Theoretical priors for quintessence. Towards a general parametrization of Horndeski cosmologies.

Coming soon. Comments welcome!

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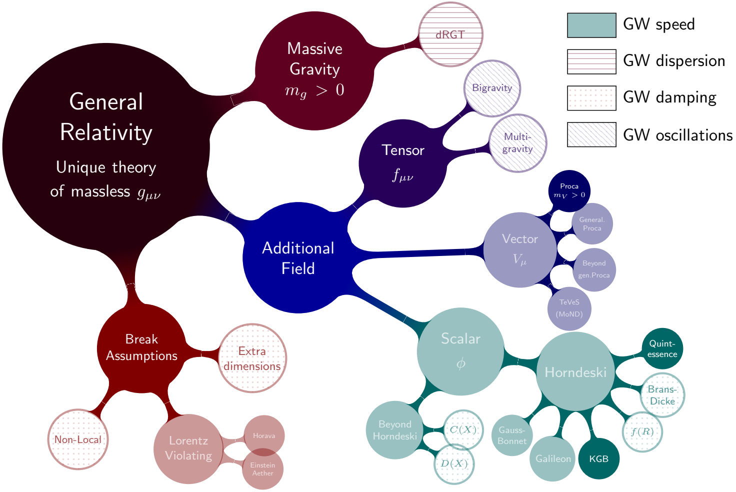
The landscape of Dark energy and modified gravity

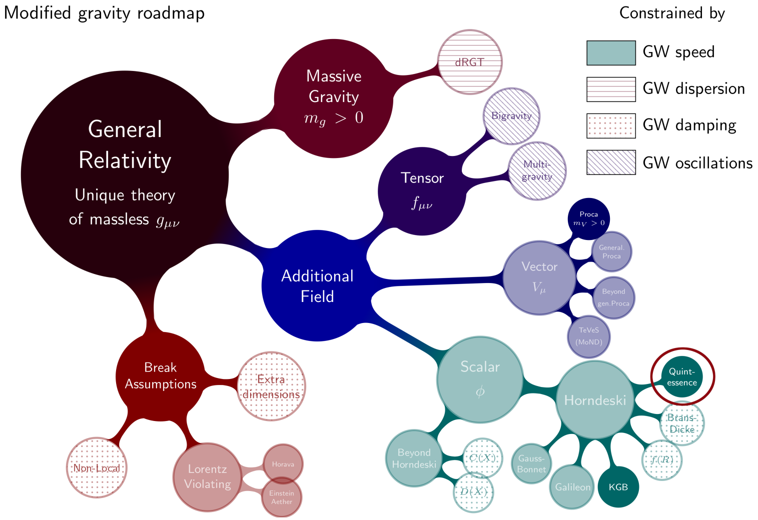
Modified gravity roadmap

Constrained by



J. M. Ezquiaga & M. Zumalacárregui (arXiv: 1807.09241 [astro-ph.CO])

The landscape of Dark energy and modified gravity



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Quintessence

- Free Λ:

$$G_{\mu\nu} + \Lambda\, g_{\mu\nu} = T_{\mu\nu} \quad \longrightarrow \quad G_{\mu\nu} + \Lambda(\phi) g_{\mu\nu} = T_{\mu\nu}$$

$$\rho_\Lambda = \Lambda \quad \longrightarrow \quad \rho = \frac{1}{2}\dot{\phi}^2 + V(\phi)$$

$$p = -\Lambda \quad \longrightarrow \quad p = \frac{1}{2}\dot{\phi}^2 - V(\phi)$$

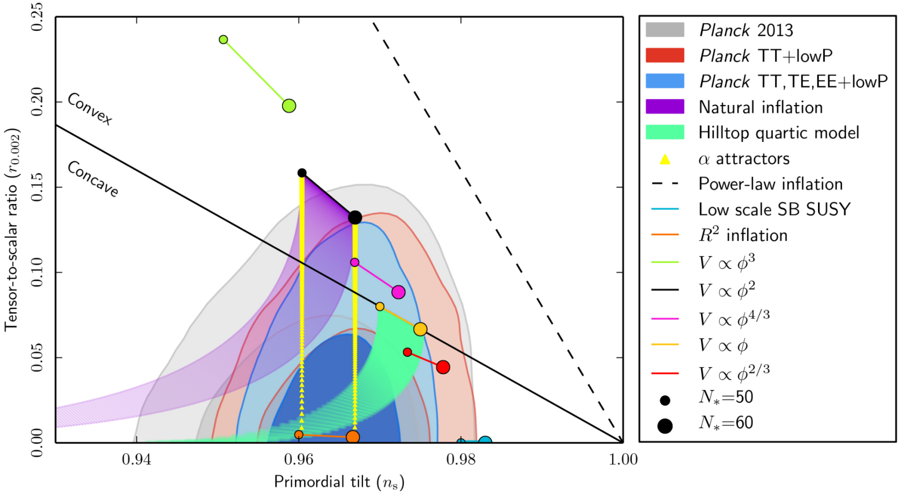
- New equation of motion:

$$\ddot{\phi} + 3H\dot{\phi} + V_{,\phi} = 0$$

- Determined by 1 function; e. g. $w = p/\rho$:

$$\rho = \rho_0 \exp\left[-3\int_0^{\log(a)} d\log(a')(1+w)\right]$$

Ideas from inflation: n_s, r equivalents for DE/MG?



