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Photometric study of the Delta Scuti variable 2MASS J13122513+5443409 in UMa

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Abstract. We keep investigating the new variable of Delta Scuti type 2MASS J13122513+5443409 discovered by our group previously. We have analyzed the data obtained not only from the relatively small telescopes of Slovakia and Ukraine, but also from the TESS mission. We calculated the pulsation period and amplitude using the Lomb-Scargle periodogram. We found that the dominant period is about 0.079 days. However, the oscillations displayed beating, indicating the presence of several pulsation frequencies.

Key words: δ Scuti – pulsating stars – variable stars

1. Introduction

Our team has discovered a variable star (Table 1) in the white dwarf SDSS J131156.70 + 544455.8 field (Figure 1) during photometric observations.

Subsequent observations yielded a variation period P of 0.079075 ± 0.000003 days. The brightness amplitude varied, reaching a peak of 0.1 magnitudes and a minimum of 0.02 magnitudes. The period and amplitude of the variations suggest the star could belong to the Delta Scuti pulsating variables. This type usually includes giants or main sequence stars of spectral classes from A0 to F5 with a magnitude variation amplitude ranging from $0.^{m}003$ to $0.^{m}9$ and a period of several hours(Breger, 2000). The shape of the light curve, period, and amplitude typically undergo significant changes. We keep studying the star with additional photometric data obtained from Stará Lesná Observatory (Slovakia), Lisnyky (Ukraine), MAO (Ukraine), and the TESS mission. The basic properties of the star, taken from the Simbad database (Wenger et al., 2000), are shown in Table 1.

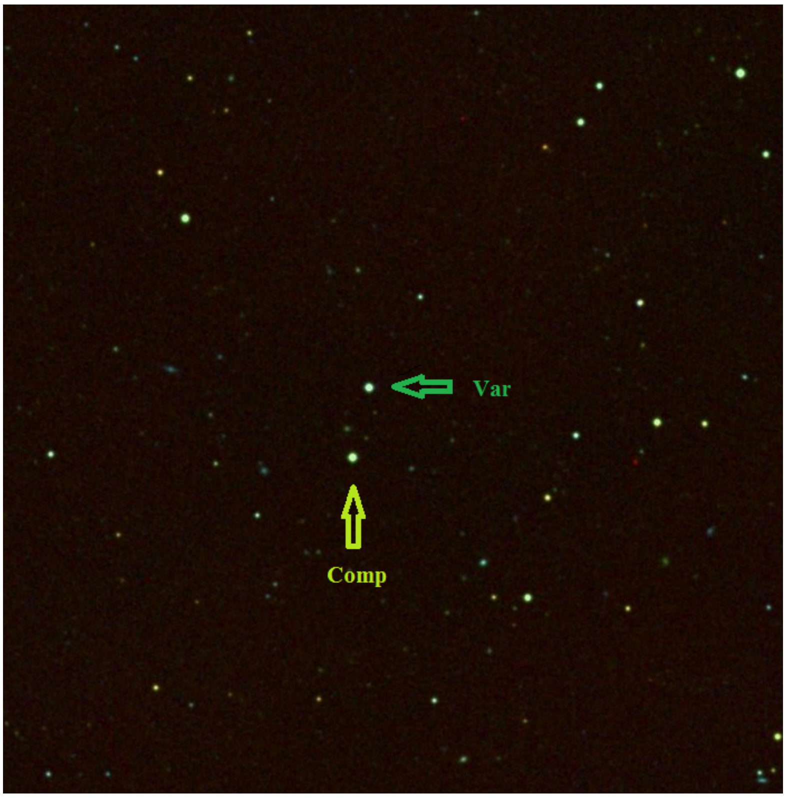

Figure 1. Color frame of variable star field created from the SDSS-frames obtained in different filters. The arrows indicate a new variable star and a comparison star

2. Observations

Ground-based photometry was made using telescopes in Slovakia (Stara Lesna) and Ukraine (MAO, Lisnyky station, Mayaky station). Their main characteristics are given in Table 2. There were 22 observation nights in total. Mainly we have observed in integral light, but Johnson filters BVRI were also applied later. Exposure time ranged from 30 to 120 seconds depending on the filter, telescope, and weather conditions.

