

Atmos. Meas. Tech. Discuss., referee comment RC2  
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## Comment on amt-2021-406

Anonymous Referee #1

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Referee comment on "Measurement of the vertical atmospheric density profile from the X-ray Earth occultation of the Crab Nebula with Insight-HXMT" by Daochun Yu et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2021-406-RC2>, 2022

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General comments:

This manuscript presents a method to retrieve atmospheric (neutral) density profiles in the mesopause/lower thermosphere region from X-ray occultation observations with Insight-HXMT. The topic of the manuscript is suitable for Atmospheric measurement techniques and novel methods to measure neutral density in the lower thermosphere are certainly of great interest for the scientific community. However, the manuscript contains many linguistic mistakes and little issues. I point out some of them, but probably not all of them. I have several general concerns regarding this paper (which is based on the analysis of a single occultation measurement):

1. It took me a while to realize that the method applied here is quite different from the usual methods to retrieve vertical profile information from occultation measurements. If I understand correctly (please correct me if I'm wrong), you don't retrieve the atmospheric density at different altitudes independently, but you simply scale the MSIS density profile by a constant factor. Is this correct?

If yes, I'm not sure what the overall quality of importance of the retrieved density profiles is, because there are potentially large errors associated with this approach. Ideally, you should carry out a vertical profile retrieval as it is done in the many other studies you cited in the introduction, that have not only 1 (or 2) degrees of freedom, but many more. A large part of the paper suggests that you do the "usual" retrieval, which is misleading. If such a simple retrieval (i.e. scaling a model profile) is used, you should at least state explicitly (already in the abstract) that a very basic retrieval is done by simply scaling a model density profile. Ideally, the retrieval should be done as the "standard" occultation retrieval, i.e. by retrieving (more or less) independent information for many different atmospheric layers.

2. Please excuse my ignorance, but you write that the X-ray photons are directly absorbed in the K- and L-shells electrons of atoms, including atoms within molecules. Does this mean that, e.g. O<sub>2</sub> counts as two absorbing "particles", because both O atoms can absorb? Or does O<sub>2</sub> count as one absorbing "particle"? This is not discussed and it will make a big difference. Please discuss this at an appropriate place in the paper.

Another general comment: in the introduction you list several existing satellite missions that provide atmospheric "density" profiles. However, most of them product density profiles of specific atmospheric species and not neutral density. Please make sure it is explicitly mentioned what species are retrieved and whether it is (total) neutral density or not.

In my opinion the manuscript requires at least a major revision, and ideally a "real" occultation retrieval should be carried out. If I interpreted the method description incorrectly, please let me know.

Specific comments:

Title: I suggest writing "Measurement of the vertical ..."

Line 5: Please spell out "HXMT". This is not defined in the entire paper, as far as I can tell.

Line 18: Please spell out "RXTE"

Line 20: "study demonstrate" -> "study demonstrates"

Line 27: "of the reentry vehicle" -> " of reentry vehicles"

Line 28: "of the reentry vehicle" -> " of reentry vehicles"

Line 39: "have been being developed" -> "have been developed"

Line 41: "uesd" -> "used"

Line 41: "and satellites." Do you really mean in-situ measurements in the middle atmosphere by satellites? I don't think this is possible.

Paragraph starting on line 41: what about falling sphere measurements? They also provide atmospheric density profiles, at least the relative vertical variation of the density.

Lines 46 – 49: Please provide more information on the Chinese cubesat project. What altitude range will these in-situ measurements cover? I doubt it is below 130 km or so.

Line 53: "and to retrieve atmospheric density"; SABER does retrieve the density profiles of several atmospheric constituents, but I doubt that there is a neutral (total) density data product. Please clarify your statement.

Line 55: "In addition to the direct measurements of atmospheric density by sounding rockets and other means"; what do you mean by "other means"? Are there really any other means?

Line 58: "There are some previous studies on the retrieval of atmospheric density"; Do you mean specific species or the "total" number density? I think you mean specific species, that should be made clear.

Line 61: "basing on" -> "based on"

Line 65: "used optimal estimation algorithm" -> "used an optimal estimation algorithm"

Page 3 in general: I'm not sure if you want to provide a complete list of all occultation

measurements, but but there are several more, i.e. SOFIE/AIM, GOMOS/Envisat, and of course the SAGE and POAM series.

