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Acoustic Dark Energy: Potential Conversion of the H_0 Tension

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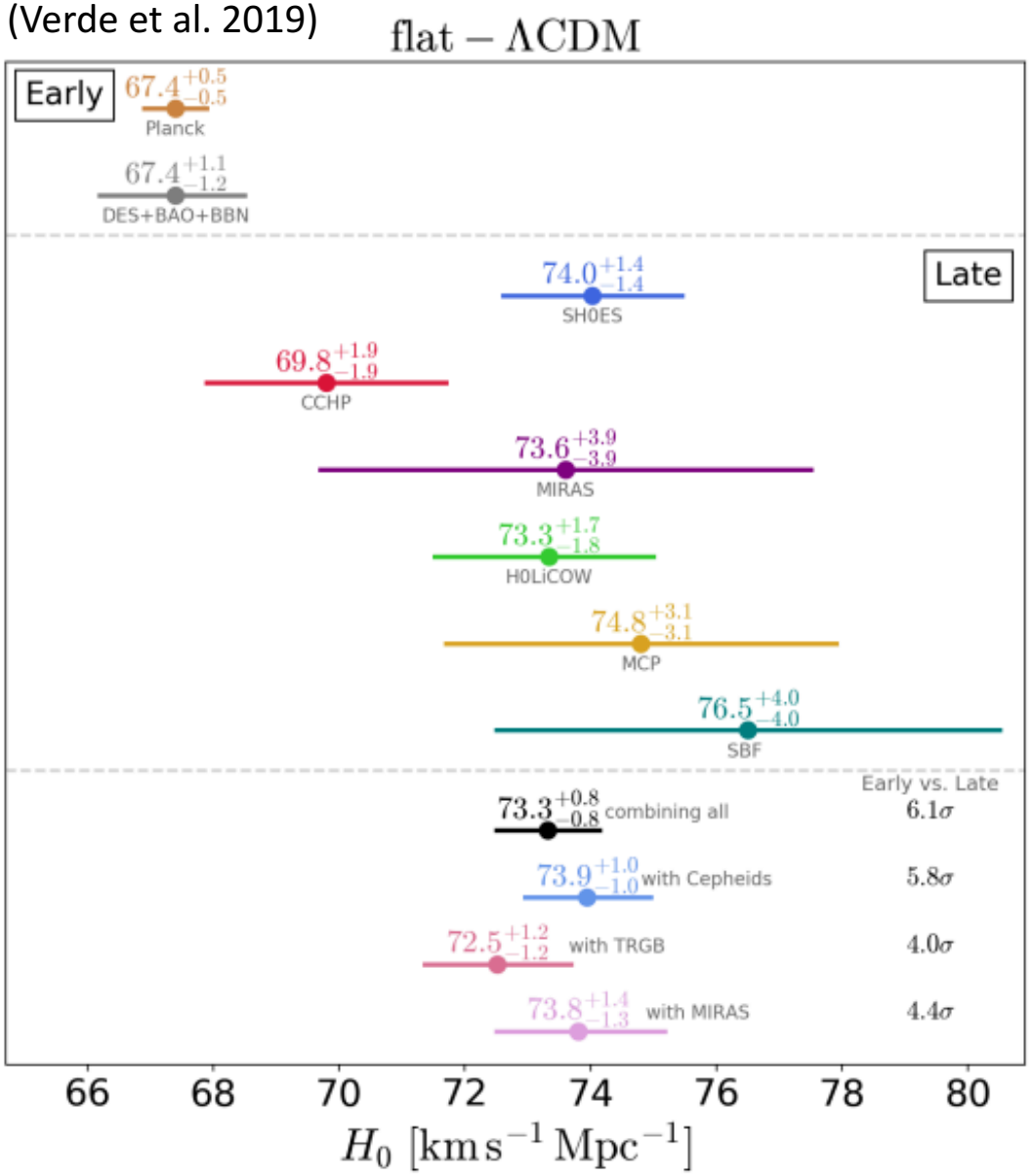
Motivation

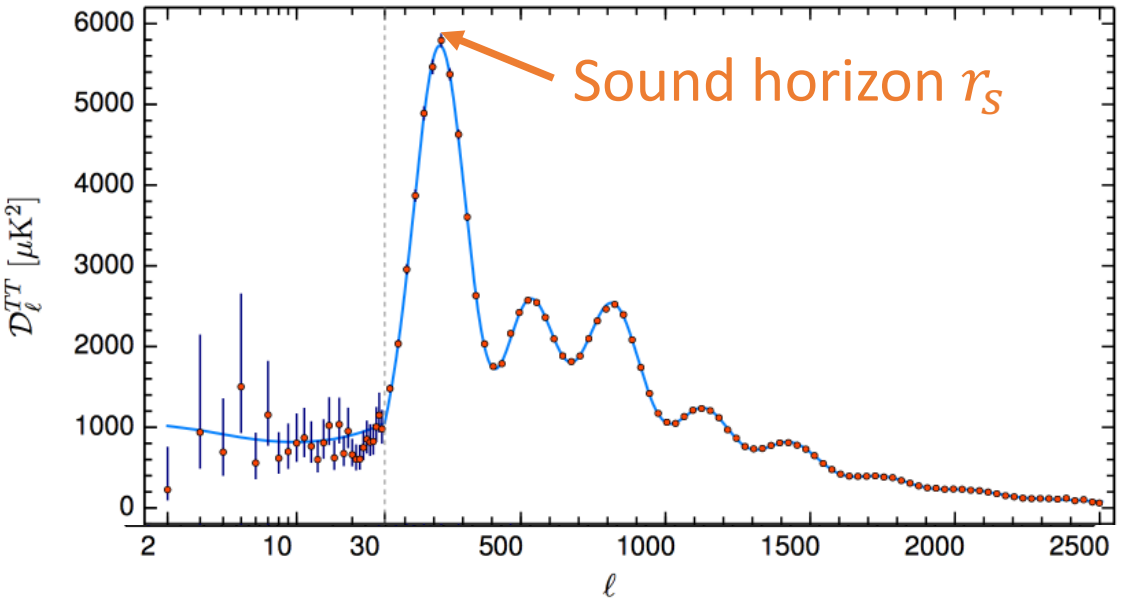
- Current Hubble tension between early and late universe H_0 measurements

(Verde et al. 2019)



