



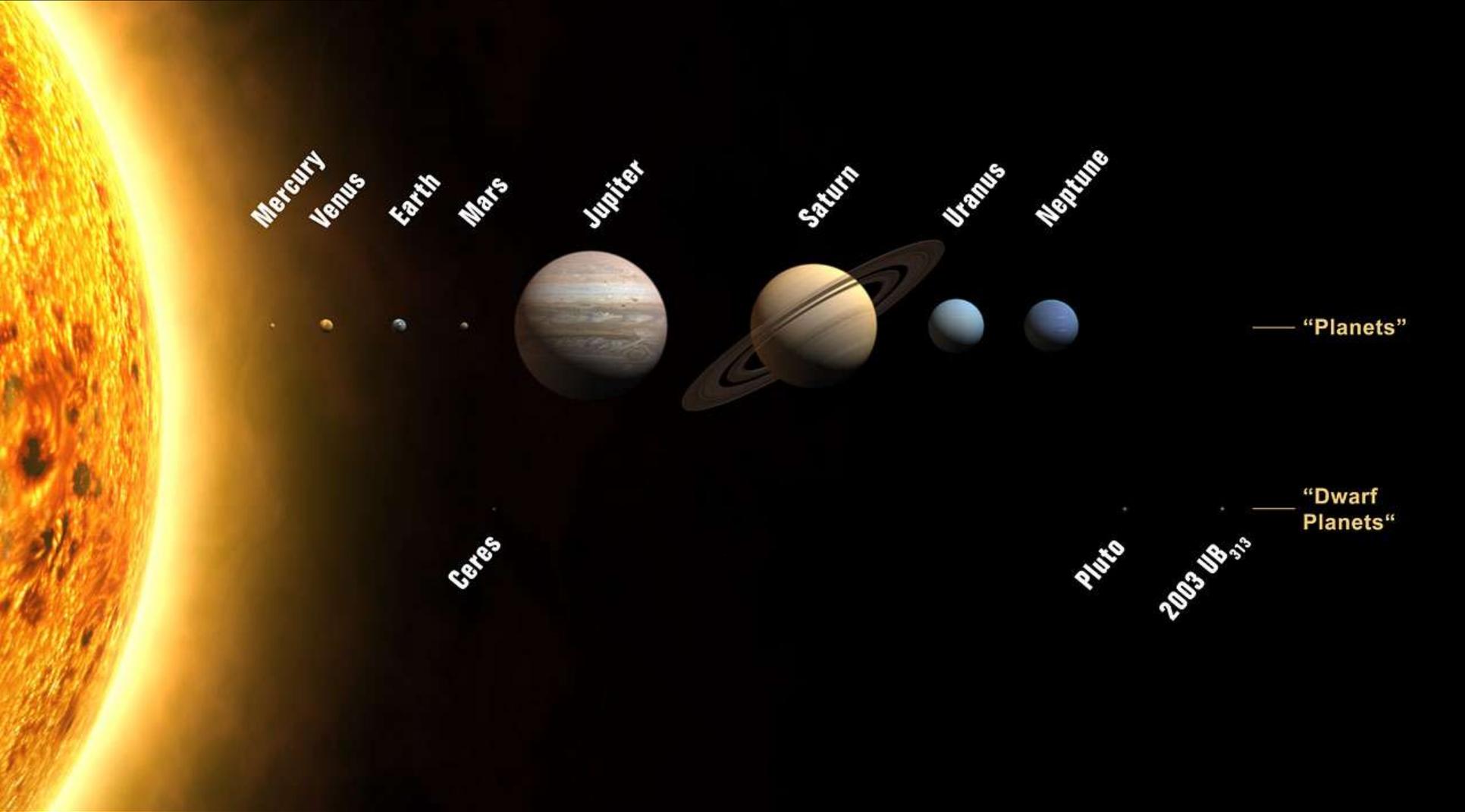
*Extra-terrestrial life:  
Is there anybody out there?...*

**Martin Hendry  
University of Glasgow**



Orkney

Dec 2011



Mercury

Venus

Earth

Mars

Jupiter

Saturn

Uranus

Neptune

— "Planets"

Ceres

Pluto

2003 UB<sub>313</sub>

- - - "Dwarf Planets"

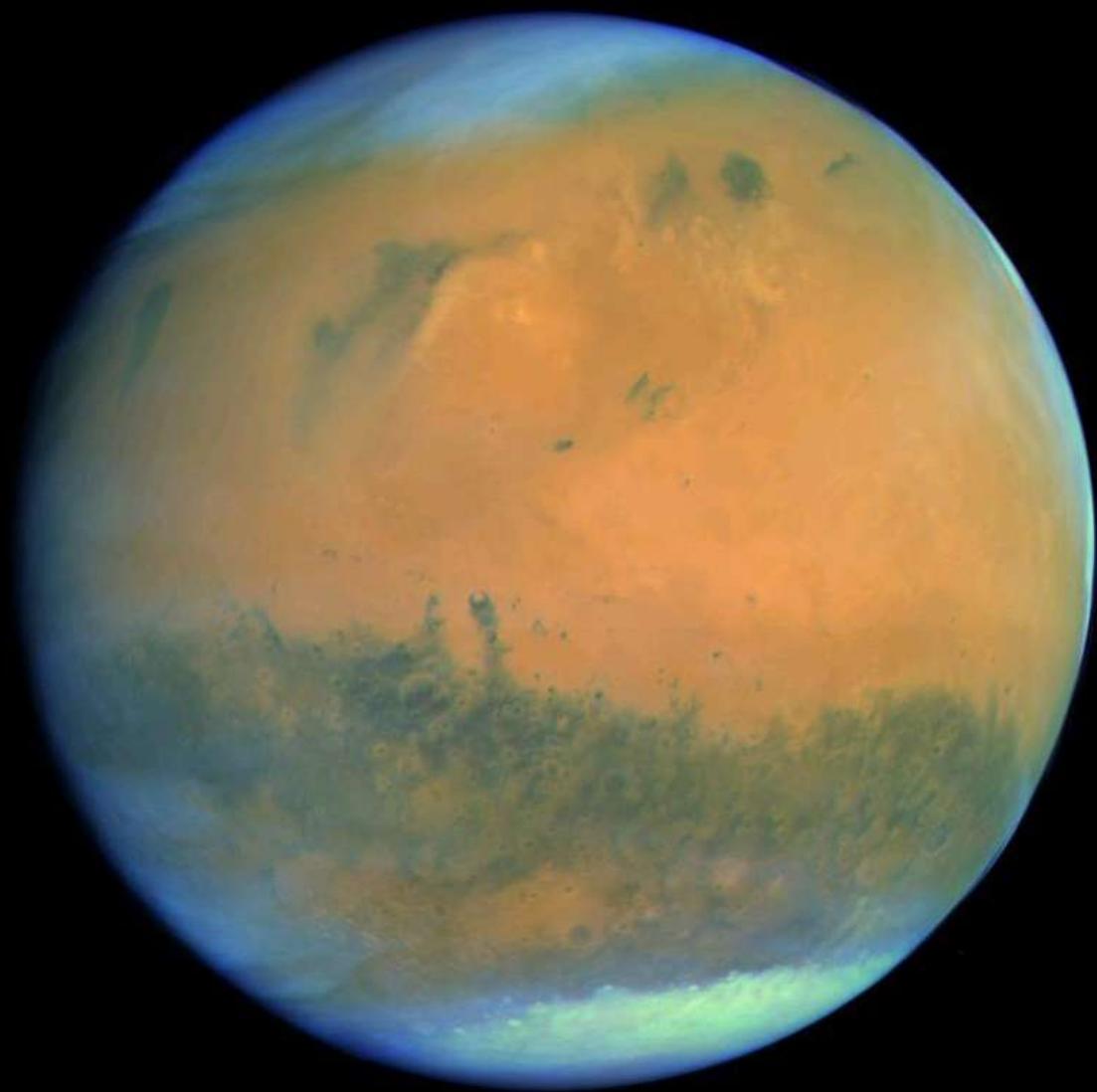




- Liquid Water
- Oxygen
- Carbon Dioxide

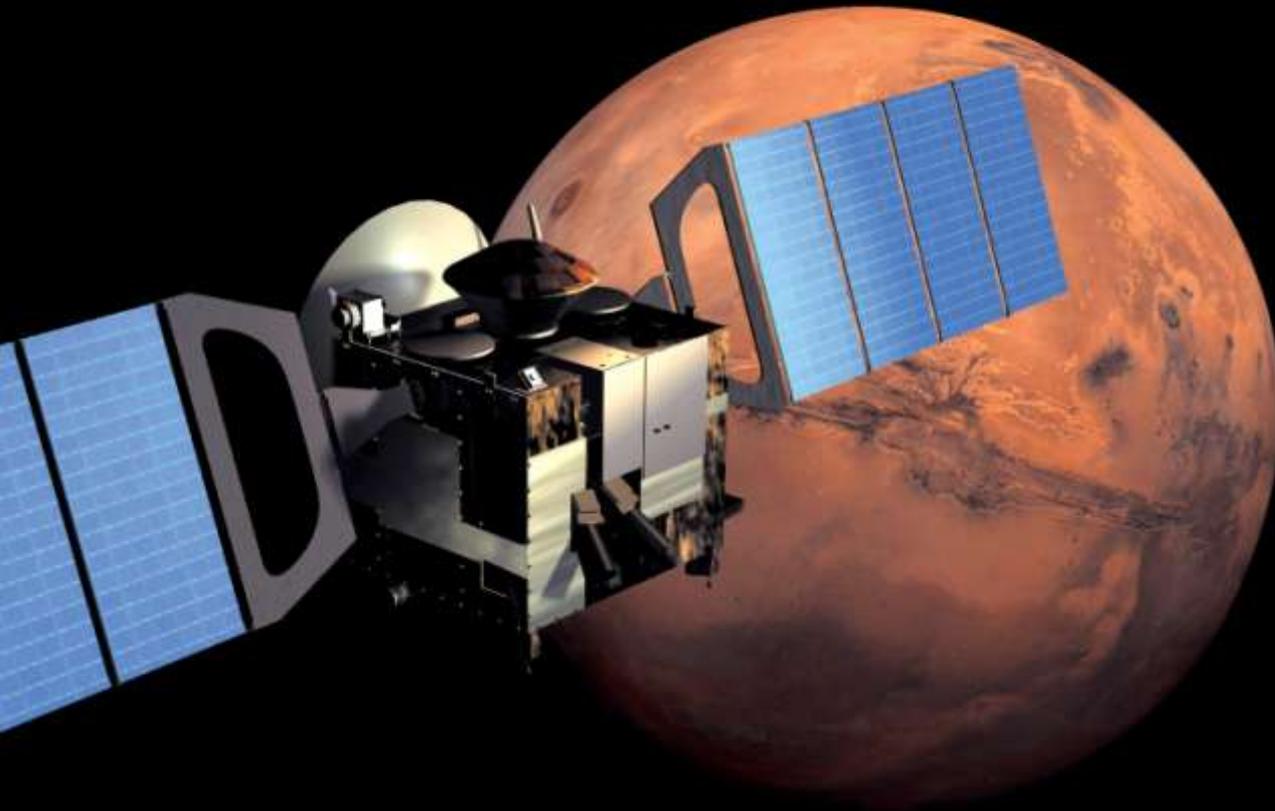
**= life!**

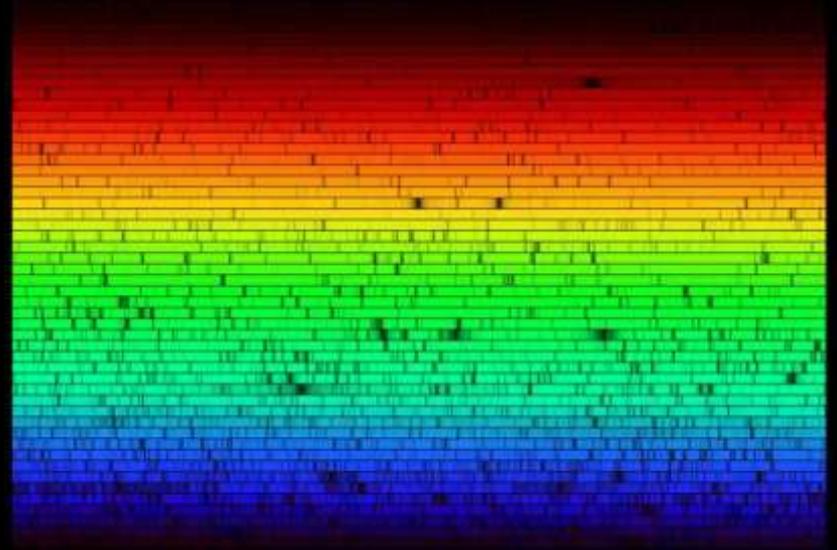
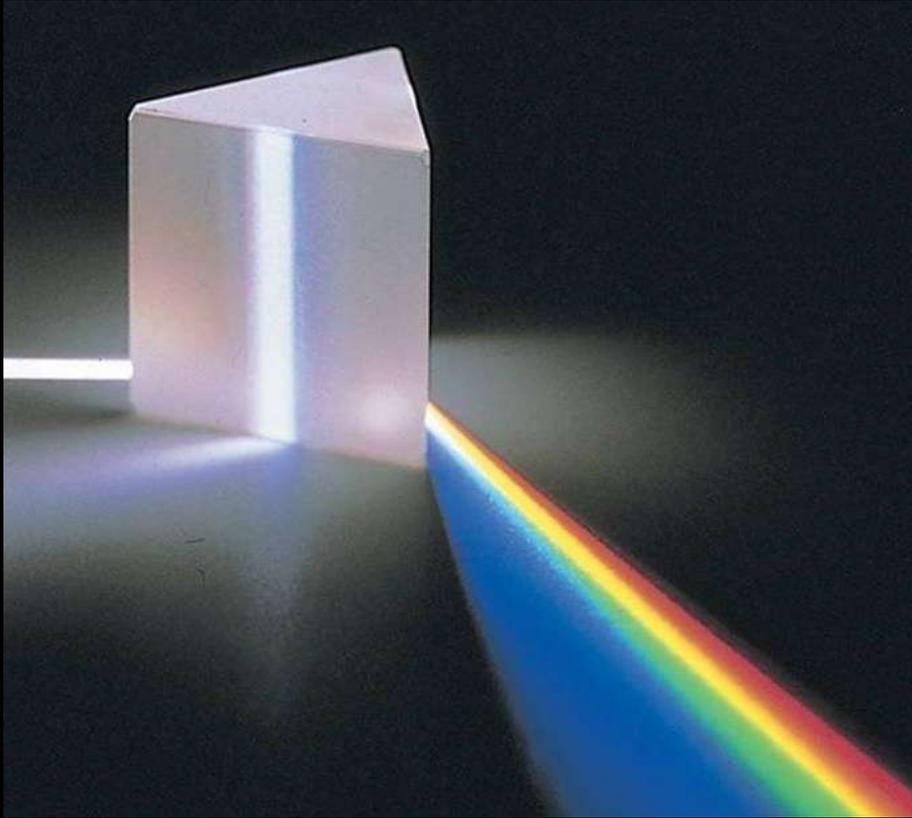




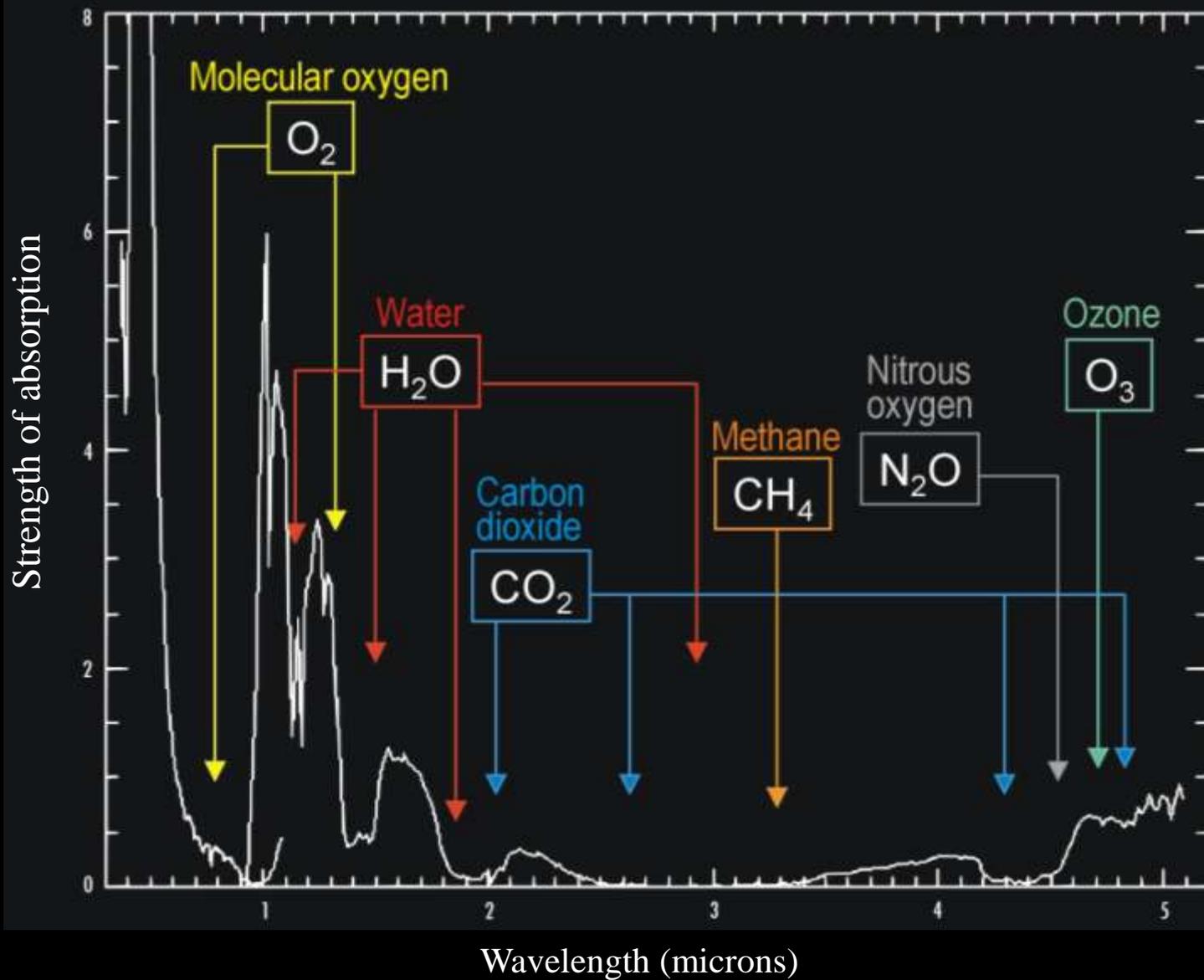
# Mars is the best bet:

- Mars Express ( + Beagle 2)
- Spirit + Opportunity





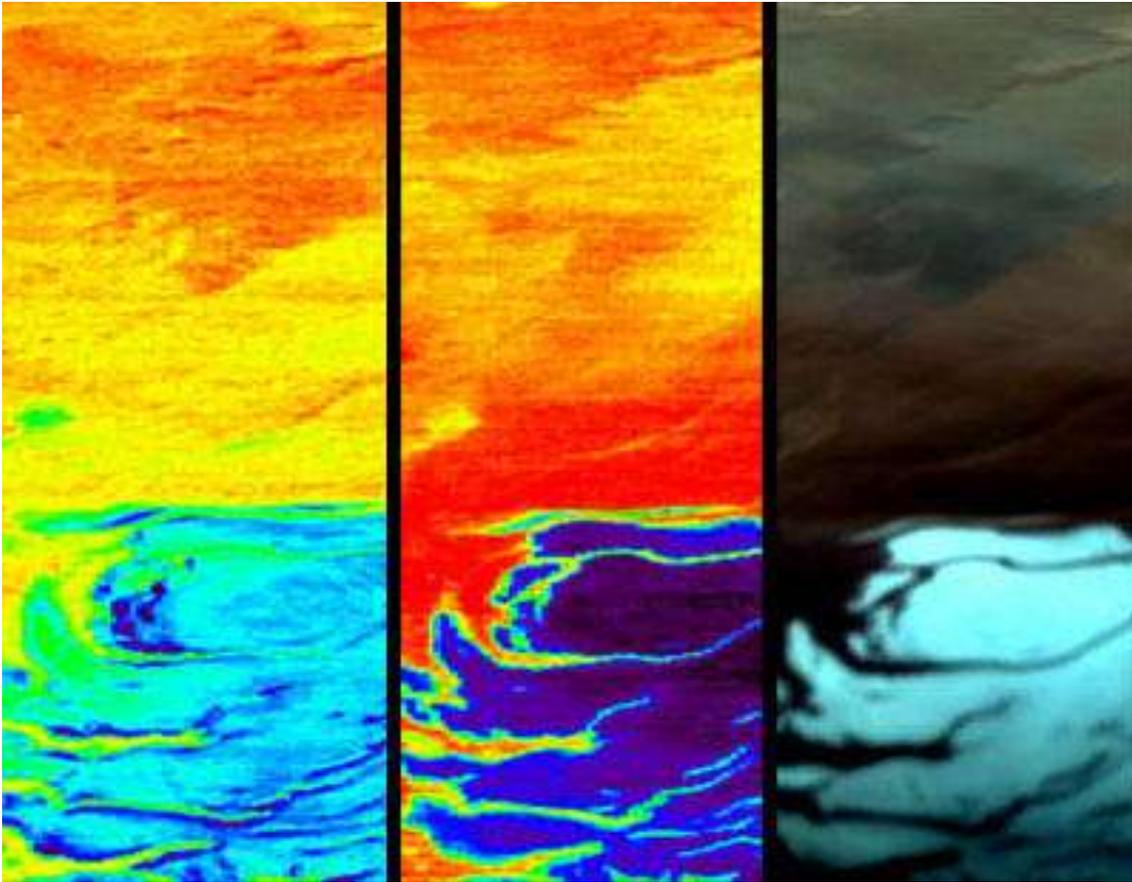
We can use **spectral lines**, like fingerprints, to identify the chemicals that stars and planets are made of.



Composition of the Earth by the Mars Express OMEGA Spectrometer

2004:

Mars Express  
Orbiter detects  
frozen carbon  
dioxide **and** water  
at the South Pole  
of Mars.



