Science Goals of the Simons Observatory

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for the SO Collaboration

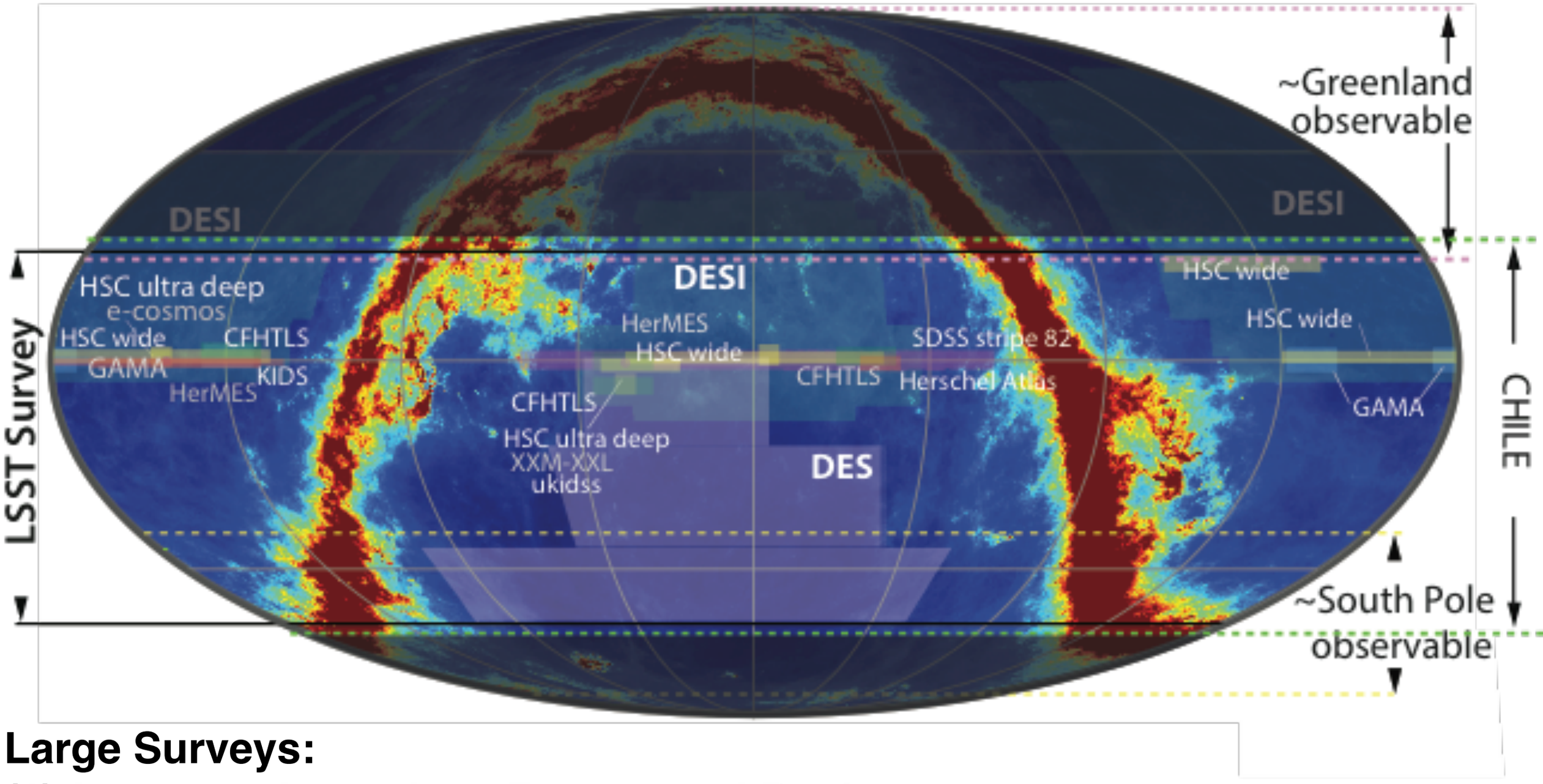
CMB at Atacama

Cerro Toco

5190 metres in the Atacama Desert

Why CMB Observations From Chile?

Foreground + optical survey coverage map



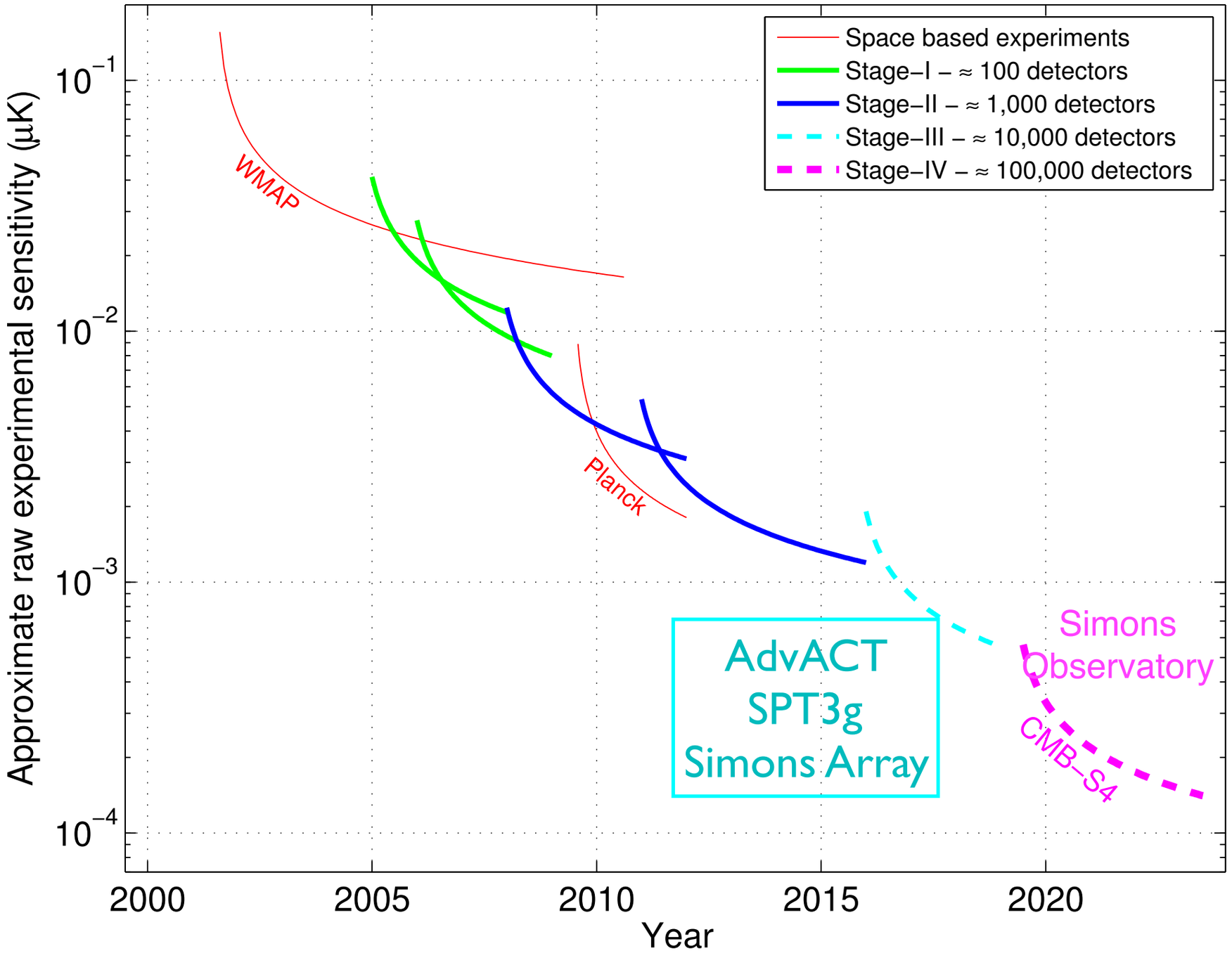
Large Surveys:

(1) Access to Large Low Foreground Regions

(2) Overlap with optical surveys

(3) Overlap with ALMA

Moore's law for CMB surveys

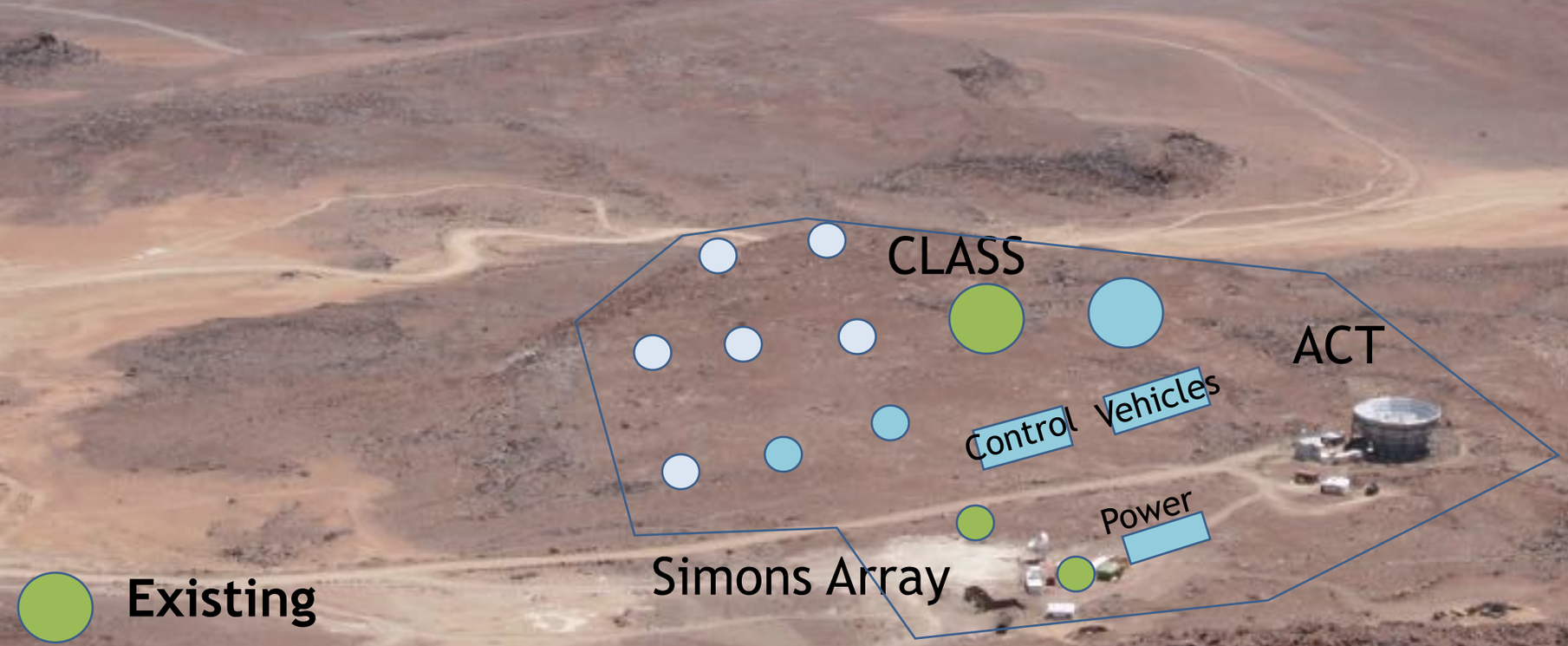


Abazajian+ 2014 (CMBS4 Snowmass white paper)

Simons Observatory

- Merger of ACT and Polarbear/ Simons Array teams

ALMA



Simons Observatory

- 8 Countries
- 45+ Institutions
- 150+ members

United States

- Carnegie Mellon University
- Columbia University
- Cornell University
- Florida State
- Haverford College
- Johns Hopkins University
- Lawrence Berkeley National Laboratory
- NASA/GSFC
- NIST
- Princeton University
- Rutgers University
- Stanford University/SLAC
- Stony Brook
- University of California - Berkeley
- University of California – San Diego
- University of Colorado
- University of Illinois at Urbana-Champaign
- University of Michigan
- University of Pennsylvania
- University of Pittsburgh
- West Chester University

Canada

- CITA/Toronto
- Dalhousie University
- Dunlap Institute/Toronto
- McGill University
- University of British Columbia

Chile

- Pontificia Universidad Catolica
- University of Chile

Europe

- APC - France
- Cardiff University
- Imperial College
- Manchester University
- Oxford University
- SISSA – Italy

Japan

- KEK
- IPMU

South Africa

- Kwazulu-Natal, SA

San Diego three weeks ago

San Diego three weeks ago

SO Members here this week: 14+

Not pictured: Aiola, Duivenvoorden, Freese, Gerbino, Gudmundsson, Ho
(apologies to anyone I missed)

Simons Observatory Timeline

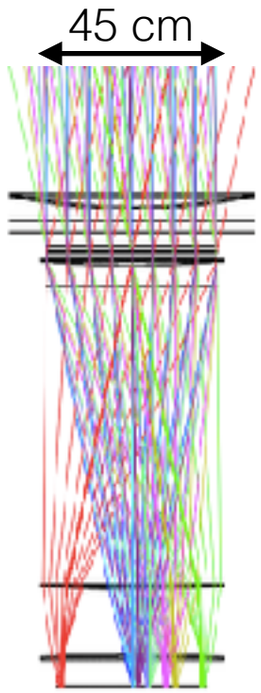
- 2016-17: Planning and technology development
- 2016-18: Logistical upgrades to the site infrastructure
- By end of 2020: Construction and installation of telescopes
- By end of 2020: Production of new CMB-S4-type receivers with partially filled focal planes
- 2021 and beyond: Observing!

