HORIZON 2061 Planetary Exploration 2061

EXPLORATION OF GIANT PLANET SYSTEMS

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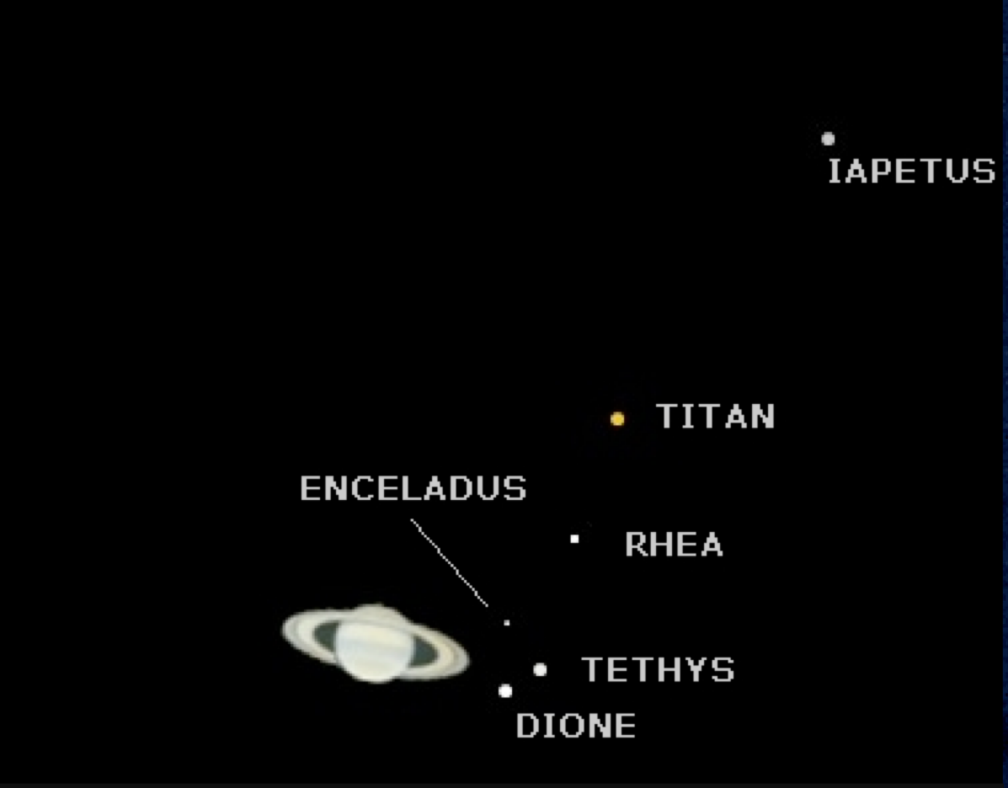
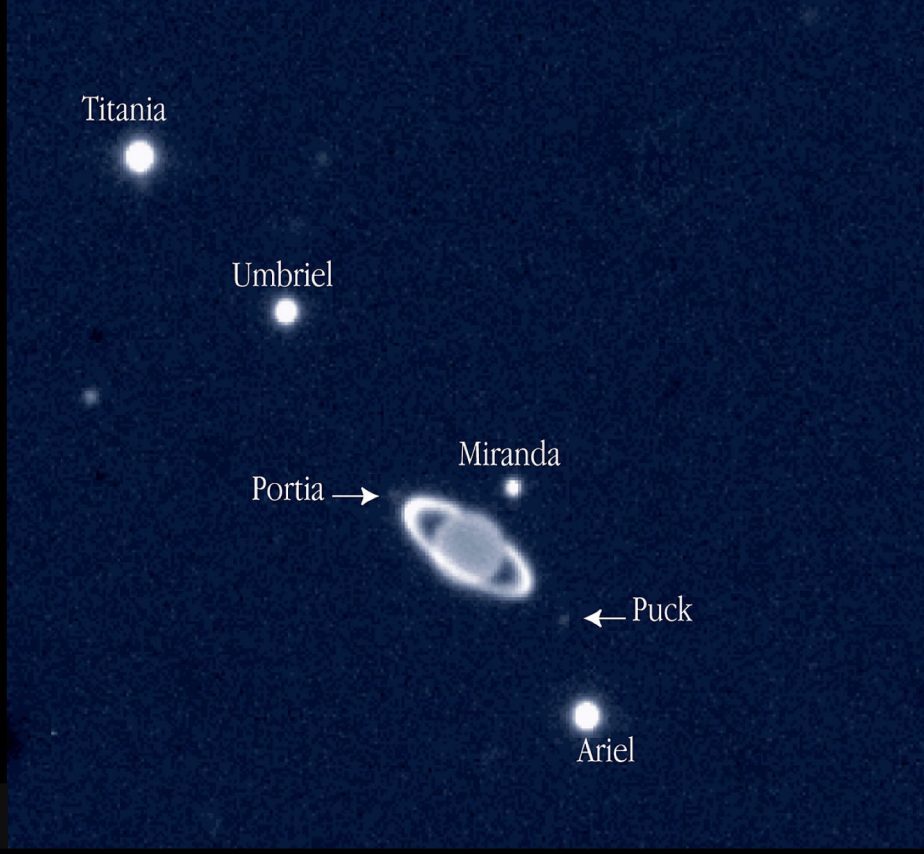

