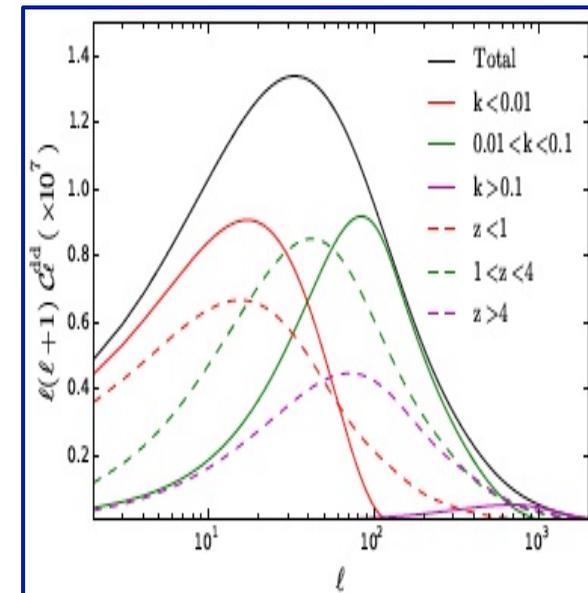


CMB Lensing and Scale Dependent New Physics

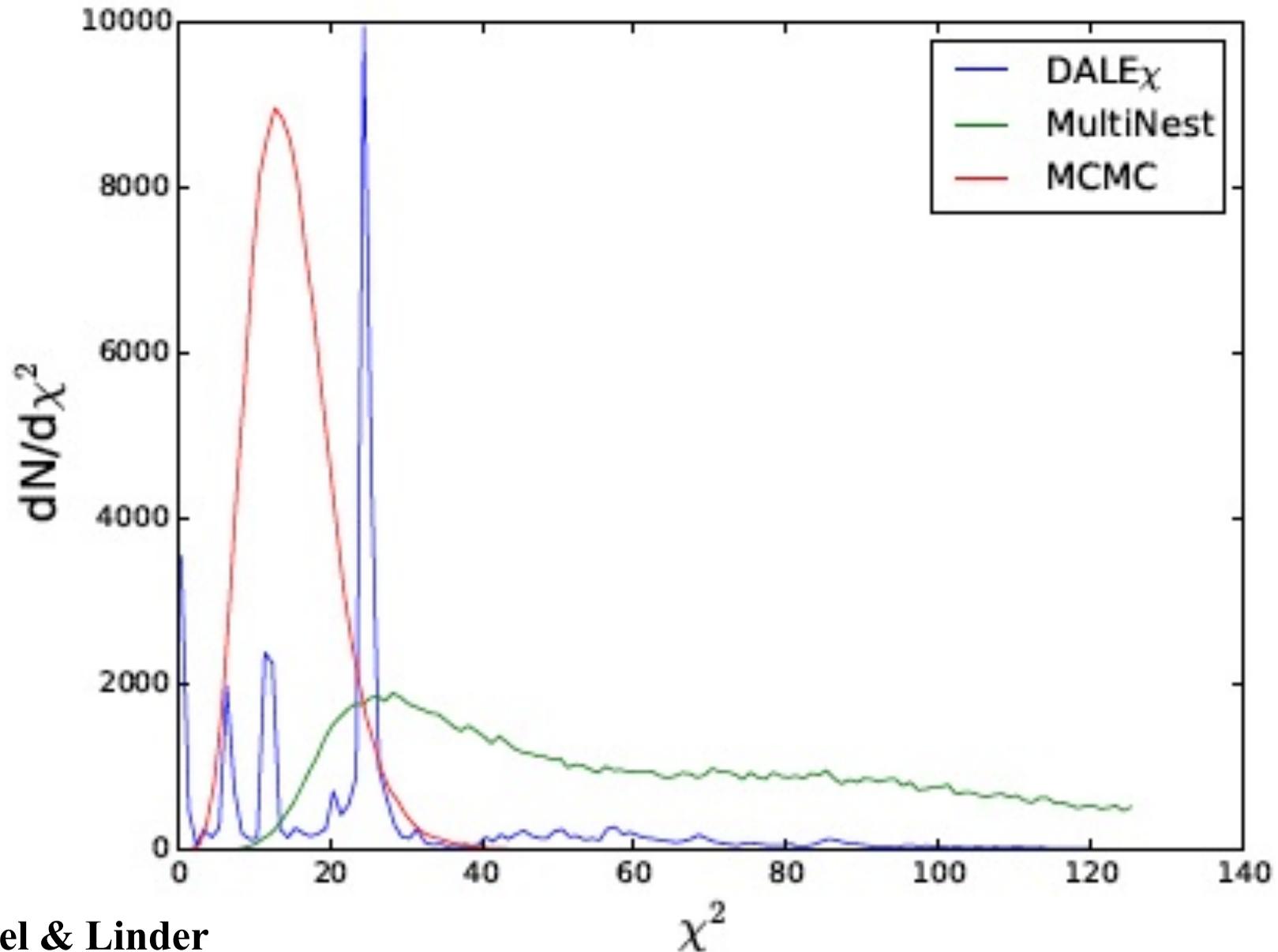
Cosmo 2015

Eric Linder

UC Berkeley & Berkeley Lab



DALE χ – Detailed Analysis of Likelihoods via Elastic Collisions on χ^2