↑  
H<sub>2</sub>O

↑  
CO<sub>2</sub>

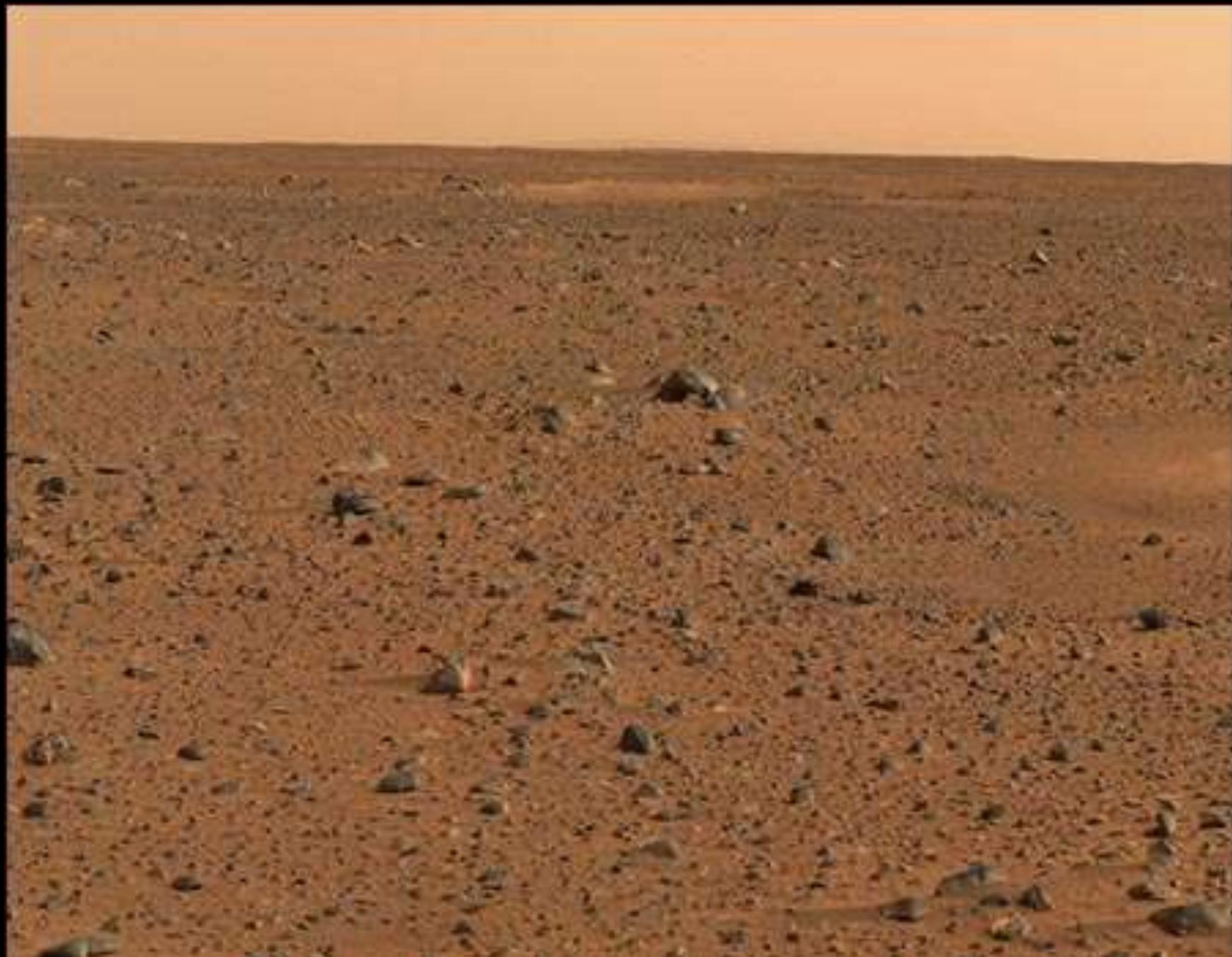
↑  
Visible light

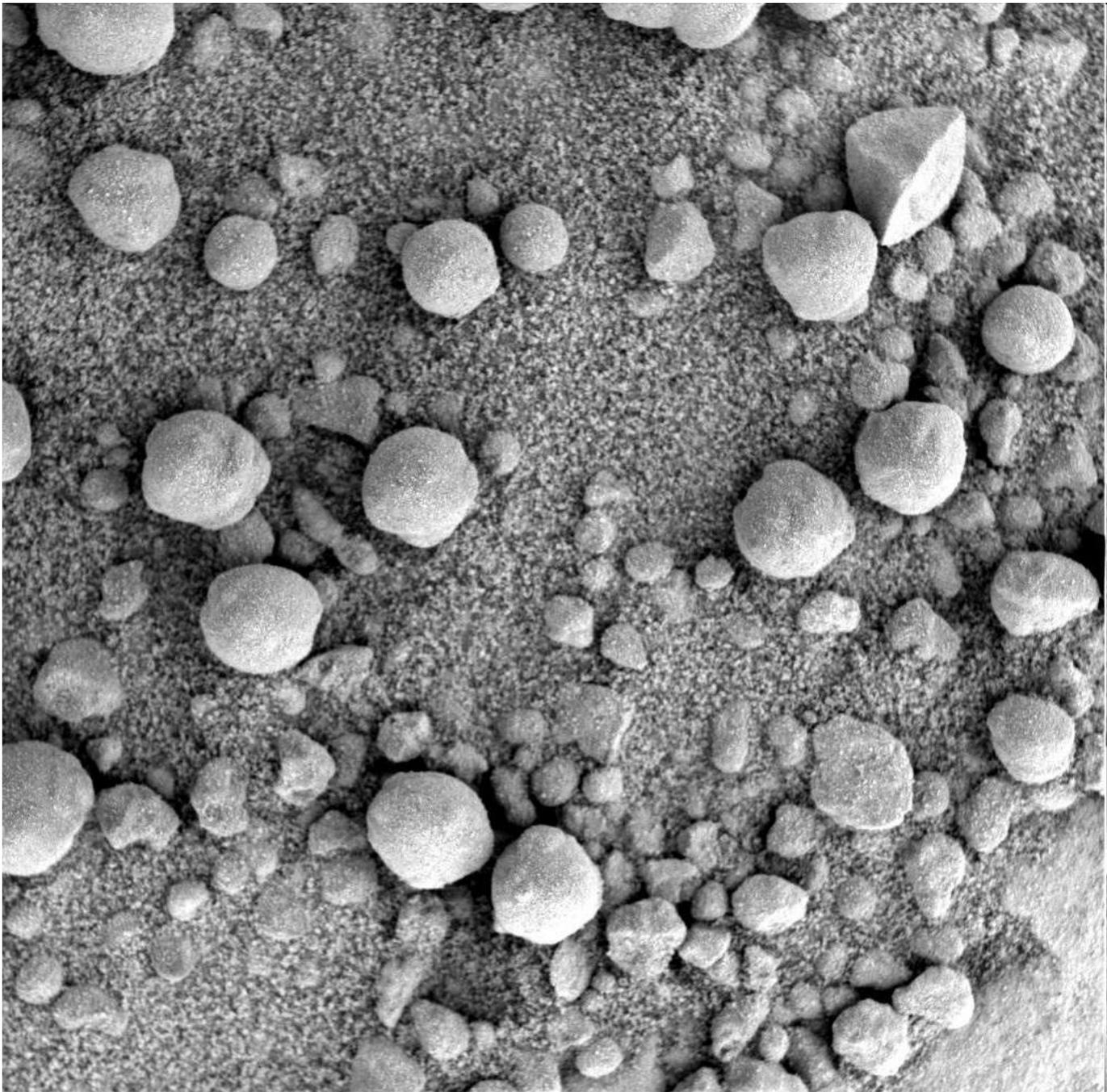


Signs of past **running water** in many Martian photographs

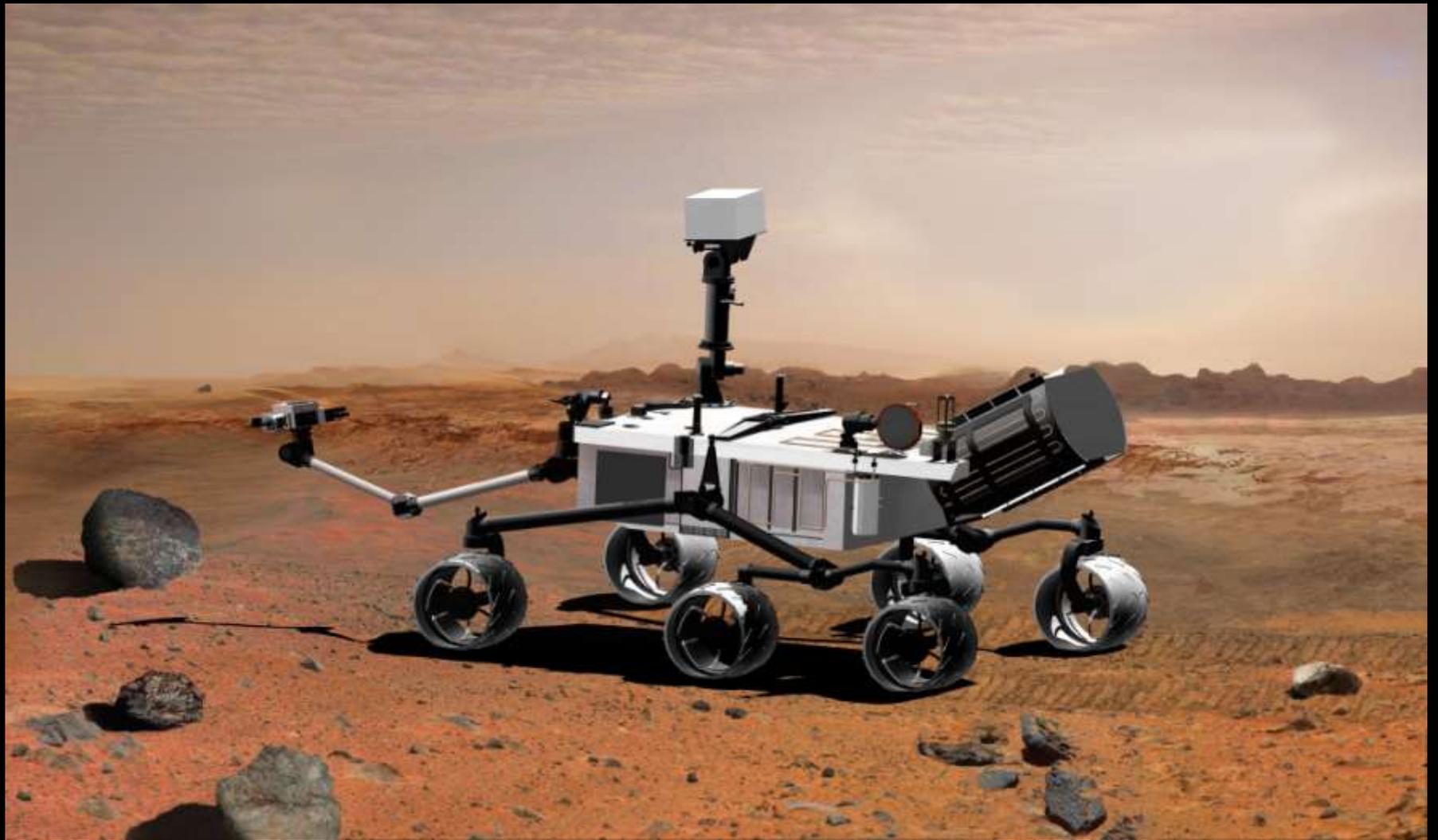






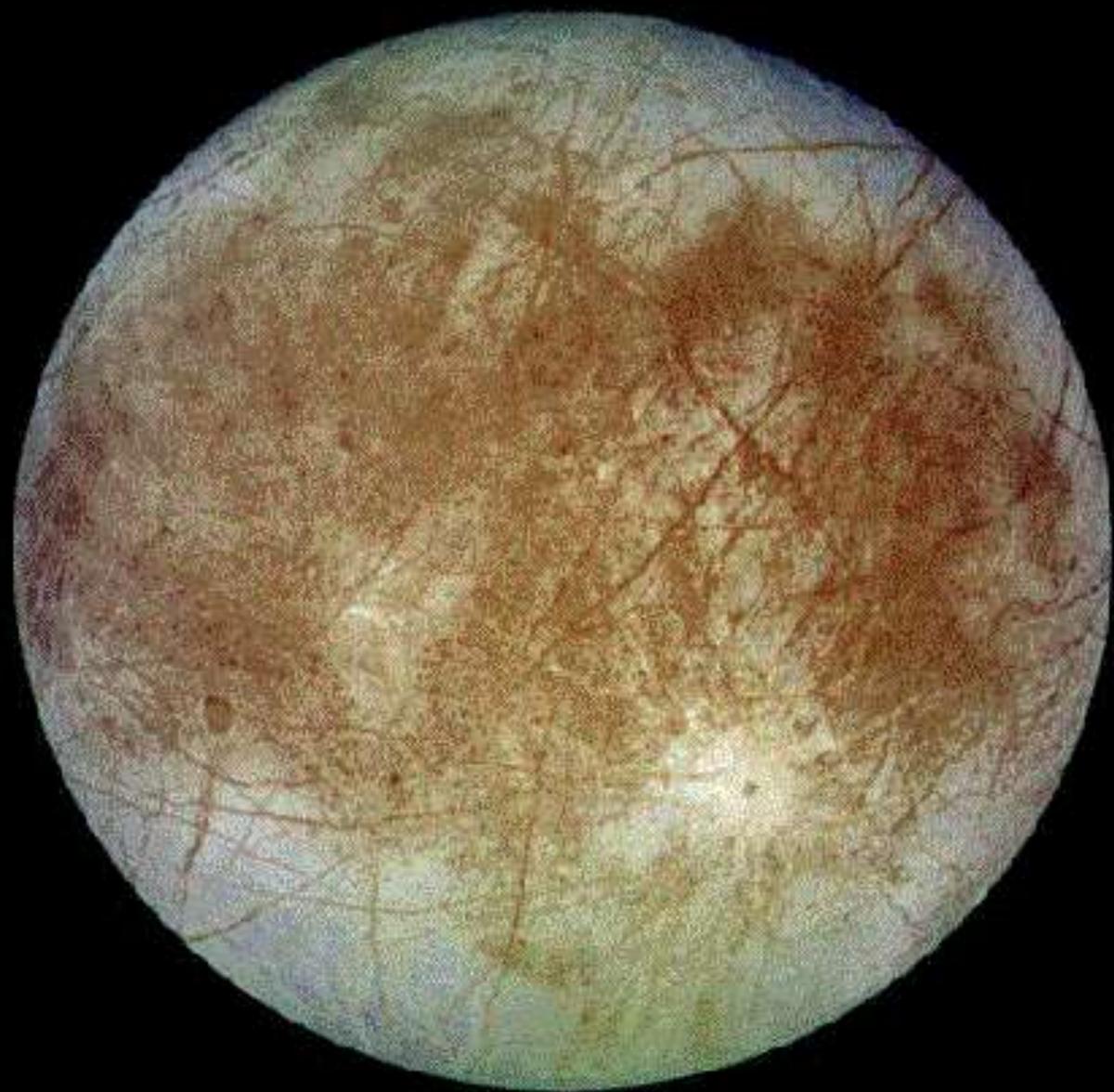




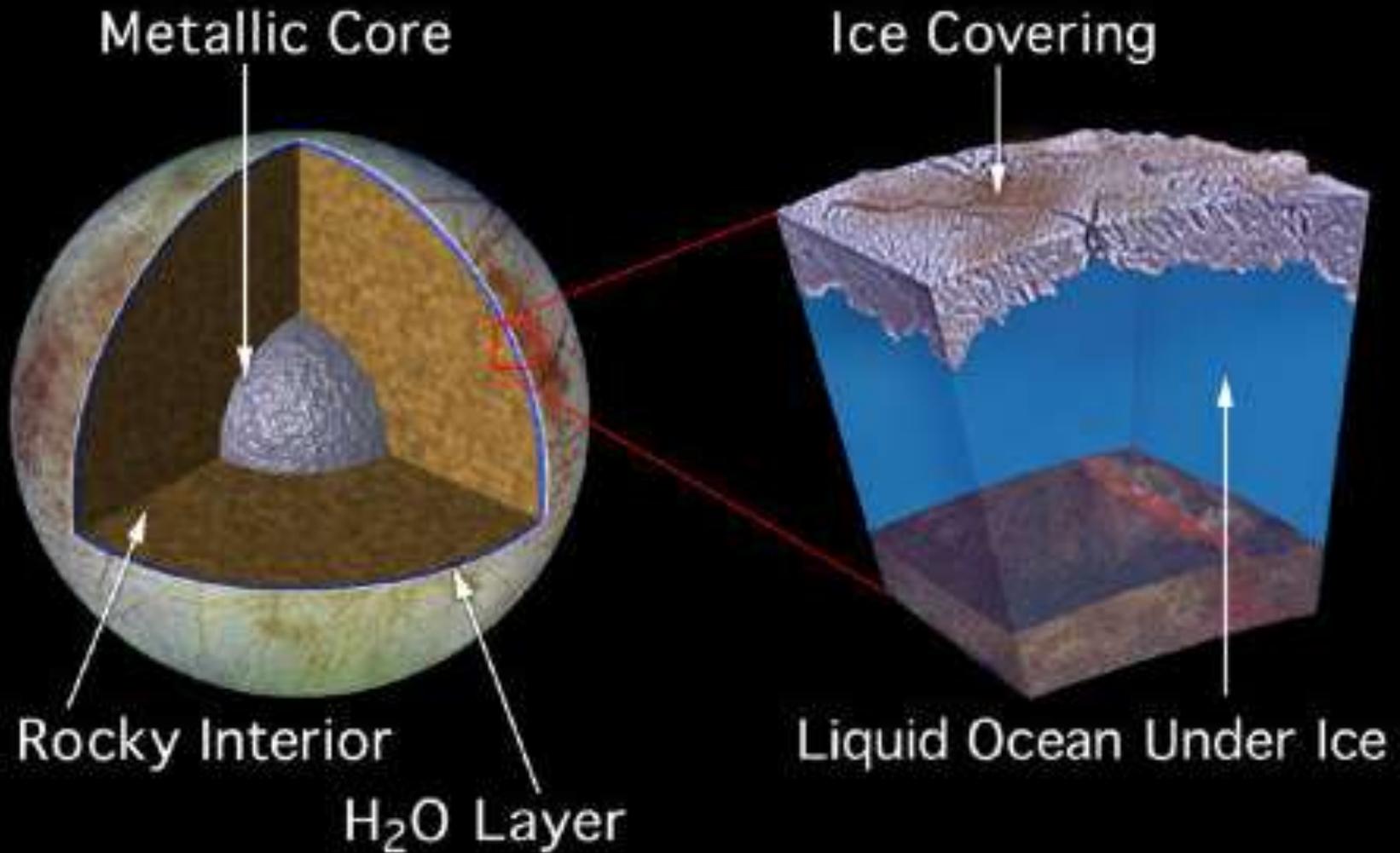


# *The moons of Jupiter*



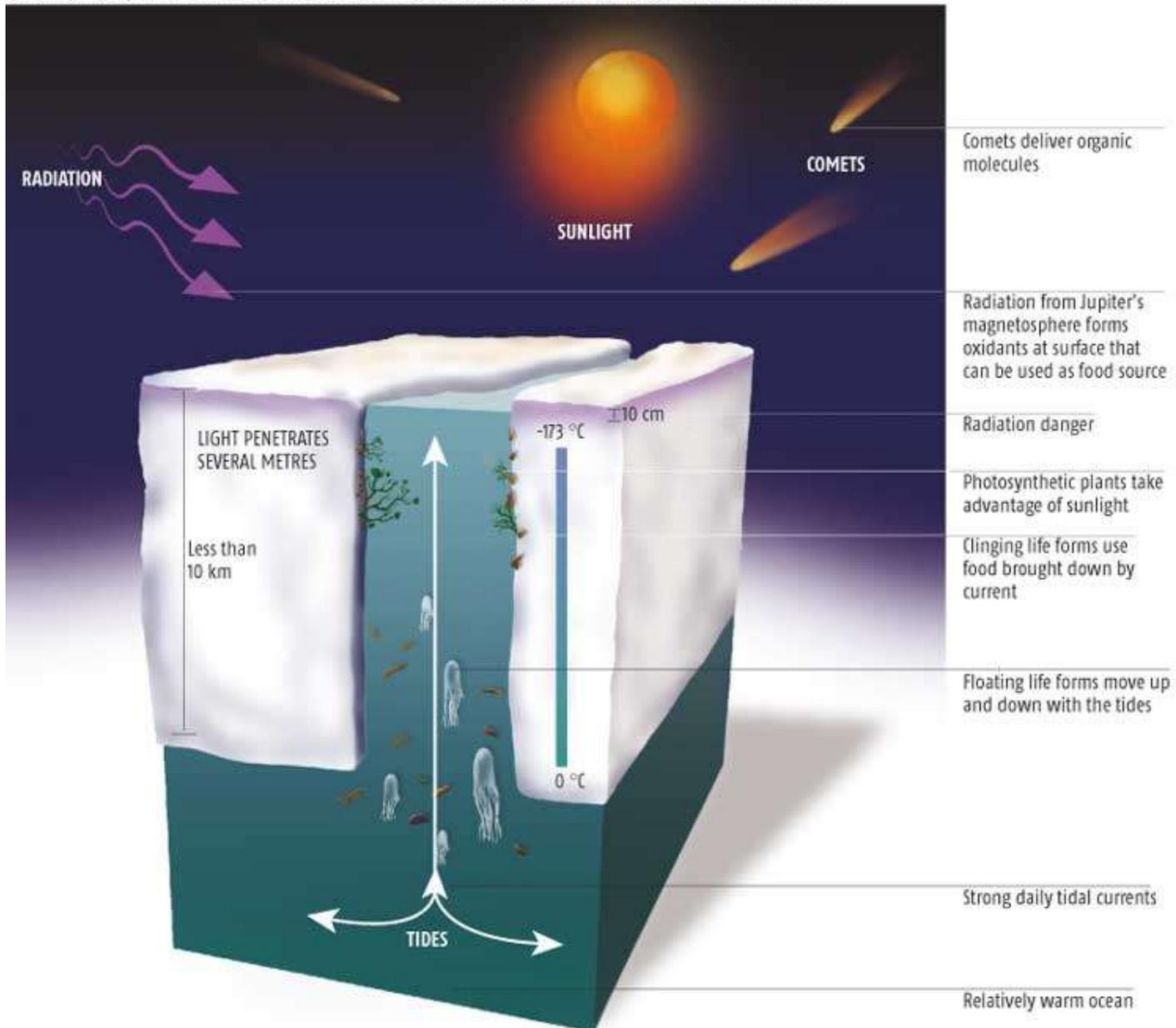


# Inside Europa

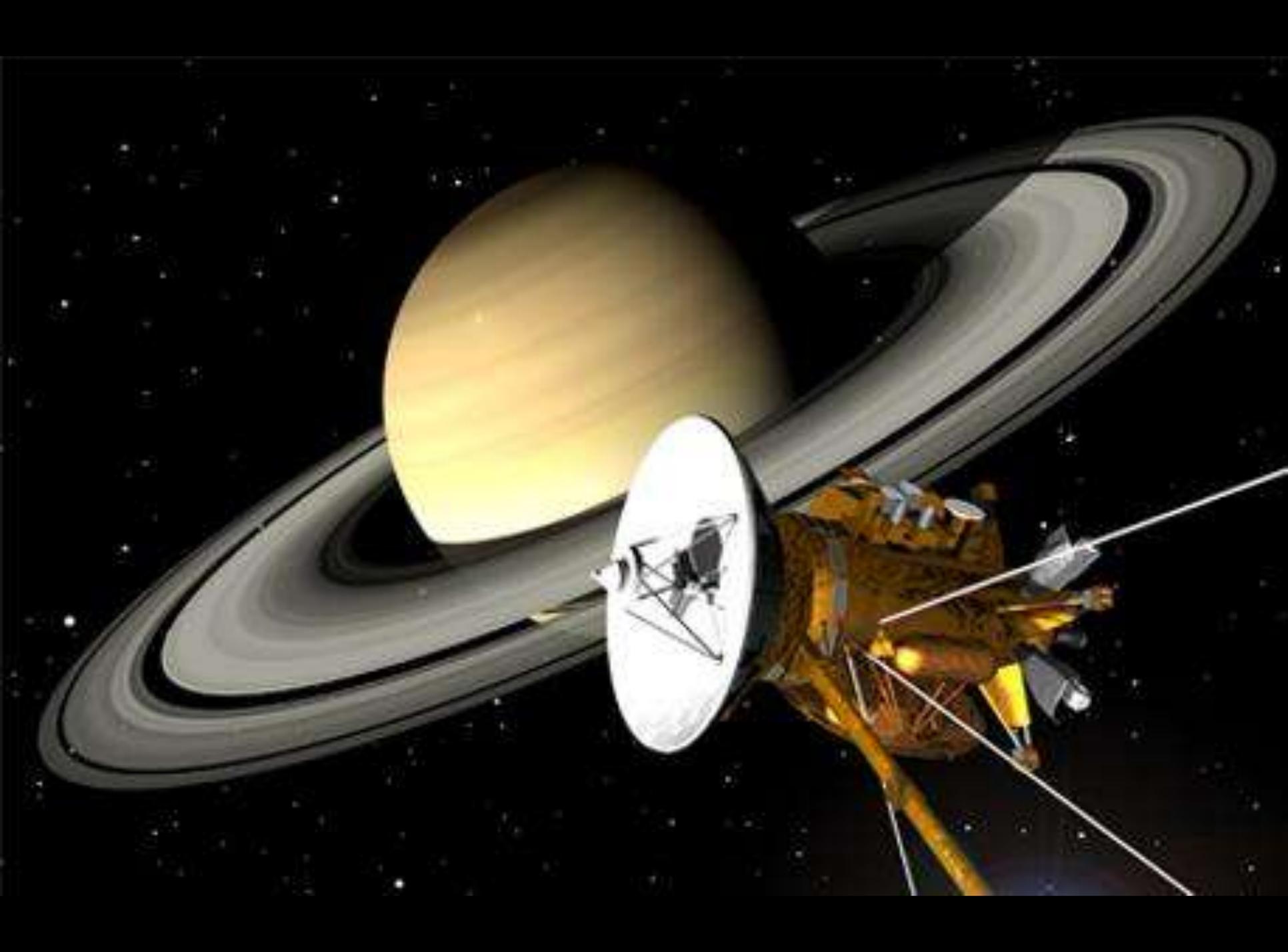


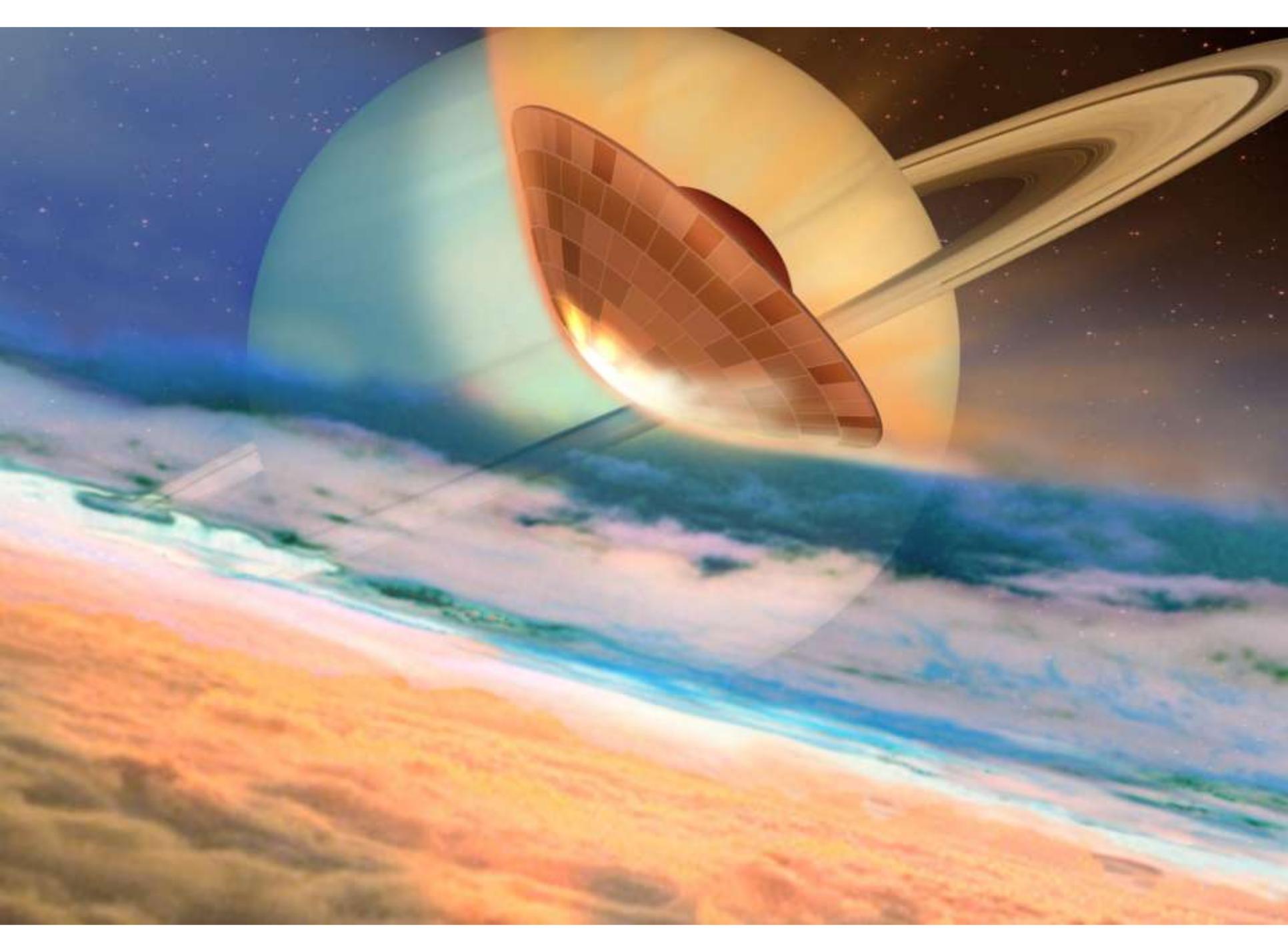
## IS THERE LIFE ON EUROPA?

