UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Representing size distributions observed during Flight 23 as gamma distributions: Updates

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Outline

1. Review of IGF fitting technique
2. New technique for multi-modal fits
3. Application to HIWC data
4. Ongoing activities

IGF Fitting Technique

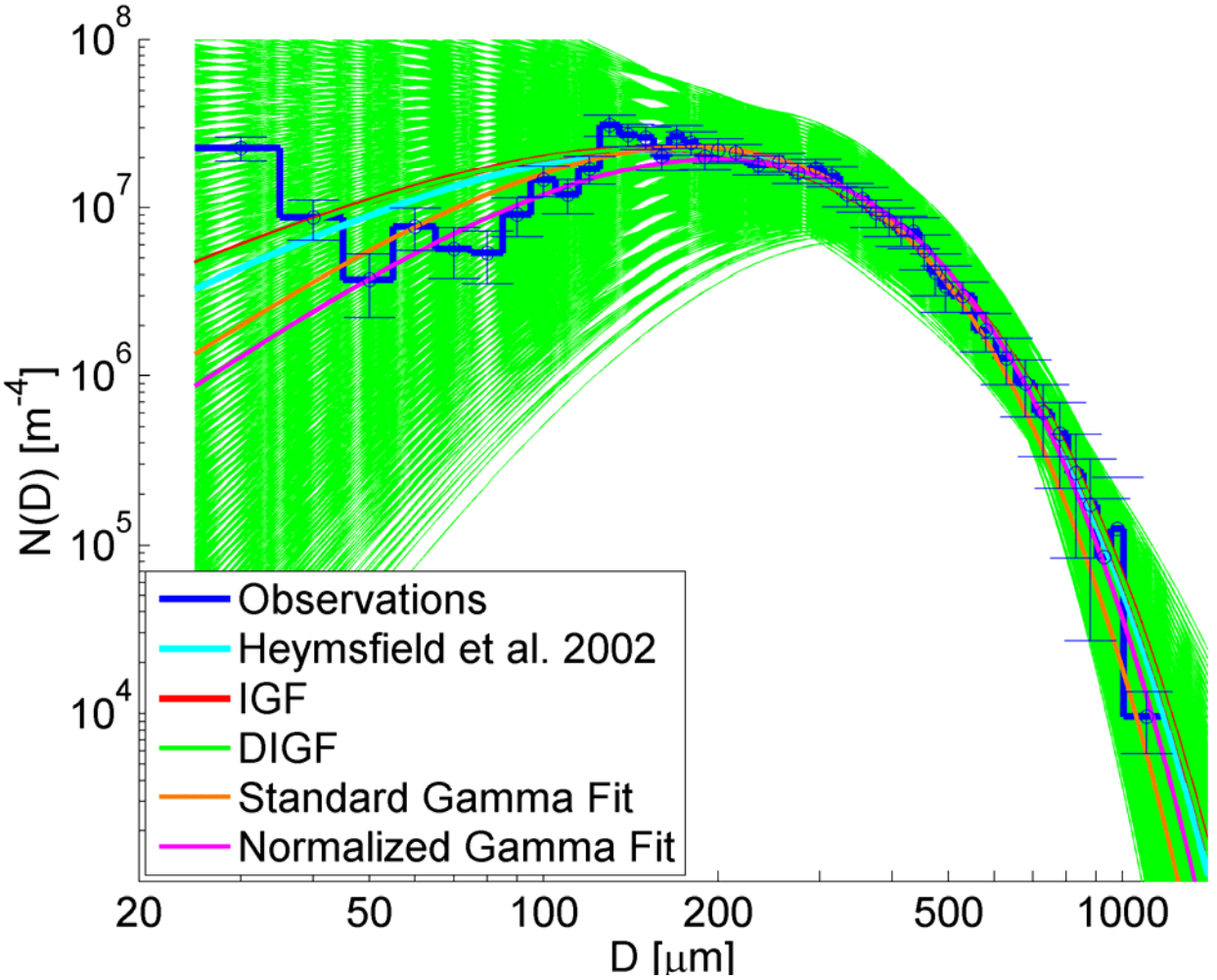
Gamma functions used to characterize SDs

$$N(D) = N_0 \; D^{\mu} \exp(-\lambda D)$$

with N_0 intercept, μ shape, λ slope

- N_0, μ, & λ determined from in-situ observations using IGF technique that minimizes χ^2 difference between fit and observed moments
- Estimates uncertainty by assuming any (N_0,μ,λ) within $\Delta\chi^2$ of minimum χ^2 is possible solution
- Also accounts for fact measured SDs do not cover complete range of particle sizes

Example of Fit to SD measured during NAMMA



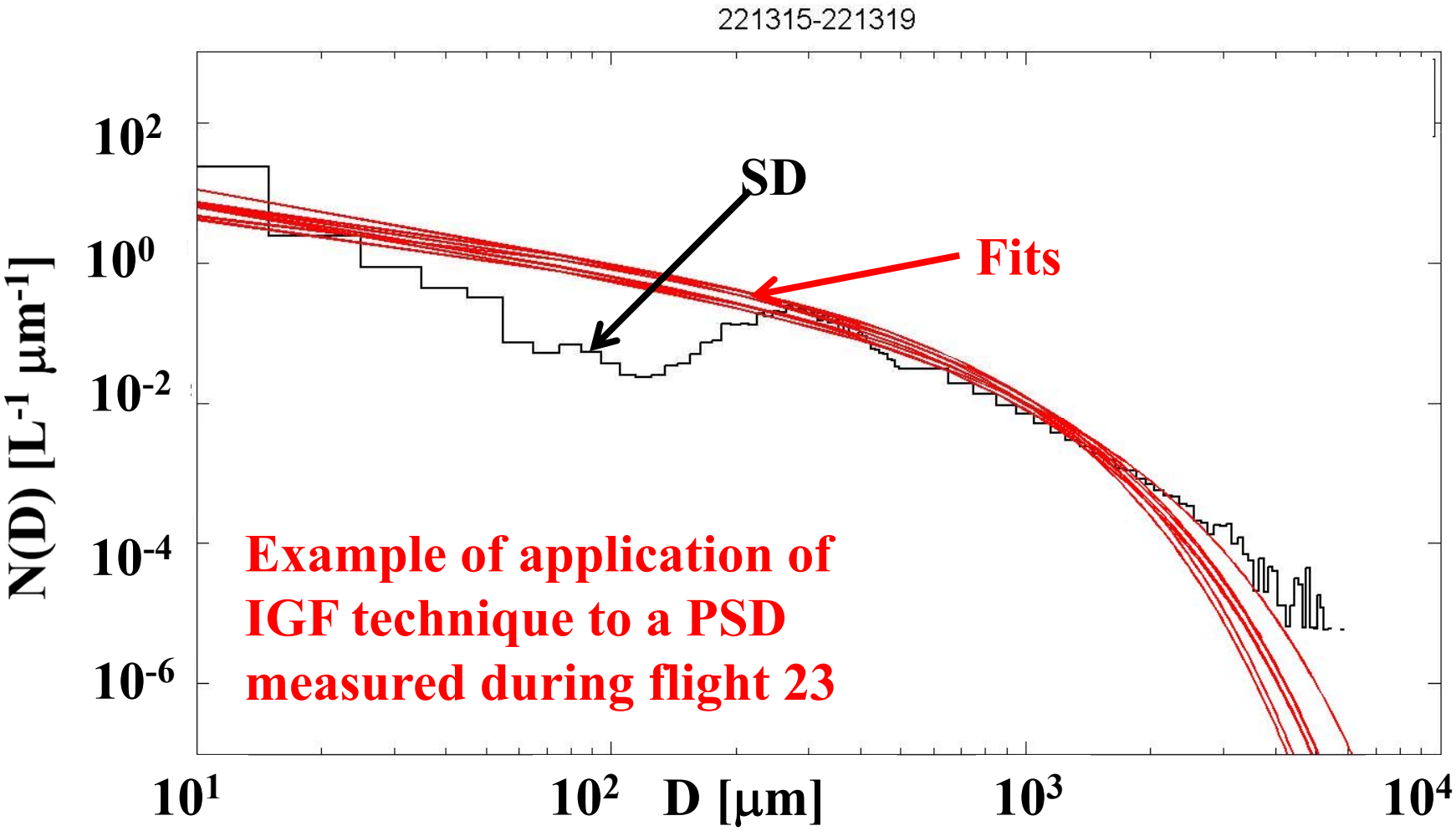
Randomly select $N_0/\mu/\lambda$ value from volume of solutions

