Laboratory spectroscopy study in support of data analysis of OVIRS and OTES instruments on board the OSIRIS-REx mission

Studio di spettroscopia in laboratorio a sostegno dell'analisi dati degli strumenti OVIRS e OTES a bordo della missione OSIRIS-Rex

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General Scientific background:

Asteroids and their role in the origin of Life

Major advances in our understanding of the origin of the solar system, and how solar system processes and materials shaped the origin of Life on Earth can be obtained only by an unaltered sample from a primitive body analysed on Earth with the most precise instruments. Asteroids contain abundant organics and volatiles, and are widely believed to be the most primitive "rocky" material present in the solar system. They appear to have been formed in a region of the solar nebula rich in frozen volatiles, possibly as far as the Kuiper Belt, and have been subsequently captured in their present locations following the migration of the giant planets. This migration is thought to be the cause of the Late Heavy Bombardment with the deliver of building blocks of life on Earth and possibly on other bodies of the Solar System.

OSIRIS-REx mission

The OSIRIS-Rex spacecraft launched in September 2016 will result in a rendezvous with carbonaceous asteroid 101955 Bennu (Apollo asteroids group) in August 2018. The science instruments on the spacecraft will survey Bennu to measure its physical, geological, and chemical properties, and the team will use these data to select a site on the surface where to land and collect at least 60g of asteroid regolith.
The team will also analyze the remote-sensing data to perform a detailed study of the sample site for context, assess Bennu's resource potential, refine estimates of its impact probability with Earth, and provide ground-truth data for the extensive astronomical data set collected on this asteroid.
To achieve the science requirements a set of scientific data products will be derived from observations made by specially designed suite of instruments: OCAMS, an imaging camera suite; OVIRS, a visible and near-infrared spectrometer; OTES, a thermal-emission spectrometer, OLA, an imaging Lidar system, and REXIS, an X-ray emission spectrometer.
After three year in situ analysis, the spacecraft will leave Bennu in 2021 and return the sample on Earth to the Utah Test and Training Range (UTTR) landing site on September 2023.
OSIRIS-Rex mission has several objectives:

- 1) Return and analyze a sample of pristine carbonaceous asteroid regolith in an amount sufficient to study in laboratory with high accuracy instruments the nature, history, and distribution of its constituent minerals and organic material. Provide sample context by documenting the regolith at the sampling site in situ at scales down to the sub-centimeter.
- 2) Map the global properties, chemistry, and mineralogy of a primitive carbonaceous asteroid to characterize its geologic and dynamic history and provide context for the returned samples.
- 3) Improve asteroid astronomy by characterizing the astronomical properties of a primitive carbonaceous asteroid to allow for direct comparison with groundbased telescopic data of the entire asteroid population.

To analyze the spectroscopic data that will be available during the approach and rendezvous to Bennu, it is desirable to reproduce in laboratory typical conditions that can be found on the asteroid, to acquire spectra of mineral analogues and to carefully interpret the spectral properties that will be obtained by OVIRS and OTES instruments. This approach will let us both to map the surface inferring the global properties of the asteroid and to select the site where to collect samples to be brought back on Earth.

PhD project and scientific work

In this project we plan to study a wide list of minerals that could be present on Bennu. Detection of key minerals is expected by global mapping of Bennu analyzing spectral indexes observed i.e. specific band position, intensity, band profile and areas. With such spectral indexes it will be possible to identify a broad range of composition or a specific chemistry using fitting methods with Gaussian profiles. For this reason any changes in spectral profiles or wavelength position and band depths will affect the spectral analysis of data.

We also plan to investigate biomolecule and mineral interactions with the aim to detect biomolecules on primitive asteroids studying chemical and physical properties of analogue samples in simulated space conditions. Analysis of space processing such as UV photo-degradation on biomolecules interacting with surface of minerals can give us estimation on the survival of biomolecules on asteroid surfaces.

The reflectance spectra of analogue samples will be acquired using the Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS). This method shows several advantages such as minimal sample preparation and manipulation, and it is an excellent in situ technique. The IR spectra will be recorded with a single beam double pendulum interferometer Vertex 70v (Bruker) working in vacuum, equipped with a Praying Mantis TM Diffuse Reflection Accessory - Harrick DRIFT.

Samples will be prepared in laboratory with various mineral grain sizes (from $< 20\mu m$ to 500-1000 μm) and diffuse reflectance analysis will obtained in vacuum at 10^{-6} $mbar$ at temperatures from 74 K to 500 K of neat dust samples in three overlapping spectral ranges 0.3-6.5 μm (sapphire window), 2.0-40 μm (KRS5 window) and 10-50 μm (polypropylene window). In the case of natural mineral, specific treatments are required because organic and biological contaminations might be present and could affect the spectroscopic behaviour. Some of the treatments that we can perform are: Solvent extraction procedure, Oxidation of organic substances with Hydrogen Peroxide, Sonication, Pyrolysis etc

Data analysis will allow to interpret the OVIRIS and OTES spectra processed by Science Processing and Operations Center (SPOC) data pipeline. Specifically we will:

- compare the observed spectra directly with our laboratory reference spectra and find the best matches. Several mathematical approaches will be used, including: least-square error, standard error, chi-square;
- determine the spectral slope and eventual diagnostic features;
- model the observed spectra, as a combination of end-member spectra.

The purpose is to find the combination of laboratory spectra able to fully reproduce the slope and general trend, as well as diagnostic features of the observed spectra, in order to identify the rocks and/or the soil types present on the surface of Bennu. The interactive procedure will include a realistic model of the surface of Bennu in order to correlate the determined composition with the corresponding surface area.

References

[1] Christensen, P.R. et al. (2017) *The OSIRIS-REx Thermal Emission Spectrometer (OTES) Instrument*, arXiv, 1704.02390, [astro-ph.IM]

[2] Hinrichs, J.L. and Lucey, P.G. (2002) *Temperature-Dependent Near-Infrared Spectral Properties od Minerals, Meteorites and Lunar Soil*, Icarus, Vol. 155, Iss. 1, pp. 169-180

[3] Lauretta, D.S. et al. (2017) *OSIRIS-REx: Sample Return From Asteroid (101955) Bennu*, Space Science Reviews, pp. 1-60

[4] Lucey, P.G. et al. (1998) *The Influence of Temperature on the Spectra of the A-asteroids and implications for their Silicate Chemistry*, Journal of Geophysical Research, Vol. 103, p. 5865

[5] Reuter, D.C. et al . (2017) *The OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS): Spectral Maps of the Asteroid Bennu*, arXiv, 1703.10574, [astro-ph.IM]

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