

## CYCLOCODE



Period Searching & Lightcurve Fitting Program; Ver. 3.6

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This program consists of two parts, which can be employed separately or simultaneously, depends on user's choice. User inputs some parameters when employing this program. Part 1 evaluates a period of lightcurve data using the PDM and/or the Spectral Analysis methods. The period is calculated in unit day (frequency of 1/day). Part 2 develops appropriate fitting curve(s) of the lightcurve. Base-level of a fitting curve can be both at about the mean level of the magnitude data and at zero magnitude by shifting of delta magnitude. The fitting curve/data for the latter is called "normalized" magnitude (normag).

This document does not explain how to compile and run this program. It is assumed that user has known them.

The input file (\*.???) must have 3 columns and time-increasing sorted:

Column 1: Time in (Modified) Julian Day (MJD/JD), or its fraction, relative to epoch;

Column 2: Magnitude or relative magnitude;

Column 3: Error of magnitude (or relative magnitude).

The output files: Part 1: \*.pdm: PDM-based period result;

\*.spc: Spectral Analysis-based period result.

Part 2: \*.pha: Rotational-phased data;

\*.roc: Rotational-phased fitting curve;

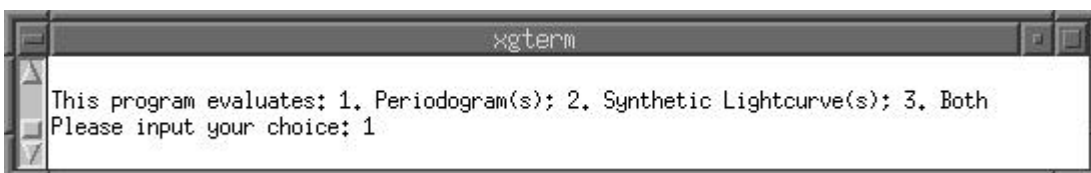
\*.fuc: Time-span fitting (continuous) curve;

\*.fud: Time-span fitting data points at the same 'Time' data.

Separate codes of the period searching and the lightcurve fitting have been previously distributed. This code is open, freely improved and distributed [🌐].

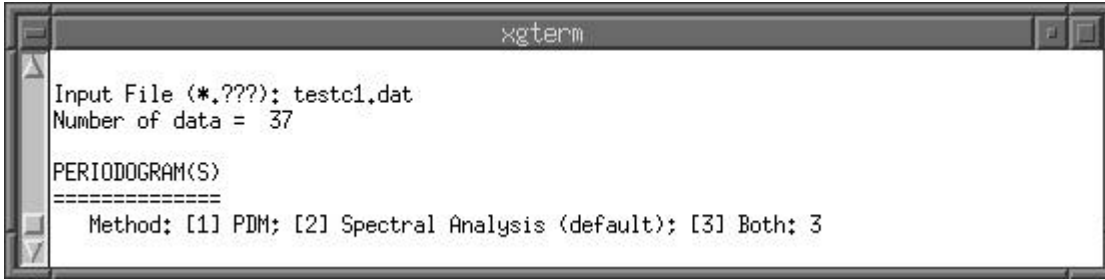
## DESCRIPTIONS

This program is interactive. When it is employed, user inputs some parameters needed for calculations. At the first stage, user selects one of the three tasks of evaluation.

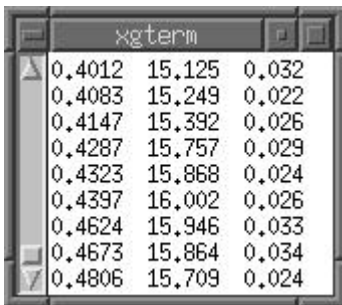


If you want to perform periodogram, type 1; or developing synthetic lightcurve, type 2; or employing them simultaneously, type 3. If you type another key, eg. the Enter key, the program automatically selects 3.

If you type 1 as in the example, you are entering the Part 1 of this program.



Type a filename (3-digit extension: <filename>.???) consisting of three columns.



