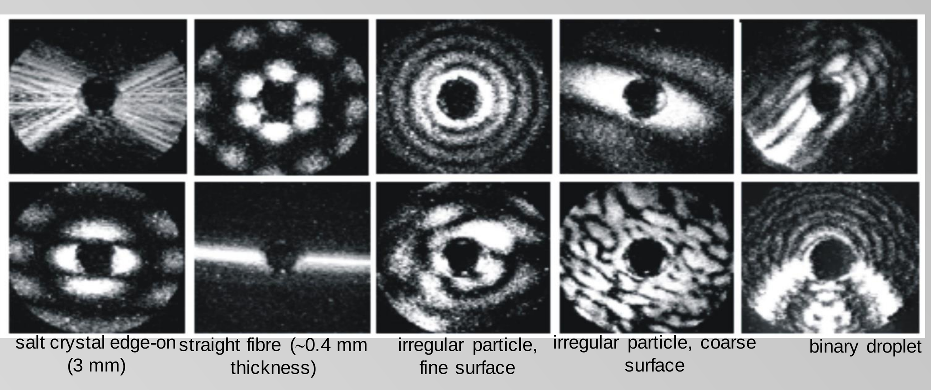
Classification of microparticles using two-dimensional scattering data and machine learning techniques

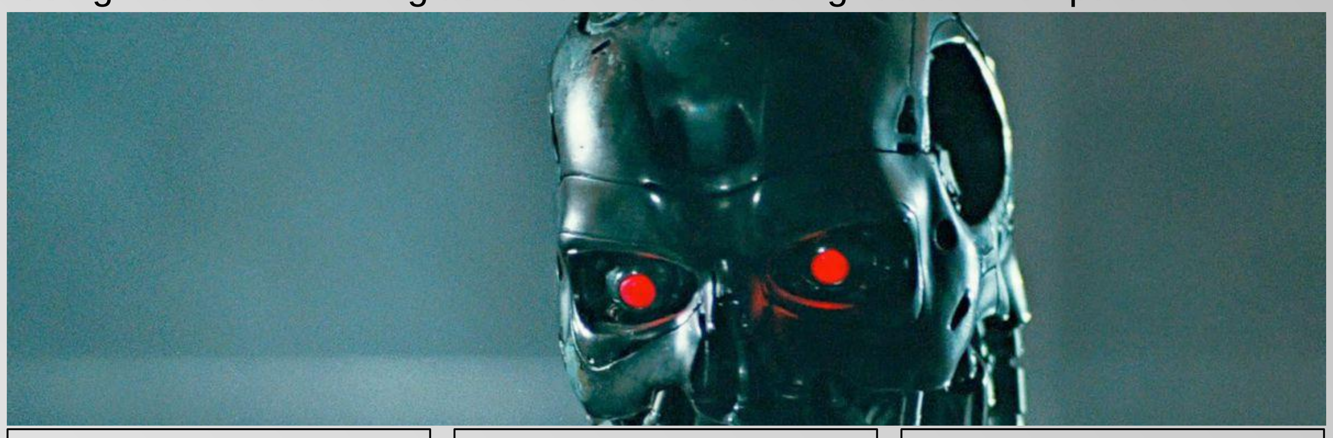
Aims and Motivation

This project aims to develop an algorithm for the classification of particles based on their scattering patterns for a range of aerosols, such as mineral dust, fungal spores, pollens, ice crystals, mineral fibres, and liquid droplets.



Pictured (left) are scattering patterns for different particles,
a reproduction from the University of Hertfordshire Proforma for Cohort 3, C. Stopford

Using Machine Learning as done in other relating research on particle



Support Vector Machine (SVM)	Random Forest Classifier	Neural Network (NN)
Aspect ration predictions (SVC) Estimating prism sizes (SVR) Estimating PAD (SVR) - Salawu et al	Predicting prism orientation - Salawu et al	Cirrus cloud ice crystal size recovery - Priori et al Sphere inverse light scattering problem - Ulanowski et al

