Romancing the Hubble: The H0 Problem and a Modified Cosmology

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Based on the work of A.S. Chudaykin, D.S. Gorbunov, N.S. Nedelko

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1. The Problem
    - Uh Oh
2. Where We Looked
    - Datasets
    - Modifying Cosmology
3. What We Found
    - Some Interesting Features

From CMB to H0

- The CMB is very well-mapped, leading to an H0 prediction with within-one-percent uncertainty: $H_0 = 67.36 \pm 0.54 \ \mathrm{km\,s^{-1} Mpc^{-1}}$ (Planck 2018)
- Any CMB-derived parameters of the "now" are heavily model-dependent

The Distance Ladder

- Independent of the CMB, can be built "from the ground up" with different sources for cross-reference
- Requires extensive observational data in many channels

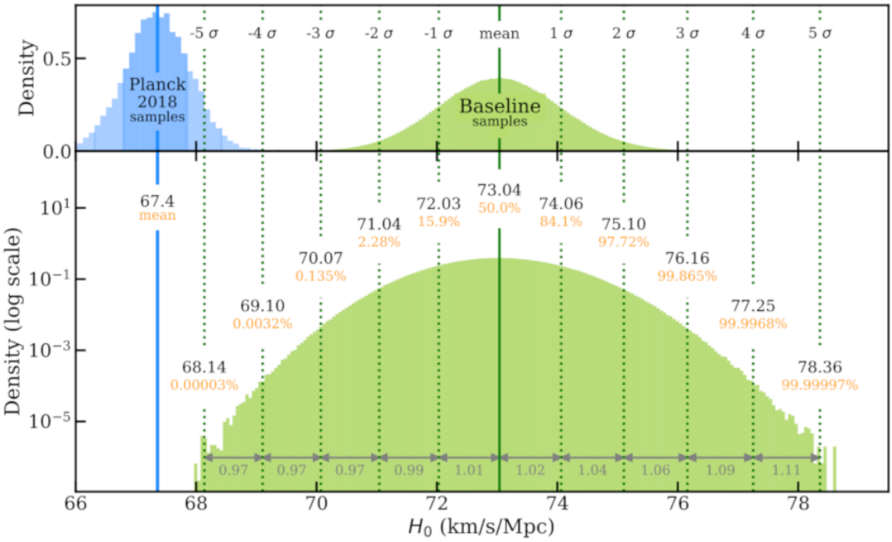


Figure: Fig.15 from Riess et al. [2112.04510]

CMB data

1. South Pole Telescope maps produce tension with Planck, but Planck also exhibits internal tensions
2. Solution: Planck (TT, $\ell_{max} = 1000$) + SPT-3G (TE, EE, lensing)
3. An impoved LCDM fit, H0 discrepancy decreases from 4.2σ to 2.7σ, but is still significant

Large Scale Structure (LSS)

1. A perturbational treatment of the BOSS DR12 LRG full-shape data
2. BAO data from SDSS, eBOSS, 6dFGS
3. Local $S_8 (= \sigma_8 \sqrt{\Omega_m / 0.3})$ measurements from KiDS-1000, DES Y3, HSC

H0 implementations

1. Basic: a plain Gaussian prior – bad for late-time modifications!
2. Better: a nuanced treatment with the `distanceladder` package [2112.11567]

Altenatively, use the Pantheon SN likelihood (which doesn't use Cepheid calibration) instead of an H0 model. Crucially, the two may not be compatible due to M_{SN} calibration differences (up to 4σ!).

PDE

Phantom-crossing Dark Energy (PDE), a generalised late-time modification

1. DE energy density has a minimum at a_m:
   $\rho_{\mathrm{PDE}}(a) = \rho_0[1 + \alpha(a - a_m)^2 + \beta(a - a_m)^3]$
2. The DE equation of state is $w_{\mathrm{PDE}}(a) = -1 - \frac{a[2\alpha(a-a_m)+3\beta(a-a_m)^2]}{3[1+\alpha(a-a_m)^2+\beta(a-a_m)^3]}$
3. Vary a_m, α and β as free parameters

Without H0 data...

