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A I M S
Analogue Icy Moon Simulations

Effects of Hydrothermal Conditions on a Model Simple Aromatic Compound using an Enceladus Ocean Laboratory Analogue

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1 AN ALIEN OCEAN

- With its subsurface liquid water ocean, rocky core, and multitude of organic and inorganic species, Enceladus is considered a potentially habitable ocean world
- Enceladus emits subsurface material as a plume of ice grains and gas from cracks in the south polar region, forming Saturn's E ring and providing direct access to material from its subsurface ocean
- Ejected ice grain composition was measured in situ within Saturn's E ring and in fresh plume material by the Cassini spacecraft
- Analysis of these grains revealed a global subsurface salty liquid water ocean containing organic compounds and evidence of ongoing hydrothermal activity [1-5]

2 THE AIMS APPROACH

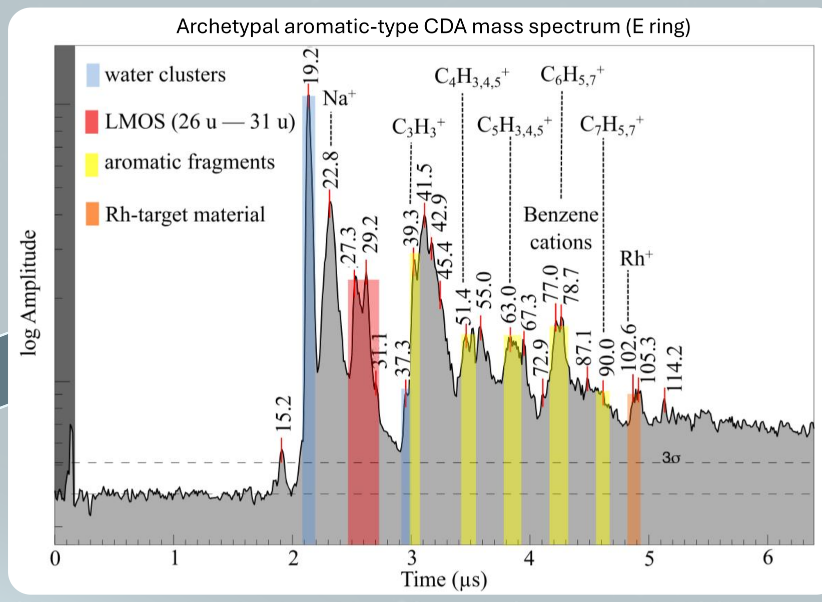
- Enceladus likely incorporated aromatic-rich organic matter during its formation, but aromatic compounds could also have been produced, transformed, or destroyed through hydrothermal processes within Enceladus
- To understand the relative importance of these processes the ERC-funded Analogue Icy Moon Simulations (AIMS) laboratory at Freie Universität Berlin enables experimental simulation of subsurface conditions and hydrothermal processes on Enceladus [6]
- This study employs the hydrothermal reactor system of the AIMS lab and novel analytical techniques simulating spacecraft observations to address the following scientific questions:

How do Enceladus-like hydrothermal conditions affect the stability or transformation of low-mass aromatic compounds, such as benzoic acid?

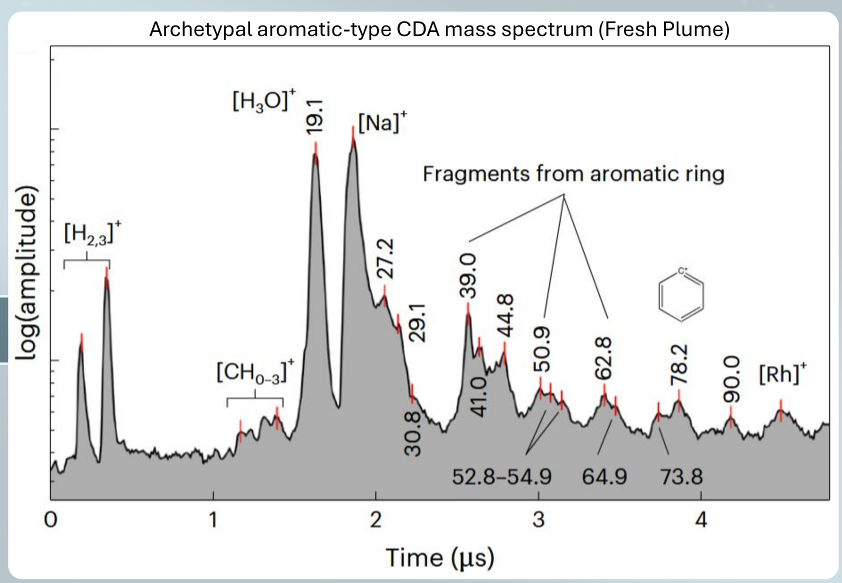
Can their chemical signatures be detected and characterized using complementary spacecraft-relevant analytical techniques?

