THE 1367 CLUSTER OF VARIABLE STARS IN CYGNUS

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This is not a real cluster of course, just a random collection that happens to appear close together, to us. This is the densest collection of variable stars in my area ‘a’ in Cygnus. The area is 10.35 arc-mins square, very close to 1/7th of the area of the full moon. In addition to the 11variables marked with crosses below there are 3 much fainter ones recently found making a total of 14 giving a density in that square of 470 variable stars per square degree!

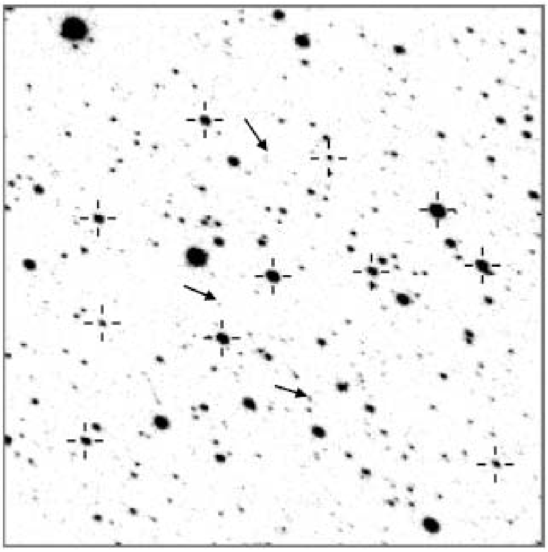

Figure 1.

The star in the middle is a01367 in my (SW) catalogue, they are all listed below with a key, and in Table 1 with their other IDs and other data. The central star a01367, has nominal picture co-ords of 3486, 2895 (in 4080 by 4080 pixels), well off centre,so some oval distortion is visible. The brightest star, top left, is too bright for the catalogue, so the first to appear is a00105. Moving away from 1367, through 105 we get to ‘k’ or star 5854. This is the only previously known variable in this plot and is V585 Cygni, a medium amplitude and period lpv, see below. At 0.5 magnitude, one might expect it to have the largest amplitude of any star in the sub-image but in fact star ‘m’, a12507 which is a W UMa type binary (p=0.45562d) varies by 0.85 magnitudes.

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vars & brighter stars listed
. . . . . . . . e . . . . . . . O   1367v
. . . . . . . . . . . . . . . . a    105
. . . . . . . . . . . . . . . . b    564v
. . . . . i . . . . . . . . . . c    732
. . . . . . . . . o . . . . . . d   1035
. . . . . . . . . . . . b . . . e   1307
. . k . . . . . . . . . . . . . f   2057
. . . . . a . O . . j . . . h . g   2207v
. . . . . . . . . . . f . . . . h   2492v
. . m . . . g . . . . . . . . . i   3769v
. . . . . . . . . . . . . . . . j   5349v
. . . . . . . . . . . . . . . . k   5854v
. . l . d . . . . . . . . . . . l   6822v
. . . . . . . . . . . . . . n . m  12507v
. . . . . . . . . . . . . . . . n  12825v
. . . . . . . . . . . . c . . . o  17496v
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Key to figure 1.

Basic ID's and values are shown for these stars in the table below.

cat. name	other ID 1	MagM	MagR	Period1
TEa00564	3593 240501	10.36	0.062	
TEa01367	3593 171801	11.327	0.058	3.3883
TEa02207	3593 221301	11.76	0.02	7.362
TEa02492	GSC 3593-1001	11.56	0.09	3.334
TEa03769	1369 445274	12.34	0.09	1.0988
TEa05349	1370 469035	12.56	0.2	110.6
TEa05854	V585 Cyg (L)	12.27	0.61	85.7
TEa06822	1370 468405	12.76	0.03	0.121807
TEa12507	1370 468435	13.43	0.85	0.45564
TEa12825	1370 469322	13.57	0.48	45.23174
TEa17496	1370 468943	14	0.4	54

V585 Cygni is also IRAS 21118+4649. Other ID 1 is the USNO B1.0 ID by default.

'MagM' is the maximum seen in the 5 years analysed (2003 -2007) so far, and 'MagR' the range of variation. At the moment the values are simply derived, where available, from the red values of a single reference star using the Carlsberg Meridian catalogue. At this point I'd like to thank Chris Lloyd for encouraging me to use these (more reliable than the U.S. Naval Observatory) values, and indeed for sorting out and sending me a subset of CMC for the purpose.

Below we look at the stars one at a time. The look must perforce be brief, but full data can be found on the website (*www.the-planet-project.com*). As usual the dates are from January 1st 2000 or JD 2451545. The earliest date from which we have reduced data is 1344 (Sept 6/7th 2003) and the latest is 2903 (Dec 13th 2007).

A number of detailed plots of star data are referred to in the text, eg: log *P/J-K* diagram, log *P/B-R*, *J-K*/log *P* diagram etc. These and many similar reference plots can be found on the website. Symbols used:

L, M, R luminosity, mass, radius. v_{tr} Transverse velocity ϕ Phase
$\gtrsim$ greater than or approximately equal to $L_\odot$ Solar luminosity μ Proper motion

Star a00564

This is clearly variable but its movement is small. The Tycho B-V is 1.051, leading to a colour temperature of 4,260K, in reasonable agreement with our estimate of 4,157K. To save space no light curve is shown for this star.

RS. A small-amplitude variable star, with m_{max} ~ 10.6 and m_r ~ 0.06 mag. The amplitude varies from year to year, and there is no obvious periodicity. The amplitude averaged over the years of the observing interval is m_r = 47 mmag.

