Monitoring of spotted RS CVn and BY Dra type stars. I. Simultaneous optical and infrared photometry

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Abstract. *UBV(RI)*$_{\rm c}$ *JHK* photometry of 6 active stars, collected at the South African Astronomical Observatory in 1996 and 1997, is presented. The light and colour curves, which are compared with those observed at previous epochs, show significant variation in their wave-like modulation and in their maximum brightness.

Key words: stars: activity – stars: late-type – stars: variables

1. Introduction

The light variability observed in active stars is believed to be due to the passage of large photospheric inhomogeneities – starspots – carried over the visible disk of the star by its rotation. In order to investigate the physical parameters and evolution of starspots and the time scale of activity cycles, active stars must be observed regularly and systematically.

The data presented in this paper will add to the long-term photometric monitoring of some active stars and can give important information on issues such as the stability of the spotted areas, differential rotation and solar-like cycles.

1.1. AG Dor

AG Dor (HD 26354) is a non-eclipsing, double-lined spectroscopic binary (SB2) which was classified as an RS CVn-type system by Kholopov et al. (1989), though a BY Dra-type classification was also feasible. Recently, from an extensive high resolution spectroscopic study, Washüttl & Strassmeier (1995) deduced projected rotational velocities, $v \sin i$, of 17 ± 2 and 10 ± 5 km s^{-1} for

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the primary and secondary components respectively. These values translate to minimum radii of 0.86 and 0.51 $R_\odot$, strengthening the BY Dra classification of K1V + K5V, and minimum inclination angles of the rotational axes of $\simeq 60^o$ and $\simeq 73^o$ for the components. For such a system, the maximum value of the inclination angle for which no eclipses are observed is $\simeq 80^o$, which restricts the range of possible inclination angles to between 73 and 80 degrees, if we assume them to be the same for both components. The secondary star would be about 1.2 magnitudes fainter in the V-band than the primary (Cutispoto 1996). The system which has an orbital period of 2.562 days (Balona 1987) was discovered to be variable, photometrically, by Lloyd-Evans & Koen (1987). They reported V-light variations with a period of 2.533 days and an amplitude of 0.09 magnitudes.

1.2. HU Vir

HU Vir (HD 106225) is a SB1 K1 subgiant (Strassmeier 1994; Cutispoto 1998). The maximum brightness from the CABS catalog (Strassmeier et al. 1993) is $V = 8.57$ and its photometric period 10.28 days (Fekel et al. 1984). Cutispoto (1998) lists new minima for the V magnitude and colour curves observed in March 1991. HU Vir also shows CaII H and K very strongly in emission (Montes et al. 1996), Hα and ultraviolet emission (Fekel et al. 1986), coronal X-ray (Dempsey et al. 1993) and radio emission (Drake et al. 1989) and spectral line variations (Strassmeier et al. 1990). Its variability in the optical has been studied recently by several authors (see Strassmeier et al. 1993, Strassmeier et al. 1997, Cutispoto 1996, 1998).

1.3. V1005 Ori

V1005 Ori (Gl 182) is a BY Dra flare star with spectral type dM0.5e (Joy & Abt 1974) and has been reported to be a rapidly rotating star flaring at an anomalously high rate (Reza et al. 1981). Byrne et al. (1984) re-examined its rate of flaring and arrived at the conclusion that it was normal for this class of stars. Gudel et al. (1993) detected it simultaneously in the ROSAT All-Sky Survey and with the VLA and measured an X-ray flux of $0.089\,10^{30}$ erg s^{-1} and a radio flux at 6cm of 0.26 mJy.

1.4. CD -28^o2525

CD −28 2525 (HD 39576) is a single-lined spectroscopic RS CVn binary with a G1V (Houk 1982) primary component which has a $v \sin i$ of 20 km s^{-1} (Strassmeier et al. 1992). The star exhibits moderately strong Ca II H and K emission and variable X-ray emission in the 1-13 keV range (Buckley et al. 1987). No orbital information is available. The minimum visual magnitude observed for this system is 9.05 magnitudes (Buckley et al. 1987).

1.5. TY Pyx

TY Pyx (HD 77137) is an eclipsing RS CVn binary in which both components seem to be slightly evolved subgiants, of a very similar spectral type (G5), and with similar radii of $1.59R_\odot$ and $1.68R_\odot$ at a separation of about $24.5R_\odot$ (Gunn et al. 1997). Strassmeier et al. (1993) list it with a minimum value for the visual magnitude of 6.835 and an amplitude variation of 0.05. Also listed are the X-ray flux, 4.63 10^{30} erg s^{-1} (Dempsey et al. 1993) and the radio flux density, 1.28 mJy (Slee et al. 1988).

