The power of CMB-lensing: AliCPT x DESI & more…

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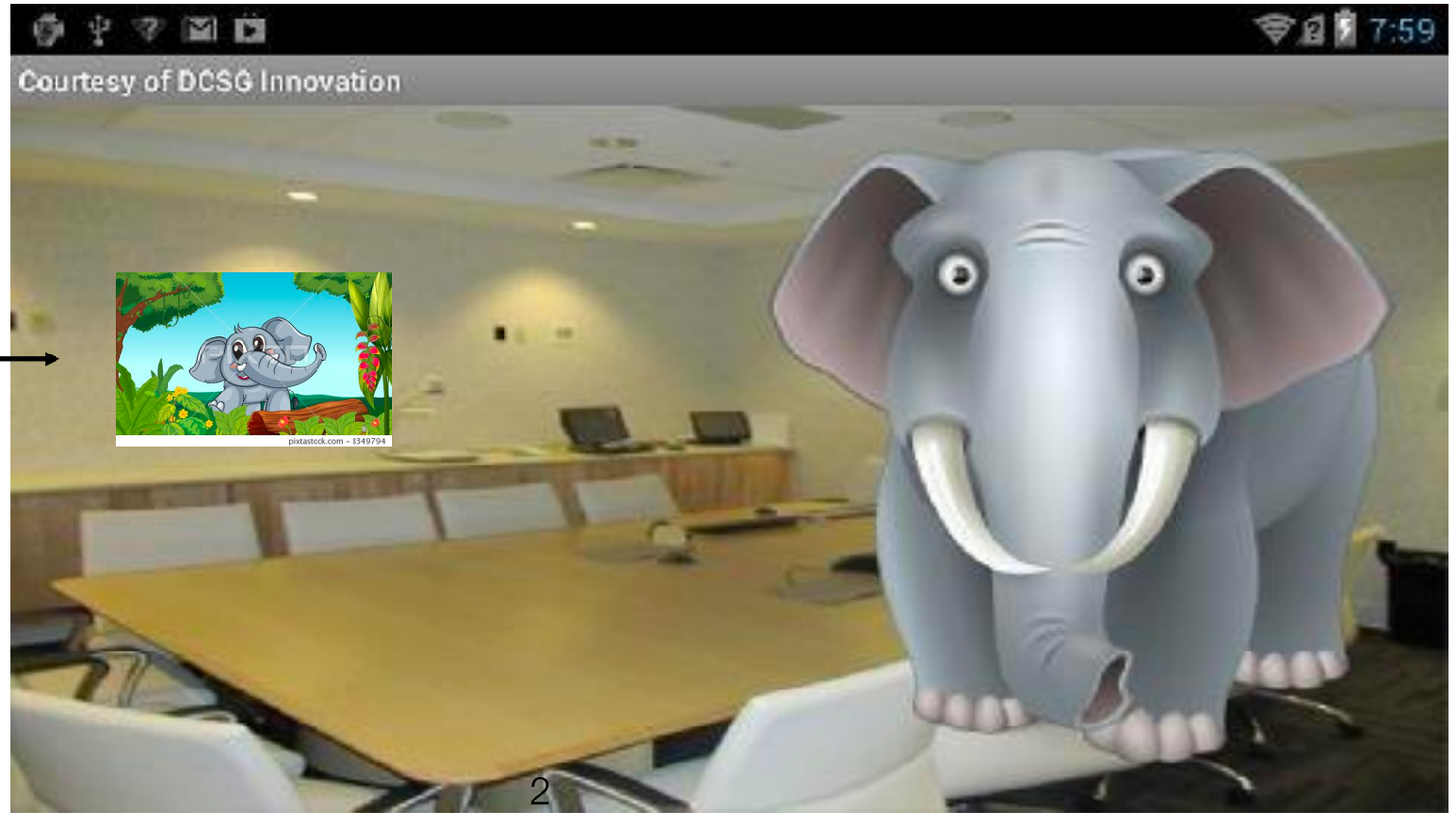
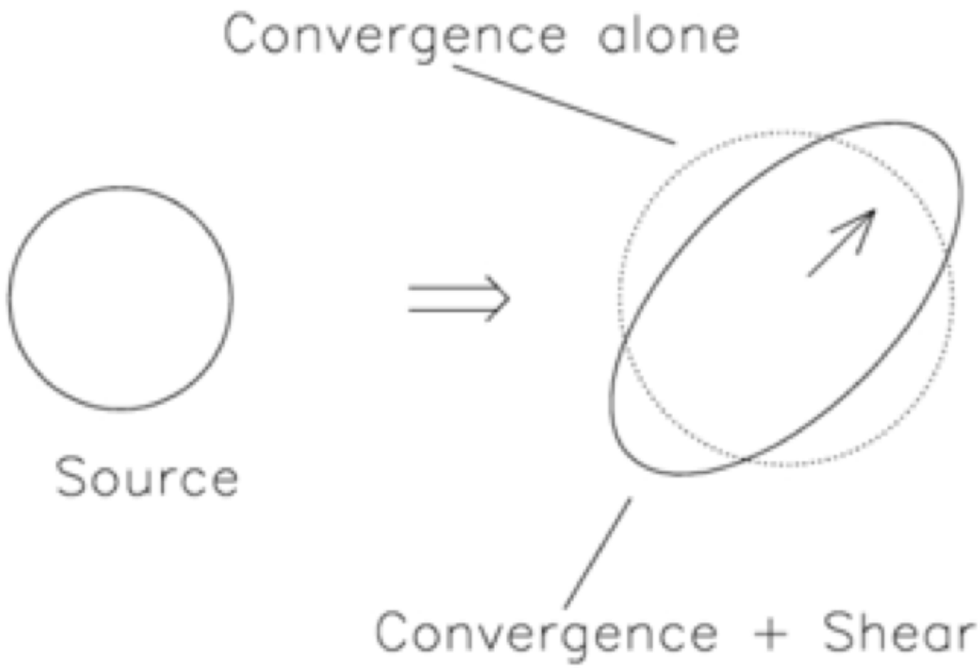
Science besides Primordial Gravitational Waves

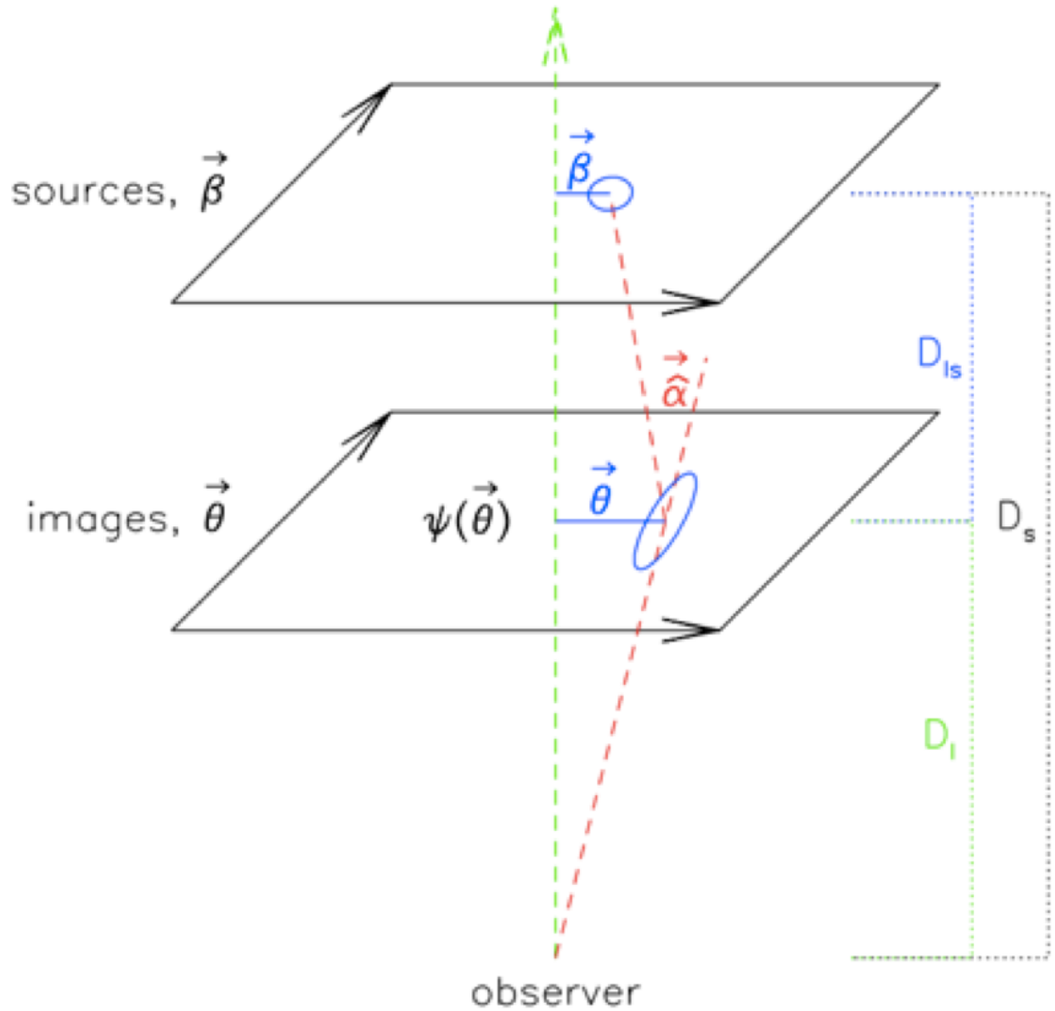
- We all know AliCPT aims to find the detection of PGWs:
- B-mode in CMB => Inflation => Nobel Prize!
- But… there is more than ONE elephant in the room! —— which is also easy to “carry out”.

CMB-lensing!

