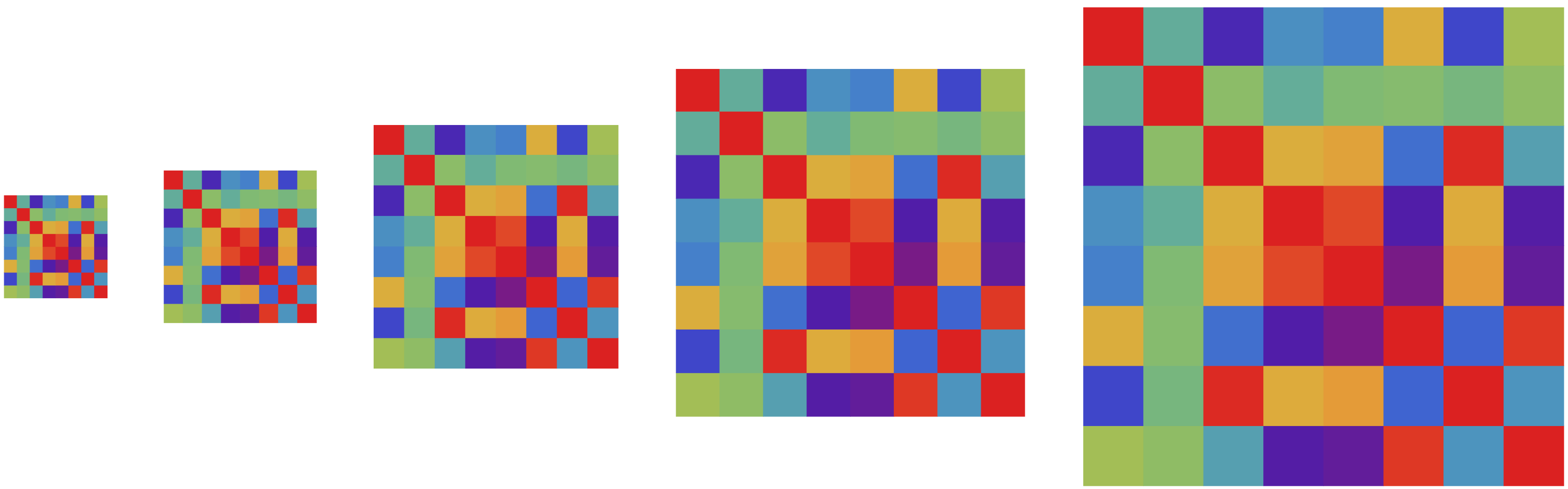
Scale symmetry, the Higgs and the Cosmos

Javier Rubio

based on Phys.Rev. D97 (2018) no.4, 043520 & Phys.Rev. D99 (2019) no.6, 063512



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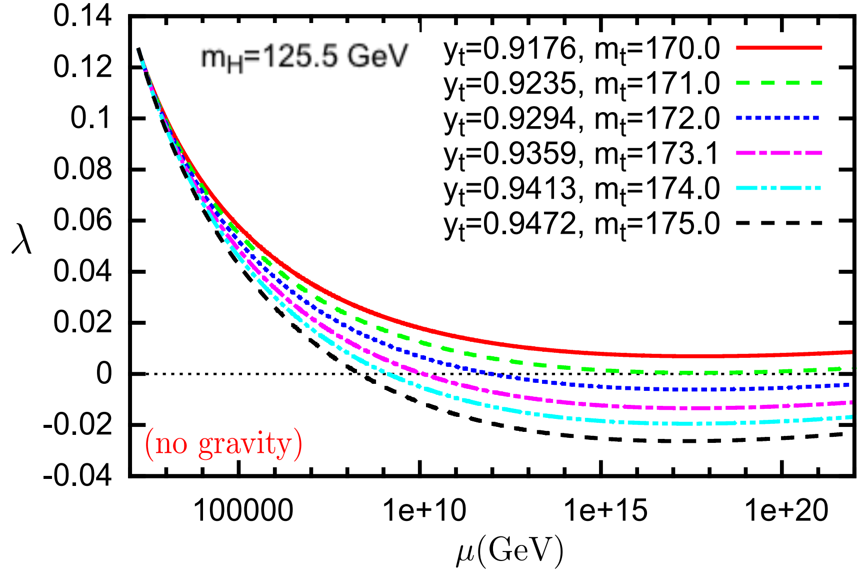
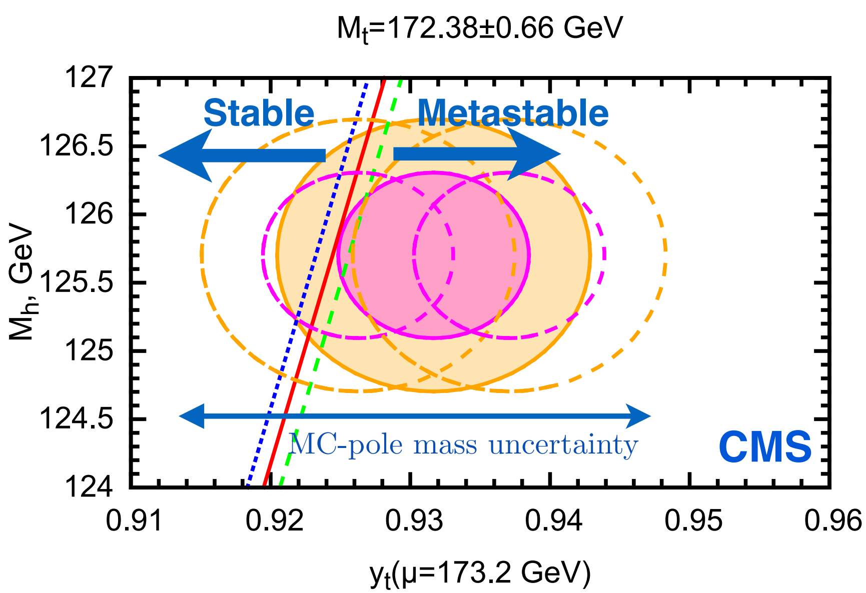
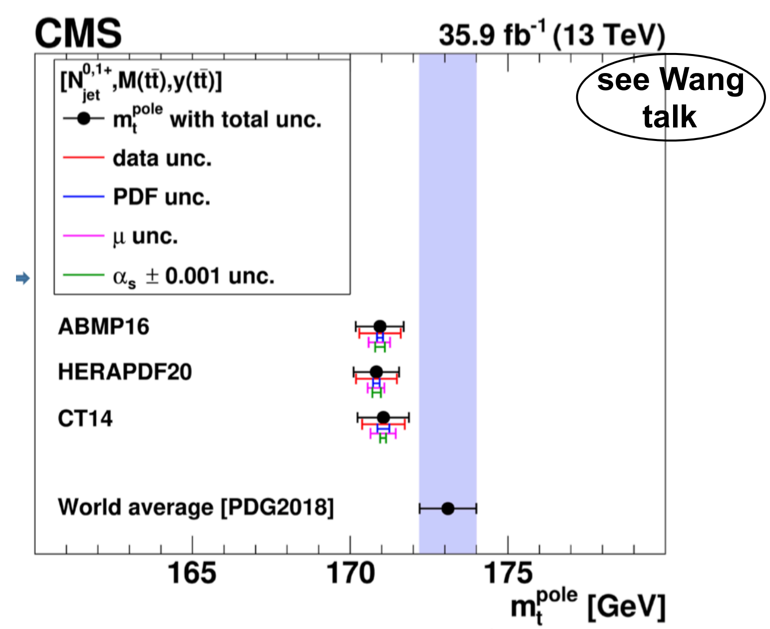
A very special Universe



between Scylla and Charybdis



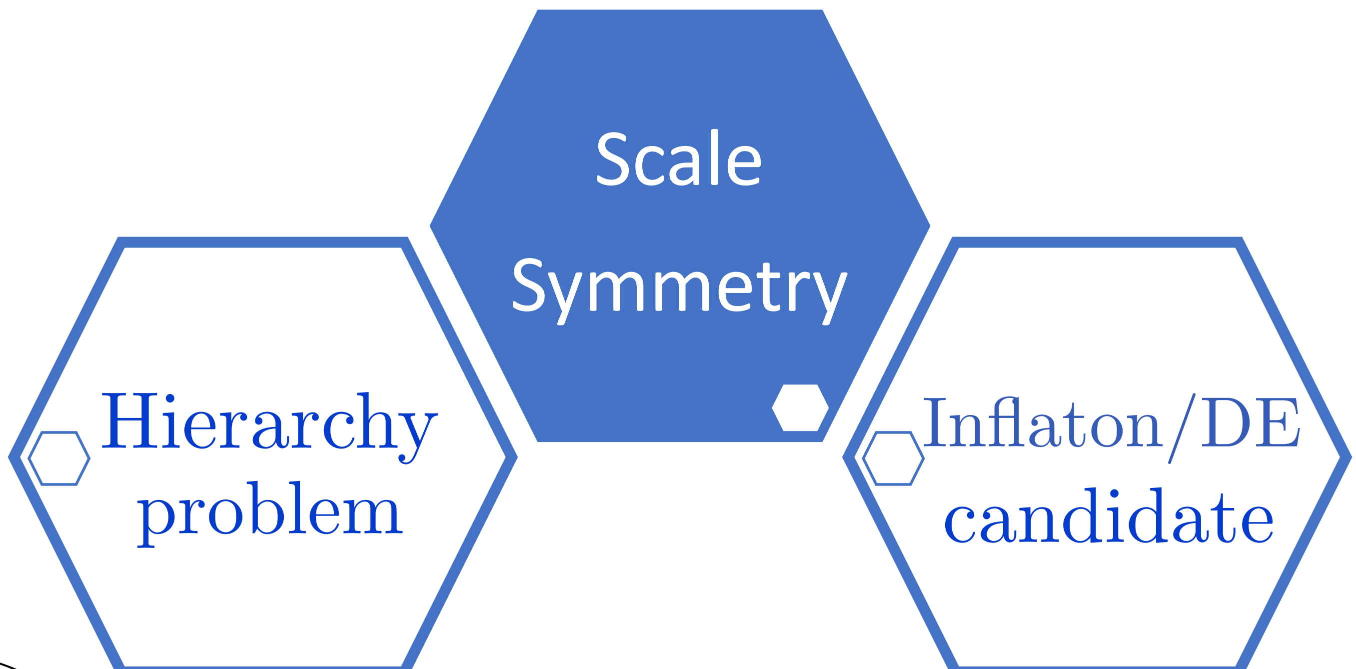


See F. Bezrukov, M. Shaposhnikov J.Exp.Theor.Phys. 120 (2015) 335-343 and references therein

If the mass of the Higgs boson is put to zero in the SM, the Lagrangian has a larger symmetry

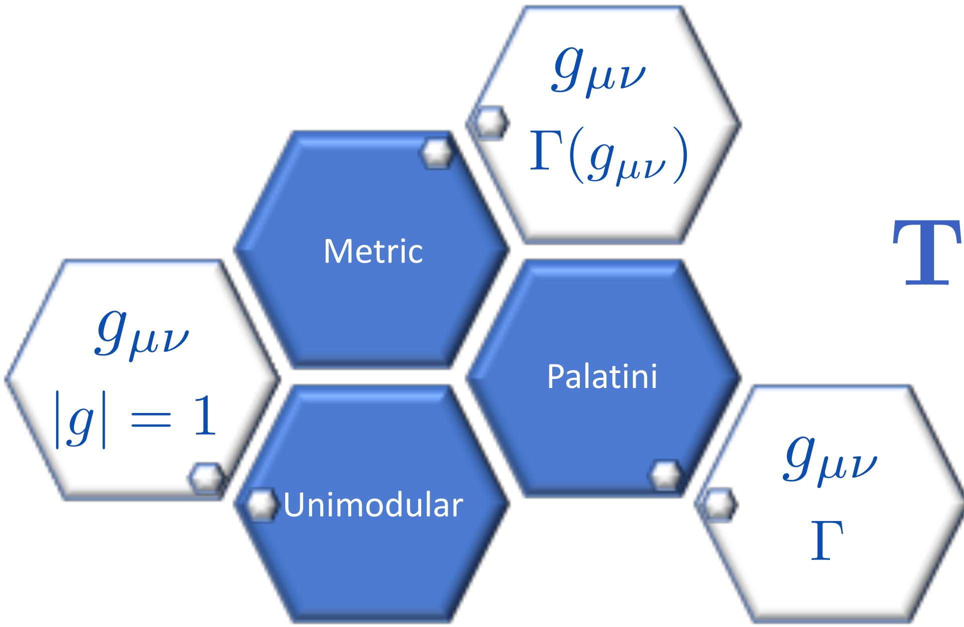
$$x^\mu \to \alpha^{-1} x^\mu \qquad\qquad \Phi_i(x) \to \alpha^{d_i} \Phi_i(\alpha^{-1} x)$$