Planck 2015 results – Ade et al. (Astron.Astrophys. 594(2016) A20)

What parameters can we use?

Parametrization must

- reproduce observables accurately for next-generation experiments:

$$\sigma_{\mathcal{O}_i} < 1\%; \quad \sigma_{D_A(z_{rec})} < 0.3\%$$

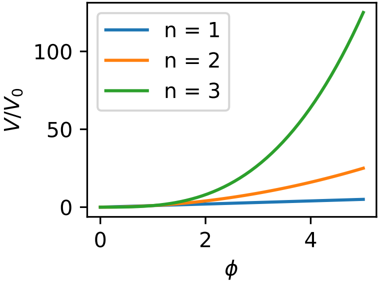
- have less parameters as possible

Finding the optimal parametrization

	Monomial	Axion	EFT	Modulus
Varied params	4	[14, 24]	[12, 17]	[13, 23]
$V(\phi) \sim$	ϕ^n	$\cos(\tilde{\phi})$	$\sum_n \tilde{\phi}^n$	$e^{\tilde{\phi}}$

E.g. Monomial quintessence ($V = V_0 \phi^n$)

- Vary free parameters:
  - 2 cosmological parameters:
    - $h \in [0.6, 0.8)$
    - $\Omega_{cdm} \in [0.15, 0.35)$
  - 2 model parameters:
    - $\phi_{ini} \in U[1, 7)$
    - $n \in U_{\mathcal{Z}}[1, 7]$
    - Note: V_0 fixed by $1 = \sum_i \Omega_i$
- Compute H, D_A and f
- Do this 20.000 times



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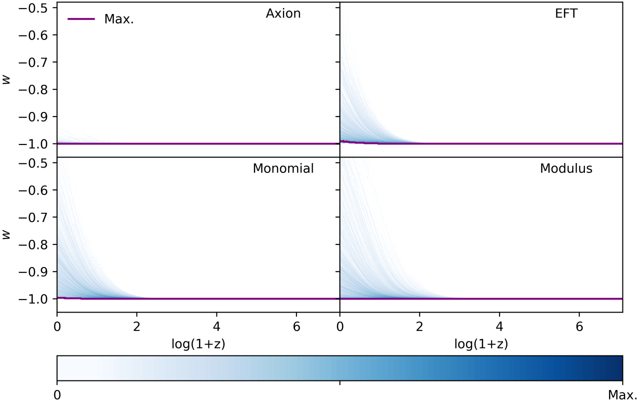

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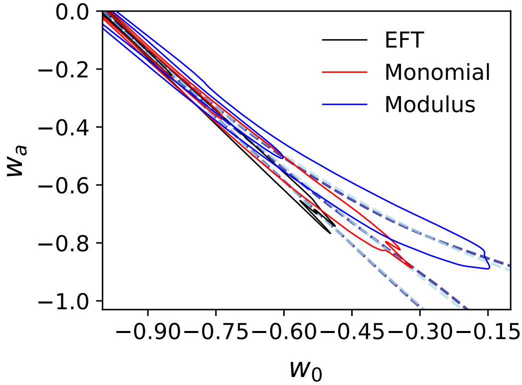


Parametrize

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

w_0, w_a that best reproduce observables at $z < z_{rec}$.

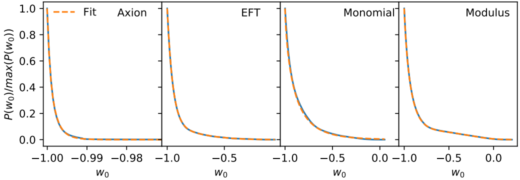
Max. error that of next-gen. experiments:

$$\sigma_{\mathcal{O}_i} < 1\%; \quad \sigma_{D_A(z_{rec})} < 0.3\%$$

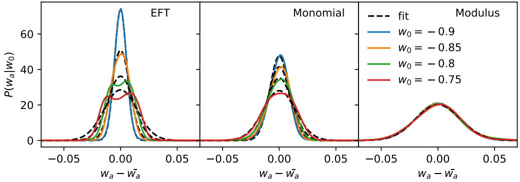
Theoretical priors for quintessence

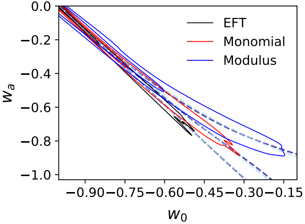
	Monomial	Axion	EFT	Modulus
Varied params	4	[14, 24]	[12, 17]	[13, 23]

$$\mathcal{P}[w_0]=A_1 e^{-\left(\frac{w_0}{w_1}\right)^{\alpha_1}}+A_2 e^{-\left(\frac{w_0}{w_2}\right)^{\alpha_2}}$$



