Single-Particle Mie Scattering and Measurement Modeling for the Rocket Lab Mission to Venus

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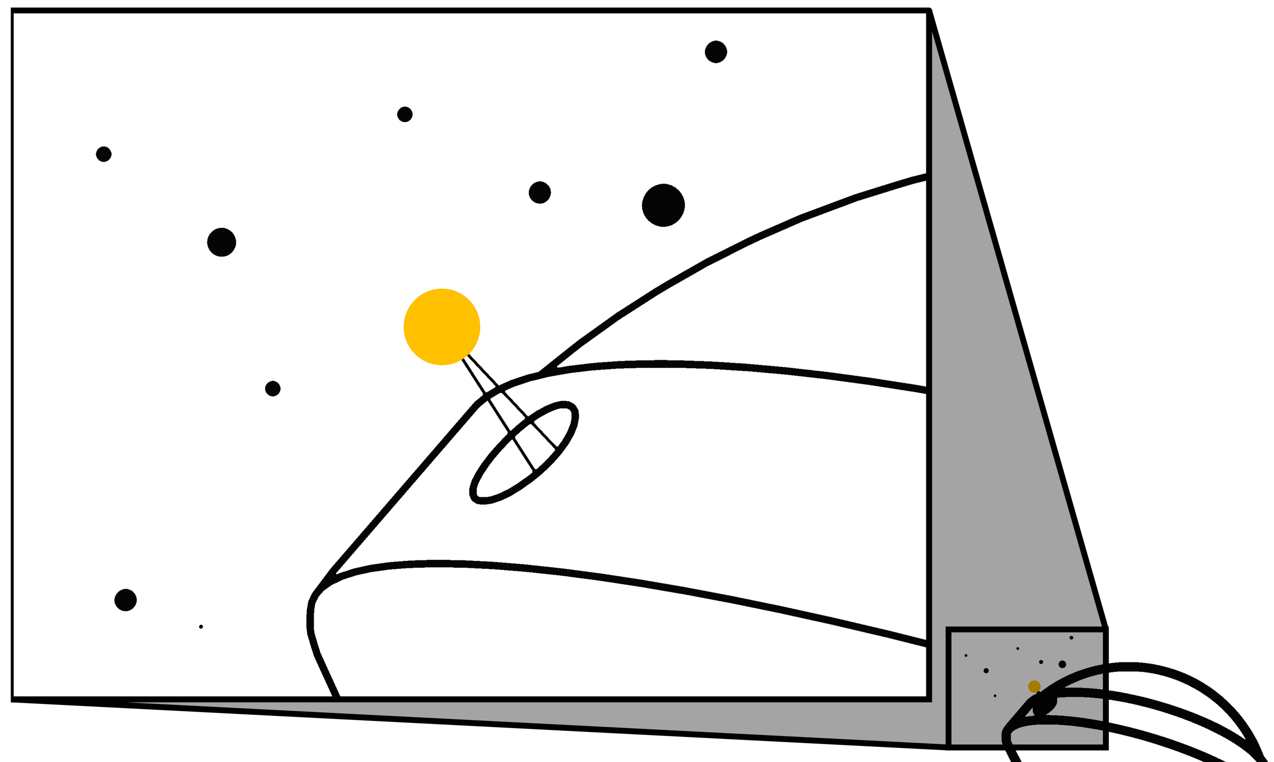
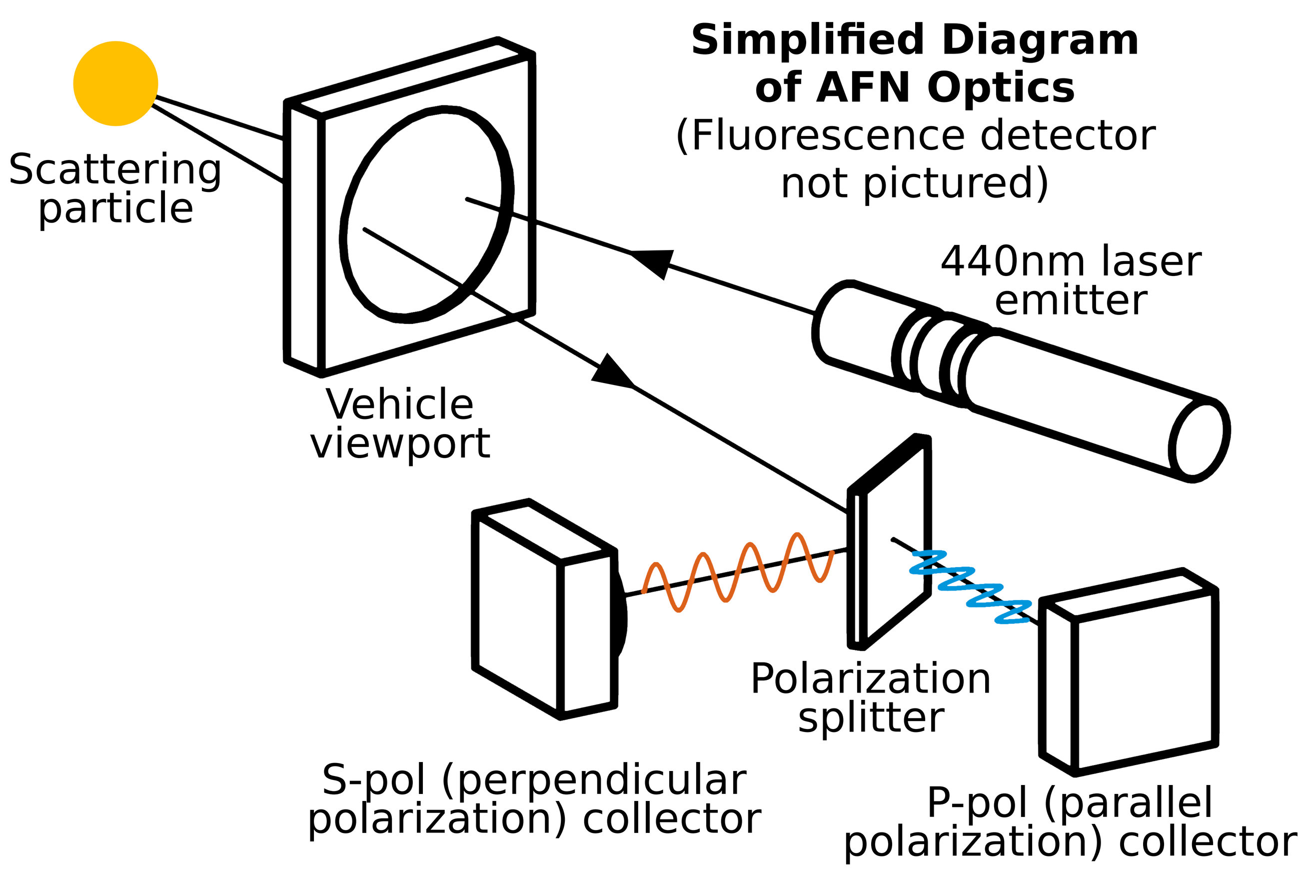
BACKGROUND



