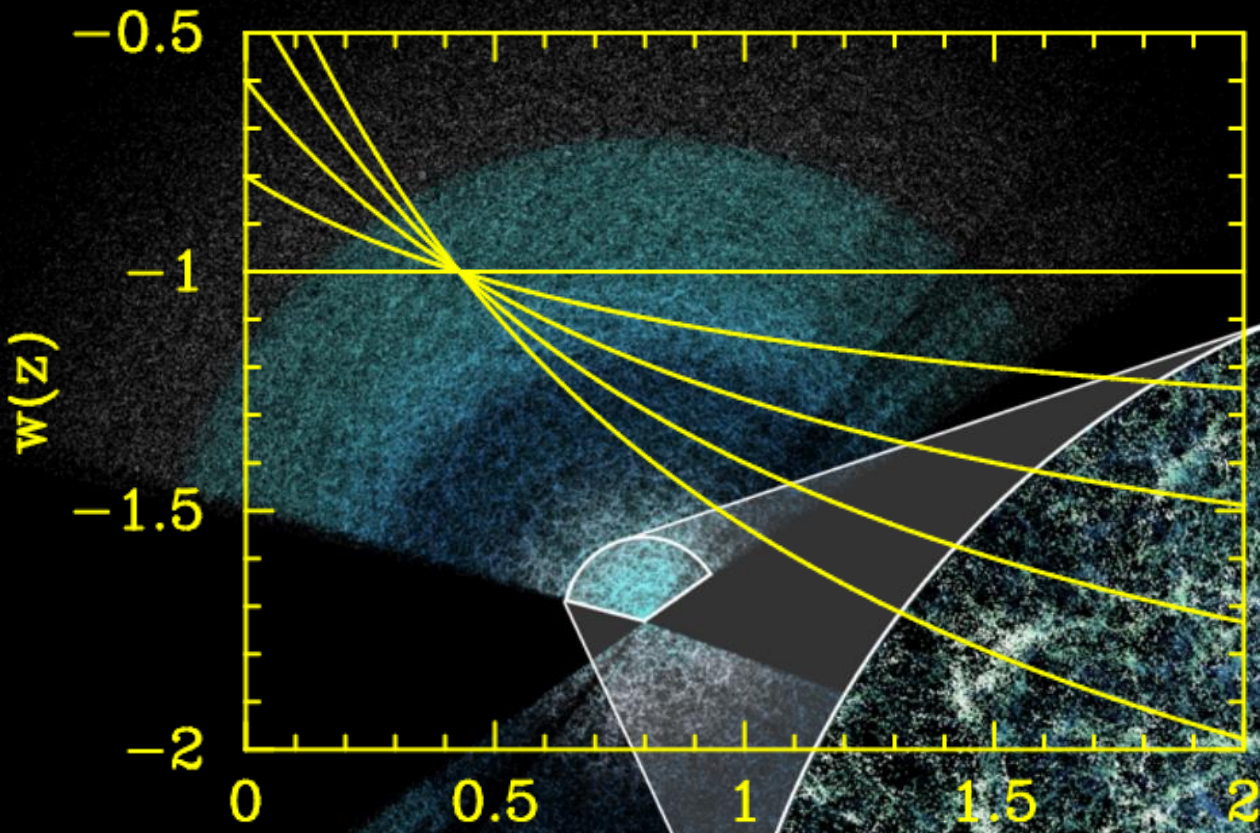
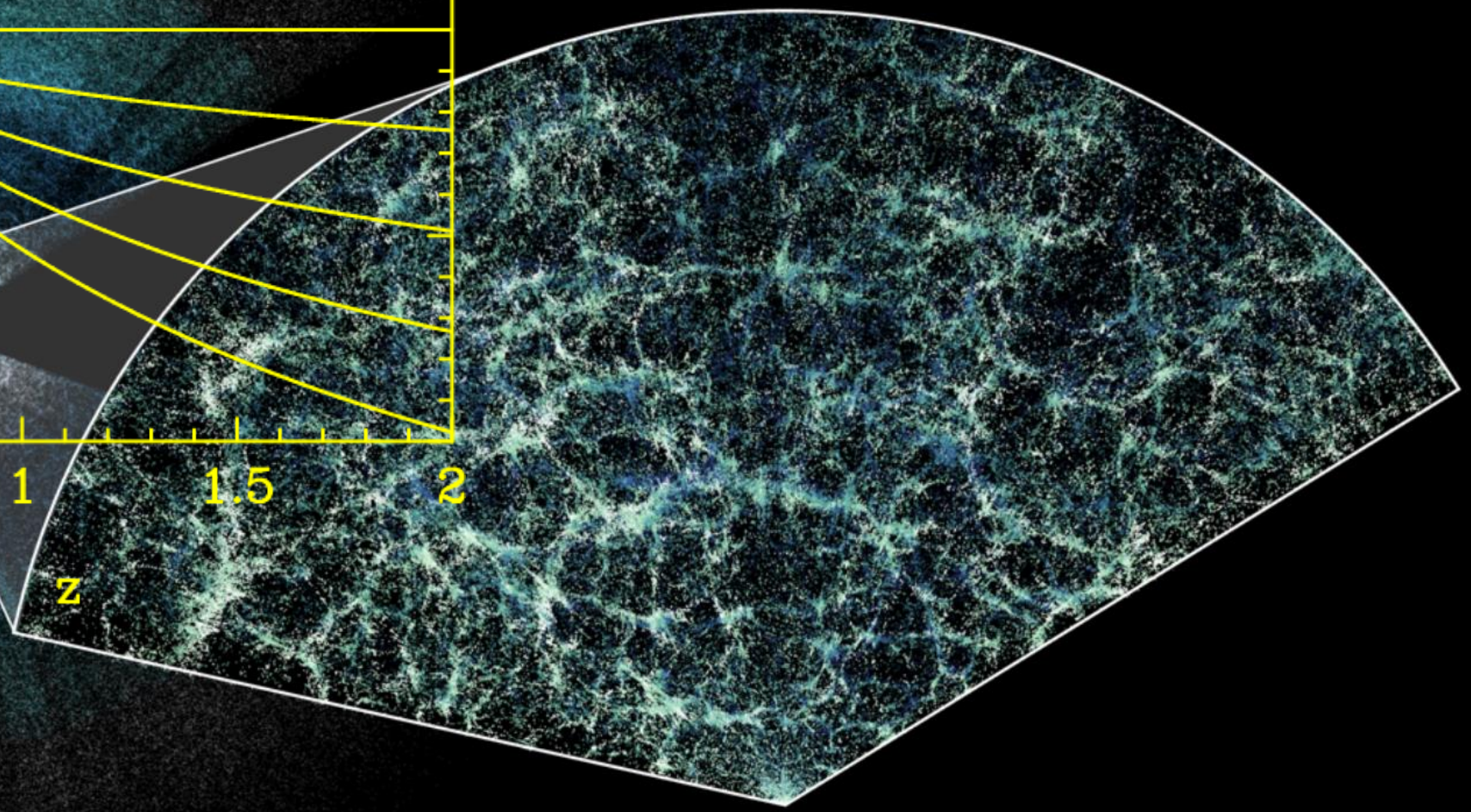
BAO from a different angle

George Efstathiou KICC Cambridge





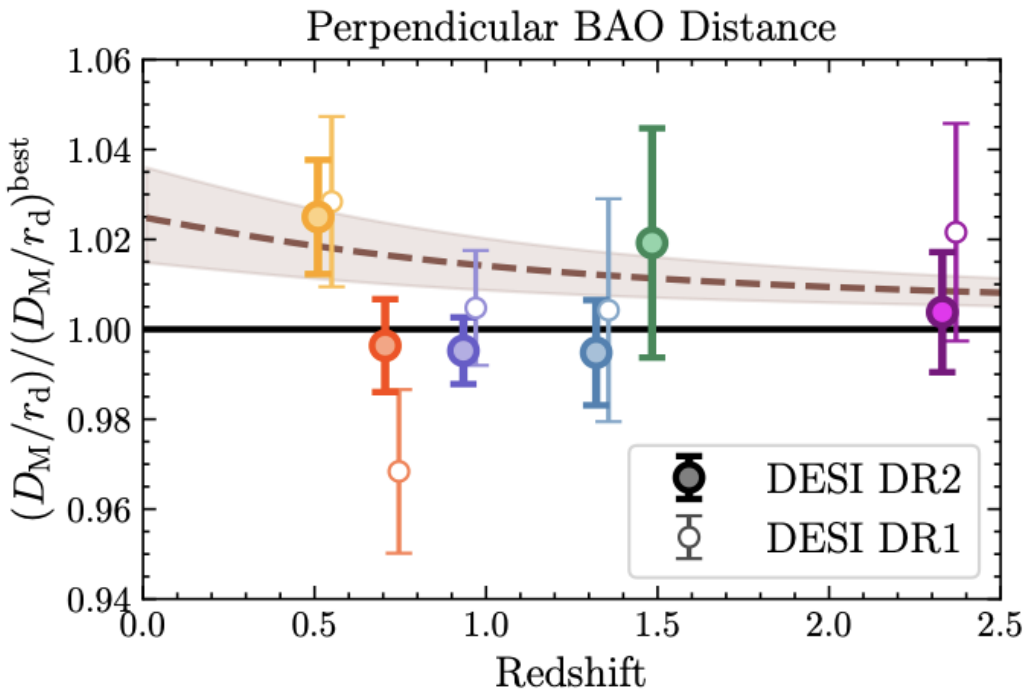
The DESI Interpretation:

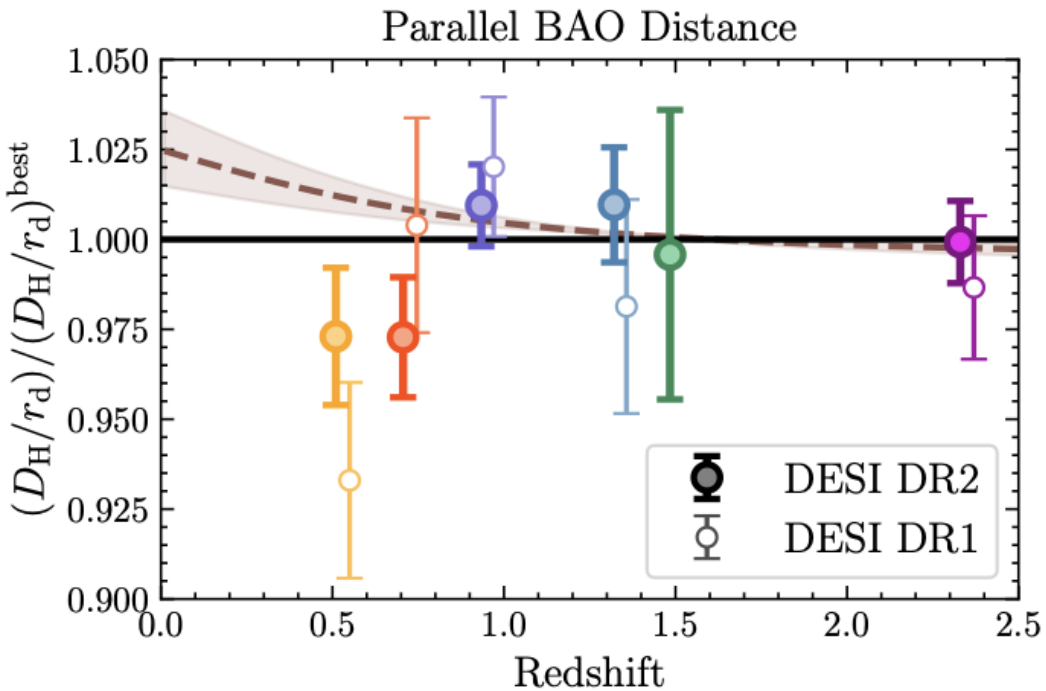
DESI BAO v Planck ΛCDM	2.3σ	50:1
w0wa v Planck ΛCDM		
DESI BAO+CMB	3.1σ	520:1
DESI BAO+CMB+Pan+SN	2.8σ	200:1
DESI BAO+CMB+Union3 SN	3.8σ	6800:1
DESI BAO+CMB+DES5Y SN	4.2σ	37500:1