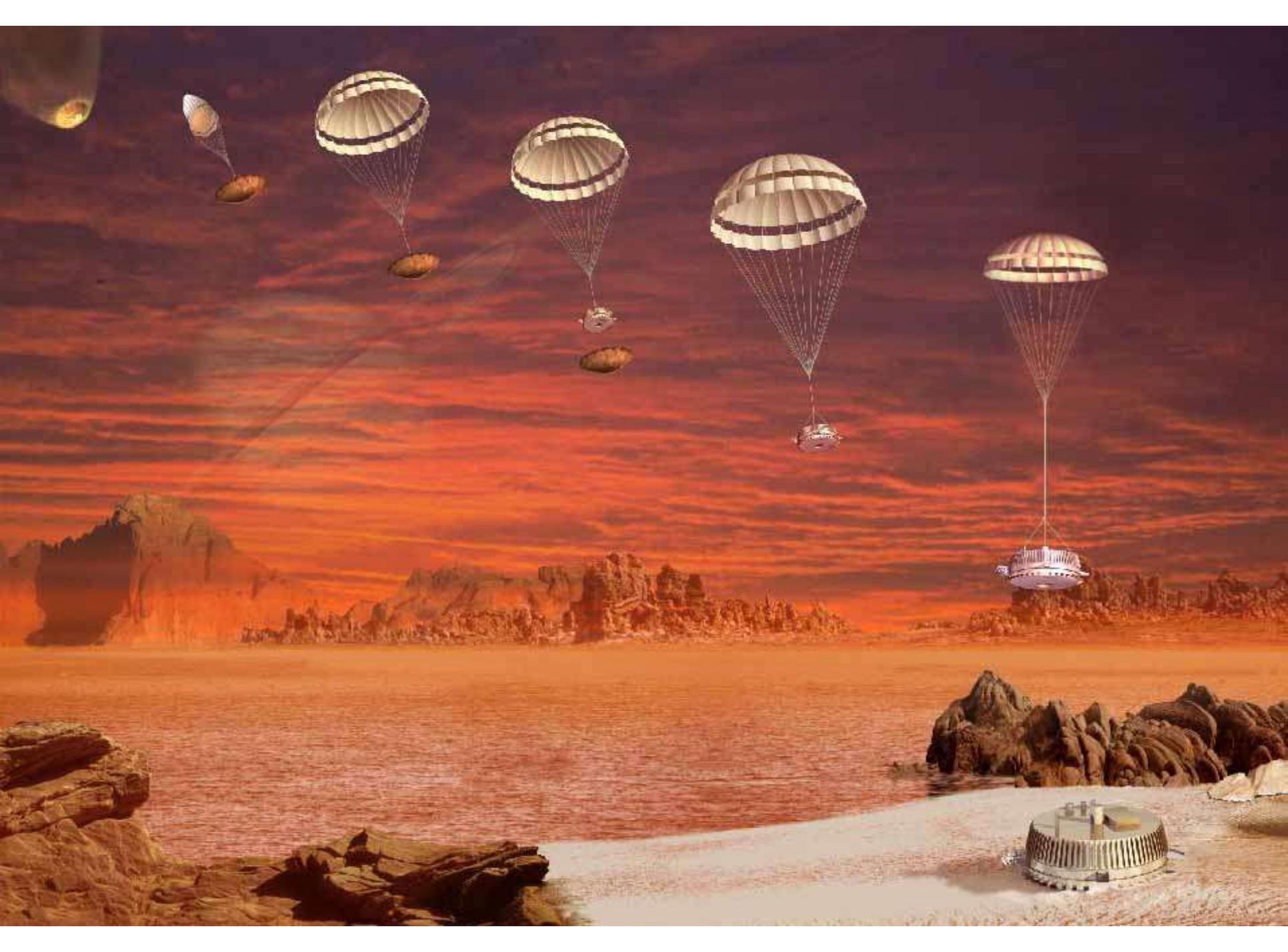
If Europa's icy crust is thin enough, cracks would provide a habitat where life could thrive

