Summary of the Pi of the Sky photometry improving methods

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Reduction and cataloging of the collected data.
Determining of the collected data quality.
Spectral correction.
Statistical data quality estimate.
Comparison of all methods.
Period detection improvement.
Summary.
Reduction and cataloging of the collected data.

- **on-line reduction.**
  - flash recognition in real time analysis frame by frame.
  - dark frame substraction.
  - fast photometry including numerical filter.
  - comparison with reference image (series of previous images).
- **off-line reduction.**
  - algorithms optimized for data reduction.
  - adding 20 subsequent frames.
  - dark frame substraction.
  - multiple aperture photometry (ASAS)
  - astrometry
  - normalization to V magnitudes from TYCHO catalog.
  - cataloging of raw data to the database.
Reduction and cataloging of the collected data.

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Reduction and cataloging of the collected data.

\[<\text{RMS}> \sim 0.04 \text{ mag for stars 7-9 mag}\]
Reduction and cataloging of the collected data.

Phased light curve and its residuals histogram before any corrections sigma ~ 0.055 mag.
Determining of the collected data quality.

Multilevel selection system dedicated to detect and mark bad measurements caused by such effects as:

- Bad weather conditions.
- Astronomical effects: strong Moon background, cosmic rays, meteors.
- Instrumental effects: opened shutters, cold/hot pixels, fluctuations.
- Satellites, planes etc.
Determining of the collected data quality.

\[<\text{RMS}> \approx 0.035 \text{ mag for stars 7-9 mag}\]
Photometry accuracy significantly improves after removing bad quality data
For stars $7^m - 10^m$
$\langle \sigma_m \rangle \approx 0.018 - 0.024$ achieved

Histogram of sigma magnitude for stars with magnitude $< 12.5$

Measured brightness dispersion vs magnitude for unfiltered measurements

Measured brightness dispersion vs magnitude for filtered measurements
Determining of the collected data quality.

Phased light curve and its residuas histogram after dp sigma ~ 0.058 mag.
Spectral correction:

- used to standardize our data with catalog data.
- takes into account spectral response of our optical system and its correlation with the observed star spectral type.
- easily calculated for catalog stars, we developed generalizing procedure.
- this procedure gives us additional information about data quality.

\[ M_{\text{corr}} - M = -0.2725 + 0.5258 \times (J - K) \]
Spectral correction.

\[ \langle \text{RMS} \rangle \sim 0.03 \text{ mag for stars 7-9 mag} \]
Spectral correction.

Phased light curve and its residuals histogram after spectral correction sigma ~ 0.038 mag.
Statistical data quality estimate:

- we are taking into account statistical properties of the group of frames.
- we compare brightness of the visible catalog stars with their median brightness calculated based on all measurements taken from the same field.
- for each catalog star we calculate $|M - Med|$ and check how many cs have $|M - Med| > 2\sigma$.
- depending on the number of bad cs the frame receives appropriate quality.
Statistical data quality estimate.

<\textit{RMS}> \sim 0.035 \text{mag for stars 7-9 mag}
Statistical data quality estimate.

Phased light curve and its residuas histogram after statistical correction sigma ~ 0.034 mag.
Comparison of all methods.

- each algorithm gives us independent determination of the data quality.
- how to find the best combination of the data quality which give us the best quality and not remove a lot of data?
Comparison of all methods.

- For each combination of the data quality we calculate lc residuas or lc residuas / sqrt(\% data) and find the minimum value.

Residuas plots.
Comparison of all methods.

Phased light curve and its residuals histogram after all corrections sigma ~ 0.033 mag.
Comparison of all methods.

\[<\text{RMS}> \approx 0.025 \text{ mag for stars 7-9 mag}\]
Comparison of all methods.

- The best results are obtained for the LCO data due to small measurements errors, caused by better weather conditions than in INTA site.
- The obtained results depend on the kind of analyzed objects and their data quality.
- The best results we get after using the best combination of the calculated data quality $\langle RMS \rangle \sim 0.025^m$.
- Spectral ($\langle RMS \rangle \sim 0.03^m$) and statistical ($\langle RMS \rangle \sim 0.035^m$) corrections gives us the best improvement.
- Use only multilevel selection system dedicated to detect and mark bad measurements improves analyzed data but not enough.
Period detection improvement.

- We calculate the Fourier coefficients for the star before and after a quality cuts.
- We generate 1000 lcs based on this Fourier coefficients (before and after the qc).
- The RMS is taken from the residuals plot made for every star before and after the qc.
- For each lc we calculate period using AOV algorithm => we get 1000 periods.
- Example histogram and the calculated $\sigma$ are given below.
Period detection improvement.

Period detection error modelling.
Period detection improvement.

Period detection error modelling.
Summary.

- we have developed three algorithms which are used to improve the Pi of the Sky photometry results.
- we have developed method which allow us to select only the best measurements based on the best combination of the obtained results.
- obtained data quality, after using our methods is about $RMS \sim 0.02^m$ for LCO’s data and about $RMS \sim 0.025^m$ for INTA’s data.
- more precise results are possible to achieve through a dedicated analysis of the selected objects.
- improving photometry of the obtained results allow as to more precise calculate lc period.