Cosmology and Large Scale Structure

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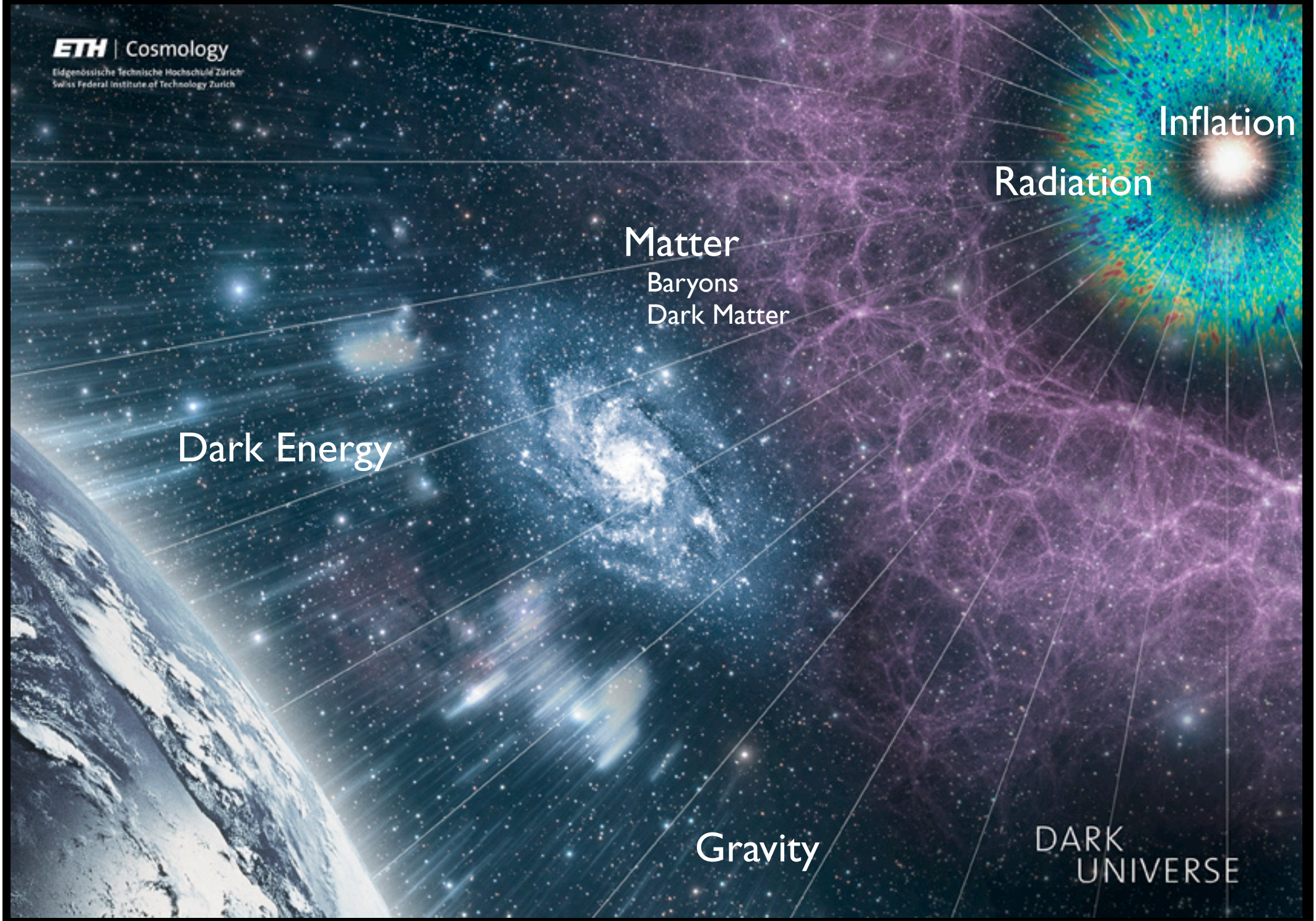
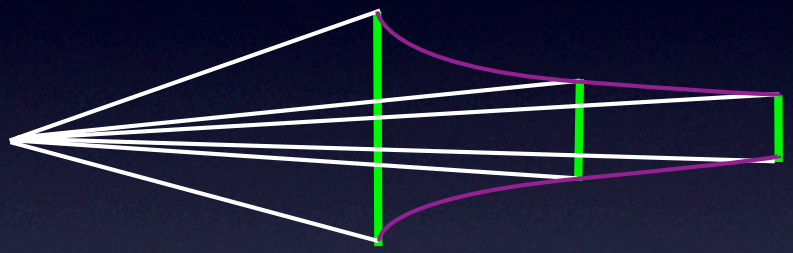
Swiss Federal Institute of Technology Zurich

PASCOS13
Taipei
11.22.2013

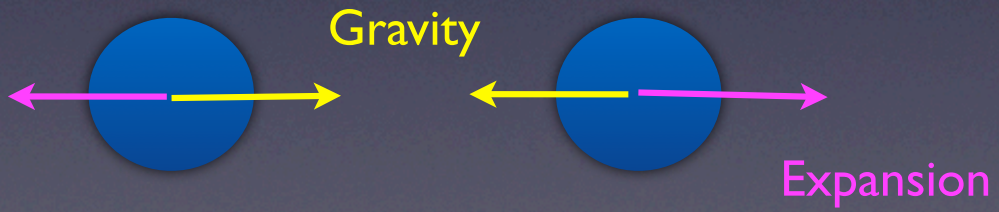

ETH | Cosmology
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich
Inflation
Radiation
Matter
Baryons
Dark Matter
Dark Energy
Gravity
DARK
UNIVERSE

