

# Large-Scale Structure Science

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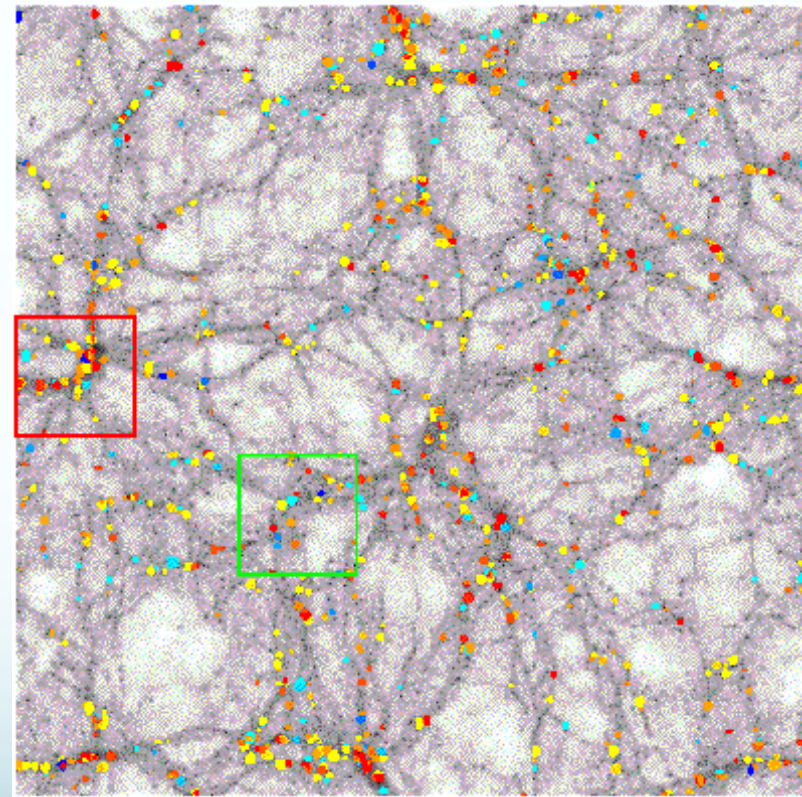


Towards a next space probe for CMB observations and cosmic origins exploration  
17-20 May 2016 CERN

# Census of the Baryons

- How do baryons flow from gas to stars and back within the cosmic web?
- **Census of the baryons**
  - Where are they: relation to dark matter
  - What are they doing: gas, dust, star formation, etc.
  - *Feedback is key, but not well understood*
- **Missing info on gas, dust, mass at critical epochs**

