National Aeronautics and Space Administration

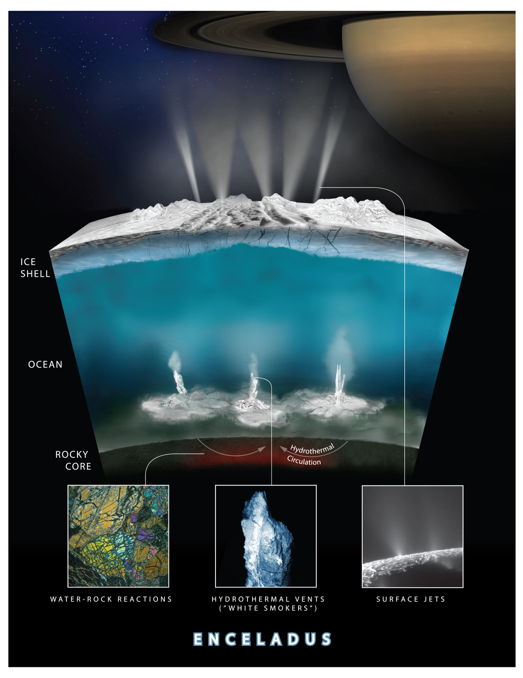
Sampling Plume Deposits on Enceladus' Surface to Search for Traces of Life and Biosignatures

M. Choukroun[1], P. Backes[1], M.L. Cable[1], E.C. Fayolle[1], R. Hodyss[1], A. Murdza[2], E.M. Schulson[2], M. Badescu[1], M.J. Malaska[1], E. Marteau[1], J.L. Molaro[1,3], S.J. Moreland[1], A.C. Noell[1], T.A. Nordheim[1], T. Okamoto[1], D. Riccobono[1,4], K. Zacny[5].

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. [2]Thayer School of Engineering, Dartmouth College, Hanover, NH. [3]Planetary Science Institute, Tucson, AZ. [4]Politecnico di Torino, Torino, Italy. [5]Honeybee Robotics, Pasadena, CA.

Introduction

Cassini has shown that Enceladus is highly active, with materials emitted from its internal ocean and re-deposited around the surface.



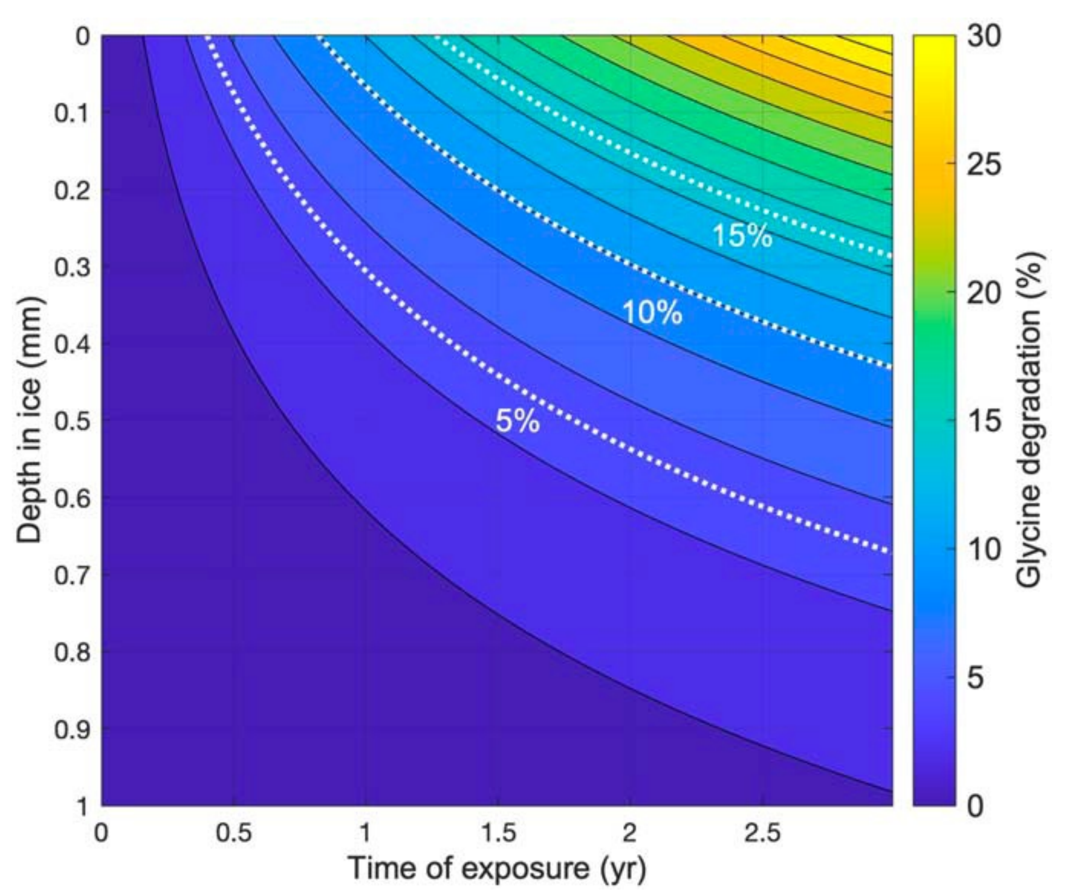
- Enceladus' ocean represents one of the best places to look for life and biosignatures.
- Future landed missions to Enceladus would be best suited at finding traces of life, similarly to the Europa Lander in pre-phase A study.
- Radiation environment on Enceladus's surface is benign in comparison to Europa.
- Instruments most sensitive to detect traces of recent or extant life will likely require acquisition of surface samples (larger sample volumes than plume fly-through).

