Design Project – SIE 2023

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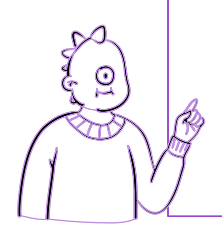


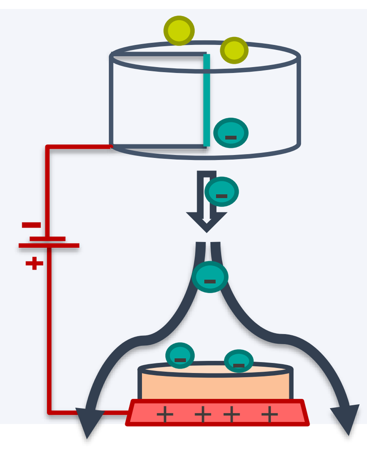
Experimental studies with novel instrumentation to measure air pollution

CONTEXT

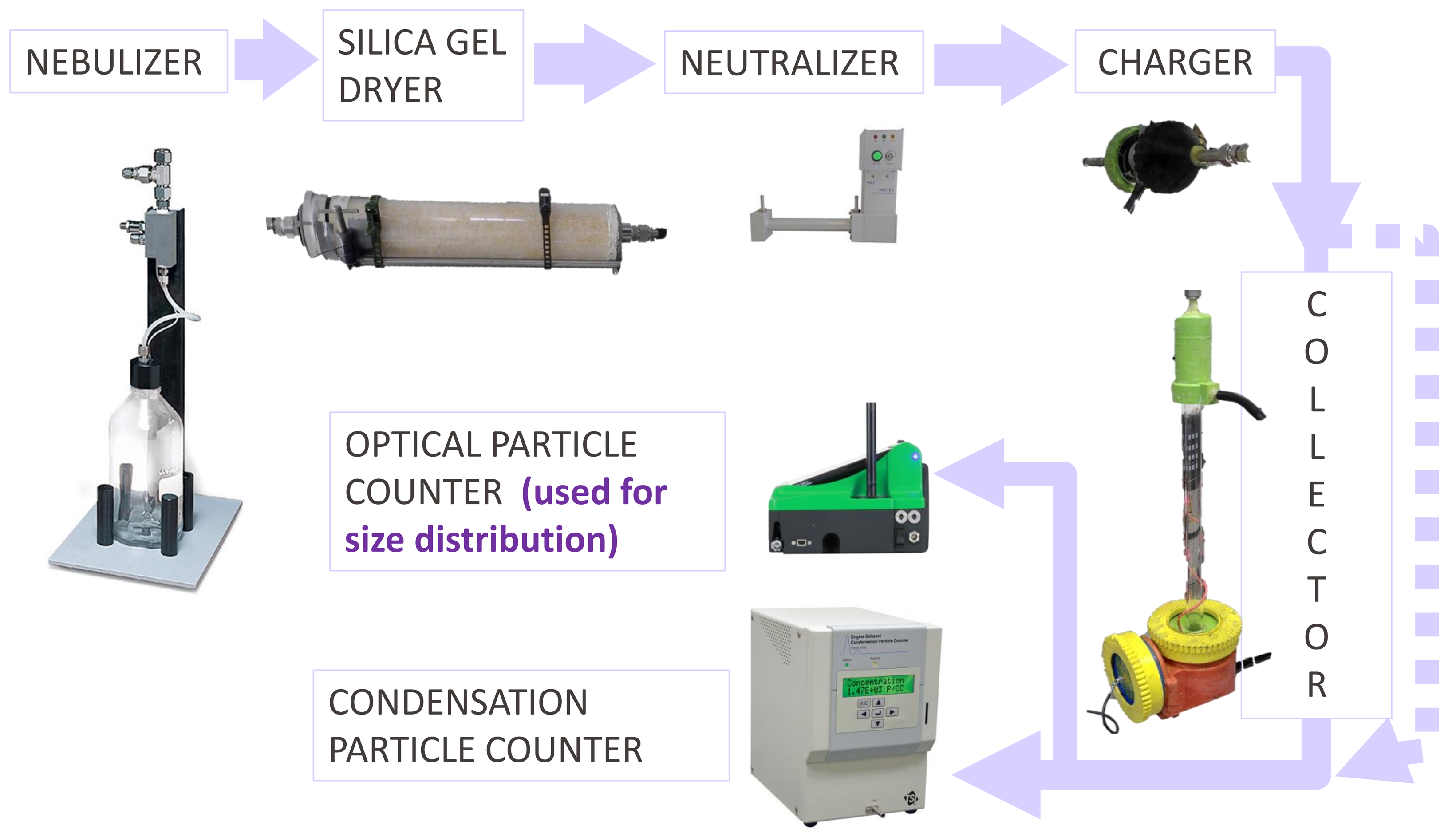
Currently, most infrared spectroscopy analysis of aerosols are performed on Polytetrafluoroethylene (PTFE) filters. These methods have limited spectral feature separability due to the membrane material strong absorption in the infrared range. AeroSpec is developing a new method for **collecting aerosols using a radial electrostatic precipitator on an IR transparent crystal.**

