Cosmology with the Shear-Peak Statistics

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with friendly support from
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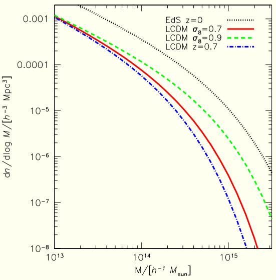
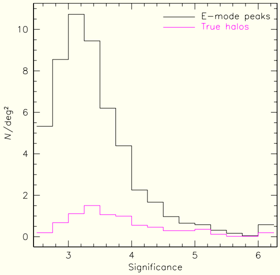
Cosmology with the Mass Function



- Evolution of cluster mass function is cosmological probe.
- A number of papers (e.g., Takada & Bridle 2007) showed that cluster cosmology and cosmic shear are complementary probes for dark energy.

Weak Lensing Searches

- Weak lensing searches will always be incomplete, except at the highest masses (Hamana et al. 2004).
- Weak lensing searches will always have false positives from projections of LSS. These projections occur with all significances.



Dietrich et al. (2007)

The Peak Statistics

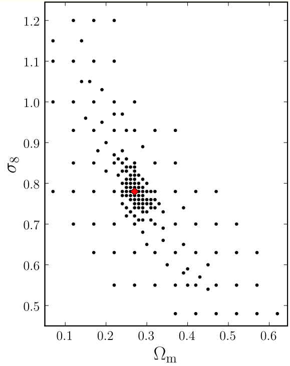
- At low SNR false positives are mainly caused by shape noise; at high SNR peaks are due to projections of large-scale structure.
- The weak lensing peaks caused by LSS are false positives only if one searches for galaxy clusters.
- LSS peaks caused by real mass along the line of sight.
- LSS peaks caused by real structure, part of the power spectrum.
- 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?

M–N-body simulations

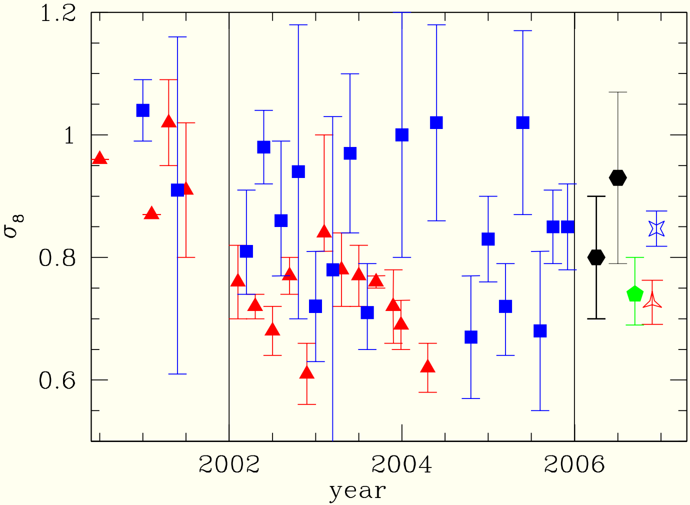
Make many N-body simulations for various cosmological parameters and raytrace through them.

- 200 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: five $6 \times 6\,\text{deg}^2$ fields.
CFHTLS like survey.

Why $\Omega_{\rm m}$, σ_8 and not Dark Energy?



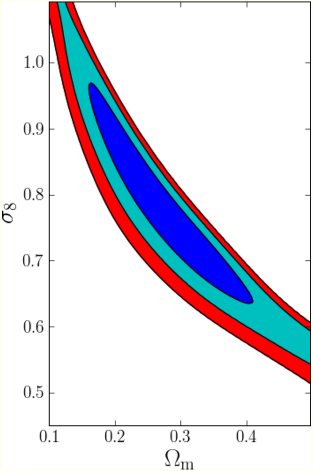
Hetterscheidt et al. 2007

Peak Finder

How we find peaks:

- Aperture mass, M_{ap}, with various SNR cuts.
  Filter follows NFW profile tuned to $6 \times 10^{14}\,M_\odot$ cluster at $z = 0.3$.
- Tomographic cluster finder of Hennawi & Spergel (2005).
  Essentially M_{ap} with redshift weights. Maximum likelihood gives 3-d position.

Constraints from $\mathrm{M_{ap}}$ Peaks



- Popular attempt to get only galaxy clusters: $\sigma(\mathrm{M_{ap}}) > 6$.
- Use σ as mass proxy.
- $\mathrm{N}(\sigma)$ starting from $\sigma = 6.0$, steps of 0.5σ.
- How much information is in the lower SNR peaks?

