The common denominator of cosmological attractors

Diederik Roest
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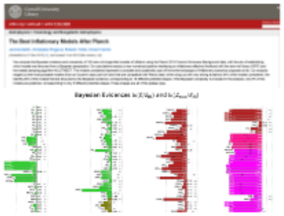
[(Galante,) Kallosh, Linde, Roest '13, '14]



Scalar potentials

Planck is pointing towards plateau-like potentials:

$$\mathcal{L} = \sqrt{-g}[\tfrac{1}{2}R - \tfrac{1}{2}(\partial\varphi)^2 - V(\varphi)]$$

Plateau at infinite / finite distance, with (inverse) polynomial / exp fall-off.

Kinetic formulation

Redefinition to trivial potential:

$$\tfrac{1}{2}R - \tfrac{1}{2}\left(\frac{a_p}{\rho^p}\right)^2(\partial\rho)^2 - \tfrac{1}{2}m^2(\rho_0-\rho)^2$$

Plateau in potential implies a singularity in kinetic term! Behaviour close to singularity is crucial.

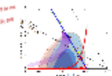
Inflationary predictions

Behaviour at N=60 determined by leading pole in Einstein-frame kinetic term:

$$K_E = \frac{a_p}{\rho^p} + \dots$$

Independent of subleading terms in K and fully independent of V: robustness of attractor!

$$n_s = 1 - \frac{p}{p-1}\frac{1}{N}$$
$$r = \# \left(\frac{a_p}{N^p}\right)^{\frac{1}{p-1}}$$



Non-minimal coupling

Jordan frame formulation:

$$\tfrac{1}{2}\Omega(\phi)R - \tfrac{1}{2}(\partial\phi)^2 - \frac{\lambda}{\xi^2}(\Omega-1)^2$$

Higgs inflation: $\Omega = 1 + \xi\phi^2$

Universal attractor: $\Omega = 1 + \xi\phi^n$

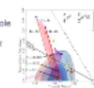
Induced inflation: $\Omega = \xi\phi^2$

Higgs inflation: $\Omega = 1 + \xi\phi^2$

Reformulation leads to quadratic potential plus

$$K_E = \frac{3}{4}\frac{1}{\rho^2} + \frac{1}{4\xi}\frac{1}{(\rho_0-\rho)\rho^2} - \frac{3}{2}(1+\frac{1}{6\xi})\frac{1}{\rho^2} + \dots$$

Infinite coupling limit:
Starobinsky model = a pure pole
Large coupling:
increases residue and hence r
Small coupling:
subleading terms important



Universal attractor: $\Omega = 1 + \xi\phi^n$

Reformulation leads to quadratic potential plus

$$K_E = \frac{3}{2\rho^2} - \frac{1}{\dots} \dots$$

Infinite coupling:
same pole
Large coupling:
suppressed poles
Order-one coupling:
other pole takes over
Small coupling:
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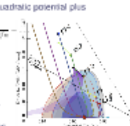
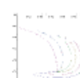
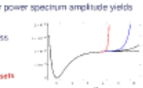




Generic deformations

Setting $\xi \sim 10^5$ for power spectrum amplitude yields at least 55 flat e-folds.

Percent-level power loss for larger N.



Single parameter that sets
- spectral index
- tensor-to-scalar ratio
- power normalization
- number of flat e-folds

[Broy, DR, Westphal '14]

Induced inflation: $\Omega = \xi\phi^2$

Reformulation leads to quadratic potential plus

$$K_E = \tfrac{3}{2}(1 + \frac{1}{6\xi})\frac{1}{\rho^2}.$$

Two contributions feeding into r:
1) positive offset from Jordan to Einstein transf.
2) second contribution due to Jordan kinetic term

- Coupling can be negative, but only in Einstein frame!
- Jordan frame imposes a lower bound r~0.003.
- Conformal value predicts zero tensors.
- Equivalent to alpha-attractors with $\alpha = 1 + \frac{1}{6\xi}$

Summary

plateau inflation = pole inflation *planck best fit*
ns and r determined by order and residue of leading pole

