Beyond ΛCDM with a Logistic RG-like Flow of the Low Redshift Cosmic Evolution

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Expanding FRW Universe

Background Cosmology is governed by Spatially-Flat FRW Metric

$$ds^2 = dt^2 - a^2(t)[dr^2 + r^2 d\Omega^2]$$

Various Distances: **Comoving Distance:** $$d_M(z) = c\int_t^{t_0} \frac{dt}{a(t)} = c\int_0^z \frac{dz'}{H(z')}$$ $$H = \frac{\dot{a}}{a}$$ **Hubble Parameter**

Angular Diameter Distance: $$d_A(z) = \frac{d_M(z)}{1+z}$$ **BAO, CMB Angular Scale**

Luminosity Distance: $$d_L(z) = (1+z)\, d_M(z)$$ **Flux measurements using SnIa**

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Initial Conditions: $D_M(0) = 0$ and $D'_M(0) = D_H(0) = 1$

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- Then use the measured Ω_{m0}, to get DE behaviour from the constrained background.

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- We propose a simple generalization: $\frac{dw_{\rm T}}{dz} = -\frac{B}{A}w_{\rm T}\left(A+w_{\rm T}\right)$. It is same as that for constant DE-EOS but with flow variable z, instead of $\log a$. This results a different evolution.

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Gupta Choudhury and AAS, arXiv:2603.16852, To appear in Phys. Rev.D

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Parameter	ΛCDM	Logistic	CPL
h		(0.1, 1.2)	
	DESI-DR2 + DES + r_d^{plc}		
Ω_{m0}	(0, 0.7)	–	(0, 0.7)
A	–	(0, 3)	–
B	–	(0, 3)	–
w_0	–	–	[−3, 1]
w_a	–	–	[−3, 2]
DESI-DR2 + CMB and DESI-DR2 + DES + CMB			
ω_b		(0.01, 0.03)	
ω_c		(0.01, 0.6)	
A	–	(0, 3)	–
B	–	(0, 3)	–
w_0	–	–	[−3, 1]
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ω_b		(0.01, 0.03)	
ω_c		(0.01, 0.6)	
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B	–	(0, 3)	–
w_0	–	–	[−3, 1]
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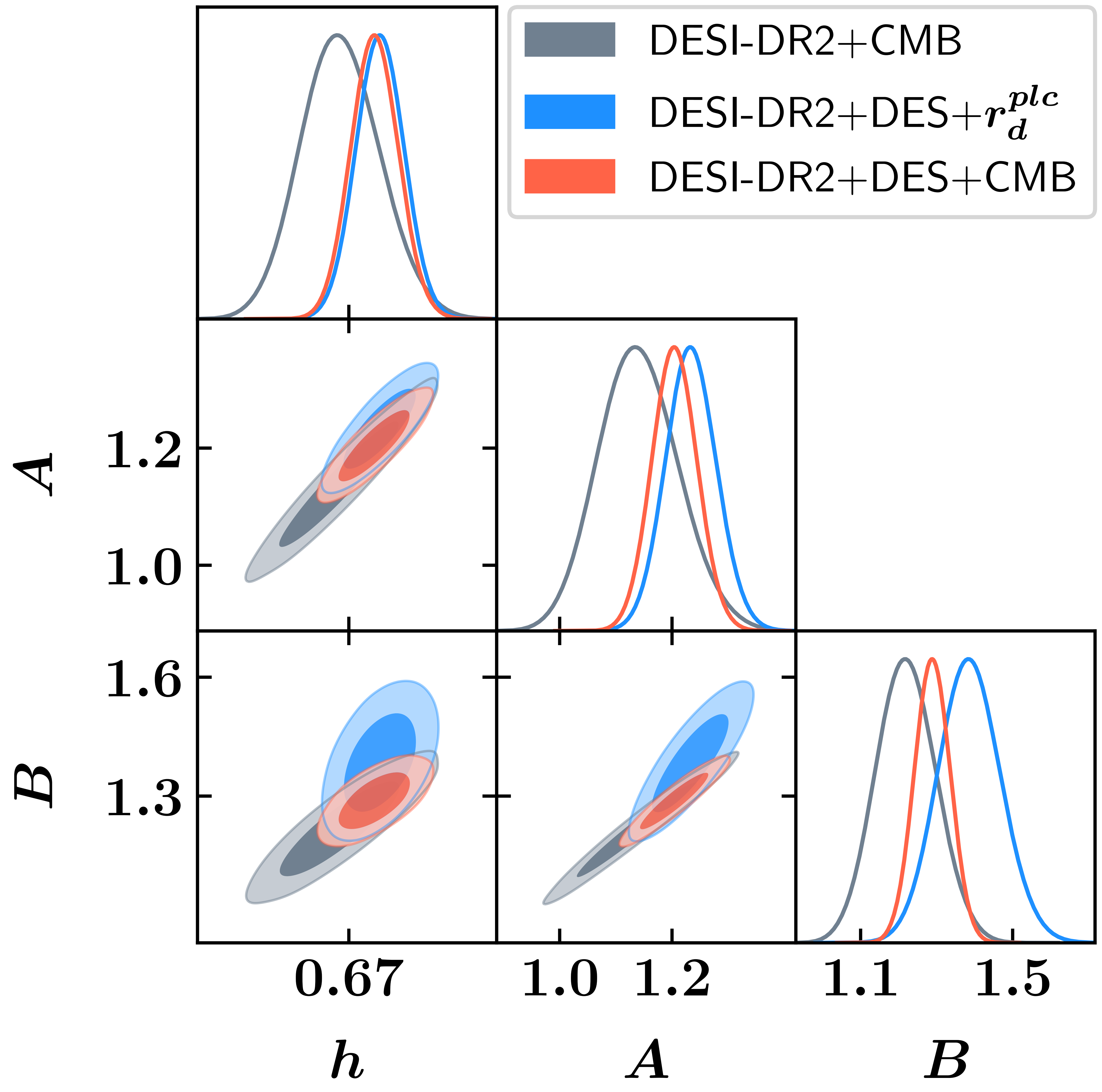
Logistic Model



