δ Scuti Behavior Detected in HD 349422

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Received February 9, 2011; revised June 13, 2011; accepted June 16, 2011

Abstract Evidence for variability in the star HD 349422 is presented. Low-amplitude variations seen in the Bessel B and Bessel V filters are presented for three nights on two different telescopes. A period of 0.0400 day in the B and 0.0413 day in the V filters, respectively, were determined. These periods agree within the determined uncertainty. The spectral type from the literature is given as F0. It is therefore proposed that due to the period and spectral type that HD349422 is a member of the δ Scuti family.

1. Introduction

HD 349422 has magnitudes of 9.19 in the B and 8.90 in the V bands, with coordinates R.A. 18^h 50^m 50.2671^s, Dec. +20° 52' 16.479" (2000). The HD catalogue spectral type is given as F0 (Nesterov *et al.* 1995). The star was first noticed to be variable when observing the eclipsing binary AD Her as part of a survey of eclipsing binaries. HD 349422 was used as the comparison star and the variability was noticed. The light curves generated from subsequent observations suggest amplitude of about 0.012 magnitude in both the B and V filters. δ Scuti stars are generally low-amplitude, short-period variables with spectral types ranging from A to F. Periods range between 0.02 and about 0.3 day. Amplitudes can either be large (> 0.30 magnitude) or small, usually on the order of tens of a millimag. The first class represents a minority of δ Scuti variables, referred to as High Amplitude δ Scuti stars, or HADS. The second class represents the majority of δ Scuti stars. They are found at the intersection of the main sequence and the instability strip. Breger (2000) estimates that between 1/3 and 1/2 of all stars at this intersection show variability between 0.003 and 0.010 magnitude. The detection of new δ Scuti stars should increase rapidly over the next years as high-precision photometric campaigns increase, especially with projects such as Kepler and CoRot. Percy (2007) and Templeton (2004) provide general overviews of δ Scuti stars. For a detailed description on the current status of δ Scuti stars see Breger (2000).

2. Observations

Observations of HD 349422 were done with two different telescopes.

All data were reduced using IRAF (Tody 1993) for bias, dark, and flat-field correction, while AIP4WIN (Berry and Burnell 2006) was used to perform the differential photometry. As AIP4WIN processes each image, a photometric error is assigned to each measurement. The errors for the variable and comparison star are obtained by a calculation involving camera gain, camera read noise, dark current, and the sky background. These errors were then added in quadrature to obtain the errors for each delta magnitude.

Table 1 summarizes the dates, amplitudes of variability in each filter, and the average errors for the differential measurements. The quoted amplitudes are measured with the half-amplitude method.

The first data set was collected with a 0.6-meter Cassegrain telescope and an Apogee Alta CCD camera located at Cerro Tololo, Chile, operated by the SARA consortium (http://astro.fit.edu/sara/sara.html). The focal ratio of the telescope is *f*/13.5, giving a plate scale of 0.6 arc sec per pixel. The first set of observations was taken in the B with exposures ranging between ten and twenty seconds on the night of June 28, 2010 (UT). The observations on this night spanned a total of four hours with mean photometric error of about 0.0015 magnitude. The comparison star used for these observations was HD 349426 (R.A. 18^h 50^m 13.317^s Dec +20° 45' 01.634" (2000)) with a field star (R.A. 18^h 50^m 18.53^s Dec +20° 45' 30" (2000)) serving as the check star. The standard deviations for the variable-comp delta mag data and the check-comp delta mag data were 0.008 and 0.004 magnitude, respectively.

