

Global-scale modeling of light scattering in the martian environment

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Abstract

The surface of Mars is covered in mineral dust, which gives the planet its recognizable red color. This dust gets uplifted to the atmosphere in storms with sizes ranging from local to global. The global dust storms (GDSs) are the most extreme in size and duration, often taking months for the atmosphere to clear up again. The roughest of these storms lift up and distribute enough dust for it to completely obscure the surface of the planet. GDSs are relatively infrequent, with there being only eight confirmed cases between the years 1950–2025.

This work provides modeling of past photometric and polarimetric observations of Mars under two conditions: one with a GDS, and the other with a calm atmosphere. In the calm atmosphere scenario, the observed signals are largely due to the visible regolith surface of the planet. The two scenarios can then be compared against each other to infer the change in photometric and polarimetric signals due to a global scale dust event on a rocky planet. The models will, in return, provide physical information of the scattering particles.

The modeling is performed with a Monte Carlo based Radiative Transfer Coherent Backscattering (RT-CB) code [1]. The studied wavelength is chosen to be 520 nanometers, which falls in the visual filter wavelength range, as defined by the Johnson–Cousins photometric system [2]. The measured scattering matrices of the MMS-2 Mars simulant samples are used as input for the scatterers in the simulation [3, 4]. Three different narrow size distributions are included in the analysis: small (S), medium (M), and large (L) samples, with effective radii of $0.3 \mu\text{m}$, $2.3 \mu\text{m}$, and $16.2 \mu\text{m}$, respectively. Photometric observations used in the work are phase curves, which show the intensity of scattered sunlight by Mars as a function of the light source–target–observer angle called the phase angle. Photometry from [5] and [6] are used for the calm and GDS conditions, respectively. Polarimetric observations are the observed degree of linear polarization, that is the portion of scattered light which is linearly polarized, as a function of the phase angle. These types of photometric and polarimetric curves are commonly used in studies of rocky Solar system bodies. The polarimetric datasets are those from [7] and [8].

Results for the GDS scenario are to be improved. The slope in the phase curve is consistently steeper than what is observed. The simulated polarimetric curves seem to align better with the clear atmosphere portion of the observational data. An inclusion of atmospheric ices, or grain alignment could be explanations to these discrepancies. Atmospheric vertical gradients in grain size are likely to improve the model accuracy if implemented. The calm atmosphere case provides more promising results. Both the simulated photometry and polarimetry align with observations. It is found that a weighed combination of the S, M, and L particle size distributions, with a large contribution from the M and L particles, is able to explain the observations.

References

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