Broadband Single Particle Spectrometer and Small-Scale Cloud Chamber for Laboratory Solar Radiation Management

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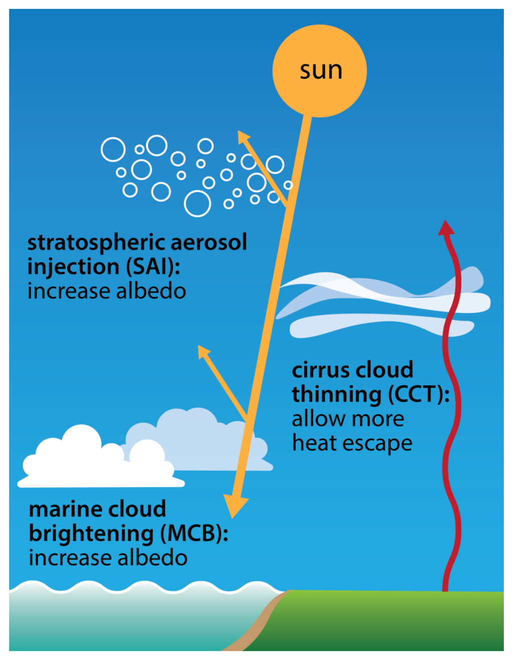
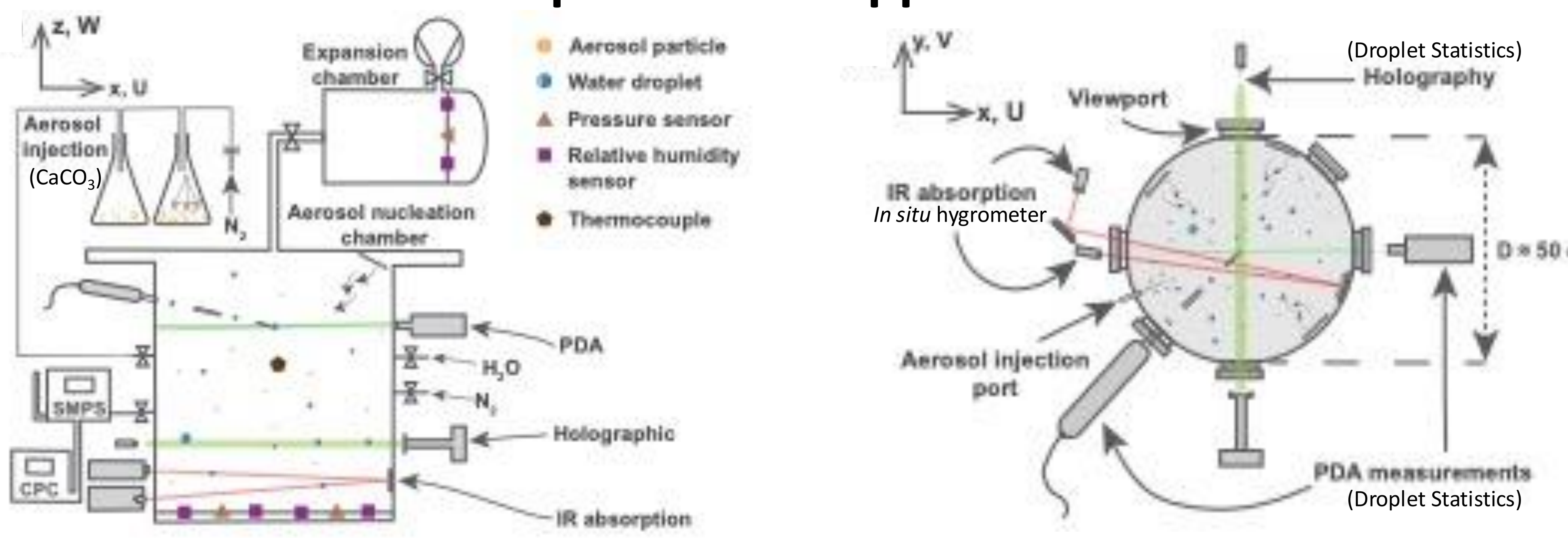
Small-Scale Cloud Chamber

