Magnification Bias in Weak Lensing

On The Beach

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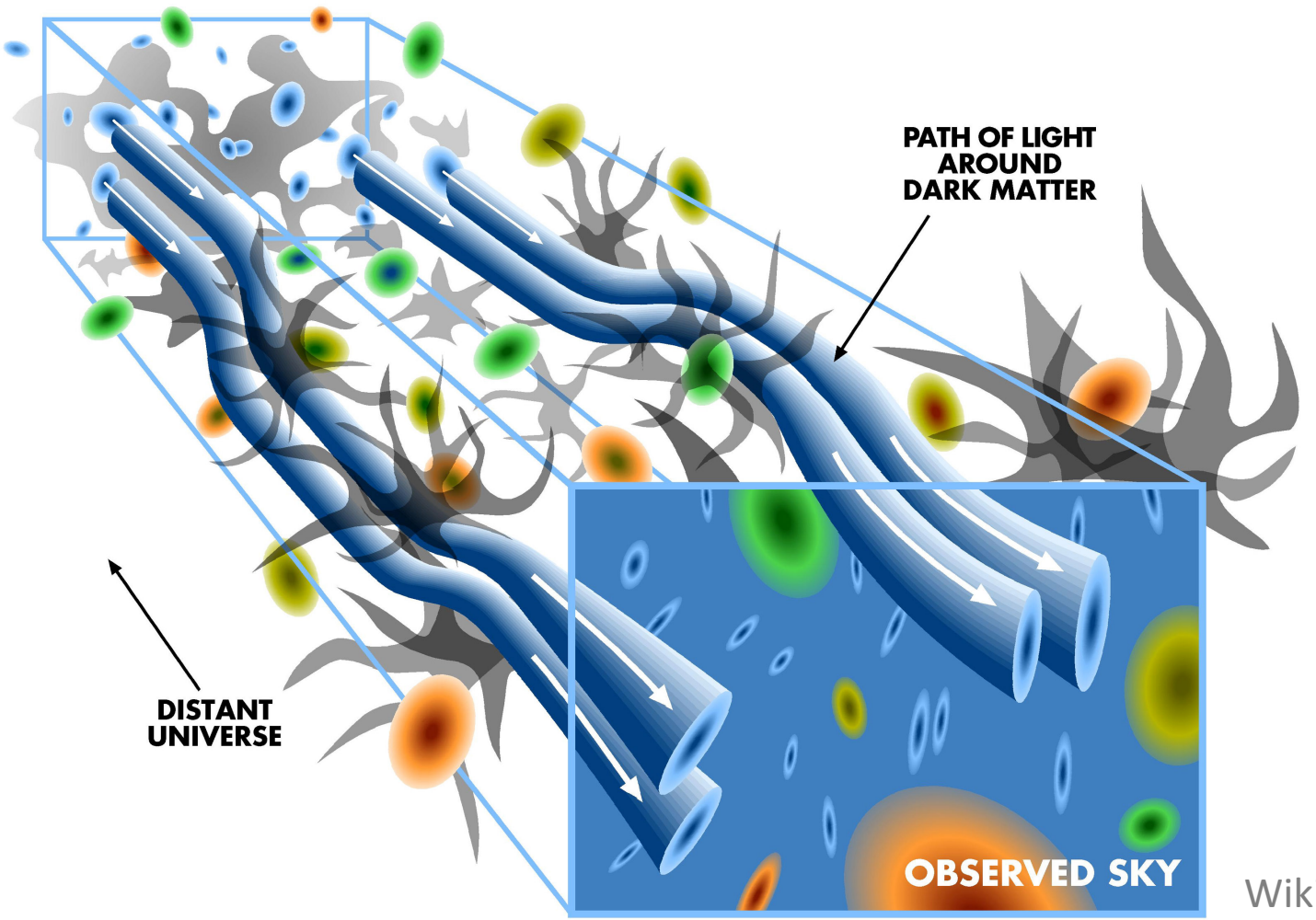
Weak Gravitational Lensing



Wikipedia

By measuring distortions of background galaxy shape (unknown), we study the foreground (dark) matter distribution (unknown).

And we say we can learn something about our Universe.