It is tempting to use this symmetry for something

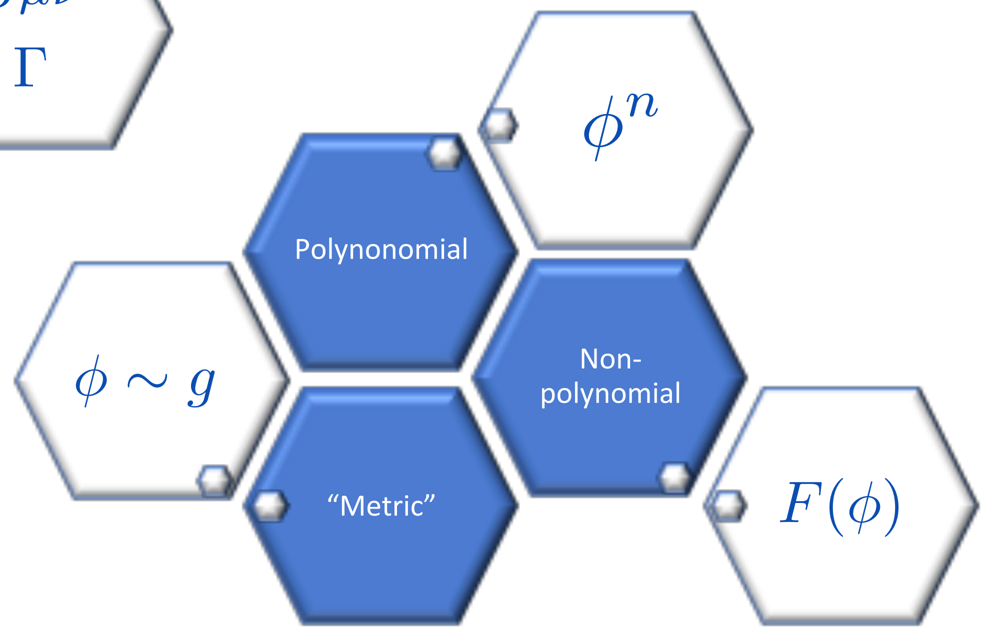


see this morning talks

The players



Theory of gravity



Scalar sector

The simplest possibility

J-frame

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{\xi_h h^2}{2} R - \frac{1}{2}(\partial h)^2 - \frac{\lambda}{4} h^4 - y h \bar{\psi}\psi$$

E-frame

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{M_P^2}{2} R - \frac{1}{2}(\partial \phi)^2 - \frac{\lambda M_P^4}{4\xi_h^2} - y\frac{M_P}{\xi_h}\bar{\psi}\psi$$

with $\phi = -\frac{M_P}{2\sqrt{|\kappa_c|}} \log \frac{M_P^2}{\xi_h h^2}$ $\qquad \kappa_c \equiv -\frac{\xi_h}{1+6y\xi_h}$

$y = 1$ for metric case $\qquad$ $y = 0$ for Palatini case

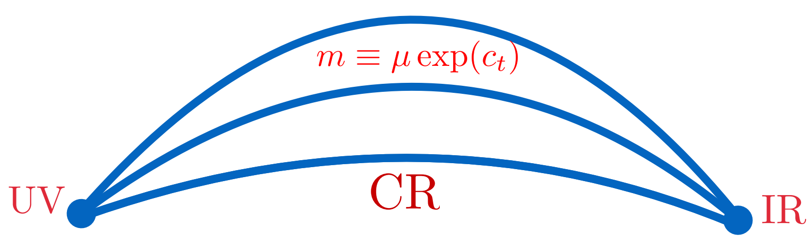
Scale symmetry must be broken in one way or another

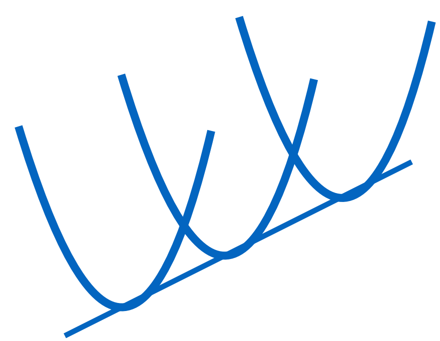
2 different perspectives

Classical
but not
Quantum

Classical
and
Quantum (SSB)

EFT





The Higgs-Dilaton model

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{1}{2}\left(\xi_\chi \chi^2 + \xi_h h^2\right) R - \frac{1}{2}(\partial h)^2 - \frac{1}{2}(\partial \chi)^2 - U(h,\chi)$$

with $\quad U(h,\chi) = \frac{\lambda}{4}\left(h^2 - \alpha\chi^2\right)^2$

A singlet under the Standard Model gauge group

All scales generated by SSB of global scale invariance

Hierarchy of scales not addressed

M. Shaposhnikov, D. Zenhausern, Phys.Lett. B671 (2009) 187-192
J. García-Bellido, JR, M. Shaposhnikov, D. Zenhausern, Phys.Rev. D84 (2011) 123504
A recent revival: P. G: Ferreira, C. T. Hill, G. G. Ross Phys.Lett. B763 (2016) 174-178, Phys.Rev. D95 (2017) no.4, 043507

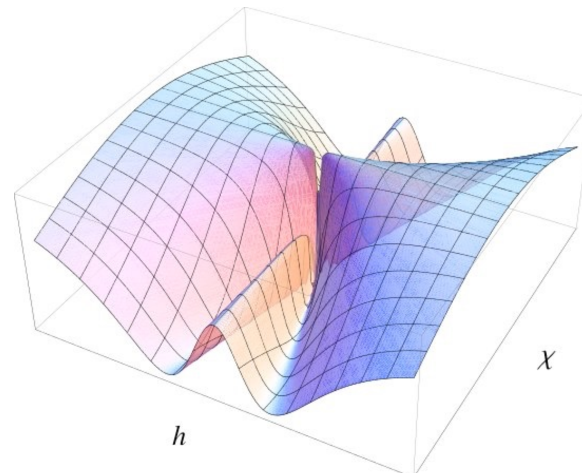
Einstein-frame formulation

$$\frac{\tilde{\mathcal{L}}}{\sqrt{-\tilde{g}}} = \frac{M_P^2}{2}\tilde{R} - \frac{1}{2}\gamma_{ab}(\Omega)\tilde{g}^{\mu\nu}\partial_\mu\varphi^a\partial_\nu\varphi^b - V(\varphi)$$

Asymptotically flat

Vacuum is infinitely degenerate

Physics independent of dilaton value



$$\gamma_{ab}(\Omega) = \frac{1}{\Omega^2}\left(\delta_{ab} + y \times \frac{3}{2}M_{\mathrm{P}}^2\frac{\partial_a\Omega^2\partial_b\Omega^2}{\Omega^2}\right)$$

$$R_{\gamma_{ab}} \neq 0 \quad \text{unless} \quad \xi_h \neq \xi_\chi$$

ISOCURVATURE
AND
NON-GAUSSIANITIES

Scale current

This current can be computed in any frame

$$g_{\mu\nu} \mapsto g_{\mu\nu} + \sigma \Delta g_{\mu\nu} \qquad \phi^i \mapsto \phi^i + \sigma \Delta \phi^i$$

In the Einstein-frame this is particularly simple

$$\Delta g_{\mu\nu} = 0 \qquad \sqrt{-g} J^\mu = \frac{\partial \mathcal{L}}{\partial \left[\partial_\mu \phi^i\right]} \Delta \phi^i$$

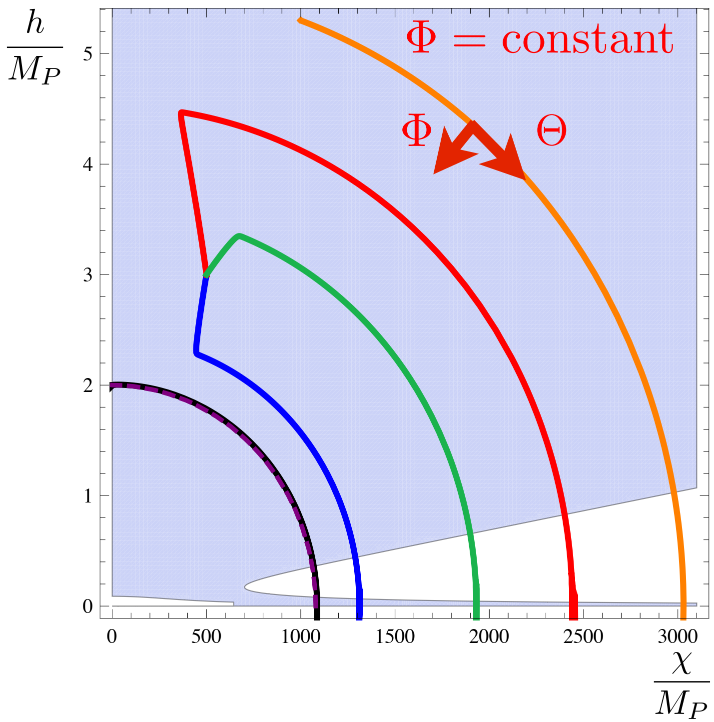
$$J^\mu = g^{\mu\nu} \frac{M_P^2}{2(\xi_\chi \chi^2 + \xi_h h^2)} \partial_\nu \left((1 + 6\, y\, \xi_h) h^2 + (1 + 6\, y\, \xi_\chi) \chi^2 \right)$$

J. García-Bellido, JR, M. Shaposhnikov, D. Zenhausern, Phys.Rev. D84 (2011) 123504

The conservation of this quantity has interesting consequences...

see Graham's talk for Jordan

Inertial symmetry breaking



$$D_\mu J^\mu = 0 \longrightarrow \Box\Phi^2 = 0$$

Independent of slow-roll

Insensitive to IR form of the potential

Easily applicable to other scenarios

$$\exp\left[\frac{2\gamma\Phi}{M_{\rm P}}\right] \equiv \frac{\kappa_c}{\kappa}\frac{(1+6\,y\,\xi_h)h^2+(1+6\,y\,\xi_\chi)\chi^2}{M_{\rm P}^2} \qquad \gamma^{-2}\Theta \equiv \frac{(1+6\,y\,\xi_h)h^2+(1+6\,y\,\xi_\chi)\chi^2}{\xi_h h^2+\xi_\chi\chi^2}$$

$$\kappa_c \equiv -\frac{\xi_h}{1+6y\xi_h} \qquad \kappa \equiv \kappa_c\left(1-\frac{\xi_\chi}{\xi_h}\right) \qquad \gamma \equiv \sqrt{\frac{\xi_\chi}{1+6y\xi_\chi}}$$

The pole structure

$$\frac{\mathcal{L}}{\sqrt{-g}} = \frac{M_P^2}{2} R - \frac{K(\Theta)}{2} (\partial \Theta)^2 - \frac{\Theta}{2} (\partial \Phi)^2 - U$$

No 5th force

$$K(\Theta) = -\frac{M_P^2}{4\,\Theta} \left(\frac{1}{\kappa \Theta + c} + \cancel{\frac{a}{1-\Theta}} \right) \qquad U(\Theta) = U_0 (1-\Theta)^2$$

$c \sim \xi_\chi$ Minkowski pole Single field

$\Theta > 0$ $\kappa \Theta + c < 0$

G. Karananas, JR, Phys.Lett. B761 (2016) 223-228

A geometrical interpretation

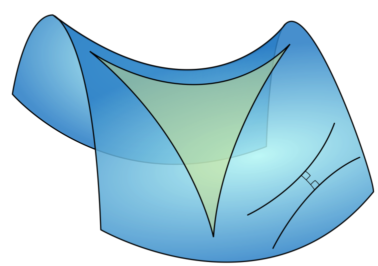
κ is the Gaussian curvature (in units of M_P) of the manifold spanned by $\varphi_1 = \Theta$ and $\varphi_2 = \Phi$

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{M_P^2}{2} R - \frac{1}{2}\gamma_{ab}(\varphi_1) g^{\mu\nu}\partial_\mu\varphi^a\partial_\nu\varphi^b - V(\varphi_1)$$