The Simons Observatory is a Stepping Stone to CMB-S4 in Chile

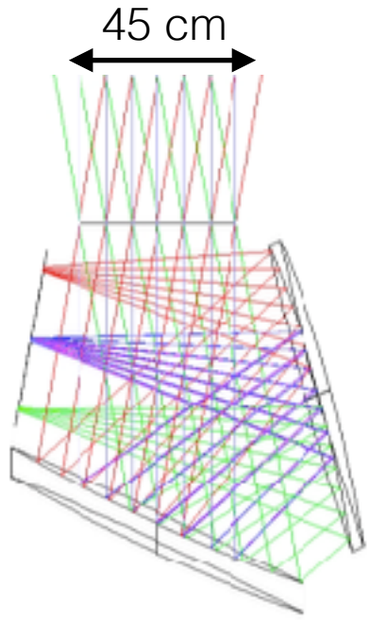
- Technology, Theory and Analysis Development
  - Detectors, Optics, Telescopes, Receivers, Simulations, Software.
- Development complements CMB-S4 funding from DOE and NSF
- S4-capable telescopes and receiver prototypes for Chile
  - Accelerate the S4 process and benefit the entire S4 community.

Small-aperture telescopes

Two possible configurations



2-refractor setup



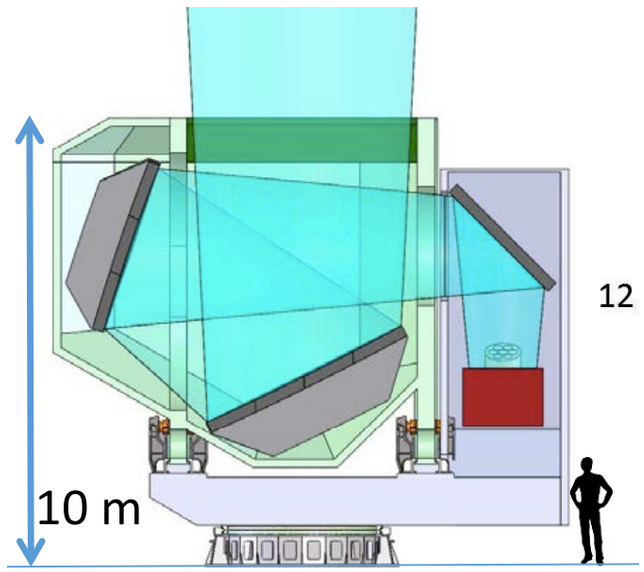
crossed Dragone setup

- Multiple telescopes, each with a single set of multichroic bands
- Include HWP (see Lyman's talk)
- Up to 8 bands between 30 - 300 GHz — details TBD

Large-aperture telescope

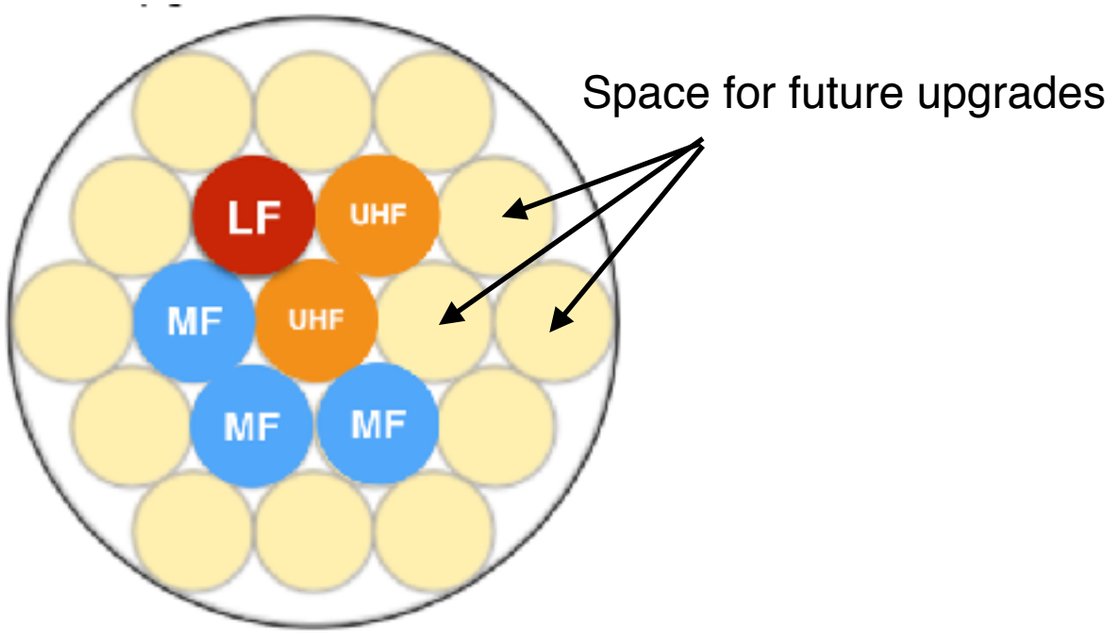
- 1’.5 - 1’.8 res at 150 GHz
  => 5+ metre aperture
- Up to 8 bands between 30 - 280 GHz — details TBD

5 m Cross Dragone



Niemack 2015

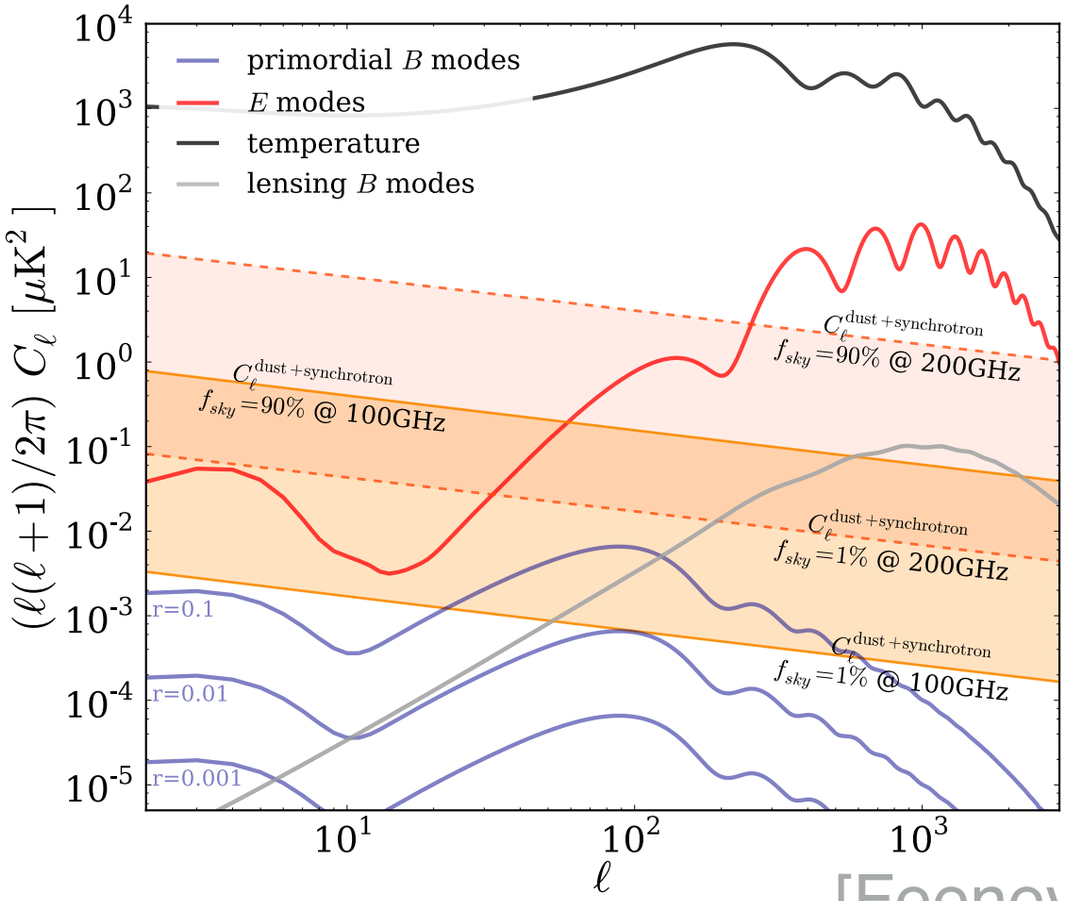
Receiver	Channel
LF	30 GHz
	40 GHz
MF	90 GHz
	150 GHz
HF	150 GHz
	220 GHz
UHF	230 GHz
	280 GHz



One possible configuration!
Choices are currently under consideration.

Science goals

r



[Feeney, Errard+2015]

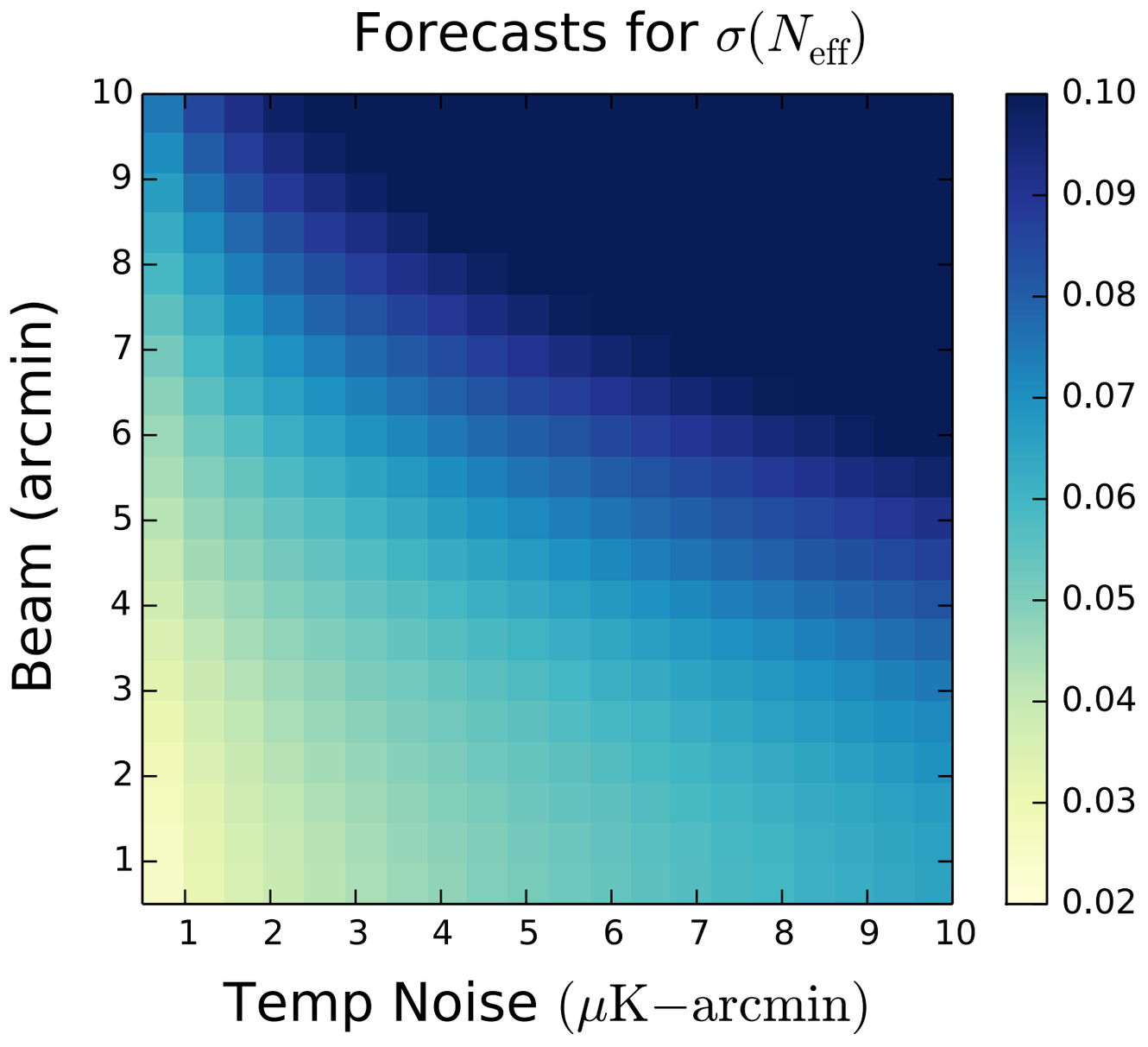
- Be able to test isotropy, frequency spectrum, scale dependence of any signal
  - Several patches of sky at f_{sky} = few % (deep)

