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DISTANT FOREGROUND AND THE HUBBLE CONSTANT TENSION

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It is possible to explain the discrepancy (tension) between the local measurement of the cosmological parameter H_0 (the Hubble constant) and its value derived from the *Planck*-mission measurements of the Cosmic Microwave Background (CMB) by considering contamination of the CMB by emission from some medium surrounding distant extragalactic sources (a distant foreground), such as extremely cold coarse-grain (grey) dust. As any other foreground, it would alter the CMB power spectrum and contribute to the dispersion of CMB temperature fluctuations. By generating random samples of CMB with different dispersions, we have checked that the increased dispersion leads to a smaller estimated value of H_0, the rest of the cosmological model parameters remaining fixed. This might explain the reduced value of the *Planck*-derived parameter H_0 with respect to the local measurements. The cold grey dust for some time has been suspected to populate intergalactic space and it is known to be almost undetectable, except for the effect of dimming remote extragalactic sources.

1 Introduction

The importance of the issue with the Hubble constant as measured by two different methods (the H_0 tension) can be appreciated from recent comprehensive reviews on the subject [1,2] and by the fact of special international conferences discussing exclusively this particular issue [a].

The *Planck* space observatory [3] revealed a statistically significant discrepancy between the cosmological parameter H_0 as calculated within the standard cosmological model by using the Cosmic Microwave Background (CMB) power spectrum, $H_0 = (67.37 \pm 0.54)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, and the values of this parameter obtained by using other methods – mostly from direct local measurements [4]. One of these local measurements is based on optical and infrared (IR) observations of variable Cepheid stars, with the recent calculation of H_0 based on this method [5] being $H_0 = (73.48 \pm 1.66)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. Both local and *Planck*-derived estimates of H_0 have passed a number of rigorous tests by considering many possible sources of systematic errors [6,7,8], but the discrepancy still remains.

Discussing the possible origin of this discrepancy, most authors and reviewers focus primarily on observational biases related to the method of standard-candles, Cepheids and type-Ia supernovae (SN), and on proposals going far beyond the standard cosmological and particle physics

[a] `https://www.eso.org/sci/meetings/2020/H0.html`

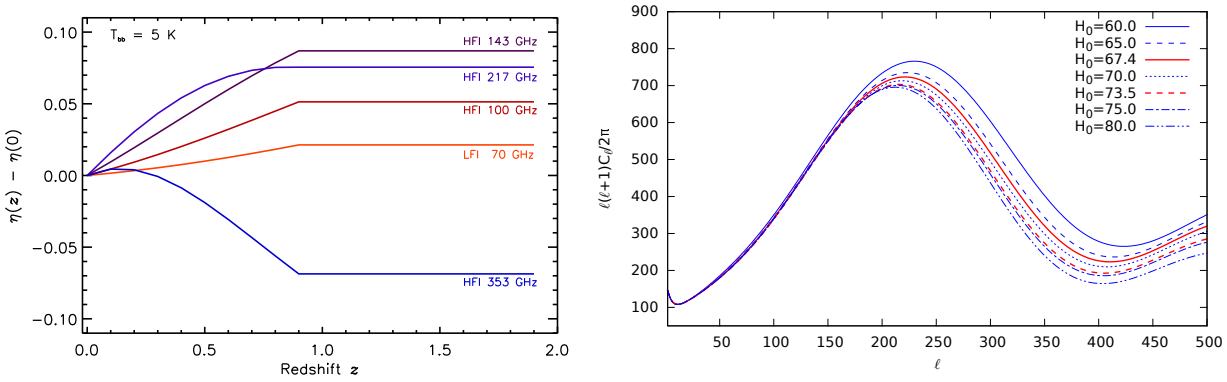

Figure 1 – *Left:* Redshift dependences of the blackbody radiation energy fraction $\eta(z)$ as observed in five *Planck* frequency bands for $T_{\rm bb} = 5\,{\rm K}$; the constant shifts of the curves with respect to each other have been normalised at $z = 0$ by subtracting from them their individual values $\eta(0)$; *Right:* CMB power spectra (in the standard normalised presentation) generated by using the code for anisotropies in the microwave background (CAMB tool) for seven different values of H_0.

models. By contrast, possible biases intrinsic to the CMB are passed by almost without further thought.

