

AN AIRBORNE DIGITAL HOLOGRAPHIC  
INSTRUMENT FOR MEASURING THE  
SPATIAL DISTRIBUTION AND LOCAL SIZE  
DISTRIBUTIONS OF CLOUD PARTICLES:  
HOLOGRAPHIC DETECTOR FOR CLOUDS 2  
(HOLODEC 2)

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# HIAPER Gulfstream GV



## C-130 Hercules Q

HOLODEC (Holographic Detector for Clouds) is an airborne instrument that measures the size, shape, and relative 3D position of cloud particles using digital in-line holography.

# SCIENCE QUESTIONS FOR HOLODEC 2

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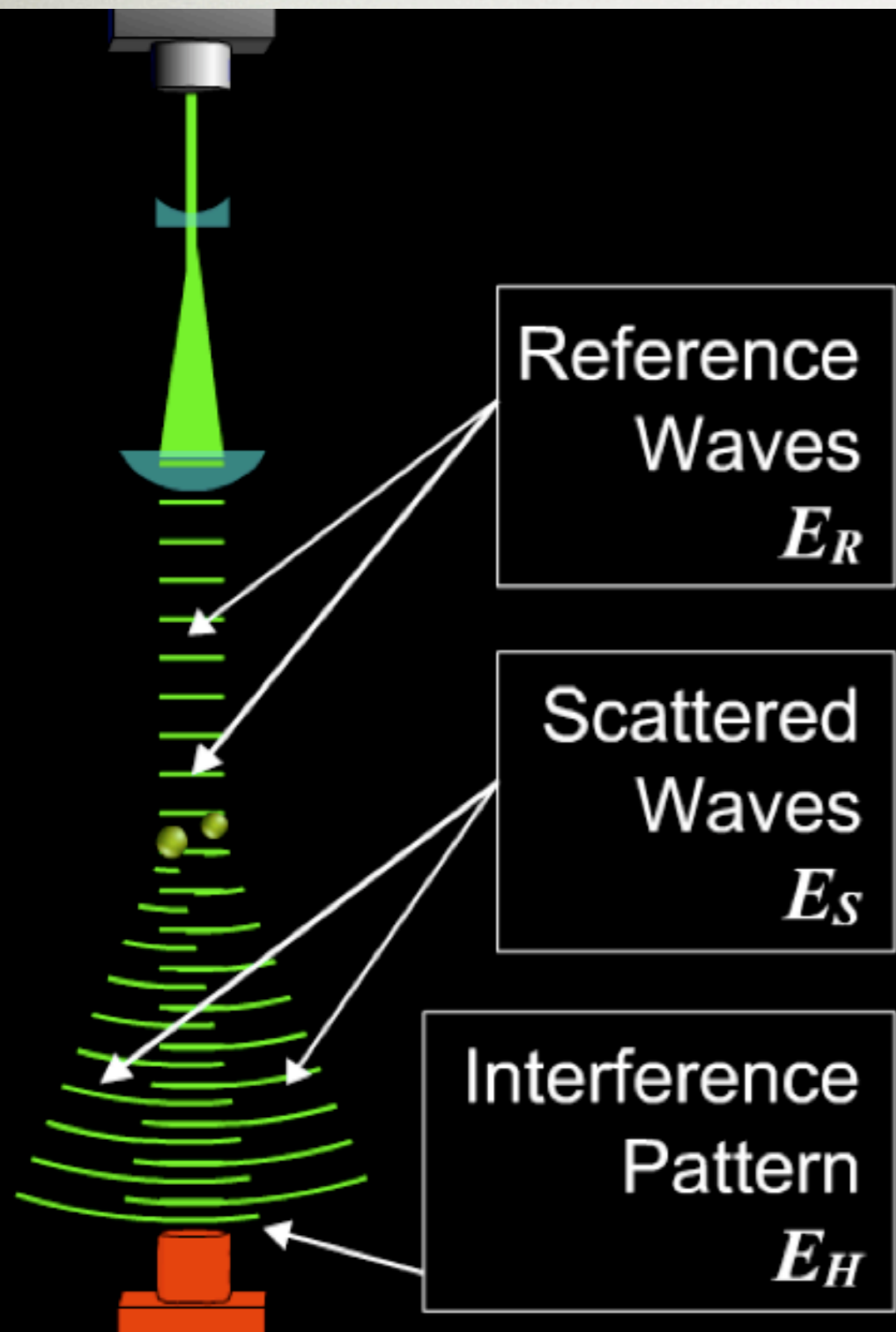
- How do local cloud particle size distributions vary inside cloud regions (edge, top, core, base), by cloud age, cloud type?
- How are cloud particles spatially distributed on sub-cm scales due to mixing, entrainment, and turbulent processes?
- How are ice and liquid water particles spatially distributed or partitioned in mixed-phase regions of cloud?

# HOLOGRAPHIC MEASUREMENT UNIQUENESS AND ADVANTAGES

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- Sample volume is the shape and size of a finger as opposed to a order 100 m long ribbon or pencil shape. Allows localized measurements.
- Sample volume size is insensitive to a particle size dependent depth of focus or air speed. More accurate particle concentration estimates.
- Measures three-dimensional position of particles. Allows view of cloud texture and structure and more accurate rejection of shattered particles.