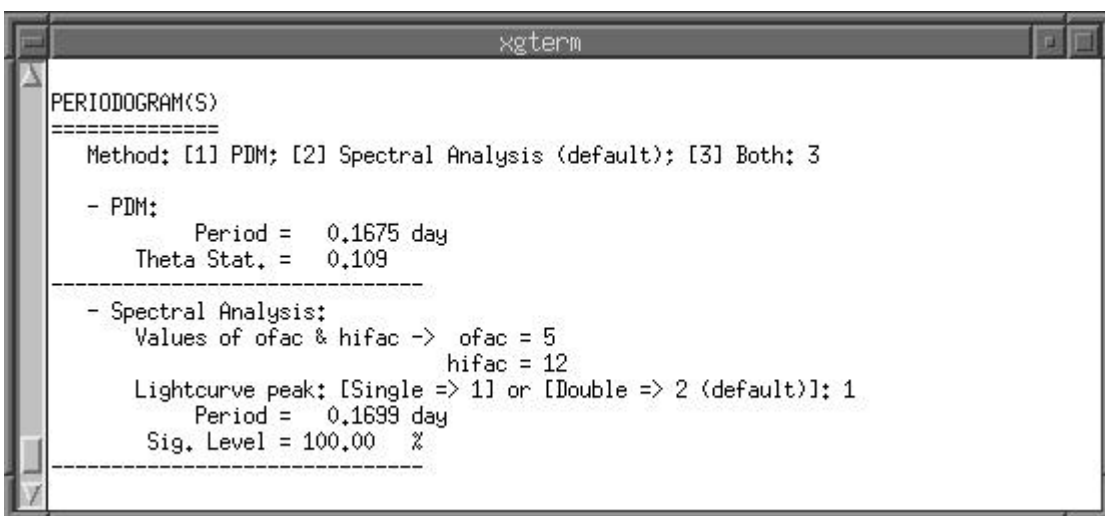
The first column is JD/MJD (or its fraction), the second one is magnitude, and the third is mag. error. The space between columns can be Space or Tab.

User must prepare such as input file before running the program.

The program then inspects number of data.

Part 1 provides two methods, the PDM and the Spectral Analysis. User can choose one of them or both by typing the selection number. Otherwise, by default the program selects 2, or simply type the Enter key.

Suppose you select both methods (3), the program will calculate a period based on both methods.



The range of trial periods in PDM is set from ~1.5 min to 10 days, with suitable period steps. The display shows a period and theta statistics, while the result is stored in file \*.pdm. The minimum of theta statistics means the most likely period.

\*.pdm

Freq. (1/d)	Per. (d)	Theta
Minimum:		
5.96956	0.1675	0.109
999.99995	0.0010	1.934
399.97598	0.0025	1.813
249.98125	0.0040	2.145
181.80330	0.0055	1.875

Freq. Period Theta stat.

\*.spc

Freq. (1/d)	Per. (d)	Power	Sig. (%)
Maximum: (S-peak)			
5.88550	0.1699	16.656	100.00
0.53505	1.8690	0.419	0.00
1.07009	0.9345	0.442	0.00
1.60514	0.6230	0.459	0.00
2.14018	0.4672	0.379	0.00

