Finding Life in the Universe

Investing in the Ultimate Question

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Inventure$ 2019, Calgary

Jet Propulsion Laboratory
California Institute of Technology

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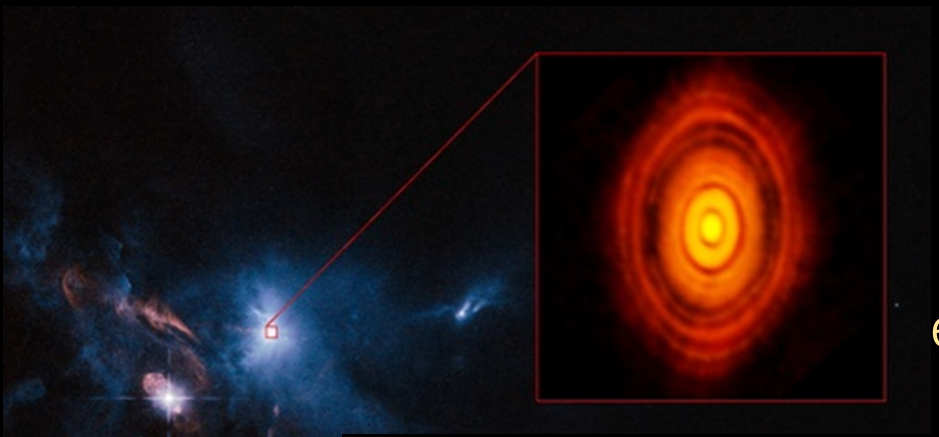
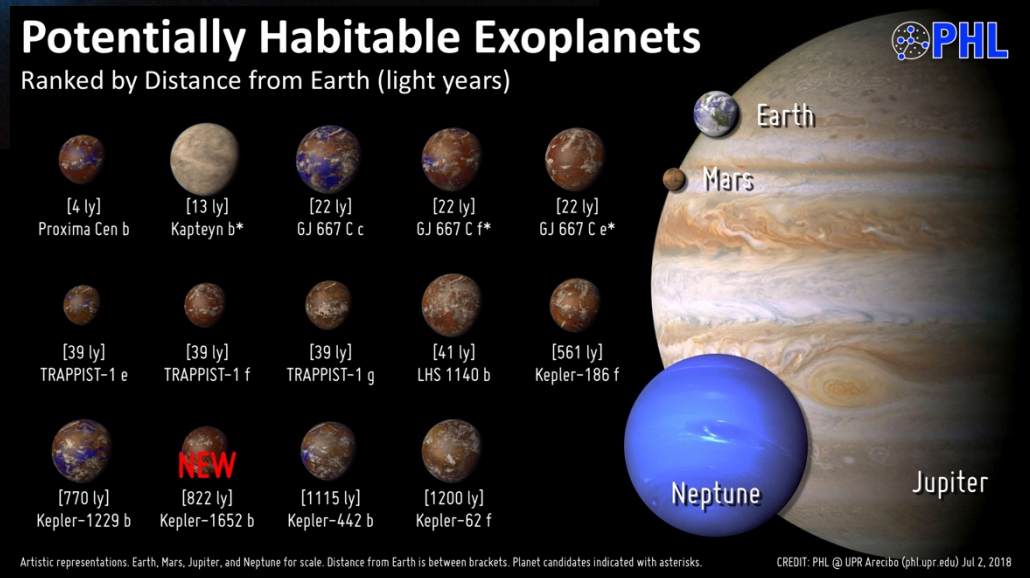
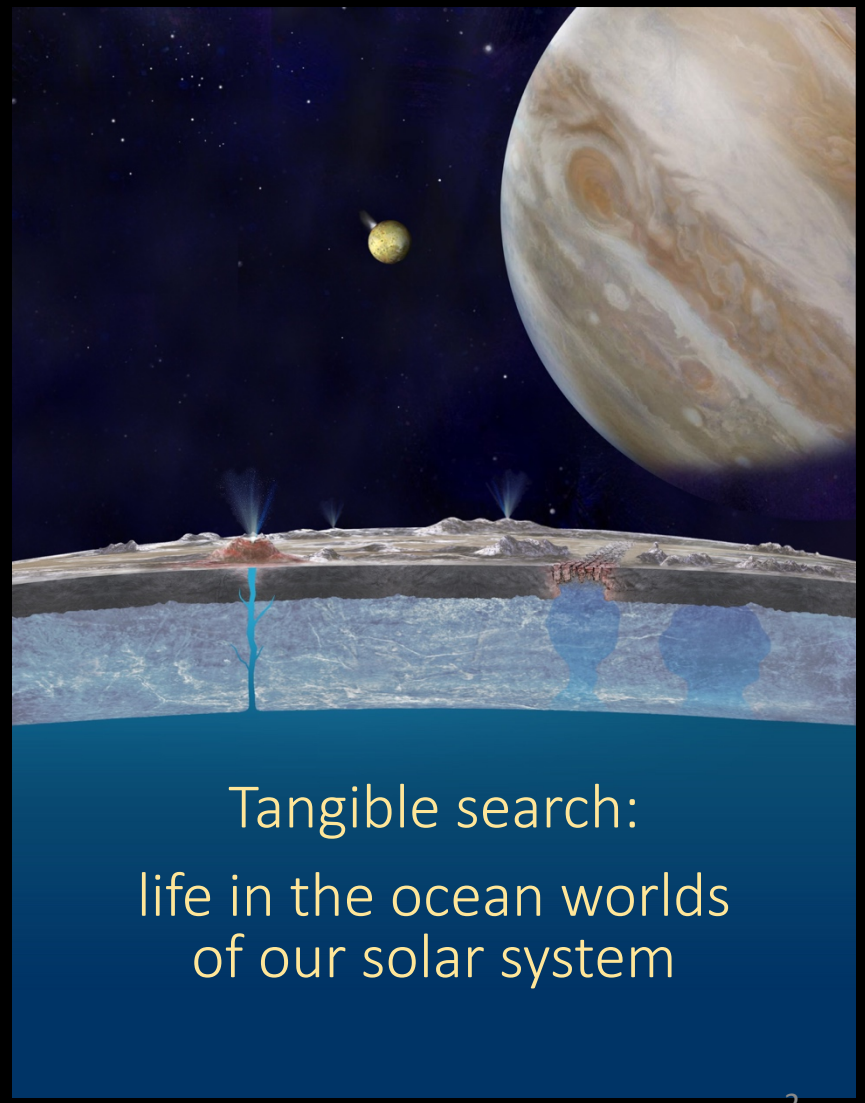
Is there life elsewhere in the universe?



Indirect search:

observation of extra-solar planets





Tangible search:

life in the ocean worlds of our solar system

Six steps to “find and understand life elsewhere”

1. Find liquid water
2. Quantify its habitability
3. Detect biosignatures in it
4. Confirm that life is present
5. Understand how that life operates
6. Learn the limits of life

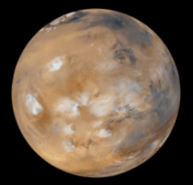
Ocean worlds contain vast quantities of water

