The Milky Way Panorama   Credit: ESO / S. Brunier

Newsletter of A Cosmology Group - September 2018

A Cosmology Group draws its mandate from the *Open Letter to the Scientific Community* to engage scientists in an open exchange of ideas beyond the mainstream framework of the Big Bang cosmology. The *ACG Newsletter* seeks to highlight published observational results which seem anomalous in terms of the ΛCDM model.

Critical examinations of the scientific methods and investigations used in cosmology are also the subject of the *Newsletter*, as long as these are supported by empirical data. Purely theoretical work and new cosmologies not yet supported by observations are deferred to future discussions at the next ACG Conference.

If you would like to suggest a paper for review, please send a direct reference to `redshift@cosmology.info`. Published work in a refereed journal and with open access (e.g. a preprint on `arXiv` or `HAL`) is preferred.

The *Newsletter* is published irregularly, editor's schedule permitting, and when interesting papers are available. ACG subscribers[1] receive notifications of *Newsletter* publications. You can subscribe to *ACG Notifications* either by sending a request to `redshift@cosmology.info`, by joining the ACG Forum 'Alt Cosmology' on *Yahoo! Groups* at `groups.yahoo.com/neo/groups/altcosmology/info#`, or by following `@CosmologyGroup` on Twitter.

ACG Editorial

What is happening with 21st-century physics? The predictive power of our science seems to be eroding away!

We think we understand the proton very well but its radius, as obtained from muonic hydrogen spectroscopy, is about 4% smaller than that derived from the Lamb shift in hydrogen! The resolution of the *proton radius puzzle* has been attempted in many different ways over the past eight years but a solution remains elusive. By reducing the measurement uncertainty even more, the disagreement has worsened to over 7σ.

How about the Hubble constant? A discrepancy appeared with the first high accuracy measurements of the most fundamental parameter of cosmology. The analysis from Planck gives 66.9 ± 0.6 km/s/Mpc, at tension with the cosmic-distance ladder which gives $H_0 = 73.5 \pm 1.6$ km/s/Mpc. The 9% difference is at a level of 3.8σ, enough to warrant a special "Crisis in Cosmology" session at the 2018 APS April meeting.

As with the *proton radius puzzle*, the H_0 *tension* arises from using two different measurement methods bridged with a physical model. Measurements are now so accurate that there is almost no doubt about their validity. The interpretation of these measurements could be at fault, but it is most likely that the model itself is inaccurate.

Amongst the multitude of explanations and hypotheses proposed to resolve the H_0 *tension*, we find:
- systematic uncertainties in CMB radiation measurements, weak lensing, or large angle CMB polarization,
- two-point diagnostics lacking the desired statistical properties, or a variance in local measurements,
- resolve by varying simultaneously 12 cosmological parameters instead of the usual 6,
- use a non-parametric reconstruction of the relation between the cosmological redshift and cosmic scale factor,
- consider massive sterile neutrinos, or a different number of neutrinos,
- explore a scenario with a new exotic energy density,

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[1]The ACG counts 57 subscribers to *ACG Notifications*, and 52 followers on *Alt Cosmology Yahoo! Group* and *Twitter*.

- modify the parameters of braneworld models,
- consider spherically symmetric mini-universes with their own cosmological parameters,
- use a void cosmology with the inhomogeneous Lemaître-Tolman-Bondi solution of Einstein's field equations,
- use a nonlocal metric-based realization of MOND, or a vacuum phase transition,
- add a parameter for time varying dark energy (e.g. $w(z) = w_0 + w_a \, z/(1+z)$),
- consider hidden charged dark matter,
- dark sector model: dark matter interacts with fermionic dark radiation through a light gauge boson (dark photon),
- a novel model in which vector dark matter and dark radiation originate from the same non-Abelian dark sector. So far, reducing measurement uncertainties have only increased the gap between the two values. Clearly, we are still in the dark (no pun intended) about the value of H_0.

A bit of epistemology here: My reason for presenting this long list of ideas is to *highlight the large number* of available hypotheses. Each one tries to generate a set of parameters that fits observational data and is consistent with the current cosmology. Because there is such a large number of hypotheses to choose from, the best one is likely to fit data within $< 1\sigma$, *not because it is correct but by statistical chance arising from the large number of attempts*. This best hypothesis will eventually become a model and will be part of the new standard cosmology.

