Effective Opacity of the Intergalactic Medium from Galaxy Spectra Analysis

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Response to the Referee Report

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We thank the referee for a careful reading of our manuscript and their comments and criticisms. We have made a number of modifications to the text and analysis in response and resubmit a revised version. Below we provide the detailed list of comments from the referee in bold text. Our responses are below each comment. If they are concise, it means we have agreed and fixed the text accordingly.

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0-Abstract

-"These are normalized...data package"--> What do you mean here? I understand you want to quickly summarize the method used in the paper but I am not sure this is the most representative way to say it.

This text has been substantially rewritten

-"previous work analyzing quasar spectroscopy"--> I believe you could change to 'quasar and galaxy spectroscopy' since you are referring to IGM galaxy analysis through the paper

We did not change this as we only directly compare to studies analyzing QSOs

-"...fit our distribution..." --> You do not fit the distribution but the redshift evolution of teff.

Fixed

-"the effective opacity (teff)" --> You should put (teff) in the first sentence of the abstract.

Fixed

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1-Introduction

-"Is is, however, a trace neutral fraction of..." --> This sentence is not clear

Rewritten

-"From sight-line to sight-line" --> A reference would be welcome here.

Added

-"no flux is observed within the 1070-1170A range" --> Why this range especially, what about lower wavelengths?

We used the 1070-1170A range to avoid continuum fitting problems associated with rapidly changing emission-line profiles, and possible contamination from the proximity effect. Pointed out that the IGM can be observed at different wavelengths (~1020-1210).

-"...is dependent on tau in the local IGM"--> What do you mean by 'local IGM'?

Cut

-"In fact the EUVB is....galaxies at z>3"--> Reference missing

Added

-"We measure teff by exploiting"--> missing space

Fixed

-"LBGs are star forming galaxies....visible ranges"--> Are talking in rest-frame or observed frame? Some precision would be welcome.

Specified

-"They are selected based....filter set"--> Reference missing

Added

-"We follow the example....as our as our"--> word repetition

Fixed

-"Together, these provide a measurement....at these 'lower' redshifts"--> This sentence is hard to understand. What do you mean here?

Rephrased

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2-CLAMATO sample selection

-First sentence: add reference to CLAMATO

These were already listed in the Introduction.

-How faint are the galaxies? How many galaxies have been observed in CLAMATO?

Added information on magnitudes and total data sample

-"CLAMATO is the not the" --> Missing word?

Fixed and rephrased

-"so an area of the sky" --> to be rephrased

Rephrased

-"The target selection procedure..."--> of what? CLAMATO? You should give a better description of the galaxy selection. That would greatly help the reader to understand the original dataset.

Added

-"2014-2017", At the beginning of the section you talk about 2016-2017. WHy did not you include earlier observations of the same program?

These were pilot observations and not applicable to our analysis. Added in the text

-Can you expand a bit more on the 2D-inidvidual exposures co-addition? If this is done within CLAMATO I am not sure it is relevant for this paper if you do not give more details.

Cut from text

-Figure 1 is not reference in the text

Figure reference added

==> Overall this section lacks a good description of CLAMATO (in order to make the paper as self sufficient as possible). How were the galaxies selected? How faint are they? It is important to give the reader an overview of the survey. Finally, the galaxies selected for the purpose of the paper should be included in this section (that could be renamed 'The CLAMATO observations and sample selection'). I believe paragraph 1&2 could be merged and a bit more information on the observation and reduction process could be given

We have reorganized the paragraphs and section, and added more detailed descriptions on CLAMATO. We also provide a Table listing all of the analyzed spectra.

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3-Composite spectrum

-I would invert sentence 1 and 2.

Inverted and rephrased

-"Are more or less consistent"--> That should be avoided. Moreover, consistent with what?

Rephrased

- As you say, you could have done the measurement based on individual teff estimation. Have you tried it? If so, is there any difference with the results presented in the paper?

The S/N of our individual spectra would not have allowed for reliable SED fitting; therefore,we did not attempt to estimate tau_eff in that way

3.1----composite sample

-"lie within 2.25<z<2.75"--> This is different from the abstract that states 2<z<3. Be consistent.

