STUDYING MERCURY SURFACE COMPOSITION BY MERCURY GAMMA-RAYS AND NEUTRONS SPECTROMETER (MGNS) FROM BEPICOLOMBO SPACECRAFT. A.S. Kozyrev[1], L.I. Gurvits[2], M.L. Litvak[1], A.A. Malakhov[1], M.I. Mokrousov[1], I.G. Mitrofanov[1], A.A. Rogozhin[3], A.B. Sanin[1], A. Owens[4], V.N. Schvetsov[5], V.I. Tretyakov[1], A.V. Vostrukhin[1], [1]Institute for Space Research, 84/32 Profsojznaja str., Moscow 117997, Russia, kozyrev@mx.iki.rssi.ru; [2]Joint Institute of VLBI in Europe, P.O. Box 2, 7990 AA Dwingeloo, The Netherlands; [3]All-Russia Scientific Research Institute of Mineral Resources named after N.M. Fedorovsky, 31 Staromonetniy per., Moscow 119017, Russia; [4]ESA/ESTEC, Keplerlaan 1, 2201 AZ, Noordwijk,The Netherlands; [5]Joint Institute for Nuclear Research, 6, Joliot-Curie, 141980, Dubna, Russia.

Introduction: Mercury is the third large body of the solar system together with Moon and Mars, which elementary composition might be studied by orbital observations of induced gamma-ray and neutron emission. The nuclear emission is produced by bombardment of energetic particles of galactic cosmic rays, which freely propagate from the interstellar space inward the inner volume of the solar system. Particles collide with nuclei inside 1-2 meters of subsurface of Moon, Mars and Mercury, and produce new nuclei and secondary high energy neutrons at 1 – 20 MeV energy range [1-3]. In the leakage process, secondary neutrons produce induced gamma-rays due to in-elastic scattering and capture reactions with soil-composing nuclei.

There are also three natural radioactive isotopes of K, Th and U in the substance of celestial bodies, which produce gamma-ray lines by spontaneous radioactive decay. Therefore, one may measure from nearby spacecraft induced gamma-rays at nuclear lines of soil constituting nuclei, together with nuclear lines of natural radioisotopes, to determine the soil composition of an atmosphere-less celestial body. Also, one may measure the energy spectrum of a leakage flux of secondary neutrons from the surface of such a body to determine the content of hydrogen in its shallow subsurface, because efficiency of moderation is mainly dependent on the content of H. Other terrestrial planets, Earth and Venus, do not produce induced nuclear emission from the surface because it is protected by thick atmospheres.

Science tasks: There are two science tasks of MGNS investigation, as part of MPO/BepiColombo mission:

- to determine the subsurface composition model(s) with a surface resolution of 400 km comparable with the relief features on Mercury and sufficient for testing composition anomalies at large impact basins and at hot meridians on the planet.

- to determine of regional distribution of volatile depositions on the polar areas of Mercury, which are permanently shadowed from the Sun and to provide a global map of hydrogen abundance.

There are nine known models of the elementary composition, which have been proposed for the Mercury. To test these models for particular geomorphological regions of Mercury, MGNS should provide statistically significant data for the set of reference nuclear lines, which are the most distinct for these models. Three natural radioactive isotopes ^{40}K, ^{232}Th and ^{238}U characterize conditions of the planet creation and also allow us to select the best scenario of Mercury surface formation. Finally, we have to study the content of hydrogen on the surface of Mercury, which was either implemented after billion years of solar wind and cosmic rays bombardment, or deposited on poles as water ice.

Instrument description: The MGNS instrument consists of neutron and gamma-ray spectrometers [4]. Three sensors of thermal and epithermal neutrons are made with similar ^{3}He proportional counters (SD1, SD2 and MD) but have polyethylene enclosures and cadmium shield for MD, cadmium shield for SD2 and no coverage for SD1. The fourth sensor for detection of high energy neutrons with energy about 1-10 MeV uses organic scintillator stylbene (CS/N) with cylindrical shape with size ø30×40 cm. For separation of neutron signal from charge particals in the stylbene crystal, it is surrounded by plastic scintillation shield.. Both signals from stylben and plastic scintillators are collected by single photomultiplier tube. The separation of different signals is produced by special electronic board with pulse-shape analyzer.