Cosmological attractors with non-minimal coupling stem from a pole of order two:
- natural permille value of r
- different contributions to coeff
- lower bound r~0.003 from Jordan frame
- relation between amplitude and # e-folds
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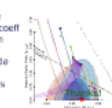

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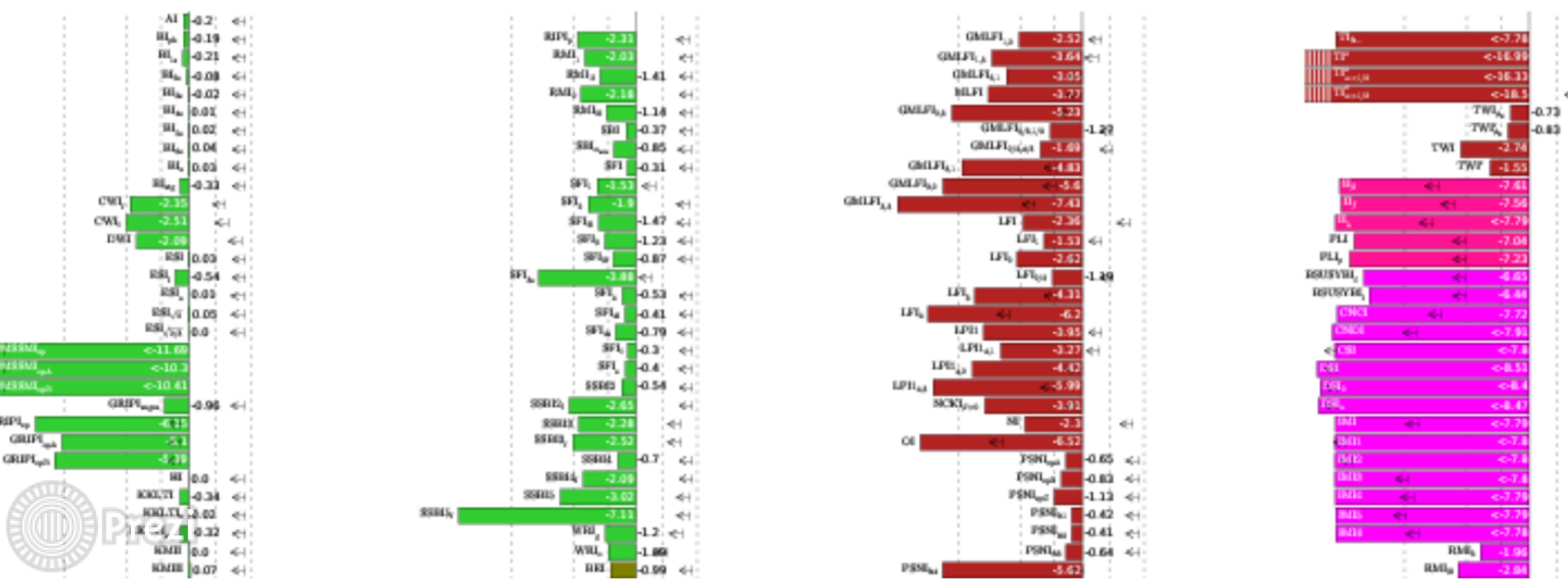
The Best Inflationary Models After Planck

Jerome Martin, Christophe Ringeval, Roberto Trotta, Vincent Vennin

(Submitted on 12 Dec 2013 (v1), last revised 3 Jun 2014 (this version, v3))

We compute the Bayesian evidence and complexity of 193 slow-roll single-field models of inflation using the Planck 2013 Cosmic Microwave Background data, with the aim of establishing which models are favoured from a Bayesian perspective. Our calculations employ a new numerical pipeline interfacing an inflationary effective likelihood with the slow-roll library ASPIC and the nested sampling algorithm MULTINEST. The models considered represent a complete and systematic scan of the entire landscape of inflationary scenarios proposed so far. Our analysis singles out the most probable models (from an Occam's razor point of view) that are compatible with Planck data, while ruling out with very strong evidence 34% of the models considered. We identify 26% of the models that are favoured by the Bayesian evidence, corresponding to 15 different potential shapes. If the Bayesian complexity is included in the analysis, only 9% of the models are preferred, corresponding to only 9 different potential shapes. These shapes are all of the plateau type.

