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

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GOALS FOR SPACE-BASED MEASUREMENTS
(OF AEROSOL)

- CUSTOMER #1 (OUR GREATLY APPRECIATED FUNDERS):
  - HIGH QUALITY MEASUREMENTS OF STRATOSPHERIC AEROSOL (EXTINCTION COEFFICIENT)
- CUSTOMER #2 (SCIENCE USERS)
  - SCIENCE BASED ON THOSE MEASUREMENTS
  - PROVIDING BULK AND OTHER PROPERTIES
    - BULK PROPERTIES LIKE SAD, VOLUME (MASS), ETC.
    - MORE DETAILED PROPERTIES LIKE SIZE DISTRIBUTION, COMPOSITION

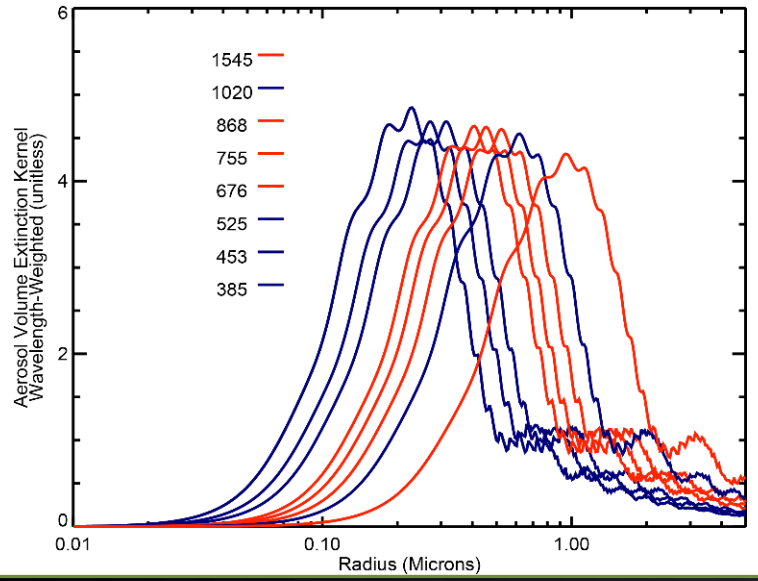
THINGS PEOPLE TEND TO FORGET ABOUT

INFERRING AEROSOL PROPERTIES FROM OPTICAL MEASUREMENTS

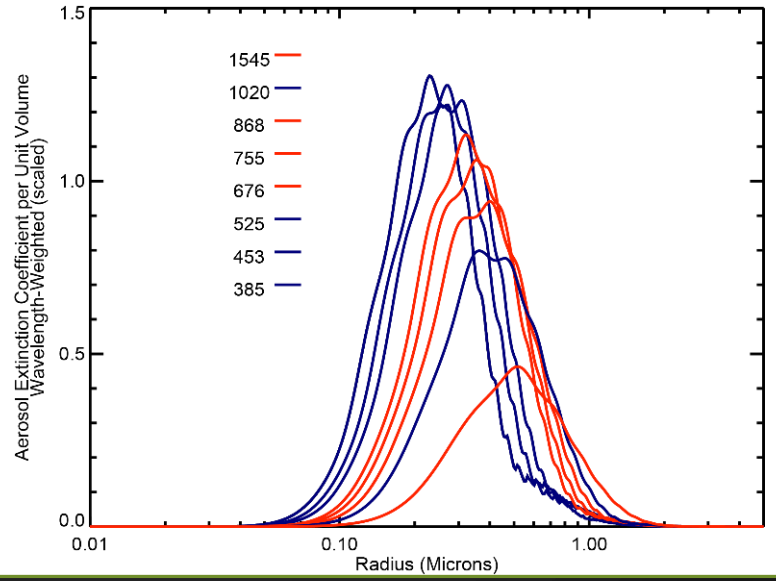
- DUE TO THE NATURE OF AEROSOL EXTINCTION KERNELS AND MEASUREMENT UNCERTAINTY, MEASUREMENTS ARE CORRELATED AND THERE IS NEVER A SITUATION THAT ADVISES SOLVING 'N-MEASUREMENTS FOR N UNKNOWNS'
- WHATEVER INFORMATION YOU MAY HAVE FROM A SET OF MEASUREMENTS, ONE DOESN'T GET TO CHOOSE WHICH PIECES OF INFORMATION THEY ARE
  - E.G., SAGE II UV/VIS MEASUREMENTS OF AEROSOL EXTINCTION EFFECTIVELY HAVE NO INFORMATION ABOUT SMALL PARTICLES (<0.1 μm) AND THUS '*DON'T KNOW*' PARAMETERS LIKE TOTAL NUMBER DENSITY AND IMPACTS INFERENCES OF PARAMETERS THAT ARE DEPENDENT ON SMALL PARTICLES (E.G., SAD IN LOW AEROSOL PERIODS)

