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Atmospheric Measurement Techniques Discussions

Interactive comment on "Note on rotational-Raman scattering in the O_2 A- and B-bands: implications for retrieval of trace-gas concentrations and terrestrial chlorophyll fluorescence" *by* A. Vasilkov et al.

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Dear Dr. Guanter:

Thank you very much for your comments that have helped us to improve our paper. Below are our responses to your comments shown for convenience in bold face.

Sioris et al: the authors should refer to two papers by Sioris et al ("Filling in of Fraunhofer lines by plant fluorescence: Simulations for a nadir-viewing satellite-

borne instrument" DOI: 10.1029/2001JD001321, and "Impact of rotational Raman scattering in the O2A band" DOI: 10.1029/2000GL012231) dealing with exactly the same topic. Even though it is now more than 10 years since Sioris et al works, I think a critical comparison of methods and results between the this work and that by Sioris et al should be included in the manuscript. Please, rephrase L21 accordingly.

Thank you for providing these references. We include those papers in the list of references in a revised version. We carried out additional radiative transfer simulations and compared our results with those reported by Sioris and Evans in a new Appendix as shown below. Corresponding corrections and additions are made in Introduction; we replaced "To the best of our knowledge, RRS effects in the O_2 A- and B-bands have not been quantified in the literature. However, RRS effects are worthy of consideration owing to the high accuracy and precision requirements..." with "RRS effects in the O_2 A- and B-bands have been quantified in the literature (Sioris and Evans, 2000). However, RRS effects are worthy of further consideration owing to the high accuracy and precision requirements..."

In the conclusions, we added "Note that our definition of RRS filling-in differs from that of Sioris and Evans (2000) who define it as a percentage of the continuum radiance. Use of different definitions of filling-in may lead to somewhat different conclusions regarding the importance of RRS, particularly within the O_2 A-band. Fluorescence contributes a signal with a similar spectral response to RRS, and low levels of fluorescence have a similar magnitude to RRS. It has also been shown that the fluorescence signal may bias xCO_2 retrievals (Frankenberg et al., 2012). Therefore, our definition is more relevant to applications related to retrievals of fluorescence and xCO_2 and leads to the conclusion that the RRS effect is small, but non-negligible even at moderate solar zenith angles."

Appendix A1: Comparison of filling-in with results of Sioris and Evans (2000)

The focus of our work is somewhat different from that of Sioris and Evans (2000) who presented calculations primarily at high solar zenith angles (near 90°). Here, we attempt to reproduce the filling-in reported by Sioris and Evans (2000) for nadir observations at high SZA (89°) with surface albedo of zero. Our calculations are done with FWHM = 0.06 nm or ~1 cm^{-1}. Figure 1 shows the results where we define filling-in as in Sioris and Evans (2000) referencing the RRS radiance to that of the continuum. Our results are very comparable to those of Sioris and Evans (2000) in terms of both spectral dependence and magnitude. Figure 2 shows computed filling-in as defined above and used throughout the manuscript. This definition of filling-in provides much higher values within the O_2 A-band, particularly at high SZA.

RRS and trace-gas retrievals: the references to trace-gas retrievals in the title and in the introduction of the manuscript seem not to be justified by the contents, given that no explicit analysis of the potential biases in trace gas retrievals by RRS in-filling is performed. The authors only speculate about the possibility of those biases by assuming that the spectral effect of RRS can be similar to that of fluorescence, which was shown by Frankenberg et al (2012) to have an impact on XCO2 retrievals. I understand that an end-to-end simulation of this effect is out of the scope of this paper, but still adding some simple analysis of how RRS in O2A would actually affect photon path length in O2A and trace gas retrievals (impact on the estimations of O2 columns?) might be good to illustrate quantitatively to what extent RRS is important.

We agree that the title of the paper may not be appropriate. We changed the title by removing “Implications for retrieval of trace-gas concentrations and terrestrial chloro-

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phyll fluorescence". To illustrate how RRS might affect a retrieval related to photon path length in the O2-A band, we changed the old Fig. 10 comparing the RRS spectral response with that of fluorescence. We removed one the upper fluorescence curve and replaced it with one showing the spectral response due to a 3 hPa change in surface pressure. This surface pressure change produces a similar magnitude and spectral response as RRS, although there are subtle differences (see Fig. 3 below).

