Understanding Acoustic Scale Measurements

The One Sided Fight Against Λ

Ewan Chamberlain
Supervisor: Antony Lewis

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Friday 04 April 2025

Lewis & Chamberlain, arxiv:2412.13894

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Now with DESI DR2!

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Outline

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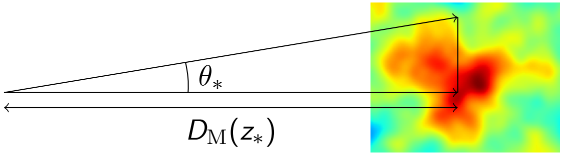
CMB and BAO

- Cosmic Microwave Background (CMB) and Baryon Acoustic Oscillations (BAO) define "standard rulers".



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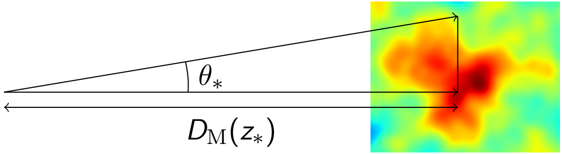

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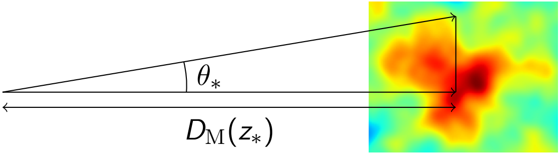

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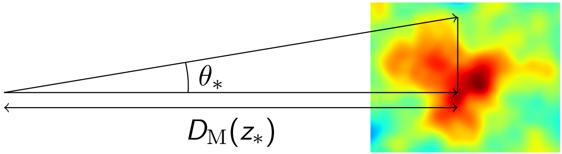
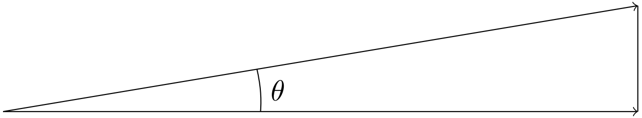
- CMB constrains the angular size of the sound horizon θ_*.
- Measured to within 0.03% by *Planck*.
- BAO measurements detect lower redshift imprints on galaxies.



BAO Measurements



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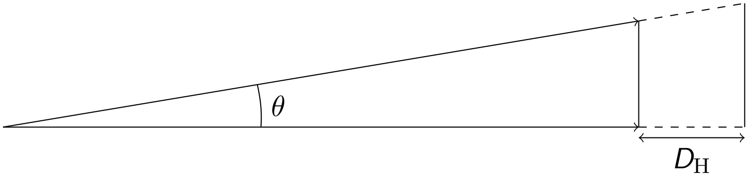

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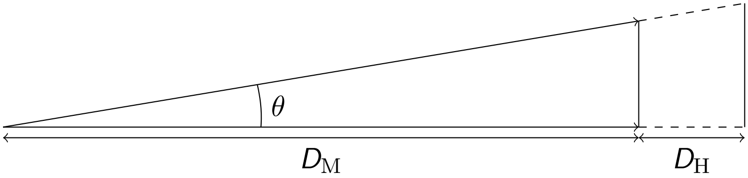

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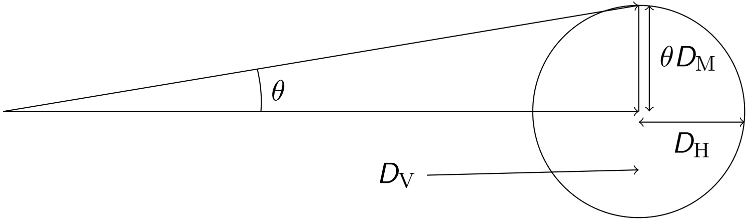

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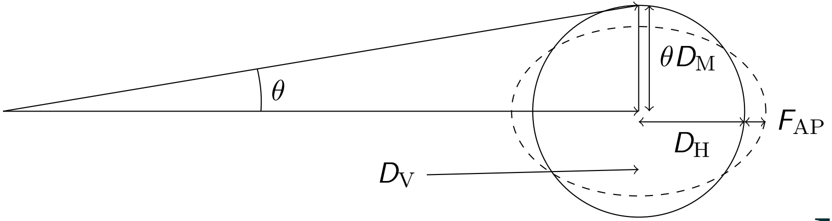
- Alcock-Paczynski parameter: $F_{\mathrm{AP}}(z) = D_{\mathrm{M}}(z)/D_{\mathrm{H}}(z)$.



