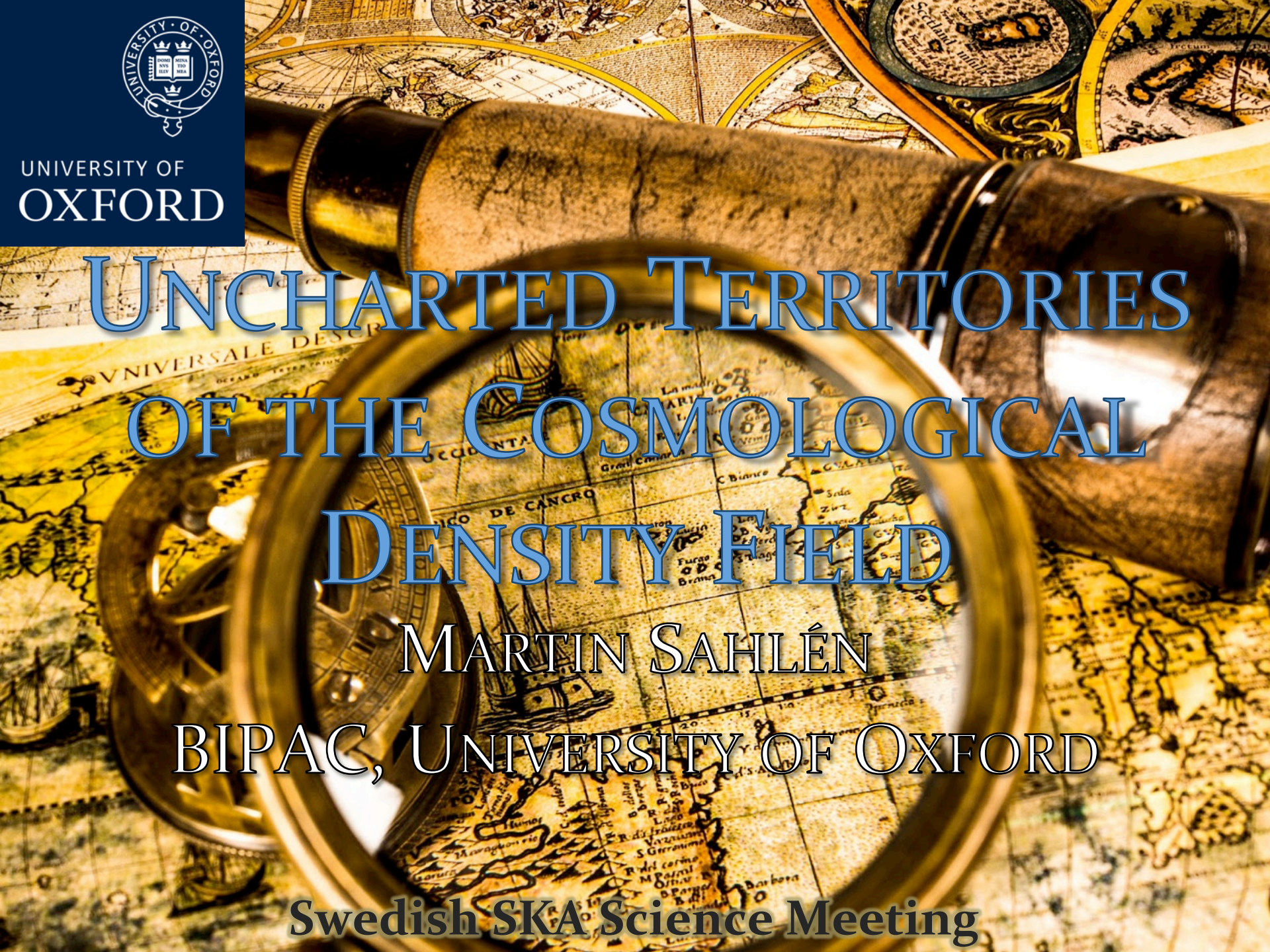


Uncharted Territories of the Cosmological Density Field

Martin Sahlén

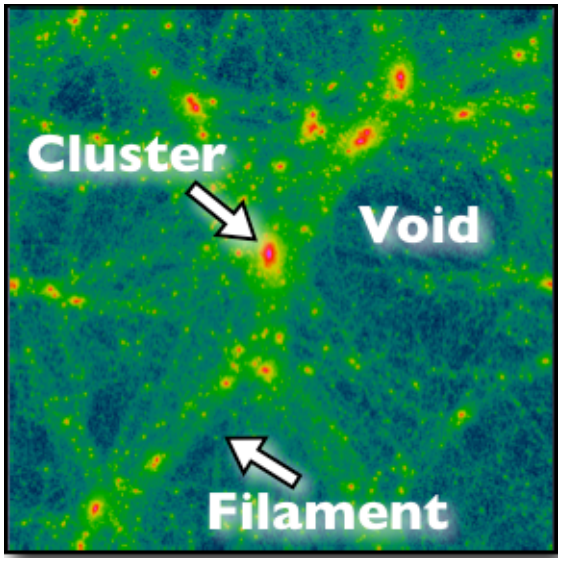
BIPAC, University of Oxford

Swedish SKA Science Meeting

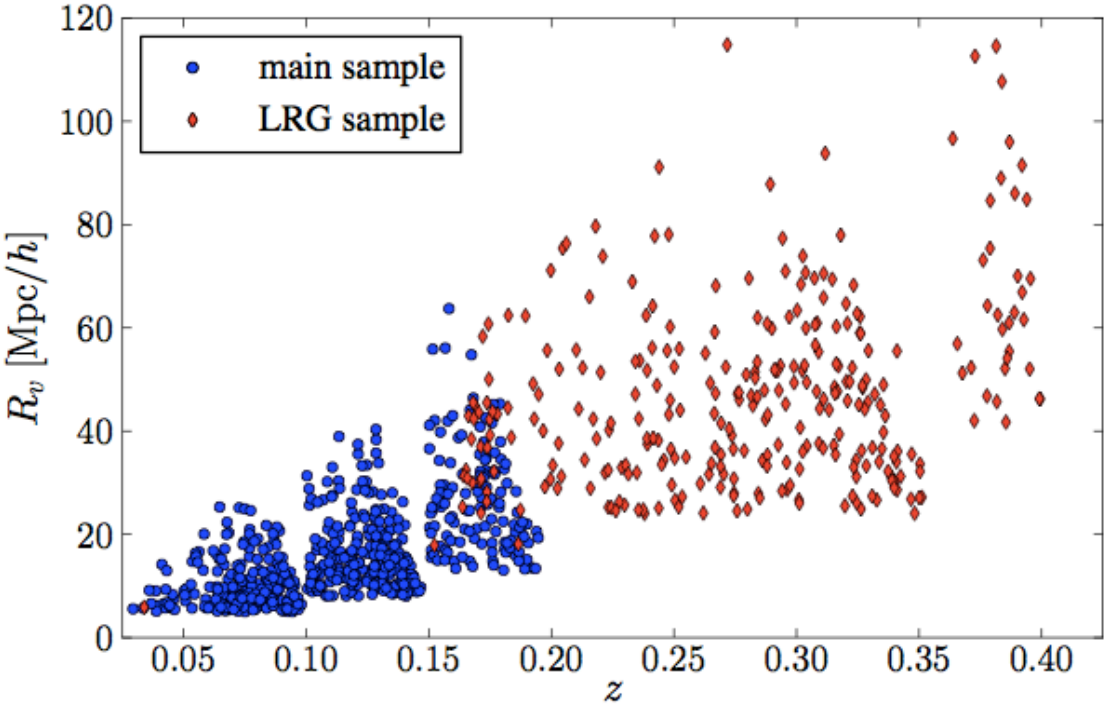
Overview

- Voids and clusters: lensing, Alcock-Paczynski [Euclid/LSST + SKA]
  - Synergy for dark energy, modified gravity
- First galaxies [JWST + SKA]
  - Complementarity/synergy for high-z power spectrum, star formation, first light, reionization
- Cluster surveys [eRosita, Euclid, SPT + SKA]
  - Complementarity/synergy for cluster physics, 'cleaning' samples
- More(?) speculative [e.g. CTA + SKA]
  - Primordial black holes, PopIII SNe, axions, gravitational infall

Voids: The Troughs Inbetween

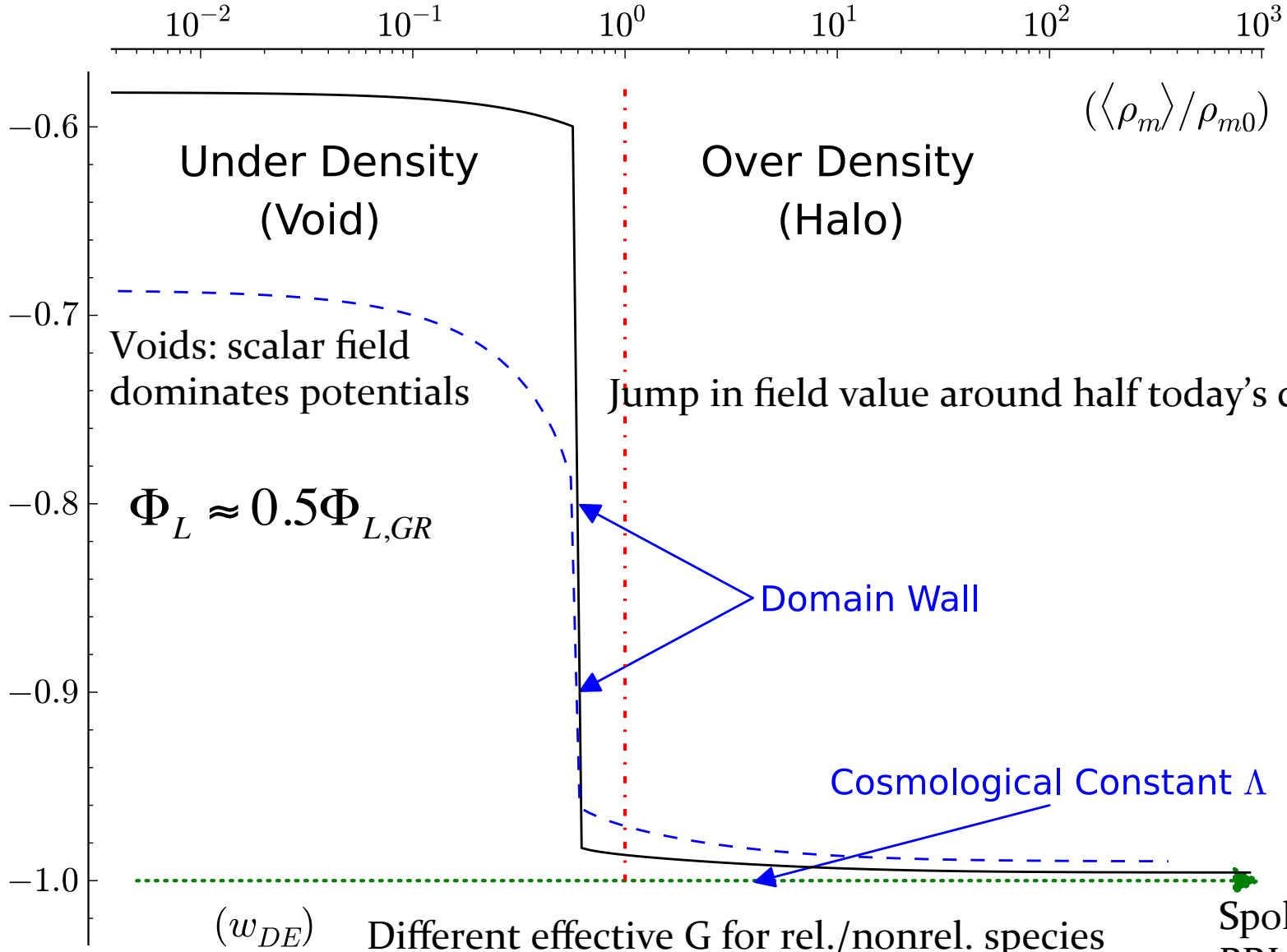


The large under-densities between filaments and clusters



Melchior et al. 2013

Test 'Vainshtein'/massive gravity



Spolyar, Sahlén, Silk
PRL 111 241103 (2013)

Observational Prospects

- Weak (de)lensing
  - Euclid, S/N ~ 15 stacked void lensing should allow discerning ~50% difference in potential (Krause et al. 2012)
- Alcock-Paczynski void shapes
  - BOSS, expect 2σ+ detection if Δw>0.25 (Dawson et al. 2013)
  - Euclid, expect 2σ+ detection if Δw>0.1 (Lavaux & Wandelt 2012)
- Galaxy power spectrum, redshift-space distortions [growth rate, scale]
- Integrated Sachs-Wolfe effect
- CMB + 21cm lensing

SKA can do these alone or synergistically in combination with e.g. Euclid, LSST – details TBD
-> Stacked lensing tomography
22nd Century: Dark Side of the Moon!

