Modified gravity interpretation of the evolving dark energy in light of DESI data

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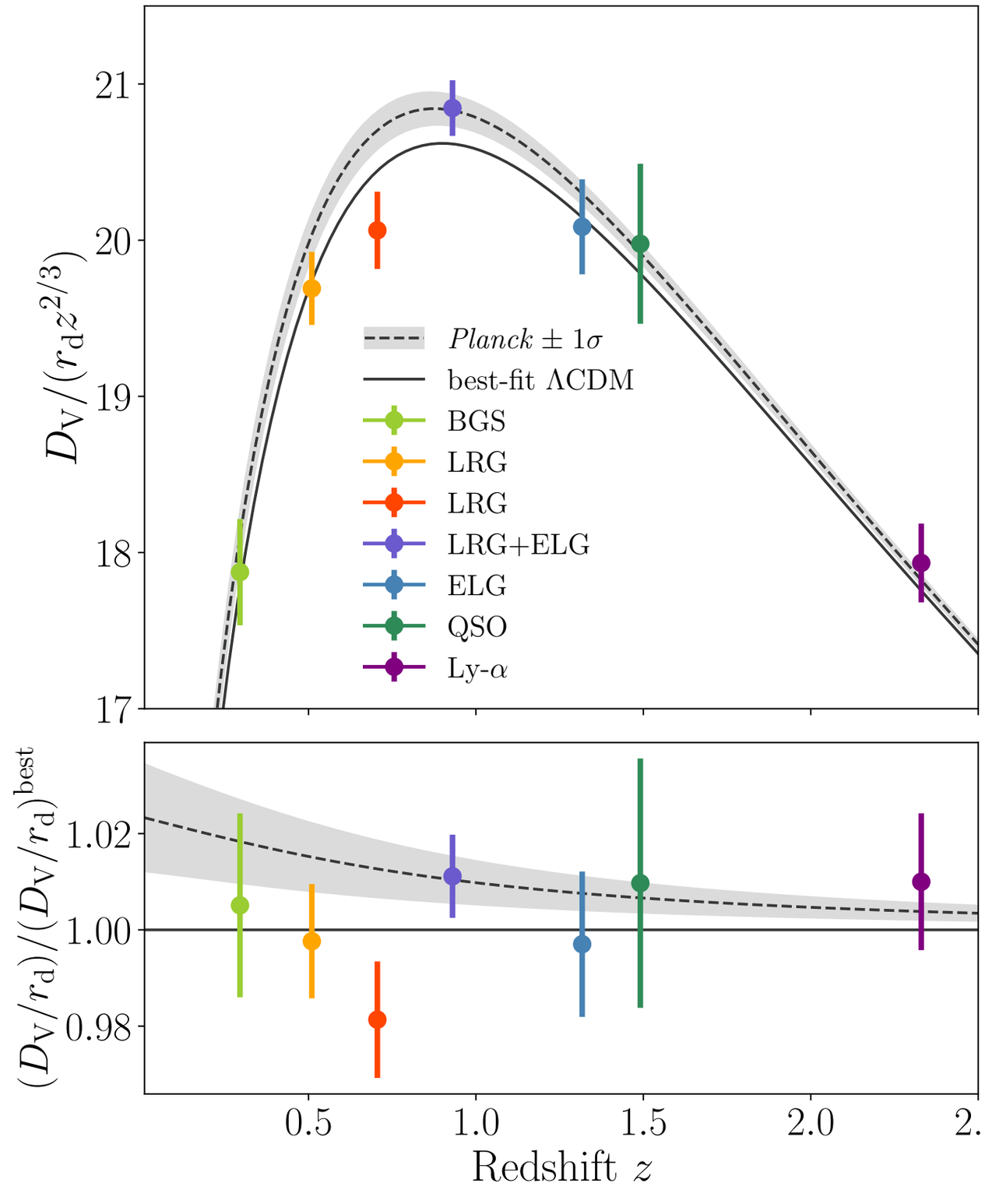
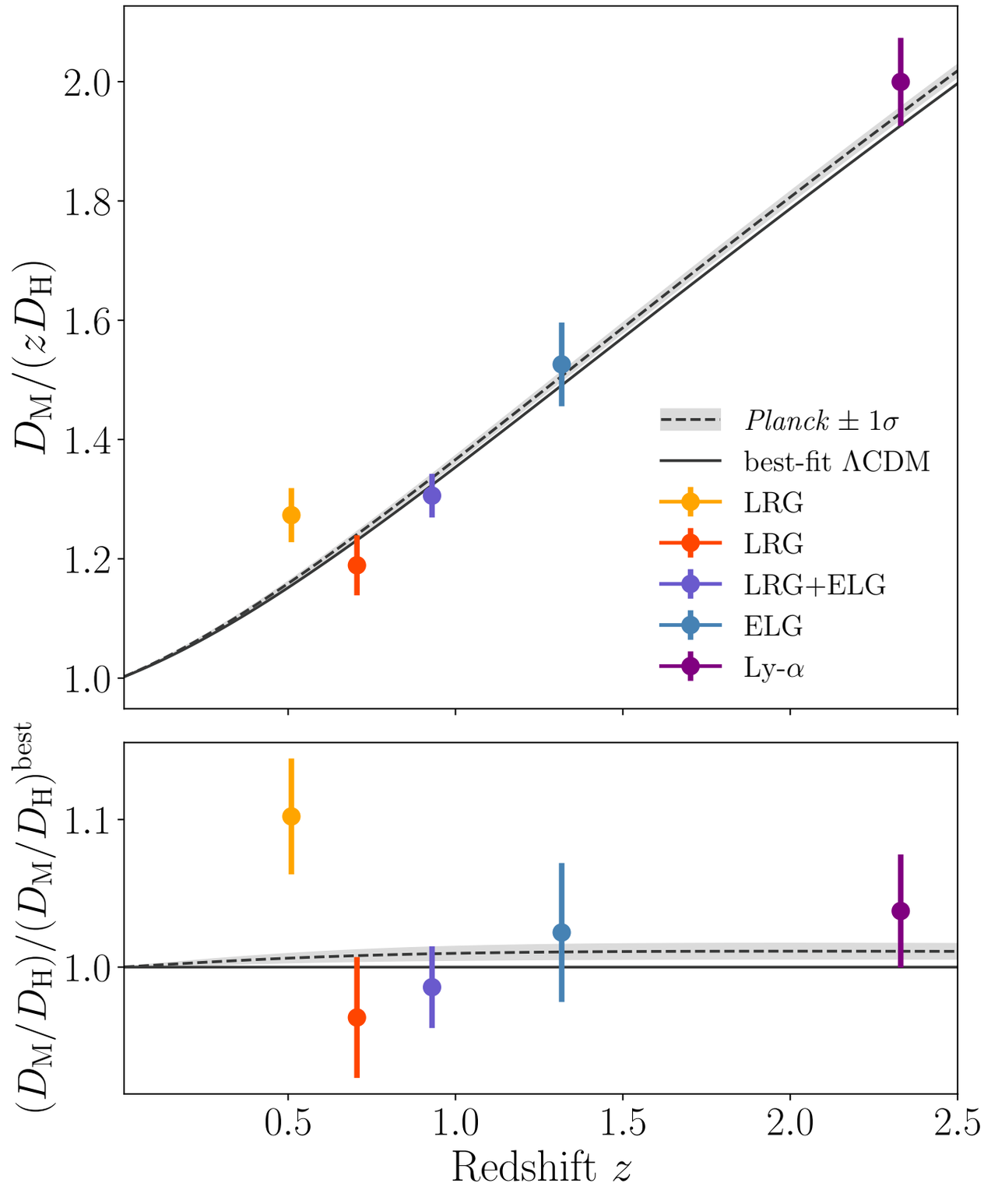
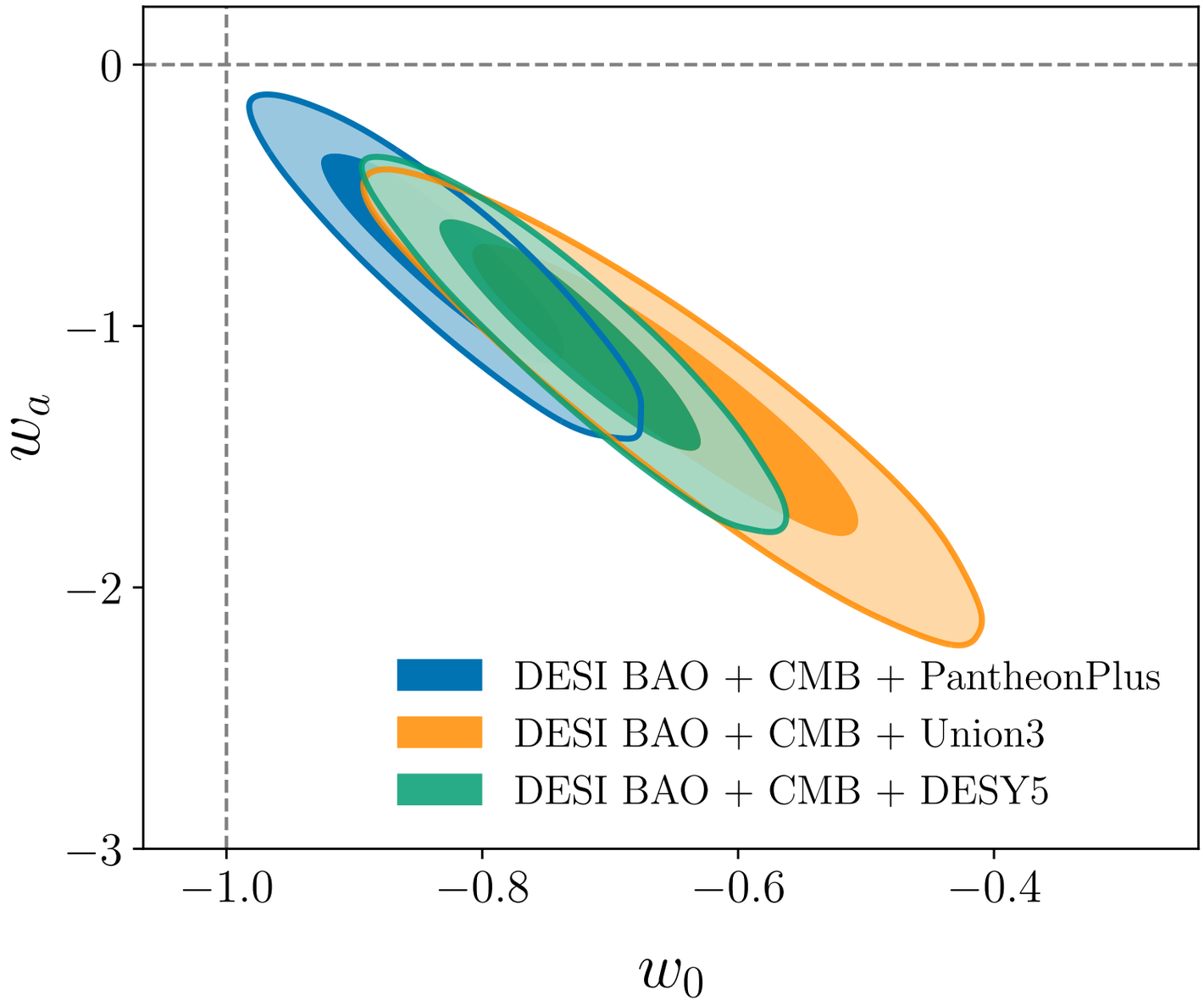
DESI BAO DR1


