Parameter discordance in Planck and low-redshift measurements

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Korea University of Science and Technology (UST)

13 February 2019, High 1 Resort

3rd IBS-KIAS Joint Workshop

* * *

Will Cosmic Gravitational Wave Sirens Determine the Hubble Constant? Part 1

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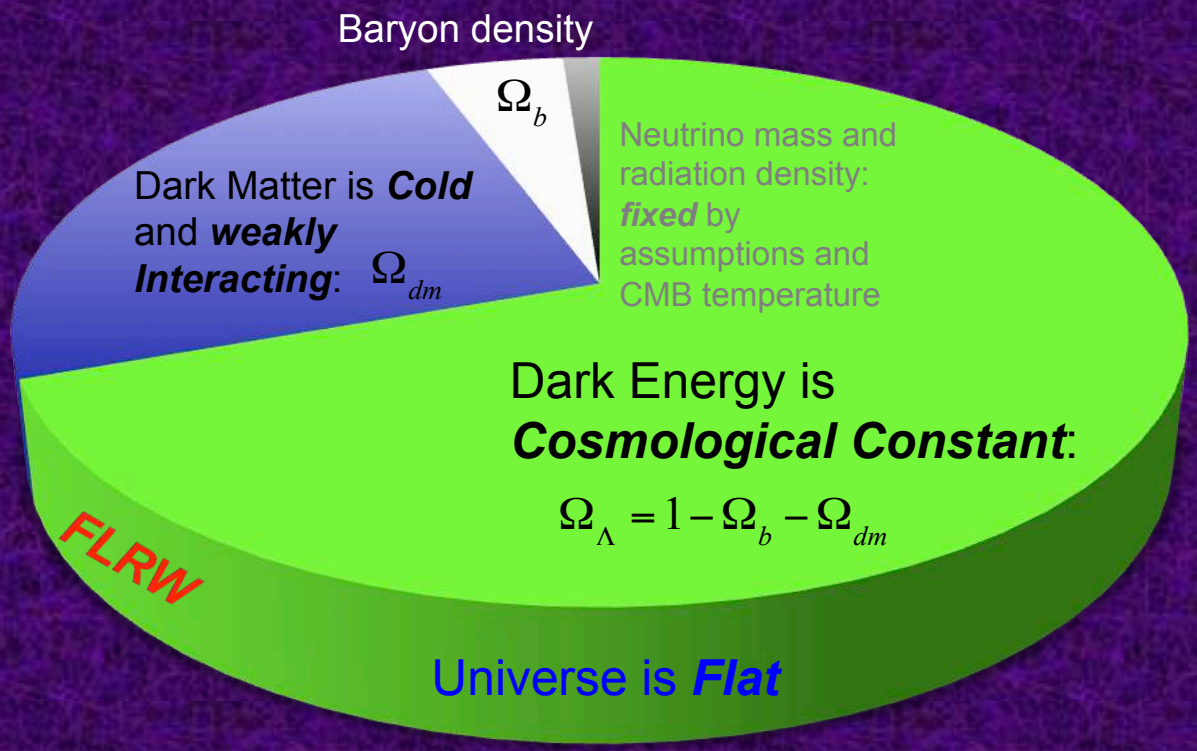
13 February 2019, High 1 Resort

3rd IBS-KIAS Joint Workshop

* * *

Standard Model of Cosmology

Using measurements and statistical techniques to place sharp constraints on parameters of the standard cosmological model.



Initial Conditions:
Form of the Primordial Spectrum is ***Power-law***

n_s, A_s

Epoch of reionization

τ

Hubble Parameter and the Rate of Expansion

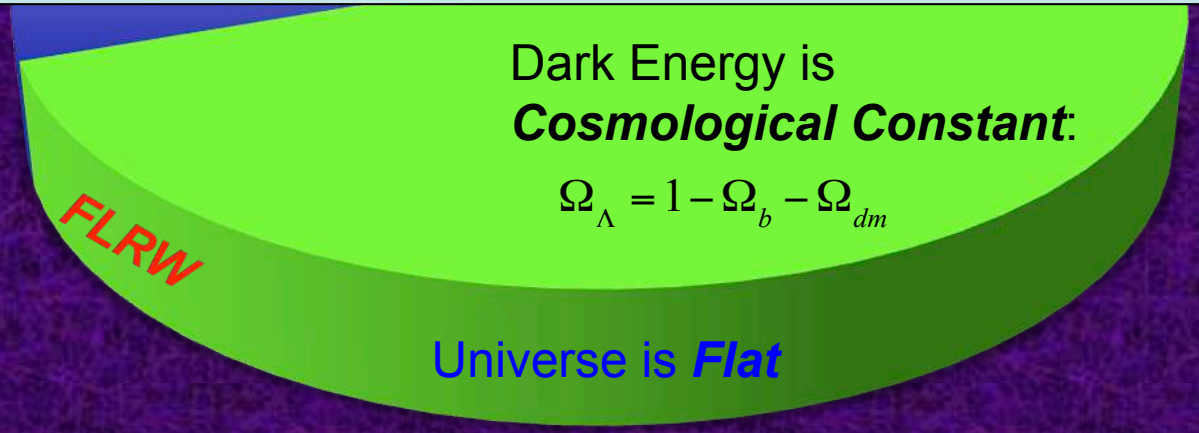
H_0

Standard Model of Cosmology

Using measurements and statistical techniques to place sharp constraints on parameters of the standard cosmological model.

Baryon density

Combination of Assumptions



n_s, Δ_s

Epoch of reionization

τ

Hubble Parameter and the Rate of Expansion

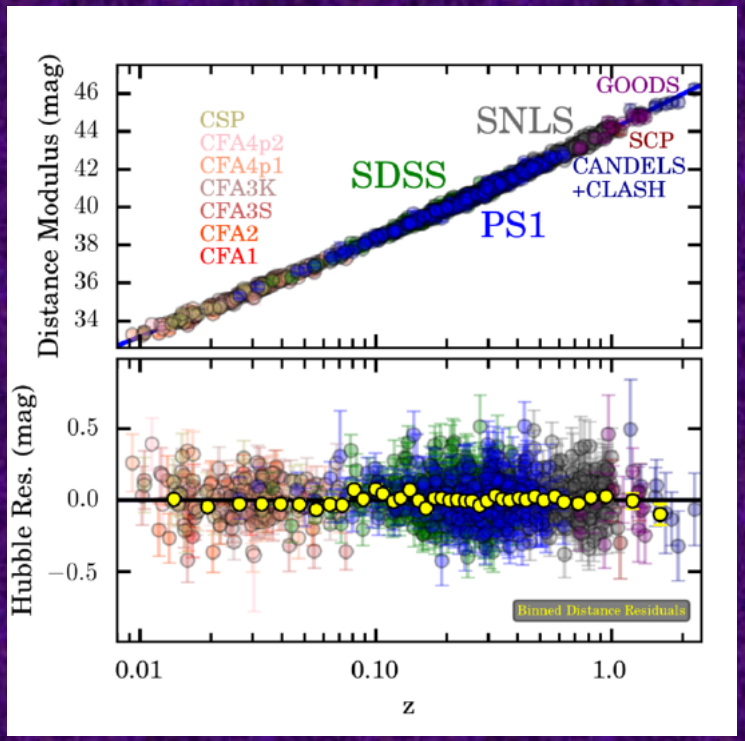
H_0

Standard Model in 2019

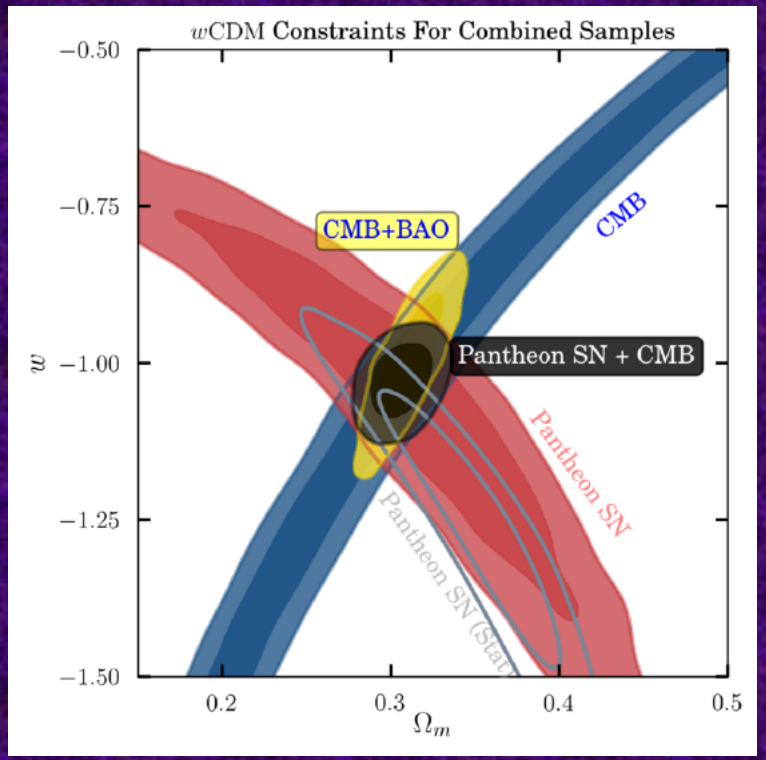
SN

20 years after discovery of the acceleration of the universe:

From 60 Supernovae Ia at cosmic distances, we now have ~1000 published distances, with better precision, better accuracy, out to z~2.0. ***Accelerating universe in proper concordance to the data.***



