Observational cosmology

More evidence for Dark Energy

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DARK ENERGY

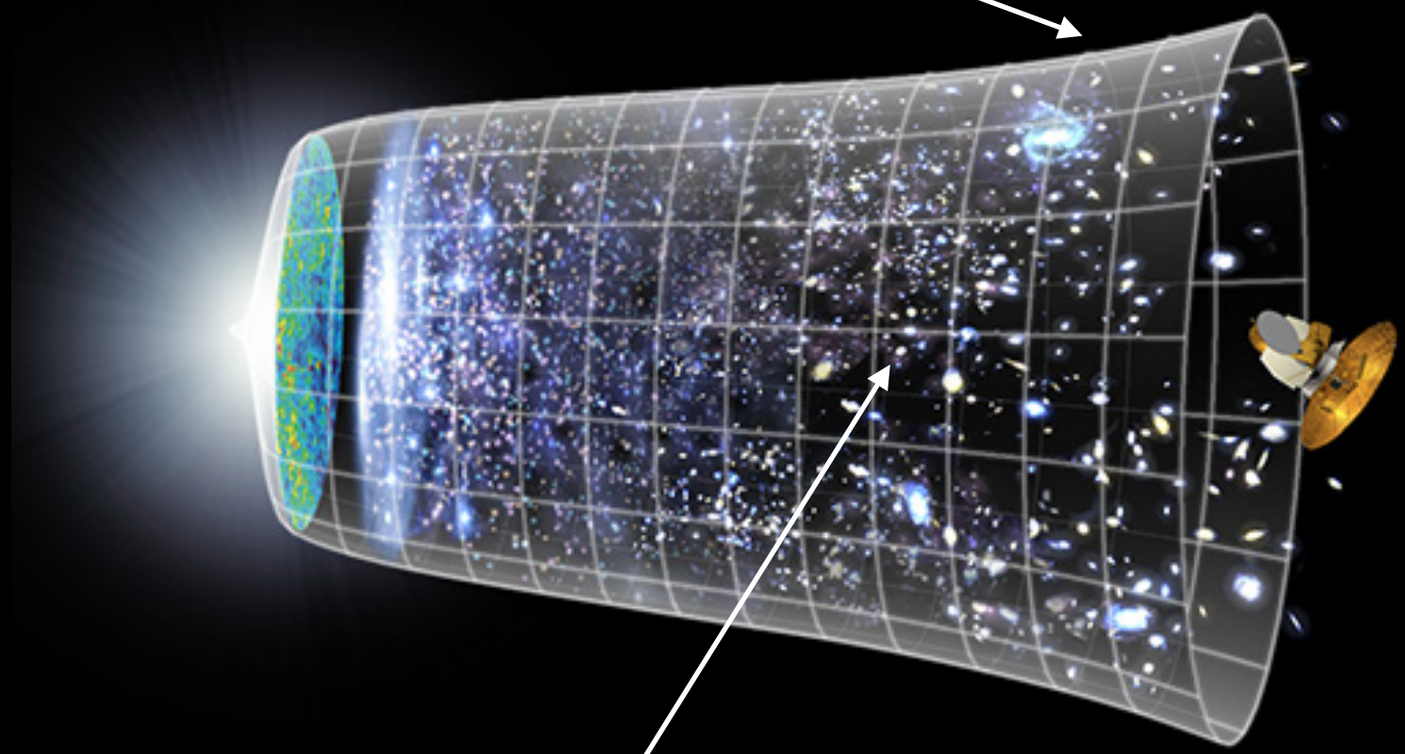
Observations of cosmological probes give evidence of:

- an expansion history, and
- a history of growth of structure

which are consistent with an accelerating expansion of the Universe.

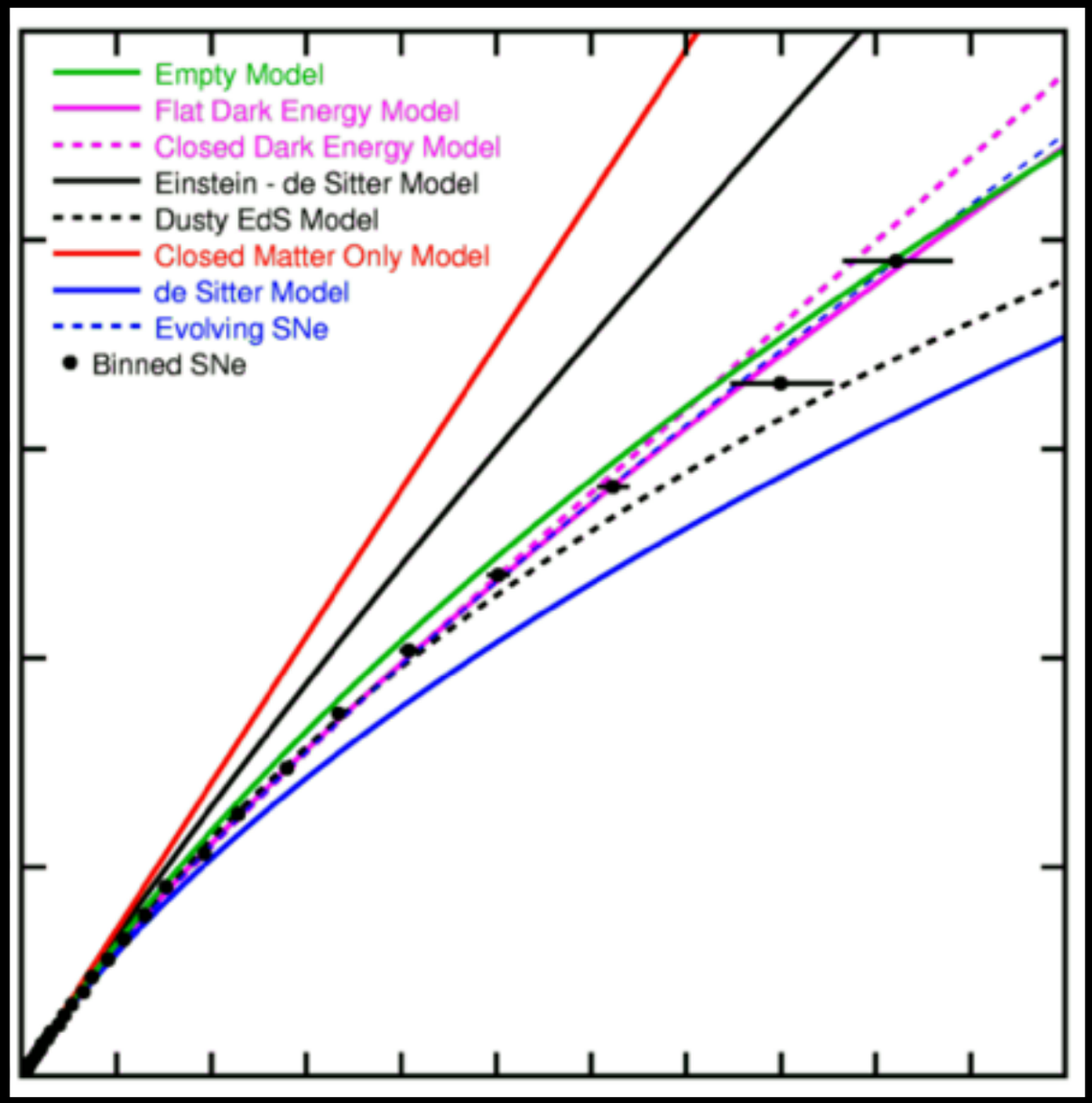
COMBINED POWER OF PROBES

Some observations constrain expansion history
(e.g. SNe, BAO, GW, SL)



Some observations constrain growth history
(e.g. RSD, weak lensing)