EARTH

CREDIT: PHL @ UPR Arecibo, NASA

About 16x as much liquid water as on Earth

Ocean Relicts



Mars

Ceres

Venus

Jovian icy moons

Europa

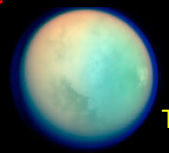
Ganymede

Callisto

Saturnian icy moons

Enceladus

Dione



Titan

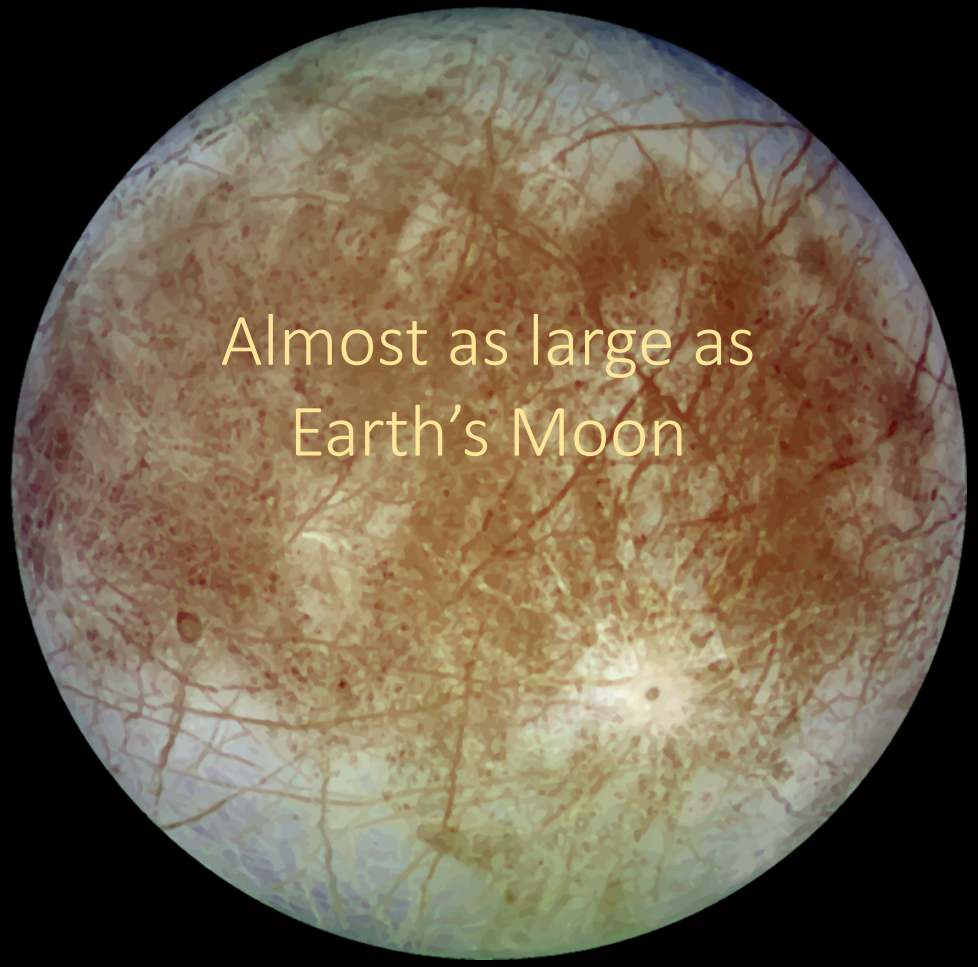
Kuiper Belt Objects

Triton

Pluto

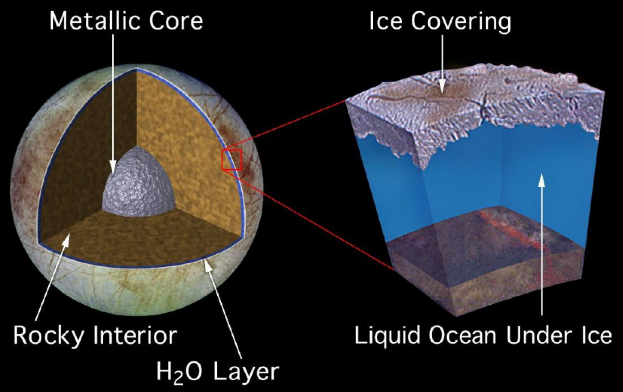
Charon

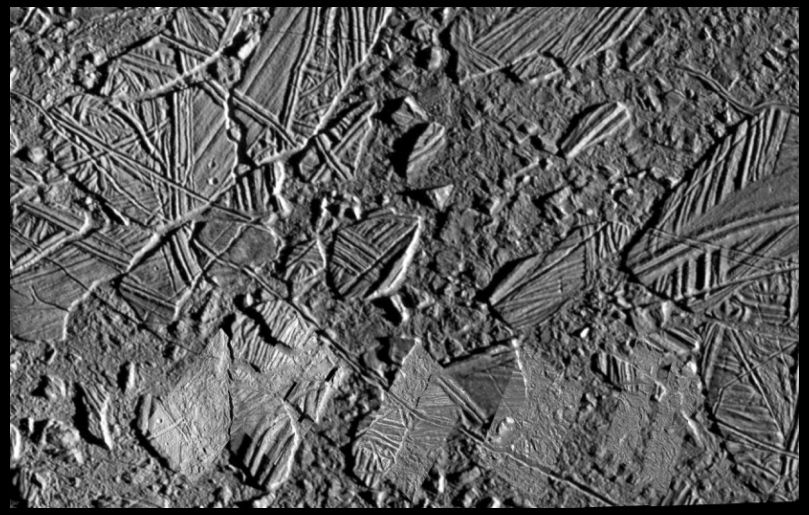
Europa: theoretically best place for life?



Almost as large as Earth's Moon

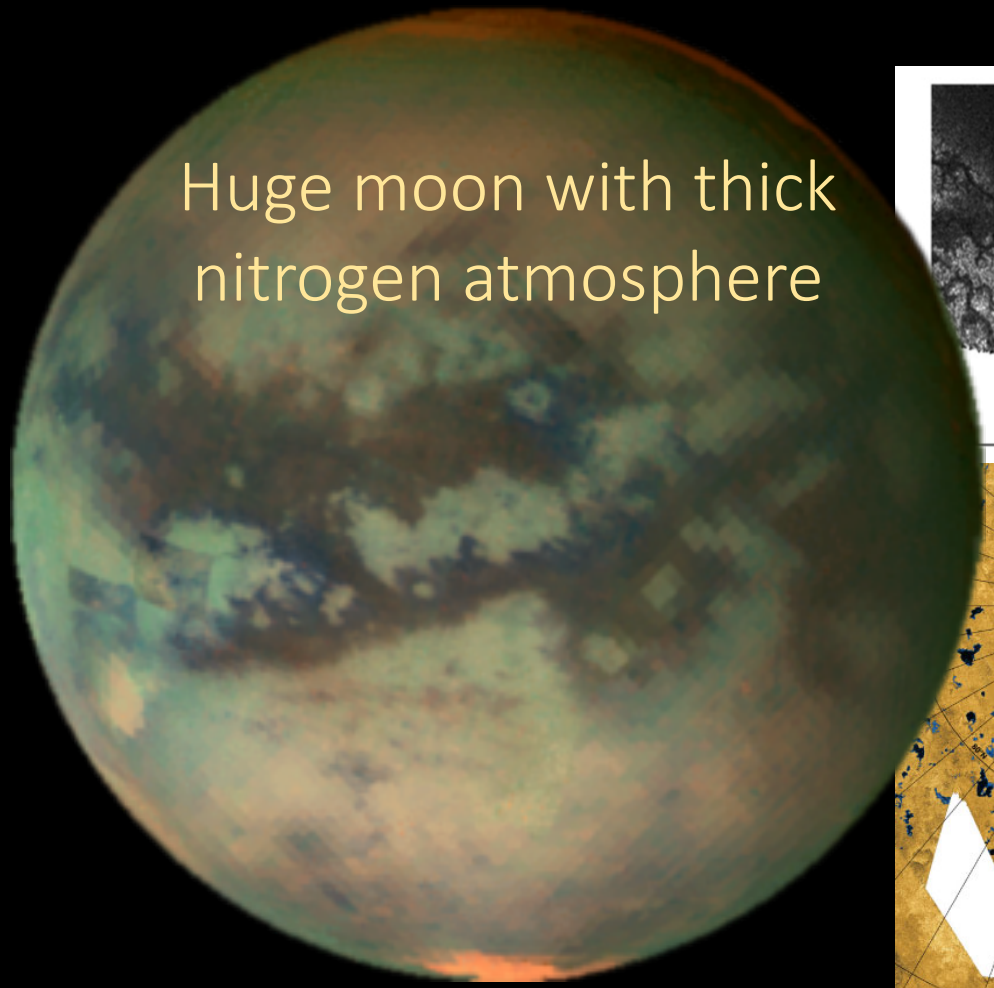
Salty ocean in contact with silicate rock