The Transiting Exoplanet Survey Satellite (TESS), a NASA space telescope designed for discovering exoplanets through the transit method, offers high-precision photometry (Ricker, 2015). In 2019, TESS performed observations in the 15th sector over 26 days with an exposure time of 30 minutes. The data was downloaded via package Lightkurve (Lightkurve Collaboration et al., 2018). It was automatically processed and detrended with TASOC pipeline (Handberg et al., 2021; Lund et al., 2021) and contains 1197 data points.

Table 1. Basic properties of the star 2MASS J13122513 + 5443409

ICRS coord. (ep=J2000)	13 12 25.138 +54 43 40.944
Parallaxes (mas):	0.2960 [0.0239]
Spectral type	A7.8 D
Magnitudes (mag)	G 14.3485 [0.0008]
	J 13.730 [0.025]
	H 13.739 [0.037]
	K 13.693 [0.053]

Table 2. The main characteristics of available telescopes

Observatory	Telescope	Number of nights	Aperture [cm]	FOV [arcmin]
Lisnyky (Ukraine)	Schmidt-Cassegrain Celestron-14"	6	35	7×7
Stará Lesná (Slovakia)	Cassegrain	13	60	14×14
MAO (Ukraine)	Schmidt-Cassegrain Celestron-14"	1	35	18×14
Mayaky (Ukraine)	Ritchey–Chrétien OMT-800	2	80	59×59
TESS	NA	26	10.5	1440×1440

3. Results

Because of various exposure times and precision, we conducted separate analyses of the photometric data obtained from TESS and ground-based telescopes. In the primary instances, we employed the Lomb-Scargle periodogram technique to identify periodicities within our dataset (Scargle, 1982).

Our periodogram derived from the TESS data is displayed in Figure 2. We clearly can see three prominent periods of 113.85±0.12(I), 120.86±0.13(II), and 122.39±0.12(III) minutes. Almost the same periods were found in the combined data from ground-based telescopes (Figure 3) listed in Tab. 2: 113.86 ± 0.12(I), 121.73 ± 0.12(II) and 122.38 ± 0.12(III) minutes. Full periodograms of both ground-based and TESS data are displayed in Figure 4. For better comparison, the results are listed in Table 3.

It is worth noticing that the combination of two or more close frequencies results in beating which means that the amplitude of the combined signal changes periodically. Such a pattern is demonstrated in Figures 5 and 6.

To check our results, we fitted the TESS lightcurve with the combination of 3 harmonic oscillations (Figure 5). The obtained periods are in good agreement with the ones we got from the periodogram - 113.85(I), 120.86(II), and

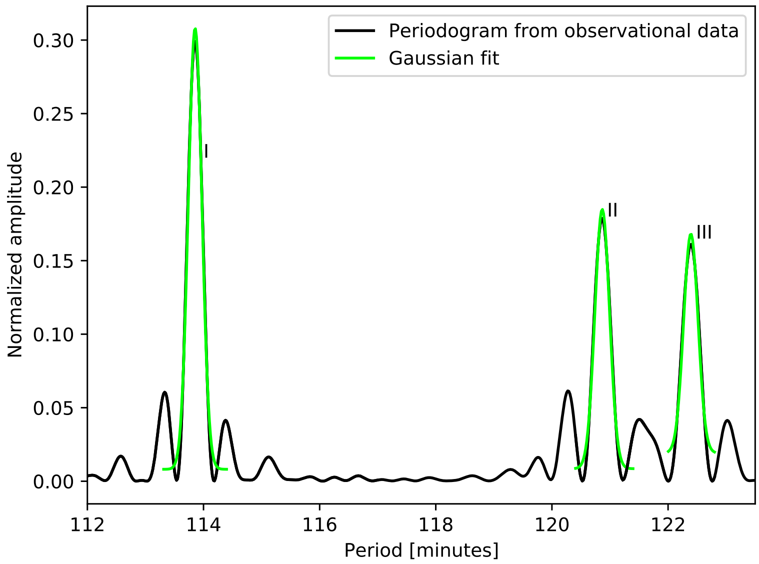

Figure 2. Periodogram based on the TESS data.

