

AST 309L

A composite image of a desert landscape at sunset. The foreground shows rolling sand dunes in shades of orange and red. In the distance, a range of mountains is silhouetted against the sky. The sky transitions from a deep purple at the top to a bright orange near the horizon. A large, bright yellow sun is positioned on the horizon, and a smaller, bright blue star is visible in the sky above it. The overall scene is serene and evocative of a planetary environment.

Saturn's Moons
And missions to the Jovian moons

Instapoll #1:

In the subsurface ocean beneath Europa's icy crust, if life exists, it most likely originated

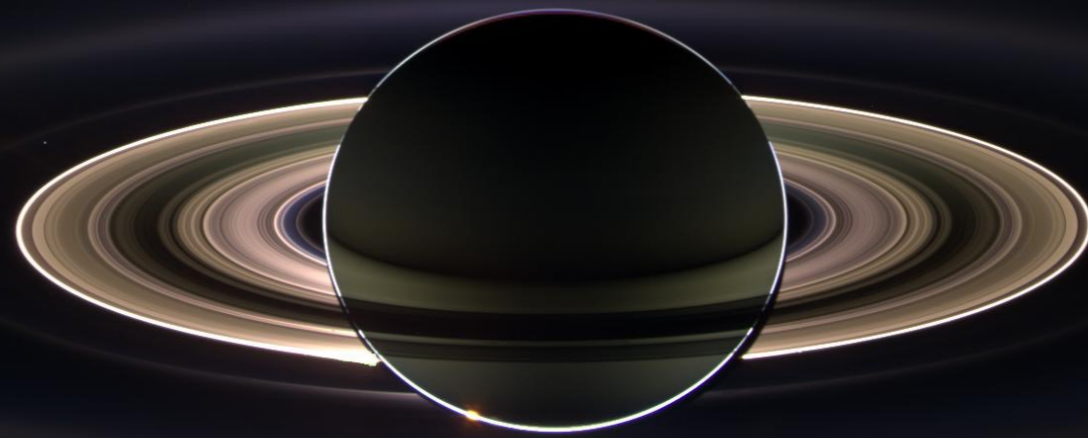
- A. close to volcanic vents on its ocean floor
- B. on the surface and then migrated down into the ocean
- C. just below the surface of its thin icy crust where sunlight is still able to penetrate
- D. via panspermia from impacts

Instapoll #2:

Compared to the total energy available to support life on Earth, the total energy available to support life in a European ocean would be:

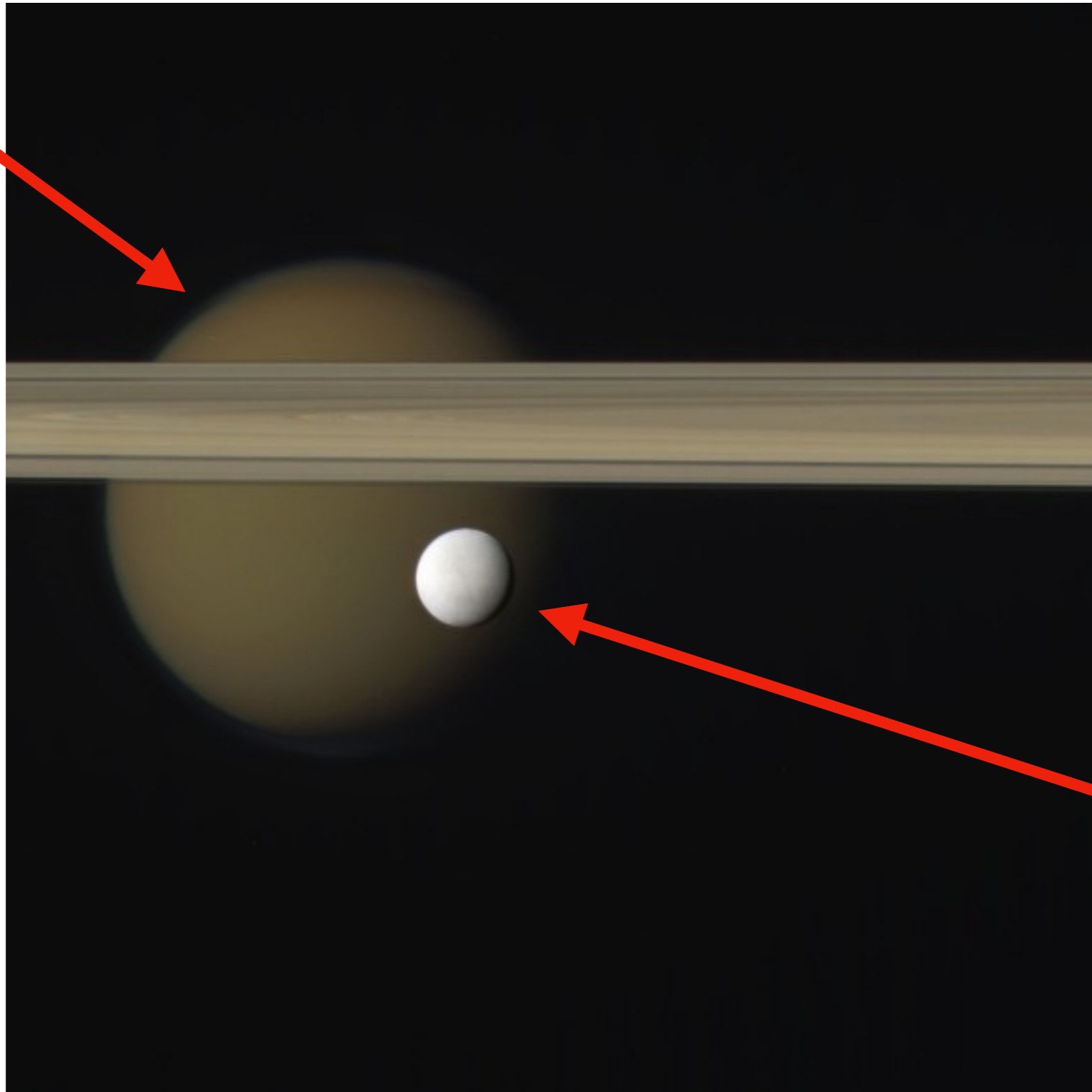
- A. about the same
- B. much larger
- C. slightly larger
- D. much smaller