1.6. YZ CMi

YZ CMi (Gl 285) is a dM4.5e star (Gliese & Jahreiss 1991) at a distance of 6 pc and belonging to both the UV Ceti class of flare stars and the BY Draconis group of variable stars. This type of star is characterized by intense flaring activity at X-ray, optical and radio wavelengths, cool atmospheres and low masses ($\sim$ 0.1 $M_\odot$). The interiors are thought to be fully convective, with magnetic fields playing an important role in heating the active coronae. YZ CMi shows the Balmer lines in emission (Doyle et al. 1988).

2. Observations

2.1. Observations from SAAO in 1996

The data were collected at the SAAO during the week of 30 January to 6 February, 1996.

The $UBV(RI)_c$ data were taken with the 0.5m telescope, which feeds a single-channel photon-counting photometer and were corrected for atmospheric extinction and transformed into the $UBV(RI)_c$ standard system. Transformation coefficients were obtained each night by observing Cousin E-region standards.

The *JHK* magnitudes were recorded with the 0.75m telescope and the Mk II infrared photometer. The infrared data were corrected for atmospheric extinction and zero-point by observing standard stars from the list published by Carter (1990).

Table 1. Target stars and comparison stars (Comp.) observed in 1996 with their respective spectral types

Program Star	Spectral Type	Comp.	Spectral Type
AG Dor	K1Vp	HD 25912	G3/G5V
HU Vir	K0IV	HD 107730	G8III-IV
V1005 Ori	M0Ve	HD 287516	K5V
CD -28° 2525	G1V	HD 39636	G8IV-V
TY Pyx	G5IV/G5IV	HD 76224	G5IV

Table 2. V magnitudes at maximum brightness and mean colours and infrared magnitudes of the program stars observed in 1996 (upper panel) and 1997 (lower panel). The standard deviations in units of milli-magnitudes (σ) for the variable–comparison V-band and K–band are given in columns 7 and 11, respectively.

Program	$V_{\rm max}$	U–B	B–V	$(V$–$R)_c$	$(V$–$I)_c$	σ	$\overline{J}$	$\overline{H}$	$\overline{K}$	σ
AG Dor	8.620	0.645	0.949	0.537	1.057	24	6.906	6.301	6.183	12
HU Vir	8.734	0.628	1.022	0.585	1.154	50	6.813	6.154	6.043	28
V1005 Ori	9.917	1.226	1.406	0.884	1.789	3	7.568	6.778	6.632	
−28° 2525	9.016	0.091	0.612	0.350	0.686	12	7.956	7.627	7.491	42
TY Pyx	6.853	0.246	0.710	0.380	0.723	12	5.648	5.306	5.247	
AG Dor	8.674	0.657	0.961	0.552	1.086	32	6.930	6.363	6.232	11
HU Vir	8.630	0.637	1.021	0.583	1.152	96	6.770	6.109	5.991	17
V1005 Ori	9.912	1.158	1.420	0.900	1.810	46	7.175	6.421	6.264	18
−28° 2525	9.030	0.083	0.614	0.352	0.695	26	7.928	7.567	7.504	45
YZ CMi	11.127	0.933	1.602	1.293	3.008	85	6.689	6.011	5.737	18

Table 3. Magnitudes and colours for the comparison stars (HD numbers, S stands for SAO number) in 1996 (upper panel) and 1997 (lower panel). The errors for the values of the V–band are given by the standard deviation (σ) in units of milli-magnitudes

Comp. star	V	U–B	B–V	$(V$–$R)_c$	$(V$–$I)_c$	σ	J	H	K	σ
25912	8.188	0.646	0.164	0.350	0.683	13	7.125	6.744	6.698	25
107730	9.173	0.997	0.740	0.515	0.996	22	7.523	6.966	6.874	25
287516	10.072	1.376	1.698	0.710	1.353	9	7.734	6.832	6.967	25
39636	9.253	0.940	0.531	0.509	1.009	20	7.595	6.939	6.873	25
76224	8.205	0.908	0.542	0.484	0.957	10				25
26779	8.571	1.258	1.232	0.627	1.189	11	6.564	5.878	5.775	12
106270	7.587	0.312	0.739	0.397	0.769	2	6.342	5.939	5.874	20
31452	8.420	0.577	0.859	0.455	0.858	11	7.043	6.580	6.526	33
S170938	9.613	0.117	0.644	0.357	0.705	15	8.453	8.093	8.043	6
S115869	8.101	0.632	0.916	0.469	0.908	18	6.594	6.105	6.042	127
40404	8.264		0.509	0.297	0.592	5				

In order to obtain accurate differential optical photometry for the variable stars (v), comparison (c) stars were chosen with similar magnitudes and spectral types and, where possible, position in the sky (see Table 1). Exposure times were sufficient to obtain a signal-to-noise ratio of 1000 in each filter (except for the U filter) with a typical observing sequence c-v-v-v-c. The variable star measurements were averaged to obtain one data point, while the sky background was also measured, especially carefully during the periods of bright moon. In Table 2 (upper panel), the V magnitude at maximum brightness and mean (U–B), (B–V), $(V$–$R)_{\rm c}$ and $(V$–$I)_{\rm c}$ colours and JHK magnitudes are reported for our program stars along with the standard deviations (σ) for the v-c differential V and K-band magnitudes in units of 0.001 magnitudes. Table 3 (upper panel) lists the magnitudes and colours of the comparison stars. The standard error of the mean V magnitude is, due to extinction and transformation errors, of the order of 0.013, with a typical standard error for a single measurement of a few millimagnitudes. The standard error for the K magnitude is of the order of ~ 0.03 mag.

