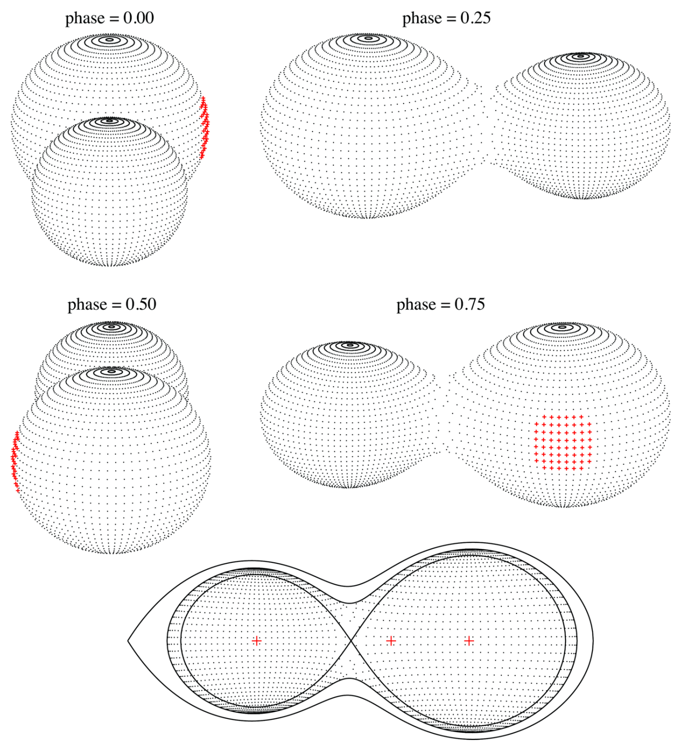

Figure 8. 3D shape of V535 Peg.

4. Acknowledgement

This work has been supported financially by the Research Institute in Astronomy and Astrophysics of Maraghah.

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Table 6. HO Psc data.

HJD	*B*	*HJD*	*V*	*HJD*	*R*	*HJD*	*B*	*HJD*	*V*	*HJD*	*R*
2457702.172	12.34	2457702.173	11.92	2457702.174	11.10	2457702.350	12.02	2457702.346	11.67	2457702.344	10.89
2457702.175	12.31	2457702.175	11.83	2457702.176	11.04	2457702.352	11.97	2457702.348	11.62	2457702.347	10.85
2457702.177	12.25	2457702.178	11.82	2457702.178	11.00	2457702.355	11.94	2457702.351	11.60	2457702.349	10.84
2457702.179	12.20	2457702.180	11.76	2457702.181	10.98	2457702.357	11.95	2457702.353	11.56	2457702.352	10.79
2457702.188	12.04	2457702.184	11.71	2457702.183	10.92	2457702.360	11.92	2457702.356	11.54	2457702.354	10.78
2457702.190	12.05	2457702.186	11.64	2457702.185	10.90	2457702.362	11.92	2457702.358	11.52	2457702.356	10.75
2457702.193	11.98	2457702.189	11.59	2457702.186	10.89	2457702.364	11.87	2457702.360	11.50	2457702.359	10.74
2457702.195	11.94	2457702.191	11.55	2457702.187	10.87	2457702.367	11.88	2457702.363	11.47	2457702.361	10.72
2457702.198	11.93	2457702.194	11.54	2457702.190	10.85	2457702.369	11.85	2457702.365	11.45	2457702.364	10.70
2457702.200	11.90	2457702.196	11.54	2457702.192	10.79	2457702.372	11.84	2457702.368	11.43	2457702.366	10.69
2457702.202	11.91	2457702.198	11.53	2457702.194	10.76	2457702.374	11.84	2457702.370	11.43	2457702.368	10.66
2457702.205	11.88	2457702.201	11.49	2457702.197	10.75	2457702.376	11.82	2457702.372	11.42	2457702.371	10.66
2457702.207	11.86	2457702.203	11.47	2457702.199	10.72	2457702.379	11.82	2457702.375	11.42	2457702.373	10.64
2457702.209	11.83	2457702.205	11.46	2457702.201	10.69	2457702.381	11.80	2457702.377	11.41	2457702.376	10.64
2457702.214	11.84	2457702.208	11.45	2457702.204	10.70	2457702.384	11.80	2457702.380	11.39	2457702.378	10.64
2457702.217	11.82	2457702.210	11.46	2457702.206	10.68	2457702.386	11.80	2457702.382	11.39	2457702.380	10.62
2457702.219	11.81	2457702.213	11.41	2457702.209	10.67	2457702.389	11.78	2457702.384	11.37	2457702.383	10.61
2457702.221	11.80	2457702.215	11.40	2457702.211	10.66	2457702.391	11.77	2457702.387	11.36	2457702.385	10.59
2457702.224	11.79	2457702.218	11.39	2457702.213	10.63	2457702.393	11.79	2457702.389	11.38	2457702.388	10.59
2457702.226	11.78	2457702.220	11.37	2457702.216	10.63	2457702.396	11.76	2457702.392	11.36	2457702.390	10.57
2457702.229	11.76	2457702.222	11.39	2457702.218	10.61	2457702.398	11.76	2457702.394	11.35	2457702.393	10.62
2457702.238	11.74	2457702.225	11.38	2457702.221	10.62	2457702.401	11.75	2457702.397	11.35	2457702.395	10.63
2457702.241	11.75	2457702.227	11.38	2457702.223	10.59	2457702.403	11.73	2457702.399	11.35	2457702.397	10.59
2457702.243	11.74	2457702.229	11.37	2457702.225	10.60	2457702.405	11.75	2457702.401	11.36	2457702.400	10.57
