

Automated morphometry with SExtractor and PSFEx

E. Bertin (IAP)



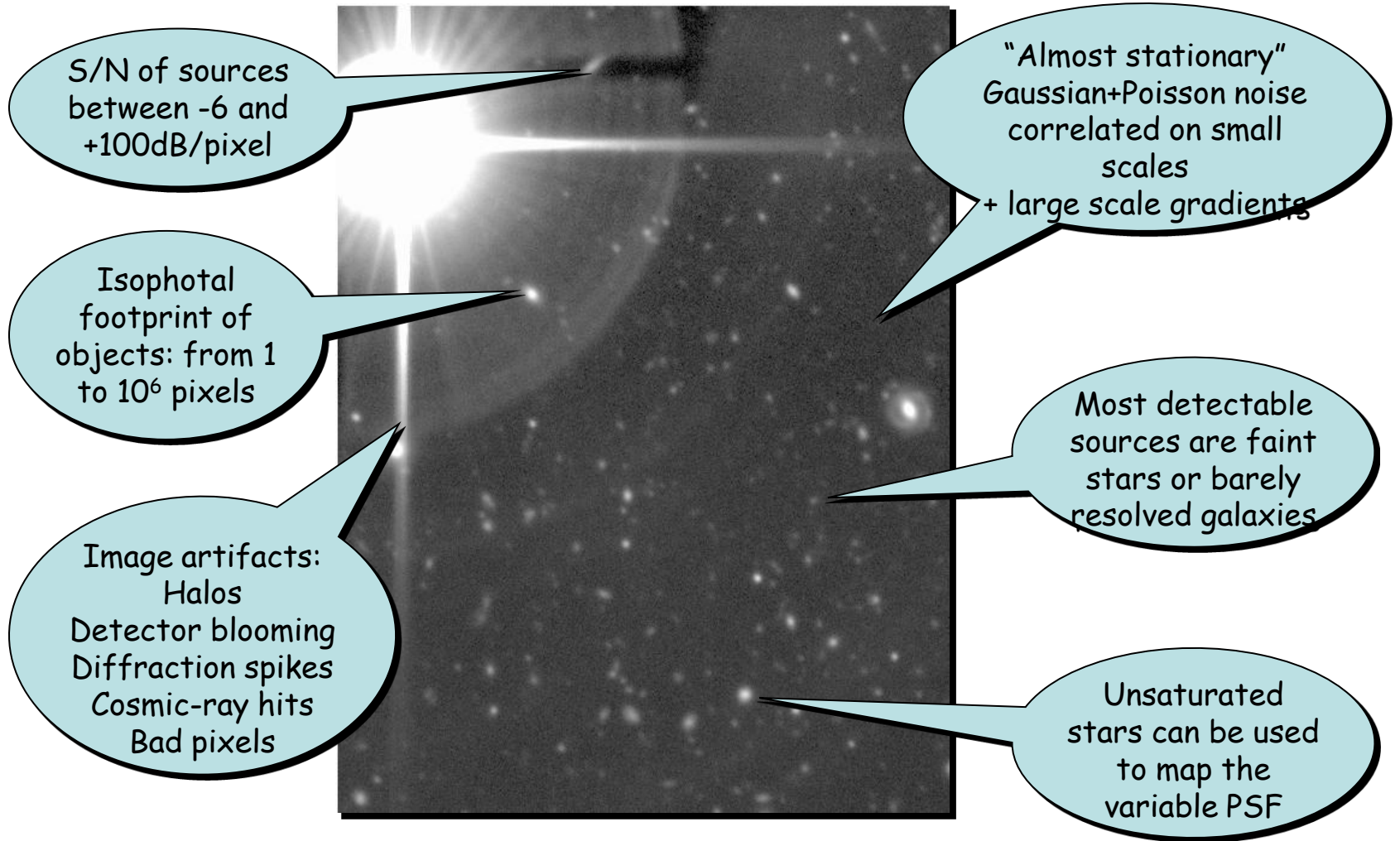
Collaborators

V1-2.x: Mireille Dantel, Frédéric Magnard, Chiara Marmo,
Gregory Sémah and the TERAPIX team at IAP

V3.x: Tony Darnell, Shantanu Desai, Greg Daues, Joe Mohr
and the Dark Energy Survey Management team at
University of Illinois and NCSA

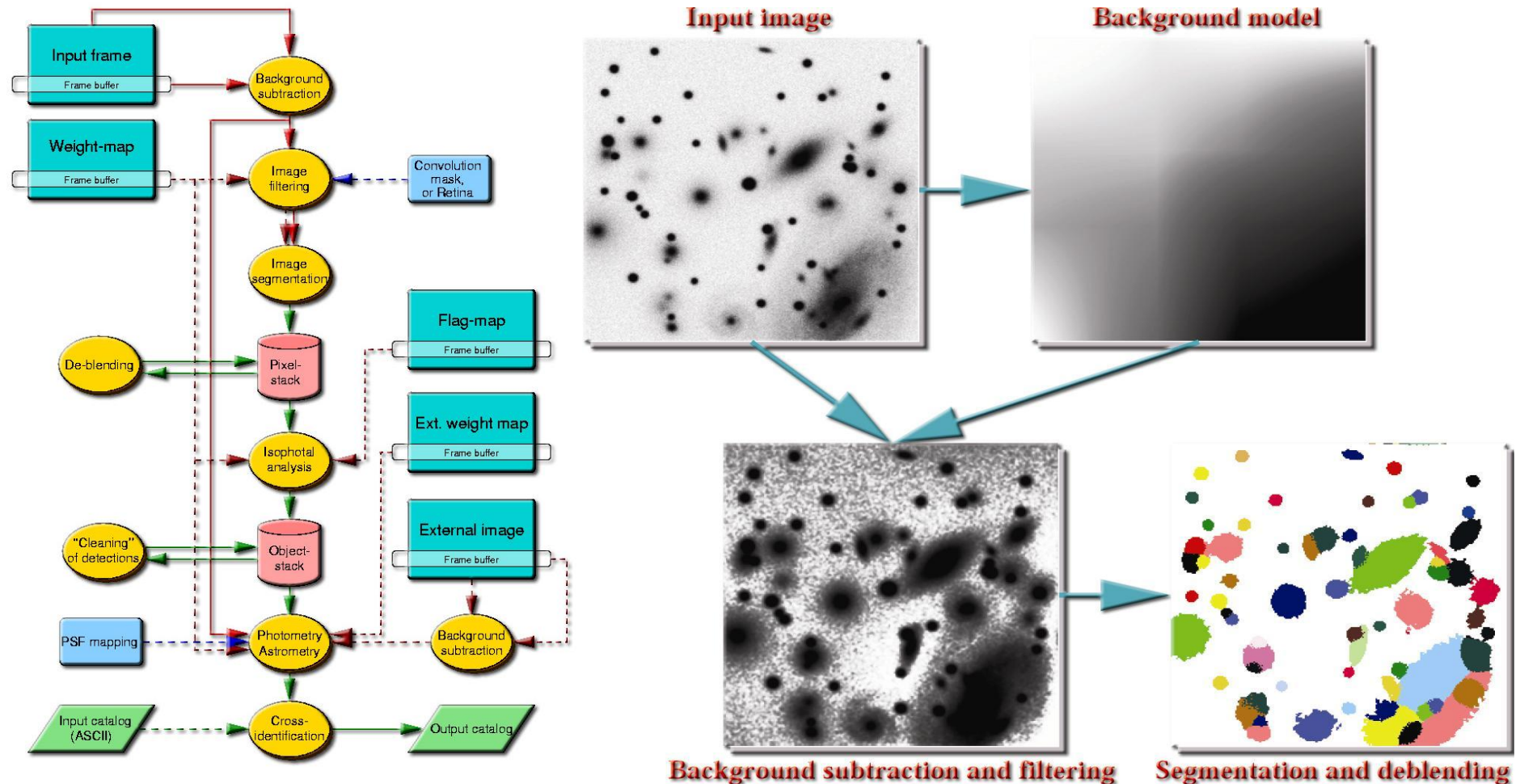
Philippe Delorme
Valérie de Lapparent
Gary Mamon

