Photometry of K2 Bulge data

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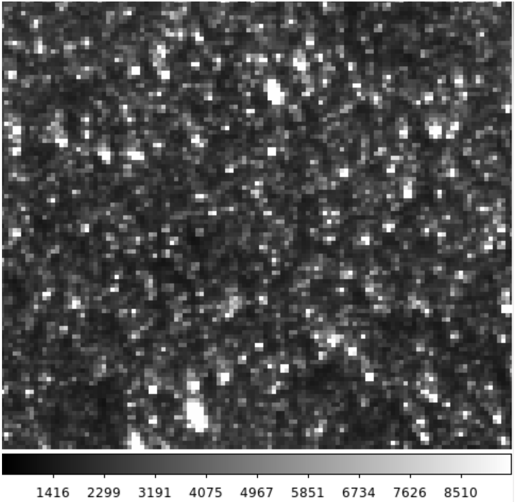
K2 – Campaigns 9 and 11

K2C9 – first space-based microlensing survey.

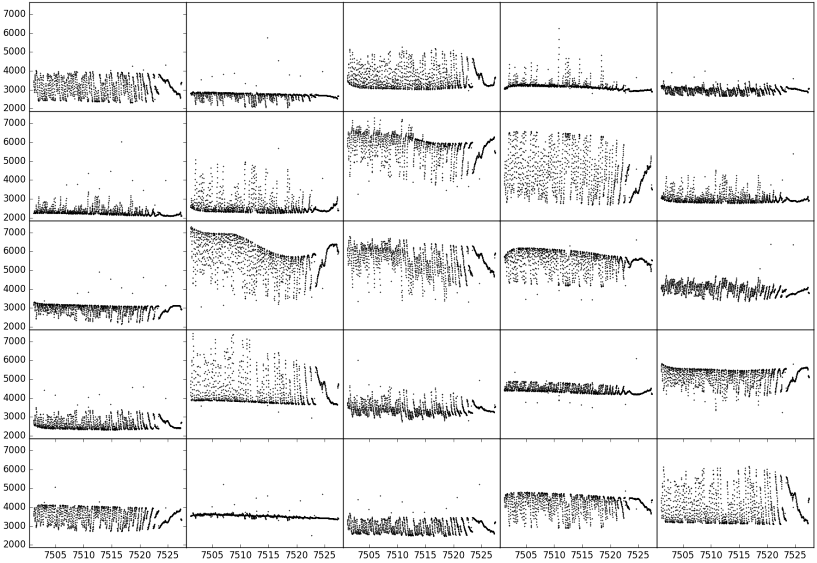
Photometry:

- unstable pointing,
- large pixel: $4'' \times 4''$,
- extended Point Response Function,
- extremely high stellar density.

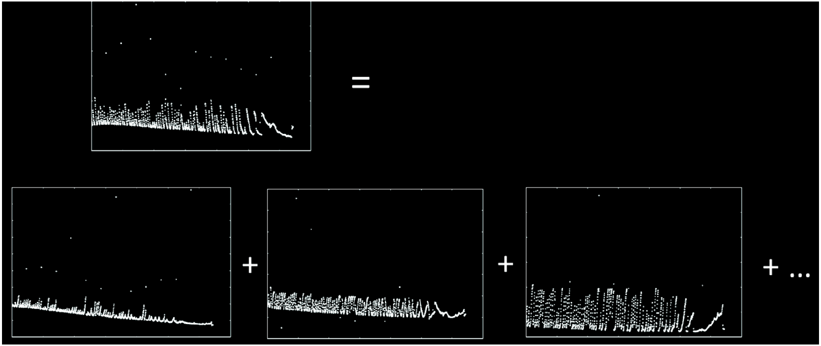


$7.6' \times 7.6'$ crop

Raw pixel curves



Causal Pixel Model – basics



by Dan Wang

$$I_{m,i} = \sum_{m'} a_{m,m'} I_{m',i} + e_{m,i}$$

Causal Pixel Model – Wang et al. 2016

Goal: K2 photometry for **transits**.

$$I_{m,i} = \sum_{m'} a_{m,m'} I_{m',i} + e_{m,i}$$

where:
i – epoch index,
m – target pixel index,
m' – some other pixels indexes,
$I_{m,i}$ – observed signal,
$e_{m,i}$ – residuum: noise and astrophysical signal,
$a_{m,m'}$ – CPM coefficients.

$$\chi^2_m = \sum_i (I_{m,i} - \sum_{m'} a_{m,m'} I_{m',i})^2 + \lambda \sum_{m'} a^2_{m,m'}$$

λ – L2-type regularization constant.

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CPM – limitations

- Works well if there is no signal most of the time, e.g., for transits.
- Could be run with astrophysical model, but added in a very simple way:

$$I_{m,i} = \sum_{m'} a_{m,m'} I_{m',i} + c_m F_i + e_{m,i}$$

- Possibility of overfitting.

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Then test new ideas on eclipsing binary OGLE-BLG-ECL-234840 ($V = 13.8$ mag, $P = 370$ d, $\Delta V = 0.3$ mag)...

MCPM – Modified CPM

Modifications:

- The astrophysical signal in given pixel: $F_i PRF_{m,i}$.
- Calculation of $PRF_{m,i}$ requires:
  - a priori knowledge of event coordinates,
  - astrometry of every epoch separately, and
  - *PRF* function (Bryson *et al.* 2010).
- Subtract astrophysical signal in given pixel **before** running CPM:

$$I_{m,i} - F_i PRF_{m,i} = \sum_{m'} a_{m,m'} I_{m',i} + e_{m,i}.$$

- Combination of multiple pixels with the same F_i.
- Set $F_i = A(t_i) F_{\rm sat}$. K2 source flux ($F_{\rm sat}$) becomes a fitting parameter.

