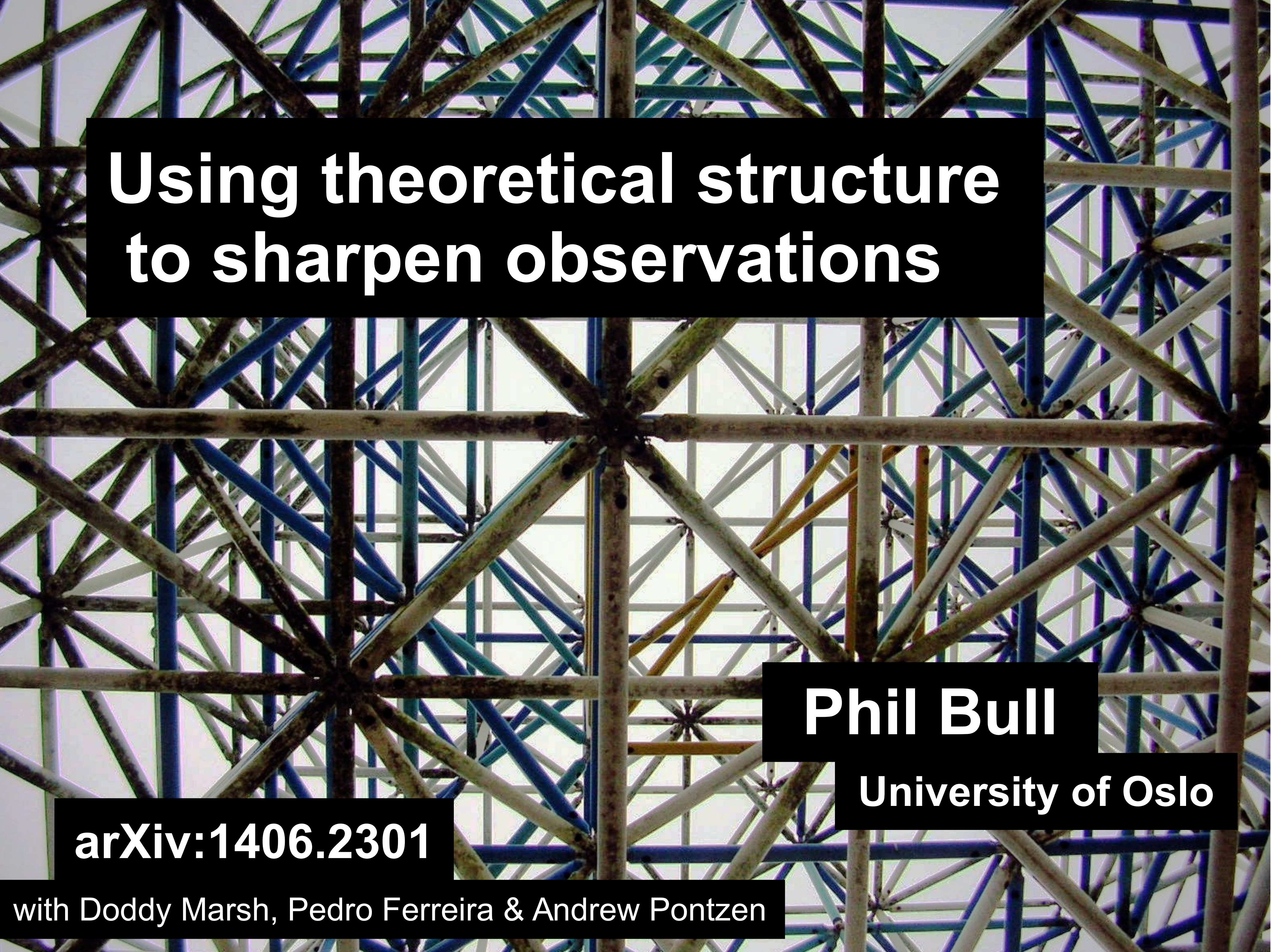


Using theoretical structure to sharpen observations

Phil Bull

University of Oslo

arXiv:1406.2301

with Doddy Marsh, Pedro Ferreira & Andrew Pontzen

How to constrain dark energy?