IAPETUS
TITAN
ENCELADUS
RHEA
TETHYS
DIONE


Titania
Umbriel
Miranda
Portia
Puck
Ariel


Europa
Callisto
Io
Jupiter
Ganymede

Giant planet exploration

- NASA
  - 1 Flagship/ 2 New Frontiers/ 5 Discovery per decade
  - for outer Solar System: 3 Flagships, 3 New Frontiers in 50 years (until 2030)

- ESA
  - 1 L-class, 2 M-class, 1 S-class per decade
  - For outer Solar System: 1 L-class, 1 M-class in 40 years

- JAXA, CNSA, Roscosmos, …
  - plans

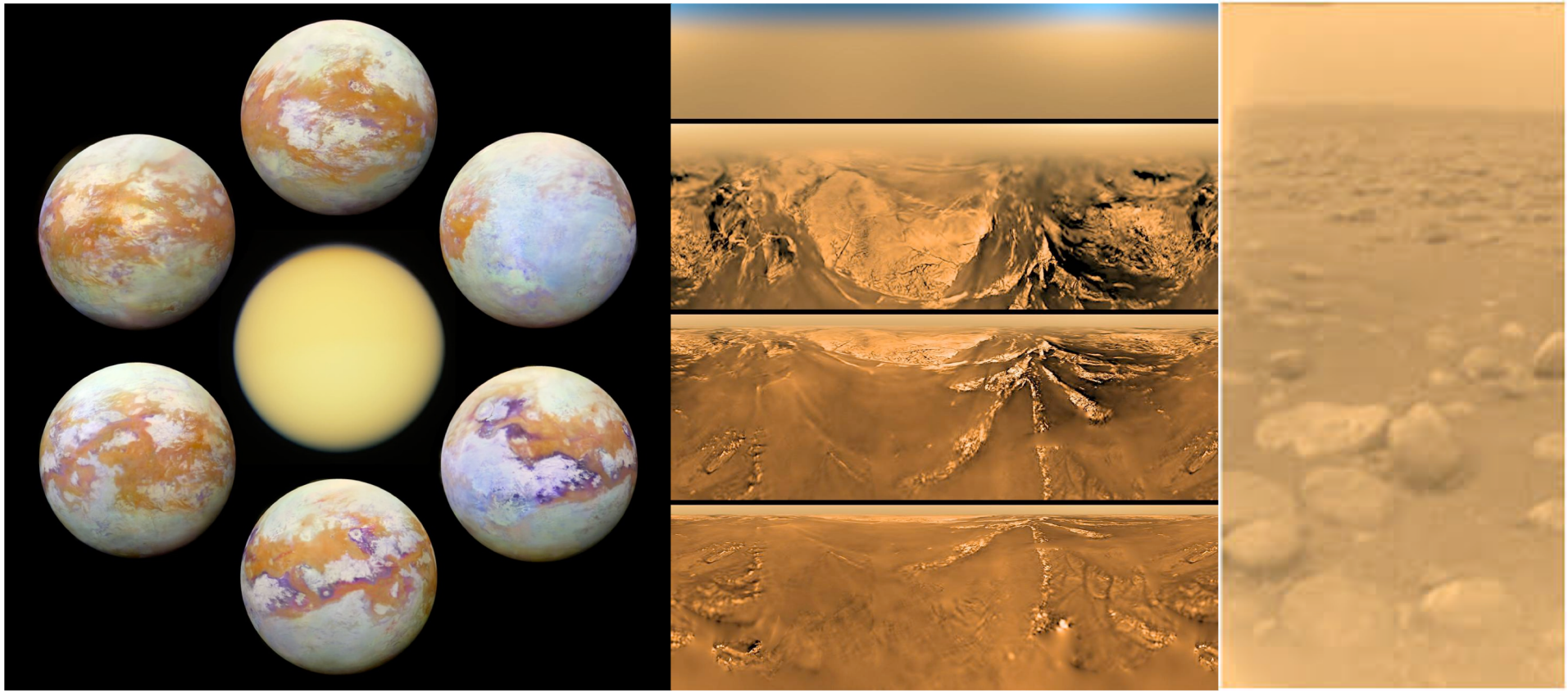
-> 2061: **2**-3 L-class, **4**-5 M-clas can be expected at the current rate …

Why in space ?