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Dataset	h	A	B
DESI-DR2 + CMB	0.6681 ± 0.0091	1.141 ± 0.071	1.220 ± 0.078
DESI-DR2 + DES + $r_d^{\rm plc}$	0.6773 ± 0.0055	1.234 ± 0.045	1.386 ± 0.082
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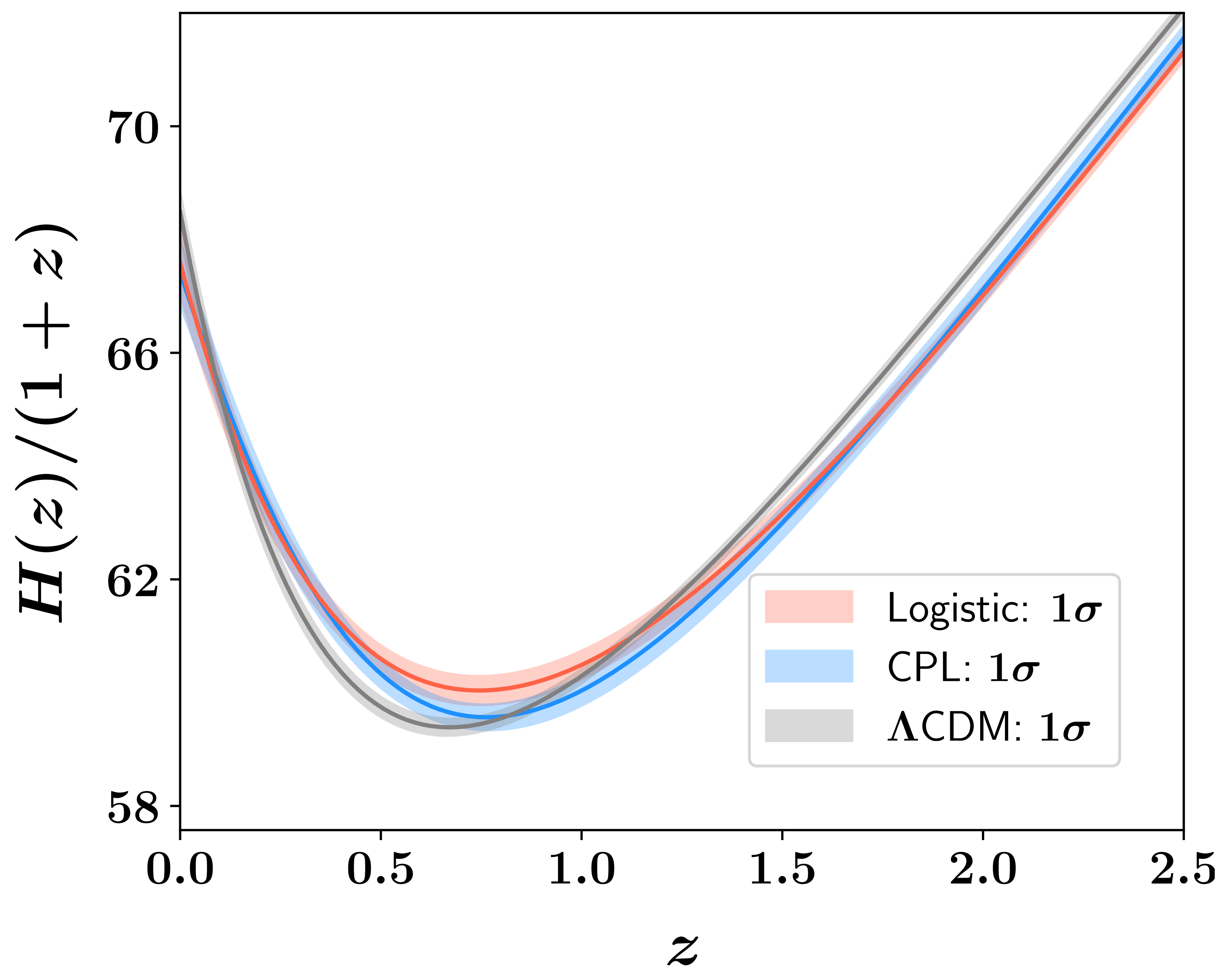

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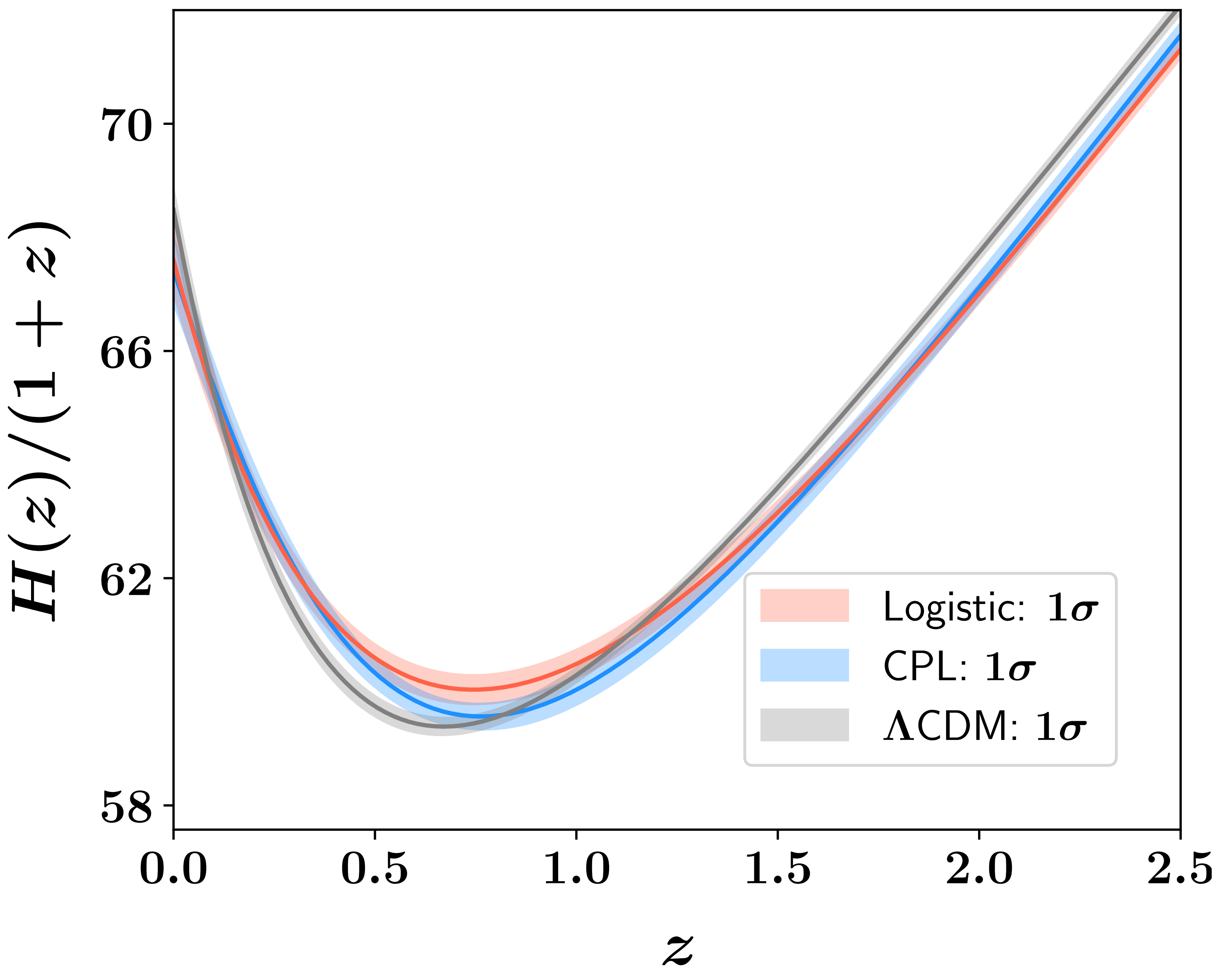