# MEASUREMENT PRINCIPLE: DIGITAL IN-LINE HOLOGRAPHY



For a single scatterer:

$$E_H = E_S + E_R$$

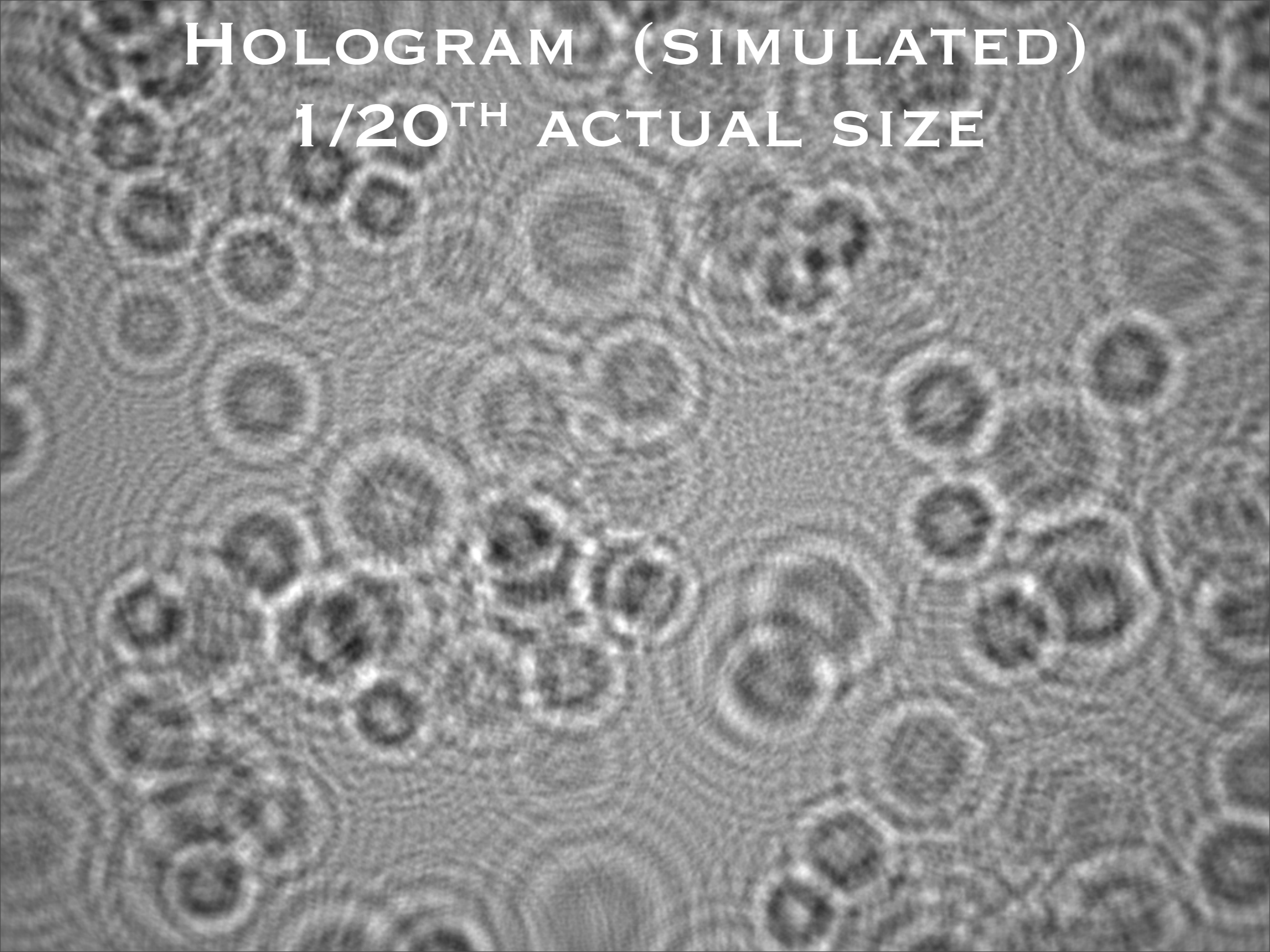
$$I_H = E_H E_H^*$$

$$I_H = E_R E_R^* + E_S E_R^* + E_R E_S^* + E_S E_S^*$$

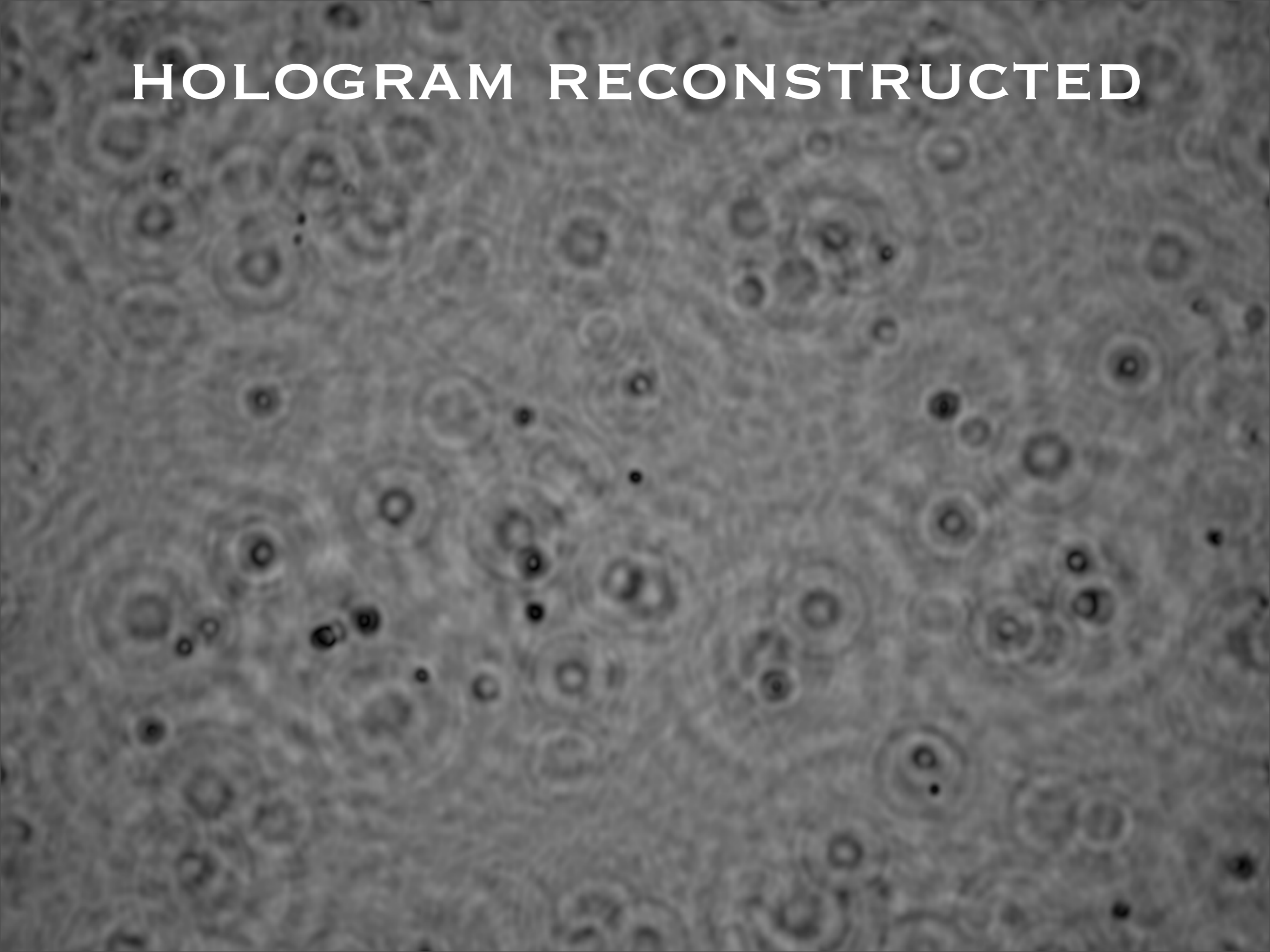
Constant	Real	Virtual	Scattered
Background	Image	Image	Intensity

