The Impact of Magnification Bias on The Weak Lensing Power Spectrum and Peak Counts

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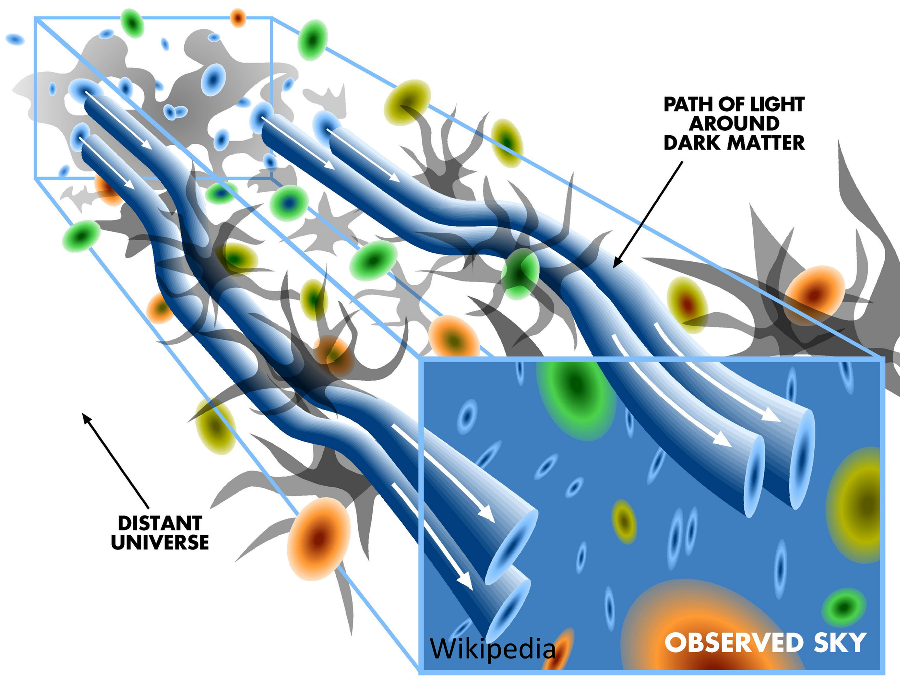
ABSTRACT

The weak lensing power spectrum is a powerful tool to probe the cosmological parameters. Additionally, peak counts contain cosmological information beyond the power spectrum. However, the constraining power of both statistics is undermined by the magnification bias due to the dark matter between the background galaxies and the observer.

We quantify this effect using convergence maps from N-body simulations and ray-tracing. We find that future weak lensing surveys, such as the ones expected from LSST, can suffer few σ deviation from the true parameters, if the magnification bias is ignored when comparing observations with models. The deviations by using the power spectrum and that by using the peak counts have different magnitudes. For derived w, power spectrum is less affected by magnification bias than the peak counts, while the opposite is true for $\sigma_8\Omega_m^{0.4}$.

Weak Gravitational Lensing



Through measuring the distortions of background galaxy shape by foreground masses, weak gravitational lensing surveys probe the mass density fluctuations throughout the cosmic span.

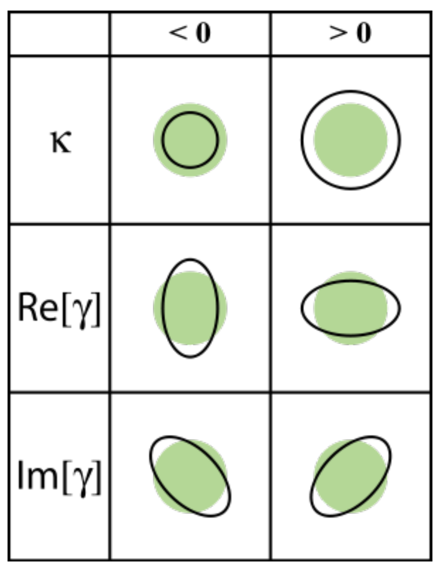
Convergence and Shear

A distortion matrix A_{ij} describes the re-mapping of the source's surface brightness distribution.