EXPANSION PROBES - SUPERNOVAE IA



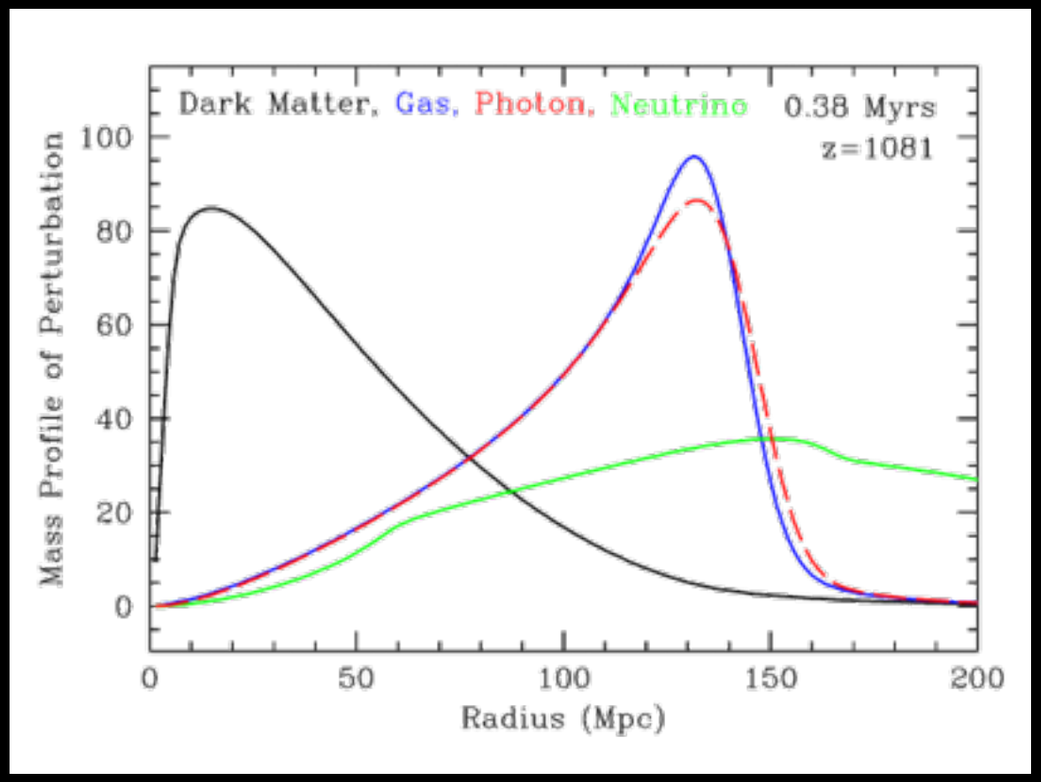
Redder

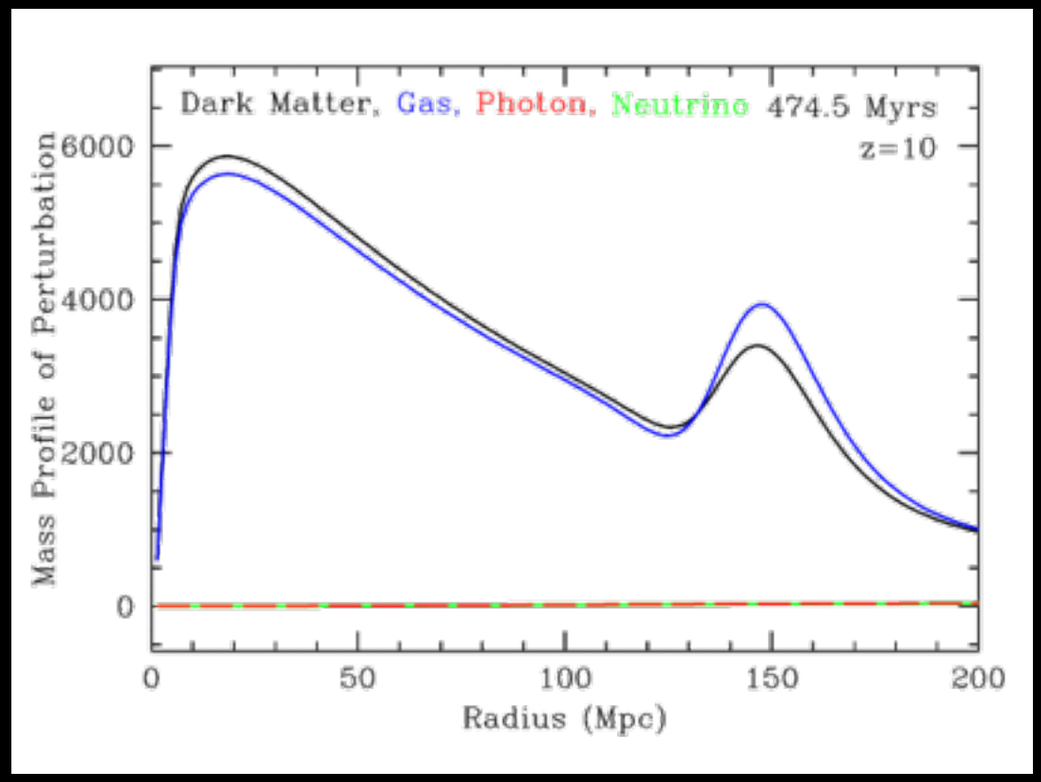
Fainter ⟶

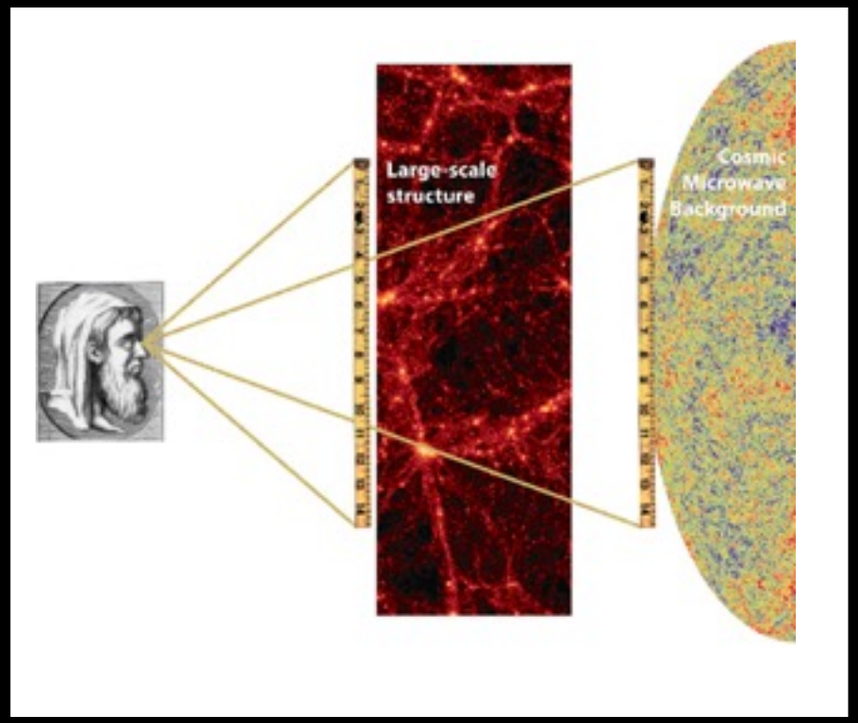
Wright 15,

Betoule et al 14

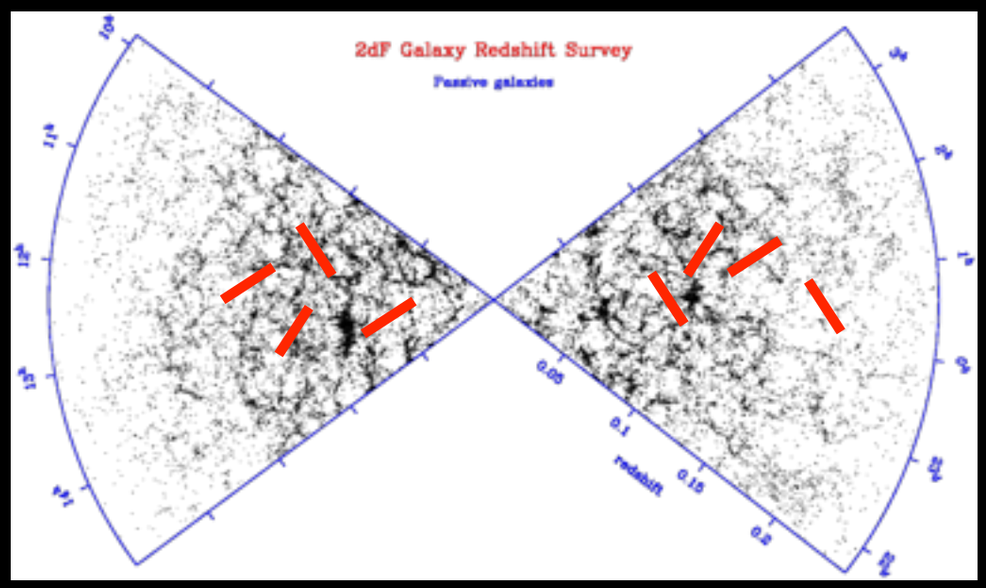
EXPANSION PROBES - BARYON ACOUSTIC OSCILLATIONS







