# ENCELADUS LIFE FINDER CONCEPT

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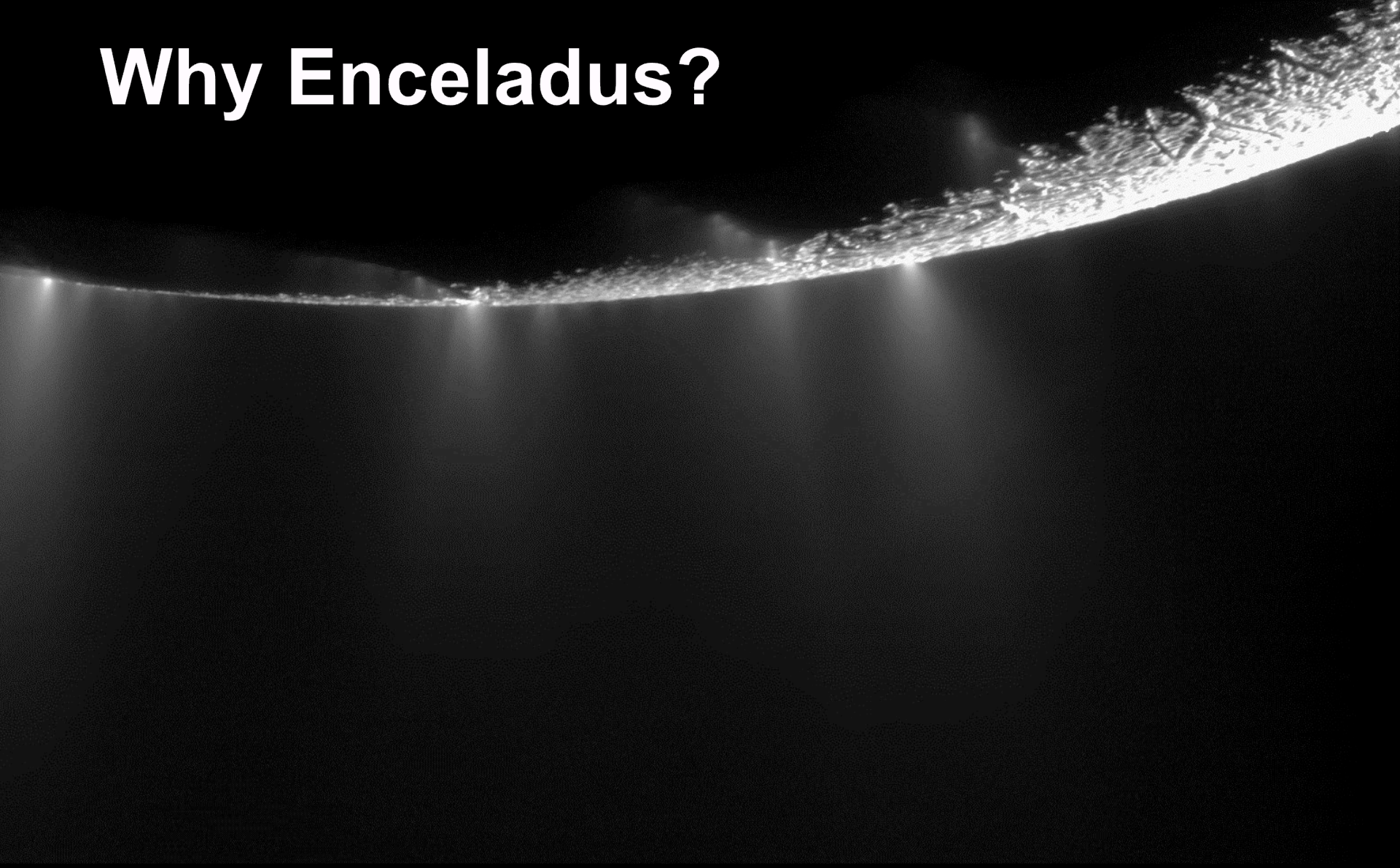
# Why Enceladus?



(Porco et al., 2006; Dougherty et al. 2006)

Image: NASA/JPL/Space Science Institute

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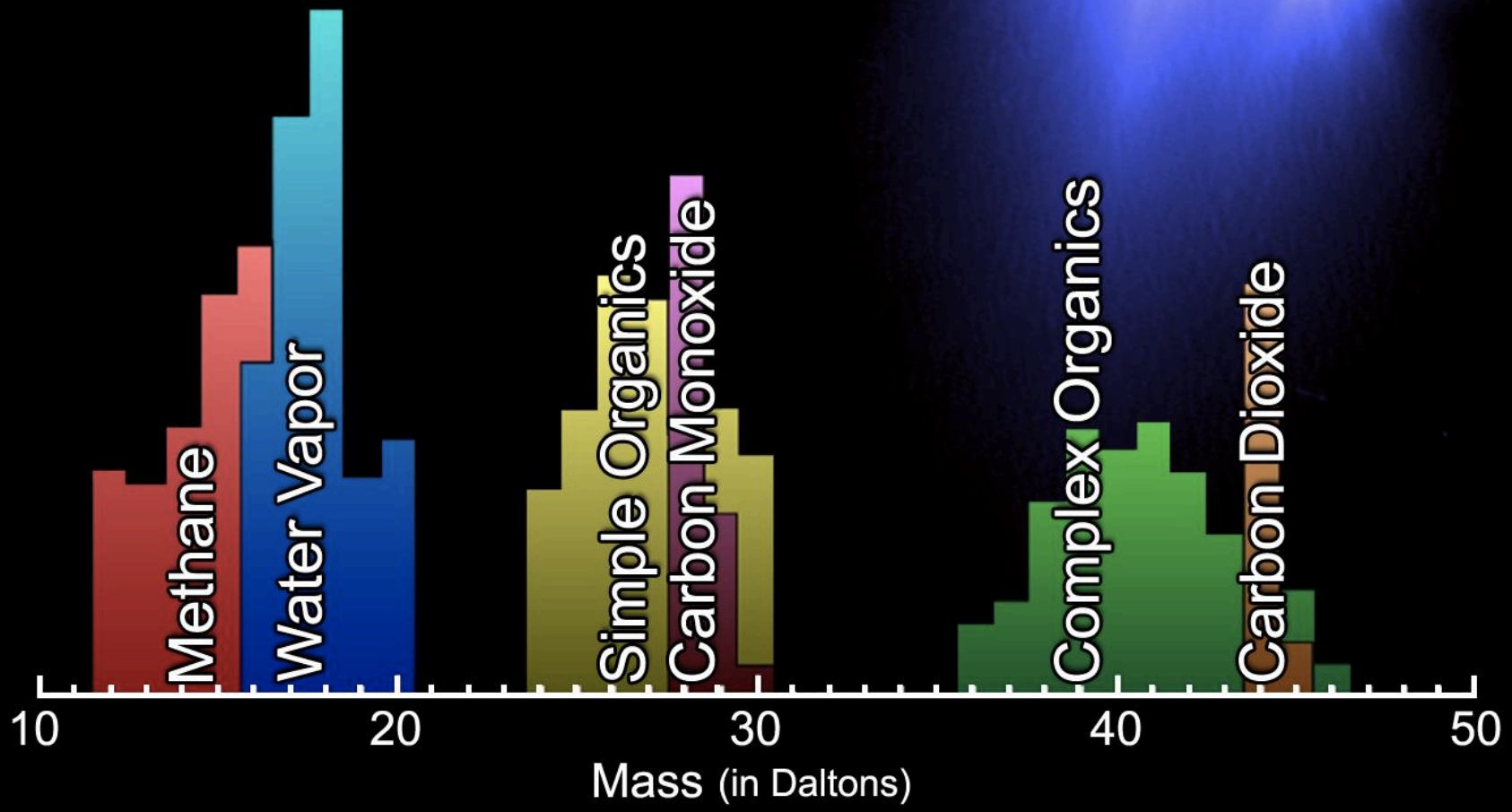


(Matson et al. 2007, Waite et al. 2008)

