Mesure d’attributs par ajustement de profils

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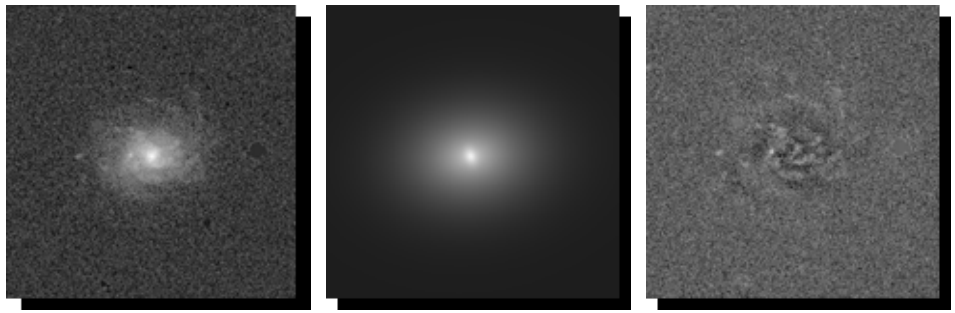
EFIGI

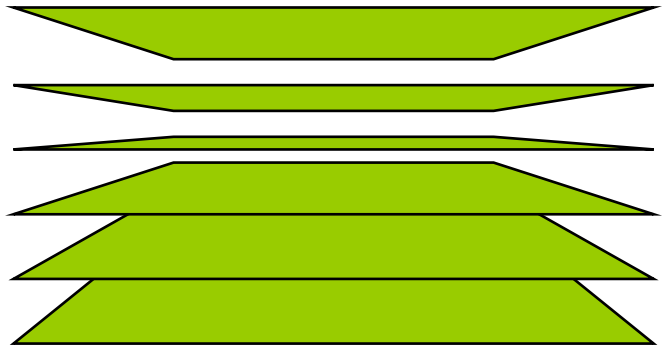
Measuring attributes using profile-fitting

- Recap of previous episodes
- Implementing profile-fitting in SExtractor
- Results on image simulations
- Fitting additional shape parameters
- Future plans

Recap of previous episodes

- « Plan B » triggered because of difficulties with the linear decomposition approach.
- Began with Marta's work in 2006 with MATLAB: Sersic fit (without a PSF).
- Implementation in C within ***SExtractor*** (http://terapix.iap.fr/soft/sextractor/) followed by the end of 2006
- Original idea:
  - Sur un processeur de type x86, une simple élévation à la puissance **`pow()`** prend environ 8 fois plus de temps qu'une interpolation bi-linéaire.
    - Donc: pourquoi ne pas utiliser des profils 2D pré-calculés au lieu de fonctions analytiques?
    - Malheureusement la variation de certains paramètres physiques (indice de Sersic par exemple) s'accommodent mal d'une interpolation image-à-image: les gradients sont trop importants.
  - Avec la compilateur Intel la tendance est inversée: un retour aux fonctions analytiques devient plus rentable!





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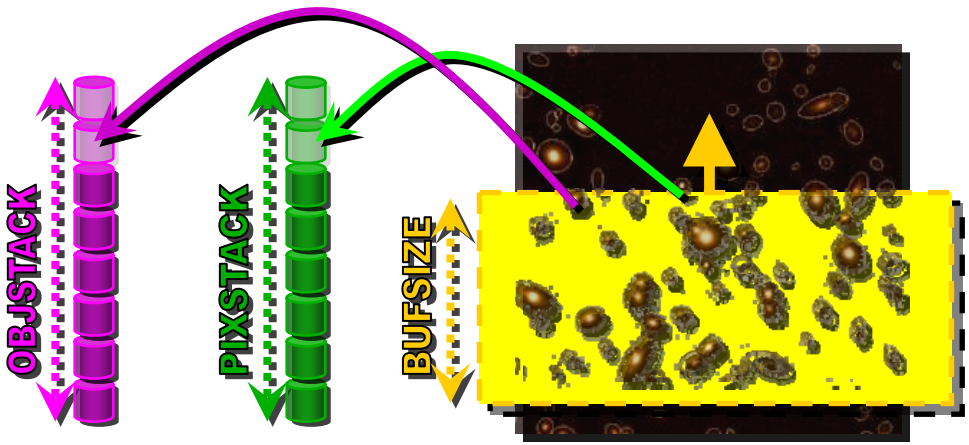
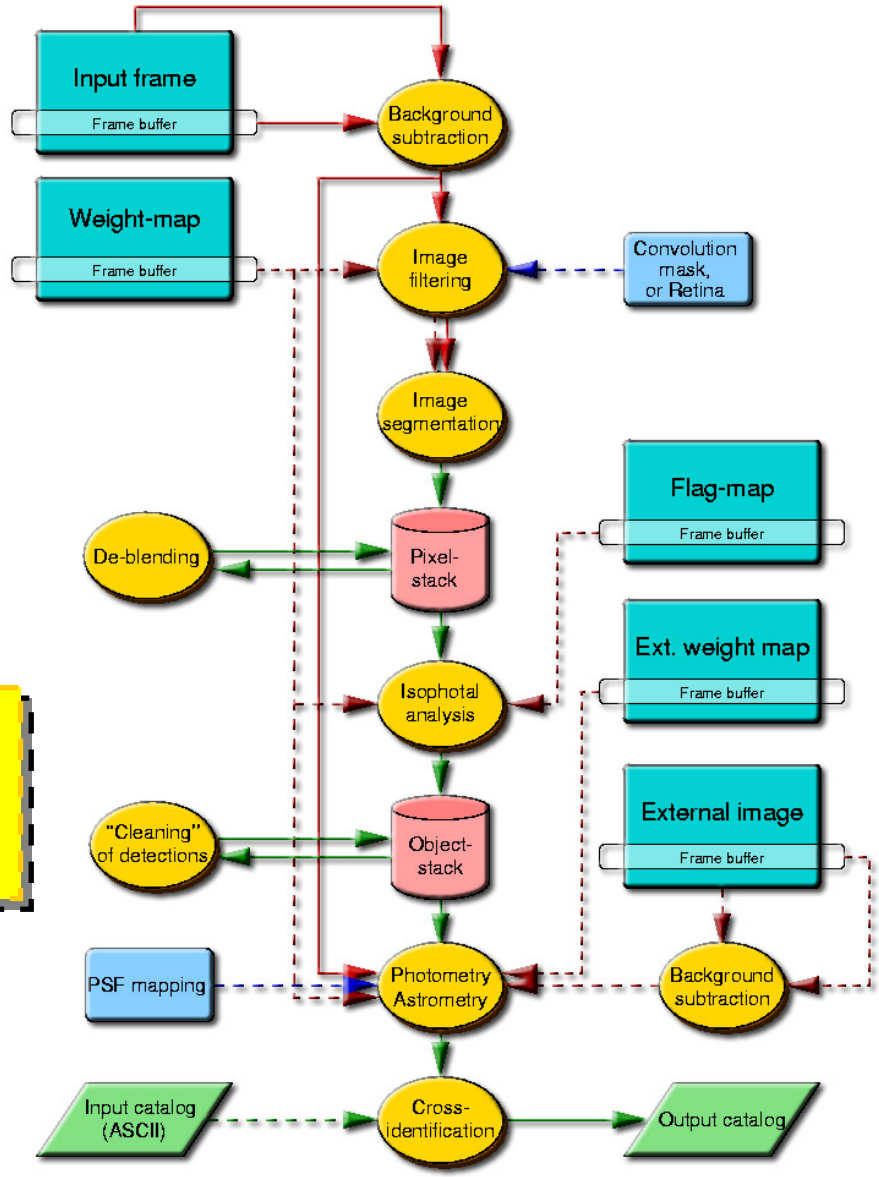
SExtractor data flow

- The tricky part is the management of all buffers and FIFO stacks:





How sources are detected in SExtractor

- 4 steps:
  - Sky background modeling and subtraction
  - Image filtering at the PSF scale (matched filter)
  - Thresholding and image segmentation
  - Merging and/or splitting of detections

