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Developing and deploying new sensors for in-situ monitoring of clouds

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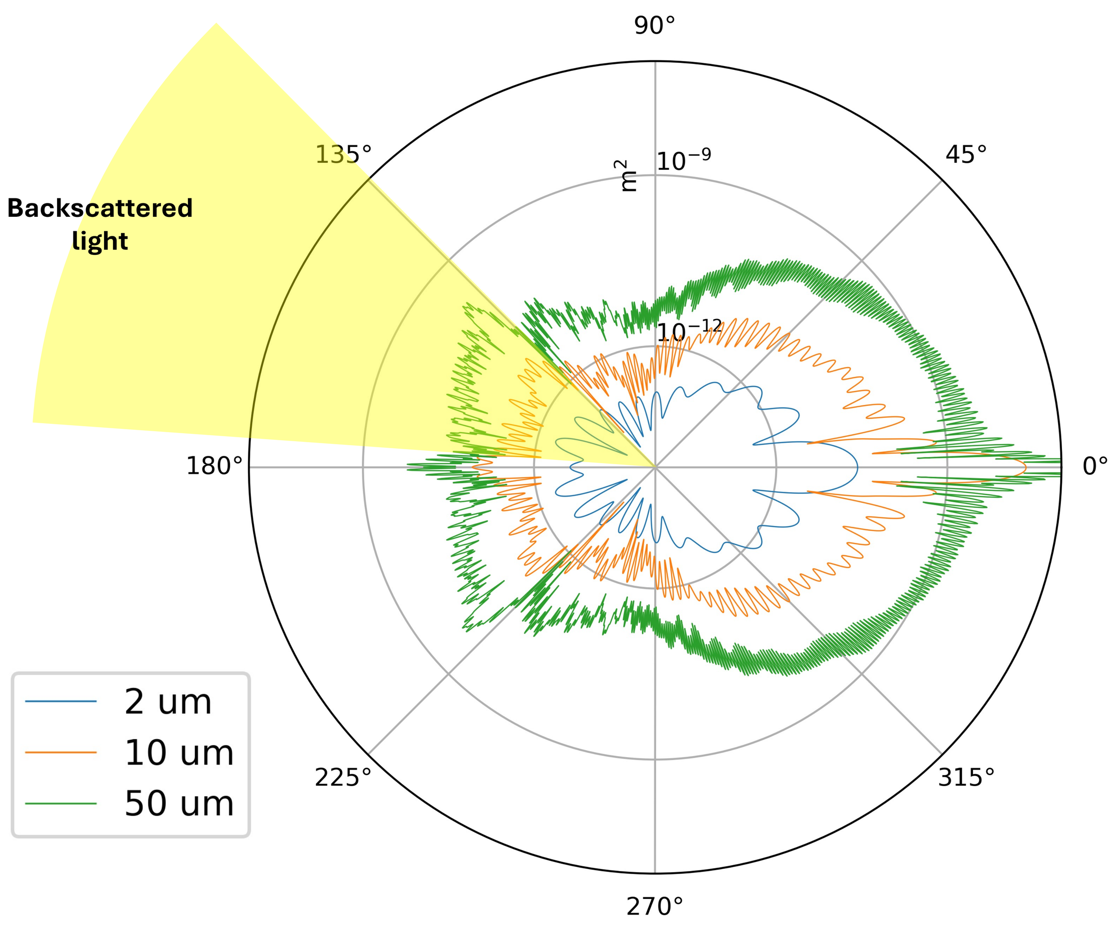
Background

