Title: Assessing observational constraints on dark energy

Speakers: David Shlivko

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

Date: July 16, 2024 - 2:30 PM

URL: https://pirsa.org/24070095

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 $w(z)$.

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

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?

Cosmological Constant (Λ)

(Pseudo-) Scalar Fields

Modified Gravity

K-essence

Multi-field

Quintessence

Power-Law

Inverse Power-Law

Exponential

Hilltop

Plateau

Using data to constrain theories

DESI 2024 I: Cosr
Constraints on The

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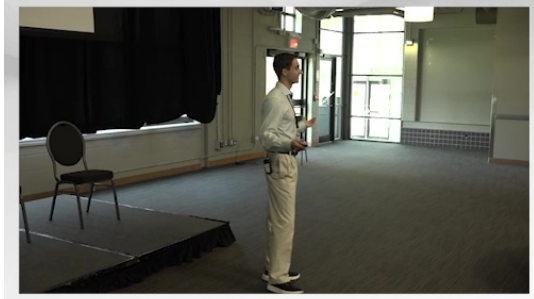
DESI 2024 VII: Cosmological Constraints on Theory G

DESI Collaboration: A. G. Adame,[1] J. Aguilar,[2] S. Ahlen,[3] S. Alam,[4] D. M. Alexander,[5,6] M. Alvarez,[2] O. Alves,[7] A. Anand,[2] U. Andrade,[8,7] E. Armengaud,[9] S. Avila,[10] A. Aviles,[11,12] H. Awan,[7] B. Bahr-Kalus,[13] S. Bailey,[2] C. Baltay,[14] A. Bault,[15] J. Behera,[16] S. BenZvi,[17] A. Bera,[18] F. Beutler,[19] D. Bianchi,[20] C. Blake,[21] R. Blum,[22] S. Brieden,[19] A. Brodzeller,[23] D. Brooks,[24] E. Buckley-Geer,[25,26] E. Burtin,[9] R. Calderon,[27] R. Canning,[28] A. Carnero Rosell,[29,30] R. Cereskaite,[31] J. L. Cervantes-Cota,[32] S. Chabanier,[2] E. Chaussidon,[2] J. Chaves-Montero,[10] S. Chen,[33] X. Chen,[14] T. Claybaugh,[2] S. Cole,[6] A. Cuceu,[34,35] T. M. Davis,[36] K. Dawson,[23] A. de la Macorra,[37] A. de Mattia,[9] N. Deiosso,[38] A. Dey,[22] B. Dey,[39] Z. Ding,[40] P. Doel,[24] J. Edelstein,[41,42] S. Eftekharzadeh,[43] D. J. Eisenstein,[44] A. Elliott,[45,46] P. Fagrelius,[22] K. Fanning,[47,48] S. Ferraro,[2,42] J. Ereza,[49] N. Findlay,[28] B. Flaugher,[26] A. Font-Ribera,[10] D. Forero-Sánchez,[50] J. E. Forero-Romero,[51,52] C. S. Frenk,[6] C. Garcia-Quintero,[18] E. Gaztañaga,[53,28,54] H. Gil-Marín,[55,53,56] S. Gontcho A Gontcho,[2] A. X. Gonzalez-Perez,[57,58] V. Gonzalez-Perez,[59,1] C. Gordon,[10] D. Green,[15] D. Gruen,[60,61]