PRL 111 241103 (2013)

Encouraging First Results: De-lensing in SDSS voids

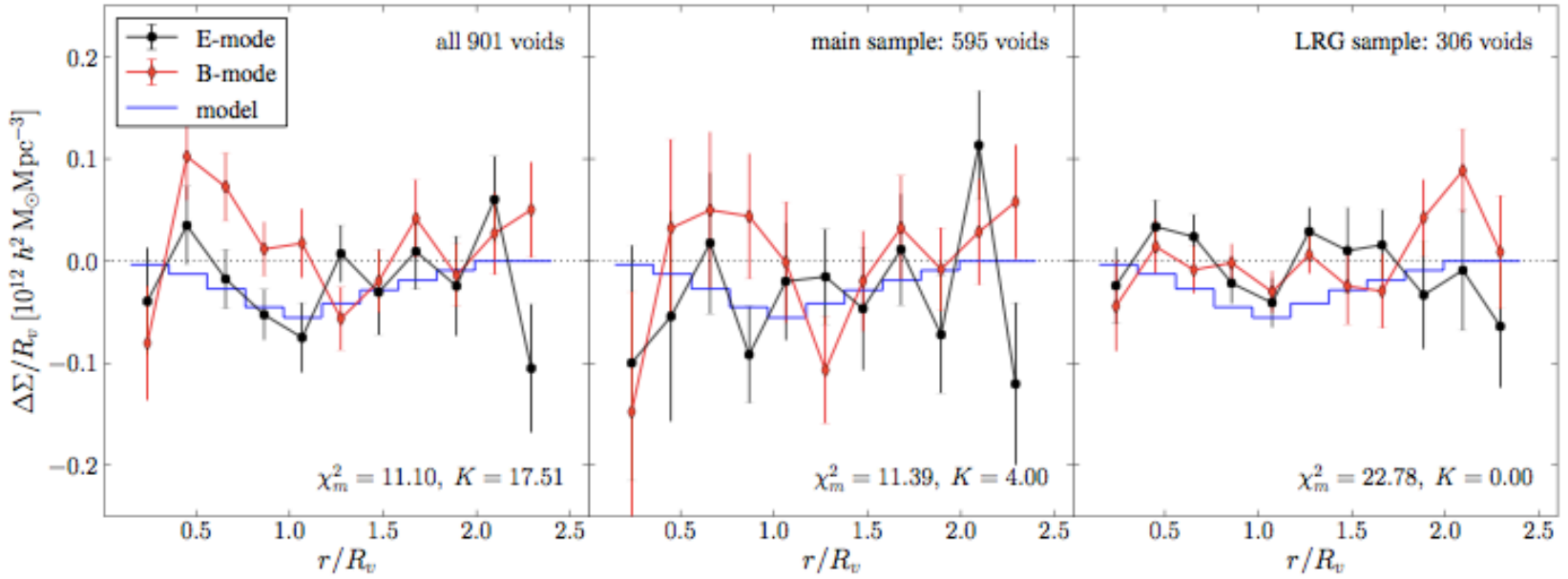
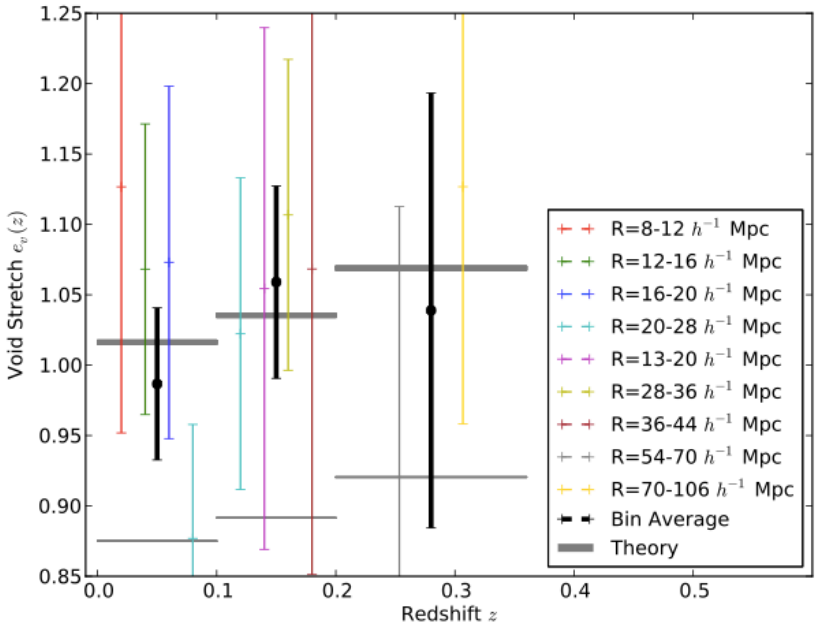
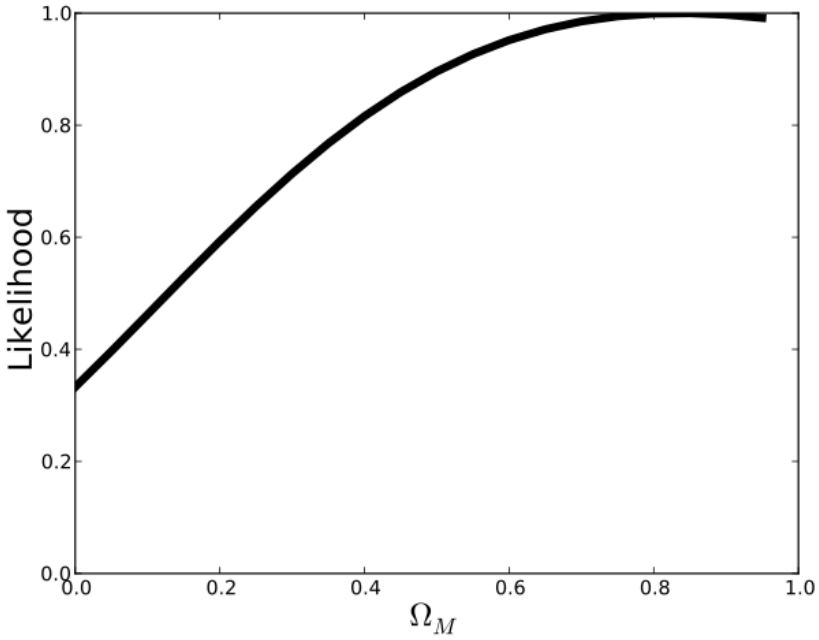