The Saturn *system*



The Saturn system

Titan



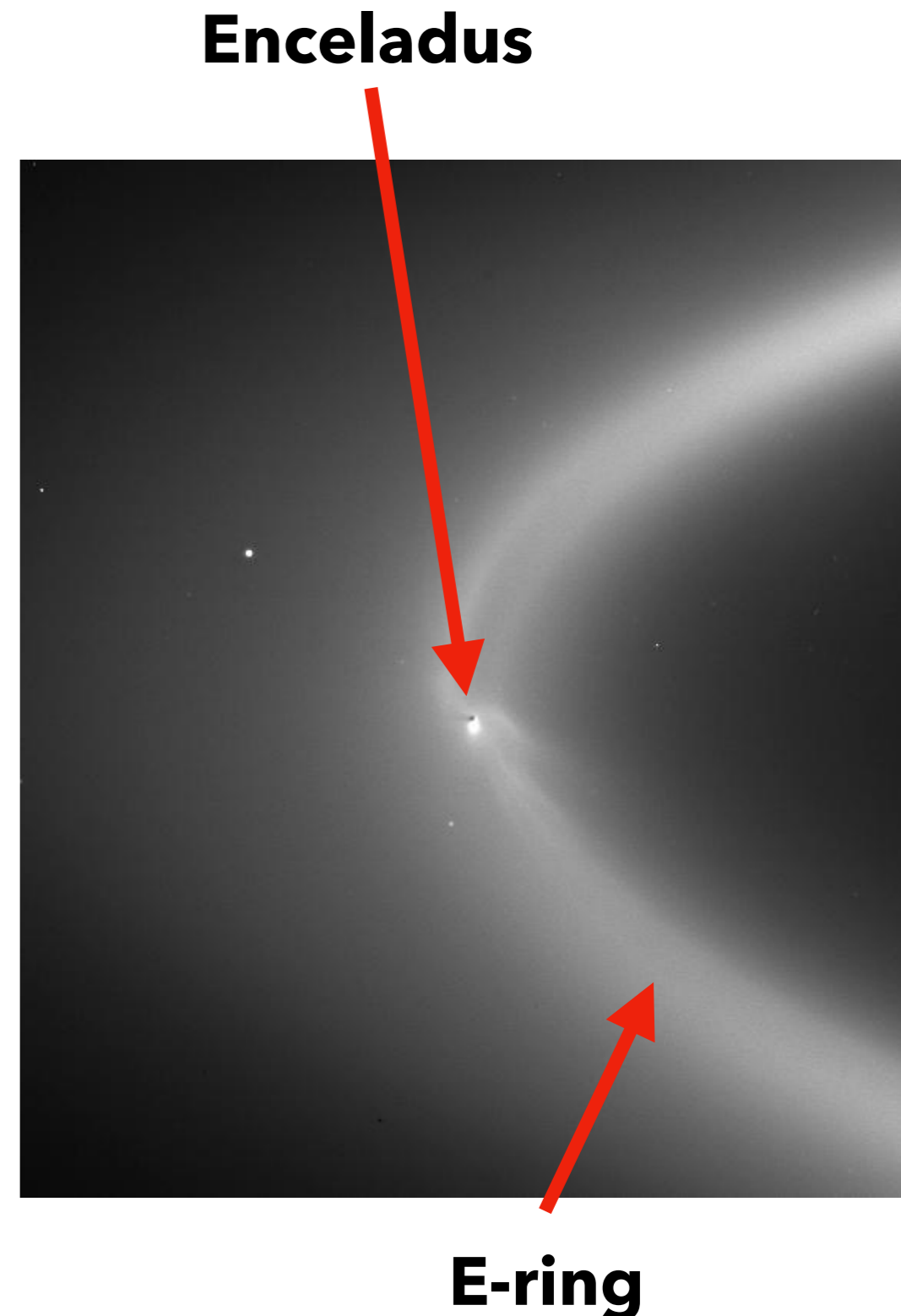
Enceladus



**We'll first discuss Enceladus,
a moon with similarities to Europa
and one of the more likely places
we'll find extraterrestrial life**

Enceladus

- Enceladus was discovered in 1789 by William Herschel, and not much was known about it for centuries.
- Enceladus orbits in the **densest part of Saturn's E-ring**, a diffuse ring of tiny particles surrounding Saturn.
- It is in an **orbital resonance** with another moon of Saturn, and has a **slightly elliptical orbit**.

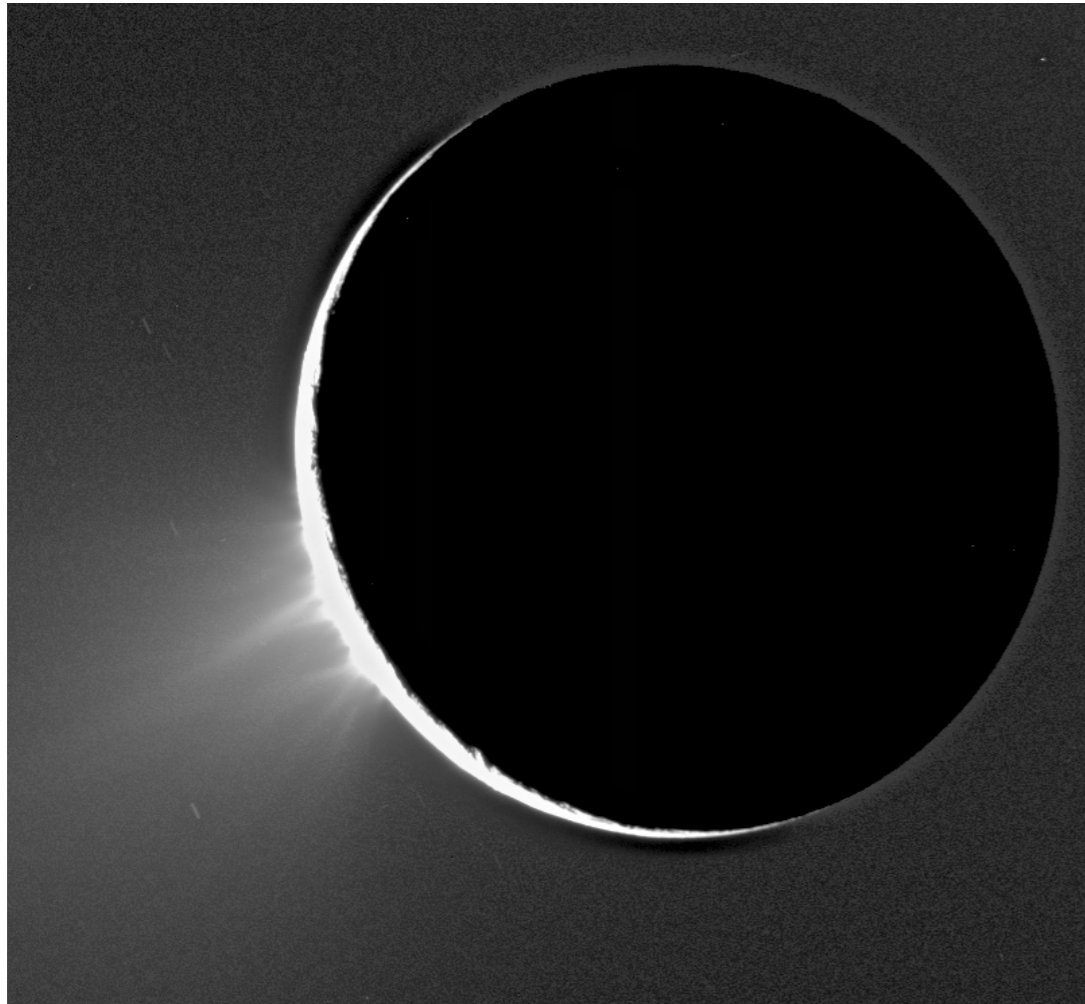


Enceladus from Voyager

- Our next discoveries on Enceladus were made with Voyager in the 1980s.
- It has one of the **most reflective surfaces** in our solar system.
- The moon has many varied surface terrains, including **cratered regions, smooth regions, and linear features.**

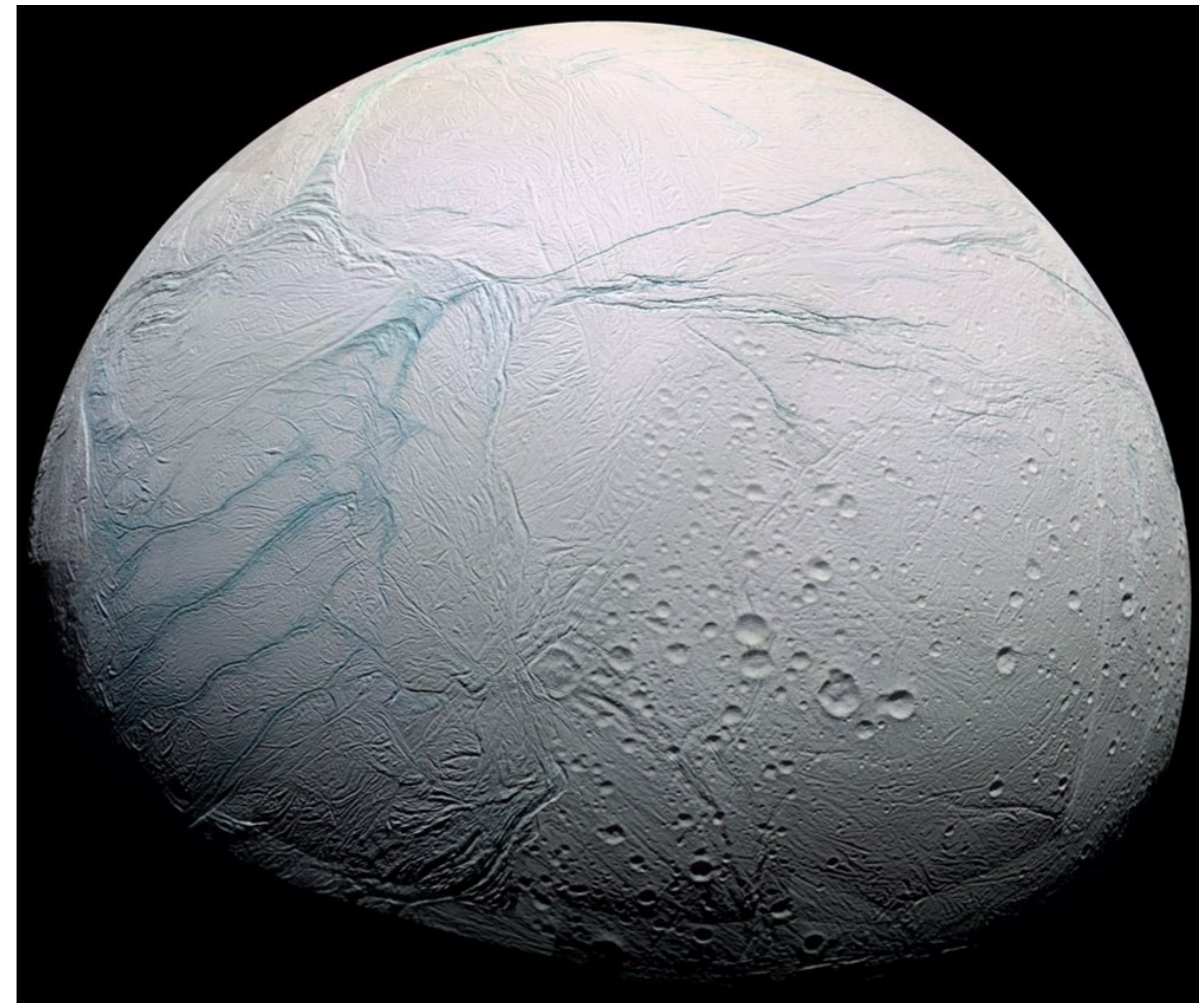


***Cassini* spots a plume coming from Enceladus!**



Enceladus's plume is emitted from "tiger stripes" on its smooth terrain, which are hot and active!