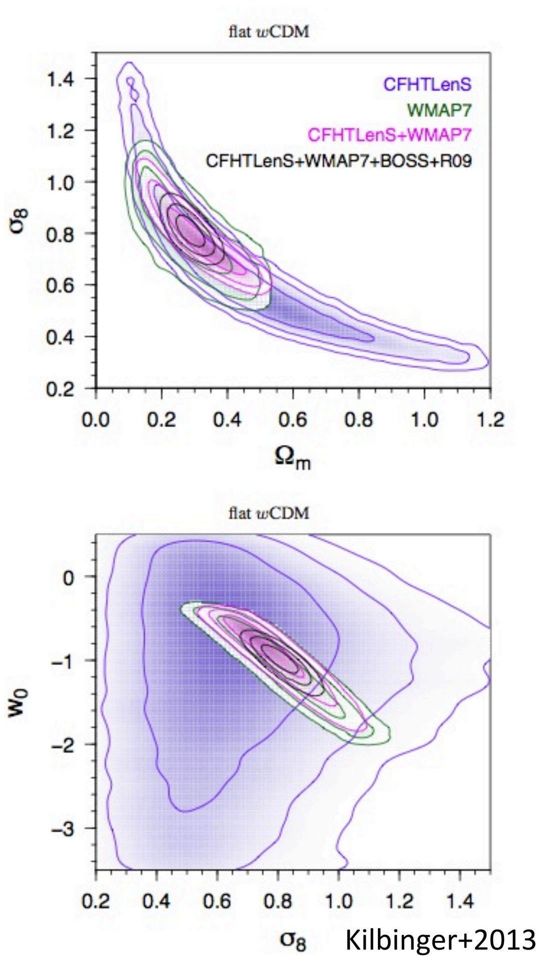
$$f_{obs}(\theta_i) = f_s(A_{ij}\theta_j)$$

$$A_{ij} = \begin{pmatrix} 1-\kappa-\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa+\gamma_1 \end{pmatrix}$$

κ convergence (magnification)
γ shear (distortion)

