# COSMOLOGICAL INFORMATION IN WEAK LENSING PEAKS AND THE IMPACT OF BARYONS

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# Introduction

Large surveys such as LSST will deliver full-sky weak lensing data. Extremely tight constraints are expected on cosmological parameters. **(e.g. DETF)**

Convergence field is non-Gaussian: two-point function and power spectrum could be missing most of the information.

We have created a suite of WL maps from ray-tracing simulations to study non-Gaussian info – e.g. ***peak counts***.

**Kratochvil et al. (PRD, 2010); Yang et al. (PRD, 2011).**

Q1: How much information is beyond the power spectrum?

Q2: What is the impact of baryons on convergence peaks and their constraining power?

# Simulation Suite

We use N-body code Gadget to generate simulations with IBM BlueGene at Brookhaven National Lab.

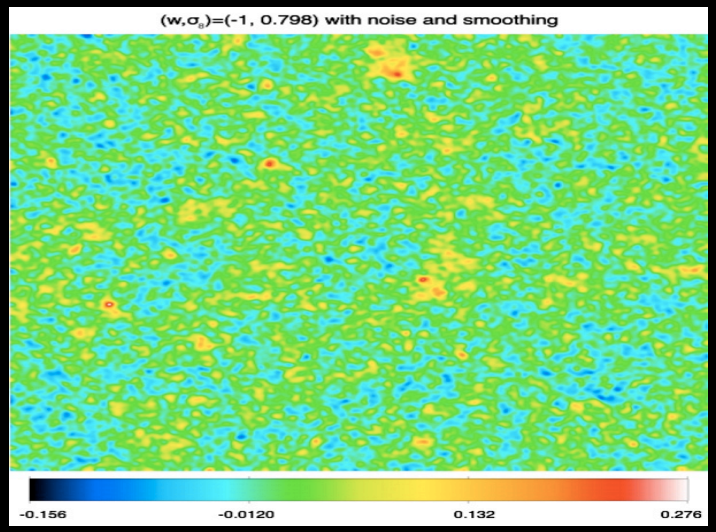
- $512^3$ particles, 240 Mpc/h box
- DM particle mass $7.4 \times 10^9$ M/h
- WMAP fiducial cosmology $\Omega_m$=0.26, $\Omega_\Lambda$=0.74, h=0.72, w=-1, $\sigma_8$=0.79
- vary $\sigma_8$, w, $\Omega_m$: total of 80 independent simulations

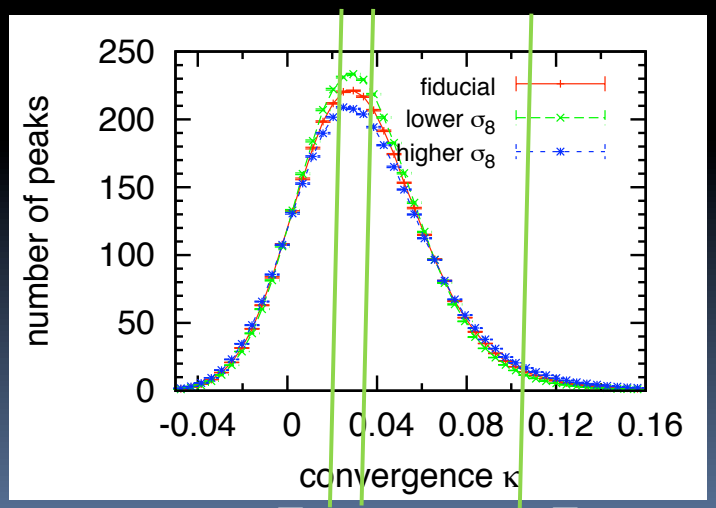
Use ray-tracing to generate WL convergence maps

- Source galaxies at z=1 and 2; 1000 realizations per cosmology
- Add galaxy shape noise (15 gal/arcmin$^2$), 1 arcmin smoothing
- Map size 3.5×3.5 deg$^2$

# Convergence Peak Count Distribution

Peak-count distribution is very useful to constrain cosmology.




low

high

Example:
Vary $\sigma_8$

Peaks: defined as local maxima on our 2D convergence maps.

