

Title: Status of Hubble tension in Cosmology

Speakers: Niayesh Afshordi

Collection: Everpresent Lambda: Theory Meets Observations

Date: November 11, 2019 - 3:30 PM

URL: <http://pirsa.org/19110066>

Hubble Trouble!

(a review)

Niayesh Afshordi

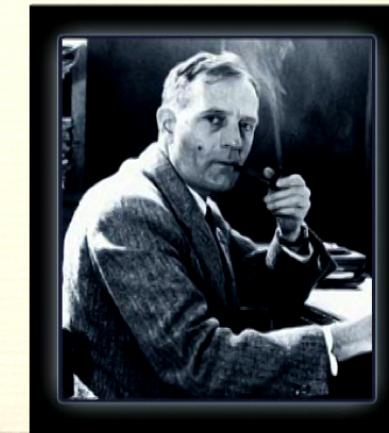
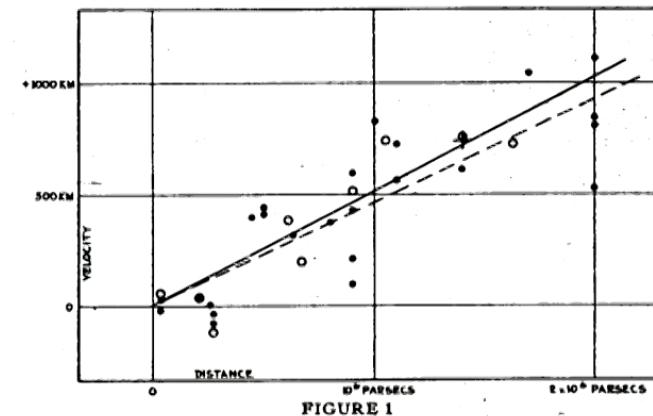
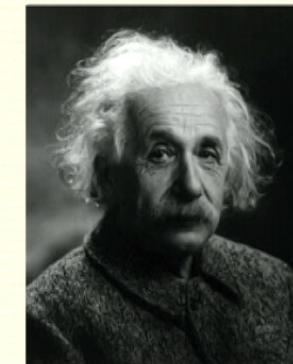


A VERY DARK COSMOS!

- Dark Energy 69%
- Dark Matter 26%
- Intergalactic plasma 4%
- Stars/Planets/Gas 0.2-0.6%
- Neutrinos 0.1-0.5%
- Stellar Black Holes 0.01 %
- Supermassive Black Holes 0.001%

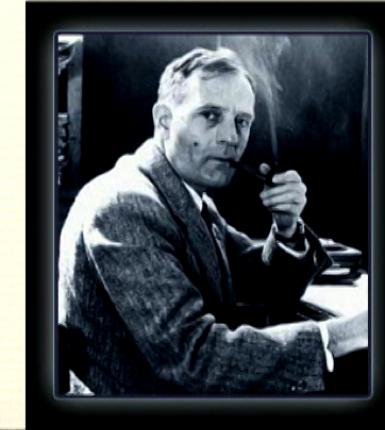
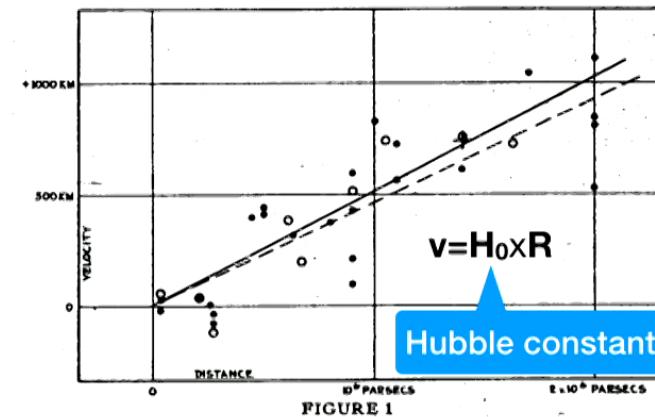
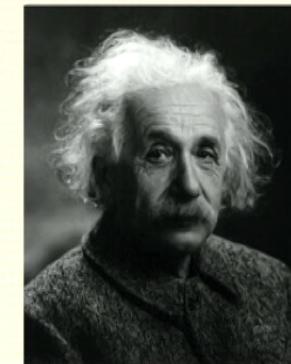
Einstein's biggest blunder

- ❖ 1917: Einstein's General Relativity
 - ❖ Curvature = Energy/Momentum + *constant*
 - ❖ Static Universe needs a *cosmological constant*
- ❖ 1929: Hubble discovers that the universe isn't static