N_{eff}

- N_{eff} defined via $\rho_{\rm r} = \rho_\gamma \left(1 + \frac{7}{8}\left(\frac{4}{11}\right)^{4/3} N_{\rm eff}\right)$
- v + other ρ_r: CMB damping
- v + free-streaming ρ_r: CMB phase shift
  (detected with *Planck*, Follin+ 2015)

$$N_{\rm eff}^{\rm CMB} = 3.04 \pm 0.18$$

- $\Delta N_{eff} >= 0.027$ for particles in TE with SM

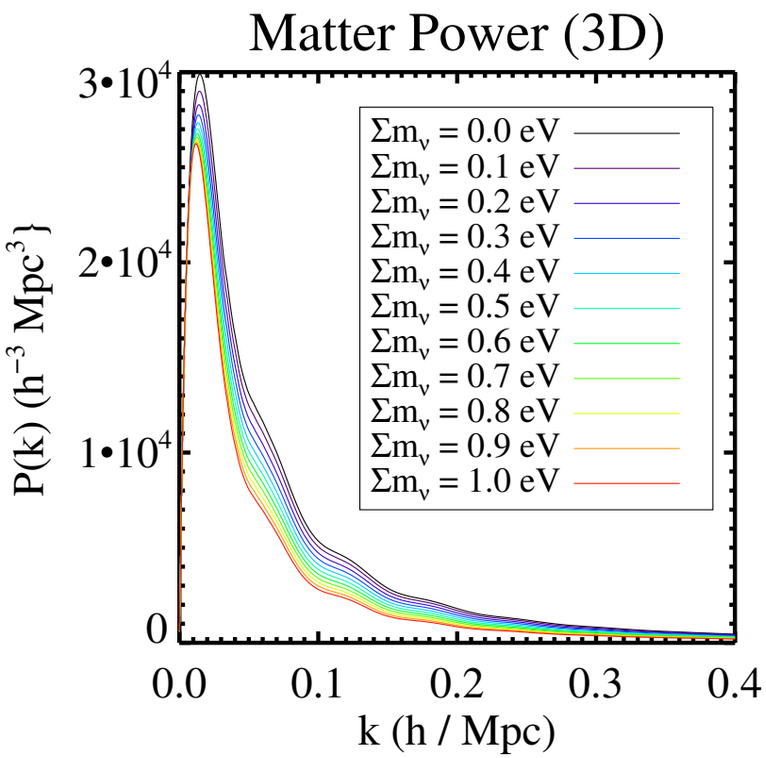


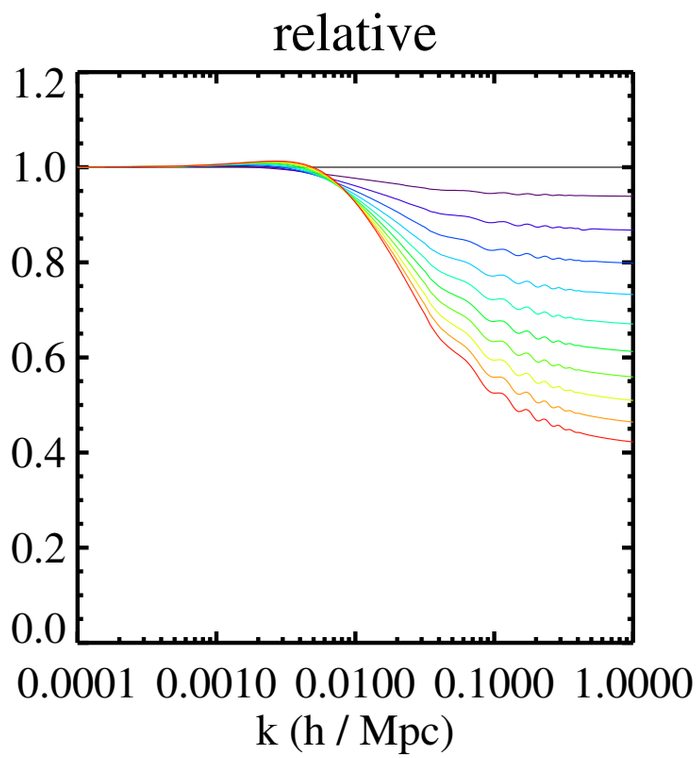
ΔN_{eff}

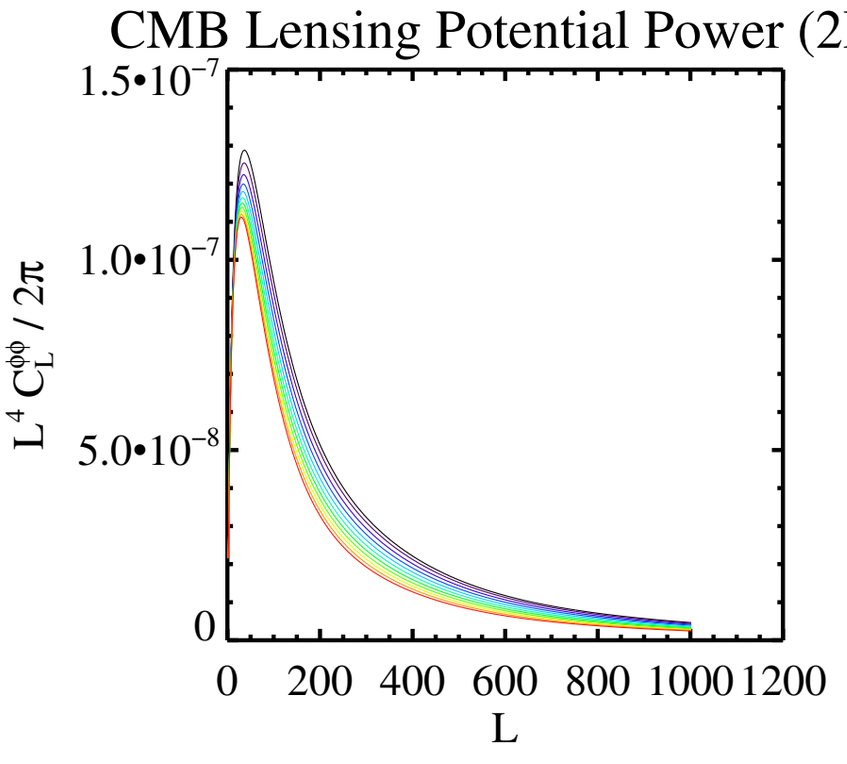
- Best results for wide survey — f_{sky} ~10-40%
  - Target noise: few uK-arcmin
  - Done in conjunction with small-patches surveys for *r*
- Driven by TE power
  Some dependence on atm. power and point sources in TT
- Possible challenge: beam systematics

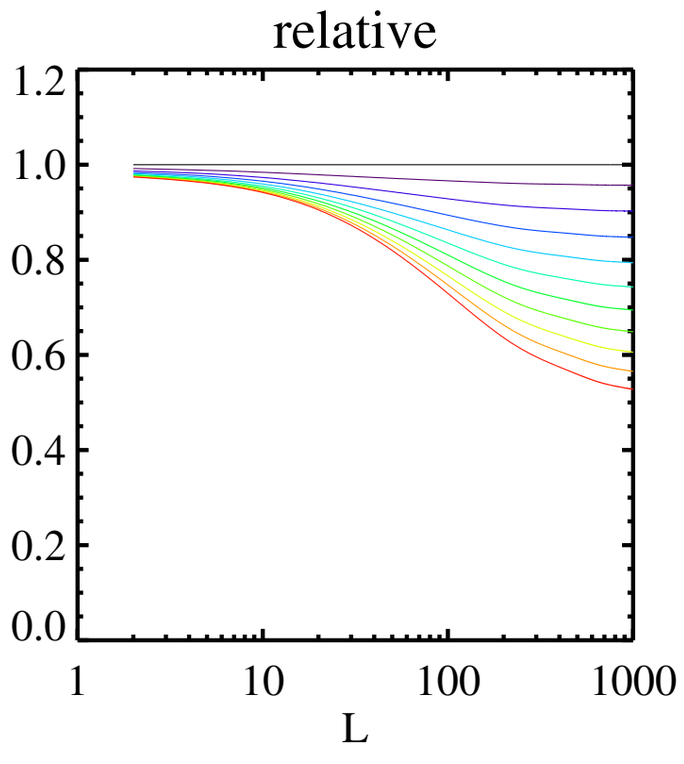
- Delensing of TT and EE can help! see Anthony Challinor's talk
  [Green, Meyers, AvE 2016]

