On the Connection Between CWA and RVA Stars

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Abstract Phase plots of ASAS-3 data of a large number of CWA and RVA variable stars reveal that there is no clear distinction in period or light curve shape between these two types of stars.

1. Discussion

An evolutionary connection has long been conjectured between CWA stars (W Vir type stars or Population II Cepheids) and RVA stars (RV Tau type stars with constant mean magnitude). For a recent review, see Wallerstein (2002). CWA stars are usually defined as pulsating yellow giants with periods between 8 and 20 days, an amplitude up to about one magnitude, and fairly stable light curves. The distinguishing feature of RVA stars is that they have alternating bright and faint minima, and more erratic light curves (subsequent cycles are not necessarily identical). Their periods (between faint minima, so with two maxima per cycle) range between 40 and 150 days.

Templeton and Henden (2007) recently revealed that W Vir, the prototype of the CWA class, also showed a small but distinct brightness difference between consecutive minima in a similar way as the RVA stars. Abt (1954) had already noted significant cycle-to-cycle variations in W Vir. Also, Arp (1955) had found two type II Cepheids in the globular clusters M5 and M10 that showed alternating minima. In view of this it may be questioned as to how much the light curves between these two types of variable stars really differ. To look into this matter ASAS-3 data (Pojmański 2002) for 136 stars classified as CWA or RVA were plotted ordered according to their (double "RVA style") period (see Figure 1). These stars were collected mostly from the GCVS (Samus and Durlevich 2004) and the ASAS-3 catalogue (Pojmański 2002), plus some yet unclassified ones with very similar light curves. Some RVB stars (RV Tau, R Sge, and U Mon) that showed only a small change in mean brightness during the years ASAS-3 observed them were also included. The complete list of stars is given in Table 1. Note that some stars are misclassified in the GCVS.

It is clear from Figure 1 that there is no progression between these light curves according to period similar to the Hertzsprung progression in Population

I Cepheids (Hertzsprung 1926). The stars in the plots show a wide variety of light curve shapes, and similarly shaped light curves are seen at quite different periods. It is also noted that a number of stars classified as RVA do not really show alternating minima, while some stars classified as CWA do. In addition the phenomenon of alternating minima is not bound exclusively to a specific period range; stars not showing alternating minima have periods between those of stars that do. The difference in depth between minima cannot be considered a means of distinguishing stars either. Although stars with longer period in general show more scatter in their phase plots, some stars with long periods do not show much scatter.

In Figure 2 the $V–H$ color of these stars is plotted against the $H–K_s$ color. The average V magnitude derived from ASAS-3 data is used and the infrared magnitudes H and K_s are taken from the 2MASS survey (Skrutskie *et al.* 2006). The $H–K_s$ color is almost free from interstellar extinction. The 2MASS data are from one epoch only, and may depend on the phase at which they were taken. However, plotting the $H–K_s$ color against phase did not reveal a particular trend, and amplitudes in the infrared are much lower anyway.

Two distinct groups may be distinguished in Figure 2, and the border between the two may be roughly defined as $H–K_s = 0.4$. The stars of the first group to the left follow more or less a linear trend. The second group to the right of the plot is a more heterogeneous group showing infrared excess. The latter is usually also considered an indication of RV Tau variability (most of the RVB stars show infrared excess as the phenomenon of changing mean magnitude is often linked to circumstellar dust). However, stars classified as CWA and RVA appear in both of these groups. Also, the fact that whether stars show alternating minima or not does not determine into which one of the color groups they fall. Furthermore, the periods of the stars with infrared excess are not confined to a specific range either, as can be seen in Figure 3.

It may be concluded that there is no real indication from light curve shape, period, or color which determines whether a given pulsating yellow giant is a CWA or RVA type variable. The border between these classes of variable stars is not clearly defined on the basis of these criteria. One may wonder whether there is any need to distinguish between them at all.

2. Acknowledgements

Matthew Templeton, Eric Broens, and John Greaves are acknowledged for enlightening discussions on this topic. The referee, George Wallerstein, is acknowledged for useful comments to improve the paper. This study used NASA's Astrophysics Data System, and the SIMBAD and VIZIER databases operated at the Centre de Données astronomiques de Strasbourg, Strasbourg, France.

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Table 1. Stars with CWA- or RVA-like light curves in the ASAS-3 data. The type listed is from the GCVS and ASAS-3 online catalogues and from VSX (Watson *et al.* 2006) when the former were not available. The (RVA style) period and the *V* range are derived from ASAS-3 data, *H* and K_s are taken from the 2MASS catalogue.

