Discovery of a Second Radial Mode in the High Amplitude Delta Scuti Star NSVS 10590484 (GSC 01489-00914)

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Abstract: During an investigation of the pulsational behaviour of Delta Scuti stars, we have identified a second radial mode in the High Amplitude Delta Scuti star NSVS 10590484 (GSC 01489-00914) which was discovered by Alexandr Ditkovsky of the VS-COMPAS team. Therefore, NSVS 10590484 is an HADS(B) star with the following elements:
P0= 0.0541911 d; P1= 0.0419105 d (P1/P0= 0.7734).

I. Introduction

Delta Scuti (DSCT) stars are pulsating variables with short periods (about 0.01 to 0.2 days) and light amplitudes ranging from a few thousandths to a few tenths of a magnitude in the visual band of the spectrum. They are located in the lower part of the Cepheid instability strip and are thus situated on or just off the densely populated main sequence. Consequently, they are among the most numerous pulsating variables among the brighter stars (cf. e.g. Percy, 2007).

DSCT stars are of intermediate mass and mostly occur between spectral types A5 to F2, usually falling into luminosity classes IV or V (e.g. Moya et al., 2010). While their typical range is on the order of a few hundredths of a magnitude, there are also DSCT stars with amplitudes of up to 0.9 mag (V). Generally, objects with an amplitude greater than 0.2 mag (V) are called High Amplitude Delta Scuti (HADS) stars. They are characterized by non-sinusoidal light curves, small rotational velocities and are rare objects; according to Percy (2007), less than one per cent of DSCT stars have amplitudes exceeding 0.3 mag (V). Another subgroup is constituted by the SX Phoenicis stars – metal-poor DSCT stars with large amplitudes that are very old objects in an advanced state of evolution and belong to Population II.

Many DSCT stars are multi-periodic and exhibit complex pulsational patterns. Because of this – and the small amplitudes of the pulsation modes – great care has to be taken in period analyses. Moreover, DSCT stars are notorious for exhibiting non-radial pulsations. In the DSCT star FG Virginis, for example, the astonishing number of 79 frequencies were detected by Breger et al. (2005), who analyzed nearly continuous photometry obtained from a multi-longitude campaign. The large-amplitude HADS stars, on the other hand, pulsate mainly in radial modes, although there is growing evidence that non-radial modes with small amplitudes may also be excited in these objects (e.g. Pigulski et al., 2006).

