Modelling of the "Pi of the Sky" detector response

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"Pi of the Sky" experiment

Faculty of Physics, University of Warsaw

Malaga, 06.VI.2011

The "Pi of the Sky" experiment

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Presented in this talk are results from the prototype running in LCO from year 2004 to 2009.

For other results see talk by Malgorzata Siudek.

The "Pi of the Sky" experiment (2)

Prototype

- CCD: 2048 $\times$ 2062 pixels, 16-bit, low-noise
- Canon lenses, f=85 mm, f/d=1.2
- Single camera FoV: 20° $\times$ 20°
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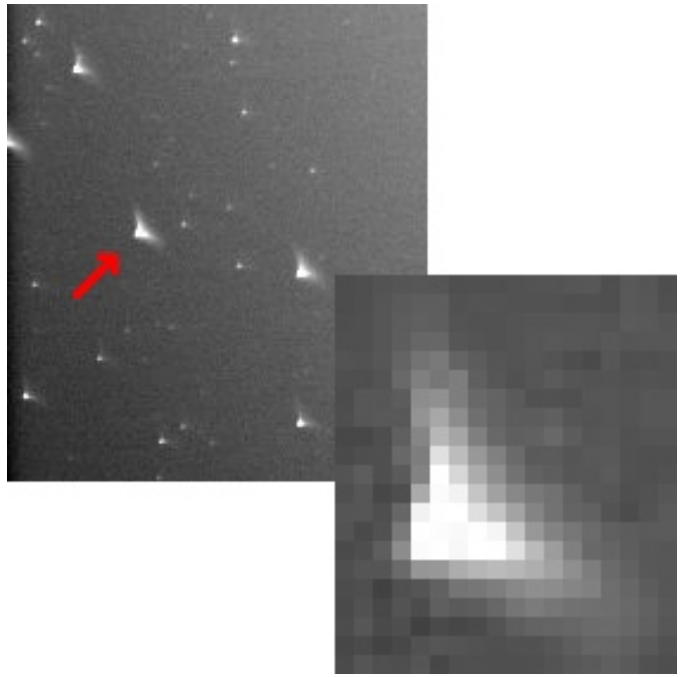

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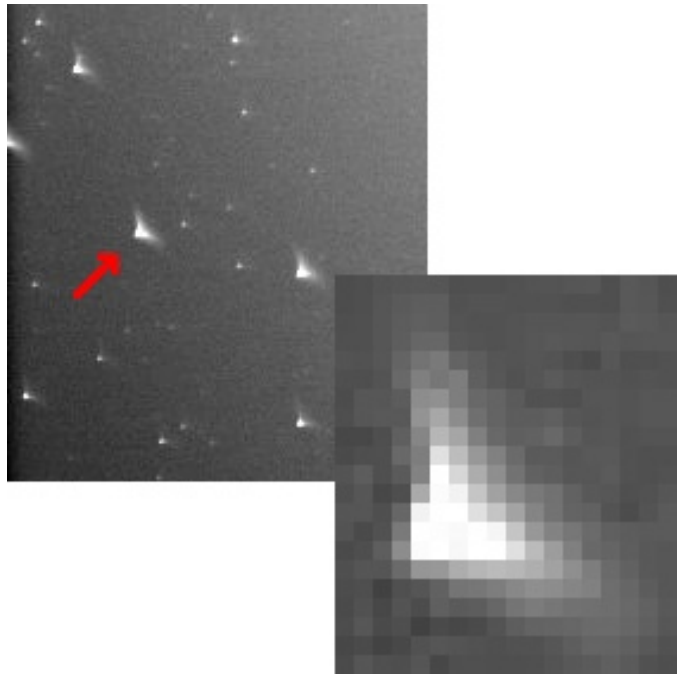

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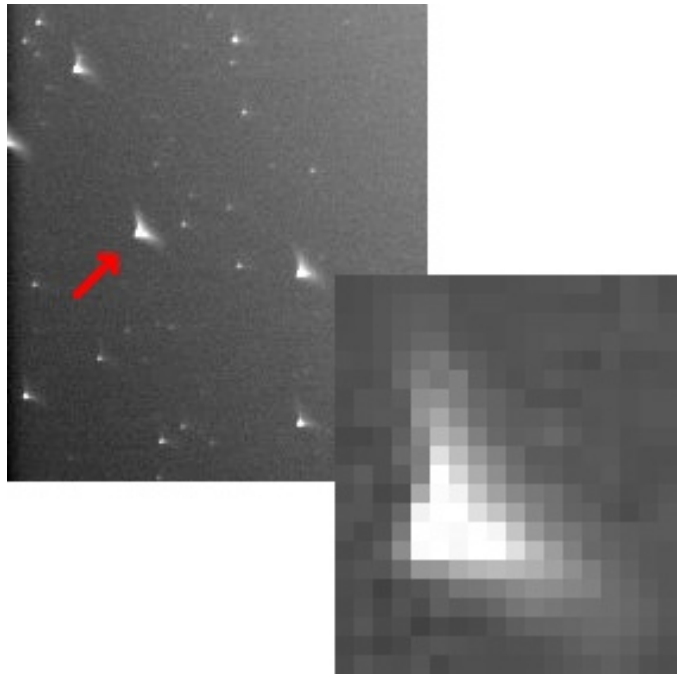

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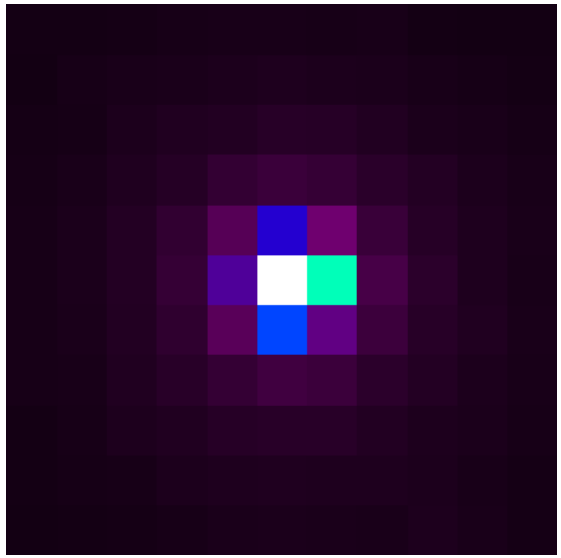
Solution: Point Spread Function (PSF) parametrization

PSF shape determination

Standard method of the PSF shape determination:

- reconstruction of a high resolution profile
  ← superposition of multiple star(s) images
- fit of the shape parameters (Gauss, Voigt, Moffat, etc. profiles)



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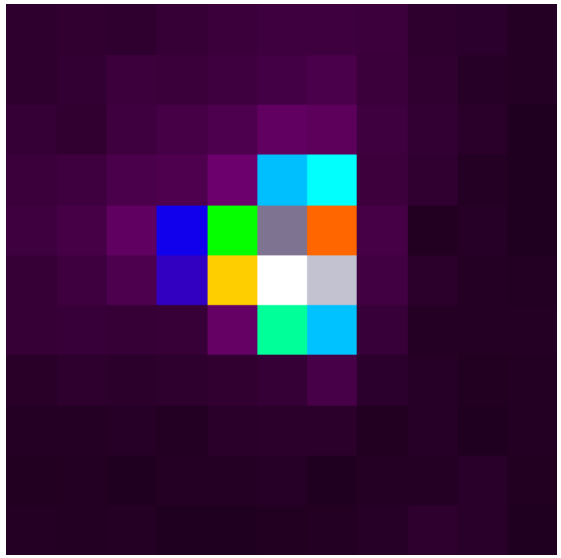

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- stars colour influence
- image blur – mount vibrations, fluctuations, etc.

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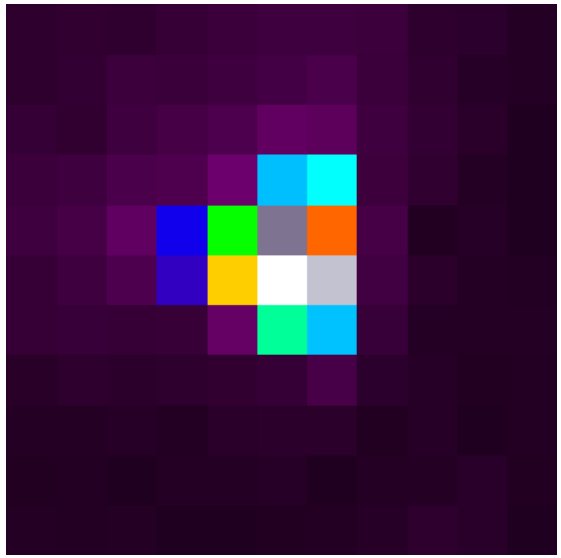

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Solution: laboratory measurements

Laboratory setup

Star

as seen from Earth – a point source

A point source

image of the source much smaller than the angular resolution given by a pixel size

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Light source,
ϕ=0.4 mm

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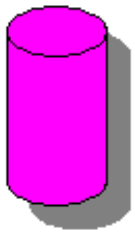

Lenses,
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CCD,
pixel: 15x15 µm