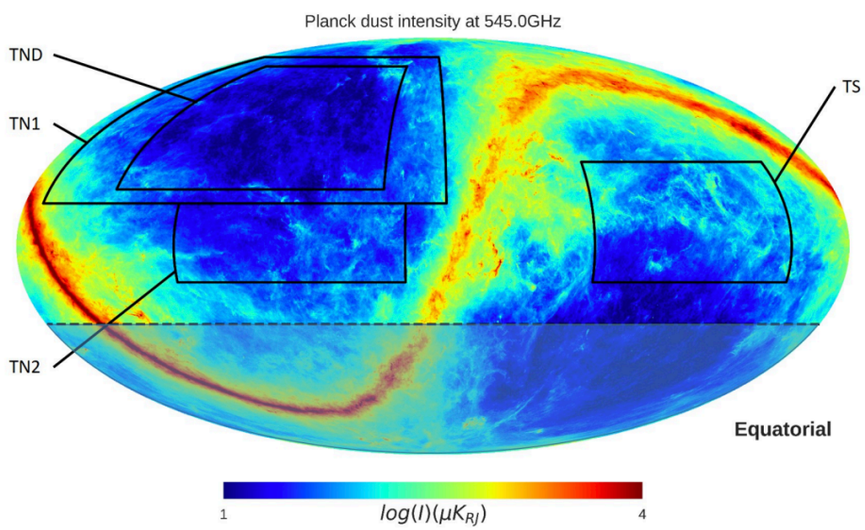


Gravitational Lensing

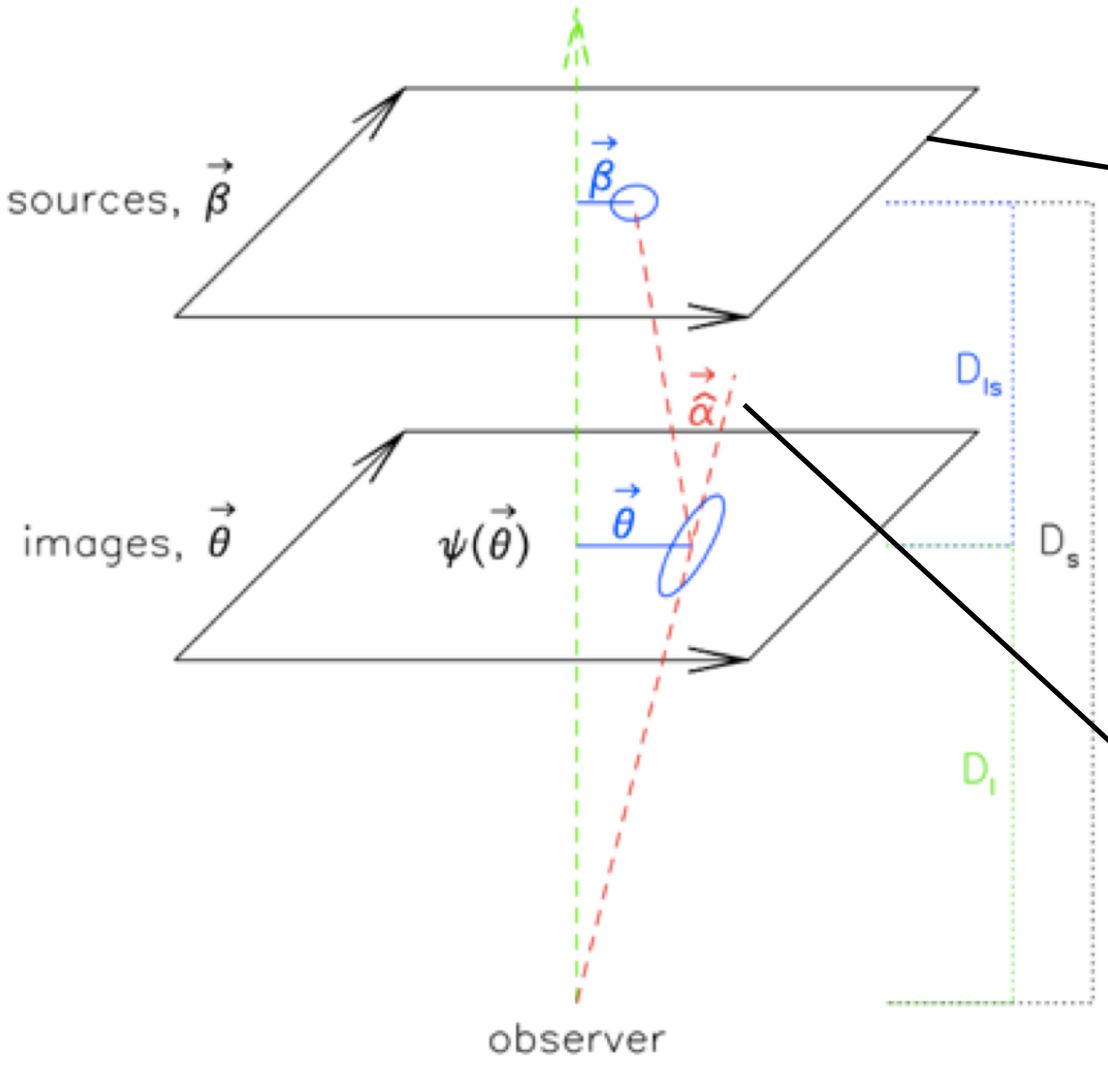


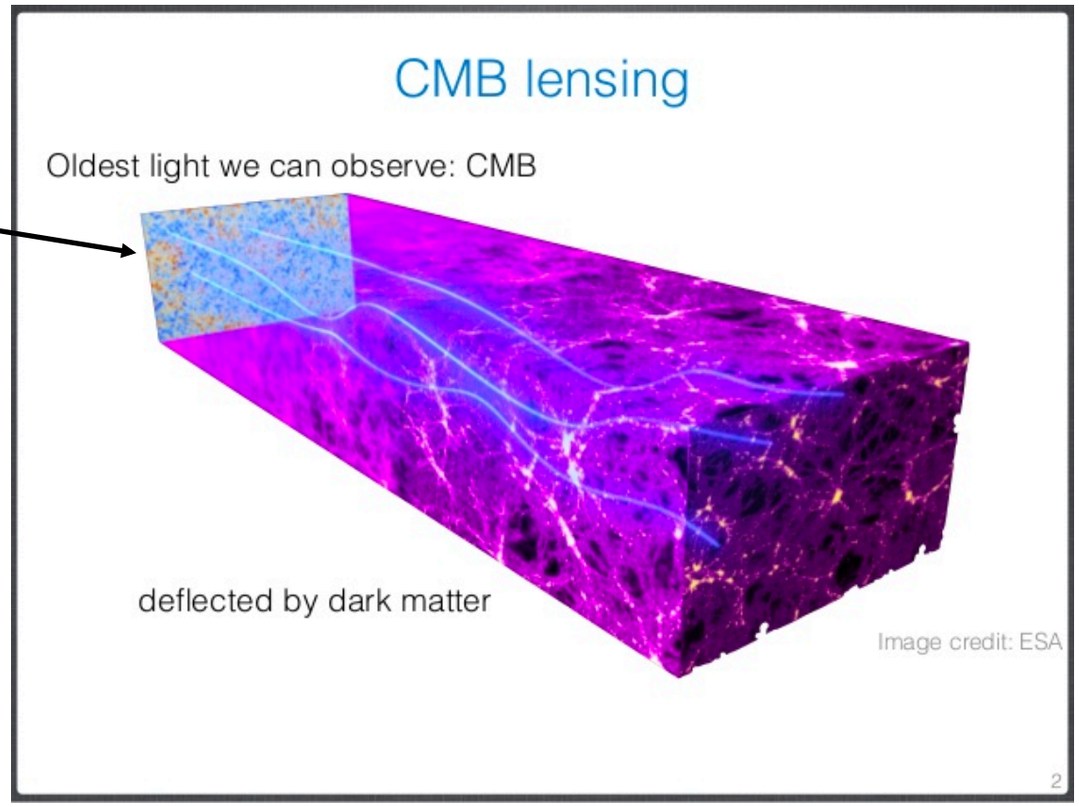


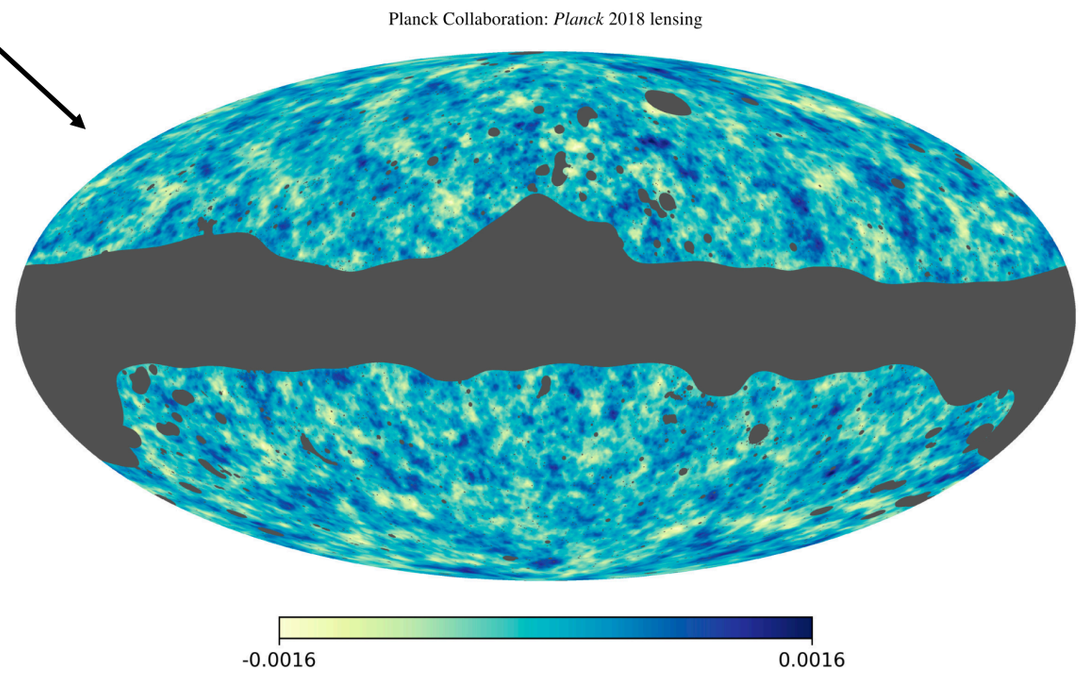
- In cosmic shear surveys, the background light is galaxies.
- For stage III surveys (KiDS, DES, HSC), one can cover ~10^3 deg^2 of the sky and contain 10^7 to 10^8 galaxies. Stage IV survey like LSST will cover ~half sky.
- For CMB-lensing, the source is CMB, large sky coverage!



CMB Lensing



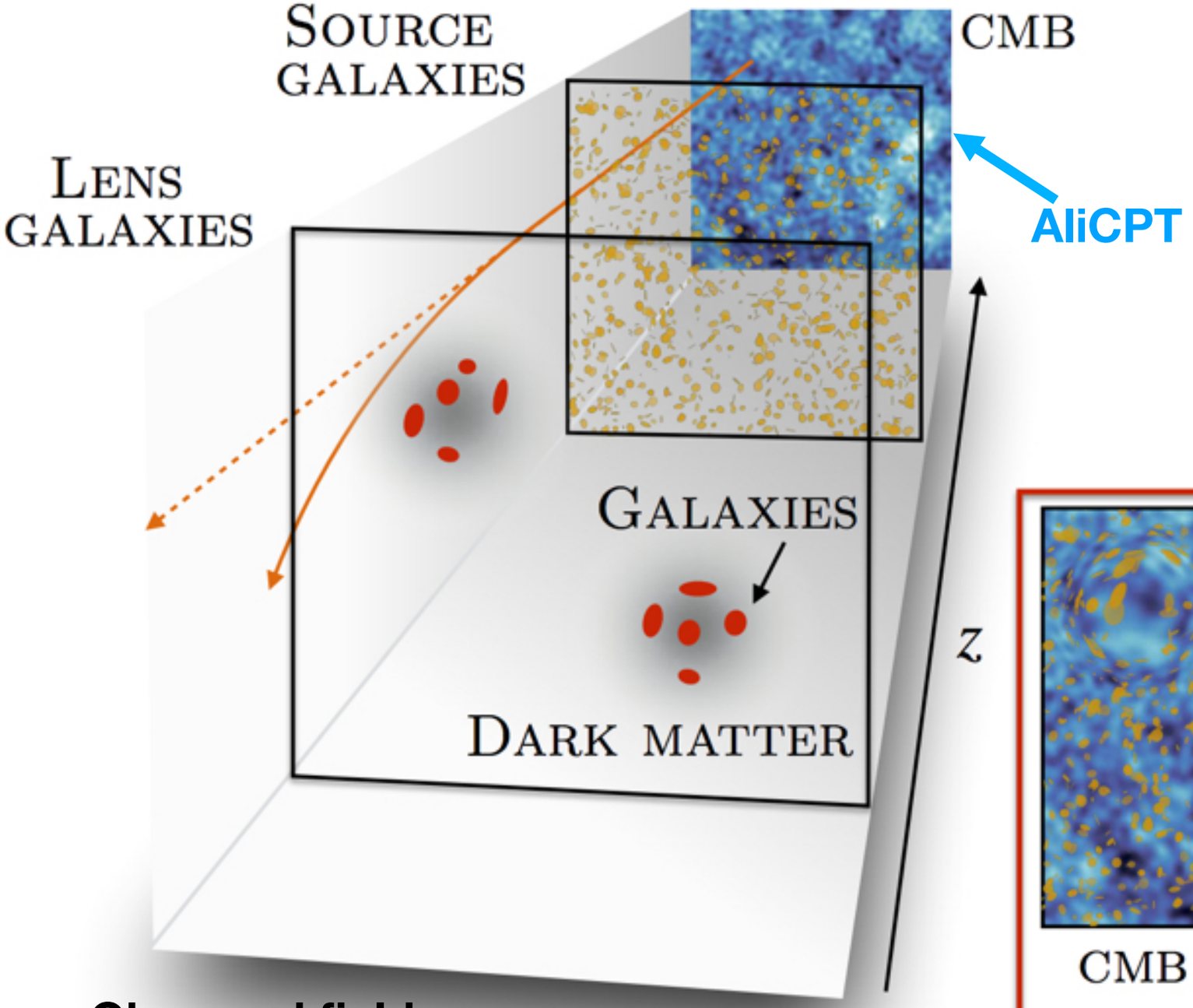




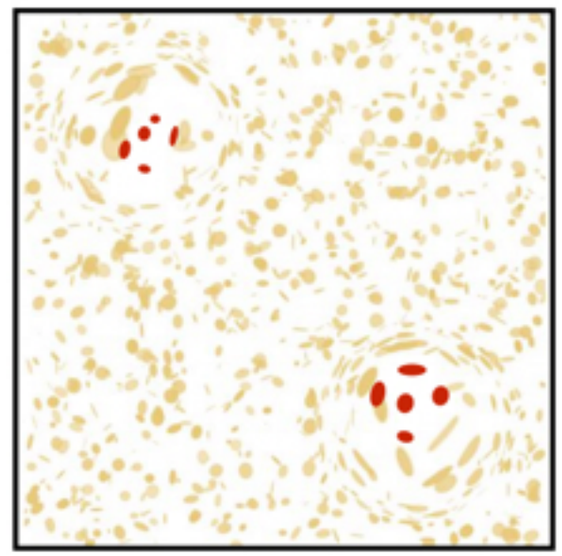
- The CMB lensing is a tracer of matter from z=0 all the way to z=1089!

Lensing

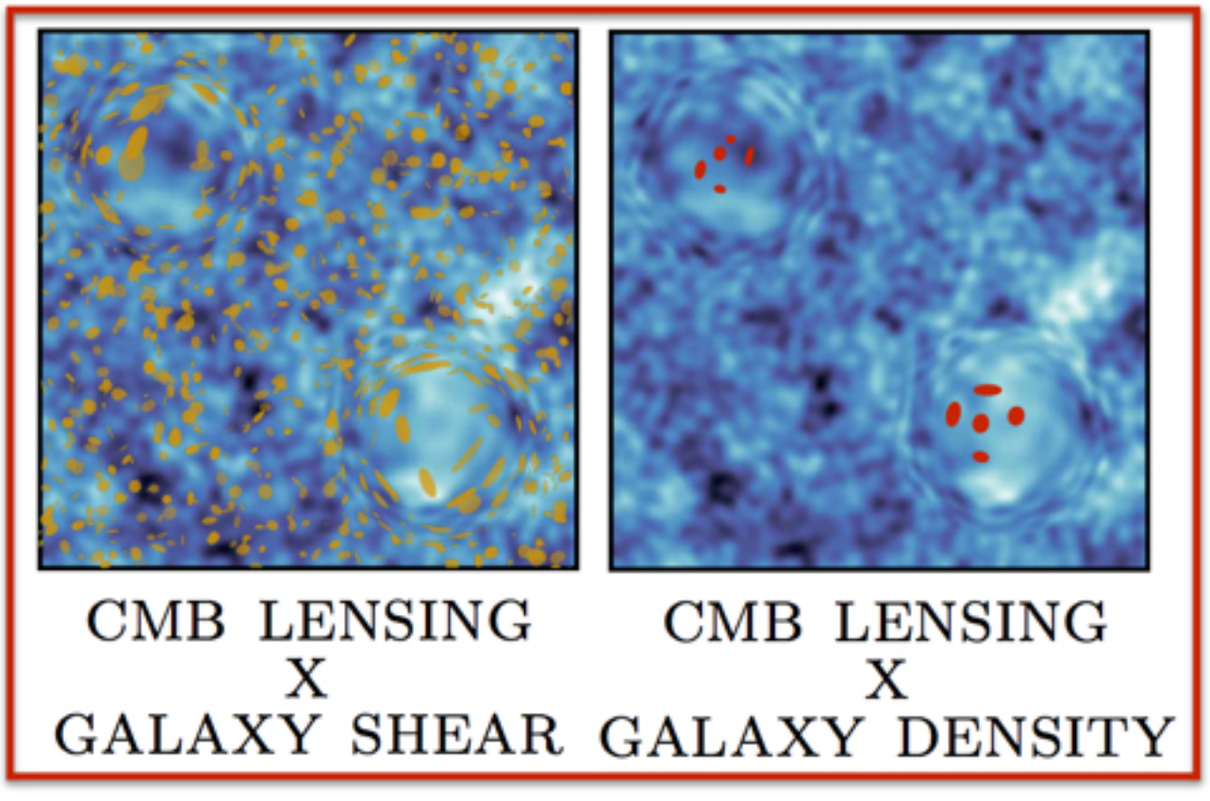
Overview: Cross-correlations



Observed fields:
galaxy number density,
galaxy shear,
CMB convergence
→ matter



GALAXY DENSITY
X
GALAXY SHEAR



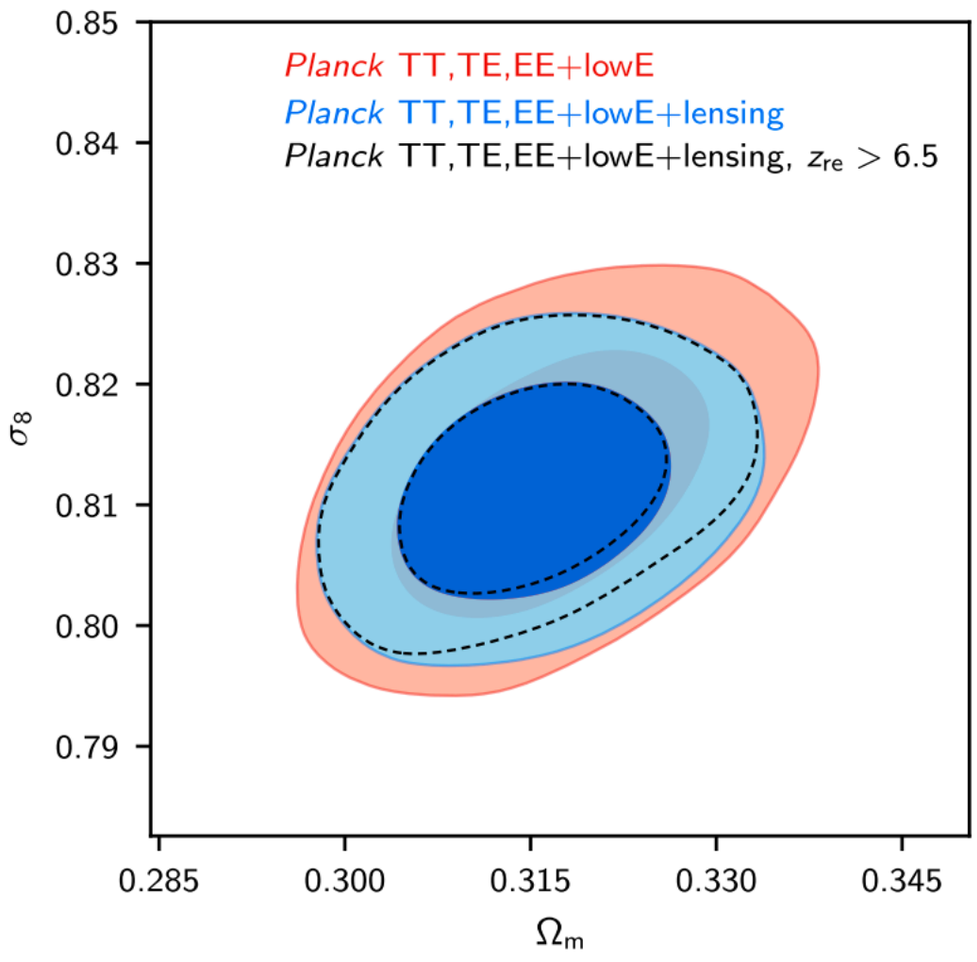
Cross-correlation:
- use the strong constraining power from CMB lensing & galaxies
- add z evolution info from galaxies