Lensing autospectrum - Σm_ν







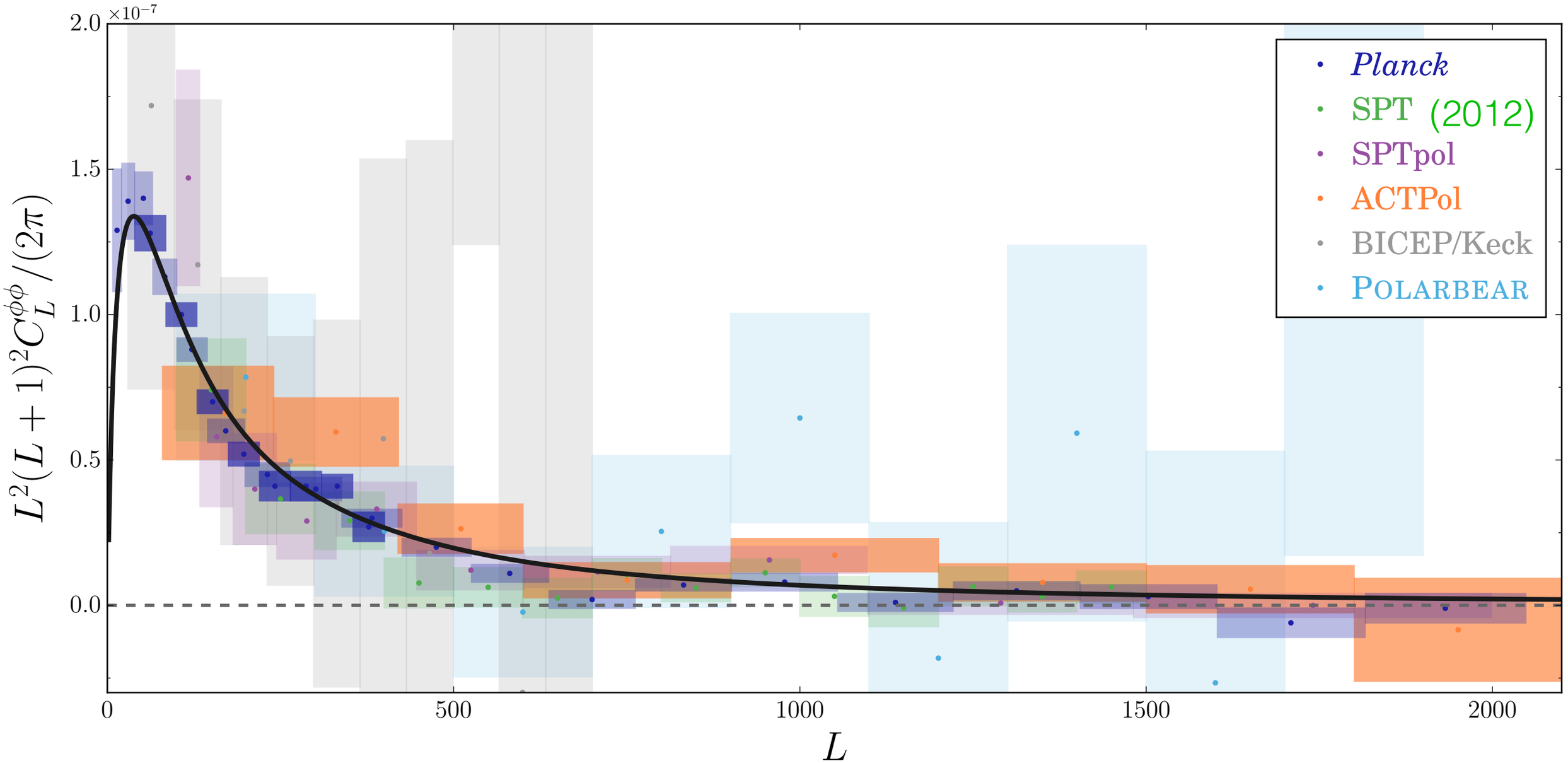


See Marilena LoVerde, Martina Gerbino talks

CMB-S4 Science Book

Lensing autospectrum - Σm_ν

Current Data

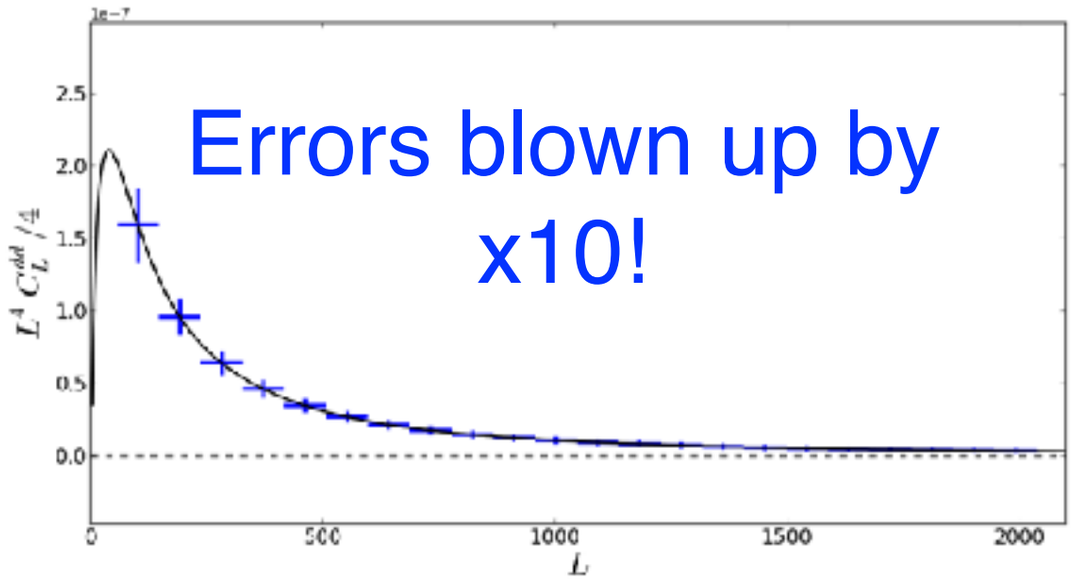


New SPT-2500 points not shown
See Kyle Story's talk

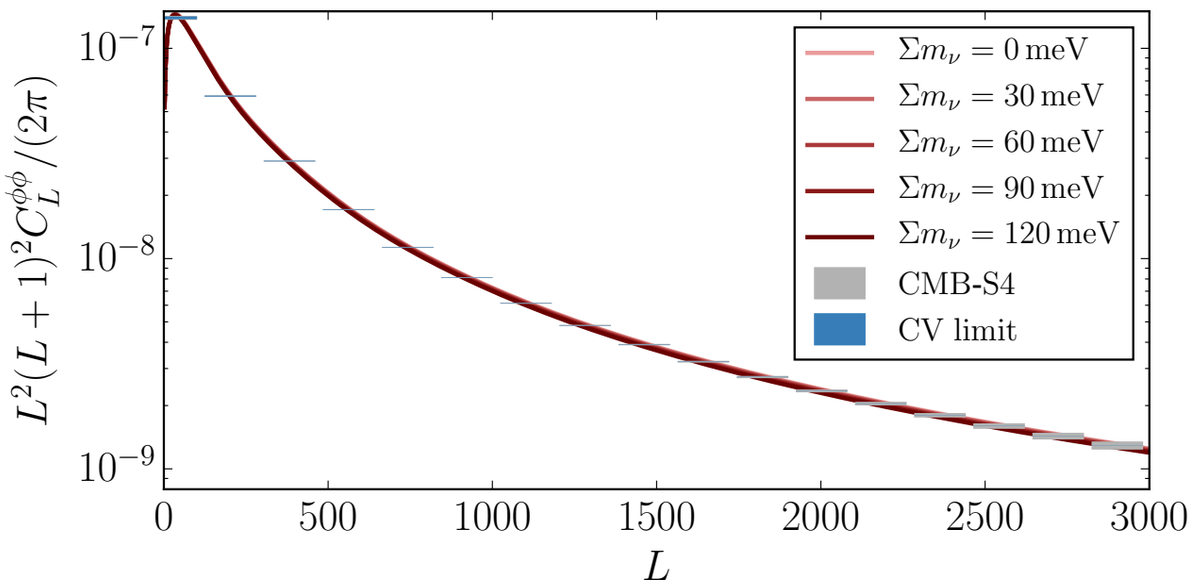
from two-season ACTPol
Sherwin, AVE ++ (2016)
See Blake Shwerwin's Talk

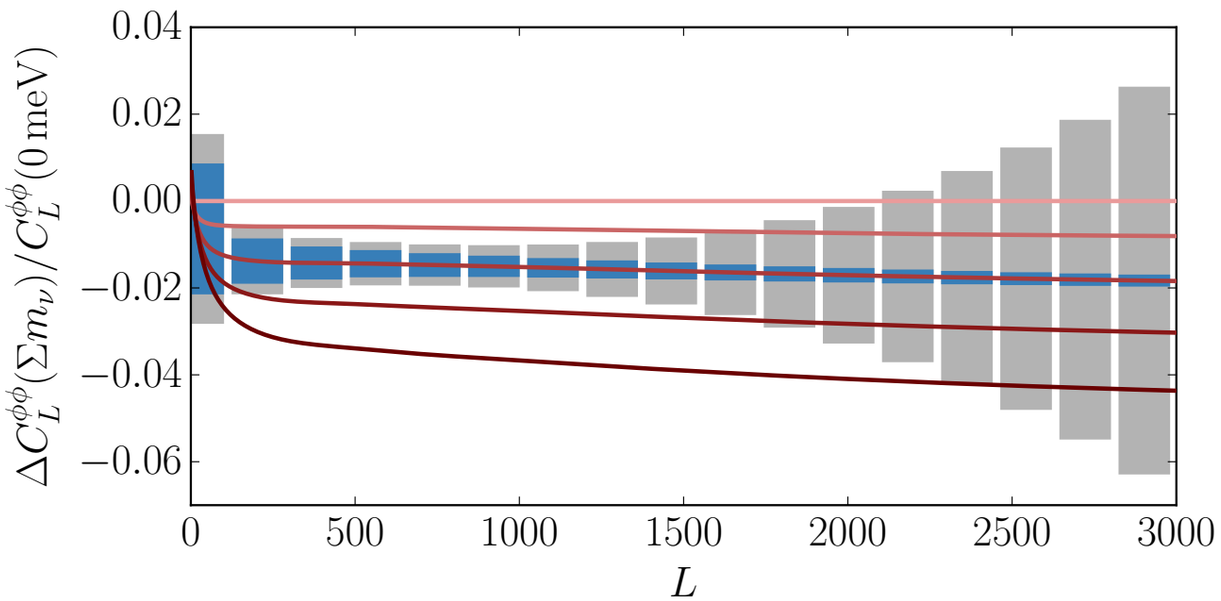
Lensing autospectrum - Σm_ν

SO forecast
<1% precision



Possibility
with CMB-S4
~0.2% precision





CMB-S4 Science Book

Lensing autospectrum - Σm_ν

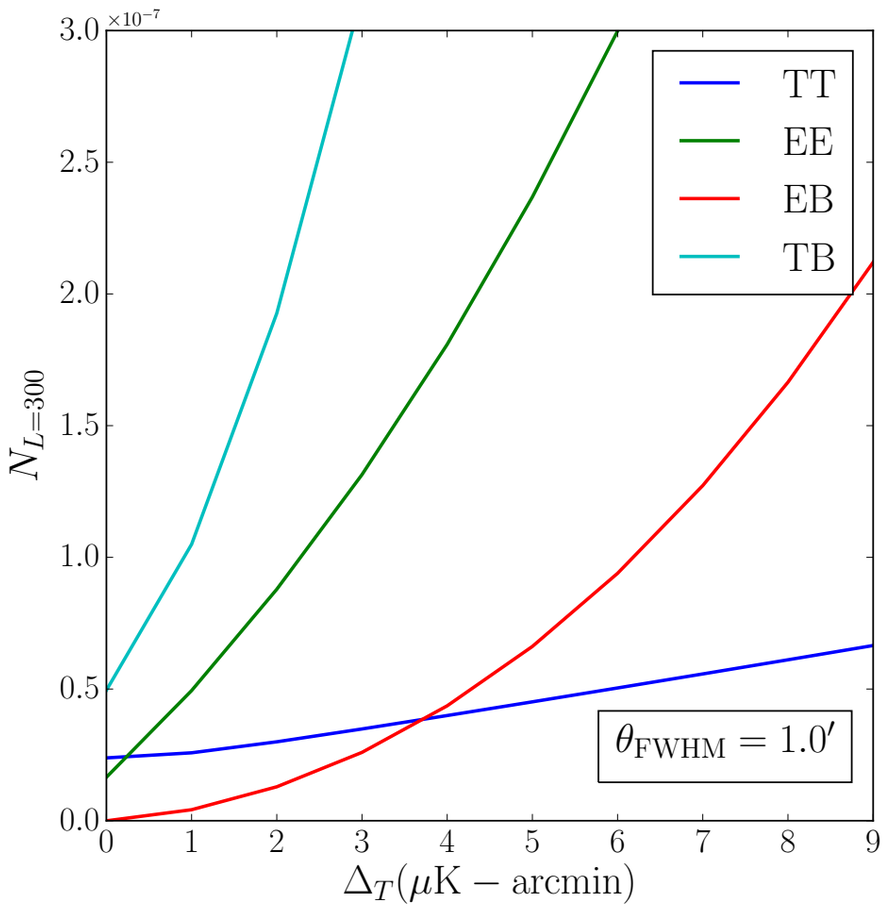
Challenges

Roughly same weight for T and P.