Open questions:

- **How fast would biosignatures degrade in plume deposits on Enceladus' surface?**
- **What range of mechanical properties should be expected for plume deposits?**
- **What type of sampling system may be best-suited to the acquisition of plume deposit samples and their transfer to analytical instruments?**

Degradation of organics is likely minimal

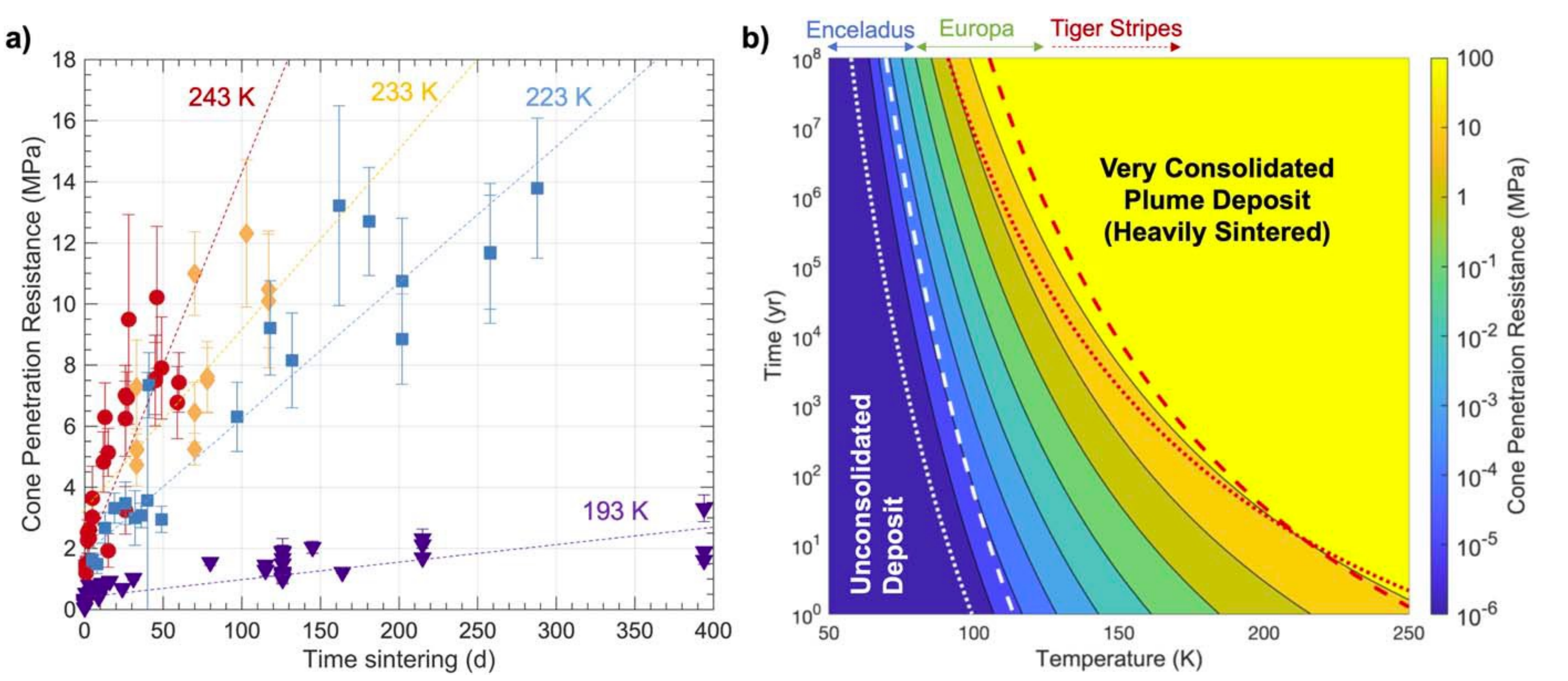
- Particle irradiation is at least 100x lower on Saturn moons than Jupiter's Europa (Nordheim et al. 2017, 2018).
- Solar UV flux is also damaging to organic molecules.
- Solar UV spectrum convolved with glycine photolysis and ice absorption suggests < 10% glycine degradation at depths of 10-100 microns or greater over 1 year (see below).
- Expanded calculations using other molecules and locations on Enceladus underway by E.C. Fayolle.