The second set of observations was collected over two nights at the Ball State University observatory using a 0.4-meter Schmidt-Cassegrain telescope with an SBIG ST-10 CCD camera on August 26 and 27, 2010 (UT) (the observations spanned two hours on the 26th and three and 3½ hours on the 27th). The *f*/6 focal ratio gave a plate scale of 0.58 arc sec per pixel. These observations were done in the V with exposures of fifty seconds. Due to a larger field of view with the second set, a brighter comparison star was available. This allowed better signal-to-noise ratios per exposure. The mean photometric errors were 0.0014 and 0.0016, respectively. Choosing a second comparison star this way ensures the variability was due to the suspected variable and not the original comparison star. It is becoming increasingly important for the photometry technique to ensure comparison stars are not low-amplitude variables. This is becoming more difficult with better CCD technology. This is the reason many new δ Scuti and γ Doradus stars are being found (this case is a good example). The comparison star for this set of observations was HD 349418 (R.A. 18^h 51^m 42.86^s Dec +20° 52' 23.0" (2000)), while HD 349420 served as the check star (R.A. 18^h 51^m 04.92^s Dec +20° 48' 14.8" (2000)).

3. Light curves

Figures 1 and 2 show the differential light curves of HD 349422 for the

night of June 28, 2010 (UT), in the B filter and the night of August 26, 2010 (UT), in the V filter. The light curves show a variation of about 0.012 magnitude in both the B and the V filters. Periods were determined using the PERANSO software package (Vanmunster 2007) with the Lomb-Scargle method (Lomb 1976; Scargle 1982). Figures 3 and 4 show the power-spectra produced. The data were searched for periods between 0.01 and 0.3 day in both filters, giving 0.0400 + 0.0022 day in B and 0.0413 + 0.0007 day in V (with the twenty-four hour aliases in V), thus giving good agreement within the determined uncertainties. Figure 3 indicates a second peak in the B filter at 0.0300 day. This is a possible signature of multi-periodicity, yet it is unconfirmed at this time. This peak is also evident after pre-whitening, seen in Figure 5, which is a power-spectrum of the B data after removing the 0.0400 day period. Figure 4 shows a secondary peak in the V filter at 0.0286 day. Figure 6 shows the power-spectrum of the V data with the 0.0413 day peak removed. The 0.0286 day peak is not evident after removing the dominant period. However, further observations are encouraged to completely determine whether this object is multi-modal. Figure 7 shows the B-filter data phased onto the dominant period.

4. Conclusions

Due to the short periodicity determined for HD 349422 and given its spectral type, it is proposed that this object be included as a member of the δ Scuti family. The F0 spectral classification falls right into the δ Scuti range of spectral types. This object was observed with two different comparison stars due to observations being done using telescopes with different light-gathering powers and different fields of view. The determined periods for both filter sets gave agreement to within the given uncertainties. However, only a small number of complete cycles and short observational time spans were obtained. The dominant period, while in agreement between the B and V filters, is still rather uncertain. Further observations are encouraged to precisely determine the dominant period and whether other periods are photometrically detectable.

5. Acknowledgements

This work was funded by the Indiana Space Grant Consortium and telescope time was provided by the SARA consortium. We would also like to thank an anonymous referee for making several helpful comments.

References

Berry, R., and Burnell, J. 2006, "Astronomical Image Processing Software," provided with *The Handbook of Astronomical Image Processing*, Willmann-Bell, Richmond, VA.

Breger, M. 2000, in *Delta Scuti and Related Stars, Reference Handbook and Proceedings of the 6th Vienna Workshop in Astrophysics, held in Vienna, Austria, 4–7 August, 1999*, eds. M. Breger and M. Montgomery, ASP Conf. Ser. 210, Astron. Soc. Pacific, San Francisco, 3.

Lomb, N. R. 1976, *Astrophys. Space Sci.*, **39**, 447.

Nesterov, V. V., Kuzmin, A. V., Ashimbaeva, N. T., Volchkov, A. A., Roeser, S., and Bastian, U. 1995, *Astron. Astrophys., Suppl. Ser.*, **110**, 367.

Percy, J. R. 2007, *Understanding Variable Stars*, Cambridge Univ. Press, New York.

Scargle, J. D. 1982, *Astrophys. J.*, **263**, 835.

Templeton, M. 2004, www.aavso.org/vsots_delsct.