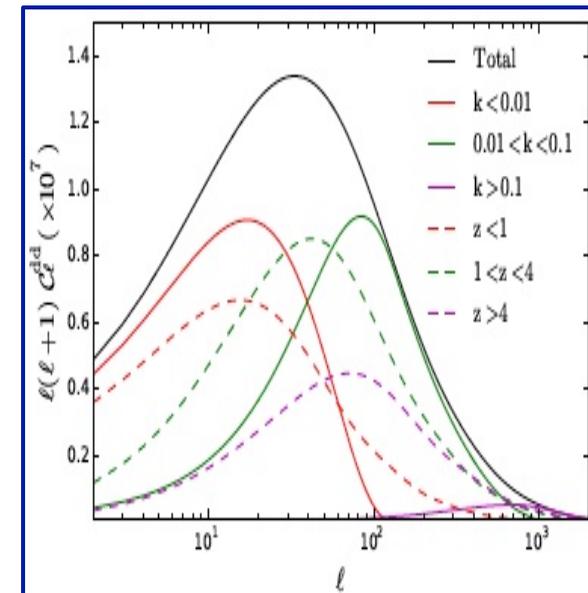


CMB Lensing and Scale Dependent New Physics

Cosmo 2015

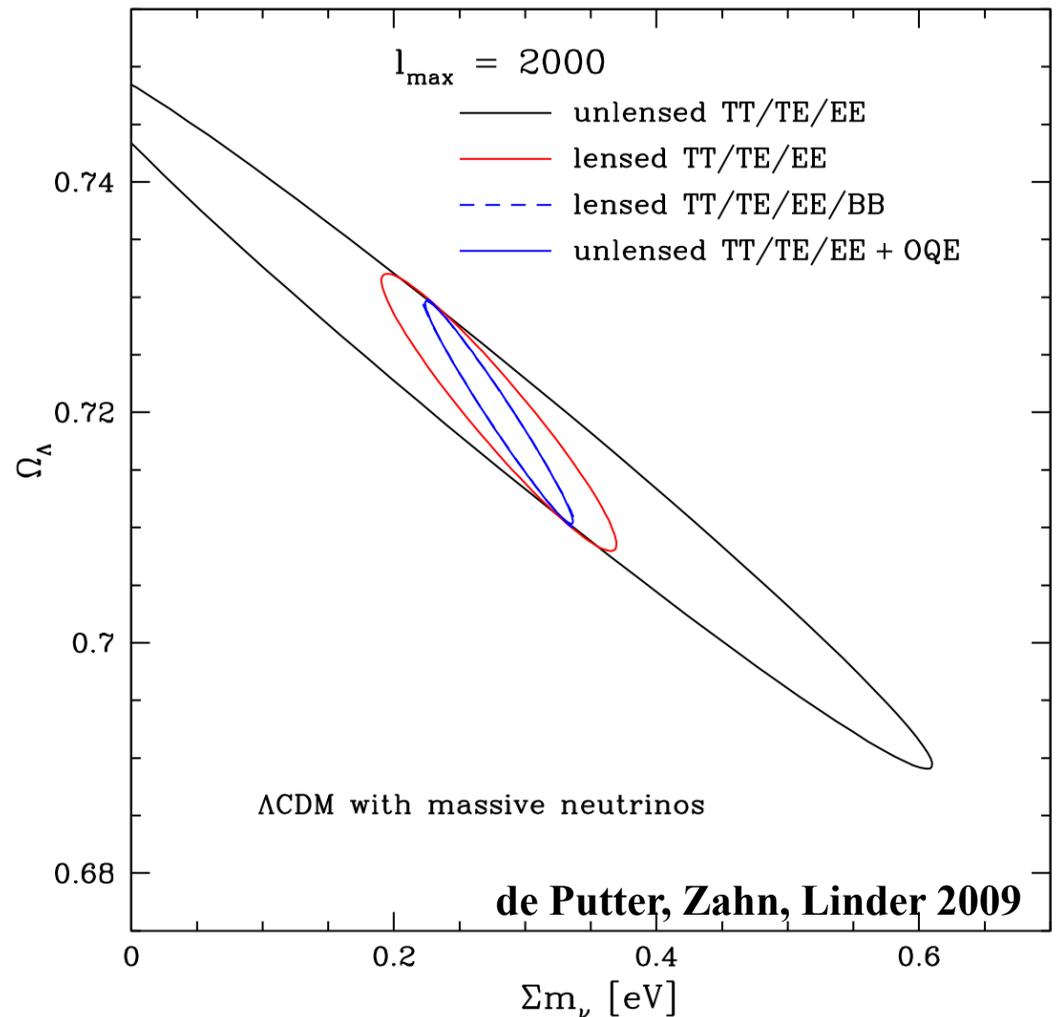
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CMB Lensing