2 Distant foreground

Various authors have reported that the contaminating emission from a medium around distant extragalactic sources should affect correlations between CMB and extragalactic cosmic structures traced by bright transient sources, like supernovae (SNe) or gamma-ray bursts. The signature of the distant foreground in the CMB, based on the WMAP and *Planck*-mission results and traced by SNe was previously reported by the author [9,10], who found a correlation between the SN redshifts, $z_{\rm SN}$, and CMB temperature fluctuations at the SNe locations, $T_{\rm SN}$.

By using different *Planck* frequency bands and computing the fractions $\eta_\nu(z)$ of blackbody radiation energy as observed in each frequency band ν for different redshifts z one can estimate the regression line slopes for these bands [11]. The functions $\eta_\nu(z)$ are shown in Fig. 1, as calculated for the blackbody temperature $T_{\rm bb} = 5\,{\rm K}$ and five of the *Planck* frequency bands $\nu = \{70, 100, 143, 217, 353\}$ GHz. Note that the temperature of the medium in thermal equilibrium with the CMB must exceed or be equal to 5 K for the redshifts $z > 0.835$, so for these redshifts the functions $\eta_\nu(z)$ appear horizontal.

We can calculate slopes ξ^c_ν of these functions for different $T_{\rm bb}$ and compare them with the observed slopes ξ^o_ν corresponding to different *Planck* frequency bands $\nu = \{70, 100, 143, 217, 353\}$ GHz which, according to our previous work [10], are the following: $\xi^o_{70} = 0.96 \pm 0.63$, $\xi^o_{143} = 1.09 \pm 0.31$, $\xi^o_{217} = 0.61 \pm 0.36$ and $\xi^o_{353} = -0.99 \pm 0.48$. The slope for the 100 GHz-band was used as a reference for normalisation, so $\xi^o_{100} = 1.00 \pm 0.39$.

The calculated slopes ξ^c_ν of these functions averaged between the temperatures $T_{\rm bb} = \{3, 4, 5, 6\}\,{\rm K}$ for each of the *Planck* frequency bands $\nu = \{70, 143, 217, 353\}$ GHz are $\xi^c_{70} = 0.45 \pm 0.03$, $\xi^c_{143} = 1.63 \pm 0.17$, $\xi^c_{217} = 0.73 \pm 0.74$ and $\xi^c_{353} = -1.48 \pm 0.43$ (again, the slope for the 100 GHz-band was used as a reference). They are within the 1-σ tolerance interval with respect to the above experimental values ξ^o_ν, which indicates that the temperature of the CMB-contaminating ingredient of the intergalactic medium is very low, likely to be between 3 K and 6 K. This can give clues as to the nature of the medium, which can be coarse-grain (grey) dust, and which for some time has been suspected to populate intergalactic space [12,13,14,15].

This "grey" dust leaves little or no imprint on the spectral energy distribution of background sources. However, it creates the long-known excess of radiation from some extragalactic objects in the far IR at $\lambda \approx 500\,\mu$m, which extends up to centimetre wavelengths and can interfere with the CMB radiation. Such a 500 μm radiation excess was confirmed and measured by the

Herschel space observatory [16]. In the 1990s, this excess was interpreted as an elevated spatial mass density of cold dust [17] with temperatures of 4 to 7 K. Here we confirm this interpretation from a completely different point of view.

