# Direct Optical Detection of Microorganisms in Exoplanet Atmospheres: Models & Results

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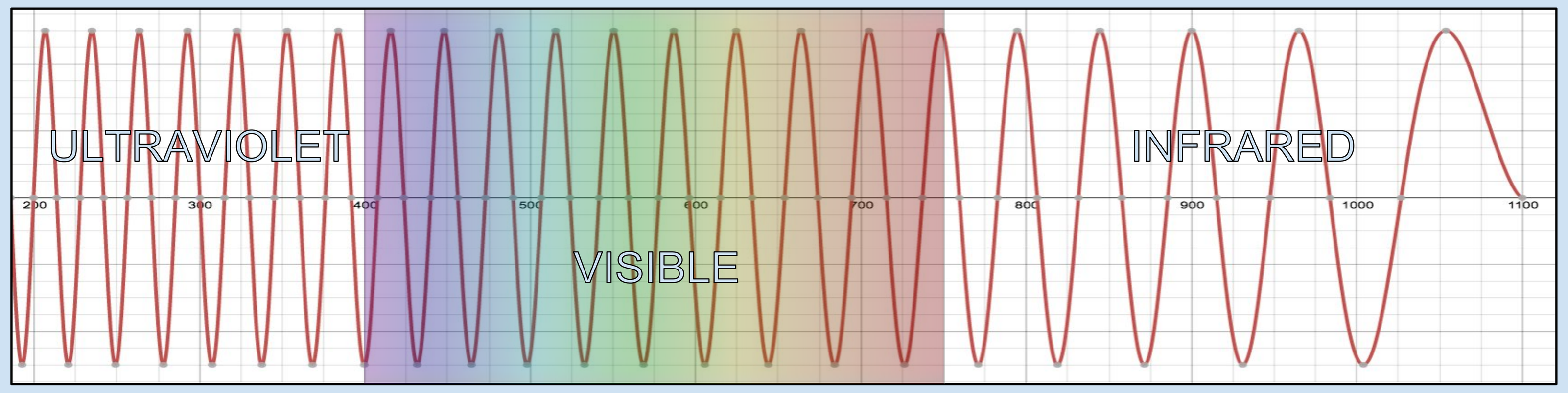
## ABSTRACT

This poster will focus on the analysis of extinction spectra obtained from simulations of exoplanet atmospheres; these spectra have been simulated using a variety of particle types and size distributions. To simulate these spectra, we have created a MATLAB program that uses mathematical models and complex algorithms to model Mie and spherical scattering. This scattering of light from aerosols has been modeled in the ultraviolet to near infrared band (200-1100 nm). We have modeled atmospheric compositions that are typical of Jovian planets, using known information about the atmosphere of Jupiter (see our first poster, entitled "Direct Optical Detection of Microorganisms in Exoplanet Atmospheres: Methods").

Extinction spectra were simulated for six particle types: *Erwinia herbicola* (EH), *Bacillus atrophaeus* (BG), ovalbumin (OV), ammonia ice, water, and water ice. Initial results show that the extinction spectra of microorganisms are distinctly different from those of water and ammonia ice clouds; all spectra resemble complex polynomial functions, but the size and location of the peaks vary according to the composition of the particles simulated. These differences are amplified when the size of the particles tested is proportional to the wavelength of the light.

There are many variables that could affect this change in extinction spectra. The resulting data from the simulations detailed above has been analyzed to determine which variables most affect the spectra. This analysis focused on the variation of four parameters: refractive index, average particle size, percent volume, and standard deviation.




This image shows the electromagnetic spectrum for our tested range of light (200-1100 nm). The red curve represents the frequency; the wavelengths are marked on the the center axis (nm).

