Single Particle Absorption Measurements in the Mid-Infrared by Exploiting Elastic Scattering

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# Single Particle Absorption Measurements in the Mid-Infrared by Exploiting Elastic Scattering

## Abstract

**Goal:** Measure the infrared absorption and scattering cross-sections for single biological and chemical aerosol particles.

**Use:** Single particle measurements are necessary for detailed modeling and understanding of test results from infrared stand-off detection systems.

**Technique:**

Two-dimensional **Angular Optical Scattering** (TAOS)

TAOS patterns depend upon particle shape, size, and **complex refractive index**
Coordinates for TAOS patterns

Scattering Parameters

Diameter: 54.2 µm
Refractive Index: 1.342 + i * 0.00
Wavelength: 3.41 µm
Size Parameter: $2\pi a/\lambda \cong 50$
Laser Polarization: Vertical

$0^\circ \leq \theta \leq 180^\circ$
$0^\circ \leq \phi \leq 360^\circ$
Extrapolate absorption cross-sections of spherical particles by comparison with Mie theory.

Changes in absorption leads to changes in the scattering profile beyond just a scale factor.
Experimental set-up to collect TAOS patterns of droplets
Collected TAOS patterns of droplets

**H₂O**
Droplet Diameter: 57.4 µm
Refractive Index: 1.405 + i 0.018

**50% H₂O - 50% D₂O**
Droplet Diameter: 54.2 µm
Refractive Index: 1.342 + i 0.010

**D₂O**
Droplet Diameter: 55.2 µm
Refractive Index: 1.279 + i 0.002
Comparison between experiment and Mie theory

<table>
<thead>
<tr>
<th>Liquid Type</th>
<th>Droplet Diameter</th>
<th>Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>D$_2$O</td>
<td>55.2 $\mu$m</td>
<td>1.279 + i 0.002</td>
</tr>
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Current work
Collaboration with MIT Lincoln Lab
(Anish Goyal, Tom Jeys, and Antonio Sanchez)

Large Angle Two-dimensional Angular Optical Scattering
LA TAOS patterns collected in the **visible** of clusters ($\lambda = 532$ nm)
LA TAOS patterns collected in the **mid-IR** of clusters ($\lambda = 3.9 \ \mu m$)

Variability within a data set is due to multiple factors: cluster size, shape, and orientation, and optical alignment distortions.
LA TAOS in the visible and mid-infrared

By increasing the wavelength, the LA TAOS technique becomes more sensitive to larger structure sizes.

SEM of Tryptophan

Visible LA TAOS pattern of Tryptophan at $\lambda = 532$ nm

Mid-IR LA TAOS patterns of Tryptophan at $\lambda = 3.9$ $\mu$m
Future Plans: Capture Dual Wavelength LA TAOS

Use two mid-infrared wavelengths to simultaneously illuminate an aerosol, then compare the LA TAOS patterns to ascertain if there is absorption at either wavelength.
Summary of Work

- Detected TAOS patterns of single 50 µm droplets composed of H₂O, D₂O, and H₂O/D₂O mixture.

- Able to achieve decent visible match with results derived from Mie theory.

- Unable to implement a minimization routine to find absorption because of aberration in the collection optics as well as an inability to determine absolute angle reference.

- Collected LA TAOS patterns of Arizona Road Dust, BG, Bovine Albumin, PSL sphere cluster, and Tryptophan