The optics-chemistry link of dark matter; investigating mass absorption cross sections of soot particles from two combustion sources

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Context

- “Soot” is a weakly defined term for particulate matter that mainly consists of elemental and organic carbon (EC, OC).
- Soot is not created equal; its intrinsic and extrinsic properties are affected by the type of combustion source and process.
- The grade of carbon graphitization, i.e., sp2 bonds, results in a mass specific optical absorption coefficient (MAC, m² g⁻¹).
- The MAC is one key property for predicting the climate forcing of soot and is essential in the standardized calibration of real time instrumentation (i.e., photo acoustic (PAS) types).
- The quasi-standard for determining the EC mass is the thermal-optical transmittance (TOT) method.
- For the accurate real-time determination of soot mass the variability of MAC values referenced to the TOT EC mass needs to be understood.

Objective

- Investigate the variability of MAC values referenced to TOT EC mass for soot generated by a diffusion flame burner and an aircraft engine.

Methods

Diffusion Flame Experiments

- Soot source: Matter CAST
- EC content > 80%
- Soot concentration set with a dilution bridge and ejector dilutor.
- Setup has calibrated over 2000 AVL Micro Soot Sensor (MSS) units.

Aircraft Engine Experiments

- Soot source: CFM56-7B26
- Thrust settings covering the landing and take-off cycle.
- Sampling system according to ICAO Annex 16, App. 7.
- Equipment connected to the diluted “PM Line”.

Light Absorption Coefficient

- The Photoacoustic Extinctiometer (PAX, Droplet Measurement Technologies) provided the absorption and light scattering coefficients in real-time and in situ at a wavelength of 870 nm.

Elemental Carbon Mass

- Filter integration times of up to 1 hr. for low concentration/engine thrust levels.
- Analysis performed according to NIOSH 5040.
- Manual OC/EC split at 540s was used for the aircraft filters.

Results and Discussion

MAC values

- Very good linearity
- Difference not statistically significant
- Higher MAC value of aircraft soot might be caused by its more graphitized internal structure.
- Fairly good agreement with the value from Bond et al. (2007).

Influence of OC content

- Aircraft PM contains up to 90% OC at thrust levels near idle.
- Low and negative MACs at high OC levels are caused by the limit of detection (LOD) of the PAX instrument and not the OC content.
- The MSS shows a good agreement with EC values down to concentration levels of 10 μg m⁻³.

Conclusions and Outlook

- Diffusion flame sources can be used for calibrating real time photoacoustic soot mass instruments operating in the near IR spectrum i.e., for aircraft emission measurements.
- The potential influence of OC content on MAC values (e.g., lensing effects) requires further investigation with a high resolution PAS instrument, but the influence in the near IR region is expected to be minimal.
- Investigation on the radiative relevance of nascent aircraft soot particles is ongoing (See Poster 19).

References