The role of stability conditions in single field Quintessence

Matteo Martinelli

Lorentz Institute, Leiden

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based on: Peirone, MM, Raveri, Silvestri
arXiv:1702.06526

Outline

Overview

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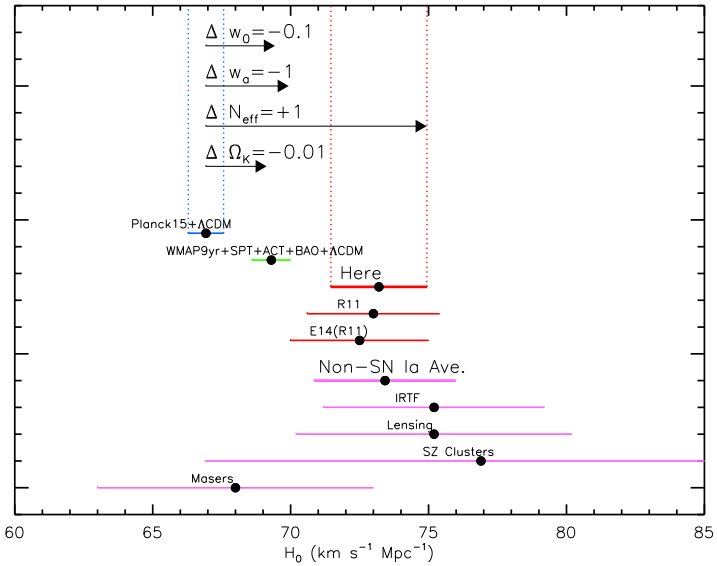
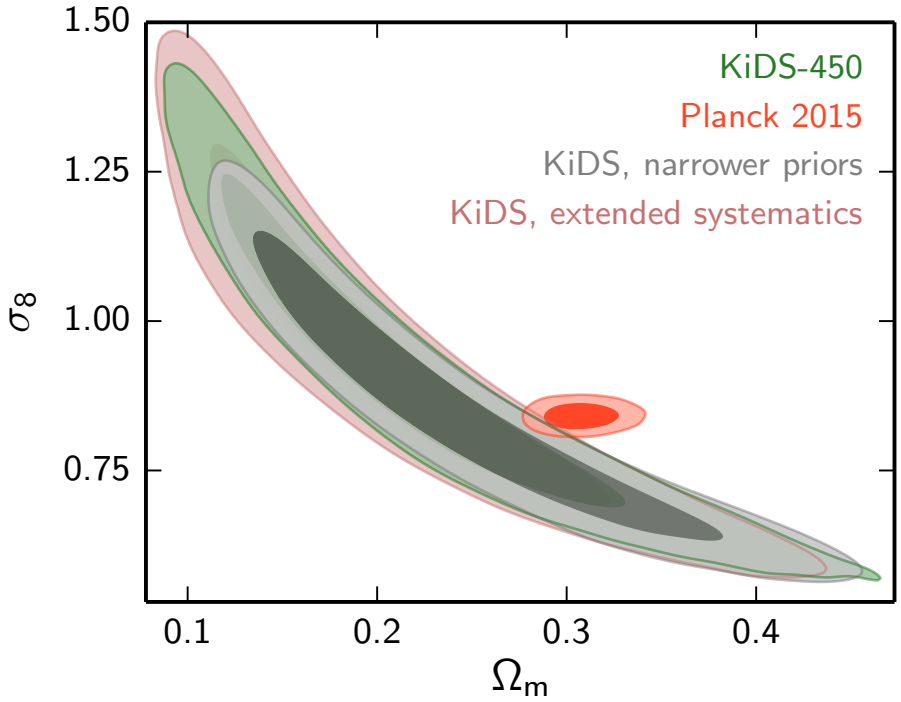