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 ($r_m = 0.1$, $\sigma = 1.6$)



$$k_\lambda = \int_o^\infty Q_\lambda(r)\pi r^2 \frac{dn(r)}{dr} dr$$

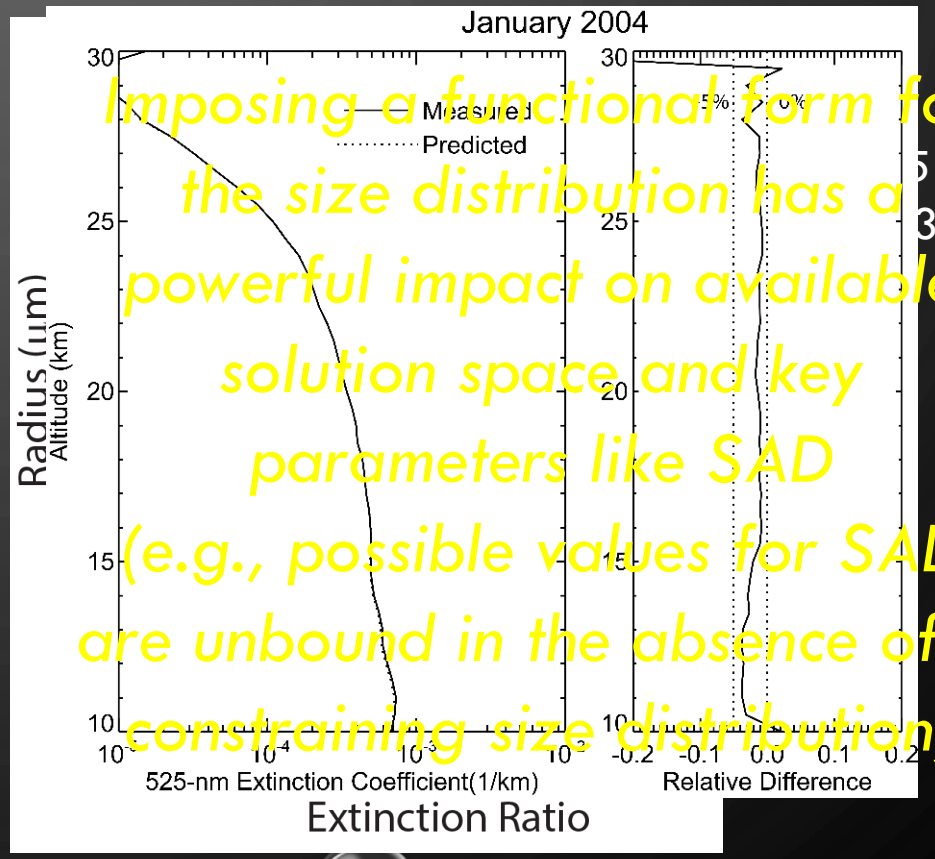
or

$$k_\lambda = \int_o^\infty \left[\frac{3}{4r} Q_\lambda(r)\right] \frac{dV(r)}{dr} dr$$

SAGE II – blue; SAGE III - all

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 SPECTRA USING A SINGLE PARTICLE SIZE (i.e., A DELTA FUNCTION SIZE DISTRIBUTION $N_o\delta(r-r_o)$).
- FOR EXAMPLE USING SAGE II:
  - THE r_o 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%