CMB lensing is weak gravitational deflections by all mass acting on a known source. It probes **both distances and growth from $z=0-1100$** .



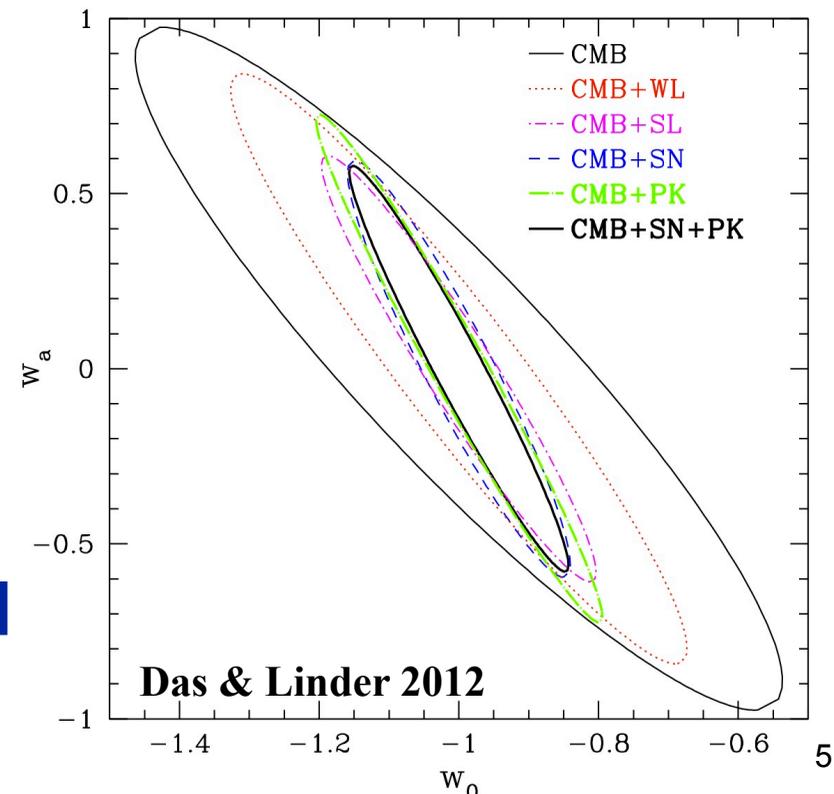
CMB + Late Time Probes

Strong constraints by combining CMB (early), CMB lensing (mid), and late time probes.

