Probing the cosmological weak-lensing statistics with three-dimensional ray-tracing in a relativistic N-body simulation

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❖ Introduction:

The gravitational lensing of distant galaxies by large-scale structure (LSS) may cause distortion of their images [1-2]. Again, due to gravitational lensing by LSS, high redshift sources suffer from magnification or demagnification. By implementing the information from a N-body simulation [3], we develop an innovative ray-tracing code to study how the light rays from far away galaxies propagates through the Universe and how its properties (e.g. energy, redshift, scale factor, size, shape) changes. We also analyse here how the local environment impacts on the weak-lensing (WL) statistics.

❖ Ray Bundle Method & N-body simulations:

- ❑ We implement here the Ray Bundle Method (RBM) [4] to know how the images of distant galaxies are getting distorted due to the WL by the LSS of the Universe. This RBM is a very feasible approach to calculate the magnification and shear for WL.
- ❑ In this work, we use a publicly available relativistic particle-mesh N-body code, namely gevolution [3] to get the weak relativistic potentials. We solve the geodesic equation for photons by taking into account the relativistic potential. The line element of FLRW metric is:

$$ds^2 = a^2(\tau)\,[-(1+2\psi)d\tau^2 - 2B_i dx^i d\tau + (1-2\Phi)\delta_{ij}dx^i dx^j + h_{ij}dx^i dx^j]$$

❖ Mapping & Angular power spectra:

- ❑ We study here various WL properties as a function of redshift from the ray-tracing algorithm and finally mapped these properties onto the healpy sphere.
- ❑ To compute the angular power spectra, at first, we need to solve the geodesic equations. The formula that we implement to calculate the angular power spectrum from healpy package is :

$$\hat{C}_\ell = \frac{1}{2\ell+1}\sum_m |\hat{a}_{\ell m}|^2.$$

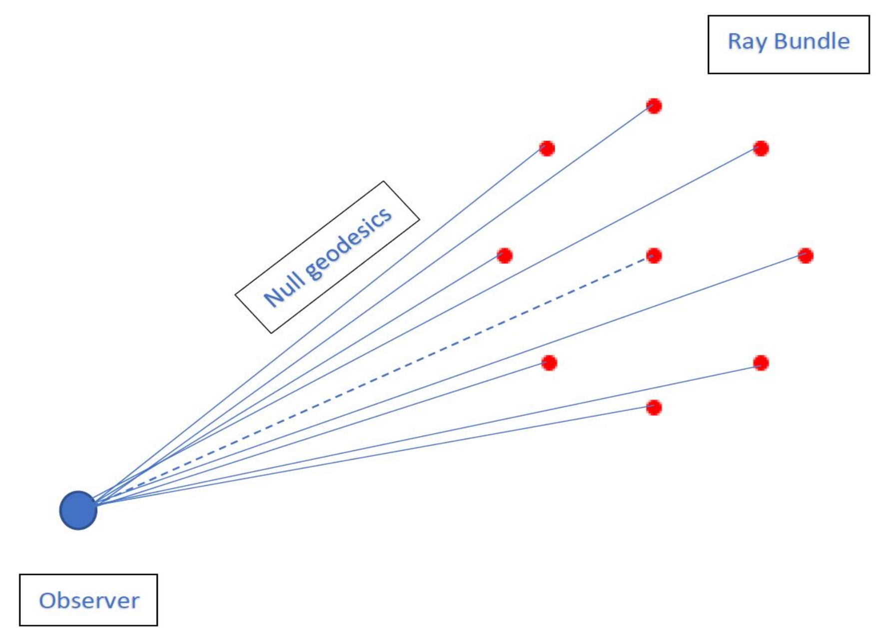

Fig.1: Scamatic diagram of RBM.

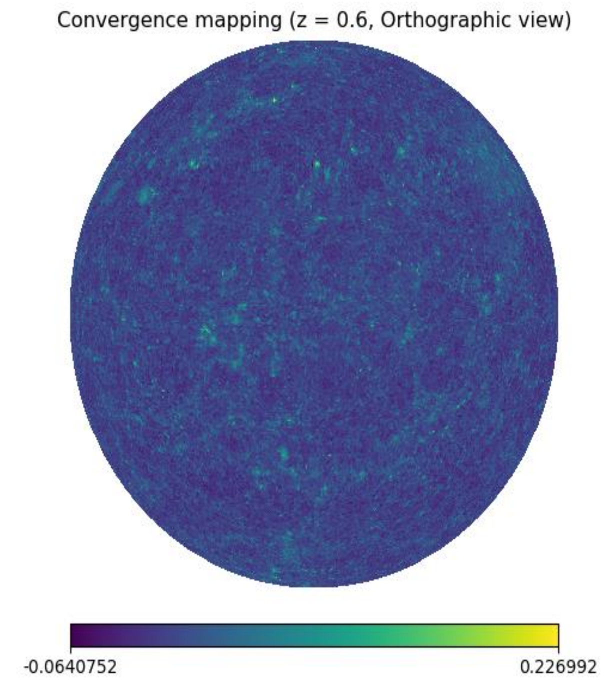

Fig.2: Mapping for convergence.

