

# **A Brief history of cosmological surveys**

**z2c 2024, A socio-historical perspective**

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# A List

## **Clustering Surveys:**

2dF Galaxy Redshift Survey  
SDSS/BOSS

DESI

## **Lensing Surveys:**

CFHTLens  
DES, KIDS, UNIONS, HSC  
Euclid, LSST

## **CMB surveys:**

COBE  
WMAP  
Planck  
ACT, SPT  
Simons Observatory

## **Radio Surveys:**

SKA

## **Supernova Surveys:**

Pantheon+, SHOEs

# An Observationalist's guide to the Universe (numbers are approximate)

	<b>Area (N/S)</b>	<b>Type</b>	<b>Z range</b>	<b>Key results</b>	<b>Tracers</b>	<b>arXiv</b>	<b>Year</b>
2dFGRS	1500 sq.deg. (S)	Spectra	[0,0.25]	BAO	BGs	0501174	2005
SDSS/BOSS	9000 sq.deg (N)	Spectra	[0,3.5]	BAO+P(k)	BGs,,LRG,ELG,QSO	<a href="https://www.sdss4.org/science/final-bao-and-rsd-measurements/">https://www.sdss4.org/science/final-bao-and-rsd-measurements/</a>	2000-??
DESI	14000sq.deg(N)	Spectra	[0.2,4]	BAO+ $W_0 W_a$	BGs,LRG,ELG,QSO	2404.03002	2019-2024
CFHTLens	154 sq.deg (N)	Image,ugriz	[0.2,1.3]	$\sigma_8(\Omega_m/0.27)^{0.6} = 0.79 \pm 0.03$	r_mag < 24	1212.3338	2012
DES	4100 sq.deg(S)	Image,grizY	[0.1,1.4]	$S8=0.802^{+0.023}_{-0.019}$	r_mag < 24.5	2305.17173	2013-19
KiDS	1200 sq.deg(S)	Image, ugrizYJHKs	[0.1,1.5]	$S8=0.759^{+0.024}_{-0.021}$	r_mag < 25	2007.15633	2020
UNIONS	5000 sq.deg(S)	Image, ugriz	[0.1,1.4]	S8	r_mag < 24.5	2204.04798	2024
HSC	416 sq.deg(N)	Image,grizy	[0,2]	$S8=0.775^{+0.043}_{-0.038}$	r_mag < 26	2304.00705	2023
Euclid	14000sq.deg(N)	Im+spec,Vis,YJH (IR)	[0,2.5]?	Dark en. EoS, S8, m_neutrino	r_mag < 26.2	1110.3193	2024-2030
LSST	18000sq.deg(N)	Image,ugrizy	[0,4]?	SNe1, Dark en. EoS, S8	r_mag < 27.8	0912.0201	2025~35
COBE	All sky	[31:90]GHz	1100	T(CMB)=2.71K	Temp spec.	9902027	1993
WMAP	All sky	[23:94]GHz	1100	Ba0.05/CDM0.25/ $\Lambda$ 0.7	Temp aniso.	1212.5225	2001-2010
Planck	All sky	[30:857]GHz	1100	$\Lambda$ CDM params	Temp aniso.	1807.06209	2009-2015
ACT/SPT	4000/500	[39:277]/[90:220]GHz	1100+[0,6]	CMBxLSS	Temp aniso.	2304.05203/2212.05642	2012-2028
SO	40% f_sky	[27:270]GHz	1100+[0,6]	r<0.002 (s/t)	Temp aniso.	1808.07445	2025-2034
SKA	20000sq.d. (S)	Radio [0.35-18.8 GHz]	[3,6]	EoR phys./21cm	Neutral hydro.	1811.02743	2027?-
Pantheon+, SHOEs,	All sky (except zodiacal light)	SNE1a	Z<2.26	$H0=73.1\pm1.1$ km/s/Mpc,	Light curve	2202.04077	2022

# 2dFGRS, Two-degree-Field Galaxy Redshift Survey

**Discovery of BAOs!**

Discoveries:

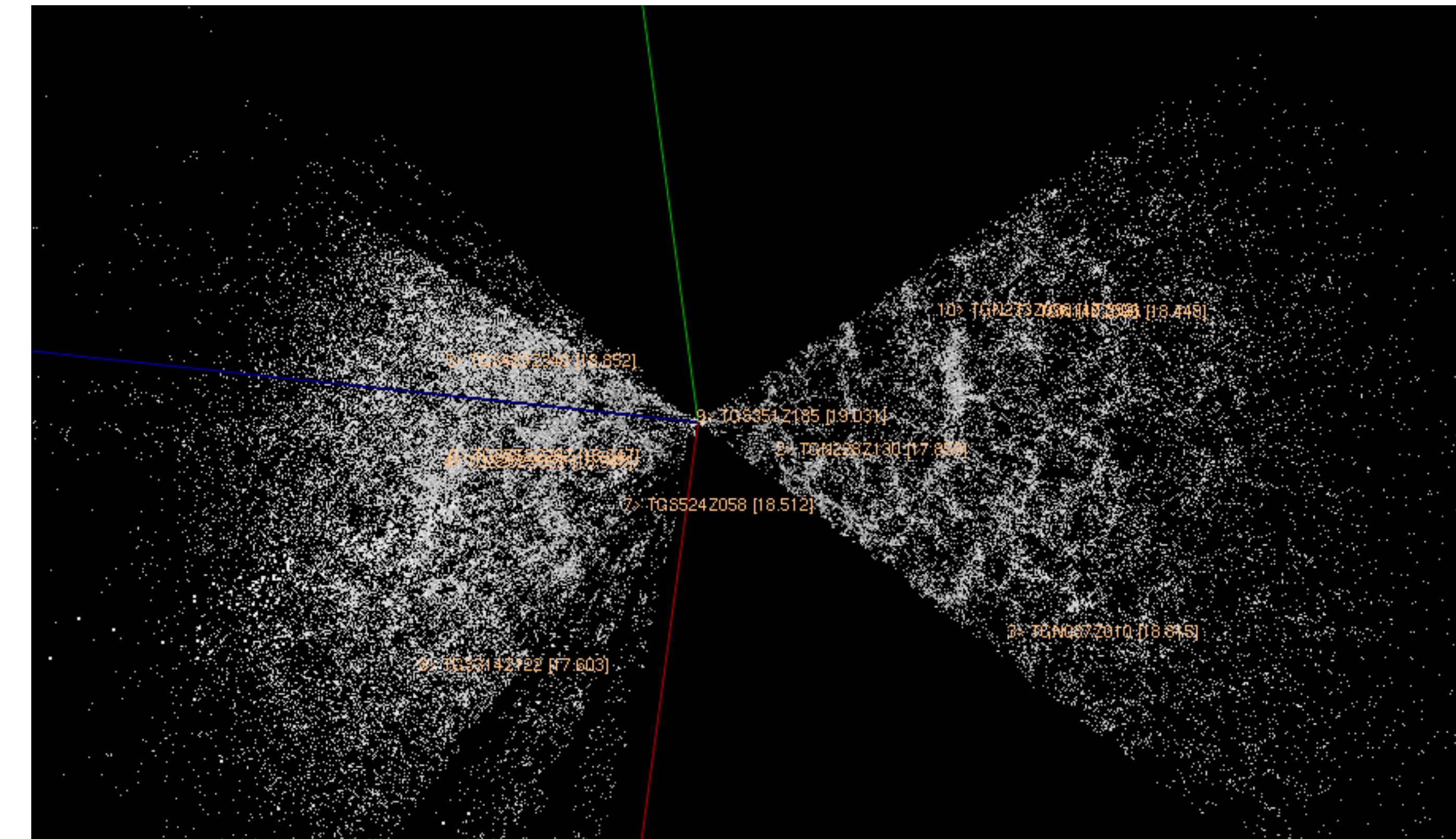
- BAO discovered at the same time as SDSS

Survey:

- 220 000 Galaxy spectra

- 1500 sq.deg

- Redshift  $z \in [0,0.25]$



# SDSS/BOSS (Sloan Digital Sky Survey/ Baryon oscillation Spectroscopic Survey)

- Lots of things apart from cosmology
- spectra for 930,000 galaxies and 120,000 quasars
- u,g,r,i,z imaging for target selection
- 9000 sq deg
- Clustering focused on large scales
  - BAO co-discovery
  - Main Tracers:
    - ELG (Emission Line galaxies)
    - LRG (Large Red Galaxies)
    - CMASS (
    - QSO (Quasi Stellar Object)

## -MANGA

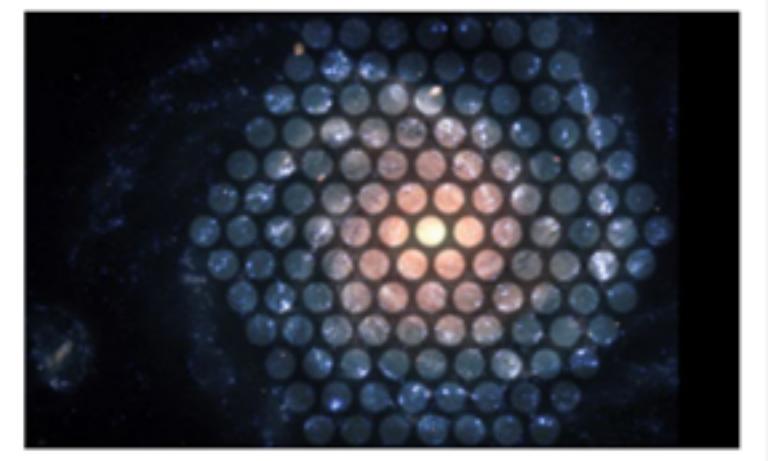
SDSS V : (started 2020)

Milky Way Mapper

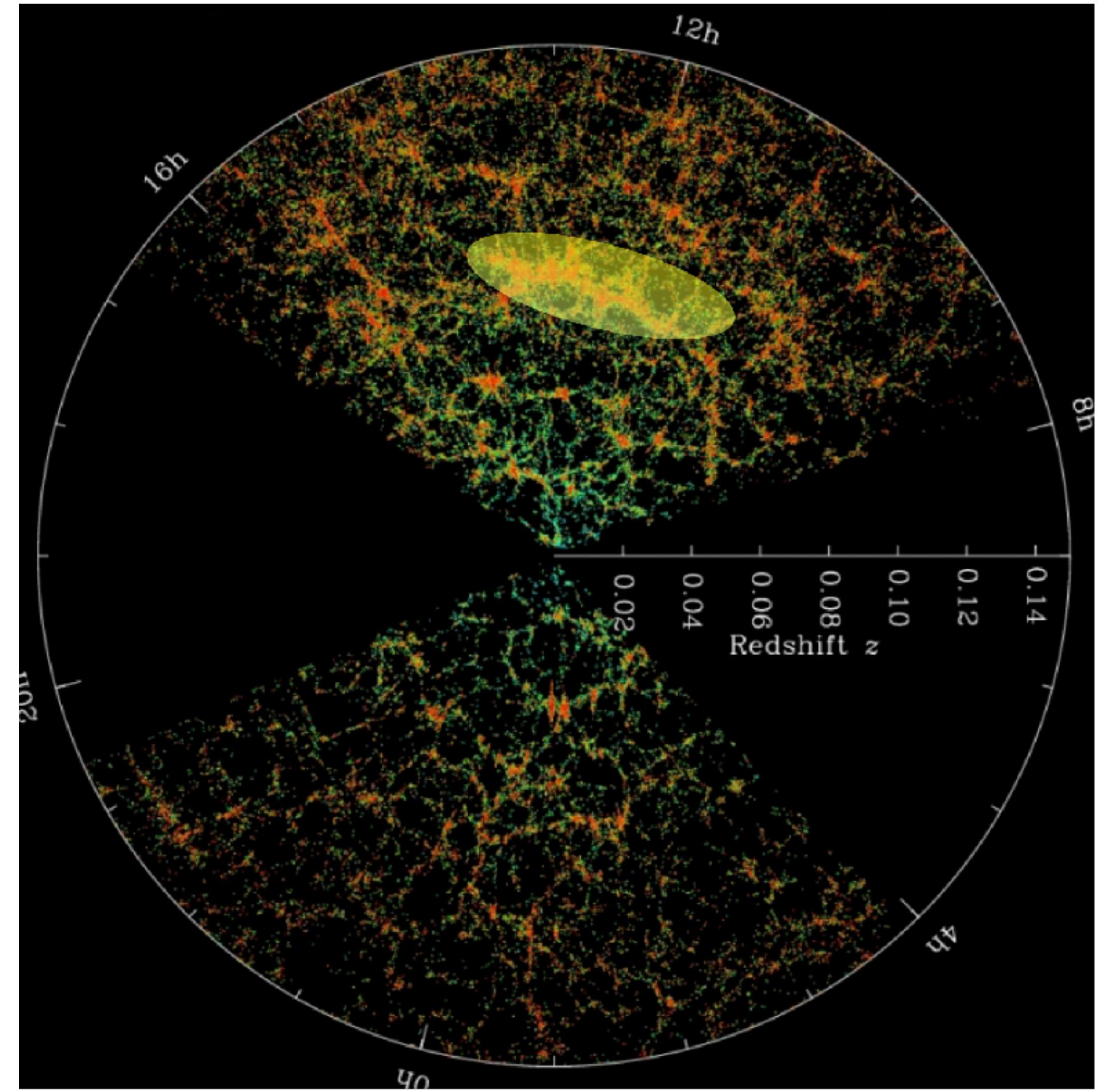
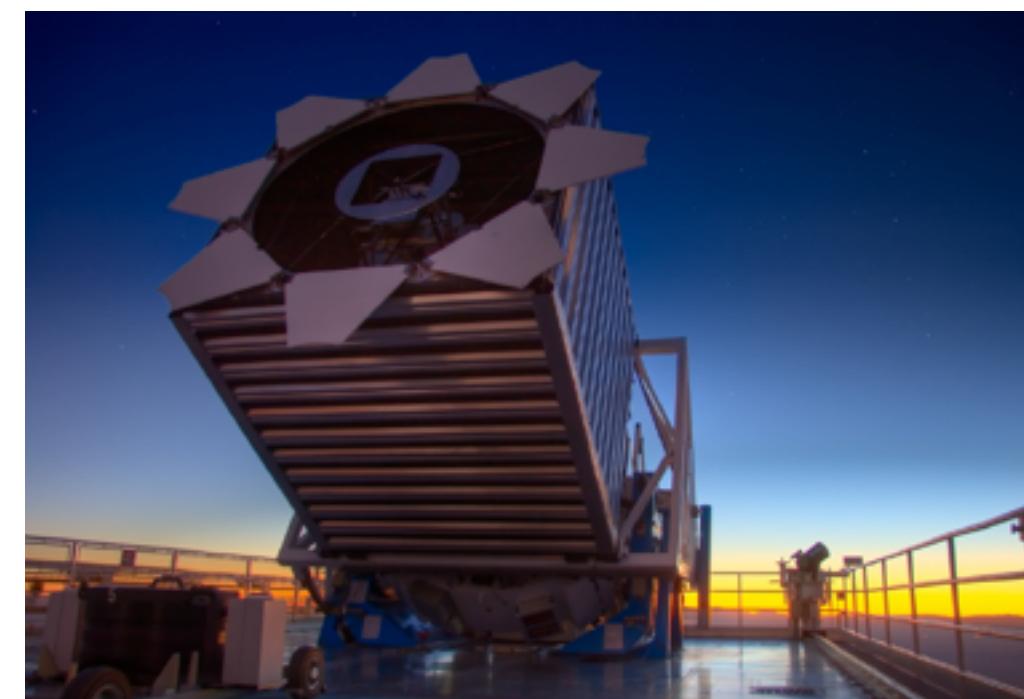
Black Hole Mapper