	ω_b	ω_c	ω_b	Ω_{de}	n_s	τ	σ_8	w_0	w_a	γ
Fiducial	0.02258	0.1093	0.001596	0.734	0.963	0.086	0.8	-1	0	0.55
$\sigma(\text{Planck})$	0.000137	0.00117	0.00175	0.124	0.00337	0.00426	d	1.10	2.48	d
$\sigma(\text{Planck}+10k)$	0.0000492	0.000682	0.000666	0.042	0.00207	0.00297	d	0.305	0.642	d
Gain	2.78	1.72	2.63	2.95	1.63	1.43	d	3.61	3.86	d

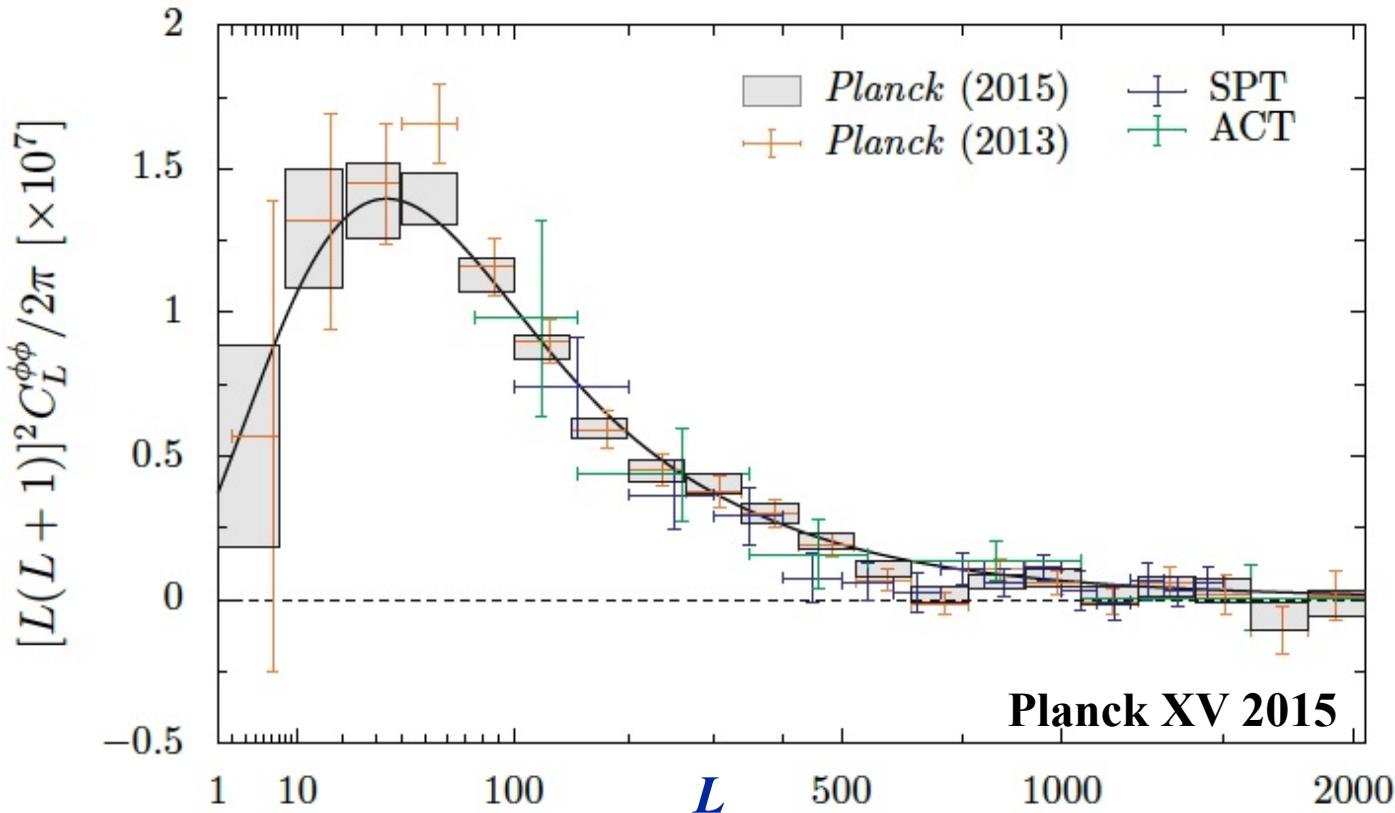
Improve m_ν constraint by 2.6,
DE FOM by 6.6,
 m_ν - σ_8 FOM (fixing GR) by 5.2.