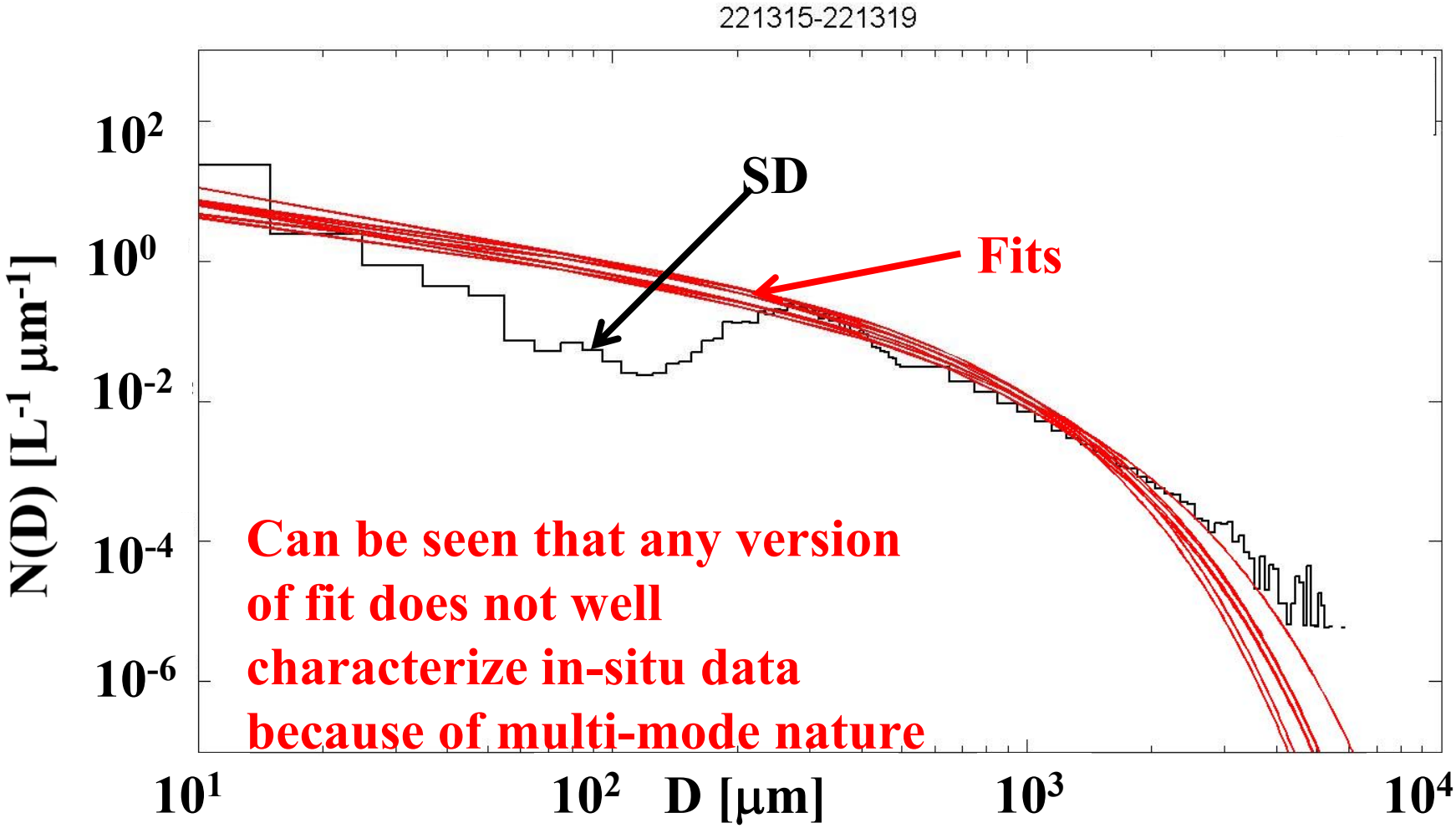
- large spread especially for D < 150 μm, but fits match data reasonably well