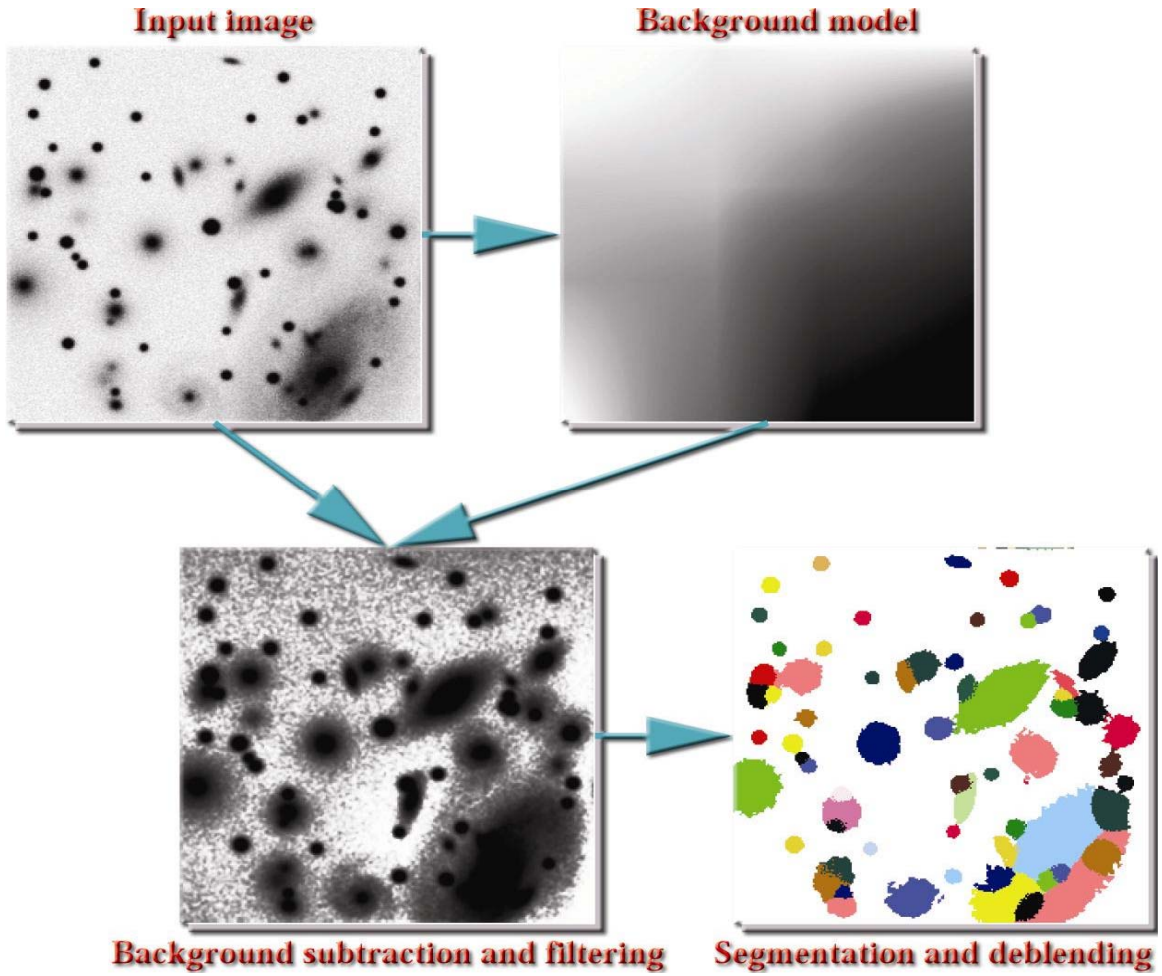
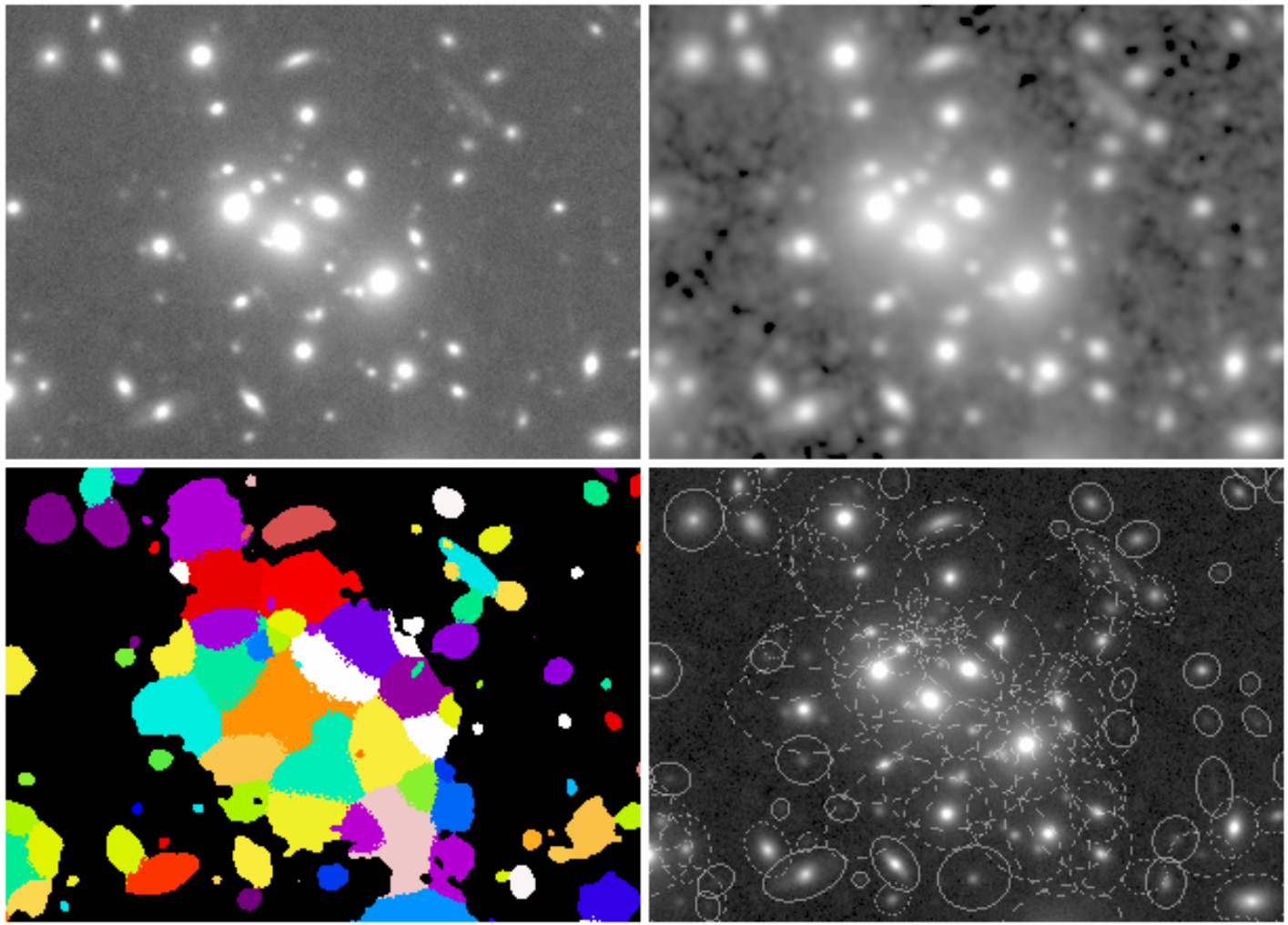


Image segmentation

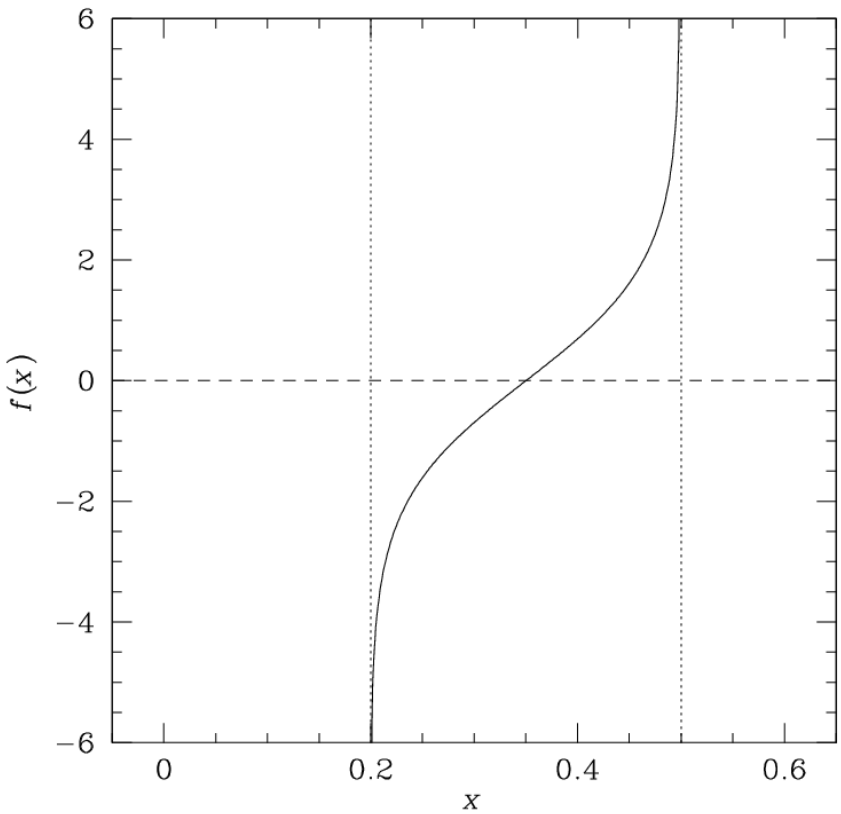


Profile-fitting: implementation

- PSF modeled using ***PSFEx***
  - Sampling automatically adjusted depending on image
  - Several improvements and bugfixes done over the past months
- Profile models are now computed with a grid size that depends on the object.
- Automatic sharing of component parameters (e.g. x,y,…)
- 6 profile components currently available:
  - Background level
  - Sersic (2 + 5 free parameters)
  - De Vaucouleurs (2 + 4 free parameters)
  - Exponential (2 + 4 free parameters)
  - Logarithmic spiral arms (3 + 7 free parameters)
  - Exponential bar (3 + 3 free parameters)
- Minimisation:
  - Two C implementations of the Levenberg-Marquardt algorithm:
    - ***lmfit*** by J.Wuttke
    - ***LevMar*** by M.Lourakis
  - Initial parameter guesses made from isophotal measurements and half-light radius.
  - Bright pixels from neighbours automatically masked by SExtractor.
  - Robust fitting