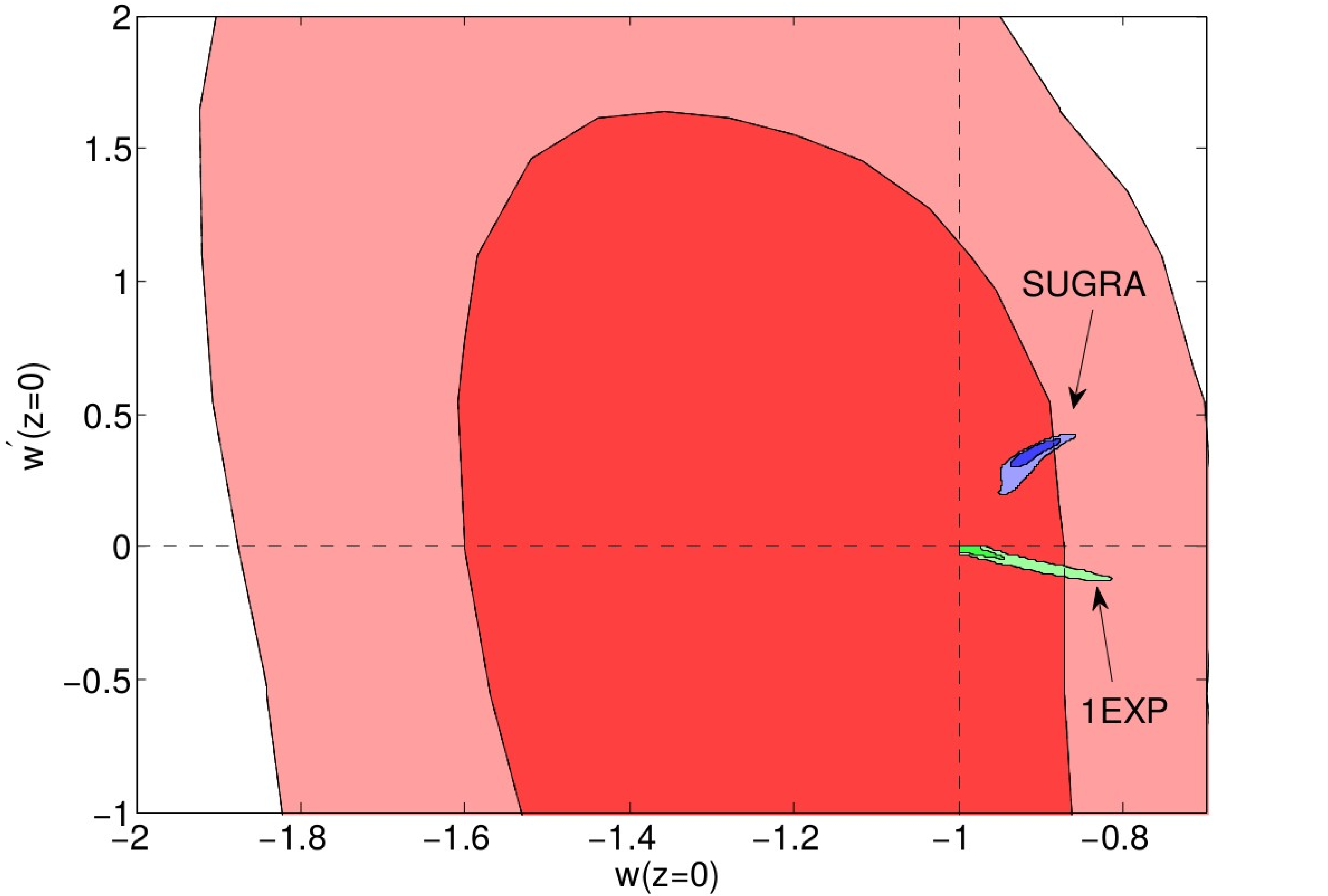
Look at individual models

- Physical insight – can target certain observables/features
- Structure: only certain values of observables are viable
- Complicated! Many available models, lots of work

Constrain phenomenological parametrisations

- Parametrise ignorance – let the data speak for itself?
- Simple: Represent many (all?) theories at once
- Lots of freedom, little structure

E. Tarrant et al., arXiv:1304.5532



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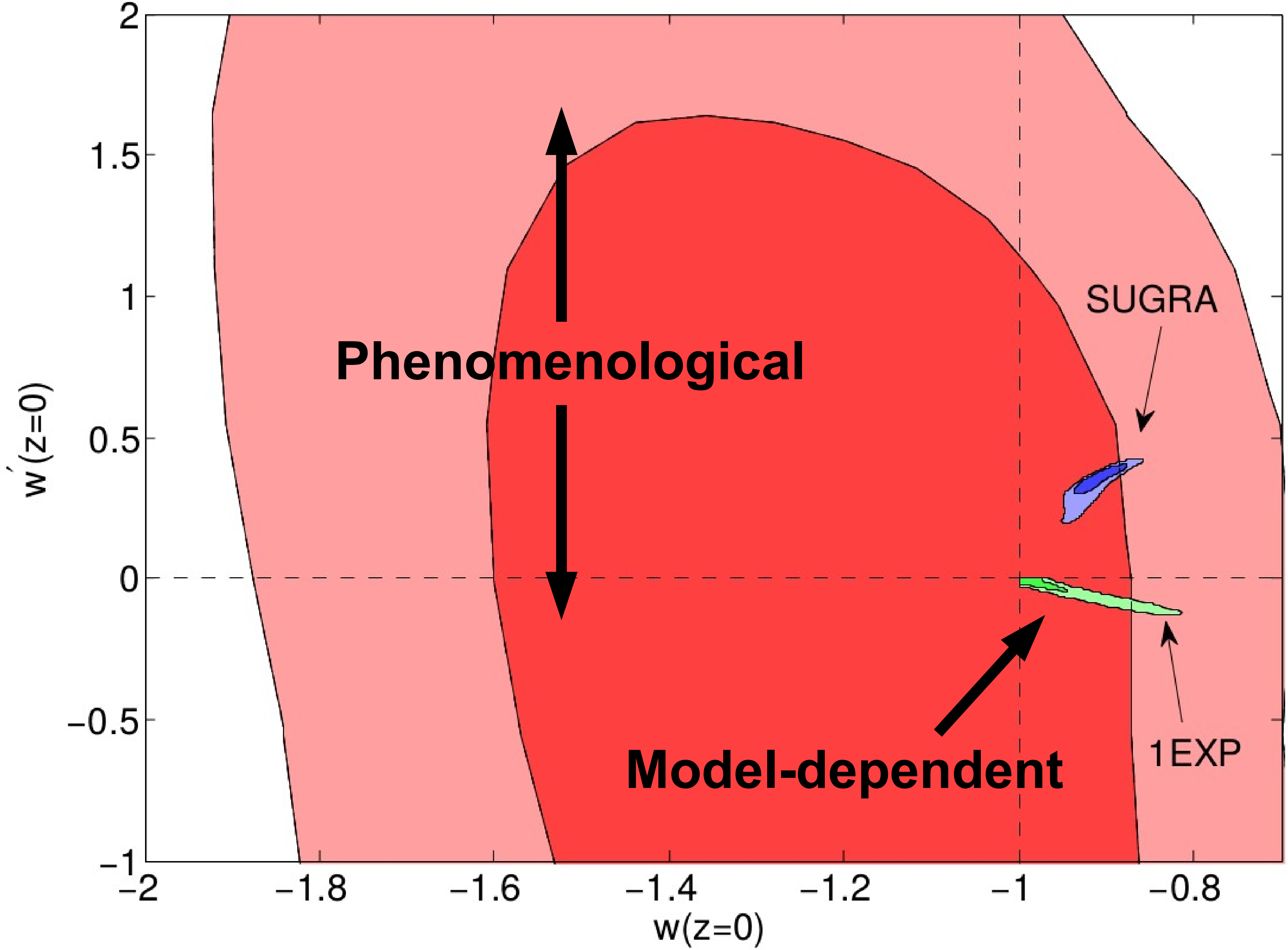

Same data

Parametrisation too broad – data says nothing

Models too specific – which to believe?