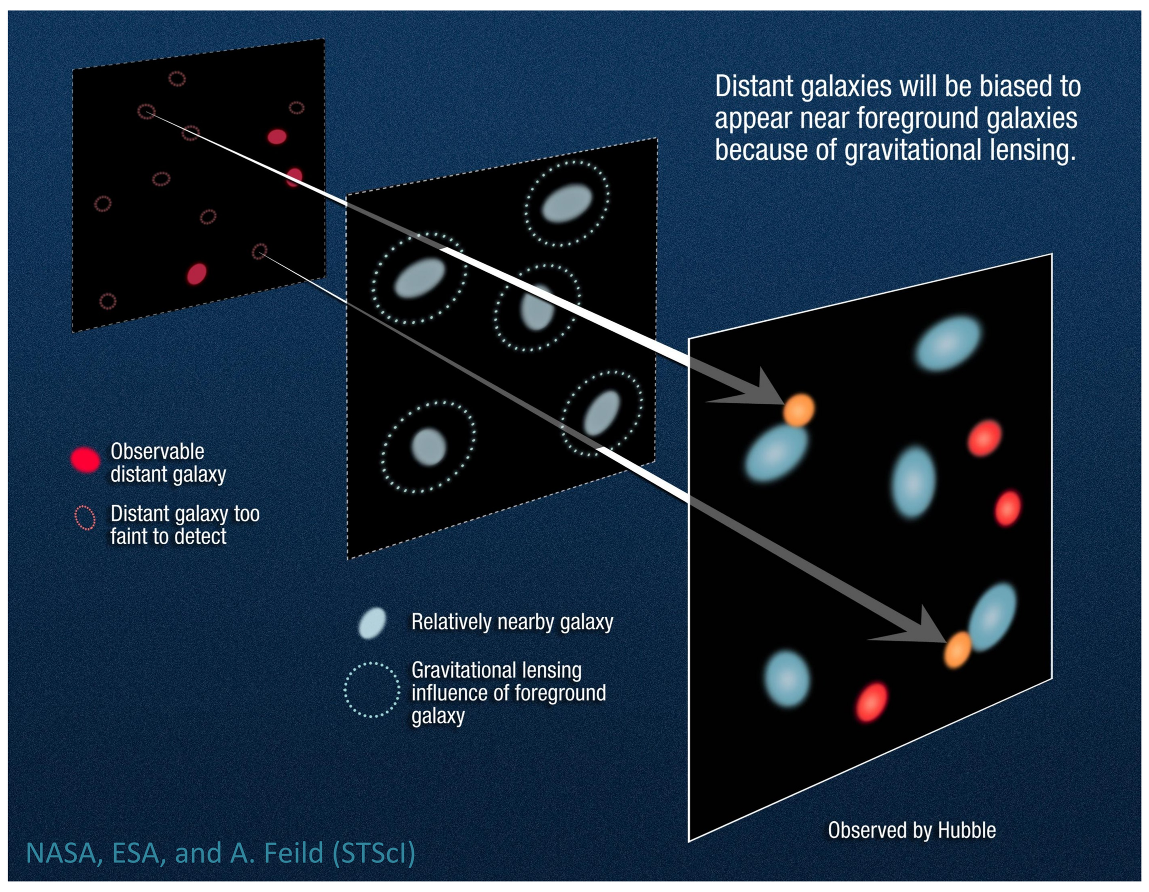


Cosmological Constraints



Weak lensing observations, combined with other methods, can be used to constrain the cosmological parameters.

Ω_m: the fractional mass density of the universe
w: the dark energy equation of state
σ_8: the r.m.s. linear mass fluctuations in a comoving sphere of diameter 8 Mpc



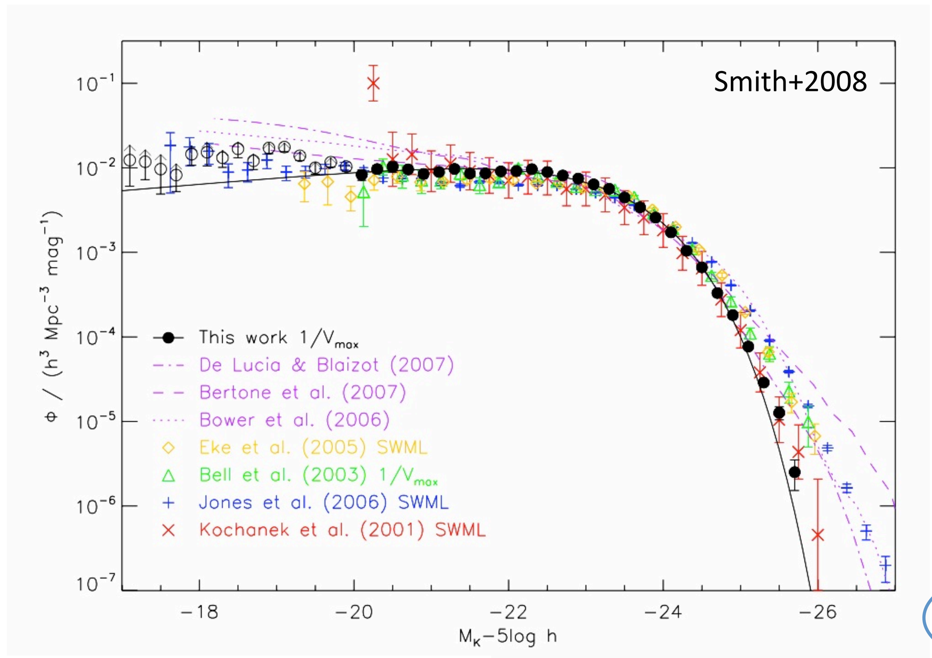
Magnification Bias $n = n_g[1+(5s-2)\kappa]$

Boost density In a magnitude-limited survey, some galaxies slightly fainter than the observation limit will now be magnified and included in the sample.