Tody, D. 1993, in *Astronomical Data Analysis Software and Systems II*, eds. R. J. Hanisch, R. J. V. Brissenden, and J. Barnes, ASP Conf. Ser., 52, Astron. Soc. Pacific, San Francisco,173.

Vanmunster, T., 2007, PERANSO period analysis software, http://www.peranso.com.

Table 1. Summary of observations for HD 349422.

Filter	*UT Date*	*HJD Range*	*Amplitude (mag)*	*Mean Error (mag)*
B	2010 June 28	2455375.6795 – 0.8455	0.012	0.0015
V	2010 August 26	2455434.71077 – 0.7929	0.012	0.0014
V	2010 August 27	2455435.5615 – 0.7020	0.012	0.0016

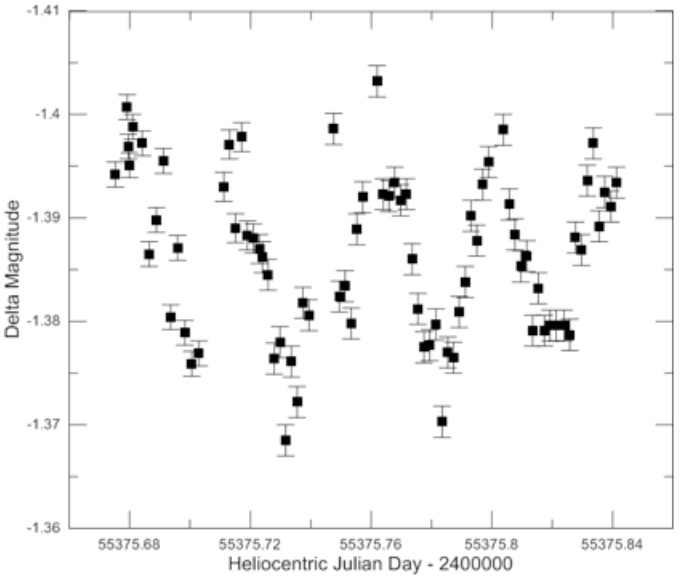

Figure 1. ΔB magnitudes of HD 349422 on the night of 2010 June 28 (UT).

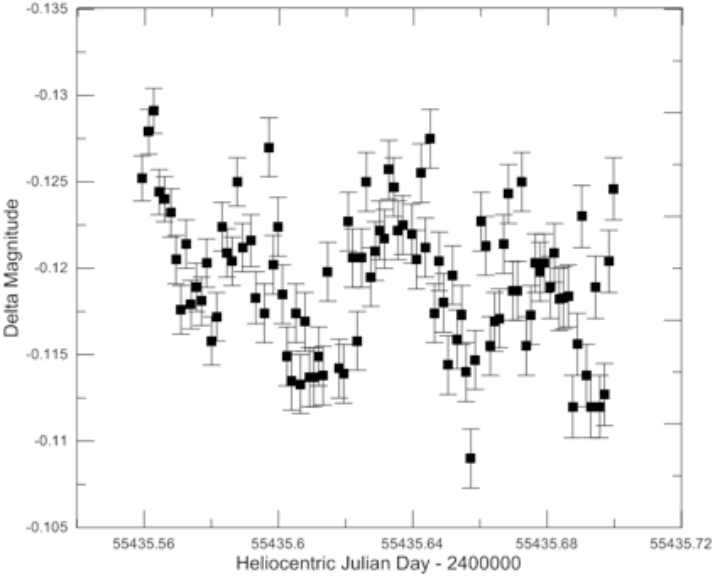

Figure 2. ΔV magnitudes of HD 349422 on the night of 2010 August 27 (UT).