Riess et al. 2016



Joudaki et al. 2016

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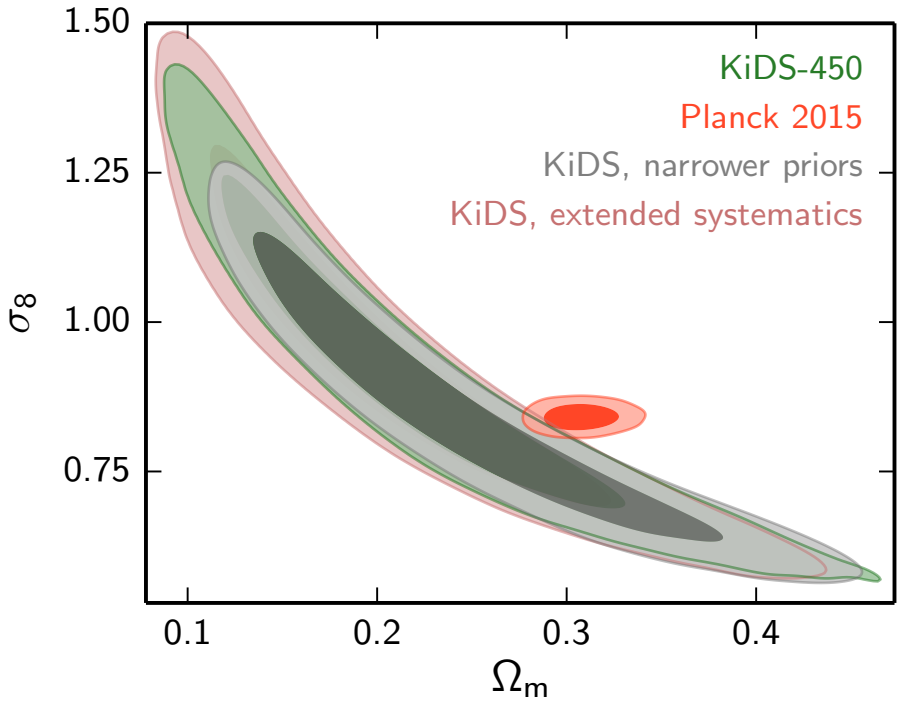
$$T(S_8) = \frac{|S_8(CMB) - S_8(WL)|}{\sqrt{\sigma^2_{S_8}(CMB) + \sigma^2_{S_8}(WL)}} = 2.1\sigma$$

$$S_8 = \sigma_8 \sqrt{\frac{\Omega_m}{0.3}}$$



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Systematics or extensions to ΛCDM

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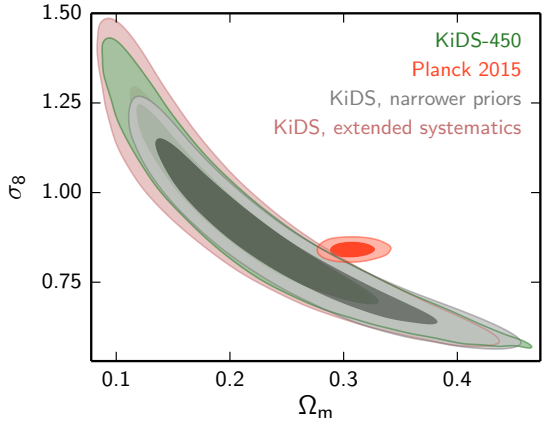

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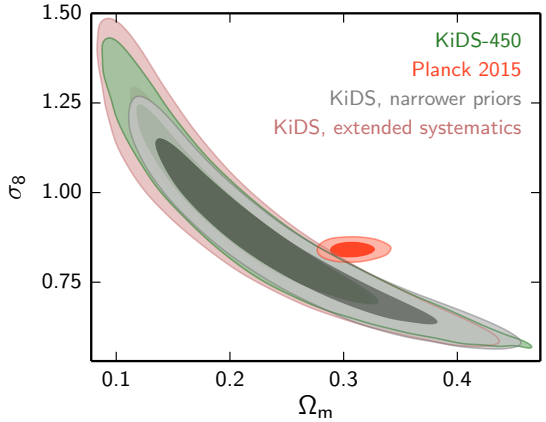

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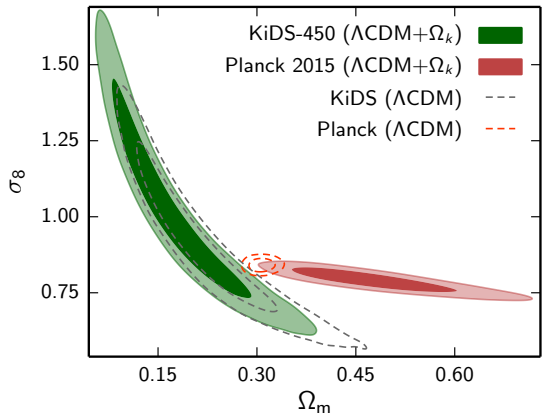