Measuring the Dark Universe

- Geometry

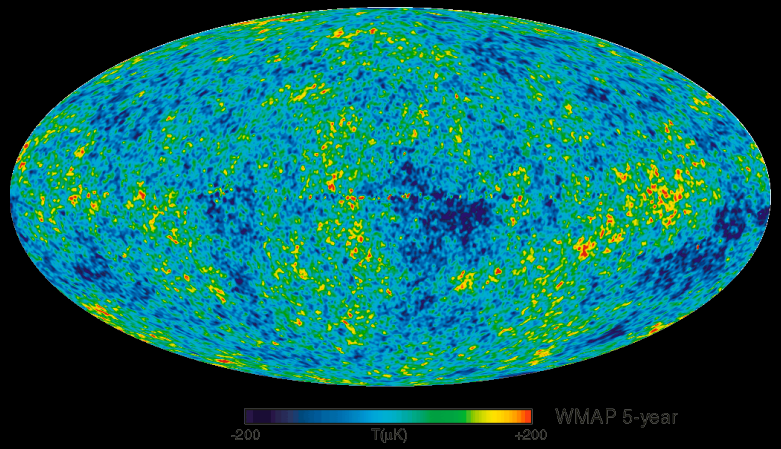


- Growth of structure

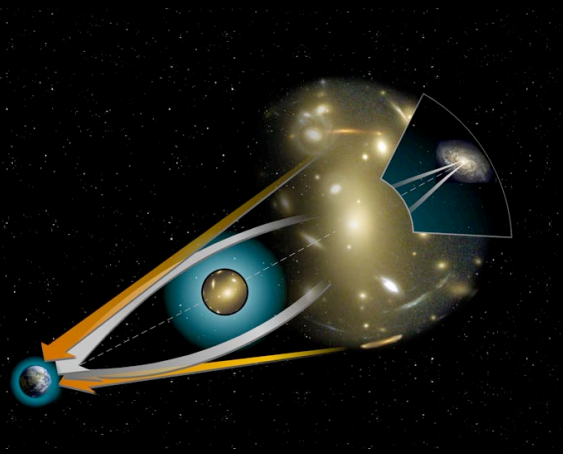


Cosmological Probes

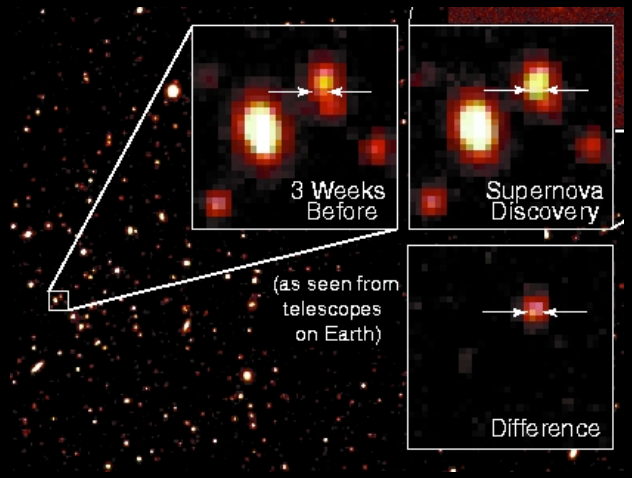
Cosmic Microwave Background



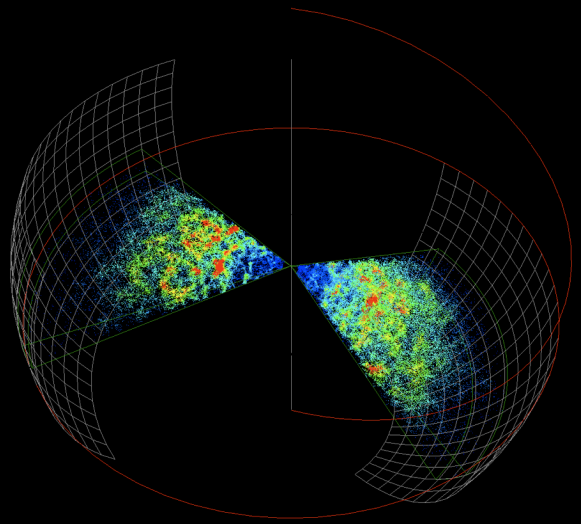
Gravitational Lensing



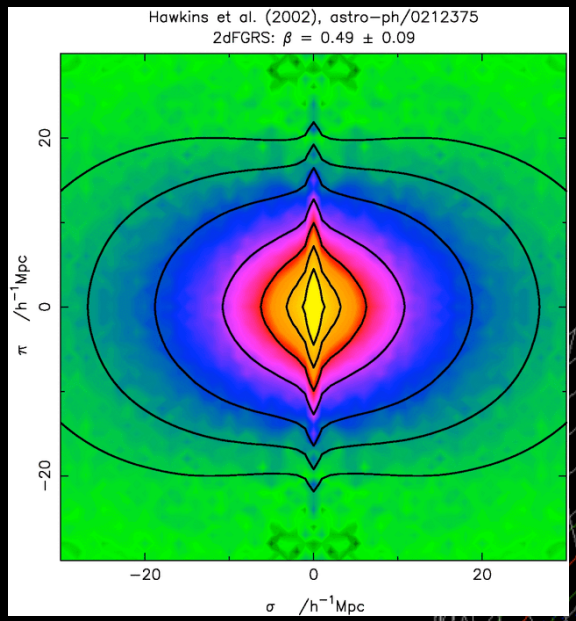
Supernovae



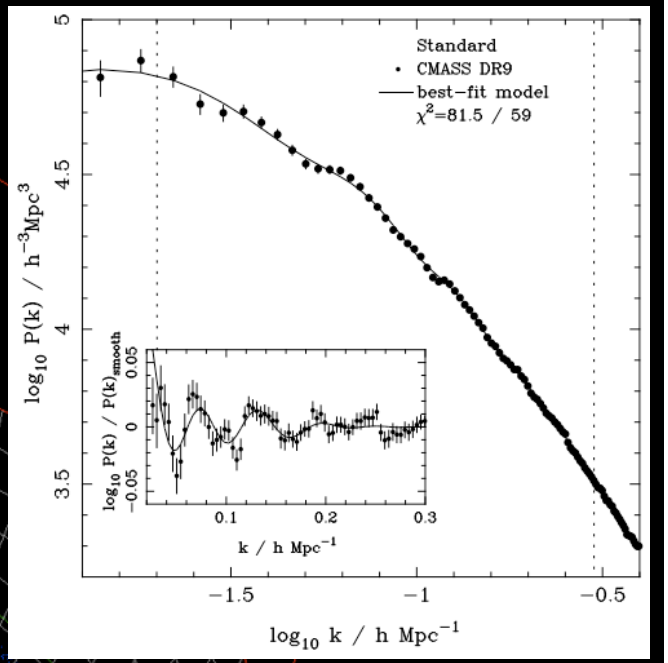
Galaxy Clustering

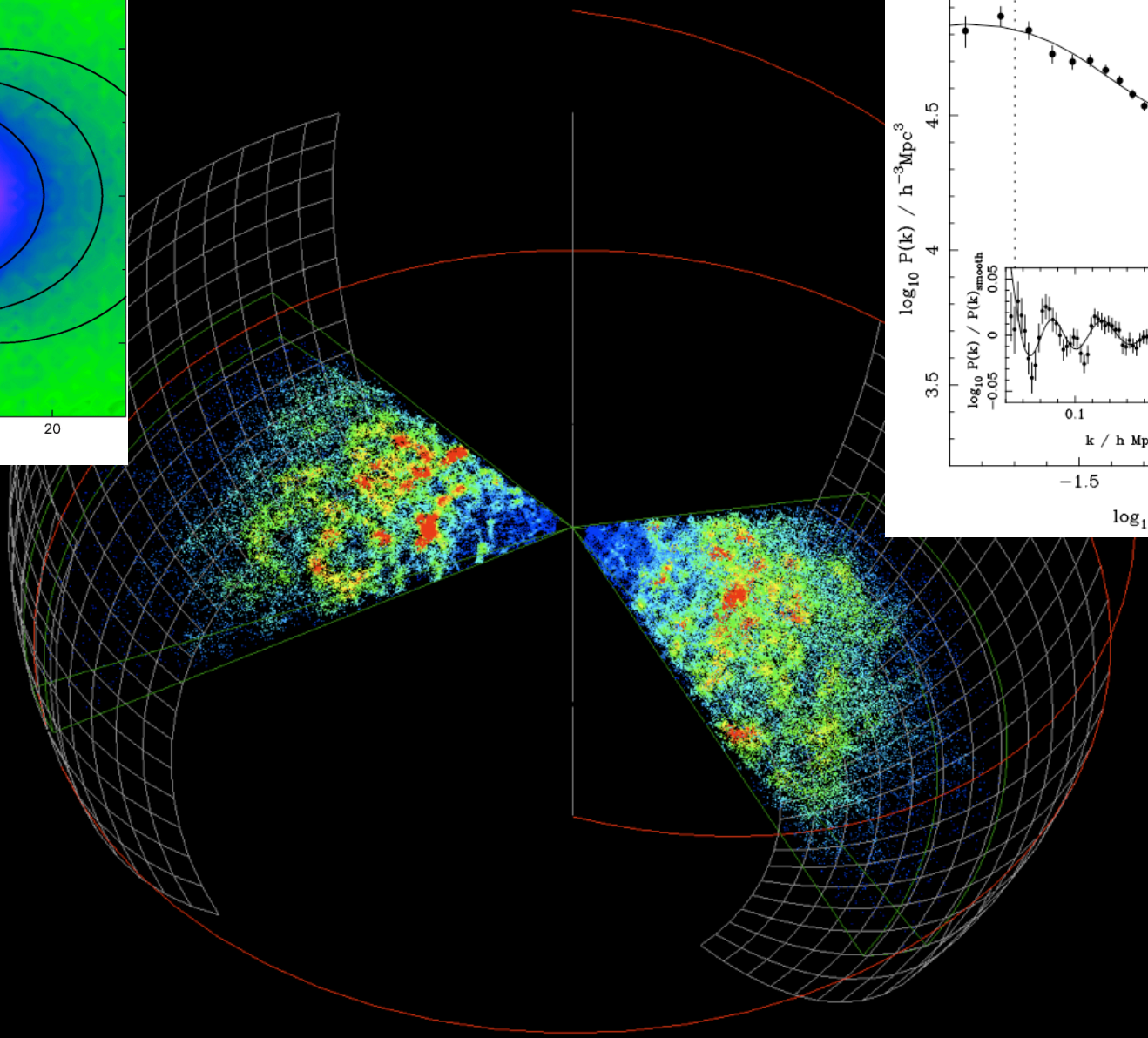


Galaxy Redshift Surveys



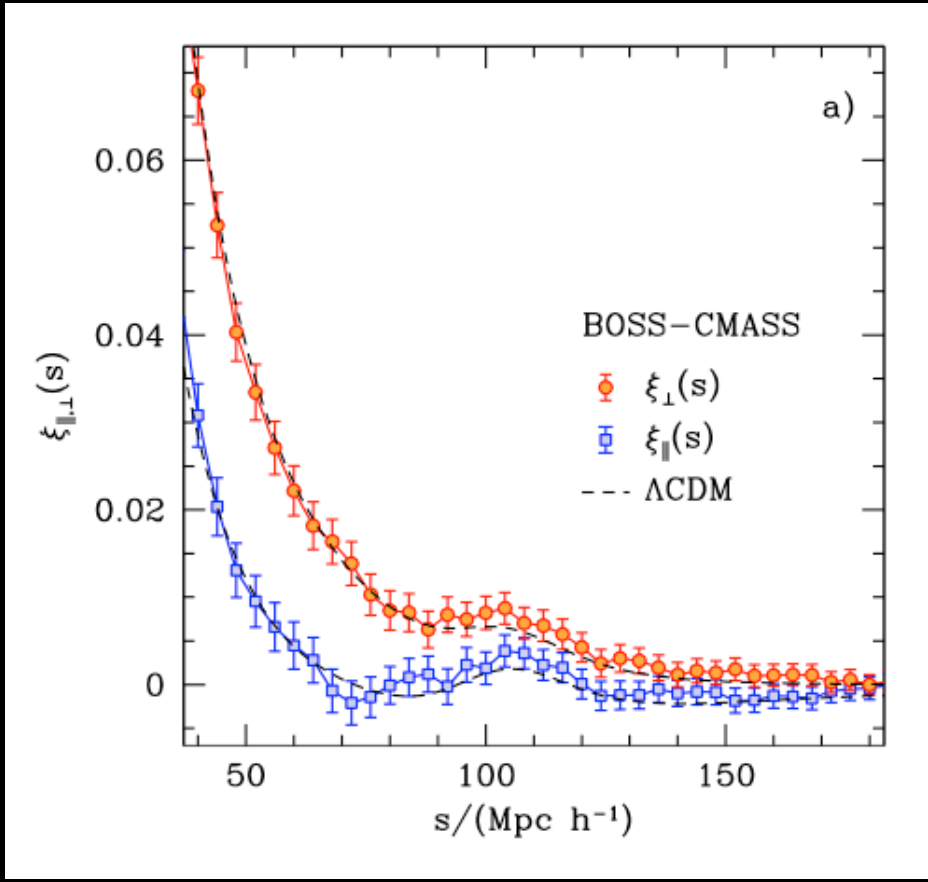
Anderson et al. 2012

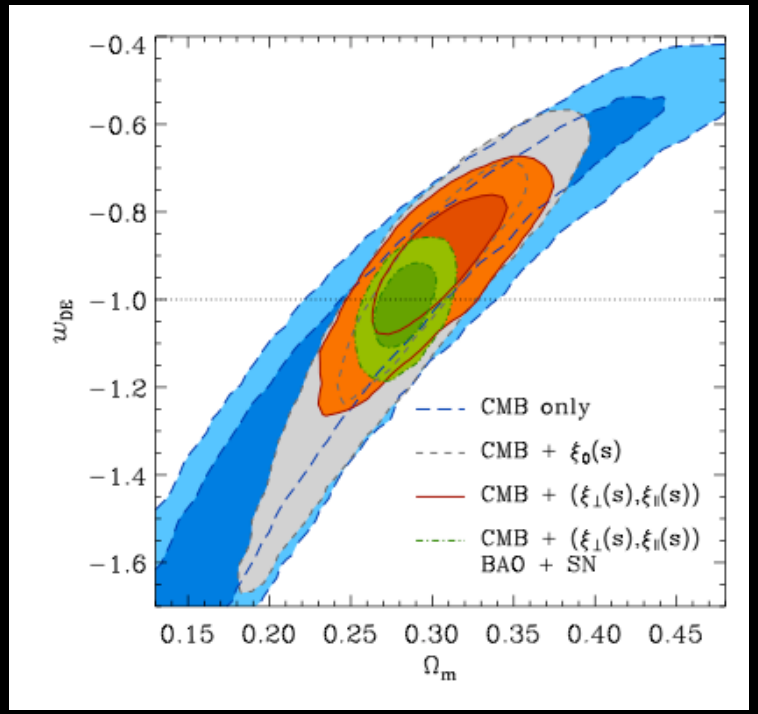


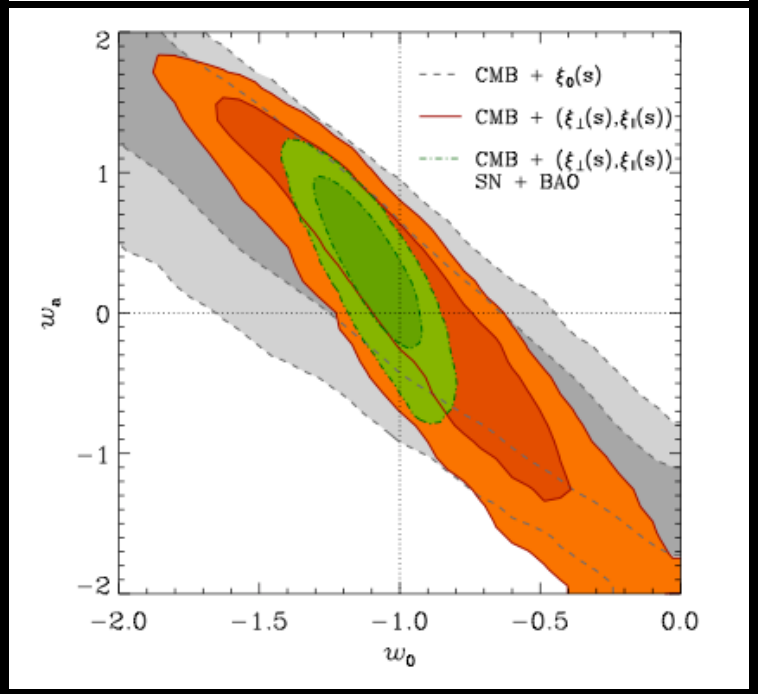


SDSS survey:
Eisenstein et al. 2004
2dF survey:
Percival et al 2004

BOSS



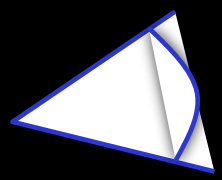


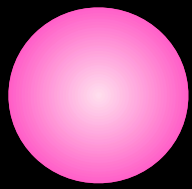


Sánchez et al. 2013

Weak Gravitational Lensing

Massey et al.
review: Refregier 2003





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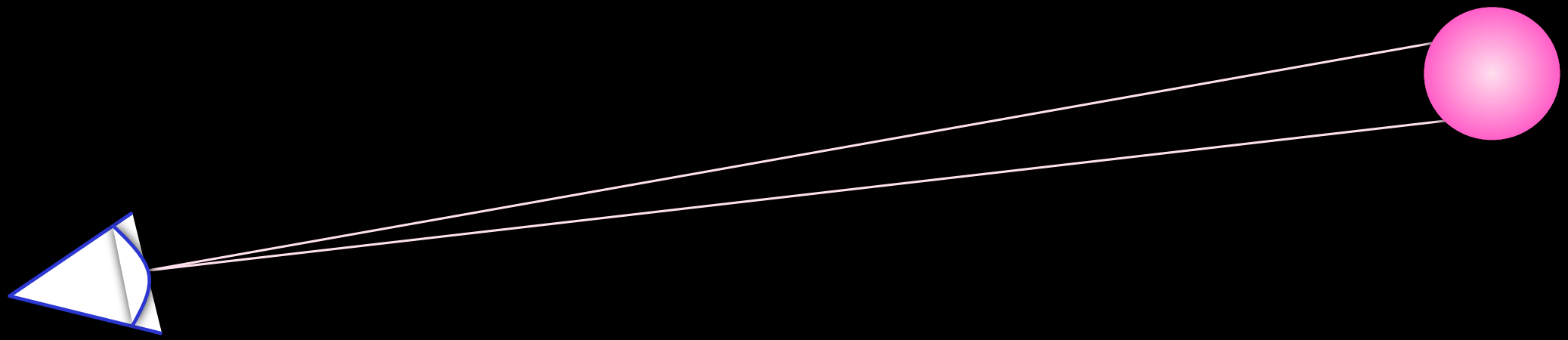

