Weak Lensing Non-Gaussian Statistics using N-body Simulations

Jia Liu[1], Andrea Petri[2], Zoltan Haiman[1], Lam Hui[2], Morgan May[2], Jan Kratochvil[3]
[1] Columbia University Astronomy Department
[2] Columbia University Physics Department
[3] University of KwaZulu-Natal Astrophysics and Cosmology Research Unit

Background

Weak gravitational lensing (WL) is one of the most promising techniques to probe dark energy (DE) with improved precision in the future. By statistically measuring the distortions in the shapes of background galaxies, the matter density fluctuations at different redshifts can be mapped, yielding constraints on the parameters of the background cosmological model.

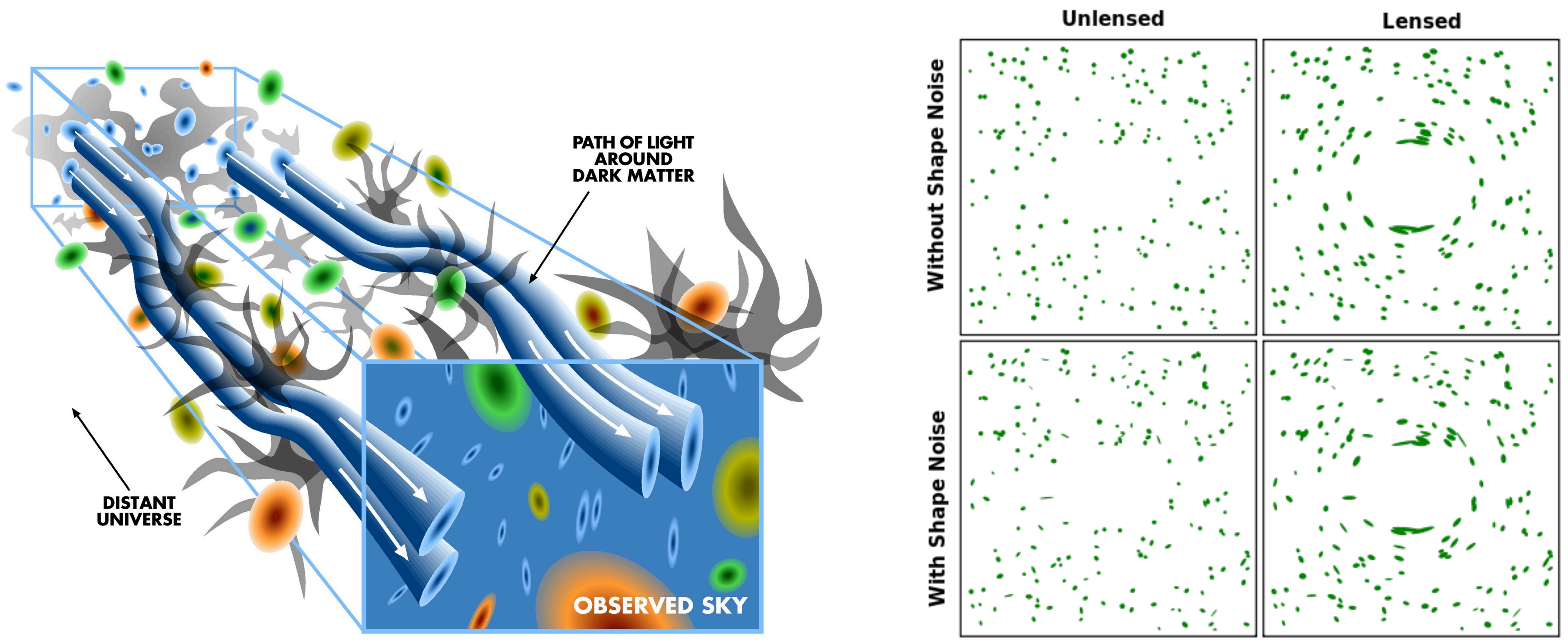

Figure 1. Distortions of background galaxies by foreground masses.
(source: wikipedia)

Non-Gaussian Statistics

Traditionally, WL data is analyzed using the two-point correlation function (2PCF), or its Fourier-space counterpart, the power spectrum. However, these statistics can not fully characterize the weak lensing shear field on small (<~ arcmin) angular scales, where it is sensitive to matter density fluctuations in the non-linear regime, and is strongly non-Gaussian. Therefore, we need to use non-Gaussian statistics (the moments, Minkowski Functionals, and peak counts) to improve cosmological constraints from WL surveys.