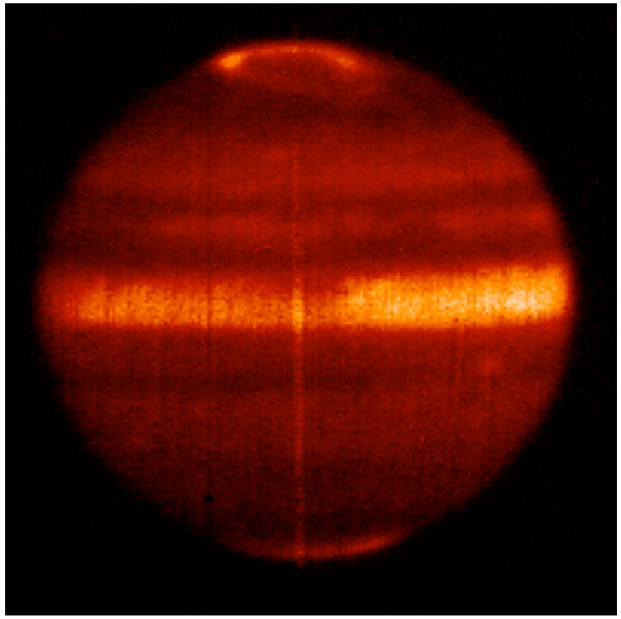
1. Global

2. Regional

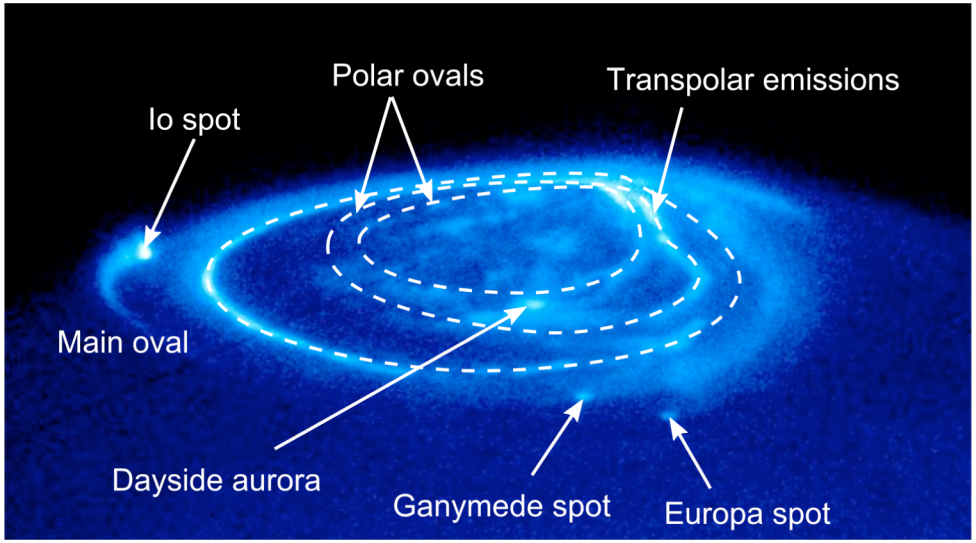
3. Local



Cassini-Huygens at Titan

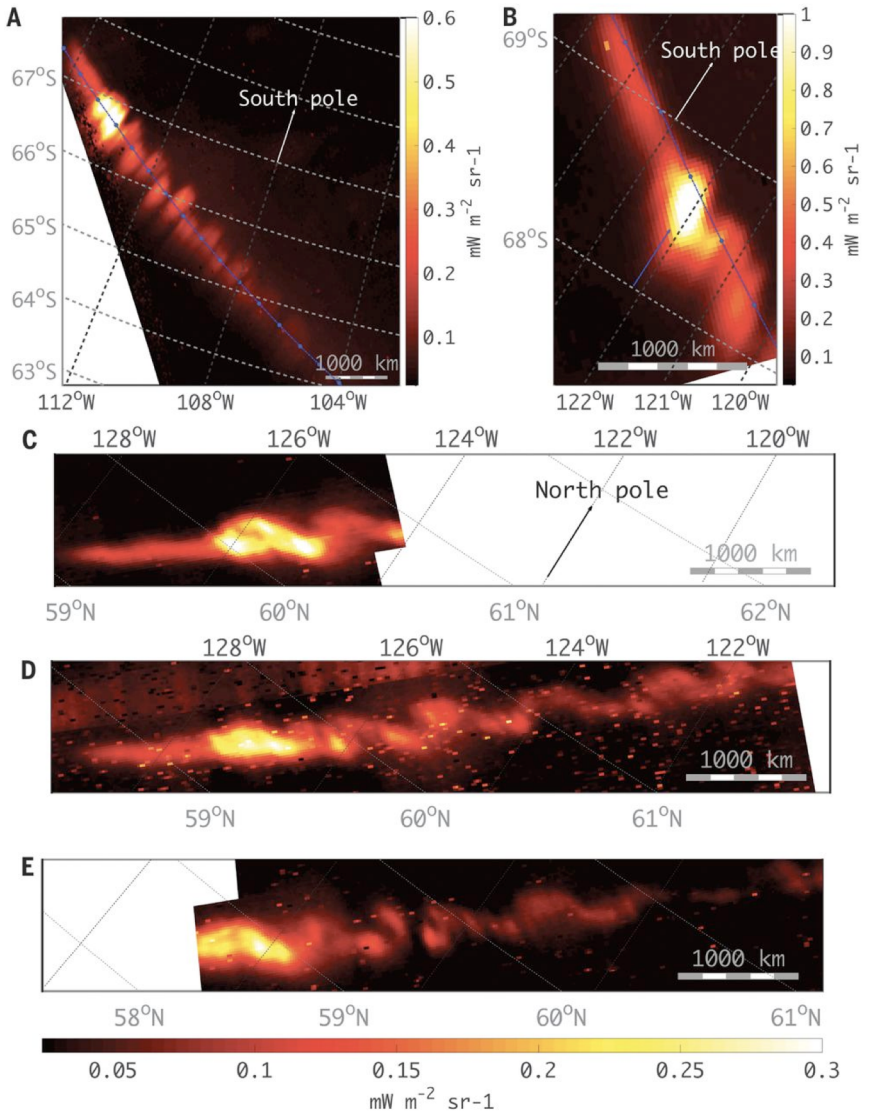


Juno at Jupiter



Why in space ?

Mura et al., 2018



Giant Planet Systems

- Complex
  - Magnetospheres
  - Atmospheres
  - Moons
  - Rings
  - Interiors

Mini Solar System on their own !

- Multiphase (gas, dust, plasma, liquid)

- Strong linkages between the components of the System
- Strong diversity between each Giant Planet
- Need for comparative science

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MISSIONS TO CHARACTERIZE ORIGIN, HABITABILITY AND SEARCH FOR EXTANT LIFE IN GIANT PLANET SYSTEMS