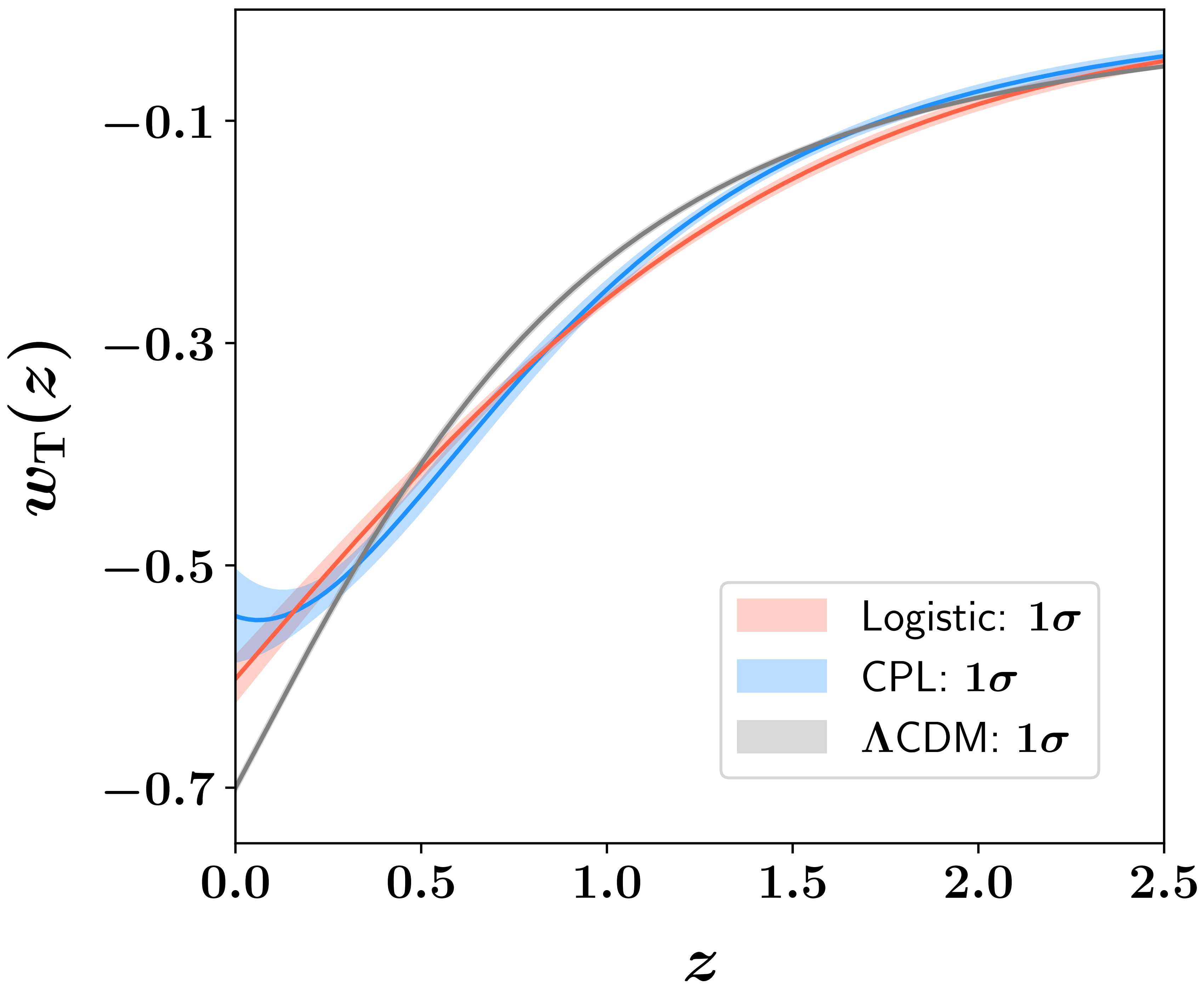

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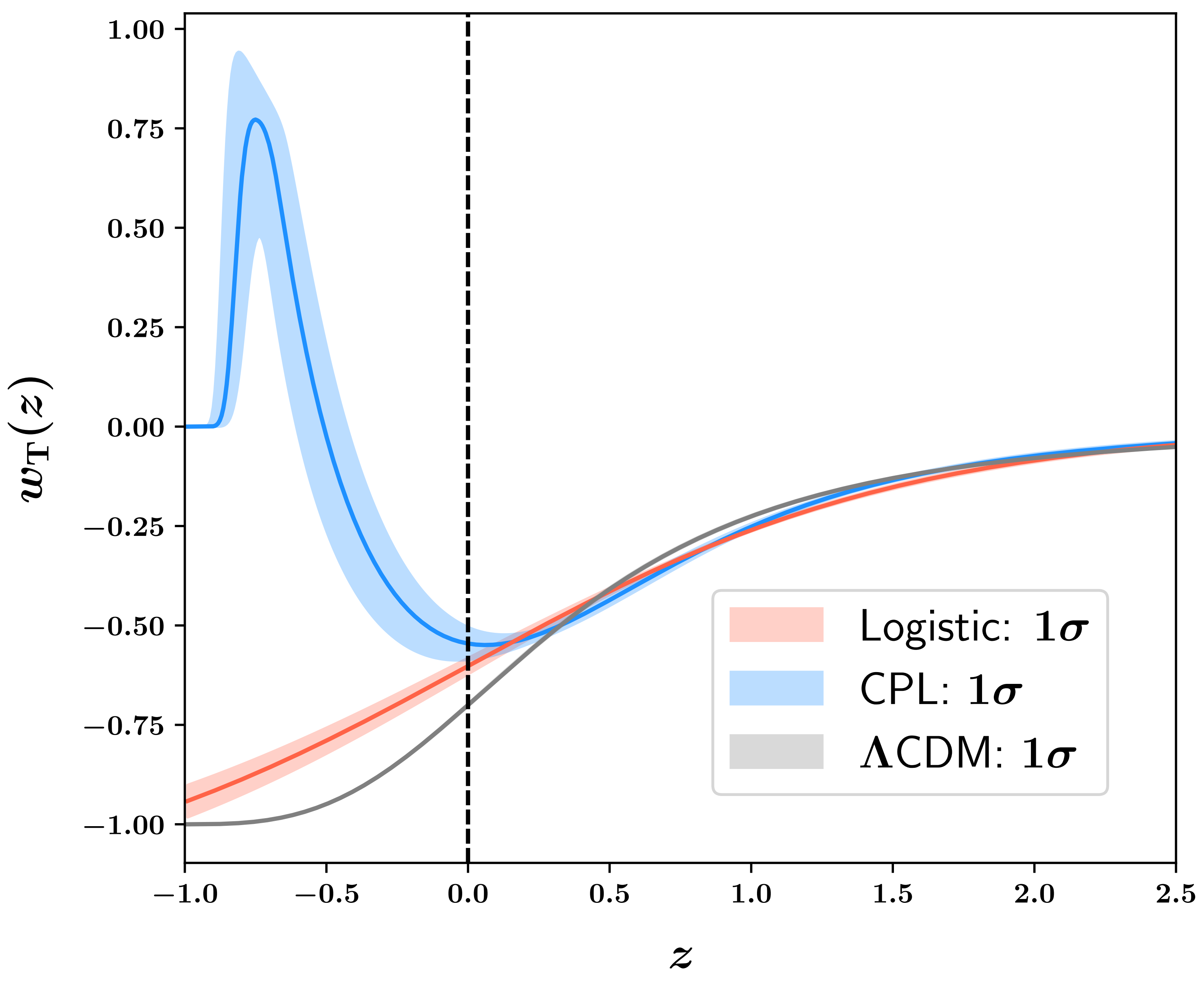
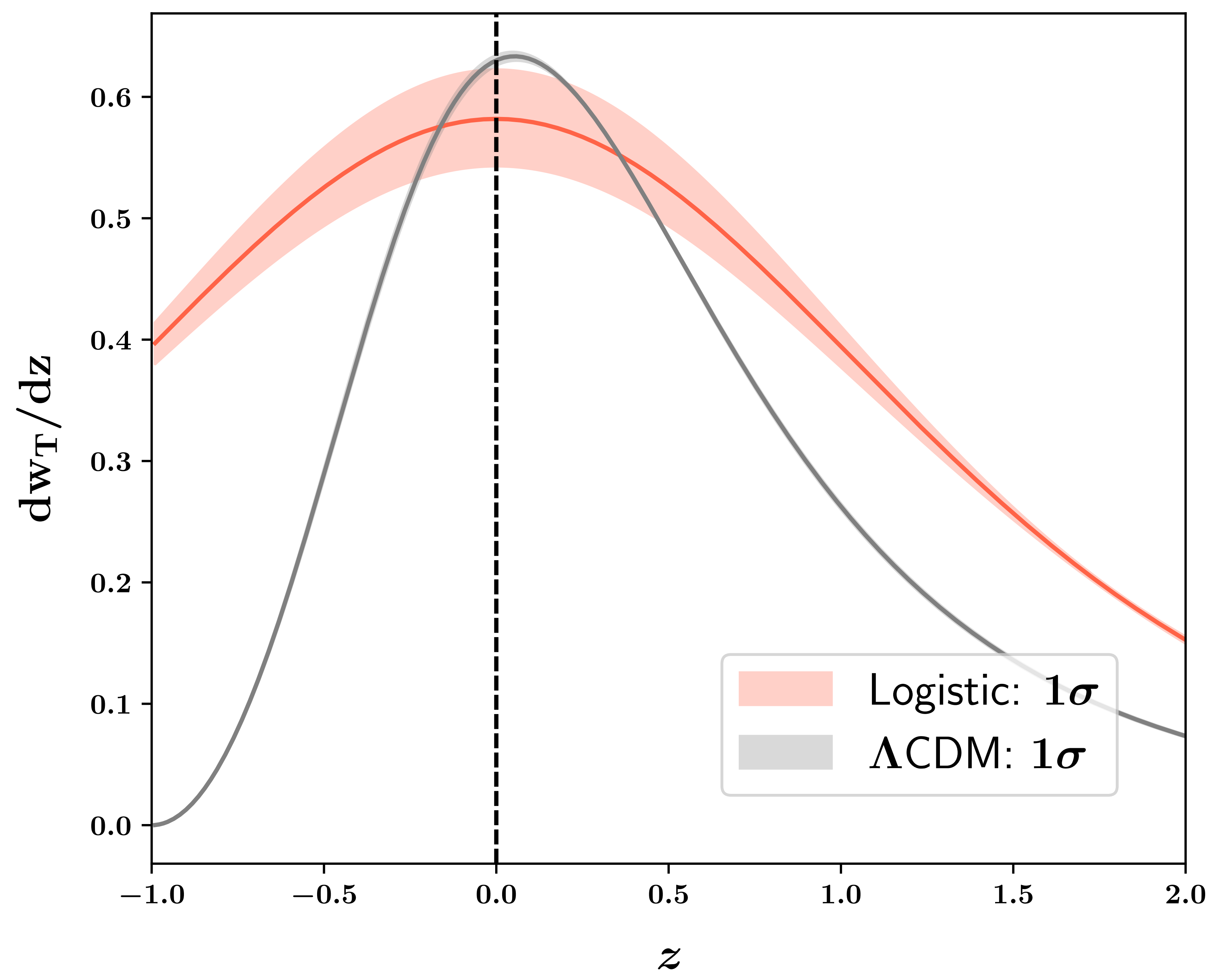


