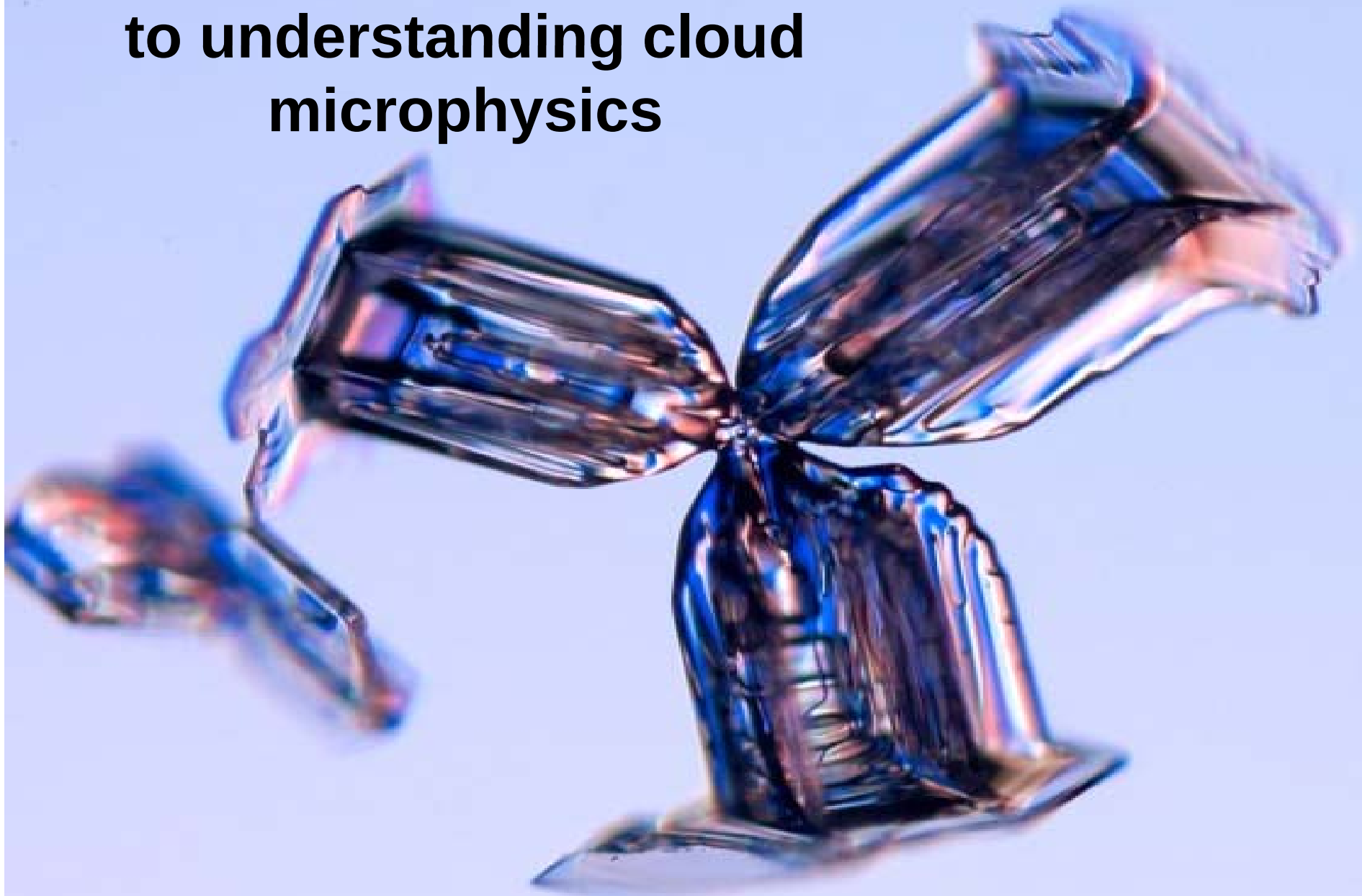


Observational approaches to understanding cloud microphysics



Microphysical measurement needs

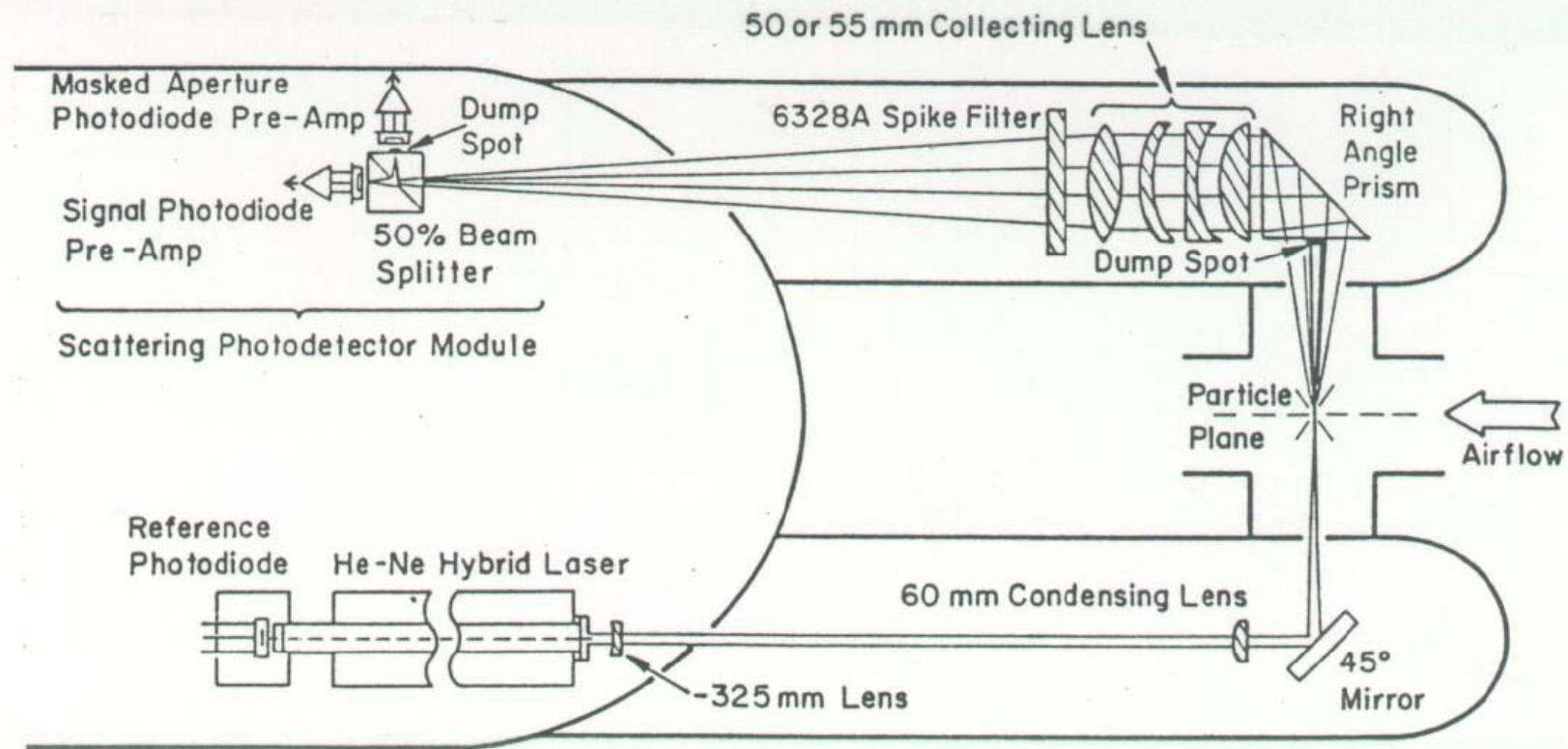
Quantitative characterization of....