1048 spectroscopically confirmed SNIa



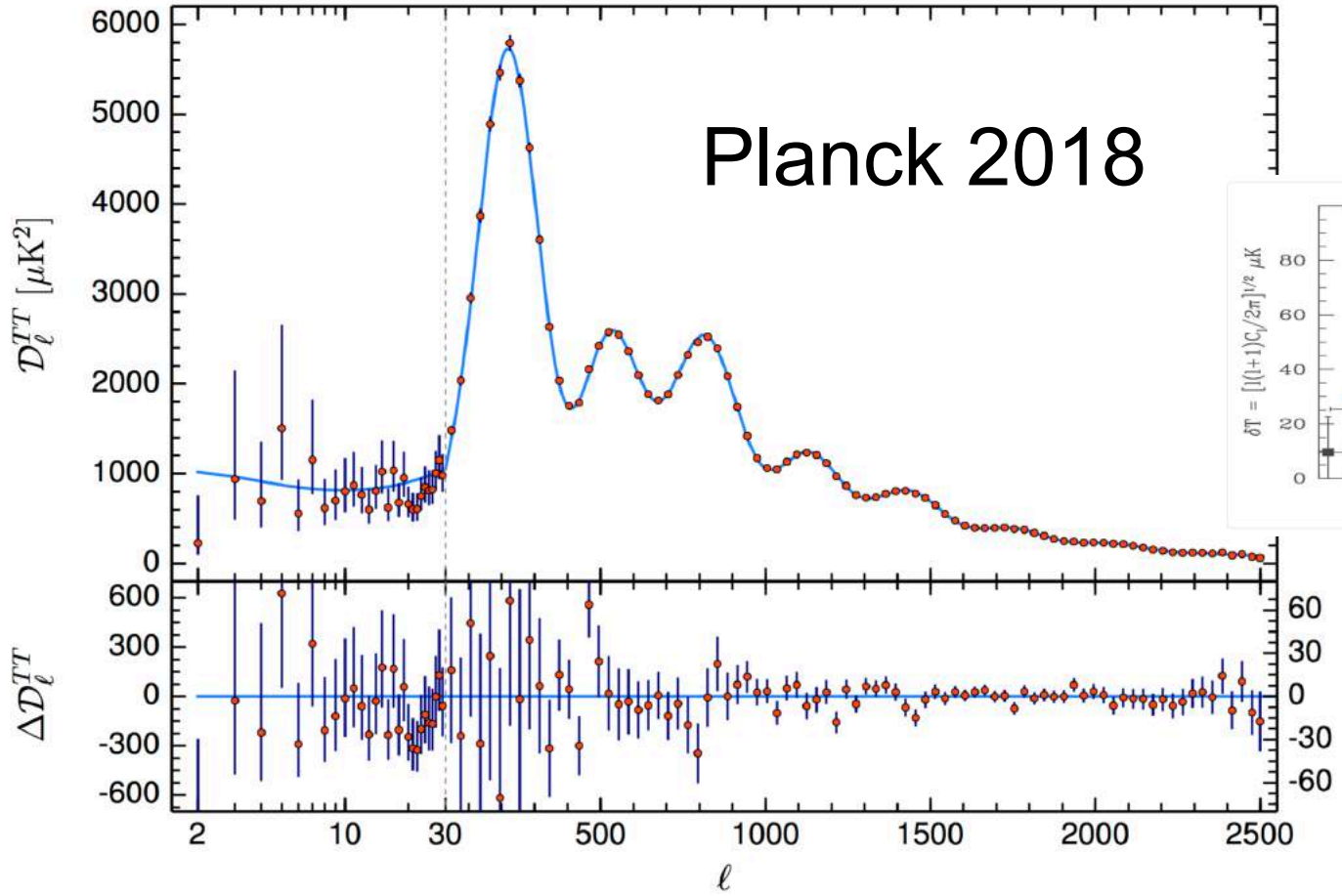
Pantheon Compilation
Scolnic et al. (2018)

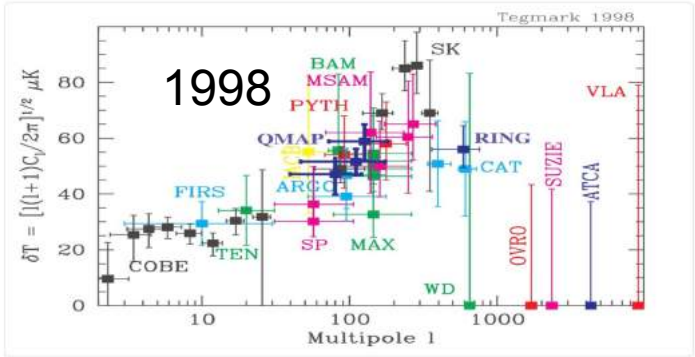
Standard Modelin 2019

CMB

Almost 20 years after discovery of the acceleration of the universe:

CMB directly points to acceleration. Didn't even have acoustic peak in 1998!

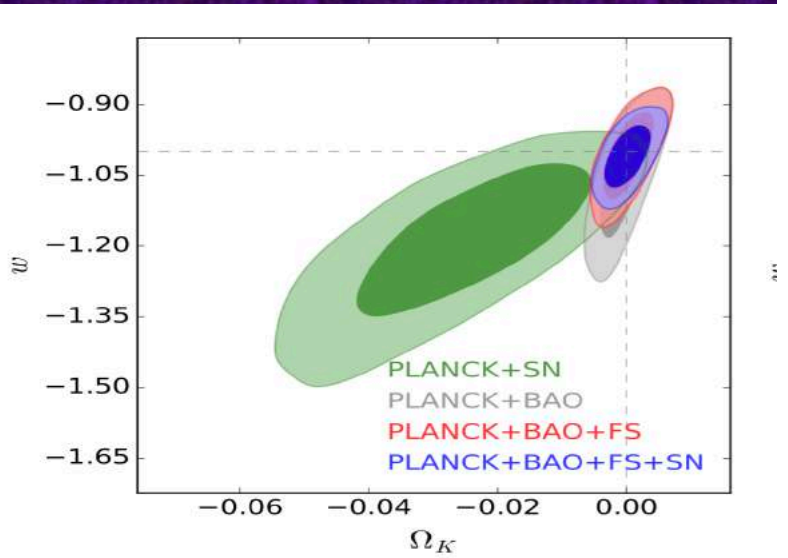


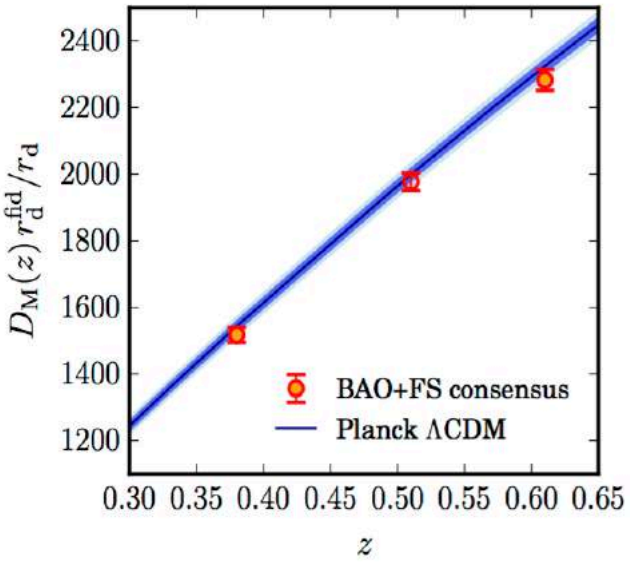


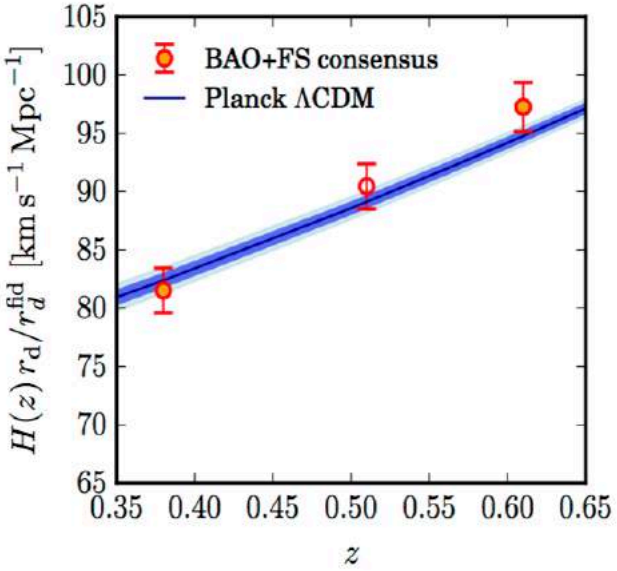
Dark Energy in 2019 LSS

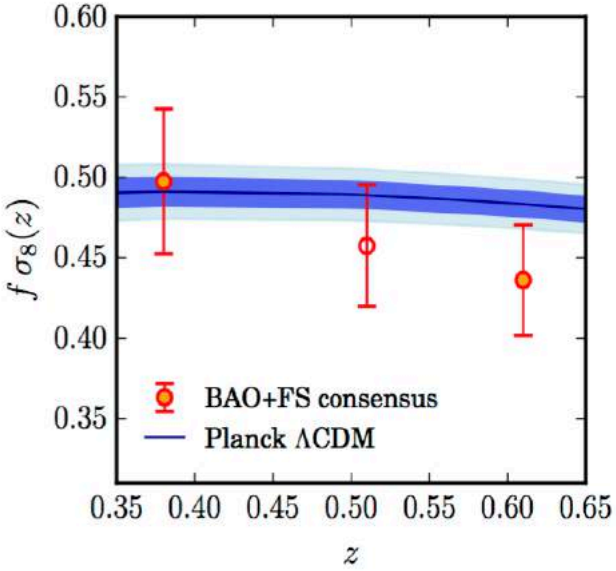
Almost 20 years after discovery of the acceleration of the universe:

