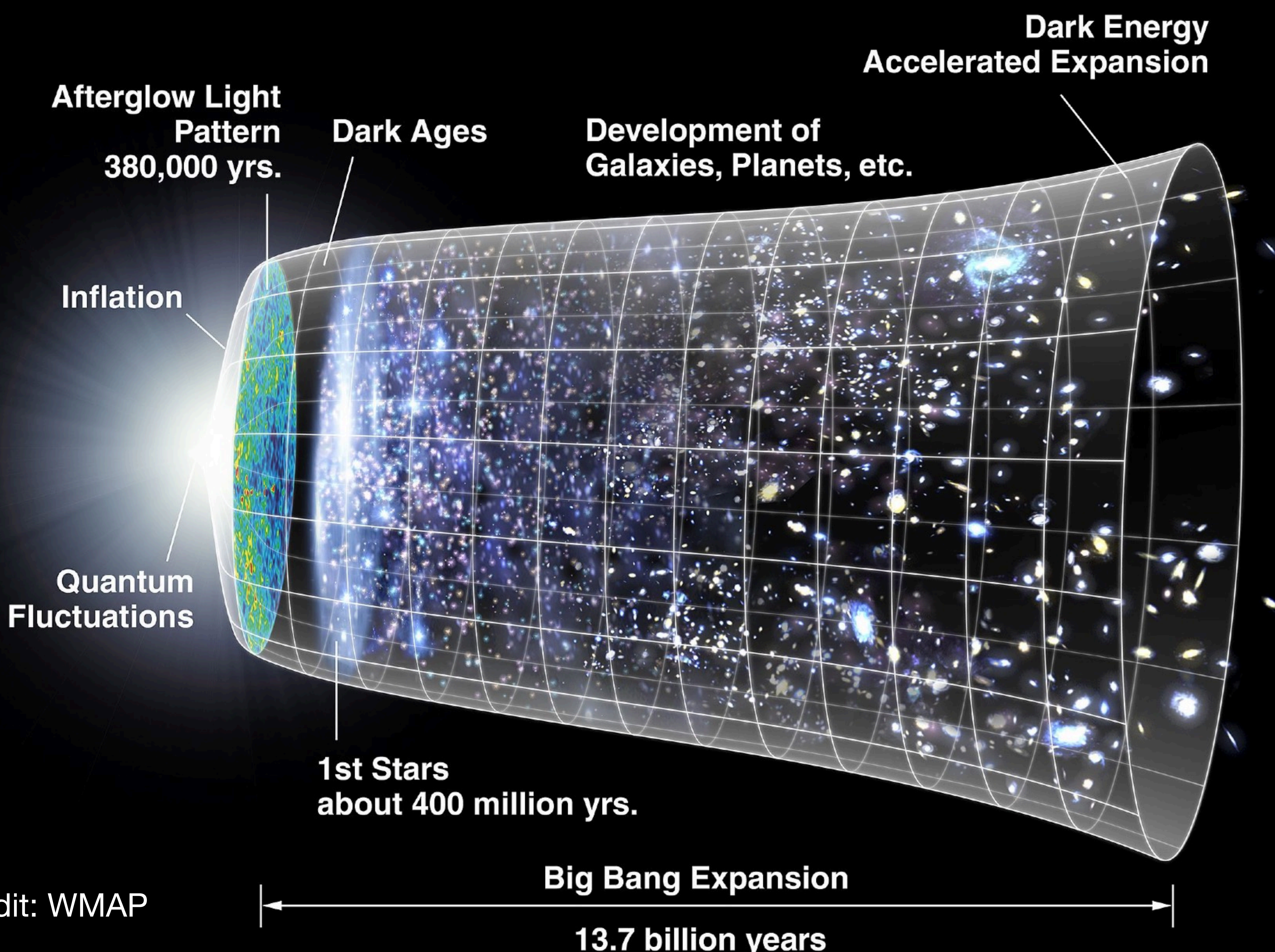
New Results from the Dark Energy Survey and the South Pole Telescope

Eric Baxter, University of Pennsylvania
with the South Pole Telescope and Dark Energy Survey collaborations

DARK ENERGY SURVEY

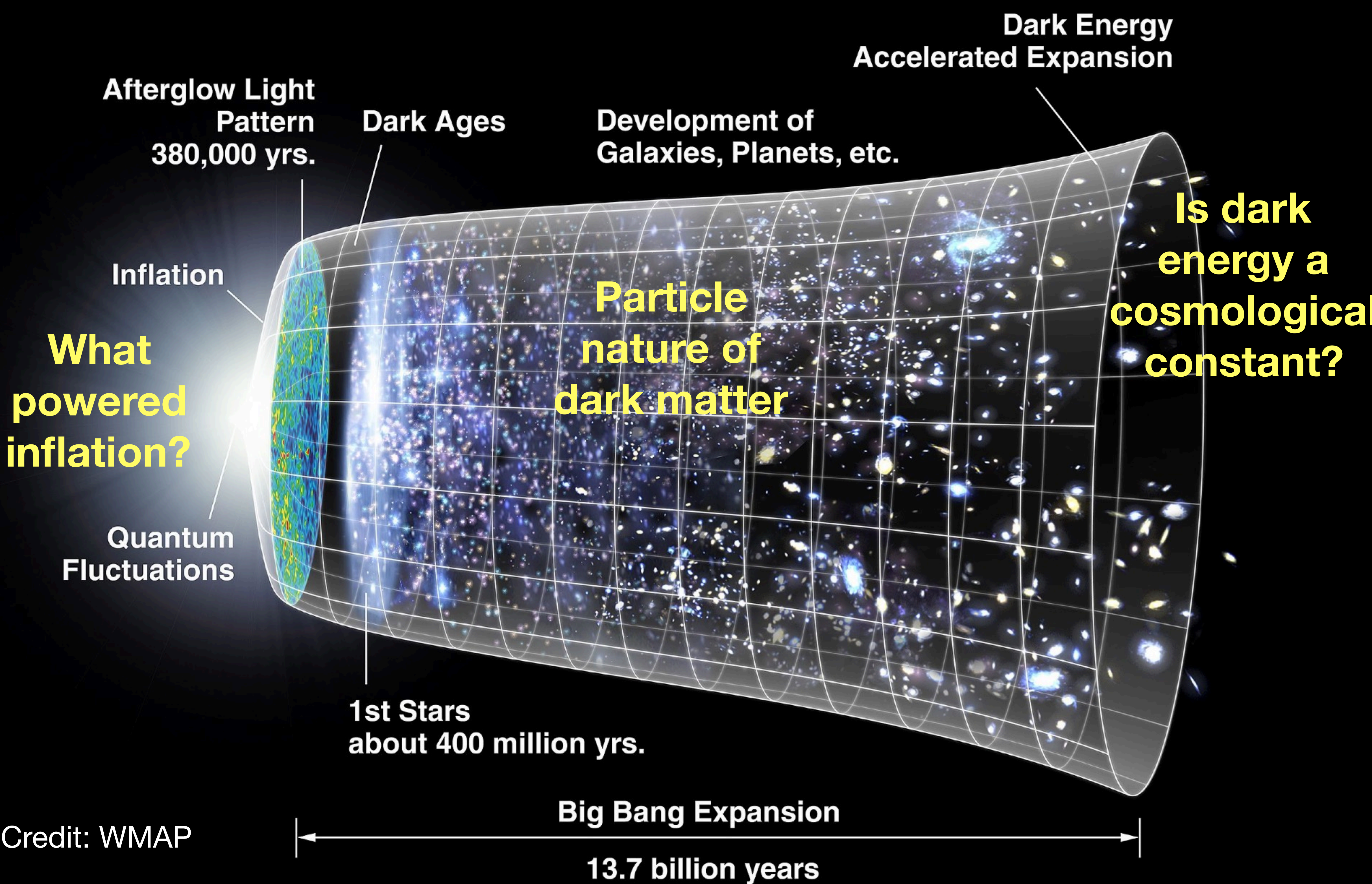
SOUTH POLE TELESCOPE

The standard cosmological model



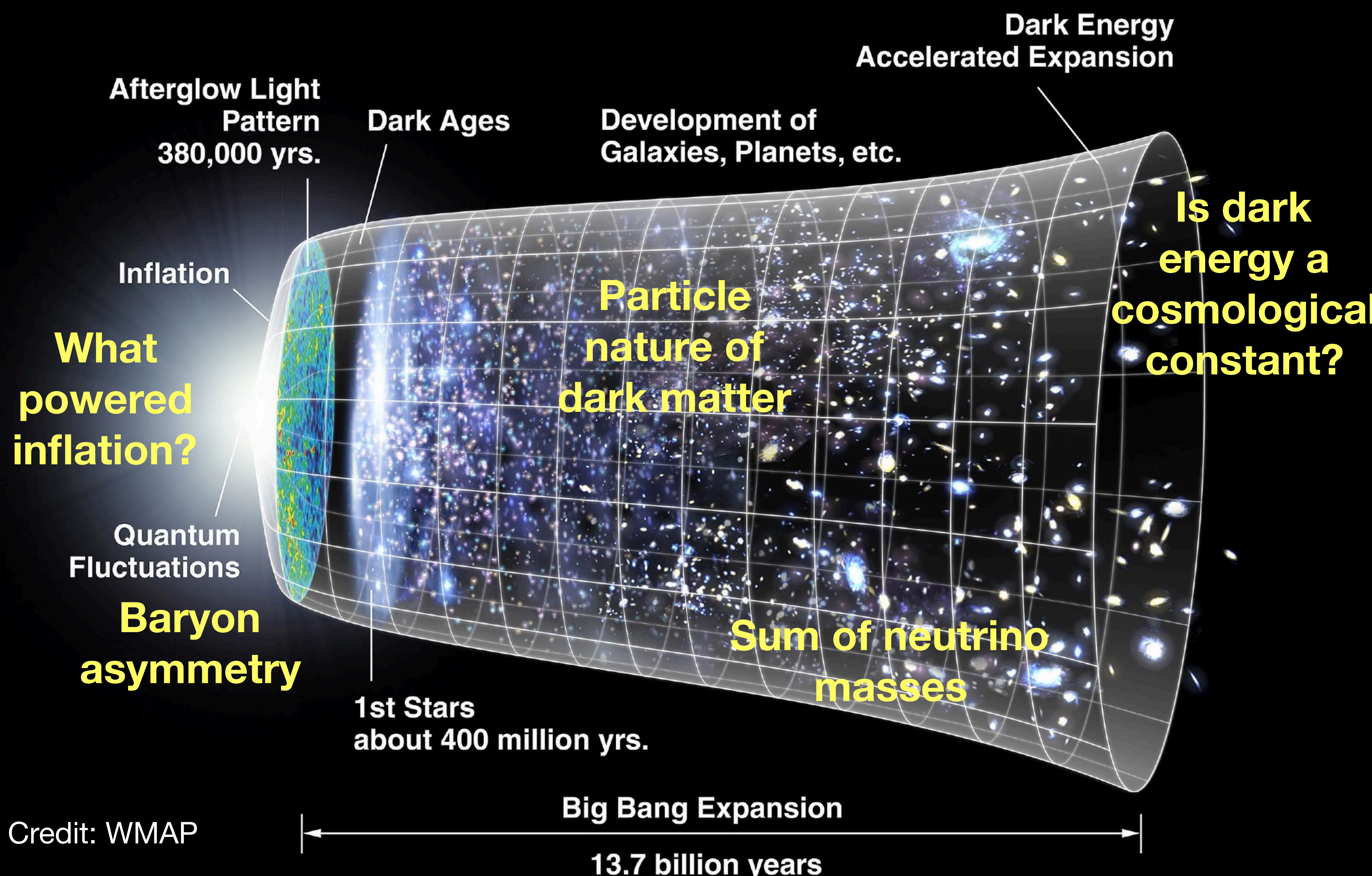
Credit: WMAP

Important unanswered questions



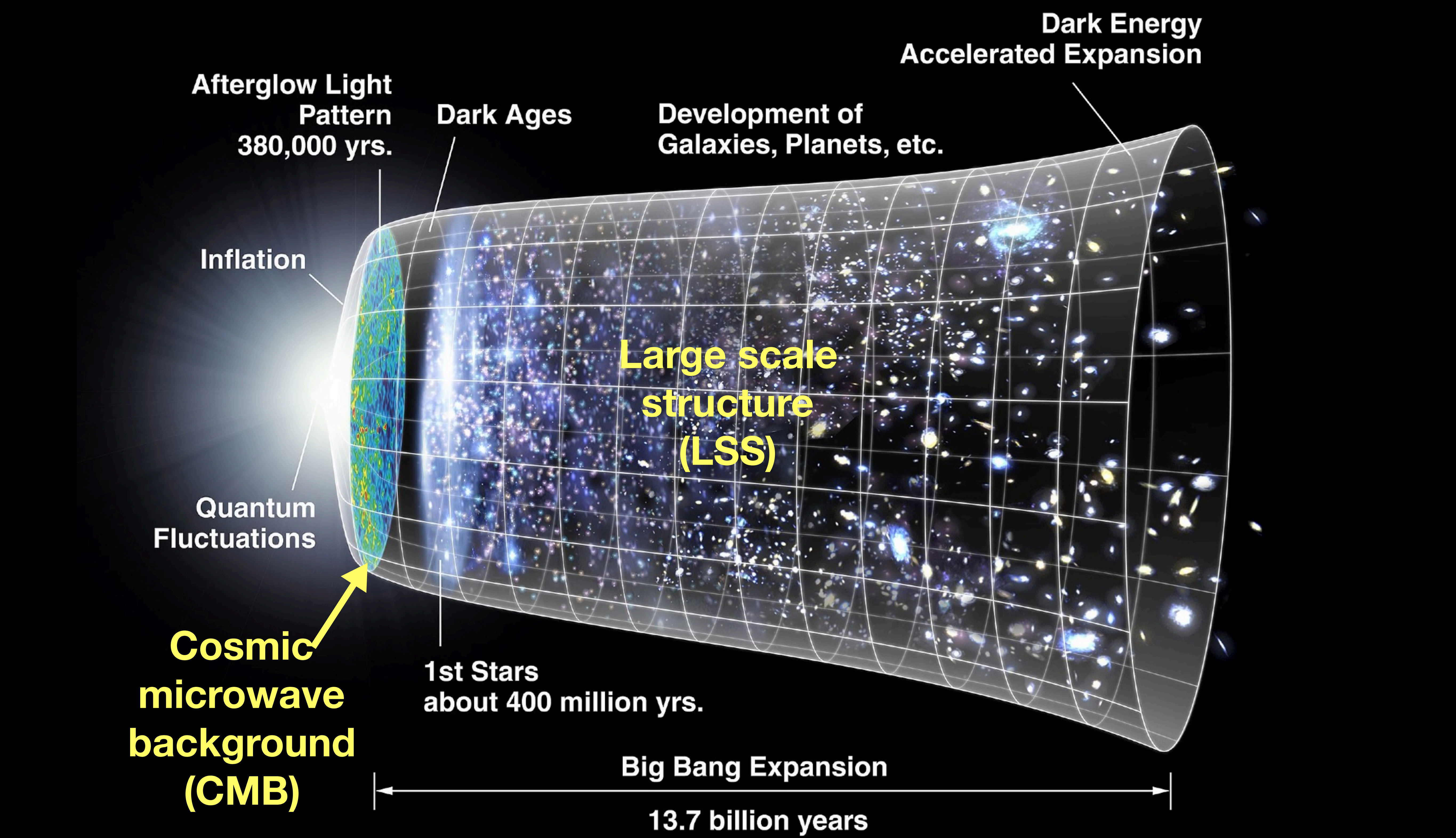
Credit: WMAP

Important unanswered questions and close connections to particle and nuclear physics

