Defocused PSF-fitting Photometry

RoPACS Network Workshop - May 2010

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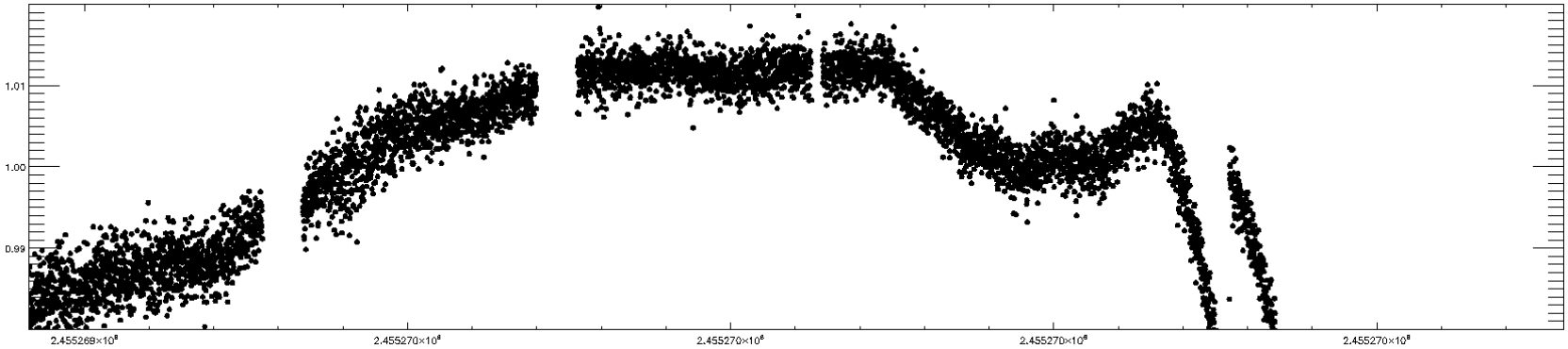