How does the electrostatic precipitator work ?

The radial electrostatic precipitator uses electric fields to charge the particles in the air and then collects them on a semiconducting crystal placed on an oppositely charged plate.



EXPERIMENT SETUP



METHODOLOGY

Sample preparation

- The aerosol samples were generated using a nebulizer.
- The compounds used in the experiments are **Ammonium Sulfate, Ammonium Oxalate, Suberic Acid, Glucose, and Ethyl Palmitate.**

Collection and spectra

- Particle count is measured with a condensation particle counter (CPC)
- Fourier-transform infrared spectroscopy (FTIR) is used to measure the infrared spectra
- The IR spectra of the crystal is measured before and after collection

Data processing

For each experiment, three processes are applied:

- Estimating total deposited particle count from CPC measurements
- Difference in FTIR measure before and after collection, with smoothing and baseline correction, to obtain the compound related absorbance
- Image analysis to estimate the collection area on the crystal

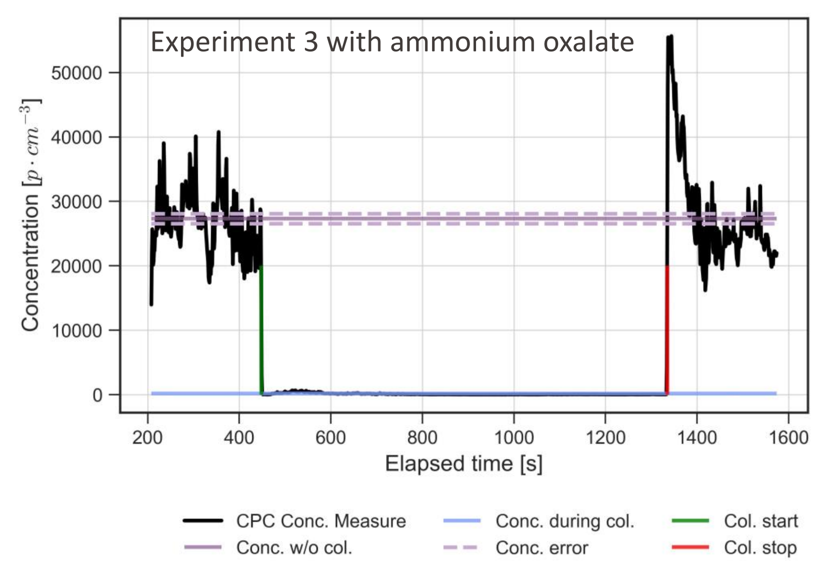
Particle count and absorbance

- The absorbance, at a wavenumber v, is related to the mass of deposited particles per unit area $m_a^*(r_b)$ on a disk of radius r_b:

$$A(v) = \alpha_{10,v}(v)\frac{m_a^*(r_b)}{\rho}$$

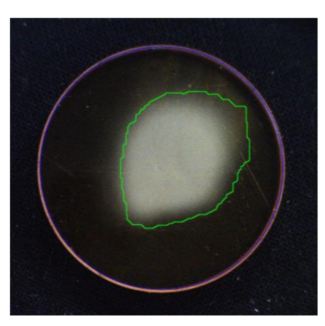
- Derived from Beer-Lambert's law using a thin film hypothesis
- The mean areal density $m_a^*(r_b)/\rho$ is computed from the total particle mass, which is estimated using the CPC, particle size estimates and particle density ρ
- $\alpha_{10,v}$ can be related to the molar attenuation