Solar Radiation Management



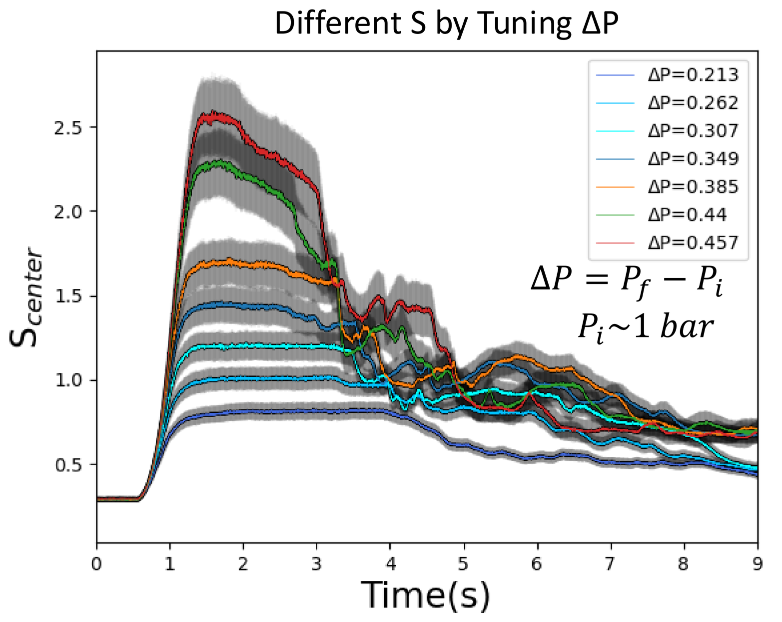
- Solar radiation management can limit climate change's temperature increase
- Aerosols underpin proposed **solar radiation management** strategies
- How do SAI and CCT particles **scatter and absorb light**? How do they act as **cloud condensation nuclei (CCN)**?

