DFT and Spectral Window Plug-In

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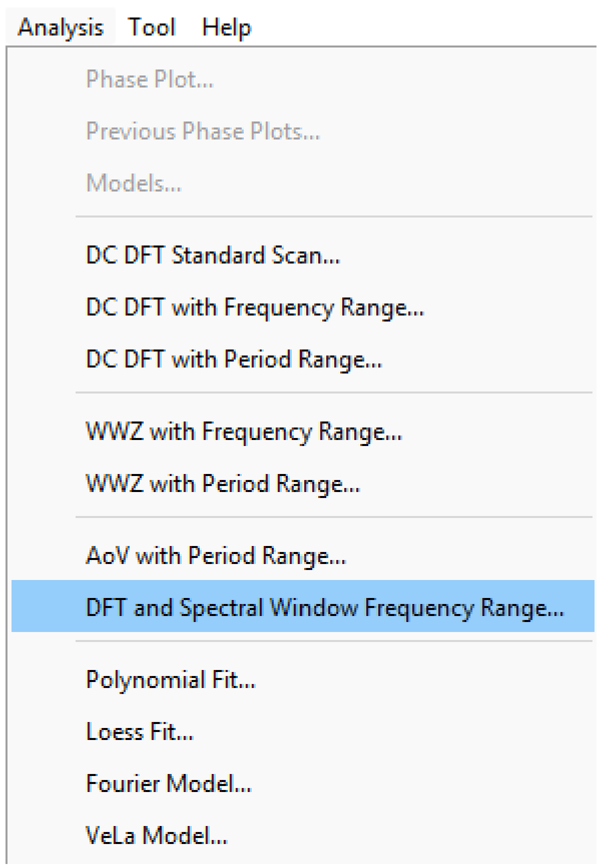
Introduction

This plug-in implements several algorithms:

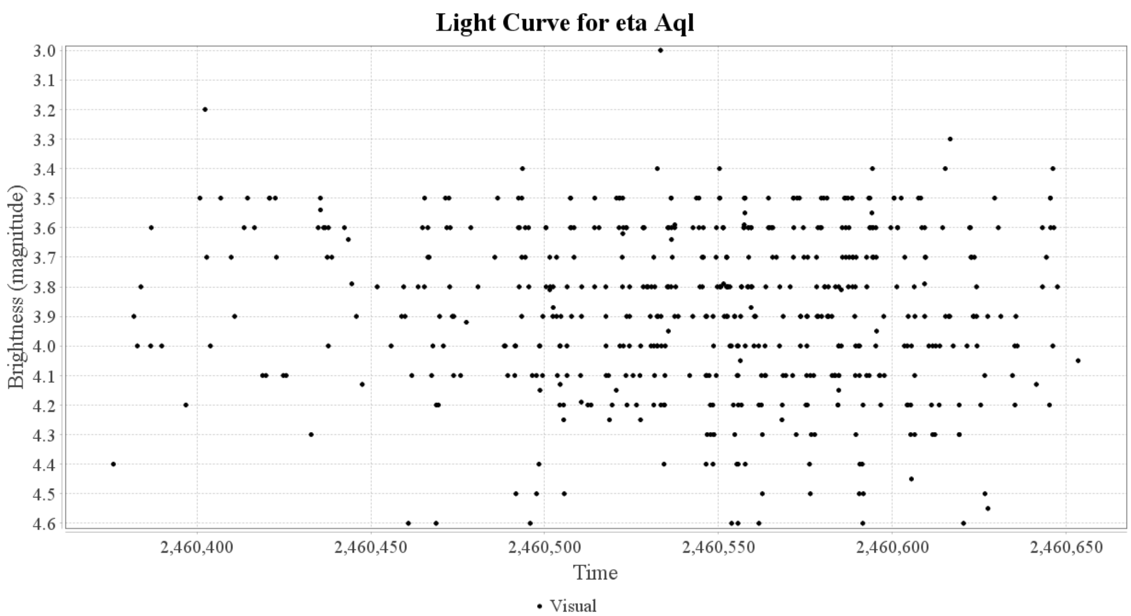
1) The 'classic' Fourier analysis algorithm (Deeming, 1975).
2) The spectral window calculation, i.e., visualization of the aliasing pattern (https://en.wikipedia.org/wiki/Aliasing).
3) Ferraz-Mello's DC DFT (Ferraz-Mello, 1981), the same as in the "DC DFT with Frequency Range" analysis, yet utilising another (not so effective yet more straightforward) algorithm
4) A multi-harmonic approach to the DC DFT, developed by I. L. Andronov (Andronov, 1994, 2020). This algorithm fits the signal (the original light curve) for each trial frequency using a sinusoid plus several harmonics (i.e., additional sinusoids with frequencies that are multiples of the trial frequency). This approach is very helpful for the analysis of eclipsing variables (which have primary and secondary minima) or periodic variables with complex light curves.

The plug-in can be installed via the *Plug-in Manager* item in the Tool menu. After VStar has been restarted, the *Analysis* menu will contain a new item for the plug-in:

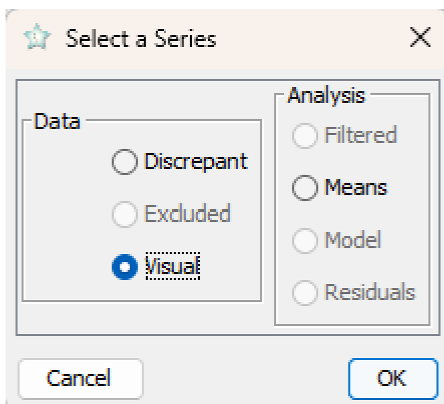


DFT

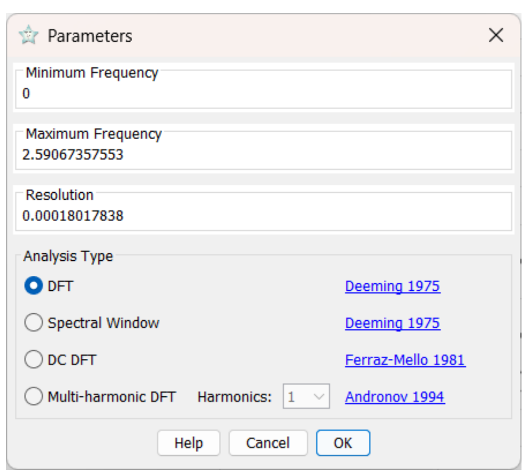
Suppose the following *eta Aql* data set (JD 2460375 to 2460654, Visual) is loaded into VStar:



Invoking the *DFT and Spectral Window Frequency Range* item from the *Analysis* menu opens a series selection dialog:

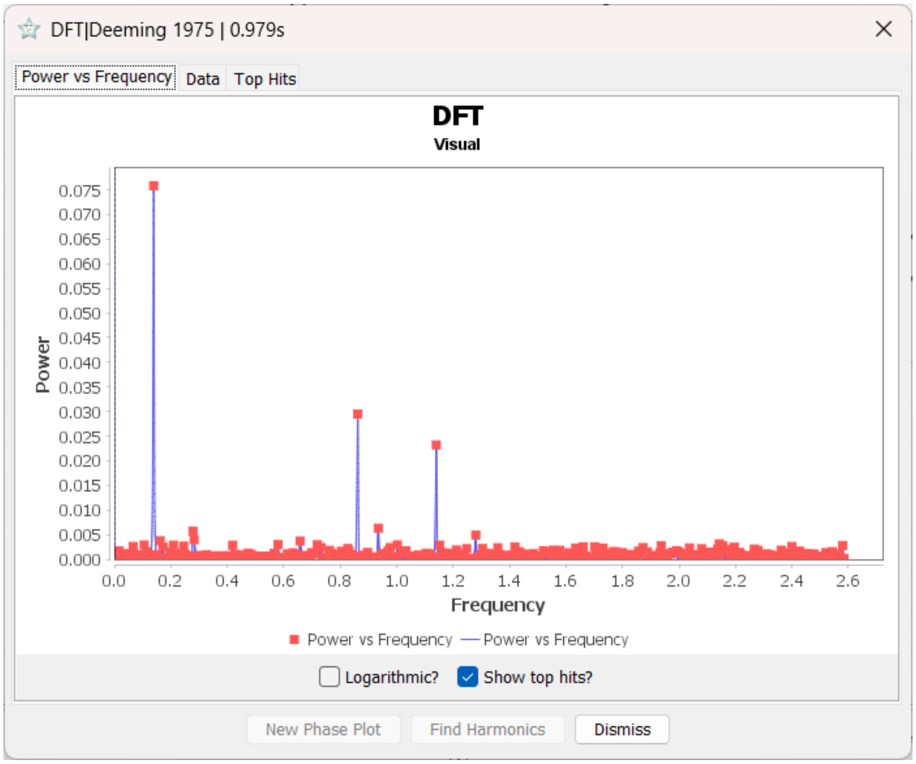


Clicking the OK button with the Visual series selected opens a parameter entry dialog:

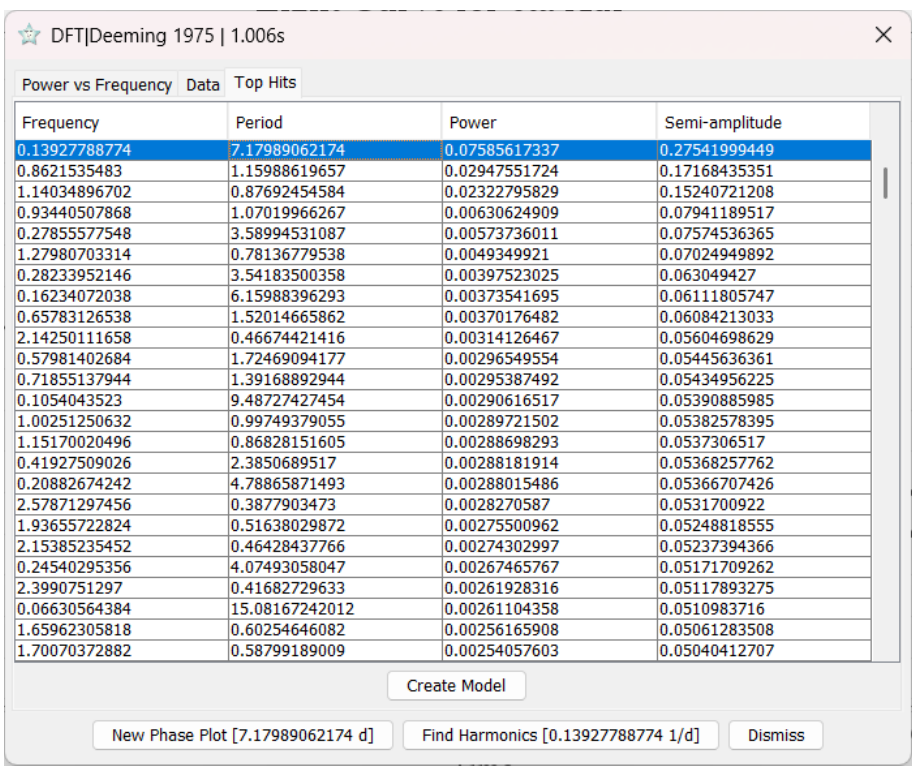


The default values for maximum frequency and resolution provide a good starting point.

Clicking the OK button starts the DFT calculations, and the result is displayed in a separate window:

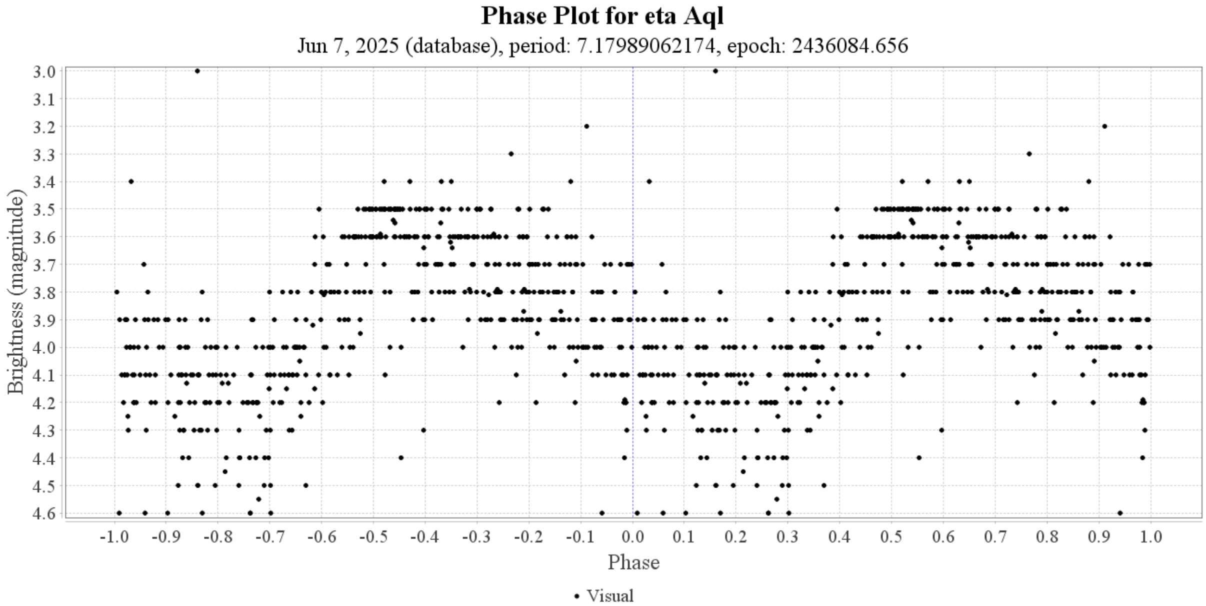


This should look familiar to anyone who has used DC DFT in VStar. As for DC DFT, top hits are shown as red squares on the plots and in tabular form on the *Top Hits* tab (unlike DC DFT, the number of top-hits is not limited -- every local maximum is marked as a top-hit).