$D_{\rm V}/(r_{\rm d}z^{2/3})$
21
20
19
18
17
Planck $\pm 1\sigma$
best-fit ΛCDM
BGS
LRG
LRG
LRG+ELG
ELG
QSO
Ly-α
$(D_{\rm V}/r_{\rm d})/(D_{\rm V}/r_{\rm d})^{\rm best}$
1.02
1.00
0.98
0.5
1.0
1.5
2.0
2.5
Redshift z


$D_{\rm M}/(zD_{\rm H})$
2.0
1.8
1.6
1.4
1.2
1.0
Planck $\pm 1\sigma$
best-fit ΛCDM
LRG
LRG
LRG+ELG
ELG
Ly-α
$(D_{\rm M}/D_{\rm H})/(D_{\rm M}/D_{\rm H})^{\rm best}$
1.1
1.0
0.5
1.0
1.5
2.0
2.5
Redshift z

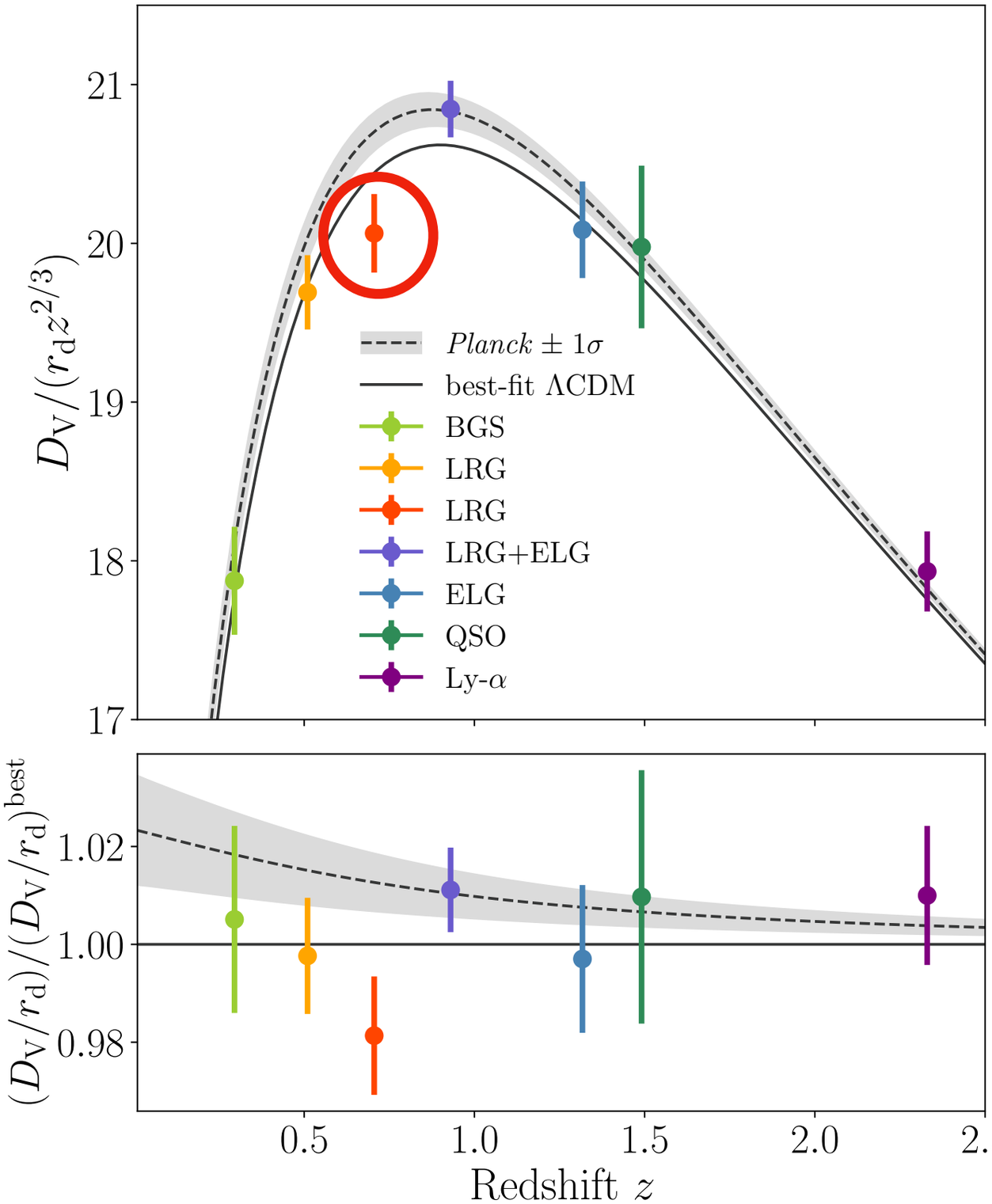
DESI+CMB+SN

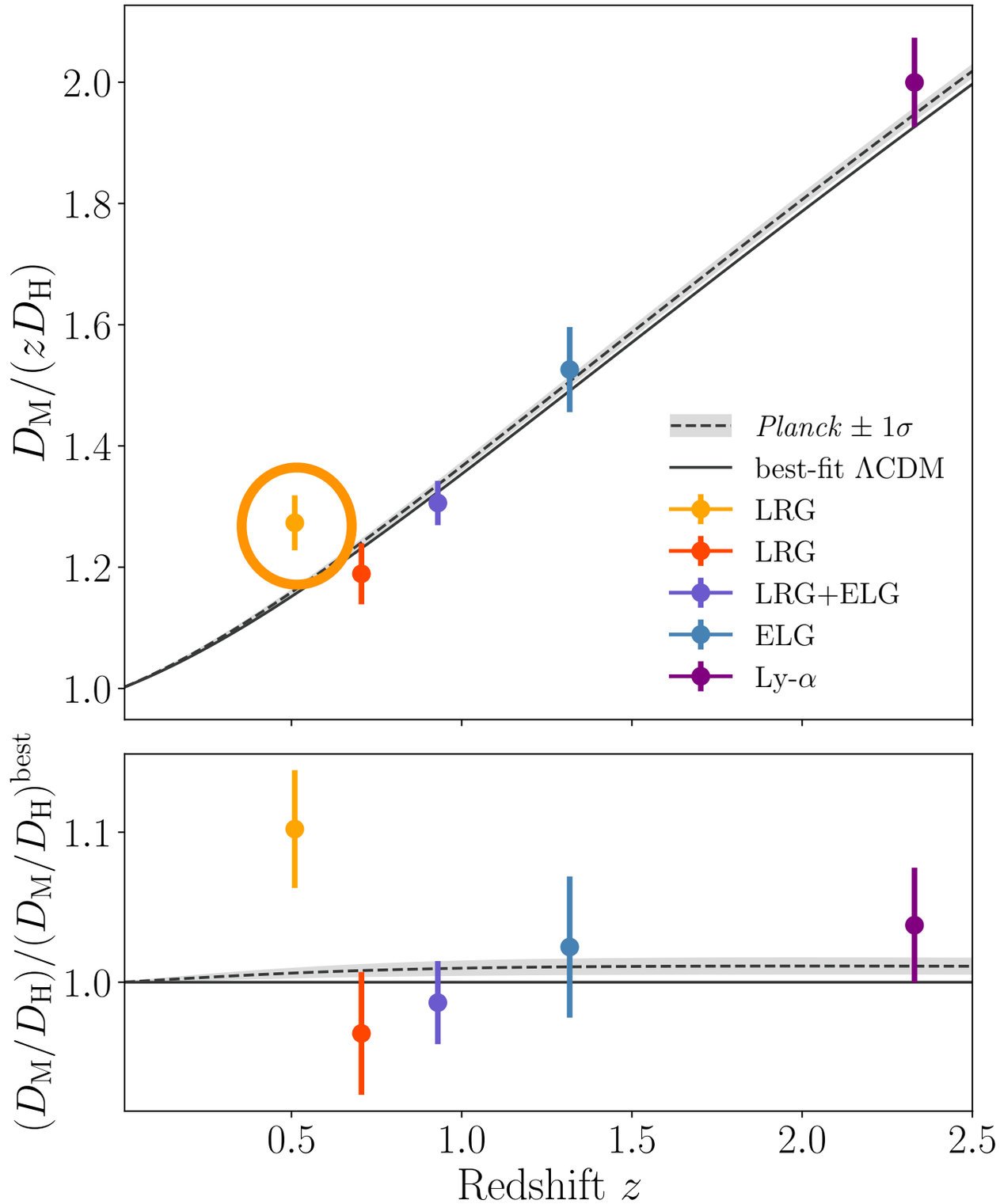


Preference for time-evolving dark energy ranges from $2.5\sigma - 3.9\sigma$

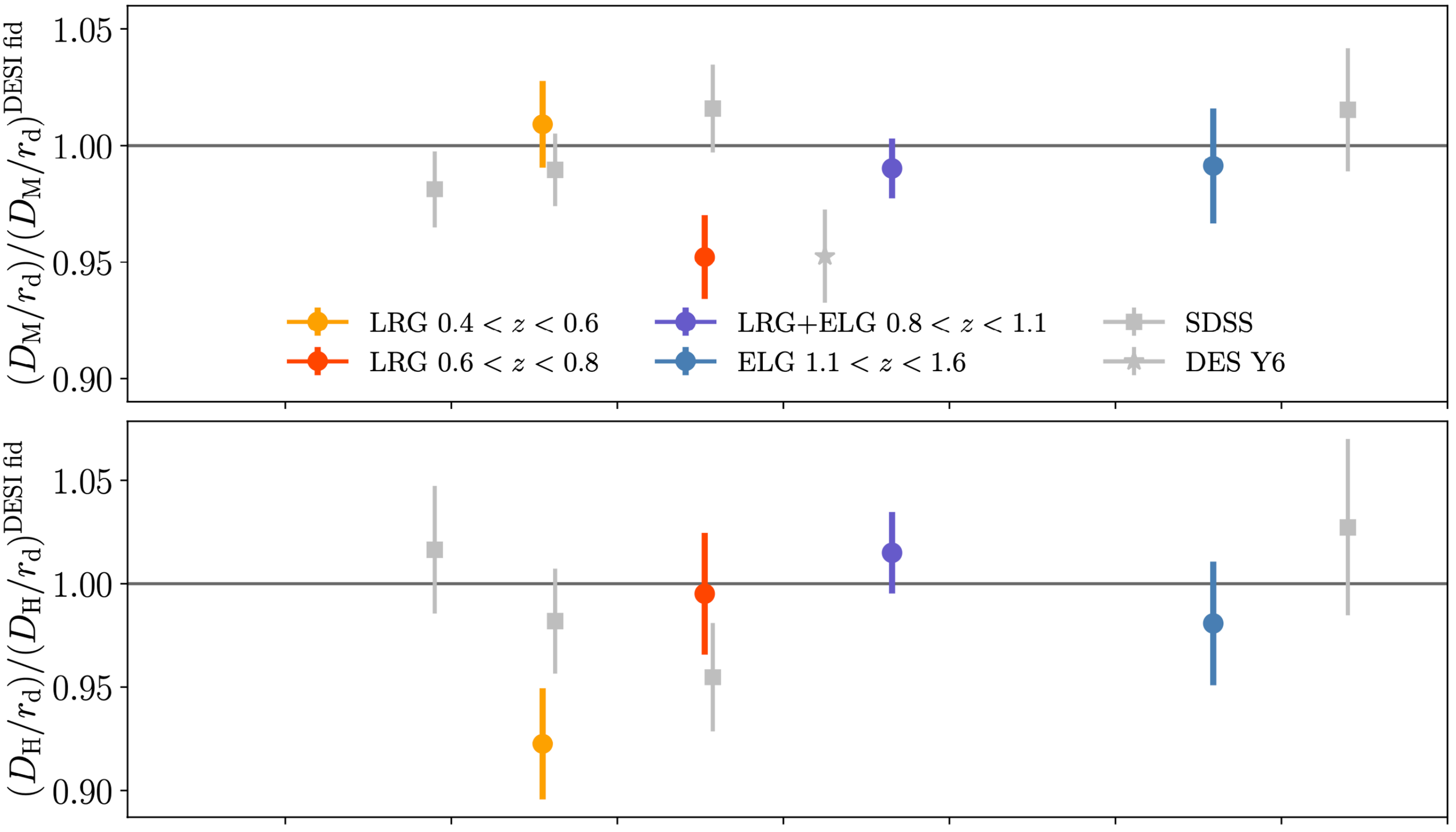
What drives this preference?