Image: NASA/JPL/SwRI

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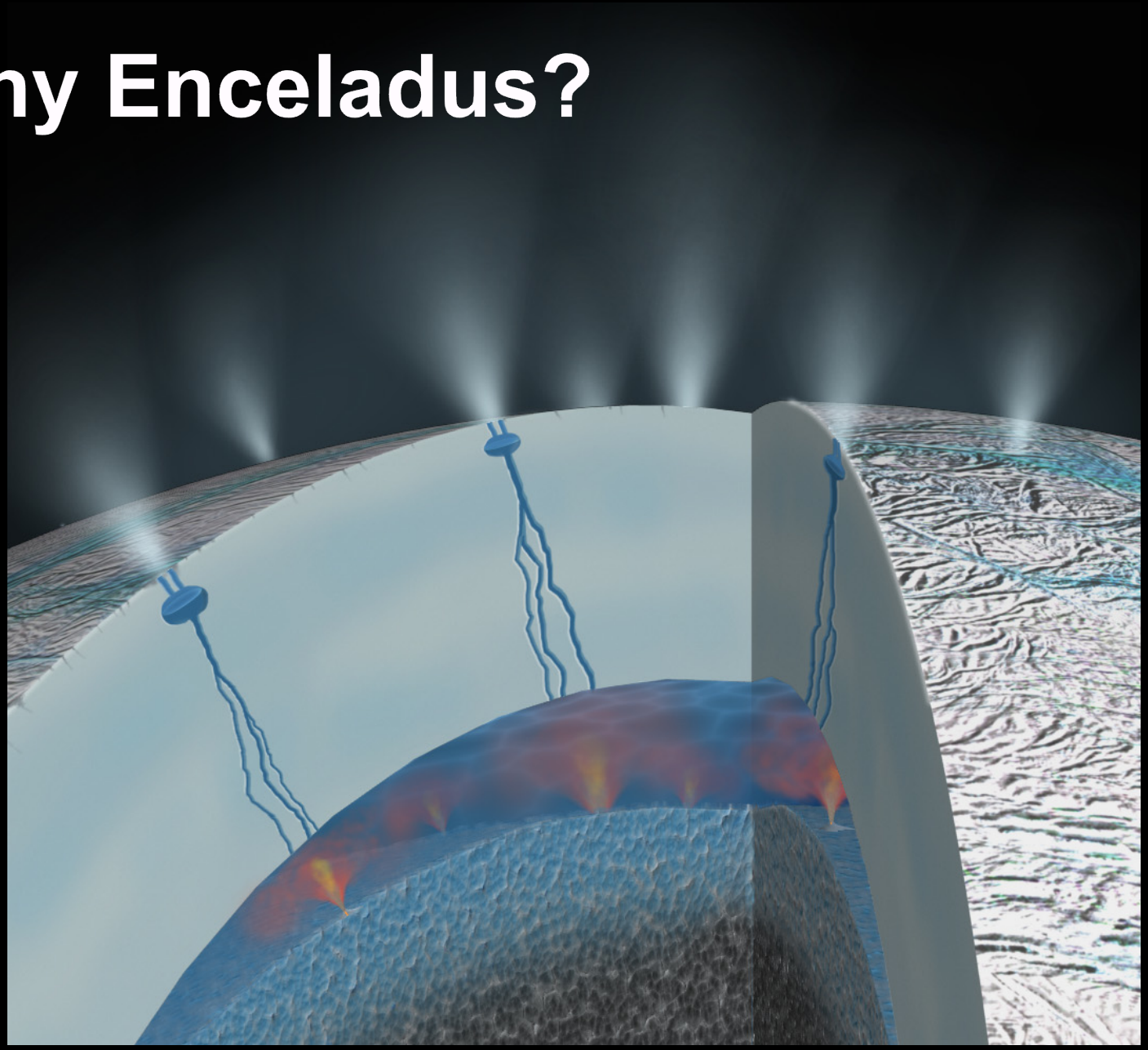

(Postberg et al., 2009, 2011)

Image: NASA/JPL

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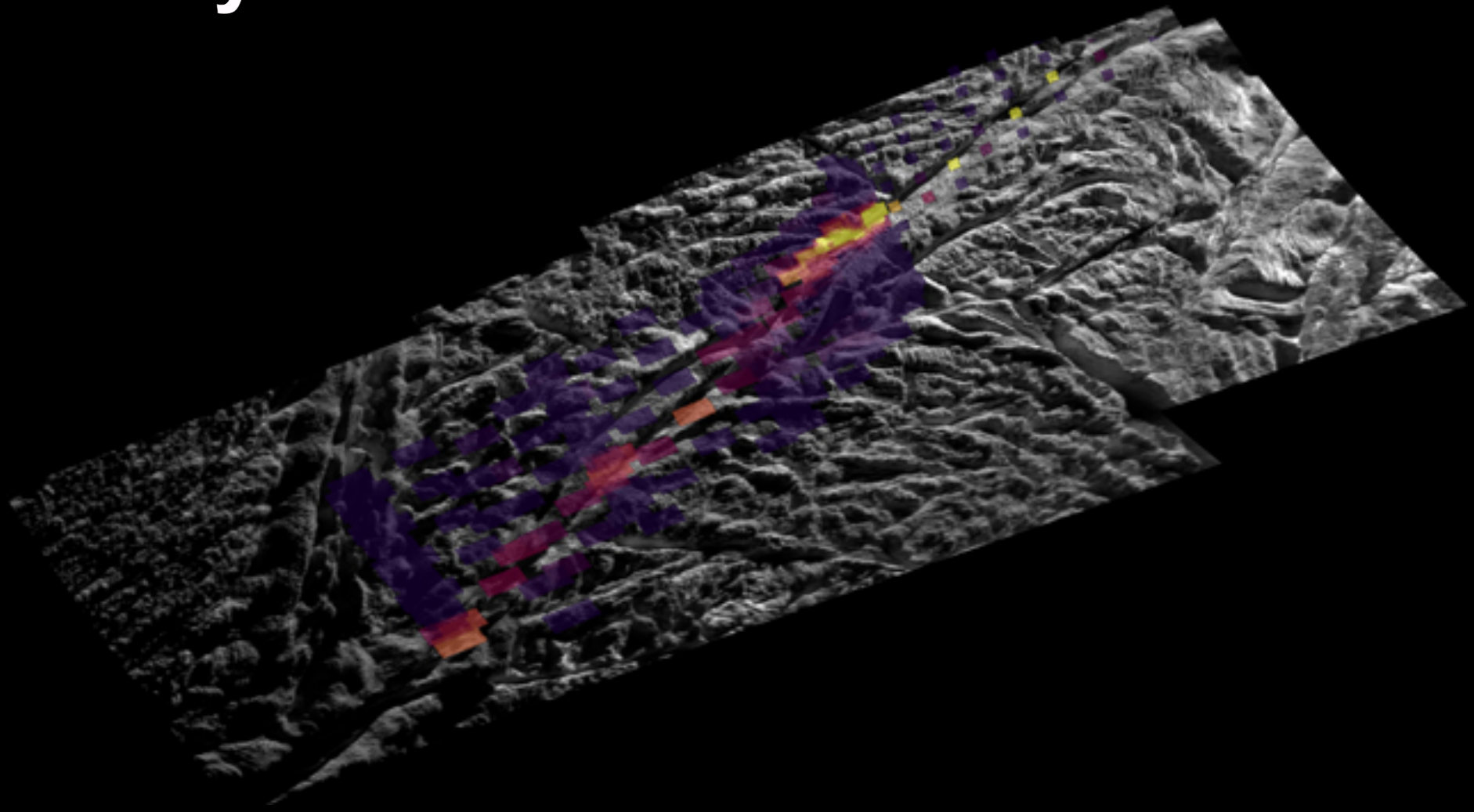

(Abramov and Spencer, 2009, Howett et al., 2011)

Image: NASA/JPL

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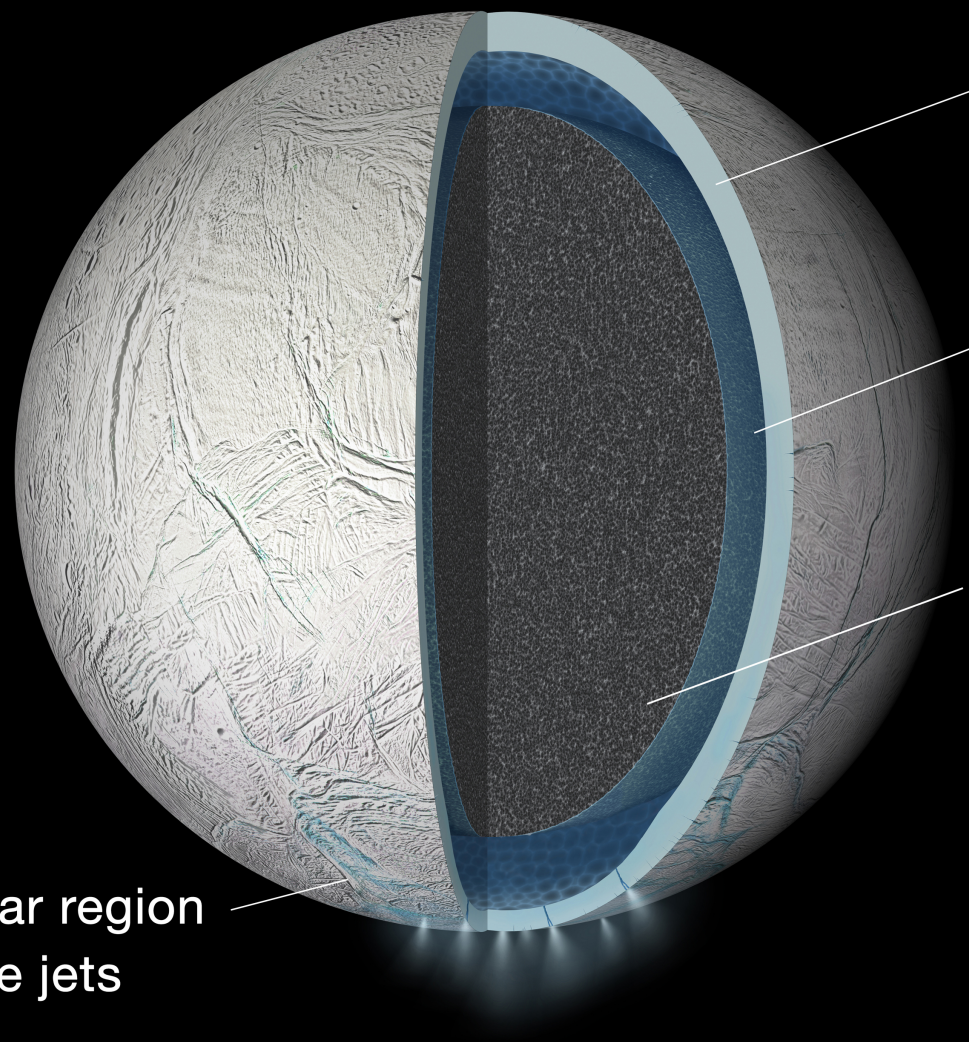


