EXPERIMENT FOR LUNAR PROBE SYSTEM HUNVEYOR-HUSAR PLANETARY SCIENCE EDUCATION PROGRAM: OBSERVATION OF THE CHANGING LEVITATING DUST CLOUD ABOVE THE LUNAR SURFACE AFTER LOCAL SUNSET AND BEFORE LOCAL SUNRISE. Gy. Hudoba[1], Á. Lang[1], Sz. Bérczi[3], B. Kurilla[4], S. Hegyi[5], T. P. Varga[6], P. Vizi[7], H. Hargitai[3],. [1]Óbuda University, Alba Regia Univ. Center, H-6000, Székesfehérvár, Budai út 45, Hungary (hudoba.gyorgy@amk.uni-obuda.hu), [2]Széchenyi István Gimnázium High School, H-9400 Sopron, Templom u. 26. Hung. (mmecurie95@gmail.com), [3]Eötvös University, Institute of Physics, Dept. Materials Physics, Cosmic Materials Space Res. Gr. H-1117 Budapest, Pázmány P. s. 1/a. Hungary (bercziszani@ludens.elte.hu), [4]National University of Public Service, Military Technological Ph.D. School, H-1101 Budapest, Hungária krt. 9-11., [5]Pécs University, Dept. Informatics, H-7624 Pécs, Ifjúság u. 6., [6]VTPatent Kft. H-1111 Budapest, Bertalan L. u. 20. Hungary, [7]Wigner Institute, H-1525 Budapest, Konkoly-Thege M. u. 29-33.

Introduction: Micrometeorite impacts grinds surface rocks and the produced lunar soil is excited by solar radiations (UV radiation, solar wind), which electrostatically produce the levitating lunar dust cloud as observed first by Surveyor-5 [1,2]. Related experiments for a Hunveyor educational space probe instruments were reported [3,4,5]. We constructed experiments to observe how the levitating dust cloud change after local sunset and before sunrise on the Moon. An educational counterpart of these experiments, tailored for the Hunveyor-Husar educational probe system, is able to observe floating dust on Earth. A laser source and a camera is the basic instrumentation for the Pathfinder type probe system of Hunveyor lander contact with Husar rover.

Horizon glow observed by Surveyors; traverse of the levitating dust over Apollo LEAM: In the 1960s at least three Surveyor probes observed the horizon glow: Surveyor-5, -6 and -7. These observations were made after passing of the local terminator (day and night range), and showed the levitating dust layer far away at the horizon. Apollo 17 LEAM experiments also indicated: „primarily detected fine lunar dust grains transported at slow speeds across the lunar surface at local sunrise."

Electrostatically charged particles are levitating because they are repelled by a like-charged (+) surface. By this proposal we had to aims: (1) teaching electrostatic effects on the illuminated dusty surfaces and (2) carrying out experiments: how to observe the changes in levitating dust-pillow, when appear and how can it be visualized that dust-pillow gradually advances in the vicinity of a space probe. (Both forward and backward scattering light effects were considered.) The horizon glow is produced by the forward scattering light on the dust.

Physical characteristics of the levitating dust layer: Illuminated lunar surface is charged because of the solar UV radiation causing electric field in the order of a few V/m [6]. However, even higher electric field forces being generated at the boundary region between dark and lightened surfaces due to the changing of the charging during the traverse [7,8]. This can occur during a shadow moving but it can be the case in every two weeks period of sunset or sunrise events. It would be an interesting challenge to observe the changing density of the levitating dust pillow over surface during the moving boundary between the illuminated and the dark surface region. The comparison of the cases „beginning of the lunar night" and the „end of the lunar night" would be also interesting. Therefore we planned an experiment to mount on Hunveyor and Husar educational space probe assemblage in order to observe the density changes of the levitating dust layer. This work continued our earlier surface physics and chemistry measuring robotics [9,10].

Measuring assemblage: The main components of our instrumentation consist of a laser source, a mirror, a lens and a camera. The measurements are based on the optical measuring of the intensity of the (forward) scattered laser light coming from the levitating dust grains.

Measuring scattered light from the dust particles: The experiment designed in such a way that it can find great number of levitating practices soon after the local sunset and before sunrise. The local - vertical profile of the dust distribution can be measured by a system when the compact laser light source is activated. In this case the intensity of the scattered light maps the cross section of the vertical dust density profile.

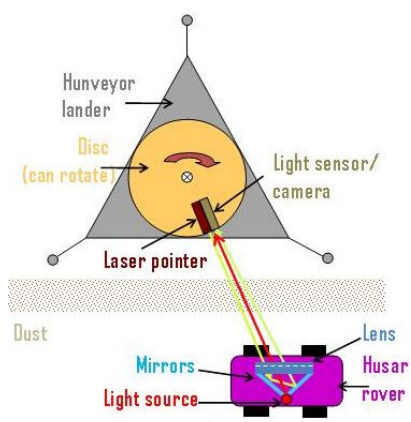

Fig. 1. The measuring arrangement for the levitating dust layer observation by a Hunveyor-Husar team.

The laser source and the camera are mounted on the (standing) Hunveyor lander while the Husar rover moves farther away, carrying a retroreflector like optical apparatus. The main difference from the retroreflector is that we

need a vertical curtain of light for mapping the dust distribution versus height, instead of a narrow beam. The modification means: using a cylindrical lens in front of a retroreflector.

According to our calculations, in the Moon's gravitational field a few (two) electron charge is enough to levitate about 1 micrometers particles, supposing about 10 V/m electric field and 3 kg/m^3 density. (For 5 micrometers grains we need 200, or much stronger electric field.) Because the size of the particles are larger than the wavelength producing by the laser, the highly asymmetric Mie scattering predominates. The scattering produces sharper and more intense forward lobe for larger particles. (The conjecture is that dust particles have the largest concentration in the height of 1 meter above the lunar surface.)