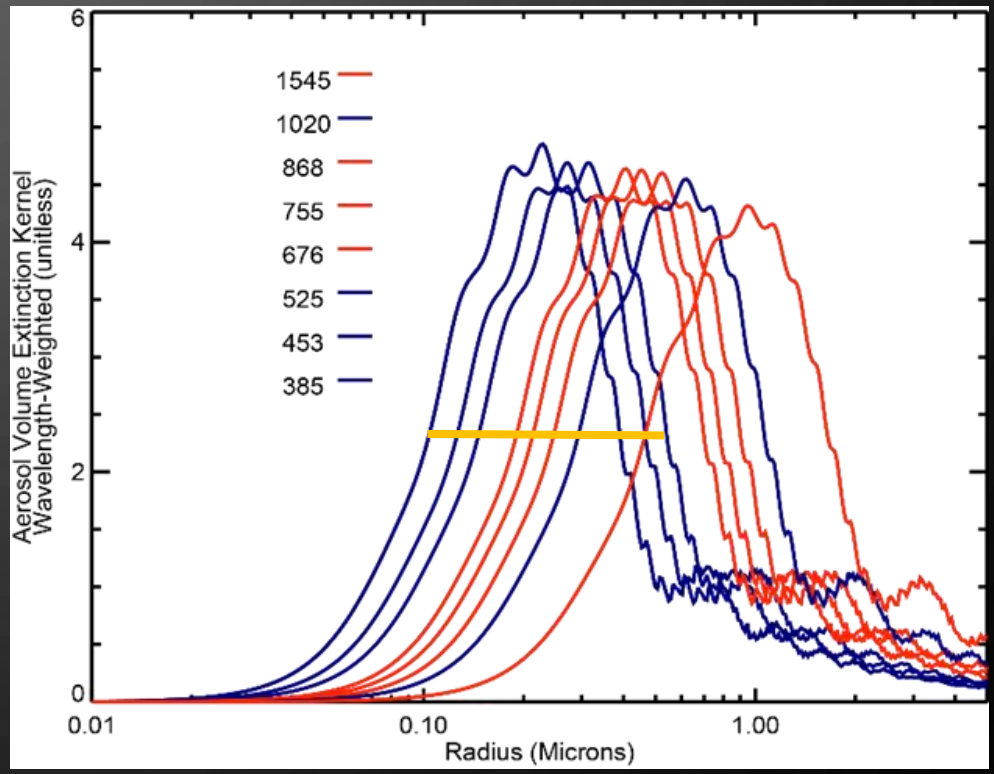
Imposing a functional form for the size distribution has a powerful impact on available solution space and key parameters like SAD (e.g., possible values for SAD are unbound in the absence of a constraining size distribution)

5 and 1020 nm

3 and 1020 nm

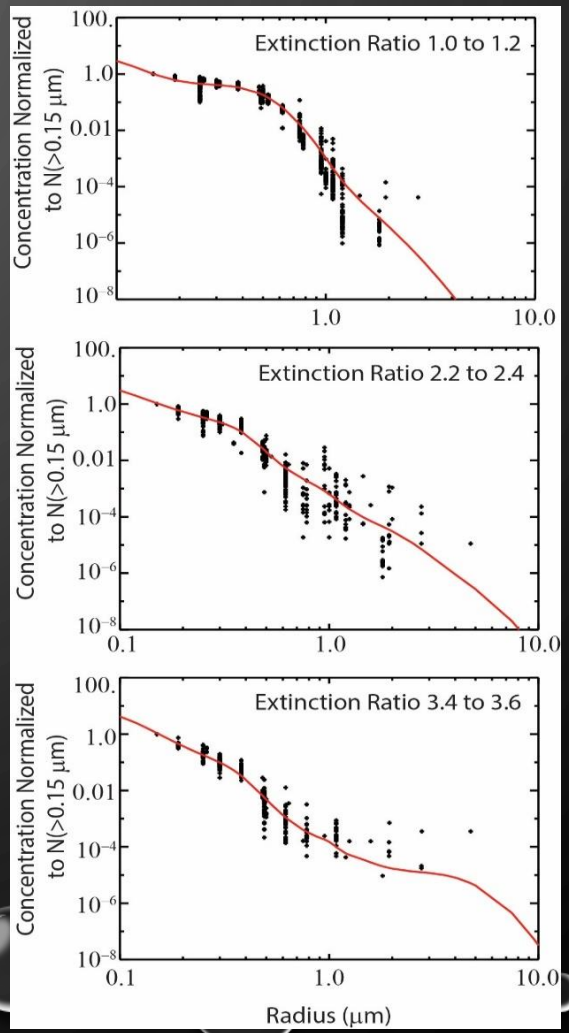
AN ALTERNATIVE: LEVERAGING *IN SITU* OBSERVATIONS

