



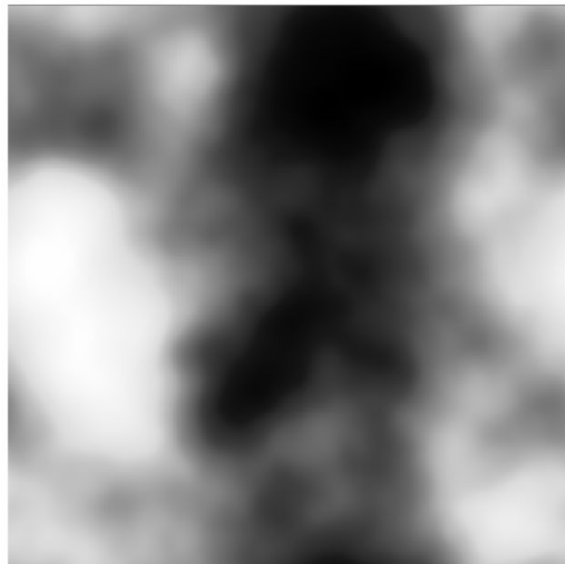
# CMB Lensing and Dark Energy

Alexander van Engelen

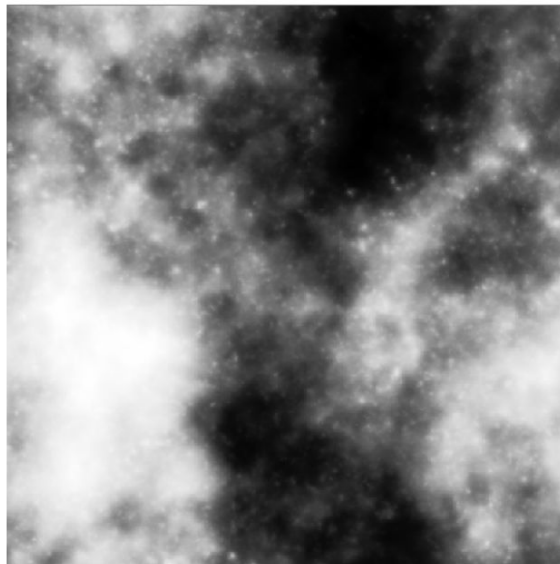
Arizona State University

# Mapping Structure with CMB-S4 Lensing

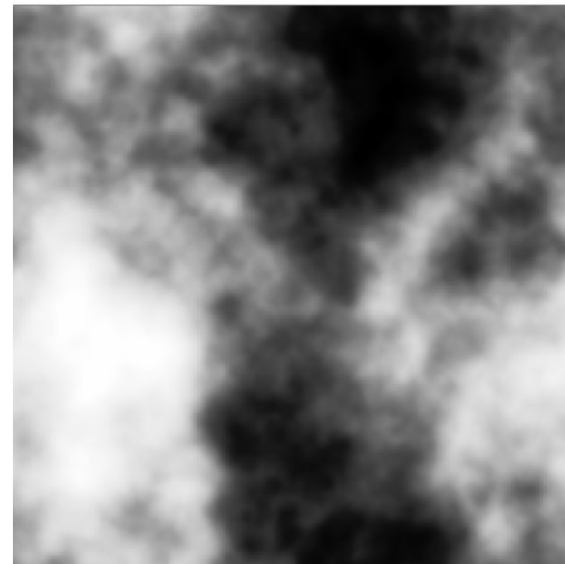