Enceladus has geysers emitting a plume that contains water ice, silicate particles, salt minerals, and organic molecules!



So Enceladus has:

A salty subsurface ocean, icy geologic activity, hydrothermal vents, organic molecules

What about life!?

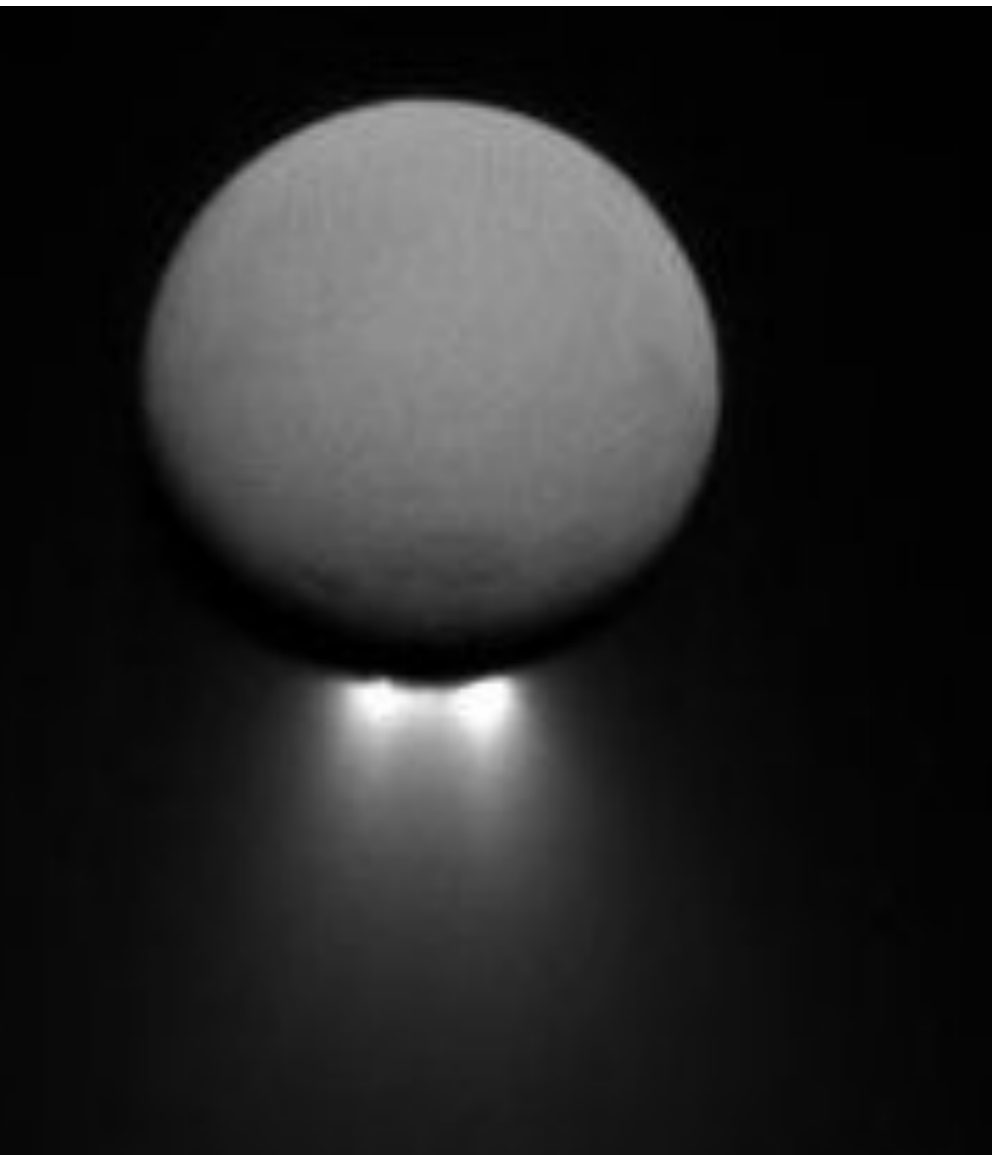
Let's recall the 3 major needs for life to develop and thrive

1. A **liquid medium** for transporting organic molecules and in which life's required chemical reactions occur
2. A **source of energy** for metabolism and growth.
3. A **source of elements and materials** (e.g. carbon) with which to form organic molecules and eventually life.

**How do you think Enceladus's
potential habitability compares
to Europa's?**

**Do you think life on these 2 moons
would be similar?**

Is there enough heating to explain Enceladus's ocean?



- Although Enceladus experiences tidal heating, there **doesn't seem to be enough heat** produced to explain the subsurface ocean.
- It's possible Enceladus had a **more elliptical orbit in its past**, and is still hot from that.
- If that's true, and Enceladus's ocean is young, **what does that mean for life there?**

How do you think Enceladus's potential habitability compares to Europa's?

Not quite as high, if the ocean isn't as old – less time for life to form

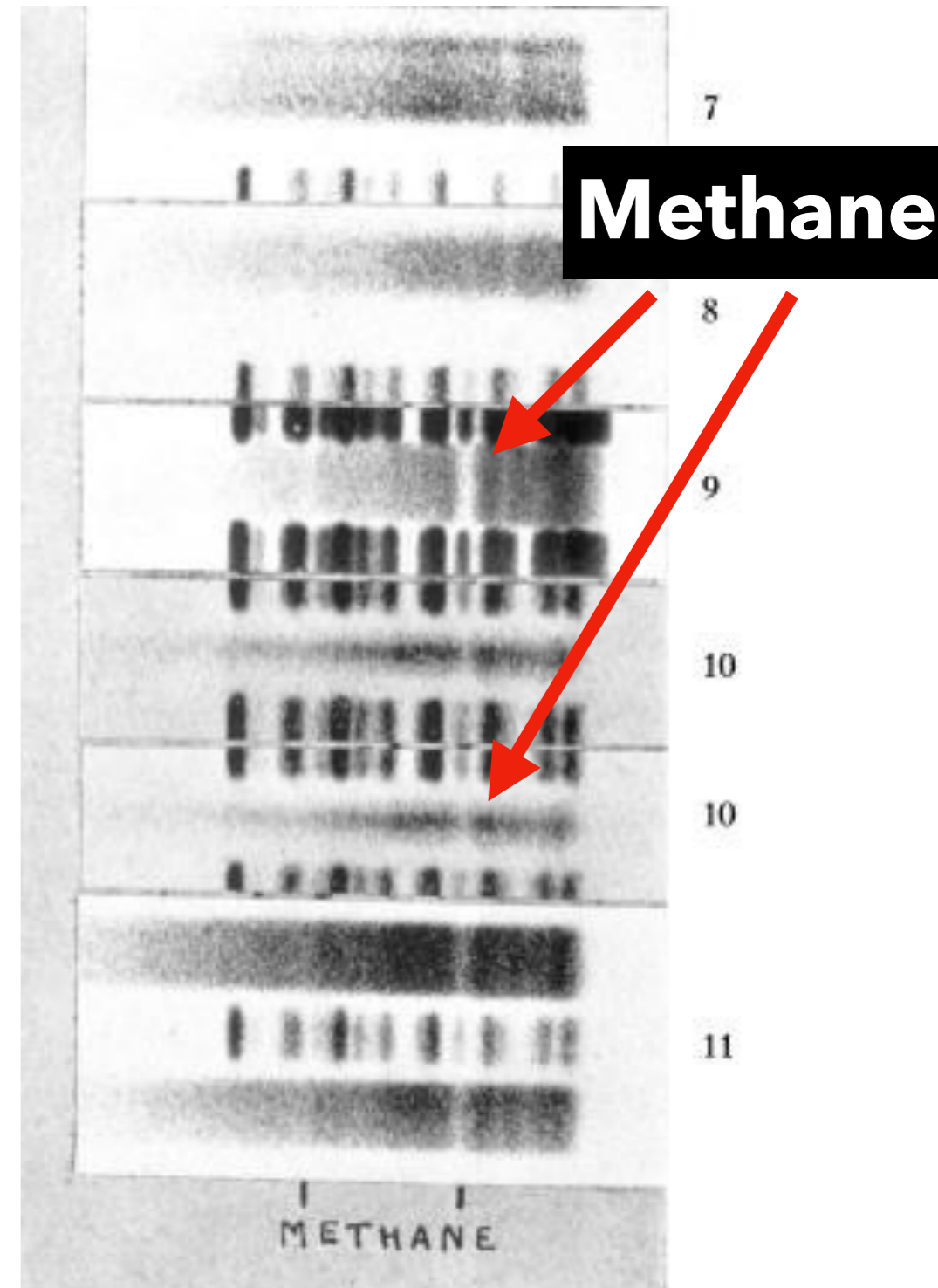
Do you think life on these 2 moons would be similar?

