Many (all) the questions have been answered during the Q&A period. Nevertheless, we ask that you provide written answers below so students can come back to read them again. Thanks!

1. (Page 12) The data differs significantly from the fit in the high frequency range 1500-2000, has there been investigation of this?

All the tests performed by the Planck collaboration can be find in the likelihood paper: https://arxiv.org/pdf/1907.12875.pdf
Higher multipoles in polarization are not really well constrained because of the sensitivity of the instrument, but better measurements have been performed by ACT and SPT. However, there are a few reanalysis of the Planck data like https://arxiv.org/pdf/2205.10869.pdf trying to improve the data analysis.

2. (Page 10) Can you explain what is being observed experimentally for each of the three quantities? Thank you!

All of these observables have been measured experimentally by different CMB experiments (for example Planck, ACT, SPT, BICEP, etc.).

3. (Page 14) I don't understand the difference between the different columns. Are they all based on Planck data or other observations included in some cases? If they are Planck only, why do we sometimes include/exclude some things?

These are the numbers of the contour plots in the previous slides. From the Planck experiment we can extract 4 independent observables: the temperature TT, cross correlation temperature polarization TE, and polarization EE power spectra, and the lensing reconstruction data. Each column gives the constraints on the parameter from a single observable, while that in red corresponds to their combination.

4. (Page 19) Am I right to conclude from the wording that SHOES does not rely on LCDM? And can the Planck data be analyzed without LCDM assumptions?

Local measurements like SH0ES are model independent, so they just rely on geometric techniques and are not sensitive to the model assumed.

Planck instead, like all the other CMB experiments and early time data, is measuring an observable in the early universe and to estimate the value of the Hubble constant (or in general of a parameter) you need to assume the expansion history of the universe. CMB data are always model dependent.

5. In the model of self-interacting sterile neutrino (model 7), is the sterile neutrino a viable dark matter? If yes, what is the typical mass range?

In this model the self-interacting sterile neutrino disappears, (for details see https://arxiv.org/pdf/1404.5915.pdf and https://arxiv.org/pdf/2006.12885.pdf). However the φ pseudoscalar can then interact with the dark matter.
The sterile neutrino mass is in this case in the eV range.

6. So far are there satisfactory theoretical models that can alleviate both H0 and S8 tensions?

It depends on the definition of satisfactory, and this is more subjective than objective. In my opinion everything that is between 2-3 sigma is not a solution but is promising. At the moment the best candidates are possibly NEDE, interacting cosmologies, or models predicting an earlier recombination, but you can find a complete compilation here https://arxiv.org/pdf/2203.06142.pdf

7. (Page 23) Tip of Red Giant Branch is described as peak brightness reached when they begin fusing hydrogen. Is there a possible bias because the observations can be soon after or longer after this transition? If this is indeed the case, which way is the bias?

Not really my field of expertise, but you can find more information on the Freedman review: https://arxiv.org/pdf/2106.15656.pdf

8. In your opinion, what is most promising or favorite interpretation(s) to clarify the different results of H0 and S8 measured in the early vs early universe?

At the moment it is difficult to prefer a solution to another, because none of them is fully satisfactory. There are models that have been more investigated by the community, so we have all the tests and we know where they fail, while many others didn't get enough

attention and seem to be working better. I really think we need more data and more investigations. Please have a look at https://arxiv.org/pdf/2203.06142.pdf

9. (Page 142) What are the additional four parameters in the extension model beyond the LCDM?

These 4 additional parameters are a total neutrino mass, Neff, a dark energy equation of state and a running of the scalar spectral index.

10. Why not known physics? Effects of magnetic fields at recombination.

Yes, everything can be and there are papers about this actually. The models proposed are more than 300 and together with primordial magnetic fields, I didn't named many other solutions, like modified gravity for example. Please have a look here https://arxiv.org/pdf/2103.01183.pdf

11. is there a possibility to explain these hubble tension, with any of the proposed dark matter model?

At the moment none of the models can really explain the tension. There are models that work better and others that do not work at all.

12. (Page 143) For the both graphs what could be the most preferable model?

None of them unfortunately!