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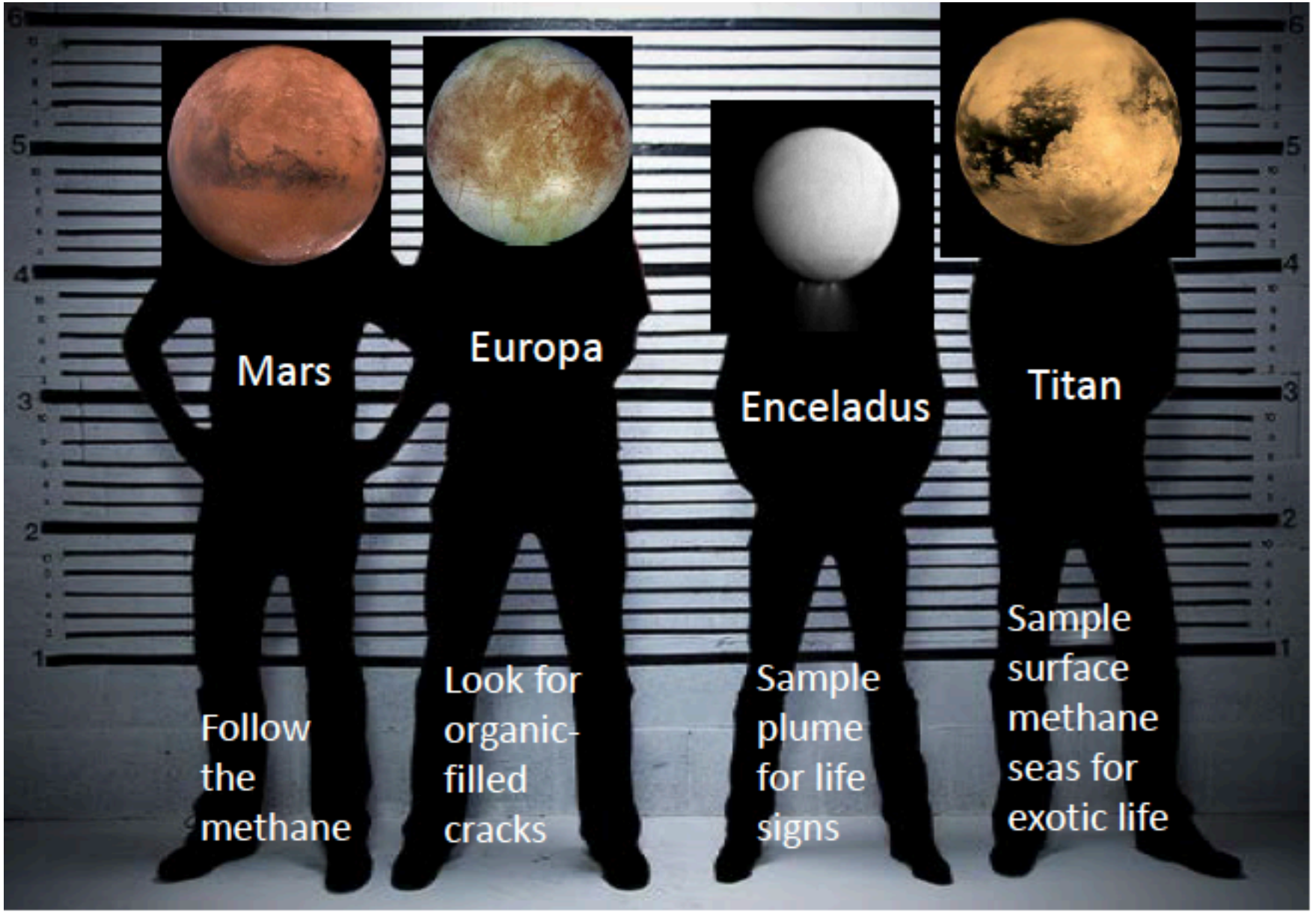