All wide-field astronomical images share similar features



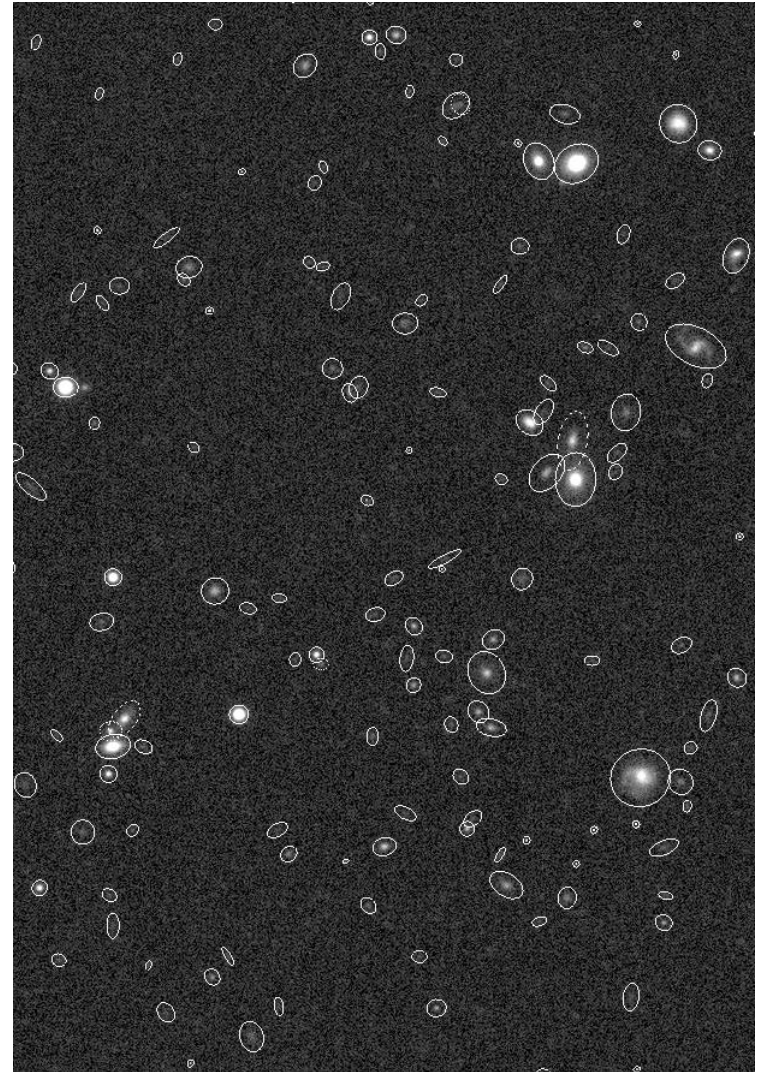
... and 10^5 to 10^7 sources per square degree

Source extraction with SExtractor



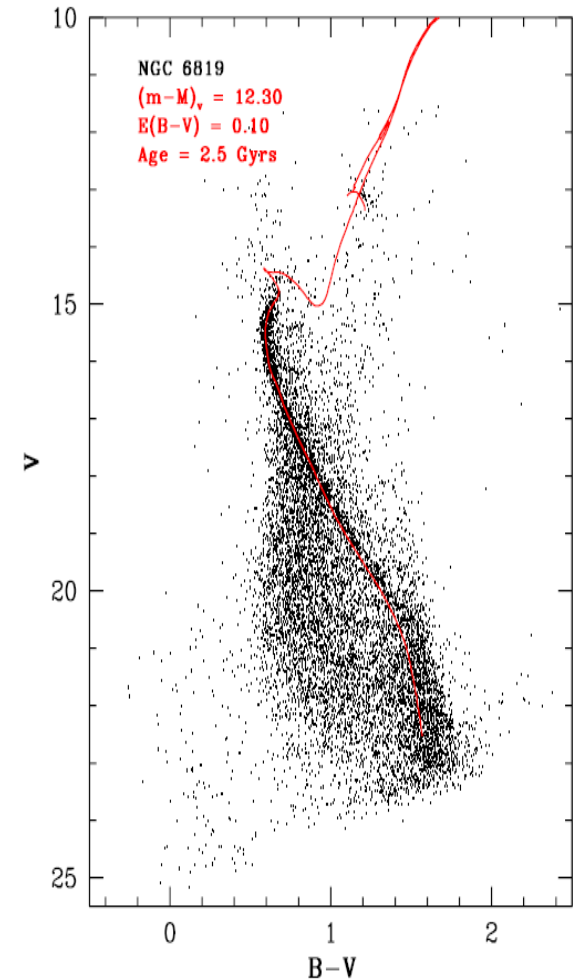
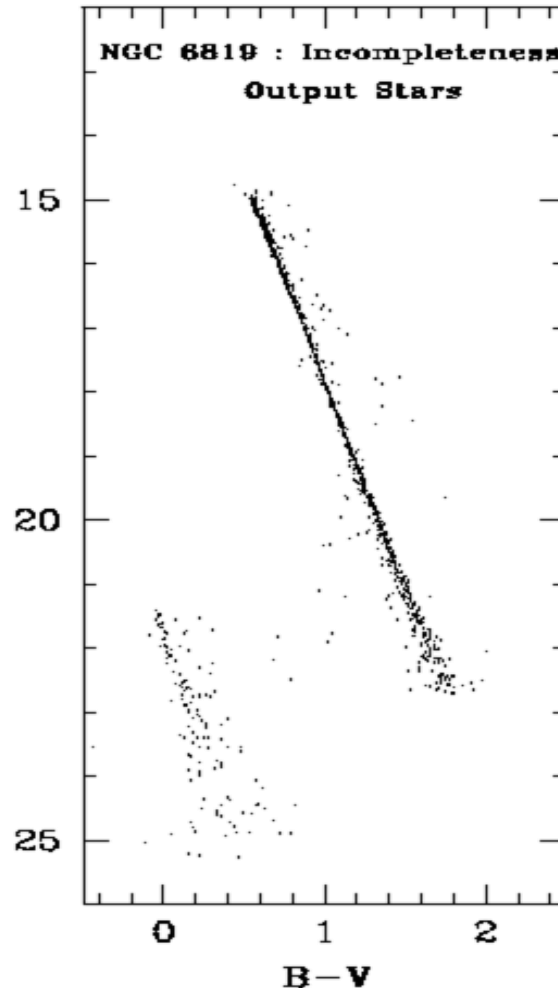
Galaxy model fitting