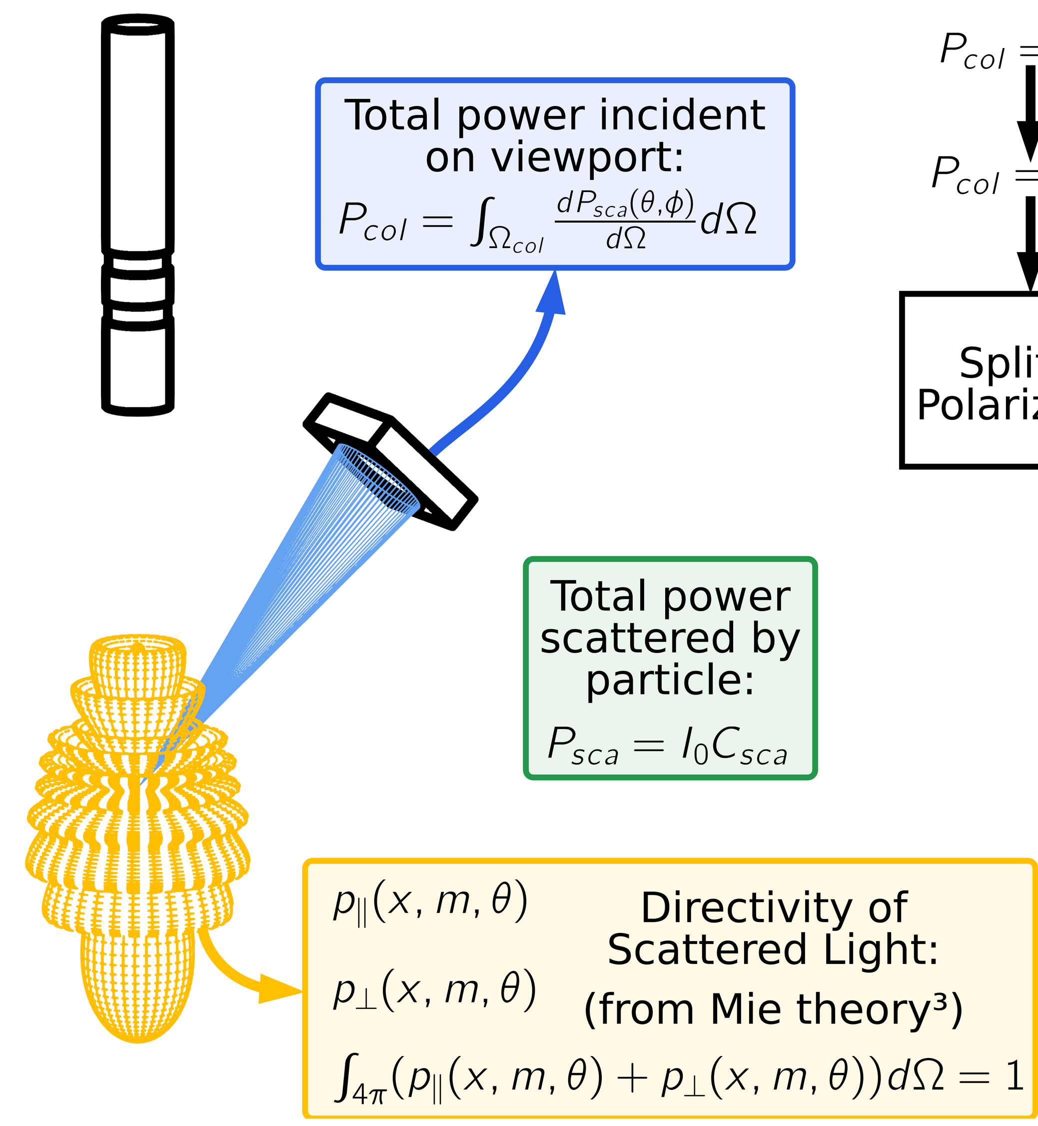
Probe Measuring Venus Cloud Particle

The Rocket Lab Mission to Venus, currently slated for launch in January 2025, will measure individual aerosol particles at depths too optically deep for remote sensing. The sole payload aboard the probe will be the Autofluorescence Nephelometer (AFN), which will measure two polarizations of 440nm light reflected by the particles[1]. Due to the non-monotonic nature of Mie theory, developing the retrieval algorithm is non-trivial[2] and requires many sample datasets for analysis and testing. While lab tests of the AFN are underway, a computational model is necessary to produce a sufficient quantity of datasets.