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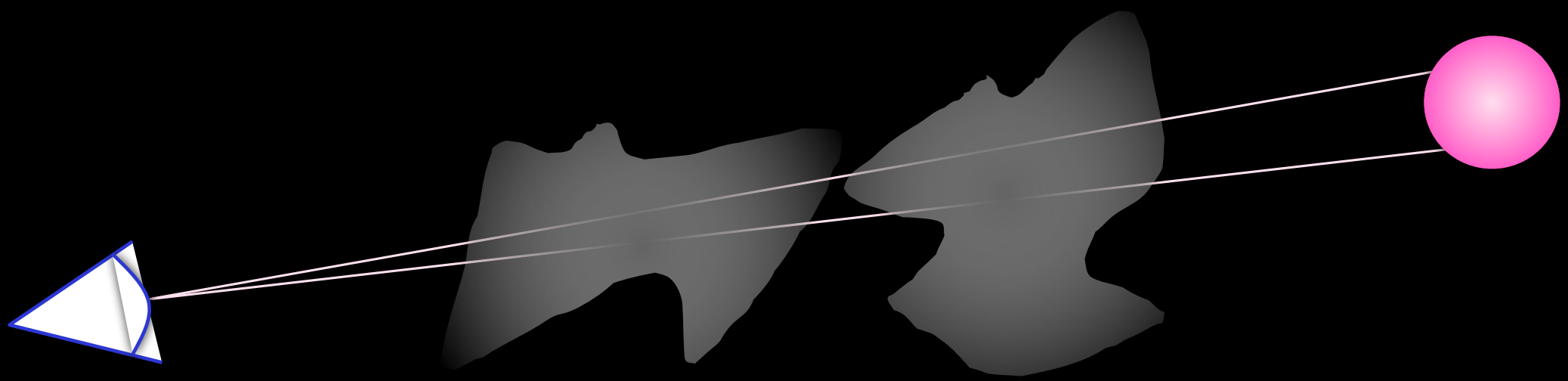

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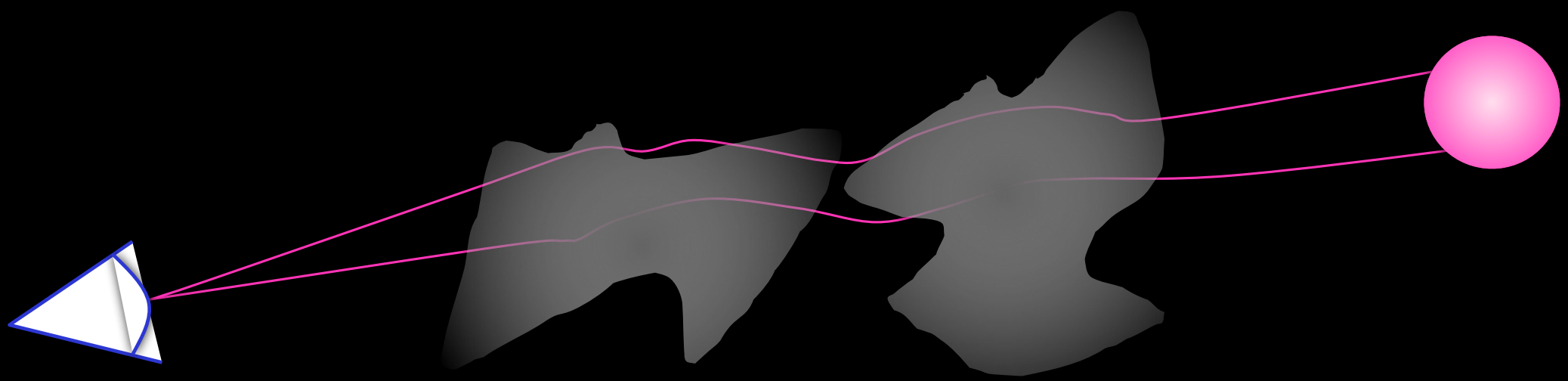

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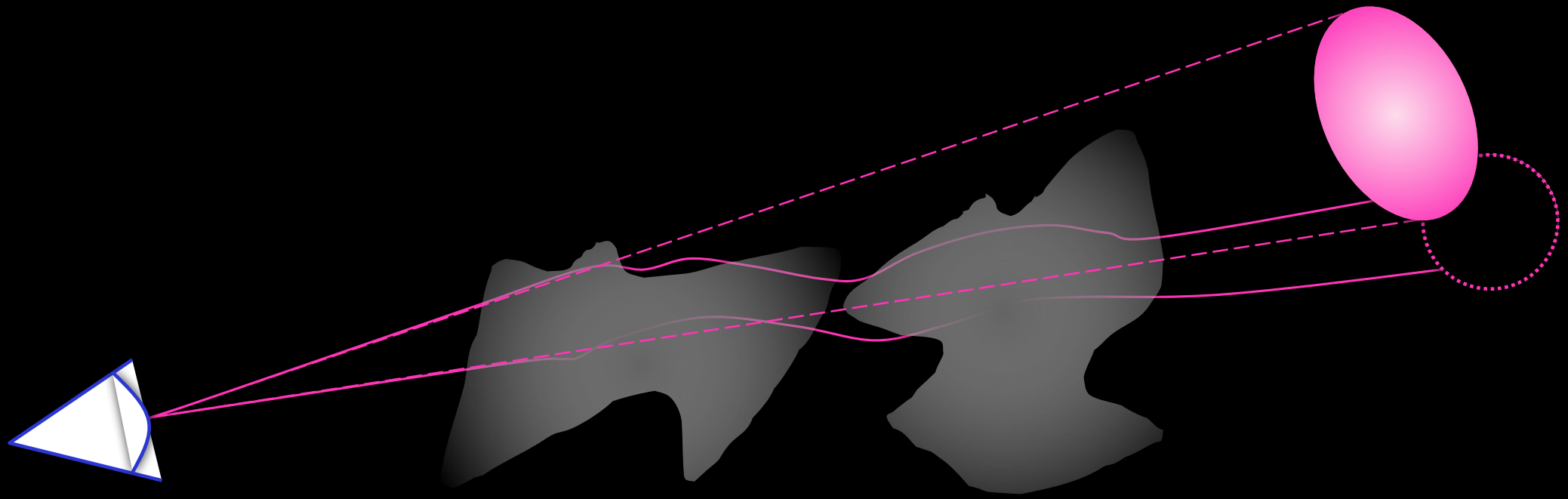

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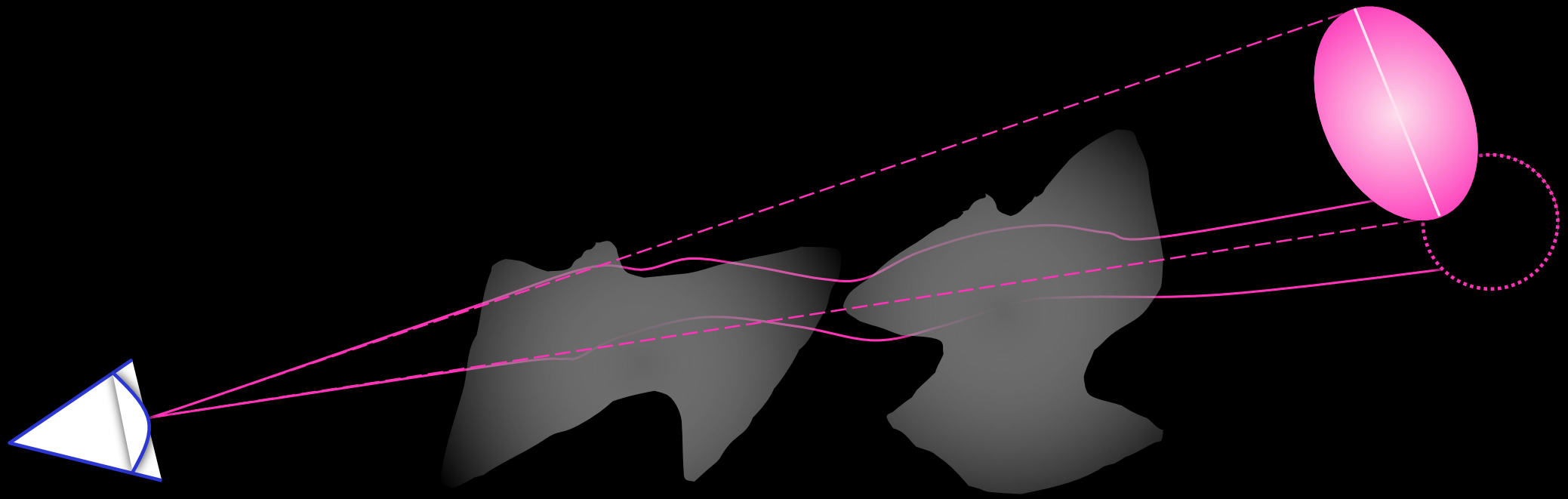

Weak Gravitational Lensing

Massey et al.
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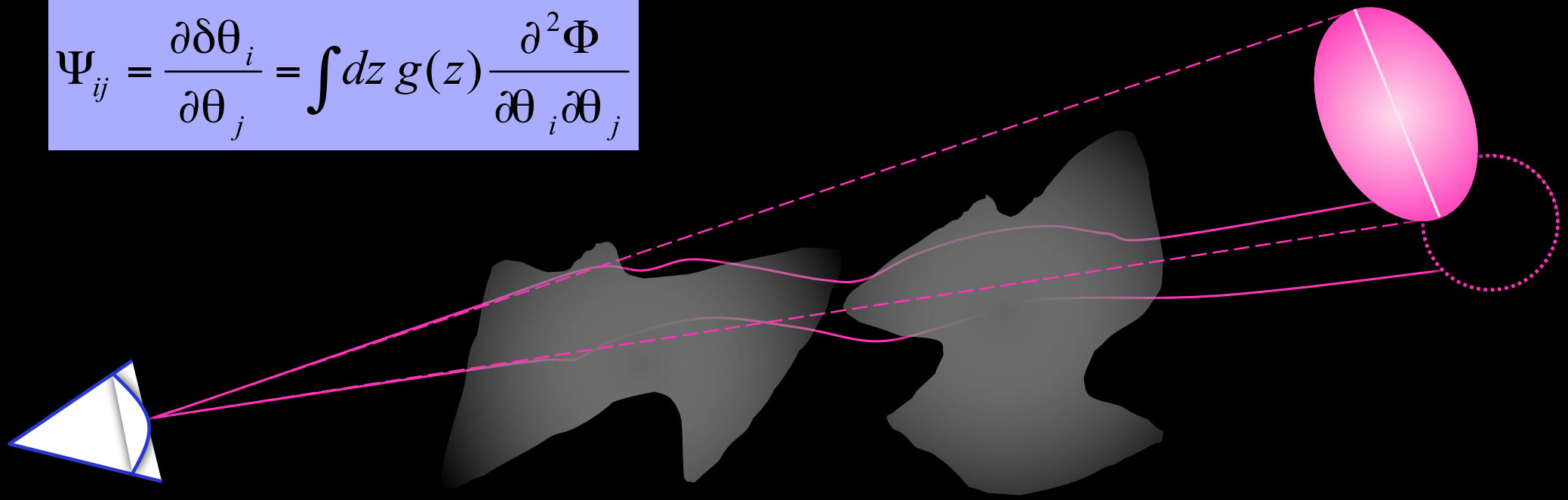
Distortion matrix:

$$\Psi_{ij} = \frac{\partial \delta\theta_i}{\partial \theta_j} = \int dz\, g(z) \frac{\partial^2 \Phi}{\partial \theta_i \partial \theta_j}$$



