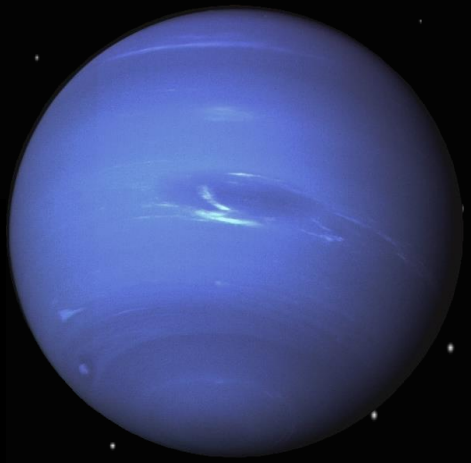
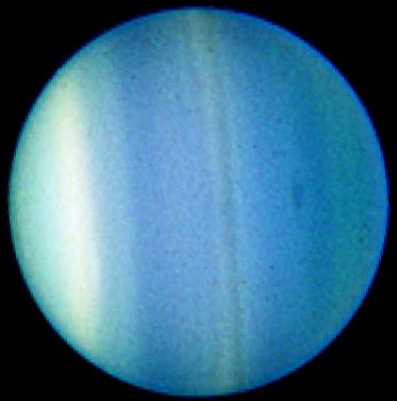
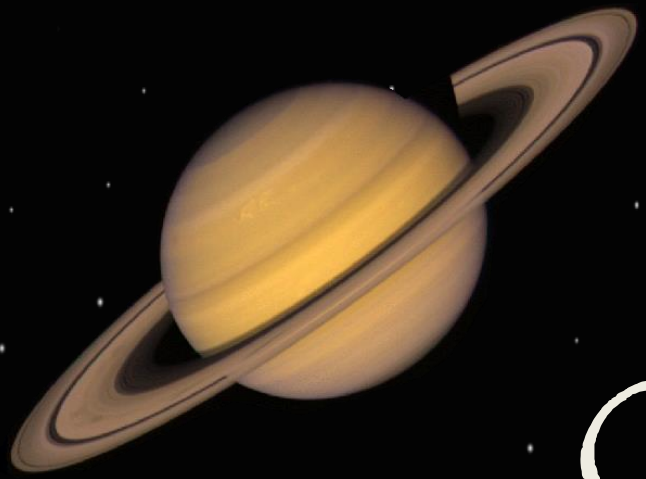
# Science Frontiers







