

# INFERRING AEROSOL PROPERTIES FROM SPACE-BASED MEASUREMENTS: AN ALTERNATIVE TO DIRECT RETRIEVAL

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# GOALS FOR SPACE-BASED MEASUREMENTS

- HIGH QUALITY MEASUREMENTS OF THE GLOBAL DISTRIBUTION OF STRATOSPHERIC AEROSOL AND SCIENCE BASED ON THOSE MEASUREMENTS
- PROPERTIES INFERRED FROM THOSE MEASUREMENTS
  - OFTEN FOR OUR 'CUSTOMERS'
  - BULK PROPERTIES LIKE SAD, VOLUME (MASS), RADIATIVE EFFECTS, ETC.
  - MORE DETAILED DESCRIPTIONS OF THE AEROSOL INCLUDING
    - SIZE DISTRIBUTION
    - COMPOSITION

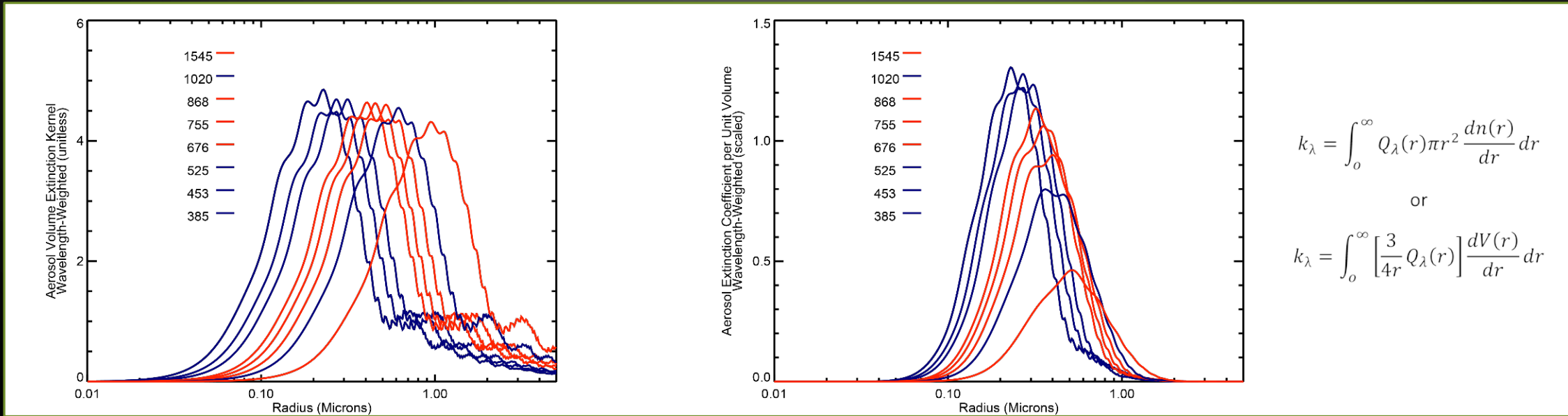
# THINGS PEOPLE TEND TO FORGET ABOUT INFERRING AEROSOL PROPERTIES FROM OPTICAL MEASUREMENTS

- DUE TO CORRELATION BETWEEN MEASUREMENTS AND MEASUREMENT UNCERTAINTY, THERE IS NEVER A SITUATION THAT ALLOWS SOLVING 'N-MEASUREMENTS FOR N UNKNOWN'S'
- FOR SAGE II, THE 3 SHORT WAVELENGTH CHANNELS ARE HIGHLY CORRELATED; KNOW ONE, KNOW THEM ALL (ALMOST)
- WHATEVER INFORMATION YOU MAY HAVE FROM A SET OF MEASUREMENTS, SELECTING WHICH PIECES OF INFORMATION THEY ARE IS NOT AN OPTION
- E.G., SAGE II UV/VIS MEASUREMENTS OF AEROSOL EXTINCTION EFFECTIVELY HAVE NO INFORMATION ABOUT SMALL PARTICLES ( $<0.1 \mu\text{m}$ ) AND THUS 'DON'T KNOW' PARAMETERS LIKE TOTAL NUMBER DENSITY. RESULTS ARE RETRIEVAL SPECIFIC.