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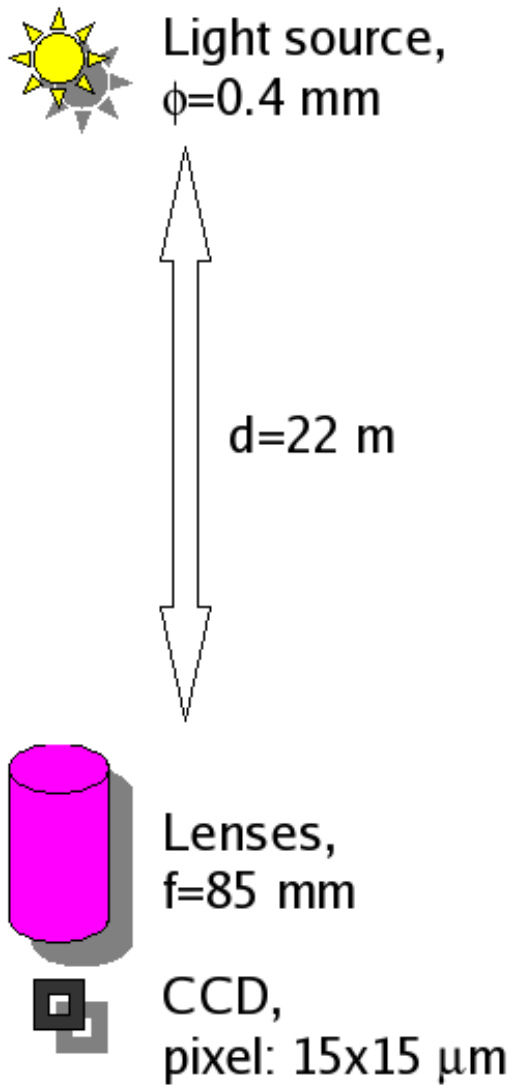
- distance: 22 m (corridor length)



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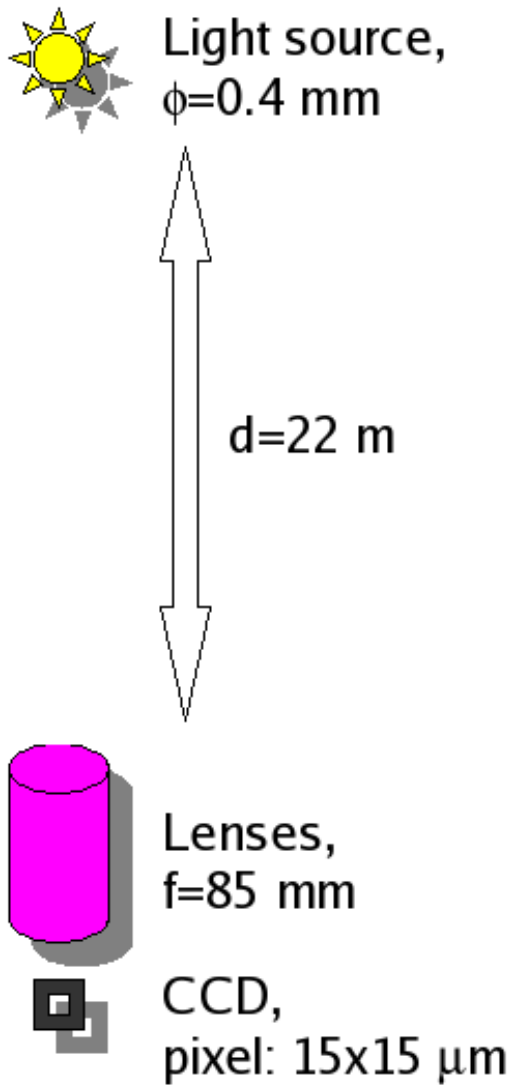

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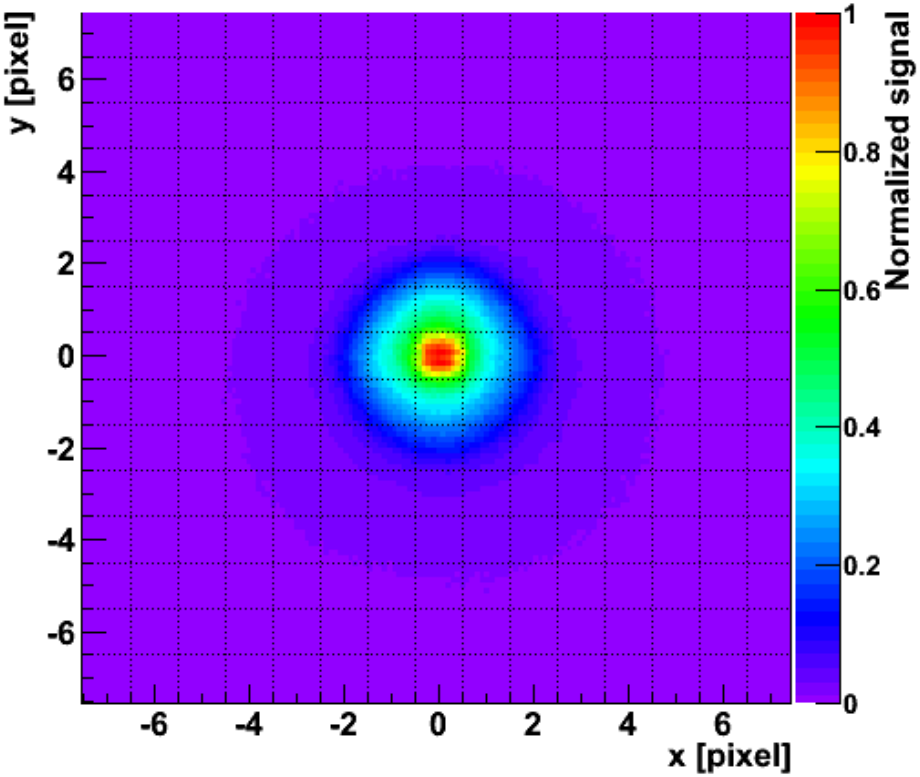

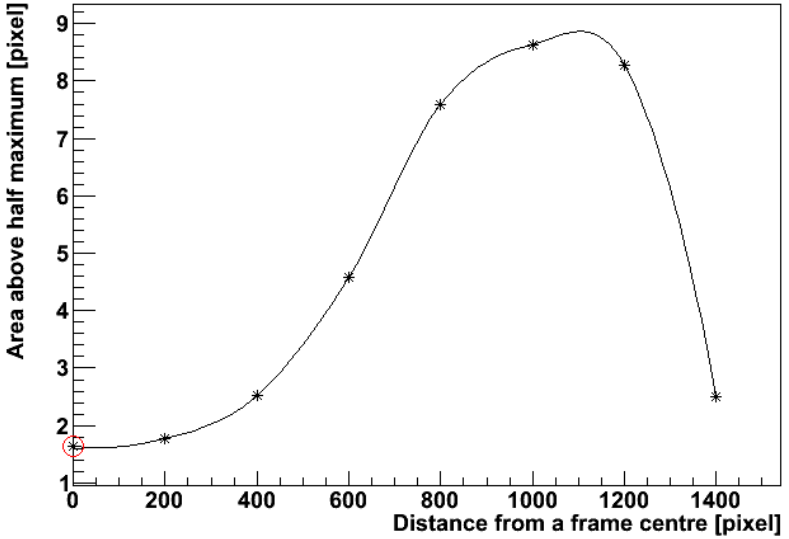

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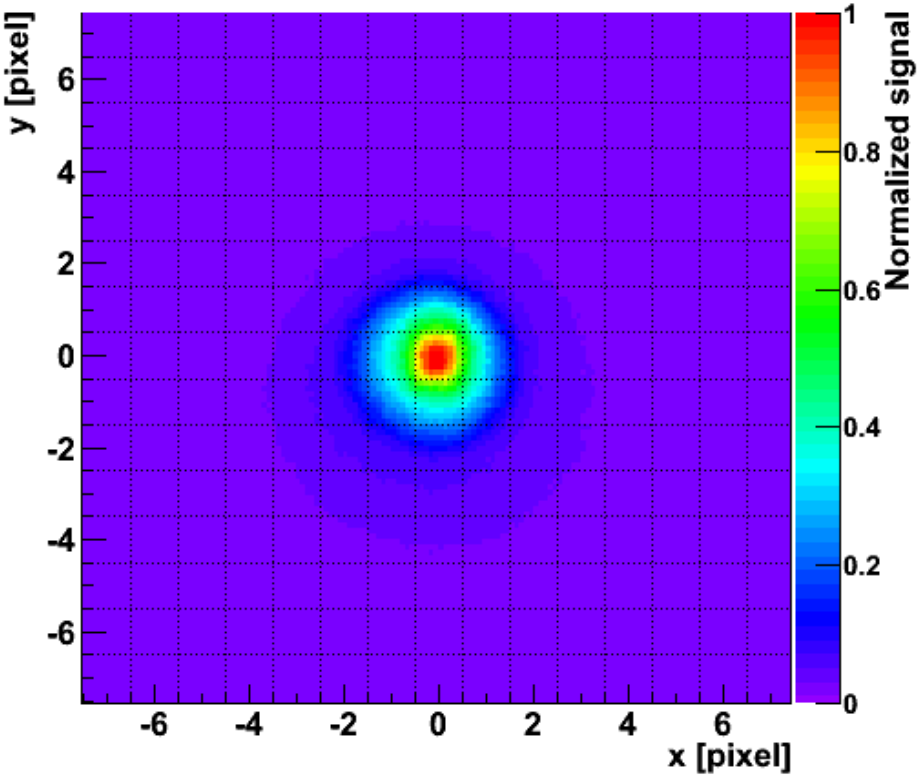

