Assessing the potential to improve polarimetric aerosol property retrievals for black carbon aerosol

QiZhi Xu[1], Barbara Bertozzi[1], Alireza Moallemi[1], Robin L. Modini[1], Benjamin T. Brem[1], Philippe Giaccari[2], and Martin Gysel-Beer[1*]

[1]Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen PSI, Switzerland
[2]Micos Engineering GmbH, Dübendorf, Switzerland

Motivation

- Angular distribution and polarization dependence of light scattered by aerosols allow the retrieval of their microphysical properties using inversion algorithms.
- Systematic bias in retrieved properties is known for light-absorbing aerosol (e.g., black carbon, BC) owing to simplified aerosol representation[1].
- Goal: Evaluating if using an aerosol model tailored towards combustion aerosol improves BC retrieval quality is worthwhile.

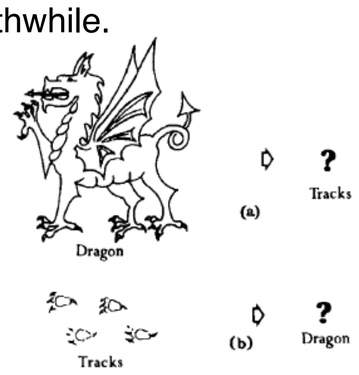

Fig.1. (a) The direct problem: Describe the tracks of a given dragon. (b) The inverse problem: Describe a dragon from its tracks[2].

Methods and Instrumentation

Approach: Combining in situ polar nephelometer with independent measurement

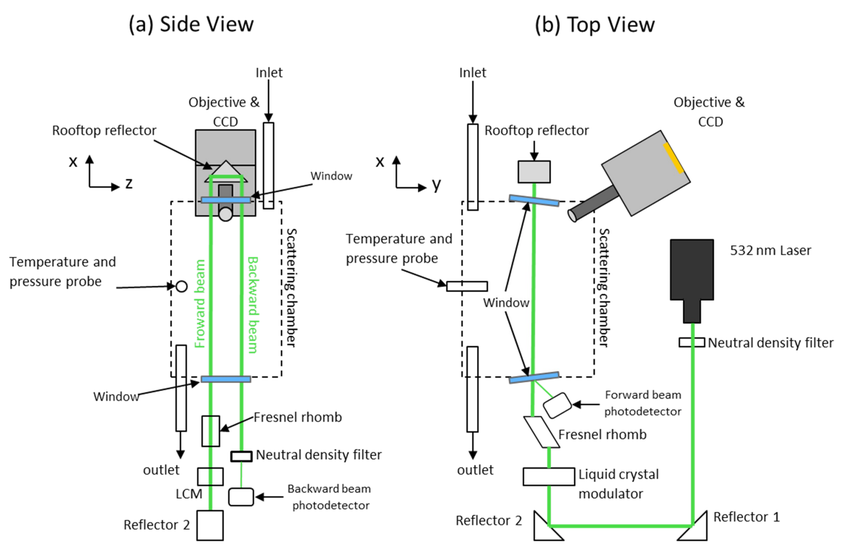

Fig.2. (a) Side view and (b) top view schematics of the uNeph instrument[3].

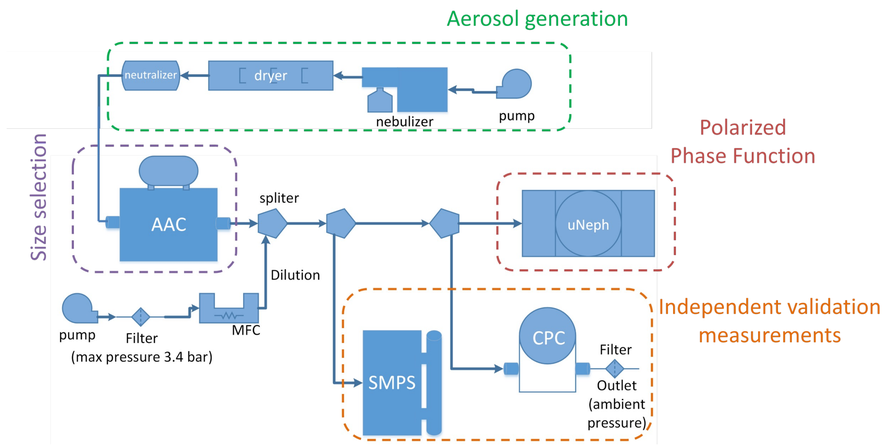

Fig.3.Experimental Set-up.

uNeph is a new prototype of laser imaging polar nephelometer[3]. The instrument is designed to measure the phase function, F11(θ), and polarized phase function, -F12/F11(θ), over the polar scattering angle range of around 10° to 170° with an angular resolution of 1° at a wavelength of 532 nm. It can provide 2*160 = 320 independent light scattering data points with good signal to noise ratio.