Experimental Apparatus

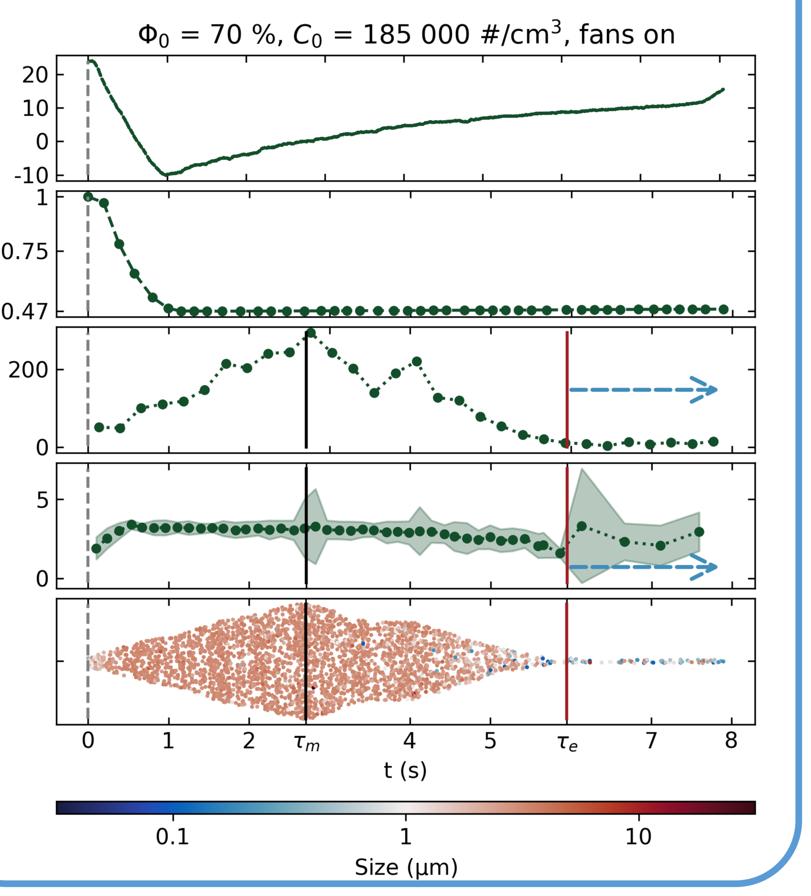


Experimental Concept

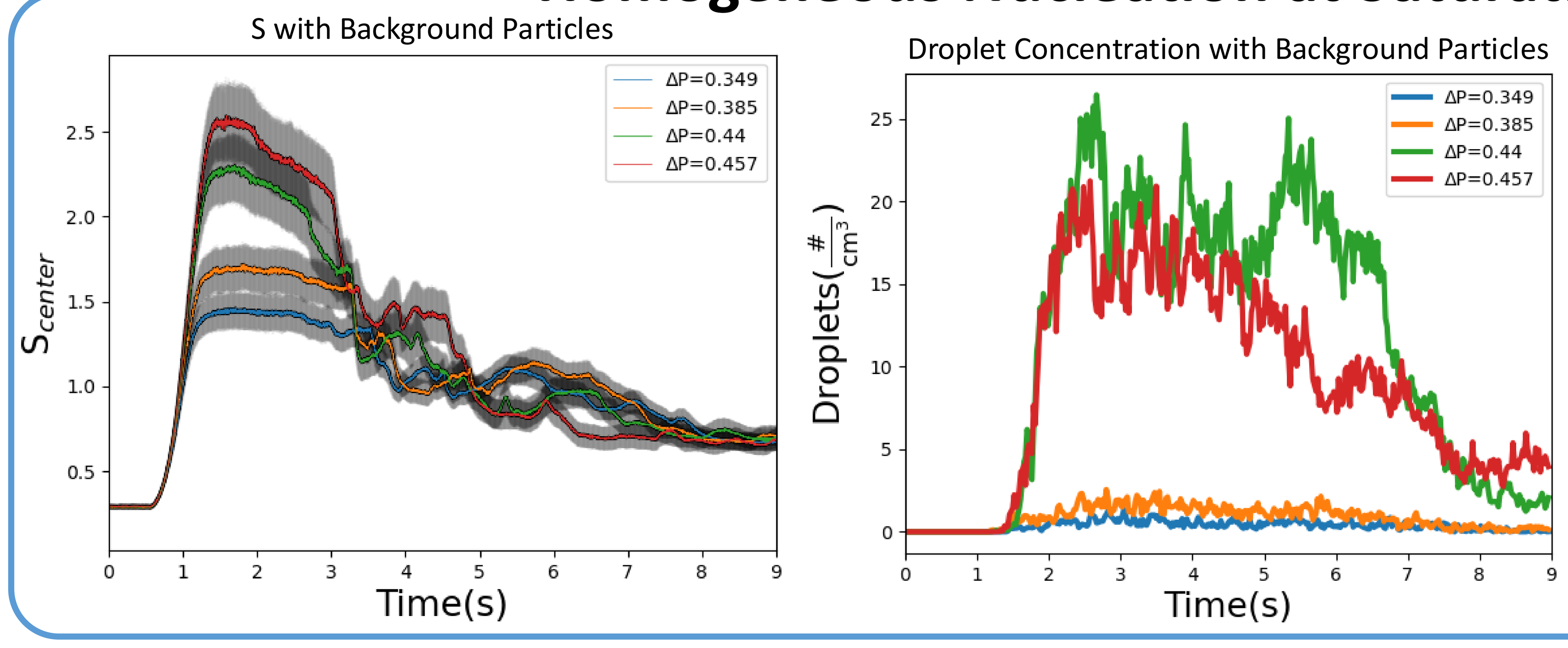
$$S = \frac{e}{e_s} = \frac{P_{H_2O}}{Equilibrium\ P_{H_2O}} \rightarrow \frac{From\ IR\ laser}{From\ temperature}$$



- Tunable ΔP results in different S values
- At large enough ΔP, droplets form



Homogeneous Nucleation at Saturation Ratio ~2?