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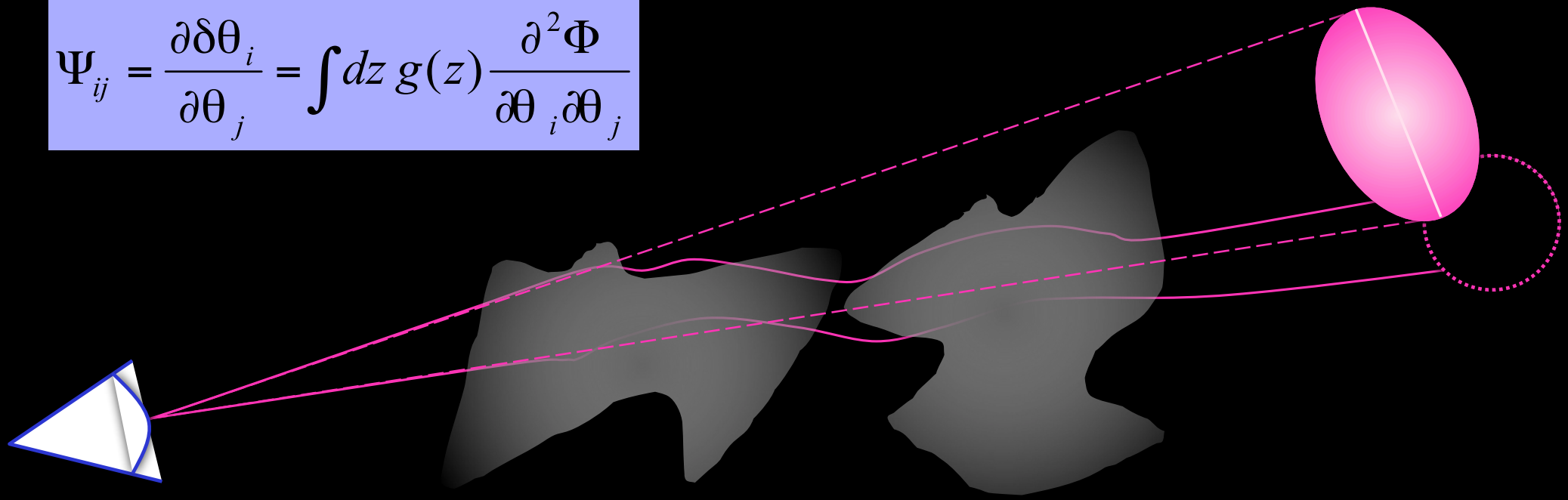
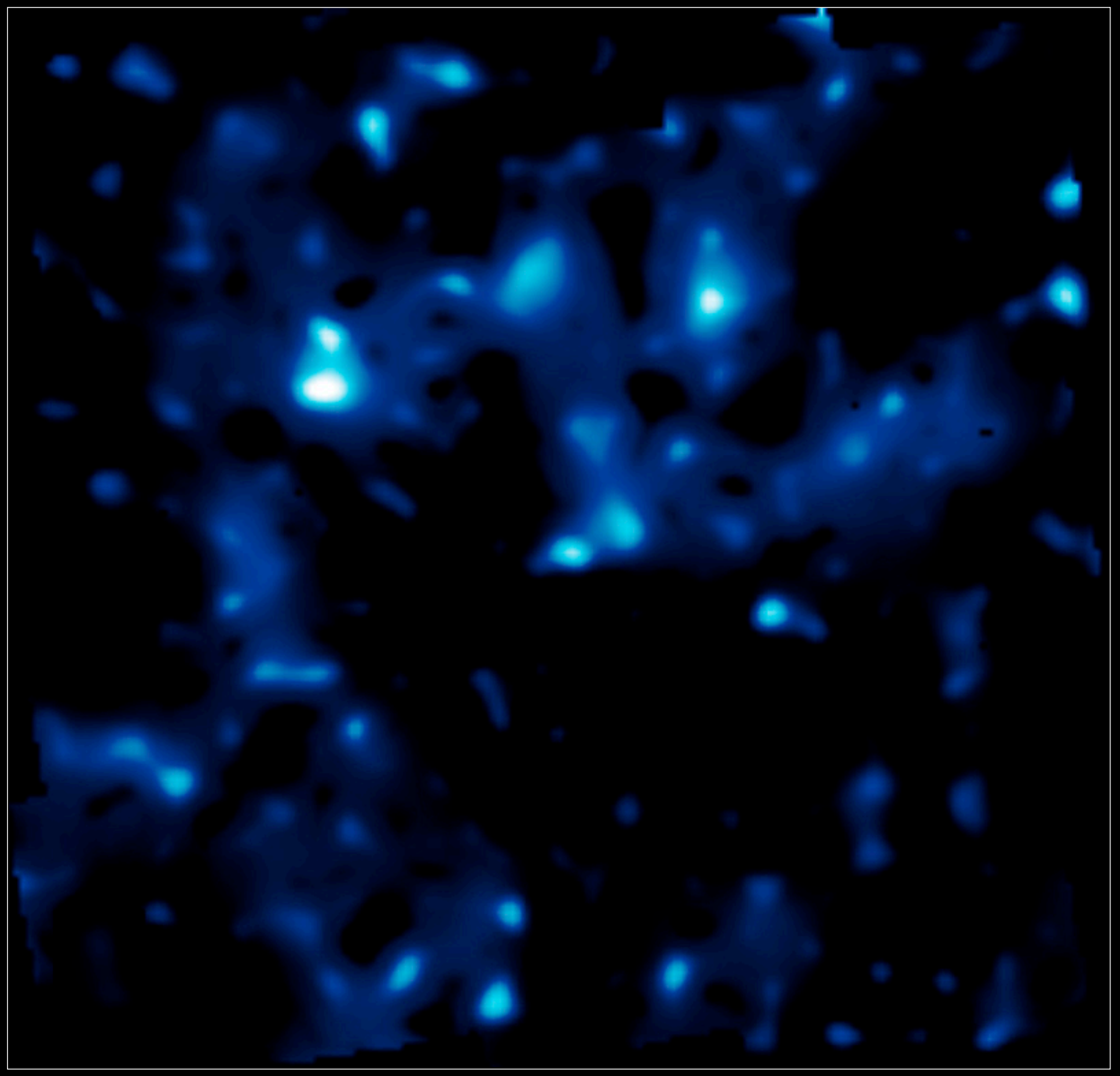


Theory

Direct measure of the distribution of mass in the universe, as opposed to the distribution of light

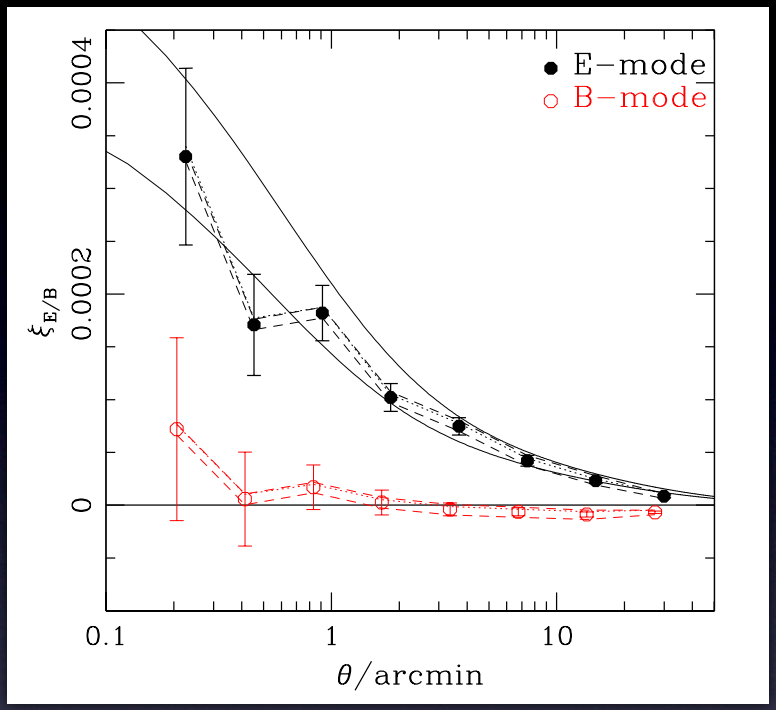
COSMOS Dark Matter Map

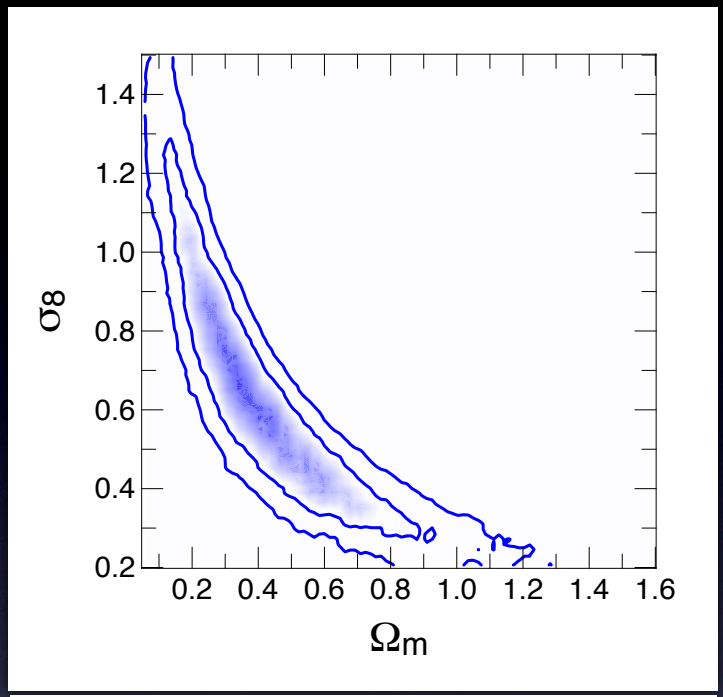


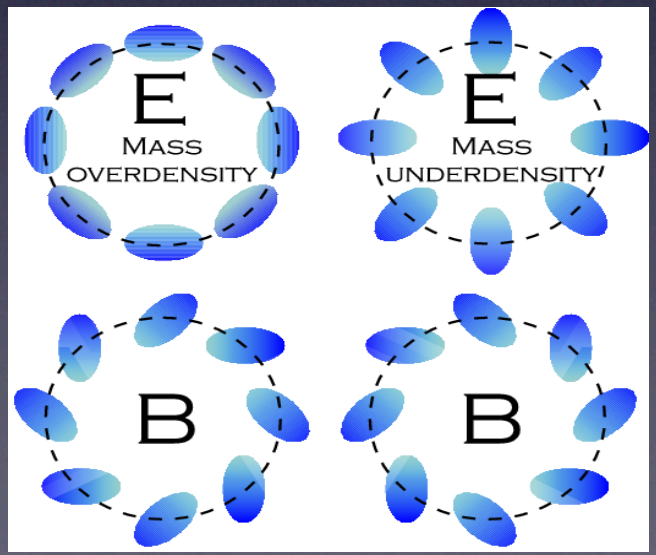
COSMOS HST
ACS survey
2 deg^2
Massey et al.
2006, Nature

