PSC Proposal

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1 Introduction and Scientific Background

Galaxy–galaxy (g–g) lensing is a powerful probe of the relation between galaxies and dark matter (DM) haloes, but its theoretical interpretation requires a careful modelling of various contributions, such as the contributions from central and satellite galaxies. For this purpose, we developed a new method using the components of lensing shear γ_1 and γ_2 instead of tangential shear to extract information from the g–g weak lensing signal by comparing it to high-resolution dissipationless simulations that resolve subhaloes. We find that this method can better constrain subhalo masses and thus enabling us to further investigate halo-galaxy connections.

From the NFW density profile, we can derive the convergence field

$$\kappa(\theta) = \frac{\Sigma(D_l\theta)}{\Sigma_{cr}} \tag{1}$$

where

$$\Sigma(\xi) = \int \mathrm{d}z \rho(\xi_1, \xi_2, z) \tag{2}$$

is the surface density, $\xi = (\xi_1, \xi_2)$ is the impact two-vector in the lens plane, z is the perpendicular coordinate to the lens plane.

$$\Sigma_{cr} = \frac{1}{4\pi G}\frac{D_s}{D_l D_{ls}} \tag{3}$$

The deflection angle can be expressed in terms of convergence as

$$\alpha(\theta) = \frac{1}{\pi}\int \mathrm{d}^2\theta' \kappa(\theta)\frac{\theta-\theta'}{|\theta-\theta'|^2} \tag{4}$$

and 2-dimensional deflection potential:

$$\Psi(\theta) = \frac{1}{\pi}\int \mathrm{d}^2\theta' \kappa(\theta) \ln|\theta-\theta'| \tag{5}$$

such that:

$$\alpha(\theta) = \nabla\Psi(\theta) \tag{6}$$

$\Psi(\theta)$ then satisfies the 2-dimensional Poisson equation:

$$\kappa(\theta) = \frac{1}{2}\nabla^2\Psi(\theta) \tag{7}$$

the lensing mapping Jacobian matrix is:

$$\mathcal{A}(\theta) = \delta_{ij} - \frac{\partial^2\Psi(\theta)}{\partial\theta_i\partial\theta_j} = \begin{pmatrix} 1-\kappa-\gamma_1 & \gamma_2 \\ \gamma_2 & 1-\kappa+\gamma_1 \end{pmatrix} \tag{8}$$

So

$$\gamma_1 = \frac{A_{11}-A_{22}}{2} \tag{9}$$

$$\gamma_2 = A_{12} \tag{10}$$

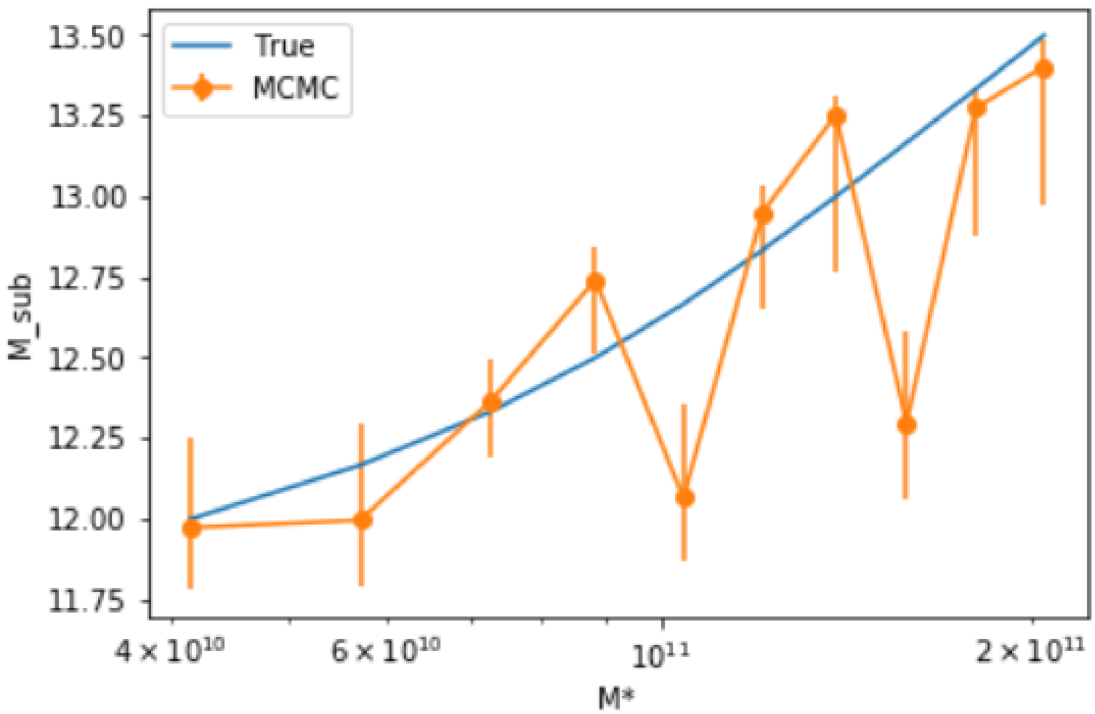

Figure 1: This plot shows the MCMC result based on γ_1 and γ_2 method comparing with true value.

2 Progress to Date and Motivation for Future Work

We constrain the subhalo masses using MCMC method, for a single sample case, the log-likelihood function is given by:

$$\begin{aligned}\log \mathcal{L}(M \mid \mathcal{D}) = \sum_k & -\frac{1}{2}(\gamma_{1,k}^{theory}(M) - \gamma_{1,k}^{data})^T \Sigma^{-1} (\gamma_{1,k}^{theory}(M) - \gamma_{1,k}^{data}) \\ & -\frac{1}{2}(\gamma_{2,k}^{theory}(M) - \gamma_{2,k}^{data})^T \Sigma^{-1} (\gamma_{2,k}^{theory}(M) - \gamma_{2,k}^{data})\end{aligned}$$

Where $\gamma_{1,k}^{theory}(M)$ and $\gamma_{2,k}^{theory}(M)$ are the theoretic prediction of γ_1 and γ_2 at pixel k, the covariance matrix is assumed to be diagonal with:

$$\Sigma = diag(\sigma_{\gamma_1}^2, \sigma_{\gamma_2}^2, ..., \sigma_{\gamma_k}^2)$$

The total log-likelihood function is given by:

$$\log \mathcal{L} = \sum_{i=1}^{n} p_i \sum_{j=1}^{m} \log \mathcal{L}(M_i \mid \mathcal{D}_{i,j})$$

Where $n = 10$ is the number of stellar mass bins, $m = 50$ is the sampling number in each bin. p_i is the lenses number factor:

$$p_i = \frac{N_i}{m} \times \frac{S_{LSST}}{S_{cosmoDC2}}$$

Where N_i is the number of lenses in the ith mass bin between $z = 0.3$ to $z = 0.4$ in cosmoDC2 simulation, $S_{LSST} = 20000\text{deg}^2$, $S_{cosmoDC2} = 440\text{deg}^2$

3 Proposed Computational Methods

Given cosmological parameters in cosmoDC2, we first generate fake galaxies with subhalo masses and stellar masses. Then we fed the fake data to emcee, a module using affine invariant Markov chain Monte Carlo (MCMC) ensemble sampler (`https://github.com/dfm/emcee`). We ran a chain with 10 mass bins (10 parameters) with 10k steps.

4 Computational Resources

NERSC GPU

REFERENCES