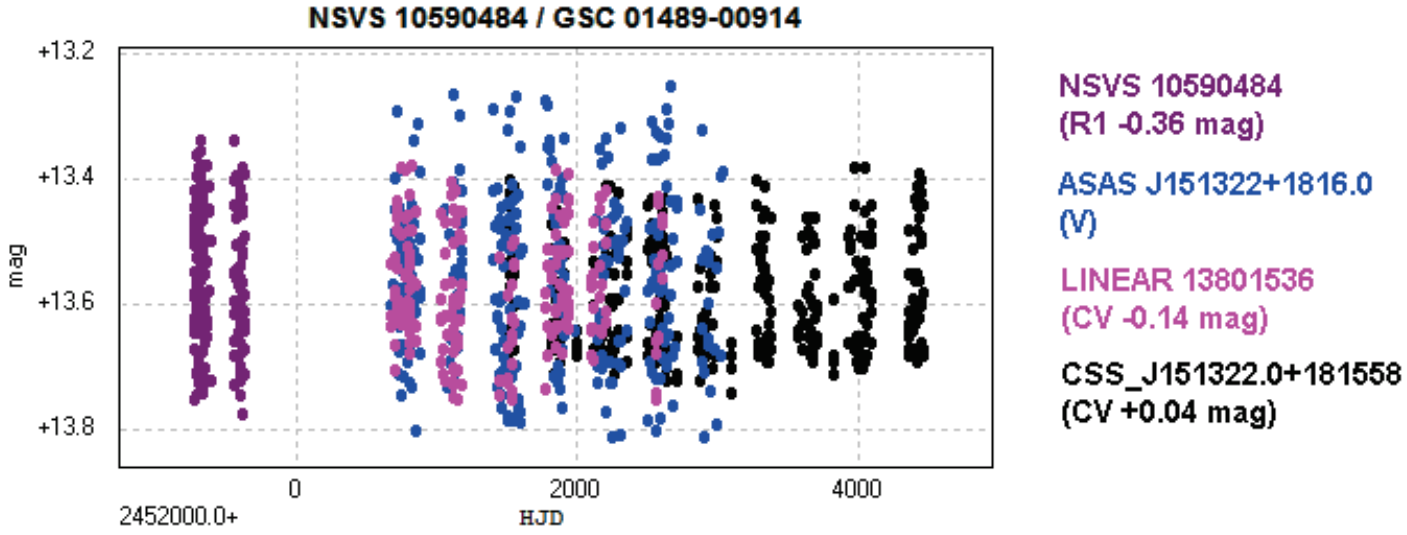

Figure 1. – Light curve of NSVS 10590484 (GSC 01489-00914), based on data from various sky surveys as indicated in the legend on the right side. In order to facilitate period analyses, NSVS, LINEAR and CSS data have been shifted by the indicated amounts to match ASAS-3 V data.