- 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 μm)
- 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

- 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 >0.5 μm
- (BASED ON OLDER OPC DATA)



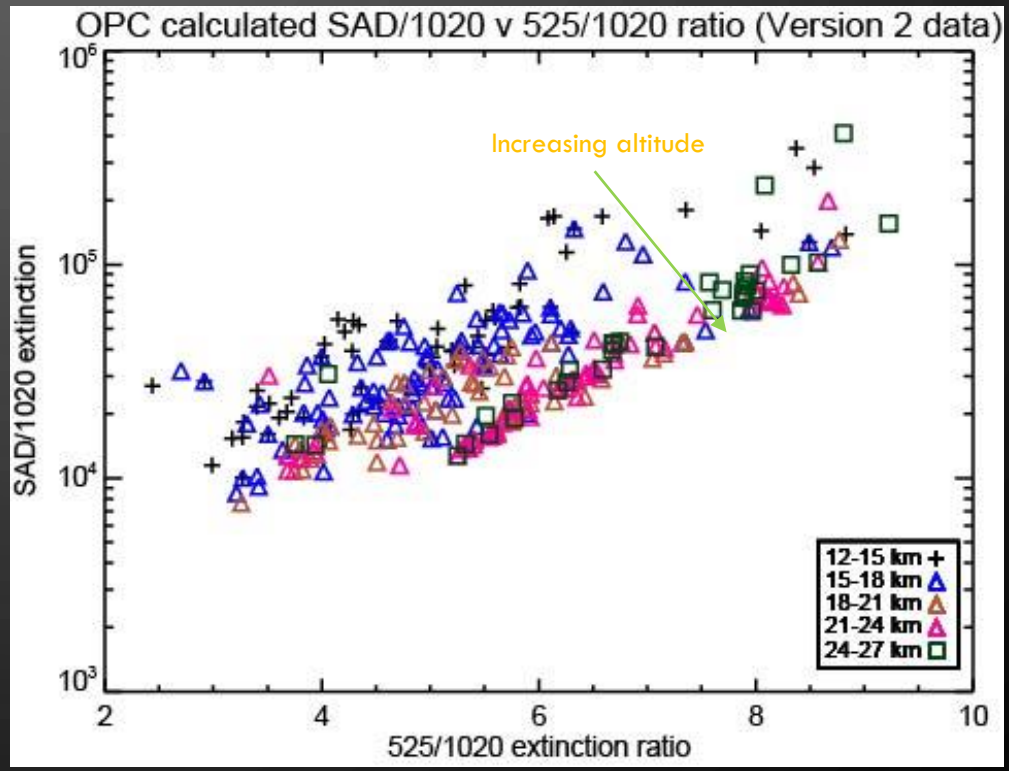
Large aerosol - Pinatubo

Recovery from Pinatubo

Pretty Clean

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)
- A COMPLICATING FACTOR IS THE DEGREE TO WHICH SPATIAL/TEMPORAL SAMPLING OF IN SITU OBSERVATIONS COMPROMISE THIS PROCESS (e.g., LOW LATITUDES)