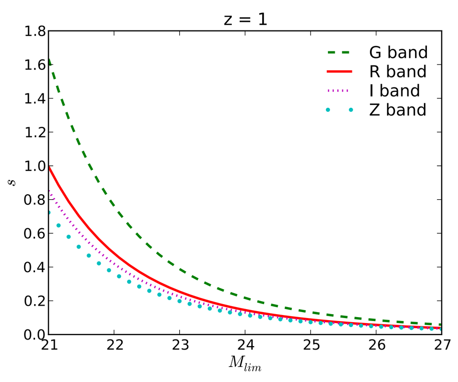
Dilute density A region on the sky appears to be larger due to the bending of light.

Galaxy Luminosity Function

The magnitude of magnification bias, $(5s-2)\kappa$, depends on the galaxy luminosity function (through s, the slope of the number count at the telescope magnitude cut-off). $s = 0.4$ is where the bias disappears.



$$s = \frac{d\log_{10} n_g}{dM}$$



	Magnitude limit	s
LSST	I ≤ 24.8	0.09
Euclid	R+I+Z ≤ 24.5	0.10
PanSTARRs	R ≤ 24 (point)	0.25
COSMOS	I ≤ 25	0.08 (z=1.25)
CFHTLS	I ≤ 24.7	0.09 (z=0.75)
DES	R ≤ 24.1	0.14
DUNE	R+I+Z ≤ 24.5	0.10
KiDS	R ≤ 25.2 (point)	0.13

Creation of Convergence Maps

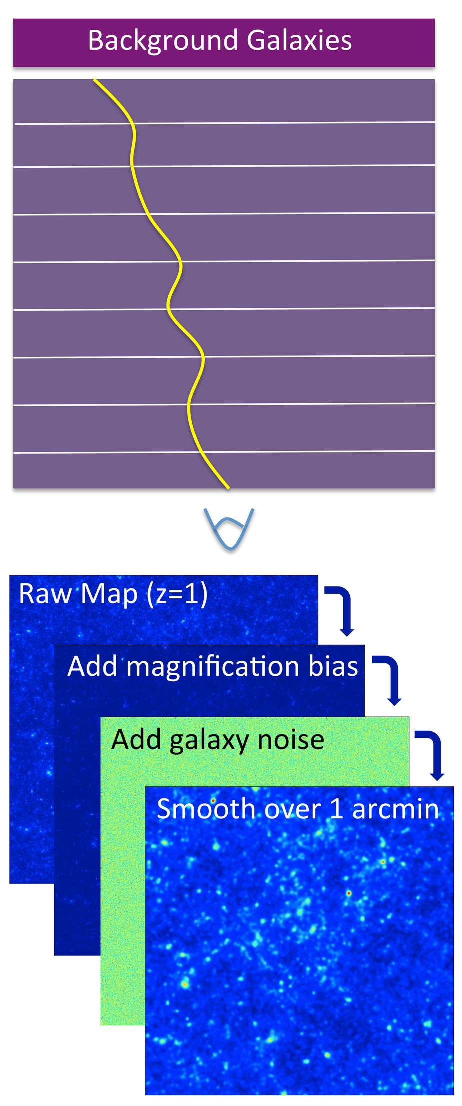
N-body simulation(Gadget-2)

- 7 cosmologies, each with 5 simulations
- Box size: 240h^{-1} Mpc (co-moving), 512^3 particles (mass res: 7.4×10^{9}h^{-1}M$_\odot$)
- Time span: z=100 to present

	σ_8	w	Ω_m	# of sims
Fiducial	0.798	-1.0	0.26	5
High-σ_8	0.850	-1.0	0.26	5
Low-σ_8	0.750	-1.0	0.26	5
High-w	0.798	-0.8	0.26	5
Low-w	0.798	-1.2	0.26	5
High-Ω_m	0.798	-1.0	0.29	5
Low-Ω_m	0.798	-1.0	0.23	5