Local Volume Mapper

**MaNGA**

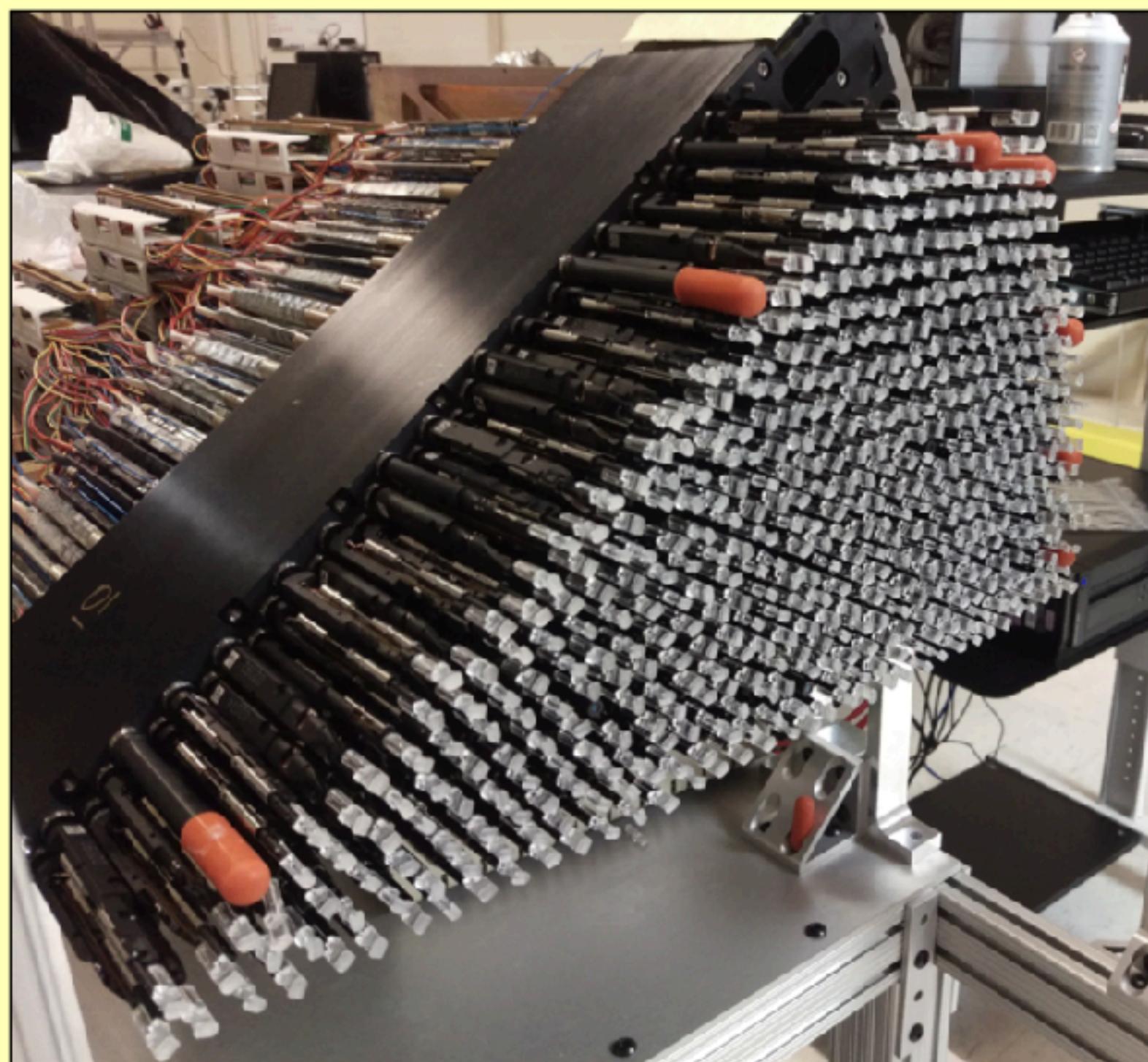


The galaxy survey for people who love galaxies! MaNGA will explore the detailed internal structure of nearly 10,000 nearby galaxies using spatially resolved spectroscopy. Subprogram MaStar will provide an optical stellar library covering thousands of stars with a wide range of parameters.