2457702.246	11.75	2457702.239	11.33	2457702.228	10.60	2457702.408	11.77	2457702.404	11.34	2457702.402	10.57
2457702.248	11.75	2457702.241	11.35	2457702.230	10.57	2457702.410	11.76	2457702.406	11.34	2457702.404	10.57
2457702.251	11.75	2457702.244	11.36	2457702.240	10.56	2457702.413	11.75	2457702.409	11.35	2457702.407	10.56
2457702.253	11.75	2457702.247	11.33	2457702.242	10.56	2457702.415	11.78	2457702.411	11.37	2457702.409	10.58
2457702.255	11.77	2457702.249	11.34	2457702.244	10.60	2457702.417	11.77	2457702.413	11.34	2457702.412	10.59
2457702.258	11.75	2457702.251	11.34	2457702.247	10.56	2457702.420	11.75	2457702.416	11.36	2457702.414	10.58
2457702.260	11.75	2457702.254	11.35	2457702.250	10.56	2457702.422	11.77	2457702.418	11.37	2457702.417	10.58
2457702.263	11.75	2457702.256	11.34	2457702.252	10.58	2457702.425	11.78	2457702.421	11.37	2457702.419	10.60
2457702.265	11.76	2457702.259	11.35	2457702.255	10.57	2457702.427	11.78	2457702.423	11.39	2457702.422	10.58
2457702.266	11.76	2457702.261	11.36	2457702.257	10.57	2457702.430	11.80	2457702.426	11.37	2457702.424	10.60
2457702.270	11.76	2457702.263	11.35	2457702.259	10.58	2457702.432	11.80	2457702.428	11.39	2457702.426	10.61
2457702.272	11.80	2457702.267	11.38	2457702.262	10.59	2457702.435	11.82	2457702.431	11.39	2457702.429	10.62
2457702.275	11.81	2457702.271	11.38	2457702.264	10.59	2457702.437	11.84	2457702.433	11.39	2457702.431	10.62
2457702.277	11.84	2457702.273	11.38	2457702.268	10.61	2457702.439	11.84	2457702.435	11.41	2457702.434	10.62
2457702.280	11.84	2457702.276	11.40	2457702.272	10.62	2457702.442	11.86	2457702.438	11.43	2457702.436	10.65
2457702.282	11.85	2457702.278	11.43	2457702.274	10.64	2457702.444	11.86	2457702.440	11.45	2457702.439	10.67
2457702.284	11.85	2457702.280	11.44	2457702.276	10.64	2457702.447	11.89	2457702.443	11.45	2457702.441	10.69
2457702.287	11.89	2457702.283	11.44	2457702.279	10.64	2457702.449	11.90	2457702.445	11.47	2457702.444	10.68
2457702.289	11.90	2457702.285	11.47	2457702.281	10.65	2457702.452	11.92	2457702.448	11.49	2457702.446	10.71
2457702.291	11.91	2457702.287	11.49	2457702.283	10.67	2457702.454	11.96	2457702.450	11.50	2457702.448	10.69
2457702.294	11.95	2457702.290	11.49	2457702.286	10.66	2457702.457	11.98	2457702.453	11.53	2457702.451	10.74
2457702.297	11.97	2457702.292	11.52	2457702.288	10.70	2457702.459	12.01	2457702.455	11.59	2457702.454	10.75
2457702.301	12.05	2457702.295	11.54	2457702.291	10.73	2457702.462	12.05	2457702.458	11.59	2457702.456	10.78
2457702.303	12.08	2457702.298	11.57	2457702.293	10.76	2457702.464	12.10	2457702.460	11.62	2457702.458	10.80
2457702.306	12.11	2457702.302	11.62	2457702.295	10.78	2457702.467	12.16	2457702.462	11.65	2457702.461	10.86
2457702.314	12.25	2457702.304	11.66	2457702.298	10.81	2457702.469	12.22	2457702.465	11.72	2457702.463	10.88
2457702.317	12.26	2457702.306	11.67	2457702.302	10.86	2457702.472	12.28	2457702.468	11.76	2457702.466	10.95
2457702.319	12.29	2457702.315	11.82	2457702.305	10.91	2457702.477	12.37	2457702.470	11.81	2457702.469	10.99