Cosmology difference is driven by low (1-2σ) peaks, rather than high (>4σ) peaks.

Main result: adding peak counts to power spectrum tightens the constraints on $\sigma_8$, $w$, $\Omega_m$ by a factor of ~two.

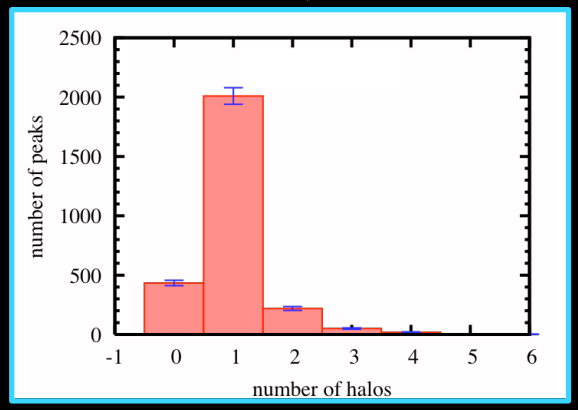
What is the origin of these low peaks ?

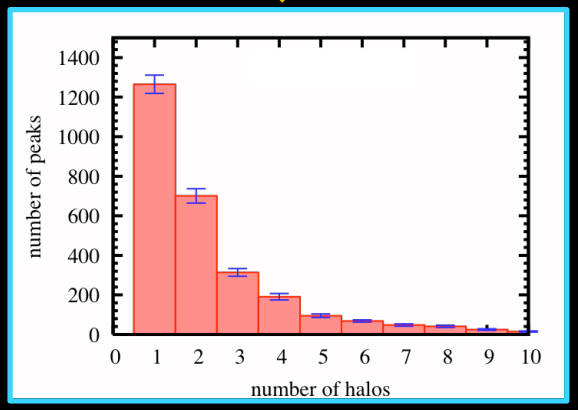
# What is the origin of WL peaks?

Identify DM halos along LOS to each peak. How many halos contribute ?

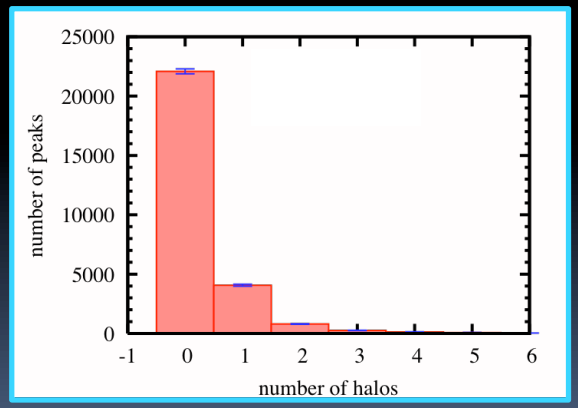
With noise

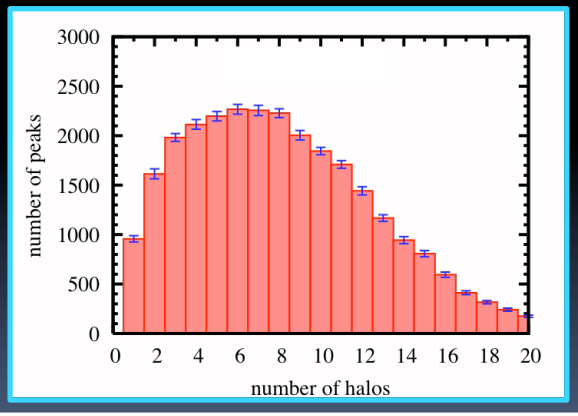
Halo only




←High




←low

**low peaks are dominated by *galaxy shape noise* and by *the sum of 4-8 halos* along the LOS**

# Quantifying the Impact of Baryons

These conclusions are from N-body simulations. How do baryons impact the result?