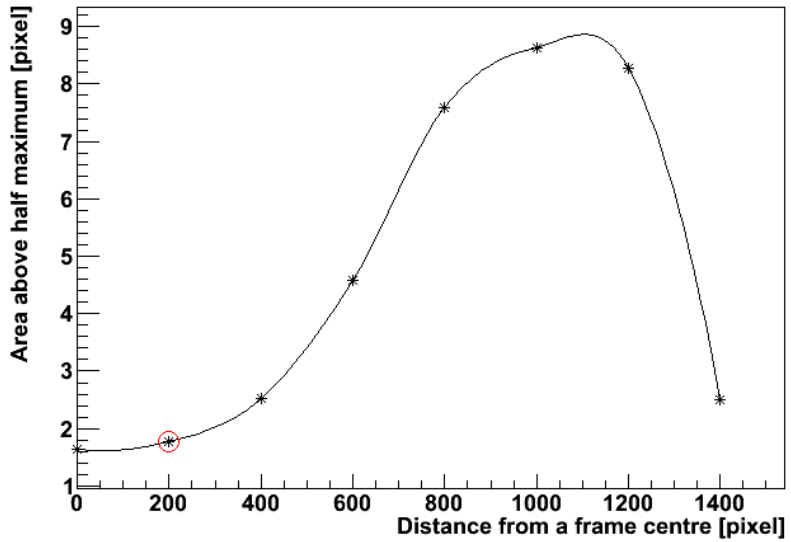

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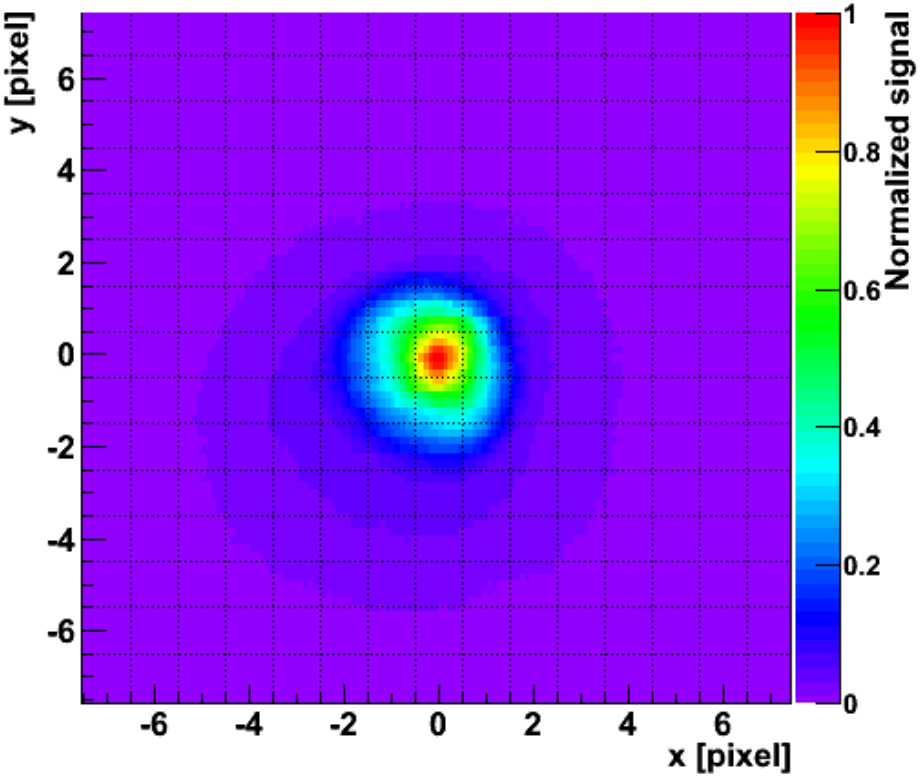

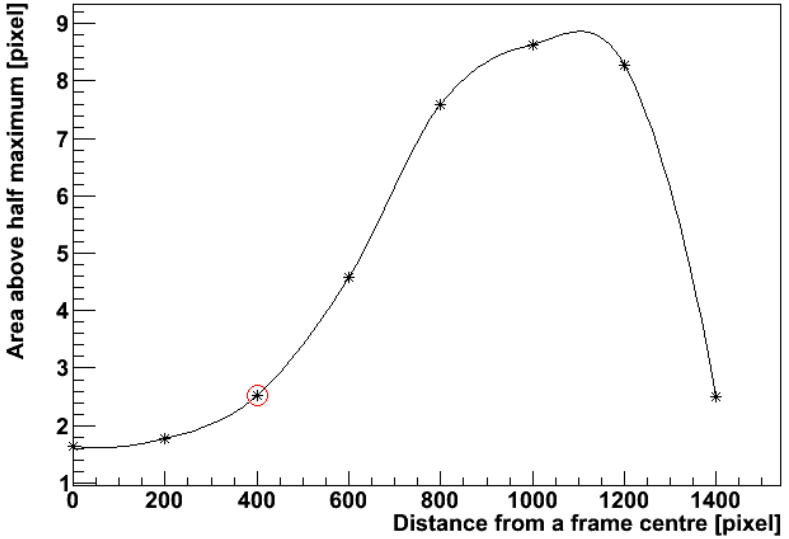

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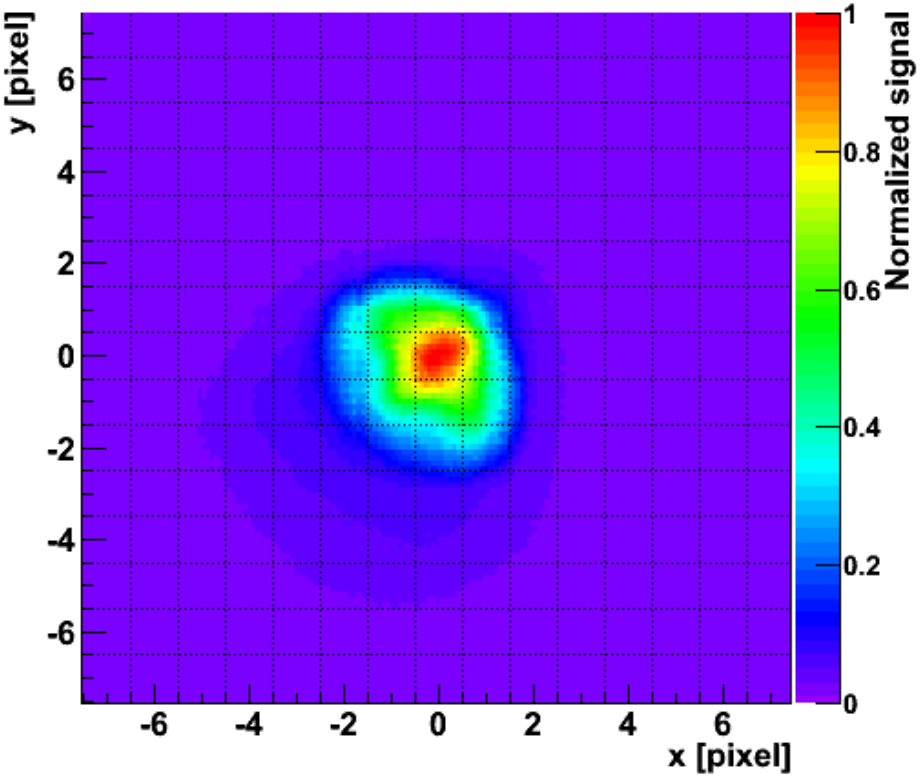

