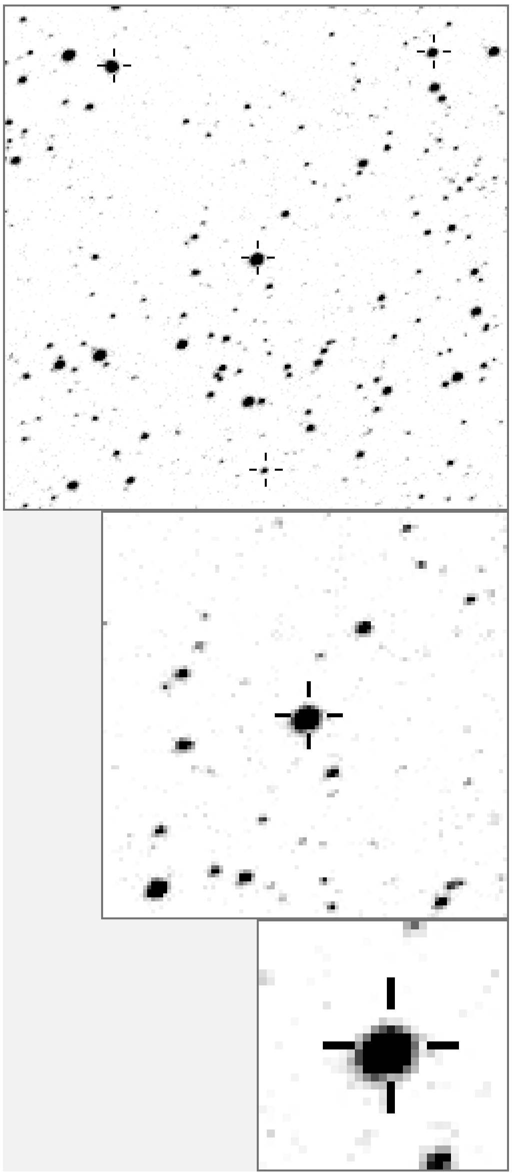
a00590



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Variable and brighter stars
· · · · · · · · · · · · · · ·   O   590 v
· a · c · · · · · · · · h · f   a  1126
· · · · · · · · · · · · k · ·   b  1153
· · · · · · · · · · · · · · ·   c  1444 v
· · · · · · · · · · · · · · ·   d  1941
· · · · · · · · · · · · · · ·   e  2185
· · · · · · · · · · · · · · ·   f  2339
· · · · · · · O · · · · · · ·   g  2489
· · · · · · · · · · · · · · ·   h  2820 v
· · · · · · · · · · · · · · j   i  2861
· i b · · g · · · · · · · · ·   j  2922
· · · · · · · d · · · m · e ·   k  2982
· · · · · · · · · · · · · · ·   l  4175
· · · · · · · n · · · · · · ·   m  4396
· · l · · · · · · · · · · · ·   n 12111 v
--------------------------------     - -
· · · · · · · · · · · m · · ·   O   590 v
· · · · · · · · · · · · · · ·   a  2489
· · · · · · · · · · · · · · ·   b  8553
· · · · · · · · · · · · · j ·   c 10013
· · · · · · · · · b · · · · ·   d 12325
· · f · · · · · · · · · · · ·   e 12884
· · · · · · · · · · · · · · ·   f 14575
· · · · · · · O · · · · · · ·   g 15652
· · e · · · · · · · · · · · ·   h 18817
· · · · · · · · g · · · · · ·   i 19626
· · · · · · · · · · · · · · ·   j 20900
· · h · · l · · · · · · · · ·   k 22298
· · · · · · · · · · · · · · ·   l 29598
· · a · i c · · · · · · k · ·   m 29678
