CLAVIUS CRATER WATER E. A. Feoktistova, S.G. Pugacheva and V. V. Shevchenko, Sternberg Astronomical Institute, Moscow University, Universitetski pr., 13, 119992, Moscow, Russia, Hrulis@yandex.ru;

Introduction: The SOFIA telescope detected infrared radiation in the area of the Clavius crater (58°37′ S, 14°44′ W) on the Moon [1] during observations in 2018. It is assumed that it may be associated with the presence of water molecules in the regolith in this area. The water content in the surface layer of the soil in the area of the Clavius crater is estimated at 100-400 ppm. Collisions of meteorites and comets with the lunar surface or the interaction of solar wind protons with hydroxyls in the regolith are named as possible sources of water molecules [1]. Clavius Crater is located in the southern part of the visible hemisphere of the Moon. The crater was formed during the Nectarian period, that is, its age is more than 3.85 billion years. The crater has a diameter of 230 km and a depth of 4.9 km. In the area of the Clavius crater there are craters Rutherford (61° 09′ S, 12° 15′ W) and Porter (56° 09′ S, 10 ° 11′ W), as well as 9 satellite craters. The floor of the Clavius crater is covered with lava. There are several central peaks in the central part of the crater.

Illumination conditions: We investigated the illumination condition in the Clavius crater area in the same way as it was done in [2]. For this, we used the data on the heights of the lunar surface in this area, obtained by the LOLA altimeter of the LRO probe [3].

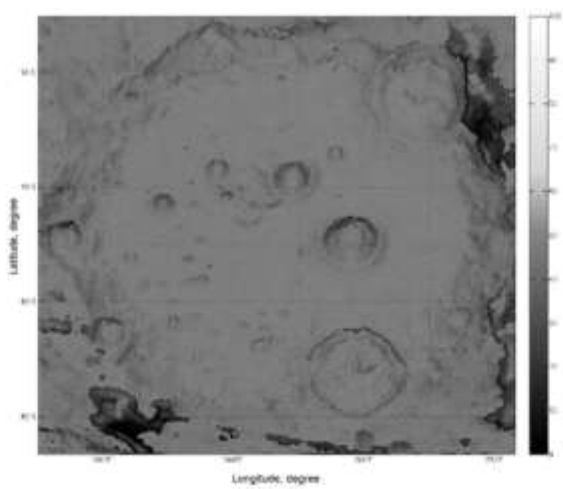

Figure. 1. Illumination conditions in the area of the Clavius crater. The duration of the lunar day is taken as 100%.

The distribution of illumination in the area of the Clavius crater is shown in Fig. 1. We found that there are no permanently shaded areas in the area.

However, in the area of Clavius crater, there are surface areas that are illuminated by the Sun during only 10% of a lunar day. Such sites are located on the outer side of the southern and western slopes of the Clavius crater, as well as in the northern parts of small satellite craters such as Clavius D, Clavius C, Clavius L and others. The area of such sites in this area reaches 4.5 km^2. Most of the Clavius crater area is illuminated by the Sun for ≥ 50% of a lunar day (Fig. 1).

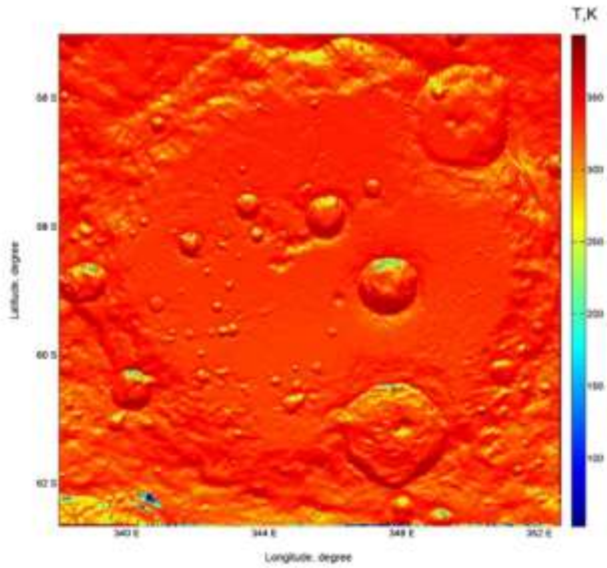

Figure. 2. Distribution of maximum temperatures in the area of the Clavius crater.

