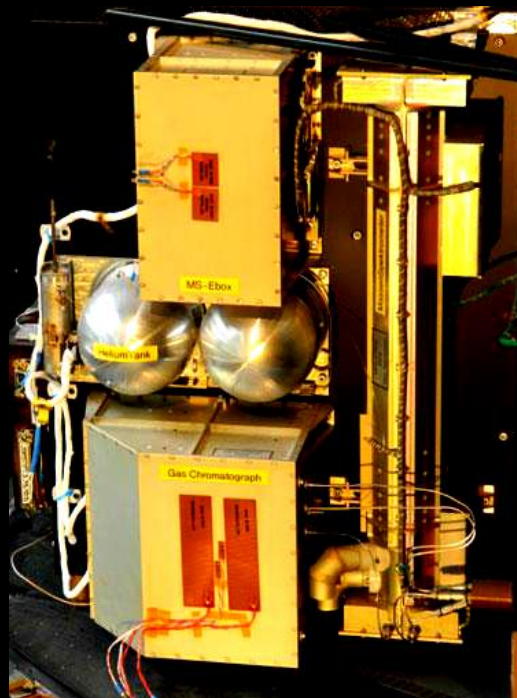


The organic composition of cometary nucleus, the COSAC experiment on Philae



Chaitanya Giri

International Max Planck Research School
for Solar System Science
at the University of Göttingen



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L'INSTRUMENT COSAC SUR LA SONDE PHILAE

Thèse dirigée par Uwe MEIERHENRICH

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THE COSAC EXPERIMENT ON PHILAE

Thesis supervised by Uwe MEIERHENRICH

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Jury

Pr. Christophe DEN AUWER

President

Pr. François RAULIN

Reviewer

Dr. Harald KRÜGER

Reviewer

Dr. Guillermo MUÑOZ CARO

Examiner

Dr. Fred GOESMANN

Examiner

Pr. Uwe MEIERHENRICH

Director of Thesis

RESUME

Cette thèse constitue un travail novateur dans l'analyse *in situ* multi disciplinaire de la surface du noyau d'une comète réalisé à l'aide du "Cometary Sampling and Composition Experiment" (COSAC). COSAC est un chromatographe en phase gazeuse et un spectromètre de masse embarqué à bord du module d'atterrissage Philae de l'Agence Spatiale Européenne dans le cadre de la mission vers la comète 67P/Tchourioumov-Guérassimenko. La thèse aborde de façon globale trois campagnes expérimentales et analytiques toutes dirigées vers les objectifs de COSAC après son futur atterrissage sur 67P. La quatrième partie, qui est un travail géologique vise à identifier le cratère de Lonar comme analogue martien.

La première des expériences mentionnée ci-dessus implique l'irradiation d'alanine racémique à l'aide de lumière polarisée circulairement (CPL) générée par synchrotron. Nous avons démontré pour la première fois qu'en changeant l'énergie de la CPL pour une hélicité donné de 6,19 eV à 6,74 eV, le signe de la valeur de l'excès énantiomérique des acides amines change (dans ce cas la *rac*-alanine). Dans une seconde partie, nous avons démontré pour la première fois la présence de carbone graphitique dans le tholin, un solide complexe et organique synthétisé à partir de l'irradiation de décharge de plasma d'un mélange de $N_2:CH_4=9:1$. Nous expliquons que la présence possible de graphite enrichi de matière organique de type tholin sur la surface de noyaux cométaires pourrait bien contribuer à leur faible albédo géométrique typique. La troisième partie comporte une évaluation des performances de COSAC-MS réalisée avec le modèle de vol de secours situé à l'Institut Max Planck pour la recherche sur le système solaire. Ces évaluations ont déterminé les paramètres de fonctionnement optimum pour COSAC-MS. Nous avons caractérisé avec COSAC-MS divers échantillons pertinents de mélanges organiques de comètes en ce qui concerne leur composition chimique, leur modèle de fragmentation de masse, et en comparant les spectres obtenus avec des bases de données de spectrométrie de masse standard. Les résultats de l'évaluation obtenus bénéficieront à la bonne interprétation des résultats fournis par COSAC au cours de sa mission. Enfin, dans une étude géologique, nous montrons que le cratère de Lonar en Inde est un important analogue aux cratères d'impacts de Mars, apparus lors de sa période hydrologique. Les découvertes de ce travail aideront à établir les objectifs de "Mars Organic Molecule Analyzer", un chromatographe en phase gazeuse, un spectromètre de masse et un spectromètre de masse à désorption laser, construit à partir de l'héritage de COSAC. Il est prévu que ce-dernier soit embarqué sur le Rover ExoMars de l'Agence Spatiale Européenne.

ABSTRACT

This cumulative thesis forms a multi-disciplinary groundwork for the pioneering in situ organic analyses of a comet nuclei surface to be performed by the Cometary Sampling and Composition Experiment (COSAC). COSAC is a Gas Chromatograph-Mass Spectrometer on board the Philae Lander probe of European Space Agency's Rosetta mission to comet 67P/Churyumov-Gerasimenko. The thesis holistically addresses three myriad experimental and analytical campaigns all directing to the objectives of COSAC subsequent to its landing on 67P. The fourth original geological fieldwork directs to the identification of Lonar Crater as a Martian analogue. Our first of the above mentioned experiments involved irradiation of racemic *rac*-alanine with synchrotron-generated circular polarized light (CPL). We demonstrated for the first time that changing the energy of a given helicity of CPL from 6.19 eV to 6.74 eV switches the sign of the enantiomeric excess value of amino acids – in this case *rac*-alanine. The second experiment for the first time demonstrated the presence of graphitic carbon in tholin, a complex organic solid synthesized from plasma discharge irradiation of a mixture N₂:CH₄=9:1. We explain that the possible presence of graphite enriched tholin-like organic material on the surface of comet nuclei could well be contributing to their typical low geometric albedos. The third experiment was directed at performance evaluation of COSAC-MS carried out with its Flight Spare Model located at the Max Planck Institute for Solar System Research. These evaluations determined optimum operating parameters for COSAC-MS and we characterized with COSAC-MS various comet-relevant organic mixture samples with regards to their chemical composition, mass fragmentation pattern, and comparing the obtained spectra with standard mass spectral databases. The obtained evaluation results will ultimately benefit the successful interpretation of the results obtained from COSAC during the mission. In the final geological fieldwork we point that Lonar Crater in India is an important analogue to impact craters occurring on a hydrologically active ancient Mars. The findings of the fieldwork complements the future objectives of Mars Organic Molecule Analyzer, a Gas Chromatograph-Mass Spectrometer-Laser Desorption Mass Spectrometer built from the heritage of COSAC, and which is planned onboard the European Space Agency's ExoMars Rover.

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Chapter 3 – Chirality, photochemistry and the detection of amino acids in interstellar ice analogues and comets

Chapter 4 – Anisotropy spectra for enantiomeric differentiation of biomolecular building blocks

Chapter 5 – Photonenergy-controlled symmetry breaking with circularly polarized light

Chapter 6 – Graphitization in tholin: Implications for cometary surfaces (under review)

Chapter 7 – Competence evaluation of COSAC Flight Spare Model Mass Spectrometer: In preparation of arrival of Philae Lander on comet 67P/Churyumov-Gerasimenko

Chapter 8 – Drainage systems of Lonar Crater, India: Contributions to Lonar Lake hydrology and crater degradation