· · · · · · · · n · · · d · ·   n 30368
```

Bitmap sizes are 251, 101 and 31 pixels square, South up. The keys to the right refer to the 1st two bitmaps. The numbers in the key are those in my catalogue 'starlistA'

Data and comments on star a00590

SWid: a00590 / **USNO id: 3588 88401 / other id: GSC 3588-0884**

Co-ordinates, x,y in image z1051: 986.1 2493

J2000 sky co-ordinates: **21 4 16.19 +46 46 45.32**

CMC r'magnitude and 2MASS J,H,K magnitudes: 10.642 9.129 8.603 8.482

USNO B1.0 magnitudes, B1,R1,B2,R2,I2: 12.35 10.4 11.6 10.33 9.81

Misc comments :

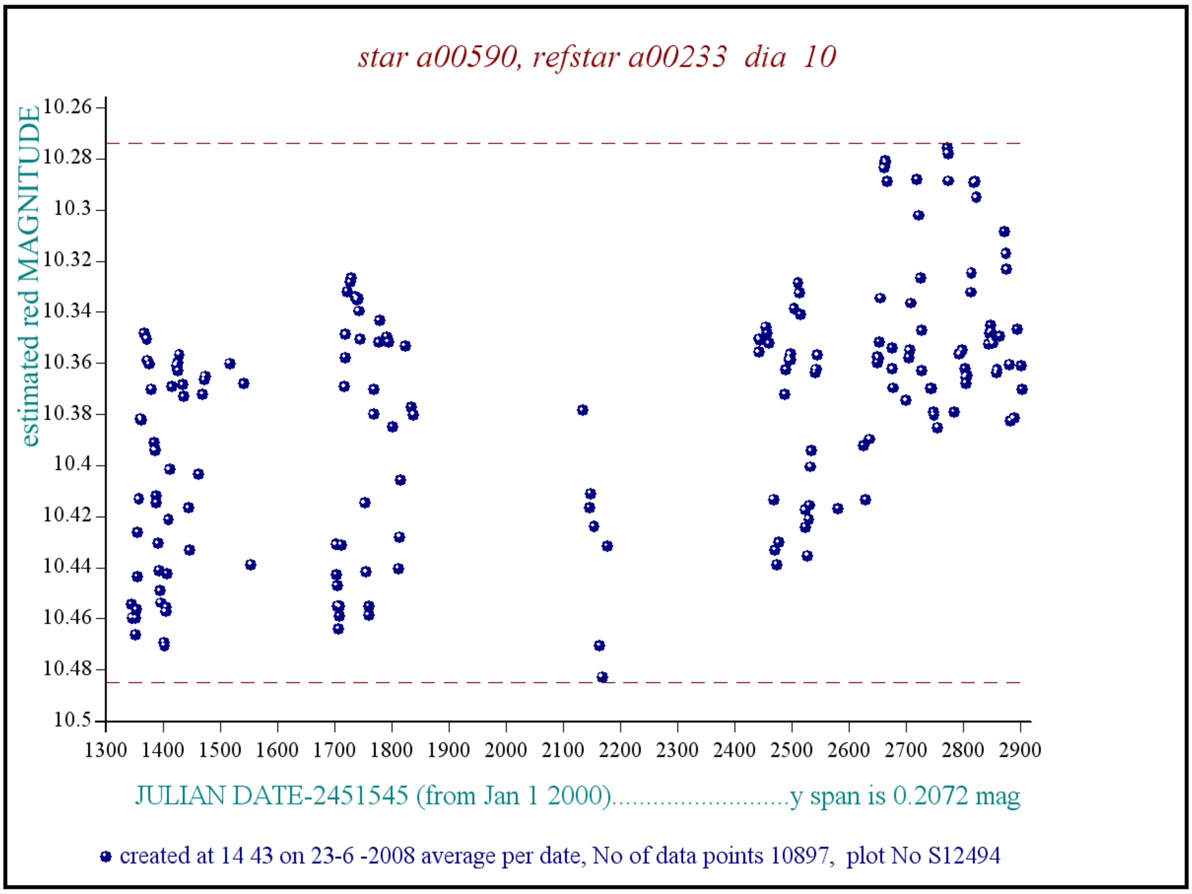
smooth, var amp osc, pd 51d, max amp in 2004 0.13mag. Irreg amp, constant period. mins at about 1349 1399 1453 1707 1758 1810 2473 2527 (51.2) (1st max at 1370) maxes at 2664 2716 2821 2871 (51.75) To 233, magm is 10.28, magr is 0.20 The pattern is more regular in 2003 and 2004, the odds in w look like a reversal from sharp down to sharp up at around 2620 and v is irregular. However the maxes w-v come to the same period. However the maxes across the gap in the 2006/7 data give a similar period, viz 1370 to 2664 is 1294 or 25×51.76. The small gap from 2509 to 2664 yields 51.7.

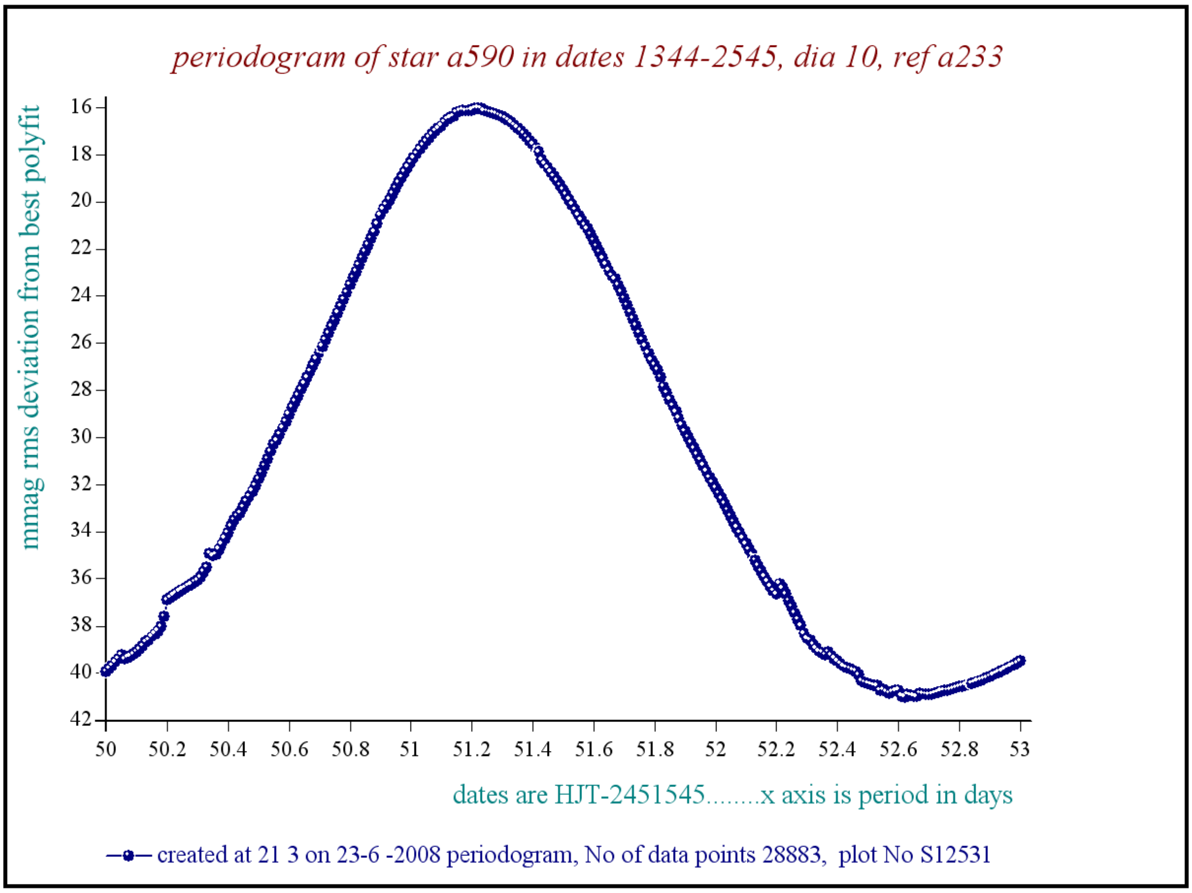
There is a detailed report from Richard Stratford appended at the end of this.