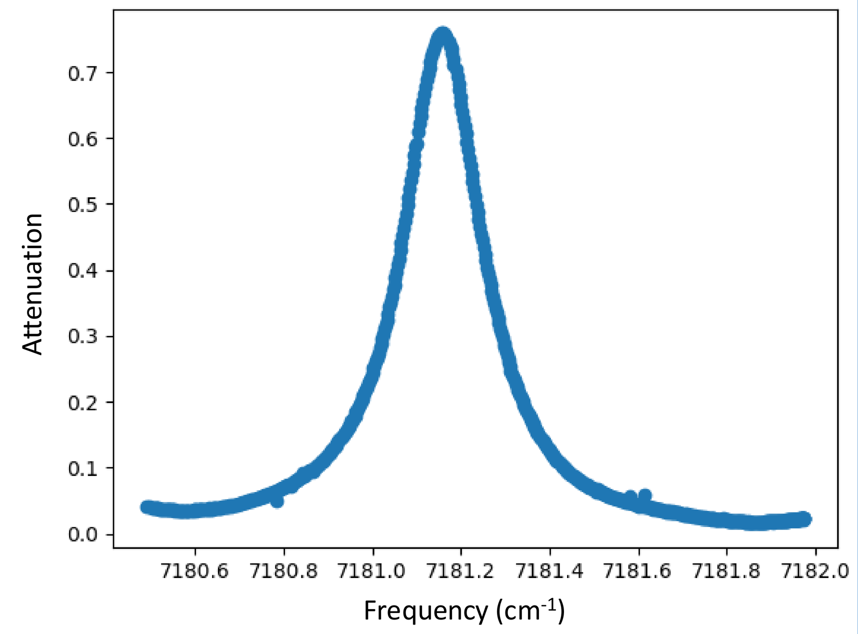
- Homogeneous nucleation of water vapor expected to occur closer to S=4
- ~1 pt/cm^3 background particles are present within the chamber prior to expansion
- Only S > 2 is needed to observe increase in number of droplets.

Two possible explanations:

1. Shockwave during expansion creates high local S values averaged over in IR measurements
2. Small droplets act as CCN allowing formation of water droplets with r= 1.73 nm at S*=2

Retrieving Water Vapor Content

- Tunable diode laser absorption spectroscopy using a distributed feedback diode laser to monitor water vapor content



$$-\ln\left(\frac{I_{out}}{I_{in}}\right) = \sigma NL = Attenuation$$

$$Peak\ area = N * S_{ij}(T) * L$$

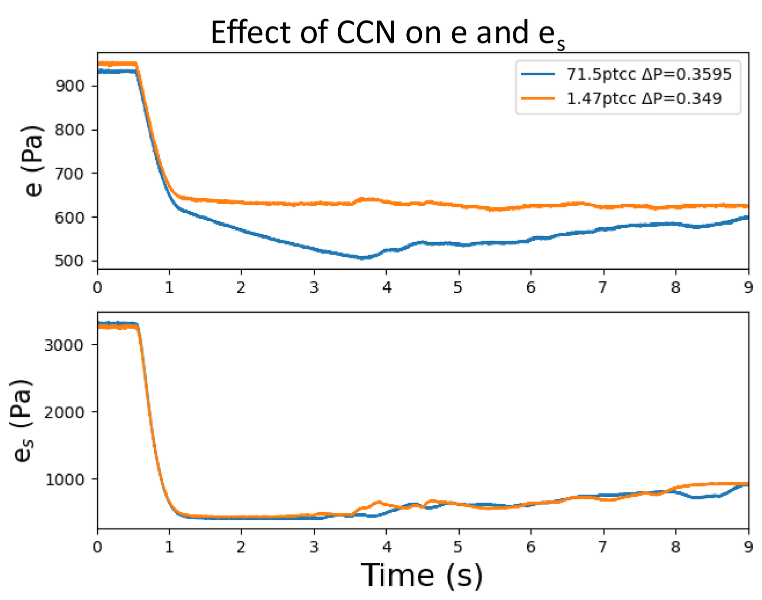
$$N = \frac{Peak\ area}{S_{ij}(T) * L}$$