Profile-fitting: fighting degeneracies

- It is mandatory to include some implicit prior in the chi2:
  - positivity constraints for fluxes
  - negativity constraints for dust band(s)
  - ellipticity constraints for the bulge and the bar
- Implementation of the box-constrained algorithm by Kanzow, N. Yamashita and M. Fukushima (2004) in levmar does not seem to work.
- House-made trick: map free parameters from a bounded space to an unbounded space
  - A sigmoid function works fine!
  - In some rares cases a free parameter can get stuck at one of the boundaries



Robust profile-fitting (cont.)

- The sky around galaxies is not « clean » because of overlapping stars, galaxies or defects. Possible solutions:
  - Use nFIGI: fast and efficient for images of individual objects.
  - The old SExtractor « CLEANer » masks out the pixels from bright neighbours, but it is not efficient enough
- The « perfect fit » does not exist, except may be for some ellipticals and spheroidals
  - dust, star formation regions, overlapping objects,…
- Minimizing fractional errors instead of absolute ones is more appropriate for bright parts of the profile
- Proposition: replace the usual residual in

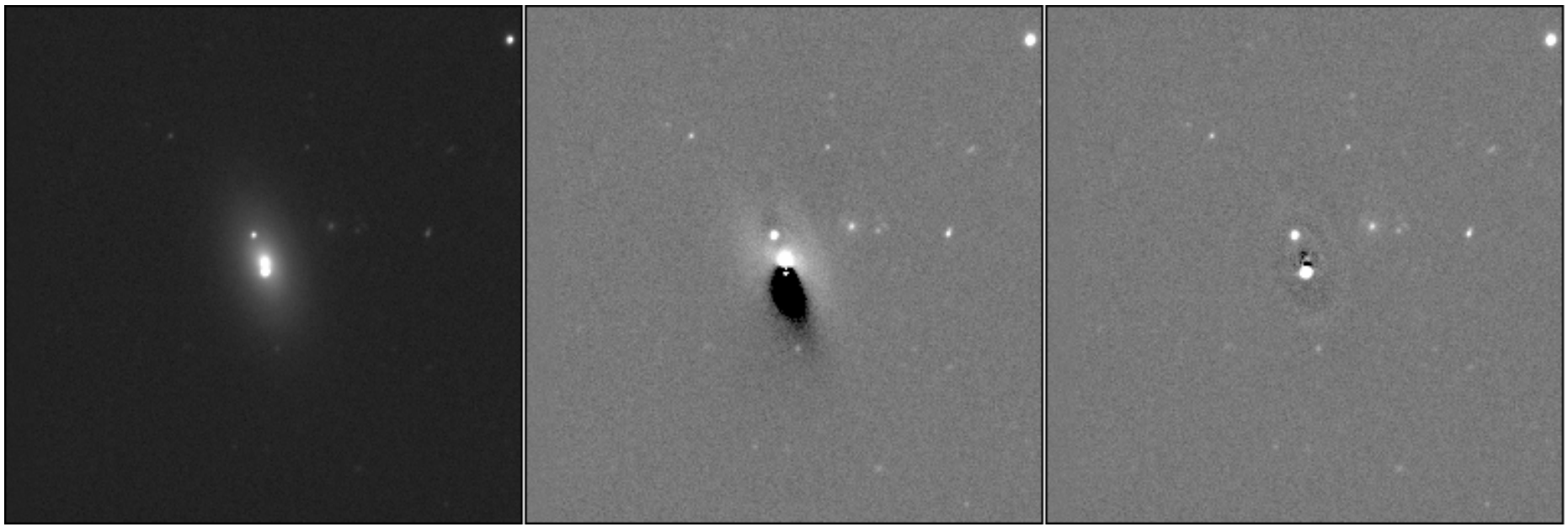
$$\chi^2 = \sum_i \frac{I_i - f(x_i)}{\sigma^2}$$

with

$$\chi^2 = \sum_i g\left(\frac{I_i - f(x_i)}{\sigma}\right)^2 \quad \text{where } g(u) = \begin{cases} \log(1+\kappa u) \text{ if } u \geq 0 \\ -\log(1-\kappa u) \text{ otherwise} \end{cases}$$

- κ~1: linear close to the noise and continuously derivable

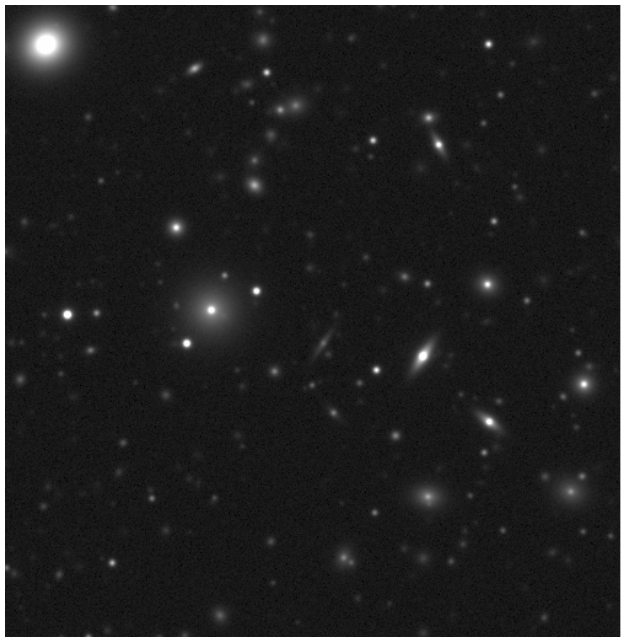
Robust profile-fitting



Galaxy | Linear weighting | Non-linear weighting

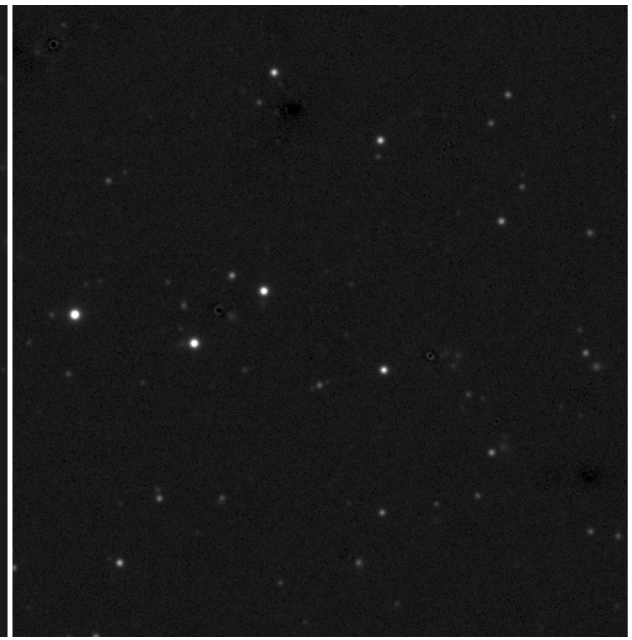
- More robust towards bright interlopers
- In rare cases, the minimization algorithm may accidentally “lock” on some bright, non-galaxy feature

