Ice Spectroscopy, Scattering and Levitation:
A New Laboratory Perspective

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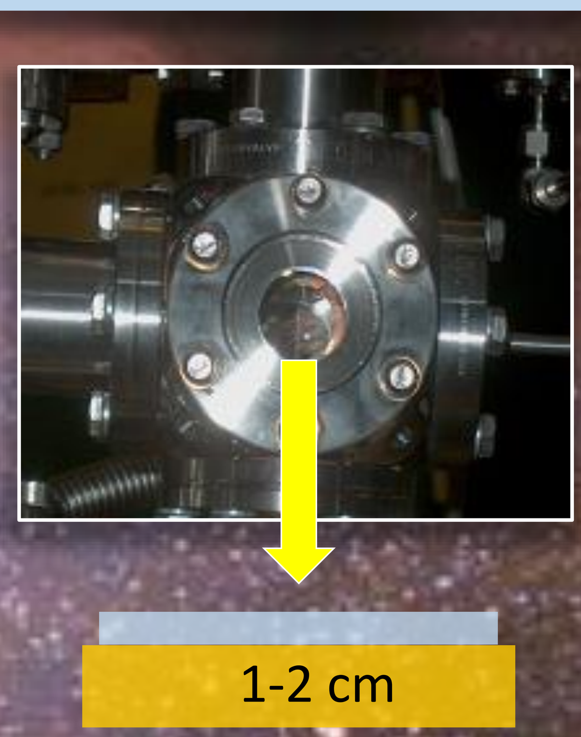
Microscopic icy dust grains play a crucial role in the chemical evolution of dense molecular clouds and are a vital component in **star and planet formation** in the interstellar medium.

However little is known about how or whether **dust grain size, structure and composition** influence the physical and chemical properties of the ice mantles that accrete upon them.

Since most of what we know about the physical and chemical properties of icy grain mantles in dense molecular clouds comes from direct **observation** and via comparison of infrared absorption features with **laboratory** spectra...