Although telescope time of one week was awarded, most stars were not observed every night. This was principally due to poor weather conditions as is confirmed by the relatively high standard deviations of the comparison stars.

2.2. Observations from SAAO in 1997

Data were also collected at the SAAO, simultaneously in the optical and the infrared, between 24 December 1996 and 6 January 1997, between 23 and 27 of January, in the optical, and 28 January and 3 February in the infrared. The same telescopes and instrumental configurations were used as for the 1996 observations.

Table 4. Program, Comparison (Comp.) and check stars and their spectral types for the observations in 1997

Program star	Spectral type	Comp.	Spectral type	Check	Spectral type
AG Dor	K1Vp	HD 26779	K1III	HD 25901	A1V
HU Vir	K0IV	HD 106270	G5	HD 105796	K0
V1005 Ori	M0Ve	HD 31452	G5	HD 32320	A0
CD -28° 2525	G1V	SAO 170938	G0	HD 39636	G8IV/V
		HD 40404	G3V		
YZ CMi	M4.5Ve	SAO 115869	G5	HD 62811	A0

Accurate differential photometry for the variable stars (v) was again achieved by observing comparison (c) and check (ck) stars (see Table 1) with a sequence of observations of c-v-v-c-ck. In Table 2 (lower panel), the V magnitude at maximum brightness and mean $(U–B)$, $(B–V)$, $(V–R)_c$, $(V–I)_c$ colours and *JHK* magnitudes for our target stars for this run are reported along with the mean v-c and ck-c differential V-band and K-band magnitudes in units of 0.001 magnitudes. Table 3 (lower panel) lists the magnitudes and colours of the comparison stars. The standard error of the V magnitude for these observations is of the order of ~ 0.01, due to extinction and transformation errors, the typical single measure standard error being a few milli-magnitudes. The standard error for the K magnitude is of the order of ~ 0.03 mag.

3. Results

For **AG Dor** the V magnitude curve in 1996 had a single peak similar to that of the 1989 season (Cutispoto 1992) but with a larger mean value, viz., 8.654. The colours show no variation within the scatter except $(V–I)_c$, which shows small variations in phase with those of the V magnitude. In 1997, the light curve was also single-peaked but shifted in phase and with a fainter mean V of 8.724 mag., making it 0.07 magnitudes fainter than in 1996. This implies that the contribution of the non-modulating distribution of spots must have increased between the two epochs. $(V–R)_c$, $(V–I)_c$ and K show small variations in phase with those of the V curve. The colours are redder at light minimum, which is consistent with the interpretation that both the brightness and colour variations are a consequence of the rotational modulation of cool dark spots. However, the possibility of hot spots should also be considered where appropriate.

In the case of **HU Vir** we have two points missing (due to bad weather) from what might have been the maximum of the light and colour curves of the 1996 season. This is very disappointing. The light and colour variations resemble those of the 1989 epoch (see Cutispoto 1993) but are shifted in phase, i.e., the curve peaks at some point between phases 0.2 and 0.5, while the infrared colours and the K light curve follow the V band in phase. In 1997, the curve is still single-peaked with about the same mean value but the maximum has shifted to phase 0.72.

The **V1005 Ori** curve in 1996 is similar in shape to that in 1997. The curves are single-peaked but the amplitudes of $\sim$ 0.1 magnitude in 1996 become somewhat larger in 1997. The minimum in 1997 appears to be shifted from phase 0.4 to phase $\sim$ 0.55. It is not possible to say whether these two curves were produced by a distribution of spots on V1005 Ori that was stable during a time span of almost a year. Detailed period analysis will follow elsewhere. For the **CD-28^{o}2525** star the maximum brightness in V in 1996 was 9.016, i.e., 0.034 magnitudes brighter than the maximum of 9.05 reported by Buckley et al. (1987). There is no clear indication of colour variations at either epoch.

TY Pyx observations display well defined 0.2 mag. differences in colours and about 0.6 mag. in V filter respectively. It is interesting to note that the $(U–B)$ and $(B–V)$ colours for **YZ CMi** seem to go in anti-phase with the V, K, $(V–R)_c$ and $(V–I)_c$ curves, i.e., the star becomes bluer in those two colours when V gets fainter and the near-infrared colours get redder. This might indicate plage-like regions associated with the spots (Catalano et al. 1995). Although this behaviour is not often found in the literature, it could be more common than previously suspected and its presence disguised by the spatial and/or temperature distribution of the active region (taking for active region the association of dark spots and bright faculae).