Results on simulations



simulations

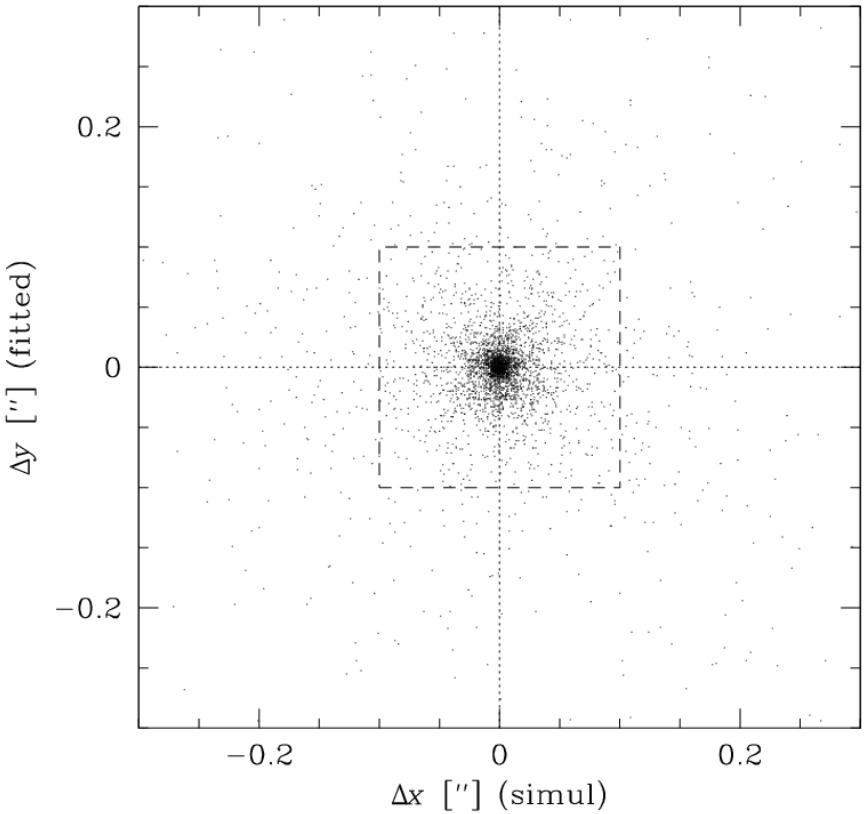
fitted models



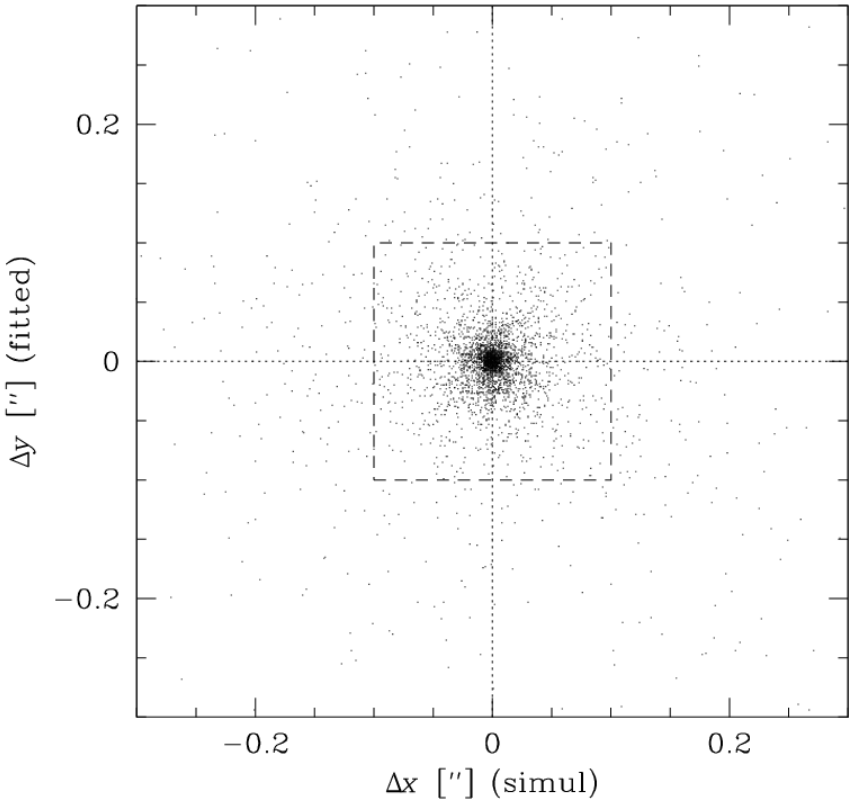
difference

- Catalog simulated with Stuff
  - ~4× true galaxy density
- Images created with SkyMaker
  - i band, 4m-class, 13000s, 50% comp.limit i~25
  - seeing=0.63”, pixel=0.2”
- 11,500 detected galaxies
- PSF model was derived from stars in the image (no trick!)

Positional accuracy

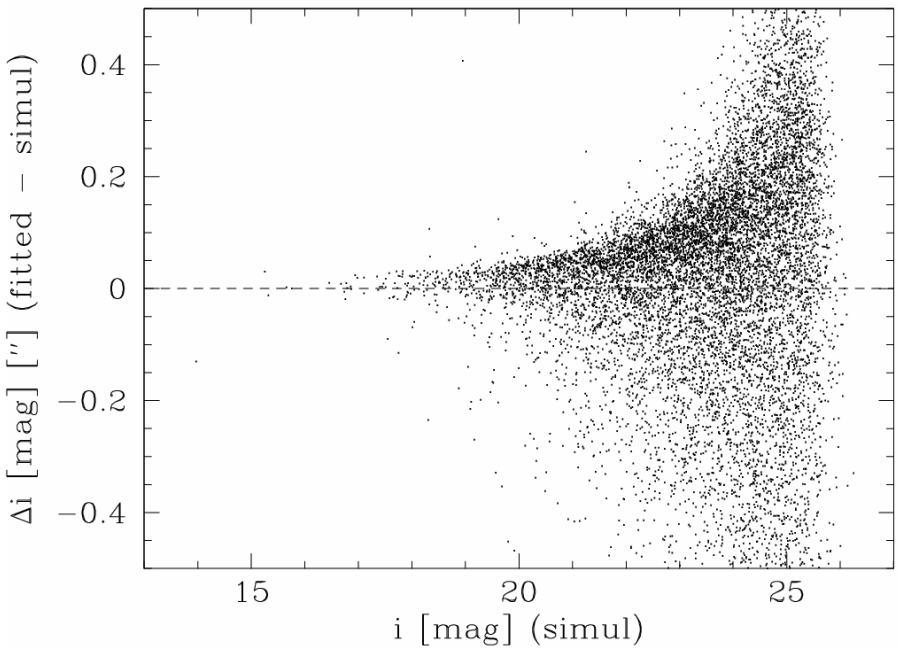


Sersic + Exponential fit (i<23)

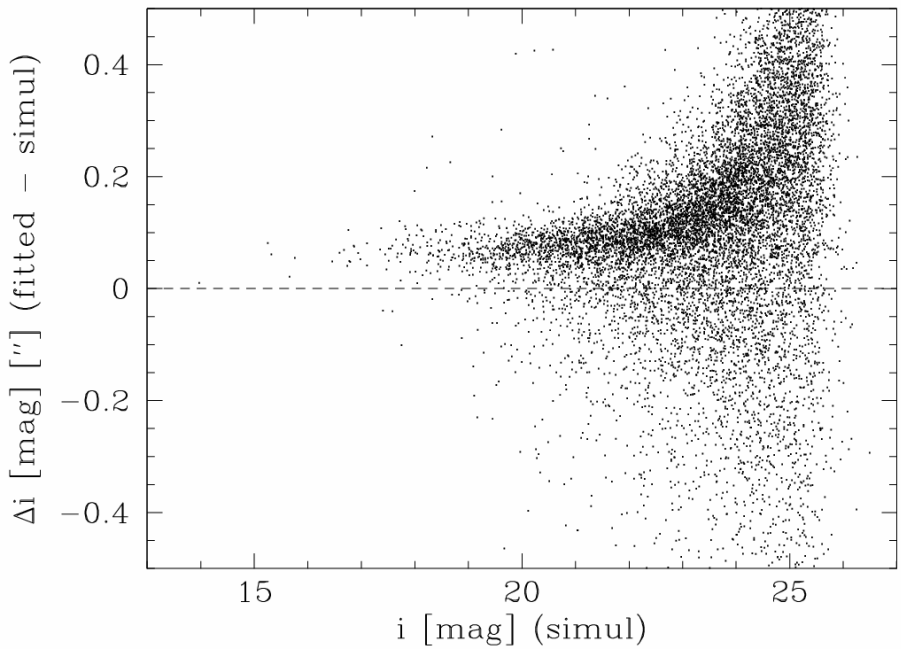


X/YWIN (i<23)