Einstein's biggest blunder

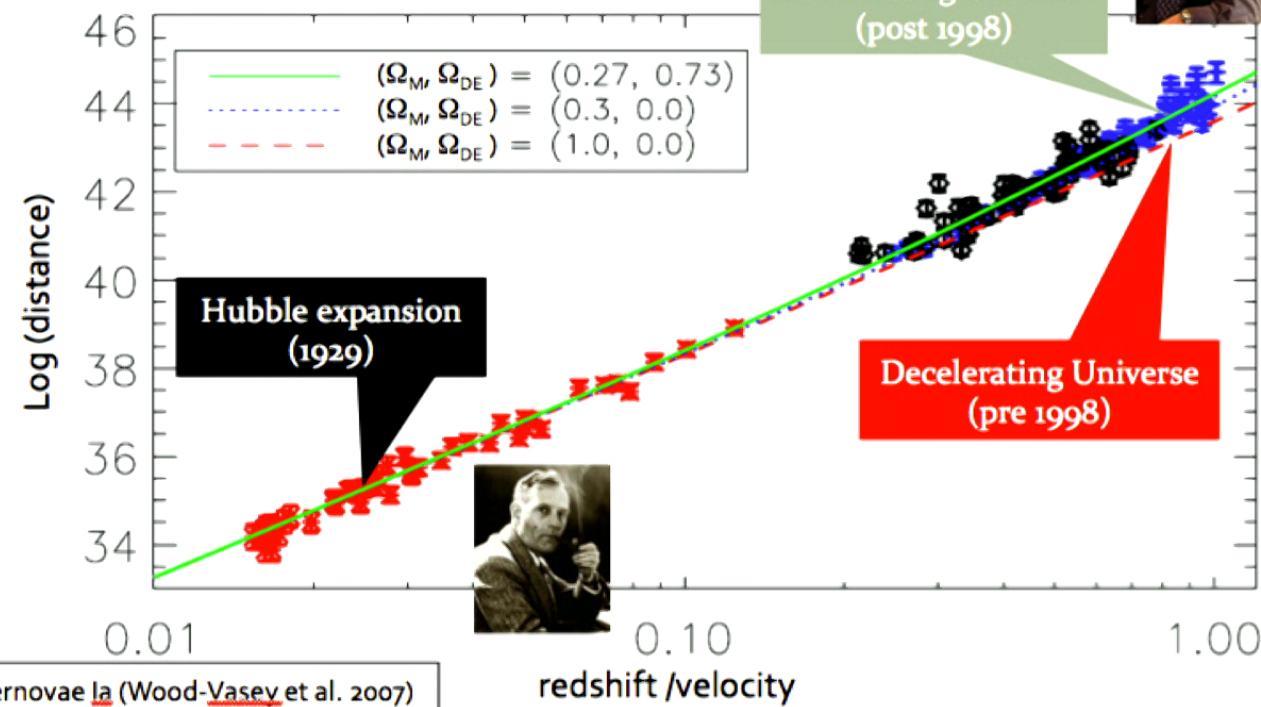
- ❖ 1917: Einstein's General Relativity
 - ❖ Curvature = Energy/Momentum + *constant*
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Return of Cosmological Constant! (or Dark Energy)



Accelerating Universe
(post 1998)

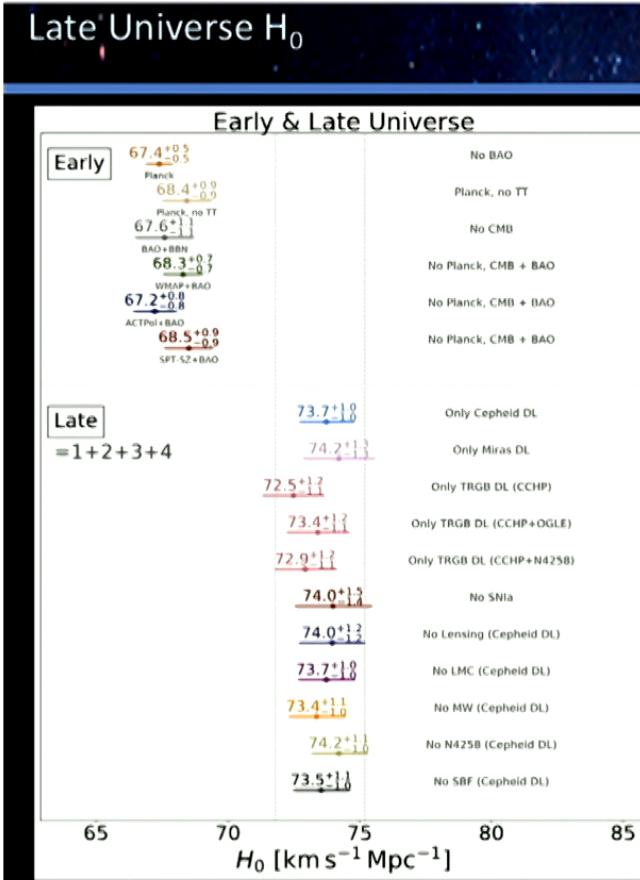


The Dark Energy!

- Largest cosmic scales dominated by a mysterious Dark Energy
- Attractive gravity becomes repulsive
- We will never be able to see beyond 63 billion light years



Hubble Trouble?!

