Towards first calibrated SNe 1a lightcurves using scene modeling

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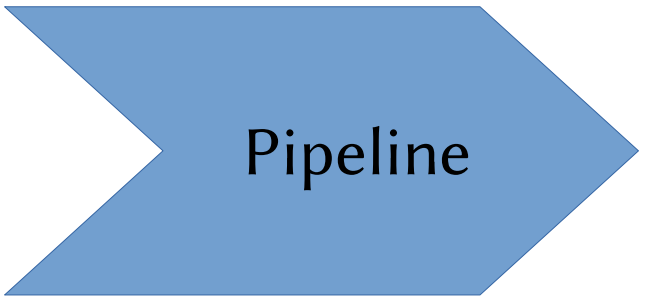
High level lightcurve calibration pipeline overview

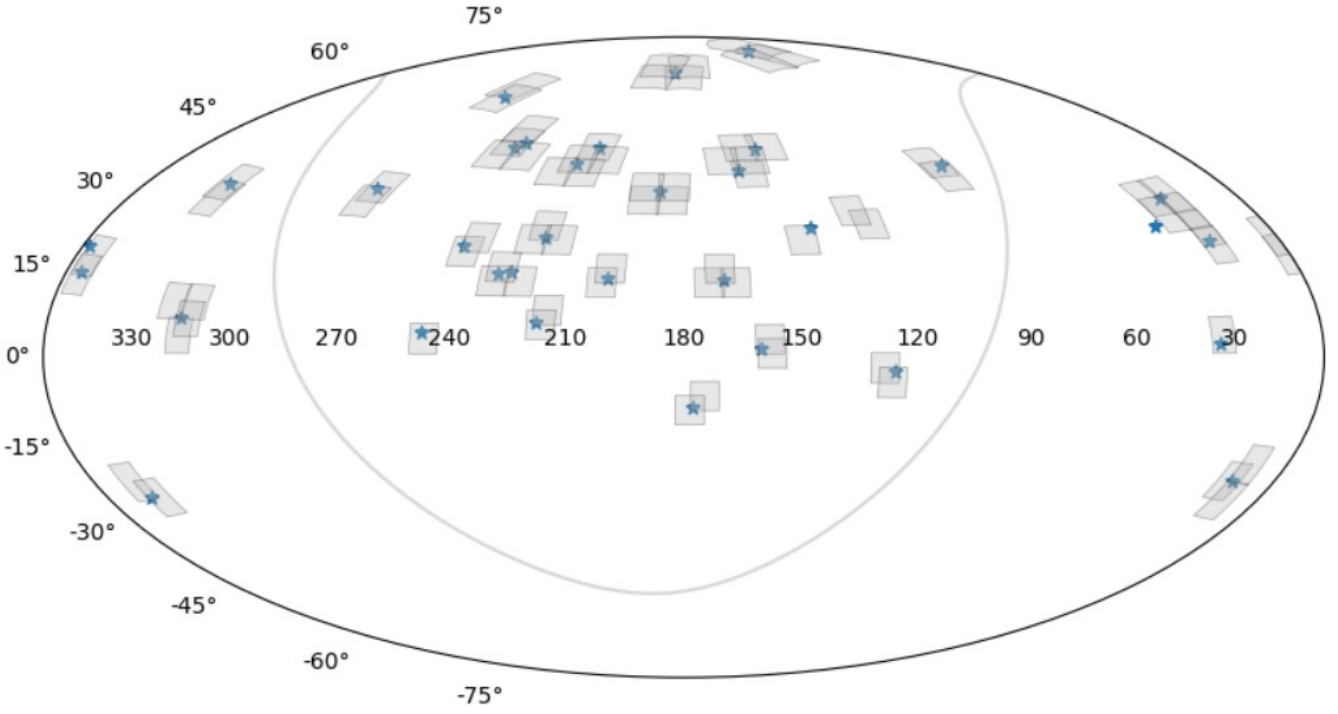
Raw pixels

- biases
- dead pixels
- flatfields