Motivation

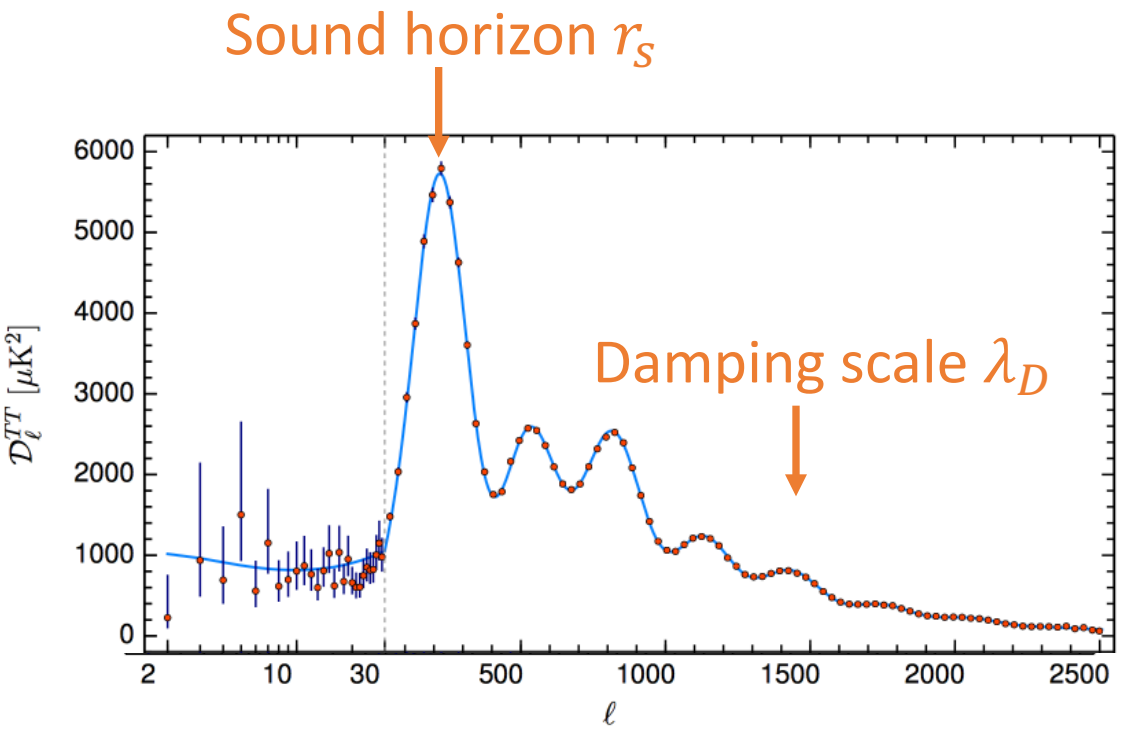
- Additional radiation-like components will increase the total energy density before recombination, thus lower the sound horizon r_s
- Lower sound horizon r_s → higher H_0



(Planck 2018)

Motivation

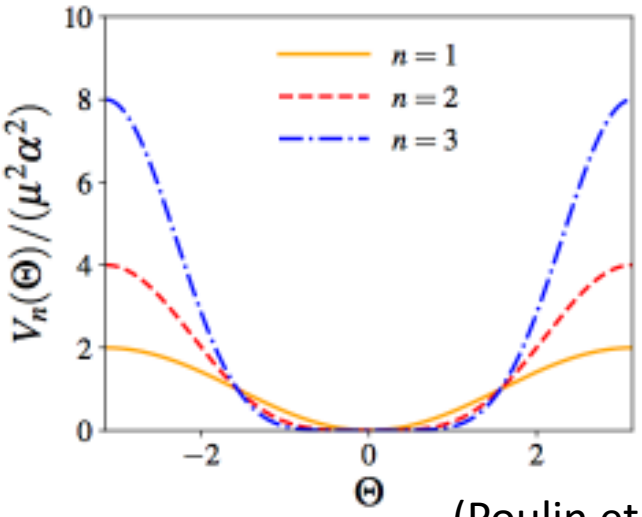
- However, the damping scale $\lambda_D \propto r_s^{1/2}$
- Sterile neutrino doesn't help



(Planck 2018)

Motivation

- Adding a dark fluid that is only important near recombination (Poulin et al 2018, Early Dark Energy paper)
- It is able to keep the ratio of the sound horizon to damping scale unchanged



(Poulin et al. 2018)

Time average fluid approx.
Effective sound speed

Higher H_0 with better CMB fit

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Motivation

- Power law potential $V \propto \phi^{2n}$ with exact Klein-Gorden solution (Agrawal et al 2019)
- Only slightly better than ΛCDM, no more better fit to CMB

See Francis-Yan Cyr-Racine's talk tomorrow

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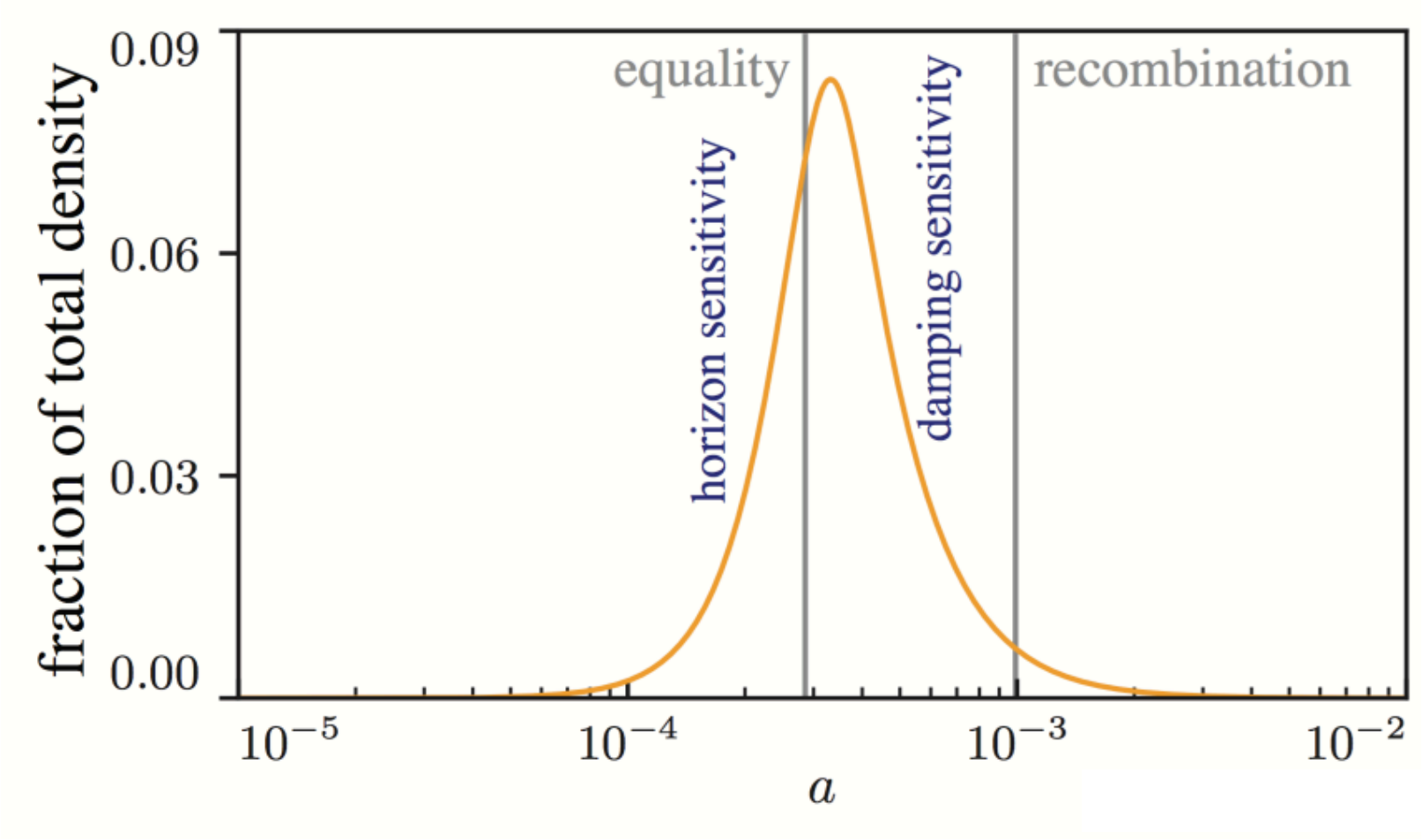
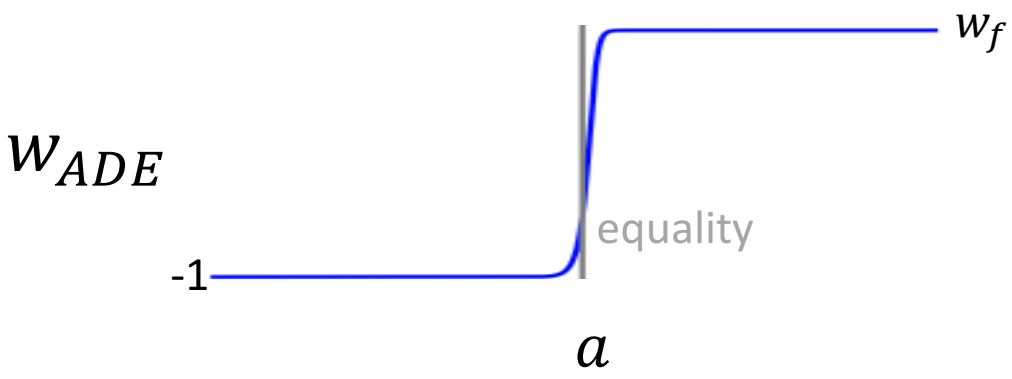
Acoustic Dark Energy (ADE)