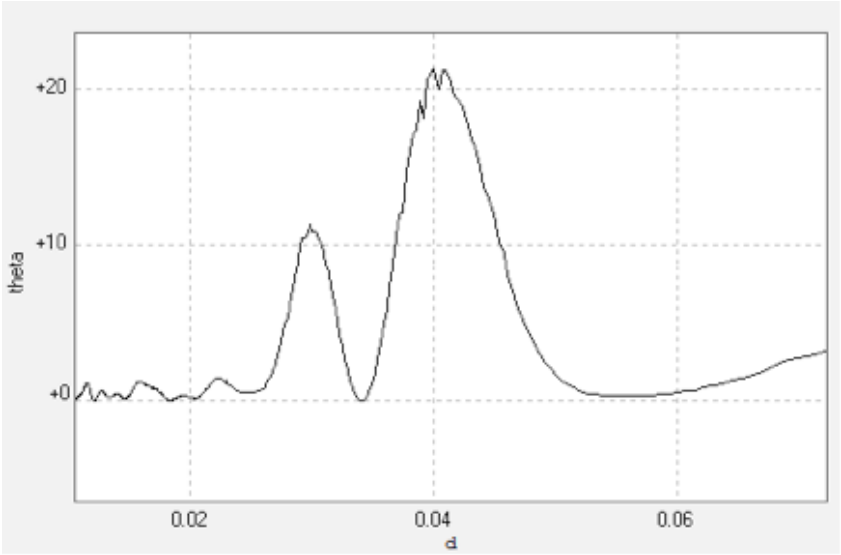

Figure 3. The power spectrum analysis of the differential B magnitudes of HD 349322 for 2010 June 28 (UT).

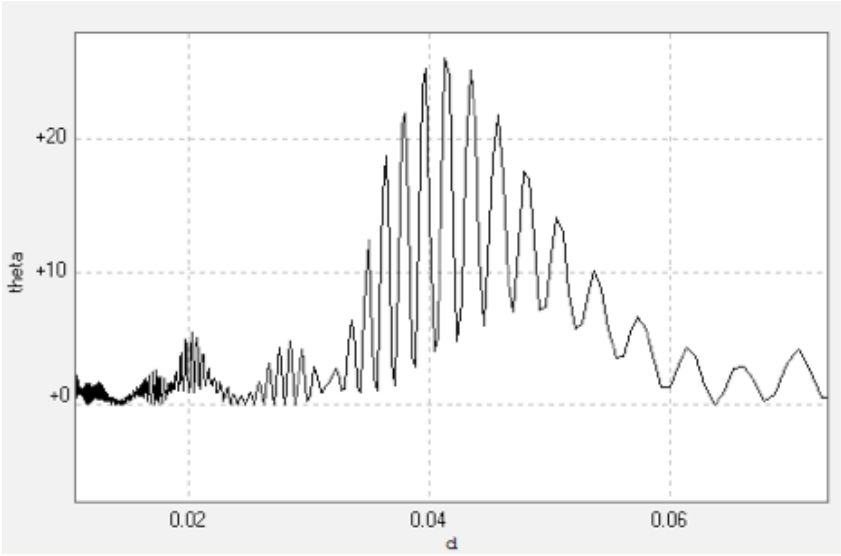

Figure 4. The power spectrum analysis of the differential V magnitudes of HD 349422 for the nights of 2010 August 26, 27 (UT).

