Theme 2: Outer Solar System

Tracing the origin of the Solar System

- Essential for our understanding of the formation and evolution of our own Solar System
- Exploration of the outer solar system has traditionally been thought by Europe as technically and financially prohibitive
- It is clear that there is now a large and vibrant community who are able to lead the science of the outer solar system and minor bodies

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Theme 2: Outer Solar System

Tracing the origin of the Solar System

- **Interdisciplinary**
  - Physics, chemistry, biology
  - Laboratory, in-situ, remote sensing, numerical modelling
  - Only by combining datasets can fundamental questions be answered

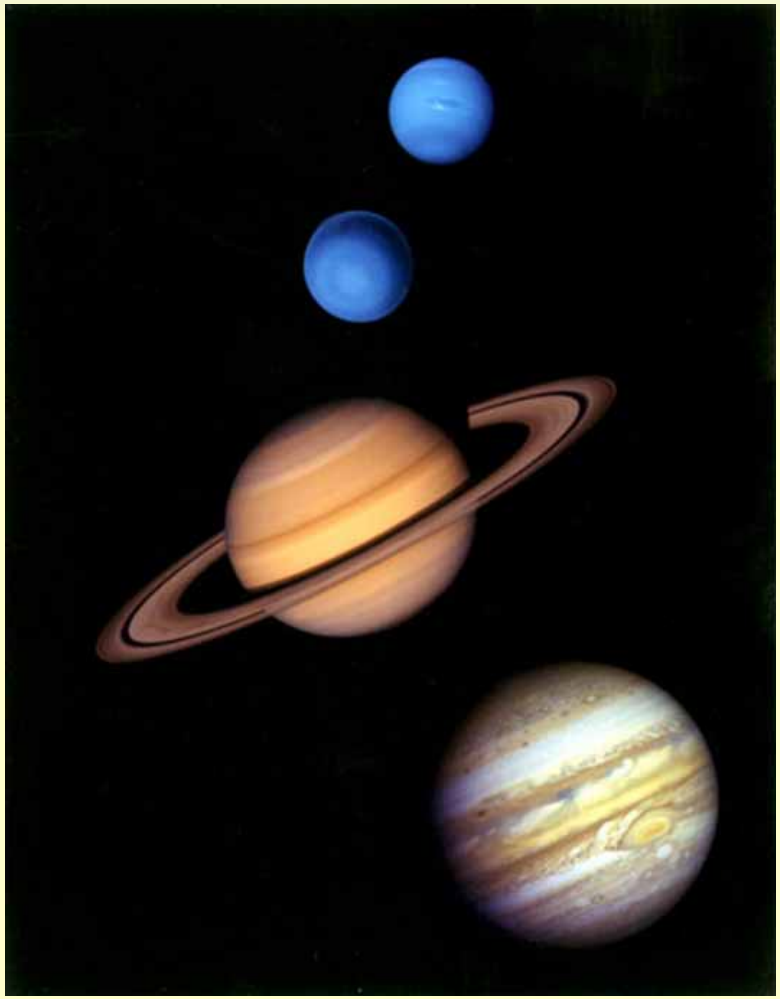
Theme 2: Outer Solar System

Tracing the origin of the Solar System

- Formation and dynamics of giant planets
- Structure and evolution of icy satellites
- Composition and structure of minor bodies

- - - - *Beyond Saturn*

Current status of knowledge



1. Formation and dynamics of giant planets

- Our knowledge from spacecraft is based mainly on data returned from the Grand Tour by the Pioneer and Voyager spacecraft in the 1970's and 1980's
- More recently we have had Galileo and now Cassini/Huygens
- Telescopic work also

(all images courtesy of ESA/NASA)