# Of the Outer Solar System

C. J. Hansen

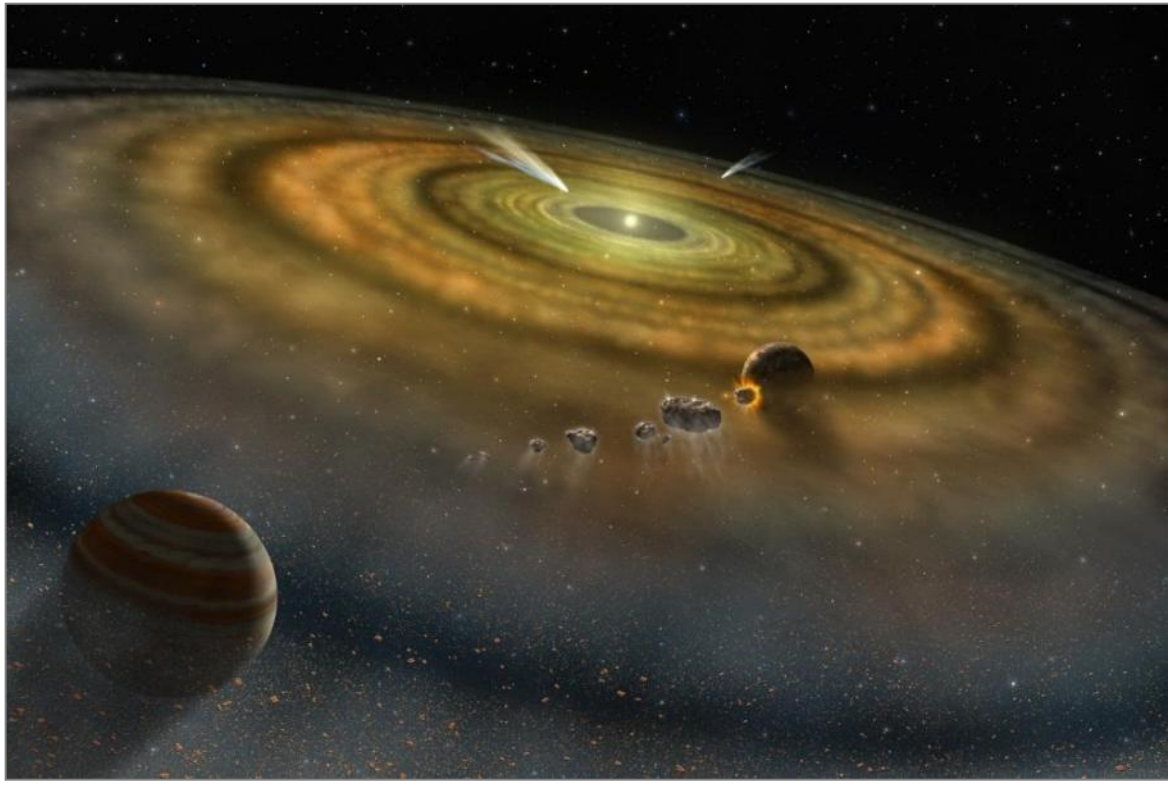
2 May 2017

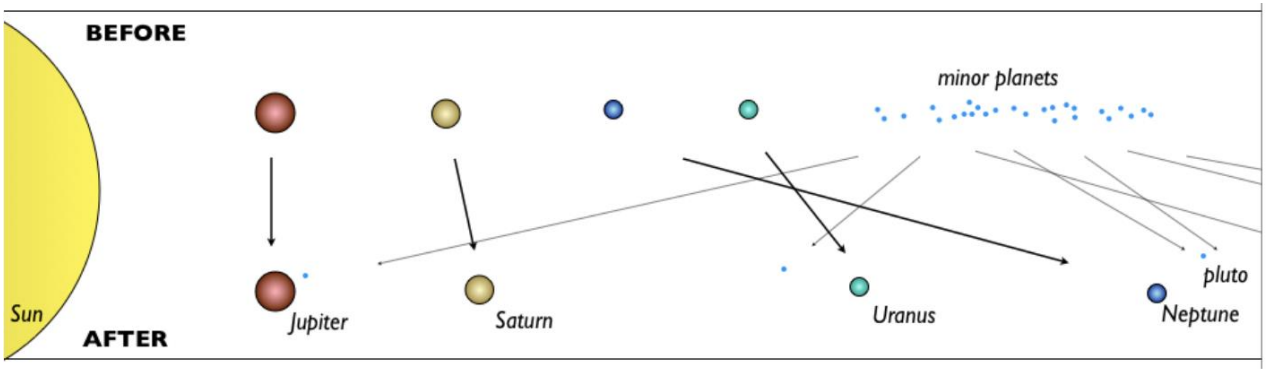
# Two Categories of Science Themes for two types of Targets: Gas Giant Planets and their Icy Moons

- **Study Jupiter, Saturn, Uranus, Neptune**
  - **– Formation and evolution of the solar system**
    - **Connection to exoplanets**
- **Explore Icy Moons' Oceans**
