Understanding Acoustic Scale Measurements

The One Sided Fight Against Λ

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Lewis & Chamberlain, arxiv:2412.13894

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Outline

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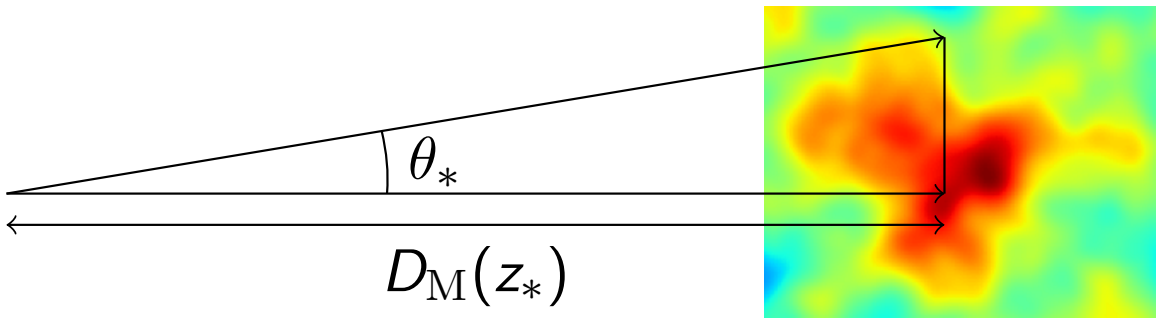
CMB and BAO

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



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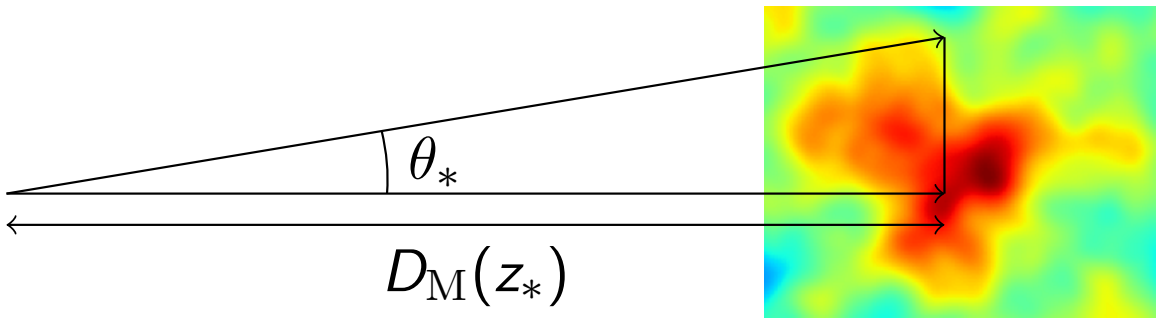

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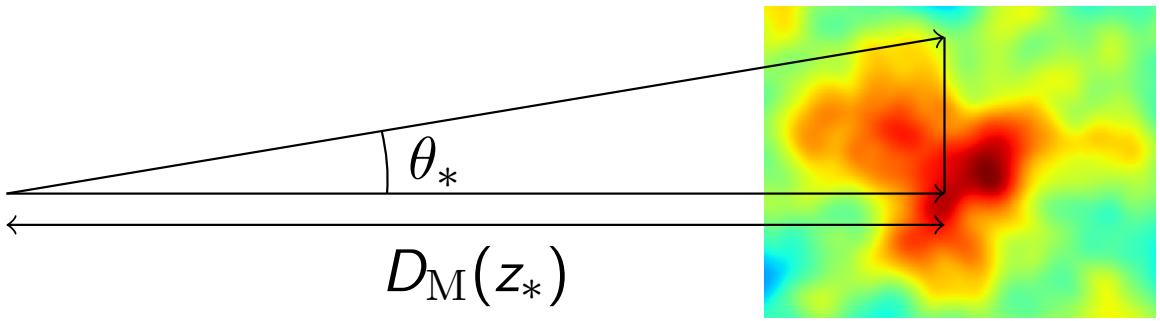

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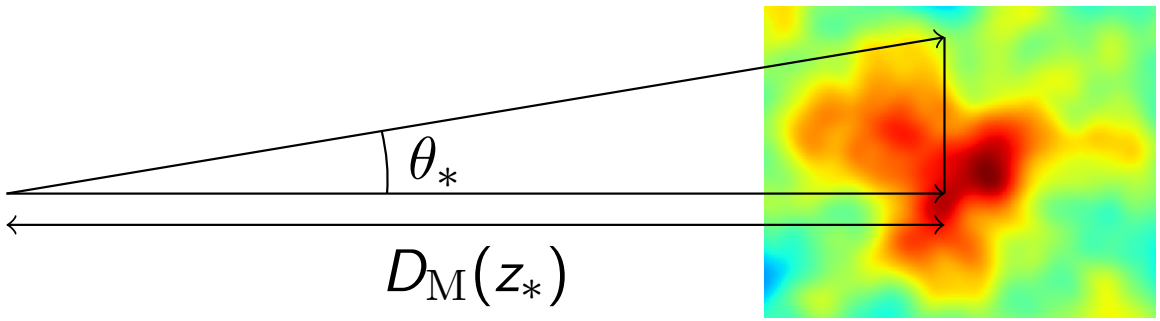
- BAO measurements detect lower redshift imprints on galaxies.



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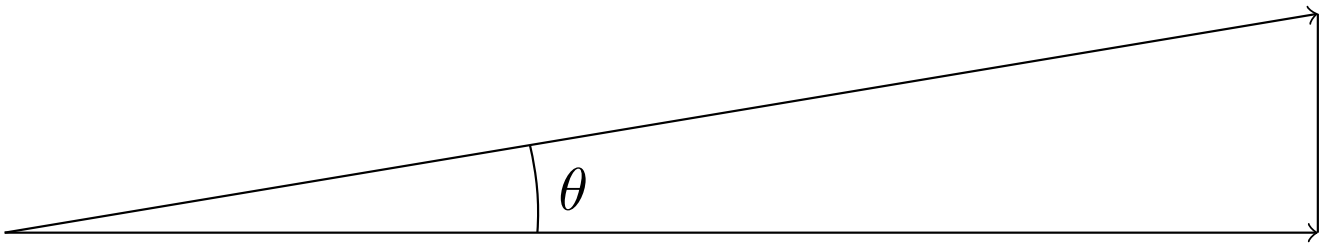
BAO Measurements



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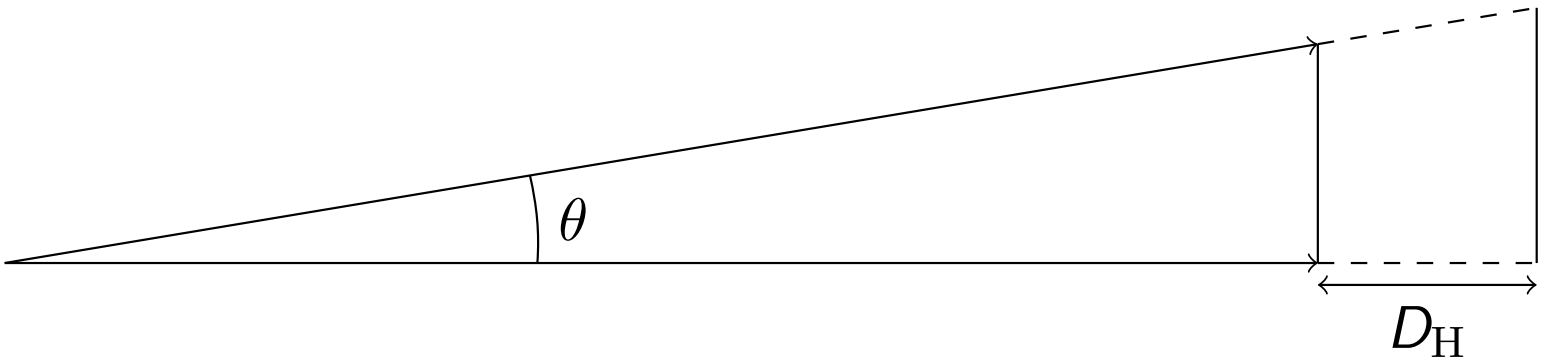