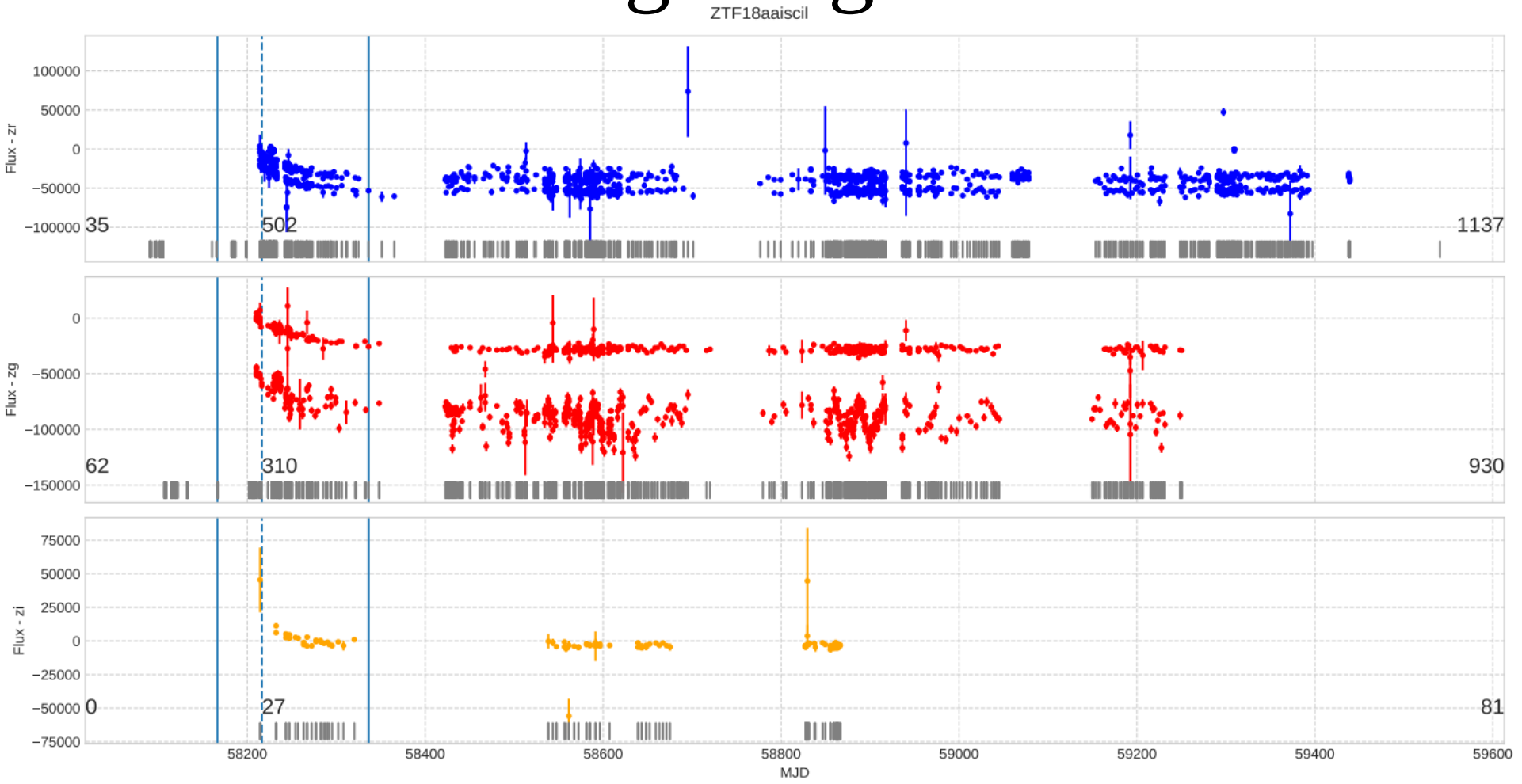


Calibrated lightcurves

Our SNe 1a selection



Some bogus light curves



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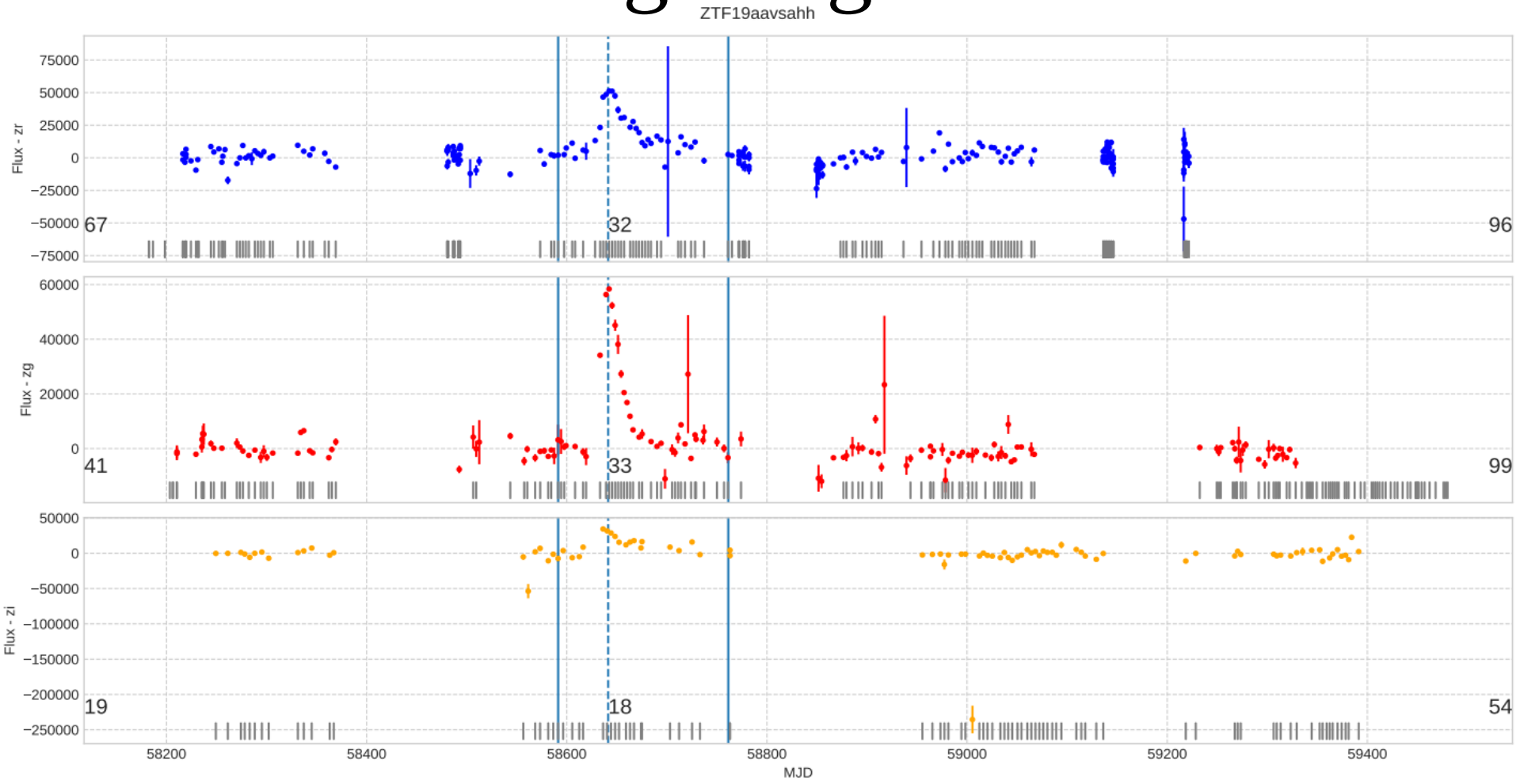
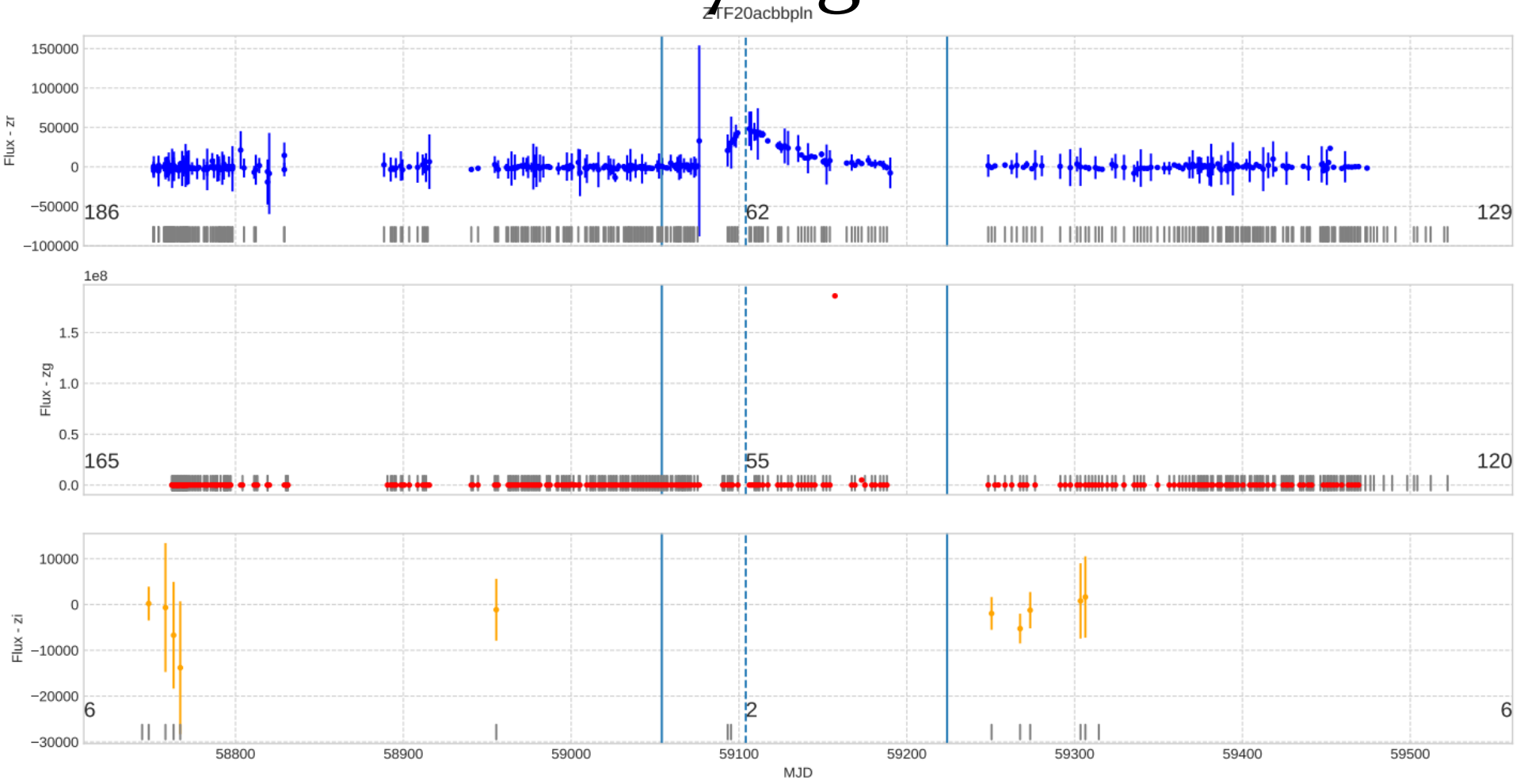
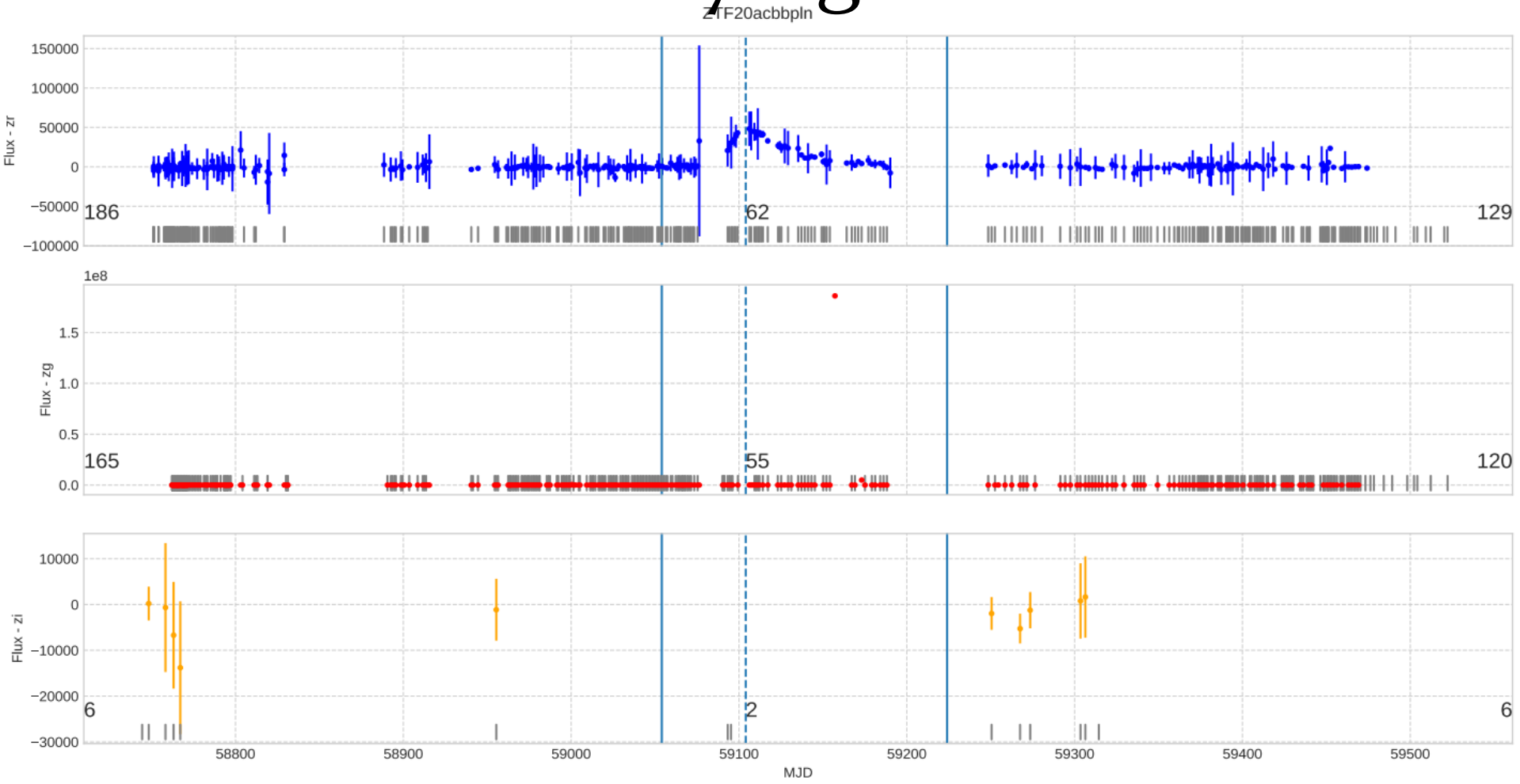