$$N = \frac{molecules}{cm^3}$$

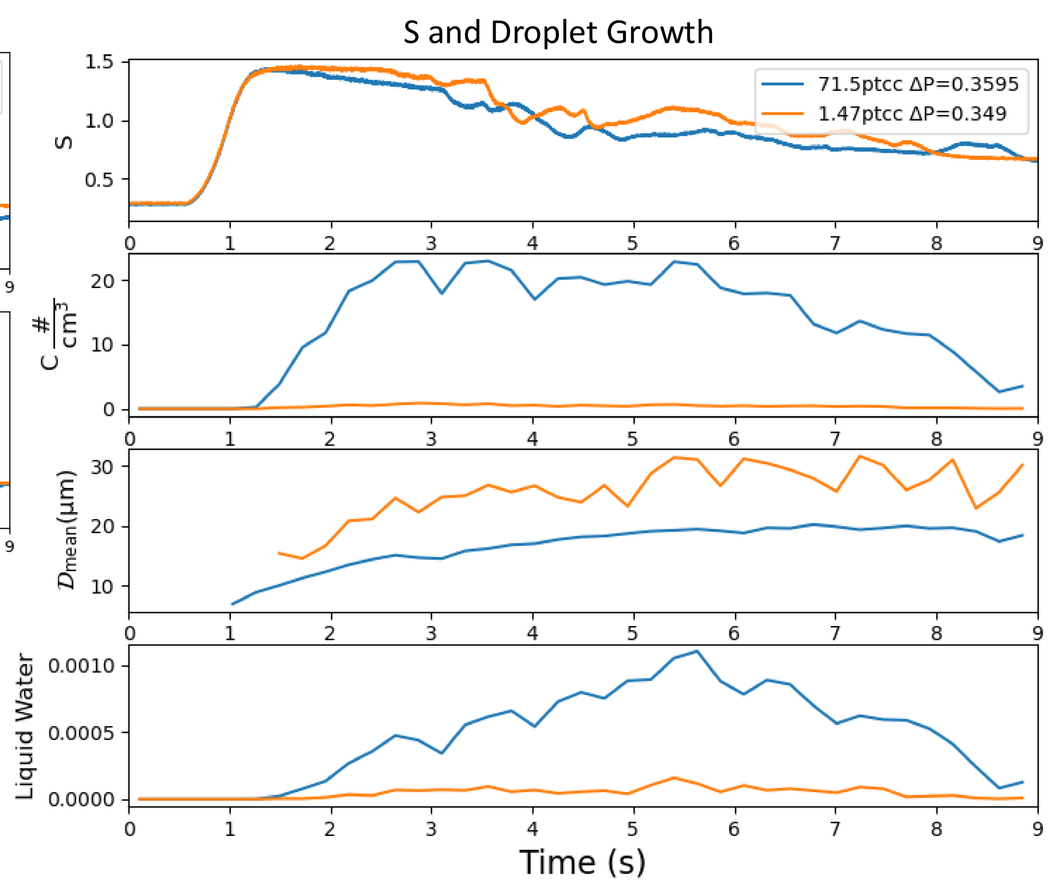
$$P = NRT$$

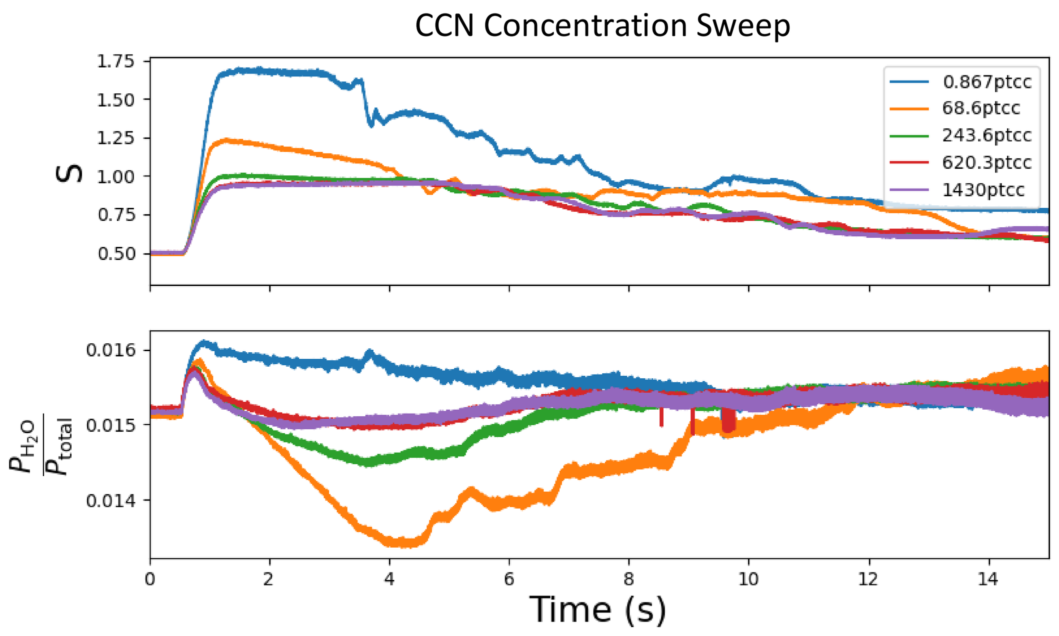
- Fitting peak retrieves $\boldsymbol{P_{H_2O}}$ at 400 Hz, which provides sufficient time resolution to track expansion.

Influence of Cloud Condensation Nuclei



- Droplets quantified *via* holography