DESI vs Planck ΛCDM

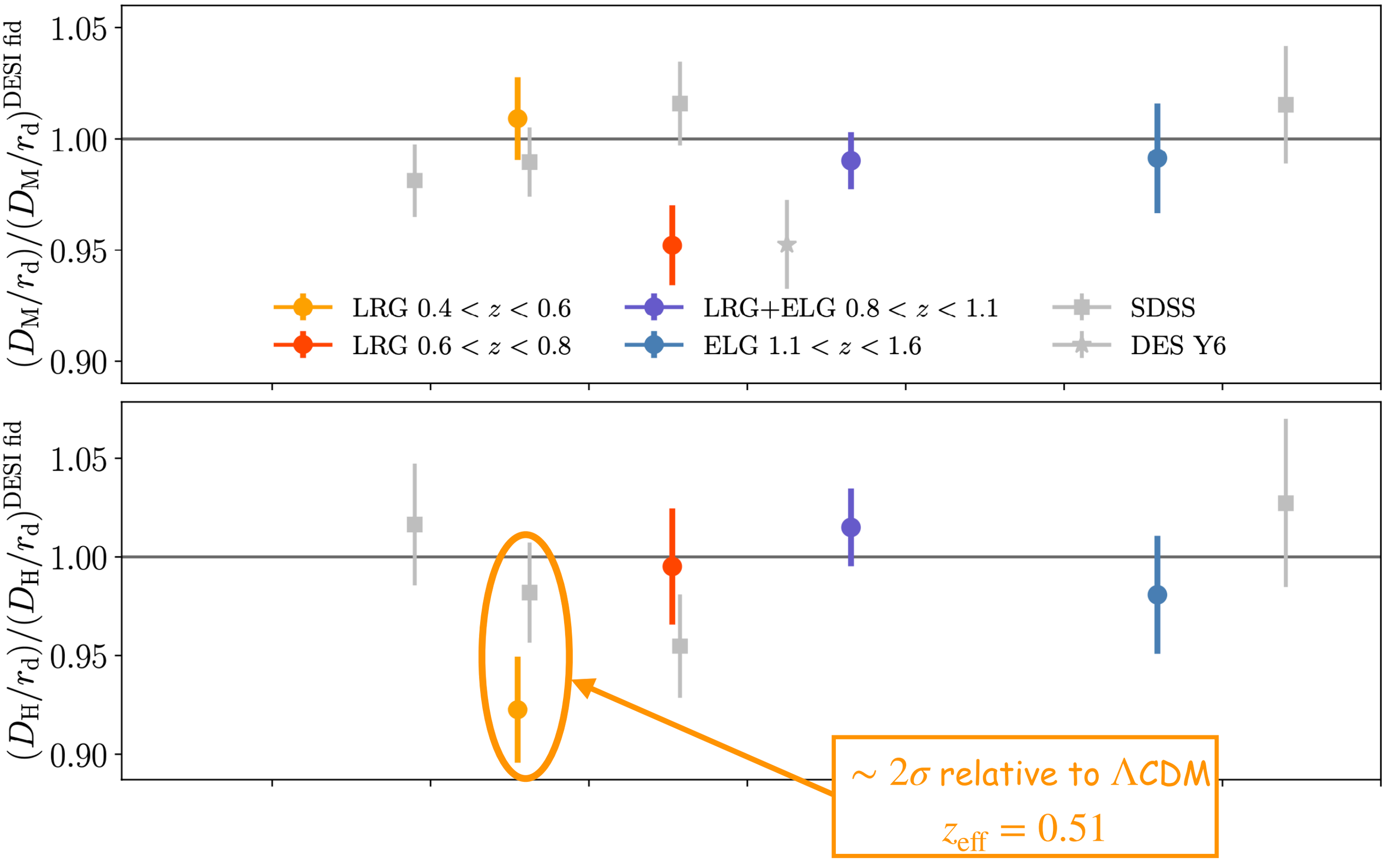




DESI vs SDSS


$(D_M/r_d)/(D_M/r_d)^{DESI\ fid}$
1.05
1.00
0.95
0.90
LRG $0.4 < z < 0.6$
LRG $0.6 < z < 0.8$
LRG+ELG $0.8 < z < 1.1$
ELG $1.1 < z < 1.6$
SDSS
DES Y6
$(D_H/r_d)/(D_H/r_d)^{DESI\ fid}$
1.05
1.00
0.95
0.90

DESI vs SDSS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SDSS
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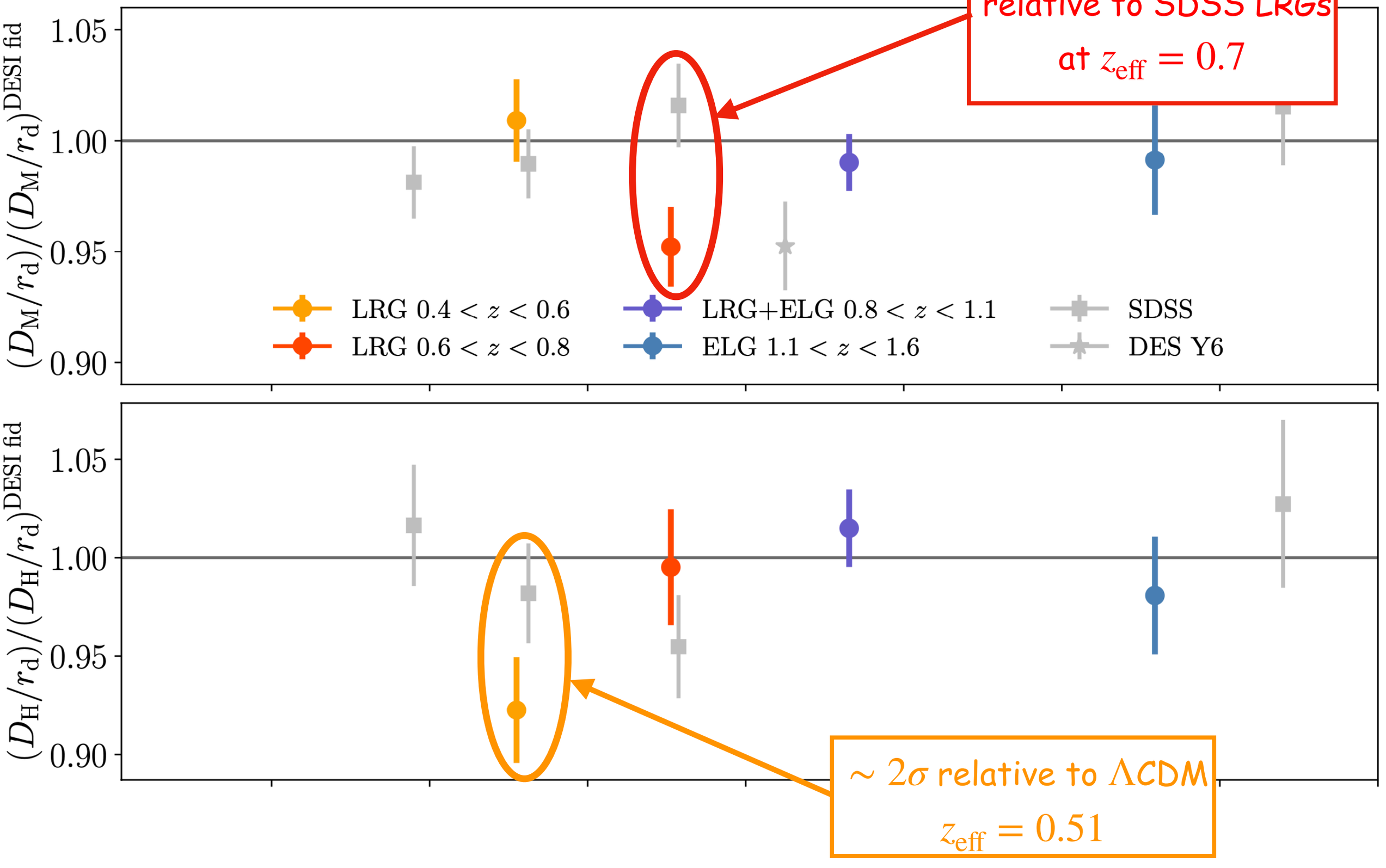
1.05
1.00
0.95
0.90
$\sim 2\sigma$ relative to ΛCDM
$z_{eff} = 0.51$

DESI vs SDSS

$\simeq 3\sigma$ discrepancy relative to SDSS LRGs at $z_{\rm eff} = 0.7$

$\sim 2\sigma$ relative to ΛCDM $z_{\rm eff} = 0.51$



w_0w_aCDM analysis

DESI:

Data	$z_{\rm eff}$	$N_{\rm data}$
BGS	0.30	1
LRG1	0.51	2
LRG2	0.71	2
LRG3+ELG1	0.93	2
ELG2	1.32	2
QSO	1.49	1
Lya	2.33	2
MGS	0.15	1
BOSS DR12	0.38 and 0.51	4
eBOSS DR16	0.7	2

CMB: Planck 2018, Planck&ACT CMB lensing

SN: Pantheon+

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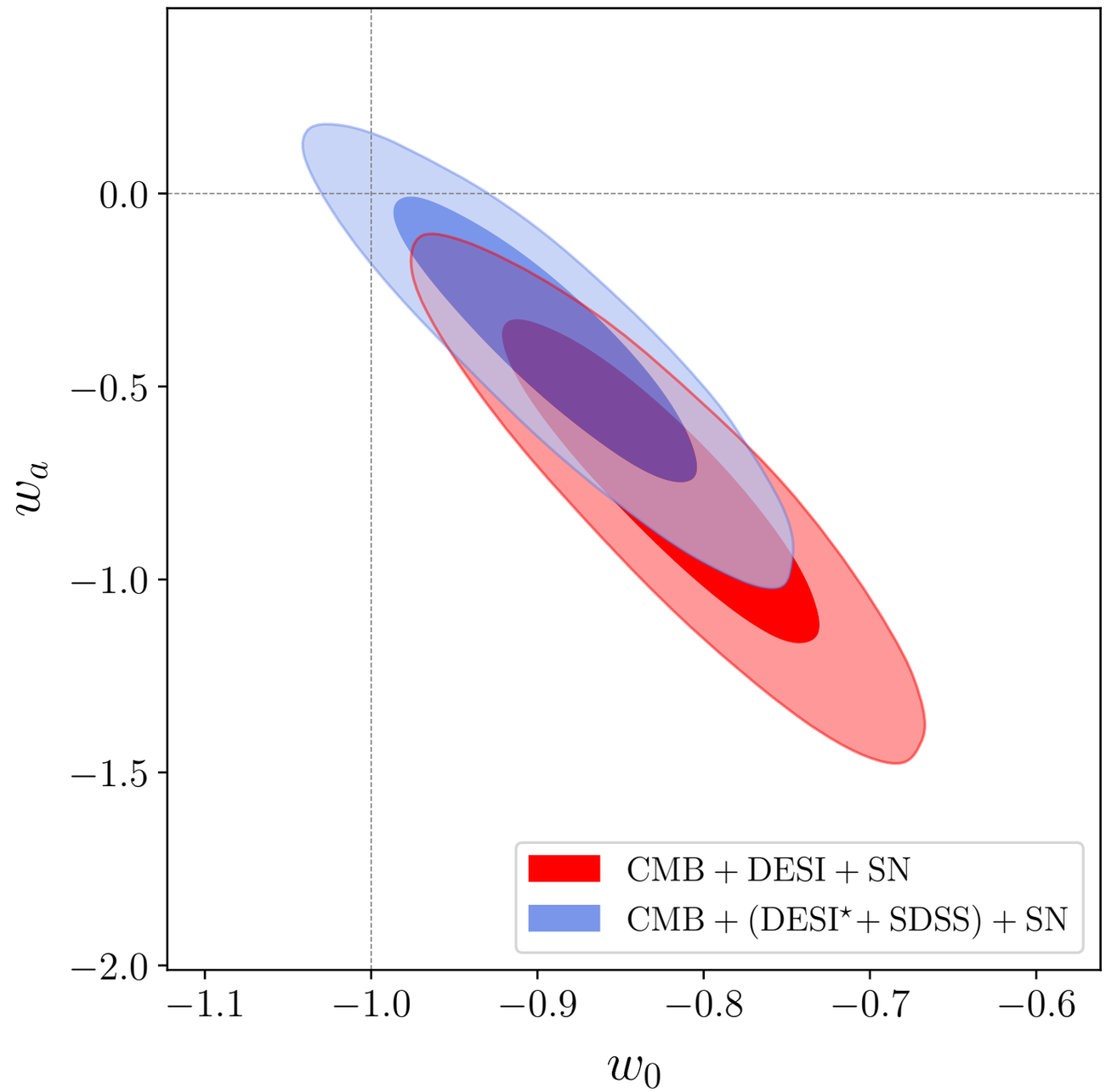

