Direct Optical Detection of Microorganisms in Exoplanet Atmospheres: Methods

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ABSTRACT

The purpose of this project is to develop an optical method for detecting the presence of life, specifically microorganisms, in the atmosphere of an exoplanet. We are developing algorithms that distinguish between aerosols of biological origin (microorganisms) from aerosols of non-biological origin (dust, hydrosols, etc.) using analysis of their respective and combined extinction spectra. The method uses large databases of computer-modeled spectra to analyze optical measurements and identify biological aerosols. Whereas most exoplanet researchers focus on detecting molecular spectral signatures, we are focusing on detecting the microorganisms directly rather than their molecular by-products. This method holds significant potential for detecting microorganisms from light scattered from an exoplanet's atmosphere.

In order to simulate exoplanet atmospheres using information available today, Jupiter's atmosphere was used as a model. This was accomplished by creating a MATLAB program that simulates the scattering of light using complex mathematical models. The optical information for clouds of different types was programmed into MATLAB, as well as the optical data for different kinds of microorganisms. Extinction spectra were simulated using many different size distributions; these distributions were centered at particle sizes typical of microorganisms, liquid clouds, and ice clouds.

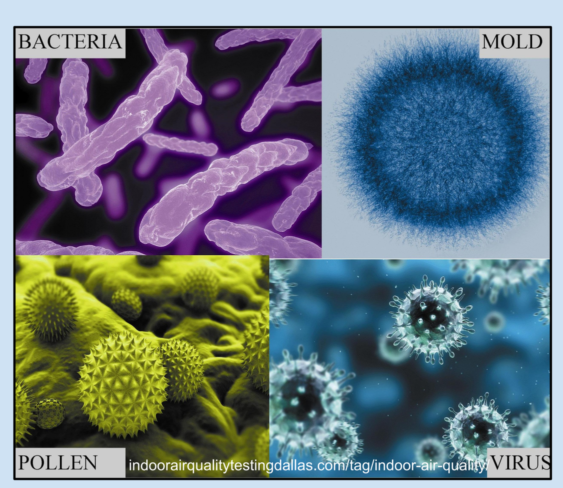
Many experiment were carried out in order to analyze the effects of different variables on the resulting extinction spectra. These experiments and their results are detailed in our second poster, entitled "Direct Optical Detection of Microorganisms in Exoplanet Atmospheres: Models & Results."

OBJECTIVE

Establish an optical method for detecting **bioaerosols** in the atmospheres of **exoplanets**.