## Conventional Method:

**Hydro simulations** + modeling cooling, star formation and feed back from supernovae and AGN, using (phenomenological) recipes

e.g. Zentner, Rudd & Hu (2008), Semboloni et al (2011)

## Our Method:

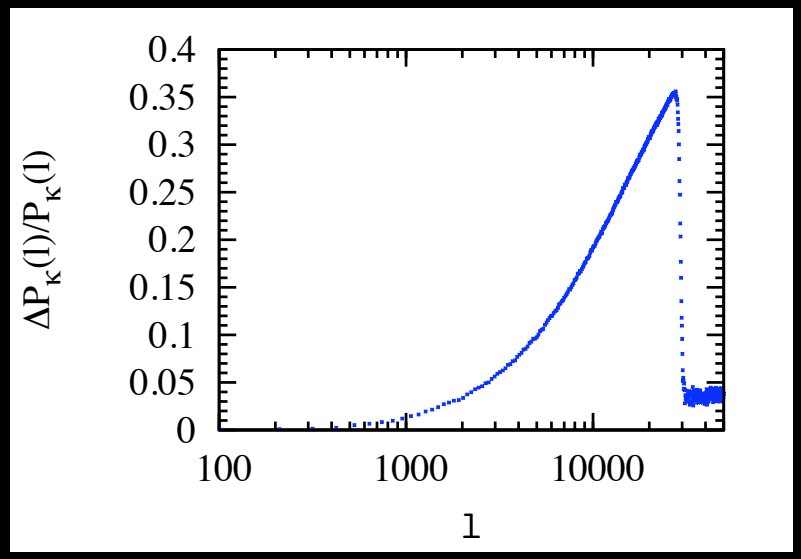
**N-body simulations** + steepening the halo density profiles by hand, by increasing concentration $c_{NFW}$

*justification*: this mimics very closely the cooling and contraction of baryons in DM halos.

*caveat*: does not capture AGN feedback

# Impact of Baryons on WL Statistics

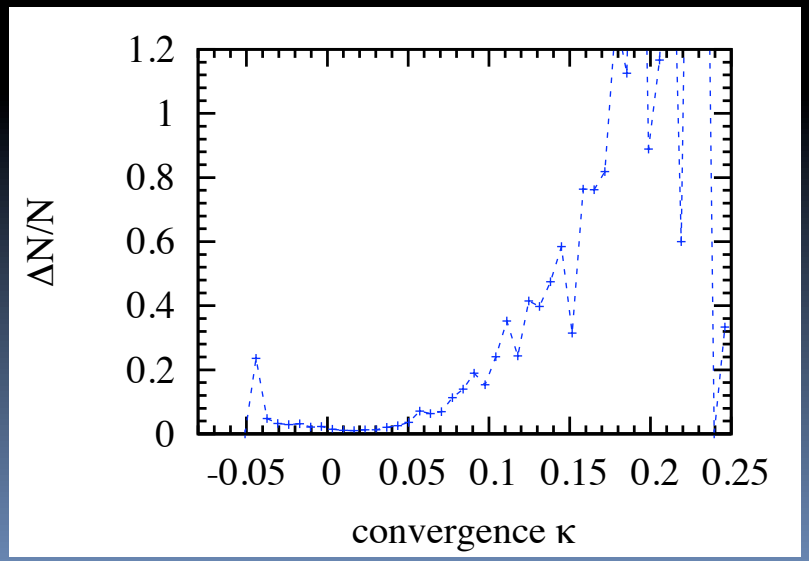
Change in power spectrum and peak counts, by 50% increase concentration parameter




power spectrum:

increase on small scales.
results agree with Zentner et al. (2008)

(sharp drop at l=20,000 is due to 1 arcmin smoothing.)




peak counts:

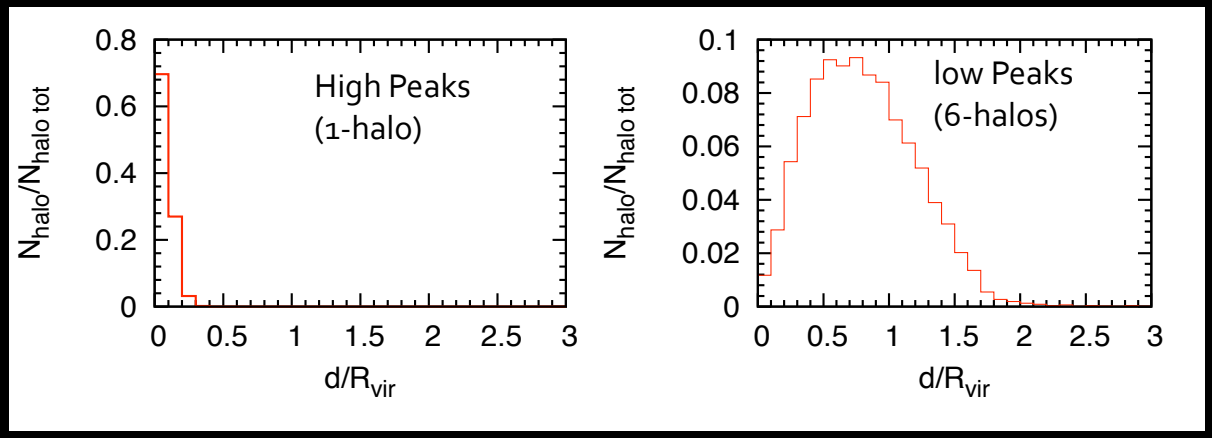
- strong increase in # of high peaks
- very little change in # of low peaks

A promising result!
low peaks contain most of cosmology info – don't need high peaks.

cf: most of the constraints are lost if power spectrum at l>1000 is ignored

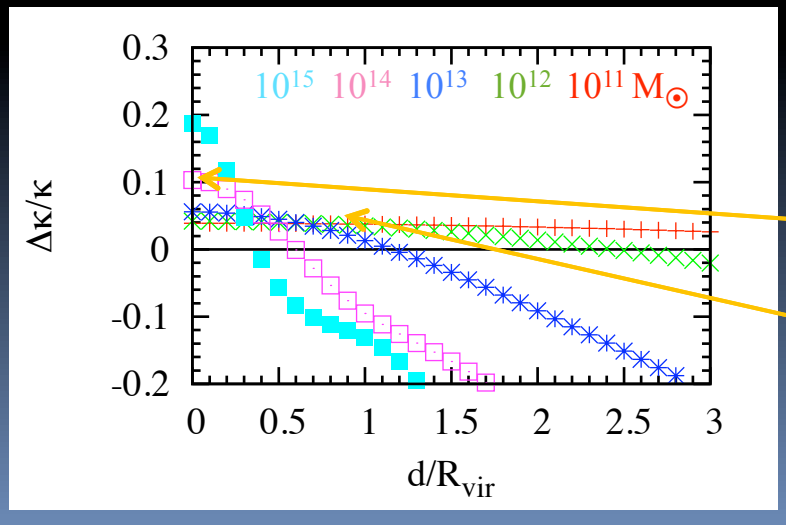
# Why Are low Peaks Robust to Baryons?

halos contributing to low peaks have lower mass ($10^{12} - 10^{13}\ M_\odot$ vs. $10^{14}\ M_\odot$ for high peaks) and larger off-set from the line-of-sight towards each peak




