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Referee Report for Manuscript [redacted]

In manuscript [redacted] the authors present the case for early-universe accelerated expansion (inflation), in addition to the late-universe one (cosmological constant), as being part of a modified theory of gravity (MG), Unimodular Gravity (UG). This is done without assuming any additional fields, as is usually done in inflation or other MG, rather only relying on UG's geometrical properties.

After presenting the analysis both at background and first order in perturbation, the authors show a strong case for such a scenario to be a worth studying alternative to the Standard model of Cosmology, ΛCDM. Moreover, the authors made a great effort in explaining every step with great detail and clarity, making the manuscript easy to follow and understand. The authors also show how their method differ from others in the literature, which makes the manuscript a good addition to it.

However, before recommending this article for publication in CQG journal, there are a few points that the authors could clarify even more, which can improve this manuscript.

In this document, these points will be listed and elaborated on. There will be comments related to the overall article, in addition to others specific for certain mentions in it. Once the authors answer them clearly, then the manuscript should be ready for publication.

Points to be Clarified by the Authors

1. The authors made it very clear that the non-conservation of the energy-momentum tensor, a characteristic of UG, is the fundamental principle of their analysis. This property results in having an extra function, called Q in the manuscript, that could explain away both inflation and Dark Energy (DE) in a dynamical way. However, can the authors elaborate on the difference between a scalar field (e.g. quintessence) and a dynamical cosmological constant? Mathematically they are the same, but there should be a different motivation to consider the latter and not the former. This could be also helpful in the context of MG with scalar fields, e.g. Horndeski theory.

2. Given that the authors considered ultra-relativistic matter to be omnipresent during the phase of accelerated expansion, could there be any back-reaction from it on the expansion?

3. The obtained values for different observables (radiation and matter energy densities, cosmological constant...) from this model have been presented assuming a particular form of the diffusion term Q. Although the authors do mention that their results should not depend on the choice of Q, yet it seems that the obtained values do depend on the parameters of this choice. Therefore, can the authors prove that indeed the obtained values do not depend on the choice of Q? Otherwise, can the authors comment on the level of fine-tuning that would be needed in choosing Q?

4. In section III of the manuscript, the authors assume an initial energy density of their fluid to be that of the Planck scale. Could the authors comment on any trans-planckian censorship arguments that could affect their analysis?

5. In the second line after eq.(15) of the manuscript, the authors mention that $\Gamma \equiv Q/\rho = 0$ corresponds to standard inflation. However, even though Q is not present in standard inflation, Γ can still be expressed in terms of the inflaton potential. Therefore $\Gamma = 0$ does not necessarily correspond to standard inflation. The authors are kindly asked to clarify this point.

6. After eq.(18) of the manuscript, the authors state that $\epsilon_1^{\rm ini} = 1$, while inflation requires $\epsilon_1 < 1$. It seems therefore that the initial condition of ϵ_1 does not allow inflation to start from the first place. Could the authors clarify this point?

7. Although the authors mention that a particular choice of ϵ_1, or Q, is not necessary for their results as long as these parameters satisfy the conditions for inflation, yet a particular choice is made in the end. Could the authors provide a motivation, or a reference, for this particular choice? For the latter is not a straightforward one to guess.

8. The authors choose the number of e-folds during inflation to be $N_f = 300$. Although it's a legitimate choice, yet it's much larger than what is usually used for inflation (60-70). Is there a reason for this choice? What happens to the results if one uses $N_f = 60 - 70$ in the authors' analysis?

9. Throughout the manuscript, the values for α used by the authors are always < 1. Is there a reason for that?

10. In Figure 1 of the manuscript, it seems that for any choice of α, ϵ_1 reached 1 at the same N. Could the authors comment on this coincidence?

11. At the end of the paragraph after eq.(27), the authors compare their plot in Figure 2 to that of Figure 1 in [1] (ref [66] of the manuscript). However, the latter shows an oscillatory behavior of ρ in a much smaller e-fold range. Unless the authors did a typo in citing this ref, could they clarify what do they mean exactly by this comparison?

12. In section IV of the manuscript, the authors assume Q to be homogeneous and does not have perturbations. Although this serves the ultimate goal of the model, yet some motivation for this choice is needed. The diffusion term can be interpreted as part of space-time's geometry, like the metric. Therefore, why the latter has perturbation terms while Q doesn't?

13. Between eqs.(37-38), the authors describe the relation between the equation of state ω and the adiabatic sound speed c_s^2. It is not clear why this part is useful for the overall analysis or the final results. Unless the authors can provide a motivation for having it in the manuscript, they are advised to remove it, or add it as a footnote. Moreover, before eq.(39), the authors' statement that *"assuming the EOS parameter $\omega = 1/3$ yields..."* gives the impression that $c_s^2 = \omega$ applies only to $\omega = 1/3$, which is not quite exact. If the authors decide to keep the part, the rephrasing of this sentence to include any constant ω will be more clear.

14. The part on gauge choice and transformations (eqs.40-42) is slightly confusing. At first, the choice of $v + B = 0$ is stated, yet later $\chi = v + B$ appears explicitly in eqs.(40-42). The authors are advised to rewrite this part in a more consistent way.

15. In Figure 4, the change in Q for $\alpha = 0.01$ is around 10 orders of magnitude during inflation. This massive change deserves some comment from the authors. Can one say that such low value of α is not well suited for the model?

16. In the paragraph before the last on page 15, the authors calculate H_0 from the previously calculated quantities. However, the latter were calculated assuming a certain value of H_0, making this part repetitive. Unless something is missing here, the authors are advised to remove this part.

17. Finally, some typos:

    - On the 8$^{\text{th}}$ line of the abstract, the commas between *"in such a way"* are not necessary.
    - Line 33 of page 1, *"approximately"*→between.
    - On line 37-38 of page 1, after citation [26], an "and" should be instead of a comma.
    - On the last line of page 1, after *"rediscovered"* there should be a comma.
    - Two lines above eq.(2), *"this restricts"*→ which restricts.
    - On the line after eq.(23), *"This is"*→ That is.
    - On line 39 of page 7 *"...,is very similar as that ...*→"...,is very similar **to** that ..."
    - At the end of line 30 on page 10, "Eq.(35b)~~,~~ depend**s**..."
    - On the line after eq.(45), *"can combined..."* should be either "can **be** combined" or without the "can".
    - On the first line of page 12, "Eq.(48) is that **it** is...".

- On line 18 of page 12, it's not clear whether the mention of UG is a typo for GR or not. If it's not, then the authors could mention a reference where conservation of energy-momentum tensor was imposed in UG.
- On line 10 of page 13, "If Q satisf**ies**...".
- On line 14 of page 13, "... is a gauge invariant quantity also in UG~~,~~ **we...**".
- On the line after eq.(58), "This action is completely analogous **to**...".
- On line 41 of page 13, "As such, in those works a k dependence **in**...".
- On the the 3$^{\text{d}}$ line of page 14, *"... to analyze"*→"in analyzing".
- At the beginning of the third line after eq.(63), "of the universe**'s** expansion...".
- In the last line of page 15, "An interest**ing**...".
- At the end of the line after eq.(68), *"this is..."*→"that is".
- At the beginning of the last paragraph's second line on page 17, a comma is needed after *"model"*.

In conclusion, the manuscript [redacted] is a very well presented case for UG as a way to explain inflation and DE. It could build up for further studies on this subject. After the authors address the points mentioned above, I believe the manuscript will be ready for publication in CQG journal.

References

[1] L. Amadei, A. Perez, Inflation from the relaxation of the cosmological constant (4 2021). arXiv:2104.08881.