**HOLOGRAM (SIMULATED)**

**1/20<sup>TH</sup> ACTUAL SIZE**



# HOLOGRAM RECONSTRUCTED



# HOLODEC 1: PARAMETERS

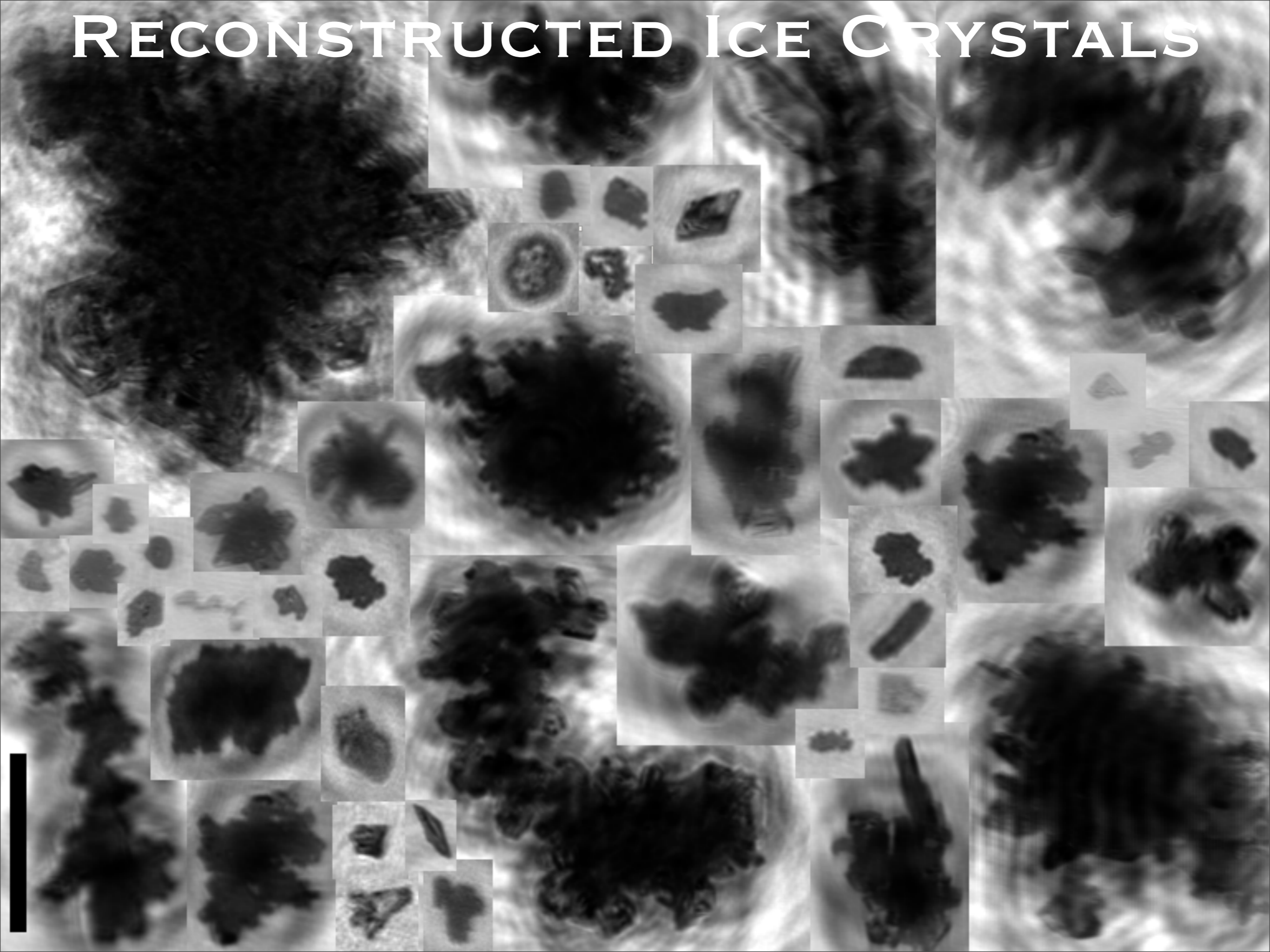
- Minimum particle size:  $\sim 22 \mu\text{m}$
- Sample volume size:  $4.8 \times 3.6 \times 30 \text{ mm}$  or  $\sim 0.5 \text{ cm}^3$
- Camera frame rate:  $\sim 15 \text{ Hz}$
- Volume sample rate:  $\sim 7 \text{ cm}^3 \text{ s}^{-1}$
- Hologram processing time:  $\sim 22 \text{ min}$