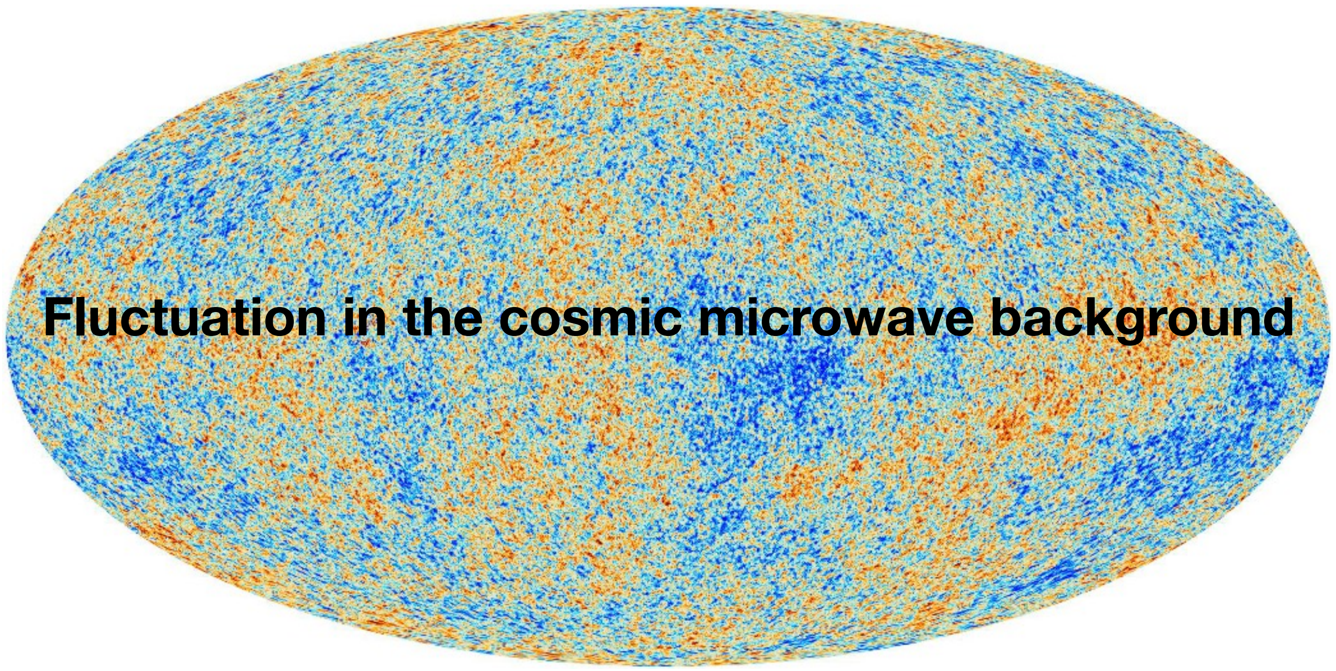


Credit: WMAP

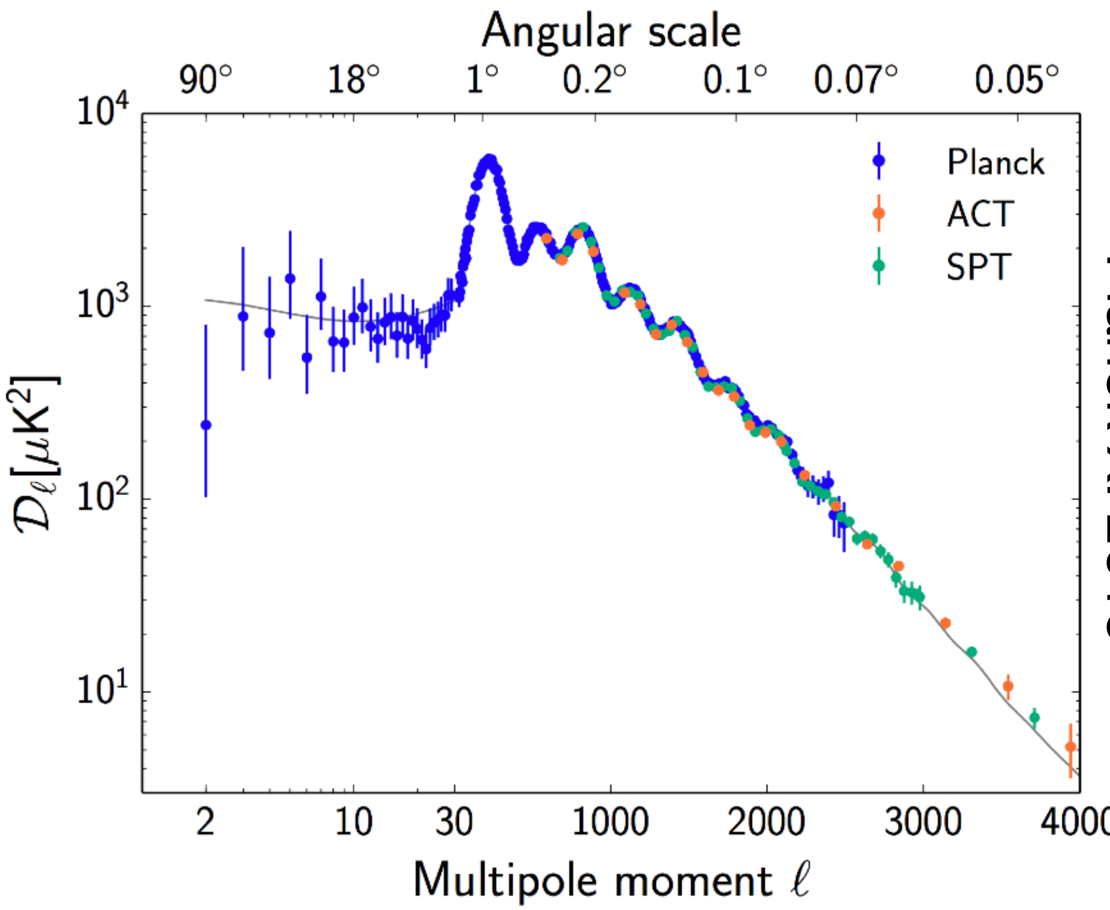
Two main tools of cosmology



How do we learn from the CMB? Primary Anisotropies



Credit: ESA (Planck)



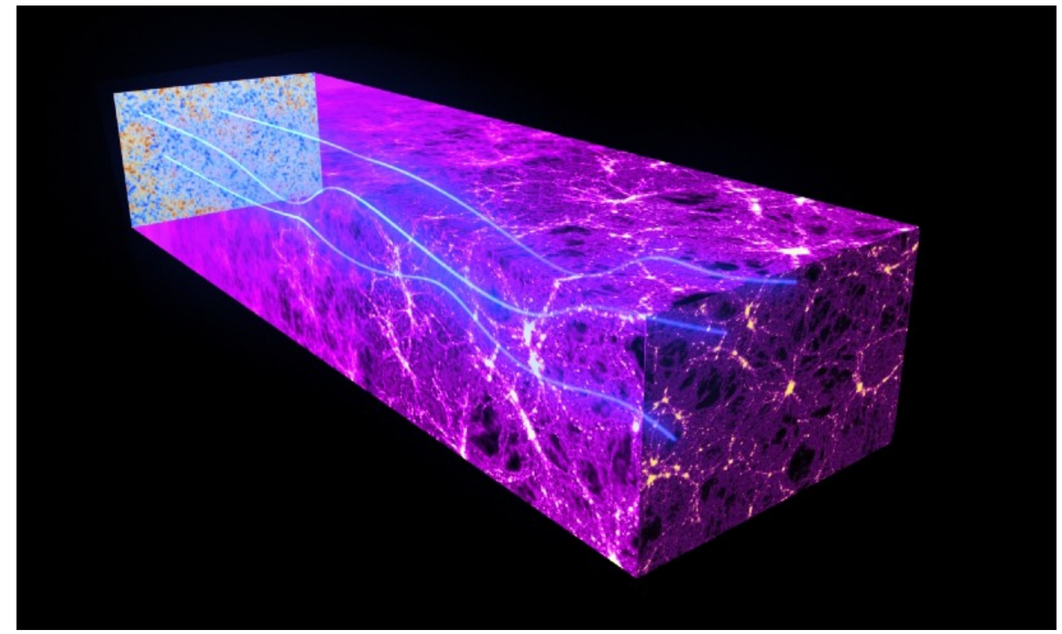
Planck XI 2015

Primary anisotropies in temperature and polarization imprinted at time of recombination

Provide snapshot of the Universe at z ~ 1100 (age ~ 400,000 years)

Sensitive to geometry, matter content, extra light degrees of freedom, inflation, …

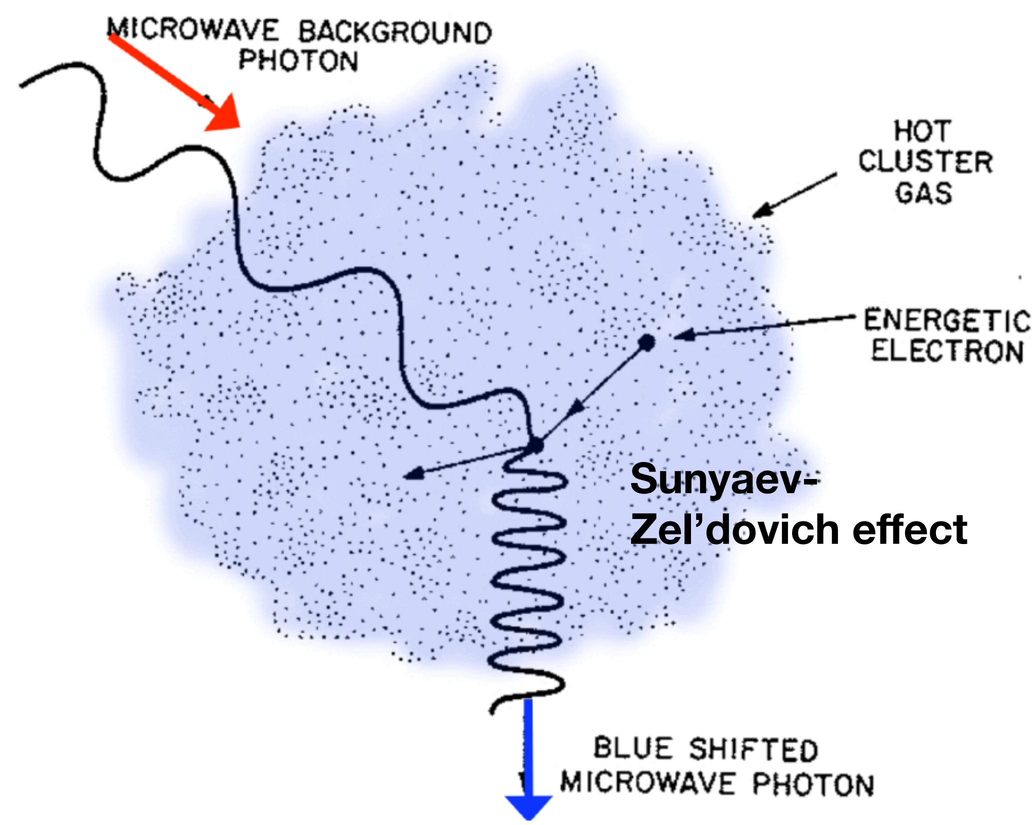
How do we learn from the CMB?
Secondary Anisotropies



Secondary anisotropies are imprinted after recombination:

Gravitational lensing
Sunyaev Zel'dovich effect
Integrated Sachs Wolfe effect

Sensitive to expansion history, growth of structure, thermal history…

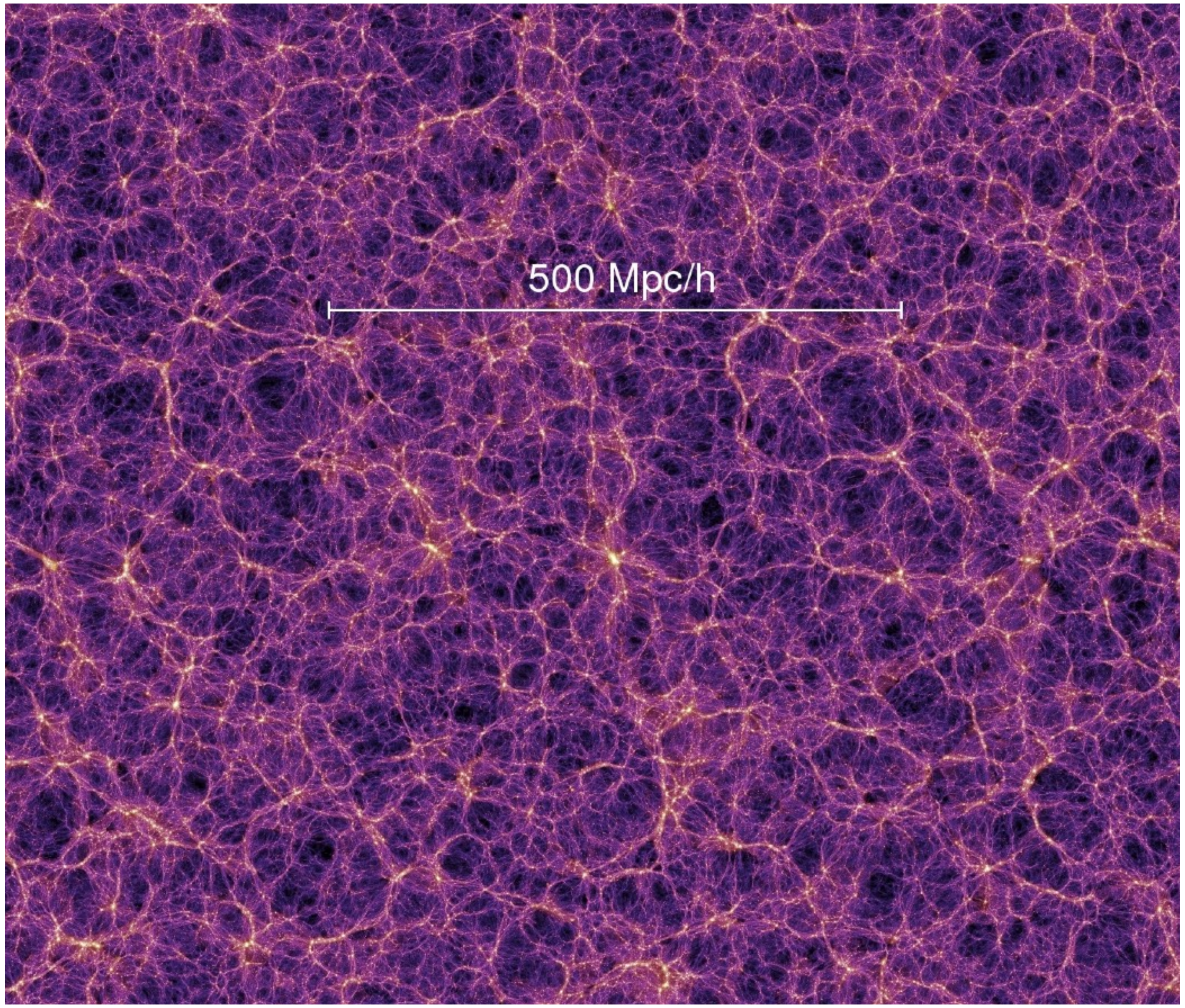


How do we learn from large scale structure?