The Cosmic Web

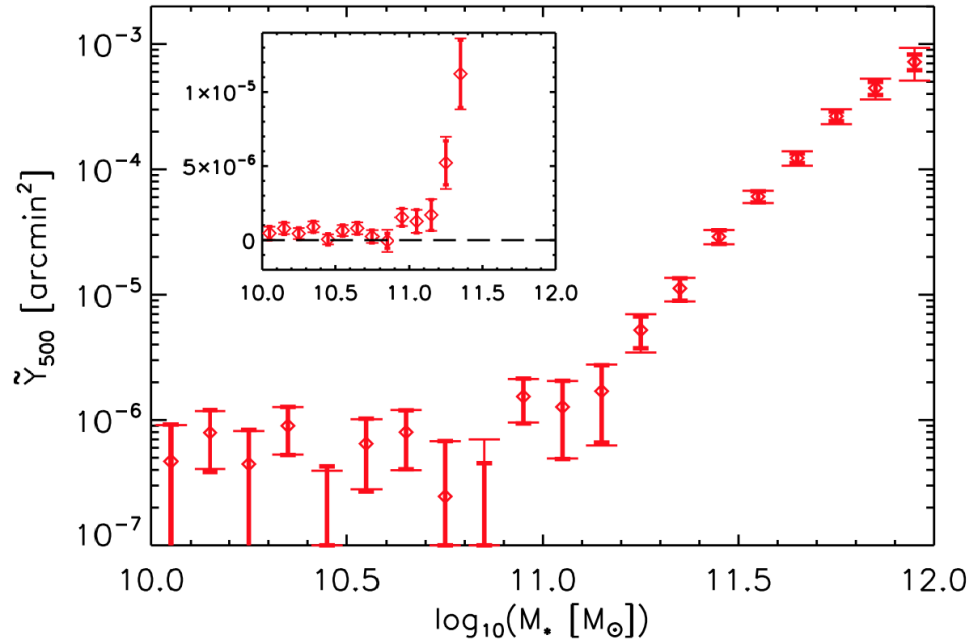


# LSS Science Case

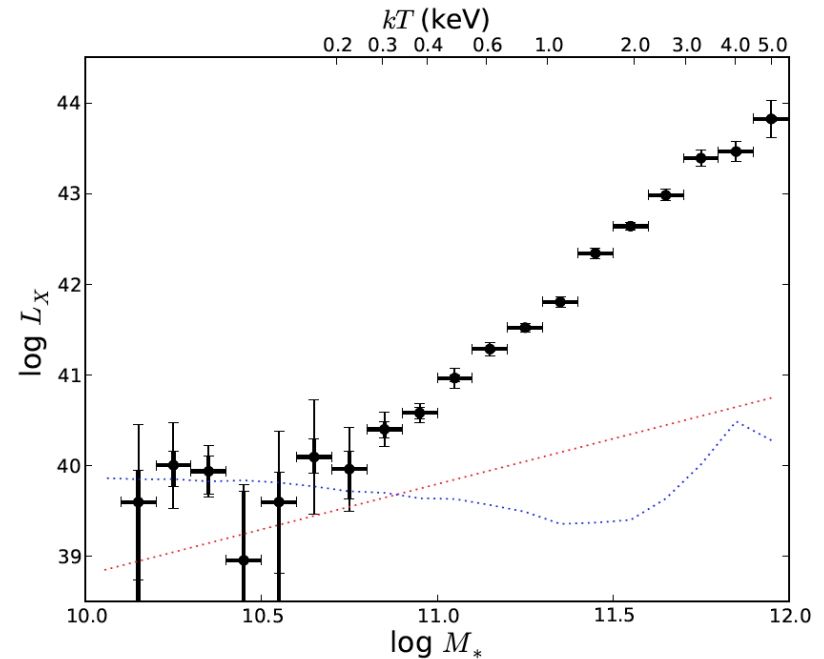
- Sub/millimeter well suited to answer this question:
  - tSZ traces gas
  - CMB lensing traces mass
  - Far-IR traces dust and star formation rate
  - Millimeter traces AGN
- Halo properties (1-halo term)
  - Binning on objects by type and redshift
  - Halo masses via CMB lensing
- Larger-scale distribution (2-halo term, filaments)
  - Cross-correlations

# Population Studies

Planck Collaboration Int. XI (2013)



Anderson et al. (2015)