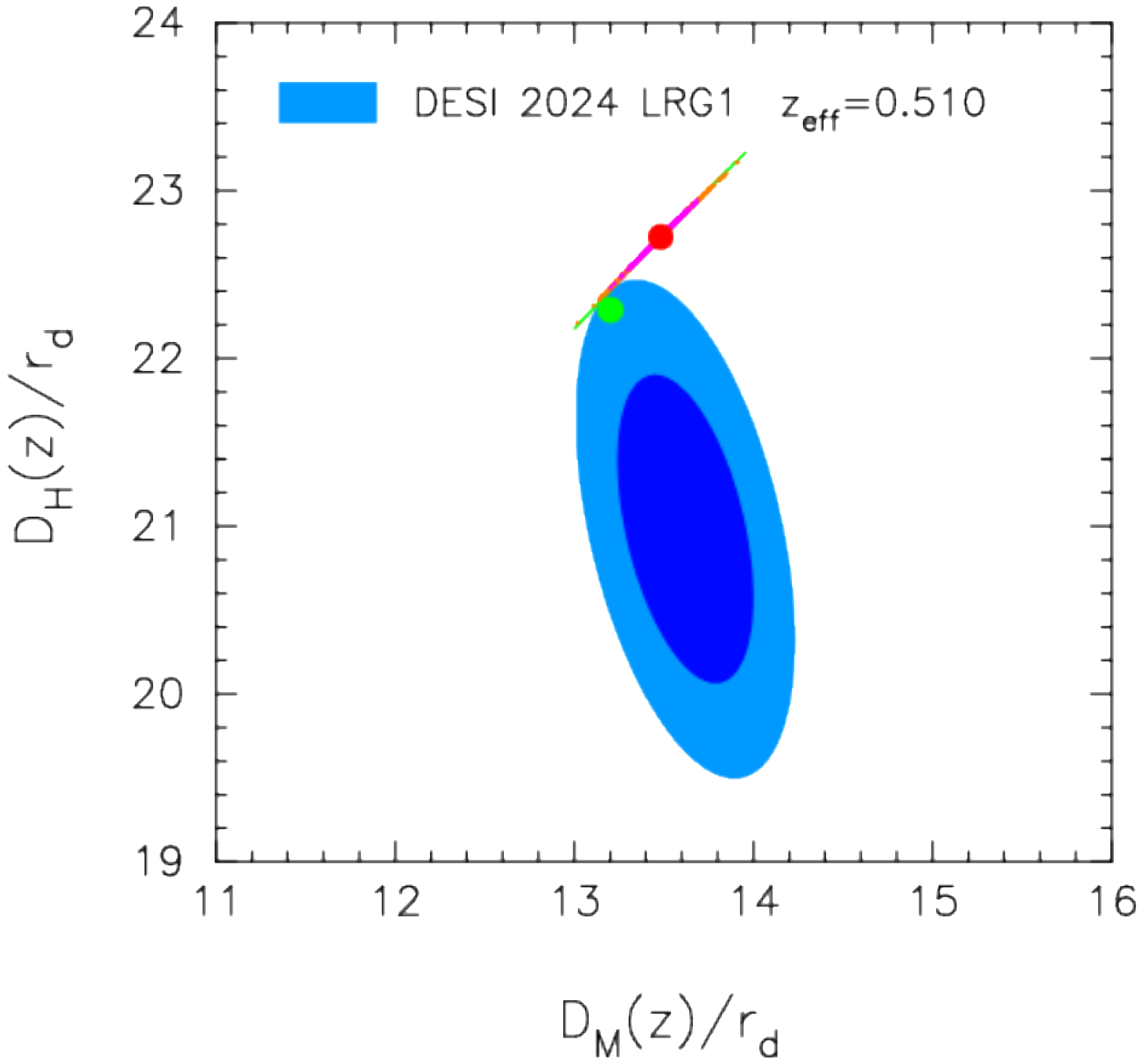
$$w(z) = w_0 + w_a \left(\frac{z}{1+z} \right)$$

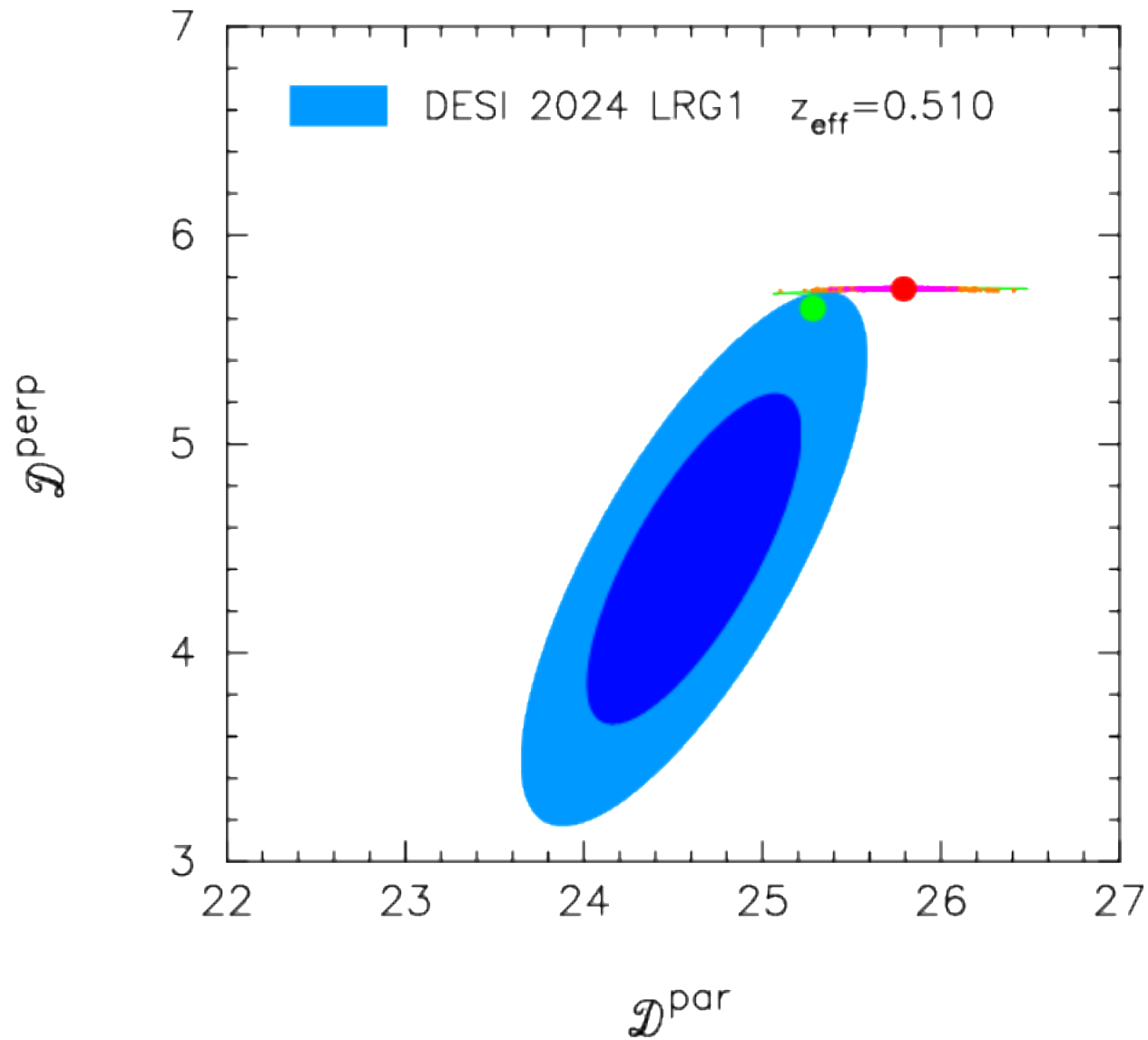
$$D_{\rm M}(z) = \int_0^z dz' \frac{c}{H(z')},$$