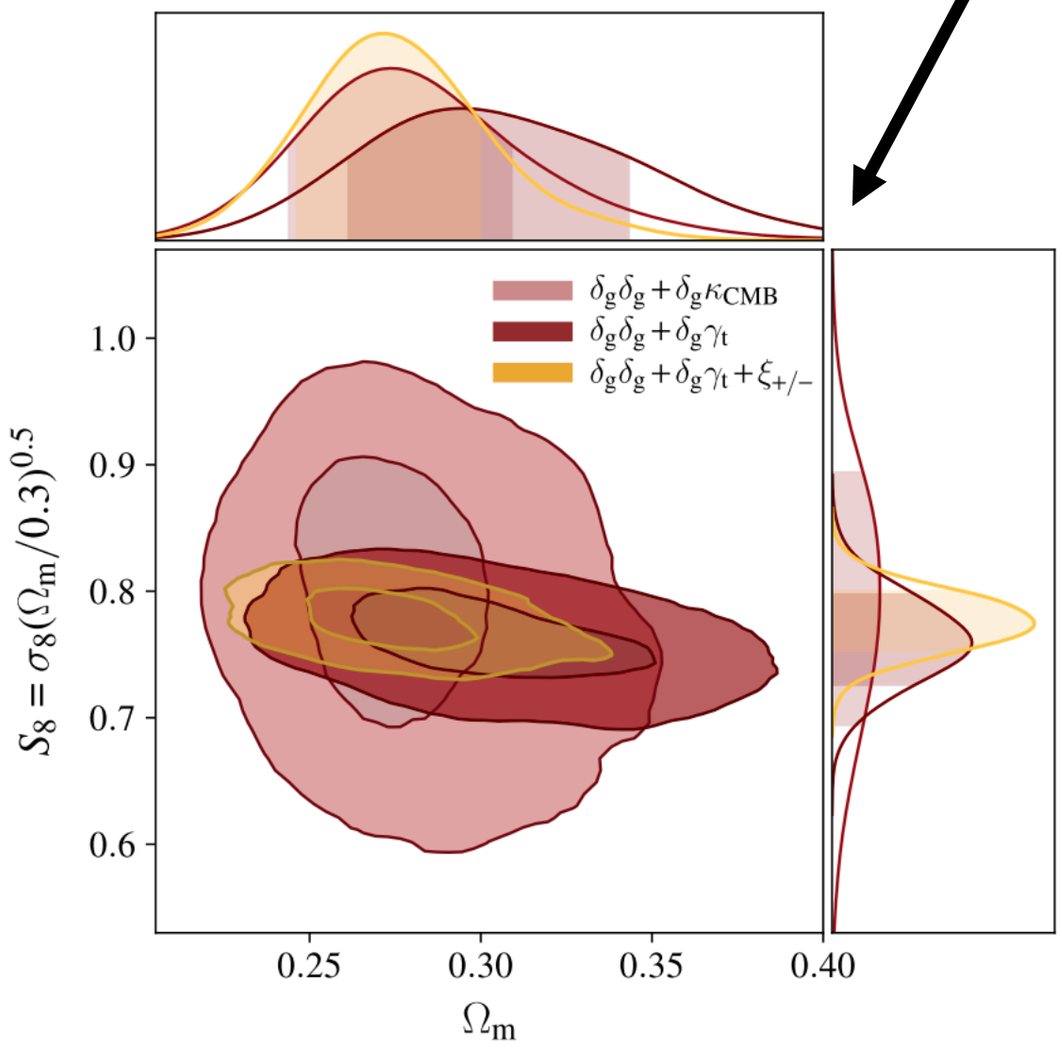
Stolen from Pablo Fosalba
DESI C^3 telecon slides

The power of CMB-lensing: extra constraining power

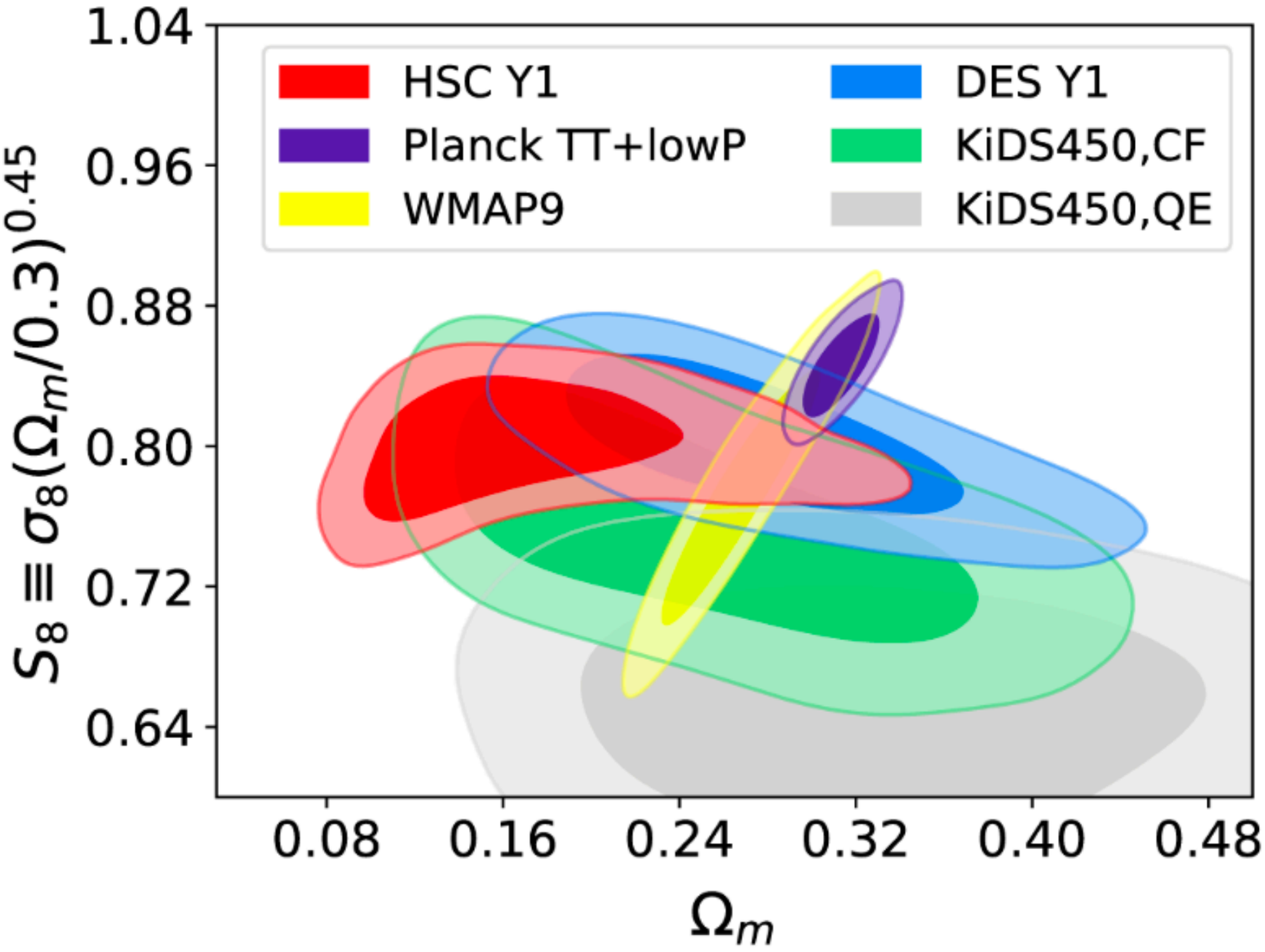
- Left: Planck auto-correlation (1807.06210)
- Right: Planck X DES cross-correlation (1810.02342)

For AliCPT X DESI, the constraining power of cross-correlation will be much strong!





The power of CMB-lensing: checking the tension between CMB and cosmic shear



1806.01191

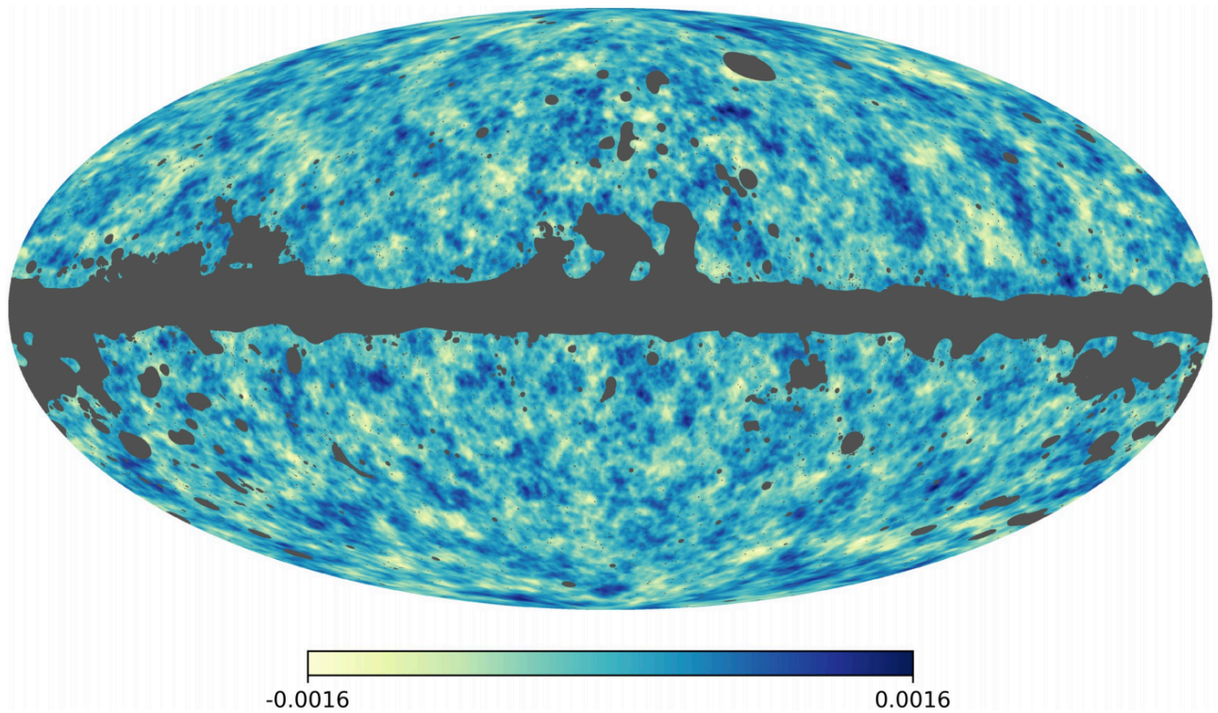
Why we need AliCPT beyond Planck…

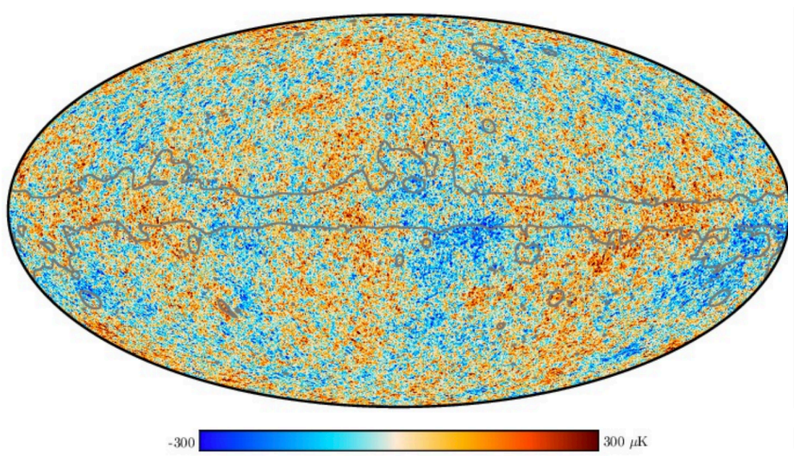
- The Planck lensing-deflection map (top) comes from temperature map (left) and polarization map (right). (1807.06205)

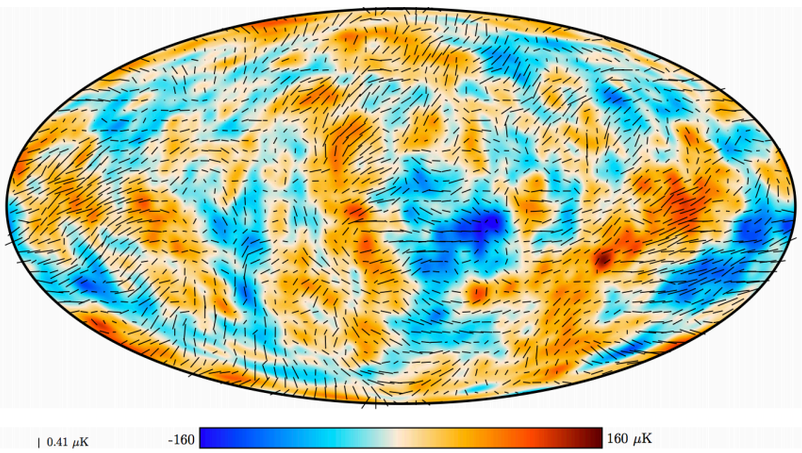
- The famous Planck H_0 tension and S_8 tension.

- AliCPT can do much better in obtaining the polarization map.