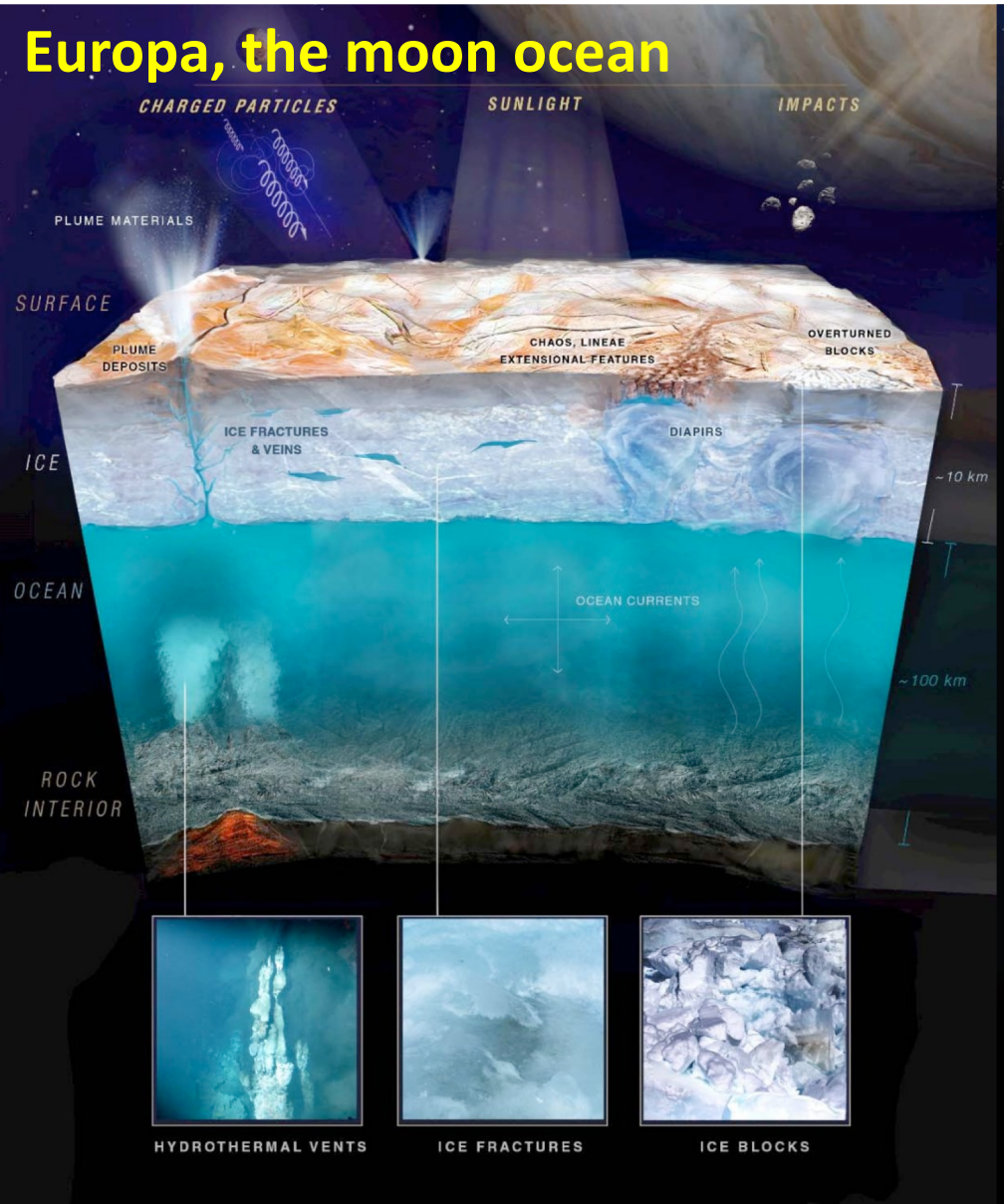
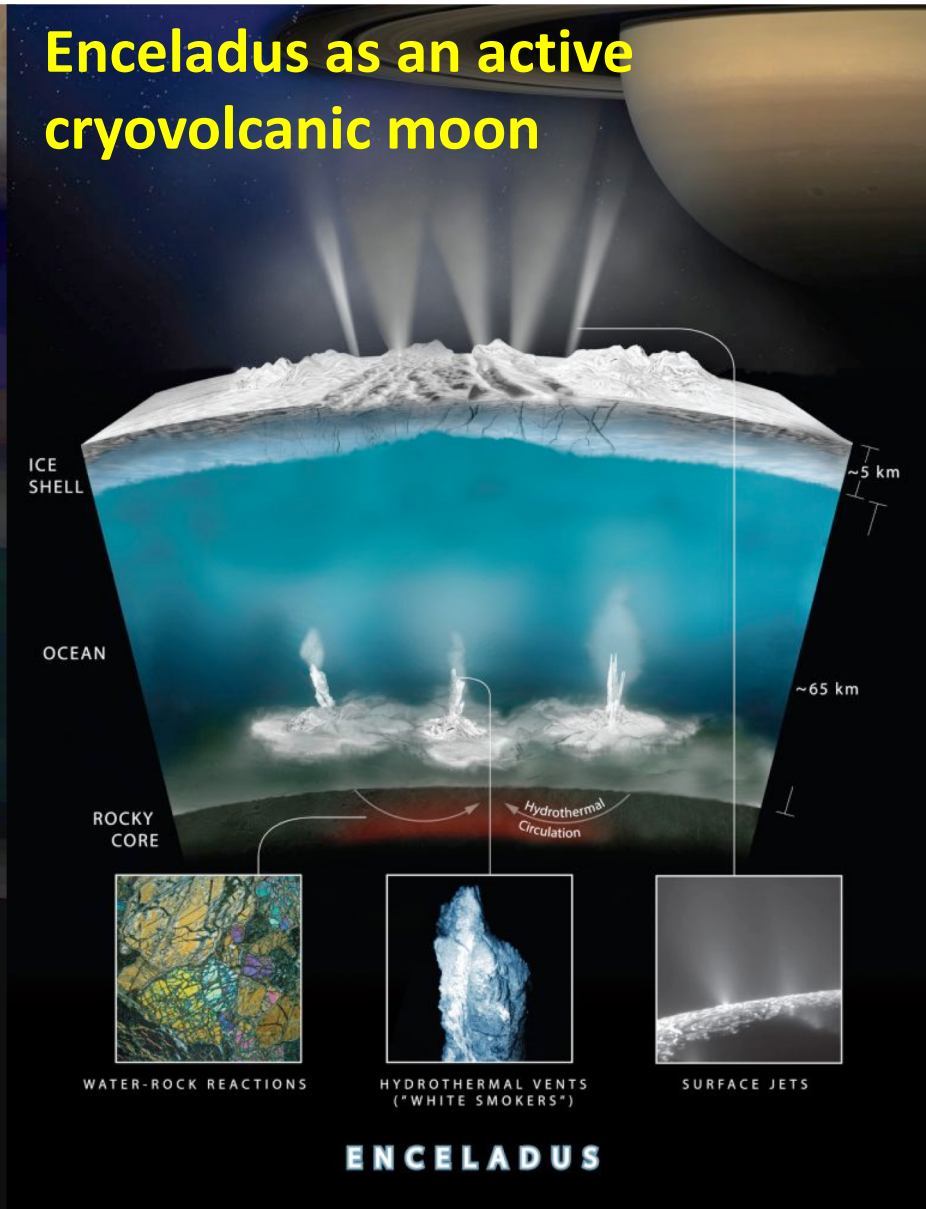
Liquid water, chemistry, and energy