# THE SAGE II/III RETRIEVAL WORLD

SAGE II/III AEROSOL VOLUME/WAVELENGTH WEIGHTED EXTINCTION KERNELS

SAGE II/III KERNELS WEIGHTED BY A SINGLE MODE LOG-NORMAL ( $r_m = 0.1, \sigma = 1.6$ )



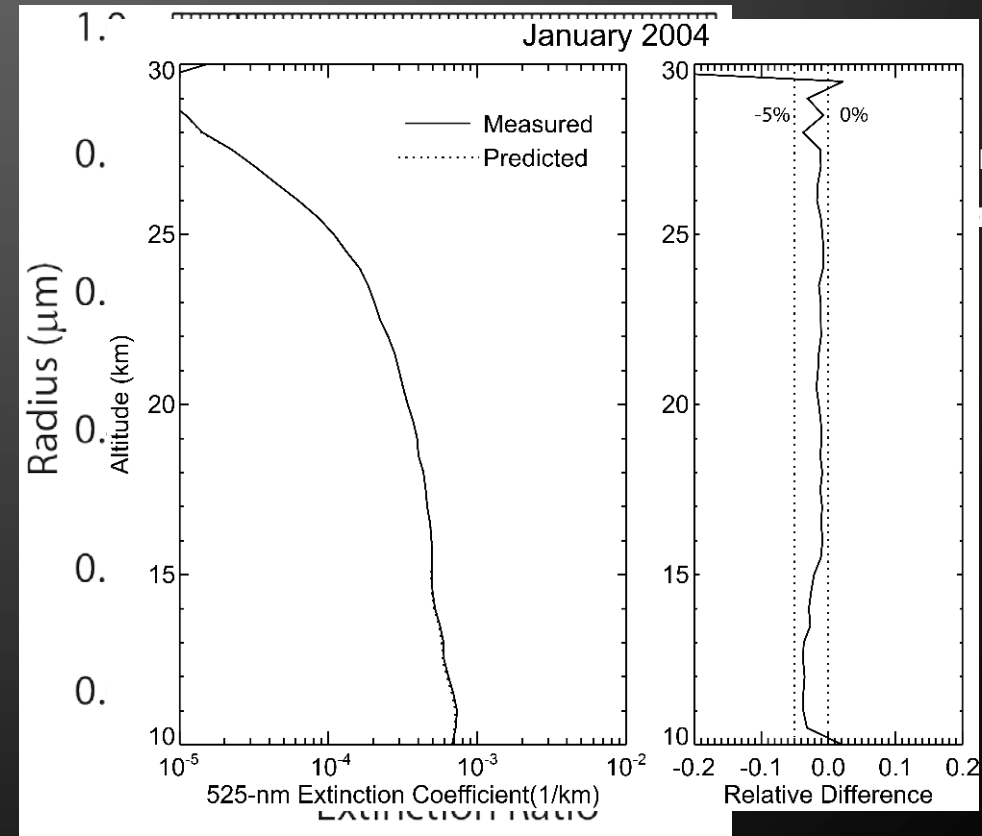
SAGE II – blue; SAGE III - all

# THE SINGLE MODE LOG-NORMAL (SMLN)

- APPLICATIONS OF SMLNS TO OPTICAL MEASUREMENTS ARE ATTRACTIVE BECAUSE
  - THEY ARE BROADLY APPROPRIATE TO STRATOSPHERIC AEROSOL
  - THEY ARE MATHEMATICALLY COMPACT (3 VARIABLES TO DO IT ALL)
  - VIRTUALLY GUARANTEE THE EXISTENCE OF A SOLUTION
- OUTCOMES OF USING SMLNS
  - THE ASSUMPTION OF SIZE DISTRIBUTION FUNCTIONAL FORM HAS A POWERFUL IMPACT ON AVAILABLE SOLUTION SPACE AND KEY PARAMETERS LIKE SAD
    - THE KNOW-NOTHING SAD UPPER LIMIT IS INFINITY
  - SMLNS FITS TO SAGE II MEASUREMENTS ARE DOMINATED BY THE POSITIVE (LARGE RADII) TAIL OF THE SIZE DISTRIBUTION
  - THEY PROBABLY DO A DECENT JOB OVER 'OPTICALLY ACTIVE' PARTICLES SIZES BUT *TEND* TO BE TOO NARROW WITH A LARGE MODE RADIUS PRODUCING (AMONG OTHER FEATURES) TOO LITTLE SAD