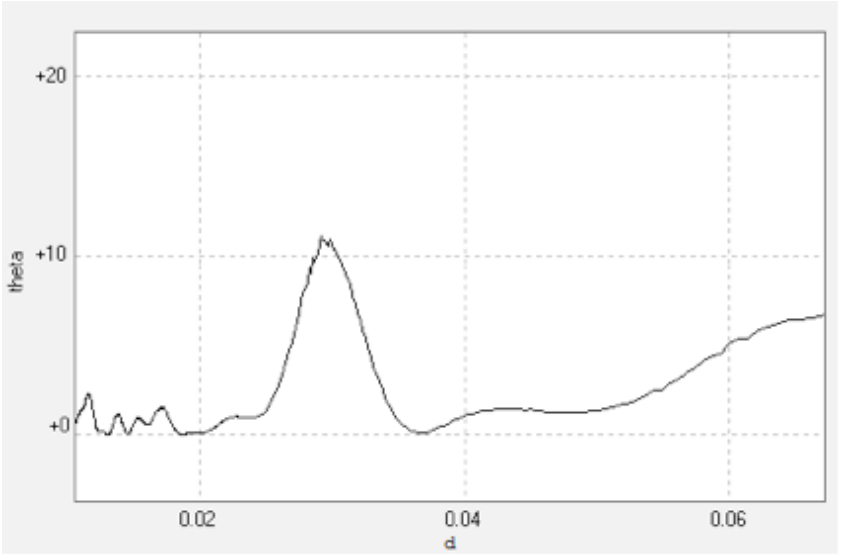

Figure 5. Results of period-searching the B data after removing the 0.0400 day period.

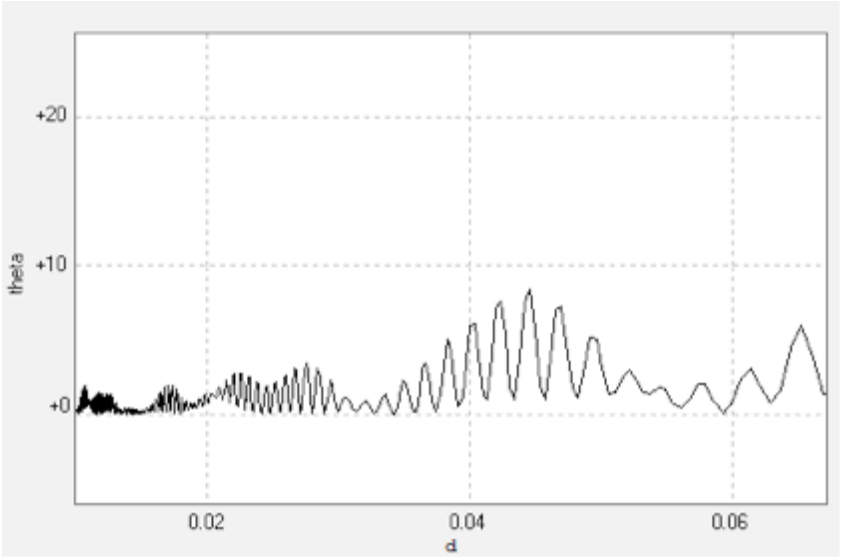

Figure 6. Results of period-searching the V data after removing the 0.0413 day period.

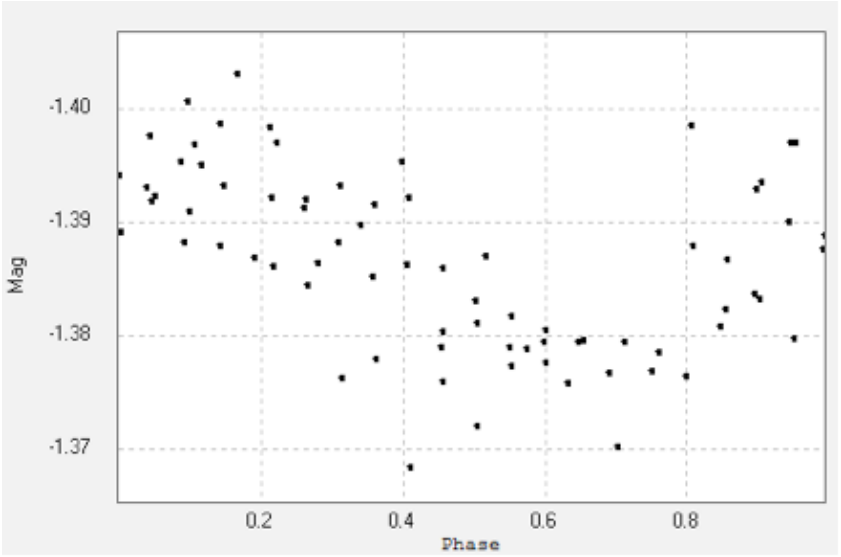

Figure 7. The differential B magnitudes of HD 349422 phased on the 0.0400 day period.