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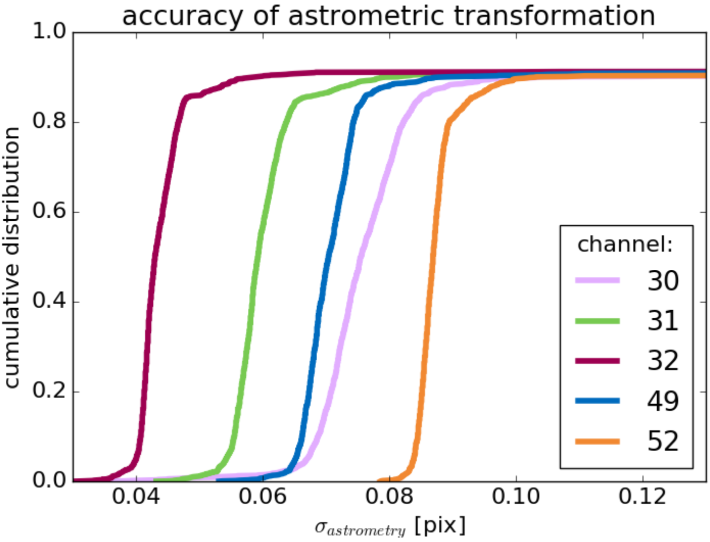
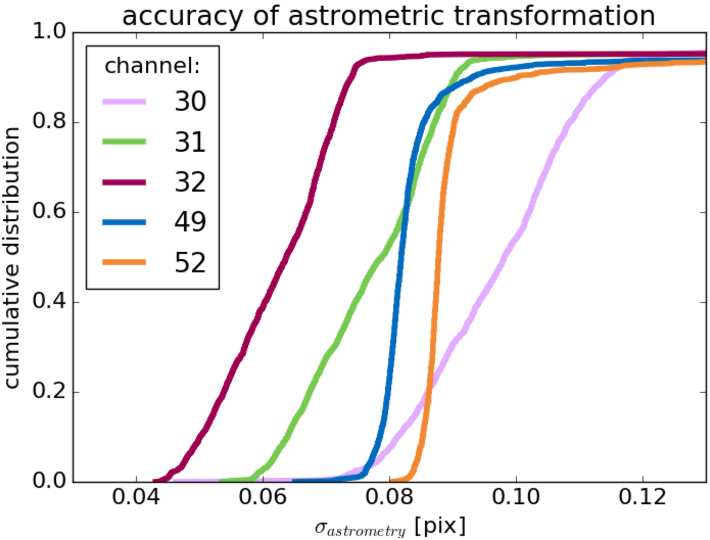
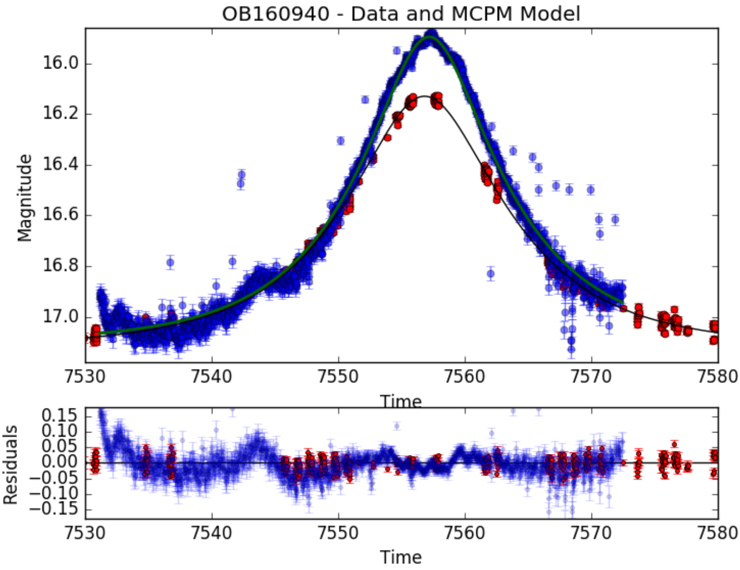
Astrometry of subcampaign 91



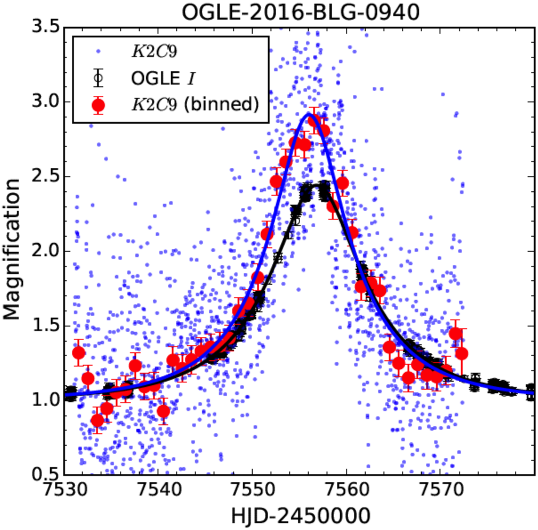
Astrometry of subcampaign 92



Example – OGLE-2016-BLG-0940



OGLE-2016-BLG-0940 – Zhu, Huang, Udalski et al. 2017



Links:

https://github.com/CPM-project/MCPM
https://github.com/rpoleski/MulensModel

Code useful for general model fitting and developed as part of WFIRST preparations by RP and Jen Yee.

Can be used in microlensing analysis challenges!

Summary:

- Simultaneous model fitting and photometry extraction is required.
- Satellite source flux is a fitting parameter.
- The MCPM method works well in general.