11.05.2010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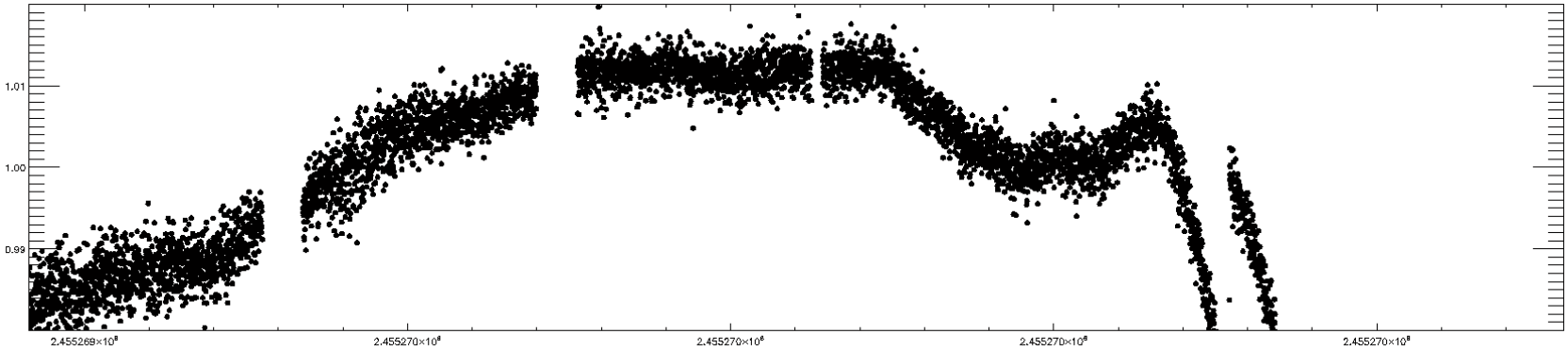
1.01
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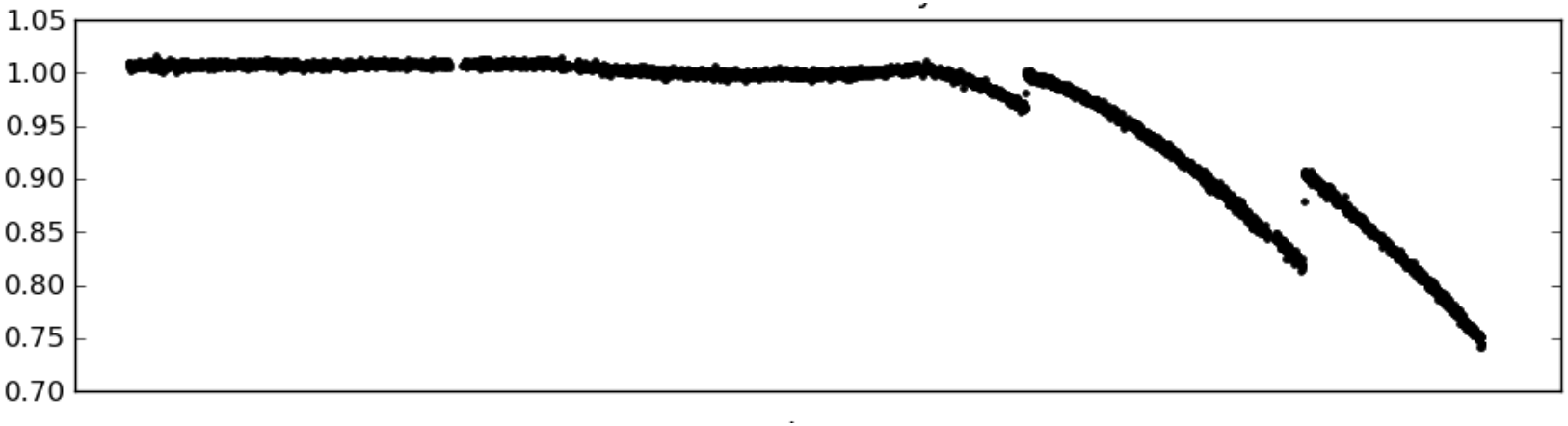