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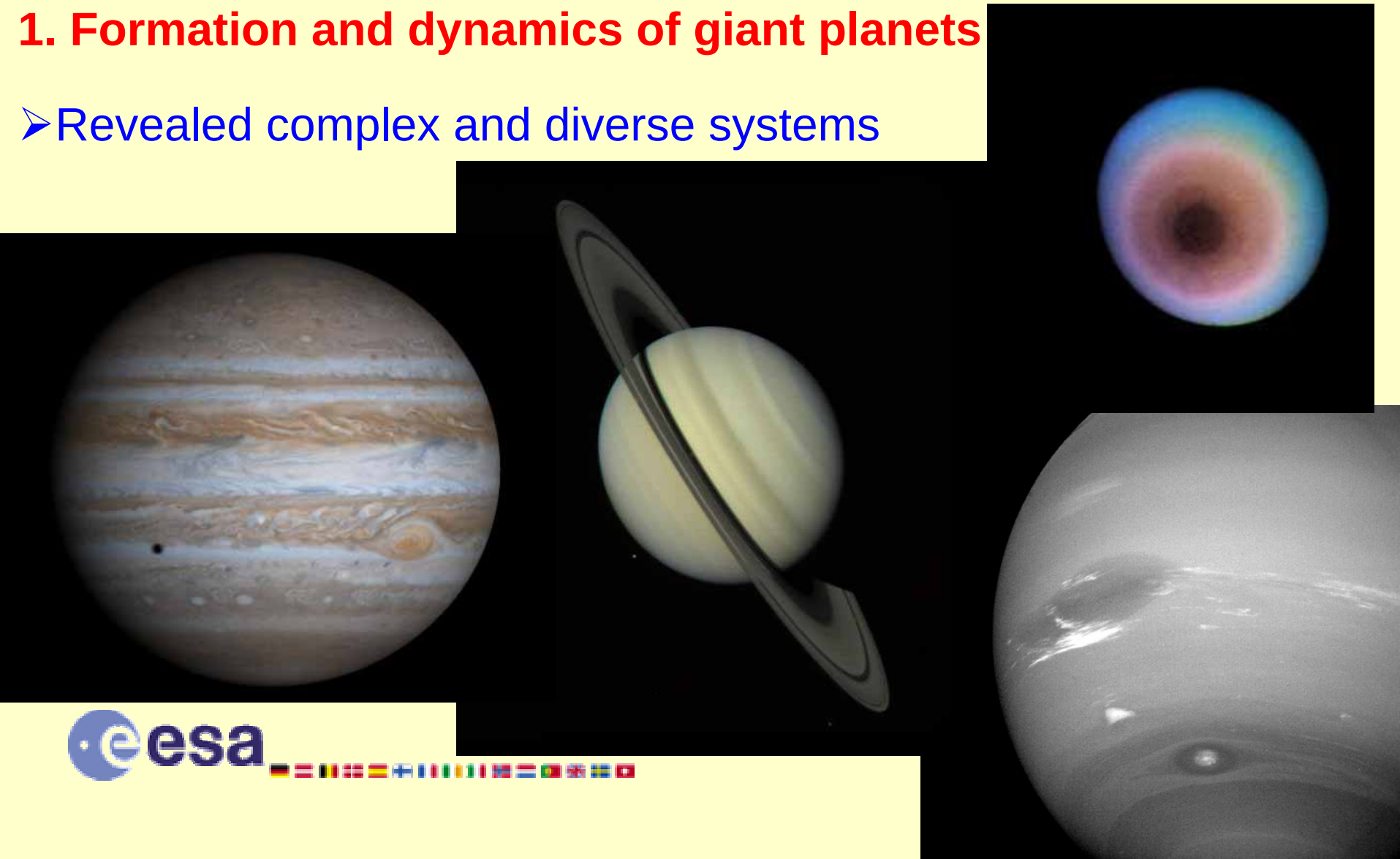
Current status of knowledge

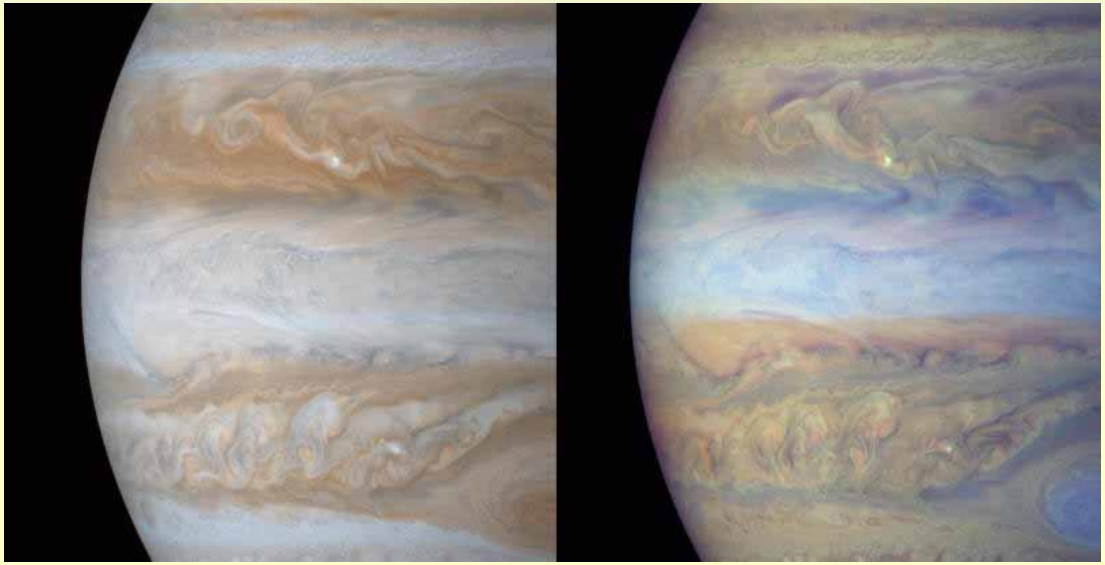
1. Formation and dynamics of giant planets