$w_0 w_a$CDM analysis

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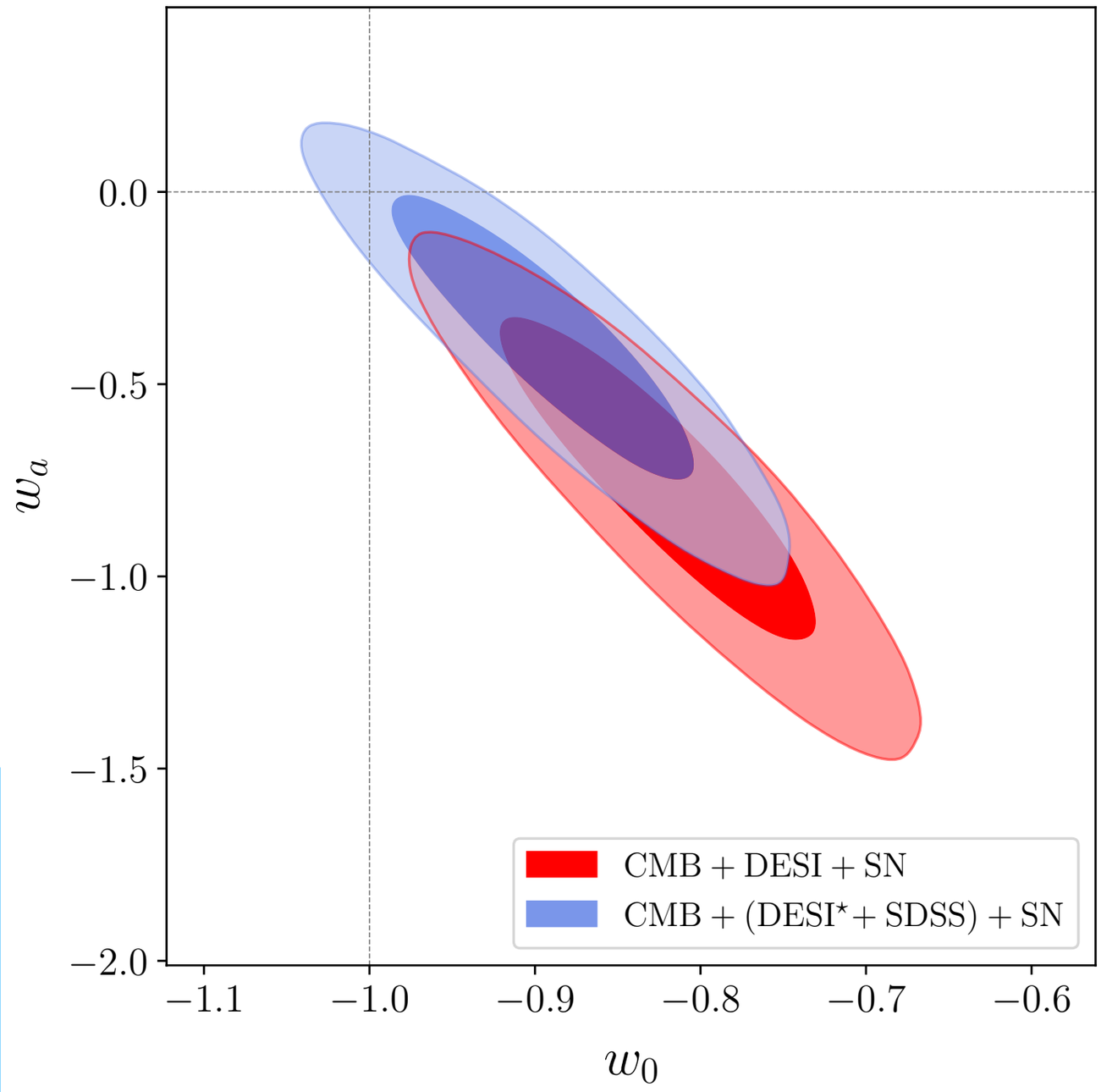
$$\Delta\chi^2 \equiv \chi^2_{w_0 w_a} - \chi^2_{\Lambda\rm CDM}$$

$$\Delta\chi^2_{\rm CMB+DESI+SN} = -8.8$$

$$\Delta\chi^2_{\rm CMB+(DESI^\star+SDSS)+SN} = -3.0$$

No significant evidence
for time-evolving $w_{\rm DE}(a)$
when using SDSS at $z < 0.8$
and DESI at $z > 0.8$