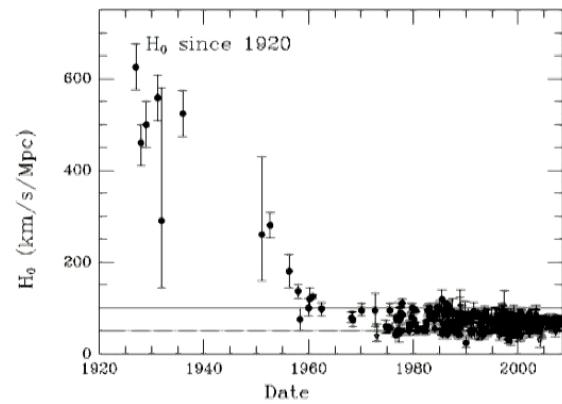


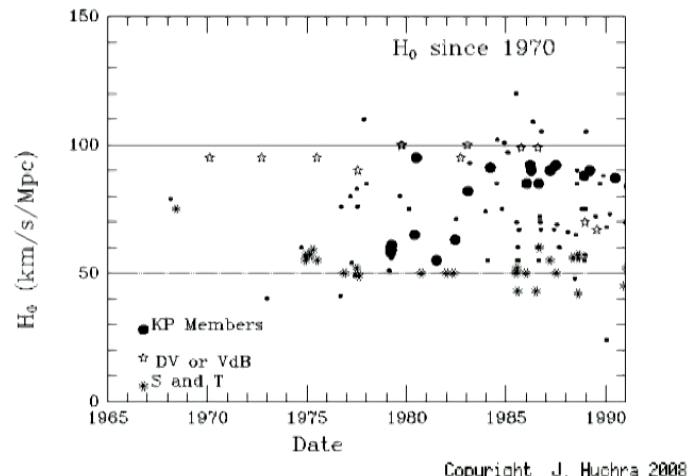
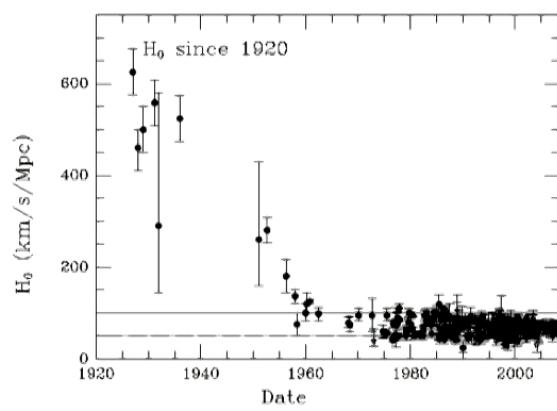
Review by Verde, Treu, Riess (2019)



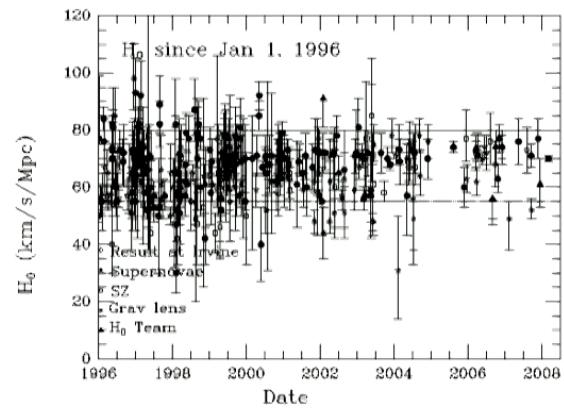
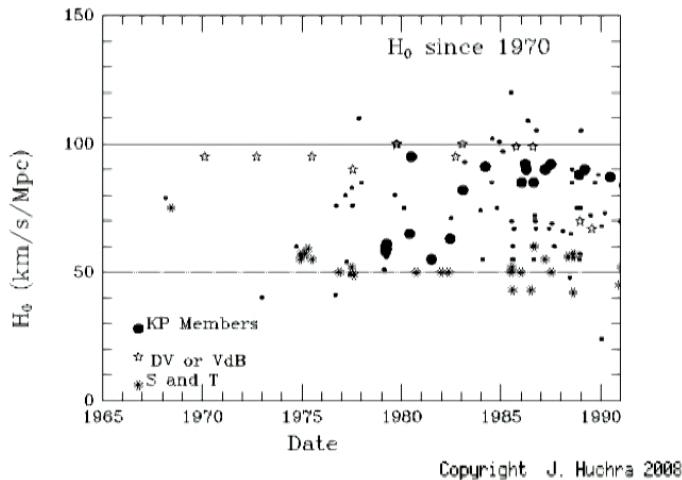
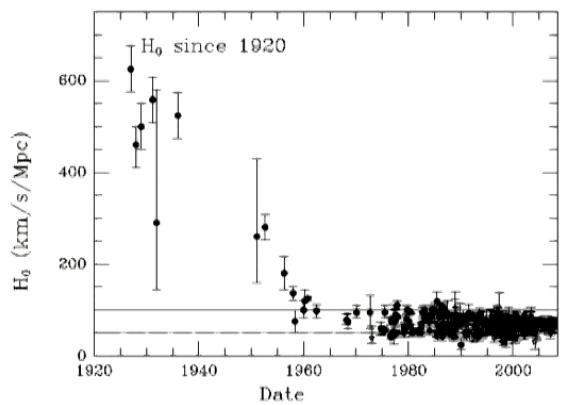
Quanta Magazine 2019

