Cosmology with the Shear-Peak Statistics

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Dietrich & Hartlap 2010, MNRAS 402, 1049
Weak Lensing Cluster Cosmology

- Evolution of cluster mass function is cosmological probe.
- Cluster cosmology and cosmic shear are complementary (Takada & Bridle 2007)
- Weak lensing searches for galaxy clusters will always be incomplete.
- Weak lensing searches will always have false positives.

Dietrich et al. (2007)
The Peak Statistics

- The weak lensing peaks caused by LSS are false positives only if one searches for galaxy clusters.
- LSS peaks caused by real mass along the line of sight.
- LSS peaks caused by real structure, matter density fluctuations.
- LSS peaks contain cosmological information.

Problem: Filaments and sheets are not collapsed structures. How do we predict the number of peaks as a function of cosmology?
N-body Simulations

Make many N-body simulations for various cosmological parameters and ray-trace through them.

- 192 N-body simulations in the $\Omega_m$-$\sigma_8$ plane.
- 166 different cosmologies ($\Omega = 1$).
- 35 simulations at the fiducial cosmology (0.27, 0.78).
- Each simulation: $256^3$ particles, 200 Mpc box (like GIF).
- Big enough to give $10^{15} M_\odot$ halos.

From each simulation: simulate five $6 \times 6$ deg$^2$ fields. CFHTLS like survey.
Peak Finder

Aperture mass, $M_{\text{ap}}$,

$$M_{\text{ap}}(\vec{\theta}_0) = \int d^2 \theta \, Q(|\vec{\theta} - \vec{\theta}_0|) \gamma_t(\vec{\theta}; \vec{\theta}_0),$$

is a matched filter for shear if filter $Q(\theta)$ follows expected shear profile.
Signal-to-Noise Ratio Data Vector

- We used SNR as a proxy for mass.
- Instead of using SNR bins, we take the cumulative SNR distribution.

With $n$ logarithmically spaced bins: $\tilde{S}(\Omega_m, \sigma_8) : \mathbb{R}^2 \rightarrow \mathbb{R}^n$
Blue contours are derived using the SNR distribution of peaks.

Green contours are constraints from counting peaks per redshift bin.

Red/cyan/blue contours are the combination of both methods.

Cannot use full $N(\sigma, z)$ because covariance is limited.

Used fitting function to interpolate between simulation points.
Combined Covariance

- Cosmic shear and peak counts both measure the same density field.
- Significant cross-covariance between both methods expected.
- Cosmic shear tomography with 2 redshift bins and 10 spatial bins from 30'' to 6 deg.
Combined Constraints

- Both methods have very similar degeneracies.
- The peak statistics give competitive constraints.
- The combination of both methods further improves constraints.
- This is probably due to the inclusion of non-Gaussian fluctuations.

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<th>Figure of Merit</th>
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<td>Cosmic shear</td>
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Where is the Information?

⇒ Most information in the low SNR regime.

► Very few real “clusters” in this regime.

► Projections of low mass objects carry a lot of information.
Summary

- Peak statistics can constrain $\Omega_m, \sigma_8$ with projected peaks containing cosmological information.
- Peak tomography does much better than $M_{ap}$.
- Peak tomography gives constraints which are competitive with cosmic shear tomography.
- The combination of both improves constraints.
- Application to surveys challenging at the moment. Emulators may be a solution.
- What about other parameters, Dark Energy?