Some noisy light curves



Some noisy light curves



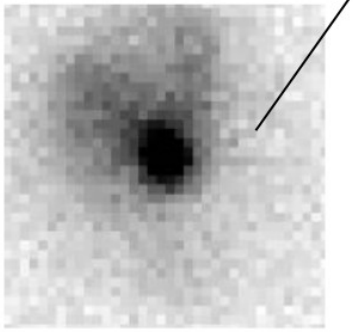
Scene modeling pipeline overview

- Process each SN 1a/band individually
- Software originally written for SNLS: the Poloka toolkit
  - ZTF dataset is quite different! (low z)

- First work on a reduced dataset (33 SN)

Scene modeling

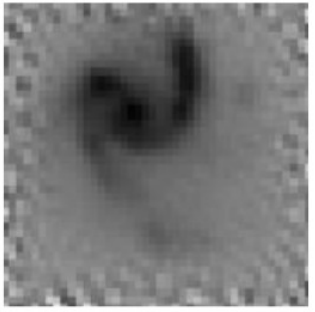
$$I_{ip} = f_i \, \phi_i + \mathrm{Gal} \otimes K_i + \ldots$$



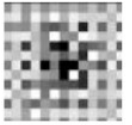
pixel p,
image i

SN
flux

PSF



Galaxy
profile



kernel

Scene modeling

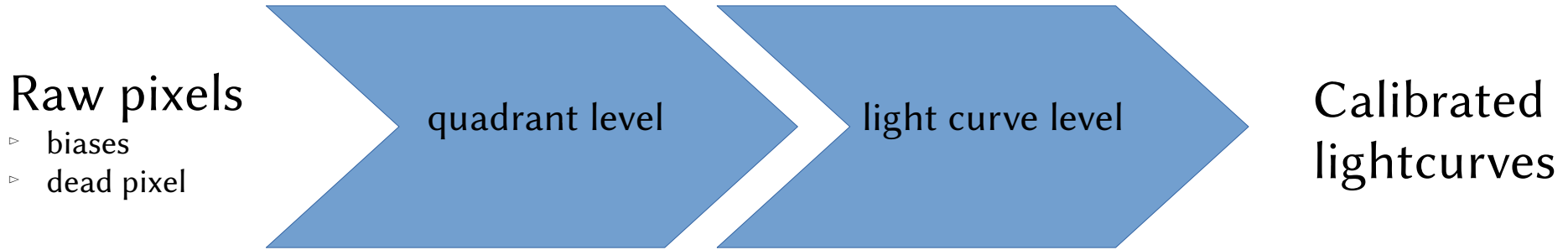
$$I_{i,p} = \alpha_i \phi_i(x_p - \varphi_i(x_{\mathrm{SN}}))f_i + \alpha_i G_p(\varphi_i^{-1}(x_p)) \circledast K_i$$

- Fit by Least Square

$$V = \begin{pmatrix} f_1 & \dots & f_n & x_{\mathrm{SN},1} & x_{\mathrm{SN},2} & G_1 & \dots & G_N \end{pmatrix}$$

Ingredients and pipeline for scene modeling

- Stamps of the stars and the SN
- PSF model ϕ_i
- Kernel K_i from reference PSF to current image PSF
- Relative astrometry φ_i
- Relative photometry α_i



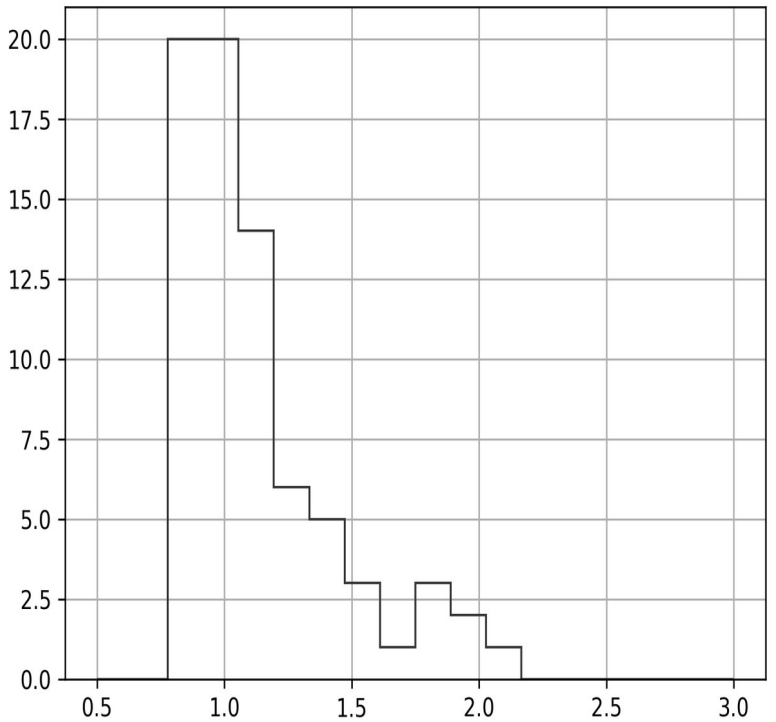
Quadrant level computations

- Segmentation step
  - Identify stars, galaxies, cosmics
    - SNLS: few stars, many galaxies
    - ZTF: many stars, few galaxies
  - Sextractor catalog
  - Sky background subtraction
- Weight map
- Aperture photometry of stars
- PSF model