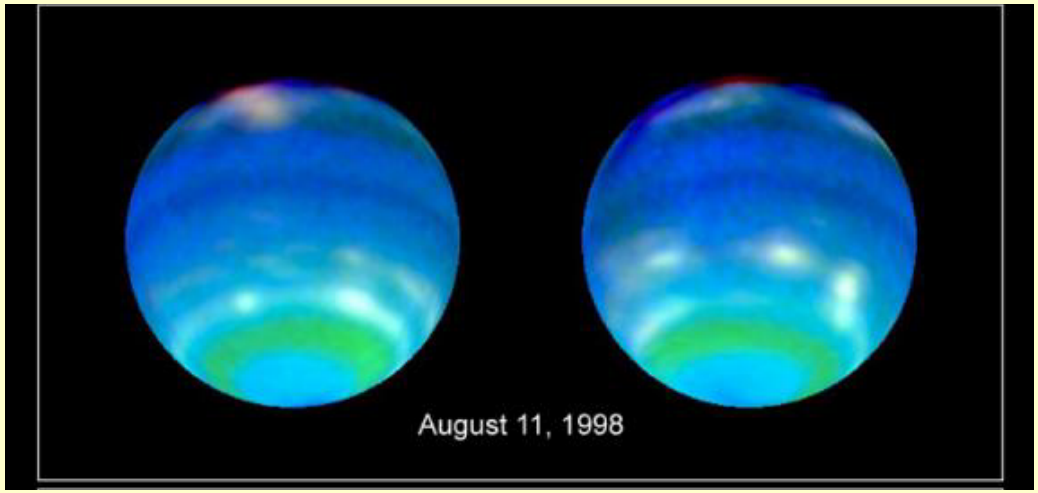
- Revealed complex and diverse systems



Current status of knowledge

- Early missions were all flybys limiting the amount of information returned
- Outer planets are dynamic on varying timescales, and therefore require long term orbiting missions





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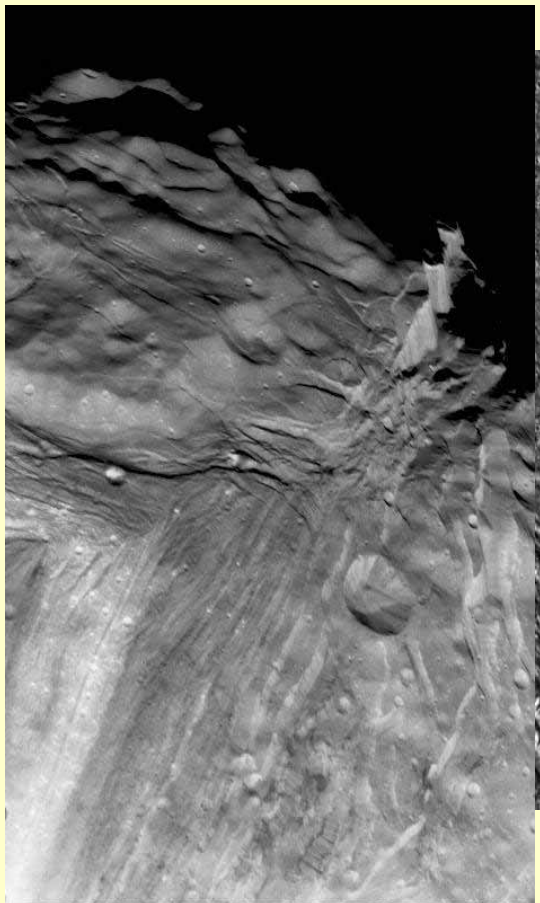
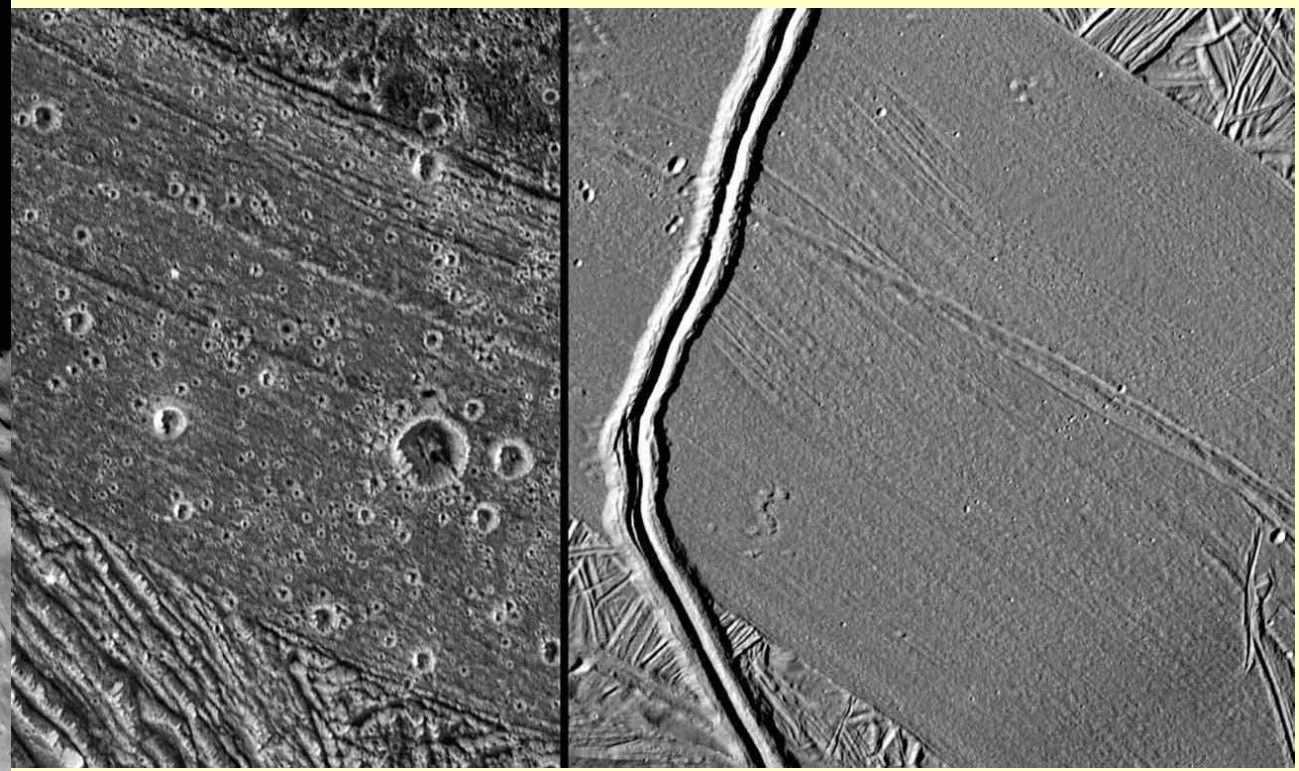
Current status of knowledge