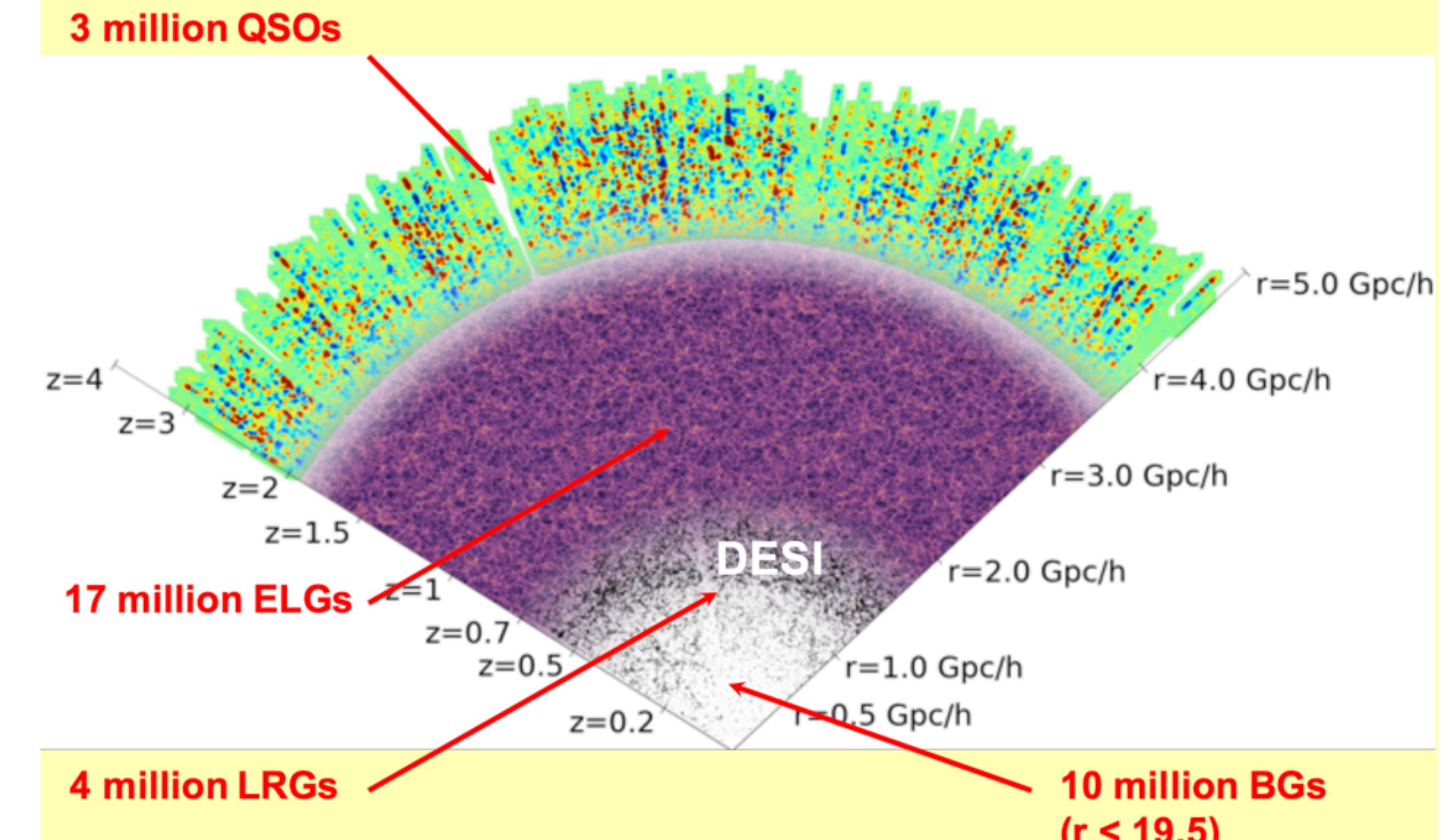


# DESI (Dark Energy Spectroscopic Instrument)

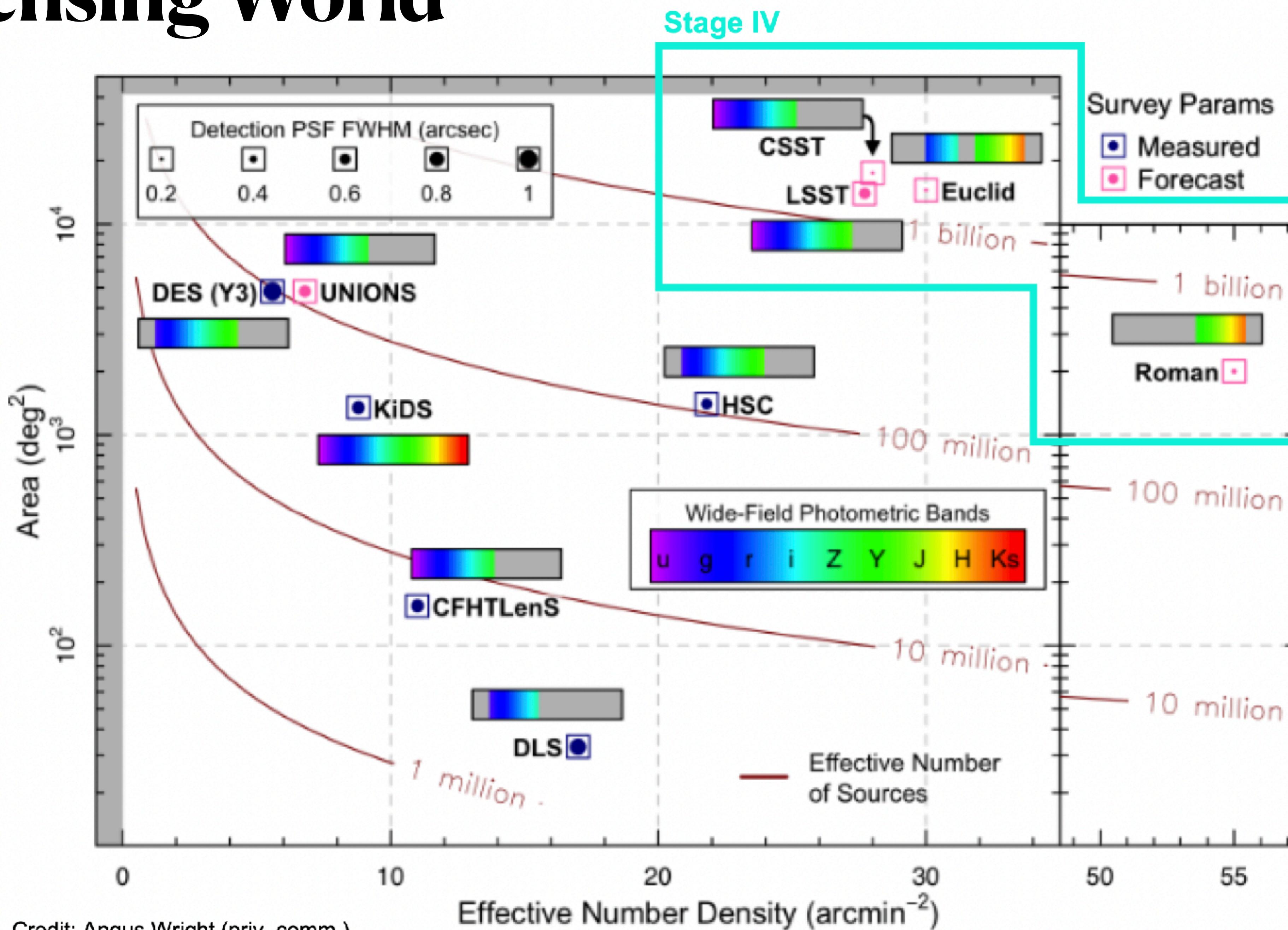
**DESI positioner**



**DESI redshift coverage**



# The Lensing World



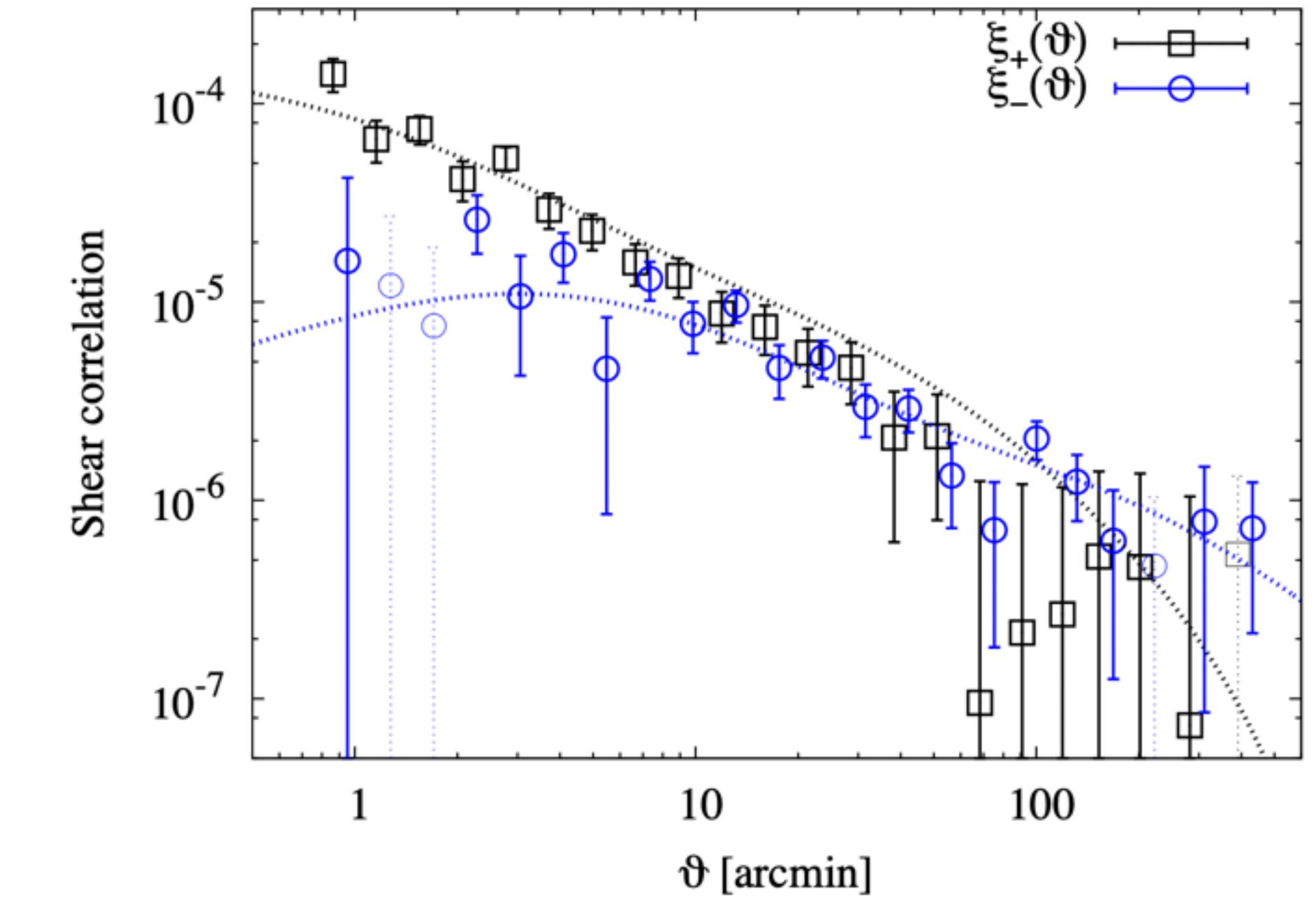
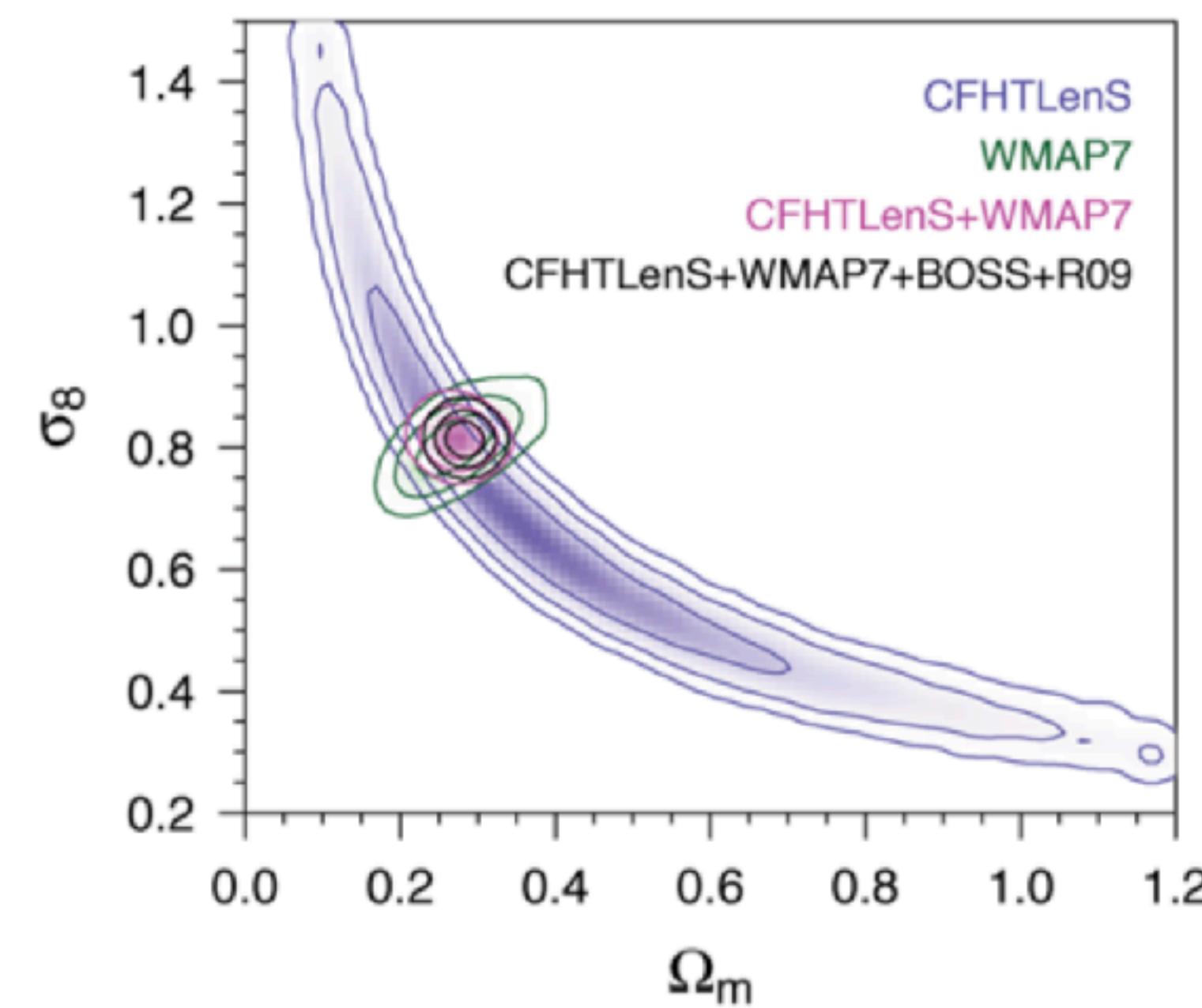
Credit: Angus Wright (priv. comm.)

# CFHTLens (Canada France Hawaii Telescope)

-4.2 million galaxies

-0.2 < z < 1.3

-154 sq.deg

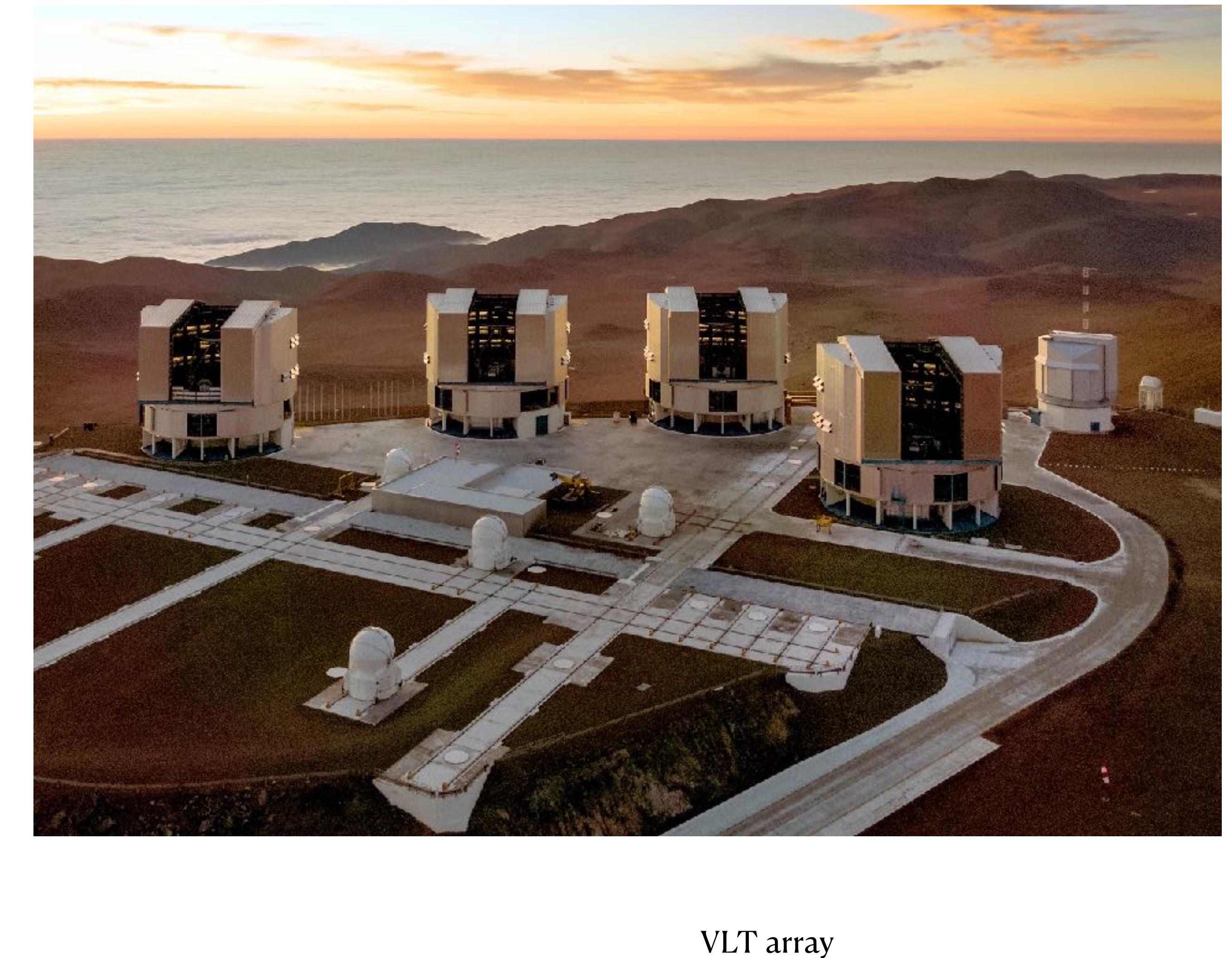
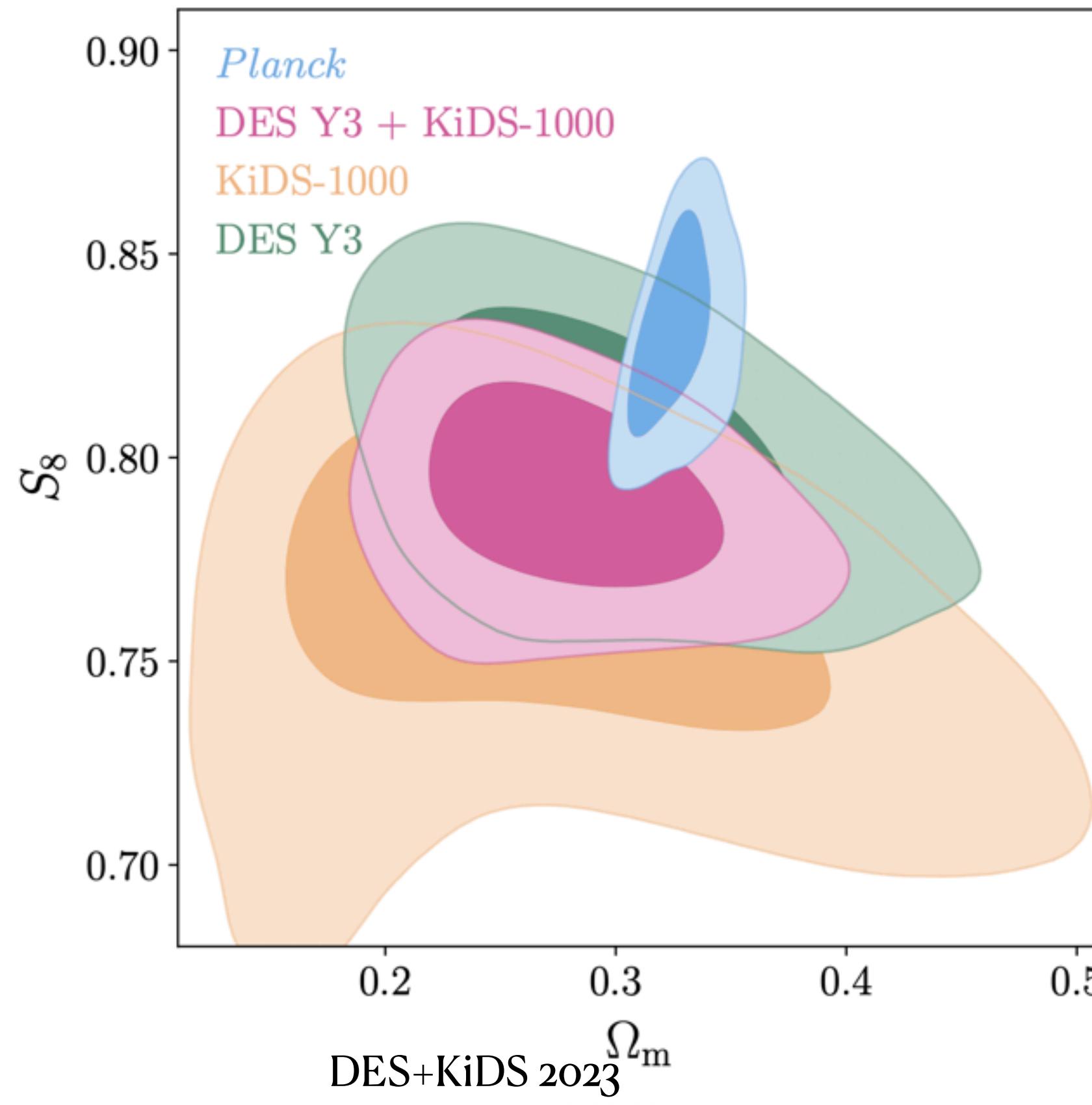


**Figure 6.** The measured shear correlation functions  $\xi_+$  (black squares) and  $\xi_-$  (blue circles), combined from all four Wide patches. The error bars correspond to the total covariance diagonal. Negative values are shown as thin points with dotted error bars. The lines are the theoretical prediction using the WMAP7 best-fitting cosmology and the non-linear model described in