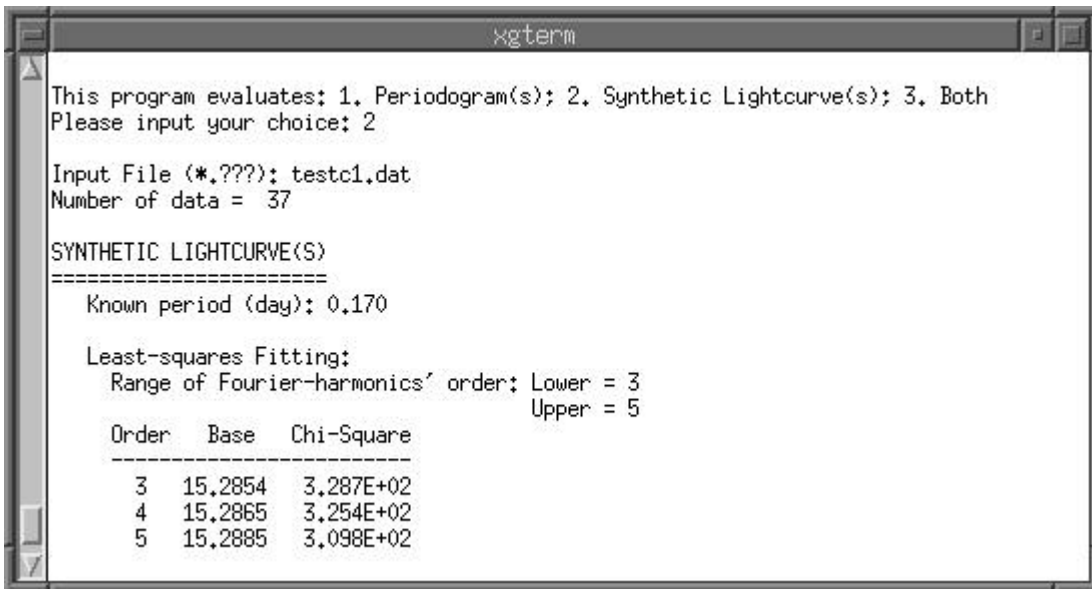
Freq. Period Power Sig. level

Single-peak  
Maximum value  
Minimum value

For Spectral Analysis, user freely inputs values of ofac and hifac. ofac is an oversampling factor suggested being  $\geq 4$ , while hifac is a high frequency factor. They are related as  $np = ofac \cdot hifac \cdot n / 2$ , where np is number of frequency and n is number of data. User also chooses whether the lightcurve is a single- or double-peak (by default is a double-peak). The display shows a period and its significance level. The maximum value of significance level means the most likely period if sig. level  $> 99\%$ . The result is stored in file \*.spc.

This is the end of Part 1. If you have selected this task at the first stage, the evaluation has been completed.

Now, suppose at the first stage you want to develop the synthetic lightcurve (2).



Type the input filename (see the previous description), and let the program inspects number of data. Now you are entering to the Part 2 of this program.

Type a period you have known regarding to the data. This period can be for a single- or double-peak lightcurve, as you like, but must in unit day. User will be asked about a range of Fourier-harmonics' order (i.e. lower and upper) for the Least-square fitting evaluation(s).

The display shows a table listing a base level of a synthetic lightcurve and its  $c^2$  for every order of Fourier-harmonics. Although generally, the minimum of  $c^2$  means the finer fitting curve, unlikely detail structures will appear parallel to increasing the harmonics' order. So, an "appropriate" fitting curve seems to be good to represent the lightcurve. All of the results are stored in files \*.pha, \*.roc, \*.fuc, and \*.fud, whose properties have been described in the beginning of this document.

*Phase-increasing sorted (original data) order delta mag. or base level*

\*.pha

Phase	JD	mag	err	3: normag	4: normag	5: normag
0.0100	0.5117	14.740	0.037	15.2854	15.2865	15.2885
0.0712	0.5221	14.549	0.028	-0.545	-0.547	-0.549
0.0976	0.6966	14.691	0.034	-0.736	-0.738	-0.740
0.1153	0.5296	14.529	0.035	-0.594	-0.596	-0.598
0.1771	0.7101	14.648	0.032	-0.756	-0.758	-0.760
				-0.637	-0.639	-0.641

Phase  $\equiv$  JD folded by the period. normag = mag - delta mag.. delta mag. plays as a shifting magnitude to zero base-level or the base-level towards the original data.

*order delta mag. or base level*

\*.roc

Phase	mag	normag	4	5
0.0000	14.708	-0.577	14.711	14.732
0.0125	14.675	-0.610	14.675	14.706
0.0250	14.647	-0.638	14.644	14.682
0.0375	14.625	-0.660	14.618	14.659
0.0500	14.608	-0.677	14.599	14.636

Phase  $\equiv$  80 equal-spaced intervals from 0 to 1. Fitting curve can be drawn both based on derived mag or normag.

