

Title: Assessing observational constraints on dark energy

Speakers: David Shlivko

Collection/Series: 50 Years of Horndeski Gravity: Exploring Modified Gravity

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Abstract:

Observational constraints on time-varying dark energy are commonly presented in terms of the two CPL parameters w_0 and w_a . Recent observations favor a sector of this parameter space in which $w_0 > -1$ and $w_0 + w_a < -1$, suggesting that the equation of state underwent a transition from violating the null energy condition (NEC) at early times to obeying it at late times. In this talk, I will demonstrate that this initial impression is misleading, by showing that simple quintessence models satisfying the NEC at all times predict an observational preference for the same sector. The upshot is that the CPL parameterization is simultaneously useful for detecting deviations from cosmological-constant dynamics ($w = -1$) but unreliable for predicting the true behavior of $w(z)$.

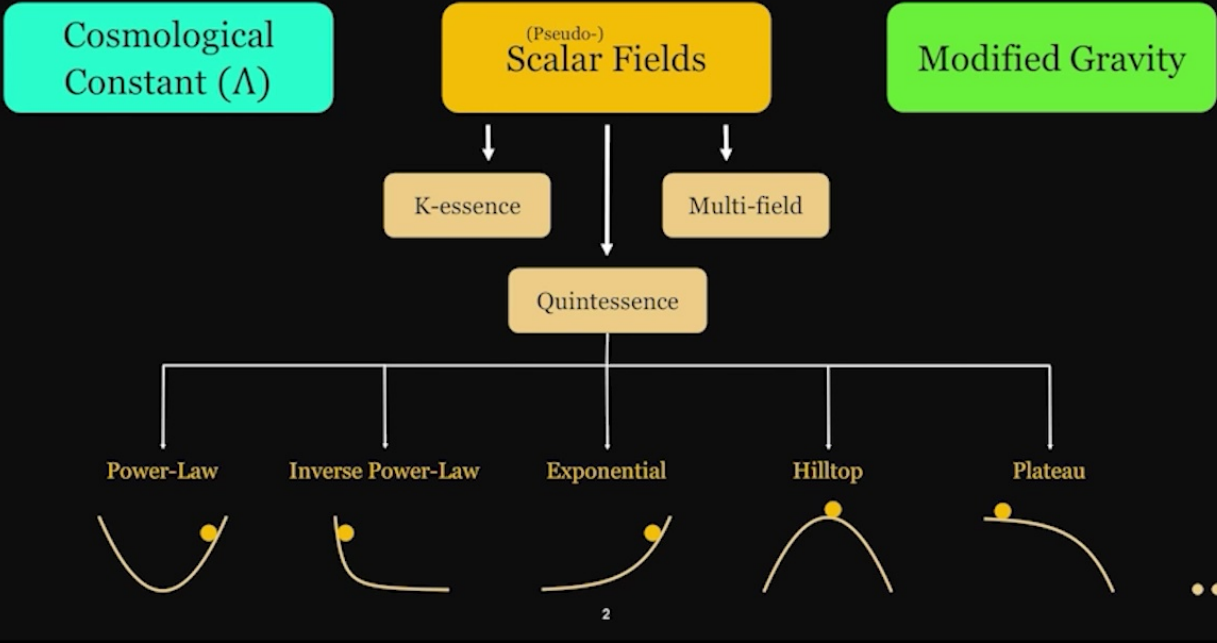
Assessing observational constraints on dark energy

David Shlivko
50 Years of Horndeski Gravity @ PI/UW
July 16, 2024

Based on **2405.03933** with Paul Steinhardt



What is dark energy?