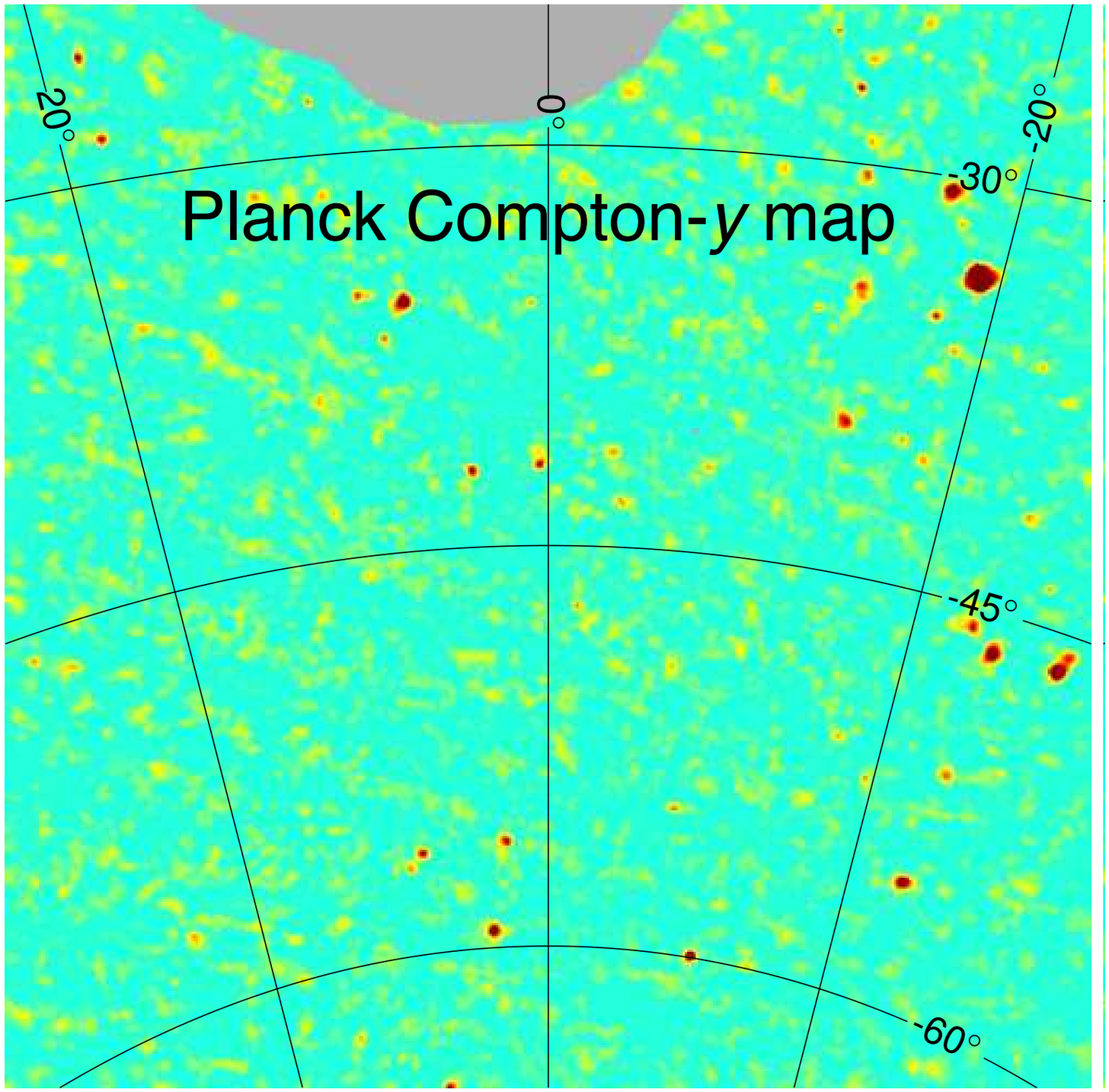
Statistically independent.

Separate systematics:

- Temp: Extragalactic NG [AvE+2013, Osborne+2015, Ferraro & Hill 2017]
- Pol: Galactic NG [Challinor+(CORE)2017, AvE+ in prep]

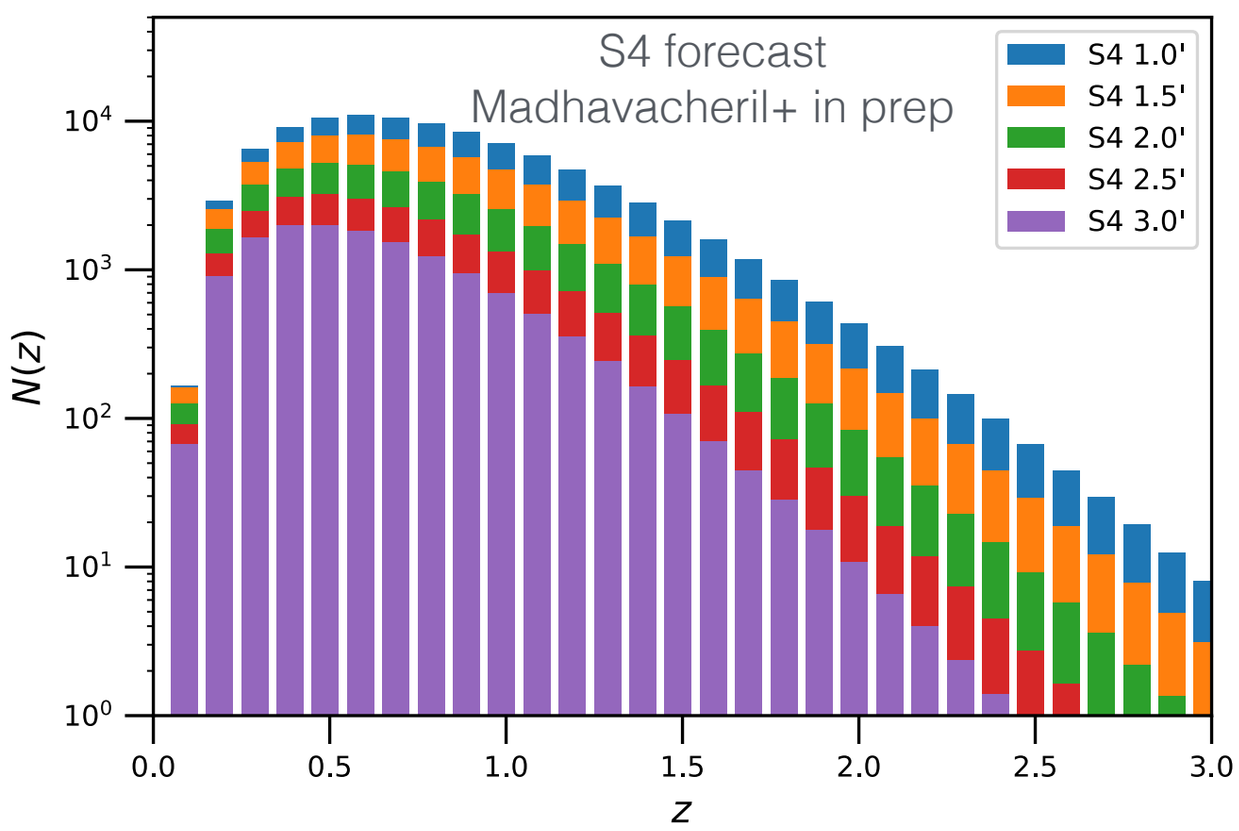


tSZ

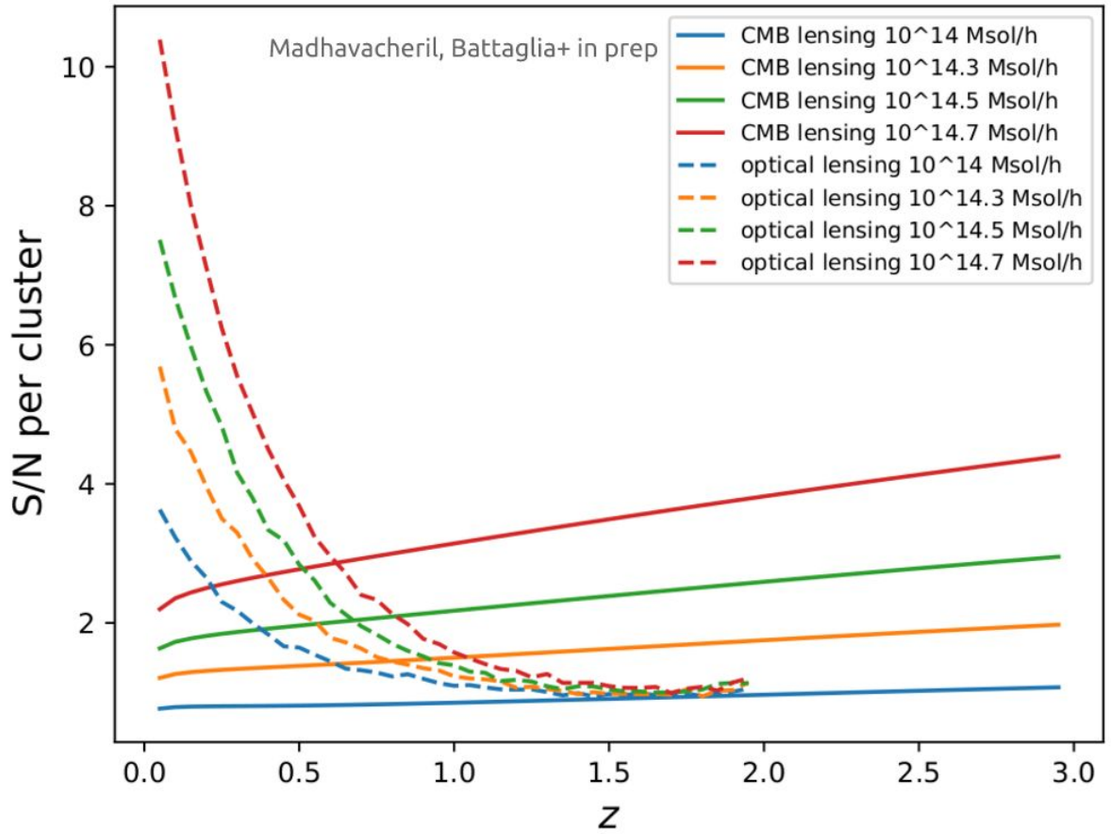


tSZ - finding & counting clusters

- Potential for discovery of ~10^4 of clusters, at high z
  (Planck: 10^3; S4: ~10^5)

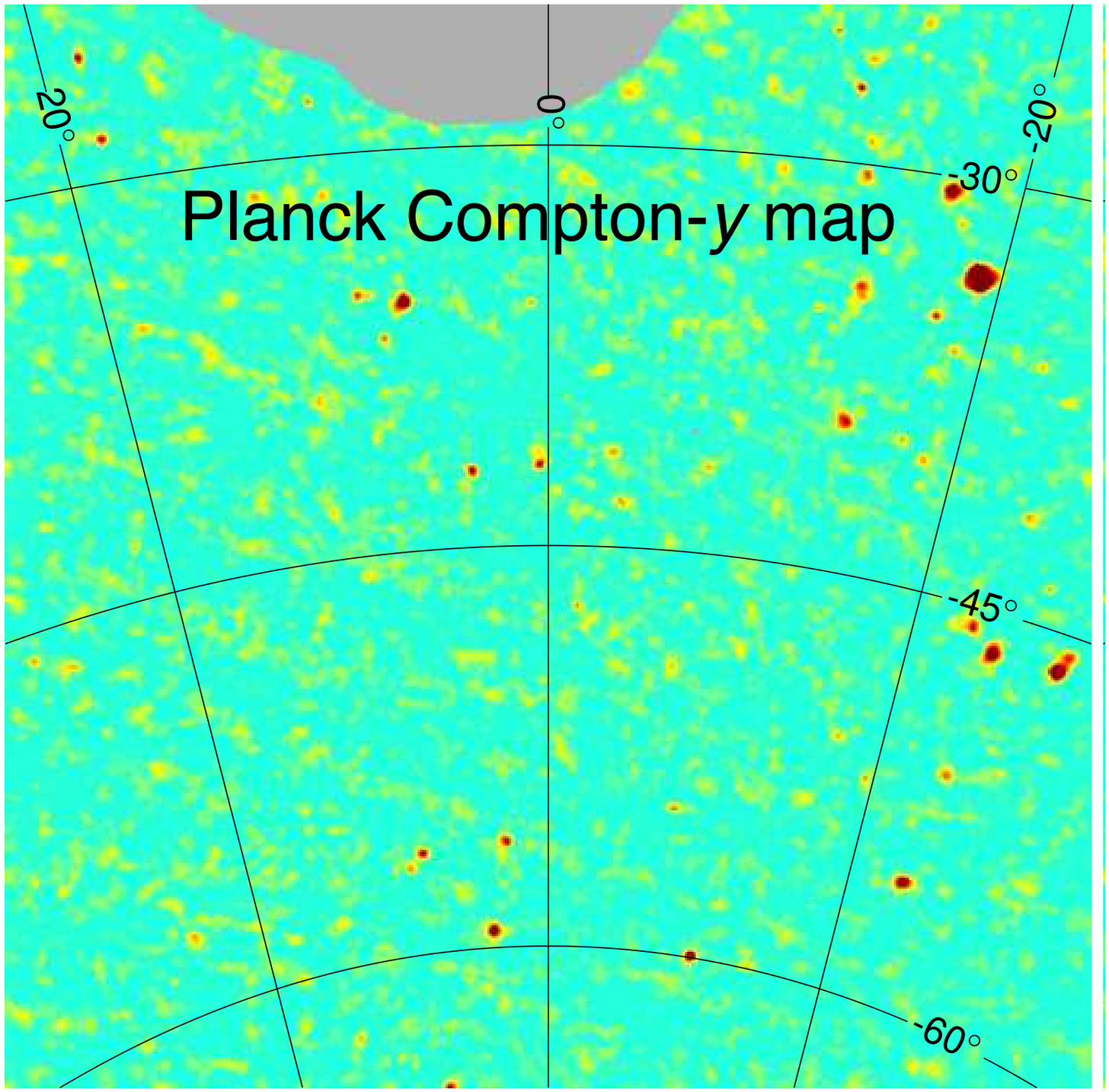


- Internal mass calibration via CMB halo lensing, or optical weak lensing
  [Louis & Alonso 2016, Madhavacheril+ in prep]