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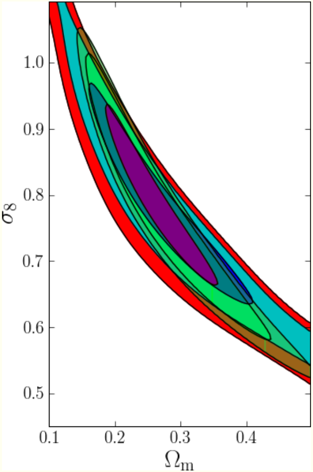

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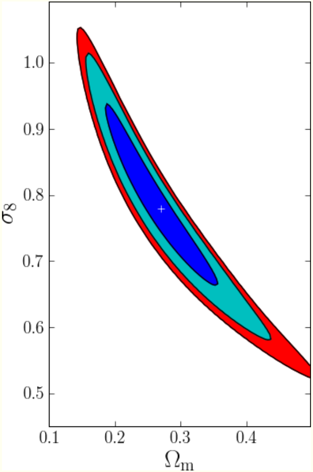

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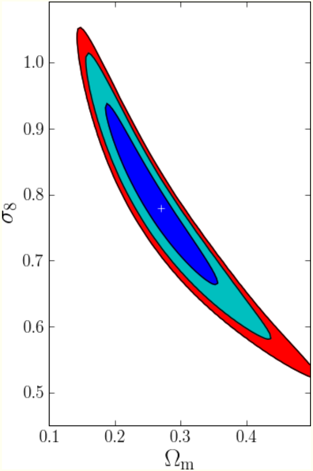

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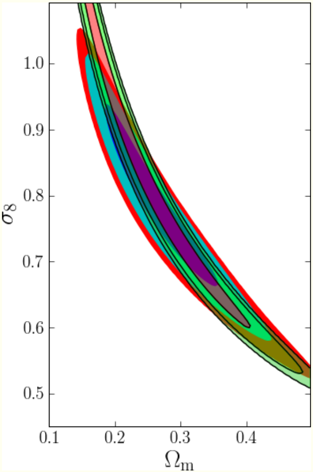

- How much more information is in peak tomography?
- A lot.
- $N(z)$ with 10 bins from $z = 0.1 \ldots 1.0$. All peaks above detection threshold counted.

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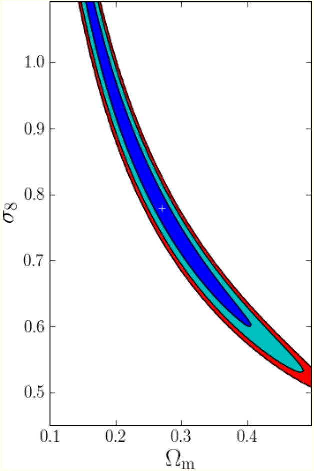
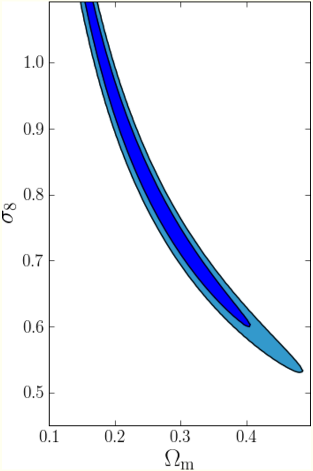


- How much more information is in peak tomography?
- A lot.
- $N(z)$ with 10 bins from $z = 0.1 \ldots 1.0$. All peaks above detection threshold counted.
- $N(\sigma)$ also works.
- Ideally, we would use $N(z, \sigma)$, but not enough simulations at fiducial cosmology.
- Maybe some linear combination of $N(z)$ and $N(\sigma)$? Work in progress (PCA)...

Peak Statistics and Cosmic Shear



- Does the peak statistics probe something other than cosmic shear?

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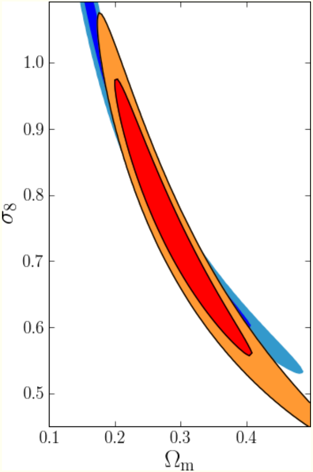

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- The “bananas” are slightly inclined.

