National Aeronautics and Space Administration

SAGE III/ISS

Stratospheric Aerosol and Gas Experiment

An Earth Science Mission on the International Space Station

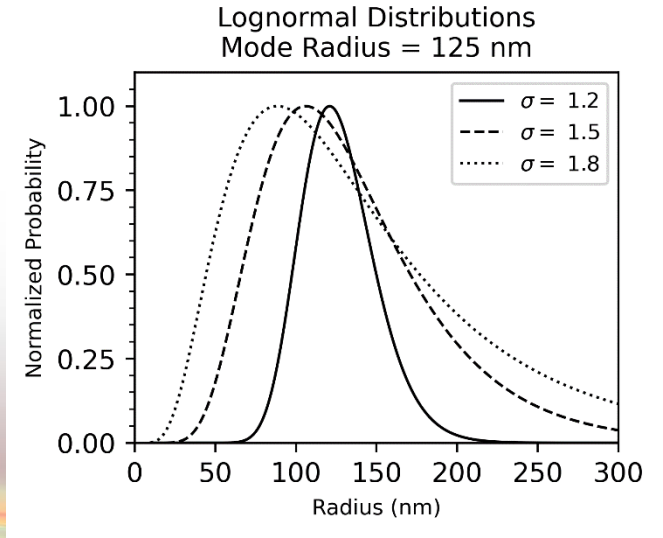
SAGE-III/ISS Science Team Meeting

Travis N. Knepp
Mahesh Kovilakam,
Stephan J. Miller,
Larry Thomason

# Quantifying Uncertainty in PSD Parameters Inferred from SAGE III/ISS Extinction Spectra

# Background

- SAGE data have been used to estimate particle size distribution (PSD) parameters
  - Mode radius
  - Distribution width (σ)



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- SAGE data have been used to estimate particle size distribution (PSD) parameters
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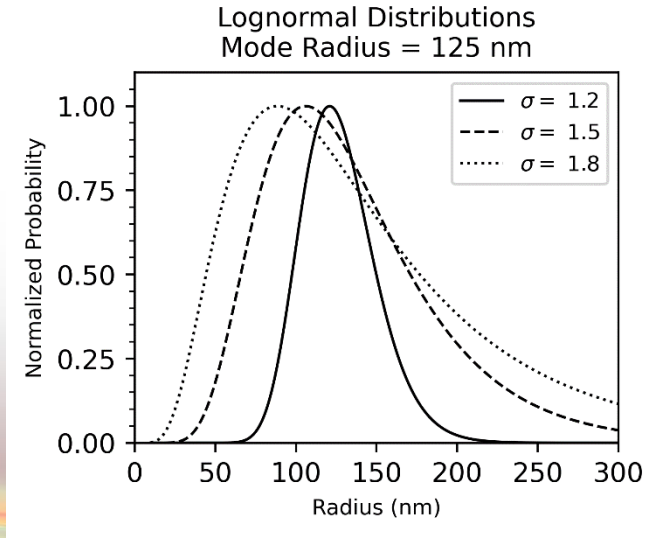
  - Distribution width (σ)

- Measurement error is often neglected
  - Wrana et al. 2021 included error

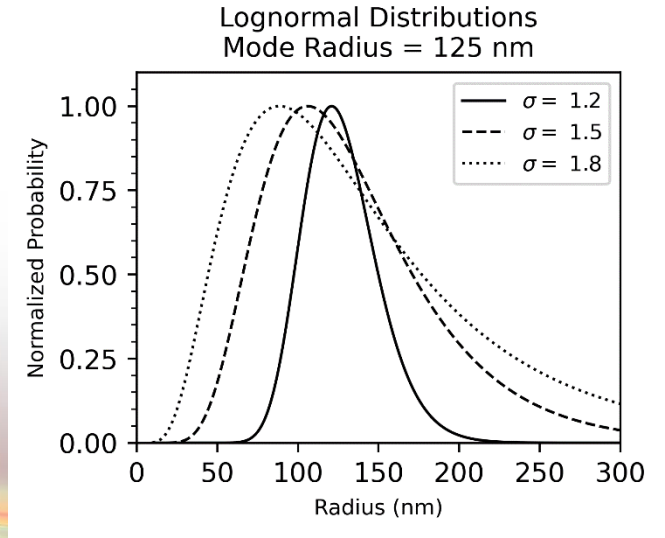


# Background

- SAGE data have been used to estimate particle size distribution (PSD) parameters
  - Mode radius
  - Distribution width (σ)

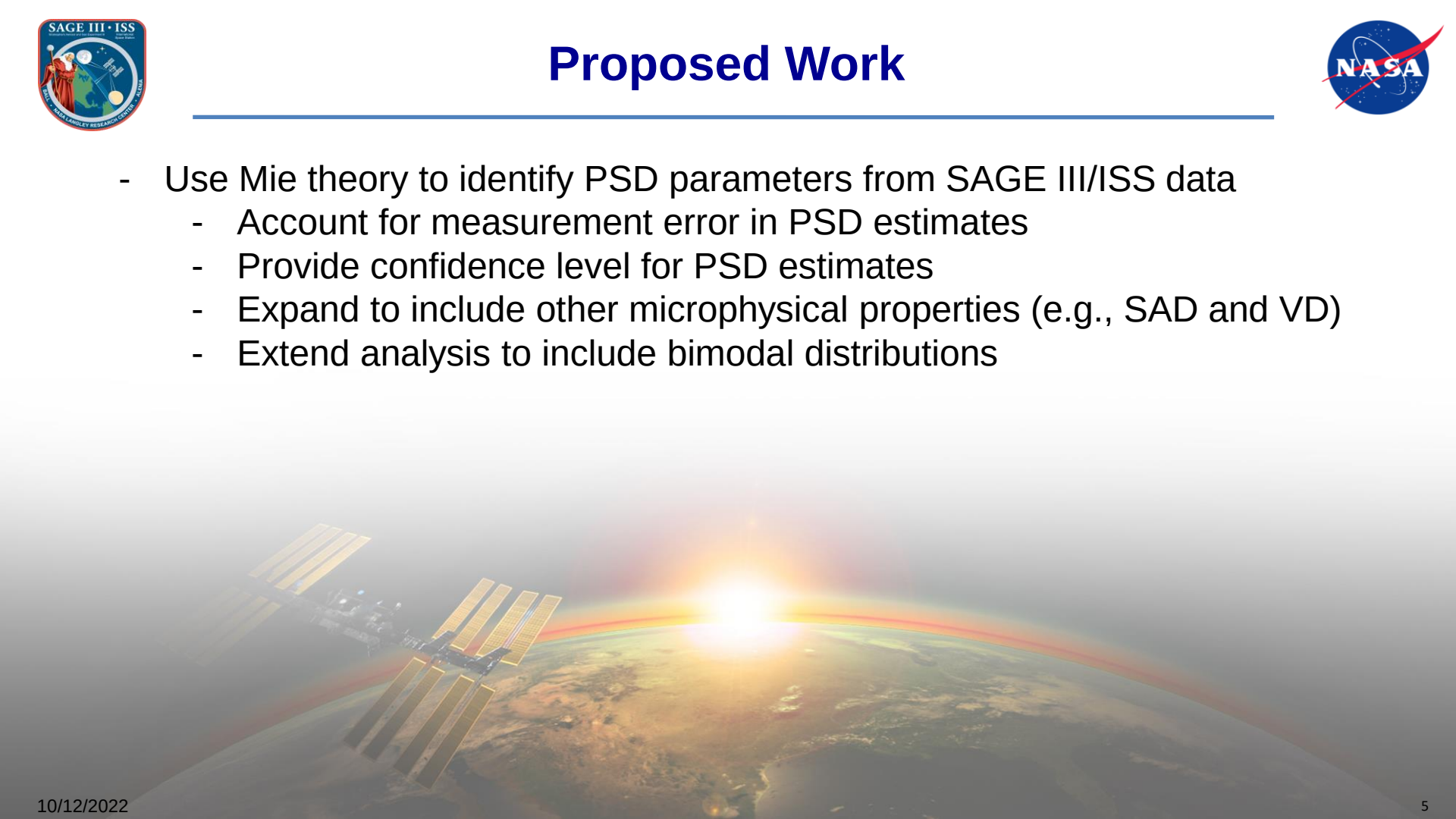
- Measurement error is often neglected
  - Wrana et al. 2021 included error

- Bimodal distributions have not been evaluated



# Proposed Work

- Use Mie theory to identify PSD parameters from SAGE III/ISS data
  - Account for measurement error in PSD estimates
  - Provide confidence level for PSD estimates
  - Expand to include other microphysical properties (e.g., SAD and VD)
  - Extend analysis to include bimodal distributions

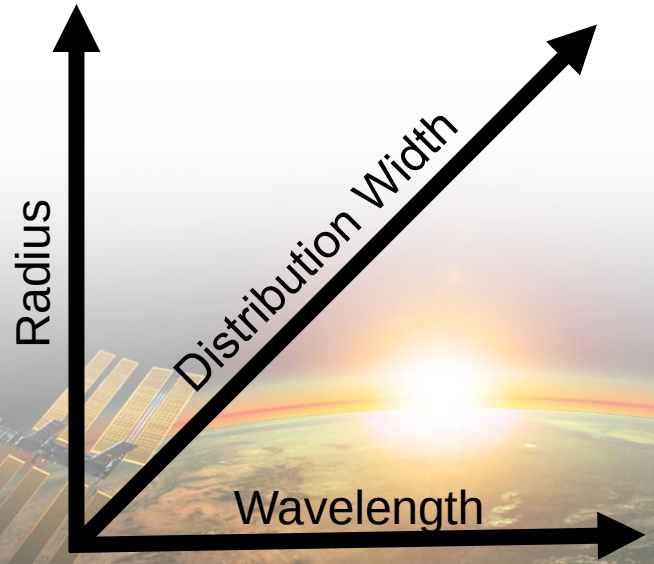


# Mie Theory Assumptions

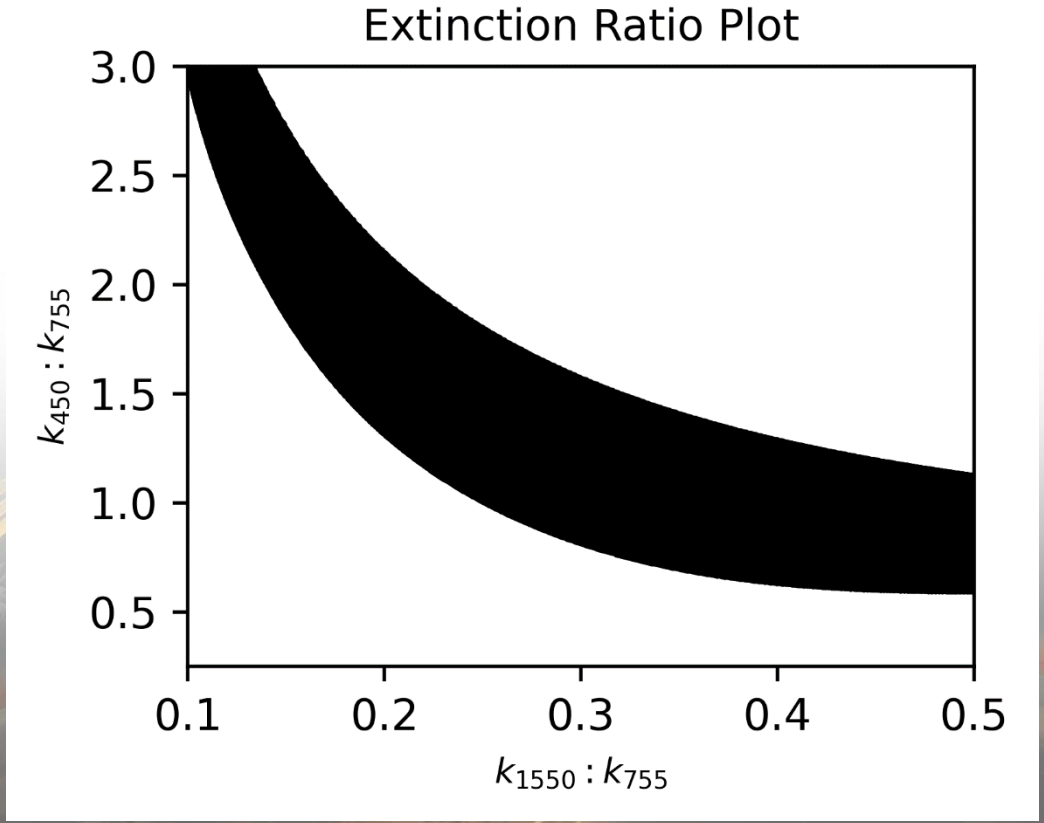
- Invoke standard Mie theory assumptions
  - all particles spherical
  - all distributions are lognormally distributed
    - mode radius range: 50 – 500 nm (1 nm resolution)
    - sigma range: 1.1 – 2.0 (0.001 resolution)
  - particles composed of 75% (wt) sulfuric acid, 25% water
    - Palmer and Williams (1975) refractive indices
  - above assumptions used in lookup table (LUT) creation

