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HD 147491 IS VARIABLE, BUT IT IS NOT A DELTA SCUTI STAR

Short-period variability of HD 147491 (α (2000.0) = $16^{\rm m}23^{\rm m}23^{\rm s}$, δ (2000.0) = $-26°22'$ 16", a few arcminutes north of the globular cluster M4) was claimed by Yao & Tong (1989, here after YT89) on the basis of 3 nights of photometry. Their observations implied a period of about 25 minutes. YT89 also gave arguments that this star has mid-A spectral type, using an estimate of the interstellar reddening of field stars in the direction of M4 and published UBV photometry. They concluded that HD 147491 is a new δ Scuti variable. Even earlier, Clementini (1979) suggested that this star is "likely to be variable", because her BVRI photometry disagreed with previously published results.

However, the data of YT89 were acquired at Beijing Observatory, located at a latitude of +40°, so that YT89 could never observe the star at air mass values lower than 2.5. Moreover, they neglected the spectral classification of HD 147491 from the Michigan Spectral Catalogue (Houk 1982), giving a spectral type of G0 V as well as the star's Hβ-index of 2.598 measured by Eggen (1983). Such a Hβ value is not typical of a δ Scuti star. Finally, YT89 find their estimated $(U-B)_0$ to be "too blue". If they dereddened the $(V-R_c)$ and $(V-I_c)$ colors of Clementini (1979) in the same way like the UBV photometry, they would have found further inconsistencies. On the other hand, assuming that HD 147491 is a G dwarf suggests that it is a foreground star relative to the objects adopted for the determination of interstellar reddening, and hence it could have lower reddening.

All this casts considerable doubt on the claim of YT89 that HD 147491 is a δ Scuti star. Therefore, it was decided to re-observe it in order to shed more light on its nature.

Observations and reductions: In March and April, 1995, HD 147491 was observed with the Modular photometer attached to the 50 cm telescope at the South African Astronomical Observatory, a dedicated instrument for high-precision photoelectric photometry. Keeping in mind the short period claimed for the star, the choice of the observing technique must be considered carefully.

In order to detect periods shorter than one hour, high-speed photometric observations can give excellent results (e. g. Handler et al., 1995), but this technique is not very useful in the presence of sky transparency variations (see Breger & Handler 1993). Therefore, it was decided to acquire differential photometry with two close comparison stars: this allows to compensate for transparency variations as well as to examine the data for possible variability of the comparison stars (the comparison star adopted by YT89 was HD 147592, for which the Michigan catalogue gives a spectral type of A0 V). Furthermore, by using close comparison stars the telescope can very quickly be moved from star to star.

For these purposes, HD 147592 (C1) and HD 147649 (C2, A5 III) were selected. Both objects are within less than 20 arcminutes distance from the program star HD 147491 (P). For each star, a 50 second integration in the V filter as well as a 10 second integration for sky background were made. The stars were observed in the order: C1–P–C2–C1–P–C2–...