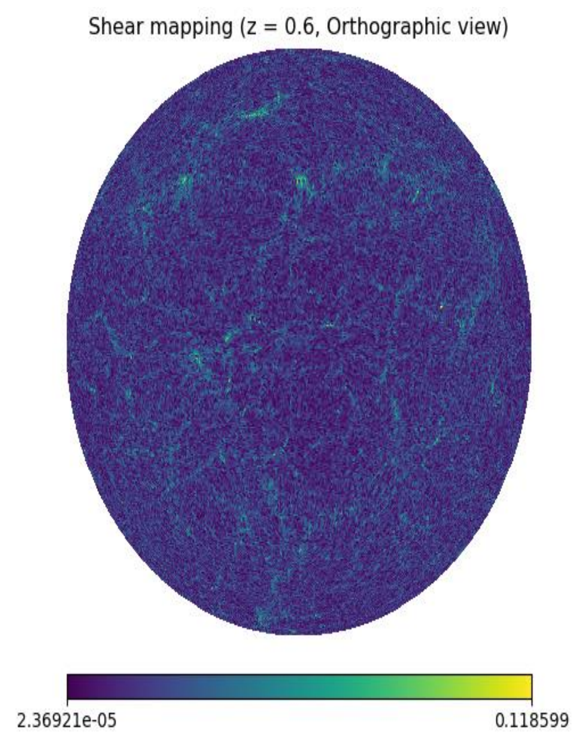

Fig.3: Mapping for cosmic shear.

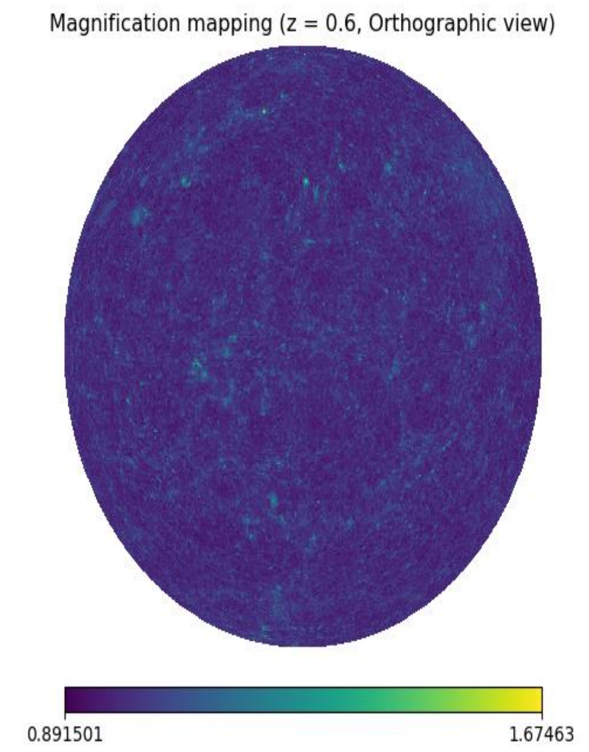

Fig.4: Mapping for magnification.