# Lookup Table (LUT)

- Use Mie theory to create lookup tables of extinction coefficients: k(r, λ, σ)
- Use same ratios as Wrana et al. 2021 (450:755 and 1550:755)



# Visualizing the Solution Space



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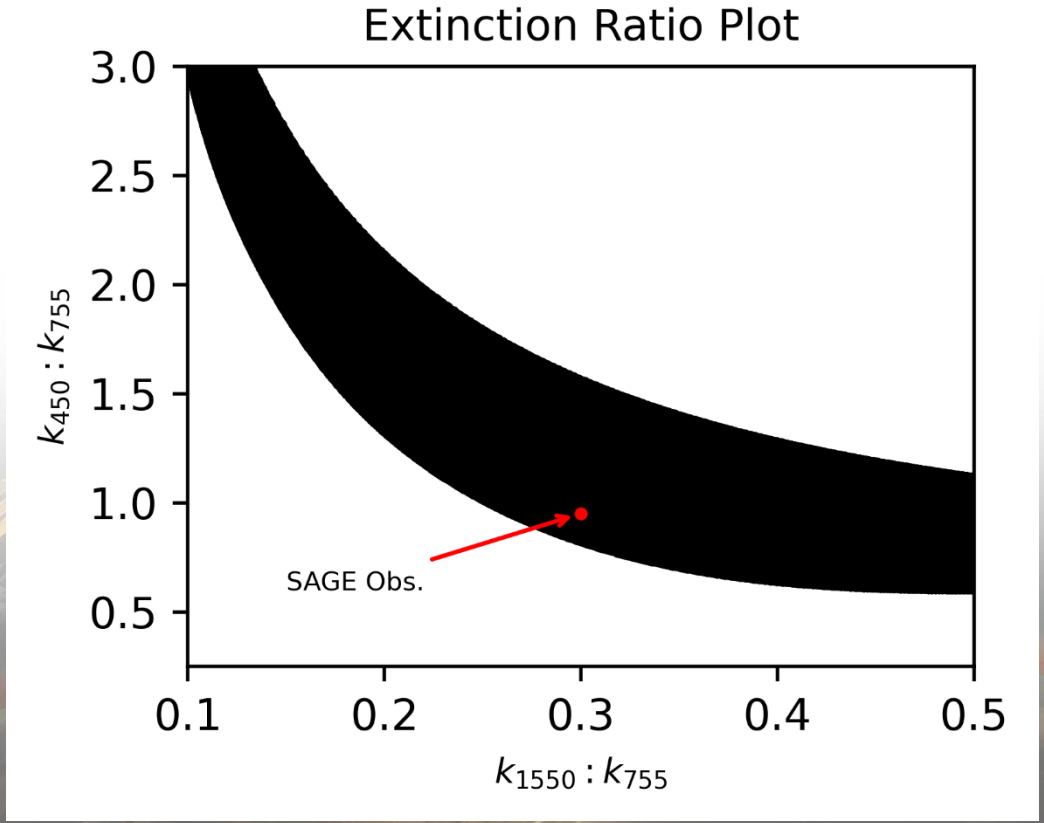

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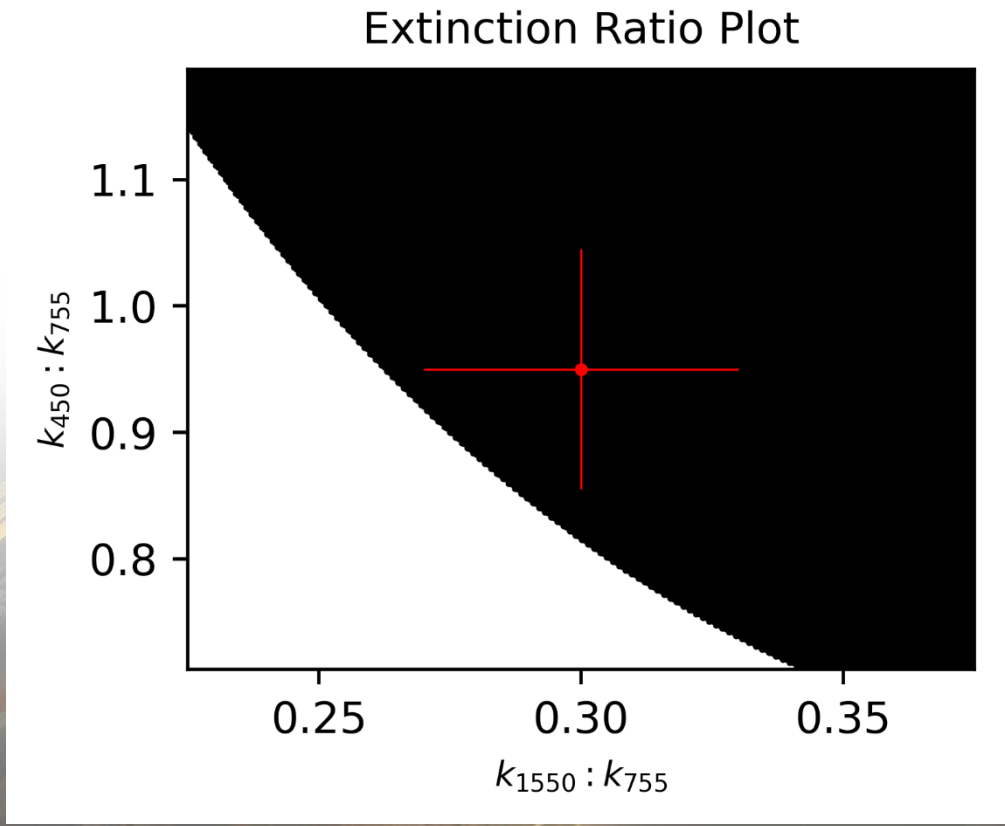

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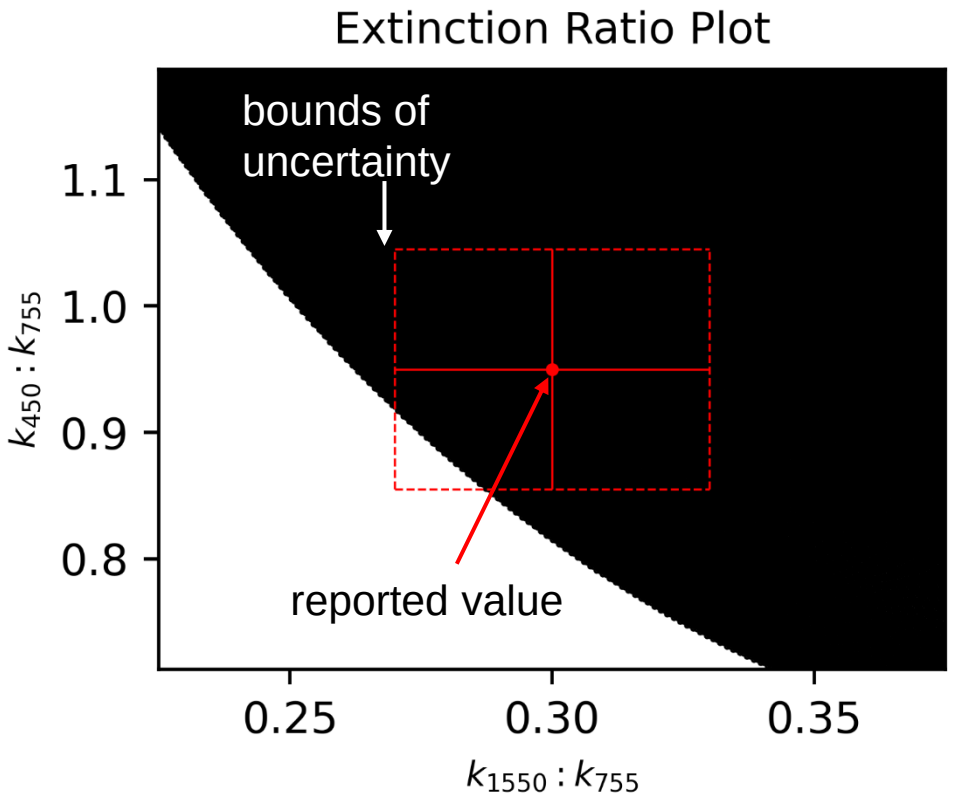
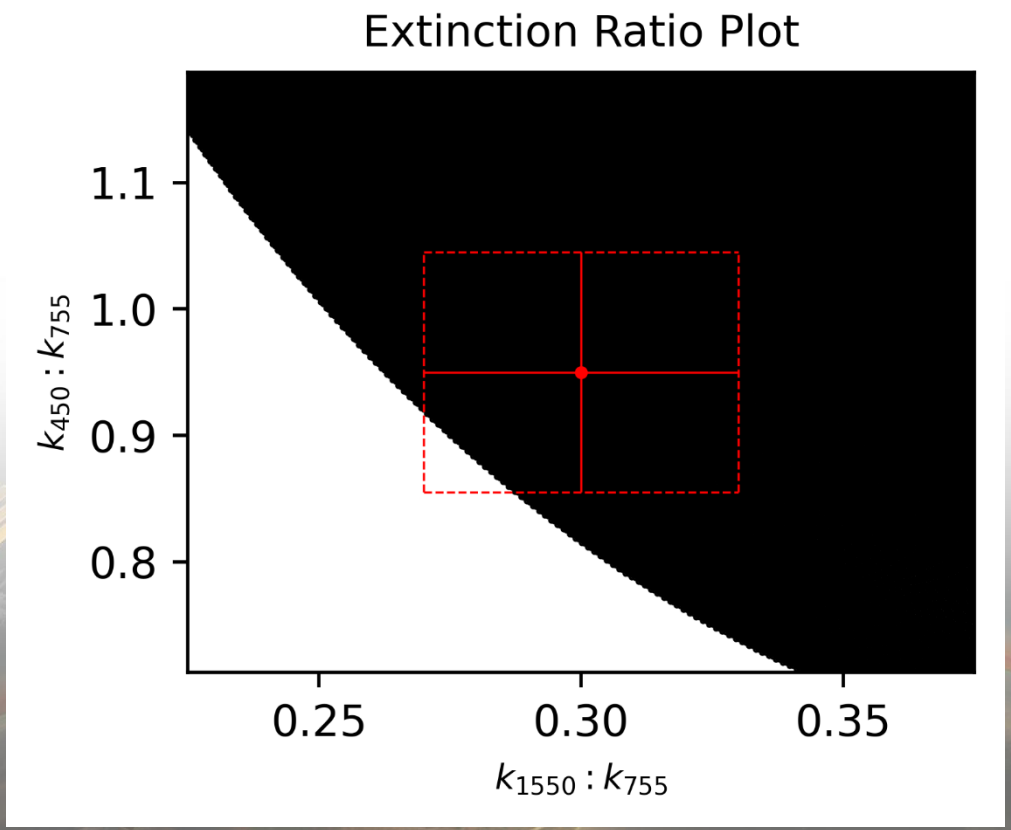



All potential solutions!

Which is right/best?

# Visualizing the Solution Space




Use distance from central point as weight

Calculate weighted statistics (e.g., median)

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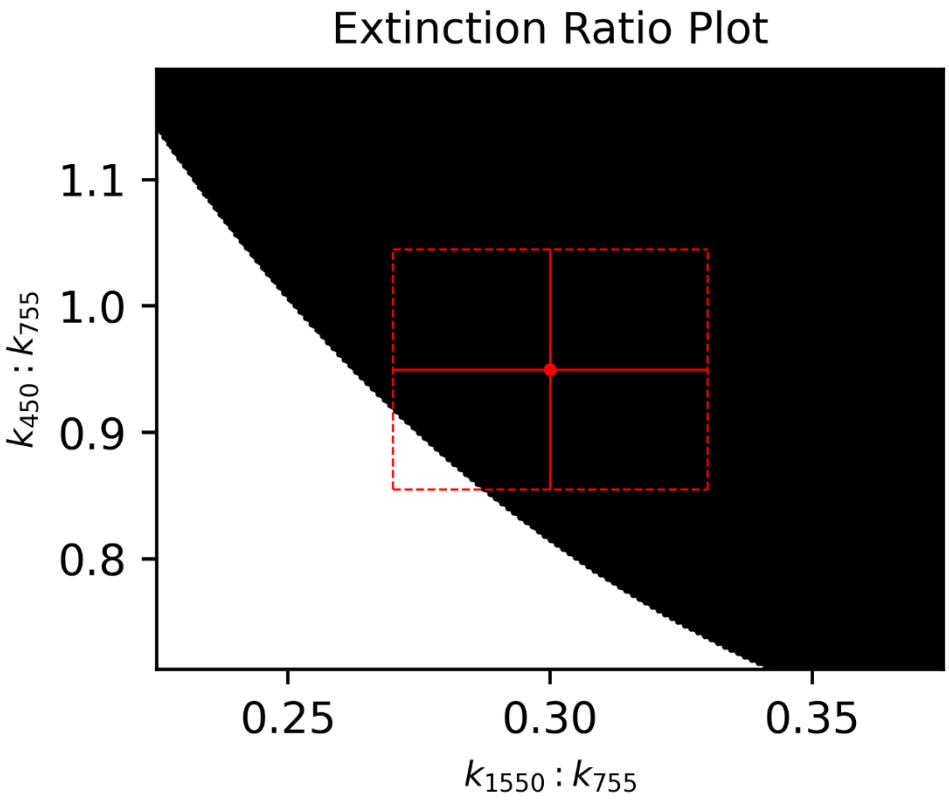



Use distance from central point as weight

Calculate weighted statistics (e.g., median)

How well does that work?