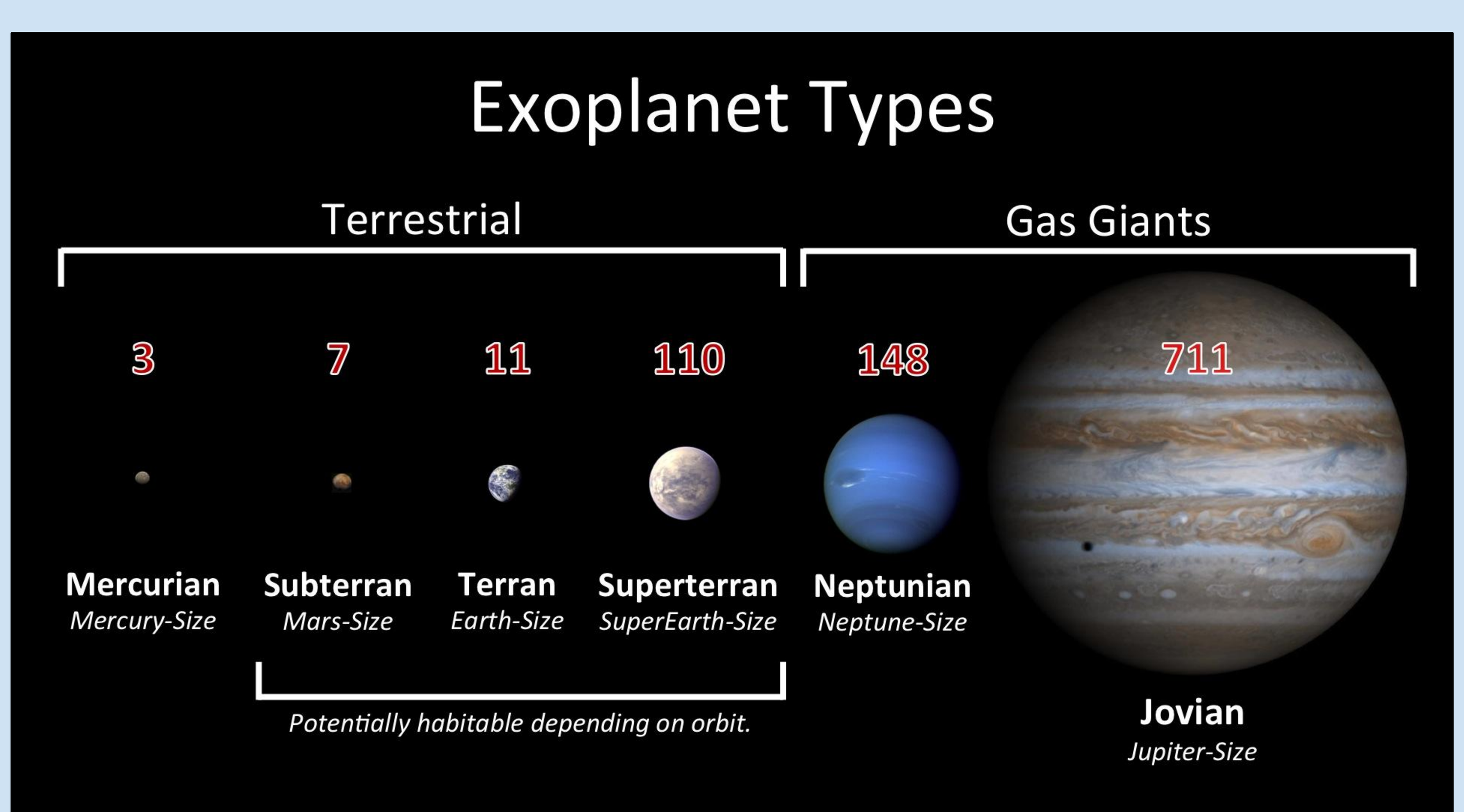
WHAT IS A BIOAEROSOL?

A **bioaerosol** (short for biological aerosol) is a suspended or airborne particle that is either a living organism or was produced by a living organism. These particles are very small and range in size from less than one micrometer (0.00004") to one hundred micrometers (0.004")[1].



WHAT IS AN EXOPLANET?

An **exoplanet** is a planet that orbits a star outside of our solar system. The majority of exoplanets that have been discovered to date are comparable in mass and size to that of Jupiter (also called Jovian or gas giants).



JUPITER AS A MODEL EXOPLANET

Jupiter was chosen as a model exoplanet for the following reasons:

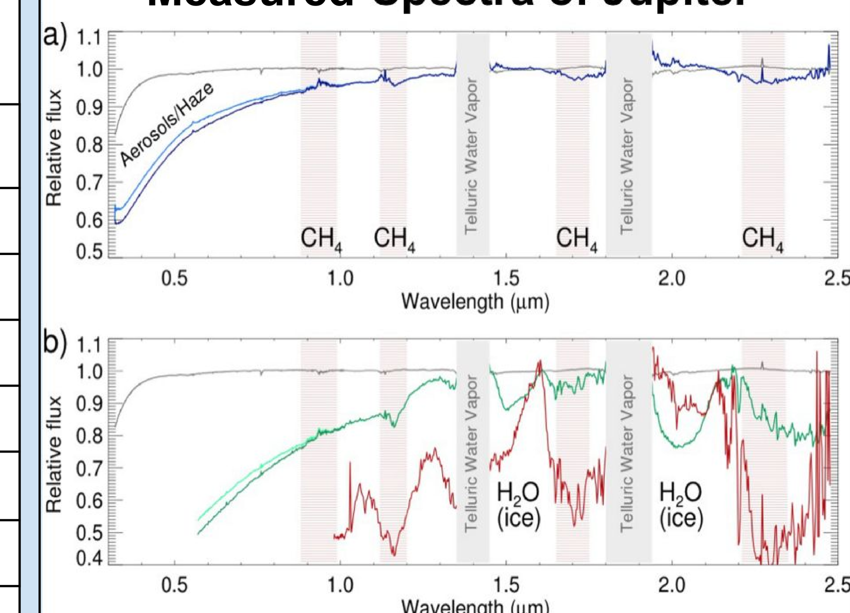
- More Jovian exoplanets have been discovered than any other type
- Jupiter does not have a solid surface; therefore, the nature of its atmosphere could allow for development of suspended microorganisms
- Astrophysical researchers are currently using Jupiter as a model to develop methods of measuring exoplanet spectra[2]