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- "Energy density cannot increase with expansion."
- DESI+CMB+SNe prefers $w_0 w_a$CDM over ΛCDM.

Outline

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Disclaimer!

Maths!!!

(Skip to slide 13 for pretty pictures)

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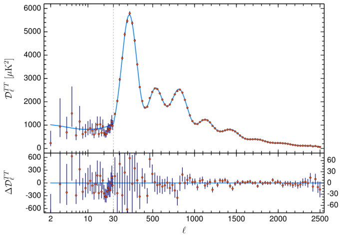
Constraints

From *Planck*:

- θ_* is fixed $\implies D_{\mathrm{M}}(z_*)$ is fixed.
- $\Omega_{\mathrm{b}} h^2$ and $\Omega_{\mathrm{c}} h^2$ fixed



Planck 2018 arXiv:1807.06209

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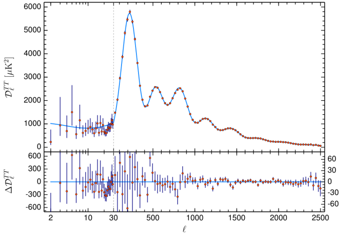

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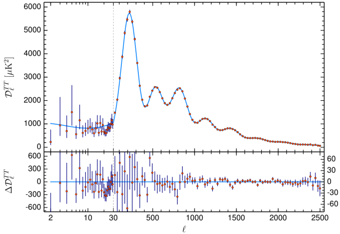

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Consider:

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$$\int_0^{z_*} \frac{\mathrm{d}z'}{\sqrt{\rho_{\mathrm{m}}(z') + \rho_{\mathrm{de}}(z')}} = \int_0^{z_*} \frac{\mathrm{d}z'}{\sqrt{\rho_{\mathrm{m}}(z') + \rho_{\Lambda}(z')}},$$
$$\implies \rho_{\mathrm{de}}(0) < \rho_{\Lambda}.$$

Hubble Distance

$$D_{\mathrm{H}}(z) \propto \frac{1}{\sqrt{\rho_{\mathrm{m}}(z) + \rho_{\mathrm{de}}(z)}},$$

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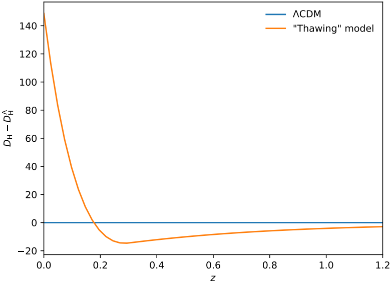

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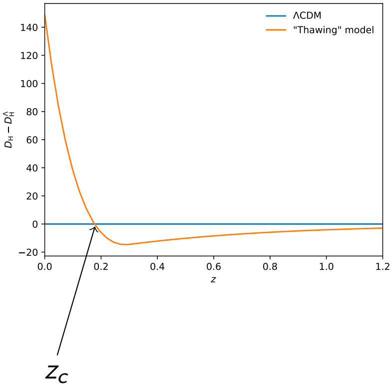