- 1) Size distribution of liquid hydrometeors from CCN size ($0.01\ \mu\text{m}$) to precipitation size ($10000\ \mu\text{m}$) – 6 orders of magnitude range of size (18 of mass!)
- 2) Size/mass distributions and habits of ice-phase hydrometeors ($1\text{-}10000\ \mu\text{m}$)
- 3) Efficacy of aerosols to act as CCN and IN
- 4) Thermodynamic and dynamic environment in which hydrometeors form, exist, grow, and evaporate

1. Liquid Hydrometers

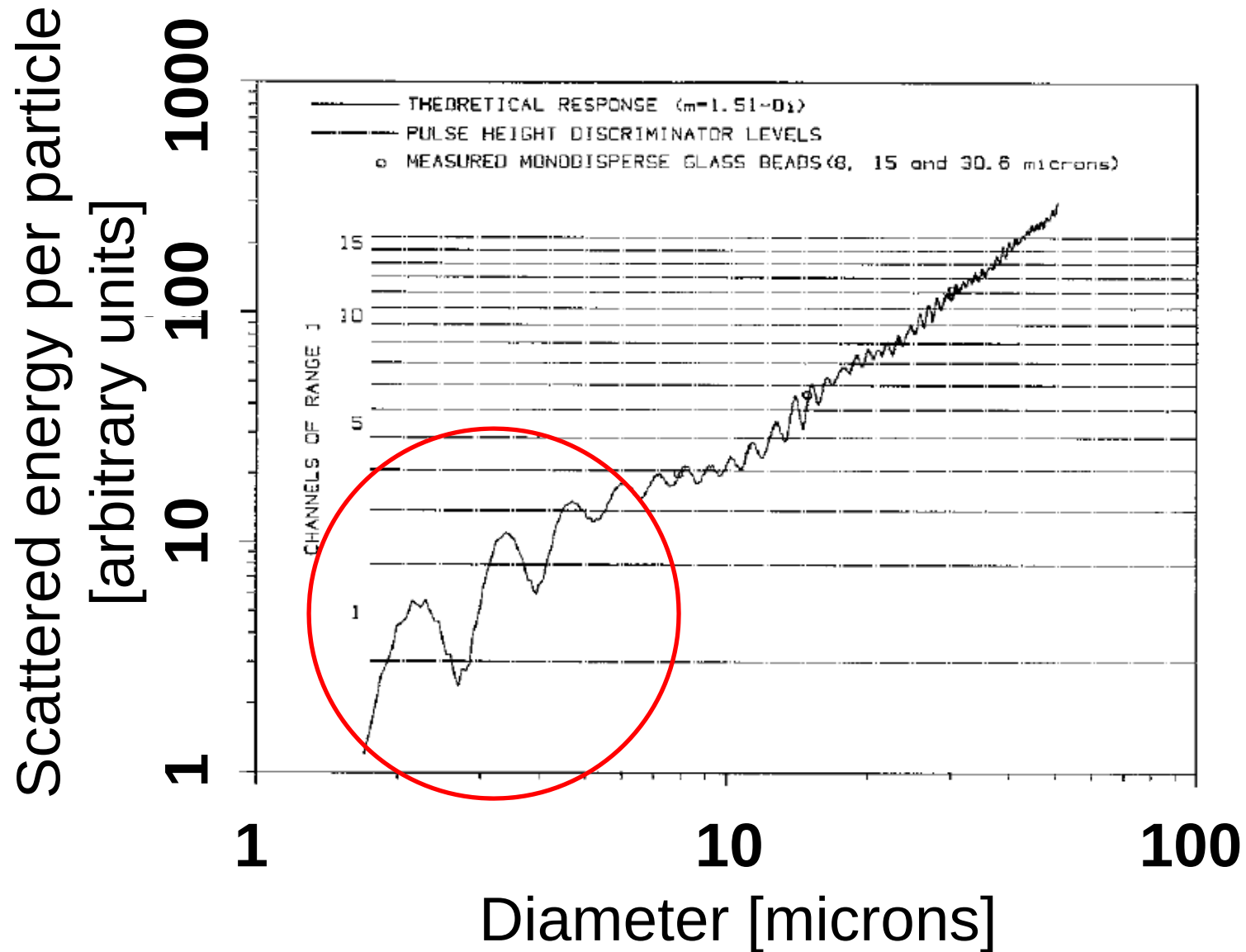
Forward Scattering Spectrometer Probe (FSSP)

Radius range 1-25 μm



NCAR

FSSP Scattered Energy

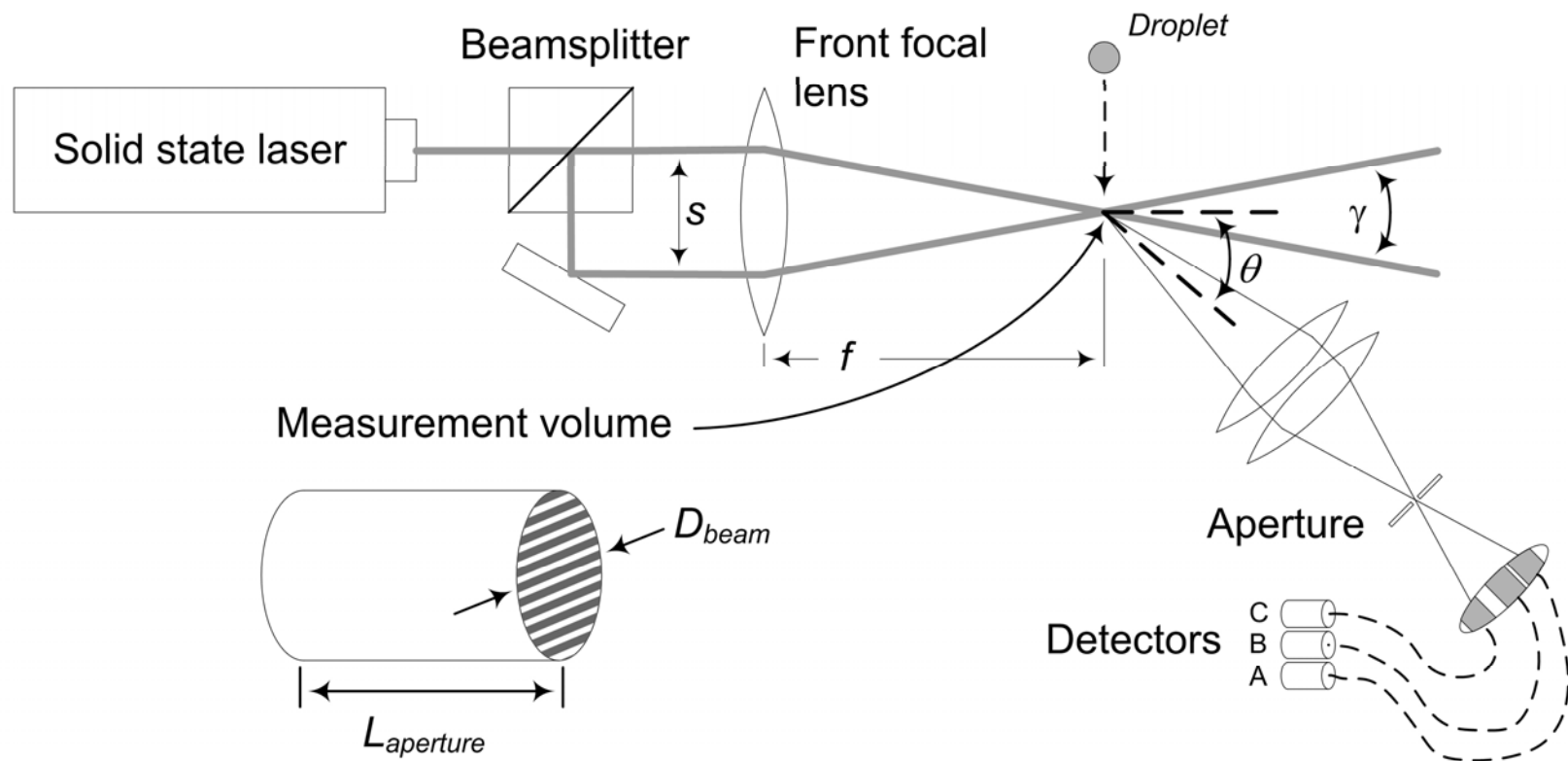


Phase Doppler Particle Interferometer (PDPI)