- AliCPT will have different foreground removal methods. (ABS paper Yao+ 2018)

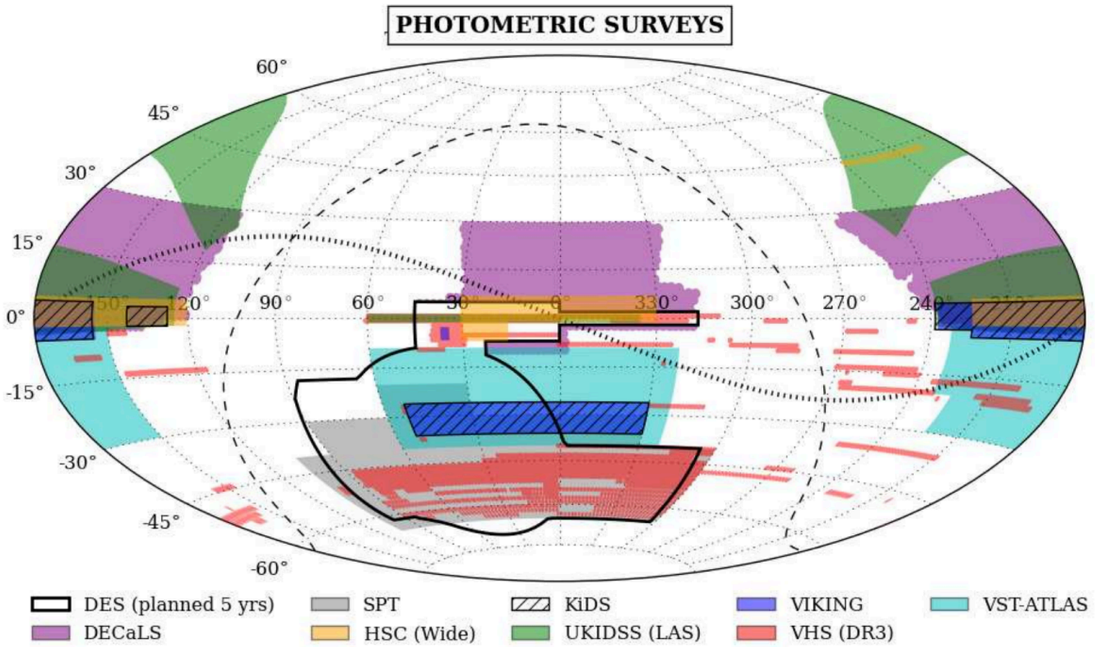


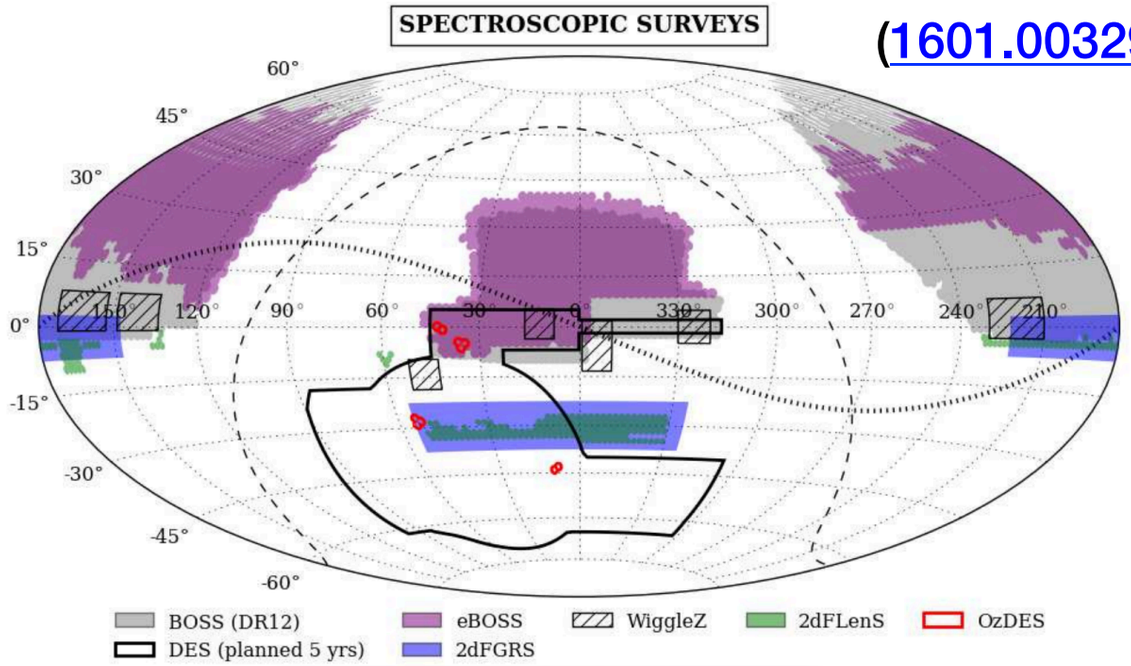




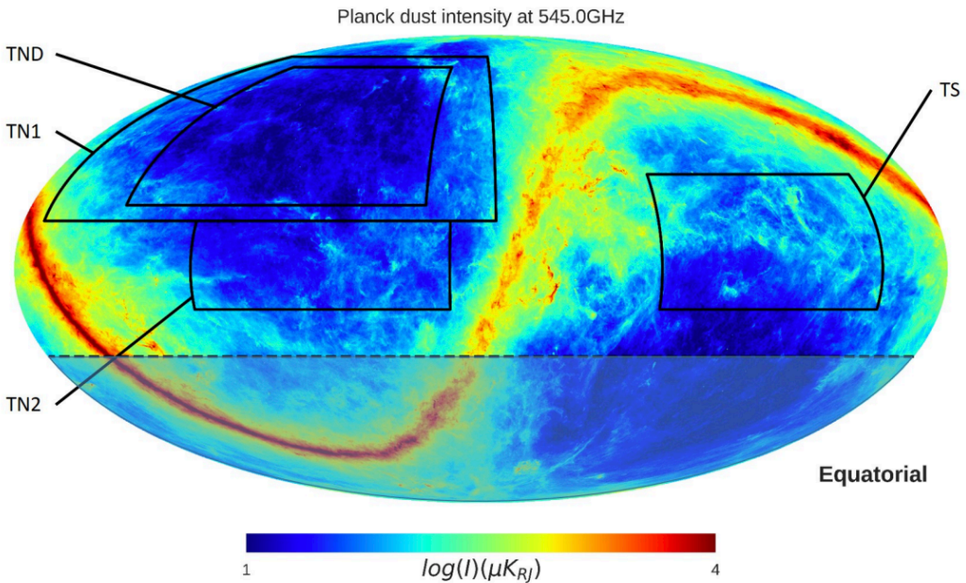
Having AliCPT X other surveys…

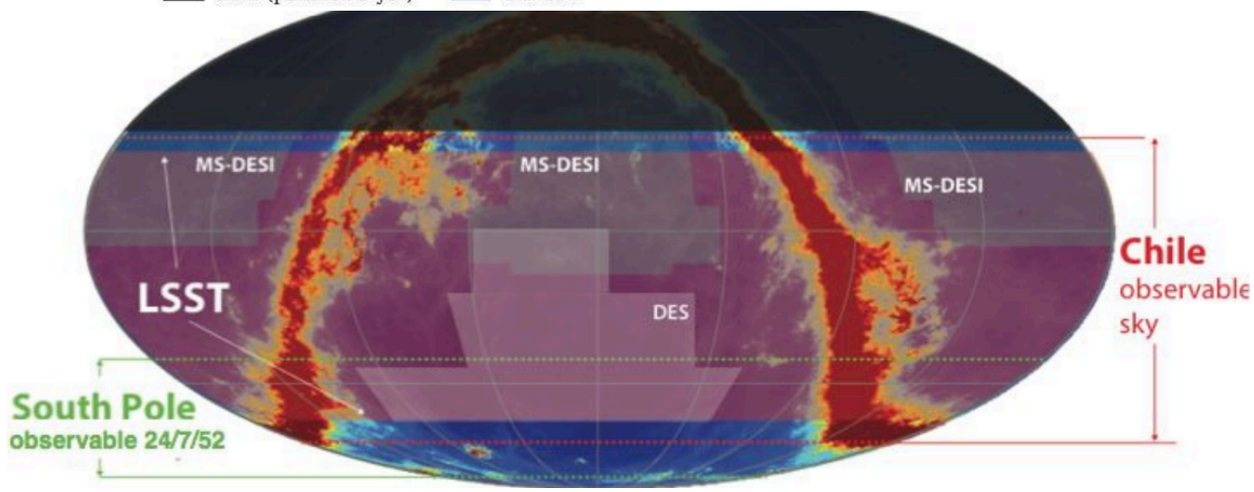
- Cosmic shear surveys: HSC (z~1.5), LSST (z~3.5), …
- Galaxy surveys: DESI (z~1.6), PFS (z~2.4), …
- For science: more probes, more data, better usage of the northern sky.
- For our astronomical/cosmological society: collaborate with the large/ advanced collaborations.





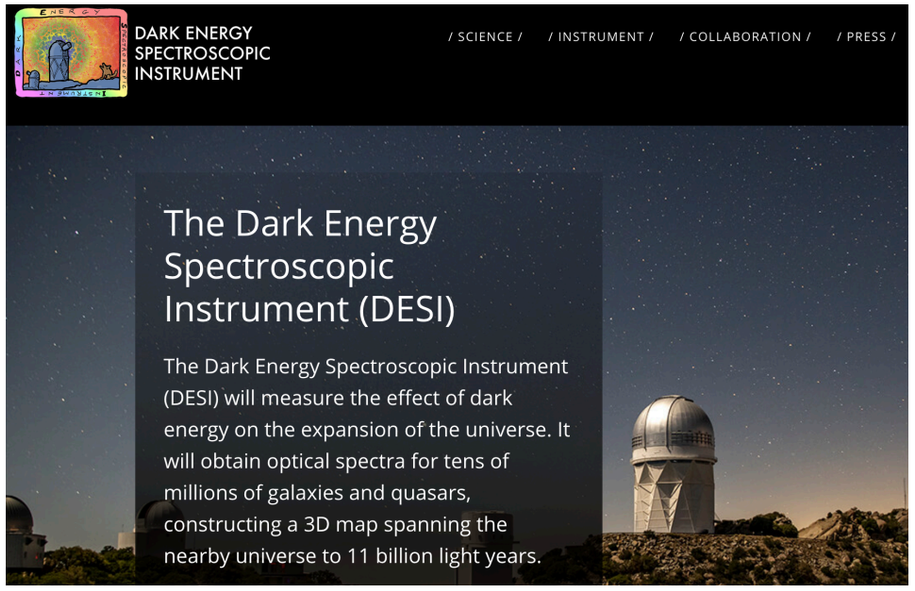
([1601.00329](1601.00329))





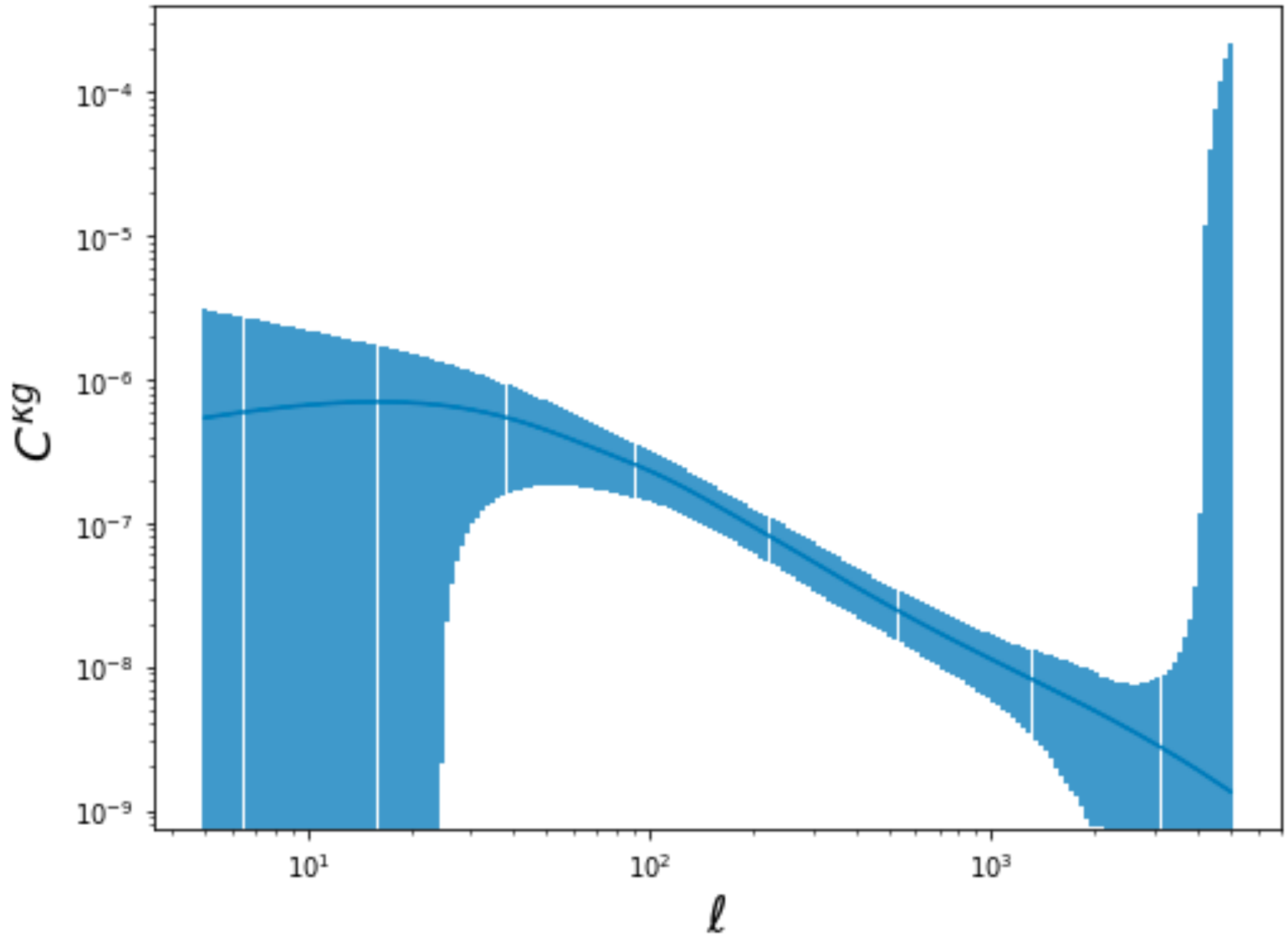
A brief intro to DESI

- DESI = Dark Energy Spectroscopic Instrument
- Stage IV, ground-based
- Scientific goals:
  - mapping the 3D universe up to z~1.6
  - > 3e7 redshifts of galaxies and quasars
  - Cosmological probes of BAO and RSD in matter power spectrum
- References: 1611.00036 & https://www.desi.lbl.gov/

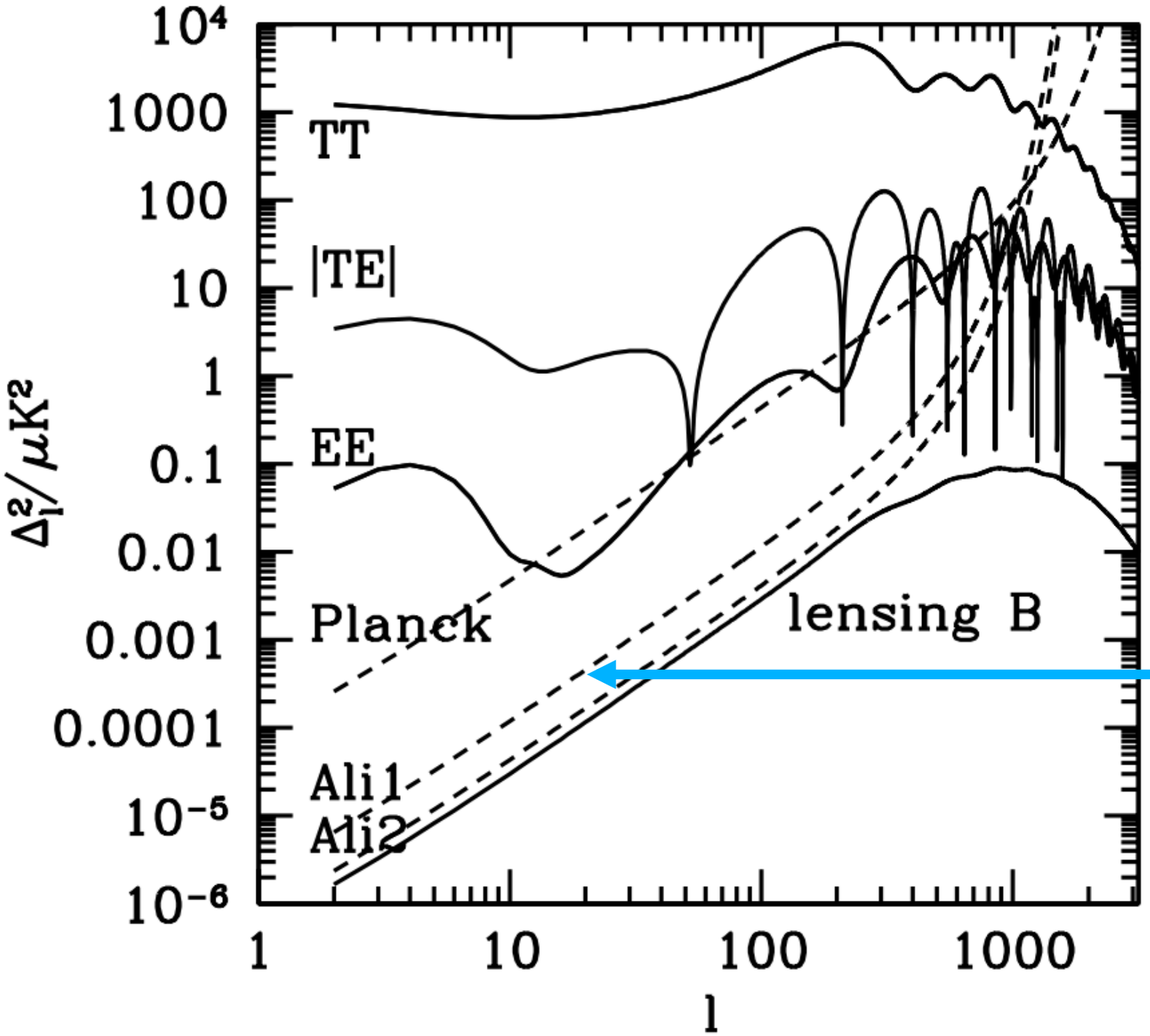


Planck X DESI forecast (Yao+ in progress)

- Forecasting the kappa (Planck) - galaxy (DESI) power spectrum.
- n_gal = 3e7 (out of 3e8 all DECaLS galaxies)
- f_sky = 5100 / 41253
- ~25 sigma in 30<ell<2000.



