Manuscript Title: A New Approach to Inversion of Multi-spectral Data with Applications to FUV Remote Sensing
Manuscript Number: egusphere-2025-5570

Dear Editor and Reviewers

Thank you again for the thoughtful reviews. We greatly appreciate the time and effort put into reviewing our work. In the following text, we have reviewer's comments in bold followed by our responses in plain text.

1 Response to Reviewer 1

- **The reference to Zhang et al., 2019 in line 45 should be removed. It is unnecessary, and while a linear relationship was reported based on experimental results, it has not been established theoretically. From a theoretical basis there are unresolved questions about the technique.**

  We have removed this reference. The text in question now contains only the reference to Cantrall and Matsuo 2021.

- **As discussed in the responses to earlier comments on lines 86-87, the relative vibrational populations in some models of the emission do not have a dependence on temperature. Until that uncertainty is resolved, the current wording may lead readers to an inappropriate direction.**

  The version of the text in question, which corresponds to lines 86-87 in the original preprint and lines 105-106 in the current version, has been updated to read

  > The forward modeling of the neutral temperature is based on the vibrational-rotational band model (Budzien et al. 2001), which supplies laboratory LBH spectra across a range of neutral temperatures given vibrational populations of N_2.

- **Laboratory LBH spectra are expected to be less representative of the observed vibrational populations than information from the flight observations, e.g. Aryal, et al. (2022). For modeling studies, either can work, but for work with observations, while not essential, prior information from the observations would be more appropriate. The Ajello et al. (2020) are not derived from the GOLD data. That statement is incorrect.**

  Regarding the statement about the Ajello populations being based on GOLD data, this has been removed (line 107 in the current version):

  > For the purposes of the study, we use the populations in Ajello et al. 2020, which are derived from laboratory data.

  We also added some additional context at the end of Section 2.4 about choosing vibrational populations (lines 231-233 in the current version):

  > For this analysis, we used the vibrational populations of Ajello et al. 2020. However, in an operational setting using instrument-derived populations (e.g. Aryal et al. 2022) should be considered.

- **Regarding the response to the comment on lines 98-99: Some of the advantages are "potential" advantages. A small wavelength range also requires knowledge of any relative variation in the instrument performance across the section of the spectrum used. A smaller versus larger wavelength range comparison involves a tradeoff between signal-to-noise in the data available for the retrieval versus the uncertainty associated with the instrument performance. Therefore, the advantages are "potential" advantages that depend on the measurements. That distinction should be made more clearly. The sentence beginning at**

the end of line 117 in the revised manuscript is incorrect. Other techniques behave similarly, having a dependence only on the relative calibration (and the absolute sensitivity, on which SNR depends).

We have updated the section in question to read

> As noted in Zhang, Paxton, and Schaefer 2019 and Cantrall and Matsuo 2021, two-channel ratio approaches have several potential advantages. These include the ease of calculating a ratio compared to fitting a full spectral model and the traceability of uncertainty by not requiring knowledge of variation in instrument performance across the whole band, rather just a small section of it (Cantrall and Matsuo 2021).

- **Regarding your response to the comments on Lines 249-250 and line 254, you presumably mean "along" the slit. Your comment, "suggests that this variation is due to the varying sensitivity of the detector across the slit" is similar to one by McClintock et al. 2020 (https://doi.org/10.1029/2020JA027809), e.g, section 5, "more accurate along-slit-sensitivity (r (λ_a, ψ_k) in equations (1) and (3)) and a wavelength-dependent background will be implemented", which acknowledges "along" the slit differences in sensitivity.**

  We have made this change.

- **Regarding your response to the comment on line 304: The populations used are noted in the paper. But the Ajello et al. 2020 populations, discussed on line 108 of the revised manuscript, are not derived from the GOLD data. The Ajello populations are acceptable model to model comparisons, but for model to GOLD data comparisons the vibrational populations from Aryal et al., 2022 are more appropriate. The laboratory work referenced uses higher energy electrons than is typical of the daytime photoelectron spectrum, and while showing the effects of cascade, are less representative than the Aryal et al. 2022 paper, which is derived from GOLD measurements.**

  We have made this change, and added a short sentence to Section 2.4 reflecting the appropriateness of instrument derived populations (shown above).

- **A comment regarding your response to the comment on line 334, in the added section 2.4: while the present text is acceptable, wavelength registration errors may be assumed insignificant for a test of the technique, the registration errors for data from GOLD or other instruments are likely to be substantially greater than 0.1 Angstroms.**

  We have slightly edited the text in question. It now reads (lines 198-200)

  > We consider the GOLD L1C data to have sufficiently accounted for these sources of uncertainty for the purposes of our exploratory analyses, but this assumption should be revisited for future operational application of these methods. It is always desirable to quantify biases due to these errors as accurately as possible.

- **Line 205 of the revised manuscript: in the first sentence you presumably mean variations in sensitivity "along" the slit.**

  Yes, we do. The text in question has been edited:

  > One important source of error in this estimation scheme is variation in the sensitivity of the instrument along the slit. Some consequences of this can be seen in Section 4. Because the method is constructed as a spatial model, it is possible such spatially correlated biases may be spread into otherwise unaffected areas of the detector. Variations in instrument sensitivity both spatially and in the frequency domain should ideally be better considered for future applications of this technique.

2 Response to Reviewer 2

- **I would like to thank the authors for their detailed responses and for incorporating the suggested changes. The manuscript is significantly improved. The demonstration of the method's performance at high solar zenith angles is a valuable contribution, and the statistical treatment of the photon count ratios is now well-justified. The methodology is sound and the results are presented clearly. I am pleased to recommend the paper for publication in its current form**

  Thank you very much for your kind words. We appreciate your thoughtful and thorough review of our work.

We sincerely thank the reviewers for their thoughtful comments and detailed discussion throughout this process, and the editor for their facilitation of the process. We hope that the updated manuscript is considered suitable for publication in Atmospheric Measurement Techniques.

Sincerely,
Matthew LeDuc
University of Colorado Boulder

References

Ajello, Joseph M. et al. (2020). "The UV Spectrum of the Lyman-Birge-Hopfield Band System of N2 Induced by Cascading from Electron Impact". In: *Journal of Geophysical Research: Space Physics*. URL: `https://doi.org/10.1029/2019JA027546`.

Aryal, Saurav et al. (2022). "Constraining the Upper Level Vibrational Populations of the N2 Lyman-Birge-Hopfield Band System Using GOLD Mission's Dayglow Observations". In: *Journal of Geophysical Research: Space Physics* 127.9. URL: `https://doi.org/10.1029/2021JA029869`.

Budzien, S. A. et al. (2001). "Thermospheric temperature derived from ARGOS observations of N2 Lyman–Birge–Hopfield emission". In: *Eos Trans. AGU, 82, Spring Meet. Suppl.*

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Zhang, Yongliang, Larry J. Paxton, and Robert K. Schaefer (2019). "Deriving Thermospheric Temperature From Observations by the Global Ultraviolet Imager on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics Satellite". In: *Journal of Geophysical Research: Space Physics* 124.7, pp. 5848–5856.