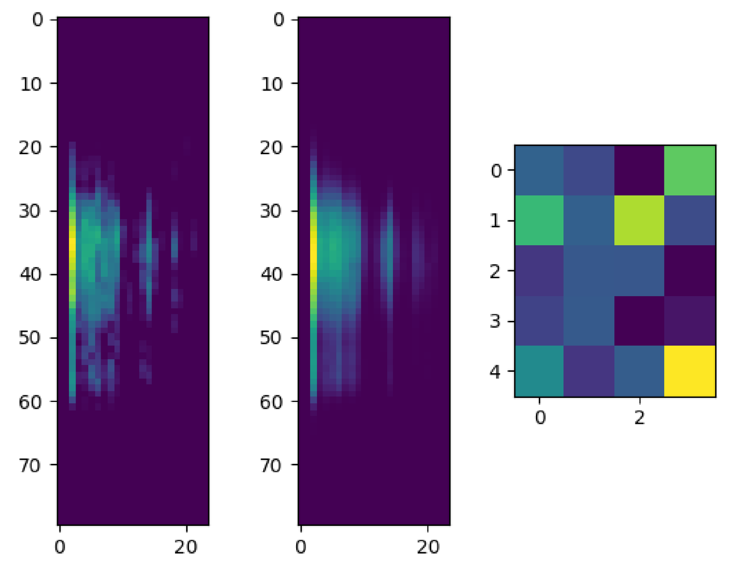
SVC are support vector classifiers and SVR are support vector regression models.

Based on existing work classifying real and modelled particles.

Thematic Broadening Sabbatical (TBS)

Project:

Implement a Convolutional Neural Network (CNN) auto encoder on time series fluorescence data to determine how to optimise minimising losses between training and test data



Shown is the normalised fluorescence of a particle in 24 time stops, the predicted image of that particle, and the image in the latent space

Objectives

Objective 1: Identifying and sourcing relevant aerosol samples, and developing laboratory techniques for safely aerosolising each

Objective 2: Sample each aerosol with the PPD-2 instrument. Use collected data to develop and apply a combination of image analysis and/or machine learning techniques to perform some classification of each of these particle

Objective 3: Investigate the useful resolution and bit-depth of the detector used for collecting scattering data, towards the development of a low-cost instrument to count, size, and classify individual airborne particles

Policy Impacts

Real time detection of air pollutants and respirable hazardous materials is important in dictating best practice for public safety, and crucial for acting decisively and promptly in the event of such disasters

Other Aerosol Science CDT projects are using machine for toxicological analyses studies

Increase in statistical correlation between dose amount and toxicology (like smoke and nuclear material) could mandate maximum aerosol amounts for different types of aerosols

Foreseeable Challenges

Challenge:
A major foreseeable challenge is integrating various image and non image classification techniques for different experiments and particle types.

This will involve rigorous understanding of the reasons for the selection of each model

Solve using a hybridisation of the different models, or by implementing a piecewise analysis criteria

Piecewise criteria will be tricky to implement because it will require some form of pre-classification

Possible solution:
Integrating the TBS approach to non-image analysis, ie. CNN (Convolutional Neural Network) autoencoders for clustering and classifying