“Total” magnitudes

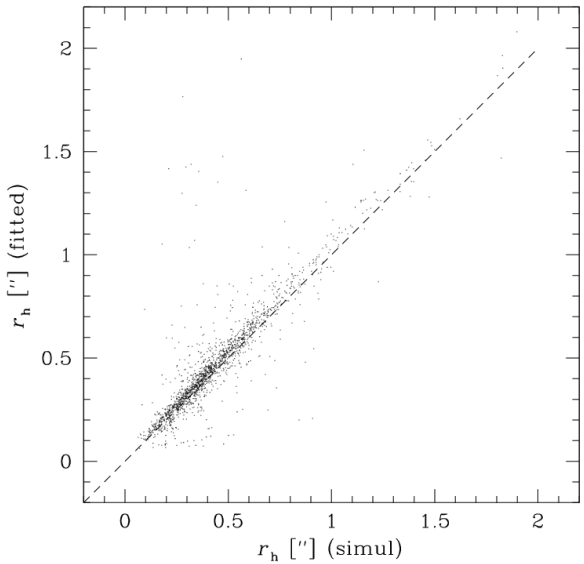


Asymptotic from Sersic+Exponential fit

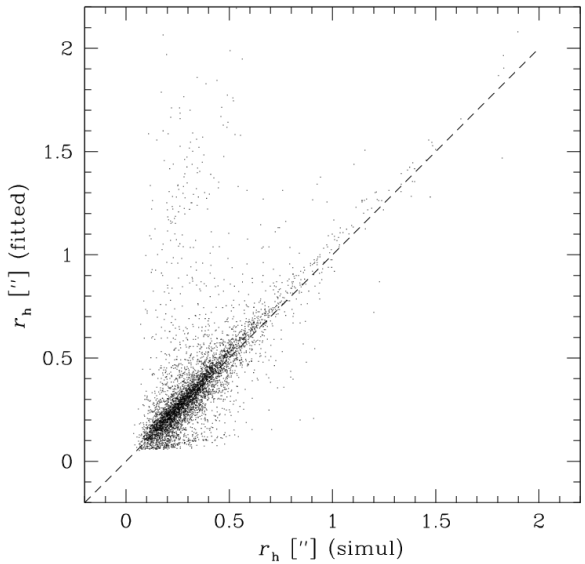


MAG_AUTO (Kron-like)

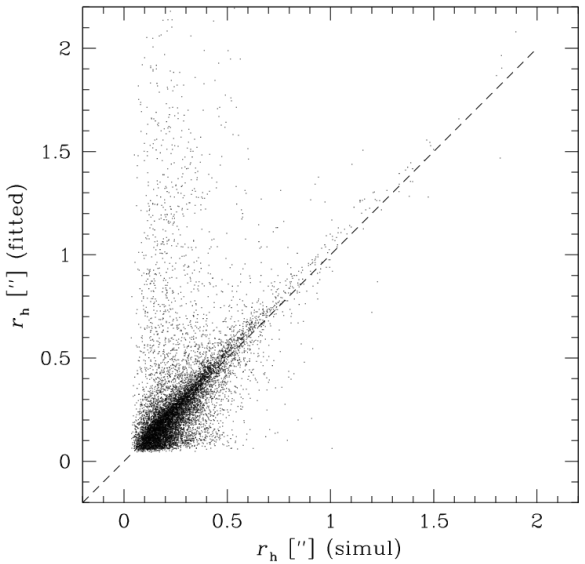
Disk scalelengths



i<22



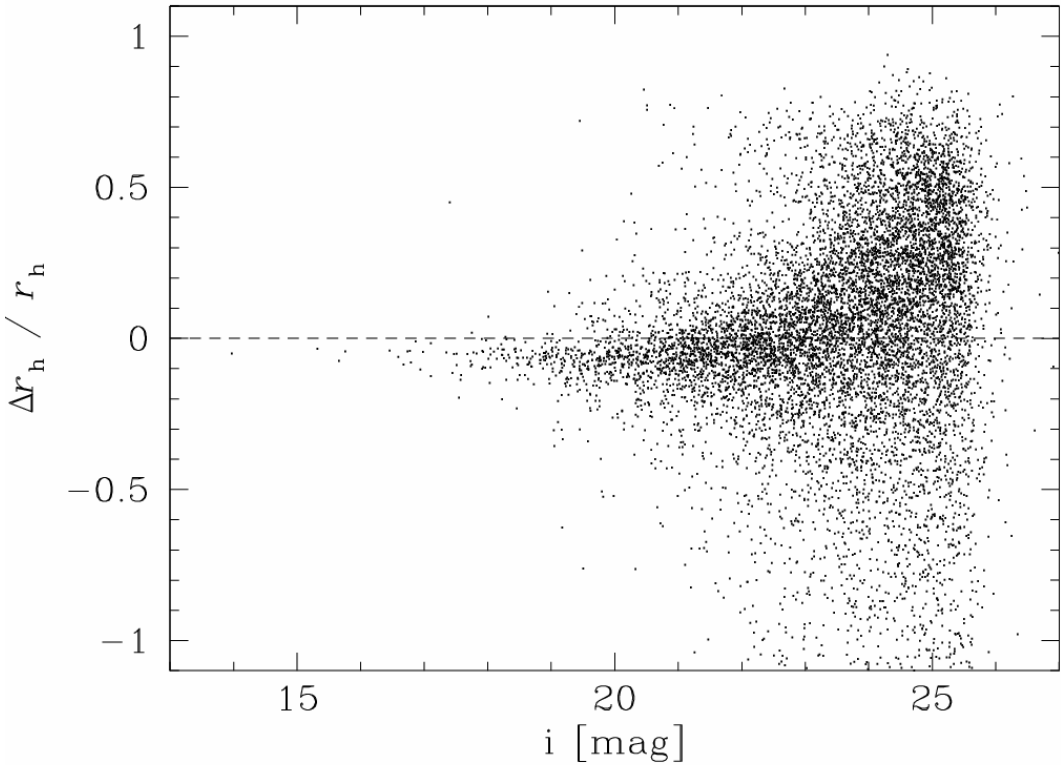
i<24



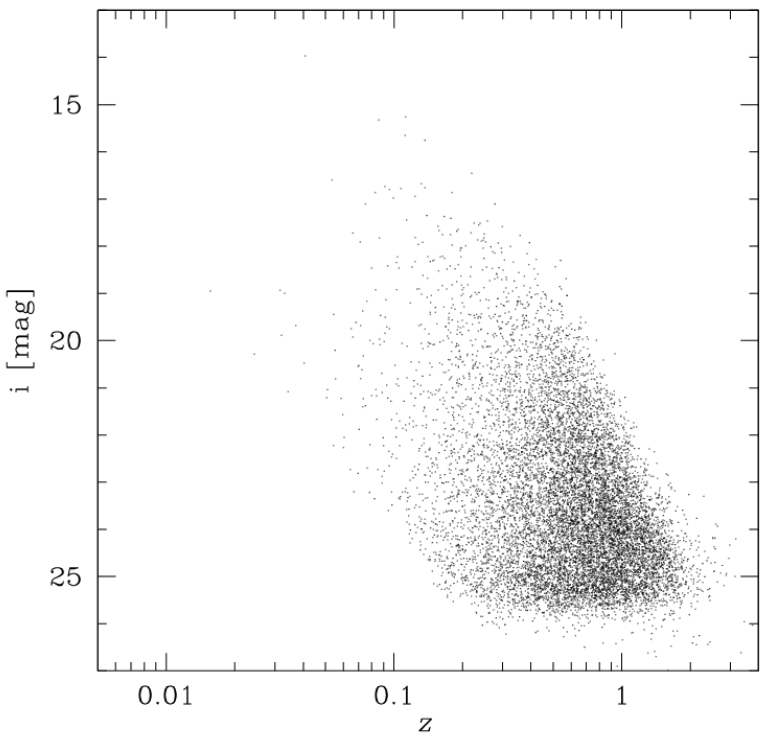
all

Sersic + exponential fit

Disk scalelengths (cont.)