Acoustic Dark Energy (ADE)

(Fluid Description)

Background:



Perturbation:

c_s^2=constant:

(The rest frame sound speed)

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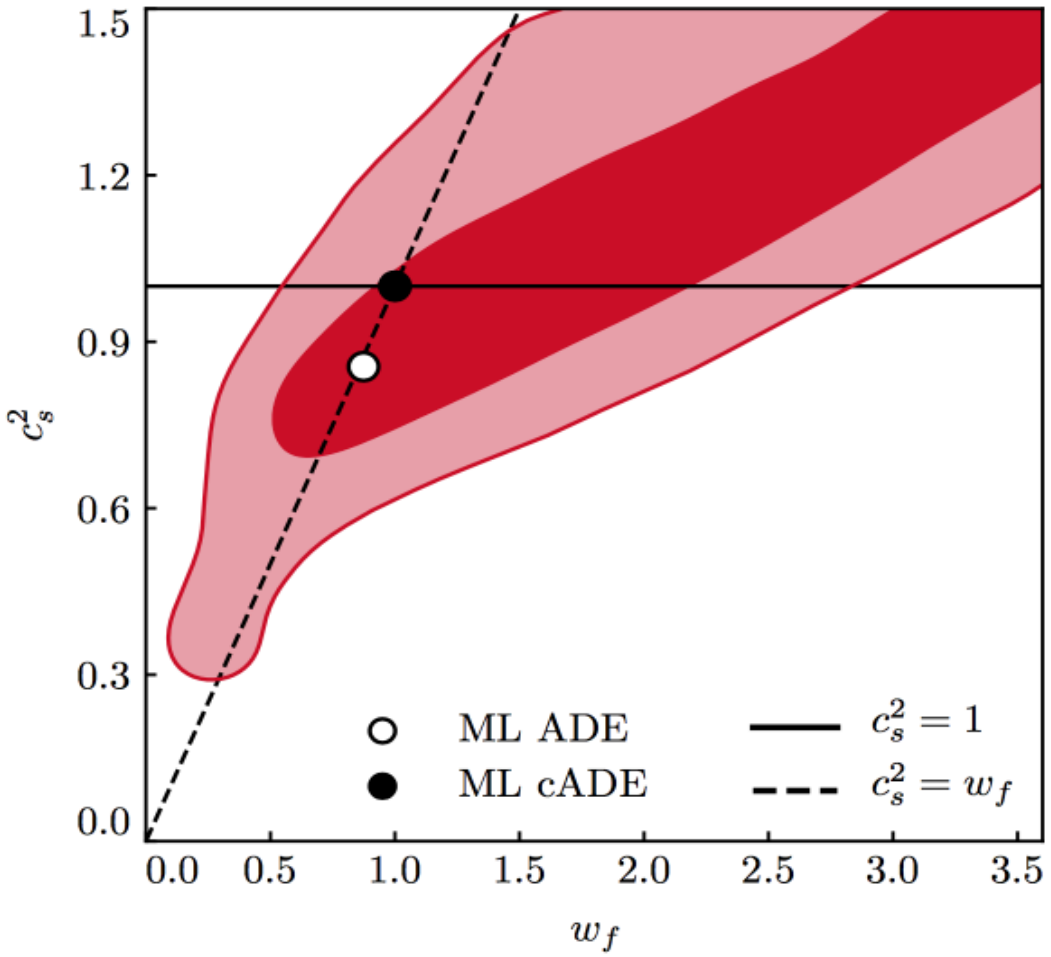
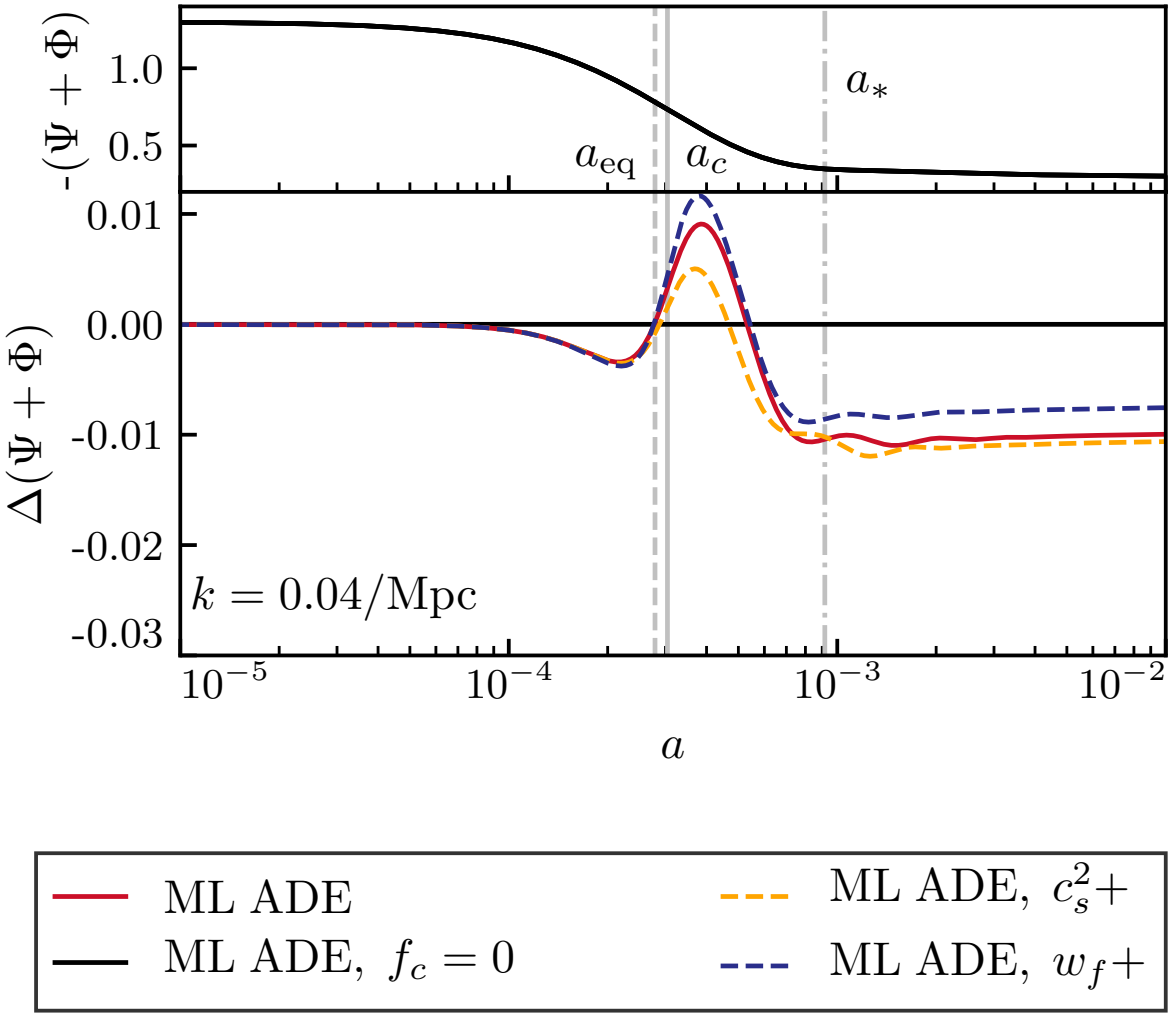
Acoustic Dark Energy (ADE)