Name	*Type*	*Period (d)*	V_{max}	V_{min}	V–H	H–K_s
VSX J192006.9+124743	CW	17.26	10.2	10.6	4.41	0.34
PZ Aql	CWA	17.51	11.3	12.1	3.57	0.25
AX Tel	CWA	19.79	12.3	13.2	1.86	0.10
ASAS 001430+1331.1	CW-FU/EC	19.80	11.8	12.7	3.45	0.22
AL Vir	CWA	20.60	9.2	9.9	1.76	0.04
AP Her	CWA	20.79	10.4	11.2	2.37	0.13
BH Oph	CWA	22.10	11.6	12.5	1.84	0.09
V775 Oph	CWA	24.29	13.3	13.9	2.49	0.16
V1304 Sgr	CWA	25.83	12.4	13.5	2.48	0.18
AL Lyr	CWA	25.96	11.8	12.6	2.95	0.18
DD Vel	CWA	26.37	12.2	13.1	3.90	0.28
KT Sco	CW-FU	26.43	12.6	13.3	2.16	0.08
V1077 Sgr	CWA	26.85	12.5	13.5	1.46	0.11
V802 Sgr	CWA	27.04	13.2	14.2	2.55	0.17
V2338 Oph	CWA:	27.32	11.6	12.3	2.81	0.08
V410 Sgr	CWA	27.56	12.2	13.2	1.65	0.17
V1185 Sgr	CWA	27.80	12.5	13.1	2.37	0.15
ASAS 050514+2145.8	CW-FU	27.87	12.2	13.2	2.65	0.19
V1834 Sgr	CWA	28.01	12.9	13.9	2.31	0.11
V1189 Sgr	CWA	28.18	11.7	12.9	2.03	0.08
V801 Aql	CWA	28.32	13.2	13.8	3.18	0.18
V445 Cen	E/DS:	28.39	11.5	12.5	2.31	0.12
YZ Vir	CWA	28.95	12.7	13.9	1.66	0.07
V833 Oph	CWA	29.42	13.6	14.7	2.07	0.07
V554 Oph	CWA	29.65	12.7	13.9	3.63	0.22
BO Tel	CWA	29.65	12.1	13.3	1.56	0.12
NW Pav	CWA	29.76	11.6	12.9	2.22	0.12
V1187 Sgr	CWA	30.21	13.3	14.0	2.62	0.15
V741 Sgr	CWA	30.29	12.3	13.4	2.15	0.14
ASAS 133028–3812.5	CW-FU	30.50	12.6	13.6	1.87	0.07
ASAS 211406+0019.2	CW-FU	30.56	11.9	13.0	2.08	0.08
V347 CrA	CWA	30.62	12.3	13.3	2.19	0.11
GSC 6666–00796	CWA	31.17	12.4	13.3	1.90	0.14
CO Pup	CWA	32.13	10.4	11.4	2.58	0.15
V557 Sgr	CWA	32.45	13.2	14.1	3.40	0.13

(Table 1 continued on following pages)

Table 1. Stars with CWA- or RVA-like light curves in the ASAS-3 data, continued.

Name	*Type*	*Period (d)*	V_{max}	V_{min}	V–H	$H–K_s$
UX Lup	CWA	32.47	12.6	13.6	2.11	0.15
SZ Mon	RVA	32.67	9.7	10.8	2.09	0.55
V478 Oph	CWA	32.83	12.6	13.5	2.53	0.08
V383 Sgr	CWA	32.86	12.3	13.7	1.93	0.14
V449 CrA	CWA	32.97	12.9	14.3	1.94	0.11
V2530 Sgr	CWA	33.66	13.0	14.0	3.11	0.25
ASAS 140434–4532.4	CW-FU	33.97	13.0	14.0	2.09	0.10
AL CrA	CWA	34.11	11.5	12.6	2.24	0.13
W Vir	CWA	34.53	9.5	10.7	1.74	0.04
V1303 Sgr	CWA	36.91	12.2	13.2	4.12	0.28
ST Pup	CWA	37.64	9.5	10.6	1.78	0.17
Z Aps	UGZ	37.89	10.9	11.7	2.71	0.19
EZ Aql	RVA	38.70	11.8	13.7	2.99	0.70
CY Vel	CWA	39.06	12.3	13.7	3.48	0.22
MR Ara	CWA	39.63	11.0	12.1	2.05	0.11
RS Pav	CWA	39.88	10.1	11.6	2.65	0.12
V1950 Oph	CWA:	42.21	12.4	13.3	3.50	0.48
EP Mus	CWA:	42.66	11.6	13.1	3.11	0.16
V760 Sgr	RVA	44.98	10.8	11.8	4.18	0.36
SY Cir	RV	46.26	11.6	13.2	3.17	0.16
V420 Cen	CWA	49.17	9.5	10.5	1.85	0.11
RX Lib	CWA	49.86	11.7	13.0	2.66	0.15
CN Cen	RVA	50.71	12.6	13.6	3.40	0.47
ASAS 202412-2457.0	CW-FU	51.37	12.4	13.7	2.19	0.09
ASAS 151825+0203.0	CW-FU	51.42	10.2	10.8	1.71	0.13
GP Mus	CWA	52.88	12.1	12.8	3.15	0.17
V2600 Oph	RV	53.10	11.6	12.8	3.48	0.15
V1831 Sgr	CWA	53.13	12.4	13.6	3.21	0.18
V415 Cen	CWA	53.16	12.3	13.4	2.72	0.14
V626 Sgr	CWA	53.45	11.8	13.4	2.33	0.07
GSC 8303-0183		53.65	11.8	13.3	2.80	0.28
GK Car	RV	55.12	11.2	12.2	2.92	0.55
V564 Sgr	CWA	55.67	12.3	13.2	2.86	0.55
V1290 Sgr	CWA	55.82	12.1	13.4	2.45	0.16
V1711 Sgr	CWA	56.88	10.4	11.1	2.15	0.49
UY Ara	RV	56.94	10.6	11.3	1.51	0.54
TW Cap	CWA	57.18	10.1	11.2	2.00	0.05
V446 Sco	CWA	57.29	12.7	13.7	3.01	0.22