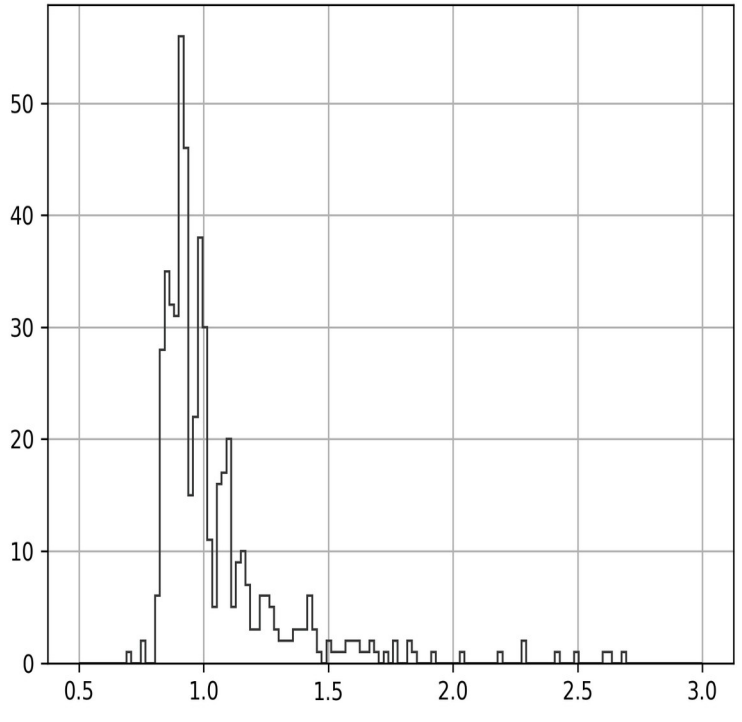
Some statistics on the reduced dataset

- 2 to 5 ZTF fields per SN
  - ~ 1500 stars per SN
- All detected stars are in the GAIA catalog
- Without modifying Poloka code: 95% success rate
- Computing time:
  - Personal laptop, 200 quadrants, 4 cores: 17 min (~ 0.2 quadrant/s)
  - At CC, 33k quadrants, 600 workers: ~ 3h (~ 3 quadrant/s)

Seeing distribution



ZTF19aavsaah – i band

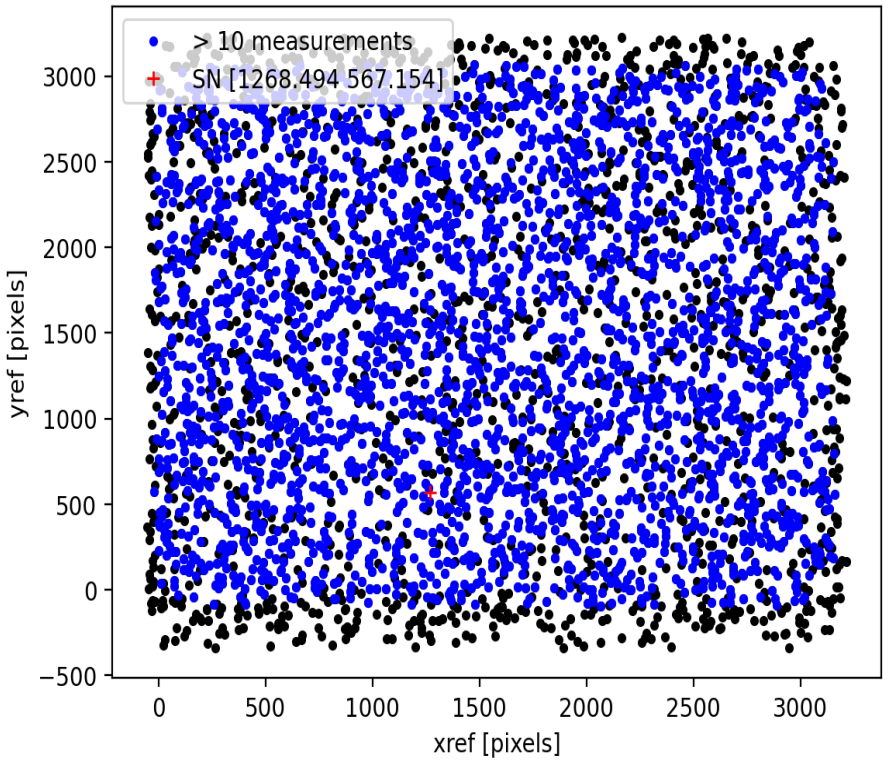


ZTF20abyptpc – g band

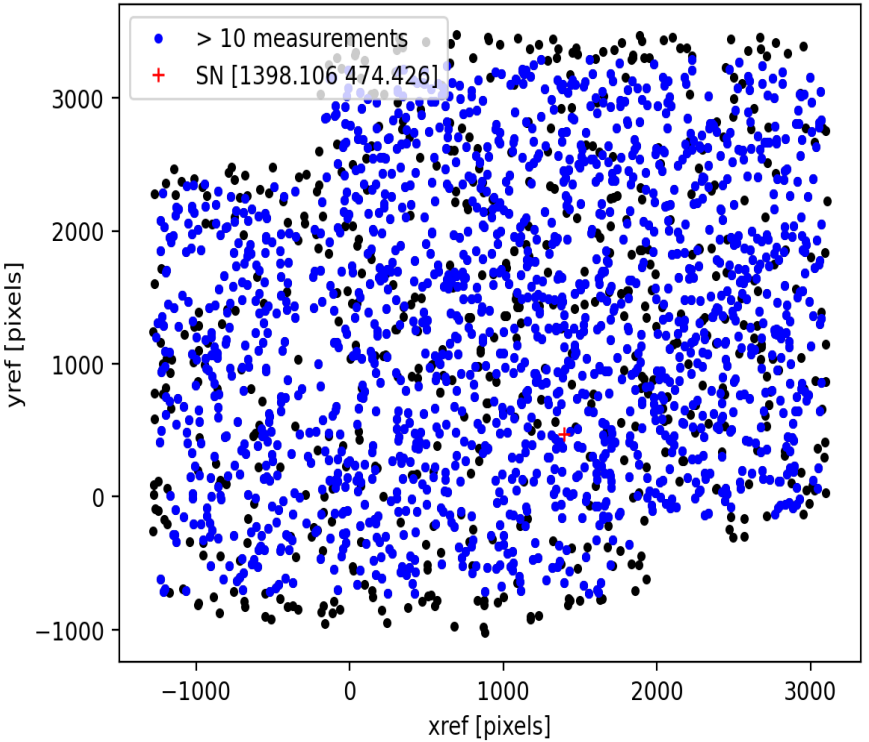
Lightcurve level computation

- Determine best seeing quadrant
  - Define it as our reference quadrant
- Group all quadrant stars into one field
  - Associate them to the GAIA catalog
- Sequentially run
  - Astrometry
  - Photometry
  - Scene modeling