Large scale structure probes,
and distance probes, each add
to **cosmological** knowledge.



CMB Lensing Measured

CMB lensing first detected via CMB alone in 2011.
Now Planck has **S/N~40** measurements.



CMB lensing not only **smears the power spectra**, but **induces nonGaussianity** (nontrivial 4pt functions) and **converts E- to B-modes**. All are detected.

As we obtain high S/N at many L , we probe many k and many z . This scale dependence (A_L *not constant*) can reveal new physics.

Atacama Cosmology Telescope, POLARBEAR/
Simons Array, South Pole Telescope are CMB
lensing machines – all are on sky.

We examine 3 types of **scale dependent new physics**:

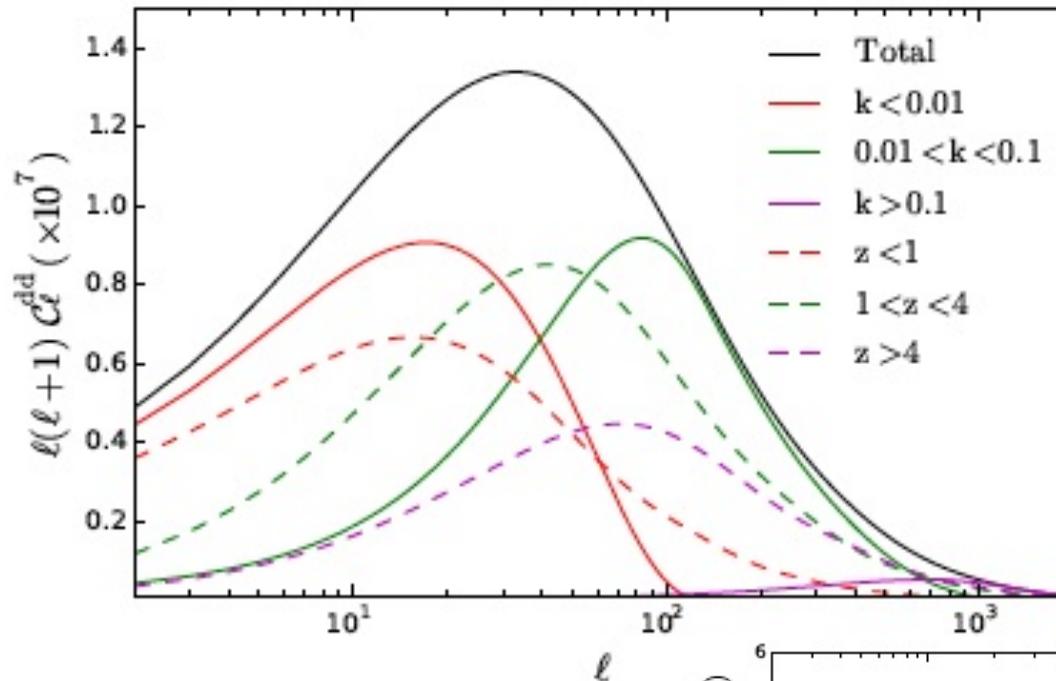
Modified gravity – scalaron Compton wavelength

Neutrino mass – free streaming length

Cold (low c_s) dark energy – sound horizon

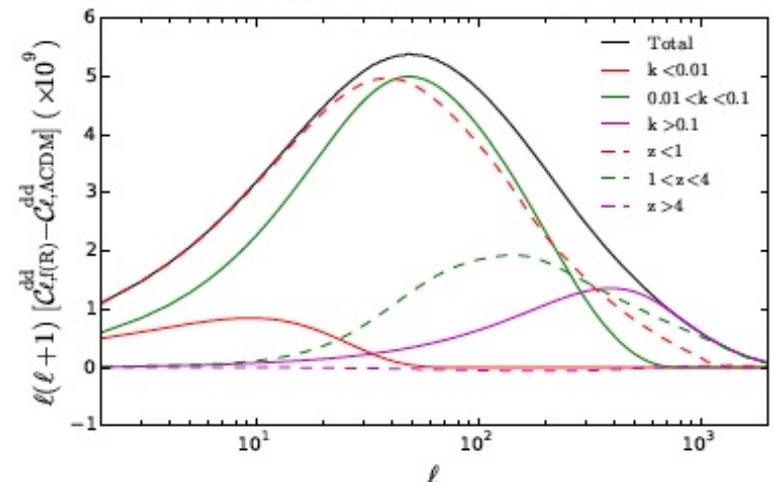
CMB Lensing On All Scales

Sensitive to **linear, quasinlinear, nonlinear scales.**
Sensitive to **all z , even $z > 4$.**



