Combining Weak and Strong Lensing in Galaxy Cluster Mass Reconstructions

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April 29th, 2009

The Reconstruction Method

In our reconstruction method we try to combine the advantages of both lensing regimes into a joint method:

- Fully non-parametric, adaptive grid method (no initial model necessary).
- Reconstruction quantity is the lensing potential ψ.
- Maximum-likelihood method. We are searching for that lensing potential which is most likely to have caused the observations:

$$\chi^2(\psi) = \chi_w^2(\psi) + \chi_s^2(\psi)$$

- Input data are:
  1. Ellipticity catalogue
  2. Arc positions
  3. Flexion catalogue (given a reliable measurement, work in progress)
  4. Multiple image positions (Bradač et al. 2005-08)
- χ^2-function is the minimised with respect to the potential on every grid position.

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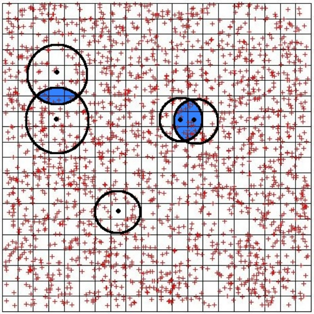
- State-of-the-art observations allow only for a ($\sim$ 10x10) pixel reconstruction grid
- Furthermore galaxies are not distributed homogeneously over the field
- Solution:
  Adaptive-averaging-process
  Problem:
  Grid points become correlated

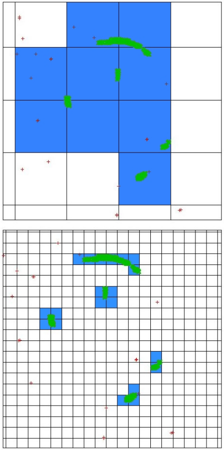


$$\chi^2_w(\psi) = \sum_{i,j} \left(\varepsilon - \frac{Z(z)\gamma(\psi)}{1 - Z(z)\kappa(\psi)} \right)_i \mathcal{C}^{-1}_{ij} \left(\varepsilon - \frac{Z(z)\gamma(\psi)}{1 - Z(z)\kappa(\psi)} \right)_j$$

ARI ITA LSW

Strong Lensing

- The exact position of the critical curve is not observable
- Position of arcs is a very good approximation for the location of the critical curve
- Arc positions are known with high accuracy
- Using weak lensing grid resolutions would result in information loss



$$\chi_s^2(\psi) = \sum_i \frac{|\det A(\psi)|_i^2}{\sigma_i^2} = \sum_i \frac{|(1 - Z(z)\kappa(\psi))^2 - |Z(z)\gamma(\psi)|^2|_i^2}{\sigma_i^2}$$

ARI ITA LSW

Some Details about the Algorithm (JM et al. 2008)

- α, γ, κ, F and G can be expressed by derivatives of ψ via finite differences.
- A specific finite difference can be written as a matrix multiplication

$$\kappa_i = \mathcal{K}_{ij}\psi_j.$$

- The minimisation of the χ^2-function can be translated into a linear system of equations.
- Furthermore the code uses a 2-level iteration scheme.
- Runtime: 2 mins - 6 hrs.

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		$-\frac{1}{6}$	• $-\frac{2}{3}$	$-\frac{1}{6}$			
		$\frac{1}{3}$	$-\frac{1}{6}$	$\frac{1}{3}$			

Implementation

- Written in C++
- Parallel code using MPI (optimised for $\sim$ 24 processes)
- Uses GSL, LAPACK, Atlas
- No "by-hand" adjustments

(Meneghetti et al. 2008)

- Use shapelet decomposition of real galaxies ($\sim$ 10000 from HUDF (b,v,i,z) and $\sim$ 3000 from GOODS (z).
- Use simulated clusters or analytic profiles to add lensing.
- Add sky background, instrumental noises and the PSF
- Produce a mock observation for different instruments.

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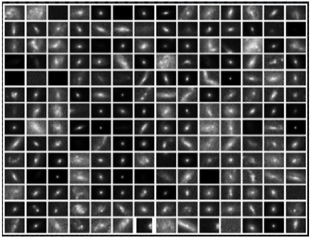

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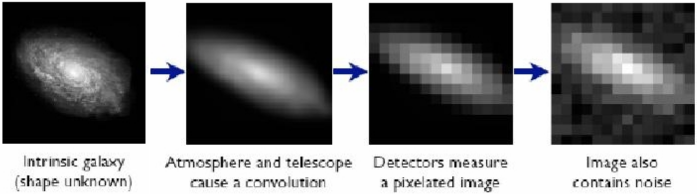

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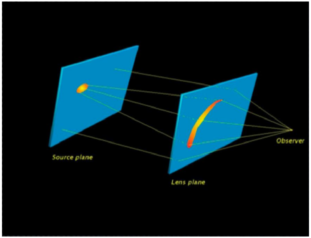