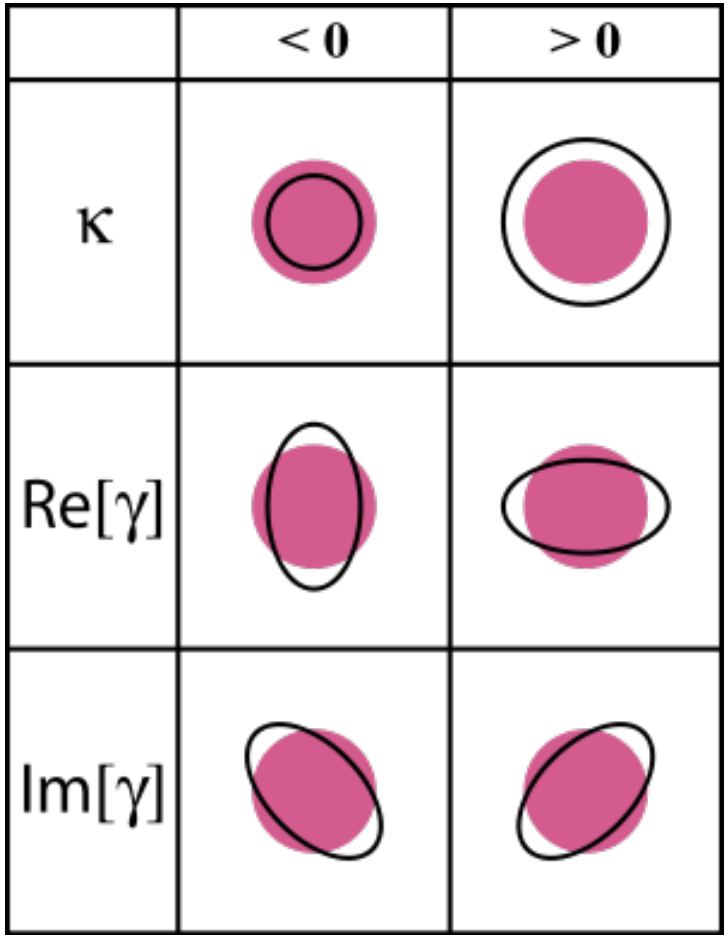
Weak Lensing Essence

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

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

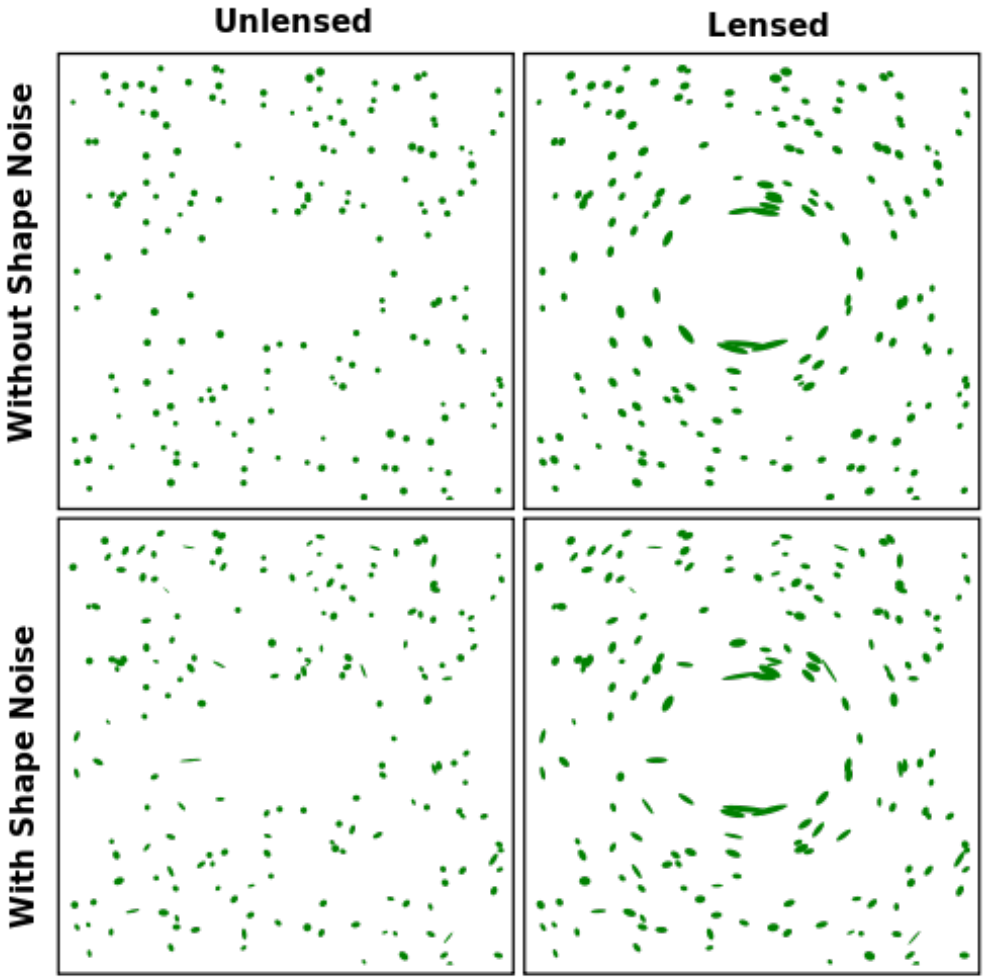
Distortion matrix $\mathbf{A_{ij}}$ describes the re-mapping of the source's surface brightness distribution.

κ convergence (magnification)
γ shear (distortion) $\gamma = \gamma_1 + i\gamma_2$

