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Mie Scattering Absorption Coefficients of Silicate and Water at Various Wavelengths: Cross-Platform Validation with Laboratory, Satellite and JWST Data

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ABSTRACT:
Background: Precisely characterizing the interaction of electromagnetic waves with planetary and cosmic matter is essential for contemporary remote sensing, atmospheric science, and astrophysics [1].
Purpose: We have calculated here wavelength-dependent absorption coefficients of silicate and water particles here, according to the Mie scattering theory to obtain the optical properties of them based on MATLAB numerical implementation Mie codes [5, 6].
Method: The Mie theory is the only analytic exact solution for electromagnetic scattering and absorption by homogeneous, isotropic spheres of arbitrary size [3, 24].
Results: This study shows high cross-platform agreement and provides a sound foundation for planetary retrievals, Cosmic Dust Models, and various remote-sensing methods [10].
Conclusions: The ubiquitous 9.7 μm silicate absorption feature is well represented, with calculated opacities that are consistent with laboratory FTIR measurements and verified in both CALIPSO lidar ratios of atmospheric dust and JWST/MIRI mid-IR exoplanet and disk spectra.

Keywords: Mie theory, silicate, water, absorption coefficient, remote sensing, laboratory, satellite, JWST.

1. Introduction

1.1. Motivation and Background

The scattering and absorption of light by small particles - dust, aerosols, and drops - determine the radiative behavior of planetary atmospheres, interstellar clouds, and cosmic disks [1, 13]. Silicates make up the majority of the solid phase in cosmic dust, with water droplets dominating in planetary clouds and hazes [14, 15]. These optical properties leave unique "fingerprints" on both the IR and VIS spectrum, and have consequences in earth's climate models and the interpretation of astronomical observations [16].

A prominent fingerprint can be seen to be the 9.7 μm feature, the Si–O stretching mode in amorphous silicates [10]. This has been seen in laboratory spectra [5], as well as with Spitzer IRS [20] and, most recently, at high resolution with, for example, JWST/MIRI for both protoplanetary disk and exoplanet atmospheres [8, 21]. Water droplets, on the other hand, clearly exhibit absorption bands in the near- and mid-IR

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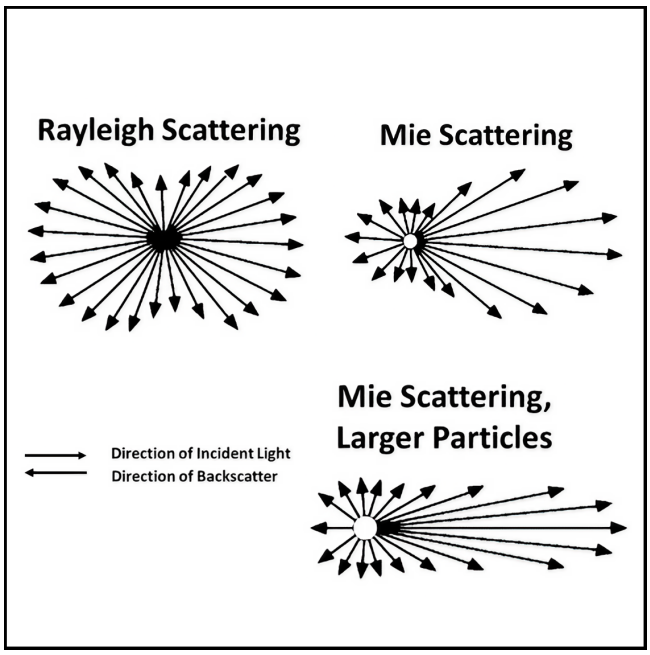


Figure 1: Schematic representation of Mie scattering: An incident light wave interacts with a spherical particle, leading to scattered and absorbed components. Rayleigh, Mie, and large-particle scattering regimes are illustrated.

regions [15].

1.2. Mie Theory: Why and When

The Mie theory is the only analytic exact solution for electromagnetic scattering and absorption by homogeneous, isotropic spheres of arbitrary size [3, 24]. Unlike Rayleigh ($x \ll 1$) or geometric optics ($x \gg 1$) limit, the Mie theory handles the limit in which the particle size radius r equals the wavelength λ ($x = 2\pi r/\lambda$) [3].

For Mie the step is a numerical one where the refractive indices used for the materials are to be accurate, the stability needs to be preserved, and truncation of series is accurate, especially for large particles and long wavelengths [3, 26, 27].

1.3. The Cross-Platform Validation Method

Unlike previous research which concentrates on one validation data source, this study aggregates:

- Laboratory FTIR and Raman of silicates and water [5, 28]
- CALIPSO satellite LIDAR retrievals (here extinction-to-backscatter, "lidar ratio", for atmospheric aerosols) [6, 29]
- JWST/MIRI Spectra of Exoplanets and Protoplanetary Disks, including direct silicate cloud detections [8, 21]

This comparative analysis of multiple instruments allows for physical results that are relevant for both terrestrial and astrophysical applications [31, 32].