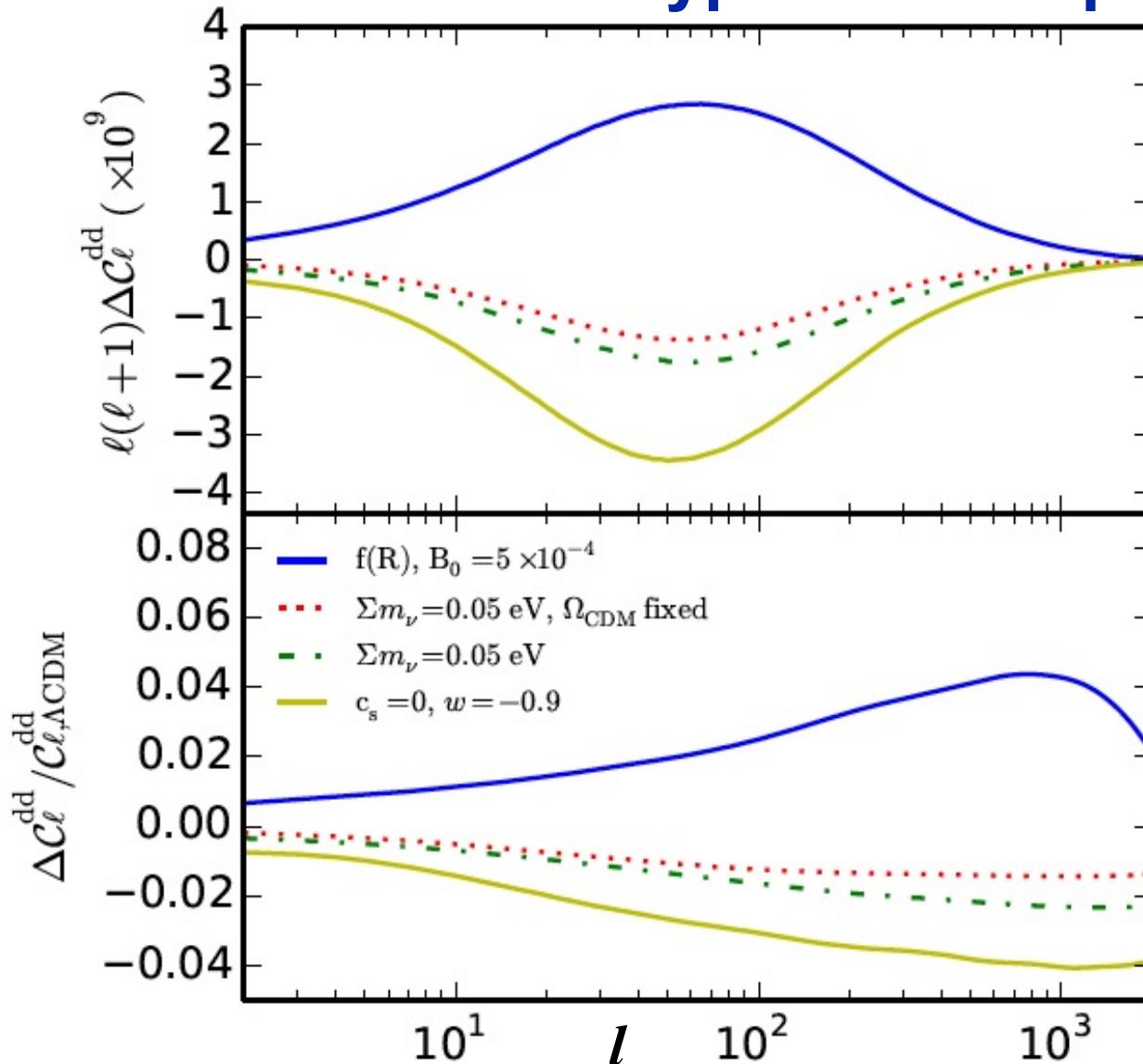
Hojjati & Linder
1507.08292

Scale dependent physics
can reweight this, e.g.
f(R) gravity.