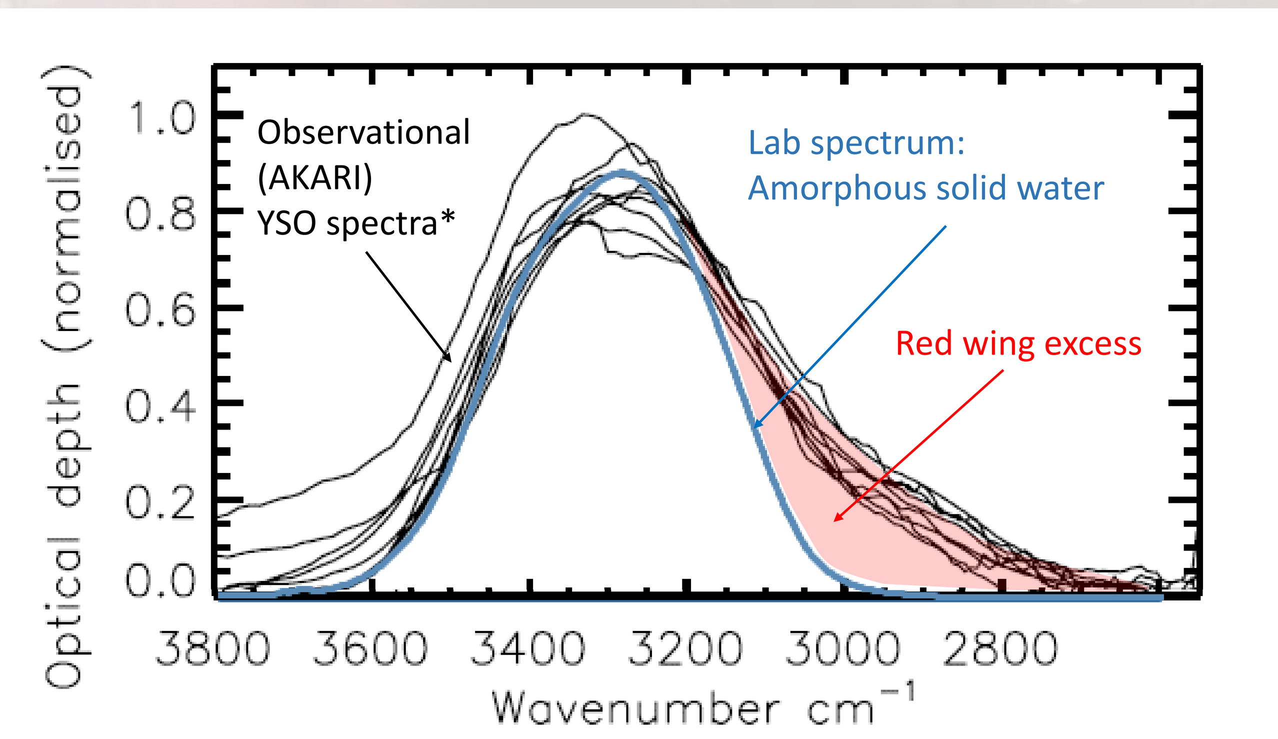
...This raises an important question →



Are ices grown in the laboratory representative of ices in the interstellar medium

Lab ice analogues	VS	Icy grains in space
• Typically polished metal/ crystal substrate • Flat cm^2 surfaces		• Carbonaceous/silicate • Possibly fractal-like • 0.1 – 0.6 µm

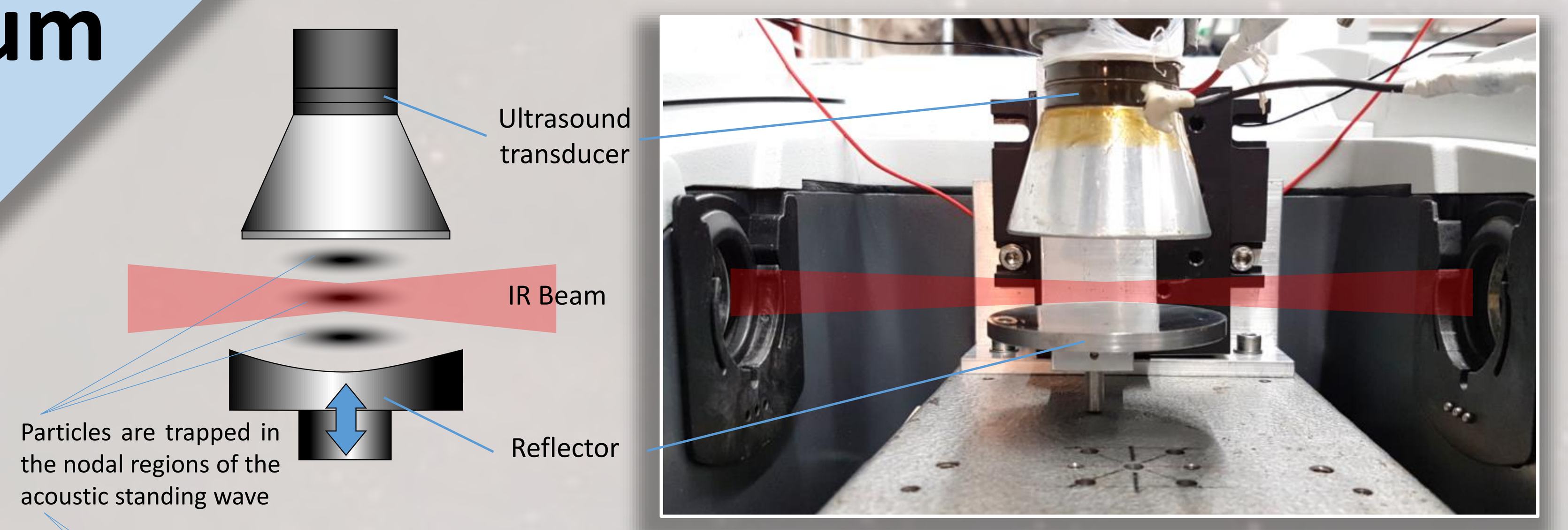
Discrepancies between Lab and Observations: the 3 µm H_2O ice absorption band profile