Well, the environments are similar, so would be an interesting test of life formation

**Now let's discuss Titan, arguably
one of the most Earth-like
bodies in our entire solar system**

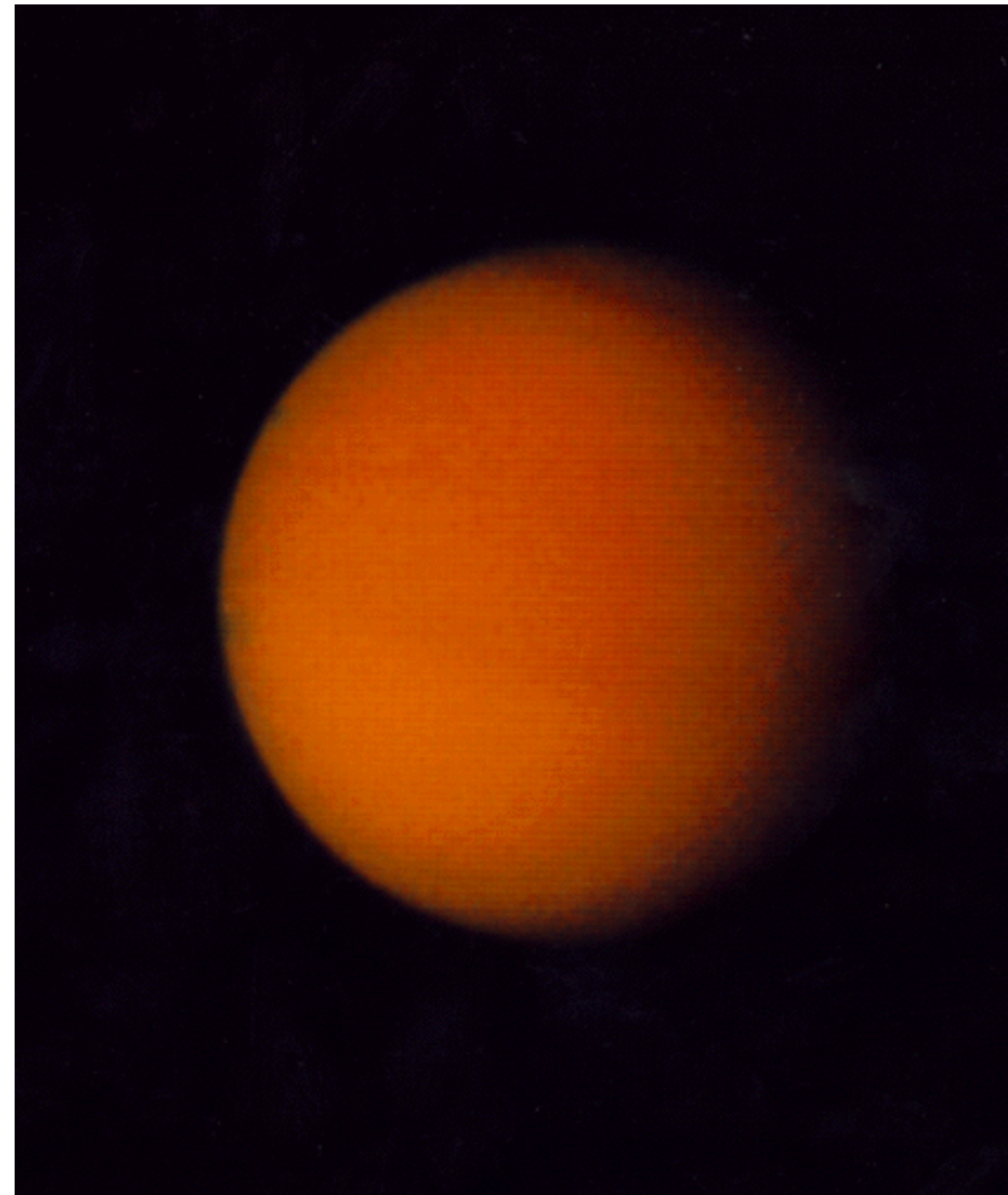
Titan

- Titan was discovered by Christiaan Huygens in 1655, inspired by Galileo's discovery of Jupiter's moons
- It is the 2nd largest moon in the solar system and **slightly larger than Mercury.**
- **Discovered to have an atmosphere** (containing methane) in 1944 by Gerard Kuiper at McDonald Observatory **in West Texas!**



Titan from Voyager

- Our next discoveries on Titan were made with Voyager in the 1980s.
- The moon is covered with a **red smog!** This is the atmosphere found in 1944, but unfortunately meant we couldn't see Titan's surface.
- Using a radio signal, we discovered **nitrogen and hydrocarbons** (like ethane and propane) in Titan's atmosphere.

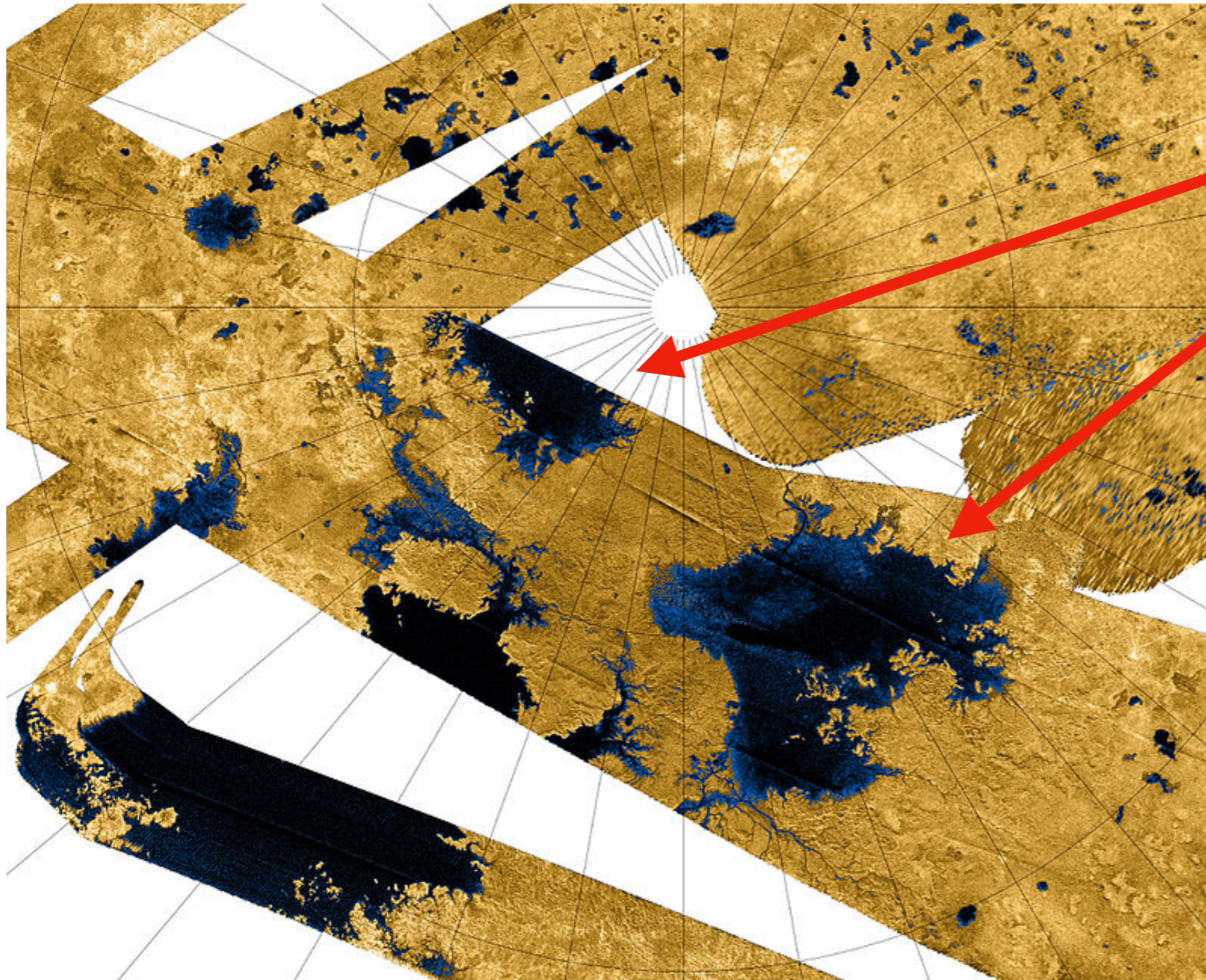


The presence of hydrocarbons was **puzzling.**

Methane gas could be turned into heavier hydrocarbons after interactions with sunlight, but then **why would so much methane gas remain in the atmosphere...?**