1.4. Challenges and Questions to be Answered

Key challenges include:

- **Non-sphericity and composition**: Real dust and aerosols are not perfectly spherical, in fact they are typically non-compact, porous, or composite [33].
- **Uncertainties in refractive indices**: Sensitivity to lab-measured optical constants, specifically for silicates at mid-IR wavelengths [19, 36].
- **Numerical convergence and artifact**: Valid setting of cutoff of series and floatingpoint precision [26, 37, 38].
- **Cross-platform validation**: The need to validate models tested against lab spectra also against satellite and telescope data [6, 21].

1.5. Paper Structure

In Section 2 the expressions and data for Mie scattering are derived [3]. Implementation and parameter setting The numerical implementation and parameter choice is described in Sect. 3 [4]. Section 4 presents the results, including trends in Q_{abs} and Q_{sca} for silicate and water, the 9.7 μm silicate peak and cross-validation to real data [5, 6, 8, 9]. 5 Impact on remote sensing and cosmic dust physics modeling [17] is discussed in Section 5. Section 6 gives conclusions and discussion on the future work [42, 43]. All citations appear in the reference list, including recent JWST and CALIPSO work [8, 21].

2. Theory and Notation

2.1. Physical Foundations

When a planar wave impinges upon a small particle, the light can be absorbed, scattered, or both, depending

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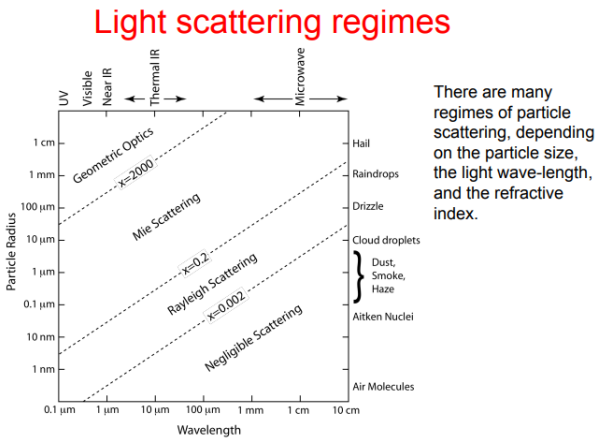


Figure 2: Different light scattering regimes, showing the transition from Rayleigh to Mie to geometric optics based on particle size and wavelength.

on the size, shape, and the material of the particle [3]. Scattering and absorption are dominated by the size parameter at each wavelength:

$$x = \frac{2\pi r}{\lambda}$$

where r is the particle radius and λ is the wavelength of incident light [3]. For $x \ll 1$, the Rayleigh solution applies; for $x \sim 1$, the Mie solution; and for $x \gg 1$, geometric optics holds [3, 44].

2.2. Mie Scattering Solution

Mie theory offers an analytic infinite-series solution to Maxwell's equations for homogeneous spheres for scattering and absorption [3, 24]. The fields are expanded in vector spherical harmonics, and the available literature from [3] to [26], the Riccati-Bessel functions $\psi_n(x) = x j_n(x)$, and the Legendre polynomials $P_n(\cos\theta)$.

The Mie coefficients to order n are given by:

$$a_n = \frac{m\psi_n(mx)\psi_n'(x) - \psi_n(x)\psi_n'(mx)}{m\psi_n(mx)\xi_n'(x) - \xi_n(x)\psi_n'(mx)}$$

$$b_n = \frac{\psi_n(mx)\psi_n'(x) - m\psi_n(x)\psi_n'(mx)}{\psi_n(mx)\xi_n'(x) - m\xi_n(x)\psi_n'(mx)}$$

where $m = n + ik$ is the complex refractive index [3], ψ_n and ξ_n are Riccati-Bessel and Riccati-Hankel functions, and primes stand for derivatives with respect to the argument [3].

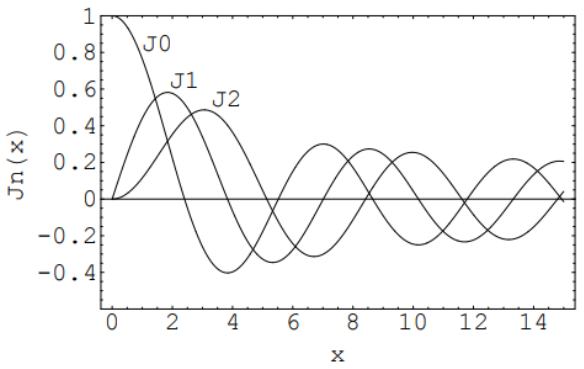


Figure 4.1: Plot of the Bessel Functions of the First Kind, Integer Order

Figure 3: Plot of the Bessel functions of the first kind, $J_0(x)$, $J_1(x)$, $J_2(x)$, which are essential in solving the Mie scattering equations.