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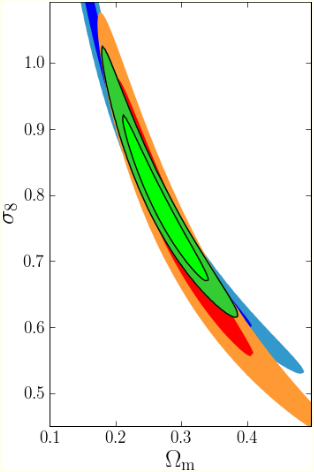
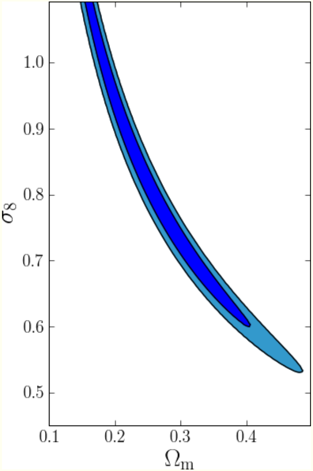


- Does the peak statistics probe something other than cosmic shear?
- $\xi_{+/-}$ with 10 bins each.
- The "bananas" are slightly inclined.
- The combination of cosmic shear and peak statistics gives stronger constraints.

	peaks	shear	comb
σ_8	$0.81^{+0.17}_{-0.15}$	$0.75^{+0.12}_{-0.14}$	$0.79^{+0.08}_{-0.07}$
Ω_m	$0.27^{+0.10}_{-0.07}$	$0.30^{+0.09}_{-0.06}$	0.27 ± 0.04

Peak Statistics and Shear Tomography



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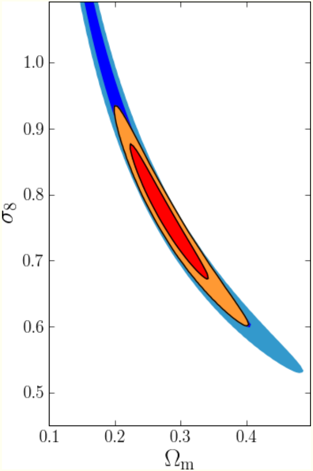

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- Shear tomography with 2 redshift bins ($z < 0.6$ and $z > 0.6$).
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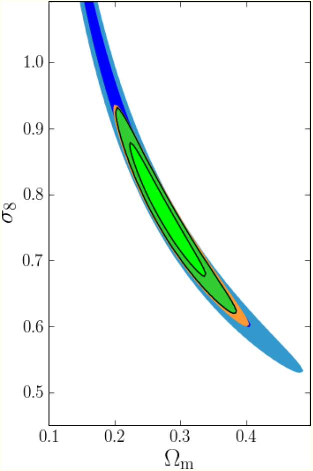
Peak Statistics and Shear Tomography



- How about the combination of peak tomography and shear tomography?
- Shear tomography with 2 redshift bins ($z < 0.6$ and $z > 0.6$).
- The cosmic shear banana tilts into the peak banana.
- The combination of both statistics gives only marginally improved constraints.

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σ_8	$0.81^{+0.17}_{-0.15}$	0.76 ± 0.06	$0.77^{+0.05}_{-0.07}$
Ω_m	$0.27^{+0.10}_{-0.07}$	0.28 ± 0.04	$0.28^{+0.03}_{-0.04}$

Can You Markov Chain This?

Not with the current setup:

Task	CPUh
N-body	140
ray-tracing	10
peak finding	40
total	190

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But you can save some time:

- Use pure PM code instead of TreePm
- Raytracing is I/O limited. Could be done in memory (if you have 32 GB).

Task	CPUh
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30 000 element Markov chain needs 2 500 000 CPUh.
Normal programs: 1 000 000 CPUh
Large programs: >2 000 000 CPUh

Pressure factor on HPC ~ 1. Ideal for grid computing.

Summary

Conclusions

- Peak statistics can constrain Ω_m, σ_8 with projected peaks containing cosmological information.
- Peak tomography does much better than M_{ap}.
- Peak tomography can partially break the Ω_m, σ_8 degeneracy of cosmic shear but adds little additional information to shear tomography.
- Modeling current surveys with N-body simulations is challenging but not entirely unrealistic.

Open issues

- Influence of the redshift distribution. The one used here is a bit weird, few projections.
- Maybe a combination of $N(z)$ and $N(\sigma)$ works better?
- How does the peak statistics perform for dark energy?