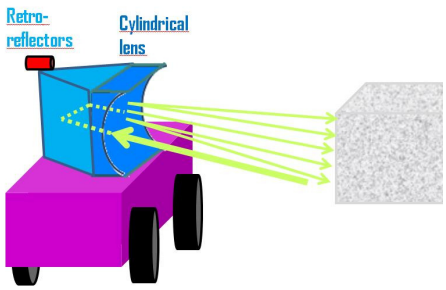

Fig. 2. Measuring arrangement for the Husar rover with the cylindrical lens, retroreflector and light path.

Description of the planetary surface experiment procedure: (1) Step one: the Husar rolls away a few tens of meters, carrying the modified retroreflector; (2) Step two: the DDM (Dust Distribution Mapping) located on the HUNVEYOR aims the retoreflector; (3) Step three: the DDM takes dark reference picture (without laser ON); (4) Step four: the DDM takes pictures with laser ON. The procedure above repeats for different distances and in different directions.

The laser source used in terrestrial counterpart experiment: The above described experiments can also be conducted on Earth, for educational purpose, with some limitations. For terrestrial realization it may be important to use a laser device producing yellowish green or yellow spectrum. We have used a CW laser with 589nm wavelength (easily observable in almost all kinds of weather conditions). The power of the laser is 50 mW average and the peak power can be even 96 mW. The basic divergence of the laser is 1.6 mrad. The system produces light at this wavelength by frequency-summing from two continuous-wave Nd:YAG lasers, where one is emitting at 1064 nm, and the other at 1319 nm. The Nd:YAG lasers reach high single-frequency power by using the injection-locking technique, in which a low-power single-frequency beam is resonantly amplified. The two wavelengths are summed in the nonlinear material lithium triborate (LBO), again using resonant techniques. [1] In the terrestrial counterpart experiment first we used an optical array in the front of the laser light source, we produced a laser line with 9.37 degrees opening angle for the experiment.

Asteroidal case: Electrostatic dust motion might be also present on airless asteroids [11, 12, 13, 14] where similar experiments can be conducted in microgravity.

Summary: The educational activity related to the Hunveyor-Husar program was to design the experiment in theory and to build both terrestrial realization and the Hunveyor-Husar experimental arrangement.

References: [1] Criswell, D. R. (1972): Horizon glow and motion of Lunar dust. *Lunar Science III*. p. 163. LPI, Houston. [2] Criswell, D. R., De, B. R. (1977), Intense localized charging in the lunar sunset terminator region: Supercharging at the progression of sunset, *J. Geophys. Res*.,82, 1005. [3] Földi T, Bérczi Sz. (2001): Quasiatmospheric Electrostatic Processes on Dusty Planetary Surfaces: Electrostatic Dust and Water molecule Coagulation … *26th NIPR Symposium Antarctic Meteorites*, NIPR, Tokyo, p. 21-23. [4] Földi T., Bérczi Sz., Koris A., Kovács B., Hegyi S., Kovács Zs. I., Roskó F. (2001): New experiment plans to the Hunveyor educational planetary landers of universities and colleges in Hungary. *32nd LPSC,* #1301, LPI, Houston; [5] Földi T., Bérczi Sz. (2002): Electrostatic Modelling of the Lunar Soil - How Electrostatic Processes in the Lunar Dust May Generate the Ion-Cloud Levitating above the Surface on the Moon - Experiments in a Model Instrument. *Acta Min. Petr., Szeged*, **XLIII**. 55-58. [6] Wang, X., Horányi, M., Sternovsky, Z., Robertson, S., and Morfill, G.E. (2007): A laboratory model of the lunar surface potential near boundaries between sunlit and shadowed regions. *Geophys. Res. Lett. 34,* L16104. [7] Sickafoose, A. A., Colwell, J. E., Horányi, M., Robertson, S. (2001): Dust particle charging near surfaces in space. *32. LPSC*. #1320, LPI, Houston. [8] Grün, E., Horanyi, M., Sternovsky, Z. (2011): The lunar dust environment. *Planetary and Space Science, 59*, pp. 1672-1680. [9] Lang Á., Szalay K., Erdélyi S., Nickl I., Panyi T. G., Makk Á., Bérczi Sz. (2009): Chemistry Experiment Measuring (Ph) of the Planetary Soil by The Husar-5, NXT-Based Rover Model of the Széchenyi István High School, Sopron, Hungary. *40th. LPSC,* #1325, LPI, Houston; [10]Lang Á., Cseh R., Varga T., Szalay K., Erdélyi S., Erdősi F., Nickl I., Panyi T. G., Kiss D., Bérczi Sz. (2010): Optical-Chemistry Experiment Measuring Gases Liberated by Heating from the "Planetary" Soil by the Husar-5 NXT-Based Rover Model of Széchenyi István High School…. *41st LPSC*, #2139, LPI, Houston [11] Hartzell C.M, Scheeres D.J, Wang X (2012) Electrostatic dust motion on asteroids: current understanding. *Asteroids, Comets and Meteors conference*, # 6055. [12] Miyamoto H., Kargel, J.S. Fink, W., Furfaro R. (2008) Granular processes on Itokawa, a small near-Earth asteroid: implications for resource utilization, *Proc. SPIE 6960, Space Exploration Technologies,* 69600I, doi:10.1117/12.784634; [13] Haugsjaa A.L, Colwell J.E. (2006) Modelling electrostatic dust transport on Eros. *37th LPSC*, #1225; [14] Tepliczky I, Kereszturi A (2002) Signs of change in the electrostatic sedimentation of Eros. *33th LPSC*, #1656.