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A SEARCH FOR γ DORADUS-TYPE VARIABLES IN THE OPEN CLUSTER M 34

The γ Doradus stars constitute a new class of low-amplitude variable stars. Krisciunas & Handler (1995) list known members and candidates. These stars typically show brightness variations of several hundredths of a magnitude on time scales of 0.5 to 3 days. γ Dor stars typically have early F-type spectra and are found on, or just above, the main sequence in the Hertzsprung-Russell Diagram. The most likely explanation for their variability is that they are exhibiting non-radial gravity mode pulsations (Aerts & Krisciunas 1996, Balona *et al.* 1996).

Eggen (1995) and Krisciunas *et al.* (1995) suggest that the γ Doradus phenomenon is age related. There is evidence that many of these stars are younger than 150 Myr. Krisciunas *et al.* (1995) searched for candidates in the Hyades (age $\approx$ 600 Myr) and found none. The basic idea is that once photospheric convection sets in, the gravity-mode pulsations no longer are observable. Given the masses of these stars ($\approx$ 1.6 $M_\odot$), their main sequence phase must last about 3 Gyr. We are naturally interested to know what fraction of their main sequence life is spent exhibiting pulsations.

Our interest in M 34 (NGC 1039) is that it is a reasonably nearby open cluster whose age is estimated to be 250 Myr (Ianna & Schlemmer 1993), which is in between the age of NGC 2516 (with eight γ Dor stars) and that of the Hyades. Ianna & Schlemmer (1993) provide a finding chart, plates coordinates, apparent magnitudes and B–V colors for the stars. Their photometry, however, is derived from photographic plates and is accurate to no better than $\approx$ 0.1 mag.

Given that early F stars listed in the *Bright Star Catalogue* have B–V colors in the range 0.26 to 0.40, and given the color excesses of the stars in M 34 (0.07 mag), we selected stars from Ianna and Schlemmer's list with $0.33 < B\text{–}V < 0.47$. With one exception (UVa 197) all of our 11 program stars have membership probabilities greater than 0.6. We used UVa 123 as our principal comparison star and UVa 166 as a check star. These two stars and 9 of our 11 program stars were observed photoelectrically by Johnson (1954). Our observing procedure was to do V-band differential photometry and observe the principal comparison star after every third program star. Transformation to the UBV system was accomplished with differential measures of the red-blue pair BS 8451 and BS 8453 (Hall 1983).

We observed at Mauna Kea with the University of Hawaii's 0.6-m telescope and an Optec SSP-5 photometer belonging to the University of Hawaii at Hilo. Our seven night run began on 19 September 1996 UT. We lost three whole nights to clouds and one to equipment problems but did manage to obtain some accurate photometry. From observations of the principal check star (UVa 166) and 5 of our program stars that appeared to be constant (UVa 135, 186, 197, 200, and 251) we estimate that the accuracy of an individual measurement was $\pm$ 5.5 mmag. (Our faintest star, UVa 236, gave a lower signal to noise ratio and a correspondingly larger internal error.)

Table 1. Summary of differential photometry of M 34 stars. The comparison star in all cases was UVa 123 ($V = 10.46$, B–$V = 0.16$). For each star we give the assigned UVa numbers of Ianna & Schlemmer (1993), the mean differential V magnitude, the internal error of a single differential value (i.e. the standard deviation of the distribution, *not* the mean error of the mean), and the number of data points

UVa	$< \Delta V >$	σ(mmag)	N
135	0.780	5.7	20
144	1.017	10.0	21
161	1.442	5.8	19
162	1.003	5.9	19
166	−0.749	4.7	21
186	0.722	3.9	19
197	0.639	5.1	18
200	1.008	6.9	18
224	1.035	11.4	18
232	0.995	7.3	19
236	2.406	16.1	18
251	1.238	7.1	18

Our individual data, amounting to 228 differential measurements, can be obtained from IAU Commission 27 as file 318E of unpublished photometry. (See Breger, Jaschek, & Dubois 1990 for further information on that archive.) We give in Table 1 a summary of the photometry obtained. The internal error of our nightly means in Table 1 compared to the differential magnitudes derivable from Table 5 of Ianna & Schlemmer (1993) is ± 0.082 mag, which we attribute to the fact that their data were derived from photographic plates. It is also revealed that the V magnitude adopted by Ianna & Schlemmer is systematically too bright. If we use as a reference the V-band values for the 10 stars observed photoelectrically by Johnson (1954), the mean internal error is ± 0.021 mag. One should adopt Johnson's value of $V = 10.46$ for the comparison star, UVa 123.