4. Conclusions

The simultaneous optical and infrared photometry from SAAO of six active late-type stars is presented. The dataset show the power, if combined with another technique (coming paper), of long-term monitoring to explore spot evolution and to provide the maximal brightness in the V light curve, (especially if inter-compared with some 'historical' maxima).

The reconstructions based on photometry alone contain little information about the location of real structures on the stellar surface. The almost complete lack of latitude information in the light curve of an arbitrarily complex spot distribution produces over-simplified images that can lead to completely spurious conclusions.

5. Photometric data obtained in 1996 and 1997

AG Dor (HD 26354)
E_0 = 2447587.52 P= 2.533 days JD=2450000.+

HJD	Phase	V	$U{-}B$	$B{-}V$	$V{-}R_c$	$V{-}I_c$	J	H	K
0113.4481	0.2080						6.898	6.319	6.197
0114.3021	0.5450						6.836	6.289	6.165
0114.3487	0.5636	8.620	0.641	0.945	0.538	1.048			
0114.4095	0.5880						6.878	6.305	6.189
0115.3435	0.9565	8.650	0.646	0.946	0.538	1.065			
0115.4258	0.9889	8.707	0.641	0.948	0.524	1.025			
0116.2797	0.3260						6.842	6.301	6.177
0116.2934	0.3310								6.169
0116.3089	0.3375	8.659	0.647	0.951	0.540	1.065			
0116.4107	0.3780						6.915	6.333	6.216
0116.4157	0.3797	8.649	0.636	0.950	0.543	1.066			
0117.2754	0.7190						6.870	6.300	6.182
0117.3129	0.7339	8.639	0.645	0.946	0.542	1.054			
0117.4134	0.7735	8.644	0.640	0.959	0.538	1.059			
0117.4265	0.7790						6.914	6.296	6.174
0118.2764	0.1140						6.794	6.212	6.077
0118.3009	0.1239	8.661	0.639	0.948	0.536	1.062			
0118.4138	0.1685	8.666	0.651	0.952	0.540	1.062			
0118.4267	0.1740						6.925	6.317	6.198
0119.2740	0.5080						6.847	6.288	6.175
0119.2997	0.5182	8.644	0.659	0.948	0.532	1.063			

V1005Ori (Gl 182)
E_0 = 2444520.00 P= 4.399 days JD=2450000.+

HJD	Phase	V	$U{-}B$	$B{-}V$	$V{-}R_c$	$V{-}I_c$	J	H	K
0442.3650	0.2979						7.136	6.406	6.248
0443.3280	0.5170						7.215	6.445	6.282
0443.4730	0.5499						7.203	6.448	6.279
0446.3870	0.2122						7.160	6.405	6.242
0446.4648	0.2300	9.971	1.155	1.407	0.897	1.802			
0446.4648	0.2300	9.979	1.152	1.411	0.902	1.824			
0447.4740	0.4593						7.196	6.444	6.278
0450.3894	0.1222	9.948	1.157	1.401	0.898	1.795			
0450.3926	0.1229	9.950	1.204	1.408	0.900	1.799			
0450.3990	0.1243						7.188	6.394	6.253
0450.3990	0.1243						7.102	6.394	6.242
0451.3644	0.3438	10.014	1.166	1.407	0.900	1.819			
0451.3679	0.3446	10.020	1.155	1.401	0.903	1.821			
0453.3545	0.7962	10.013	1.143	1.399	0.907	1.811			
0453.3576	0.7969	10.007	1.130	1.407	0.899	1.809			
0453.4250	0.8123						7.160	6.420	6.266
0453.4250	0.8123						7.172	6.415	6.258
0454.3822	0.0298	9.912	1.156	1.401	0.888	1.788			
0454.3852	0.0305	9.913	1.164	1.396	0.888	1.775			
0454.4680	0.0493						7.148	6.393	6.232
0472.3541	0.1153	9.979		1.522	0.907	1.811			
0472.3602	0.1167	9.972		1.568	0.903	1.816			
0473.3574	0.3434	10.004		1.404	0.896	1.816			
0473.3636	0.3448	9.999		1.421	0.888	1.803			
0474.3467	0.5682	10.081		1.404	0.910	1.840			
0474.3524	0.5695	10.079		1.414	0.910	1.843			
0475.3455	0.7953	10.022		1.410	0.904	1.807			
0475.3515	0.7967	10.029		1.395	0.911	1.825			
0476.3522	0.0241	9.956		1.414	0.896	1.798			
0476.3579	0.0254	9.943		1.404	0.896	1.794			
0477.3000	0.2396						7.181	6.413	6.256
0478.3200	0.4715						7.197	6.436	6.276
0481.3400	0.1580						7.140	6.397	6.241
0482.3300	0.3830						7.195	6.435	6.285
0483.2900	0.6013						7.204	6.442	6.293