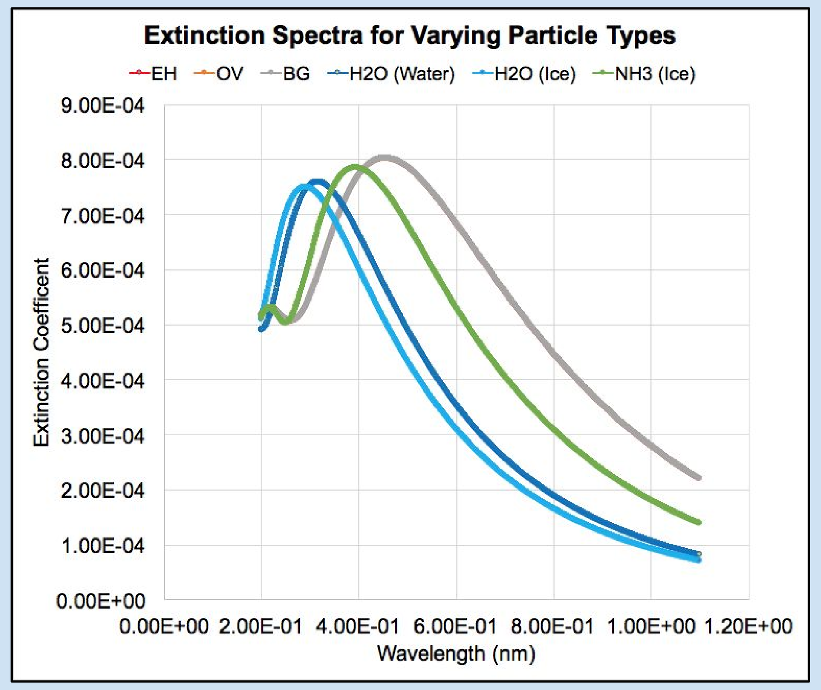
## OBJECTIVE & METHODS

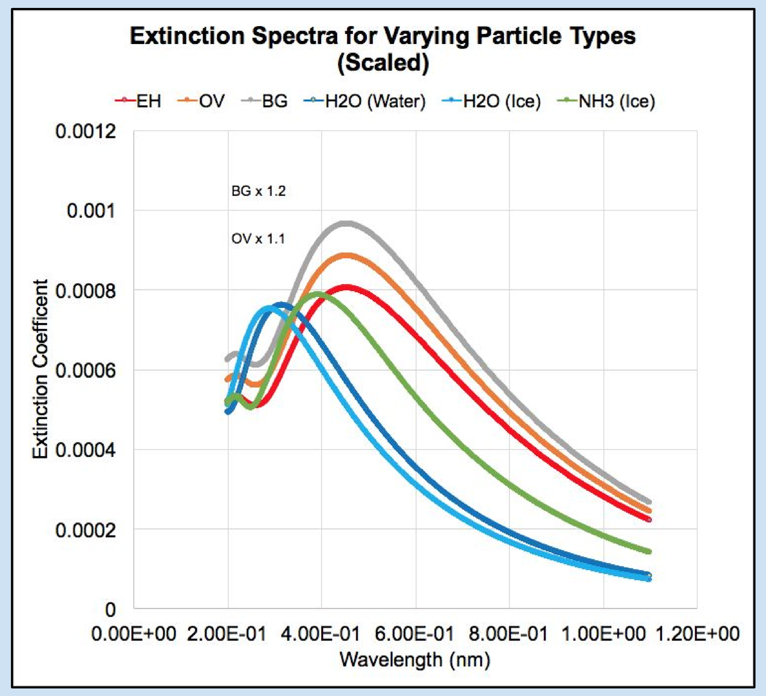
Determine the parameter that most affects the extinction spectra of a simulated atmosphere. Four experiments were conducted, each to test the spectra's sensitivity to variations in **refractive index**, **average particle size**, **percent volume**, and **standard deviation,** respectively.

## EXPERIMENT 1: REFRACTIVE INDEX

Using a constant size distribution, simulate the extinction spectra of six different particle types. This is to test the sensitivity of the spectra to changes in refractive index.

- Particle types tested: EH, BG, OV, water, water ice, and NH3 Ice
- Size distribution tested: Gaussian, centered at 0.5 um