We clarified some discussion in the conclusions relating to impact on xCO2 and fluorescence retrievals to make it more quantitative. It now reads "The calculations of Frankenberg et al. (2012) showed that an additive signal from fluorescence of 1% of the continuum could lead to ~1 ppm errors in retrieved xCO_2. Assuming linearity, the neglect of RRS filling-in within the O_2 A-band may then lead to biases in satellite-retrieved xCO_2 of approximately 0.3 ppm." We also rearranged the conclusions a bit and changed "Our calculations show that RRS filling-in of telluric lines is comparable with small to moderate amounts of filling-in due to terrestrial chlorophyll fluorescence" to "Our calculations show that RRS filling-in of telluric lines is spectrally comparable with small to moderate amounts of filling-in due to terrestrial chlorophyll fluorescence (of the order of 0.5 $\mathrm{mW\,m^2\,sr^{-1}\,nm^{-1}}$)."

Figures: a total of 12 figures may be excessive for such a short technical note. Some of them could be grouped in single figures with several sub-figures (e.g. Figs. 4-7 and 89 or 911). Also, either Fig. 4 or 5 could be removed. Please, give the spectral window of the calculations (O2A) in Fig. 8.

We agree. We combined Fig. 4 and 6 and Fig.9 and 11 into single figures and moved Figs. 5 and 7 to an Appendix in a revised version. Appropriate adjustments in the text are also inserted.

We specify the spectral window, 760-762 nm, of calculations in Fig. 8 in the figure caption as well as text.

On behalf of the authors, Alexander Vasilkov and Joanna Joiner

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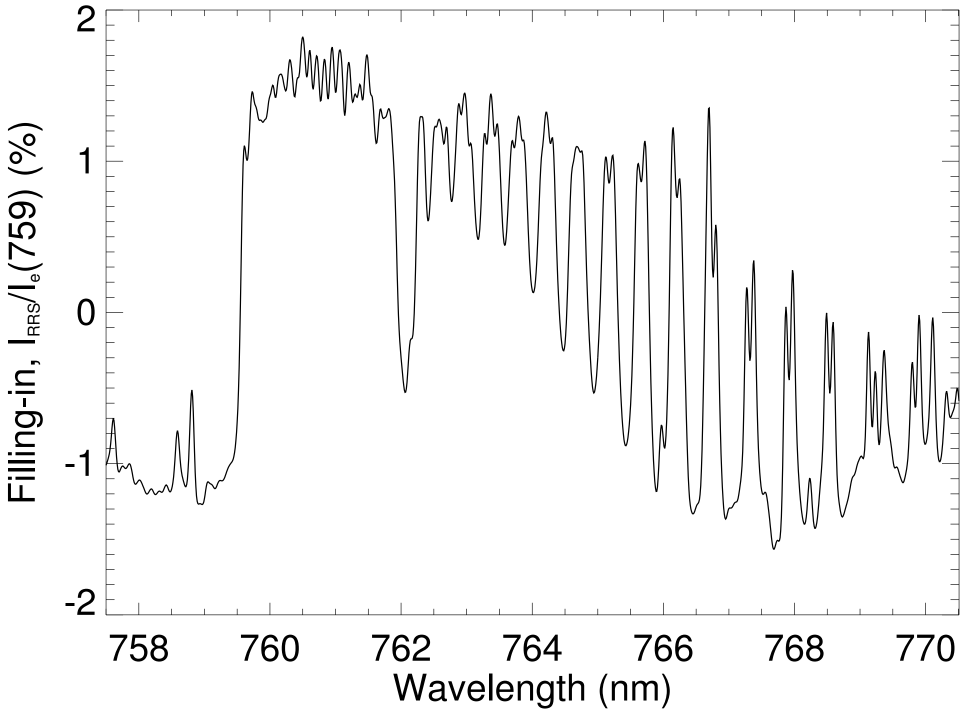

Fig. 1. RRS filling-in computed for conditions similar to Sioris and Evans (2000) with their definition of filling-in.