  - **– Ocean composition, physical properties**
  - **– Search for life**

# Solar System Formation

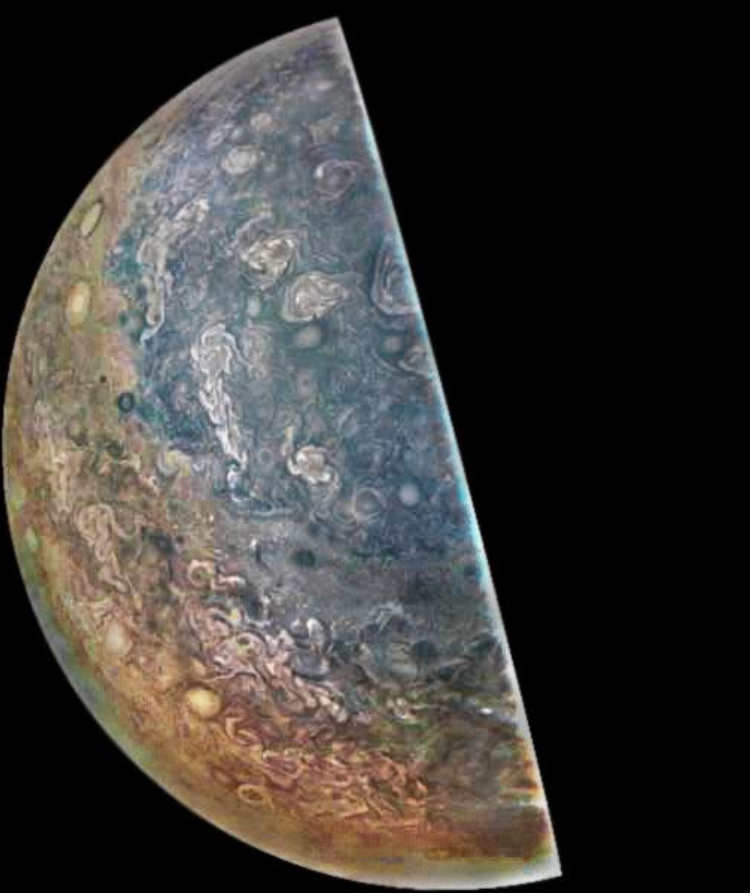
- Over what period in the early solar system did gas giants form?
- Did they start where they are now?
- Or drift in or out, scattering planetesimals along the way? (leading to the Late Heavy Bombardment and forming the Kuiper Belt)






