Icarus 208 (2010) 20–30

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Probable swirls detected as photometric anomalies in Oceanus Procellarum

Yu. Shkuratov [a,*], V. Kaydash [a], S. Gerasimenko [a], N. Opanasenko [a], Yu. Velikodsky [a], V. Korokhin [a], G. Videen [b], C. Pieters [c]

[a] Astronomical Institute of Kharkov V.N. Karazin National University, Sumskaya 35, Kharkov 61022, Ukraine
[b] Space Science Institute, 4750 Walnut St., Suite 205, Boulder, CO 80301, USA
[c] Dept. of Geological Sciences, Brown University, Providence, RI 02912, USA

ARTICLE INFO

Article history:
Received 13 September 2009
Revised 8 January 2010
Accepted 27 January 2010
Available online 4 February 2010

Keywords:
Moon, Surface
Photometry
Regoliths

ABSTRACT

Images of the lunar nearside obtained by telescopes of Maidanak Observatory (Uzbekistan) and Simeiz Observatory (Crimea, Ukraine) equipped with Canon CMOS cameras and Sony CCD LineScan camera were used to study photometric properties of the lunar nearside in several spectral bands. A wide range of lunar phase angles was covered, and the method of phase ratios to assess the steepness of the phase function at different phase angles is applied. We found several areas with photometric anomalies in the south-west portion of the lunar disk that we refer to as Oceanus Procellarum anomalies. The areas being unique on the lunar nearside do not obey the inverse correlation between albedo and phase-curve slope, demonstrating high phase-curve slopes at intermediate albedo. Low-Sun images acquired with Lunar Orbiter IV and Apollo-16 cameras do not reveal anomalous topography of the regions, at least for scales larger than several tens of meters. The areas also do not have any thermal inertia, radar (70 and 3.8 cm), magnetic, or chemical/mineral peculiarities. On the other hand they exhibit a polarimetric signature that we interpret to be due to the presence of a porous regolith upper layer consisting of dust particles. The anomalies may be interpreted as regions of very fresh shallow regolith disturbances caused by impacts of meteoroid swarms consisting of rather small impactors. This origin is similar to one of the hypotheses for the origin of lunar swirls like the Reiner-γ formation. The photometric difference between the shallow and pervasive (Reiner-γ class) swirls is that the latter appear to have a significant amount of immature soils in the upper surface layers.

1. Introduction

The strong backscattering of sunlight by the Moon over a large range of phase angles has been a topic of investigation for many distant years (e.g., Barabashev, 1922; Rougier, 1933; Fedorets, 1952; van Diggelen, 1964; Gehrels et al., 1964; Akimov, 1979). The amplitude of the backscattering surge varies over the lunar surface and reveals a correlation with roughness on all scales. Thus, photometric measurements of the Moon potentially suggest knowledge of the structure and microstructure of its surface, including information about lunar swirls which are albedo formations having no topographic signatures on scales larger than several tens of meters (e.g., Schultz, 1976; Schultz and Srnka, 1980).

To describe the bidirectional reflectance R of a surface, the photometric function $F(i, e, \varphi)$ is used: $R(i, e, \varphi) = R_0F(i, e, \varphi)$, where i and e are the angles of incidence and emergence, respectively, and φ is the azimuth angle between planes of incidence and emergence. The value R_0 is the reflectance at a standard illumination/observation geometry; e.g., R_0 can be considered as $R(0, 0, 0)$. In lunar photometry another suite of angles is often used to describe the illumination/observation geometry: the photometric longitude γ, the photometric latitude β, and the phase angle α (the relationship between (i, e, φ) and (α, β, γ) is presented below). We note that the values β and γ are functions of lunar surface coordinates (selenographic coordinates).

It is convenient to express the photometric function $F(\alpha, \beta, \gamma)$ as follows (e.g., Hapke, 1993): $F(\alpha, \beta, \gamma) = f(\alpha)D(\alpha, \beta, \gamma)$, where $f(\alpha)$ is the brightness phase function and $D(\alpha, \beta, \gamma)$ is the disk function. The phase function describes a component that is independent of the photometric coordinates (β, γ). The disk function describes the global brightness distribution over the lunar disk. "Global" means ignoring albedo variations and relates only to the global spherical shape of the Moon; i.e. large-scale topography is also ignored. To study the phase function $f(\alpha)$ using different lunar images one needs to compensate for the global brightness distribution, i.e. a measured distribution $F_{measured}(\alpha, \beta, \gamma)$ should be divided by a theoretical or empirical function $D(\alpha, \beta, \gamma)$: $f(\alpha) = F_{measured}(\alpha, \beta, \gamma)/D(\alpha, \beta, \gamma)$.

* Corresponding author. Fax: +380 57 700 5349.
E-mail addresses: shkuratov@astron.kharkov.ua, shkuratov@vk.kh.ua (Y. Shkuratov).

0019-1035/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.icarus.2010.01.028