1. General comments

The paper addresses an important issue of modern Earth observation satellite missions: how to reduce the costs of the instruments while increasing their spatial resolution. As the authors rightly point out, with increased spatial resolution also the signal-to-noise of the spectrometers might need to be increased. One option to increase the signal-to-noise of a spectrometer is to increase the etendue, this is demonstrated by applying basic optic principles and by the use of volume and mass scaling of the instrument. With smaller, lighter instruments used in parallel the launch could be cheaper.

As an example to compare the new approach with, the Sentinel 5 Precursors mission with its instrument TROPOMI is used. From this example and the article's title, my expectation is that the presented approach shows to have similar or better performance for the use of atmospheric observations. However, the current content of the paper does not yet justify its title. The discussion on performance of the new design is so far mostly limited to ground pixel size and signal. Other key performance parameters, such as absolute radiometric accuracy, pointing knowledge and stability, co-registration error (deemed very important for example for the future CO2 mission, https://esamultimedia.esa.int/docs/EarthObservation/CO2M_MRD_v3.0_20201001_Issued.pdf) are not mentioned. The proposal does not seem to include a means for solar observations to normalize the observed radiance. How can comparable radiometric accuracies be achieved in this way? These points should be addressed in an update of the manuscript.

And is the throughput of current state of the art instruments really the limiting factor for their performance? At least for TROPOMI there seems to be so much signal in some of the spectral bands that detector saturation occurs. A higher spatial resolution would in theory be possible for TROPOMI, but is – to my knowledge - limited by internal data rate restrictions.

The main assumption of the paper is that the used scaling approach for volume and mass is valid even for a large scaling factors. When looking at power or thermal lines, or shielding of detectors from cosmic radiation, there certainly is a limit to how small things can be built while keeping their functionality (and withstand the harsh space environment). Also for the spectral and radiometric stability a bigger (thermal) mass has a positive impact. As the validity of the scaling is the main assumption in the paper, a justification and the limits of the assumption should be added to the revised manuscript. For a space-borne mission power consumption is also an important factor, this should also be added.

When comparing the proposal to the example instrument, the numbers as-built should be used for the comparison, and scaled where necessary. Without the SWIR part for example, TROPOMI would be much smaller (and lighter).

As pointed out in the paper, a very good argument to use multiple spectrometers is the redundancy. On the other hand using hundreds or even thousands of devices will certainly add to the complexity of the mission. The increased complexity needs to be addressed in some way in the paper. I could imagine that there is additional data (more overhead, more housekeeping ...) to be accounted for, that (cross)calibration can be more challenging and that the combination of the data of the different spectrometers will be more complicated.

Considering how large a portion the nominal operation of a mission is of the total costs, the increased complexity in instrument control or science data processing is a trade-off which needs to be made. This needs to be made clear in the article.

To conclude, the suggestion to scale down spectrometers and use them in parallel to increase the etendue is a novel idea. As a proposal to replace or improve large high-quality space borne hyper-spectral imagers, the argumentation still shows too many gaps. I'd like to recommend to fill those taking into account the reviewers' comments and to then allow for a second review.

Section 2 of this review lists specific comments and questions about the content and understanding of the paper.
Section 3 contains a few suggestions where to edit the text to allow for a smoother read, minor spelling and grammar errors and formatting issues.

This review is based on the version amt-2020-521.pdf retrieved on the 23rd of April 2021 from https://amt.copernicus.org/preprints/amt-2020-521/. The earlier version (amt-2020-521-manuscript-version1.pdf retrieved on the 20th of January 2021) was not considered.

2. Specific comments

2.1. Figures 1, 3 and 4:

Please adapt Figures 1,3 and 4 such that it shows a properly constructed imaging path. It should also show how slit width and aperture size influence the instantaneous field of view in both along- and across-track dimension.

2.2. Figure 7

Please adapt Figure 7 such that it shows a more realistic scenario. At the swath width under discussion the Earth can certainly not be viewed as flat and the curvature of the Earth should be taken into account. For atmospheric retrievals also the pathlength (slant range) through the atmosphere is a point worthwhile of discussion.

2.3. Table 2

Please refer to the TROPOMI as-built numbers and not the design values, see for example https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-Level-1B-ATBD, https://doi.org/10.5194/amt-13-3561-2020 and https://doi.org/10.5194/amt-11-6439-2018

The telescope design for OMI and TROPOMI differ quite a bit, so it seems weird to compare to a mix of instruments, but title it "TROPOMI type".