Glycine degradation by solar UV as function of time in ice with 0.1% glycine at latitude of 60˚ S.

Plume deposits on Enceladus are anticipated to consist of weakly consolidated icy particles

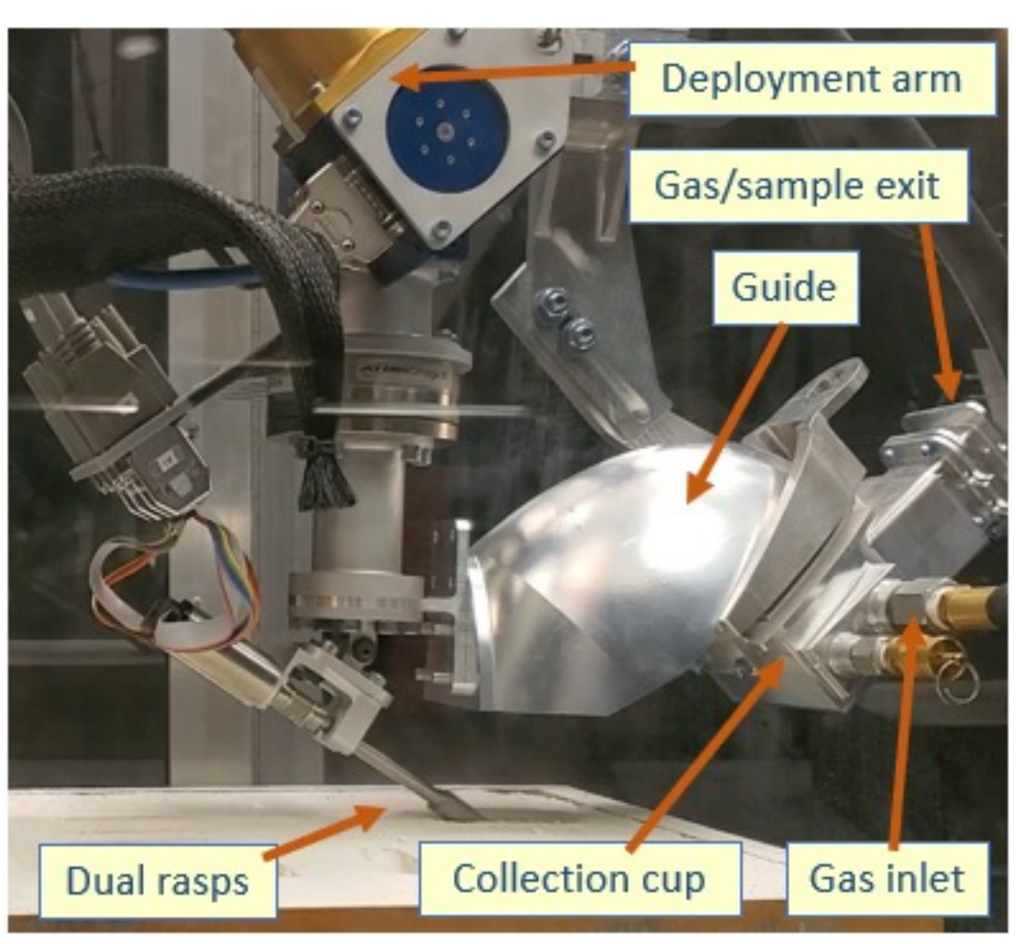
- Plume particles are mostly comprised of crystalline water ice and of mean radius in range of 1-3 μm.
- Sintering of plume deposits is temperature dependent and poorly understood under Enceladus' conditions (Molaro et al. 2019).
- Laboratory experiments (Choukroun et al. 2020) with ice microspheres investigated sintering and strength evolution as function of time.
- Cone penetration resistance increases linearly over time, at rates that decrease exponentially with temperature.
- Extrapolation of strengthening rate to Enceladus' surface suggests < 1 MPa strength after 100 Myr at 80 K.
- Preliminary compressive strength measurements on ice sintered for 60 days at 243 K suggest unconfined compressive strength on order as cone penetration resistance (Choukroun et al. 2021), as observed in fresher snow.