Simplified Diagram of AFN Optics
(Fluorescence detector not pictured)

CALCULATING AFN SIGNAL FROM MIE THEORY



$$P_{col} = \boxed{I_0 C_{sca}} \boxed{\int_{\Omega_{col}} (\boxed{p_{\parallel}(x,m,\theta)} + \boxed{p_{\perp}(x,m,\theta)}) d\Omega}$$

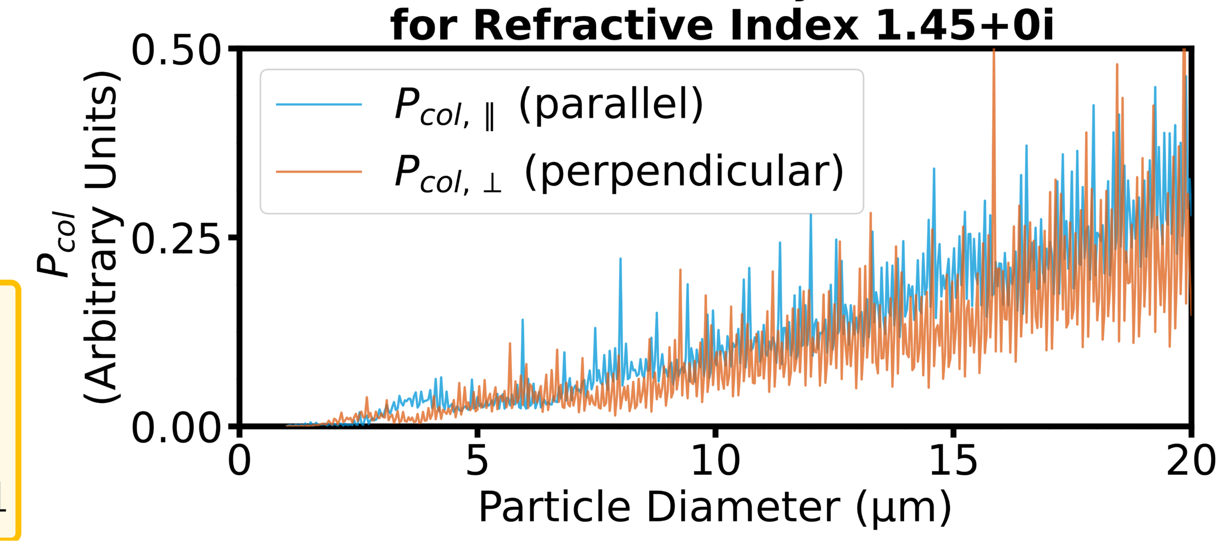
$$P_{col} = I_0 C_{sca} \int_{\theta_{min}}^{\theta_{max}} \int_{\phi_{min}}^{\phi_{max}} (p_{\parallel}(x,m,\theta) + p_{\perp}(x,m,\theta)) \sin\theta \, d\phi \, d\theta$$

Split by Polarization

$$P_{col,\parallel} = I_0 C_{sca} \int_{\theta_{min}}^{\theta_{max}} p_{\parallel}(x,m,\theta) \sin\theta \, (2\phi_{col}(\theta)) \, d\theta$$

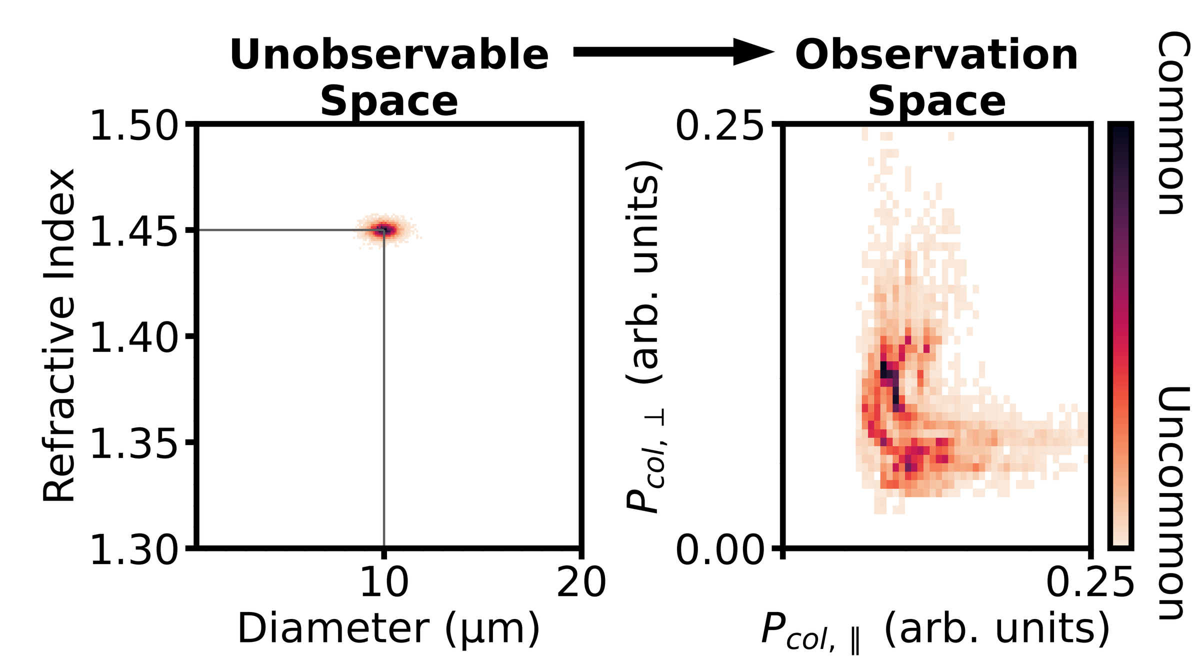
$$P_{col,\perp} = I_0 C_{sca} \int_{\theta_{min}}^{\theta_{max}} p_{\perp}(x,m,\theta) \sin\theta \, (2\phi_{col}(\theta)) \, d\theta$$