Using data to constrain theories

DESI 2024 I: Cosmological Constraints on Theory G

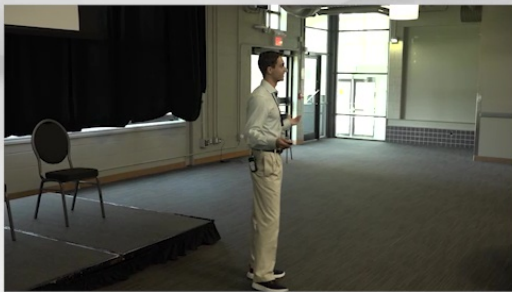
DESI Collaboration: A. G. Adar, S. Alam¹, D. M. Alexander², A. Anand³, U. Andrade^{4,5}, E. Armengaud⁶, S. Avila⁷, H. Awan⁸, B. Bahr-Kalus⁹, S. Bailey¹⁰, D. Bianchi¹¹, A. Brodzeller¹², E. Burtin¹³, R. Calderon¹⁴, J. L. Cervantes-Cota¹⁵, J. Chaves-Montero¹⁶, S. Cole¹⁷, A. Cuceu^{18,19}, T. M. Davis²⁰, K. Dawson²¹, A. de la Macorra²², B. Dey²³, Z. Ding²⁴, S. Eftekharzadeh²⁵, D. J. Eisenstein²⁶, P. Fagrelus²⁷, K. Fanning^{28,29}, N. Findlay³⁰, B. Flaugher³¹, A. Font-Ribera³², E. Forero-Romero³³, J. E. Forero-Sánchez³⁴, S. Gontcho A Gontcho³⁵, A. X. Gonzalez-Morales³⁶, V. Gonzalez-Perez³⁷, C. Gordon³⁸, R. Gupta³⁹, G. Gutierrez⁴⁰, C. Hahn⁴¹, M. M. S. Hanifi⁴², K. Honscheid^{43,44}, C. Howlett⁴⁵, M. Ishak⁴⁶, S. Juneau⁴⁷, N. G. S. Kent^{48,49}, D. Kirkby⁵⁰, M. Lan⁵¹, Y. Lai⁵², T.-W. Lan⁵³, J.M. Le Goff⁵⁴, L. Le Guillou⁵⁵, A. Leauthaud^{56,57}, T. S. Li⁵⁸, E. Linder^{59,60}, K. Lodha^{61,62}, C. Magneville⁶³, D. Margala⁶⁴, P. Martin^{65,66}, M. Maus⁶⁷.

DESI 2024 VII: Cosmological Constraints on Theory G

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DESI 2024 VI: Cosmological Constraints on Theory G

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Parameterized deviations from Λ

$$\frac{d \log \rho}{d \log a} = -3[1 + w(a)]$$

$$a = \frac{1}{1+z}$$

$$w_{\Lambda}(a) = -1$$

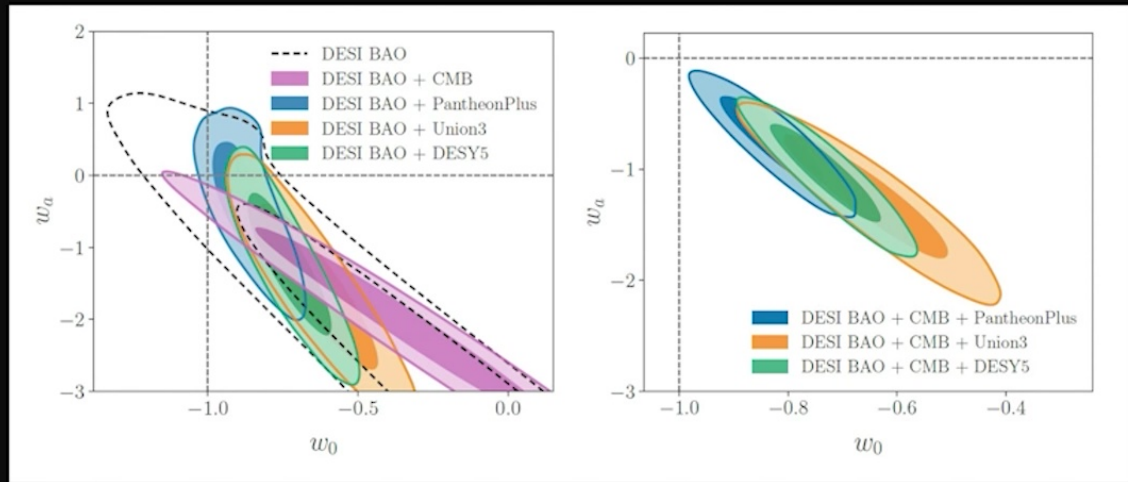
$$w_{\Lambda}(z) = -1$$

$$w_{CPL}(a) = w_0 + w_a(1 - a)$$

$$w_{CPL}(z) = w_0 + w_a \frac{z}{1+z}$$



Observational constraints on deviations from Λ



DESI 2024 Cosmological Constraints: 2404.03002



DESI incompatible with quintessence?