Acknowledgements

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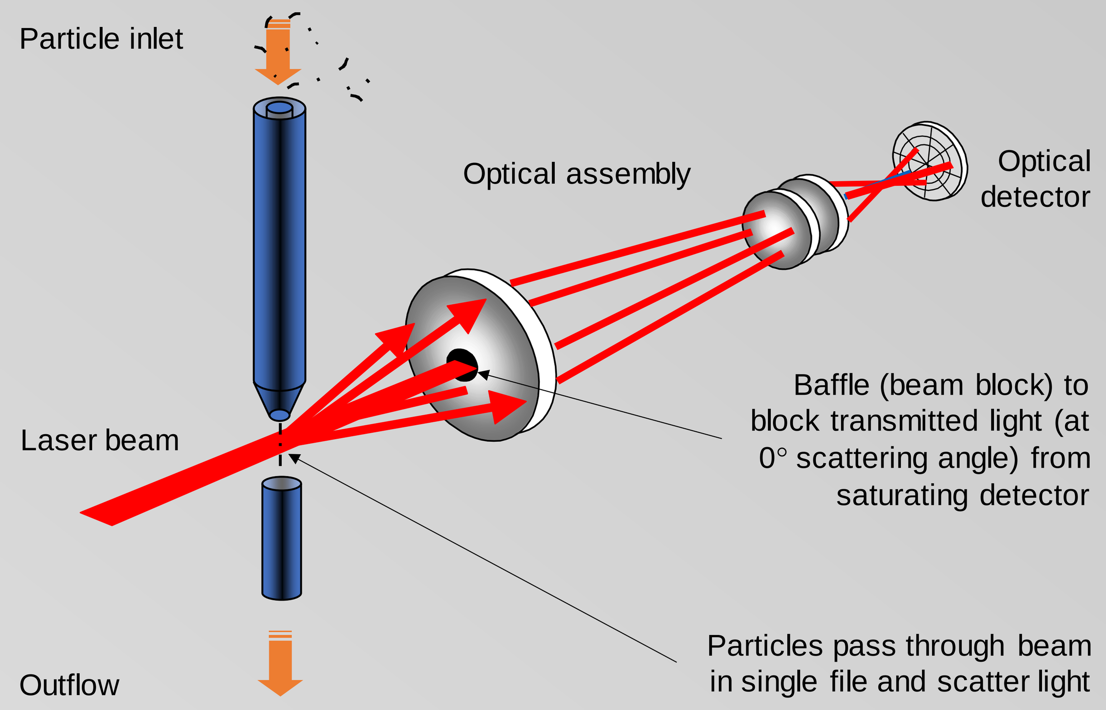
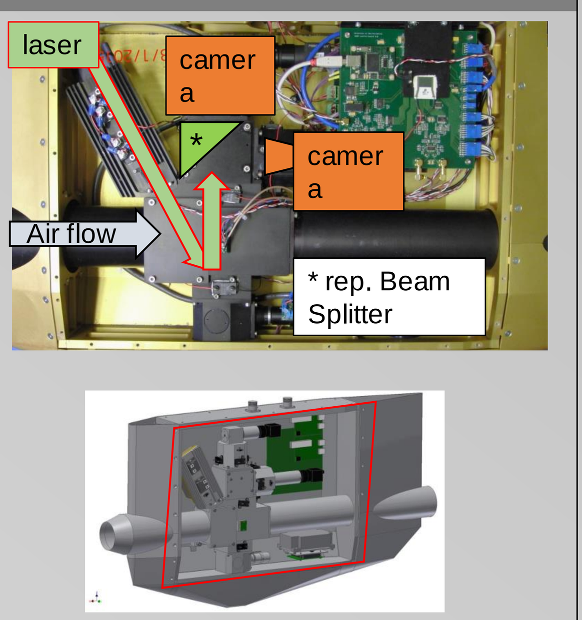
Scattering Experiments

Scattering experimental setup



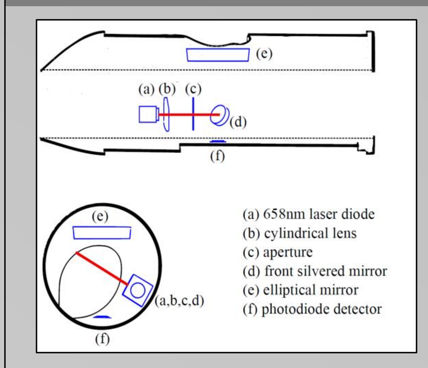
Scattering experimental setup

Aerosol Ice Interface Transition Spectrometer (AIITS)



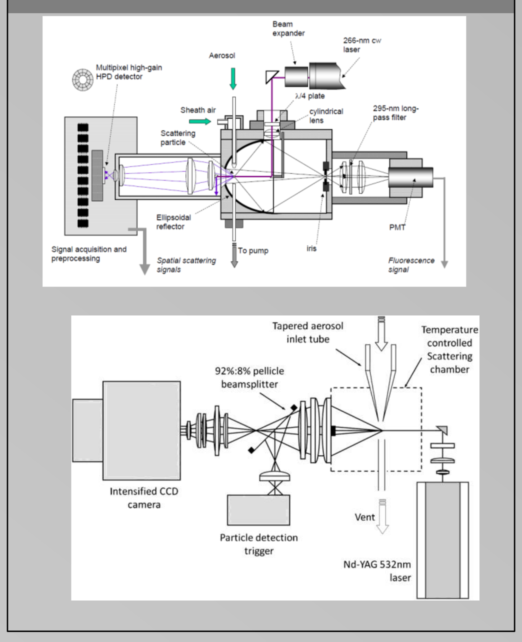
AIITS,
Stopford et al, "Preliminary light scattering data from Tropical Tropopause Layer cirrus"

Universal Cloud and Aerosol Sounding System(UCASS)