2457702.321	12.32	2457702.317	11.86	2457702.316	11.04	2457702.480	12.31	2457702.475	11.86	2457702.471	11.02
2457702.324	12.31	2457702.320	11.88	2457702.318	11.08	2457702.482	12.38	2457702.478	11.95	2457702.476	11.09
2457702.326	12.30	2457702.322	11.89	2457702.320	11.10	2457702.485	12.40	2457702.481	11.96	2457702.479	11.16
2457702.329	12.29	2457702.325	11.90	2457702.323	11.10	2457702.487	12.38	2457702.483	11.97	2457702.481	11.17
2457702.331	12.25	2457702.327	11.87	2457702.325	11.10	2457702.489	12.39	2457702.485	12.01	2457702.484	11.14
2457702.333	12.26	2457702.329	11.88	2457702.328	11.09	2457702.496	12.30	2457702.488	12.00	2457702.486	11.23
2457702.336	12.23	2457702.332	11.87	2457702.330	11.07	2457702.500	12.20	2457702.494	11.96	2457702.488	11.18
2457702.338	12.19	2457702.334	11.81	2457702.332	11.06	2457702.502	12.18	2457702.498	11.90	2457702.495	11.12
2457702.341	12.13	2457702.336	11.79	2457702.335	11.02	2457702.509	12.07	2457702.501	11.80	2457702.499	11.08
2457702.343	12.10	2457702.339	11.75	2457702.337	10.98	2457702.511	12.07	2457702.507	11.73	2457702.501	11.03
2457702.345	12.06	2457702.341	11.72	2457702.340	10.97	2457702.513	12.00	2457702.509	11.65	2457702.508	10.94
2457702.348	12.06	2457702.344	11.69	2457702.342	10.92	2457702.516	11.97	2457702.512	11.63	2457702.510	10.88

Table 7. V535 Peg data.

HJD	*B*	*HJD*	*V*	*HJD*	*R*
2458038.175	11.52	2458038.176	10.58	2458038.176	10.60
2458038.178	11.50	2458038.178	10.57	2458038.179	10.60
2458038.181	11.53	2458038.181	10.56	2458038.182	10.63
2458038.183	11.56	2458038.184	10.49	2458038.184	10.64
2458038.186	11.60	2458038.187	10.64	2458038.187	10.62
2458038.189	11.56	2458038.189	10.65	2458038.190	10.63
2458038.191	11.61	2458038.192	10.67	2458038.192	10.70
2458038.194	11.66	2458038.195	10.71	2458038.195	10.71
2458038.197	11.66	2458038.197	10.71	2458038.198	10.75
2458038.199	11.69	2458038.200	10.77	2458038.200	10.80
2458038.202	11.75	2458038.203	10.77	2458038.203	10.82
2458038.205	11.78	2458038.205	10.81	2458038.206	10.87
2458038.207	11.78	2458038.208	10.83	2458038.208	10.87
2458038.210	11.81	2458038.211	10.87	2458038.211	10.89
2458038.213	11.82	2458038.213	10.89	2458038.214	10.91
2458038.216	11.83	2458038.219	10.86	2458038.219	10.92
2458038.218	11.96	2458038.253	10.62	2458038.254	10.63
2458038.253	11.56	2458038.256	10.55	2458038.257	10.59
2458038.256	11.50	2458038.293	10.44	2458038.293	10.52
2458038.292	11.44	2458038.296	10.46	2458038.296	10.53
2458038.295	11.43	2458038.298	10.43	2458038.299	10.49
2458038.298	11.42	2458038.301	10.46	2458038.301	10.44
2458038.300	11.42	2458038.303	10.50	2458038.304	10.52
2458038.303	11.38	2458038.306	10.49	2458038.307	10.54
2458038.306	11.35	2458038.309	10.47	2458038.309	10.54
2458038.308	11.41	2458038.311	10.44	2458038.312	10.52
2458038.311	11.43	2458038.314	10.42	2458038.314	10.51
2458038.314	11.43	2458038.317	10.51	2458038.317	10.58
2458038.316	11.39	2458038.319	10.51	2458038.320	10.54
2458038.319	11.42	2458038.322	10.51	2458038.322	10.54