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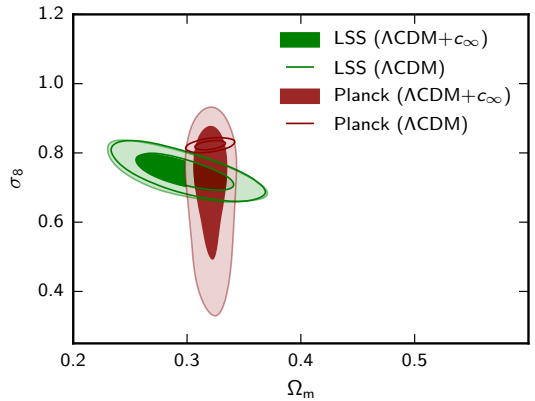

Camera, MM, Bertacca 2016

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The CMB-WL tension can be washed away abandoning the cosmological constant

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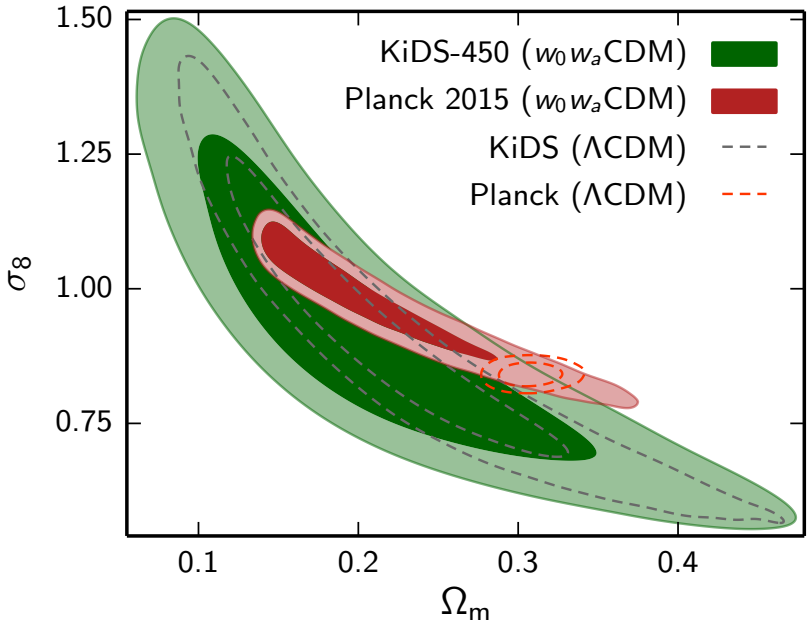

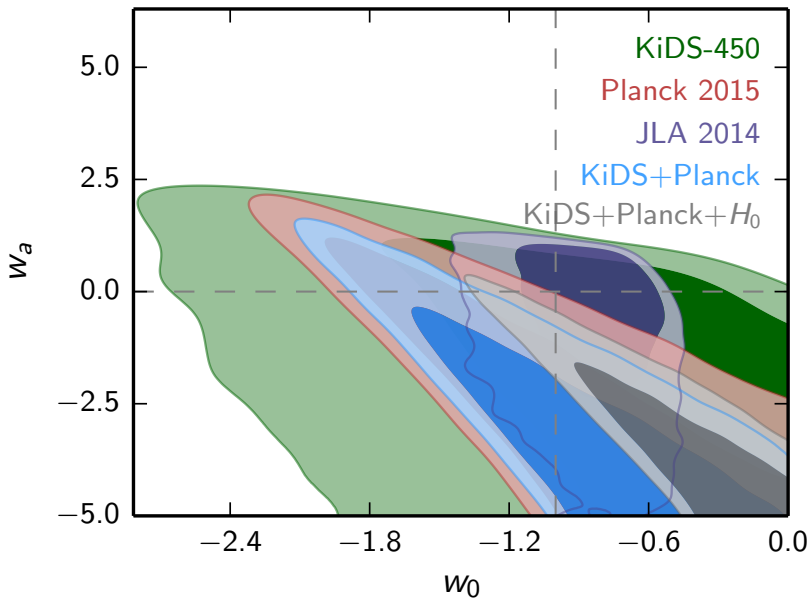

$$T(S_8) = 0.91\sigma \text{ with } \Delta DIC = -6.4$$

Joudaki et al. 2016

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The CPL $w(z)$ crosses the phantom divide ($w = -1$), where equations for DE perturbations become singular.