Because the differential magnitudes of our check star, UVa 166, and five of our program stars were constant, we have great confidence that our comparison star, UVa 123, is constant. Therefore, any variations observed in the other program stars can be attributed to those stars. Six of our eleven program stars showed evidence of low-amplitude variability and are deserving of further study. UVa 144, 224, 232, and 236 showed evidence of differing nightly means, while UVa 161, 162, 224, and 232 showed some evidence for variations over the course of a single night. While we do not yet have data sufficient to prove that any of these stars are *bona fide* γ Doradus-type variables (one would want enough to obtain a decent power spectrum), we show below the light curve of the best γ Dor candidate in M 34, UVa 224. It is reminiscent of parts of other single-site light curves of γ Dor stars. See for example Mantegazza, Poretti, & Zerbi (1994).

If it is confirmed that one or more of the early F stars in M 34 vary by several hundredths of a magnitude on a time scale of 0.5 to 3 days, we will then know for certain that the γ Doradus phenomenon extends to an age of 250 Myr in the lives of main sequence stars of mass ≈ 1.6 $M_\odot$.

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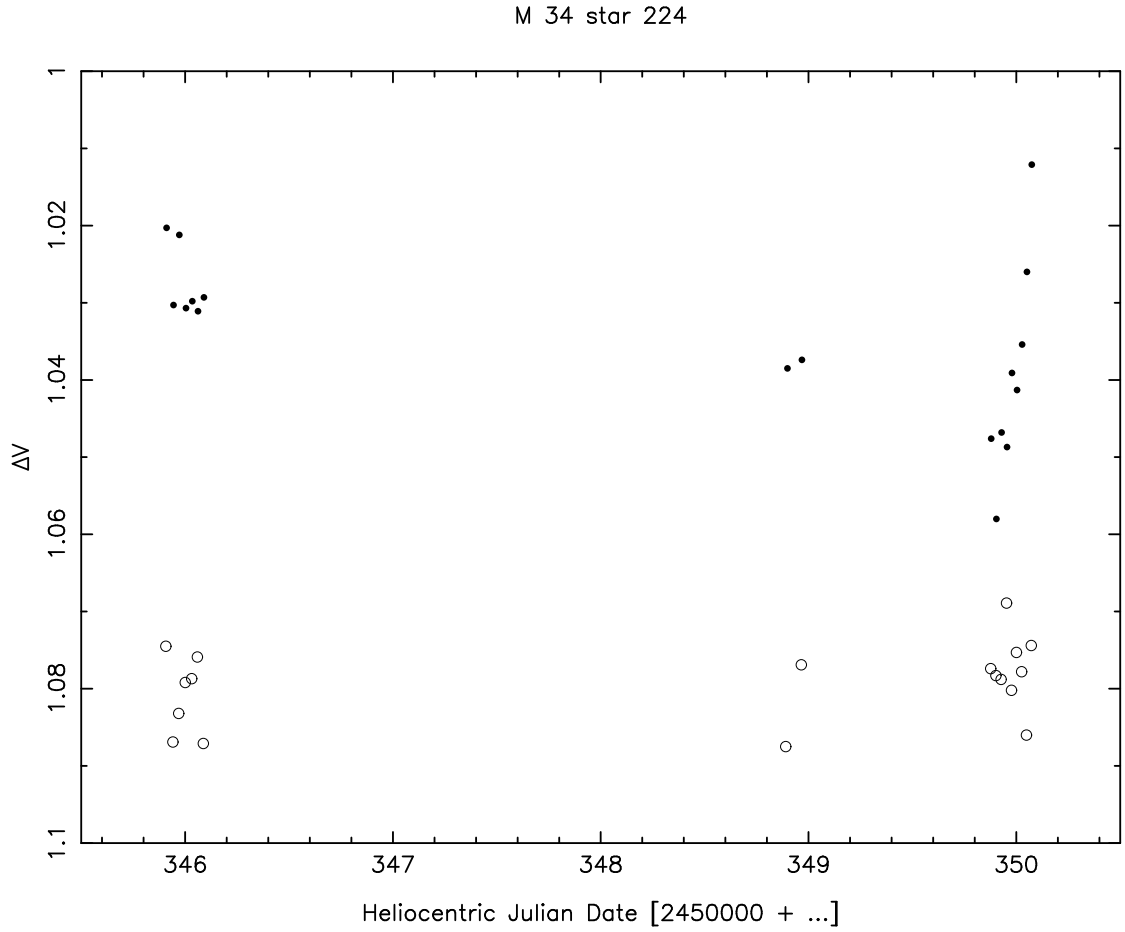

Figure 1. Differential V–band photometry of UVa 224 vs. UVa 123 (dots). Data for the star UVa 197 vs. UVa 123 (open circles) are also shown, offset by an arbitrary amount

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