Jovian-Based Exoplanet Atmosphere Model[3]

Cloud Composition	Altitude (km)*
Water ice	20
Ammonium hydrosulfide ice	40
Ammonia ice	70
Erwinia herbicola (bacteria)	20-70
Bacillus atrophaeus (bacteria)	20-70
Ovalbumin (protein)	20-70

*The 0 km point has been taken to be 100 km below the top of the troposphere.

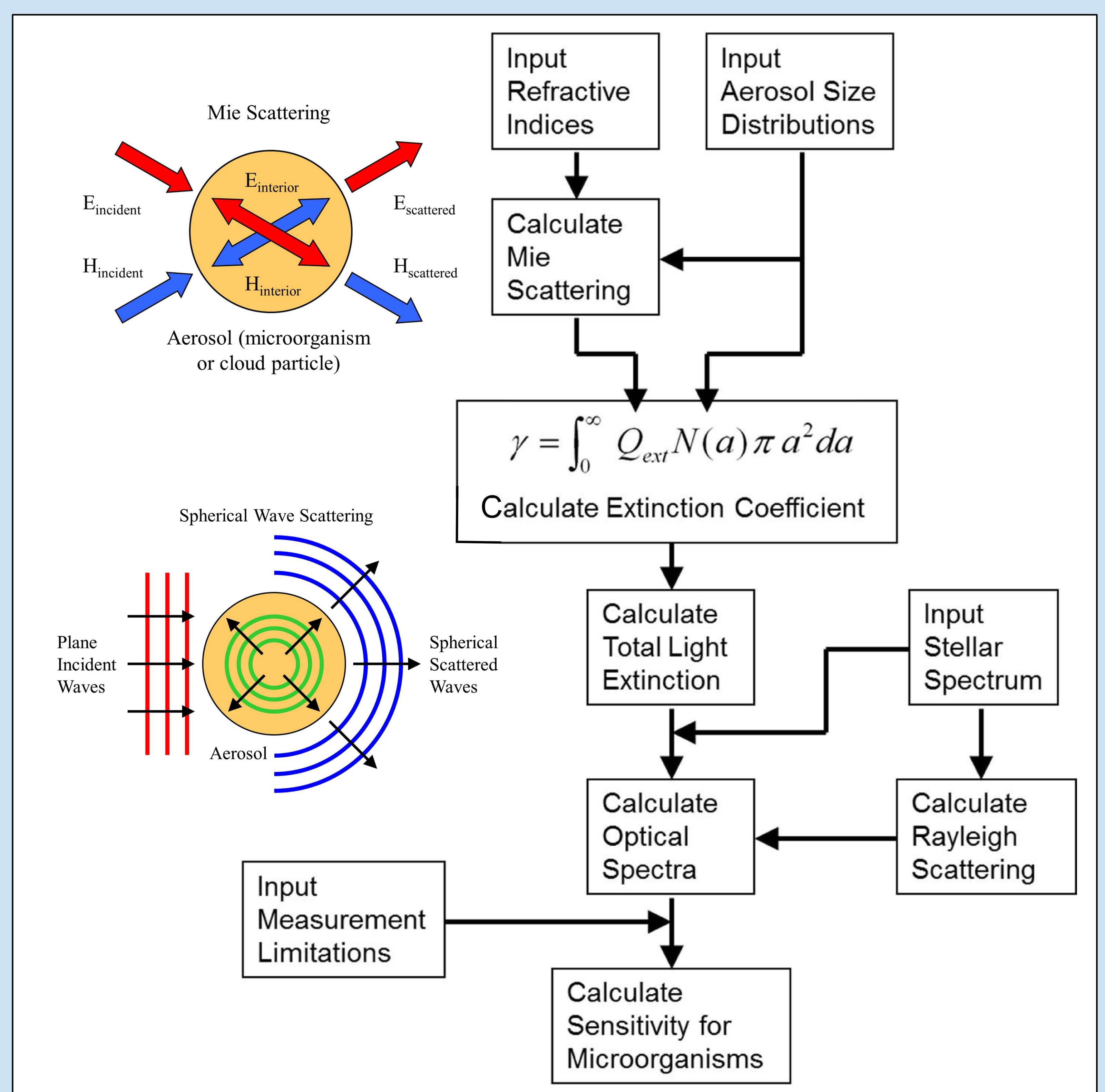