Frequency	Period	Power	Semi-amplitude
0.13927788774	7.17989062174	0.07585617337	0.27541999449
0.8621535483	1.15988619657	0.02947551724	0.17168435351
1.14034896702	0.87692454584	0.02322795829	0.15240721208
0.93440507868	1.07019966267	0.00630624909	0.07941189517
0.27855577548	3.58994531087	0.00573736011	0.07574536365
1.27980703314	0.78136779538	0.0049349921	0.07024949892
0.28233952146	3.54183500358	0.00397523025	0.063049427
0.16234072038	6.15988396293	0.00373541695	0.06111805747
0.65783126538	1.52014665862	0.00370176482	0.06084213033
2.14250111658	0.46674421416	0.00314126467	0.05604698629
0.57981402684	1.72469094177	0.00296549554	0.05445636361
0.71855137944	1.39168892944	0.00295387492	0.05434956225
0.1054043523	9.48727427454	0.00290616517	0.05390885985
1.00251250632	0.99749379055	0.00289721502	0.05382578395
1.15170020496	0.86828151605	0.00288698293	0.0537306517
0.41927509026	2.3850689517	0.00288181914	0.05368257762
0.20882674242	4.78865871493	0.00288015486	0.05366707426
2.57871297456	0.3877903473	0.0028270587	0.0531700922
1.93655722824	0.51638029872	0.00275500962	0.05248818555
2.15385235452	0.46428437766	0.00274302997	0.05237394366
0.24540295356	4.07493058047	0.00267465767	0.05171709262
2.3990751297	0.41682729633	0.00261928316	0.05117893275
0.06630564384	15.08167242012	0.00261104358	0.0510983716
1.65962305818	0.60254646082	0.00256165908	0.05061283508
1.70070372882	0.58799189009	0.00254057603	0.05040412707

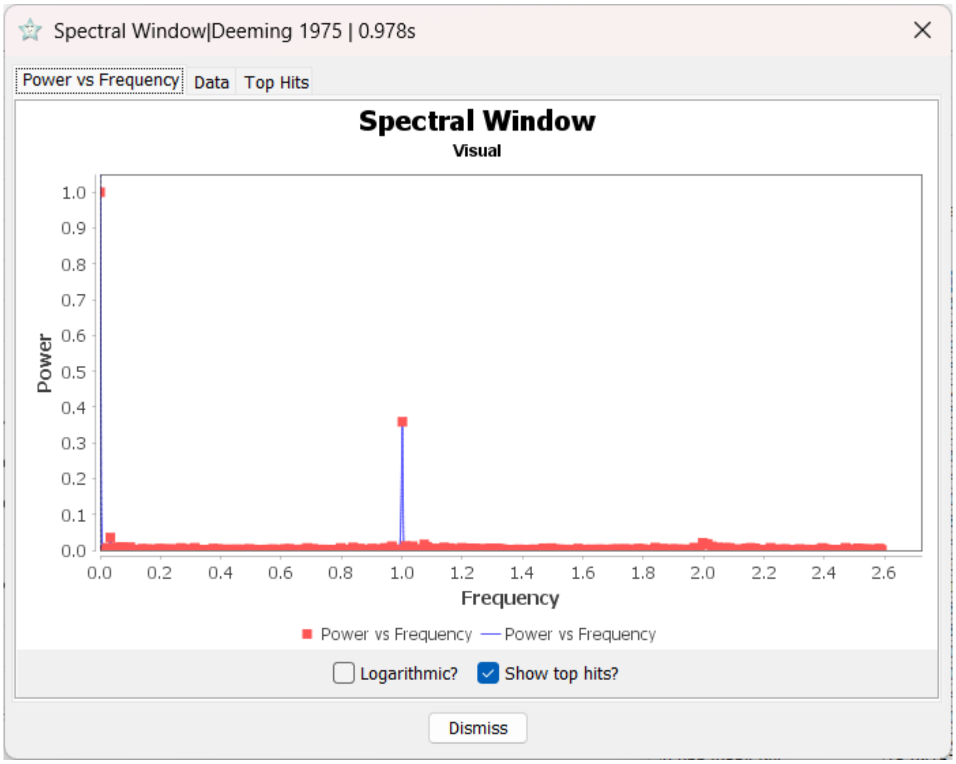
A point on the plot or a table row can be selected, and a phase plot can be created by clicking the *New Phase Plot* button.



Spectral Window

Not all peaks in the periodogram represent the 'real' frequencies in the star's oscillation spectrum. Some are aliases that arise due to gaps in observations, the finite observation interval, and the inability to observe during the daytime. Since observations are limited to nighttime and observers are not uniformly distributed by longitude, gaps with a period of one day are common.

Let us inspect the spectral window calculated for the data above. To do this, invoke the DFT and Spectral Window Frequency Range item from the menu, select the Visual series, and, in the Parameters dialog, choose the 'Spectral Window' radio button. Then, click the OK button. Once the calculations are finished, you will see the following pattern:



There is always a peak at zero frequency. The width of this peak corresponds to the theoretical resolution of the analysis -- the wider the observation time span, the narrower the peak. However, we also see a peak at a frequency of 1 d^{-1}, which is an alias.

Look at the periodogram we calculated earlier. Along with the primary peak at 0.139 d^{-1}, you can see a peak at 1.140 d^{-1}, which is an alias of the primary peak. This peak has no physical meaning and is merely a calculation artifact.

Thus, the spectral window is a useful tool for identifying and rejecting aliases.

DC DFT

This is equivalent to the *DC DFT with Frequency Range* analysis. For details, please refer to the VStar documentation.

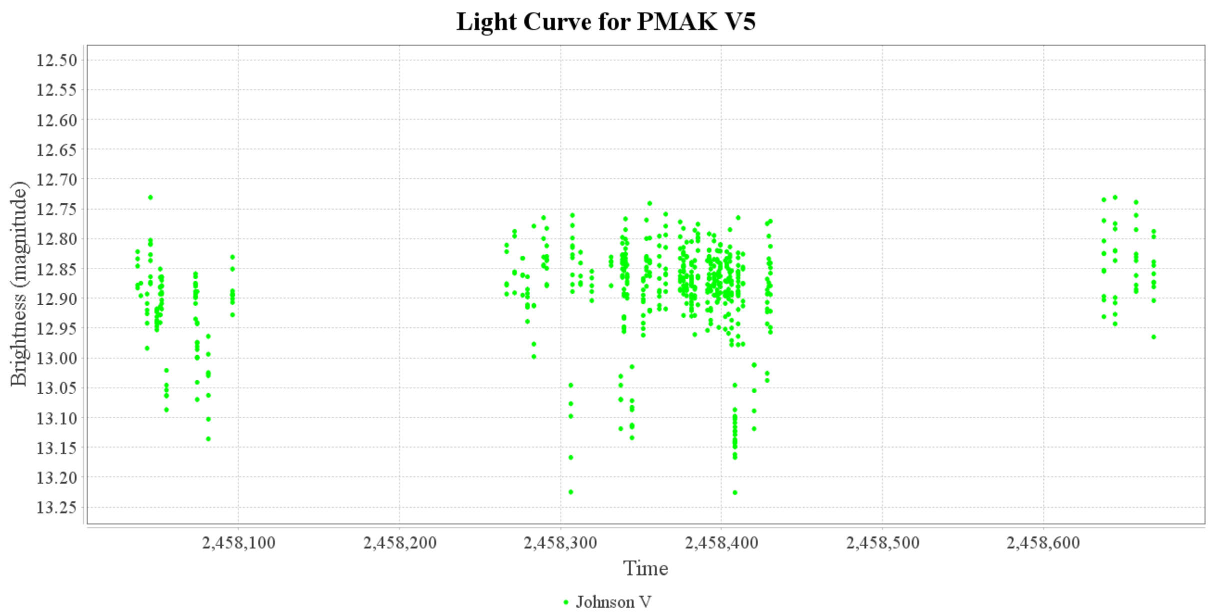
Multi-Harmonic DFT

This method models the signal (the original light curve) for each trial frequency using a sinusoid along with several harmonics -- additional sinusoids whose frequencies are multiples of the trial frequency. The *Harmonics* parameter specifies the number of multiplied frequencies used in the fitting process. If this parameter is set to 1, the algorithm functions essentially the same as DC DFT.