Like the CMB, galaxies and gravitational lensing probe underlying matter fluctuations

Many more modes than CMB (3D vs. 2D)

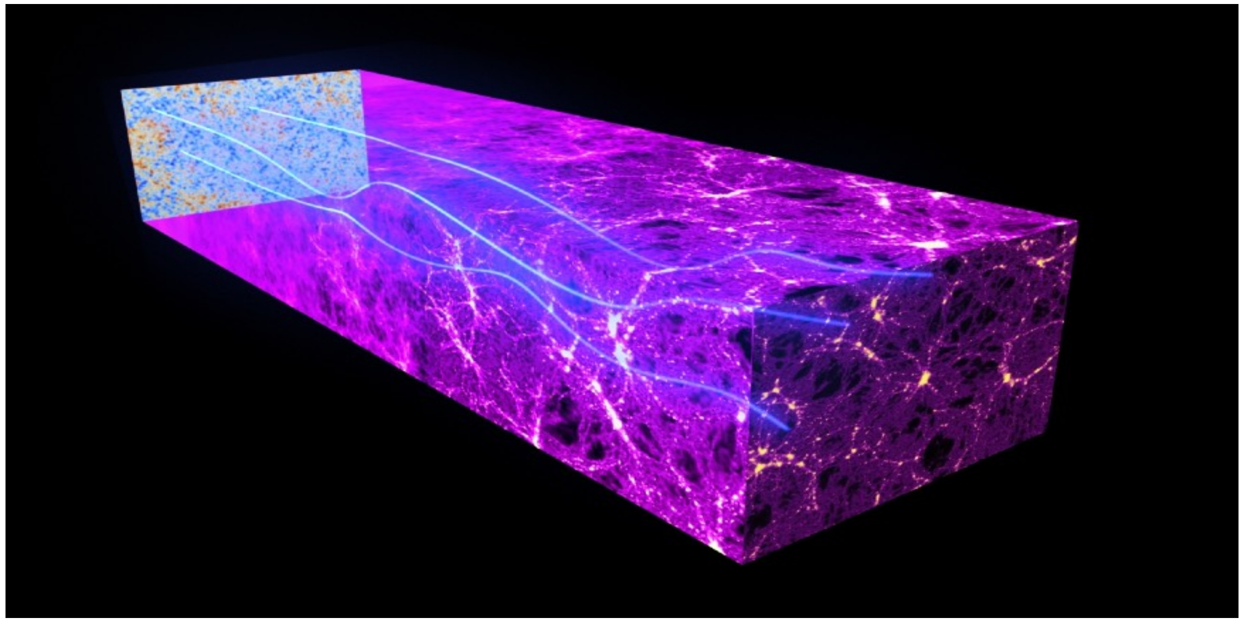
But nonlinear!



credit: Millennium simulation, Springel et al. 2005

Cross-correlations between the CMB and LSS

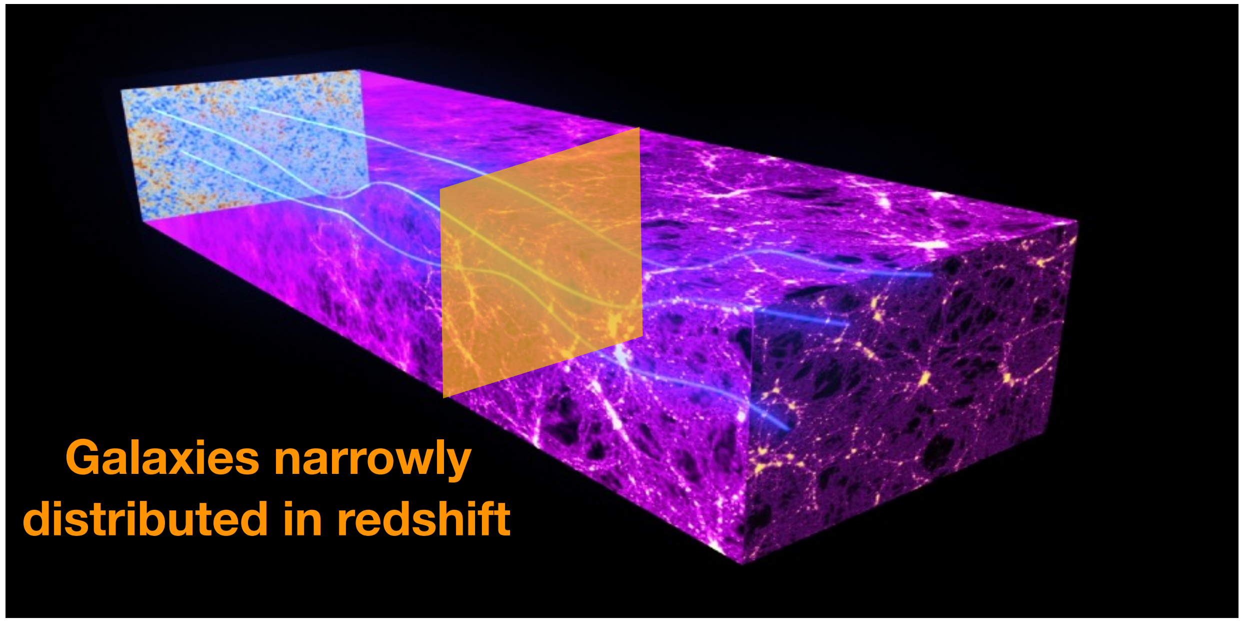
Secondary anisotropies **induce correlation between CMB and LSS**



Cross-correlation between tracers of large scale structure and CMB can be used to isolate contributions to secondary anisotropy as a function of redshift

Cross-correlations between the CMB and LSS

Secondary anisotropies **induce correlation between CMB and LSS**



Cross-correlation between tracers of large scale structure and CMB can be used to isolate contributions to secondary anisotropy as a function of redshift

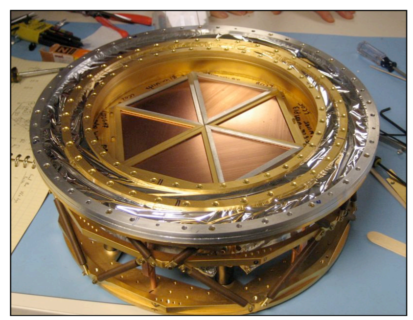
Outline

1. The South Pole Telescope and the Dark Energy Survey
2. Overview of recent results from both experiments
3. Future data from SPT and DES

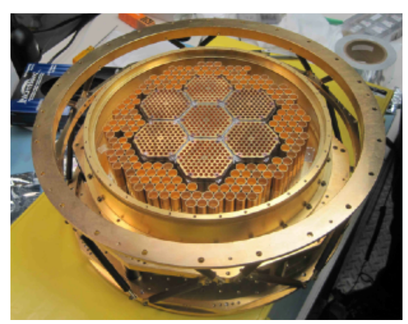
The South Pole Telescope

10-meter sub-mm wavelength
Roughly 1 arcmin resolution

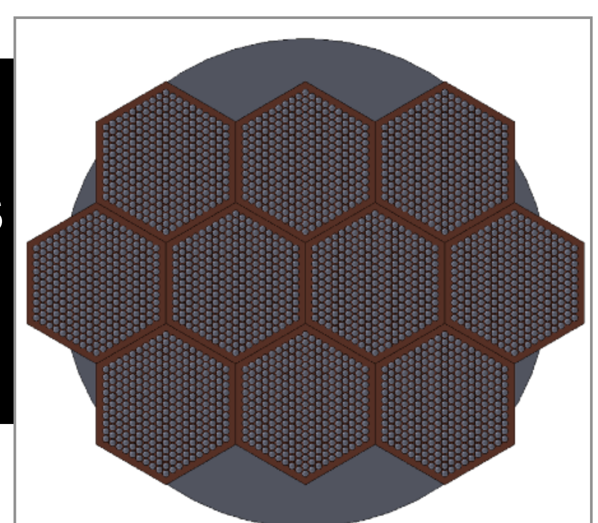
2007: SPT-SZ
960 detectors
100,150,220 GHz



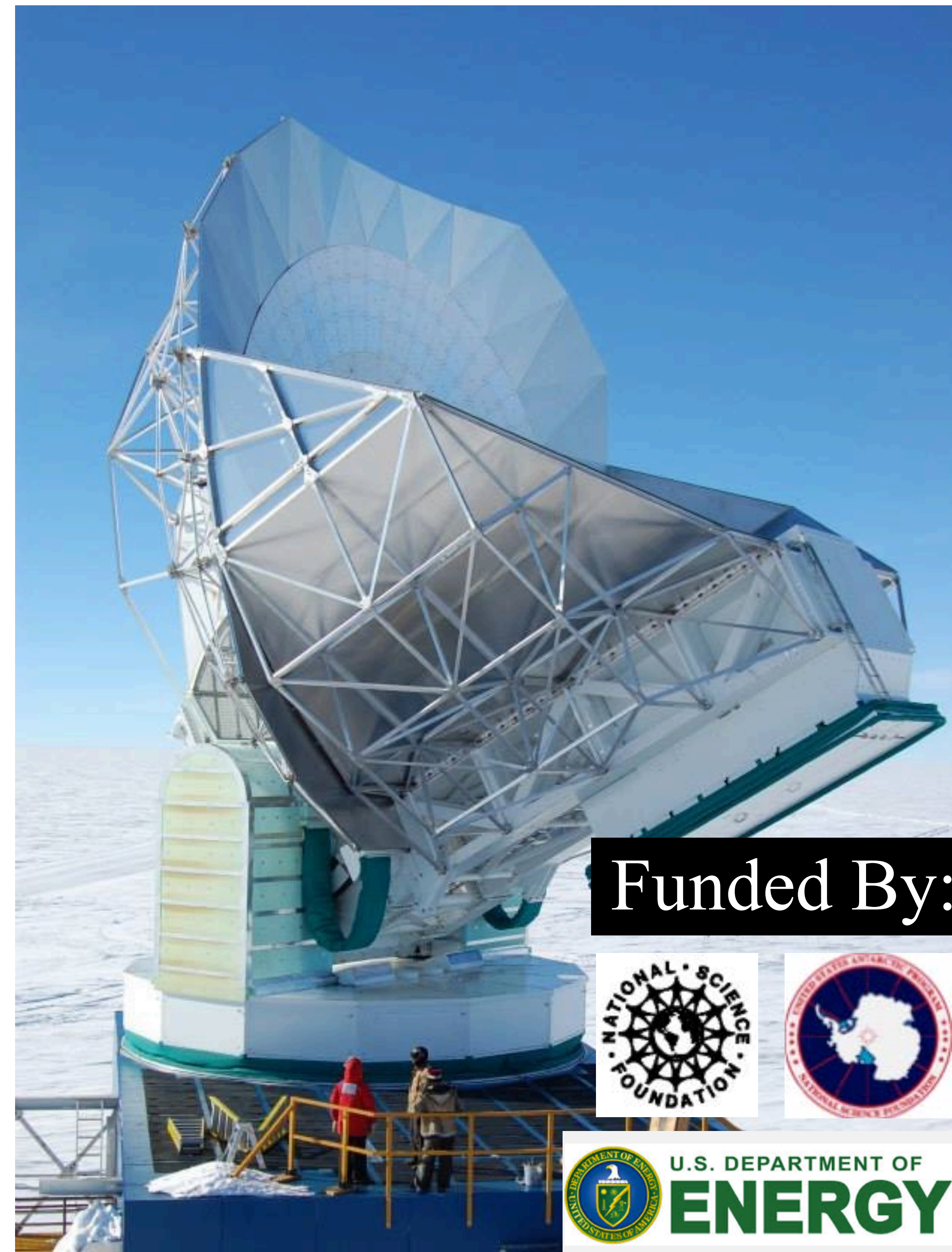
2012: SPTpol
1600 detectors
100,150 GHz
+Polarization