(Table 1 continued on following pages)

Table 1. Stars with CWA- or RVA-like light curves in the ASAS-3 data, continued.

Name	*Type*	*Period (d)*	V_{max}	V_{min}	V–H	$H–K_s$
V594 Pup	RV	57.86	11.1	12.5	2.66	0.11
DI Car	*	58.34	9.7	11.8	2.48	0.26
ASAS 132605-4723.7	CW-FU	58.53	10.5	11.6	1.61	0.11
V541 Oph	CWA	58.92	13.1	14.3	4.88	0.24
V1670 Sgr	CWA	59.21	12.4	13.3	2.59	0.18
V423 Sco	RV	59.70	12.9	14.1	3.30	0.18
V2510 Sgr	CWA	60.66	12.7	14.1	3.37	0.22
CQ Sco	CWA	60.91	12.1	13.2	2.86	0.17
DY Ori	RV:	60.94	11.3	12.0	4.19	0.40
TT Oph	RVA	61.13	9.5	10.7	2.66	0.11
GSC 5663-0767		61.36	13.2	14.2	4.01	0.23
KQ CrA	CWA	61.74	11.9	12.8	2.50	0.15
IRAS 11472-0800		62.56	11.5	12.0	2.64	0.42
V2526 Sgr	CWA	63.05	12.9	13.9	3.31	0.15
V558 Sgr	RV	63.35	12.6	13.4	2.67	0.21
RR Mic	CWA	63.50	11.0	11.8	1.70	0.13
LN Aql	RV	64.71	13.0	14.0	2.68	0.15
RU Cen	RV	64.81	8.6	9.6	1.80	0.27
HI Tel	RVA	66.28	10.6	11.6	2.03	0.12
AD Aql	RVA	66.44	11.2	11.8	2.30	0.13
CT Ori	RV:	67.06	10.1	10.8	2.49	0.32
RX Cap	RV	67.83	11.1	12.1	2.10	0.09
V532 Sgr	CWA	68.97	12.7	13.5	3.04	0.17
NW Tel	RVA	68.99	11.1	11.9	1.99	0.12
R Sge	RVB	71.15	8.9	9.7	2.08	0.70
ASAS 160723-2957.2	CW-FU	74.13	12.6	13.5	2.84	0.14
V1004 Sgr	CWA	75.12	12.4	13.0	3.27	0.20
AC Her	RVA	75.36	7.3	8.3	2.30	0.26
V729 Ara	SR	75.91	10.2	11.3	3.59	0.53
V Vul	RVA	76.09	8.1	9.5	2.62	0.62
RT Ara	SRD	76.63	10.3	11.1	2.00	0.08
DS Aqr	RVA	77.50	10.3	11.2	1.39	0.11
RV Tau	RVB	78.43	9.3	10.6	4.30	0.71
V385 CrA	RV	78.60	11.1	12.2	2.36	0.16
V1284 Sgr	RV:	80.03	12.1	12.8	3.73	0.38
V1009 Sgr	RVA	80.95	12.5	13.2	3.04	0.32
V453 Oph	RVA	81.19	10.4	11.5	2.35	0.16
V1864 Sgr	RV	81.71	11.8	12.3	1.99	0.26

(Table 1 continued on following page)

Table 1. Stars with CWA- or RVA-like light curves in the ASAS-3 data, continued.