BOSS collaboration DR12 (2016),
arXiv:Alam et al, MNRAS 2016

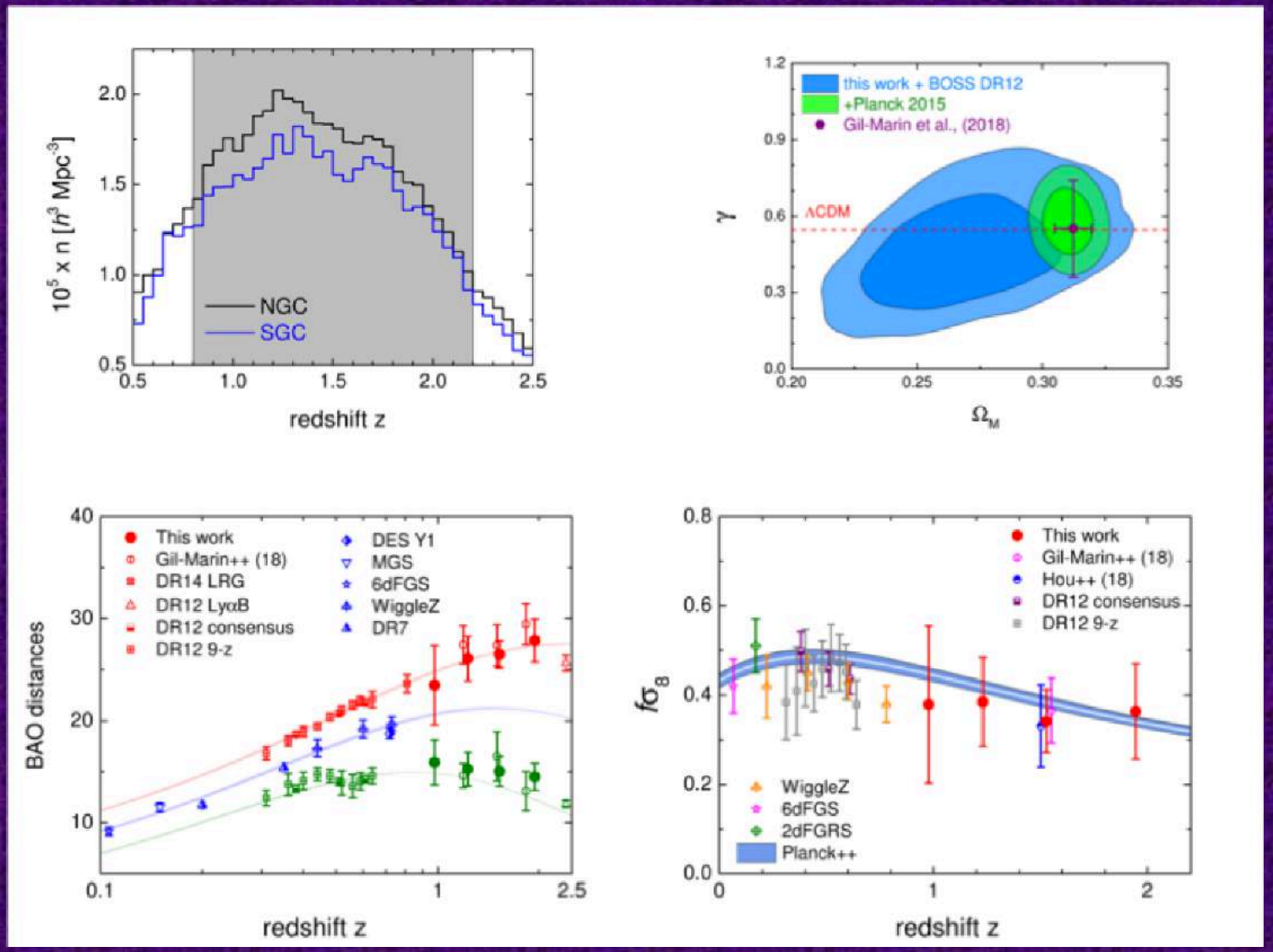








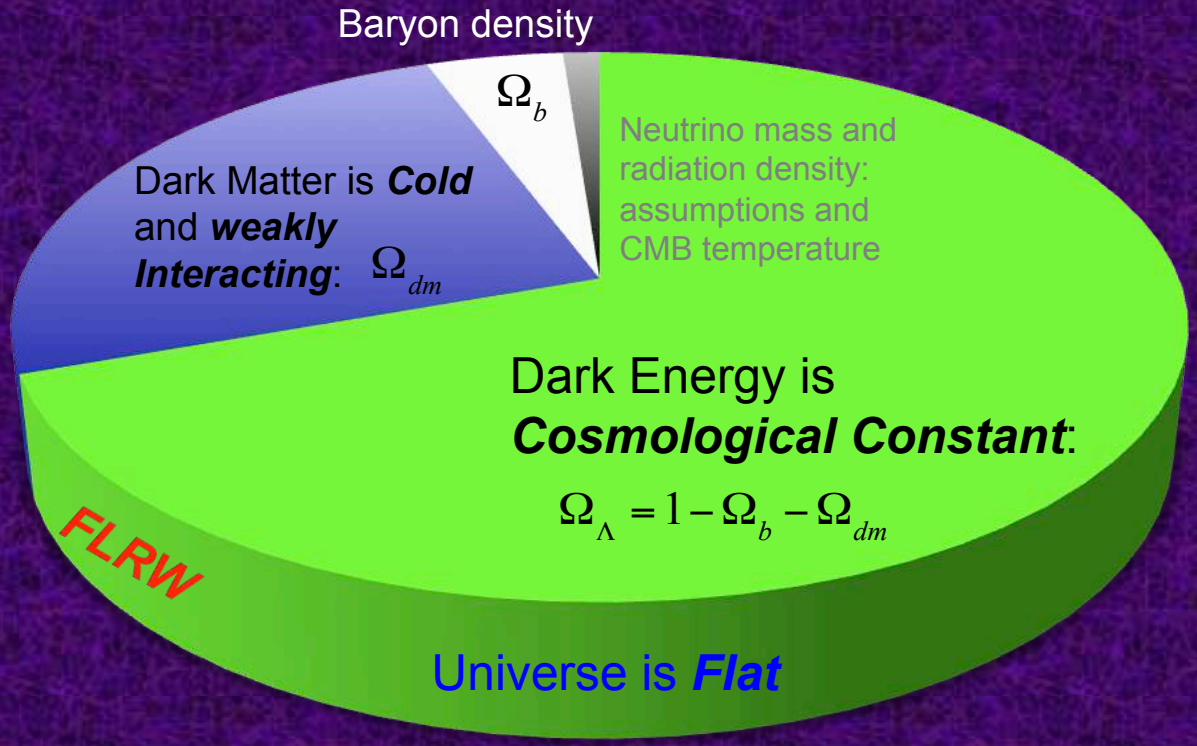
BOSS DR14Q



eBOSS collaboration: Zhao et al. MNRAS 2018

Standard Model of Cosmology

combination of *reasonable* assumptions, but…..



Initial Conditions:
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n_s, A_s

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Hubble Parameter and the Rate of Expansion

H_0

Beyond the Standard Model of Cosmology



- The universe might be more complicated than its current standard model (Vanilla Model).
- There might be some extensions to the standard model in defining the cosmological quantities.
- This needs proper investigation, using advanced statistical methods, high performance computational facilities and high quality observational data.

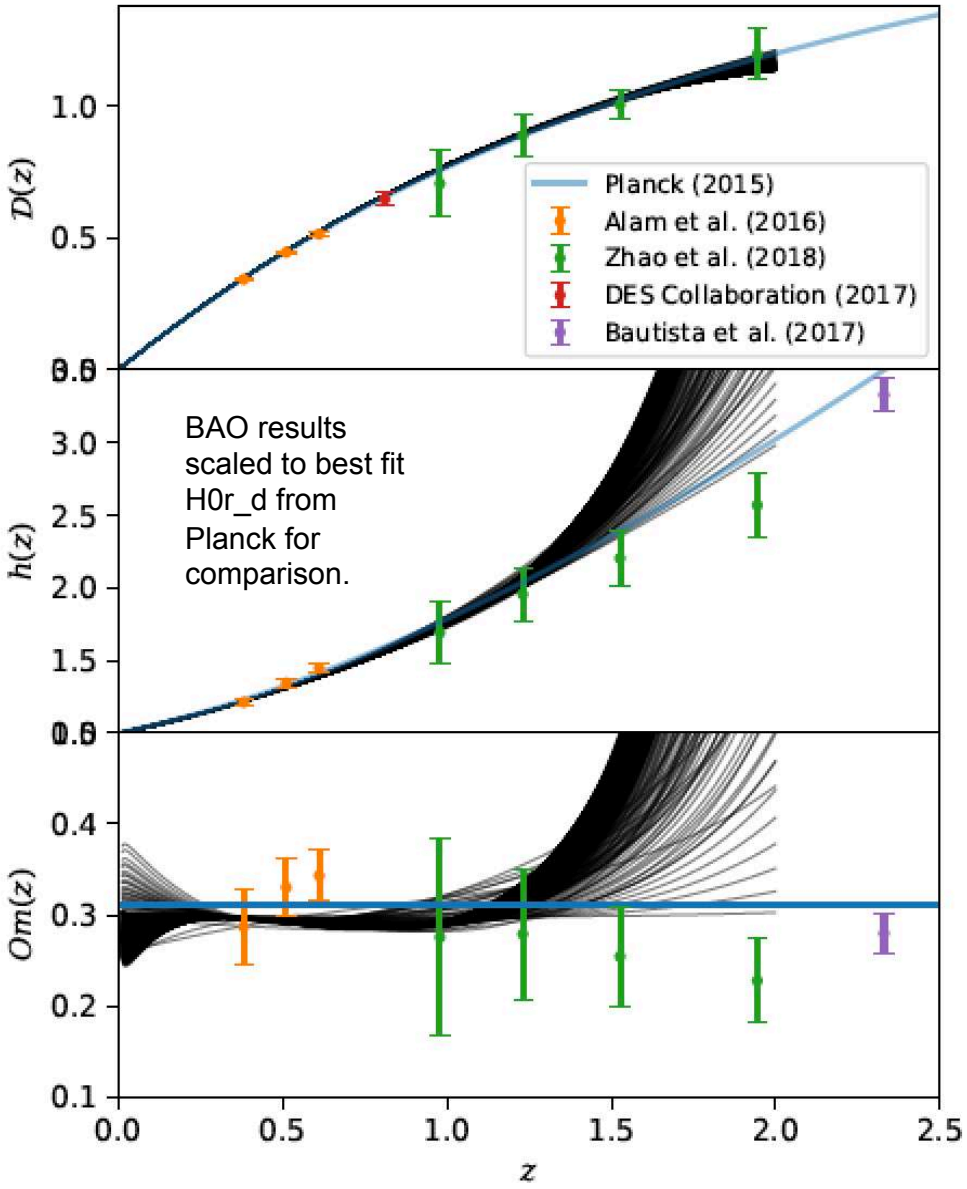
How to go Beyond the Standard Model of Cosmology?

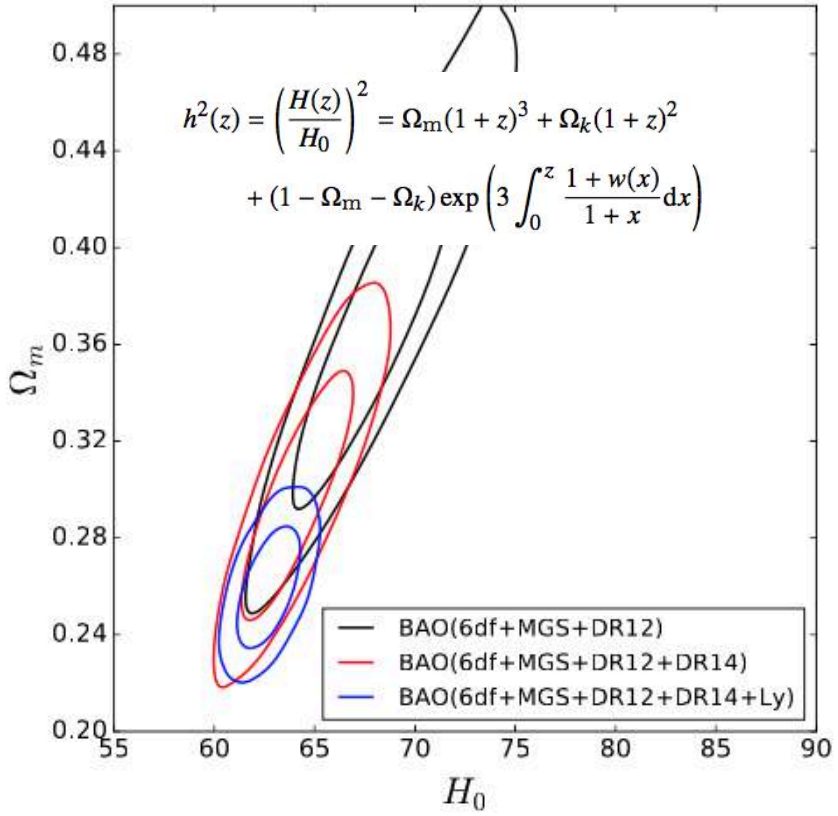


- Finding features/deviations in the data beyond the flexibility of the standard model using model-independent reconstructions.
- Falsifying the standard model using litmus tests.
- Introducing theoretical/phenomenological models that can explain the data better (statistically significant) than the standard model.
- Finding tension among different independent data assuming the standard model (making sure there is no systematic).