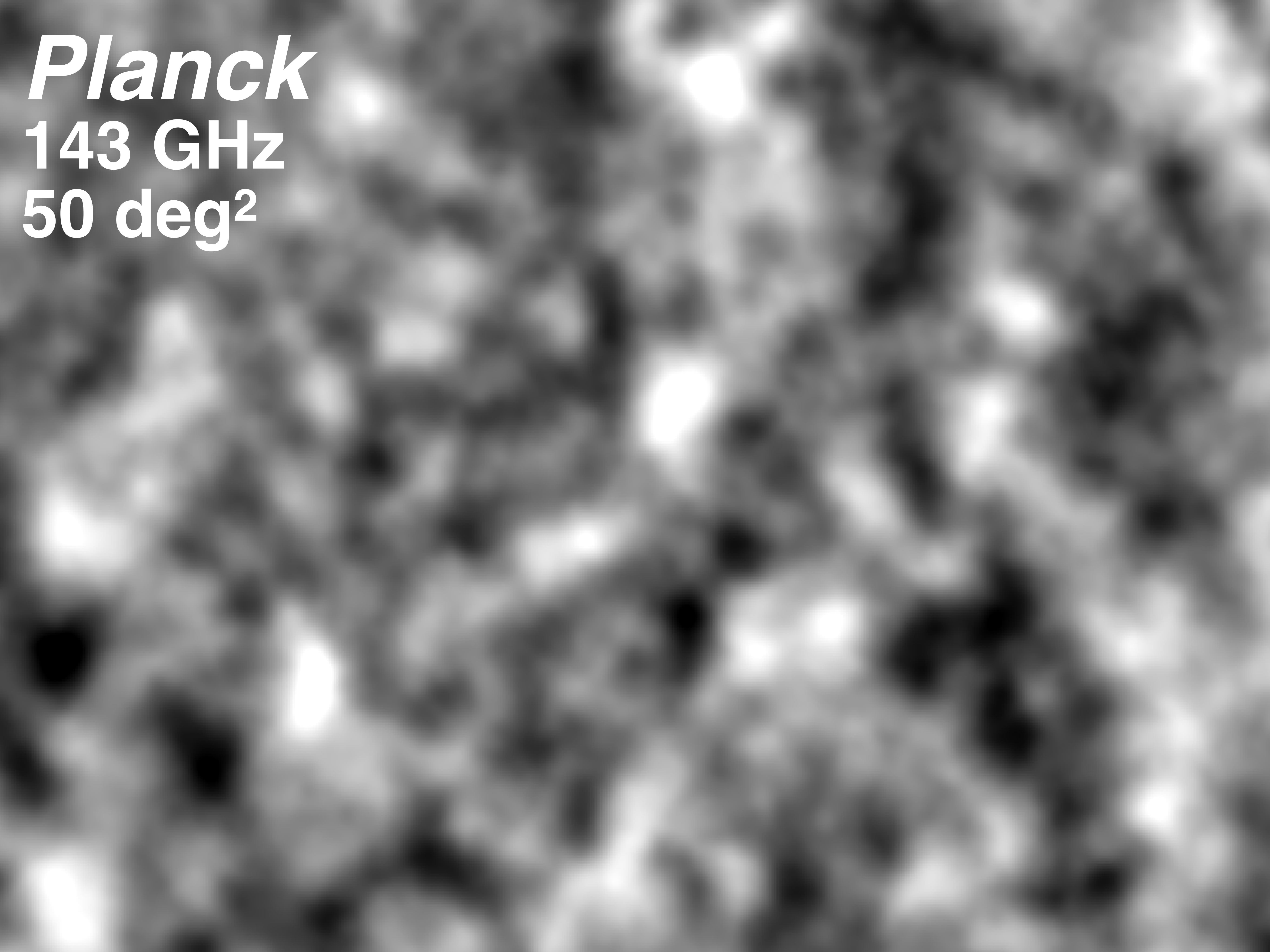


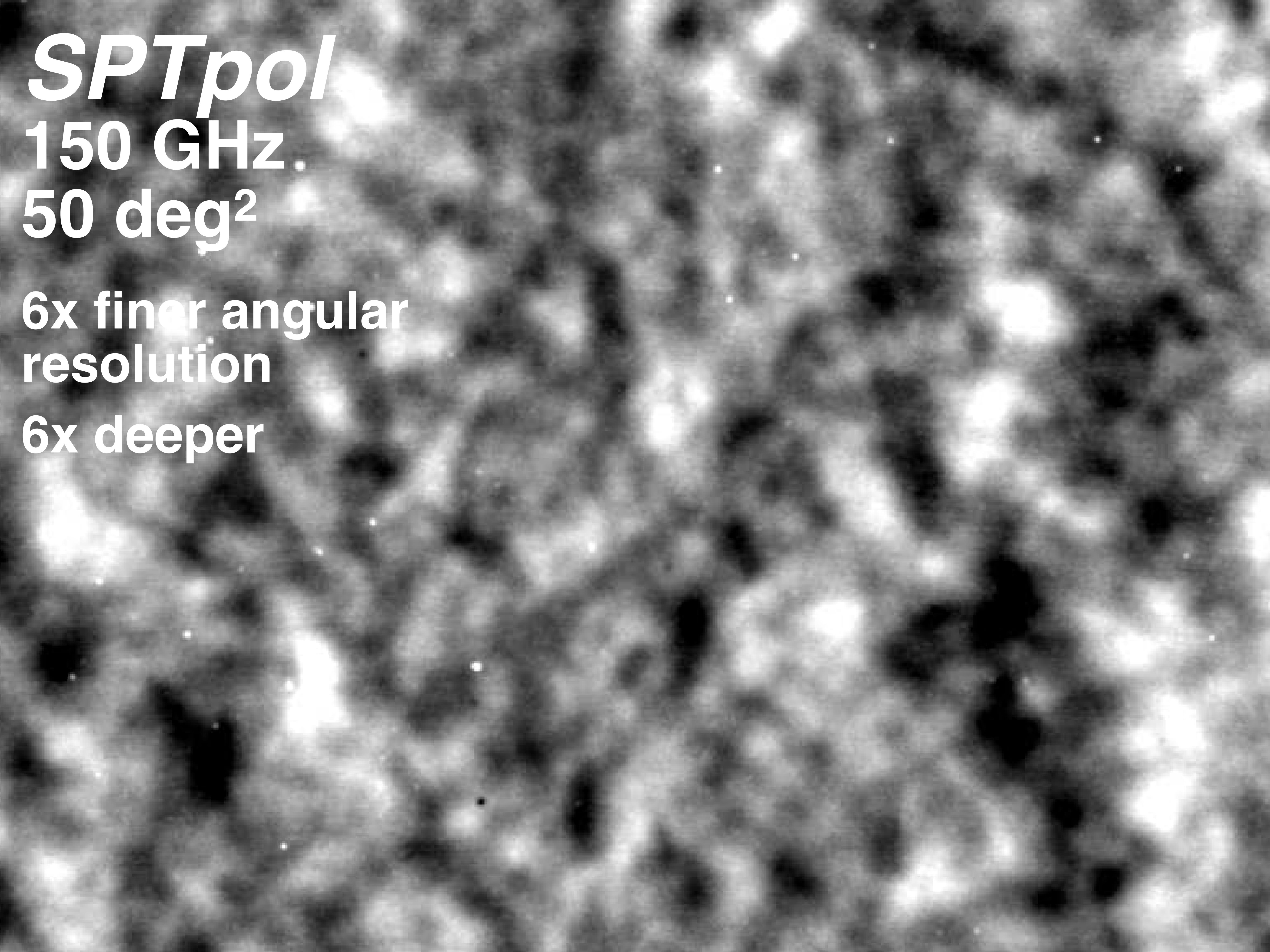
2016: SPT-3G
~15,200 detectors
100,150,220 GHz
+Polarization



Credit: Brad Benson




Planck
143 GHz
50 deg^2

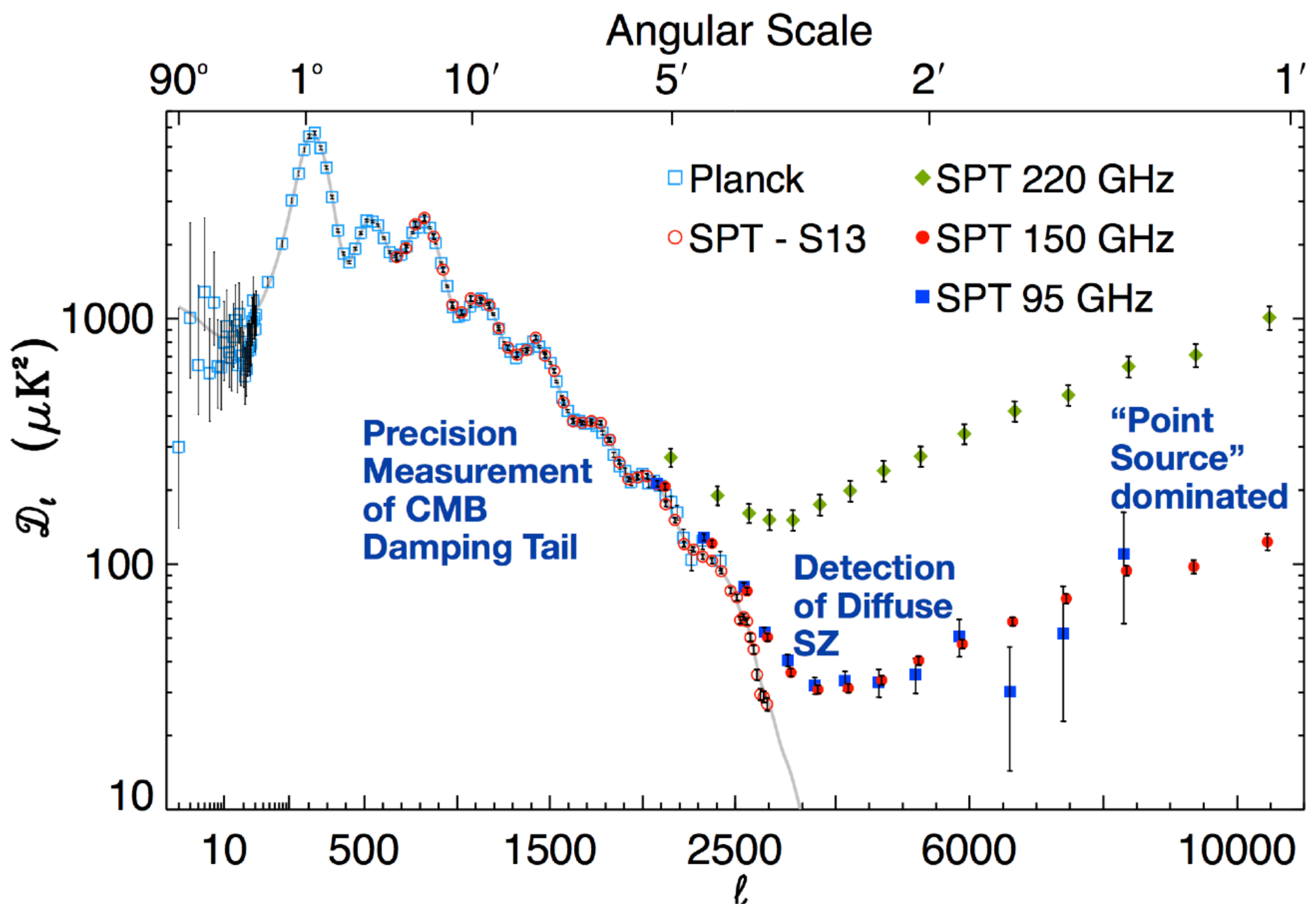

SPTpol
150 GHz
50 deg^2
6x finer angular resolution
6x deeper

Science with SPT

High angular resolution and low noise

Secondary anisotropies
- Gravitational lensing
- Galaxy clusters

Polarization
- Lower foregrounds at high ell
- Inflationary B-modes



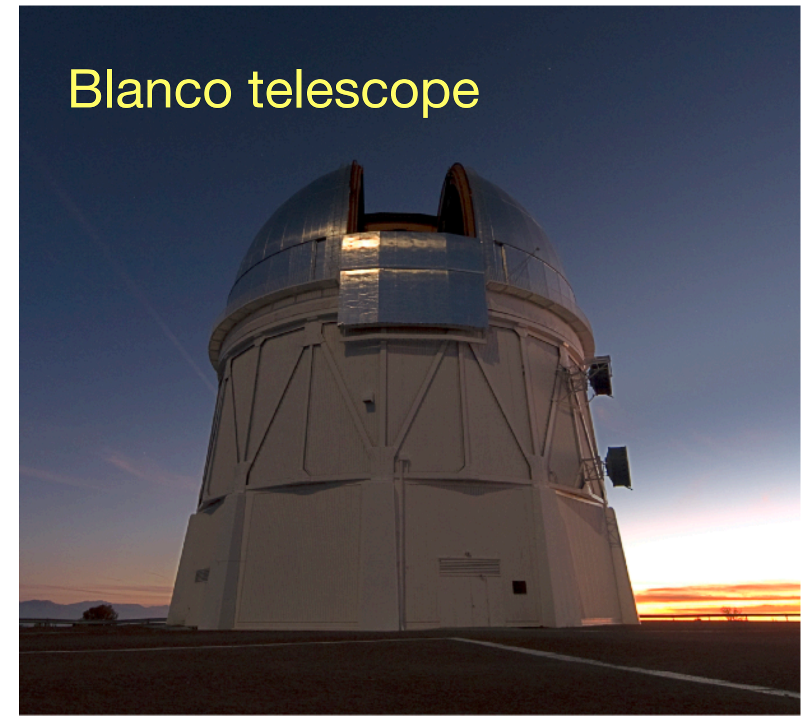
George et al. 2014

The Dark Energy Survey

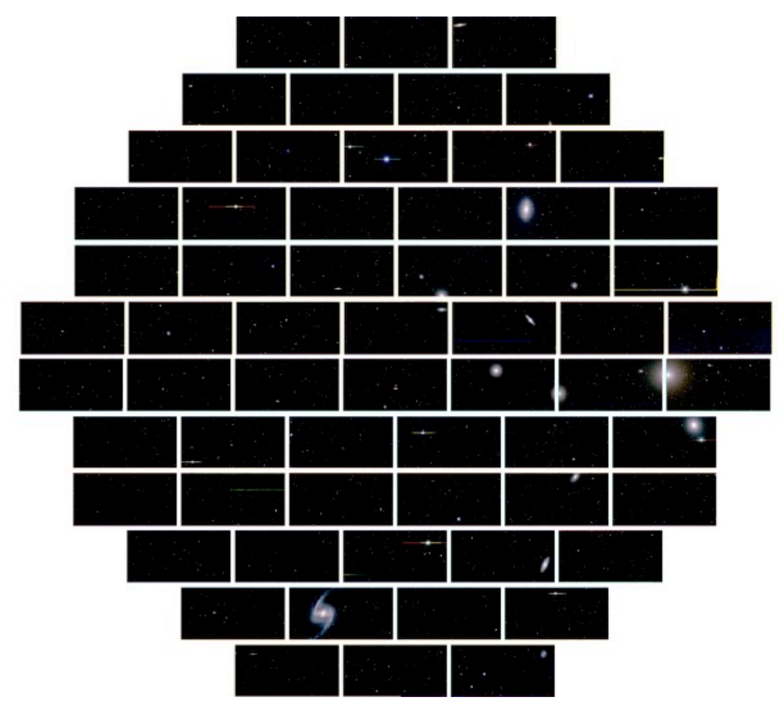
5.5 year survey of southern sky in optical wavelengths (year 1 results recently released)

4 m mirror telescope

Dark energy camera (DECam)
wide field of view, 62 CCDs, optimized for high redshift