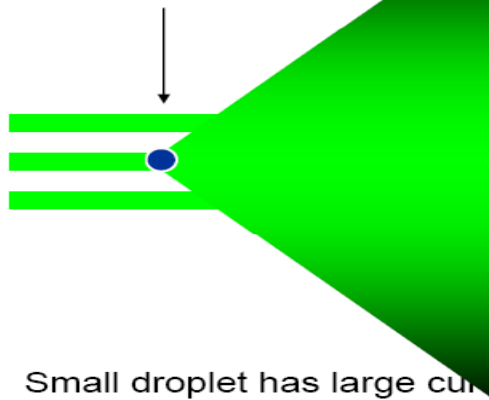
Size range 1-1000 μm



Interferometry



Drop passes through
Probe Volume with Fringes



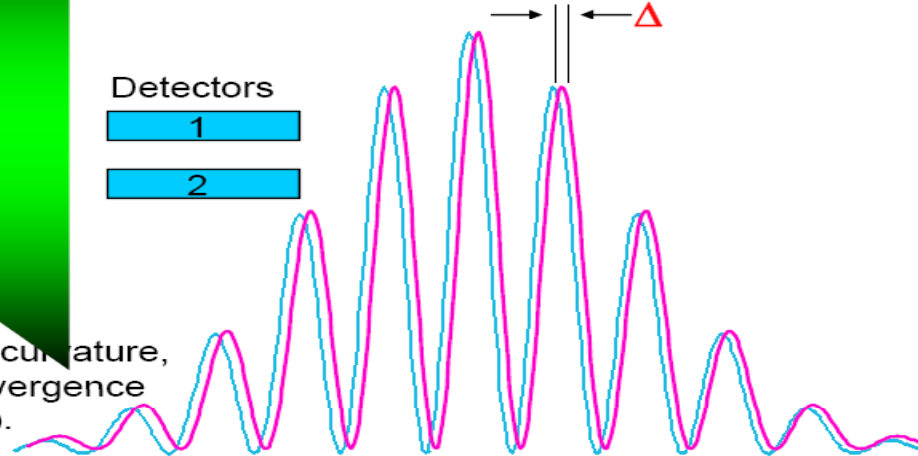
Detectors

1

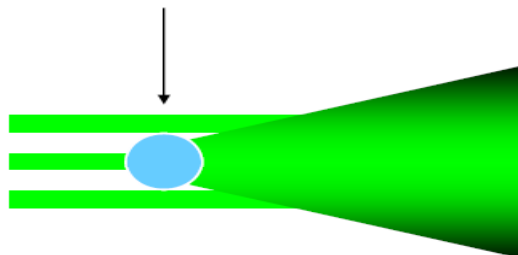
2

Small droplet has large curvature,
which causes large divergence
(just as a lens).

This leads to a
small phase
difference Δ .



Drop passes through
Probe Volume with Fringes



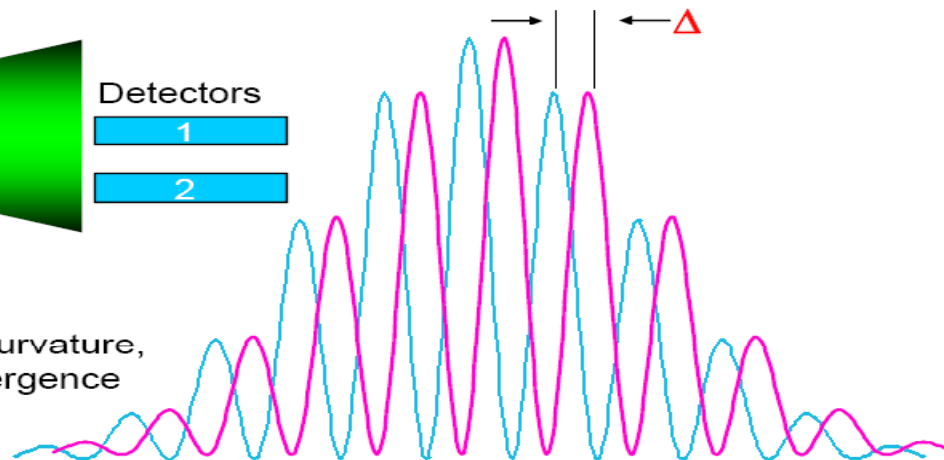
Detectors

1

2

Large droplet has small curvature,
which causes small divergence
(just as a lens).

This leads to a
large phase
difference Δ .



Larger particles $D \gg \lambda$

- Optical Shadow Probes (Optical Array Probes, OAPs)

Size range
10-10000 μm

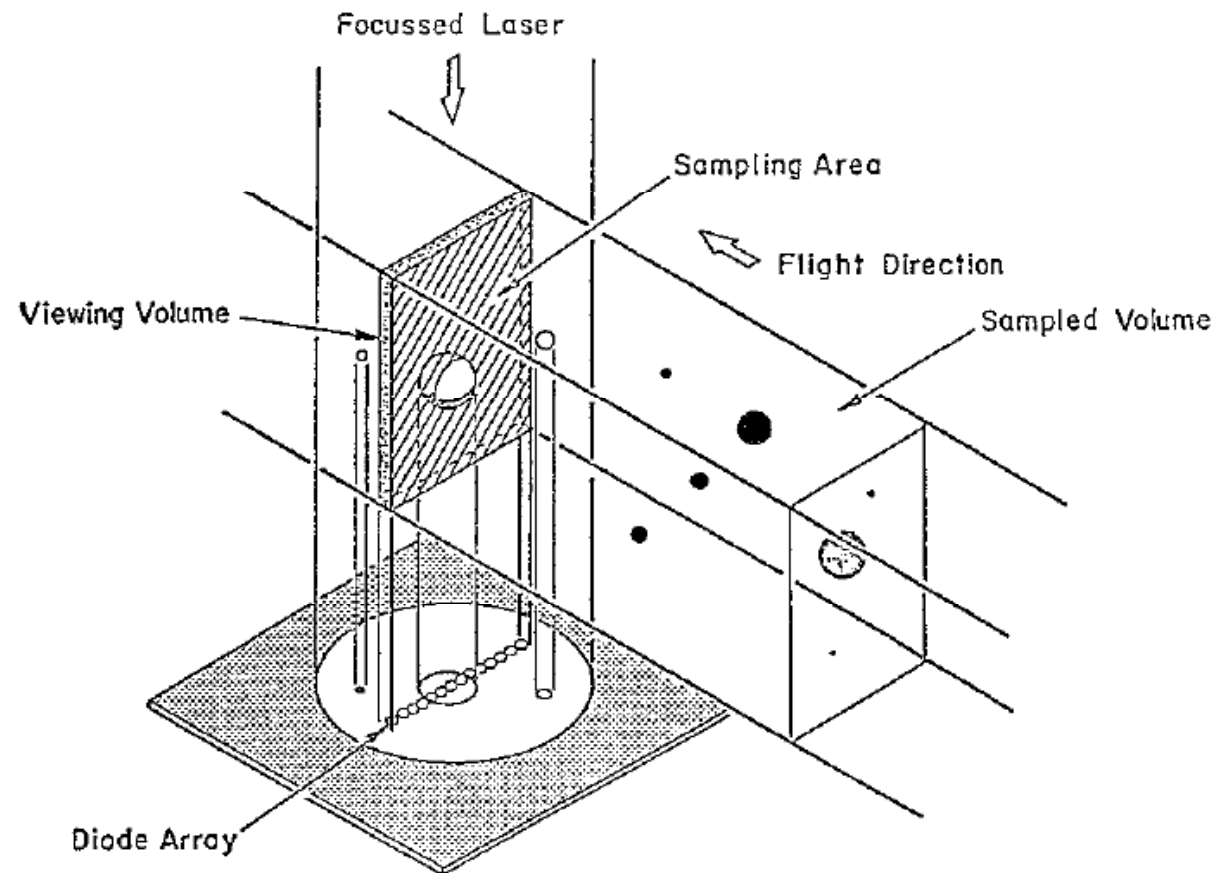
Examples:

260-X

2D-C

2D-P

HVPS



Baumgardner and Korolev, J Atmos. Ocean Tech., 1997

Comparison of FSSP and OAPs

- Problems in overlap zone

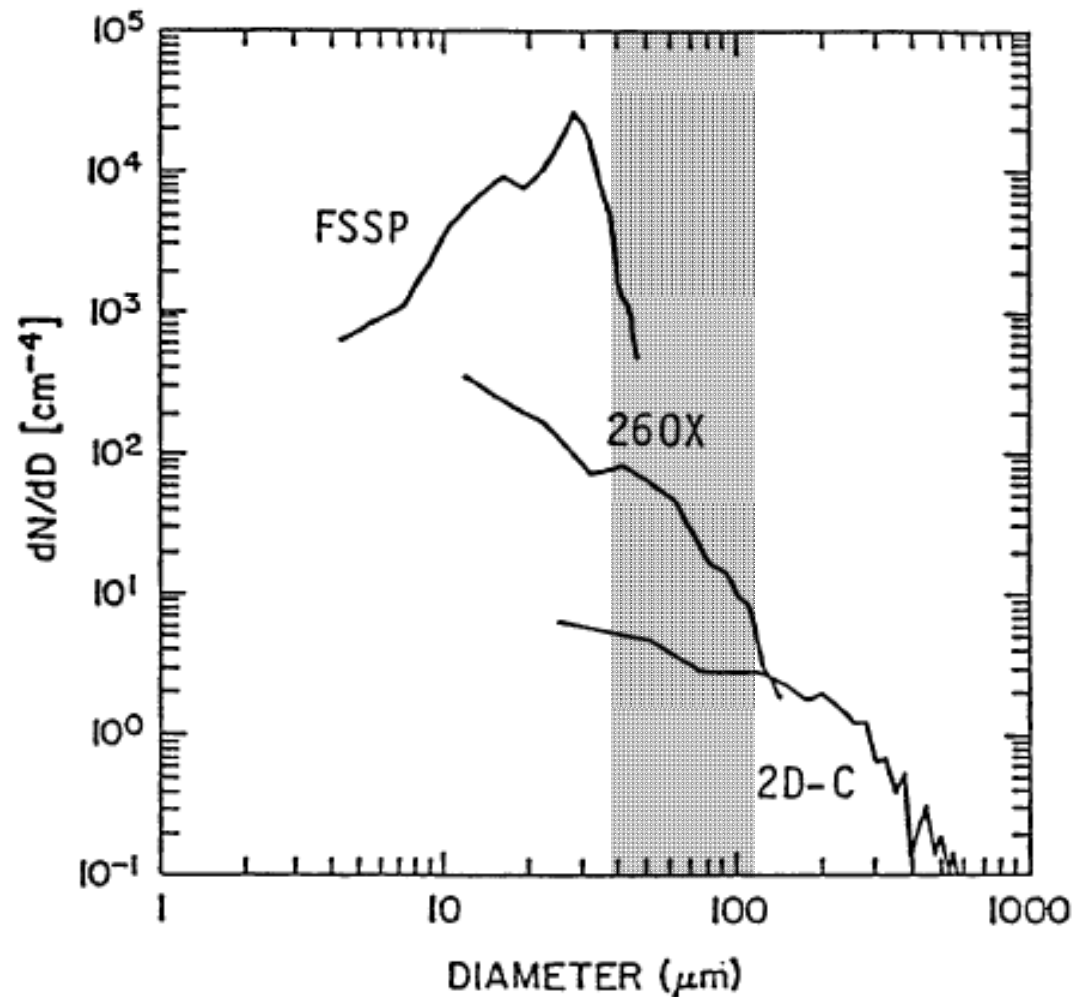


FIG. 2. Typical size distributions of droplets in a marine cumulus cloud are shown here as measured with a PMS FSSP-100, 260X 1D OAP, and 2D-C OAP using the manufacturer's depth of field specifications.

2. Ice Hydrometeors

Small ice – the perennial problem

- FSSPs can be used, but....