3 ICY AROMATICS

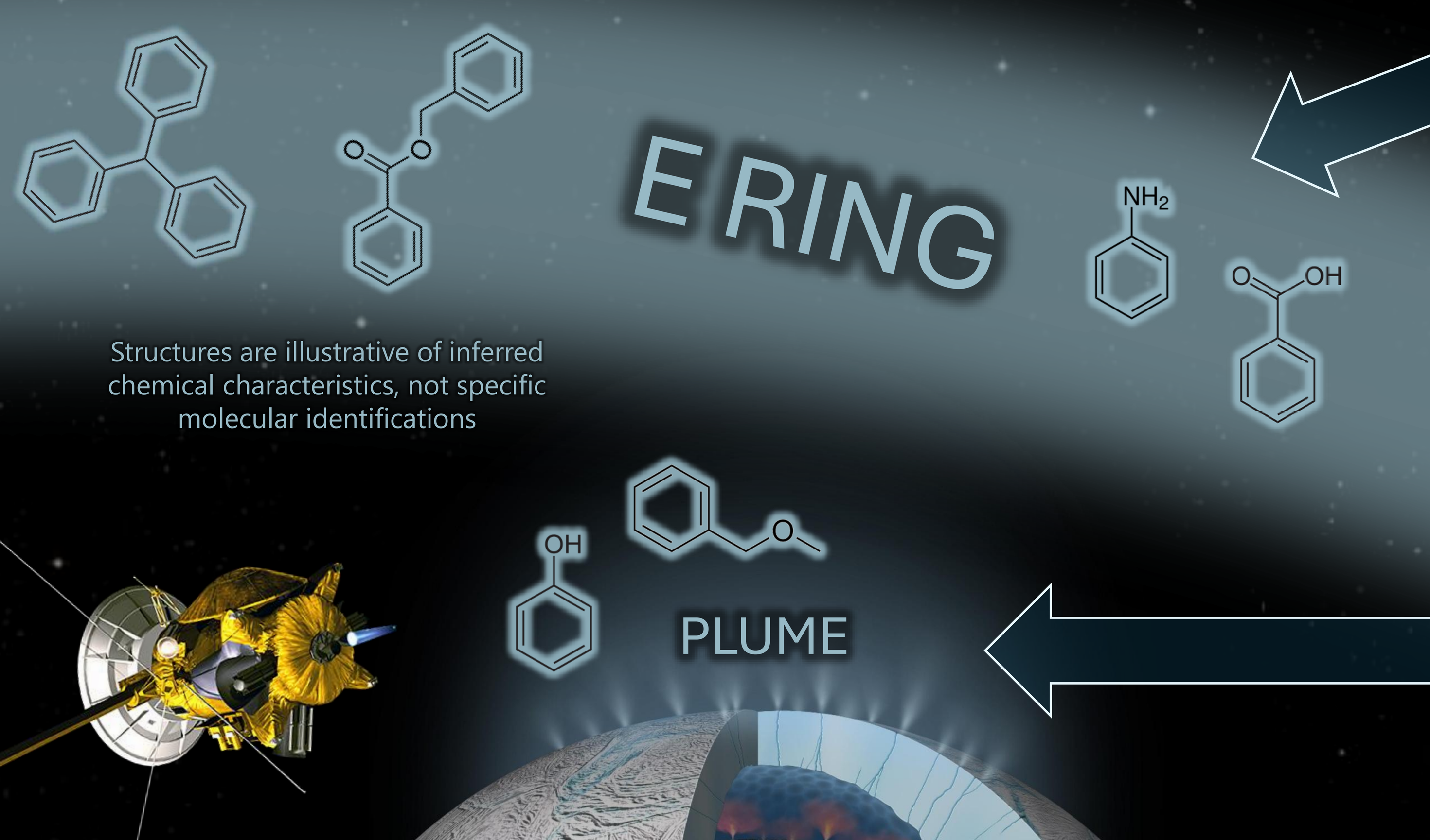
- Cassini's impact ionization mass spectrometer, the Cosmic Dust Analyzer (CDA), identified aromatic rings within macromolecular organic compounds, low-mass single-ring aromatic compounds, and evidence of carbonyl functional groups in Saturn's E ring and in freshly ejected Enceladus plume ice grains [7-9]
- Interpretation of CDA impact-ionization mass spectra such as these is facilitated by direct comparison with laboratory analogue spectra such as those produced by LILBID-ToF MS



CDA spectra showing Low Mass Organic Signatures (LMOS) of aromatics in E ring ice grains [8]