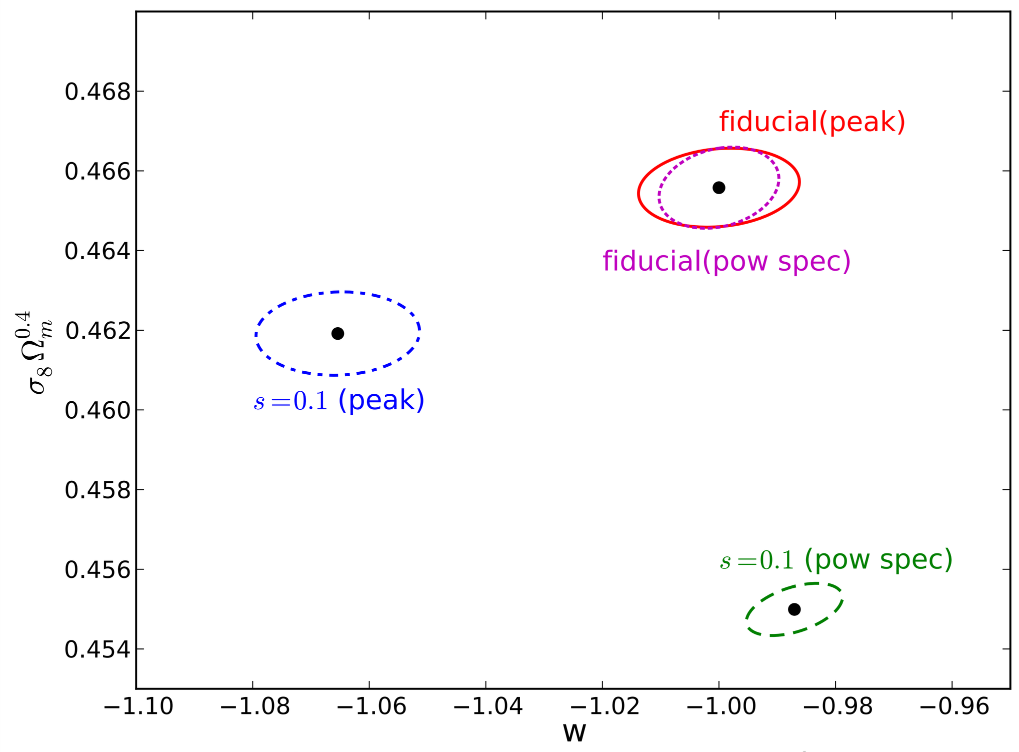
Ray tracing

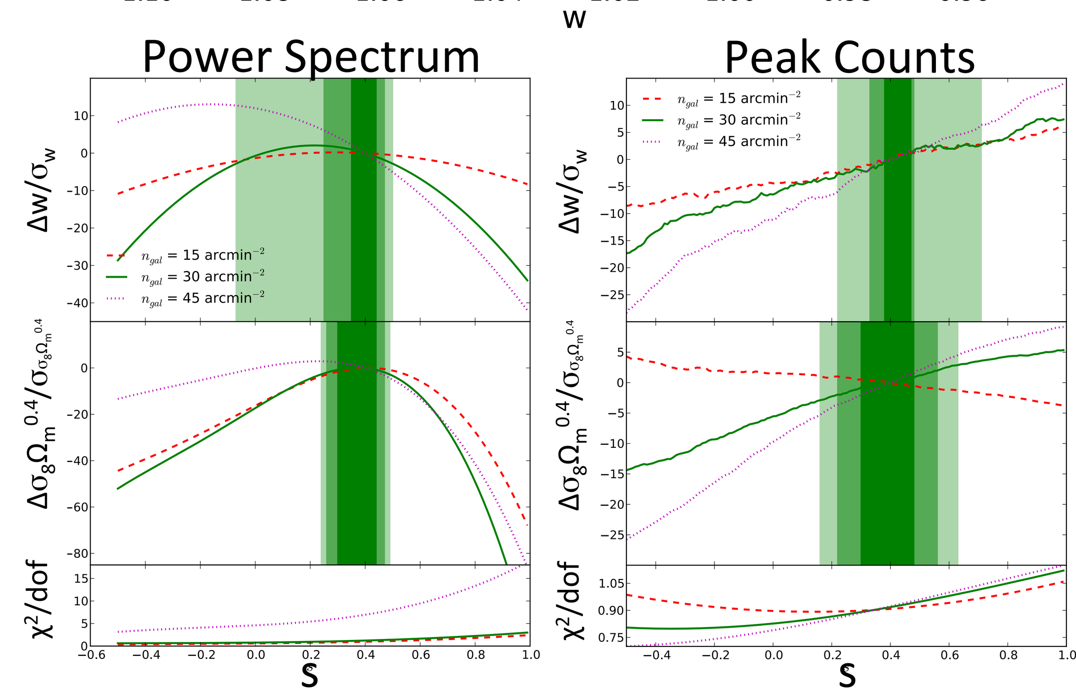
- Project 3D masses onto parallel 2D planes ⊥ to LOS
- Convert the surface density to gravitational potential at each plane using Poisson's equation