Preliminary: Forecasting the power of AliCPT (Zhang+ in progress)



With wider angular \ell bining, the instrument noise will drop more significantly

Preliminary: AliCPT X DESI forecast (Zhang+ in progress)

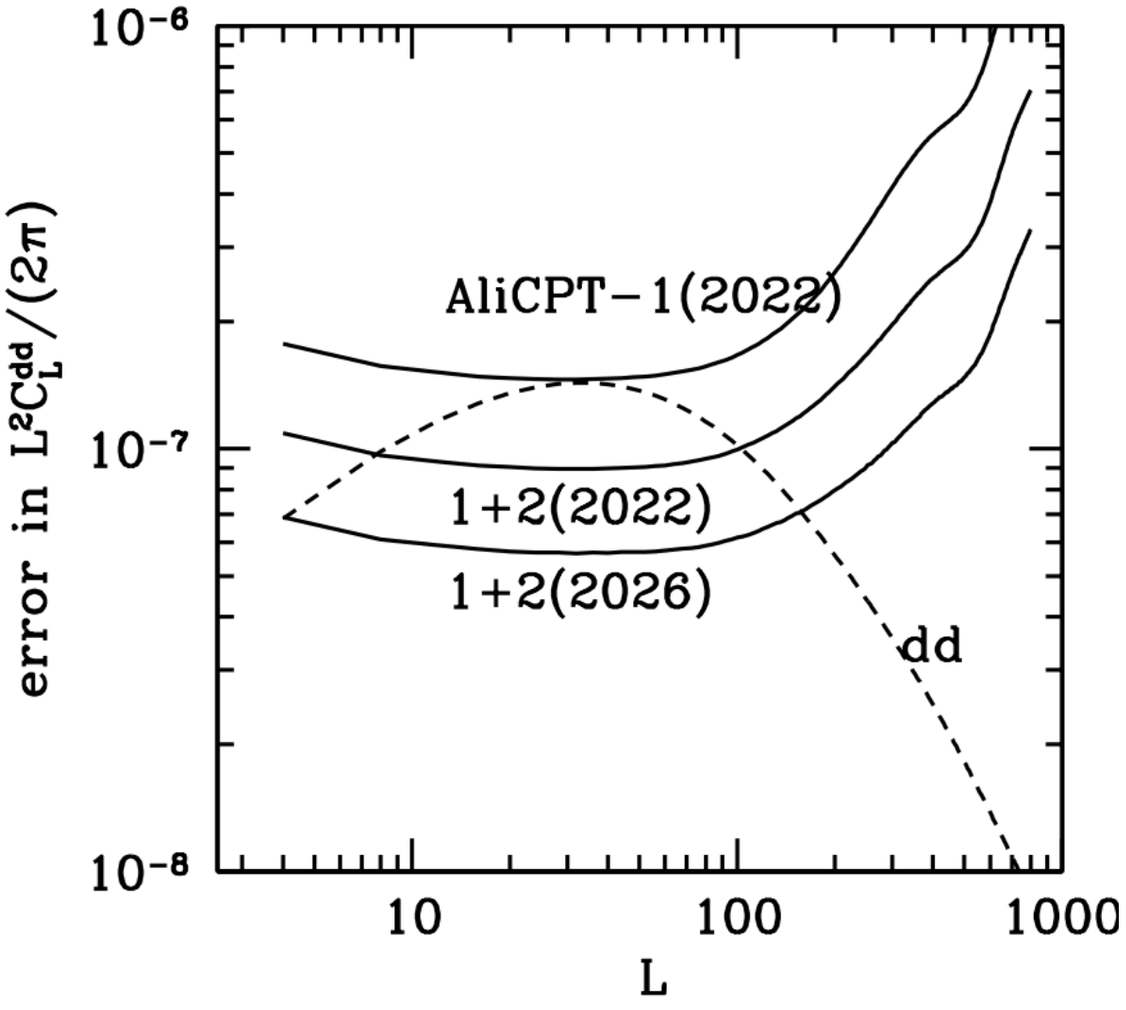


Figure 4. The lensing reconstruction error per L mode for AliCPT-1 and AliCPT1+2 (-2022). CMB lensing measurement of AliCPT-1 will be CMB error dominant. The overall S/N will be 30. AliCPT1+2(-2022) will be cosmic variance limited at $L \sim 50$, with an overall S/N of 46. For a hypothetical survey of AliCPT1+2 extending to the year 2026, the CMB lensing reconstruction will be cosmic variance limited over the range $L \lesssim 100$. The total S/N will reach 63. The cross-correlation with DESi will exceed 100σ.

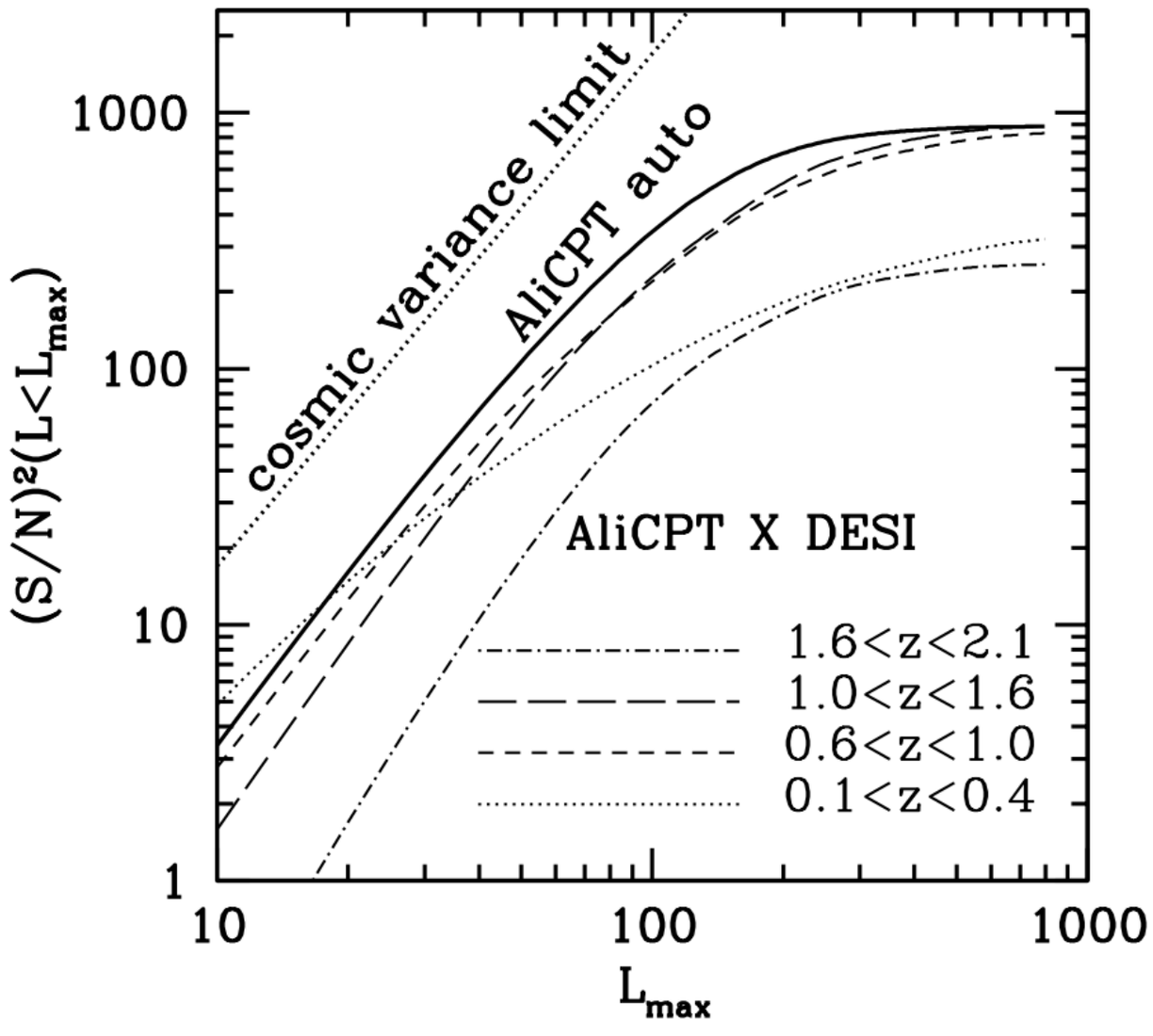
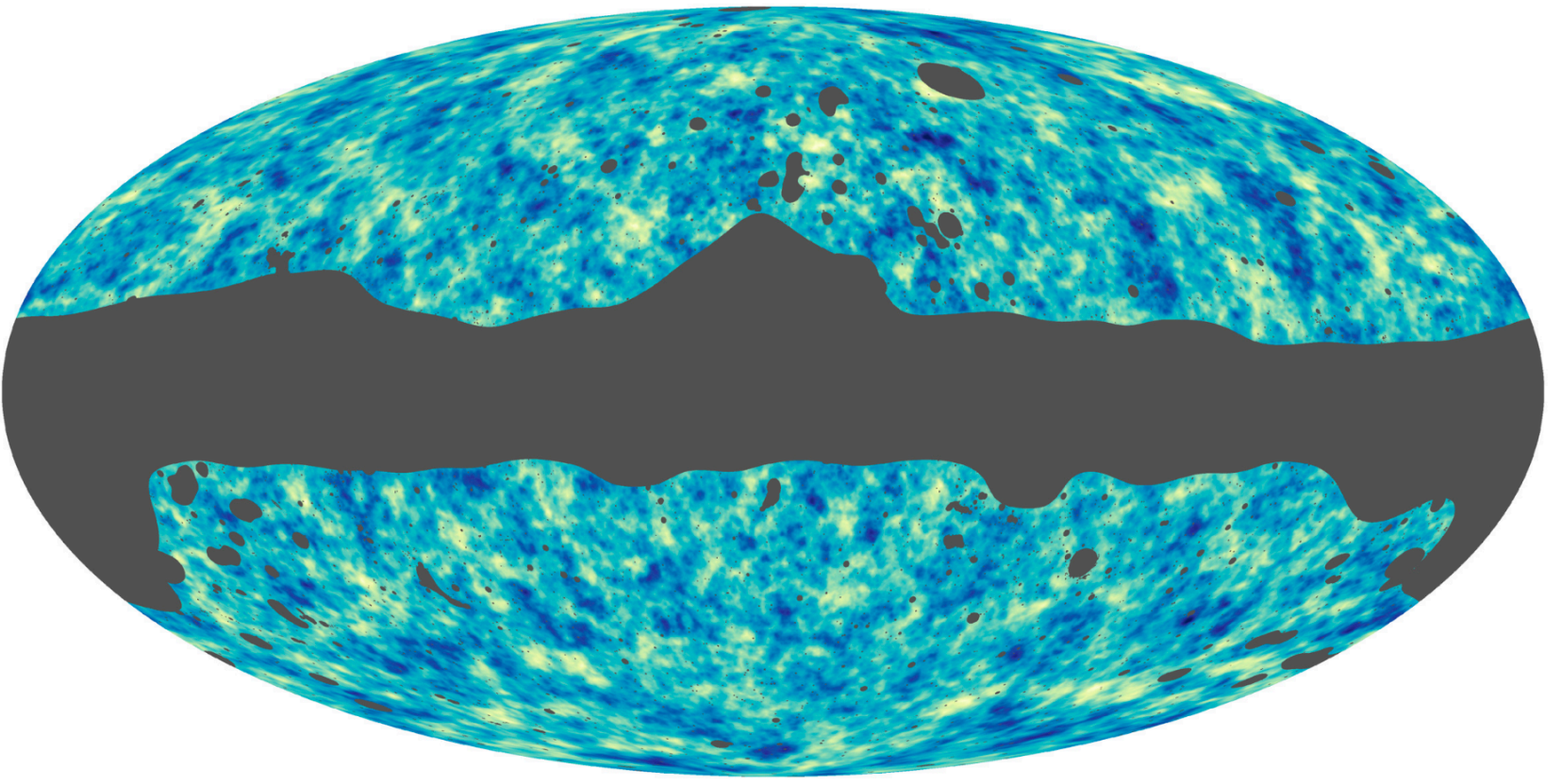
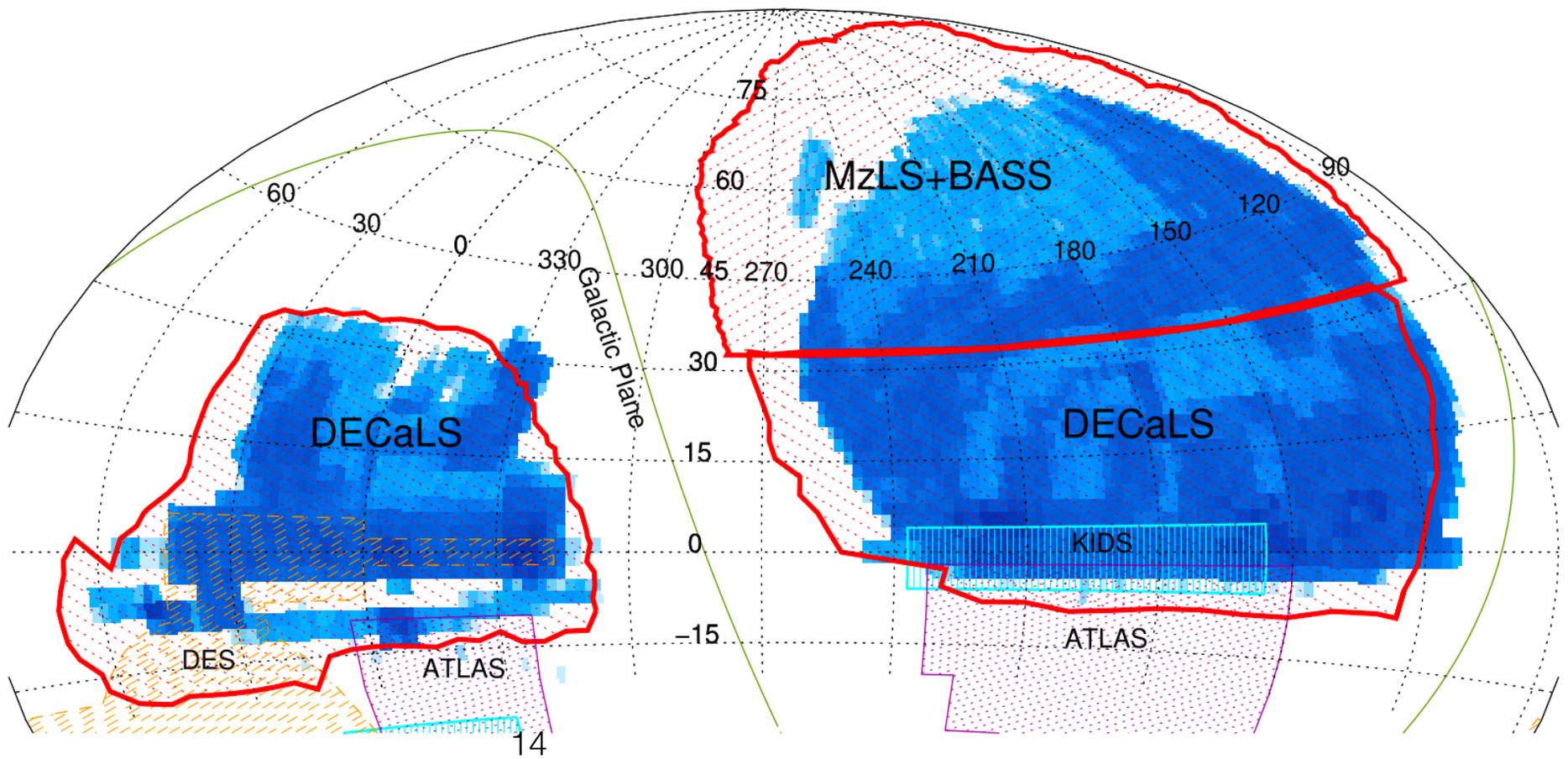