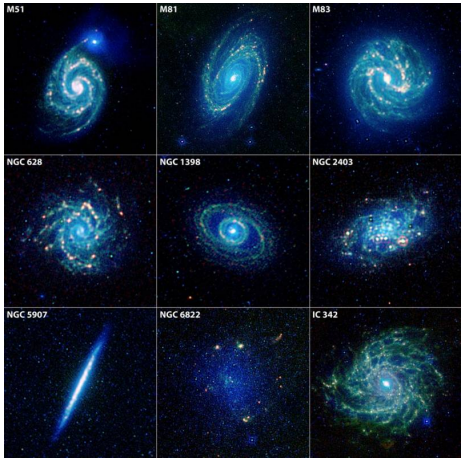


Wikipedia

Weak Lensing, A Statistical Estimate

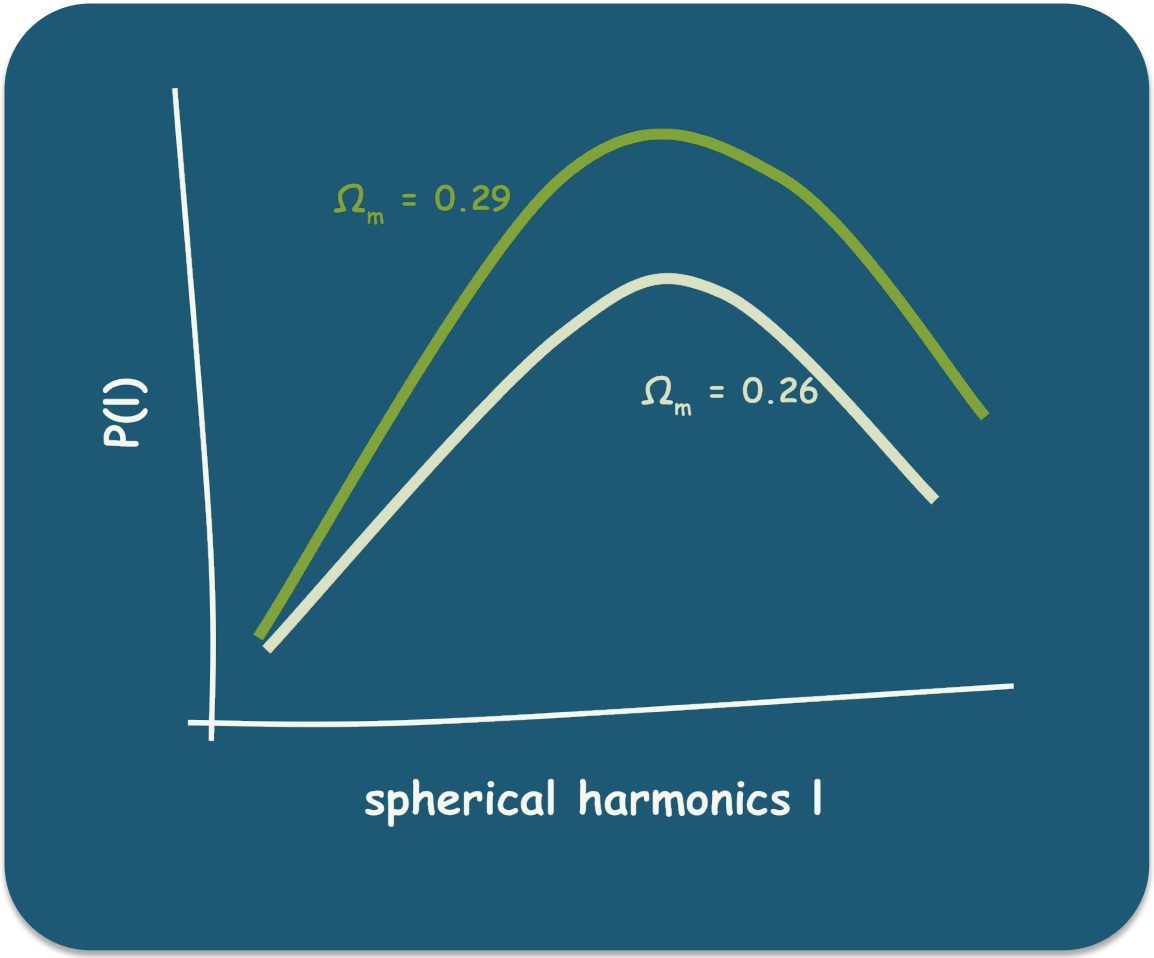


Note that the distortion shown here is greatly exaggerated relative to real astronomical systems. (Wikipedia)