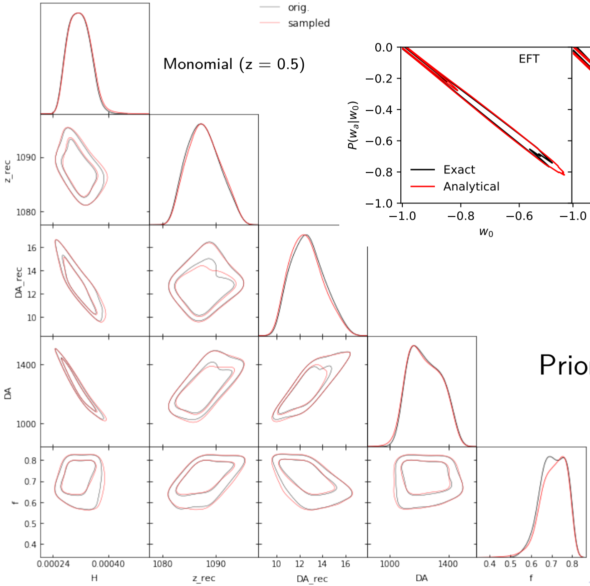
$$\mathcal{P}[w_a|w_0]=\frac{1}{\sqrt{2\pi\sigma^2(w_0)}}\exp\left[-\left(\frac{w_a-\bar{w_a}(w_0)}{2\sigma(w_0)}\right)^2\right]$$

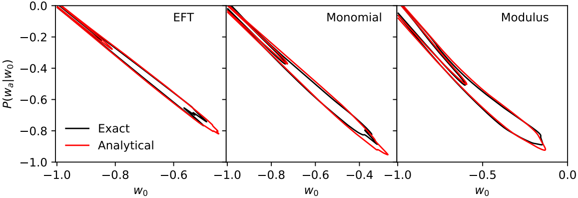




- $\bar{w}_a(w_0)\simeq\beta_0+\beta_1 w_0+\beta_2 w_0^2$
- $\sigma(w_0)\simeq\sigma_0+\sigma_1 w_0+\sigma_2 w_0^2$

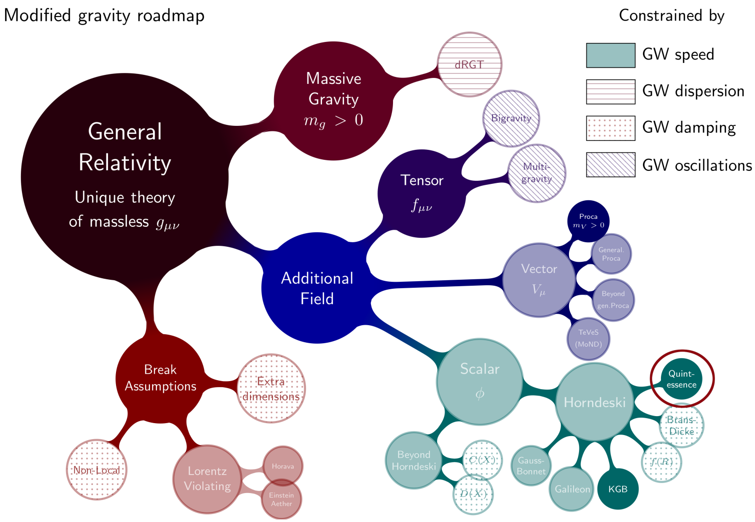
Theoretical priors for quintessence: test





Priors reproduce observables

Towards a general framework for Dark Energy



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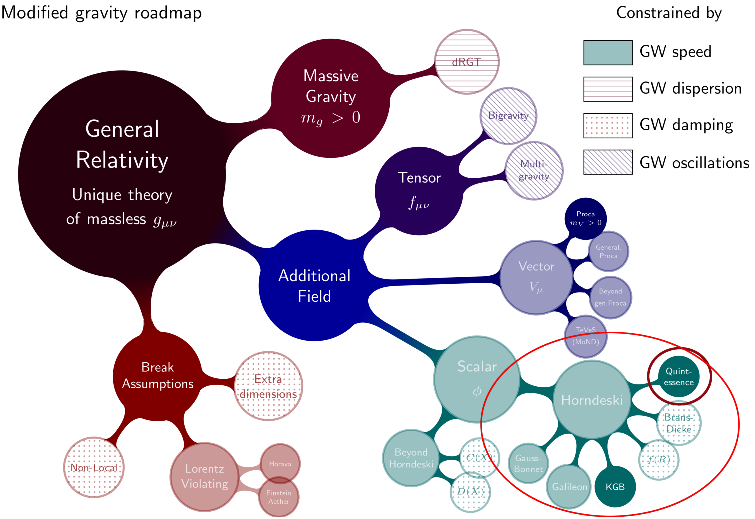