Line 81: "However, the Earth's atmospheric density retrieved results are significantly lower" -> "However, the retrieved atmospheric densities are significantly lower"

Line 83: "temperature profile difference" -> „temperature profile differences"

Same line: "gravity wave" -> "gravity waves"

Line 90: "X-ray" -> "X-rays"

Line 90: "XEOS can retrieve the neutral atmospheric density in the upper mesosphere and lower thermosphere, which cannot be detected by other means."; I don't think this is true. I'm aware of a neutral density retrieval in the MLT region from limb-scatter observations with the SCIAMACHY instrument. This retrieval has not been published, but it is possible to perform these retrievals from limb measurements in the optical spectral range.

Line 115: "for the studying of" -> "for the study of"

General question/comment on the method and Fig. 1: How important is extinction by scattering? Is it negligible compared to absorption? I don't know, and it would be of interest to the reader, I think. Please provide some information on this point.

Caption Fig. 1, line 6: "black solid line" -> "black solid lines"

Line 130: "Only observations from the small FOV detectors excluding the detector ID of 29 and 87"; Please mention why these detectors were excluded.

Figure 2: please explain "barn". The typical reader of AMT will probably not know what it means.

Text around Fig. 3: I suggest mentioning what wavelength range the energy range from 1 - 10 keV corresponds to.

Figure 4: I'm sorry, but I don't understand this Figure? It doesn't make sense to me. What orbit is the spacecraft in? A LEO, right, according to Fig. 1. The Figure suggests that the Earth is observed from a great distance. Please explain in the caption, how the Figure should be interpreted. How long is  $t_F$ ?

Figure 5: What is the reason for the relatively large variability above 100 km tangent height?

Caption Fig. 5, line 1: "are observations data" -> "are observation (or observational) data"

Same caption, line 2: "represent the trend"; How was the "trend" determined? "Trend" is a very vague term here.

Same line: "regions correspond" -> "region corresponds"

Same caption, line 3 AND line 5: "height ranges" -> "height range"

Same caption, line 4: "The blue shadow colored regions correspond" -> "The blue colored region corresponds"

Same line: "For clarity, the extinction process for occultation"; please rephrase, it is not

the "extinction process" that is shown here, but the height range, where it is relevant.

Line 155: "represent the trend"; What does "trend" mean here? What function is used?

Line 157: "height ranges" -> "height range"

Line 163: Please delete "X-ray" in "for X-ray atmospheric density".

Line 164: "The ionized states, electronic states and chemical bonds within the molecules of atmospheric components have no effect on the absorption of X-rays in the extinction process."; What about O<sub>2</sub> (or N<sub>2</sub>). Does O<sub>2</sub> count as 2 absorbing "particles" or as one? If each atom counts, then one has to make assumptions on the relative abundance of atomic and molecular constituents (O vs. O<sub>2</sub> and N vs. N<sub>2</sub>) in the retrieval.

Line 168: "It is impossible to distinguish atoms from molecules"; please see last comment.

Caption Fig. 7, line 1: "The predicted lightcurves from Insight-HXMT"; Are they predicted (i.e. modelled) or "from" the measurements? Please clarify.

Caption Fig. 7, line 3: "basis function"; I'm not sure why the term "function" is used here? I'd use "input data" or something like that.

Caption Fig. 7, line 4: "occultation depth"; What do you mean by "occultation depths". Please rephrase or define.

Equation (2): I don't really understand this equation. The integral is the integral along the line of sight, right? If yes, this should be mentioned explicitly. If you integrate along the line of sight, why is  $N_s$  the column density of each component along the line of sight. That doesn't make sense. I think something is wrong here.

I'm also not sure, why the correction factor  $\gamma_s$  is needed here. The optical depth is determined by number densities (or the integral thereof) of the relevant species and the cross section. At this stage, not correction should be required.

I think that the number densities here are the MSIS model number densities, which are corrected by the correction factor. Is this the case? This must be mentioned explicitly, otherwise one cannot understand what is done here.

Also: There is no mention on the ray-tracing through the spherical atmosphere, i.e. the determination of the slant column densities. How do you do this? What assumptions is it based on?