Implementing well cooked statistical approaches to get the most out of the data is essential!

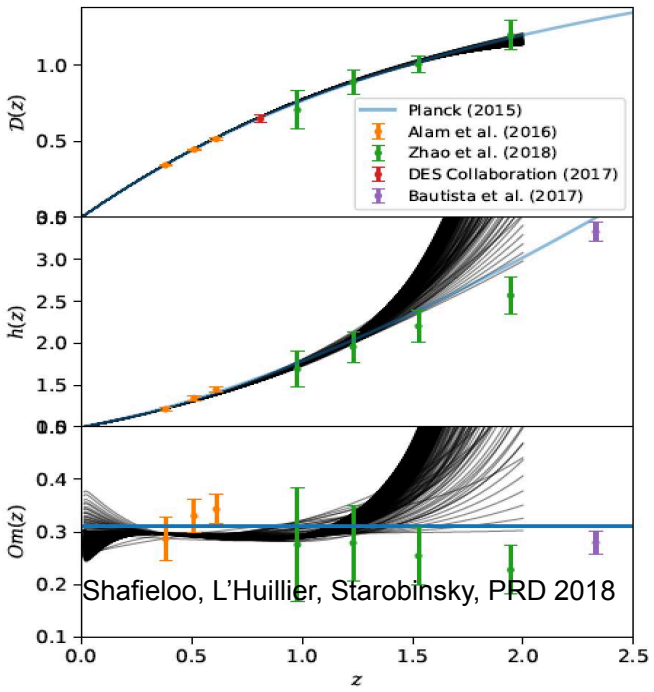
What is exactly going on?



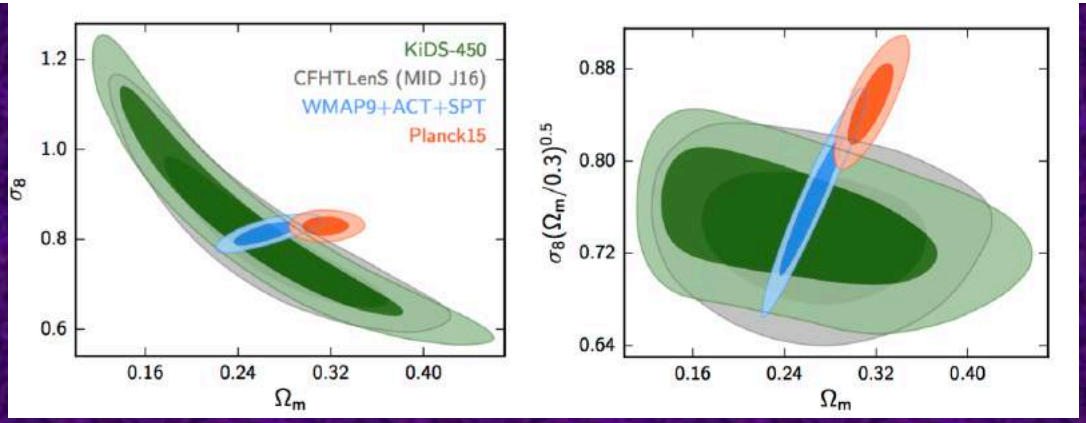


Shafieloo, L'Huillier, Starobinsky, PRD 2018

Li, Shafieloo, Sahni, Starobinsky, in prep

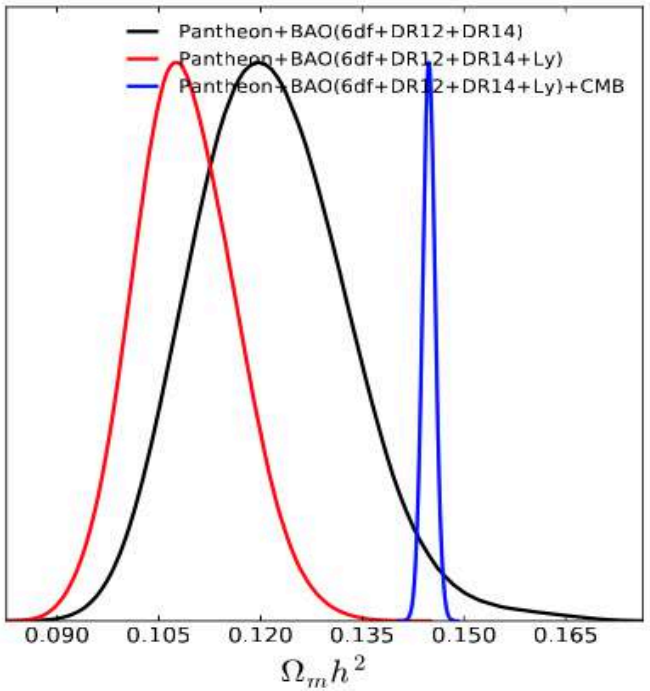


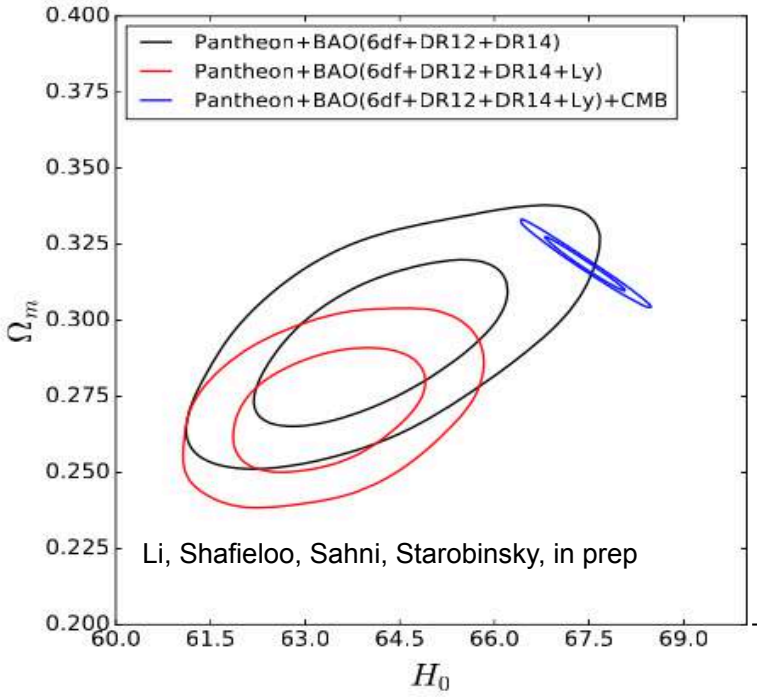
Shafieloo, L'Huillier, Starobinsky, PRD 2018



Hildebrandt et al, MNRAS 2017

It is not only about H0 and CMB. Low H(z)r_d is suggested by BAO and low matter density by WL.





Li, Shafieloo, Sahni, Starobinsky, in prep

Local H0 constraints

How to resolve the tensions?



Tensions may disappear by themselves if they are due to statistical fluctuations

- With popular pseudo-solutions: such as proposing models with more degrees of freedom (having more parameters) and get larger confidence contours which looks like there are better consistencies (more overlap between larger contours). [OK to do that but better to stop over-selling]

- Finding systematics in different data [Sinful Adam? Not to be confused with primordial sin]

- Touching any aspect of the concordance model, means going beyond the standard cosmology (which is great!) and its time to consider different possibilities:

➔ Current tensions seems to be persistent at the background level. So just touching GR (modified gravity models) cannot help.

➔ Evolving dark energy? Possible but not yet so easy to satisfy all observations.

➔ Neutrinos? As always they are a possibility (they may not be able to help much though)

➔ Early Universe and seeds of fluctuations? ***We can try!***

How to resolve the tensions?



Tensions may disappear by themselves if they are due

And, how about measuring H0 directly using the brand new gravitational sirens?

GR (modified gravity models) cannot help.

- ➔ Evolving dark energy? Possible but not yet so easy to satisfy all observations.
- ➔ Neutrinos? As always they are a possibility (they may not be able to help much though)
- ➔ Early Universe and seeds of fluctuations? ***We can try!***

Couple of months ago and in many conferences….

MENU

nature
International journal of science

Letter | Published: 17 October 2018

A two per cent Hubble constant measurement from standard sirens within five years

Hsin-Yu Chen ✉, Maya Fishbach & Daniel E. Holz

Nature **562**, 545–547 (2018) | Download Citation ↓

Abstract

Very Recently!

arXiv.org > astro-ph > arXiv:1901.01540

Search or Article ID | All fields

(Help | Advanced search)

Astrophysics > Cosmology and Nongalactic Astrophysics

First measurement of the Hubble constant from a dark standard siren using the Dark Energy Survey galaxies and the LIGO/Virgo binary-black-hole merger GW170814

The DES Collaboration, the LIGO Scientific Collaboration, the Virgo Collaboration: M. Soares-Santos, A. Palmese, W. Hartley, J. Annis, J. Garcia-Bellido, O. Lahav, Z. Doctor, H. Lin, M. Fishbach, M. E. S. Pereira, A. Garcia, K. Herner, R. Kessler, H. V. Peiris, M. Sako, S. Allam, D. Brout, A. Carnero Rosell, C. Conselice, J. deRose, J. deVicente, H. T. Diehl, M. S. S. Gill, J. Gschwend, I. Sevilla-Noarbe, D. L. Tucker, R. Wechsler, E. Berger, P. S. Cowperthwaite, B. D. Metzger, P. K. G. Williams, T. M. C. Abbott, F. B. Abdalla, S. Avila, K. Bechtol, E. Bertin, D. Brooks, E. Buckley-Geer, D. L. Burke, M. Carrasco Kind, J. Carretero, F. J. Castander, M. Crocce, C. E. Cunha, C. B. D'Andrea, L. N. da Costa, C. Davis, S. Desai, P. Doel, A. Drlica-Wagner, T. F. Eifler, A. E. Evrard, B. Flaugher, P. Fosalba, J. Frieman, E. Gaztanaga, D. W. Gerdes, D. Gruen, R. A. Gruendl, G. Gutierrez, D. L. Hollowood, B. Hoyle, D. J. James, T. Jeltema, K. Kuehn, N. Kuropatkin, T. S. Li, M. Lima, M. A. G. Maia, J. L. Marshall, F. Menanteau, R. Miquel, E. Neilsen, R. L. C. Ogando, A. A. Plazas, A. K. Romer, A. Roodman, E. Sanchez, V. Scarpine, R. Schindler, M. Schubnell, S. Serrano, M. Smith, R. C. Smith, F. Sobreira, E. Suchyta, M. E. C. Swanson, G. Tarle, R. C. Thomas, A. R. Walker, W. Wester, J. Zuntz, B. P. Abbott, R. Abbott, T. D. Abbott, S. Abraham, F. Acernese, K. Ackley et al. (1103 additional authors not shown)