Merged star fields



ZTF19aavsaah – i band

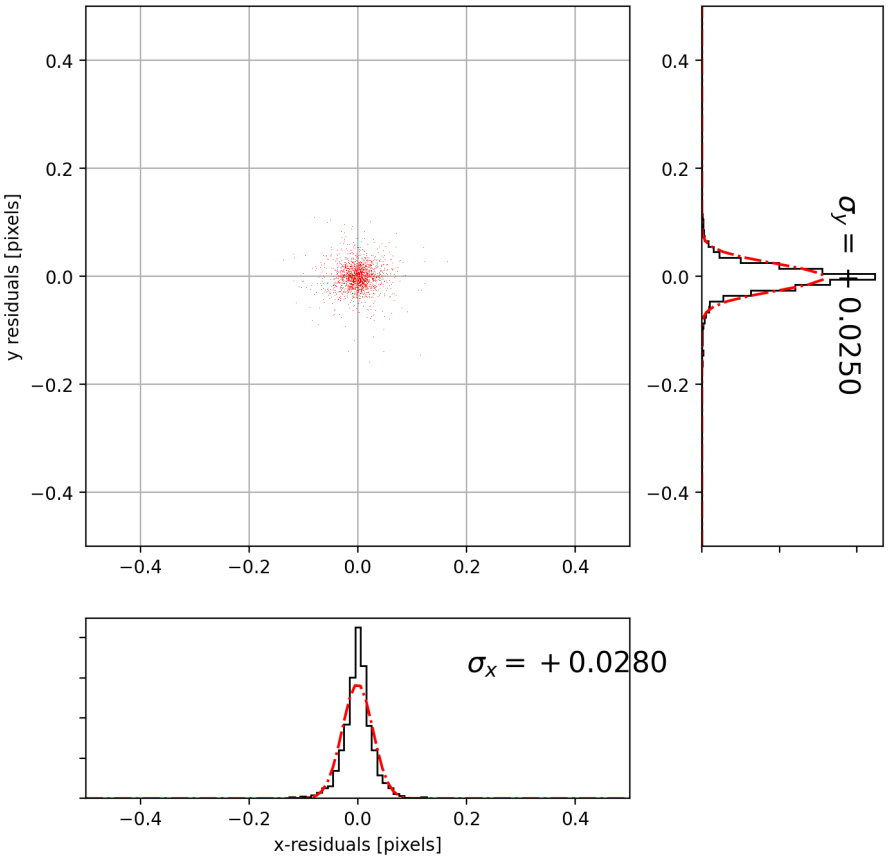


ZTF20abyptpc – g band

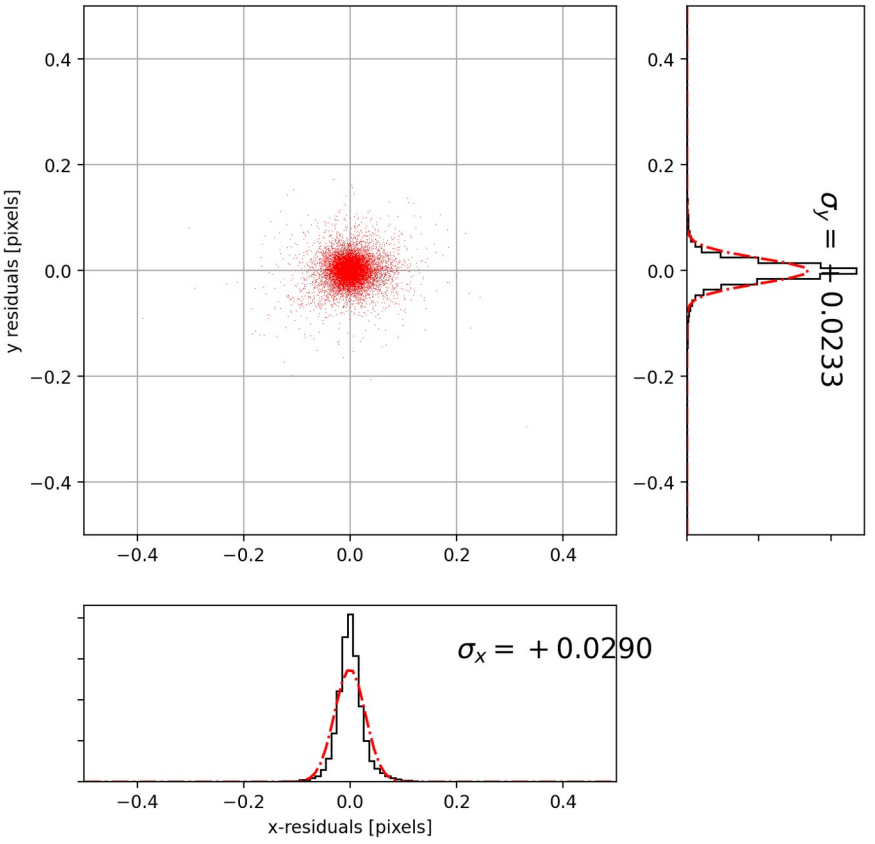
Relative astrometry

- Register stars positions onto reference stars
  - Polynomial model (directly optimize WCS in the future?)
- Estimate proper motion
  - Compare it to the GAIA measured ono
- Fit by Least Square