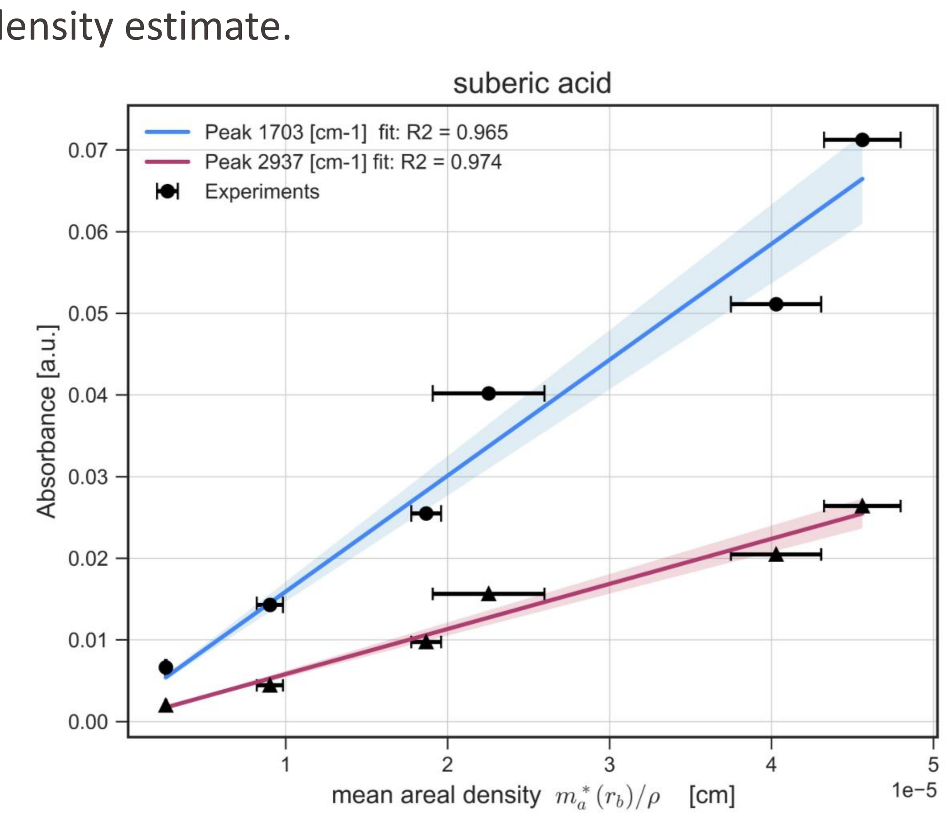
RESULTS



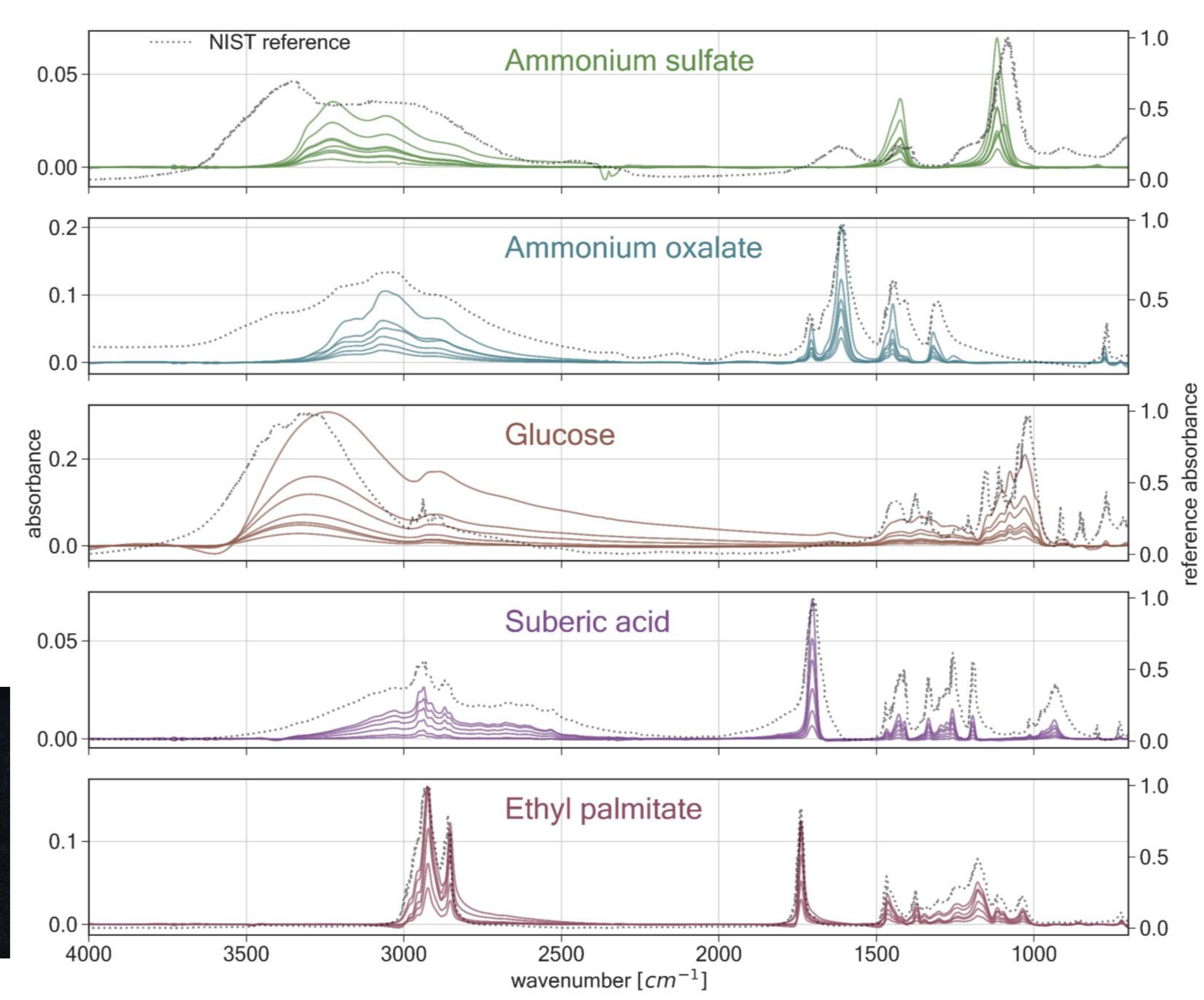
As illustrated in figure above, during the collection stage the concentration measured by the CPC drops by more than 80%.

The collection area on the crystal is found to vary. The figure here on the right illustrates one **estimated collection area** for ammonium oxalate. This estimation is necessary for a good areal particle density estimate.





The **particle count is related to absorbance** for characteristic absorbance peaks observed in the FTIR spectra. Two peaks are represented in the figure above for Suberic Acid. A linear regression analysis allows to estimate the absorptivity coefficient, $\alpha_{(10,v)}$.



The figure above displays the computed **absorbance spectra for each compound and experiment**, comparing them to a reference spectra represented by a dotted line. Experiments are conducted for each compound with varying collection times ranging from 3 to 60 minutes.

LIMITATIONS

- Electrical **fouling** of the charger, only at particle concentrations which are not expected in the atmosphere
- **Baseline correction** of the absorbance spectra is not unified
- Manual involvement is high

CONCLUSION

The experimental method developed by AeroSpec was first replicated using ammonium sulfate, and then extended to four more compounds. Then, using a linear regression, molar absorptivities were calculated for our experiments and can be compared to ones found in literature. An automated version of the instrument is in development by AeroSpec, addressing many of the limitations encountered in this work. **Absorbance measurements reflect the mass with a linear relationship for multiple compounds**. The instrument therefore works as a mass measurement instrument.