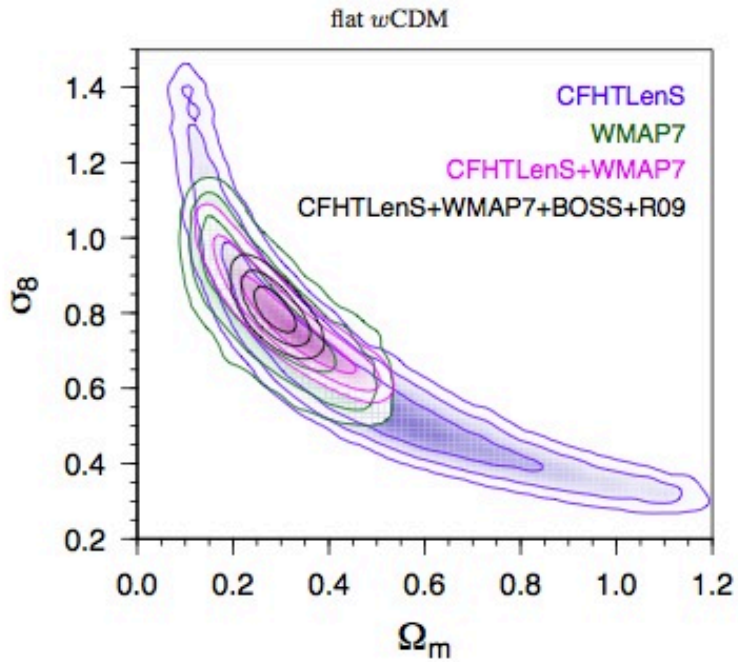


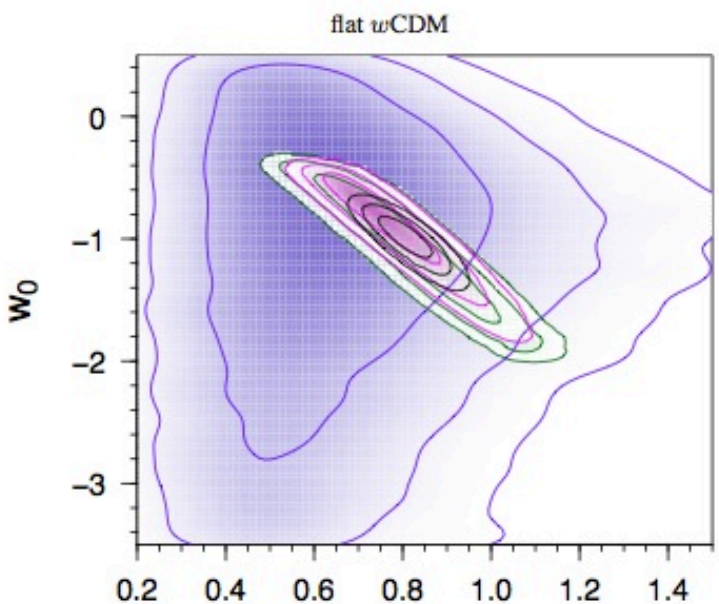
Due to the intrinsic galaxy shape noise, we don't care about individual galaxies, but rather their statistical properties.

e.g. the power spectrum



Cosmological Constraints



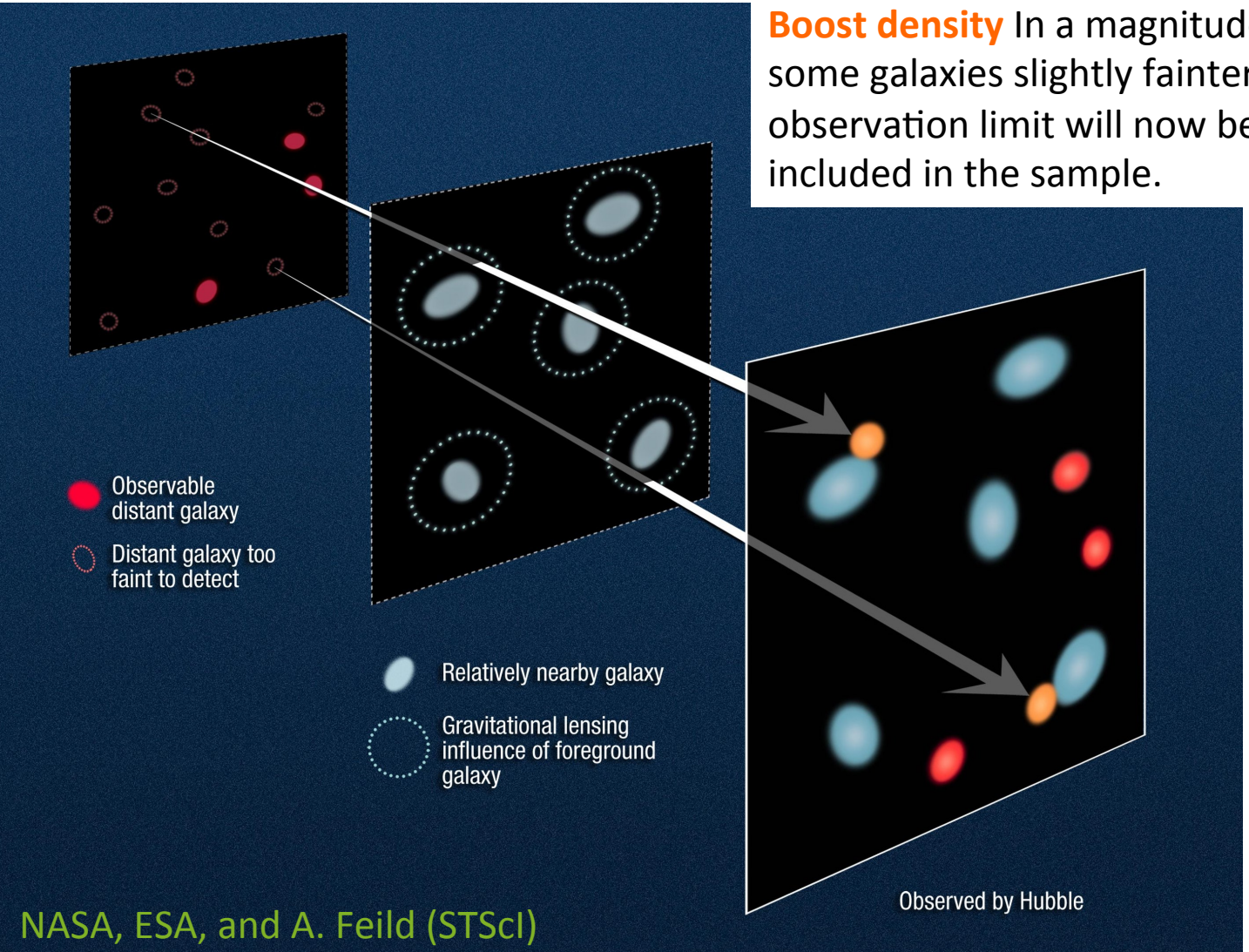


Kilbinger+2013

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: $n_{obs}=n_g[1+(5s-2)\kappa]$



NASA, ESA, and A. Feild (STScI)

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.