AG Dor (HD 26354)

E_0 = 2447587.52 P= 2.533 days JD=2450000.+

HJD	Phase	V	$U{-}B$	$B{-}V$	$V{-}R_c$	$V{-}I_c$	J	H	K
0442.4130	0.0798						6.879		
0442.4111	0.0790							6.331	
0442.4090	0.0782								6.201
0443.3532	0.4509	8.696	0.631	0.964	0.545	1.066			
0443.3561	0.4521	8.703	0.639	0.949	0.551	1.079			
0443.3798	0.4614						6.891		
0443.3775	0.4605							6.330	
0443.3747	0.4594								6.211
0446.3650	0.6399						6.899		
0446.3631	0.6392							6.341	
0446.3608	0.6383								6.201
0450.4470	0.2515	8.676	0.657	0.955	0.538	1.069			
0450.4500	0.2527	8.674	0.646	0.958	0.537	1.069			
0450.4751	0.2626						6.871		
0450.4736	0.2620							6.301	
0450.4716	0.2612								6.193
0450.4751	0.2626						6.877		
0450.4736	0.2620							6.321	
0450.4716	0.2612								6.203
0451.3615	0.6125						6.900		
0451.3631	0.6131							6.345	
0451.3650	0.6139								6.211
0451.3615	0.6125						6.903		
0451.3631	0.6131							6.337	
0451.3650	0.6139								6.209
0451.4125	0.6326	8.739	0.673	0.958	0.554	1.092			
0451.4162	0.6341	8.740	0.673	0.956	0.557	1.096			
0451.4201	0.6356	8.739	0.664	0.961	0.549	1.088			
0452.3261	0.9933	8.734	0.669	0.961	0.555	1.090			
0452.3295	0.9947	8.774	0.668	0.965	0.557	1.093			
0452.3408	0.9991						7.008		
0452.3388	0.9983							6.369	
0452.3313	0.9954								6.215
0453.3193	0.3854						6.889		
0453.3208	0.3860							6.326	
0453.3224	0.3867								6.202
0453.3193	0.3854						6.886		
0453.3208	0.3860							6.327	
0453.3224	0.3867								6.196
0453.3709	0.4058	8.695	0.667	0.963	0.549	1.081			
0453.3740	0.4070	8.701	0.663	0.964	0.553	1.081			
0453.4740	0.4465						6.926		
0453.4719	0.4457							6.342	
0453.4694	0.4447								6.207
0453.4740	0.4465						6.897		
0453.4719	0.4457							6.330	
0453.4694	0.4447								6.197
0454.4078	0.8152						6.935		
0454.4057	0.8143							6.355	
0454.4026	0.8131								6.217
0454.4078	0.8152						6.914		
0454.4057	0.8143							6.353	
0454.4026	0.8131								6.215
0454.4253	0.8221	8.748	0.654	0.961	0.551	1.098			
0454.4284	0.8233	8.744	0.661	0.966	0.552	1.085			
0454.4747	0.8416	8.750	0.662	0.956	0.550	1.094			
0454.4776	0.8427	8.751	0.667	0.953	0.554	1.100			
0454.4917	0.8483						6.908		
0454.4899	0.8476							6.349	
0454.4884	0.8470								6.235
0455.4968	0.2451	8.687	0.640	0.960	0.555	1.070			
0455.4999	0.2463	8.689	0.658	0.957	0.549	1.082			
0455.5033	0.2477						6.889		
0455.5019	0.2471							6.327	
0455.5004	0.2465								6.198
0472.3301	0.8907	8.756		0.959	0.558	1.095			
0472.3365	0.8932	8.759		0.969	0.563	1.098			
0473.3322	0.2863	8.708		0.955	0.547	1.081			
0473.3378	0.2885	8.694		0.966	0.549	1.079			
0474.3232	0.6775	8.750		0.966	0.554	1.099			
0474.3287	0.6797	8.749		0.961	0.560	1.093			
0475.3228	0.0722	8.746		0.973	0.551	1.092			
0475.3287	0.0743	8.749		0.964	0.555	1.090			
0476.3301	0.4699	8.704		0.962	0.553	1.078			
0476.3353	0.4719	8.705		0.960	0.550	1.084			
0477.2900	0.8488						6.926	6.353	6.229
0478.3300	0.2594						6.898	6.334	6.208
0481.3300	0.4437						6.876	6.320	6.195
0482.3200	0.8346						6.943	6.373	6.253
0483.2800	0.2136						6.905	6.337	6.212