- Follow 2048 × 2048 light rays from z = 0 backwards through the planes
- Convergence and shear are calculated at each plane for each light ray (between the planes, the light rays travel in straight lines)



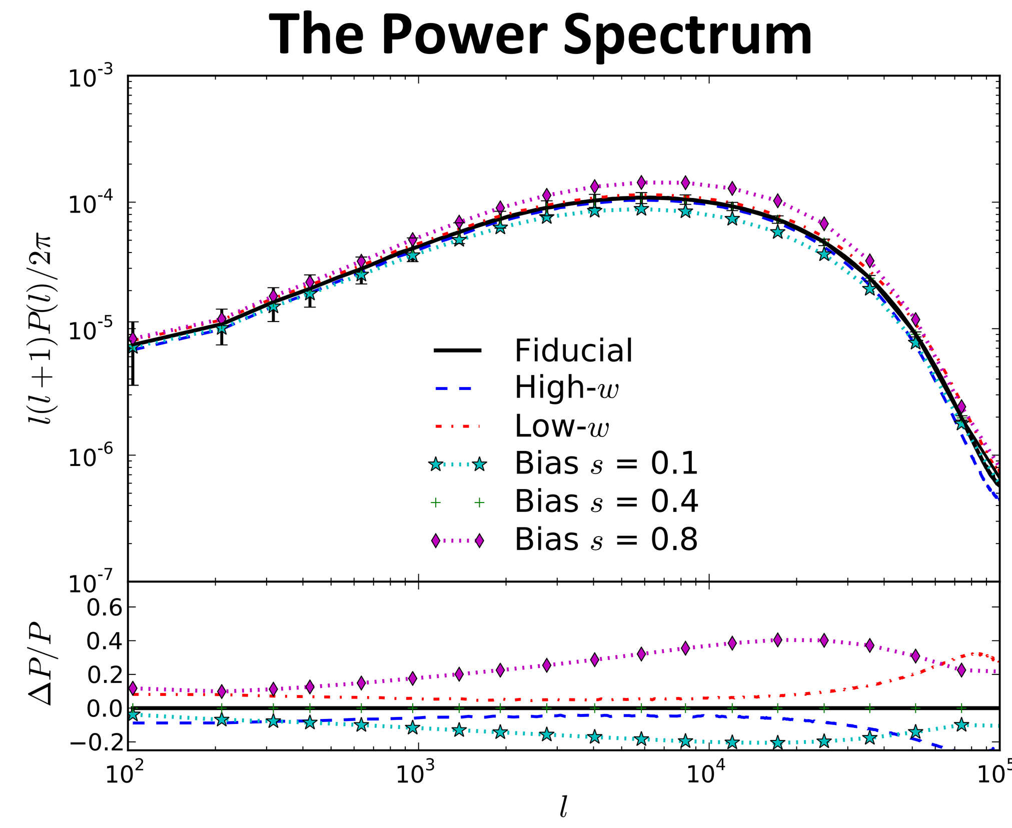
Cosmological Parameters (Key Result)