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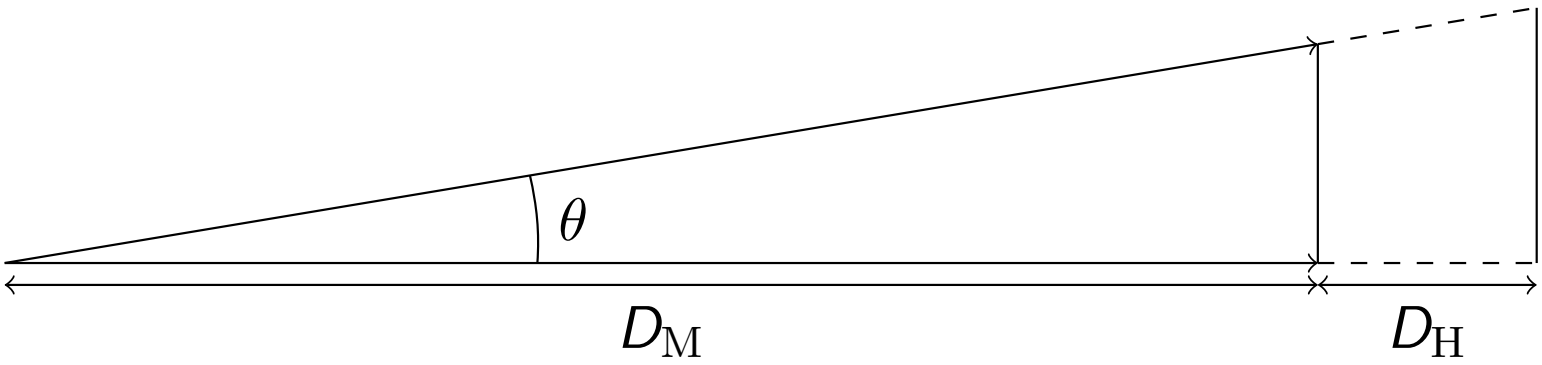

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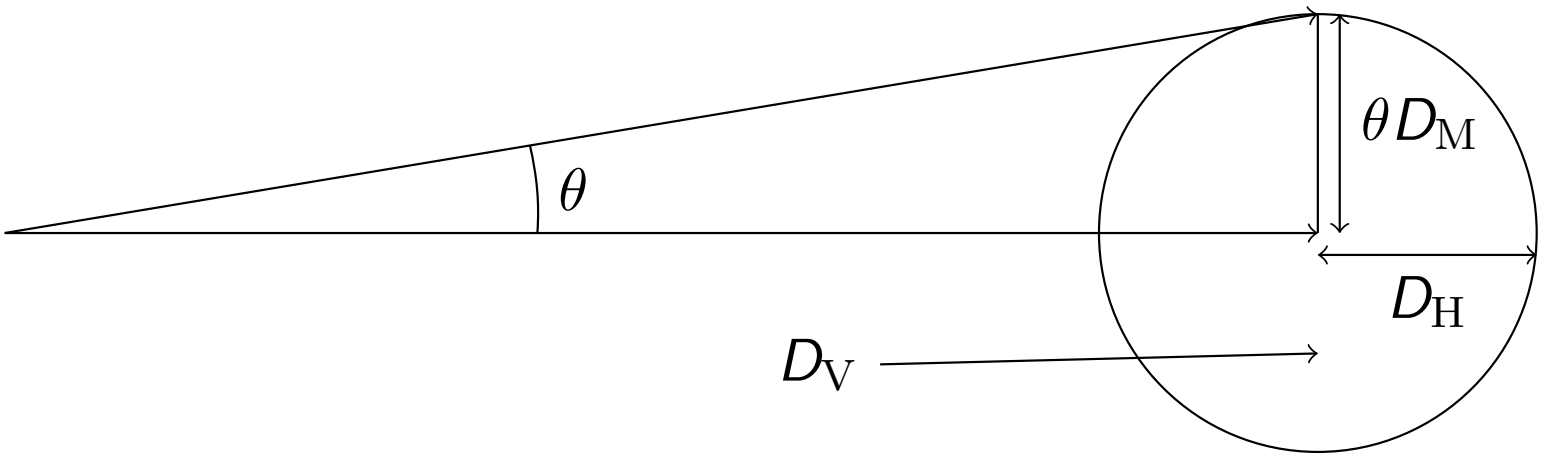

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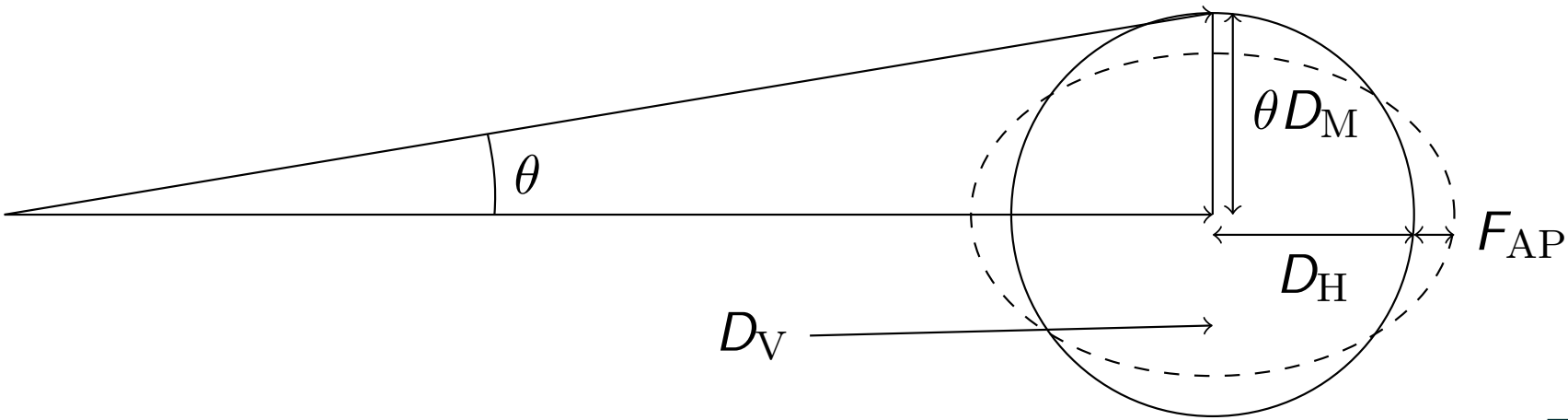
- Angle-averaged BAO scale: $D_{\rm V}(z) = \left[zD_{\rm M}^2(z)D_{\rm H}(z)\right]^{1/3}$.
- Alcock-Paczynski parameter: $F_{\rm AP}(z) = D_{\rm M}(z)/D_{\rm H}(z)$.