2. Structure and evolution of icy satellites

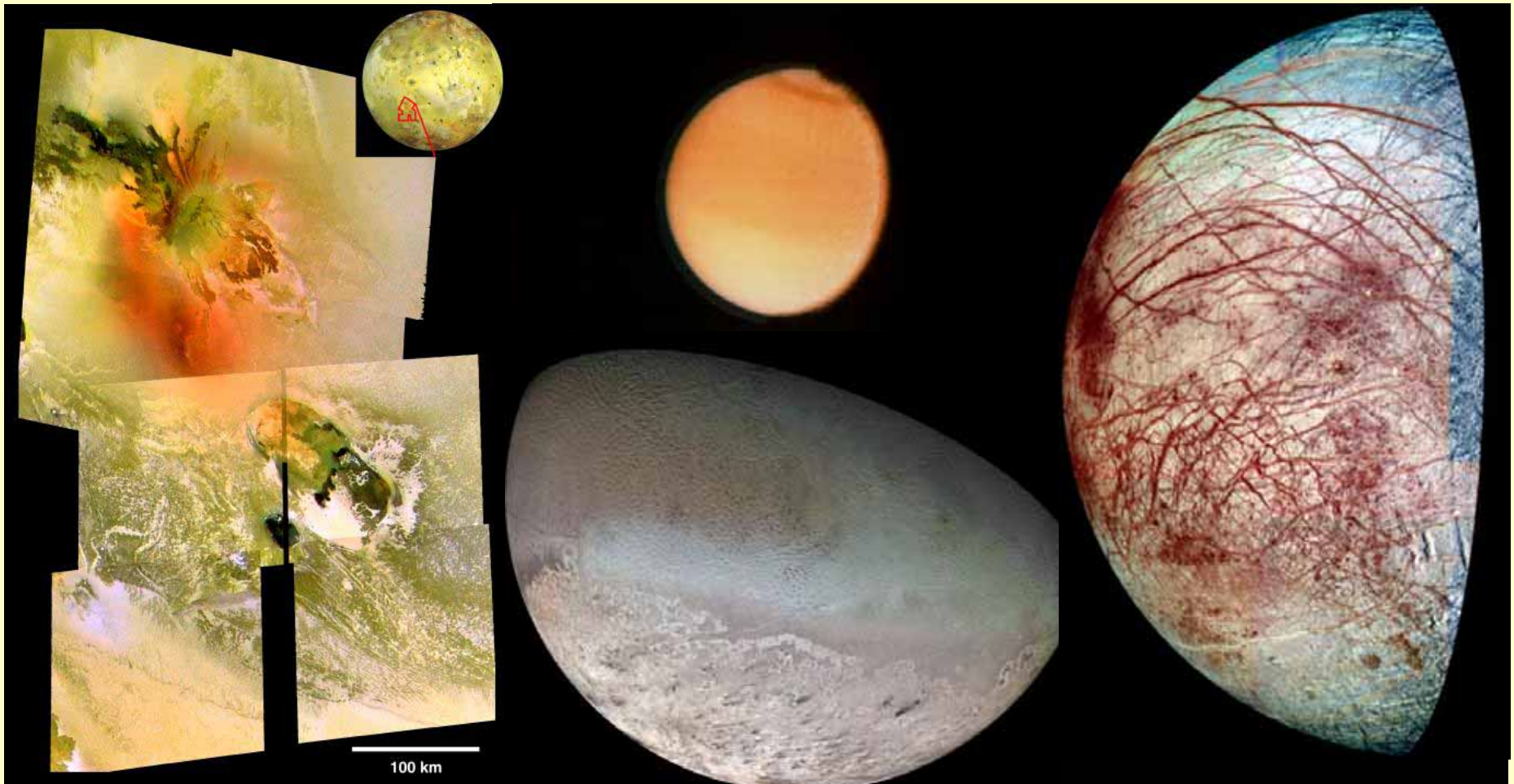
- Grand Tour also gave us our first close up view of the satellites of the outer planets