Eisenstein



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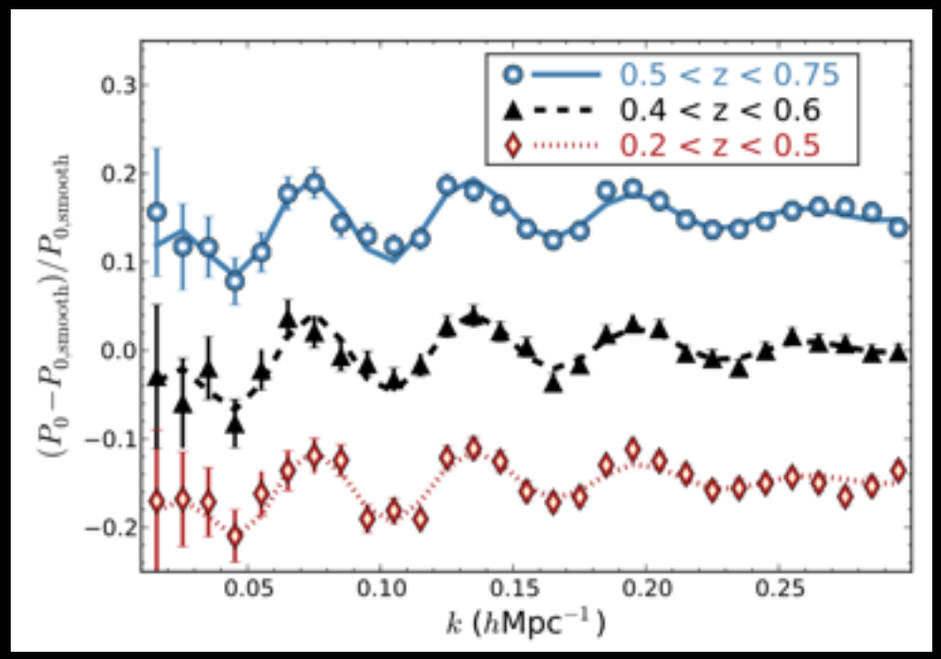
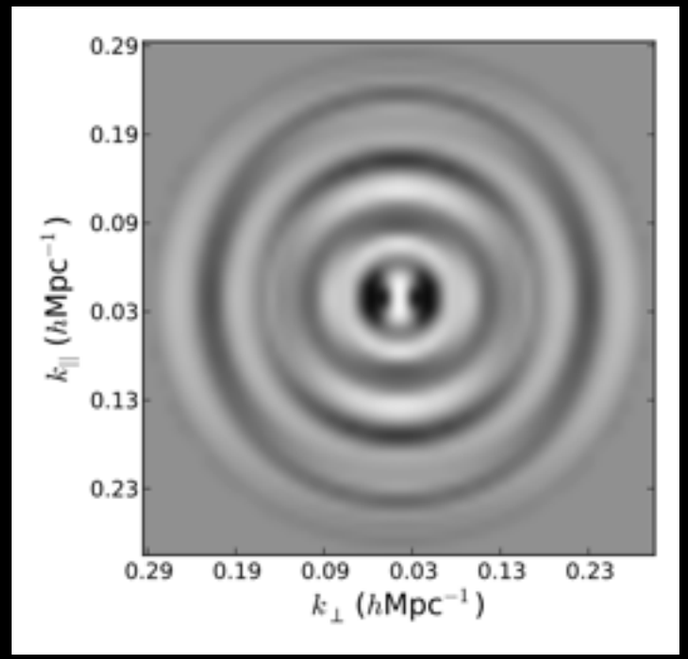
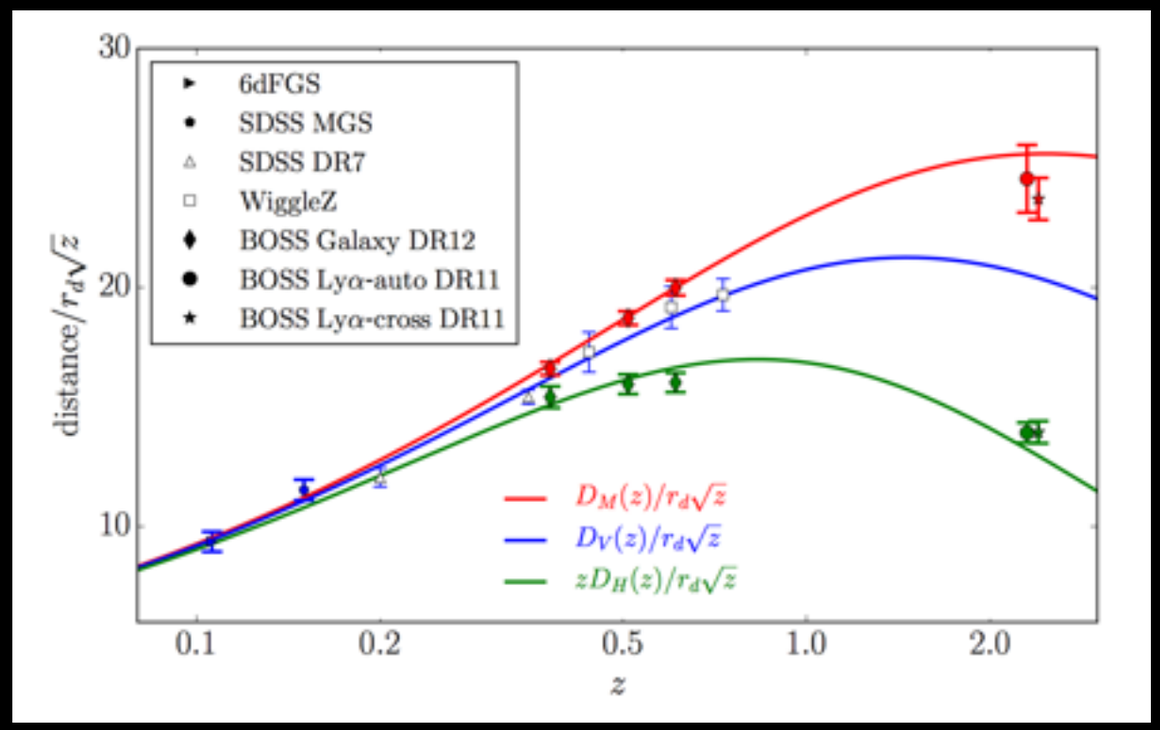
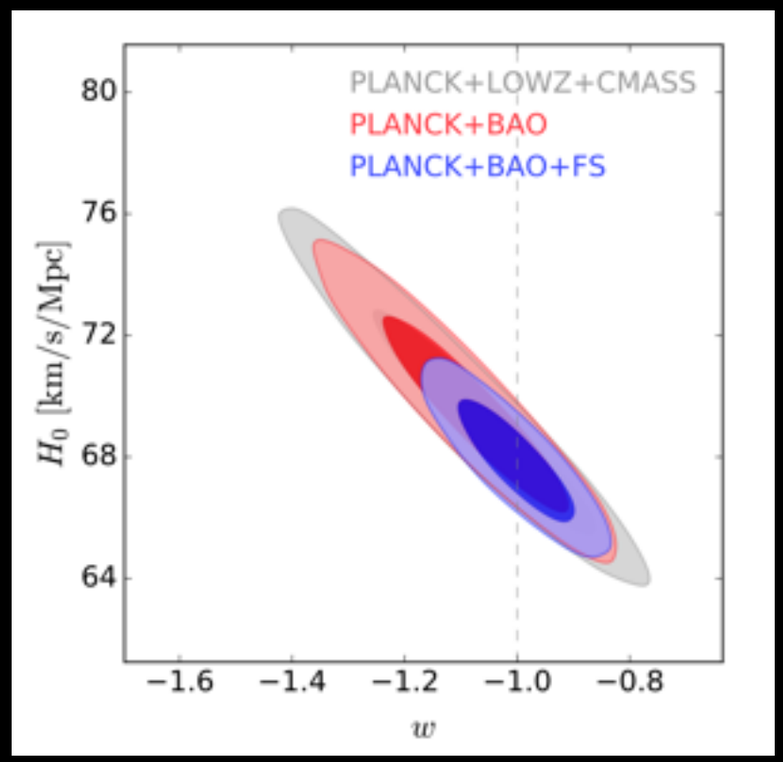