Name	*Type*	*Period (d)*	V_{max}	V_{min}	V–H	$H–K_s$
AR Sgr	RVA	86.76	9.1	10.3	1.59	0.27
UZ Oph	RVA	87.57	10.1	12.2	2.81	0.15
SS Gem	RVA	89.83	8.6	9.5	2.59	0.19
U Mon	RVB	91.36	5.8	7.1	2.04	0.23
V1833 Sgr	CWA	97.23	12.1	13.3	3.17	0.17
LR Sco	SRD	101.3	10.2	11.0	3.22	0.90
ET Vul	CWA	108.1	12.0	12.5	3.83	0.25
NSV 10164	RVA	110.8	10.0	12.0	2.98	0.25
AZ Sgr	RVA	111.2	10.8	11.5	2.26	0.15
V590 Aql	RVA	117.0	11.9	12.8	3.22	0.20
V691 Ara	RV:	129.7	11.6	12.1	3.36	0.18
QV Aql	RV	130.6	11.4	12.2	3.58	0.16
V411 Sco	RV	133.3	12.5	13.1	3.13	0.22
TX Oph	RVA	134.1	9.9	11.1	2.42	0.21
NSV 7708	I	135.2	11.2	11.6	2.90	0.70
RY Ara	RV	144.0	8.8	10.9	2.82	0.25
QT CrA	SRD:	158.8	10.4	11.2	3.26	0.17
V820 Cen	RV	159.7	8.6	9.5	2.73	0.17
GSC 7735-1239		160.8	12.9	13.6	3.50	0.24
BU Cen	RV:	169.0	10.4	11.3	3.26	0.18
V794 Sgr	RV	172.3	11.0	13.6	5.74	0.39
CK Vir	SRD	177.9	10.1	10.7	3.02	0.21
AT Del	SRD:	225.3	11.3	12.7	4.30	0.25
UY CMa	SRD	227.0	10.5	11.5	2.34	0.61
V3955 Sgr	SRD	240.5	9.9	11.1	3.84	0.29

Figure 1 *(on following pages)*. Phase plots for CWA and RVA variables from ASAS-3 data, arranged by period (defined in the RVA sense with two maxima per cycle). The heading for each plot lists the name, period, and the GCVS type, when available, of the star. Tick marks on the vertical axis are separated by 0.1 magnitude.

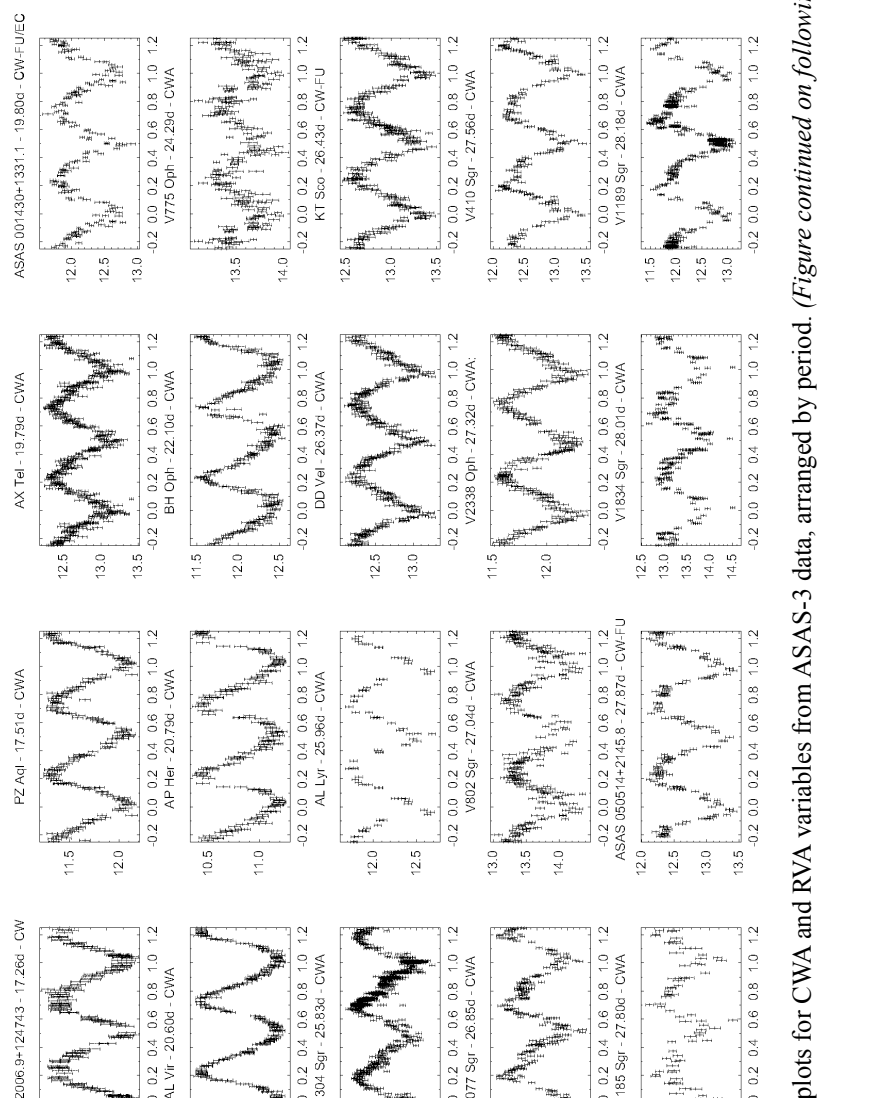

Figure 1. Phase plots for CWA and RVA variables from ASAS-3 data, arranged by period. *(Figure continued on following pages.)*