Inequalities

Inequality	Redshift
$D_{\rm H}(0) \geq D^{\Lambda}_{\rm H}(0)$	At $z = 0$
$D_{\rm H}(z) \geq D^{\Lambda}_{\rm H}(z)$	For $0 \leq z \leq z_c$
$D_{\rm H}(z) \leq D^{\Lambda}_{\rm H}(z)$	For $z_c \leq z \leq z_*$
$D_{\rm M}(z) \geq D^{\Lambda}_{\rm M}(z)$	For all z
$\frac{D_{\rm H}}{D^{\Lambda}_{\rm H}} \leq \frac{D_{\rm M}}{D^{\Lambda}_{\rm M}}$	For all z
$F_{\rm AP} \geq F^{\Lambda}_{\rm AP}$	For all z
$D_{\rm V} \geq D^{\Lambda}_{\rm V}$	For $0 \leq z \leq z_c$
$\frac{D_{\rm V}}{D^{\Lambda}_{\rm V}} \geq \left(\frac{F_{\rm AP}}{F^{\Lambda}_{\rm AP}}\right)^{-1/3}$	For $z > z_c$

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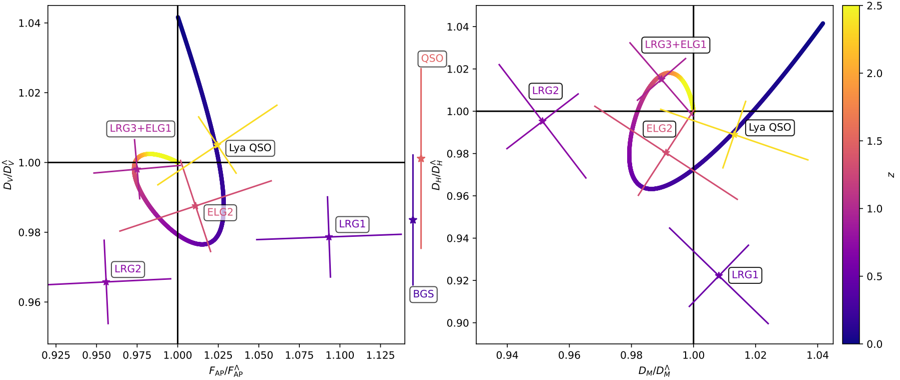
DESI BAO Measurements

$w_0 = -0.45,\ w_a = -1.79$



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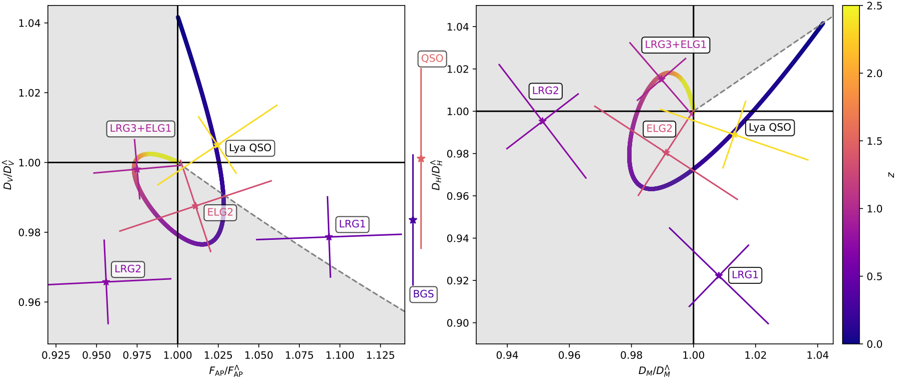
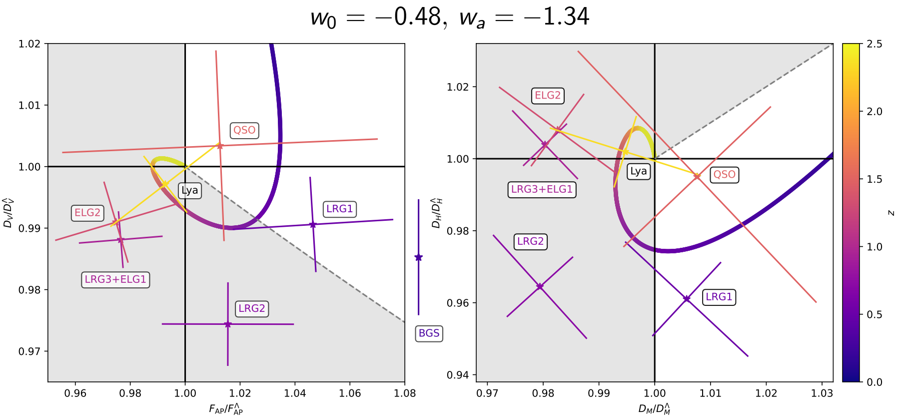