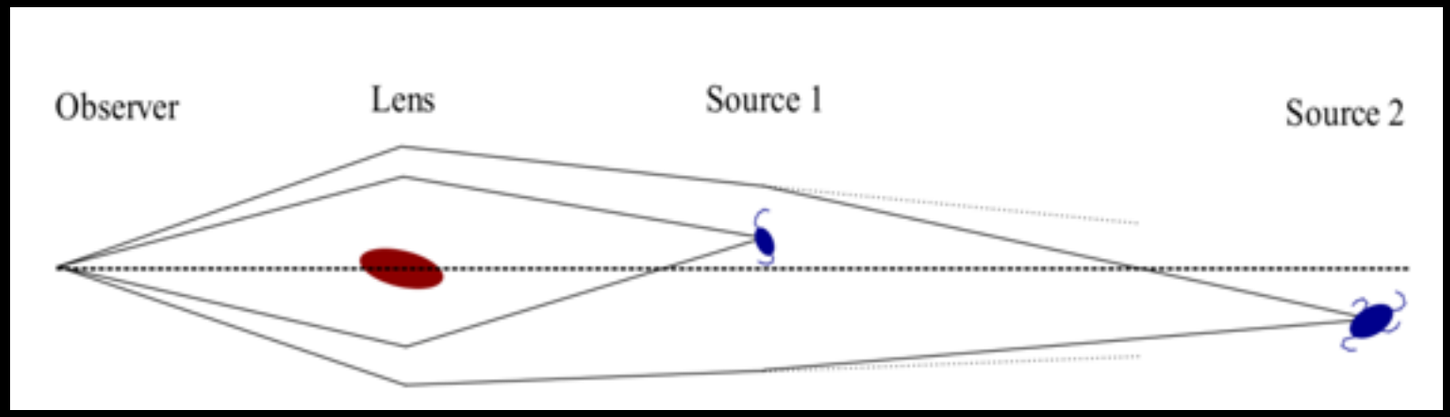
SDSS-III
BOSS DR12
1.9M gal,
9300 sq deg

Alam et al 16

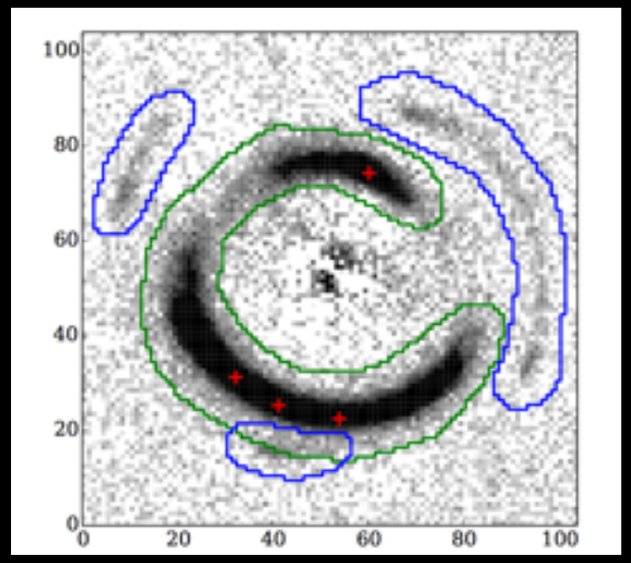


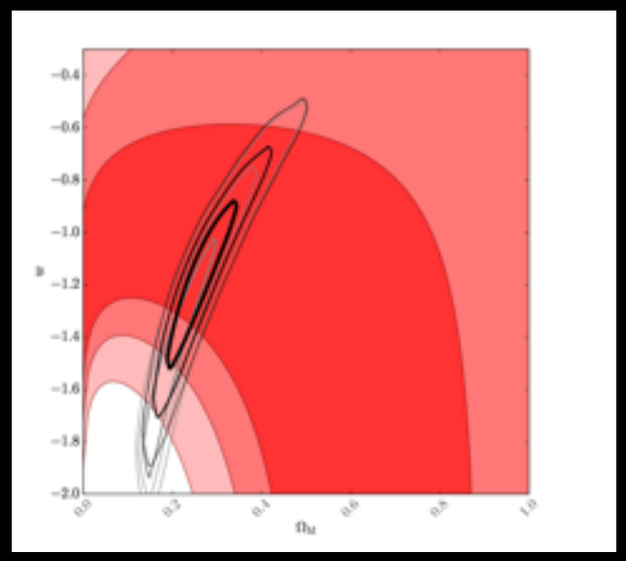


EXPANSION PROBES - STRONG LENSING



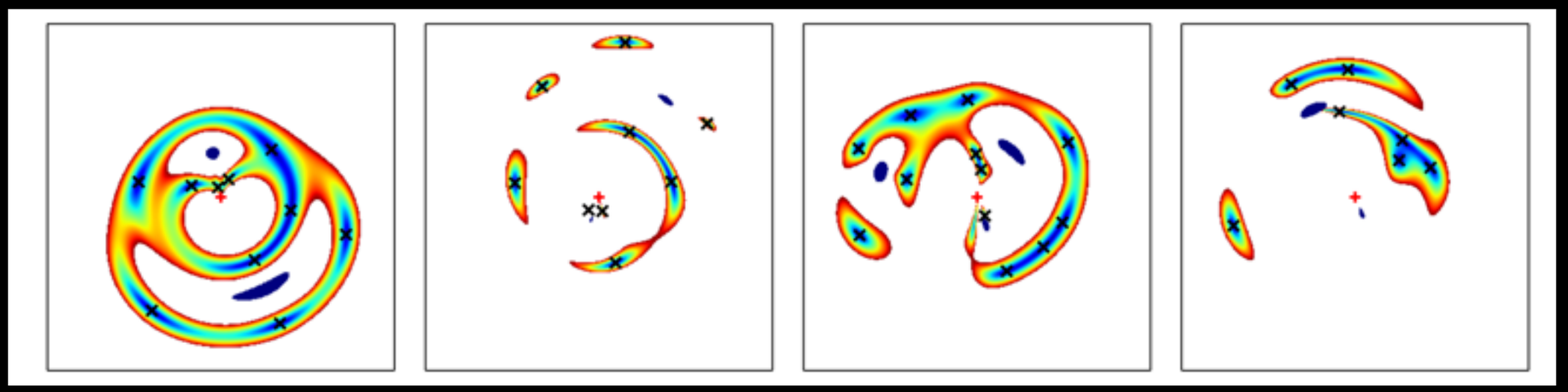
SDSSJ0946+1006





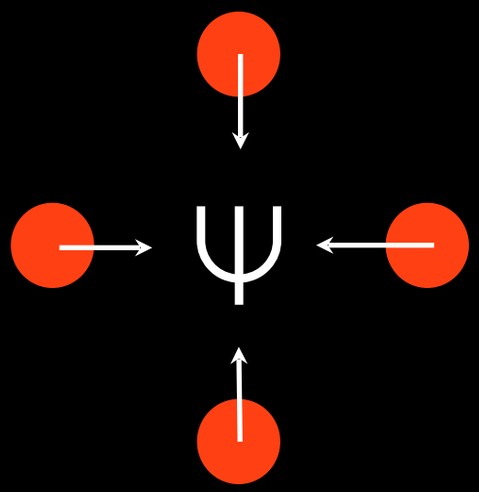
Collett
& Auger 14

High multiplicity lenses possible; *n*=8 expected with LSST

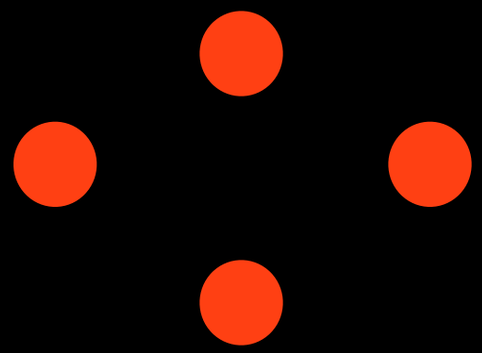


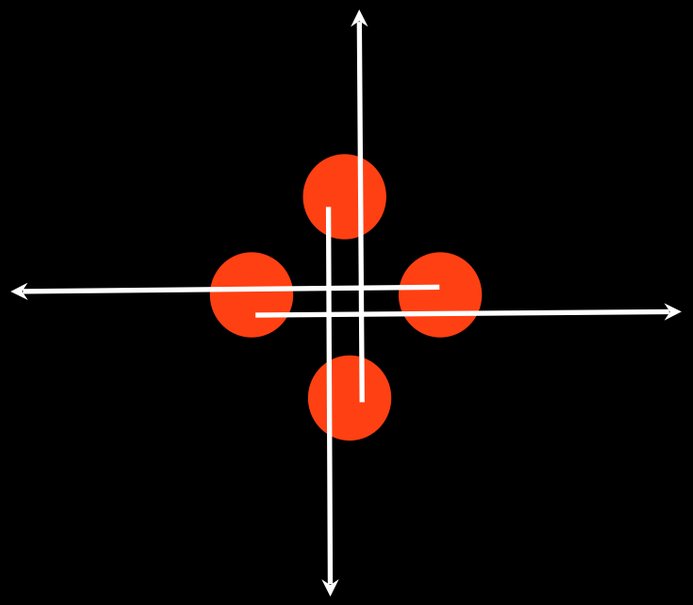
Collett
& Bacon 16

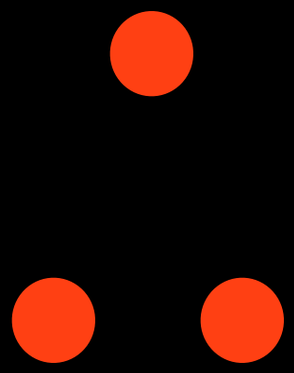
GROWTH PROBES - REDSHIFT SPACE DISTORTIONS