Aerosol samples:

- **PSL:** polystyrene latex spheres, calibration standard
- **Nigrosin:** black dye, spherical absorbing particles
- **Aquadag:** ultra-fine graphite, compact particles with low effective density
- **Fullerene soot:** artificial soot particles, fractal-like morphology, proxy for atmospheric soot

Polarimetric Retrieval

Examples for Spherical Particles

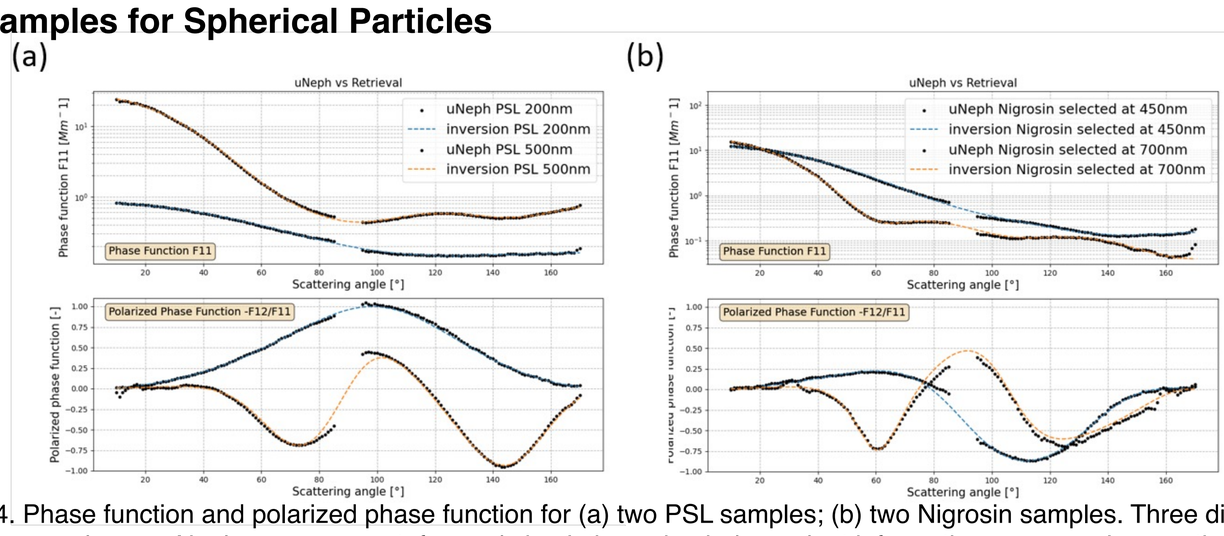

Fig.4. Phase function and polarized phase function for (a) two PSL samples; (b) two Nigrosin samples. Three different data types are shown: uNeph measurement, forward simulation using independent information on aerosol properties, and fit to measurement data by the inversion algorithm.

Examples for Non-Spherical Particles

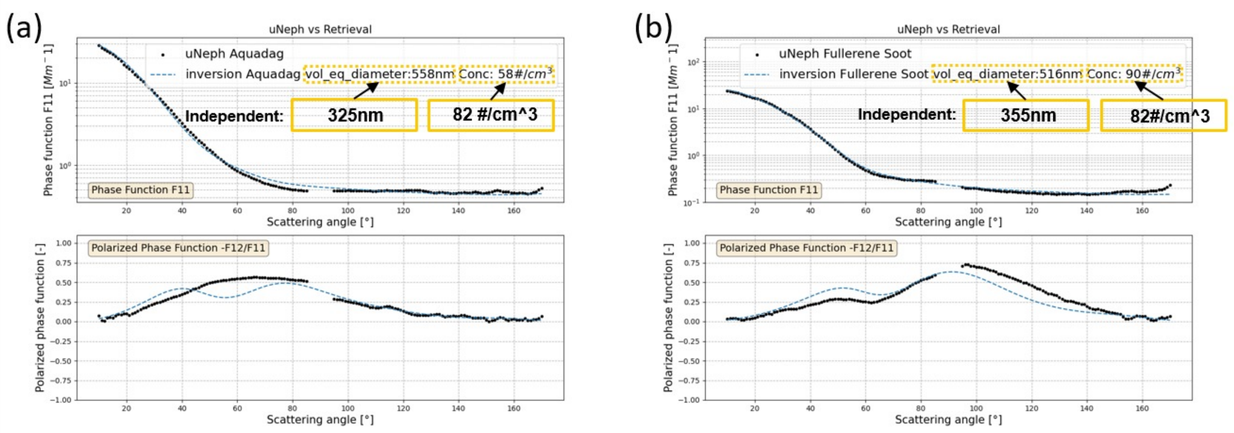

Fig.5. Phase function and polarized phase function for (a) two Aquadag samples; (b) two Fullerene soot samples. Two different data types are shown: uNeph measurement and fit to measurement data by the inversion algorithm.

