Combining Weak and Strong Lensing in Galaxy Cluster Mass Reconstructions

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Abstract

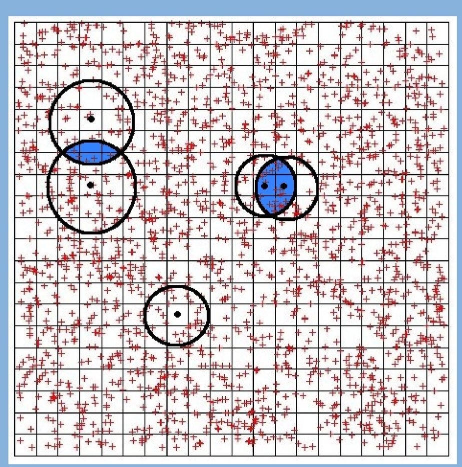
While weak lensing cannot resolve cluster cores and strong lensing is almost insensitive to density profiles outside the scale radius, combinations of both effects promise to constrain density profiles of galaxy clusters well, and thus to allow testing the CDM expectation on dark-matter halo density profiles.
We develop an algorithm further that we have recently proposed for this purpose. It recovers a lensing potential optimally reproducing observations of both strong and weak-lensing effects by combining high resolution in cluster cores with the larger-scale information in weak lensing.

The Reconstruction Method

Combining Weak and Strong Lensing

Regarding the advantages and disadvantages of both methods, it seems clear that an ideal reconstruction method based on gravitational lensing should make use of both lensing effects. There have been several attempts to implement a joint reconstruction method. We refer here to Bradač et al. (2005); Cacciato et al. (2006); Diego et al. (2007).
In the following we summarise the main ideas of our combined weak and strong lensing reconstruction method. For a more detailed description, see Merten et al. (2008).

This figure shows an adaptive averaging process for the background galaxies. This procedure is necessary for a efficient weak lensing reconstruction at a reasonable resolution. Since the averaging areas may overlap, one has to take into account correlations in the weak lensing χ^2, as shown in this formula.

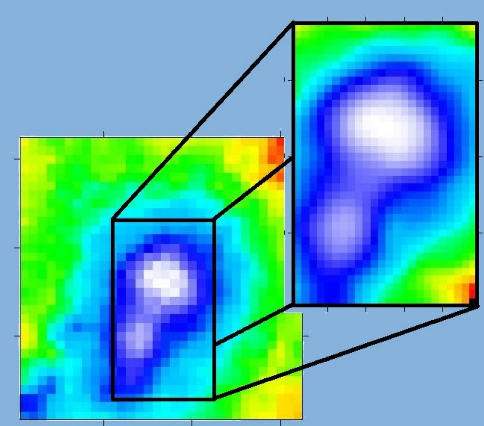


Features:

- Maximum-likelihood method
- Fully non-parametric
- Reconstruction quantity is the lensing potential ψ
- Minimising the χ^2-function leads to the result

Input data:

- Ellipticity catalogue
- Arc positions
- Flexion catalogue
- Multiple image positions



Since strong lensing constraints can be resolved very well by observations, using the coarse weak lensing reconstruction grid would result in a waste of information. Thus, we refine the grid resolution in the centre of the cluster, until the reconstruction can follow strong lensing features like arcs.

$$\chi^2(\psi) = \chi^2_w(\psi) + \chi^2_w(\psi)$$

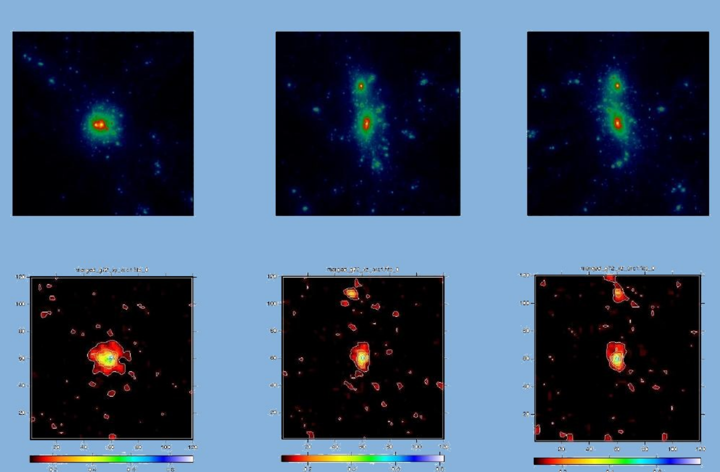
$$\chi^2_w(\psi) = \sum_{i,j} \left(\varepsilon - \frac{Z(z)\gamma(\psi)}{1 - Z(z)\kappa(\psi)}\right)_i C^{-1}_{ij} \left(\varepsilon - \frac{Z(z)\gamma(\psi)}{1 - Z(z)\kappa(\psi)}\right)_j$$