(Iess et al., 2014, McKinnon, 2015, Thomas et al, 2015)

Image: NASA/JPL

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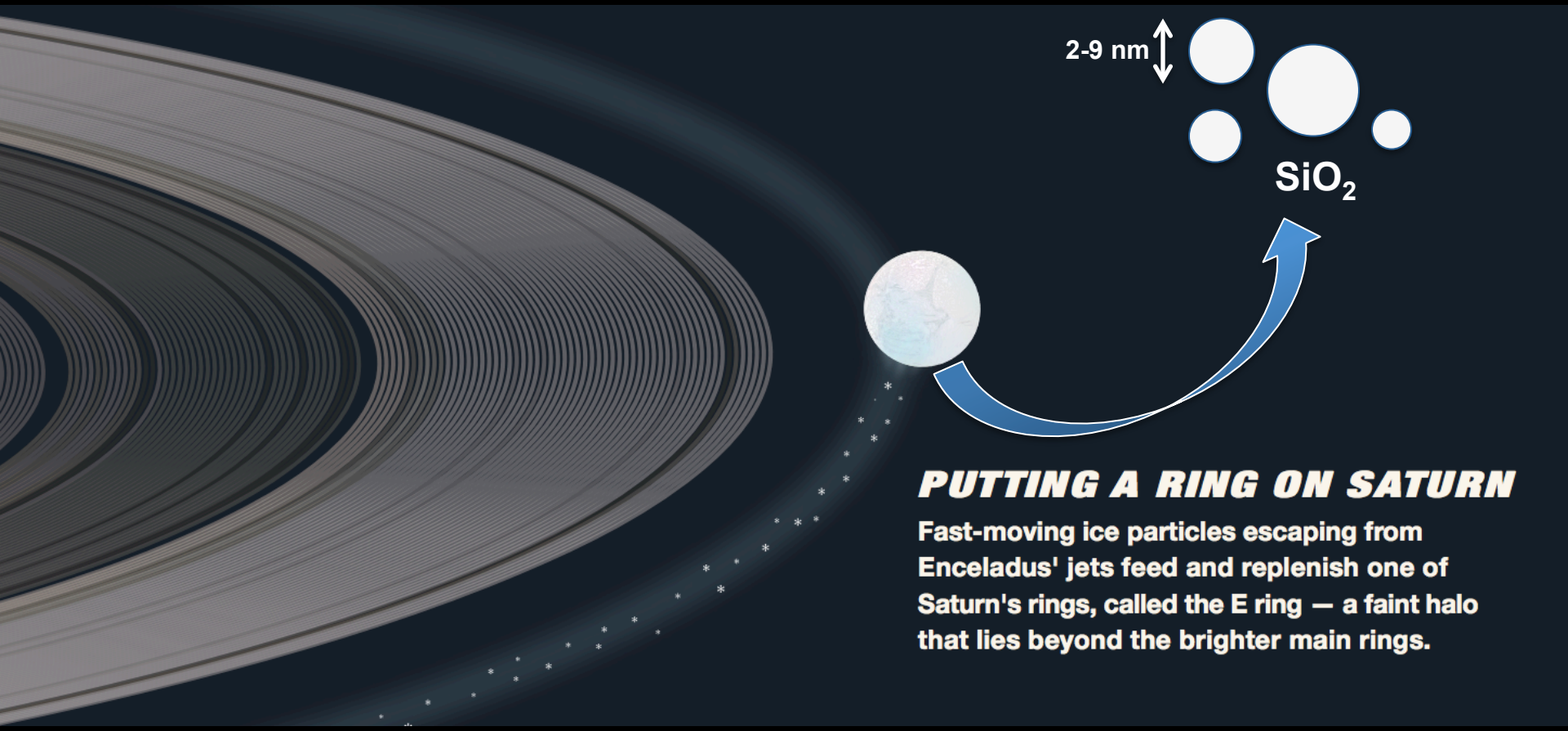


(Hsu et al., 2015)

Image: NASA/JPL

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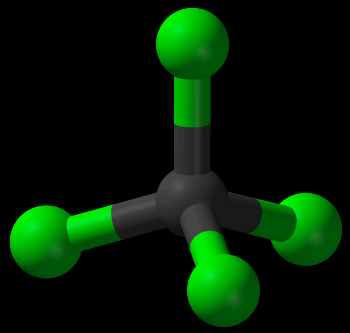
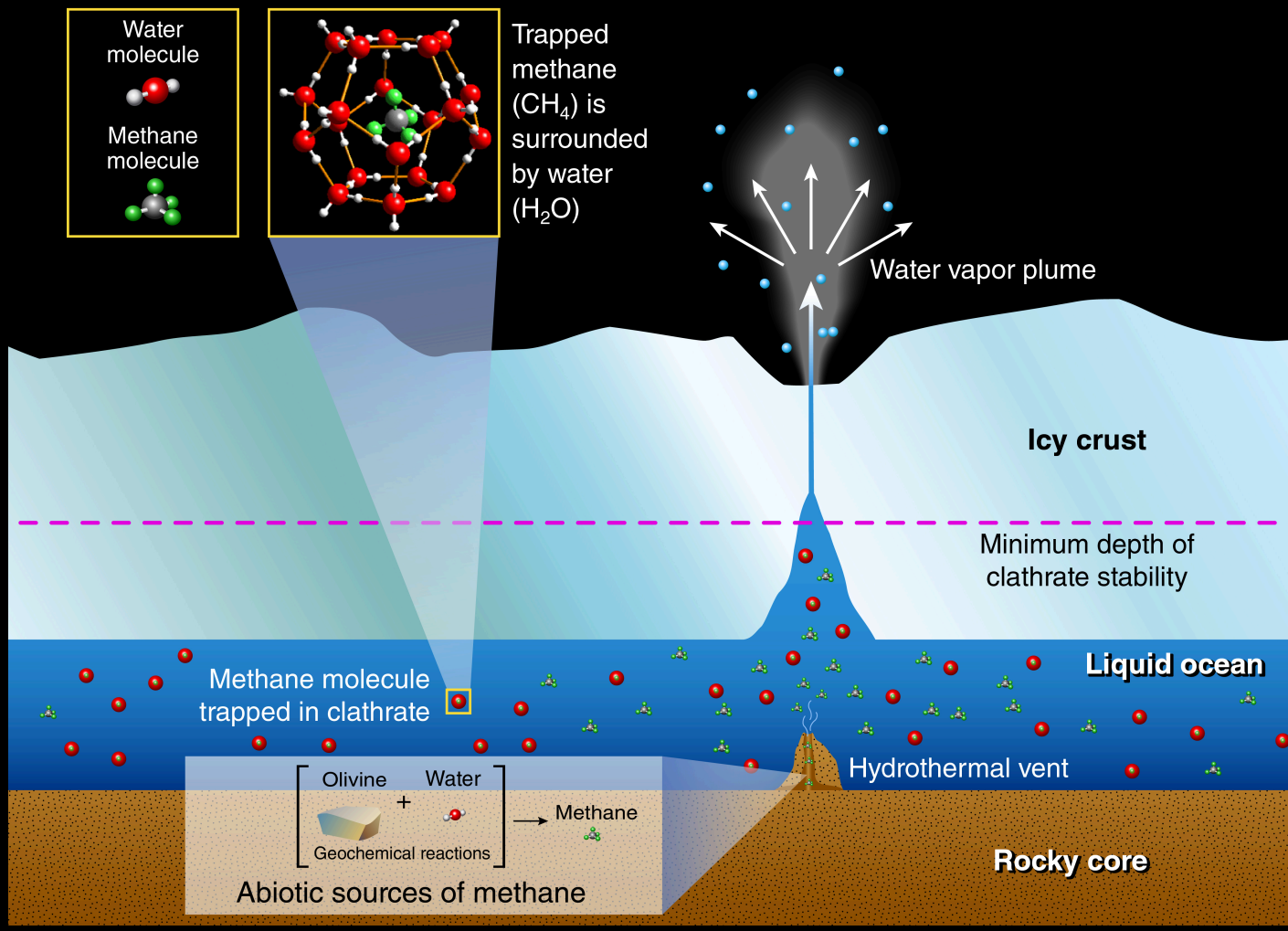


**Methane ($CH_4$)**




(Bouquet et al., 2015)