**Distribution of impact parameters $d/R_{vir}$**

*0 - 0.2 (high peaks)*
*0.5 - 0.9 (low peaks)*




**Effect of baryons on convergence:**

*Large near halo center ( high peaks )*

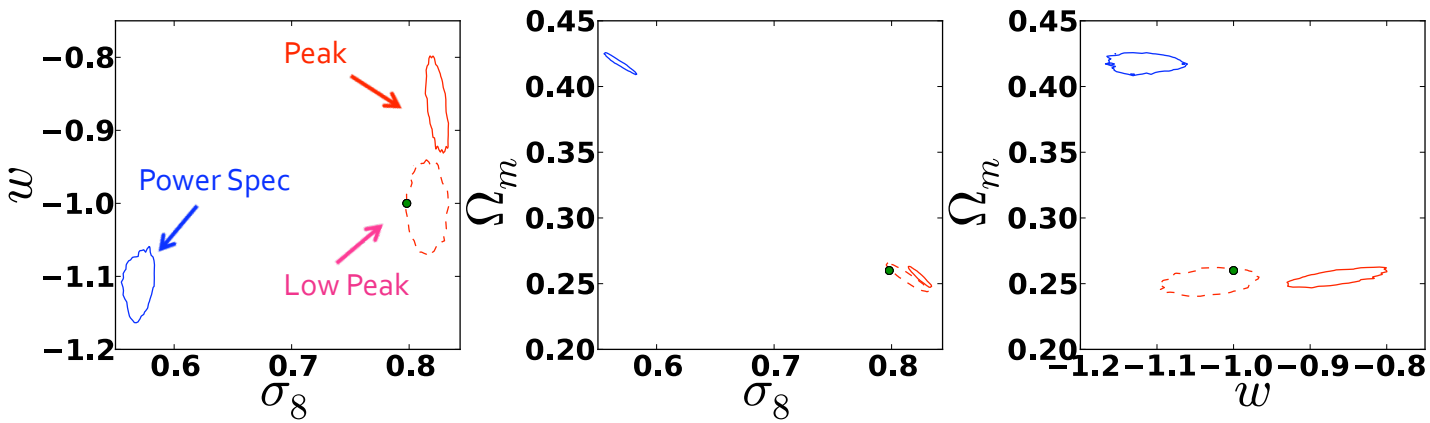
*Modest farther out ( low peaks )*

# Bias in the Inferred Cosmology

**From 1000 12 deg$^2$ maps, we generate 10,000 20,000 deg$^2$ maps by bootstrapping.**

**For each of the 10,000 maps in our fiducial ΛCDM, with baryonic effect included, we find a best-fit baryonless cosmology ($\chi^2$ minimization).**

**This gives a distribution of 10,000 WRONG best-fit parameter sets**
95% CL contours, LSST survey, 20,000 deg$^2$ field.




Conclusion: low peaks yield relatively little bias, and retain most of the info

Preliminary result: peak counts much ***less*** bias than power spectrum, and in ***different direction***.

➔ suggests possibility of ***self-calibration***: in a real survey, one can simultaneously fit for cosmological and baryonic "nuisance" parameters

# Conclusions

- Peak counts significantly improve the constraints compared to power spectrum alone (factor of ~two)
- Cosmological constraints are dominated by low (1-2σ) peaks, constellation of 4-8 halos along LOS
- Toy model reveals low peaks are much more robust to baryons than high peaks or power spectrum.
- Cosmology inferred from peak counts is biased ***less*** and in ***different direction*** than from power spectrum
- Possibility to ***self-calibrate***: fit simultaneously for cosmology and for baryon parameters

# THANKS

# Bias in inferred Cosmology

**We fit the baryonic observable to non-baryonic model if baryonic effect is neglected.**

$$\chi^2(r,p) \equiv \sum_{i,j} \Delta N_i(r,p)[Cov^{-1}(p_0)]_{ij} \Delta N_j(r,p)$$

Where

$$\Delta N_i(r,p) \equiv N^{bar}{}_i(r,p_0) - \langle N_i(p) \rangle$$

$\langle N_i(p) \rangle$ is the number of peaks in bin i averaged over 1000 realizations in ΛCDM model with cosmology parameter p

$N^{bar}{}_i(r,p)$ is the number of peaks in bin i in a single realization in baryonic model with cosmology parameter $p_0$

For each Monte Carlo realization, we minimize $\chi^2$ with respect to p.