Implications for feedback: gas pushed out to  
 $R_{500} < R < 5R_{500}$

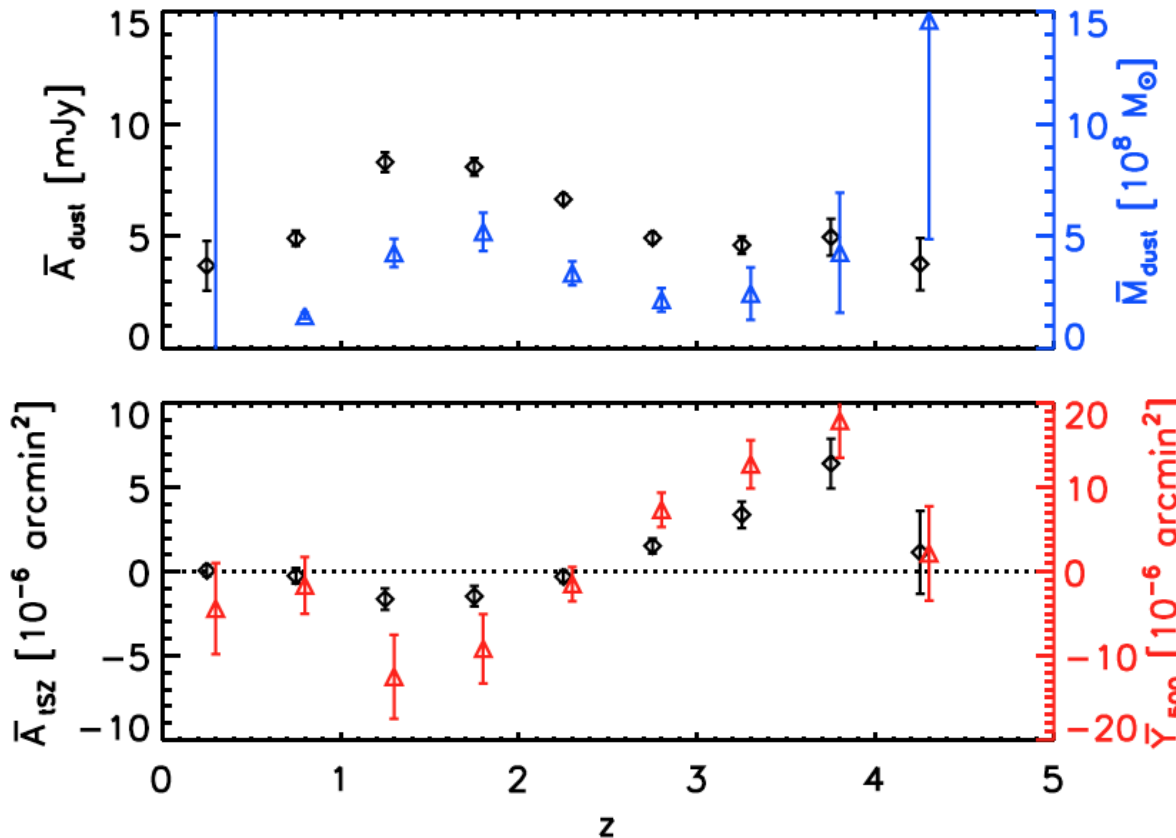
# Population Studies: QSOs

Verdier et al. (2016): Planck

Tracer of SF

tSZ at  $z > 3$ !