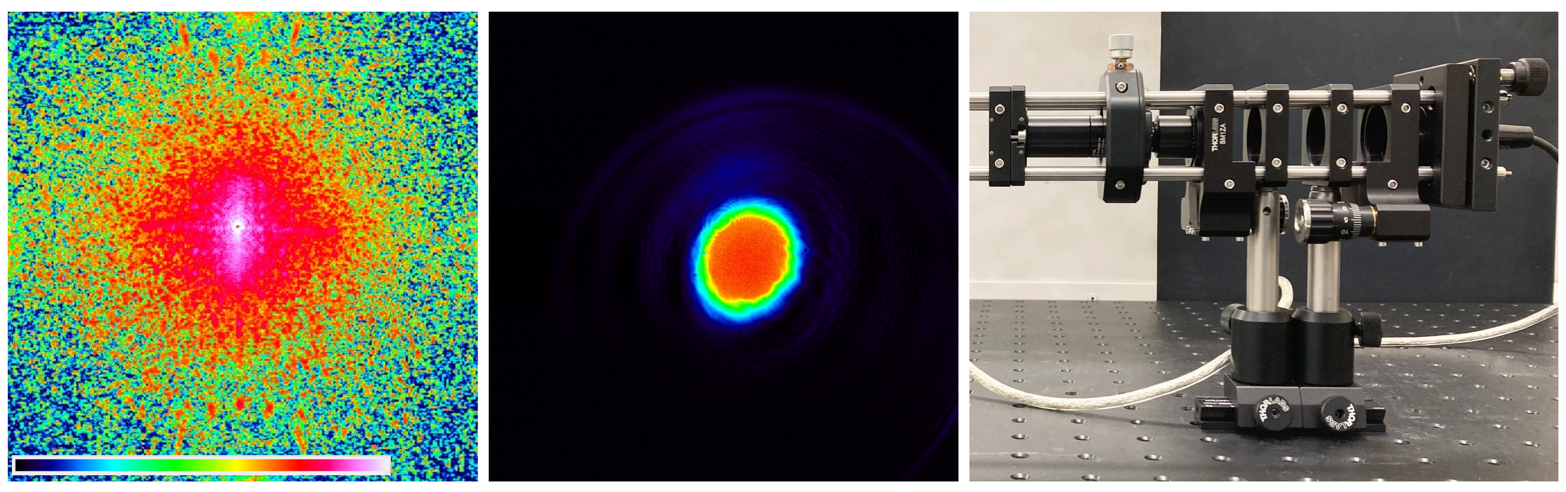
- Cloud droplet probes typically use forward-scattered light (from a laser) to measure cloud droplet size distribution.
- Backscattered light could provide means for a more practical measurement technique that (doesn't require a detector in front of the laser and) could be more easily used on non-specialist platforms e.g. commercial jets.
- **Research Aim:** Investigate feasibility of using backscattered light for accurate cloud droplet size distribution measurement.



'Phase' diagram for spherical water droplets – Scattered light intensity (differential scattering cross-section) over polar angle of an unpolarized 550nm beam (incident at 0°), spherical droplets scatter light symmetrically about the azimuth angle relative to the scattering plane.