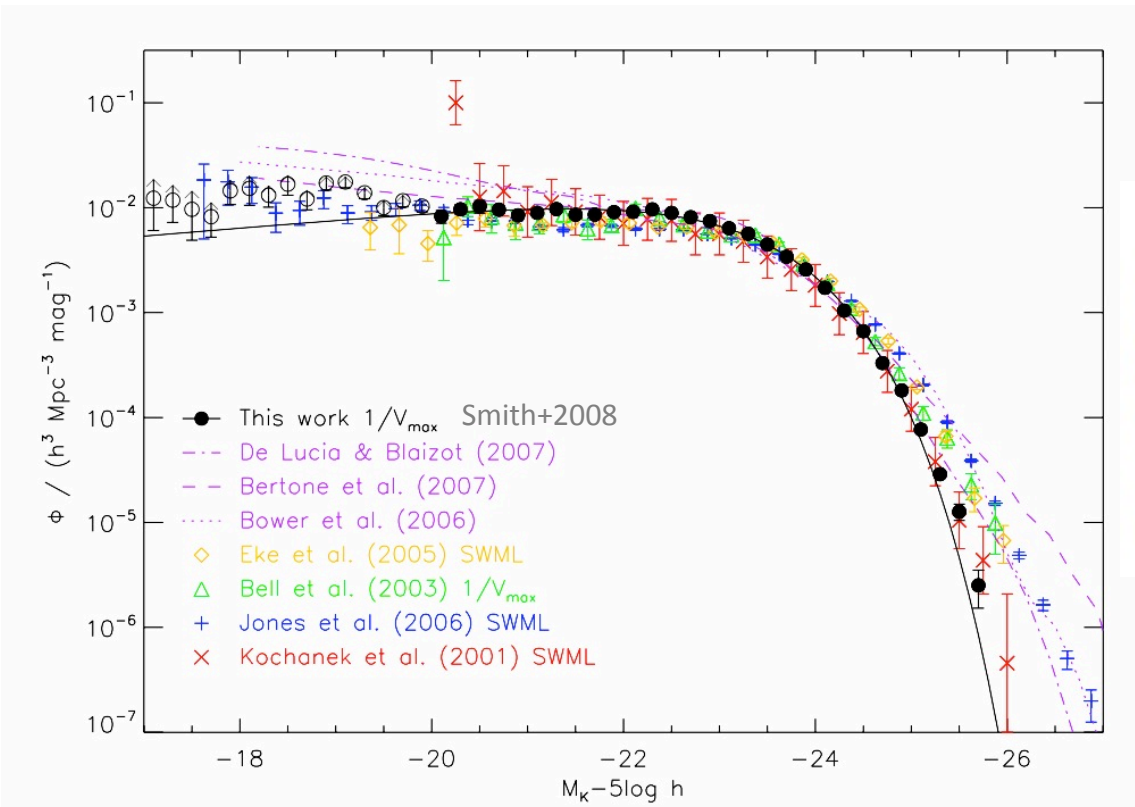
(Hui+2007)

Luminosity Function

$$s = \left.\frac{d\log_{10}\left(\int_{-\infty}^{M_{\rm lim}} \Phi\, dM\right)}{dM}\right|_{M_{\rm lim}}$$

~~The Schechter function~~ The gamma function

$$\Phi(M)dM = (0.4\ln 10)\Phi^*\left[10^{-0.4(M-M^*)}\right]^{\alpha+1} \times \exp\left[-10^{-0.4(M-M^*)}\right]dM$$

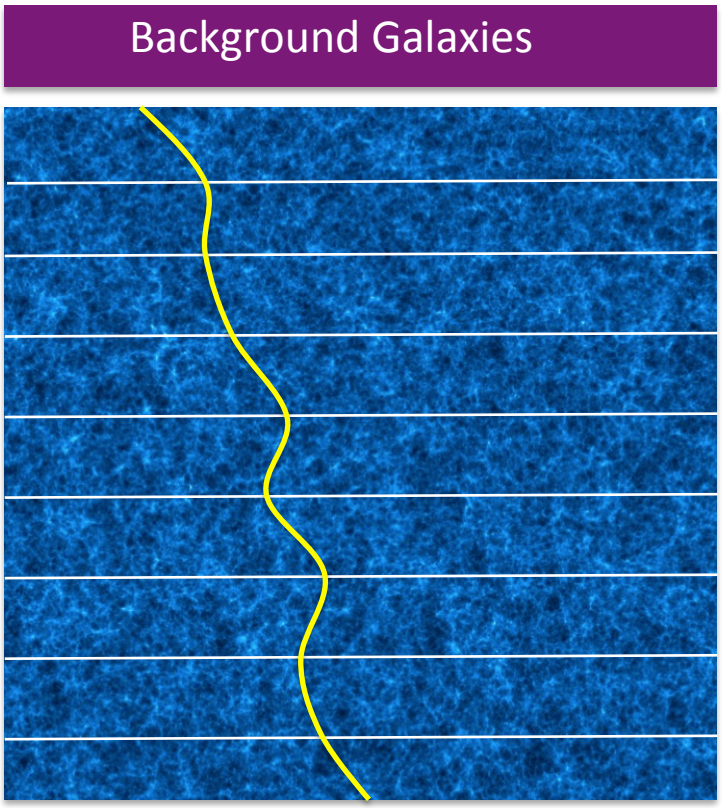


	Magnitude limit	$s(z=0.5)$	$s(z=1.0)$
LSST	$I \leq 24.8$	0.19	0.38
Euclid	$R+I+Z \leq 24.5$	0.20	0.43
COSMOS	$I \leq 25$	0.19	0.35
CFHTLS	$I \leq 24.7$	0.19	0.39
DES	$I \leq 24.3$	0.21	0.46
DUNE	$R+I+Z \leq 24.5$	0.20	0.43
KiDS	$R \leq 25.2$ (*)	0.24	0.69
HSC	$I \leq 26.2$ (*)	0.18	0.32

calculated using observation
by Gabasch+2004,2006

Simulation

(Kratochvil+2009,2011)