(Submitted on 6 Jan 2019)

We present a multi-messenger measurement of the Hubble constant H_0 using the binary-black-hole merger GW170814 as a standard siren, combined with a photometric redshift catalog from the Dark Energy Survey (DES). The luminosity distance is obtained from the gravitational wave signal detected by the LIGO/Virgo Collaboration (LVC) on 2017 August 14, and the redshift information is provided by the DES Year 3 data. Black-hole mergers such as GW170814 are expected to lack bright electromagnetic emission to uniquely identify their host galaxies and build an object-by-object Hubble diagram. However, they are suitable for a statistical measurement, provided that a galaxy catalog of adequate depth and redshift completion is available. Here we present the first Hubble parameter measurement using a black-hole merger. Our analysis results in $H_0 = 75.2^{+39.5}_{-32.4}$ km s^{-1} Mpc^{-1}, which is consistent with both SN Ia and CMB measurements of the Hubble constant. The quoted 68% credible region comprises 60% of the uniform prior range [20,140] km s^{-1} Mpc^{-1}. This result shows that even a single dark siren can provide a constraint on the Hubble constant, albeit a weak one. Future combinations of many sirens will lead to improved constraints. A multifold increase in the LVC event detection rate is expected in the coming years, and this bodes well since future combinations of many additional sirens will lead to improved constraints.

Comments: 19 pages, 3 Figures, submitted to ApJL
Subjects: **Cosmology and Nongalactic Astrophysics (astro-ph.CO)**
Report number: FERMILAB-PUB-18-629-AE
Cite as: arXiv:1901.01540 **[astro-ph.CO]**
(or arXiv:1901.01540v1 **[astro-ph.CO]** for this version)

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Google Scholar

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Problem is that they assume a cosmological model and even fix its other parameters! That's how precision is coming from.

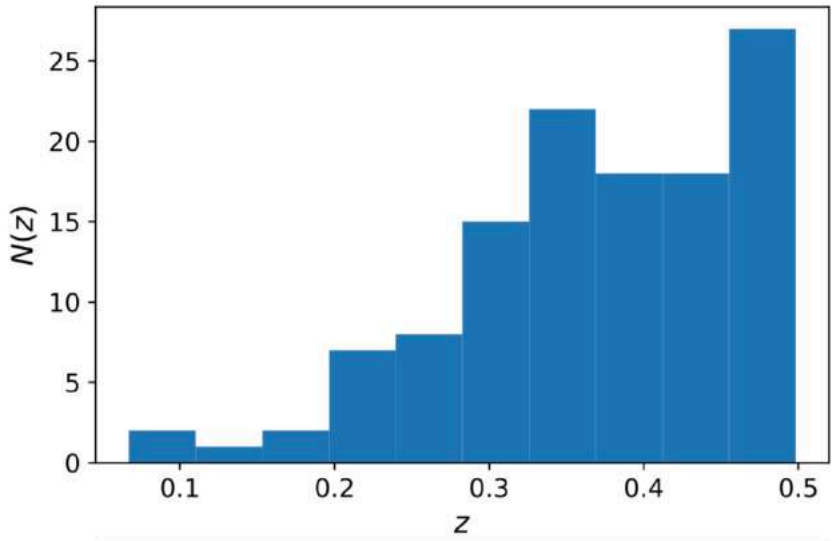
$$D_L(z) = (1+z)\frac{c}{H_0}\int_0^z \frac{dz'}{h(z')},$$

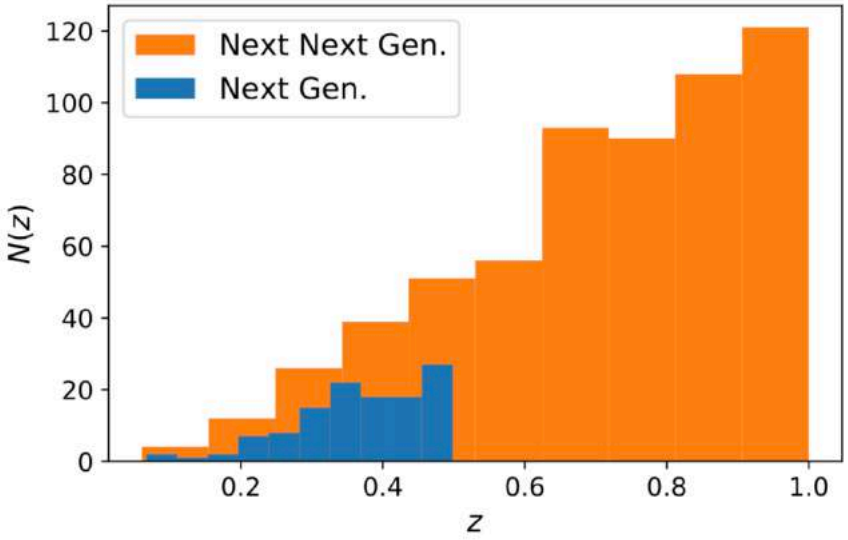
$$h^2(z) = \Omega_{\rm m}(1+z)^3 + 1 - \Omega_{\rm m}.$$

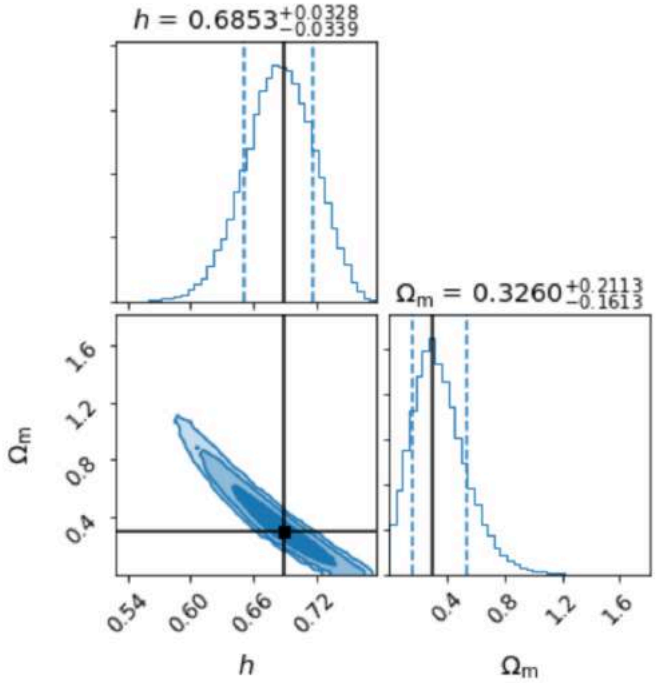
GW events of different kinds with electromagnetic counterpart

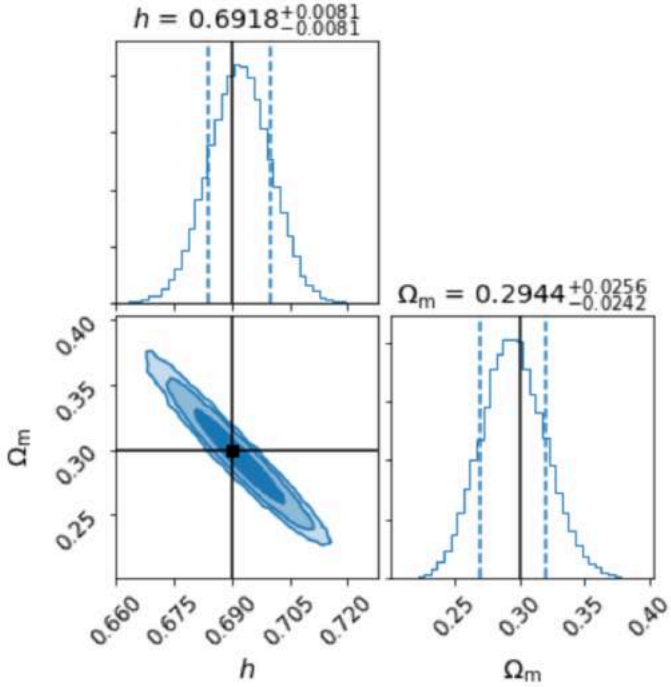
$$N(z) = \frac{dN}{dz} = \frac{dN}{dV_c}\frac{dV_c}{dz},$$

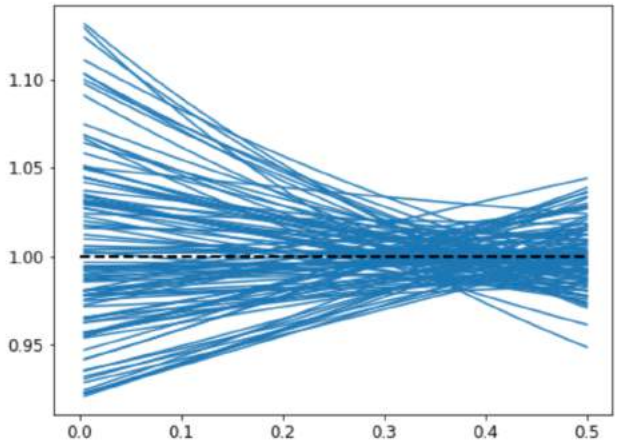
Shafieloo, Keeley, Linder, arXiv:1812.07775