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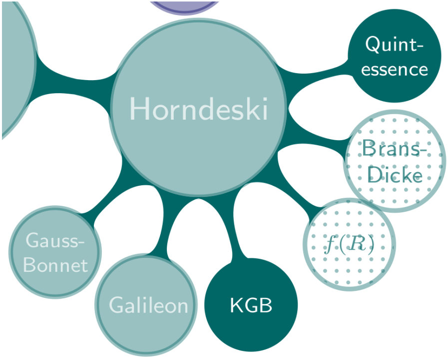
Next step: Horndeski

- Most general theory:
  - $g_{\mu\nu}$ and ϕ
  - Local
  - 4D
  - Lorentz invariance
  - 2^{nd} order eq. motion
- $\mathcal{L} = \sum_{i=2}^{5} G_i(\phi, (\partial\phi)^2) L_i$
- Linear perts, w + 4 $\alpha_i(z)'s$:
  - $\alpha_K \to c_s^2$,
  - $\alpha_B \to$ mix $g_{\mu\nu}$ & ϕ
  - $\alpha_M \to M_P$
  - $\alpha_T \to c_{gw}^2$



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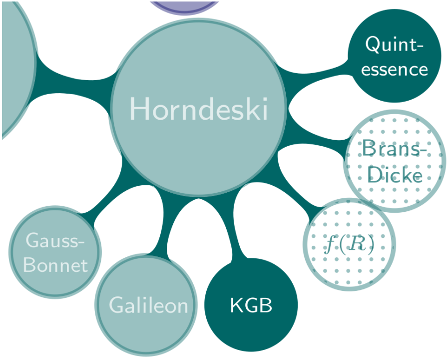

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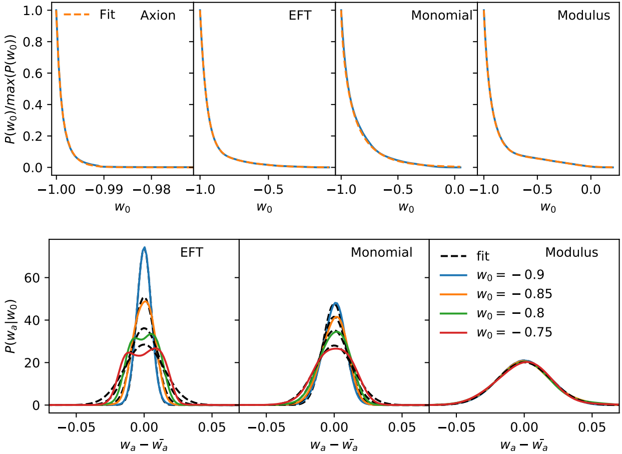
Fortunately. . .

$$\boxed{\text{GW170817} \rightarrow \alpha_T = 0 \rightarrow G_5 = 0 \text{ and } G_4 = G_4(\phi)}$$

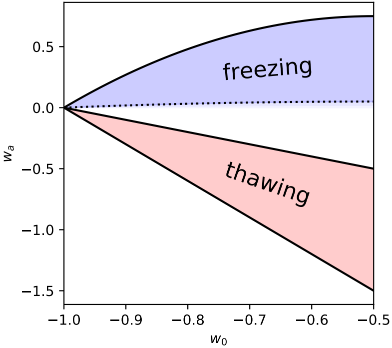
Only 2.5 functions remain.

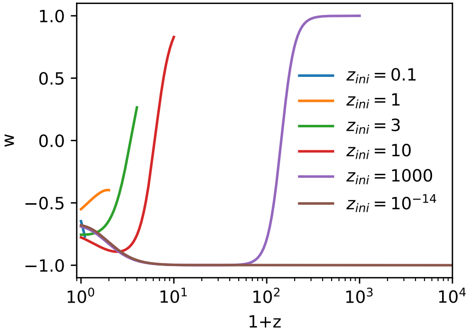
Summary: framework for quintessence

- $w = w_0 + w_a(1-a)$ fitting observables ($z < z_{rec}$)
- Accurate for next-gen experiments
- Analytical expression for $P[w_0, w_a]$ (Results with data coming soon!)



Freezing models and z_{ini}





Fit w vs fit observables