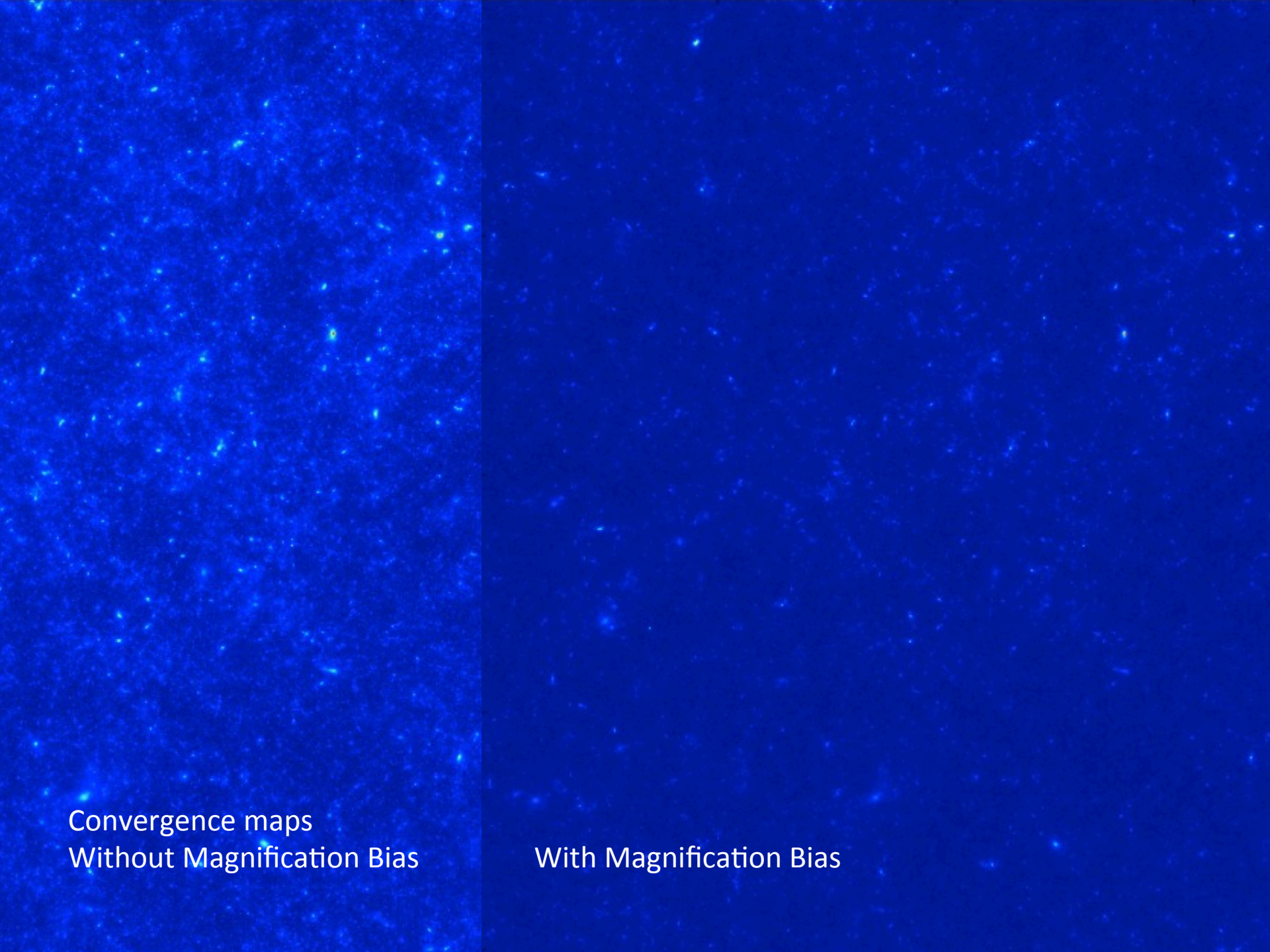


N-body simulation (Gadget-2)