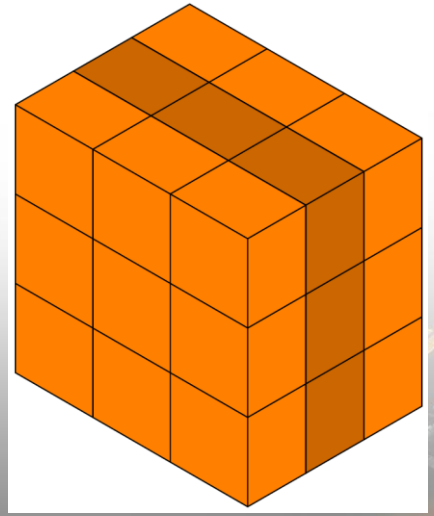
# Sensitivity Study

- How accurately can we reproduce “known” values?
  - How does this change as a function of measurement uncertainty?

- Evaluate under 2 scenarios:
  - We get the composition correct
  - We get the composition wrong

# Sensitivity Study: Correct Composition

Imaginary atmosphere
75% $H_2SO_4$



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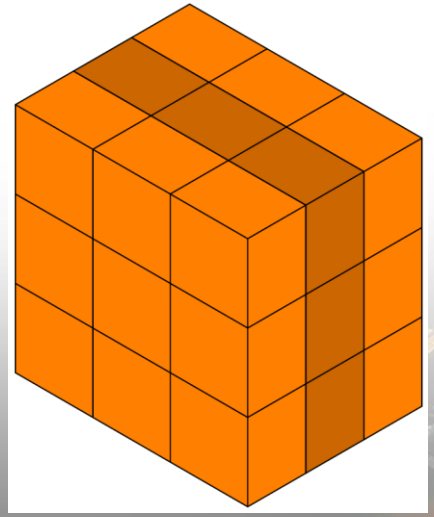
Pull out single extinction ratio of known r, λ, σ



$k(r, \lambda, \sigma) + err$

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Find matches in
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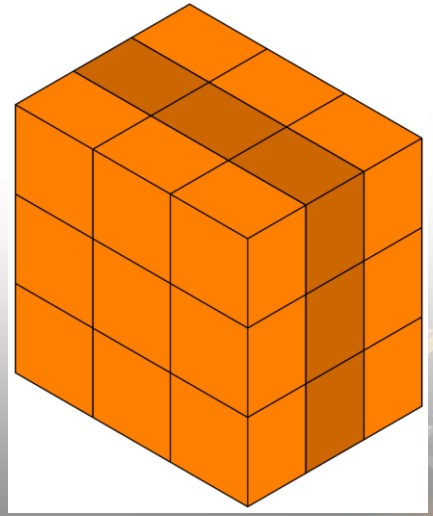

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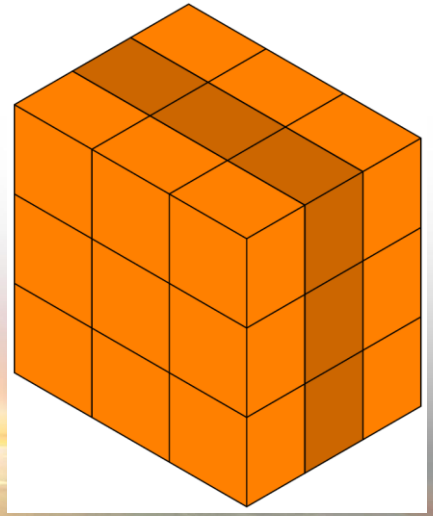

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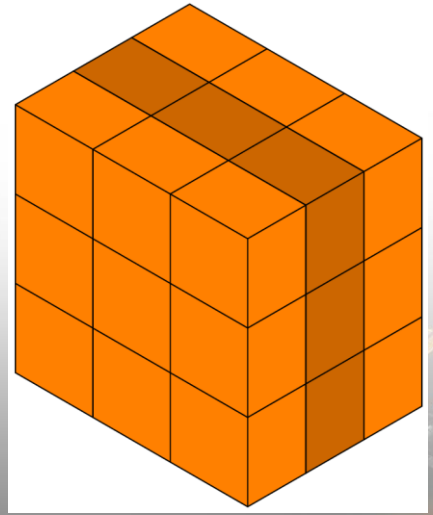
Find matches in 75% $H_2SO_4$ LUT

Calculate statistics for inferred values



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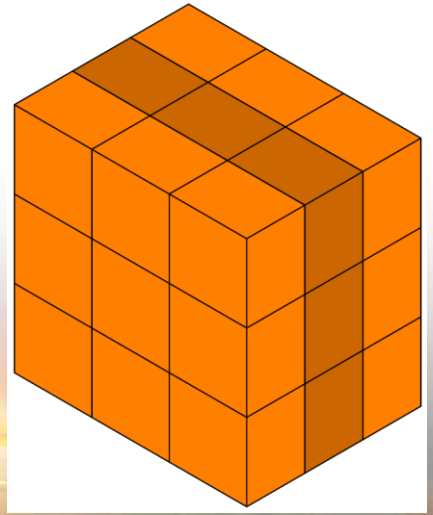

mean
median
Q1, Q3,
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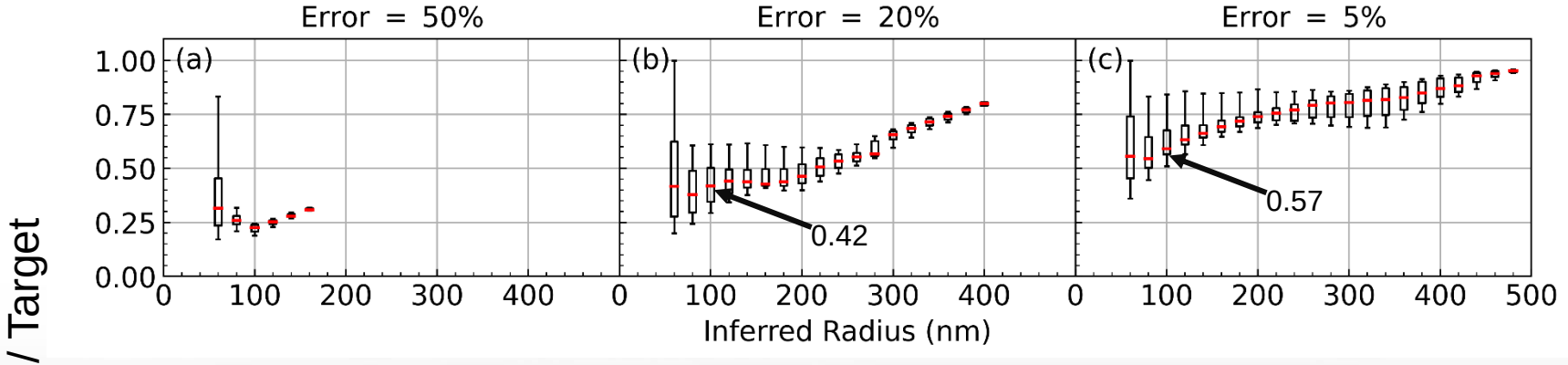
# Sensitivity Study Continued
# Influence of Error



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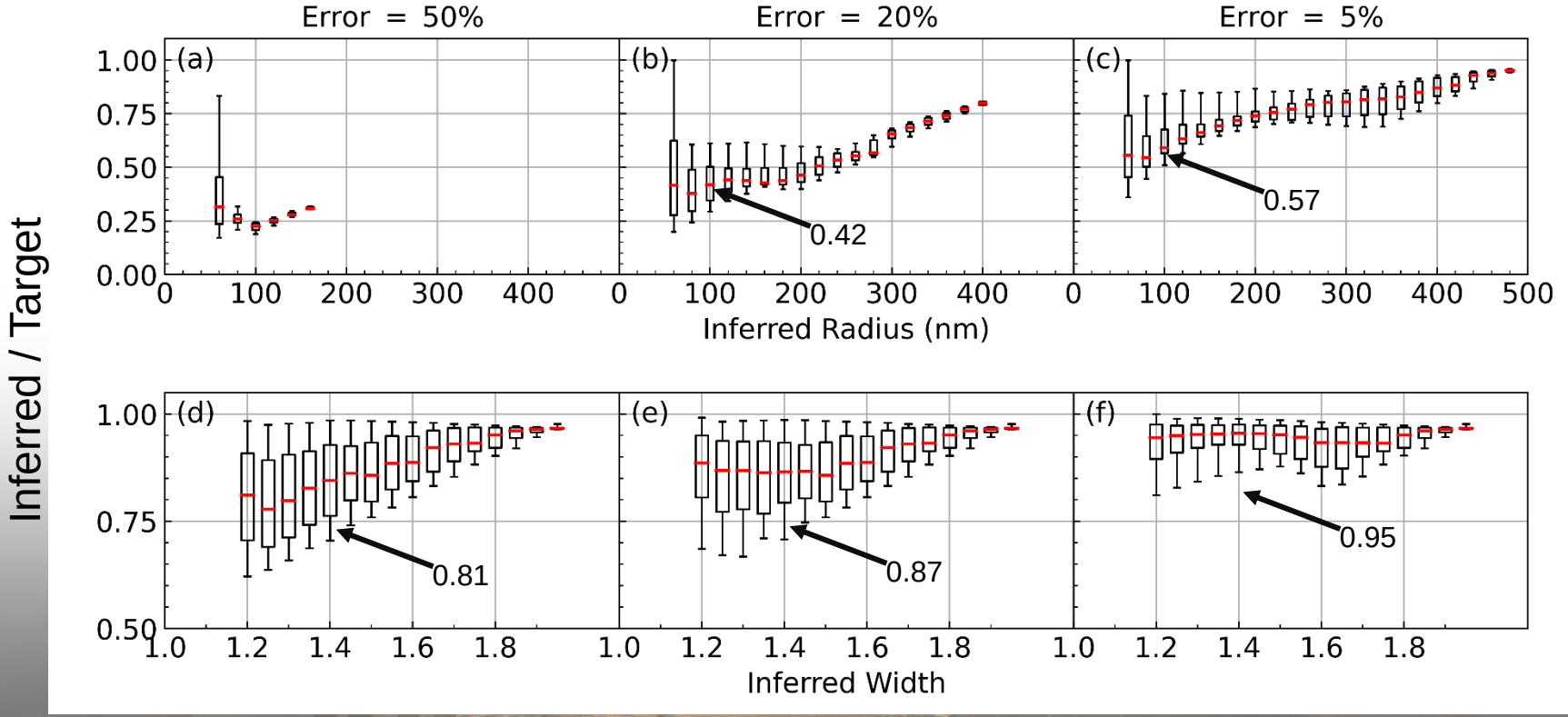

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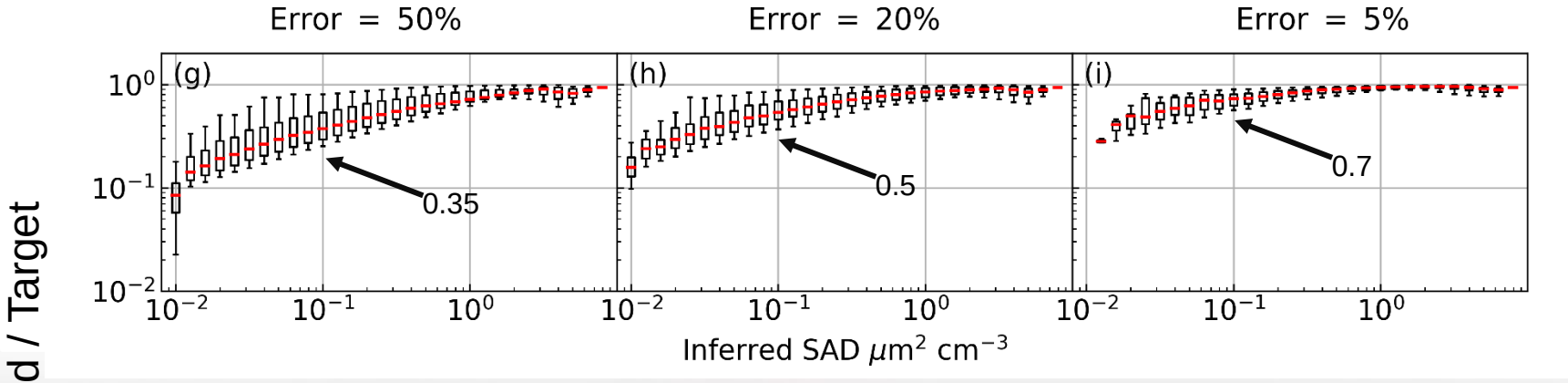