*JD-increasing sorted order delta mag. or base level*

\*.fuc

JD	Phase	mag	normag	4	5
0.3587	0.1100	14.594	-0.691	14.584	14.565
0.3608	0.1225	14.603	-0.682	14.597	14.566
0.3629	0.1350	14.616	-0.670	14.613	14.576
0.3651	0.1475	14.631	-0.654	14.634	14.594
0.3672	0.1600	14.650	-0.636	14.657	14.621

JD and Phase are calculated continuously along the time-span (one period has 80 equal-spaced interval) to fill gap (if any), and with the time-span offset of  $\mp$ period/4. Fitting curve can be drawn both based on derived mag or normag.

*JD-increasing sorted order delta mag. or base level*

\*.fud

JD	Phase	mag	normag	4	5
0.4012	0.3600	15.193	-0.092	15.182	15.155
0.4083	0.4018	15.349	0.064	15.348	15.350
0.4147	0.4394	15.494	0.208	15.504	15.531
0.4287	0.5218	15.787	0.502	15.793	15.781
0.4323	0.5429	15.850	0.565	15.848	15.831

JD and Phase are the original data. Derived mag and normag are calculated at the same JD.

This is the end of Part 2 and the evaluation has been completed.

Now, the following is a description when user selects both parts (3) at the first stage, and the input file contains combined daily data. Previously, it is highly suggested that user find the daily base-level of magnitude data by employing this program separately for daily data, and then combine the obtained daily normmag (the best if refer to the same harmonic order).

```

xterm
This program evaluates: 1. Periodogram(s); 2. Synthetic Lightcurve(s); 3. Both
Please input your choice: 3

Input File (*.???): testcz.dat
Number of data = 85
Base-level of the mag. data is zero mag. [y/Y (default) or n/N]: 

PERIODOGRAM(S)
=====
Method: [1] PDM; [2] Spectral Analysis (default); [3] Both; 3

- PDM:
    Period = 1.2311 day
    Theta Stat. = 0.099
-----
- Spectral Analysis:
    Values of ofac & hifac -> ofac = 5
                             hifac = 12
    Lightcurve peak: [Single => 1] or [Double => 2 (default)]: 
    Period = 0.3517 day
    Sig. Level = 100.00 %
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The obtained period used for developing synthetic lightcurve(s)
=====
[1] PDM; [2] Spectral Analysis (default): 

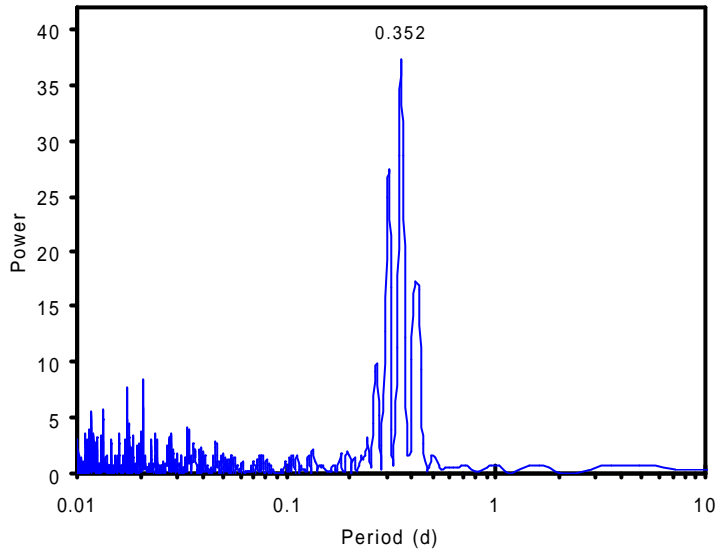
SYNTHETIC LIGHTCURVE(S)
=====
Least-squares Fitting:
Range of Fourier-harmonics' order: Lower = 5
                                   Upper = 6

Order  Base  Chi-Square
-----
  5     0.0105  1.852E+03
  6     0.0099  1.821E+03
    
```