HOLODEC 1

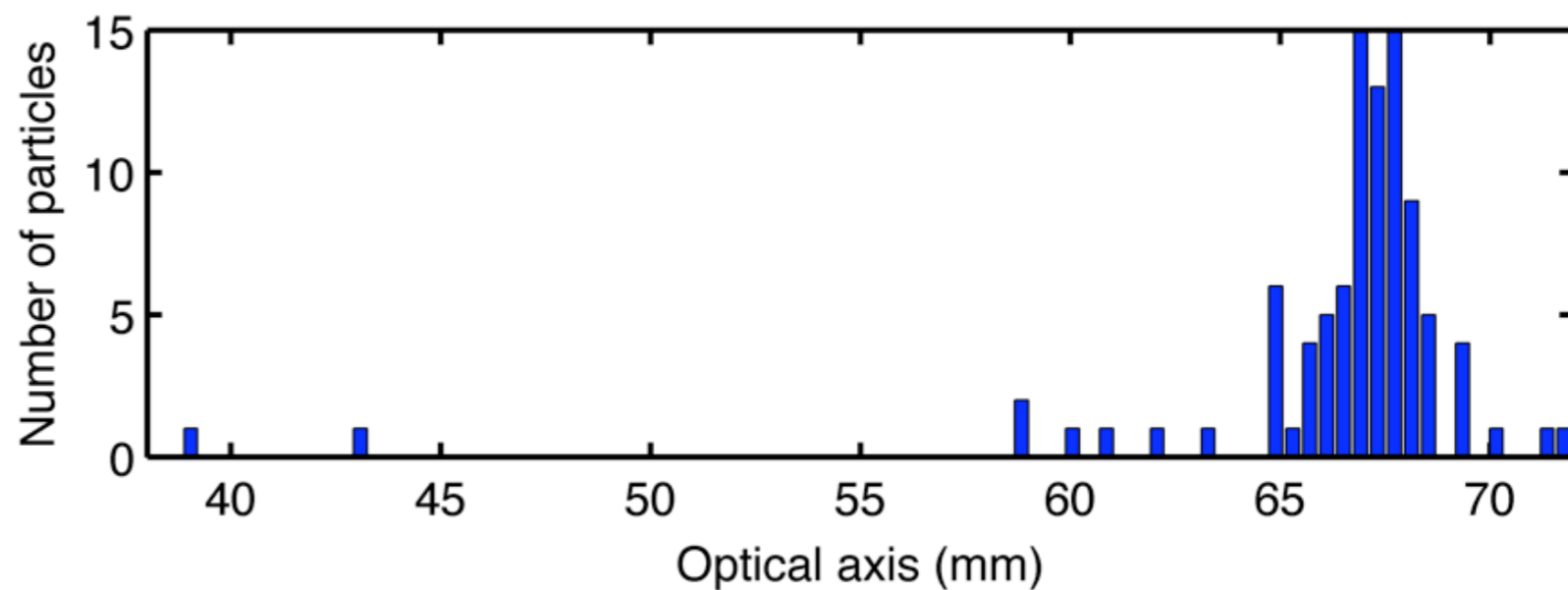
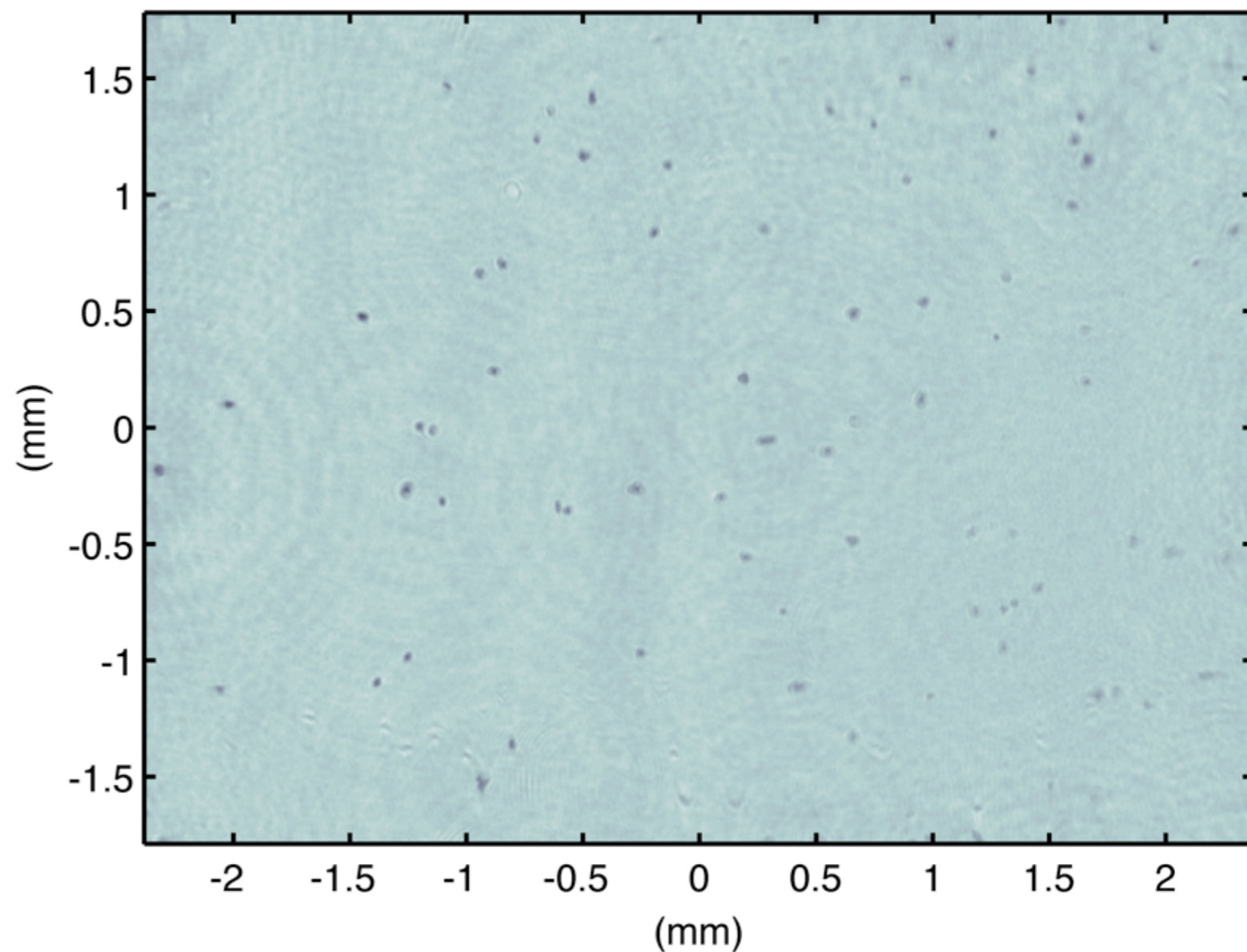