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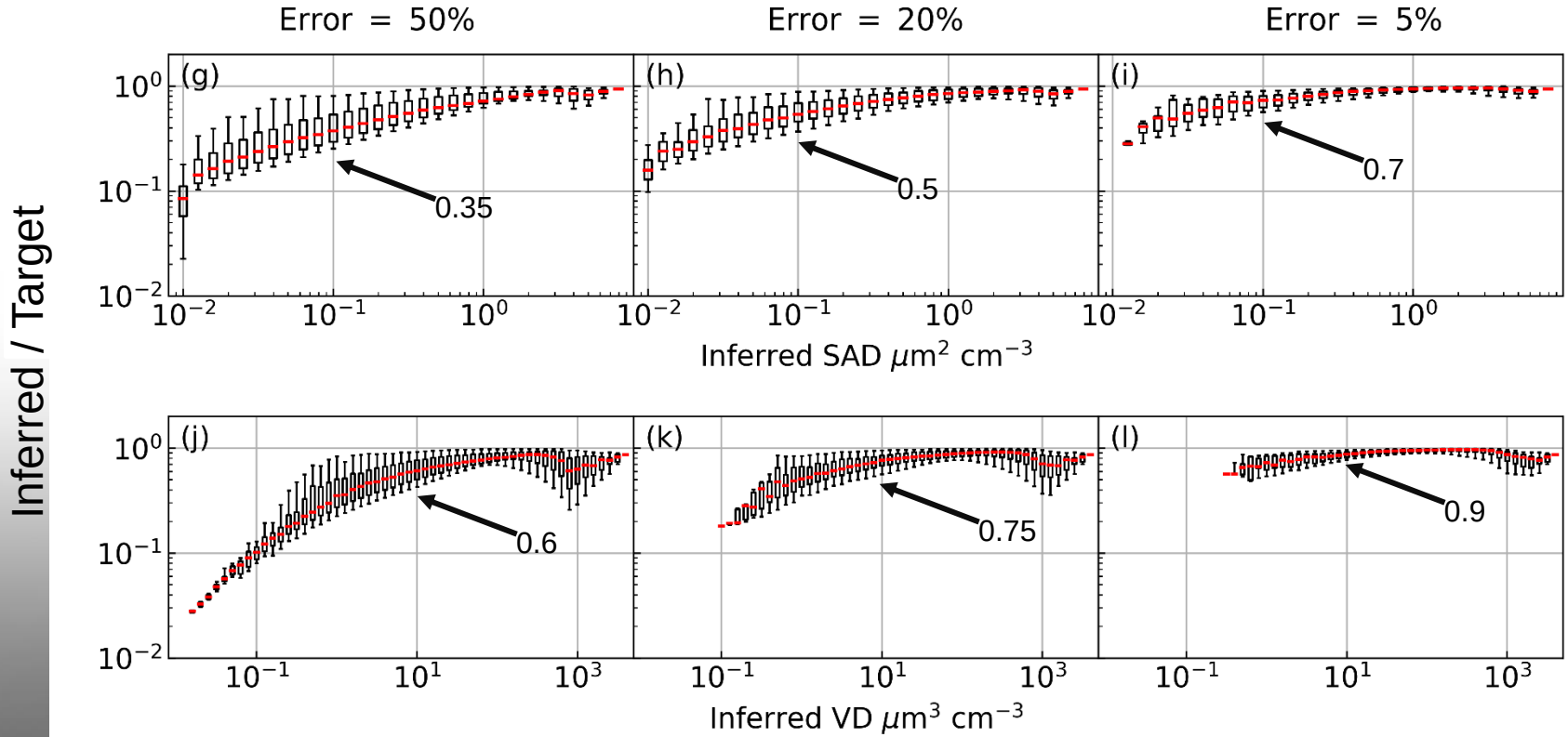
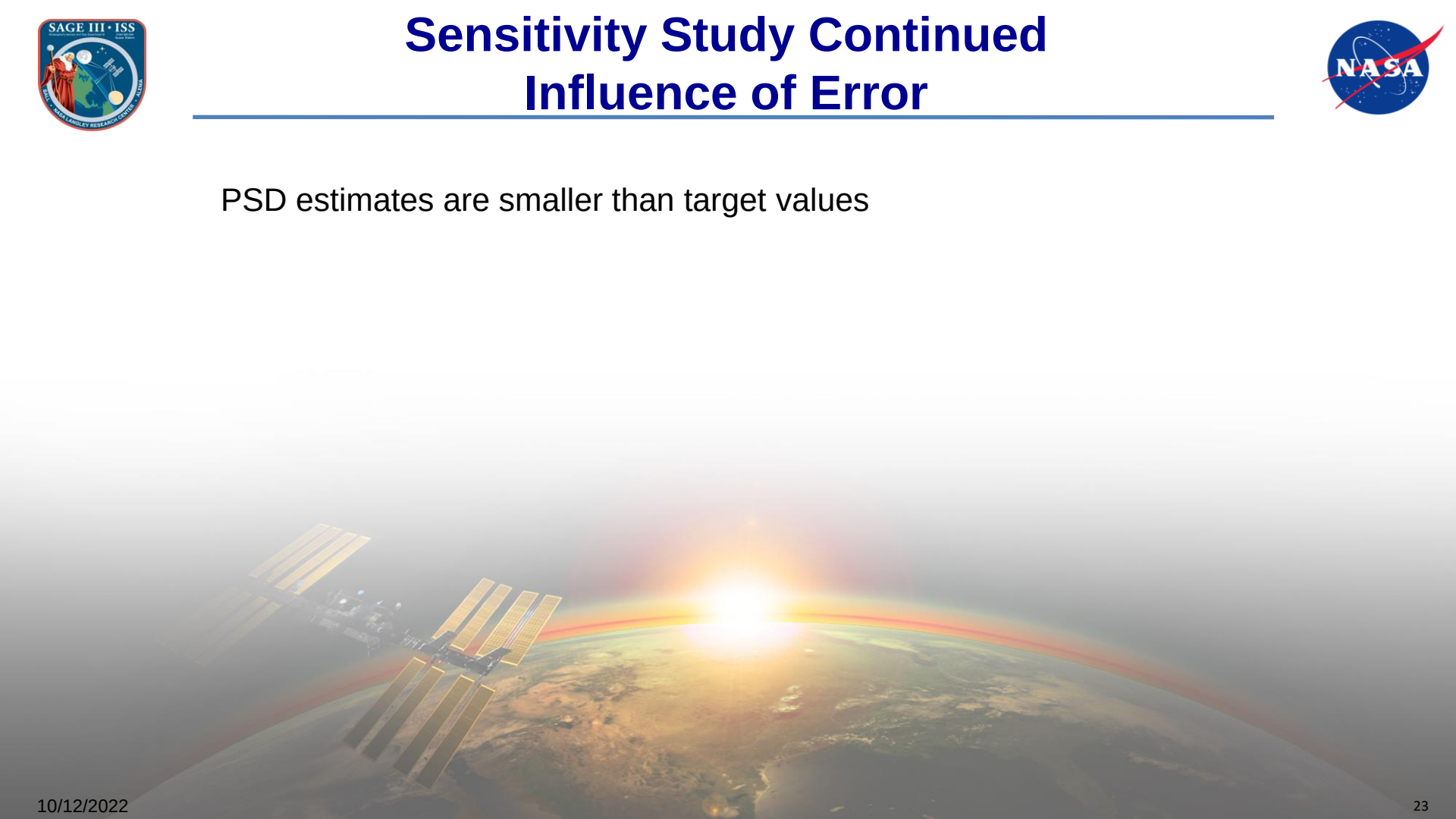


# Sensitivity Study Continued
# Influence of Error

PSD estimates are smaller than target values



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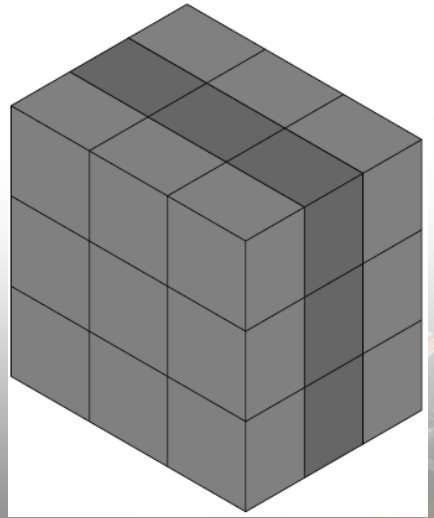

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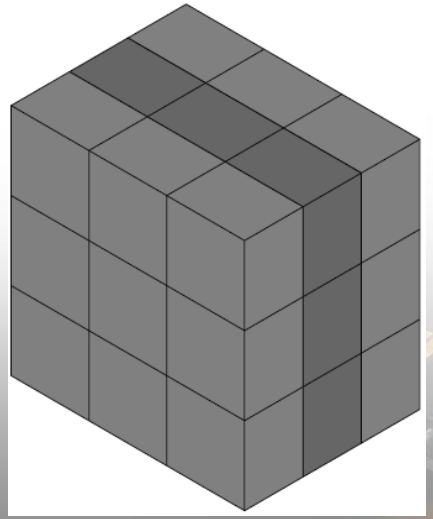

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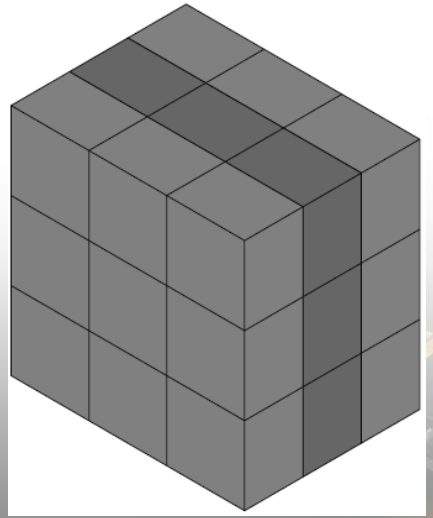

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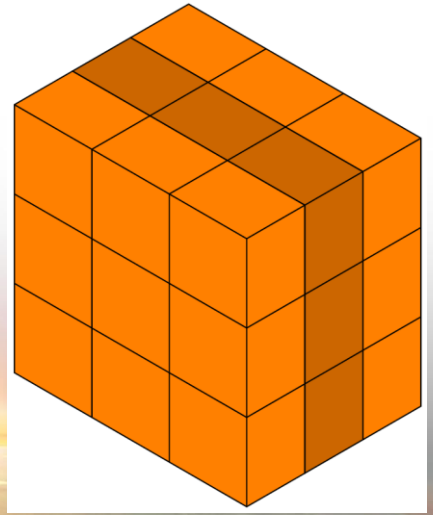

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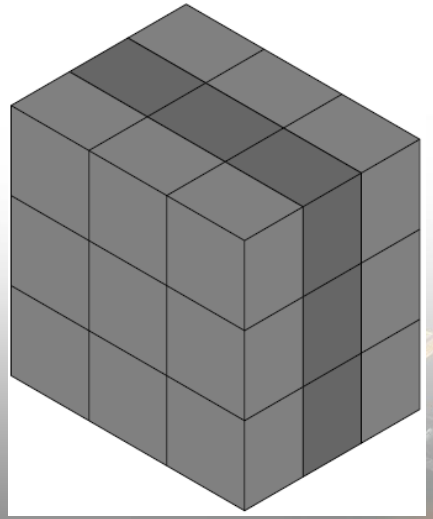