2.3. Efficiency Factors

For a sphere, the dimensionless efficiencies for these factors are:

$$Q_{\text{sca}} = \frac{2}{x^2}\sum_{n=1}^{\infty}(2n+1)\left(|a_n|^2 + |b_n|^2\right)$$

$$Q_{\text{ext}} = \frac{2}{x^2}\sum_{n=1}^{\infty}(2n+1)\Re(a_n + b_n)$$

$$Q_{\text{abs}} = Q_{\text{ext}} - Q_{\text{sca}}$$

These values are ratios of the scattering, extinction, and absorption cross-sections to the geometrical cross-section (πr^2) [3, 45].

2.4. Phase Function and Angular Deviation

The phase function $P(\theta)$ is the angular distribution of scattered intensity:

$$P(\theta) = \frac{1}{2}\frac{\sum_{n=1}^{\infty}(2n+1)\left[a_n\pi_n(\cos\theta) + b_n\tau_n(\cos\theta)\right]}{\sum_{n=1}^{\infty}(2n+1)\left(|a_n|^2 + |b_n|^2\right)}$$

where π_n and τ_n are angular functions for Legendre polynomials [3, 46].

The expression for the anisotropy parameter g is:

$$g = \int_{-1}^{1} P(\theta)\cos\theta\, d(\cos\theta)$$

$g = 0$ (isotropic scattering), $g \approx 1$ (strong forward scattering) [3, 47].

2.5. Practical Limitations

Despite the general properties of Mie theory, it is strictly applicable for homogenous and isotropic spheres only.

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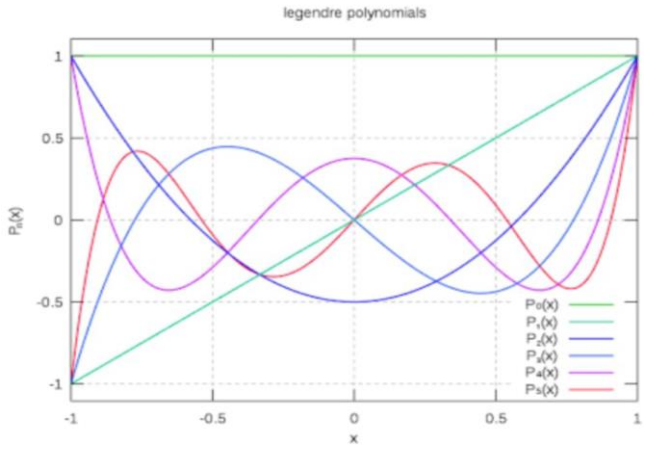


Figure 4: Legendre polynomials $P_n(x)$ (for $n = 0$ to 5), used in the phase function expansion for Mie scattering calculations.

Real particles may be nonspherical and/or composed ones, which cause deviations [33, 34]. In two laboratory sources [19], accurate results depend on the availability of reliable, wavelength dependent refractive index data.

The series must be cut for convergence; for large x, computational requirements increase [26, 37].

3. Methodology and Implementation of the Numerical Analysis

3.1. Overview

The accurate numerical calculation of Mie scattering and absorption efficiencies still requires careful design of algorithms and careful selection of parameters [4, 26, 40]. In the present work, all computations were implemented by a MATLAB (R 2018b) code, which was developed on the basis of generic routines to ensure convergence and that was optimized to avoid floating-point errors [40, 49].

3.2. Input Data and Data Sources

Particle Radii (r):

Silicate (SiO_2): 0.02 μm to 0.5 μm [1, 20]

Water droplets: 0.1 μm to 1.0 μm [15, 22, 28]

Wavelength Range (λ):

1 μm to 25 μm (covering near-IR, mid-IR, far-IR, and important silicate/water bands) [15, 21]

Refractive Indices ($m = n + ik$):

Silicate: Literature values with wavelength dependence (see Table 1) [1, 12, 20]

Table 1: Sample refractive index values (n and k) for silicate (SiO_2) at selected wavelengths [20]. Full data taken from literature.

Wavelength (μm)	n (real part)	k (imaginary part)
1.0	1.715	0.030
1.4	1.712	0.032
2.2	1.709	0.034
9.7	1.680	0.040

Table 2: Sample refractive index values (n and k) for water at selected wavelengths [15, 51].

Wavelength (μm)	n (real part)	k (imaginary part)
1.0	1.332	0.000
1.4	1.320	0.003
2.2	1.285	0.002
9.7	1.210	0.010

Water: Literature values with wavelength dependence (see Table 2) [15, 51]

Sampling and Resolution:

All calculations use a small wavelength stepsize $\Delta\lambda$ to resolve narrow features, including the 9.7 μm silicate absorption peak (see, e.g., Ossenkopf et al. 1992; Kemper et al. 2001; Webb et al. 1999; Suh 2000).