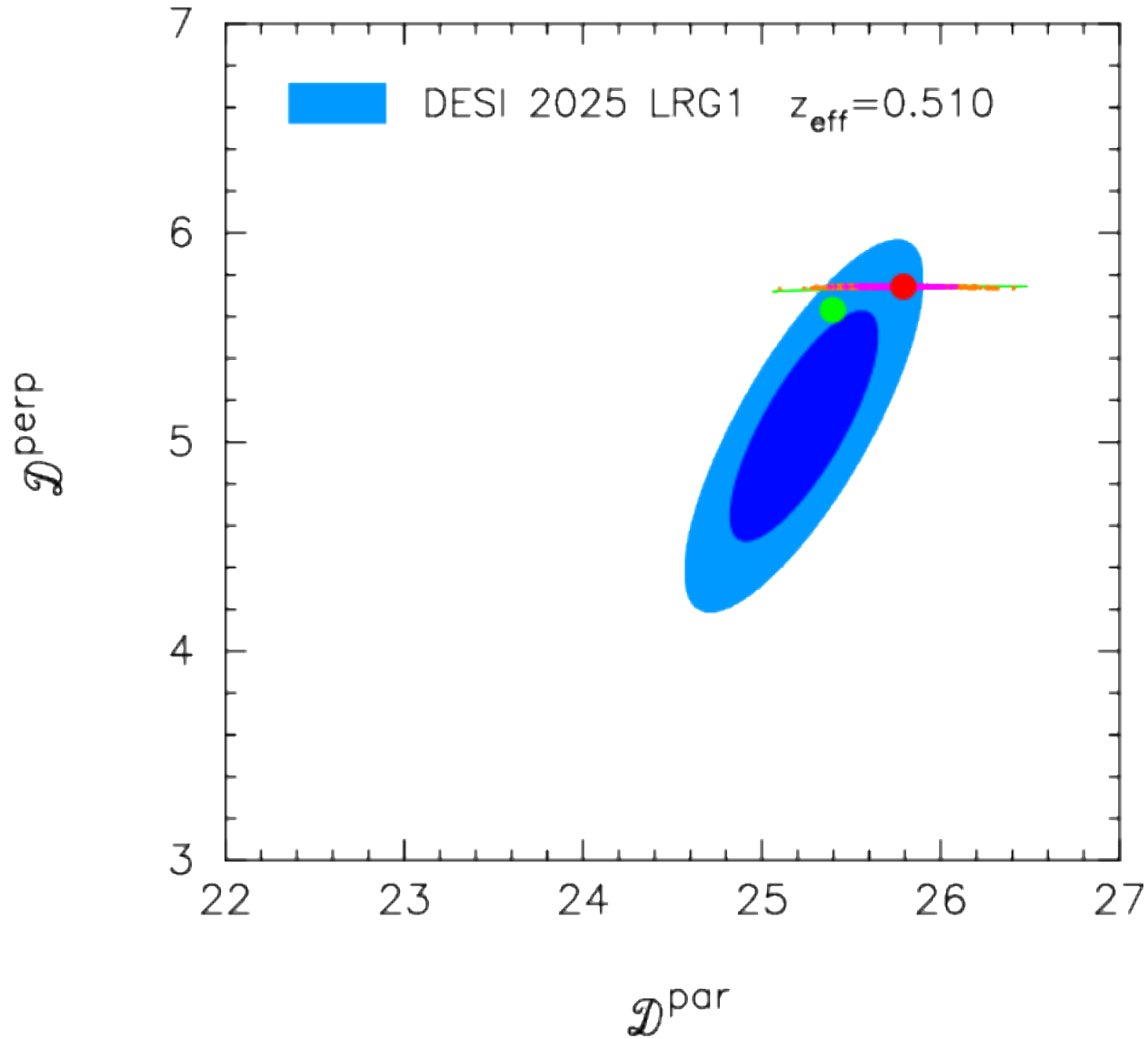
$$D_H(z) = \frac{c}{H(z)},$$

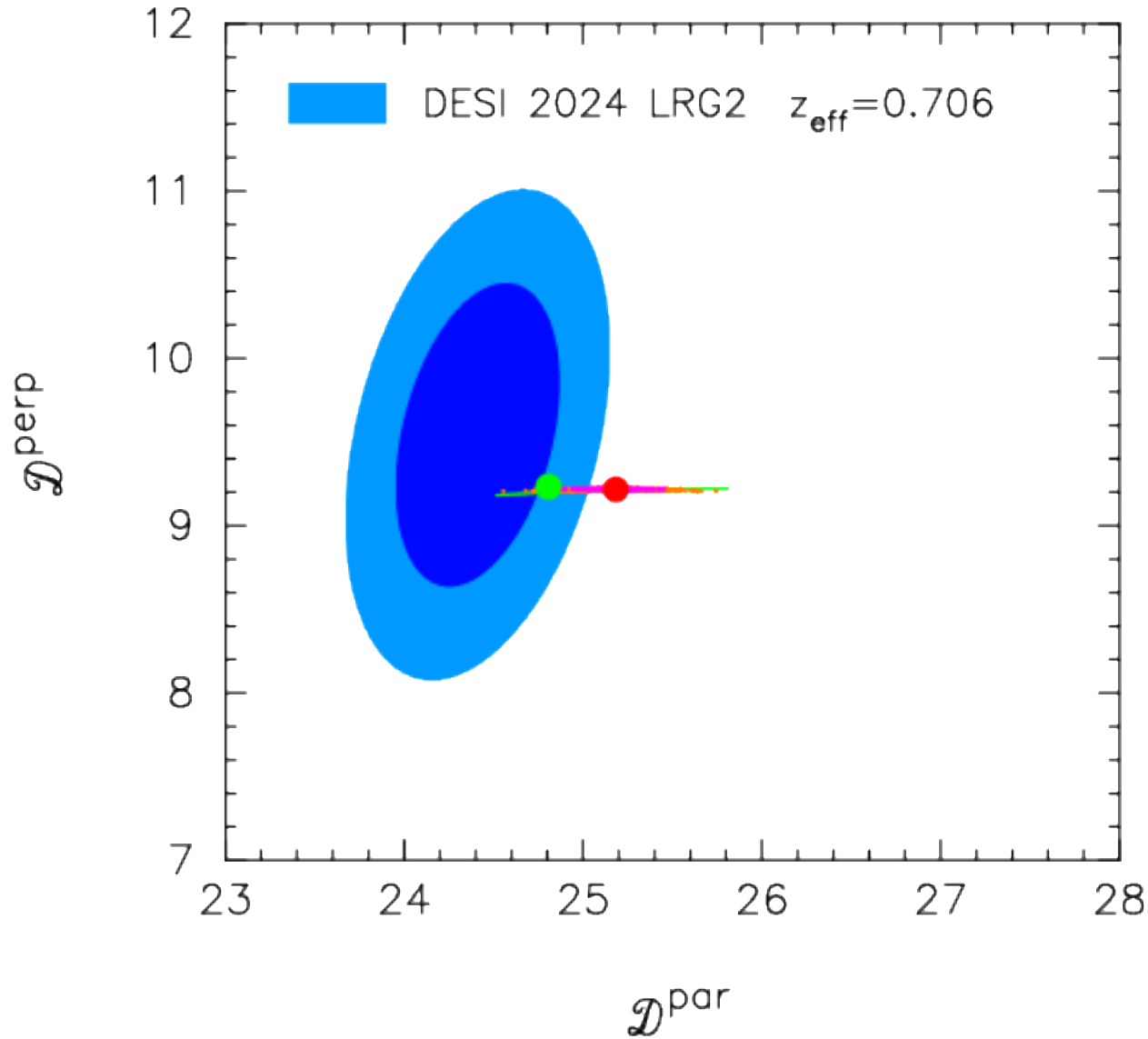


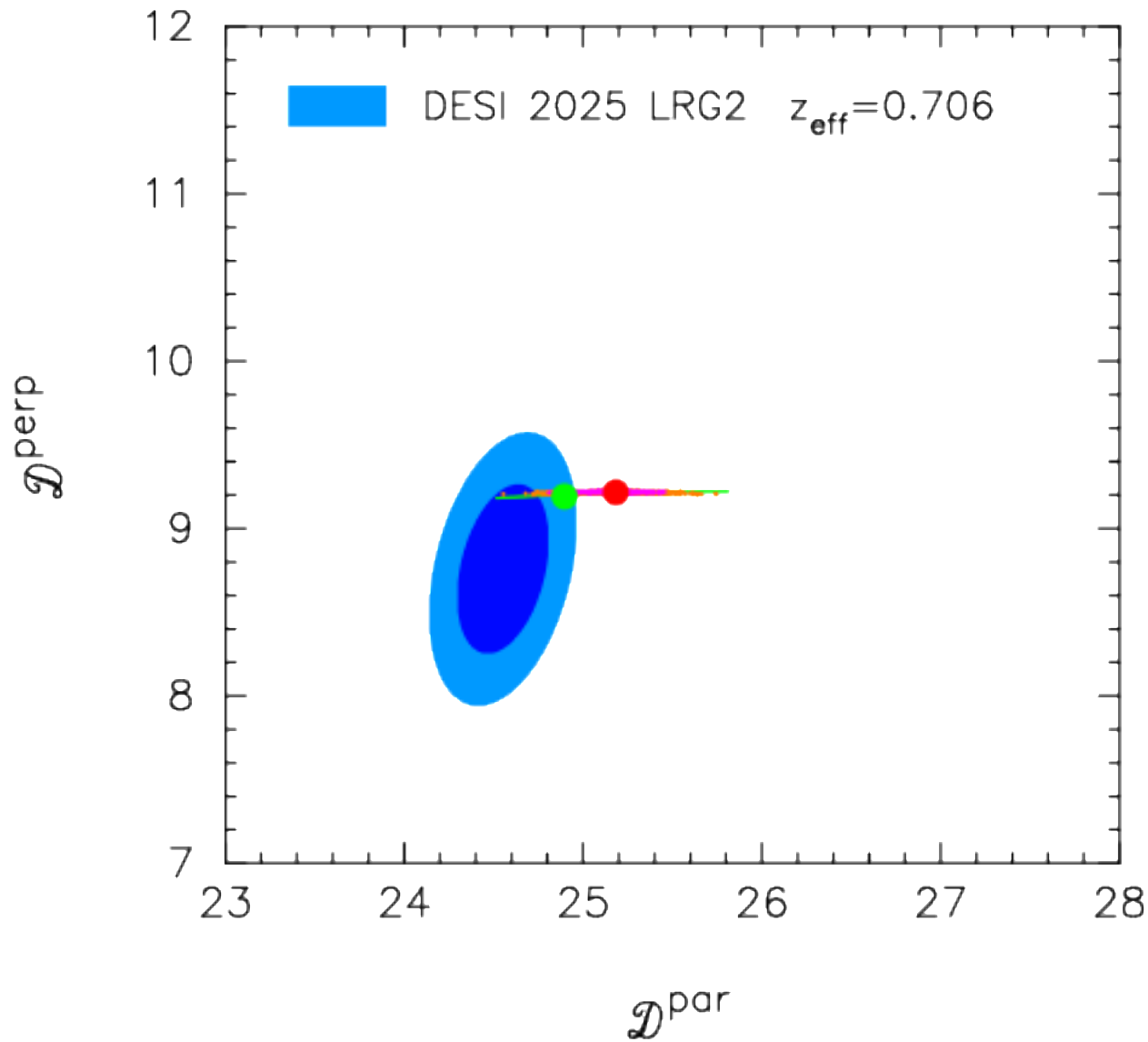


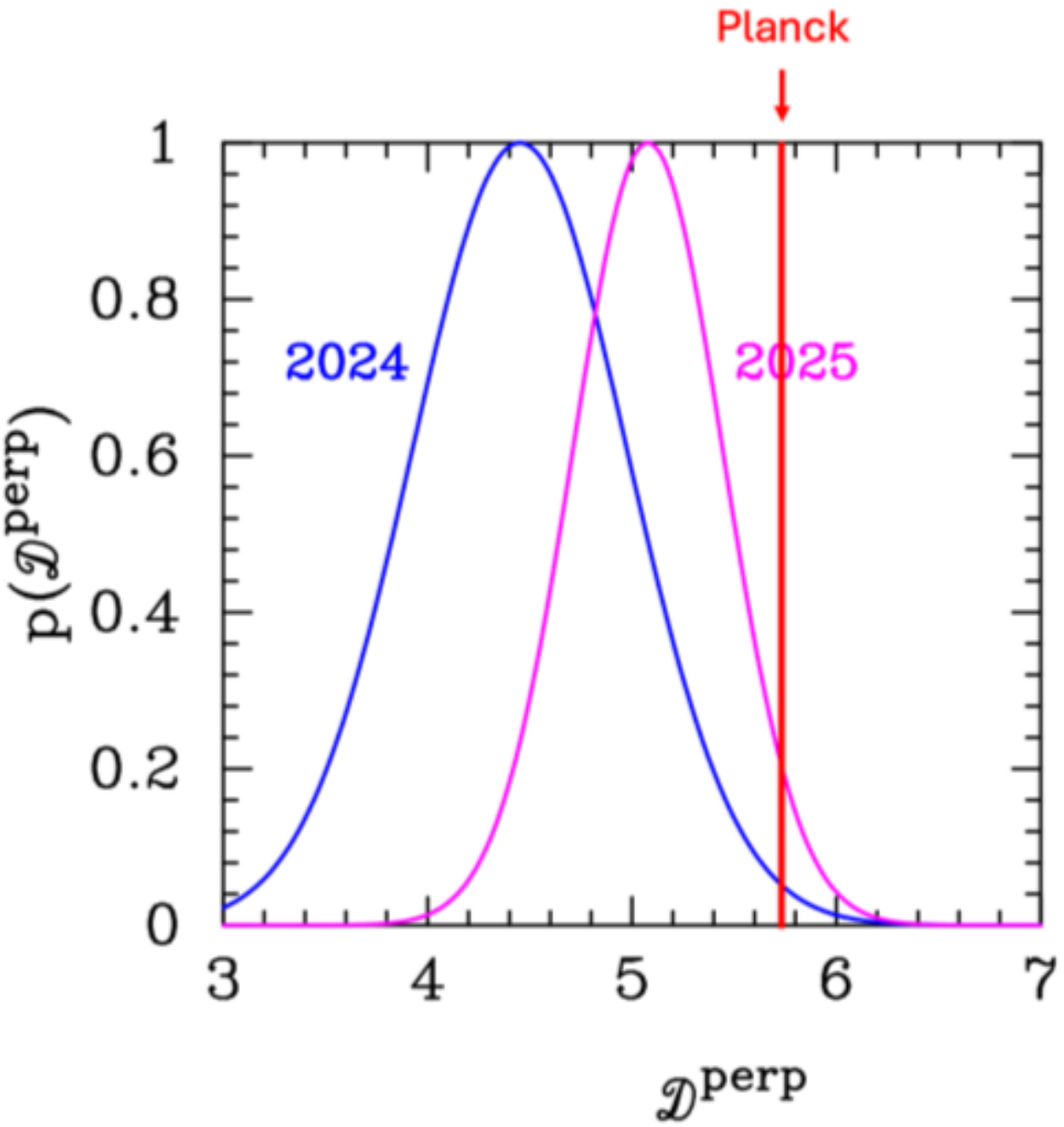

DESI 2024 LRG1 z_{eff}=0.510
$D_H(z)/r_d$
$D_M(z)/r_d$
24
23
22
21
20
19
11
12
13
14
15
16


DESI 2024 LRG1 z_{eff}=0.510
$\mathcal{D}^{perp}$
$\mathcal{D}^{par}$
7
6
5
4
3
22
23
24
25
26
27


DESI 2025 LRG1 z_{eff}=0.510
$\mathcal{D}^{perp}$
$\mathcal{D}^{par}$
7
6
5
4
3
22
23
24
25
26
27


DESI 2024 LRG2 z_{eff}=0.706
12
11
10
9
8
7
23
24
25
26
27
28
$\mathscr{D}^{perp}$
$\mathscr{D}^{par}$


DESI 2025 LRG2 z_{eff}=0.706
12
11
10
9
8
7
23
24
25
26
27
28
$\mathscr{D}^{perp}$
$\mathscr{D}^{par}$