χ^2-analysis

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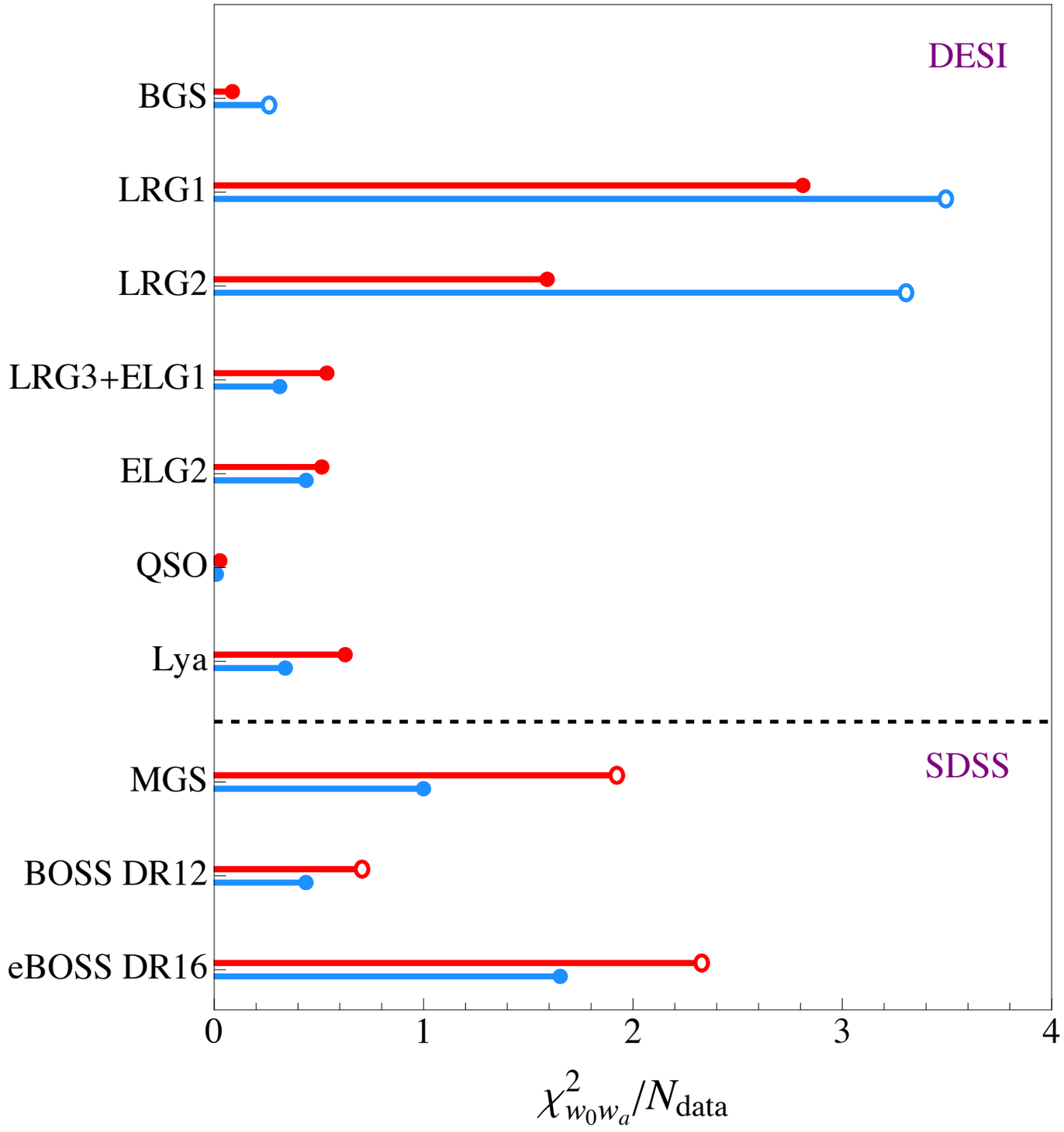
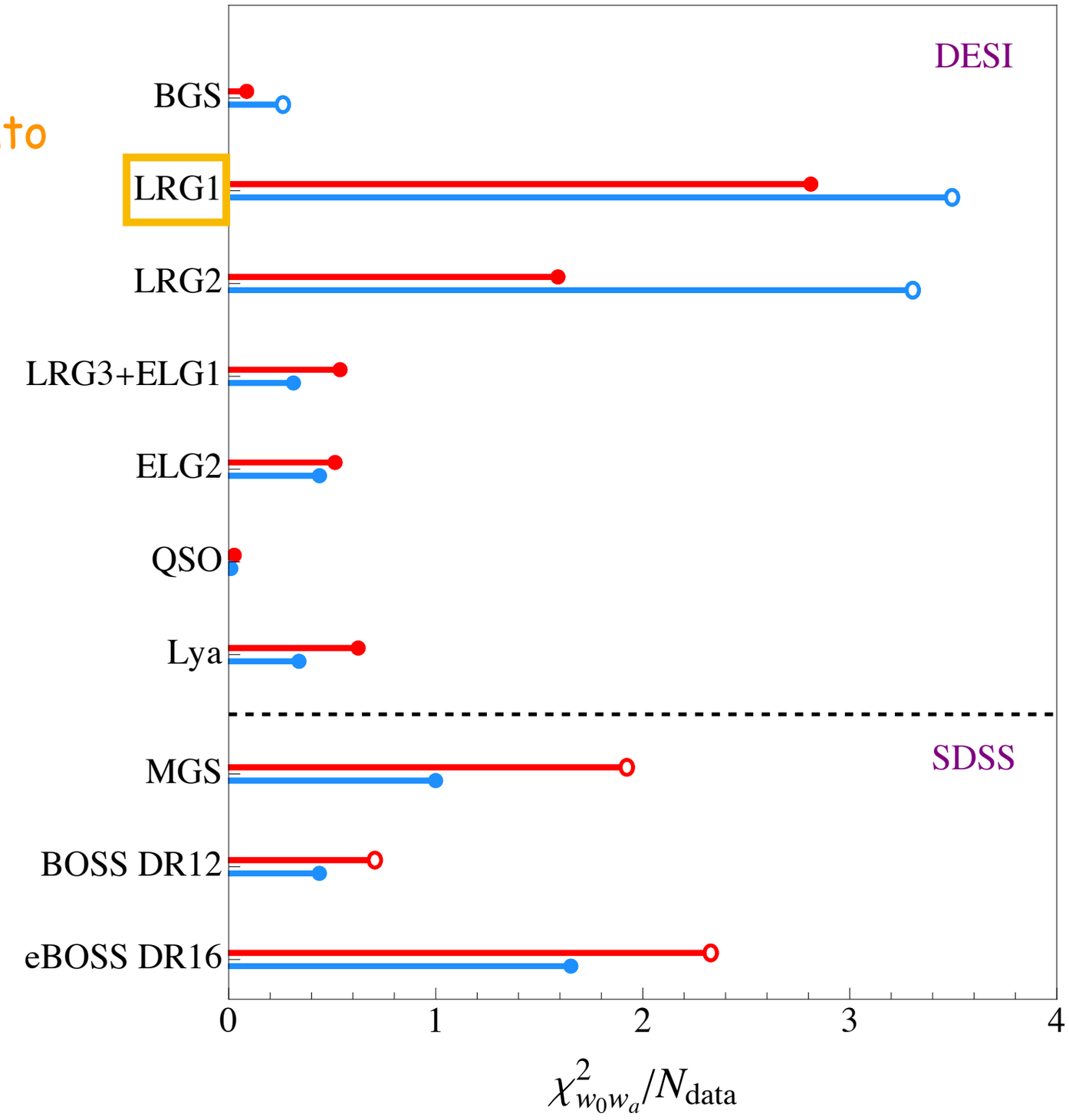


χ^2-analysis

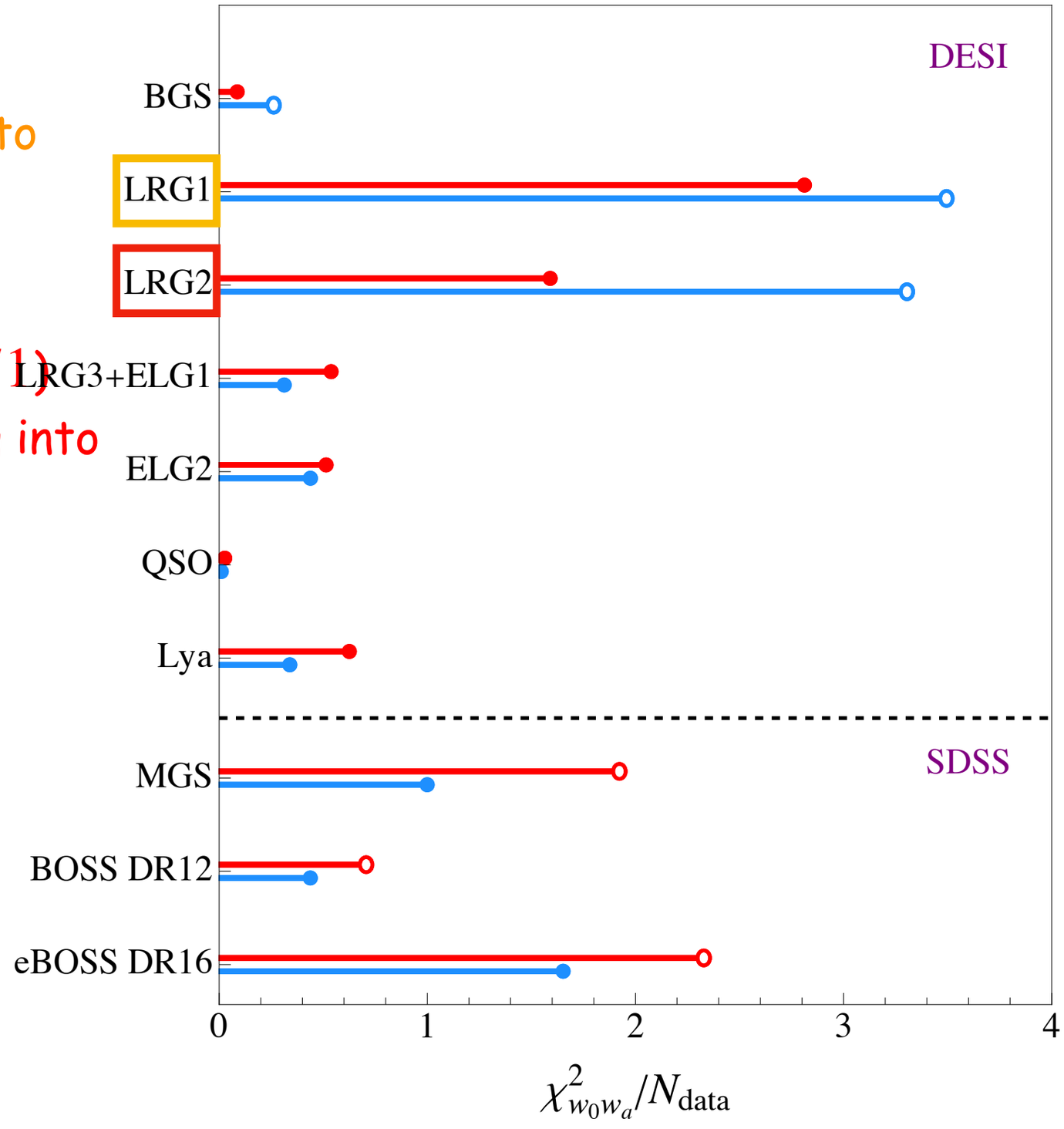
I) Fit to LRG1 ($z_{\rm eff} = 0.51$) is not significantly improved after taking into account the full DESI data



χ^2-analysis

I) Fit to LRG1 ($z_{\rm eff} = 0.51$) is not significantly improved after taking into account the full DESI data

II) Minimum χ^2 for LRG2 ($z_{\rm eff} = 0.71$) improves by a factor of 2 after taking into account the full DESI data



χ^2-analysis

$$\Delta\chi^2_{w_0w_a} \equiv \chi^2_{w_0w_a} - \chi^2_{\Lambda\mathrm{CDM}}$$

I) Fit to LRG1 ($z_{\rm eff} = 0.51$) is not significantly improved after taking into account the full DESI data