Figure 2. Void lensing signal in the range of $r/R_v = 0.15$ .. 2.4 of all voids (*left*), the main void sample (*center*), and the LRG sample (*right*). A 3σ-outlier rejection has been applied in each bin to reduce the impact of strongly discrepant measurements. The errorbars show 68% confidence intervals, estimated from 5,000 bootstrap realizations of the outlier-rejected mean in each bin. The blue curve shows the reference LW12 void model calculated from Equation 3, binned in the same way as the data.

Melchior et al. 2013

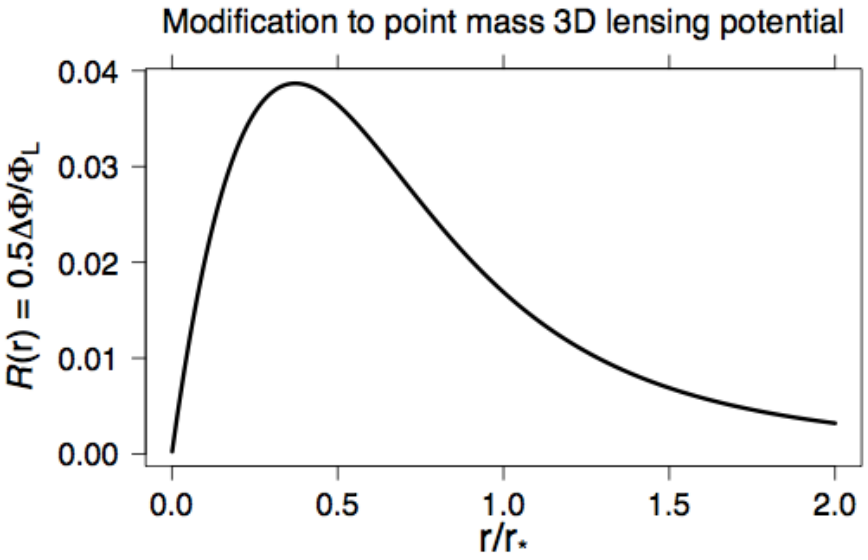
Encouraging First Results: Alcock-Paczynski with SDSS voids