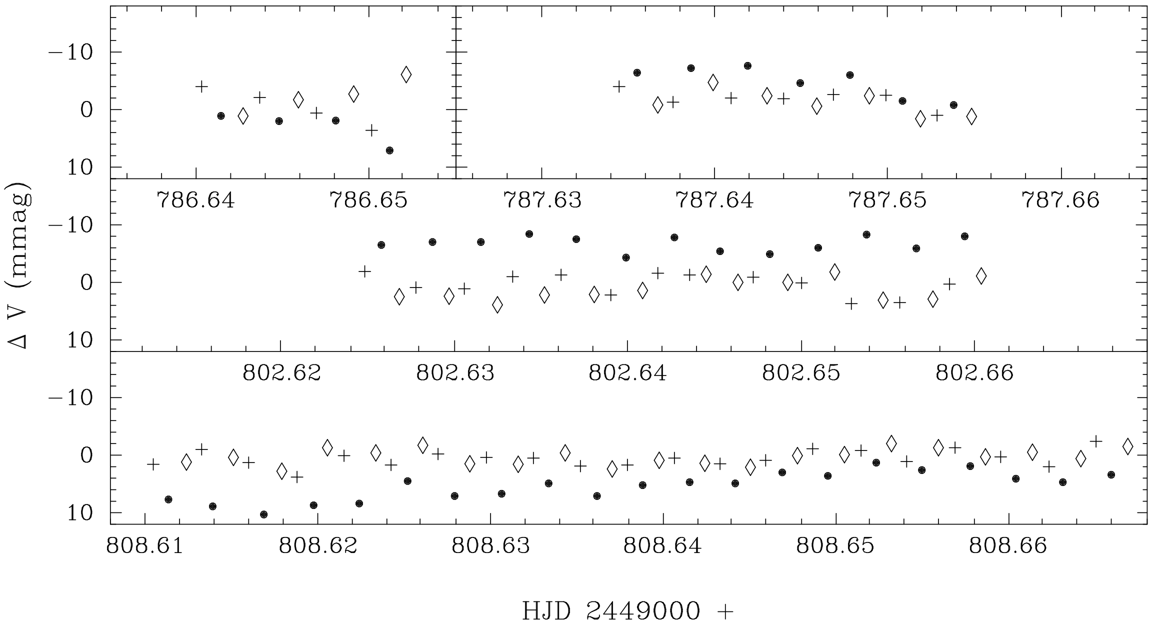

Figure 1: Differential time-series photometry of HD 147491 (filled circles), HD 147592 (crosses) and HD 147649 (diamonds)

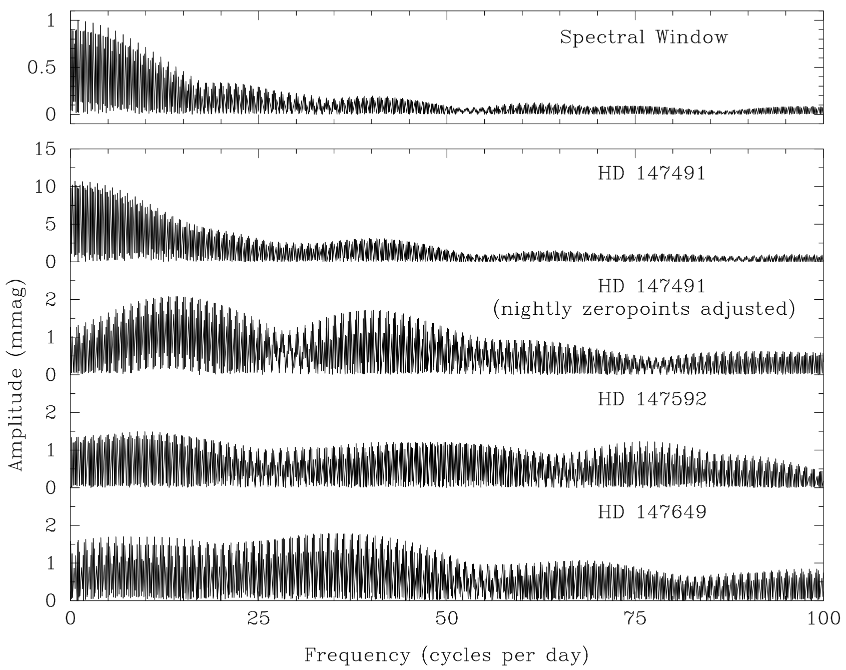

Figure 2: Amplitude spectra and spectral window of the data of Figure 1. The panels (from top to bottom) show the spectral window of the data, the amplitude spectrum of the program star data, as well as the amplitude spectra of the comparison star data.

