

Response to the Referee's Reports

We would like to thank the reviewers for their positive and insightful comments on our manuscript, which we entitled "Phenomenology of axion-like particles coupling with photons in the jets of active galactic nuclei". We carefully considered your comments and recommendation to revise our manuscript. Below is our response to the issues raised in the review reports. We hope that these revisions improve the paper such that the editor and the reviewers now deem it worthy of publication in the South African Institute of Physics (SAIP)-2019 Conference Proceedings. We want once again to extend our appreciation for taking the time and effort necessary to provide such insightful guidance.

Response to Reviewer #1:

1. **COMMENT: As a first note: The paper is written in very poor English, and I find it annoying and disturbing that, obviously, the second author and student supervisor has not taken the time to proofread the paper before it was submitted. A careful language review is required before the paper can be seriously considered for publication.**

RESPONSE: We thank the reviewer for addressing this point. We carefully considered reviewing the manuscript looking for misspelling and typos and corrected it as possible.

2. **COMMENT: I have trouble following the logic of the paper in general: First, parameters of the photon-ALP conversion process are re-derived using gamma-ray spectra of 3C454.3. This step seems to be simply a repetition of the work in Ref. [21], whose results are being reproduced. This is obviously nothing new. In a second step, the resulting X-ray emission from a putative CAB of keV thermal energies is calculated. This was motivated by an X-ray excess of the Coma cluster, so I do not see why M87 is used as test case for the environmental parameters here. Furthermore, the ALP-photon conversion parameters ($m_a, g_{a\gamma}$) used for this step are totally different from those derived based on 3C454.3. So, what was the point of the 3C454.3 exercise, if the results are being ignored?**

RESPONSE: The logic of the paper is as follows. We followed the model of Mena and Razzaque in ref. [21] to study ALP-photon mixing in the jets of AGNs. Then, we use the validation example of

3C454.3 to test the model parameters in this environment. After that, we applied this model for the environment of the AGN M87 to calculate the soft X-ray spectrum from CAB ALPs conversion into photons. In the previous step, we used the same ALP mass and APL-photon coupling used in ref. [23] that gives a model explaining the Coma cluster soft X-ray excess based on CAB ALP conversion into photons. We found that using the same parameters used in ref. [23] over-produce the X-ray emission for M87. We argue that this put some doubts in the parameters used in the CAB Coma model in ref. [23].

The motivation of considering the M87 AGN is that it is the best characterized AGN in the literature and the availability of information and data about it. A clarification has been added between the second and third lines in the paragraph below figure 2 on page 5.

Discussing the example 3C454.3 was to verify the parameters used for ALP-photon mixing model in ref. [21] and to ensure that the simulation is reproduced in the correct way. Then, we used the suitable parameters related to the M87 environment and the soft X-ray excess CAB model for the Coma cluster, because we aim to use the M87 environment to test the CAB Coma model.

3. COMMENT: In addition to this very general criticism, a couple of specific points on the presentation, as we go through the paper:

I. COMMENT: Introduction, line 4-5: "... the nature of DM can be understood through looking for light scalar candidates of DM..." It is not clear at all wheter the nature of DM can be understood this way - this is just investigating one possibility, which may not explain anything after all.

RESPONSE: We revised this sentence to: "Looking for light scalar candidates of DM such as axions and axion-like particles (ALPs) is one of the well-motivated hypotheses to explain the nature of DM".

II. COMMENT: Last paragraph of the Introduction: What "misalignment" are the authors talking about here? Misalignment between what? The same occurs in the last sentence of Section 5.

RESPONSE: We meant the misalignment between the AGN jet direction and the line of sight. We added the clarification text "between the AGN jet direction and the line of sight" to the introduction and the conclusion after mentioning the misalignment.

III. COMMENT: In Section 2: From the description of the process (and the Lagrangian in Eq. (1)), it is unclear why the electron density (and its profile) is relevant at all. Please explain.

RESPONSE: The ALP-photon mixing is described by the model in equation (2). The parameters Δ_{\perp} and Δ_{\parallel} are defined in the first line of equation (4) in terms of Δ_{QED} and Δ_{pl} . The definition of Δ_{pl} in line 3 of equation (4) implies that it is a function of the electron density where

$$n_e = \eta \left(\frac{R}{10^{18} \text{cm}} \right)^{-s} \text{cm}^{-3}.$$

IV. COMMENT: Section 4, 1st line: Please mention the year of the observations.

RESPONSE: The year has been added to the text.

V. COMMENT: Line 6 on page 4 (above Fig. 1): the 0 in the photon-ALP vector on the l.h.s. of the in-line equation should probably be "a".

RESPONSE: The typo has been corrected.

VI. COMMENT: In Fig. 1, the axis labels and legends are way too small and thus illegible. Furthermore: The text talks about "fitting [Fermi-LAT] data" - but there are no data points plotted in the figure. It is therefore impossible to judge whether the curves shown are actually acceptable fits to the data. In fact, this renders the figures useless.

RESPONSE: The size of figure 1 has been increased in the revised version to make sure that the axis labels and legends are clear enough. We also modified the plots in figure 1 to show observational data as well as the simulation. Then we compare it with the results shown in ref. [21] to verify that the simulation we used is working in the correct way.

VII. COMMENT: Paragraph below Fig. 1: According to Eq. (3), the parameters phi and eta should be dimensionless (as is done correctly in the next paragraph).

RESPONSE: This issue has been corrected in the revised version.

VIII. COMMENT: Please be consistent in the use of g vs. $g_{a\gamma}$.

RESPONSE: We are now restricted with using $g_{a\gamma}$.

IX. COMMENT: Fig. 2 has the same problem as Fig. 1 in that there is a claim that "it is evident" that the model overshoots the data, but there are no data plotted in the figure. So, it is not evident at all.

RESPONSE: Actually we are only comparing the value for the total flux produced using our model for the M87 AGN with the value of the flux obtained on ref. [28] based on using observational data. We revised this part to be clear about this point.

Response to Reviewer #2:

- a. **COMMENT:** I understand that the spectral-energy distributions plotted in figure 1 are for comparing with published results. It is mentioned in the manuscript they fittings to data were done and the best-fitting models have been plotted. However, I do not see any data shown in figure 1. Data should be shown in the plots and results of chi-square fitting per degree of freedom should be reported in the text, so that readers can judge the goodness of fit.

RESPONSE: We thank the reviewer for raising this point. We modified the plots in figure 1 to show observational data as well as the simulation. Then we compare it with the results shown in ref. [21] to verify that the simulation we used is working in the correct way.

- b. **COMMENT:** In figure 2, Ayad and Beck plotted some energy spectrum in soft X-ray for the jet of M87 AGN. It has not been explained how this plot was made, no data are shown and there is no way to verify that this calculation or the claim that it is two orders of magnitude higher than the observed X-ray flux. At the least, 1. the ALP input flux that was used must be shown on the plot, 2. X-ray data points for M87 jet must be shown on the plot, 3. a justification must be given in the text with reference for using the ALP flux.

RESPONSE: We were not very clear here. We are not really fitting the energy spectrum produced with our model and observations. We only compare the value for the total flux produced using our model for the M87 AGN with the value of the flux obtained on ref. [28] based on using observational data. We revised this part to be clear about this point.

- c. **COMMENT:** There are few typos, e.g., *discus* (para above Section 2), *the the* (after eq.1), *the parallel sign after A should be subscript in eq.2*, *politicization* (after eq.4), *for the for the* (para below fig.2), etc. These should be corrected.

RESPONSE: The mentioned typos have been corrected.