Current status of knowledge

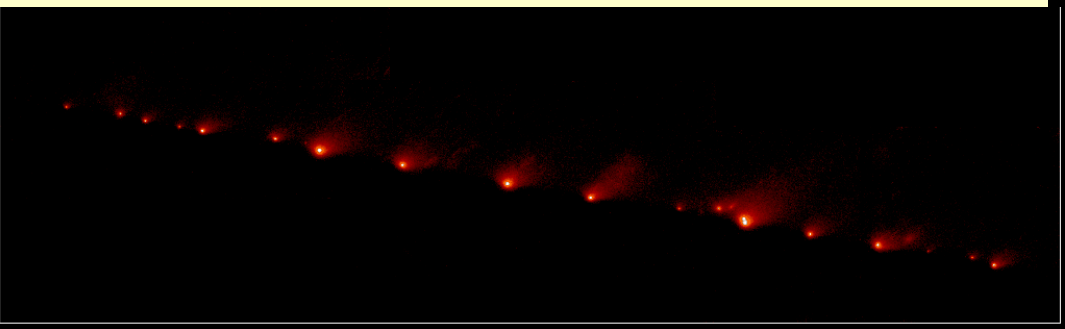
- Vast range of composition, geology and evolutionary history
- Current activity and endless mystery

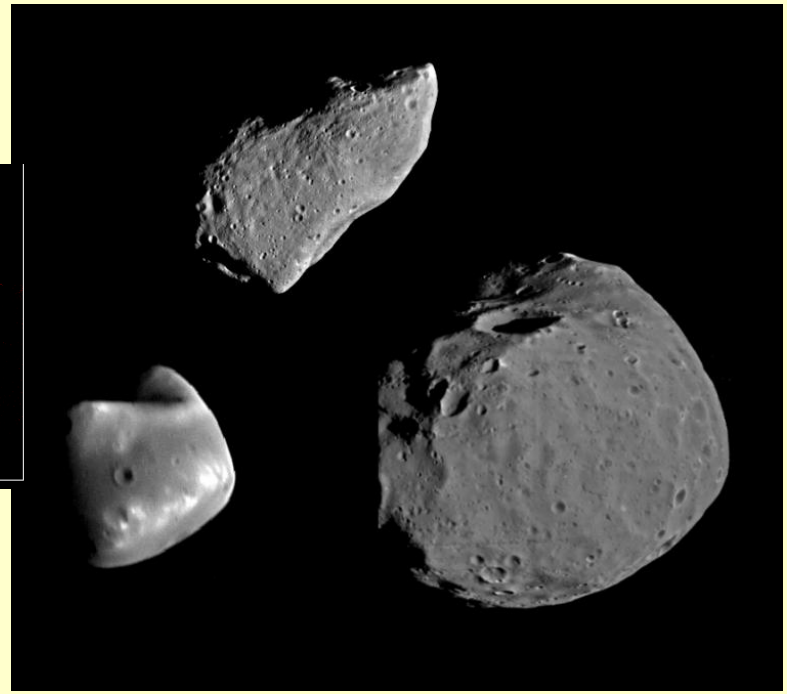


Current status of knowledge

3. Composition and structure of minor bodies

- Study of Comet Halley
  - Revealed spectacular information
- Flybys & rendezvous of asteroids
- Telescopic studies, meteorite studies





Looking Ahead: *to 2015 and beyond*

1. Formation and dynamics of giant planets

- No approved mission in Europe or elsewhere for the dedicated study of any giant outer planet
  - New Horizons – Pluto/Kuiper belt flyby
- All outstanding questions now will still be there in 2015
- This leads to a number of fundamental questions that will need to be answered, such as…

Looking Ahead: *to 2015 and beyond*

1. Formation and dynamics of giant planets

- What were the formation and evolution scenarios of the giant planetary systems?
- What is the composition and dynamics of the atmosphere of the giant planets?
- What is the internal structure and dynamics of these planets?
- What is the nature of the complex space environment around these planets, and how do they compare to one another?
- What is the nature of the dust phenomena (i.e. ring systems) and how does it interact to produce the system we see today?