Planck fidelity



Simulated sky

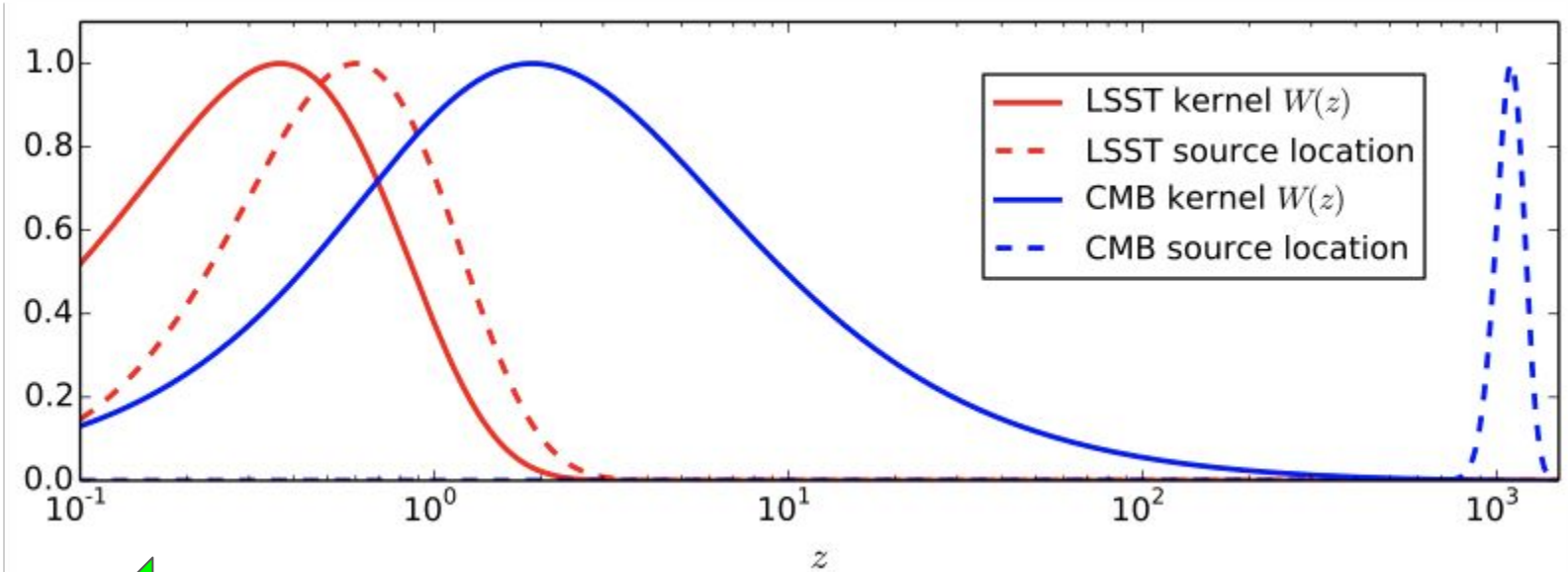


CMB-S4 fidelity



Lensing

# Redshift Kernel Overlap

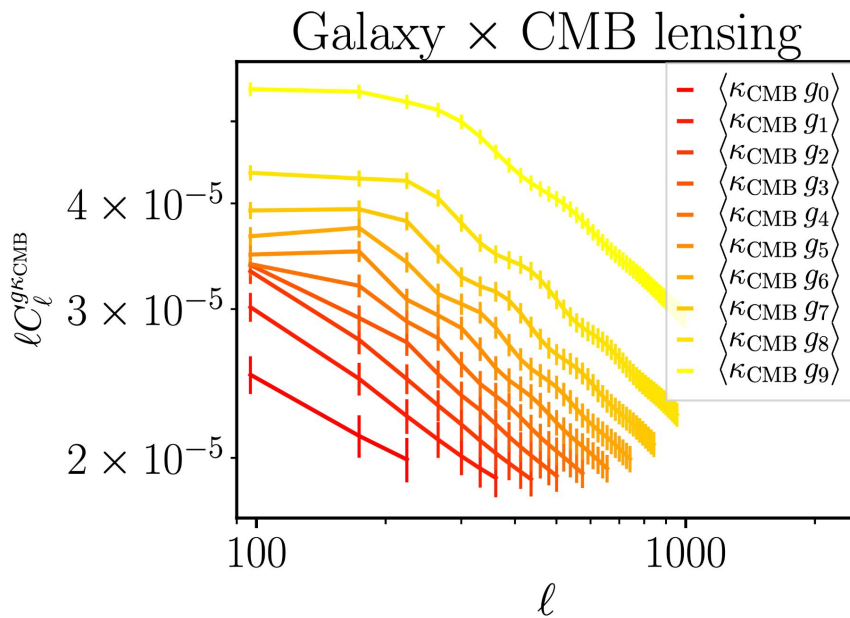
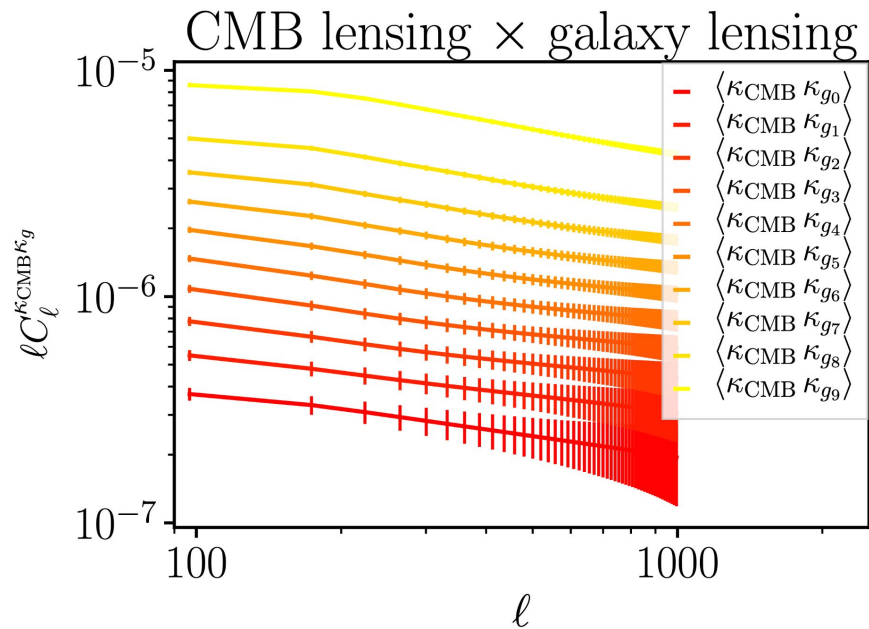