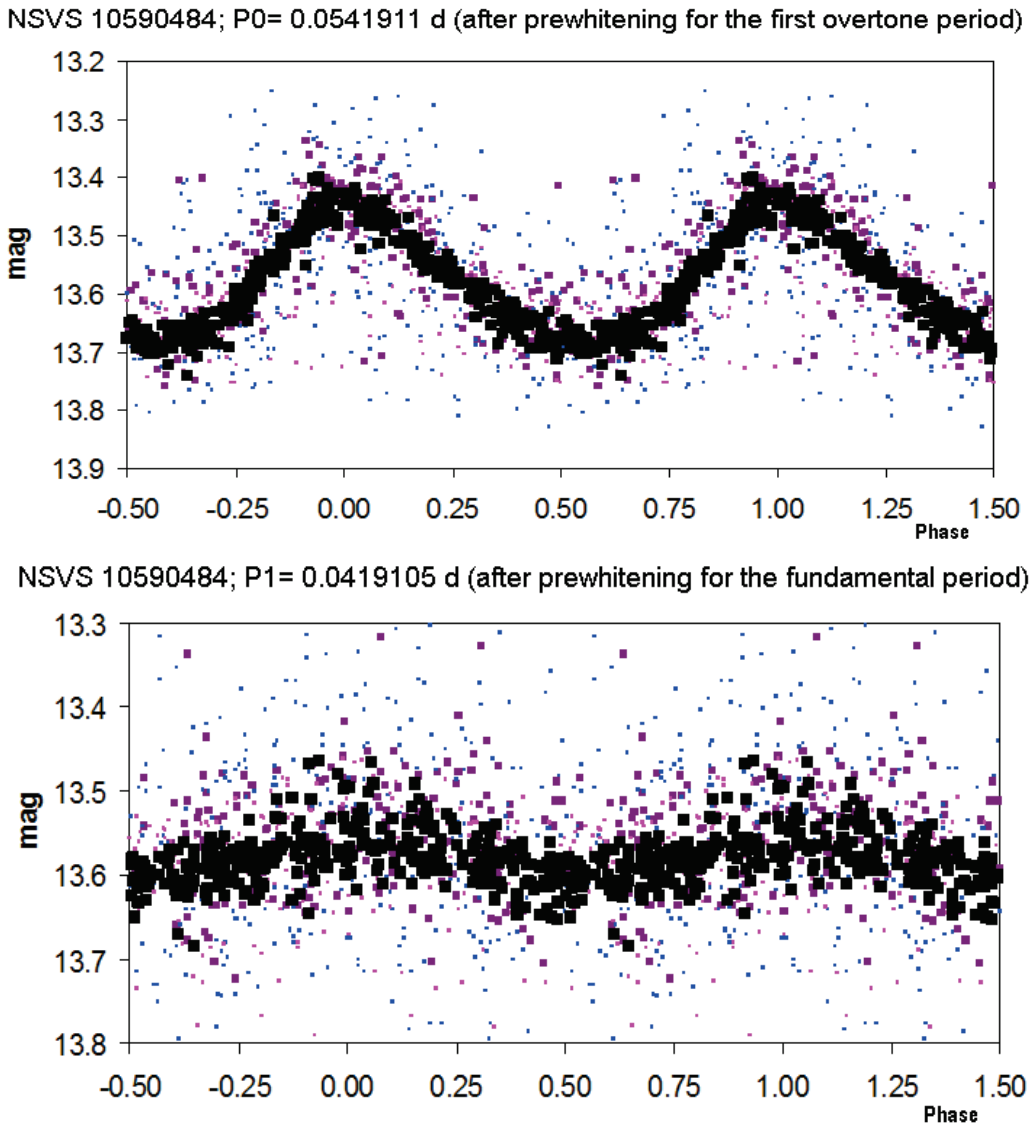

Figure 2. – *Phase plots of NSVS 10590484 (GSC 01489-00914), illustrating the fundamental and first overtone modes. Data and colours are the same as in Figure 1.*

II. NSVS 10590484 (GSC 01489-00914)

NSVS 10590484 (GSC 01489-00914), located in the constellation Serpens (RA, Dec (J2000)= 15:13:22.007 +18:15:58.31; UCAC4), was identified as an HADS variable by Alexandr Ditkovsky from the VS-COMPAS team in 2012 (http://www.aavso.org/vsx/index.php?view=detail.top&oid=283102). The star was submitted to the AAVSO International Variable Star Index (VSX; Watson et al., 2006) with the elements

HJD(Max)= 2455981.032 + 0.0541911 * E. (1)

During an investigation of the pulsational behaviour of HADS stars, we have analyzed available data from the NSVS (Woźniak et al., 2004), ASAS-3 (Pojmański, 2002), LINEAR (Stokes et al., 2000) and CSS (Drake et al., 2009) databases for NSVS 10590484 using Period04 (Lenz and Breger, 2005). In addition to confirming the period determined by Ditkovsky, we were able to identify an additional peak in the power spectrum of NSVS 10590484 at a frequency of 23.860351 cycles per day which corresponds to a period of P= 0.0419105 days (cf. Figure 3). While this signal is of low amplitude, the derived signal-to-noise ratio of 6.3 – calculated using Period04 – indicates a significant detection. Furthermore, the period ratio of P1 / P0= 0.7734 is indicative of radial pulsation and unmasks the additional period as the first overtone mode. We are thus confident of the reality of the detected additional frequency.

The light curve of NSVS 10590484 is given in Figure 1. Phase plots illustrating the fundamental and first overtone periods are shown in Figure 2. A Petersen diagram – a diagram plotting the period ratios versus the fundamental mode periods – is often used to study double-mode radial pulsating stars (cf. e.g. Poretti et al., 2005). We present a Petersen diagram of a sample of well known Galactic double-mode HADS stars and NSVS 10590484 in Figure 4. The location of NSVS 10590484 in this diagram is consistent with that of other Galactic HADS(B) stars.