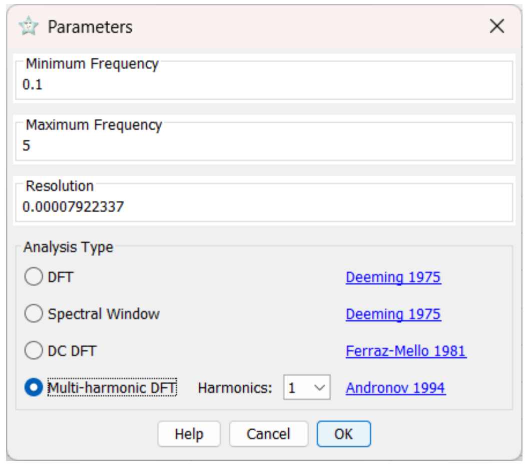
Example 1: PMAK V5

Let us consider the application of the algorithm on the example of the PMAK V5 eclipsing variable.

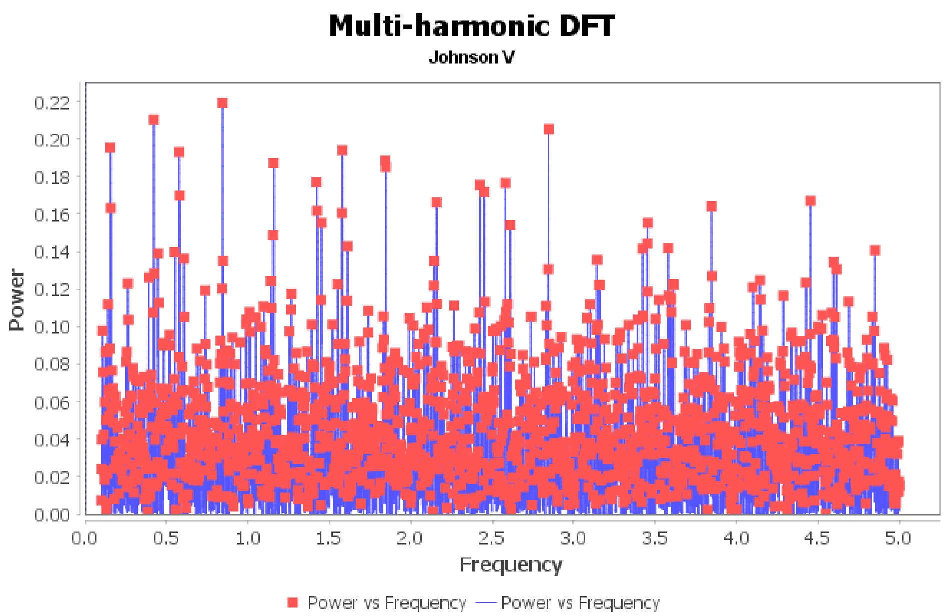
Load observations of the PMAK V5 variable from the AAVSO International Database into Vstar and convert dates to HJD. These are Johnson V data:



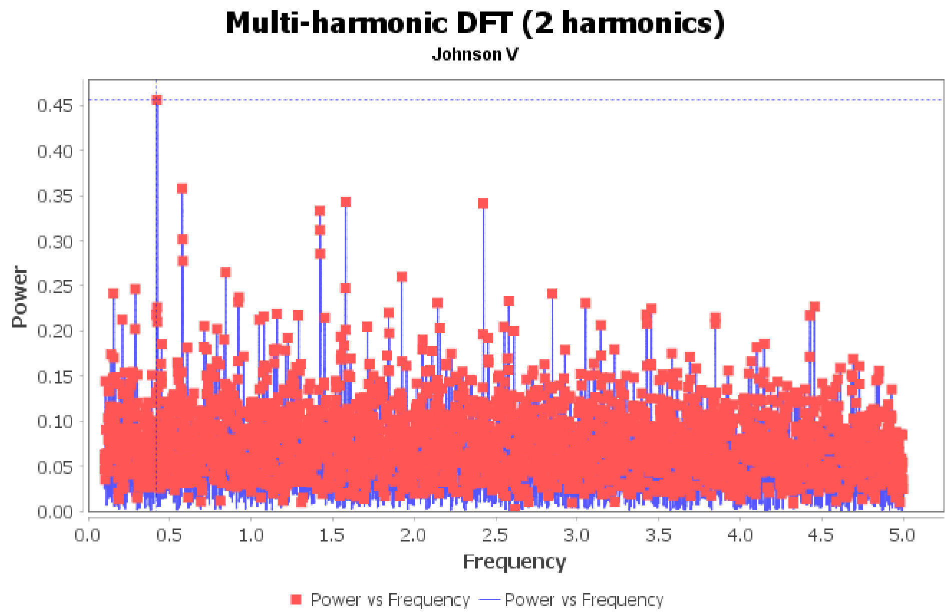
Then, invoke the DC DFT with Frequency Range plug-in. Let's assume we suspect the variable's period falls somewhere between 0.2 and 10 days, so we set the parameters accordingly:



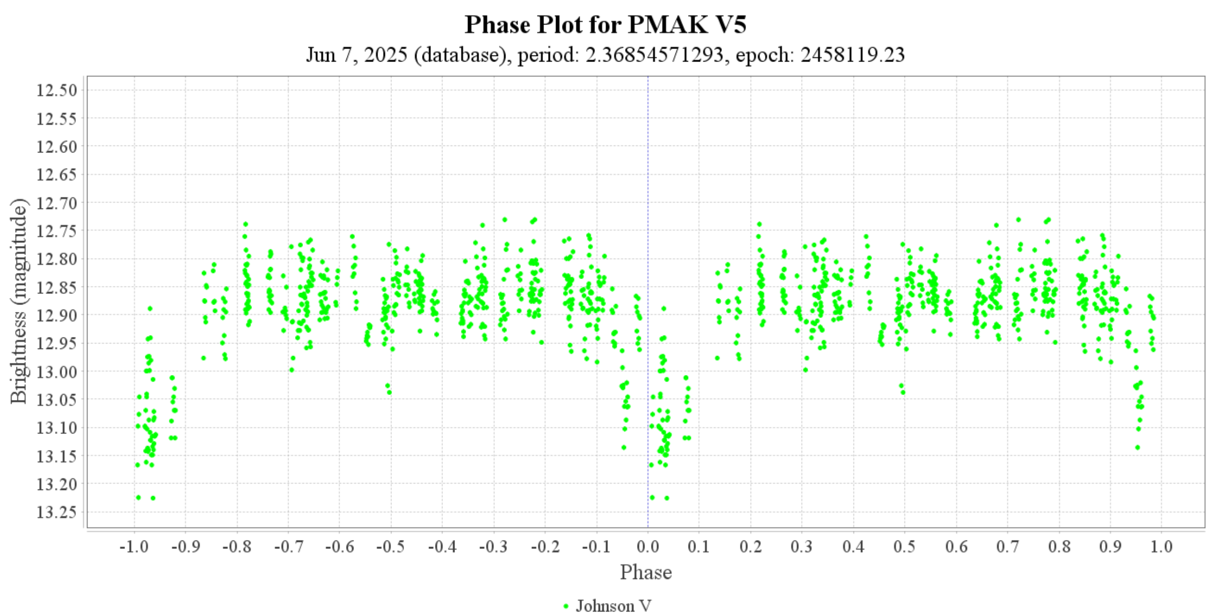
For the first run, set Harmonics to 1. Here is the resulting periodogram:



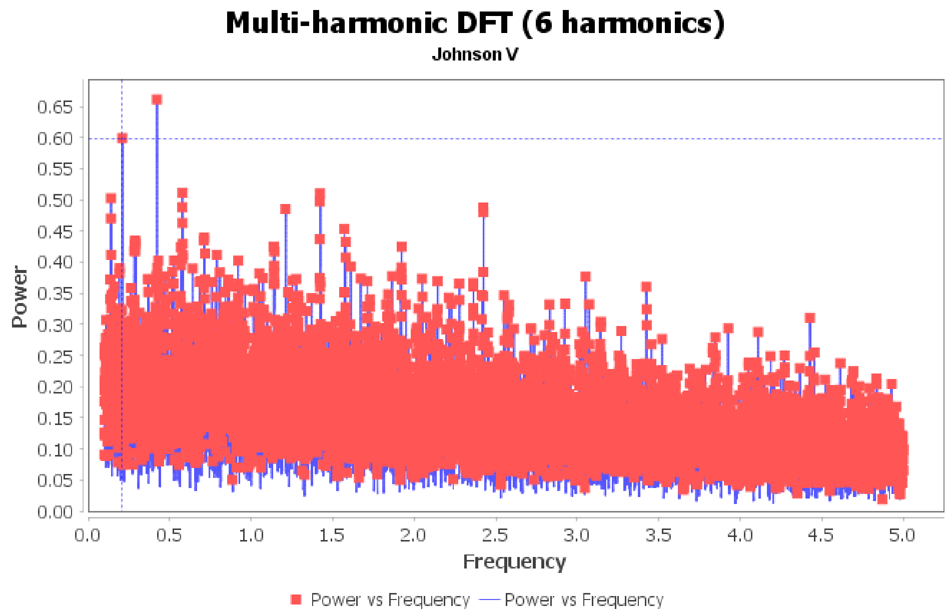
There is no obvious frequency. So, try setting Harmonics to 2. Please note that as the number of harmonics increases, it is advisable to increase the resolution by the same factor. So, set Resolution to 0.00004 (i.e., reduce the frequency step size by half):



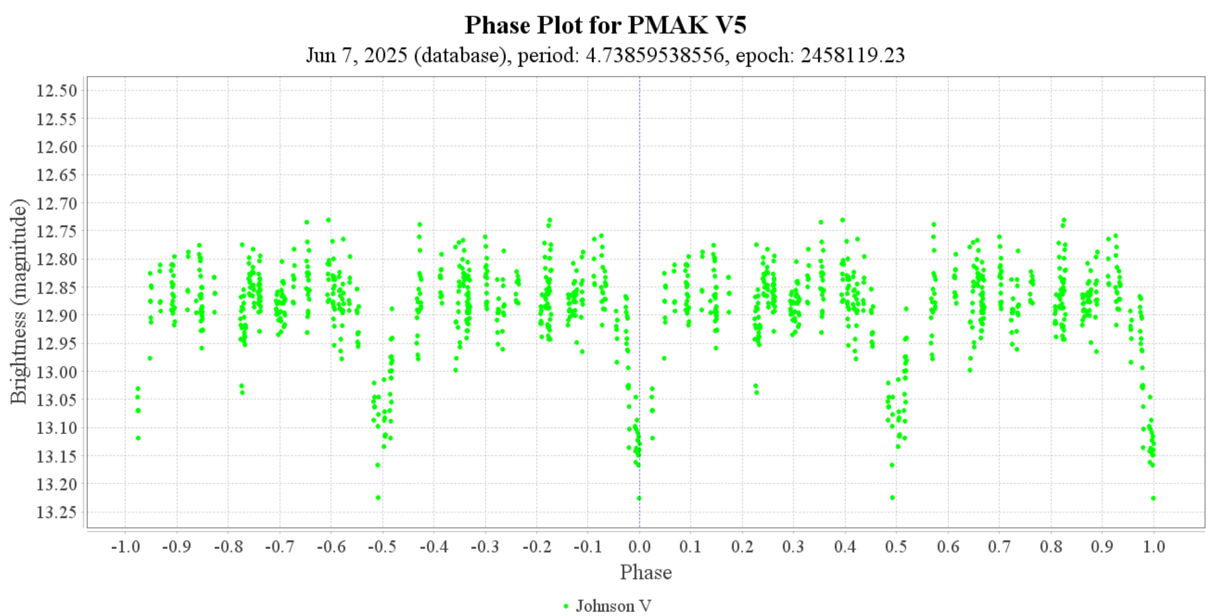
Let us select a frequency with the highest power and build the phase plot for it:



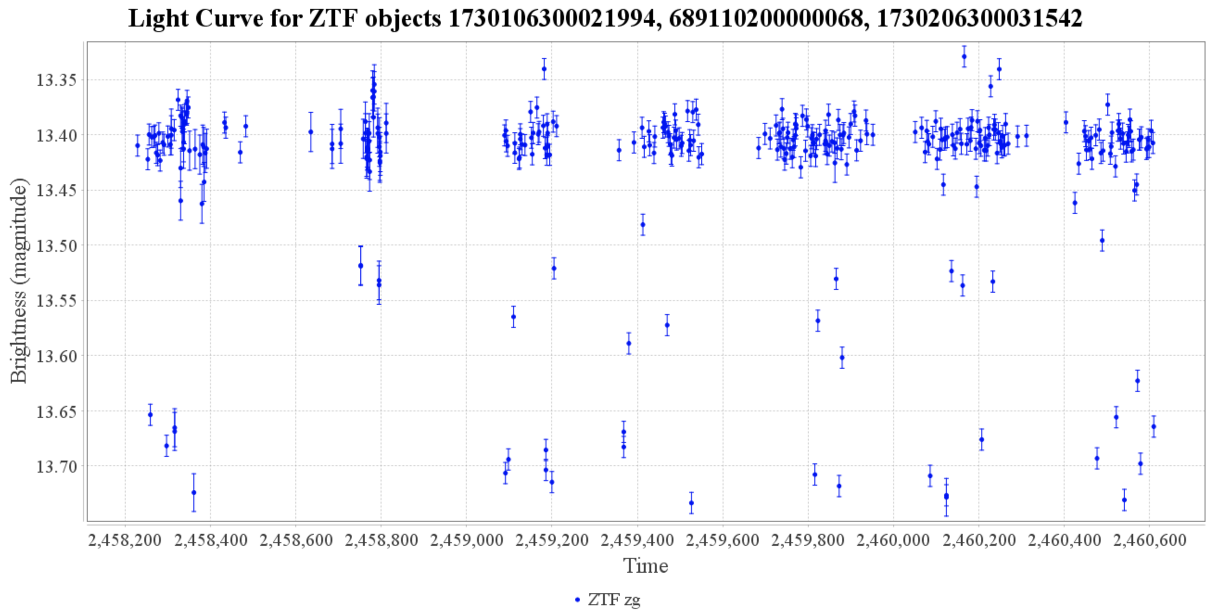
This already resembles the light curve of an Algol-type eclipsing variable; however, we do not see the secondary minimum. Let us try setting Harmonics to 6 and Resolution to 0.000013:



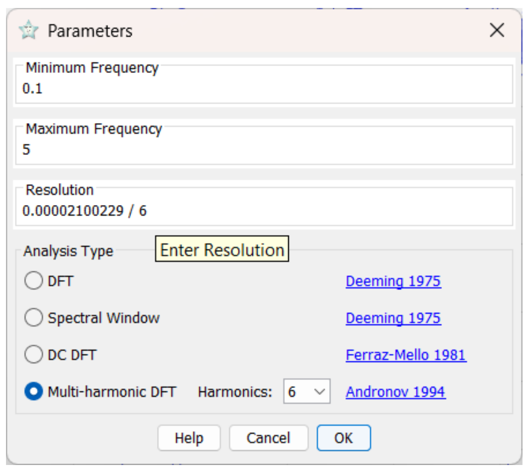
The most prominent peak remains the same; however, we can now see a second peak at a period of 4.7377. Here is the phase plot for it:



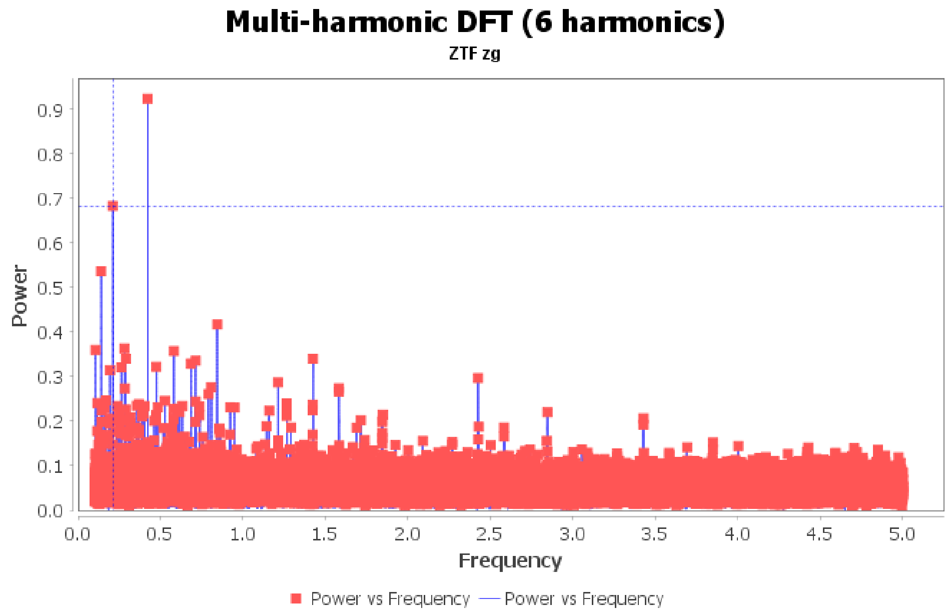
To prove this, we can try higher-quality data from ZTF for this star:



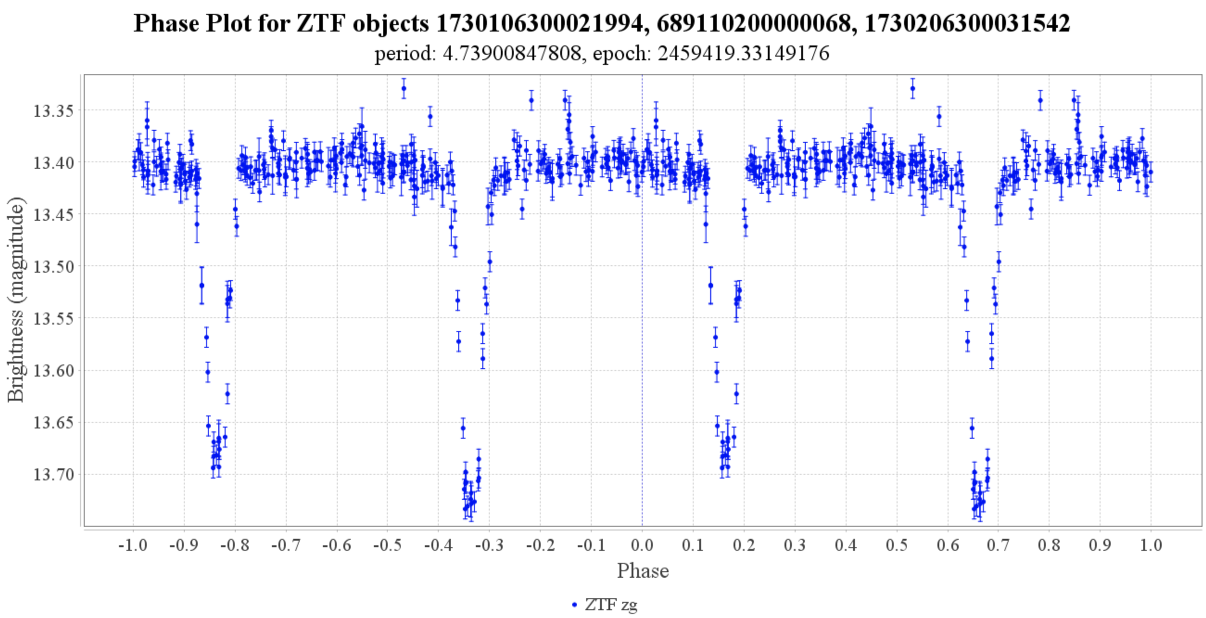
Trying the same approach for the ZTF zg data:



The second top-hit in the resulting periodogram is at almost the same frequency as in the previous periodogram:



The corresponding phase plot shows the classic EA light curve:

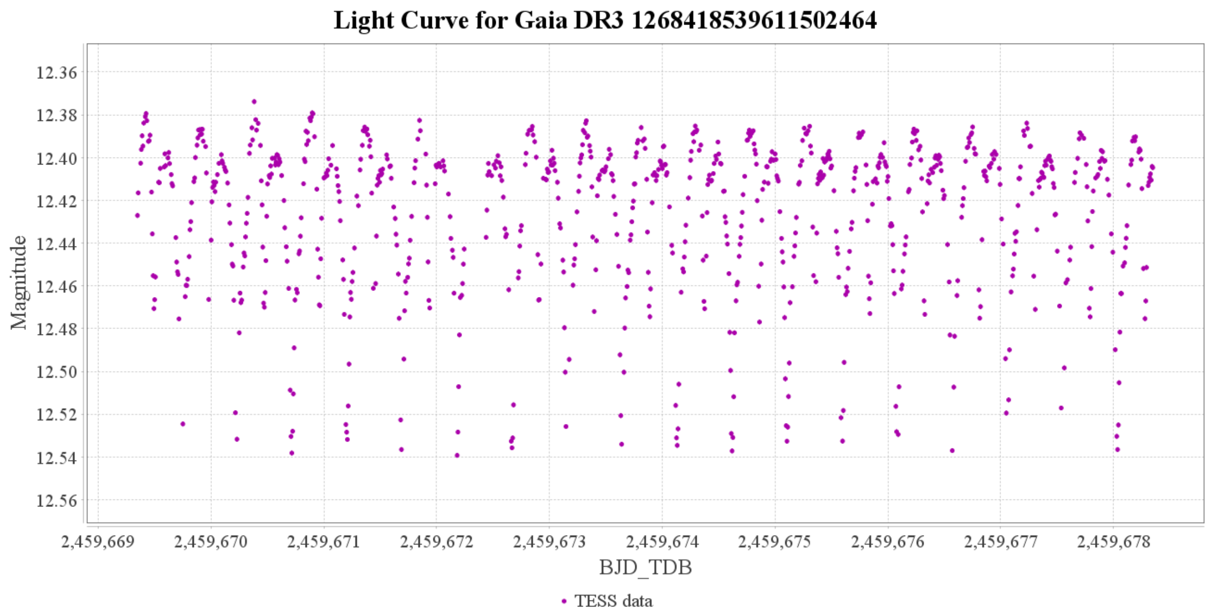


We obtained a period of 4.739 days, which is in excellent agreement with the VSX value (4.7391 d).