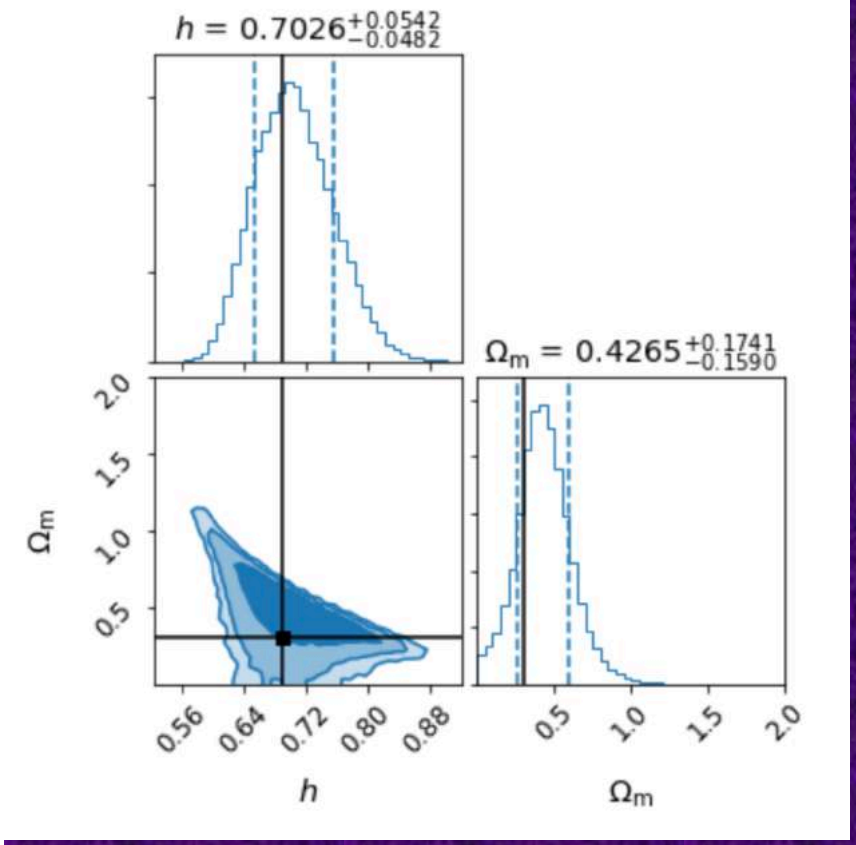


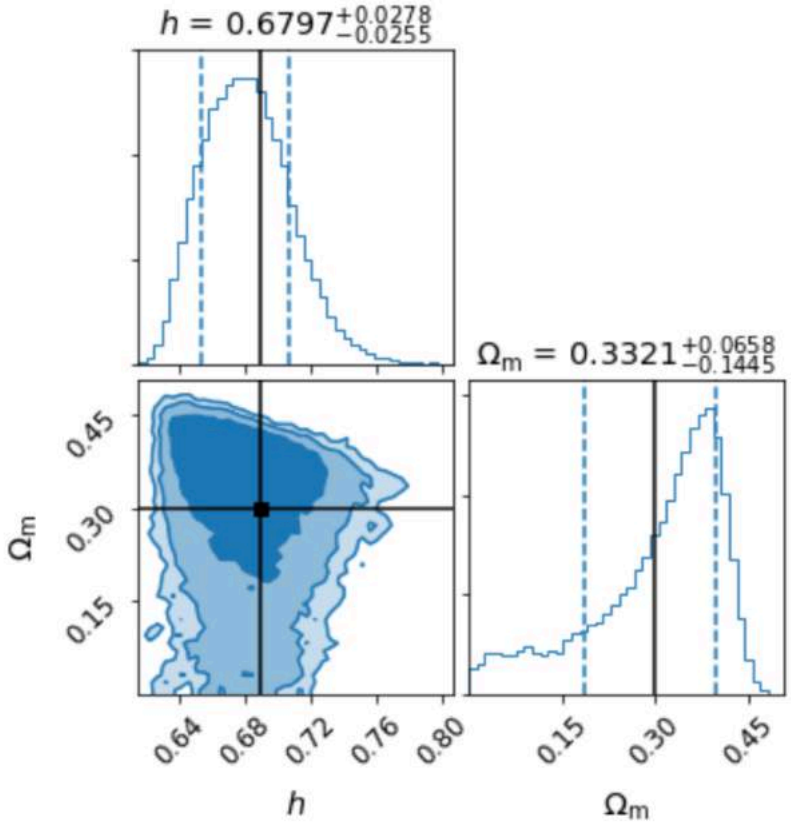




Just varying matter density precision drops substantially

Shafieloo, Keeley, Linder, arXiv:1812.07775



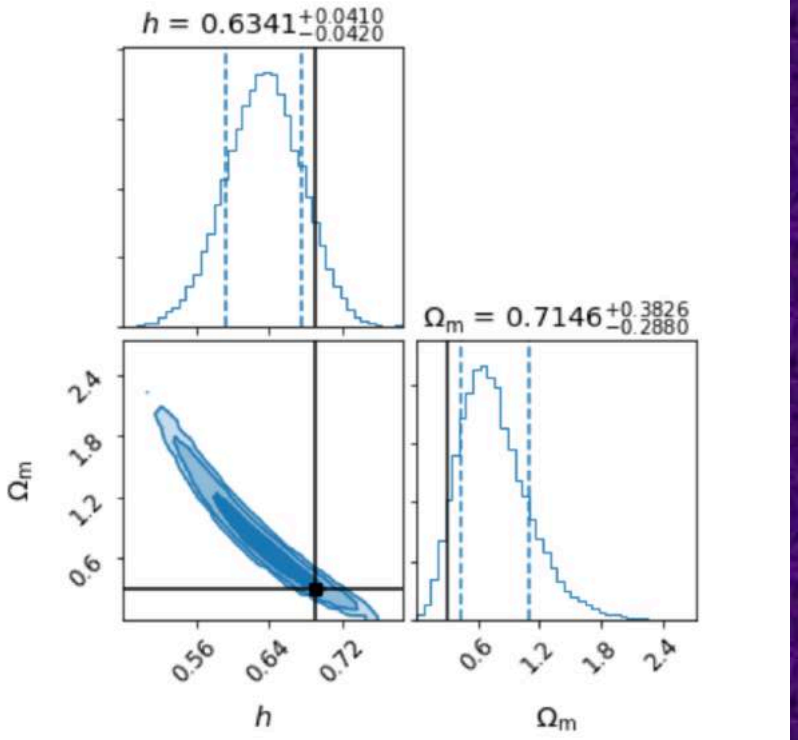


Shafieloo, Keeley, Linder, arXiv:1812.07775

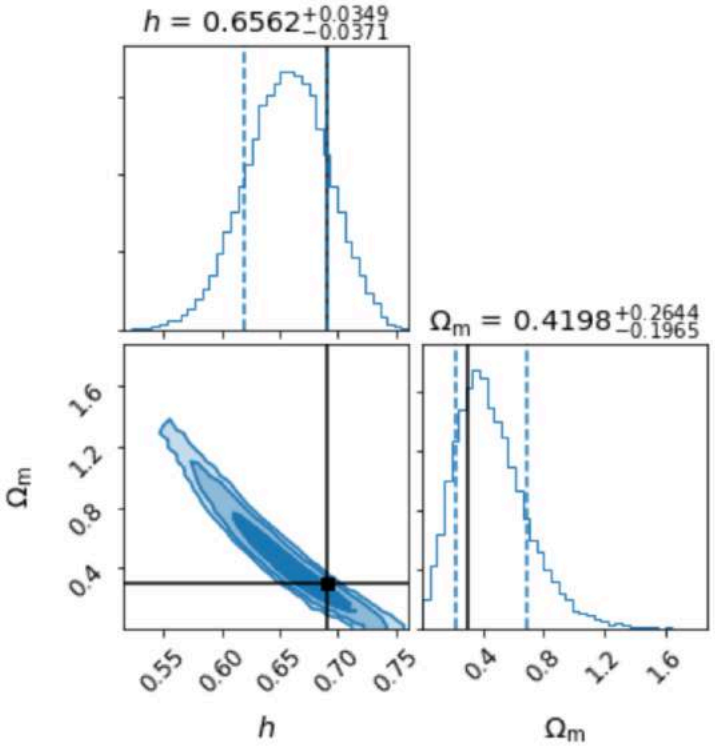
Background	Prior	$\sigma(h)$	$\sigma(h)/h$
ΛCDM	none	0.036	5%
ΛCDM	$\sigma(\Omega_m) = 0.03$	0.010	1.4%
ΛCDM	fix Ω_m	0.0083	1.2%
w_0–w_a*	none	0.039	6%
w_0–w_a*	$\sigma(\Omega_m) = 0.03$	0.039	6%
w_0–w_a*	fix Ω_m	0.039	6%

Varying matter density and allowing evolving DE, make things absolutely a mess…..

There is NO precision!



Adorable BIAS!



What if the assumed model is wrong?!