Kilbinger 2012

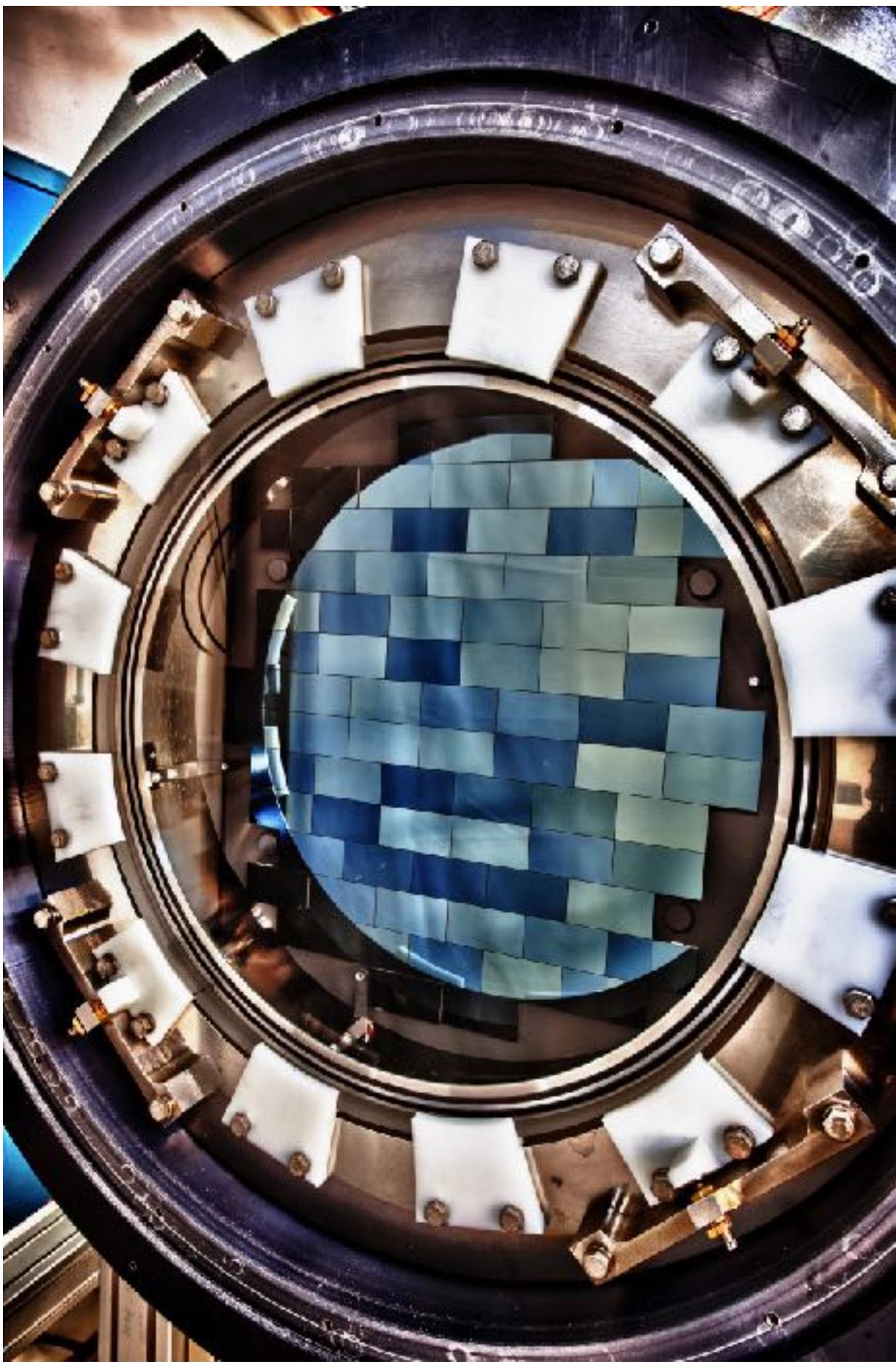
# KiDS (Kilo Degree Survey)

- Unique coverage of 9 bands
- First strong S8 claim



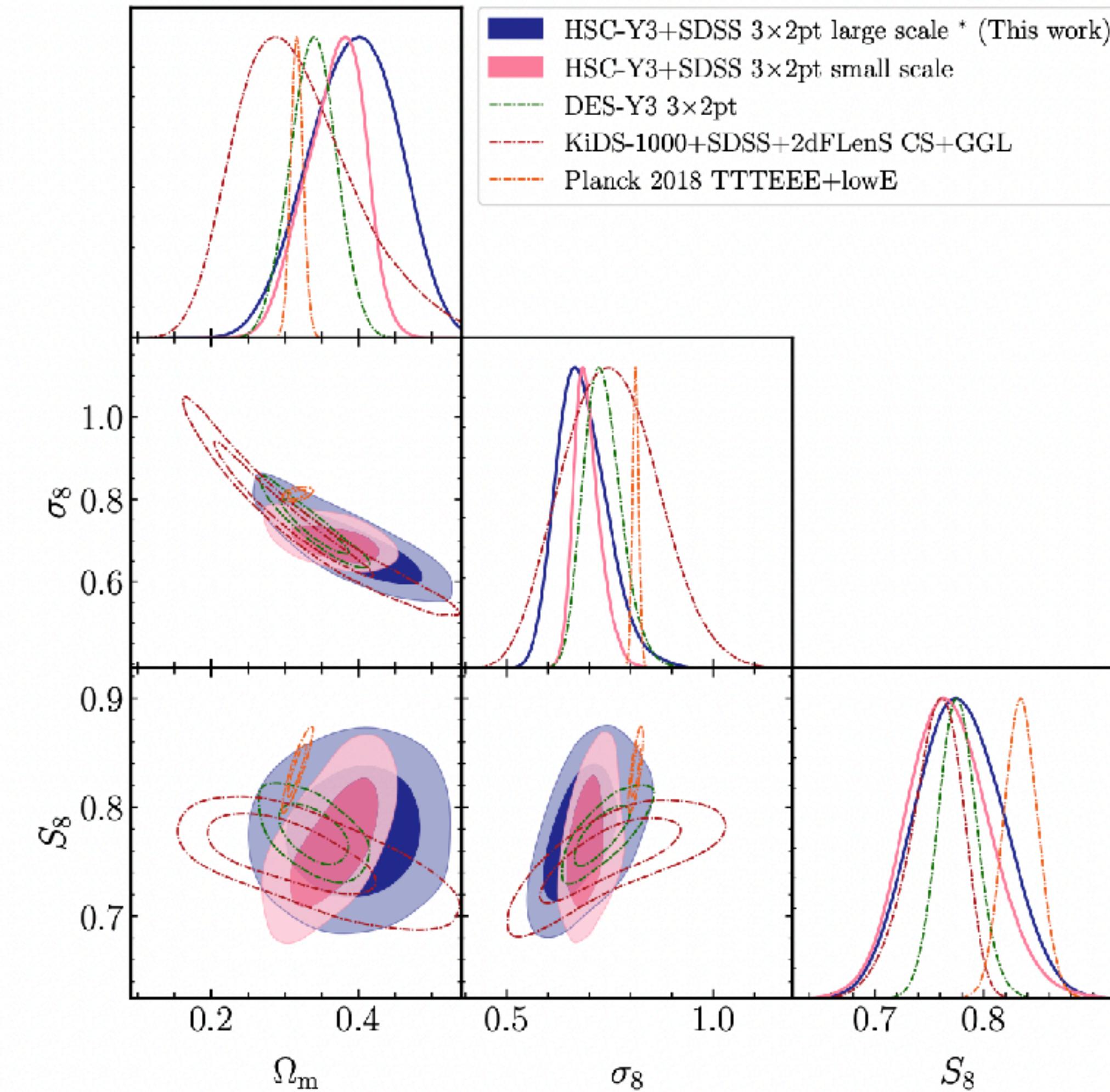
# DES (Dark Energy Survey)

- Can do clusters and Supernova
- A lot of methodology developed for LSST



# HSC (Hyper Suprime-Cam)

- Noticeably deep survey ( $r < 26$ )
- Allows good preparation for stage 4
- Y<sub>3</sub> Shape catalogue available next week?
- Small area but equal number of galaxies



# UNIONS (Ultraviolet Near Infrared Optical Northern Survey)



Canada-France-Hawaii Telescope



Pan-STARRS



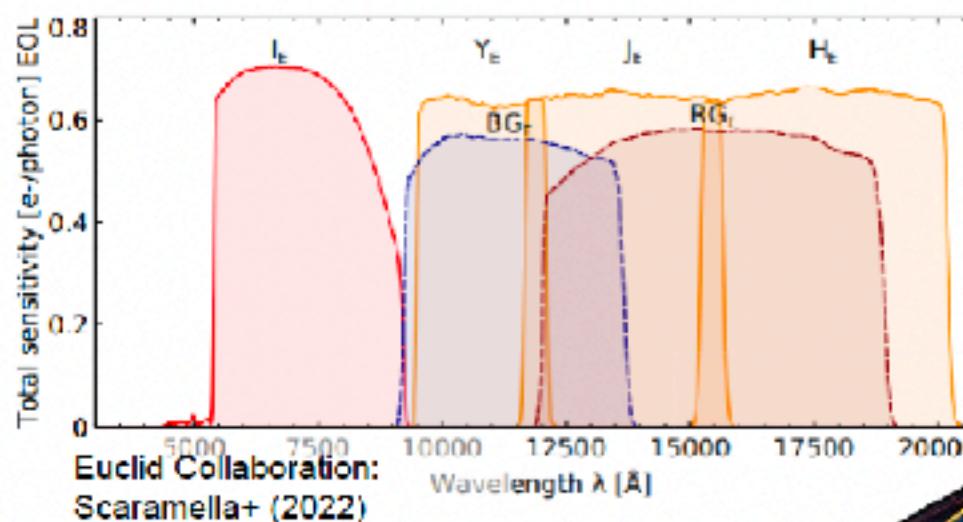
Subaru Telescope

# Euclid

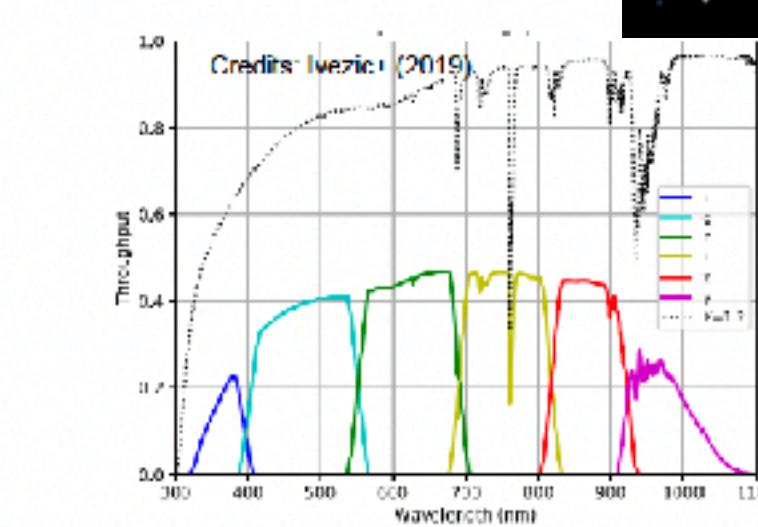
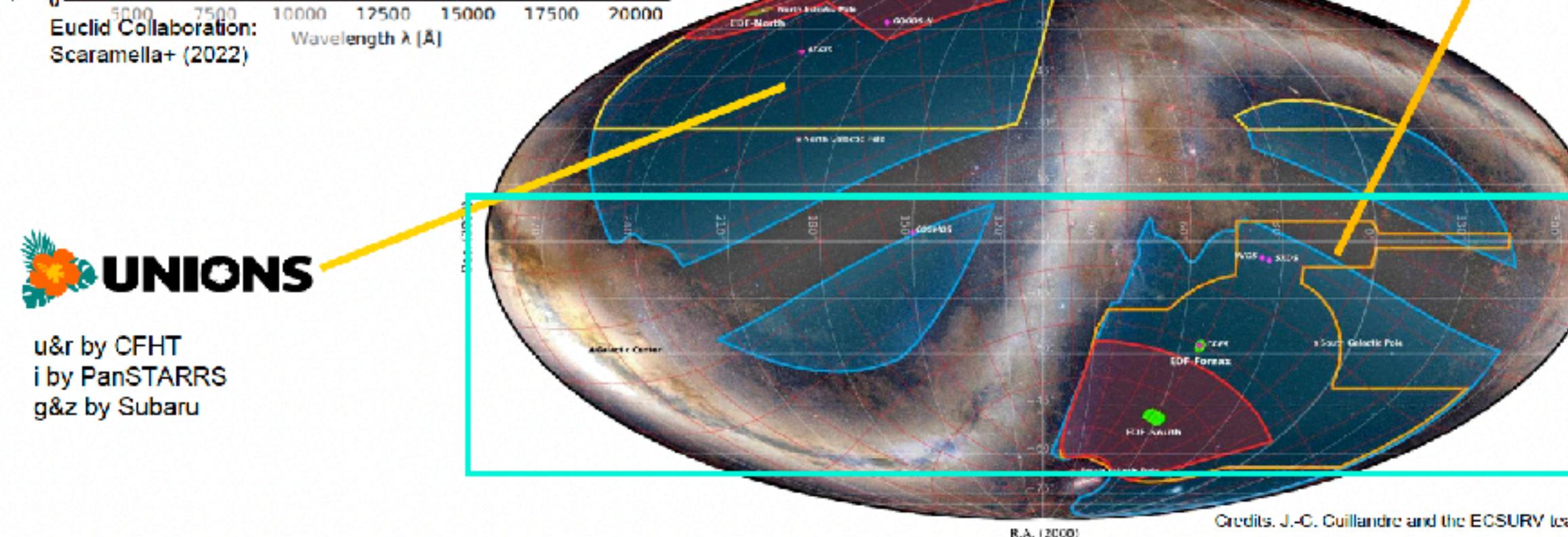
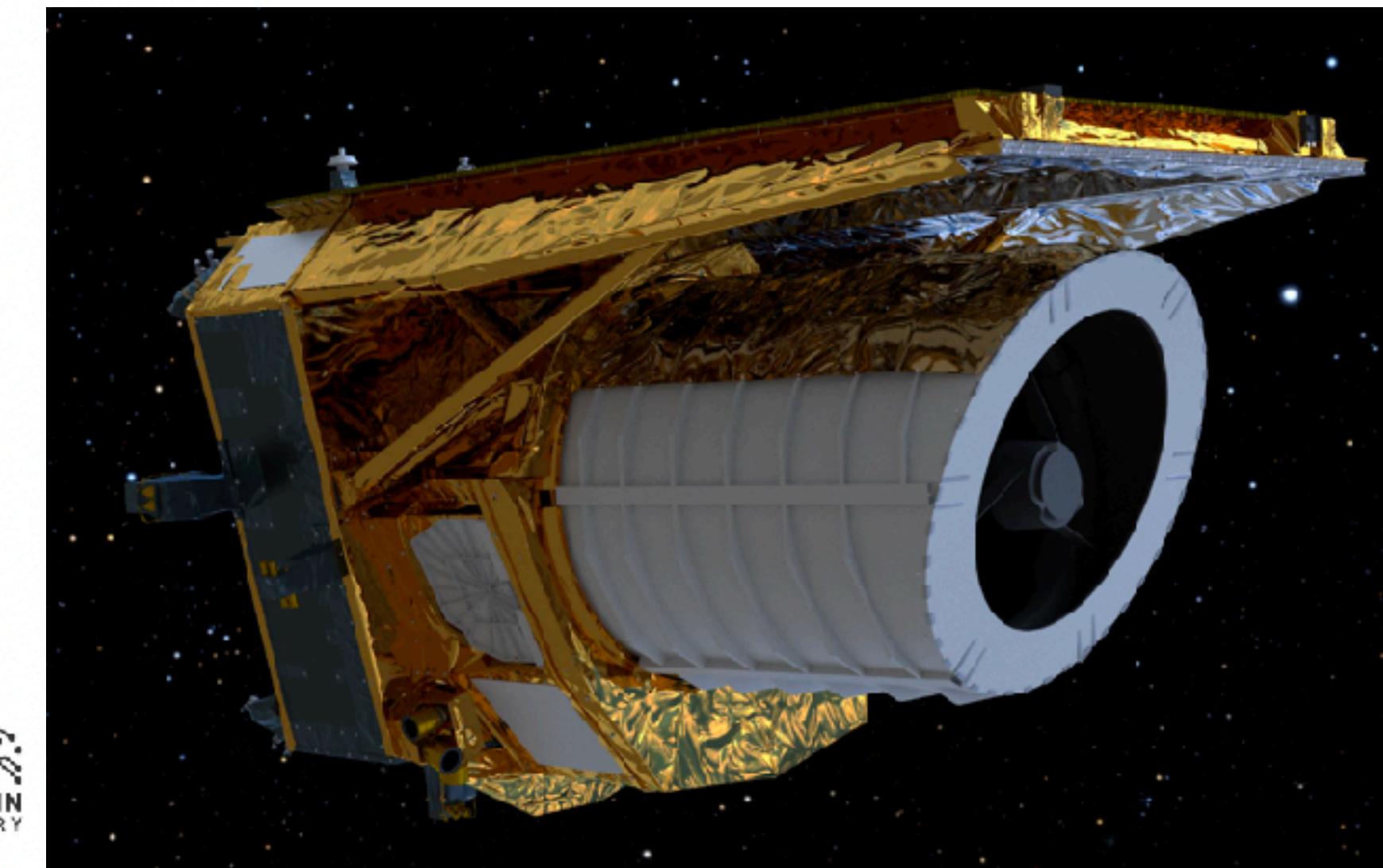
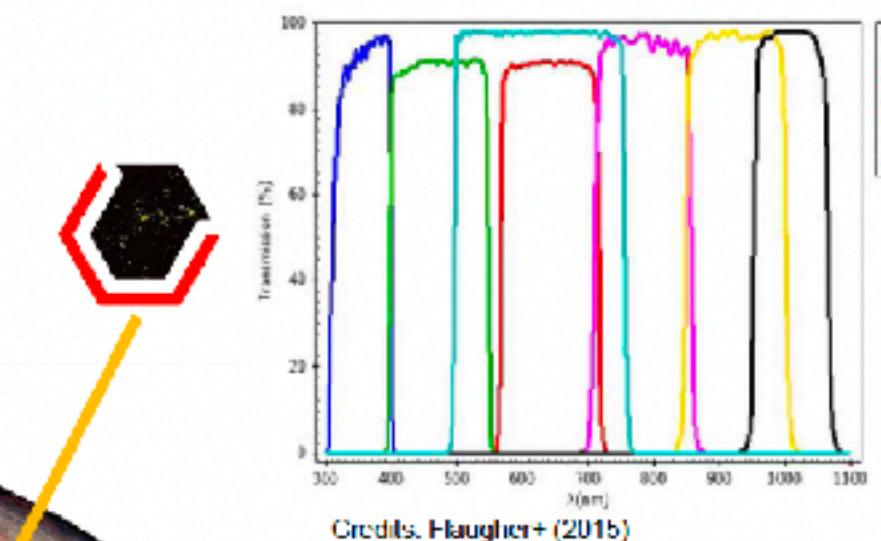
# -Hubble space Telescope quality on 14000 sq deg