Parametrized Post-Friedmann (PPF) prescription, which assumes smooth Dark Energy field(s), stabilizes the model.

Fang, Hu, Lewis 2008

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We use the EFT approach to DE/MG (see Filippo's talk).
These requirements give conditions on the EFT functions which translates to limitations on the parameter space.
Stability conditions are implemented in EFTCAMB

Hu, Raveri, Frusciante, Silvestri 2014 and 2015

Single field Quintessence

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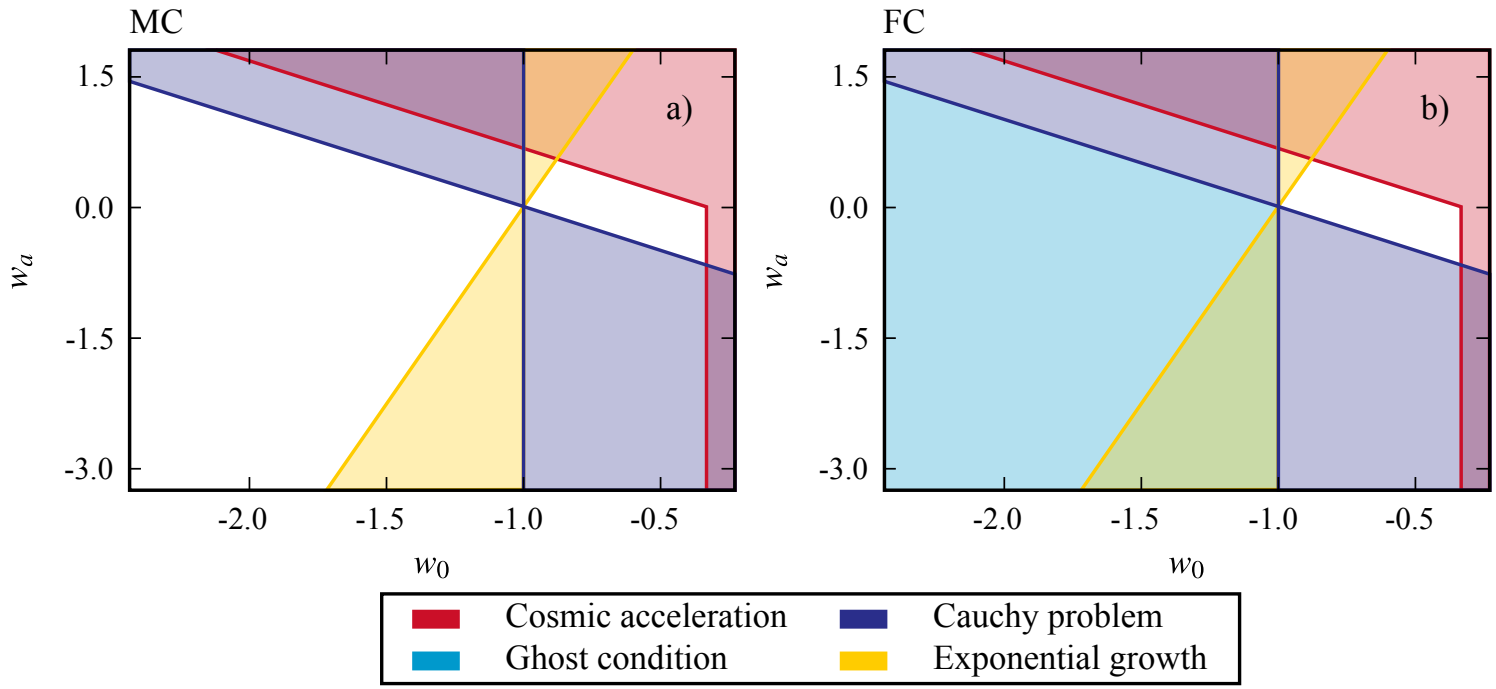