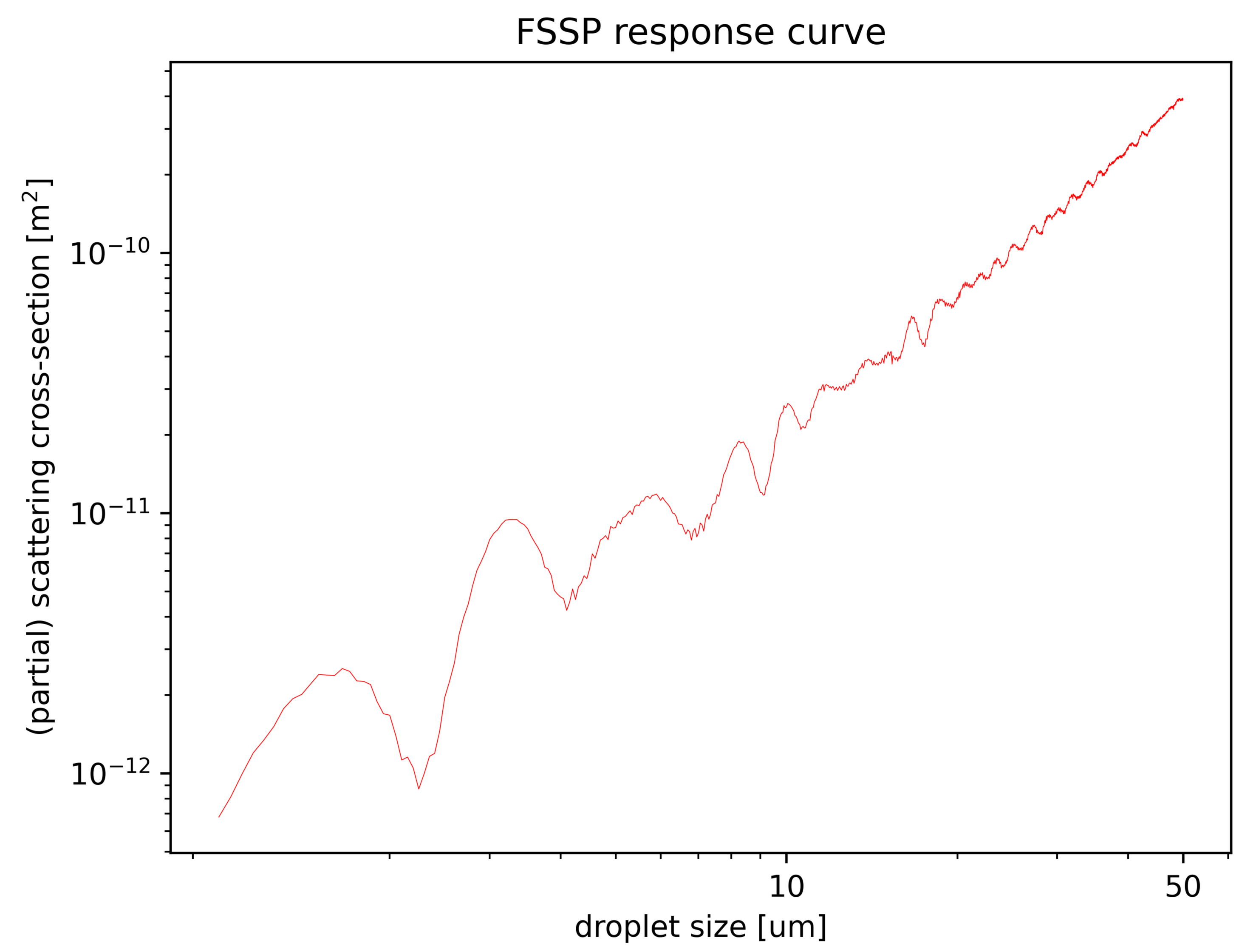
Method

- A model has been developed to produce droplet scattering 'response curves', for a collection optic displaced from an incident beam by a polar angle and will be used to inform optimum backscattering arrangements.
- An optical assembly is being developed to measure backscattered light experimentally and assess arrangements for droplet measurement.
- The assembly will consist of a laser source(s) directed at a scattering target and photodetector(s) that can be adjusted to assess different arrangements and parameters.