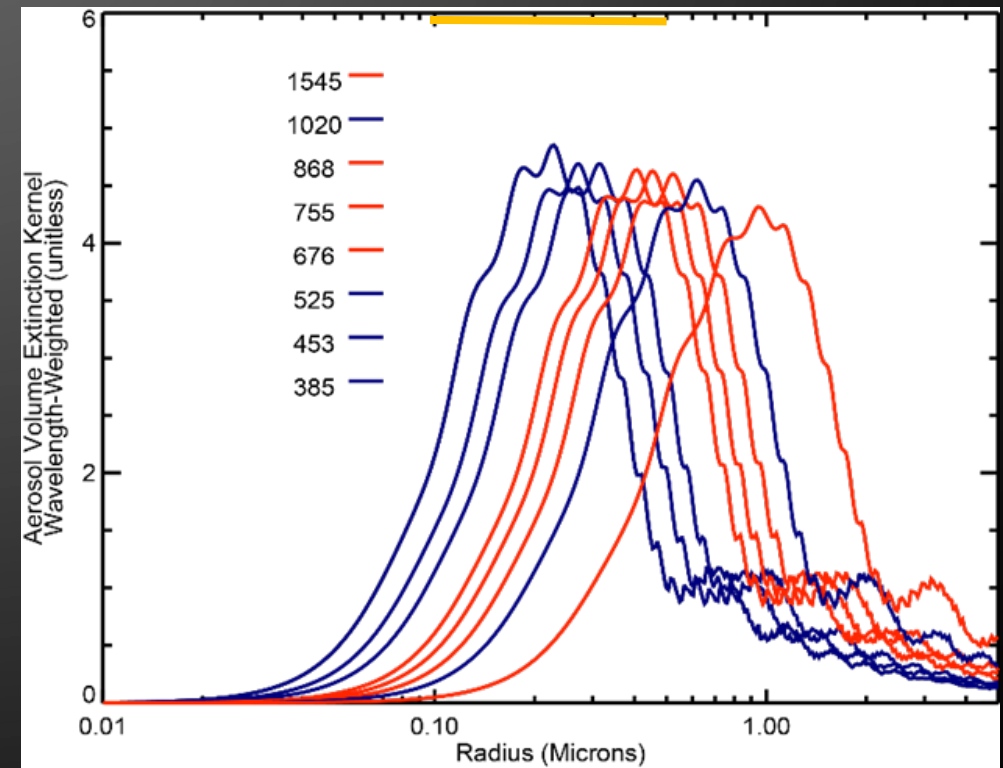
# AN EXAMPLE OF WHY THE SD RETRIEVAL PROCESS IS HARD or ONE SIZE FITS ALL

- IT IS POSSIBLE TO GET REASONABLE FITS TO OBSERVED EXTINCTION USING A SINGLE PARTICLE SIZE (i.e., A DELTA FUNCTION SIZE DISTRIBUTION  $\delta(r-r_0)$ ).
- FOR EXAMPLE USING SAGE II:
  - THE  $r_0$  CAN BE INFERRED USING 453 AND 1020 nm EXTINCTION RATIO AND THEN USED TO PREDICT EXTINCTION AT 525 nm
  - GENERALLY WITHIN 10% OF THE MEASURED VALUE AT 525 nm OFTEN WITHIN 5%