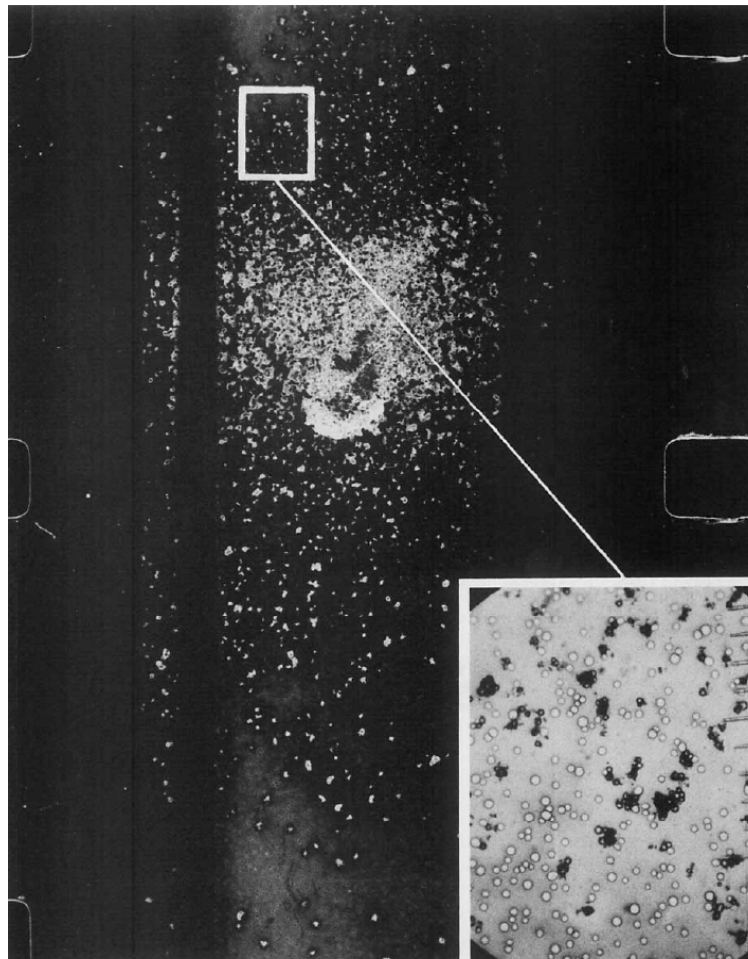
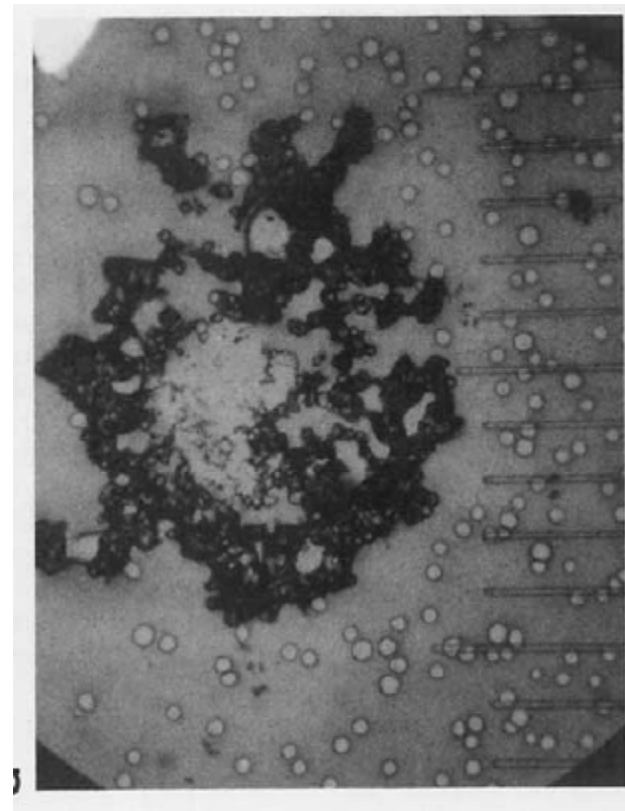
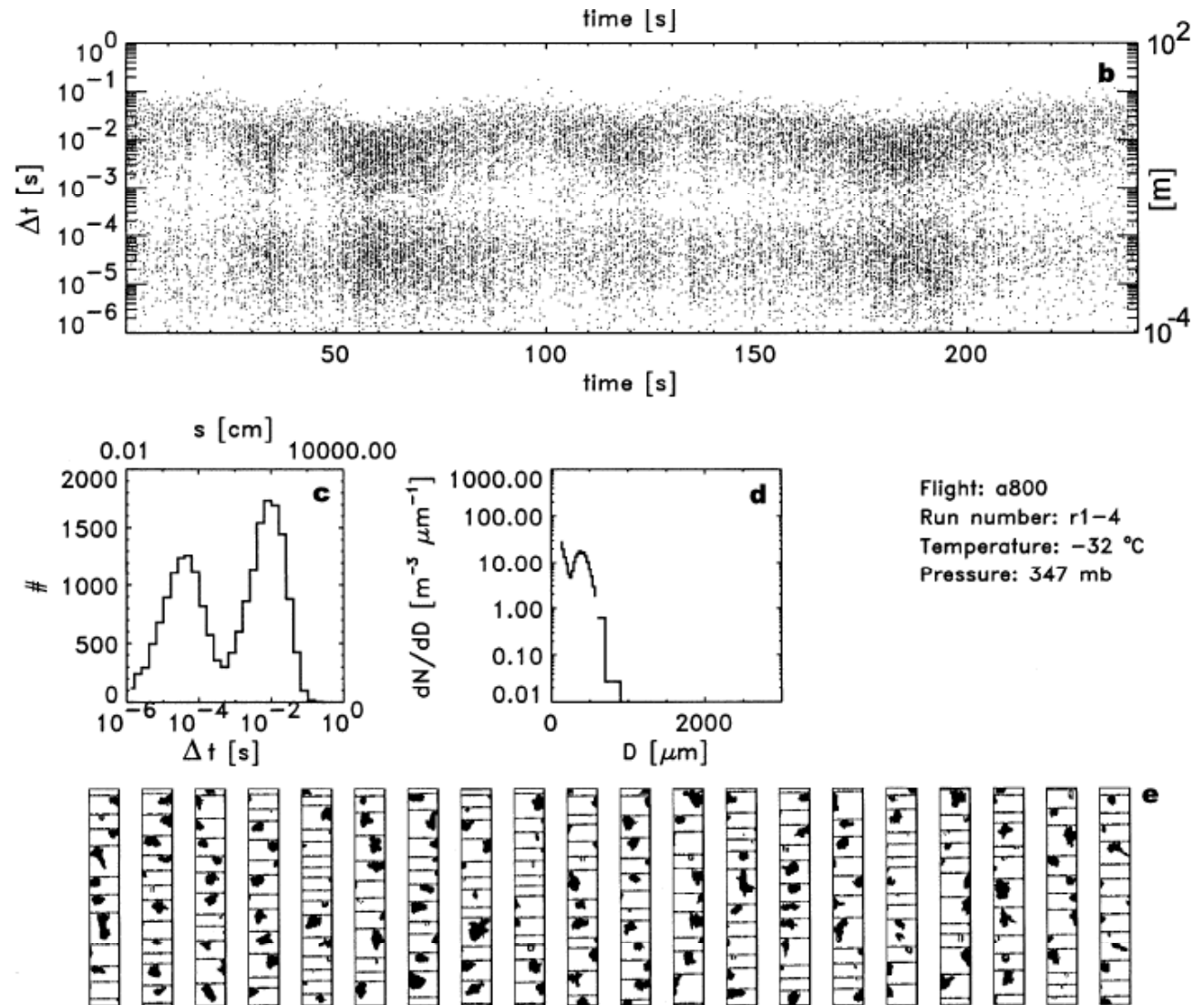


FIG. 9. Breakup of graupel particle on impact with formvar replica on 16 mm film. Several hundred particles $\sim 100 \mu\text{m}$ in diameter are produced. As the particles are collected in the formvar, they freeze supercooled droplets with which they come into contact. These can be distinguished by their darker appearance in the inset (scale $100 \mu\text{m}$).



Interarrival times in ice clouds

- Bursts of particles observed
- Shattering of large ice giving impression of many small xtals



Field et al., *J Atmos. Ocean Tech.*, 2003

Small ice – the perennial problem

...and

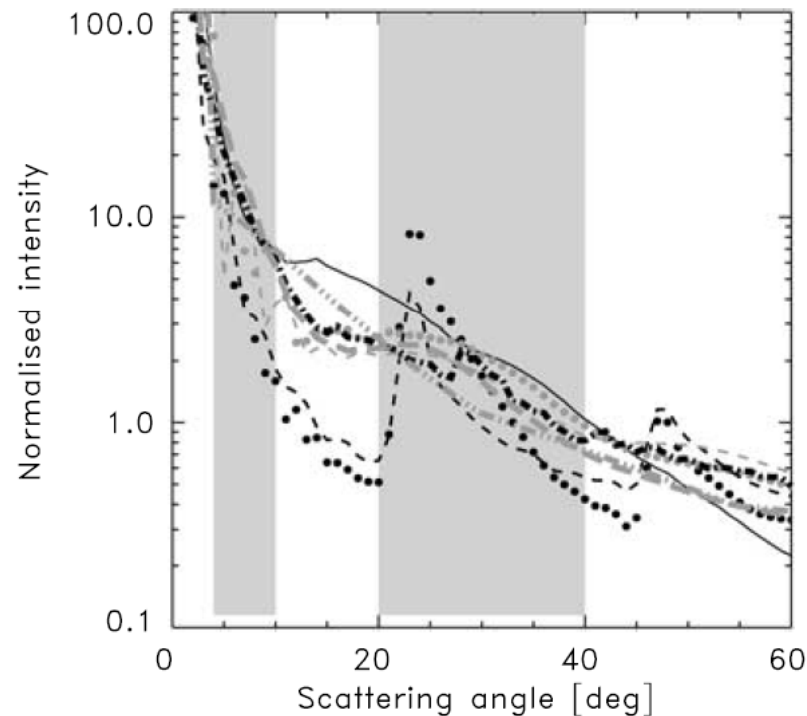
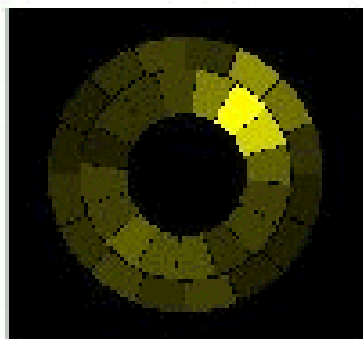
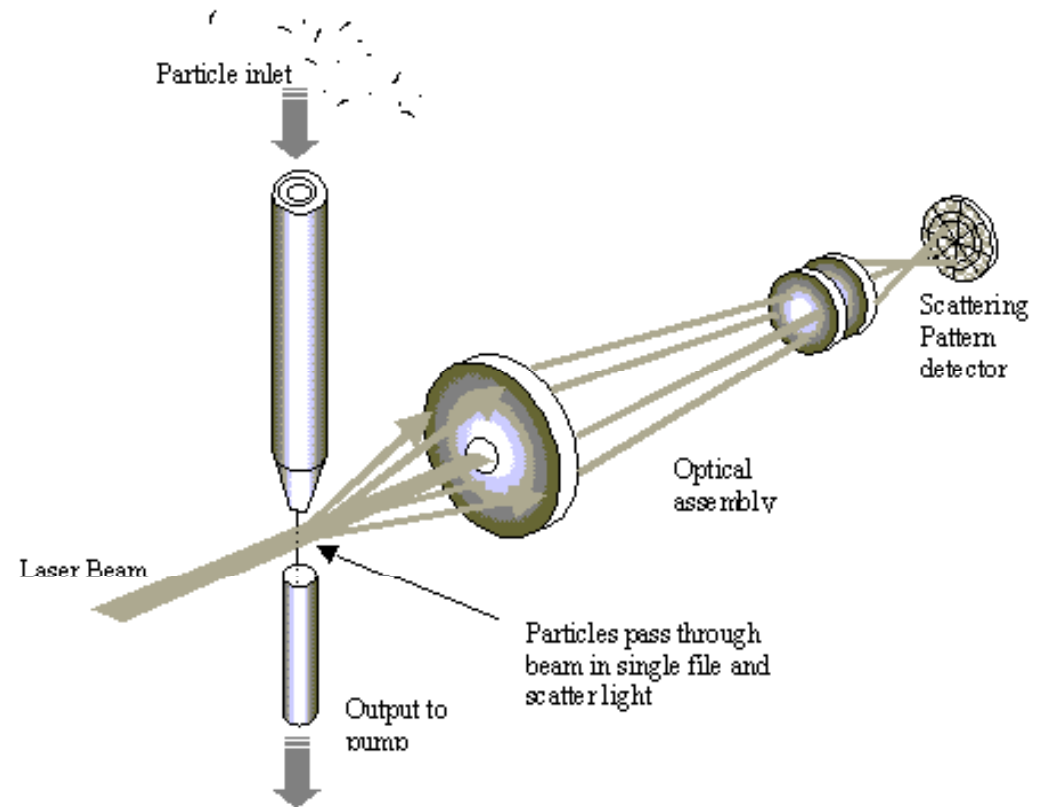


