Uranus Pathfinder

Exploring the Origins and Evolution of Ice Giant Planets

L. Lamy, N. André, D. Gautier, C. Briand, S. Charnoz, B. Christophe, T. Fouchet, S. Hess, Y. Langevin, J.-P. Lebreton, O. Mousis, G. Tobie, P. Zarka et al.

Lead Proposer : Chris Arridge [UK]

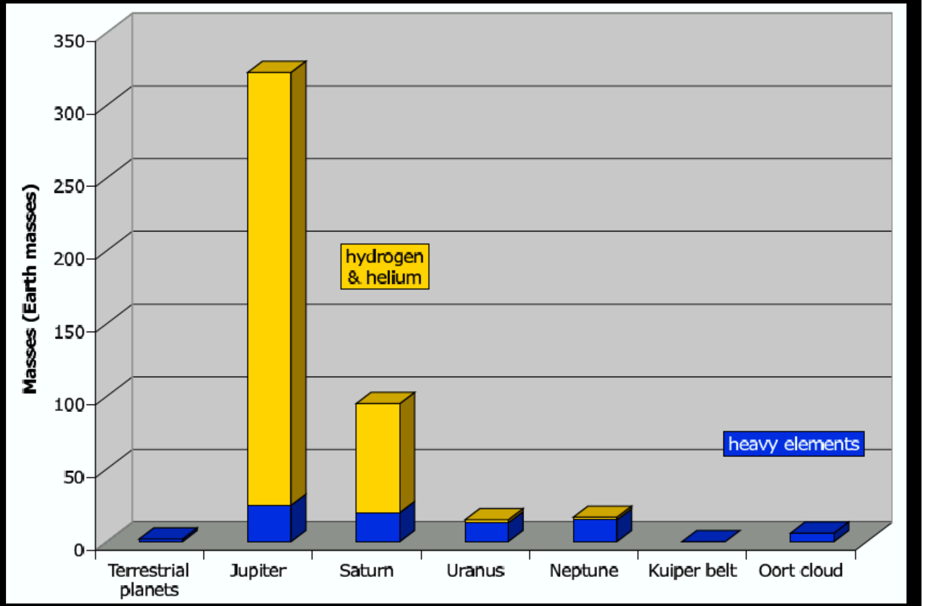
Community of 258 (190 in Europe, 68 in France) scientists world-wide.

Auditions CNES ESA-M4, Paris 7, 19 Nov. 2014

What are the Ice Giants?

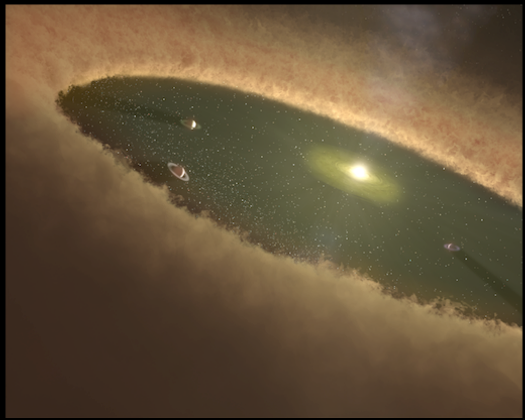
Uranus Pathfinder

- **Uranus** and **Neptune** are not Gas Giants – they are **Ice Giants**.
- Planetary ices (**H_2O, CH_4, NH_3**) are abundant in their envelopes.
- Also have large (relative to their mass) rocky cores.