Water content of the gas giants is a clue

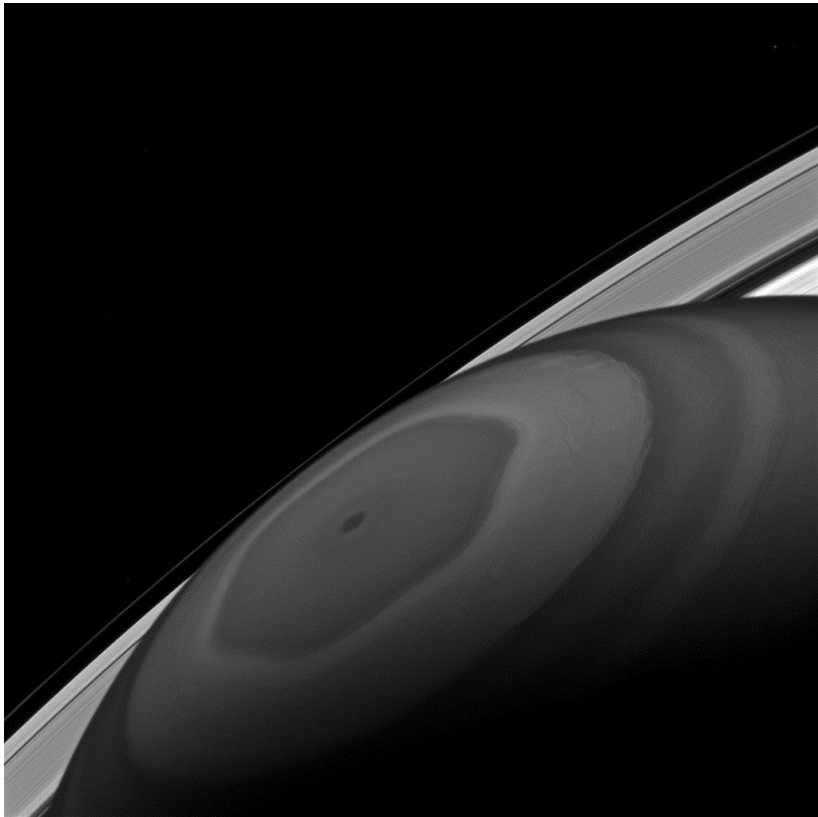
# Solar System Evolution



South pole of Jupiter

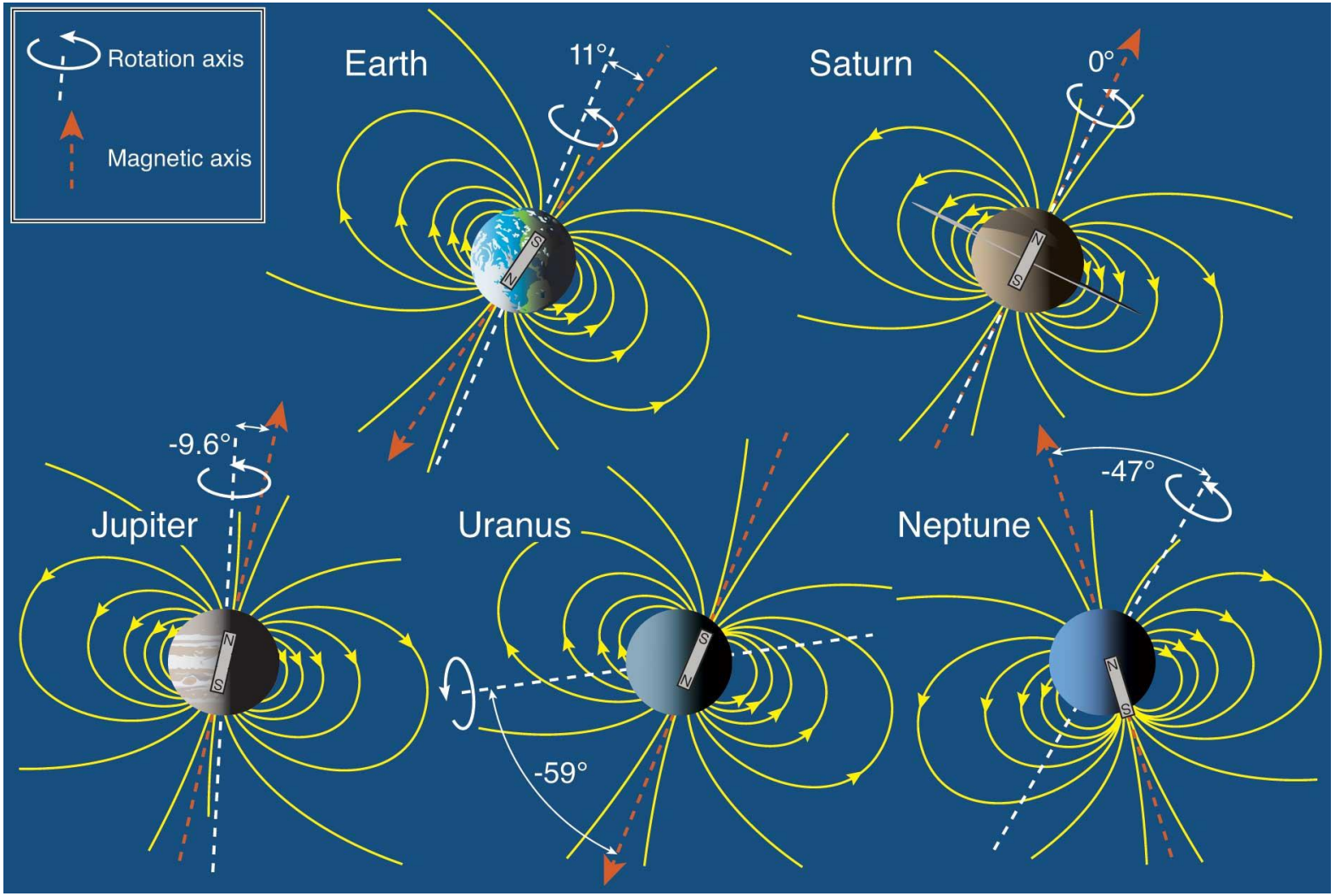
How similar is the *composition* of the giant planets to the sun (and what processes led to differences)?

North pole of Saturn



*Atmospheric circulation* – Jupiter, Saturn, Uranus and Neptune have entirely different atmospheres than the terrestrial planets, and each other!