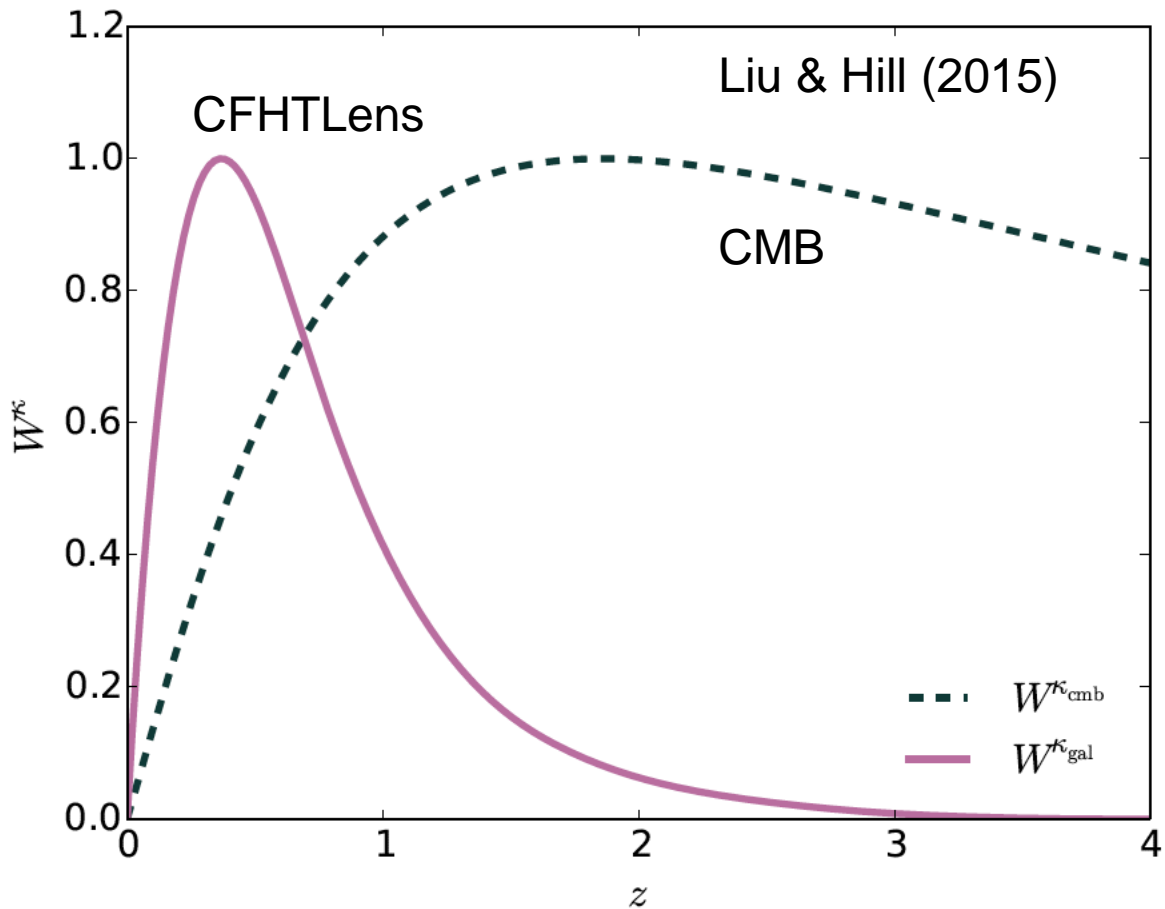
Constraints on  
QSO feedback



See also Crichton et al. (2016): ACT