Distinguishing New Physics

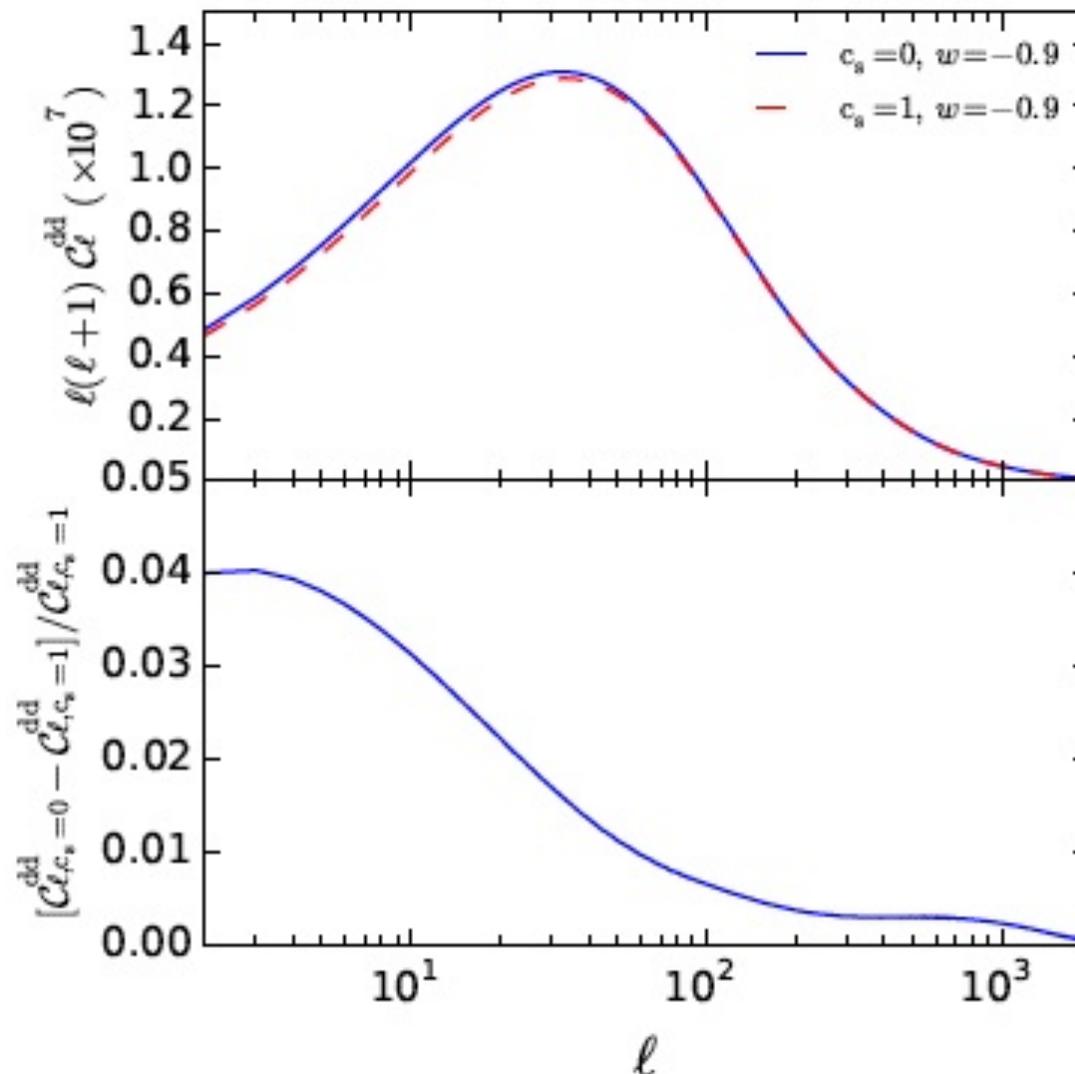
Distinct scale dependent deviations from Λ CDM,
and between the types of new physics.