Bayesian Evidences $\ln(\mathcal{E}/\mathcal{E}_{\mathrm{HI}})$ and $\ln(\mathcal{L}_{\max}/\mathcal{E}_{\mathrm{HI}})$



Scalar potentials

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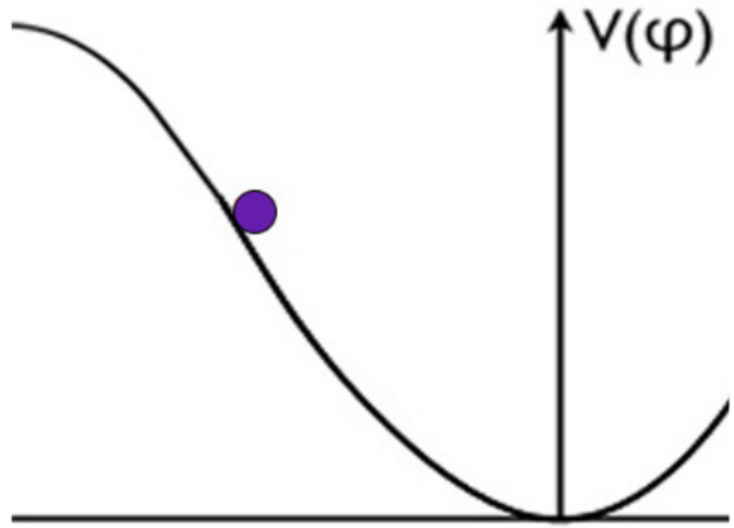
Plateau at infinite / finite distance, with (inverse) polynomial / exp fall-off.



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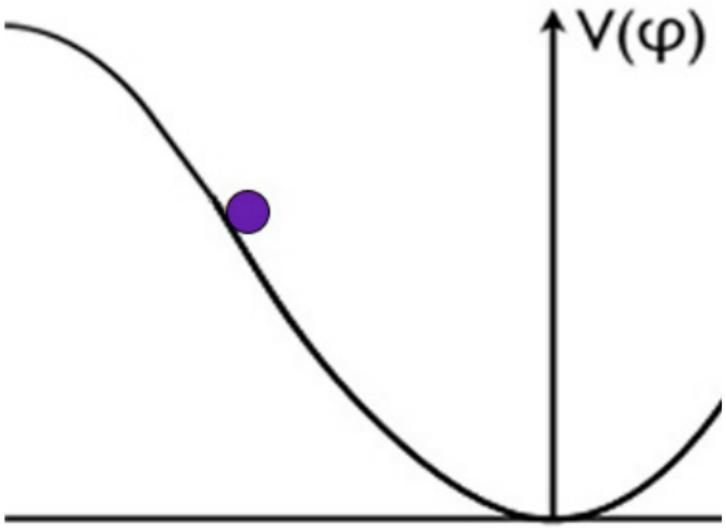
Kinetic formulation



Redefinition to trivial potential:

$$\frac{1}{2}R - \frac{1}{2}\left(\frac{\partial\varphi}{\partial\rho}\right)^2 (\partial\rho)^2 - \frac{1}{2}m^2(\rho_0 - \rho)^2$$

Similar to V in terms of Hubble!

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Inflationary predictions

Behaviour at N=60 determined by leading pole in Einstein-frame kinetic term:

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$$n_s = 1 - \frac{p}{p-1}\frac{1}{N}$$

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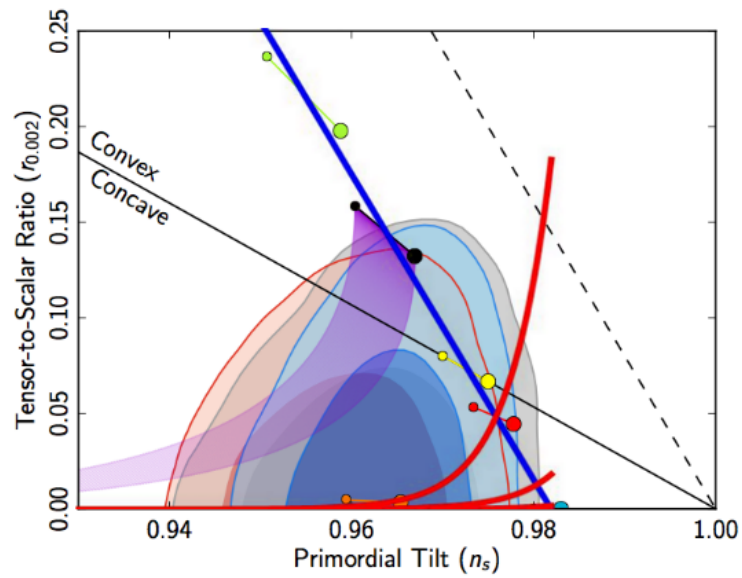
Note: same coeff in ns and power in r [Mukhanov 2013; DR 2013]