Image: NASA/JPL/SwRI

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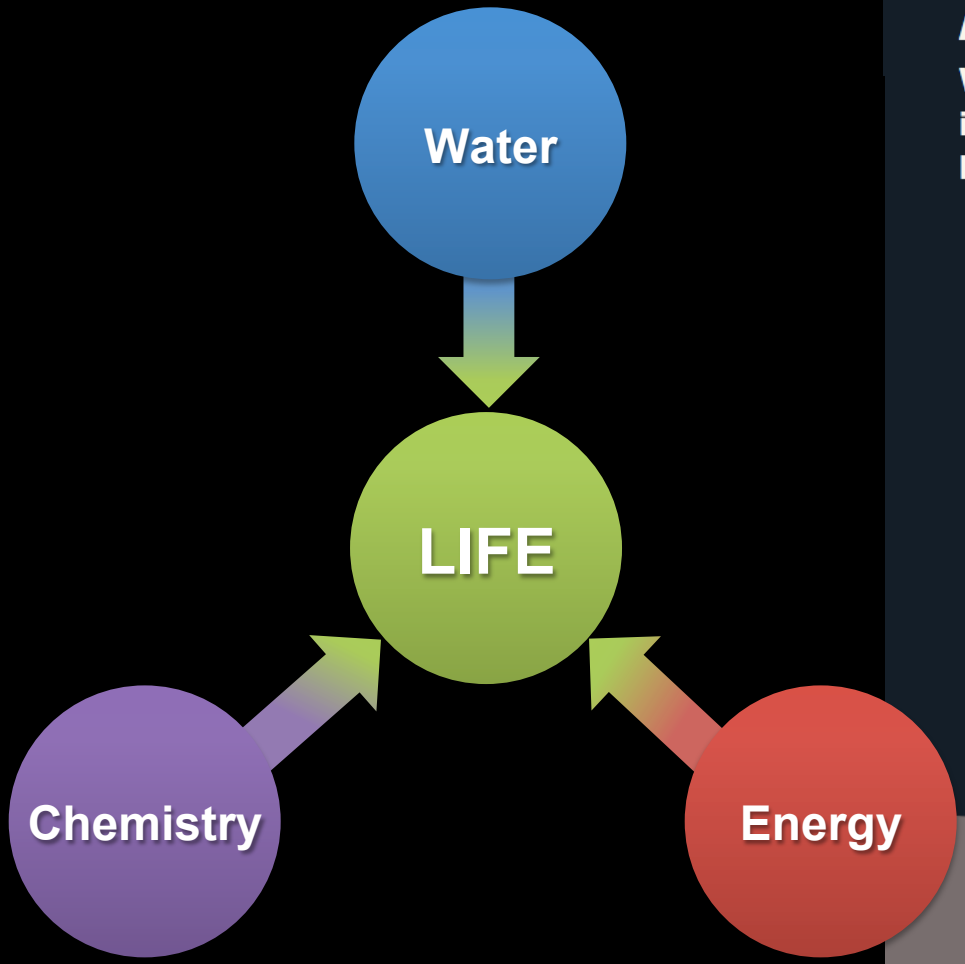
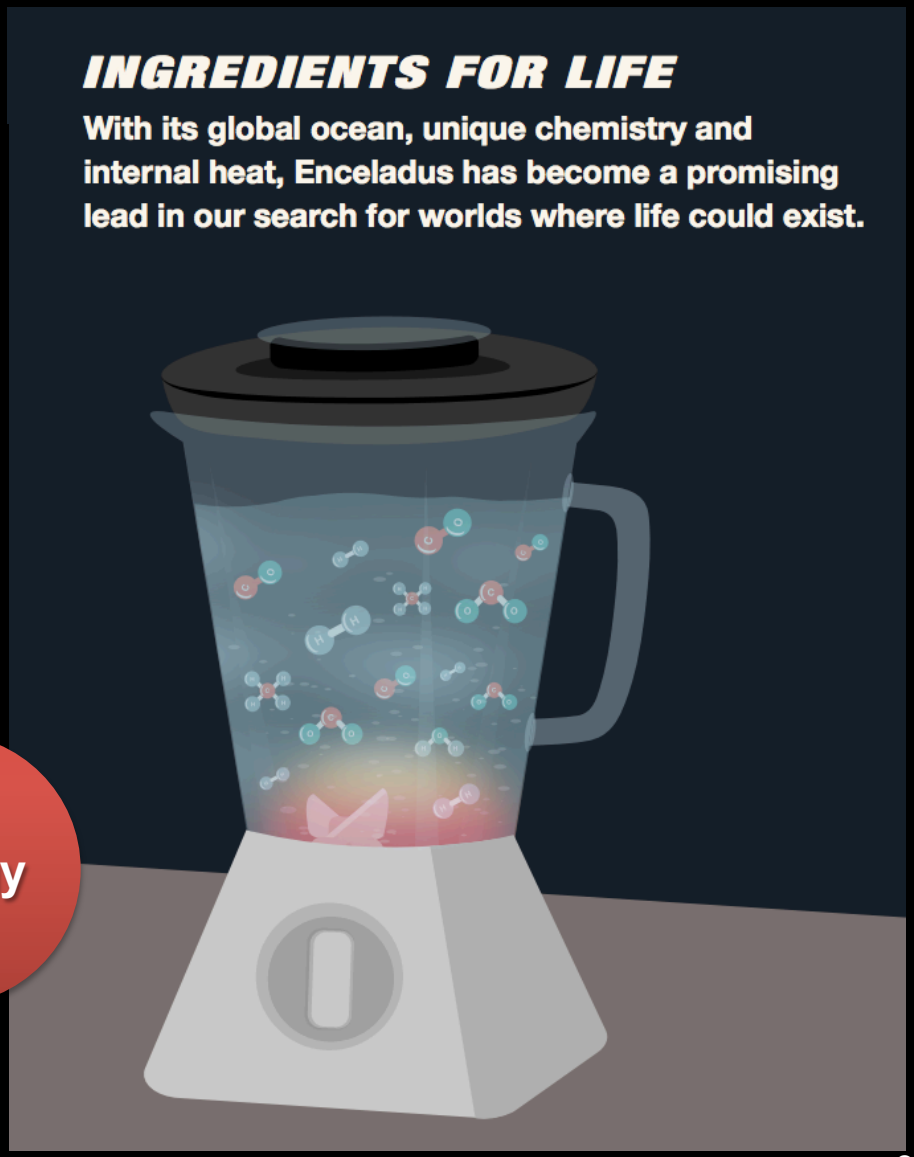
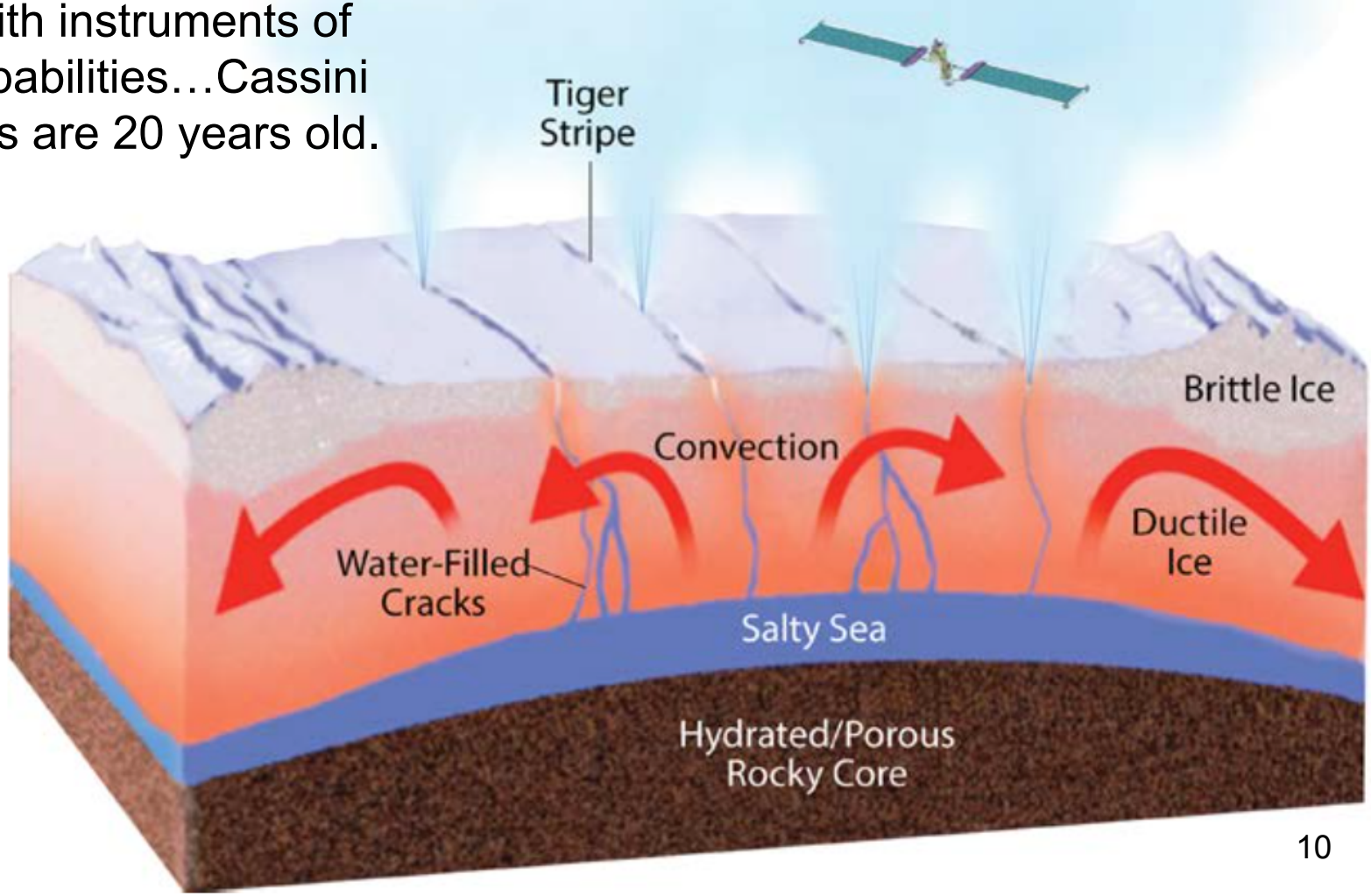



http://saturn.jpl.nasa.gov/files/enceladus_infographic_full.pdf

# ELF Concept: The Enceladus Life Finder

- Fly through the Enceladus plume just like Cassini did….
- But do it with instruments of today's capabilities…Cassini instruments are 20 years old.