Sutter et al. 2012

Galileon Observational Signature: Enhanced Lensing – Shear

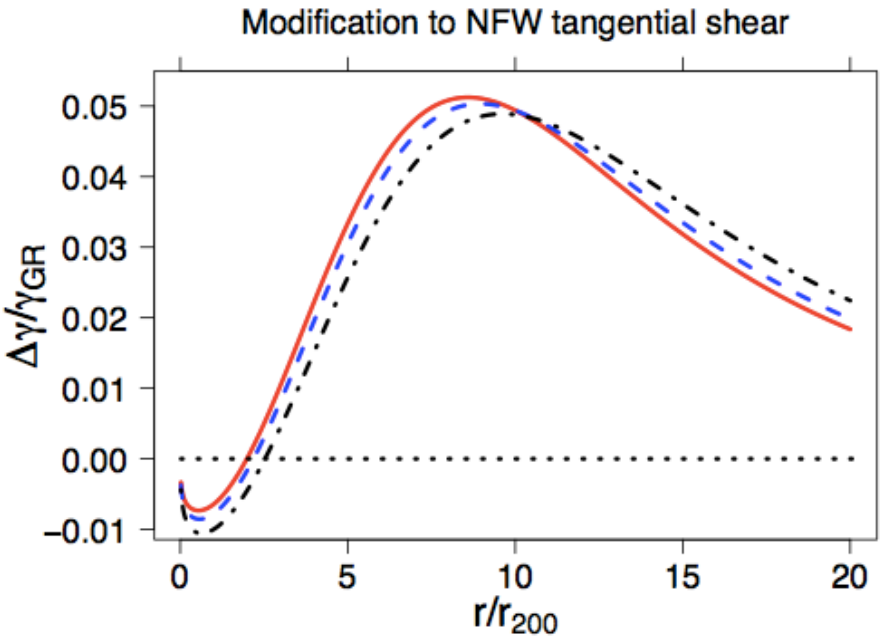


~ 5% effect

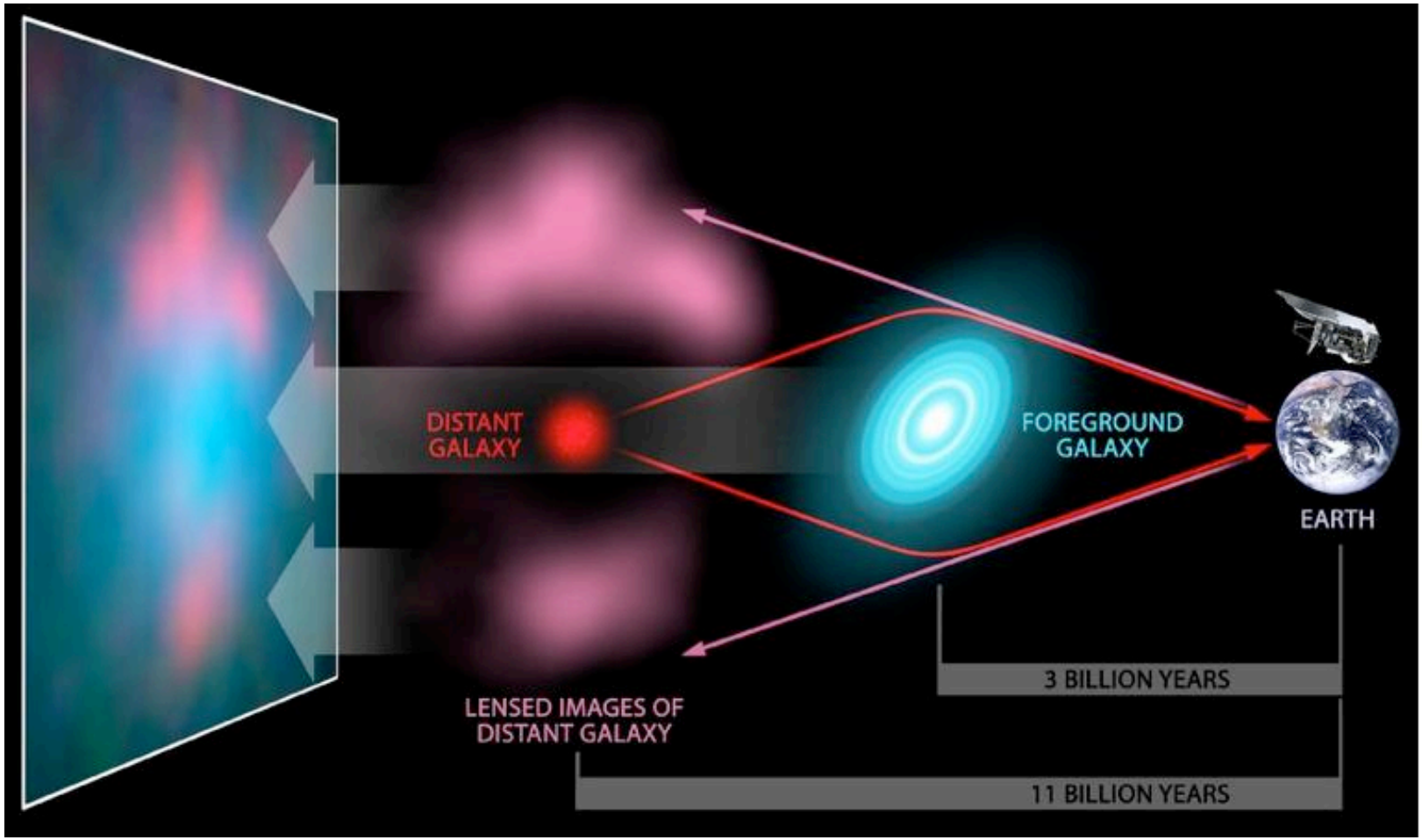
$$\Delta\Phi = \frac{\beta}{\Lambda_3^3}(\partial_r \pi)^2$$

Clusters + voids = big lever arm on parameters

Wyman 2011



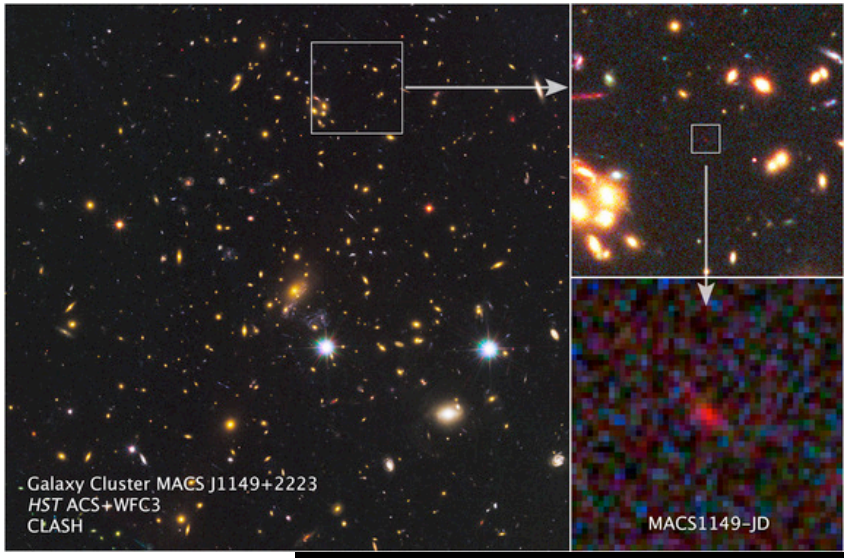
High-Redshift Galaxies: A Lookout for the First Structures



Preliminary work, with J. Silk, D. Spolyar, and others

Two Ancient Mariners

- MACS1149-JD
  - $z = 9.6$ (~500 Myr)
  - $M_* \sim 10^8\ M_\odot$
- MACS0647-JD
  - $z = 10.7$ (~400 Myr)
  - $M_* \sim 10^8 - 10^9\ M_\odot$



CLASH

See e.g. Zheng et al. 2013

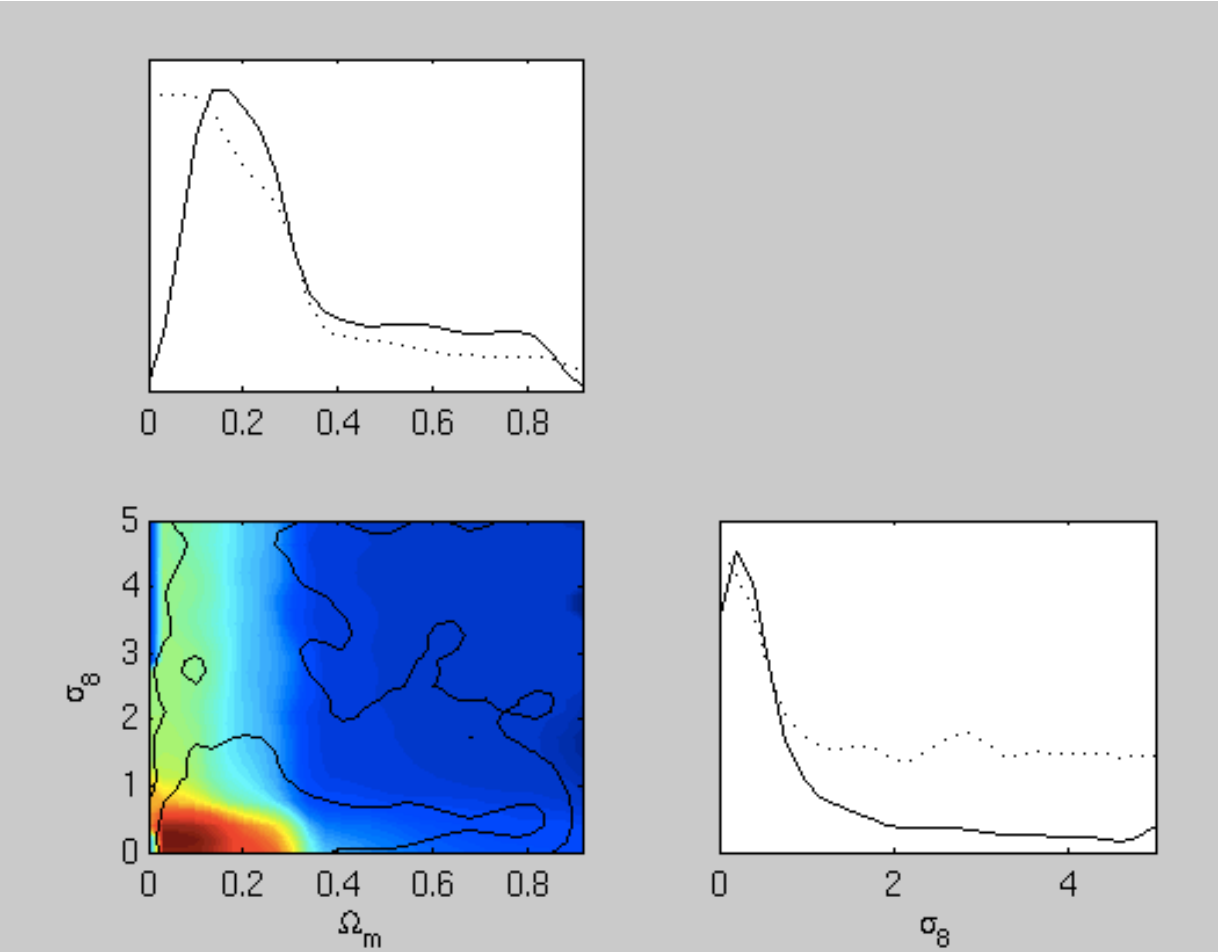
How to Tell Their Story?