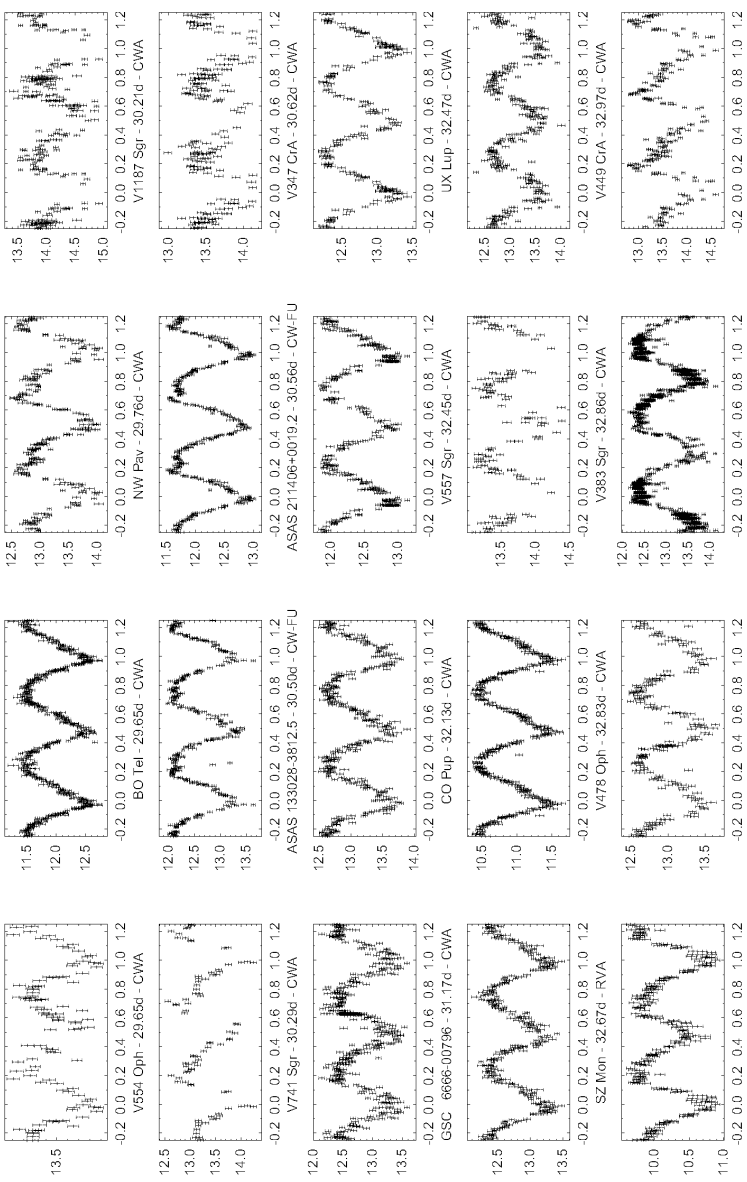

Figure 1, continued. Phase plots for CWA and RVA variables from ASAS-3 data. *(Continued on following pages.)*