For most WL surveys, the galaxy number count at their cut-off magnitude has slope $s = 0.1$. As a result, the derived cosmological parameters will deviate from the true value by −1.3σ for w and −10.4σ for $\sigma_8\Omega_m^{0.4}$ when using the power spectrum, and by −4.6σ for w and −3.7σ for $\sigma_8\Omega_m^{0.4}$ when using peak counts. These results are scaled to WL observations expected from LSST. However, for recent surveys, such as PanSTARRs, COSMOS, CFHTLS and KiDS, the deviation is < 1σ due to either less sensitivity or smaller sky coverage.

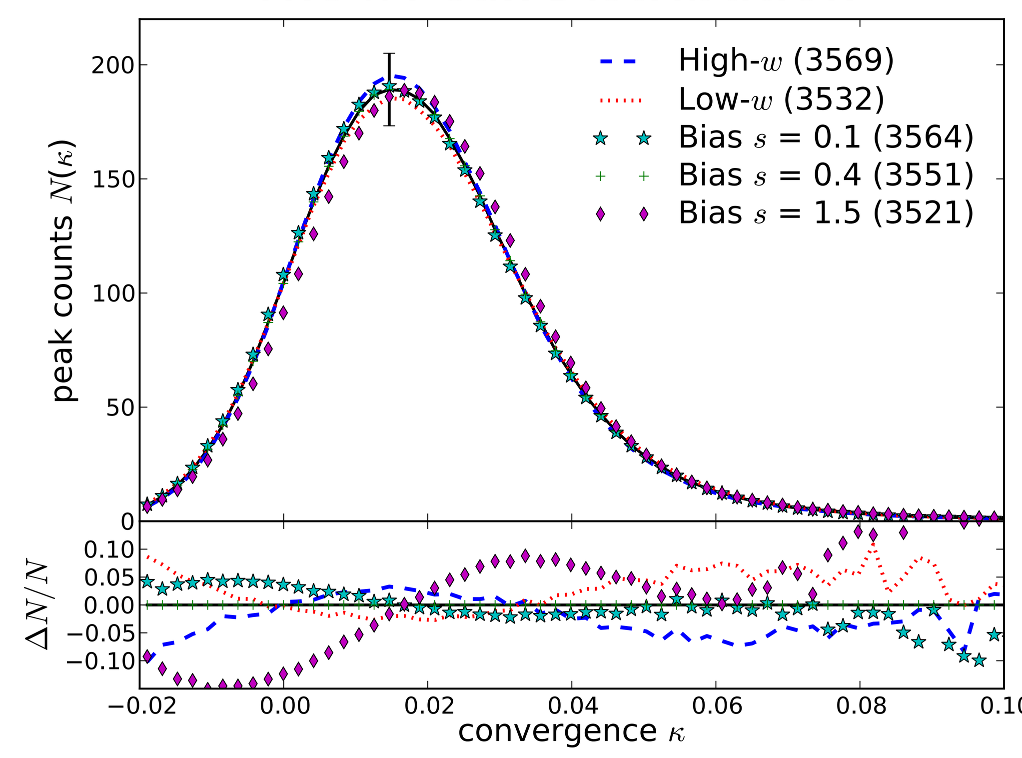




The Power Spectrum



The κ Peak Distribution



Peak Counts received increasing attention in recent years as a way to access information in a weak lensing survey beyond the power spectrum. The distribution of κ peaks has a non-Gaussian shape and has been shown to have cosmological sensitivity. Peak count is simply done by recording the peaks in a 2D shear or convergence map.