Mars
Europa
Enceladus
Titan
Follow the methane
Look for organic-filled cracks
Sample plume for life signs
Sample surface methane seas for exotic life

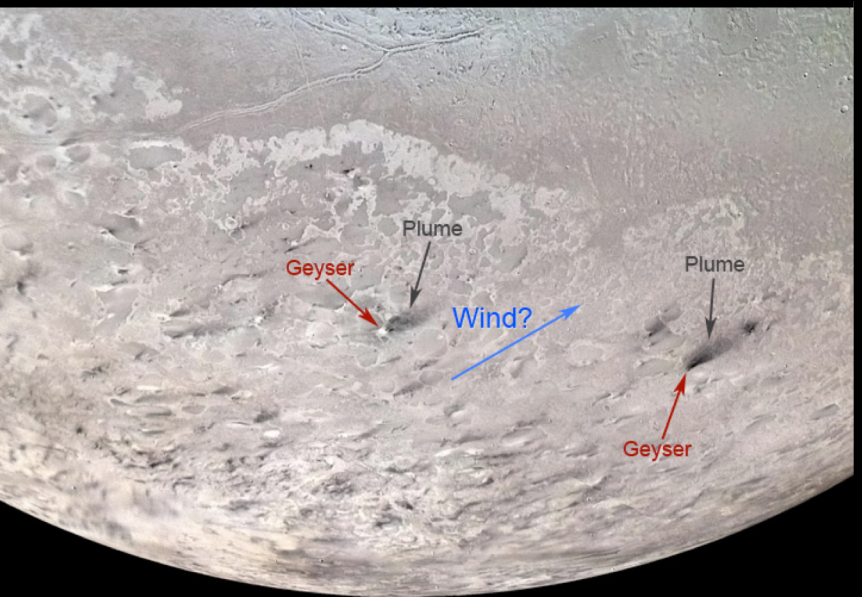
Europa & Enceladus

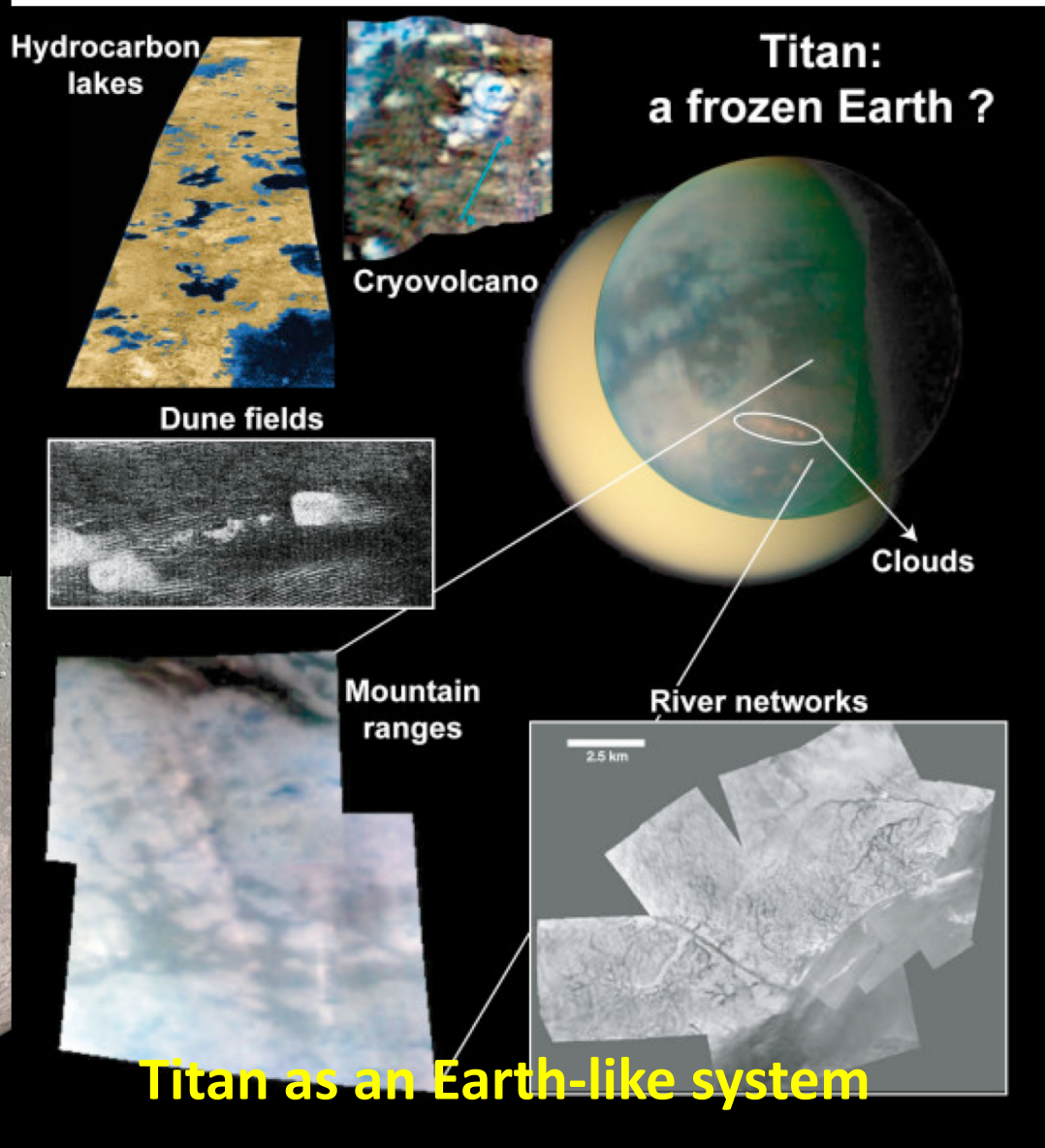




Triton & Titan

Triton as an icy Kuiper belt object

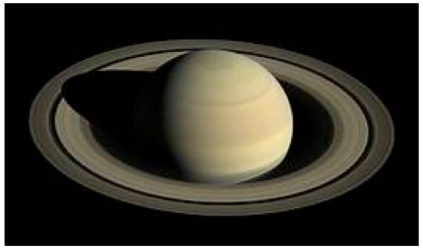




Titan as an Earth-like system

Atmosphere	Magnetosphere	Io	Europa	Ganymede	Callisto	Trojans
PREVIOUS STEPS						
Galileo **JUICE** (remote) **Galileo** **Probe** (in-situ)	**Galileo** **Juno** **JUICE** (3D)	**Galileo** (flybys)	Galileo JUICE **Europa** **Clipper** (flybys)	**JUICE** (orbiter)	Galileo **JUICE** (flybys)	
NEXT STEPS						
In-situ (O. Mousis)	Multipoint Measurements (long- duration)	Flybys *Orbiter*	Orbiter Lander (in-situ)	*Lander*	Orbiter *Lander*	Flybys Lander Sample Return

Atmosphere	Magnetosphere	Titan	Enceladus
PREVIOUS STEPS			
Cassini (remote) (in-situ)	**Cassini** (3D)	**Cassini** (flybys) **Huygens** (lander) **Dragonfly** (mobile)	**Cassini** (flybys)
NEXT STEPS			
In-situ (O. Mousis)	Multipoint Measurements (long-duration)	Flybys/ Orbiter &/or Balloons &/or Landers	Flybys/ Orbiter &/or Lander (in-situ) &/or Sample Return



Uranus/Neptune Atmosphere	Uranus/Neptune Magnetosphere	Triton (Neptune)	Moons Uranus	KBOs
