

CEPHEIDSQT - Multimodal Cepheids SOFTWARE

1. Introduction

CepheidsQt – Multimodal Cepheids is a user-friendly software created for analysis of multimodal Cepheids. The program demands Qt libraries (version 4.6.3) and root software (version v5.26.00). Software design allows to read and write data directly from Pi of the Sky database or binary files. It is an effective tool searching for period of pulsation of single or multimodal variable stars.

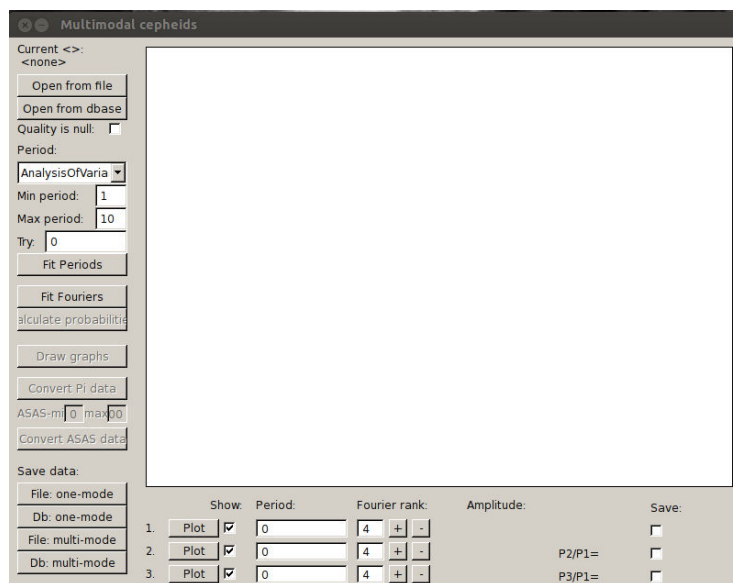


Figure 1: CepheidsQt – Multimodal Cepheids Interface.

2. Options

Program allows to read data from two different sources shown in Figure 2:

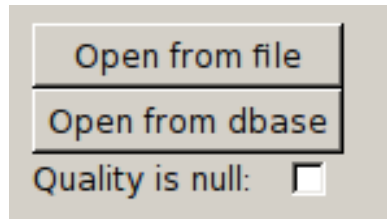
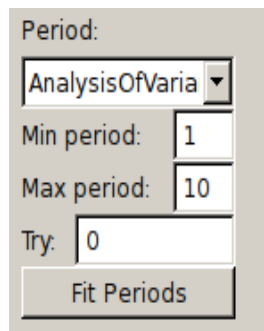


Figure 2: User can load data from file or directly from Pi of the Sky database. When reading from database user can exclude observations with low quality by checking box 'Quality is null'.

- read data from file – opening binary file with dataset. In file there should be two columns, the first one with time of observation and the second one with brightness observed in each part of time. The file should have an extension 'txt' or 'dat'. Do not load program files, which are not binary files or have format other than specified above.
- read data from database – loading data directly from Pi of the Sky databases. This option works only on Pi of the Sky servers.
- 'Quality is null' – program will reject the measurements affected by detector imperfections or observations conditions when reading data from Pi of the Sky databases. Measurements that are infected by hot pixels, bright background caused by open shutter or moon halo, or by planet or planetoid passage, can be excluded from light curve.

After reading the data the light curve is drawn. Main goal of this program is to find period, thus several



methods are available:

Figure 3: If period is known user can write it down in box 'Try' or program can be found by one of the available methods.

- If period is known user can write it down in box 'Try'.
- By clicking 'Fit' button program will determine period of pulsation from selected range (user should define values in fields 'Min' and 'Max') using one of selected method:
 - Analysis of Variance – Like in PDM method (see below) the interval is divided into bins. In each bin number of observations, average and variance is computed. The interval is covered fNc times by those bins. Each covering is shifted by $T/fNb/fNc$ from the previous one. So in total there is $fNb*fNc$ bins which overlap. For all those bins sigma is computed and the total sigma is the estimated from that sigma from bins. For details see: A. Schwarzenberg-Czerny, On advantage in using analysis of variance for period determination, M.N.R.A.S. 241 (1989), 153.