- Higher droplet counts when more particles are present.
- Significantly more water vapor depletion observed at higher particle counts

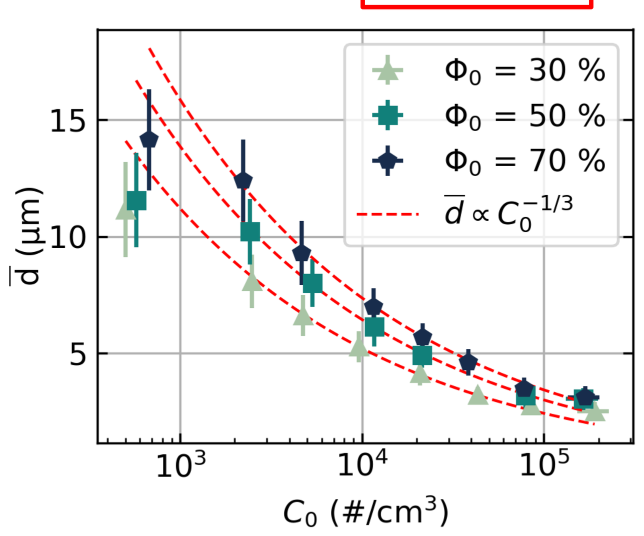




- S buffered at higher particle concentrations
- Above 240 pt/cm^3, competition for water vapor lowers water vapor depletion associated with droplet formation