Relate galaxy properties to halo distribution

- use halo-stellar-mass relation to connect to dark matter halo distribution
- use halo mass function to estimate number density
- estimate lensed survey volume
- assume here that they are central galaxy

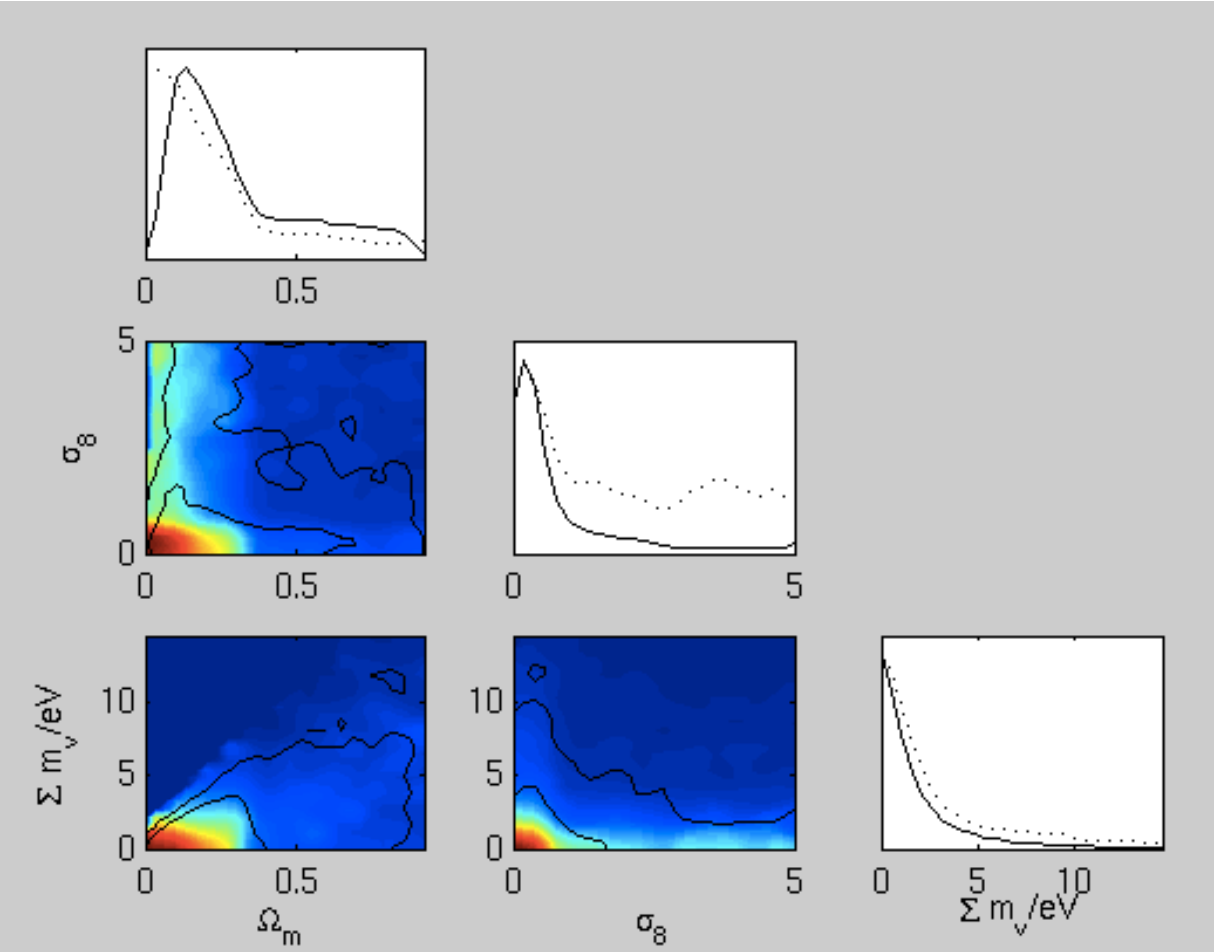
Preliminary work, with J. Silk, D. Spolyar, and others

First constraints at z ~ 10 / t_U ~ 500 Myr
Power spectrum



Preliminary work, with J. Silk, D. Spolyar, and others

First constraints at z ~ 10 / t_U ~ 500 Myr
Neutrino masses



Preliminary work, with J. Silk, D. Spolyar, and others

JWST UDF + SKA?