For large field values, the field space of the Higgs-Dilaton model is

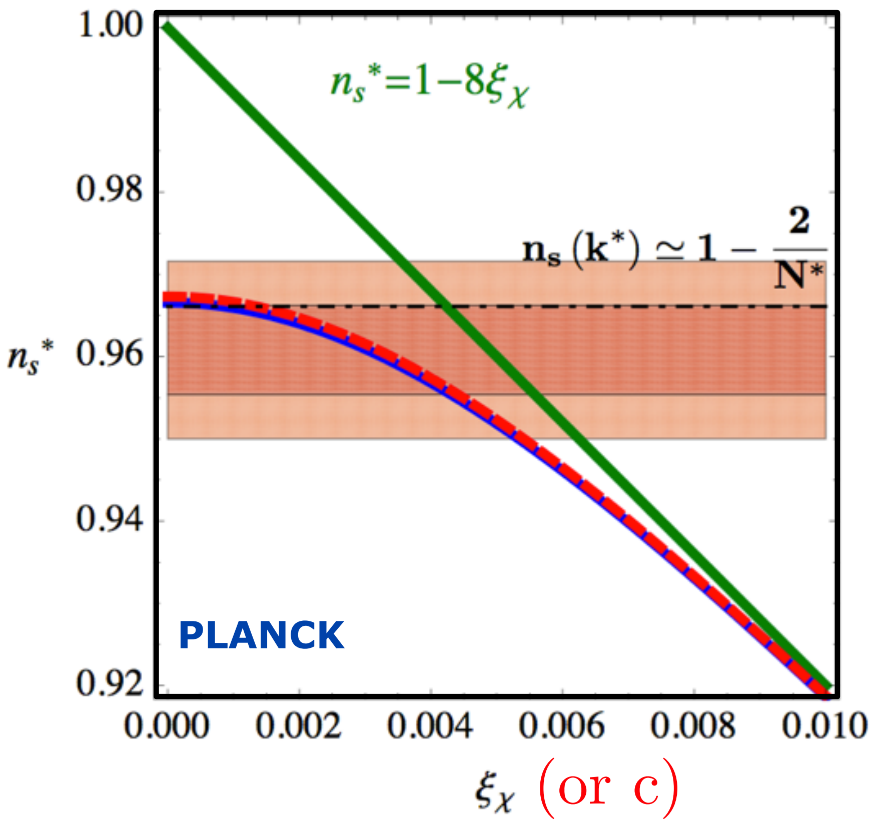
MAXIMALLY SYMMETRIC

$$\kappa \equiv \kappa_c \left(1 - \frac{\xi_\chi}{\xi_h}\right)$$



G. Karananas, JR, Phys.Lett. B761 (2016) 223-228

Inflationary observables



$$A_s = \frac{\lambda \sinh^2(4cN_*)}{1152\pi^2\xi_h^2\, c^2}$$

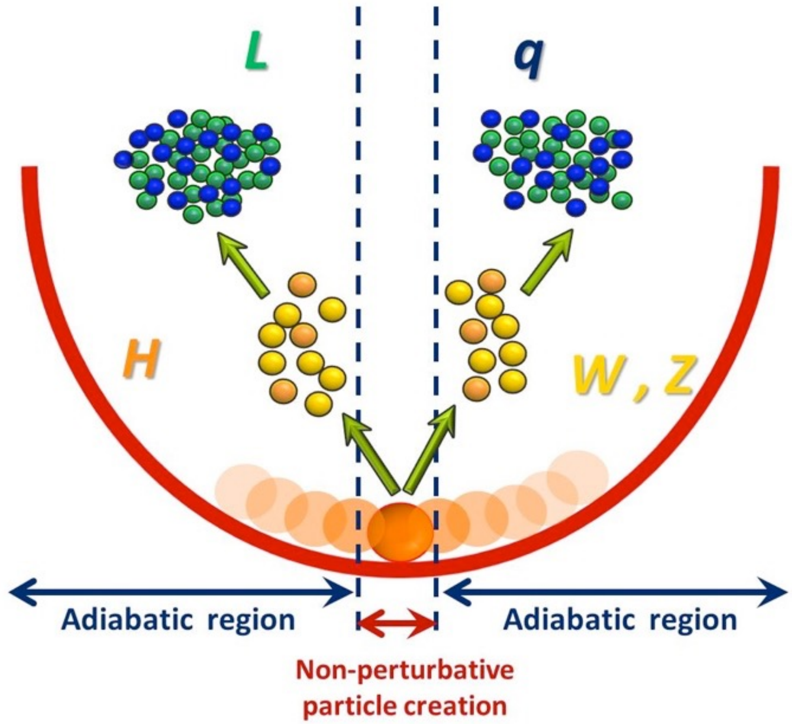
$$n_s = 1 - 8\, c \coth(4cN_*)$$

$$r = \frac{32\, c^2}{|\kappa_c|} \sinh^{-2}(4cN_*)$$

No free parameters left

J. García-Bellido, JR, M. Shaposhnikov, D. Zenhausern, Phys.Rev. D84 (2011) 123504
G. Karananas, JR, Phys.Lett. B761 (2016) 223-228

Onset of hot big bang

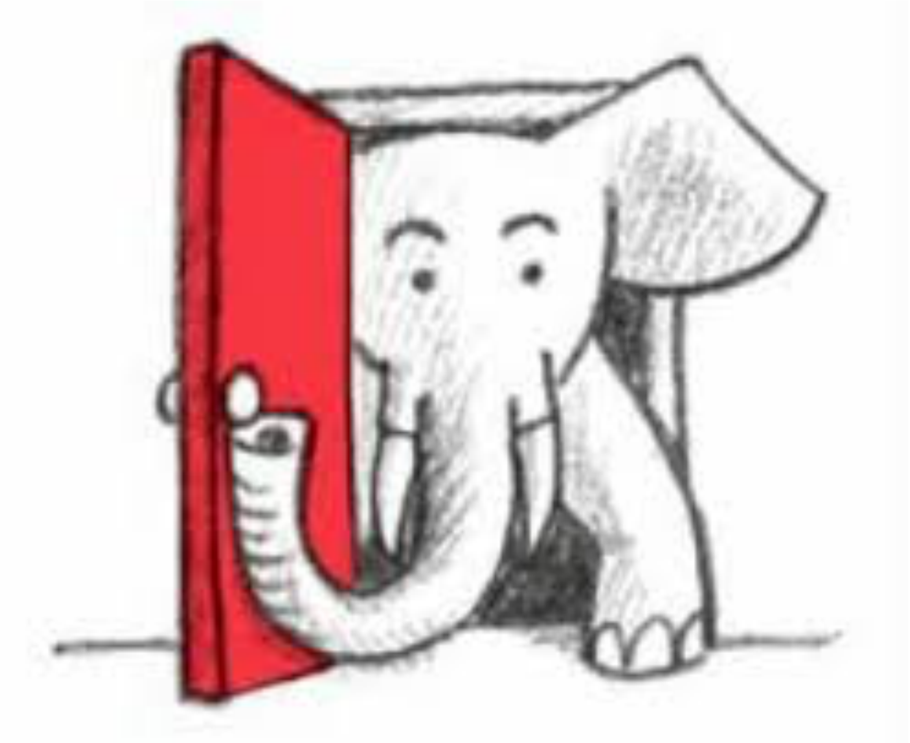


$$\Delta N_{\rm eff} \equiv \frac{g_0}{g_\nu}\left(\frac{g_f}{g_0}\right)^{4/3} C \approx 2.85\, C \qquad \text{with} \qquad C \equiv \frac{\rho_D}{\rho_{SM}} \ll 1$$

No extra relativistic degrees of freedom

J- Garcia-Bellido, M. Shaposhnikov, JR Phys. Lett. B718 (2012) 507

Late-time acceleration ?



SI and Unimodular gravity

General Relativity

CC at the level of the action

$$S = \int d^4x \left(\mathcal{L}\left(g_{\mu\nu}, \partial g_{\mu\nu}, \Phi, \partial\Phi\right) + \Lambda_0 \right)$$

Unrestricted metric determinant

$$|g|$$

Unimodular Gravity

No CC at the level of the action

$$S = \int d^4x \mathcal{L}\left(g_{\mu\nu}, \partial g_{\mu\nu}, \Phi, \partial\Phi\right)$$

Restricted metric determinant

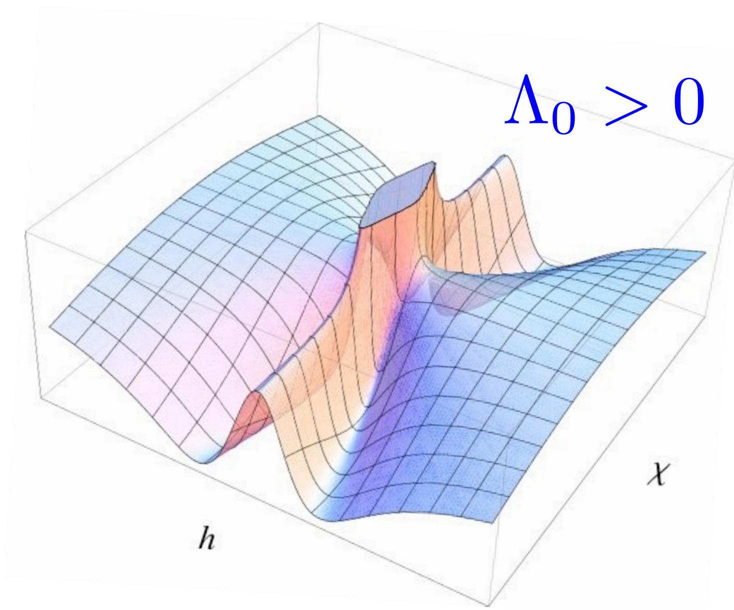
$$|g| = 1 \qquad \partial_\mu \lambda(x) = 0$$

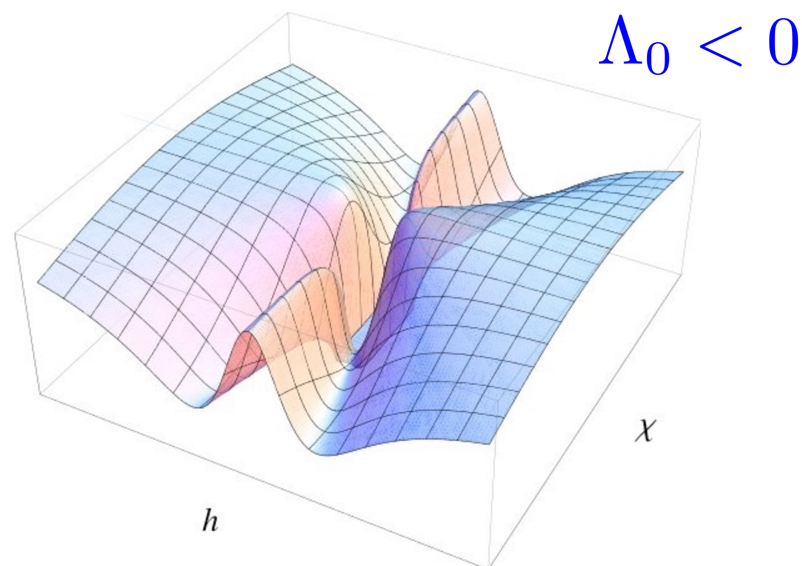
The Cosmological Constant reappears ...

... with a very different interpretation: the strength of a potential

$$U_\Lambda(\Phi) = \frac{\Lambda_0}{c^2} e^{-\frac{4\gamma\Phi}{M_P}}$$

Back to the 80's!
C. Wetterich 1988





All the new parameters determined by inflation

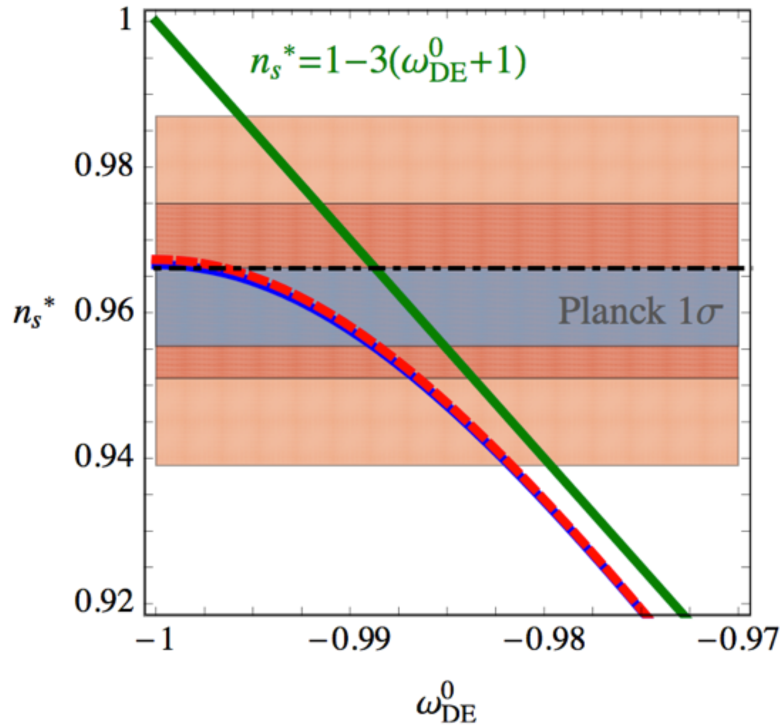
J. García-Bellido, JR, M. Shaposhnikov, D. Zenhausern, Phys.Rev. D84 (2011) 123504

Consistency relations

$$n_s = 1 - \frac{2}{N_*} X \coth X$$

$$r = \frac{2}{|\kappa_c| N_*^2} X^2 \sinh^{-2} X$$

$$X \equiv 4cN_* = \frac{3N_*(1+w)}{4F(\Omega_{\rm DE})}$$



with

$$F(\Omega_{\rm DE}) = \left[\frac{1}{\sqrt{\Omega_{\rm DE}}} - \Delta \tanh^{-1}\sqrt{\Omega_{\rm DE}}\right]^2 \qquad \Delta \equiv \frac{1-\Omega_{\rm DE}}{\Omega_{\rm DE}}$$

Present data constraints

MCMC analysis

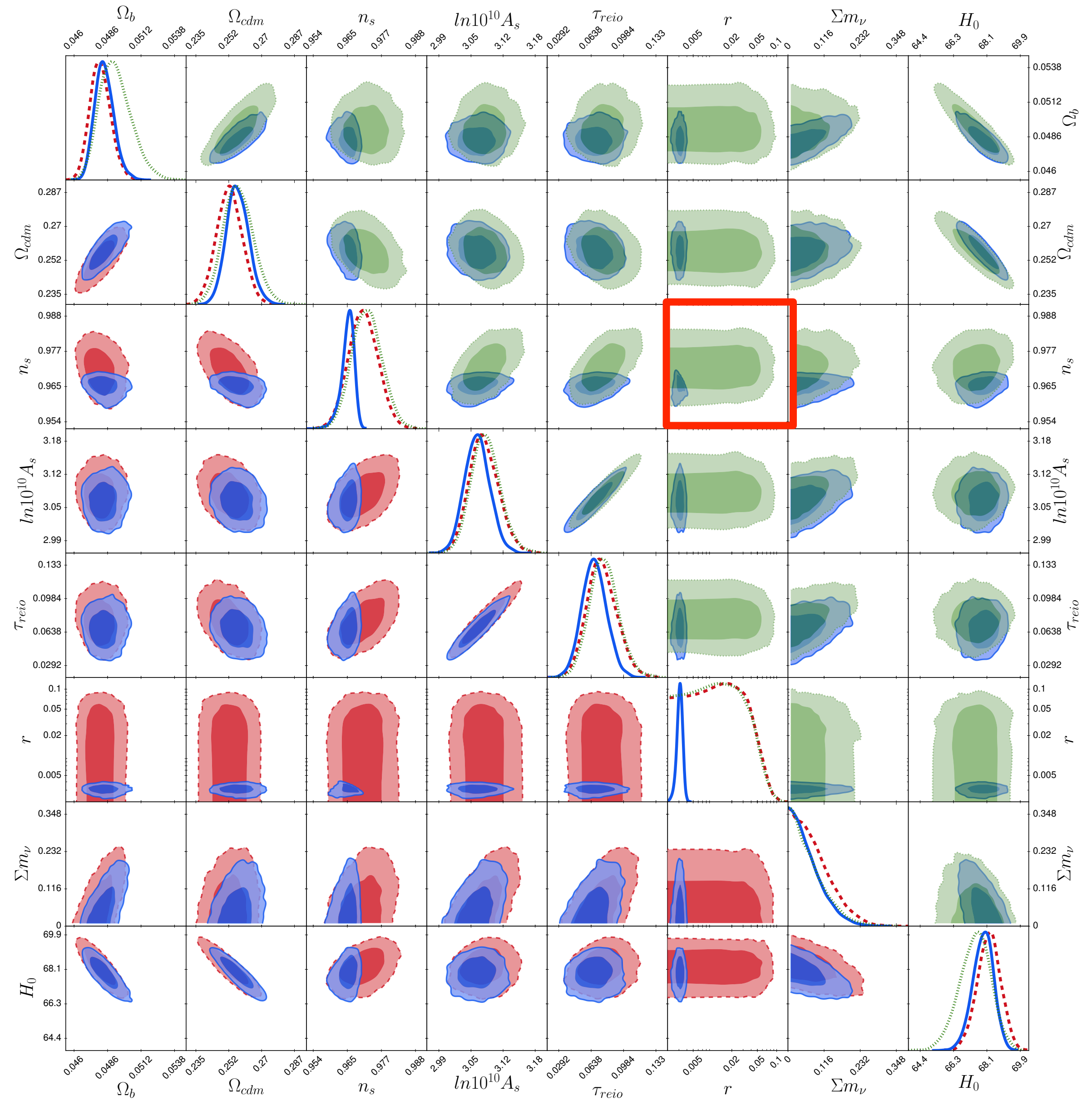
Planck TT+pol, Keck/BICEP2, JLA,

6dF, SDSS, BOSS.