Comparison reference star(s) co-ordinates:
a00233: 21 5 24.62 +46 50 36.91

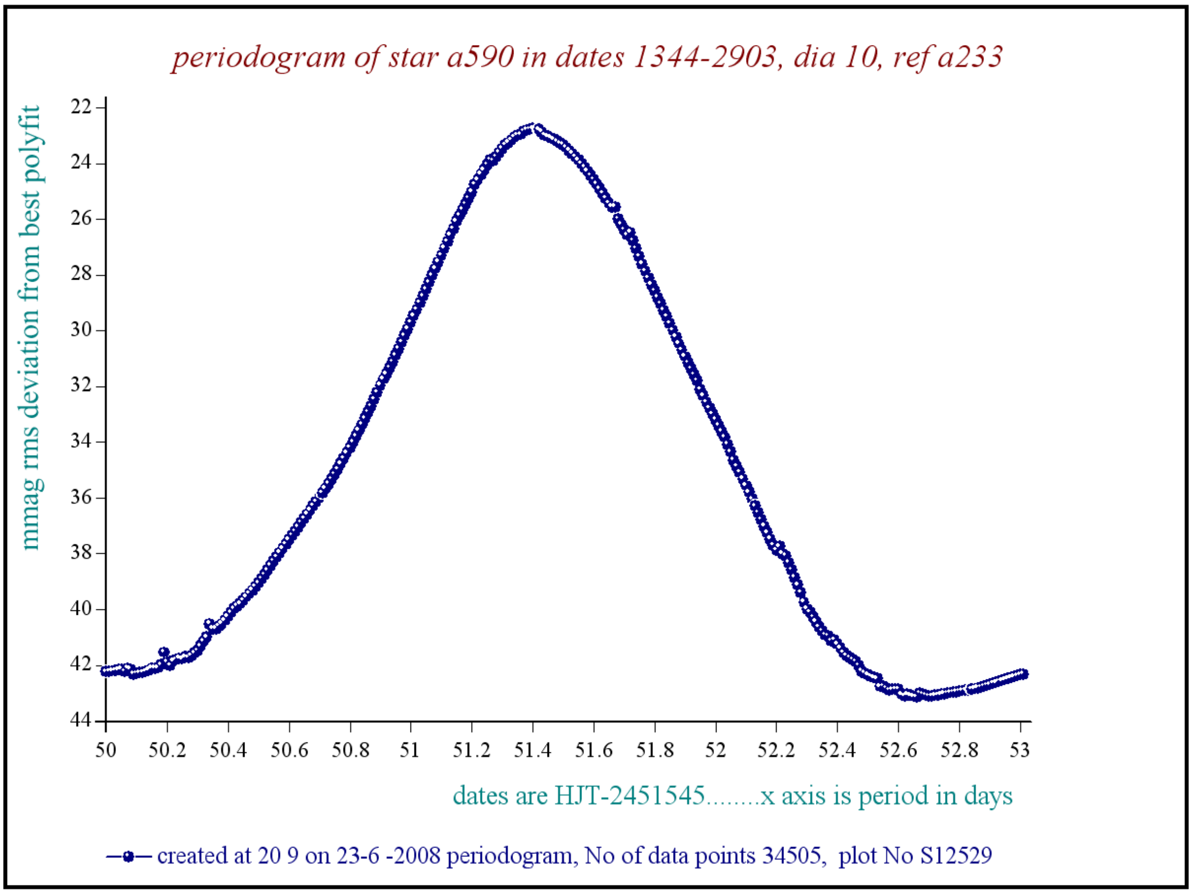
Reminder: **All dates, JD and HJD are from Jan 1st 2000**

season 1: dates 1316 to 1553 is 9/8/2003 to 3/4/2004	**(a)**
season 2: dates 1696 to 1838 is 23/8/2004 to 12/01/2005	**(z)**
season 3: dates 2085 to 2177 is 16/9/2005 to 17/12/2005	**(y)**
season 4: dates 2442 to 2755 is 8/9/2006 to 19/7/2007	**(w)**
season 5: dates 2772 to 2903 is 4/8/2007 to 13/12/2007	**(v)**
season 6: dates 2930 to 3266 is 9/1/2008 to 10/12/2008	**(u)**
season 7: dates 3403 to 3539 is 26/4/2009 to 10/9/2009	**(t)**

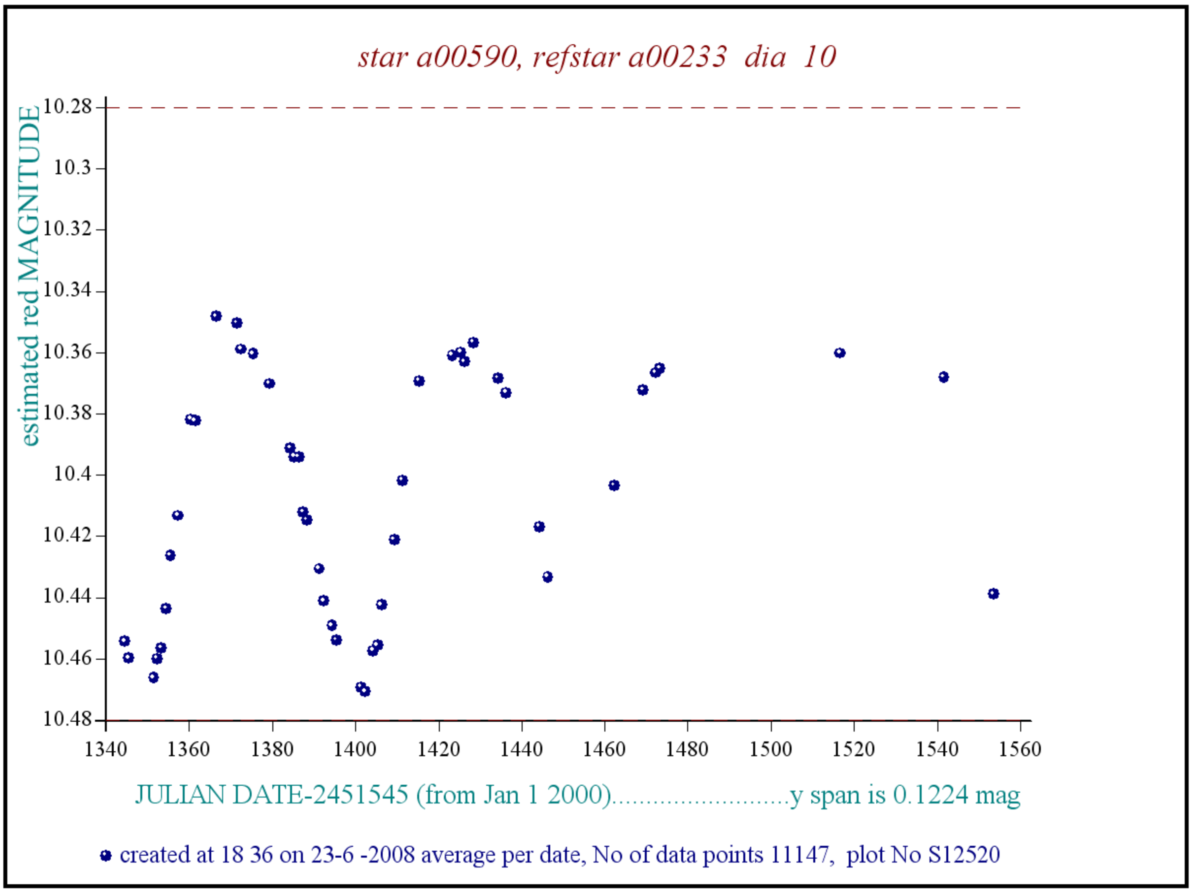


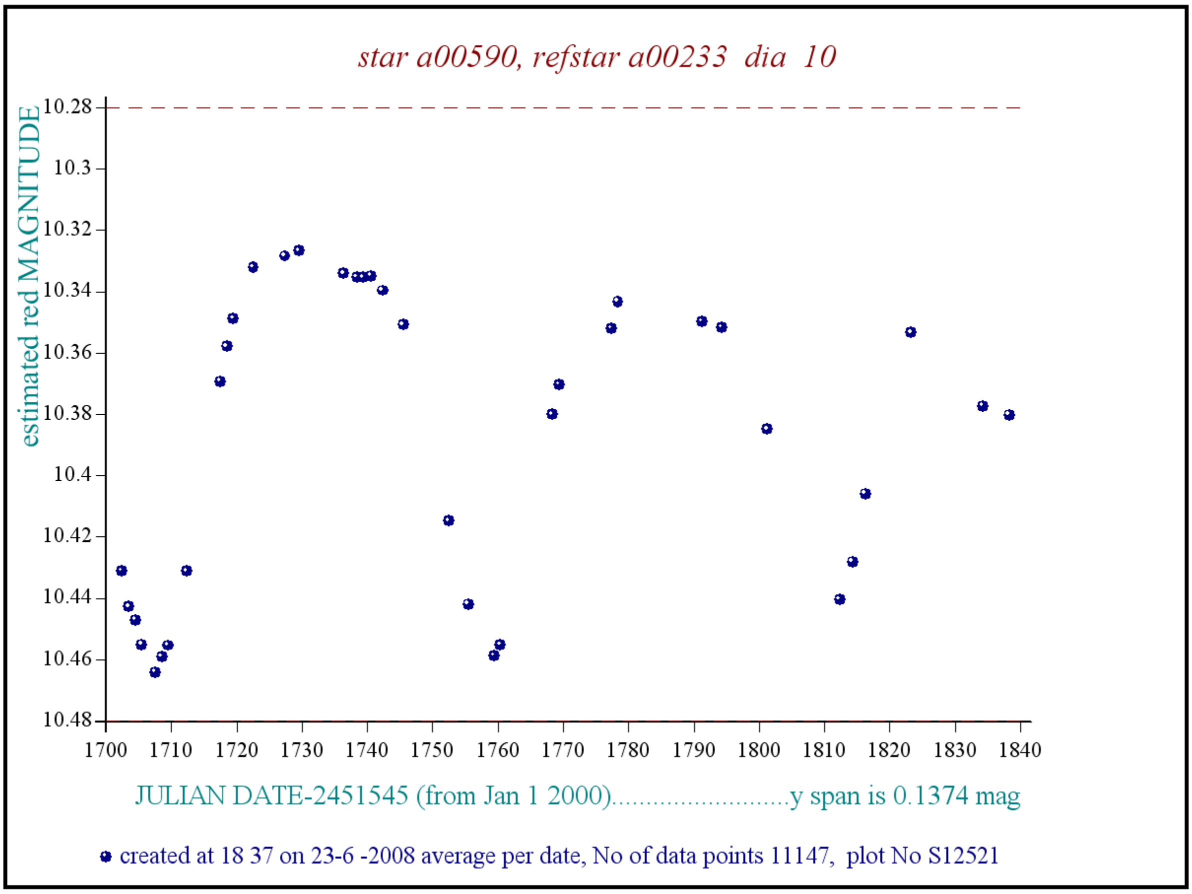


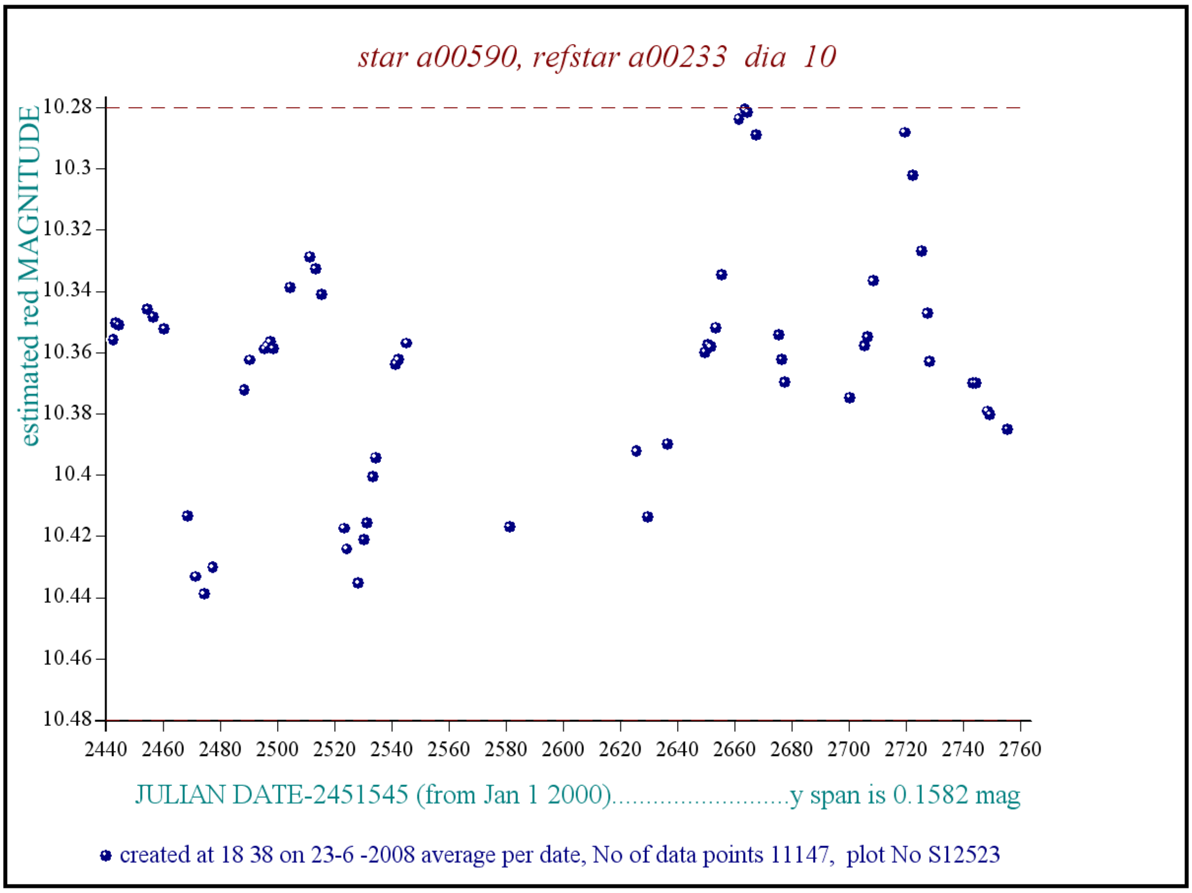
periodogram of star a590 in dates 1344-2545, dia 10, ref a233