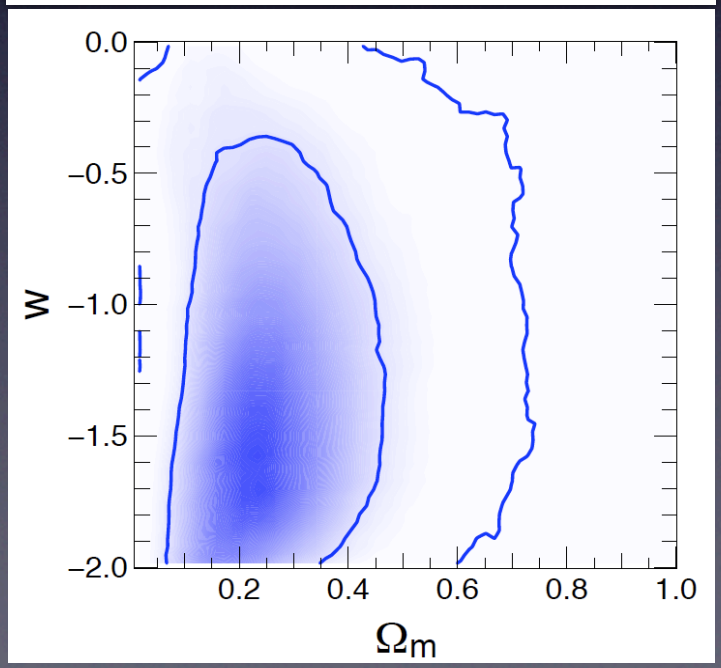
COSMOS

Schrabback et al. 2010





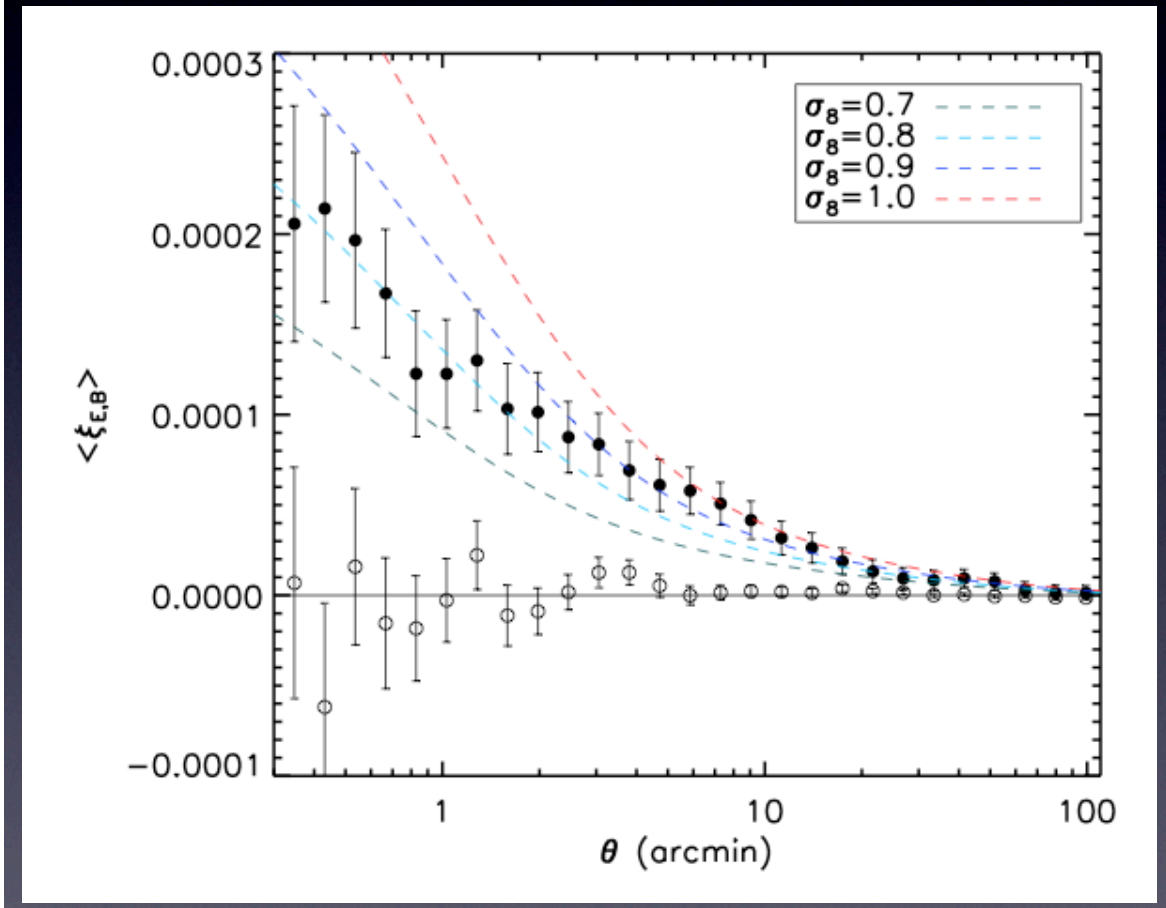


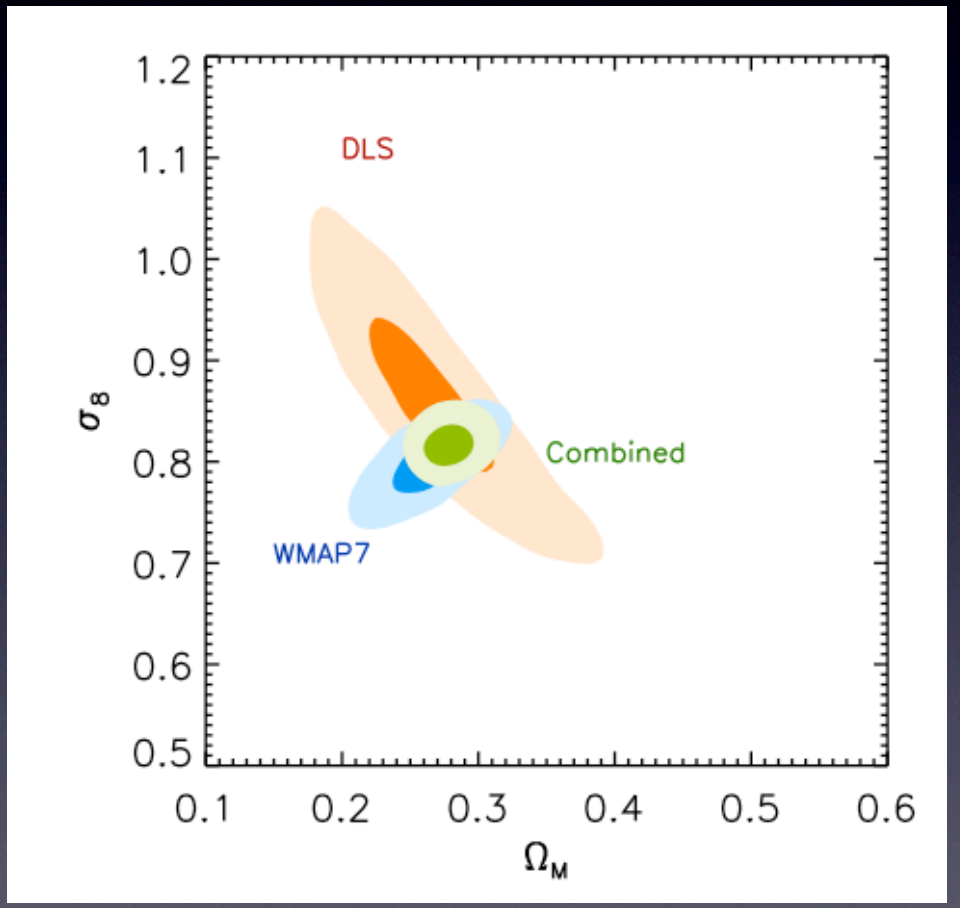


Deep Lens Survey

Jee et al. 2013

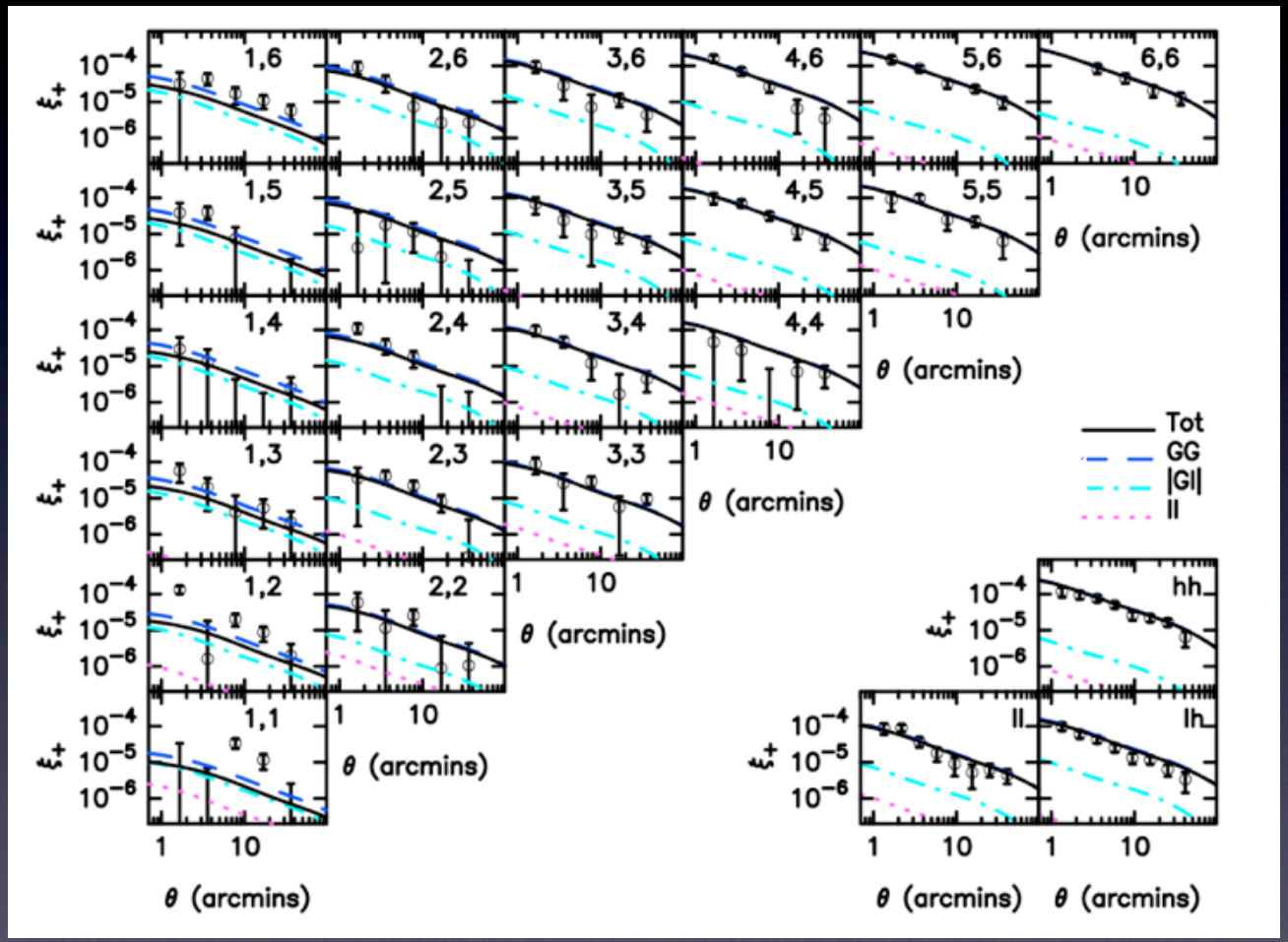
NOAO Blanco and Mayall 4m
20 sq. deg, mag<26.5, median z~1

