a9980 = GSC 3592-2803= USNO-B1.0 1369-0435874

A short-period variable star, mostly between m = 12.95 and m = 13.15, but with a deep minimum (m_{min} ~ 13.3) at 1393.

2003/4 minima: <1344.378, >13.118 (m_{max} ~ 12.975, eclipse ends at ~1344.451, so $\Delta t/2$ > 0.073 d); >1354.602, >13.268 (eclipse begins at ~1354.500, so $\Delta t/2$ > 0.10 d); 1355.599±0.003, 13.350 (E = -4.5, $\Delta t/2$ ~ 0.085 d?); **1360.500, 13.304 (E = 0.5,** V-shaped, Δt ~ 0.170, some variation before beginning of eclipse?); 1361.502, 13.208 (E = 1.5); <1366.380, >13.260 (E = 6.5); 1384.486, 13.343 (E = 25); ≳1385.457, ≳13.308 (E = 26); <1387.454 (E = 28); 1388.414, 13.285 (E = 29); ~1391.350, 13.298 (E = 32); 1394.280, 13.310 (E = 35); ≲1395.260, ≳13.286 (E = 36); 1411.413, 13.281 (E = 52.5); 1436.387, 13.325 (E = 78); <1444.245, ≳13.291 (E = 86); <1446.224, >13.161 (E = 88); >1462.303, >13.12 (E = 104.5); <1469.235, >13.18 (E = 111.5); 1516.699, 13.329 (E = 160); and ~1541.671, 13.271 (E = 185.5). The minimum at 1360.500 is probably a secondary minimum. There appears to be an 'arched variation' between maxima, but the observations during 2004/5 do not confirm this. The average period for 2003/4 is P = 0.979302 d.

P ~ 0.9792/4 d or 1.9584/8 d?

This yields a good light curve for P = 0.97925 d, with m_{max} = 12.97-12.98, m_{minI} = 13.330, m_{minII} ~13.295 or 13.344; ϕ_{II} = 0.50.

2004/5 minima: 1707.656, 13.326 (E = 355, $\Delta t/2$ ~ 0.074 d); >1708.640, >13.336 (E = 356); >1709.586, >13.197 (E = 357); 1717.458, 13.335 (E = 365, Δt ~ 0.144 d);

~1718.436±0.002, 13.348 (E = 366, $\Delta t/2$ ~ 0.079 d); 1719.412, 13.341 (E = 367, Δt ~ 0.163 d); <1722.403, >13.093 (E = 370); ≳1729.685, ≳13.316 (E = 377.5, $\Delta t/2$ ≳ 0.071 d); ~1736.549, ~13.316 (E = 384.5); 1738.511, 13.333 (E = 386.5, Δt ~ 0.168 d); >1739.456, >13.178; ~1740.471, ~13.293 (E = 388.5, $\Delta t/2$ ~ 0.072 d); ~1742.427, ~13.332 (E = 390.5); <1745.417, >13.103; >1755.606, >13.134; 1759.565, 13.285 (E = 408, $\Delta t/2$ ~ 0.078 d); ~1760.540, 13.285 (E =409, $\Delta t/2$ ~ 0.094 d); 1768.381, 13.326 (E = 417); 1769.359, 13.347 (E = 418, Δt ~ 0.156 d); <1777.242, >13.133; 1794.326, 13.300 (E = 443.5); ~1812.454, ~13.297 (E = 462); ~1814.407, ~13.245 (E = 464); ~1823.226, ~13.335 (E = 473); >1838.369, >13.178.

P ~ 0.97927/31 d. Perhaps better P ~ 0.97930/2 d. The average duration of the eclipses is Δt ~ 0.157 d.

This yields a good detached EA light curve for P = 0.97930 d, with m_{max} = 12.99 and no appreciable variation during the maxima, m_{minI} = 13.347, m_{minII} = 13.326, and ϕ_{II} ~ 0.500. The minima from 1707.656 to 1719.412 are primary minima. The period for the year 2004/5 appears to be P ~ 0.9794 d, so the period may be increasing slightly.

2005/6 minima: ≳2085.678, ≳13.269 (E = 741); 2146.397, 13.313 (E = 803); 2148.360, 13.338 (E = 805); ≲2154.237, ≳13.380 (E = 811); and 2177.246, 13.315 (E = 834.5).

P = 0.97931/2. The average period for 2004/6 is P = 0.97933 d, and for 2005/6 is 0.97934 d; the period may be increasing slightly, by ~ 6×10^{-8} days per period.