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Dark Energy

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- GR's cosmological constant Λ ($w_\Lambda = -1$) used to explain this.
- Other models e.g. scalar field quintessence, $w_0 w_a$CDM:

$$w(a) = p(a)/\rho(a) = w_0 + w_a(1-a).$$

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Null Energy Condition

- $w_0 w_a$CDM not necessarily consistent with the Null Energy Condition (NEC): "energy density cannot increase with expansion."

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- $w_0 w_a$CDM not necessarily consistent with the Null Energy Condition (NEC): "energy density cannot increase with expansion."
- DESI+CMB+SNe prefers $w_0 w_a$CDM over ΛCDM.

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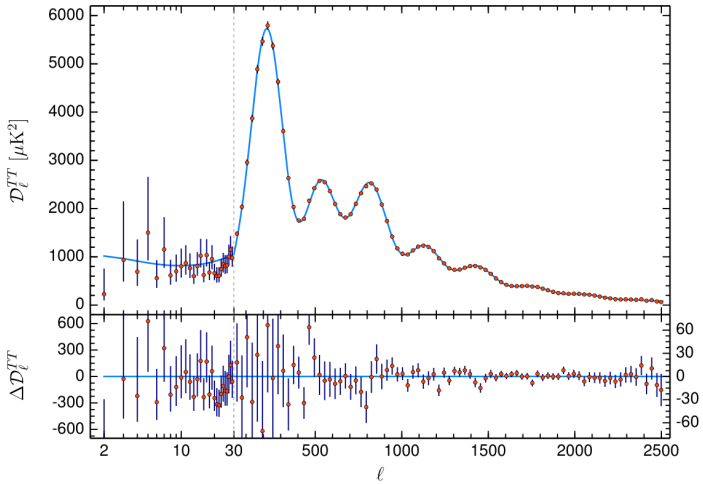
Constraints

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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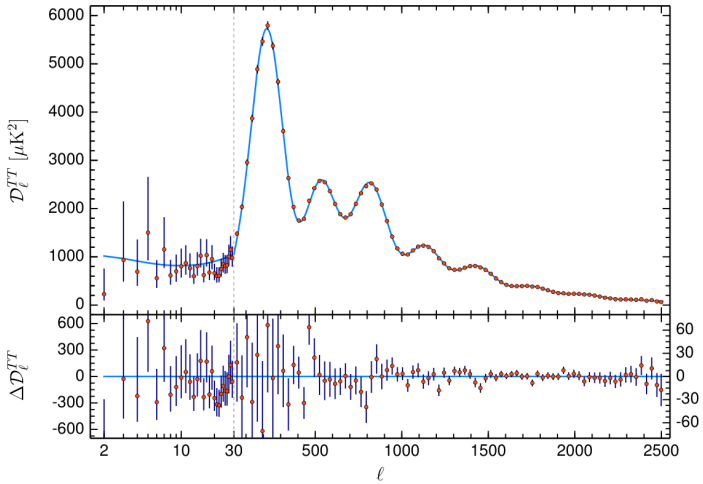

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Consider:

- Null energy condition (NEC) requires that for all fluids $\rho + pc^2 = \rho(1+w) \geq 0 \implies \mathrm{d}\rho/\mathrm{d}z \geq 0$.

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Inequalities

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

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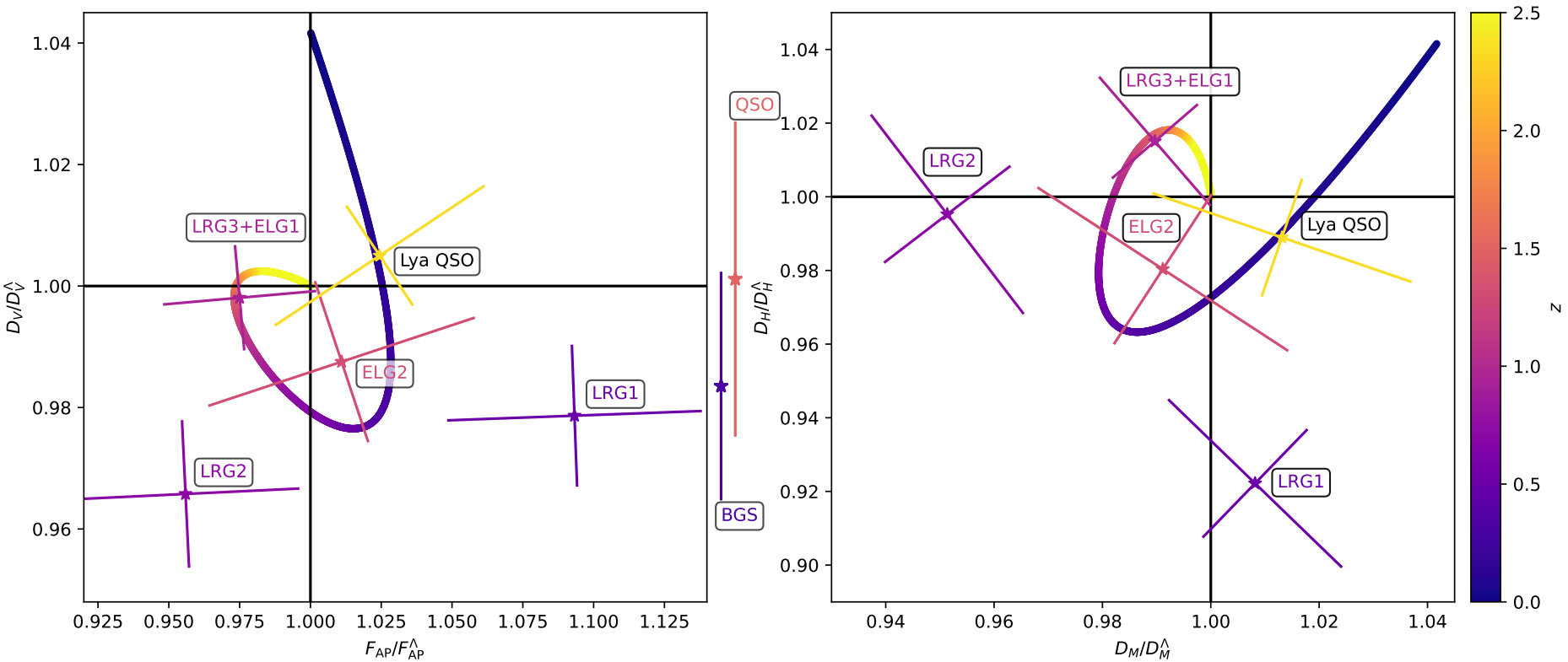
$$w_0 = -0.45,\ w_a = -1.79$$