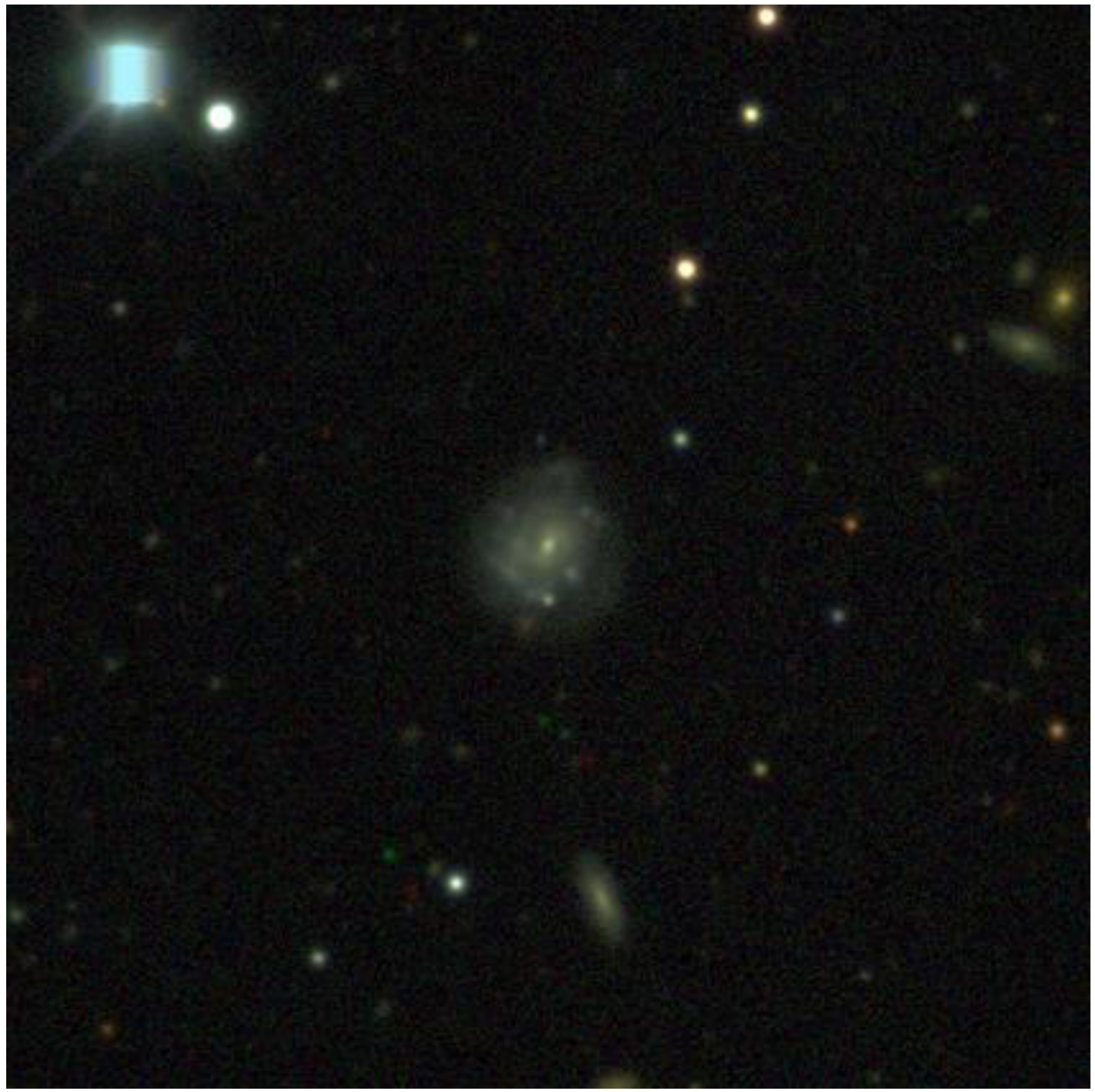
DECam focal plane



Funded by:
U.S. DEPARTMENT OF ENERGY | Office of Science
NSF
GOBIERNO DE ESPAÑA | MINISTERIO DE EDUCACIÓN, CULTURA Y DEPORTE
Finep INOVAÇÃO E PESQUISA

Galaxy image from the Sloan Digital Sky Survey (DR7)

H. Dominguez Sanchez et al. 2018



Same galaxy with DES (Year 1)

H. Dominguez Sanchez et al. 2018

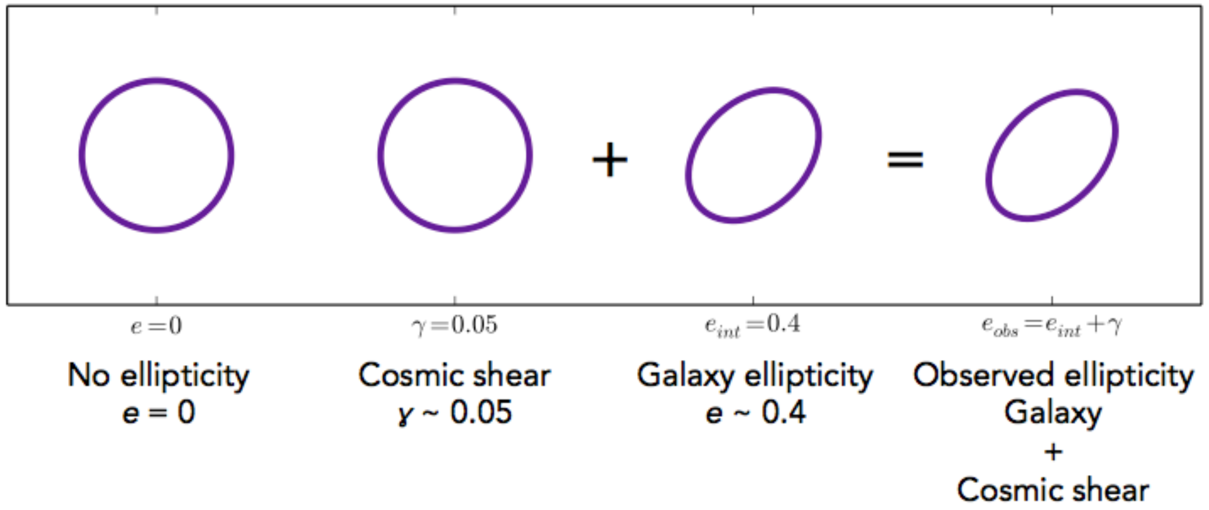
Science with DES

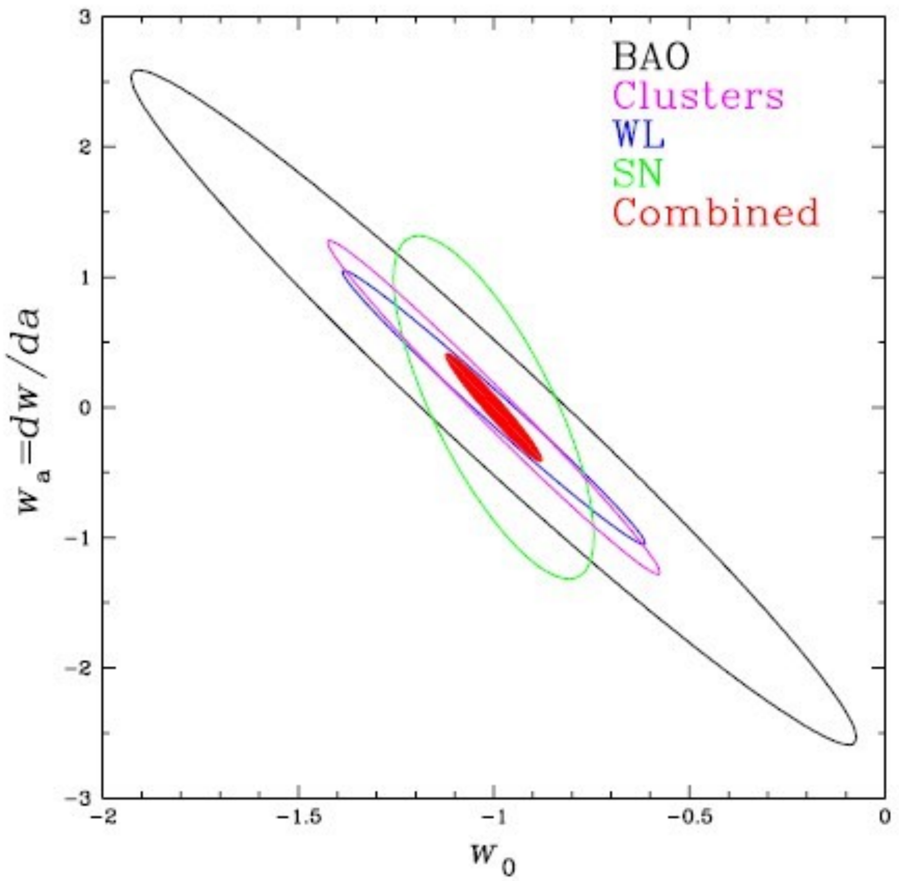
DES strengths:
- Wide area (5000 sq. deg.)
- Sensitivity to high redshifts
- Weak lensing quality imaging

Multicomponent cosmology strategy:

Gravitational lensing
Galaxy clustering
Galaxy cluster counts
Supernovae

Credit: University of Manchester





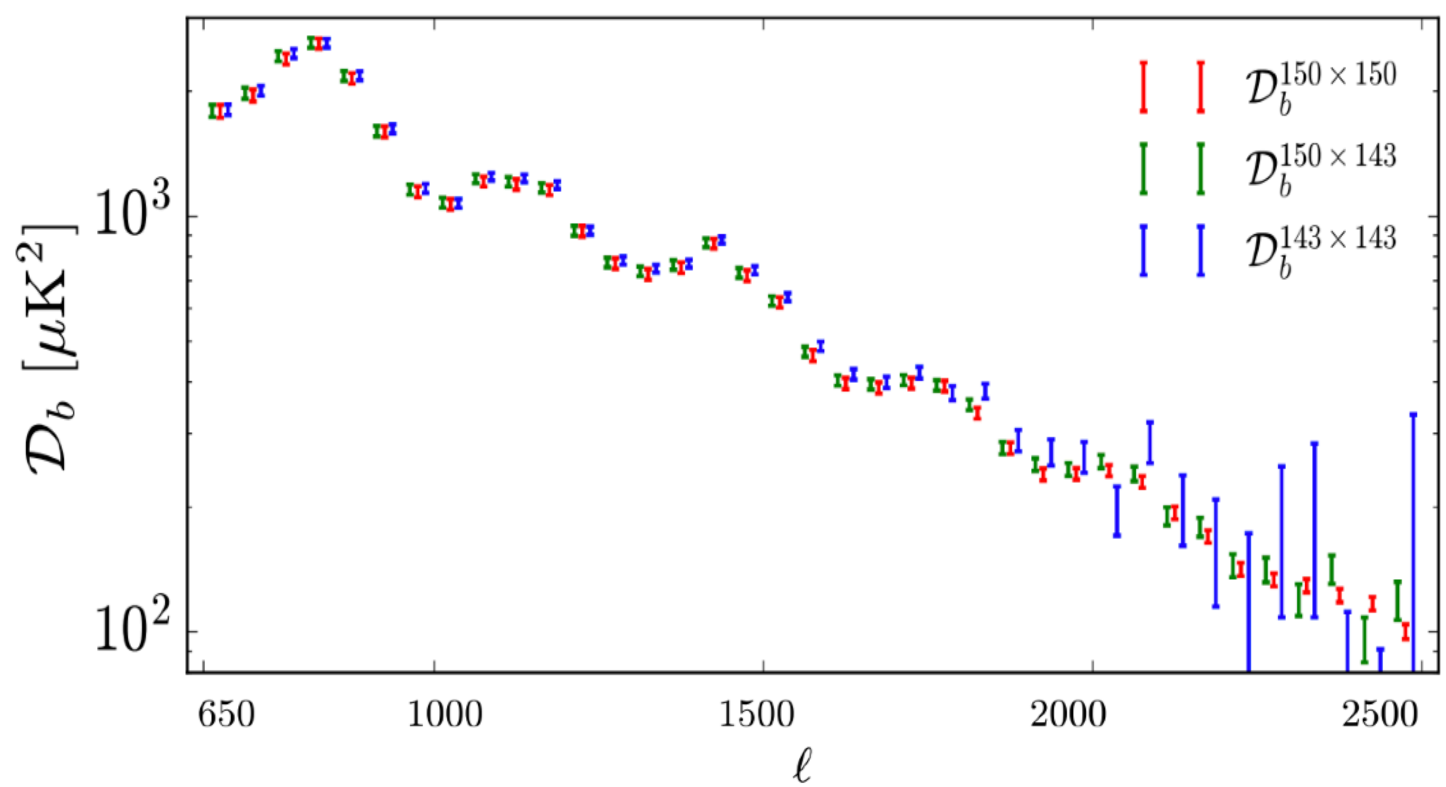
w0 and wa describe equation of state of dark energy

Recent results from SPT

Recent results from SPT:
Are SPT and Planck consistent?

No evidence for inconsistency between SPT and Planck over same patch of sky and same modes, 650 < ell < 2000 (Aylor et al. 2017, Hou et al. 2018)

Hou et al. 2018



PTEs Between Planck full-sky and SPT

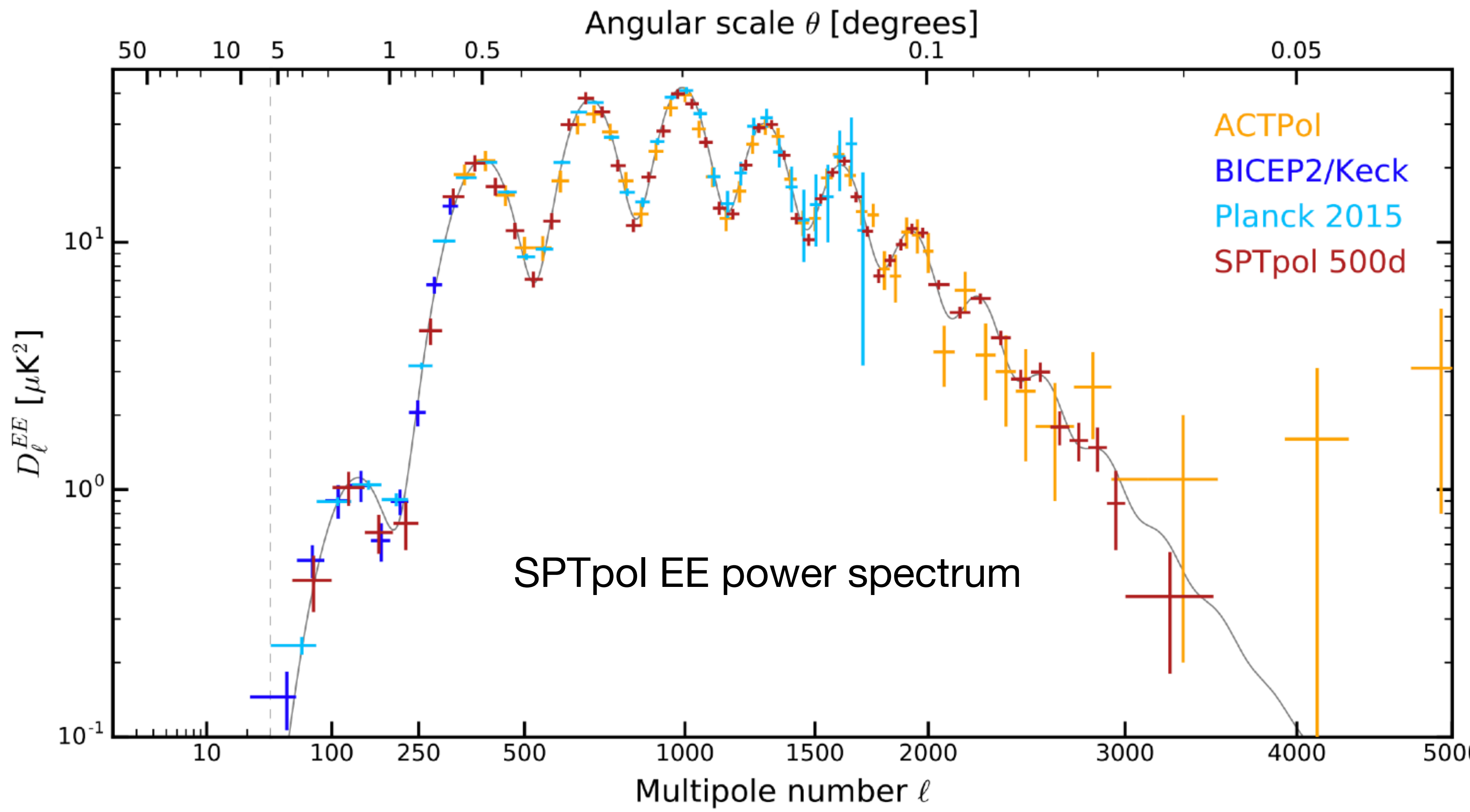
	$\ell_{\max}$			
	1800	2000	2500	3000
150×150	0.21	0.24	0.094	0.032

Aylor et al. 2017

Mild tension (pte = 0.03) between SPT cosmology constraints over 650 < ell < 3000 and Planck full sky

- Tension requires **both** high ell SPT data and Planck data not in SPT patch

Recent results from SPT: SPTpol 500 sq. deg.



