EPSC Abstracts
Vol. 15, EPSC2021-723, 2021
European Planetary Science Congress 2021

Evolution and alteration of organic material on Ceres, a pathway towards the understanding of complex geological and chemical history of a wet small body

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Summary

Ceres is the largest object in the Solar System main belt. Clearly, Ceres experienced extensive water-related processes and geochemical differentiation and nowadays it is a body with a complex geological and chemical history [1]. Its surface is characterized by dark materials, phyllosilicates, ammonium-bearing minerals, carbonates, water ice, and salts. In addition to a global presence of carbon bearing chemistry, local concentration of aliphatic organics has been detected by Dawn [2].

In this context, we have started a series of laboratory spectroscopy measurements targeted to study the physicochemical interactions between organic material and minerals possibly present on Ceres. The goal is to understand the transformations induced on these samples by ultraviolet radiation, neutral atoms, and fast ions, under experimental conditions that simulate the environment of Ceres. The spectroscopic data obtained in laboratory experiments allow, through the comparison with the observations of the VIR spectrometer aboard the Dawn mission, to clarify the nature and origin of organic material identified on Ceres.

Introduction

Organic material in the minor bodies of the Solar System is an important component to understand planetary evolution and, eventually, the origin of life. Nevertheless, our knowledge on the subject is still limited. Recently the Dawn mission, thanks to the data collected by the Italian instrument VIR [3], showed clear evidence of a high amount of aliphatic organic material on the surface of Ceres [4, 5, 6] (Fig 1). This evidence has raised new questions about the origin and preservation of this material, especially when considering its high estimated abundance and the mineralogical context.