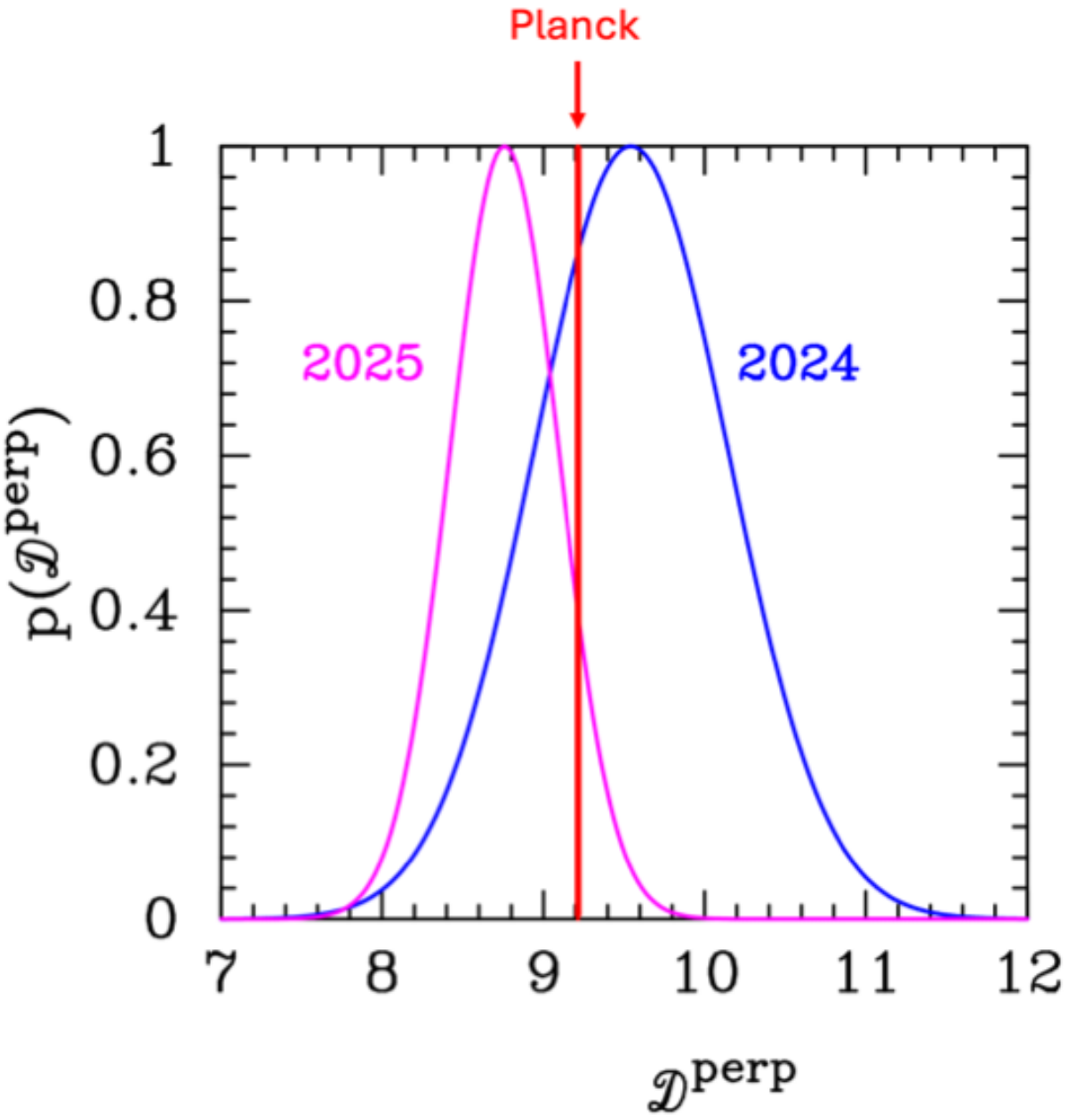


LRG1

Planck $D^{perp} = 5.736$

DESI 2024 $D^{perp} = 4.450 \pm 0.524$ 2.45σ $p = 0.016$

DESI 2025 $D^{perp} = 5.077 \pm 0.367$ 1.80σ $p = 0.075$

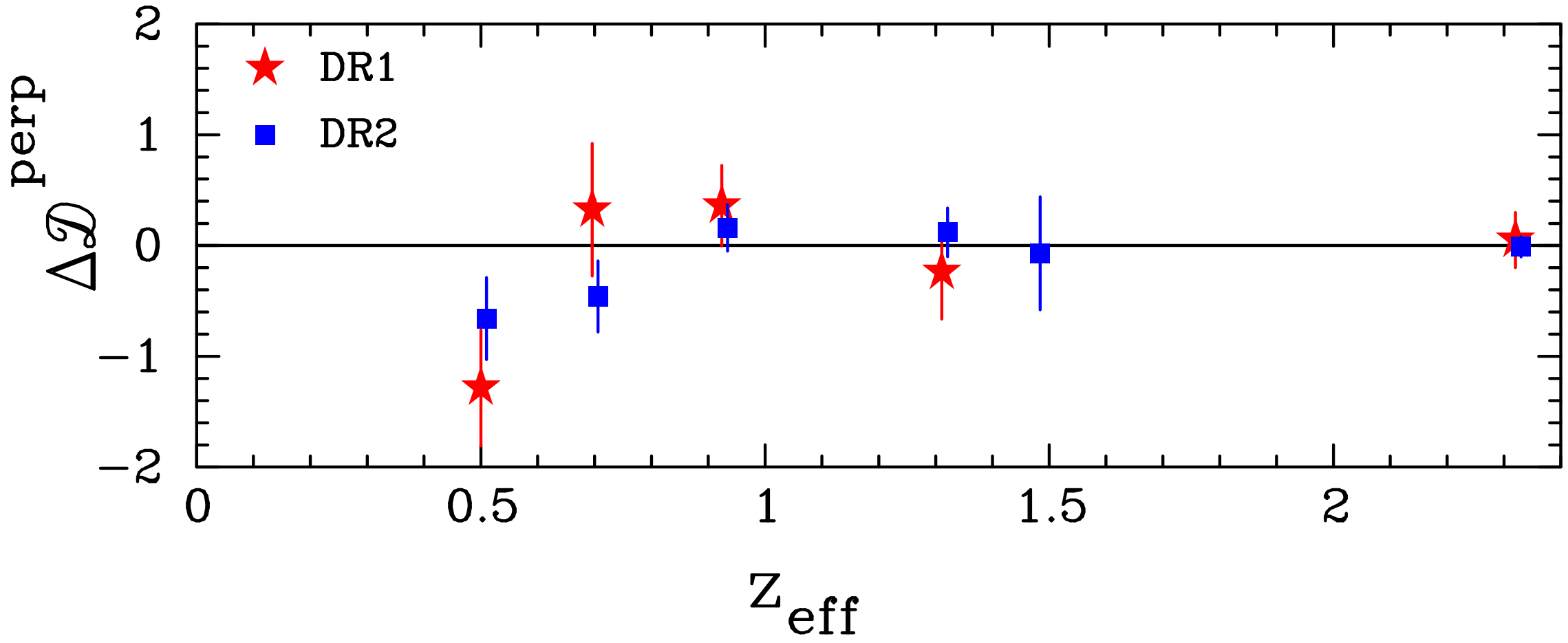


LRG2

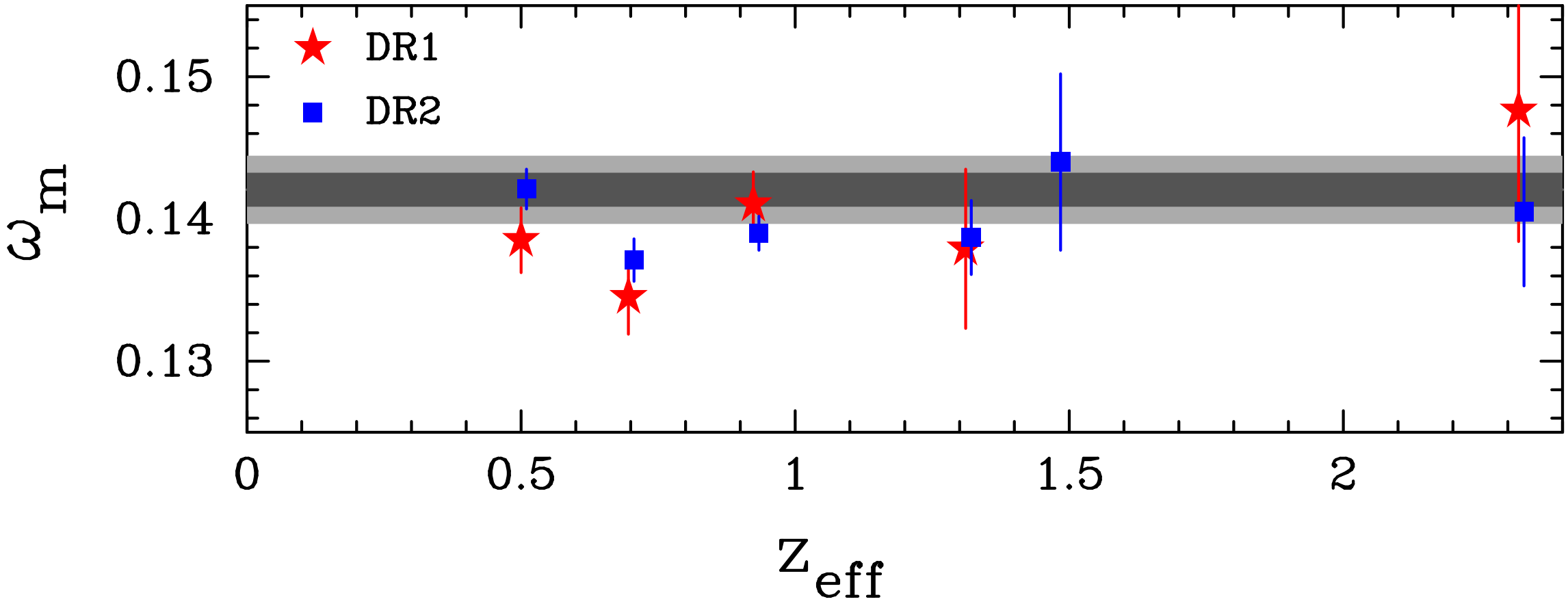
Planck D^{perp} = 9.227

DESI 2024 D^{perp} = 9.543±0.603 0.54σ $p = 0.60$

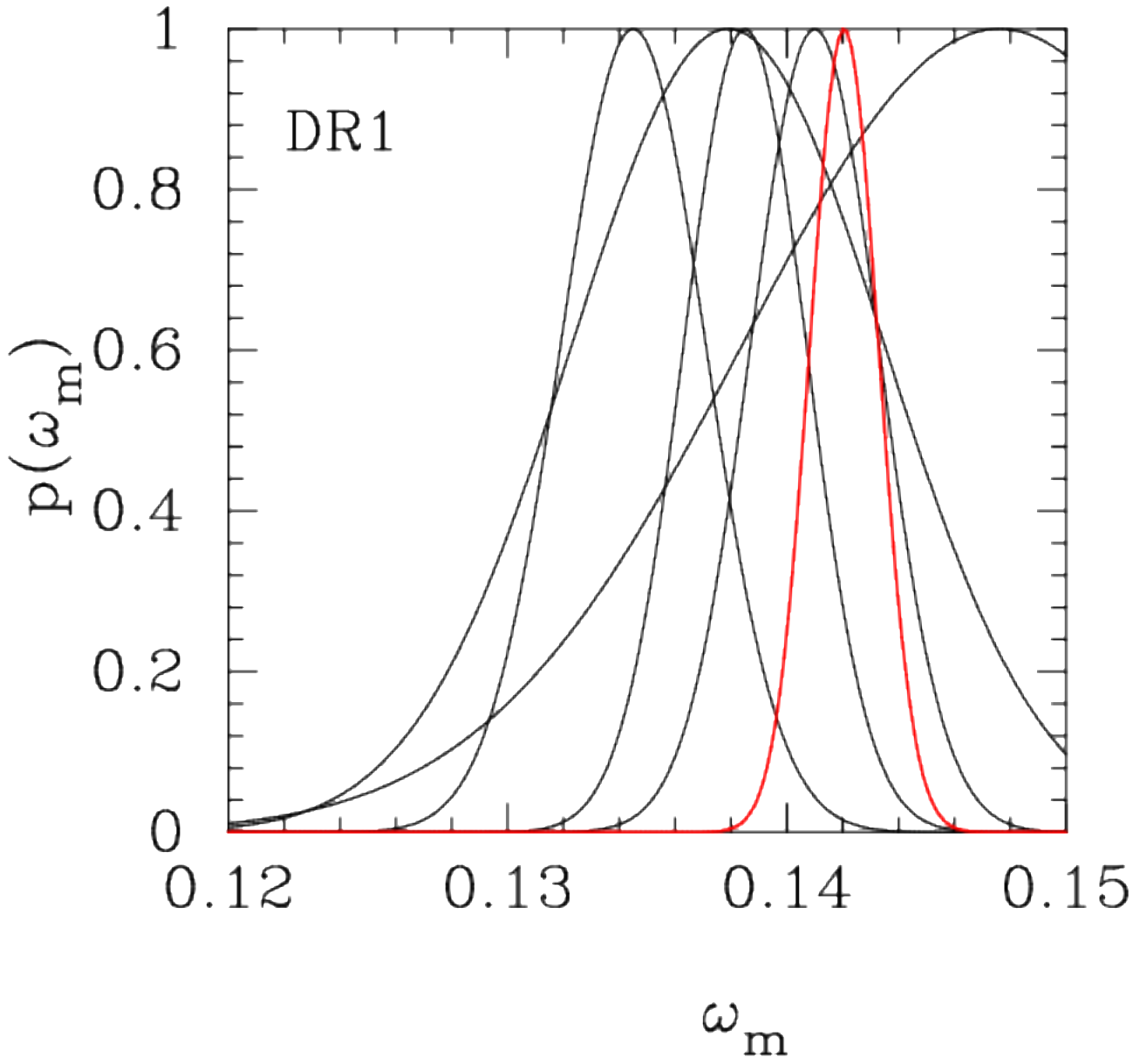
DESI 2025 D^{perp} = 8.758±0.336 1.35σ $p = 0.16$

