Observations of cepheids in the Pi of the Sky experiment

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Types of cepheids
- Cepheids - pulsating stars
- Classical cepheids
- Classical cepheids pulsating in first-overtone mode
- Population II cepheids

Searching for cepheids in Pi of the Sky data
- Selection of cepheids
- Fourier analysis

Analysis of Pi of the Sky data
- Program CepheidsQT
- Fourier parameters

Analysis of not identified stars
- Candidate for classical cepheid
- Candidate for overtone cepheid

Summary
Cepheids - pulsating stars

- Period: 1-135 days
- Amplitudes from several hundredths to 2 mag in V
- Spectral type: F (maximum light), G-K (minimum)
- Period correlate to spectral type
- The instability strip - small range of temperature, and full range of luminosity

Hertzsprung - Russell diagram
Pulsation

- **Radially pulsating**
  The star remains spherical and simply changes its volume.

- **The number of nodes:**
  - $n = 1$ Fundamental mode:
    stars move in and out as a continuous whole
  - $n = 2$ First - overtone mode (1FO):
    part of the star expanding while other parts contract

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Second overtone of radial pulsation.
Cepheids come in two types:

- **Type I:**
  metal rich, more luminous, stars of the galactic disk (young stars, open clusters and galactic spiral arm)

- **Type II:**
  metal poor, less luminous, stars of globular clusters and the galactic bulge

The period-luminosity relationship makes cepheids useful for obtaining distances.
Classical cepheids or Delta Cep-type variables (DCEP)

- Young disk population, open clusters
- Comparatively young objects that have left the main sequence and evolved into the instability strip of the H-R diagram

Phased light curve of T Cru star, period = 6.7339d. Data from Pi of the Sky collected during period 2006-2009.
Classical cepheids pulsating in first-overtone mode (DCEPS)

- Period: <7d
- Amplitudes <0.5 mag in V
- Almost symmetrical light curves

Phased light curve of V0397 Car star, period = 2.0635d. Data from Pi of the Sky collected during 2006-2009.
Population II cepheids (CW)

- Period: 0.8-35 days
  - P > 8d: CWA (W Vir)
  - P < 8d: CWB (BL Her)
- Amplitudes:
  0.3 - 1.2 mag in V
- For equal period fainter than the DCEP stars by 0.7 - 2 mag

Selection of cepheids:

- Stars in GCVS and ASAS database identified as cepheids population I
  - consider only objects found in P. Moskalik catalog and DDO catalog (David Dunlap Observatory)
  - separate classical cepheids, overtones cepheids and double mode (based on P. Moskalik and DDO catalogs)

- Stars in GCVS and ASAS database identified as cepheids population II

Prepared list consists of 238 cepheids:
- classical cepheids: 178
- overtones cepheids: 18
- population II cepheids: 42

Stars found in Pi of the Sky:
- classical cepheids: 100
- overtones cepheids: 31 (14 + 17 from another resources)
- population II cepheids: 8
Classical cepheids (DCEP)

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Overtones cepheids (DCEPS)
Population II cepheids (CW)
Fourier analysis

- Classification of pulsation mode
- Fourier decomposition techniques

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

\[ f = \frac{1}{P} \]

- \( V_r \) - magnitude observed at time \( t \), \( A_0 \) - the mean magnitude, \( A_k \) - amplitude of \( k \)-component, \( f \) - frequency, \( P \) - pulsation period, \( \phi_k \) - the \( k \)-th phase at \( t = t_0 \).
- \( 2f, 3f, 4f \) - First, second, third harmonic of the main frequency
- \( N \) - order of fit
Fourier parameters

- Define the shape of the light curves
- Two groups:
  - The amplitude ratios:
    \[ R_{ij} = \frac{A_i}{A_j} \]
  - The phase shifts:
    \[ \phi_{ij} = j\phi_i - i\phi_j \]
- Rising time: the phases of maximum and of minimum brightness (M-m)

In plots of Fourier parameters against period is clear separation between classes of cepheids
Function of CepheidsQT

- reading data from file or Pi of the Sky database,
- finding period (method of string length)
- calculating Fourier parameters
- creating phased light curve, plot of Fourier parameters against the logarithm of period
- calculating probability of the type of analyzing star
Fourier parameter plots for reference star: $A_1$, $M-m$
Fourier parameter plots for reference star: R21, R31
Fourier parameter plots for reference star: $\phi_{21}$, $\phi_{31}$
Candidate for classical cepheid - phased light curve

- Star not identified by ASAS or GCVS
- RA: 18h:09m:48s Dec: -18°22'39"
- \( P = 7.2878 \) days
- 94% DCEP

Pi of the Sky light curve (left) and ASAS (right)
Candidate for overtone cepheid - phased light curve

- star not identified by ASAS or GCVS
- ra: 21h:40m:25s dec: -28°04′43″
- P = 2.1874d
- 60% DCEPS

Pi of the Sky light curve (left) and ASAS (right)
Summary:

- Catalog of 150 cepheids observed by Pi of the Sky with more than 200 measurements
- User-friendly program for Fourier analysis
- Identification of new cepheids
THE END