RETRIEVAL OF OPTICAL CONSTANTS AT UV-VIS-NIR FOR MARTIAN DUST ANALOGUES BY MODELLING LIGHT SCATTERING.

J. Martikainen, J. C. Gómez Martín, O. Muñoz, *Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain (juliamar@iaa.es)*, **T. Jardiel, M. Peiteado,** *Instituto de Cerámica y Vidrio, CSIC, Madrid, Spain*, **M. Wolff,** *Space Science Institute, Boulder, Colorado, USA*, **and the RoadMap team.**

Introduction

Particle composition in light-scattering and radiative-transfer models is parameterized through the wavelength-dependent optical constants, i.e., the complex refractive indices ($m = n + ik$). The real part of the complex refractive index, n, describes the ratio of the speed of light in a vacuum to the phase velocity of light in the material, whereas the imaginary part, k, describes the absorption of light inside the material.

Optical constants are needed from modelling single-particle scattering within the atmospheric dust to simulating the global Martian climate. Reliable complex refractive indices of Martian dust are difficult to find in the literature for the wavelengths used in the simulations. Previous studies by Wolff et al. (2009) & (2010) have obtained optical constants from analysing the observed dust storm spectra at 258-2900 nm region by using cylindrical particle shapes, however, these values could not be supported with direct laboratory measurements.

In this work, we retrieve the complex refractive indices of three Martian dust analogues at UV-vis-NIR wavelengths by using the measured size distributions, diffuse reflectance spectra, and an advanced light-scattering model with realistic particle shapes. We compare the retrieved values to those in literature.

Samples and Size distributions

For this study, we selected three Martian analogues relevant to the atmospheric dust of Mars: JSC Mars-1 (Johnson Space Center regolith simulant), MMS-2 (Mojave Mars Simulant), and MGS-1 (Mars Global Simulant). Each sample represents a different region on Mars and has a distinctive chemical composition, texture, and color (see Fig. 1).

The JSC Mars-1 and MMS-2 simulants were processed to produce two well-defined narrow size distributions in the geometric optics region ($r >> \lambda$): a particle size fraction from 63 to 100 µm, and a second fraction from 20 to 40 µm in diameter. The MGS-1 simulant was processed until a particle size fraction from 20 to 40 µm was obtained.

We measured the size distributions of the final samples with a laser light scattering particle sizer (Malvern Mastersizer 2000). A detailed description of the particle sizer and the retrieval process can be found in Gómez Martín et al. (2020). In Fig. 2, we show the measured projected surface area distributions $S(r)$ and number distributions $n(r)$.

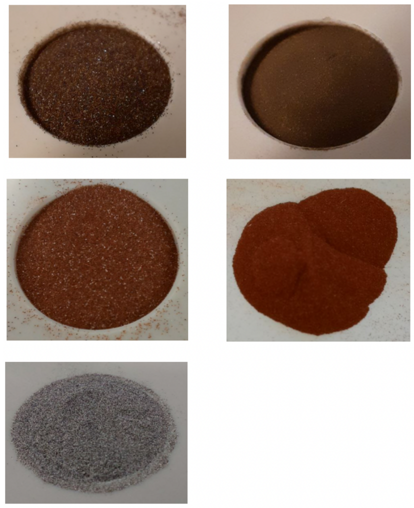

Figure 1: The Martian dust samples. Top row is the JSC Mars-1 sample with 63-100 µm (left) and 20-40 µm (right) size fractions, middle row is the MMS-2 sample with 63-100 µm (left) and 20-40 µm (right) size fractions, and bottom row is the MGS-1 sample with a 20-40 µm size fraction.

Spectral Measurements

The diffuse reflectance measurements were carried out over the range of 200 to 2000 nm using the Cary 5000 UV-vis-NIR integrating-sphere spectrophotometer at Centro de Instrumentación Científica, University of Granada. The instrument is equipped with a deuterium arc source for the UV wavelengths and a tungsten-halogen source for the vis-NIR region. Each measurement was calibrated using a polytetrafluoroethylene (PTFE) reflectance standard. We present the measured spectrum of the MGS-1 simulant in Fig. 3.

Model

To retrieve optical constants from a reflectance spectrum, a light-scattering model is needed for the sample

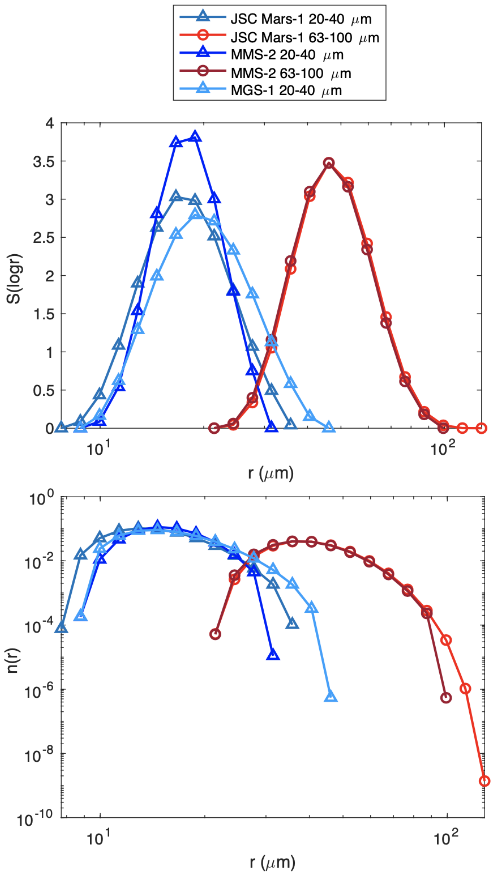

Figure 2: Projected surface area distributions (top) and number distributions (bottom) of the JSC Mars-1 20-40 μm and 63-100 μm fractions, the MMS-2 20-40 μm and 63-100 μm fractions, and the MGS-1 20-40 μm fraction.