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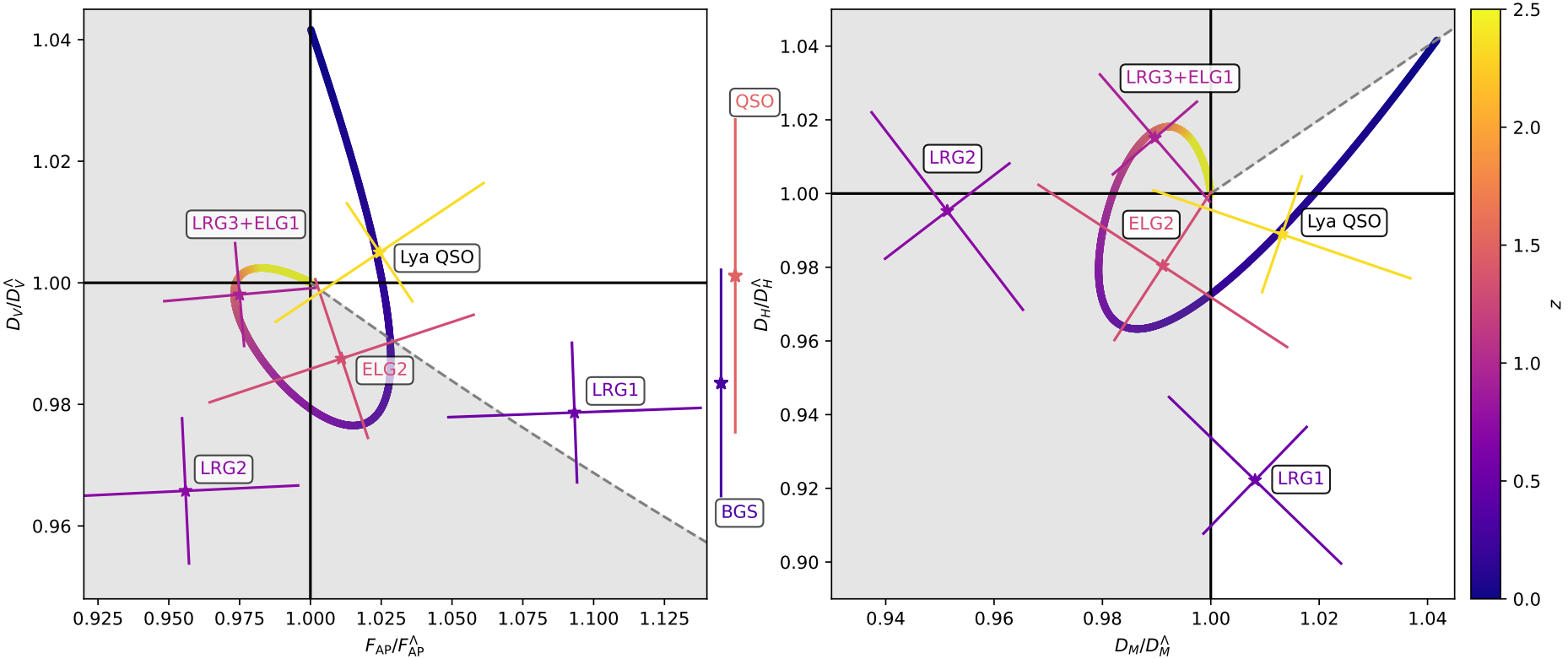

$w_0 w_a$CDM

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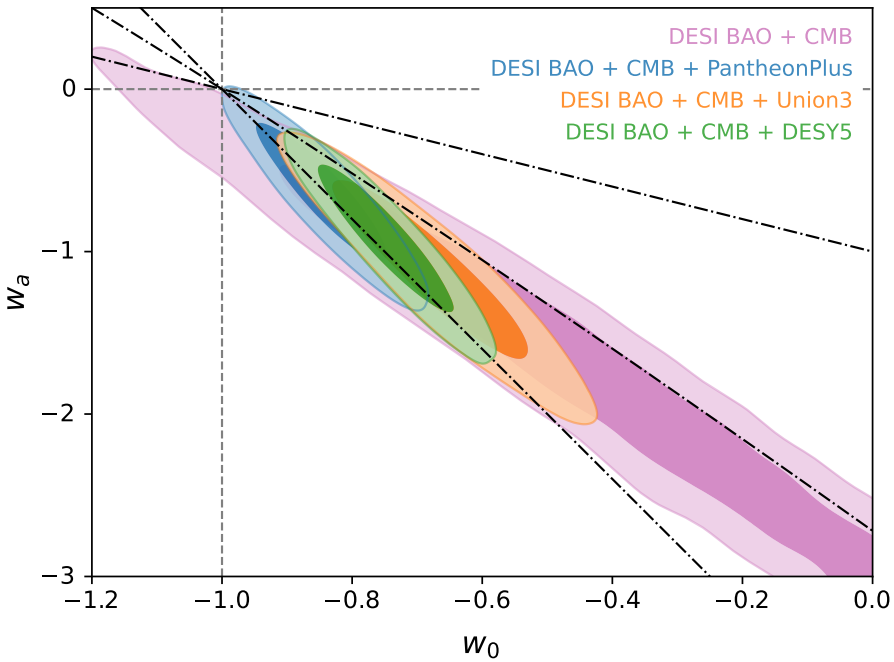
$$w(a) = w_0 + w_a(1 - a)$$



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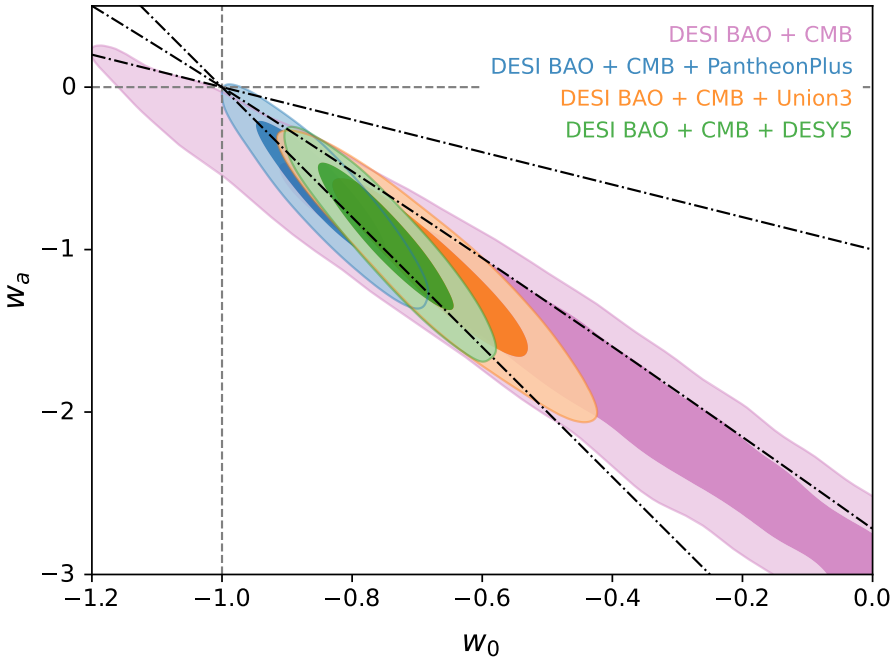

Max-$w_0 w_a$CDM

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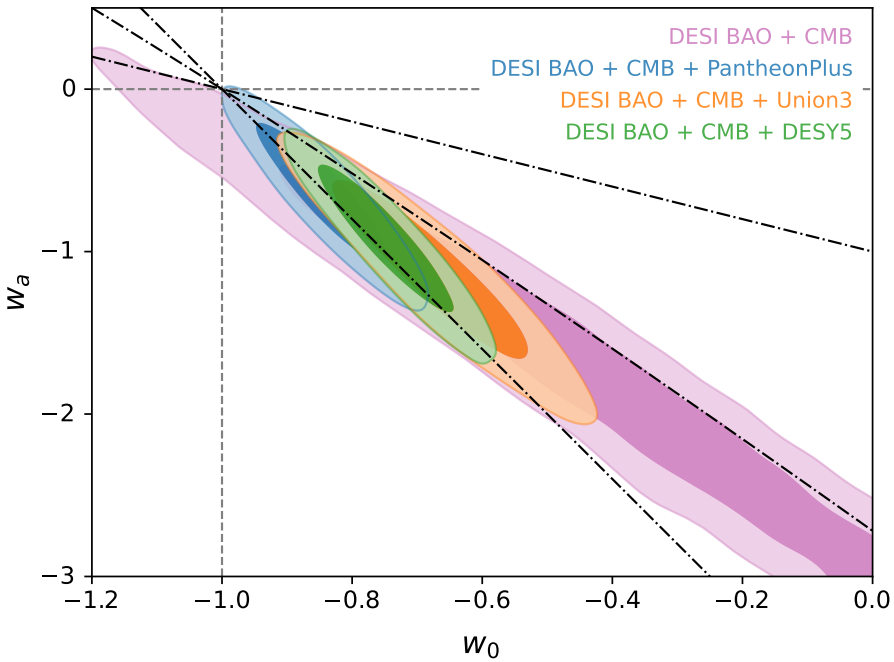