mmag rms deviation from best polyfit
16
18
20
22
24
26
28
30
32
34
36
38
40
42
50
50.2
50.4
50.6
50.8
51
51.2
51.4
51.6
51.8
52
52.2
52.4
52.6
52.8
53
dates are HJT-2451545........x axis is period in days
created at 21 3 on 23-6 -2008 periodogram, No of data points 28883, plot No S12531



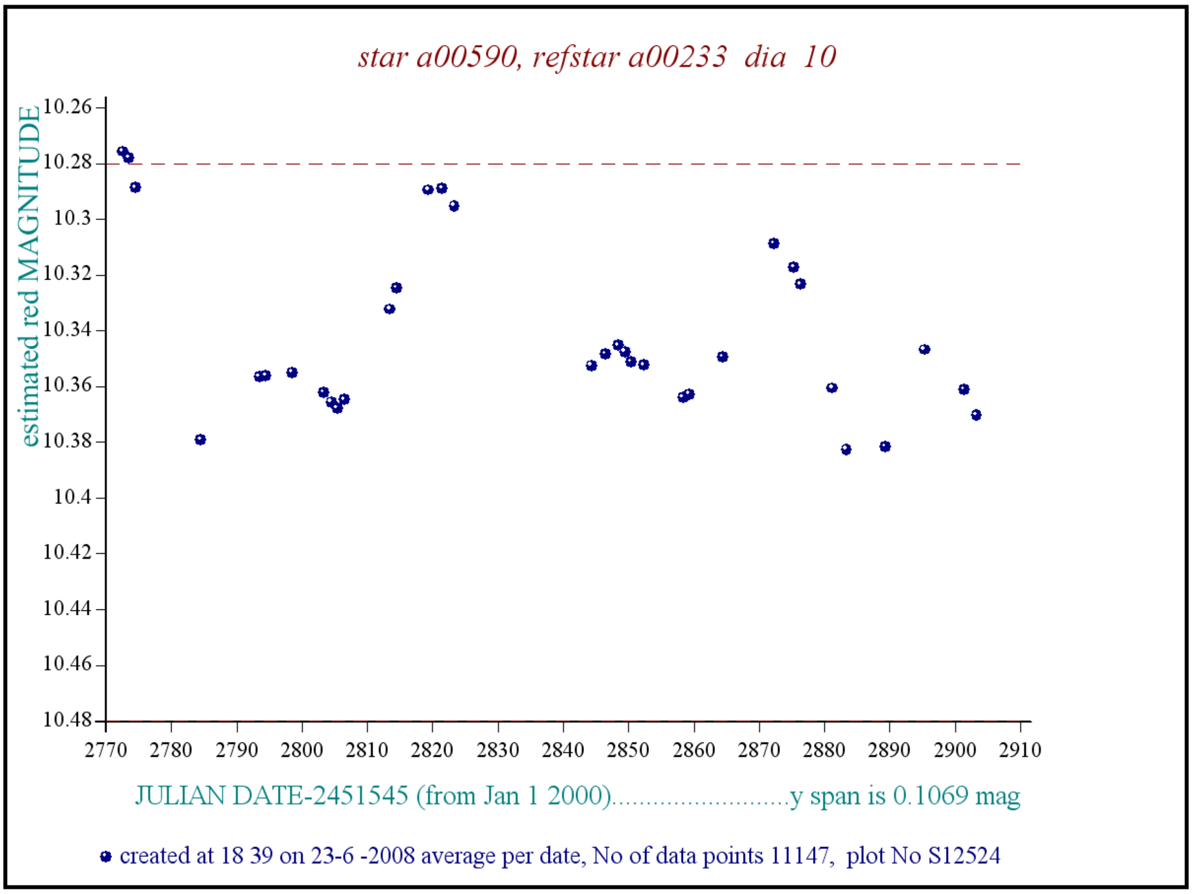
periodogram of star a590 in dates 1344-2903, dia 10, ref a233
mmag rms deviation from best polyfit
22
24
26
28
30
32
34
36
38
40
42
44
50
50.2
50.4
50.6
50.8
51
51.2
51.4
51.6
51.8
52
52.2
52.4
52.6
52.8
53
dates are HJT-2451545........x axis is period in days
created at 20 9 on 23-6 -2008 periodogram, No of data points 34505, plot No S12529


star a00590, refstar a00233 dia 10
estimated red MAGNITUDE
10.28
10.3
10.32
10.34