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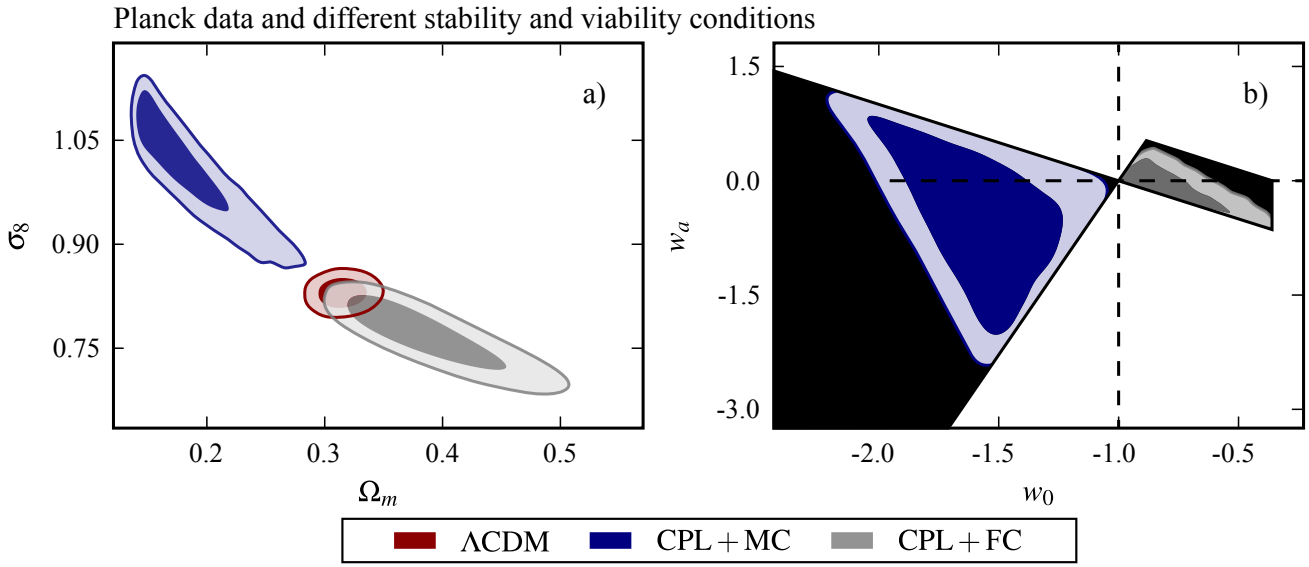
Overview

Theoretical priors

These conditions are not imposed a posteriori on the analysis, but rather included in the prior probability $P(\theta)$.

$$P(\theta|D) \propto L(D|\theta)P(\theta)$$



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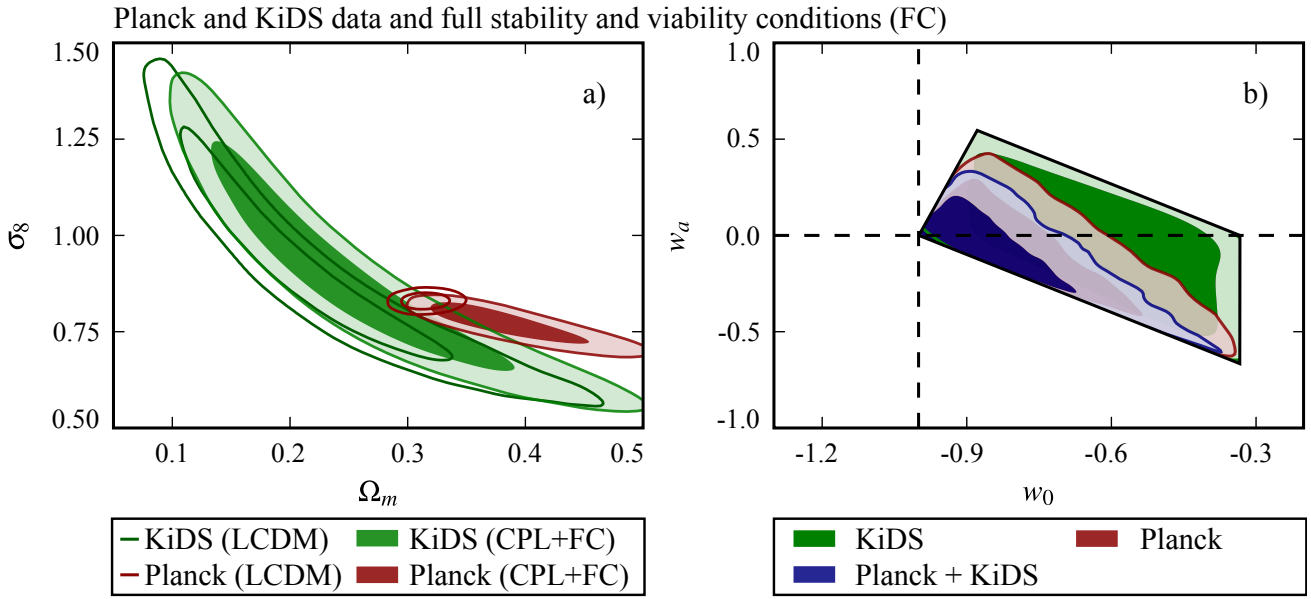