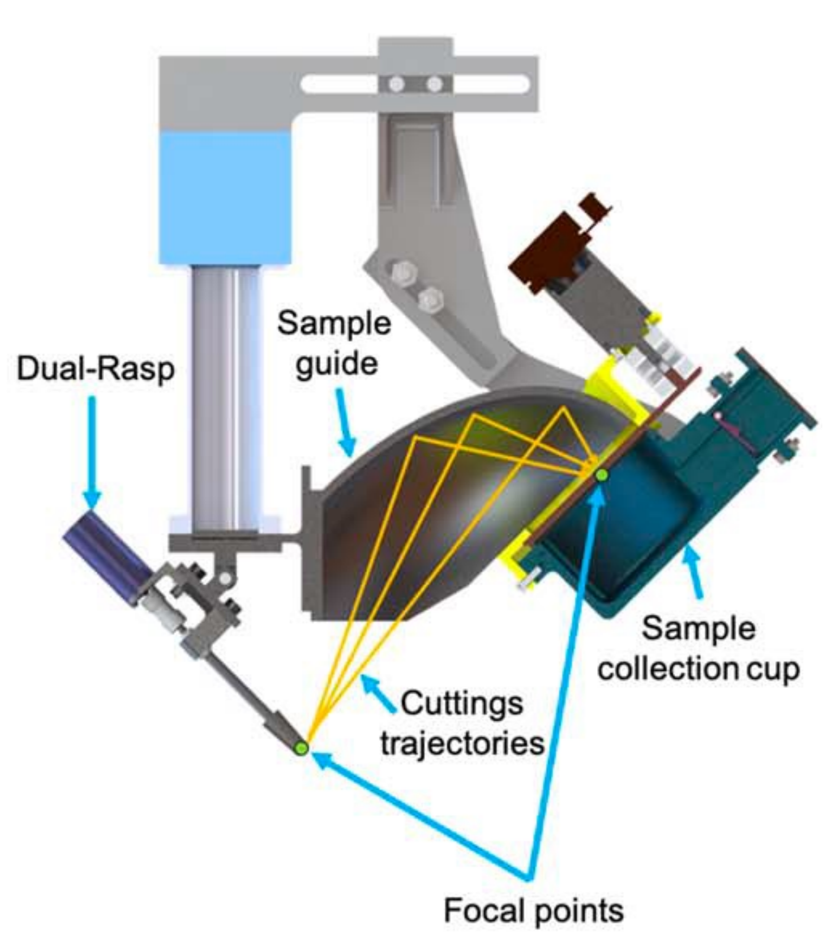


Strengthening of ice plume deposit analogs as function of temperature and time. a) Experimental data suggests linear strengthening in early stages of sintering. b) Model suggests that plume deposits are unlikely to develop substantial strength on Enceladus (less than order of 1 MPa cone penetration resistance and unconfined compressive strength).