The JHK colour indices (J = 7.461, J-H = 0.865, H-K = 0.316) are very similar to those of the **M5 III SRb** variable star V Horologii (J-H = 0.874, H-K = 0.299).
The star has a measurable proper motion: $\mu_\alpha \cos\delta$ = -0.01007″ a^{-1}, μ_δ = -0.00382″ a^{-1}, so μ = 0.01077″ a^{-1} in the direction W21°S (position angle 249°), i.e. at ~28° to the Galactic

plane (going north and to decreasing longitude). If M_V for an M5 III star is -0.3, then, with V = 11.439, d ~ 2.2 kpc and v_{tr} ~ 110 km/s.

The M_K-m_r diagram for Stan's variable stars yields M_K ~ -3.76, where as the M_K-log m_r diagram yields M_K ~ -3.11. If we take the average value, M_K = -3.44, then, with K = 6.280, ***d* ~ 880±140 pc** and v_{tr} ~ 45±7 km s^{-1}. These results are obviously inaccurate, but they give some impression of the distance and transverse speed of the star; the lower values of d and v_{tr} are probably nearer to the truth.

——————a01367——————

SW & RS. The central star in this group. We don't yet even know its period for certain. Below is a double wave curve formed from the 50,000 points of the whole data set (averaged by 10's after phase overlay). It should be possible to choose between this and a half period with some further investigation. One obvious problem we have is that the star temperature deduced from our measurements, even after correction, is still at 8000 K, very different from the published B-V figures which yield 6530K. However the published JHK photometry supports the hotter value.

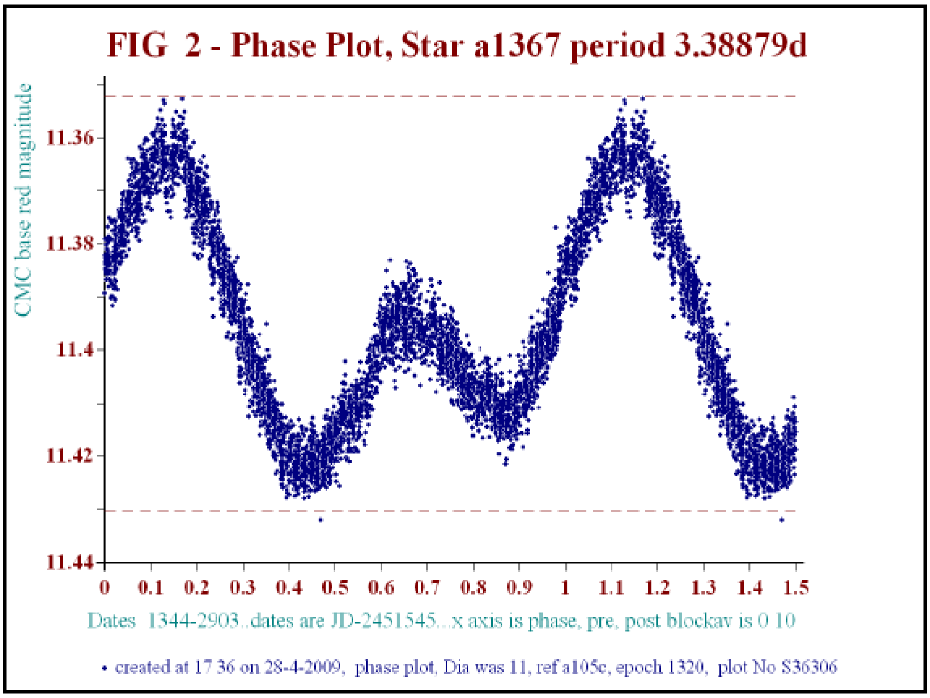


Figure 2: **An unusual variable star, possibly with a double-wave light curve.**

For the entire observing period, ***P* ~ 3.38879±0.00007 d.**

Max. I = 1340.610 + 3.38879 *E*.

The photometry is anomalous: the JHK photometry (J-H = -0.009, H-K = +0.03) implies that this is an early A-type star, or perhaps an Ap-type star, whereas the published BVR photometry (V = 11.500, B-V = 0.424, V-R = 0.28) makes it an F-type star (perhaps about F5, with T ~ 6530 K and M_V ~ +3 for a main-sequence star). However, our measurements from 2003 suggest an A2-3 star in agreement with the JHK photometry, so we take that as more probable. From the light curve and the period, this could very well be a rotating variable, a magnetic Ap-type star, i.e. an ACV star; it is not likely to be a pulsating variable or an eclipsing binary.

Unfortunately, it is probably too faint for spectroscopic investigation. The distance for a main-sequence star is d ~ 500-800 pc, so, with μ = 0.0024″ a^{-1}, v_{tr} ~ 8±2 km s-1.

——————————Star a02207——————————

Another low amplitude problematic one, but certainly a hot star, we make is about 10,900K. The most likely period is 7.358 days. A phase plot from 2007/8 is shown. The ephemeris is **Max. = 1335.144 + 7.358 E**.