← DE Domination

CMB-S4 Science Book ('16)

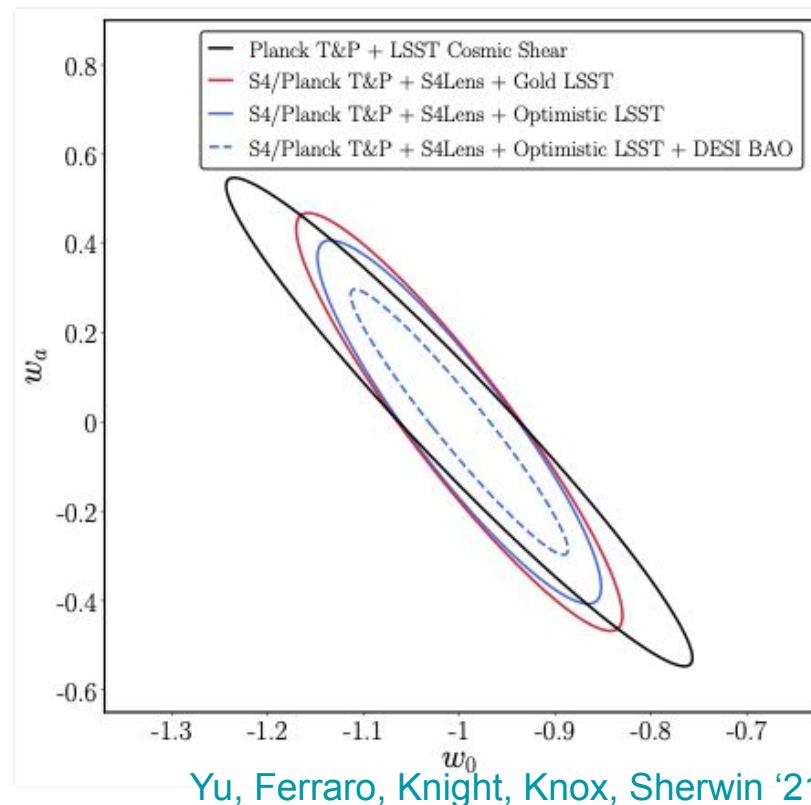
# Correlating CMB lensing with optical surveys

- Many cross spectra will be measured! (c.f. Chihway Chang's talk)