Quintessence models

$$\mathsf{V}(\phi) = c_\Lambda \xi_\Lambda + f(\phi) + \sum_{n_{\min}}^{n_{\max}} c_n \xi_n b_n(\phi)$$

Quintessence models

$$\mathrm{V}(\phi) = c_\Lambda \xi_\Lambda + f(\phi) + \sum_{n_{\min}}^{n_{\max}} c_n \xi_n \phi_n(\phi)$$

Random variables

Quintessence models

$$\mathrm{V}(\phi) = c_\Lambda \xi_\Lambda + f(\phi) + \sum_{n_{\min}}^{n_{\max}} c_n \xi_n b_n(\phi)$$

Model	$b_n(\phi)$	c_n	$n_{\min}$	$f(\phi)$	ϕ_i
Kac	ϕ^n	1	1	0	$[-1, 1]$
Weyl	ϕ^n	$1/\sqrt{n!}$	1	0	$[-1, 1]$
Mono.	0	–	–	ϕ^N	$[0, 4]$
EFT	ϕ^n	$(\varepsilon_{\mathrm{F}})^n$	p_E	$\xi_2 \varepsilon_{\mathrm{F}}^2 \phi^2 + \xi_4 \varepsilon_{\mathrm{F}}^4 \phi^4$	$[-\varepsilon_{\mathrm{F}}^{-1}, \varepsilon_{\mathrm{F}}^{-1}]$
Axion	$\cos(n\varepsilon_{\mathrm{F}}\phi)$	$(\varepsilon_{\mathrm{NP}})^{n-1}$	2	$1 + \cos \varepsilon_{\mathrm{F}}\phi$	$[-\frac{\pi}{\varepsilon_{\mathrm{F}}}, \frac{\pi}{\varepsilon_{\mathrm{F}}}]$
Modulus	$e^{\alpha(p_D - n)\phi}$	$(\varepsilon_{\mathrm{D}})^n$	0	0	$[-1, 1]$

Theory priors

Parameter	Model	Dist.
$\log_{10} A$	All	$\mathrm{U}(-1,1)$
N	Monomial	$\mathrm{U}_{\mathbb{Z}}(1,7)$
n_{max}	Kac, Weyl, Ax., Mod.	$\mathrm{U}_{\mathbb{Z}}(10,20)$
n_{Q}, p_E	EFT	$\mathrm{U}_{\mathbb{Z}}(5,10)$
$\log_{10} \varepsilon_{\mathrm{F,NP,D}}$	EFT, Ax., Mod.	$\mathrm{U}(-3,-1)$
p_D	Modulus	$\mathrm{U}_{\mathbb{Z}}(1,5)$
α	Modulus	$\mathrm{U}(0,1)$

Theory priors

Overall scale of potential

(should be vaguely close to obs. DE density)

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p_D	Modulus	$\mathrm{U}_{\mathbb{Z}}(1, 5)$
α	Modulus	$\mathrm{U}(0, 1)$

Very general – allow lots of terms etc.

Observational cuts

$$\Omega_{\rm DE} \in [0.6, 0.8]$$

$$h \in [0.6, 0.8]$$

$$z_{\rm eq} \in [2000, 4000]$$

Observational cuts

$$\Omega_{\mathrm{DE}} \in [0.6, 0.8]$$

$$h \in [0.6, 0.8]$$

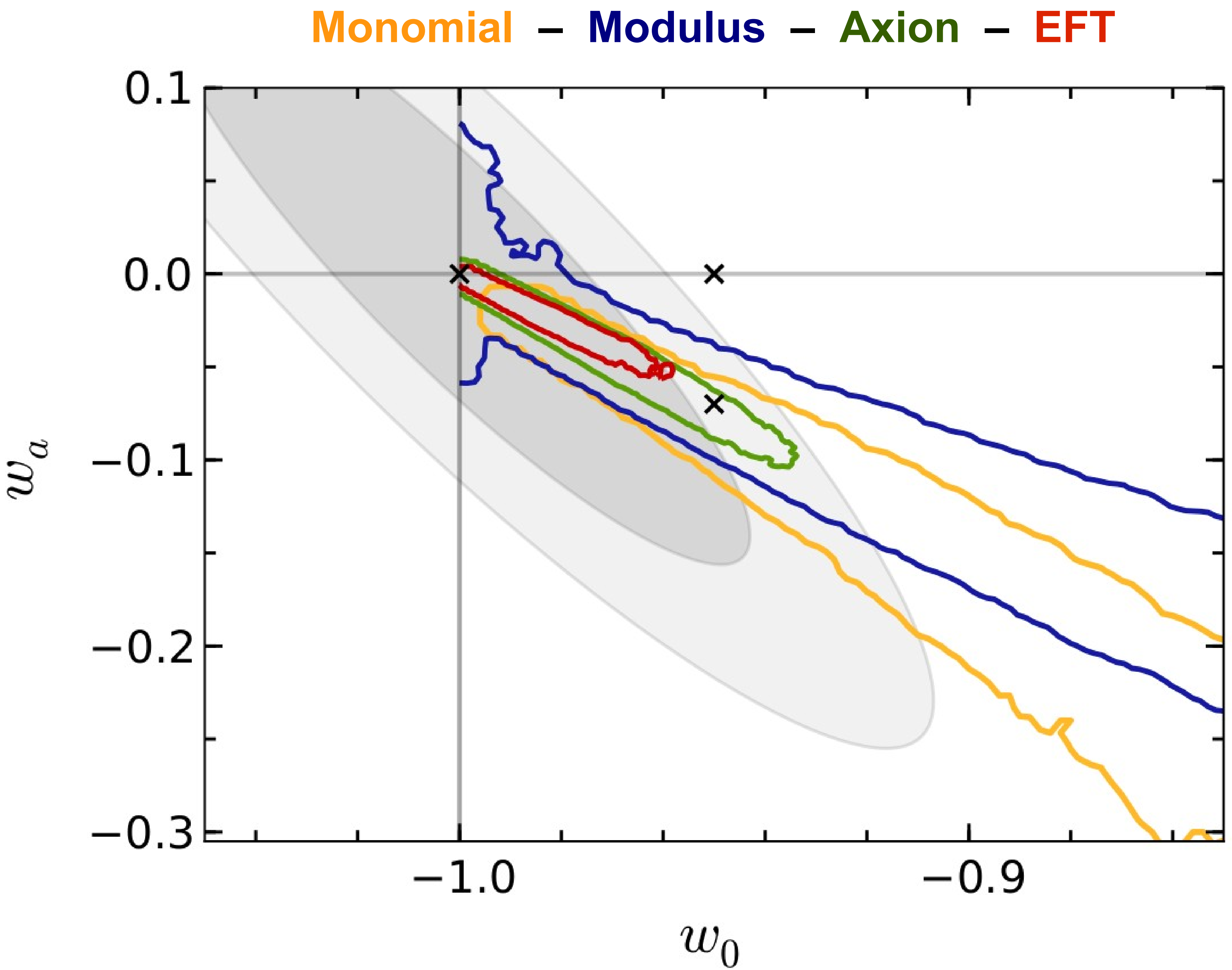
$$z_{\mathrm{eq}} \in [2000, 4000]$$

(Very weak compared to current best estimates)