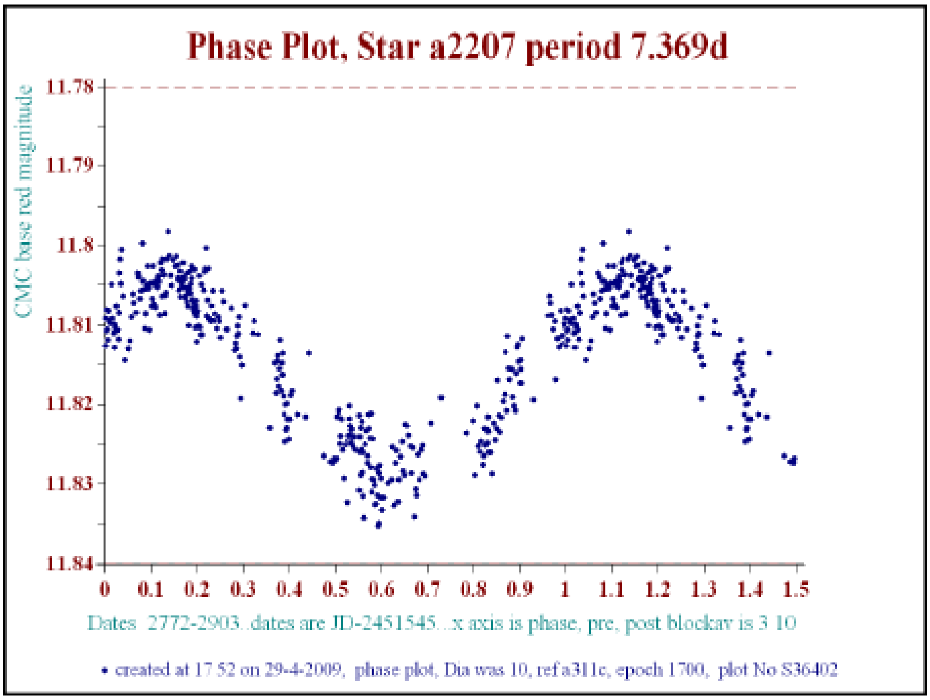


Figure 3.

R.S.... The BVR photometry (V = 11.787, B-V = 0.138, V-R = 0.077) suggests that this is a middle A-type star, with M_V ~ +1.9 and d ~ 950 pc; the *JHK* photometry (J = 11.298, J-H = -0.016, H-K = +0.055) suggests a slightly earlier spectral type and is compatible with an Ap star. The observed proper motion (μ = 0.0090″ /a) yields v_{tr} ~ 40 km s^{-1}.
There are three possible explanations for this star, namely a small-amplitude RR Lyrae star (of subtype RRc), a short-period Cepheid or W Virginis star or an Ap star. In other

respects, the star falls among Stan's 'anomalous Cepheids', which include a1367, and is bluer than the RR Lyr stars.
From the P-M_V relation given by Cooper and Walker (*Getting the Measure of the Stars*), p. 214 for W Virginis stars, $M_V \sim -1.8$ ($L \sim 450L_\odot$). With $v = 11.787$, $d \sim 5.2$ kpc (17,000 light-years). With this distance, $v_{tr} = 220$ km s^{-1}; if all this is correct, the star is very definitely a member of Population II.

However, the best explanation for the relatively long period, the small amplitude, and the nearly symmetrical light curve, is probably that the star is an ACV star seen nearly pole-on, so that we see only one of the magnetic poles.

Star a02492

This is a slightly eccentric and noisy eclipsing binary. Approximate values are (using our star a00054 as a comparison and USNO red magnitudes) as in the box below. A phase plot is shown for 2004 data plus a primary eclipse plot.

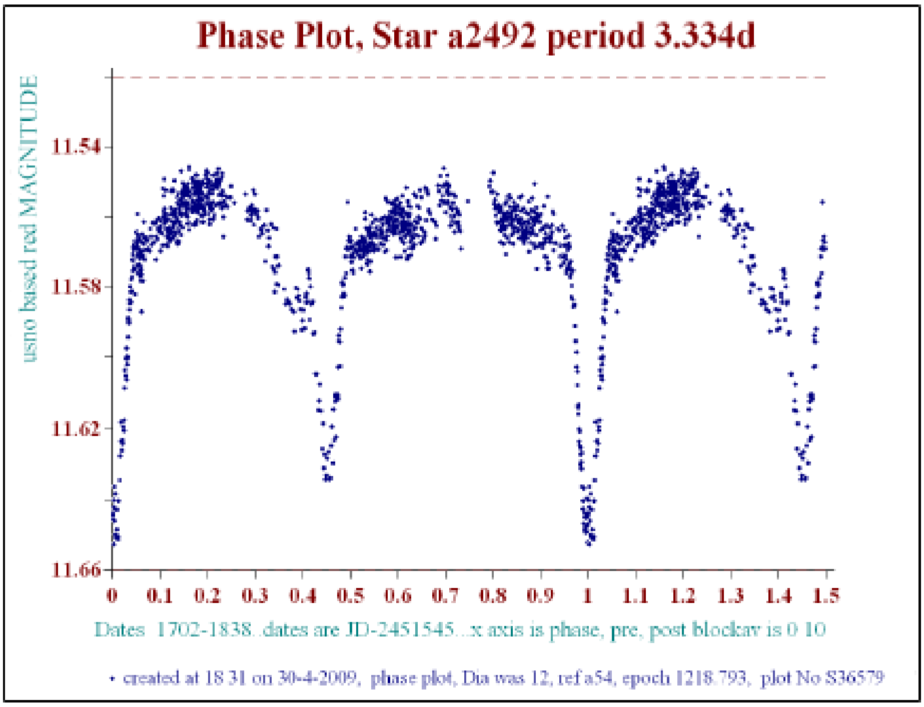


Figure 4.