# Solar System Evolution

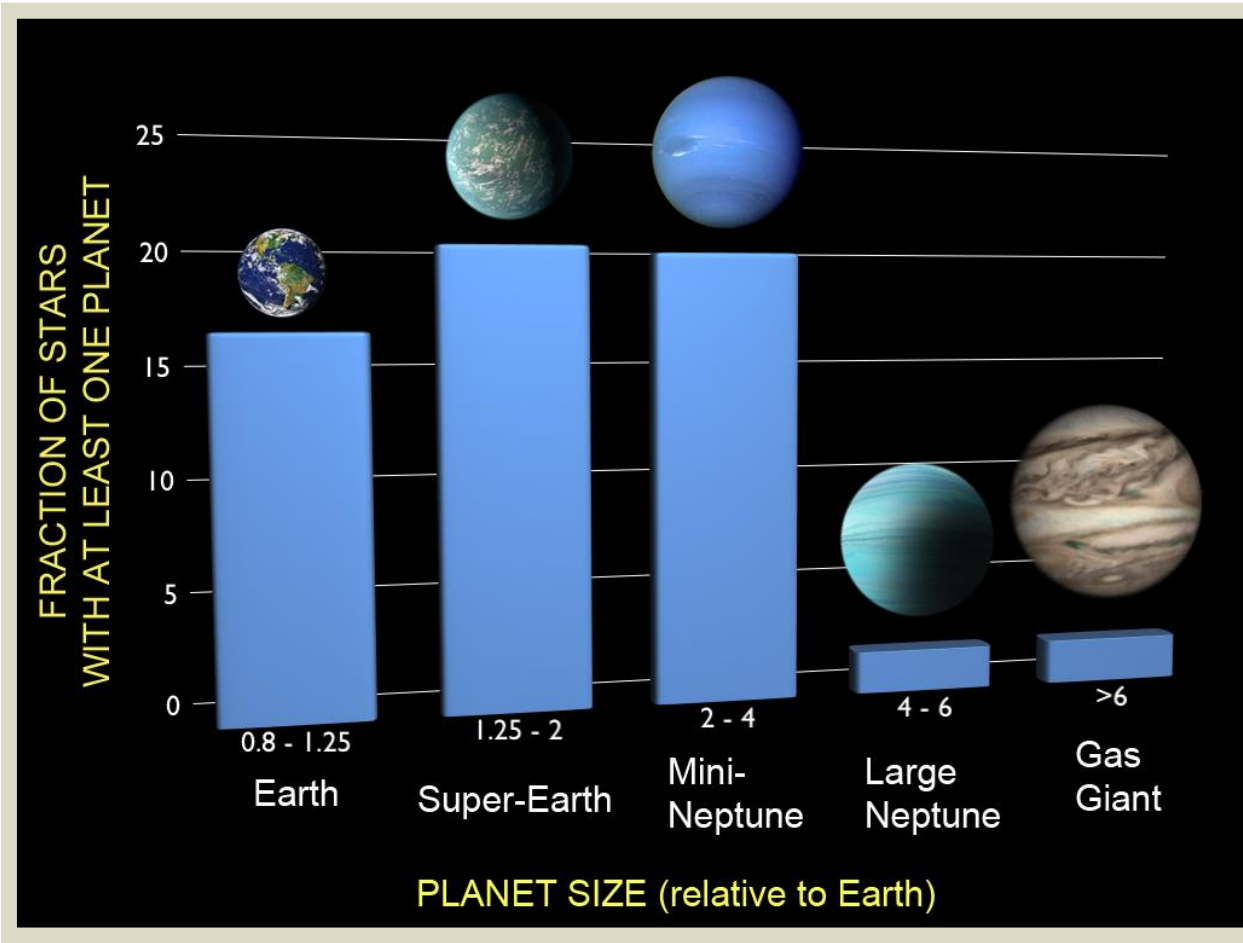



*Magnetospheres* – the variety of the outer solar system challenges our understanding of how magnetospheres form and are structured

# Formation and Evolution of our Solar System – the Exoplanet Connection

With the discovery of planetary systems around other stars to compare to, we ask

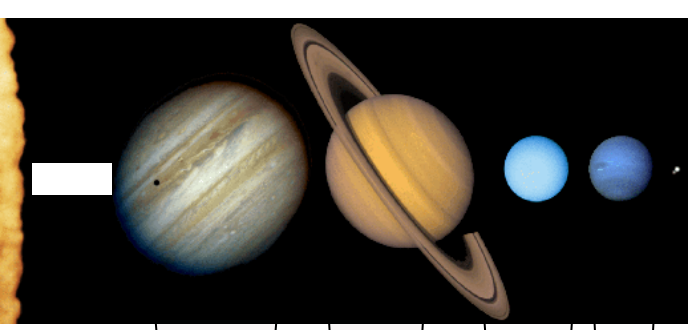
- How do planetary systems form and evolve in general?
- How common are solar systems like our own, and why is our solar system (apparently) unusual?

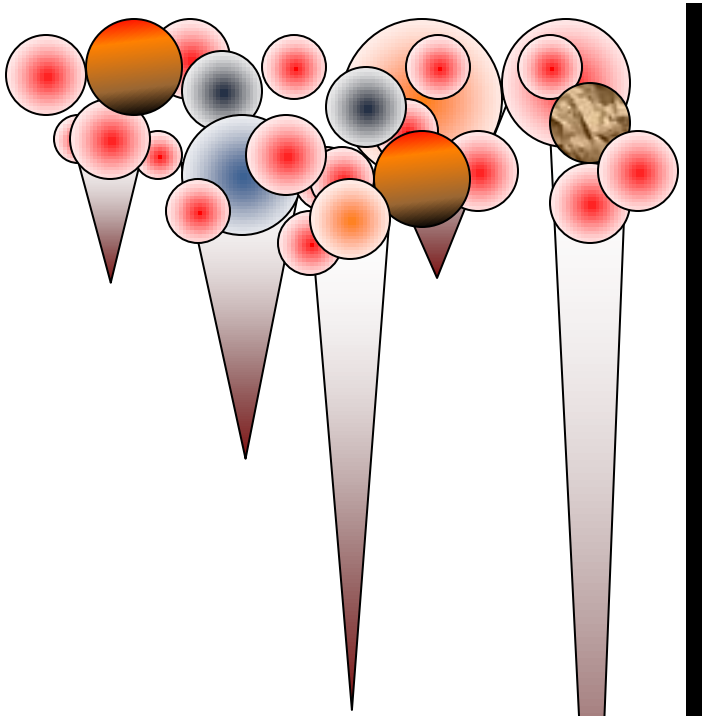


# Planetary Systems' Investigation

Outer Solar System
(Narrow + Deep)

Exoplanets
(Broad + Shallow)





Detail

**Orbits and architectures**

**Rudimentary physical parameters**

**Interior and atmosphere**

**Atmospheric characterization**

**Detailed properties**

**Environment**

# Planetary Systems' Investigation

Outer Solar System
(Narrow + Deep)