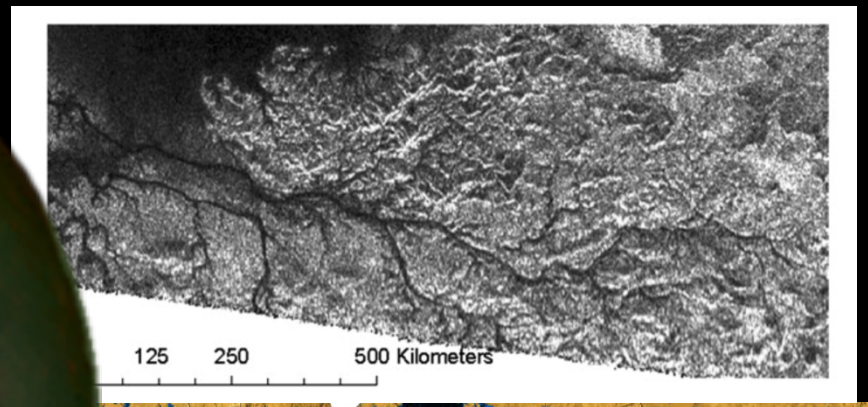


A source of oxidants

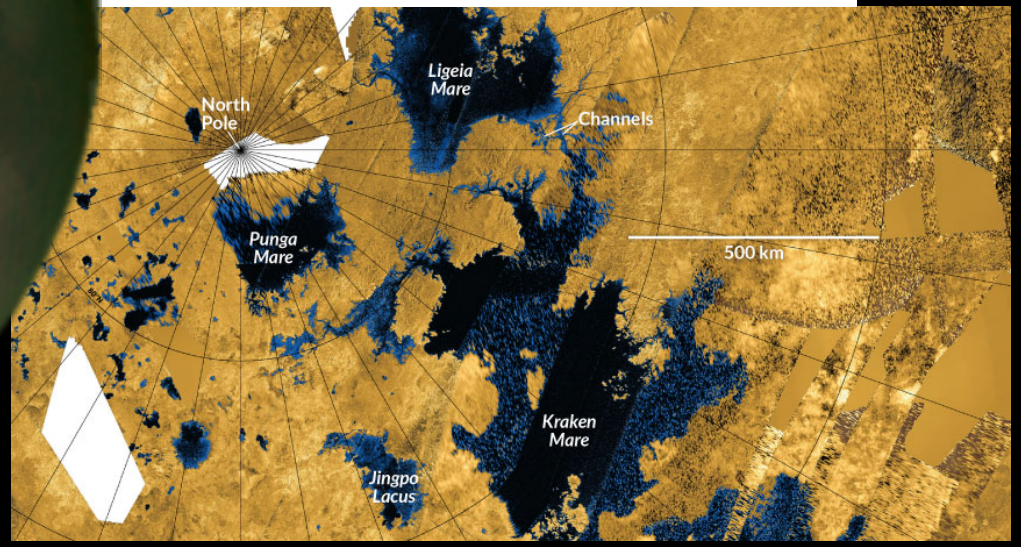
Titan: best place to look for weird life?