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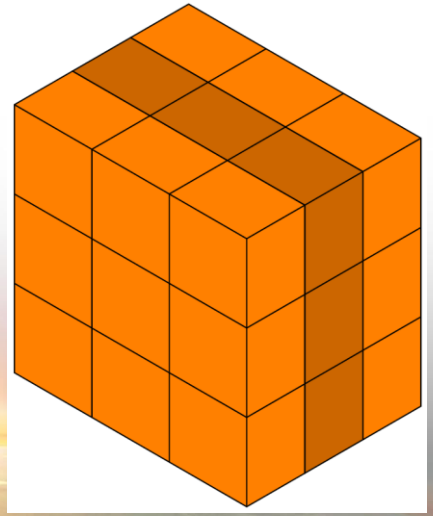

mean
median
Q1, Q3,
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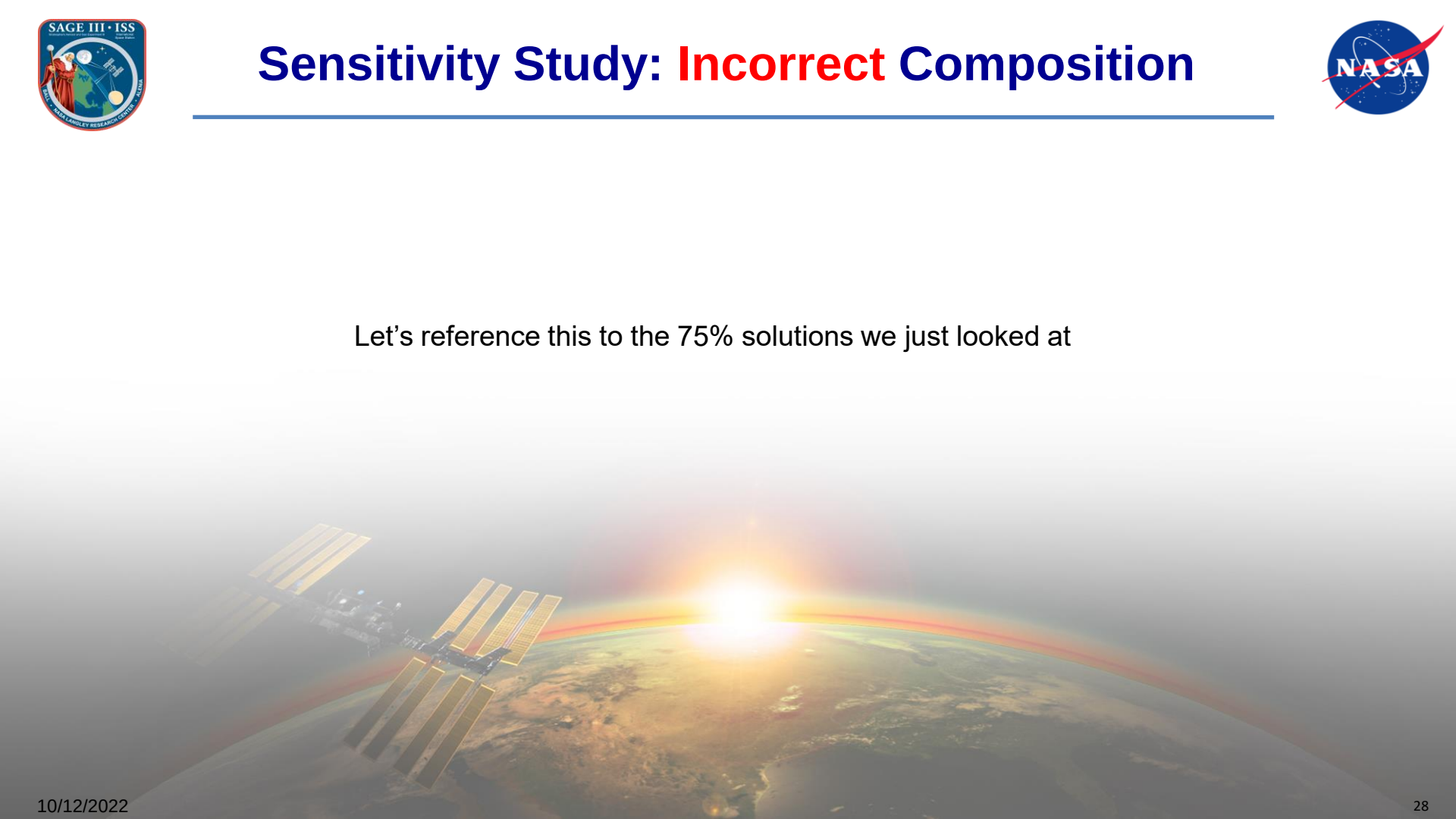
# Sensitivity Study: Incorrect Composition

Let’s reference this to the 75% solutions we just looked at



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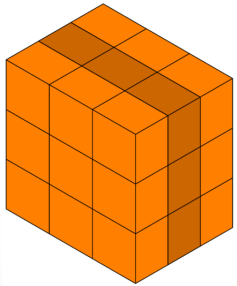
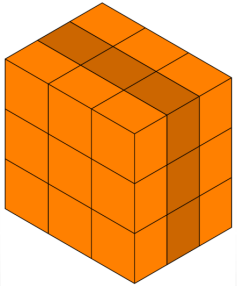


$k(r, \lambda, \sigma) + err$

Find matches in 75%
$H_2SO_4$ LUT



Stats ($S_1$)

# Sensitivity Study: Incorrect Composition

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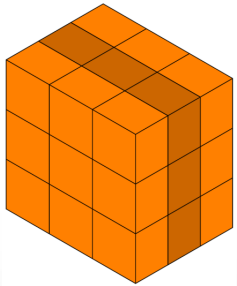

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Find matches in 75%
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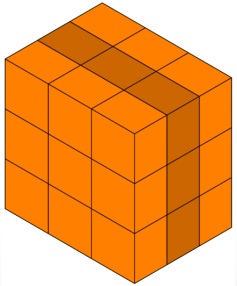

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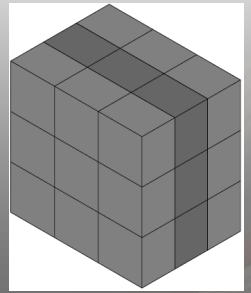

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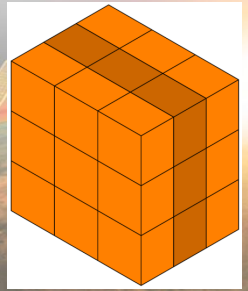

Stats ($S_2$)

# Sensitivity Study: Incorrect Composition

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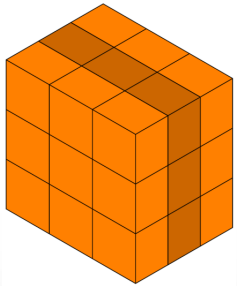
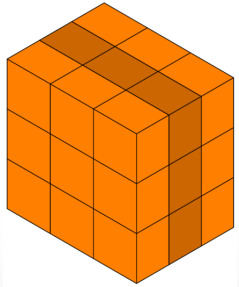


k(r, λ, σ) + err

Find matches in 75%
$H_2SO_4$ LUT



Stats ($S_1$)

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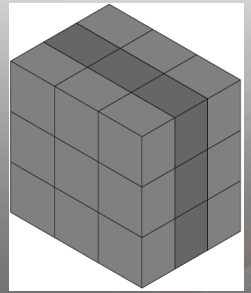
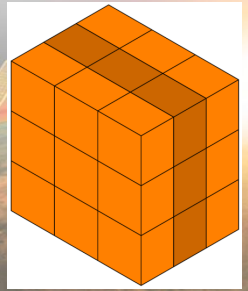


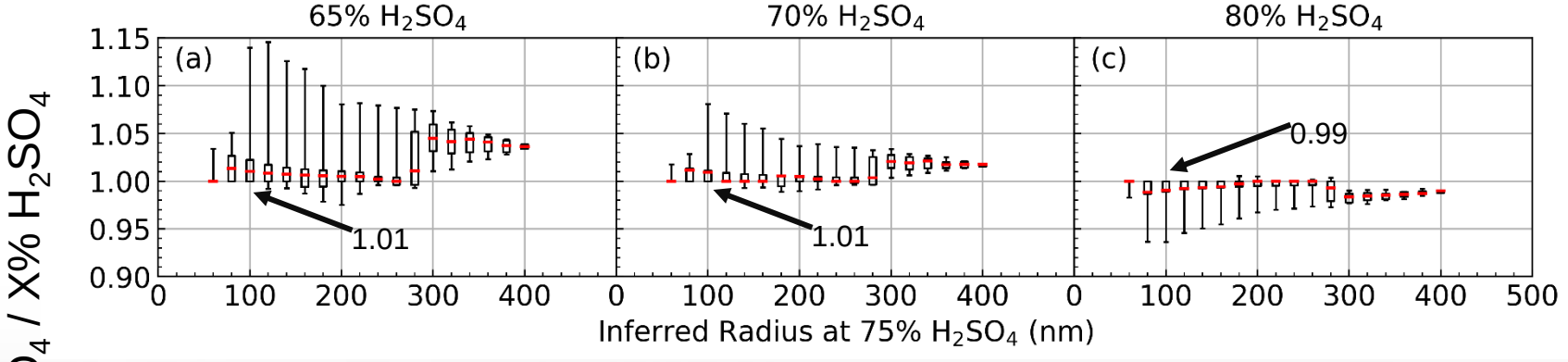
k(r, λ, σ) + err



Stats ($S_2$)

$$\frac{S_1}{S_2}$$

# Sensitivity Study Continued
# Wrong $H_2SO_4$ Composition



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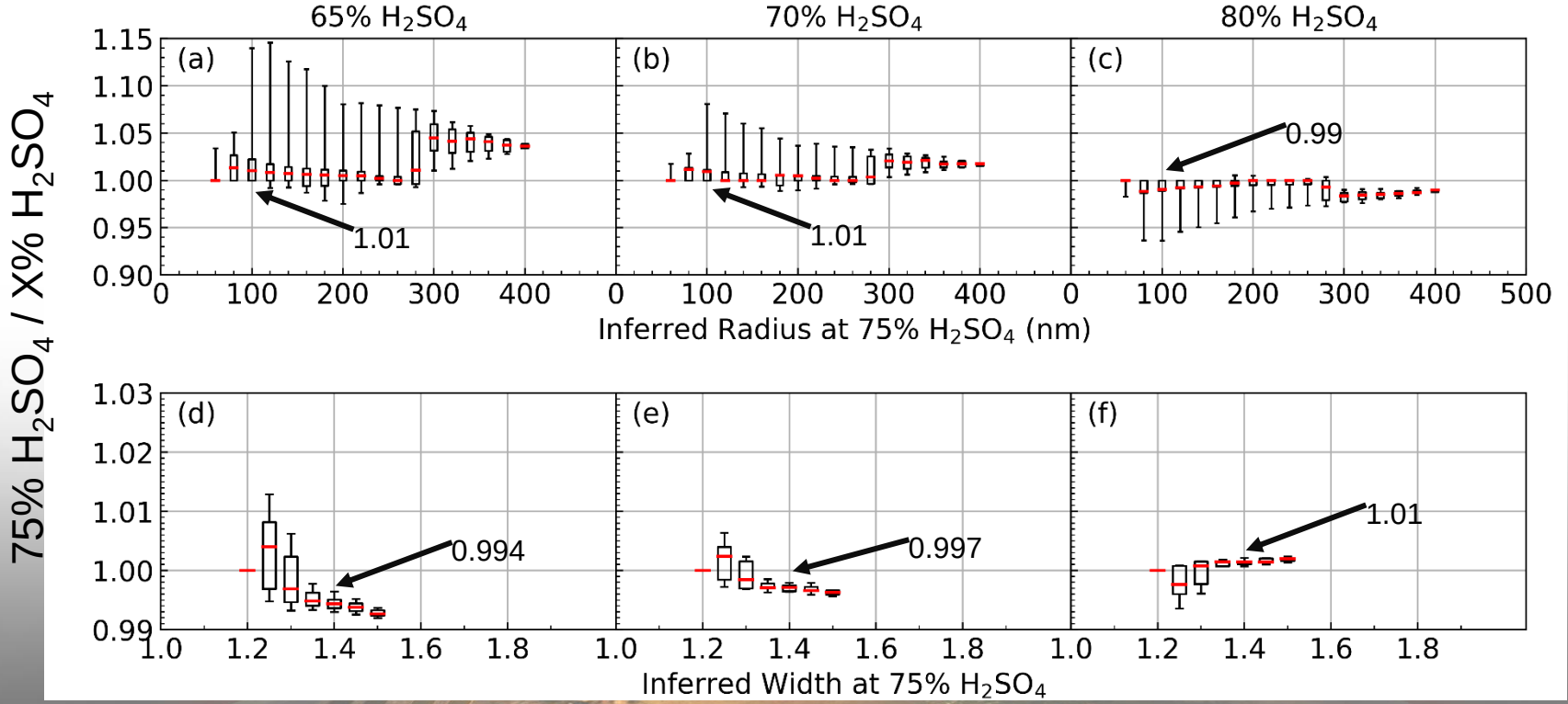