w_f - c_s^2 Degeneracy!

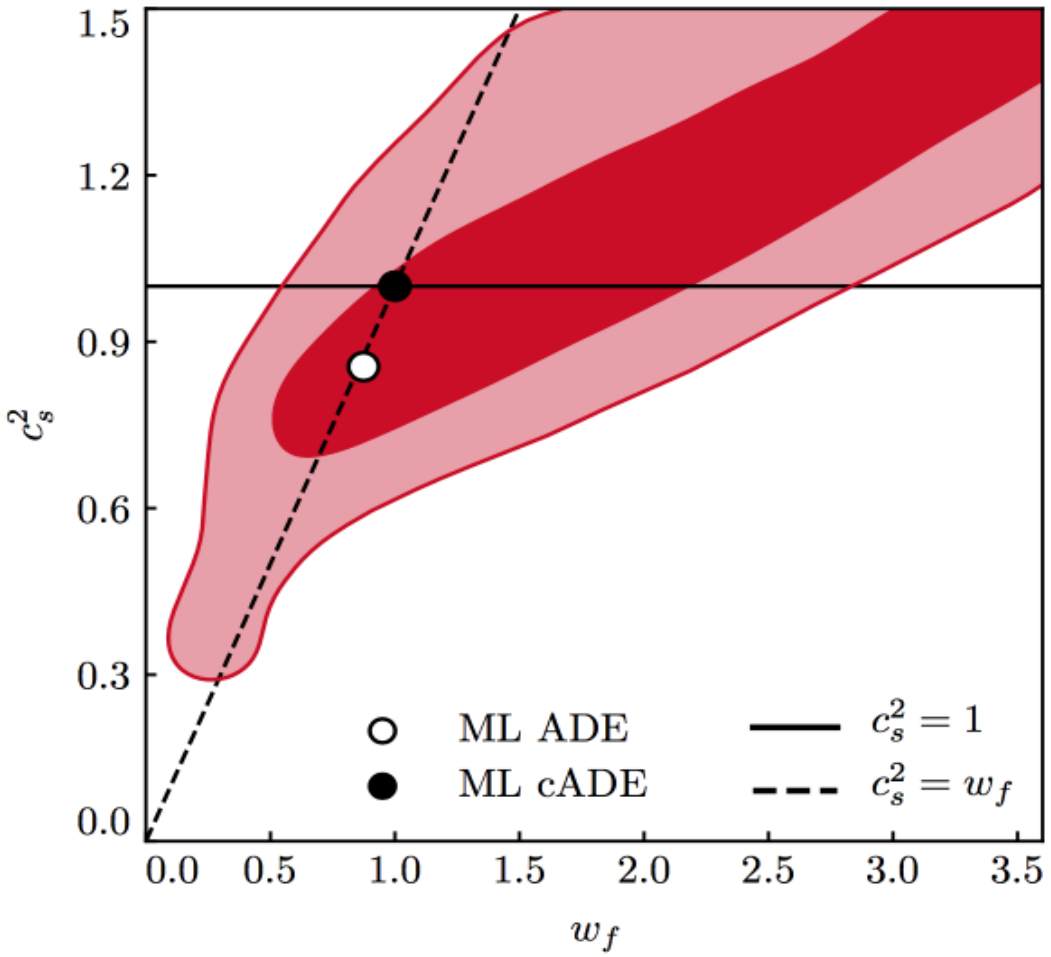


ADE acoustic oscillation due to Jeans stability impacts the potential drop

Weyl potential evolution drive CMB peaks

Balance between c_s^2 and w_f

Acoustic Dark Energy (ADE)



w_f - c_s^2 Degeneracy!