Table 1. $UBVR_cI_c$ photometry of the program and comparison stars

Star	V	$B-V$	$U-B$	$V-R_c$	$V-I_c$
HD 147491	9.587	0.613	0.066	0.365	0.740
HD 147592	8.936	0.298	0.200	0.177	0.388
HD 147649	9.648	0.442	0.271	0.277	0.575

Thus, consecutive measurements of HD 147491 could be obtained about every 245 seconds (corresponding to a Nyquist frequency of 176 cycles per day), which is more than sufficient to detect a conjectured periodicity of 25 minutes. During the time-series photometric observations, the air mass never exceeded 1.07. As a further check of data quality, the E-region standards E690 (A2 V) and E629 (G5 V) were measured at the beginning of each run.

All data were corrected for dead-time losses as well as for sky background and mean extinction. Mean zeropoints (of all nights of observation considered together) of P, C1 and C2 were calculated relative to each other and subtracted from the time-series data. The zero-point subtracted data are plotted in Figure 1, where the variability of the program star is evident. It is also clear, however, that the light modulation occurs on a time scale much longer than 25 minutes. Moreover, Figure 1 shows that only very small transparency variations occurred during our measurements.

It should also be mentioned that the standard deviation of the zeropoints between the comparison stars and the E-region stars were comparable to the rms error of a single measurement of the standard stars. The rms errors of a single measurement of the data displayed in Figure 1 are 1.9 mmag for HD 147592, 2.1 mmag for HD 147649, but 6.0 mmag for HD 147491.

$UBVR_cI_c$ photometry was also acquired for these three stars (Table 1); the transformation into the standard system was secured by measuring several E-region standards. We conservatively estimate the rms errors with 0.020 mag in V, 0.010 mag in $B-V$ and $V-R_c$ as well as 0.015 mag in $U-B$ and $V-I_c$. Note that HD 147491 is variable and therefore the results for this star must be treated with caution.

Analysis and discussion: Since the photometric conditions were very stable during our observations, amplitude spectra can be calculated for each star separately, i.e. we do not consider differential data between the stars. These amplitude spectra are shown in Figure 2. Inspection of Figure 2 again suggests that the time scale of the variability of HD 147491 is longer than 25 minutes; it is at least several hours. However, the spectral window is far too complicated and the data are too sparse to make a more definite statement about the real time scale. In order to examine the possibility that the low-frequency variability could "mask" shorter-period variations, we have also calculated an amplitude spectrum for the HD 147491 data after removing the nightly zeropoint variations; once again there is no hint for a 25-minute periodicity.

What kind of variable can HD 147491 be? Considering the $UBVR_cI_c$ photometry in Table 1 as well as uvbyβ data for the star (Handler 1995), we find that it is unreddened. Hence, it is far too cool to be a δ Scuti star.

Applying the calibration of Crawford (1975), we find an absolute magnitude of $M_V = 4.0$. Thus, our results are perfectly consistent with Houk's (1982) spectral classification of HD 147491 (G0 V) as well as with colors measured by Lee (1977), and Clementini (1979).

Due to the small amount of data we obtained, we cannot pinpoint the cause of the light variability of HD 147491. However, we wish to emphasize that the star might be interesting for researchers studying variability of solar-type objects caused by starspots. If HD 147491 would be a related object, then its amplitude is rather high (note that Eggen (1983) found the star to be fainter than HD 147649) and it would be one of the most active solar-type stars. The photometric behavior of HD 147491 clearly requires a more thorough study. A spectrogram of the star with sufficient resolution to examine it for chromospheric emission or for a possible secondary spectrum would also be useful.

Summary and conclusions: We showed that HD 147491 is an early G-type main sequence star which exhibits light modulation on a time scale of at least several hours. Contrary to a previous claim, we demonstrated that it cannot be a δ Scuti star; it is far too cool.

It is suggested that authors reporting low-amplitude variability of certain objects critically check if the quality of their data is sufficient to assure that their claims are not a result of spurious effects, e. g. caused by the usage of a non-optimal observing technique. Quantitative statements about data quality (such as the rms scatter of comparison star measurements) are imperative.

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