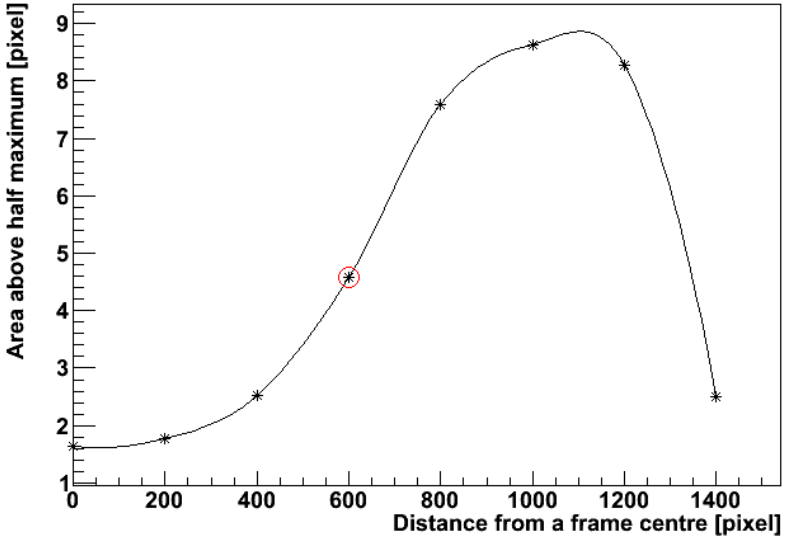

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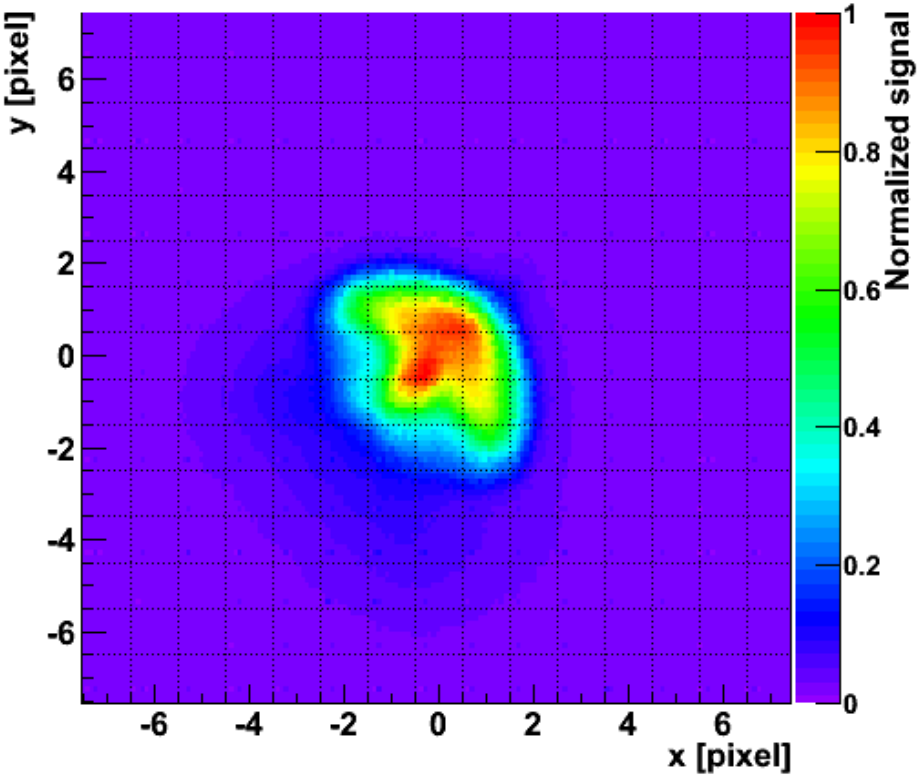

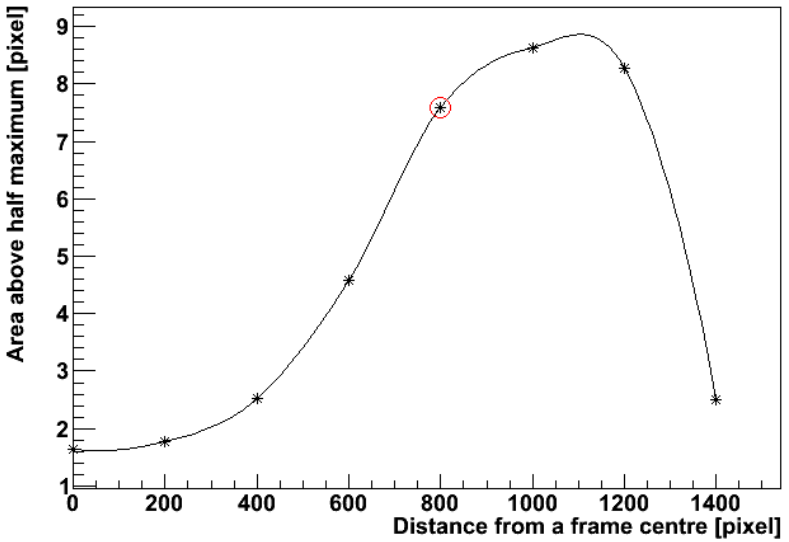

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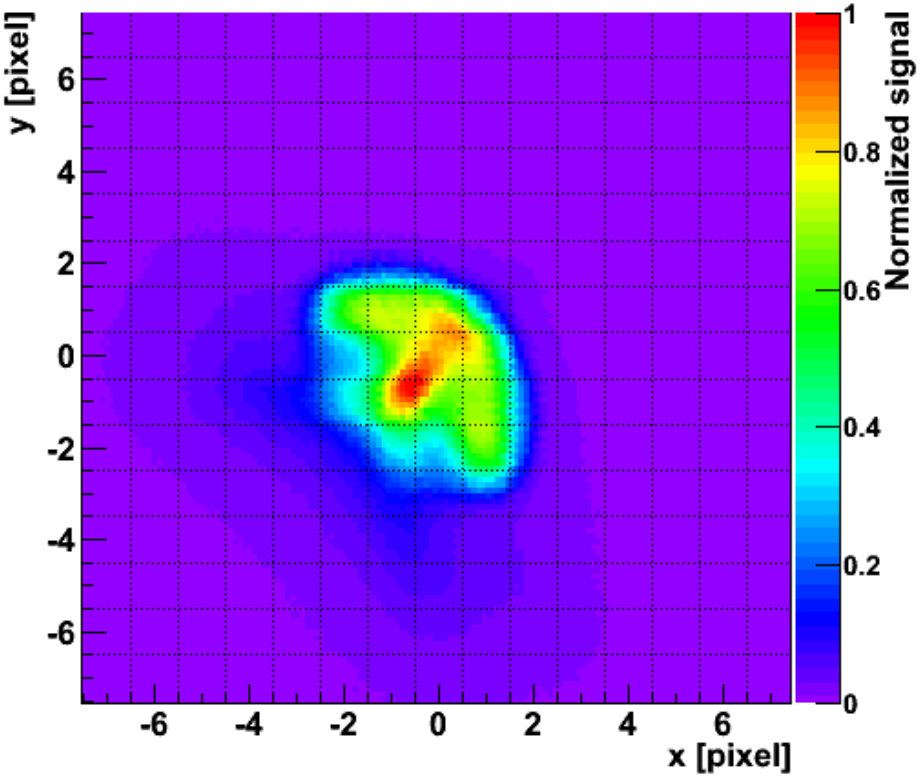

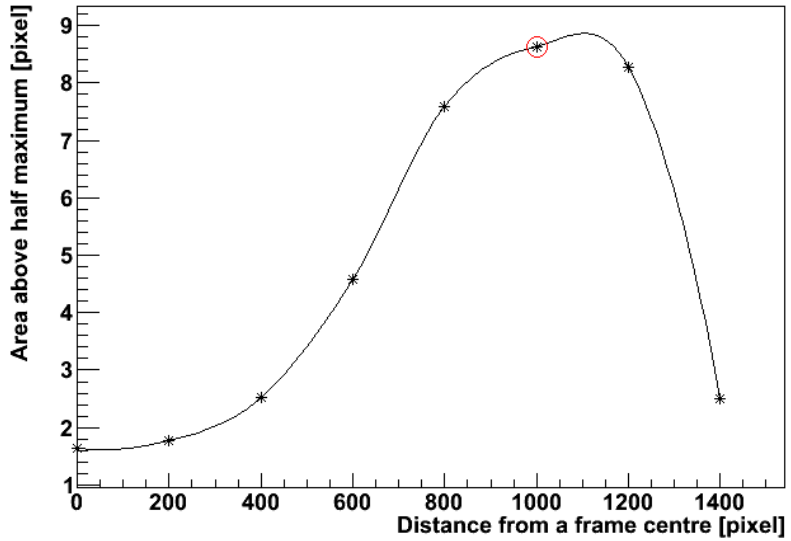

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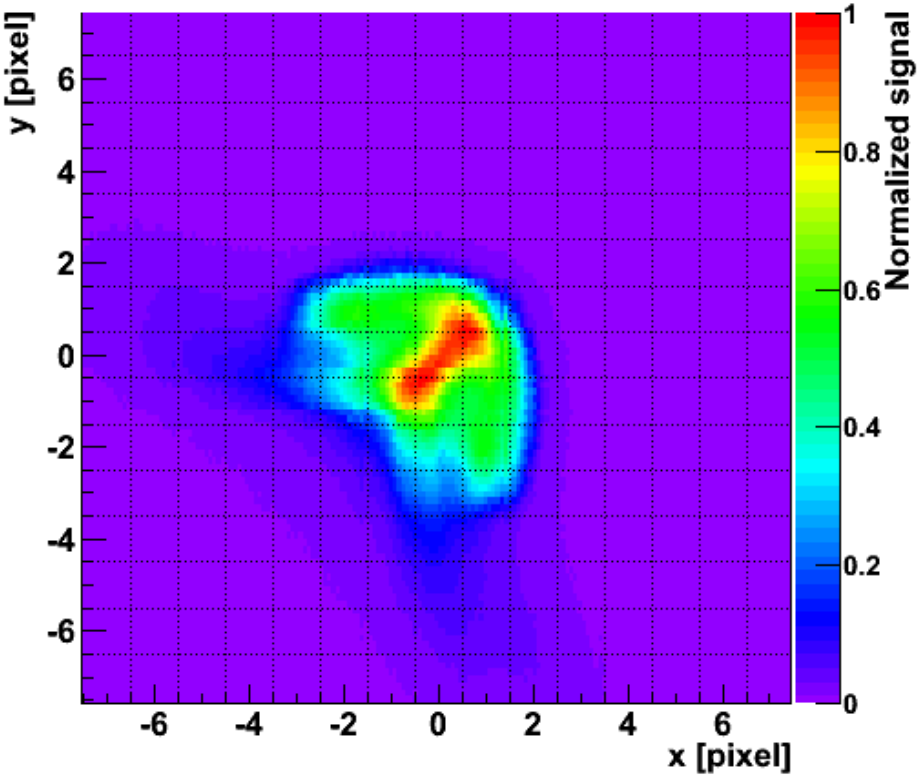