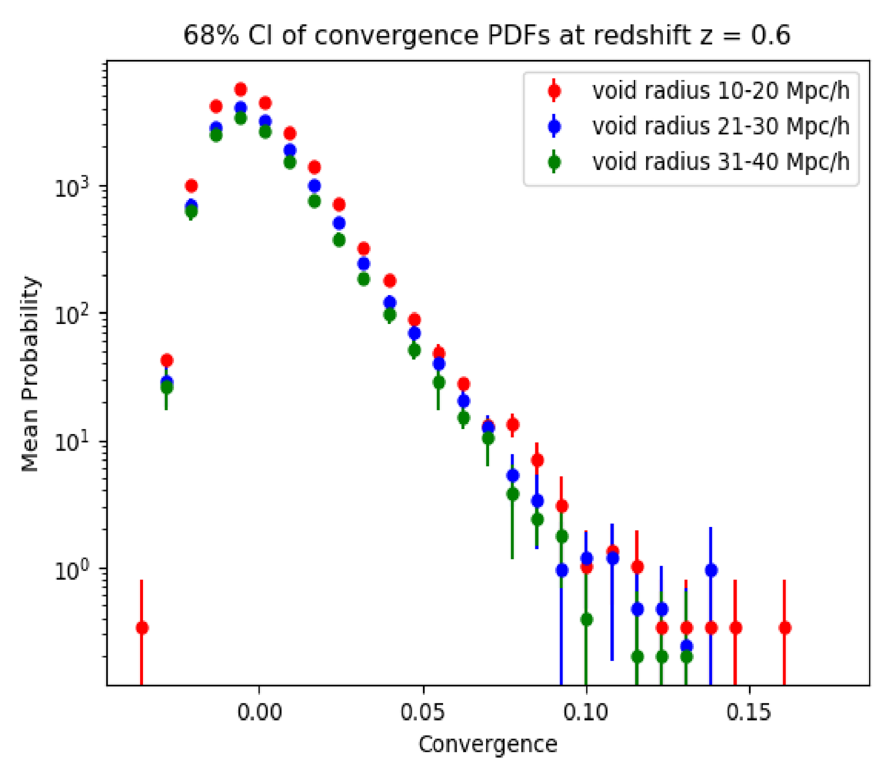

Fig.5: Convergence PDFs for voids having different radii.

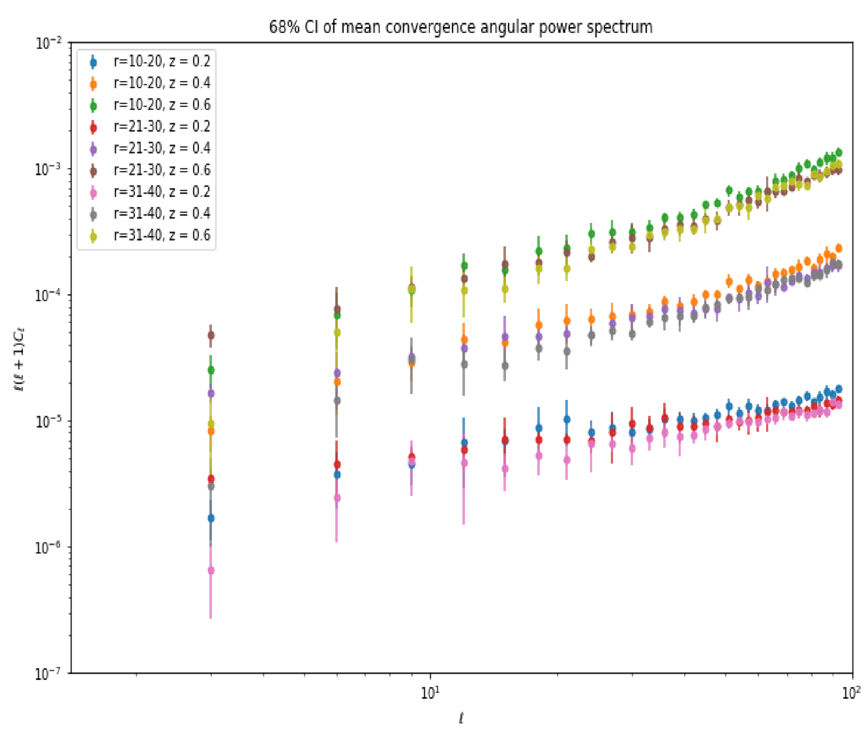

Fig.6: Convergence angular power spectra for voids having different radii.

