# The Impacts of Phase Separation and Particle Shape on Aerosol Optical Properties

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## Introduction

- Aerosols in the atmosphere are known to regulate global climate through radiative forcing.
- The extent of this is poorly understood resulting in large uncertainties in climate models.
- A deep understanding of the **optical properties** of aerosols with diverse shapes and those of multiphase composition remains elusive.
- Understanding these optical properties can allow us to infer the physical properties, allowing refinement of climate models.
- Applications out with environmental science, such as investigation of multiphase bio-aerosol to understand disease transmissions.
- UV based sterilisation devices may also be designed to eliminate airborne pathogens in the environment at a high level of disinfection should their interaction with light be better understood.
- The development of innovative approaches like this to counteract quickly evolving superbugs is needed, where pathogens are becoming resistant to the standard chemical approach.

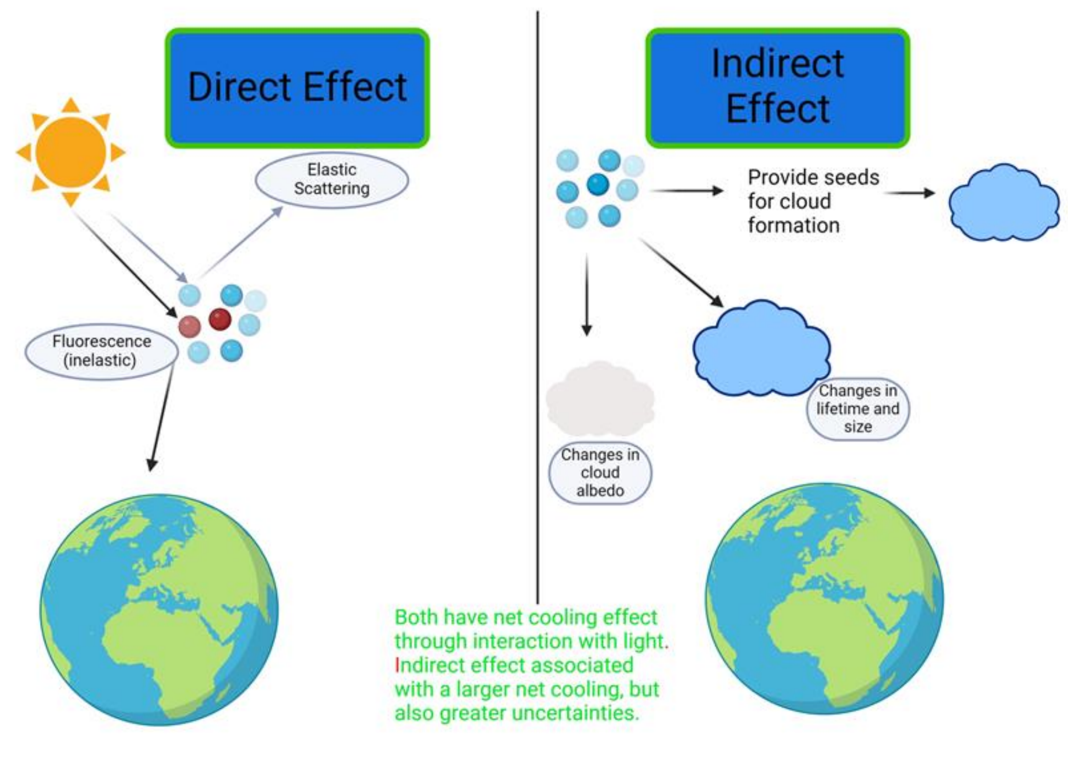



*Figure 1 describing the direct and indirect effect of radiative forcing.*

## Methods

### EDB Quadrupole

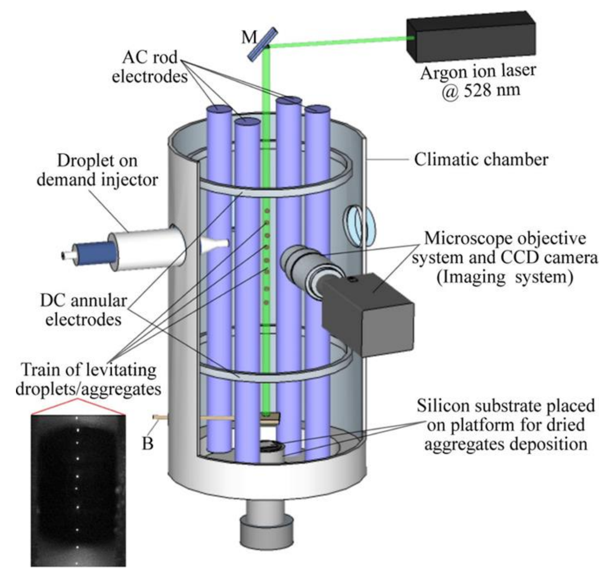
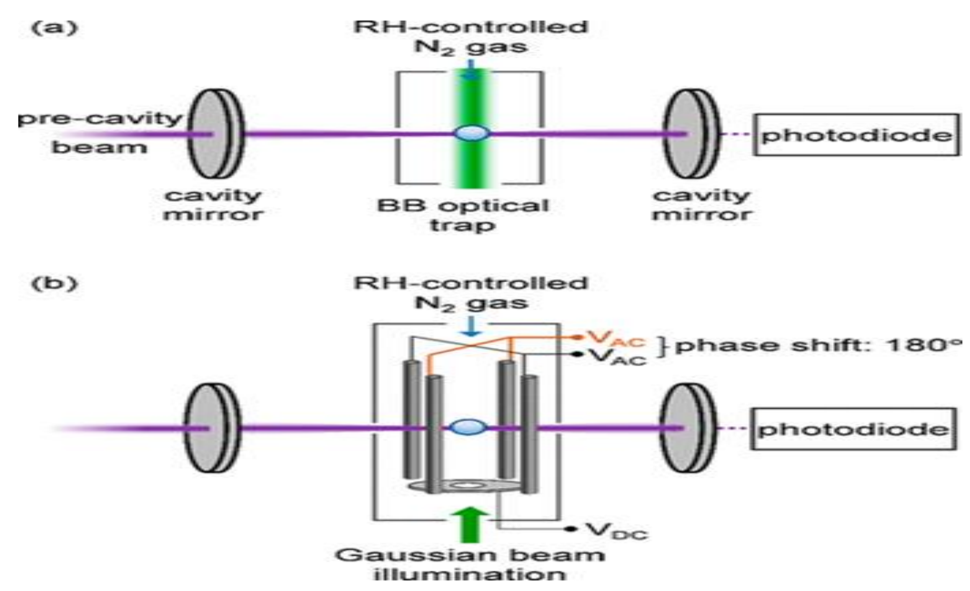



*Figure 2 by Archer, Kolwas et al. 2019[1] illustrating the components of a quadrupole electrodynamic balance.*

- The trap applies a DC voltage above and below generating a static electric field.
- Insufficient to hold levitated particles in place to allow for precise measurements.