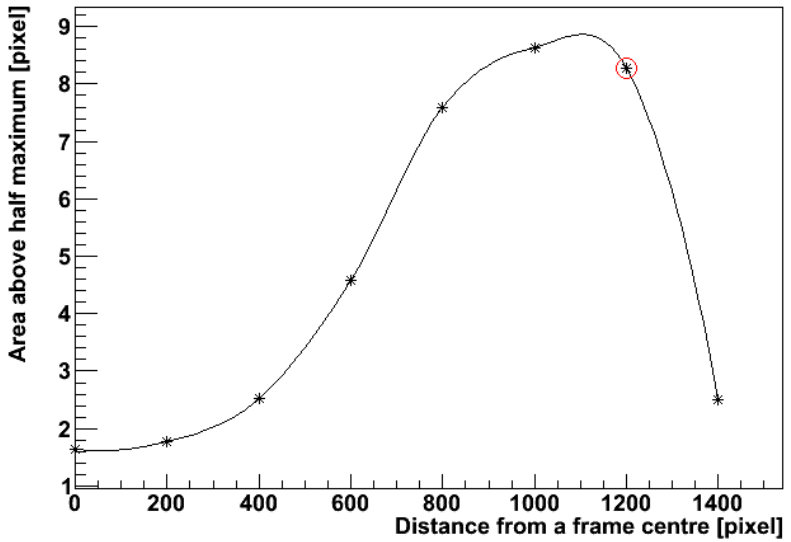

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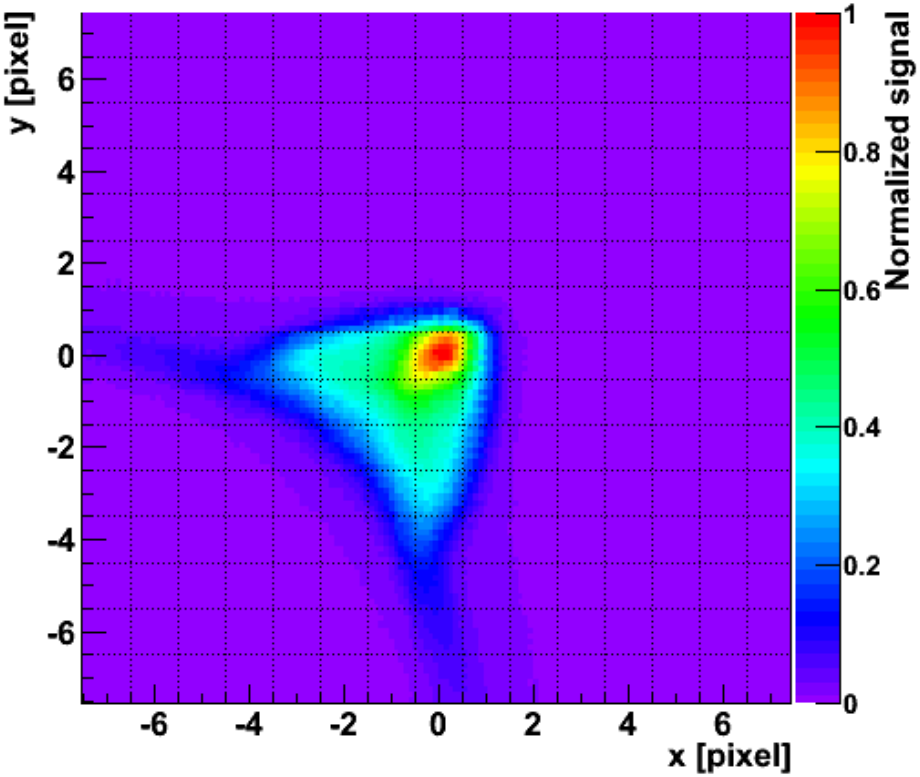

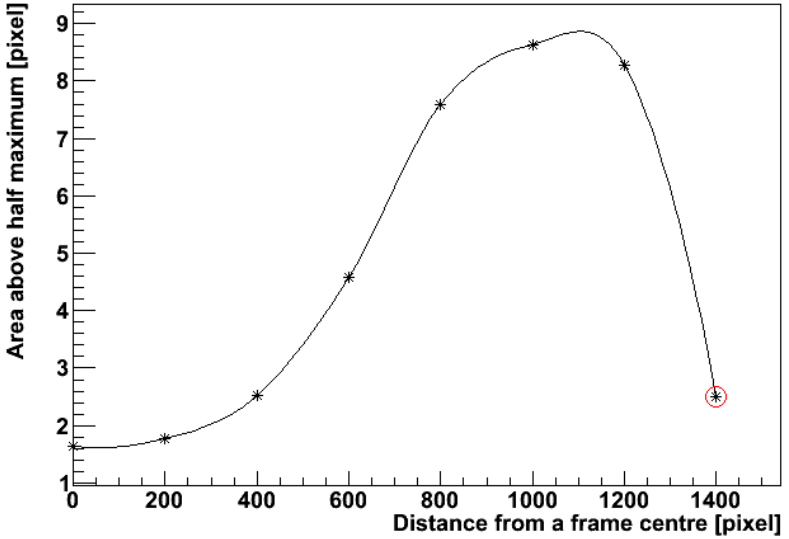

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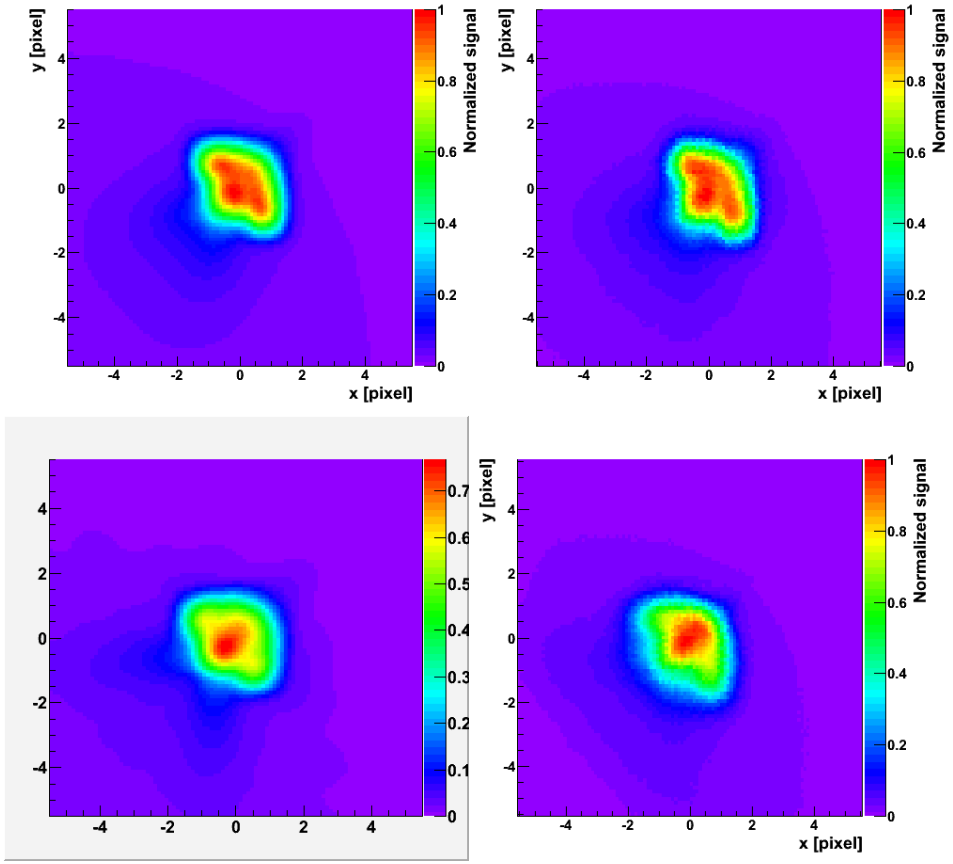
   $\Leftarrow$ very demanding computation, no success



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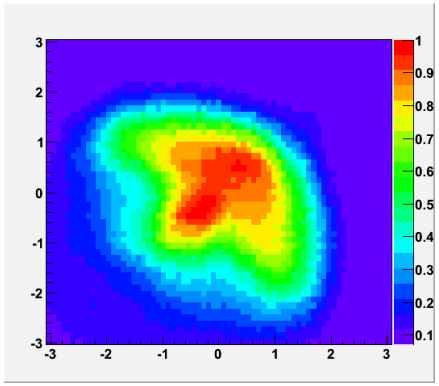

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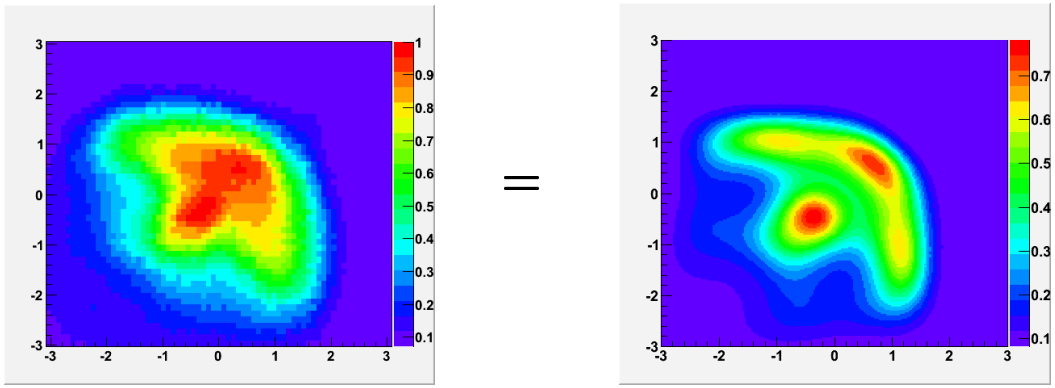