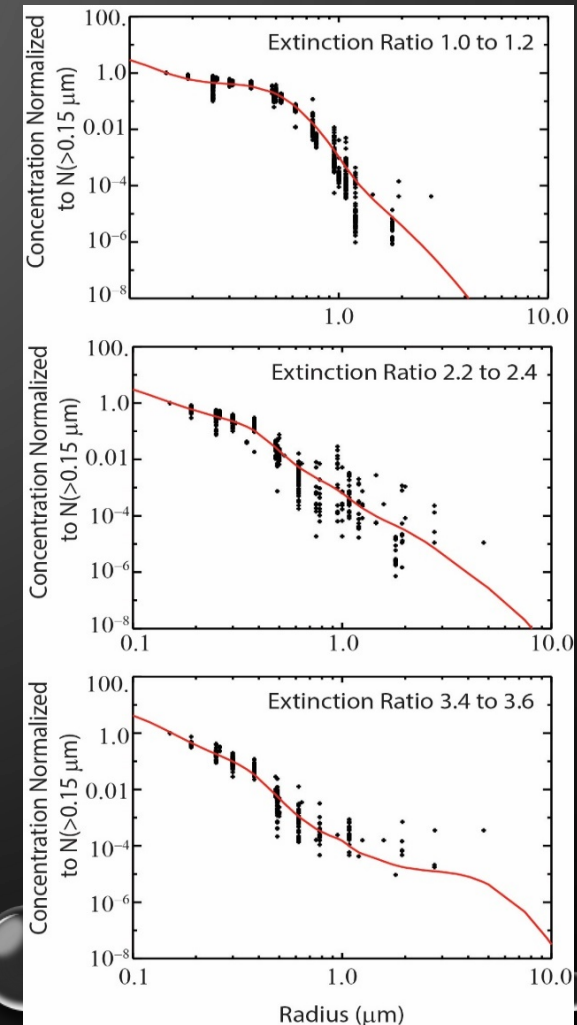
# AN ALTERNATIVE: LEVERAGING *IN SITU* OBSERVATIONS

- UW OPC AND SAGE II EXTINCTION COEFFICIENTS ARE IN REASONABLE AGREEMENT AT ALL AEROSOL LEVELS FROM PINATUBO TO BACKGROUND
- OPC SIZE DISTRIBUTIONS THAT YIELD THE SAME 525 TO 1020-nm EXTINCTION RATIO MUST BE SIMILAR IN PARTICLE NUMBER DENSITY (SLOPE) OVER THE ACTIVE RANGE OF AEROSOL SIZES (ROUGHLY 0.1 TO 0.5  $\mu\text{m}$ )
- CAN AVERAGING OPC S.D. AS A FUNCTION OF COMPUTED 525 AND 1020 EXTINCTION COEFFICIENT RATIO PRODUCE A 'REPRESENTATIVE' SIZE DISTRIBUTION FOR APPLICATION TO SAGE II OBSERVATIONS?
  - HOW DIFFERENT ARE THE 'INVISIBLE' AEROSOL THAT PRODUCE THE SAME 525 TO 1020 NM EXTINCTION RATIO?