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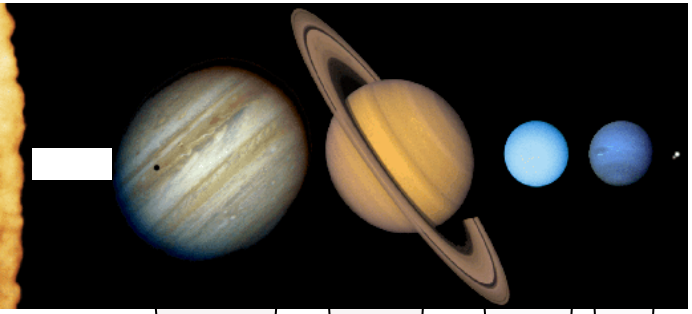


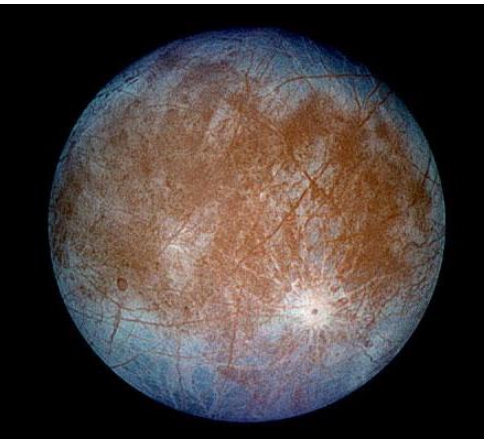
Juno and Cassini are studying Jupiter and Saturn, resp.

Need new missions(s) to study Uranus and Neptune

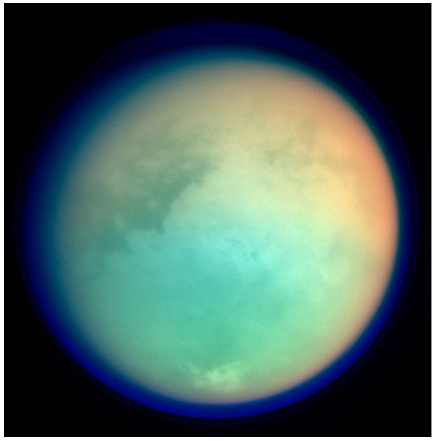
Detail

- **Orbits and architectures**
- **Rudimentary physical parameters**
- **Interior and atmosphere**
- **Atmospheric characterization**
- **Detailed properties**
- **Environment**

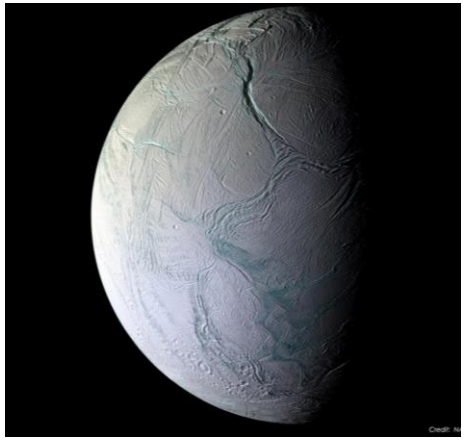
# Oceanography on Other Worlds
# The Icy Moons of the Outer Solar System



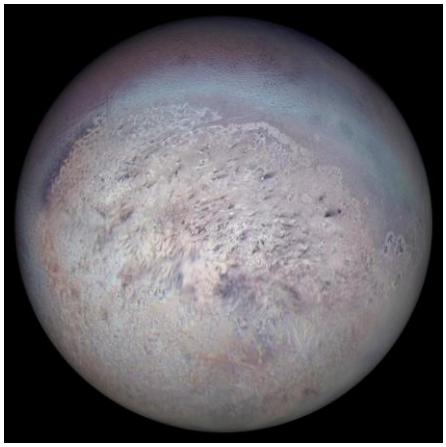
Europa (Jupiter)



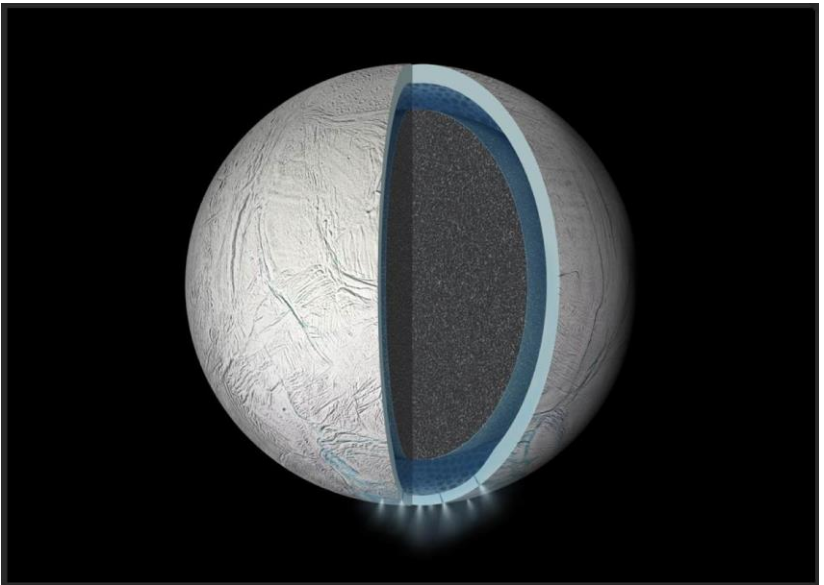
Titan (Saturn)



