Regional photometric properties on asteroid Ryugu in visible wavelength

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Introduction: Hayabusa2 revealed the detailed shape of the Cb-type asteroid 162173 Ryugu. The surface of Ryugu is divided into east and west regions by a trough [1,2,3]. The western region (160 - 290˚E) is called the Western bulge, and the wider eastern region is called the Eastern Hemisphere. Ryugu has an equatorial ridge, and the ridge spans across both east and west regions [1,2,3]. A model for the evolution of the ridge has been proposed, in which pebbles/regolith from the ridge have migrated towards the mid-latitudes [4]. The Western bulge has fewer craters [5] and fewer boulders (D>5 m) [6] than the Eastern hemisphere. The photometric analysis of Hayabusa2 Telescopic Onboard Navigation Camera (ONC-T) data reported that the Western bulge has a slightly higher v-band (0.55 μm) reflectance than the Eastern hemisphere when observed at a solar phase angle of 19˚ [2]. However, the ONC-T opposition observations (zero phase angle observations) show a similar range of values in both regions for the normal albedo [7]. We therefore hypothesize that this difference in optical properties between the east and west regions may be due to surface properties other than the albedo of the surface materials. To help understand the evolutionary history of these regions (Eastern hemisphere, Western bulge, and Equatorial ridge), we conducted a regional photometric analysis of the ONC-T data using the Hapke photometric model [8,9].

Data and method: We used seven sets of Ryugu global observations (2.1 m/pixel) acquired in the ONC-T v-band. The phase angles of the observations ranged from 0 to 42˚. In order to reduce the number of free parameters, we fixed three of the five parameters of the Hapke photometric model [8,9]. The fixed parameters were: opposition surge strength B_0 = 0.98, opposition surge width h = 0.075, and phase function parameter b = 0.388. These values are the global averages from a recent photometric study [10]. The two free parameters were the single scattering albedo, w, and the macroscopic roughness, θ-bar. A 32 x 32 m (4x4˚) mesh was defined on the Ryugu surface, and values of the radiance factor (I/F) and photometric angles (incident (i), emission (e), and phase (α) angles) were collected from the ONC images from the pixels within each mesh. Averaging binning was used to mitigate the bias of the data distribution in the three dimensional photometric angle space (Binning width: $\Delta i = \Delta e = 1$˚; $\Delta \alpha = 0.1$˚ for α = 0-2˚, $\Delta \alpha = 0.2$˚ for α = 2-5˚, and $\Delta \alpha = 1$˚ for α >5˚). Finally, Hapke model fitting (Levenberg-Marquardt method) was performed for each mesh to determine w and θ-bar.

Results: The spatial distribution of w appears similar to that of the normal albedo. On the other hand, the spatial distribution of θ-bar was similar to the reflectance map in [2], which was made from observations at α=19˚. This suggests that a difference in surface roughness/texture at small scales (cm to μm order) may exist between the east and west regions. We also found that the ridge has smaller θ-bar values than the Eastern hemisphere. This feature is consistent with the pebbles/regolith migration hypothesis [4]. The present analysis shows that the regional differences in photometric properties can be detected in the

ONC-T data. Further investigation of the history of the Eastern hemisphere, Western bulge, and ridge will require comparison with other roughness-related studies (e.g., densities of crater/boulder, thermal infrared data, and LIDAR data).

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