There would **need to be a methane source to replenish the atmosphere**

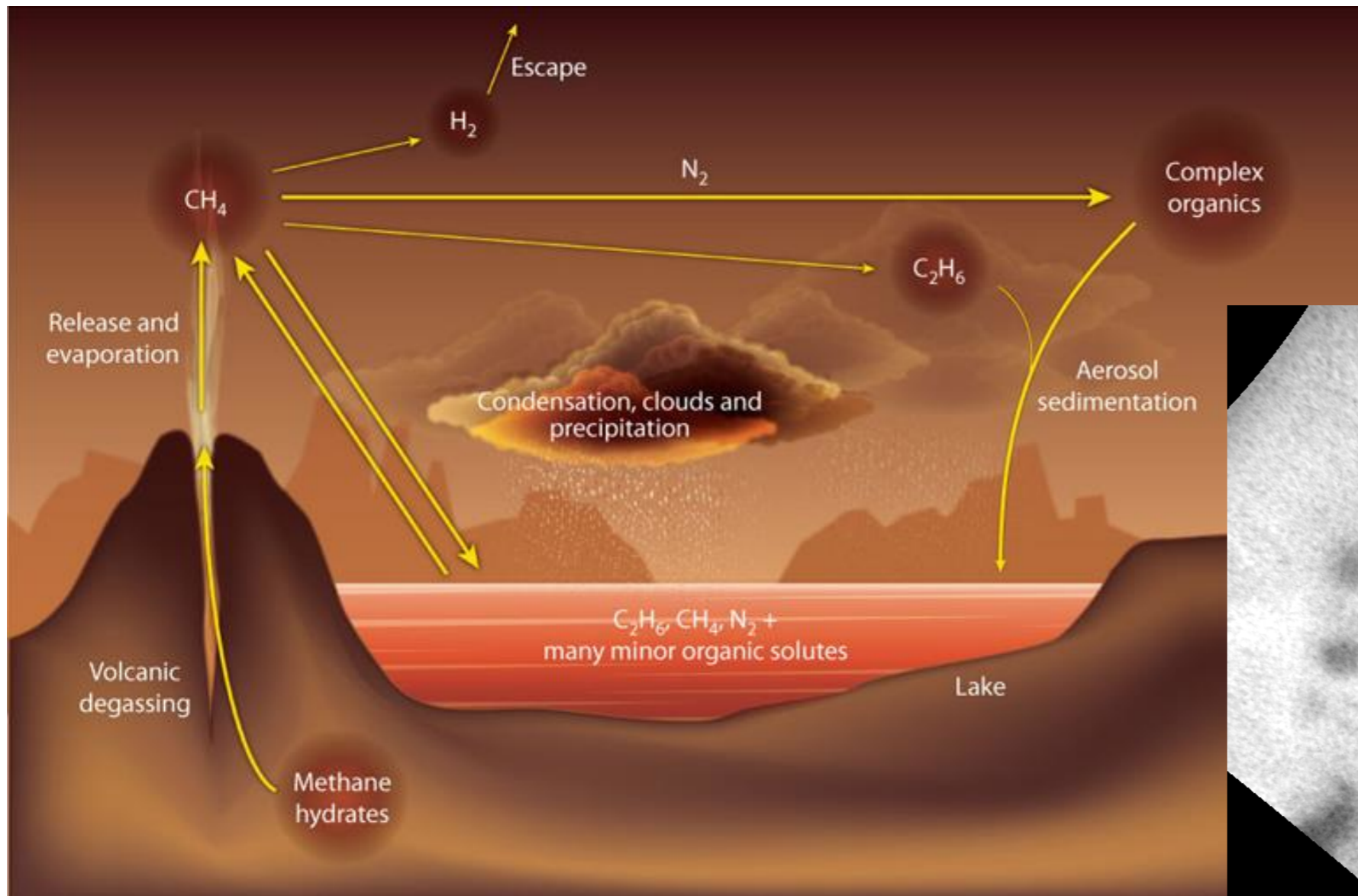
Methane source!



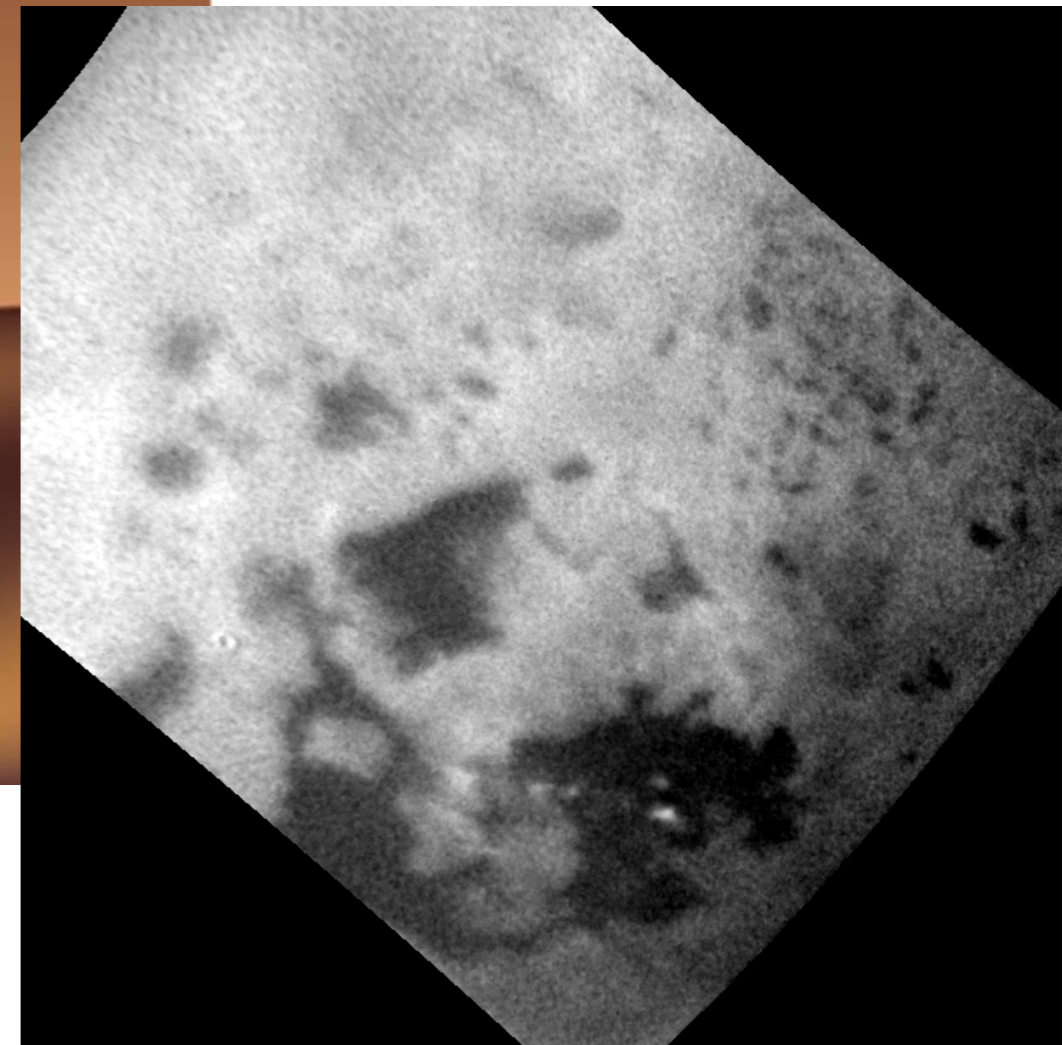
Seas of liquid hydrocarbons!

Titan has a methane cycle similar to Earth's water cycle, and is the only other place in the solar system to have standing bodies of liquid!