Data favor $c_s^2 = w_f$

The canonical model with $c_s^2 = w_f = 1$ is within 1-σ

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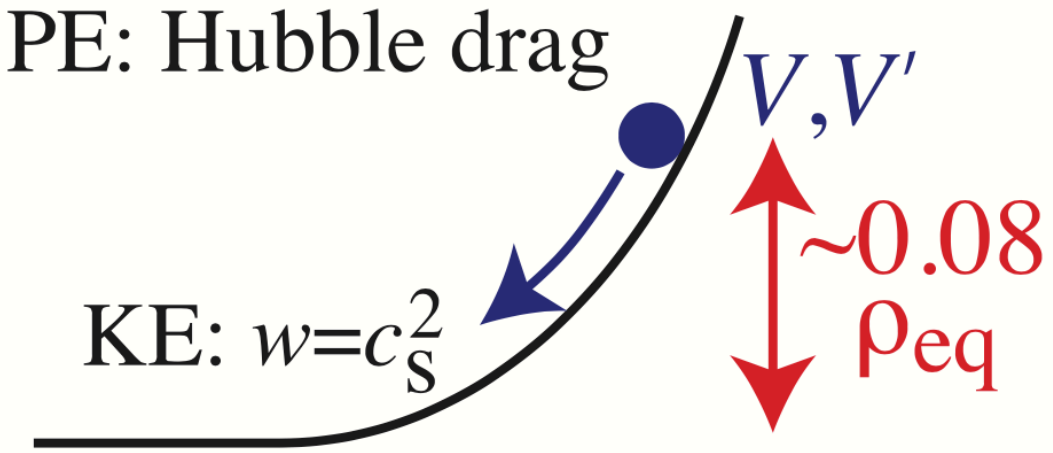
Acoustic Dark Energy (ADE)

(K-essence field theory realization)



Converting potential energy to kinetic energy at matter radiation equality!

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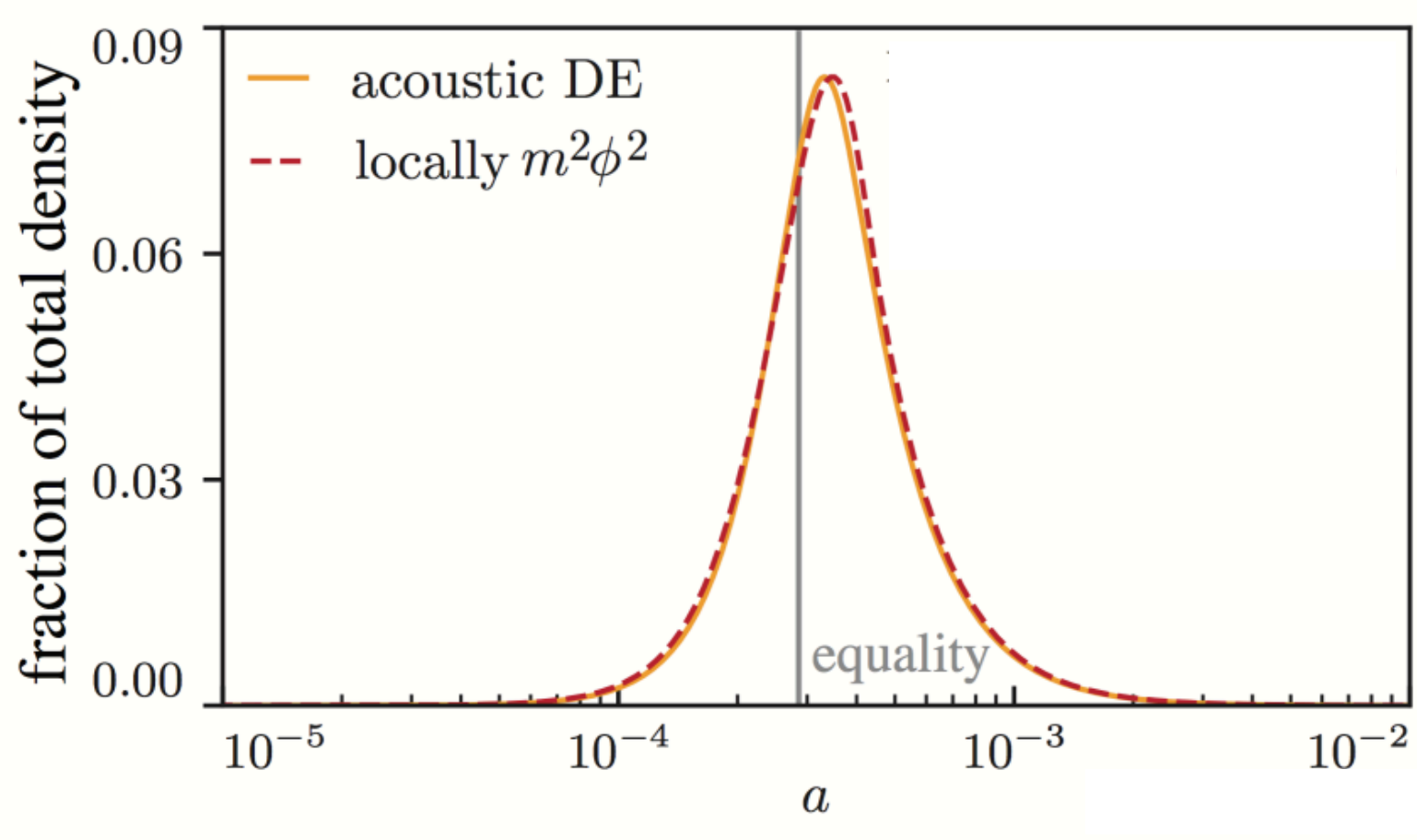
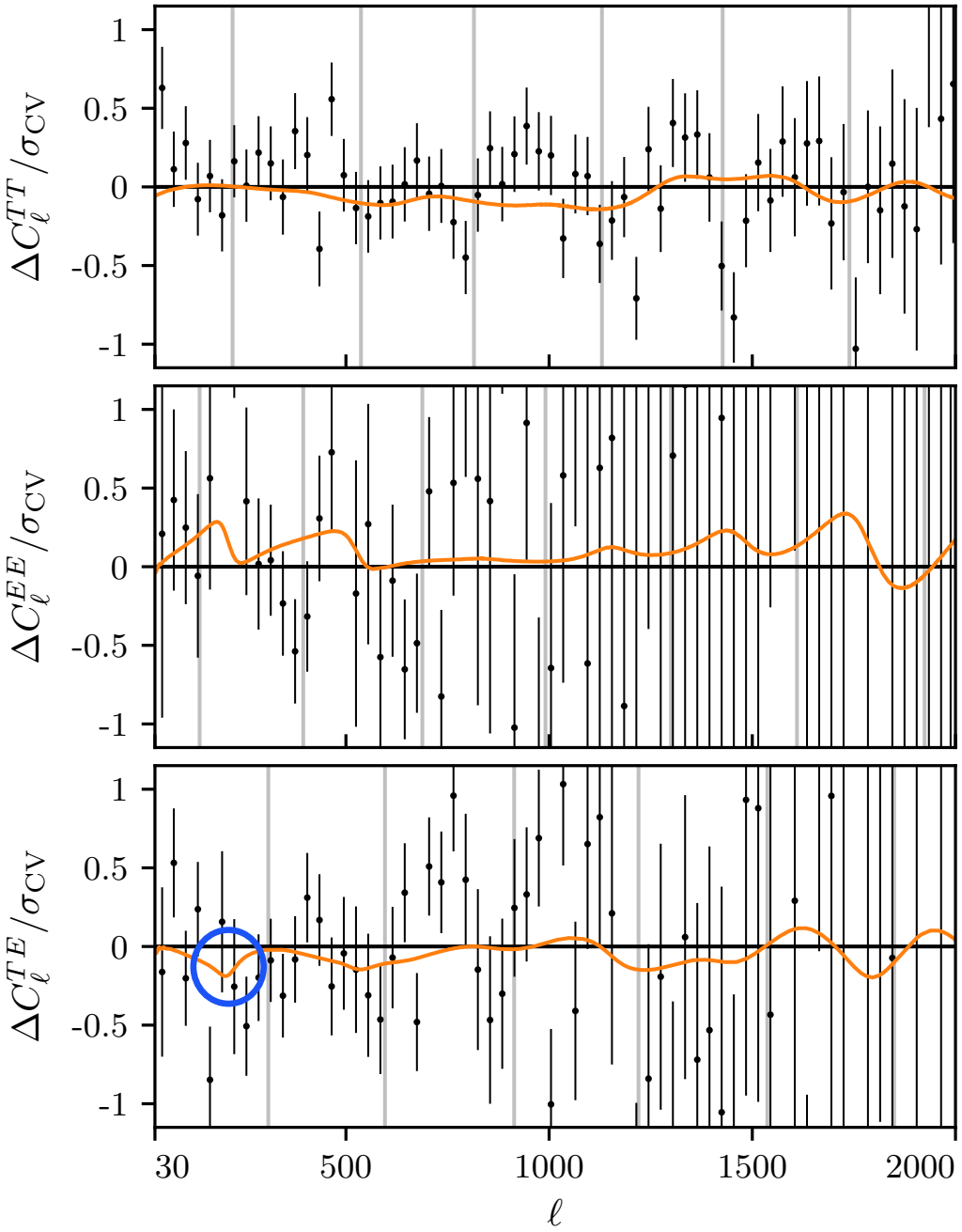
Acoustic Dark Energy (ADE)