Henning et al. 2014

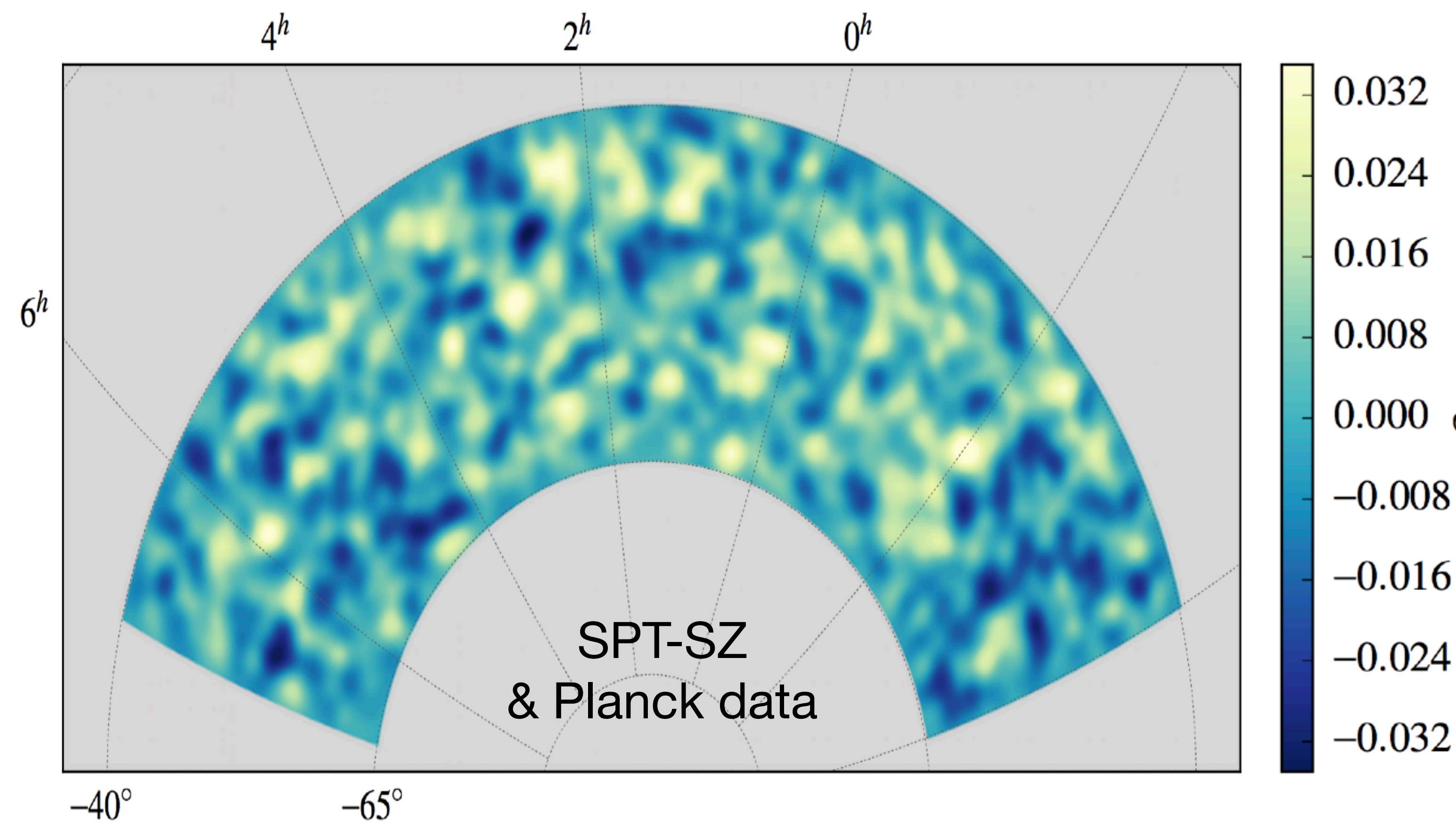
Most sensitive measurements to date of EE and TE power spectra at high ell

For ell < 1000, consistent with Planck cosmological constraints
For ell > 1000, prefers slightly higher H_0 and lower σ_8
Full dataset in mild tension (2.1σ) with LambdaCDM

Recent results from SPT: Gravitational lensing

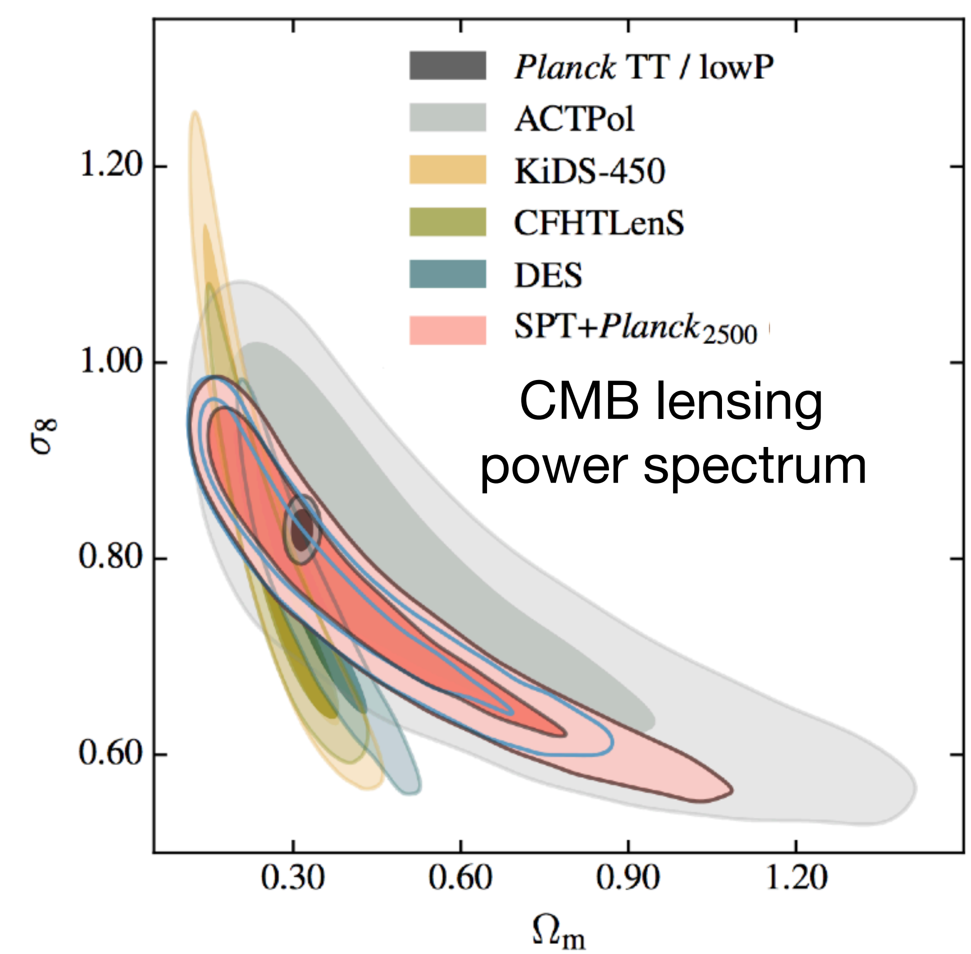
Can use observed pattern of anisotropies to map gravitational lensing strength

Better constraints from combination of Planck (large scale) and SPT (small scale) data

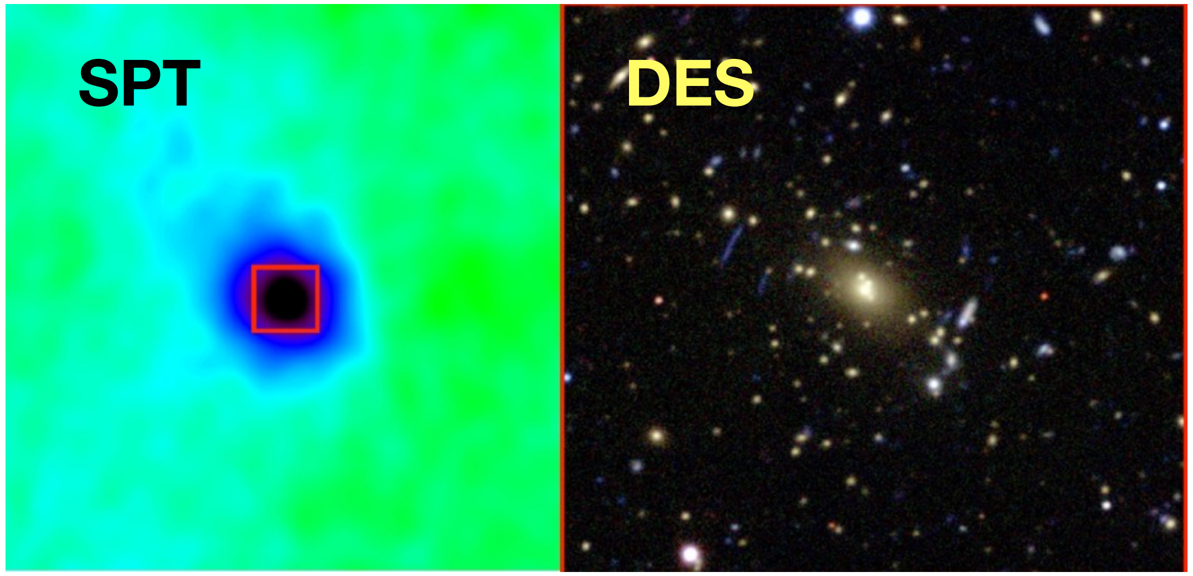


Omori et al. 2017

Simard et al. 2018



Recent results from SPT: Galaxy clusters



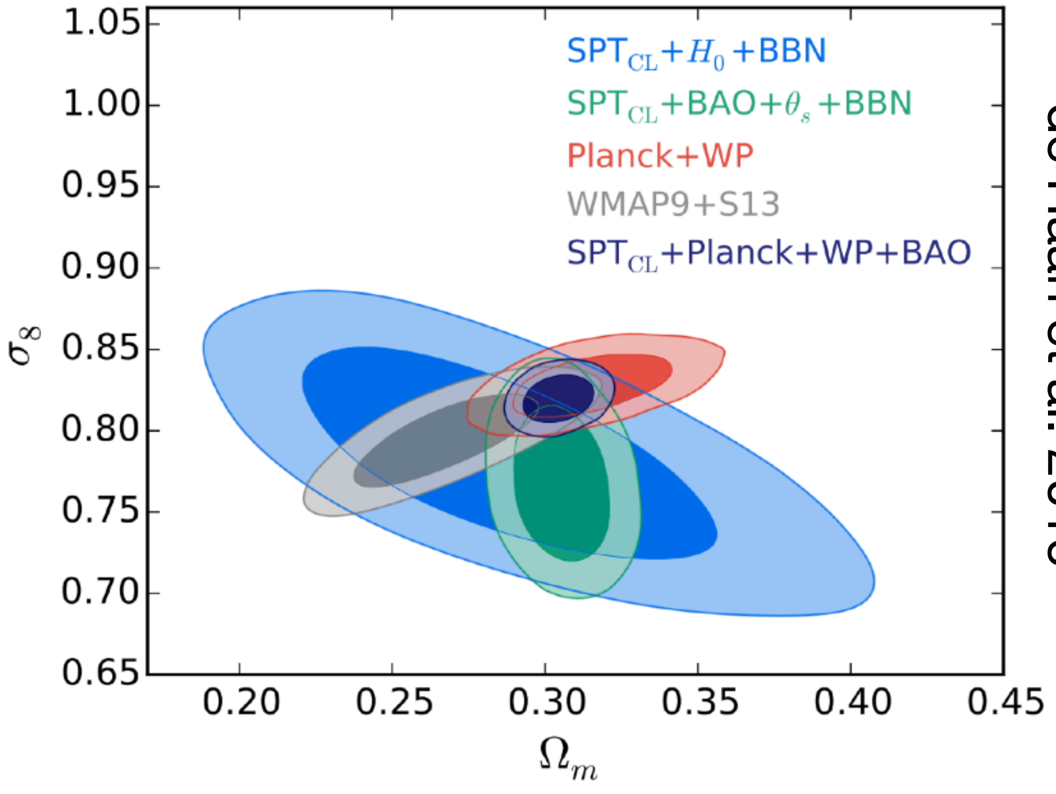
Credit: Brad Benson

SPT detects galaxy clusters via Sunyaev-Zel'dovich effect

Abundance of galaxy clusters is a sensitive cosmological probe

Can use CMB lensing to measure cluster masses

First detection of gravitational lensing of CMB by SZ-selected galaxy clusters (Baxter et al. 2015)