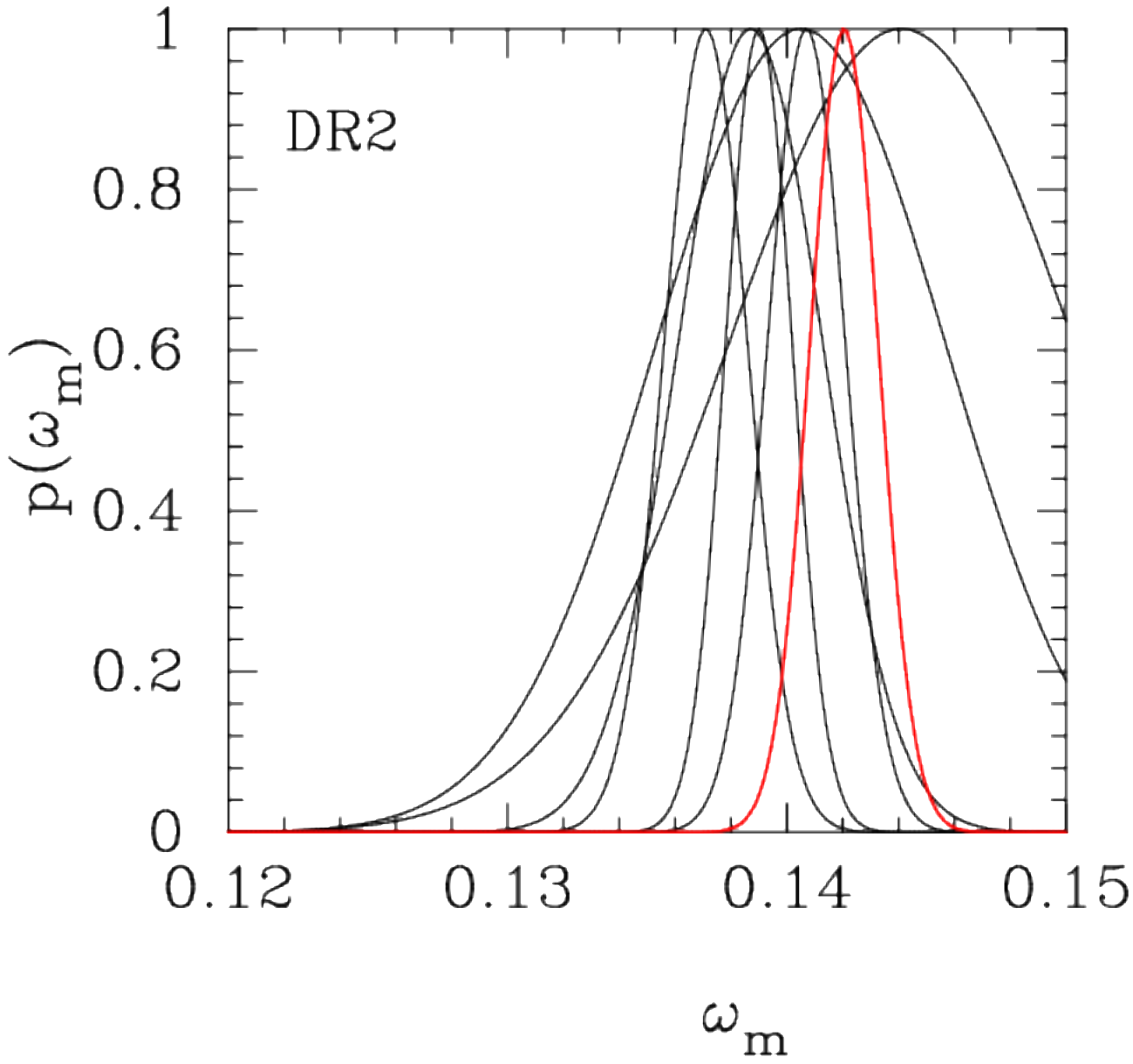


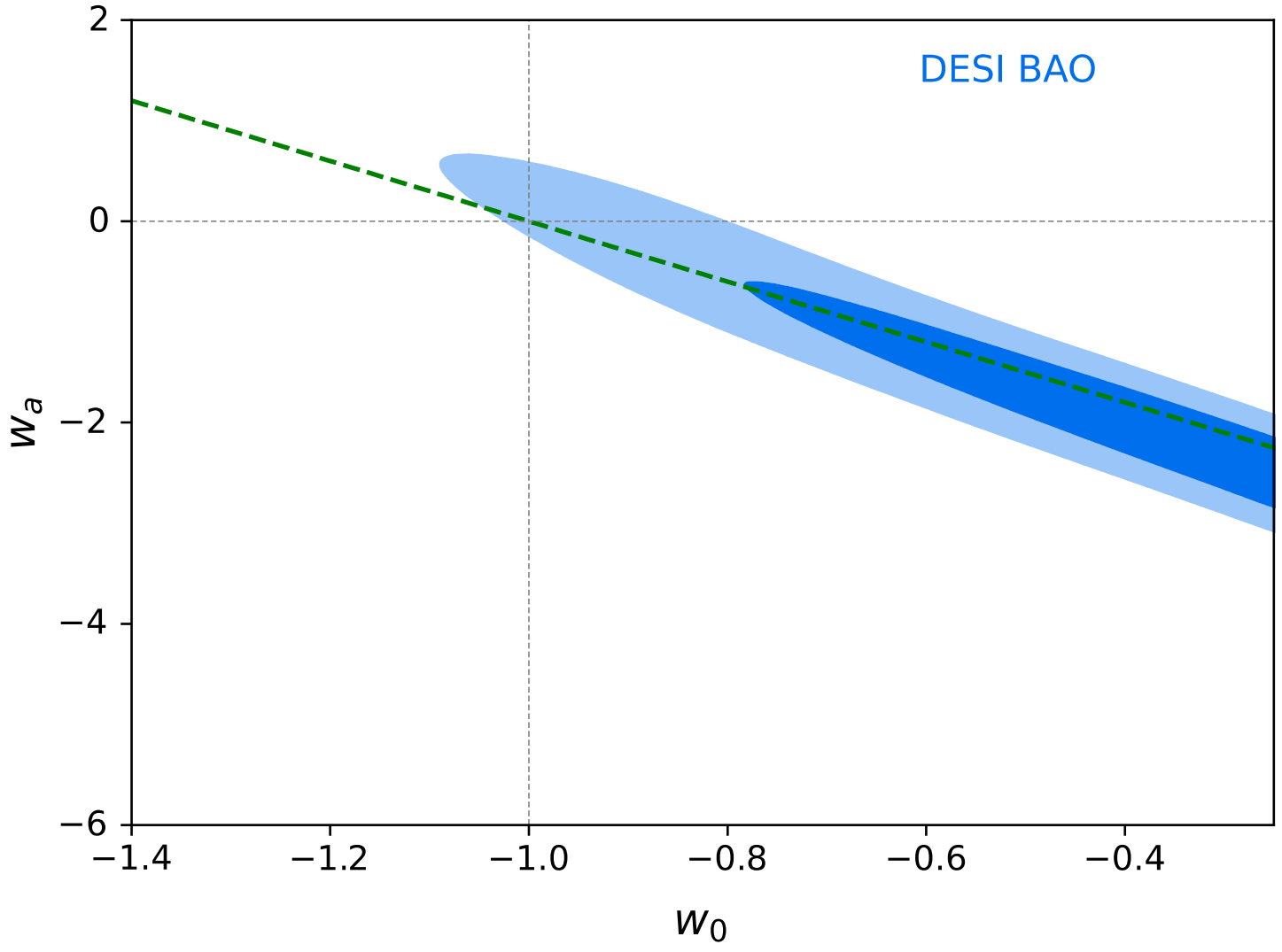
DR1: $\chi^2 =$ 7.79 (5 data points) 0.9σ
DR2: $\chi^2 =$ 5.92 (6 data points) 0.02σ



Planck	$\omega_m = 0.14205 \pm 0.00123$	
DESI DR1	$\omega_m = 0.1384 \pm 0.0015$	(1.9σ)
DESI DR2	$\omega_m = 0.1391 \pm 0.0007$	(2.1σ)
P-ACT	$\omega_m = 0.1425 \pm 0.0012$	