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Non-minimal coupling

Jordan frame formulation:

$$\tfrac{1}{2}\Omega(\phi)R - \tfrac{1}{2}(\partial\phi)^2 - \frac{\lambda}{\xi^2}(\Omega - 1)^2$$

Always leads to quadratic potential in pole coordinate!

Higgs inflation: $\Omega = 1 + \xi\phi^2$ [Salopek, Bond, Bardeen '89, Bezrukov, Shaposhikov '07]

Universal attractor: $\Omega = 1 + \xi\phi^n$ [Kallosh, Linde, DR '13]

Induced inflation: $\Omega = \xi\phi^2$ [Giudice, Lee '14]

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Large coupling:

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Small coupling:

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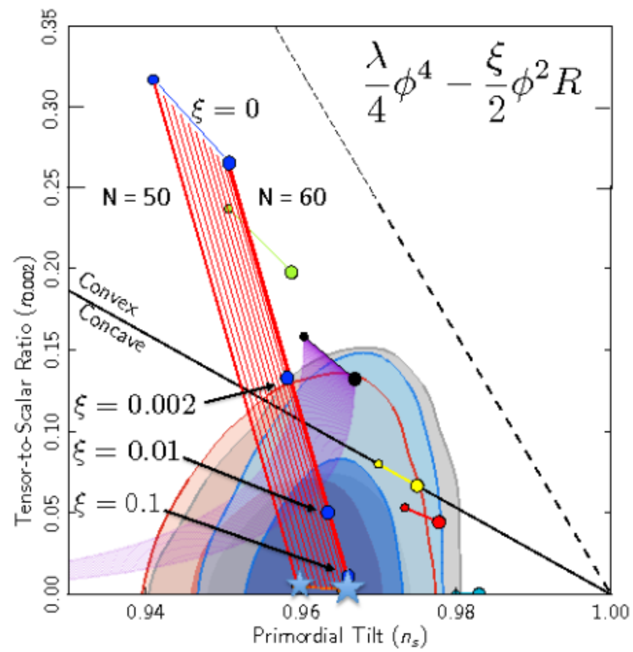

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Universal attractor: $\Omega = 1 + \xi\phi^n$

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$$K_{\rm E} = \frac{3}{2\rho^2} + \frac{1}{n^2 \xi^{2/n} \rho^{1+2/n}} + \ldots$$