$T(S_8) = 1.3\sigma$ with $\Delta DIC = 4.6$

Assuming single field Quintessence, ΛCDM is again the better model

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Overview

Conclusions

- Tensions between cosmological datasets can be seen as hints of failure of ΛCDM and used to test for extended models
- Phenomenological parameterizations allow to probe departure from standard paradigm, without assuming any specific model.
- if one wants to stick to physically viable theories, theoretical priors should be included in the analysis
- Simple example: imposing $w(a)$ comes from single field quintessence, hints for departures from ΛCDM are removed.

We knew already that in quintessence $w(a) \geq -1$... Is this useful?

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- for more complex theories we don't have a simple intuition... theoretical conditions can avoid exploring unphysical parts of parameter space
- conditions can be generalized to broader class of theories and to other theory health requirements
  (see *De Felice, Frusciante, Papadomanolakis 2016*)

SAFETY

SLIDES

Quintessence in the EFT formalism

Starting from the EFT action

$$S \propto \int d^4x\sqrt{-g}\{\frac{m_0^2}{2}\left[1+\Omega(\tau)\right]R + \Lambda(\tau) - a^2 c(\tau)\delta g^{00} + ...\}$$

Assuming a specific $w(z)$ completely specifies the $\Lambda(\tau)$ and $c(\tau)$ functions.

$$\frac{c(\tau)a^2}{m_0^2} = \frac{1}{2}\frac{a^2\rho_{DE}}{m_0^2}(1+w_{DE})$$

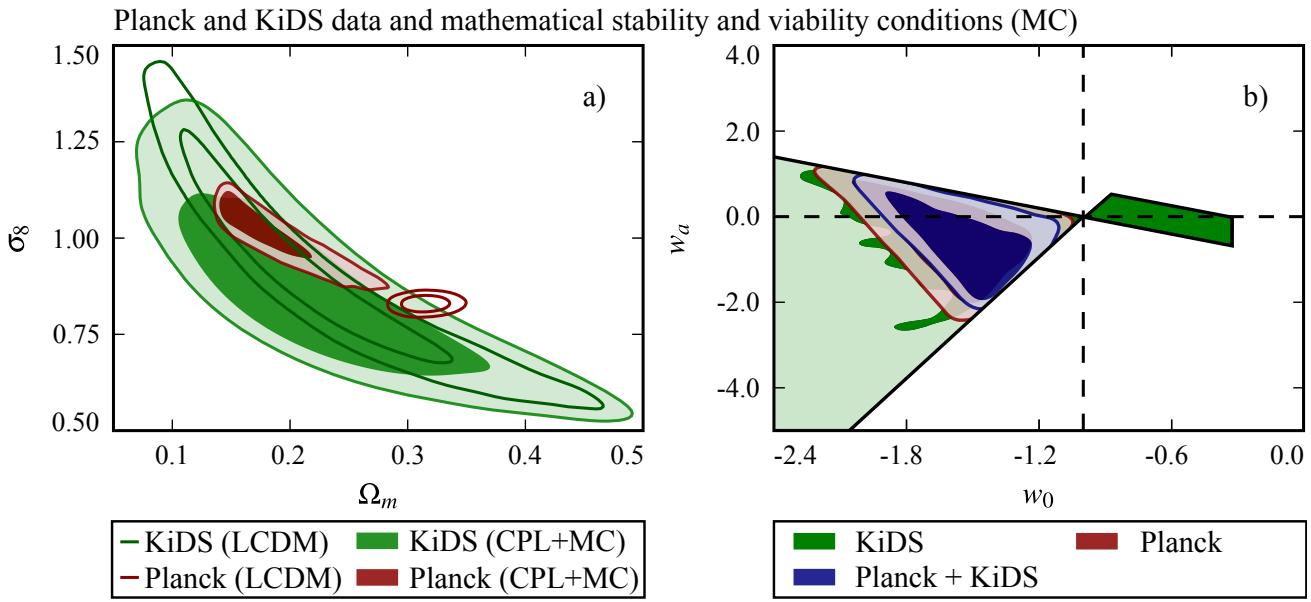
$$\frac{\Lambda(\tau)a^2}{m_0^2} = \frac{a^2\rho_{DE}}{m_0^2}w_{DE}$$

The assumption of a minimally coupling quintessence sets $\Omega(\tau) = 0$ (together with the perturbations operators).
Mathematical and Physical conditions translate on constraints on the 2 free functions and, consequently, on w_0 and w_a.