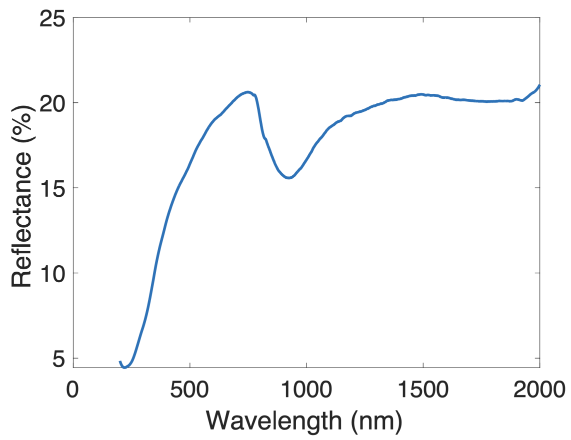

Figure 3: The measured reflectance spectrum of the MGS-1 sample.

particles. We derived the imaginary parts of the complex refractive indices, k, using a model based on the retrieval by Martikainen et al. (2018). The code was upgraded to take into account different size distributions. We fixed the real part of the complex refractive index to 1.5 as it does not change significantly at the modeled wavelength region.

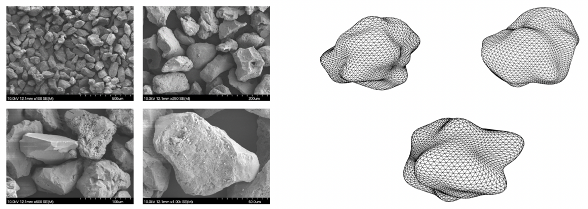

Figure 4: Example particle shapes used in the model (right) compared to the JSC Mars-1 63-100 μm size distribution FE-SEM image (left).

The retrieval was carried out with an optimization code that uses the measured absolute reflectance and the SIRIS4 (Muinonen et al. 2009; Lindqvist et al. 2018; Martikainen et al. 2018) ray tracer that simulates light scattering by Gaussian-random-sphere (GRS) particles larger than the wavelength of the incident light. The shapes of the GRS particles were defined by the auto-correlation function of the logarithmic radial distance, ν_G, and the standard deviation of the particle radius, σ_G (Muinonen et al. 2009). In our model, we used $\nu_G = 3$ and $\sigma_G = 0.2$ so that the model particles were as realistic as possible (see Fig. 4).

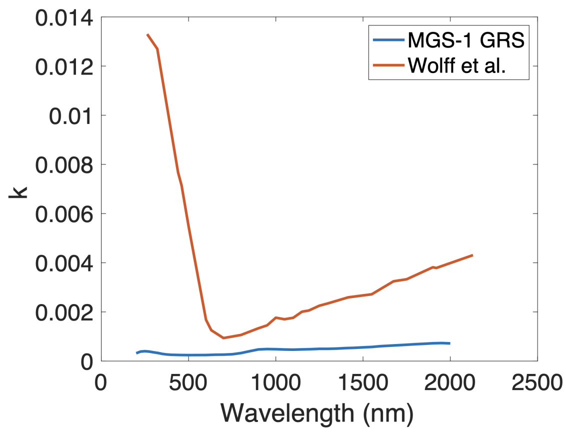

Figure 5: The derived k of the MGS-1 sample compared to the values retrieved by Wolff et al. (2009) & (2010).

Results and Discussion

The derived imaginary parts of the refractive indices for the MGS-1 sample are shown in Fig. 5 together with the values retrieved by Wolff et al. (2009) & (2010) that are widely used in the Martian atmospheric studies. The preliminary results indicate that the values retrieved with the advanced light-scattering model are much smaller than those obtained in previous studies. The differences can be partly explained by the choice of particle shapes: real dust particles are known to be irregular and thus using cylinders or spheres will introduce an error in the retrieved optical constants. Furthermore, the exact grain sizes in the observed dust storms are poorly known and may contain material different from the analogues that we used.

As the three samples used in this work are significantly distinct from each other, the retrieval gives a good estimation of the range of optical constants of Martian dust. In future studies, it will be important to use realistic values to accurately interpret laboratory measurements and in-situ observations.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101004052 (RoadMap).

References

Gómez Martín et al. (2020). Computational study of the sensitivity of laser light scattering particle sizing to refractive index and irregularity, *Journal of Quantitative Spectroscopy & Radiative Transfer*, **241**,106745.

Lindqvist et al. (2018). Ray optics for absorbing particles with application to ice crystals at near-infrared wavelengths. *Journal of Quantitative Spectroscopy & Radiative Transfer*, **217**,329–337.

Martikainen et al. (2018). Spectral modeling of meteorites at UV-vis-NIR wavelengths , *Journal of Quantitative Spectroscopy & Radiative Transfer*, **204**,144–151.

Muinonen et al. (2009). Light scattering by Gaussian particles with internal inclusions and roughened surfaces using ray optics. *Journal of Quantitative Spectroscopy & Radiative Transfer*, **110(14)**,1628–1639.

Wolff et al. (2009). Wavelength dependence of dust aerosol single scattering albedo as observed by the Compact Reconnaissance Imaging Spectrometer. *JGR Planets*, **114**, E00D04.

Wolff et al. (2010). Ultraviolet dust aerosol properties as observed by MARCI. *Icarus*, **208**, 143–155.