Infinite coupling:
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    other pole takes over
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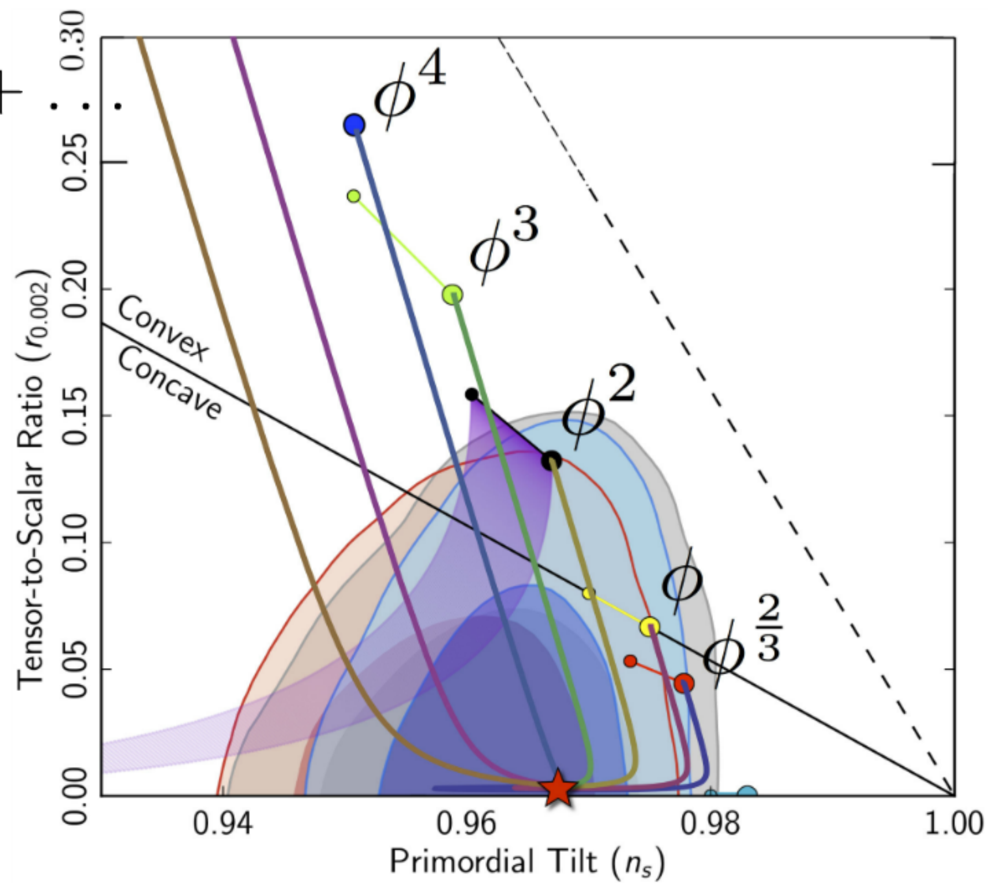