Fixed

-"We only use the majority interval" --> What do you mean?

Made clear in the text

-"566 objects"--> in What??

Rephrased to state: “566 galaxy spectra in the $2.0 \leq z \leq 3.0$ interval”

-So you use in the end 134+126=260 galaxies? at the end of the introduction you mention 202. Please check the numbers.

Numbers updated

--> This part 3.1 would be more suited at the end of section 2.

Reorganized

3.2-----stacking

-You mention the de-reddening by Milky-Way dust which is an important correction to the spectroscopy. Did you consider any other correction (e.g. atmospheric extinction, slit loss due to atmospheric diffraction)?

LRIS has an atmospheric dispersion corrector, so that is not an issue. The fluxing of the spectra did have a term accounting for atmospheric extinction. This was added to the text.

-"We normalize using values.."--> What do you normalize? The individual spectra? If so, state it.

Now stated

-"We trimmed..."--> What do you mean by trimming?

Cutting the edges. should be clear in context

-"We shifted the the"--> Repetition of 'the'

Fixed

-"Quite noisy"--> What does that mean? give numbers.

Rephrased and quantified

3.3----Bootstrapping

-'We chose a random selection of spectra'--> How many?

Number added

- More details about point [5] and [6] would help to understand the process. In general, here you describe what you do but why you do it is not clear.

Clarifications and justifications added

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4-SED modelling

-Why not trying to fit individual galaxies as in Thomas+17?

Justification in section 3

-How is E(B-V) sampled during the fit? This is an important parameter to take into account when fitting galaxies, in particular when the region of interest is the IGM.

Dust model cited. Possible range: (0.0-5.0) for E(B-V) added

-Why only 10 stellar ages? 40Myr seems very young as an upper value.

As star light between 1200-2000A is dominated by young massive O-stars, we only look at these young ages. Justification and citation added.

-If I understand well you fit only a short wavelength range (1225-1400). How stable is the fit in such a small fraction of the spectrum? What are the other fitted parameters?

Added information about how the fitted parameters vary based on input. And as noted below, we have validated using an LBG analog at low redshift.

--> To validate your method you must show that the fitting process is robust. This is for the moment not the case

We agree with the referee that this is a key aspect of the paper. To address this issue, we have analyzed the SED of an LBG analog at low-z which has negligible IGM attenuation. We show that the extrapolation of the SED shortward of Lya accurately reproduces the spectrum. We include a new figure and text describing this analysis.

Table1: Add in the caption: 'Based on the fit of stacked spectrum'. Also the number of additional spectra would be welcome in the table.

Added

Figure 5: No reference made to that figure in the text.

Figure reference added

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5-ANALYSIS

-Equation 1--> please describe each component of the equation (l_i, z_med, z_i, l_1216)

Descriptions added

-Equation 1--> Why do you introduce this new redshift? What does z_i represent?

Context given and redefined variable to be z_piv

-You take z_med = 2.32, why?

Number updated and justification provided in the text

5.1---errors

-You should combined this sub-section with the beginning of section 5 (maybe call it 'teff measurement and associated errors')

Combined

5.2---Redshift evolution

-No reference to Fig.6 in the text.

Figure reference added

-You have a set of measurements (2.1<z<2.25) that is well above the trend. Can you elaborate on them? Why are they so out?

Discussion in the text. It is our expectation that these are a statistical fluke. Note that they are correlated with one another, i.e. not strictly independent which explains their systematic appearance.

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6-SUMMARY

-2] I think the most direct way to improve the fit would be to use the IGM during the sed fitting.

While this is worth further consideration, for now prefer to avoid prescribing a functional form for the redshift evolution of tau_eff. Instead, we explored the results independent of any such assumption.

-3] The comparison to the literature should not be in the summary but rather in section 5.2. Not reference to Fig.7 done in the text.

reorganized

-4] Where is Becker+13 in the plot? The author are mentioning the accepted predictions for the evolution of teff'. What are these?

Becker+13 added to the plot and discussed in the text. citations added for predictions of tau_eff

-5]A general conclusion would be a nice addition to the paper.

Summary and forward looking remarks added