# CMB Halo Lensing

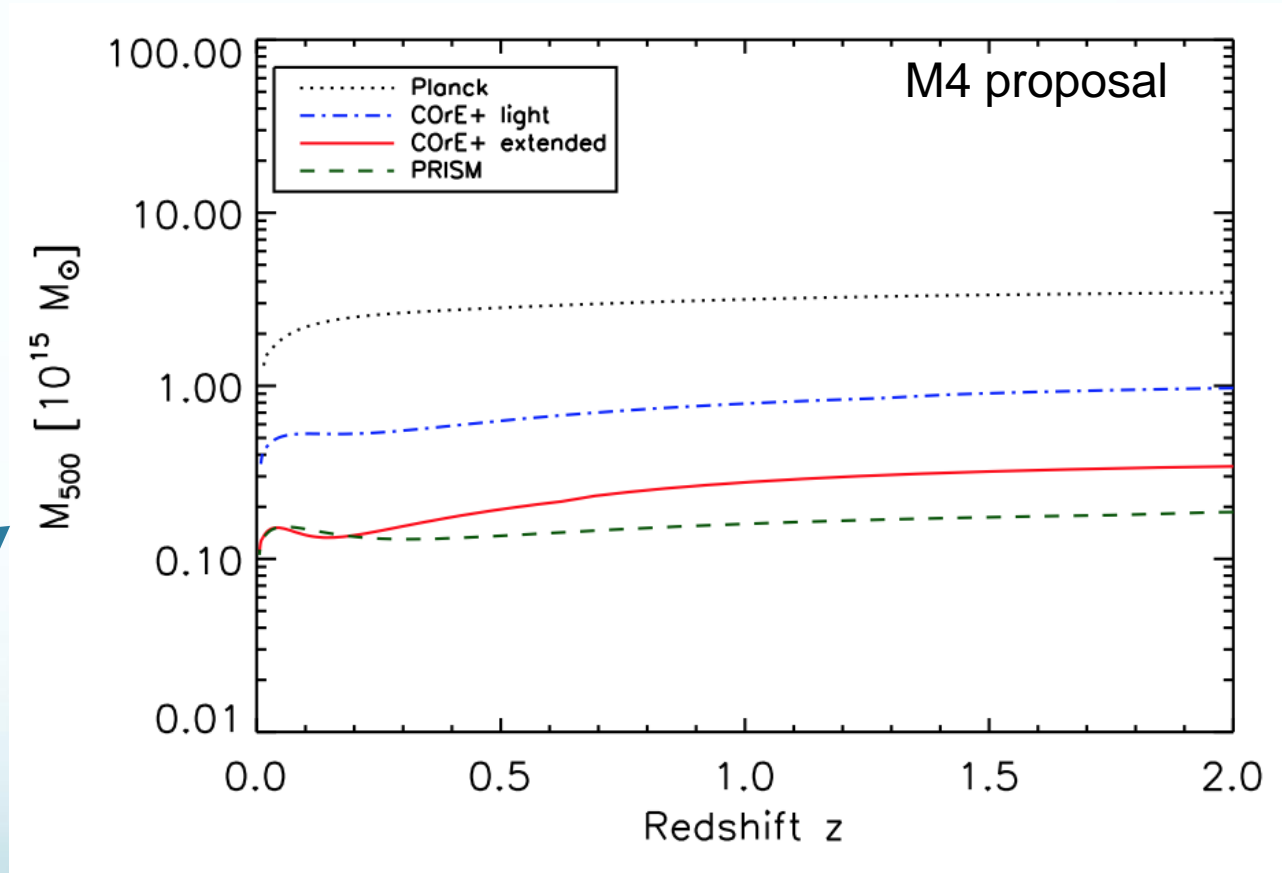
- CMB: Much broader lensing kernel
- Reach critical high- $z$  epochs