Huge moon with thick nitrogen atmosphere



Salt water inside, complex organics outside



Methane weather

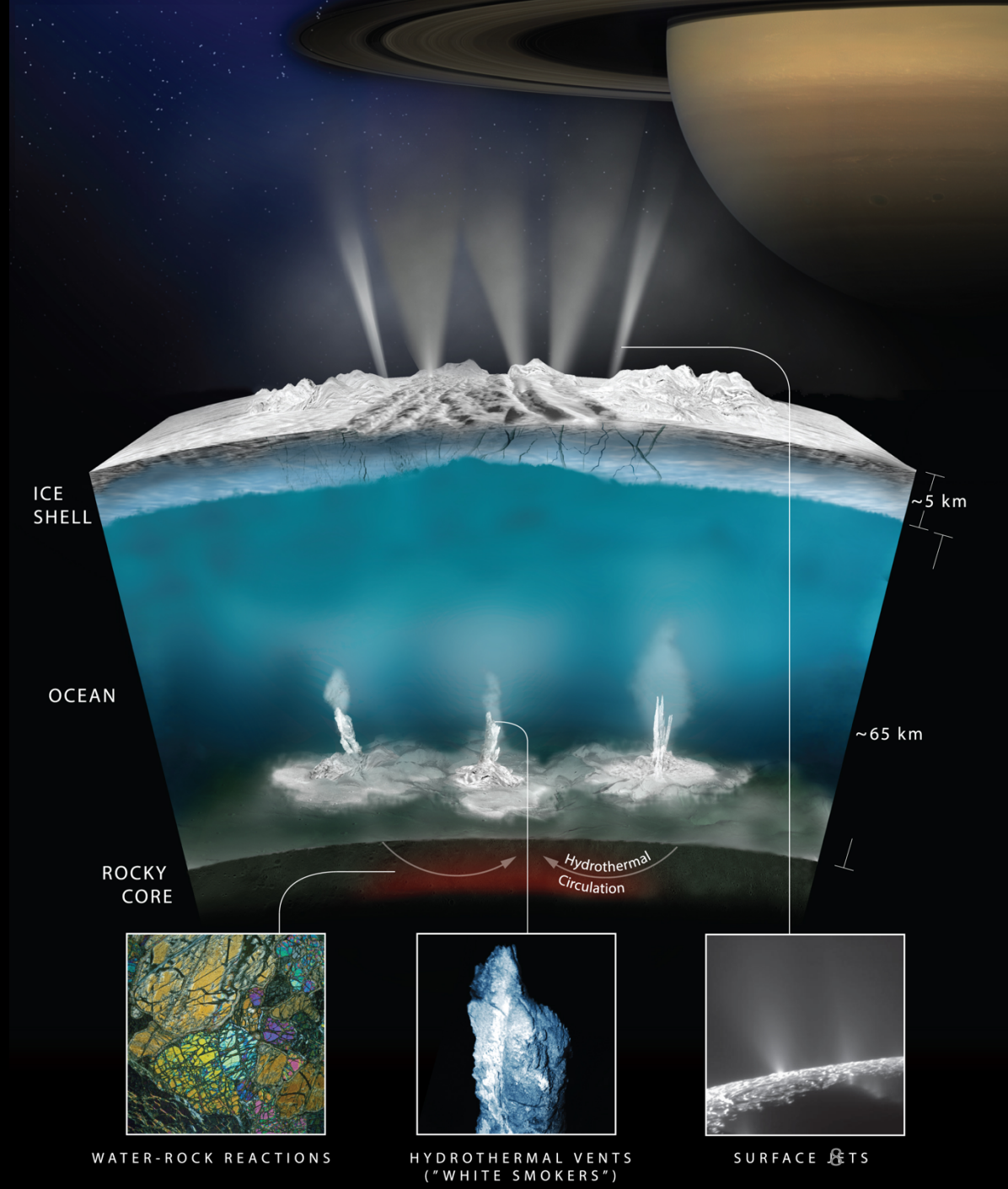
Enceladus

is the most

habitable

off-Earth place

we know of



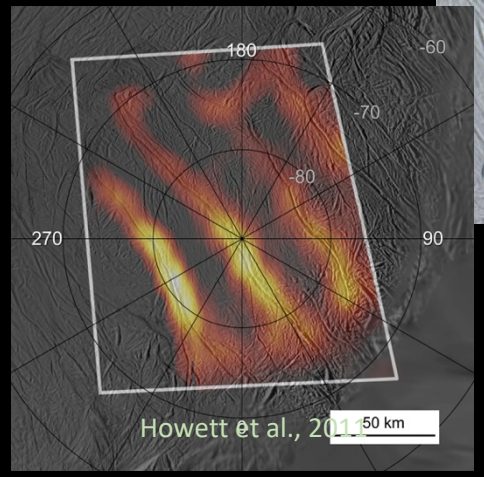
A tiny but active world

Global ocean beneath an ice shell, kept temperate by tidal heating

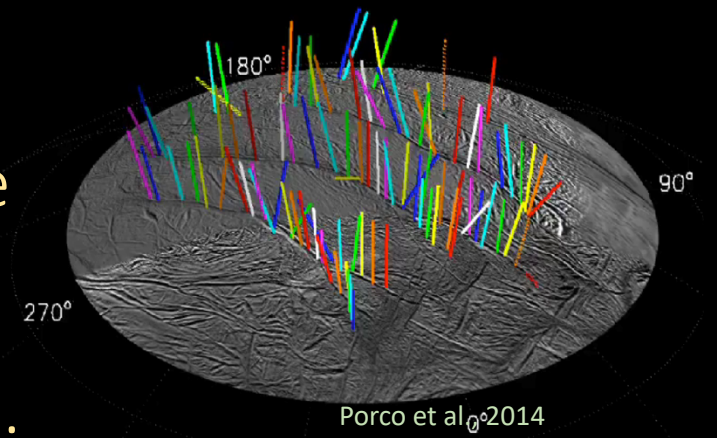
Polar crust is split by a system of warm fissures...

...venting gas, dust, and ice grains through 101 jets.

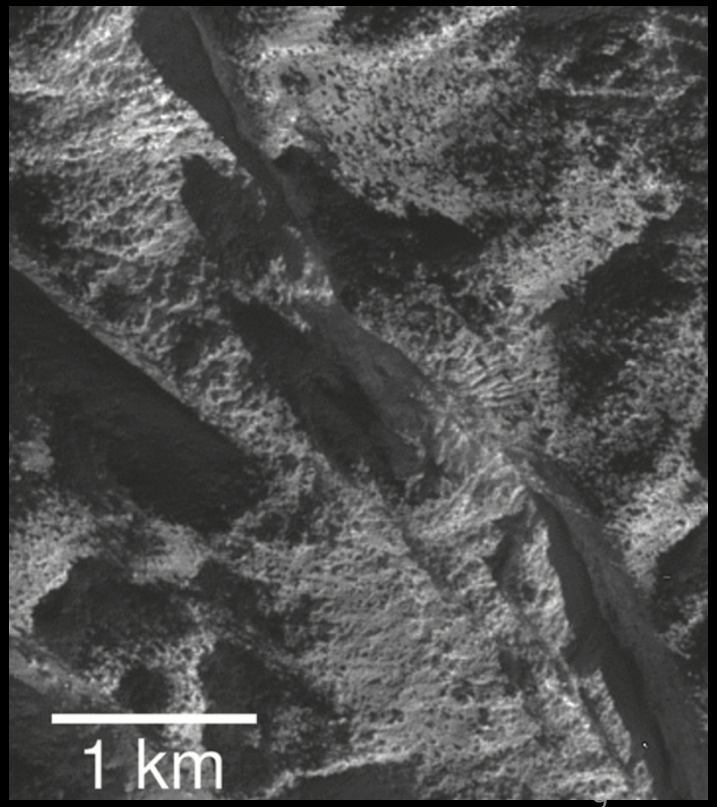
The ocean comes out here.

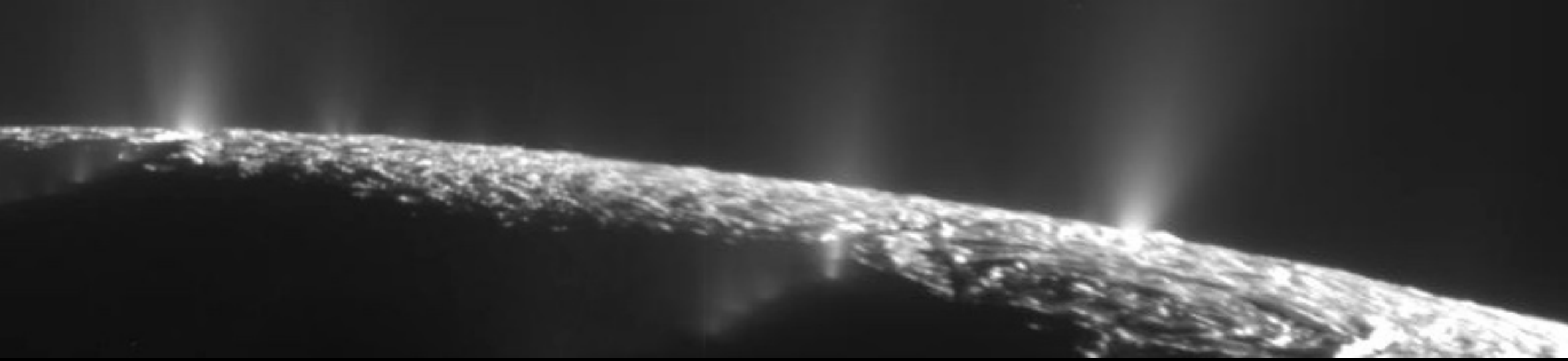


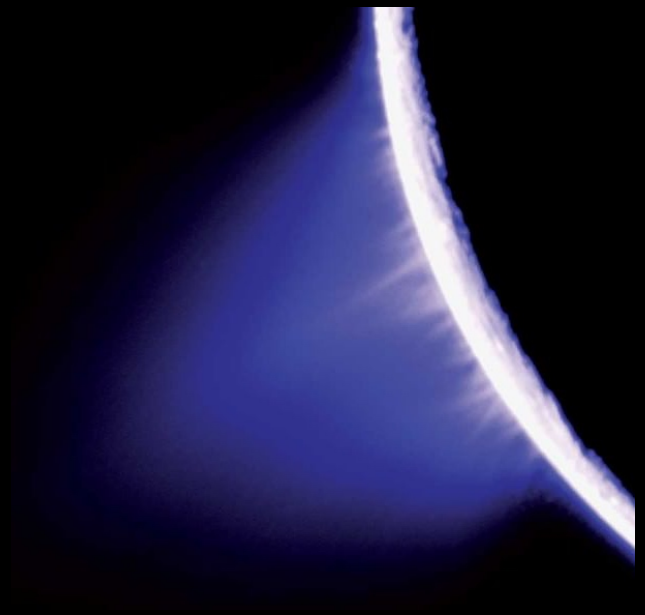
Howett et al., 2011



Porco et al. 2014







Cassini sampled the plume seven times:

Ice grains of frozen ocean spray → alkaline salt water

Silica dust → 90℃ seafloor hydrothermal circulation

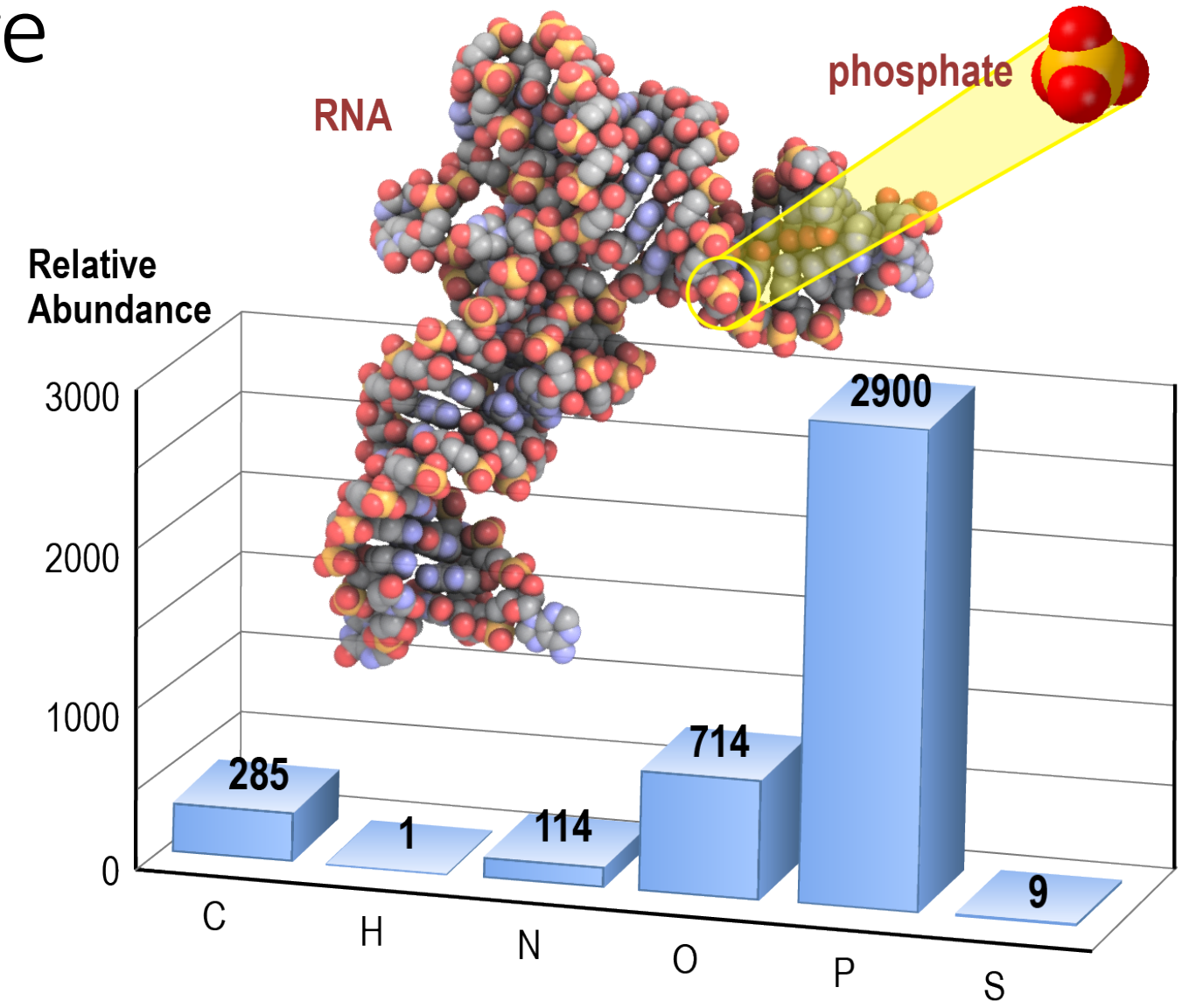
Detected: organic chemistry, excess hydrogen

Ingredients for life

Phosphorus is a "habitability limiter"

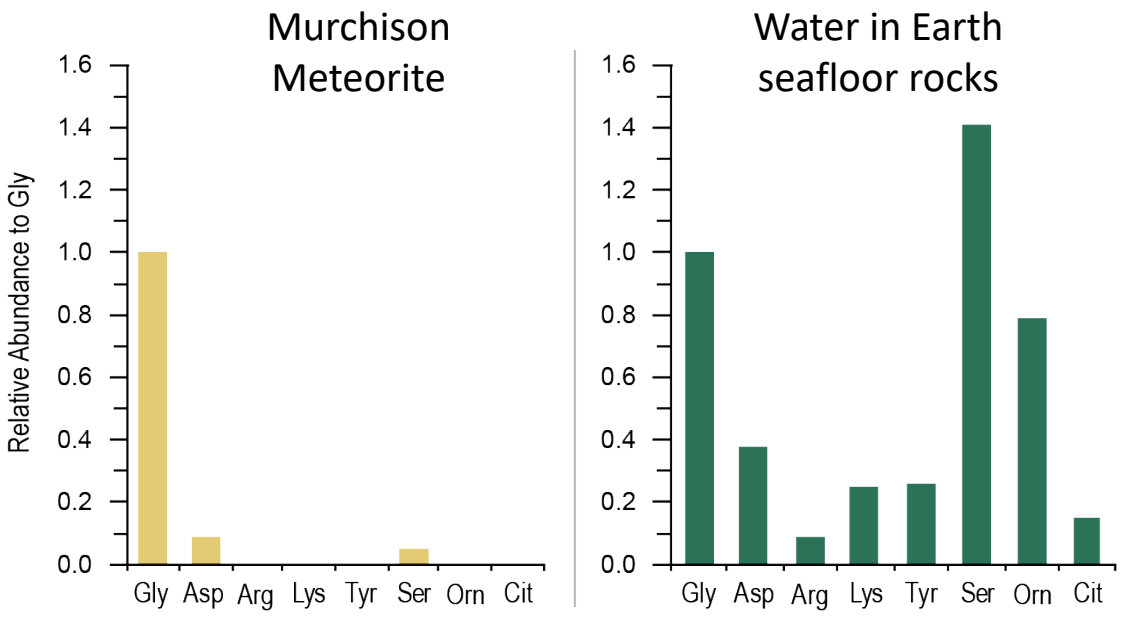
Critical for energy storage in living systems