- Should be
 - fast
 - robust
 - fully automated
 - integrated in preexisting SExtractor code
- PSF model
 - Requires a first pass through the data
 - Modeling implemented in a separate tool: **PSFEx**

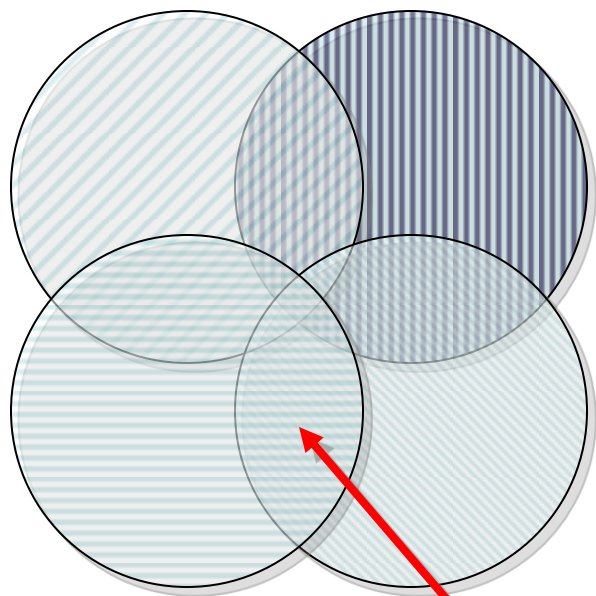


Experimenting with PSF modeling and fitting

- PSF modeling and fitting in PSFEx/SExtractor operating in an experimental way since 2001 (e.g. Cuillandre et al. 2001, Kalirai et al. 2001)
- Fitting routine fits groups of blended stars
 - currently maintained by Philippe Delorme.
- Much work went into handling arbitrary PSFs and undersampled data.

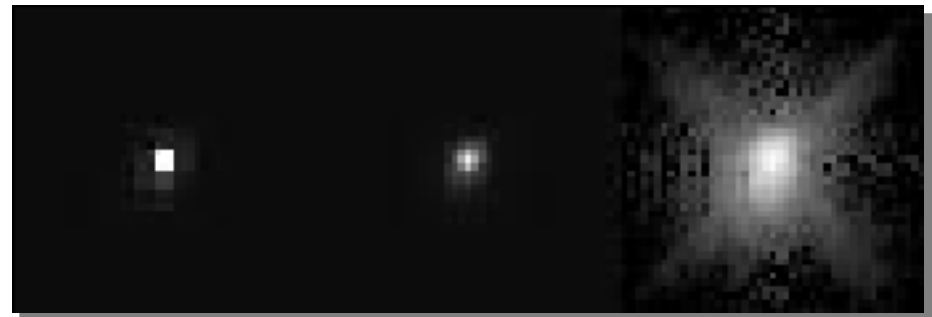


Modeling the PSF: Solving in Fourier space



Aliased portion of the spectrum

Reconstructed
NICMOS PSF



Lauer 1999

Problem: noise is seldom stationary on astronomical images!

PSFEx: solving in direct space

- A resampling kernel h , based on a compact interpolating function (*Lanczos3*), links the “super-tabulated” PSF to the real data: the pixel j of star i can be written as

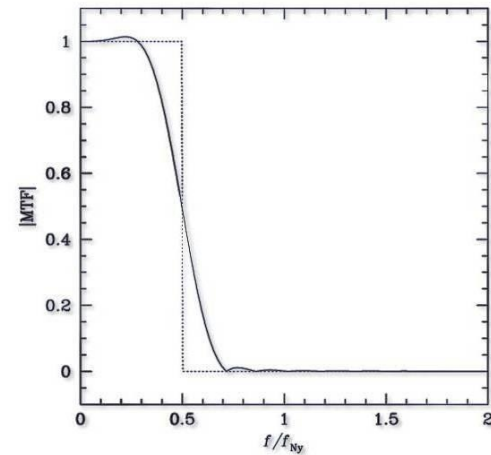
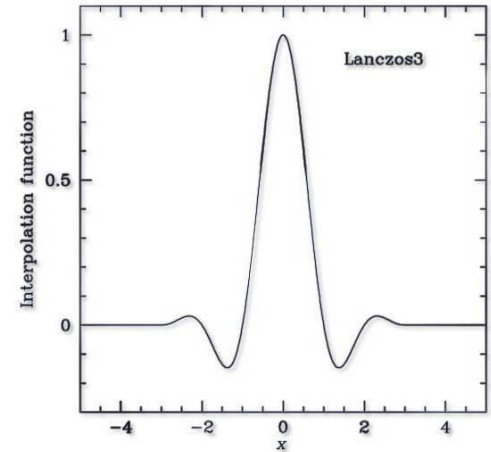
$$P_{ij} = a_i \sum_b \sum_k h_i(\mathbf{x}_k - \mathbf{x}_j) c_b \psi_{bk}$$

- The c_b 's are derived using a weighted χ^2 minimization.
- The a_i 's are obtained from “cleaned” aperture magnitude measurements
- Regularisation required for highly undersampled PSFs (FWHM < 1.5 pixel)
 - ℓ^2 norm (Tikhonov)
- PSF variations are assumed to be a smooth function of object coordinates
 - ☞ The variations can be decomposed on a polynomial basis X_l