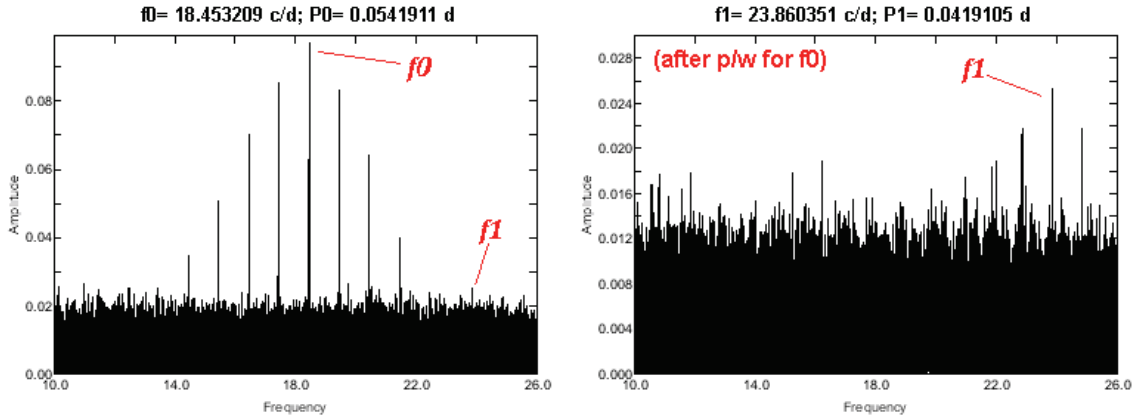

Figure 3. – *Power spectra of NSVS 10590484 (GSC 01489-00914) for the combined dataset as specified in Figure 1 (left side) and after substraction of the fundmental mode frequency (right side).*

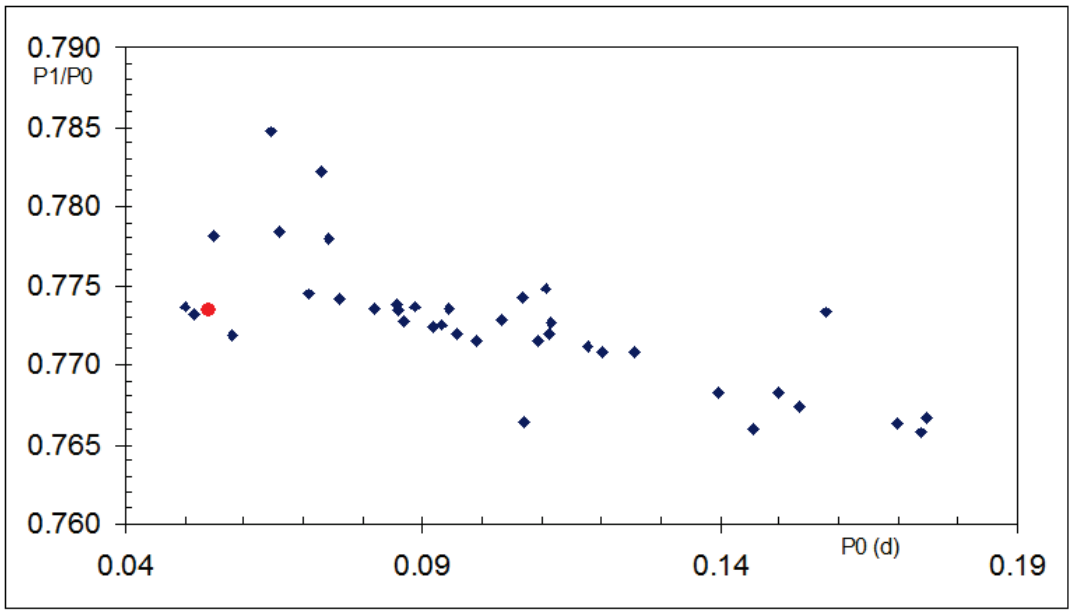

Figure 4. *– Petersen diagram for a sample of well-known Galactic double-mode HADS stars with period ratios in the range between 0.76 and 0.79 (blue diamonds; N= 38) and NSVS 10590484 (red circle). Data were taken from the VSX.*

We encourage further photometric and spectroscopic studies with high time resolution.

III. References

- Breger, M. et al., 2005, Astronomy and Astrophysics, 435, 955
- Drake, A. J. et al., 2009, Astrophysical Journal, 696, 870
- Lenz, P.; Breger, M., 2005, Comm. in Asteroseismology, 146, 53
- Moya, A. et al., 2010, ArXiv e-prints, arXiv:1004.0100
- Percy, J. R., 2007, "Understanding variable stars", Cambridge University Press
- Pigulski, A. et al., 2006, Memorie della Società Astronomica Italiana, 77, 223
- Pojmański, G., 2002, Acta Astronomica, 52, 397
- Poretti, E. et al., 2005, Astronomy and Astrophysics, 440, 1097
- Project VS-COMPAS, 2011-2014, http://vs-compas.belastro.net/
- Stokes, G. H., 2000, Icarus, 148, 21
- Watson, C.; Henden, A. A.; Price, A., 2006, SASS, 25, 47
- Woźniak, P. R. et al., 2004, Astronomical Journal, 127, 2436

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