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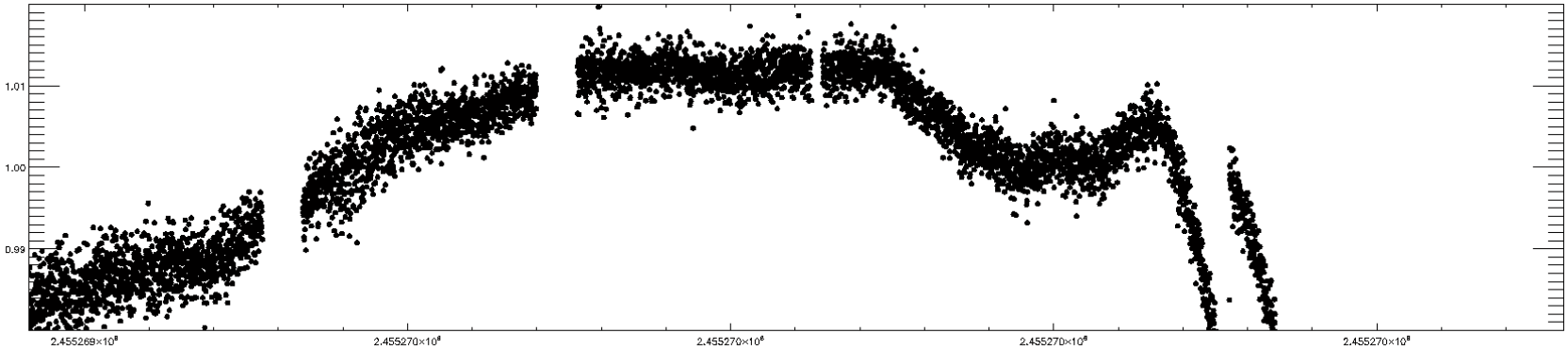
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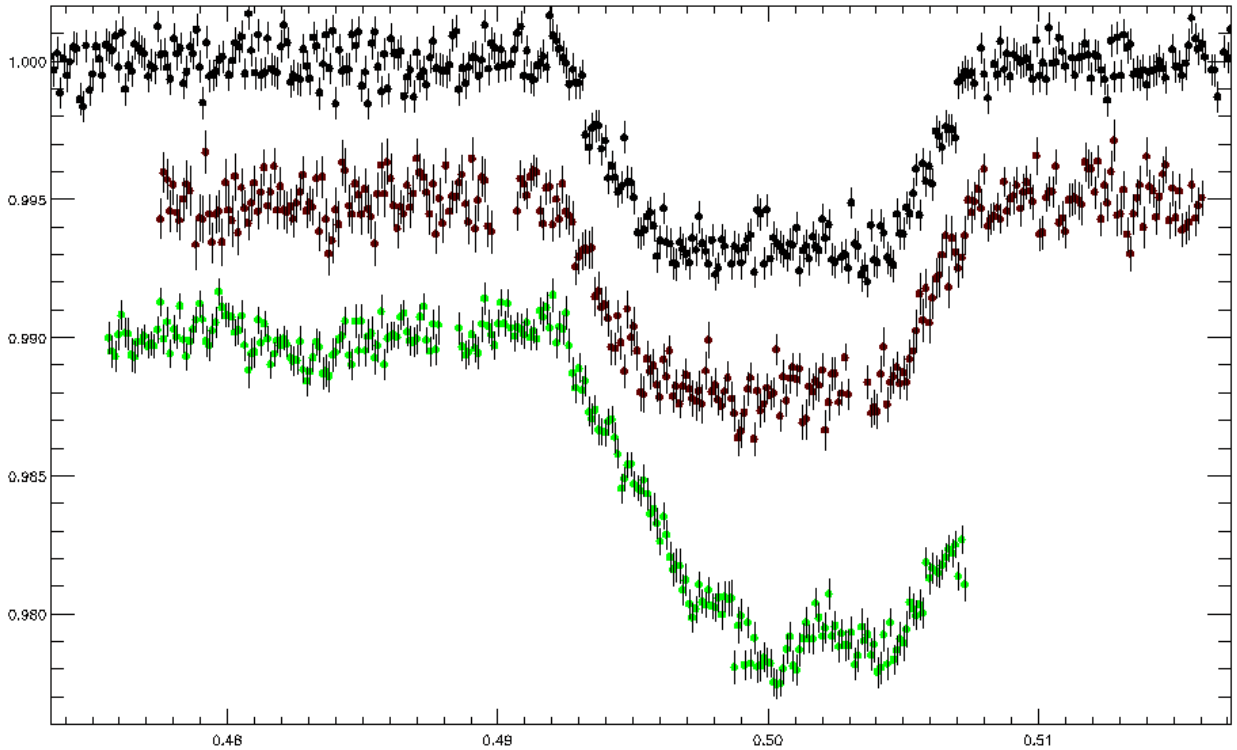
1.000