# SAMPLES OF MEAN OPC SIZE DISTRIBUTIONS

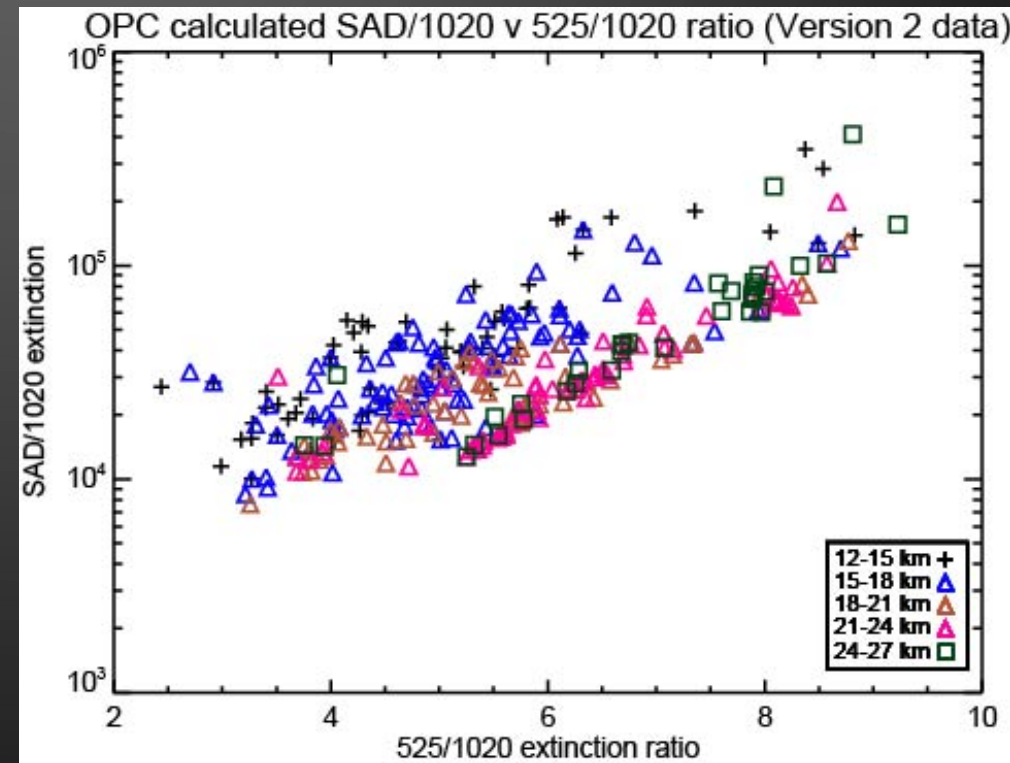
- THREE EXAMPLES OF OPC SIZE DISTRIBUTIONS FOR 525 TO 1020-NM EXTINCTION RATIOS FROM LARGE (1-1.2) TO SMALL (3.4-3.6)
  - GENERALLY SEE ORGANIZED BEHAVIOR
    - 10 DECADE LOG SCALE CAN HIDE A MULTITUDE OF SINS
  - QUITE A BIT OF VARIABILITY PARTICULARLY ABOVE 0.5  $\mu\text{m}$
  - SOME SORTING OF ALTITUDE/TIME
- (USING OLDER DATA)