**Euclid's success is fueled by synergies with other missions**

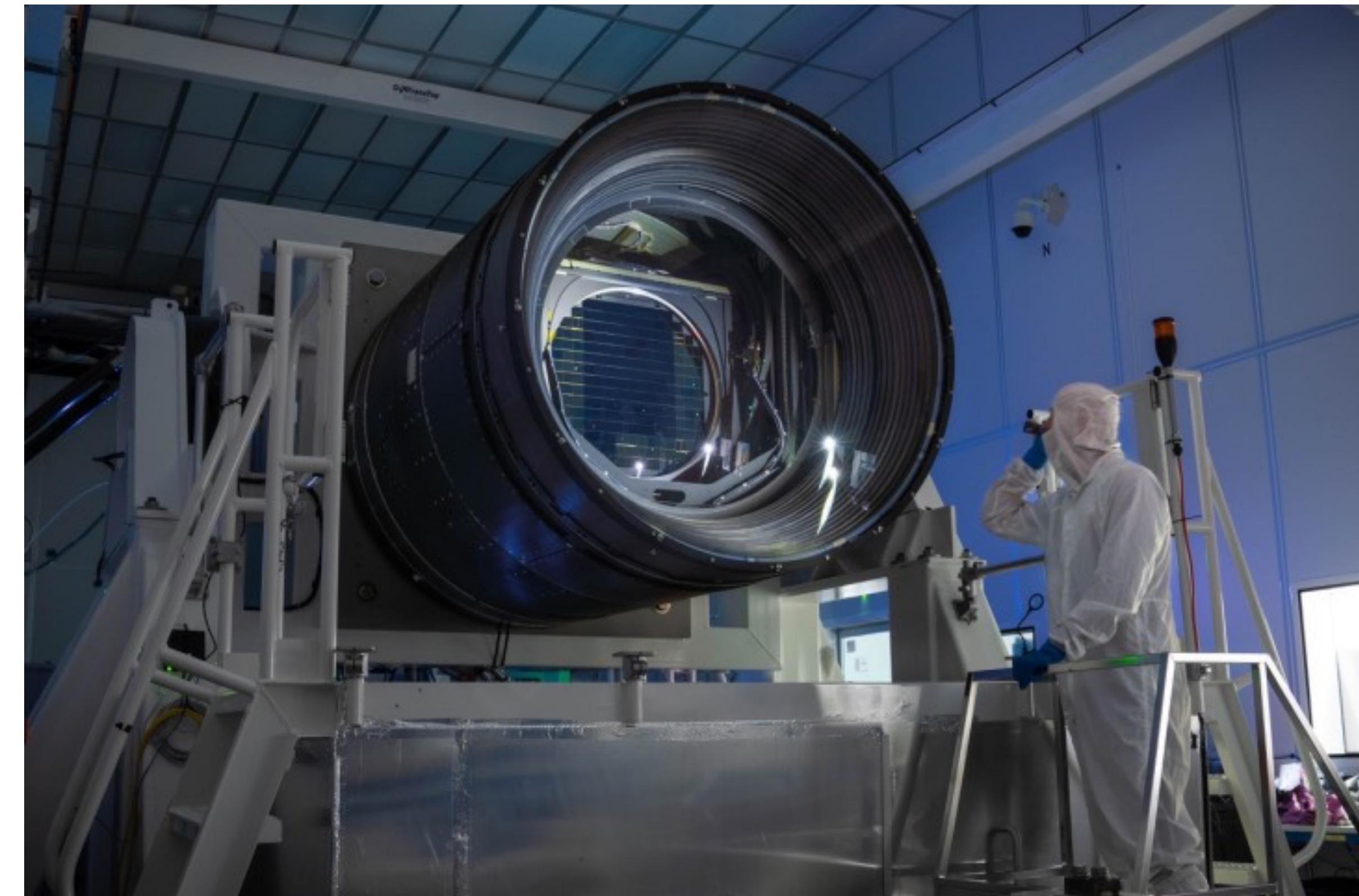


VIS alone cannot give us photometric redshift estimates!



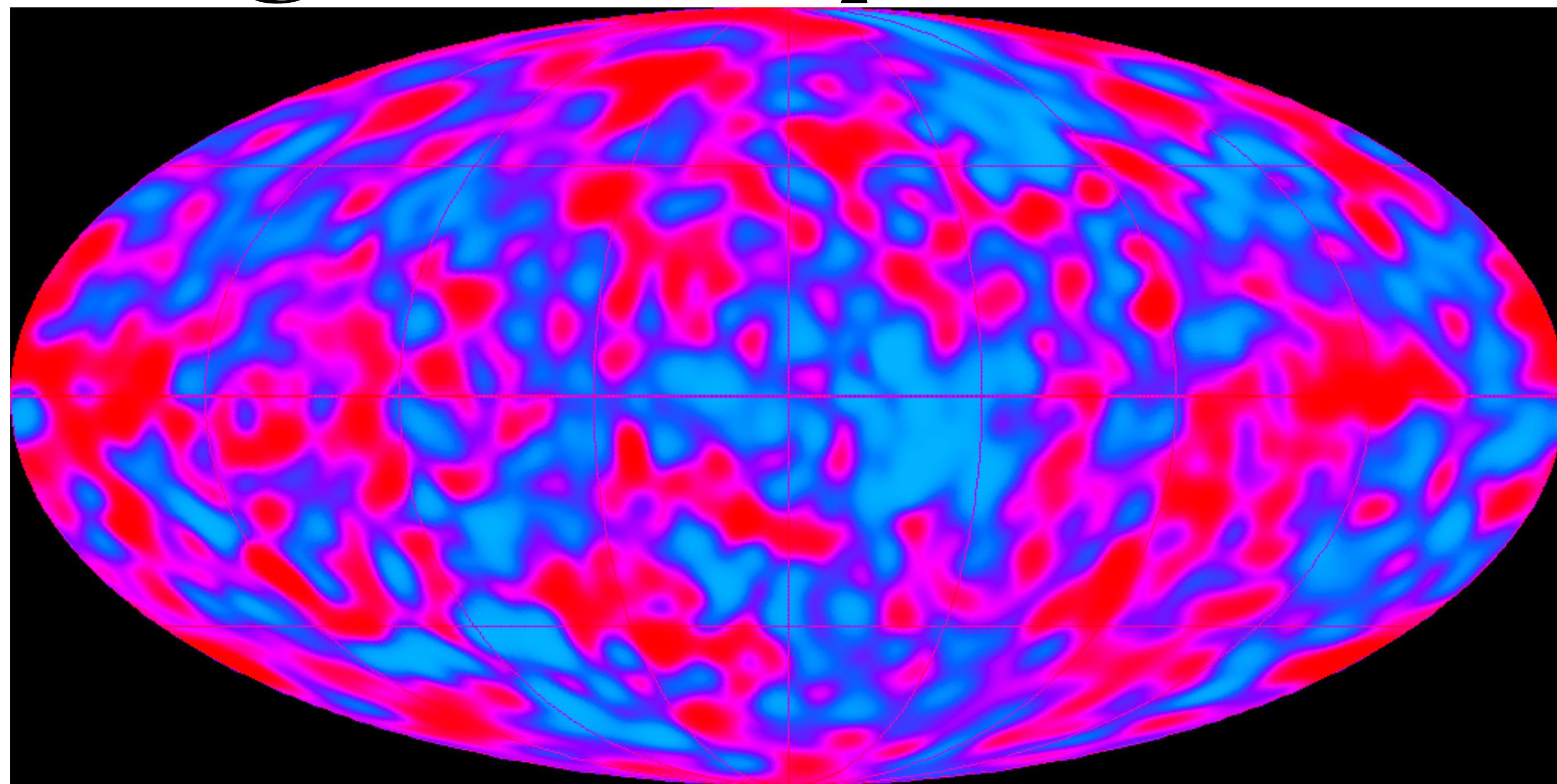
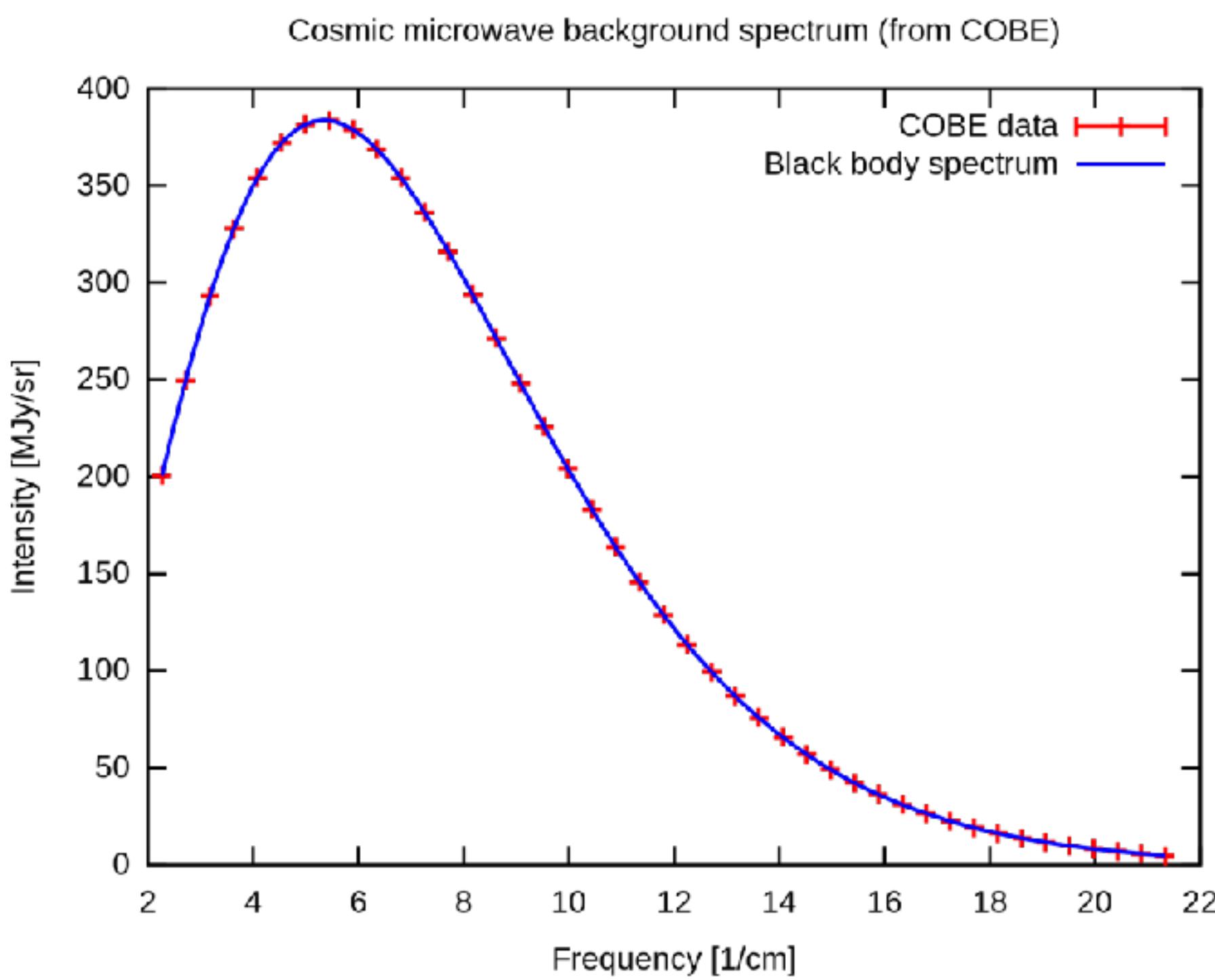
# LSST (Large Survey of Space and Time)