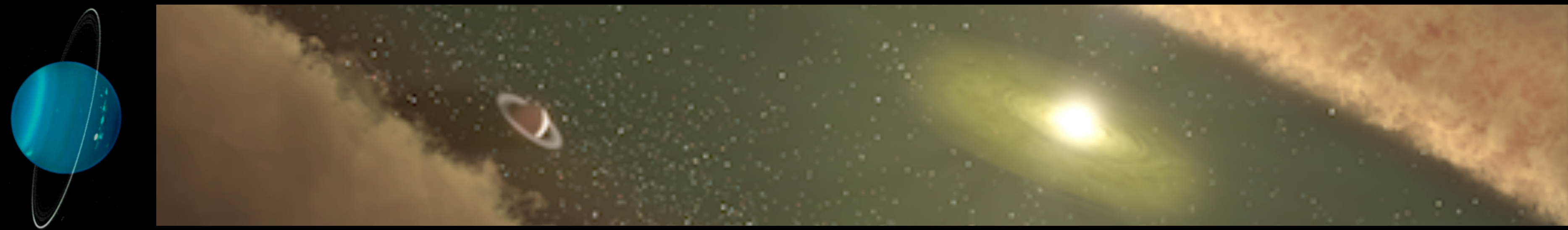
T. Guillot

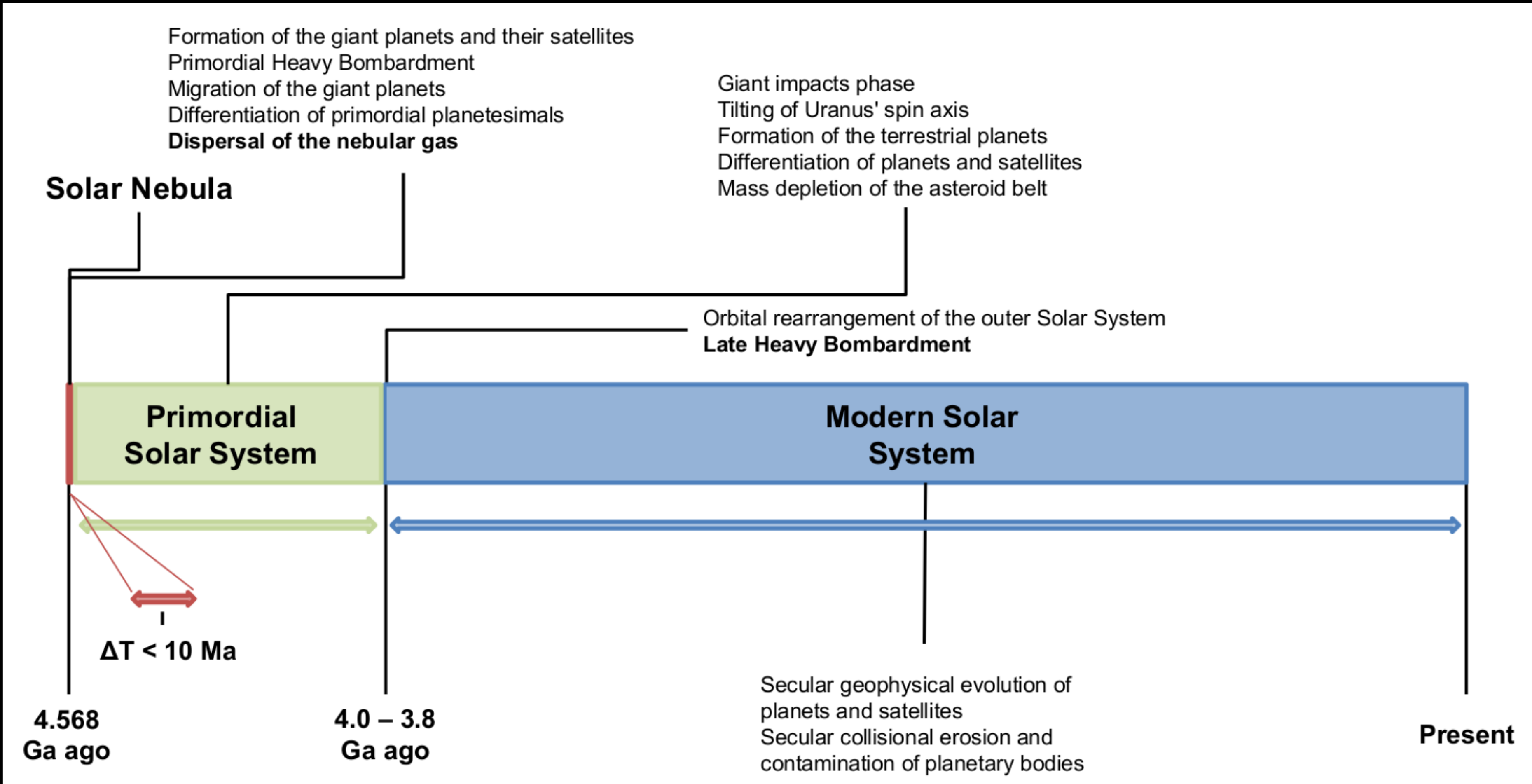
- Different formation environment hence a **unique window into the formation of the Solar System**.
- Also:
  - Interior composition and large heliocentric distance yield **unique physicochemical conditions**.
  - Fascinating **planetary and magnetospheric environments**.



NASA/JPL-Caltech/T. Pyle (SSC)