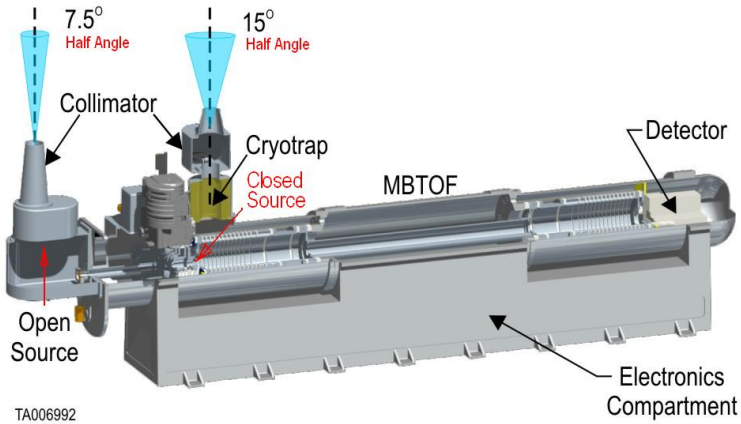
# The ELF Mission Concept

**10 flybys... 2 instruments... 1 profound question: Is there life beyond Earth?**

## MASPEX

**MAss SPectrometer for Planetary EXploration**

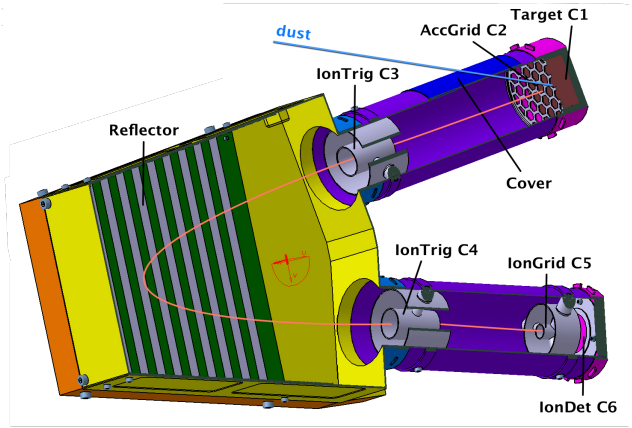
- Target: Plume **gas**
- Extended mass range for heavy organic molecules
- Enhanced mass resolution for critical isotopes
- Enhanced dynamic range for high S/N
- Improved sensitivity (better than 1 ppt with cryotrap) for rare noble gases



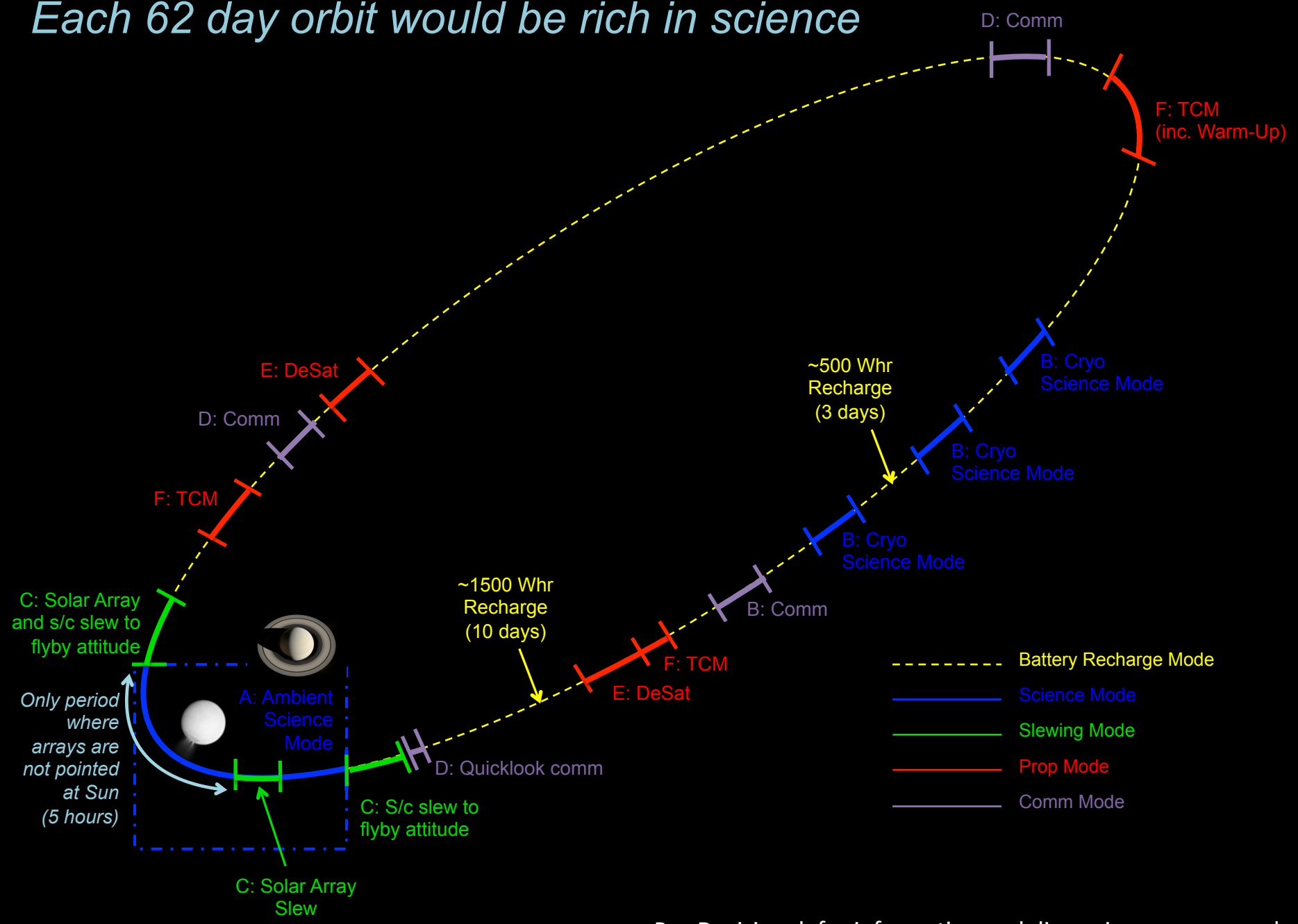

## ENIJA

**ENceladus Icy Jet Analyzer**

- Target: Plume **grains**
- Heritage : Giotto, Stardust CIDA but improved ion optics, ion detector, trigger logic, spectra processing
- Segmented target for low and high-rate spectra mode (compositional profile with 100 m spatial resolution)
- Complete composition of each ice grain, over a wide mass range