# CMB Halo Lensing

- Stack on selected objects

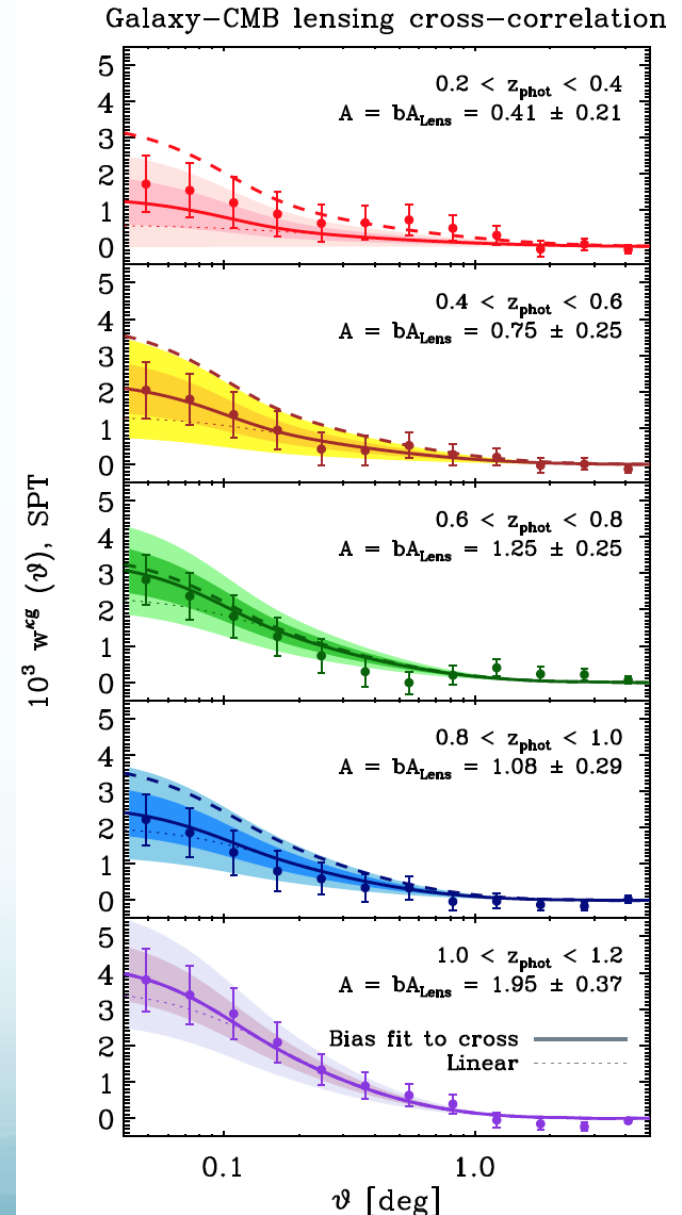
1-sigma filter noise  
(Melin & Bartlett 2015)



# Cross Correlations

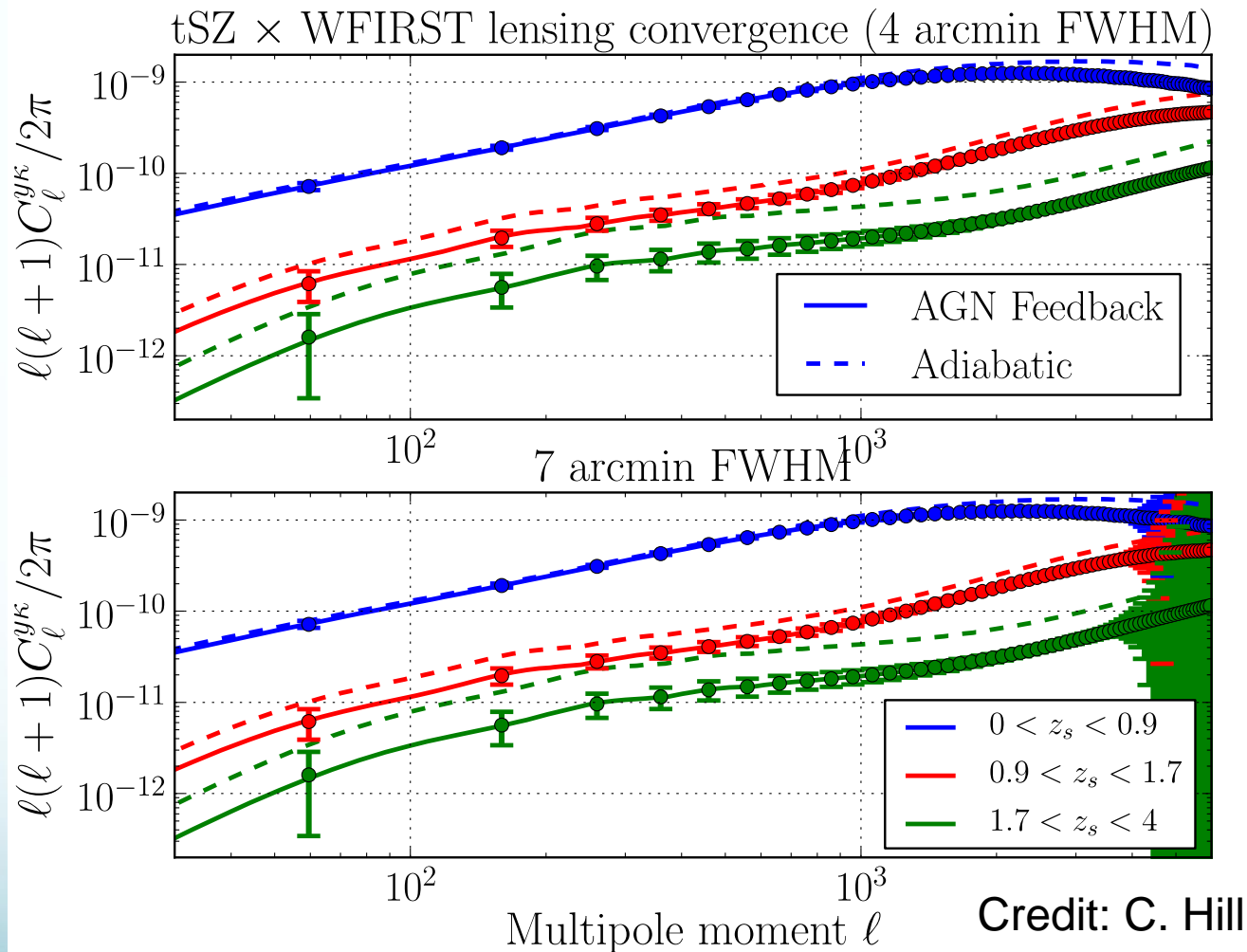
- SPT CMB lensing
- Dark Energy Survey SV galaxies
- Tomography
  - Galaxy bias
  - Structure growth rate (neutrino mass, dark energy, modified gravity)