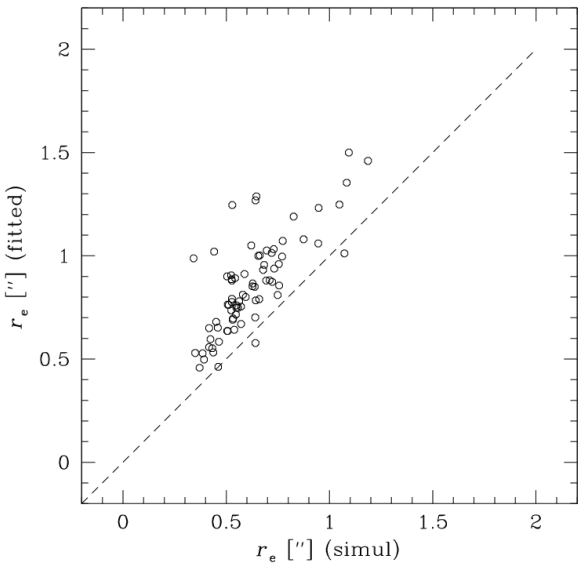


Fractional error as a function of magnitude

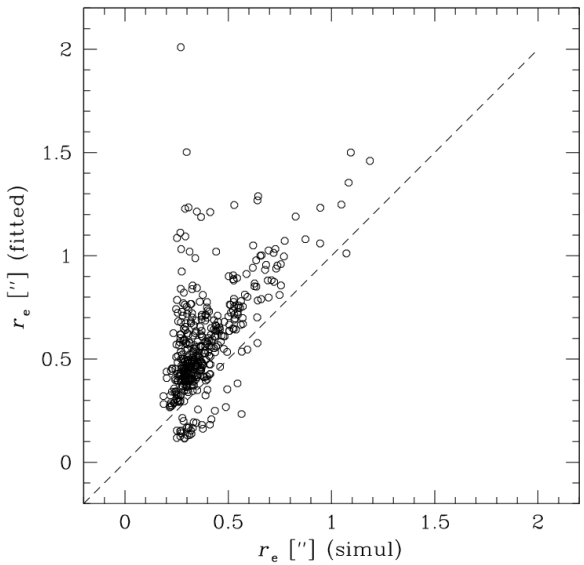


Hubble diagram
of the simulation

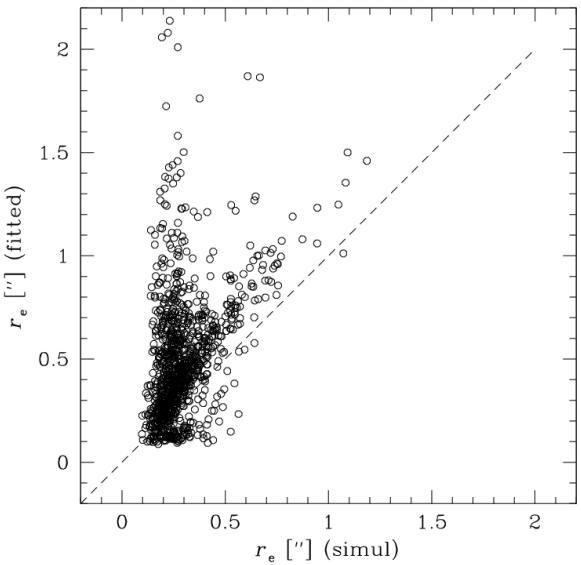
Bulge equivalent radii



i<19 and B/T>0.5



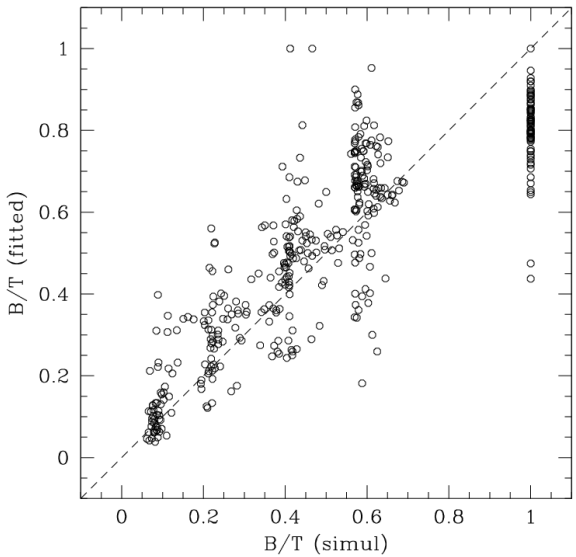
i<21 and B/T>0.5



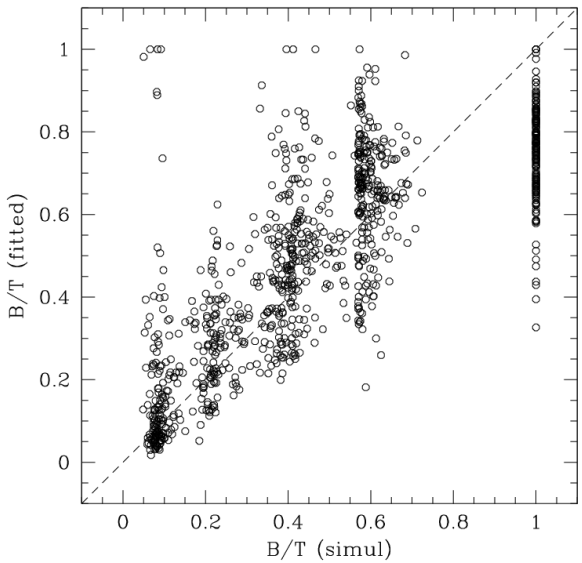
i<23 and B/T>0.5

Sersic + exponential fit

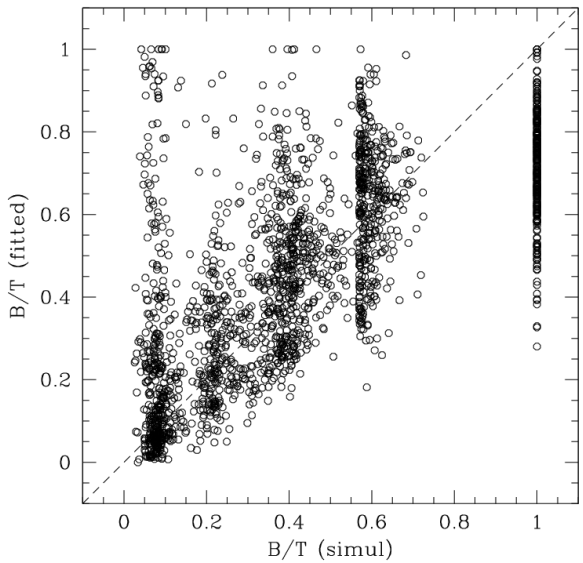
Bulge to Total ratio



i<20



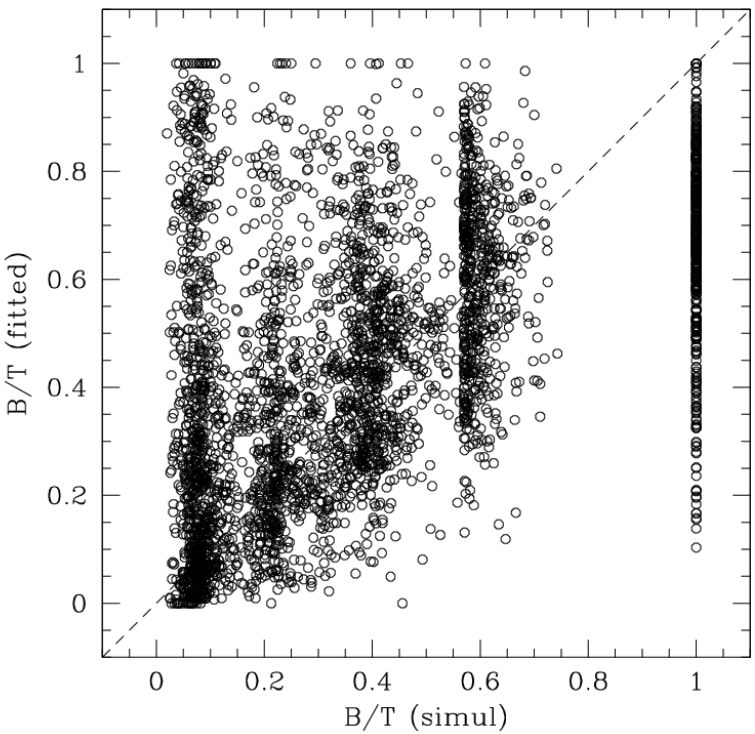
i<21



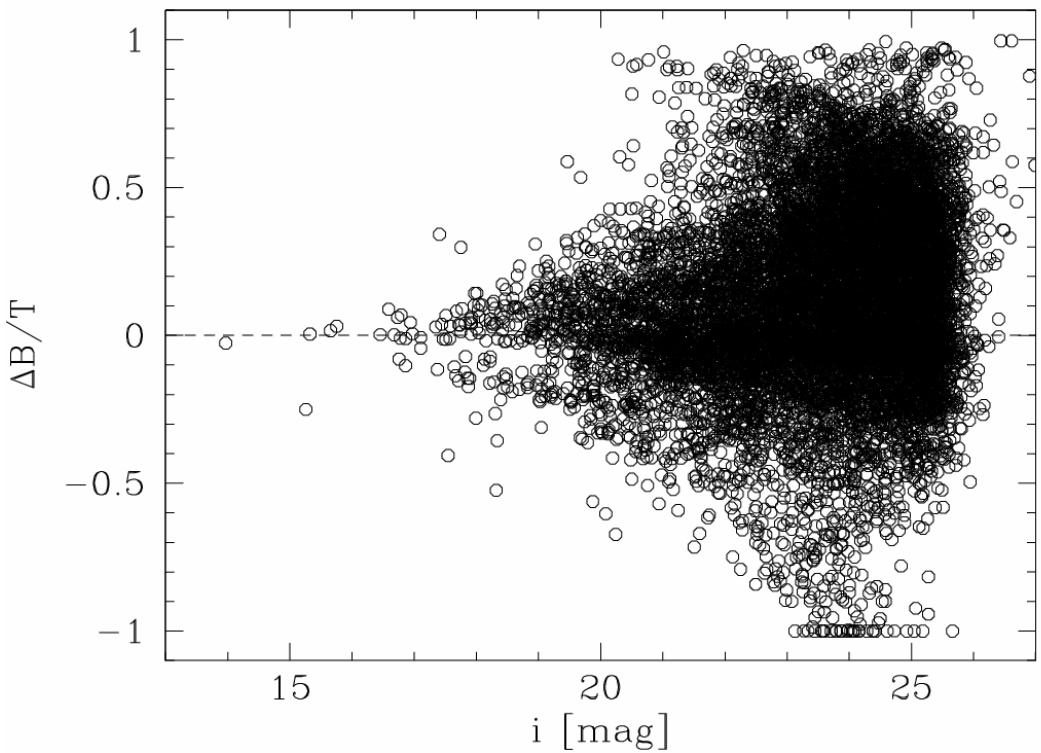
i<22

Sersic + exponential fit

Bulge to Total ratio (cont.)