# SAD AND EXTINCTION RATIO FROM UW OPC OBSERVATIONS – SOME PRELIMINARY RESULTS

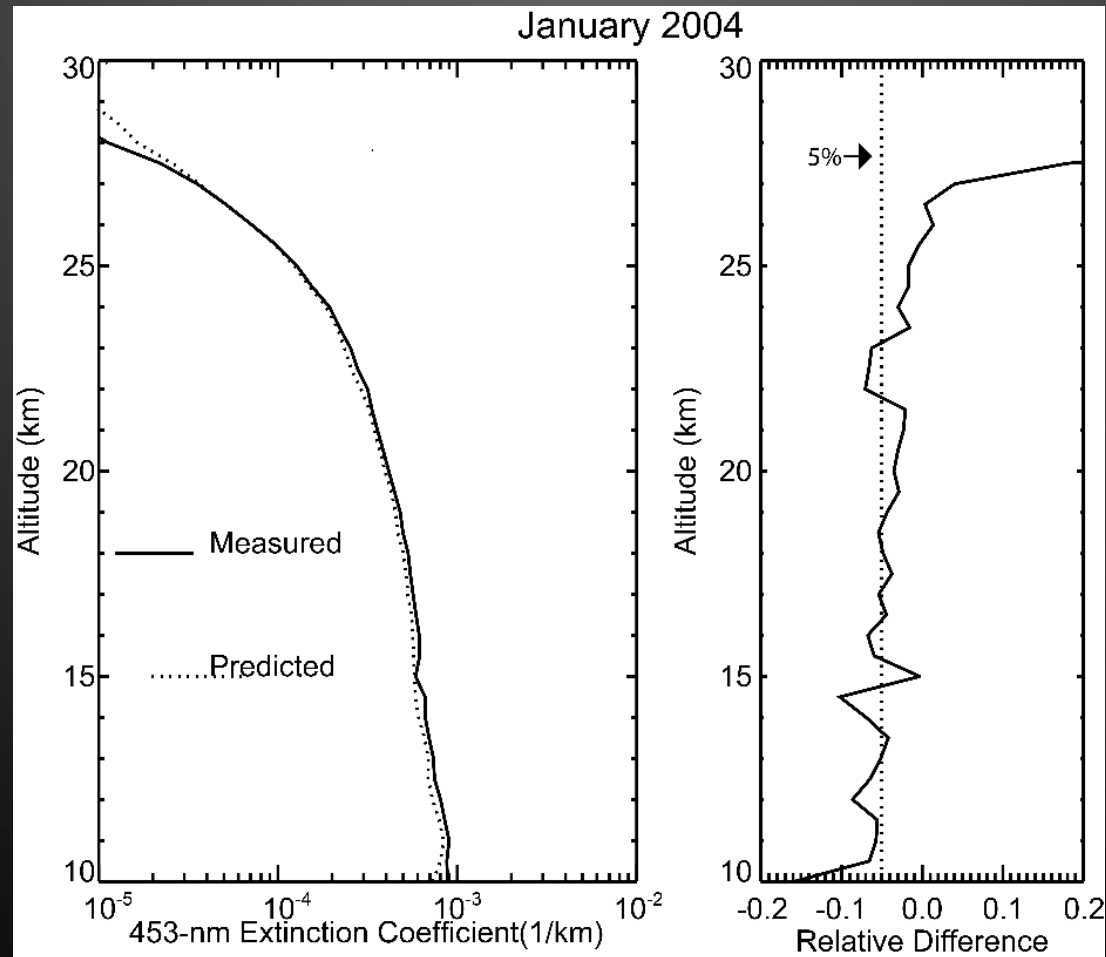
- OPC-COMPUTED 525 TO 1020-nm EXTINCTION RATIO VS. OPC-COMPUTED SAD TO 1020-NM RATIO
- AT TIMES, THERE IS STILL A FAIRLY LARGE RANGE OF OUTCOMES FOR ABOUT THE SAME EXTINCTION RATIO (NO SOLUTION)
- AN UNKNOWN COMPLICATING FACTOR IS THE DEGREE TO WHICH SPATIAL/TEMPORAL SAMPLING OF IN SITU OBSERVATIONS COMPROMISE THIS PROCESS (e.g., LOW LATITUDES)



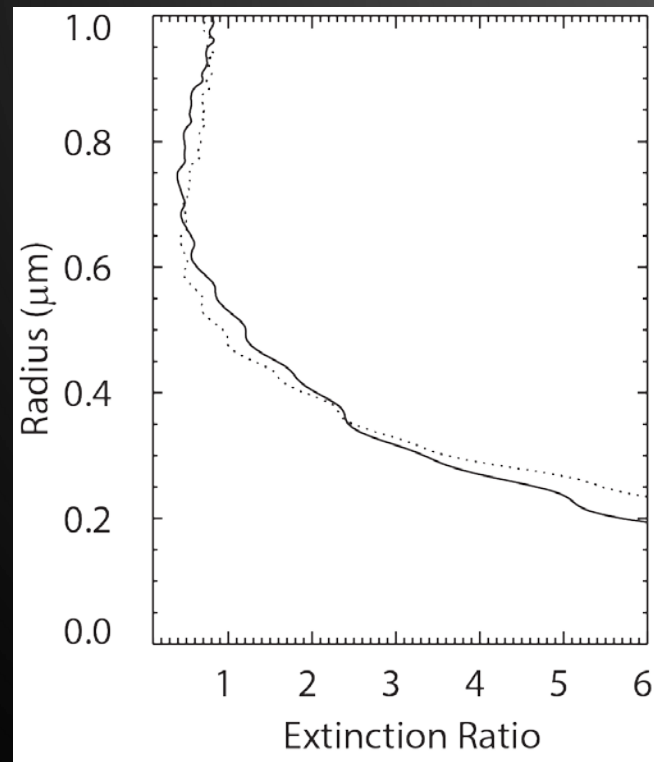
# SUMMARY

- THERE IS POTENTIAL FOR USING THE EXTENSIVE IN SITU OBSERVATIONS TO HELP SPACE-BASED MEASUREMENTS PRODUCE IMPROVED INFERENCES OF AEROSOL PROPERTIES
- HOPING TO HAVE A PROTOTYPE FOR THE PROCESS THIS SUMMER