HU Vir (HD 106225)
E_0 = 2447548.86 P= 10.314 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0113.5268	0.6590						6.812	6.151	6.049
0113.5337	0.6595	8.734	0.661	1.034	0.585	1.154			
0114.5239	0.7555	8.776	0.642	1.022	0.595	1.170			
0115.5260	0.8526	8.831	0.661	1.034	0.587	1.165			
0116.5027	0.9473	8.828	0.635	1.016	0.601	1.179			
0116.5075	0.9480						6.851	6.193	6.079
0117.5058	0.0446	8.765	0.628	1.009	0.584	1.152			
0117.5077	0.0450						6.791	6.122	6.027
0118.4982	0.1408	8.686	0.591	0.999	0.573	1.133			
0118.5139	0.1420						6.799	6.149	6.016

CD -28^o 2525 (HD 39576)
E_0 = 2448630.00 P= 2.7 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0442.4565	0.2802						7950		
0442.4589	0.2810							7.567	
0442.4647	0.2832								7.502
0443.4212	0.6375						7.919		
0443.4192	0.6367							7.556	
0443.4173	0.6360								7.493
0443.5053	0.6686						7.910		
0443.5034	0.6679							7.564	
0443.5013	0.6671								7.473
0446.4730	0.7678						7.913		
0446.4748	0.7684							7.557	
0446.4771	0.7693								7.491
0446.4730	0.7678						7.902		
0446.4748	0.7684							7.562	
0446.4771	0.7693								7.494
0446.4973	0.7768	9.050	0.077	0.615	0.356	0.701			
0447.5301	0.1593	9.059	0.098	0.610	0.354	0.706			
0447.5345	0.1609						7.933		
0447.5360	0.1615							7.612	
0447.5383	0.1623								7.547
0450.4736	0.2495	9.062	0.093	0.615	0.349	0.694			
0450.4393	0.2368						7.928		
0450.4377	0.2362							7.561	
0450.4357	0.2354								7.510
0450.4393	0.2368						7.919		
0450.4377	0.2362							7.570	
0450.4357	0.2354								7.501
0451.3960	0.5911						7.900		
0451.3975	0.5917							7.552	
0451.3995	0.5924								7.515
0451.3960	0.5911						7.914		
0451.3975	0.5917							7.558	
0451.3995	0.5924								7.518
0453.3555	0.3168						7.933		
0453.3570	0.3174							7.553	
0453.3587	0.3180								7.485
0453.3555	0.3168						7.944		
0453.3570	0.3174							7.563	
0453.3587	0.3180								7.488
0453.4053	0.3353	9.047	0.085	0.614	0.351	0.688			
0453.5158	0.3762						7.878		
0453.5138	0.3755							7.537	
0453.5112	0.3745								7.523
0453.5112	0.3745								7.505
0453.5158	0.3762						7.885		
0453.5138	0.3755							7.501	
0453.5112	0.3745								7.431
0453.5249	0.3796	9.030	0.067	0.599	0.349	0.697			
0454.4440	0.7200	9.051	0.086	0.612	0.352	0.690			
0454.5297	0.7517						7.960		
0454.5315	0.7524							7.559	
0454.5336	0.7532								7.478
0454.5336	0.7532								7.497
0454.5403	0.7557	9.041	0.080	0.626	0.350	0.692			
0455.4854	0.1057	9.062	0.087	0.614	0.362	0.698			
0455.5195	0.1183						7.923		
0455.5181	0.1178							7.558	
0455.5165	0.1172								7.515
0472.3745	0.3609	9.034		0.612	0.352	0.691			
0473.3790	0.7330	9.055		0.614	0.353	0.700			
0474.3659	0.0985	9.059		0.613	0.346	0.691			
0475.3655	0.4687	9.054		0.605	0.354	0.693			
0476.3711	0.8412	9.058		0.623	0.358	0.701			
0477.3500	0.2037						7.923	7.563	7.522
0478.3500	0.5741						7.925	7.567	7.511
0481.3600	0.6889						7.906	7.558	7.484
0482.3500	0.0556						8.109	7.741	7.619
0483.3100	0.4111						7.908	7.552	7.490