3 CMB distrortion

The angular sizes of the observed regions with the 500 μm emission [16,18] range from 0.02° to 0.5°. So this emission would effectively distort the CMB power spectrum at the multipole moments $\ell \approx 360$ and higher, which would change the estimated parameter H_0. In order to quantify these changes we have used the code for anisotropies in the microwave background [19] (CAMB) which allows the extraction of different cosmological parameters from theoretical CMB power spectra generated by the same code. The calculated changes are shown on the right panel of Fig. 1 for the first trough of the CMB power spectrum, where its effect on the calculated parameter H_0 is quite strong.

In this code, the coefficients C_ℓ of the CMB power spectrum are calculated as sums of the integrals $a_{\ell m}$, $|m| \leq \ell$, which include temperature fluctuations $\Delta T(x, \phi)$ over the celestial sphere, where $x \in [-1, 1]$ is the cosine of the latitude and $\phi \in [0, 2\pi]$ is the longitude. Conversely, the functions $\Delta T(x, \phi)$ are calculated by summing up the integrals $a_{\ell m}$. For a given CMB power spectrum, we have calculated a set of corresponding values of $\Delta T(x, \phi)$ by using random $a_{\ell m}$ for $\ell = 0, 1, \ldots, \ell_{\mathtt{max}}$ with the restriction $\ell_{\mathtt{max}} = 500$. We have taken five equal-spaced values of H_0, namely, 60, 65, 70, 75 and 80 [km s^{-1} Mpc^{-1}] plus the values 67.4 [km s^{-1} Mpc^{-1}] (solid red curve on the right panel of Fig. 1) and 73.5 [km s^{-1} Mpc^{-1}] (dashed red curve on the same panel) corresponding, respectively, to the *Planck* result and to the local measurements of H_0.

Additionally, for checking the consistency of our calculations we have taken a few sets of normally distributed randomised values of $a^i_{\ell m}$, $i = 1, 2, \ldots, 5$, so that for each of the selected values of H_0, we have obtained five samples of $a^{H_0,i}_{\ell m}$ and, correspondingly, five samples of values $\Delta T^{H_0,i}$. For each of them, we have calculated the average of the CMB temperature fluctuations $\overline{\Delta T}$ and its standard deviation σ_T.

Here we are mainly interested in the way the values σ_T change when the parameter H_0 is varied. For each of these generated sequences, the trend of the calculated values σ_T was practically the same. Namely, when the dispersion of the CMB temperature fluctuations increases, the value of the estimated H_0 decreases, the difference between the two discussed H_0 values 73.5 and 67.4 [km s^{-1} Mpc^{-1}] being related to $\Delta\sigma_T = -0.60 \pm 0.04\,\mu$K. This value is the measure of CMB contamination by photons from the medium surrounding remote clumps of matter, and it can thus be used for estimating the amount of cold coarse-grain dust in the intergalactic medium.

4 Discussion

Between 2012 and 2019, new studies have appeared demonstrating that the dimming of the type-Ia supernovae was different in different directions [20,21,22,23,24,25,26]. Most of the authors of these studies interpret their results in terms of anisotropic acceleration of the Universe.

However, anisotropy of acceleration violates the main cosmological principle. Therefore, the grey-dust interpretation of the type-Ia supernovae anisotropic dimming becomes preferable: it would be much more logical to assume non-uniform distribution of dust rather than the Universe having different properties in different directions.

What might be the origin of this coarse-grain dust? Apart from the initial formation of dust particles within galaxies with their further transport into the intergalactic space, dust formation can also occur directly in the intergalactic medium [27]. The observational evidence for cold molecular clouds at the cooling flows in galaxy clusters and the presence of dust in these regions is widespread [28]. Besides this detectable dust clouds, there exists yet another possibility

of almost undetectable coarse-grain dust existing in the intergalactic space which, according to recent studies, should be seriously taken into consideration. Namely, these macroscopic dust particles can be formed by the process of hydrogen solidification under sufficiently low temperatures, e.g., when the CMB temperature gets below 10 K at $z < 2$, which was proposed in 1968 by F. Hoyle [29] and further discussed in the 1990s and early 2000s [30,31,32]. In the last decade, it was shown by experimental physicists that H_2 ice became stable in vacuum and do not sublime if it contains impurities [33,34,35] transported from galaxies into the intergalactic medium.