Titan's Methane Cycle

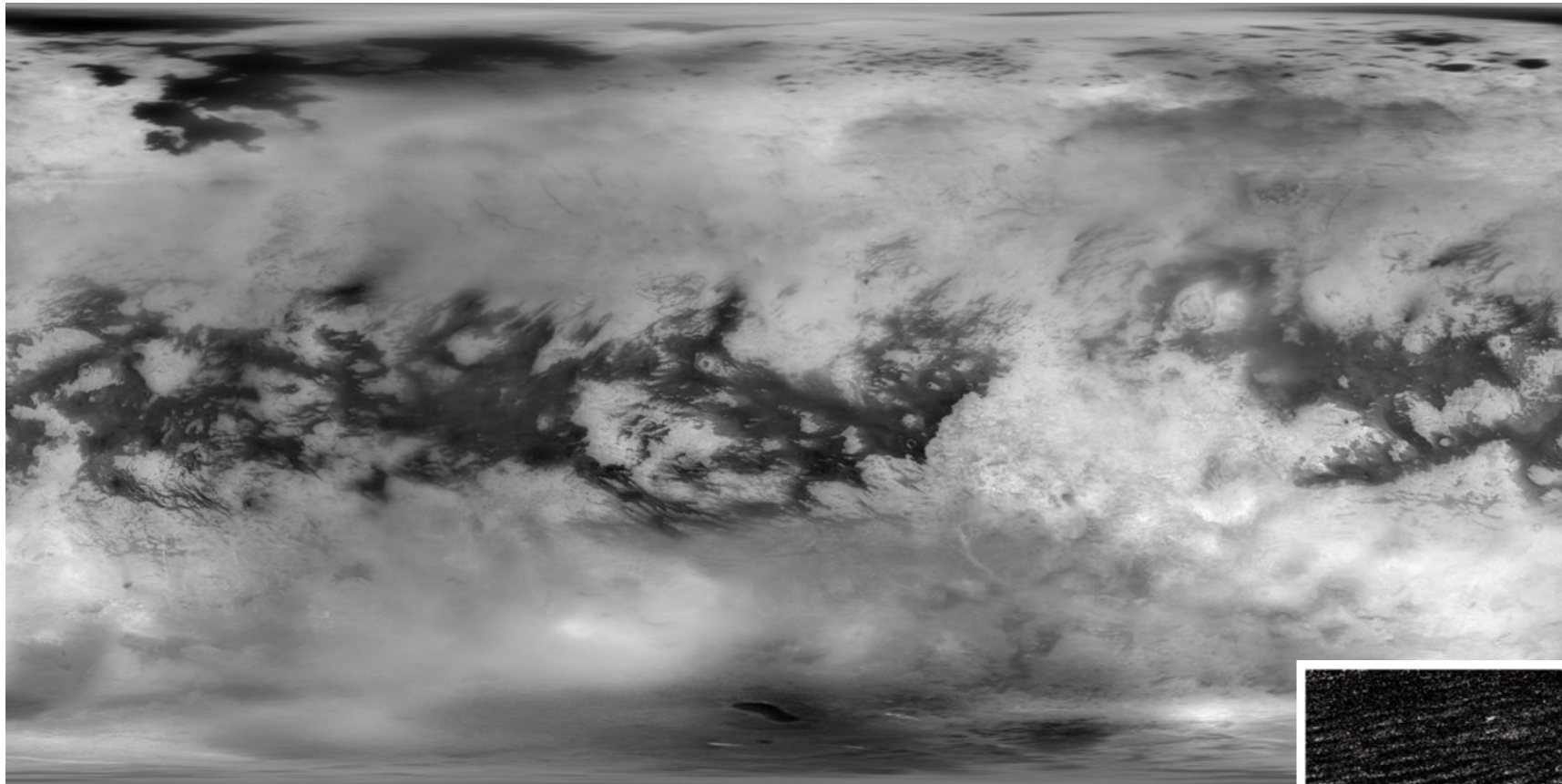


Example of clouds on Titan



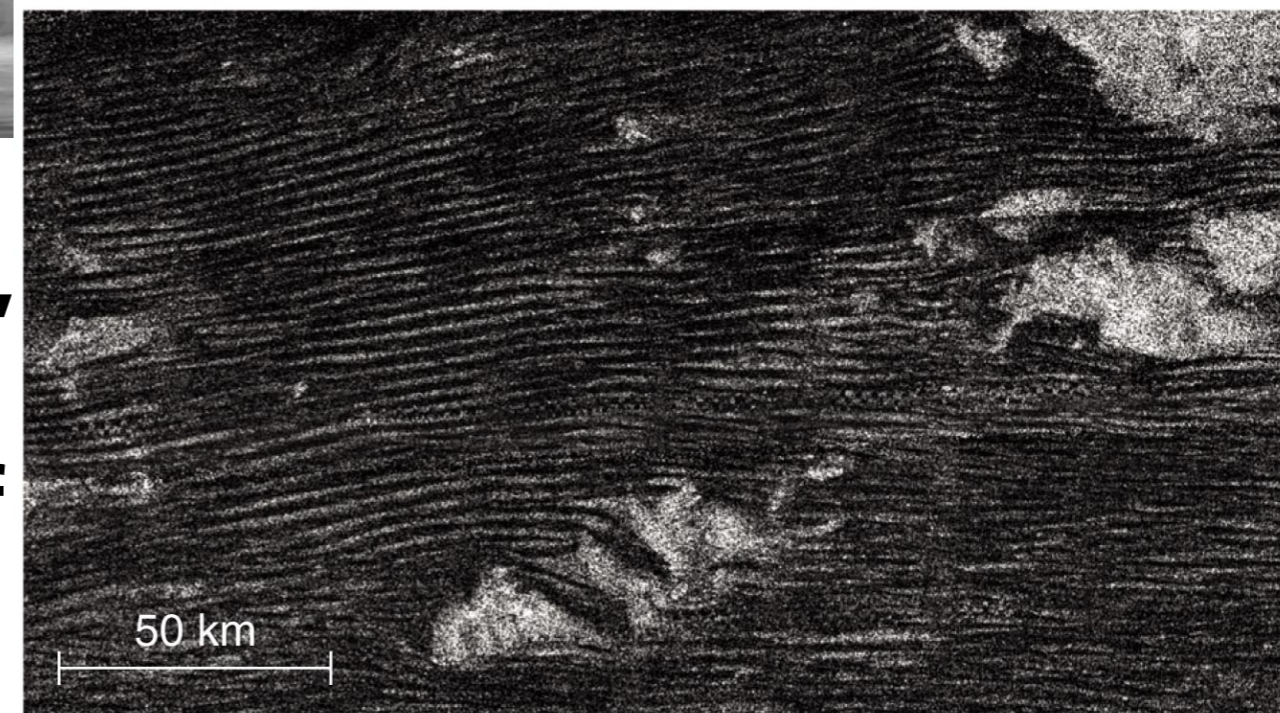
Cryovolcanism is the most likely source of Titan's methane

Titan from the *Cassini* orbiting mission



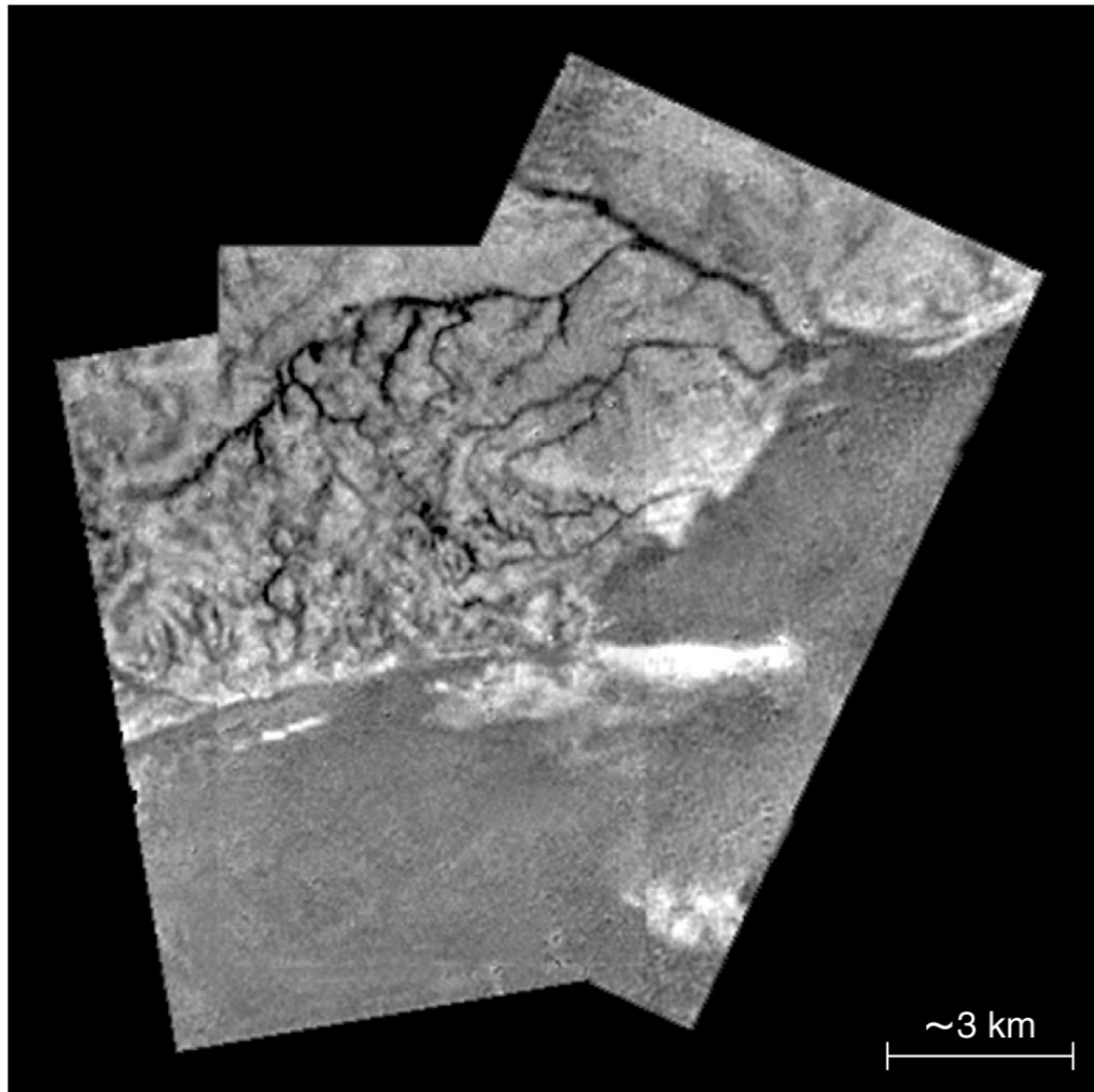
Example of solid **hydrocarbon dunes** on the surface of Titan, likely **formed by storms** not winds