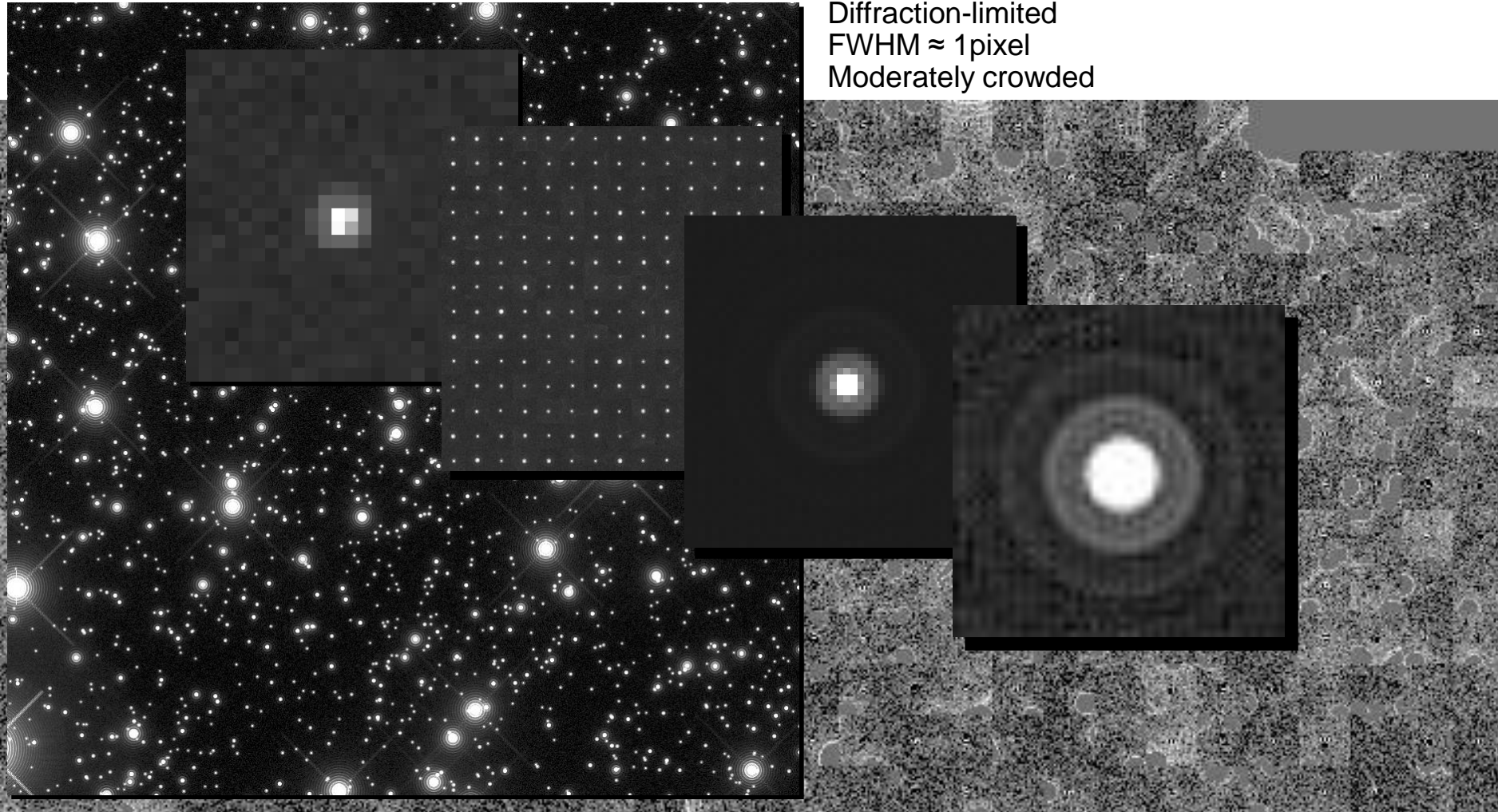
$$P_{ij} = a_i \sum_l X_l(\mathbf{x}_i) \sum_b \sum_k h_i(\mathbf{x}_k - \mathbf{x}_j) c_b \psi_{lbk}$$