Since H_0 is a fundamental property of any cosmology, it is important for ACG to discuss its interpretation. Two radically different interpretations of H_0 arise from an expanding cosmology and a static cosmology. In an expanding universe we start from $H(t) \equiv \dot{a}(t)/a(t)$, expressing the normalized rate of change of the scale factor. Then, simply, $H_0 \equiv H(\text{today})$. In a static cosmology, H_0 is a proportionality constant involved in the redshift-distance relationship arising from a physical effect which is not expansion. H_0 is the same at all times.

For the static cosmologist, the H_0 *tension* is not surprising since the Planck estimate is completely unrelated to the redshift-distance relationship. Models such as baryonic acoustic oscillations, decoupling from an a opaque universe, and evolution with redshift have no meaning in a static cosmology. We might then wonder how can the Planck collaboration obtain a value that is close to $H_0 = 73.5 \pm 1.6 \, \text{km/s/Mpc}$? The answer comes from the large number of hypotheses that have been made available to build the ΛCDM model. As explained above, a selection process favoured a few models (baryonic oscillations, acoustic horizon, decoupling, etc.) over several other hypotheses because of their close agreement with a redshift-distance relationship measured with the *model-independent* cosmic-distance ladder. The value given by Planck & ΛCDM may only be serendipitous.

Based on these considerations, it will be interesting to see how the *'tension'* and the *'puzzle'* are resolved.

Louis Marmet, September 24, 2018
redshift@cosmology.info

Reviewed Publications

Most of the text given here is quoted and adapted from the original articles.
My emphasis in italics and `comments in typewriter`.

"**Hubble Trouble: A Crisis in Cosmology?**"
S. Chen, APS NEWS, Vol. 27, No. 5, May 2018
2018: https://www.aps.org/publications/apsnews/201805/hubble.cfm

Applying the standard model of cosmology – the Lambda Cold Dark Matter (ΛCDM) model – researchers used the CMB map to calculate the Hubble constant [...] But that number disagreed with calculations based on telescope observations of supernovae and pulsating stars. [...]

Unfortunately, no one knows where the discrepancies come from. [...] It's *"tempting,"* says Stephen Feeney of the Flatiron Institute, *to think that some part of the standard model of cosmology is wrong.*   (!)

"**Dark matter component decaying after recombination: lensing constraints with Planck data**"
A. Chudaykin, D. Gorbunov, I. Tkachev, Phys. Rev. D 94, 023528 (2016)
2016: https://journals.aps.org/prd/abstract/10.1103/PhysRevD.94.023528
See also: arXiv:1602.08121

It has been recently suggested that emerging tension between cosmological parameter values derived in high-redshift (CMB anisotropy) and low-redshift (cluster counts, Hubble constant) measurements can be reconciled in a model which contains a subdominant fraction of dark matter decaying after recombination. [...] the Decaying Dark Matter model [...] exhibits better fit (by $1.5 - 3\sigma$ depending on the lensing priors) compared to that of the concordance ΛCDM cosmological model.
`Doing this adds one more parameter to the standard cosmology.`

"**A 2.4% determination of the local value of the Hubble constant**"
A.G. Riess *et al.*, The Astrophysical Journal, Vol. 826, No. 1, 2016
2016: http://iopscience.iop.org/article/10.3847/0004-637X/826/1/56/meta
See also: arXiv:1604.01424

Our best estimate of $H_0 = 73.24 \pm 1.74$ km/s/Mpc [...] is 3.4σ higher than predicted by ΛCDM with 3 neutrino flavors having a mass of 0.06 eV and the new Planck data [...] systematic uncertainties in CMB radiation measurements may play a role in the tension. [...] one plausible explanation could involve an additional source of dark radiation in the early universe in the range of $\Delta N_{eff} \approx 0.4 - 1$.
`Riess at al. are confident about their results. One more parameter must be added the standard`
`cosmology.`

"**Reconciling Planck with the local value of H_0 in extended parameter space**"
E. Di Valentino *et al.*, Physics Letters B, Vol. 761, p. 242, 2016
2016: https://doi.org/10.1016/j.physletb.2016.08.043
See also: arXiv:1606.00634 and hal-01470237

We perform a combined analysis of the Planck and Riess results in an extended parameter space, varying simultaneously 12 cosmological parameters instead of the usual 6. We find that a phantom-like dark energy component, with effective equation of state $w = -1.2$ can solve the current tension [...] in an extended ΛCDM scenario. [...] However, when BAO measurements are included we find that some of the tension with Riess remains, as also is the case when we include the supernova type Ia luminosity distances from the JLA catalog.
`Phantom dark energy with` $w < -1$ `is disfavoured by many tests.`