Cells have much more of it than do nonliving systems

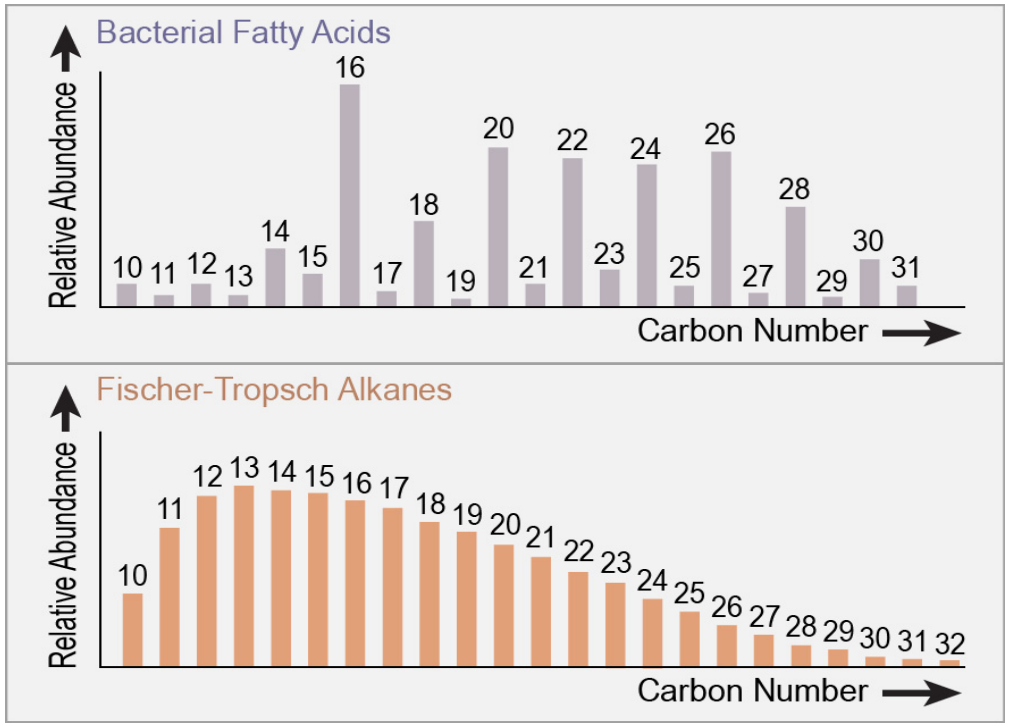


Compositional analysis

Straightforward for space flight mass spectrometers

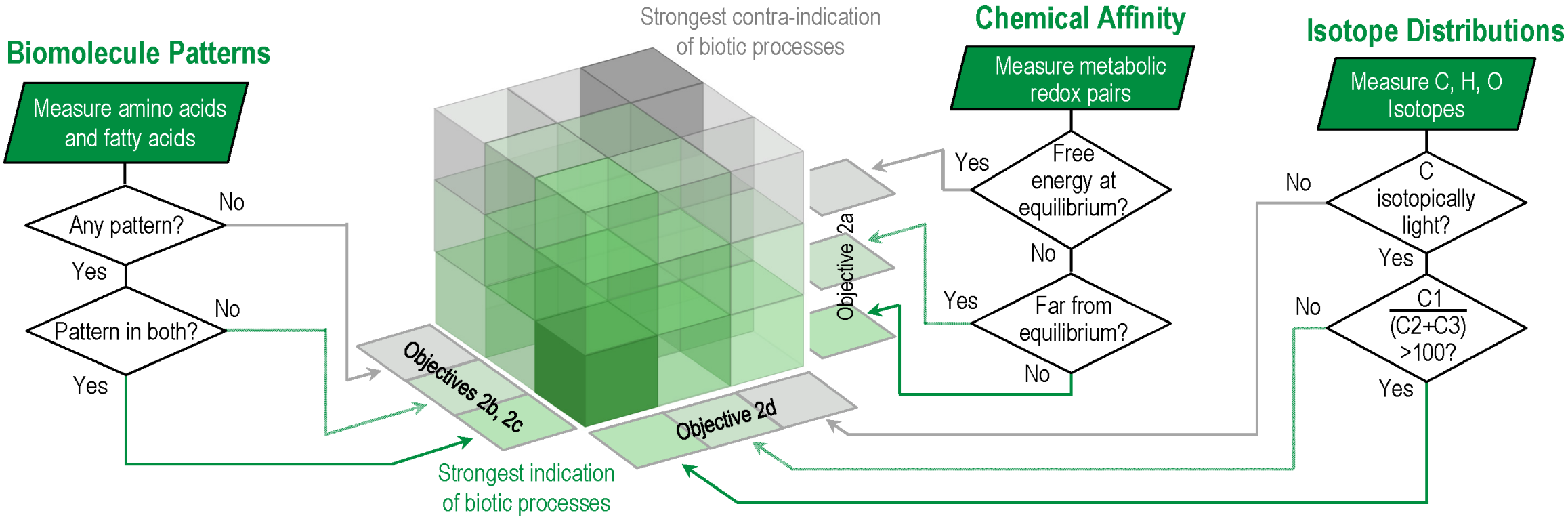


Relative abundance within organic families

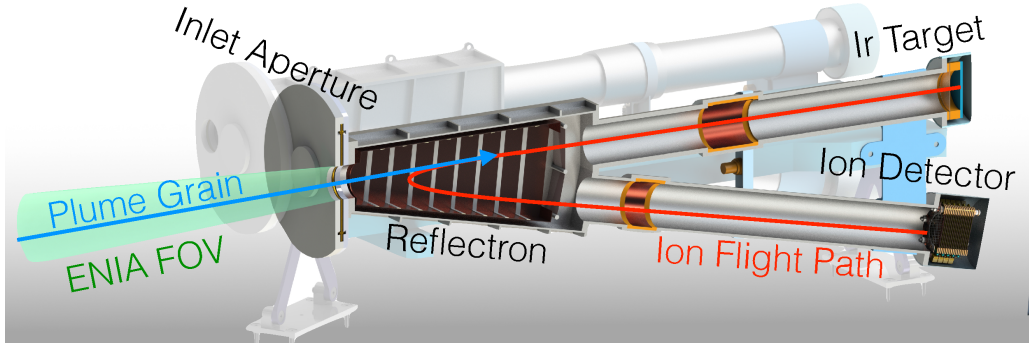


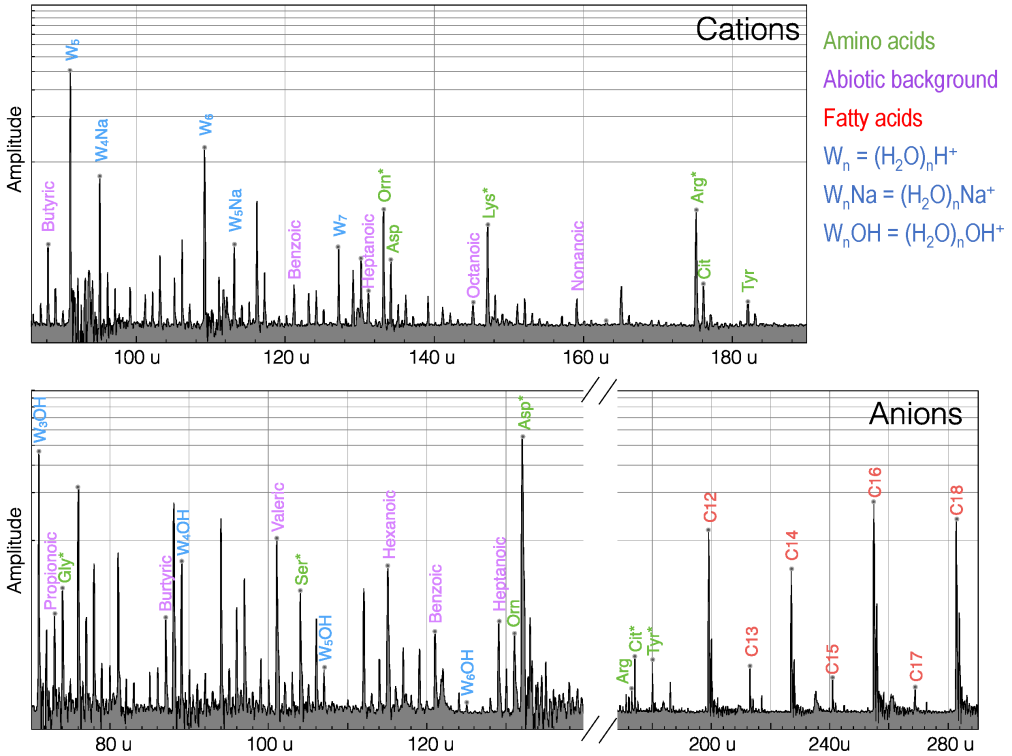
Molecular construction patterns

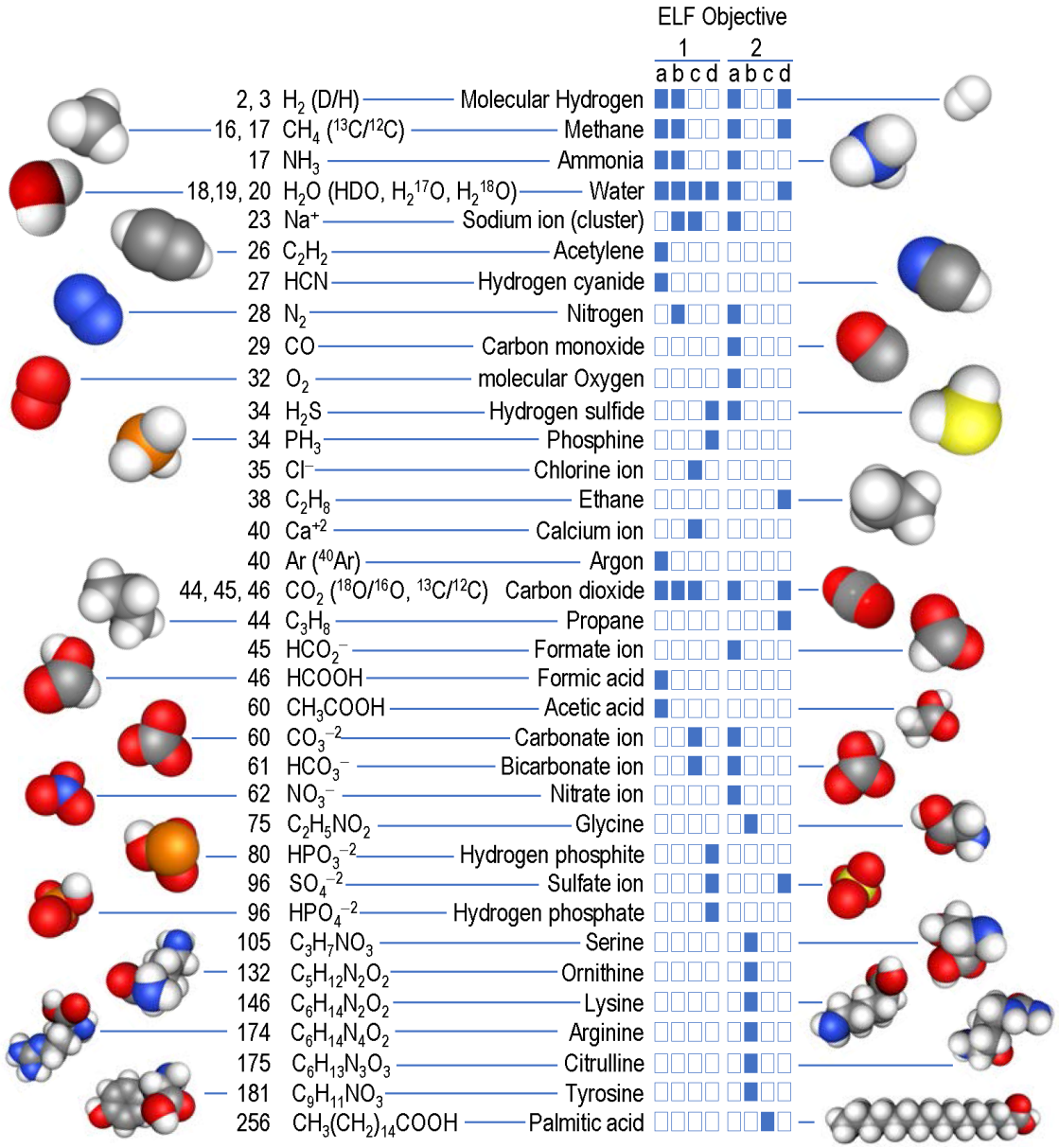
We need multiple independent tests



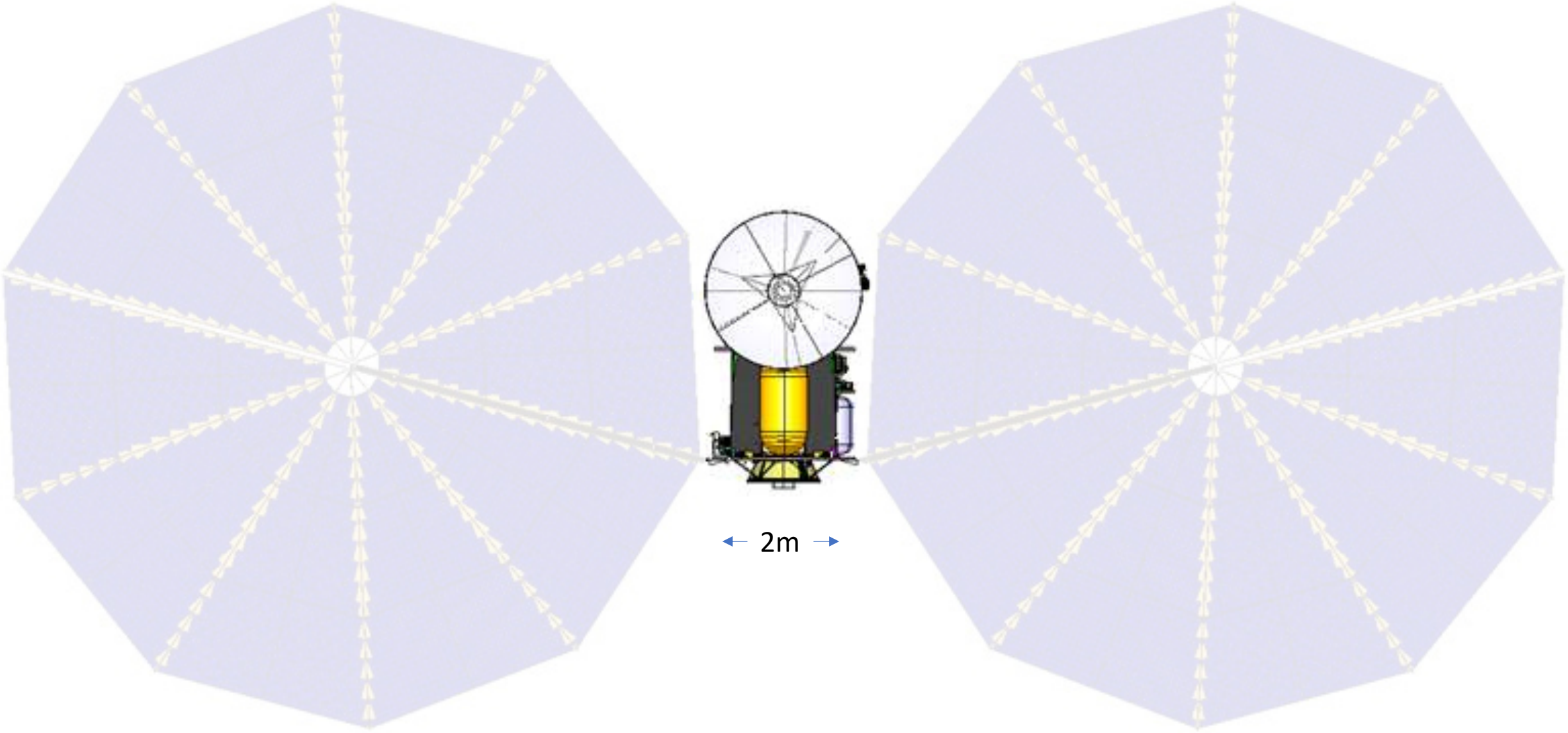
Chemistry experiment by three types of mass spectrometer







...on a solar-powered spacecraft to Saturn



A Flyby design flows down from science requirements

50 ±8 km altitude, within ±10° of the pole (meets gas and grain min-density requirements)
~100 jets form one plume above 40 km altitude, ensuring sufficient sample.

2 flyby velocities

- **Two at 8.0 ± 0.4 km/s** (experiment control: Cassini E21 @ 7.7 km/s); ideal for ENIA ionization and fragmentation of grain species
- **Eight at 5.0 ±0.4 km/s** (= 0.130 ± 0.001 eV/u); optimal for MASPEX cadence; ideal for ENIA and MARINE ionization of grain biomolecules with minimal fragmentation

B Data return and DSN link

8-hr 2-way DSN pass (2-way ranging)

C 62-d repetitive orbit ops

PI-led Science-Team decision protocols assess Priority Data (low-res summary and quick-look spectra); review instrument settings, e.g., aperture, ROI (region of interest), for possible update.

