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June 25, 2021

Referee #1  
Annales Geophysicae

Dear Sir or Madam

Thank you for taking the time to review our submission *Observations of sunlit  $N_2^+$  aurora at high altitudes during the RENU2 flight*. This response will reference each paragraph individually.

- *From line 170: It is still not clear what 'not included' implies and it would be helpful if it was explained more clearly how this 'omission' is related to the ionisation rates estimated in this section, and the implications.*
  - We agree it was not completely clear. The paragraph has been rewritten.
- *Regarding the statement "The exact amount (of resonant scattering of sunlight) is hard to determine. . .", a quick search suggests that more recent work than Romick (2001) on this topic is Jokiahho et al. (Ann. Geophys., 27, 3465–3478, 2009), which is a statistical study from Svalbard. It shows how the proportion of scattered  $N_2^+$  depends very strongly on both the energy of precipitation and shadow height. They state that this energy dependence means that case studies are more relevant than a statistical approach, given the many possible variations in auroral conditions. In the present work, the conditions over Svalbard during the rocket flight were quite variable. There is a discrepancy likely between the measurements (and model) from the rocket, and the brighter and more active auroral conditions within the MSP scans. Why not put the rocket track on the 427.8 nm MSP scans, and use this as a discussion point for the above comparison?*
  - The referenced paper is a study of remote data with a steady state model. As the paper and the reviewer also states, the conditions over Svalbard at the time of the rocket were anything but steady. Furthermore the referenced paper in its conclusion states its limitations and explains that the model is limited, which does not contradict the statement that "the exact amount is hard to determine".

As for putting the rocket track on the 427.8 nm MSP scans (similarly discussed in "paragraph 4" of the previous response), it is put on the 630.0 nm track in figure 7, and could be copied to the 427.8 nm track, though we don't feel that it would add any value, as figure 1 shows that the rocket only crossed the track at one point. As these rockets are not steerable, the accuracy is not sufficient to guarantee a flight along the MSP line (which would not be possible anyway due to the location of the launch pad). The error, if the MSP data was directly compared with the rocket, would be large given the discrepancy in position. This was also discussed in the paragraph 4 in the previous response.

We have rewritten the paragraph and included an explanation of why the comparison is not done.

- *There is still a question (see previous paragraph 3) about the statement: “..it was found that sunlit aurora was a major part ( 40%) of the observed 427.8 nm emission.” Section 4.1.3 provides an estimate of the ionisation rates from both photoionization and electron impact, and so it confirms the known fact that their ionization efficiencies are very similar and very hard to distinguish (also stated by Jokiah, 2009). The real significance of the 40% figure for 427.8 nm emission that is novel and of importance, needs to be made clearer.*
  - The significance of the estimation comes from the fact that it uses *in situ* data, compared to the indirect remote sensing data as input to a static model in Jokaiho et al. 2009. To make it clearer, *in situ* has been added to the abstract and *found* changed to *estimated*.
- *Discussion of Fig.6 (wrongly named 4.1.5 in text around line 200) is still hard to follow, not helped by some unintended repetition of a sentence within this paragraph (lines 201 and 204). The statement “The resonance scattering emission vastly exceeds the direct auroral emission” is followed by a sentence with “therefore...” but the logic of this sequence is unclear. The sentence that is repeated is vague - “could affect some of the observations.” I presume the sentence should be in its second position, leading on to the discussion of 630.0 nm. The paragraph needs to be rewritten to be a logical entity.*
  - Sorry the wrongly labeled reference, it was due to an obscure L<sup>A</sup>T<sub>E</sub>X error. We are also sorry for the confusion by the duplicate sentences. We have rewritten this paragraph, see the difference document.
- *The comparison of the data and the model is still not easy using this figure. The answers to the previous review do not attempt to help this situation. Having to compare the presented results with those from the published Hecht paper is not ideal. I wonder if some helpful labels or shaded regions could be included to aid the eye. If I have followed correctly, it is claimed that there is a good comparison with the model between 550-600 from precipitation induced ions which have scattered emission, but between 500-640 the ‘plateau’ is not seen in the model, hence it must be from extra N<sub>2</sub><sup>+</sup> ions from upflows in the precipitation region. If I am correct in my interpretation, then these features would be easier to see if they were shaded or marked in some way, and then the text made more clear. I have had to read the two paragraphs many times while examining the figure to check I was seeing the features as described.*
  - The paragraph has been rewritten in an attempt to clarify this better. See the difference document for the changes.

Kind regards on behalf of the authors

Pål Gunnar Ellingsen