2006/7 minima: ~2442.64, ~13.254 (E = 1105.5); 2454.394, 13.355 (E = 1117.5); 2456.350, 13.329 (E = 1119.5); <2460.295, >13.253; ~2468.588±0.002, 13.308 (E =

1132); 2471.515, 13.274 (*E* = 1135); 2477.411, 13.406 (*E* = 1141, flat-bottomed, τ_{cent} ~ 0.008 d); >2490.614, ~13.321; ~2495.526±0.001, 13.375 (*E* = 1159.5, V-shaped); 2496.516, 13.314 (*E* = 1160.5); 2497.480, 13.328 (*E* = 1161.5); ~2498.453, 13.319 (*E* = 1162.5); ~2504.341, 13.327 (*E* = 1168.5, roughly flat-bottomed, τ_{cent} ~ 0.013 d?); 2523.436, 13.335 (*E* = 1188, V-shaped); 2524.413, 13.359 (*E* = 1189); 2528.337, 13.338 (*E* = 1193); ~2530.300, 13.314 (*E* = 1195); 2531.273, 13.347 (*E* = 1196); ~2533.232, 13.311 (*E* = 1198); <2534.237, >13.269; ~2629.694, 13.305 (*E* = 1296.5); 2636.539?, 13.230 (*E* = 1303.5); <2647.517?, >13.41?; *2649.514*, *13.295 (spurious)*; >2653.674, >13.307; >2655.628, >13.267; <2663.492, >13.212; 2664.463, 13.332 (*E* = 1332); 2705.590, 13.310 (*E* = 1374); ~2706.578, ~13.304 (*E* =1375); 2708.525, 13.335 (*E* = 1377, flat-bottomed, τ_{cent} ~ 0.009 d); and 2755.532, 13.324 (*E* = 1425).

The period for 2003 to 2007 is probably *P* ~ 0.97931/2. The period for 2006/7 is *P* ~ 0.979318 d.

The ephemeris derived from the *O*-*C* diagram is: **Min I = HJD 2452929.489 + 0.979319 *E*.** There is no evidence of variations in the period. A period of 0.4896595 d is less good, since it shows no sign of a secondary minimum, whereas the minima with the 0.979-day period appear to be of different depths.

The period is strikingly short; in fact it is the shortest that I have found so far for a detached binary star. The JHK colours (*J* = 12.742, *J*-*H* = 0.075, *H*-*K* = 0.029, *J*-*K* = 0.104) suggest an early F-type star or a late A-type star; they are very similar to those of τ Bootis (F7 V), but this star is itself too blue in JHK for its spectral type. The BVR colours (*V* = 13.41, *B*-*V* = -0.18, *V*-*R* = 0.72, *B*-*R* = 0.54) are all over the place, and in particular the R-magnitude (*R* = 12.69) is much brighter than Stan's value for it. An F0 V star

should have B-V ~ 0.30, V-R ~ 0.21, B-R ~ 0.53; in fact, the Vizier magnitudes yield B-R = 0.54, so we should have V ~ 12.93, which is in fair agreement with Stan's value for m_{max}. If we accept this V-magnitude, the proper motion ($\mu_\alpha \cos \delta$ = -0.002"/yr, μ_δ = -0.006"/yr, μ = 0.0063"/yr towards S18°W, but see below) yields an M_V that is at least consistent with an F-type star. The 'stepscolour' index of 0.481 yields T_{eff} = 7442 K, consistent with a spectral type of A9.

The two stars have essentially the same T_{eff} and spectral type, so if we assume that they are both F0 V stars, $M_* \sim 1.8 \times M_\odot$ and $M_{tot} \sim 7.2 \times 10^{30}$ kg. With P = 84613.2 s and an average, the formula $R_* = (V \times \Delta t)/4 = ((2\pi G)^{1/3}(M_1 + M_2)^{1/3} \times \Delta t)/(4P^{1/3}) \Rightarrow R_* \sim 1.1 \times 10^6$ km ~ 1.6 $R_\odot$. This is reasonably consistent with an F0 V star, which should have R_* ~ 1.35 $R_\odot$. The orbital semi-major axis is ~4.43 Gm ~ 6.4 $R_\odot$ ~ 4R_*, so the system is reasonably well detached.

If P = 0.4896595 d = 42306.6 s, the orbital semi-major axis is a ~ 2.8 Gm ~ 4.0 $R_\odot$ ~ 2.5-2.7R_*, so the system would be barely detached, even with R_* = 1.5-1.6 $R_\odot$. The duration of the eclipse (Δt = 0.157 d =13600 s) then implies $R_* \sim 1.4 \times 10^6$ km = 1.4 Gm ~ 2 $R_\odot$, rather too large for a late A or an F-type star, and too large for the system to be detached. All this tends to confirm that the 0.979-day period is the correct one.

If both stars are of spectral type F0, they have M_V ~ +2.7, so that the absolute magnitude of the system is M_V ~ 2.0, whence, if V ~ 12.93, d ~ 1.5 kpc and $v_{tr} = 4.74\ \mu \times d$ ~ 45 km s^{-1}. However, according to Vizier the most recent catalogues give larger values for the

proper motion. Roeser *et al.* (2008) give $\mu_\alpha \cos\delta$ = -0.01576”/yr and μ_δ = 0.00098”/yr, whence μ = 0.01579”/yr towards S3.6°E; for d = 1.5 kpc, v_{tr} = 112 km s^{-1}. The UCAC3 catalogue of Zacharias *et al.* (2009) gives $\mu_\alpha \cos\delta$ = -0.0155”/yr and μ_δ = 0.0046”/yr, whence μ = 0.0162”/yr towards S16.5°E; for d = 1.5 kpc, v_{tr} = 115 km s^{-1}. The larger values for μ suggest that the star is closer than 1.5 kpc; probably it is dimmed by interstellar extinction.