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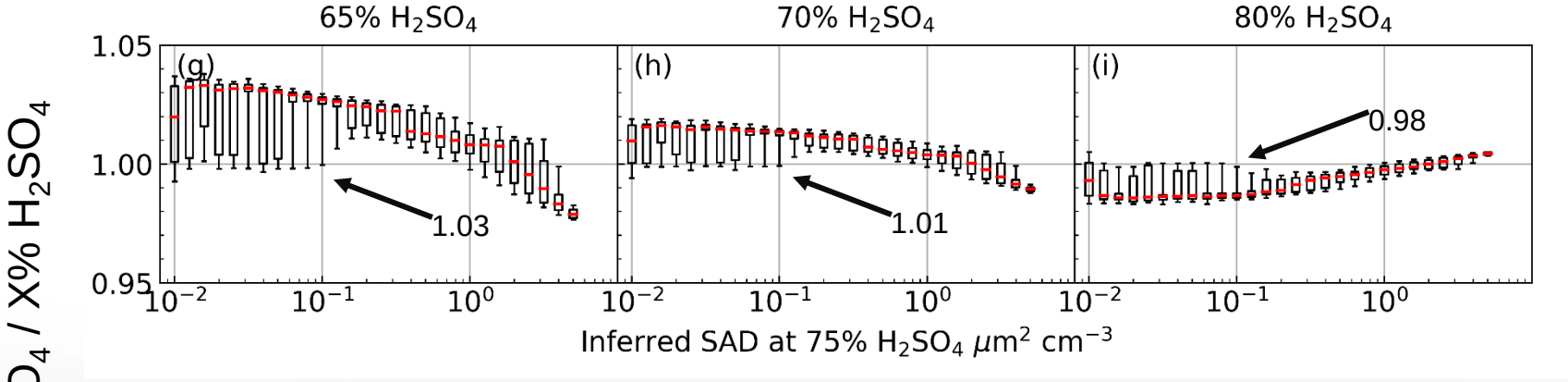
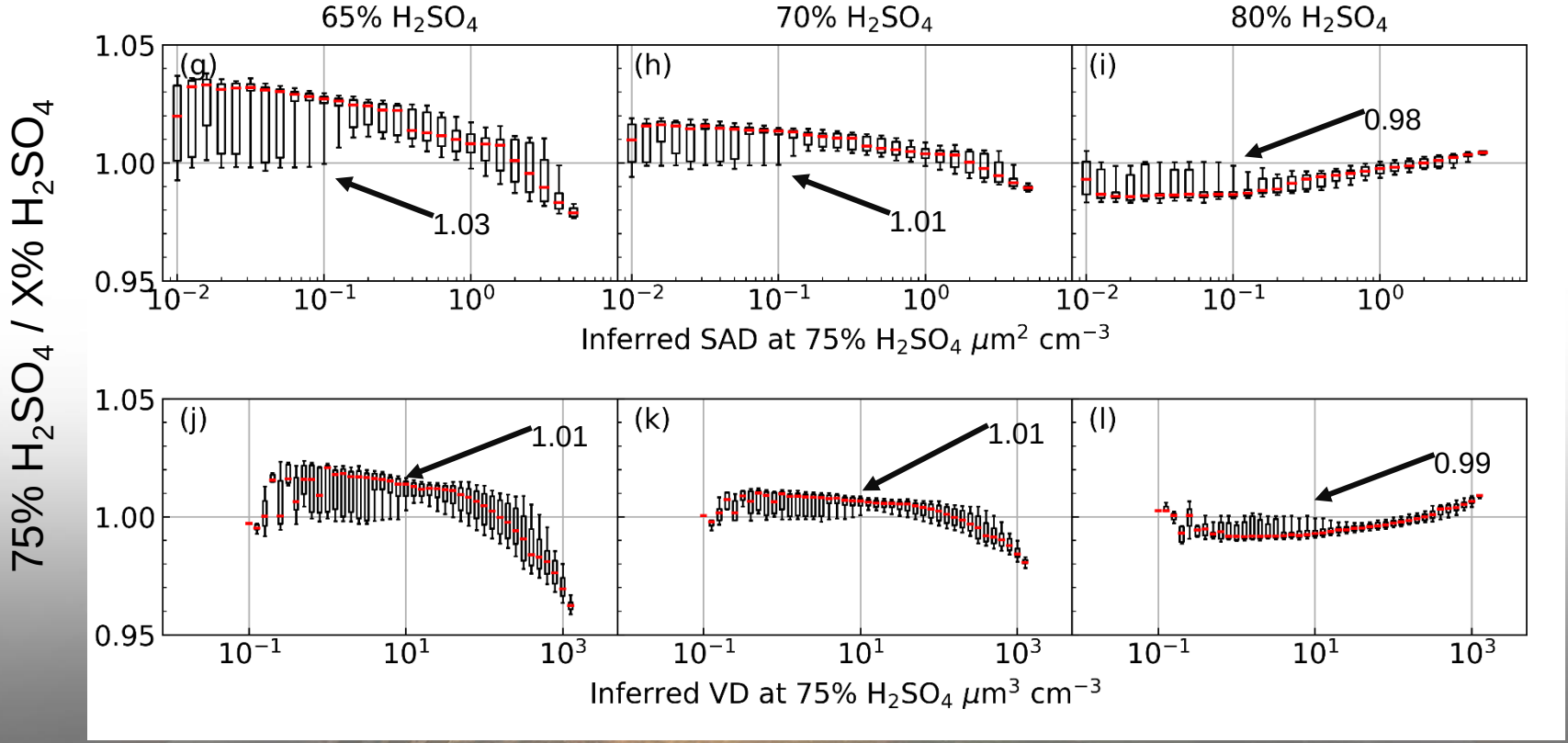
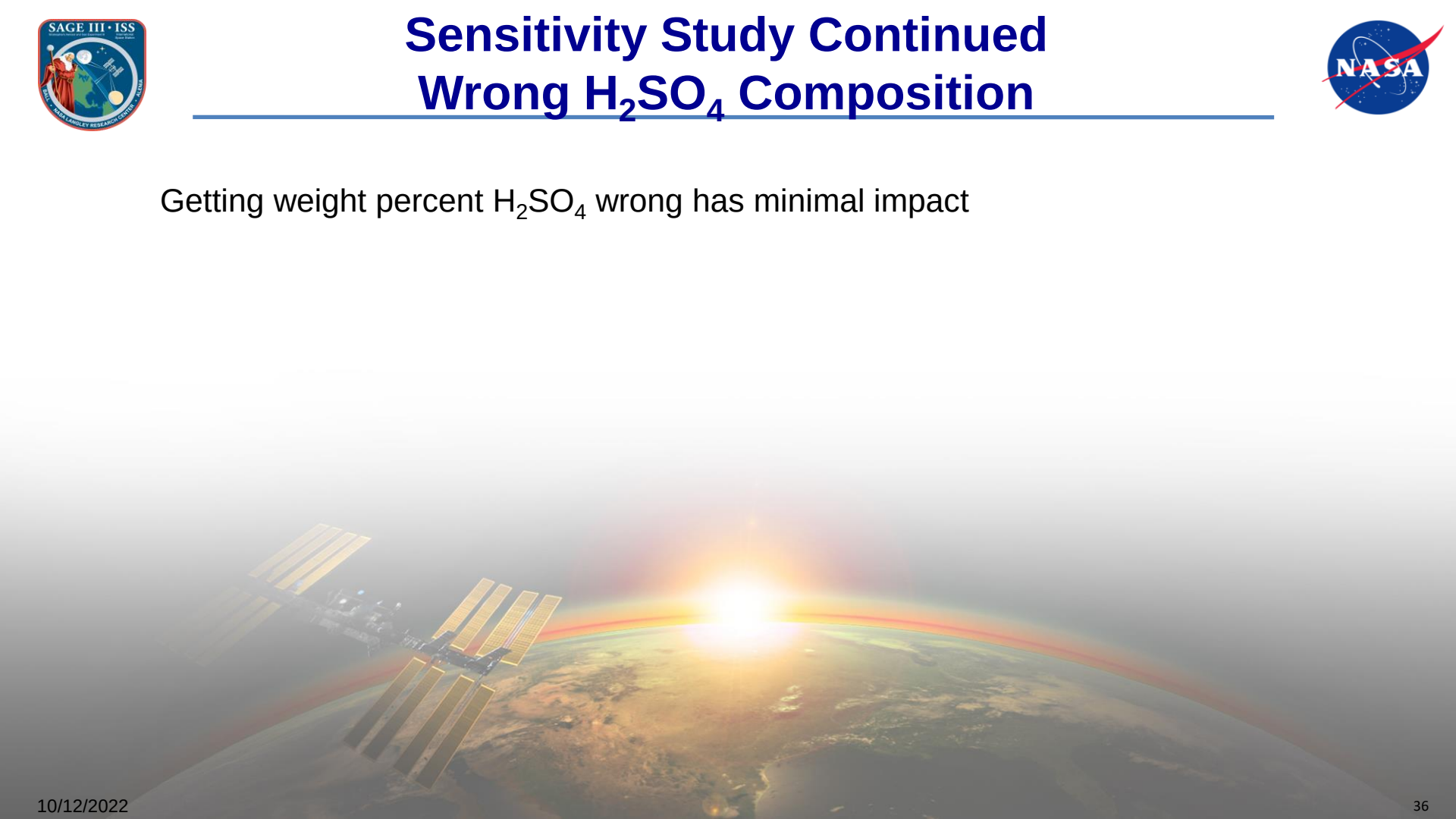