- Quadrupoles apply AC voltage to generate an oscillating electric field.
- This field can respond to changes in the position of the particle in space, keeping the particle still in accordance with newtons second law.

### SP-Cavity Ring Down Spectroscopy




$$\alpha_{ext} = \frac{L}{lc}\left(\frac{1}{\tau} - \frac{1}{\tau_0}\right)$$

$c$: speed of light
$L$: distance between the two reflective mirrors.
$l$: cavity length occupied by the sample

*Figure 3 by Cotterall, Knight et al[2] showing a diagram of a SP-CRD spectrometer. Equation on how to calculate the extinction co-efficient from cavity ring down measurements.*

- Two highly reflective mirrors flank optical cavity resulting in constructive interference.
- Light leaks out the back mirror, of which the intensity decays at an exponential rate.
- Referred to as the ring down time.
- Difference in ring down time of empty cavity and that with sample gives the above relationship.

### Modelling Techniques

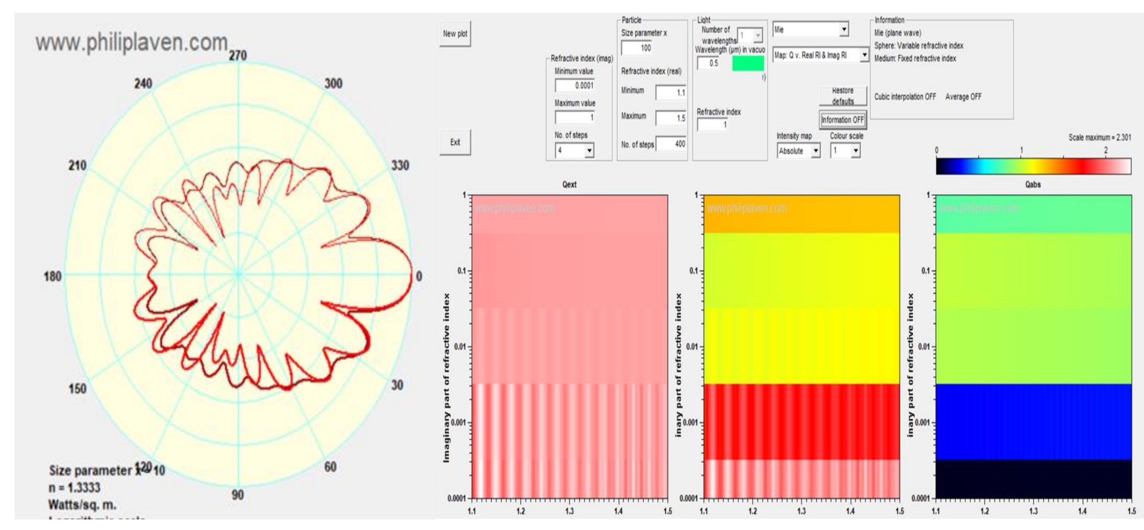



*Figure 4 showing plots generated in Mieplot. The left-hand side shows a polar plot of intensity vs scattering angle (phase function). The right-hand side shows the refractive index(imaginary) vs the absorbance efficiency (Qabs).*

- "Wet lab" techniques such as SP-CRDS will be used to retrieve the extinction cross sections and particle size may be retrieved using angularly resolved elastic light scattering.
- Complementary Mieplot software can then be used to retrieve phase state and particle shape.
- T-Matrix add on may be used for non-spherical particles (solids).