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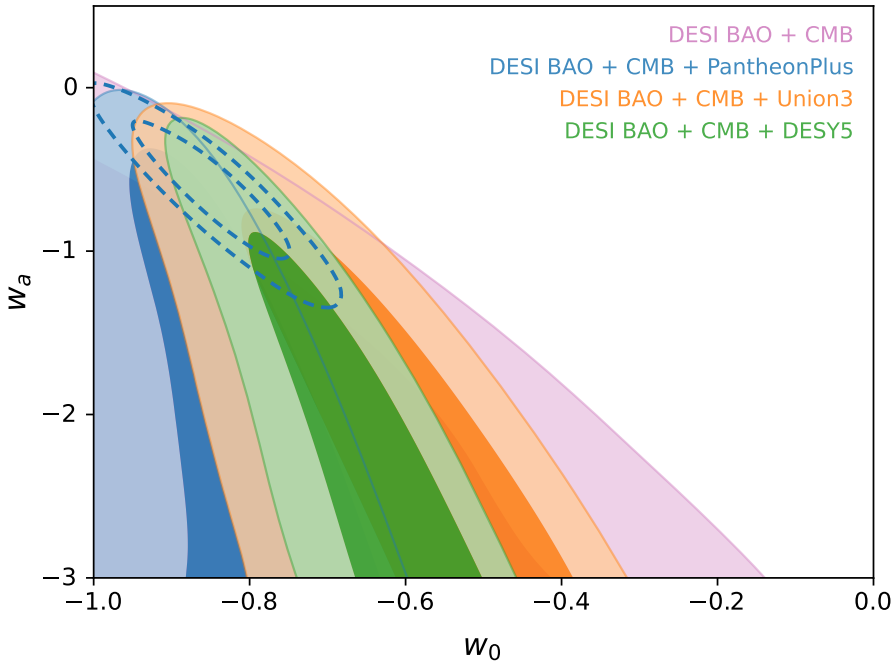

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Paper: arXiv:1807.06209

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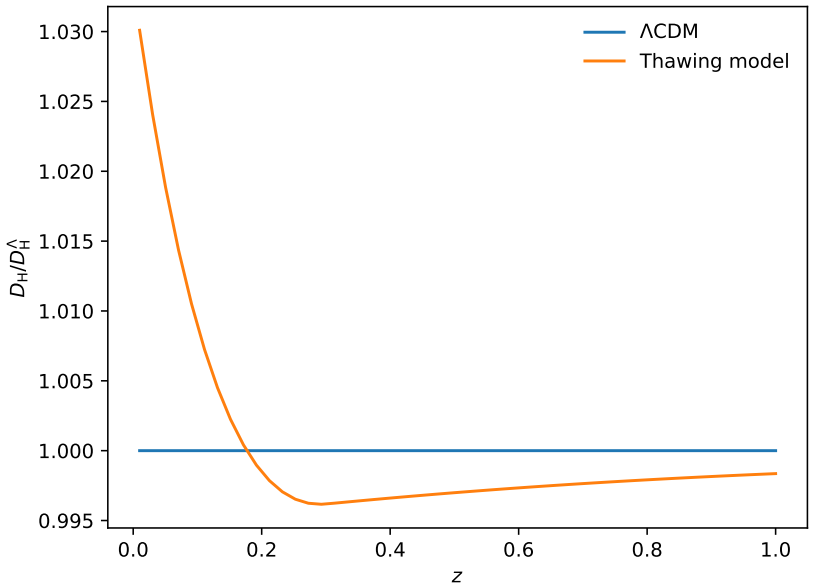

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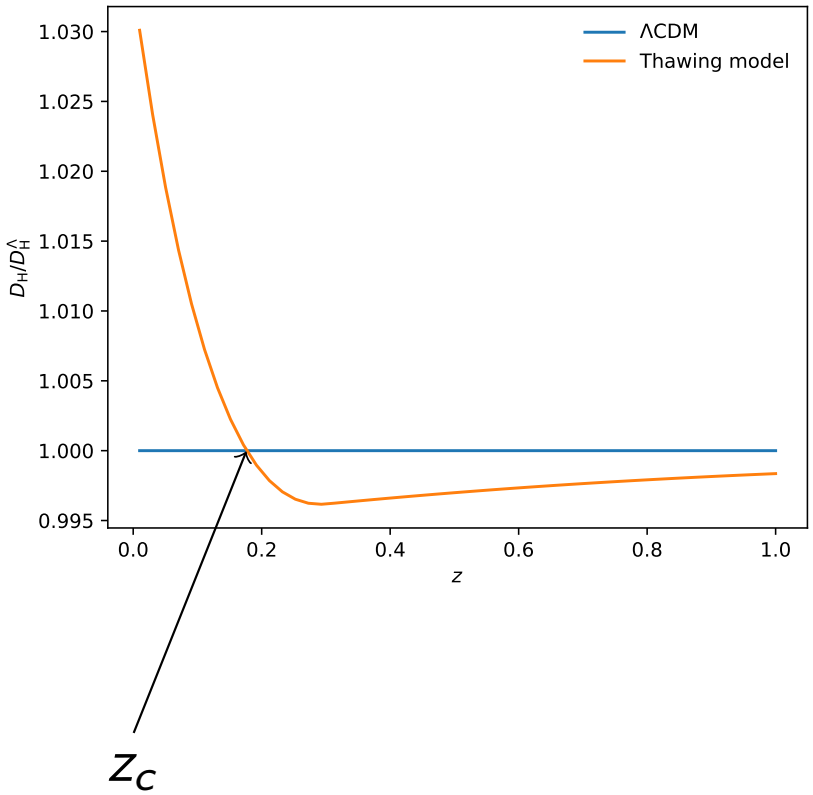