Looking Ahead: *to 2015 and beyond*

1. Formation and dynamics of giant planets

- A comprehensive study of the Jupiter system was considered to be a high priority among proposers

- Orbiting spacecraft – remote sensing
- Environmental monitoring
- Atmospheric probes
- Possible relay satellite outside radiation belt

Looking Ahead: *to 2015 and beyond*

2. Structure and evolution of icy satellites

- The same situation exists for the satellites of the outer planets
- More complex because of the range of challenging technology required and wide variety and high number of important satellites to explore
  - i.e. Europa, Io, Callisto, Titan etc.

Looking Ahead: *to 2015 and beyond*

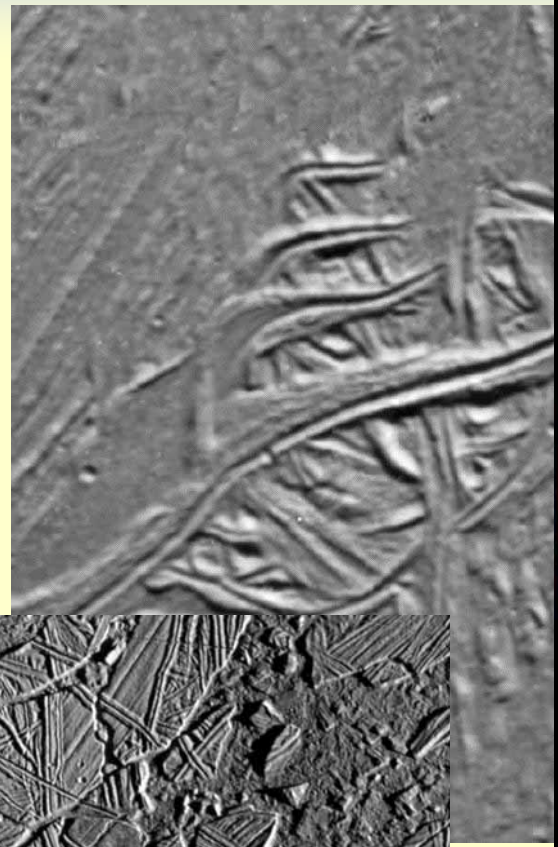
2. Structure and evolution of icy satellites

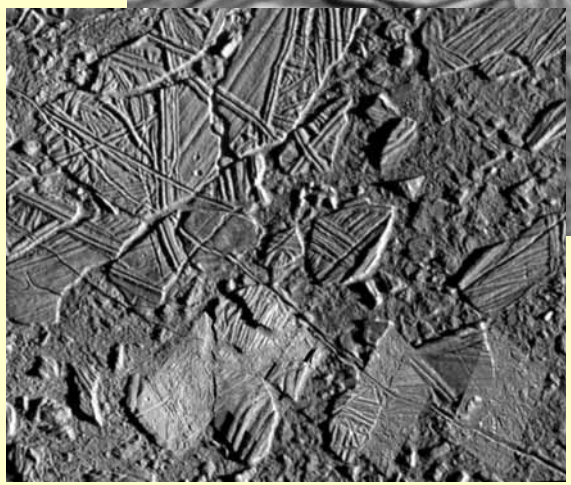
- How did the icy satellites form, and what was their evolutionary path?
- How much liquid water is there in Europa (or Callisto) and how does this relate to the possible paths of prebiotic material and life in the outer solar system?
- What were the processes involved in the evolution of the (often tenuous) atmospheres of satellites?
- How do tidal forces and orbital motion affect the evolution of satellites?
- How do the satellites interact with their host planet and how does this affect them?