uNeph-LSM retrieval versus independent data

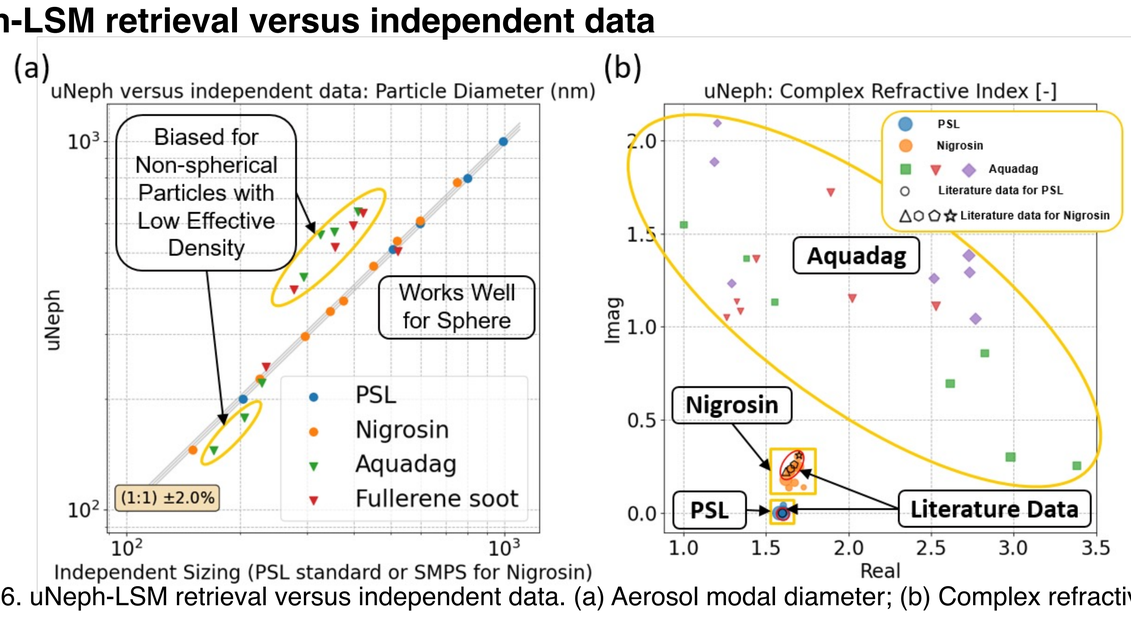

Fig.6. uNeph-LSM retrieval versus independent data. (a) Aerosol modal diameter; (b) Complex refractive index.

A good agreement between Mie curves and the uNeph measurement is achieved for PSL spheres and light-absorbing spherical nigrosin particles (Fig. 4). The retrieved complex refractive index was independent of probed particle diameter and in agreement with literature data (Fig. 6b). Good agreement was also achieved for aerosol number and volume concentration. By contrast, it is not possible to fit Mie curves that match both phase function and polarized phase function measured by the uNeph for non-spherical Aquadag and fullerene soot samples (Fig. 5). Consequently, the retrieved geometric mean diameter is highly biased compared to independent data (Fig. 6a). The retrieved complex refractive indices vary greatly depending on probed particle diameter, spanning a large range in the complex plane (Fig. 6b). This result obviously is physically unreasonable, hence confirming the hypothesis that poor retrieval results for light absorbing BC particles are driven by a poor choice of aerosol model and associated optical forward kernel.

Conclusion

- Accurate retrieval of particle size, number concentration and complex refractive index successfully demonstrated for spherical particles.
- Retrieval of aerosol properties is considerably biased for non-spherical particles, due to spherical particle assumption in the retrieval.

Future Work

- Measurement of more realistic soot generated under well-constrained conditions.
- A better forward model that can match uNeph observations hence providing more accurate retrievals. Insights from lab experiments shall later be applied to ambient aerosol to assess the potential for improved retrieval of light absorption from polarimetric data.

Reference
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qizhi.xu@psi.ch; barbara.bertozzi@psi.ch; martin.gysel@psi.ch

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