# Sensitivity Study Continued
# Wrong $H_2SO_4$ Composition

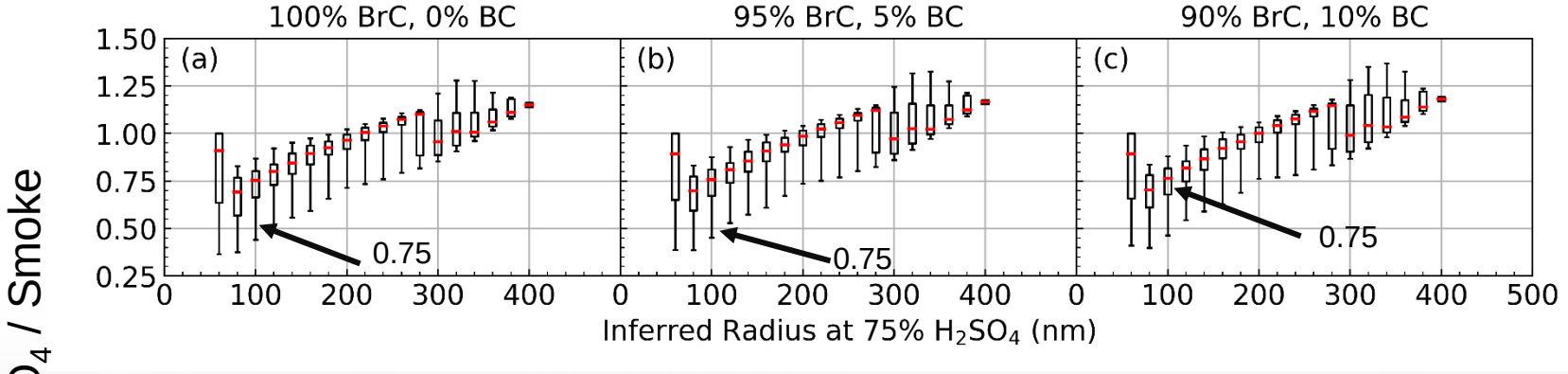


# Sensitivity Study Continued
# Wrong $H_2SO_4$ Composition

Getting weight percent $H_2SO_4$ wrong has minimal impact



# Sensitivity Study Continued
# Wrong Composition: With smoke



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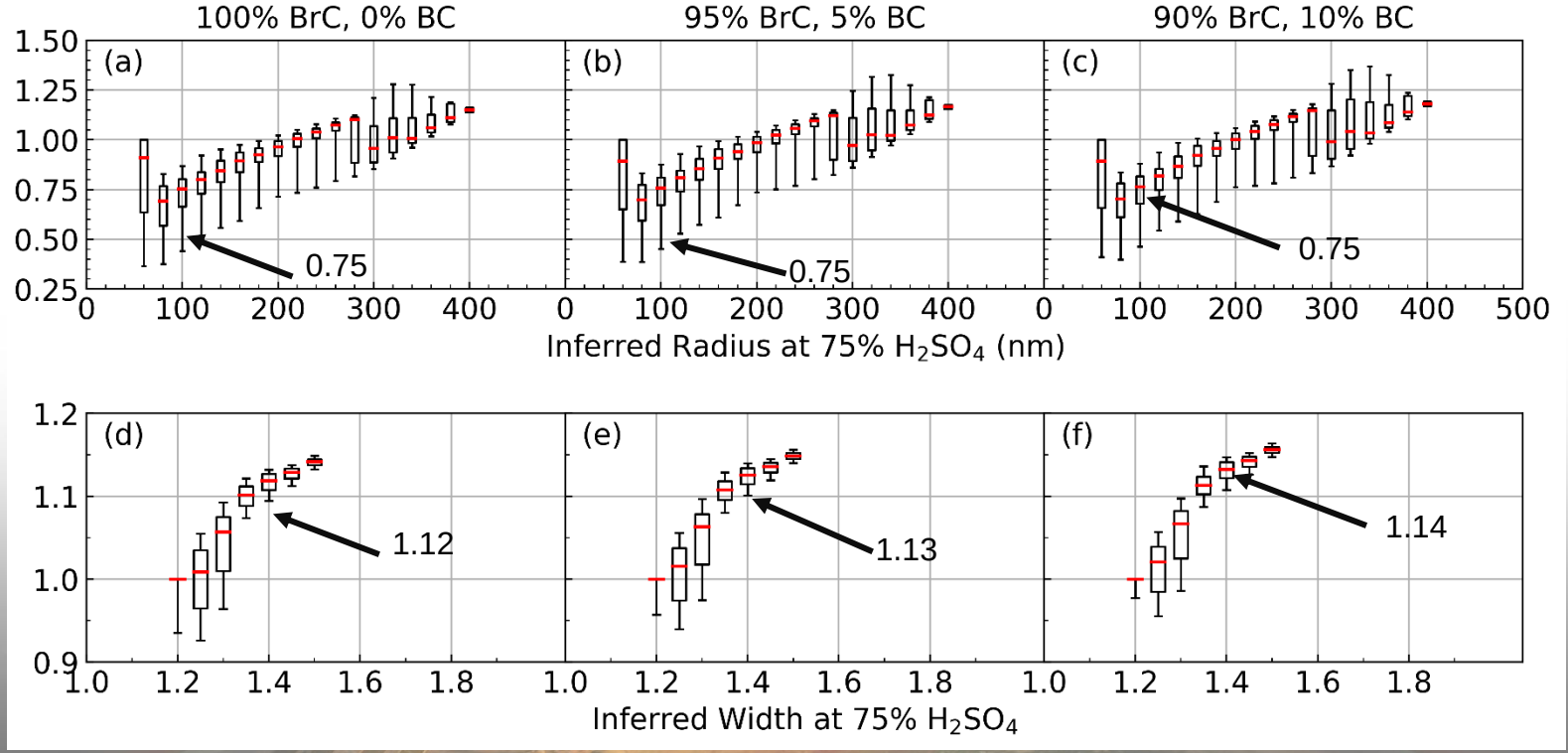
# Wrong Composition: With smoke



# Sensitivity Study Continued
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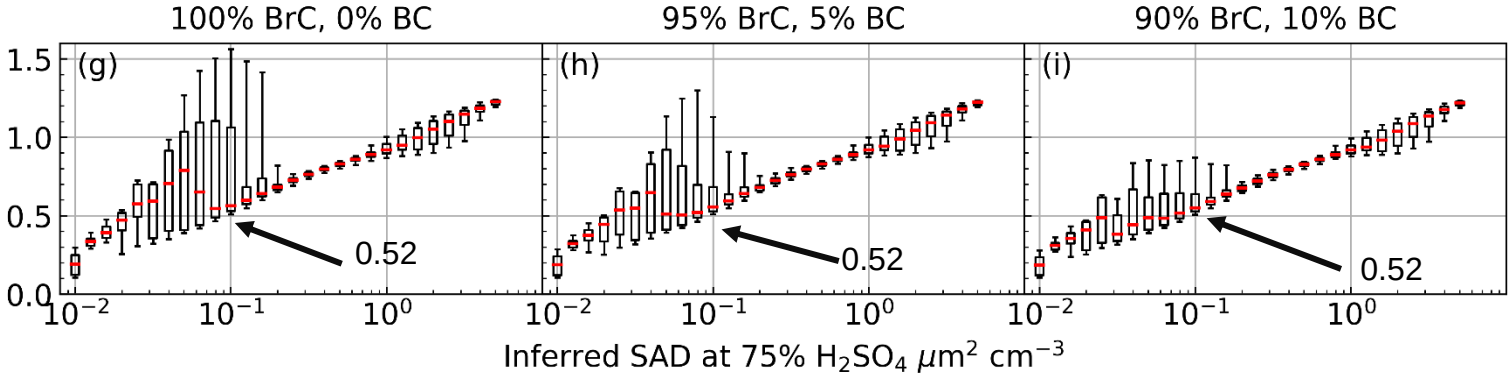

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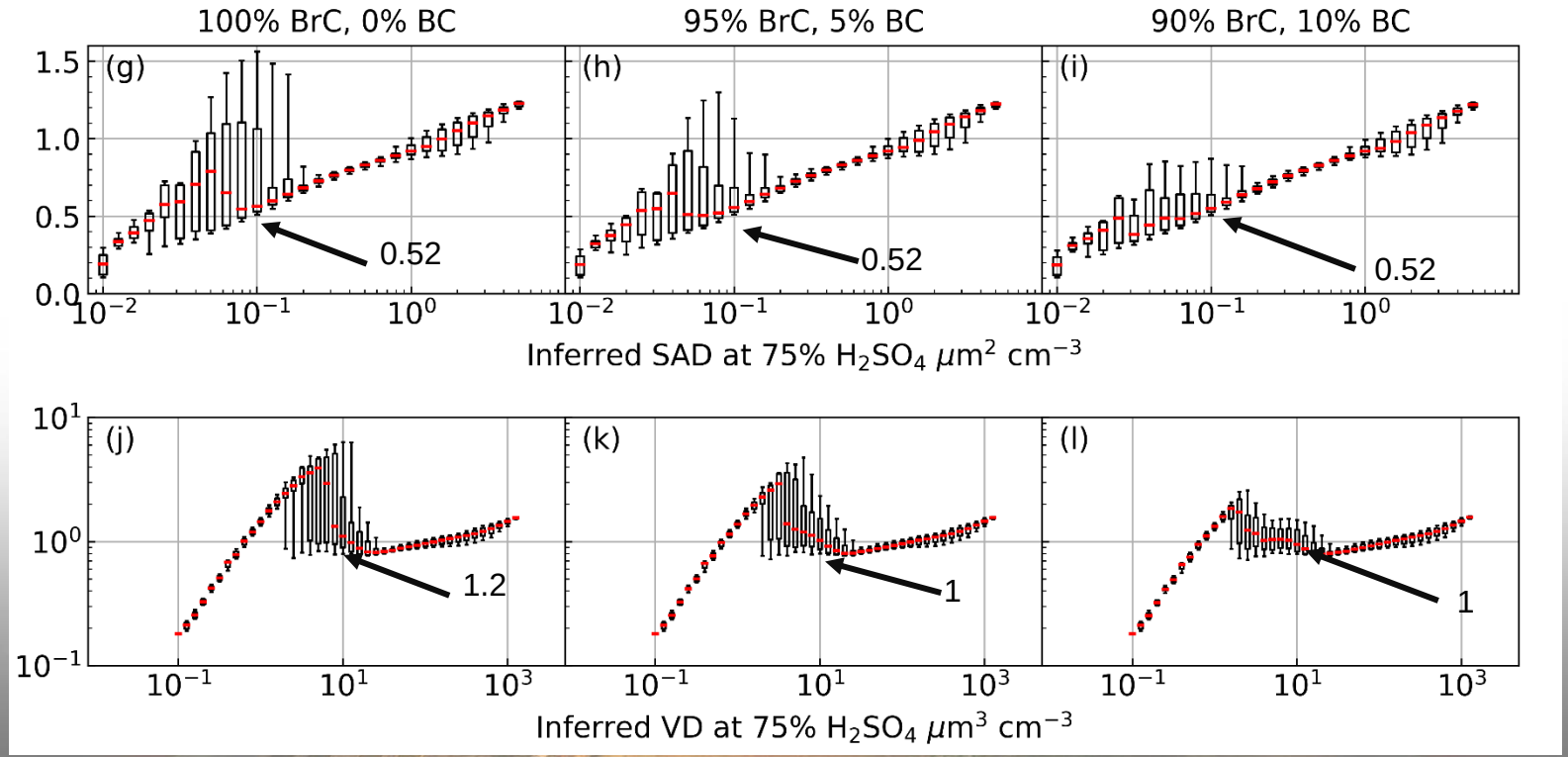
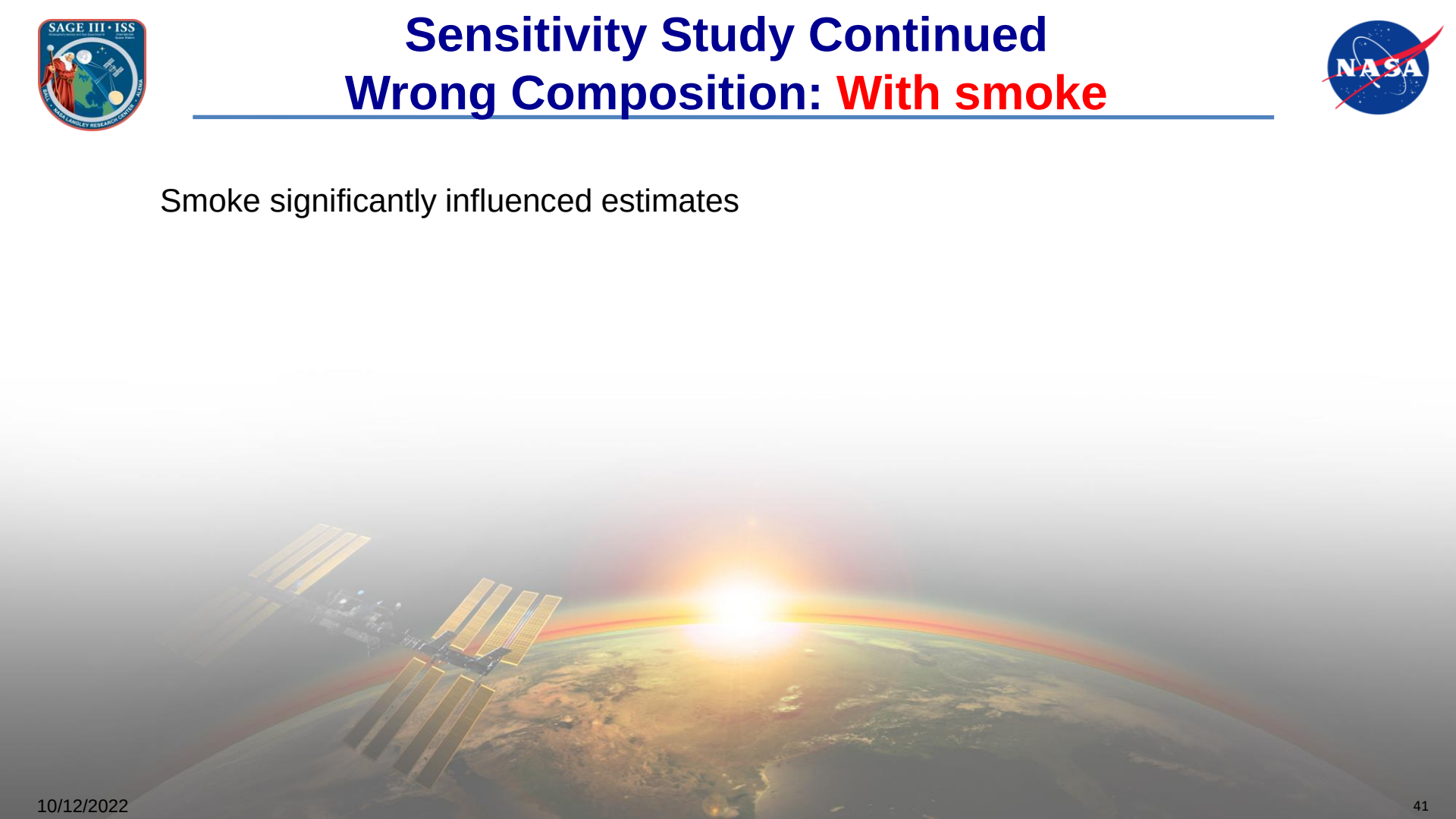