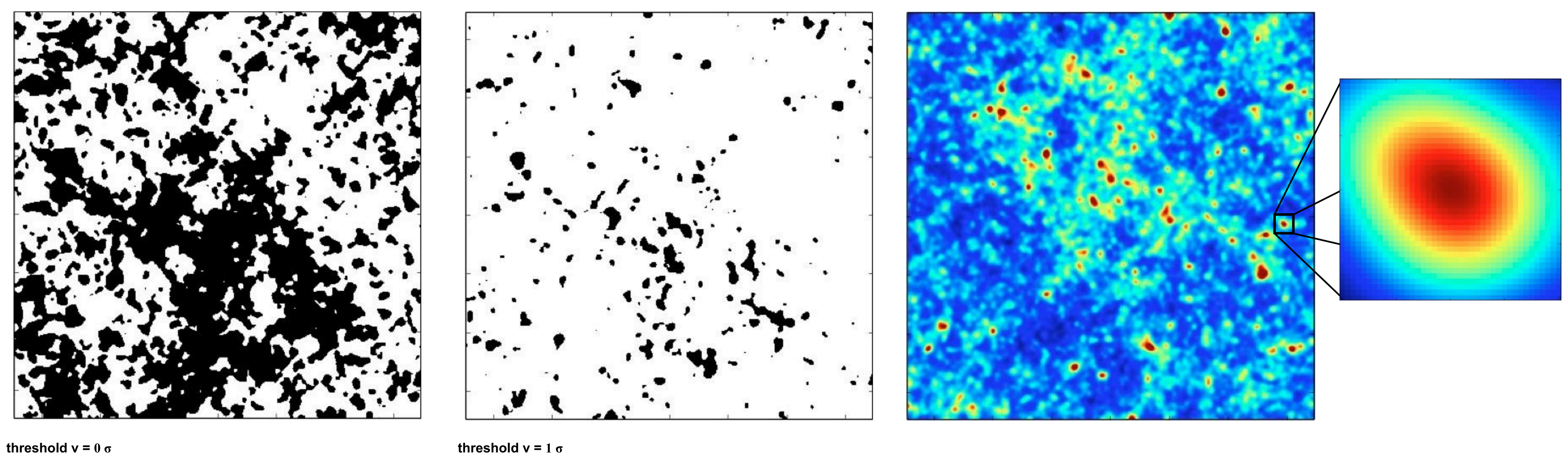

Figure 2. Minkowski Functionals (left & middle) and peak counts (right).

N-body Simulations

In this work, we use the publicly available CFHTLenS data on ≈ 4.2 million galaxies, combined with a suite of ray-tracing simulations in 91 different cosmological models, to constrain the cosmological parameters, Ωm, σ8, and the DE equation of state w, using the moments, Minkowski Functionals and peak counts.

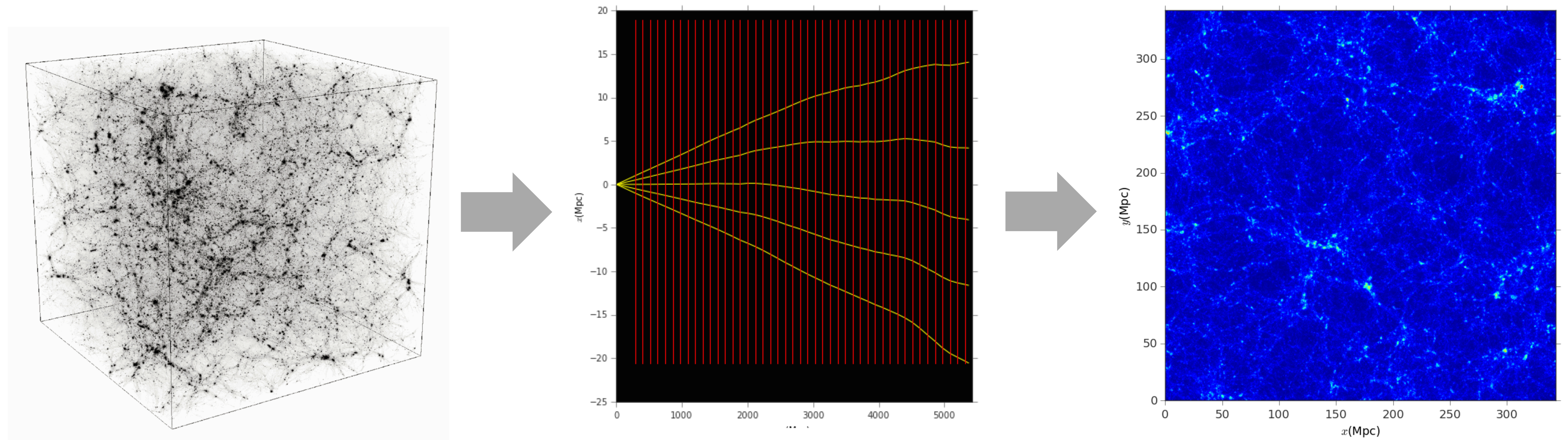

Figure 3. N-body simulations and ray-tracing.