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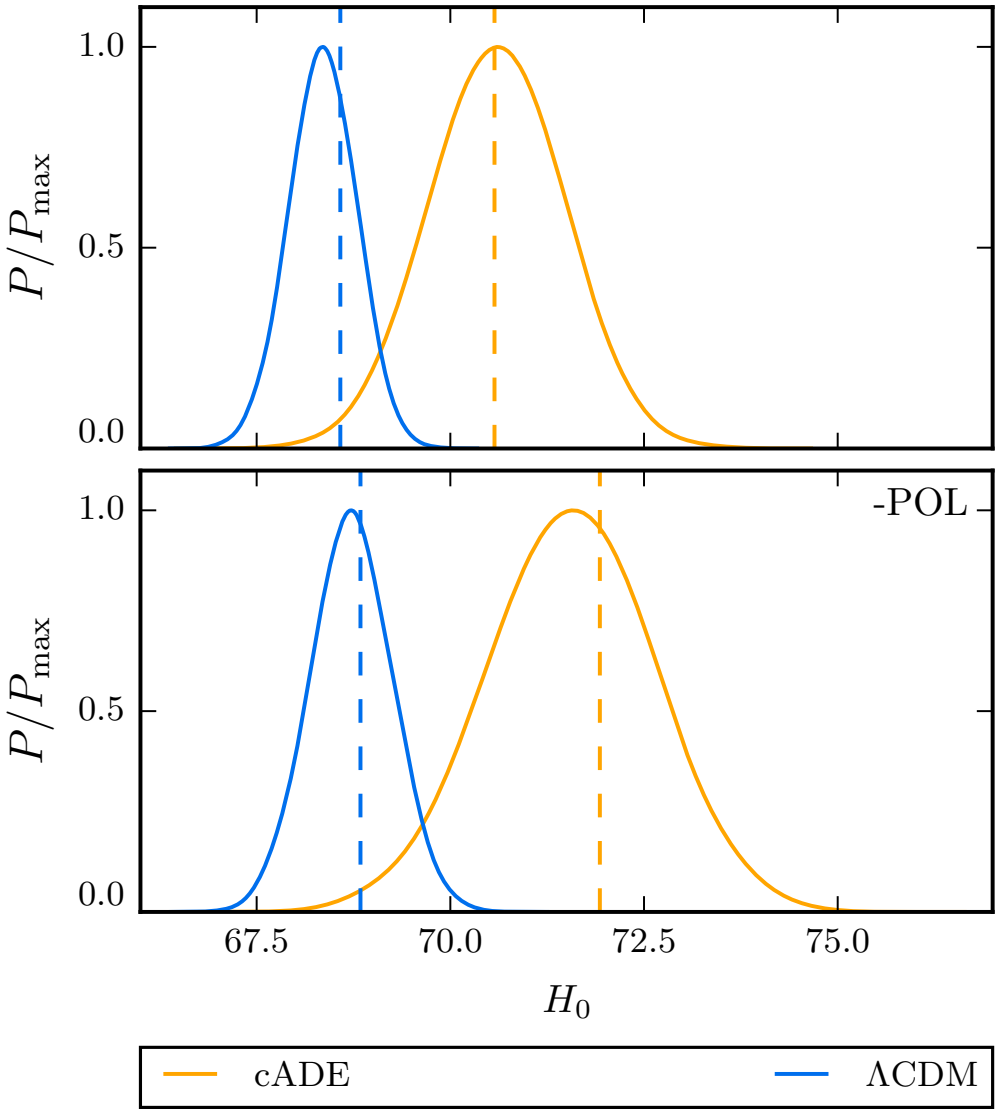
2 parameters for $\Delta\chi^2 = -12.7$