ΛCDM

wCDM

HD

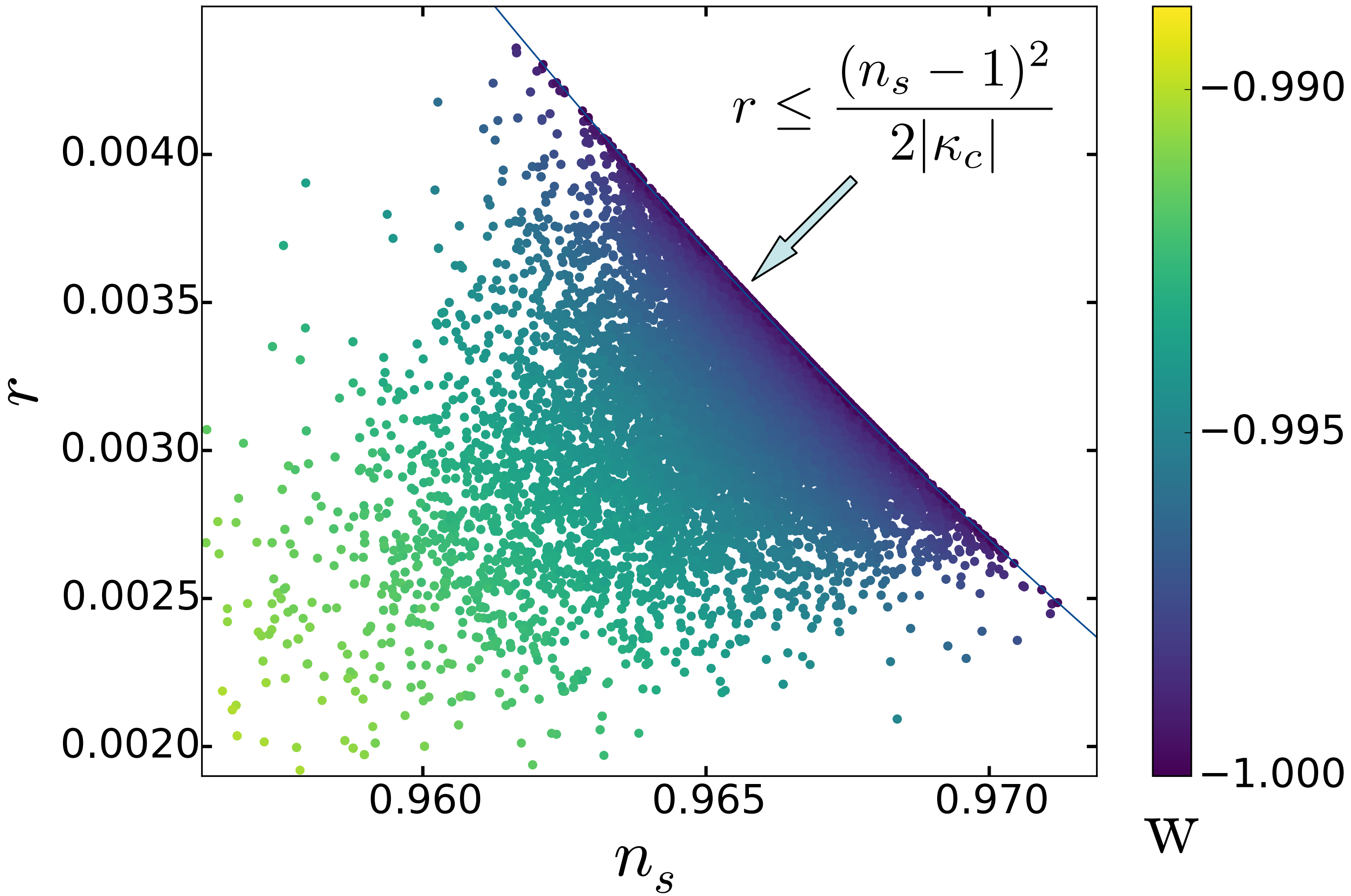


$$B(M) = \frac{p(\mathbf{x}|M)}{p(\mathbf{x}|M_{\Lambda\mathrm{CDM}})}$$

Model	**ΛCDM**	**HD**	**wCDM**
$\ln B$	0.00	0.88	−2.63

S. Casas, M. Pauly, JR, Phys.Rev. D97 (2018) 043520

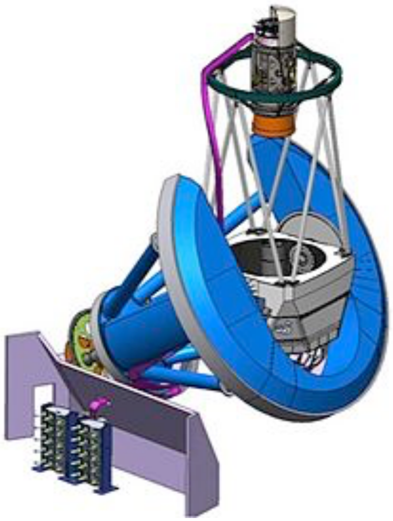
Consistency relations



$$n_s = 1 - \frac{2}{N_*} X \coth X \qquad r = \frac{2}{|\kappa_c| N_*^2} X^2 \sinh^{-2} X \qquad X \equiv 4cN_* = \frac{3N_*(1+w)}{4F(\Omega_{\rm DE})}$$

Future surveys

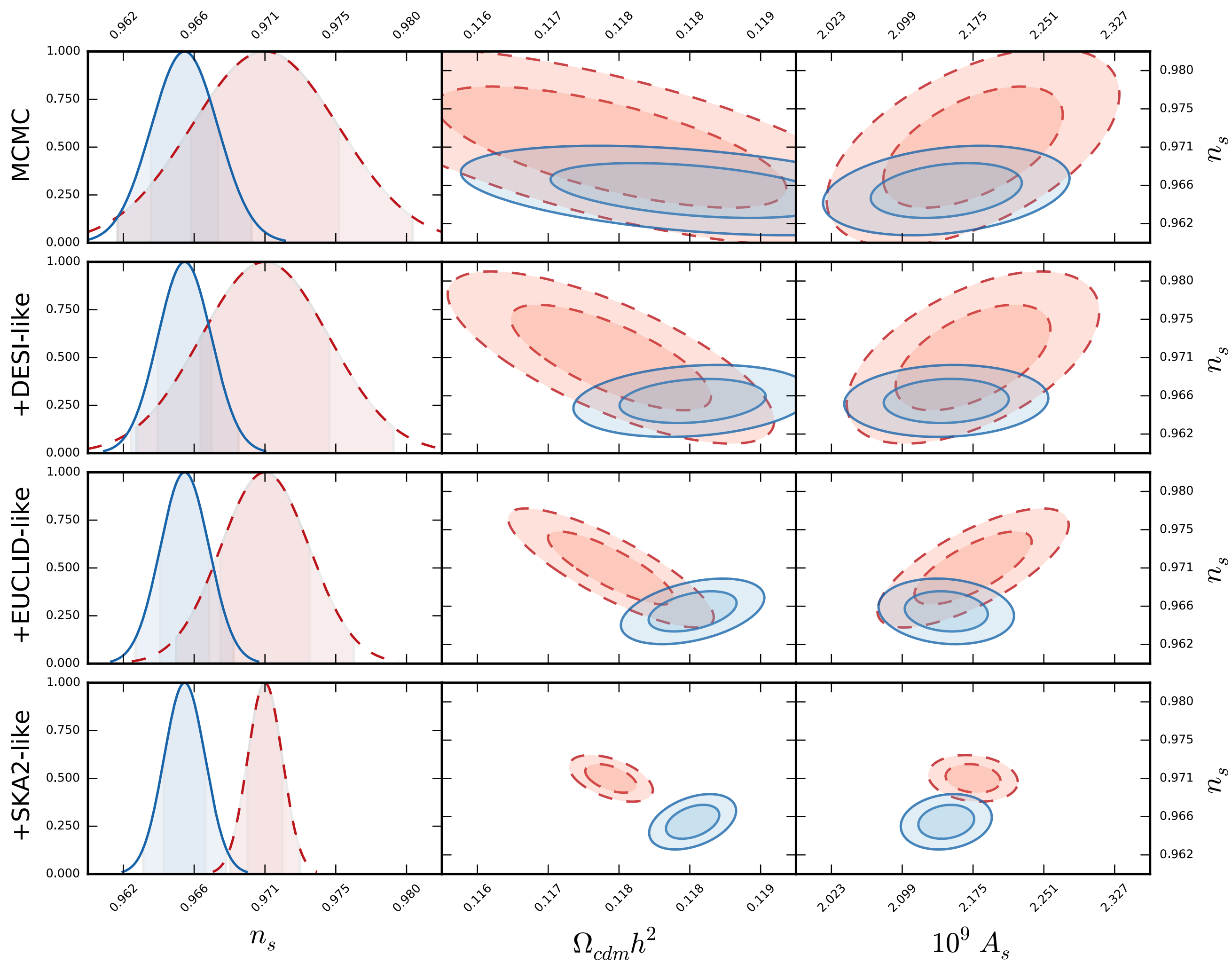
✳ **Dark Energy Spectroscopic Instrument (DESI)**
ground-based experiment (Arizona)
30 million spectroscopic redshifts
2018—> 2019



✳ **Euclid**
satellite
100 million spectroscopic redshifts
2019 –-> 2020 —> 2021—> ?

✳ **Square Kilometer Array (SKA1 and SKA2)**
array of radio telescopes (S. Africa & Australia)
1000 million spectroscopic redshifts
2030

Fisher forecast

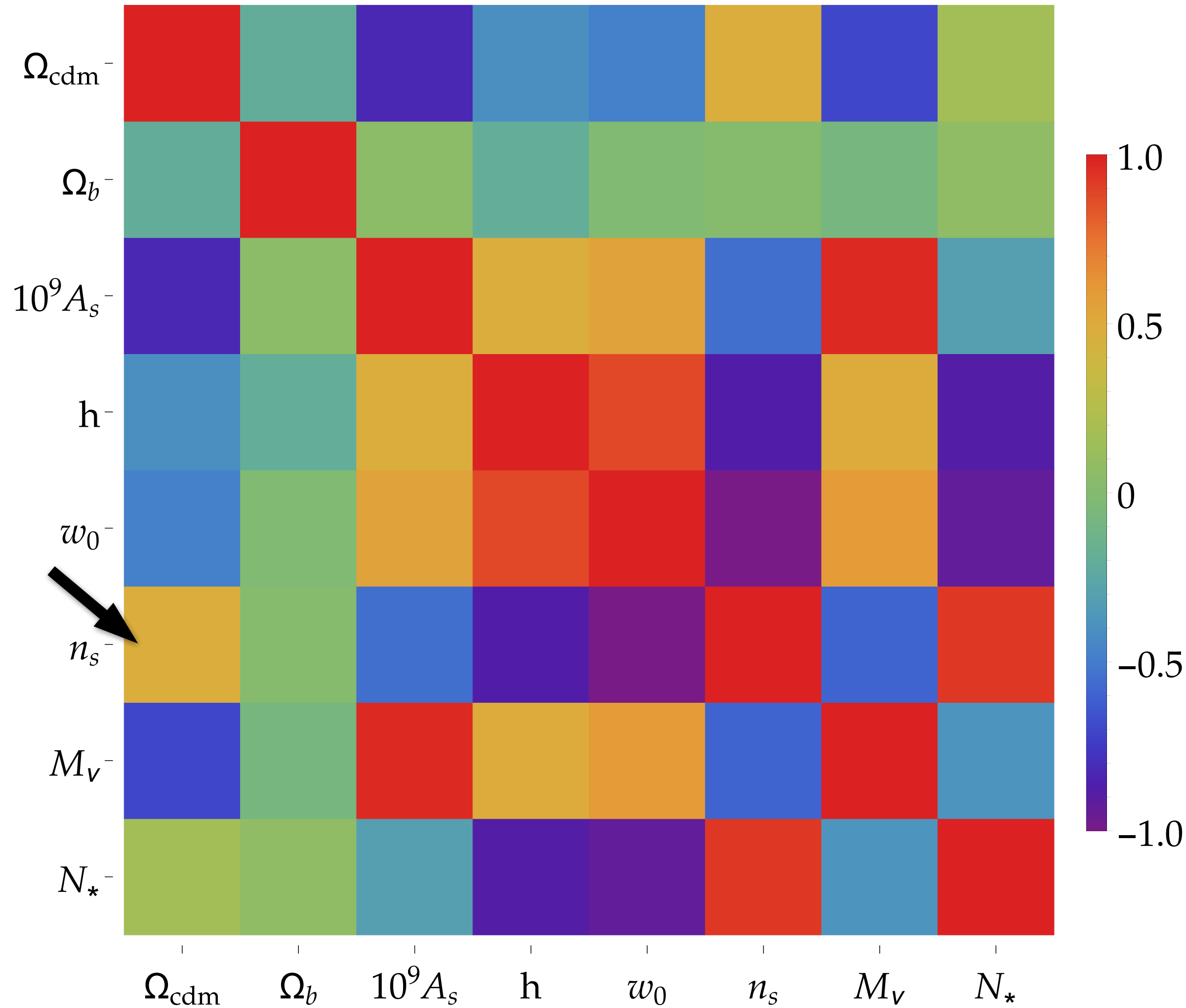


Models centered on the fiducial values obtained from its own MCMC run
To be improved by Stage-IV CMB experiments