Figure 5. The cumulative $(S/N)^2$ in the auto and cross correlation measurement. The total S/N of the auto power spectrum mesurement is 30. For each redshift bin, the cross correlation measurements have lower S/N. However, the combined S/N is 48.

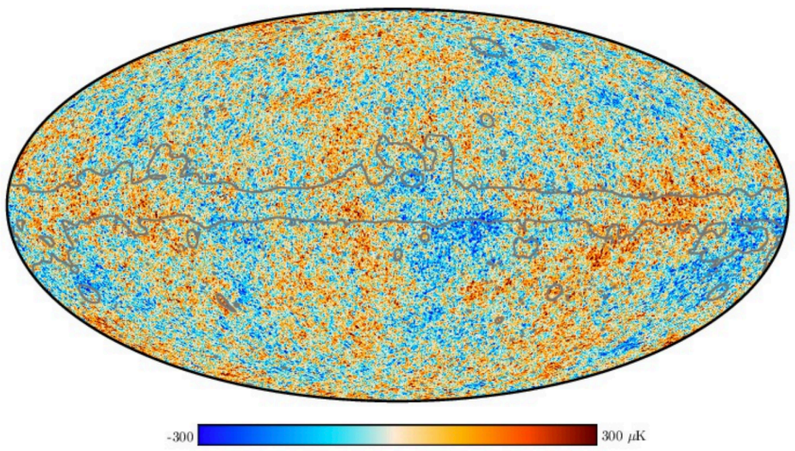
Why a DESI-like survey can boost AliCPT

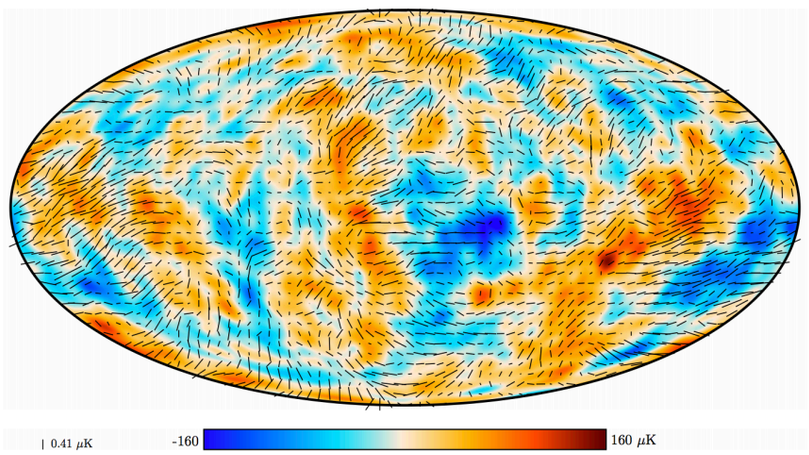


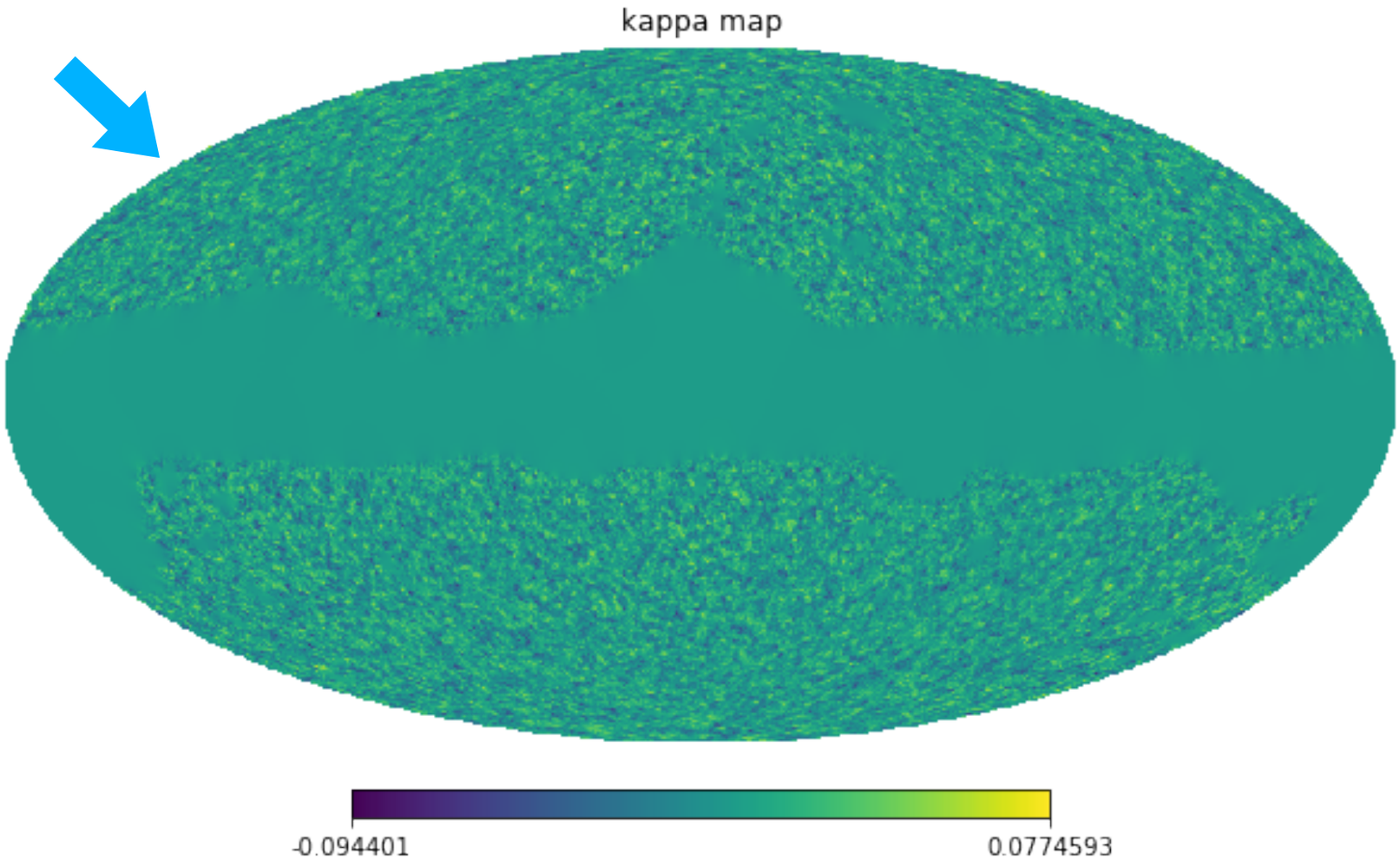
Preliminary: Planck X DECaLS (Yao+ in progress)