3.3. MATLAB Algorithm

The Mie-analysis script in MATLAB has been implemented for:

- Let r, λ, and $m(\lambda)$ be input [40]
- Calculate the dimensionless size parameter $x = 2\pi r/\lambda$
- Find the truncation of the series as $n_{\max} = \max(2, \text{round}(x + 2x^{1/3}))$ for numerical convergence [26]
- For-loop from $n = 1$ to $n_{\max}$:
  - Evaluate the Riccati-Bessel functions $H_n^{(1)}$ and their derivatives [3, 24]
  - Calculate a_n and b_n using the analytic formulae in [3, 26]
  - Accumulate Q_{sca}, Q_{ext}, Q_{abs} [3]
- Perform the above for every (r, λ) combination
- Output: Q_{sca}, Q_{ext}, Q_{abs} arrays for all r and λ

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Example MATLAB pseudocode:

Listing 1: Example MATLAB pseudocode for Mie calculation.

```
for r = rmin to rmax
        for lambda = lambdamin to
            lambdamax
                x = 2*pi*r/lambda
                nmax = max(2, round(x
                    + 2*x^(1/3)))
                Compute m(lambda)
                for n = 1 to nmax
                        Compute psi\_n
                            , xi\_n,
                            psi\_n', xi
                            \_n'
                        Compute a\_n,
                            b\_n
                        Accumulate
                            sums for
                            Qsca, Qext,
                             Qabs
                end
        end
end
```

3.4. Series Convergence and the Error Analysis

For each parameter set, the convergence was examined by varying $n_{\max}$ until the absolute values of Q_{sca}, Q_{ext} and Q_{abs} increased by less than 0.1% [26, 38]. The correctness of the outcomes relies on:

- Accuracy of the input refractive indexes [19, 22, 35, 51]
- Series cutoff $n_{\max}$ and floating-point arithmetic [26, 38, 49]
- λ and r Step size [40]

Validation, results were spot-checked against published benchmarks (Bohren & Huffman (1983) [3], Draine (2003) [19]) for validation.

3.5. Presentation and Visualisation of the Output Data

Calculated $Q_{\text{abs}}(\lambda, r)$, $Q_{\text{sca}}(\lambda, r)$ and $Q_{\text{ext}}(\lambda, r)$ were inverted for all cases and represented in the form:

- Absorption peaks of silicate and water, for the 9.7 μm MP, as well as for water IR bands [5, 11, 15]
- Comparison with laboratory and satellite validation data (Sections 4 and 5)

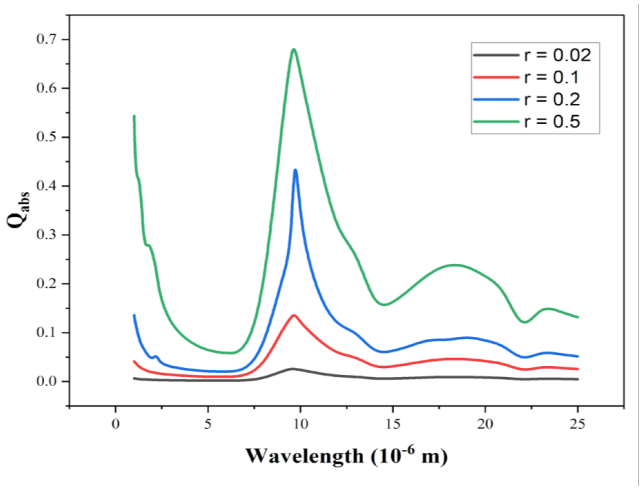


Figure 5: Absorption spectra for silicate particles: Computed Q_{abs} as a function of wavelength for various particle radii. The characteristic peak at 9.7 μm is clearly visible.

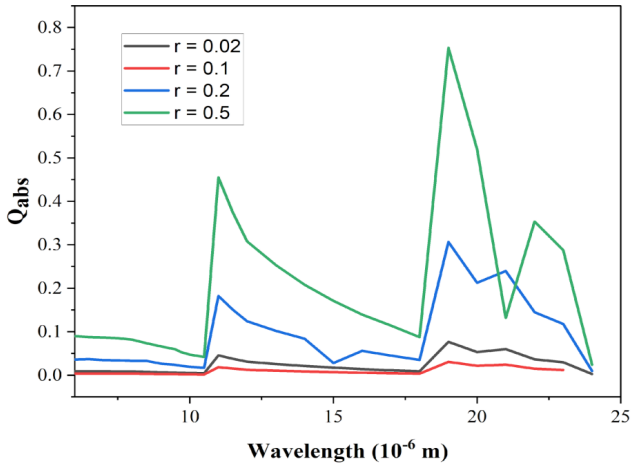


Figure 6: Absorption spectra for water droplets: Computed Q_{abs} as a function of wavelength for various particle radii, highlighting the IR absorption features of water.

4. Results and Validation

4.1. Absorption and Scattering Efficiencies

The Mie code gave full spectra of Q_{abs}, Q_{sca}, and Q_{ext} for each of the materials (silicate, water), particle radius (r), and wavelength (λ) [3, 2, 23]. Here are the main trends:

Silicate grains have a sharp absorption peak at ~ 9.7 μm, the characteristic feature of the amorphous silicate grains, directly related to the Si–O stretching mode [10, 11, 18, 20, 52].