YZ CMi (GJ 285)
E_0 = 2443909.98 P= 2.78 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0442.5300	0.8382						6.699		
0442.5284	0.8376							6.012	
0442.5263	0.8368								5.740
0443.4050	0.1529	11.278	0.682	1.581	1.311	3.006			
0443.4089	0.1543	11.245	0.981	1.499	1.280	2.986			
0447.5540	0.6453						6.694		
0447.5555	0.6459							6.011	
0447.5574	0.6466								5.738
0450.4226	0.6772	11.585	0.936	1.659					
0450.4275	0.6789	11.248	1.000	1.609	1.306	3.027			
0450.4226	0.6772	11.498	0.958	1.616	1.279	2.984			
0450.4275	0.6789	11.335	0.860	1.594	1.317	3.026			
0450.5148	0.7104						6.706		
0450.5132	0.7098							6.023	
0450.5114	0.7092								5.750
0450.5148	0.7104						6.692		
0450.5132	0.7098							6.018	
0450.5114	0.7092								5.741
0450.5747	0.7319	11.322	0.958	1.579	1.314	3.029			
0450.5781	0.7331	11.323	0.860	1.594	1.317	3.026			
0451.3847	0.0233	11.230	1.043	1.625	1.259	2.964			
0451.3879	0.0244	11.227	0.977	1.624	1.249	2.954			
0451.4330	0.0407						6.682		
0451.4348	0.0413							5.995	
0451.4370	0.0421								5.724
0451.4330	0.0407						6.682		
0451.4348	0.0413							5.999	
0451.4370	0.0421								5.726
0453.3298	0.7230	11.312	0.841	1.600	1.305	3.024			
0453.3336	0.7243	11.309	0.910	1.579	1.292	3.026			
0453.3977	0.7474						6.687		
0453.3962	0.7469							6.014	
0453.3945	0.7463								5.748
0453.3977	0.7474						6.687		
0453.3962	0.7469							6.017	
0453.3945	0.7463								5.744
0454.4635	0.1308						6.673		
0454.4619	0.1302							6.004	
0454.4603	0.1296								5.731
0453.4783	0.7764	11.339	0.988	1.594	1.288	3.034			
0453.4818	0.7776	11.325	0.972	1.616	1.259	2.946			
0454.4023	0.1087	11.266	1.044	1.617	1.283	2.996			
0454.4053	0.1098	11.259	1.056	1.618	1.282	2.982			
0454.5261	0.1533	11.268	1.024	1.607	1.290	3.012			
0454.5292	0.1544	11.127	1.037	1.598	1.291	2.986			
0454.5261	0.1533	11.127	1.077	1.617	1.286	2.992			
0454.5292	0.1544	11.268	0.984	1.588	1.295	3.006			
0455.4583	0.4886	11.349	0.818	1.586	1.290	3.025			
0455.4612	0.4896	11.351	0.835	1.567	1.294	3.020			
0455.5317	0.5150	11.318	0.807	1.560	1.320	3.030			
0455.5348	0.5161	11.307	0.878	1.605	1.299	3.026			
0455.5317	0.5150	11.319	0.807	1.557	1.318	3.041			
0455.5348	0.5161	11.306	0.878	1.608	1.301	3.015			
0455.5510	0.5220						6.705		
0455.5495	0.5214							6.024	
0455.5380	0.5209								5.751
0472.4107	0.5866	11.271		1.505	1.285	2.999			
0472.4167	0.5888	11.304		1.610	1.302	3.030			
0473.4129	0.9471	11.276		1.633	1.277	2.997			
0473.4183	0.9490	11.282		1.672	1.289	3.007			
0474.3994	0.3020	11.287		1.639	1.298	3.012			
0474.4057	0.3042	11.298		1.602	1.304	3.021			
0475.3995	0.6617	11.350		1.732	1.320	3.044			
0475.4050	0.6637	11.314		1.625	1.295	3.017			
0476.4009	0.0219	11.271		1.589	1.288	2.998			
0476.4068	0.0240	11.276		1.564	1.294	3.004			
0477.4100	0.3849						6.681	6.002	5.726
0478.4000	0.7410						6.689	6.007	5.731
0481.4200	0.8273						6.683	6.009	5.735
0483.5200	0.5827						6.689	6.020	5.740

TY Pyx (HD 77137)

E_0 = 2443187.2304 P= 3.199 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0114.5059	0.7360								11.004
0114.5120	0.7370						11.161	10.914	10.846
0114.5666	0.7545	6.855	0.266	0.709	0.382	0.730			
0115.5360	0.0580						5.688	5.329	5.284
0115.5499	0.0619	6.881	0.274	0.709	0.382	0.732			
0116.3349	0.3073	6.883	0.265	0.705	0.385	0.735			
0116.5643	0.3791	6.870	0.278	0.703	0.384	0.725			
0116.5940	0.3880						5.698	5.344	5.270
0117.3343	0.6198	6.884	0.264	0.703	0.389	0.742			
0117.4108	0.6440						5.673	5.311	5.247
0117.5422	0.6850						5.648	5.306	5.256
0117.5553	0.6889	6.869	0.261	0.708	0.385	0.737			
0118.3231	0.9289	6.853	0.246	0.710	0.380	0.723			
0118.5512	0.0002	7.394	0.259	0.708	0.385	0.728			
0118.5597	0.0030						6.228	5.890	5.843
0119.3209	0.2409	6.878	0.262	0.710	0.386	0.725			

V1005Ori (Gl 182)