Better CMB fit: $\Delta\chi^2_{\rm CMB} = -3.6$

TE glitch $\ell\sim165$ is sensitive


1.0
0.5
0.0
$P/P_{\max}$
-POL
67.5
70.0
72.5
75.0
H_0
cADE
ΛCDM

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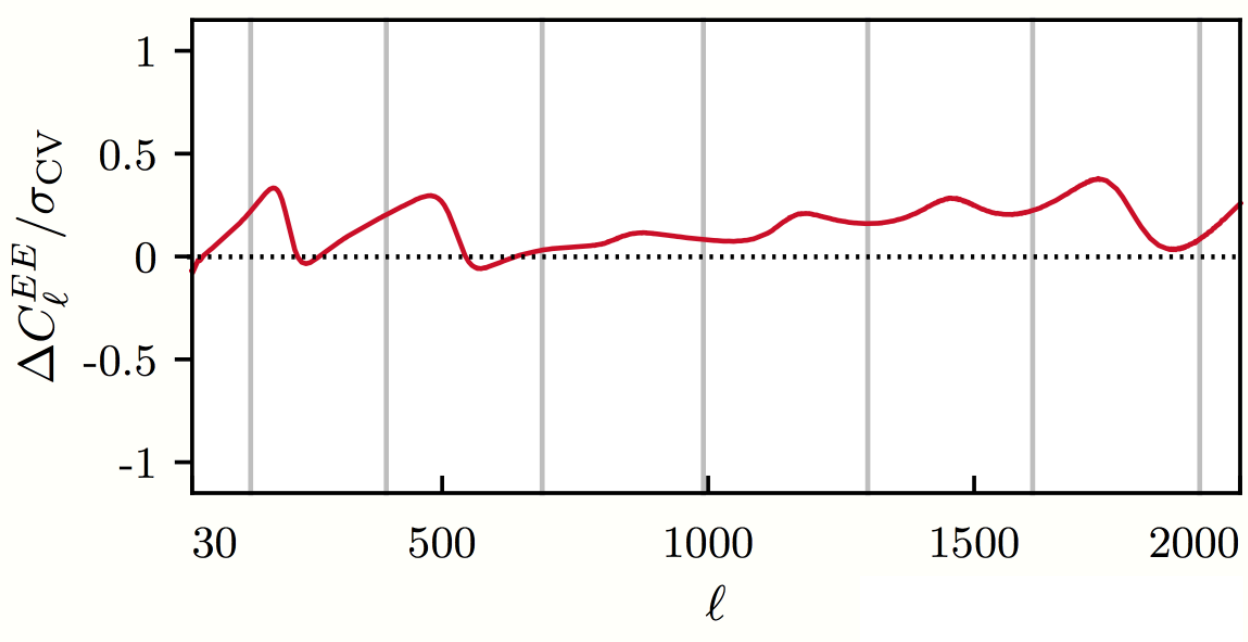
For the future: polarization!



EE residual are ~0.3 vs cosmic variance per multipole.
Future more precise EE data can distinguish the model!

Summary

- Acoustic Dark Energy (ADE) can help to relieve the H_0 tension: 2 parameters for $\Delta\chi^2 = -12.7$
- ADE can be realized by a simple and robust K-essence scalar field theory that suddenly convert nearly all potential to kinetic energy at matter radiation equality
  - Looking for more natural realizations
- Future precise CMB polarization data can better test these models

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BACKUP

Acoustic Dark Energy (ADE)

(K-essence field theory realization)

$$P(X,\phi) = \left(\frac{X}{A}\right)^{\frac{1-c_s^2}{2c_s^2}} X - V(\phi) \quad \Rightarrow \quad c_s^2 = \text{constant}$$