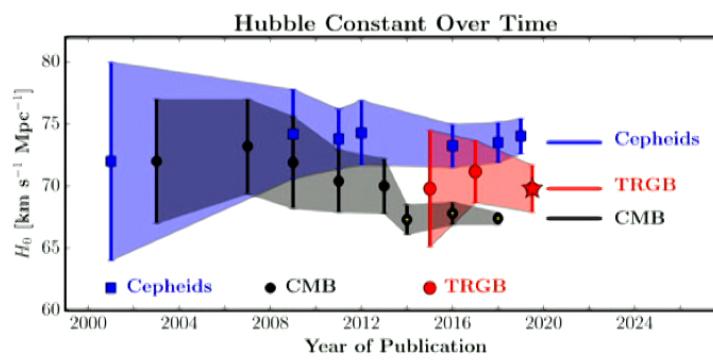
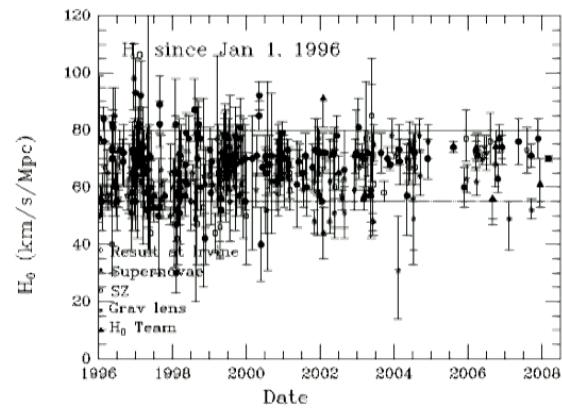
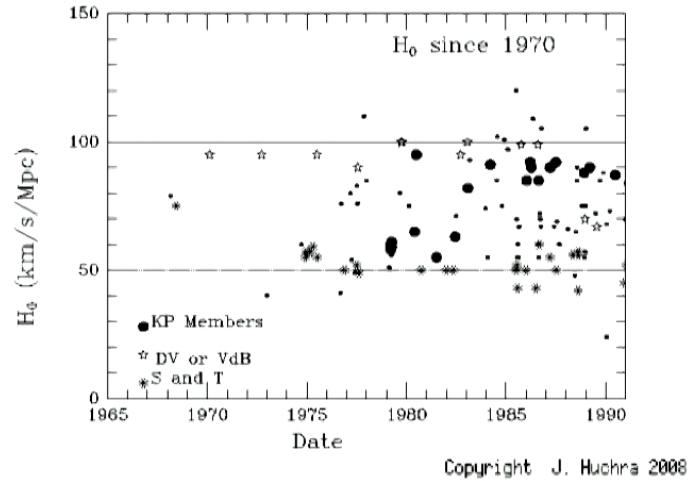
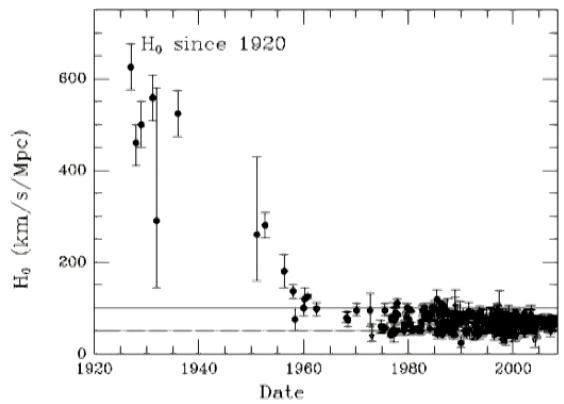
Colloquium by Adam Riess (Sep. 2019, Perimeter Institute, <http://pirsa.org/19090086/>)





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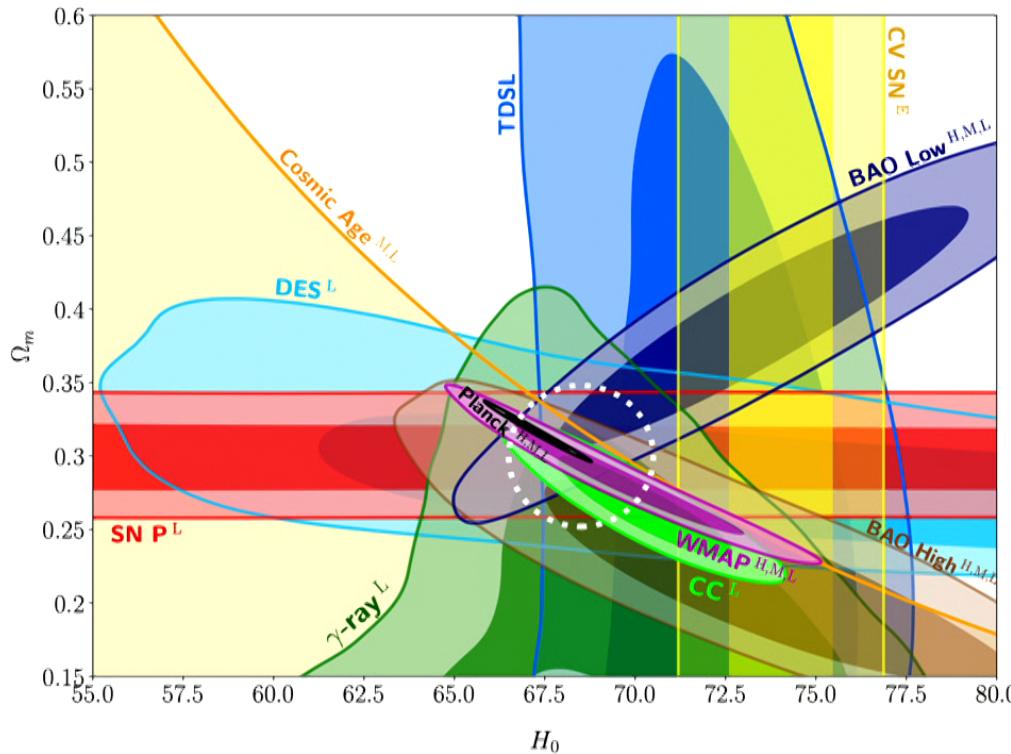