- Complementary constraints at z ~ 10-20
- With a cosmology prior [from e.g. SKA+...], can constrain at z~10-20 e.g.
  - Star formation [SFR, IMF]
  - First light [Threshold halo mass]
  - Reionization [e.g. f_esc]
- Handle on Malmquist/Eddington bias
- Useful cross-check of CD/EoR 21cm measurements and other cosmological probes
- Constrain SFR evolution z~5-10 including lower-z sample

Clusters of Galaxies

- Expect >10^6 clusters up to z~1 with 100h Rotation Measure (RM) survey; complete to mass limit 10^{13} h^{-1} $M_\odot$ [Krause 2009]
- Overlap with e.g. eRosita [Xray], Euclid, LSST [Opt], SPT [SZ]
- Baryonic (and DM?) physics [calibrate mass fn]
- 'Clean samples'
- Potential for significantly tighter cosmological constraints?

More speculative?

- Primordial black hole explosions [e.g. CTA+SKA]
  - Gamma-ray transients [Hawking + secondary emission]
  - Radio transients [charged particles in magn. field]
  - Probe high-energy physics, inflation
- PopIII SNe [e.g. CTA+SKA]
  - May produce gamma-ray + radio transients
  - Probe 'Cosmic Dawn'?
- Gravitational infall on clusters
  - Probe baryonic physics + modified gravity?
- Axion-photon conversion
  - Magnetic field tomography + QSO polarization measurements, luminosity correlation
  - Probe high-energy physics

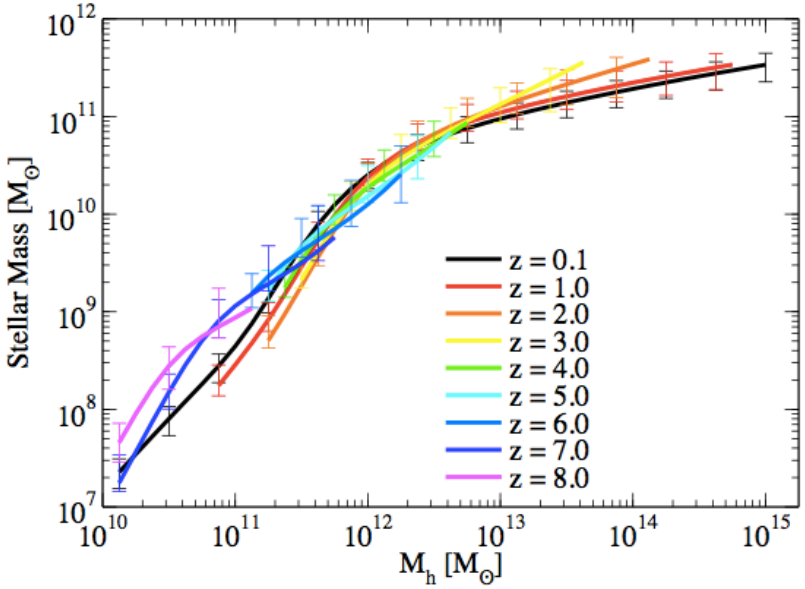
Feel free to ask for ref's

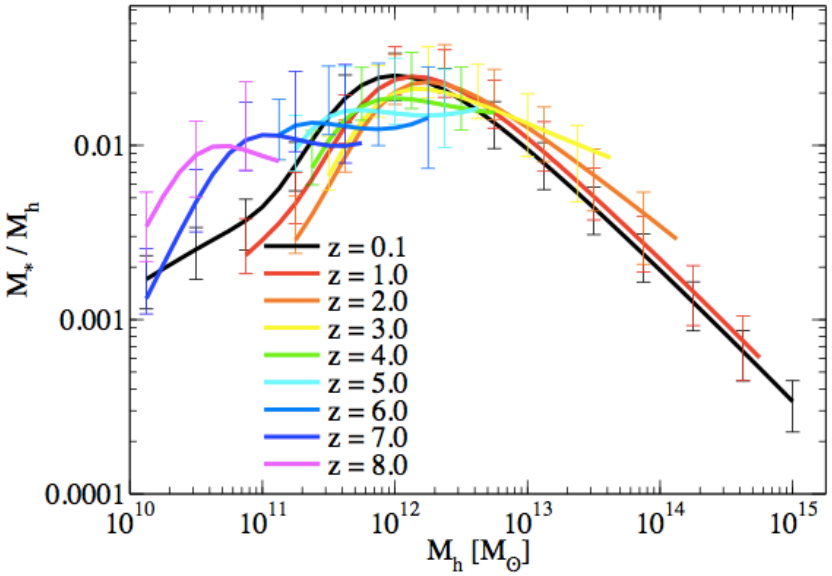
Conclusions

- SKA+Euclid, LSST
  - Voids and clusters, density & lensing profiles
  - Dark energy/gravity in untested domains
- SKA+JWST
  - Complementary tests of inflation, structure formation, star formation, reionization
- SKA+Euclid+eRosita+e.g. SPT
  - Constraints on cluster/baryonic physics, dark matter physics?
  - Order of magnitude increase in number of clusters?
- SKA+e.g. CTA
  - Exotic transients e.g. primordial black holes, early SNe, dark matter physics?
- SKA (+spectroscopy?)
  - Constraints on axion-photon conversion, cluster accretion and gravitational infall