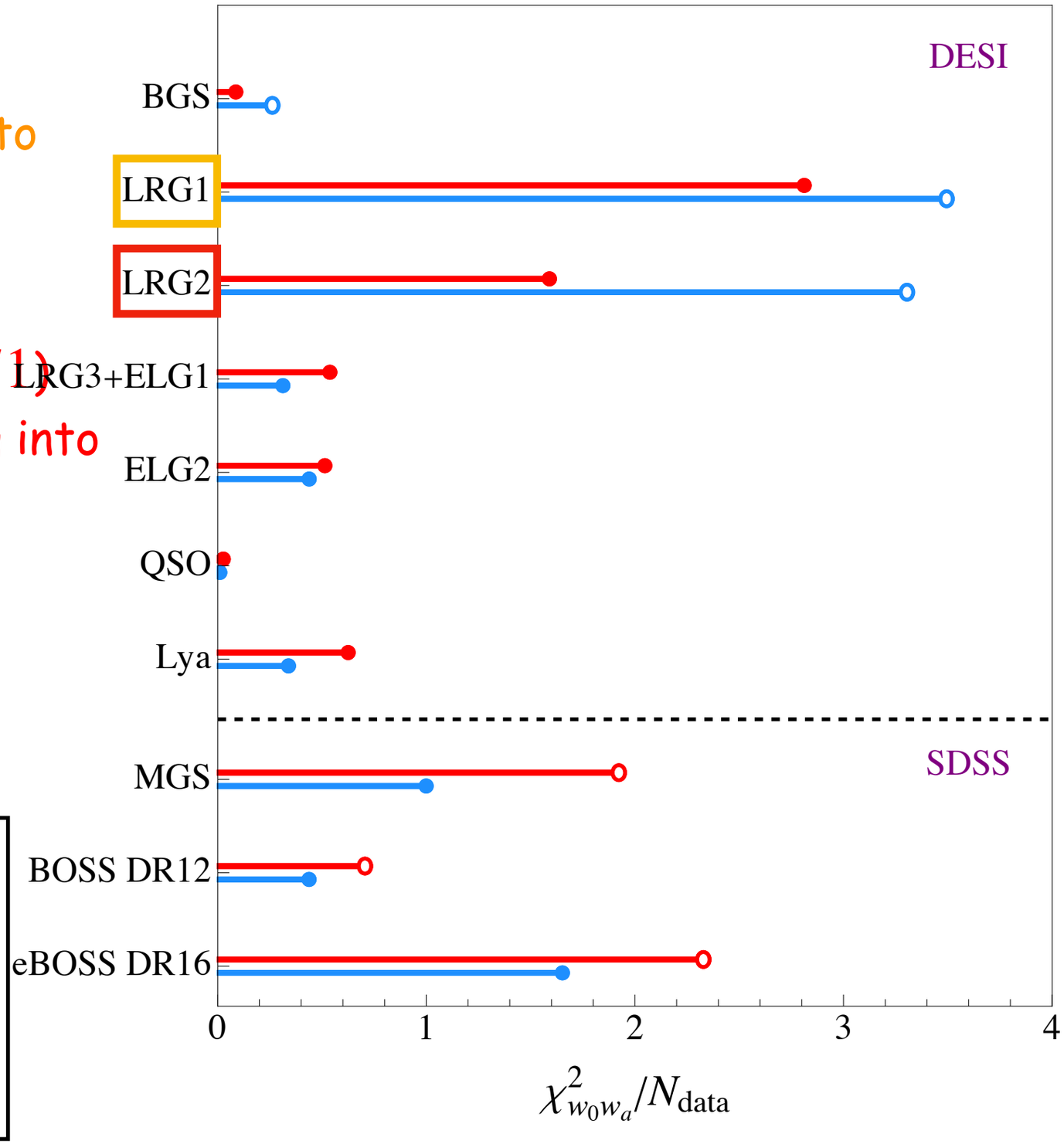
II) Minimum χ^2 for LRG2 ($z_{\rm eff} = 0.71$) improves by a factor of 2 after taking into account the full DESI data