E_0 = 2444520.00 P= 4.565 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0113.3990	0.5160						7.159	6.417	6.245
0114.4084	0.7455	9.954	0.928	1.389	0.876	1.770			
0114.4114	0.7462	9.953		1.375	0.872	1.763			
0114.4139	0.7467	9.951			0.865	1.754			
0115.3999	0.9709	9.929	1.283	1.411	0.859	1.772			
0115.3999	0.9709	9.917	1.254	1.400	0.866	1.767			
0116.3923	0.1965	9.988	1.304	1.384	0.891	1.807			
0116.3966	0.1975				0.888	1.792			
0117.3613	0.4168						8.615	8.011	7.932
0117.3884	0.4229	10.018	1.110	1.410	0.891	1.811			
0117.3915	0.4236	10.029			0.905	1.818			
0118.3453	0.6404						7.051	6.295	6.132
0118.3880	0.6502	9.987	1.479	1.470	0.899	1.800			
0118.3911	0.6508	9.989			0.902	1.811			
0118.3928	0.6513	9.985			0.898	1.807			
0118.3928	0.6513	9.974			0.886	1.790			
0119.3476	0.8683						7.447	6.391	6.219

HU Vir (HD 106225)

E_0 = 2447548.86 P= 10.314 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0442.5576	0.5600						6.746	6.093	5.973
0447.5749	0.0466	8.762	0.673	1.038	0.581	1.166			
0447.5777	0.0469	8.770	0.675	1.025	0.595	1.179			
0447.5779	0.0469						6.779	6.107	5.986
0450.5190	0.3321	8.828	0.649	1.027	0.592	1.172			
0450.5236	0.3325	8.831	0.650	1.022	0.596	1.169			
0451.4856	0.4258	8.833	0.683	1.129	0.621	1.194			
0451.4891	0.4261	8.953	0.883	0.991	0.611	1.193			
0453.5469	0.6256	8.667	0.598	1.002	0.578	1.134			
0453.5505	0.6260	8.670	0.598	1.002	0.579	1.128			
0454.5696	0.7248	8.634	0.626	1.010	0.566	1.129			
0454.5729	0.7251	8.630	0.629	1.016	0.569	1.128			
0455.5619	0.8210	8.683	0.640	1.022	0.572	1.140			
0455.5656	0.8214	8.682	0.638	1.027	0.576	1.139			
0455.5765	0.8224						6.763		5.986
0472.5568	0.4688	8.806		1.033	0.593	1.175			
0472.5639	0.4694	8.804		1.029	0.593	1.170			
0473.5317	0.5633	8.743		1.021	0.582	1.153			
0473.5372	0.5638	8.753		1.029	0.589	1.159			
0473.5733	0.5673	8.743		1.025	0.584	1.162			
0473.5788	0.5678	8.750		1.017	0.585	1.156			
0474.5494	0.6620	8.690		1.010	0.576	1.138			
0474.5551	0.6625	8.690		1.019	0.582	1.140			
0474.6026	0.6671	8.688		1.017	0.577	1.140			
0474.6077	0.6676	8.687		1.014	0.574	1.139			
0476.5503	0.8559	8.726		1.025	0.594	1.161			
0476.5561	0.8565	8.722		1.033	0.586	1.155			
0477.6100	0.9587						6.745	6.090	5.971
0478.5900	0.0537						6.742	6.078	5.972
0481.5800	0.3436						6.827	6.168	6.050
0483.5800	0.5375						6.790	6.121	6.000

CD -28^o 2525 (HD 39576)
E_0 = 2448630.00 P= 2.7 days JD=2450000.+

HJD	Phase	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	J	H	K
0113.4720	0.4341	9.045	0.110	0.596	0.355	0.690			
0114.3862	0.7727	9.056	0.093	0.618	0.356	0.695			
0114.4833	0.8086	9.052	0.123	0.626	0.365	0.713			
0115.4766	0.1765	9.016	0.108	0.616	0.331	0.666			
0115.5010	0.1856						8.066	7.596	7.572
0116.3541	0.5015	9.034	0.092	0.619	0.347	0.689			
0116.4726	0.5454	9.050	0.106	0.607	0.355	0.695			
0117.3502	0.8705	9.041	0.088	0.619	0.352	0.693			
0117.4760	0.9170							8.101	7.515
0117.4794	0.9183	9.034	0.086	0.609	0.350	0.690			
0117.4860							7.761	7.548	7.468
0118.3180	0.2289						7.984	7.546	7.502
0118.3386	0.2365	9.044	0.082	0.620	0.358	0.696			
0118.4630	0.2826	9.029	0.070	0.614	0.342	0.686			
0118.4720	0.2859						7.934	7.499	7.453
0119.3180	0.5993						8.001	7.550	7.462
0119.3371	0.6063	9.051	0.091	0.619	0.356	0.690			
0119.4664	0.6542	9.054	0.098	0.612	0.356	0.695			
0119.4680	0.6548						7.990	7.545	7.466

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