$w_\mathrm{T}(z)$
z
Logistic: 1σ
CPL: 1σ
ΛCDM: 1σ
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5



$\mathrm{d}w_\mathrm{T}/\mathrm{dz}$
z
Logistic: 1σ
ΛCDM: 1σ
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0

Which Model Gives a Better Fit?

Model	k	$\chi^2_{\min}$	AIC	ΔAIC	BIC	ΔBIC	$\ln Z$	$\Delta \ln Z$
ΛCDM	3	1668.1	1674.1	0.0	1690.4	0.0	-850.6	0.0
Logistic	5	1649.2	1659.2	-14.9	1686.4	-4.0	-848.8	$+1.8$
CPL	5	1653.2	1663.2	-10.9	1690.4	0.0	-849.2	$+1.4$

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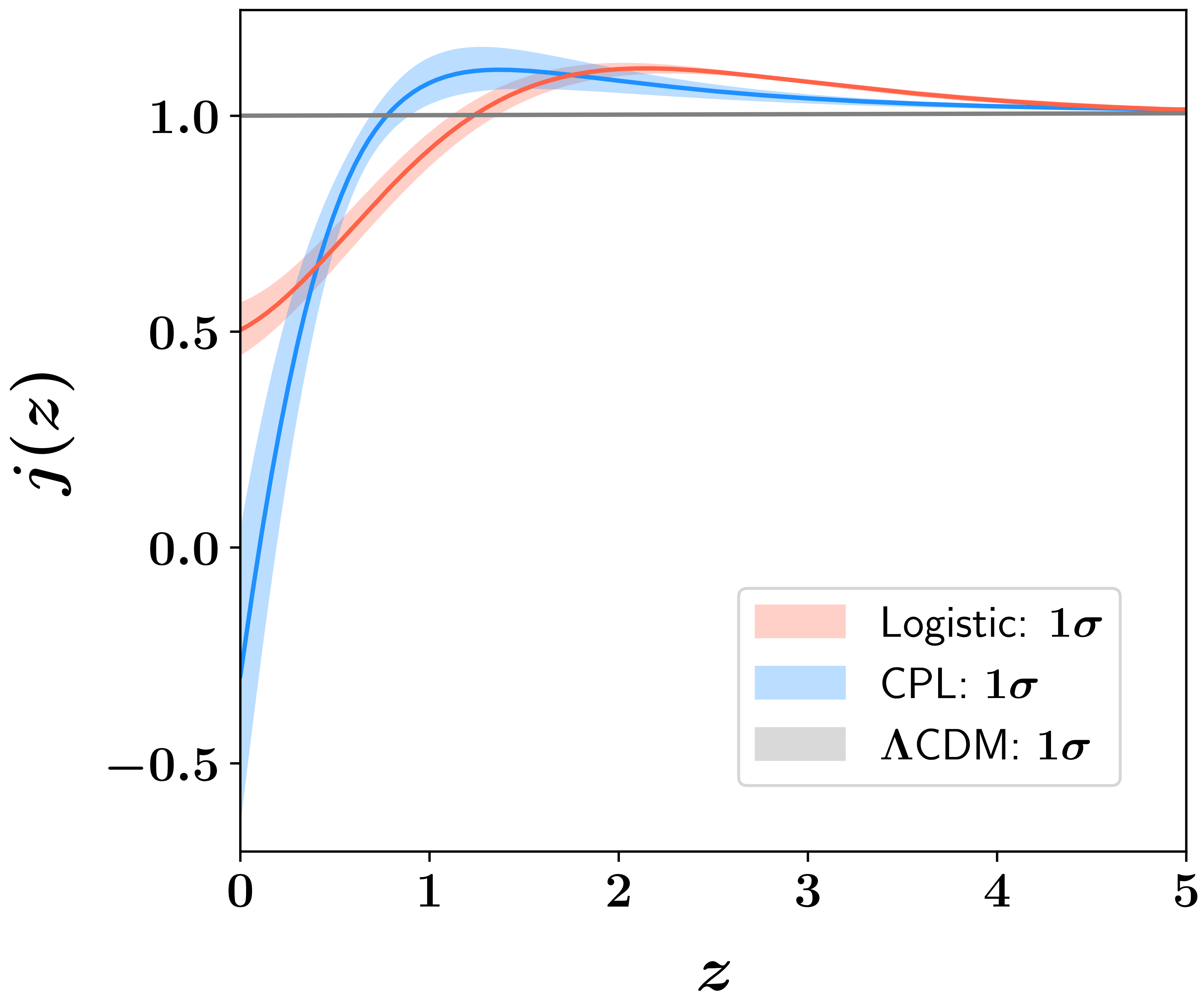
Logistic Model gives ***Statistically Better Fit*** *to the data compared to both ΛCDM and CPL.*