"**Elucidating ΛCDM: Impact of Baryon Acoustic Oscillation Measurements on the Hubble Constant Discrepancy**"
G.E. Addison *et al.*, The Astrophysical Journal, Vol. 853, No. 2, 2018
2018: http://stacks.iop.org/0004-637X/853/i=2/a=119
See also: arXiv:1707.06547

`This seems like a good observational investigation of the problem by using combinations of`
`various datasets.`
We examine the impact of baryon acoustic oscillation (BAO) scale measurements on the discrepancy between the value of the Hubble constant (H_0) inferred from the local distance ladder and that from Planck cosmic microwave background (CMB) data. While the BAO data alone cannot constrain H_0, we show that combining the latest BAO results with WMAP, Atacama Cosmology Telescope, or South Pole Telescope CMB data produces values of H_0 that are 2.4–3.1σ lower than the distance ladder, independent of Planck, and that this downward pull was less apparent in some earlier analyses that used only angle-averaged BAO scale constraints rather than full anisotropic

information. At the same time, the combination of BAO and CMB data also disfavors the lower values of H_0 preferred by the Planck high-multipole temperature power spectrum. Combining galaxy and Lyα forest BAO with a precise estimate of the primordial deuterium abundance produces $H_0 = 66.98 \pm 1.18$ km/s/Mpc for the flat ΛCDM model. This value is completely independent of CMB anisotropy constraints and is 3.0σ lower than the latest distance ladder constraint, although 2.4σ tension also exists between the galaxy BAO and Lyα BAO. *These results show that it is not possible to explain the H_0 disagreement solely with a systematic error specific to the Planck data. The fact that tensions remain even after the removal of any single data set makes this intriguing puzzle all the more challenging to resolve.*

"Tight H_0 constraint from galaxy redshfit surveys: combining baryon acoustic osillation measurements and Alcock-Paczynski test"

Xue Zhang, Qing-Guo Huang, Xiao-Dong Li, arxiv:1801.07403, 2018

We report a tight Hubble constant constraint $67.78^{+1.21}_{-1.86}$ km/s/Mpc derived from galaxy redshift surveys. We combine the BAO measurements from 6dFGS, the SDSS DR7 main galaxies, the BOSS DR12 galaxies, and eBOSS DR14 quasars, and also apply the tomographic Alcock-Paczynski (AP) method to the BOSS DR12 galaxies, to place constraints on H_0 in the spatially flat ΛCDM framework. Our result is fully consistent with the CMB constraints from Planck, but in 2.58σ tension with local measurements of Riess et al. 2016. Compared with the BAO alone constraint, the BAO+AP combined result reduces the error bar by 32%. This shows the strong power of the tomographic AP method in extracting cosmological information from galaxy redshift surveys.

`It is interesting that the tomographic Alcock-Paczynski method yields the lower value of ` H_0`.`

"A More Accurate and Competitive Estimative of H_0 in Intermediate Redshifts"

G.P. da Silva, A.G. Cavalcanti, Brazilian Journal of Physics, Vol. 48, Issue 5, p. 521, 2018
2018: https://doi.org/10.1007/s13538-018-0581-9
See also: arXiv:1805.06849

In order to clarify the tension between estimates of the Hubble Constant (H_0) from local ($z \ll 1$) and global ($z \gg 1$) measurements, Lima and Cunha (LC) proposed a new method to measure H_0 in intermediate redshifts ($z \approx 1$), which were obtained $H_0 = 74.1 \pm 2.2$ km/s/Mpc (1σ), in full agreement to local measurements via Supernovae/Cepheid dataset. However, Holanda et al. affirm that a better understanding of the morphology of galaxy clusters in LC framework is needed to a more robust and accurate determination of H_0. [...] We found that the exclusion of the sample of galaxy clusters from the determination initially proposed by LC leads to significantly different results. We performed a new determination where we obtained $H_0 = 68.0 \pm 2.2$ km/s/Mpc (1σ) with statistical and systematic errors. Contrary to those obtained by LC, these values are in full harmony with the global measurements via Cosmic Microwave Background (CMB) radiation and to the other recent estimates of H_0 in intermediate redshifts.