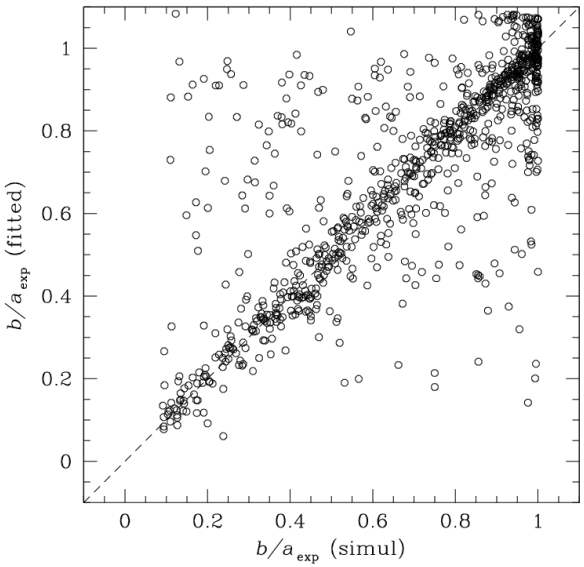


i<23

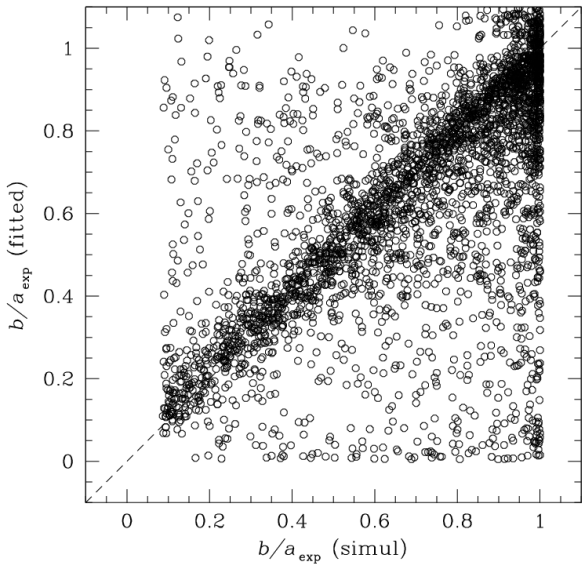


error as a function of magnitude

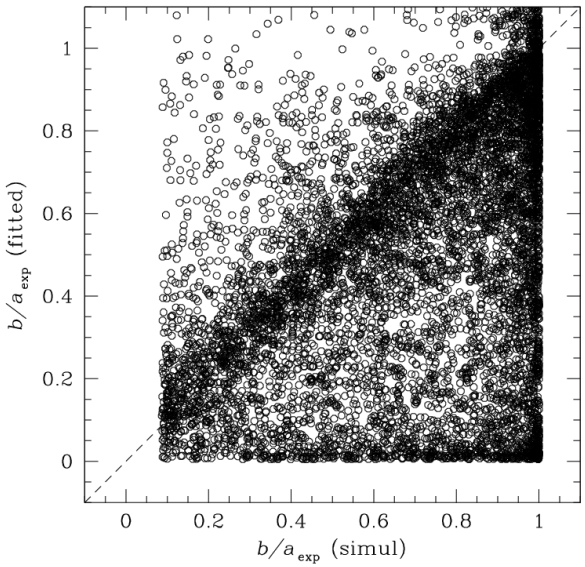
Disk aspect ratio



i<21



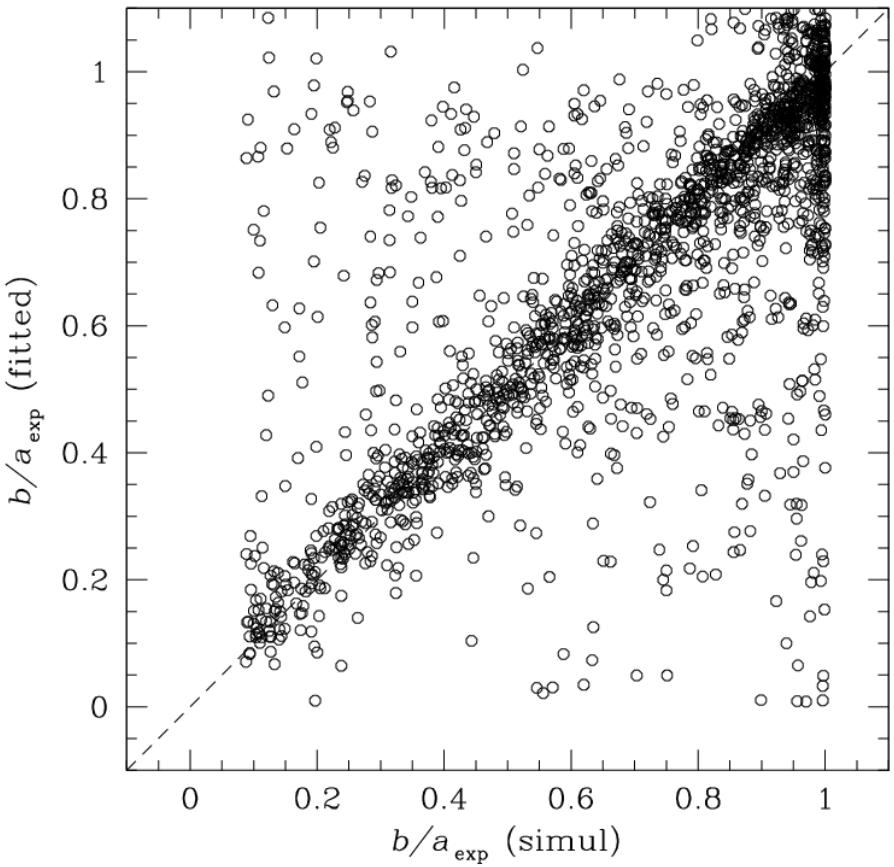
i<23



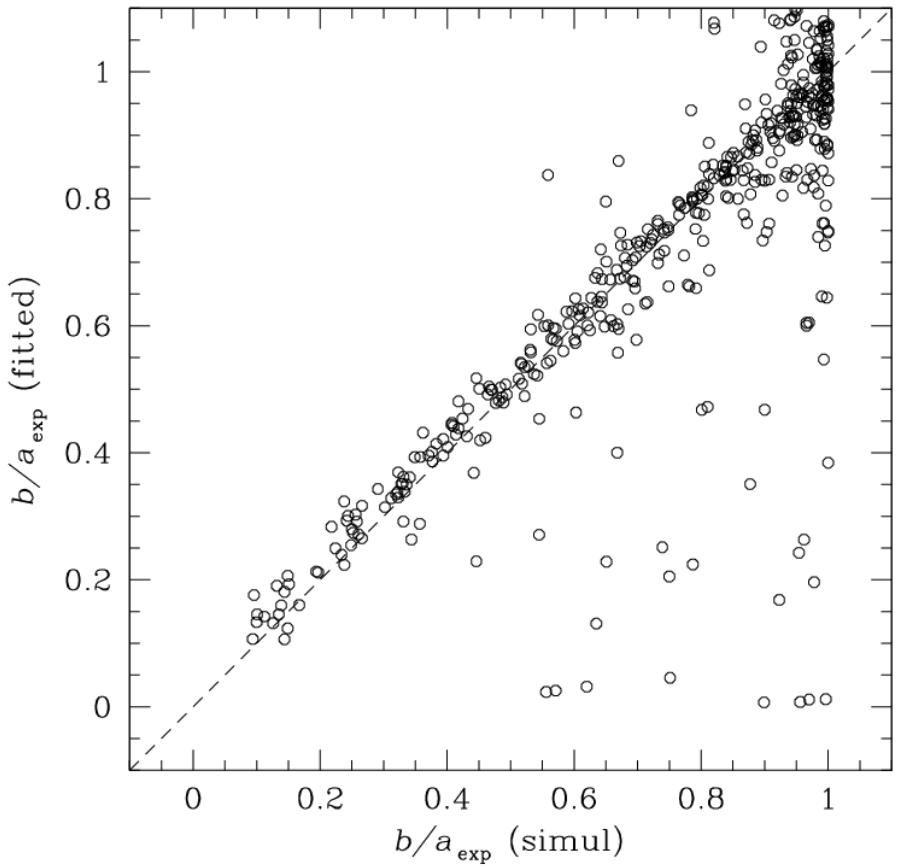
all

Sersic + exponential fit

Disk aspect ratio (cont.)