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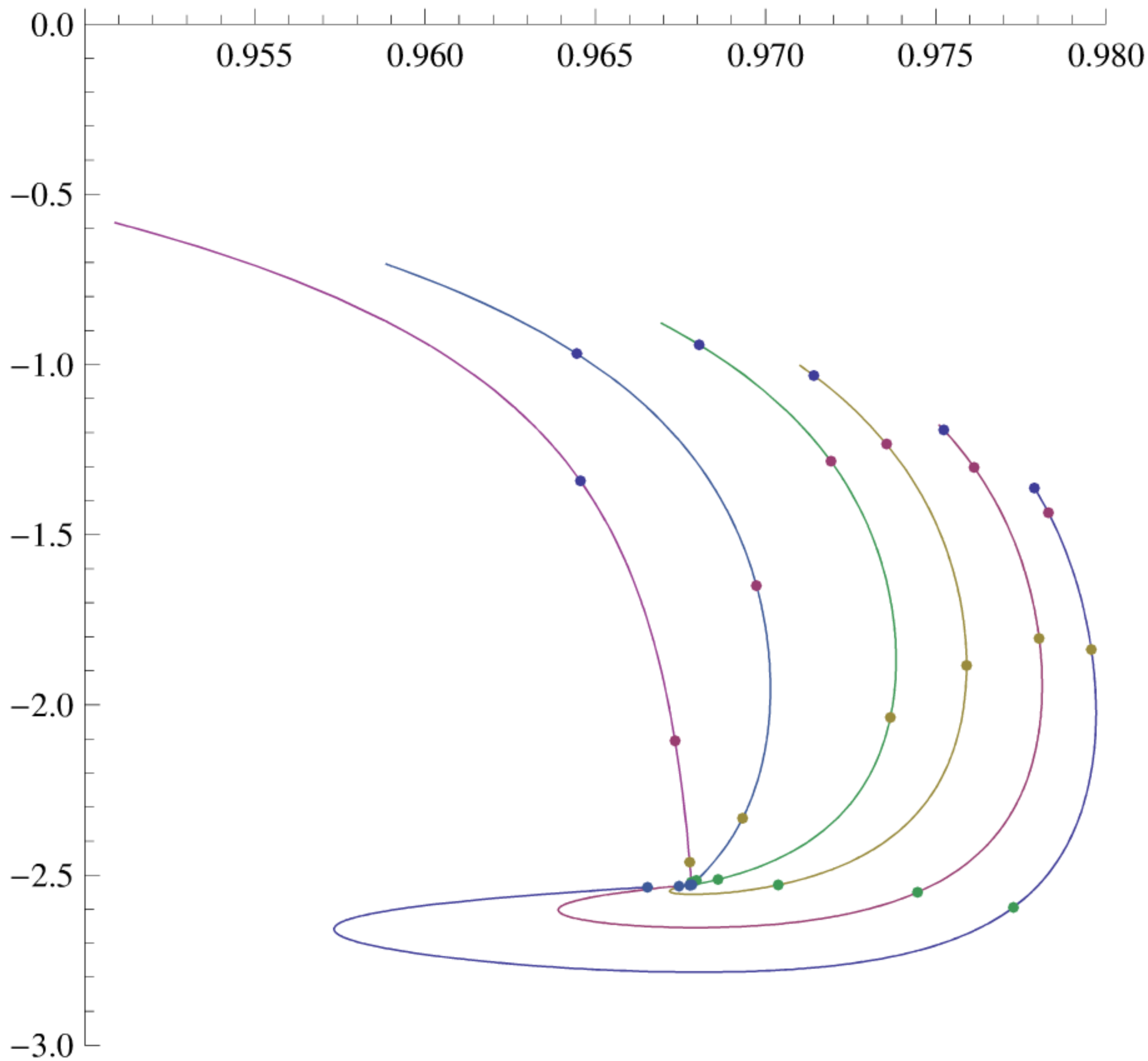
0.0
0.955
0.960
0.965
0.970
0.975
0.980
−0.5
−1.0
−1.5
−2.0
−2.5
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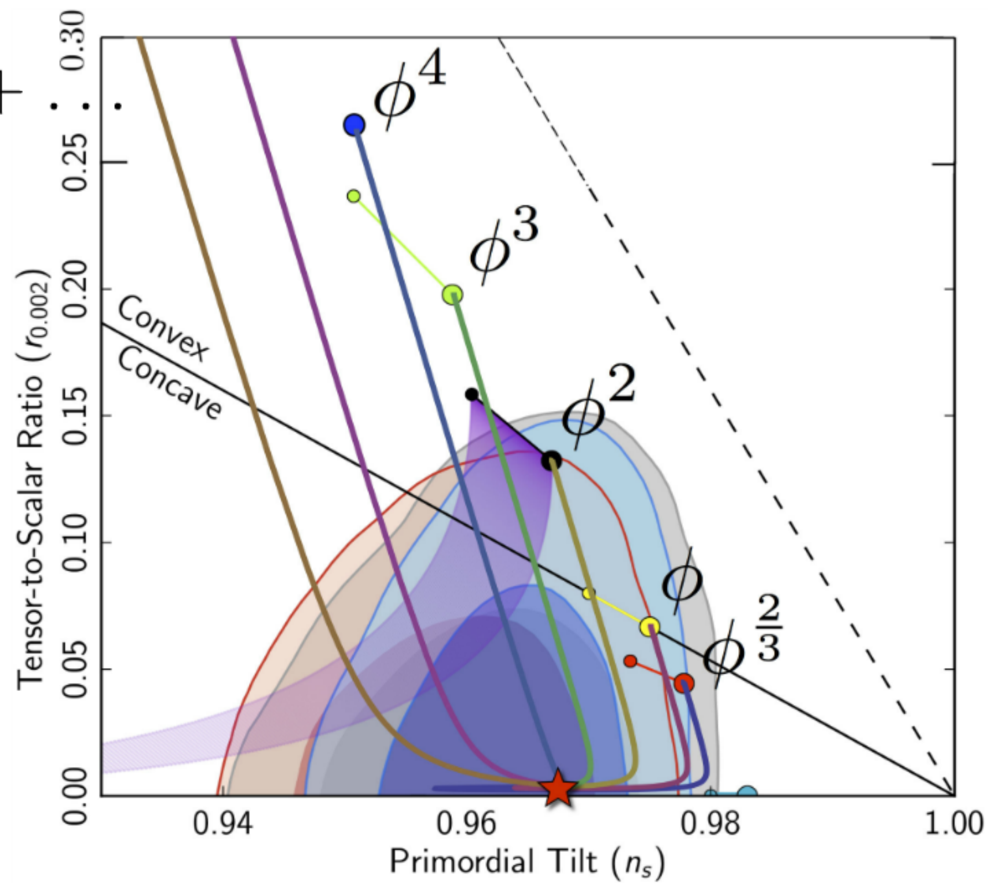