Hu, Raveri, Frusciante, Silvestri 2014 and 2015

Removing the physical conditions

Without the PC, we are implicitly assuming that ghost instabilities do not develop on the time scale of interest.
This scenario is approximately corresponding to the PPF case



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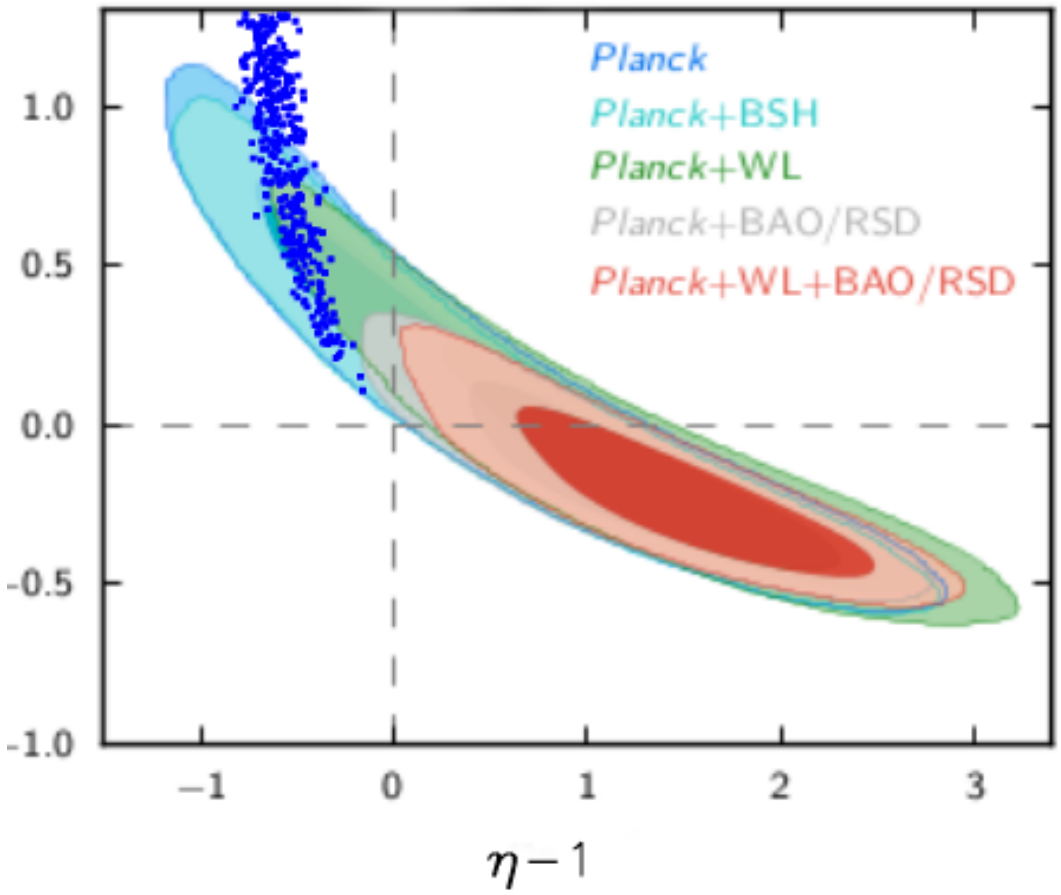
Conditions on Modified Gravity

Stability requirements applies to all kinds of phenomenological parameterizations



Perenon et al. 2015

Deviance Information Criterion

The DIC is used as a model comparison tool.

$$DIC \equiv \chi^2_{\rm BF} + 2p_D$$

where p_D is a term accounting for the complexity of the model

$$p_D = \bar{\chi^2} - \chi^2_{\rm BF}$$

The results show $\Delta DIC = DIC^{ext} - DIC^{\Lambda CDM}$, thus $\Delta DIC < 0$ highlights a preference of the data for the extended model.

A better estimate would be given by the Bayesian Evidence, but it's generally complicated to compute, specially for a non trivial prior volume.