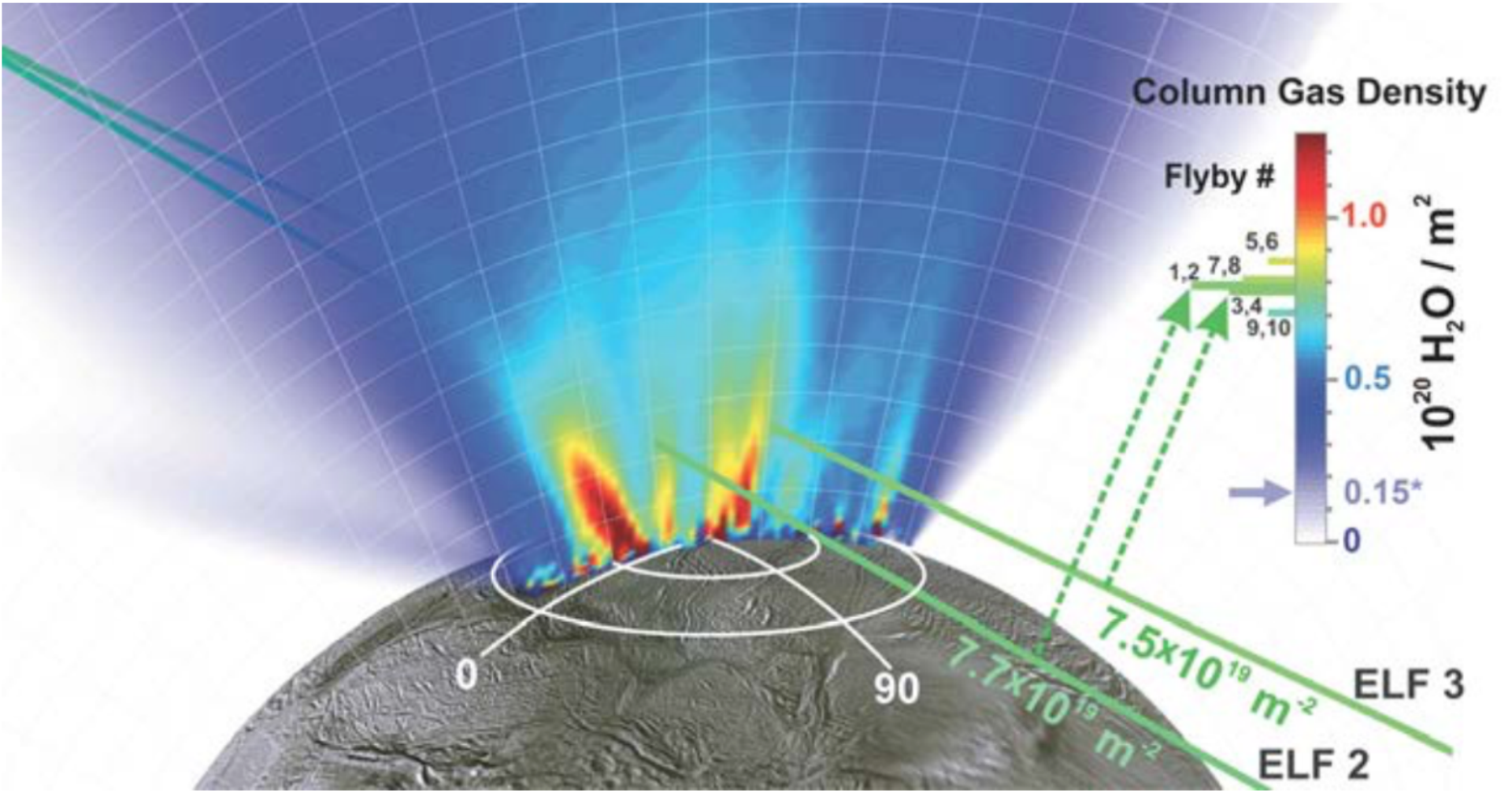


# *Each 62 day orbit would be rich in science*




Pre-Decisional: for information and discussion purposes only.

# The Plume was Well Characterized by Cassini



# Proposed ELF Science Investigation

Evolution

Habitability

Life

## Science Objective 1 – Evolution

Determine if Enceladus' volatiles, including organics, have evolved over time.

**Nitrogen as an Indicator**

**1a.** Determine the original molecular carrier for nitrogen as an indicator of the degree of volatile evolution on Enceladus.

**Reactions with Water**

**1b.** Quantify the fraction of the volatile population that has not reacted with liquid water.

**Hydrothermal Alteration**

**1c.** Confirm whether the ocean has been, or is, in contact with hydrothermal systems at its base.



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# Proposed ELF Science Investigation

Evolution

Habitability

Life

## Science Objective 2 – Habitability

Determine if the ocean of Enceladus satisfies the basic requirements of habitability.

| Temperature | Redox Energy | Oxidation State | pH |
|---|---|---|---|
| **2a.** Determine the temperature of the ocean and possible hydrothermal systems to within 100 K. | **2b.** Quantify the amount of redox energy available. | **2c.** Determine the oxidation state of the ocean. | **2d.** Determine the pH of the ocean to within an accuracy of 1 unit. |



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# Proposed ELF Science Investigation

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## Science Objective 3 – Life

Determine if the plume of Enceladus contains chemical signatures of biology.

**Amino Acids**

**3a.** Look for patterns in the **amino acid** distribution indicative of biological synthesis, e.g. underrepresentation of glycine relative to other amino acids that are energetically more difficult to form.

**Membrane Molecules**

**3b.** Determine the **long-chain fatty acid** (C12–C30) distribution to look for patterns such as the even-odd disparity due to C2 addition in biological synthesis.

**Isotopic Trends**

**3c.** Determine the hydrocarbon abundance distribution, D/H ratio and the $^{13}C/^{12}C$ distribution in hydrocarbons and $CO_2$, to look for patterns consistent with biological synthesis.



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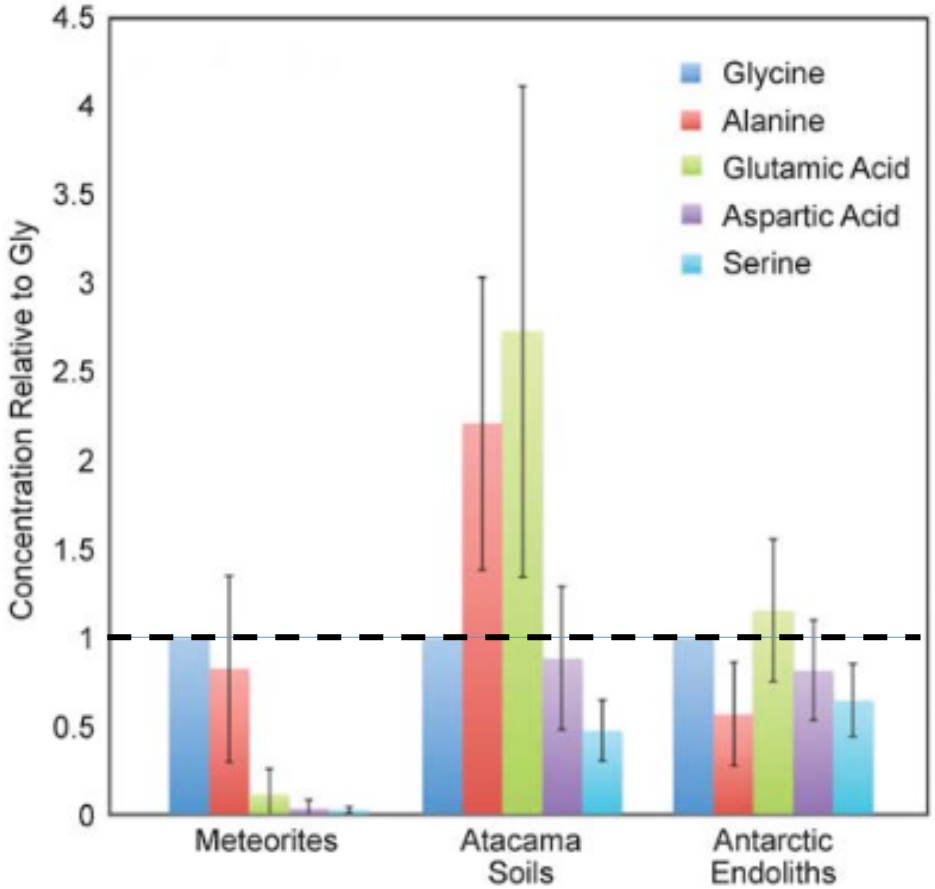
# Proposed ELF Science Investigation: Life

1. Amino acid pattern deviating from abiotic.

Glycine and alanine dominate in abiotic systems, but not in biotic systems.




(Davila and McKay, 2014)



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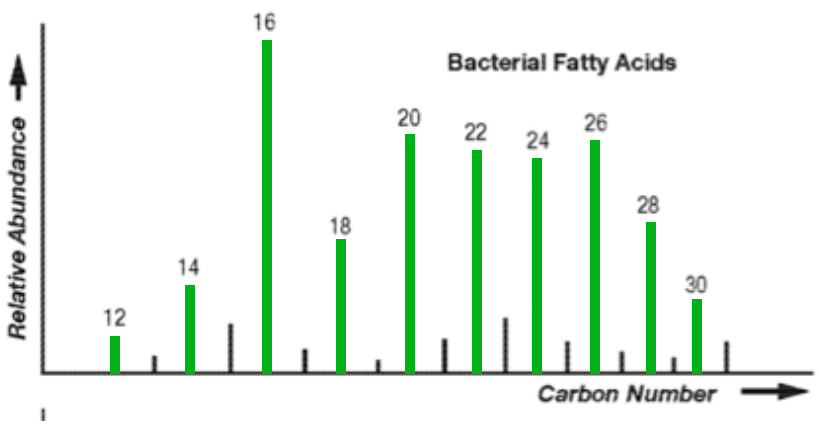
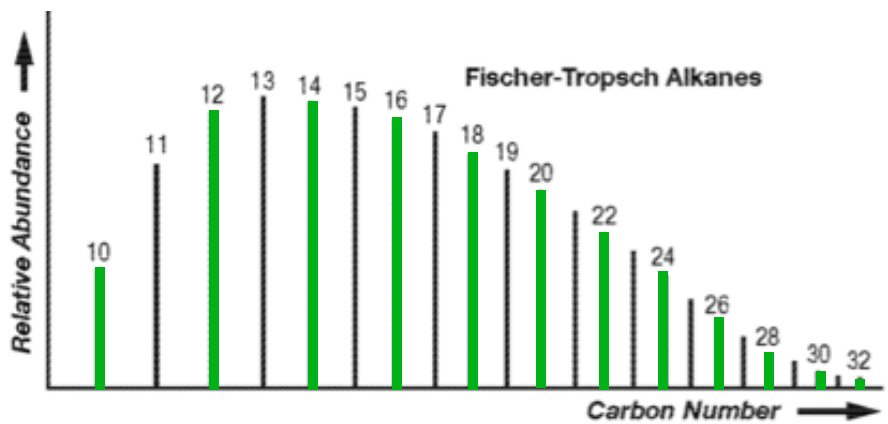
# Proposed ELF Science Investigation: Life

2. Repeating subunits and clustering in membrane-building molecules.

Biotic membranes exhibit repeating carbon subunits; abiotic environments do not.