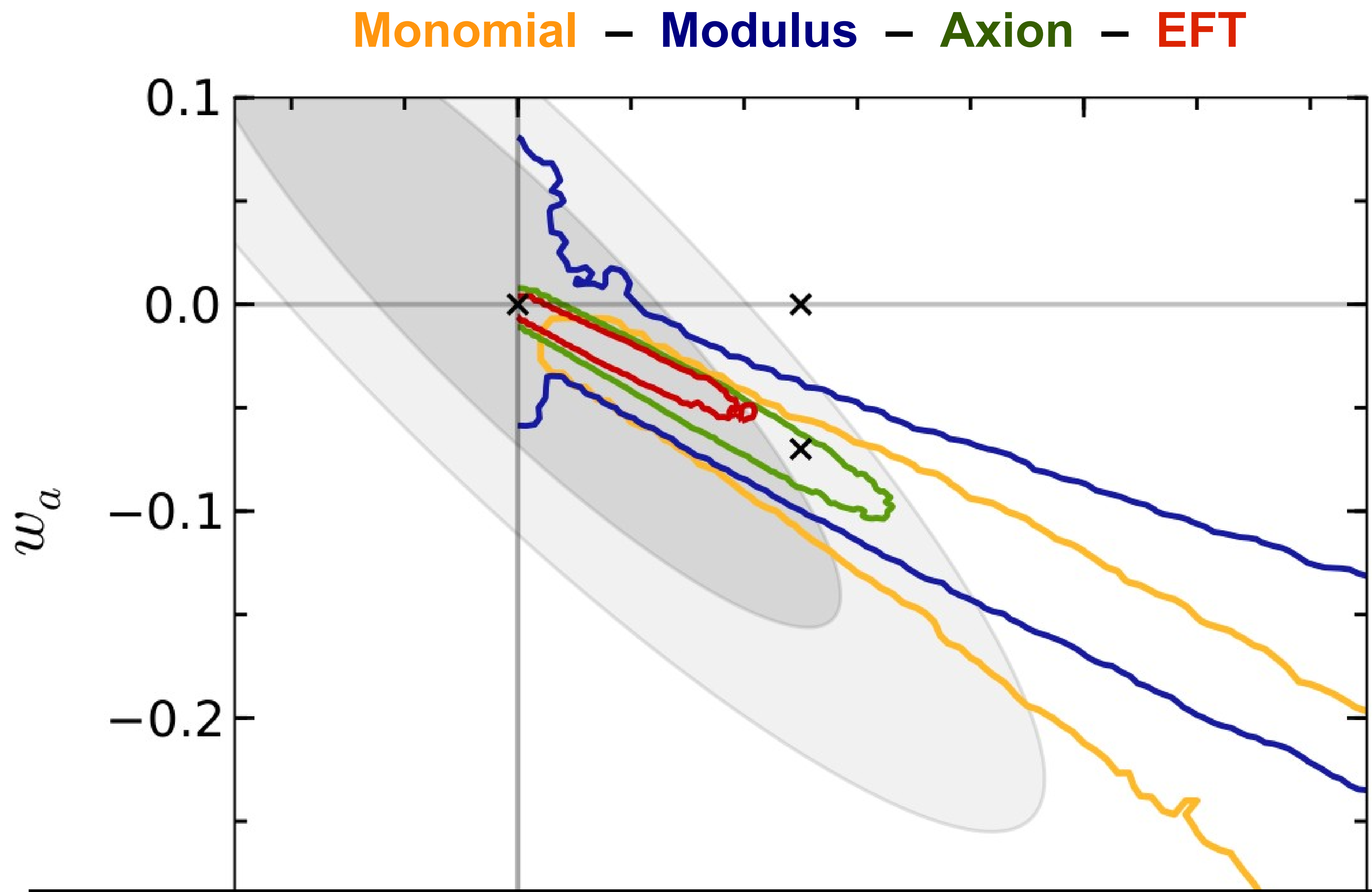
(1) Monte Carlo millions of random potentials

(2) Apply weak, sensible observational cuts

(no real data; only priors)



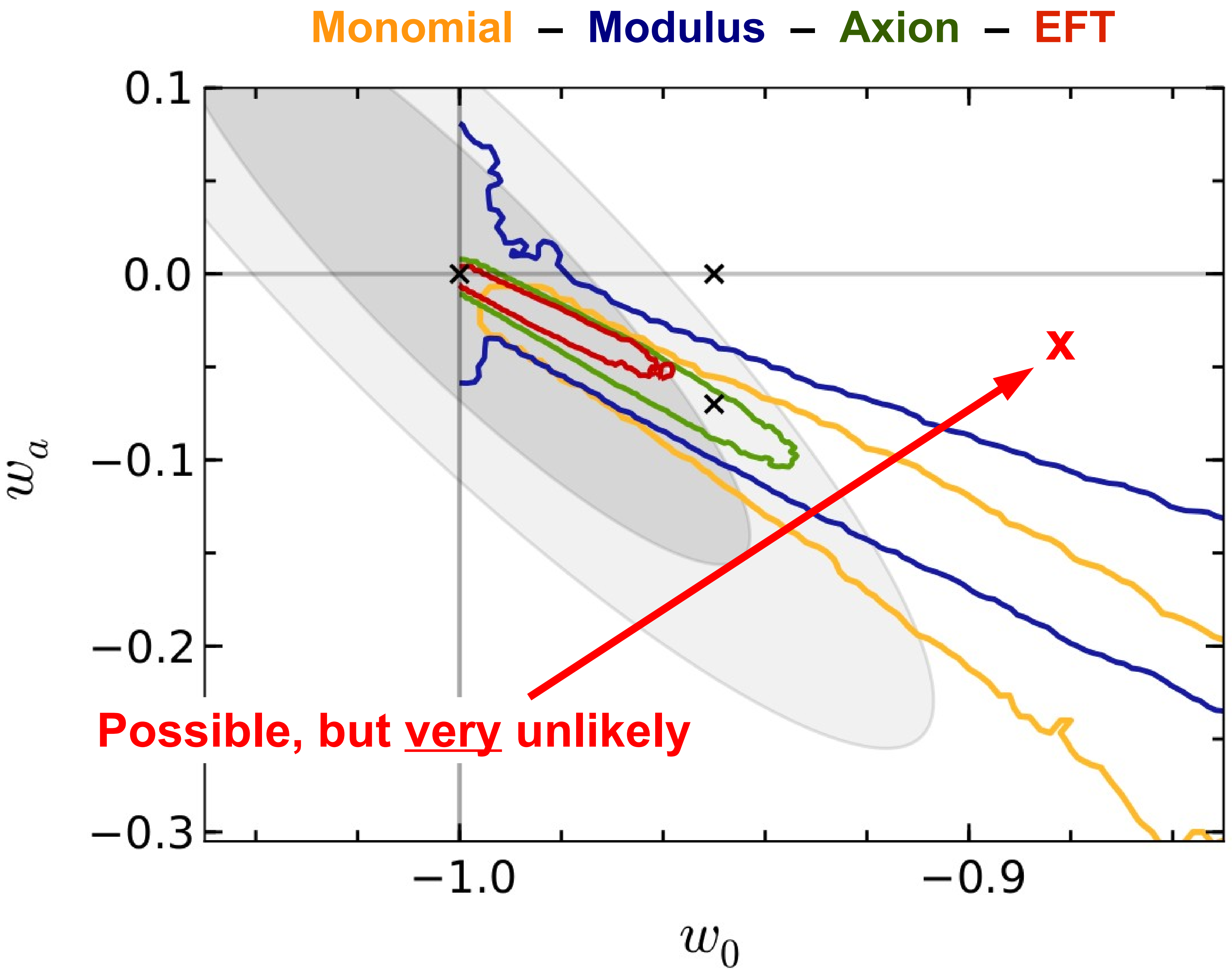
Monomial – Modulus – Axion – EFT
0.1
0.0
−0.1
−0.2
−0.3
w_a
−1.0
−0.9
w_0