max 11.554	ϕ2=0.452	p=3.3340d
m1 =11.647	d1 0.093 mag	
m2 =11.628	d2 0.074 mag	

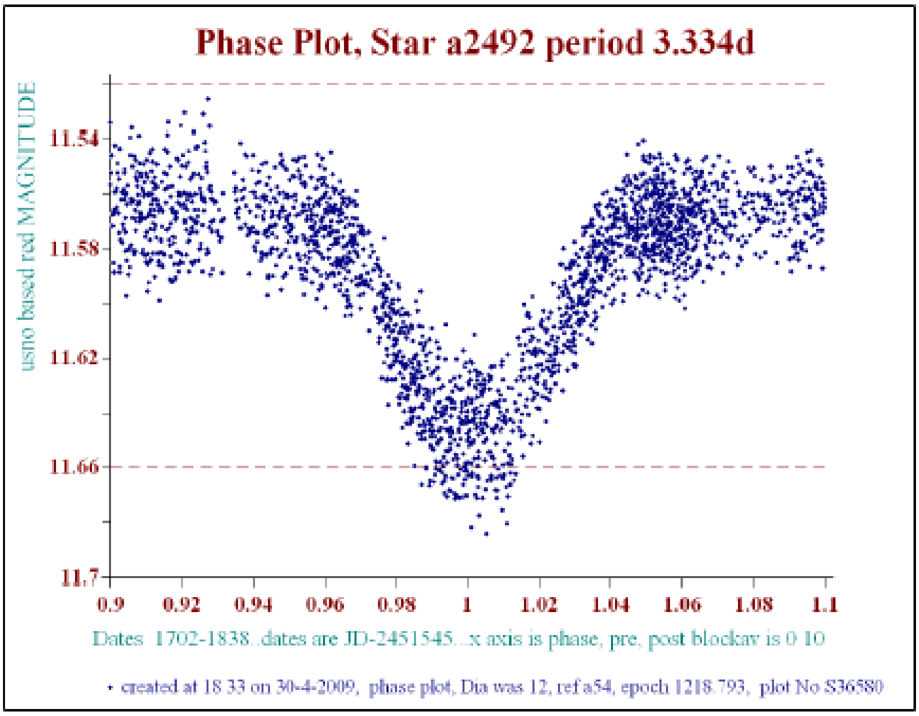


Figure 5: Primary eclipse of star a2492.

R.S. The BVR colours are impossible; the JHK colours suggest an early A-type star (perhaps similar to the A4 V star δ Leo) or a reddened B-type star. There is no proper motion or parallax. There is a strong reflection effect. This is probably a partially eclipsing, detached binary system, that consists of two similar early A-type or late B-type stars.

Star a03769

Another pulsator with a small and variable amplitude. The pulsation amplitude of this star has varied from 54 mmag in 2003, 90 in 2004, 76 in 2005, a low of 26 in 2006, and 68 in 2007. In addition its mean brightness seems to have declined by 0.1mag in that time, viz: average per date plot left. The scatter on the 5 year (av per date) phase plot opposite page, is caused by the period being close to 1 day.

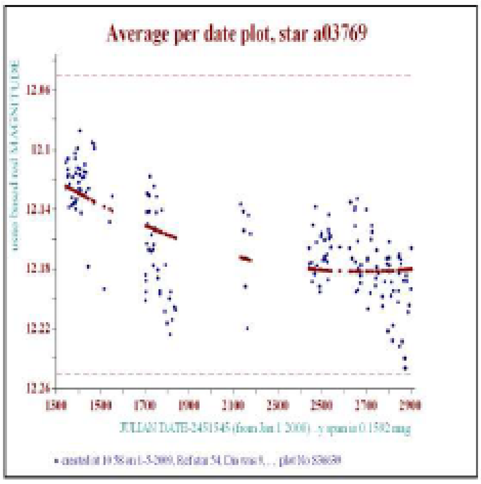


Figure 6.

The star may be a long-period RR Lyrae star, or short-period W Virginis star. The star appears to have faded over the observing period, from m_{ave} ~ 12.12 in 2003/4 to m_{ave} ~ 12.19 in 2007, i.e. by ~ +20 mmag./yr. The ephemeris is **Max. = 1340.461 + 1.09787 *E*.**

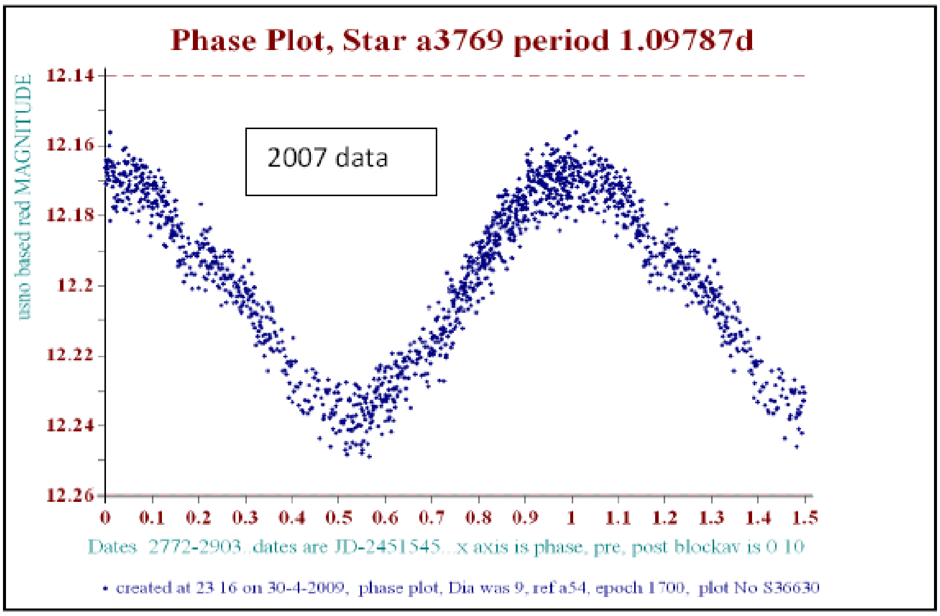


Figure 7.

In the various two-colour diagrams, a03769 falls among the δ Cephei and W Virginis stars, and is much redder than the RR Lyrae stars. In the *J-K*/log *P* diagram, it suggests a reddened (E_{J-K} ~ 0.25, E_{B-R} ~ 0.4-0.7) RR Lyrae, or short-period W Virginis star. In the log μ/V diagram, its estimated position puts it among the low-μ RR Lyrae, or the W Virginis stars. If the star has V = 12.86 and M_V = +0.6 (typical of an RR Lyr star), d ~ 2.8 kpc, and v_{tr} ~ 90 km s^{-1}, it is a fairly high-velocity star.

Star a05349

The light curve of this star is fairly similar to star a05854 (V585) except that it's slightly weaker (0.2 mag compared to 0.5) and slower (110d compared to 85d). One wonders why it escaped notice when V585 was found. Our estimate of its colour temperature (5000K) is quite at variance with its published B-V which gives 8780K.