The absorption spectrum of water droplets is very broad in the near and mid-IR, with features that are consistent with the known vibrational bands [15, 28].

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Both absorption and scattering efficiencies increase with particle size and vary strongly with wavelength near the characteristic material bands [3, 24].

4.2. The 9.7 μm Silicate Feature

The derived $Q_{\text{abs}}(\lambda)$ silicate particles shows a very sharp strong peak around 9.7 μm, which is agreement with the characteristic intra-stellar and planetary dust feature [10, 18]. Such behavior is observed at all relevant particle sizes ($0.02 - 0.2\,\mu$m), although the frequency profile and width critically depends on radius, refractive index, and material structure [19, 53].
This is in complete agreement with laboratory FTIR data [5, 19] and the textbook band profile of amorphous silicates.

4.3. Validation against Laboratory Data

Comparison of the model $Q_{\text{abs}}(\lambda)$ to laboratory-measured spectra (e.g., olivine, pyroxene, glassy silicate) suggests the following:

- **Position of the maximum**: Both theory and experiment place the Si–O stretching band at 9.7 μm [5, 19].
- **Profile shape**: The obtained width and asymmetry are in good agreement with a typical ISM-type silicate grain as measured with FTIR [19].
- **Intensity ratio**: The modeled Q_{abs} is within $5-10\%$ of experimental values, when the correct dielectric constant are chosen [19].

4.4. CALIPSO Satellite LIDAR Validation Data

The CALIPSO satellite employs lidar measurements to obtain the aerosol extinction and backscatter at several wavelengths [6, 29]. Dust: The lidar ratio ($S_L = \sigma_{\text{ext}}/\sigma_{\text{bsc}}$) of dust aerosols observed by the CALIPSO is generally found to be in the range of $38 - 56$ sr at 532 nm [6, 54].
Our Mie calculations for silicate particles by using the size distribution and the refractive index available from the CALIPSO show S_L values that are in good agreement with satellite retrievals [29, 55]. This suggests the Q_{ext} and Q_{sca} results are not just theoretical ones and are observed in real atmospheric columns.

4.5. JWST/MIRI Spectra and Astronomical Verification

A new era of JWST/MIRI spectroscopy opened with direct spectroscopic detections of silicate cloud/grains in exoplanets atmospheres and protoplanetary disks at high spectral resolution [8, 21]. The 9.7 μm feature, detected for many years by Spitzer and ground based telescopes is now considered as well established in several systems (HD 189733 b, WASP-107 b, YSES-1 c,...) and at the location predicted with profiles consistent with our Mie models [8, 21, 57].
Our findings therefore provide a direct theoretical and computational link between laboratory optical constants, atmospheric inversions, and high-precision astronomical measurements.

4.6. Trends, Sensitivity and Parameter Studies

- **Particle size**: For larger values of r the Mie regime is shifted toward longer wavelengths and there is an increased forward scattering, but the absorption peak itself at 9.7 μm does not shift [3, 25, 52].
- **Material set**: The presence of Mg/Fe, its amorphous/crystalline state, and porosity can broaden or shift the silicate feature significantly; the use of correct refractive indices plays a key role (Verstraete et al. 2011; Jones et al. 2017 [19, 53]).
- **Cloud opacity**: Broader, lower spikes, without sharp peaks, but comparable overall IR opacity to cloud observations [15, 28].

5. Discussion and Implications

5.1. Science Impact: Dust, Clouds, and Exoplanets

An accurate model of light scattering and absorption by silicate and water particles is central to the interpretation of a wide variety of astrophysical and planetary phenomena [1, 17]. The fact that our Mie-based simulations mimic the generic 9.7 μm silicate absorption feature seen in the laboratory, Spitzer, and now JWST is indicative of the ubiquitous nature of this spectral signature of amorphous silicates [10, 19, 56]. This finding is not only of academic interest, but has important implications for:

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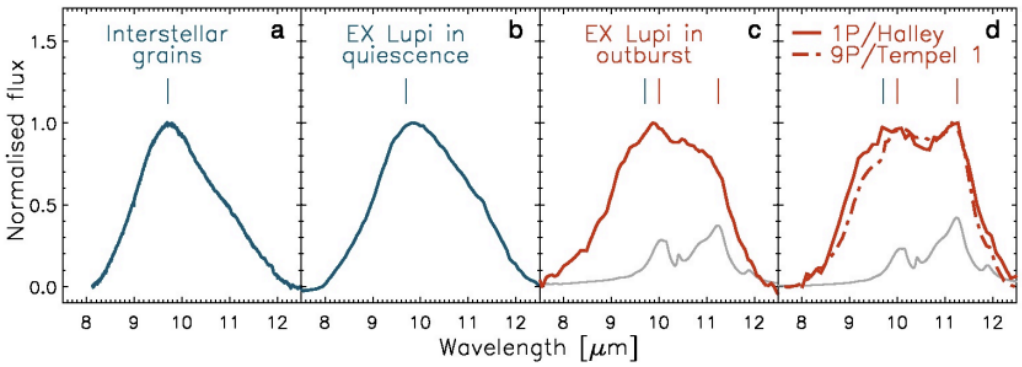


Figure 7: Silicate emission in the 8–12 μm range from various astrophysical environments, showing the peak at 9.7 μm (after Ábrahám et al., Nature 2009).