2458038.322	11.44	2458038.325	10.55	2458038.325	10.56
2458038.324	11.48	2458038.327	10.56	2458038.328	10.59
2458038.327	11.45	2458038.330	10.56	2458038.330	10.58
2458038.329	11.53	2458038.333	10.56	2458038.333	10.59
2458038.332	11.52	2458038.335	10.59	2458038.336	10.63
2458038.335	11.50	2458038.338	10.59	2458038.338	10.61
2458038.338	11.53	2458038.341	10.63	2458038.341	10.64
2458038.340	11.54	2458038.343	10.62	2458038.344	10.70
2458038.343	11.60	2458038.346	10.64	2458038.346	10.67
2458038.345	11.61	2458038.349	10.67	2458038.349	10.69
2458038.348	11.59	2458038.351	10.70	2458038.352	10.72
2458038.351	11.61	2458038.354	10.71	2458038.354	10.77
2458038.353	11.71	2458038.357	10.75	2458038.357	10.77
2458038.356	11.73	2458038.359	10.80	2458038.360	10.82
2458038.359	11.73	2458038.362	10.87	2458038.362	10.87
2458038.361	11.76	2458038.365	10.86	2458038.365	10.90
2458038.364	11.83	2458038.367	10.90	2458038.368	10.96
2458038.367	11.85	2458038.370	10.95	2458038.370	10.96
2458038.369	11.93	2458038.373	10.96	2458038.373	10.99
2458038.372	11.89	2458038.375	10.96	2458038.376	11.02
2458038.375	11.95	2458038.378	11.04	2458038.378	11.01
2458038.377	11.91	2458038.381	10.97	2458038.381	11.02
2458038.380	11.97	2458038.383	11.03	2458038.384	11.00
2458038.383	11.95	2458038.386	10.97	2458038.386	10.95
2458038.385	11.93	2458038.389	10.95	2458038.389	10.94
2458038.388	11.96	2458038.391	10.88	2458038.392	10.87
2458038.391	11.89	2458038.394	10.86	2458038.394	10.89
2458038.393	11.83	2458038.397	10.82	2458038.397	10.80
2458038.396	11.75	2458038.399	10.71	2458038.400	10.76
2458038.399	11.78	2458038.402	10.75	2458038.402	10.77
2458038.401	11.69	2458038.405	10.65	2458038.405	10.71
2458038.404	11.70	2458038.407	10.67	2458038.408	10.71
2458038.407	11.55	2458038.410	10.64	2458038.410	10.66
2458038.409	11.53	2458038.413	10.54	2458038.413	10.60
2458038.412	11.50	2458038.415	10.62	2458038.416	10.59
2458038.415	11.46	2458038.418	10.56	2458038.418	10.63
2458038.417	11.44	2458038.421	10.50	2458038.421	10.56
2458038.420	11.47	2458038.423	10.44	2458038.424	10.52
2458038.423	11.41	2458039.147	10.45	2458038.426	10.49
2458038.425	11.27	2458039.149	10.32	2458039.148	10.34
2458038.428	11.25	2458039.151	10.35	2458039.149	10.35
2458039.147	11.45	2458039.153	10.59	2458039.151	10.46
2458039.148	11.30	2458039.155	10.51	2458039.153	10.59
2458039.150	11.33	2458039.156	10.61	2458039.155	10.64
2458039.152	11.56	2458039.158	10.64	2458039.157	10.67
2458039.154	11.59	2458039.160	10.66	2458039.159	10.68
2458039.156	11.55	2458039.162	10.75	2458039.161	10.69
2458039.158	11.62	2458039.164	10.78	2458039.162	10.71
2458039.160	11.63	2458039.166	10.74	2458039.164	10.75
2458039.162	11.61	2458039.168	10.77	2458039.166	10.76
2458039.163	11.61	2458039.171	10.79	2458039.168	10.84
2458039.165	11.68	2458039.173	10.73	2458039.171	10.79
2458039.167	11.60	2458039.175	10.85	2458039.173	10.84
2458039.171	11.73	2458039.177	10.82	2458039.175	10.82
2458039.172	11.76	2458039.199	10.81	2458039.200	10.84
2458039.174	11.76	2458039.201	10.76	2458039.202	10.76