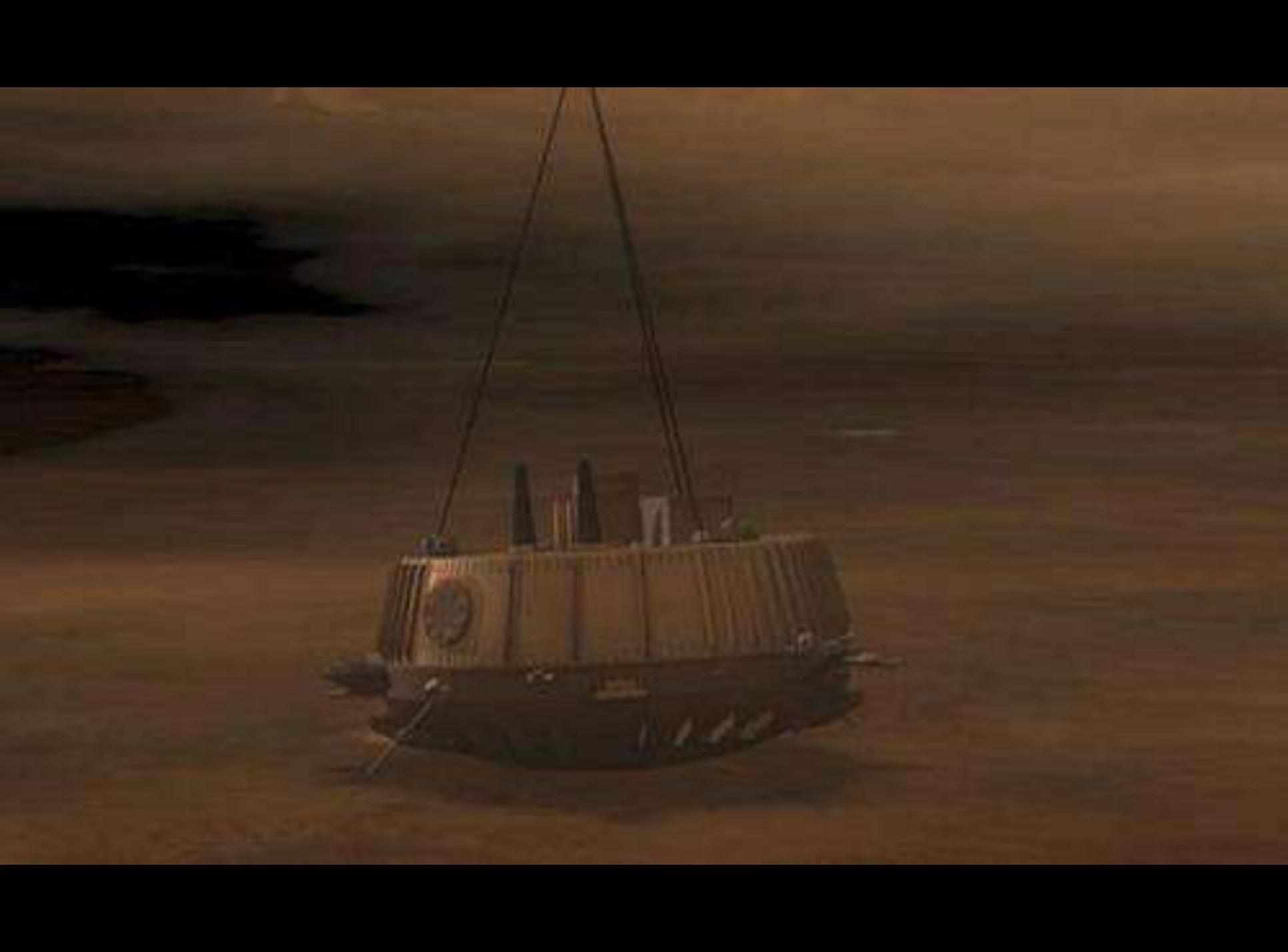




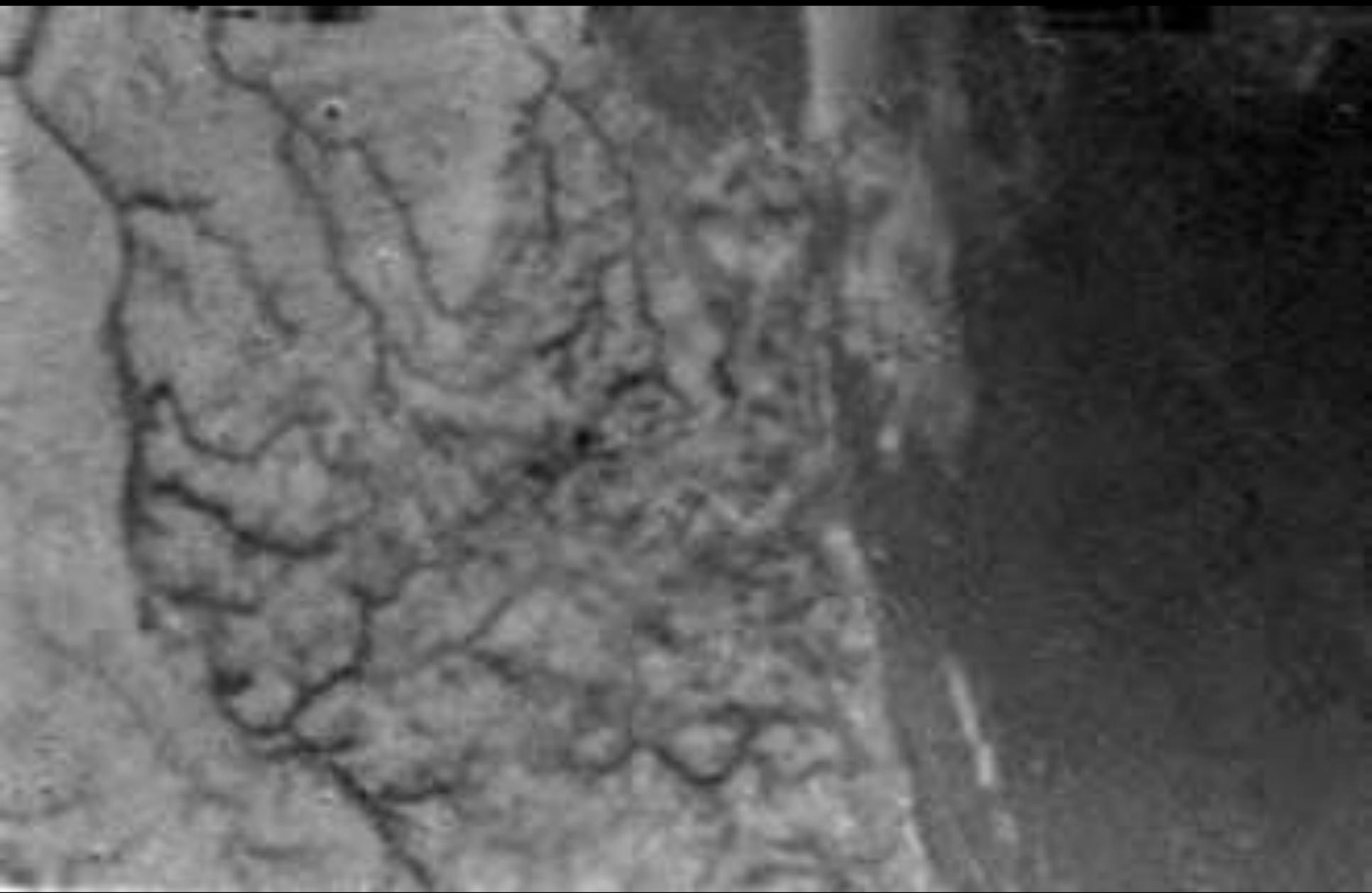


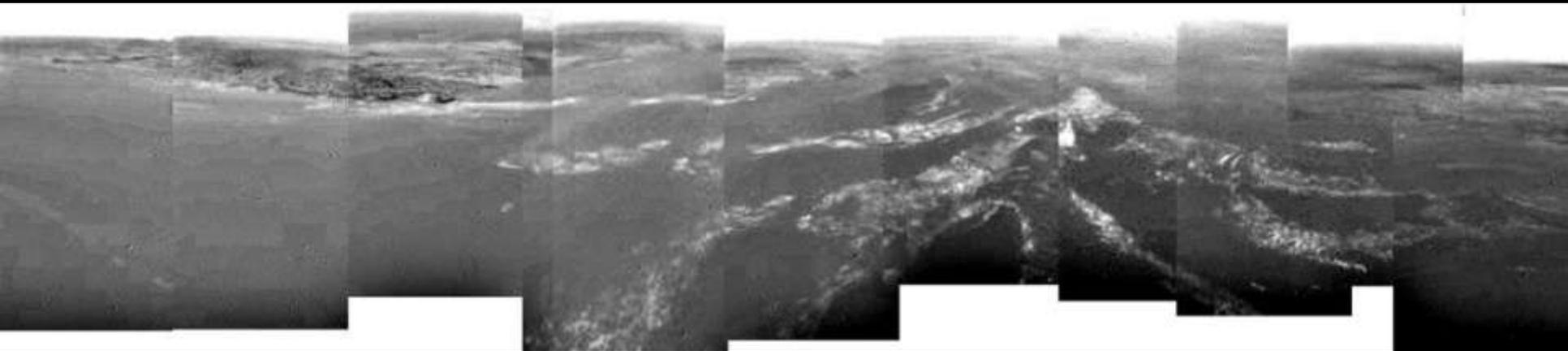


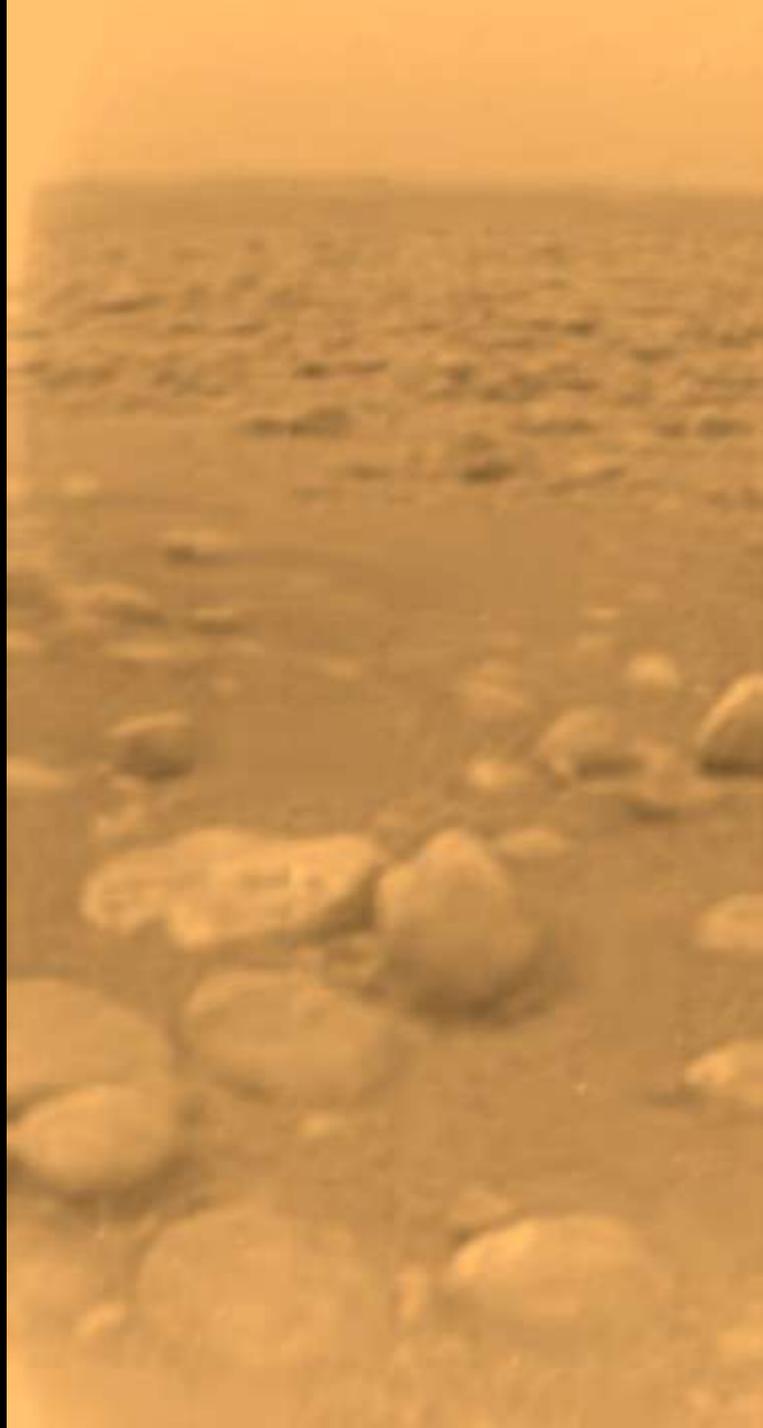


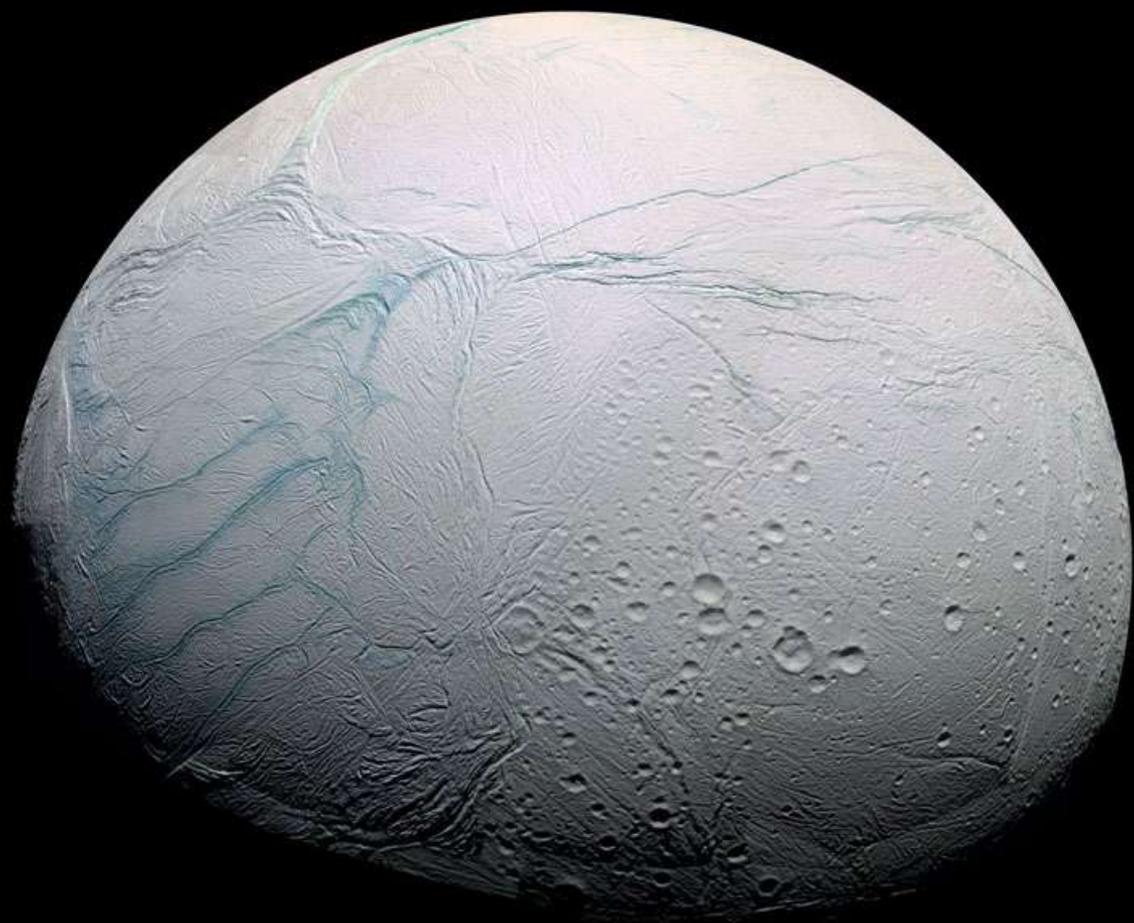




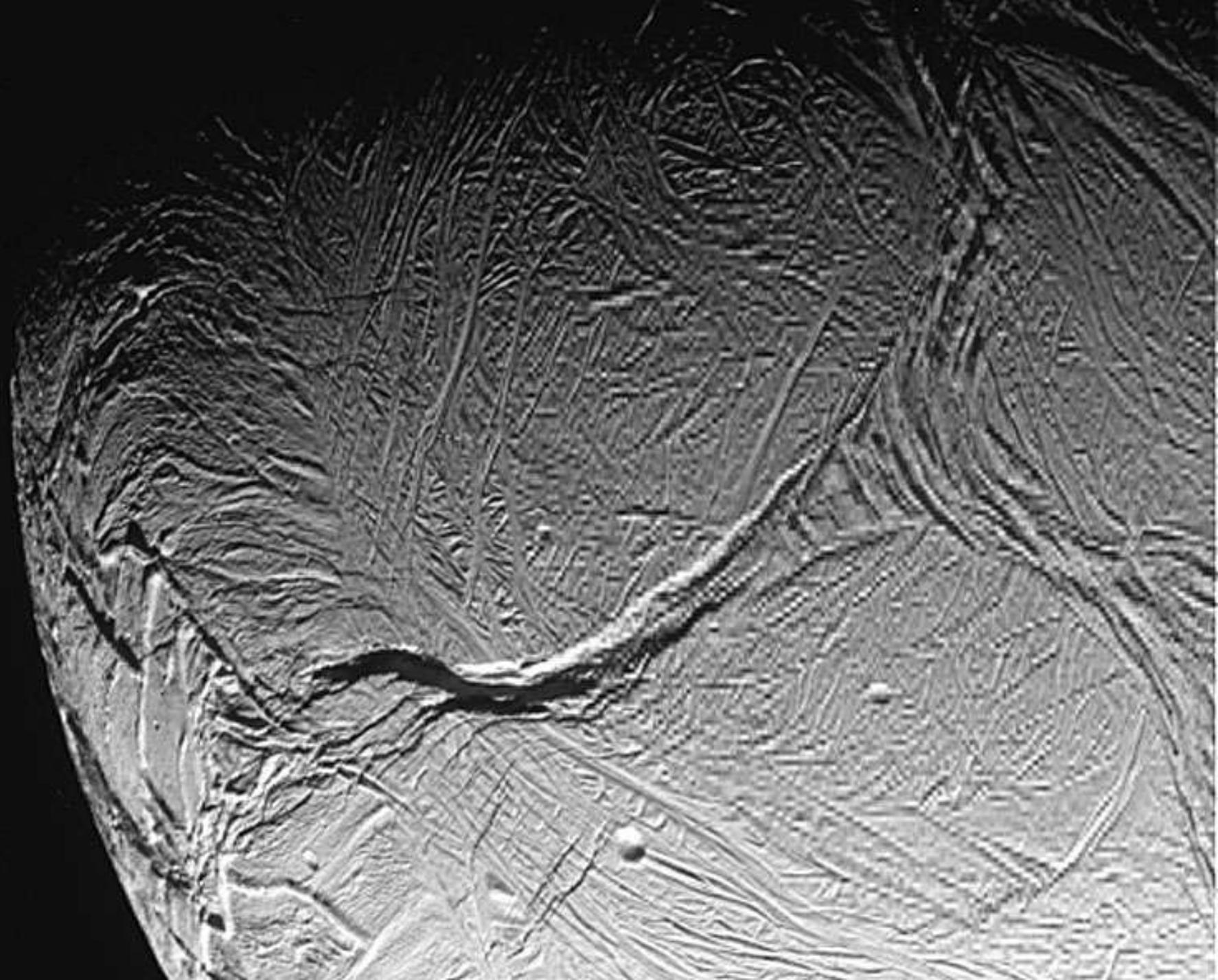
















# How can we detect planets around other stars?

This isn't easy because:

- other stars (and their planets) are very far away
- planets don't shine by themselves, they just reflect light from their star, so they get lost in the glare.



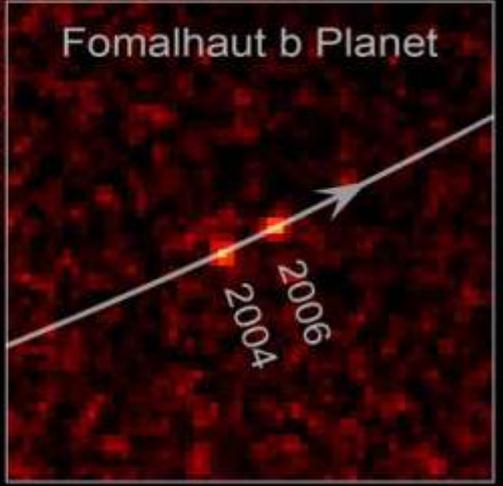
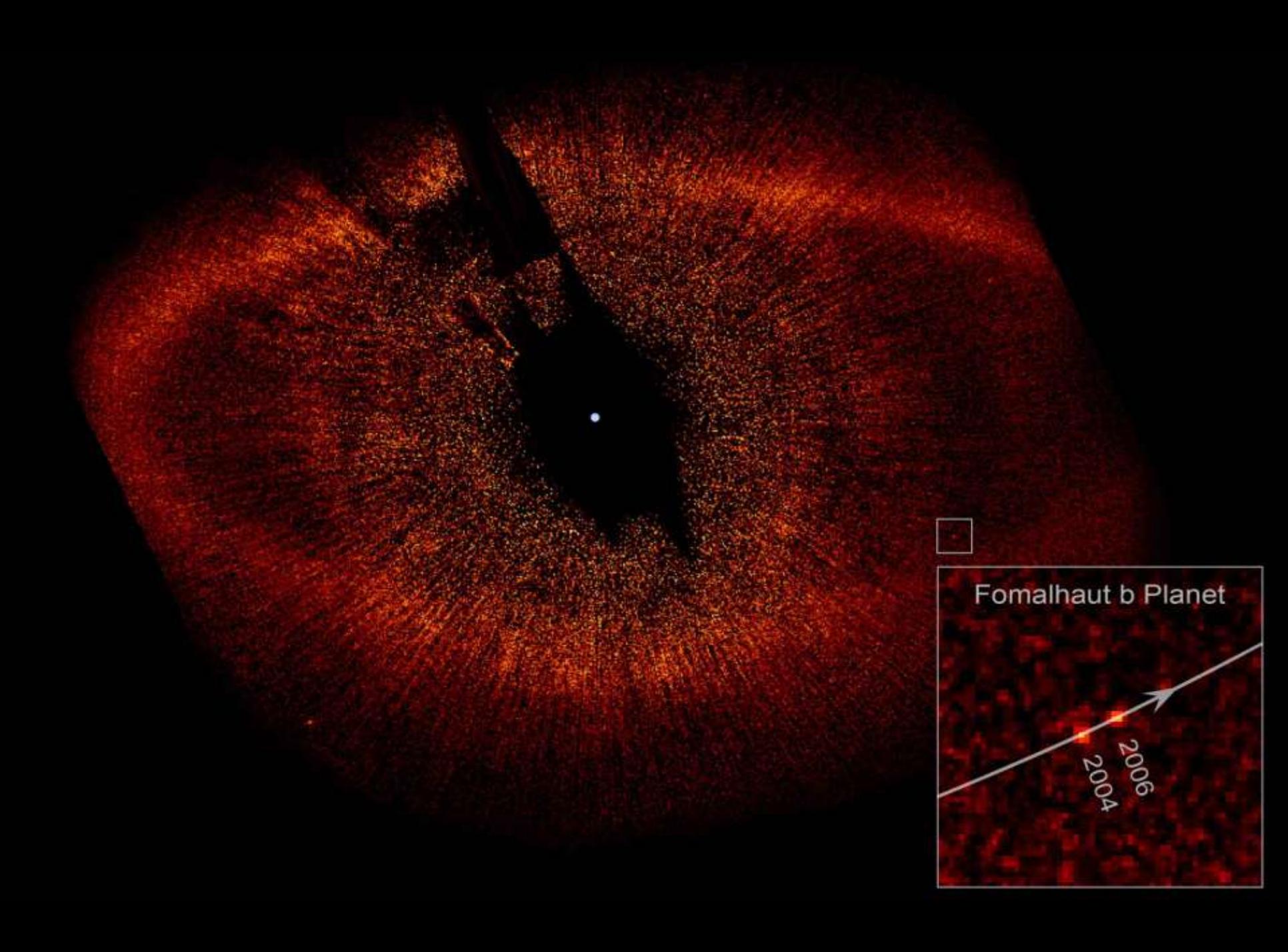
The distance from the Earth to the Sun is **150 million km**.

It takes sunlight more than **eight minutes** to travel this distance.

The light from the *next* nearest star, Alpha Centauri, takes more than **four years** to reach the Earth.

Exoplanets are 'drowned out' by their parent star. That makes them very hard to see directly with current telescopes (~10m mirrors)...

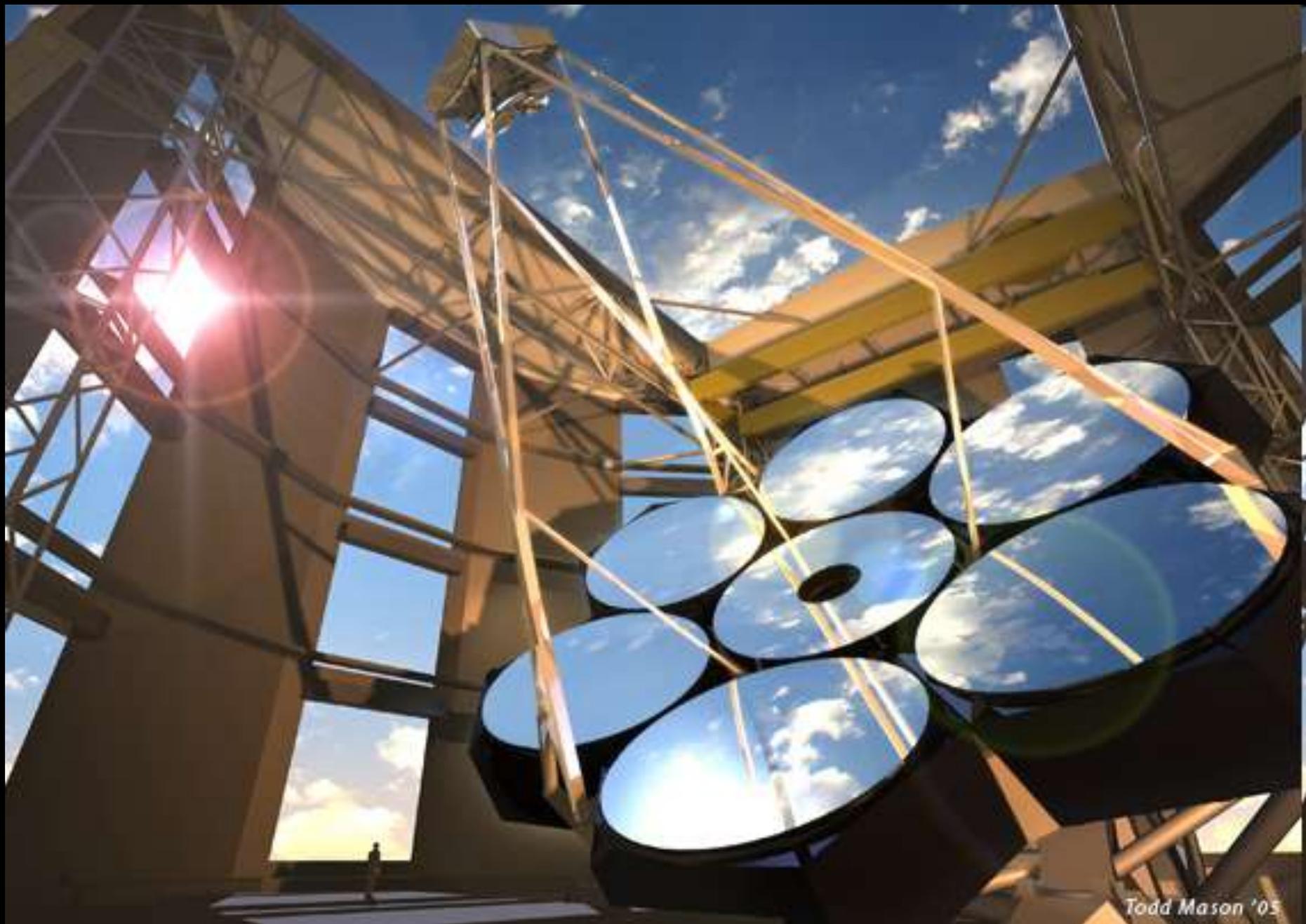




Fomalhaut b Planet

2004

2006



Todd Mason '05

# The European Extremely Large Telescope project



# The European Extremely Large Telescope project

## 42m mirror: to be completed by 2020



'Jupiter' at 30 l.y.