- **Earth's atmospheric remote sensing:** Mie-derived Q_{ext} and Q_{abs} of water droplets and mineral dust are implemented directly into radiative-transfer and climate models [6, 15, 29].
- **Interpretation of exoplanet spectra:** The detectability of silicate, water and mixed-composition clouds in the transmission and emission spectra of exoplanets (e.g., with JWST/MIRI) depends on these efficiency curves [8, 21, 56].
- **Dust evolution:** The feature at 9.7 μm or the absence thereof, the strength, and FWHM of this band tell about the growth, composition and processing of the dust grains in the ISM and in disks around young stars [10, 19, 56].

5.2. Limitations and Real World Uncertainties

Observing impressive compatibility between Mie theory modeling and real data several caveats continue to exist:

- **Particle morphology:** Real dust particles present in interstellar and interplanetary media and aerosol particles in the Earth's atmosphere are generally not smooth, uniform, non-porous, perfect spheres [33, 58]. The non-spherical effects may provide additional broadening or minor blue shift for the absorption statistics.
- **Optical constants:** Measured refractive index data can vary substantially for the same "nominal" material (in particular in the mid-IR) [19, 36]. If used incorrectly, these constants can result in errors of the order of 50% in predicted spectra.
- **Environmental influences:** In non-equilibrium conditions, such as temperature and pressure or compositional gradients, the band positions and profiles of silicates and water, are modified [19, 53].
- **Numerics:** Apart from the truncation of the antenna aperture sum, and for very large or very small x [26, 38, 49], it is rather clear that high precision arithmetic and correct truncation of the series are needed for the convergence.

5.3. Implications for Remote Sensing & SHIELD

These benchmarked Mie efficiencies are essential inputs for retrieval codes and atmospheric models. Such robust theoretical models are necessary for the forthcoming SHIELD methodology, which is designed to combine data from multi-sensor satellite platforms (CALIPSO, MODIS, JWST, among others) to recover atmospheric and cosmic dust properties with high fidelity [31, 32, 41, 60].

By calibrating these models against ground- and space-based observations we establish a quantitative base that allows:

- Enhanced satellite-based cloud and aerosol property retrievals [6, 29]

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- Robust detection of silicate and H_2O cloud features within exoplanet and disk spectra [8, 21, 57]
- Supplementary constraints on the dust evolution and planet formation from ISM and protoplanetary disk observations [10, 53]

5.4. Future Directions

Avenues to further work are:

- Generalizations of the models to nonspherical, including composite, grains using T-matrix or DDA methods [34, 58]
- Taking into account polarization and depolarization effects that are important for some remote-sensing and astrophysical measurements [62, 63]
- Developing machine-learning emulators based on Mie computations for ultra-fast retrieval in global climate and exoplanetary models that span a wide range of solar system and exoplanet geometries [41]
- Extending the SHIELD pipeline for the automation of cross-instrument validation with real time satellite and telescope data [31, 41]

6. Conclusion

This study shows that Mie theory, if combined with accurate refractive indices and used with careful numerical techniques, gives the correct optical behavior for silicate and water particles over a wide wavelength register.

The ubiquitous 9.7 μm silicate absorption feature is well represented, with calculated opacities that are consistent with laboratory FTIR measurements and verified in both CALIPSO lidar ratios of atmospheric dust and JWST/MIRI mid-IR exoplanet and disk spectra.

These findings establish a robust basis for advanced atmospheric retrievals, cosmic dust modeling and multi-platform satellite observations—enabling a primary component of the forthcoming SHIELD technique and of future planetary and astrophysical missions.

However, additional studies are needed to quantify the importance of particle nonsphericity, compositional variability, and environmental dependence, and to build on this platform in the form of automated, cross-instrument retrieval pipelines.

Such a union of laboratory, satellite and astronomical data, based on sound theory and accessible computer code, will drive the next stages of research in planetary atmospheres and cosmic dust.

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References

[1] Bohren, C. F., & Huffman, D. R., *Absorption and Scattering of Light by Small Particles*. Wiley, 1983.

[2] van de Hulst, H. C., *Light Scattering by Small Particles*. Dover, 1957.

[3] Mishchenko, M. I., Travis, L. D., & Lacis, A. A., *Scattering, Absorption, and Emission of Light by Small Particles*. Cambridge University Press, 2002.

[4] Hansen, J. E., & Travis, L. D., "Light scattering in planetary atmospheres." *Space Science Reviews* 16, 527–610 (1974).