S. Casas, M. Pauly, JR, Phys.Rev. D97 (2018) 043520

Correlation matrices

Negative in ΛCDM



This breaks degeneracies in param.space/ helps to constrain other

S. Casas, M. Pauly, JR, Phys.Rev. D97 (2018) 043520

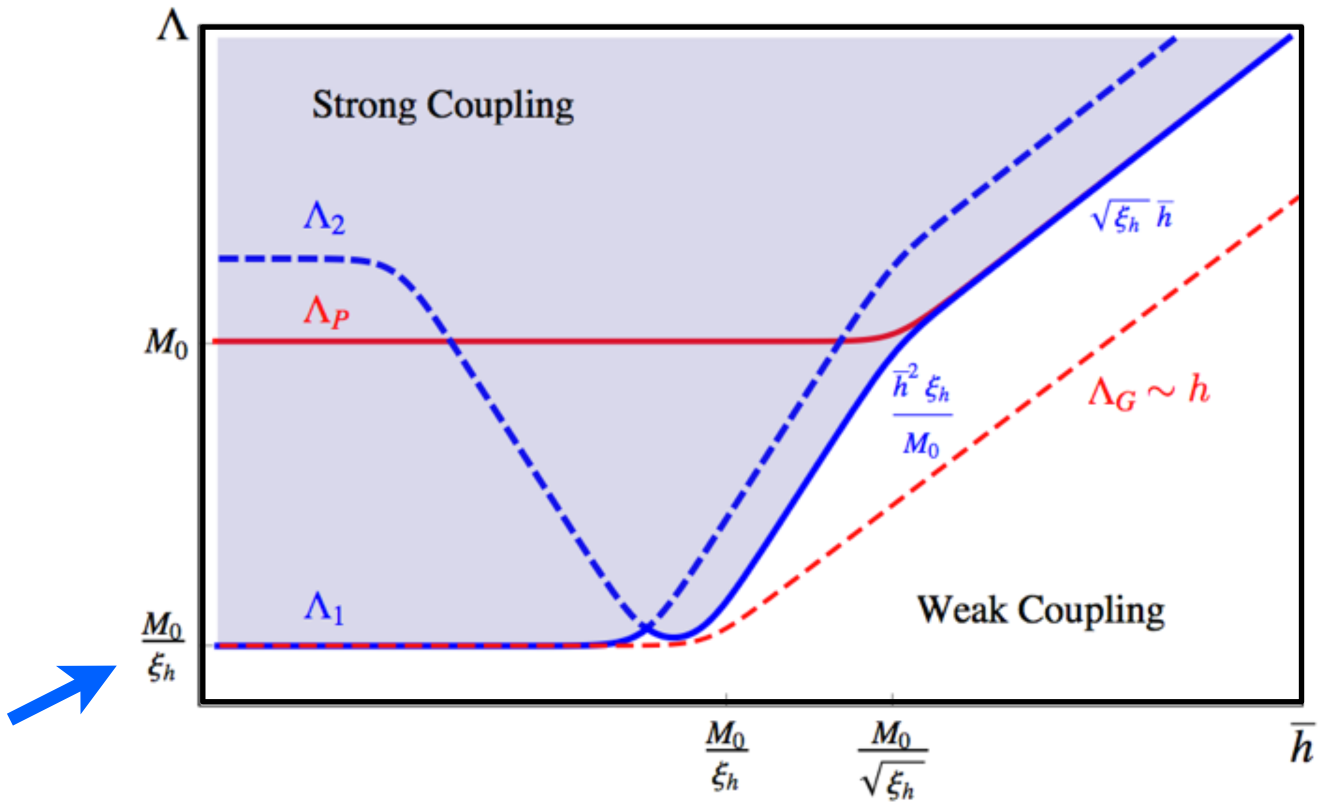
A bunch of nice properties

1. 2- fields but single field dynamics
2. Maximally symmetric E-frame kin. sector
3. Excellent agreement with infl. observables
4. No isocurvature perturbations
5. No non-gaussianities
6. No fifth-force effects
7. Almost massless DE field without massless d.o.f
8. <u>Testable</u> relations between early and late Universe

OPEN ISSUES

We deal with an EFT

$$\frac{1}{\Lambda_1(h,\chi)}(\delta\hat{h})^2\Box\delta\hat{g} \quad , \quad \frac{1}{\Lambda_2(h,\chi)}(\delta\hat{\chi})^2\Box\delta\hat{g} \quad , \quad \frac{1}{\Lambda_3(h,\chi)}(\delta\hat{h})(\delta\hat{\chi})\Box\delta\hat{g} \quad , \quad \text{etc ...}$$



Cutoffs are parametrically larger than all the energy scales involved in the history of the Universe

GENERALIZATIONS

Dilaton as part of the metric

TDiff: minimal gauge group including spin-2 polarizations

$$x^\mu \mapsto \tilde{x}^\mu(x), \text{ with } J \equiv \left|\frac{\partial \tilde{x}^\mu}{\partial x^\nu}\right| = 1 \qquad \textit{with} \qquad \begin{array}{c} \delta x^\mu = \xi^\mu \\ \partial_\mu \xi^\mu = 0 \end{array}$$

TDiff action contains arbitrary functions of g

$$\frac{\mathcal{L}_{\rm TDiff}}{\sqrt{g}} = \frac{\rho^2 f(g)}{2} R - \frac{1}{2}\rho^2 G_{gg}(g)(\partial g)^2 - \frac{1}{2} G_{\rho\rho}(g)(\partial\rho)^2 - G_{\rho g}(g)\rho\,\partial g\cdot\partial\rho - \rho^4 v(g)$$

invariant under $\quad g_{\mu\nu}(x) \to g_{\mu\nu}(\lambda x) \qquad \rho(x) \mapsto \lambda\rho(\lambda x)$

TDiff as Diff

TDiff action describes 3 propagating degrees of freedom

A equivalent Diff version can be obtained using the Stückelberg trick

$$a = J^{-2} \qquad\qquad \theta = g/a$$

J-frame

$$\frac{\mathcal{L}_{\rm Diff}}{\sqrt{g}} = \frac{\rho^2 f(\theta)}{2} R - \frac{1}{2}\rho^2 G_{gg}(\theta)(\partial\theta)^2 - \frac{1}{2} G_{\rho\rho}(\theta)(\partial\rho)^2 - G_{\rho g}(\theta)\rho\,\partial\theta\cdot\partial\rho - \rho^4 v(\theta)$$

invariant under $\quad g_{\mu\nu}(x) \to g_{\mu\nu}(\lambda x) \qquad \rho(x) \mapsto \lambda\rho(\lambda x) \qquad \theta(x) \mapsto \theta(\lambda x)$

Goldstone

E-frame

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{M_P^2}{2} R - \frac{M_P^2}{2}\Big[K_{\theta\theta}(\theta)(\partial\theta)^2 + 2K_{\theta\rho}(\theta)(\partial\theta)(\partial\log\rho/M_P) + K_{\rho\rho}(Z)(\partial\log\rho/M_P)^2\Big] - V(\theta)$$

To be restricted using theoretical and phenomenological criteria

Potential criteria

Theoretical

Existence of a constant flat solution

Absence of ghosts & tachyons

Decoupling of gravitational interactions

No strong coupling

Tree level unitarity

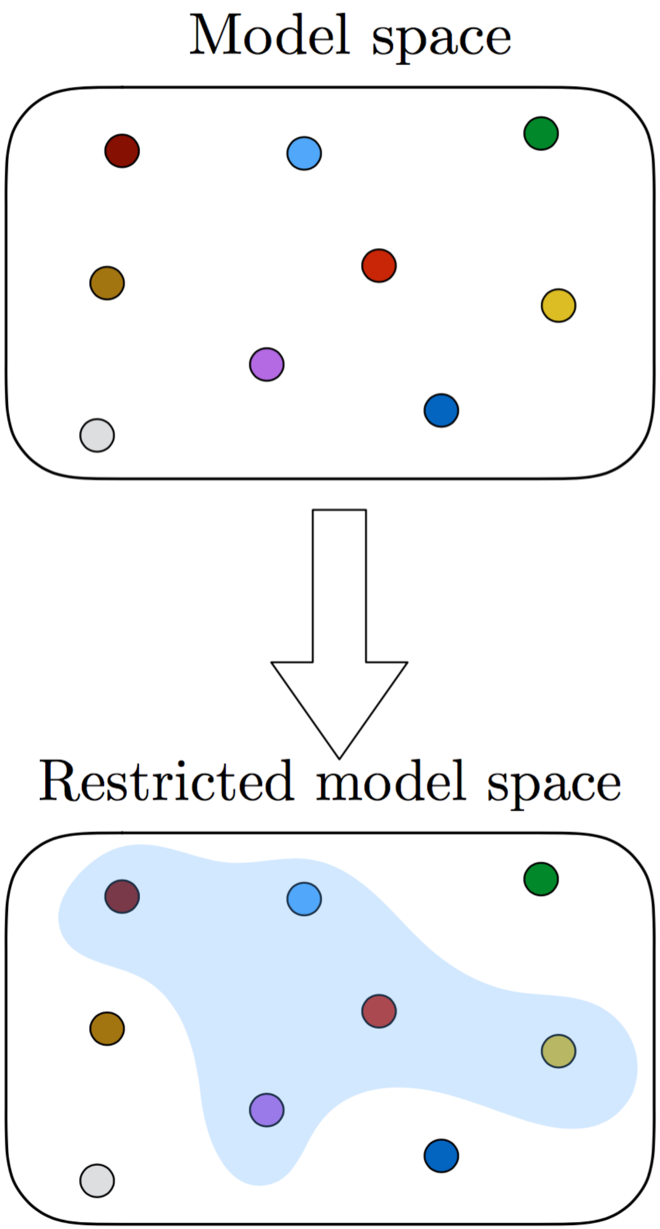
Phenomenological

Equivalence with Abelian Higgs model

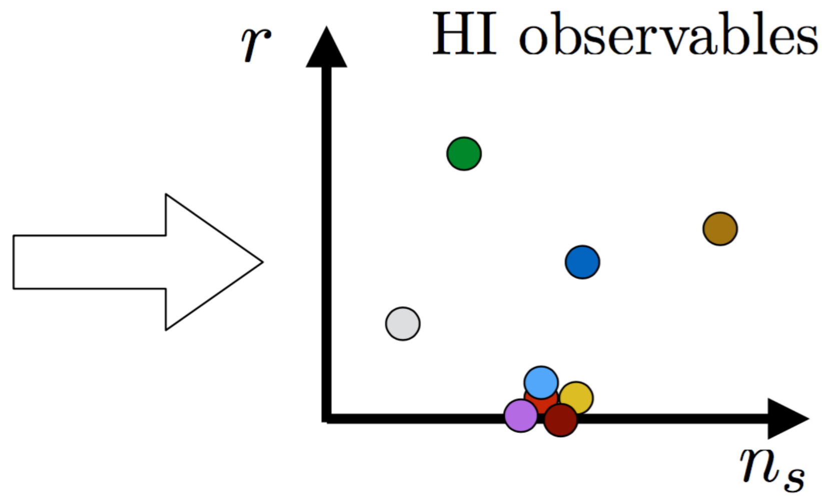
Dilaton production

"Good" inflationary predictions

Consistency relations



Which sets of
theory defining functions
give rise to the same
inflationary observables?