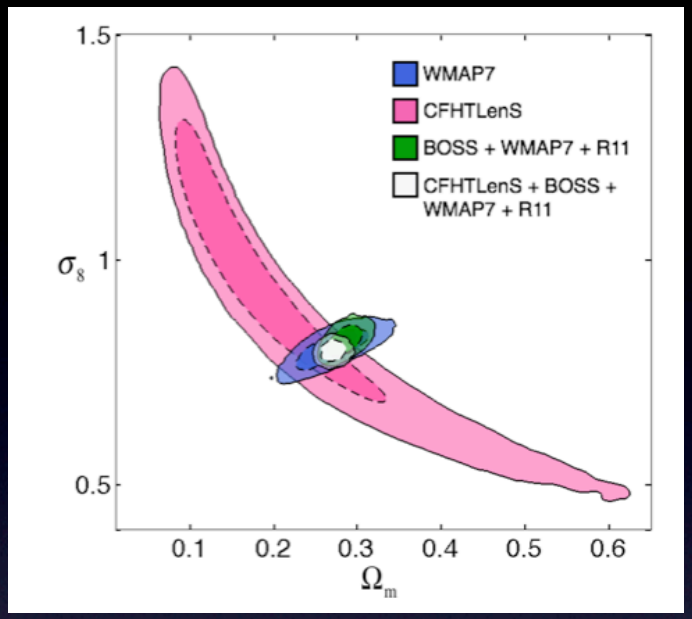


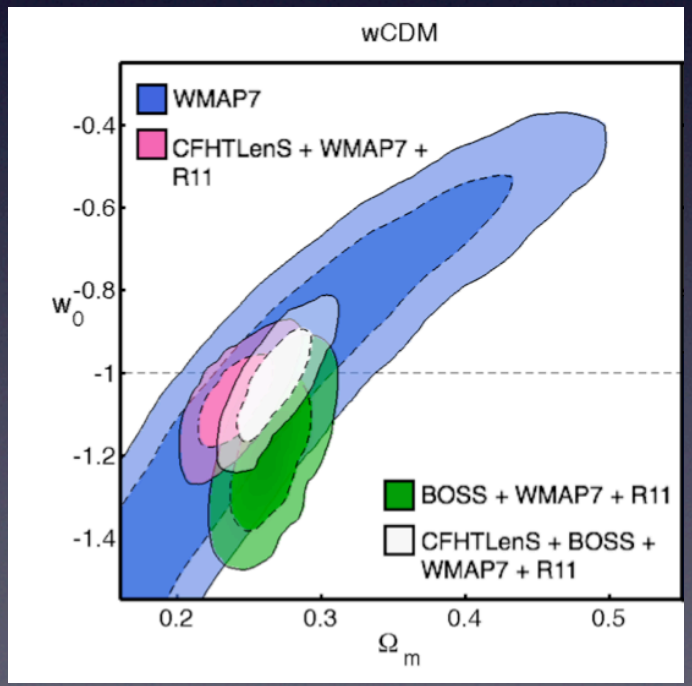


CFHTLenS

Heymans et al. 2013

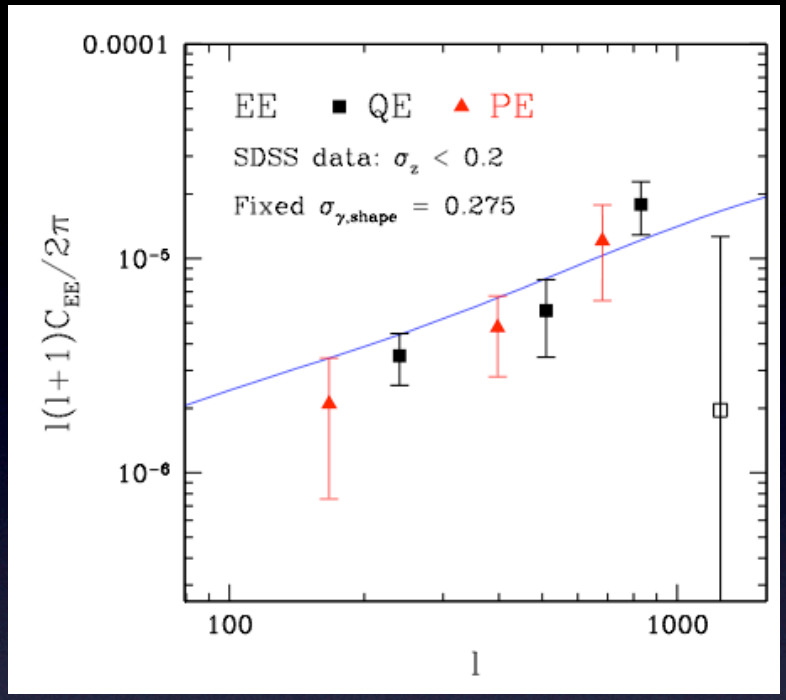






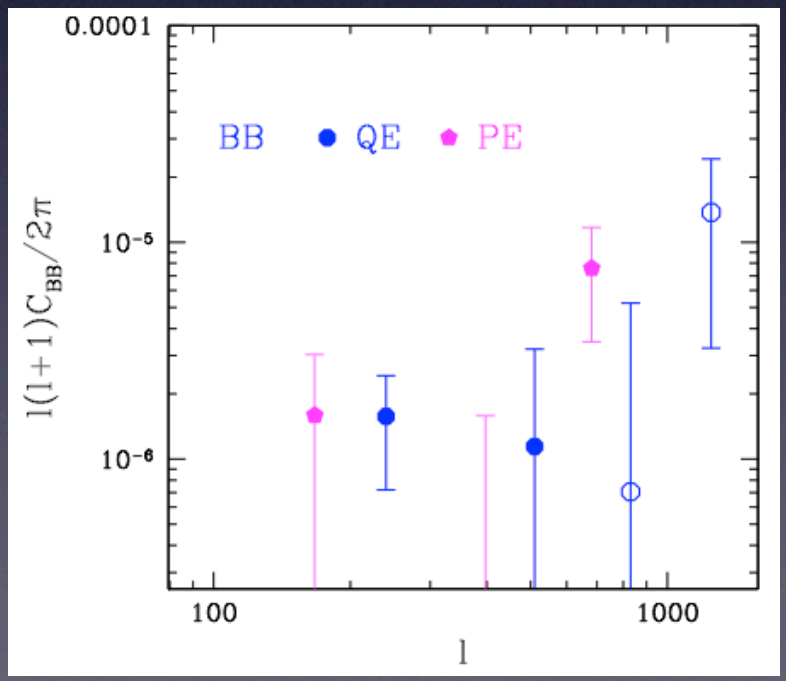
154 sq. deg., median z~0.7

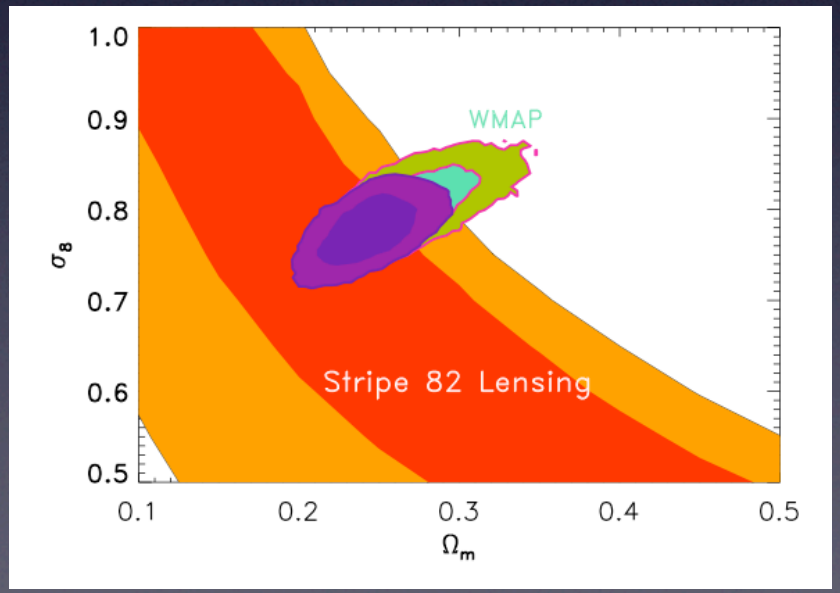
SDSS Stripe 82



Lin et al. 2011

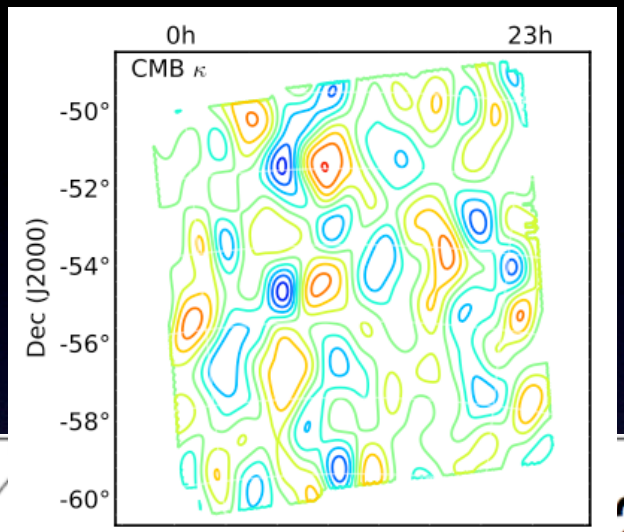
275 sq. deg.
20-30 coadded exposures
<2" seeing
18<i<24, median z~0.6