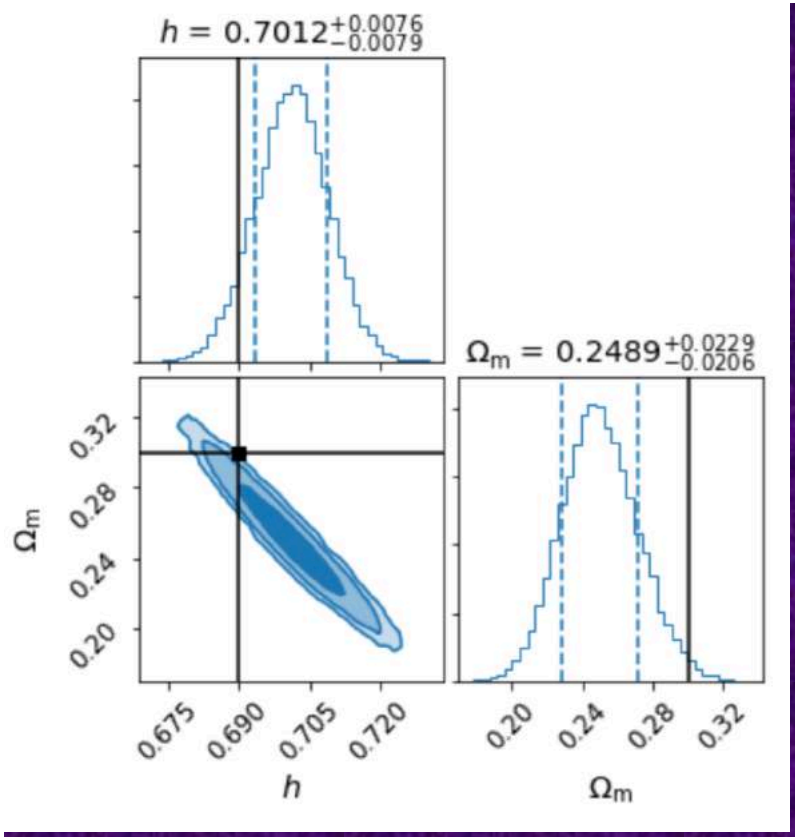
$(w_0, w_a) = (-0.90, -0.75)$

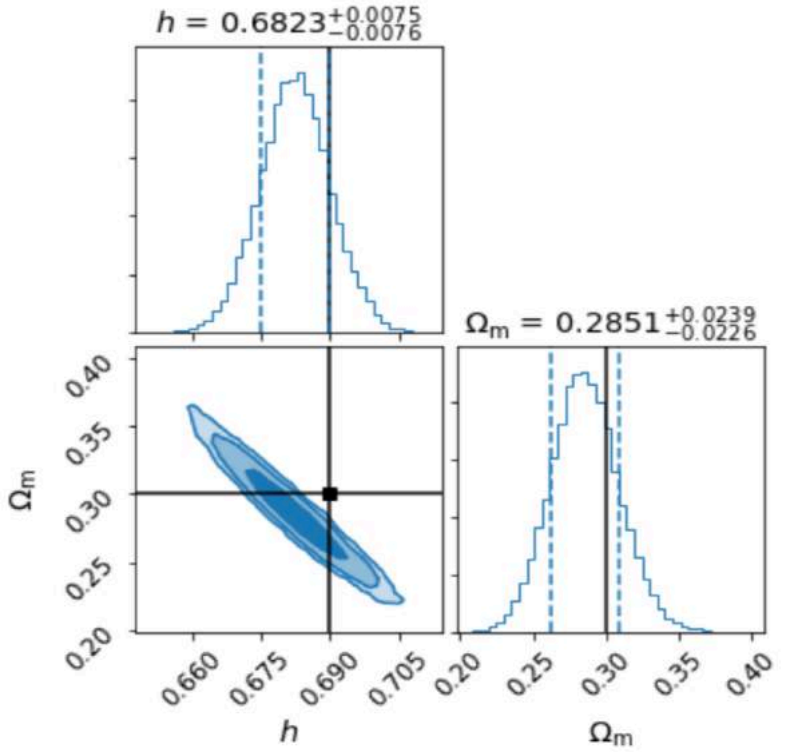
$\Omega_m = 0.3,\ h = 0.69$

$(w_0, w_a) = (-1.14, 0.35)$

$\Omega_m = 0.3,\ h = 0.69$

Shafieloo, Keeley, Linder, arXiv:1812.07775





Wrong model assumption: Bias increases by having better quality of the data!

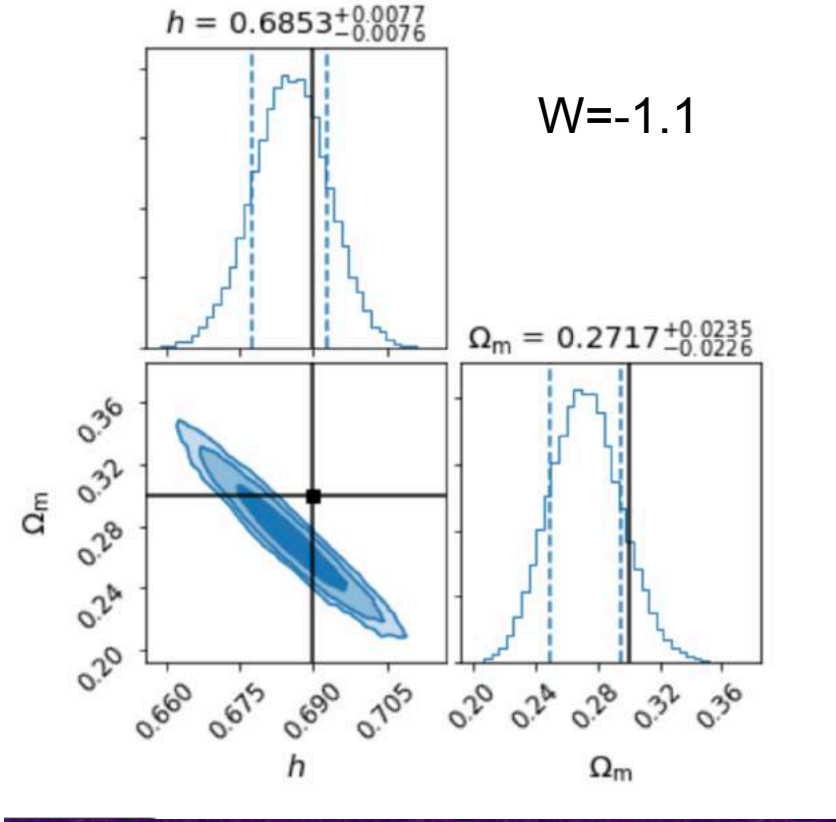
$(w_0, w_a) = (-0.90, -0.75)$

$\Omega_m = 0.3,\ h = 0.69$

$(w_0, w_a) = (-1.14, 0.35)$

$\Omega_m = 0.3,\ h = 0.69$

Shafieloo, Keeley, Linder, arXiv:1812.07775



W=-1.1

Even for a simple case of w=-1.1 things would be a mess.

Conclusion (1):

- Cosmic gravitational sources CANNOT estimate Hubble constant independently with any high precision.
- Precision drops as soon as we vary the parameters.
- Bias can be introduced by any model assumption.
  Things get worse by having better data!
- Or, we need many many NS-NS binary sources at very low redshifts ($z<0.05\sim0.1$).

How to resolve the tensions?



Tensions may disappear by themselves if they are due to statistical fluctuations

- With popular pseudo-solutions: such as proposing models with more degrees of freedom (having more parameters) and get larger confidence contours which looks like there are better consistencies (more overlap between larger contours). [OK to do that but better to stop over-selling]

- Finding systematics in different data [Sinful Adam? Not to be confused with primordial sin]

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➔ Neutrinos? As always they are a possibility (they may not be able to help much though)

➔ Early Universe and seeds of fluctuations? ***We can try!***

Lets play!

- Lets keep omega_CDM and omega_b equal to their best fit flat LCDM values from Planck : $\omega_{\rm CDM} = \Omega_{\rm CDM} h^2$ $\omega_{\rm b} = \Omega_{\rm b} h^2$

Why?: Height and dept of the CMB angular power spectrum acoustic peaks will remain the same and hence minimal changes at large CMB scales

- Lets assume H0=73.48 and consequently Omega_m=0.259.

Why?: This automatically satisfies local H0 observations and weak lensing constraints by having large H0 and low matter density. It may help BAO as well.

- Task is now to find a form of Primordial Power Spectrum that by having a kernel with above background parameters can result to exactly the same form of the angular power spectrum as given by the best fit Flat LCDM Planck model (No data involved).

Why?: To explore the possibility, looking for possible systematics, theoretical implications .

How?: We use the MRL deconvolution algorithm we developed over the years for the purpose of reconstruction.

Direct Reconstruction of the Primordial Spectrum

Modified Richardson-Lucy Deconvolution

➔Iterative algorithm.
➔Not sensitive to the initial guess.
➔Enforce positivity of P(k).
[$G(l,k)$ is positive definite and C_l is positive]

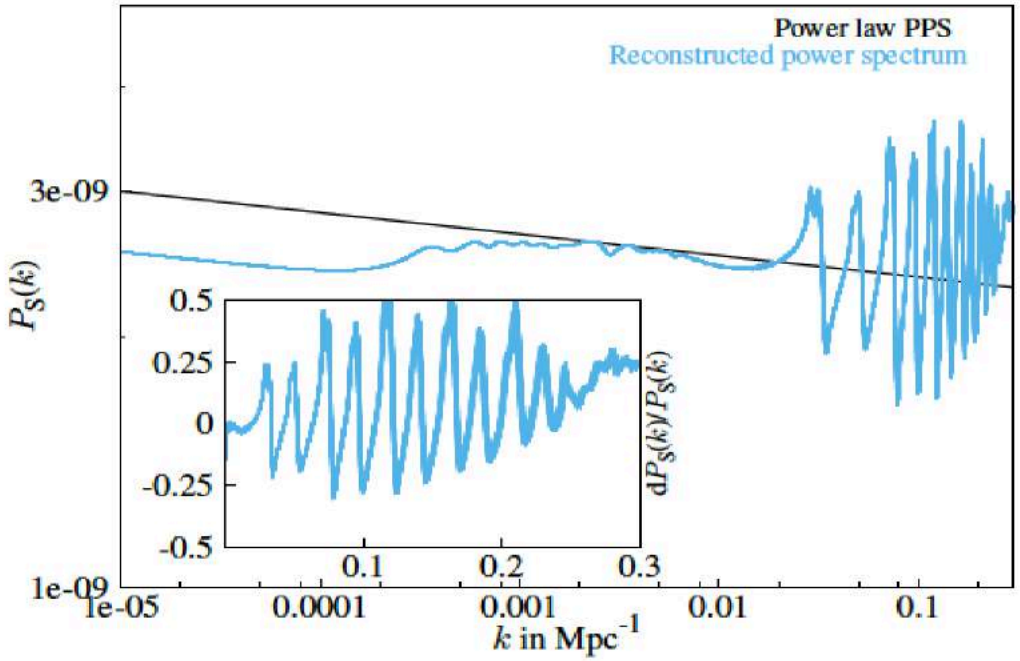
$$C_\ell = \sum_i G_{\ell k_i} P_{k_i}$$

$$P_k^{(i+1)} - P_k^{(i)} = P_k^{(i)} \times \left[\sum_{\ell=2}^{\ell=900} \tilde{G}_{\ell k}^{\rm un-binned} \left\{ \left(\frac{C_\ell^{\rm D} - C_\ell^{\rm T(i)}}{C_\ell^{\rm T(i)}} \right) \tanh^2 \left[Q_\ell (C_\ell^{\rm D} - C_\ell^{\rm T(i)}) \right] \right\}_{\rm un-binned} + \sum_{\ell_{\rm binned}>900} \tilde{G}_{\ell k}^{\rm binned} \left\{ \left(\frac{C_\ell^{\rm D} - C_\ell^{\rm T(i)}}{C_\ell^{\rm T(i)}} \right) \tanh^2 \left[\frac{C_\ell^{\rm D} - C_\ell^{\rm T(i)}}{\sigma_\ell^{\rm D}} \right]^2 \right\}_{\rm binned} \right], \quad (1)$$

$$Q_\ell = \sum_{\ell'} (C_{\ell'}^{\rm D} - C_{\ell'}^{\rm T(i)}) COV^{-1}(\ell, \ell'),$$

Shafieloo & Souradeep PRD 2004 ;
Shafieloo et al, PRD 2007;
Shafieloo & Souradeep, PRD 2008;
Nicholson & Contaldi JCAP 2009
Hamann, Shafieloo & Souradeep JCAP 2010
Hazra, Shafieloo & Souradeep PRD 2013
Hazra, Shafieloo & Souradeep JCAP 2013
Hazra, Shafieloo & Souradeep JCAP 2014
Hazra, Shafieloo & Souradeep JCAP 2015