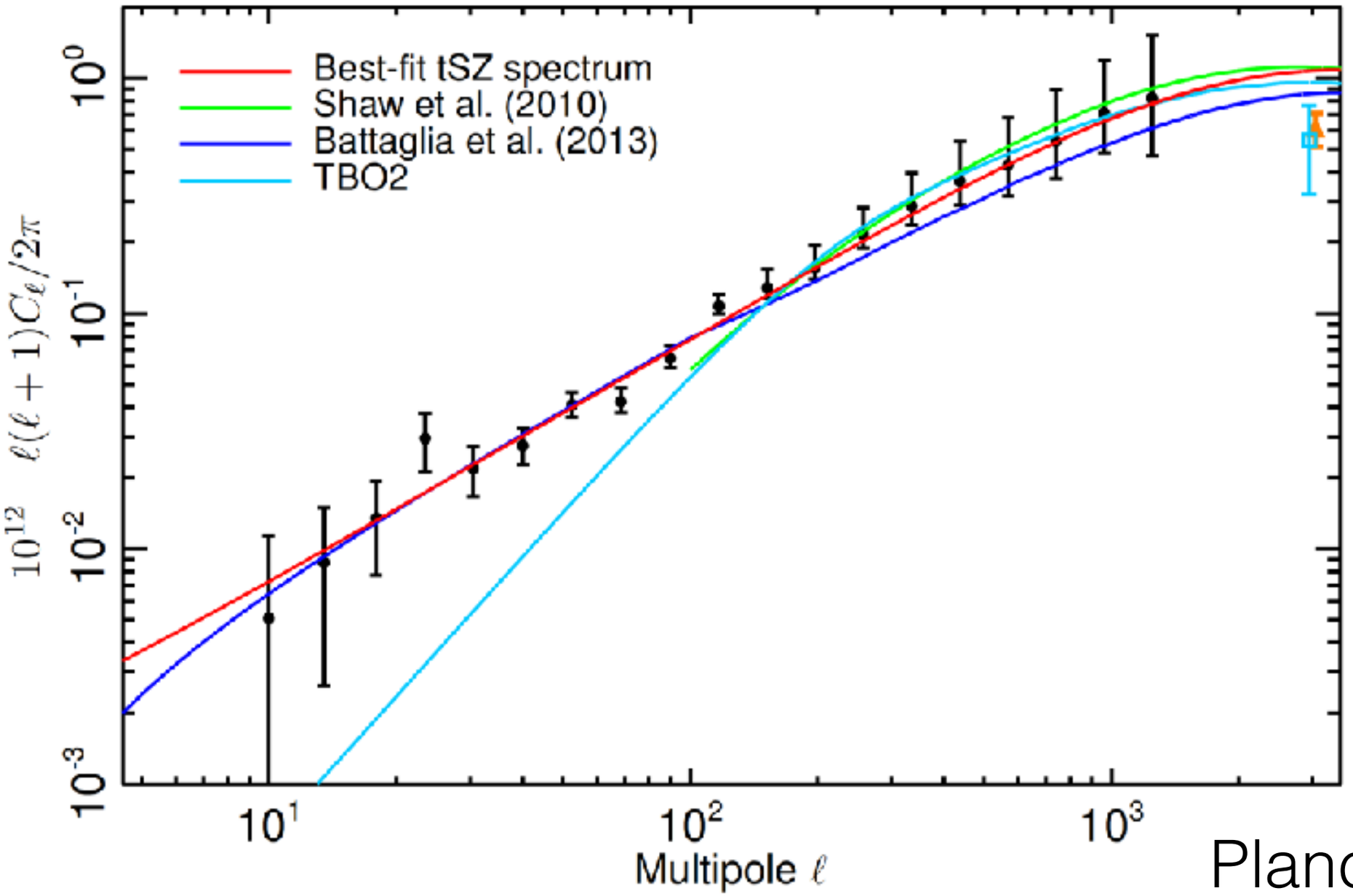
- Can be competitive with lensing for Σm_ν

tSZ



tSZ - power spectrum

Abundance (σ_8) and gas physics
Low-M, high-z halos

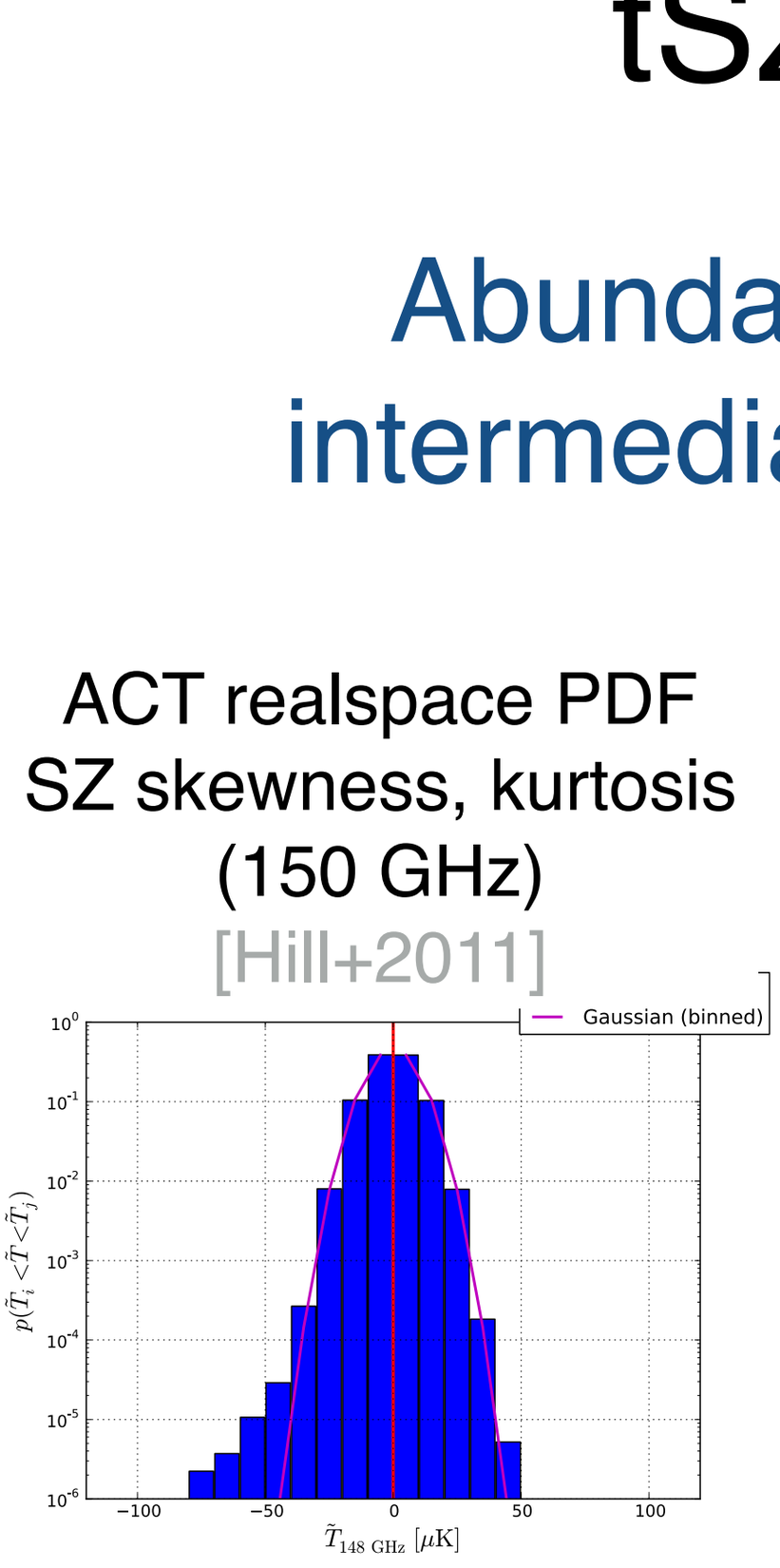


Planck 2015

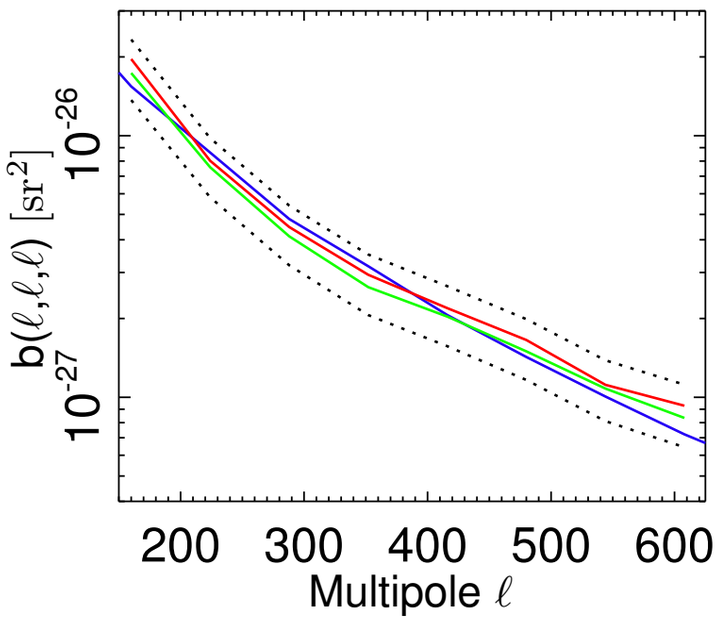
tSZ - higher order

Abundance (σ_8) and gas physics intermediate-M, intermediate-z halos

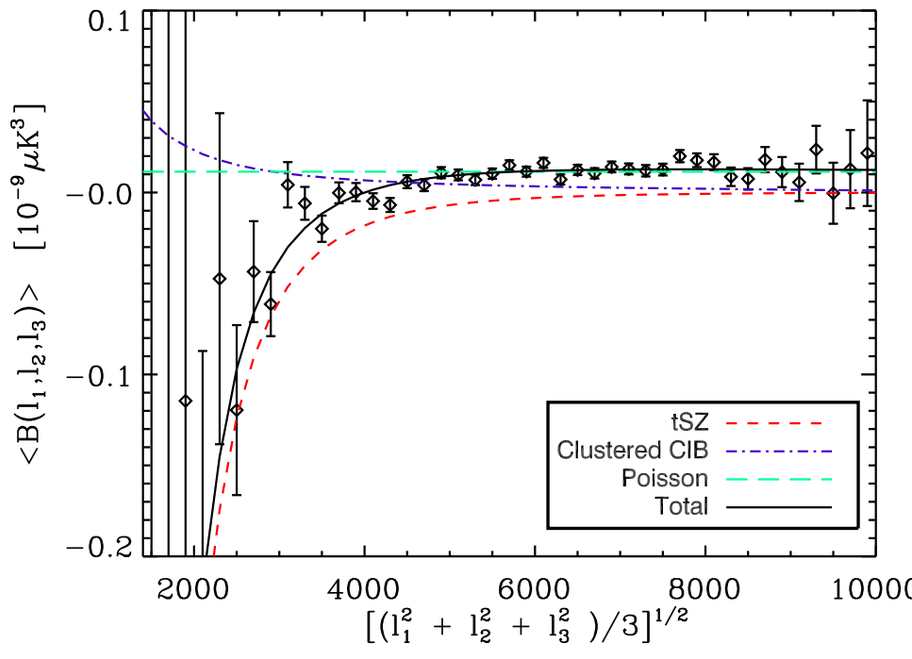
ACT realspace PDF
SZ skewness, kurtosis
(150 GHz)
[Hill+2011]



Planck SZ Bispectrum
[XXII 2015]



SPT SZ Bispectrum
(150 GHz)
[Crawford+2012]