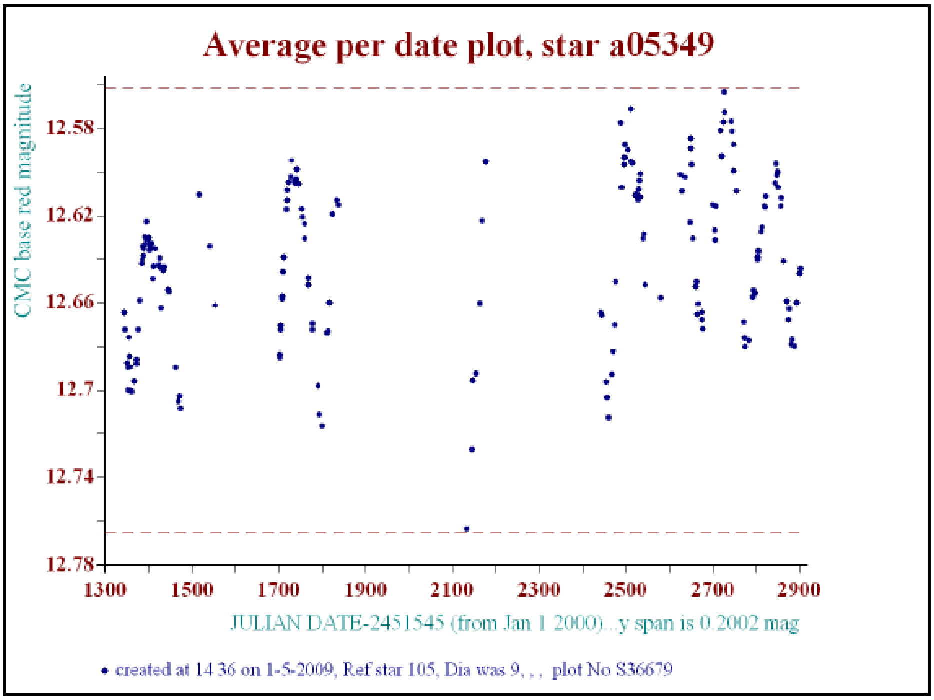


Figure 8.

RS. A very interesting small-amplitude variable star, with m_{max} ~ 12.41 and m_{min} ~ 12.61. The period, P ~ 110 d, suggests a semi-regular (SRa?) variable, but the IR colour indices (J = 10.901, J-H = 0.556, H-K = 0.122) suggest an earlier type star, perhaps something on the Cepheid instability strip or even an SRd star. Counting maxima suggests P ~ 110.6 d. Max. ~ 1398 + 110.6 E.

The star is much too 'blue' for a red giant variable star, and it appears to fall in the Cepheid instability strip. The JHK colours are J = 10.901, J-H = 0.556, H-K = 0.122; the BVR colours are V = 13.26, B-V = 0.18, V-R = 0.91, which seem very doubtful. In the JHK two-colour diagram it falls among the Cepheids, the W Virginis stars, and the RV Tauri (RVA) stars. The B-R and J-K colours are very similar to those of the W Virginis star κ Pavonis and the RVA star AC Herculis. In the log P/J-K diagram, the star falls among the RVA stars and is rather less red than most of the SRd stars. In the log P/B-R diagram, the star falls on top of the RVA star AZ Sagittarii and among the RV Tauri stars and the bluer SRd stars.

The star has a measured proper motion, of $\mu_\alpha \cos\delta = 0.00003''$ a^{-1}, $\mu_\delta = 0.00769''$ a^{-1}, and μ = 0.00769″ a^{-1}, in the direction N0.22°E. The proper motion is at 41° to the Galactic plane, going north and to increasing Galactic longitude; the star appears to be a member of Population II. In the V-log μ diagram, it falls among the W Virginis and RV Tauri stars and on an extrapolated continuation of the SRd stars to fainter values of V; its proper motion is $\gtrsim$10 times what one would expect of a 13th magnitude classical Cepheid.

A very tentative estimate of the absolute magnitude yields M_V ~ -0.4, whence, d ~ 6.4 kpc and v_{tr} ~ 230 km s^{-1}, but these estimates can be little better than guesswork. The great estimated distance implies that the star must be heavily reddened, but this is inconsistent with the low value of *B-V* and the modest value of *B-R*.

Star a05854=V585Cygni

As far as we are aware this is the only variable in this group that was previously known.

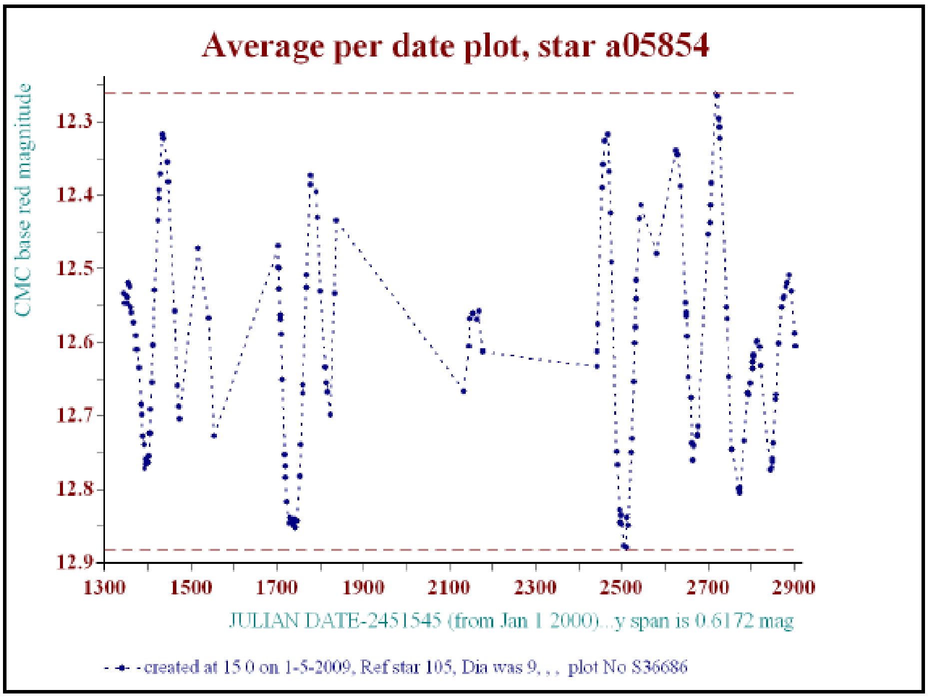


Figure 9.