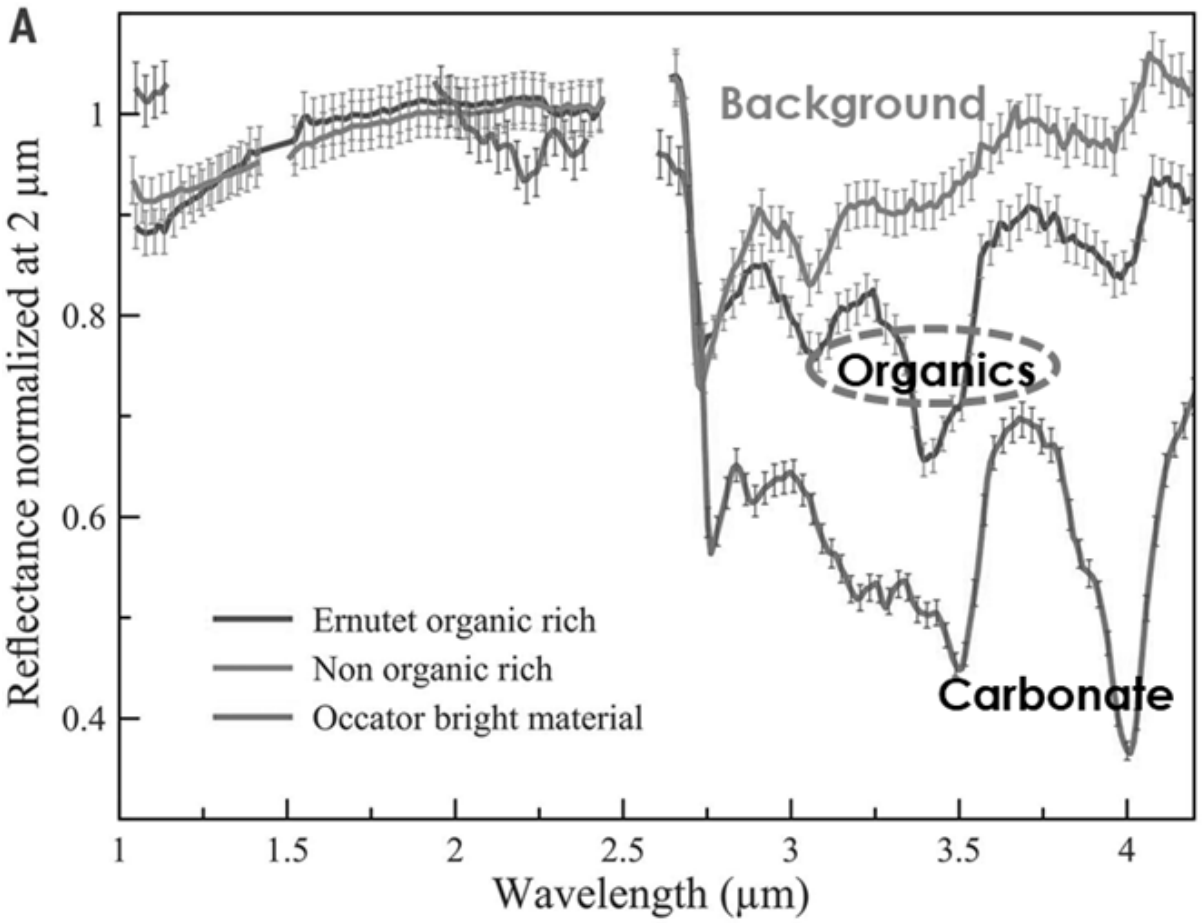

Fig 1 Ceres spectra of the organic-rich area in Ernutet crater (label "Organics"); of a background organic-poor area from a region southeast of Ernutet (label "Background"); and of Occator bright material (label "Carbonate") [4].

In order to understand the organic chemical species and in particular their abundance on Ceres, laboratory studies were performed [7]. The importance of having a direct comparison between laboratory and remote sensing data can provide a further investigation clues to shed light on the origin and evolution of Ceres. Through this project, we intend to study, through dedicated experiments, the interaction between minerals, water, and organic concerning the environmental conditions of Ceres. Making a synergistic use of complementary and indispensable skills present within INAF (Italian National Institute of Astrophysics) laboratories we investigated a complex issue such as that concerning the origin and preservation of organic molecules on planetary surfaces. Within INAF, complementary and unique realities coexist which, thanks to joint and coordinated work, can give a new interpretation of the physical-chemical processes active on Ceres.

Project development and results

In this study, we prepare mixtures of materials resembling the Ceres surface composition [8, 9] adding organic molecules in order to:

(i) understand how organic molecules behave and eventually degrade on Ceres, in particular, how aliphatic molecules degrade by energetic processing with fast ions (keV-MeV) and UV photons [10, 11]. Moreover, the physico-chemical properties of the materials exposed to a flux of neutral atoms are investigated [12, 13].

(ii) evaluate the interaction between ammoniated minerals and simple organic molecules that may lead to the synthesis of complex compounds. In the presence of ultraviolet (UV) radiation, these minerals present on the surface of Ceres can show photocatalytic effects accelerating the photo-reactions, which generally destroy the original organic molecule and in the synthesis of new complex organic molecules [14].

(iii) evaluate the role of minerals in the protection or degradation of organic compounds. Some studies indicated a fundamental role of clays in the catalysis and preservation of organic materials [15]. Ceres is rich in clays and other hydrated minerals, making the interactions with the observed organics of particular interest.

The project is carried out by several INAF institutes and laboratories. In detail: INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali prepared the analog mineral mixtures taking into account the compositional information gained by VIR observations. INAF - Osservatorio Astrofisico di Arcetri subsequently doped the mixture with several organic investigating UV photostability in Ceres analog conditions and the influence of temperature. INAF -Osservatorio Astronomico di Capodimonte studied irradiation with atoms and temperature effect while INAF - Osservatorio Astrofisico di Catania performed irradiation with fast ions. Finally, results of laboratory measurements were compared with data obtained by VIR instrument onboard Dawn mission.

Acknowledgements
This work is support by INAF Main Stream programme, grant 1.05.01.86.08 Evoluzione ed alterazione del materiale organico su Cerere (ref. Maria Cristina De Sanctis).

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