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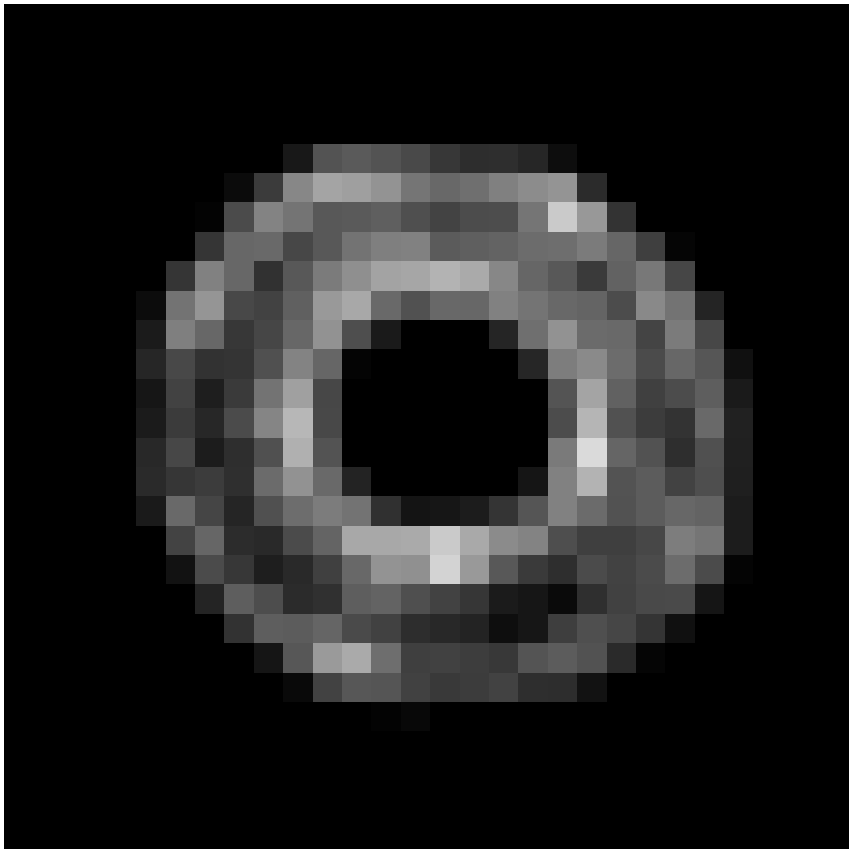
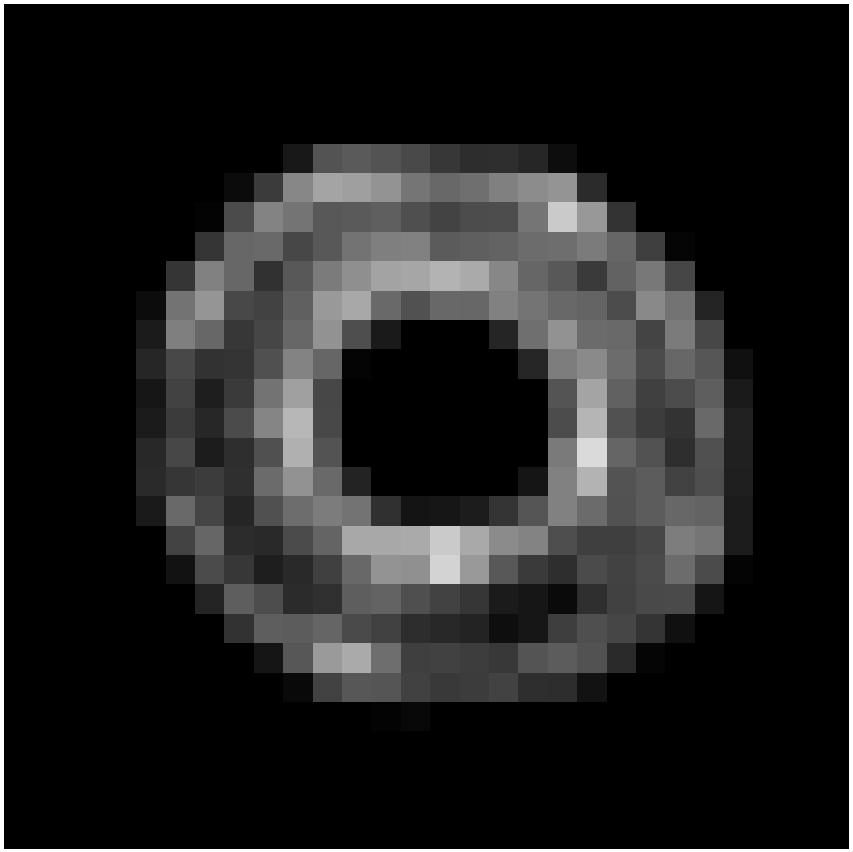
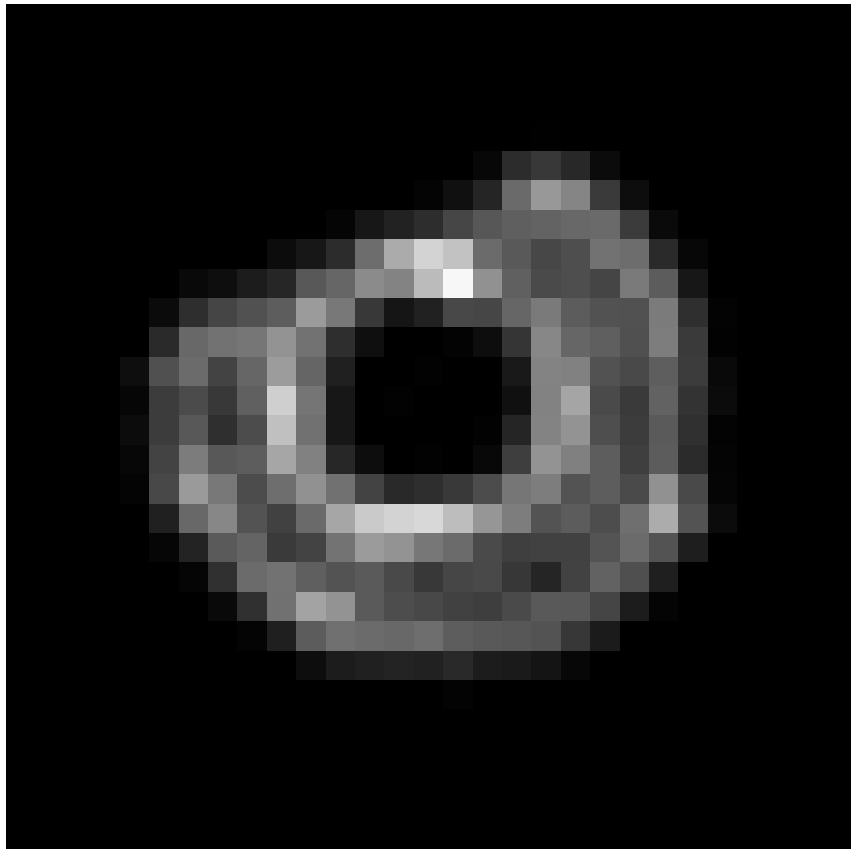
0.980
0.48
0.49
0.50
0.51