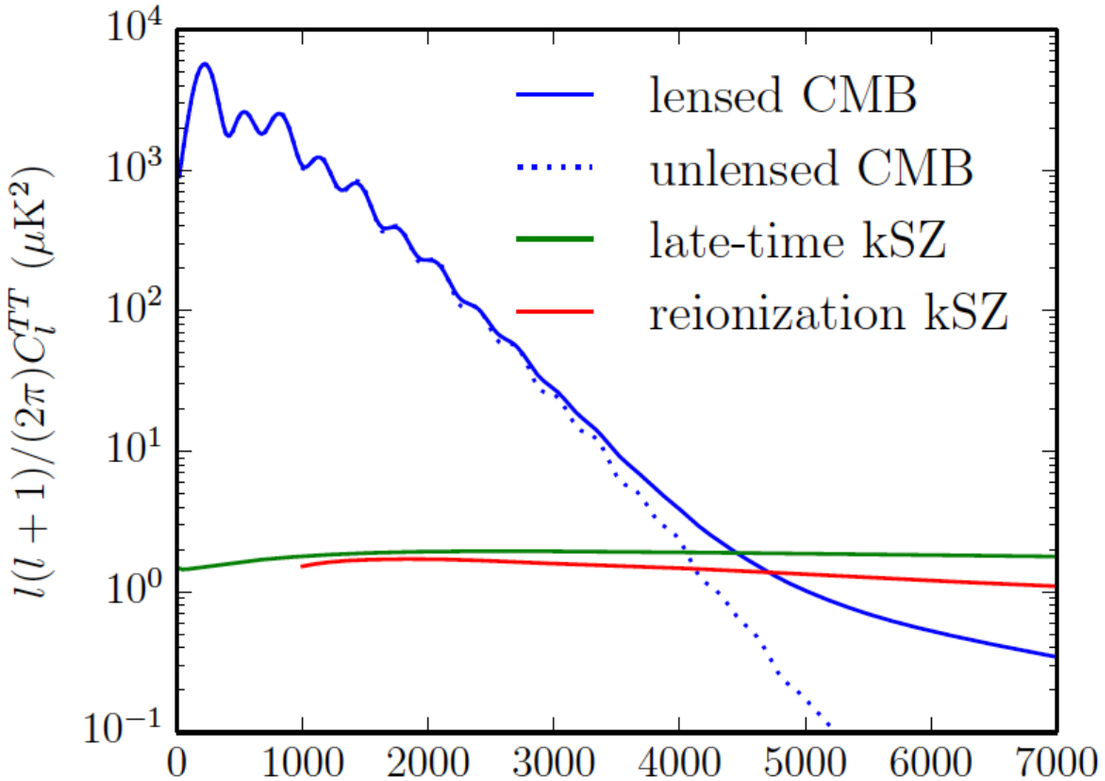


See Will Coulton's Poster

kSZ

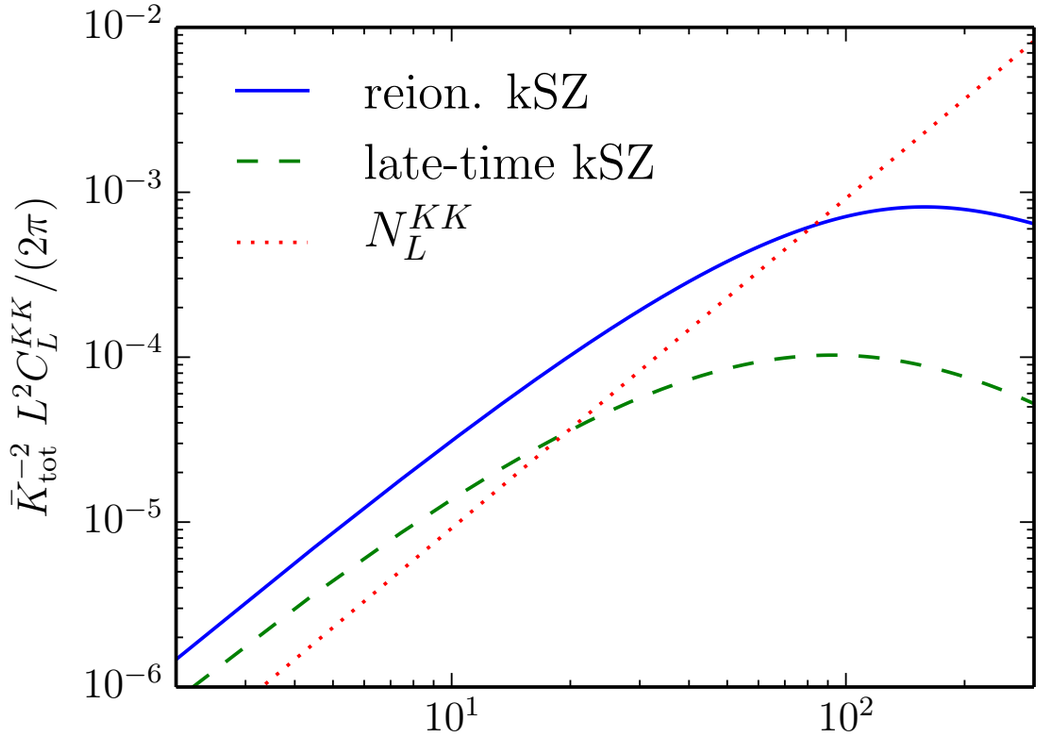
- Power spectrum

  10% constraint on Δz
  (fixed late-time)



- Power spectrum of the power spectrum
  see Simone Ferraro's talk for details

- also, cross-corr with tracers Emmanuel Schaan



Smith&Ferraro 2016

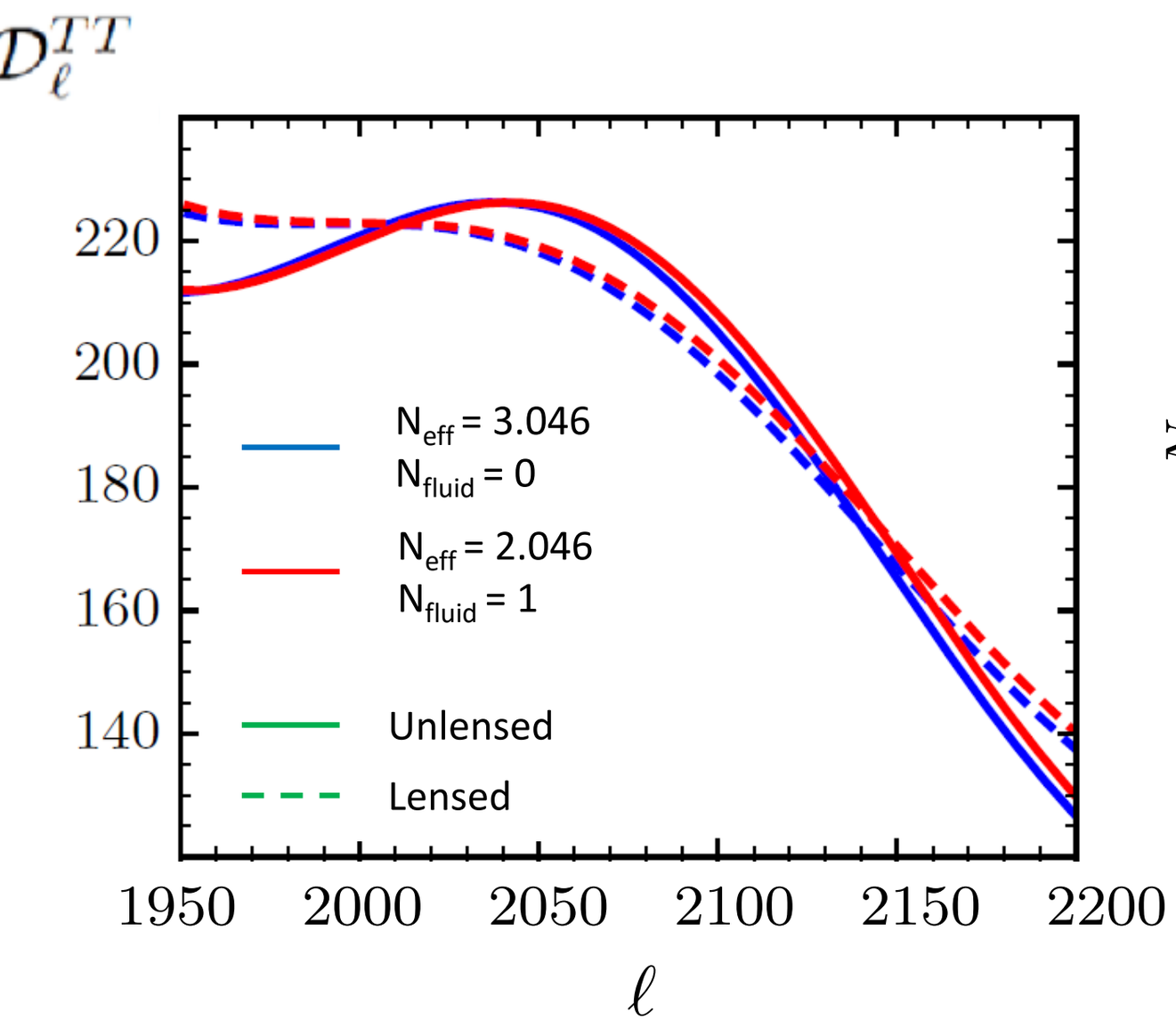
Summary

- Simons Observatory will happen, & soon!
  Construction in 2020, observing in 2021+
- Planning and optimization currently ongoing
- Many science targets:
  - r, mnu, N_{eff}, w, (g)astrophysics
- Through a number of separate channels:
  CMB power spec at high ell
  lensing auto
  lensing crosses
  tSZ in several ways
  kSZ in several ways