$X_l =$ *cste* x x^2 x^3 y xy x^2y y^2 xy^2 y^3

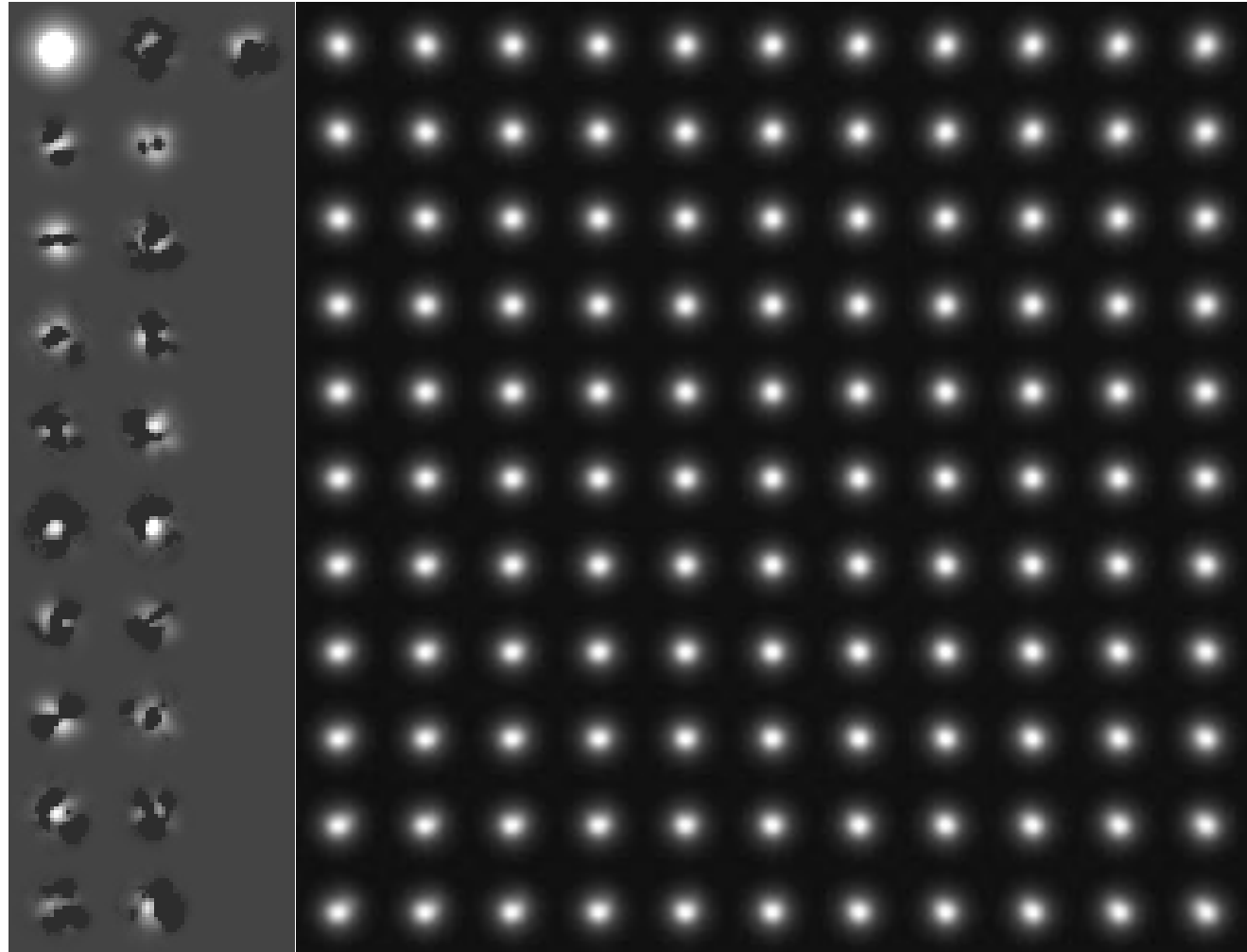


Recovered PSF with simulated, undersampled data



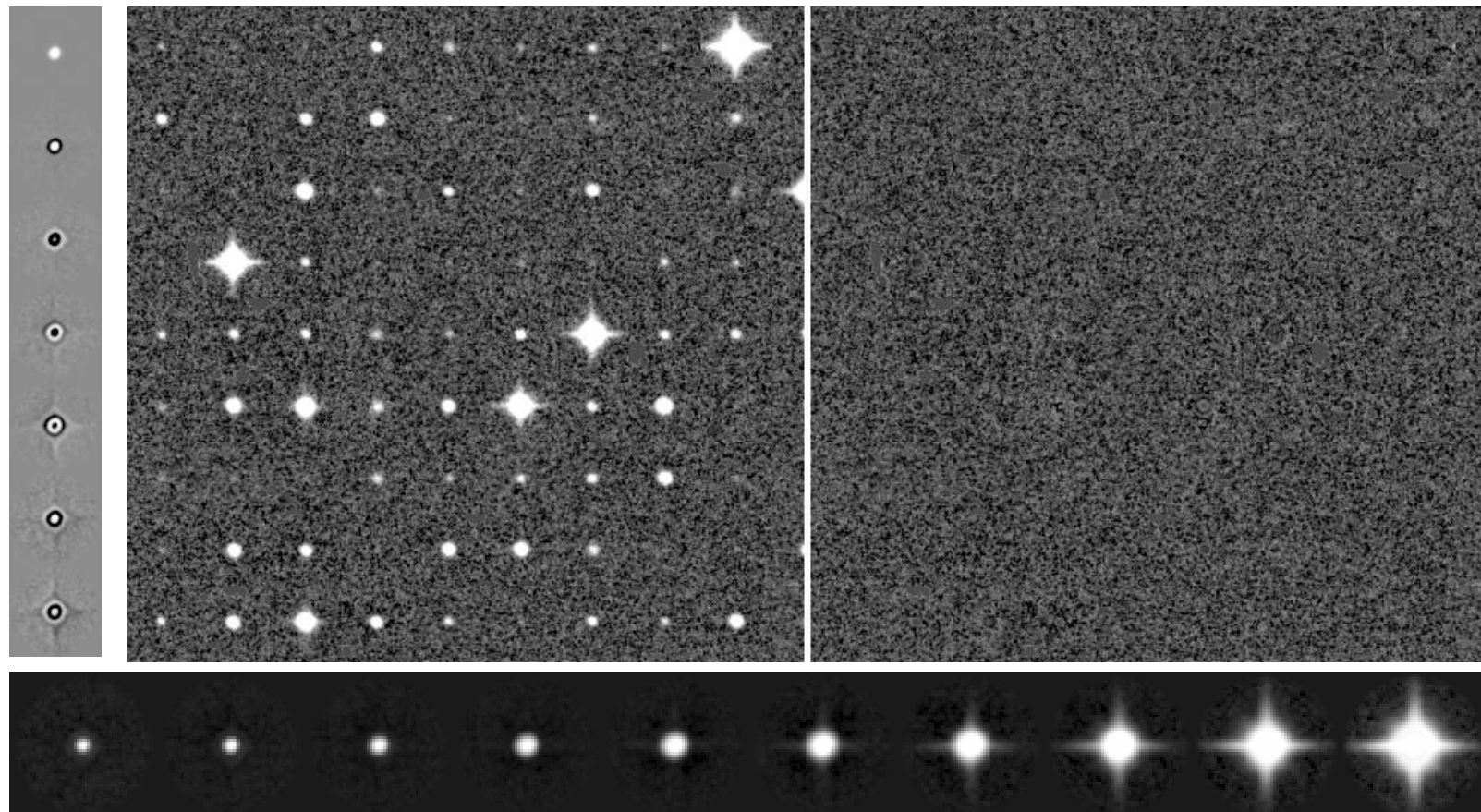
Modelling PSF variations: Reconstructed MEGACAM average PSF in the i-band

- 5th order polynomial in x,y :
`-PSFVAR_KEYS X_IMAGE,Y_IMAGE -PSFVAR_DEGREES 5`
- Derived from 19,000 point sources
- $\chi^2/\text{d.o.f.} \sim 1.3$
 - Proper motions make the PSF “noisy”
- Processing time $\sim 100\text{s}$ on a 2GHz processor



PSF modeling on “non-linear” media

- 1670 point-sources from the central 4096×4096 pixels of a photographic scan (SERC J #418 survey plate, courtesy of J. Guibert, CAI) FWHM \approx 3pixel
- 6th order polynomial in MAG_AUTO



PSFEx quality control and metadata

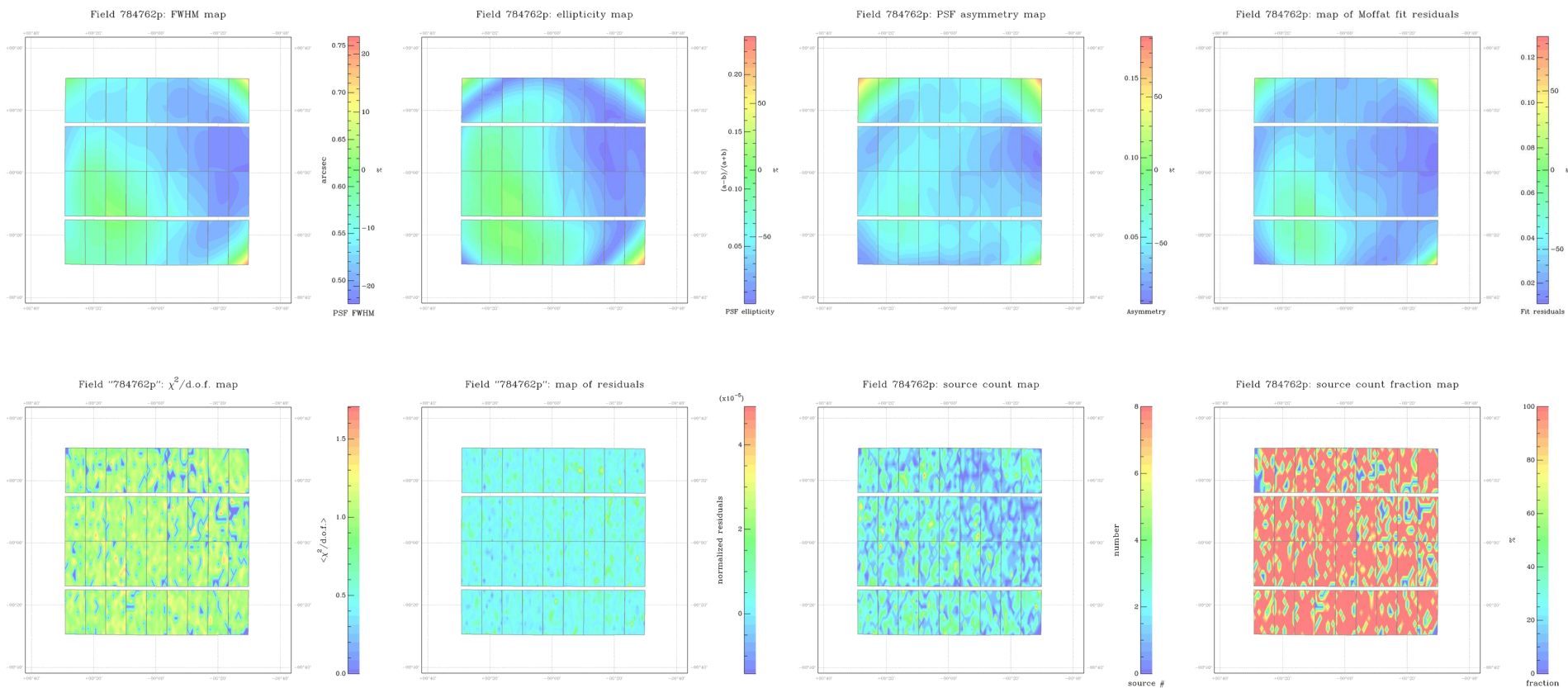
- PSFEx runs a variety of diagnostics
 - Various 2D histograms are produced
 - Numbers are written to a metadata file in XML-VOTable format at the end of each run.
 - An XSLT stylesheet that translates to HTML comes with the PSFEx package.
 - High level libraries such as vo.table for Python can be used to parse the VOTable