Figure 1. Different constraints in the H_0 and Ω_m space based on a flat Λ CDM model. Dark and light contours show the 68% and 95% confidence regions of each posterior. Parameter space outside the orange region is excluded by the cosmic-age bound. Most constraints with different degeneracy directions consistently overlap on the region indicated by the guiding white dashed circle. Note that the circle *does not* represent a joint constraint. Such a common region is however not overlapped by the Cepheid-based local determination of H_0 (CV SN). Contours correspond to SN P (red), BAO Low (brown), BAO High (navy), γ -ray (dark green), CC (light green), TDSL (blue), DES (light blue), WMAP (magenta), Planck (black), CV SN (yellow) and cosmic age ($t_{\text{age}}^{100} > 13.535$ Gyr; orange). See the text for descriptions and sources of those constraints. Each constraint in the figure is labeled according to whether they can be changed by nonstandard high- z models (H), mid- z models (M), low- z models (L), or local environmental factors (E). See the text for the definition of those model categories. We leave the TDSL technique without a label because it is relatively insensitive to the underlying cosmological model.

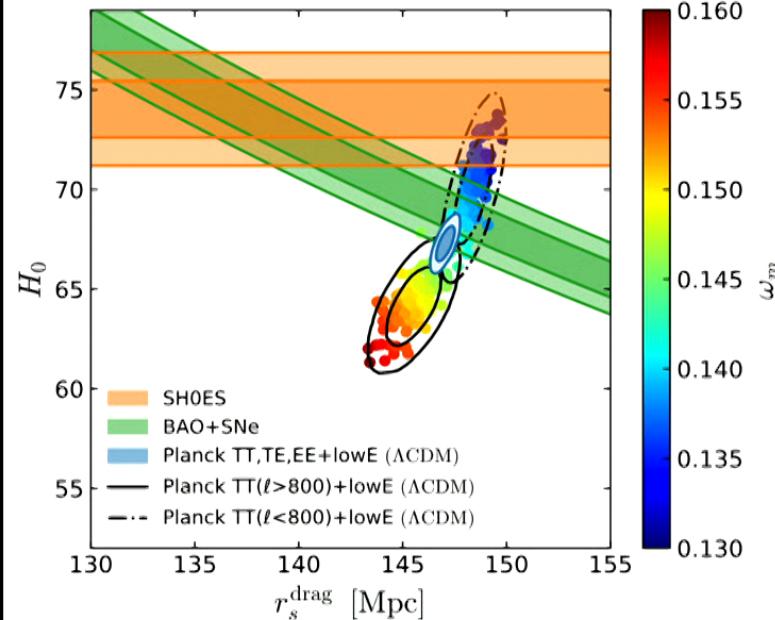
arXiv:1910.02978

Astrophysics > Cosmology and Nongalactic Astrophysics

The Hubble Hunter's Guide

Lloyd Knox, Marius Millea

(Submitted on 10 Aug 2019 (v1), last revised 16 Sep 2019)



$$r_s^* = \int_0^{t_*} \frac{dt}{a(t)} c_s(t) = \int_{z_*}^{\infty} \frac{dz}{H(z)} c_s(t),$$

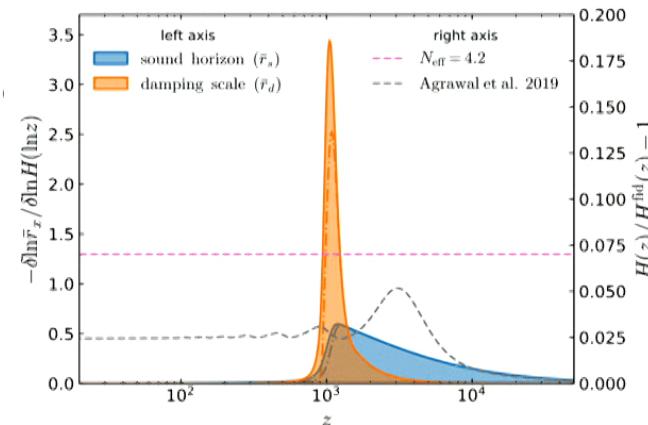
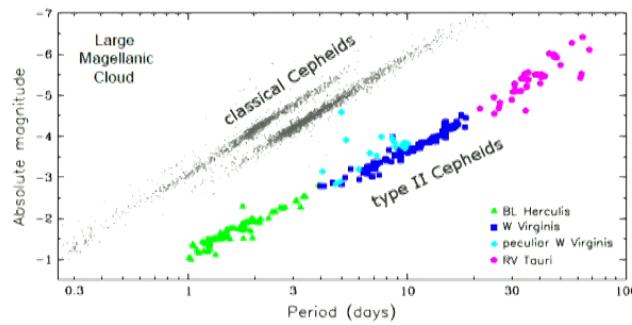