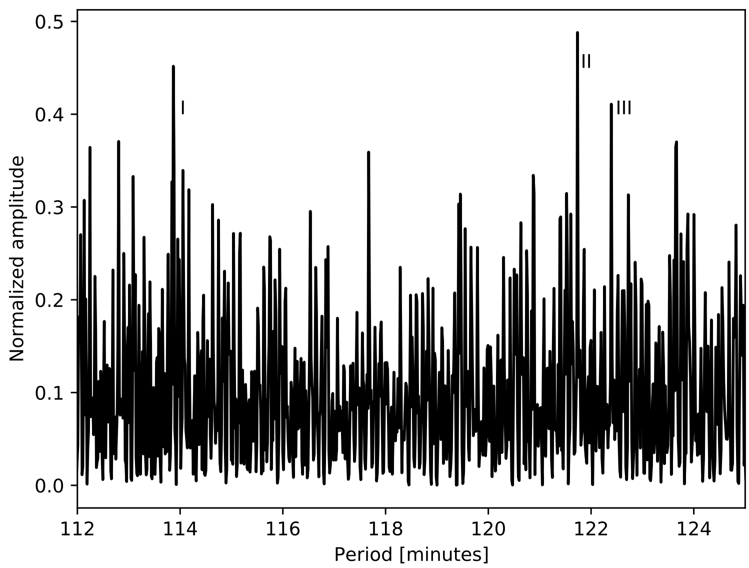

Figure 3. Periodogram from ground-based telescopes.

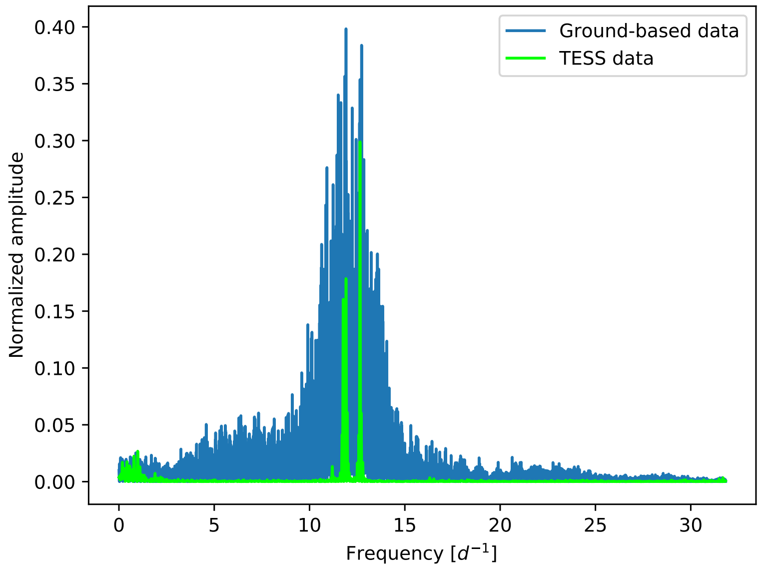

Figure 4. Full periodogram.

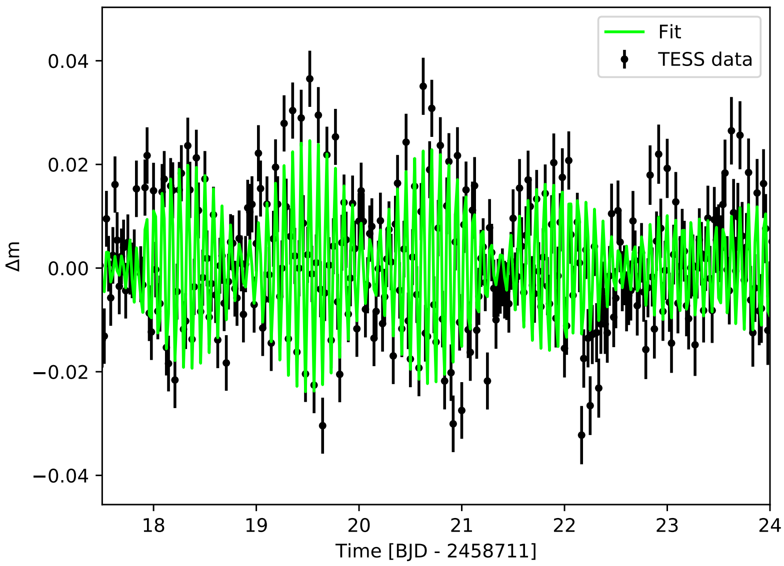

Figure 5. TESS lightcurve(black) with our model(green).