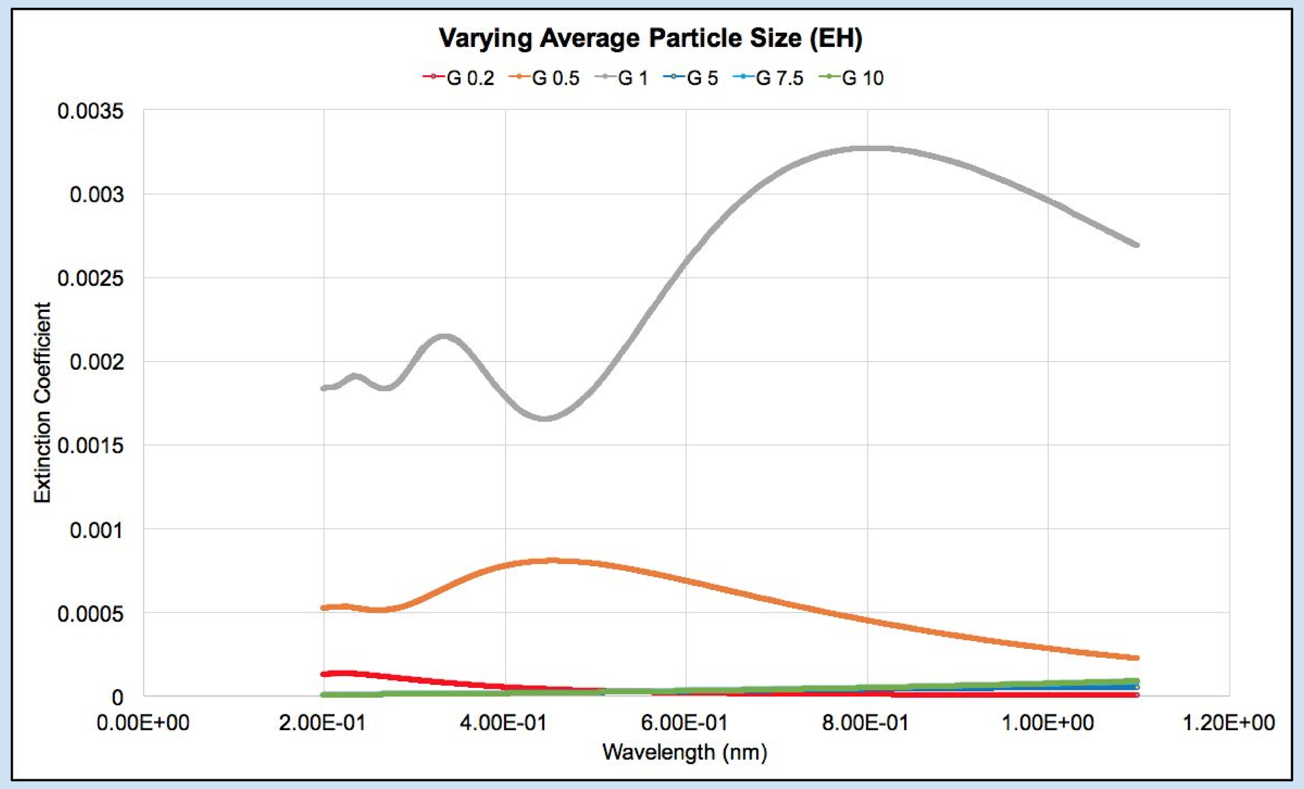

## RESULTS

The preceding graphs show the extinction spectra for six different particle types simulated with a constant size distribution. The spectra of the bioaerosols are virtually identical; therefore, the spectra in the second graph have been individually scaled in order to increase visibility. Although each spectrum has a similar shape, the biological spectra lie distinctly above those of the liquid and ice clouds. Therefore, we can conclude that **while the refractive index does not drastically affect the shape of the extinction spectra, it does vary features of the spectrum, such as local extrema and range.** This result is somewhat conclusive; we now know that variations in refractive index could account for change in features of measured extinction spectra.

## EXPERIMENT 2: AVERAGE PARTICLE SIZE

Using a constant refractive index, simulate extinction spectra for six different Gaussian size distributions. This is to test the sensitivity of the spectra to changes in average particle size.

- Particle types tested: EH and water ice
- Size distributions tested: Gaussian distributions for particle sizes typical of microorganisms (0.5 um), ice clouds (1.0 um), and liquid clouds (10.0 um); additionally, distributions centered at 0.2, 5.0, and 7.5 (um)
  - Lognormal distributions were also tested for identical average particle sizes; results showed that the type of distribution (Gaussian or lognormal) had virtually no effect on the shape of the resulting spectra.