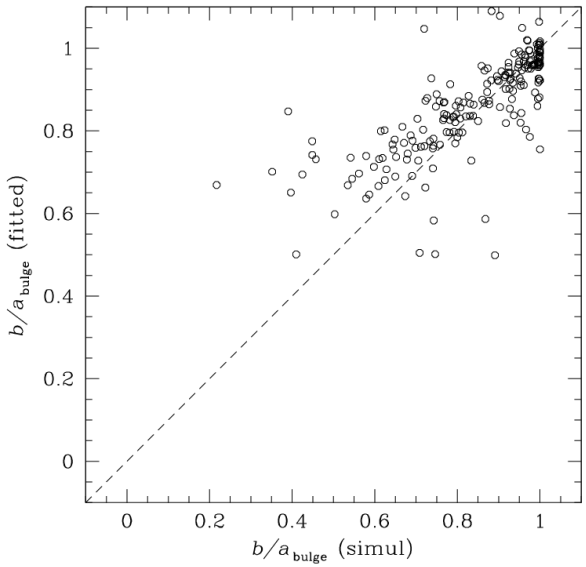


i<22

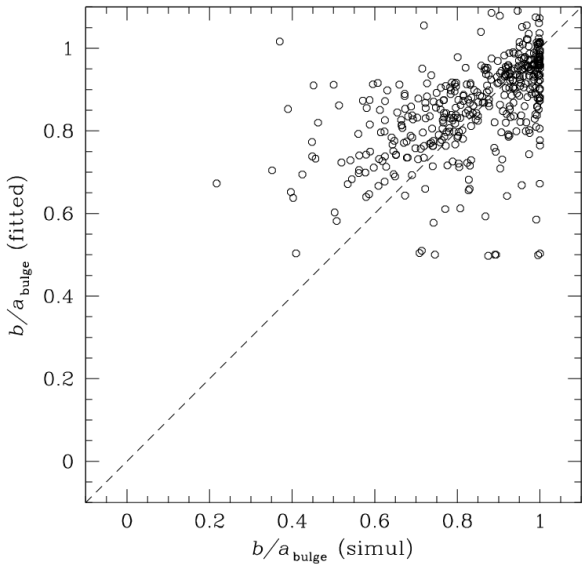


i<22 and B/T < 0.2

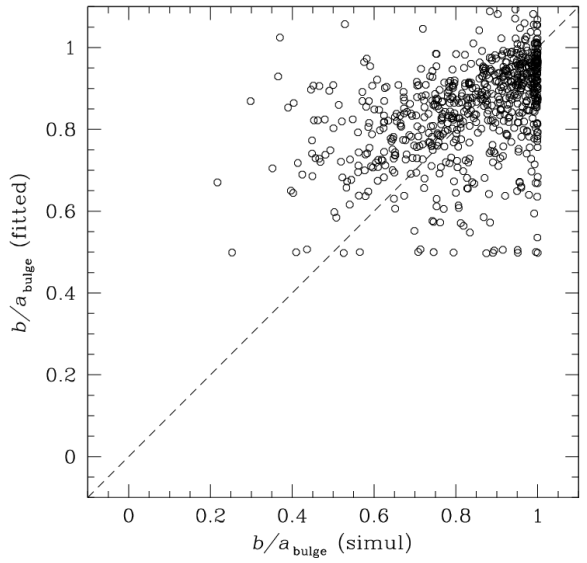
Bulge aspect ratio



i<20 <u>and</u> B/T>0.5



i<21 <u>and</u> B/T>0.5

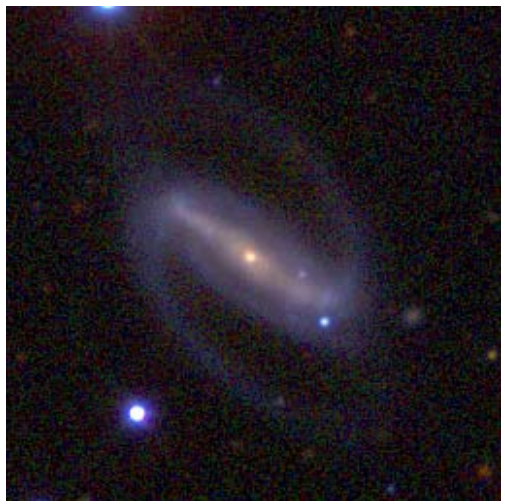


i<22 <u>and</u> B/T>0.5

Sersic + exponential fit

Adding arms and bars

- The next step: a logarithmic spiral and a bar
  - Most spirals have 2 or 4 arms (or are of the flocculent type)
  - In at least half of the cases (at current times, in the visible), a central bar can be seen.
- Models currently implemented
  - spiral arms: 2D exponential ellipse multiplied by $\cos^2\theta$ (mode m=2). Mode m=4 has not yet been tested.
    - Free parameters: amplitudes of m=2 and m=4 modes, scalelength (with respect to disk), pitch angle, position angle, arm width and start radius (as a fraction of scalelength),
  - bar: rectangle with exponential cross-section
    - Free parameters: amplitude, aspect ratio and position angle



EFIGI

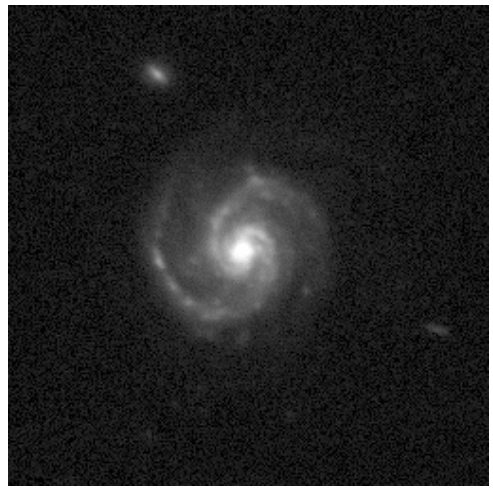
Adding arms and bars (cont.)

Initial guesses and convergence

- The spiral pattern happens to converge fairly rapidly provided that the model has the right « chirality »
  - The estimator used for the PCA decomposition is found to be quite unreliable

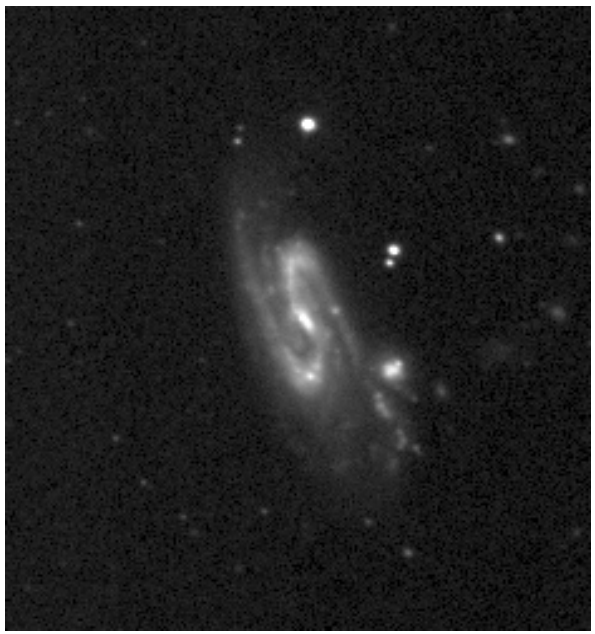
$$\int_{\text{profile}} w(r,\theta)\frac{\partial I}{r\partial\theta}\frac{\partial I}{\partial r}rdrd\theta$$

  - The safer alternative is to make one minimization for each orientation
    - doubling of computation time
- Fitting the bar is not yet very reliable



Convergence with levmar and lmfit

- Computing times and solution are comparable:
  - typically 1-4 Sersic+exponential fits/s for faint galaxies on a 2GHz core
  - typically 2×15s for a full Sersic+exponential+arms+bar profile fitting (21 free parameters).



levmar

lmfit

Conclusions and future plans

- Sersic + exponential profile fitting is now operational in SExtractor. What has still to be done:
  - Oversampling requires some tuning to represent accurately models with high Sersic index.
  - Optimization of profile and residual calculations
  - Cleaning up of the interface to parameters
  - Investigate
    - simultaneous fitting of two overlapping profiles
    - simultaneous bulge+disk fitting in two bands
- Arms+bar fitting still requires extensive testing and tuning
  - Preliminary results are encouraging
  - Need to check what happens at very low resolutions
  - Compare with measurements made by astronomers on the PGC
- Additional attributes will be added this summer: m=4 spiral mode,spiral asymmetries, dust lane and rings.
- Implementation as a web-service