Residuals

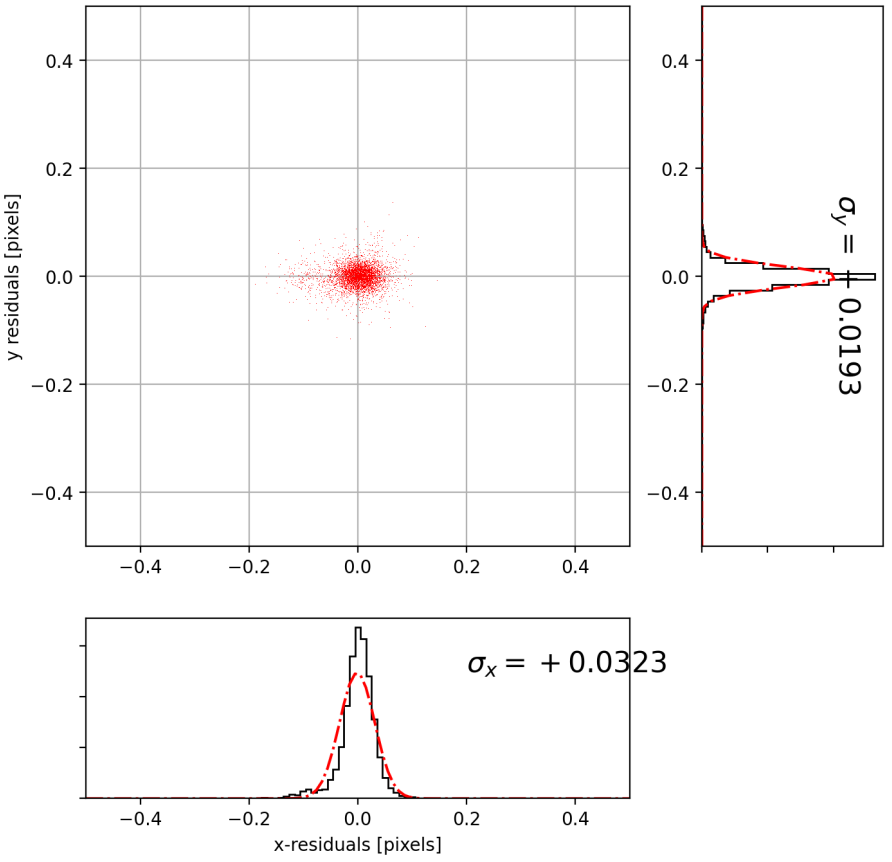


ZTF19aavsaah – i band

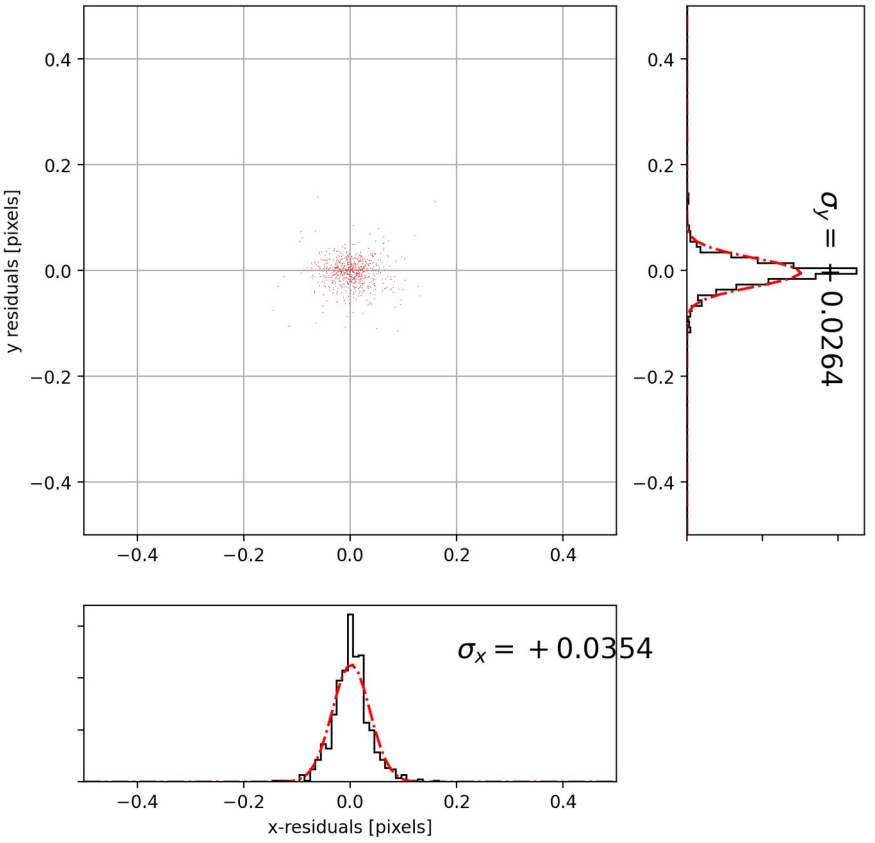


ZTF20abyptpc – g band

Asymmetric residuals ?