Titan has a **variety of surface features**, including regions of water ice, seas of methane and ethane, and plains of solid hydrocarbons



Titan from the *Huygens* landing probe

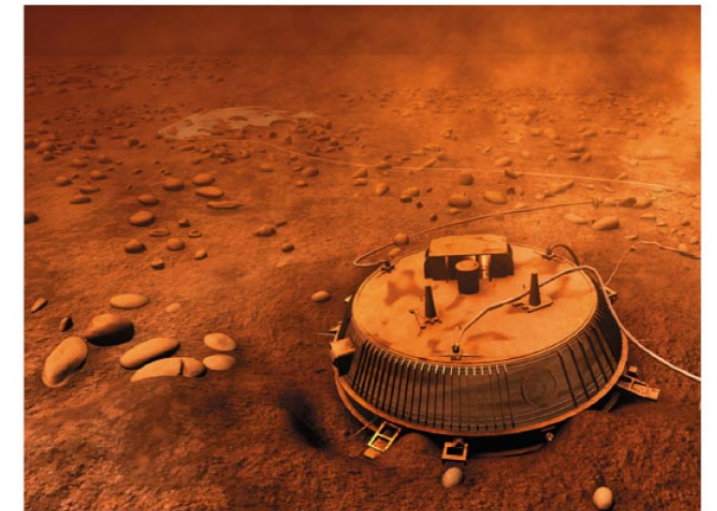
Titan has **river channels and deltas**
carved by liquid methane and ethane



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Titan has rocks of
water ice that show
**signs of erosion
and weathering
from liquid**

So Titan has:
seas, rivers, surface geology,
weather, dunes, a thick atmosphere,
organic molecules...

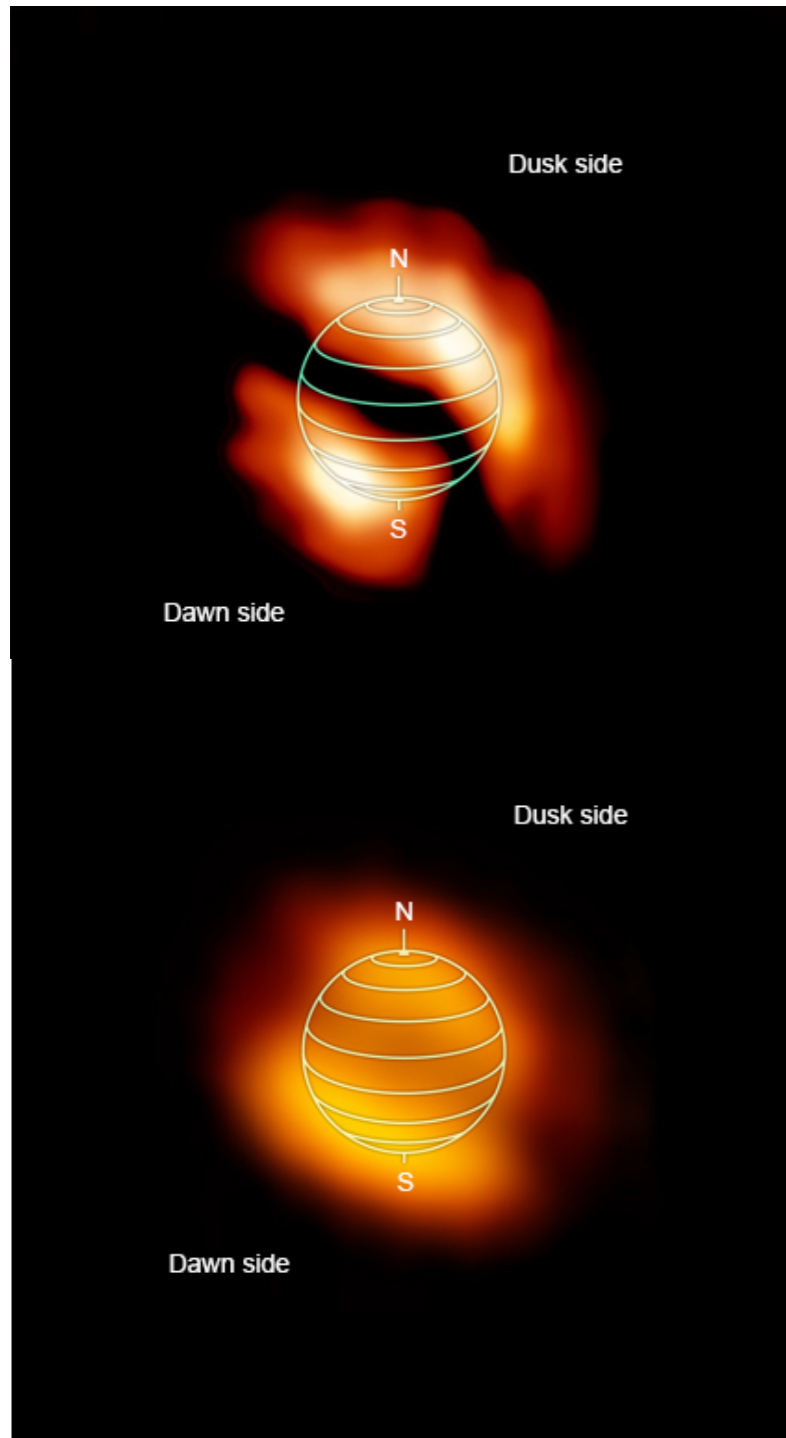
What about life!?