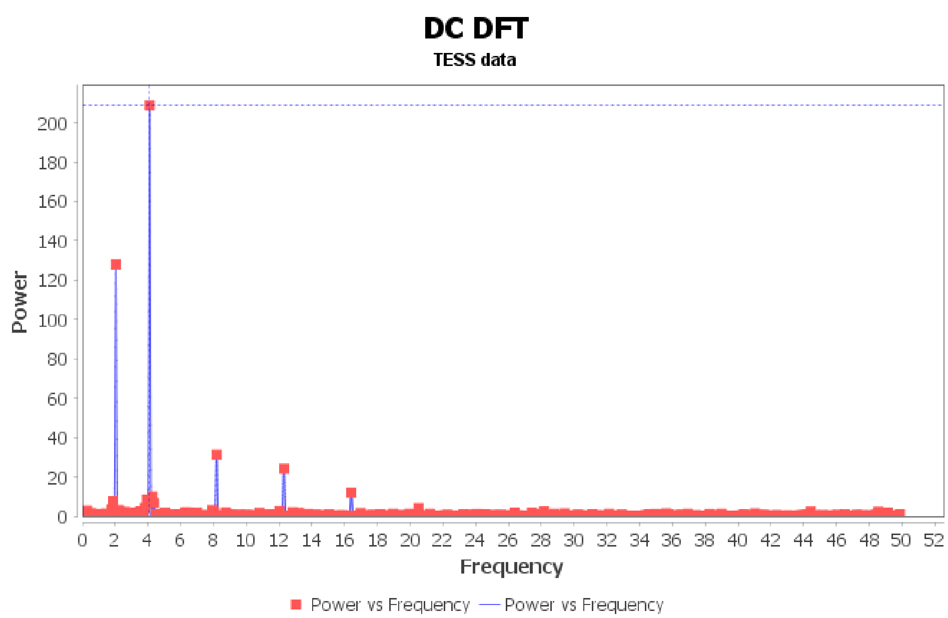
Example 2: TIC 229887190 (Gaia DR3 1268418539611502464)

The star Gaia DR3 1268418539611502464 is listed in the VSX catalogue. As of June 7, 2025, it has no definitive variability type. The period recorded in VSX is 0.0389788 d (revision 1).

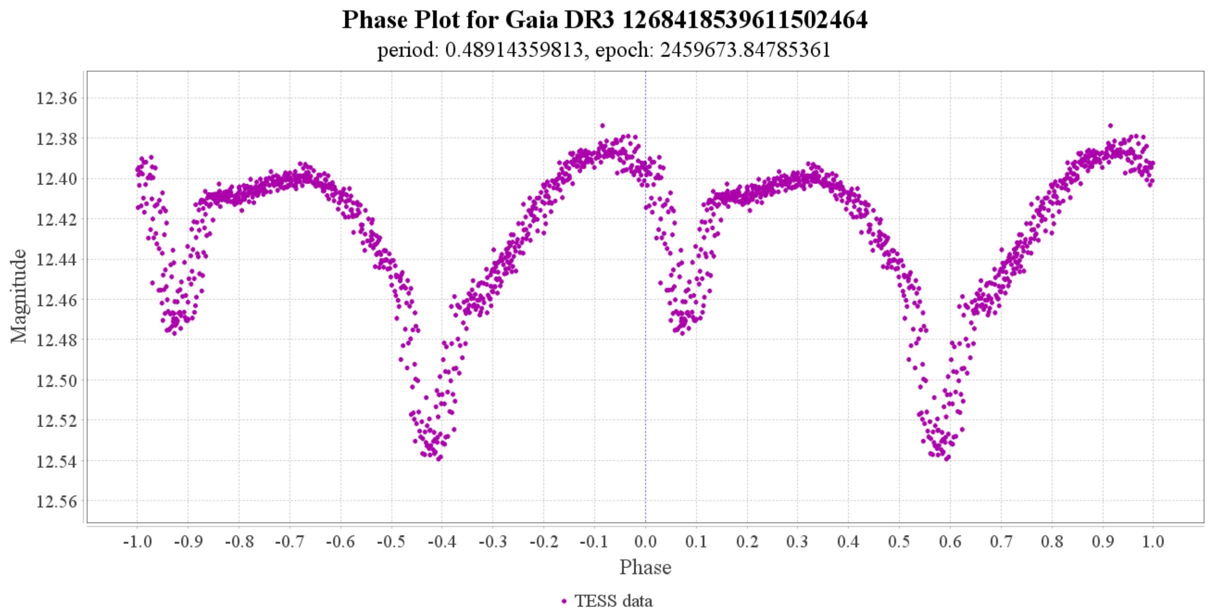
Here is part of its TESS QLP light curve (Sector 50):



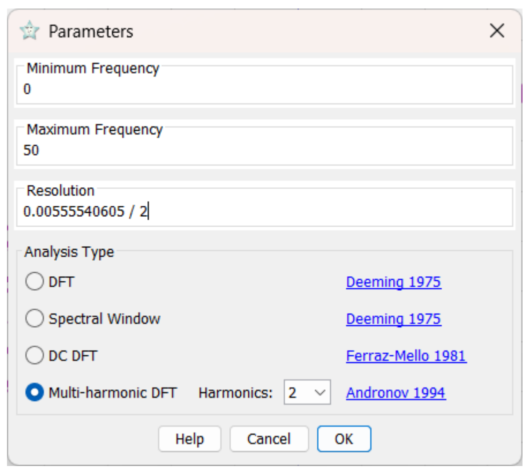
Standard DC DFT with the default parameters (Minimum Frequency = 0, Maximum Frequency = 50, Resolution = 0.00555540605, DC DFT mode) gives the most prominent period of 0.2439 days.



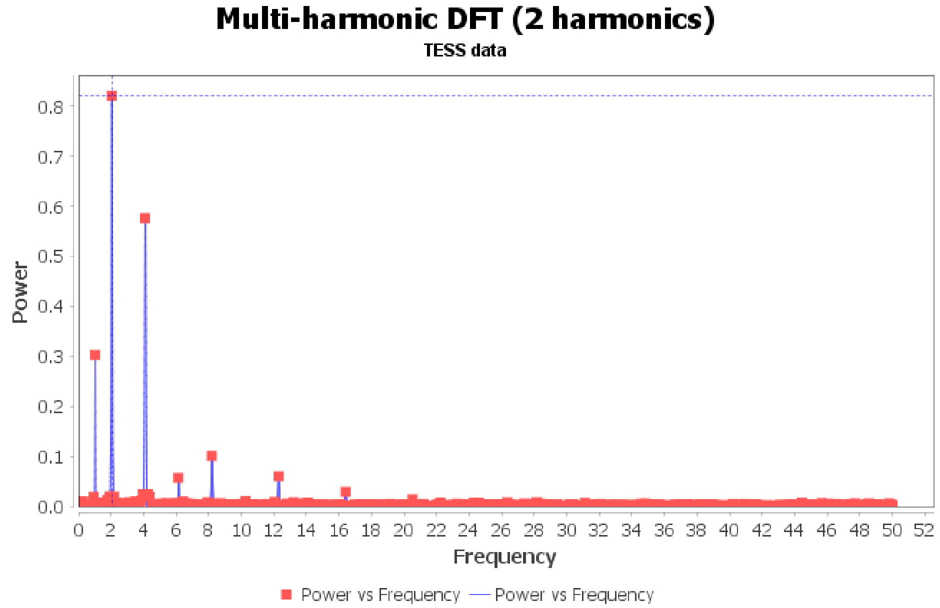
However, the light curve clearly indicates that it is an EA-type variable. By estimating the period from the light curve, we can conclude that it is quite close to the second top hit (0.4891 days). Here is the corresponding phase plot:



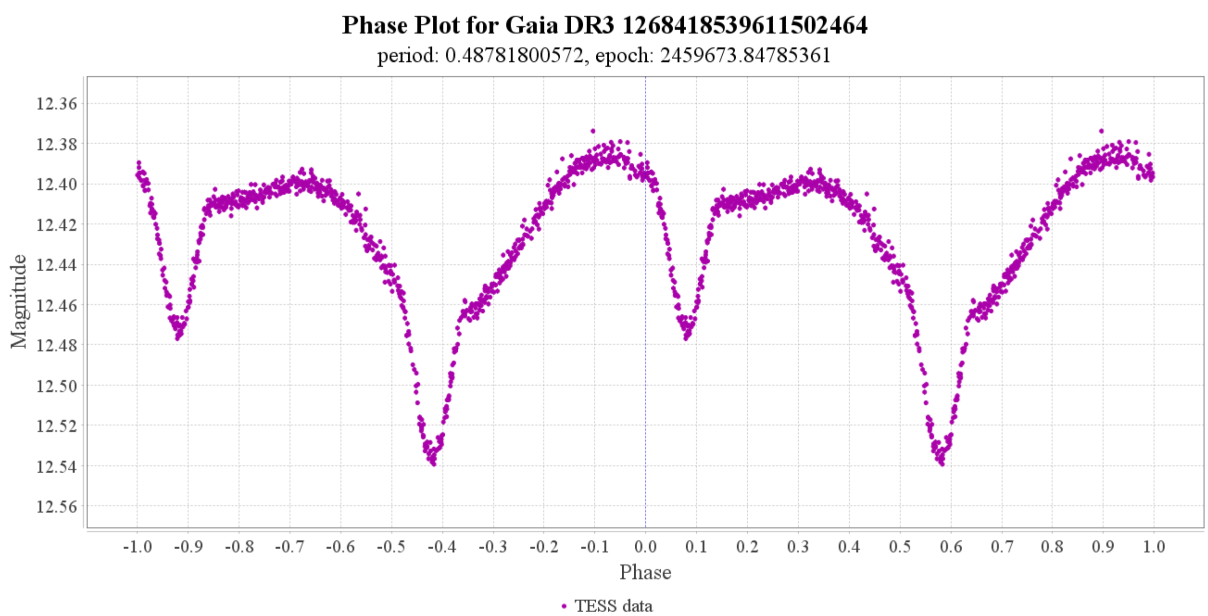
It is evident that the estimated period is not highly accurate. Next, try Multi-harmonic DFT -- select 2 harmonics and increase the resolution:



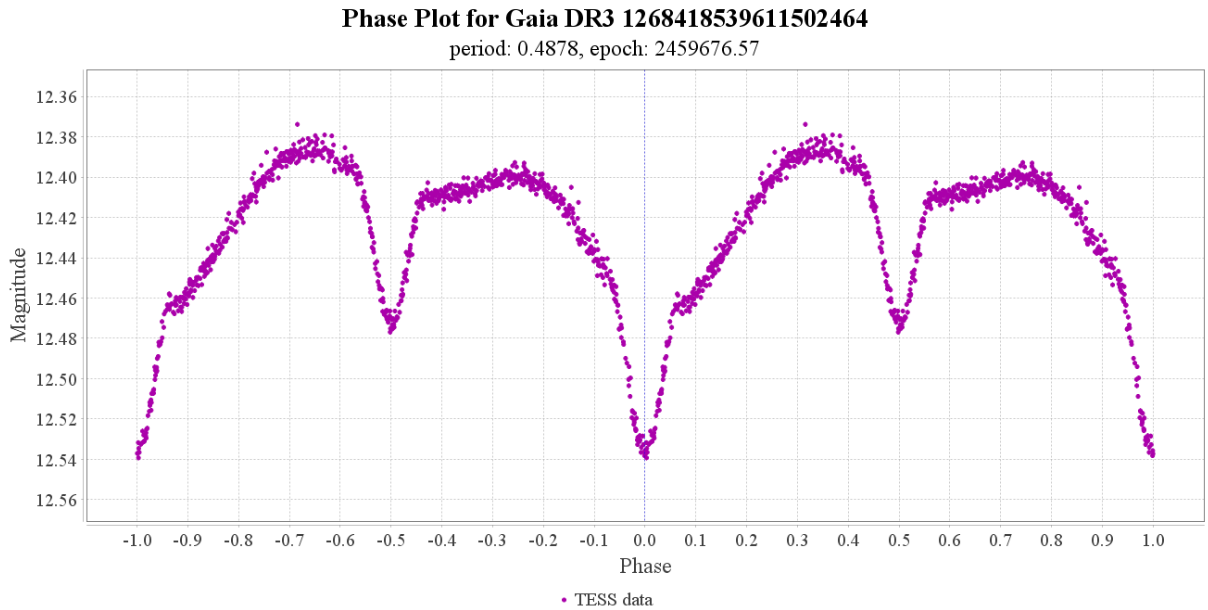
Next, select the most prominent frequency from the resulting periodogram:



The resulting phase plot is nearly perfect; we only need to adjust the initial epoch:



Here is the final phase plot with the corrected initial epoch and the period without insignificant digits:



References

Deeming, T. J., 1975, Fourier Analysis with Unequally-Spaced Data, Astrophysics and Space Science, Volume 36, Issue 1, pp. 137-158, Bibcode: 1975Ap&SS..36..137D

Ferraz-Mello, S., 1981, Estimation of Periods from Unequally Spaced Observations, Astronomical Journal, Volume 86, p. 619, 1981, Bibcode: 1981AJ.....86..619F

Andronov, I. L., 1994, (Multi-) Frequency Variations of Stars. Some Methods and Results, Odessa Astronomical Publications, Volume 7, pp. 49-54, Bibcode 1994OAP.....7...49A

Andronov, I. L., 2020, Advanced Time Series Analysis of Generally Irregularly Spaced Signals: Beyond the Oversimplified Methods, Knowledge Discovery in Big Data from Astronomy and Earth Observation, 1st Edition. Edited by Petr Skoda and Fathalrahman Adam. ISBN: 978-0-128-19154-5. Elsevier, 2020, p.191-224, Bibcode 2020kdbd.book..191A

Revision History

Rev	Date	Description	Author
B	07.06.2026	Updated along with the plug-in update	Maksym Pyatnytskyy (PMAK)
A	26.12.2024	Initial release	Maksym Pyatnytskyy (PMAK), partially based on David Benn's AoV plug-in documentation.