Temperature regime in the area of the Clavius crater: We calculated the temperature regime in the area of the Clavius crater. Figure 2 shows the distribution of maximum temperatures in this area. The values of daytime temperatures here lie in the range of 70 K-380 K. Nighttime temperatures in this area are in the range of 70 K- 110 K. The lowest values of daytime temperatures (200 K- 250 K) are found in the area of the northern parts of the inner slopes of the satellite craters Clavius D, C, N, J, K, L, as well as Rutherfurd crater. Daytime temperatures of the flat bottom of the crater reach values of 300 K- 350 K (Fig. 2).

Our results show that the existence of water deposits on the surface is impossible in the area of the Clavius crater. This confirms the assumption [1] that water molecules can be found in voids between regolith particles in the soil.

Migration of water molecules: The volatile compounds in the polar regions of the Moon could be accumulated as a result of the endogenous activity such as subsoil degassing and volcanic activity on the planet's surface. On the Moon, a lot of proof of the past volcanic activity are discovered. Exogenous sources are the solar wind and crashes with meteors, asteroids, and comets. The solar wind protons can create the molecules of water and hydroxyl during the interactions with the regolith [4].

The migration of volatile compounds in the exosphere of the Solar System celestial bodies has been the subject of numerous studies [5-7]). We have modeled the water molecules motion in the exosphere of the planet by the Monte-Carlo method. Modeling in this research included 1000 000 water molecules. The water molecule on the surface can be destroyed as a result of photolysis or can evaporate as a result of thermal desorption. Velocity of emission of molecules was determined by the Maxwell-Boltzmann distribution as a function of surface temperature, similar to [7]. The temperature of the surface in the region where the molecules were situated was calculated, using the position of the Sun and the local time. The direction of molecule motion and the angle of the starting trajectory were defined randomly. During the calculation of the particle's flying up angle, the roughness of the surface has not been considered. In [5], the roughness of the surface was accepted as the same for Mercury and for the Moon and equaled 5° on average. We assumed that if the particle emergent angle was less than 5°, the particle was considered not to take off at the moment and the emergent simulation continued until the value of the emergent angle exceeded 5°. The molecules that flew up were migrating in the planet's exosphere through ballistic trajectories. The trajectory and the duration of each molecular jump were calculated as they have been in [8]. During the flight, molecules could be destroyed during photolysis, or could evaporate from the exosphere if their speed overpassed the escape velocity for the Moon. If the molecule wasn't destroyed in photolysis and if its speed were not enough to leave the exosphere, it went down back on the surface. The coordinates of the landing location were calculated according to [5] and comprised the rotation of the Moon on its axis and around the Sun during a particle's flight time. If the particle was landing on the "night" side of the planet, it's been considered that it stays in its location until the sunrise, and period of time when the particle stays on the surface included the time of the "night" left until the sunrise lights up "night" side.

It was shown above that the existence of water ice deposits on the surface in the area of the Clavius crater is impossible. Molecules entering the crater area during the day remain on the surface for an average of ~ 10^{-4} s before either take off again or are destroyed as a result of photolysis on the surface. In this case, a possible source of water could be molecules that migrated to this area during the moonlit night, which lasts 14.75 Earth days. According to our estimates, the proportion of such molecules is 0.1% of the total number of water molecules migrating in the lunar exosphere.

References:

[1] Honniball C.I. et al. (2020) Nat Astronomy https://doi.org/10.1038/s41550-020-01222-x. [2] Pugacheva S.G et al. (2018) *Cos Res*, 56, 169 -179. [3] http://ode.rsl.wustl.edu/moon/. [4] Crider D.H. and Vondrak R.R. (2003) *JGR, 108*, doi:10.1029/2002JE002030. 5079. [5] Butler B. J. (1997) *JGR, 102*, 19283 – 19291. [6] Moores J. E. (2015) *JGR*, *121*, 46 - -60. [7] Schorghofer N. (2015) *Phys Rev*., *91*, 052154. [8] Wurz P.and Lammer H. (2003) *Icarus 164*, 1-13.