# Conditional Entropy Method to Detect Periods on Variable Stars

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## Introduction

- Necessity of method to work on data with gaps.
- Based on Information Theory and Shannon Entropy.
- The statistics is well know and developed.
- The Shannon Entropy measures the lack of information about a system.
- The correct period minimizes entropy.

## Conditional Entropy

The conditional entropy is calculated in the following way.

$$H = \sum_{i,j} p(m_i, \phi_j) \ln \left( \frac{p(\phi_j)}{p(m_i, \phi_j)} \right)$$

Where:

- $p(m_i, \phi_j)$ is the probability of $m_i$ given $\phi_j$.
- $p(\phi_j)$ is the probability over the jth phase bin.

## Method

- For a range of periods (0.1 to 32 days), we phased the data for each period and calculate the CE.
- Phase: $\phi_i = \frac{t_i}{perid} - \left\lfloor \frac{t_i}{period} \right\rfloor$
- The correct period will return a ordered lightcurve and will return a small value for the CE.

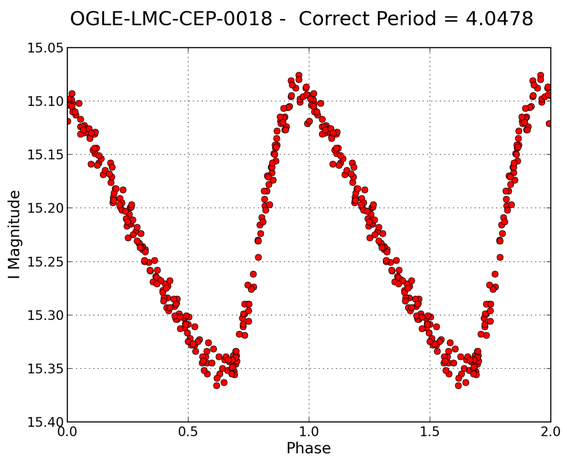


Figure 1 : Data phased with correct period

- A wrong period will produce a random arrangement of points.
- Also, a wrong period will have a higher CE value.

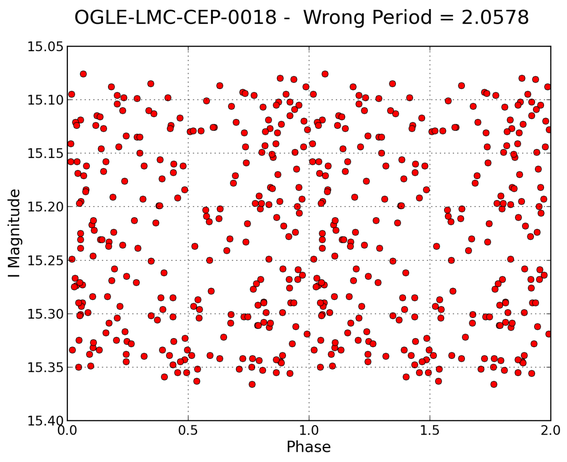


Figure 2 : Data phased with wrong period

## Results

- Method applied for fundamental mode (FU) Cepheids on OGLE Catalog.

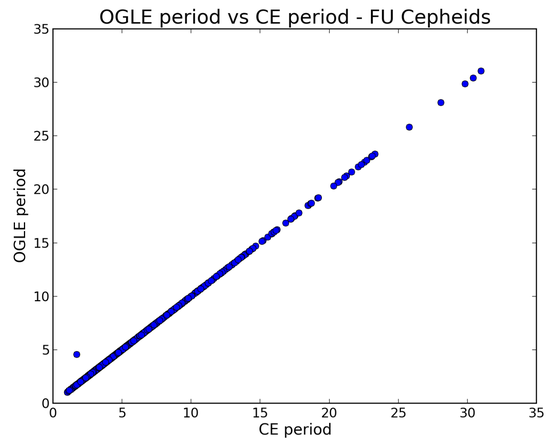


Figure 3 : OGLE period vs. CE period for Fundamental Mode Cepheids

- For all FU Cepheid just one star with different period.
- OGLE period = 4.567 , CE period = 1.7162

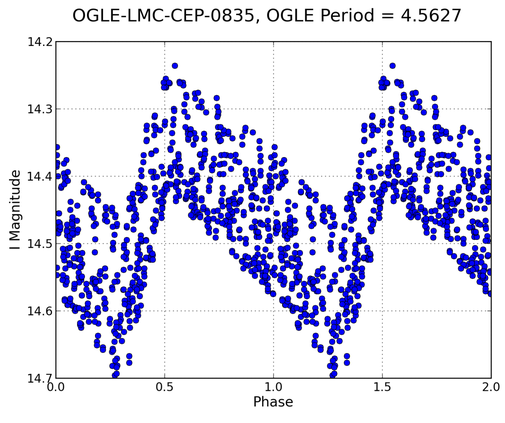


Figure 4 : Data phased with OGLE period

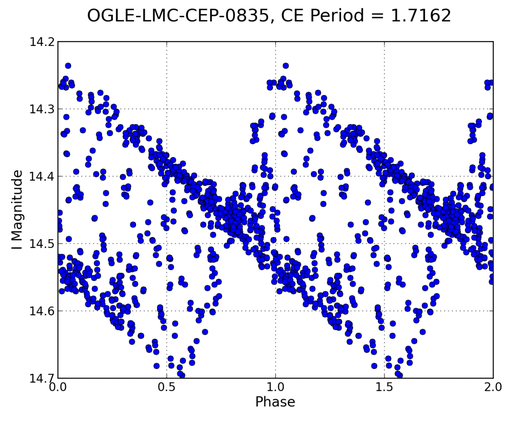


Figure 5 : Data phased with CE period

- CE period presents a good gathering of points
- OGLE period presents a better shape