What The Jerk Parameter Tells?



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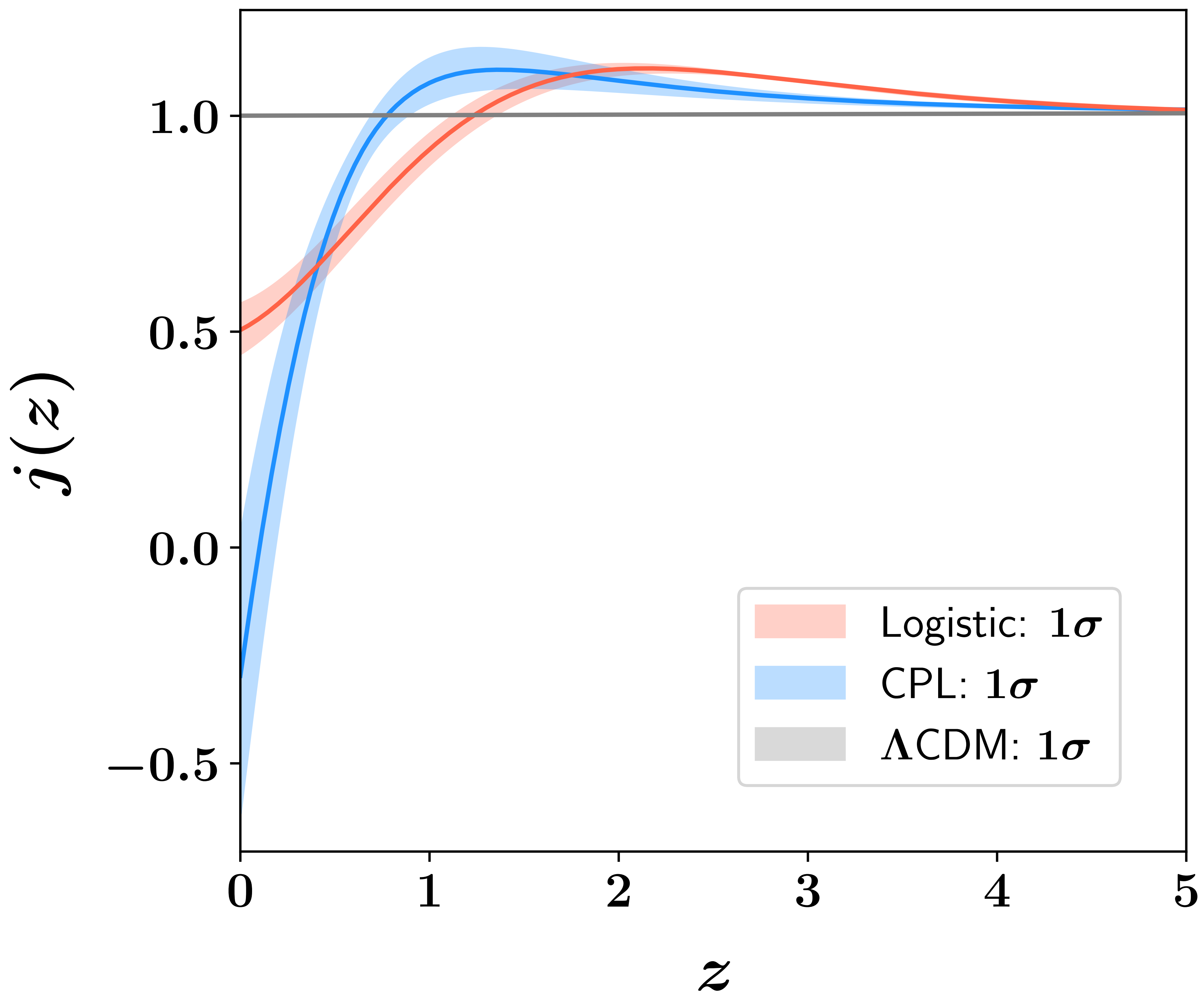

z	Logistic		CPL	
	$j(z)$	**Tension** (σ)	$j(z)$	**Tension** (σ)
0.0	$0.506^{+0.052}_{-0.062}$	9.5	-0.295 ± 0.321	4.03
0.1	$0.533^{+0.048}_{-0.057}$	9.73	-0.004 ± 0.262	3.83
0.2	$0.566^{+0.045}_{-0.052}$	9.64	0.251 ± 0.201	3.73
0.3	$0.606^{+0.043}_{-0.049}$	9.16	0.465 ± 0.146	3.66
0.4	$0.650^{+0.042}_{-0.046}$	8.33	0.639 ± 0.100	3.61
0.5	0.697 ± 0.043	7.05	0.777 ± 0.067	3.33
1.0	0.922 ± 0.035	2.23	$1.081^{+0.042}_{-0.057}$	1.42