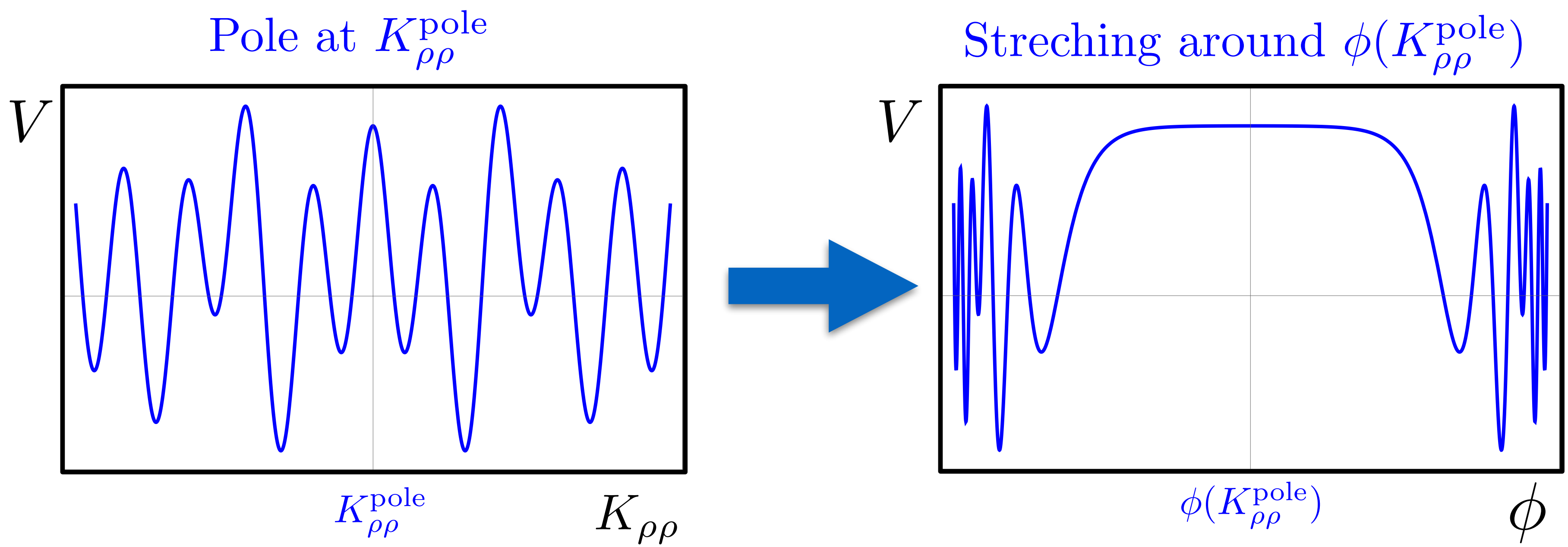


Canonical field stretching

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{M_P^2}{2} R - \frac{M_P^2}{2}\left[- \frac{(\partial K_{\rho\rho})^2}{4\, K_{\rho\rho}(\kappa_0 K_{\rho\rho} + c)} + K_{\rho\rho}(\partial\rho)^2 \right] - V(K_{\rho\rho})$$

Canonically normalized field

$$\phi = \int \frac{dK_{\rho\rho}}{\sqrt{4\ K_{\rho\rho}(|\kappa_0| K_{\rho\rho} - c)}}$$



The pole structure

$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{M_P^2}{2} R - \frac{M_P^2}{2} \left[- \frac{(\partial K_{\rho\rho})^2}{4\, K_{\rho\rho}(\kappa_0 K_{\rho\rho} + c)} + K_{\rho\rho}(\partial\rho)^2 \right] - V(K_{\rho\rho})$$

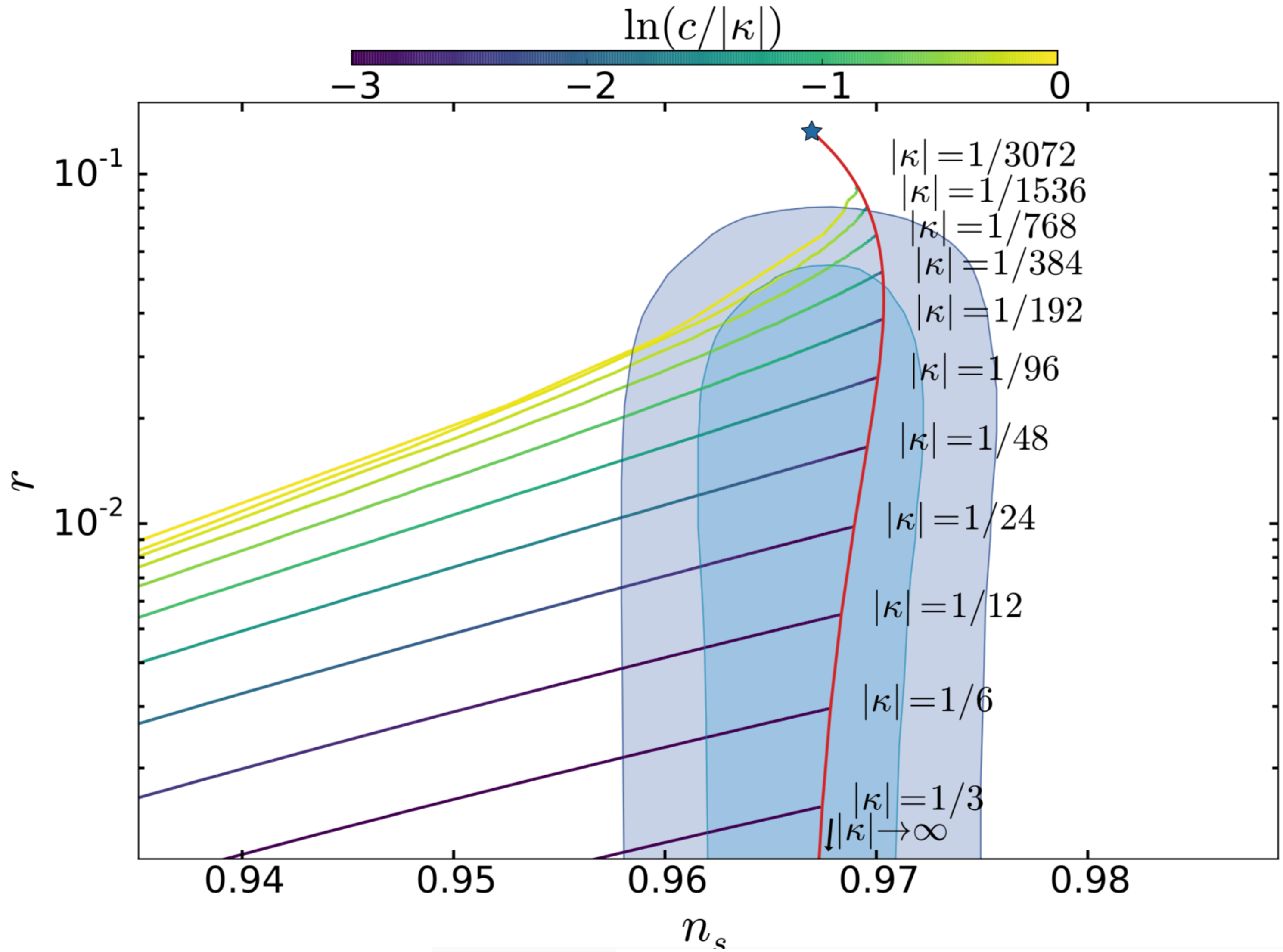
$\lvert c \rvert \to 0$ $K_{\rho\rho} \to \lvert c/\kappa_0 \rvert \to 0$	Quadratic pole Asymptotic flatness $K_{\rho\rho} = e^{-2\sqrt{\lvert\kappa_0\rvert}\frac{\phi}{M_P}}$
$\lvert c \rvert \neq 0$ $K_{\rho\rho} = 0$ unreachable	Linear pole Restricted flatness $K_{\rho\rho} = \frac{c}{-\kappa_0} \cosh^2\left(\frac{\sqrt{-\kappa_0}\phi}{M_P}\right)$ $\frac{M_P}{\sqrt{-\kappa_0}}$ non-compact analog of axion decay constant

G. Karananas, JR, Phys.Lett. B761 (2016) 223-228

Inflationary observables

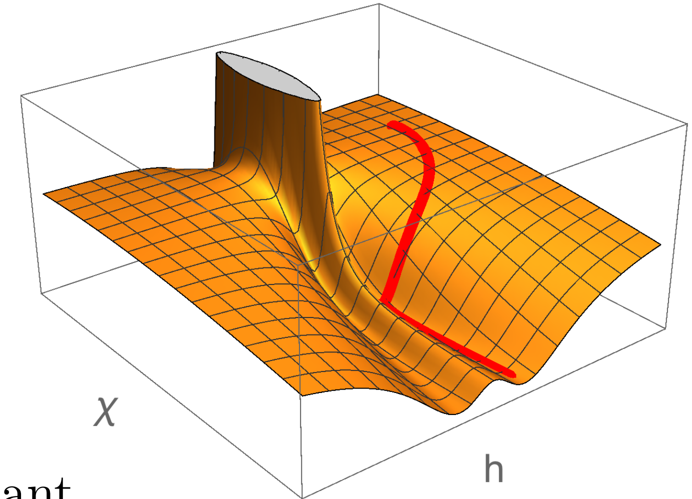
$$\frac{\mathcal{L}}{\sqrt{g}} = \frac{M_P^2}{2} R - \frac{M_P^2}{2} \left[- \frac{(\partial K_{\rho\rho})^2}{4\, K_{\rho\rho}(\kappa_0 K_{\rho\rho} + c)} + K_{\rho\rho} (\partial \rho)^2 \right] - V(K_{\rho\rho})$$

$\lvert c\rvert \to 0$ $K_{\rho\rho} \to \lvert c/\kappa_0\rvert \to 0$	Quadratic pole $n_s \simeq 1 - \frac{2}{N}$ $\quad r \simeq \frac{2}{\lvert\kappa_0\rvert N^2}$
$\lvert c\rvert \neq 0$ $K_{\rho\rho} = 0$ unreachable	Linear pole $\mathcal{O}\left(c^2/\kappa_0\right)$ $n_s \approx 1 - 4\lvert c\rvert$ $\quad r \approx 32 \lvert c\rvert^2 \, e^{-4\,\lvert c\rvert\, N}$



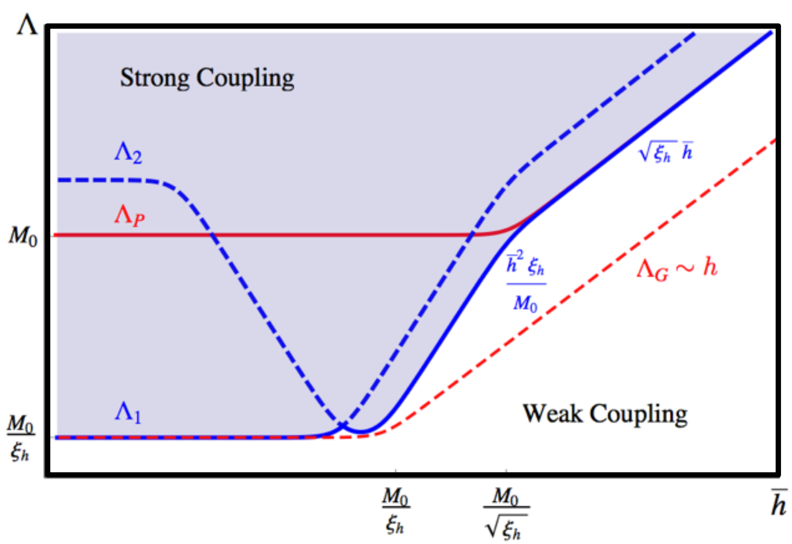
$$r = \frac{128\,|\kappa|}{(1+\mathcal{W}_{-1})^2}\,, \qquad n_s = 1 - 16|\kappa|\frac{1-\mathcal{W}_{-1}}{(1+\mathcal{W}_{-1})^2}$$

Conclusions



SM extensions involving SI + UG

- Unique source for masses / scales.
- Inflation with a graceful exit
- Dark energy without a cosmological constant
- Non-trivial relations between inflationary and DE observables
- Natural embedding in a TDiff framework: dilaton as a metric d.o.f

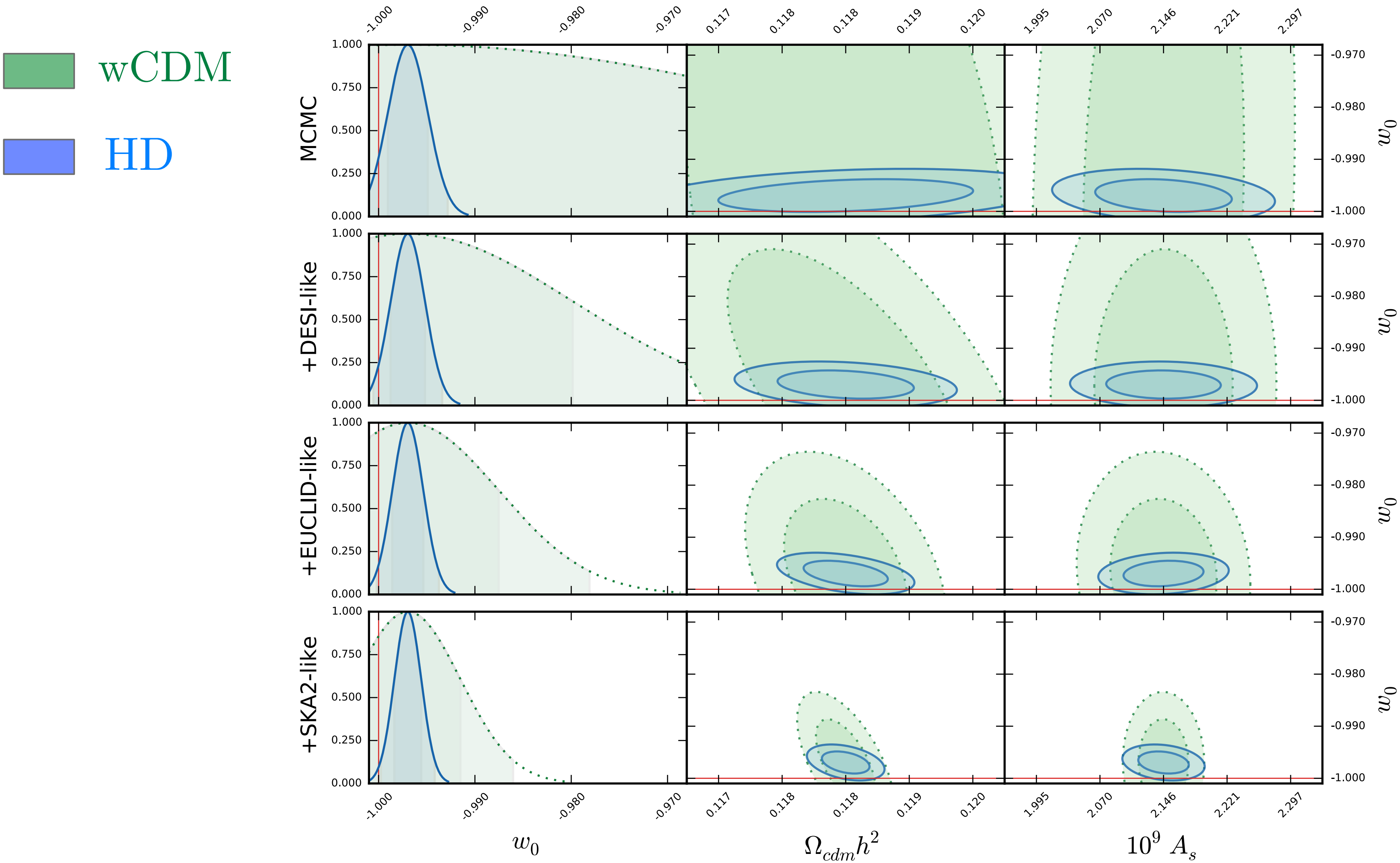


Beyond EFT?