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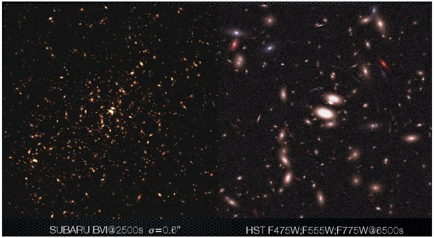
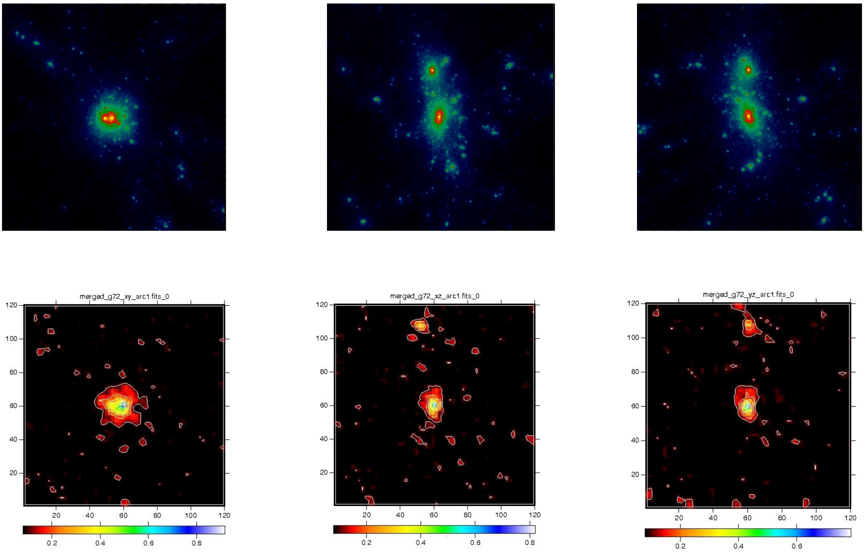
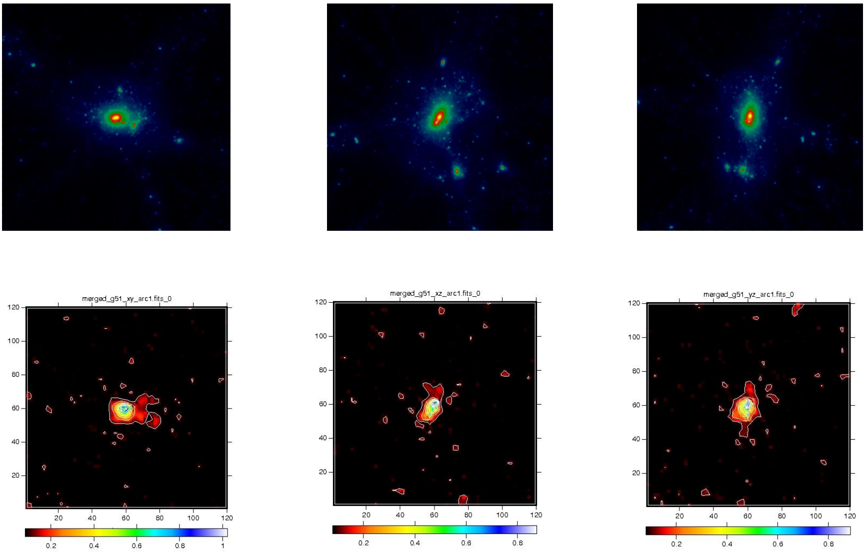


A Realistic Test: g72



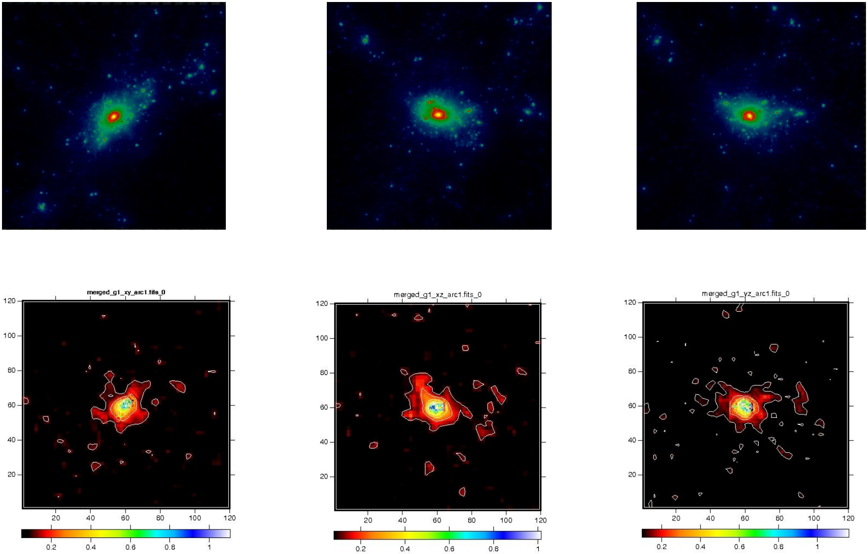
(Meneghetti, JM et al. in prep.)