- Nominal ground pixel dimension at nadir 5.5 x 3.5
- Instant. ground pixel : this is not very clear what is meant here. Do you mean the IFOV of the optics? For the TROPOMI value it should then be about 1.8 x 1.8 (so no binning applied).
- Ground pixel dimension at the edge of the swath: for TROPOMI about 9 km for across-track (no binning applied for UVIS at the edge)

- Ground pixels : as far as I know, it's less when looking at the binned nominal radiance data. Something of the order of 450. Unbinned it's around 860 pixels for the illuminated region of the detectors.
- With updated values for the focal length, F-Number (see ATBD), also the etendue needs to be recalculated
- The co-addition time is 0.84 s for the 5.5 km ground pixels
- The mass of TROPOMI is around 200 kg the total volume around 700 l. This however covers the 4 spectrographs for the four spectral regions. So if you want to restrict yourself to the UV/UVIS the smaller OMI instrument (65 kg, 70 l) would give a more realistic comparison. To make a proper comparison for mass and volume between the new proposal and the old type, the parts concerning the disregarded spectrometers, the calibration port and data handling would need to be subtracted. If you apply a mass and volume scaling here, it should be mentioned.

#	Page	Line	Section	Comment
SC0	2	4	1	"down to 7 x 3.5 km2 (TROPOMI)" , it's even 5.5 x 3.5, see https://sentinel.esa.int/documents/247904/3541451/Sentinel-5P-Level-1b-Product-Readme-File
SC1	2	8	1	"It appears clearly desirable to further shrink the ground pixel size." A justification for this statement is missing. A reference to the tracking of plumes maybe?
SC2	2	17-19	1	It's not only the shot noise adding to the noise, the read-noise and dark current noise also needs to be taken into account. In addition a detector pixel can only hold a certain amount of signal before it saturates, this depends on pixel size, technology and temperature. So the detector needs to be chosen carefully matching throughput and read-out speed.
SC3	2	17-20	1	"longer exposure times t_{exp}" : at least for OMI and TROPOMI multiple exposures are co-added digitally on-board, the number of co-additions could theoretically still be further reduced. A single exposure needs to be long enough that the SNR is limited by the shot noise rather than the electronic read-out noise.
SC4	5	all	2.3.1	How does the increase in entrance slit area influence the spatial and spectral resolution? If the slit size gets larger in along-track direction, the instantaneous field of view along-track will get larger, or not? What is the limit for a sun-synchronous orbit?
SC5	5	24	2.3.1	A major part of the argumentation in this paper relies on the scaling laws for weight/size used in this paper: There are limits where the scaling does not work that well anymore. I miss a discussion/ a remark on the limits of scaling, see for example Space Mission Analysis and Design: Wertz, James R., Larson.
SC6	6	9	2.3.2	"For satellite instruments in the literature no F-numbers are given". Please add some F-numbers, for OMI and TROPOMI, see for example http://dx.doi.org/10.1109/TGRS.2006.869987 and https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-Level-1B-ATBD

#	Page	Line	Section	Comment
SC7	10	Tab1	2.3.5	"No limit to scaling" at the last diffraction should be limiting, or not?
SC8	11	All	3.2	The mechanical stability is just one aspect that comes in with the scaling. For high-quality space borne observations the thermal stability and shielding from cosmic radiation is also very important. Please explain the impact here.
SC9	11	All	3.2	At least the detectors (and possibly thermal control) will need wiring. If more detectors are used I assume also more wiring (and power) is needed. This is neglected in the discussion. How does this influence the scaling? Please note that the wires cannot easily be reduced in thickness.
SC10	13	All	3.4	For the amount of straylight, the distance to scattering surfaces (optics but also surrounding mounts/walls) does play a role. I cannot follow the argumentation that it shouldn't and that the amount of relative straylight is the same for smaller spectrometers. Also the separation of unwanted grating orders is trickier if less space is available. Please provide evidence for this statement.
SC11	13	All	3.6	For the case study of this paper – individual spectrometers covering the large swath, this section does not add anything. However the point of combining the data on-board is a very important point and deserves a much more detailed discussion. In how far does the amount of data increase when using a lot of spectrometers? What is the fraction of needed overhead (data packaging, housekeeping, controlling...) compared to the large spectrometer case? Considering that a lot of the high spatial resolution missions are struggling with the data volume, this is a crucial aspect to be addressed in more detail in this paper.
SC12	14	All	3.8	It is great, that the authors investigate what is technically possible at the moment. This section would certainly profit from extending this discussion. What springs to my mind are improvements on the grating technology (prism grating prism combination, immersed gratings, freeform optics, use of fibre optics...). An order of magnitude of reduction in volume has also been proposed for single spectrometer, see for example also Crisp et al. https://www.osapublishing.org/ao/fulltext.cfm?uri=ao-59-32-10007&id=442323
SC13	14	30	4	An order of magnitude of reduction in volume has also been proposed for single spectrometer, see for example also Crisp et al. https://www.osapublishing.org/ao/fulltext.cfm?uri=ao-59-32-10007&id=442323
SC14	15	25	4.1	"there are a number": please be specific
SC15	15	30	4.1	What do you define as separate spectrograph? A telescope + slit + dispersive device + imaging system? Or the number of dispersive devices with their own imaging and detector? If it is the latter, TROPOMI has four spectrometers. If it's the former the other numbers are not correct.