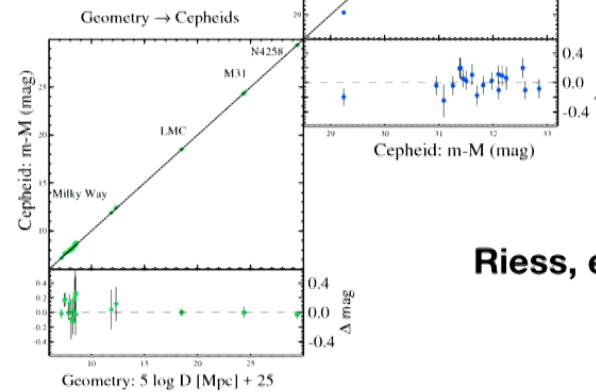
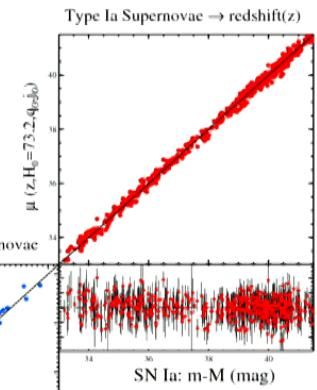
FIG. 2. On the left axis (the filled curves), we show the fractional linear response of the “visibility-averaged” \bar{r}_s and \bar{r}_d to a fractional change in $H(z)$ in some logarithmic interval in z (see Appendix A for exact definitions). For each curve, the dot-dashed line shows what the response would be without accounting for the dependence of the visibility function on $H(z)$. The right axes (dashed curves) show the fractional change in $H(z)$ relative to our Λ CDM fiducial model for two cases which reduce \bar{r}_s . The first has $N_{\text{eff}} = 4.2$ (which lowers \bar{r}_s by 7%) and the second is the best-fit ϕ^4 model from Agrawal *et al.* [19]. One can read off the (linearized) change to \bar{r}_s and \bar{r}_d from these two models by multiplying the dashed lines by either the blue or orange regions, respectively, then integrating across z .

Cepheids/Supernoave Ia



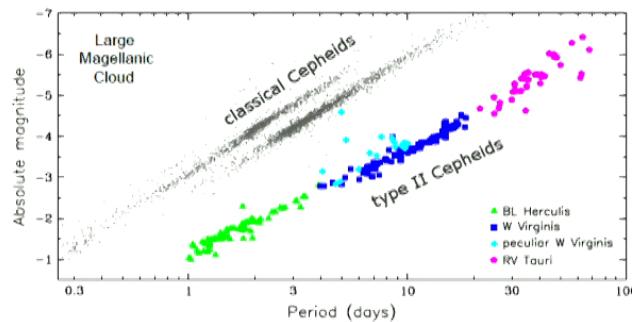
http://ogle.astrouw.edu.pl/atlas/type_II_Cepheids.html