DESI BAO DR2 Measurements



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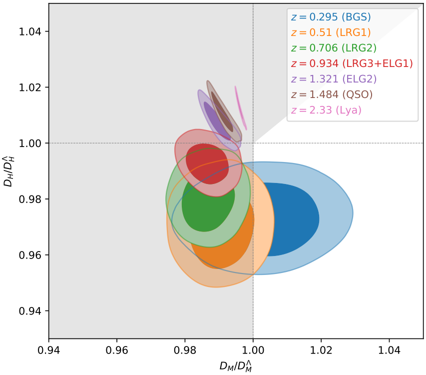
DESI BAO Measurements + SNe



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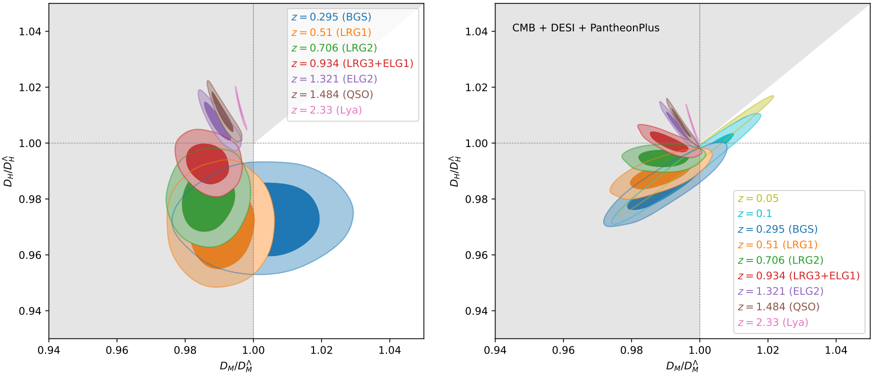
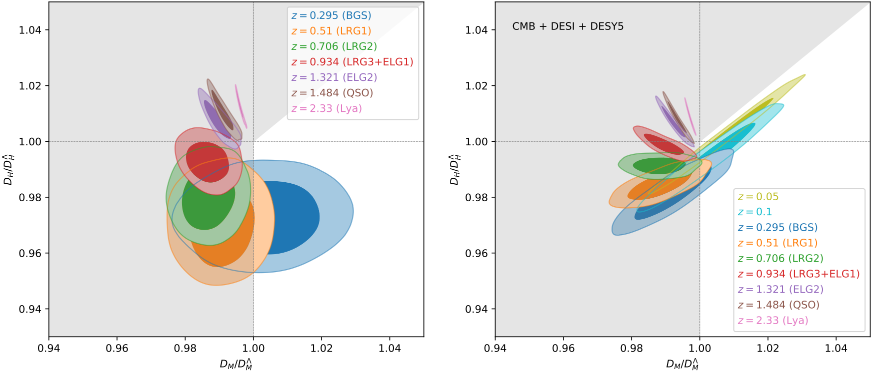