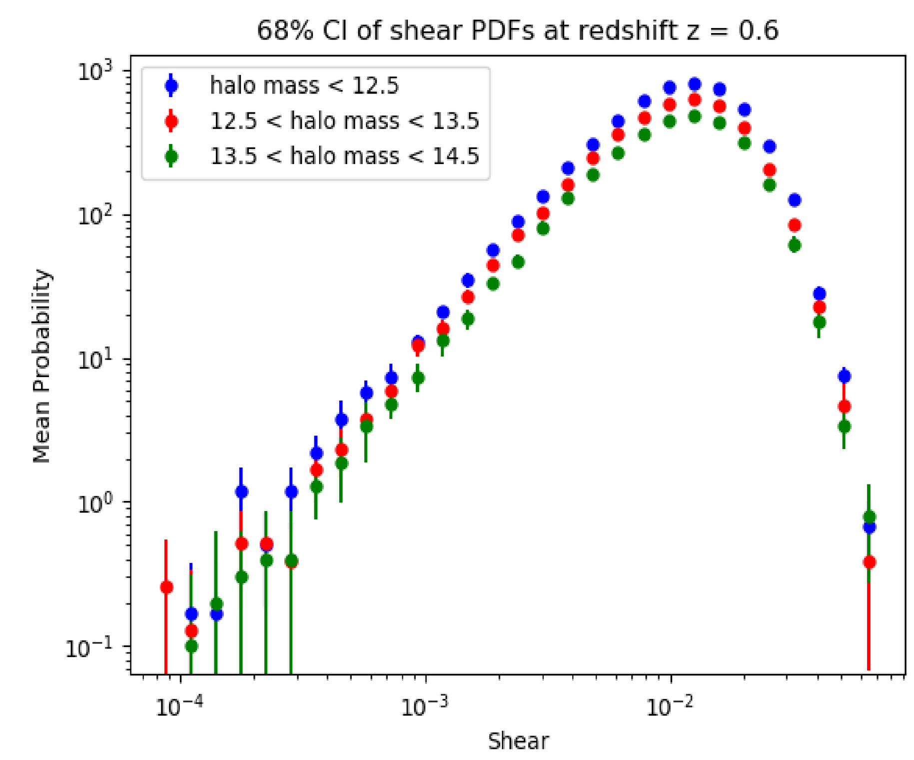

Fig.7: Shear PDFs for halos having different masses.

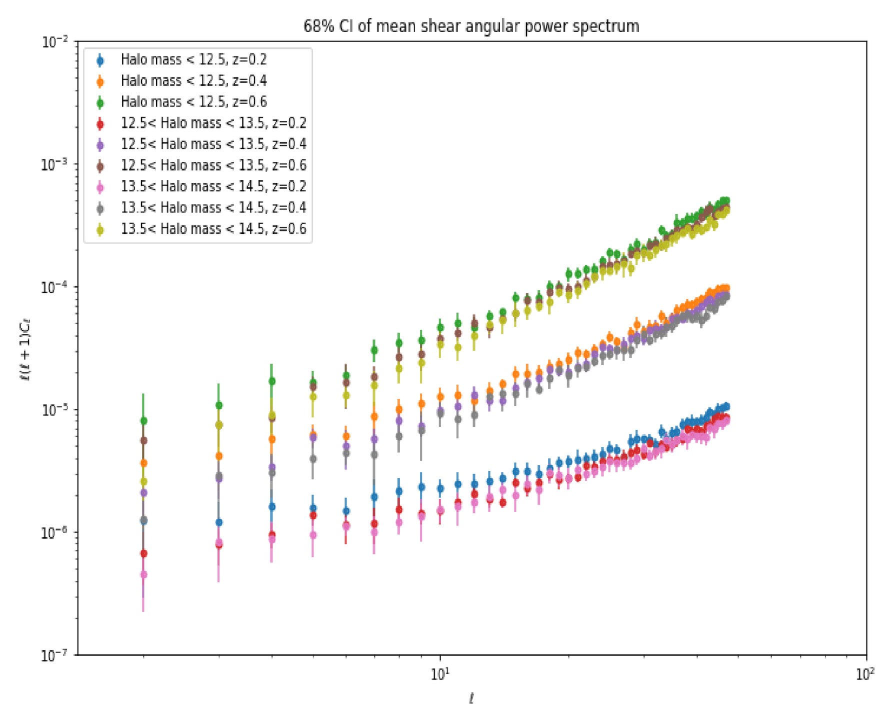

Fig.8: Angular power spectra of shear for halos having difference masses.