Broad, generic model structure
→ tight restrictions on obs. parameters

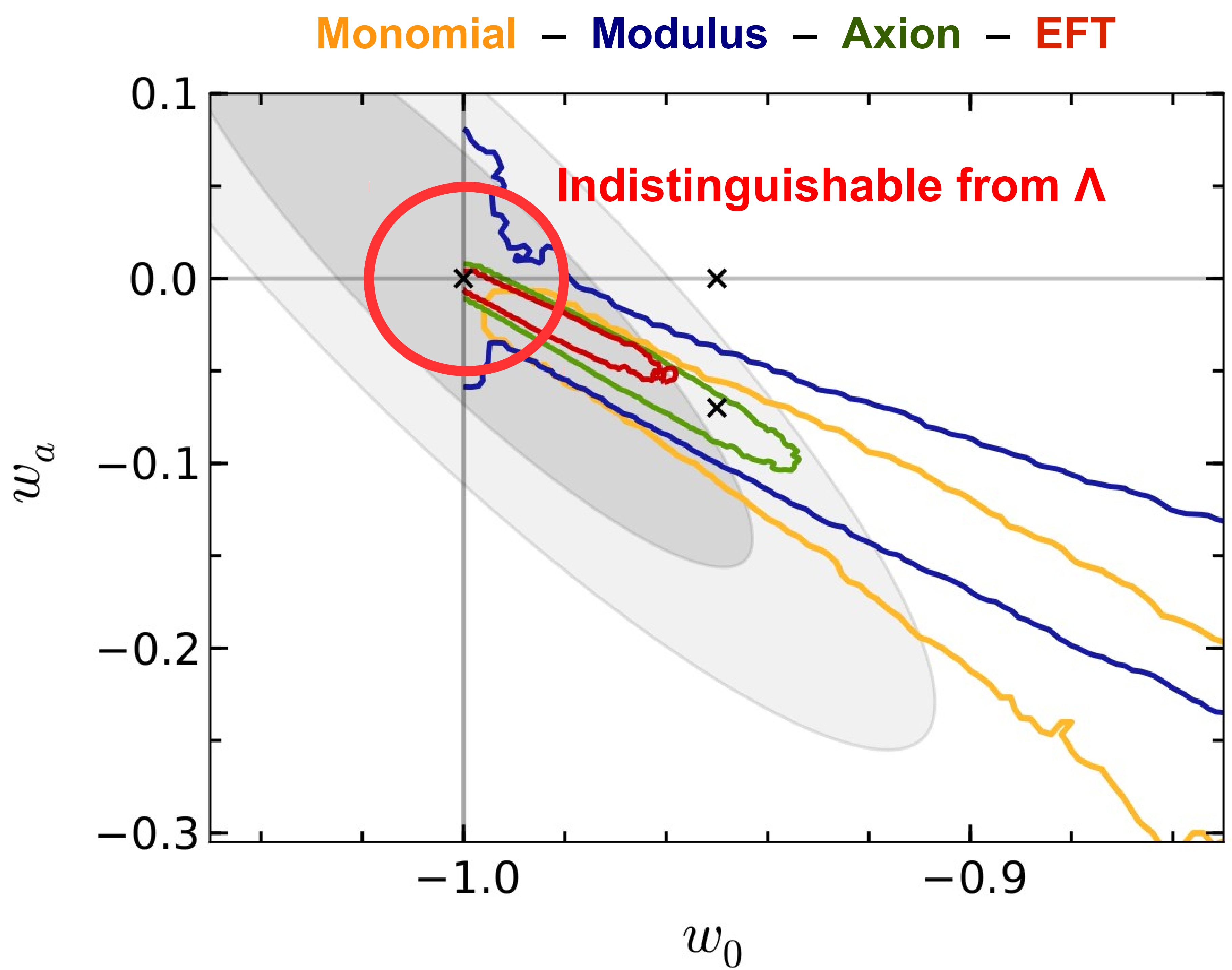
Even **very generic** theory structure disfavours vast regions of pheno. parameter space

Putting flat priors on pheno parameters favours **extremely weird** models



Monomial – Modulus – Axion – EFT
0.1
0.0
−0.1
−0.2
−0.3
−1.0
−0.9
w_a
w_0
x
Possible, but very unlikely

Data alone **don't provide enough info**



Monomial – Modulus – Axion – EFT
Indistinguishable from Λ
0.1
0.0
−0.1
−0.2
−0.3
w_a
−1.0
−0.9
w_0

Even **very generic** theory structure disfavours vast regions of pheno. parameter space