DESI+DESY5



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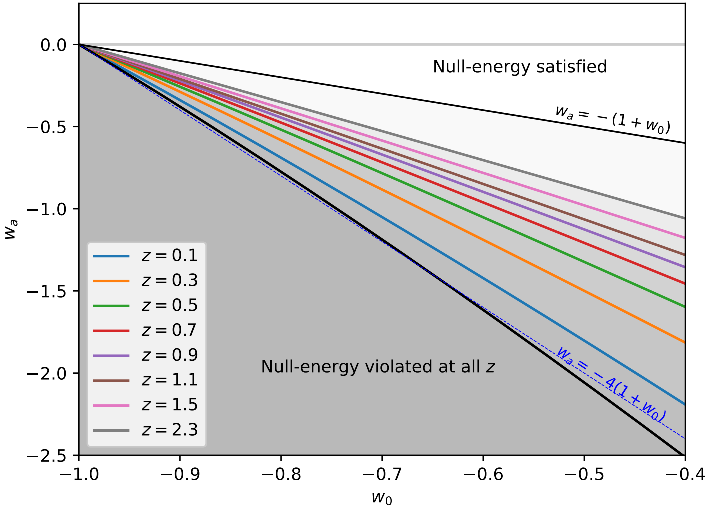
Redshift Bounds



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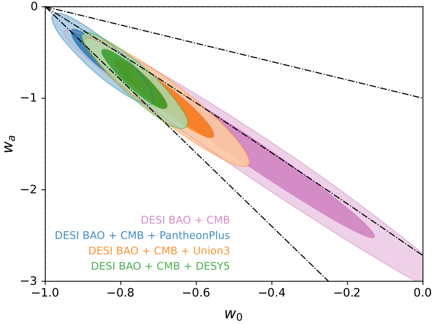
$$w(a) = w_0 + w_a(1 - a)$$



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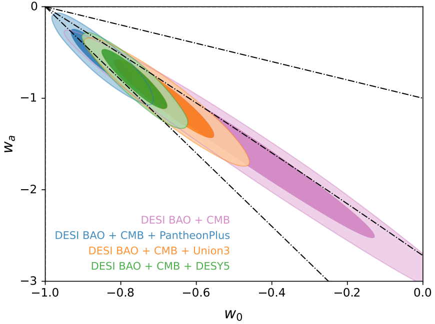

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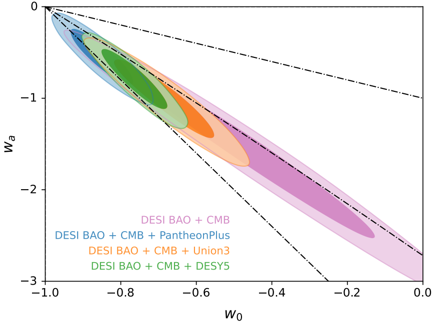

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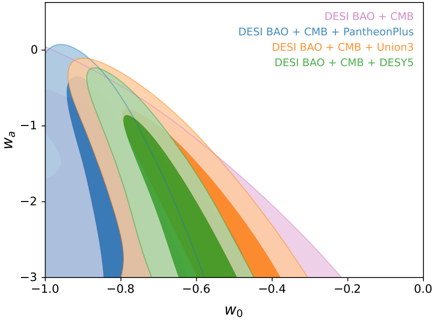

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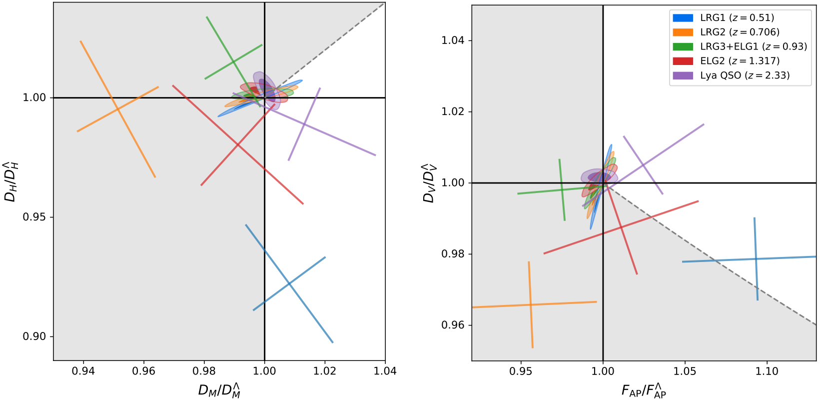
DESI ΛCDM