10.36
10.38
10.4
10.42
10.44
10.46
10.48
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
1560
JULIAN DATE-2451545 (from Jan 1 2000)..........................y span is 0.1224 mag
created at 18 36 on 23-6 -2008 average per date, No of data points 11147, plot No S12520


star a00590, refstar a00233 dia 10
estimated red MAGNITUDE
10.28
10.3
10.32
10.34
10.36
10.38
10.4
10.42
10.44
10.46
10.48
1700
1710
1720
1730
1740
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
JULIAN DATE-2451545 (from Jan 1 2000)..........................y span is 0.1374 mag
created at 18 37 on 23-6 -2008 average per date, No of data points 11147, plot No S12521



star a00590, refstar a00233 dia 10
estimated red MAGNITUDE
10.28
10.3
10.32
10.34
10.36
10.38
10.4
10.42
10.44
10.46
10.48
2440 2460 2480 2500 2520 2540 2560 2580 2600 2620 2640 2660 2680 2700 2720 2740 2760
JULIAN DATE-2451545 (from Jan 1 2000).........................y span is 0.1582 mag
created at 18 38 on 23-6 -2008 average per date, No of data points 11147, plot No S12523



star a00590, refstar a00233 dia 10
estimated red MAGNITUDE
10.26
10.28
10.3
10.32
10.34
10.36
10.38
10.4
10.42
10.44
10.46
10.48
2770 2780 2790 2800 2810 2820 2830 2840 2850 2860 2870 2880 2890 2900 2910
JULIAN DATE-2451545 (from Jan 1 2000).........................y span is 0.1069 mag
created at 18 39 on 23-6 -2008 average per date, No of data points 11147, plot No S12524

a00590 = GSC 3588-0884

This is a rather puzzling star. It shows regular variations, at least from 2003 to 2007, with m_r ~ 0.12 mag. (10.35-10.47).