Giannantonio et al. (2016)



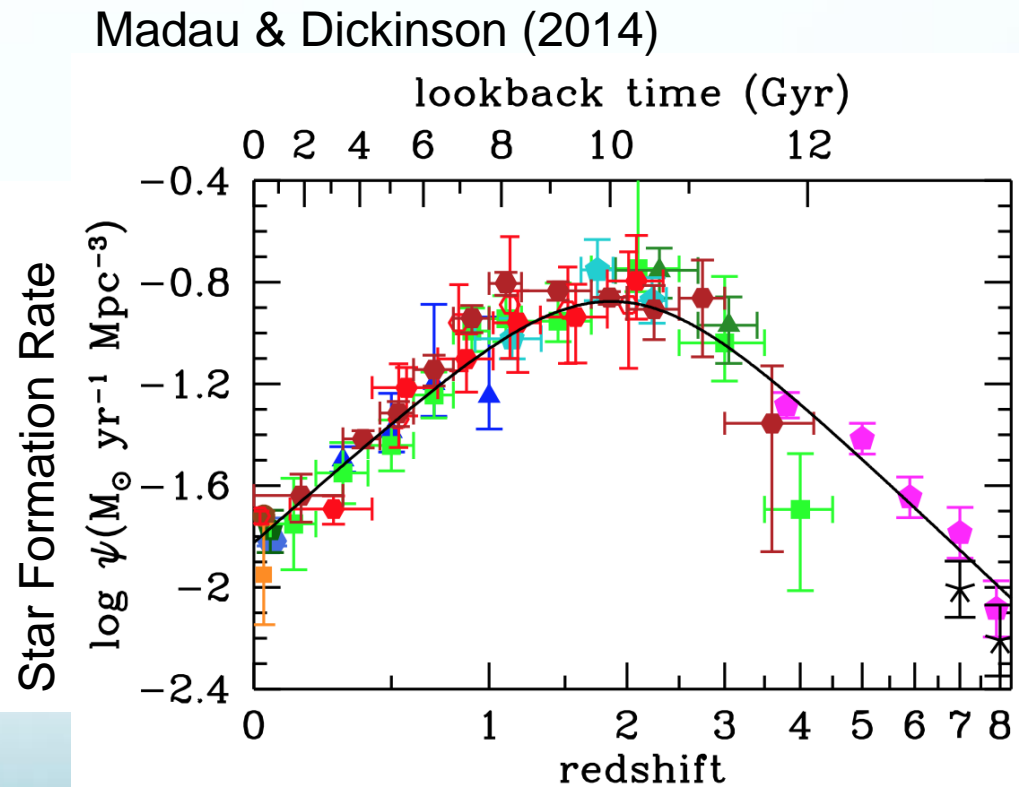


# Cross-Correlations



# Unique Science

- Probe critical epochs of galaxy formation:  $z \sim (1-8)$



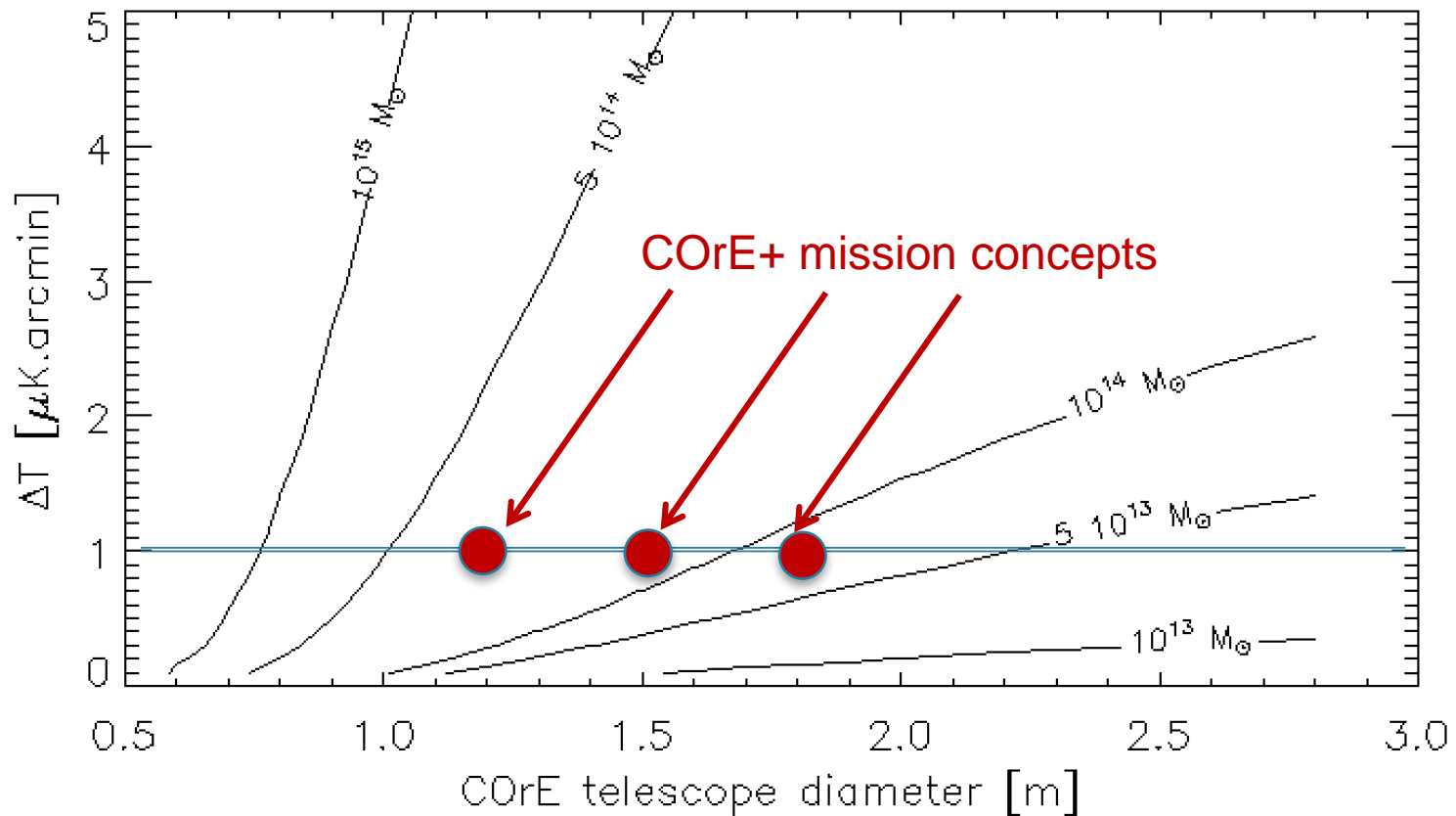
# Unique Science

- Probe critical epochs of galaxy formation:  $z \sim (1-5)$
- Trace hot gas phase over critical epochs
  - Feedback mechanism running thermal cycle
  - **Recall: galaxy formation is inefficient: Why?**
- Trace dust during critical epochs
  - Metal production
  - Star formation activity
- Trace dark matter
  - Host halos
  - Larger-scale distribution