Line 187: "is shown" -> "are shown"

Line 187: ".. from Insight-HXMT"; Are they predicted (i.e. modelled) or "from" the measurements? Please clarify.

Line 188: Please define "occultation depths" or use another term.

Line 190: "our basis function"; again, why "function"? Is it really a function in the mathematical sense?

Line 195: "fitting is good" -> "fit is good"

Caption Fig. 8, line 2: "of the fitting" -> "of the fit"

Line 198: "of the fitting" -> "of the fit"

Line 202: "but their total atmospheric density (N+O)"; Does "N" here stand for N and N<sub>2</sub>? This should be made clear.

Line 203: "Ar is an atmospheric composition" -> "Ar is an atmospheric constituent"

Line 207: "The number density of each atmospheric component needs to be given as a basis function"; What does basis function mean here? Does function mean a parametrization of the vertical density variation? This is not clear.

Line 208: "the atmospheric model" -> "the atmospheric models"

Line 209: "as our basis function"; see above comment.

Table 3, column 4: what does "average" mean here for the F10.7 cm radio flux? Over what time or spatial range did you average and why?

Equation (3): Shouldn't the background noise  $B$  be zero on average? Why is this not the case?

Equation (5): "!" at the end; Is this intentional, i.e. is this a factorial? of  $D_i$ ?

Line 247: "for the correction factor  $\gamma_s$ "; Please state explicitly, whether the entire MSIS density profile is scaled with this single factor, or whether the factor depends on altitude.

Line 250: "where the first 1000 steps in each walker are burned."; What does "burned" mean here?

Line 256: "basis functions"; see above comments.

Line 276: "This indicates an overestimation for the density from NRLMSISE-00 model prediction."; Only if the NRLMSIS 2.0 result is correct, which we don't know. I suggest deleting this statement. The difference between the model versions is already stated in the previous sentence.

Line 305: Please mention, how many degrees of freedom (dof) are there. Also: "dof" has not been defined.

Line 320: "and the gaps" -> "and gaps"

Line 333: "altitude range .. overlaps" -> „altitude ranges .. overlap"

Line 337: "This is because the XEOS method is an altitude-dependent method, different energy

bands have different sensitive altitude ranges .."; It may also be a consequence of your basic approach to use a scaling factor (if I understand correctly) rather than retrieving the actual vertical variation.

Line 341: "by solar activities and geomagnetic activities" -> "by solar activity and geomagnetic activity"

Line 343: Same comment

Line 346: delete "the" in "under the extreme" and "and the very"

Same line: "the severe geomagnetic storm" -> "a severe geomagnetic storm"

Line 347: delete "the" in "and the quiet .."

Line 351: Please explain AIC and BIC. What do the numbers mean? These criteria are not discussed in the paper so far.

Line 361: "the density profile is retrieved."; Please state explicitly, whether only a scaled version of the MSIS density profile is "retrieved" or a vertical density profile with more than one degree of freedom.

Line 366: "And the extinction curve can be better described by the XEO retrieved density profile."; I don't think this has to be mentioned explicitly. That should be obvious. If it is not the case there is something wrong with the retrieval.

Line 371: "The XEO retrieved density profile in the altitude range of 95–125 km has a

better description for the XEO extinction lightcurve than the NRLMSISE-00/NRLMSIS 2.0 model .."; Again, this does not have to be mentioned explicitly. Please delete.

Line 383: "The Insight-HXMT satellite can join the family of the XEOS."; Well, you should first do a full vertical profile retrieval, not just a scaling.

First text block on page 18: One can use the information from different spectral channels in a simultaneous retrieval. This should be the goal.

Line 393: The differences can also be due to model errors and/or retrieval errors.

Line 395: "gravitational waves"; I doubt it. You mean gravity waves, not gravitational waves, right.

Lines 391 and 395: add space before Determan reference.

Line 398: "retrieval method need" -> „retrieval methods needs"

Figure 11: Why do you ratio the HXMT results and the MSIS profiles for Sep 30, 2018 by the MSIS profile on Nov 14 2005? That doesn't make sense in my opinion. It would make more sense to use an MSIS profile for Sep 30, 2018, because this date is the focus of the current paper.

Figure 13: Please mention in Figure caption, which model was used for these simulations.