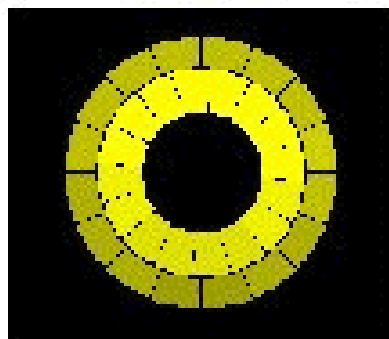
Figure 1. Normalised randomly oriented phase functions for 10 μm (radius) spheres (solid), column (7.5 μm , grey dots; 25 μm black dots), plate (7.5 μm , grey dash; 25 μm black dash), polycrystal (dot-dash), aggregate (thin grey dash) and analytic (dot-dot-dot-dash). The shaded regions mark the scattering angles covered by the SID probe.

The Small Ice Detector (SID)

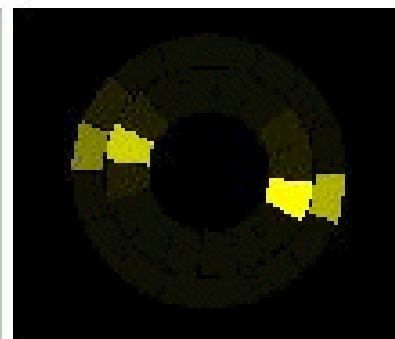
- Examines angular dependence of scattering
- Irregular particles



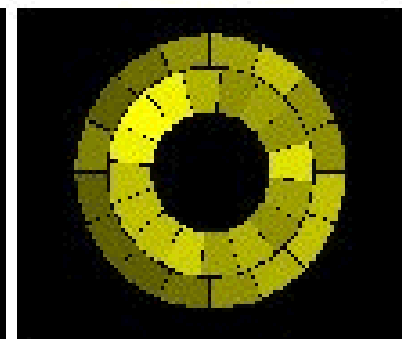
Flake particle



Water droplet



Fibre



Irregular cubic particle

Large ice crystals: OAPs

Size range 25-4000 μm

- OAP images

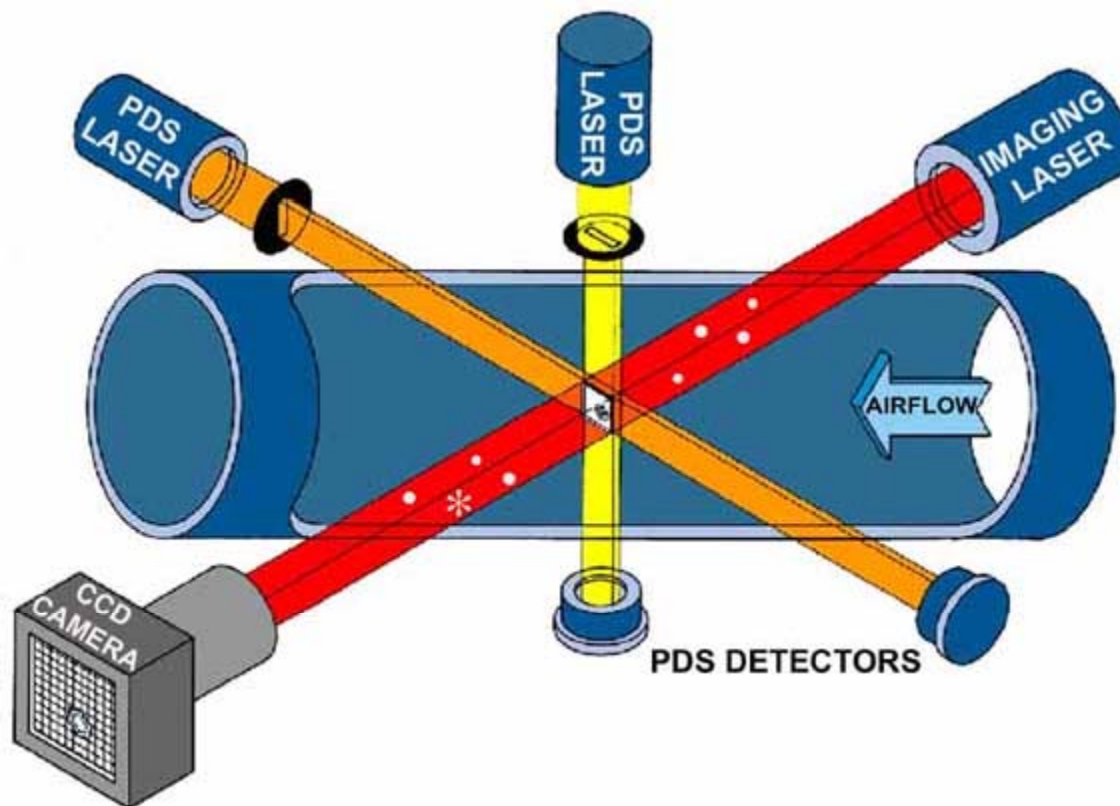
↔ 1000 microns [1 mm]