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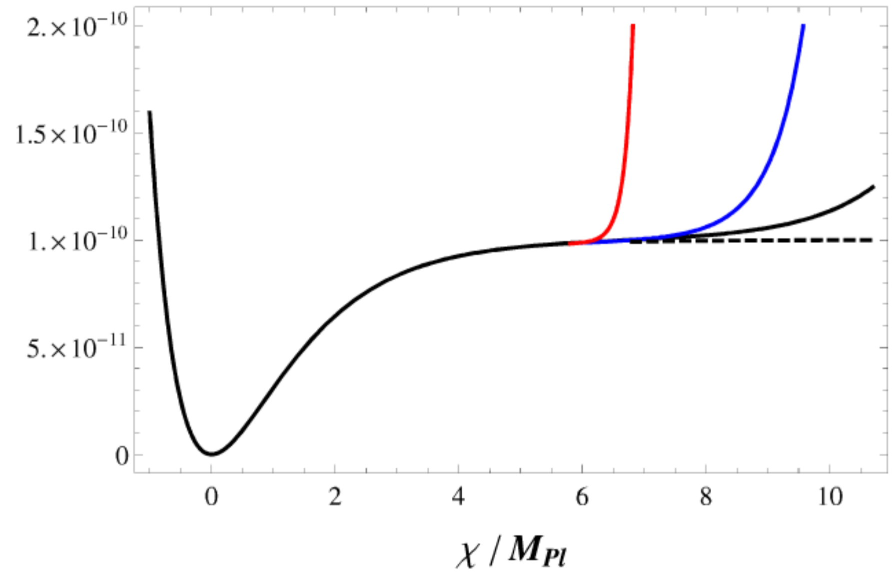

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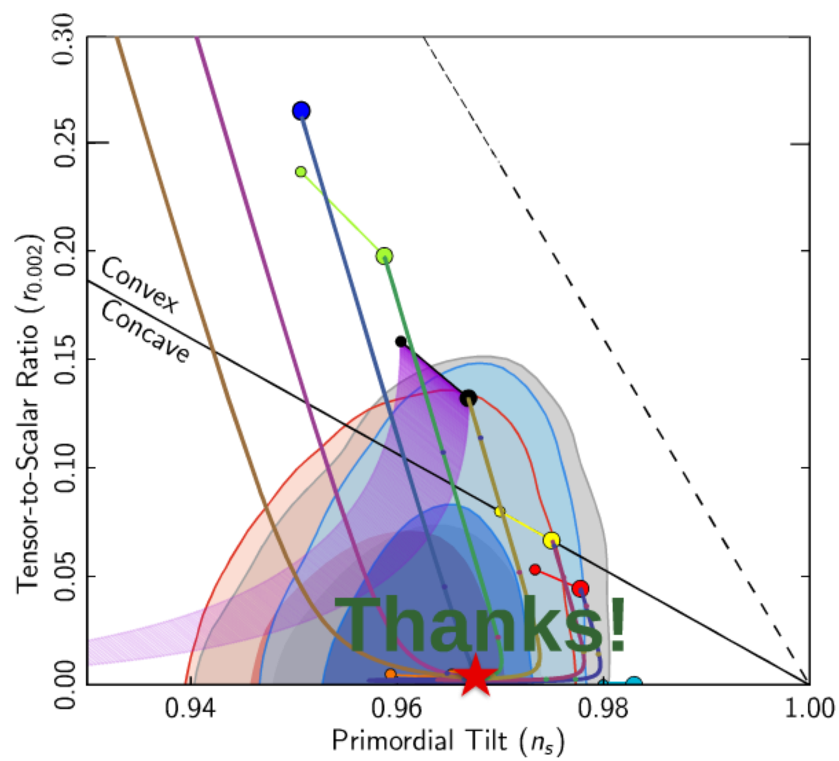