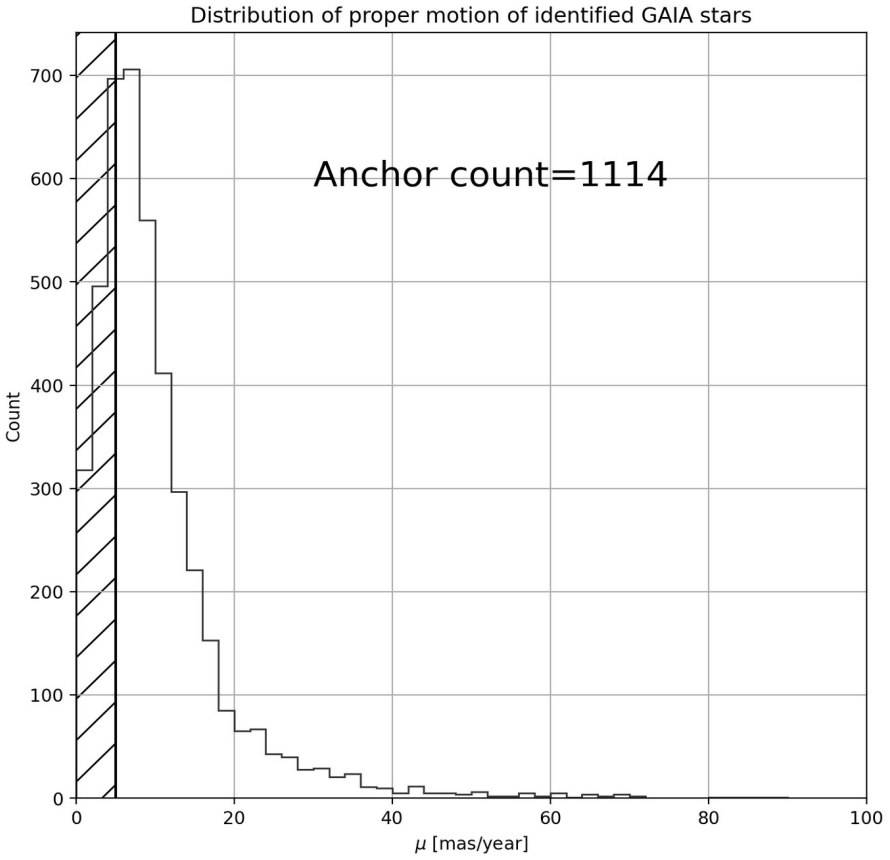


ZTF19aauhbua – g band

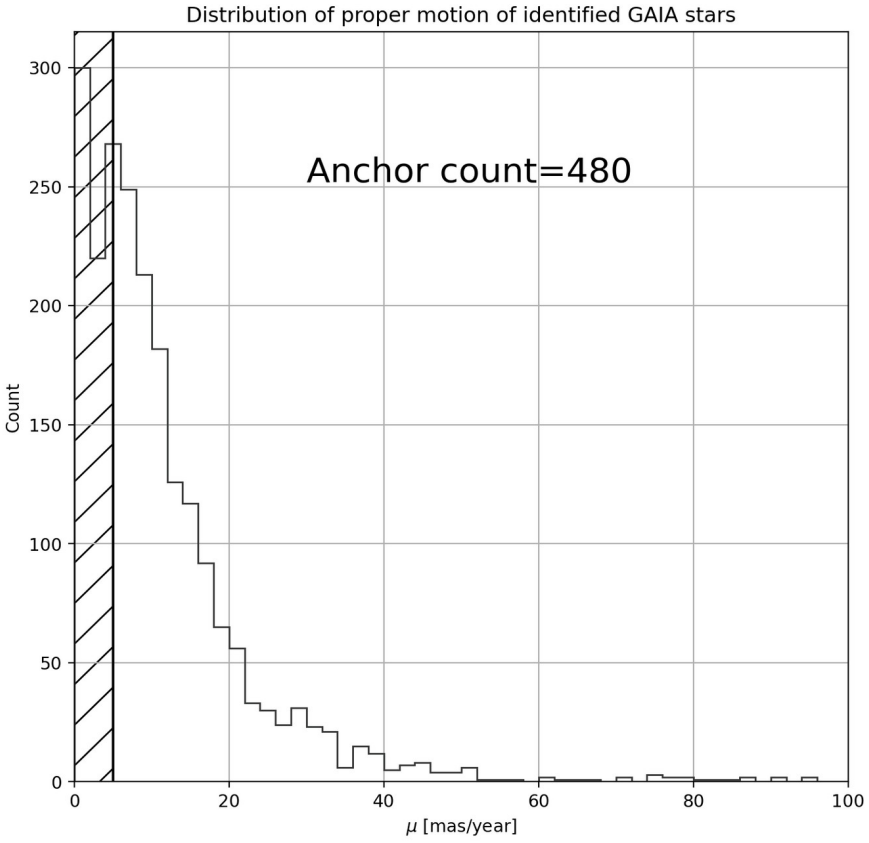


ZTF19aanbojt – i band

Proper motion distribution

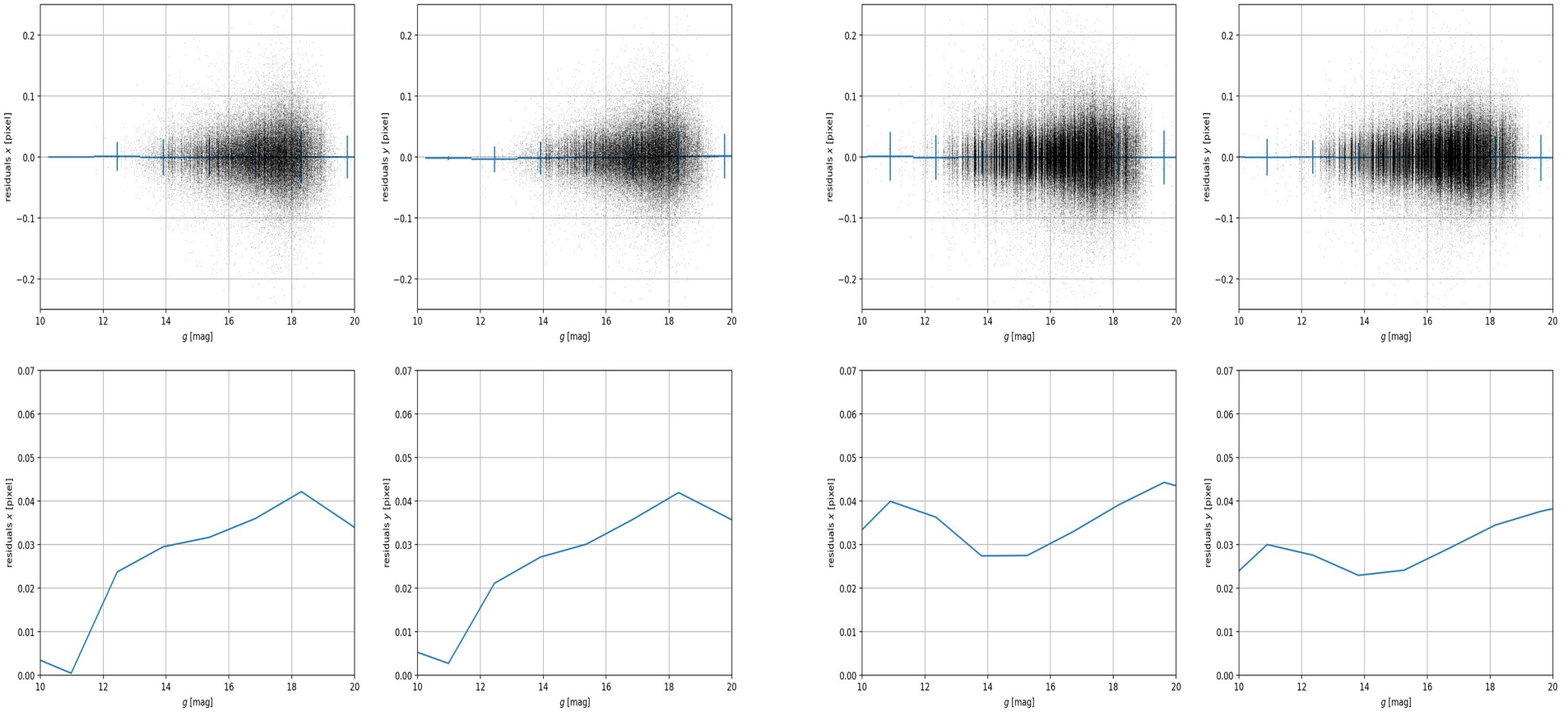


ZTF19aavsaah – i band



ZTF20abyptpc – g band

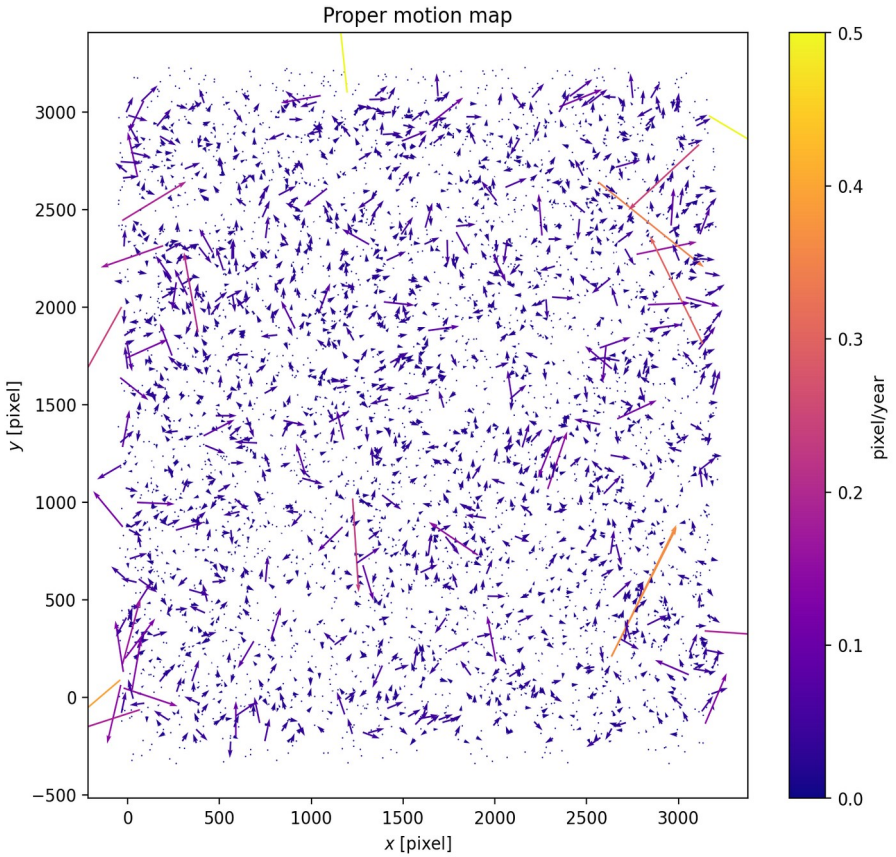
Residuals vs magnitude



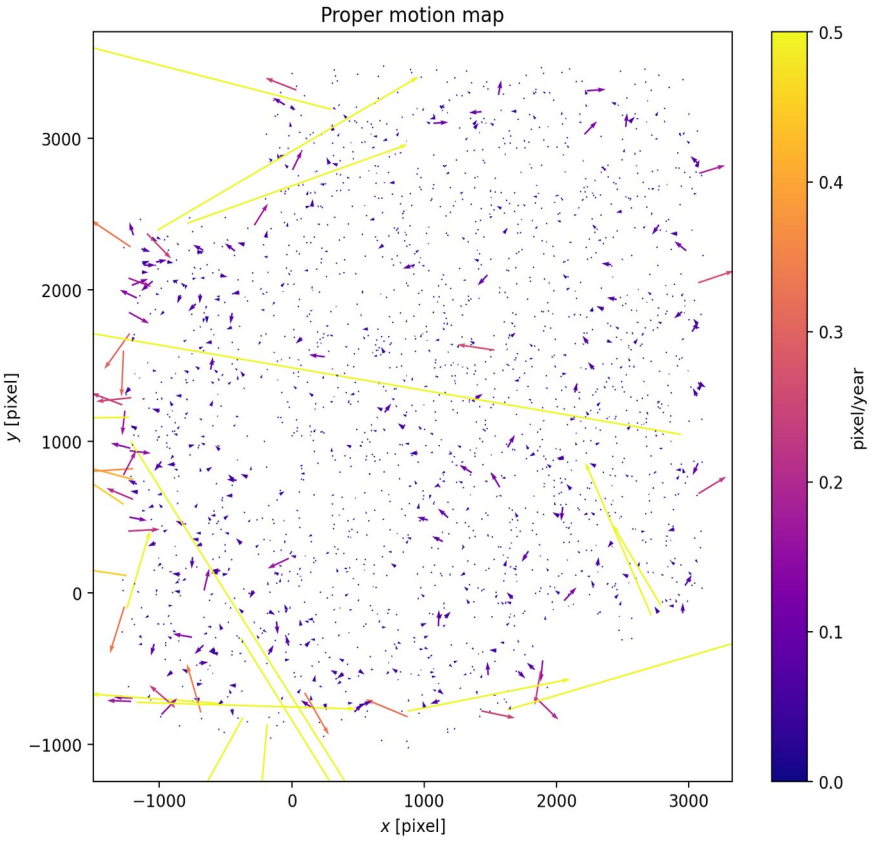
ZTF19aavsaah – i band

ZTF20abyptpc – g band

Proper motion sky distribution



ZTF19aavsaah – i band



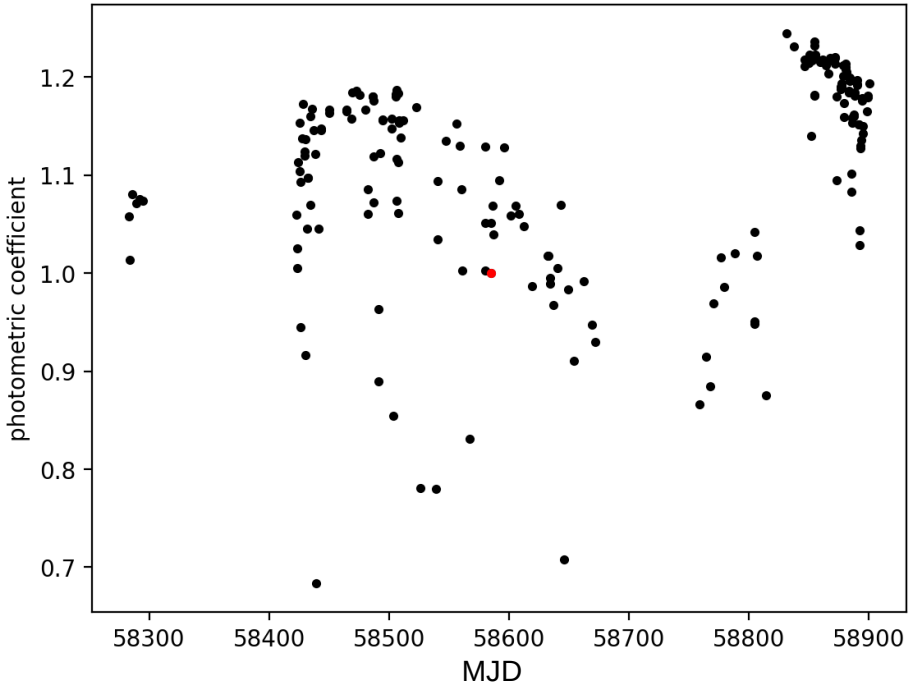
ZTF20abyptpc – g band

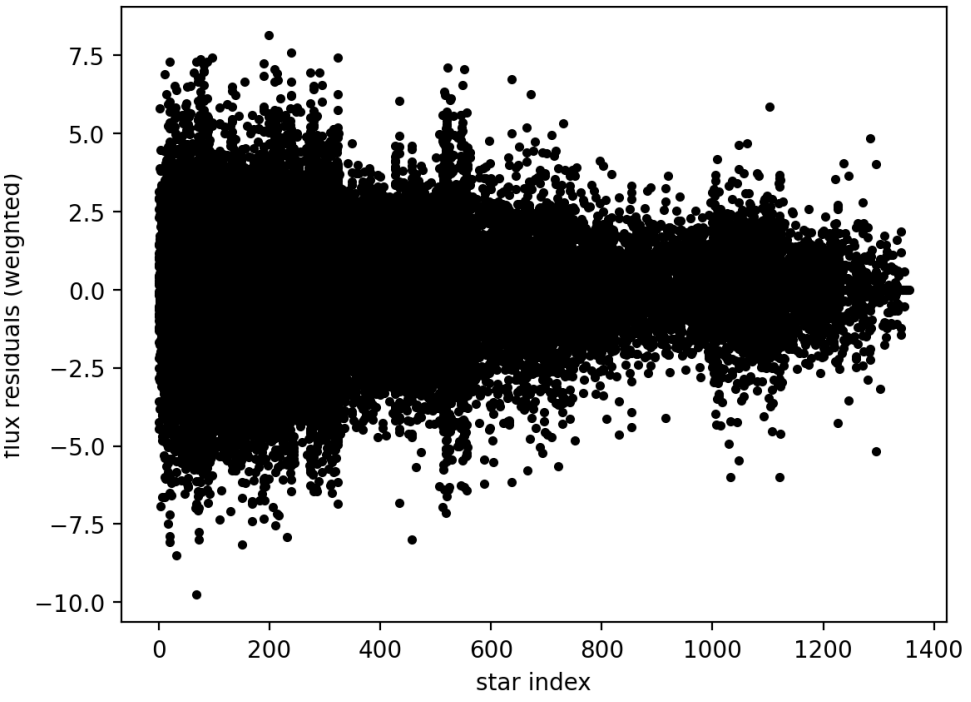
Relative photometry

- Variable stars detection