**Compton scale
plus screening vs
free streaming vs
sound horizon.**

Cold Dark Energy

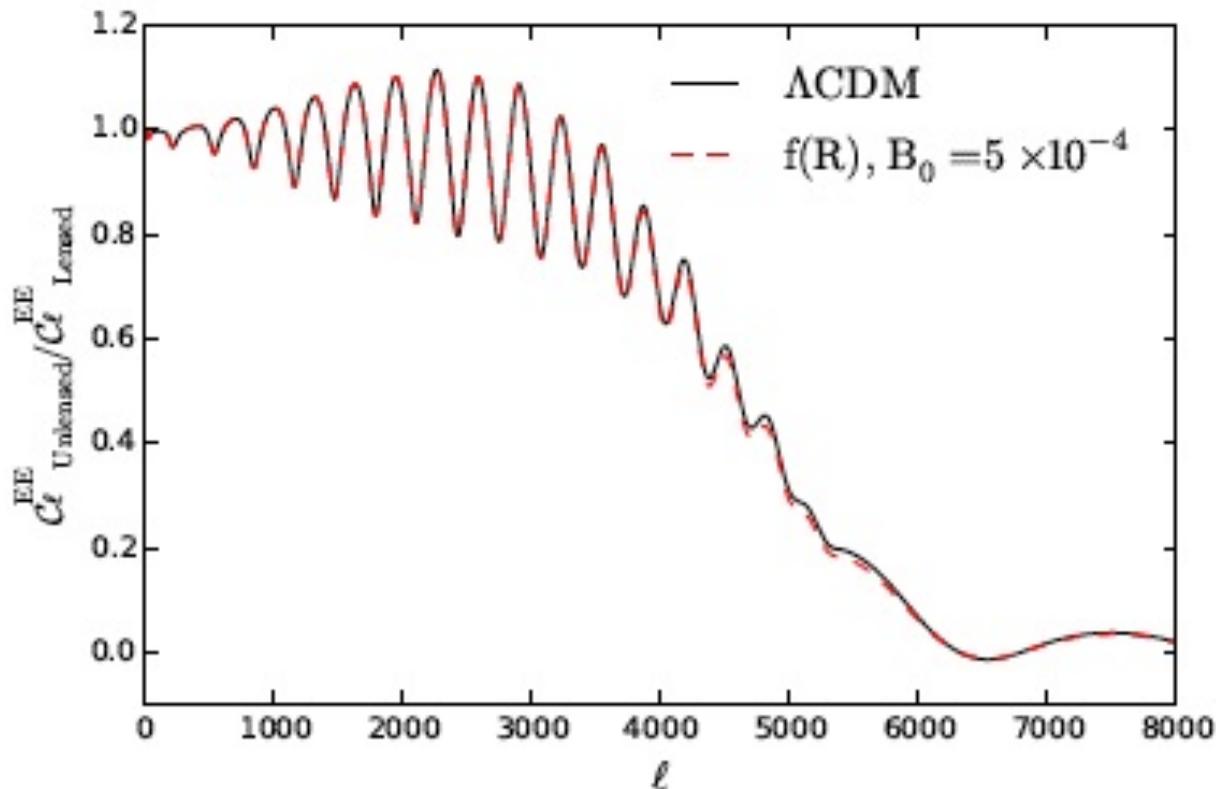
Cold (low c_s) dark energy can **cluster**, enhancing CMB lensing.



Scale Dependence

Scale dependence also shows up in the **matter power spectrum** – but also scale dependent bias, baryonic effects, etc., and in the **CMB power spectra** – but must separate from primordial effects.

One fascinating exception:



EE spectrum at $l > 5000$ is almost pure lensing.

Accessible to beams $<$ few arcmin.

Summary

CMB lensing has become a **high S/N cosmological probe**.

Sensitive to many scales and redshifts, and so **new scale dependent physics**.

Ignoring scale dependence can **bias cosmology**, including delensing of **B-modes (and r)**.

Data is coming in now, with 3rd generation starting, and CMB-S4 in future. These high res experiments can also see **pure lensing in E at $l > 5000$** .

Can distinguish new physics from Λ CDM, and **modified gravity vs neutrino mass vs cold dark energy**.