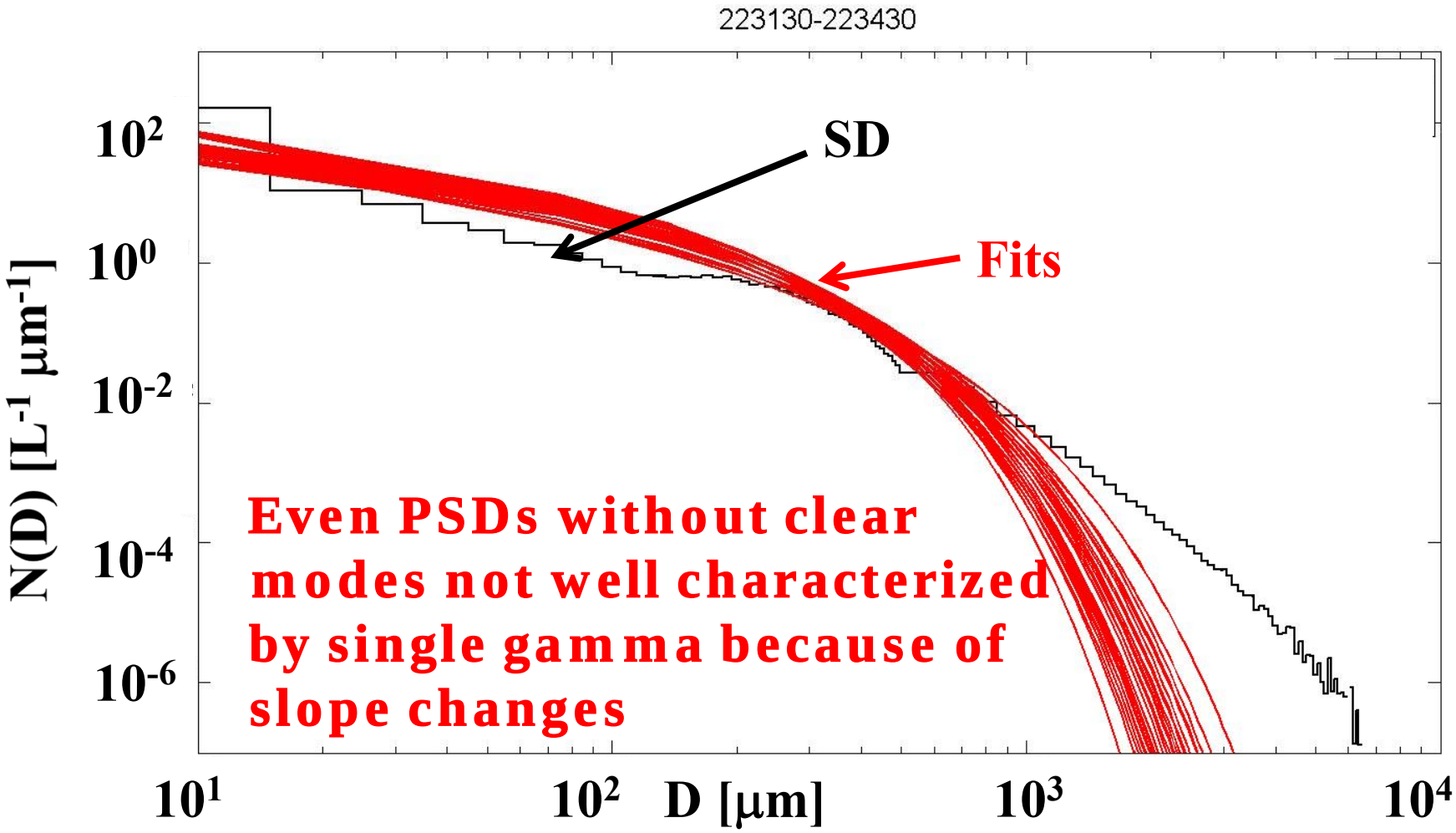
HIWC/HAIC Flight 23

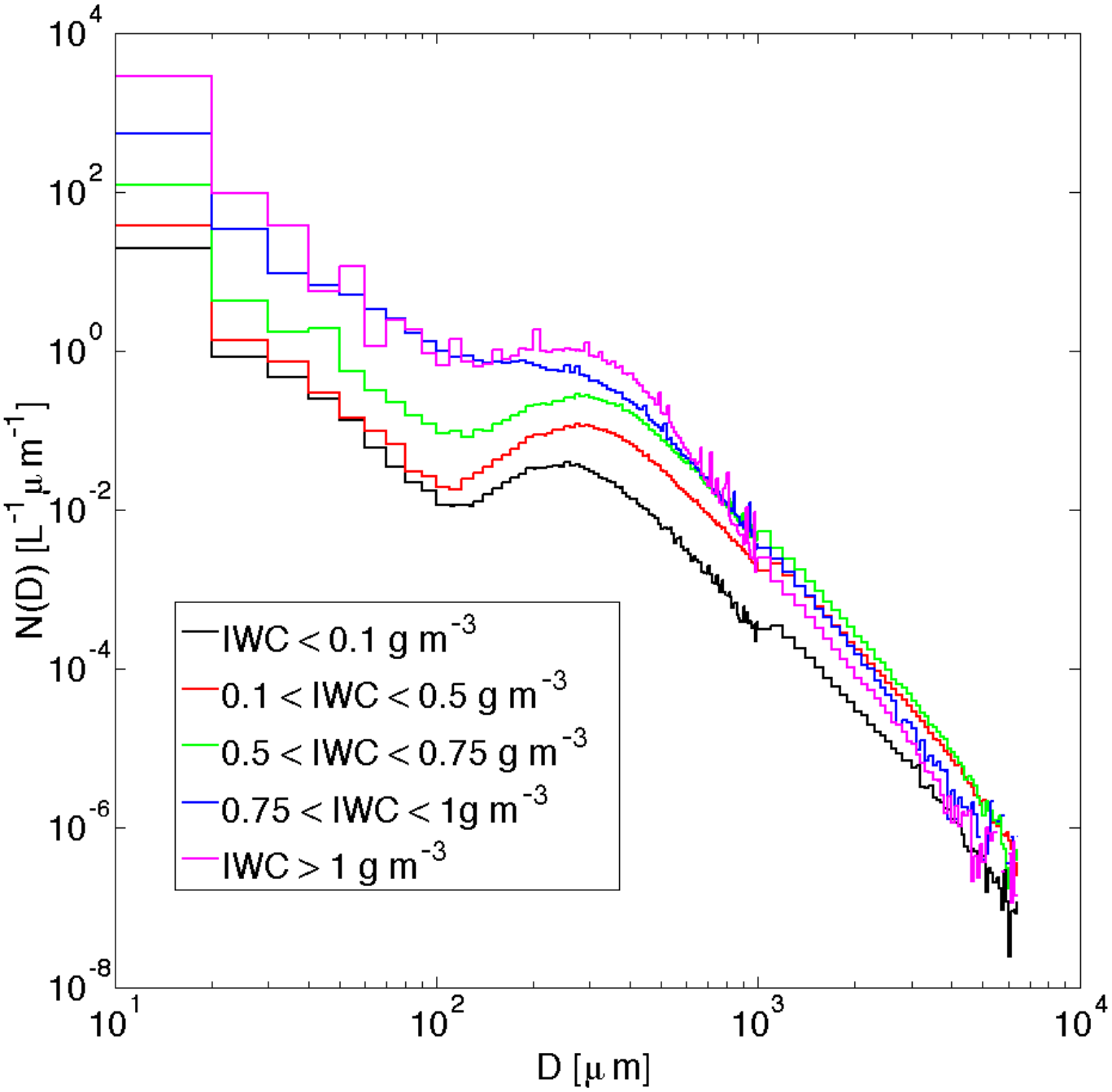
- We have tried to apply our techniques to data collected during HIWC flight 23

  → Have completed modification of our technique to account for multi-modal nature of SDs not seen in earlier projects

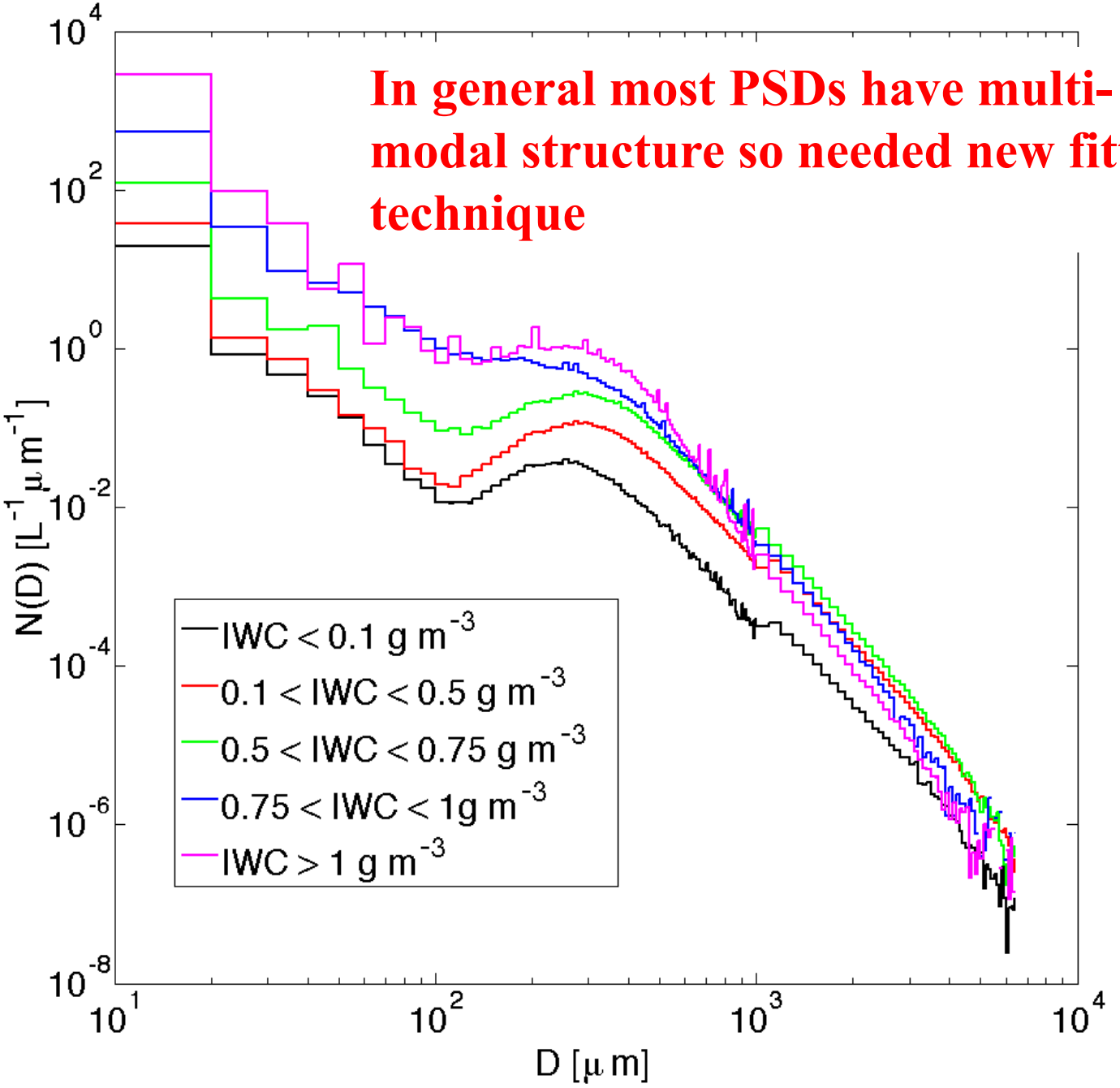

221315-221319
SD
Fits
N(D) [L-1 µm-1]
10^2
10^0
10^-2
10^-4
10^-6
10^1
10^2
D [µm]
10^3
10^4
Example of application of
IGF technique to a PSD
measured during flight 23