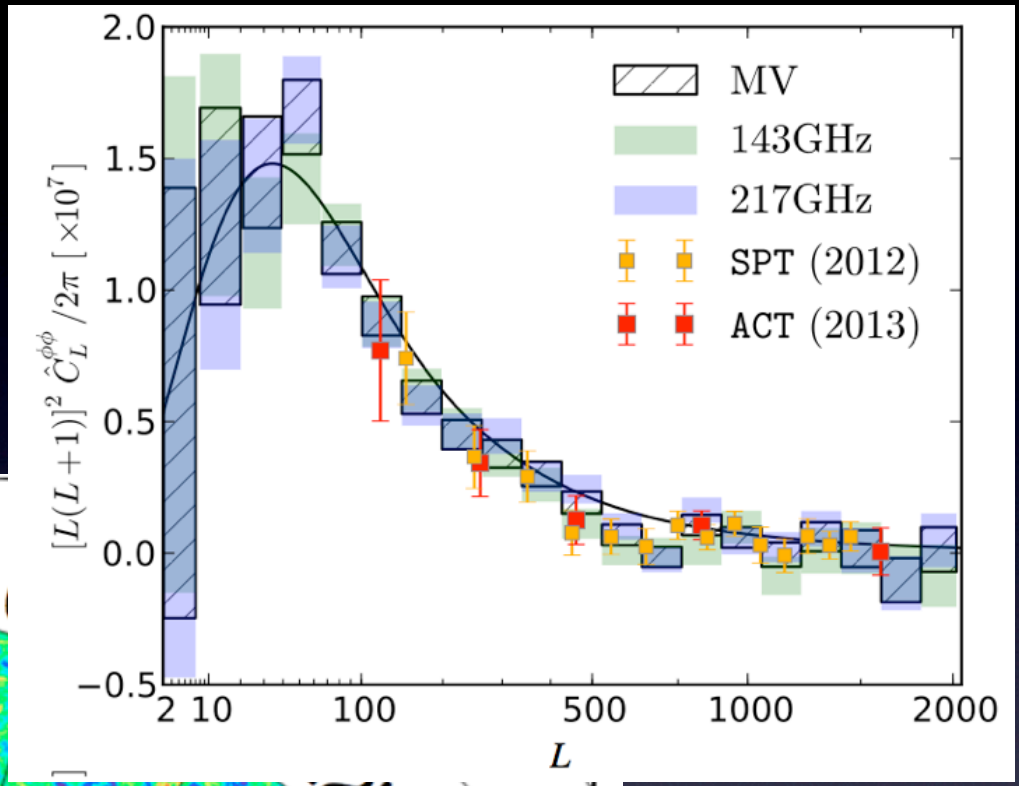
CMB Lensing

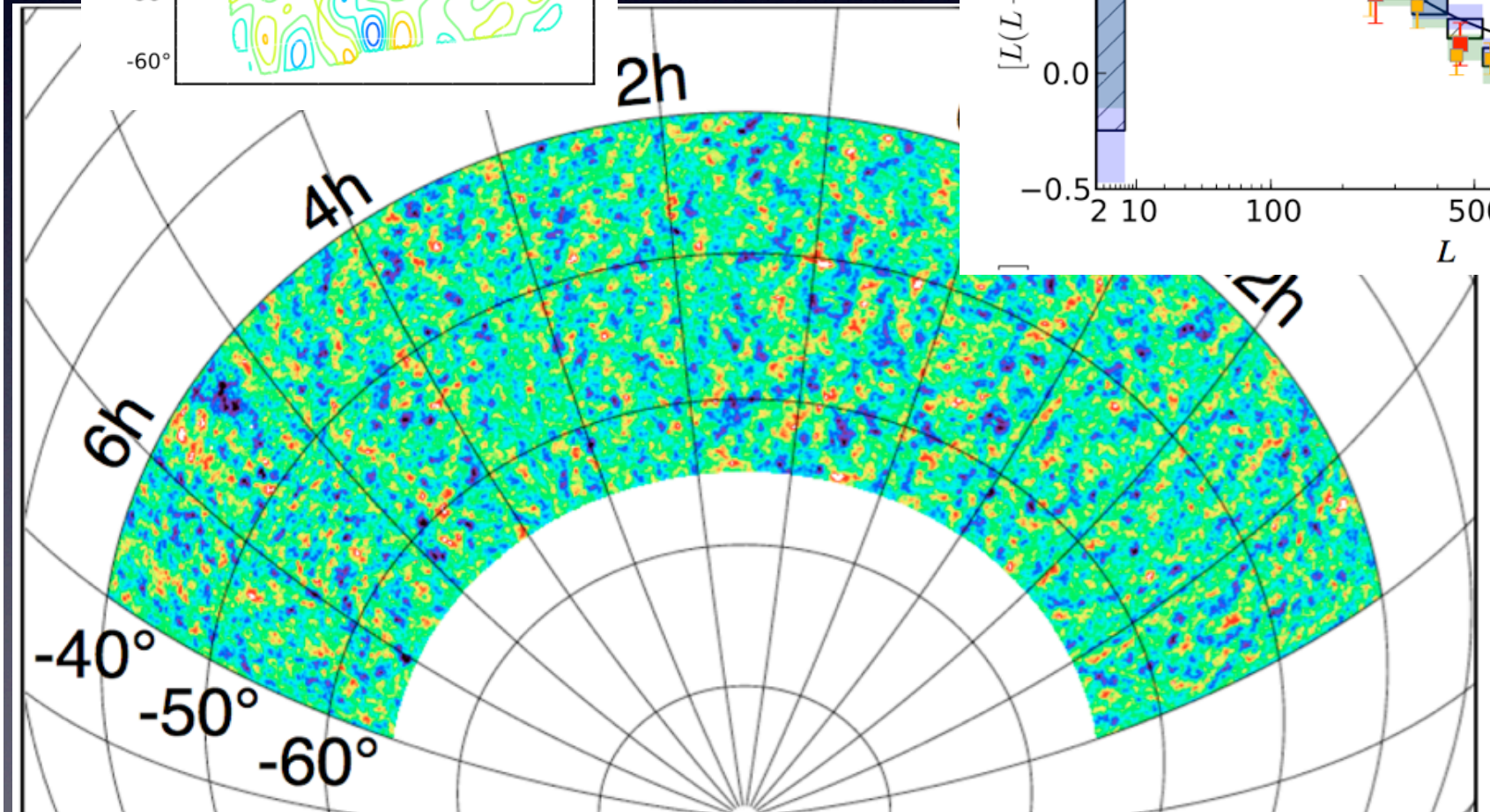
Holder et al. 2013



SPT deep
100 deg^2
lensing

Planck XVII, 2013



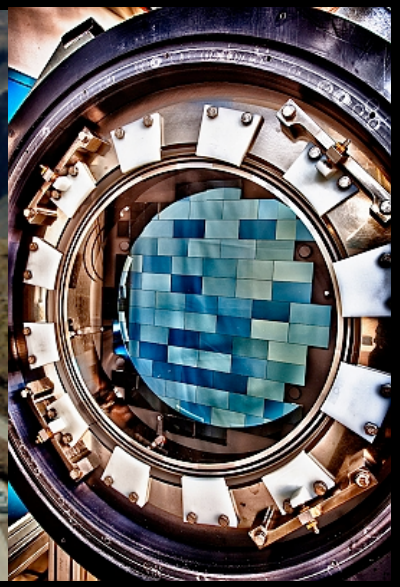


SPT 2540 deg^2
Temperature
Story et al. 2011

Wide-Field Instruments

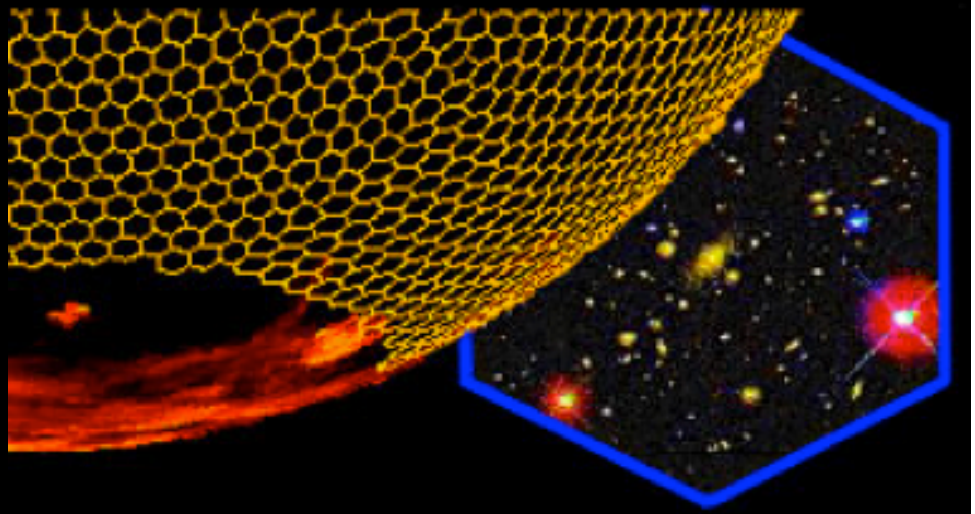
CMB		Planck, SPT, ACT
VIS/NIR	Imaging	VST, DES, Pann-STARRS, LSST Euclid, WFIRST, Subaru
	Spectro	Boss, Wigglez, DESI, HETDEX
Radio		LOFAR, SKA

Dark Energy Survey



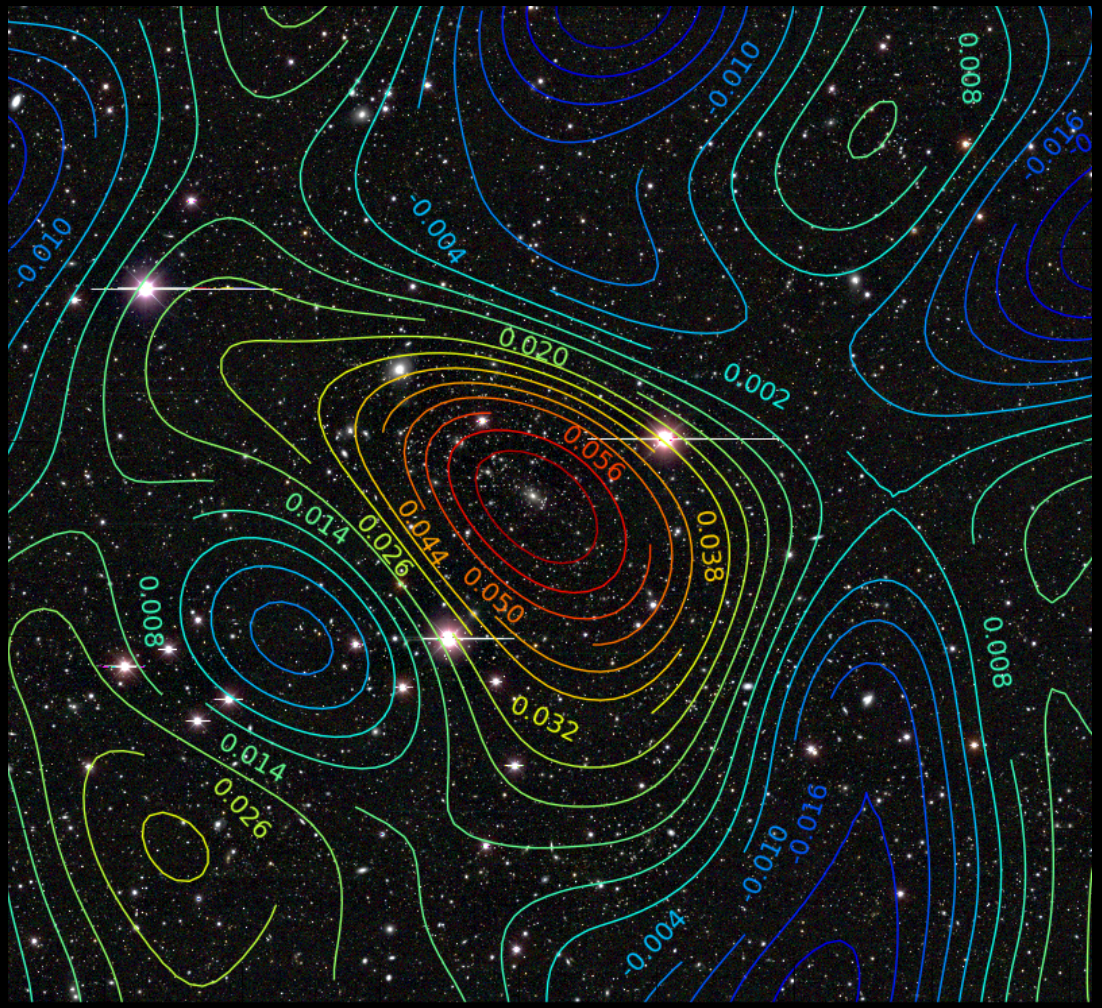
Blanco 4m at CTIO
74 2k×4k CCDs, 0.27”/pix
2.2 deg^2 FOV
5000 deg^2 survey (+SNe survey)
g,r,i,z,y to mag 24
200M galaxies