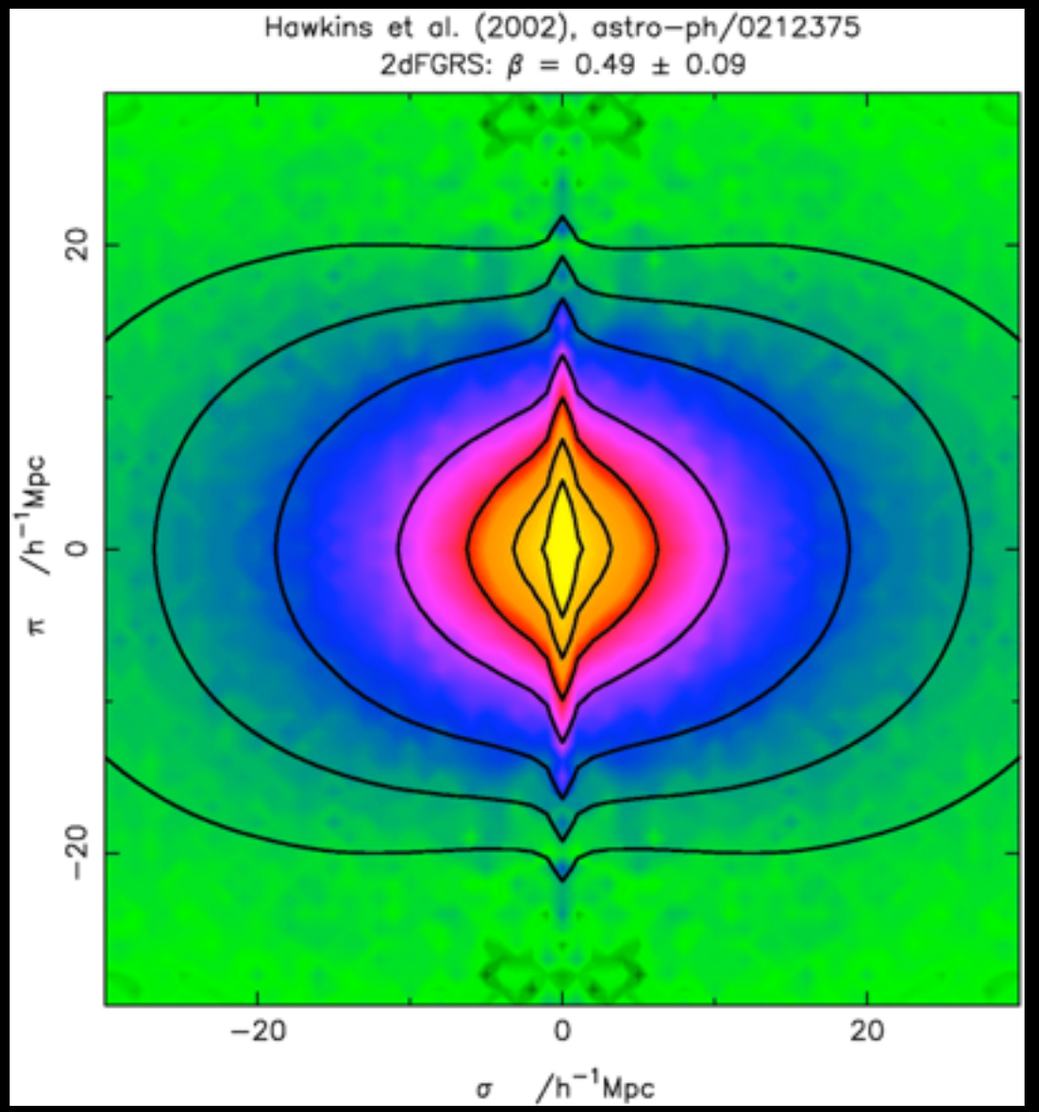


Observed



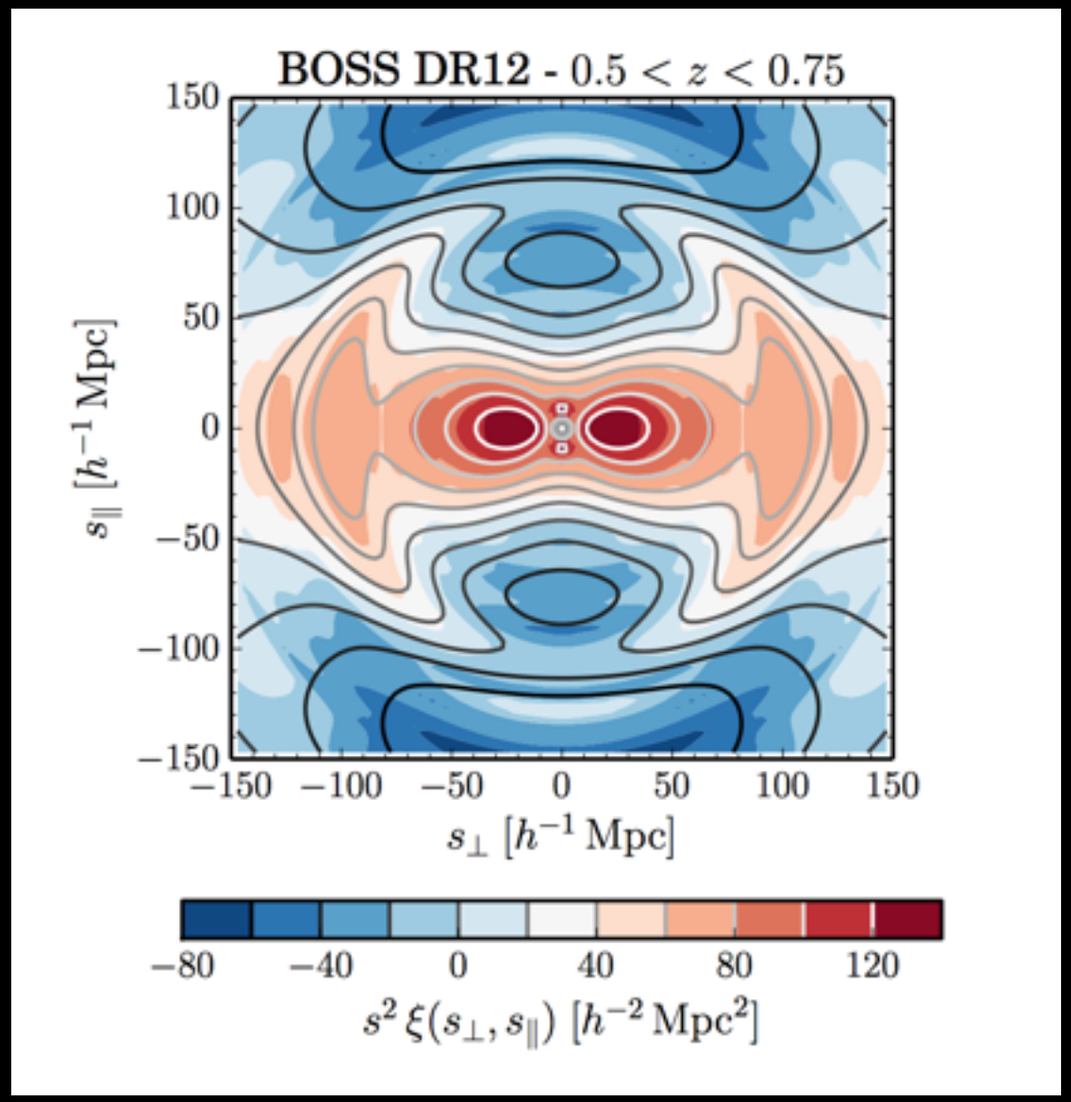




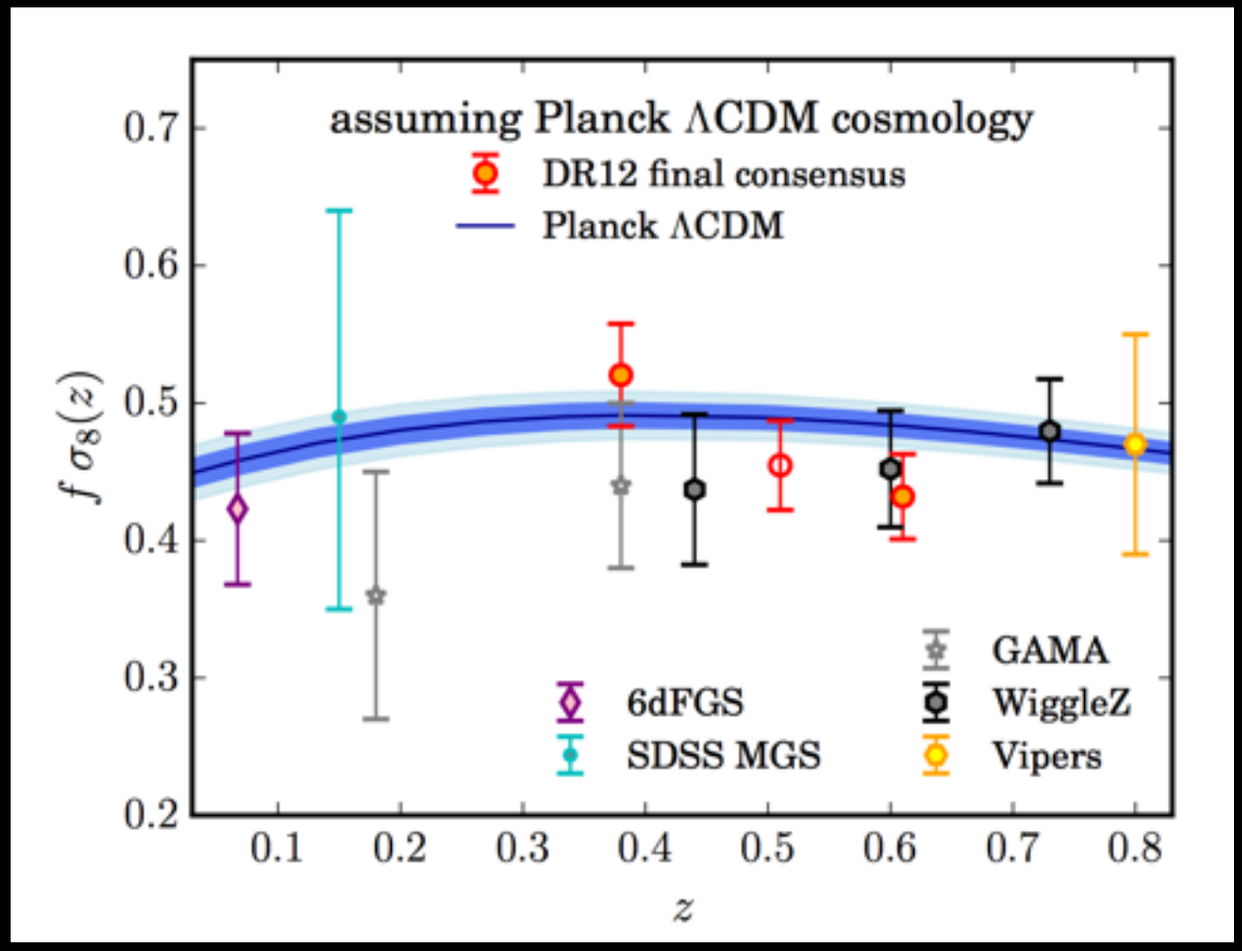


- Fingers of God

GROWTH PROBES - REDSHIFT SPACE DISTORTIONS



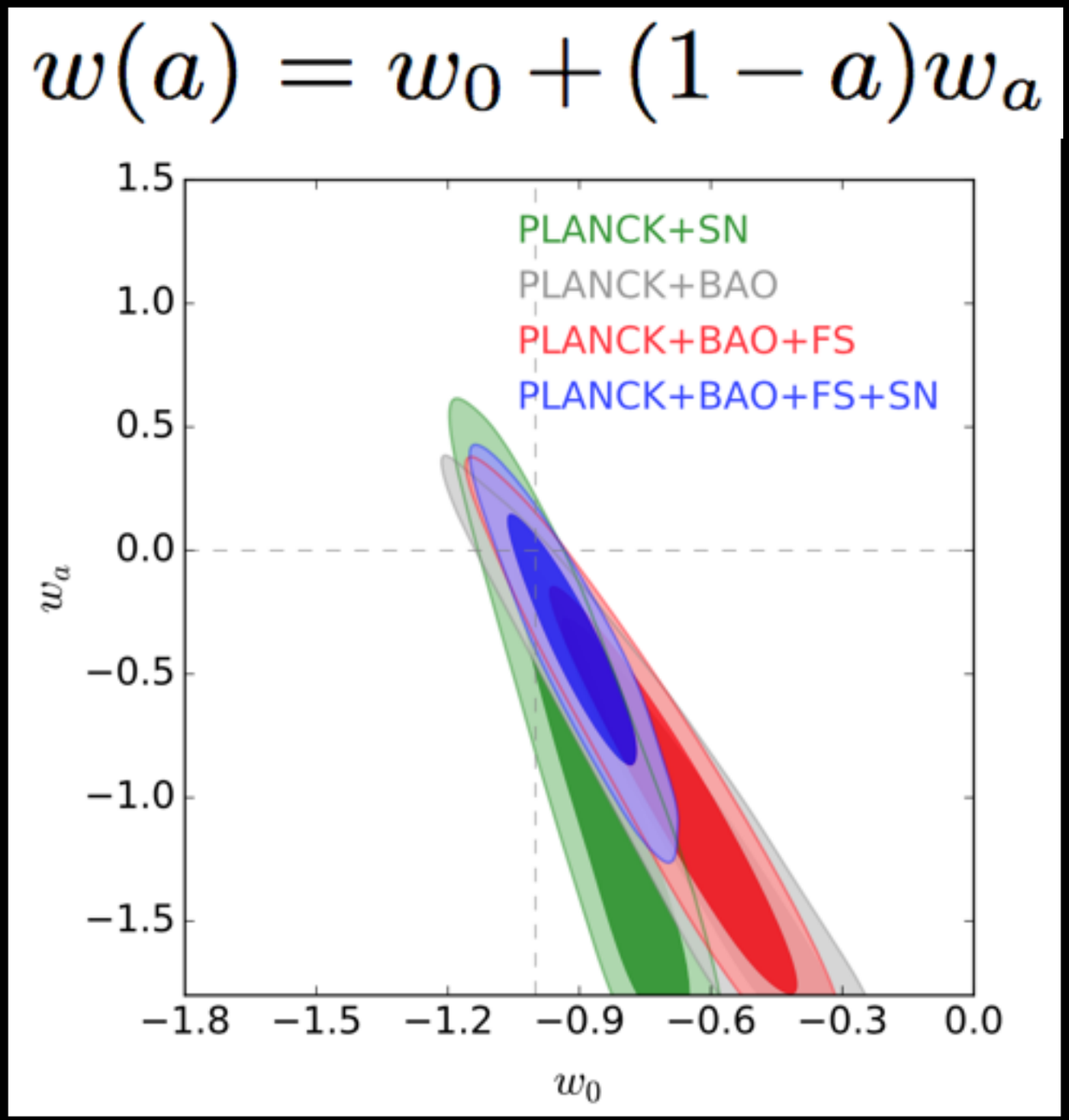