D Day 1 Flyby Science: plume ambient analysis

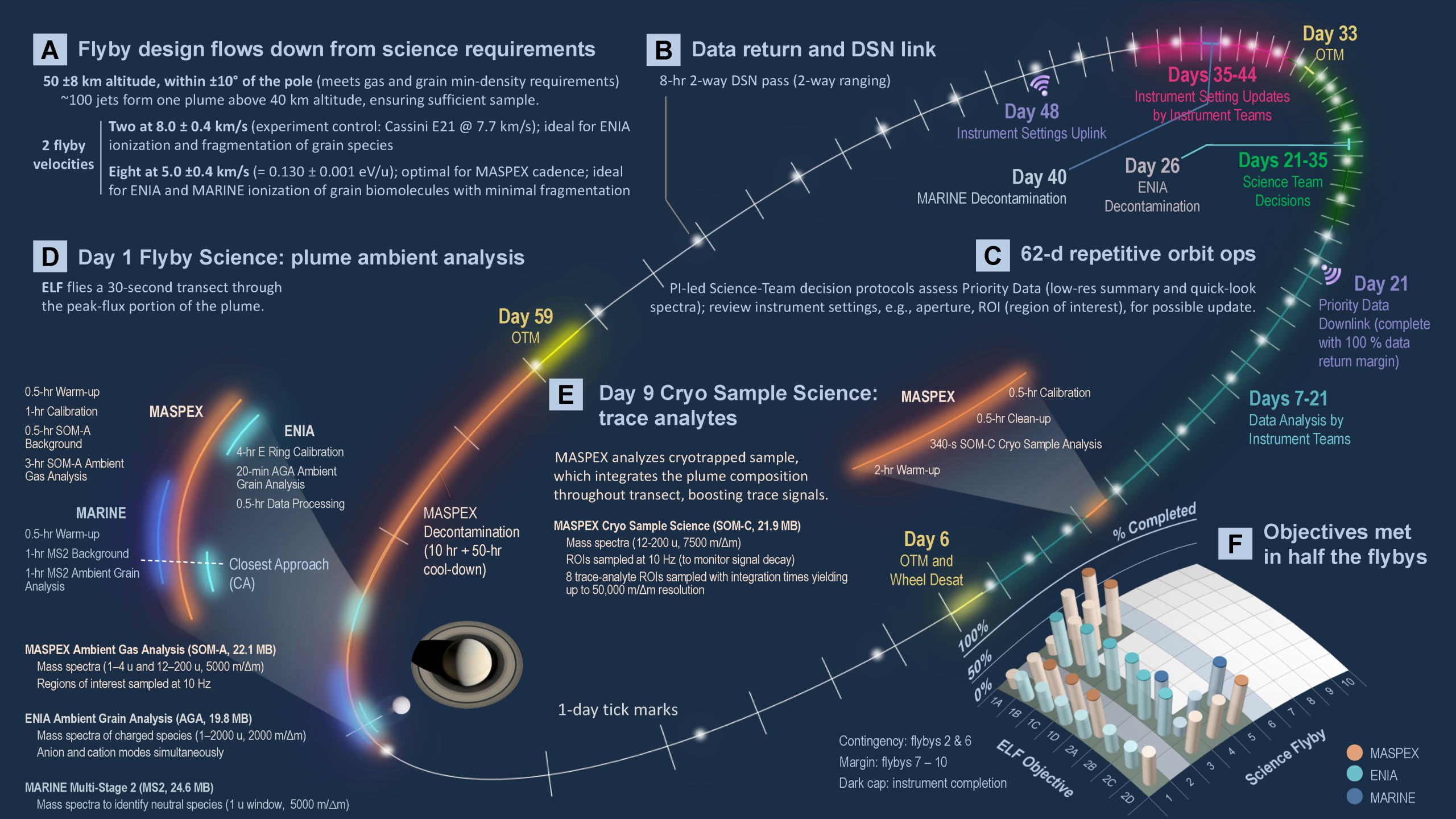
ELF flies a 30-second transect through the peak-flux portion of the plume.

E Day 9 Cryo Sample Science: trace analytes

MASPEX analyzes cryotrapped sample, which integrates the plume composition throughout transect, boosting trace signals.

MASPEX Cryo Sample Science (SOM-C, 21.9 MB)
- Mass spectra (12-200 u, 7500 m/Δm)
- ROIs sampled at 10 Hz (to monitor signal decay)
- 8 trace-analyte ROIs sampled with integration times yielding up to 50,000 m/Δm resolution

F Objectives met in half the flybys



ELF has had significant investment already:

$2M in its engineering,

$3.6M in its science

NASA has no standard way to select ELF before 2023

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

E L F | the Enceladus Life Finder

2016 version

MISSION OVERVIEW

- Launch Feb 25, 2024. Backup +1 year
- Int - Low LV, launch mass 1952 kg
- EVEE gravity assist, 10-year cruise
- Saturn arrival Mar 2034
- Orbital pump-down via 3 Titan flybys
- Disposal into Tethys, Jan 2037

Ten 50-km alt. plume transects (4 needed)

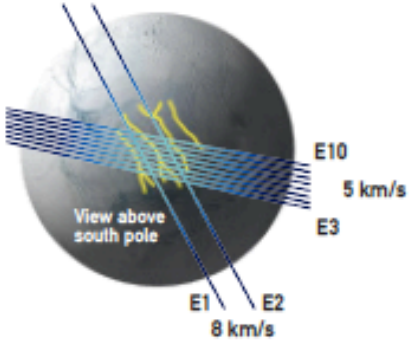
SPACECRAFT

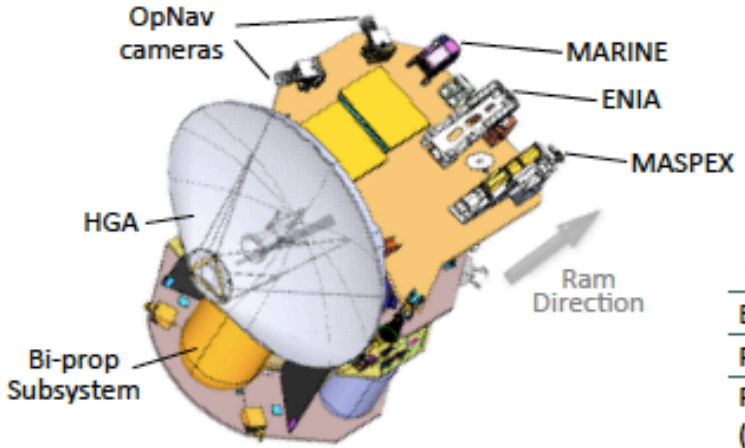
- Heritage: Odyssey, Phoenix, Juno
- Dual-mode bi-prop, X-band telecom
- 9.7-m UltraFlex solar arrays
- Two OpNav cameras (capable of lander-scale surface images)
- Margins: 32% dry mass; 58% orbit-average power; ≥130% downlink data volume

Principal Investigator	**Jonathan Lunine (Cornell)**
Deputy PI	J. Hunter Waite (SwRI)
Project Scientist	Linda Spilker / Morgan Cable
Project Manager	Rick Nybakken
Project SE	Steven Lee

PARTICIPATING ORGANIZATIONS

Cornell	PI Institution
JPL	Project Management SE, SMA, MD, Nav, Ops MARINE instrument
SwRI	MASPEX instrument
CU-LASP	ENIA instrument
Lockheed Martin	Spacecraft and I&T





INSTRUMENTATION

3 Complementary Mass Spectrometers

No sample handling		**Mass Range**	**Mass Resolution**
MASPEX	Gas	1–1000 u	40,000 m/Δm at 62 u
ENIA	Ice Grain – Ions	1–2000 u	2000 m/Δm at 400 u
MARINE	Ice Grain – Neutrals	12–1000 u	5000 m/Δm with MS^2

COST ($FY15M)	**Phases A-D**	**Phases E-F**	**Total**
Base	563.4	174.2	737.6
Reserves	197.2 (35%)	34.8 (20%)	232
PI-MMC (A-D Cap = 850)	760.6	209	969.6
Contributions			
Non-Science*	4.4	1.5	5.9
Science Team	1.9	2.4	4.3
Total Mission Cost	**766.9**	**212.9**	**979.8**

** No hardware contributions: GFE (0.3), Cornell (0.9), JPL (2.2), U of Stuttgart (1.25), Heidelberg U. (1.25)*

$1B
(plus launch)

By 2035 you could learn whether Enceladus has life

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