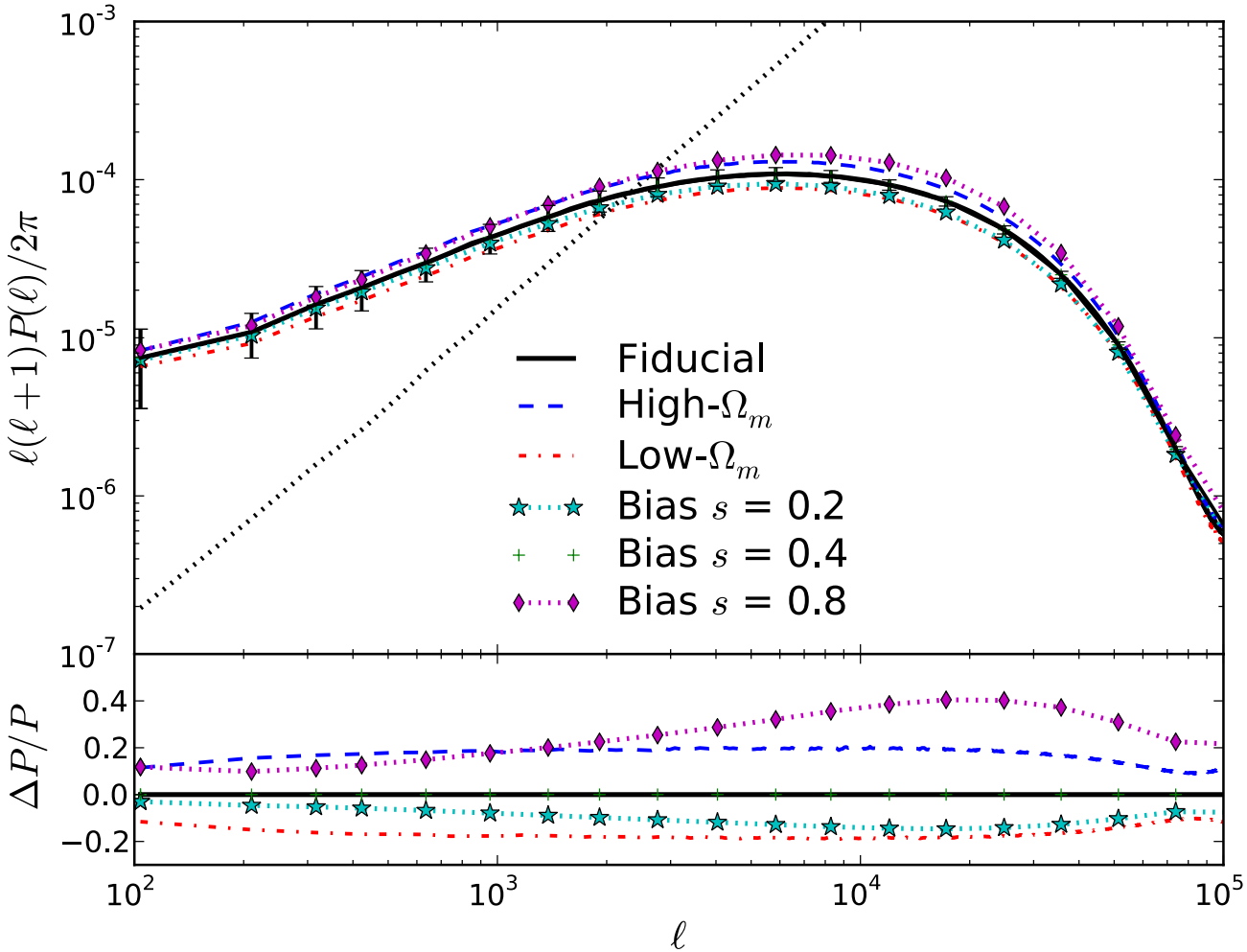
- 7 cosmologies
- box size: $240h^{-1}$ Mpc (comoving)
  512^3 particles
  (mass resolution: $7.4 \times 10^9 h^{-1} M_\odot$)
- time span: z = 100 to z = 0