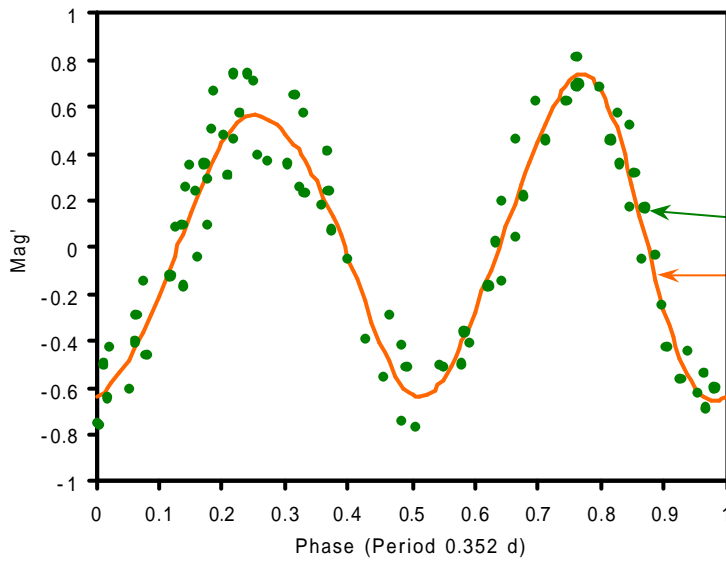
At the first stage, as usual, you will be asked to select an evaluation task, and type the input filename. After the program recognizes number of data and the time-span is more than one day, you need to confirm whether or not the base-level of the data is (about) zero. Actually the program will run regardless the base-level. However, header of the output files revealed in Part 2 will be different, i.e. normmag becomes mag' if the data has zero base-level. Shifting magnitude is not needed if the base-level is zero. But, the base-level for the combined data is not exactly zero after completing Part 2 (see the above display table at the column Base).

Period revealed by the PDM and the Spectral Analysis can be different, even you select a single- or double-peak lightcurve. Hence, user must choose which period will be used for developing synthetic lightcurve(s). Preferring the Spectral Analysis than the PDM is highly recommended. Refer to the previous explanations for the output files.

Sample plots:



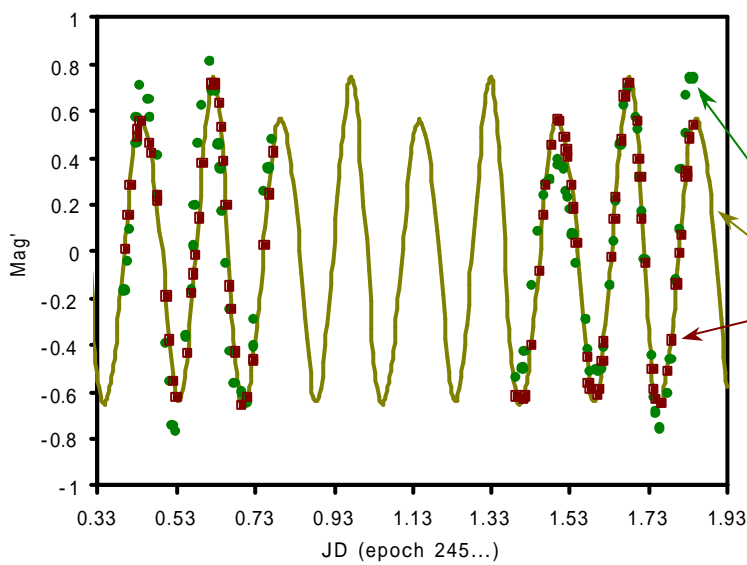
Spectral Analysis [*\*.spc*]



Rotational-phased lightcurve

"Data" [*\*.pha*]

Rot.-phased fitting curve [*\*.roc*]



All time-span lightcurve

"Data" [*\*.pha*]

Time-span fitting curve [*\*.fuc*]

Fitting data points [*\*.fud*]