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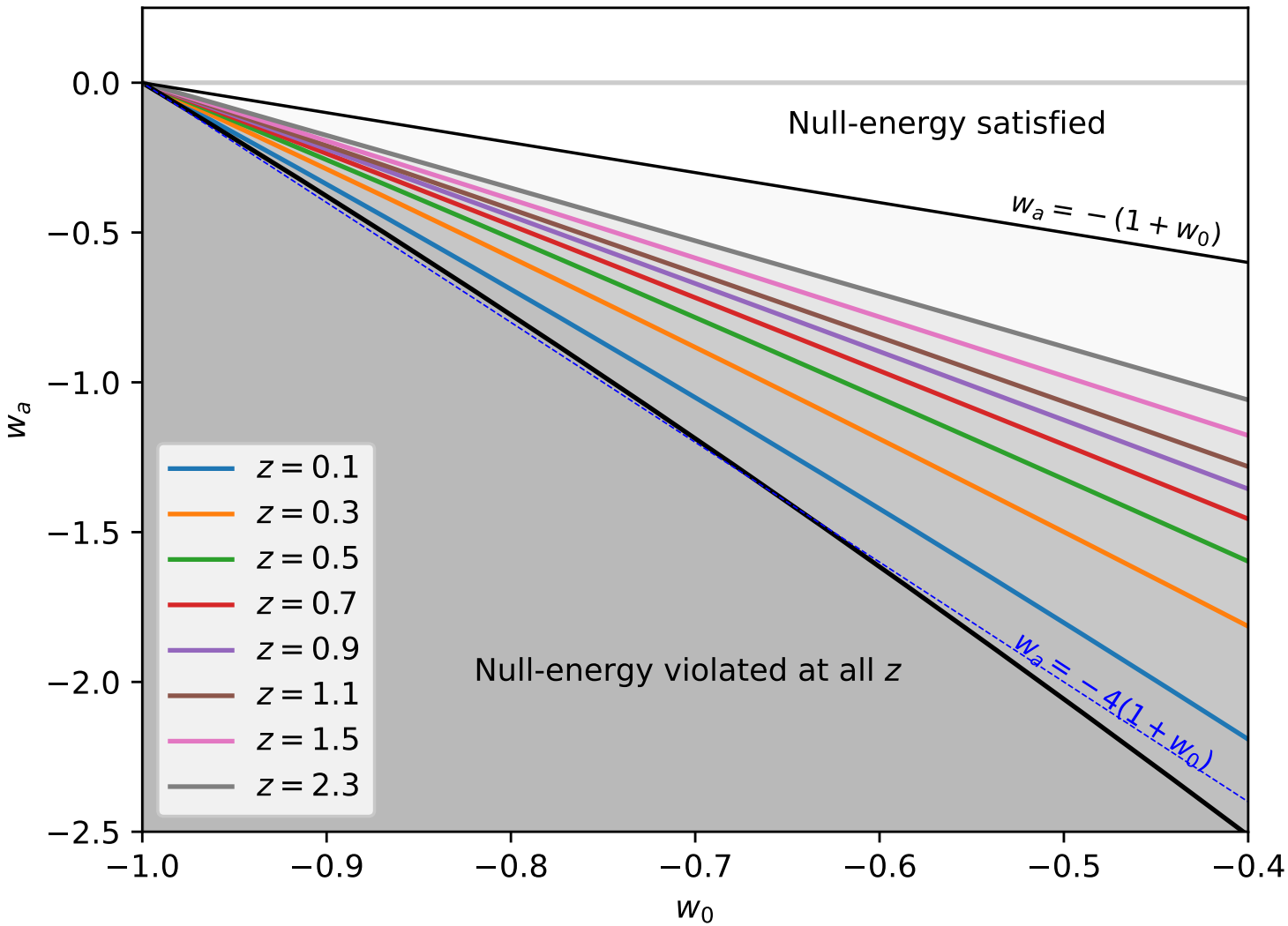
Redshift Bounds



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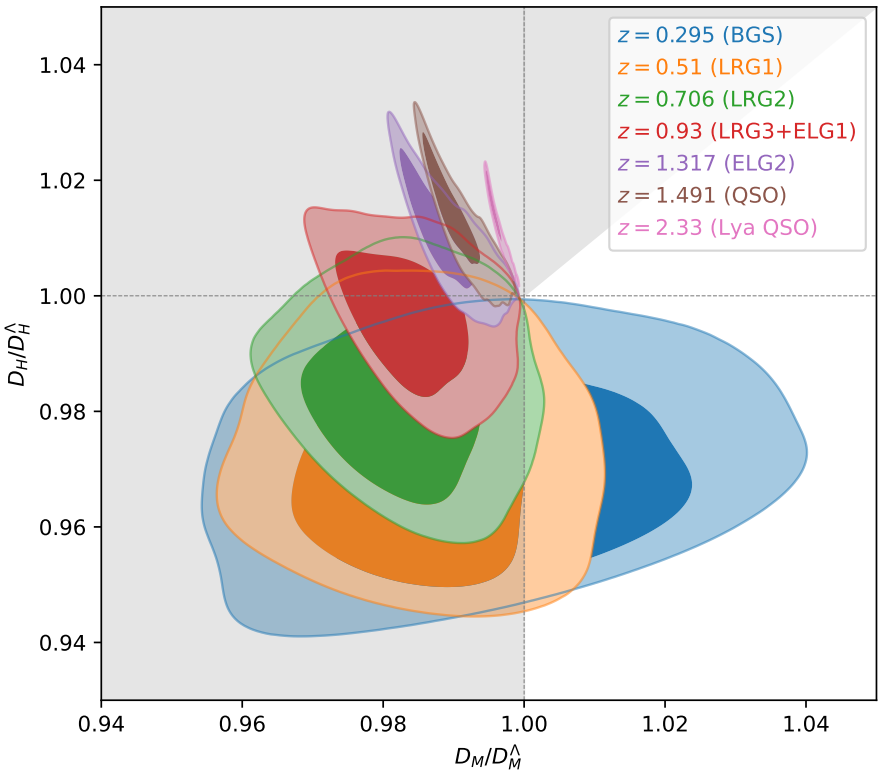
DESI BAO Measurements + SNe



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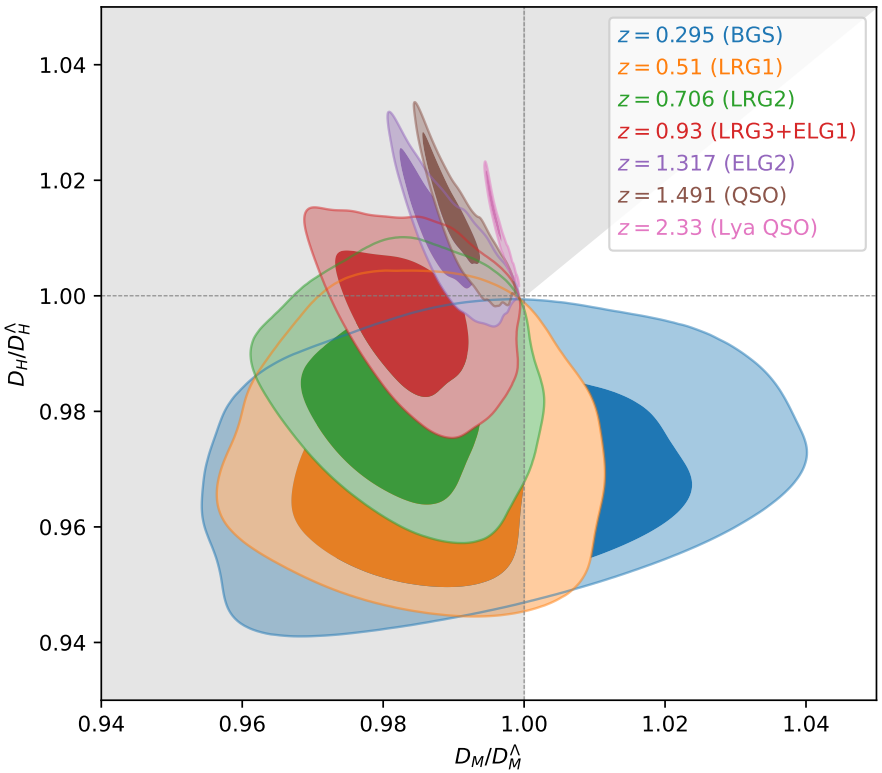