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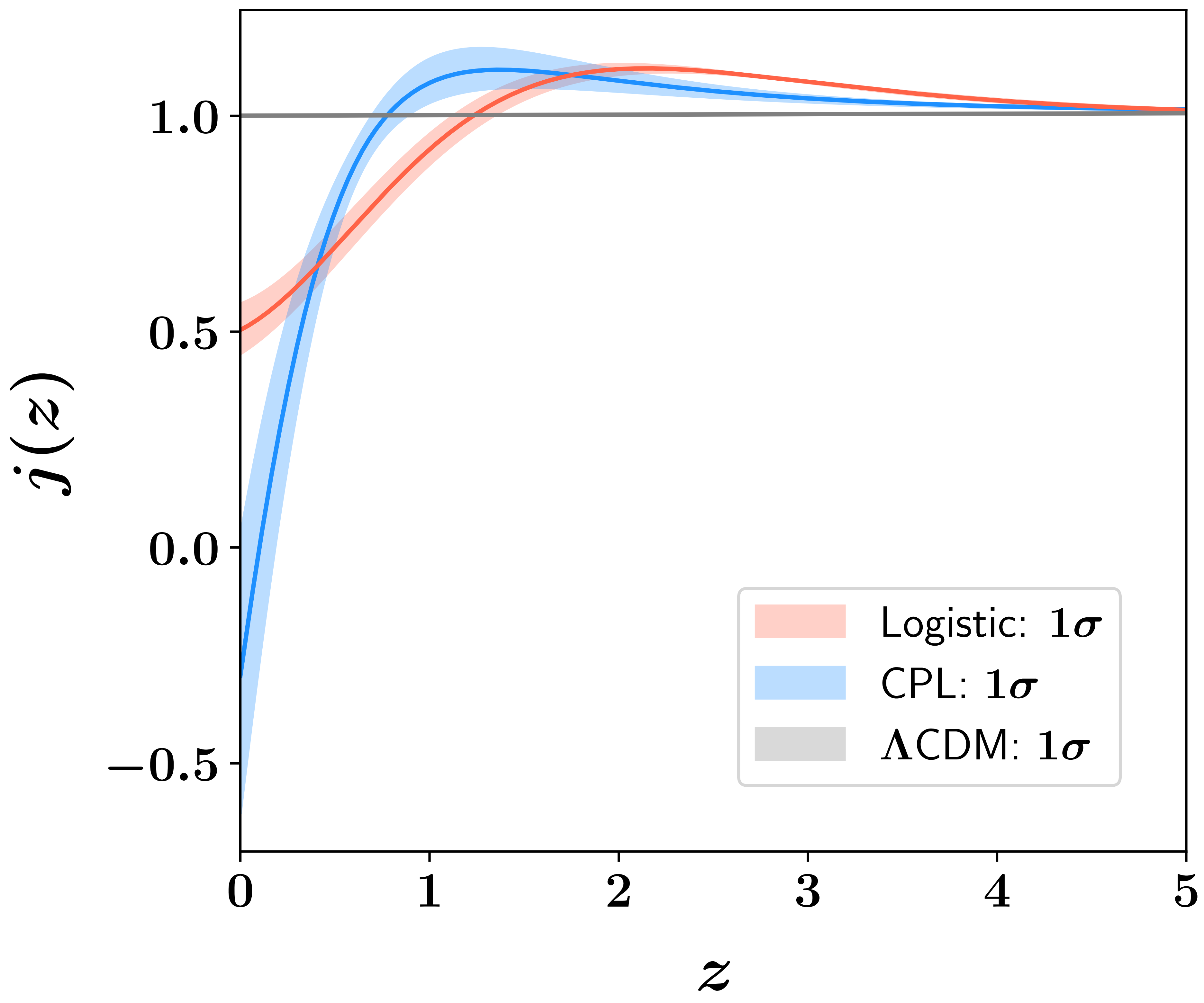

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Given that Logistic is a non-nested model w.r.t to ΛCDM,
a large deviation from $j=1$ probably indicates a new class of low-redshift cosmological evoution.

Constraining Ω_{m0} from Growth Data

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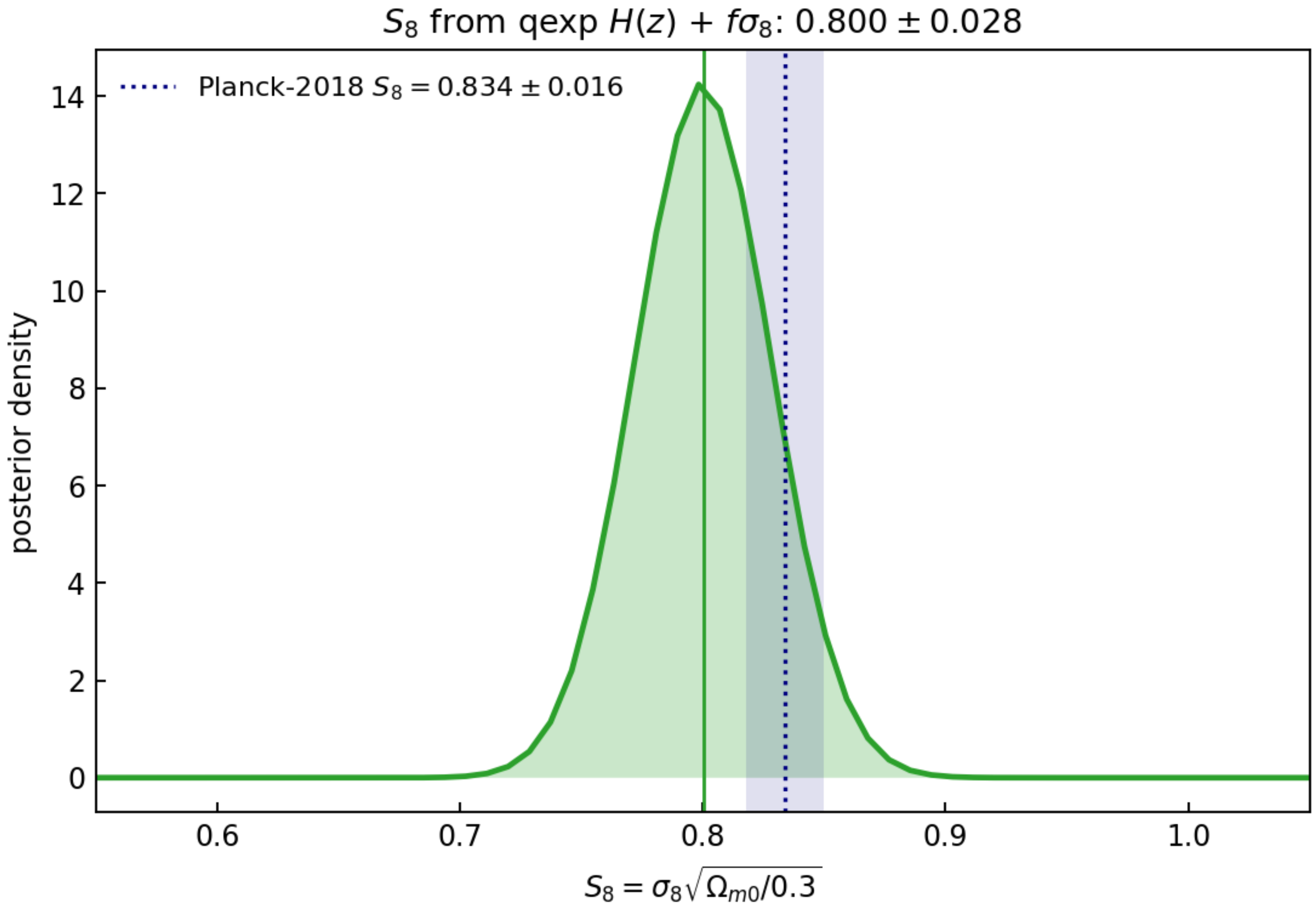
We also need the $\sigma_8(0)$ information. But we can constrain $S_8 = \sigma_8(\Omega_{m0}/0.3)^{1/2}$