A Realistic Test: g51



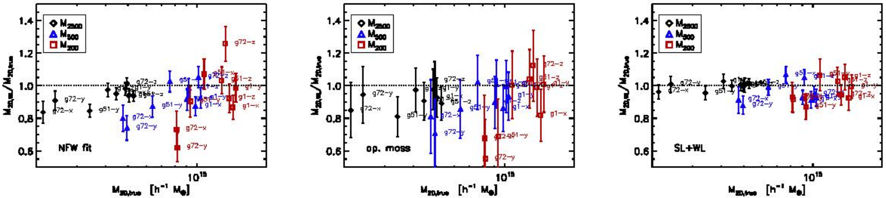
(Meneghetti, JM et al. in prep.)

A Realistic Test: g1

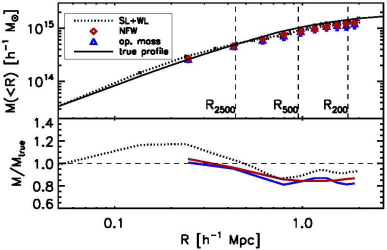


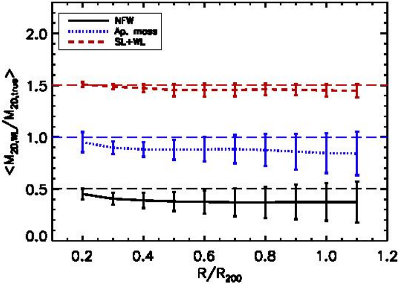
(Meneghetti, JM et al. in prep.)

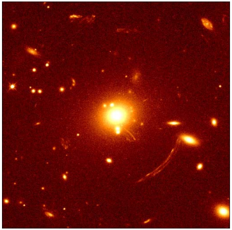
Quantitative Results

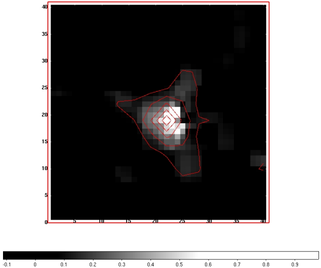


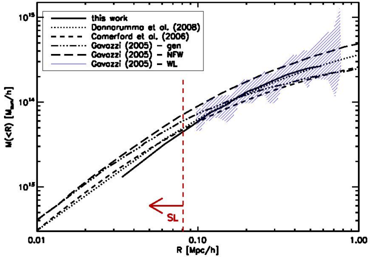
(Meneghetti, Rasia, Merten, Bellagamba, Ettori, Mazzota, Dolag, almost submitted)





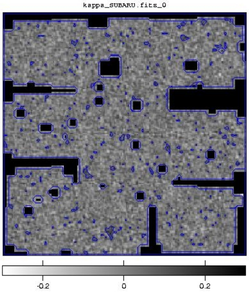


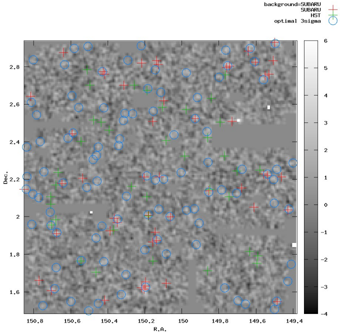


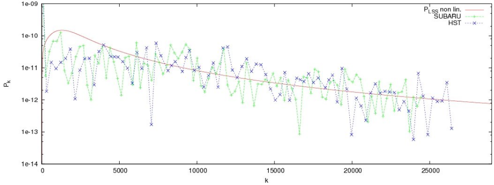

this work
Donnarumma et al. (2008)
Comerford et al. (2006)
Gavazzi (2005) – gen
Gavazzi (2005) – NFW
Gavazzi (2005) – WL
SL
0.01
0.10
1.00
R [Mpc/h]

(JM et al. 2008)

An Extreme Test: The COSMOS field







(with M. Maturi,
very preliminary)

Open questions to discuss

1. We showed that we developed a reliable method to reconstruct the mass and mass distribution of galaxy clusters. To which samples should we apply the method?
2. For our analysis we need weak lensing shape-measurement pipelines. What is the most reliable method, right now?
3. The next step is the inclusion of gravitational Flexion (JM et al. in prep.). Can one expect a reliable measurement in the future?
4. We can measure the mass distribution on a wide range of scales but still we are limited regarding the innermost core. Should we incorporate parametric strong lensing methods in our reconstruction?
5. Our method allows not only for lensing constraints. Should we also include X-Ray observables in the reconstruction?