The screenshot shows the 'Astromatic.net Processing summary' page. The header features the 'Astromatic.net' logo with a star and a galaxy, and the text 'Processing summary'. Below the header, the page displays the following information:

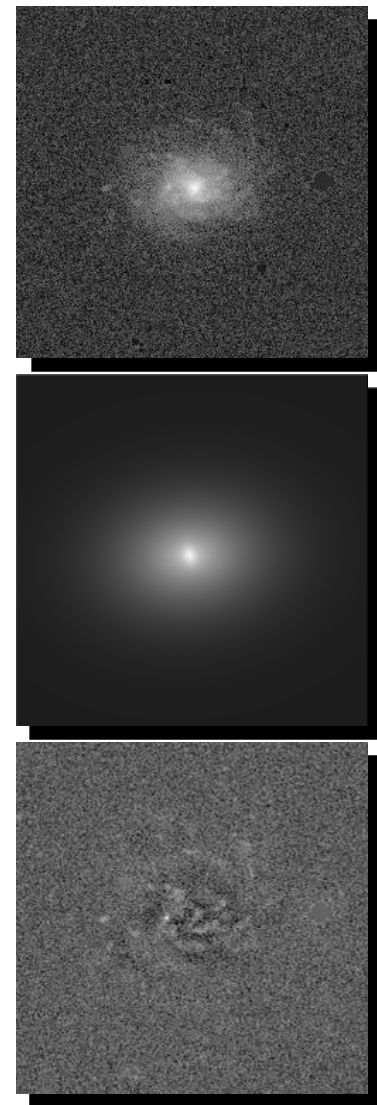
- PSFEx 3.8.1 started on 2010-05-09 at 01:38:43 with 4 threads (run time: 3 min 13 s) by user **bertin** from **kiravix.iap.fr** in /disk2/psfex/t05
- PSF stats per Input File ↓
- PSF stats per Extension ↓ (with 'Prefix.exe' visible below the button)
- Configuration File: **default.psfex** ↓
- Command Line ↓
- Warnings (limited to the last 1000) ↓

PSFEx quality control (cont.)

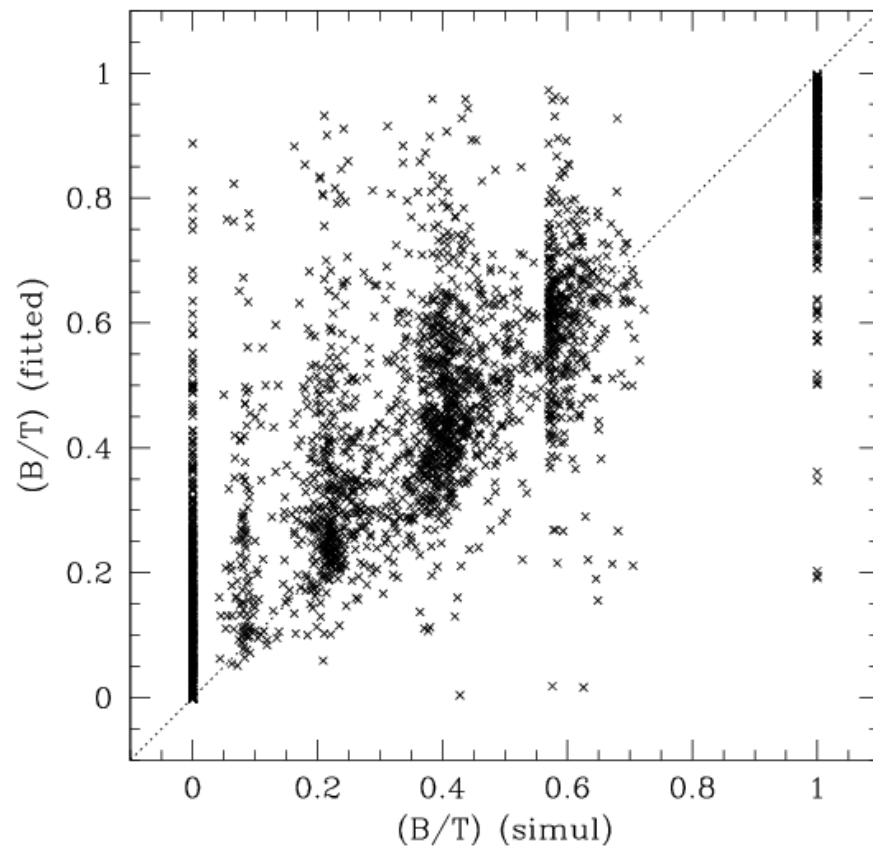
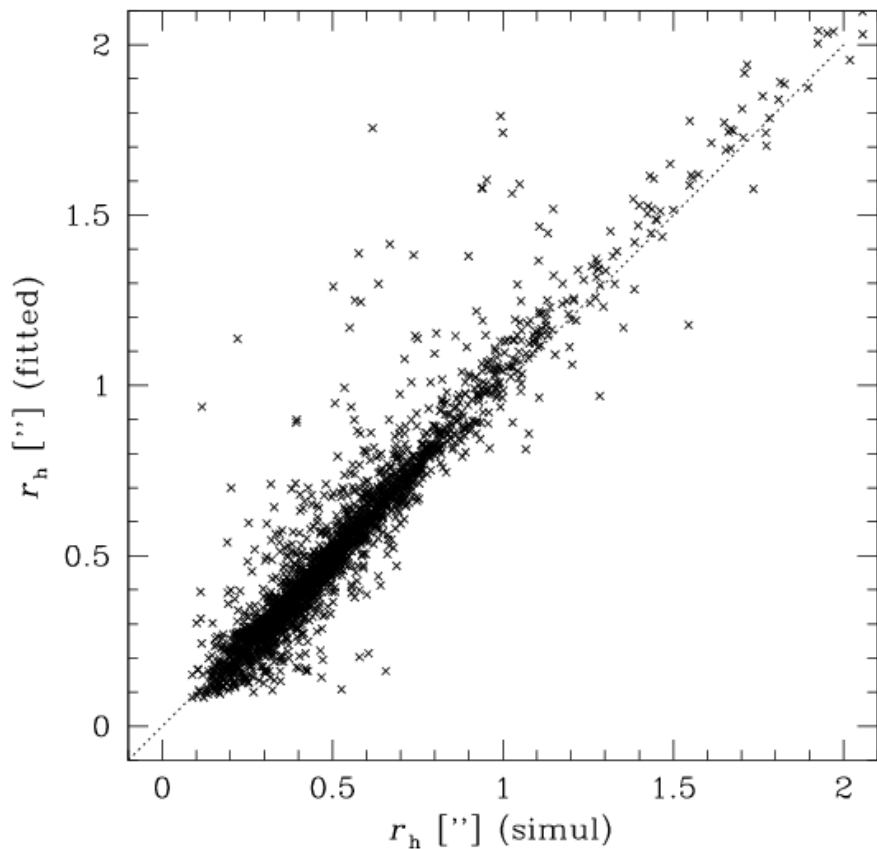