My conclusion is that the mechanism of contamination of CMB radiation by some distant foreground emission from cold dust can explain the discrepancy between the local measurements of H_0 and the *Planck*-derived value, without invoking unnecessary assumptions that violate the basic cosmological principles or break the standard cosmological and particle physics models.

References

1. Di Valentino E. *et al.*, Class. Quantum Grav. **38**, 153001 (2021)
2. Shah P., Lemos P., Lahav O., *Astron. Aph. Rev.* **29**, 9 (2021)
3. Planck Collaboration, *Astron. Aph.* **641**, A6 (2020)
4. Riess, A. G., Nat. Rev. Phys. **2**, 10 (2020)
5. Riess, A. G. *et al.*, *Aph. J.* **855**, 136 (2018)
6. Efstathiou G., *MNRAS* **440**, 1138 (2014)
7. Planck Collaboration, *Astron. Aph.* **607**, A95 (2017)
8. Follin, B., Knox, L., *MNRAS* **477**, 4534 (2018)
9. Yershov V.N., Orlov V.V., Raikov A.A., *MNRAS* **423**, 2147 (2012), arXiv:1205.5139
10. Yershov V.N., Orlov V.V., Raikov A.A., *MNRAS* **445**, 2440 (2014), arXiv:1410.5814
11. Yershov V.N. *et al.*, *MNRAS* **492**, 5052 (2020), arXiv:2001.09152
12. Eigenson M.S., *Astron. Zh.* **26**, 278 (1949)
13. Zwicky F., *Morphological Astronomy*, Springer-Verlag, Heidelberg (1957)
14. González, R.A. *et al.*, *Aph. J.* **506**, 152 (1998)
15. Alton, P.B., Bianchi, S., Davies, J., *Aph. Sp. Sci.* **276**, 949 (2001)
16. Galliano F. *et al.*, *Astron. Aph.* **536**, A88 (2011)
17. Reach W. T. *et al.*, *Aph. J.* **451**, 188 (1995)
18. Lisenfeld, U. *et al.*, *Astron. Aph.* **382**, 860 (2002)
19. Lewis A., *Phys. Rev.* D **87**, 103529 (2013)
20. Cai, R.-G., Tuo, Z.-L., 2012, *J. Cosmol. Astropart. Phys.* **02**, 004 (2012)
21. Cárdenas V. H., Bernal C., Bonilla A., *MNRAS* **433**, 3534 (2013)
22. Bernal C., Cárdenas V. H., Motta V., *Phys. Lett.* B **765**, 163 (2017)
23. Colin J., Mohayaee R., Rameez M., Sarkar S., *Astron. Aph.* **631**, L13 (2019)
24. Zhao D., Zhou Y., Chang Z., *MNRAS* **486**, 5679 (2019)
25. Rameez M., *Preprint* arXiv:1905.00221 (2019)
26. Luongo O. *et al.*, *Preprint* arXiv:2108.13228 (2021)
27. Fabian, A.C., Johnstone R.M., Daines S.J., *MNRAS* **271**, 737 (1994)
28. Russell H.R. *et al.*, *Aph. J.* **836**, 130 (2017)
29. Hoyle F., Wickramasinghe N.C., Reddish V.C., Nature **218**, 661 (1968)
30. Pfenniger D., Combes F., Martinet L., *Astron. Aph.* **285**, 79 (1994)
31. Wardle M. J., Walker M. A., *Aph. J.* **527**, L109 (1999)
32. Pfenniger D., Proc. IAU Symp. **220**, 241 (2004)
33. Schaefer J., Chem. Phys. **332**, 211 (2007)
34. Walker M. A., *MNRAS* **434**, 2814 (2013)
35. Kettwich S.C. *et al.*, *MNRAS* **450**, 1932 (2015)