# PART 2, USING 525 AND 1020 TO PREDICT 453

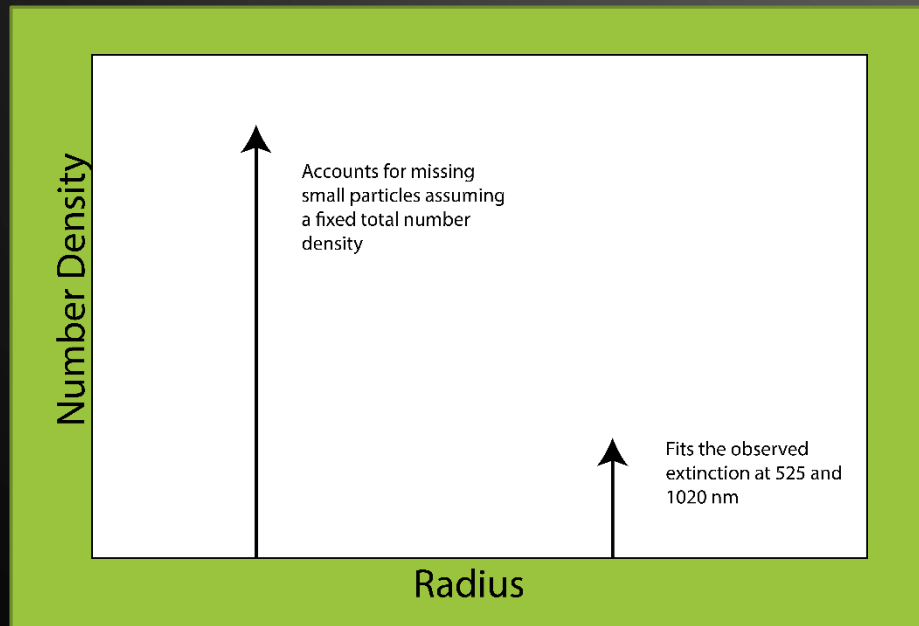


# THE APOSTATE RETRIEVAL APPROACH (2008)



- STARTED AS A BET “I CAN FIT OBSERVED SAGE II SPECTRA WITH A DELTA FUNCTION SIZE DISTRIBUTION”
- RESULT:
  - FIT IS NOT QUITE PERFECT BUT PRETTY DARN CLOSE
  - NUMBER DENSITIES AND SAD (UNSURPRISINGLY) ARE QUITE SMALL (E.G.,  $\sim 1 \text{ CM}^{-3}$  FOR NUMBER DENSITIES)
  - USE A SECOND ‘INVISIBLE’ DELTA FUNCTION TO BRING TOTAL NUMBER DENSITY TO  $20 \text{ CM}^{-3}$  AS A ‘MAXIMUM’ SAD
  - OBVIOUSLY, NOT A REAL SIZE DISTRIBUTION BUT BULK OUTCOMES ARE NOT RIDICULOUS EITHER
  - RESULTS ARE STORED IN VERSION 7.0 AND IN THE GLOSSAC DATA SET MORE TO BRACKET RANGES IN SAD, VOLUME THAN ANYTHING ELSE.

# 2-MODE DELTA FUNCTION SIZE DISTRIBUTION



- EFFORT TO BRACKET THE POTENTIAL RANGE OF SAD
- LARGE (LOW NUMBER DENSITY -  $\sim 1 \text{ CM}^{-3}$ ) MODE FITS THE OBSERVED EXTINCTION AT TWO WAVELENGTHS
- EFFECTIVELY PRODUCES THE MINIMUM SAD CONSISTENT WITH THE MEASUREMENTS
- SECOND 'INVISIBLE' MODE MAKES UP FOR (VERY) LOW NUMBER DENSITY USING A SMALL MODE WITH HIGH NUMBER DENSITY
- TOTAL NUMBER DENSITY OF  $20 \text{ CM}^{-3}$
- YES IT'S A RIDICULOUS SIZE DISTRIBUTION BUT...