Ray tracing

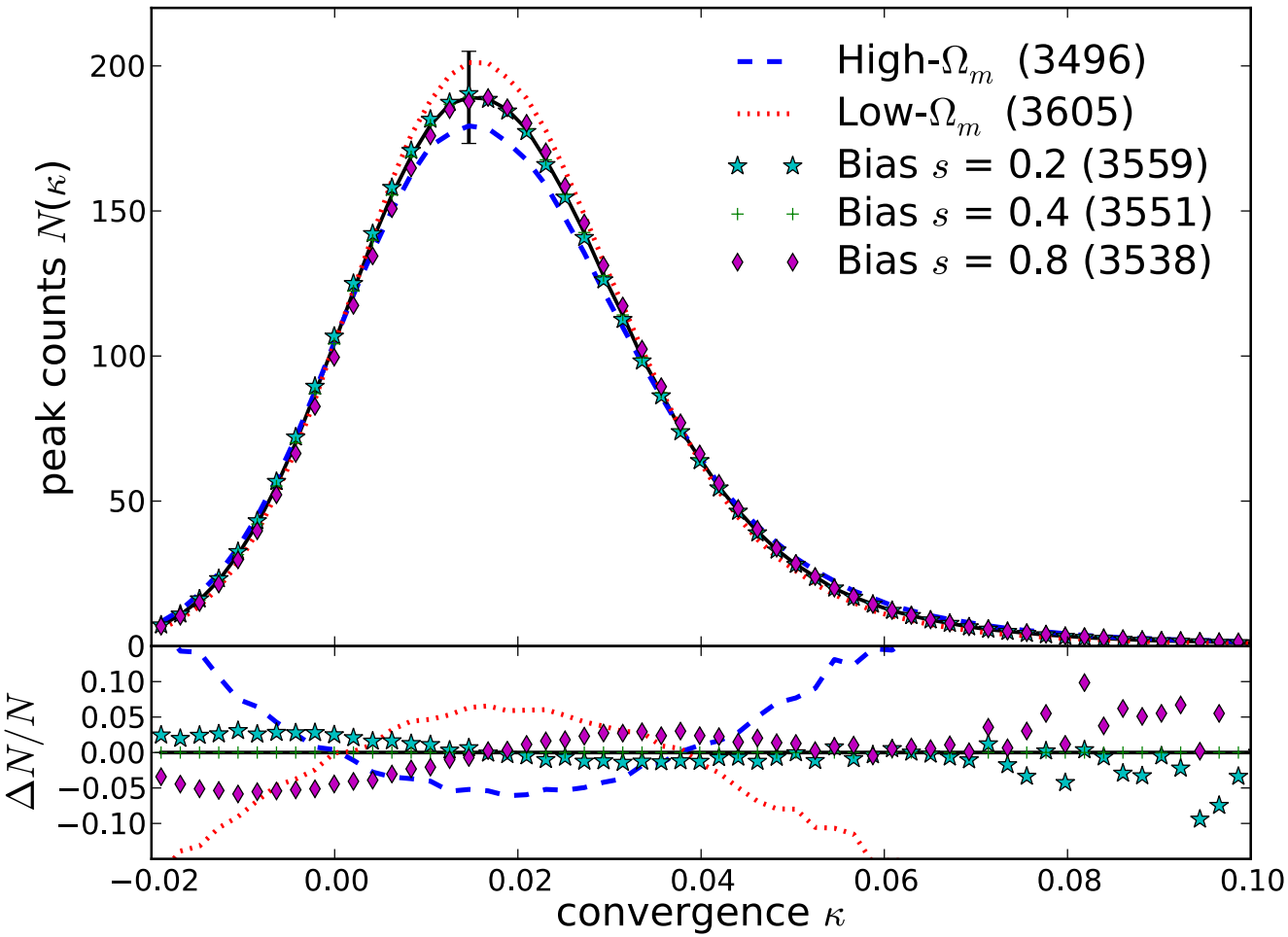
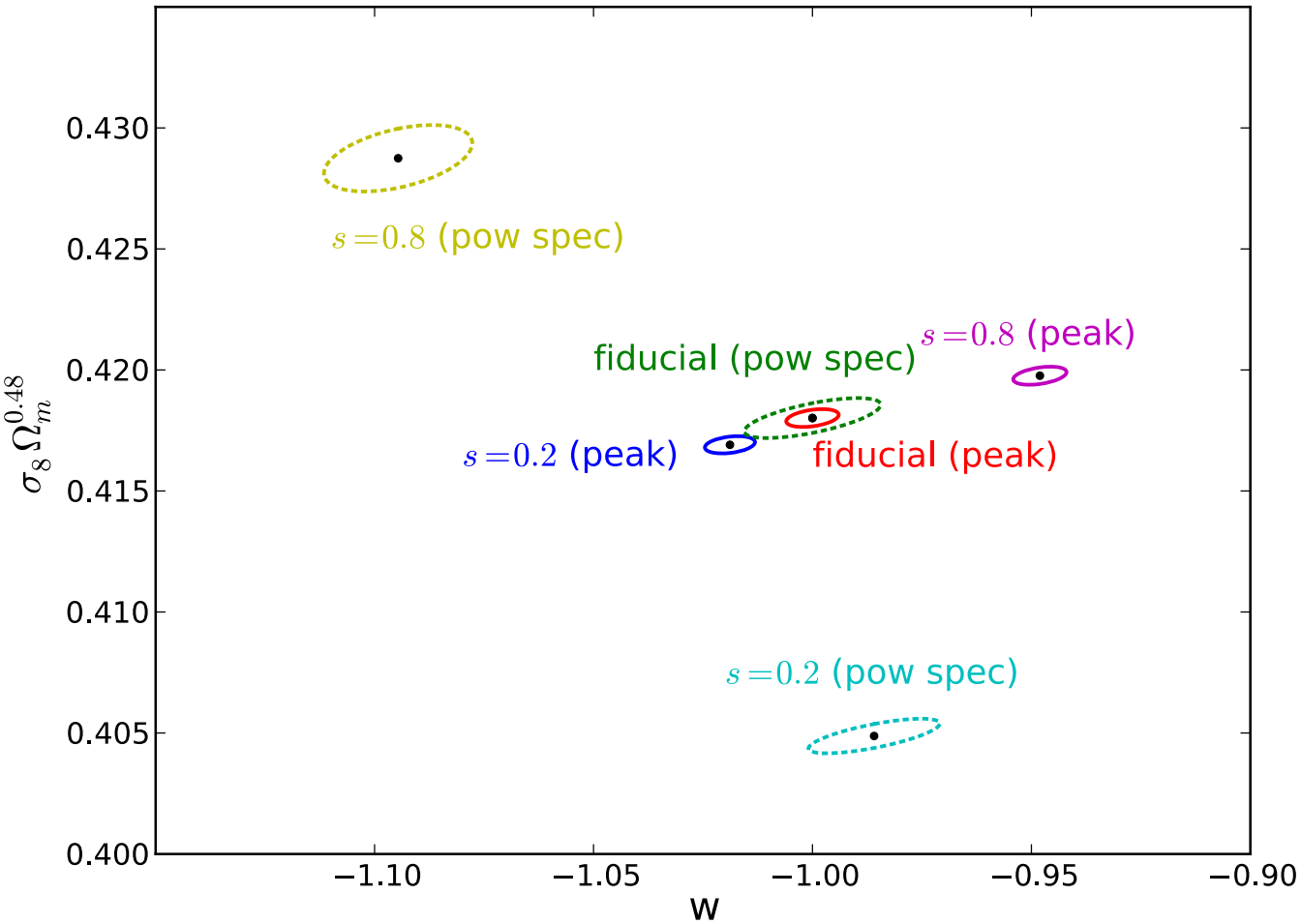
- project 3D masses onto 2D planes
- convert ρ to Φ
- follow light rays from z = 0 backwards to get γ & κ


Convergence maps
Without Magnification Bias
With Magnification Bias

Result 1/3: The Power Spectrum



Result 2/3: Peak Counts*



Result 3/3: Cosmological Parameters