RADON OUTGASSING FROM THE SURFACE OF MERCURY EVIDENCED BY ITS LOW TH/U RATIO. P.-Y. Meslin[1], P. Peplowski[2], G. Deprez[1], [1]Institut de Recherche en Astrophysique et Planétologie (IRAP), UPS/CNRS/CNES, Toulouse, France (pmeslin@irap.omp.eu); [2]Johns Hopkins University, APL, Laurel, MD, USA.

Introduction: After preliminary measurements acquired during its three flybys of the planet [1], the MESSENGER spacecraft has made the first measurement of the Th and U content of the surface of Mercury with its Gamma-Ray Spectrometer (GRS) [2]. Surprisingly, it measured a Th/U ratio of 2.5 ± 0.9 [2], which is significantly lower than its chondritic value, whose estimates vary between 3.53 ± 0.10 [3] and 3.9 ± 0.2 [4]. The bulk Th/U ratio of terrestrial planets is expected to be close to the chondritic value, or slightly larger as uranium can behave as a moderately volatile element [3], and the crustal Th/U ratio of terrestrial planets does not deviate much from this value (e.g., Th/U~3.9 in the Earth's crust, ~3.7 in lunar rocks [5], ~3.75 to 4.4 in SNC meteorites [6,7]). A large scale process that could have led to a fractionation of these two lithophile, incompatible elements, and which was proposed for Mercury, is the depletion of the relatively more volatile UO_3 species upon formation and evolution of this planet at high temperatures, or preferential incorporation of U in the core. However, these processes would lead to an increase of the Th/U ratio, contrary to what is observed. Therefore, the strongly sub-chondritic Th/U ratio characteristic of the Hermean surface remains to be explained. We propose hereafter that it actually reflects a relatively strong outgassing of radon from the regolith, and we show that the mobility of radon should be considered to derive accurate uranium concentrations of Mercury's crust.

Influence of radon exhalation on the Th/U ratio: The measurement of ^{238}U by gamma-ray spectroscopy is actually made through the analysis of two of its decay products, ^{214}Bi and ^{214}Pb, assuming secular equilibrium between these species in the regolith. These two radionuclides are decay products of ^{222}Rn, a radioactive gas (with 3.8 days half-life) that can escape from its mineral host by recoil and then diffuse to the surface and migrate through the exosphere, leading to an excess of ^{214}Bi and ^{214}Pb in the upper few centimeters of the regolith. If radon migration to the surface is efficient enough, the presence of these unsupported radionuclides can significantly increase the apparent uranium content and strongly bias the Th/U ratio. The very same process was proposed to explain the abnormally low Th/U ratio measured on Mars by *Mars Odyssey* GRS [8], and was confirmed by a refined analysis of uranium lines at several energies [9], which revealed a characteristic decrease of the apparent U/Th ratio with gamma-ray energy.

Modeling of radon transport: In order to simulate this effect, we have developed a 3D thermal model of the subsurface of Mercury (based on [10]), coupled to an adsorption-diffusion gas transport model. It uses as inputs the radon emanation factor of lunar samples (< 1%) [11] and the adsorption coefficient measured by [12], which is strongly dependent on temperature. Its output (a time-variable map of the exhalation rate) is injected into a Monte-Carlo code simulating the exospheric transport of radon (incl. surface adsorption) and the escape or implantation of its decay products into the surface. One of the outputs of the model is a prediction of the apparent U/Th ratio as a function of γ-ray energy (i.e., the ratio that would be measured by a spacecraft after correcting for the attenuation of γ-rays through the upper cm of the regolith).

Preliminary results and comparison to the lunar case: When running the model with typical lunar values for the emanation factor, regolith specific surface area and regolith thickness (~5m), we find an increase of the apparent U/Th ratio, which is larger at lower energies, but not to the same extent as that observed by MESSENGER (Fig. 1). However, the high temperatures of the Hermean surface may lead to a larger emanation factor of radon: an emanation factor of ~3% accounts well for the observed U/Th ratio. Alternatively, since the diffusion length of radon can probably reach ~10m at ~300 K [12], the high apparent U/Th can also be explained by the presence of a thicker regolith, which would be consistent with the analysis of the topographic roughness of Mercury, which indicates that the regolith of Mercury may be 3 times thicker than the lunar one [13].

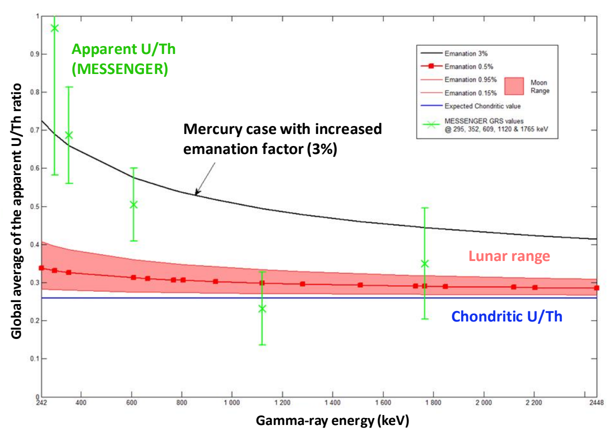

Fig. 1: Apparent U/Th vs. γ-ray energy (revised values from [2]): comparison between MESSENGER values and outputs of the model for the lunar case and for a case with a larger emanation factor.

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