UCASS,
Smith et al, "The Universal Cloud and Aerosol Sounding System (UCASS): a low-cost miniature optical particle counter for use in dropsonde or balloon-borne sounding systems"

Experimental schematic

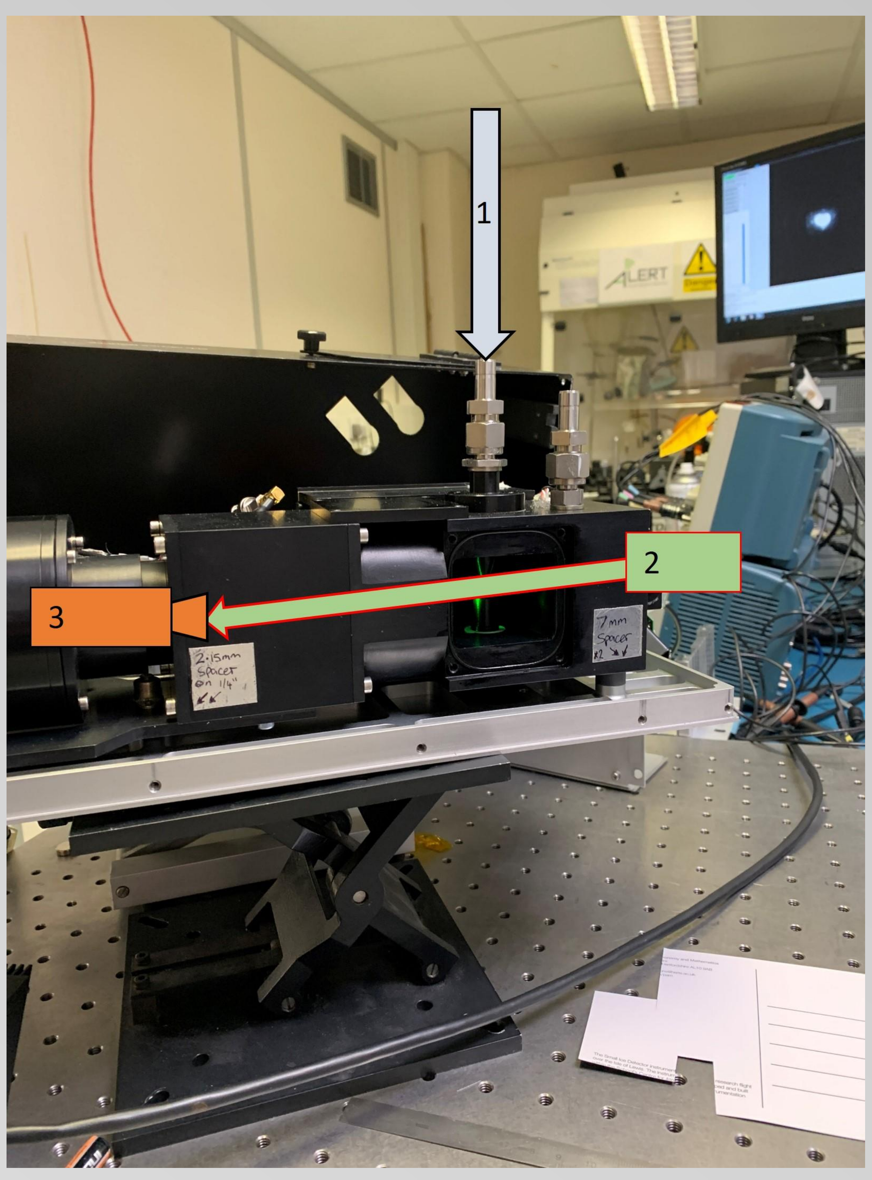


Schematic of instrument employing spatial scattering analysis and single-channel fluorescence to provide real-time particle characterisation (top) [1],
Schematic of the ice crystal scattering instrument (bottom) [2]

Introducing the PPD-2
2nd gen Particle Phase Discriminator

The main detector to be used for this project

Incident light from a laser (2) is scattered by a single particle in a moving air stream (1) , with a camera (3) to capture the images formed as a result of the scattering. Gas with aerosol (1) is pumped through the path of the laser and scatters the light onto the camera, resulting in scattering patterns to be classified using ML.



Reference:
1 - Hirst et al, "An instrument for the simultaneous acquisition of size, shape, and spectral fluorescence data from single aerosol particles"
2 - Kaye et al, "Classifying atmospheric ice crystals by spatial light scattering"