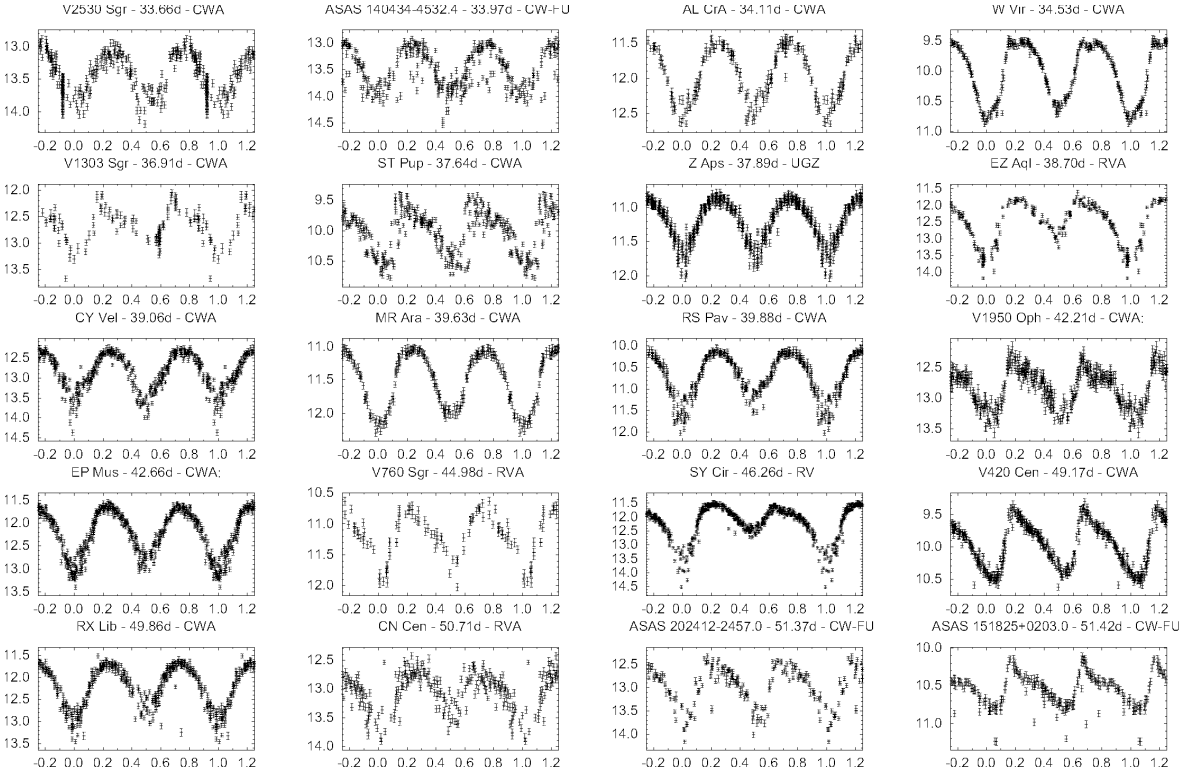

Figure 1, continued. Phase plots for CWA and RVA variables from ASAS-3 data. *(Continued on following pages.)*

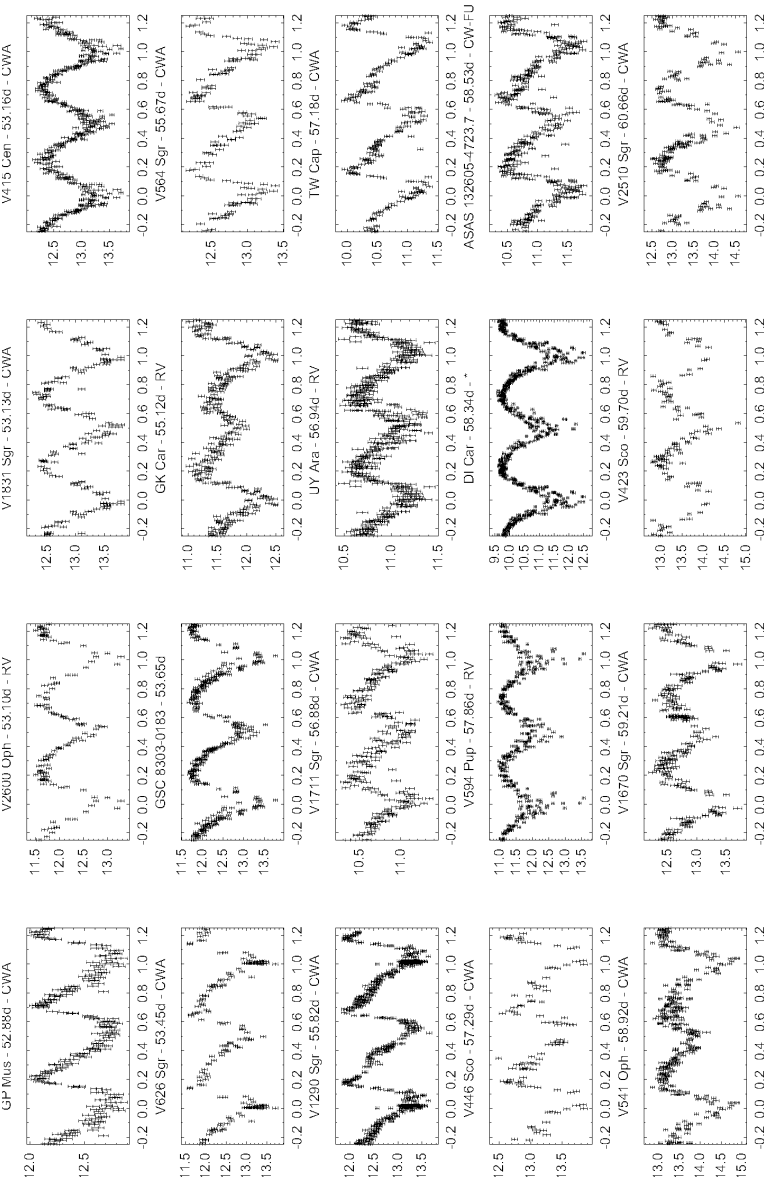

Figure 1, continued. Phase plots for CWA and RVA variables from ASAS-3 data. *(Continued on following pages.)*