1.00
0.95
0.90
D_H/D_H^Λ
0.94
0.96
0.98
1.00
1.02
1.04
D_M/D_M^Λ
LRG1 ($z = 0.51$)
LRG2 ($z = 0.706$)
LRG3+ELG1 ($z = 0.93$)
ELG2 ($z = 1.317$)
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1.02
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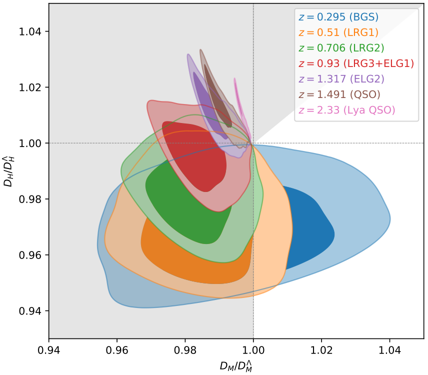
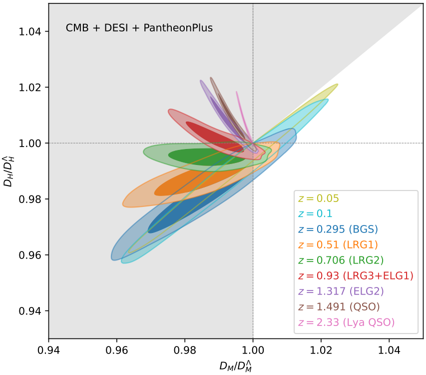
1.05
1.10
F_{AP}/F_{AP}^Λ

DESI DR1 BAO Measurements + SNe





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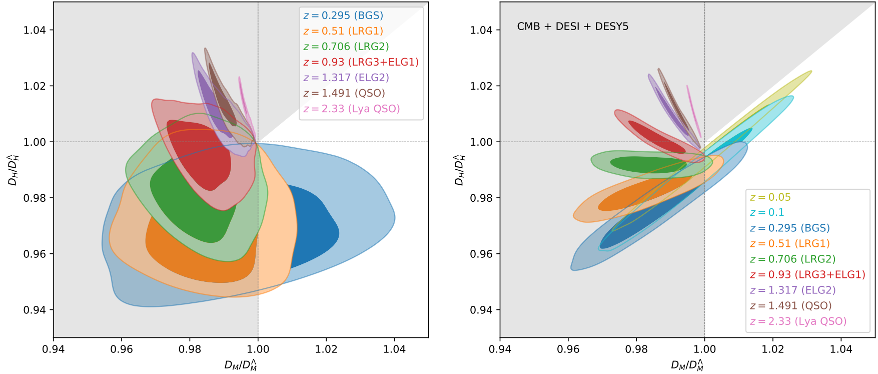
DESI DR1+DESY5



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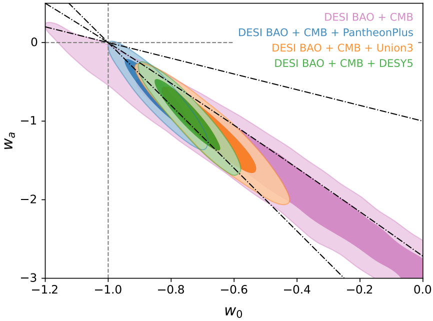

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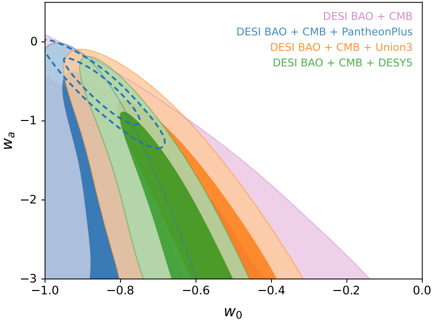

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Growth of Structure