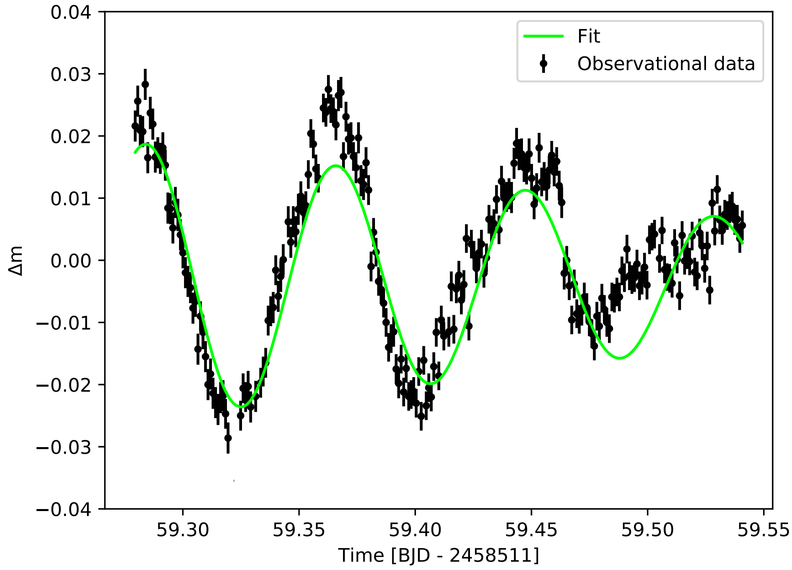

Figure 6. Lightcurve from the ground-based telescope in Stara Lesna (black) with our model (green). The amplitude is decaying at this part of observations

122.39(III) minutes. Amplitudes are estimated as $0^m.009$, $0^m.008$, $0^m.0075$ respectively. The same periods within the error we obtained from data collected with small telescopes (Figure 6), despite the light curve and periodogram being noisy. Both fits are good but not perfect, leaving the root mean square residual of $0^m.007$. At least three significant frequencies are present in the periodic oscillations of our star. This phenomenon is not particularly rare.

Table 3. Values of the periods in minutes based on TESS and ground-based data

Ground-based	113.86 ± 0.12	121.73 ± 0.12	122.38 ± 0.12
TESS	113.85 ± 0.12	120.86 ± 0.13	122.39 ± 0.12

Freyhammer et al. (2001) reports findings of 13 δ Scuti stars with ten of them exhibiting oscillations in two or more frequencies.

4. Conclusions

We found at least three significant frequencies in the oscillation spectra of 2MASS J13122513+5443409. The combination of these frequencies results in beating with a dominant period of about 32 hours. Multiperiodic Delta Scuti stars are of great interest to astroseismology as they offer a unique opportunity to probe the complex physical processes occurring within the stellar interiors. By analyzing their pulsation frequencies and modes, researchers can gain insights into properties such as stellar ages, masses, and evolutionary stages.

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References

Breger, M., δ Scuti stars (Review). 2000, in Astronomical Society of the Pacific Conference Series, Vol. **210**, *Delta Scuti and Related Stars*, ed. M. Breger & M. Montgomery, 3

Freyhammer, L. M., Arentoft, T., & Sterken, C., Multimode delta Scuti stars in the open cluster <ASTROBJ>NGC 7062</ASTROBJ>. 2001, *Astronomy and Astrophysics*, **368**, 580, DOI: 10.1051/0004-6361:20010020

Handberg, R., Lund, M. N., White, T. R., et al., TESS Data for Asteroseismology: Photometry. 2021, *Astronomical Journal*, **162**, 170, DOI: 10.3847/1538-3881/ac09f1

Lightkurve Collaboration, Cardoso, J. V. d. M., Hedges, C., et al. 2018, Lightkurve: Kepler and TESS time series analysis in Python, Astrophysics Source Code Library

Lund, M. N., Handberg, R., Buzasi, D. L., et al., TESS Data for Asteroseismology: Light-curve Systematics Correction. 2021, *Astrophysical Journal, Supplement*, **257**, 53, DOI: 10.3847/1538-4365/ac214a

Ricker, G. R., The Transiting Exoplanet Survey Satellite (TESS): Discovering New Earths and Super-Earths in the Solar Neighborhood. 2015, in AAS/Division for Extreme Solar Systems Abstracts, Vol. **47**, *AAS/Division for Extreme Solar Systems Abstracts*, 503.01

Scargle, J. D., Studies in astronomical time series analysis. II. Statistical aspects of spectral analysis of unevenly spaced data. 1982, *Astrophysical Journal*, **263**, 835, DOI: 10.1086/160554

Wenger, M., Ochsenbein, F., Egret, D., et al., The SIMBAD astronomical database. The CDS reference database for astronomical objects. 2000, *Astronomy and Astrophysics, Supplement*, **143**, 9, DOI: 10.1051/aas:2000332