SExtractor morphometry

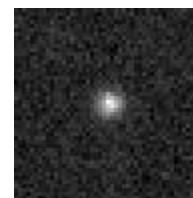
- PSF modeled using **PSFEx**
 - Sampling automatically adjusted depending on image
- Models are computed using a grid size that depends on sampling and on the object
 - Image and model rasters are rebinned for very large objects
- Several model components currently available:
 - Background level, Point source (2 + 1 free parameters), Sersic (2 + 5), De Vaucouleurs (2 + 4), Exponential (2 + 4)
 - others currently in development
 - The presence of model parameters in the SExtractor `.param` file triggers the fitting process
- Minimization uses the **LevMar** implementation of the Levenberg-Marquardt algorithm by M.Lourakis
 - Adaptive Jacobian
 - Initial parameter guesses made from « classical » SExtractor measurements
 - Robust fitting
 - Bright pixels from neighbours automatically masked by SExtractor.
- Processing speed: 10-30 galaxies/s on a single 3GHz CPU core.
 - ~ one million galaxies per day and per compute node.



Recovered galaxy parameters

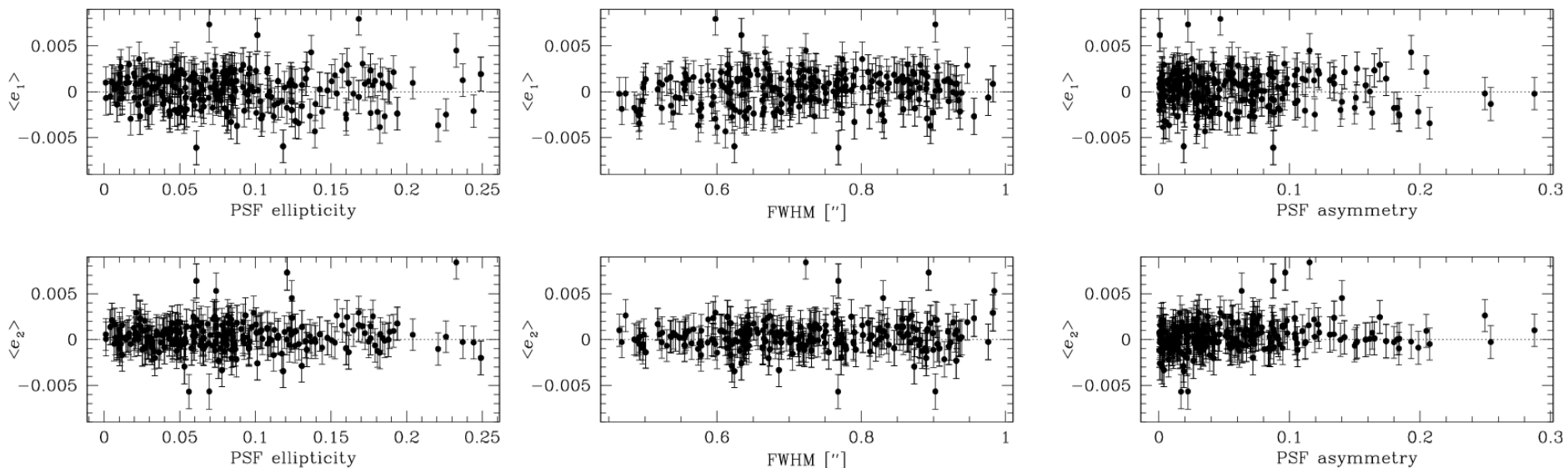


Sersic ($n=4$) + Exponential fit for $i < 21$



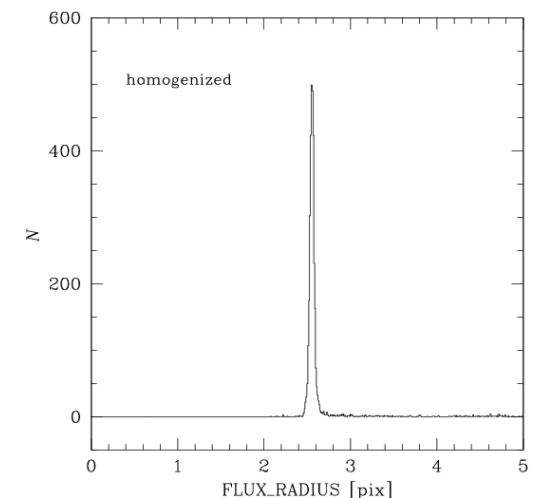
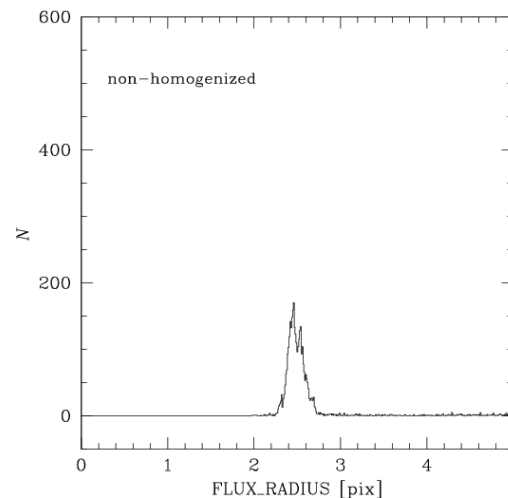
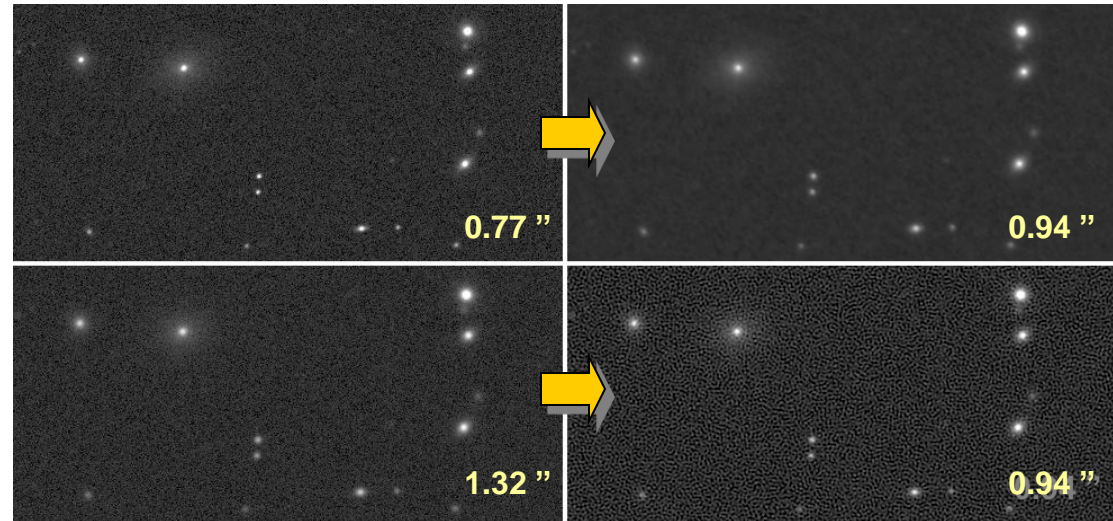
Weak shear measurements with SExtractor