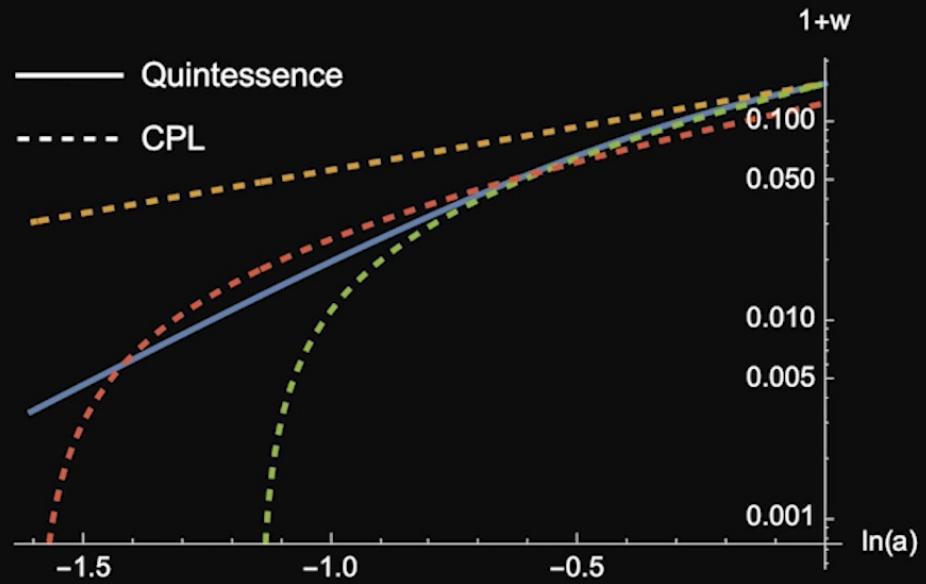
$$\mathcal{L} = \frac{1}{2} \dot{\varphi}^2 - V(\varphi)$$

$$P = \frac{1}{2} \dot{\varphi}^2 - V(\varphi) \qquad \rho = \frac{1}{2} \dot{\varphi}^2 + V(\varphi)$$

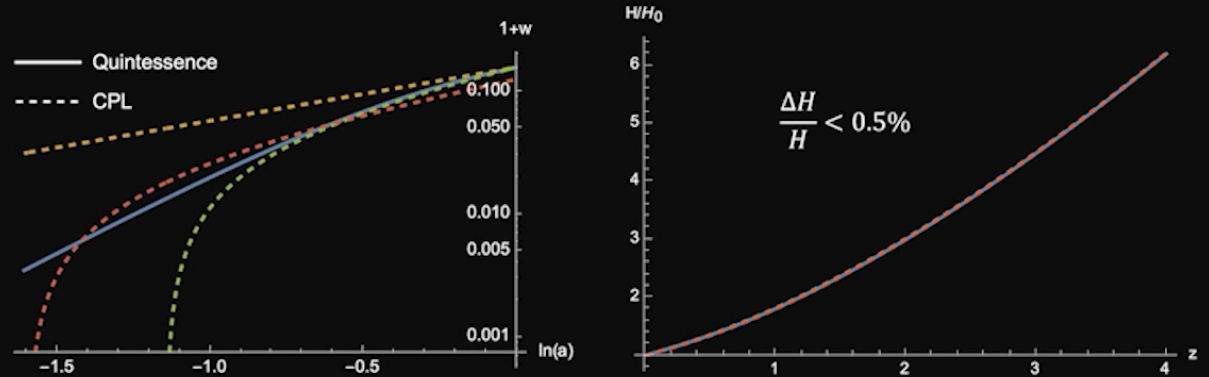
$$w = \frac{\frac{1}{2} \dot{\varphi}^2 - V(\varphi)}{\frac{1}{2} \dot{\varphi}^2 + V(\varphi)} \geq -1$$