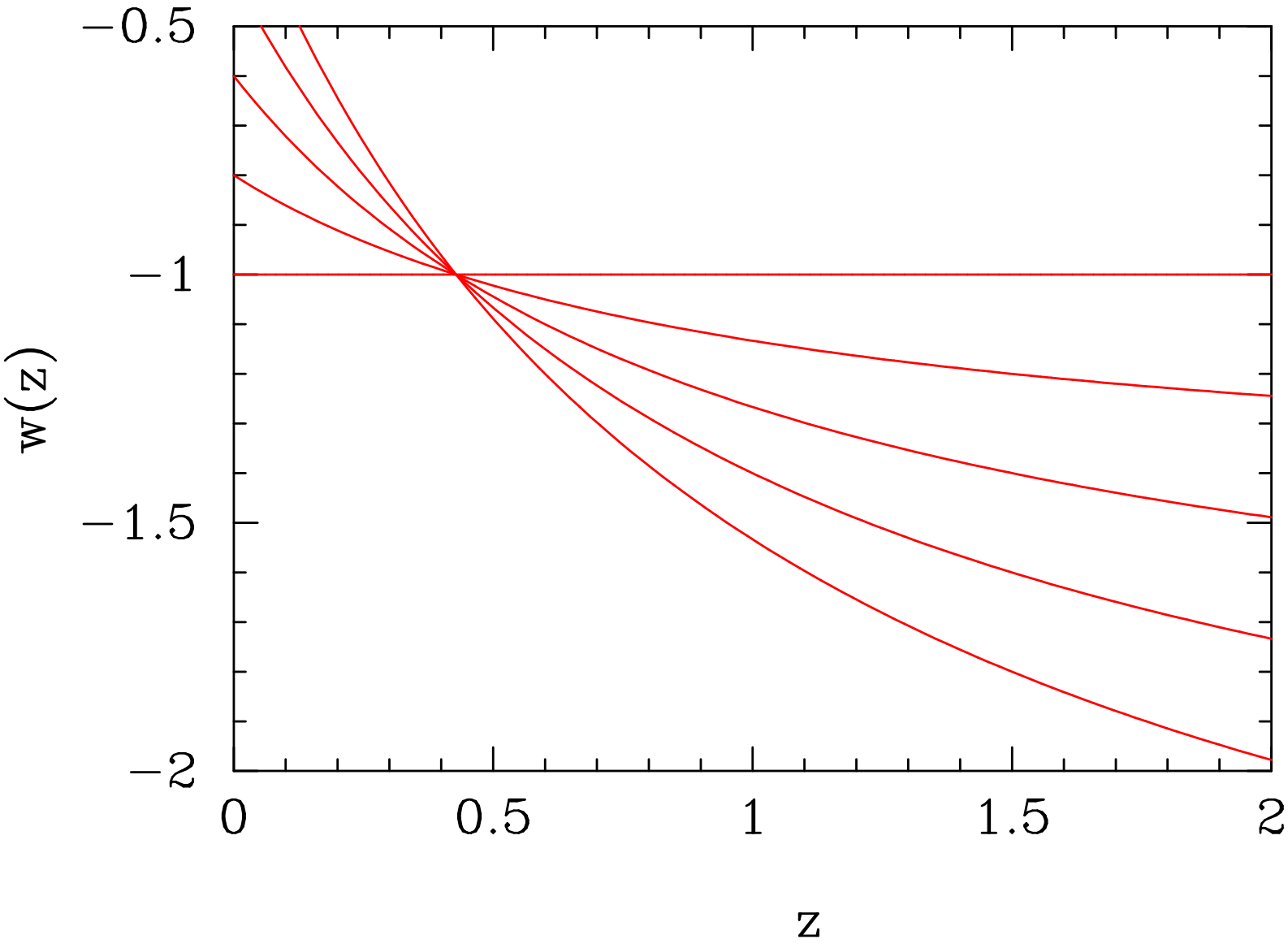

DR1
1
0.8
0.6
0.4
0.2
0
p(ω_m)
0.12
0.13
0.14
0.15
ω_m


DR2
1
0.8
0.6
0.4
0.2
0
p(ω_m)
0.12
0.13
0.14
0.15
ω_m

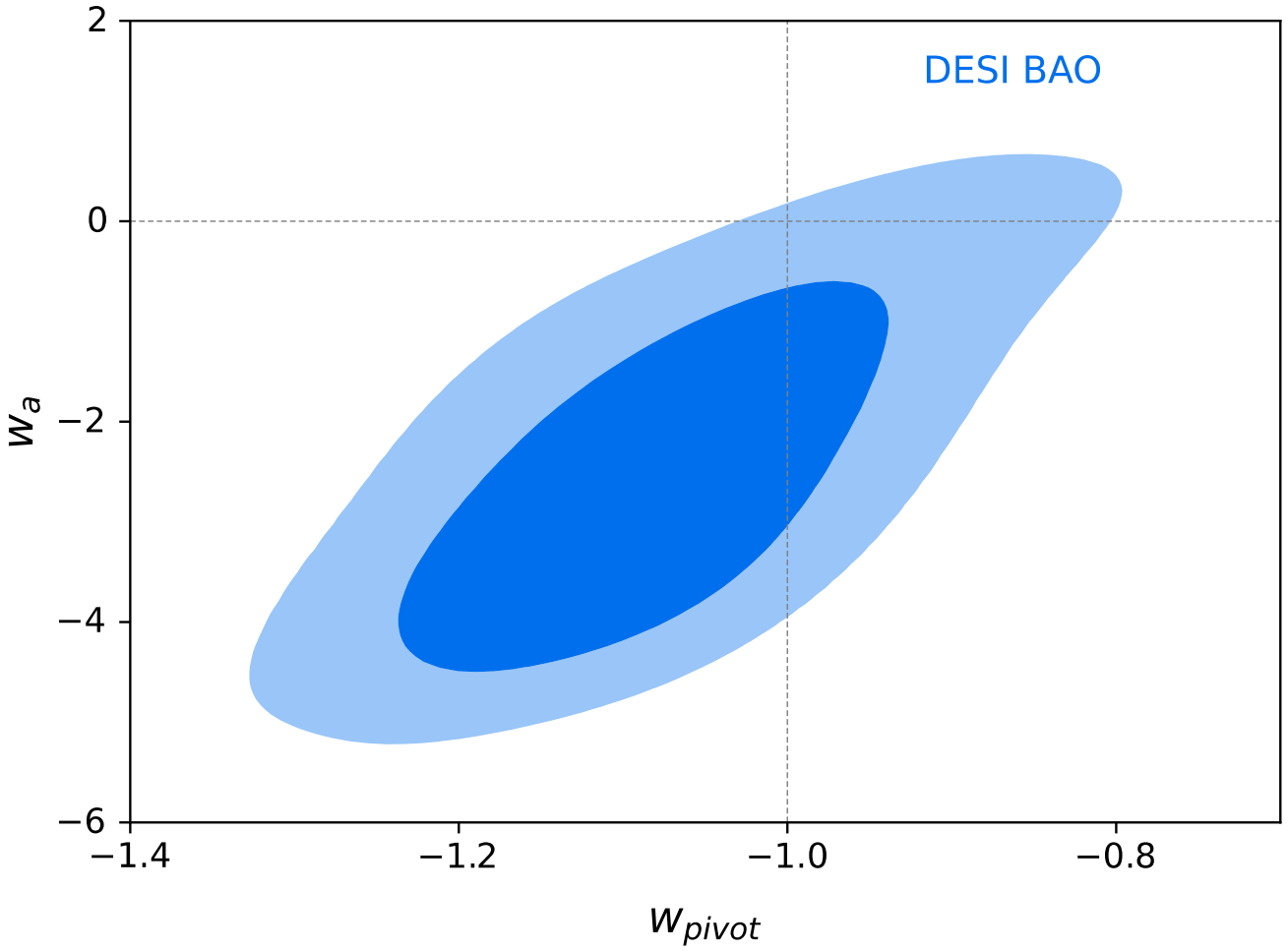


$$w_{\rm piv} = w_0 + w_a \left(\frac{z_{\rm piv}}{1 + z_{\rm piv}} \right)$$

$$w_0 = -1 - w_a \left(\frac{z_{\rm piv}}{1 + z_{\rm piv}} \right)$$



w_0	w_a
-1	0