- Amazing combination of time domain and wide images by continuous scanning of the sky (every N days)
- Amazing depth in 5 bands
- Necessary for Euclid
- Blurring of the atmosphere will be a limit (PSF+blends)



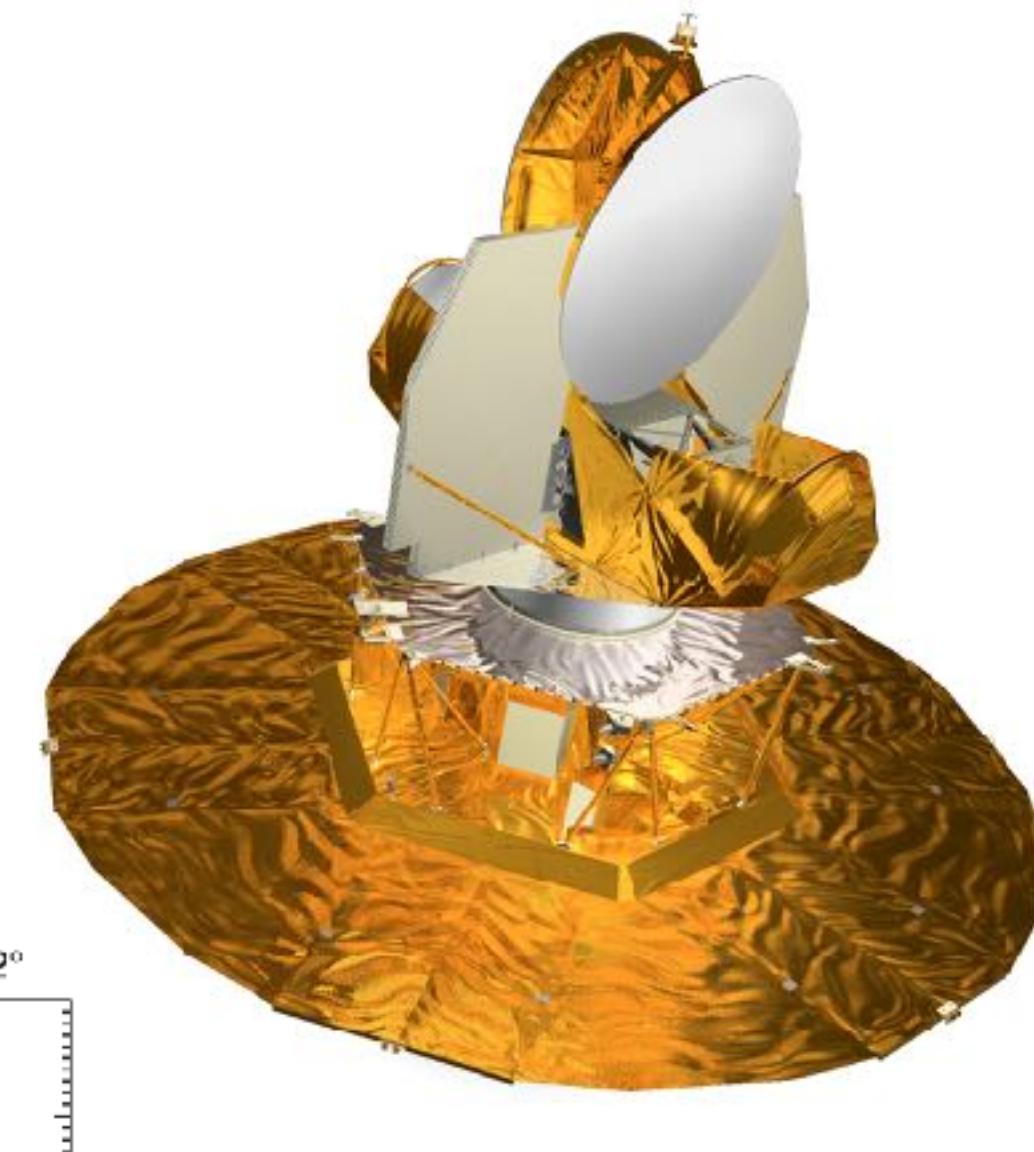
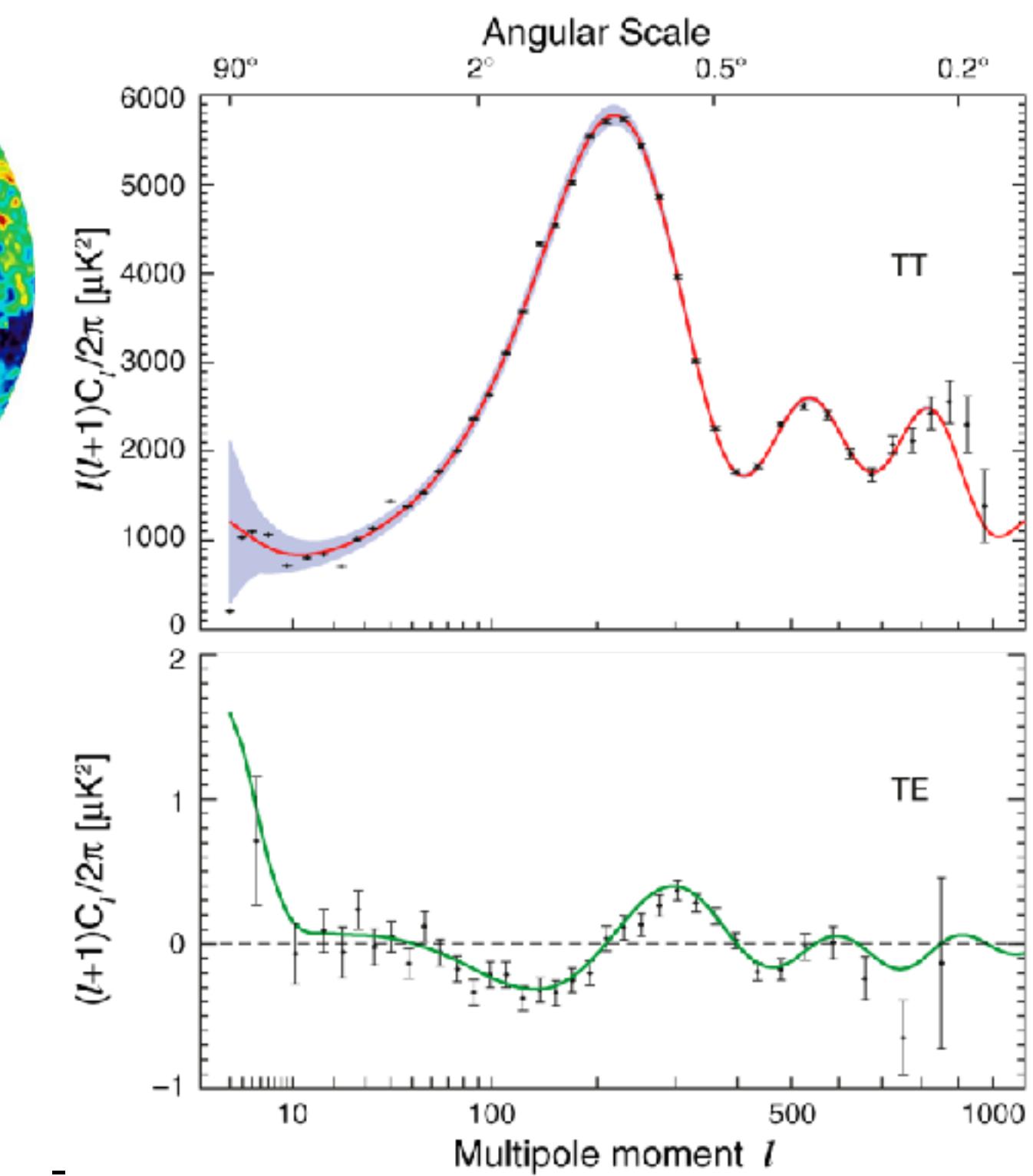
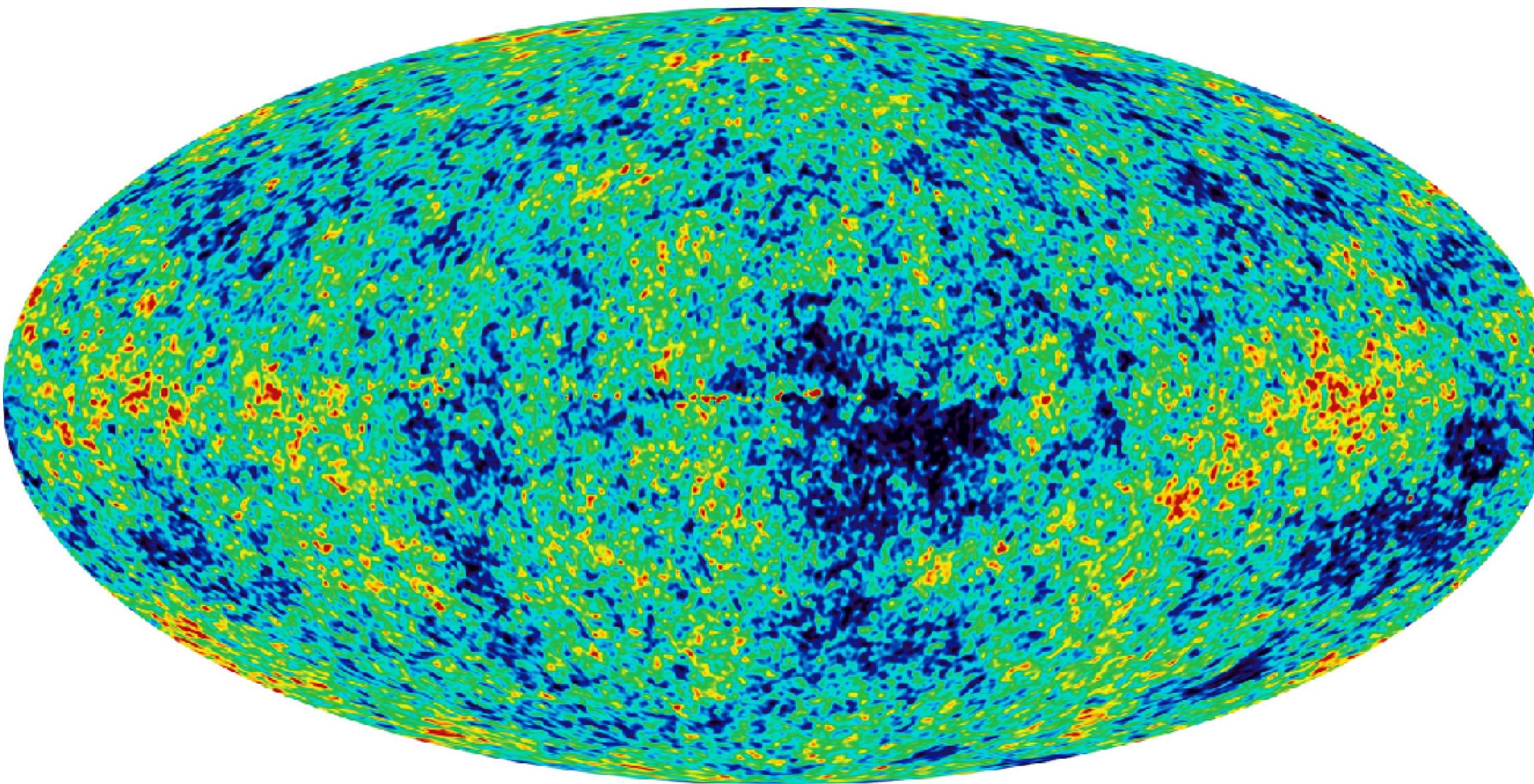
# COBE (Cosmic Background Explorer)

- A window that hasn't bee probed in a long time (full Black Body spectra)
- Only full spectrum measurement