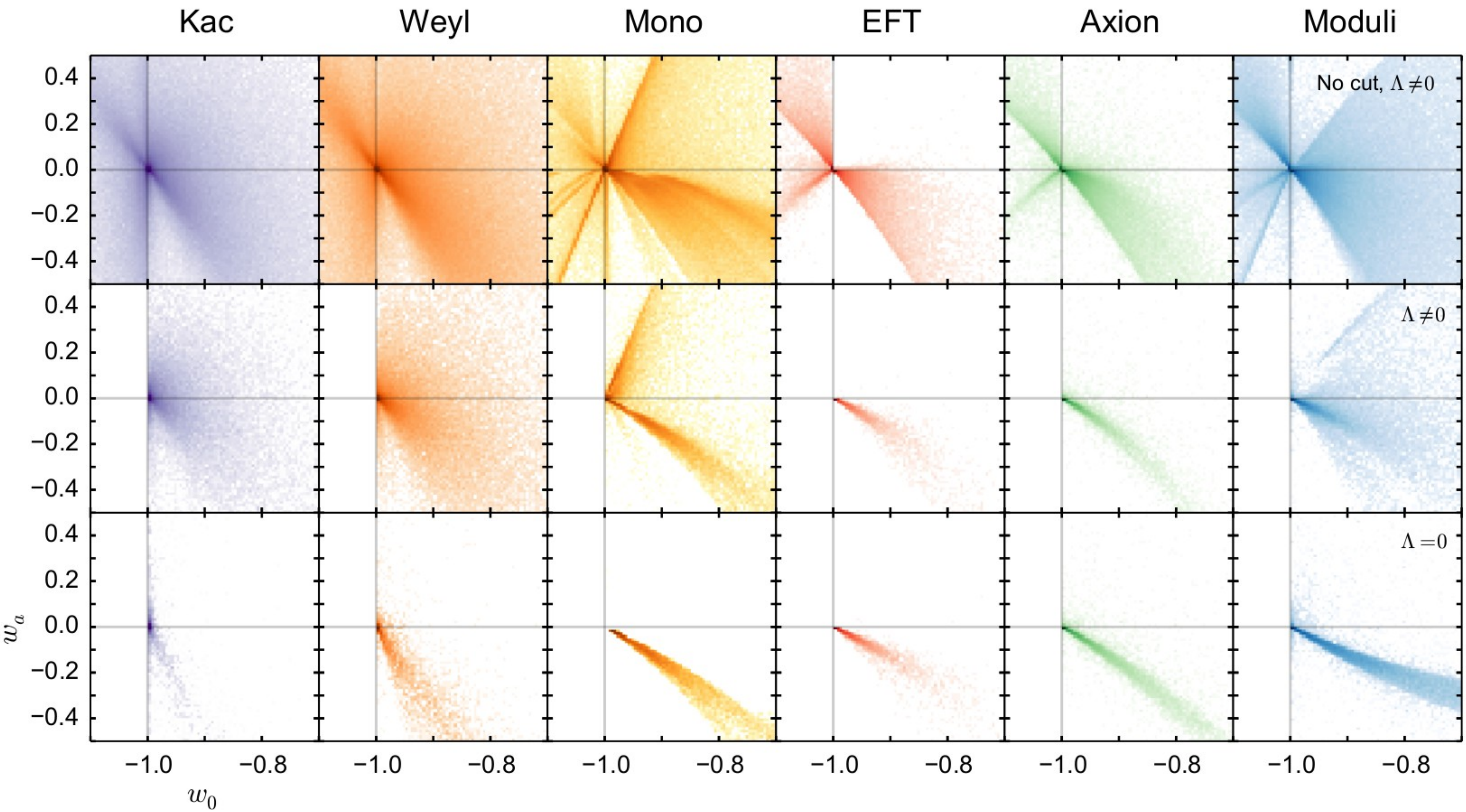
Data alone **don't provide enough info**

Putting flat priors on pheno parameters favours **extremely weird** models

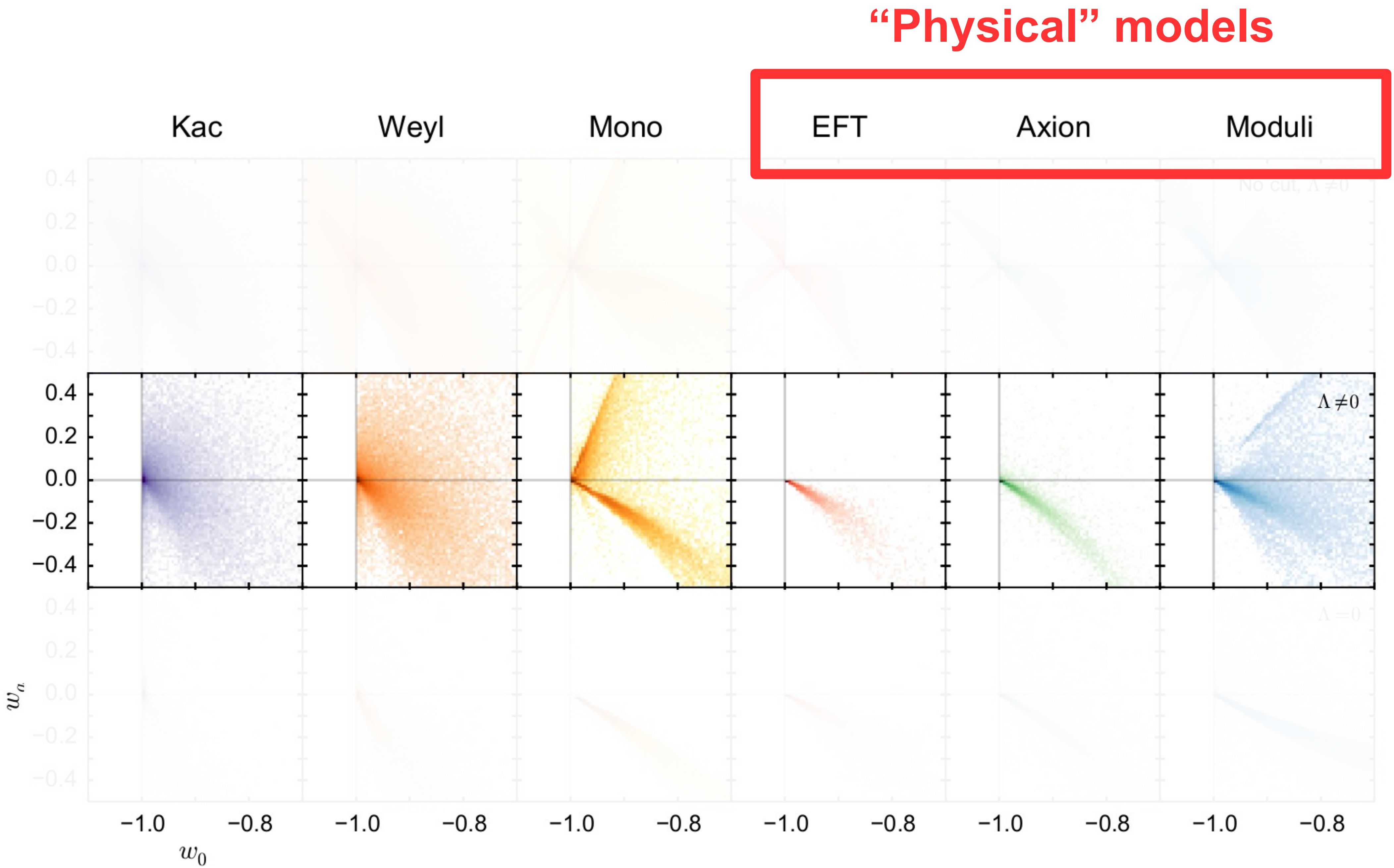
Details in arXiv:1406.2301

Title picture: ppix/Flickr (CC-BY-NC-SA 2.0)