`Their 'more accurate' estimate doesn't seem to be very robust to sample selection.`

"Milky Way Cepheid Standards for Measuring Cosmic Distances and Application to *Gaia* DR2: Implications for the Hubble Constant"

A. Riess *et al.*, The Astrophysical Journal, Vol. 861, No. 2, 2018
2018: http://iopscience.iop.org/article/10.3847/1538-4357/aac82e

`A recent paper by Riess et al. working hard to reduce measurement uncertainties.  As of July 2018, the ` H_0 `tension is at 3.8`σ`.`

We present Hubble Space Telescope (HST) photometry of a selected sample of 50 long-period, low-extinction Milky Way Cepheids measured on the same band photometric system as extragalactic Cepheids in Type Ia supernova host galaxies. [...] We use the new Gaia DR2 parallaxes and HST photometry to simultaneously constrain the cosmic

distance scale and to measure the DR2 parallax zeropoint offset appropriate for Cepheids. [...] The precision of the distance scale from DR2 has been reduced by a factor of 2.5 because of the need to independently determine the parallax offset. The best-fit distance scale is inconsistent with the scale needed to match the Planck 2016 cosmic microwave background data combined with ΛCDM. We identify additional errors associated with the use of augmented Cepheid samples utilizing ground-based photometry and discuss their likely origins. *Including the DR2 parallaxes with all prior distance-ladder data raises the current tension between the late and early universe route to the Hubble constant to* 3.8σ *(99.99%).*

`The increasing precision is encouraging:  this is what might trigger a paradigm shift!`

"**Easily interpretable bulk flows: continuing tension with the standard cosmological model**"
S. Peery, R. Watkins, H.A. Feldman, Monthly Notices of the Royal Astronomical Society, Vol. 481, Issue 1, 2018
2018: https://doi.org/10.1093/mnras/sty2332
See also: arXiv:1808.07772

`  Here is a different way to look at it: perhaps a local cosmic flow causes the discrepancy.`
We present an improved minimal variance method for using a radial peculiar velocity sample to estimate the average of the three-dimensional velocity field over a spherical volume. [...] The resulting bulk flow estimate is particularly insensitive to smaller scale flows. We also introduce a new constraint into the method that ensures that bulk flow estimates are independent of the value of the Hubble constant H_0; this is important given the tension between the locally measured H_0 and that obtained from the cosmic background radiation observations. We apply our method to the *Cosmicflows-3* catalogue and find that, while the bulk flows for shallower spheres are consistent with the standard cosmological model, there is some tension between the bulk flow in a spherical volume with radius $150h^{-1}$Mpc and its expectations; we find only a ~ 2 per cent chance of obtaining a bulk flow as large or larger in the standard cosmological model with Planck parameters.

"**Can the H_0 tension be resolved in extensions to ΛCDM cosmology?**"
R.-Y. Guo, J.-F. Zhang, X. Zhang 2018: arXiv:1809.02340

`  Checking a few more models...`   We investigate whether there is an extension to the base ΛCDM cosmology that can resolve the tension between the Planck observation of the cosmic microwave background anisotropies and the local measurement of the Hubble constant. We consider various plausible extended models in this work [...] we conclude that *none of these extended models can convincingly resolve the H_0 tension.*

"**The Carnegie-Chicago Hubble Program. IV. The Distances to NGC 4424, NGC 4526, and NGC 4536 via the Tip of the Red Giant Branch**"
D. Hatt *et al.*, The Astrophysical Journal, Vol. 861, No. 2, 2018
2018: http://iopscience.iop.org/article/10.3847/1538-4357/aac9cc
See also: arXiv:1806.02900

`  This latest paper from the ''Carnegie-Chicago Hubble Program'' reports their progress on a`
`  recalibration of the extragalactic distance scale.  So far so good.`
The Carnegie-Chicago Hubble Program is undertaking a re-calibration of the extragalactic distance scale, using SNe Ia that are tied to Tip of the Red Giant Branch (TRGB) distances to local galaxies. We present here deep Hubble Space Telescope ACS/WFC imaging of the resolved stellar populations in the metal-poor halos of the SN Ia-host galaxies NGC 4424, NGC 4526, and NGC 4536. [...] For these three galaxies, the distances are the first that are based on the TRGB, and for NGC 4424 and NGC 4526, they are the highest-precision distances published to date, each measured to 3%. We report good agreement between our TRGB distances and the available Cepheid distances for NGC 4424 and NGC 4536, *demonstrating consistency between the distance scales currently derived from stars of Population I and II.*