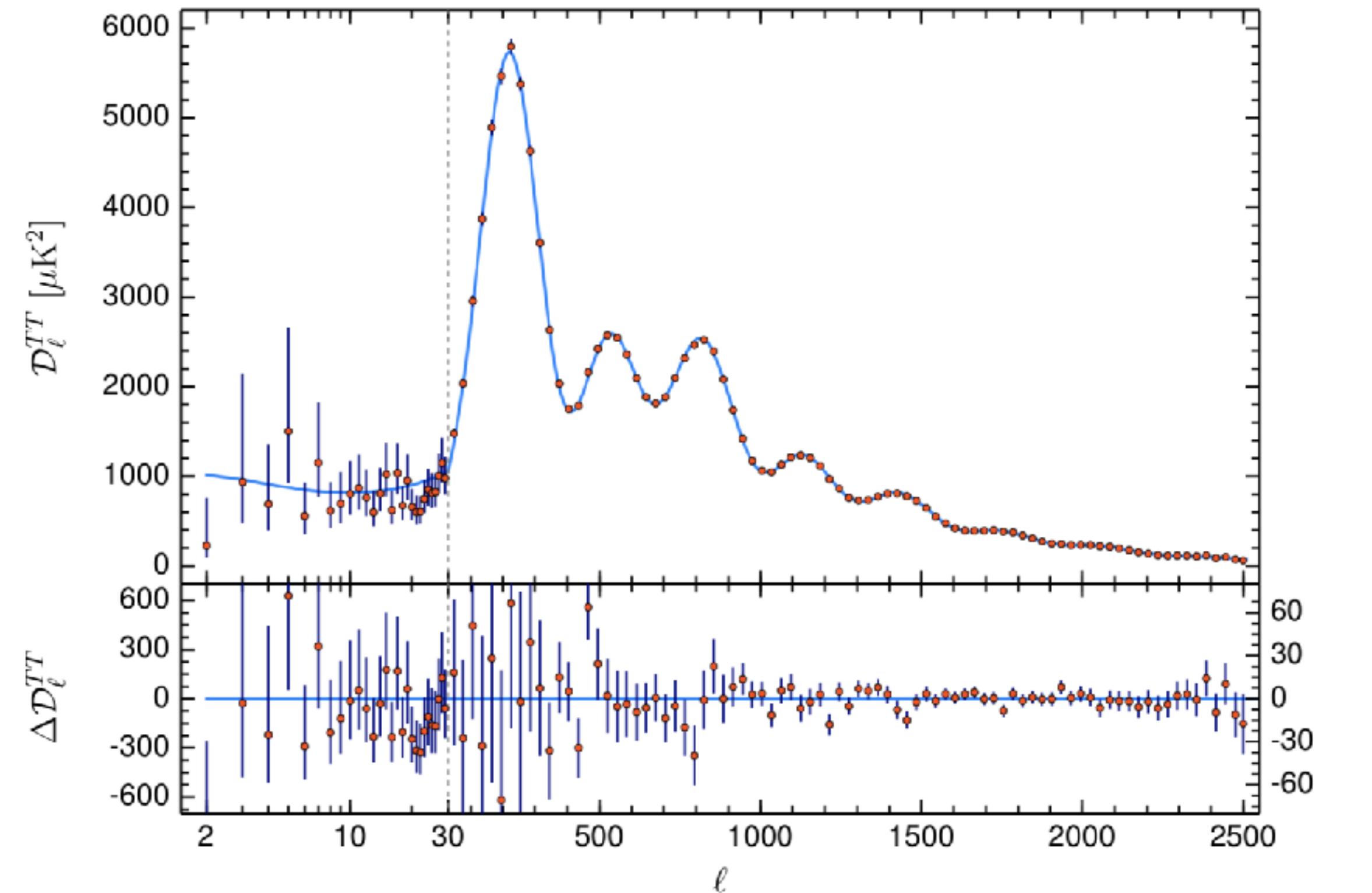
# WMAP (Wilkinson Microwave Anisotropy Probe)

- WMAP's measurements played a key role in establishing the current Standard Model of Cosmology
- Limited bandwidth means little cleaning of dust possible (no polarisation)

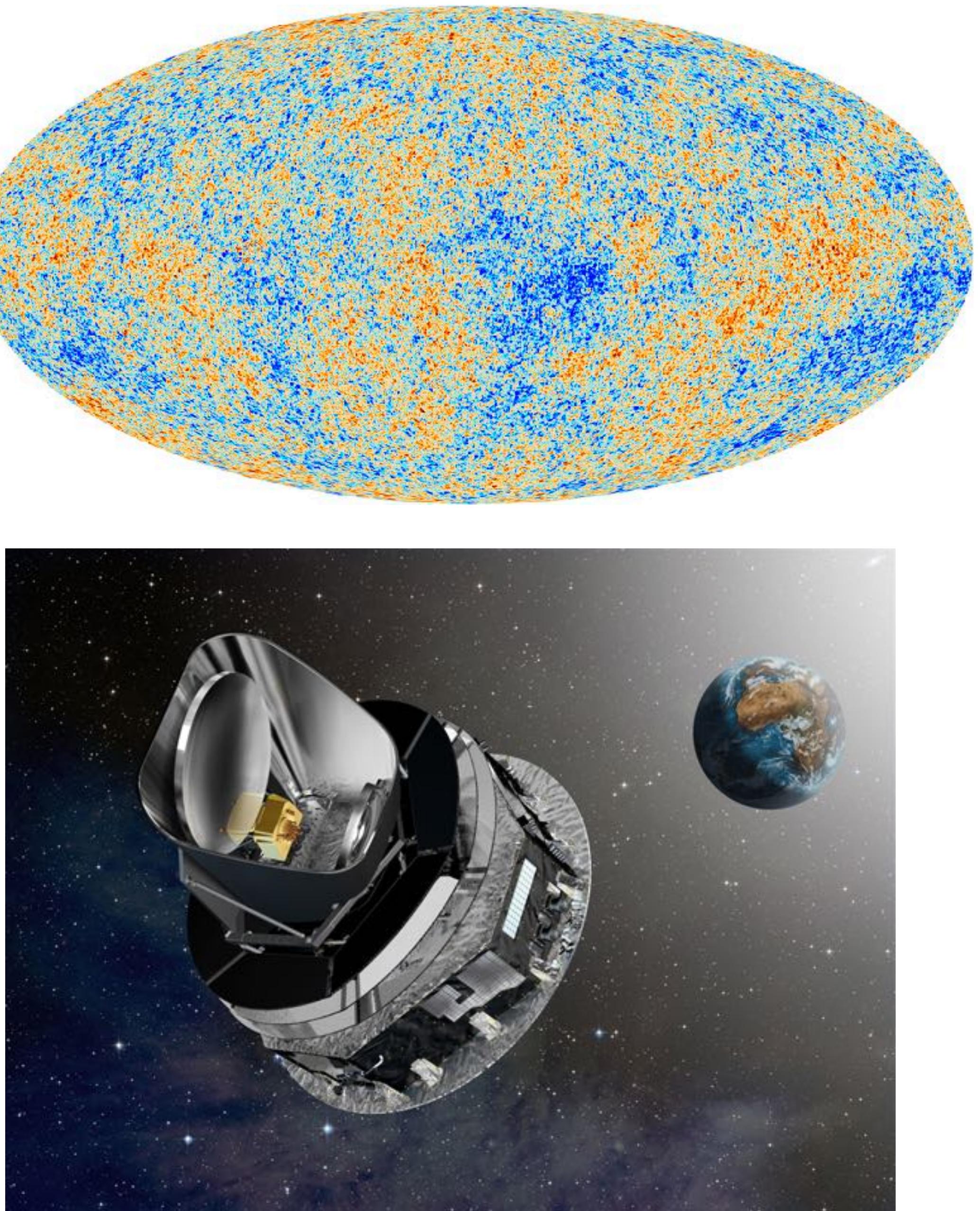


# Planck

- $\Lambda$ CDM is king
- Strong polarisation measurements
- No B-mode
- Has something to say about everything in cosmology

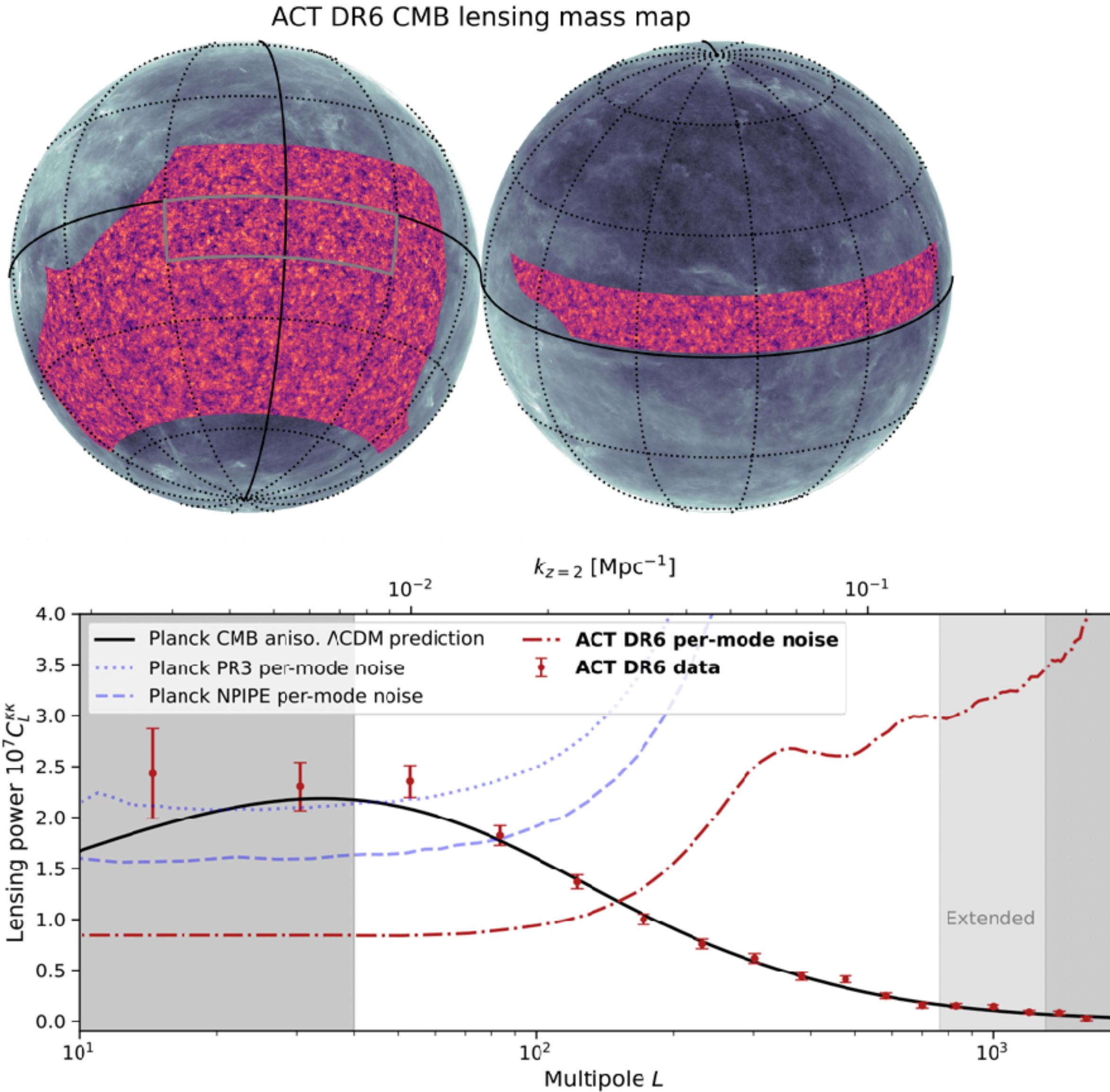


**Fig. 1.** *Planck* 2018 temperature power spectrum. At multipoles  $\ell \geq 30$  we show the frequency-coadded temperature spectrum computed from the Plik cross-half-mission likelihood, with foreground and other nuisance parameters fixed to a best fit assuming the base- $\Lambda$ CDM cosmology. In the multipole range  $2 \leq \ell \leq 29$ , we plot the power spectrum estimates from the Commander component-separation algorithm, computed over 86 % of the sky. The base- $\Lambda$ CDM theoretical spectrum best-fit to the *Planck* TT,TE,EE+lowE+lensing likelihoods is plotted in light blue in the upper panel. Residuals with respect to this model are shown in the lower panel. The error bars show  $\pm 1\sigma$  diagonal uncertainties, including cosmic variance (approximated as Gaussian) and not including uncertainties in the foreground model at  $\ell \geq 30$ .



1.9x1.5m mirror

# ACT (Atacama Cosmology Telescope) / SPT (Southern Polar Telescope)



## The South Pole Telescope

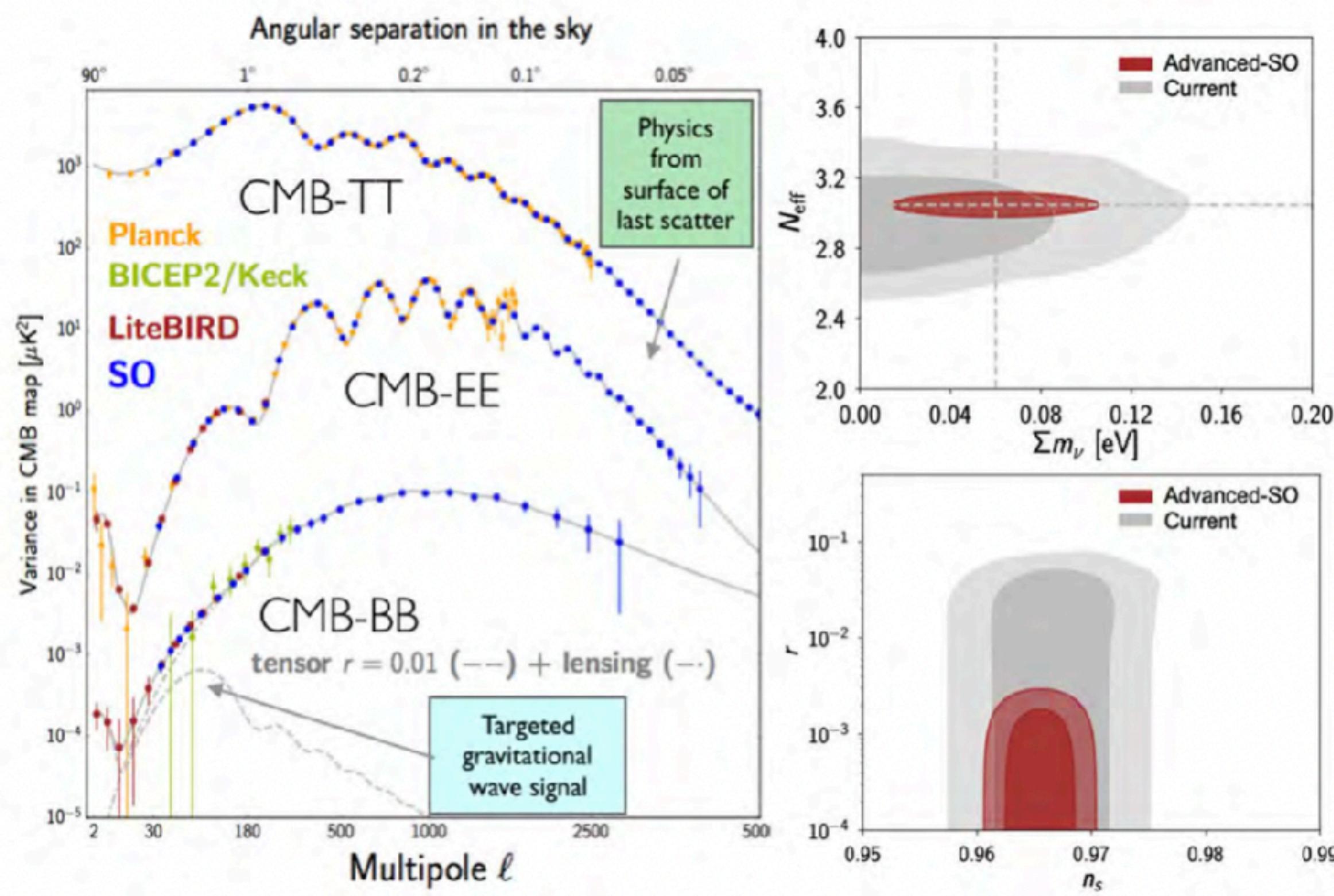
- 10 m primary mirror telescope
- Off-axis Gregorian optics design
- Location:  
Amundsen-Scott station,  
South Pole
- Dedicated to CMB observations with  
high angular resolution  
(~1 arcmin)
- Funded by