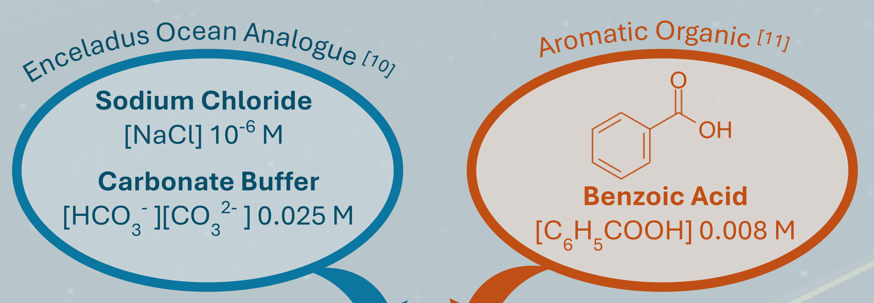


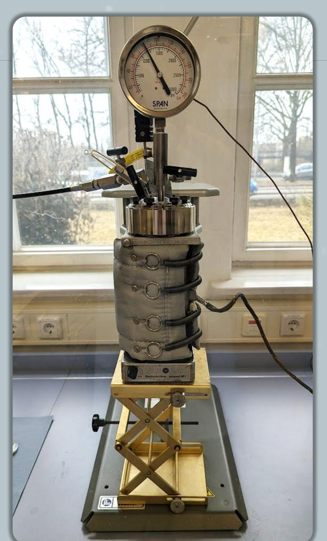
CDA spectra showing aromatic fragments in freshly ejected plume material [9]



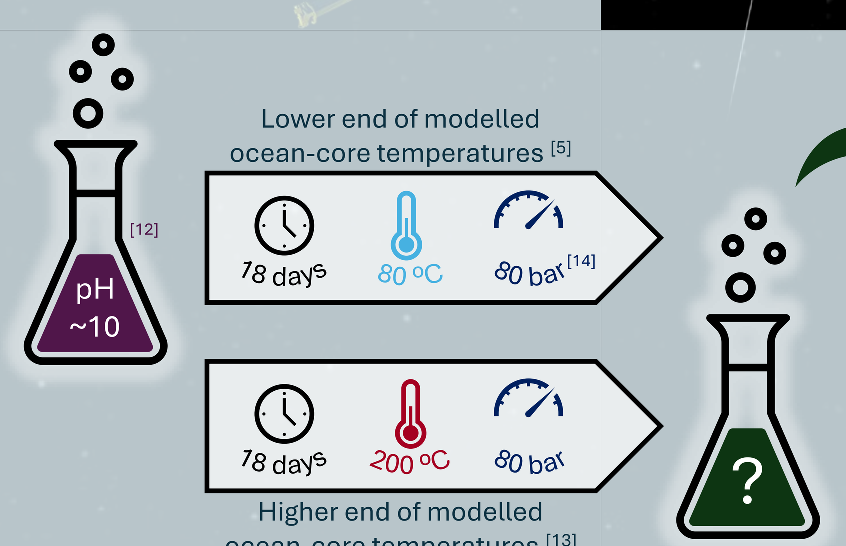
4 EXPERIMENTAL DESIGN

- Benzoic acid contains both a phenyl and carbonyl functional group, characteristics shared by organics found within the Enceladus ice grains
- Although only one of many possible aromatic compounds at Enceladus' core, benzoic acid serves here as a model compound for investigating the effects of Enceladus-like hydrothermal conditions on small aromatics