PREVIOUS STEPS				
Voyager2 (flyby)	Voyager2 (flyby)	Voyager2 (flyby)	Voyager2 (distant flybys)	New Horizons (flybys)
NEXT STEPS				
In-situ (O. Mousis)	Orbiter (3D)	Close Flybys *Orbiter*	Close Flybys	Flybys

Technologies/Infrastructure

- INSTRUMENTATION
  - Sample capsule instrument / Data curation / Sample analysis
  - Spectrometers optimized for gas, dust, and plasma (composition)
  - Smart bio-signature characterization package (surface)
- POWER SOURCES
  - Radioactive
  - Solar Sails
- TELECOMMUNICATIONS
  - Future DSN
  - On board data selection
- AOCS, GNC
  - Autonomous guidance, navigation and control (e.g., Enceladus)
  - Descent, Landing systems (Europa)
  - Aerial platforms (Titan)
- LAUNCH SYSTEMS
  - Heavy launchers

Challenges

- Planetary protection (Europa, Enceladus, Titan, Triton)
- Radiation (Jupiter)
- Hardware longevity (All)
- Operations (long cruise phase, All)

Conclusions (Giant Planet Systems)

- Exploration: classical (space agencies only ?)
- Future missions: science focused
- Main focus: Habitability and search for extant life
  - A large diversity of candidates, make your choice
- Giant planet system deserve to be explored with multi-scale, multi platform missions
  - Complex coupled systems, need for both global, regional, and local views (at the same time)