

An integrated in-situ organic biosignature analysis instrument based on supercritical CO₂ and subcritical H₂O

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We present a novel organic analysis instrument with unprecedented sensitivity that reduces or eliminates common scientific and technical risks inherent to in-situ life detection.

The core sample processing unit, called *SCHAN* (Supercritical CO₂ and Subcritical H₂O Analysis instrument), uses a holistic approach with integrated extraction, preconcentration, and separation (chromatography). It has been designed to reduce the risks of degradation, alteration, and contamination by using lower temperatures (≤ 250 °C) and only water and supercritical carbon dioxide as solvents. The complementarity of these two simple solvents enables analysis of a wide range of molecules, from lipids (e.g., fatty acids and sterols) to polar analytes (e.g., chiral amino acids). We have demonstrated lower limits of detection of 20 pg/g (parts-per-trillion) for lipids, 25 pg/g for chiral amino acids, and 10⁴ cells/mL with an integrated cell lysis protocol based on supercritical CO₂. Despite *SCHAN*'s simple and straightforward approach, our detection limits are ≥ 3 orders of magnitude lower than those of previously flown instruments.

We have recently developed an end-to-end analysis instrument, which integrates the core *SCHAN* unit with a Sample Handling and Distribution (SHaD) subsystem and a Quadrupole Ion Trap Mass Spectrometer (QITMS). The SHaD subsystem comes in two configurations, one for ice or liquid samples for Enceladus-type missions

and one for solid (or mixed or unknown) samples compatible with, for example, Mars missions. QITMS, which has been monitoring the atmosphere onboard the International Space Station for several years, has been adapted for use with the *SCHAN* instrument to detect high-priority organic biosignatures. The core of the system, namely *SCHAN* and QITMS, remains the same independent of sample type. The fully integrated system provides a simple and low-risk option for organic-seeking or life-detection-focused missions to Solar System bodies like Mars, Enceladus, or Europa.

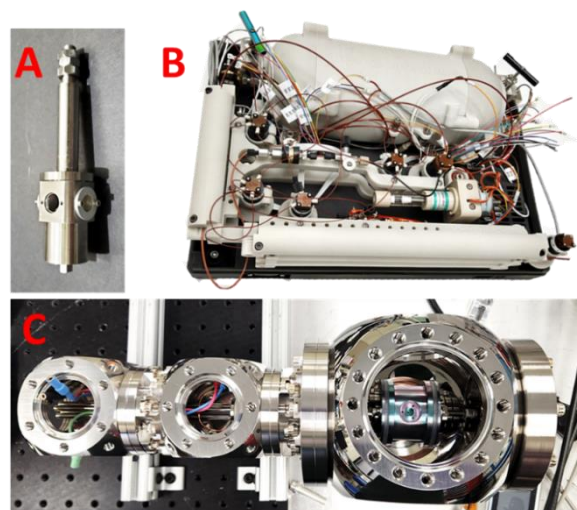


Figure 1. Photos of the three subsystems used for sensitive organic biosignature analysis: **(A)** Enceladus Sample Handling and Distribution (E-SHaD); **(B)** Supercritical CO₂ and Subcritical H₂O Analysis (*SCHAN* instrument); **(C)** Quadrupole Ion Trap Mass Spectrometer (QITMS).