**Subject title:**

**Radon in extraterrestrial environments: Application to DORN / Chang'E 6**

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***Presentation of the subject:***

The noble radioactive gas radon-222 (Rn), produced in the pore space of rock and soil by alpha disintegration of Ra-226 in the U-238 decay chain, and its progeny are a powerful tool to trace the transport of gases, fluids and aerosols in the Earth's lithosphere, hydrosphere and atmosphere. Similar applications can be considered on other planetary bodies, since Rn has been detected on Mars [1,2], Mercury [3] and the Moon [4]. At the Moon surface, enigmatic variations of Rn and polonium (Po) measured from lunar orbit indicate ongoing outgassing events whose origin remains to be explained. In the Martian atmosphere, the Rn distribution is controlled by its source term and the atmospheric circulation, and the Po-induced radioactivity of Martian dust provides a unique way to trace its atmospheric transport [1]. To better constrain the Rn flux outgassing from a planetary body and understand differences between planets, an improved assessment of its source term (emanating power) and transport properties in regoliths is needed. The DORN experiment (*Detection of Outgassing RadoN*) onboard China's Chang'E 6 lunar mission, led by P.-Y. Meslin at IRAP, provides an ideal opportunity to study Rn in extraterrestrial environments, since Rn will be measured *in situ* and returned samples from the landing site will be available for laboratory studies and comparison to *in situ* data. This PhD is aimed at preparing the interpretation of DORN data and measurements of returned samples.

To study Rn emanation and adsorption in extraterrestrial environments where Ra-226 concentration and the mass of available samples are small, the use of alpha radioactivity instruments with high sensitivity [5,6] under relevant pressure and temperature conditions is necessary. This can be done on analogue or artificial samples [7], meteorites [8,9] or returned samples. With DORN, the first alpha spectrometry measurement of Rn and Po at the Moon surface is planned for 2024, as well as radioactivity measurement on a small fraction of returned samples from the lunar regolith.

First, the metrological activity will consist in developing and improving the measurement method of Rn emission from small (<10 g) to extremely small (<0.1 g) mass samples under extraterrestrial conditions (inert atmosphere, low temperature and pressure). Rn will be trapped cryogenically in the scintillating liquid contained in dedicated flasks. A high-sensitivity method measuring Po-214 period by liquid scintillation has been developed by B. Sabot at LNHB [5,6], but the detection limit will need to be improved by one or two orders of magnitude. Promising avenues such as the installation of a lead or active (cosmic VETO) shielding, the development of a compact photomultiplier-based instrumentation and the use of the *Pulse Shape Discrimination* (PSD) technique will be explored. This PhD is expected to provide a breakthrough in the radiological characterization of geological and extraterrestrial samples.

Various analogue samples of the lunar regolith and meteorite samples will be used. The meteorite samples (intact or powdered) will be selected in the collection of the National History Museum of Vienna in Austria in collaboration with L. Ferrière. Comparison will be done with U and Ra concentrations obtained at the LAFARA laboratory (OMP, Toulouse) in collaboration with the team of P. van Beek. Once the protocol established and test phases validated, unequaled Rn measurements will be done on returned lunar regolith samples (Apollo, Chang'E 5 and 6).

Second, nurtured by these new results, the modelling activity will improve significantly Rn transport models on planetary bodies considering diffusion, adsorption, source term and temperature dependence. Outputs will be compared with DORN *in situ* measurements [6] and will be necessary to achieve DORN top science objectives. The model will be applied to other planetary bodies such as Mars and Mercury, smaller objects (planetesimals, asteroids) and to the history of a meteorite.

The unprecedented Rn emission values on extraterrestrial samples will be compared with meteorite or analogue data and other datasets such as noble gases concentration. The developed method may be applied to the study of other noble gases in extraterrestrial environments. This work will help to quantify the possible effect of Rn leakage on U-Pb dating. This PhD will be an asset to applied concerns in space science, environmental radioactivity and the industry.

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3. Meslin et al 2018 LPI Contrib No 2047
4. Gorenstein et al 1973 Science 179:4075
5. Sabot et al 2016 Appl Radiat Isot 118:167-174
6. Pierre et al 2021 Metrologia 58:06015
7. Meslin et al 2011 Geochim Cosmochim Acta 75:2256-2270
8. Girault et al 2017 Geochim Cosmochim Acta 208:198-219
9. Sadaka 2022 M Sc thesis IPGP-UPC
10. Meslin et al 2020 51st Lunar Planet Sci Conf 1741