- 49 -



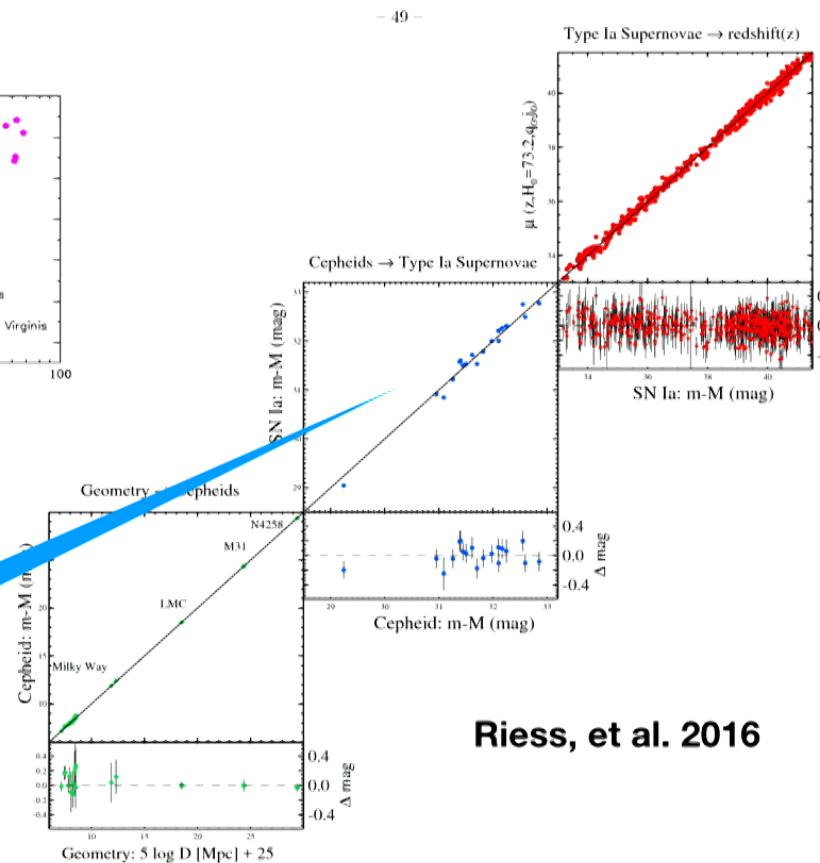
Riess, et al. 2016

Cepheids/Supernoave Ia



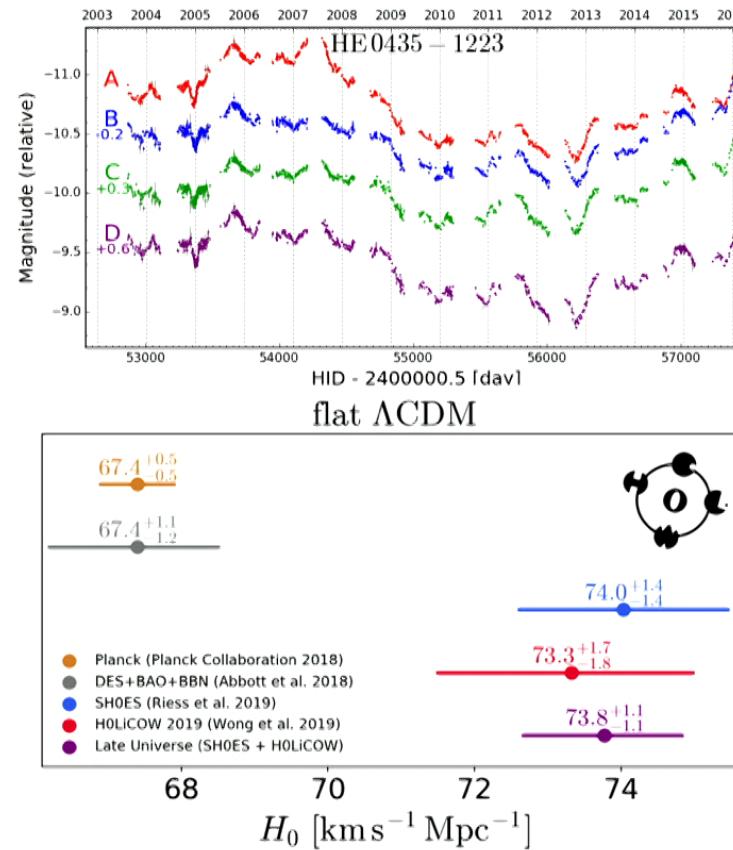
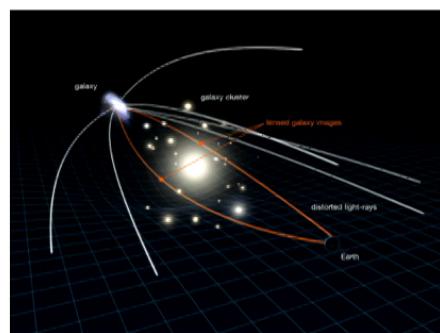
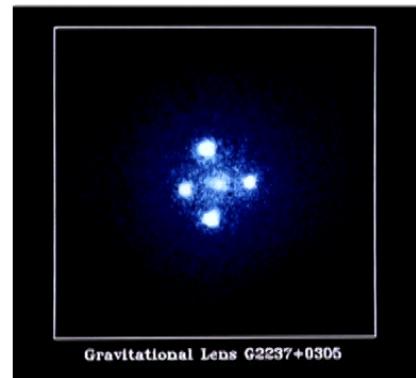
http://ogle.astrouw.edu.pl/atlas/type_II_Cepheids.html

weakest link?!