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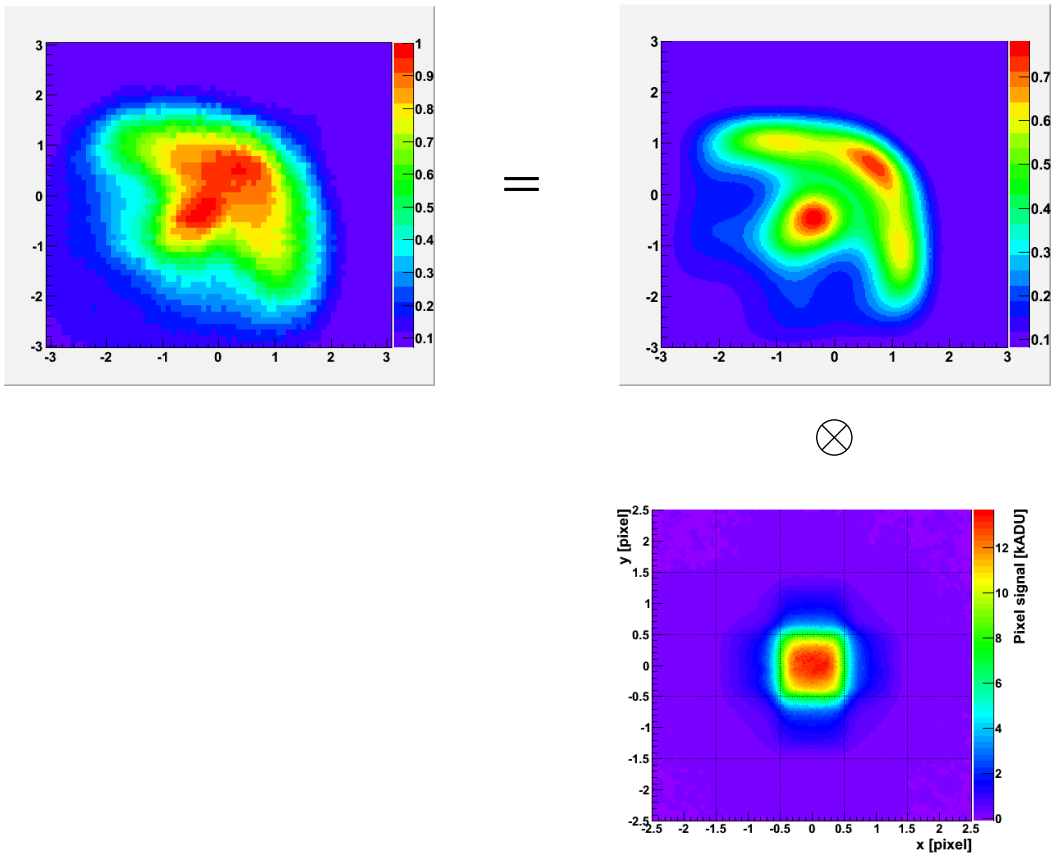

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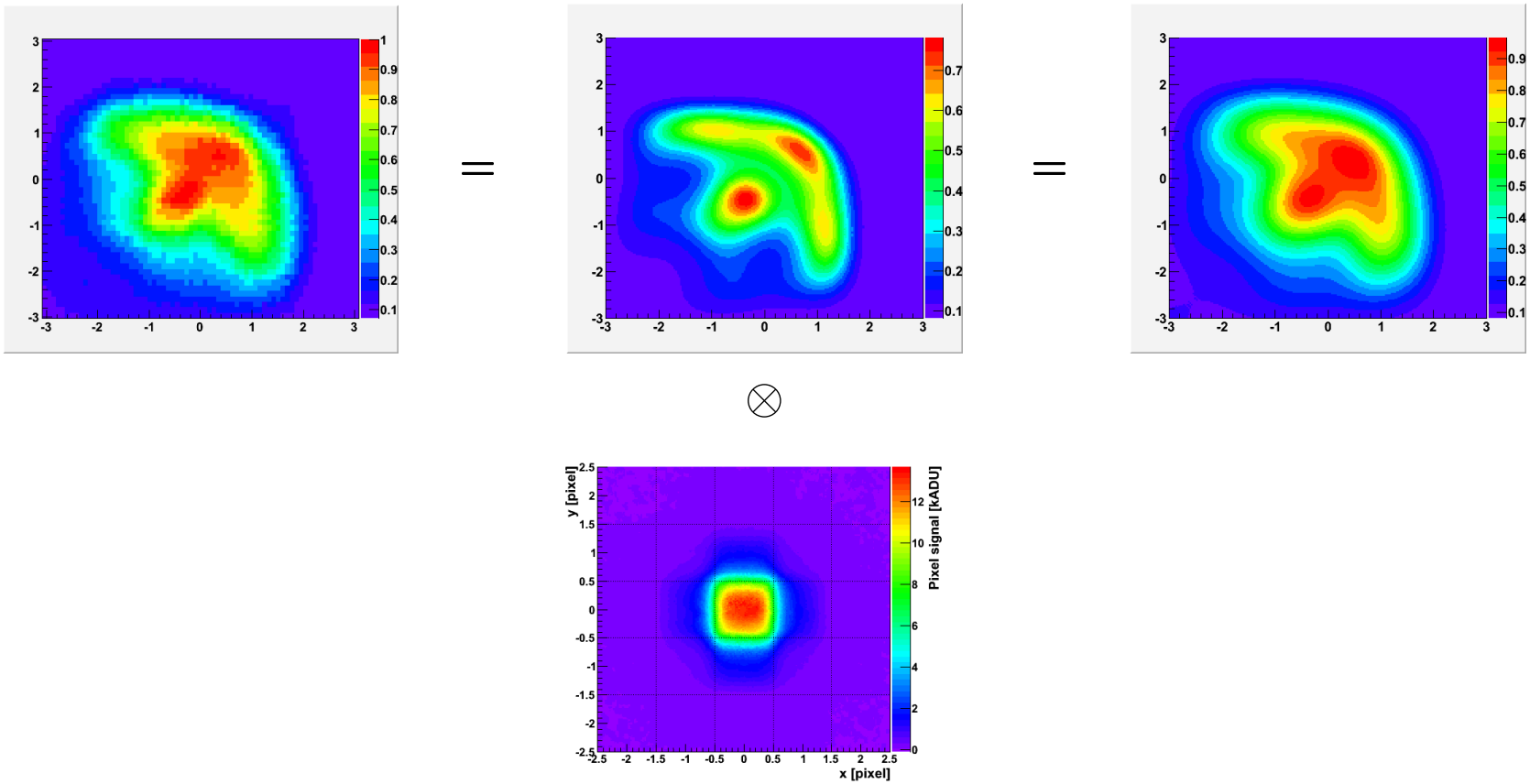

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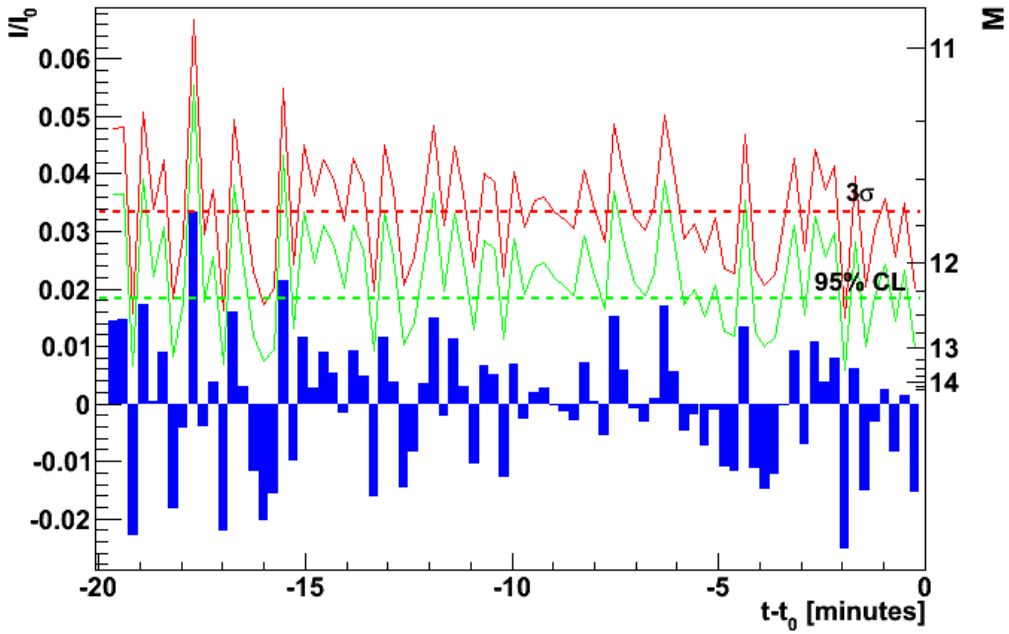
The polynomial model has been used to:

- GRB precursor search – no signal exceeding 3σ has been found
- more precise limit determination