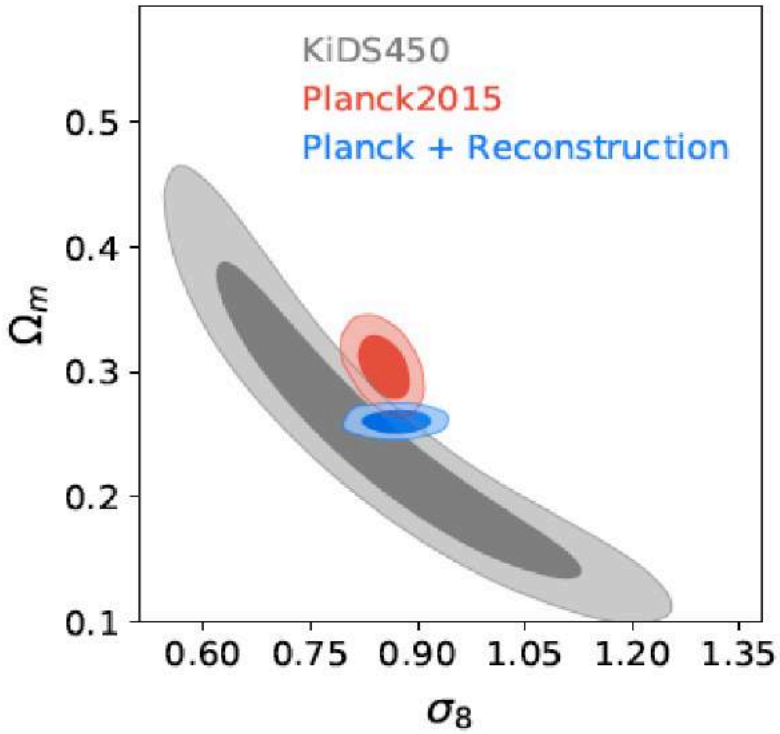
Hazra, Shafieloo, Souradeep, arXiv:1810.08110

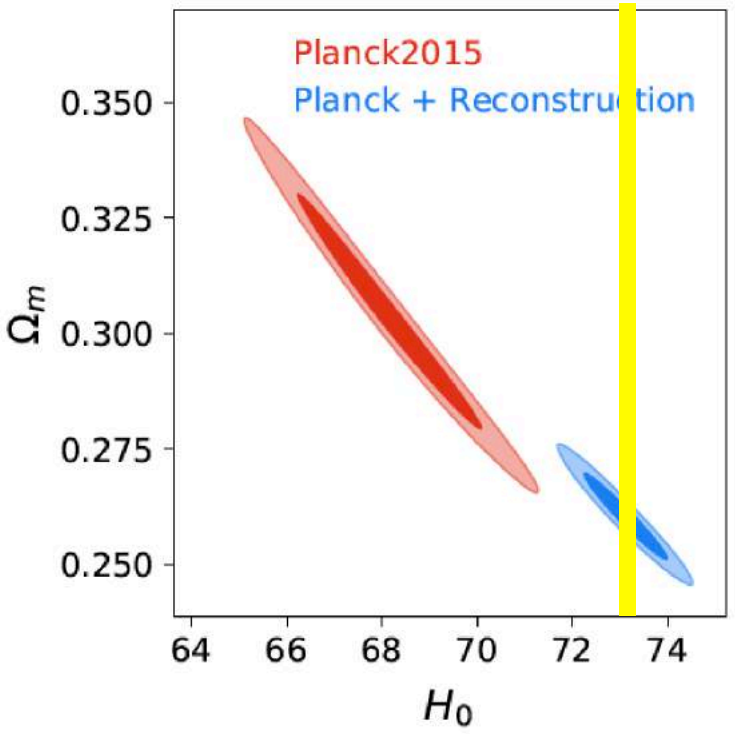


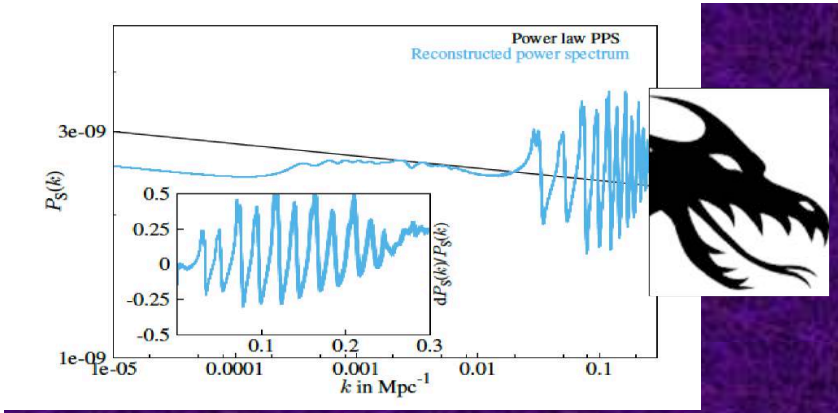
Hazra, Shafieloo, Souradeep, arXiv:1810.08110

It Is POSSIBLE!

We use the reconstructed PPS for parameter estimation, similar to what we do with PL.







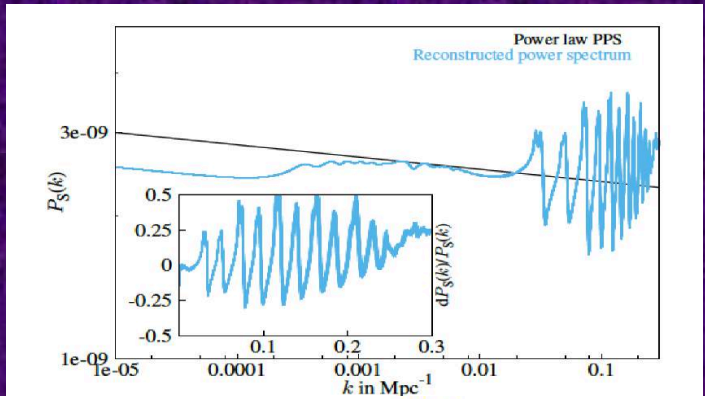
Issues:

1. it appears to be unnatural to generate the complex form of the reconstructed PPS within an inflationary scenario without extreme fine tuning. However, we do not provide any conclusive reason to close the possibility of a physical early Universe explanation.
2. Using polarization data it should be possible to validate further the possibility of the reconstructed form of the PPS. Likewise, using polarization data we might be able to look for a more optimized form of the PPS to remove tensions from different observations.
3. A wider exploration of the underlying parameter space of the cosmological model would be essential to reveal potential routes to ameliorate the disagreements in cosmological parameters inferred.
4. Need for a comprehensive iterative approach to derive observational constraints and confront vs theoretical/phenomenological models.
5. Lensing templates! Are they reliable?

Issues:

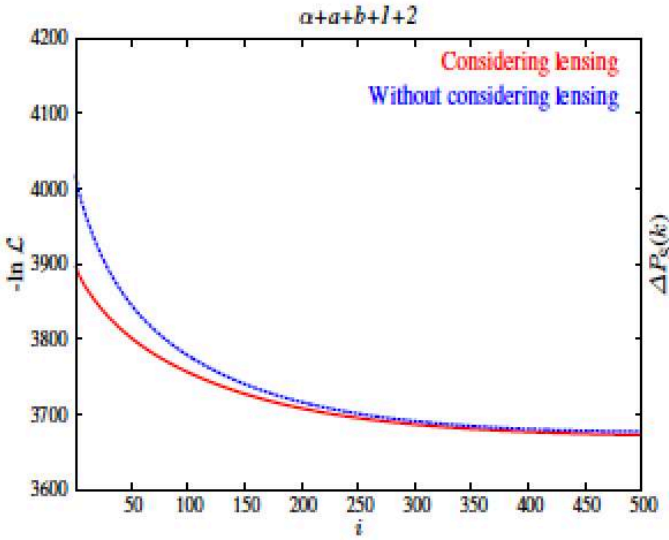
5. The features at high k values are very similar to the features we reconstructed previously when we did not consider CMB lensing (trying to project the effect on the form of the PPS). Can lensing templates play a key role?

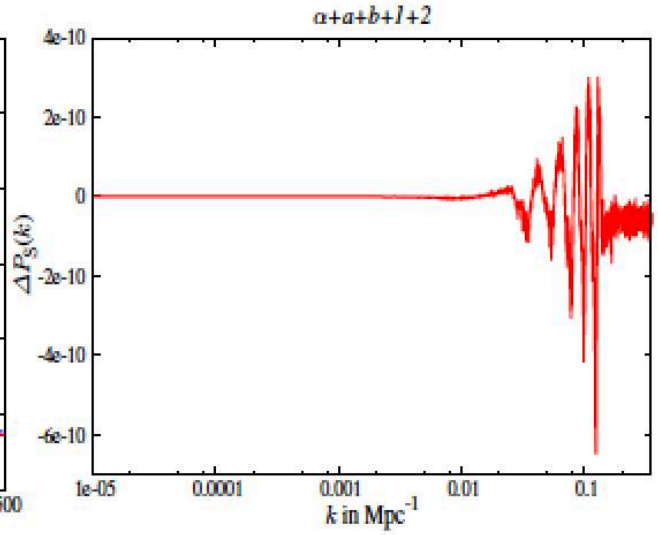
Also see: Kable, Addison, Bennett, arXiv:1809.03983

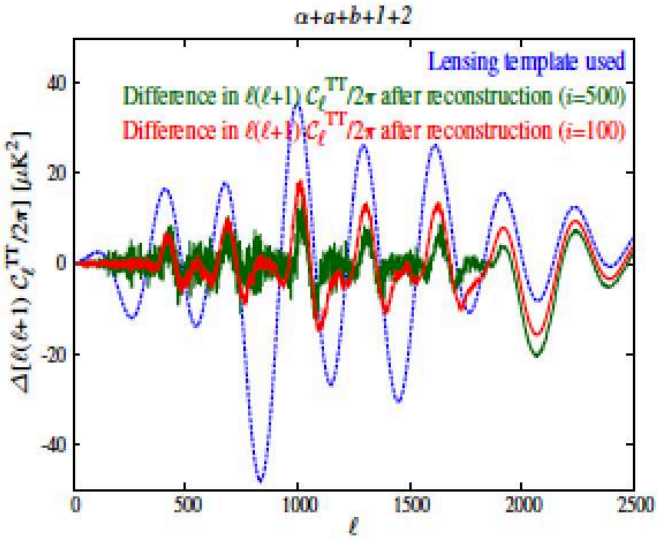


Hazra, Shafieloo, Souradeep, arXiv:1810.08110

Hazra, Shafieloo, Souradeep, JCAP 2014







Conclusion (2)

- The current standard model of cosmology seems to work fine but this does not mean all the other models are wrong.
- ***Combination of different cosmological data hints towards some tension with LCDM model. If future data continues the current trend, we may have some exciting times ahead!***
- ***It is possible to put all the blame on PPS but we need suitable EU scenario to explain reconstructed features.***
- ***High multiple CMB lensing: Suspicious (no strong claim though, yet!)***
- First target can be testing different aspects of the standard 'Vanilla' model. If it is not '*Lambda*' dark energy or power-law primordial spectrum then we can look further. It is possible to focus the power of the data for the purpose of the falsification. Next generation of astronomical/ cosmological observations, (DESI, Euclid, SKA, LSST, WFIRST etc) will make it clear about the status of the concordance model.