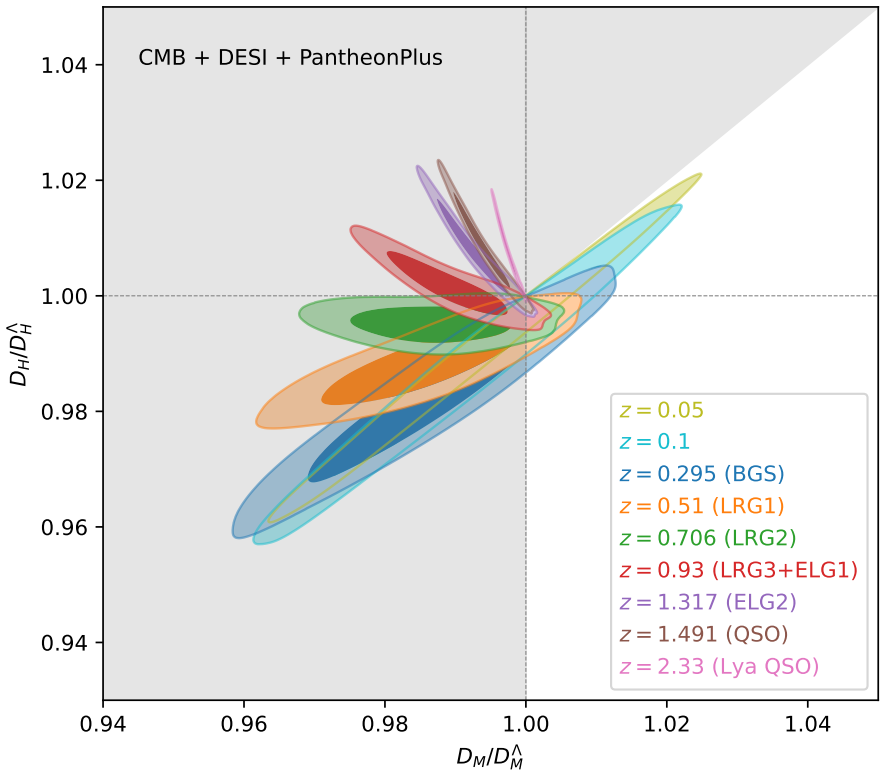

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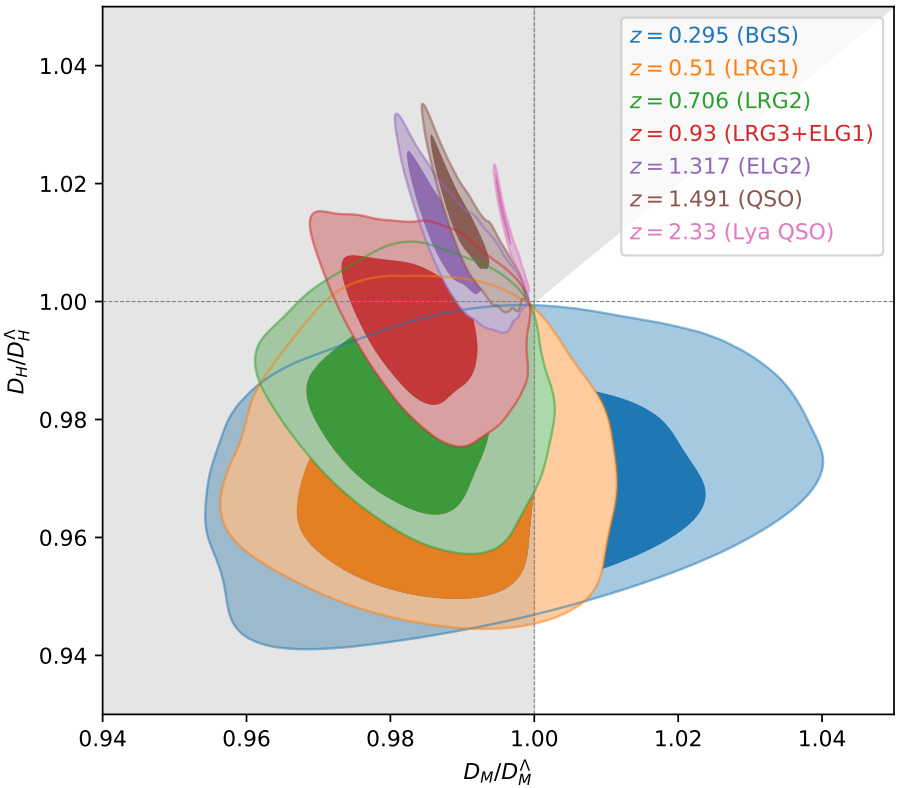
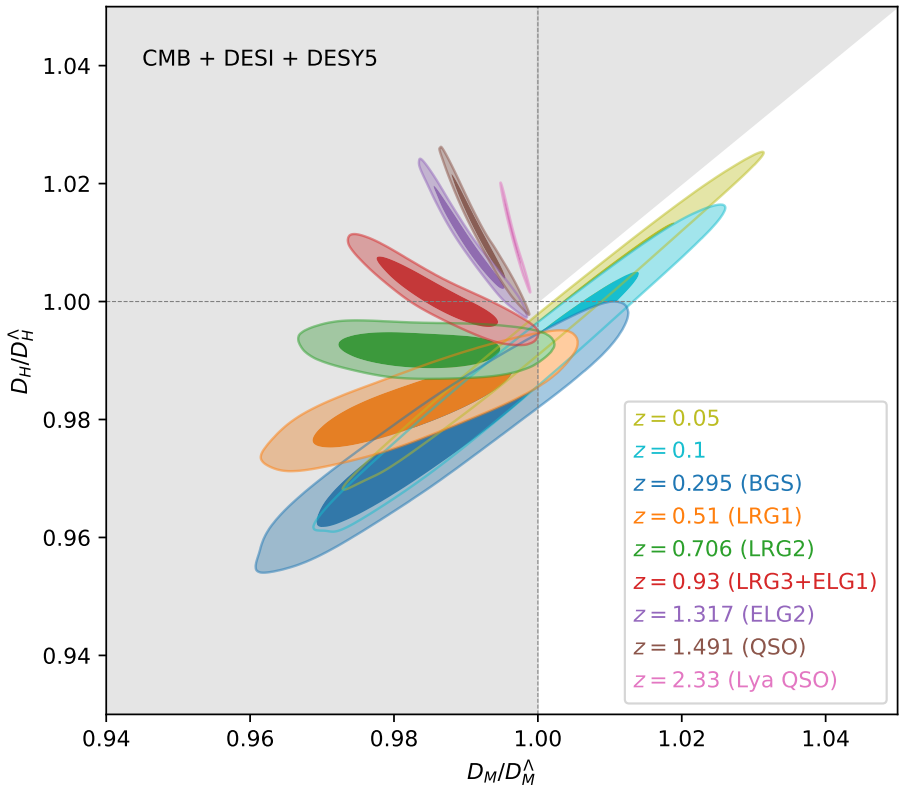
DESI+DESY5