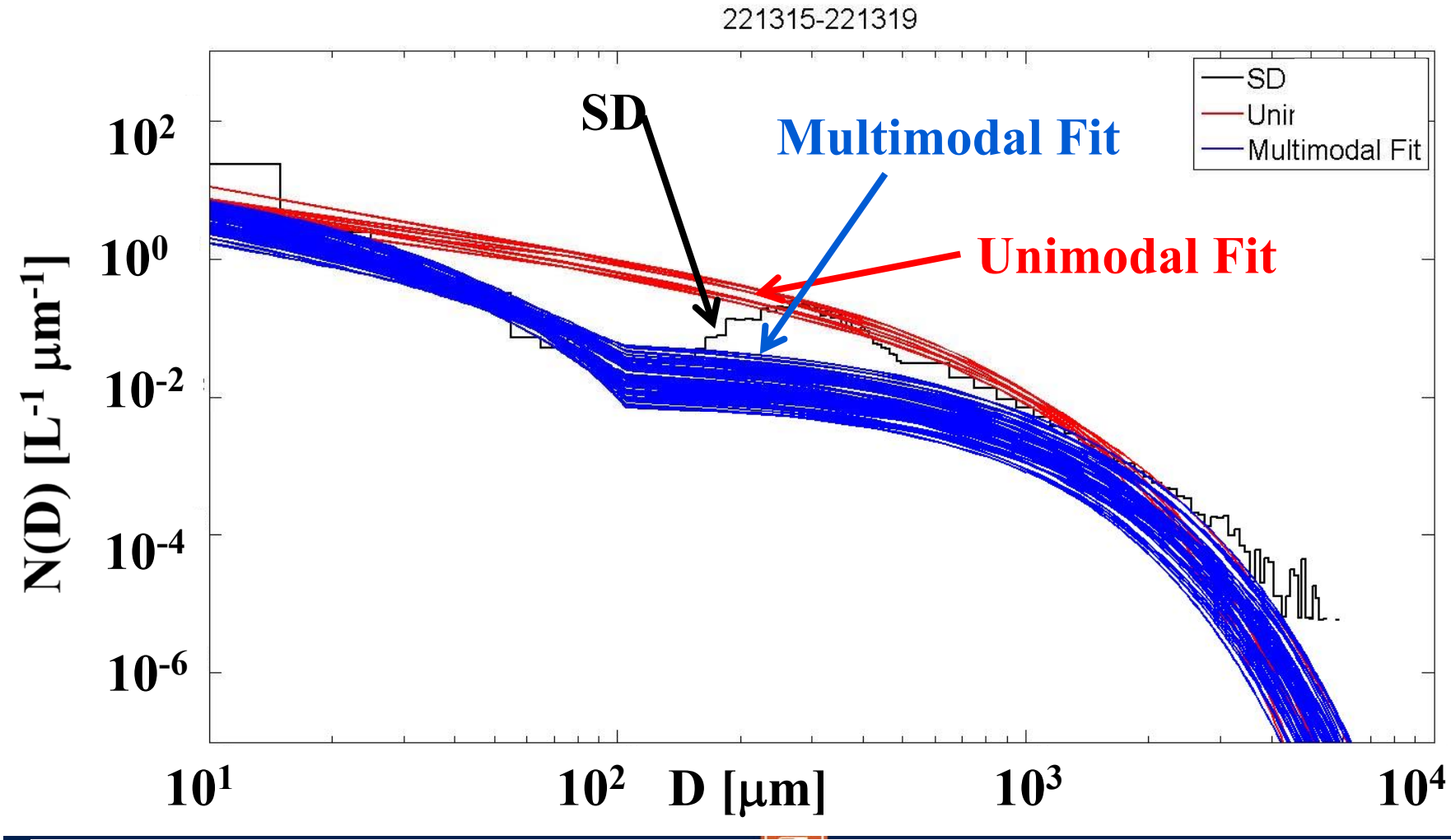

221315-221319
SD
Fits
N(D) [L-1 µm-1]
10^2
10^0
10^-2
10^-4
10^-6
10^1
10^2
D [µm]
10^3
10^4
Can be seen that any version
of fit does not well
characterize in-situ data
because of multi-mode nature


223130-223430
SD
Fits
Even PSDs without clear modes not well characterized by single gamma because of slope changes
N(D) [L-1 µm-1]
10^2
10^0
10^-2
10^-4
10^-6
10^1
10^2
D [µm]
10^3
10^4

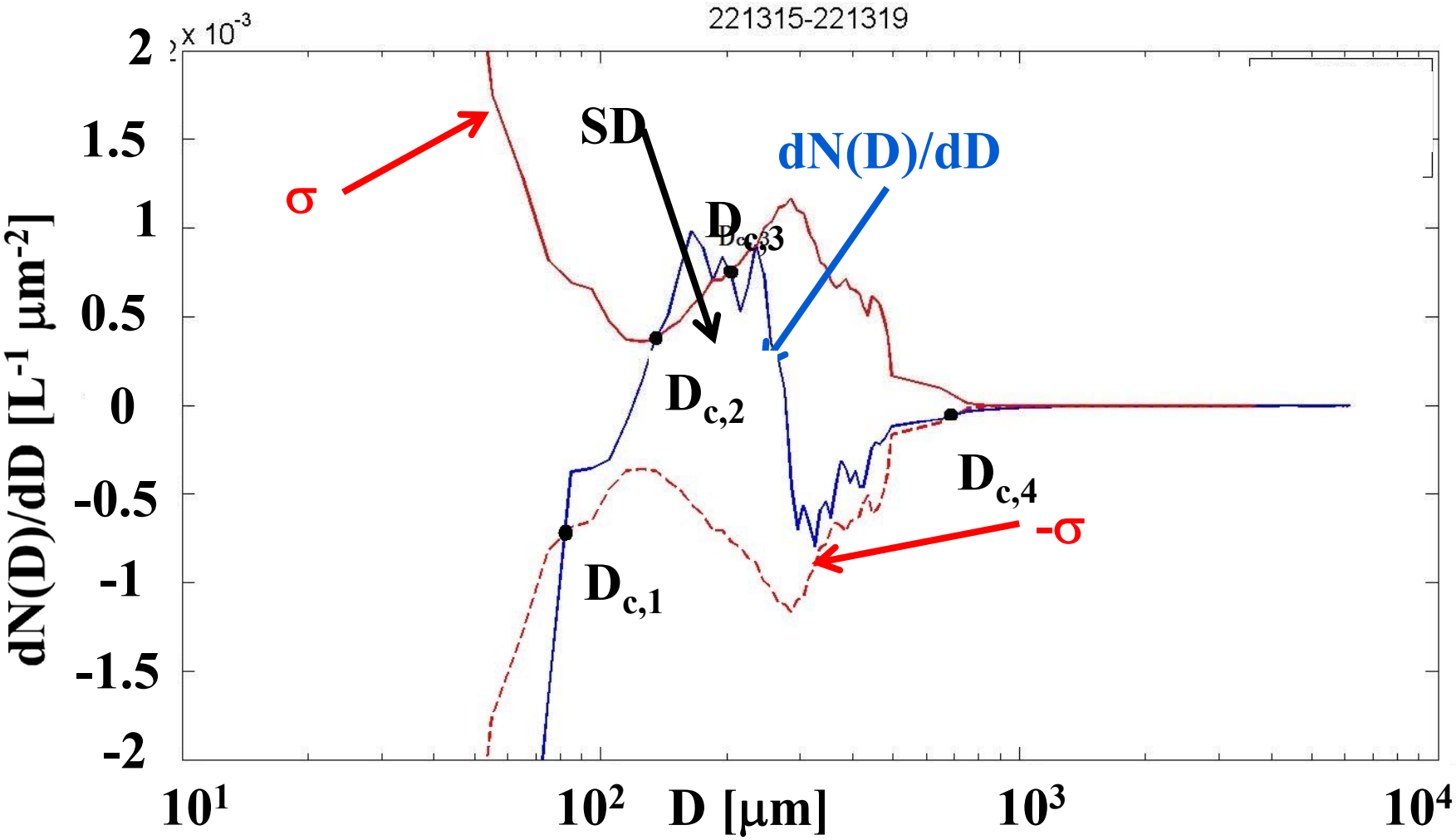

10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
N(D) [$L^{-1}\mu m^{-1}$]
10^1
10^2
10^3
10^4
D [μ m]
IWC < 0.1 g m^{-3}
0.1 < IWC < 0.5 g m^{-3}
0.5 < IWC < 0.75 g m^{-3}
0.75 < IWC < 1g m^{-3}
IWC > 1 g m^{-3}