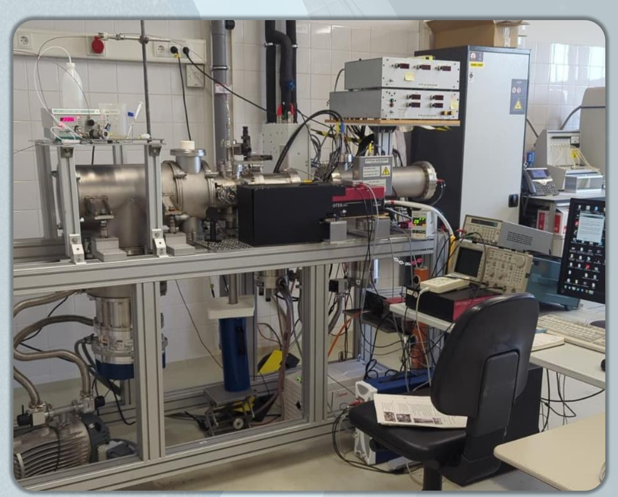


AIMS Lab hydrothermal reactor



Analysis with LILBID / UV-VIS / HPLC

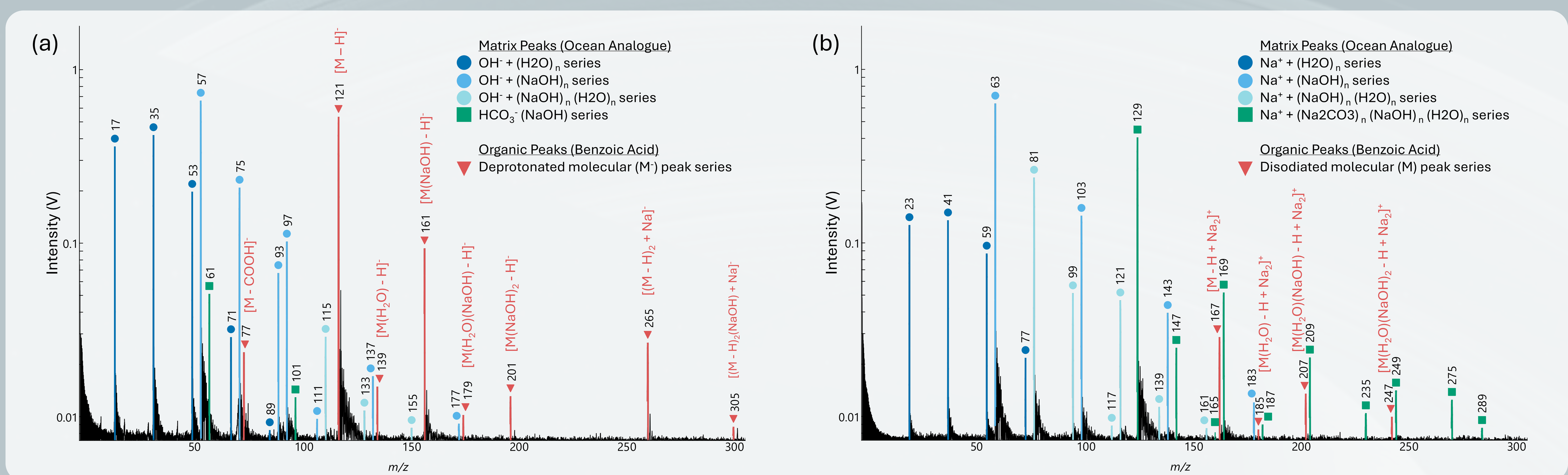
- Samples were analyzed using complementary LILBID-ToF MS, UV-Vis, and HPLC-MS measurements to assess benzoic acid stability and identify potential hydrothermal transformation products



LILBID-ToF setup at Freie Universität Berlin

5 LILBID ANALYSIS

- Laser-Induced Liquid Beam Ion Desorption time-of-flight mass spectrometry (LILBID-ToF MS) is a laboratory technique that produces mass spectra by laser desorption and ionization of compounds from a liquid water beam
- This process simulates ice-grain impact ionization signatures measured by CDA [15] and proposed future Enceladus proposed dust analyzers of mission such as the High Ice Flux Instrument (HiFi) [16]



LILBID spectra with highlighted matrix (Enceladus Ocean Analogue) and organic (benzoic acid) peaks. Anion mode (a) shows characteristic benzoic acid molecular and fragment ions, while cation mode (b) is characterized by sodium adducts of benzoic acid and the surrounding matrix. Experimental settings simulate an ice grain impact speed of ~8-10 km/sec.

6 RESULTS

Benzoic acid produces a distinct matrix-dependent mass spectral signature in the ocean analogue, however no evidence of benzoic acid transformation was observed following hydrothermal processing under Enceladus-like conditions

LILBID-ToF MS Mass Spectrometry	BA retained with no new ions detected
HPLC-MS	BA retained with no new detected products
UV-Vis Spectroscopy	BA profile retained with no new features

7 IMPLICATIONS

- The stability of benzoic acid suggests that some aromatic compounds inherited from primitive organic material may survive hydrothermal processing and remain detectable in relatively unaltered form in Enceladus' plume material
- Benzoic acid represents only one of many possible aromatic compounds and may not reflect the abundance or chemical behavior of all aromatics present in primitive material
- Extending this work to additional aromatic compounds will help constrain which organics survive, transform, or decompose under Enceladus-like hydrothermal conditions
- The strong influence of ocean chemistry on organic detectability in LILBID-ToF mass spectra can guide interpretation of existing CDA data and future impact-ionization measurements such as those by Europa Clipper's SUrface Dust Analyzer (SUDA) [17]
- These findings may support science planning and interpretation of future measurements by ESA's proposed L4 mission to Enceladus

8 REFERENCES

Find out more about the AIMS Project

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