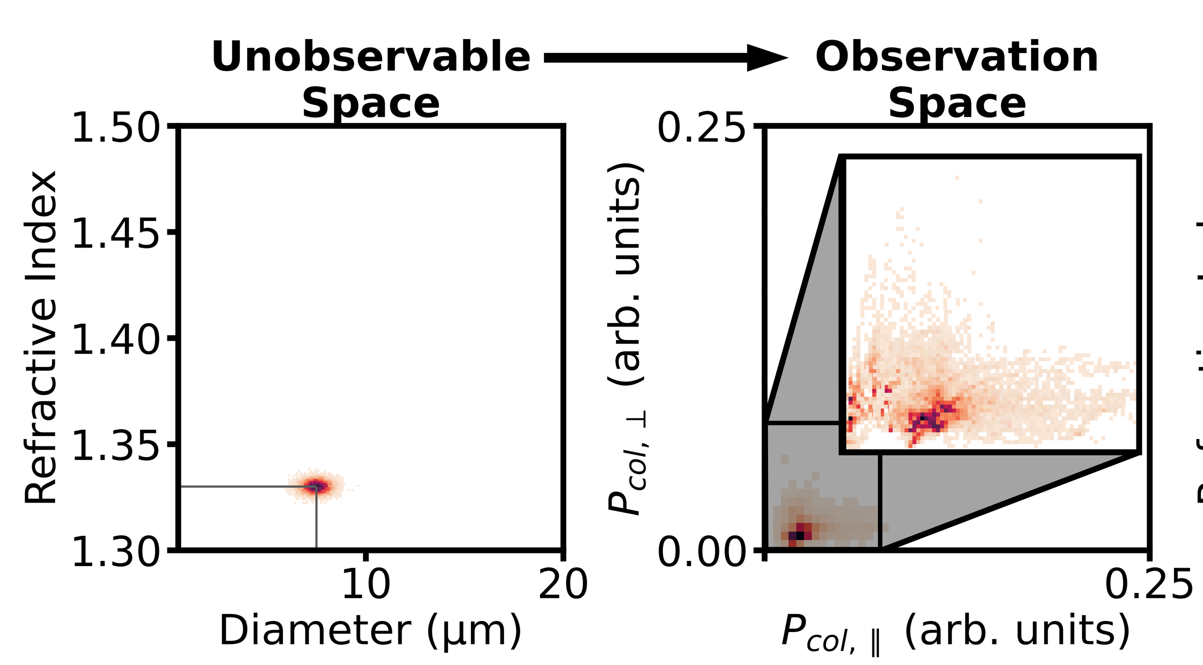
Calculated AFN Intensity Measurements for Refractive Index 1.45+0i