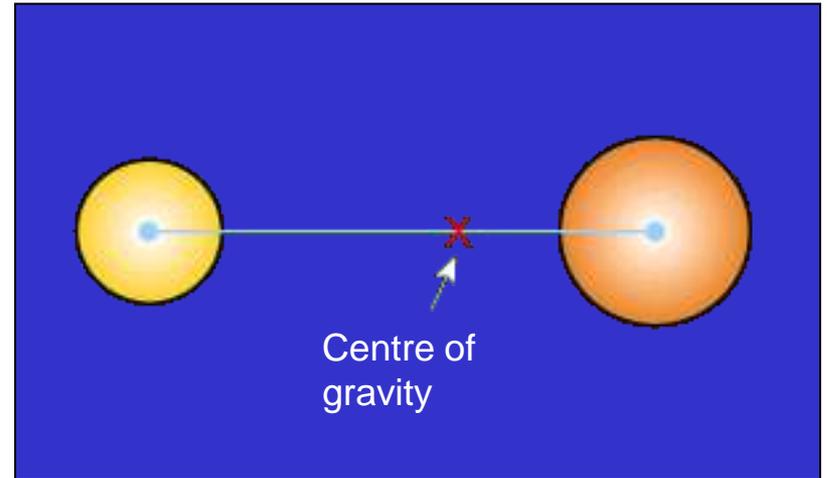
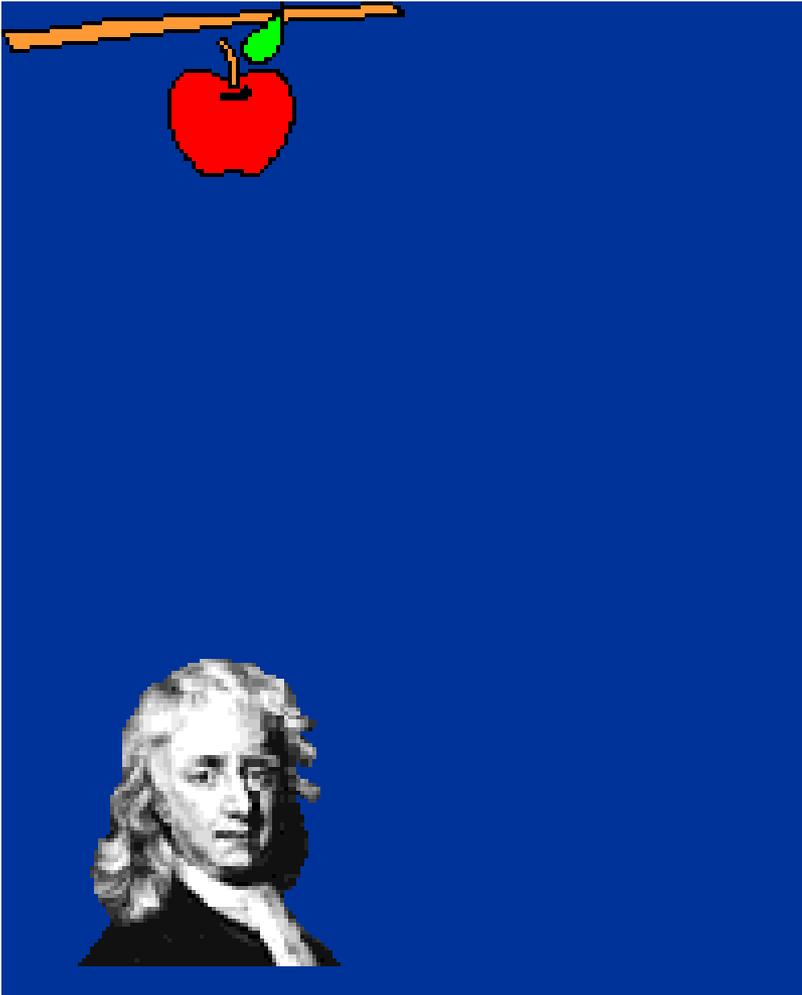
## 2. How can we detect planets around other stars?

This isn't easy because:

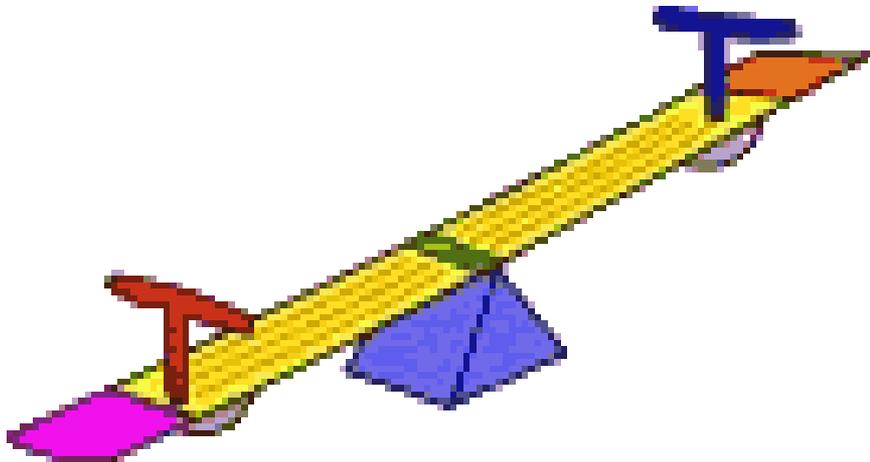
- other stars (and their planets) are very far away
- planets don't shine by themselves, they just reflect light from their star, so they get lost in the glare.

We can tell that planets are there by the effect they have on their star.

# Planets cause their parent star to 'wobble'



Star + planet orbit  
about centre of gravity



Star + planet orbit  
about centre of gravity

Can see star 'wobble',  
even when we can't see  
the planet.

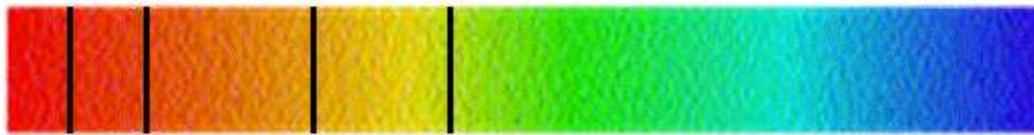


Star + planet orbit  
about centre of gravity

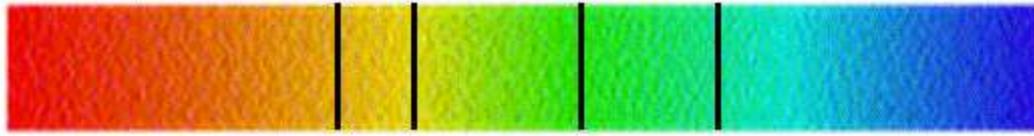
We can also see the  
motion of the star  
from its spectral  
lines.



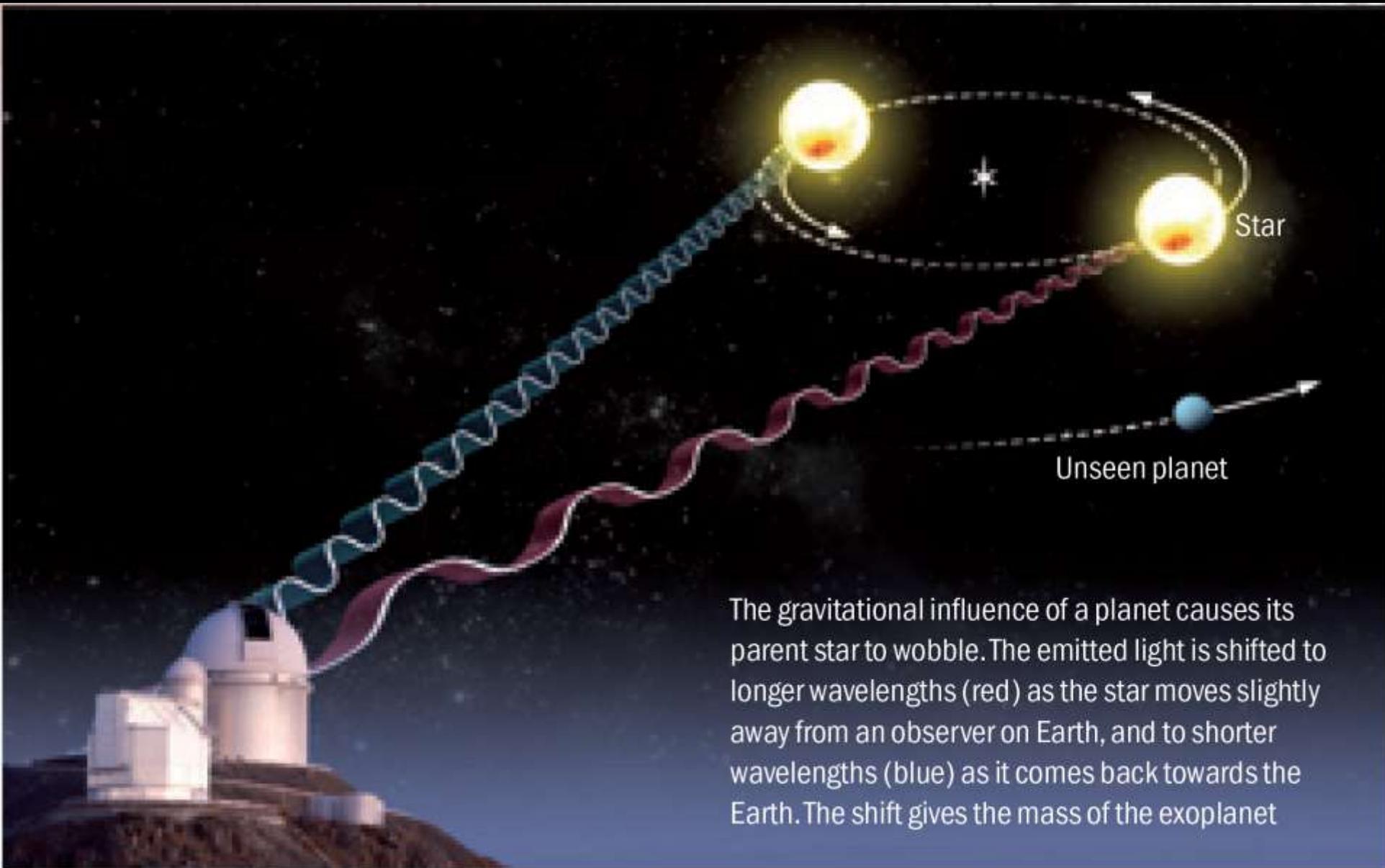
Direction  
to Earth



Star



Laboratory



The gravitational influence of a planet causes its parent star to wobble. The emitted light is shifted to longer wavelengths (red) as the star moves slightly away from an observer on Earth, and to shorter wavelengths (blue) as it comes back towards the Earth. The shift gives the mass of the exoplanet

In the past 16 years we have found many planets orbiting other stars in our galaxy...

The screenshot displays the Planet Quest website interface. At the top left is the NASA logo and the text "Jet Propulsion Laboratory California Institute of Technology". A navigation menu includes "JPL HOME", "EARTH", "SOLAR SYSTEM", "STARS & GALAXIES", and "SCIENCE & TECHNOLOGY". Below this is the slogan "BRING THE UNIVERSE TO YOU:" followed by links for "JPL Email News", "RSS", "Podcast", and "Video", along with social media icons for Twitter, Facebook, and YouTube.

The main header features the "PLANET QUEST THE SEARCH FOR ANOTHER EARTH" logo. To its right, a statistics box shows "2,326 CANDIDATES = 3,035 EXOPLANETS" with "709 CONFIRMED" listed below. Further right is a "DISCOVER NEW WORLDS ATLAS" section, described as "a visual guide to exoplanets".

A horizontal navigation bar contains tabs for "NEWS", "SCIENCE & TECHNOLOGY", "IMAGES & VIDEO", "INTERACTIVES", and "EDUCATION", followed by a search bar with "SEARCH" and "GO" buttons.

The central content area features a large background image of a red planet (Mars) and a bright star. On the left, a "TOP STORY" section titled "Tiny trio" reports that astronomers using data from NASA's Kepler mission have discovered the three smallest planets yet detected orbiting a star beyond our sun. A "read more" link is provided below the text, and a video player control bar is visible at the bottom of this section.

At the bottom, there are two promotional banners. The left one is titled "ALIEN vs. EDITOR" and features a portrait of astronomer Steve, with the text "Astronomer Steve answers your questions", "January 12, 2012", and "Austin announcements NASA brings the exos to Texas". The right banner is titled "EXPLORE" and "EXTREME PLANET MAKEOVER", showing a stylized planet.

### 3. Could some of those planets be like the Earth?

Most planets we've found so far are 'hot Jupiters':

gas giants, much bigger and closer to their parent star than the Earth is to the Sun.



These are not good places to look for life like us:

no water,  
no oxygen,  
much too hot!

In the past 16 years we have found many planets orbiting other stars in our galaxy...

The screenshot shows the NASA Jet Propulsion Laboratory website for Planet Quest. The header includes the NASA logo and the text "Jet Propulsion Laboratory California Institute of Technology". Navigation links include "JPL HOME", "EARTH", "SOLAR SYSTEM", "STARS & GALAXIES", and "SCIENCE & TECHNOLOGY". A secondary navigation bar says "BRING THE UNIVERSE TO YOU:" with links for "JPL Email News", "RSS", "Podcast", and "Video". Social media icons for Twitter, Facebook, and YouTube are also present.

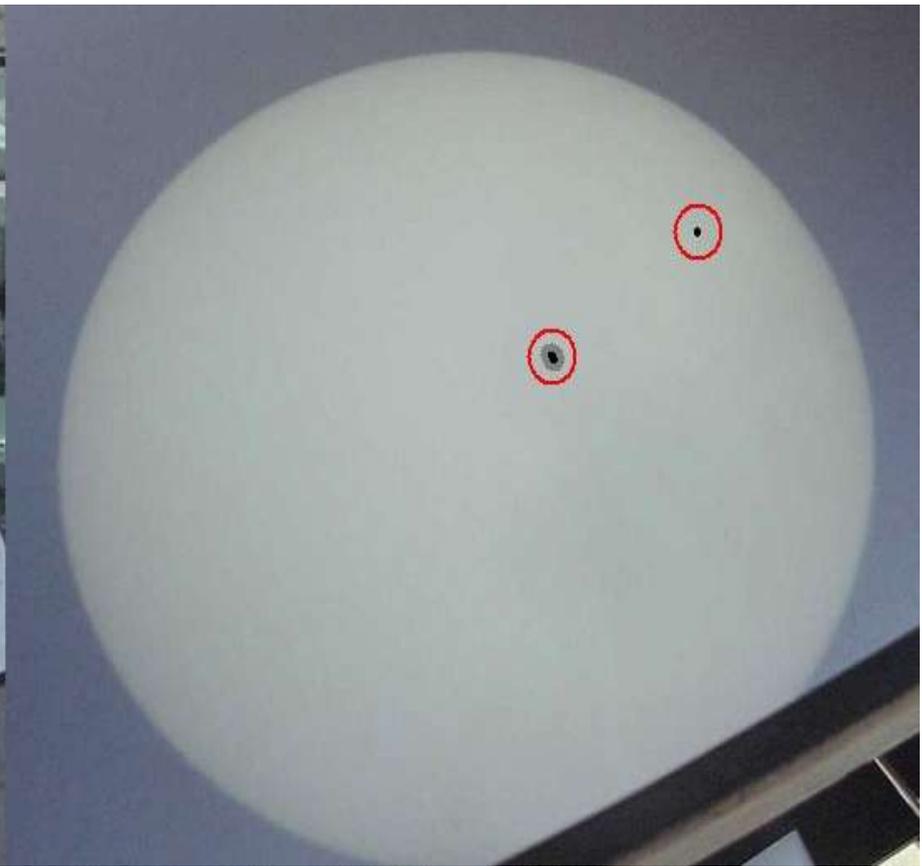
The main content area features the "PLANET QUEST THE SEARCH FOR ANOTHER EARTH" logo. To the right, a statistics box displays: "2,326 CANDIDATES = 3,035 EXOPLANETS" with "709 CONFIRMED" below the candidates. Further right is a "DISCOVER NEW WORLDS ATLAS" section, described as "a visual guide to exoplanets".

A navigation bar below the logo includes "NEWS", "SCIENCE & TECHNOLOGY", "IMAGES & VIDEO", "INTERACTIVES", and "EDUCATION", along with a search bar and a "GO" button.

The main visual is a large image of a red planet (Mars) in the foreground, with a bright star and two smaller planets in the background. A "TOP STORY" section on the left is titled "Tiny trio" and contains the text: "Astronomers using data from NASA's Kepler mission have discovered the three smallest planets yet detected orbiting a star beyond our sun." Below this is a "read more" link and a video player control bar.