The spectrometer of gamma-rays (GRS) contains scintillation crystal $LaBr_3$ for detection of gamma-ray photons with very high spectral resolution of 3 % at 662 keV. This level of resolution is the best for scintillation-based gamma-ray spectromrters. The total mass of MGNS instrument is 5.2 kg; it consumes 4.0 W of power and provides 9.0 Mb of telemetry data per day. The main view of mechanical design of MGNS instrument is presented in the Figure 1.

Instruments development status: At present, the MGNS instrument is in a stage of the final developments of mechanical and electronic design. The instrument team successfully gone trough MGNS PDR stage. In accordance of instrument development time schedule, the structural and thermal unit and electrical interface simulator of the MGNS instrument will be created abd tested.

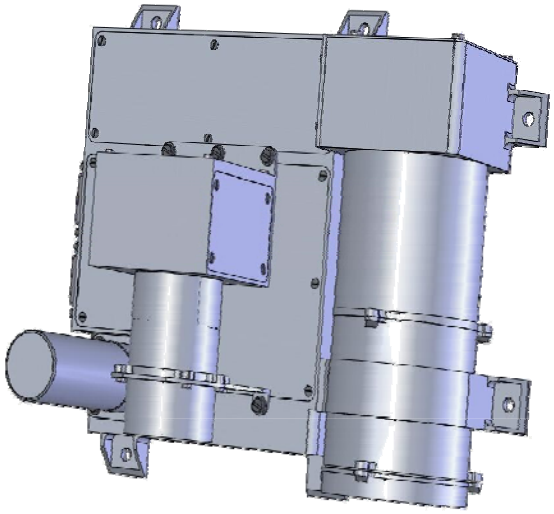

Figure 1. The mechanical design for MGNS instrument.

Conclusions: MGNS instrument is shown to have necessary capabilities to characterize the elementary composition of subsurface layer of Mercury and to test the presence of water ice deposits at both polar regions of the planet. The data from MGNS is complementary with the data from another instruments onboard Mercury Planetary Orbiter, which constitute the group of instruments for studies of geochemistry of subsurface [5]. They are SIMBIO-SYS and MERTIS for mineralogy and MIXS for elemental abundance. The data from BELA for Mercury altimetry will also be very useful to determine the contours of permanently shadowed polar regions, which are possible cold traps for water vapor deposition. Therefore, the synergism of the suite of MPO science instrumentation will enforce the capability of each particular investigation..

Instrument MGNS is Russian-made Russian-paid contribution of Federal Space Agency into the ESA's mission BepiColombo to Mercury.

Instrument MGNS will have space protoflight. Very similar neutron and gamma-ray spectrometer NS HEND will be installed on board of Russian spacecraft "Phobos-Grunt" for Phobos landing and soil return. Instrument NS HEND will have practically the same set of four neutron sensors, as MGNS, and its gamma-ray spectrometer with be down-scaled option of one for MGNS. The crystal of $LaBr_3$ of 2 inches will be used for NS HEND in comparison with 3 inches crystal for MGNS. The main measurements of NS HEND will be performed in the surface of Phobos, when exposure time of landing site could be as long as the time of surface operations. Therefore, smaller sensitivity of gamma-ray detector for NS HEND will be compensated by much longer exposure time for measurements of the spectrum of gamma-rays.

Experiment with NS HEND will allow to test the main design elements of MGNS in the conditions of space flight. The scheduled launch date of October 2009 of "Phobos-Grunt" still allows to take into account for the MGNS all experience of NS HEND operations. On the other hand, the data from these two similar experiments would be very useful for direct comparison of elemental composition of Mercury and Phobos. Difference and/or similarity of elemental abundance of these two bodies, together with available data for Moon and for Mars, will allow to make important step in understanding of origin and evolution of celestial bodies in the internal part of Solar System.

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