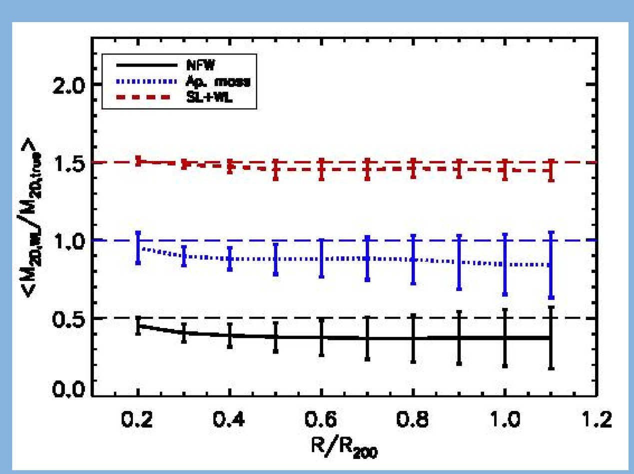
$$\frac{\partial \chi^2(\psi)}{\partial \psi_l} = \frac{\partial \chi^2_w(\psi)}{\partial \psi_l} + \frac{\partial \chi^2_s(\psi)}{\partial \psi_l} \overset{!}{=} 0$$

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

Results

Simulated Clusters





Left Panel: An example of three projections of a simulated lensing scenario using the lensing simulator described in Meneghetti et al. (2008). *Right Panel:* Mean ratio between estimated and true 2D-masses as a function of the distance from the center normalized by R_{200} . The results are shown for three different weak-lensing methods.

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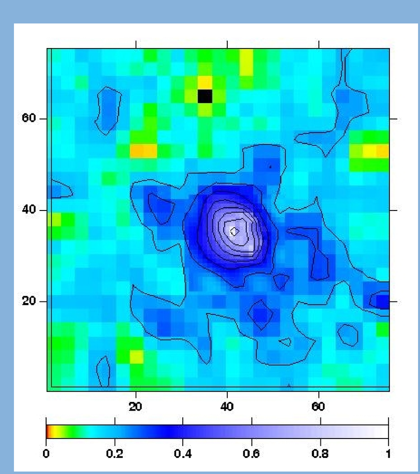

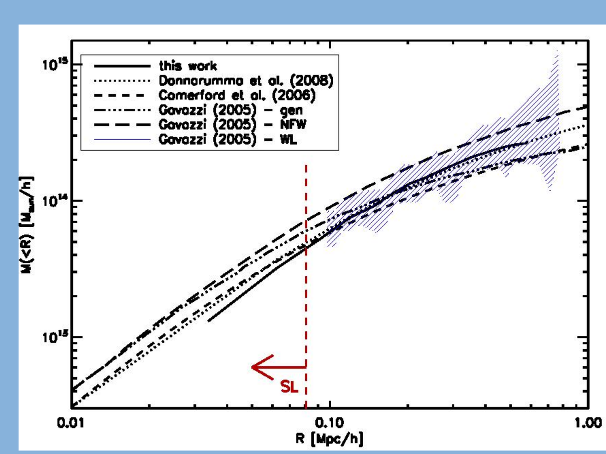

Left Panel: High resolution convergence map on a refined 40 x 40 pixel grid. The side length corresponds to 1.8 MPc. *Right Panel:* Comparison of our results with other reconstructions. The plot shows the reconstructed mass within a certain radius. Also indicated is the transition between the weak and the strong lensing regime.

Additional Information

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