Conclusions

We have found that while constraints from the Minkowski Functionals on the (Ωm, σ8) doublet suffer from a bias, the moments provide a tight unbiased bound on the former parameters, with the main contribution coming from quartic moments of gradients; Combining peak counts with the power spectrum can reduce the area of the 2D error contour by a factor of ≈ 2 compared to using the power spectrum alone.

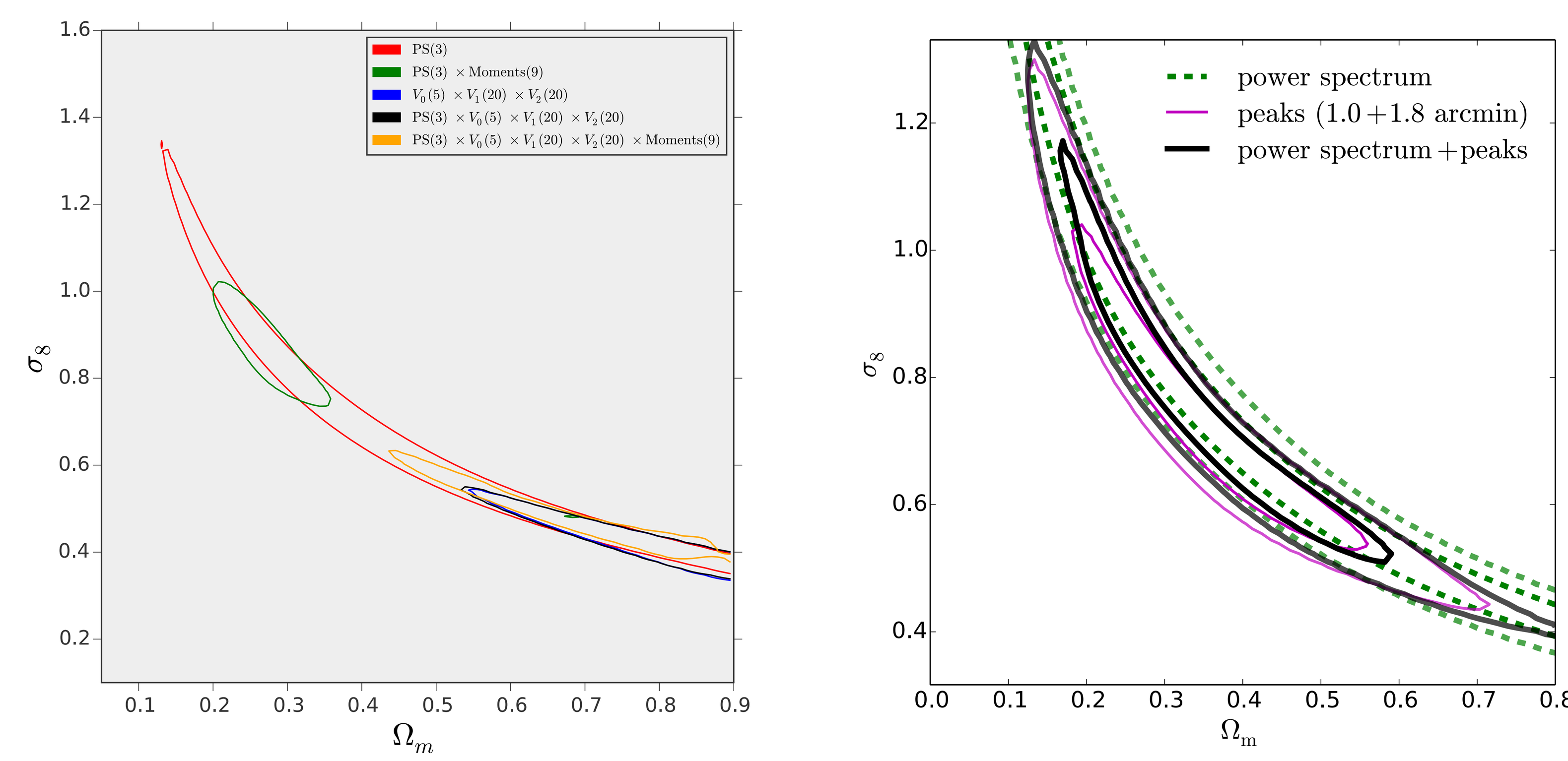

Figure 4. Cosmological constraints from the moments and MF (left), and peak counts (right).

Acknowledgments

Simulations for this work were performed at the NSF XSEDE cluster, supported by grant number ACI-1053575, and at the New York Center for Computational Sciences. This work was supported in part by the DOE under Contract No. DE-AC02-98CH10886 and Contract No. DE-SC0012704, the NSF grant AST-1210877, and the ROADS program at the Institute for Data Sciences and Engineering at Columbia University.