First light Sept 2012



Preliminary Cluster Mass Map

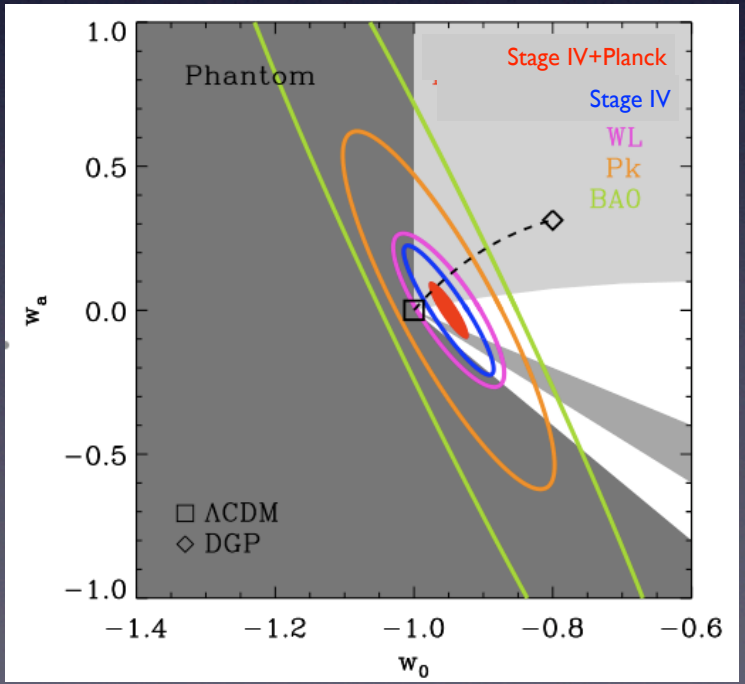
Preliminary cluster mass map from DES Science Verification data
(by OSU, Penn groups)



Impact on Cosmology

Amara et al. 2008

	Δw_p	ΔW_a	$\Delta\Omega_m$	$\Delta\Omega_\Lambda$	$\Delta\Omega_b$	$\Delta\sigma_8$	Δn_s	Δh	DE FoM
Current+WMAP	0.13	-	0.01	0.015	0.0015	0.026	0.013	0.013	~10
Planck	-	-	0.008	-	0.0007	0.05	0.005	0.007	-
Weak Lensing	0.03	0.17	0.006	0.04	0.012	0.013	0.02	0.1	180
Imaging Probes	0.018	0.15	0.004	0.02	0.007	0.0009	0.014	0.07	400
Stage IV	0.016	0.13	0.003	0.012	0.005	0.003	0.006	0.020	500
Stage IV+Planck	0.01	0.066	0.0008	0.003	0.0004	0.0015	0.003	0.002	1500
Factor Gain	13	>15	13	5	4	17	4	7	150



Stage IV Surveys will challenge all sectors of the cosmological model:

- Dark Energy: w_p and w_a with an error of 2% and 13% respectively (no prior)
- Dark Matter: test of CDM paradigm, precision of 0.04eV on sum of neutrino masses (with Planck)
- Initial Conditions: constrain shape of primordial power spectrum, primordial non-gaussianity
- Gravity: test GR by reaching a precision of 2% on the growth exponent ($d\ln_m/d\ln a_m$)

→ Uncover new physics and map LSS at 0<z<2: Low redshift counterpart to CMB surveys

Challenges

Current:

Radiation-Matter transition

High-precision Cosmology era with CMB

Next stage:

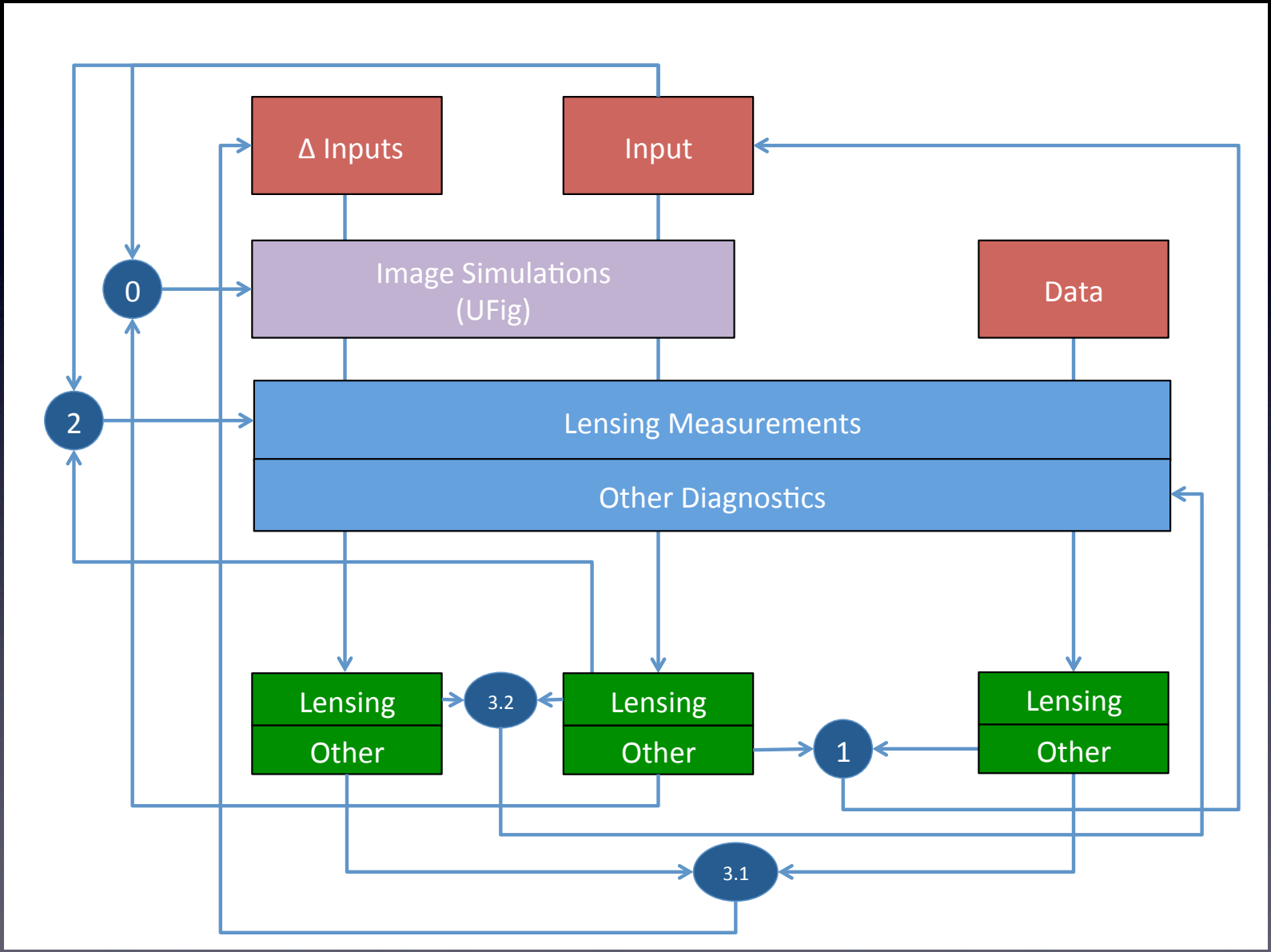
Matter-Dark Energy transition

High-precision Cosmology with LSS surveys, different from CMB:

- 3D spherical geometry
- Multi-probe, Multi-experiments
- Non-gaussian, Non-Linear
- Systematics limited
- Large Data Volumes

Monte-Carlo Control Loops

Refregier & Amara 2013

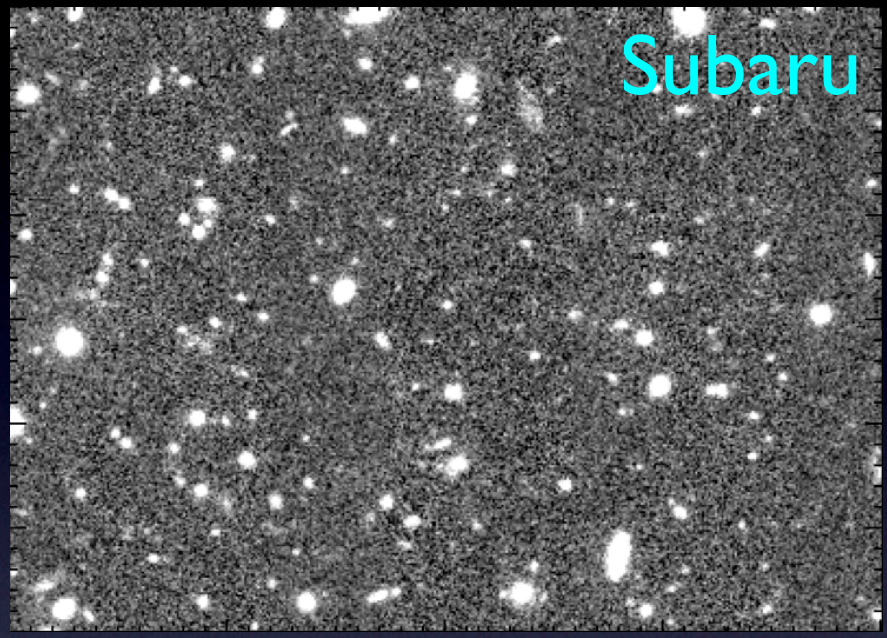


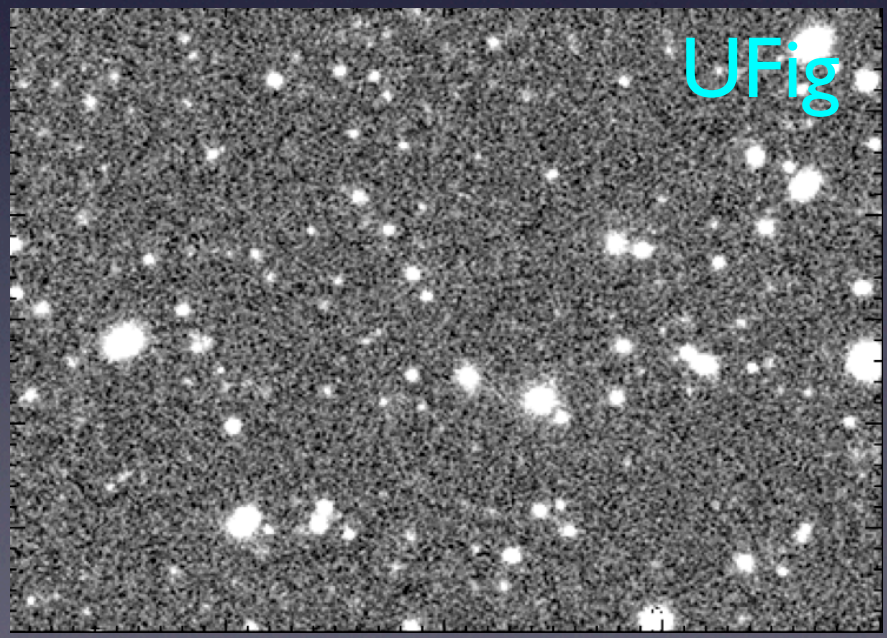
UFig Ultra Fast Image Generator

Bergé et al 2012

Subaru Image (0.25 deg^2,R~26,10k×8k) generated in:
-30sec on a laptop
-30µsec per galaxy

Speed:
» existing simulation codes
~ SExtractor analysis





Conclusions

- Large-Scale Structure Surveys are a powerful probe of the Dark Universe

- Upcoming and Future LSS surveys will provide strong constraints but also pose challenges to achieve high-precision

- Forward Modeling and Fast algorithms will be important for the control of systematics and model extensions

謝謝