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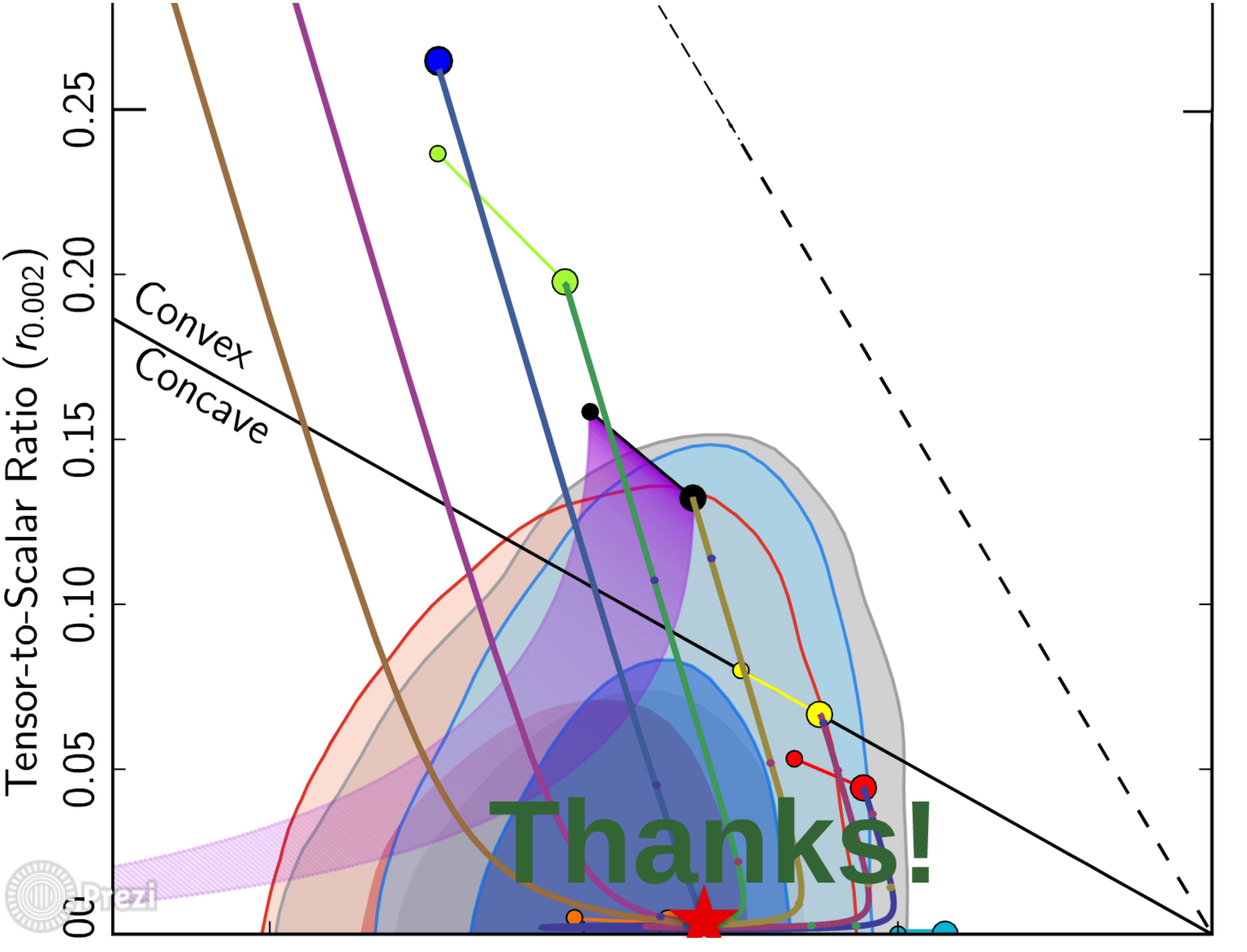

Tensor-to-Scalar Ratio ($r_{0.002}$)
0.25
0.20
0.15
0.10
0.05
0.0
Convex
Concave
Thanks!
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