RS. A medium-amplitude variable star, with m_{max} ~ 12.25-12.3 and m_r ~ 0.5-0.6 mag. According to the GCVS it is an irregular variable star (type L), but Stan's light curves show fairly regular light variations. The minima tend to be flat-bottomed. The average period derived from counting maxima and minima is P_{ave} = 85.7±0.2 d, and the period is consistent enough to justify classifying the star as an SRa-type semi-regular variable; if the amplitude were larger, I should classify it as a Mira variable. The minima brighten from m_{min} = 12.86 in November 2006 to m_{min} = 12.72 in October 2007, and the amplitude decreases dramatically during 2007. The ephemeris is Max. ~1434 + 58.7 *E*.

The average $\phi_{\rm min}$ determined from six minima is $\phi_{\rm min}$ = 0.49±0.07, so the light curve is nearly symmetrical.

This is one of the reddest of Stan's variable stars, with *J* = 6.623, *J-H* = 1.040, *H-K* = 0.484; these colours are similar to those of the M7 IIIe Mira variable star R Aquilae (*P* = 300 d).

The star fits well into the *P-L-C* relations for Stan's other red variables, except that the amplitude m_r appears to be slightly larger than the average for its period. The star is perhaps redder in *J-K* than normal for its period and amplitude, but that may be the effect of interstellar reddening. The estimated $M_K \sim -5.7$; with $K = 5.099$, $d \sim 1.4$-1.5 kpc.

Star a06822

This star had an amplitude of about 26 mmag in 2003, 33 mmag in 2004 (shown), but only 21 in 2006, and 16 in 2007. Its period seems to be the same in all years.

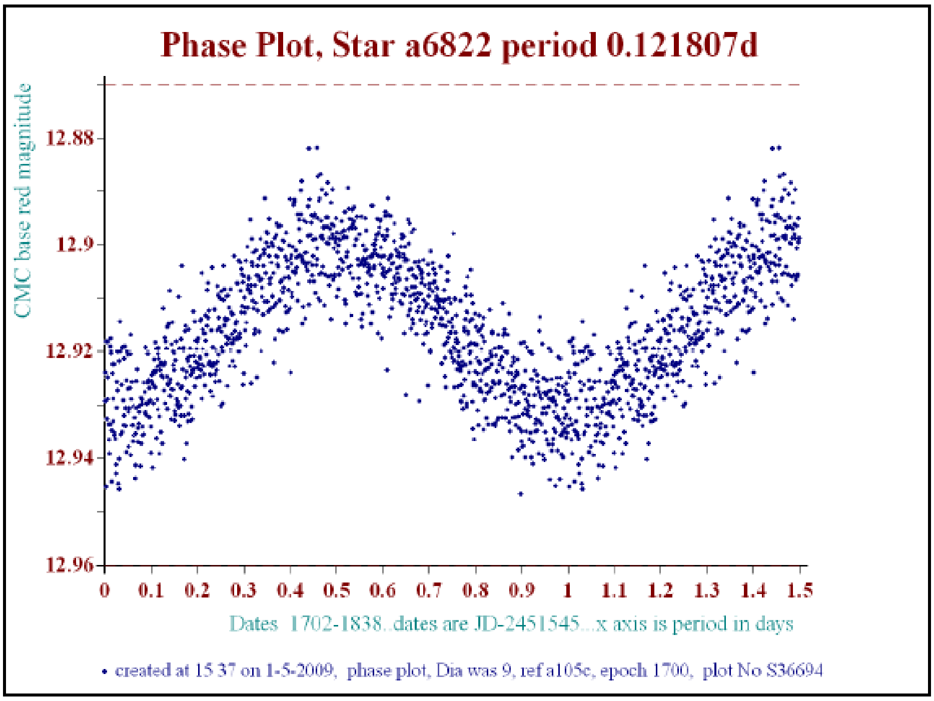


Figure 10.

RS. A small-amplitude variable star (typically $m_r \sim 20$-35 mmag.) with $m_{max} \sim 12.87$ and $P = 0.121807$ d. The light variations change from night to night.

The *JHK* photometry ($J = 11.946$, J-$H = 0.132$, H-$K = 0.112$) suggests that this is an F-type star; the JHK colours are similar to those of β Cas (F2-5 III-IV). The *BVR* photometry ($V = 13.03$, B-$V = 0.03$, V-$R = 0.74$) is obviously inaccurate, but the *B-R* colour is again consistent with an F-type star. The period and the inferred spectral type imply that this is a δ Scuti type star.

The one point against the interpretation of the star as a δ Sct variable, is the proper motion ($\mu_\alpha \cos\delta = 0.0106''$ a^{-1}, $\mu_\delta = 0.01575''$ a^{-1}, $\mu = 0.0190''$ a^{-1}). In the V-log μ diagram, the star falls among the SX Phoenicis stars rather than among the δ Scuti stars. The position angle of the star's proper motion is $\theta = 34°$, only about 7° from the Galactic plane, so it is probably a disc star. The period is longer than that of most SX Phoenicis stars, but XX Cygni closely resembles a6822 in its JHK indices and its period. If a6822 has the same M_V as XX Cygni ($M_V = 2.87$), d ~ 1.1 kpc and v_{tr} ~ 100 km s^{-1}, on the low side for an SX Phoenicis star but rather high for a δ Scuti star.