Field, JAS, 1999

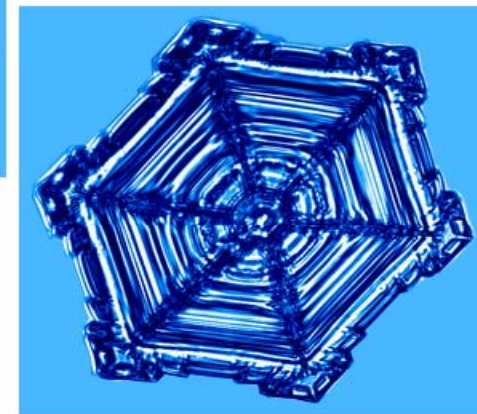
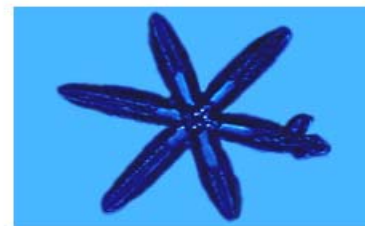
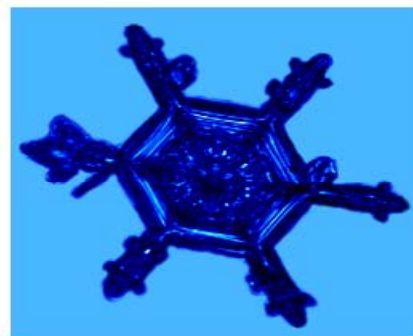
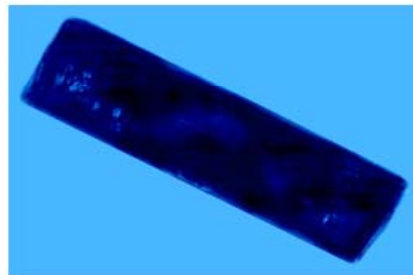
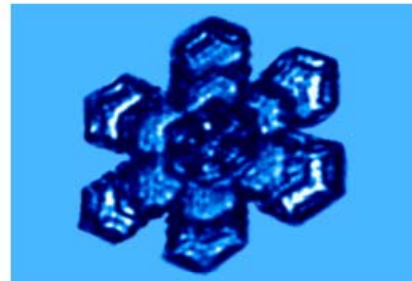
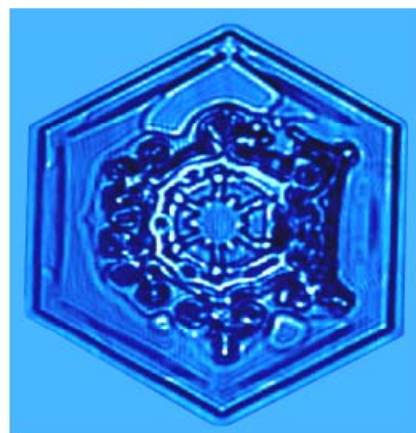
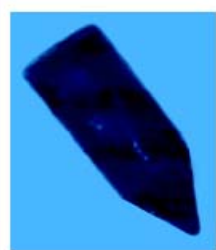
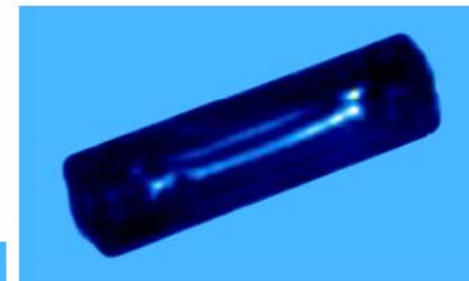
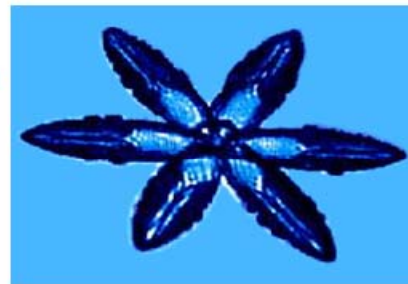
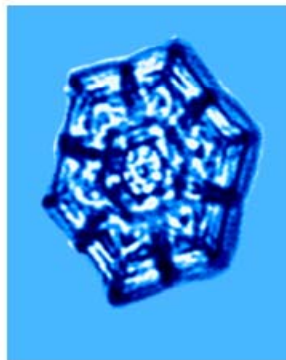
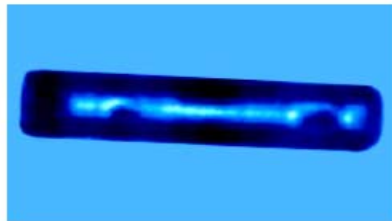
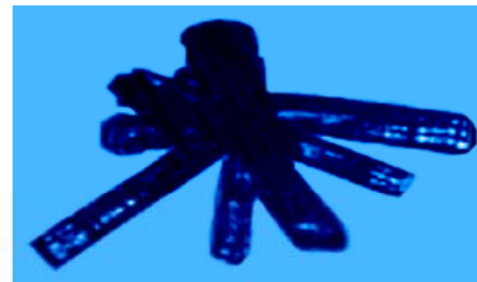
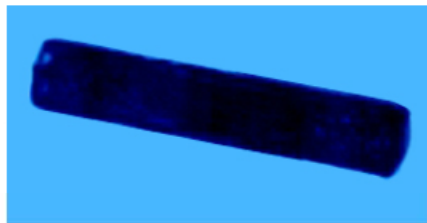
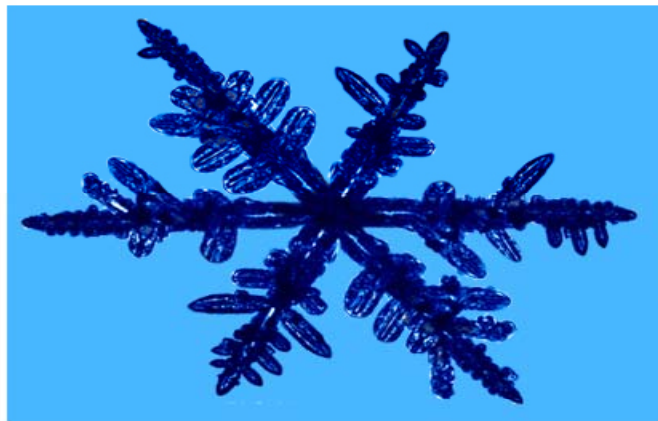
Large ice crystals: Cloud Particle Imager (CPI)

Size range 10-4000 μm

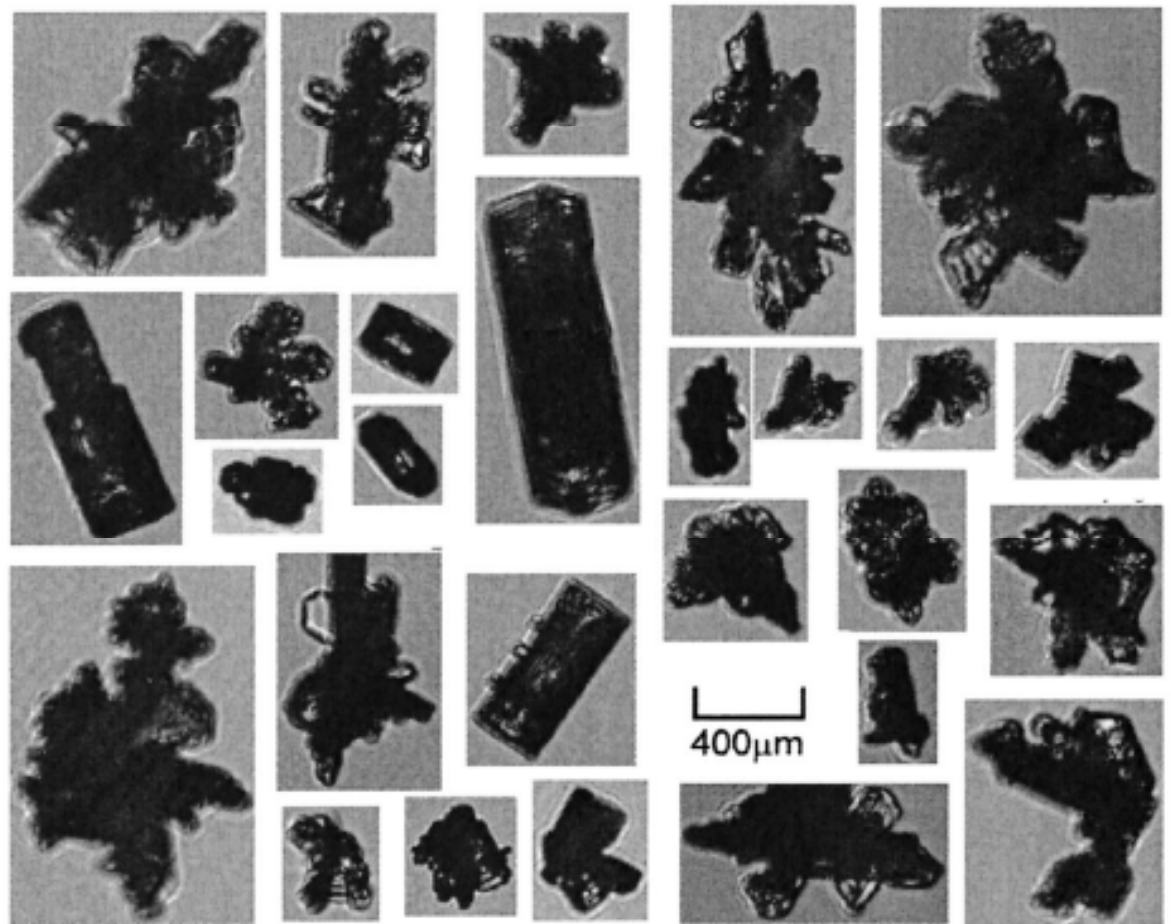
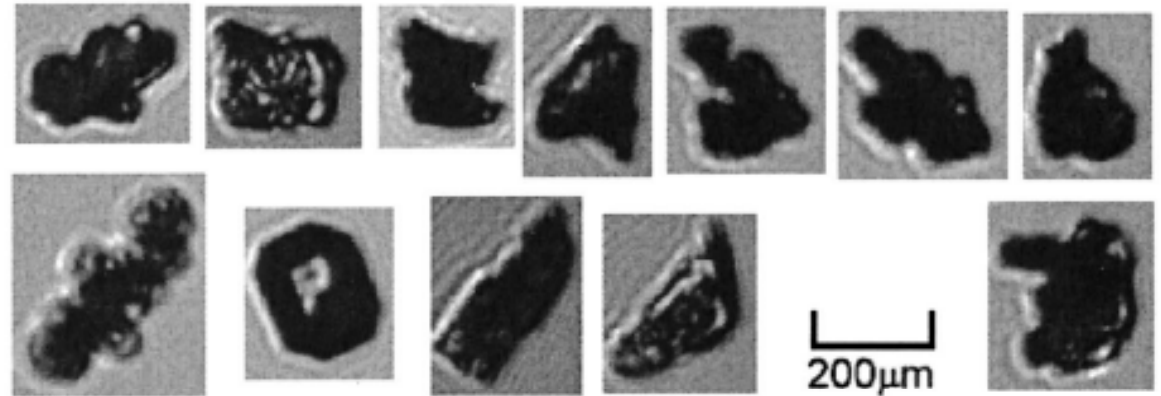