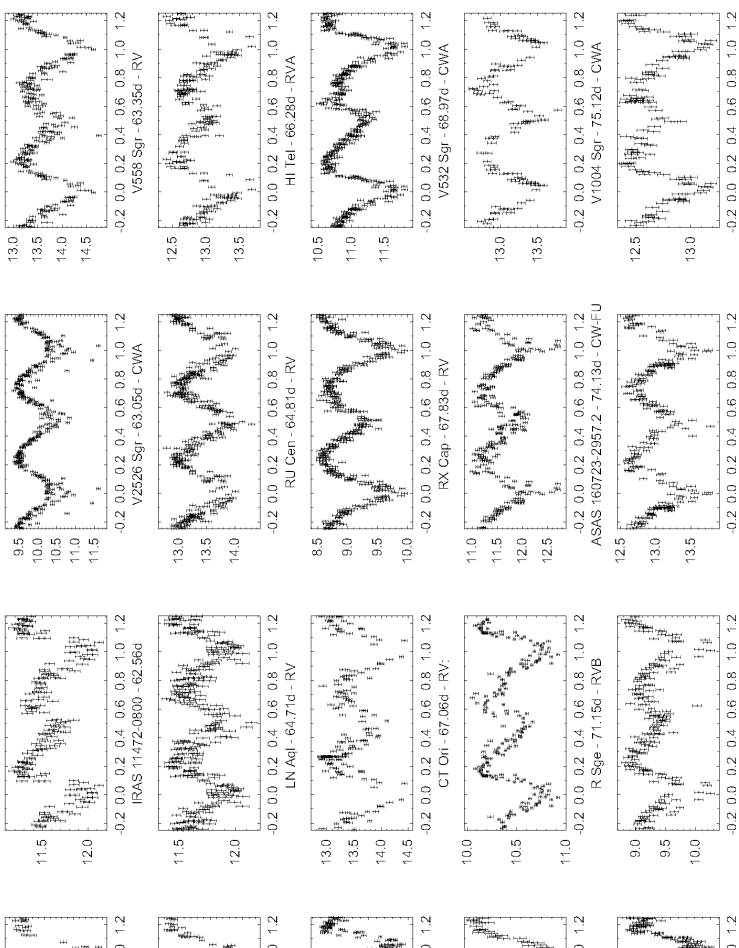

Figure 1, continued. Phase plots for CWA and RVA variables from ASAS-3 data. *(Continued on following pages.)*

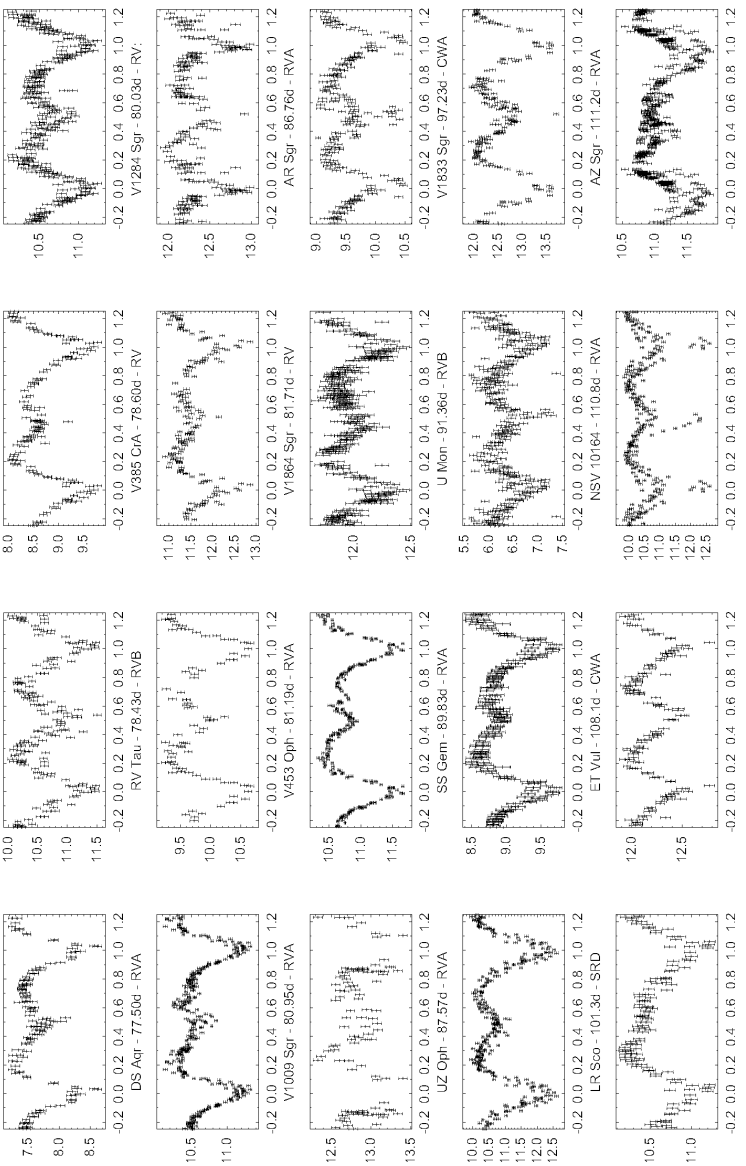

Figure 1, continued. Phase plots for CWA and RVA variables from ASAS-3 data. *(Continued on following page.)*