ACT

# Simons Observatory (SO)

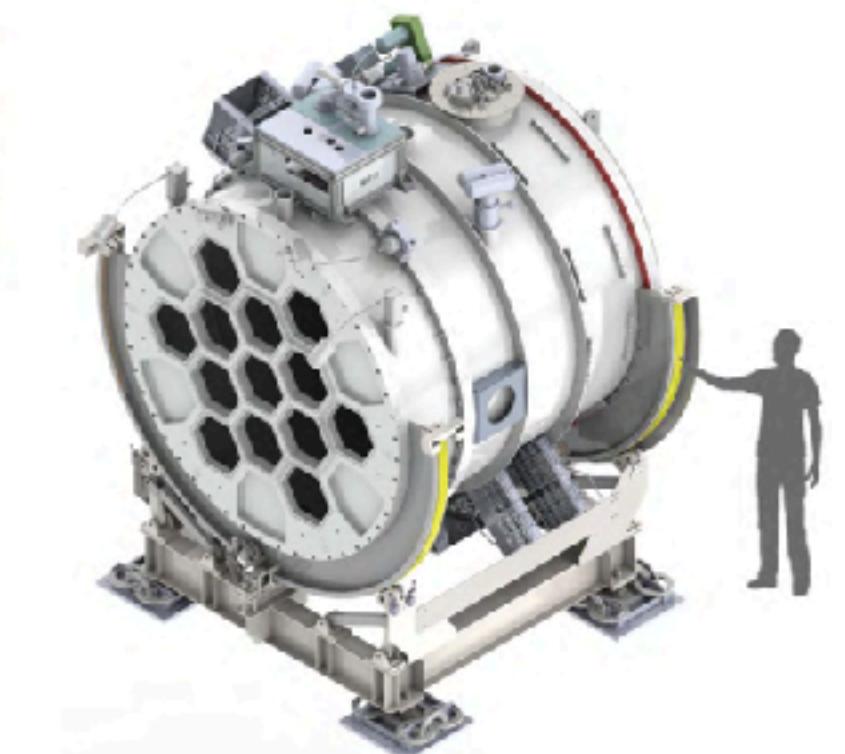
- r scalar to tensor ratio would indicate Gravitational Waves from inflation (CMB B-mode polarisations)
- They had first light in 2023 and start in 2025



**Small Aperture Telescopes (SATs)**

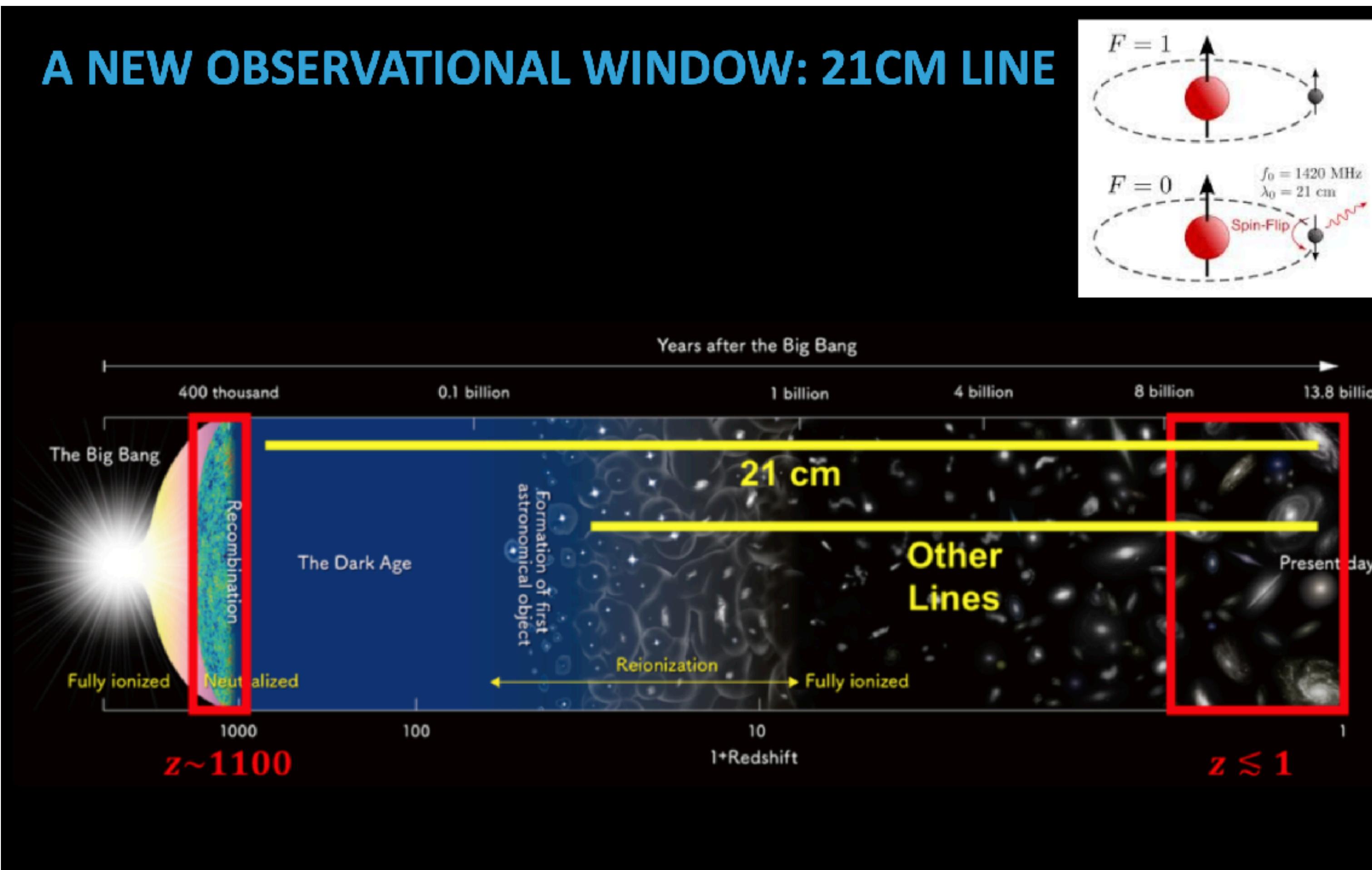


**Large Aperture Telescope**

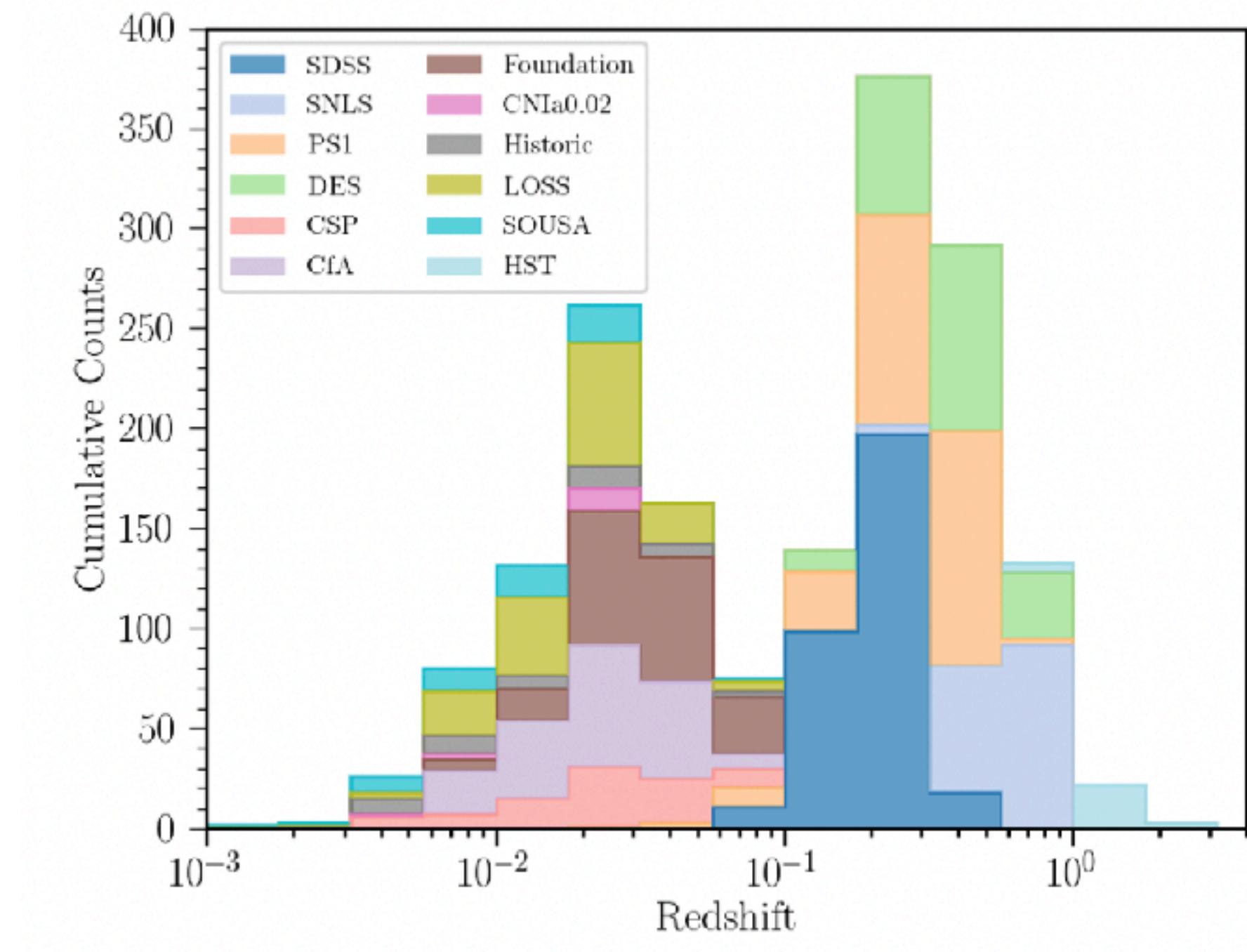
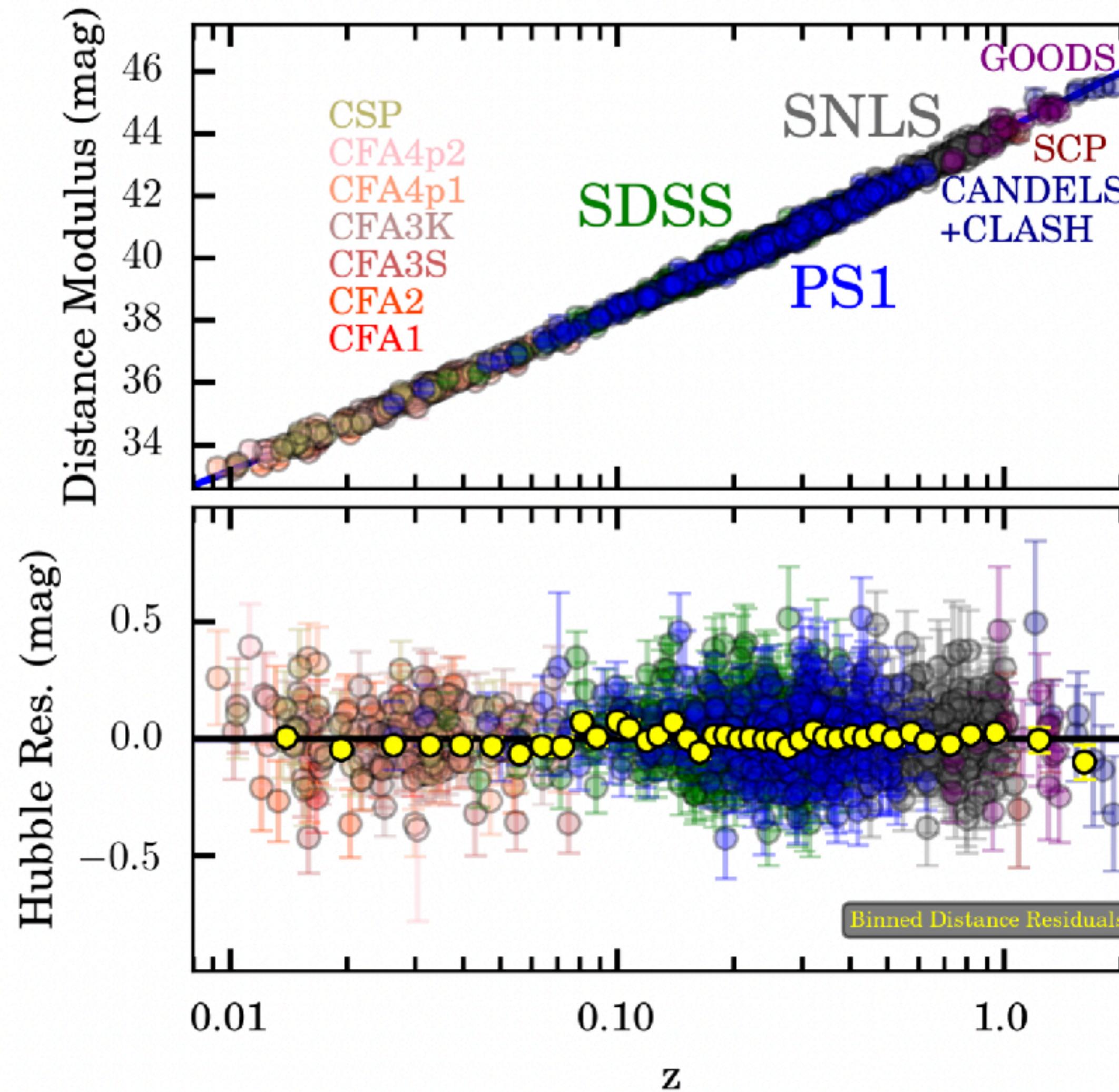


**Large Aperture Telescope Receiver**

# SKA (Square Kilometre Array)



# Pantheon+, SHOEs, (LSST)



Pantheon+ compilation

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