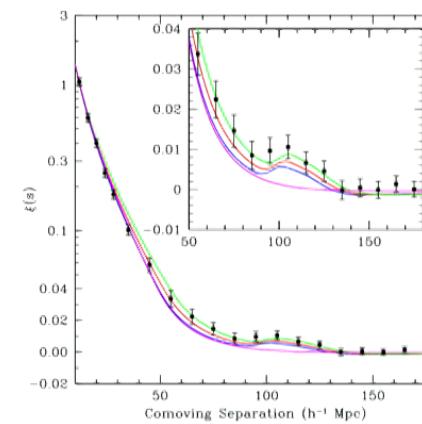
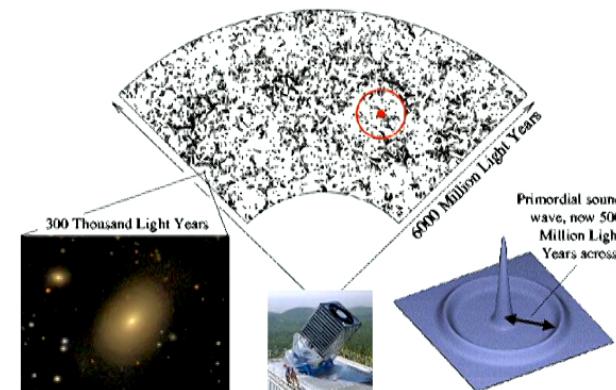
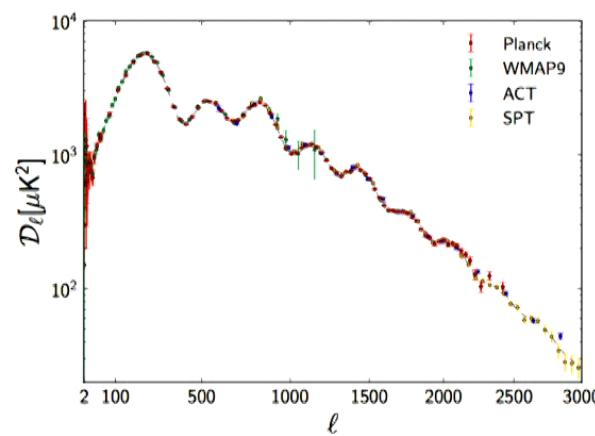
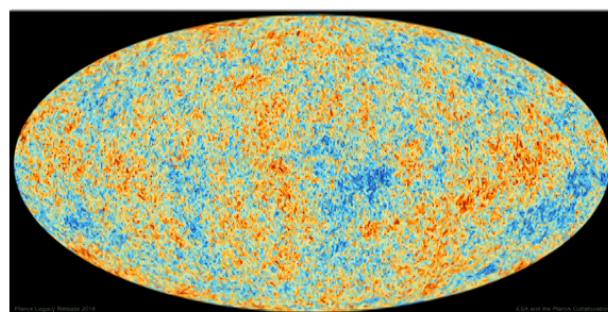


Riess, et al. 2016

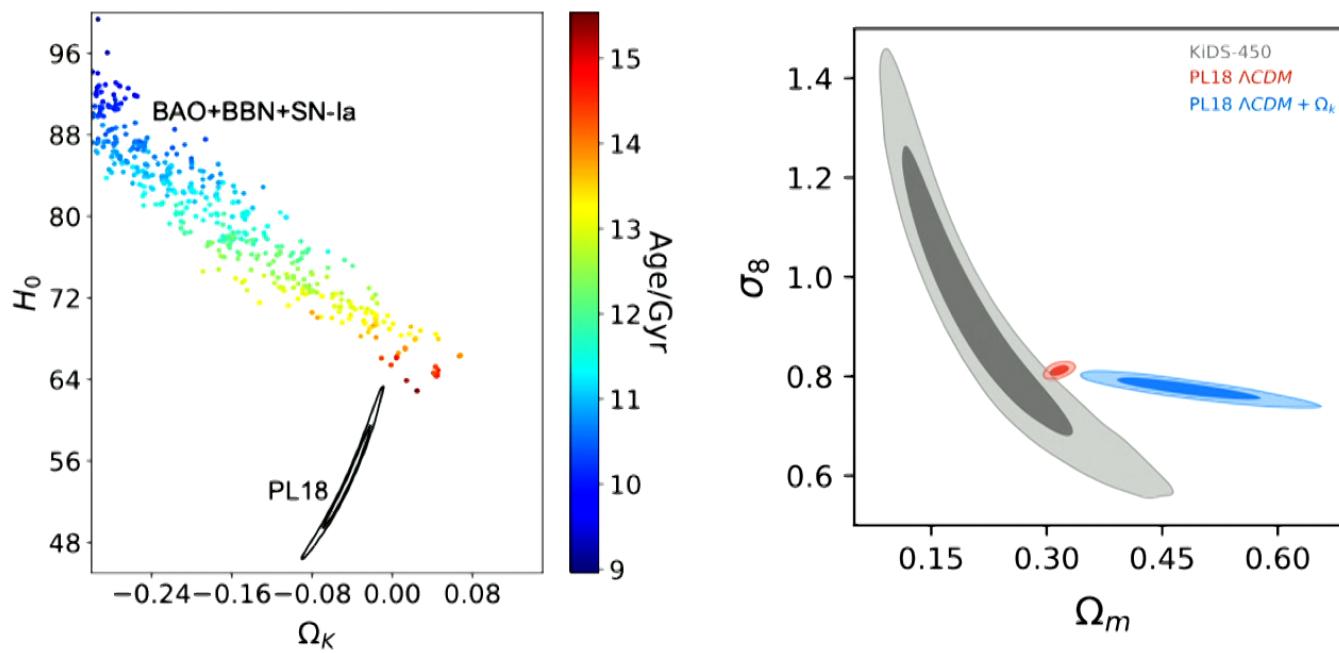
Gravitational Lensing



CMB+BAO: cosmic sound waves



Other Tensions! σ_8 , Ω_K



1. [arXiv:1911.02087 \[pdf, other\]](https://arxiv.org/abs/1911.02087)

Planck evidence for a closed Universe and a possible crisis for cosmology

Eleonora Di Valentino, Alessandro Melchiorri, Joseph Silk

Comments: 35 pages, 8 figures

Journal-ref: Published on Nature Astronomy (4th November 2019)