BOSS DR12



Alam et al 16

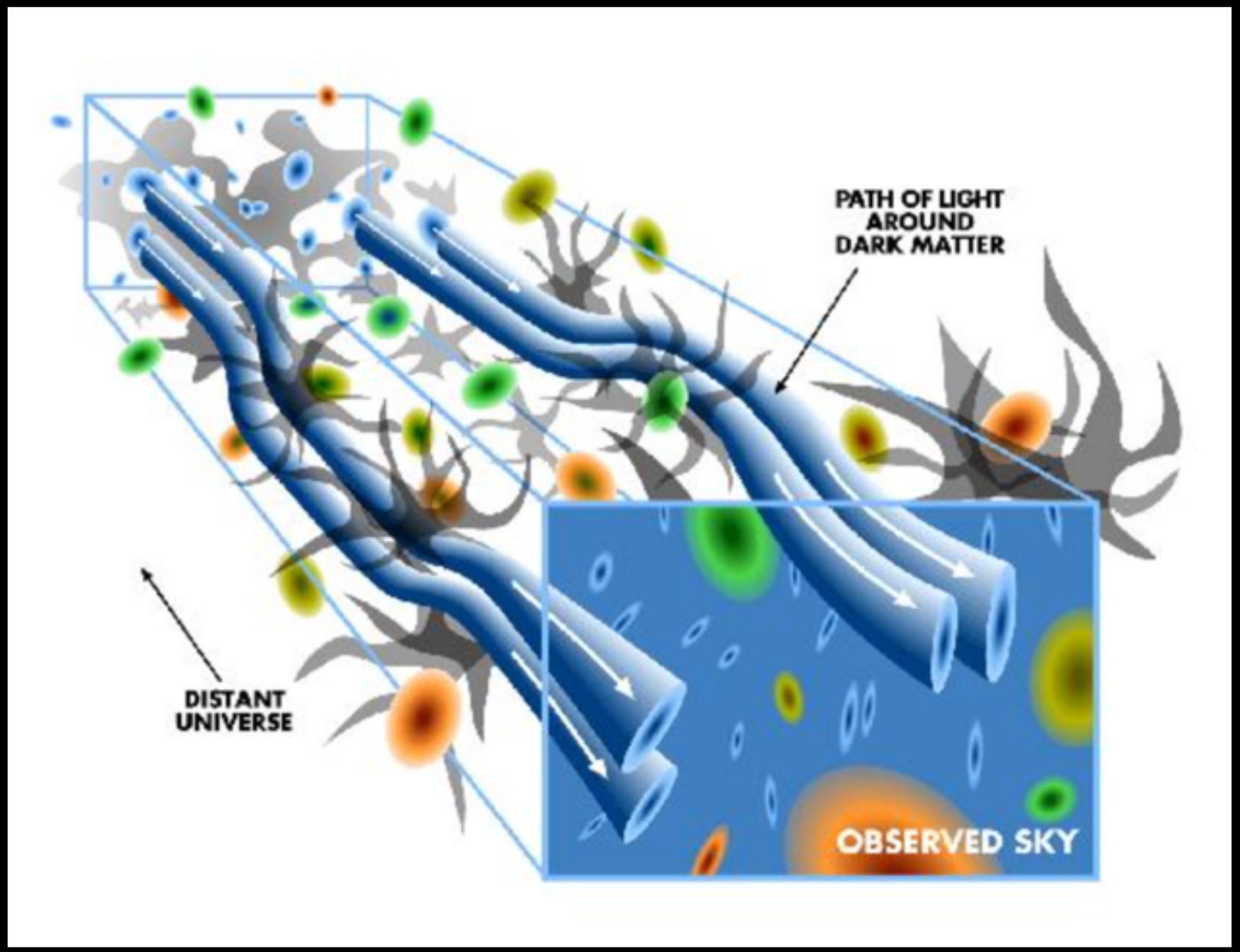
DARK ENERGY PHYSICS

$$w(a) = w_0 + (1-a)w_a$$



Alam et al 16

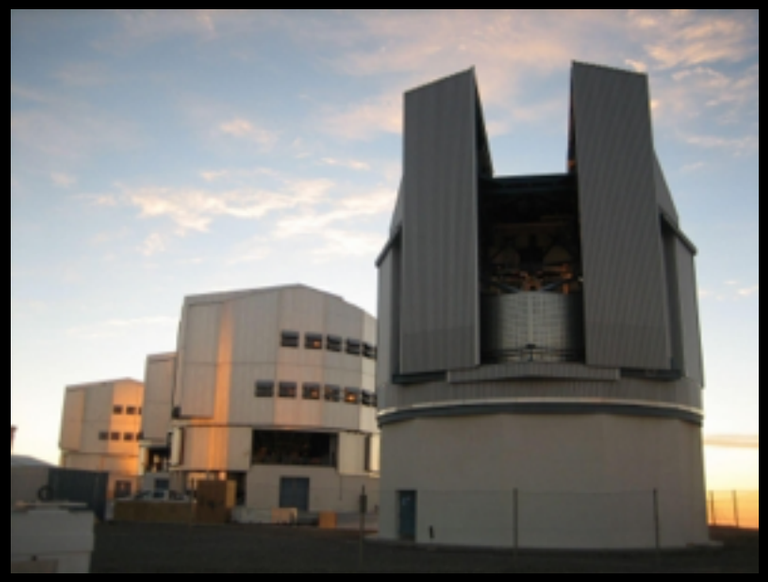
GROWTH PROBES - WEAK GRAVITATIONAL LENSING



Wittman et al 00

