Too many coincidences?

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Recent developments in precision cosmology have presented theoretical physicists with a tantalizing picture of the universe. By a combination of all data, there is undisputable evidence that our universe is accelerating [1]. This means that about 70% of the energy density in the universe is made up by a mysterious component, coined dark energy, with an equation of state $-1.2 \leq w_X \leq -0.8$ at 68% confidence level [2].

Two fundamental questions arise in addressing the dark energy (DE) puzzle which make this problem notoriously difficult to answer: its magnitude $\rho_X \simeq 10^{-122} M_P^4$ is 122 orders less than the expected value M_P^4. This is known as the fine-tuning problem; DE domination time over matter energy density in driving the expansion of the universe occurs around redshifts $z \simeq 0$ when the present value of the Hubble radius is $H_0 \simeq 10^{-33} eV$. The latter is known as the coincidence problem of DE [3]

Cosmic microwave background (CMB) measurements have proven a powerful tool in confirming a concordance ΛCDM picture in cosmology, although we still lack an understanding of the origin and nature of DE and dark matter. Together these components make for about 95% of the energy density in the universe's budget.

The $WMAP$ balloon born experiment confirmed the CMB picture of concordance cosmology as previously measured by $COBE$. One of the more surprising findings of $WMAP$ was the suppression of power at large angles, (low multipoles l), of temperature correlations C_l^{TT} in the CMB anisotropy spectrum [4]. These findings can not be considered as conclusive evidence because of the limitations set by cosmic variance. However they are intriguing enough to motivate further effort in circumventing cosmic variance. This can be achieved by means of complimentary data like cosmic shear from weak lensing [5] and cross-correlations with the polarization spectra [6]. Analysis along these lines is lending support to $WMAP$ findings that indeed power is suppressed at low multipoles l. The suppressed modes correspond to perturbation wavelengths of the order of our present Hubble horizon $\lambda \simeq H_0^{-1} \simeq 10^4 Mpc, k \simeq H_0 \simeq 10^{-33} eV$. Contrary to theoretical expectations based on the inflationary paradigm, not only do we have to explain the reason why these modes are suppressed but we also have to address why the suppression occurs at the DE scale, $H_0 \simeq 10^{-33} eV$. Power suppression at horizon sized wavelengths thus introduces a *second cosmic coincidence* to theoretical cosmology. Recall that in an inflationary universe perturbations produced near the end of inflation leave the horizon whenever their wavelength becomes larger than the inflationary horizon H_i due to 'super-luminal' propagation. These modes re-enter the horizon at later times when the Hubble parameter once again becomes equal to their wavelength. This is known as the horizon crossing condition $k = a(t)H(t)$. Thus the largest wavelengths are the first ones to leave the horizon and the last ones to re-enter. Modes currently re-entering $k_0 = a_0 H_0$ have wavelengths horizon size,which means they have been outside of the Hubble horizon for most of the history of the universe. Thus they have not been contaminated by the internal evolution and nonlinearities of the cosmic fluid inside the Hubble radius. These modes carry the pristine information of the unknown physics which sets the Initial Conditions of the universe [7].

Although these cosmic coincidences associated with the two currently observed phenomena namely, DE domination and CMB power suppression at horizon sized wavelengths, are dominantly displayed at low energies, for the reasons mentioned above it is reasonable to expect that they may originate from processes occurring in the very early universe.

This is a strange world. A vacuum energy component should enhance power of long wavelengths due to the integrated Sachs Wolf effect (ISW). Hence we can not dismiss that the observational data seems to point us to the existence of two cosmic coincidences at the present Hubble radius. The bizarre picture of the universe emerging from observational findings for these 'seemingly unrelated' cosmic coincidences occurring at the same energy scale, may likely provide clues of new physics.

String theory and quantum gravity are possible candidates of the unknown physics of the early universe. There are current models in literature that offer an explanation for the CMB power suppression, by having the Initial Conditions set within the framework of string theory [7,8] loop quantum gravity [9] or an unknown hard cutoff [10]. There is also an ongoing search for a possible UV/IR mixing of gravitational scales [11]. However a theoretical model that would successfully accommodate all observed cosmic coincidences around the scale $H_0 \simeq 10^{-33}eV$ is yet to be found.

Perhaps, as the data is suggesting, there is something special about our present Hubble scale. It might be a fundamental scale of very low energy physics. Or perhaps a new scale of low energies derived from a fundamental scale of high energy physics through a possible UV/IR. This radical possibility is not yet realized in a concrete model.

At the moment, our theoretical knowledge of the relation between beauty and a strange world still lies in the realm of speculations while pushing forward the discovery of new physics.

References:

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