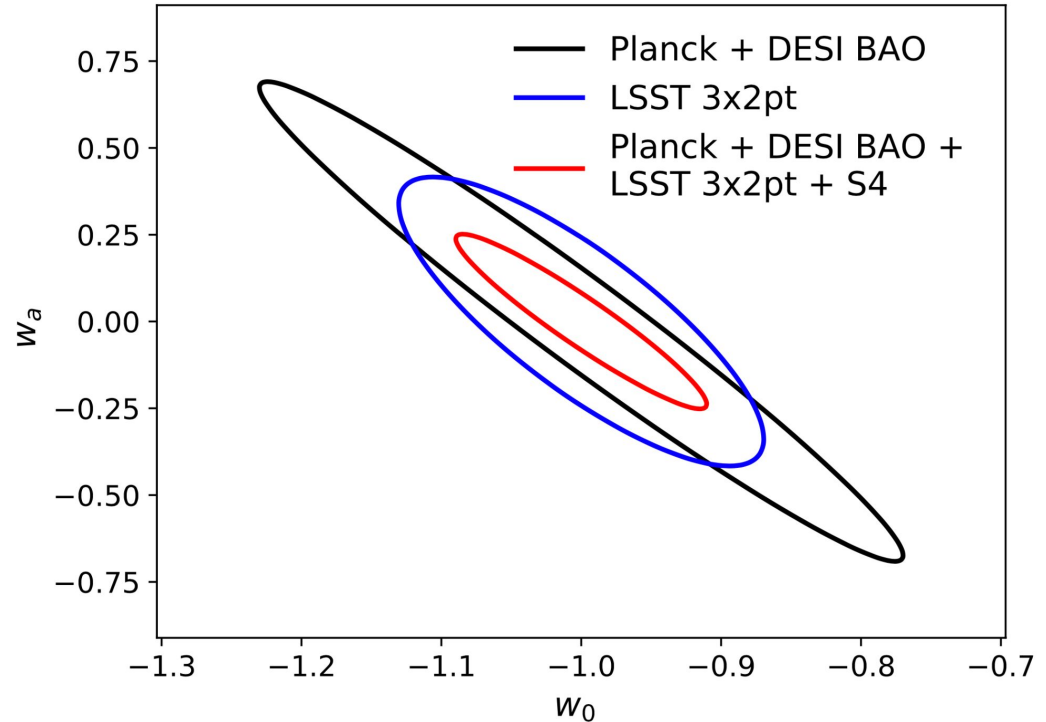
# CMB-S4 lensing + VRO clustering

- “CMB lensing tomography”
- Idea: on large scales,
  - $\langle gg \rangle \sim b_g^2 \sigma_8^2$
  - $\langle gK_{\text{CMB}} \rangle \sim b_g^1 \sigma_8^2$
- Combining these measurements we break degeneracy, get  $\sigma_8(z)$
- Measure both growth and geometry.  
A promising, unique probe of DE



# CMB-S4 lensing + VRO full “3x2pt”

- Black: Planck  $T, P$  + DESI BAO
  - FoM  $\sim 70$
- Blue: VRO/LSST “3x2pt”  $\langle yy \rangle + \langle yg \rangle + \langle gg \rangle$ 
  - FoM  $\sim 70$  (200 with Planck+Desi)
- Red: “3x2pt” plus CMB-S4  $T, P$ , and lensing
  - FoM  $\sim 400$   
partly from breaking  $m_\nu$  degeneracy



# Summary

- CMB lensing with CMB-S4 gives a high-redshift “anchor” for studies of growth of structure at lower redshift
- “CMB lensing tomography” is a unique way to measure growth (& geometry)
  - $\langle gg \rangle + \langle gk_{\text{CMB}} \rangle$
- Can help with systematics for VRO cosmic shear (dN/dz, IA, shear.biases)
  - $\langle \gamma\gamma \rangle + \langle \gamma k_{\text{CMB}} \rangle$
- Potential to improve DE FoM over full VRO “3x2pt” by x2.5
  - $\langle \gamma\gamma \rangle + \langle \gamma g \rangle + \langle gg \rangle + \langle \gamma k_{\text{CMB}} \rangle + \langle gk_{\text{CMB}} \rangle + \langle k_{\text{CMB}} k_{\text{CMB}} \rangle$

# Bonus slide



# CMB-S4 lensing + VRO shear

- Benefit to VRO shear: adding a high-z source screen with completely different systematics
- Shear measurement biases
  - Das+13, Vallinotto 12, Schaan+ 16
- Also, some potential impact on intrinsic alignment and source photo-z uncertainties
  - Hall & Taylor '14, Troxel & Ishak 14, Fang+21, Schaan+20