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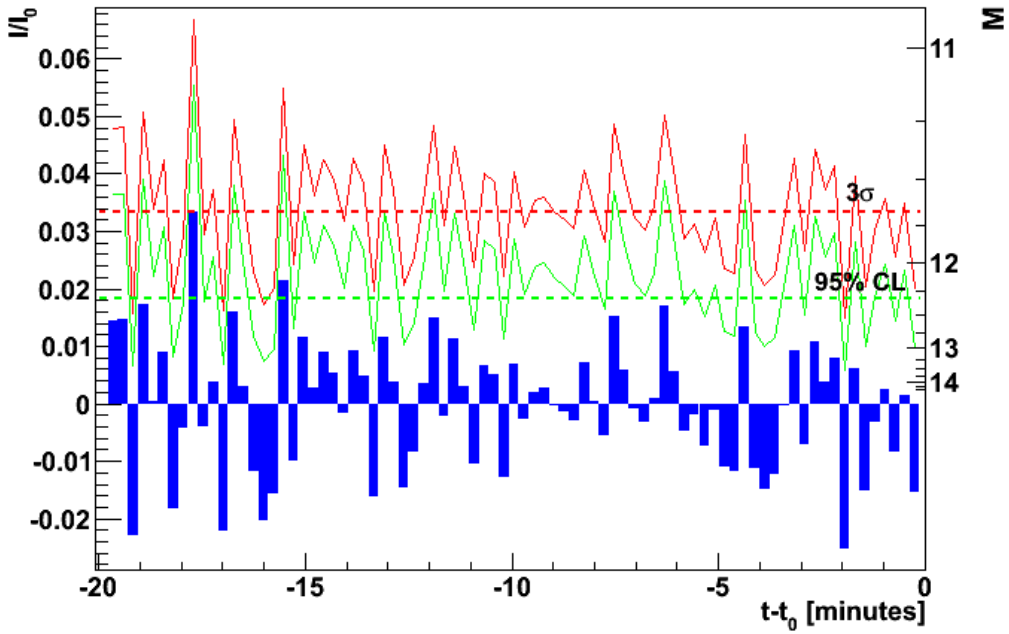
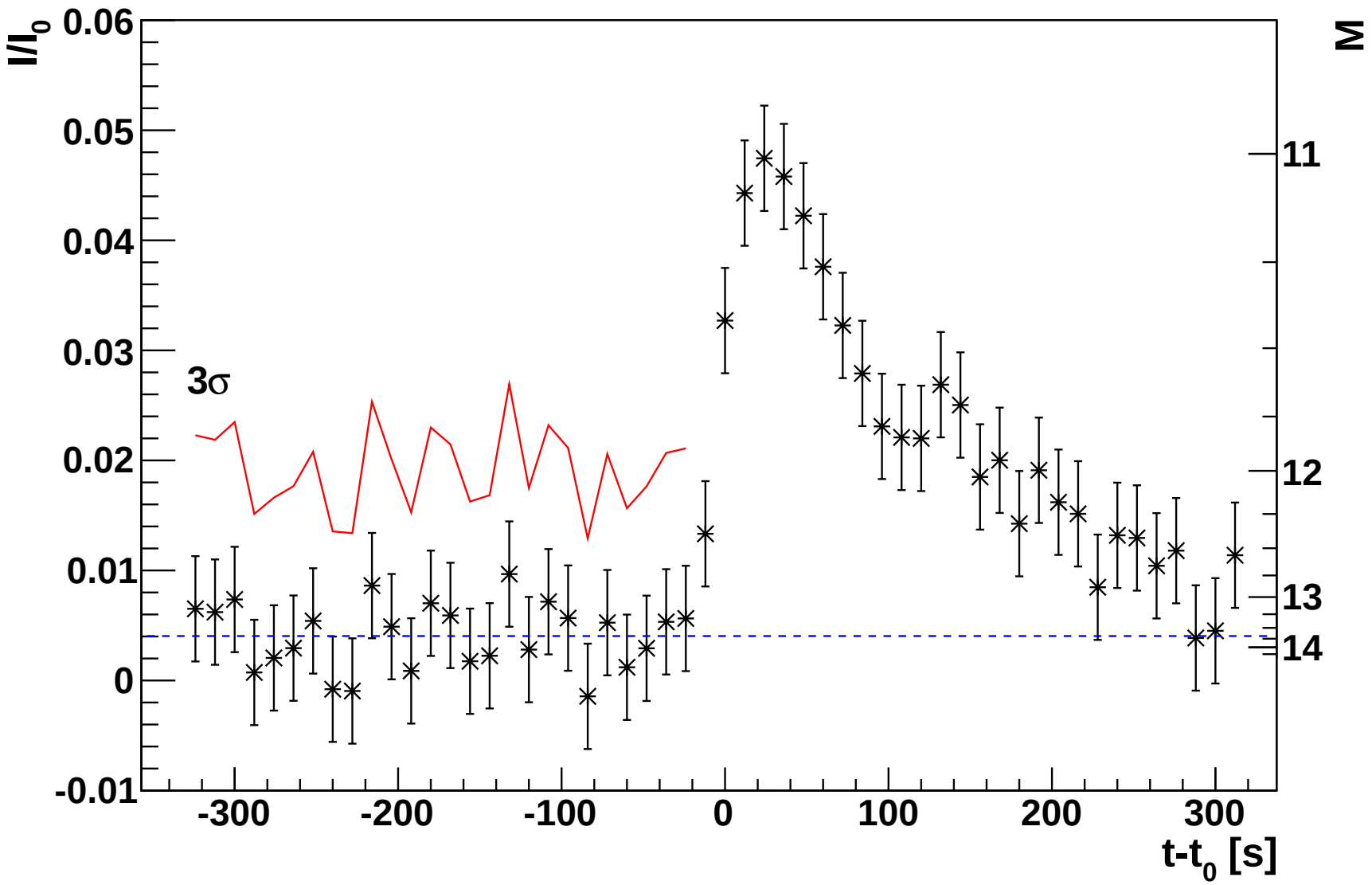


New limit: 12.25^{m} compared to previous 11.5^{m}. 0.75^{m} limit improvement.

EG UMa outburst – INTA

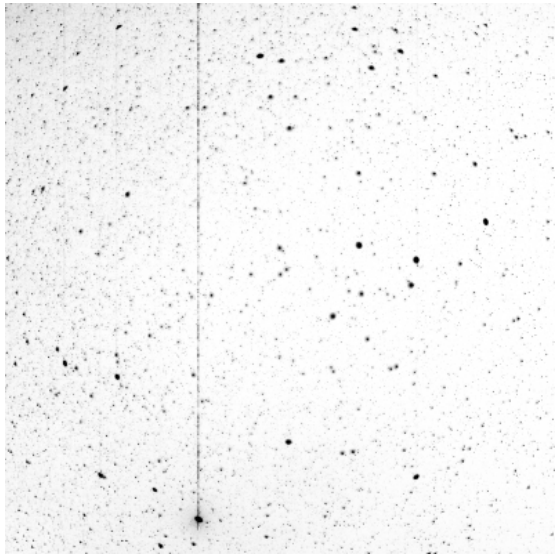
Preeliminary

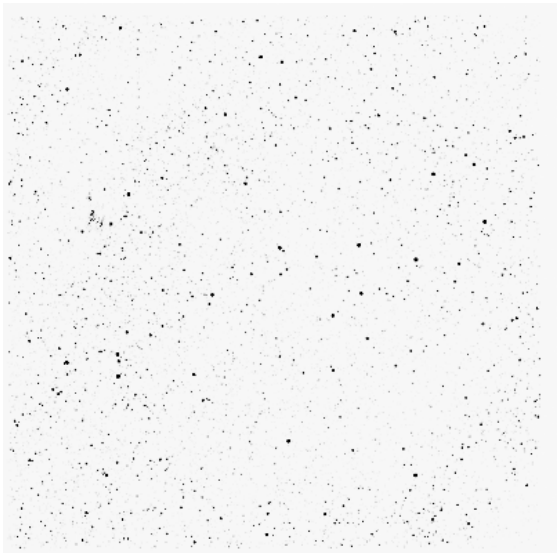


The "Pi of the Sky" frame simulator

The "Pi of the Sky" frame simulator, based on the polynomial model:

- generates frame with catalogue stars position and brightness





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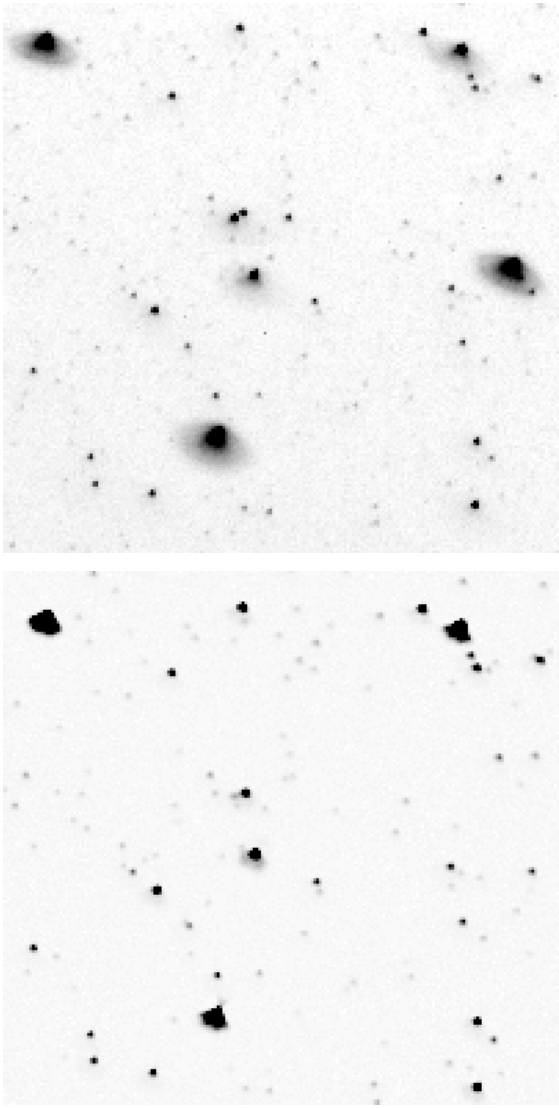