PSF



PSF





Observations

Observations

GJ436(b)

- Bright (6.3 in H)
- Distance 10.2 pc

Observations - 13.03.2010

- H filter
- 1.5 s. integration
- Defocused to $\approx$ 8 pix ring
- 200 images / cube
- W-setup (4.6' fow)
- 40 cubes $\rightarrow$ 8000 images

Challenges (problems)

- No comparison star
- Misbehaving dome $\rightarrow$ vignetting

Defocusing

- Reduces the noise due to pixel-to-pixel variation
- Smooths out the noise due to sky variation
- Allows for longer integration of bright targets

PSF Fitting Photometry

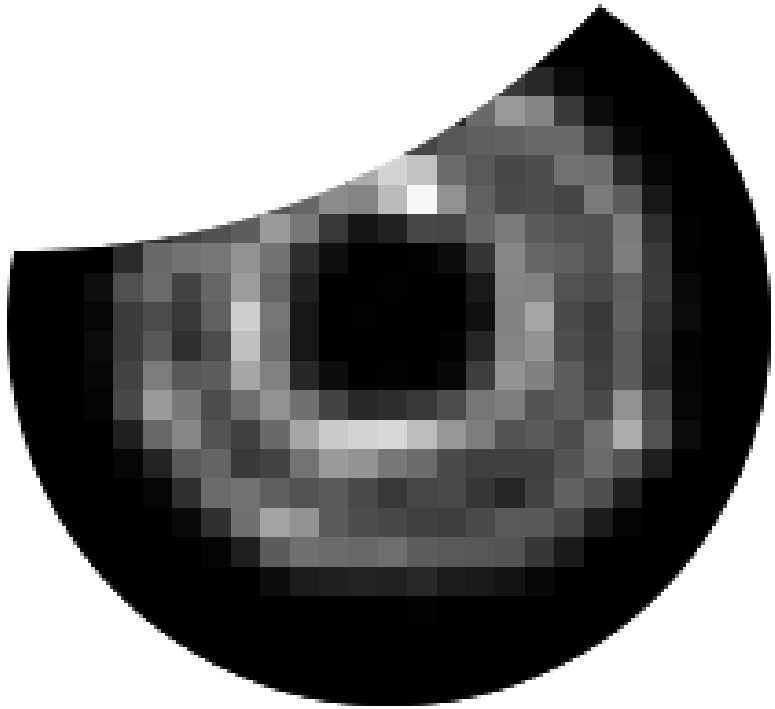
Why?