# RECONSTRUCTED ICE CRYSTALS

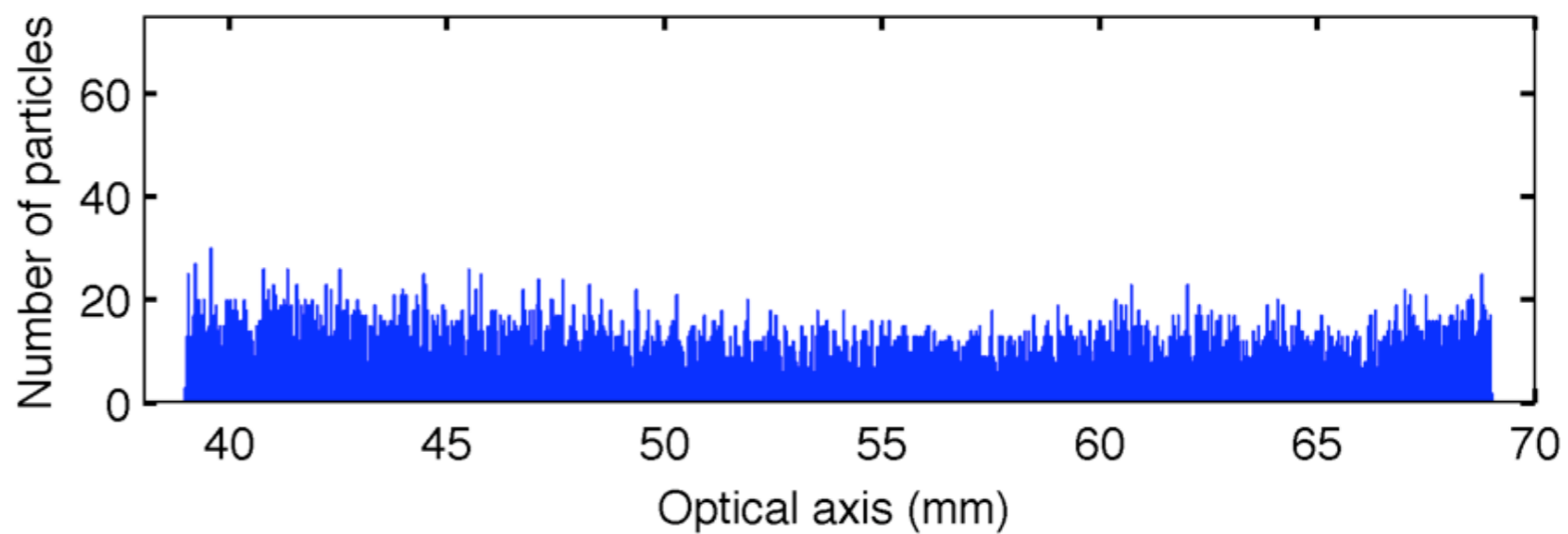
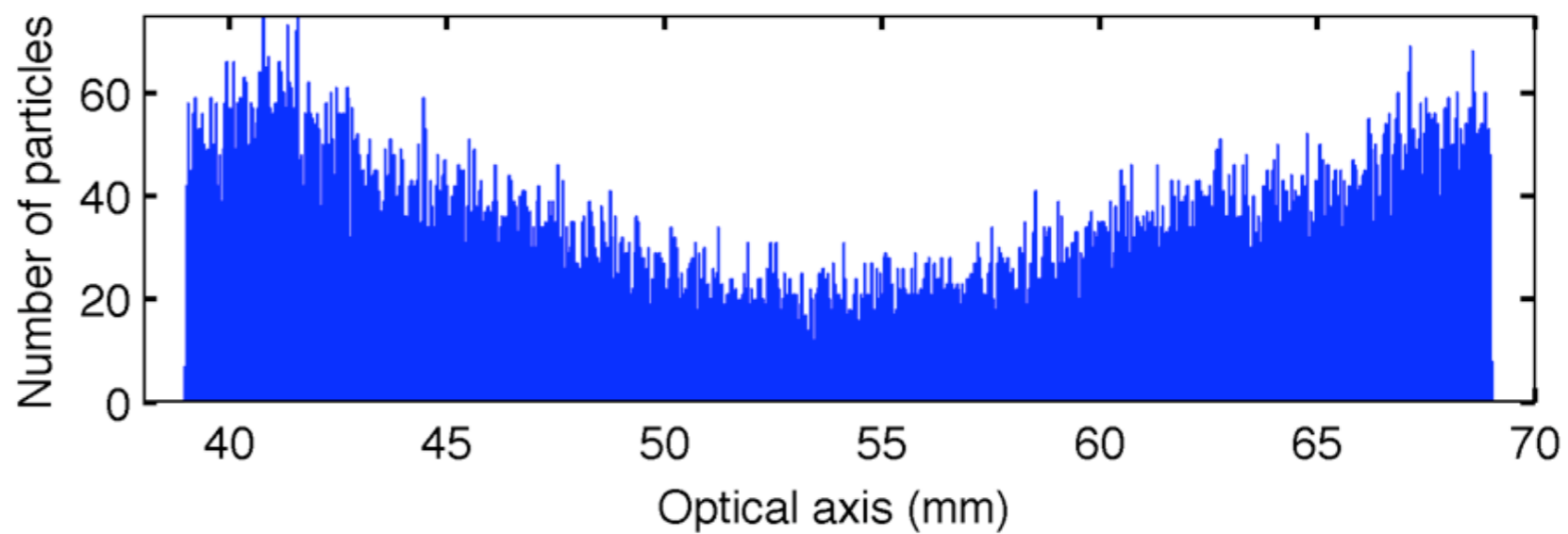
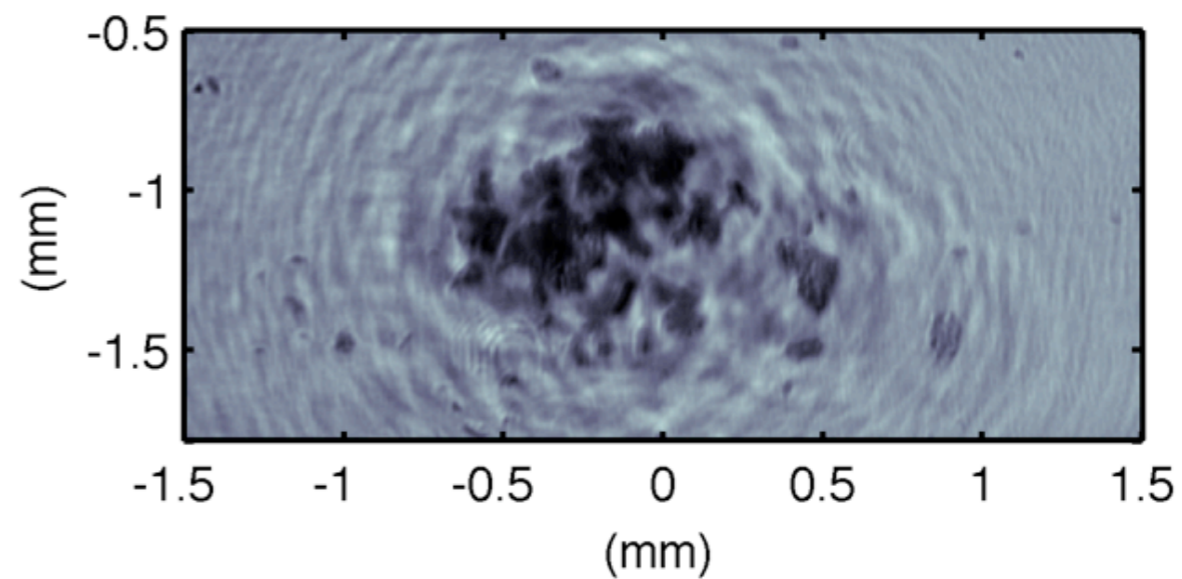