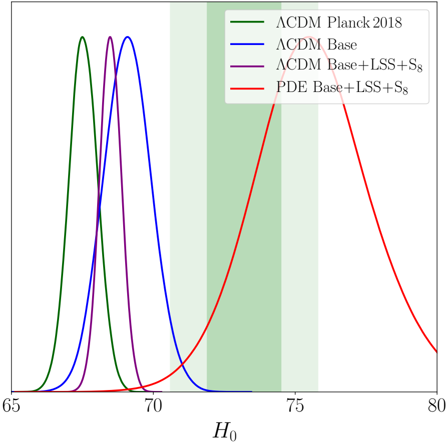


Figure: In PDE CMB+LSS produces a large H0 without any additional priors

Some Interesting Features

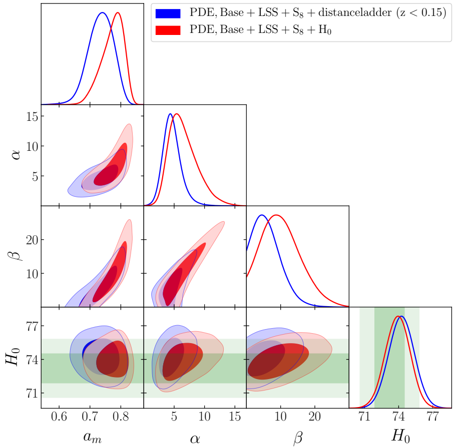


Figure: With a $z < 0.15$ cap (same as in Riess et al.) on the SN sample, `distanceladder` produces an H0 distribution nearly identical to using a prior, but different PDE parameter distributions

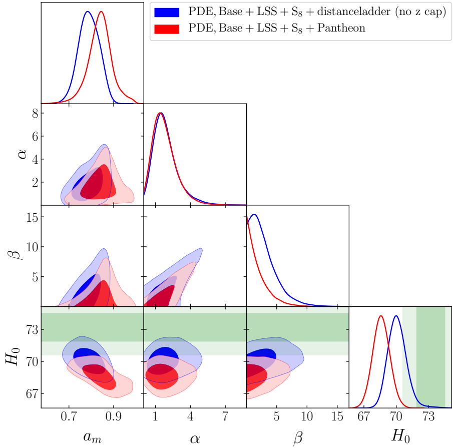
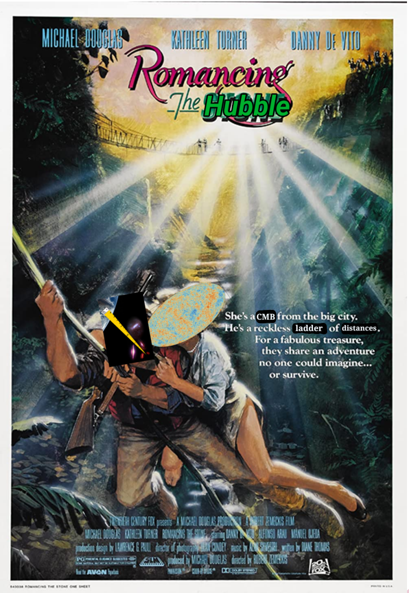


Figure: Without a z cap, `distanceladder` produces a low H0 value, closer to using CMB-calibrated Pantheon data

Conclusions

- Detailed modelling of H0 observations is very important
- Keep calibration in check when using SN Ia data
- Better understanding of high-z SNe is needed
- Impovement in accuracy of non-SN ladder methods will be crucial


MICHAEL DOUGLAS
KATHLEEN TURNER
DANNY DE VITO
Romancing The Hubble
She's a CMB from the big city.
He's a reckless ladder of distances.
For a fabulous treasure,
they share an adventure
no one could imagine...
or survive.