What

- Model the shape of the psf
- Fit the model to the data
- Calculate flux from the model

Why

- PSF spread over a large number of pixels
- Vignetted part can be excluded
  - But only if the effects due to the vignetting are confined
  - Less pixels to fit $\rightarrow$ increases scatter



PSF model

PSF model

- Center (x, y)
- n concentric rings
  - Amplitude
  - Width
  - Radius

Rings

- Gaussians
  - Evaluation of exp is slow!
  - Infinite support
- Quartic polynomials
  - Only multiplications
  - Less elegant but fast
  - Clipping $\rightarrow$ finite support

Quartic polynomial

$$f_i(r) = a + 4a\left(r^4/4w - r^2/2w\right)$$

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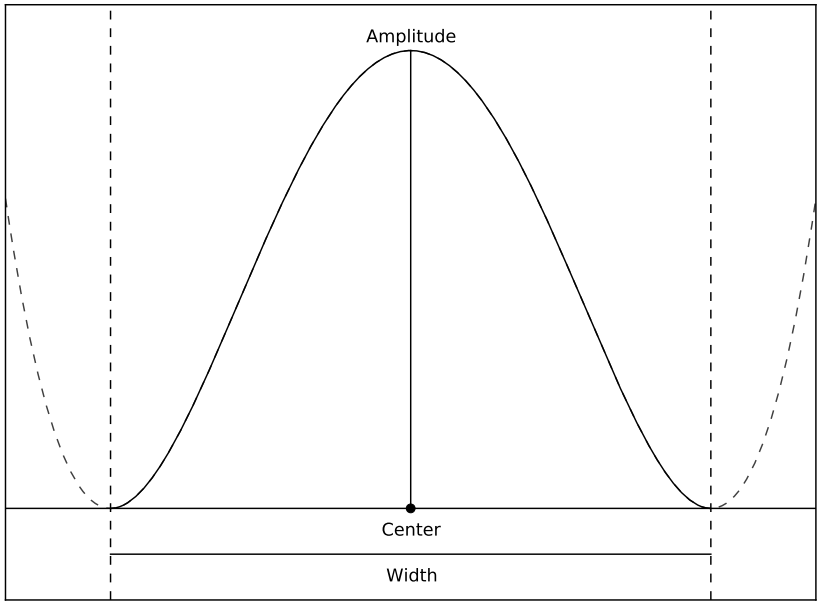

Quartic polynomial

$$f_i(r) = a + 4a\left(r^4/4w - r^2/2w\right)$$

PSF model

PSF model

$$\mathrm{PSF}(r) = \sum_i^n \mathrm{f_i}(r)$$

Flux

$$\mathrm{F}(r) = 2\pi \int r\mathrm{PSF}(r)\mathrm{d}r$$

$$\mathrm{F}(r) = 2\pi \int r \sum_i^n \mathrm{f_i}(r)\mathrm{d}r$$

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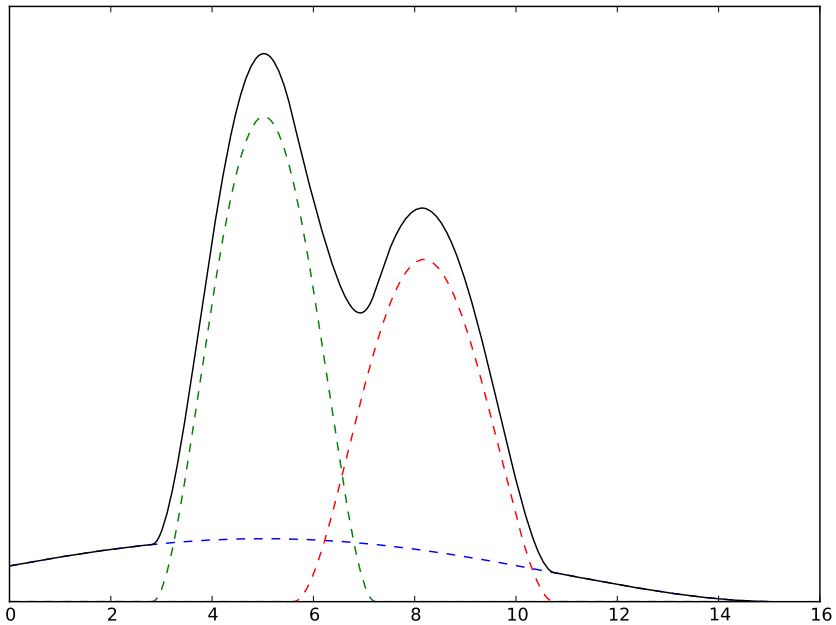