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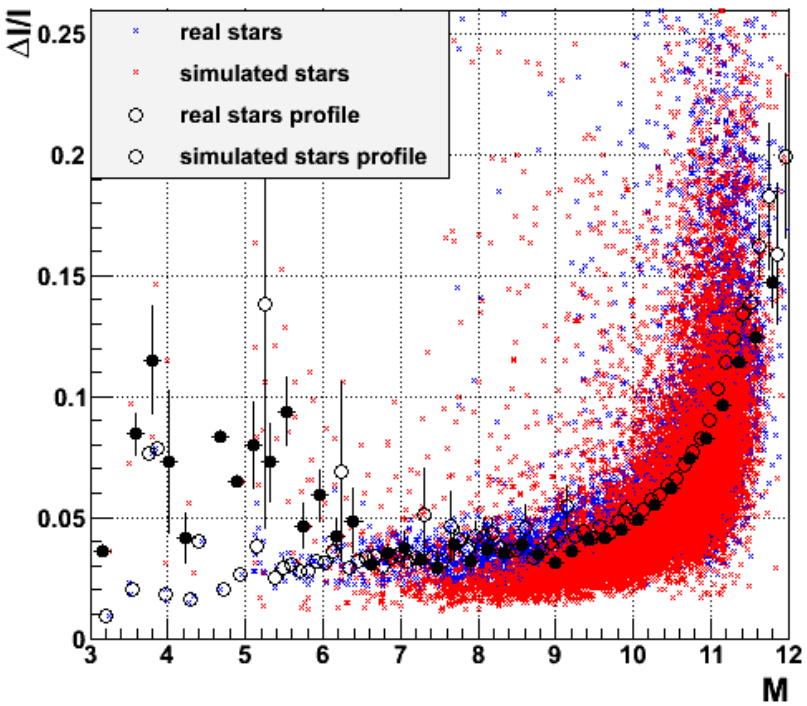
- simulates miscellaneous fluctuations (Poisson, gain, readout noise, etc.)
  - properly reproduces $\frac{\Delta I}{I}(M)$



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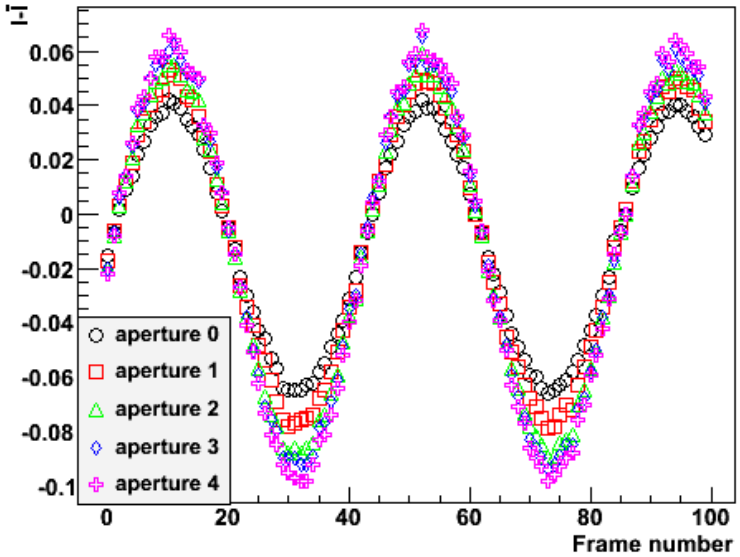

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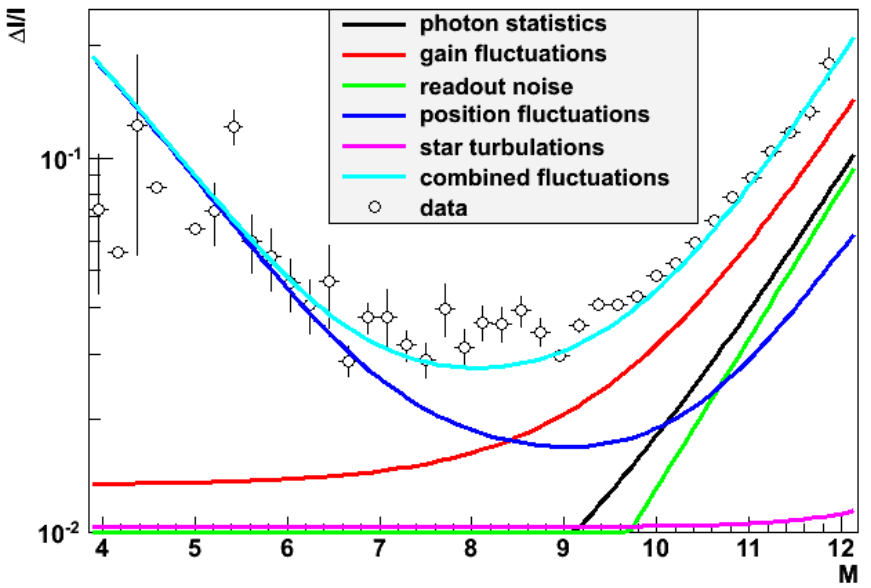

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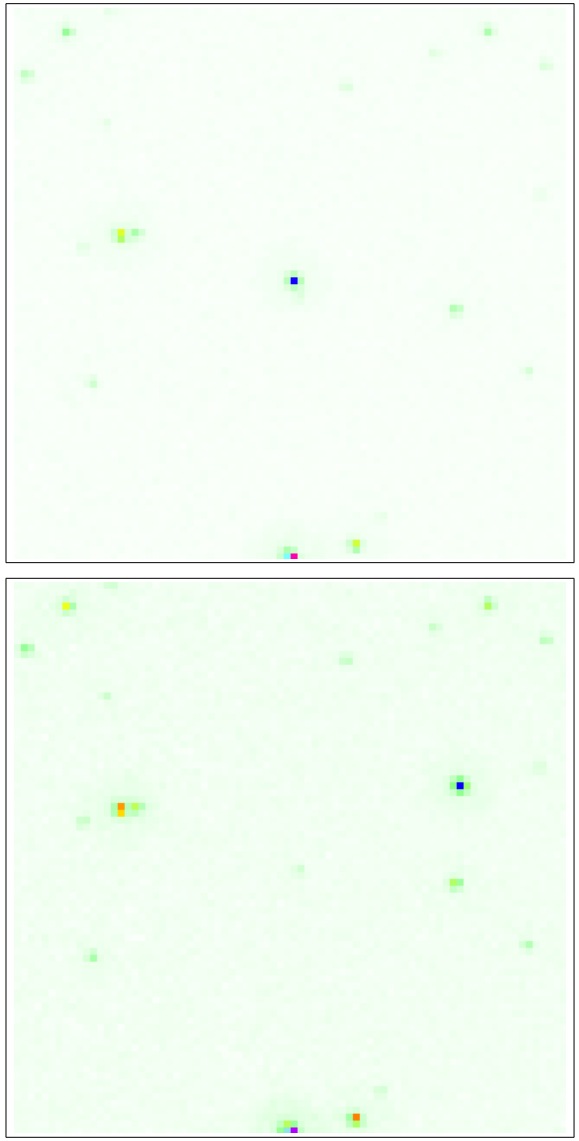
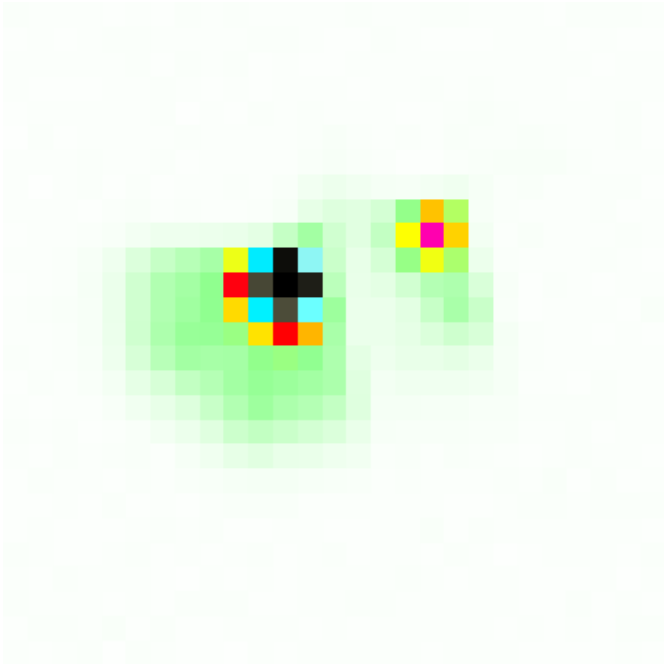
- analyse photometric uncertainties
- test parallax determination



The "Pi of the Sky" frame simulator

The "Pi of the Sky" frame simulator, based on the polynomial model:

- generates frame with catalogue stars position and brightness
- takes into account stars PSF
- simulates miscellaneous fluctuations (Poisson, gain, readout noise, etc.)
  - properly reproduces $\frac{\Delta I}{I}(M)$
- simulates requested stars variability



The simulator can be used to:

- analyse photometric uncertainties
- test parallax determination
- test algorithms on crowded fields
- etc.

Summary

- A well working polynomial model of PSF has been created
- Basic model-based photometry and astrometry has been tested
  - model-based photometry equal to existing, may improve on new hardware
  - model-based astrometry performs much better
- Additionally models can be used for:
  - search for weak signals
  - precise limits determination
- A realistic simulator of a frame has been created, useful for testing algorithms and hardware of the "Pi of the Sky"
- Developed model could be used in future experiments with very large FoV

More details on the covered topics are available in my PhD thesis:
`http://www.fuw.edu.pl/~lewhoo/phd_thesis.pdf`.