Star a12507

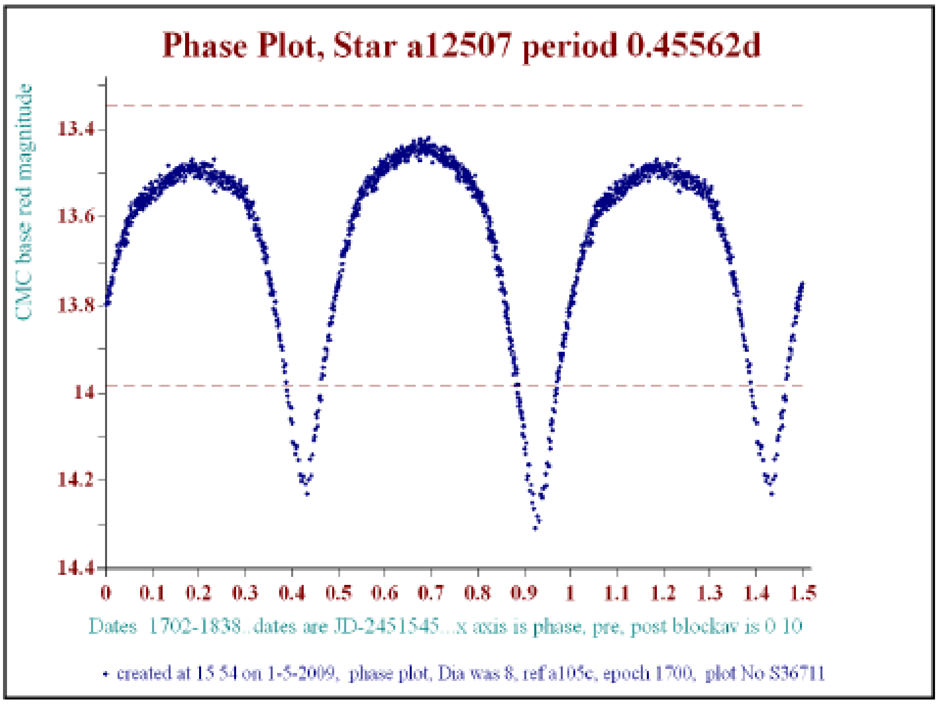


Figure 11.

RS. This is a W Ursae Majoris star, with very similar eclipses. The quadratic ephemeris for the interval 2003-7 is $\mathbf{Min\ II = 1344.570 + 0.455637}\ \boldsymbol{E}\ \mathbf{-6.6\times10^{-10}}\boldsymbol{E^2}$. It appears that the minima change places; the secondary minima during 2003/4 and 2007 are the primary minima during 2004/5 and 2006. During the first part of 2007, the two minima are of equal depths. There is no systematic difference in the shapes of the primary and secondary minima, and it is therefore not clear whether the larger or the smaller star is the hotter component.

The B-V colour ($V = 14.00$, B-$V = +0.44$) suggests that this is an early F-type star (F0-F5); however, the JHK colours ($J = 12.159$, J-$H = 0.429$, H-$K = 0.121$) are almost identical to those of α Centauri A (G2 V) and definitely imply that it is a G-type star.

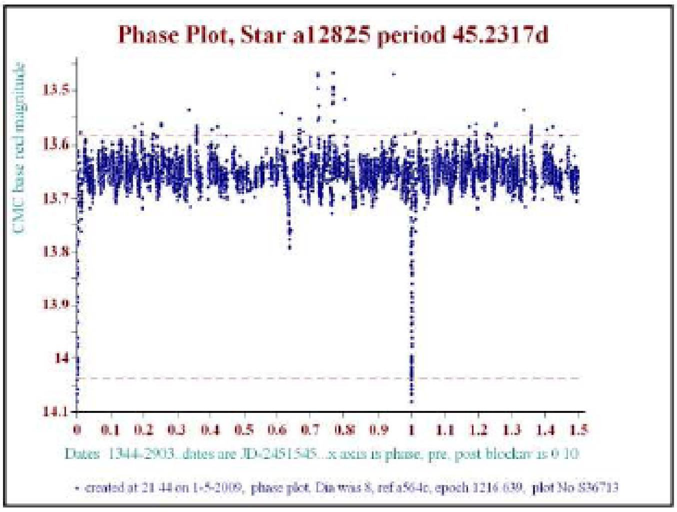
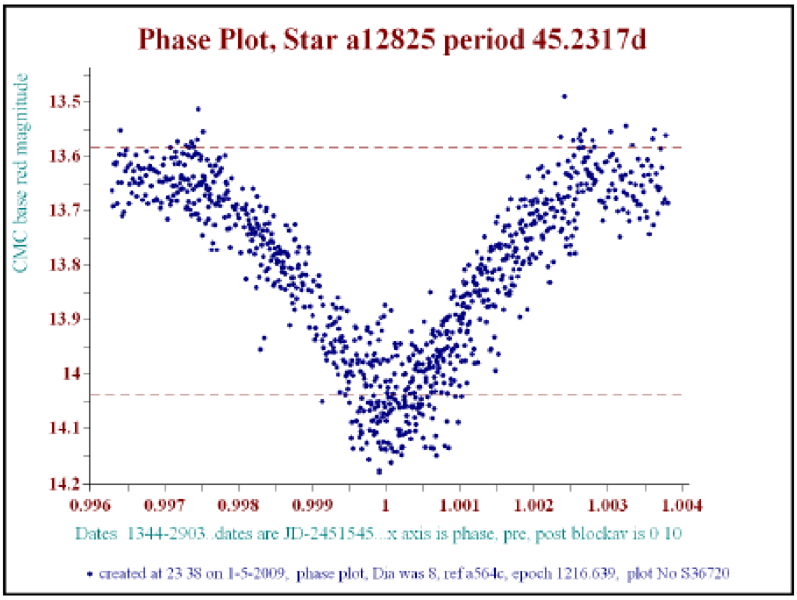


Figure 12.