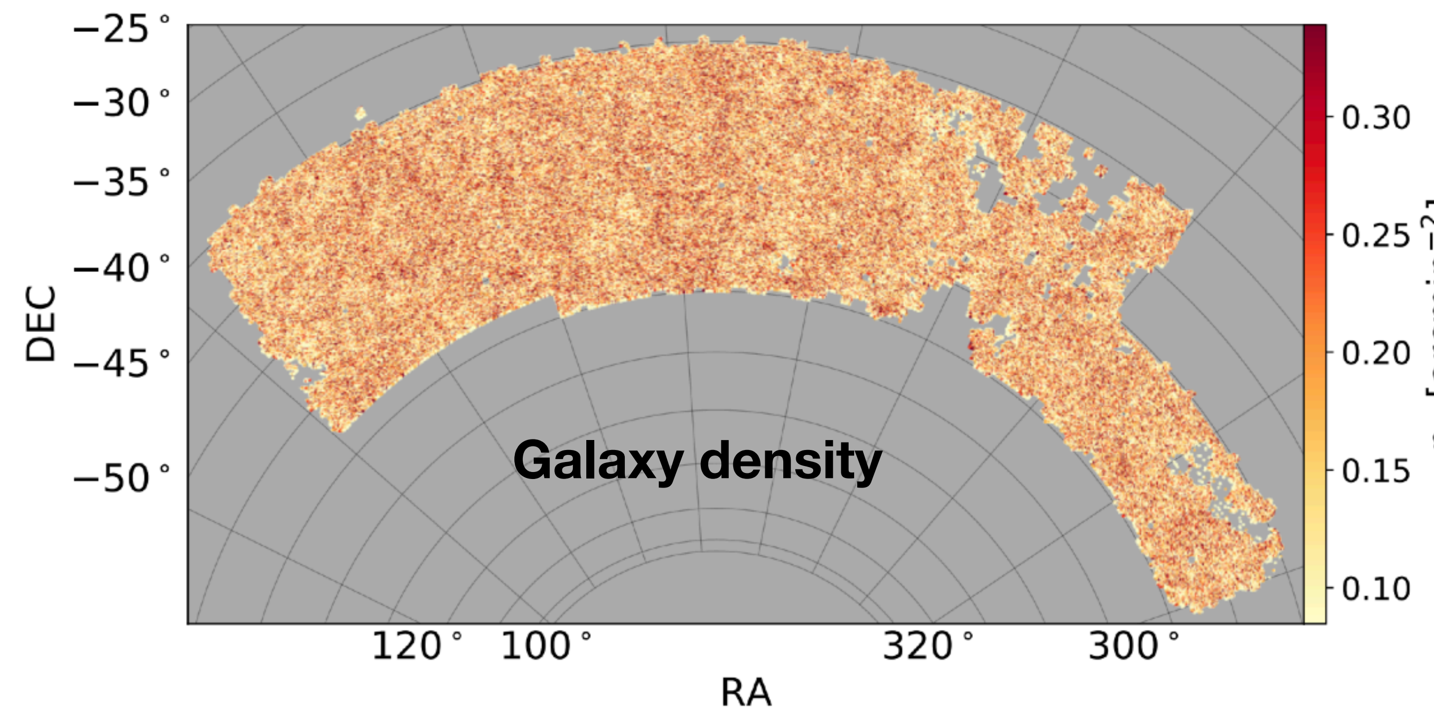


de Haan et al. 2016

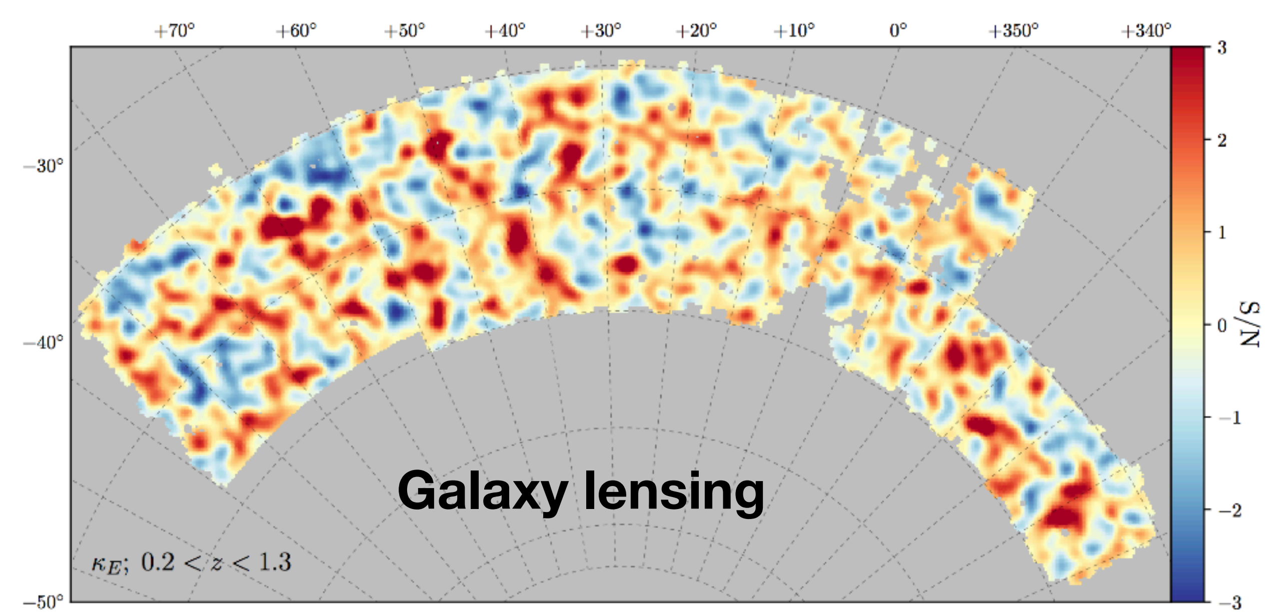
Recent results from DES

Recent results from DES:
Cosmological constraints from 2pt functions

Two-point correlations between **galaxy positions** and **gravitational lensing** are sensitive to cosmology:



Elvin-Poole et al. 2017

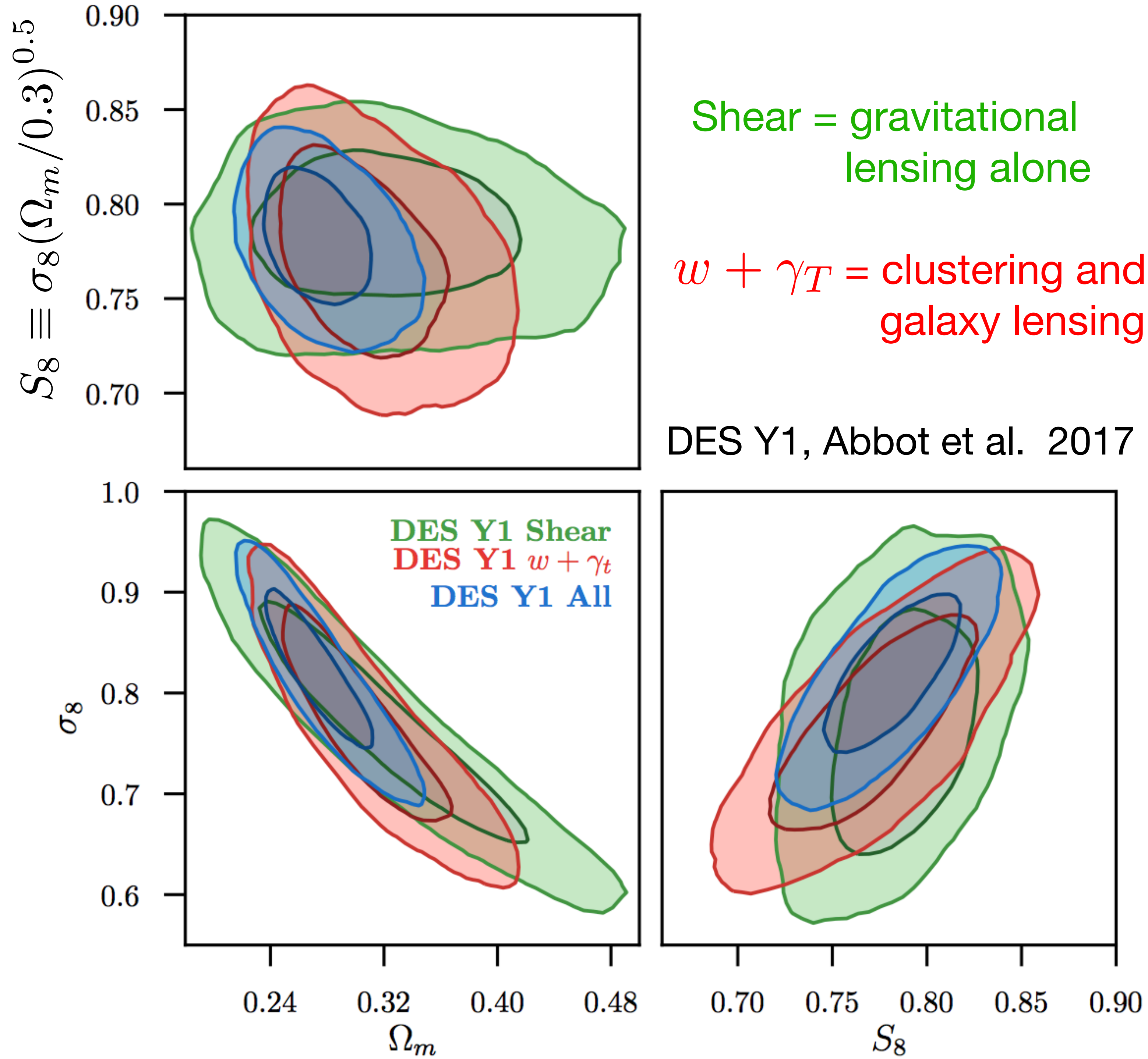


Chang et al. 2017

Recent results from DES: Cosmological constraints from 2pt functions

Two-point correlations between **galaxy positions** and **gravitational lensing** are sensitive to cosmology

DES Y1 joint two-point analysis (3x2pt)
  Tightest cosmological constraints from a single galaxy survey!



Shear = gravitational lensing alone

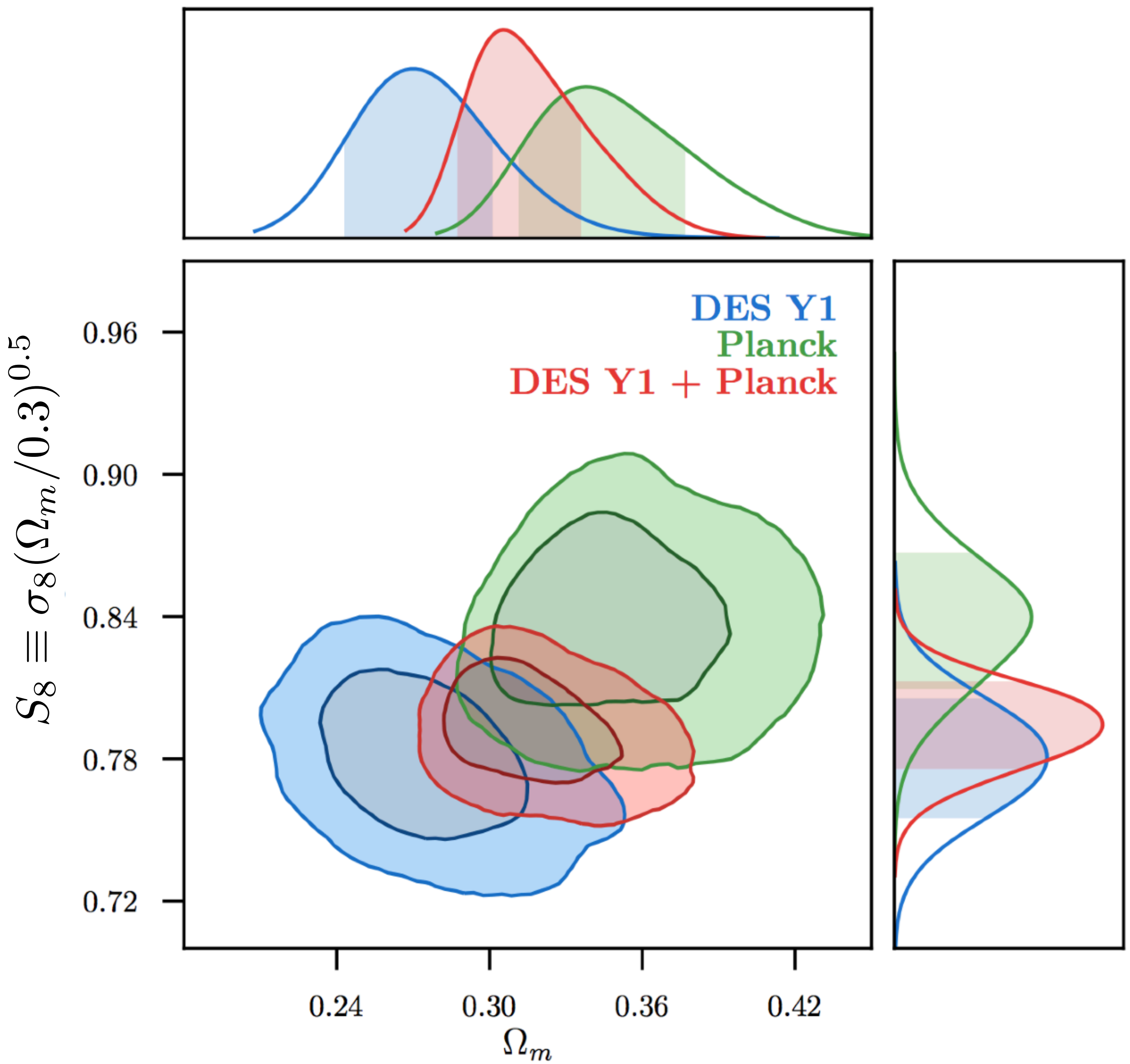
$w + \gamma_T$ = clustering and galaxy lensing

DES Y1, Abbot et al. 2017

Recent results from DES: Cosmological constraints from 2pt functions

DES prefers slightly lower value of S8

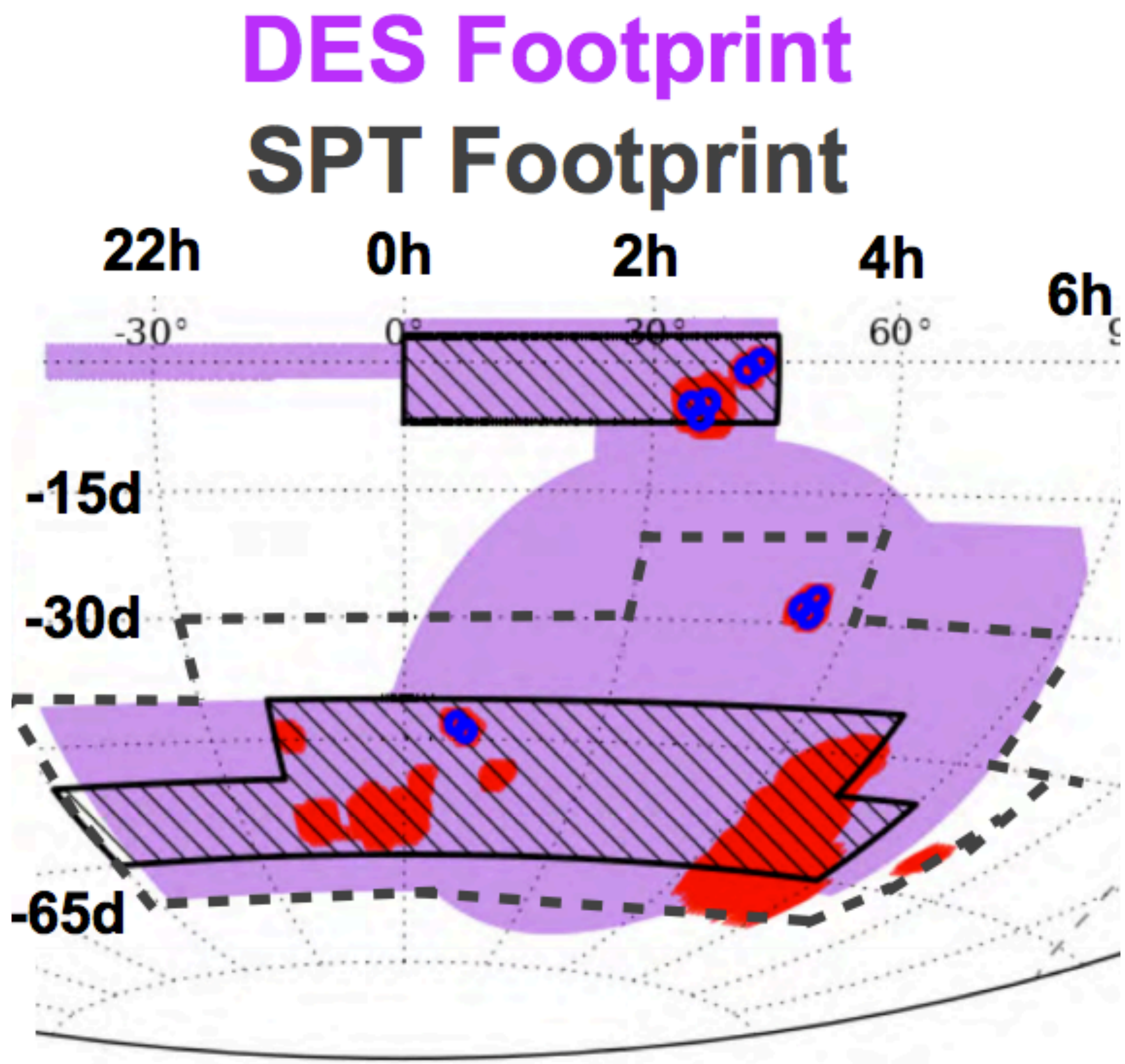
- Same as earlier lensing results
- But **not** statistically significant