$$\Delta\chi^2_{w_0w_a}(\mathrm{DESI}) = -3.8$$

$$\Delta\chi^2_{w_0w_a}(\mathrm{LRG1}) = -1.8$$

$$\Delta\chi^2_{w_0w_a}(\mathrm{LRG2}) = -3.3$$

$$\Delta\chi^2_{w_0w_a}(\mathrm{DESI\ w/o\ LRGs}) = +1.4$$



χ^2-analysis

LRG1 and LRG2 largely contribute

into the DESI's preference

for evolving dark energy

? Statistical fluctuation

? New physics

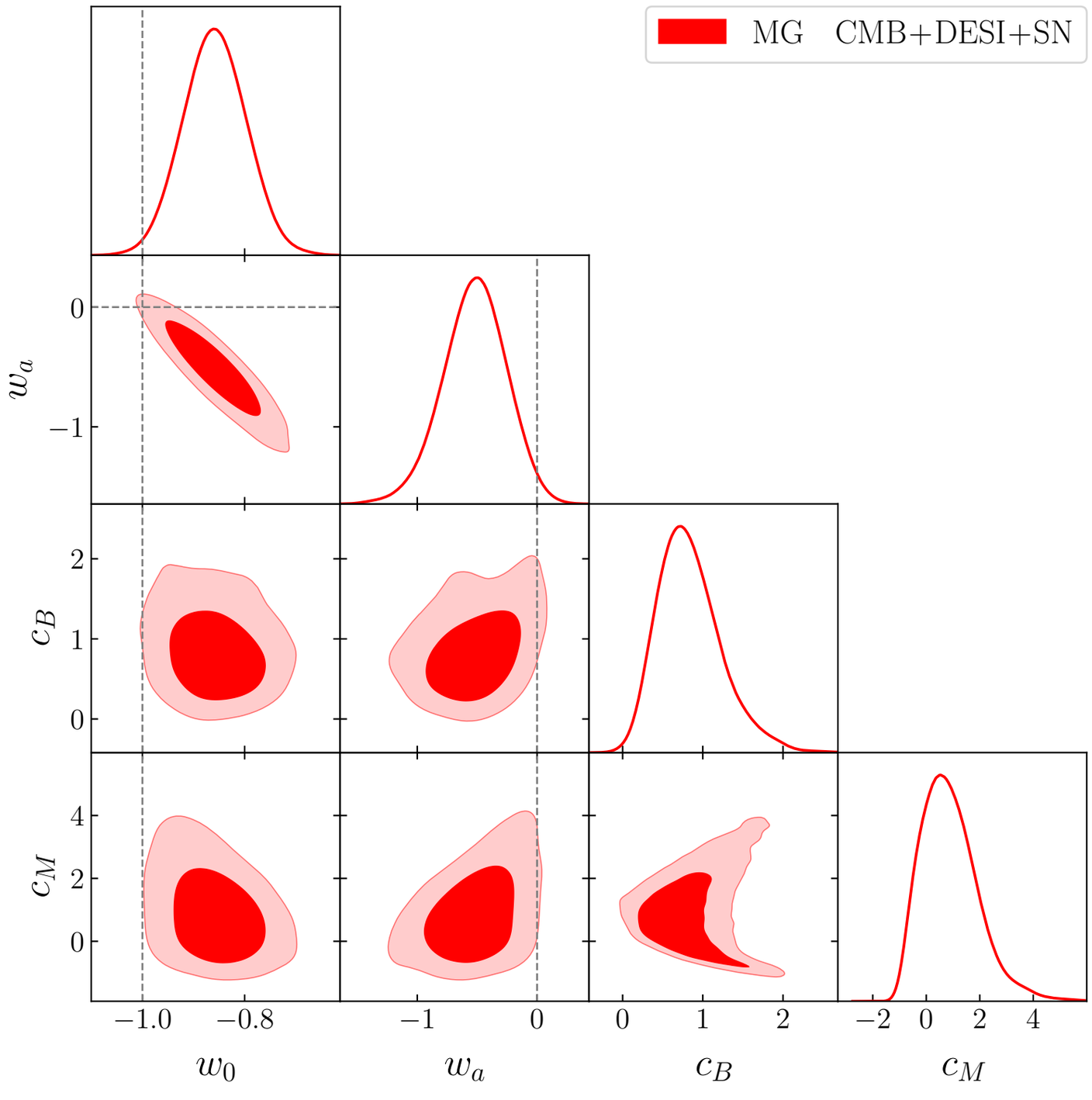
EFT of Dark Energy

$$\alpha_i(a) = c_i\,\Omega_{\rm DE}(a)$$

$$c_K = 1 \quad c_T = 0$$

$$\boxed{(w_0, w_a, c_B, c_M)}$$

EFT of Dark Energy



$$\alpha_i(a) = c_i\,\Omega_{\rm DE}(a)$$

$$c_K = 1 \quad c_T = 0$$

$$\boxed{(w_0, w_a, c_B, c_M)}$$

$$w_0 = -0.856 \pm 0.062$$

$$w_a = -0.53^{+0.28}_{-0.26}$$

$$c_B = 0.82^{+0.31}_{-0.46}$$

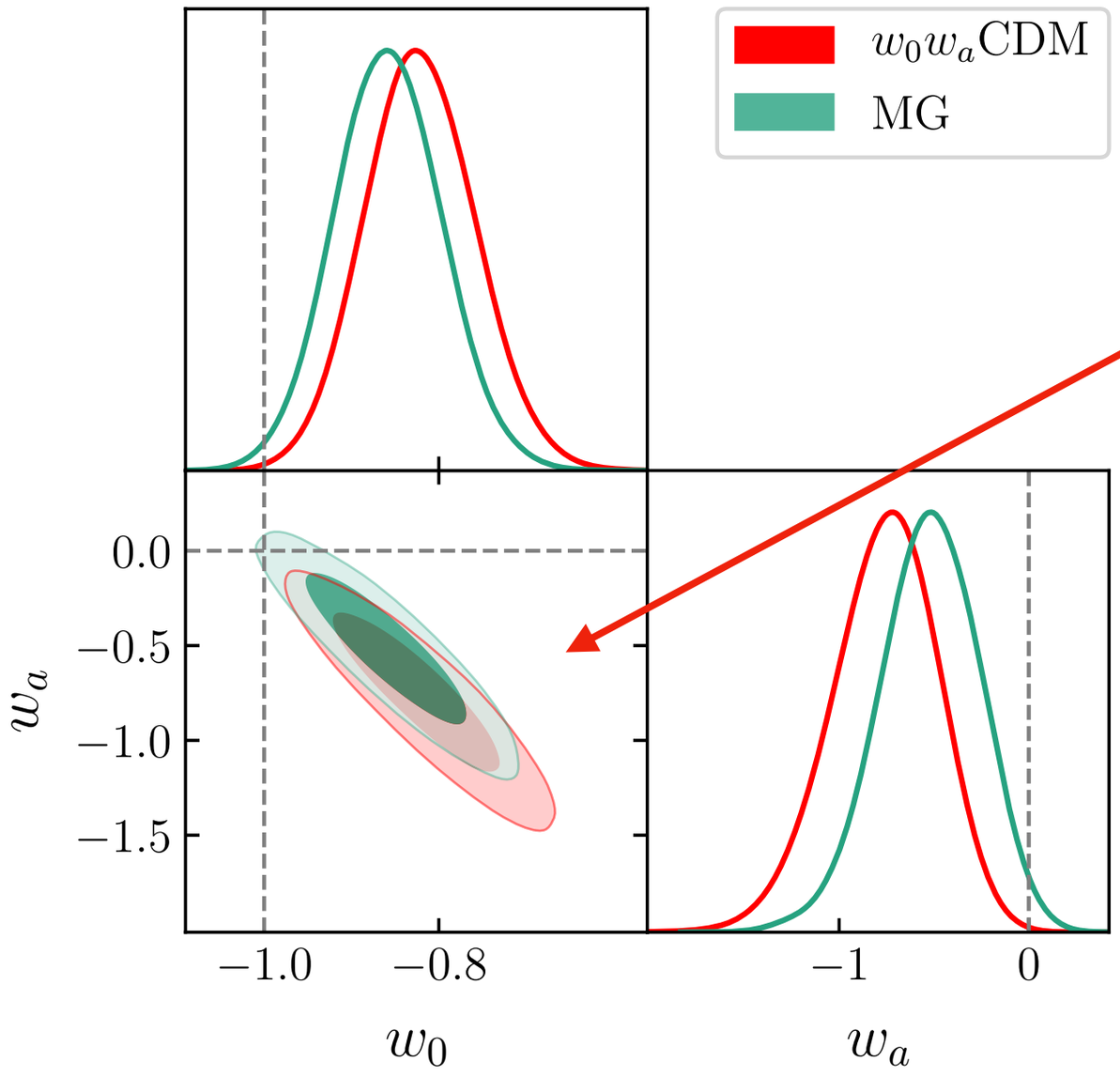
$$c_M = 0.88^{+0.75}_{-1.28}$$

Modified gravity shows

2.4σ preference over ΛCDM

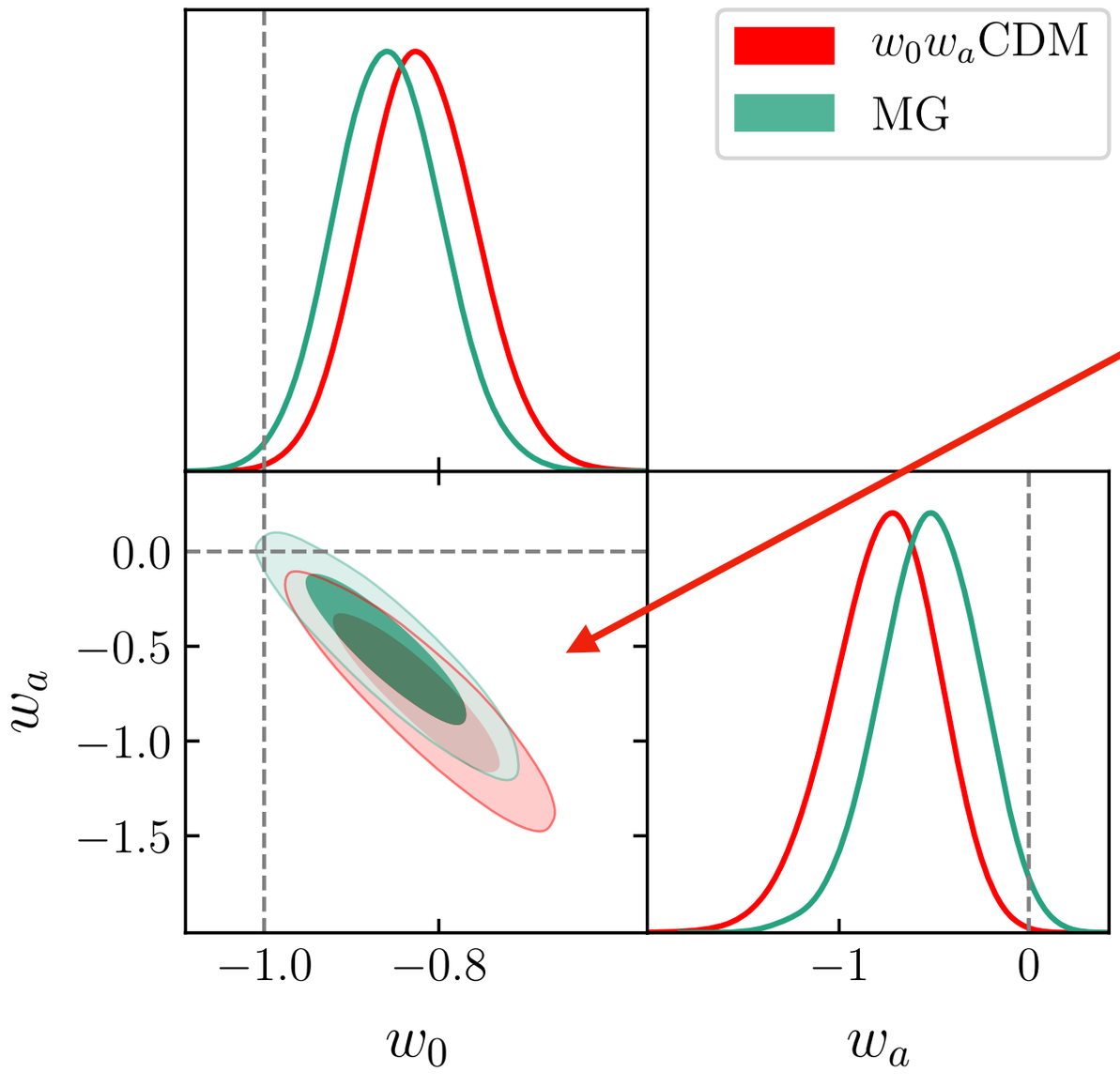
based on best-fit χ^2 values

EFTofDE vs w_0w_aCDM



Posteriors are consistent with w_0w_aCDM

EFTofDE vs $w_0 w_a$CDM



Posteriors are consistent with $w_0 w_a$CDM

Model selection analysis

Model	$w_0 w_a$CDM	MG
$\Delta\chi^2_{\rm min}$	-8.8	-12.2
ΔAIC	-4.8	-4.2
ΔDIC	-4.9	$+1.7$

While modified gravity does not show a preference over ΛCDM, it offers a physical mechanism to safely cross the phantom divide

Conclusions

☑ DESI's preference for evolving dark energy is largely driven by the two LRG samples at $z_{\rm eff} = 0.51$ and 0.71, with the latter having the most significant impact

☑ Modified gravity offers a viable physical explanation for DESI's preference for evolving dark energy

☑ Future DESI DR3 and Euclid BAO data will help to clarify whether this is a statistical fluctuation or due to new physics in the dark sector

Backup

CMB
CMB + DESI
CMB + DESI + SN

Ω_m H_0 σ_8 w_0 w_a α_B α_M