EGU21-690, updated on 19 Jan 2022
https://doi.org/10.5194/egusphere-egu21-690
EGU General Assembly 2021

The "Ideal Spectrograph" for Atmospheric Observations

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The analysis of atmospheric trace gas distributions by absorption spectroscopy of scattered sunlight in the near UV to near IR spectral ranges has proven to be extremely useful. A central parameter for the achievable sensitivity and spatial resolution of spectroscopic instruments is the étendue (product of aperture angle and entrance area) of the spectrograph, which is at the heart of the instrument. The étendue of an instrument can be enhanced by (1) up-scaling all instrument dimensions or (2) by changing the instrument F-number, (3) by increasing the entrance area, or (4) by operating many instruments (of identical design) in parallel. While options (1) and (4) allow enhancement by (in principle) arbitrary factors, the effect of options (2) and (3) and measures like better grating efficiency is limited.

We present new ideas and considerations on how instruments for the spectroscopic determination of atmospheric gases could be optimized with respect to étendue per volume (or mass) by using new possibilities in spectrograph design and manufacturing. Particular emphasis is on arrays of massively parallel instruments for observations using scattered sunlight. Such arrays can reduce size and weight of instruments by orders of magnitude, while preserving spectral resolution and light throughput. We also discuss the optimal size of individual spectrographs in a spectrograph array and give examples of grating spectrograph systems for use on a (low Earth orbit) satellite including one with sub-km ground pixel size and daily global coverage.