Constraints from Growth



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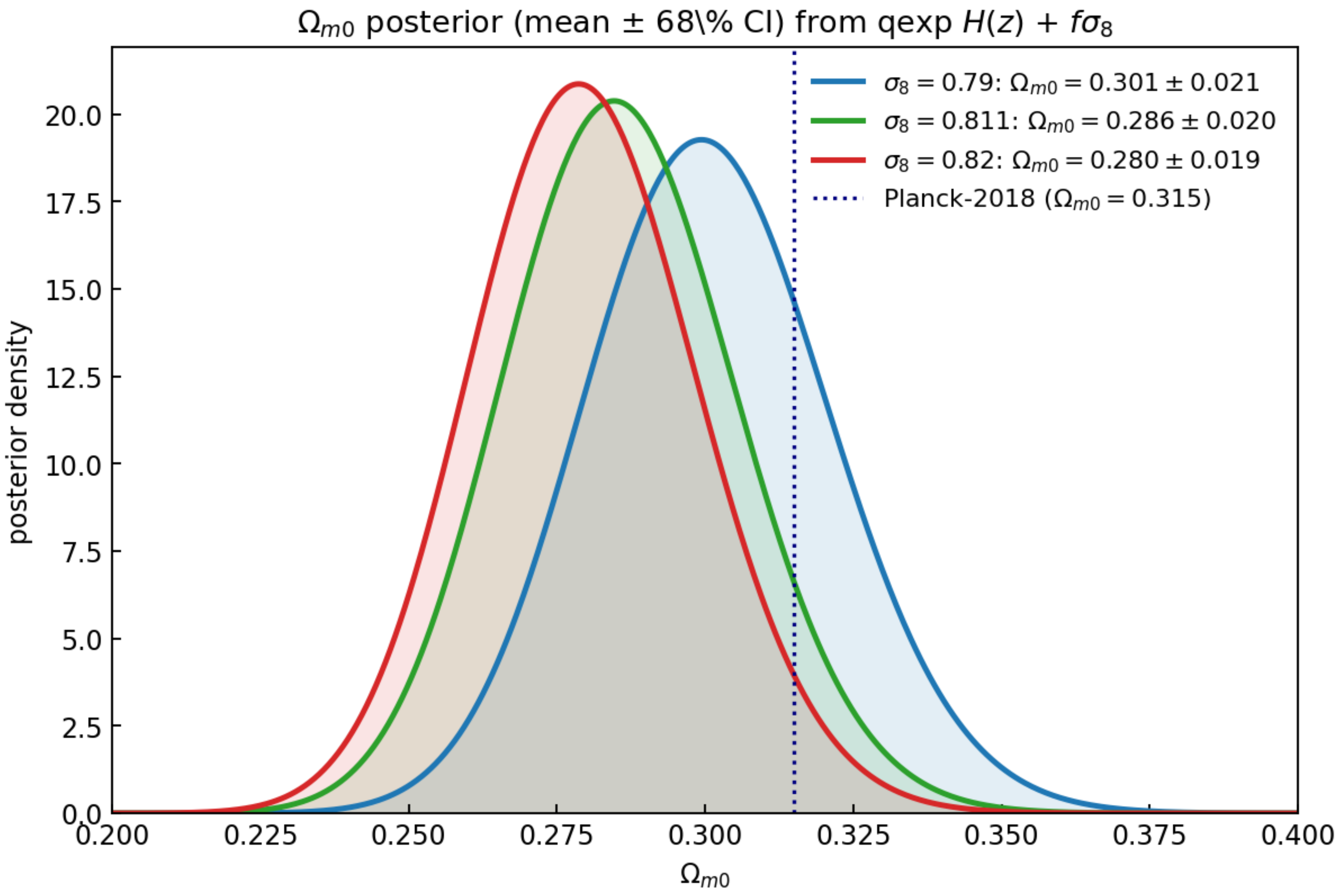

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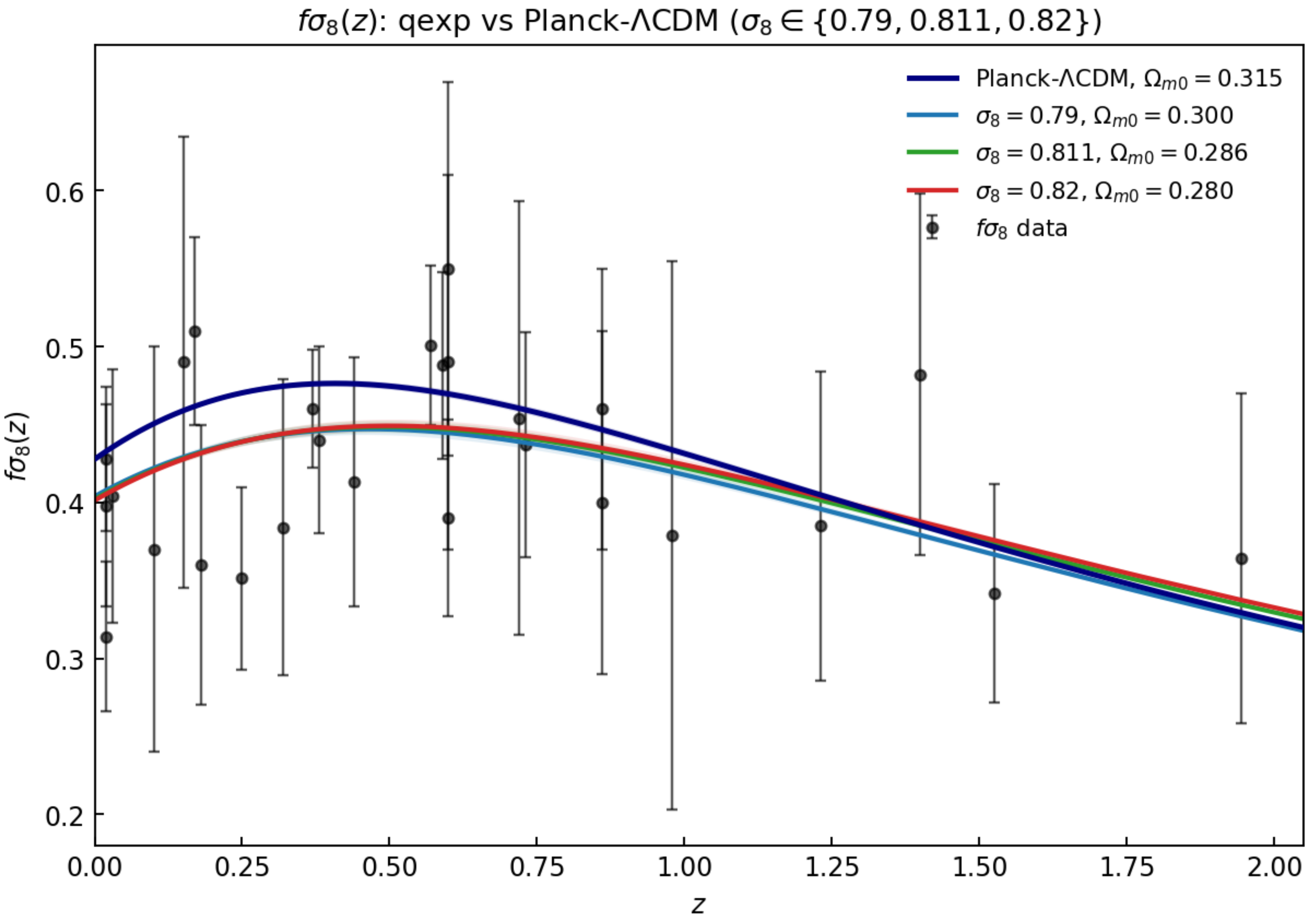
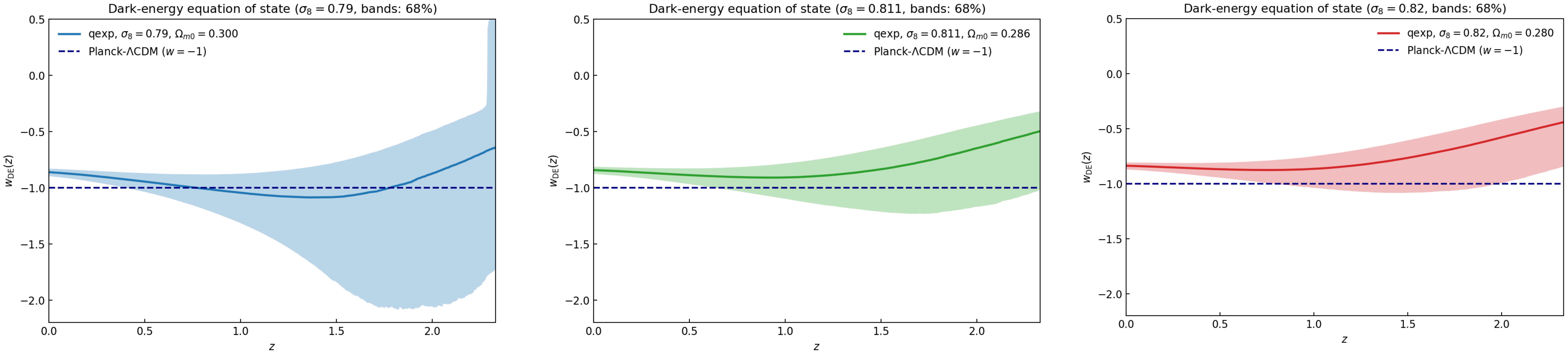