- CCD camera takes photographs of particles

SPEC Inc, Boulder

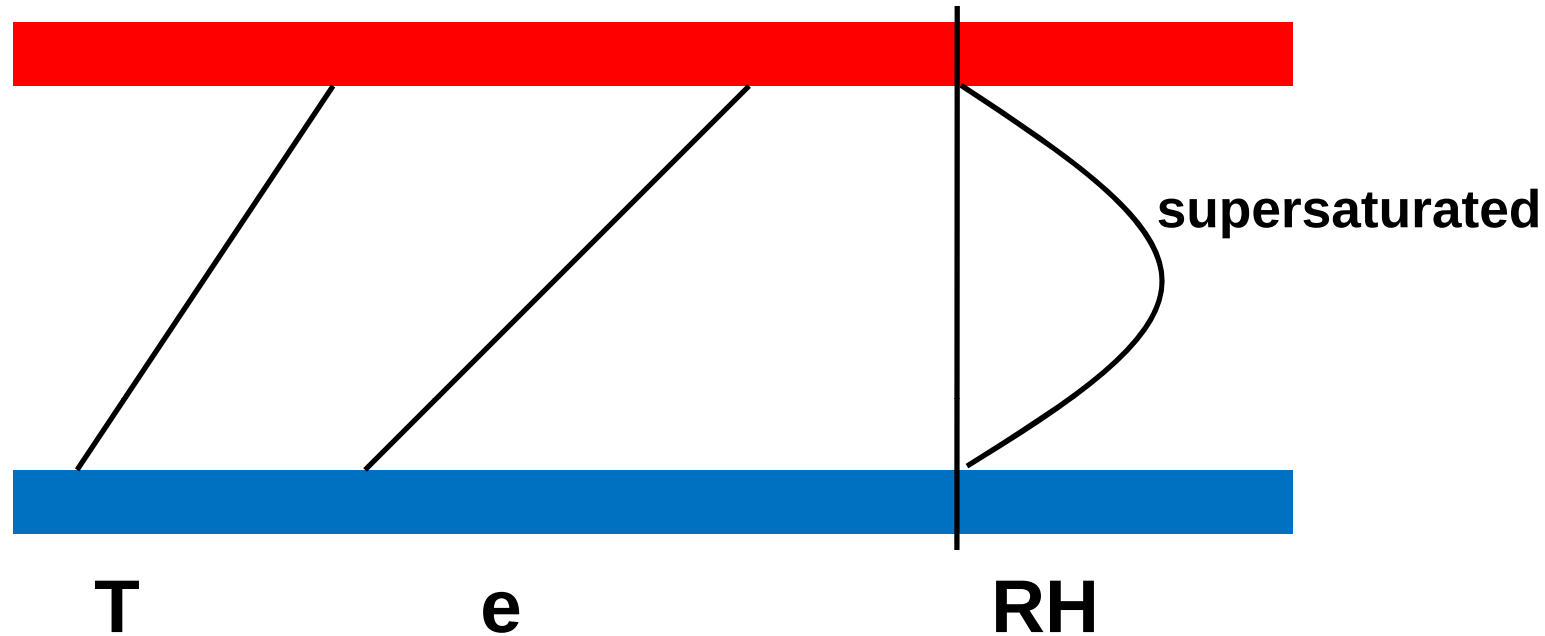


More common crystals



3. CCN/IN characterization

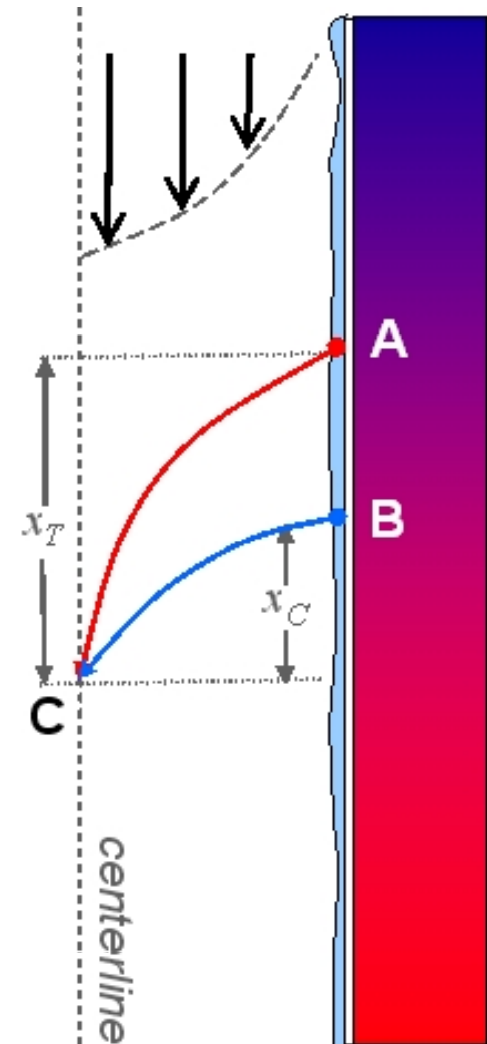
Thermal diffusion chamber



- Supersaturation maximizes in center of chamber and can be controlled by ΔT
- Subject aerosols to known supersaturation and check for rapid growth using a droplet counter
- Vary ΔT and obtain a CCN spectrum

Thermal diffusion chambers

- New designs allow for:
 - continuous flow in chamber
 - Multiple supersaturations simultaneously
- Can be used at between ice and water saturation to characterize heterogeneous deposition nuclei



IN characterization

- Cannot measure (in-situ):
 - Contact freezing IN
 - Immersion freezing IN

4. Characterization of thermodynamic environment

- Temperature
- Vapor content
- Liquid water content

Humidity

- High concentrations:
 - Optical (Lyman-alpha)
 - Tunable diode laser
 - Dewpoint Hygrometer
- Low concentrations:
 - Fluorescence hygrometer

Liquid water content

- Hotwire probes
- Nevzorov probes
- Lyman-alpha, total water content