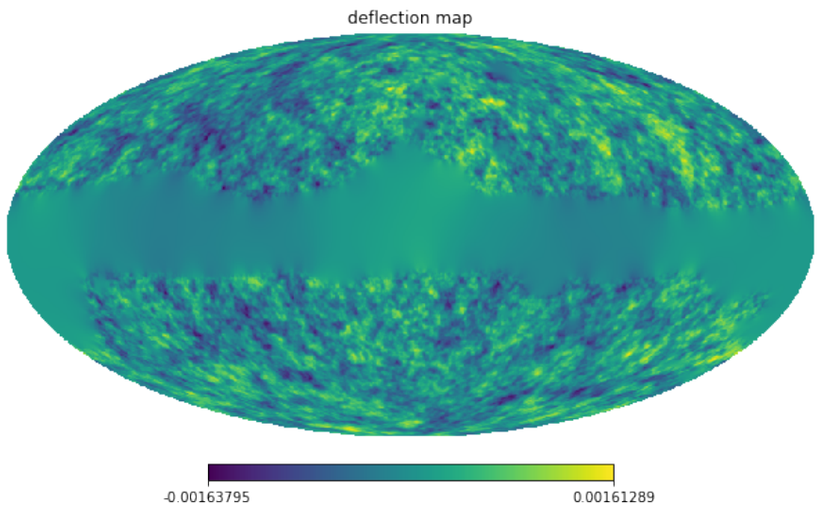


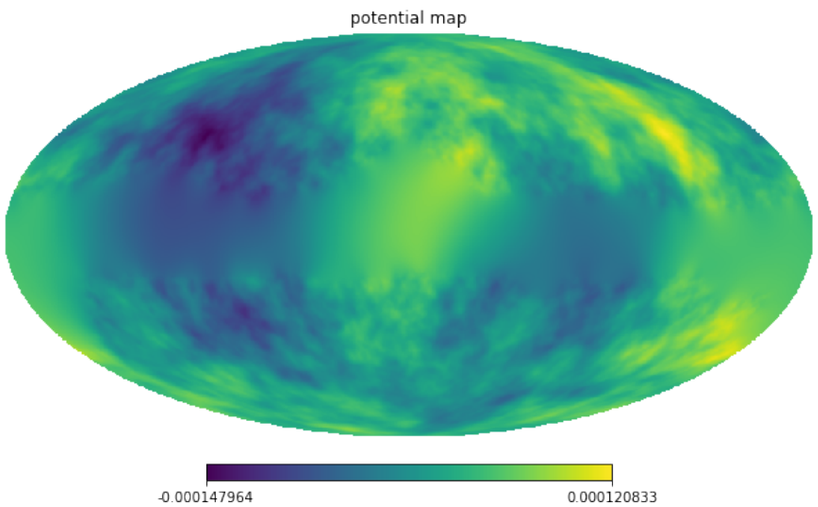
Planck data


-300
300 μK


0.41 μK
-160
160 μK

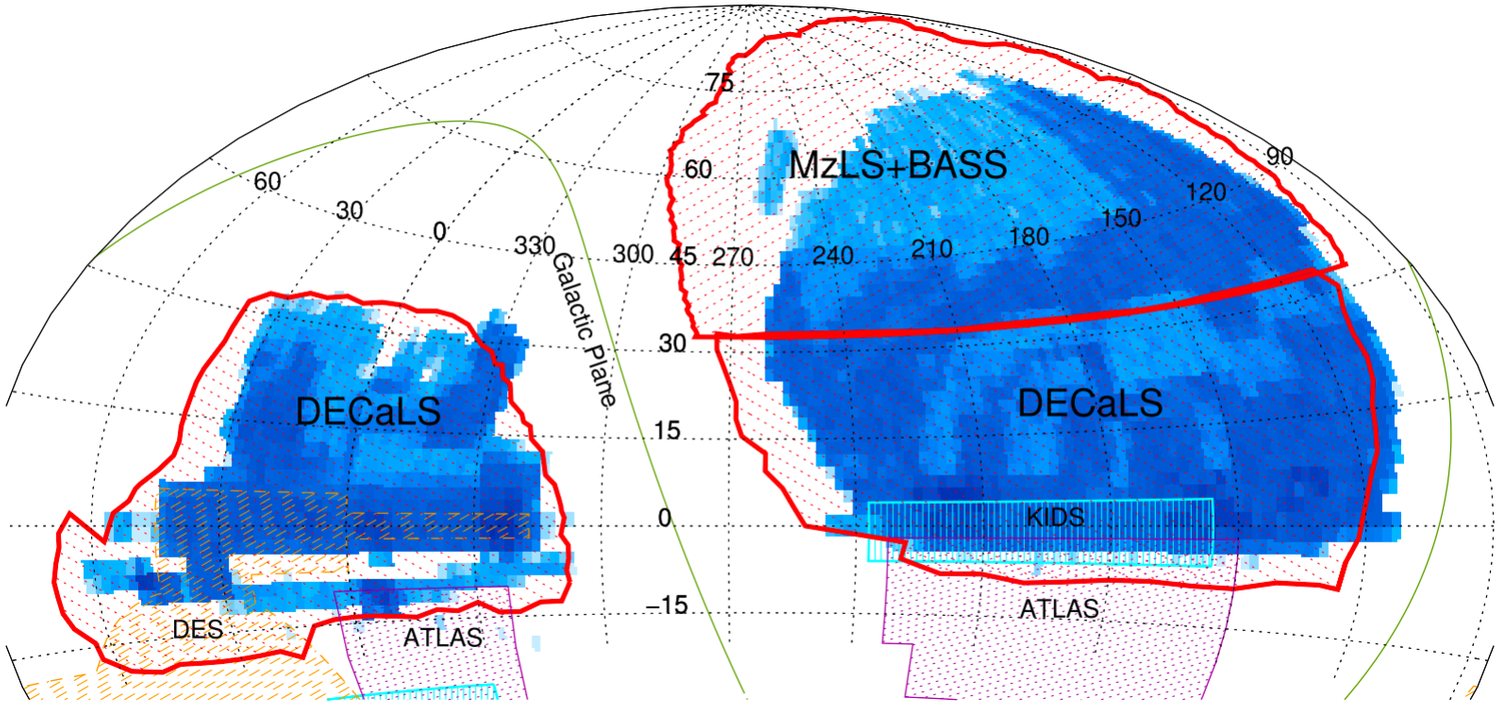

kappa map
-0.094401
0.0774593

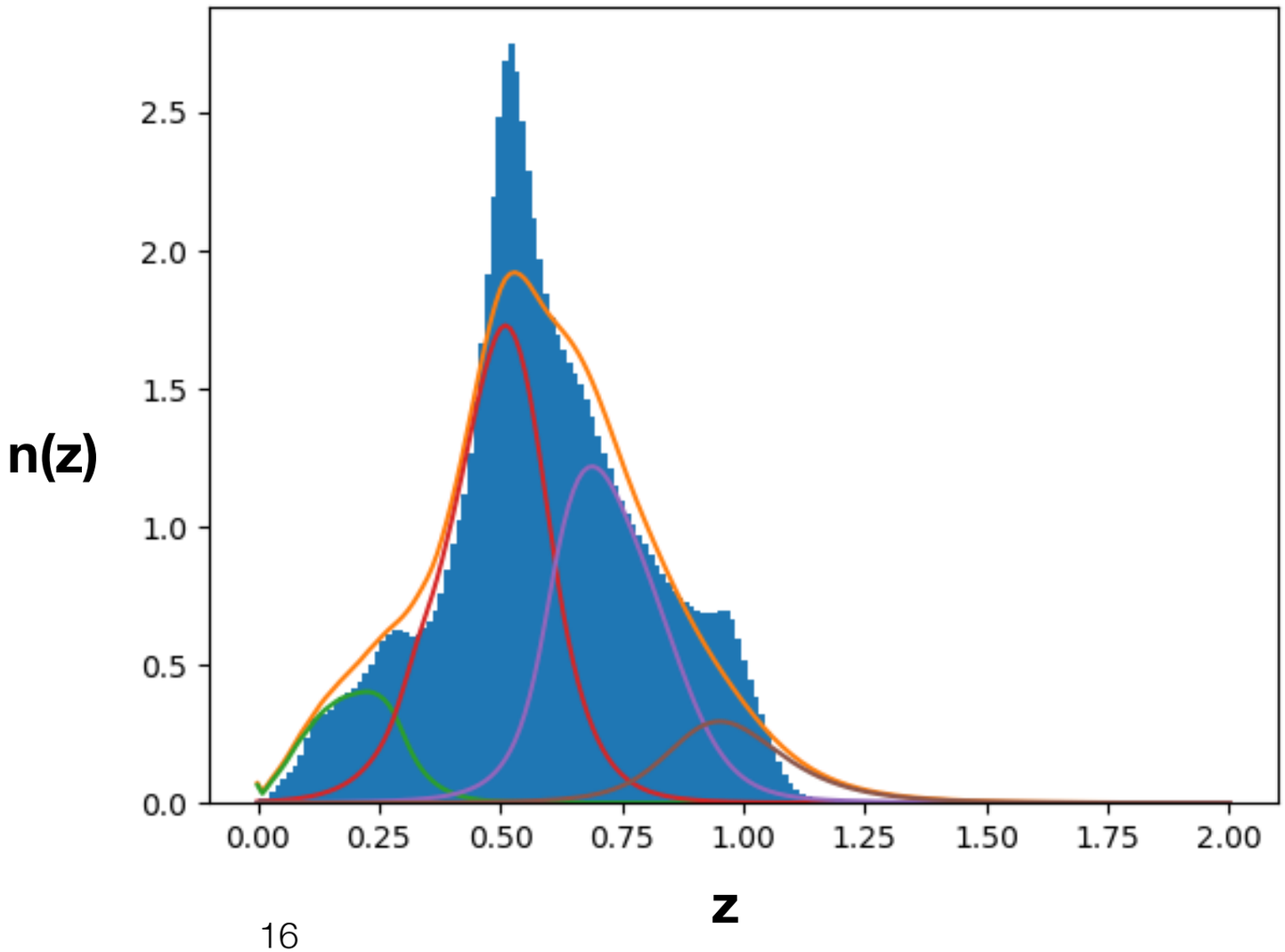

deflection map
-0.00163795
0.00161289


potential map
-0.000147964
0.000120833

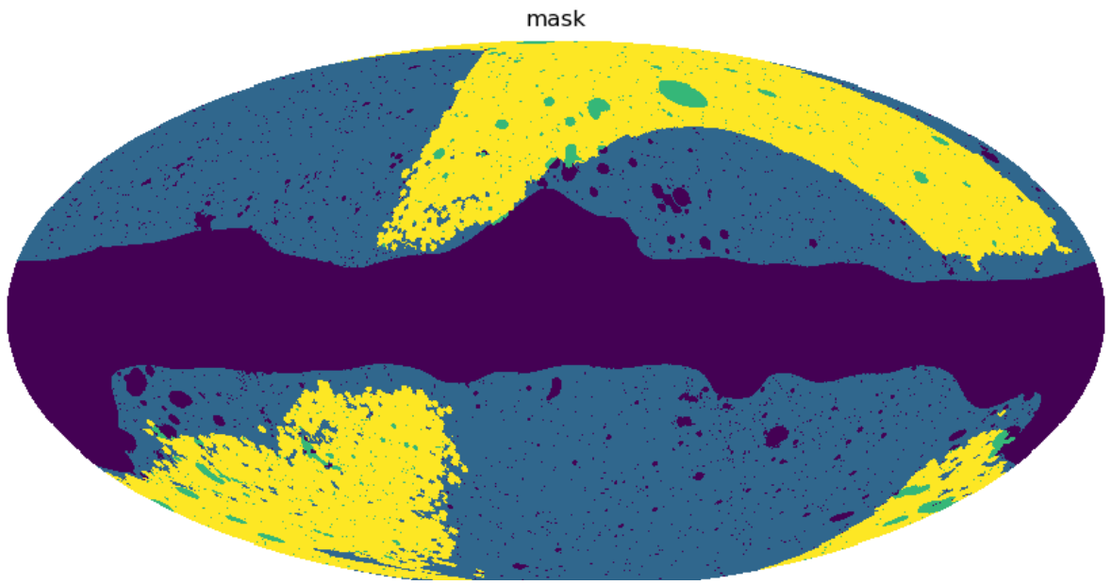
DECaLS data

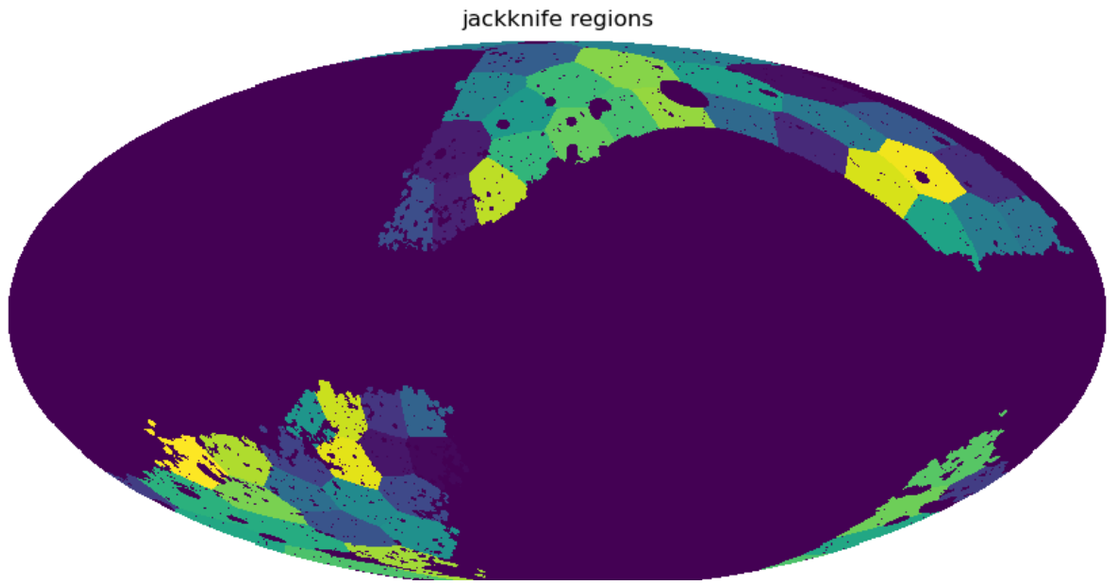
- Photo-z: Zou+ 2019
- ~1e8 galaxies
- r<23
- 0.11 < (g-r) < 2.25
- 0.04 < (r-z) < 1.99
- 0.88 < (r-W1) < 3.58
- 1.47 < (r-W2) < 3.22
- My tomographic bins: (0, 0.3), (0.3, 0.6), (0.6, 0.9), (0.9, 1.2)