Possible Dark Energy Behaviour

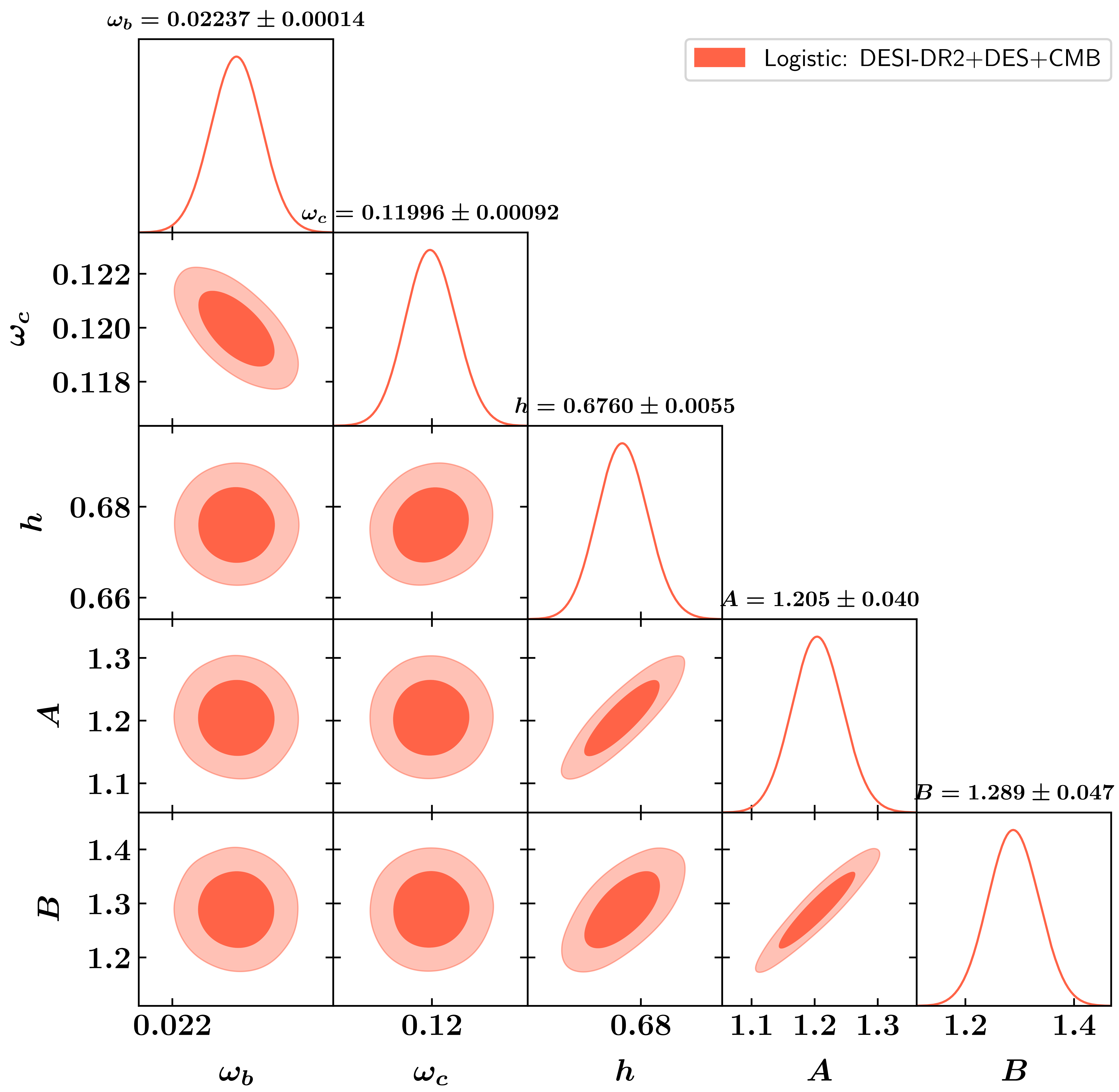


$w_{de}(z)$ crucially depends on Growth History plus the $\sigma_8(0)$ normalization.

Conclusions

- We show a different way to parametrise the low redshift cosmological evolution using the certain Logistic Evolution of ω_T (total equation of state of the Universe).
- The model is not nested with ΛCDM behaviour.
- The Logistic Evolution gives statistically better fit to DESI/DES/CMB (compressed) data than both ΛCDM and CPL parametrisation.
- The constrained evolution of ω_T is different than CPL case, especially around present day and in future.
- Also there is a significantly large deviations from $j = 1$ making the low-redshift tension worse than anticipated.
- With the constrained background, one can use the growth data to get Ω_{m0} and subsequently $w_{de}(z)$.
- In this approach, the whether dark energy evolution crucially depends on Growth History of the Universe together with the σ_8 normalization.

Thank You For Your Attention



$\omega_b = 0.02237 \pm 0.00014$
$\omega_c = 0.11996 \pm 0.00092$
$h = 0.6760 \pm 0.0055$
$A = 1.205 \pm 0.040$
$B = 1.289 \pm 0.047$
Logistic: DESI-DR2+DES+CMB
ω_c
0.122
0.120
0.118
h
0.68
0.66
A
1.3
1.2
1.1
B
1.4
1.3
1.2
0.022
0.12
0.68
1.1
1.2
1.3
1.2
1.4
ω_b
ω_c
h
A
B

What Kind of DE Model?

A preliminary study: DE consists of a Cosmological Constant plus a X-fluid with EOS:

$$w_X = -\frac{1}{2}\left[1 + \tanh\left(\frac{z - z_0}{\Delta}\right)\right]$$

$(\Omega_{m0} = 0.2974,\ \Omega_\Lambda = 0.570,\ z_0 = 0.198, \text{ and } \Delta = 0.451)$