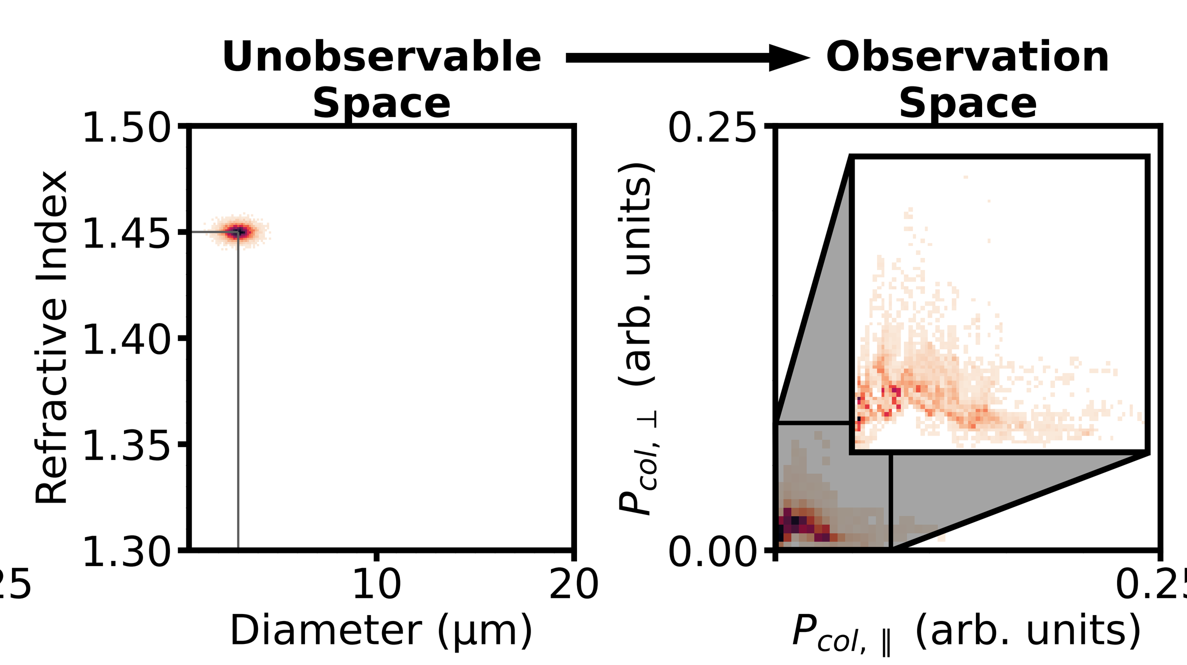


MAPPING OF PROBABILITY SPACES

For multiple bivariate Gaussian distributions in unobservable space, 10,000 particles were sampled, their measurements simulated, and the measurements for each ensemble were plotted in bivariate histograms. 3 ensembles are displayed here, highlighting the effects of particle size on measurement distributions and the unpredictability of measurement distributions for small particles.







CONCLUSIONS

An expression for the detector signal of an off-axis polarizing nephelometer was derived with no small-collector assumption. Synthetic probability distributions in unobservable space were created and mapped to observable space using Monte-Carlo methods.

As expected, despite having the same covariance matrix in unobservable space, the distributions from larger particles exhibited higher variance in measurement space, and generally had higher magnitudes of measurement. Also, in many instances, it can be seen that points far from each other in unobservable space map to the same point in observation space.

FUTURE WORK

Once lab-measured datasets have been produced with known diameter and refractive index distributions, they will be compared to simulated measurement distributions. Adjustments will be made to the model to account for discovered discrepancies, which could include slight misalignment of optics, the finite width of the laser, and any polarization characteristics of the incident beam.

The model will then be used to inform the development of the reconstruction algorithm, providing both a way to observe the effects of different particle distributions and to test the algorithm on its ability to identify distributions in the presence of noise.

ACKNOWLEDGMENTS

SCHMIDT FUTURES

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REFERENCES

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[3] Prahl, S. 2023 (Zenodo), https://zenodo.org/record/8218010

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