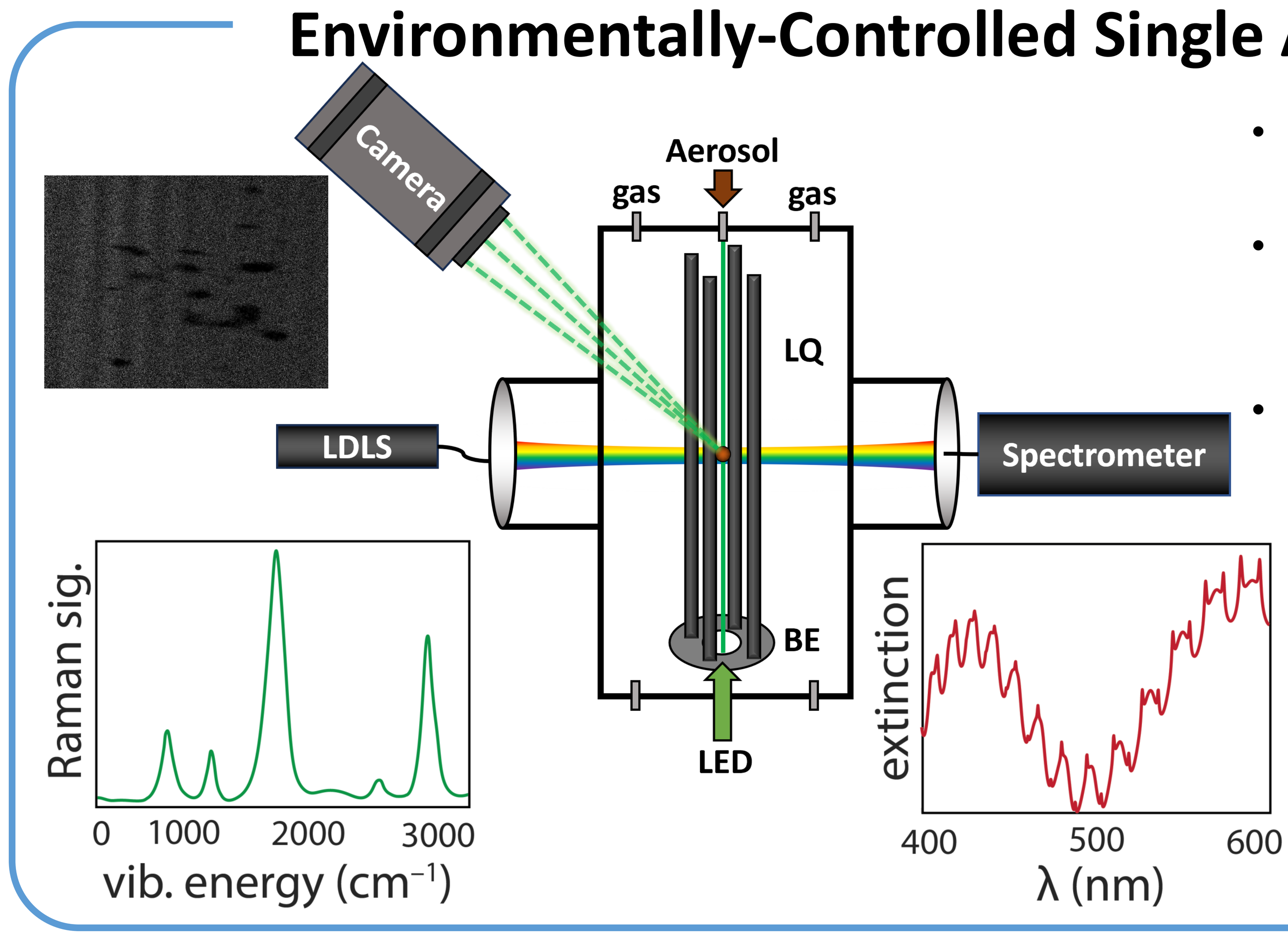
- For same water vapor content and pressure drops, average diameter decreases with the number of CCN