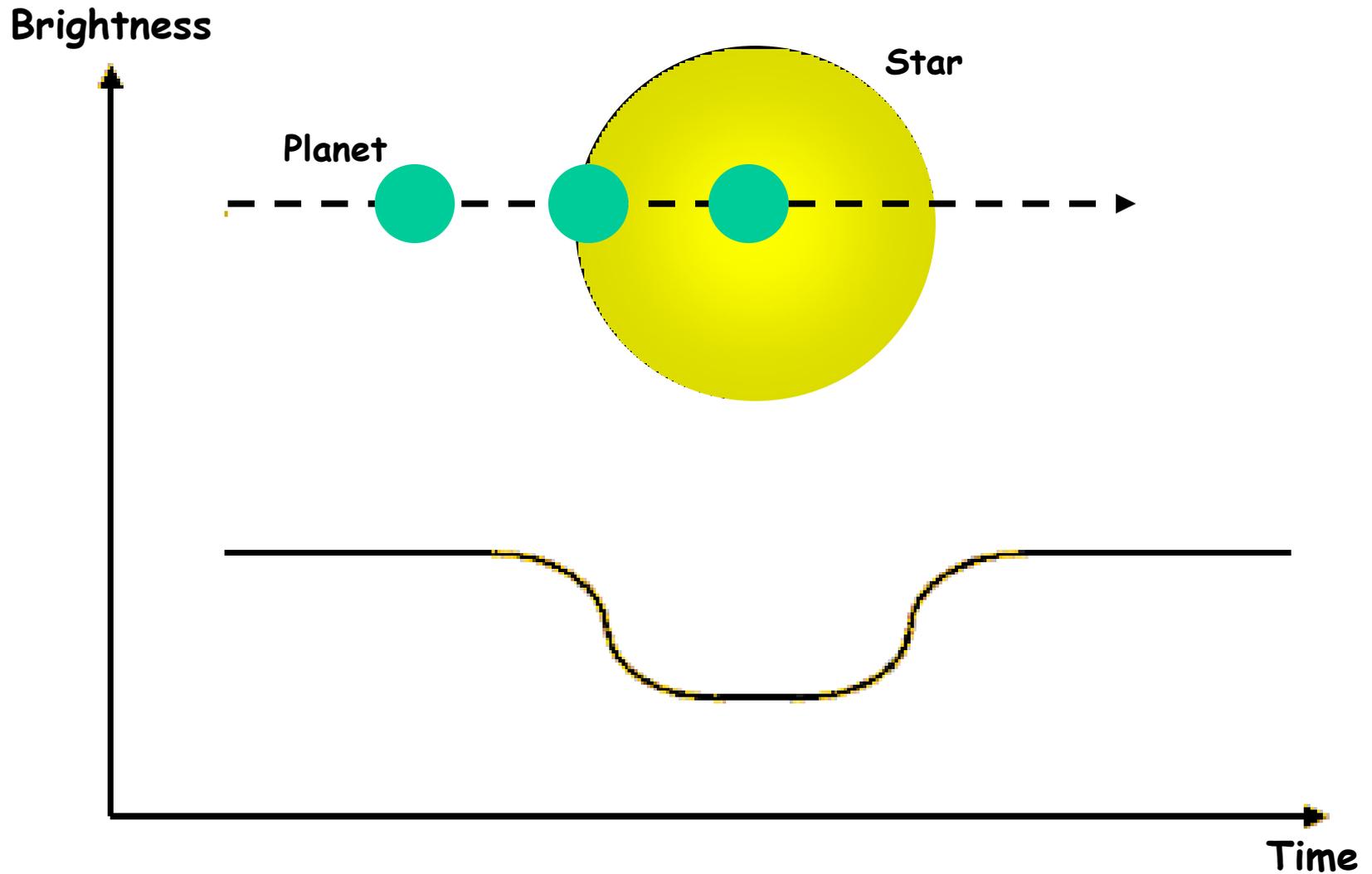
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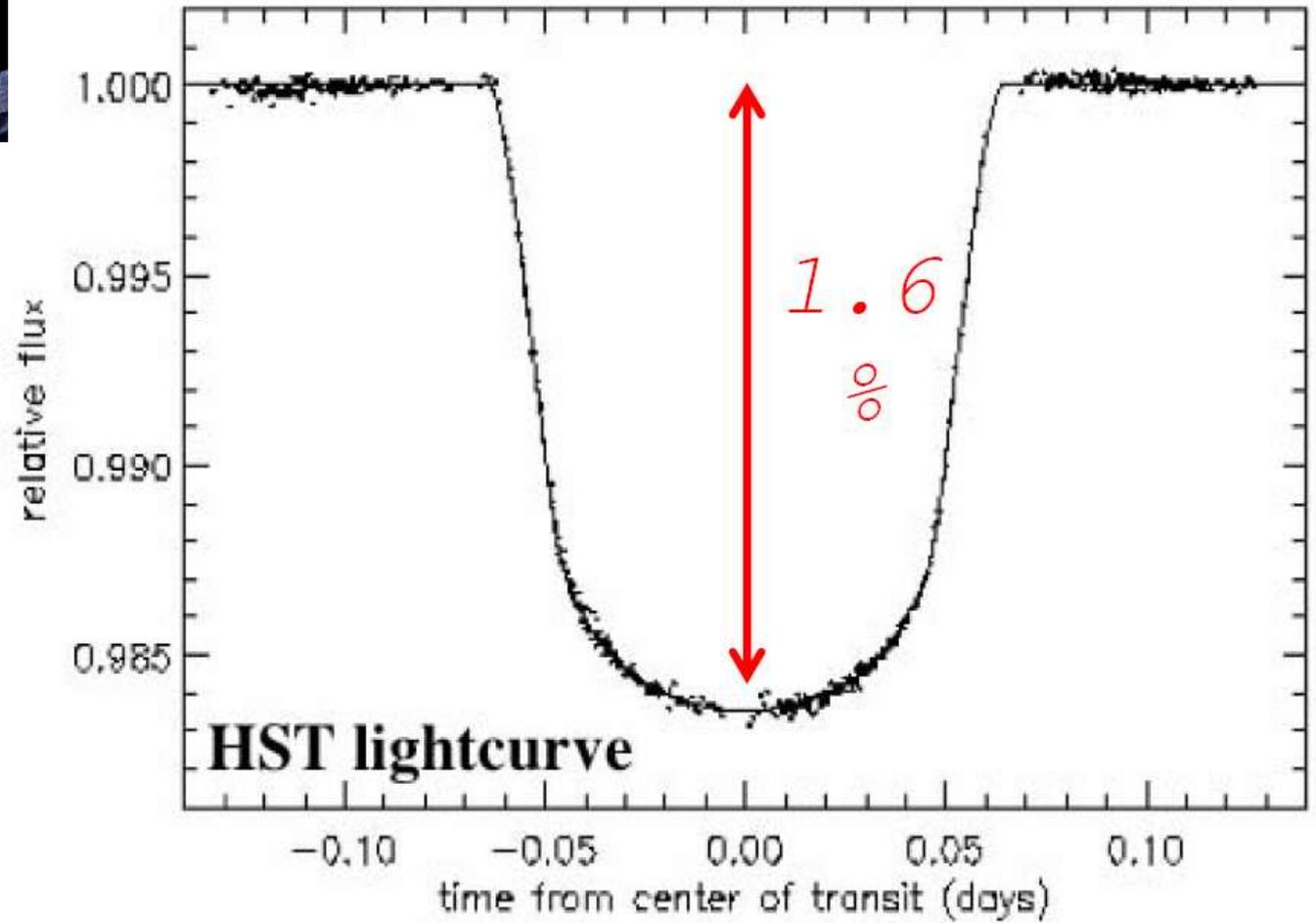
*No Earth-like planets, yet? ....*