#	Page	Line	Section	Comment
SC16	15	44-45	4.1	For the missions the paper uses as reference (GOME, OMI, TROPOMI) the instrument's alignment and the knowledge thereof is rather critical for the mission. I would imagine that multiplying the number of telescopes will also multiply the need for alignment effort and calibration measurements. That seems to be worth mentioning.
SC17	15	46-48	4.1	This statement is not very clear "a somewhat different function for each viewing direction" is the reason for striping? To my knowledge the striping is caused by subtle differences in uncorrected residuals (for example dark current fluctuations) when using Sun-normalized reflectance data. And the suggested design does not seem to include a solar port, is that correct? Also no mention is made of shutters to be able to measure dark current.
SC18	16	12	4.1	It would be helpful here to include that the increase of ground pixel size towards the edges of the swath is mainly caused by the curvature of the Earth and the resulting slanted view towards ground. It is certainly an intriguing idea to try and reduce this effect. I do however wonder how this would impact the complete (gapless) coverage of the swath. To match the along-track size a shorter co-addition time would need to chosen, or not? If the IFOV is reduced at the edges, gaps will be produced. And considering the slanted view, will a smaller sampling distance indeed increase the resolution for the L2 retrievals?
SC19	17	23	4.1	More up to date information for TROPOMI instrument parameters can be found in: https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-Level-1B-ATBD, https://doi.org/10.5194/amt-13-3561-2020 and https://doi.org/10.5194/amt-11-6439-2018
SC20	18	Tab 2	4.1	See separate section.
SC21	19	1-35	4.2-44	These sections do not really add information to the paper. Please consider to omit them.
SC22	19/20	39-5	5.1	The design challenges are at least partly addressed. What has not been shown satisfactorily is that the arrays can also compete with the performance of the larger instruments. What should be discussed, are for example absolute and relative radiometric accuracy; the achievable pointing accuracy and knowledge; and the co-registration knowledge. The individual spectrometers will hardly have identical response, how will this impact the processing and combination of the data?
SC23	20	14-16	5.2	For a CUBESAT surely the date rate to downlink must be limiting, or not? Also the attitude control is more limited than with larger S/C. So while sensitivity and spatial resolution might be improved, can all the data be used? Can you have global daily coverage? What is the pointing knowledge?

#	Page	Line	Section	Comment
SC24	20	19-23	5.2	Again, it also needs to be shown that the performance needed for accurate atmospheric retrievals can be met. So not only groundpixel size and amount of signal , but also radiometric accuracy/stability (over the entire mission), pointing knowledge, co-registration error....
SC25	20	33	5.2	It's good that you mention technical hurdles. The challenges of this approach would deserve much more discussion and should be covered in more detail earlier in the paper.

3. Technical corrections

The article is written in good English and easy to understand and well readable.

In the following a few minor typos and style oversights which I noticed while reading:

#	Page	Line	Section	Comment
TC1	1	40	1	A central component of these instruments ~~is a~~ are moderate resolution [...] grating spectrographs.
TC2	15	47	4.1	This approach would have not more drawbacks, (no more means not any at all, that is not what you're trying to say I think)
TC3	18	8	4.2	There seems to be a reference missing.