- Flatten stars light curves
  - Linear model
- Fit by Least Square

- Total (astrometry+photometry) mean run time : 1-5 min
  - Rarely, no convergence

Photometric ratios and residuals





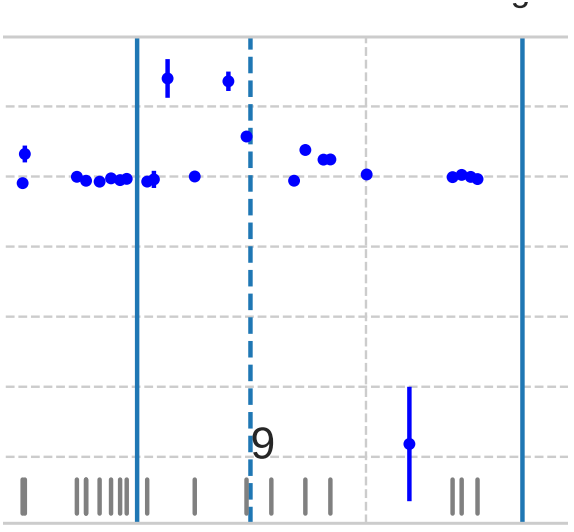
Implementation details

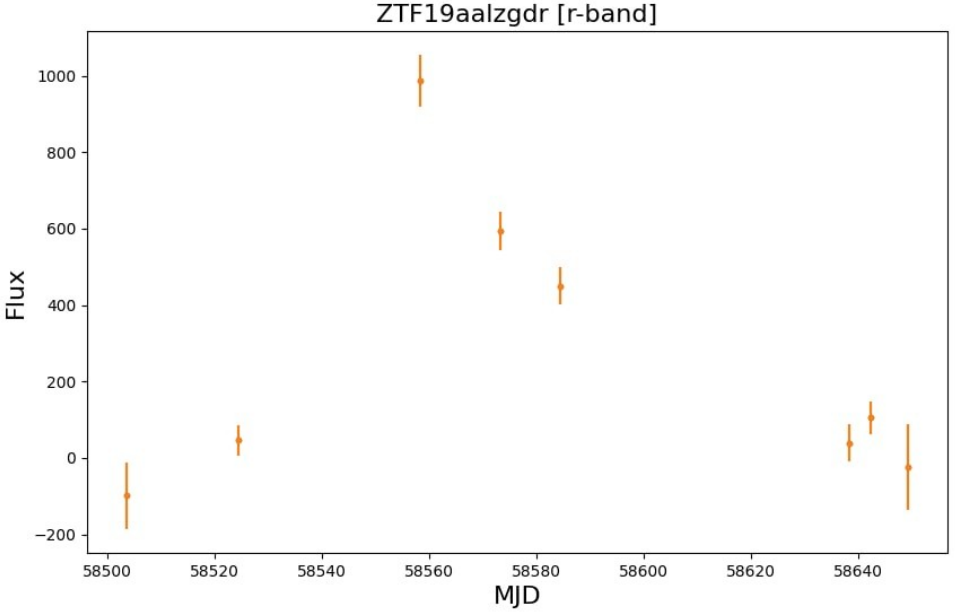
- Map/reduce computation scheme implemented on Dask
- Files mapped into ram disk
  - Poloka is very IO intensive
- Instrumented code

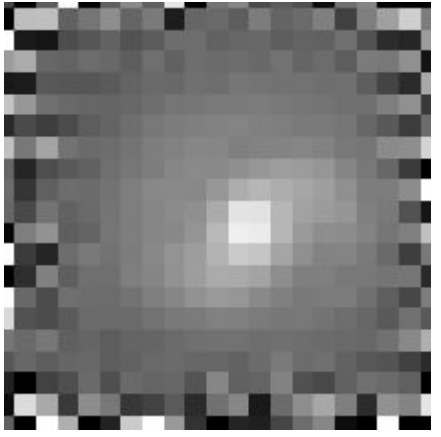
First calibrated light curves: when?

Well?

Breaking news: first preliminary results







Breaking news: first preliminary results