Transit of Mercury: May 7<sup>th</sup> 2003

# Detecting exoplanets from transits



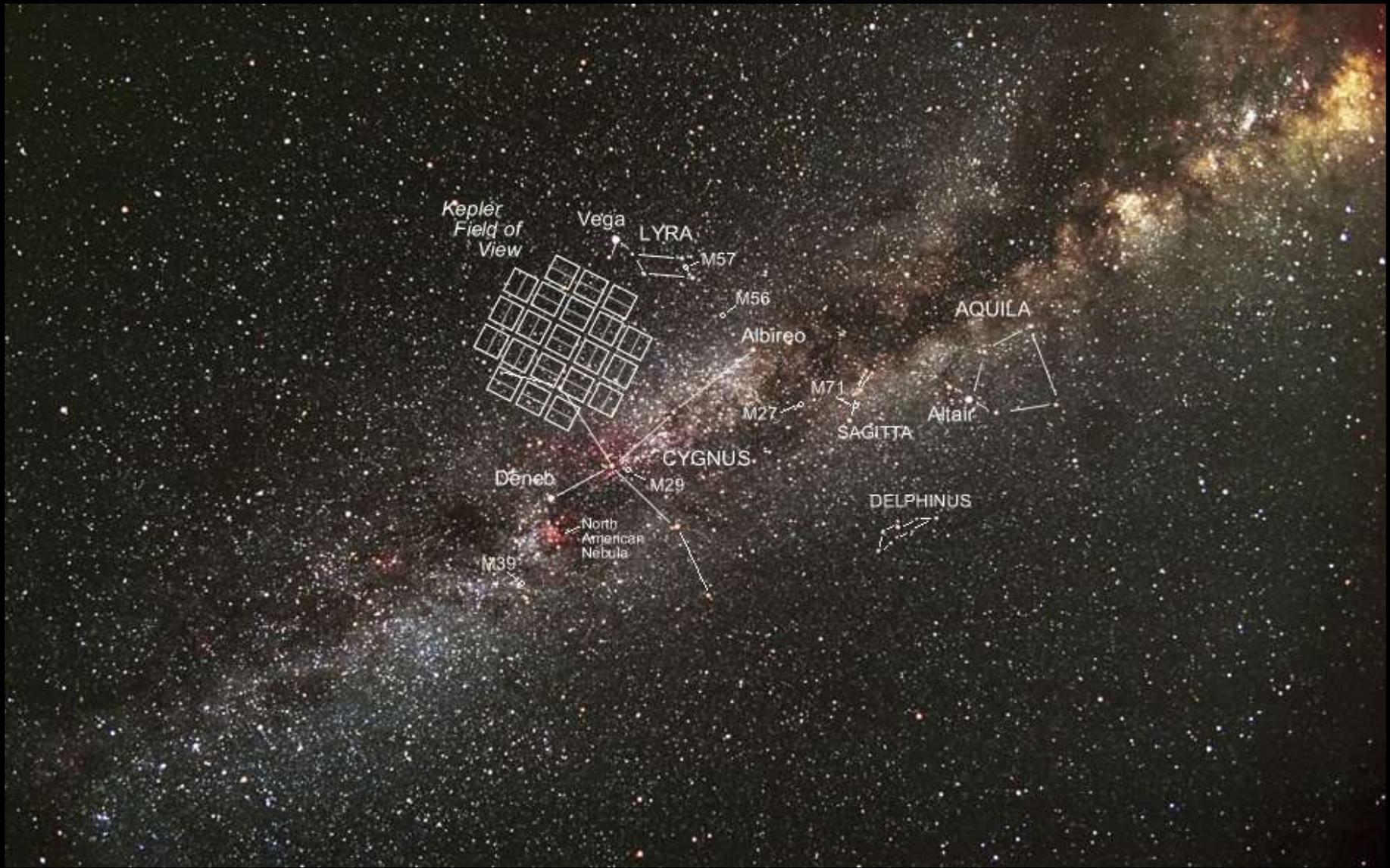


# Kepler

NASA's first mission capable of finding Earth-size and smaller planets

**Launched: March 5<sup>th</sup> 2009**





Kepler  
Field of  
View

Vega

LYRA

M57

M56

Albireo

AQUILA

Altair

SAGITTA

CYGNUS

Deneb

M29

DELPHINUS

North  
American  
Nebula

M39

M27

M71

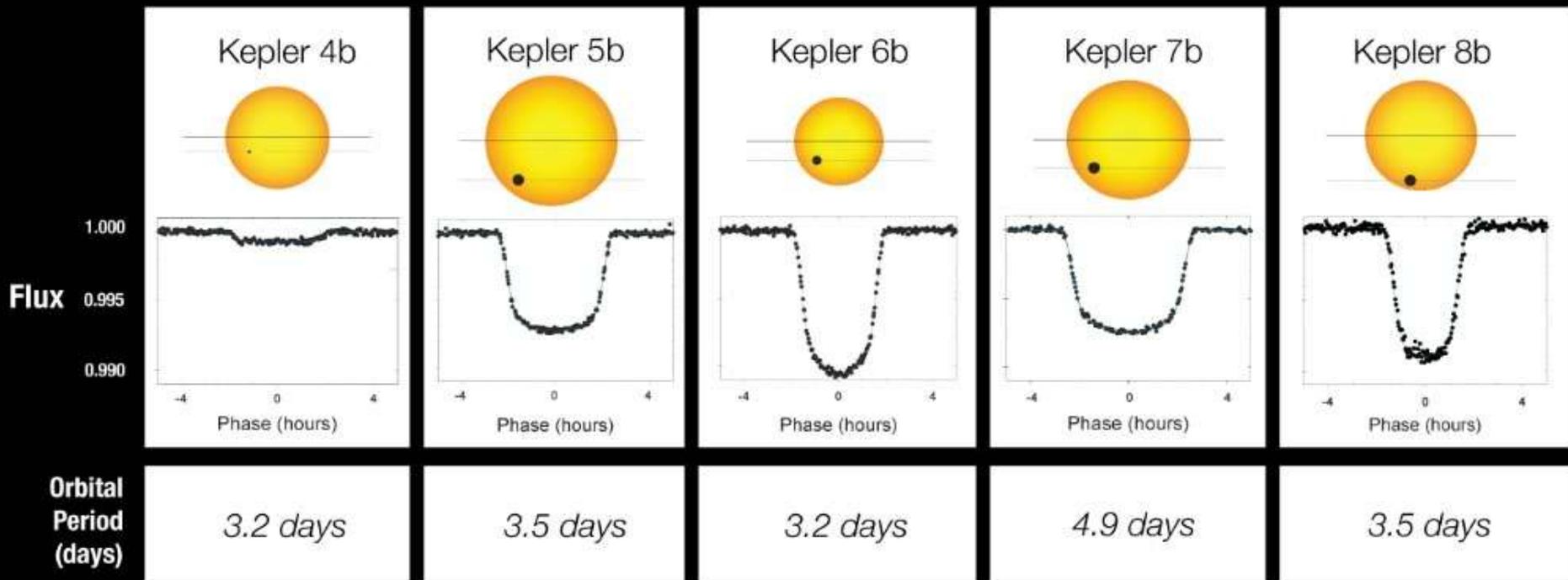


BRIGHTNESS

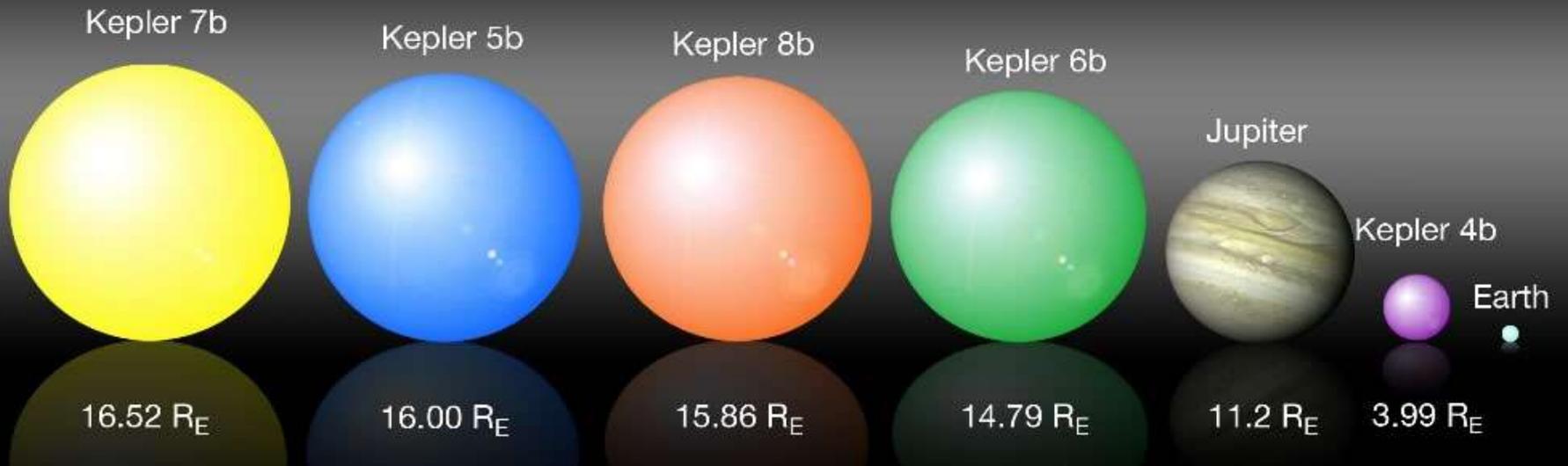


TIME IN HOURS

# Transit Light Curves

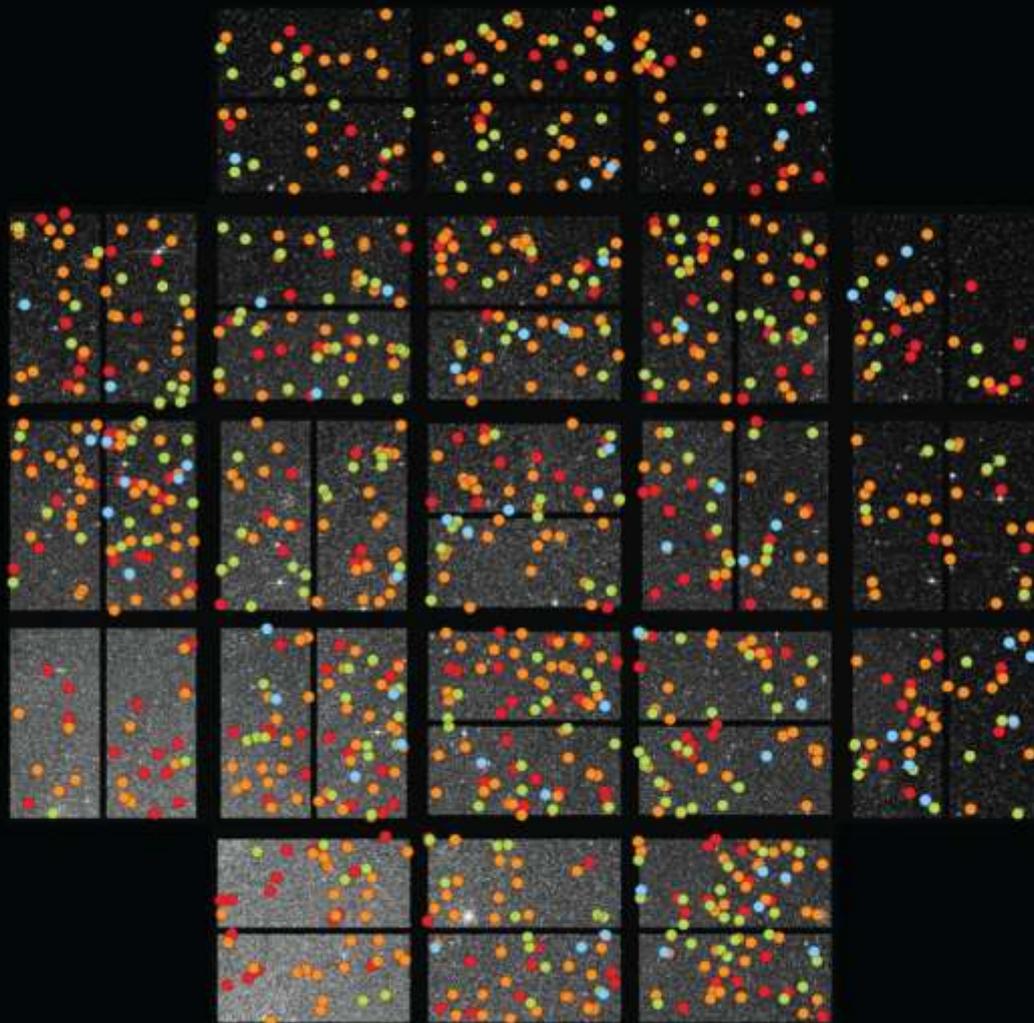


# Planet Size



# Locations of Kepler Planet Candidates

- Earth-size
- Super-Earth size  
1.25 - 2.0 Earth-size
- Neptune-size  
2.0 - 6.0 Earth-size
- Giant-planet size  
6.0 - 22 Earth-size



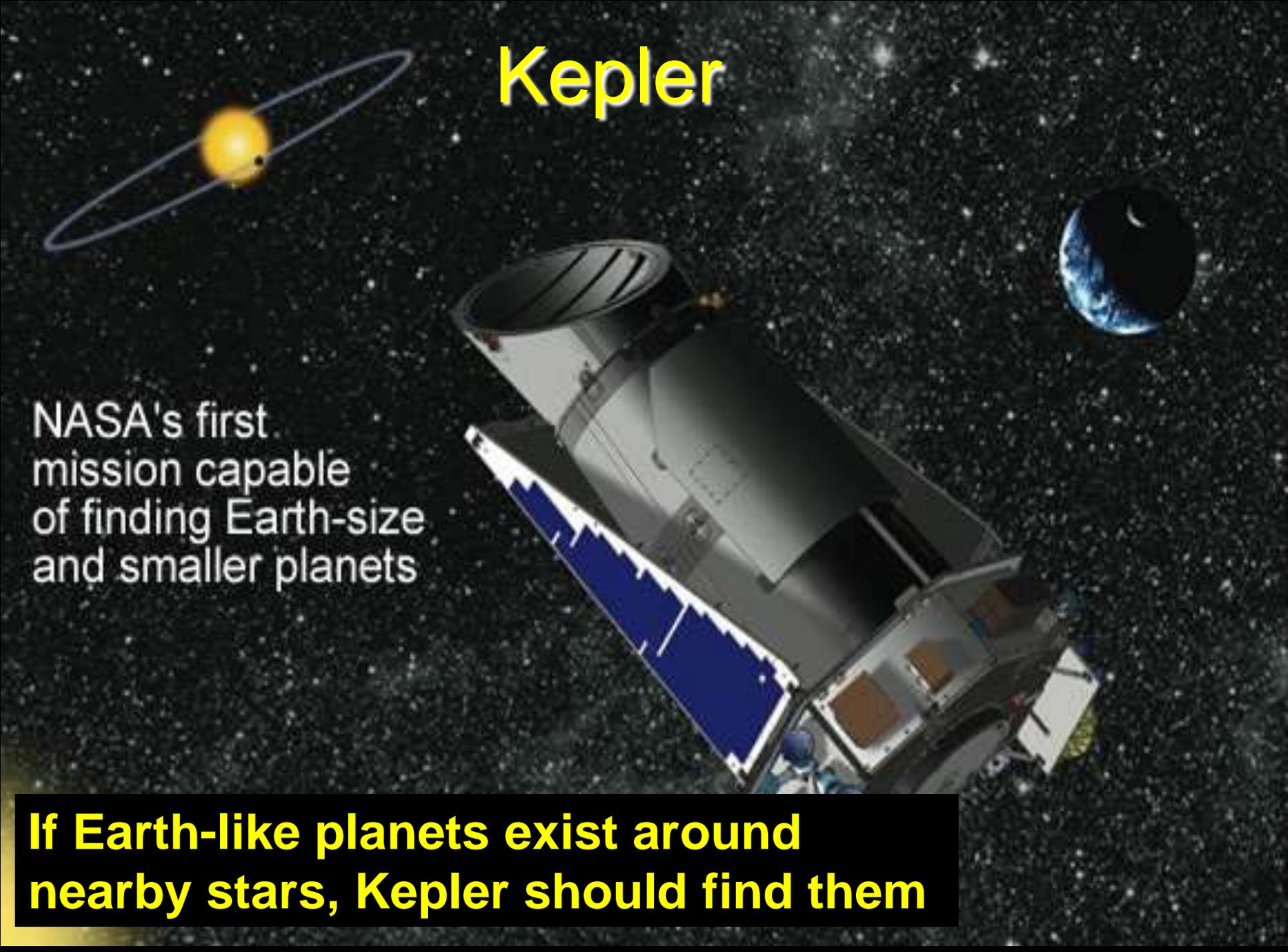




# Kepler

NASA's first mission capable of finding Earth-size and smaller planets

**If Earth-like planets exist around nearby stars, Kepler should find them**



## Kepler-22 System

## Solar System

Habitable Zone



Kepler-22b

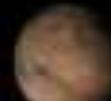
Mercury



Venus



Earth

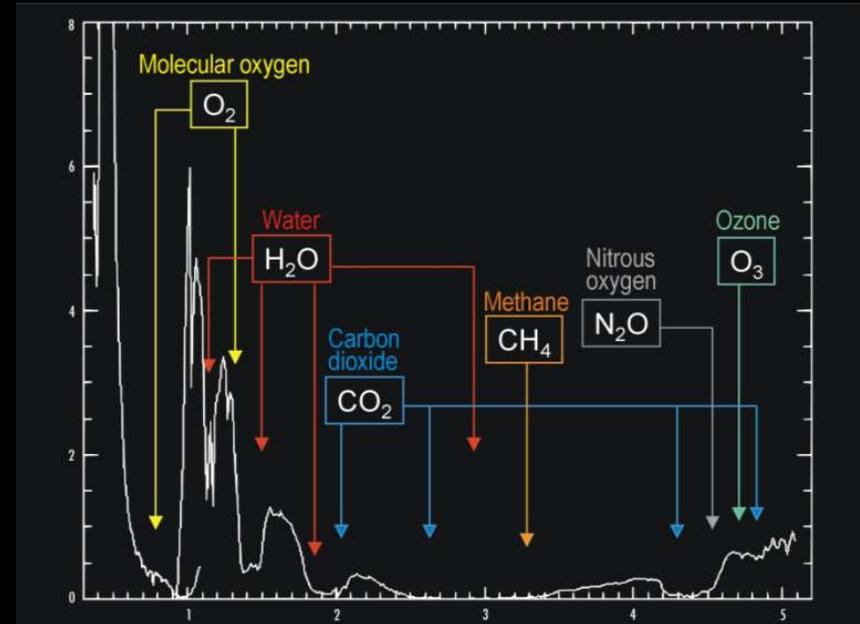


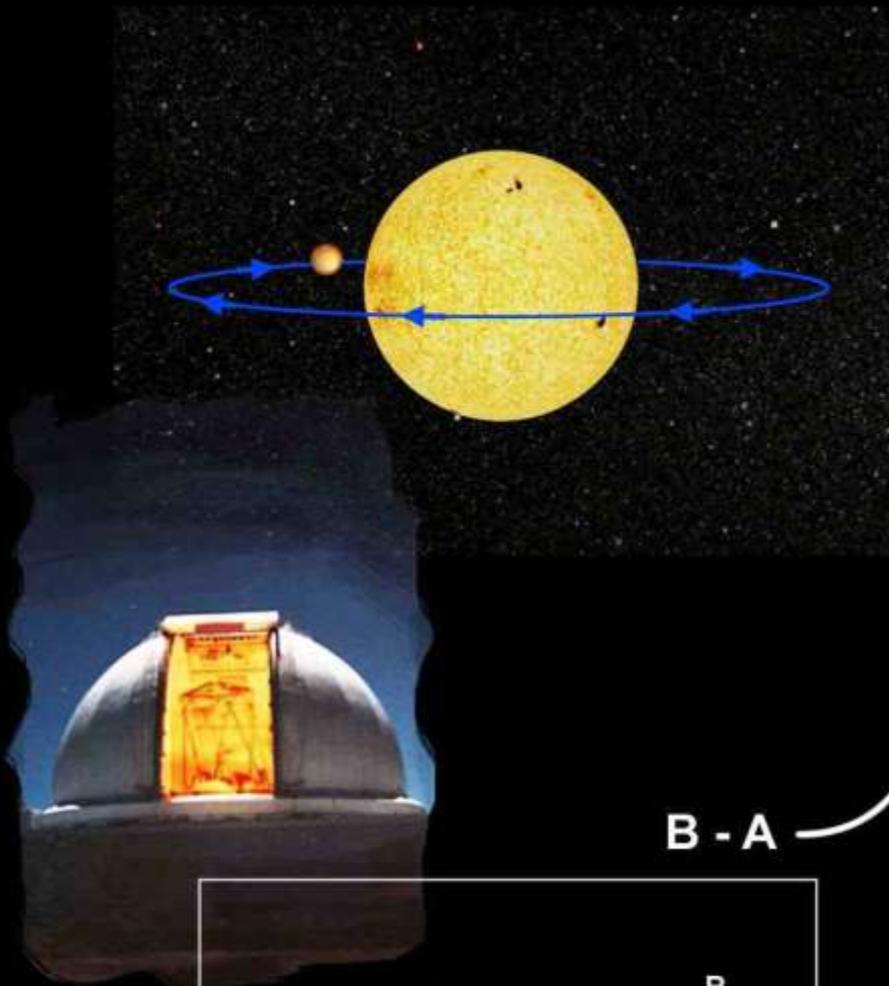
Mars



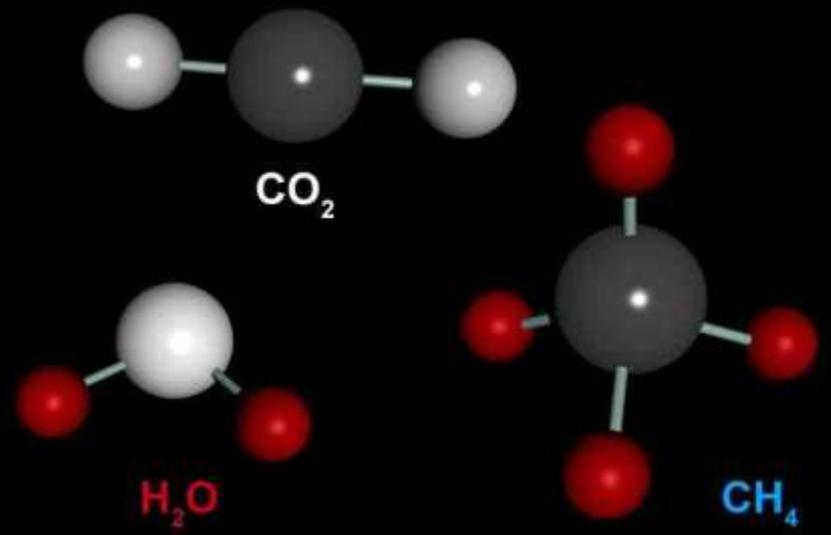
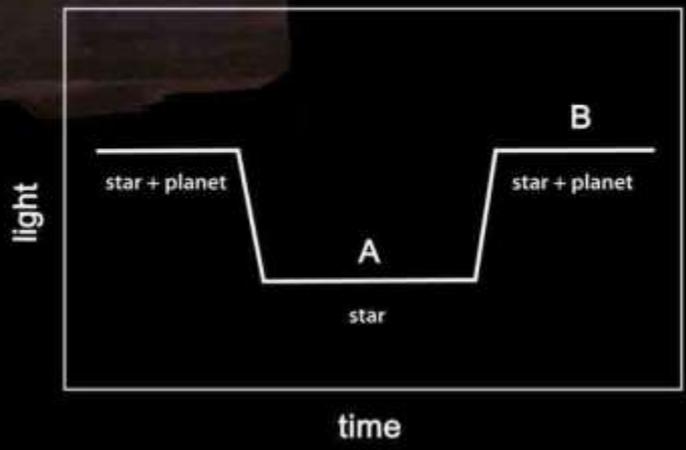
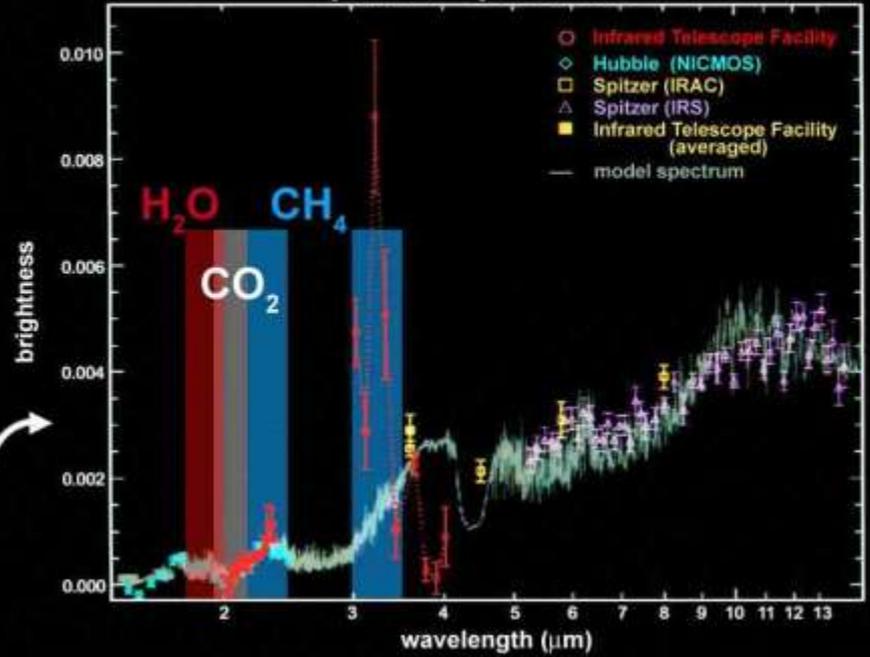
# Could there be ET life like us on those planets?

Finding water, carbon dioxide, and especially **oxygen** would be a very big clue, but we really don't know!





planet spectrum



# Could there be ET life like us on those planets?

Finding water, carbon dioxide, and especially **oxygen** would be a very big clue, but we really don't know!

If life *does* exist, what would it look like?

How would this depend on the type of planet and star?...