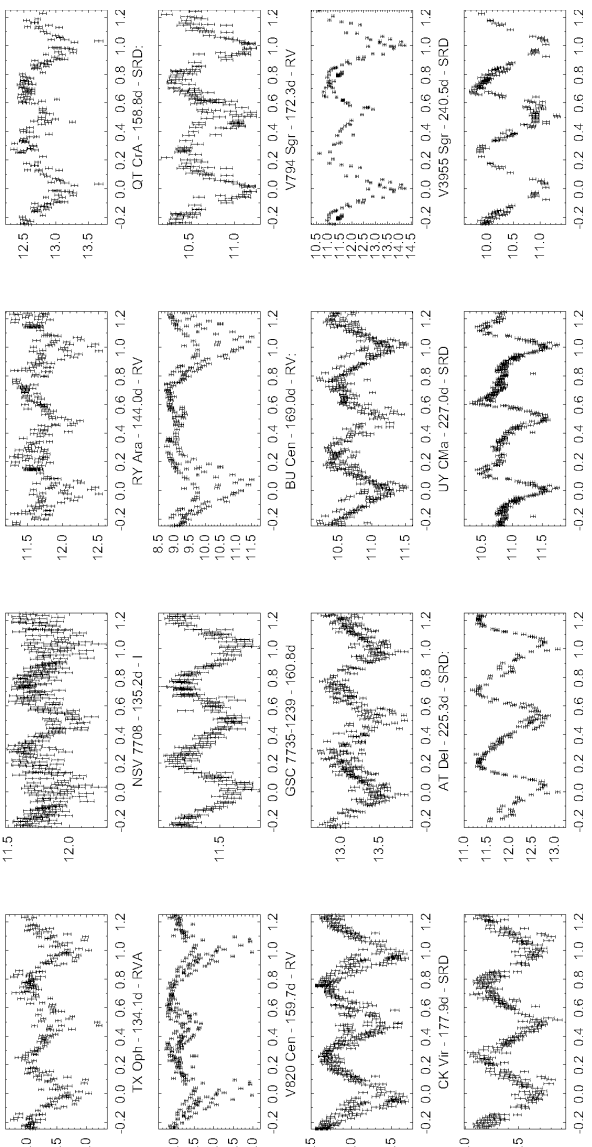

Figure 1, continued. Phase plots for CWA and RVA variables from ASAS-3 data.

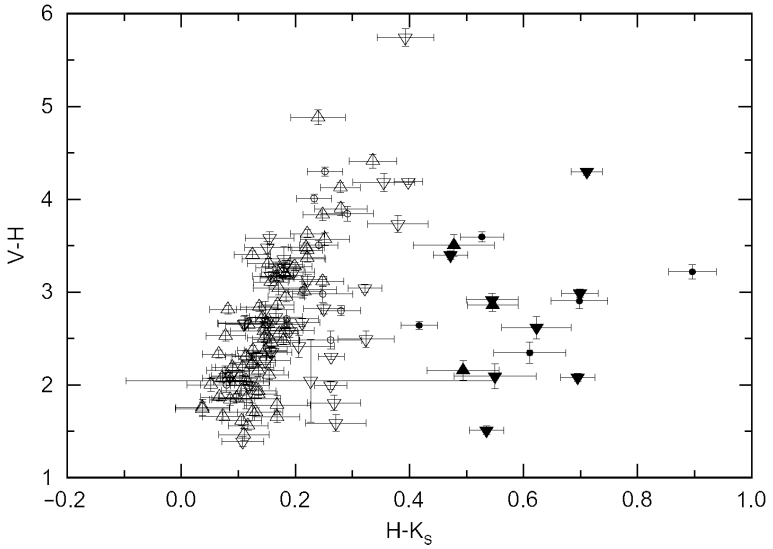

Figure 2. *V–H* plotted against $H–K_s$ for the stars in Figure 1. Stars classified before as CW are plotted as triangles pointing upwards and those classified as RV as triangles pointing downwards. Stars not classified before or classified differently are plotted as small circles. The stars with $H–K_s < 0.4$ are plotted with open symbols, those with $H–K_s > 0.4$ with filled symbols.

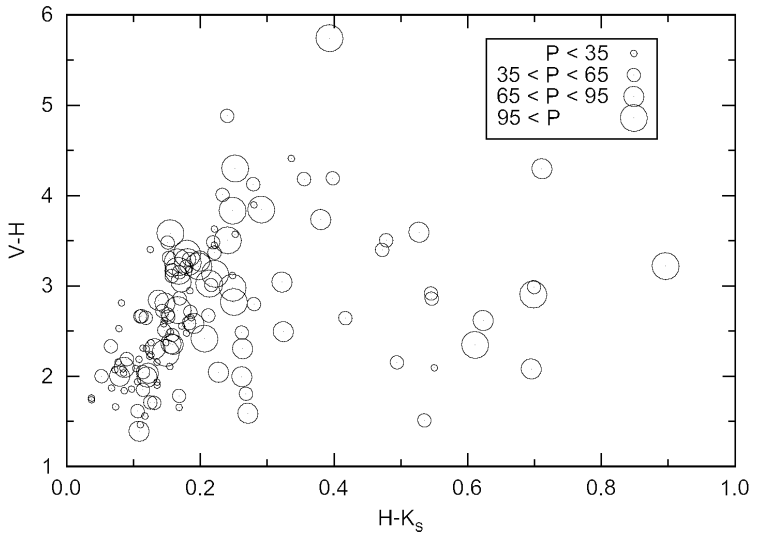

Figure 3. Same as Figure 2, but this time with the size of the symbols depending on the period.