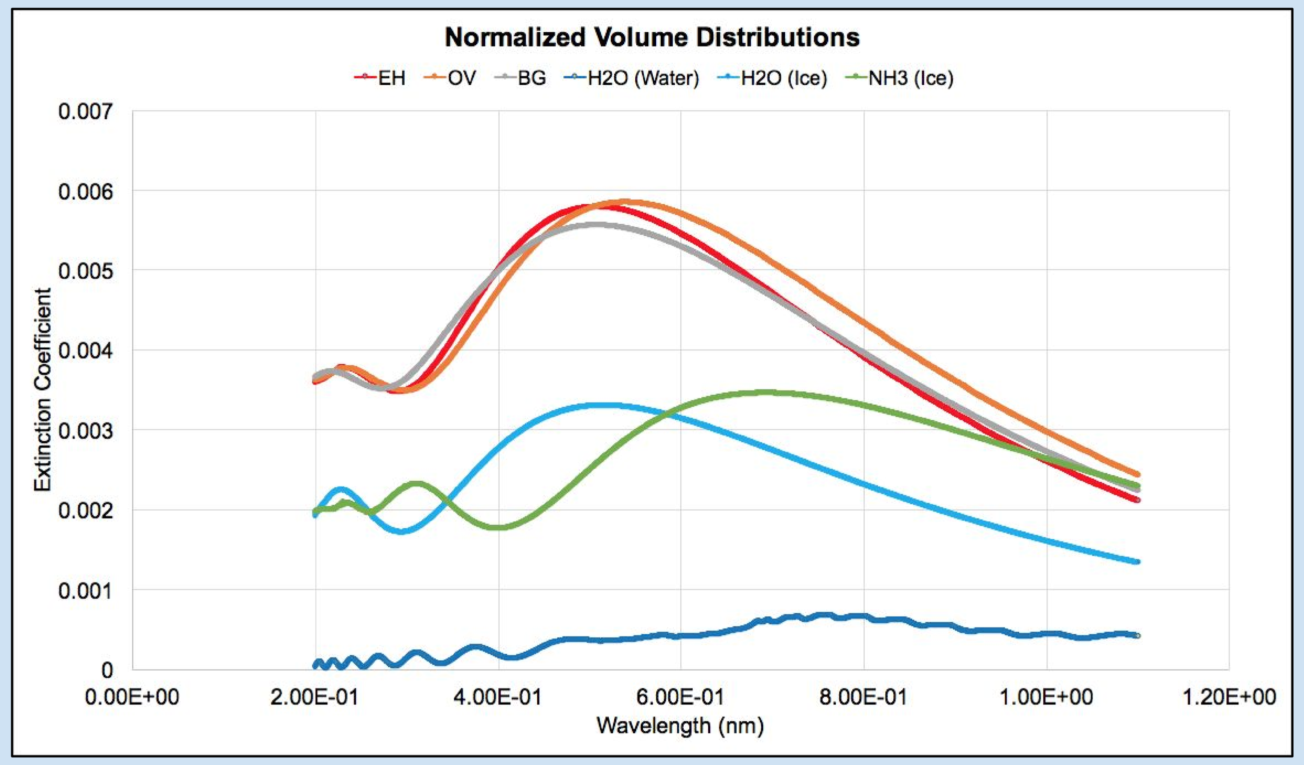

## RESULTS

A noticeable difference can be seen between the spectra of distributions centered at 0.5 and 1.0 (um); however, the spectra simulated from the remaining distributions show little to no variation. This data suggests that **extinction spectra show the most variation when the particles are modeled near their actual sizes (0.5 - 1.0 um for EH).** This result is positive; it introduces the possibility of identifying the size of atmospheric particles from their extinction spectra alone. To summarize, **the average particle size of a distribution does affect the shape of the extinction spectra; the amplitude decreases as simulated particle size diverges from natural particle size.**

## EXPERIMENT 3: PERCENT VOLUME

Simulate extinction spectra for particle size distributions that vary by percent volume; in this experiment, each simulation will compare the spectra of two particle types that are present in relative volumes. This is to test how the spectra react to changes in percent volume of bioaerosols, liquid clouds, and ice clouds.

- Particle types tested: EH, BG, OV, water, water ice, and NH3 Ice
- Size distributions tested: Gaussian, centered at 0.5, 1.0, and 10.0 (um)
- Percent volumes tested: microorganisms present at 10% volume, microorganisms present at 50% (normalized) volume