- Self-healing mechanism?
- New degrees of freedom?
- Asymptotic safety?

BACKUP SLIDES

Future surveys (Fisher forecast)



The models are centered at the HD central values to facilitate the comparison

S. Casas, M. Pauly, JR, Phys.Rev. D97 (2018) 043520

de Sitter and massless fields

Quantum Instability of De Sitter Space

Ignatios Antoniadis (SLAC), J. Iliopoulos (Ecole Normale Superieure), T.N. Tomaras (Crete U.)

Phys.Rev.Lett. 56 (1986) 1319

Abstract (APS)
The graviton propagator in a de Sitter background is found to be divergent. We show that as a consequence of this divergence, de Sitter space is not a solution of the equations of motion of the complete theory. If we start from de Sitter space as a classical ground state, quantum corrections change it into flat Minkowski space.

The Massless Minimally Coupled Scalar Field in De Sitter Space

Bruce Allen, Antoine Folacci (Meudon Observ.)

Phys.Rev. D35 (1987) 3771

Abstract (APS)
We quantize the massless minimally coupled scalar field in de Sitter space, and find a one-complex-parameter family of O(4)-invariant Hadamard Fock vacua which break de Sitter invariance. The different Fock spaces corresponding to the different choices of vacuum are subspaces of a single space of states. We make some remarks about the existence of E(3)- and O(1,3)-invariant Fock vacuum states.

Graviton fluctuations erase the cosmological constant

C. Wetterich (U. Heidelberg, ITP)

Phys.Lett. B773 (2017) 6-19

Abstract (Elsevier)
Graviton fluctuations induce strong non-perturbative infrared renormalization effects for the cosmological constant. The functional renormalization flow drives a positive cosmological constant towards zero, solving the cosmological constant problem without the need to tune parameters. We propose a simple computation of the graviton contribution to the flow of the effective potential for scalar fields. Within variable gravity, with effective Planck mass proportional to the scalar field, we find that the potential increases asymptotically at most quadratically with the scalar field. The solutions of the derived cosmological equations lead to an asymptotically vanishing cosmological "constant" in the infinite future, providing for dynamical dark energy in the present cosmological epoch. Beyond a solution of the cosmological constant problem, our simplified computation also entails a sizeable positive graviton-induced anomalous dimension for the quartic Higgs coupling in the ultraviolet regime, substantiating the successful prediction of the Higgs boson mass within the asymptotic safety scenario for quantum gravity.

Unimodular gravity

The Quantization of unimodular gravity and the cosmological constant problems

Lee Smolin (Perimeter Inst. Theor. Phys.) **Phys.Rev. D80 (2009) 084003**

Abstract (arXiv)
A quantization of unimodular gravity is described, which results in a quantum effective action which is also unimodular, ie a function of a metric with fixed determinant. A consequence is that contributions to the energy momentum tensor of the form of the metric times a spacetime constant, whether classical or quantum, are not sources of curvature in the equations of motion derived from the quantum effective action. This solves the first cosmological constant problem, which is suppressing the enormous contributions to the cosmological constant coming from quantum corrections.

Quantum Corrections to Unimodular Gravity

Enrique Álvarez, Sergio González-Martín, Mario Herrero-Valea (Madrid, Autonoma U. & Madrid, IFT), Carmelo P. Martín (Madrid, Autonoma U.)

JHEP 1508 (2015) 078

Abstract (Springer)
The problem of the comological constant appears in a new light in Unimodular Gravity. In particular, the zero momentum piece of the potential (that is, the constant piece independent of the matter fields) does not automatically produce a cosmological constant proportional to it. The aim of this paper is to give some details on a calculation showing that quantum corrections do not renormalize the classical value of this observable.

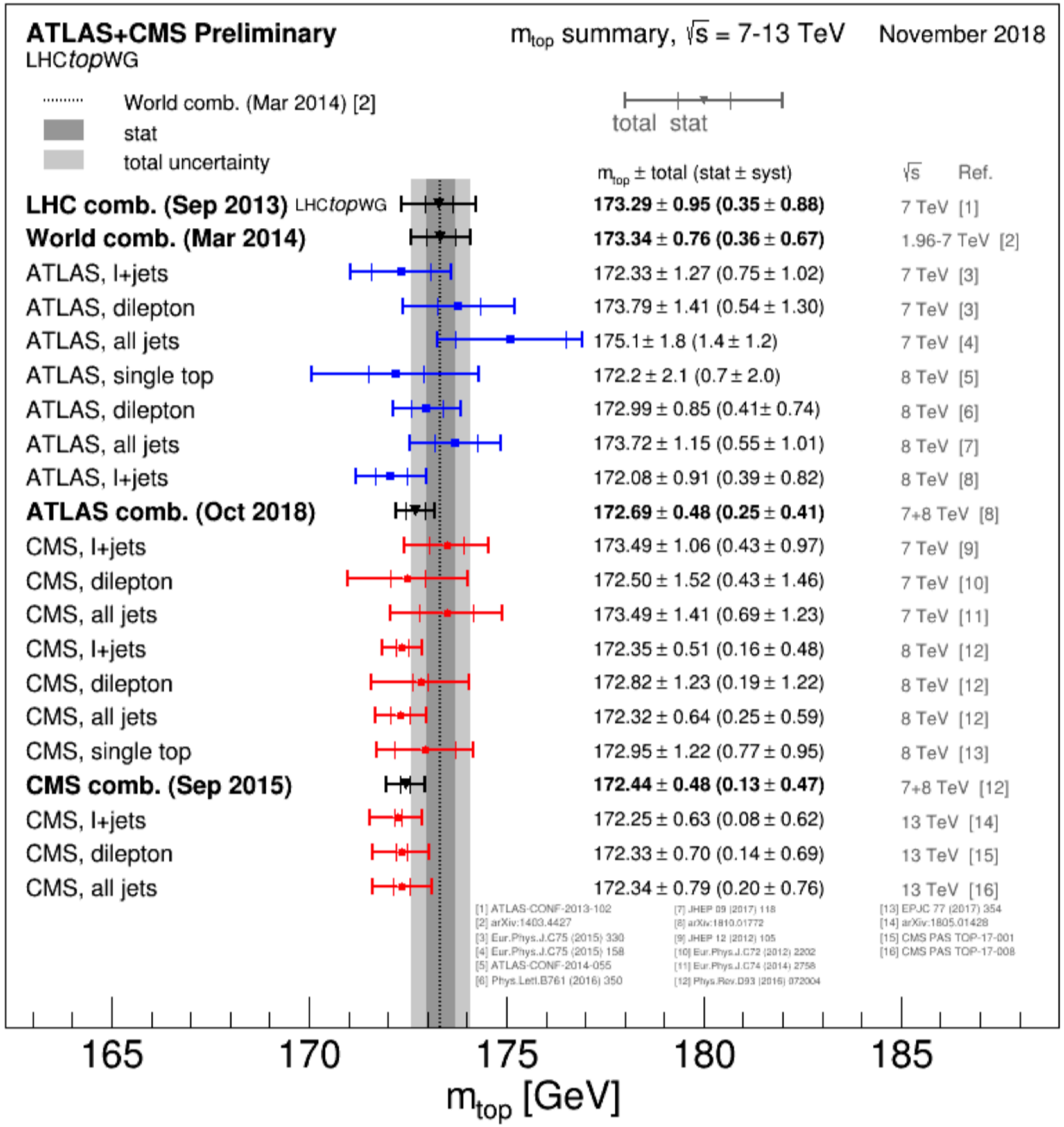
On unimodular quantum gravity

Astrid Eichhorn (Perimeter Inst. Theor. Phys.)

Class.Quant.Grav. 30 (2013) 115016

Abstract (IOP)
Unimodular gravity is classically equivalent to standard Einstein gravity, but differs when it comes to the quantum theory: the conformal factor is non-dynamical, and the gauge symmetry consists of transverse diffeomorphisms only. Furthermore, the cosmological constant is not renormalized. Thus the quantum theory is distinct from a quantization of standard Einstein gravity. Here we show that within a truncation of the full renormalization group flow of unimodular quantum gravity, there is a non-trivial ultraviolet (UV)-attractive fixed point, yielding a UV completion for unimodular gravity. We discuss important differences to the standard asymptotic-safety scenario for gravity, and provide further evidence for this scenario by investigating a new form of the gauge-fixing and ghost sector. Communicated by P R L V Moniz

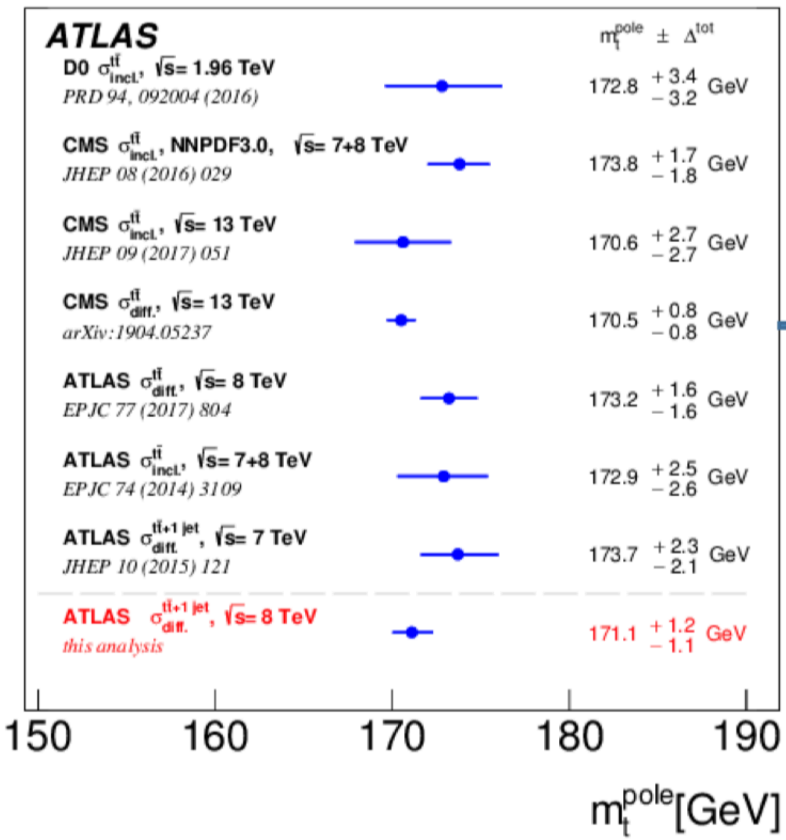
Top mass determination

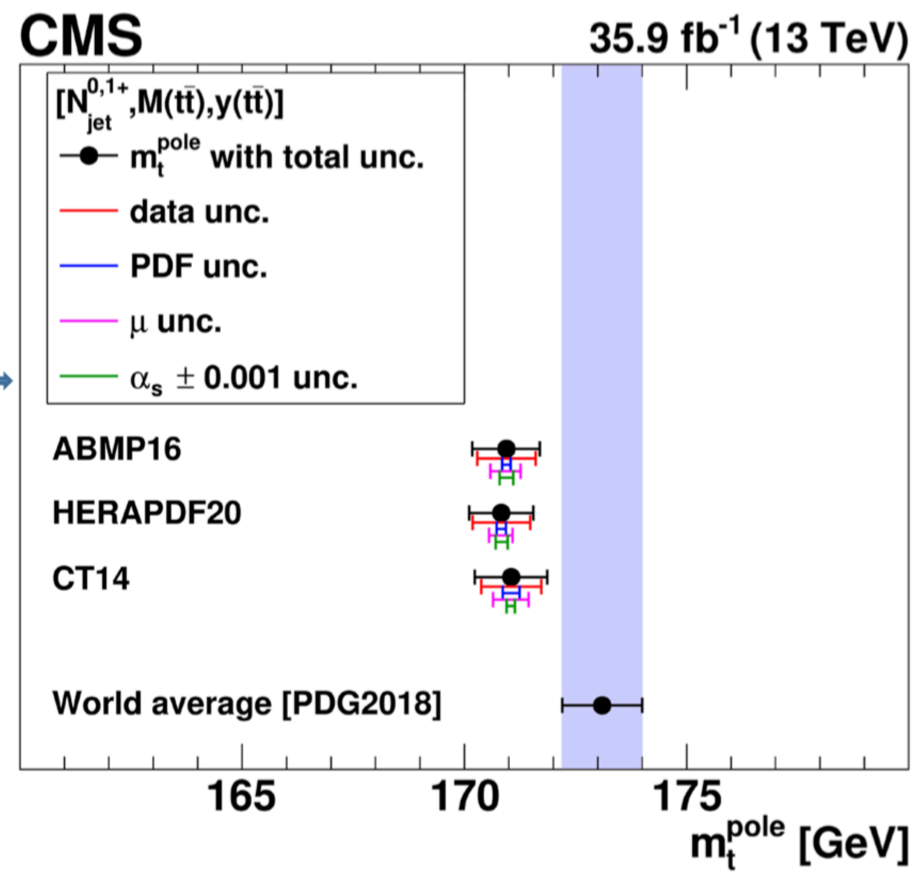


From Wang talk

Indirect measurement of the m_t^{pole} in ATLAS

- Recent indirect measurement of the pole mass m_t^{pole} extracted from differential measurement in ATLAS arXiv:1905.02302 and CMS arXiv:1904.05237