# Sensitivity Study Continued
# Wrong Composition: With smoke

Smoke significantly influenced estimates



# Recap

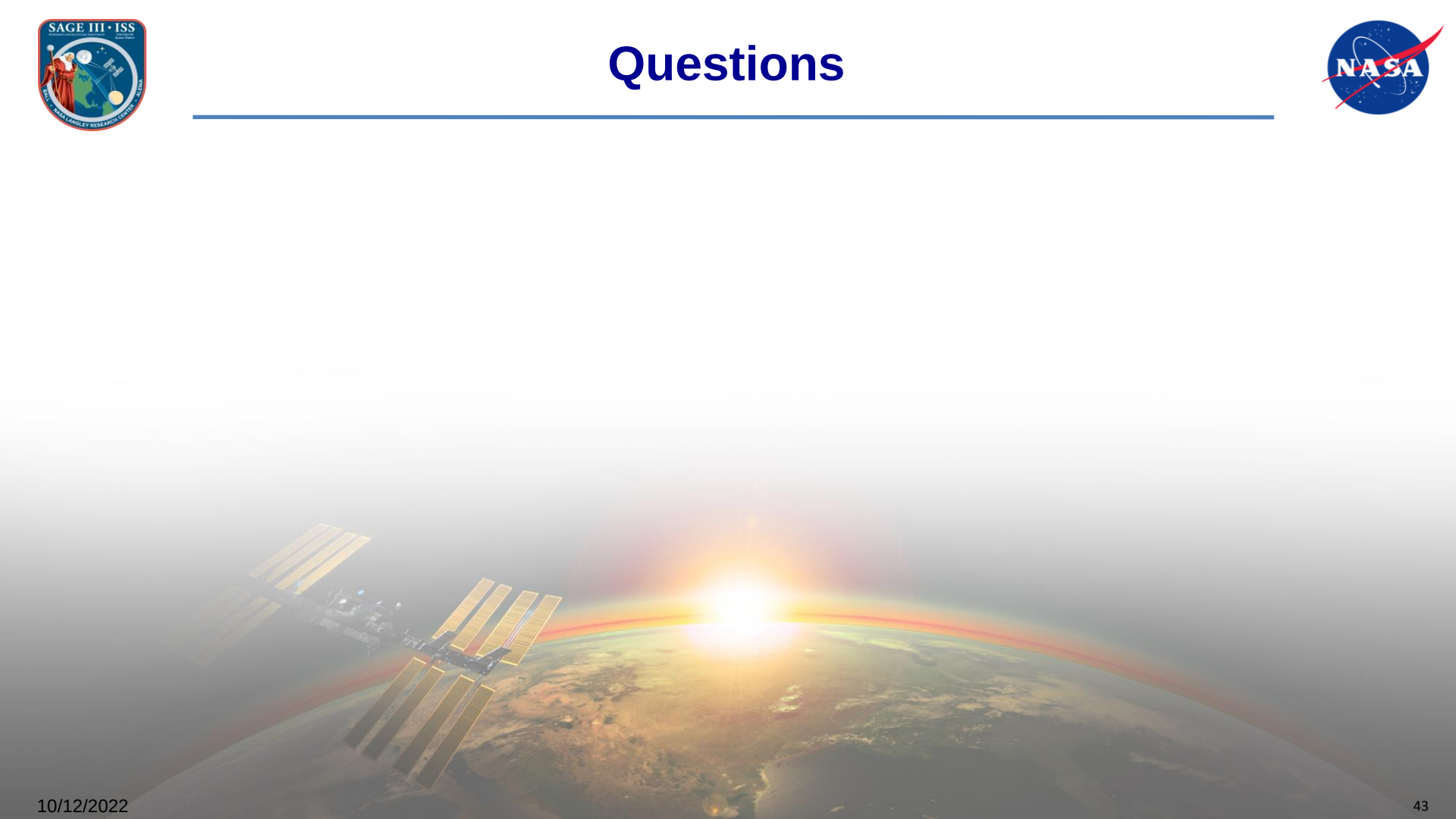
- SAGE III/ISS extinction data will be used to estimate PSD parameters
  - we expanded scope of proposed work to include microphysical properties (SAD, VD)

- When composition is known:
  - PSD estimates are generally too small

- When composition is unknown:
  - Getting $H_2SO_4$ weight percent wrong has minimal impact
  - Ignoring smoke makes radius, SAD, and VD estimates larger
  - Ignoring smoke makes distribution width smaller

- Bimodal code is nearly complete

# Questions



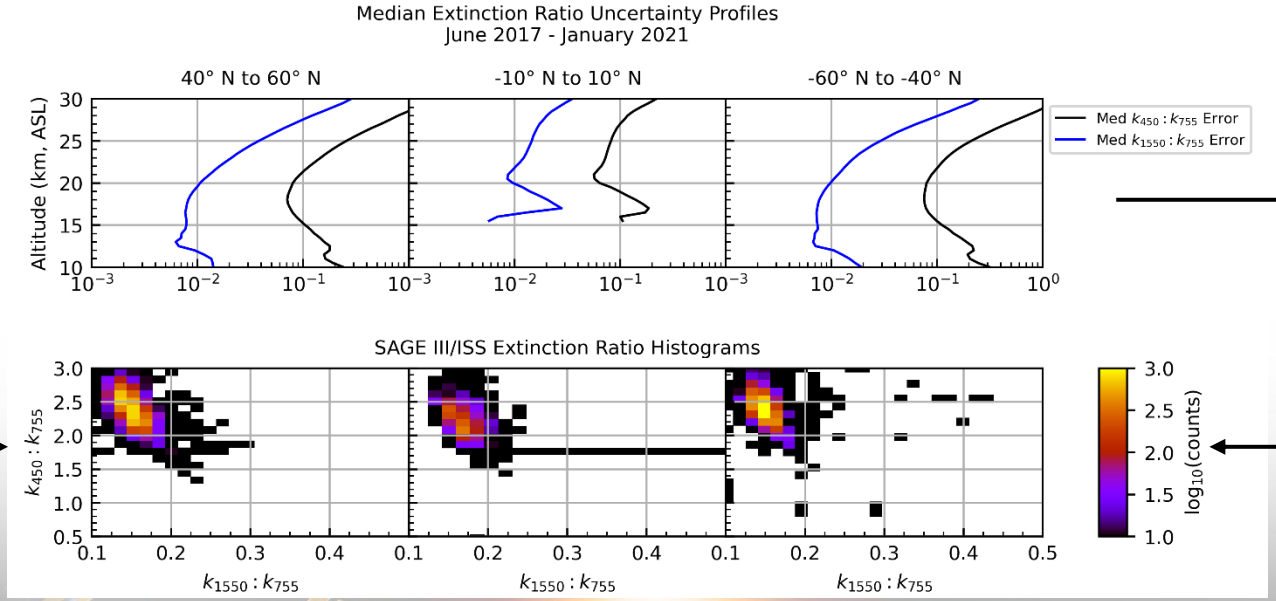
# Sensitivity Study Method

- Build LUTs of known compositions
  - 65%, 70%, 75%, 80% $H_2SO_4$
  - Black carbon (BC) and brown carbon (BrC) smoke

- Assume composition is correct
  - pull extinction ratios from 75% $H_2SO_4$ and find solutions in the 75% $H_2SO_4$ LUT
    - i.e., source and LUT match

- Look for solutions in 75% $H_2SO_4$ LUT
  - pull extinction ratios from X% $H_2SO_4$ (or smoke) and find solutions in the 75% $H_2SO_4$ LUT
    - i.e., source and LUT do **not** match

# Reading the Tea Leaves of Uncertainty




20 km only

Ext. Ratio errors used to define bin widths

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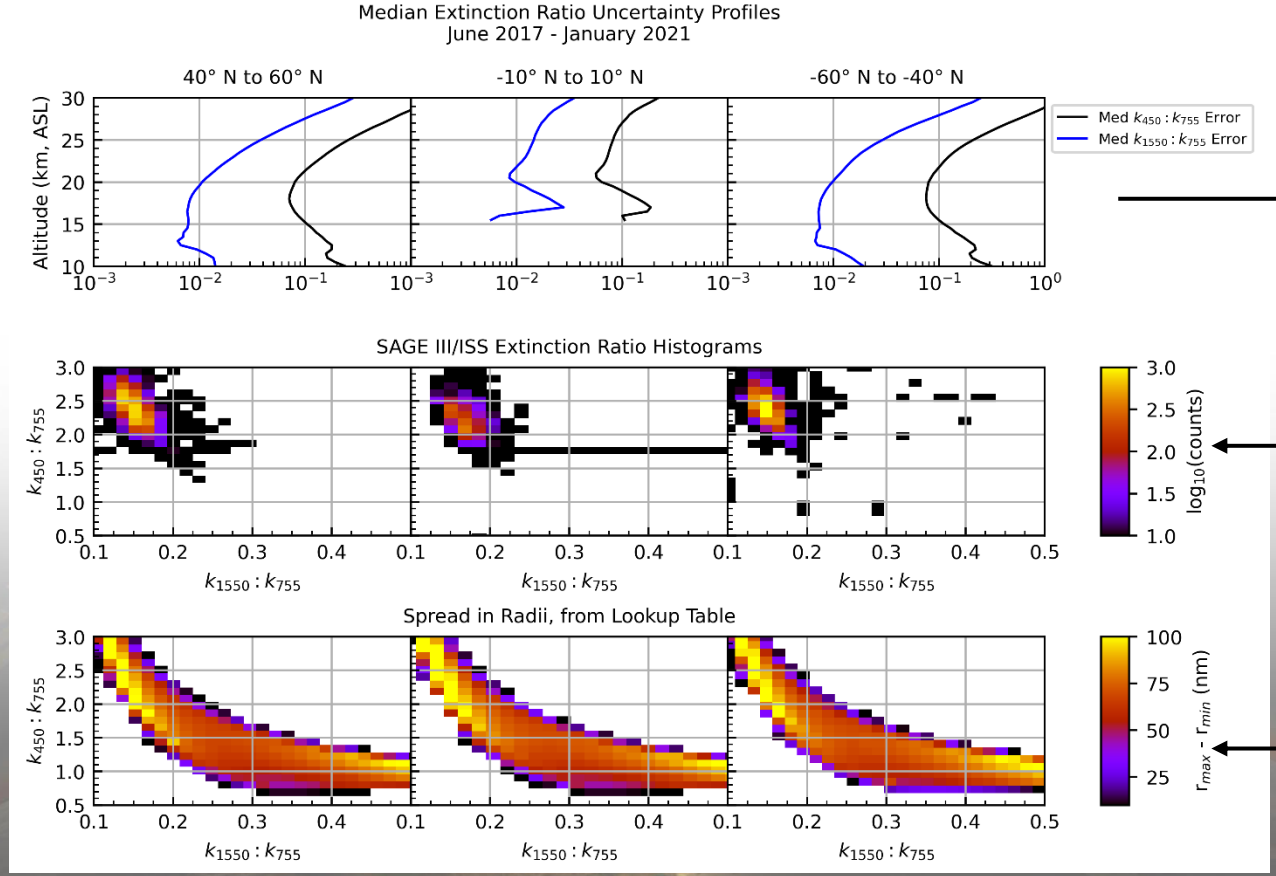


Ext. Ratio errors used to define bin widths

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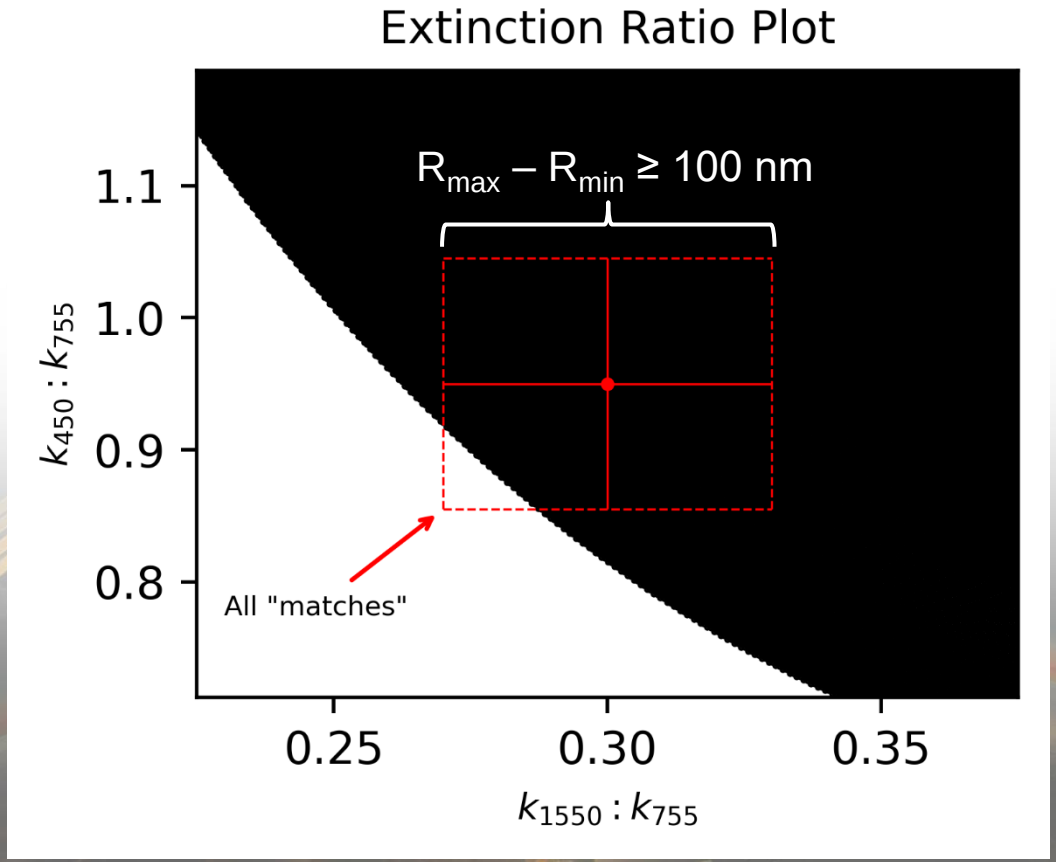


Worst-case scenario