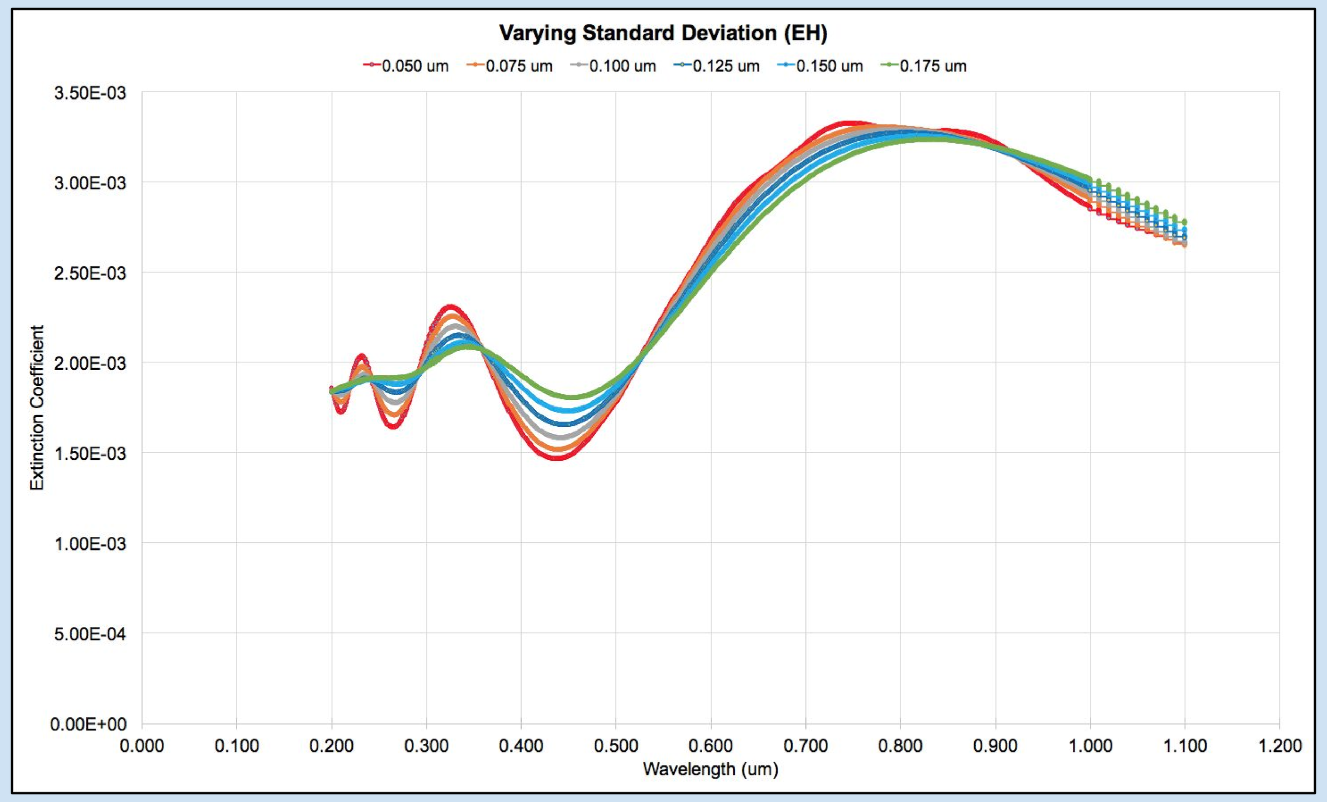

## RESULTS

When the distributions tested are normalized by volume, it can be seen that the spectra of the bioaerosols lie distinctly above those of the liquid and ice particles. Furthermore, when the spectra are combined to simulate an atmosphere, **the effect of the microorganisms is much greater than the effect of the nonbiological particles.** In fact, further simulations showed that the bioaerosols need only occupy 10% of the total volume for each particle type to affect the extinction spectra equally.

## EXPERIMENT 4: STANDARD DEVIATION

Using a constant refractive index and average particle size, simulate extinction spectra for eight distributions that vary by standard deviation. This experiment was designed after concluding that extinction spectra are highly sensitive to changes in particle size within a certain range.

- Particle type tested: EH
- Size distributions tested: Gaussian, centered at 0.5 um, with standard deviations of 0.050, 0.075, 0.100, 0.125, 0.150, and 0.175 (um)




## RESULTS

These simulated spectra show that **variations in standard deviation do indeed affect extinction spectra; the severity of the spectra's trends decreases as standard deviation increases.** This result confirms that simulated spectra are highly sensitive to individual factors in a size distribution.

## CONCLUSION

The results of these four experiments show that each variable does affect simulated extinction spectra, but in different ways. Varying the percent volume showed that **bioaerosols affect combined spectra much more drastically than non biological particles**; this positive results suggests that detection of bioaerosols may be possible, even if they are only present in small volumes. Furthermore, our results show that **variations in size distribution drastically affect the shape of the extinction spectra, whereas variations in refractive index merely shift features of the spectra.** These conclusions are beginning to show us how to decipher the composition of an atmosphere from its measured extinction spectrum alone. Our further research will focus on determining how size distribution varies by aerosol type; this will help us further understand, simulate, and analyze the distributions of natural bioaerosols.