Potential energy dominated: $w_{ADE} \rightarrow -1$

Kinetic energy dominated: $w_{ADE} \rightarrow c_s^2$

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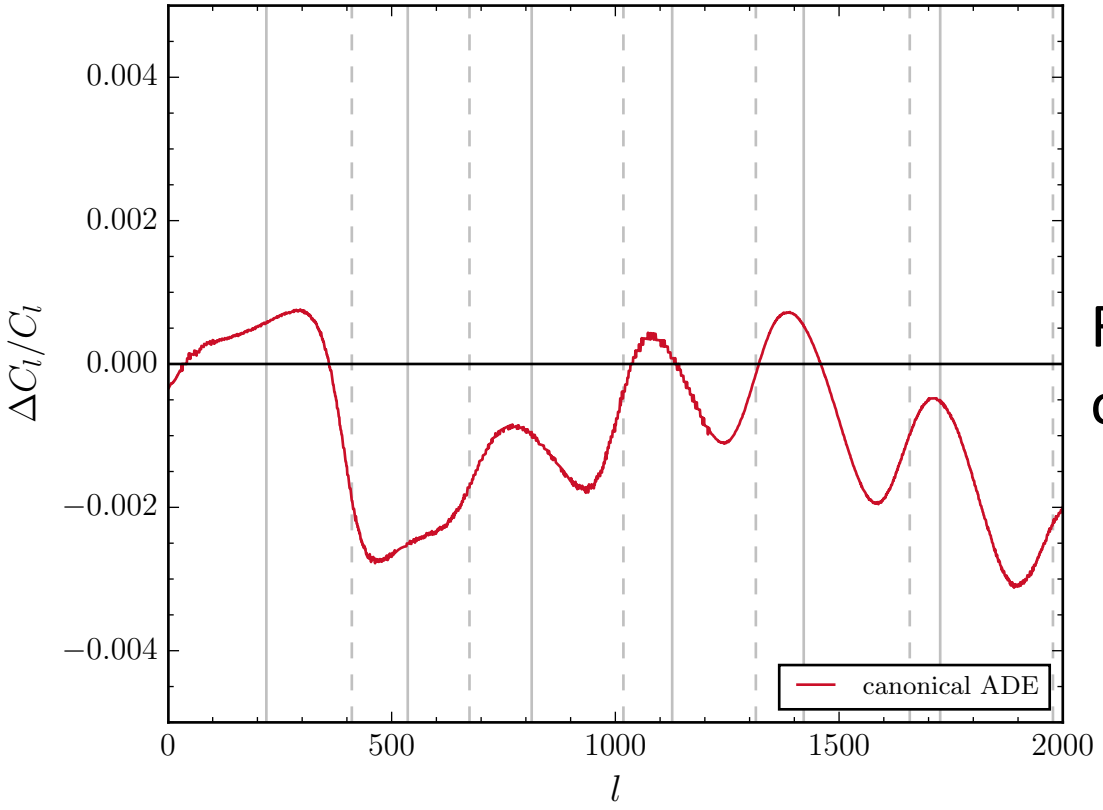
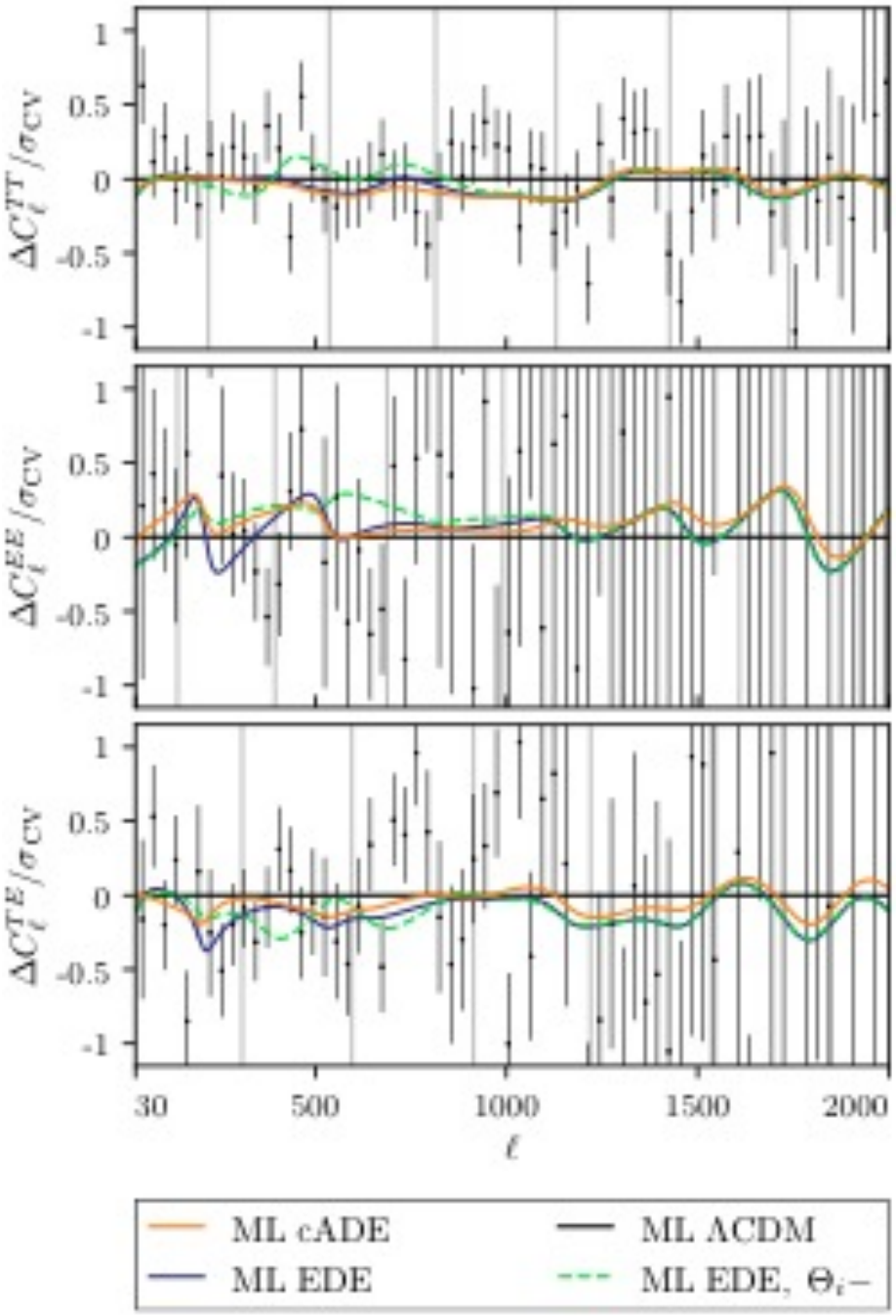
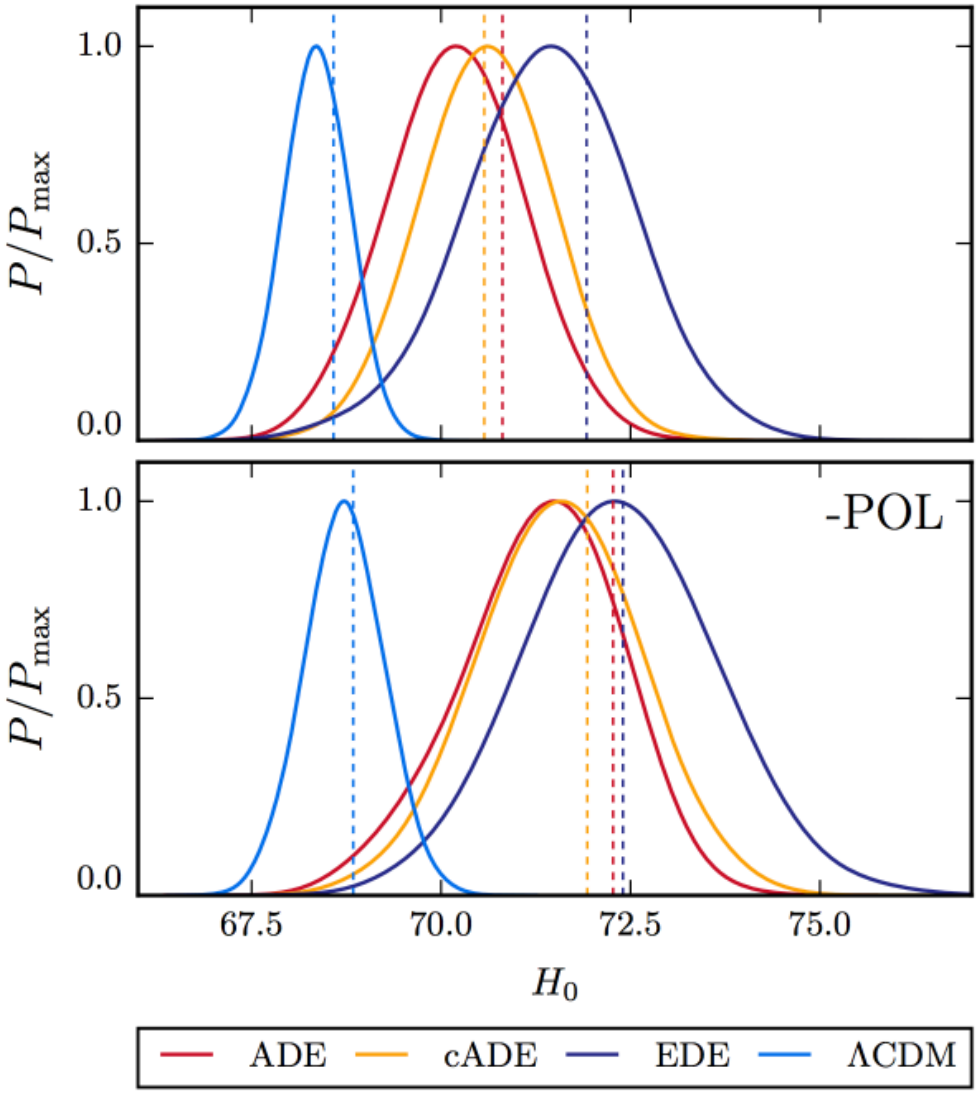
Acoustic Dark Energy (ADE)

(fluid VS K-essence field theory)



Reference: exact KG solution of scalar field model


$\Delta C_\ell^{TT}/\sigma_{\rm CV}$
$\Delta C_\ell^{EE}/\sigma_{\rm CV}$
$\Delta C_\ell^{TE}/\sigma_{\rm CV}$
1
0.5
0
-0.5
-1
30
500
1000
1500
2000
ℓ
ML cADE
ML EDE
ML ΛCDM
ML EDE, Θ_i-


1.0
0.5
0.0
$P/P_{\max}$
-POL
67.5
70.0
72.5
75.0
H_0
ADE
cADE
EDE
ΛCDM

model (data)	ΔN	H_0	$\Delta\chi^2_{\rm tot}$	$\Delta\chi^2_{\rm CMB}$	$\Delta\chi^2_{\rm H0}$
cADE	2	$70.57(70.60\pm0.85)$	-12.7	-3.6	-8.8
ADE	3^*,4	$70.81(70.20\pm0.88)$	-14.1	-3.7	-9.6
EDE	4	$71.92(71.40\pm1.09)$	-16.6	-3.7	-12.5
cADE(-POL)	2	$71.93(71.55\pm1.05)$	-12.8	-0.4	-11.2
ADE(-POL)	3^*,4	$72.27(71.30\pm1.03)$	-15.1	-2.4	-11.8
EDE(-POL)	4	$72.40(72.35\pm1.25)$	-15.9	-2.9	-12.1

Compared to EDE

$$V(\phi) \propto [1 - \cos(\phi/f)]^n$$