There are minima at about 1351 (E = 0), 1401-2, 1446, 1707, 1759, 1801-12, ~2164 (E = 16), ~2474 (E = 22), 2528 (E = 23), 2629 (E = 25), ~2688 (E = 26), ~2784, ~2833, ~2886 (E = 30).

In 2003/4, there are maxima at about 1366 and 1428 (the maximum is poorly defined), and minima at 1351 and 1402. The light curve is therefore asymmetric, with $\phi_{\rm min}$ ~ 0.71 (or $\phi_{\rm max}$ ~ 0.29).

In 2004/5, there are rounded maxima at about 1729 and at about 1778-91 and sharp minima at 1707 (E = 7), about 1759 (E = 8), and about 1801-12 (E = 9). The light curve is less asymmetric, with $\phi_{\rm max}$ ~ 0.42-0.45 (or $\phi_{\rm min}$ ~ 0.55-0.58). The star has m_{max} = 10.34 and m_r ~ 0.15 mag.

In 2006/7 (2440-2550), the asymmetry of the light curve is in the other sense. There are sharp minima at 2474 and 2528 and a rounded maximum at 2511, so that ϕ_{max} ~ 0.685 (or $\phi_{\rm min}$ ~ 0.315). The other parameters are m_{max} ~ 10.36 and m_r ~ 0.11 mag. From 2600 to 2760, the light curve is very different, with sharp maxima at 2663, 10.301 and 2719, 10.307, with an inferred minimum at ~2688 (E = 26), >10.40. There is a more definite minimum at 2629 (E = 25).

In 2007/8, the light curve is poorly defined, and quite different in shape from the light curves of previous years; there are sharp maxima (2772, 10.288; 2821, 10.300; 2872, 10.323), and the amplitude has fallen to m_r ~ 0.07-0.1 mag. The light curve, with P = 48.5 d, bears some resemblance to that of an RV Tauri star, with alternating deep and shallow minima, the deeper minimum at (ϕ_{min} ~ 0.34) immediately following the higher and sharper maximum.

It seems fairly certain that the period P ~ 51-52 d is the true period rather than an *alias*; there are only small-amplitude variations during a single night. The long-term average period is P_{ave} ~ 51.2 d.

The star is in a fairly sparse area of sky, but this matter needs more detailed examination.

The JHK photometry (J-H = 0.526, H-K = 0.121) suggests that this is a K-type giant or supergiant star. Using the P-M_V relation for δ Cephei stars, namely M_V = -2.76log P – 1.4, we obtain M_V = -6.11. The period-colour relation for δ Cephei stars is $(B\text{-}V)_0$ = 0.325log P + 0.28, yielding $(B\text{-}V)_0$ = 0.835, whereas B-V = 1.033. From this, $E_{B\text{-}V}$ ~ 0.198 and A_V ~ 0.614, so V_0 ~ 10.49, and d ~ 21 kpc! Although this is discouraging, the evidence suggests that this is some sort of Cepheid or W Vir star rather than a semi-regular variable. The P-L-C relation for W Vir stars in the LMC yields M_V ~ -1.4±0.7, which is not impossible. The relation is M_V = -0.61±0.20 – 2.95±0.12 log P + 5.49±(0.35) <$(V\text{-}R)_0$> Since V-R = +0.778 and log P ~ 1.71, M_V ~

-1.39±0.68 (log $L/L_{\odot}$ ~ 2.47±0.27). Since V = 11.108, d ~ 3.2±1.1 kpc. Obviously, for such a distant star, reddening is likely to vitiate the estimates of M_V and d.

Alternatively, the star could be an RV Tau star or a yellow semi-regular (SRd) star. The period is on the short side for a star of this type, since most of them have P ~ 45-170 d (Glasby, 1968, p. 137), and the amplitude is very small for an RV Tau star. Percy shows the W Vir stars as having log ($L/L_{\odot}$) ~ 3 (M_{bol} ~ -2.5) and the RV Tau stars as having log ($L/L_{\odot}$) ~ 4 (M_{bol} ~ -5); since star a00590 has a very long period for a W Vir star, I would expect it to be a high-luminosity object, perhaps with log ($L/L_{\odot}$ ~ 3.5 (M_{bol} ~ -4). Any long-term variations in the mean magnitude have amplitudes of only a few hundredths of a magnitude, so, if a590 is an RV Tau star, it is an RVA star rather than an RVB (see below).