Probing a combination of expansion, structure and gravity

GROWTH PROBES - WEAK GRAVITATIONAL LENSING



Kilo-Degree Survey (KiDS)

1500 sq degrees

Dark Energy Survey (DES)

5000 sq degrees

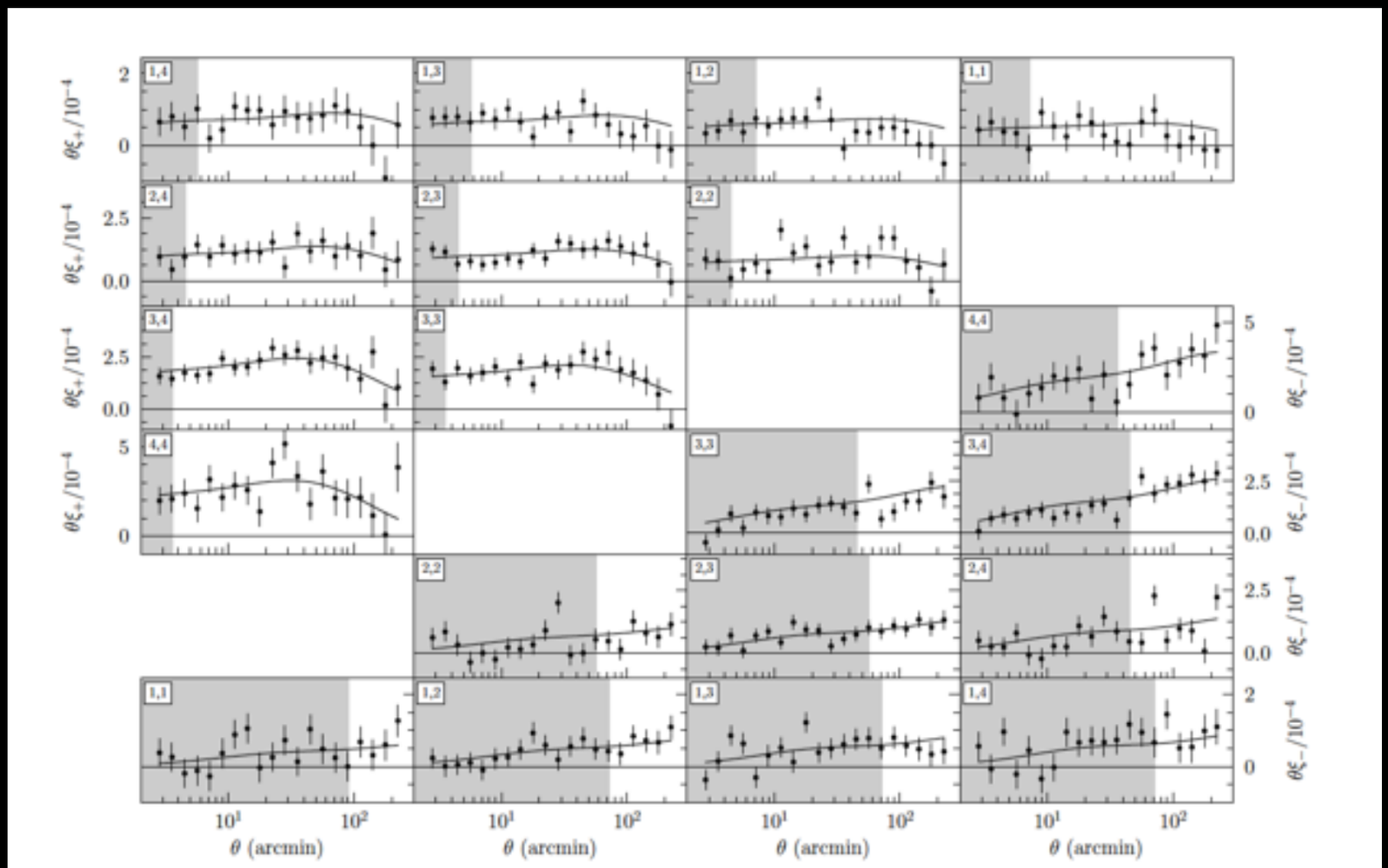
Hyper Suprime-Cam (HSC)