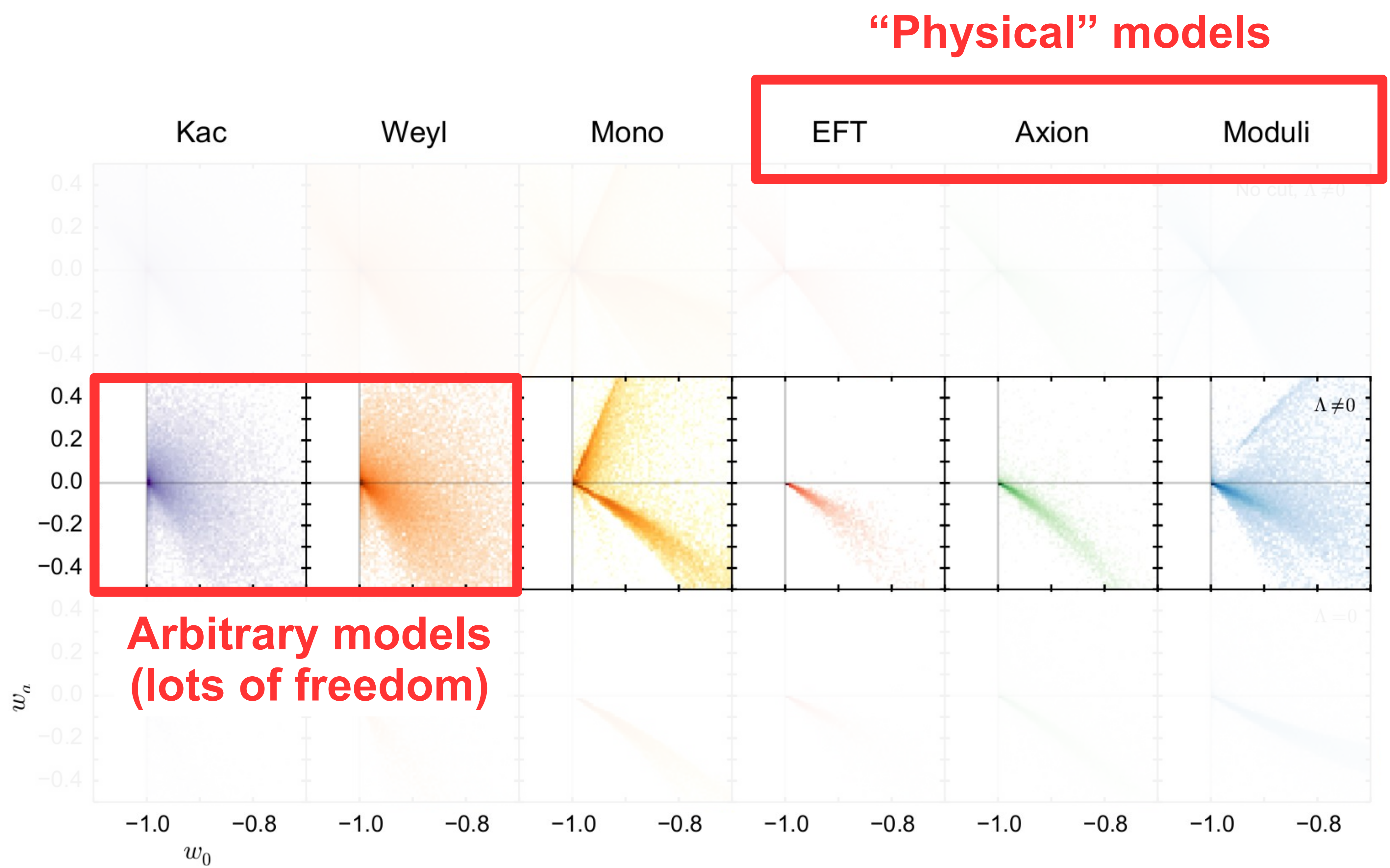
Thanks



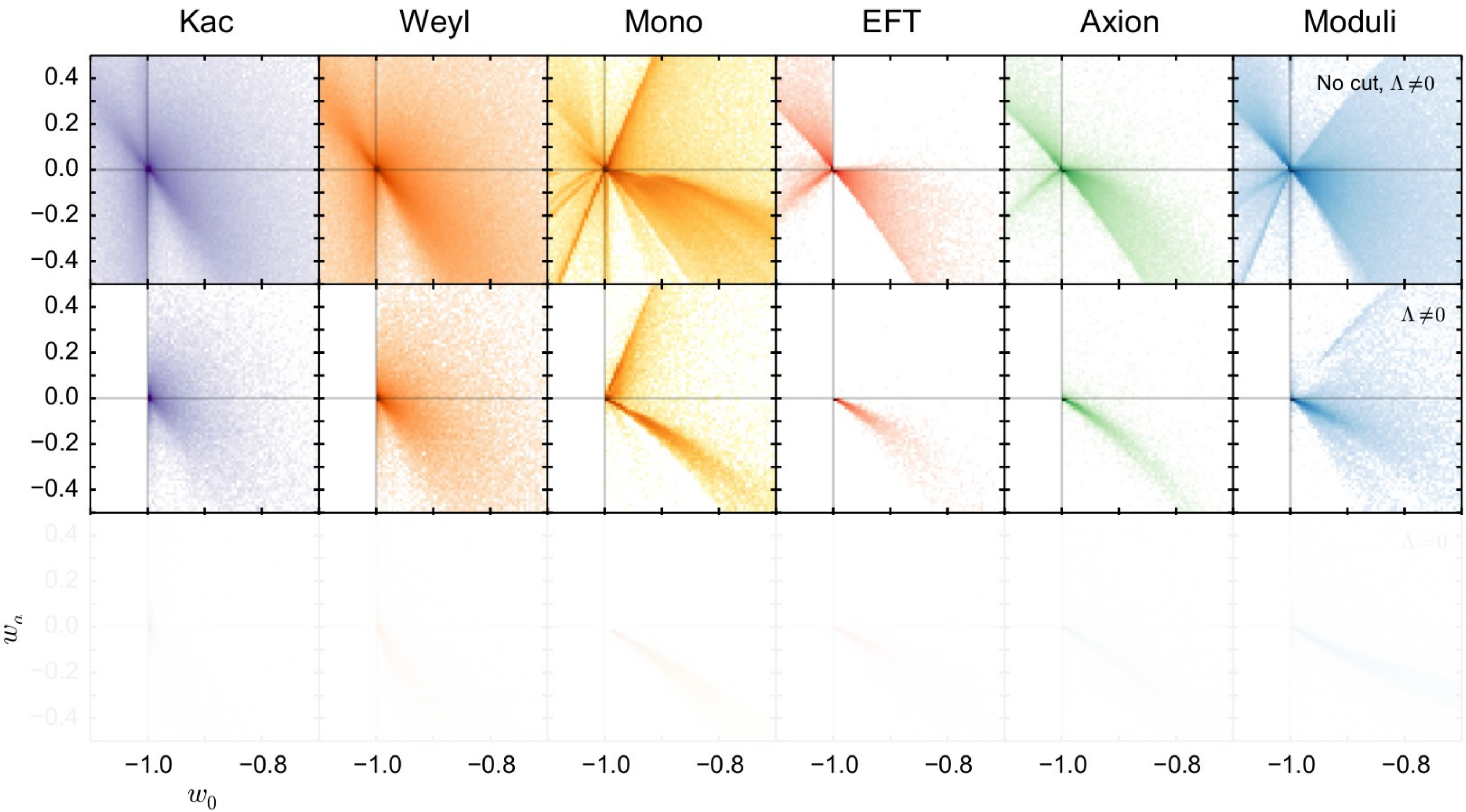
Kac
Weyl
Mono
EFT
Axion
Moduli
No cut, $\Lambda \neq 0$
$\Lambda \neq 0$
$\Lambda = 0$
0.4
0.2
0.0
−0.2
−0.4
−1.0
−0.8
w_a
w_0