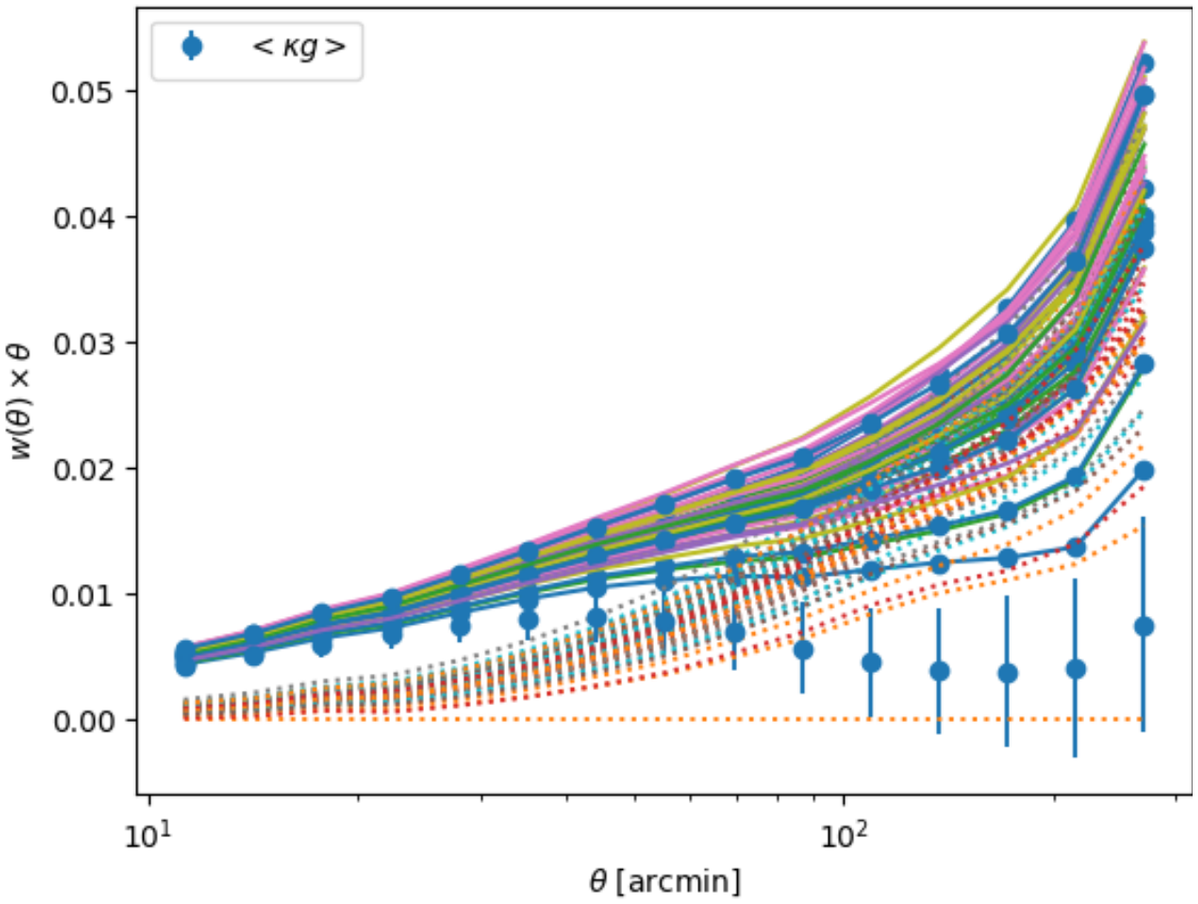


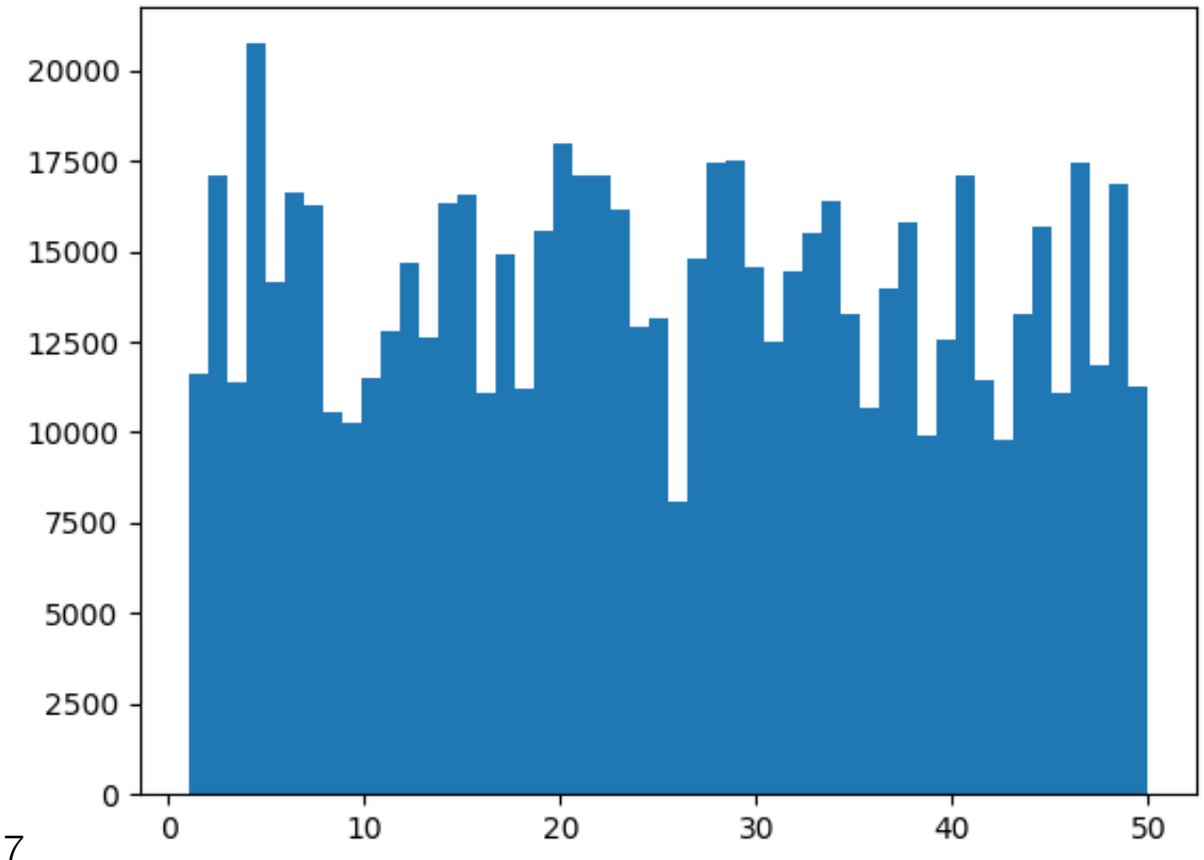


Jackknife resampling
& random catalog correction

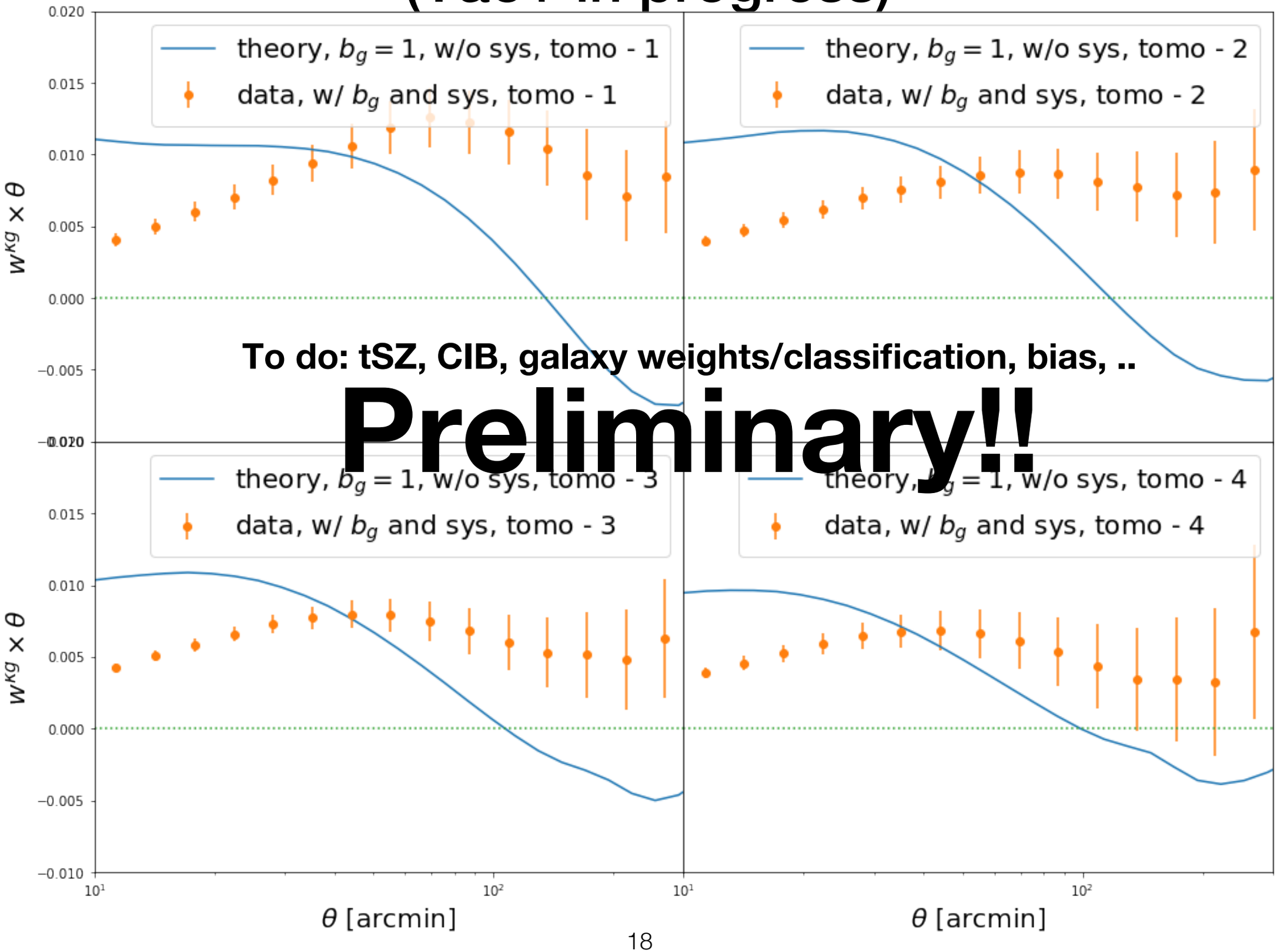








Measurement v.s. Theory (Yao+ in progress)



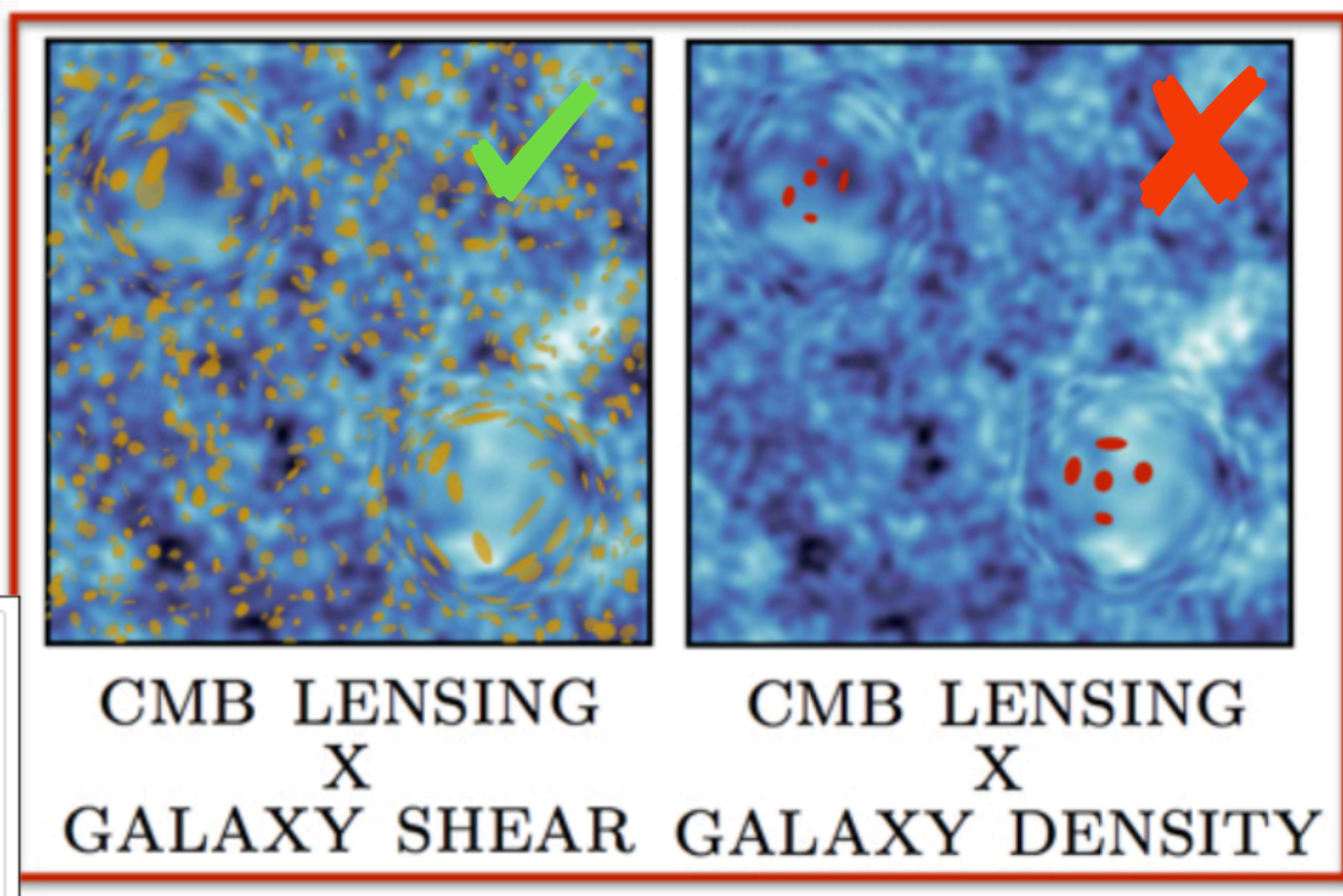
To do: tSZ, CIB, galaxy weights/classification, bias, ..

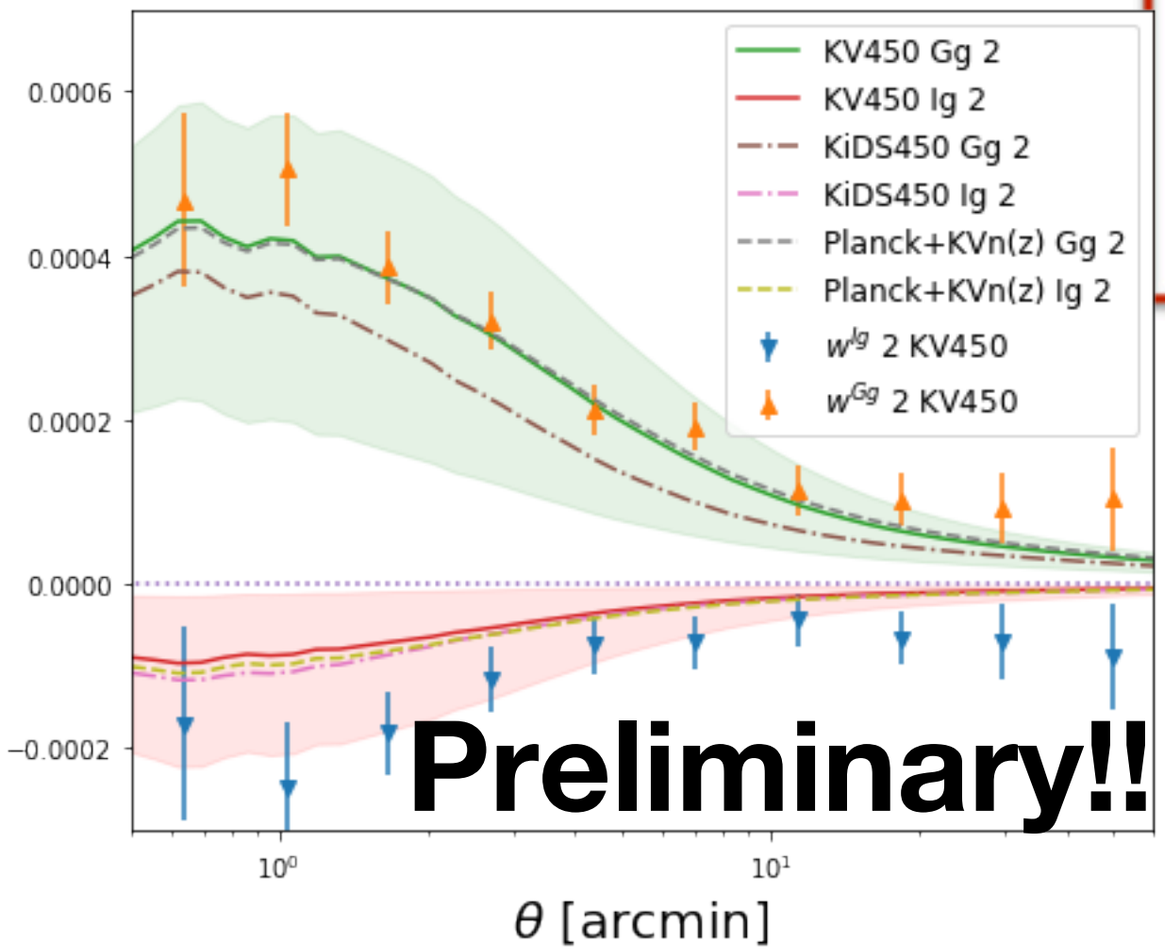
Preliminary!!

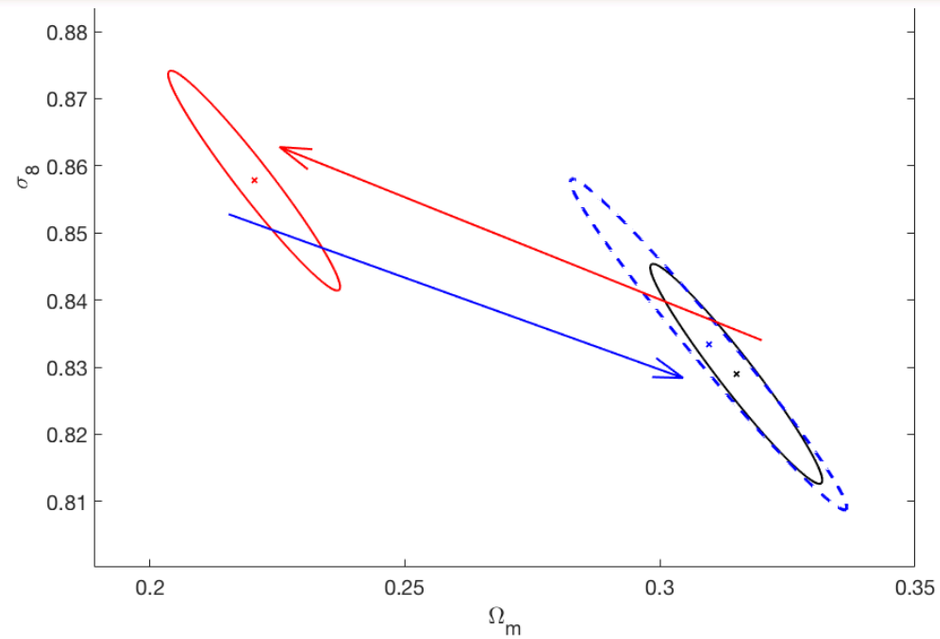
Preliminary: cleaning the intrinsic alignment (IA) contaminations in cosmic shear / CMB-lensing

$$\gamma^{\rm obs} = \gamma^G + \gamma^N + \gamma^I$$

Reducing the IA bias:
In forecast, 1707.01072 (bottom-right)
In data, Yao+ 2019 in prep. (bottom-left)

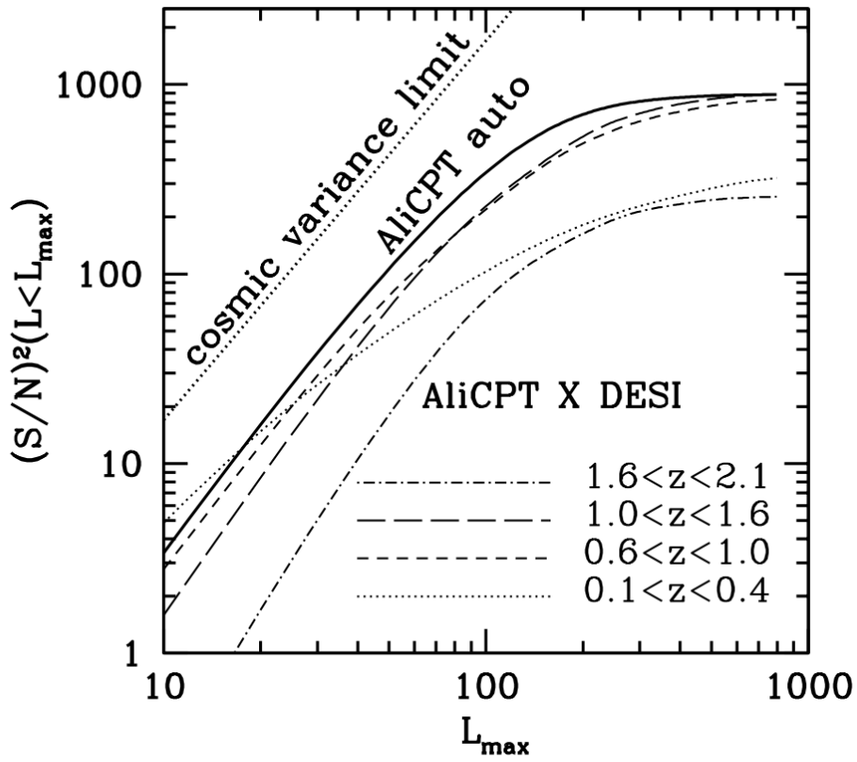






Summary

- AliCPT can do way more than only B-mode detection.
- Plenty of cosmological information beyond GWs, with AliCPT:
  - CMB lensing X galaxy (take-home message: AliCPT X DESI and more)
  - CMB lensing auto correlation
  - CMB lensing X shear



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