DESI 2024 VI: Cosmological
ints on Theory F



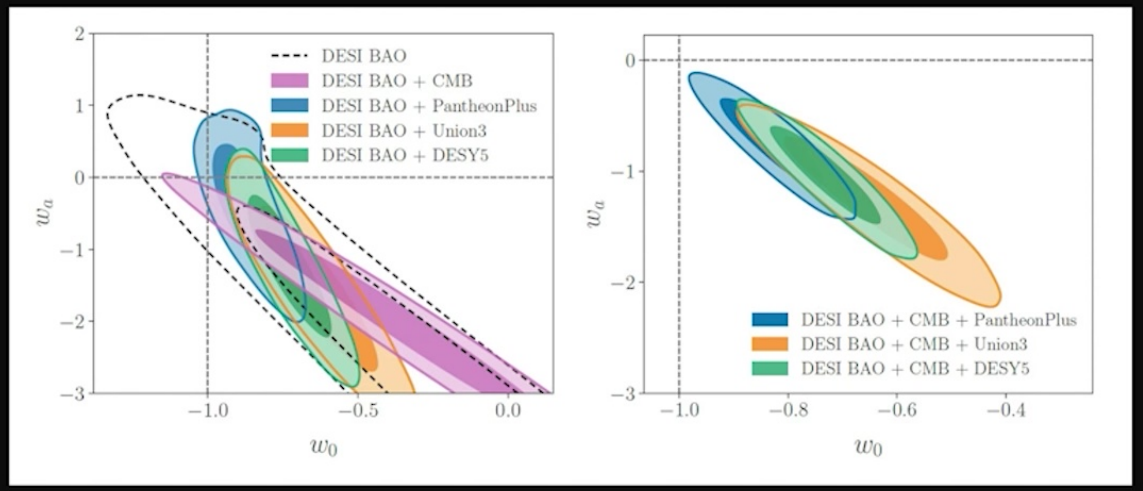
Parameterized deviations from Λ

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

$$w_\Lambda(a) = -1 \qquad w_\Lambda(z) = -1$$

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

Observational constraints on deviations from Λ



DESI 2024 Cosmological Constraints: 2404.03002

5

DESI incompatible with quintessence?

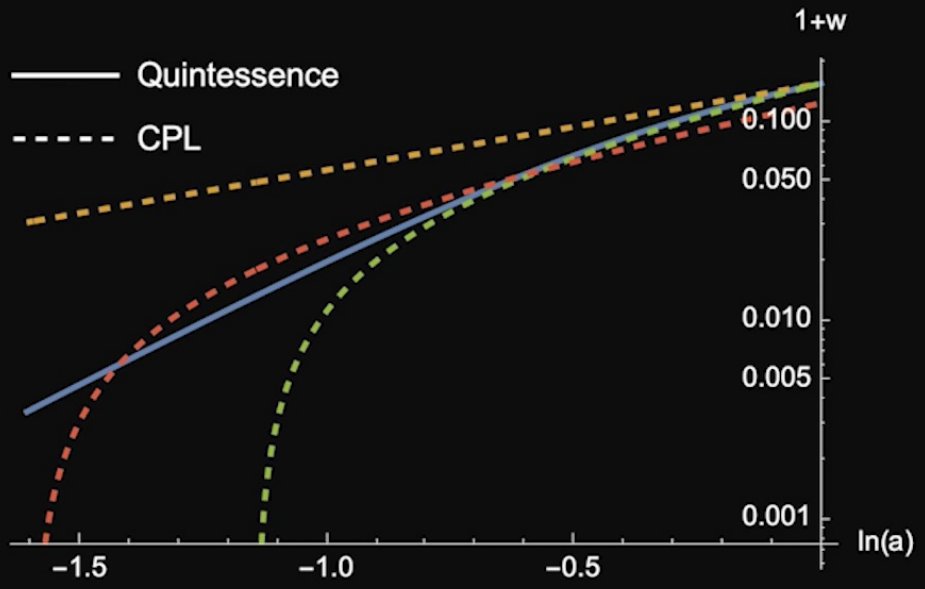
$$\mathcal{L} = \frac{1}{2}\dot{\varphi}^2 - V(\varphi)$$