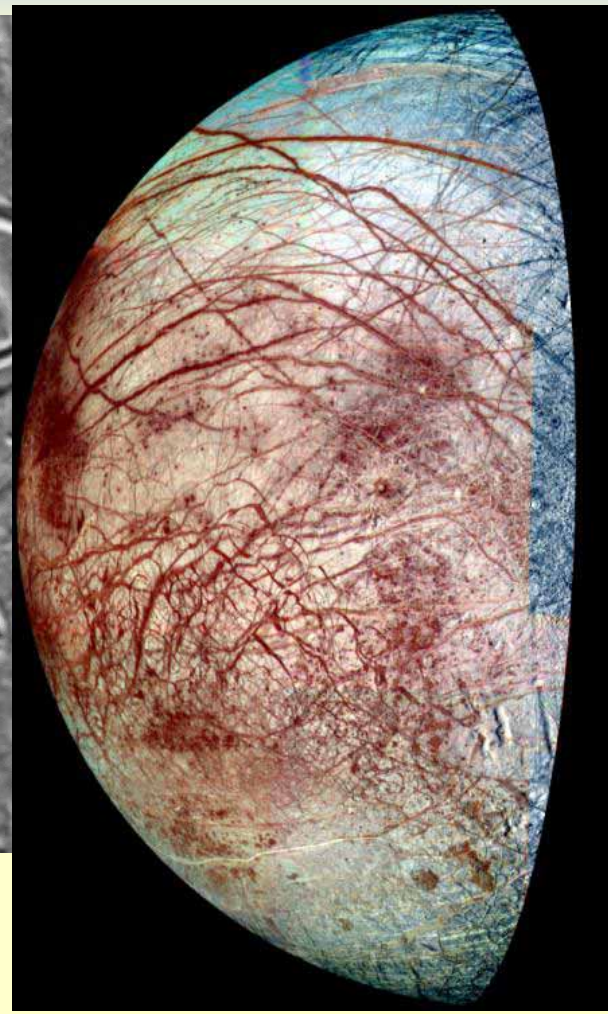
Looking Ahead: *to 2015 and beyond*

2. Structure and evolution of icy satellites

- Europa was a major target for proposers, crossing strongly with Theme 3
- Lander
- In-situ studies
- Drilling/heating probe
- Remote sensing







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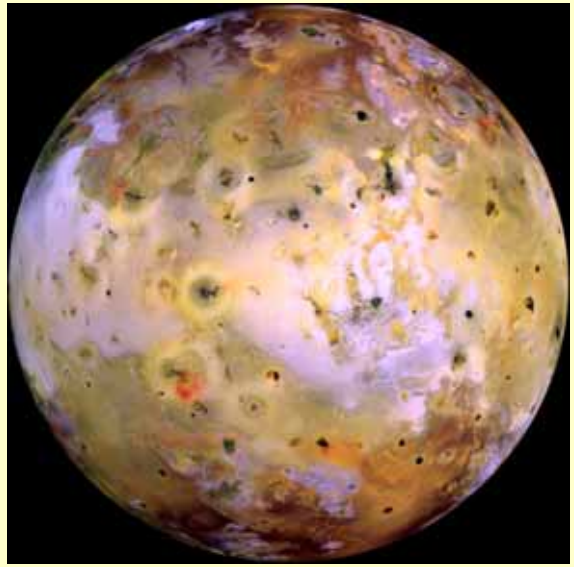
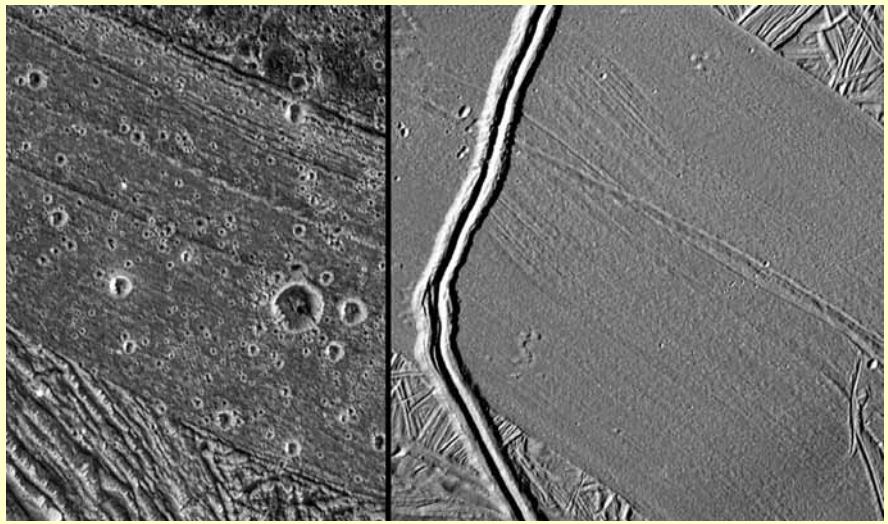
Looking Ahead: *to 2015 and beyond*

2. Structure and evolution of icy satellites



- Other Jovian satellites, especially Io, spanning a wide range of geological and evolutionary histories also important



- Remote sensing
- Long term monitoring
- Interaction with host planet and environment

Looking Ahead: *to 2015 and beyond*

3. Composition and structure of minor bodies

- The situation for minor bodies is more healthy
- Several missions operational/in the pipeline:
  - Stardust – cometary dust sample collection/return
  - Rosetta – Comet rendezvous/landing
  - Hayabusa – asteroid sample return
  - Deep Impact – comet impact & investigation
  - Dawn – Ceres/Vesta exploration