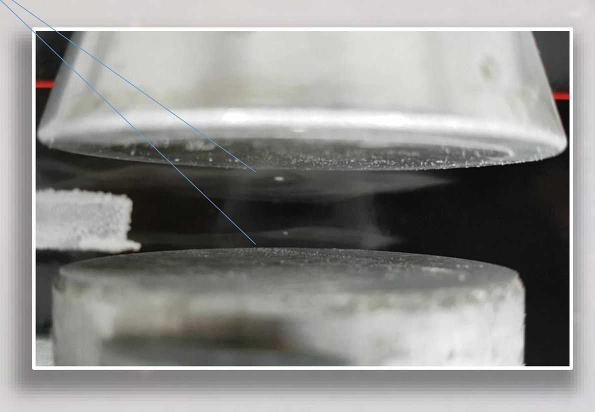


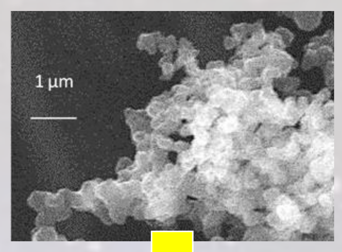
* Noble et al, The Astrophysical Journal, 775(2), p. 85 (2013)

- The 3 µm (3333 cm^{-1}) interstellar OH stretch band profile exhibits a **red wing** excess
- This has not been reproduced in the laboratory
- Suggested causes are
  - Other molecular species (e.g. methanol)
  - Aromatic and aliphatic carbonaceous grain CH stretches
  - Grain size and shape effects

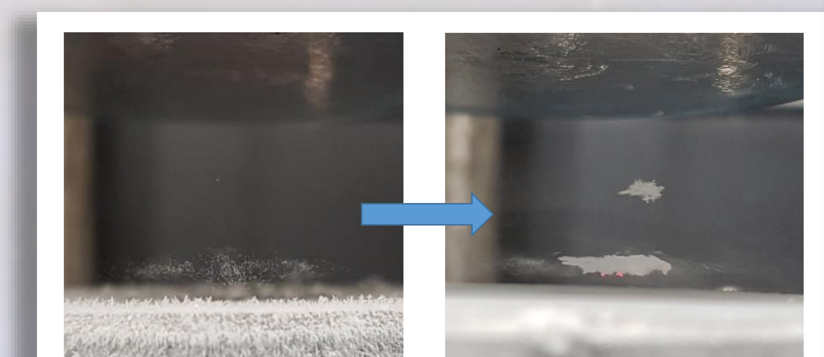
A novel laboratory technique: Acoustic levitation







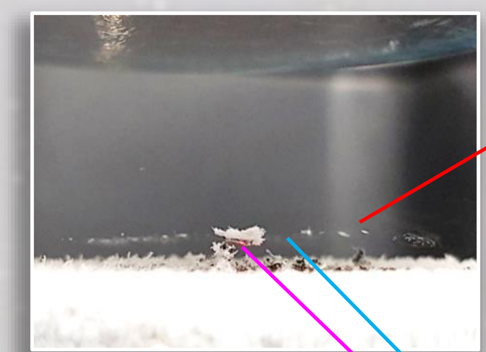
Soot as a preliminary carbonaceous interstellar dust grain analogue



Levitated ice micro-particles aggregate forming 'snowflakes'

Levitated soot particles (left) act as condensation nuclei for ice mantle formation (right)