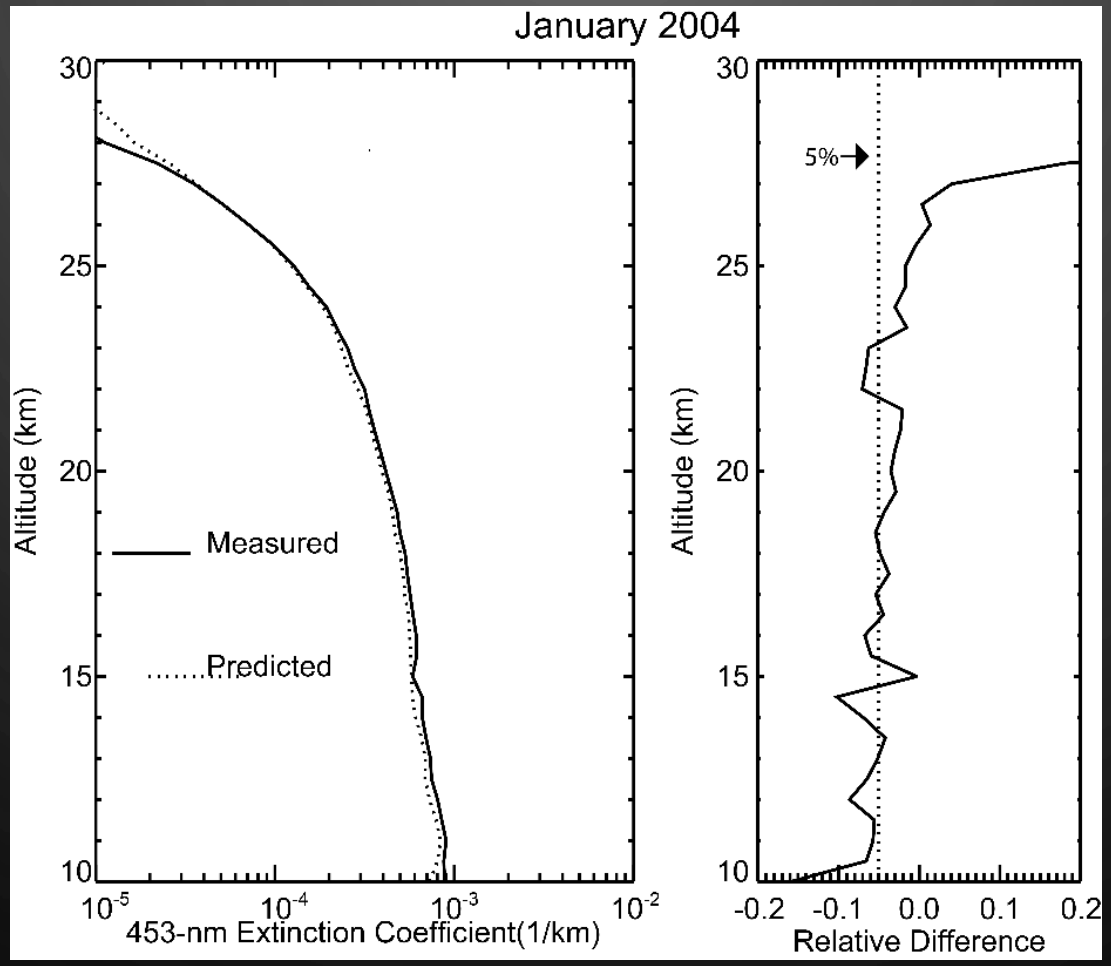
SUMMARY

- THERE IS POTENTIAL FOR USING THE EXTENSIVE IN SITU OBSERVATIONS TO HELP SPACE-BASED MEASUREMENTS PRODUCE IMPROVED INFERENCES OF AEROSOL PROPERTIES
- EXTENSION TO OTHER INSTRUMENTS SAGE III AND OTHER LONG-TERM DATA SETS (OSIRIS), ROLE IN LIMB SCATTERING
- POSSIBLY INCORPORATE INTO THE GLOBAL SPACE-BASED STRATOSPHERIC AEROSOL CLIMATOLOGY (GLOSSAC)
- EXPECT TO HAVE A PROTOTYPE FOR THE PROCESS BY THIS SUMMER