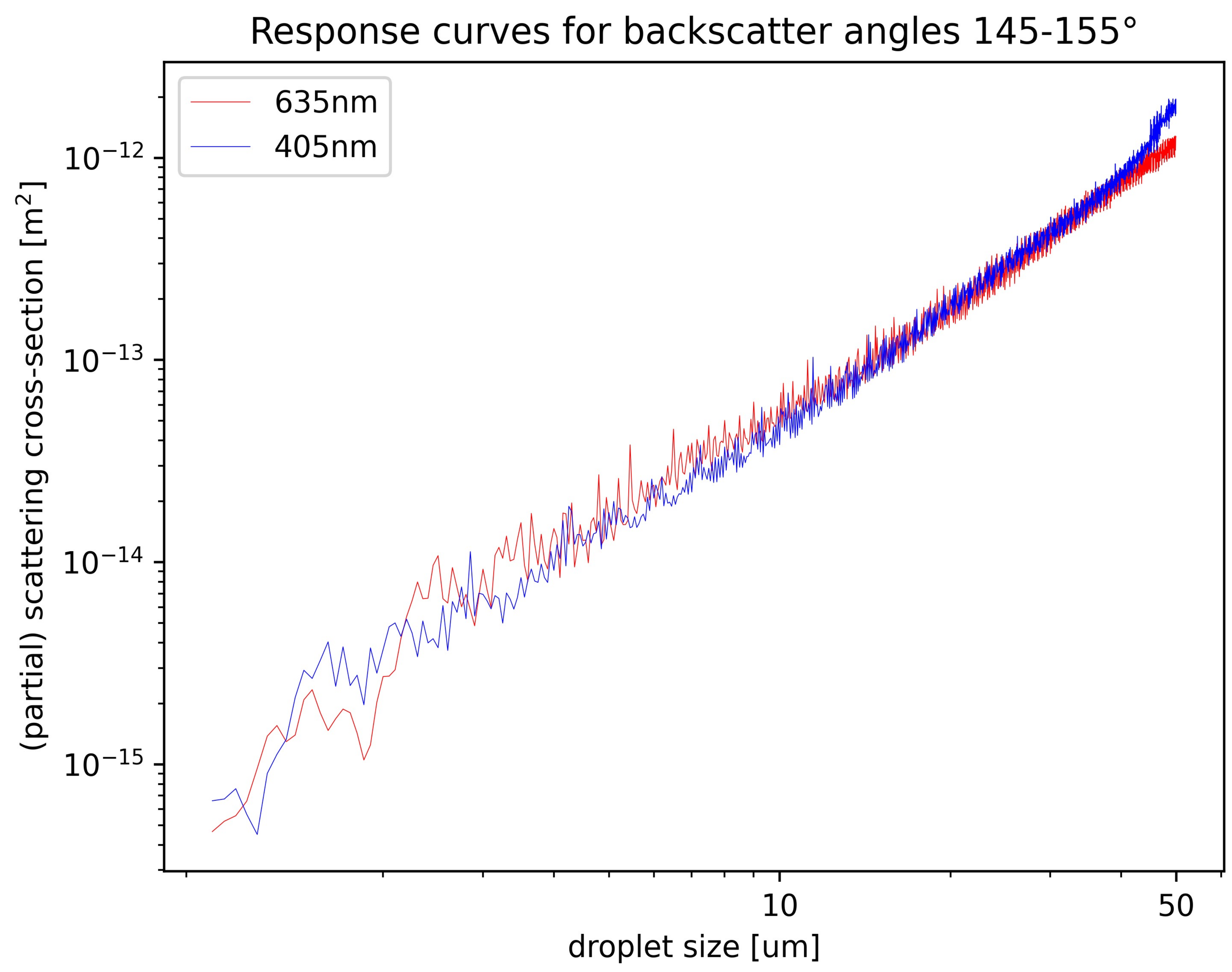


(L) Backscatter Cloud Probe (BCP) beam profile – The BCP is an existing backscatter instrument, but is limited for quantitative measurement [1]; variation of beam intensity within the sample area is one source of uncertainty.
(C) Beam profile produced by a spatial filter – A more confined and uniformly intense laser beam profile could help improve backscatter size measurement.
(R) Spatial filter and laser source – A spatial filter consists of three stages; an aspheric lens, a pinhole and a collimating (plano-convex) lens.

(Color maps to a linear intensity scale of greyscale pixel value from black to white)



Forward Scattering Spectrometer Probe (FSSP) response curve – The FSSP collects forward scattered light from a 632.8nm red laser between 4.6 and 12.8° polar angles using an annular photodetector and has been widely used in cloud droplet research; the instrument response curve used to measure droplet size is replicated by the model [3], (the model is implemented in Python and uses the Python module *scattnlay* to calculate scattering amplitudes [4]).



Backscattered light response curve – backscattered cross-section against droplet size, collected by an optic offset from the incident beam (0°) between 145 and 155° polar angles in red and blue wavelengths; non-monotonicity presents an uncertainty in the mapping of roughly ±2.5um.

Next Research

- A 'clean' spatially filtered laser beam could help define the sample area and reduce uncertainty due to varying beam intensity, which remains a challenge in single-droplet cloud spectrometers [2].
- Use of multiple wavelengths (sources) or detectors may also help define the sample area and reduce measurement uncertainty.
- Backscatter arrangements are being investigated experimentally that could be suitable for a compact instrument module.

[1] Beswick, K., et al. "The backscatter cloud probe–a compact low-profile autonomous optical spectrometer." Atmospheric measurement techniques 7.5 (2014): 1443-1457.
[2] Lance, Sara, et al. "Water droplet calibration of the Cloud Droplet Probe (CDP) and in-flight performance in liquid, ice and mixed-phase clouds during ARCPAC." Atmospheric Measurement Techniques 3.6 (2010): 1683-1706.
[3] Dye, James E., and Darrel Baumgardner. "Evaluation of the forward scattering spectrometer probe. Part I: Electronic and optical studies." Journal of Atmospheric and Oceanic Technology 1.4 (1984): 329-344.
[4] K. Ladutenko, U. Pal, A. Rivera and O. Peña-Rodríguez, "Mie calculation of electromagnetic near-field for a multilayered sphere," Computer Physics Communications, vol. 214, May 2017, pp. 225-230.