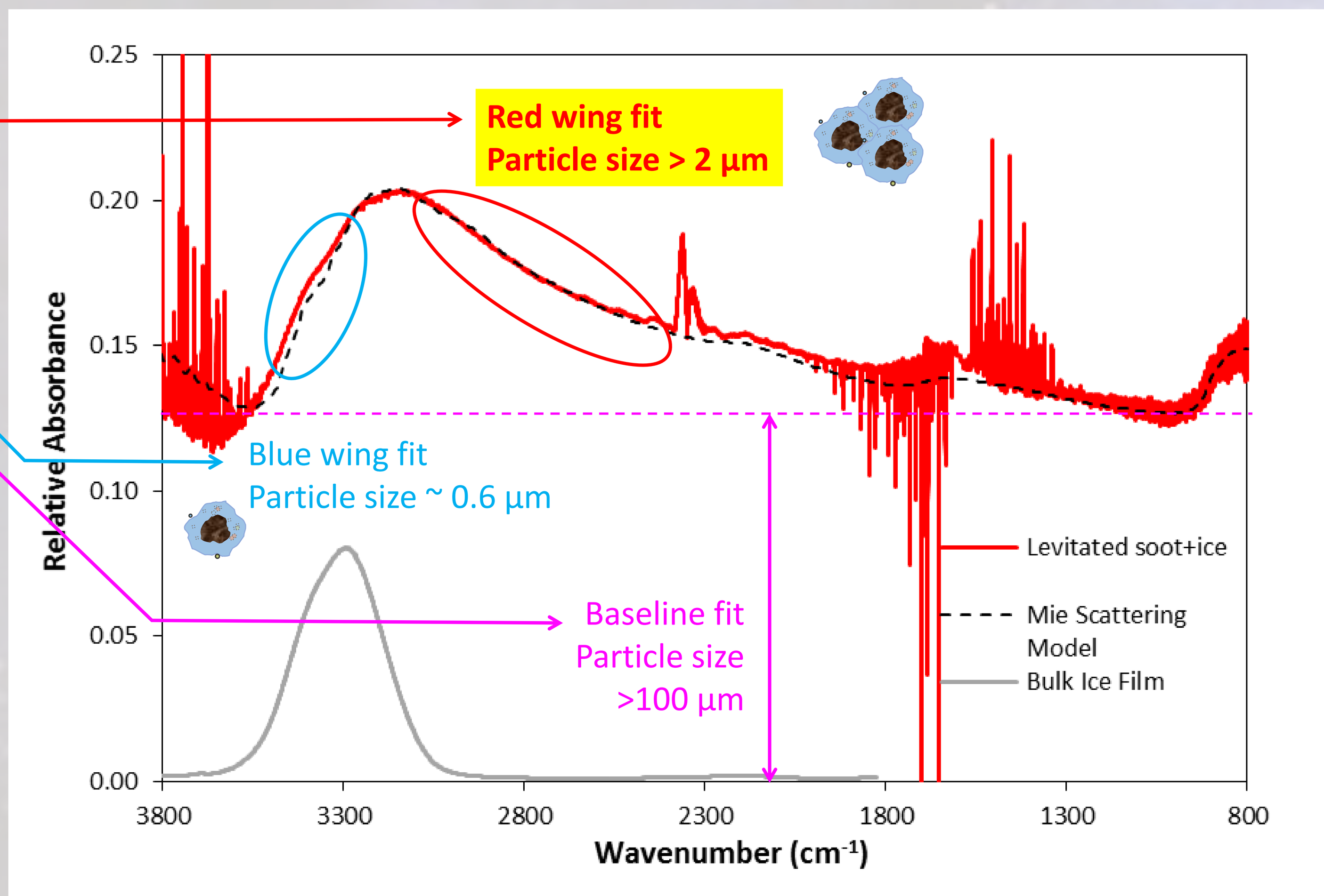
First laboratory results: an answer to the red wing problem?



Icy soot particles levitated in the acoustic trap.

Infrared spectrum of the levitated particles above (red), fitted with a Mie scattering model (dashed black) and compared to a lab spectrum of an ice film on a substrate (grey).

A sub micron sized 'cloud' of particles aggregate to form micron sized particles which in turn aggregate to form the larger mm-sized in the centre



- Mie scattering (spherical particle) model best fit with a tri-modal distribution of crystalline ice particles:

Particle Size (µm)	0.6	2	100
Relative number density	100	10	0.05
Spectral contribution	Blue wing	Red wing	Baseline

Extended red wing:

- Strikingly comparable to observational spectra
- Well fitted with a Mie scattering model
- Indicative of icy grain aggregation (micron sized particles)

Work in progress...

Further development of the acoustic trap to control **ice** temperature (amorphous vs crystalline) and composition, **dust** structure and composition (silicate vs carbonaceous) and investigate the factors that govern **aggregation**

... and compare with observations