DES Y1, Abbot et al. 2017

Recent results from SPT x DES

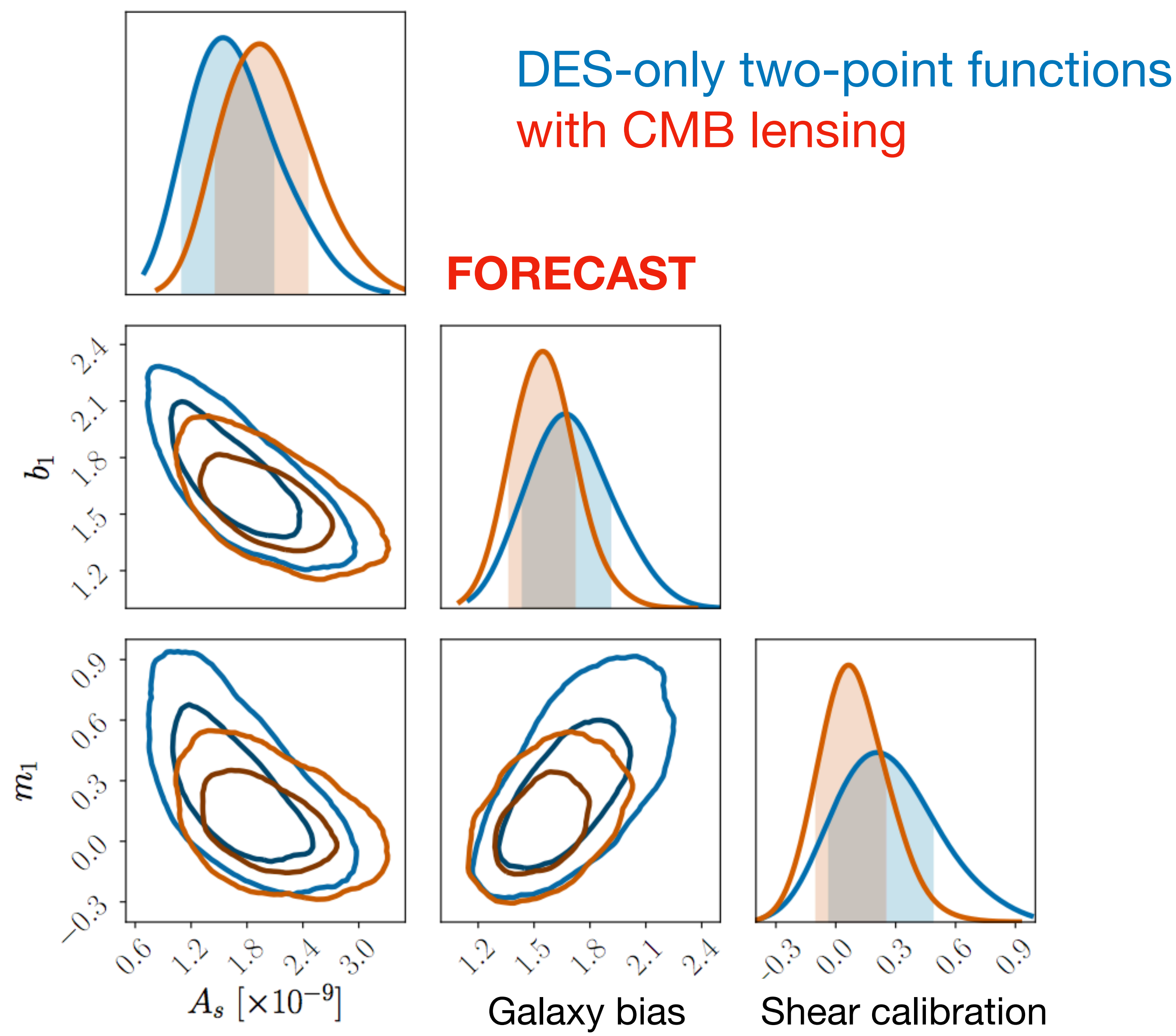
Significant overlap between SPT and DES surveys makes cross-correlation analyses possible



Recent results from SPT x DES: Joint 2pt function measurements

Two-point correlations between DES **galaxies** and **shears** with SPT measurement of **CMB lensing**

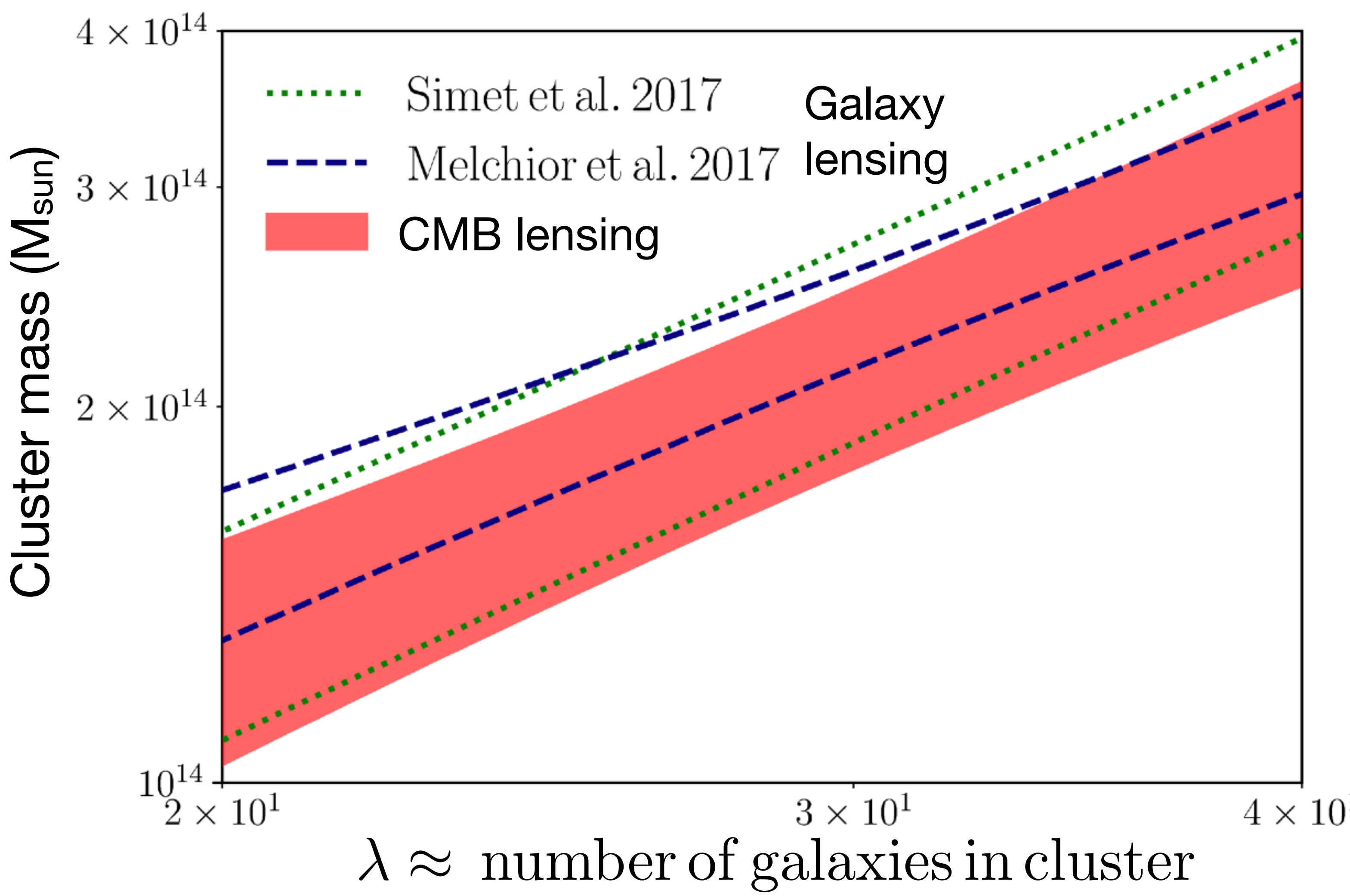
- Provides consistency test
- Breaks parameter degeneracies
- Adds signal-to-noise



Baxter et al. 2018a

Recent results from SPT x DES: Using the CMB to measure masses of DES galaxy clusters

SPT CMB lensing measurements place competitive constraints on masses of DES galaxy clusters!



Baxter et al. 2018b

Future: SPT-3G

SPT-3G
Order of magnitude more detectors than SPTpol
20x mapping speed

~10,000 galaxy clusters
- Masses calibrated to ~3% with CMB lensing

~150σ measurement of CMB lensing power spectrum

First light on Jan. 30th 2017

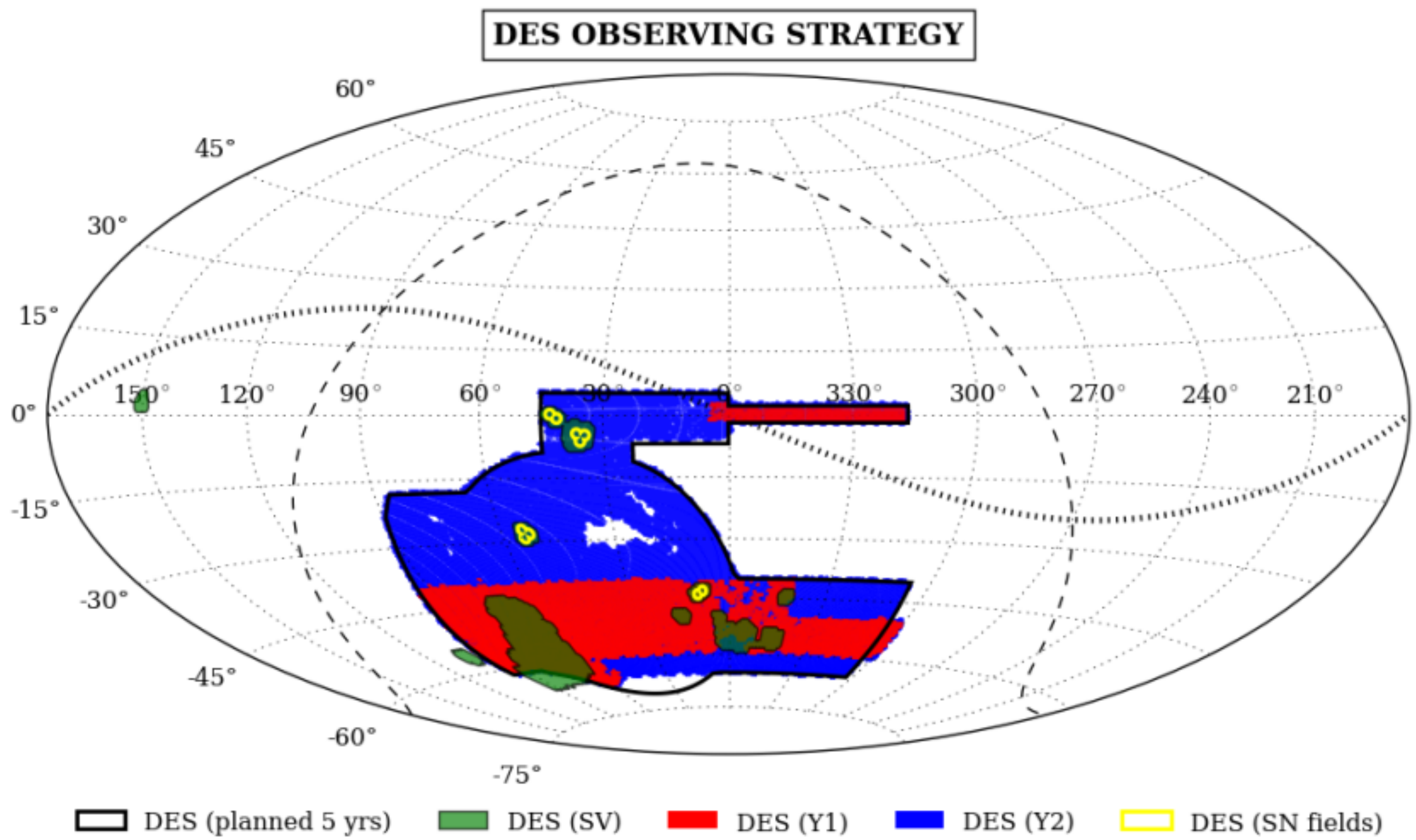
Projections
(w/ Planck priors)

	SPT-3G (2019)
$\sigma(r)$	0.011
$\sigma(N_{eff})$	0.058
$\sigma(\Sigma m_\nu)$	0.061 eV*

* Includes BOSS prior

Benson et al. 2014

Future: DES Year 5.5



Year 5 data already collected, currently being processed

- Deeper imaging, more area
- Improved shear estimates
- Expanded galaxy catalogs
- Analysis improvements

Future: cross-correlation science

Future DES and SPT data

- **More overlap**
- **Better CMB lensing maps**

DES x Atacama Cosmology Telescope

AdvancedACT has low noise and large overlap with DES

Highlights of cross-correlation science

- Improved cosmological constraints with **CMB lensing cross-correlations**
- Improved cosmological constraints from **multi-wavelength galaxy cluster observations**
- **Constraints on gas physics** in dark matter halos from measurement of thermal and kinematic Sunyaev-Zel’dovich effects

Summary

Many different probes from two fundamentally different experiments are broadly consistent with same cosmological model (with possible hints of tensions)

High level of synergy between SPT and DES experiments

- Overlap enables exciting cross-correlation science

Stay tuned for new results!

DARK ENERGY SURVEY

SOUTH POLE TELESCOPE

Thank you!