Enceladus (Saturn)



Triton (Neptune)

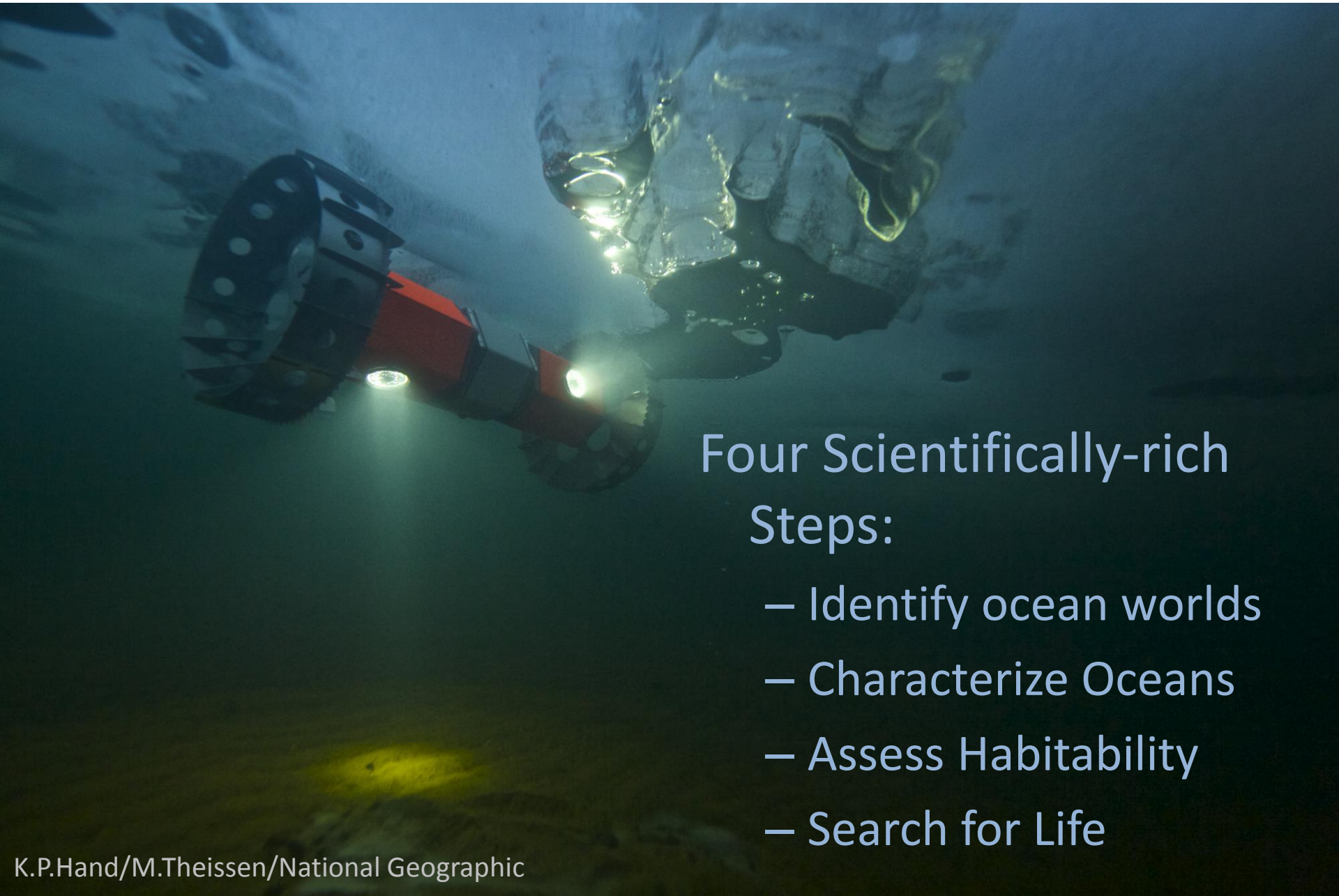


- **At least 5 icy moons in the outer solar system have liquid water mantles beneath an icy crust**

**Our goal is to**

- **Explore these ocean worlds, evaluate their habitability, search for life and ultimately understand any life we find**