# DETECTING ICE PARTICLE SHATTERING

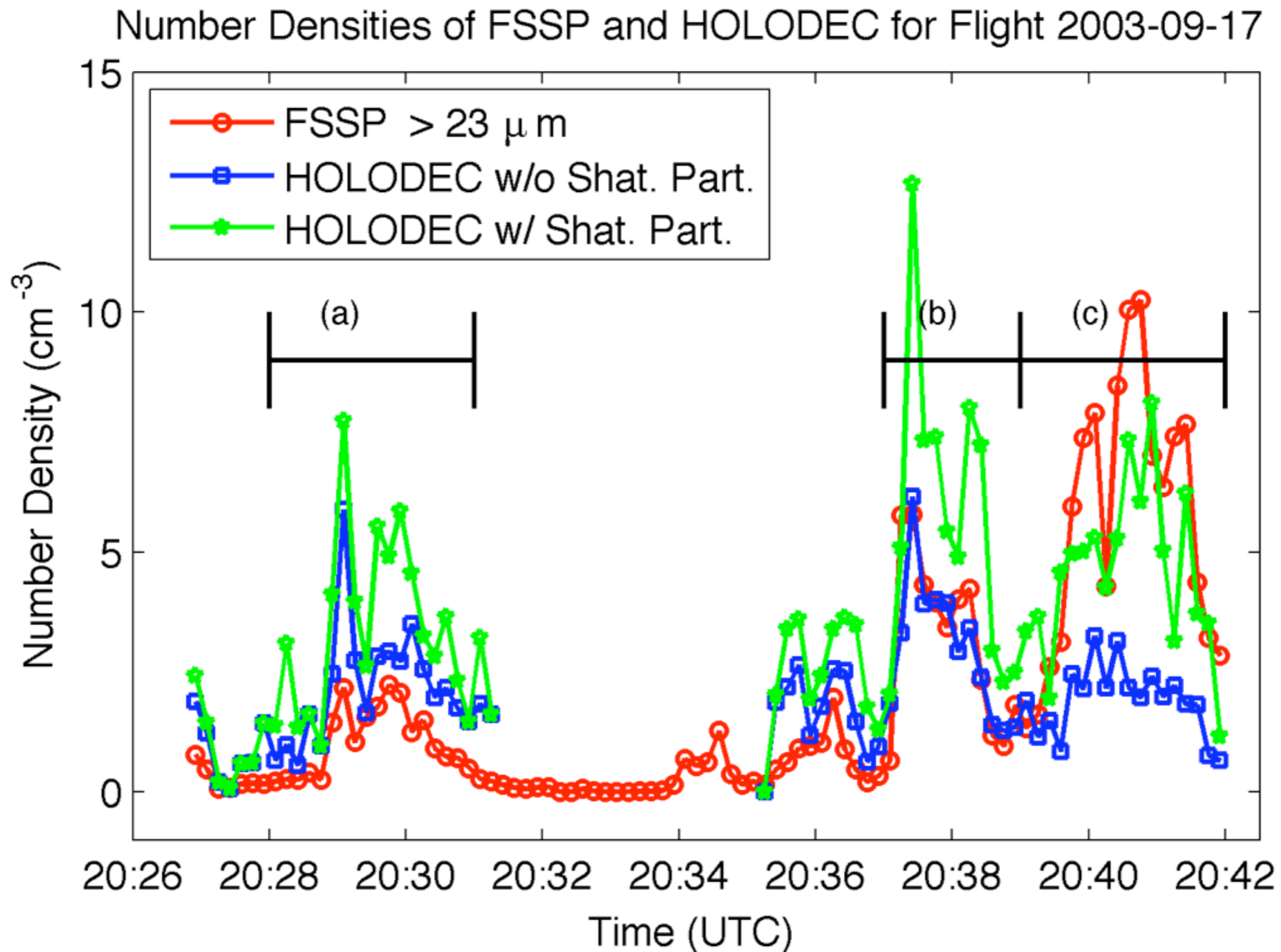
Hologram reconstructed to 66.5 (mm)