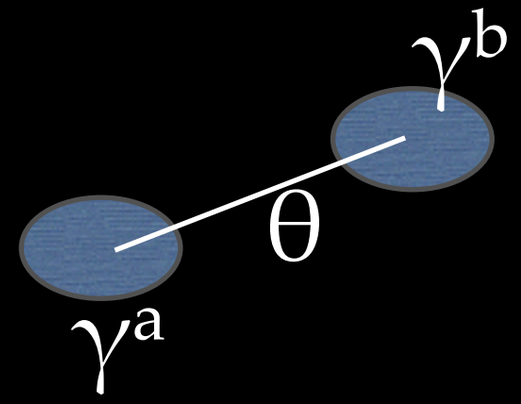
1400 sq degrees

DES data- need to estimate shear for these galaxies

Fit shape of galaxy images

LENSING STATISTICS





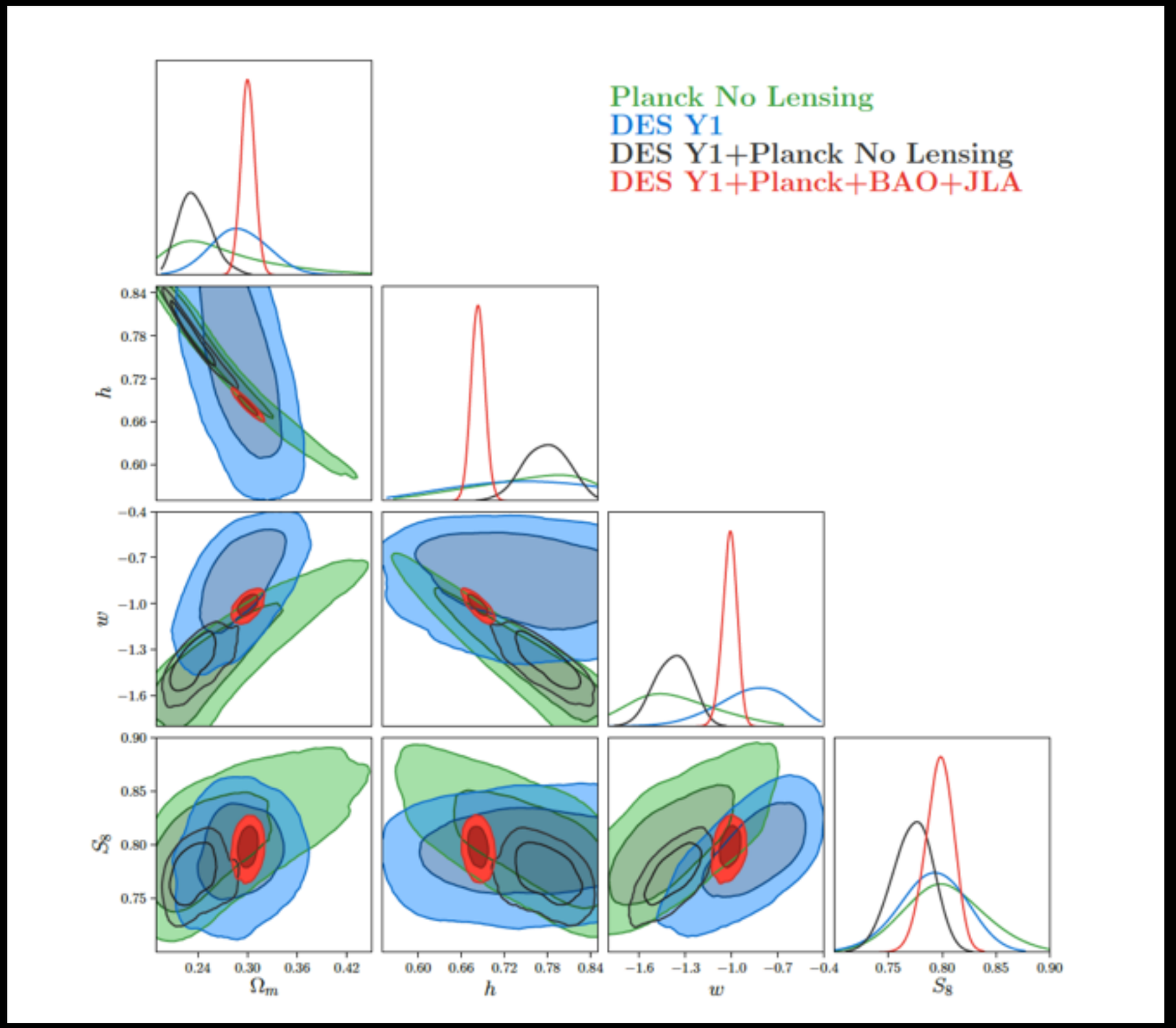
Troxel et al 17

COMBINED RESULTS

Expansion rate

Dark energy pressure/ density

Matter clustering



Matter density

Expansion rate

Dark energy pressure/ density

Matter clustering

DES 17

THE SHAPE OF THINGS TO COME

What do we make of the tensions between current datasets?

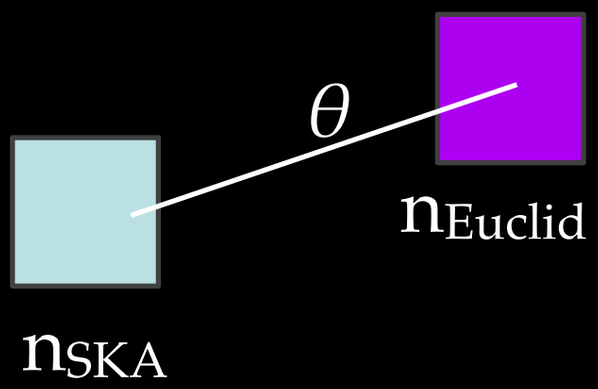
Perhaps these will become more pronounced in future datasets.

Some of the tension may herald exciting physics.

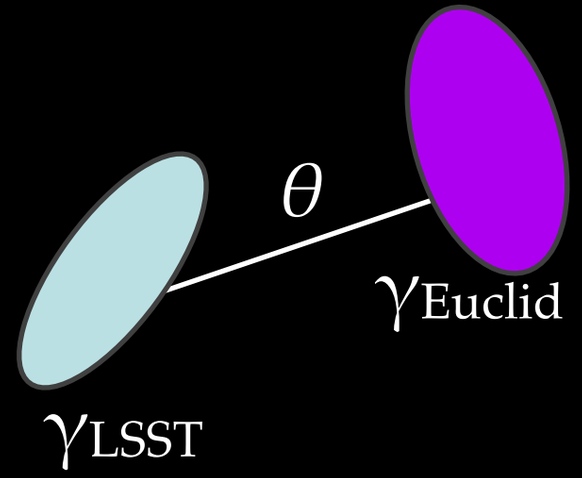
Some may indicate systematic effects.

Need careful calibration, modelling and cross-correlation.

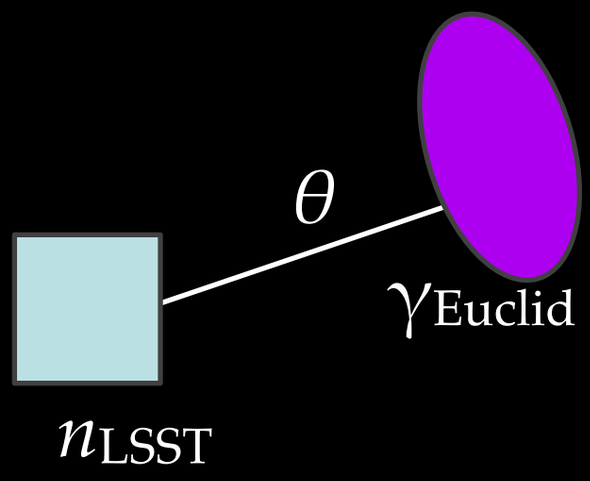
COMBINING PROBES - OVERCOMING SYSTEMATIC ERRORS



Cross correlation of clustering picks out fluctuations which are not due to instrumental effects or e.g. stars.



Cross correlation of lensing shear picks out signal which is not due to telescope systematics.



Cross correlation of clustering and lensing picks out signal with different combination of systematics, and measures galaxy bias.

SUMMARY

We can learn about the dark energy with:

- Probes of the expansion history, e.g. SNe, strong lensing, baryon acoustic oscillations;
- Probes of the growth history, e.g. redshift space distortions, weak lensing

A simple model with w=-1 is currently ~OK

But some very interesting tensions in both expansion rate and growth.