**Fatty acids in bacteria**




**Abiotic chemistry**

(Georgiou and Deamer, 2014)



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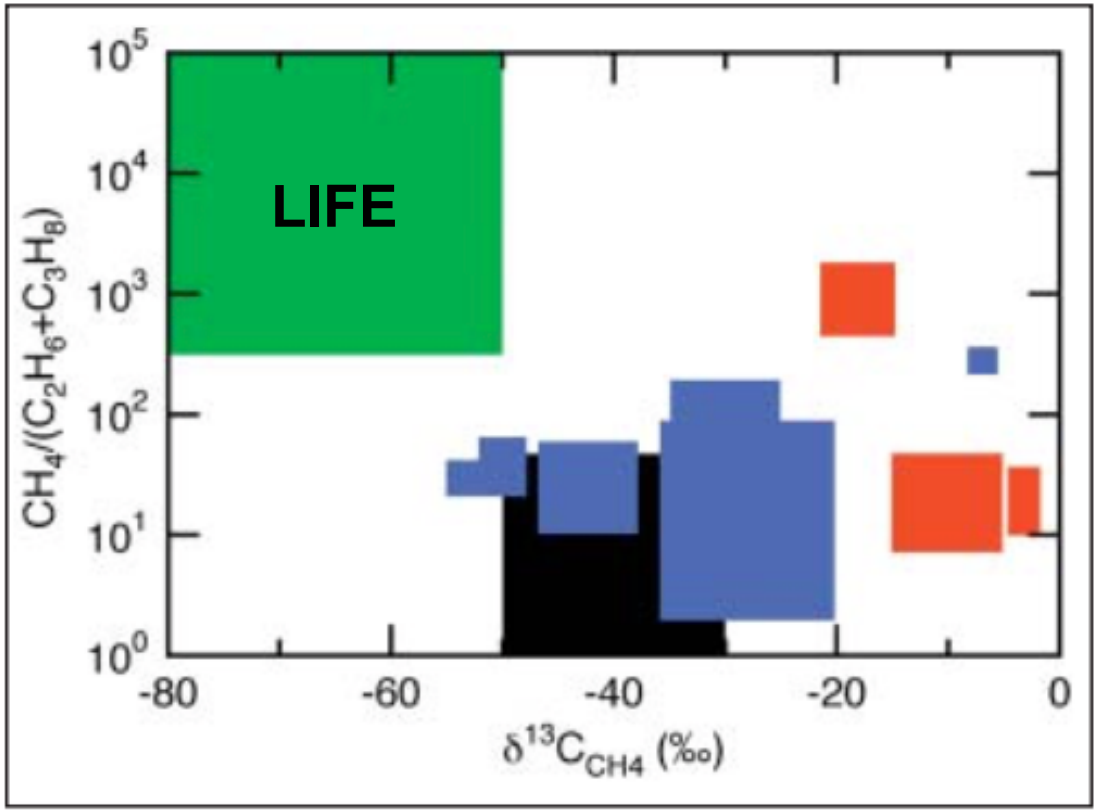
# Proposed ELF Science Investigation: Life

3. Combined isotopic and compositional trends.

Measurement of isotopes in carbon bearing species and abundances relative to hydrogen are used to distinguish biotic from abiotic methane on Earth.



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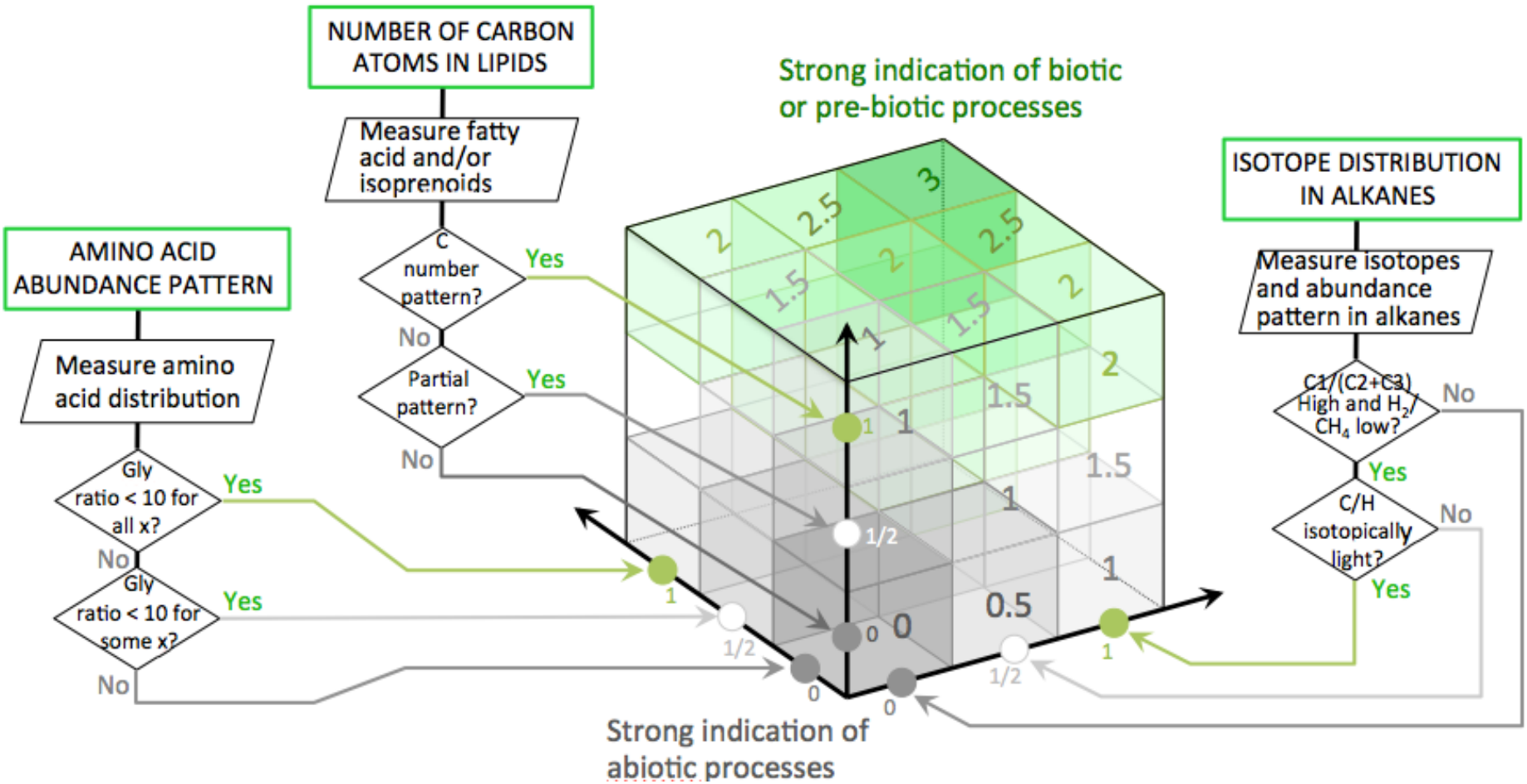
# A Life Investigation Within Reach




Multiple, independent tests for patterns associated with life would provide for a robust science investigation.