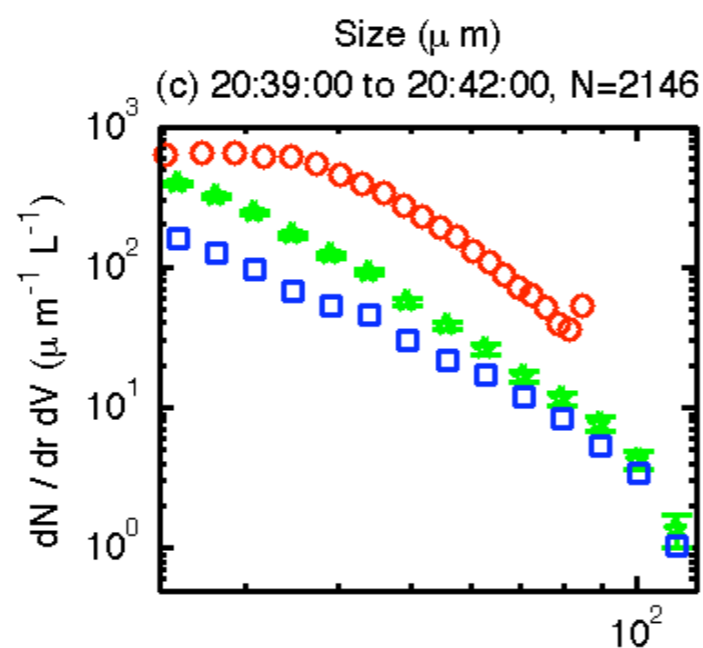
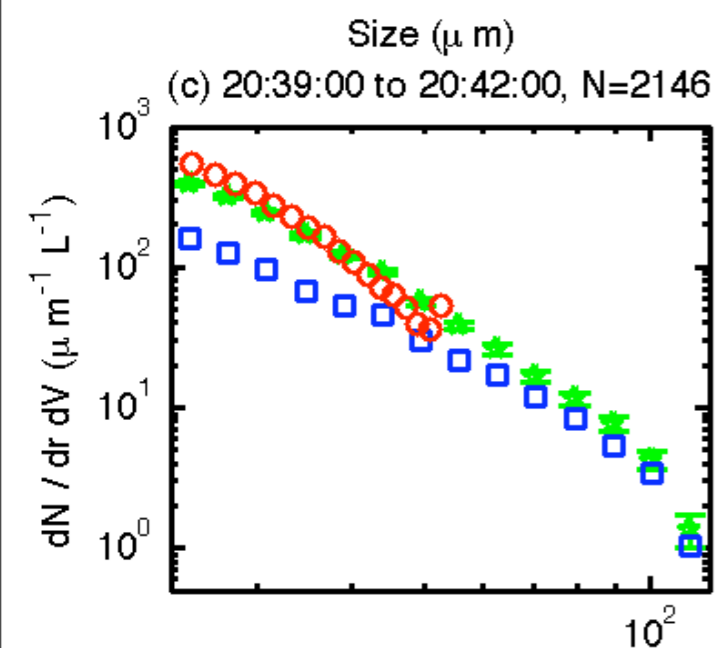
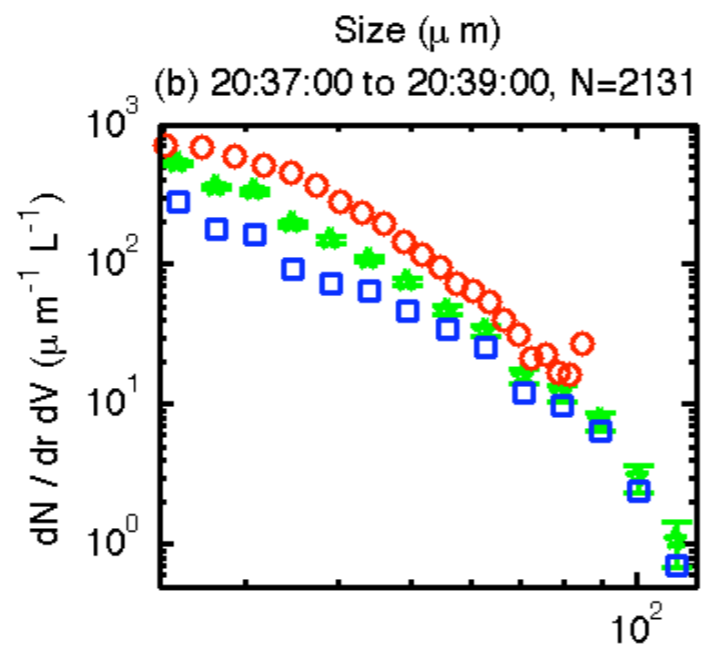
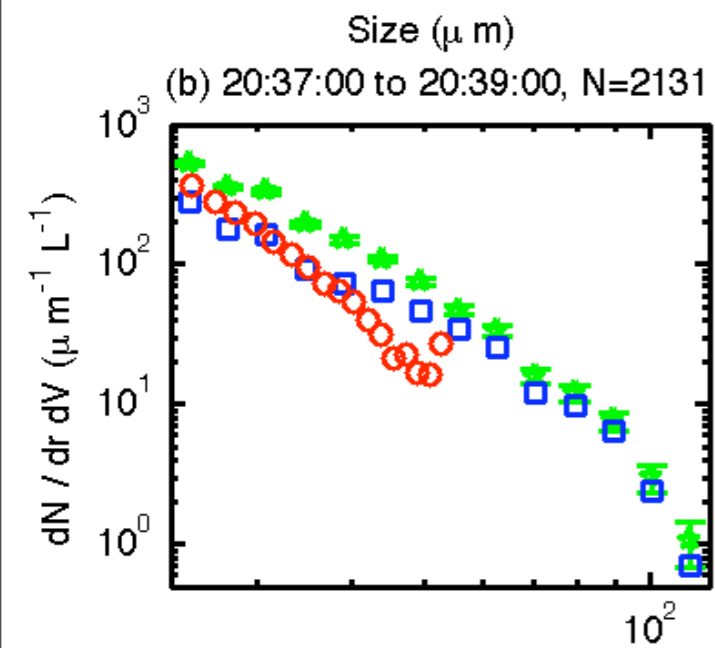
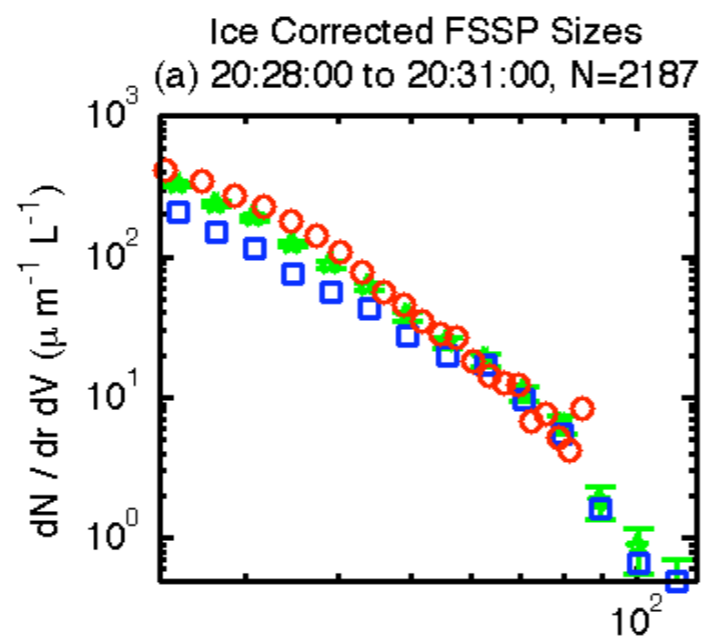
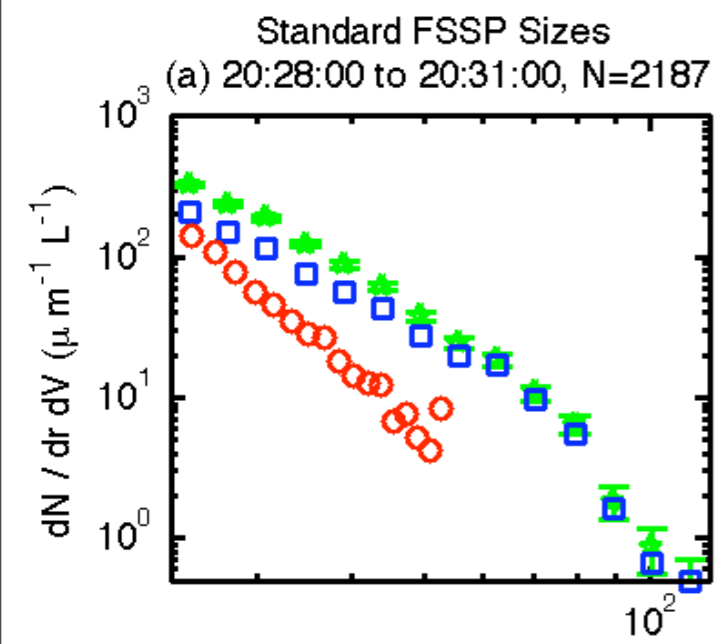