Flux integration

- Flux is a sum of polynomials
- Fast, minimizes numerical errors

Fitting

Differential evolution (DE)

- Global optimization algorithm
- Fast, robust, easy to implement
- Price, Storn, and Lampinen (2005)

Implementation

- Fortran, Python, NumPy, and PyFITS
- Trivial parallelization with MPI

Implementation

- Iterative optimization of parameter space bounds
- Increases stability

Performance

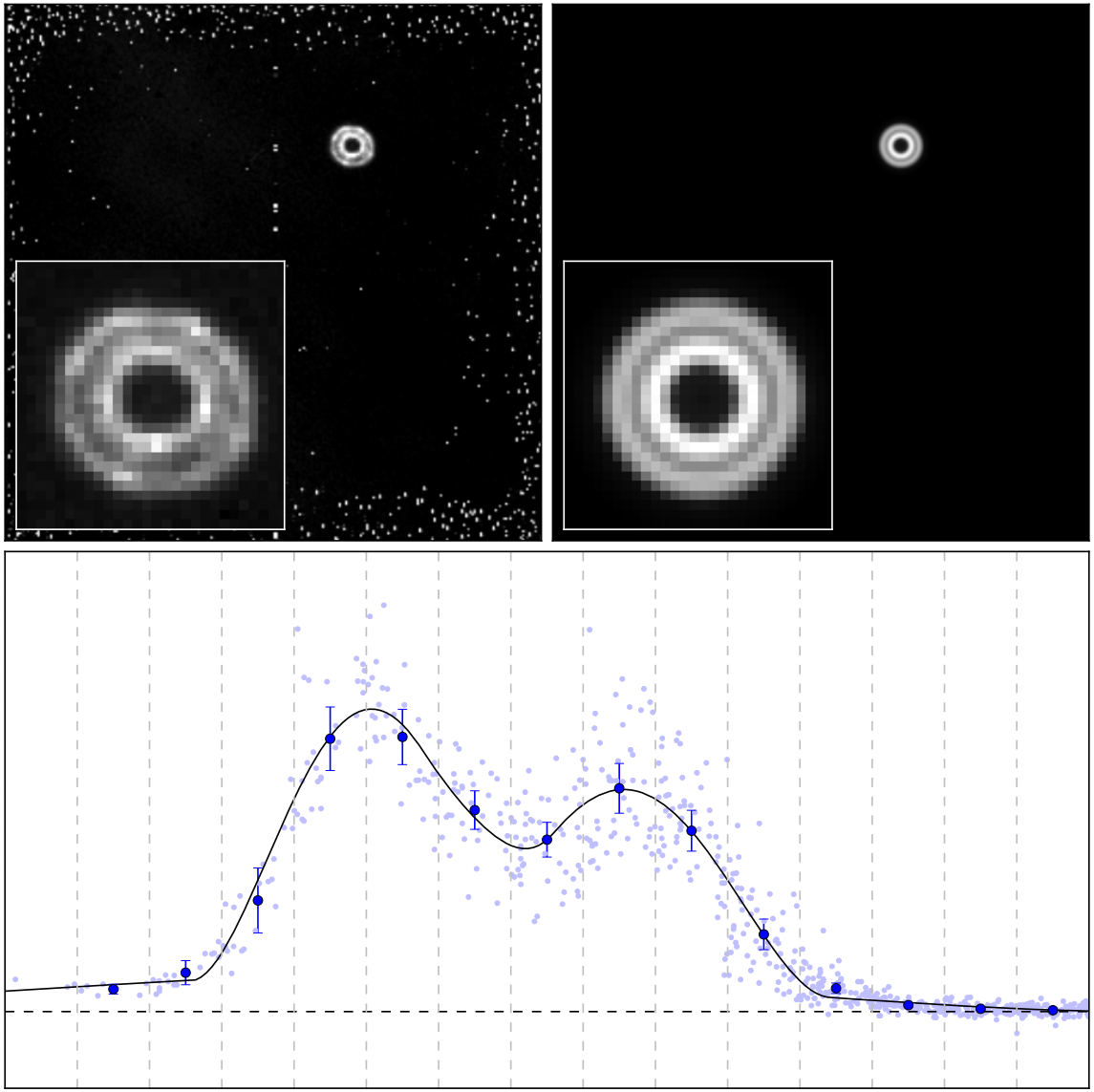
- 0.2 - 0.8 sec/image for the 3 ring model (11 free parameters)