- Slow Fourier Transformation – Fourier transform for irregular intervals.
- Lafler -Kinman method – For details see: J. Lafler, T. D. Kinman, An RR Lyrae Survey With The Lick 20-inch Astrograph II. The Calculation of RR Lyrae Periods By Electronic Computer, ApJS 11, 216-222.
- Phase Dispersion Minimization – the whole interval T (the period) is divided into fNb bins. The interval is covered fNc times by those bins. Each covering is shifted by $T/fNb/fNc$ from the previous one. So in total there is $fNb*fNc$ bins which overlap. For all those bins sigma is computed and the total sigma is the estimated from that sigma from bins. For details see: F. Stellingwerf, Period Determination Using Phase Dispersion Minimization (PDM), ApJ 224 (1978), 953-960.
- AOV Multiharmonic Periodogram for Uneven Sampling & NO Weights (AOVHM) – Fits equivalent of Fourier series of nh harmonics, by fast recurrence algorithm involving projection onto orthogonal trigonometric polynomials. Particularly sensitive for detection of sharp signals (eclipses, narrow pulses). Fast algorithm based on recurrence formula for orthogonal polynomials. Enables use of LONG Fourier series with reasonable computing overhead (scales linearly with nh). For $nh=1$ reduces to AOV (i.e. SignalPower/Residual Power) transformation of the Lomb-Scargle Periodogram. In statistical sense (sensitivity) it never performs worse than either Lomb-Scargle or Power Spectrum. For non-sinusoidal signal and suitable $nh>1$ performs much better than the above mentioned methods. For more details see: A. Schwarzenberg-Czerny, Fast and Statistically Optimal Period Search in Uneven Sampled Observations, Astrophys. J. 460 (1996), L107.

Program calculates periods for three modes.

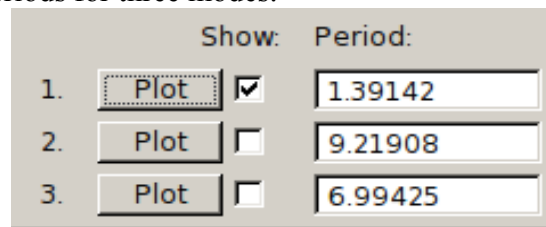
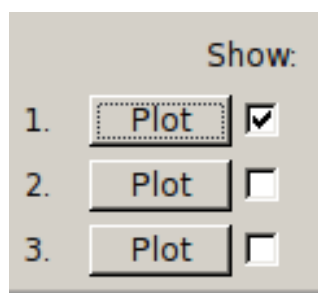


Figure 4: Calculated periods are shown on the panel.



- Drawing a phased light – phased light curved can be drawn for selected mode.

Figure 5: Drawing a phased light curve for selected mode.

- Fitting Fourier series to light curve – the light curves are fitted with:

$$V_r(t) = A_0 + \sum_{k=1}^N A_k \sin(2\pi kf(t-t_0) + \varphi_k)$$

where $f = 1/P$, N is the order of fit (default is $N = 4$ but user can changed it), f is the frequency and P is the pulsation period.

Next the Fourier phases $\varphi_{k1} = \varphi_k - k\varphi_1$ and the amplitudes ratios $R_{k1} = A_k/A_1$ are calculated. Also the parameter $M - m$ (M is the phase of maximum brightness and m the phase of minimum brightness) is computed, which measures the light curve asymmetry. Computed amplitudes and period ratios are shown next to the panel with Fourier ranks, all Fourier parameters can be saved to the file.

Fourier rank:	Amplitude:	
4 + -	0.364669	
4 + -	0.141968	P2/P1=6.62566
4 + -	0.118334	P3/P1=5.02669

Figure 5: Fourier series are fit with $N = 4$, user can change order of the fit for each mode.

- Saving Fourier parameters – computed Fourier parameters (period, φ_{k1} , R_{k1} with errors) are saved to the file or directly to Pi of the Sky database (File or Db). User can choose which data are saved:
 - one-mode – data for the light curve phased with the first period are saved.
 - Multi-mode – data for selected modes (user should use checkboxes in the right side of the window) are saved.

1.	2.	3.
Plot <input checked="" type="checkbox"/>	Plot <input type="checkbox"/>	Plot <input type="checkbox"/>
1.39142	9.21908	6.99425
4 + -	4 + -	4 + -
0.364669	0.141968	0.118334
	P2/P1=6.62566	P3/P1=5.02669
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 6: Fourier parameters can be saved to the file or directly to the database. User can choose which data want to save.