ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title :	Hyperspectral remote sensing of the arid environments on Earth and Mars
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Host lab/Team:	**IPGP – Planetary and Space Science – UMR 7154**
Financing:	**Doctoral contract with or without teaching assignment**

Presentation of the subject

Present-day Earth and ancient Mars share certain geological environments, with arid climates and slightly moist soils. Hyperspectral remote sensing of their surfaces allows the detection and spectral characterization of primary minerals of the original crust, as well as secondary hydrated phases that trace a variety of geochemical conditions related to atmospheric, hydrological and volcanic processes. On Mars, dozens of regions of interest, whose morphological and mineralogical features indicate past aqueous activity, have been studied in detail for more than a decade by ESA's Mars Express (2003-2024), NASA's Mars Reconnaissance Orbiter (2006-2023), and ESA's TGO/ExoMARS missions, producing an exceptional harvest of remote sensing data. However, due to the strong influence of surface physical conditions on the spectra and the general lack of ground truth, the interpretation of mineral signatures is sometimes ambiguous and the quantitative estimation of mineral abundances is uncertain. On Earth, analogous desert sites have been the subject of geophysical, geological, and hydrological studies, both in situ and by remote sensing, also generating a wealth of images, spectra and related data.

In this context, the dissertation will have two main objectives: (i) to improve our ability to map surface mineral composition in contrasting arid environments in relation to surface physical properties, such as sub-pixel surface roughness and soil/rock microtexture and (ii) to undertake comparative studies of the geological environments of Mars and Earth. It will also be part of the preparations for the Biodiversity hyperspectral space mission, which will acquire images of the Earth with a spatial resolution of 10 m.

The Asal-Ghoubbet rift (Republic of Djibouti) is an arid region of planetary interest in Africa due to its igneous lithology (basaltic and rhyolitic lava flows), hydrothermal alteration, Holocene evaporitic deposits (gypsum and halite), and a salt lake. The dissertation is based on four EnMAP hyperspectral images of the rift acquired between January and June 2024 (Guanter et al., 2015). From these atmospherically corrected images, we plan to identify the minerals present on the surface and to derive quantitative mineralogical maps at a resolution of 30 m/pixel. For this purpose, state-of-the art methods for linear/nonlinear unmixing based on signal processing (Heylen et al., 2014) or machine learning (Rasti et al., 2022) will be used. These maps will be interpreted in conjunction with the other products resulting from the analysis of recent work (Labarre, 2017; Labarre et al., 2019 ; Nguyen, 2024; Nguyen et al., 2025). As part of the CNES-funded CAROLInA and SURFACEs projects, a large dataset has been acquired on the Asal-Ghoubbet rift. It includes reflectance spectra measured in the laboratory on soil and rock samples taken from about twenty sites, their mineralogical composition determined by X-ray diffraction, millimeter-scale digital elevation models, and a 1:50,000 scale geological reference map. A description of the spatial variation in microtexture and granularity of surface materials has been derived from the analysis of 21 multi-angular Pleiades 1B images acquired in January 2013 and sampling the surface BRDF.

The mineralogical composition and microtexture of surface materials, combined with morphological interpretation, will provide a tracer of the geological processes (volcanism, hydrological cycle, wind erosion) that have shaped this region and similar regions on Mars (Fernando et al., 2016). Finally, simulations of the BRDF of desert surfaces using the CESBIO's DART-Lux ray-tracing model (Wang et al., 2022) will give us a better understanding of the ability of hyperspectral (and multi-angular) remote sensing to extract the compositional and physical parameters of igneous basaltic environments undergoing alteration activity in desert climates. This applies to EnMAP, but also to Mars orbiting sensors such as the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on MRO and future instruments of this type.

Candidate profile

- Engineer or MSc student in Remote Sensing / Planetary science / Geophysics / Physics
- Interest in land and planetary surfaces, radiative transfer modeling, radiometric measurements, image processing
- Autonomy, rigor, good knowledge of spoken, read and written English
- Mobility: The dissertation will be carried out mainly in Paris (IPGP), with extended stays in Grenoble (IPAG)

Contact

The dissertation will be co-supervised by Prof. Stéphane Jacquemoud (IPGP, jacquemoud@ipgp.fr) and Dr. Sylvain Douté (IPAG, sylvain.doute@univ-grenoble-alpes.fr). Please send an email to these two people, attaching your CV, a motivation letter and Master's grades.

References

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