INTERSTELLAR MATTER ON THE MOON. V.V. Shevchenko, Sternberg State Astronomical Institute, Lomonosov Moscow State University, Moscow, 119992, Russia (vladislav_shevch@mail.ru)

Introduction: Hydrogen has been inferred to occur in enhanced concentrations within permanently shadowed regions and, hence, the coldest areas of the lunar poles. Neutron flux measurements of the Moon's south pole region from the Lunar Exploration Neutron Detector (LEND) on the Lunar Reconnaissance Orbiter (LRO) spacecraft were used for hydrogen mapping of the lunar south pole area. The final value corresponds to a water (as ice) content of ~4% by weight (), which is in good agreement with independent estimates of the water content associated with the LCROSS Centaur impact site [2]. The maximum total water vapor and water ice within the instrument field of view was 155 kilograms. Given the estimated total excavated mass of regolith that reached sunlight, and hence was observable, the concentration of water ice in the regolith at the LCROSS impact site is estimated to be 5.6 % by mass. Authors of work [2] say: "In addition to water, spectral bands of a number of other volatile compounds were observed, including light hydrocarbons, sulfur-bearing species, and carbon dioxide (H_2S/H_2O, NH_3/H_2O, SO_2/H_2O, and CO/H_2O). Of interest is the indication from this preliminary analyses that some volatiles other than water are considerably more abundant (some by orders of magnitude) than the ratios found in comets, in the interstellar medium, or predicted from gas-gas reactions in the protoplanetary disk".

Comet impacts on the Moon: The nature of diffuse albedo anomalies on the lunar surface that look like "swirls" is one of most interesting mystery in current lunar studies. There are two main classes of hypothesises of the swirl origin: formation of the swirls in the regions antipodal to large impact basins (1), and formation of the swirls in result of cometary impacts (2). The first hypothesis proposes that swirls represent regions whose higher albedo have been preserved due to deflection of the solar wind ion bombardment by strong crustal fields. The most likely magnetization mechanism was proposed by Hood [3], in which the ionized vapor cloud produced in a hypervelocity basin-forming impact expands around the Moon and concentrates the pre-existing ambient magnetic field at the basin antipode. For example, the data obtained by the *Lunar Prospector* showed that swirl features are associated with magnetic anomalies and they lie on regions antipodal to the Imbrium, Serenitatis, and Crisium basins. The second hypothesis does not suggest correlation between the swirl locations and the regions antipodal to basins. Gold and Soter suggested a mechanism of a local magnetic field origin on the Moon in result of cometary impact [4]. The local shock produced by collision of the main mass of a comet nucleus with the Moon will indeed occur just when the ambient solar wind fields have been strongly enhanced, as the large partially ionized cometary coma is compressed against the lunar surface. Schultz and Srnka [5], Bell and Hawke [6], Shevchenko [7] Pinet at al. [8] considered that swirl patterns on the lunar surface could be related to the imprint of recent cometary impacts. In order to investigate the features of the swirl distribution along lunar surface there were identified and mapped swirl locations within regions where they were observed. The areas of all identified swirl fragments were measured and statistical analysis of the distribution was performed. The more strong correlation is observed for youngest large basins: Orientale and Imbrium. The swirls are absent in region antipodal to youngest (second age group, more younger than Imbrium basin) but small (320 km) Schrodinger basin. The swirl area is observed on region antipodal to Serenitatis basin, but any swirl markings are absent on regions antipodal to Humorum, Hertzprung, and Humboldtianum basins in spate of similar age and diameter of them. On the other hand, there are two cases of absence of correlation between swirl areas and regions antipodal to impact basins (for small swirl formations). The Reiner Gamma formation is most obvious example of that the correlation mentioned above is not statistically strong and do not exclude the swirl origin associated with external reason, such as cometary impact. So, the most convincing model for the swirls origin seems to be lunar surface contact with the gas/dust coma of comets passing by or falling onto the Moon. It's possible to show that the most probable scenario for origin of the water ice polar deposits is the falls of young comets onto the Moon during comet showers. Characterized by their low average density and large nuclei as well as in the considerable mass of the matter they brought even several falls of such young comets could provide for the revealed ice concentration on the lunar pole.

Comet matter on the Moon: In particular the comet Hale-Bopp has become a sufficiently convincing confirmation of the existence of the bodies with gigantic nuclei. Thus its parameters can serve as the first interaction data for the quantitative assessment of the lunar ice with a comet origin. The lowest limit of the nucleus substance density can be less than 0.1 g/cm^3 if this comet nucleus rotation period is 11.47 hours [9]. The fall of a body with a density of 0.1 g/cm^3 and an impact velocity of 40 km/s (these parameters are similar to those of the Hale-Bopp comet) results in a collision with the same physical parameters as a solid body with a density of 1.0 g/cm^3 and a collision velocity of 10.5 km/s does [10]. According to the other model the initial temperature of the vapour collision formed cloud will be about 6300^{o}C. The most probable thermal velocity of the atoms will be about 5.5 km/s. This means that the dissipating part of the cloud mass will be 0.9 of its total mass taking into account the parabolic velocity for the Moon of 2.4 km/s. Nucleus diameter of the Hale-Bopp comet was estimated to be about 40 km. Consequently after a similar body with a density of 0.1 g/cm^3 falls on the lunar surface a vapour cloud with a mass of about 3.4x10^{18}g is formed. The water melting, surface, and crush-up energies are neglected. According to the above given assessment the mass of the volatile compounds which stay in the lunar environment will be 3.4x10^{17}g. Assuming that these substances, distributed equally above the lunar surface, will further cool and deposit in the regolith upper layer, the assessed mass will be about 10^{10} g per a square kilometer. Fig. 1 shows fragments of swirl in Mare Ingenii region. (Image from LROC http://wms.lroc.asu.edu/lroc).

Fig. 1

It is obvious that the subsequent preservation of the deposit is only possible in cold traps located near to the poles. Thus for the given assessments of the total area for both the southern and northern poles where the neutron spectrometer of the *Lunar Prospector* fixed the ice presence (3700 km^2), the calculated mass of the volatile deposits of comet origin can be up to 3.7x10^{13} g for each giant comet fall. If common mass of lunar polar ices is about 3x10^{15}g it is needed about 300 falls of new giant comet to form such amount of deposits.

Whence the comet came into inner part of Solar System: The Hale-Bopp comet is a similar potential impactor. In that time Szab´o et al. [11] detected comet Hale–Bopp at 30.7 AU, which is the most distant detection of a comet so far. It's position between Kuiper Belt and Oort Cloud. Oort Cloud comets are currently believed to have formed in the Sun's protoplanetary disk and to have been ejected to large heliocentric orbits by the giant planets. Detailed models of this process fail to reproduce all of the available observational constraints, however. In particular, the Oort Cloud appears to be substantially more populous than the models predict. Levison et al. presented numerical simulations that show that the Sun captured comets from other stars while it was in its birth cluster [12]. The results imply that a substantial fraction of the Oort Cloud comets, perhaps exceeding 90%, are from the protoplanetary disks of other stars!

Conclusions: We know that other stars have circumstellar clouds of dust or icy bodies that may be analogous to the Kuiper Belt in the Solar System. So, we can propose that a particles of a dust may be brought on the Moon by giant comet from other star system!

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