Life on Titan's surface: Organic materials

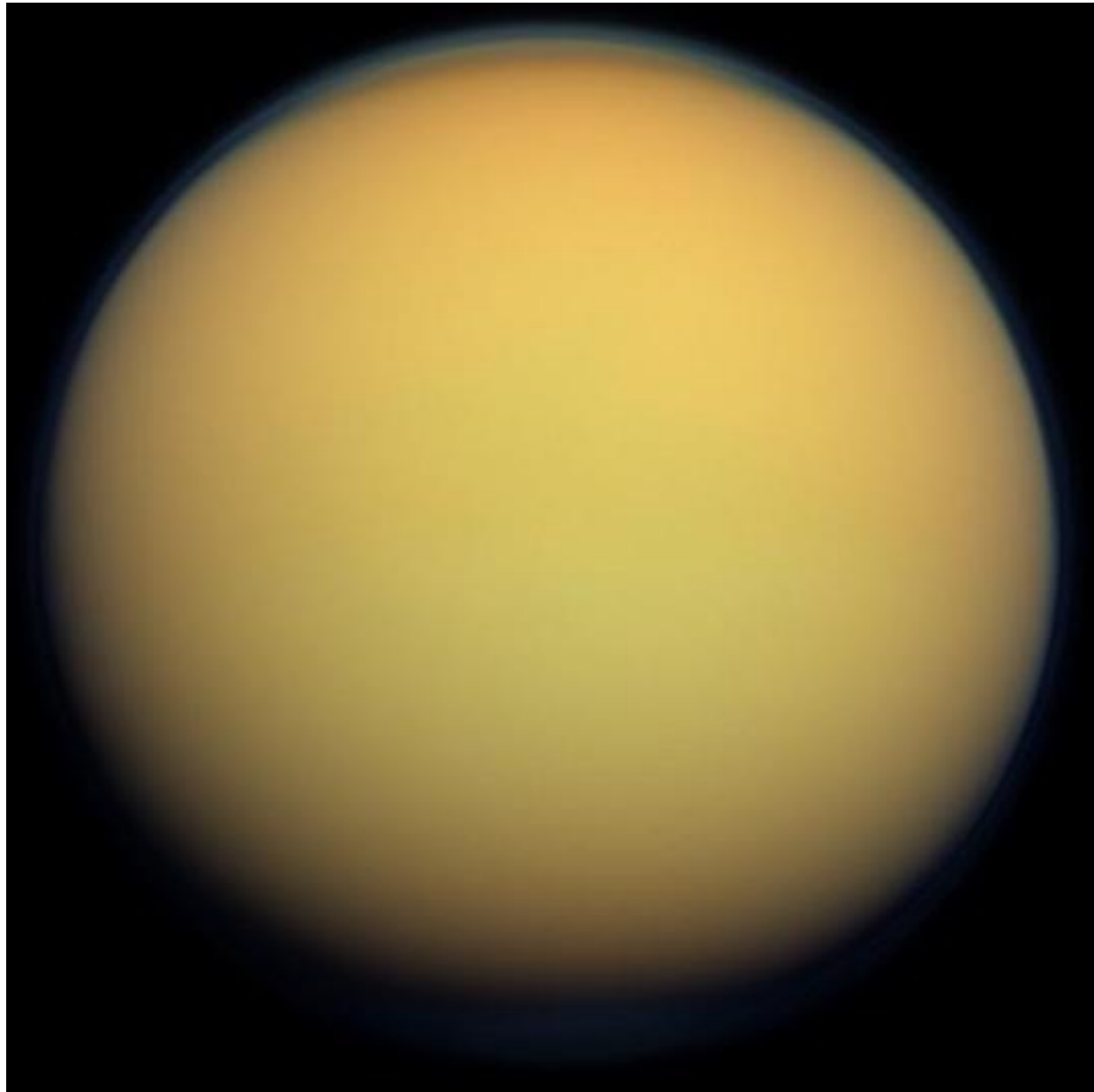
Absolutely!

This one is a freebie on Titan... it is covered in organic molecules, and has **plenty of H, C, N to make life's building blocks.**

The picture to the left shows Titan **enshrouded in organics!**



Life on Titan's surface: Energy source

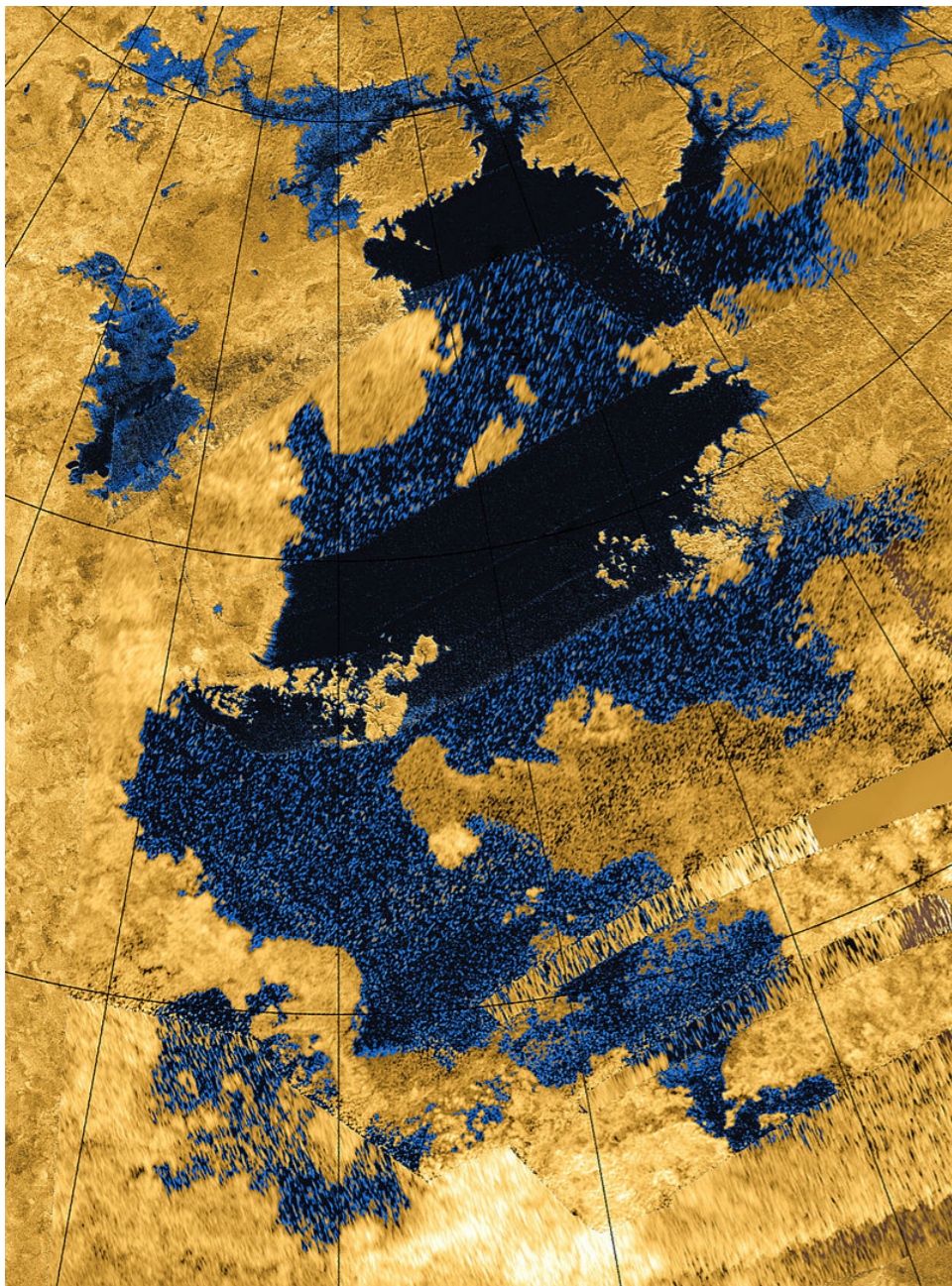


Haze covered Titan

**There are two main sources of energy for life we've discussed:
the Sun and chemistry**

Would both of these work on Titan? Which one would be better?

Life on Titan's surface: Liquid medium



**We know that there's liquid
on Titan's surface...
just **not liquid water!****

**Why do we think water is a
particularly good liquid
medium for life?**

Life on Titan's surface: Liquid medium

Water

Polar! It can dissolve other materials quite easily. Can make hydrogen bonds easily.

Liquid over a wide temperature range! A full 100 deg. Celsius.

Ice is less dense than liquid water! It floats when it freezes.

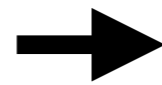
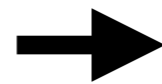
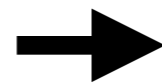
Life on Titan's surface: Liquid medium

Water

Polar! It can dissolve other materials quite easily. Can make hydrogen bonds easily.

Liquid over a wide temperature range! A full 100 deg. Celsius.

Ice is less dense than liquid water! It floats when it freezes.



Methane/Ethane

Not Polar! Biologic reactions would proceed more slowly (harder to break bonds).

Yes and no! Ethane (but not methane) is liquid over large temperature range.

No! Neither methane nor ethane float when frozen.

Instapoll #3:

Enceladus's subsurface ocean is kept liquid due to internal heat generated by:

- A. radioactive decay
- B. tidal forces from Saturn
- C. gravitational energy remaining from its formation
- D. Saturn's magnetic field

Instapoll #4:

Finding evidence for life on Titan would indicate:

- A. Life can form in either a polar or non-polar liquid medium
- B. Life forms in a broad range of environments and is likely to be ubiquitous in the universe
- C. Life requires liquid water to form and survive
- D. A and B
- E. A, B, and C

Jigsaw Activity!

Choosing a mission to a jovian moon

- **Individually read about one (of six) potential missions** to one of the jovian moons we've discussed (Europa, Titan, Enceladus)
- In your groups, **discuss that mission and become experts** on it! There's a worksheet to help guide discussion.
- Move into new groups with one person from each mission. **Do group worksheet (attendance for day) and decide which mission you would choose to fund!**

**Discussing missions
to jovian moons!**