- trends as a function of PSF ellipticity, FWHM, or asymmetry kept below the 10^{-3} level



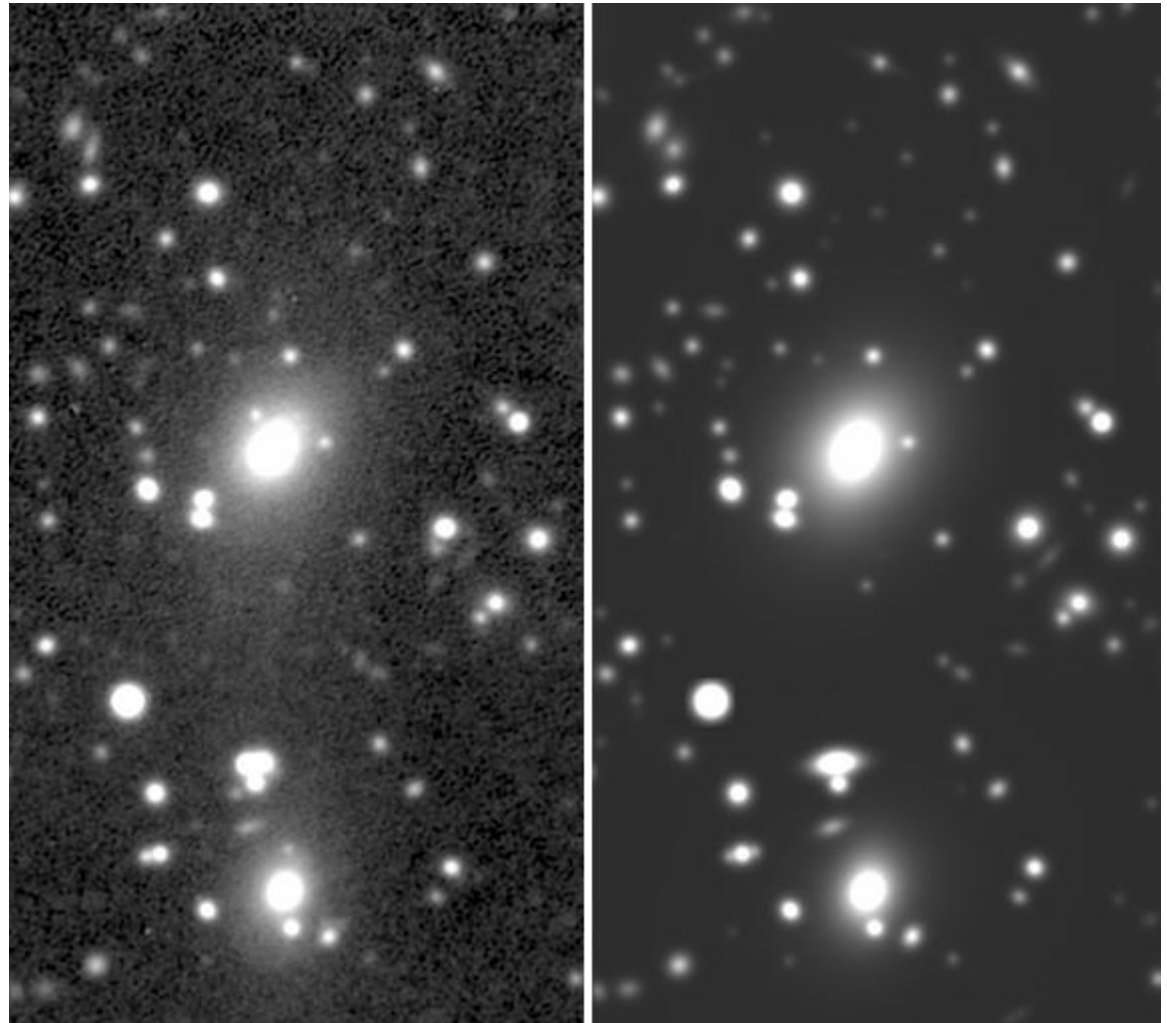
PSF homogenization in the Dark Energy Survey

- Co-addition: large pointing offsets + small number of exposures create jumps in the PSF at image boundaries
 - Combine exposures with variable image quality
 - ➔ PSF homogenization required
 - Bring all images to the same, circular PSF, using the variable PSF models
 - “Cheap” alternative to image fusion/Bayesian inference.
 - DECam images are properly sampled
 - Impose the target PSF with median seeing to minimize noise correlation
 - Handle noise correlations on arcsec scales
 - Masking and interpolation critical



Future plans and improvements

- Multi-threading
- Multi-source model-fitting
- Intelligent deblending
- Improved background model
- Multi-band model-fitting



Visit AstrOmatic.net



The screenshot shows the homepage of AstrOmatic.net. The header features the site's logo, "AstrOmatic.net", with the tagline "Your first stop for astronomical pipeline software" and a RSS feed icon. The main content area is divided into several sections:

- Welcome to AstrOmatic!**: A large heading followed by a paragraph of introductory text about the website's purpose, including links to software, documentation, a discussion forum, and development repositories. It also mentions a technical blog and a registration process for commenting.
- Most recent post:**: A section titled "SWarp 2.19.1 release" with a sub-header. Below it, the post is attributed to Emmanuel, dated September 4, 2010. A "Comments (0)" link is visible.
- Image:** A cartoon character stands next to a chalkboard that says "New Release!".
- Text:** A short paragraph stating: "SWarp 2.19.1 has been released! This version brings several new bugfixes and features:"
- Content sidebar:** A list of links including "Welcome to AstrOmatic!", "About", "AstrOmatic software", "Technical blog", "Gallery", and "Web services".
- Recent Posts sidebar:** A list of recent releases: "SWarp 2.19.1 release", "MissFITS 2.4 release", "SCAMP 1.7.0 release", "STIFF 2.1 release", "STIFF 2.0 release", "CFHTLS interactive image gallery", "Tuning up your display for optimal viewing of astronomical images", and "SCAMP 1.6.2 release".
- Support sidebar:** A link to the "AstrOmatic forum".