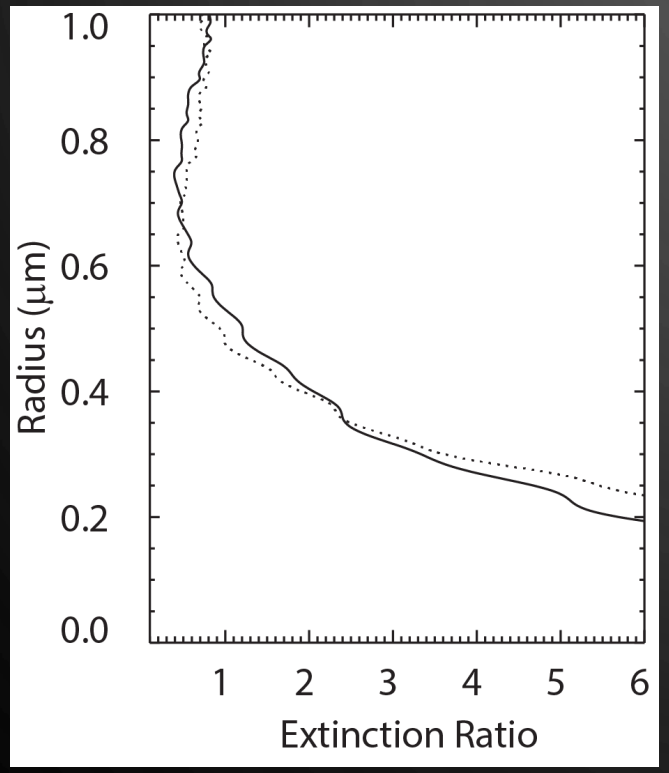
THE SINGLE MODE LOG-NORMAL (SMLN)

- 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) AND A SOLUTION ALMOST ALWAYS EXISTS
- OUTCOMES OF USING SMLNS
  - THE ASSUMPTION OF SIZE DISTRIBUTION FUNCTIONAL FORM HAS A POWERFUL IMPACT ON AVAILABLE SOLUTION SPACE AND KEY PARAMETERS LIKE SAD
  - SMLNS FITS TO SAGE II MEASUREMENTS DO A DECENT JOB PRODUCING A SIZE DISTRIBUTION ACROSS 'OPTICALLY ACTIVE' PARTICLES SIZES (THE POSITIVE TAIL) BUT THE SMALL AEROSOL REFLECT THE FIT AT LARGER SIZES RATHER THAN BEING CONSTRAINED BY INFORMATION ABOUT SMALLER PARTICLES *TEND* TO BE NARROW WITH FEW SMALL PARTICLES AND SAD TOO SMALL

PART 2, USING 525 AND 1020 TO PREDICT *453*

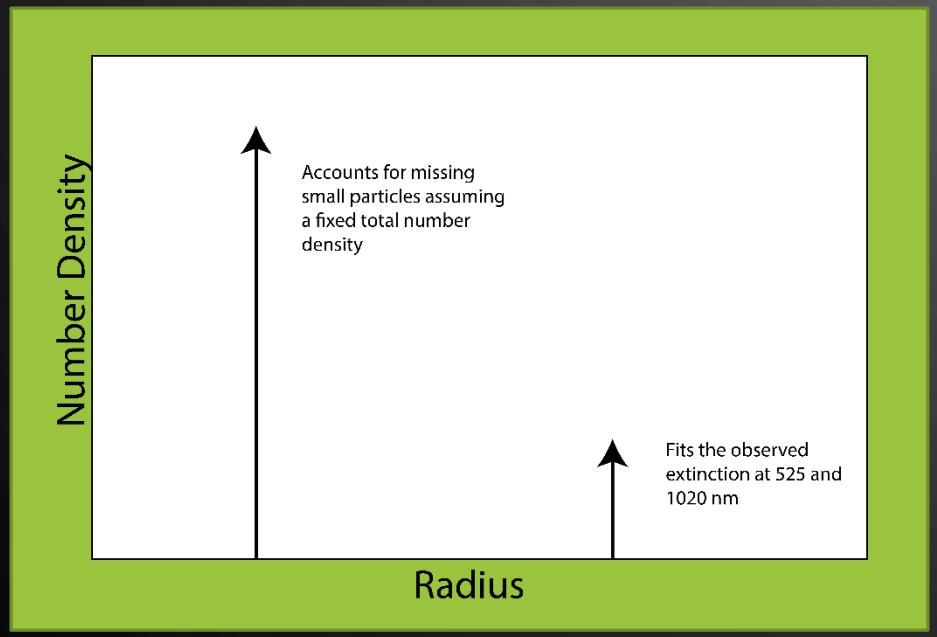


THE APOSTATE RETRIEVAL APPROACH (2008)



- 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., ~1 CM-3 FOR NUMBER DENSITIES)
  - USE A SECOND 'INVISIBLE' DELTA FUNCTION TO BRING TOTAL NUMBER DENSITY TO 20 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 - ~1 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 CM-3
- YES IT'S A RIDICULOUS SIZE DISTRIBUTION BUT…