# Impact on Mission

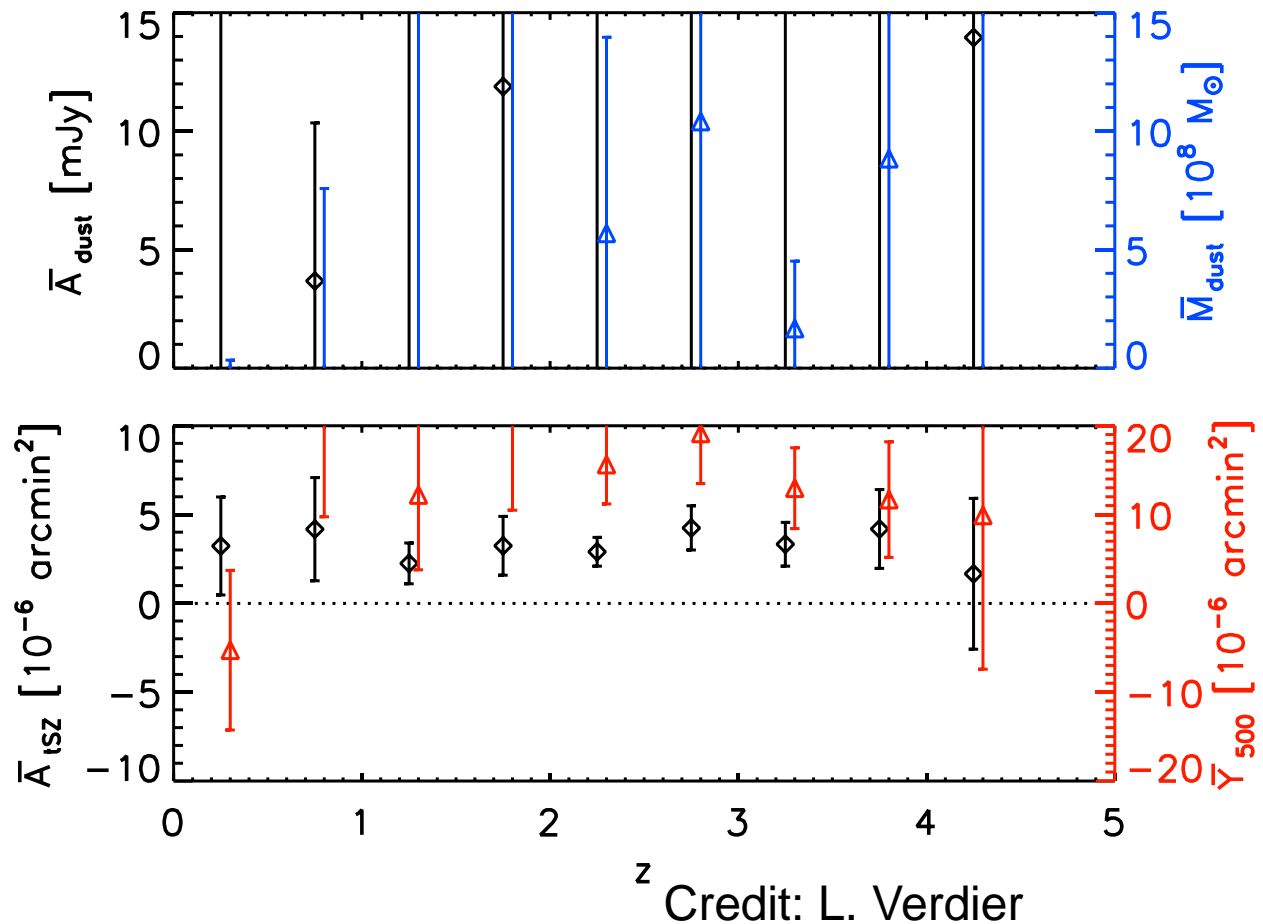
- Frequency coverage for tSZ and Dust
  - Population studies: +resolution
  - Large-scale distribution: e.g., CIB/SZ separation
- Resolution for CMB halo lensing

# CMB Halo Lensing



# Frequency Coverage

- QSO study with: 70, 100, 143 & 217 GHz
- Loose dust information
- Bias SZ signal
- **Need high frequencies**



# Work

- Sell science case
  - Outside our community
- CMB halo lensing
  - Minimum variance estimator
- Sensitivities for SZ, dust & mass stacks
- Cross-correlation predictions
- Studies for different mission profiles

# Work

*Astronomy & Astrophysics* manuscript no. corelss  
May 19, 2016

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## ***COrE+*: Large-Scale Structure Science**

The *COrE+* Collaboration  
James G. Bartlett, Jean-Baptiste Melin et al.

Received ; accepted

### **ABSTRACT**

This is the abstract.

**Key words.** Large-Scale Structure

- 1. Introduction**
- 2. Census of the Baryons**
- 3. Halo Lensing**
- 4. Cross-Correlations**
- 5. Conclusion**

*Acknowledgements.* Here are the acknowledgements...