Photometric Properties of Soils at the Zhurong Landing Area

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Introduction:

The Navigation and Terrain Camera (NaTeCam) onboard the Zhurong rover conducted extensive observations of soils widely distributed across the landing area during its traverse mission, under varying illumination and viewing geometries. These multi-angle observations contain valuable information on the surface scattering properties of the landing area. In this study, we selected data acquired over five sols during which NaTeCam performed panoramic imaging within a short time. A surface Digital Elevation Model (DEM) was generated from NaTeCam stereo images to calculate the illumination geometry for each pixel and to extract soils phase curves. Combined with a sky brightness model constructed using the DISORT radiative transfer model, corrections for diffuse sky light effects were applied. Based on the Hapke radiative transfer model and a parallel Monte Carlo algorithm, we retrieved the photometric properties of the surface soils at the Zhurong landing area, providing new in-situ photometric ground-truth data for Martian remote sensing research.

Data and Methods:

The NaTeCam consists of two cameras (left and right eyes), enabling the generation of stereo image pairs. Each camera has three bands (R: ~650 nm, G: ~550 nm, B: ~480 nm) [1]. In this study, we used the Level 2B radiance data from NaTeCam for analysis. Based on the stereo pairs, we constructed a surface Digital Elevation Model (DEM) of the landing area and calculated the local illumination geometry for each pixel, including incidence angle, emission angle, and phase angle. Using this information, we extracted the phase curves of the most widely distributed soils at the landing area (as shown in Fig. 1).

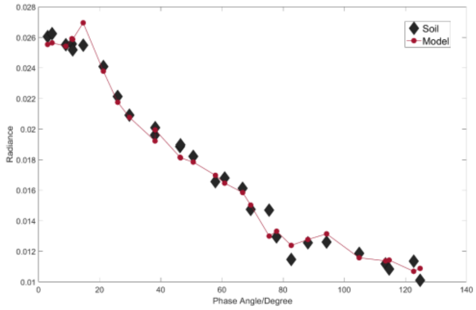

Fig.1 Phase curve of soil for Sol 58 in the R band. The black diamonds represent the phase curve extracted from in-situ NaTeCam observations, while the red line shows the modeled result under the same illumination geometry.

To account for the contribution of diffuse skylight, we incorporated this effect into the surface reflectance modeling, thereby removing the influence of diffuse sky light. The sky brightness model was developed using the DISORT radiative transfer model [2] and the Martian atmospheric scattering parameters reported by Ockert-Bell et al. (1997) [3]. For the surface reflectance modeling, we adopted the Hapke radiative transfer model and used a two-term Henyey–Greenstein (HG) function to represent the single-scattering phase function [4,5]. A parallel Monte Carlo method was employed to randomly sample different scattering parameters, simulate the surface scattering process at the Zhurong landing area, and compare the simulated results with the in-situ phase curves. This enabled retrieval of the five scattering parameters (ω, b, c, h, θ) that characterizing the surface scattering behavior. It should be noted that our parameter c is defined consistently with the Hapke model, and its relation to the backward scattering fraction c (denoted here as *cb*) used by Johnson et al. is given by $c = 2 \times cb - 1$ [6-9].

Results:

Based on the NaTeCam data acquired over five different Martian sols, we retrieved the five parameters (ω, b, c, h, θ) that characterize the surface photometric properties. Fig. 2 shows the inversion results for the parameters **b** and **c** in the single-scattering phase function. The photometric properties of the landing area soils are generally similar to those of particles classified as *spheres with moderate internal scattering*. An outlier in the **b-c** parameters ($b \approx 0.85$, $c \approx -0.2$) was derived from Sol 05 data, during which observations were conducted around the lander. The detected soil may have been disturbed and compacted by the exhaust plume during the lander's descent. Excluding the Sol 05 result, the average scattering parameters at the Zhurong landing area are **ω=(0.60(R band), 0.42(G band), 0.38(B band))**, **b = 0.28**, **c = 0.33**, **h = 0.07**, and **θ = 14**.

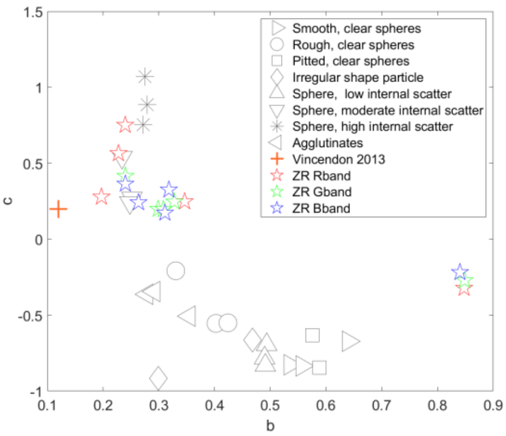

Fig.2 **b** versus **c** in Zhurong landing area. The grey background dots represent artificial particles from McGuire and Hapke (1995) [10]. The orange cross indicates the global mean value derived by Vincendon (2013) [11] using OMEGA and CRISM data.

References: [1]. Liang X. et al.(2021) Space Science Reviews. [2] Stamnes K. et al. (1988) Appl. Opt. [3] Ockert-Bell M. et al. (1997) JGR [4] Hapke B. (1993) Cambridge Univ. Press. [5] Hapke B. (2012) Cambridge Univ. Press. [6] Johnson JR. (2006a) JGR. [7] Johnson JR. (2006b) JGR. [8] Johnson JR. (2015) Icarus. [9] Johnson JR. (2021) Icarus. [10] McGuire A. and Hapke B. (1995) Icarus. [11] Vincendon M. (2013) Planetary and Space Science.