NUMERICAL INVESTIGATION OF THE LEAKAGE GAMMA-RAY AND NEUTRON FLUXES FROM MARIAN MOONS. M. Naito[1] N. Hasebe[2] H. Nagaoka[1] K. Yoshida[1] J. Ishii[1] D. Aoki[1] H. Kusano[2], [1]School of Advanced Science and Engineering, Waseda Univ., 3-4-1 Okubo Shinjuku-ku, Tokyo 169-8555, Japan (comnm@akane.waseda.jp), [2]Research Institute for Science and Engineering, Waseda Univ., Tokyo 169-8555, Japan

Introduction: The origin of two Martian moons, Phobos and Deimos, is still mysterious. There are two leading ideas of giant impact and captured asteroid, for the origin of the two moons. However, any conclusive evidences to decide the definitive idea have never been obtained. If the giant impact made the Martian moons, it is considered that a large fraction of the Martian moons has similar composition to Mars, and volatile elements such as hydrohen derived from the impactor were evaporated because of impact heat. On the other hands, if the primitive asteroids were captured by the Martian gravity, chondritic compositions, which enrich with volatile elements (e.g., H, S), are expected as elemental compositions of the Martian moons.

According to Martian meteorite samples [1], Shergotty tend to be rich in Si and Ca while H is depleted. In contrast, chondrites are considered to be poor in Si and Ca and rich in volatile elements such as H [2]. Therefore, the ratios of Si/Fe and Ca/Fe, and H content are powerful indicators to distinguish between Martian composition and chondritic composition. Gamma-ray and neutron spectrometer is one of most powerful tool to measure elemental composition (H, Si, Ca, Fe, K, Th) of planetary surface. To obtain the elemental concentrations of the Marian moons' surface, gamma-ray and neutron spectrometer is effective.

In this work, we have investigated the leakage gamma-ray and neutron fluxes induced by Galactic Cosmic Rays (GCRs) from the Martian moons by numerical simulations. Gamma-ray and neutron fluxes emitted from planetary surface changes depending on its elemental composition and the amount of water hydrogen.

Simulation setting: Transportation of the GCRs- and their secondaries of gamma-rays and neutrons was calculated by using the Monte Carlo simulation code PHITS (Particle and Heavy Ion Transport code System) [3] and the ICNT (Intra-Nuclear Cascade of Liége) nuclear interaction model [4]. Schematic drawings of the simulation settings are shown in Fig. 1. The calculation was divided into two parts to shorten calculation time. The GCRs were injected toward 20 m × 20 m × 20 m cubic target from 20 m × 20 m plane on the target surface to calculate induced gammar-ray and neutron fluxes (Fig. 1(a)). The emitted gamma-rays and neutrons were injected toward the detectors, respectively, to estimate energy deposition in the detectors (Fig. 1(b)). The injected GCR energy spectrum corresponds to that of solar minimum phase.

Firstly, the compositions of target material were assumed as average compositions of Martian meteorites, and CI chondrite is considered to be the most primitive chondrite [1, 2]. As was menthioned in the introduction, since there are large differences in the abundance of Si and Ca between Martian meteorites composition and CI chondrite composition, their gamma-ray count ratios to Fe were used to distinguish Martian from primitive chondritic samples. To investigate the effects of H concentration in the neutron fluxes, H atoms corresponding to water were added to one of the dried elemental composition of Martian meteorites “Shergotty” and CI chondrite in the range of 0-10000 ppm. Shergotty were selected since it was the majority in Martian meteorites.

Results and conclusions: The Si/Fe and Ca/Fe of weight fraction and gamma-ray conunt rates induced by neutron capture and inelastic scattering for each elemental composition were shown in Fig. 2. The results of Martian meteorites show high values of the Si/Fe and Ca/Fe while that of CI chondrite tend to have small values. Statistical precision required to decide whether the Martian moons have Martian or chondritic composition is 20 % in the Si/Fe ratio. Since there is a large variation in the Ca/Fe ratio, whether the Ca peak exists or not can also decide the Martian origin.

Count rates of thermal (< 0.5 eV) and epithermal (0.5 eV-500 keV) neutrons, when the H atom concentration in Shergotty and CI chondrite compositions was changed, are shown in Fig. 3. Those count rates decrease with increasing the H-concentration. Epithermal neutron count rate is effective to determine the H-concentration since it is especially sensitive to the amount of H content [5]. The differences in the neutron count rates become clear in 1000 second measurement when the difference of the H-concentration in sample become over 100 ppm. The statistical error when observed by that interval is about 1 %. By using these neutron fluxes, the H-concentration will be determined by short time measurement such as landing for sample return since the count rate of the neutrons is large comparing to that of the gamma-rays.

Japanese mission to the Martian moons “Mars Moon eXploration (MMX)” is planned to reveal the origin of the Martian moons. The mission is a sample return mission to pick up rock and soil samples from the Martian moons to the Earth. The returned sample will be analyzed in details by cutting edge technology in laboratories to obtain geochemical informations of the Martian moons. The mission directly to explore the Martian moons is a first attempt. Our gamma-ray and neutron spectrometer will obtain an important restraint of the origin by remote observation before landing.

Summary: The gamma-ray and neutron spectrometer is proposed as a payload of Japanese Martian moon exploration to give a restraint of the origin by remote sensing before landing for sampling. The leakage gamma-ray and neutron fluxes from Martian and chondritic samples, as most probable candidates, were estimated by numerical simulations. Whether the Martian moons are derived from Martian composition or primitive composition will be suggested not only by the gamma-ray ratios of Si/Fe and Ca/Fe, but also by the H contents observed by neutron fluxes.