Measured Spectra of Jupiter



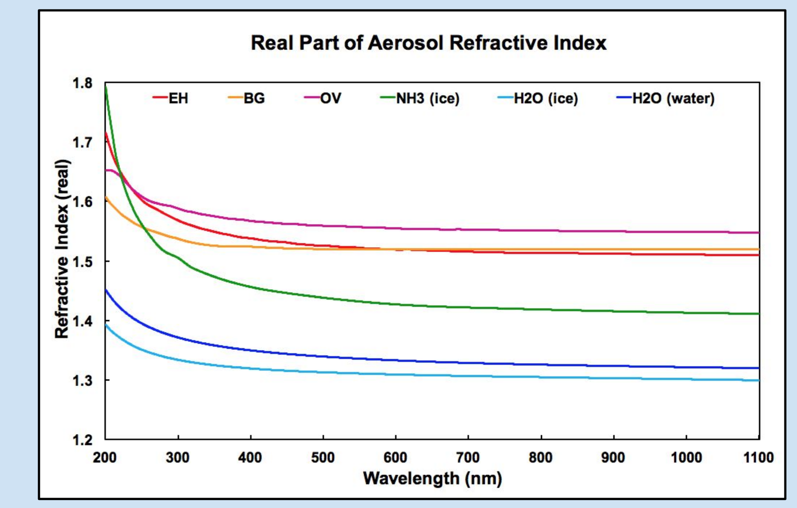
The above image shows Jupiter's spectrum during the penumbra (a) and umbra (b) phases[2].

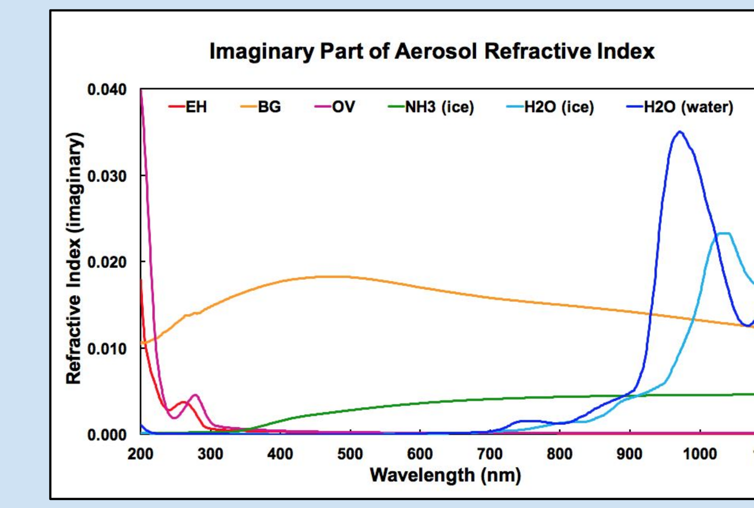
ANALYZING SPECTRA

Instead of working to measure spectra, we have been developing computer programs to model spectra and analyze the differences between them.