By simply assuming that W Vir stars have $M_V = M_V$(Cep) + 1.5, we have M_v = -2.76log P + 0.1 for W Vir stars, where P is in days. This yields M_V = -4.6 (log($L/L_{\odot}$) ~ 3.75) and d ~ 14 kpc! Even this enormous distance is compatible with the proper motion (μ ~ 0.9 m" a^{-1}), which implies v_{tr} ~ 60 km s^{-1}. The Galactic latitude of a00590 is b = -0.091° (=00°5.5'), so even if d = 14 kpc, the star is only 22 pc below the Galactic plane (z = -22 pc). Cooper and Walker, in *Getting the Measure of the Stars* present (Fig. 14.2) period-luminosity relations for Cepheids and W Vir stars that imply M_V ~ -3.5 for a590 if it is a W Vir star. If so, d ~ 8.3 kpc and z ~ -13 pc. If BC = -0.2 mag., M_{bol} ~ -3.7 and log ($L/L_{\odot}$) ~ 3.4.

According to Percy, the W Vir stars are thermally pulsing He-burning stars on the asymptotic giant branch (TP-AGB stars). As a result of helium shell flashes they undergo 'blue loops' in the H-R diagram that result in their crossing the instability strip. The W Vir stars have M ~ 0.5-0.6 $M_{\odot}$, so they should be extreme Population II stars of the Galactic halo. However, from what I can make out of their kinematics, they appear to be intermediate Population II stars of the thick disc; perhaps they have lost mass during the red giant phase of evolution. Even on this interpretation, it is quite likely that the W Vir stars had M_0 ~ $M_{\odot}$ and that they are older than the Sun (t ~ 5-10 Gyr?). The 'anomalous Cepheids', or BL Boo stars, have periods similar to those of 'long-period' RR Lyr stars (BL Boo itself has P = 0.8213 d), but have M ~ 1.5$M_{\odot}$; they may be coalesced binary stars.

The RV Tauri stars may also be TP-AGB stars, but they could also be stars that have completed their asymptotic giant branch evolution and have passed through the Mira stage and are now ejecting their envelopes and moving to the blue side of the H-R diagram to become the nuclei of planetary nebulae. In any case, they are very luminous stars, and must have only a short lifetime as RV Tau stars. The SRd stars may be in the same evolutionary stage, and there may be an unbroken transition between the regularly pulsating RV Tau stars and the semi-regular SRd stars. The SRd stars have systematically higher radial velocities than the RV Tau stars, and are therefore Population II stars, but radial velocity is, of course, a continuous variable and there may be some stars whose radial velocities fall between those of the RV Tau and SRd stars. Notice, though, that the RVB stars, which show long-period variations in their mean magnitude, are strong IR sources and presumably have massive circumstellar envelopes, whereas the RVA stars, which have constant mean magnitudes, and the SRd-stars are not.

According to Wikipedia, SRd stars have P = 30-1100 d and Δm = 0.1-4 mag. The star a00590 has P = 51-52 d and Δm = 0.17 mag., so it is at the short-period low-amplitude end of these ranges. Examples of SRd variables are WY And, KK Aql, Z Aur, AG Aur, W LMi, SX Her, WW Tau, and SV UMa.

The 'steps' function yields T = 5175 K, consistent with an early G-type giant or supergiant.

In the spreadsheet for RR Lyr stars and Cepheids (the one that includes Stan's short-period 'Cepheids', a00590 falls among the long-period Cepheids; in fact, in the log *P-B-V* diagram it appears to be bluer than classical Cepheids of the same period. However, from Stan's light curves, the star appears more irregular than a classical Cepheid ought to be. It would be useful to examine the colours and kinematics of RV Tau and SRd-variables to compare them with classical Cepheids, W Vir stars, and a00590.

In the various visible and near-IR two-colour diagrams, the log *P-C* diagrams, and the log μ-*V* diagram, a00590 generally falls among the shorter-period RV Tau (RVA) stars, rather than among the RVB or SRd-variables. It is not as red in *J-K* as the RVB stars. A rough statistical analysis of the values of ε(CI) (= $(\mathrm{CI})_{590} - (\mathrm{CI})_{ave}$ for the three classes of variable stars tends to confirm this conclusion: $E = \surd((\Sigma\{\varepsilon(\mathrm{CI})/\sigma(\mathrm{CI})\}^2)/7)$ = 0.70 for a sample of 12 RVA stars; E = 0.92 for 12 RVB stars; and E = 0.99 for 12 SRd-stars. A similar statistical analysis of the log P distributions of the RVA, RVB and SRd variables puts a00590 closest to the RVB stars and farthest from the SRd-stars.

The 'stepscolour/B-V' and 'stepscolour/V-R' relations yield *B-V* ~ 0.490 and *V-R* ~ 0.579. These colours would be consistent with a late F or early G-type star, but they are inconsistent with the measured colours obtained from Vizier. In the log*P*/*B-V* and log *P*/*V-R* diagrams, a590 falls among the RV Tau stars; in the *B-V/H-K* diagram it falls along the Cepheid-W Vir-RVA trend, not among the RVB stars. In the *V*-logμ diagram, a00590 falls among the RVA stars.