2458039.176	11.73	2458039.203	10.76	2458039.204	10.79
2458039.199	11.77	2458039.205	10.72	2458039.205	10.70
2458039.201	11.74	2458039.207	10.69	2458039.207	10.75
2458039.203	11.75	2458039.209	10.71	2458039.209	10.69
2458039.204	11.72	2458039.211	10.68	2458039.211	10.72
2458039.206	11.68	2458039.212	10.68	2458039.213	10.71
2458039.208	11.67	2458039.214	10.69	2458039.215	10.78
2458039.210	11.66	2458039.216	10.64	2458039.217	10.63
2458039.212	11.63	2458039.218	10.59	2458039.218	10.63
2458039.214	11.59	2458039.220	10.60	2458039.220	10.66
2458039.216	11.62	2458039.222	10.60	2458039.222	10.63
2458039.218	11.58	2458039.230	10.58	2458039.231	10.61
2458039.219	11.58	2458039.232	10.53	2458039.233	10.59
2458039.221	11.57	2458039.234	10.57	2458039.235	10.56
2458039.230	11.50	2458039.236	10.53	2458039.236	10.61
2458039.232	11.50	2458039.238	10.54	2458039.238	10.55
2458039.234	11.53	2458039.240	10.50	2458039.240	10.55
2458039.236	11.50	2458039.242	10.50	2458039.242	10.53
2458039.237	11.45	2458039.244	10.49	2458039.244	10.53
2458039.239	11.70	2458039.245	10.48	2458039.246	10.50
2458039.241	11.45	2458039.247	10.49	2458039.248	10.54
2458039.243	11.45	2458039.249	10.51	2458039.249	10.53
2458039.245	11.43	2458039.251	10.46	2458039.251	10.47
2458039.247	11.45	2458039.253	10.47	2458039.253	10.50
2458039.249	11.42	2458039.255	10.45	2458039.255	10.50
2458039.250	11.43	2458039.289	10.49	2458039.290	10.59
2458039.252	11.45	2458039.291	10.55	2458039.291	10.58
2458039.254	11.39	2458039.293	10.61	2458039.293	10.67
2458039.289	11.44	2458039.295	10.58	2458039.295	10.70
2458039.291	11.45	2458039.297	10.52	2458039.297	10.61
2458039.292	11.52	2458039.299	10.56	2458039.299	10.64
2458039.294	11.50	2458039.300	10.65	2458039.301	10.63
2458039.296	11.52	2458039.302	10.52	2458039.303	10.61
2458039.298	11.48	2458039.304	10.55	2458039.305	10.72
2458039.300	11.46	2458039.306	10.57	2458039.306	10.67
2458039.302	11.49	2458039.308	10.64	2458039.308	10.66
2458039.304	11.52	2458039.310	10.60	2458039.310	10.64
2458039.306	11.54	2458039.312	10.54	2458039.312	10.67
2458039.307	11.52	2458039.313	10.69	2458039.314	10.70
2458039.309	11.55	2458039.315	10.63	2458039.316	10.70
2458039.311	11.57	2458039.317	10.65	2458039.318	10.65
2458039.313	11.63	2458039.319	10.73	2458039.319	10.72
2458039.315	11.58	2458039.321	10.78	2458039.321	10.71
2458039.317	11.59	2458039.323	10.66	2458039.323	10.85
2458039.319	11.60	2458039.325	10.69	2458039.325	10.77
2458039.320	11.60	2458039.326	10.78	2458039.327	10.81
2458039.322	11.72	2458039.328	10.78	2458039.329	10.80
2458039.324	11.73	2458039.330	10.86	2458039.331	10.84
2458039.326	11.72	2458039.332	10.88	2458039.332	10.88
2458039.328	11.73	2458039.334	10.88	2458039.334	10.93
2458039.330	11.76	2458039.336	10.91	2458039.336	10.90
2458039.332	11.79	2458039.338	10.94	2458039.338	10.93
2458039.333	11.79	2458039.339	10.92	2458039.340	10.95
2458039.335	11.83	2458039.341	10.99	2458039.342	10.96
2458039.337	11.92	2458039.343	11.04	2458039.344	11.02