# Explore Ocean Worlds

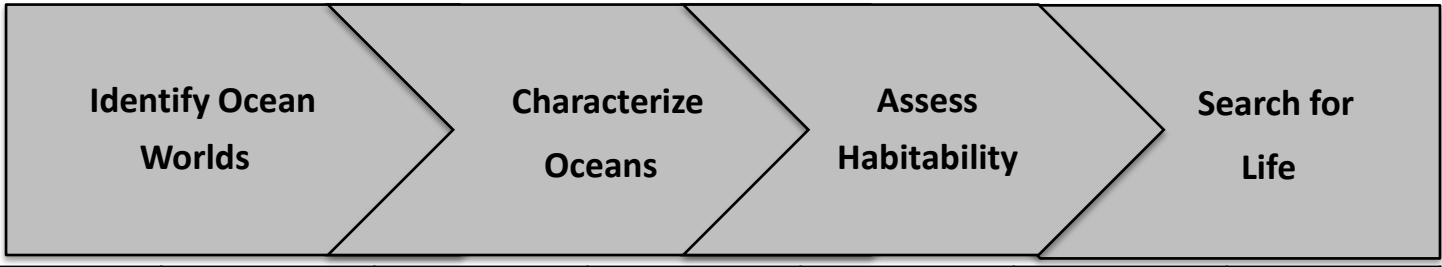


Four Scientifically-rich Steps:

- Identify ocean worlds
- Characterize Oceans
- Assess Habitability
- Search for Life

K.P.Hand/M.Theissen/National Geographic

# Progress Report



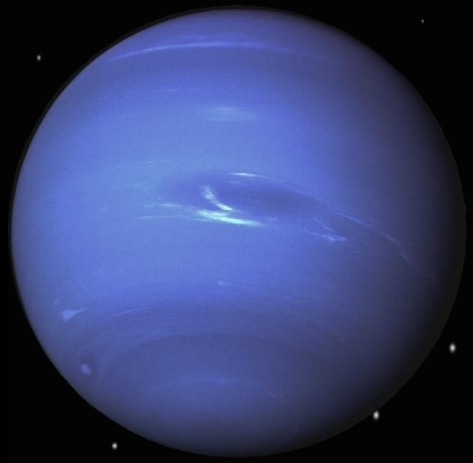

| | | Energy Sources | Ocean Signatures | Solvents | Rock/Ocean Interface | Energy for Life | Physico-chemical Conditions for Life | Biomarkers |
|---|---|---|---|---|---|---|---|---|
| Ocean Worlds | Enceladus | | | | | | Ready to look! | |
| | Europa | | | | | Need to identify site to land (or fly through plume if exists / is predictable) – need reconnaissance | | |
| | Titan | | | | New different instrument technology req'ts | | | |
| | Ganymede | | | Access is challenge | | | | |
| | Callisto | | | Access is challenge | | | | |
| Possible Ocean Worlds | Triton | | Validate ocean exists | | | | | |
| | Pluto | | | | | | | |

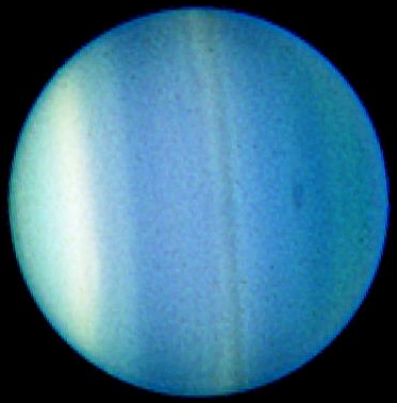
**In our solar system, in addition to earth, is there life**

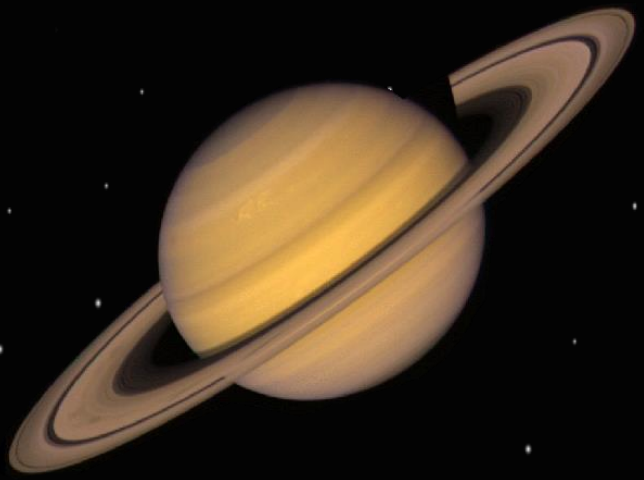
- **Somewhere?**
- **Anywhere that…?**
- **Everywhere?**

**Under what conditions does life thrive?**

# Outer Solar System Exploration







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*Worth the journey*