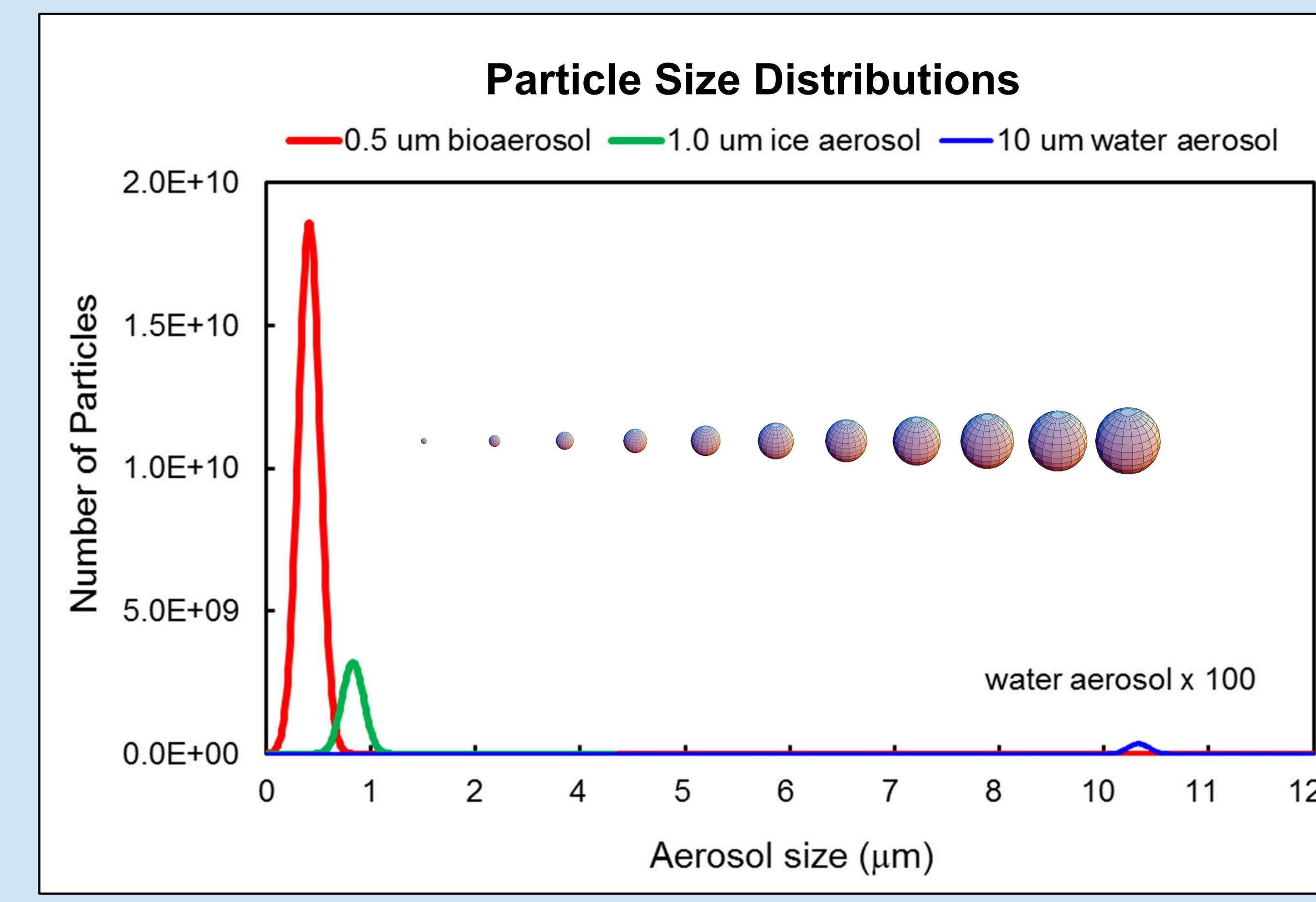


PROGRAM INPUT DATA





The above images show the real and imaginary parts of the refractive index information for the six particles types simulated; these are: EH (*Erwinia herbicola*)[4], BG (*Bacillus atrophaeus*)[5], OV (ovalbumin)[6], ammonia ice[7], water ice[8], and water[9].



The above graph shows two Gaussian particle size distributions; the first is centered at 5 micrometers, and the second at 25 micrometers. The spheres of increasing size display how the particle diameter increases along the x-axis.

CONCLUSION

This poster summarizes the necessary background information for our project, and also includes details of the program algorithms and input data. Our efforts thus far have centered on using Jupiter as model exoplanet, due to the availability of its atmospheric information and its similarity to the majority of discovered exoplanets. The program we have written uses mathematical functions to calculate optical extinction spectra by simulating scattering of light; we have calculated extinction spectra using many different particle types and size distributions. Our subsequent experiments and their results are detailed in our second poster, entitled "Direct Optical Detection of Microorganisms in Exoplanet Atmospheres: Models & Results."

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