Cosmology with the Shear-Peak Statistics

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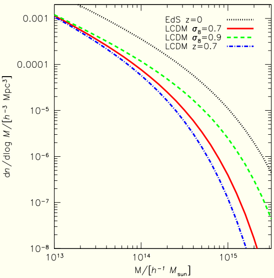
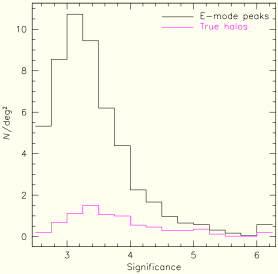
Dietrich & Hartlap 2010, MNRAS 402, 1049

Weak Lensing Cluster Cosmology





Dietrich et al. (2007)

- 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.

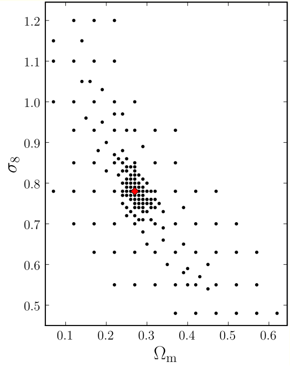
The Peak Statistics

- 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 Ω_m-σ_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.

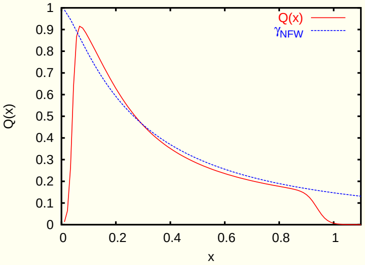
From each simulation: simulate five $6 \times 6\,\mathrm{deg}^2$ fields. CFHTLS like survey.

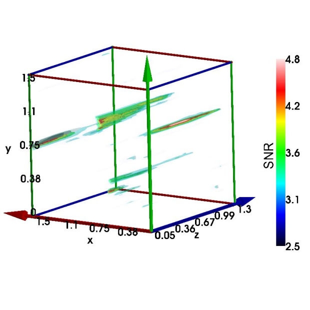
Peak Finder

Aperture mass, M_{ap},

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

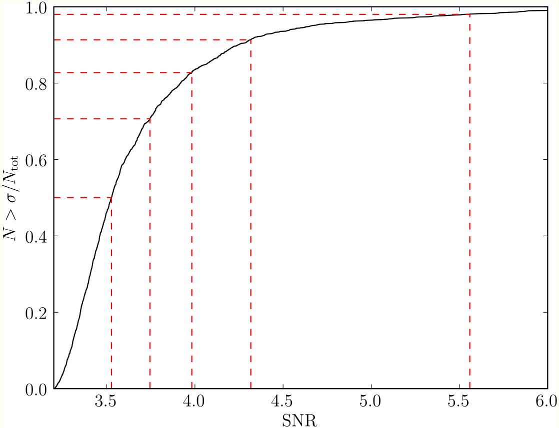
is a matched filter for shear if filter $Q(\vartheta)$ follows expected shear profile.





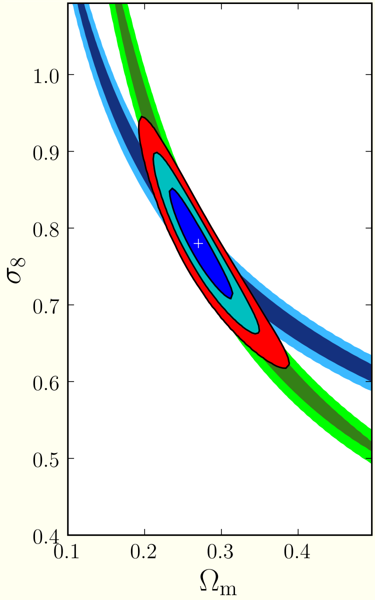
Signal-to-Noise Ratio Data Vector

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



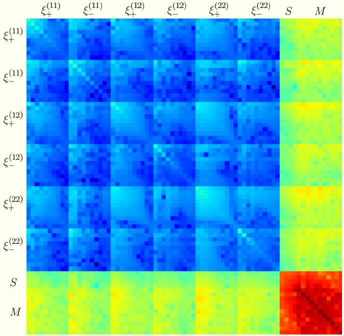
With n logarithmically spaced bins: $\vec{S}(\Omega_m, \sigma_8) : \mathbb{R}^2 \rightarrow \mathbb{R}^n$

Constraints from Tomographic Peaks



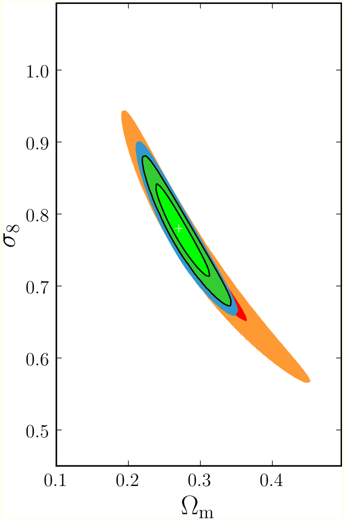
- Blue contours are derived using the SNR distribution of peaks.
- Green contours are constraints from counting peaks per redshift bin.
- Red/cyan/blue contours are the combination of both methods.
- Cannot use full $N(\sigma, z)$ because covariance is limited.
- Used fitting function to interpolate 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.

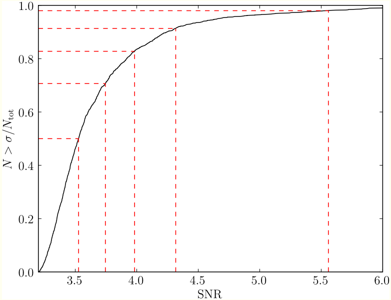
Combined Constraints



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

Type	Figure of Merit
Cosmic shear	71
Peak statistics	123
Combined	173

Where is the Information?



f_{min}	f_{max}	n_{bin}	σ_{min}	FoM
0.50	0.98	5	3.2	48
0.08	0.50	5	3.2	34
0.50	0.98	5	4.0	7
0.08	0.98	10	3.2	48

$\Rightarrow$ 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 $\Omega_{\rm m}, \sigma_8$ with projected peaks containing cosmological information.
- Peak tomography does much better than $M_{\rm ap}$.
- Peak tomography gives constraints which are competetive 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?