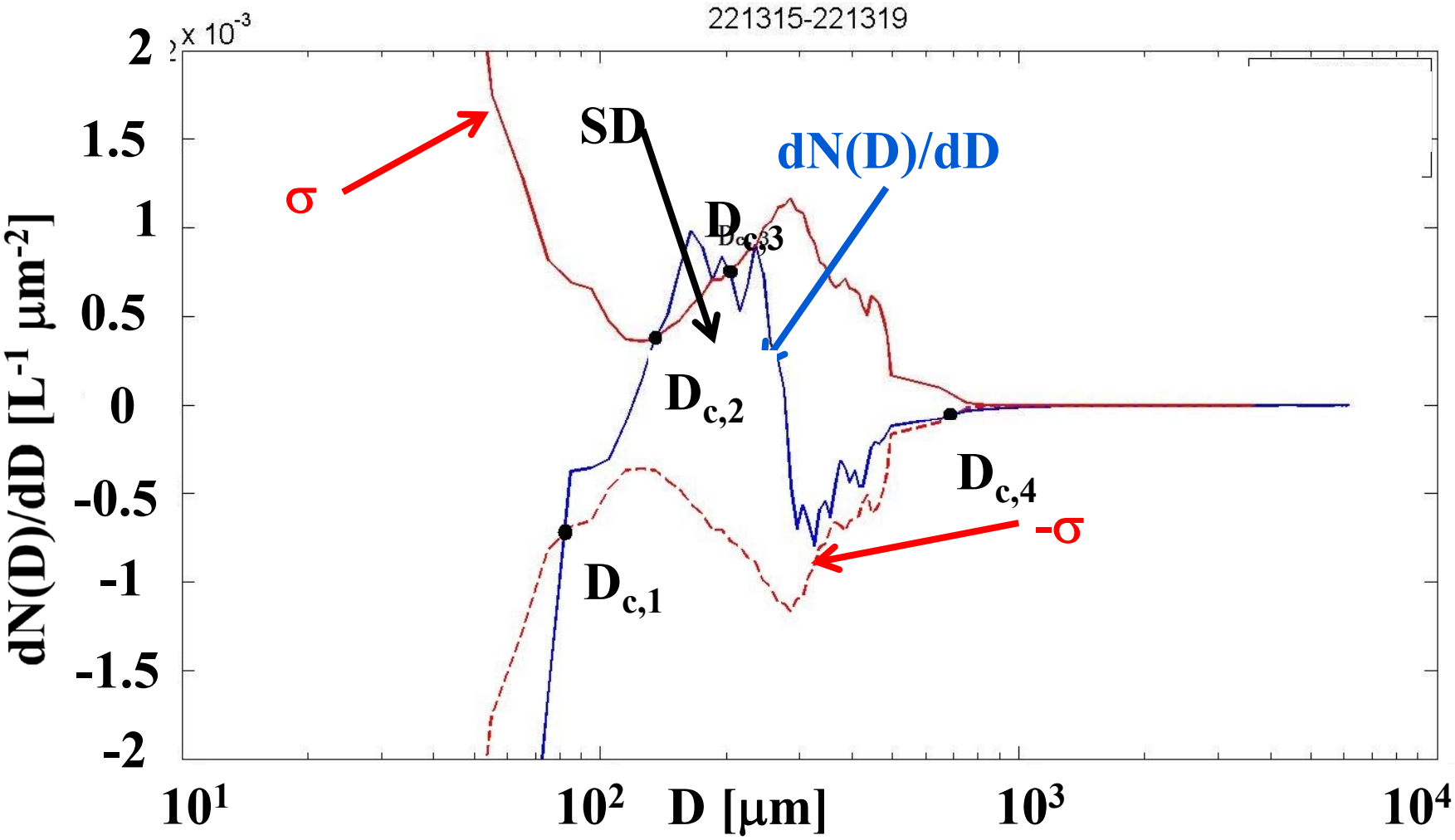
In general most PSDs have multi-modal structure so needed new fitting technique



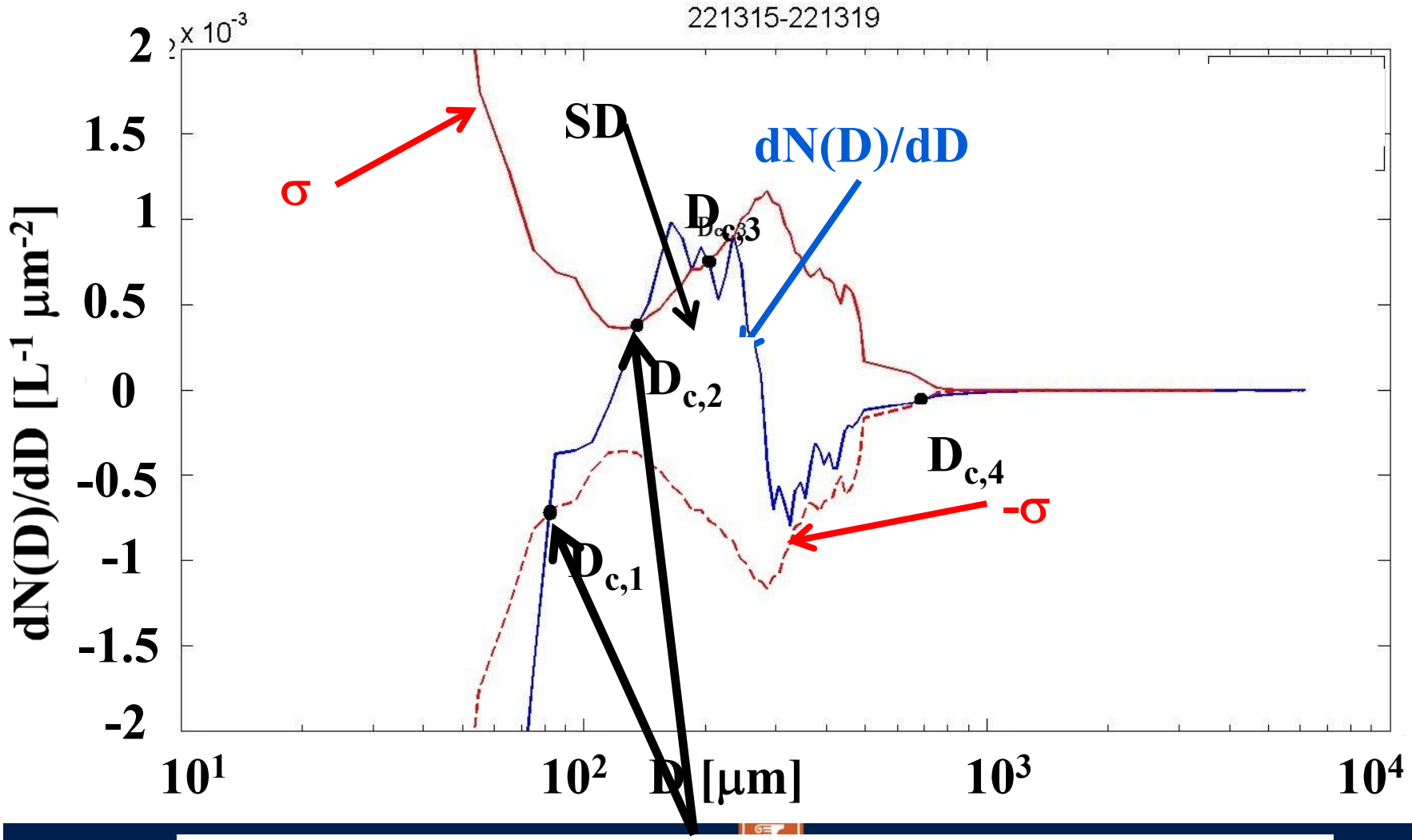


SDs with multiple modes existed during HIWC → represent fit as sum of two gamma functions