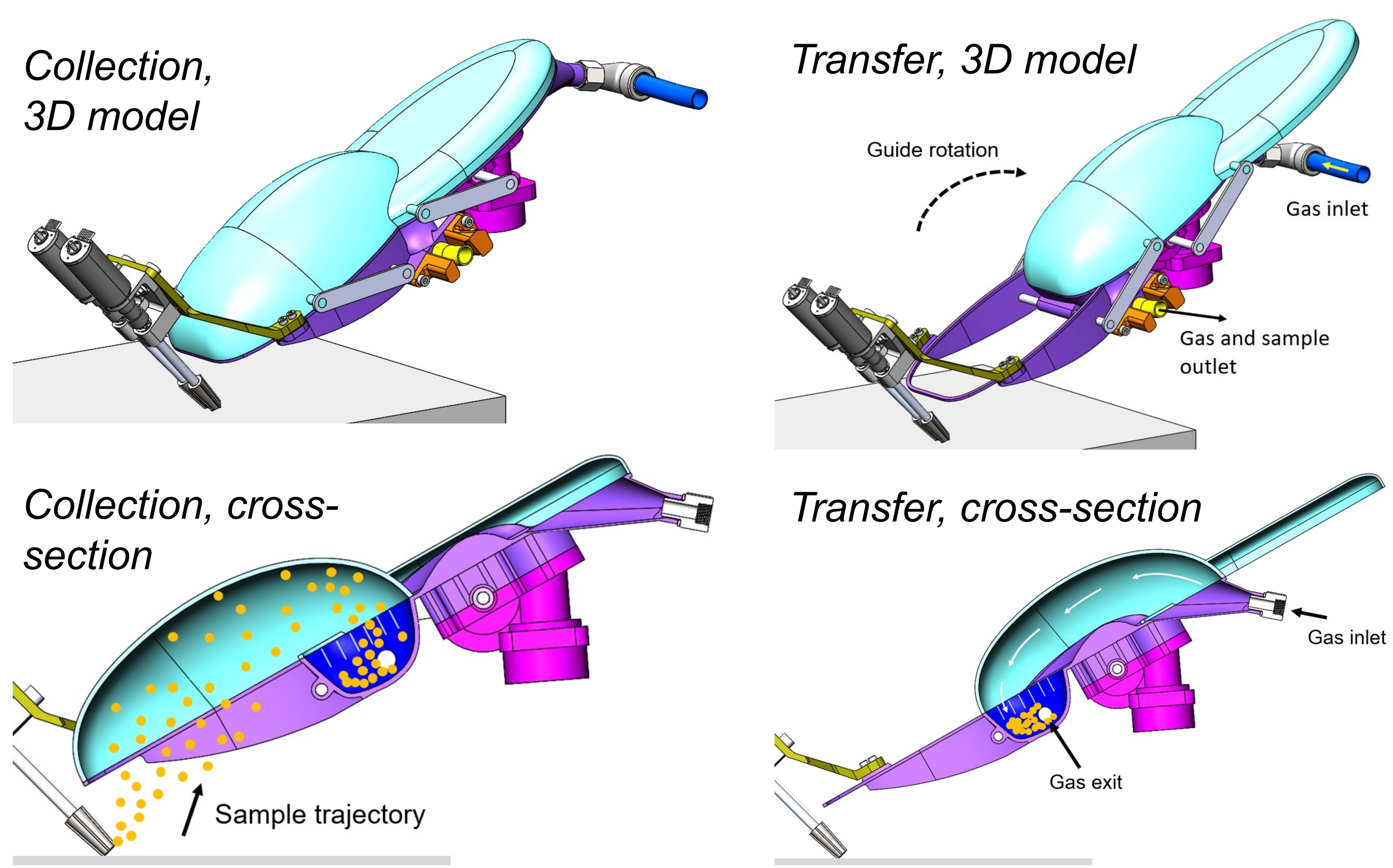
The Dual-Rasp sampling system is under development to enable the acquisition of plume deposits and transfer them to analytical instruments

- Novel Dual-Rasp sampling system (Backes et al. 2020) developed to meet Enceladus surface sampling challenges: low gravity (requires low reactive forces < 8 N), cryogenic environment.
- Two counter-rotating rasps cut surface material, throw cuttings up and direct them by a guide into a sample collection cup equipped with a gridded pattern to prevent cuttings from bouncing off.
- Closed pneumatic transfer system is nominal approach to transfer cuttings from collection cup to inlet of analytical instrument(s). Open pneumatic transfer approach under consideration and testing.
- Sample acquisition capability of the Dual-Rasp has been tested and demonstrated in zero-gravity flight (Badescu et al. 2021).
- Dual-Rasp is undergoing validation testing for sample acquisition under cryogenic and high-vacuum conditions to achieve TRL 5-6 in August-September 2021, and end-to-end sample acquisition and pneumatic transfer will be tested in September 2021.





Two counter rotating rasp-type heads cut through consolidated or loose material and throw cuttings up between them and into a guide that causes them to flow into a collection cup.



After collection, the tool head reconfigures into a closed cavity with the sample cup, and compressed gas transfers the sample to an instrument sample inlet.

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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