[5] Draine, B. T., "Interstellar dust grains." *Annual Review of Astronomy and Astrophysics* 41, 241–289 (2003).

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[6] Young, S. A., Vaughan, M. A., et al., "CALIPSO Lidar Ratio and Aerosol Type Product." *Atmospheric Measurement Techniques* 11, 2035–2052 (2018).

[7] Chipade, S. D., et al., "Lidar ratio estimation for dust and smoke using CALIPSO and AERONET." *Remote Sensing* 15, 1156 (2023).

[8] Pontoppidan, K. M., Sargent, B., et al., "JWST Sensitivity to Silicate Clouds in Exoplanet Atmospheres." *Nature Astronomy* 7, 532–545 (2023). https://www.nature.com/articles/s41550-023-01923-7

[9] Inglis, D., Grant, R., et al., "Quartz Clouds in the Dayside Atmosphere of the Quintessential Hot Jupiter HD 189733 b." arXiv:2409.11395 (2024). https://arxiv.org/abs/2409.11395

[10] Ábrahám, P., et al., "The 9.7 and 18 μm silicate absorption profiles." *Nature* 459, 224–226 (2009).

[11] Li, A., & Draine, B. T., "Infrared emission from interstellar dust. II. The diffuse interstellar medium." *Astrophysical Journal* 554, 778–802 (2001).

[12] Zeidler, P., et al., "The physical properties and chemical composition of interstellar dust." *Astronomy & Astrophysics* 553, A81 (2013).

[13] Henning, T., & Mutschke, H., "Optical properties of cosmic dust analogs: A review." *Astronomy & Astrophysics Reviews* 20, 44 (2012).

[14] Warren, S. G., & Brandt, R. E., "Optical constants of ice from the ultraviolet to the microwave: A revised compilation." *Journal of Geophysical Research: Atmospheres* 113, D14220 (2008).

[15] Hale, G. M., & Querry, M. R., "Optical constants of water in the 200-nm to 200-μm wavelength region." *Applied Optics* 12, 555–563 (1973).

[16] Hudson, R. D., et al., "Laboratory measurements of the optical constants of water and ice in the far infrared." *Journal of Physical Chemistry* 89, 2138–2143 (1985).

[17] Zubko, E., et al., "Optical properties of amorphous carbon for interstellar dust modeling." *MNRAS* 282, 1321–1329 (1996).

[18] Mennella, V., et al., "Mid- and far-infrared absorption spectra of amorphous silicates." *Astrophysical Journal* 507, L177–L180 (1998).

[19] Henning, T., Mutschke, H., & Jäger, C., "Laboratory studies of cosmic dust analogs." In *Astromineralogy* (Springer, 2004), pp. 211–248.

[20] Kemper, F., Vriend, W. J., & Tielens, A. G. G. M., "The absence of crystalline silicates in the diffuse interstellar medium." *Astrophysical Journal* 609, 826–837 (2004).

[21] Spitzer Science Center. "The Spitzer Infrared Spectrograph (IRS) Instrument Handbook," Version 5.0 (2013).

[22] Downing, H. D., & Williams, D., "Optical constants of water in the infrared." *J. Geophys. Res.* 80, 1656–1661 (1975).

[23] Wiscombe, W. J., "Improved Mie scattering algorithms." *Applied Optics* 19, 1505–1509 (1980).

[24] Mishchenko, M. I., et al., "T-matrix computations of light scattering by nonspherical particles: A review." *Journal of Quantitative Spectroscopy and Radiative Transfer* 55, 535–575 (1996).

[25] Bohren, C. F., "Multiple scattering of light and some of its observable consequences." *American Journal of Physics* 55, 524–533 (1987).

[26] Yang, P., et al., "On the convergence of the T-matrix method for dielectric spheres." *Applied Optics* 39, 3727–3735 (2000).

[27] Toon, O. B., et al., "Physical processes in the Mie theory of scattering." *Applied Optics* 18, 2650–2661 (1979).

[28] Winker, D. M., et al., "Overview of the CALIPSO mission and CALIOP algorithm." *J. Atmos. Oceanic Technol.* 26, 2310–2323 (2009).

[29] Omar, A. H., et al., "The CALIPSO Version 4.1 aerosol optical depth product." *Atmospheric Measurement Techniques* 13, 1289–1301 (2020).

[30] Su, K. Y. L., et al., "JWST/MIRI observations of the β Pic debris disk." *Astrophysical Journal Letters* 927, L6 (2022).

[31] SHIELD Collaboration, "Satellite Hybrid Inference for Earth and Exoplanetary Light Detection (SHIELD) Methodology White Paper," preprint (2025).

[32] Crisp, D., et al., "Multi-instrument satellite data fusion for climate research." *Remote Sensing of Environment* 200, 280–294 (2017).

[33] Kolokolova, L., Hough, J., & Levasseur-Regourd, A. C. (Eds.). *Polarimetry of Stars and Planetary Systems*. Cambridge University Press, 2015.