-0.8	-0.666
-0.6	-1.333
-0.4	-2.0
-0.2	-2.666



$w_{piv} = -0.996 \pm 0.046$

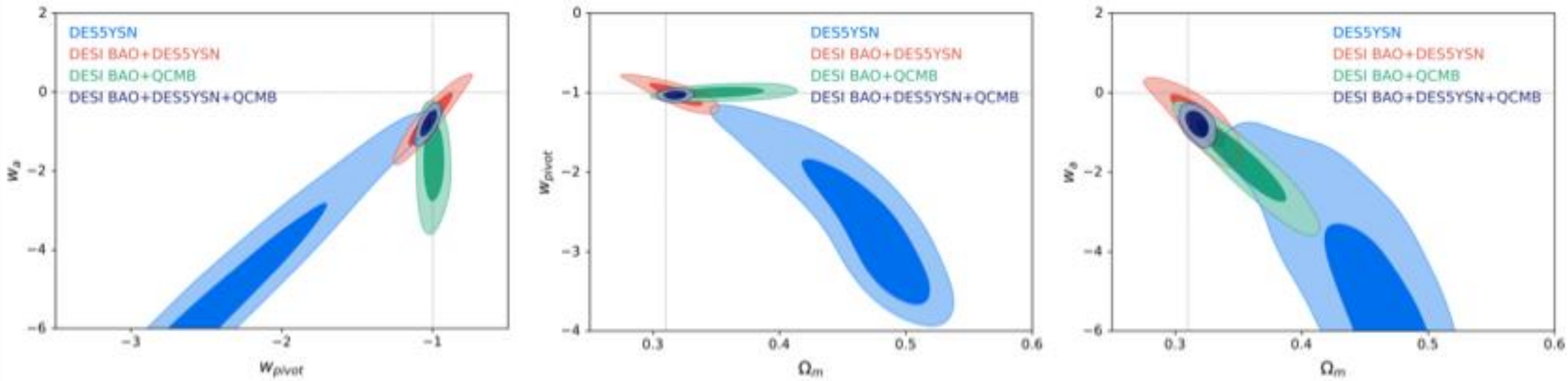
$w_a = -1.78 \pm 0.79$

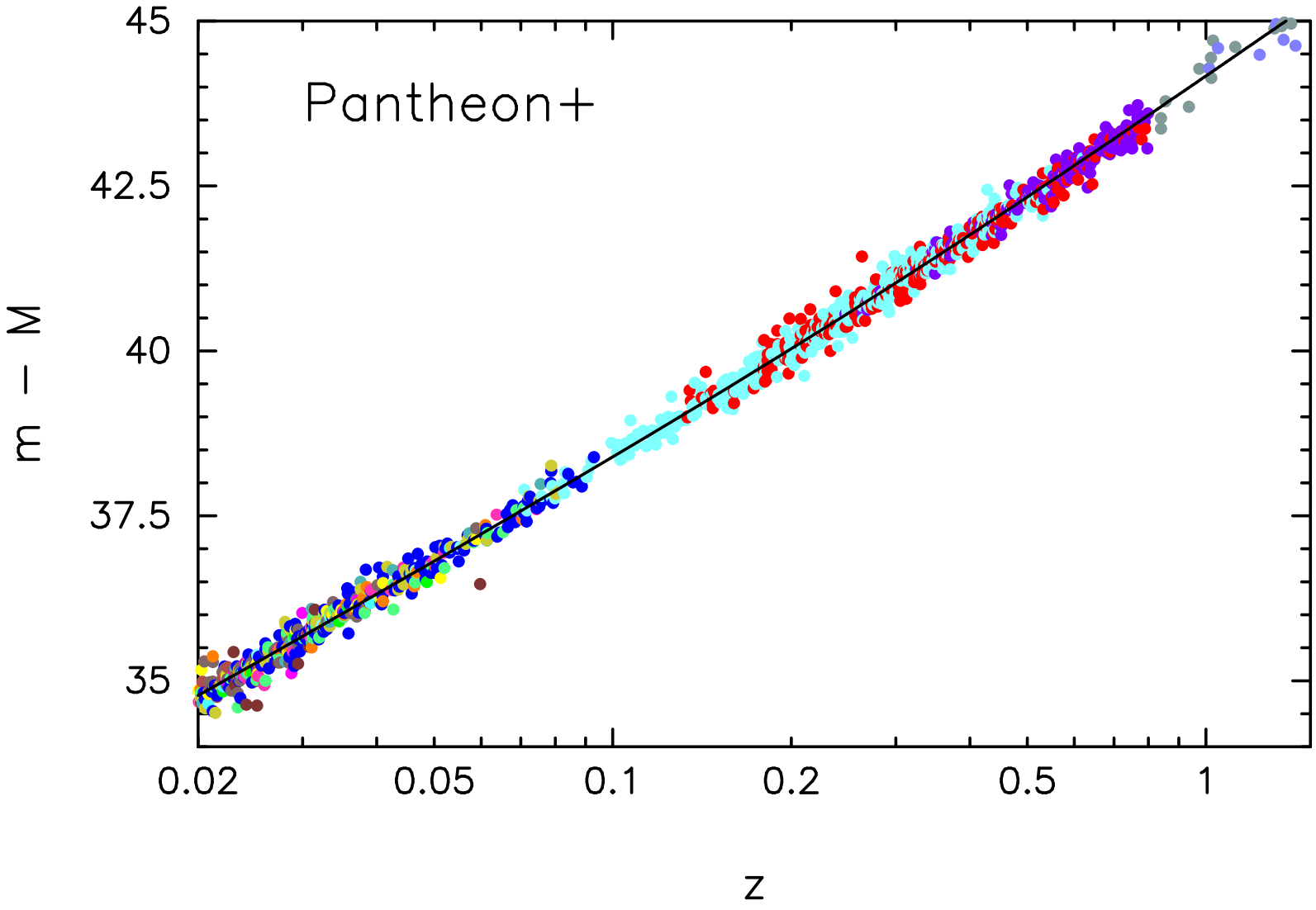
Frankensigmas

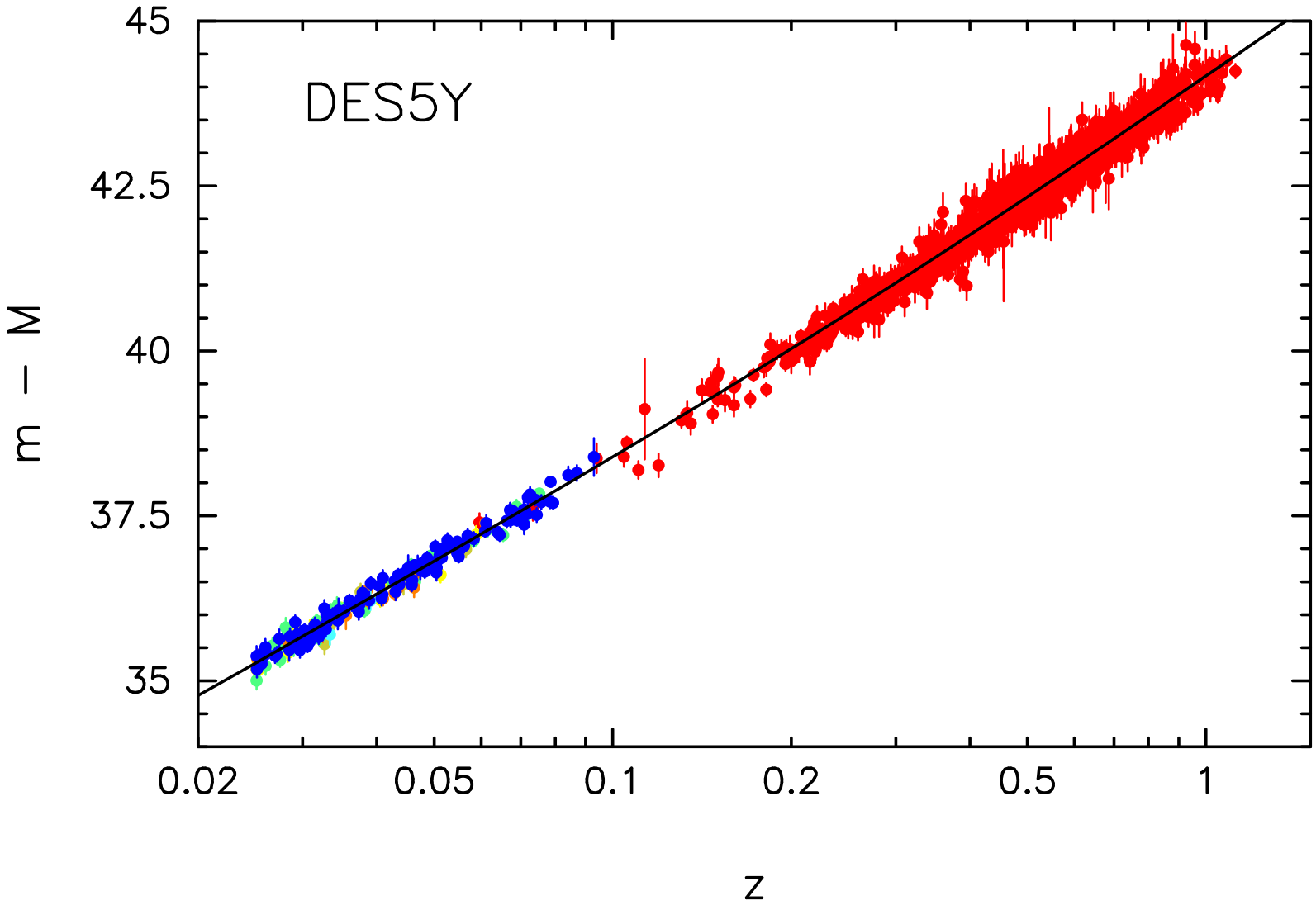
Model	$\Delta\chi^2$	p-value	σ (two-tailed)	σ (one-tailed)
$w_{piv}\, w_a$	8.0	0.0183	2.4	2.1
w_a	8.0	0.0047	2.8	2.6