Other

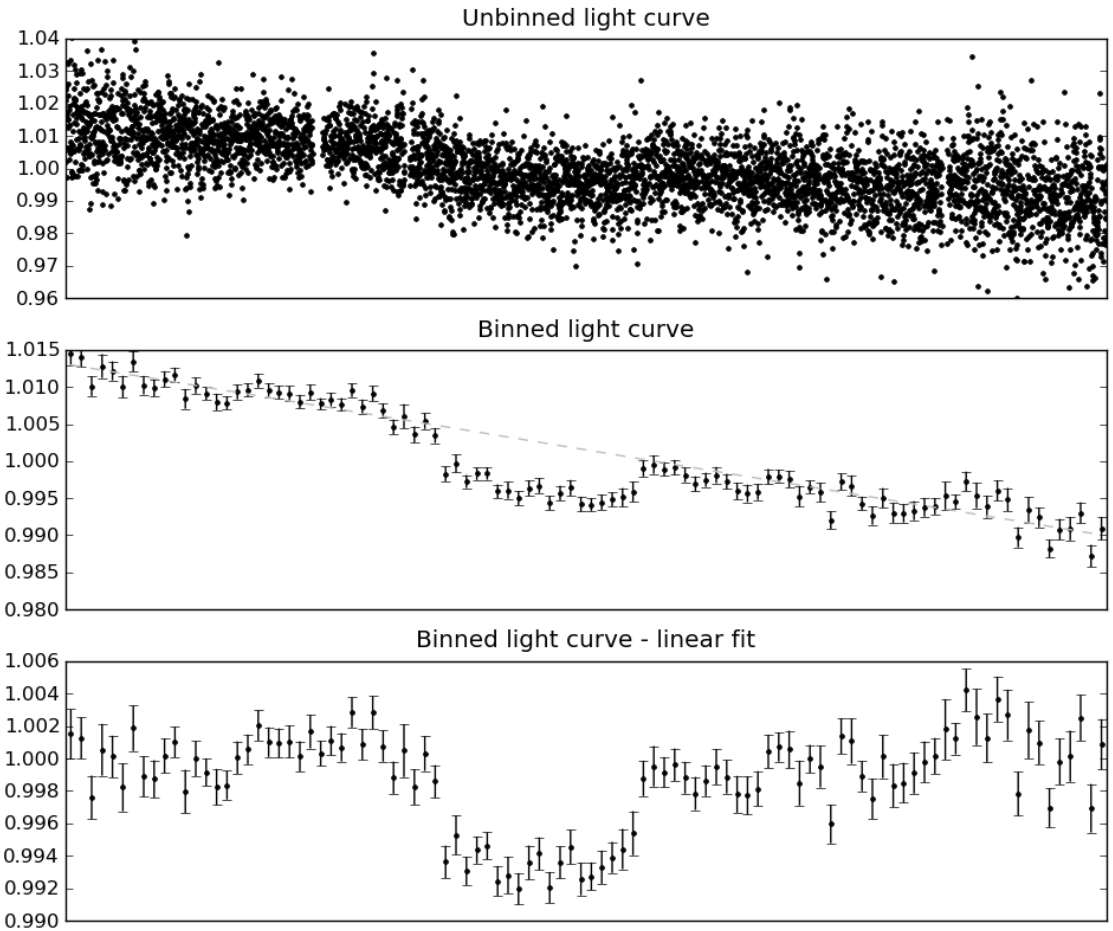
- Calculates centers of defocused psf's $\longrightarrow$ aperture photometry

Results

PSF fitting example



Final light curve



Thank you!