New Cosmological Data and the Values of the Fundamental Parameters
IAU Symposium, Vol. 201, 2005
Anthony Lasenby and Althea Wilkinson, eds.

Gravitational Lensing Studies of High Resolution Cluster Simulations

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Abstract. In our ongoing work, we use high resolution cluster simulations to study gravitational lensing. These simulations have a softening length of $0.7\ h^{-1}$kpc and a particle mass of $4.68 \times 10^7 \mathrm{M}_\odot$ (Springel 1999). Questions that can be addressed include the accuracy with which substructure on various scales can be recovered using the information from lensing. This is very important in determining the power of lensing in studying the evolution of cluster substructure as a function of redshift. We briefly consider how a weak lensing non-parametric reconstruction technique and the M_{ap}-statistic can be applied to the simulations.

1. Introduction

Here, our cluster lens was obtained by projecting a 4 Mpc cube from a simulation onto the x-y plane, giving a 1024×1024 pixel map of the dimensionless surface mass density, κ (see lhs panel of Fig.1). The shear field (γ) and reduced shear ($g = \gamma/(1-\kappa)$) which govern how lensed images are distorted, can be obtained using Fourier transform techniques (we thank Nick Kaiser for kindly providing his imcat software). Catalogues of randomly distributed galaxies with number density n_γ (30 arcmin^{-2} for ground-based, 80 arcmin^{-2} for current space-based and 200 arcmin^{-2} for future space-based observations), and a random ellipticity assigned from a Gaussian probability distribution with $\sigma_\epsilon = 0.3$ were "lensed". With these synthetic catalogues in hand, the projected mass distribution responsible for the lensing can be recovered and compared with the true distribution.

2. Mass reconstruction

The mass distribution of the cluster was recovered on a 206×206 grid, by applying a reconstruction algorithm (Seitz & Schneider 1998) to the synthetic catalogues, assuming different n_γ. Comparison of the reconstructed maps shows that the main features are picked up but at higher signal-to-noise as n_γ is increased. The rhs panel of Fig.1 shows a resultant mass map obtained when $n_\gamma = 200$ arcmin^{-2}.

https://doi.org/10.1017/S0074180900216744 Published online by Cambridge University Press

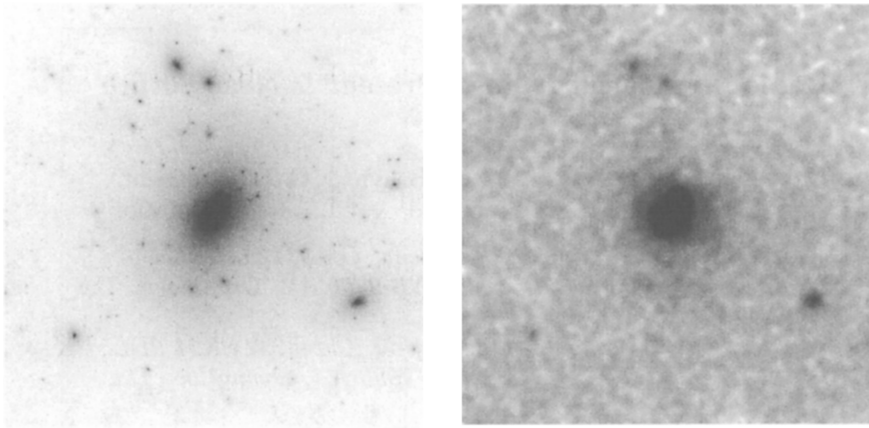

Figure 1. The left-hand panel shows κ for the cluster. The right-hand panel shows a mass reconstruction using a synthetic lensed catalogue where $n_\gamma = 200$ arcmin^{-2}.

3. $M_{\rm ap}$-statistic

This statistic (Kaiser 1994; Schneider 1996) measures the *local* κ field, convolved with a compensated filter function $\mathcal{U}$ which can be chosen to maximise the contrast for a particular scale of mass distribution. Equivalently, $M_{\rm ap}(\boldsymbol{\theta})$ can be expressed in terms of the tangential shear $\gamma_{\rm t}$, derived from the observed distorted images of background galaxies:

$$M_{\rm ap}(\boldsymbol{\theta}) = \int {\rm d}^2\boldsymbol{\phi}\ \gamma_{\rm t}(\boldsymbol{\phi})\mathcal{Q}\left(|\boldsymbol{\phi}-\boldsymbol{\theta}|\right); \quad \mathcal{Q}(\phi) = \frac{2}{\phi^2}\int_0^\phi {\rm d}\phi'\,\phi'\mathcal{U}(\phi') - \mathcal{U}(\phi)\,. \quad (1)$$

In practice this integral is a summation over the synthetic lensed galaxies, since the shear field is sampled at discrete points. The significance of a $M_{\rm ap}$ detection can easily be assessed by multiple randomisations of the background galaxies, recalculation of the statistic, and comparison with the "lensed" value.

For instance, we calculated $M_{\rm ap}$ over a 40×40 pixel grid and performed 1000 randomisations. Increasing n_γ between 30 and 200 arcmin^{-2} greatly enhances the detection significance of the feature to the SW. The lower signal-to noise mass concentration to the SE is undetected at 3σ confidence when $n_\gamma = 30$ arcmin^{-2}, whereas when $n_\gamma = 200$ arcmin^{-2}, it is detected over 5 contiguous pixels at greater than 3.8σ confidence.

References

Kaiser, N. 1994, CITA-94-39

Schneider, P. 1996, MNRAS, 283, 837

Seitz, S. & Schneider, P. 1998, astro-ph/9802051

Springel, V. 1999, Ph.D. thesis, Ludwig-Maximilians-Univ. München