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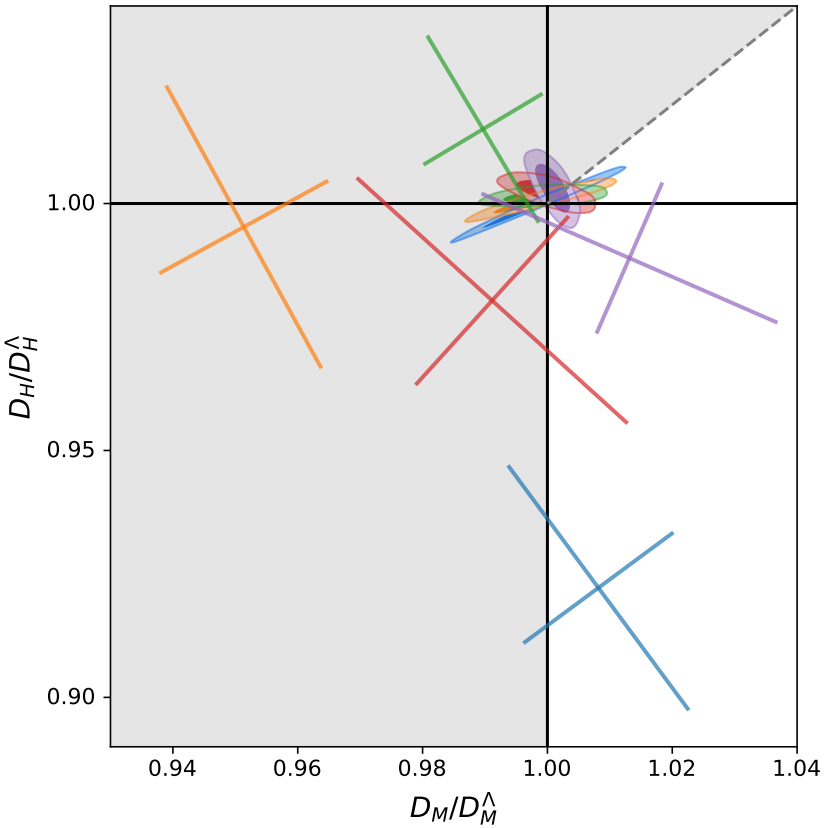
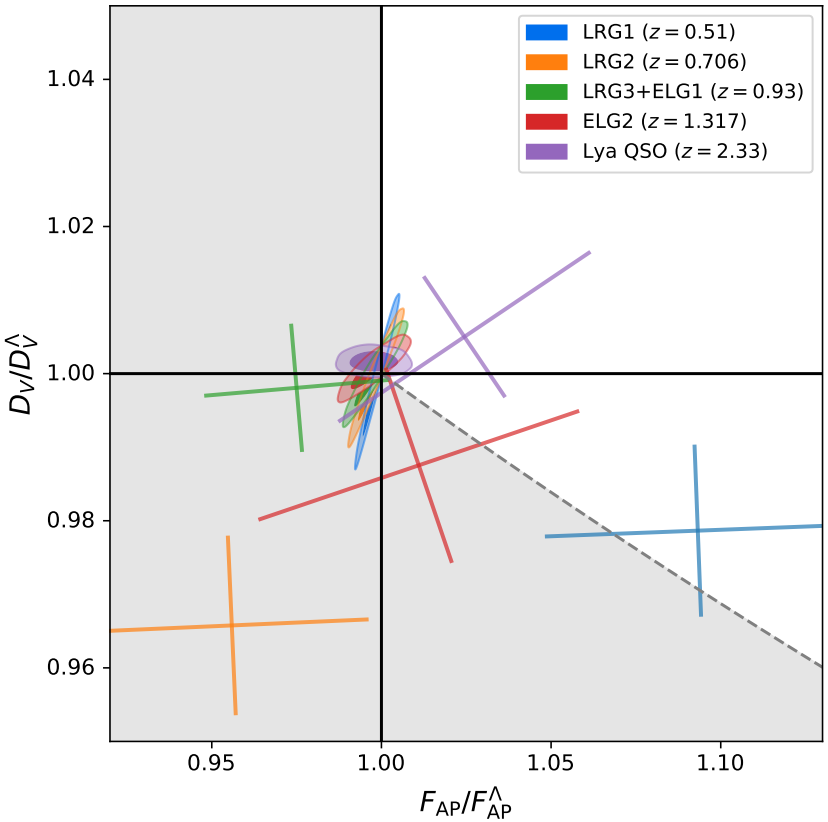
DESI ΛCDM





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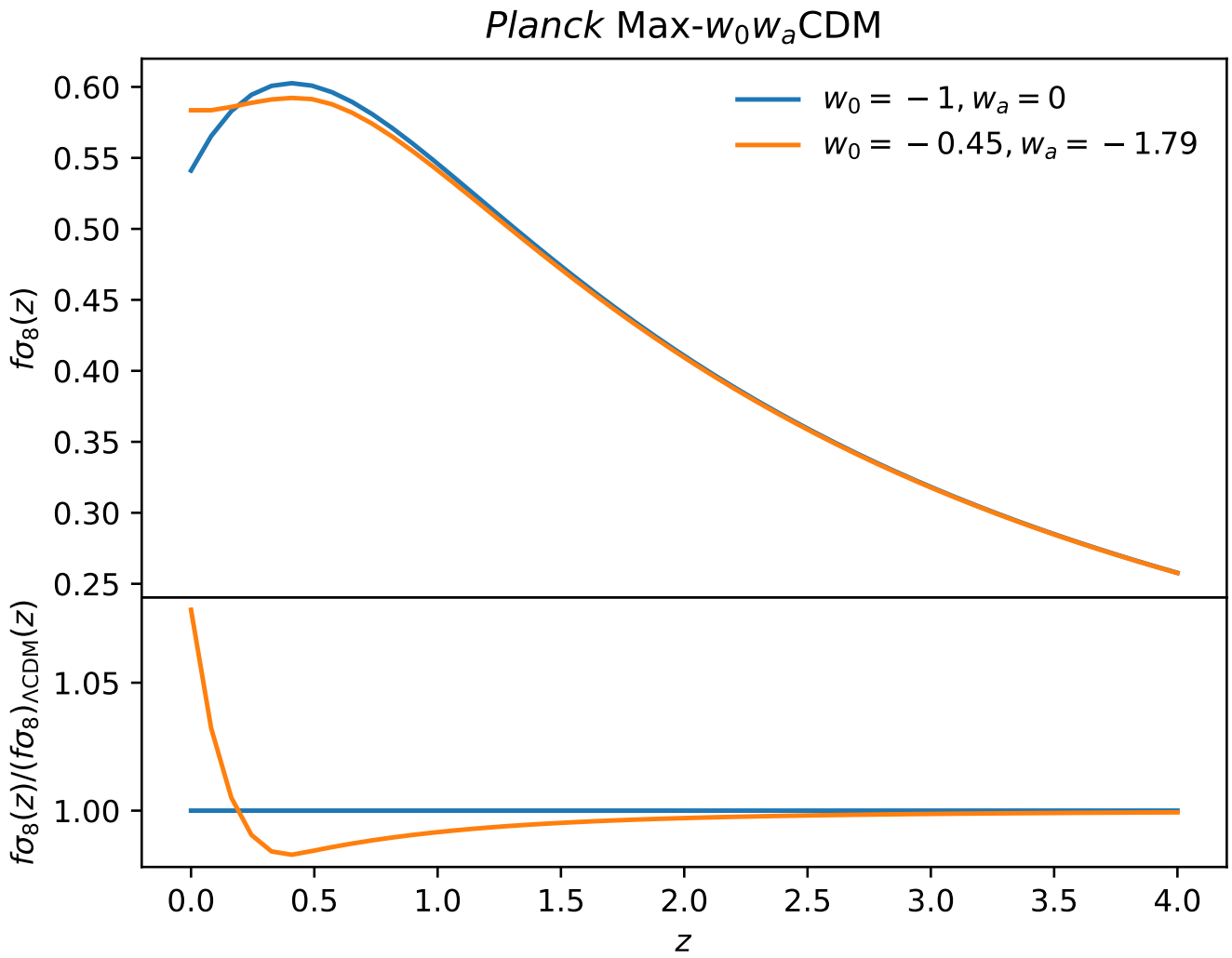
Growth of Structure



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