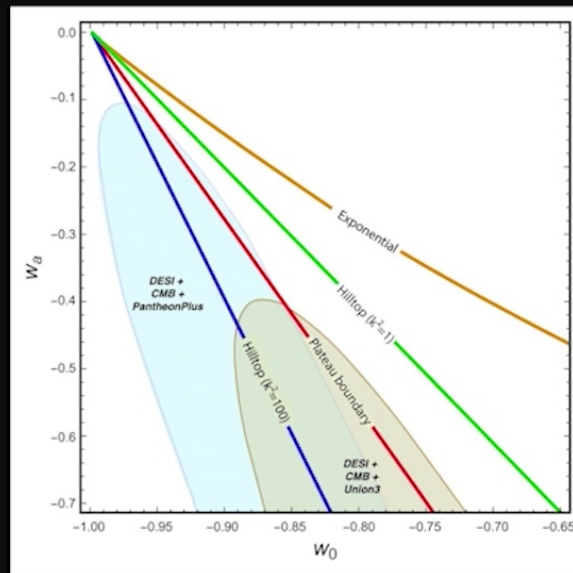
Thawing quintessence example vs. CPL



$H(z)$'s can match even when $w(z)$'s do not.



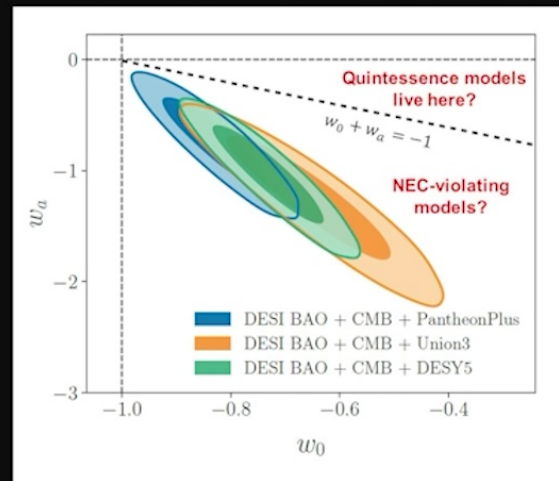
Matching $H(z)$'s to constrain quintessence



- Phase I: Consistency at a glance
- Phase II: Detailed analysis



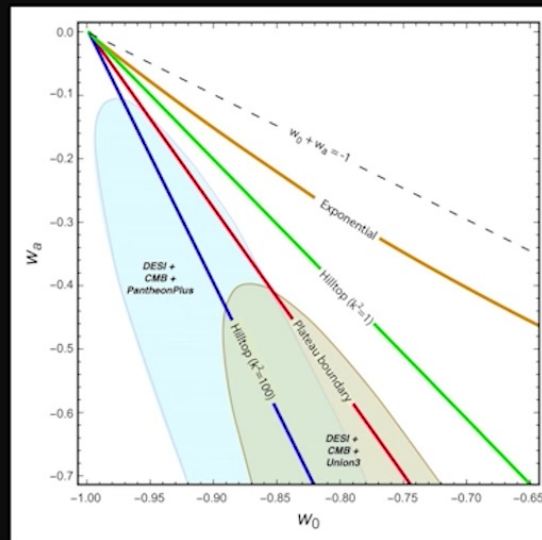
(Mis)interpretations of the w_0 - w_a plot



- Indication of non- Λ dynamics
- Indication that $w(z)$ is growing over time
- Indication that $w(z) < -1$ for $z \gg 1$
 → Dark energy violates NEC early on



(Mis)interpretations of the w_0 - w_a plot



- Indication of non- Λ dynamics
- Indication that $w(z)$ is growing over time
- ~~• Indication that $w(z) \ll -1$ for $z \gg 1$~~
- ~~• Dark energy violates NEC early on~~



Summary

- We shouldn't take observational (CPL) constraints on $w(z)$ at face value
 - ... except for the qualitative indication that $w(z)$ is growing over time
- We can still (indirectly) evaluate models of quintessence from $\{w_0, w_a\}$ constraints
- The observationally preferred region ($w_0 + w_a < -1$) is compatible with quintessence
- Future work: Alternative parameterizations of w or H

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