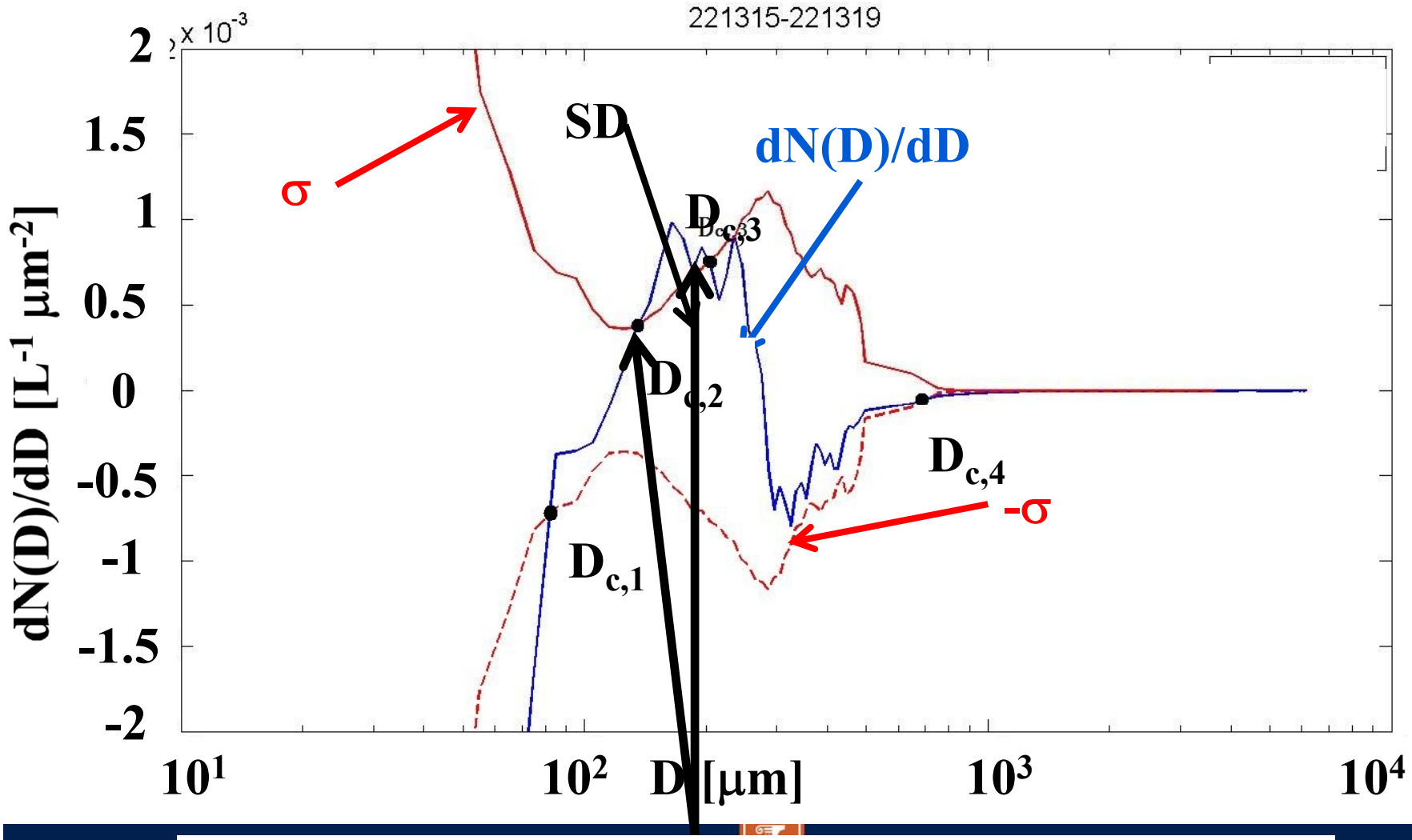

221315-221319
x 10^-3
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
dN(D)/dD [L^-1 µm^-2]
σ
SD
dN(D)/dD
D_c,3
D_c,2
D_c,4
-σ
D_c,1
10^1
10^2
D [µm]
10^3
10^4



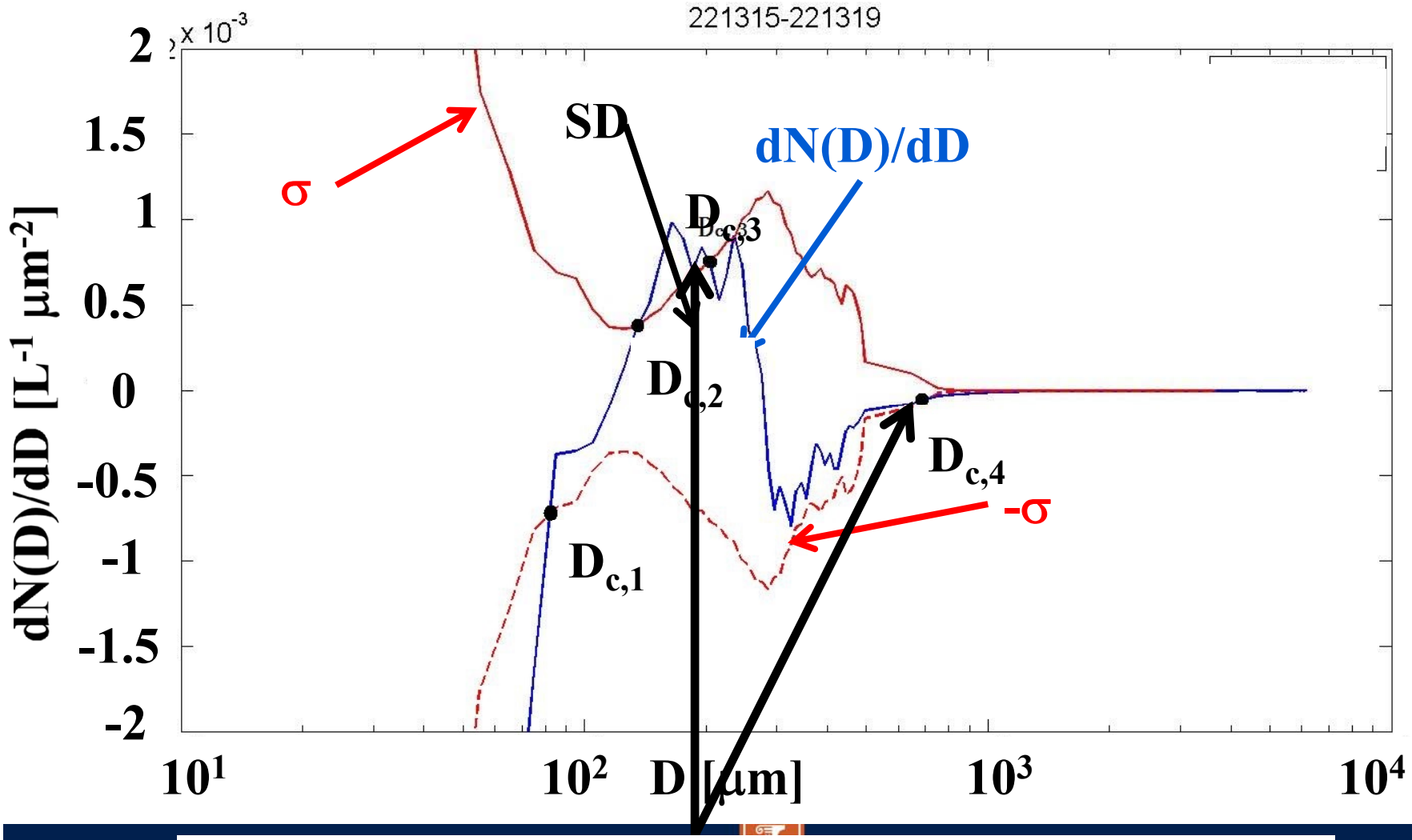
Find points where first derivative crosses noise threshold



First derivative increases → local minimum
Boundary between modes half way between