This eccentric eclipsing binary is a challenge and not yet solved. Left is a phase plot from full 5years data and below a phase plot of what we assume is primary minimum.

Figure 13.



RS. The orbit is definitely eccentric, with ϕ_{II} ~ 0.64±0.005, if the period is correct. The parameters of the light curve are m_{max} ~ 13.64±0.01, m_{minI} ~ 14.06, m_{minII} > 13.77, ϕ_{II} ~ 0.64±0.05. We do not have observations of a full minimum at $\phi = 0.64$ so we do not know whether it is the primary or the secondary minimum; for the time being, I shall assume that it is Min. II. This assumed secondary minimum falls about 28.95 days after one primary minimum and about 16.28 days before the next; this minimum is also much broader (Δt >

0.49 d) than the primary minimum (Δt ~ 0.22 d), implying that secondary minimum occurs near apastron.

The JHK photometry (J-H = 0.260, H-K = 0.083) suggests that this is an early G-type star, and this is consistent with our temperature estimate, T = 6021 K; the JHK colours are quite similar to those of the Sun. The BVR photometry is less clear; V = 13.83 and B-V = 0.19, consistent with an A-type star, but V-R = 0.65, more consistent with a K-type dwarf star. The B-R colour (0.84) is consistent with a late F or early G star. There is no proper motion, so the star is probably fairly distant.

The star is in the north-east of Stan's cloud, in a region of patchy obscuration and a fairly sparse stellar density; however, the exact location of the star seems to be in a denser star cloud, perhaps marking a 'window' of reduced extinction. Since the JHK colours should not be grossly affected by interstellar extinction, this is probably a comparatively unreddened F or G star rather than a distant reddened early-type star; the photometry, with an absolute magnitude M_V ~ +4.5, implies d ~ 700 pc.

The existence of an F/G-type eclipsing binary star with a relatively long-period and an eccentric orbit may have some bearing on the formation of planetary systems around solar-type stars.

Star a17496

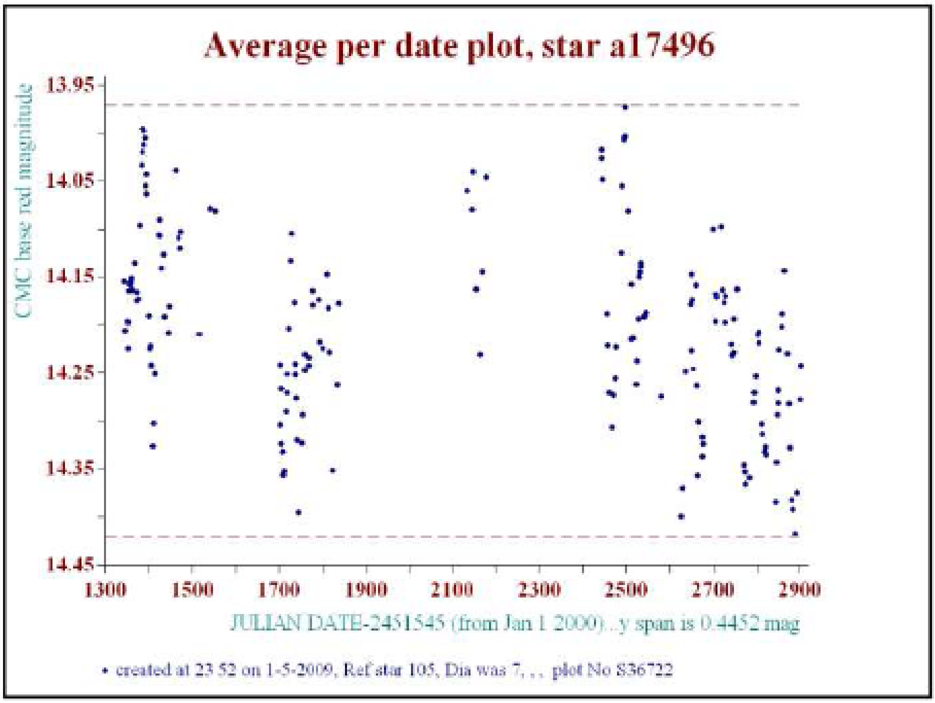


Figure 14.

A small-amplitude variable star (m_{max} ~ 14, m_r ~ 0.33 mag.), with light variations on a time-scale of about 50-60 d. The amplitude appears to be fairly constant (m_r ~ 0.3±0.03 mag.) but the maxima and minima may be variable by ~0.2 mag. The light variations are semi-regular at best.

The star appears to have episodes of regular or semi-regular variation, alternating with episodes of chaotic light variations. During the episode of regular variations in early 2006 and 2007/8, P ~ 55 d.
During 2003/4, we get P = 75.48 d (=50.32 d×1.5); this period yields a light curve that is very noisy.

The star appears to be a SRb star rather than an irregular variable; an average period P ~ 54 d, with m_r ~ 0.25 mag. seems reasonable. The star fits well into the period-luminosity-JHK colours relations found for Stan's other red variable stars.
The JHK colour indices of the star (J = 8.192, J-H = 1.058, H-K = 0.452) are similar to those of the carbon stars S Centauri, X Cancri and T Caeli, so a17496 could well be a carbon star, with a spectral type of about C4-6. However, the period is probably too short for a carbon star and the amplitude is too small.
The star does not have a measured proper motion. The period of 54 d yields M_K ~ -5.01, so, with K = 6.682, and assuming that there is no interstellar extinction in the K-band, we find d ~ 2.2 kpc.

Fainter Stars

We now know there are at least three other variable stars in this patch, marked with arrows in the bitmap. Two are Rmag 15.4, the brightest one (bottom of the three) is about R14.4. They have not been studied properly yet but we do know that one is a W Ursae Majoris type star, one is a red variable and one is a pulsator with a period of 0.18361 days.

Figure 15: Stan's observatory.