SPARE SLIDES

Halo-to-Stellar-Mass Relation

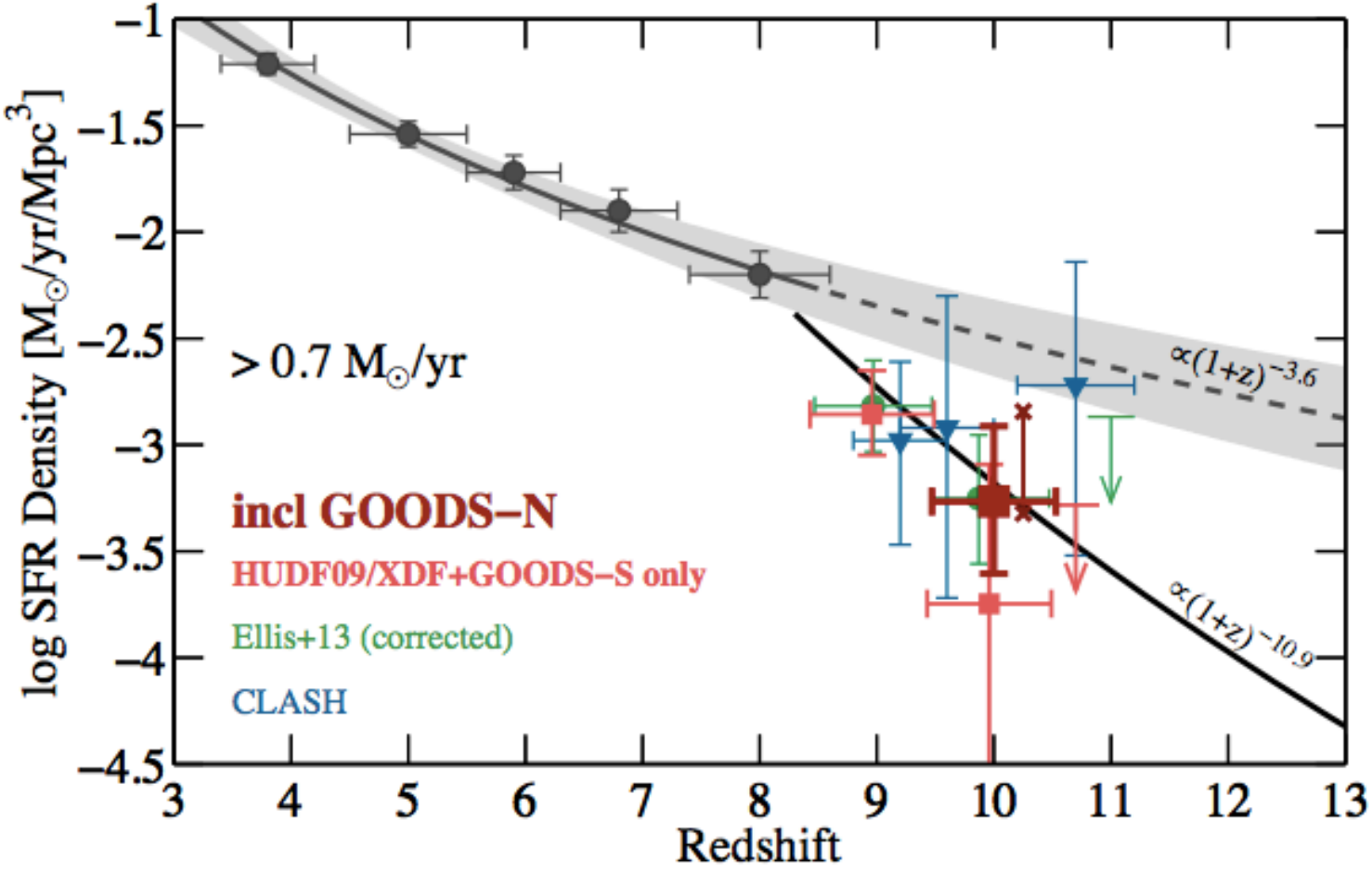




Hints of evolution at z > 4; how extends at z > 8?

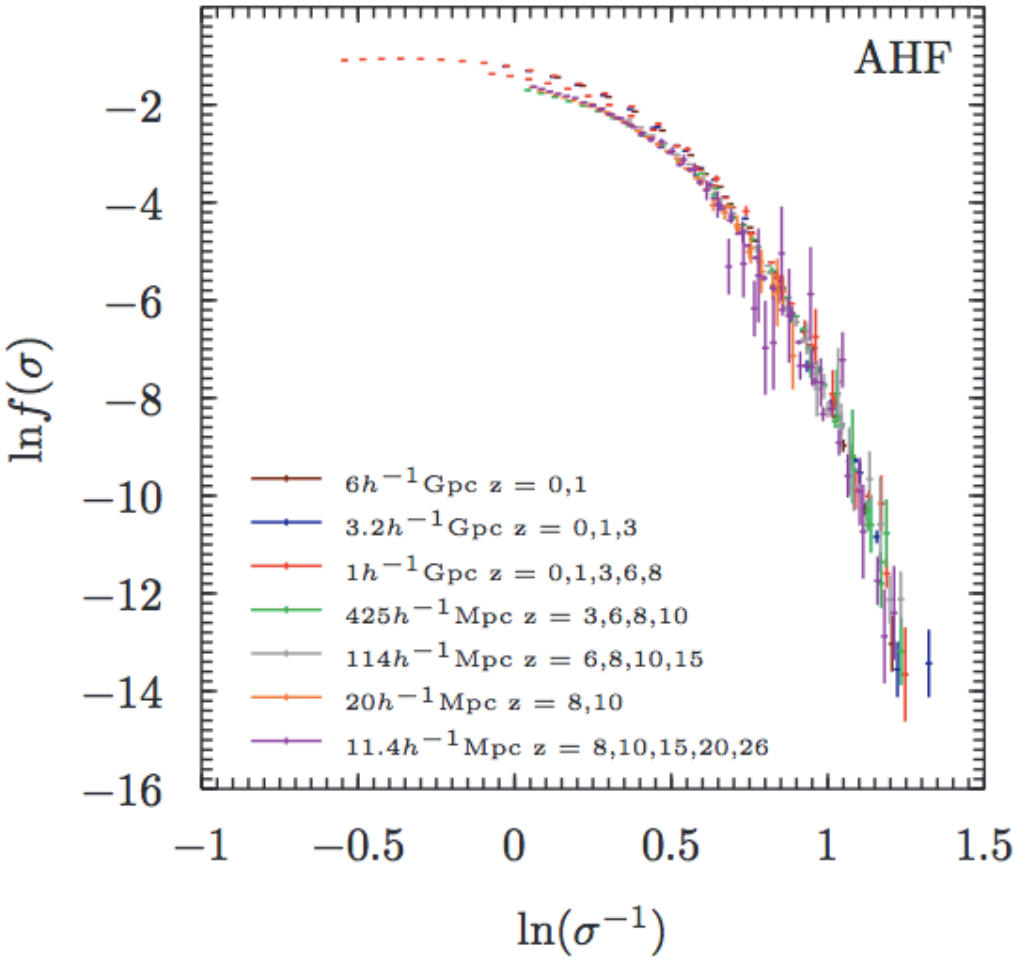
Behroozi et al. 2012

SFR Density: Signs of Evolution



Oesch et al. 1309.2280

Halo Mass Function: Watson et al. 1212.0095



Includes redshift trend, calibrated at relevant z and σ

Not including baryon-depletion effects, expect rel. small at z~10