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

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

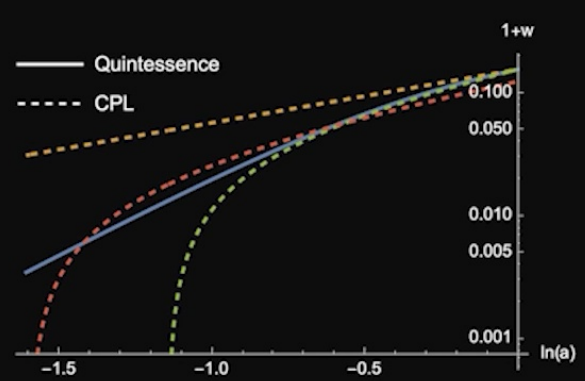
6

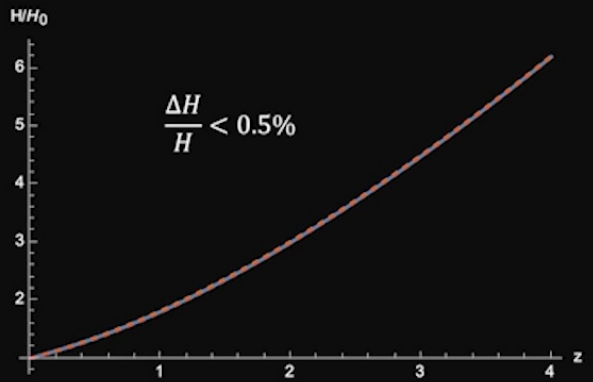
Thawing quintessence example vs. CPL



7

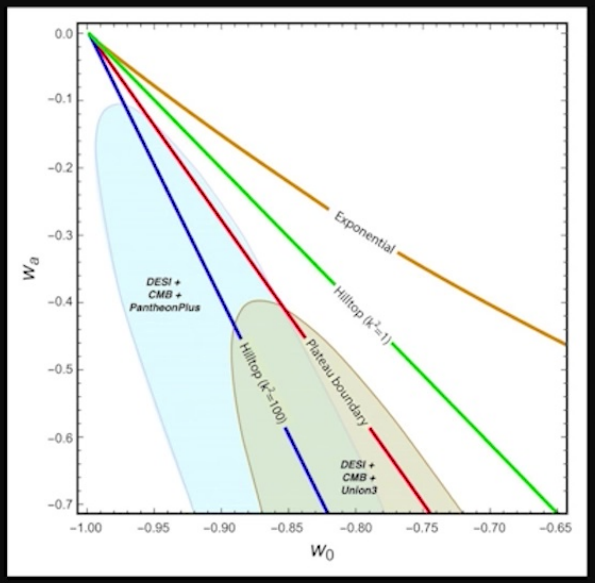
$H(z)$'s can match even when $w(z)$'s do not.





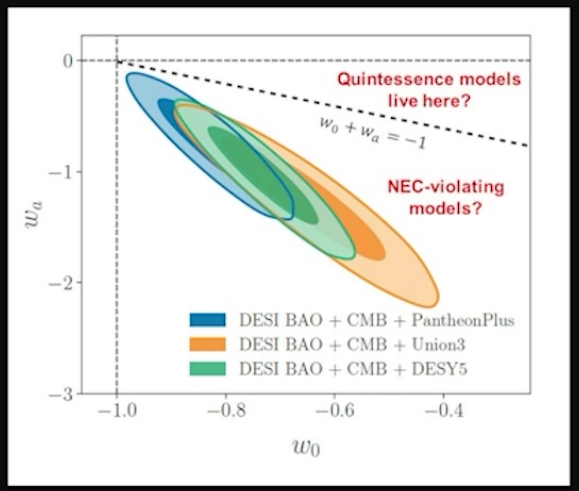
8

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

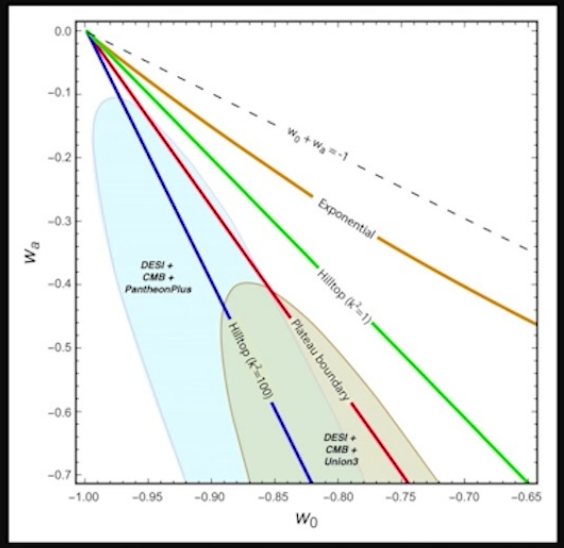


- Indication of non-Λ dynamics
- Indication that $w(z)$ is growing over time
- Indication that $w(z) < -1$ for $z \gg 1$

  ➡ Dark energy violates NEC early on

10

(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~~

11

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

12