# DETECTING ICE PARTICLE SHATTERING



# NUMBER DENSITIES





# SIZE DISTRIBUTIONS

# CURRENT HOLODEC 2 PARAMETERS

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- Minimum particle size:  $\sim 5 \mu\text{m}$  diameter
- Sample volume:  $\sim 10 \text{ cm}^3$
- Sample Volume Spacing @  $200 \text{ m/s}$ :  $66 \text{ m}$
- Volume sample rate:  $\sim 30 \text{ cm}^3 \text{ s}^{-1}$
- Hologram processing time:  $\sim 2 \text{ hours}$

# HOLODEC 2 PARAMETERS WITH A FAST CAMERA

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- Minimum particle size:  $\sim 5 \mu\text{m}$  diameter
- Sample volume:  $\sim 1 \text{ cm}^3$
- Sample Volume Spacing @  $200 \text{ m/s}$ :  $40 \text{ cm}$
- Volume sample rate:  $\sim 400 \text{ cm}^3 \text{ s}^{-1}$

# HOLODEC 2 PARAMETERS IN GENERAL

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- Size uncertainty is order 1 pixel width or 3  $\mu\text{m}$ . Can be improved with better hologram processing algorithms.
- Particle phase determination is by shape so works for particles order 10 pixel widths or 30  $\mu\text{m}$  diameter.
- Low power, lightweight, standard PMS canister form factor except for Gig-E connection.
- Autonomous operation possible. Instrument is essentially a airborne digital camcorder.



# CURRENT PLANS

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- Planned test flights in Summer 2009
- Intended hologram processing computer:  
US NSF sponsored Teragrid supercomputer  
Lincoln, heterogenous (CPU & GPU)  
compute cluster.

# SUMMARY

- Digital in-line holography allows in-situ measurements of three-dimensional position, and two-dimensional profile and size of each cloud particle in a prism-shaped well-defined sample volume.
- Using these measurements HOLODEC 2 will be able to measure local size distributions of cloud particles without shattering artifacts, or sample volume size and air speed uncertainties.
- We will also be able to examine the fine scale structure of clouds to learn more about mixing, entrainment, and turbulence processes (particle clustering), and the fine-structure of mixed-phase clouds.