$\Phi = \%RH$ $\quad r \propto C_0^{-\frac{1}{3}}$



Single Aerosol Spectrometer

Environmentally-Controlled Single Aerosol Chamber

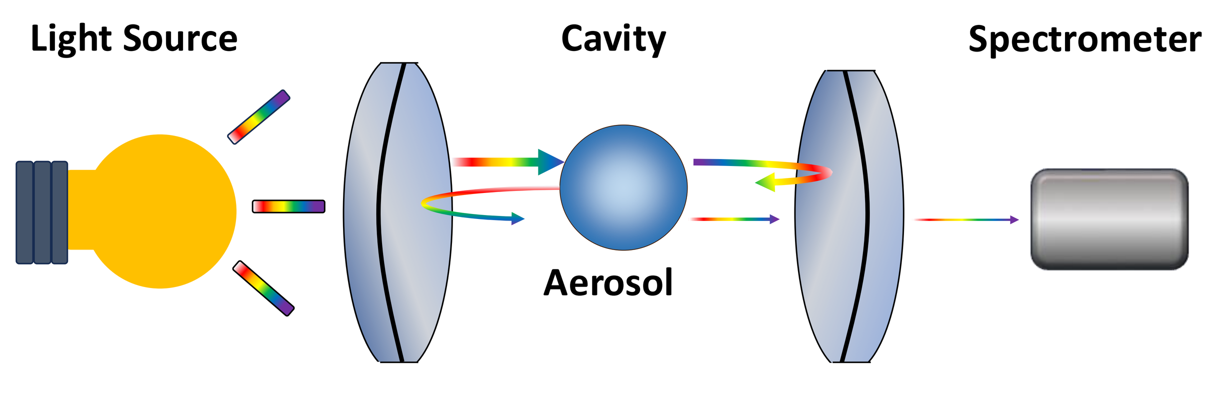


- A **Linear Quadrupole Electrodynamic Balance** is used to levitate single particles
- Fit fringes observed in angularly resolved scattered light are used to **determine particle size**
- **The complex refractive index** is determined by fitting Mie Resonances with changing particle size across a wide wavelength range

Atmospheric Processing and Chemistry:

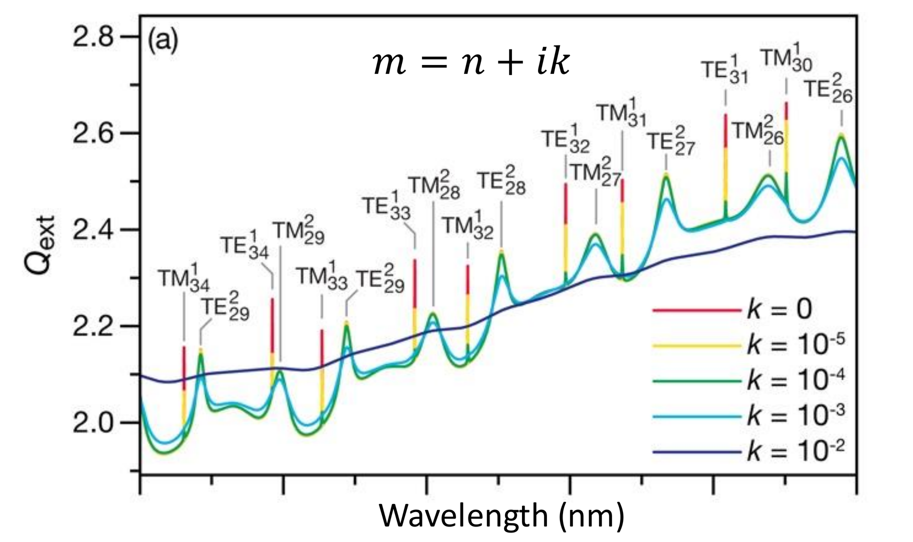
- Humidity, exposure to organic molecules, photochemistry
- Monitor refractive index properties and Raman vibrations for mechanistic insight

Incoherent Broadband Cavity-Enhanced Spectroscopy



- **Broadband Light Source:** Laser Driven Light Source provides light from 200 nm-2400 nm
- **High-Reflectivity Mirrors:** Enhance pathlength for necessary sensitivity to measure light extinction by single aerosol

$\boldsymbol{m}$ Retrieval



- Isolated individual aerosols with careful environmental control
- Retrieve complex refractive index by fitting Mie Resonances
- Higher precision than bulk aerosol measurements

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