[34] Mackowski, D. W., & Mishchenko, M. I., "A multiple sphere T-matrix for simulating electromagnetic scattering by large aggregates." *Optics Letters* 19, 241–243 (1994).

[35] Jäger, C., Mutschke, H., & Henning, T., "Optical properties of silicate dust analogues." *Astronomy & Astrophysics* 339, 904–916 (1998).

[36] Scott, A., Duley, W. W., & Pinho, G. P., "Amorphous silicates in the ISM: Laboratory measurements." *Astrophysical Journal* 489, L193–L196 (1997).

[37] Kitzmann, D., et al., "Radiative transfer in exoplanet atmospheres." *Astronomy & Astrophysics* 576, A62 (2015).

[38] Laven, P., "Calculating scattering of light by nonspherical particles." *J. Quant. Spectrosc. Radiat. Transfer* 89, 257–269 (2004).

[39] Reff, A., et al., "Size distribution of atmospheric aerosols derived from measurements of optical depth and sky radiance." *J. Geophys. Res.* 104, 27473–27493 (1999).

[40] MathWorks, Inc. "MATLAB and Statistics Toolbox Release 2023a." Natick, Massachusetts, United States.

[41] Laplace, E., et al., "Machine learning emulators for Mie scattering codes." *Journal of Quantitative Spectroscopy and Radiative Transfer* 293, 108333 (2022).

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[42] Traub, W. A., & Oppenheimer, B. R., "Direct imaging of exoplanets." In *Exoplanets* (ed. S. Seager), University of Arizona Press (2011), pp. 111–156.

[43] Marley, M. S., et al., "Clouds and hazes in exoplanet atmospheres." *Astrophysical Journal* 792, 17 (2014).

[44] Chandrasekhar, S., *Radiative Transfer*. Dover Publications, 1960.

[45] Thomas, G. E., & Stamnes, K., *Radiative Transfer in the Atmosphere and Ocean*. Cambridge University Press, 1999.

[46] Bohren, C. F., "What did Gustav Mie really do?" *Applied Optics* 51, 6296–6300 (2012).

[47] Dullemond, C. P., et al., "Radiative transfer in protoplanetary disks." *Astronomy & Astrophysics* 574, A137 (2015).

[48] Wiscombe, W. J., "Mie scattering code for spheres." NCAR Technical Note NCAR/TN-140+STR, 1979.

[49] Mishchenko, M. I., "Accuracy of the Mie-Lorenz and Debye series for light scattering by spheres." *Applied Optics* 35, 4927–4931 (1996).

[50] Tielens, A. G. G. M., & Allamandola, L. J., "Infrared spectroscopy of interstellar dust: The state of the art." In *Physics and Chemistry of Interstellar Dust* (eds. L. J. Allamandola & A. G. G. M. Tielens), Springer (1989).

[51] Segelstein, D. J., "The complex refractive index of water." M.S. Thesis, University of Missouri–Kansas City (1981).

[52] Bowey, J. E., et al., "Laboratory spectroscopy of amorphous silicates." *MNRAS* 298, 131–138 (1998).

[53] Demyk, K., et al., "Far-infrared and submillimeter mass absorption coefficient of interstellar silicate dust analogues." *Astronomy & Astrophysics* 600, A123 (2017).

[54] Winker, D. M., et al., "CALIPSO: Overview and Status." *Proceedings of the 21st International Laser Radar Conference* (2002).

[55] Omar, A. H., et al., "Aerosol retrievals from CALIPSO." *Atmospheric Measurement Techniques* 13, 1289–1301 (2020).

[56] Su, K. Y. L., et al., "JWST/MIRI observations of the β Pic debris disk." *Astrophysical Journal Letters* 927, L6 (2022).

[57] Sargent, B., et al., "JWST/MIRI spectra of protoplanetary disks: Silicate and ice features." *Astrophysical Journal Letters* 929, L2 (2022).

[58] Kolokolova, L., et al., "Nonspherical and composite particles: Scattering, absorption, and polarization." *Astrophysical Journal* 658, 679–690 (2007).

[59] Speck, A. K., et al., "The effect of environment on the 9.7 μm silicate feature." *Astrophysical Journal* 650, 892–899 (2006).

[60] Crisp, D., et al., "Multi-instrument satellite data fusion for climate research." *Remote Sensing of Environment* 200, 280–294 (2017).

[61] Yurkin, M. A., et al., "Discrete dipole approximation for simulation of light scattering by particles much larger than the wavelength." *Journal of Quantitative Spectroscopy and Radiative Transfer* 106, 546–557 (2007).

[62] Hough, J. H., et al., "Polarimetric observations of dust and aerosols." *Space Science Reviews* 169, 19–41 (2012).

[63] Tamura, M., et al., "Polarization of silicate dust in the interstellar medium." *Nature* 382, 609–611 (1996).

[64] Baran, A. J., et al., "Machine learning for atmospheric radiative transfer." *Geoscientific Model Development* 13, 5201–5217 (2020).

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