## Entropy vs Period

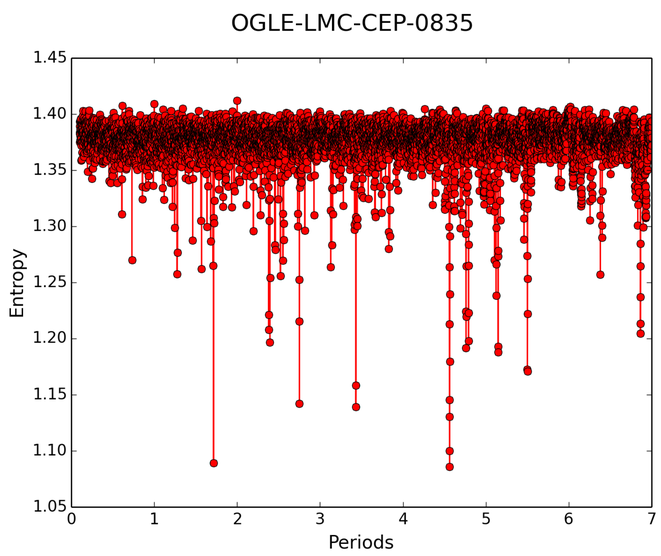


Figure 6 : Entropy vs Period - OGLE-LMC-CEP-0835

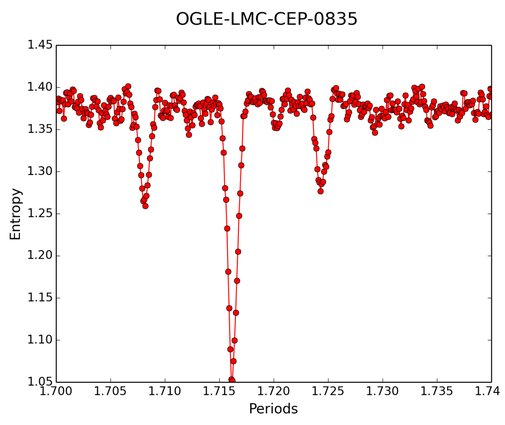


Figure 7 : Entropy vs Period - 1.7 to 1.74

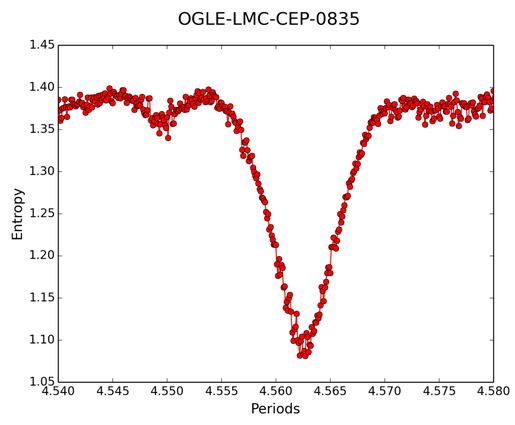


Figure 8 : Entropy vs Period - 4.54 to 4.58

- The peak on the CE period has a interference pattern.
- On the other hand, the peak on OGLE period has a better shape.
- This interference pattern could be another pulsation mode.

## First Overtone Cepheids

- Results for First Overtone (FO) Cepheids on OGLE Catalog

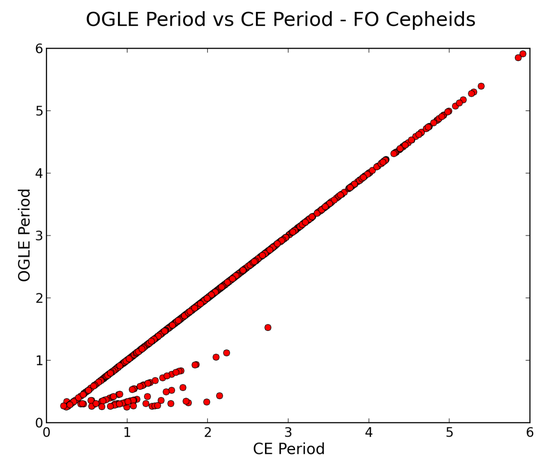


Figure 9 : OGLE period vs. CE period for FO Cepheids

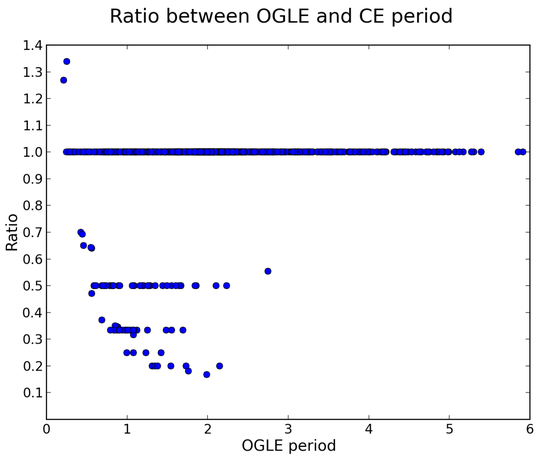


Figure 10 : Ration between OGLE period and CE period

- The CE code returned some different results.
- Figure 10 shows the ratio between OGLE and CE period.
- Some different results are harmonics of the correct period.

## Forthcoming Research

- Implement a filter for periods multiples of one day and for harmonics.
- Develop a method for peak significance criterion.
- Apply for multi-mode stars.
- Optimize code to run faster.

## References

[1] M. J. Graham, A. J. Drake, S. G. Djorgovski, A. A. Mahabal, and C. Donalek.
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