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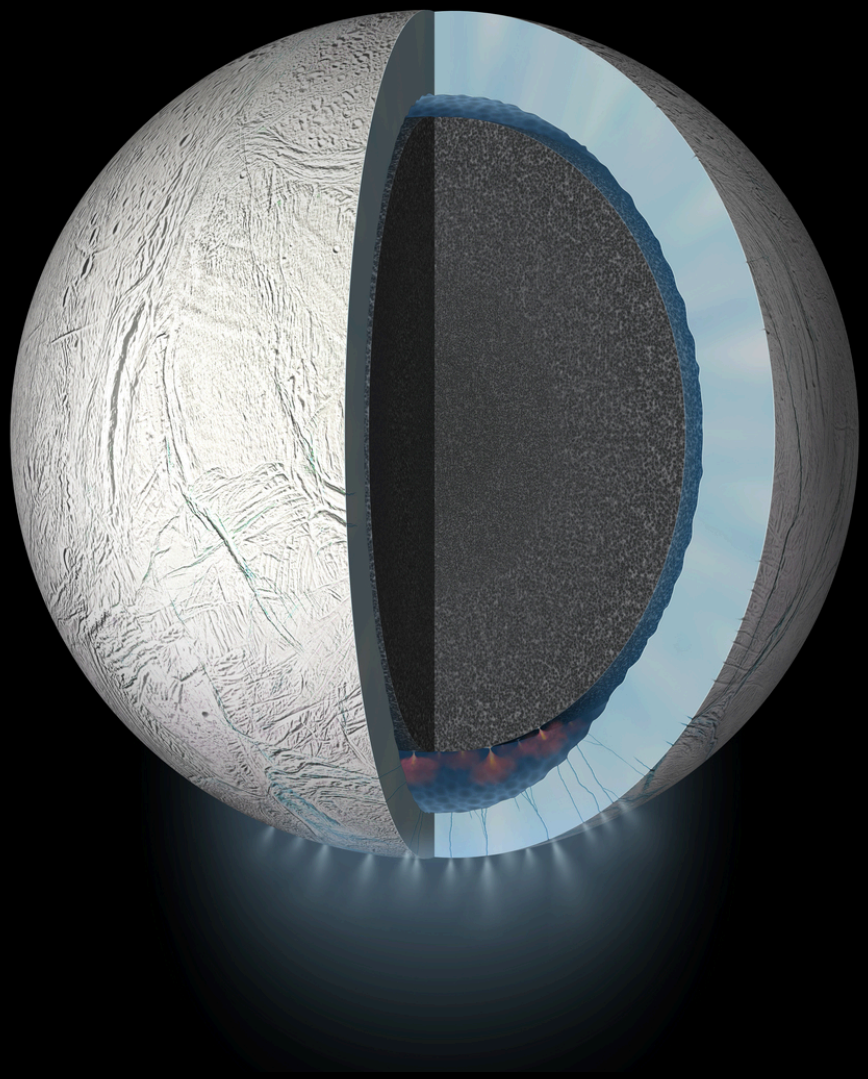
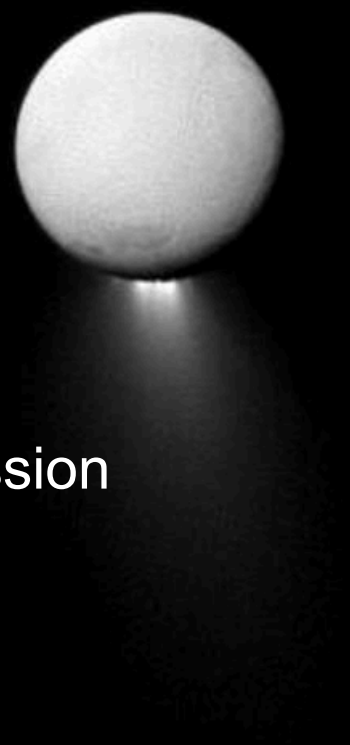
# Conclusions



- There is definitive evidence of a subsurface global ocean with organics, salts, and free energy.
- The plume of Enceladus includes ocean material and is readily analyzed for evidence of life—a goal of the Enceladus Life Finder concept.

# Acknowledgements


- Jonathan Lunine, Principal Investigator
- Hunter Waite, Deputy PI
- Linda Spilker, Project Scientist
- Frank Postberg, ENIJA Instrument Scientist
- Karla Clark, Capture Lead
- Kim Reh, Solar System Exploration Mission Formulation
- Brent Sherwood, Solar System Exploration Mission Formulation
- The entire ELF Team

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# Backup

# Why Discovery for an Enceladus mission?

- Classic Discovery mission—follows on from Flagship with a well-proven analysis technique (Cassini did it, at a range of flyby speeds and altitudes that allow us to fine-tune our fly-throughs).
- We will not do costlier, high-risk missions at Enceladus without knowing something more about its biological potential
- There is “too much” to do in the outer solar system… do with Discovery what you can do with Discovery.

| Name • Role | Institution • Funding | Key Responsibilities and Relevant Experience (for lead role team members) |
|---|---|---|
| **Science Leadership** | | |
| **Jonathan Lunine • PI** | **Cornell University • NASA** | **Provide top-level project and science leadership. Fully responsible for all aspects of the project.** ***Cassini-Huygens, JWST, Juno, Voyager*** |
| Hunter Waite • DPI | SwRI • NASA | Responsible for supplying the MASPEX instrument and coordinating the processing, analysis and archiving of MASPEX data analysis, as well as the library of lab data for MASPEX signatures. Provides backup to the PI on day-to-day tasks. *Cassini-Huygens, Rosetta/Rosina* |
| Linda Spilker • PS | JPL • NASA | Interface between project and science team. Assists PI in ensuring overall scientific and programmatic success of the mission. Involved in all aspects of project implementation, decision-making and reporting. *Cassini-Huygens, Voyager* |
| Frank Postberg • Co-I | Univ. of Heidelberg | ENIJA Instrument Scientist. Responsible for calibration of flight models; supports ENIJA development, functional testing and software development; processing, analysis and archiving of ENIJA data, and library of lab data for ENIJA signatures. *Cassini-Huygens, Stardust* |
| Morgan Cable • Co-I | JPL • NASA | Assistant Project Scientist (mentored for eventual succession as PS). Involved in interpretation of amino acids, fatty acids, and isoprenoids as biological indicators. *10+ years' experience in biomarker detection* |
| **MASPEX Science** | | |
| **Tim Brockwell • Co-I** | **SwRI • NASA** | **MASPEX Instrument Scientist. Supports instrument validation, operations, in-flight calibration, and data analysis.** ***Cassini-Huygens*** |
| Peter Wurz • Co-I | Univ. of Switzerland, Bern | MASPEX calibration support using Univ. Bern CASYMIR facility |
| Rob Hodyss • Co-I | JPL• NASA | Interpretation of MASPEX fragmentation patterns in terms of species identification |
| Ben Teolis • CL | SwRI | Modeling of gas emission from Enceladus' plume. In support of data analysis and interpretation |
| **ENIJA Science** | | |
| **Ralf Srama • Co-I** | **Univ. of Stuttgart** | **ENIJA Instrument Lead. Coordination of analysis and interpretation of MASPEX data. MASPEX data processing and archiving.** ***Cassini-Huygens, LADEE*** |
| Jürgen Schmidt • Co-I | Univ. of Oulu | Modeling of the particle emission from Enceladus' plume |
| Carolyn Porco • Co-I | SSI • NASA | Analysis of plume dynamics and ice abundance/size distribution |
| Bernd Abel • CL | Univ. of Leipzig | Upgrade and optimize laser experiments (Heidelberg, Leipzig) for ENIJA simulations. Lead development of Ice Grain Accelerator. |
| Jonathan Hillier • CL | Univ. of Kent | Analysis of impact ionization spectra for ENIJA simulations |
| **Objective 1: Evolution** | | |
| **Christophe Sotin • Co-I** | **JPL • NASA** | **Science Lead for STM Objective 1. Coordinates overall analysis and interpretation to achieve science Objective 1. Interpretation of rock-water interactions and energy sources of Enceladus.** ***Cassini-Huygens; JPL Chief Scientist for Solar System Exploration*** |
| John Robert Brucato.• Co-I | Agenzia Spaziale Italiana | Interpretation of species in terms of primitive reservoirs in the solar system; lab experiments to determine limits of organics detection |
| Mike Malaska • CL | JPL | Interpretation of MASPEX data in terms of organic reaction mechanisms in abiotic systems |
| Tom Spilker • CL | SSSE | Interpretation of high-rate MASPEX data in terms of jet emission mechanisms and presence of varied (wet, dry) source regions |
| **Objective 2: Habitability** | | |
| **Everett Shock • Co-I** | **ASU • NASA** | **Science Lead for STM Objective 2. Coordinates overall analysis and interpretation to achieve science Objective 2. Modeling of hydrothermal and geochemical processes in the Enceladus ocean from ELF data.** ***30+ years experience in geochemistry, modeling*** |
| John Eiler • Co-I | Caltech • NASA | Interpretation of ELF data in terms of geochemical & physical parameters of the ocean. Laboratory experiments to interpret MS data. |
| Hauke Hussman • Co-I | DLR | Interpretation of derived physical parameters in terms of ocean-rock core interactions. Also supports ENIJA environmental testing. |
| Chris Glein • CL | Univ. of Toronto | Uses ELF data and chemical modeling to derive ocean parameters (pH, temperature, redox state, chemical potential) |
| **Objective 3: Life** | | |
| **Chris McKay • Co-I** | **NASA Ames • NASA** | **Science Lead for STM Objective 3. Coordinates overall analysis and interpretation to achieve science Objective 3. Interpretation of amino acid data as a potential bio-signature.** ***Cassini-Huygens, Phoenix, MSL*** |
| Ariel Anbar • Co-I | ASU • NASA | Interpretation of isotopic and abundance data as a potential bio-signature |
| Mark Sephton • Co-I | UKSA | Interpretation of fatty acid, isoprenoid data; identification of unexpected organics. Pyrolysis experiments for interpretation of MS data. |
| Sascha Kempf • CL | Univ. of CO, Boulder | Interpretation of ENIJA data in terms of particle size and hence origin (oceanic, surface). Supporting role in ENIJA calibration. |