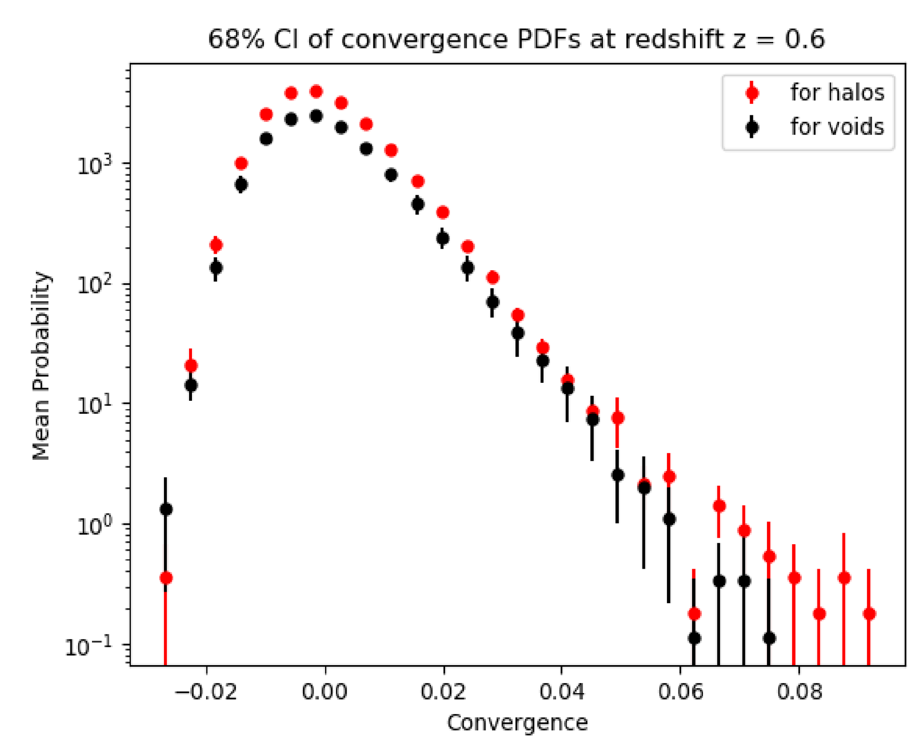

Fig.9: Convergence PDFs for halos and voids.

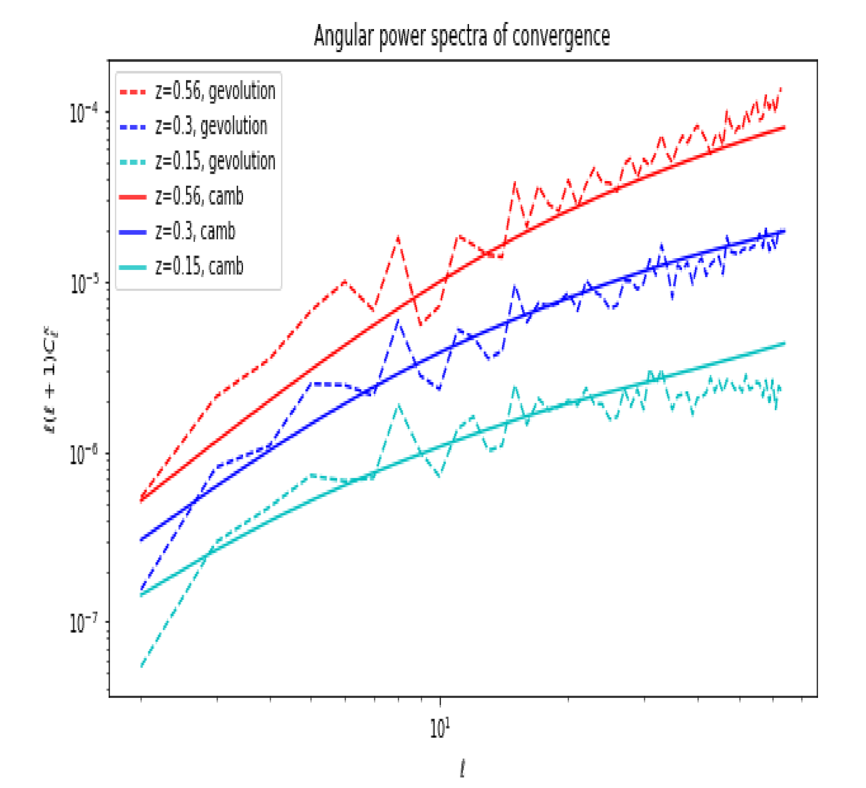

Fig.10: Comparison between numerical data and theoretical prediction.

❖ Results & Conclusion:

- ❑ Our ray tracing algorithm is a well-organized code and people can easily implement this code with any other simulation to study the WL statistics.
- ❑ Our code will be helpful to observe the nonlinear perturbation of the LSS of the Universe with unprecedented precision.
- ❑ A FLRW observer will observe non-identical scenario at different overdense and underdense regions on the LSS of the Universe.
- ❑ The PDFs and angular power spectra of the WL statistics can be biased by the locations of the observer.
- ❑ The numerical data are closely similar to the theoretical prediction and the results of our analysis will be important to analyse data from future WL surveys.

❖ Future work:

- ❑ We have a plan to run a big simulation by considering larger boxsize (where photon can travel a few Gpc/h ranges) so that we can be able to see the effects of magnification, shear, convergence and their corresponding angular power spectra when light travels such distances.
- ❑ Parameter estimation; because this will allow us to make comments about the percent level of precision.
- ❑ Study the influence of the global parameters on the WL statistics.

❖ References:

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4. Fluke, C. J., Webster, R. L., & Mortlock, D. J., MNRAS, **331**, 180 (2002).