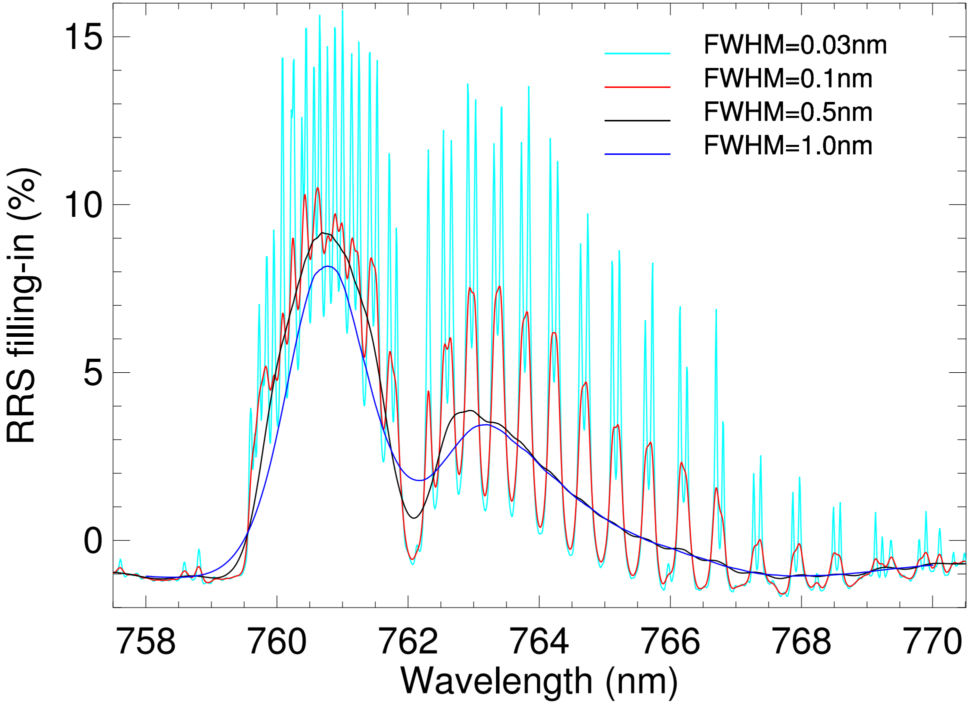

Fig. 2. Filling-in computed for the same conditions as in Fig. 1 with our definition of filling-in and different spectral resolutions.

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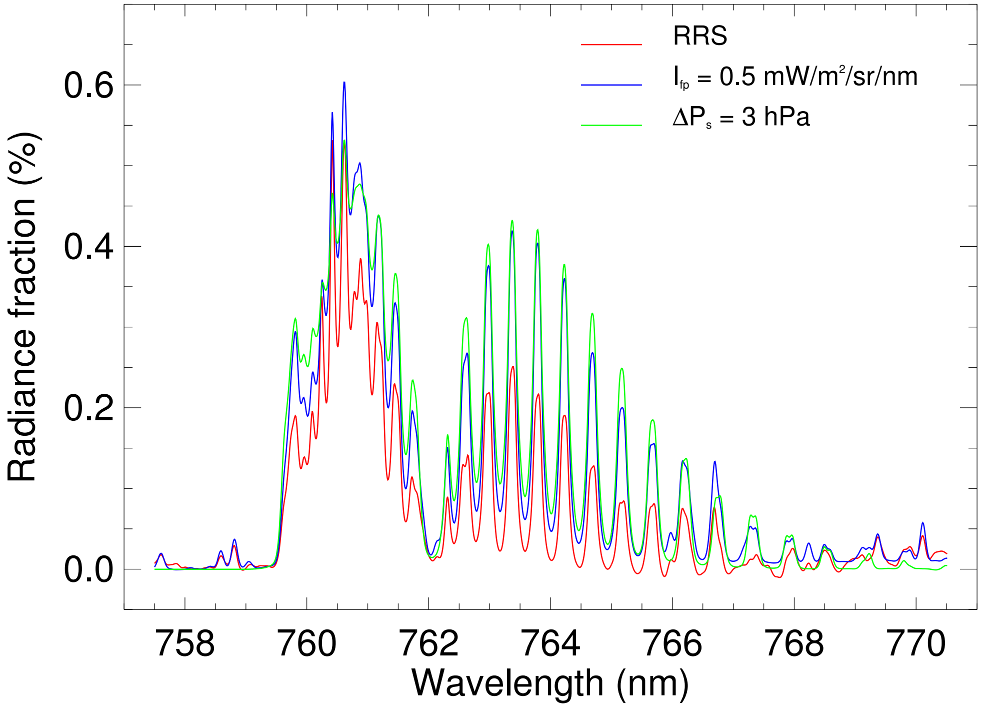

Fig. 3. Comparison of fractional radiance effect of RRS (red), fluorescence (blue), and surface pressure change of 3hPa (green) for FWHM=0.1nm, SZA=45 degrees at nadir, surface albedo=0.3.

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