Looking Ahead: *to 2015 and beyond*

3. Composition and structure of minor bodies

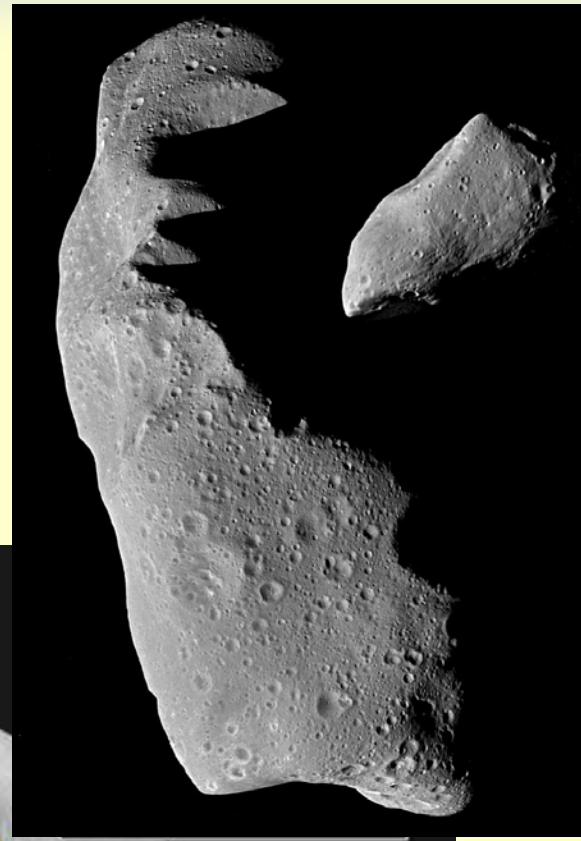
- What are the properties of the minor bodies and how do they differ in different parts of the solar system?
- What is the internal structure of asteroids and other minor bodies?
- How do asteroids relate to the meteorite samples we have on Earth?
- What are the processes occurring in the primitive solar system and accompanying planet formation?

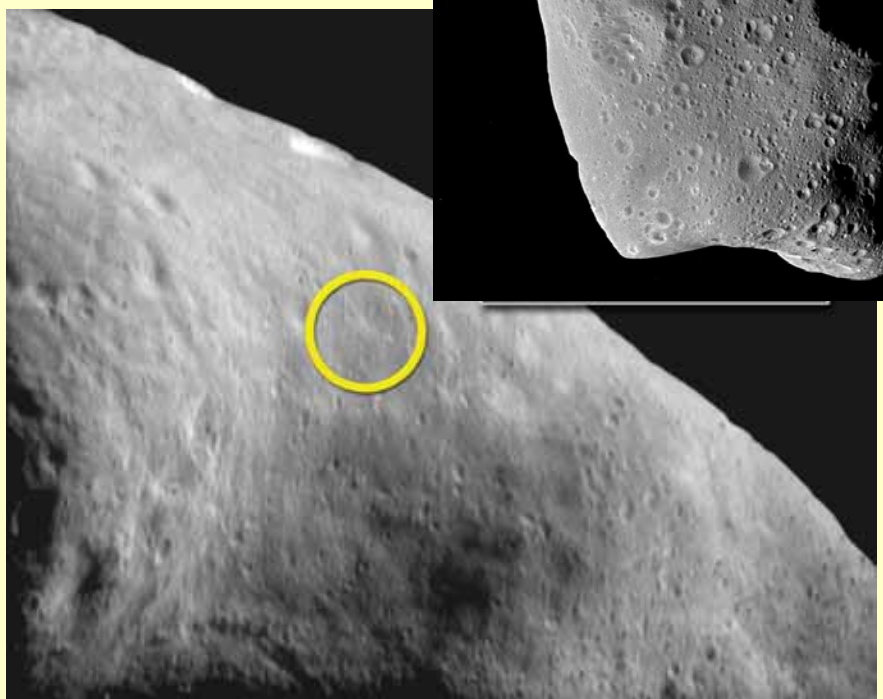
Looking Ahead: *to 2015 and beyond*

3. Composition and structure of minor bodies

- Asteroid belt and NEO's were high priority objects for the proposers

- Rendezvous mission
- Remote sensing
- sample return missions
- Multi-missions to explore multiple examples of same class of object, and to look at a selected range of classes





Requirements for the future

The forward look: Beyond Saturn

- To get a complete view of the outer solar system we need studies of the **Uranus and Neptune** systems
- **Kuiper belt** mission will be important future step to accessing the most primitive source of material
- These investigations will be the next logical step in the exploration of the outer solar system both scientifically and technologically

Requirements and Challenges

- Payload
  - *Minaturisation*
  - *Withstanding harsh environments*
- Landers
  - *Descent and sample return technology*
- In-situ surface technology
  - *Surface operation*
  - *Drilling*
- Multispacecraft missions
  - *Building on existing European strength (i.e. Cluster)*
- Propulsion
  - *Long journey to outer planets*
- Autonomy and navigation
  - *Multispacecraft missions*
- Communication
  - *With Earth*
  - *Between spacecraft*

Summary points

- The most important requirement is that the science has to be interdisciplinary in order to answer the fundamental and important questions
- The European community has expertise in all areas required to undertake the programmes needed for the Cosmic Vision in this theme
- Solar System community in particular is a vibrant, young and growing one, able to lead important outer solar system science well into the future.