First derivative > 0, no critical point



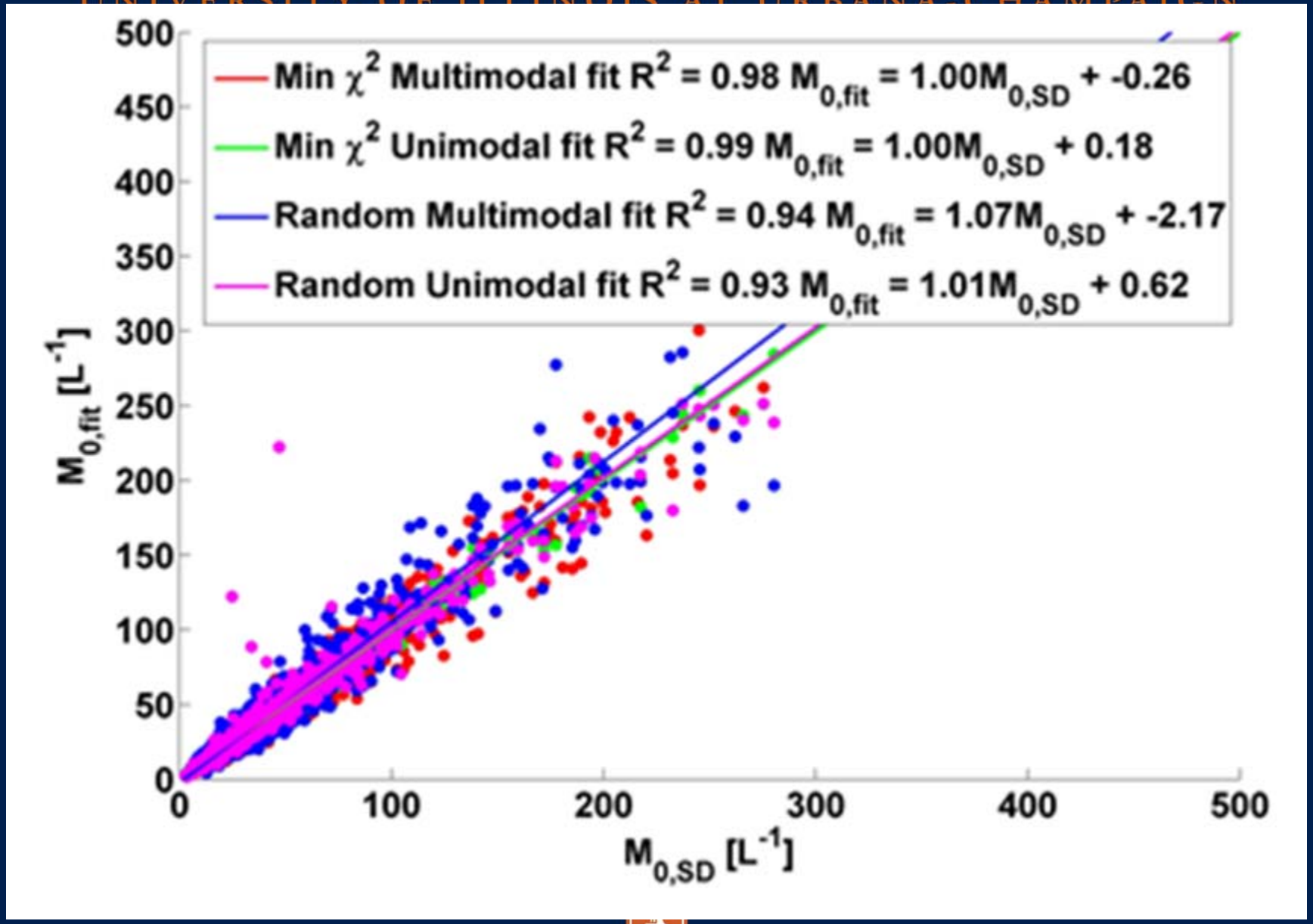
First derivative decreases → local maximum (not a mode boundary)

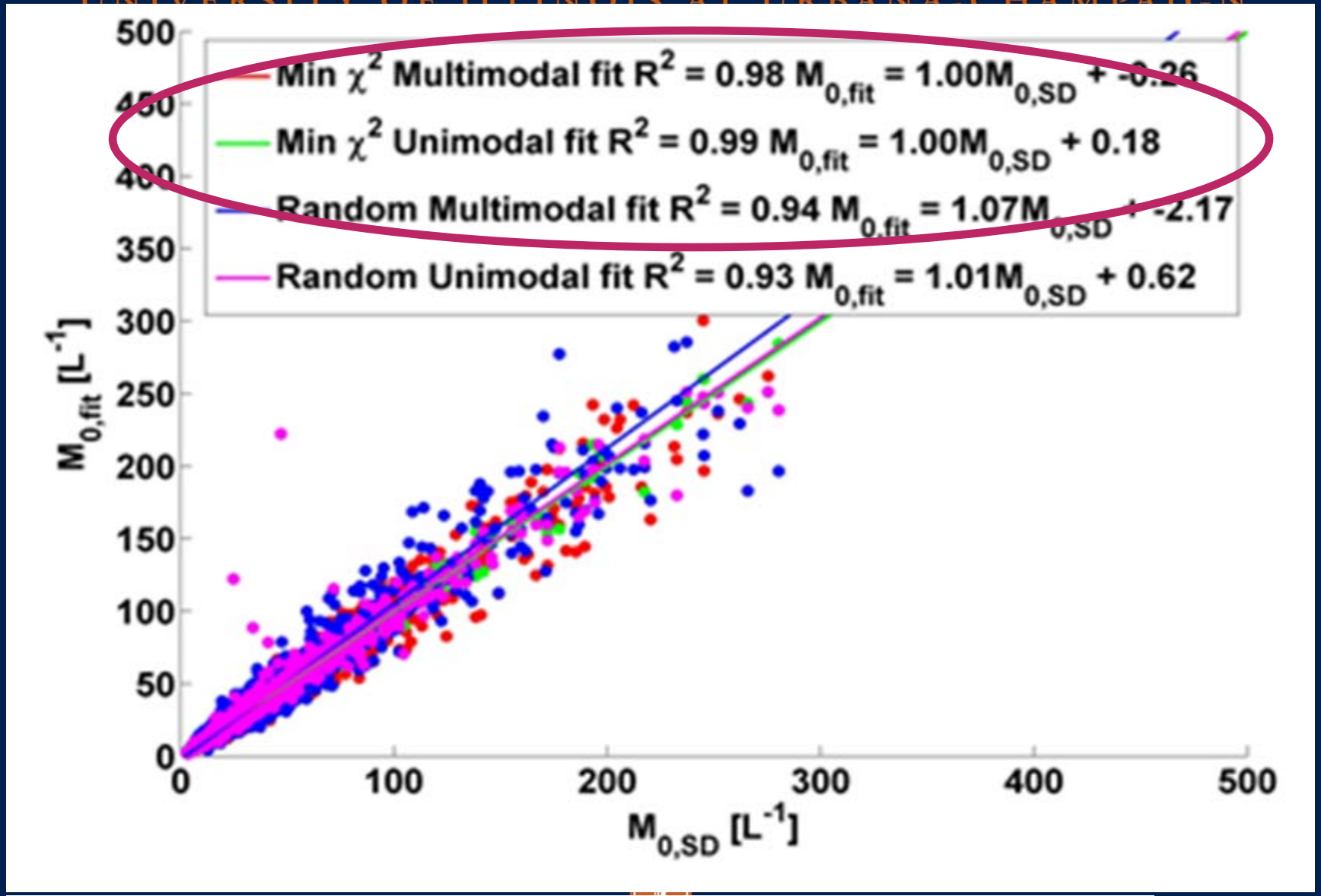
Choosing random multimodal fit

- (N0, μ, λ) chosen randomly from volume representing mode from smallest D
- Correction factor f for mode *i* is:

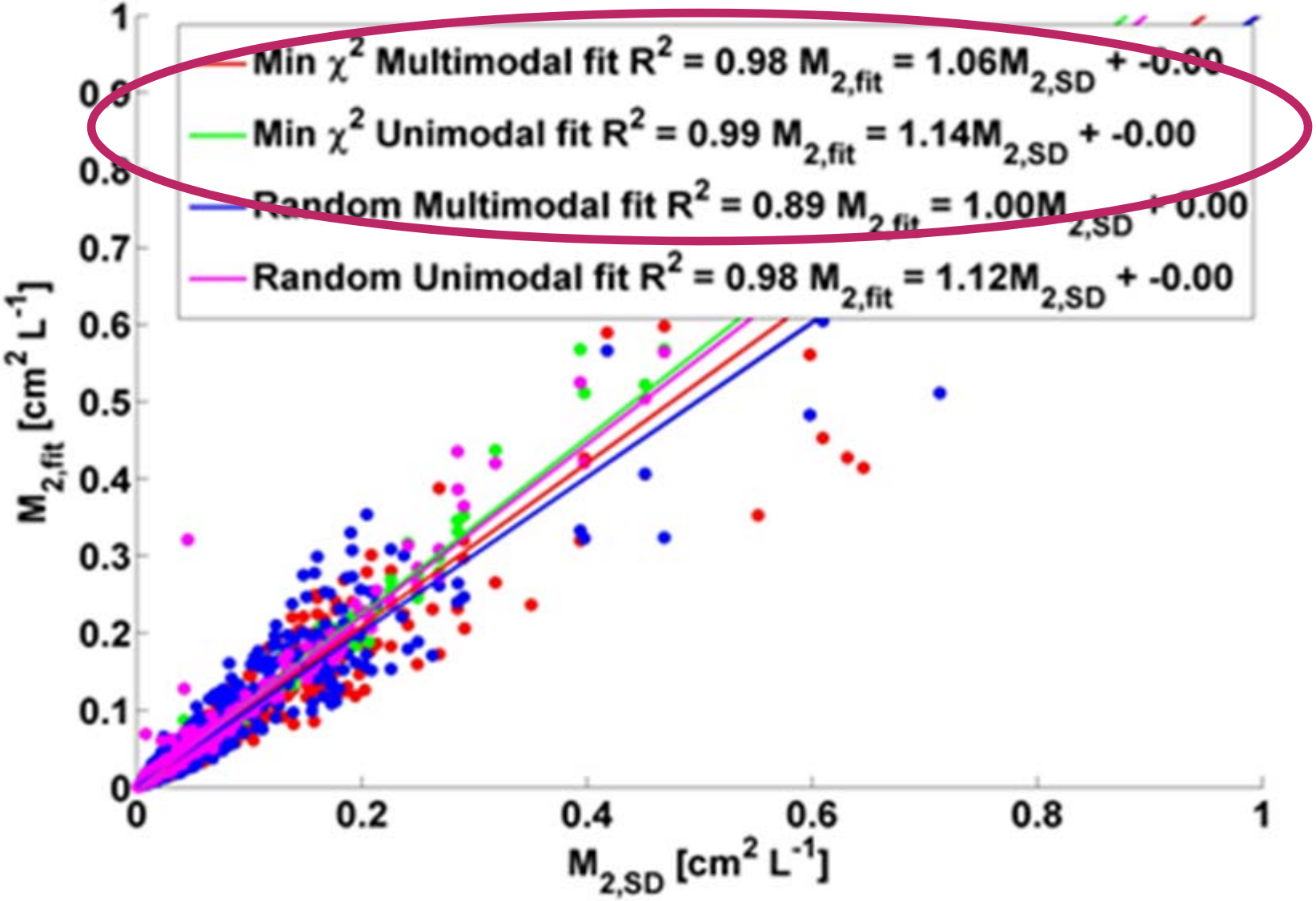
$$f = N_{0i}\left(\frac{D_{max_i}}{D_0}\right)^{n+\mu_i} e^{-\lambda_i D_{max_i}} / N_{0_{i+1}}\left(\frac{D_{max_i}}{D_0}\right)^{n+\mu_{i+1}} e^{-\lambda_{i+1} D_{max_i}}$$

- If 0.6 < f < 1.67, then point is chosen, otherwise try again. If no such point exists after 40 tries, SD is discontinuous.
- Multiply moment integrated from mode *i + 1* by *f*.

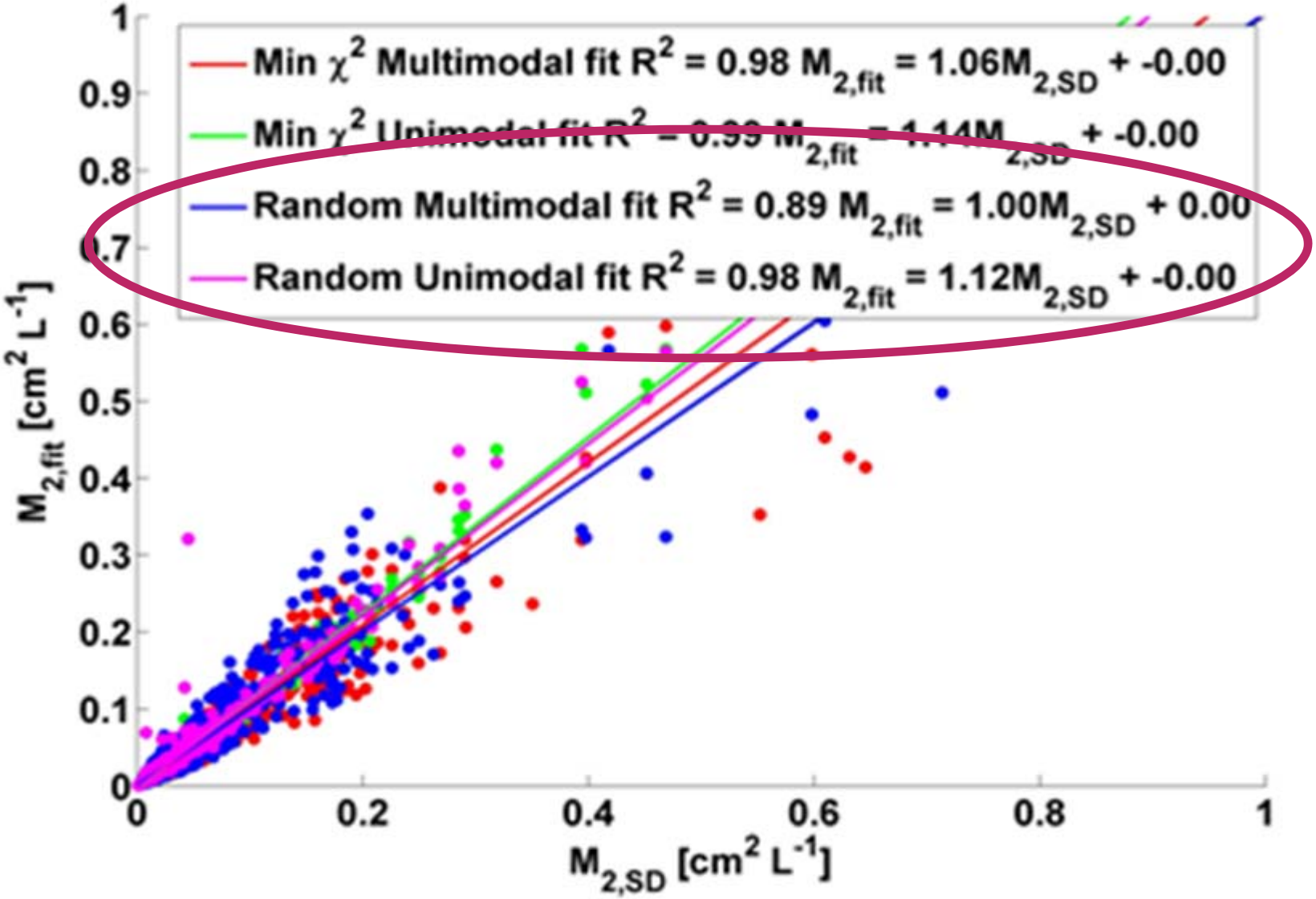

Min χ^2 Multimodal fit R^2 = 0.98 $M_{0,fit}$ = 1.00$M_{0,SD}$ + -0.26
Min χ^2 Unimodal fit R^2 = 0.99 $M_{0,fit}$ = 1.00$M_{0,SD}$ + 0.18
Random Multimodal fit R^2 = 0.94 $M_{0,fit}$ = 1.07$M_{0,SD}$ + -2.17
Random Unimodal fit R^2 = 0.93 $M_{0,fit}$ = 1.01$M_{0,SD}$ + 0.62
$M_{0,fit}$ [L^{-1}]
$M_{0,SD}$ [L^{-1}]
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500



Unimodal and multimodal fits both agree with observed 0^{th} moment equally well



Multimodal fits agree better than unimodal with observed 2nd moments.



Randomizing selection of N0, μ, λ both give equally good agreement with obs. moments

How to apply to families of SDs from HIWC?

Going to apply multi-moment technique to HIWC data from all flights

- See how (N_0,λ,μ) volumes vary according to T, IWC, w, particle habits, and other conditions
- Have not had time to complete this work, will report results at next STM (after SD comparisons)
- What is physical significance of modes?

Conference Presentations

McFarquhar, G.M., S. Zhu, W. Wu, J.W. Strapp, A. Schwarzenboeck, A.V. Korolev, and D. Leroy, 2015: A probabilistic framework for the representation of ice crystal size distributions observed during the High Ice Water Content (IWC) Campaign as gamma functions, 26th International Union of Geodesy and Geophysics General Assembly, Prague, Czech Republic, 22 June-2 July 2015, Submitted.

Data Sets being Used

Currently Using:

In-Situ microphysics:

- 2DS Data
- 2DP Data
- IKP Data

State Parameter Data

- Temperature, humidity

Future Use Envisioned:

Robust Probe TWC

CDP

Want to Move Beyond Just use of Flight 23

Research Collaboration

Varble/Zipser:

Incorporation of new parameterizations in models

Schwarzenboeck/Leroy/Korolev:

Intercomparison of Processing Algorithms