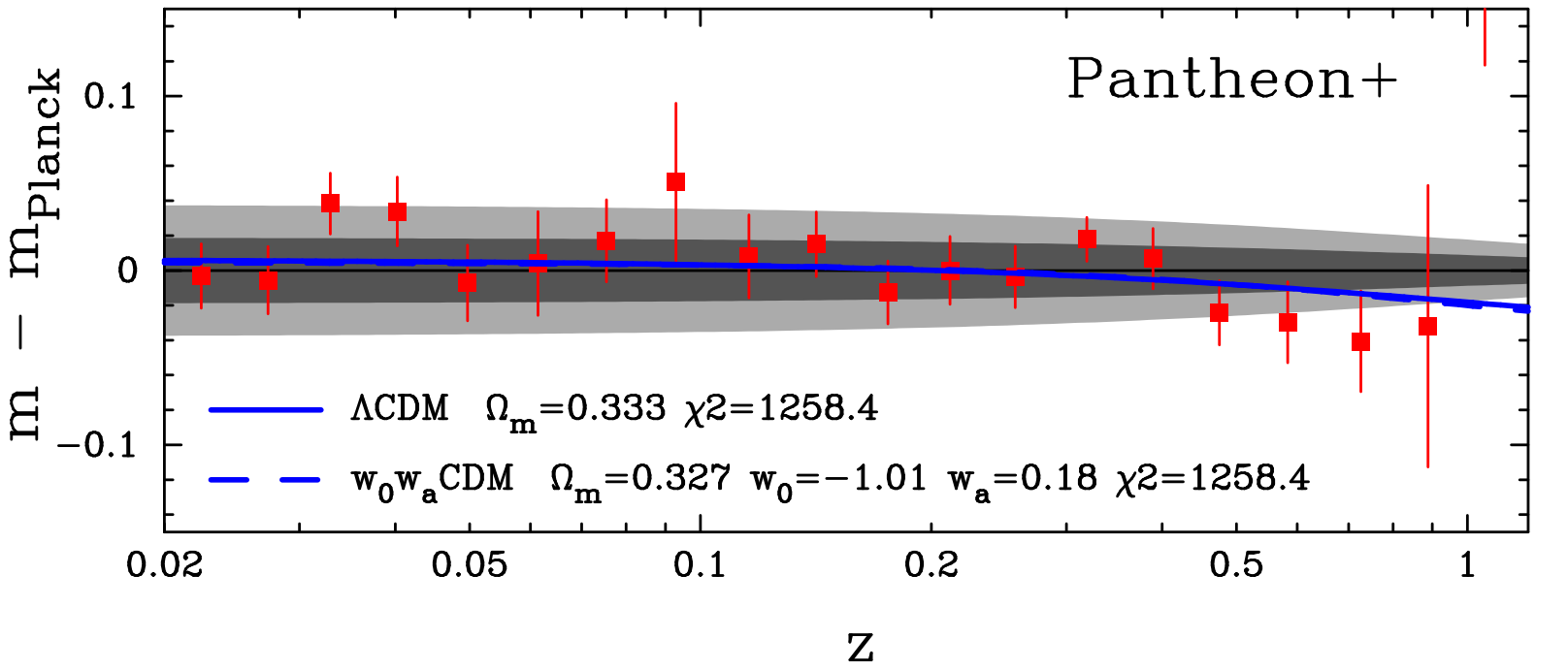
Probability is degree of belief. To believe that the data points to evolving dark energy you have to:

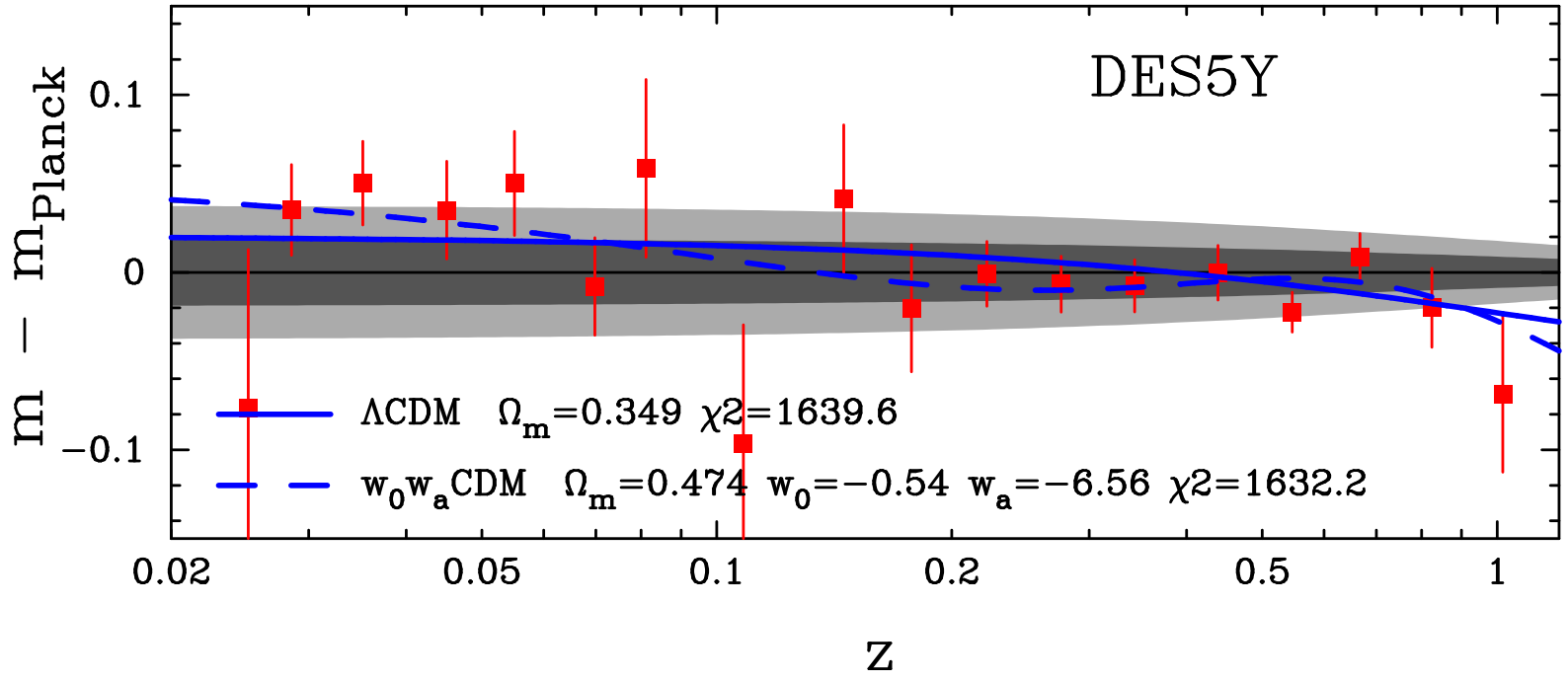
- ❑ believe that any model in the w_0 , w_a, plane has the same prior probability as Λ.
- ❑ believe that of all possible models of evolving dark energy those favoured by the data belong to the 'mirage dark energy' family for which the angular diameter distance to last scattering is the *same* as ΛCDM. (Hence w is close to -1 at the redshift where w is best constrained by the data and w_{piv} decorrelates with $w_{a.}$)
- ❑ believe that the heuristic $\Delta\chi^2_{MAP}$ statistic accurately accounts for overfitting of the data
- ❑ disregard the fact that with the substantial increase in statistical power of DESI DR2 over DR1, the fit to Planck ΛCDM *improves*.
- ❑ discount the fact that the inclusion of powerful new CMB data from ACT does not strengthen the evidence for evolving dark energy.


DES5YSN
DESI BAO+DES5YSN
DESI BAO+QCMB
DESI BAO+DES5YSN+QCMB
w_a
w_{pivot}
w_{pivot}
Ω_m
w_a
Ω_m

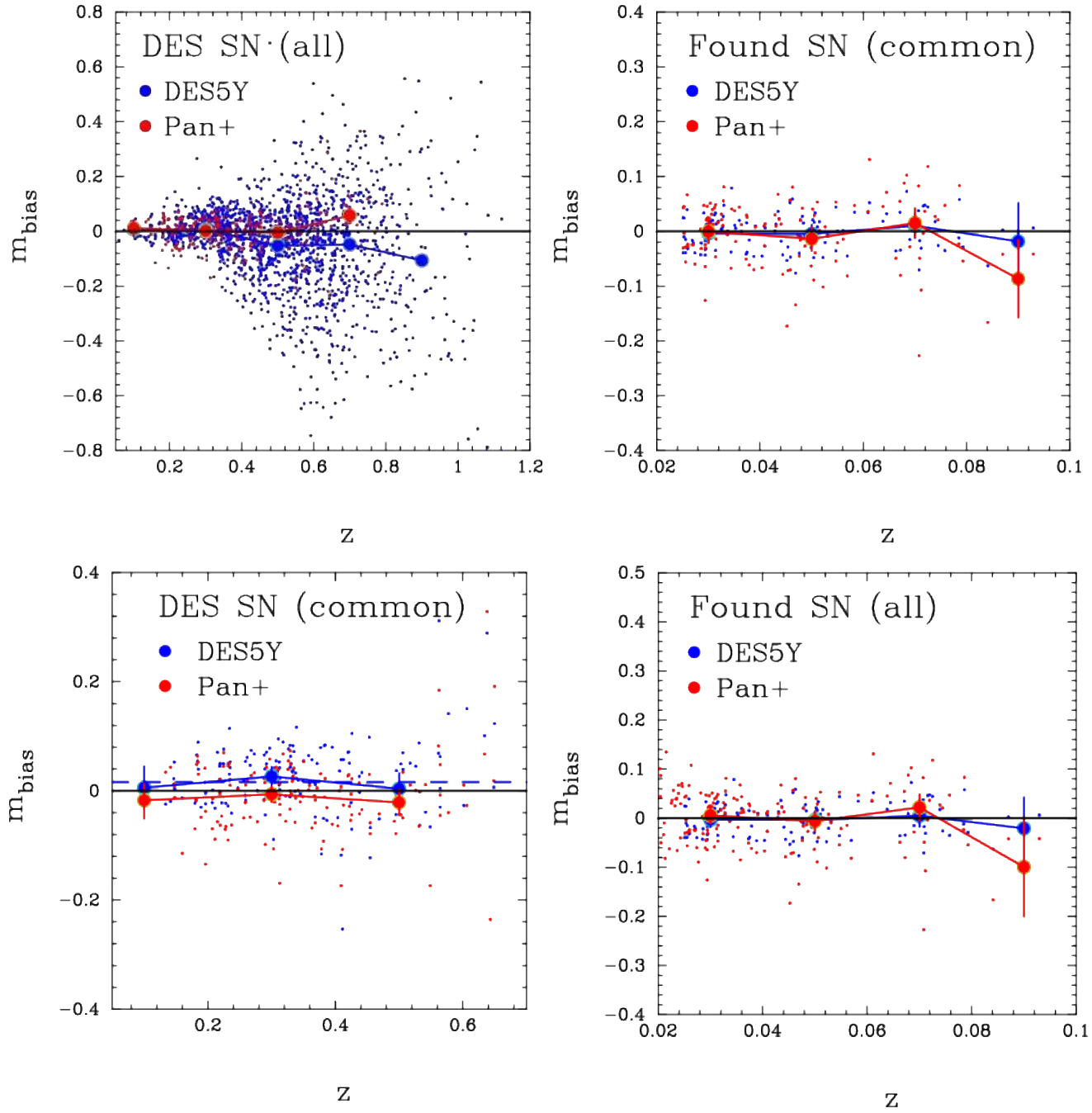

Pantheon+
m − M
z
45
42.5
40
37.5
35
0.02
0.05
0.1
0.2
0.5
1


DES5Y
45
42.5
40
37.5
35
m − M
0.02
0.05
0.1
0.2
0.5
1
z


Pantheon+
m − m_Planck
0.1
0
−0.1
ΛCDM Ω_m=0.333 χ2=1258.4
w_0w_aCDM Ω_m=0.327 w_0=−1.01 w_a=0.18 χ2=1258.4
0.02
0.05
0.1
0.2
0.5
1
z


DES5Y
m − m_Planck
0.1
0
−0.1
ΛCDM Ω_m=0.349 χ2=1639.6
w_0w_aCDM Ω_m=0.474 w_0=−0.54 w_a=−6.56 χ2=1632.2
0.02
0.05
0.1
0.2
0.5
1
z

$$E(M) = \int d\boldsymbol{\theta} P(D|\boldsymbol{\theta} M) \pi(\boldsymbol{\theta}|M)$$


DES SN (all)
DES5Y
Pan+
Found SN (common)
DES5Y
Pan+
DES SN (common)
DES5Y
Pan+
Found SN (all)
DES5Y
Pan+
m_{bias}
z