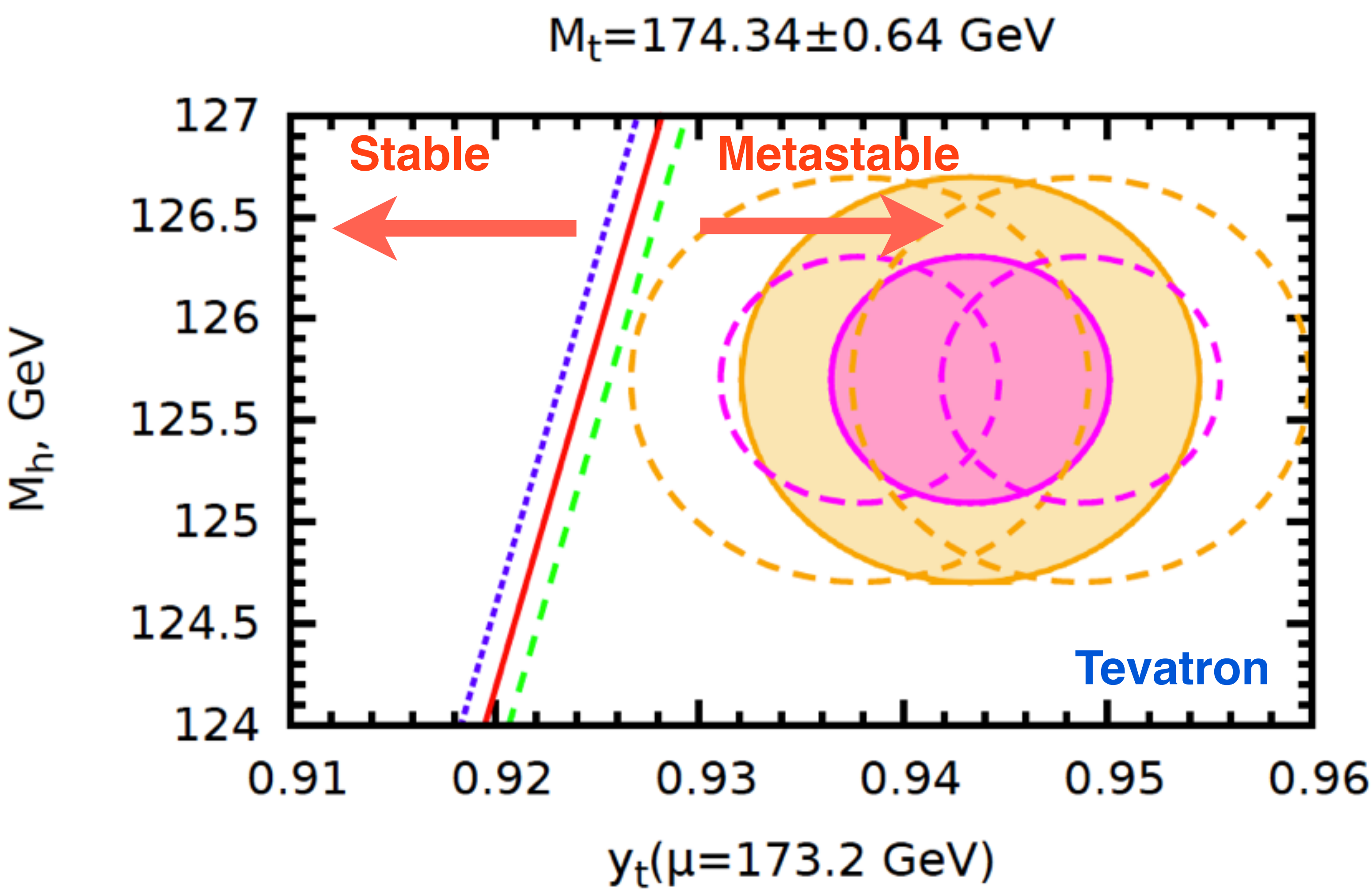




most precise result so far

Top quark & vac. instability

$$y_t^{\rm crit} = 0.9223 + 0.00118\left(\frac{\alpha_s - 0.1184}{0.0007}\right) + 0.00085\left(\frac{M_h - 125.03}{0.3}\right)$$



See F. Bezrukov, M. Shaposhnikov J.Exp.Theor.Phys. 120 (2015) 335-343 and references therein

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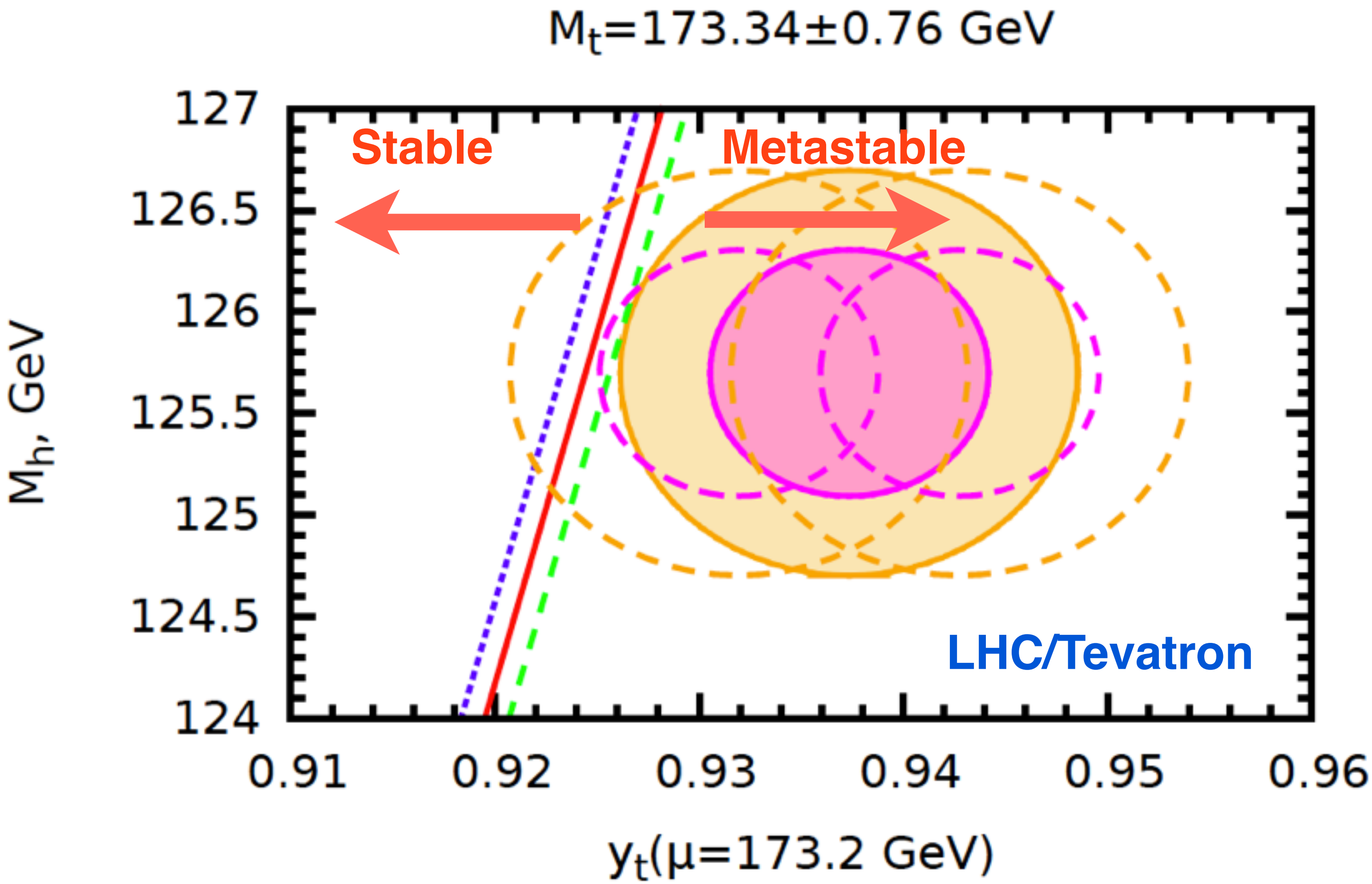

See F. Bezrukov, M. Shaposhnikov J.Exp.Theor.Phys. 120 (2015) 335-343 and references therein

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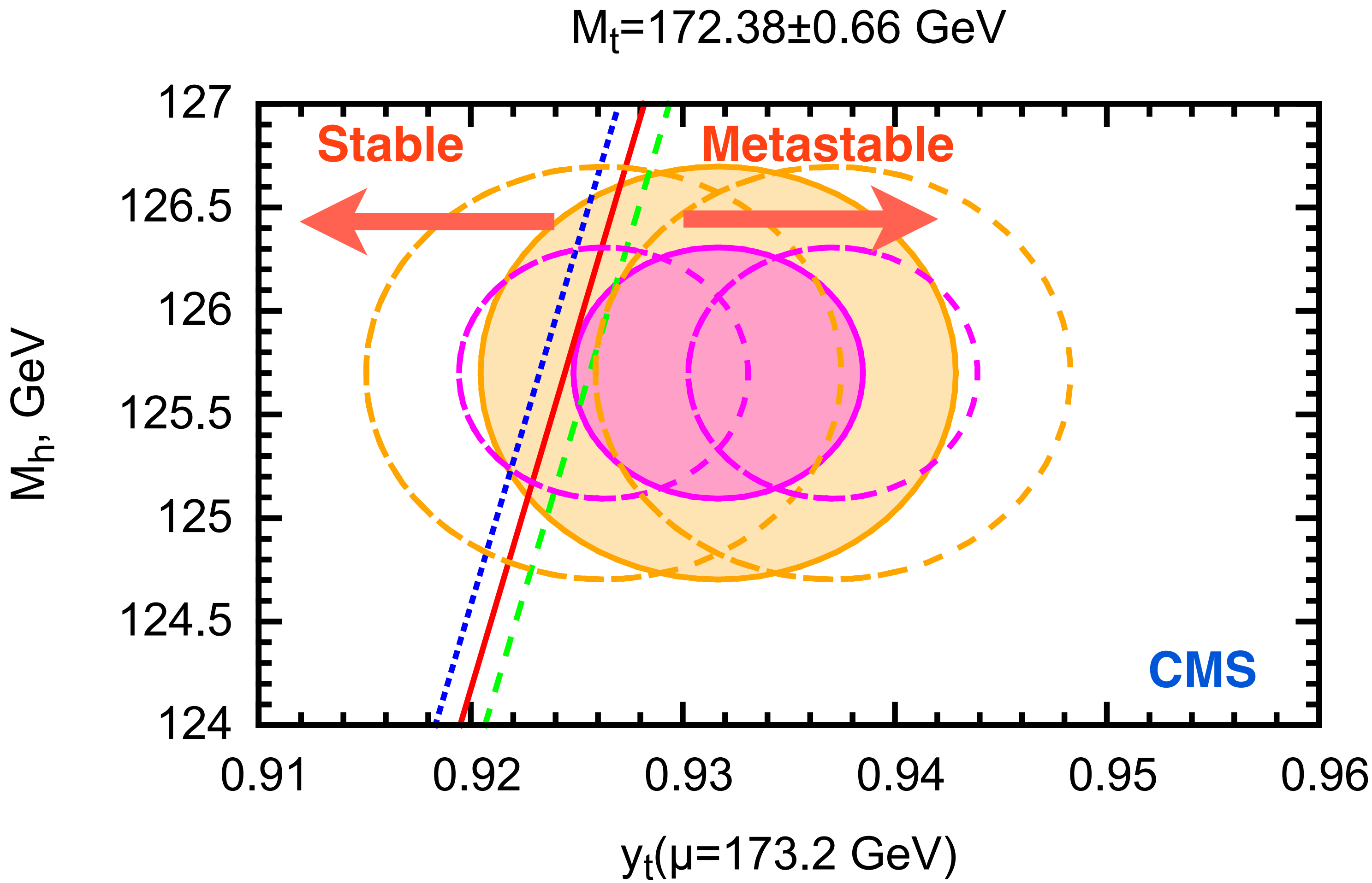

See F. Bezrukov, M. Shaposhnikov J.Exp.Theor.Phys. 120 (2015) 335-343 and references therein