## Workflow

### Year 1

Non-Absorbing Particles During LLPS

Atmospherically relevant aerosol particle with core shell morphology.

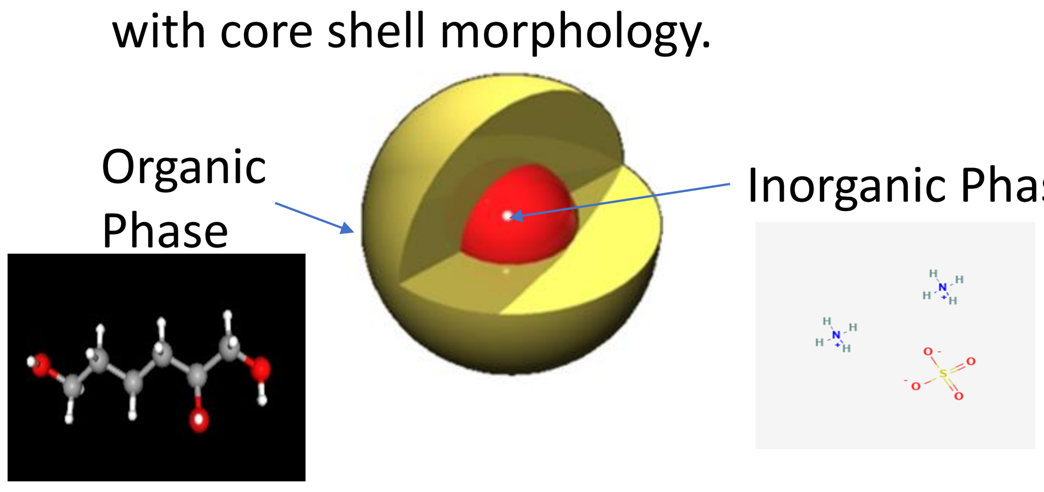



*Figure 5 showing the core shell morphology adopted by many composite aerosols with both an organic and inorganic component.*

### Year 2

Absorbing Particles During LLPS

**Refractive Index** $m = n + ik$

$$n = \frac{c}{v}$$

- Where n is the real refractive index, and ik is the imaginary refractive index, measuring the attenuation of light by absorption.
- The real part refers to the speed of light in a vacuum over that in a medium, such as an aerosol droplet.

### Year 3

Non-Spherical Particles (Solids)

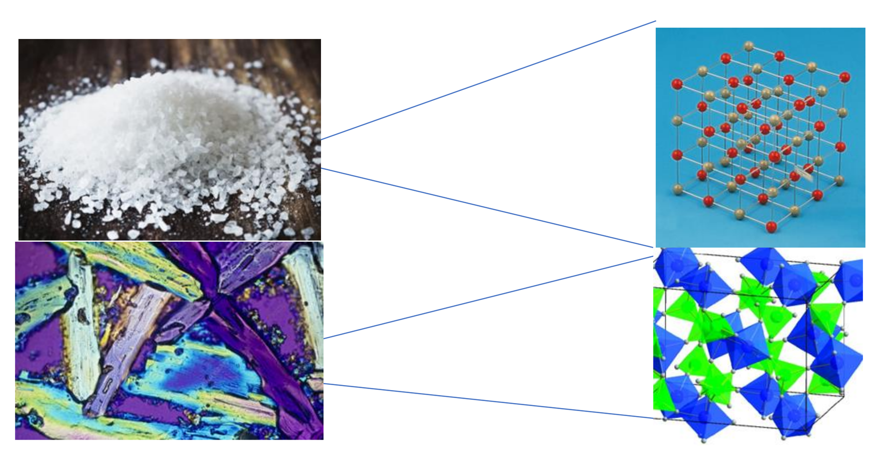


*Figure 6. Unit cells of atmospherically relevant salts. NaCl(top) and ammonium sulphate(bottom)*

## References

1) Archer, J., et al. (2019). "Sodium dodecyl sulfate microaggregates with diversely developed surfaces: Formation from free microdroplets of colloidal suspension." The European Physical Journal Plus **134**.
2) Cotterell, M. I., et al. (2022). "Accurate Measurement of the Optical Properties of Single Aerosol Particles Using Cavity Ring-Down Spectroscopy." The Journal of Physical Chemistry A **126**(17): 2619-2631
3) Brunamonti, S., et al. (2015). "Redistribution of black carbon in aerosol particles undergoing liquid-liquid phase separation." Geophysical Research Letters **42**(7): 2532-2539