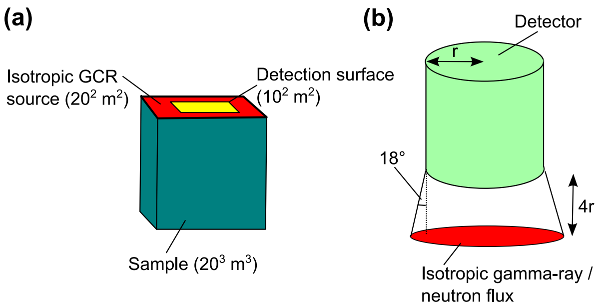

Figure 1. Schematic drawings of geometry of the numerical simulations. Source size in (b) was decided by calculating solid angle of Phobos at 20 km altitude. The gamma-ray detector was assumed as ϕ63 mm × 63 mm thick. The neutron detector was assumed as ϕ100 mm × ϕ51 × 76 mm thick.

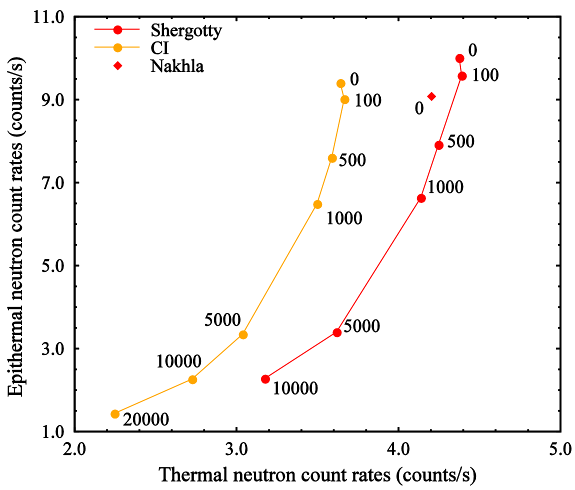

Figure 3. Simulation of thermal and epithermal neutron fluxes when H-concentration was added to Shergotty and CI chondrite compositions. A plot of Martian sample used for the gamma-ray estimation is also shown in this figure. Values representing the H-concentration for each sample are shown in the figure.

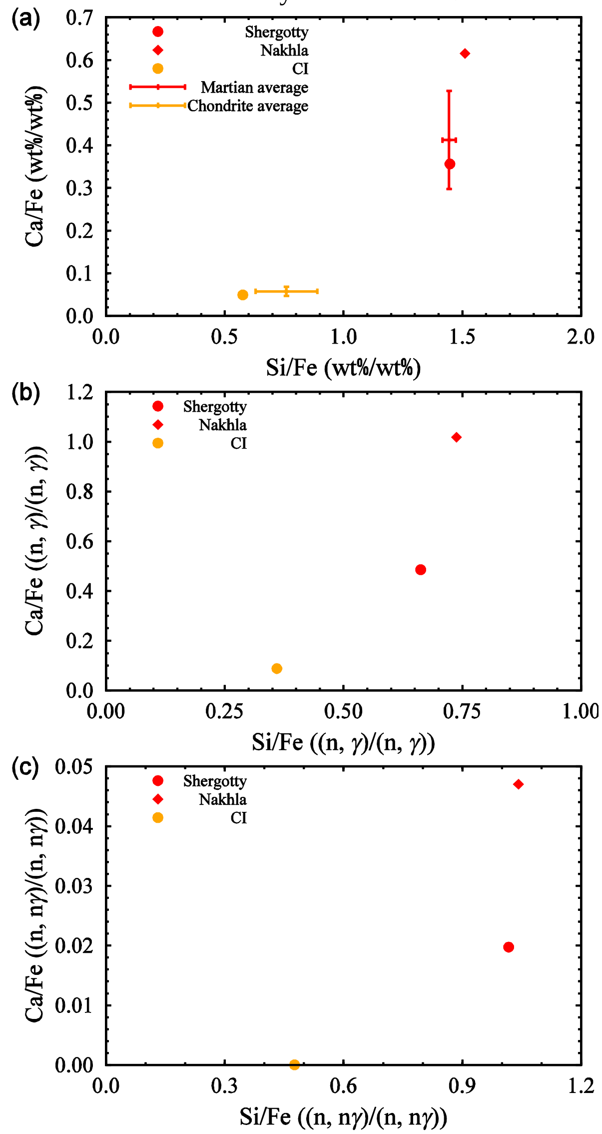

Figure 2. Comparisons of the Si/Fe and Ca/Fe concentration ratios between Martian meteorites and CI chondrite. Red and yellow plots represent Martian meteorites and CI chondrite, respectively. Red and yellow lines representing Martian and chondrite average are also shown in (a). (a) shows the ratios of weight fraction. (b) and (c) show the ratios of calculated gamma-ray fluxes induced by neutron capture and inelastic scattering, respectively.

References: [1] NASA Martian meteorite Compendium, http://curator.jsc.nasa.gov/antmet/mmc/. [2] Jorosewich E. (1990) *Meteoritics*, 25, 323-337. [3] Sato T. et al. (2013) *J. Ncl. Sci. Technol.*, 50, 913-923. [4] Boudard A. et al. (2013) *Phys. Rev. C87*, 014606. [5] Prettyman T. H. et al. (2012) *Sci.*, 338, 242-246.