

Peer Review

Review of: "Is the Observational Dark Energy Universe Completely a Coincidence?"

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Dear Author,

I have reviewed your manuscript titled “Is the Observational Dark Energy Universe Completely a Coincidence?”. While I admire the idea of looking at one of the most pressing issues in modern cosmology in a new light, and I have found the idea proposed here original and well thought out, I think some work has to be done regarding the presentation of such an idea.

More specifically, from the abstract, it is unclear to me in which way the analysis in the paper wishes to link the anthropic principle, dark energy, and observations of high-redshift objects like the CMB and the recently found AGNs. I also think the bibliography is too short, especially given that this is a novel theoretical analysis; it should be extensively extended by considering papers that are of fundamental importance regarding the ongoing discussion on Dark Energy (like, as just an example, arXiv:2203.06142). Overall, I think the paper can be an interesting contribution to the vast discussion behind dark energy found in the literature, but some work, especially regarding the presentation, should be done.

I will now go into more detail in each section.

Abstract

As I previously mentioned, I find it quite unclear. I think the “coincidence” should be clarified in what it is. It should also be explained what the causal connection is between “At any epoch of the universe, to an arbitrary local observer living well below the scale of the Hubble horizon, the observational universe appears to be accelerated expanding” and “In other words, the anthropic principle might be

unnecessary for the dark energy universe ‘coincidence’,” given that I think this is the fundamental point the article wishes to prove.

Introduction

In general, I think it should be extended, while also adding more bibliography related to Dark Energy observations, why its value can be problematic, how it has been reintroduced in the cosmological discussions, and recent measurements of it. The discussion on the anthropic principle should also be amplified. Dark Energy has been first introduced by Einstein for keeping the universe stationary (as the author mentioned), but was later introduced to explain the observed accelerated expansion of the universe found by looking at SNe Ia. While all these notions are present in the paper, I think they should also be mentioned here to give a proper “full story” of dark energy since the introduction. As it stands, it is unclear the link between Dark Energy and the anthropic principle, whose definition is not “civilized observer needs to be born in an environment where the dense structure of the universe is diluted by dark energy” but is something way more general, i.e., the assumption that all the possible observations we can do in our universe are possible only in a Universe which is capable of developing intelligent life. It is also unclear why the dark energy is “unsatisfying “ for this reason. (Of course, I am not saying that it is satisfying not knowing what 70% of our universe is made up of, as it is the case for the Λ CDM model!)

Einstein equation with positive cosmological constant

In general, I find this section well written; maybe I would extend some parts, especially regarding the definitions and theorems used for the derivation, as well as some causal connections between various sentences found in this dissemination.

“In the original Einstein’s equation Λ was an extra term added with no good explanation within classical general relativity” It is true that the cosmological constant was added by Einstein for reasons that were later revealed to be wrong (fitting with a stationary universe model), but there is also no reason why that constant should NOT be there. From this point of view, setting $\Lambda = 0$ is also arbitrary. One has to fit this value according to the observations and theoretical reasons found “a posteriori”.

The following section, I think, should also be expanded a little bit, maybe giving more definitions regarding the terms introduced.

“Frobenius’ theorem gives the sufficient and necessary condition allowing this choice, which I will mention in the following derivation.” I would go into more detail about the Frobenius theorem since it

is mentioned here.

A little note on the nomenclature: The indexes for 4-D tensors are usually indicated with the Greek alphabet. Of course, one can use the nomenclature they like, given they keep it consistent, but I still would suggest using the Greek alphabet for dissemination simply for clarity reasons.

“decompose B_{ab} into time-like, space-like...” I think the definition of θ should be added here, after Eq. (5).

“In addition, the failure of ξ_a ’s trivial transportation should not be ignored like one conventionally does, for the following reason.” I think it should be clarified what “failure of trivial transposition” means.

“We learned in the textbook.” I think this is improper wording.

“It is a mathematically correct but often disobeyed statement in the physical world.” This sentence should also be clarified.

“According to Frobenius’s theorem..” Could it be possible to explain in more detail why the asymmetric term can be dropped according to this theorem? Could it also be possible to explain how we can go from Eq. (6) to Eq. (7) and some of the intermediate passages you have to do to move from Eq. (8) to Eq. (9)?

Cosmological Effect

In general, I can follow the discussion here, but I would have preferred if more quantitative comparisons were present, with real data and observations (like with the CMB, which the author has mentioned in the abstract but has simply briefly mentioned in the caption of Fig. 3), but I also understand that this would be enough material for future work. So, I would suggest simply adding some other considerations regarding possible comparisons with real cosmological probes.

“Such accelerated expansion reality is fairly homogeneous.” According to the Cosmological Principle, once you are in the Hubble Flow, this expansion is homogeneous and isotropic, so I would say you can safely erase the word “fairly” here.

“ $\langle \alpha \rangle$ ’s calibration to zero is hidden in the intuitive presumption that our whole observational universe is ‘free-falling’, namely evolving in the shortest path along the time direction that we choose as an observer.” If α , according to the derivation in the previous section, is the positive-defined novel dark energy equivalent, then why should its calibration be 0? Also, it is unclear to me why the “free-falling” should explain so.

“Here I do not serve an ultimate solution to the homogeneous principle of the universe.” Going back to the Cosmological Principle, does this assume that it is not valid in the novel approach proposed in this manuscript? Could the author please go into more detail on this fundamental point for the standard cosmological model?

“ $\sigma_2(a) \sim \rho_m$ ” I think this important assumption needs to be further clarified. Indeed, in the standard cosmological model, dark energy is something different from the matter component of the densities in the Universe. Here, instead, we see that the novel element, substituting the usual negative pressure, is linked to the matter density as well, so how is this different from the Ω_M part of the cosmic pie?

Caption Fig. 2: “the Hubble horizon $\lambda H=1/H$ at that epoch (in our chronicle) is much smaller than us, thus such a shell accommodates many Hubble bubbles.” Could the author please clarify what was written here?

It is interesting to see the behavior of Dark Energy in the model proposed in Fig. 3 with the scale factor a , which of course is completely different from the constant Dark Energy of the standard Cosmological model. This trend, I think, can also be found in Extended theories of cosmology, or more simply in w CDM models considering the so-called quintessence. Can these be compared with the theory the author proposes? Also, instead of taking guesses for $\Lambda(a)$, could it be possible to fix it using real data?

Declarations

Potential competing interests: No potential competing interests to declare.