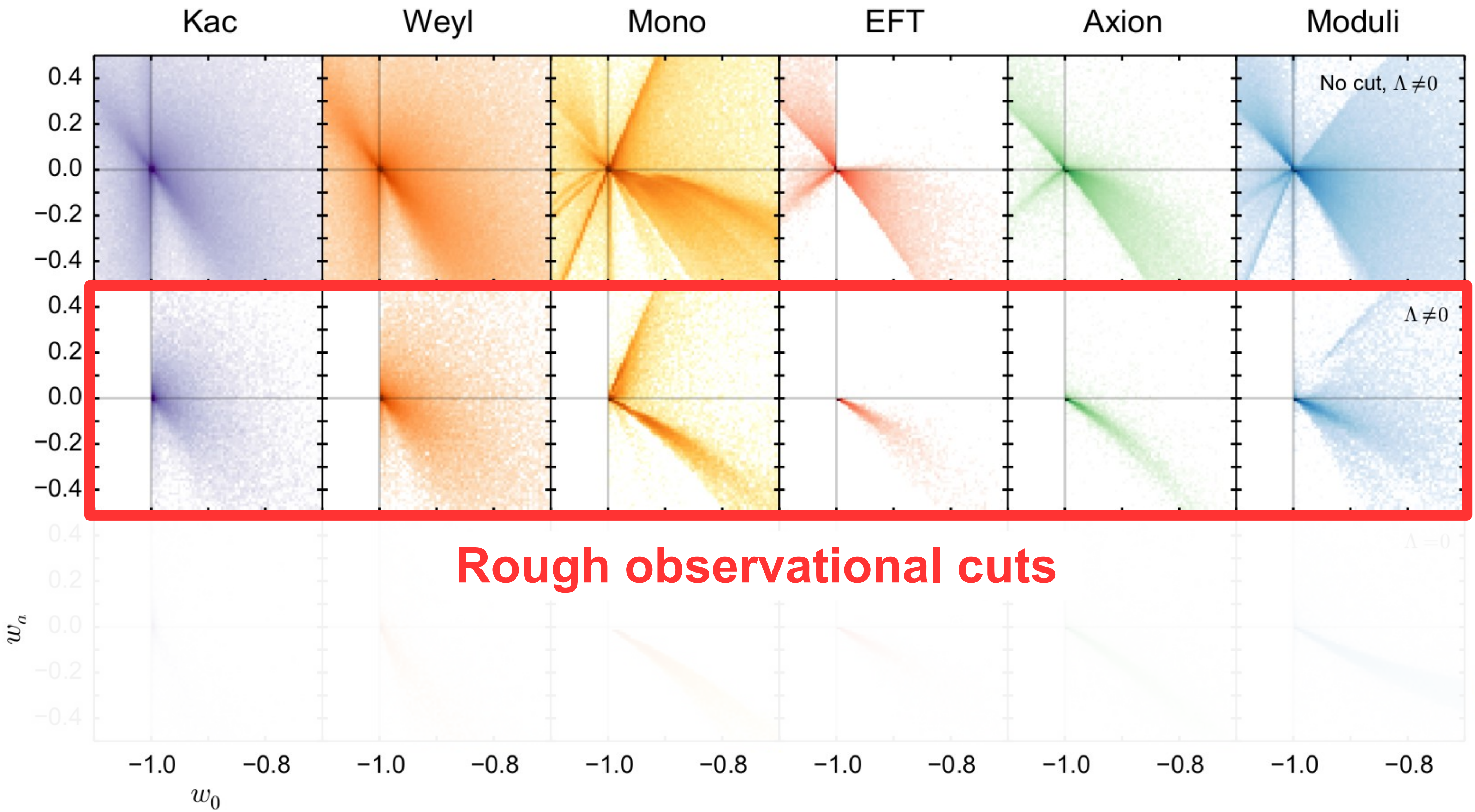
“Physical” models
Kac
Weyl
Mono
EFT
Axion
Moduli
Λ ≠0
0.4
0.2
0.0
−0.2
−0.4
−1.0
−0.8
w_a
w_0



“Physical” models
Kac
Weyl
Mono
EFT
Axion
Moduli
Λ ≠0
Arbitrary models
(lots of freedom)
0.4
0.2
0.0
−0.2
−0.4
w_a
−1.0
−0.8
w_0



Kac
Weyl
Mono
EFT
Axion
Moduli
No cut, $\Lambda \neq 0$
$\Lambda \neq 0$
$\Lambda = 0$
0.4
0.2
0.0
−0.2
−0.4
−1.0
−0.8
w_a
w_0


Kac
Weyl
Mono
EFT
Axion
Moduli
No cut, $\Lambda \neq 0$
$\Lambda \neq 0$
Rough observational cuts
w_a
w_0
0.4
0.2
0.0
−0.2
−0.4
−1.0
−0.8