Extra slides

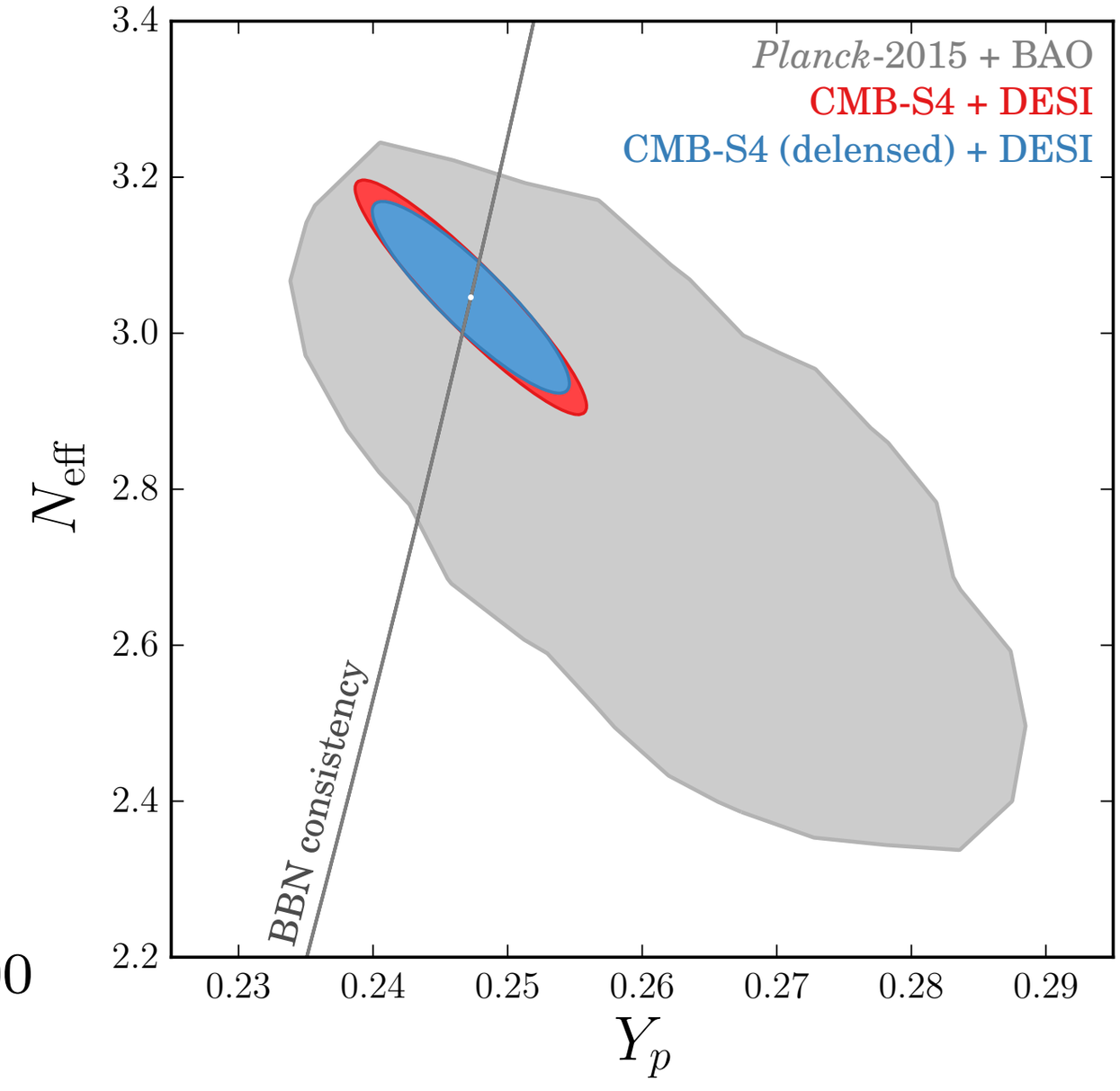
$N_{eff} + Y_p$

- Phase shift info affected by lensing



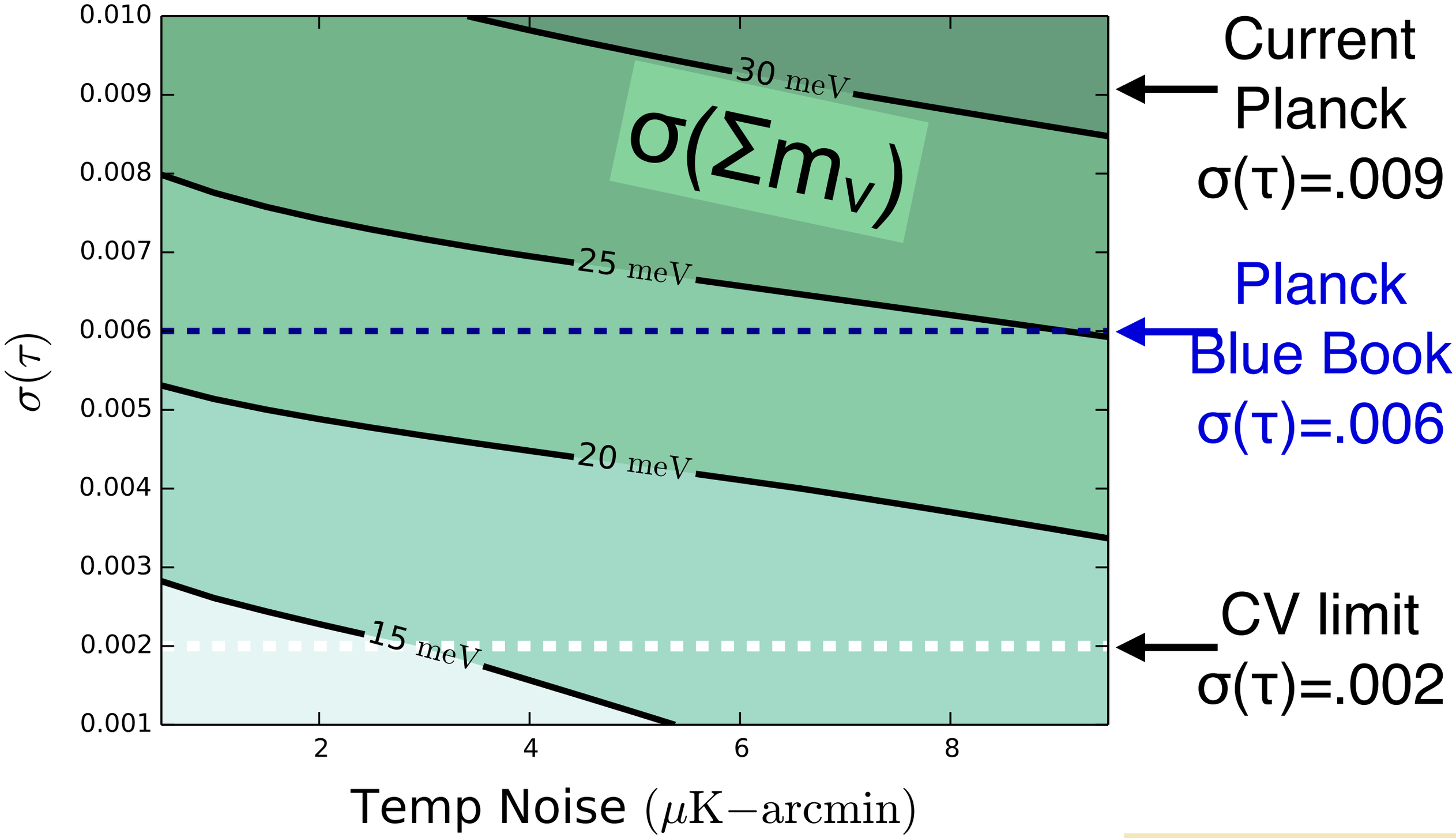
Baumann, Green, Meyers, Wallisch 2015

- Delensing TT, EE (see Anthony Challinor's talk) breaks degeneracy



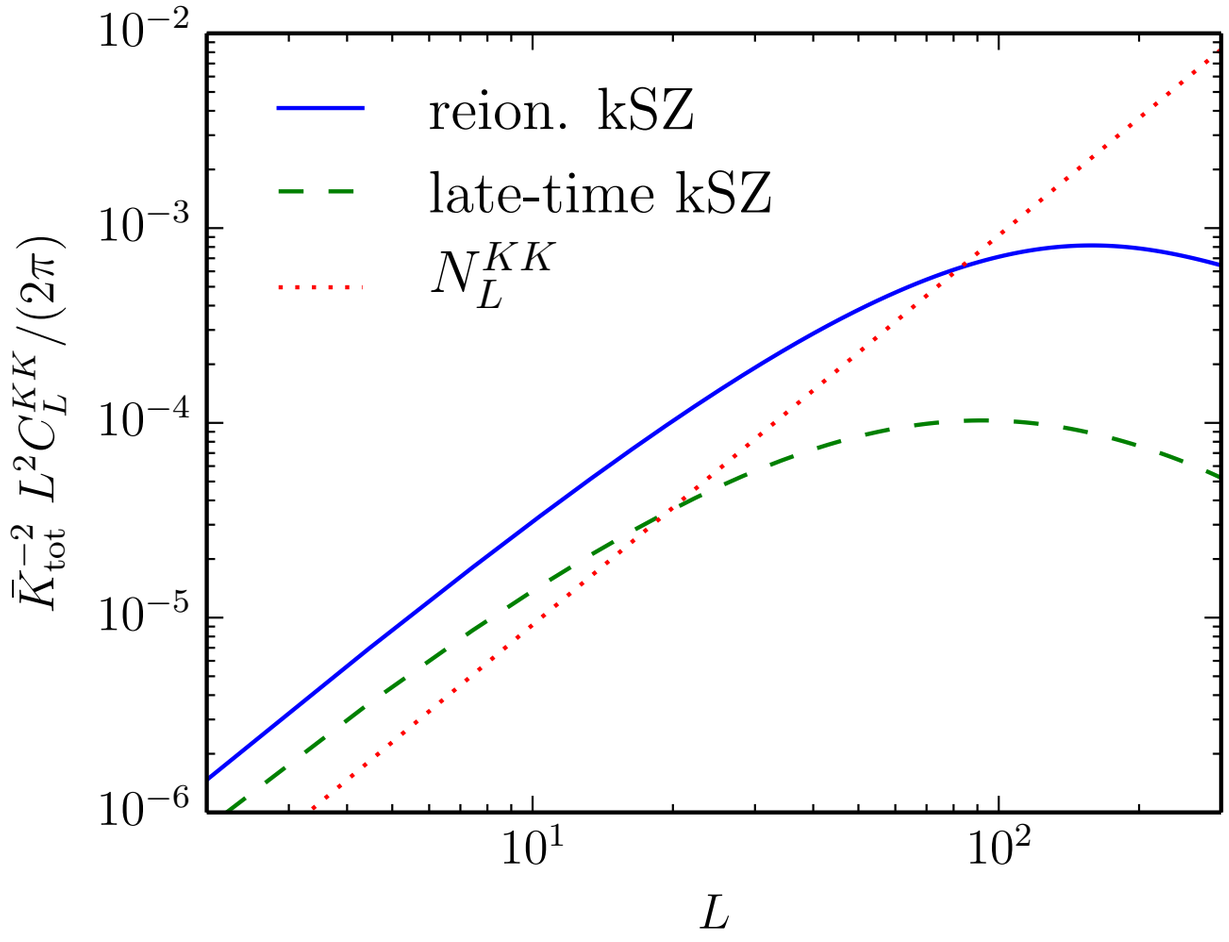
CMB-S4 Science Book
Green, Meyers, van Engelen 2016

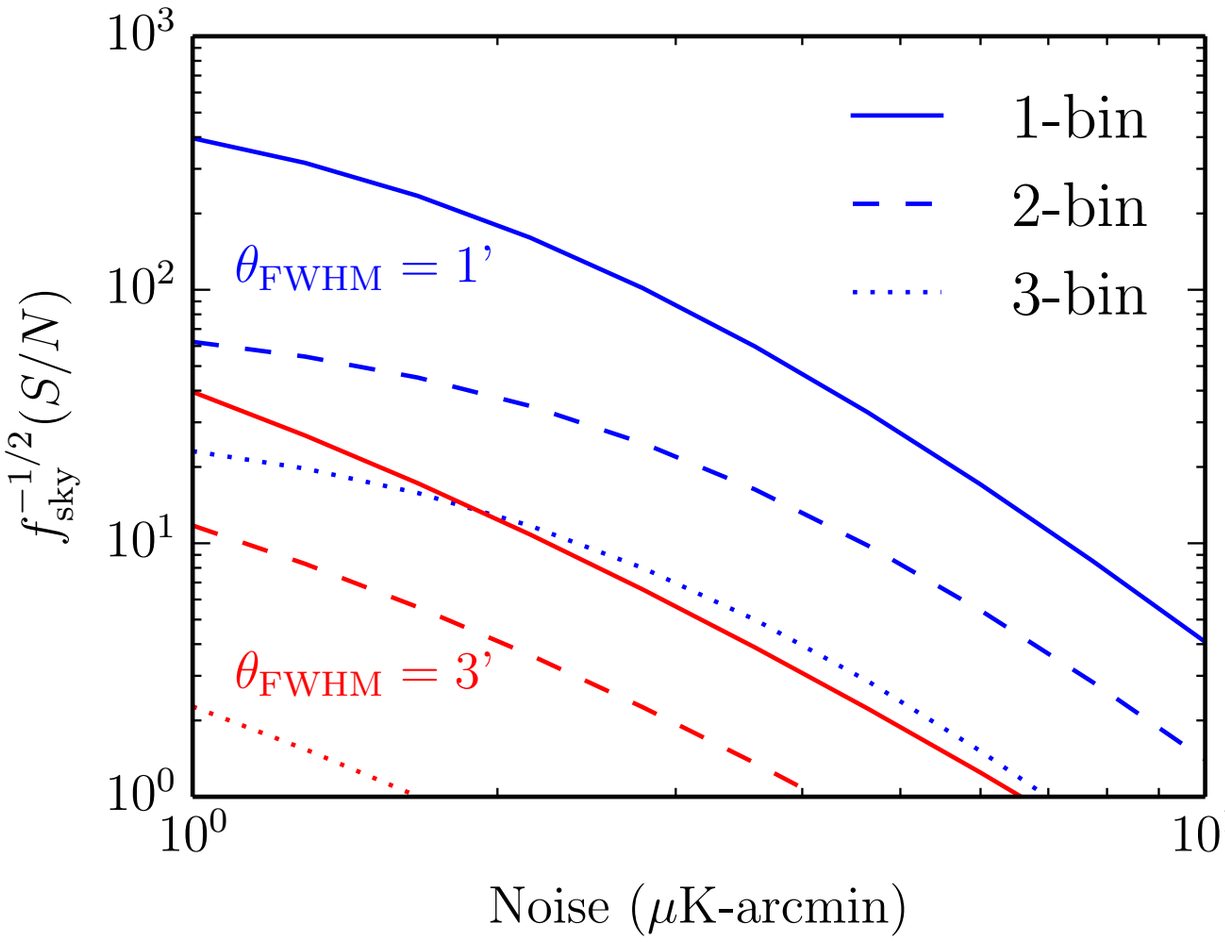
Lensing autospectrum - Σm_ν



kSZ² power spectrum

See Simone Ferraro's talk





Smith & Ferraro