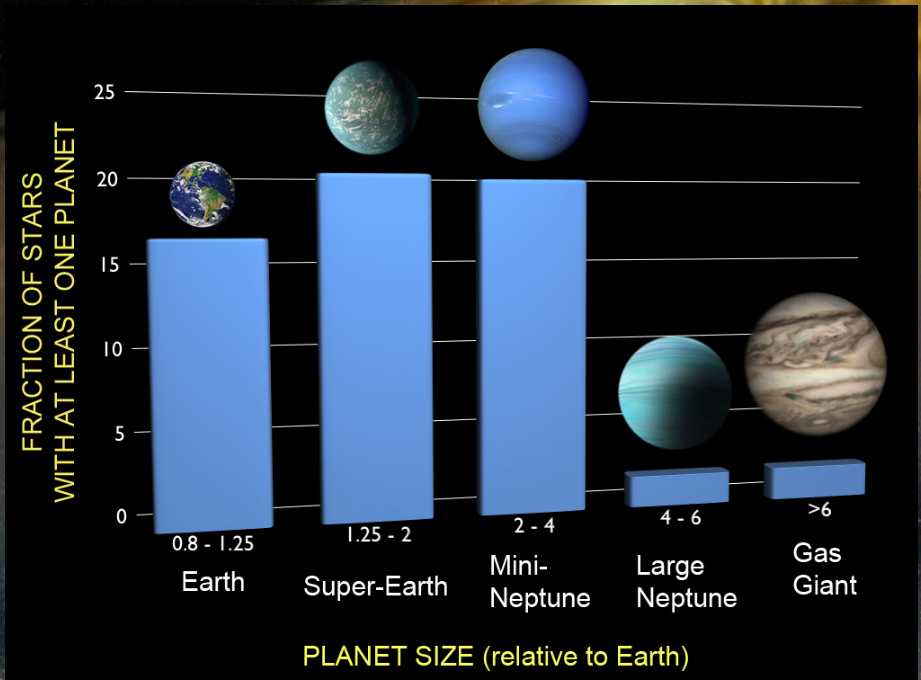
Origin of the Solar System

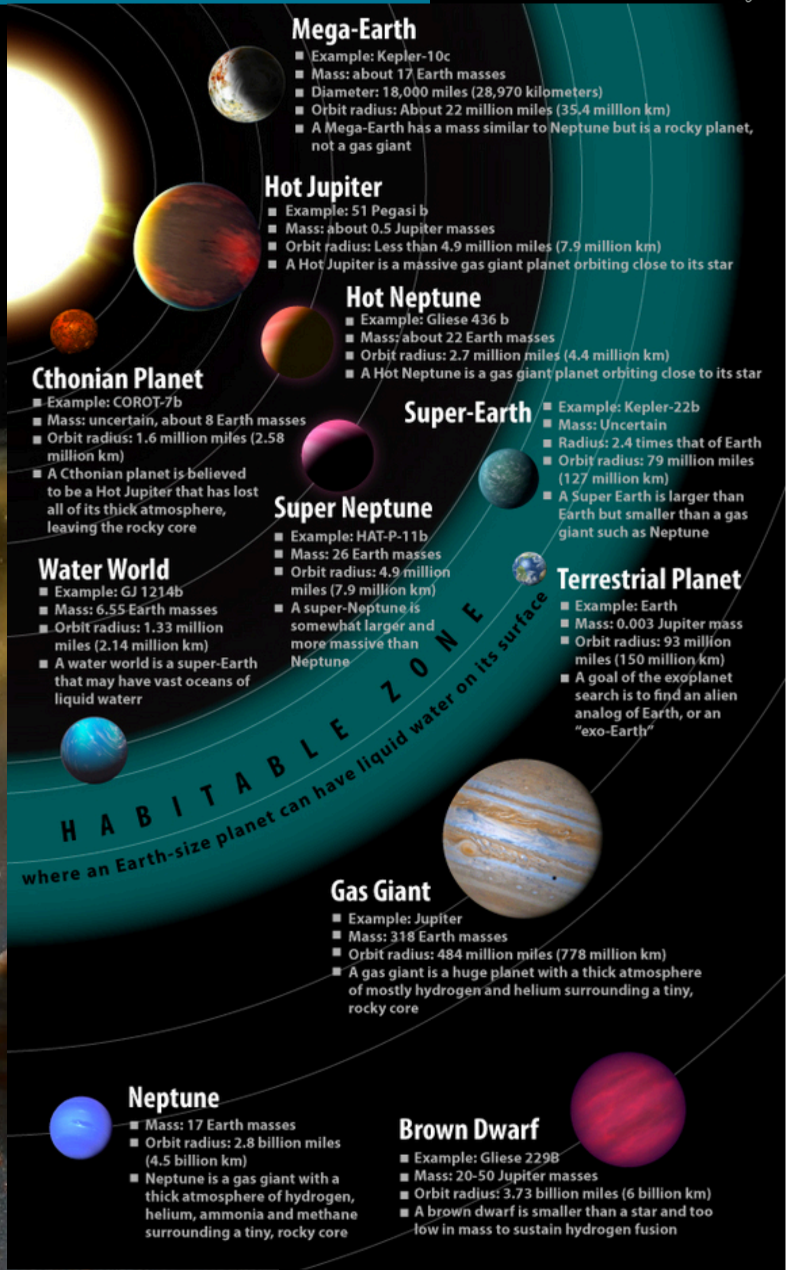




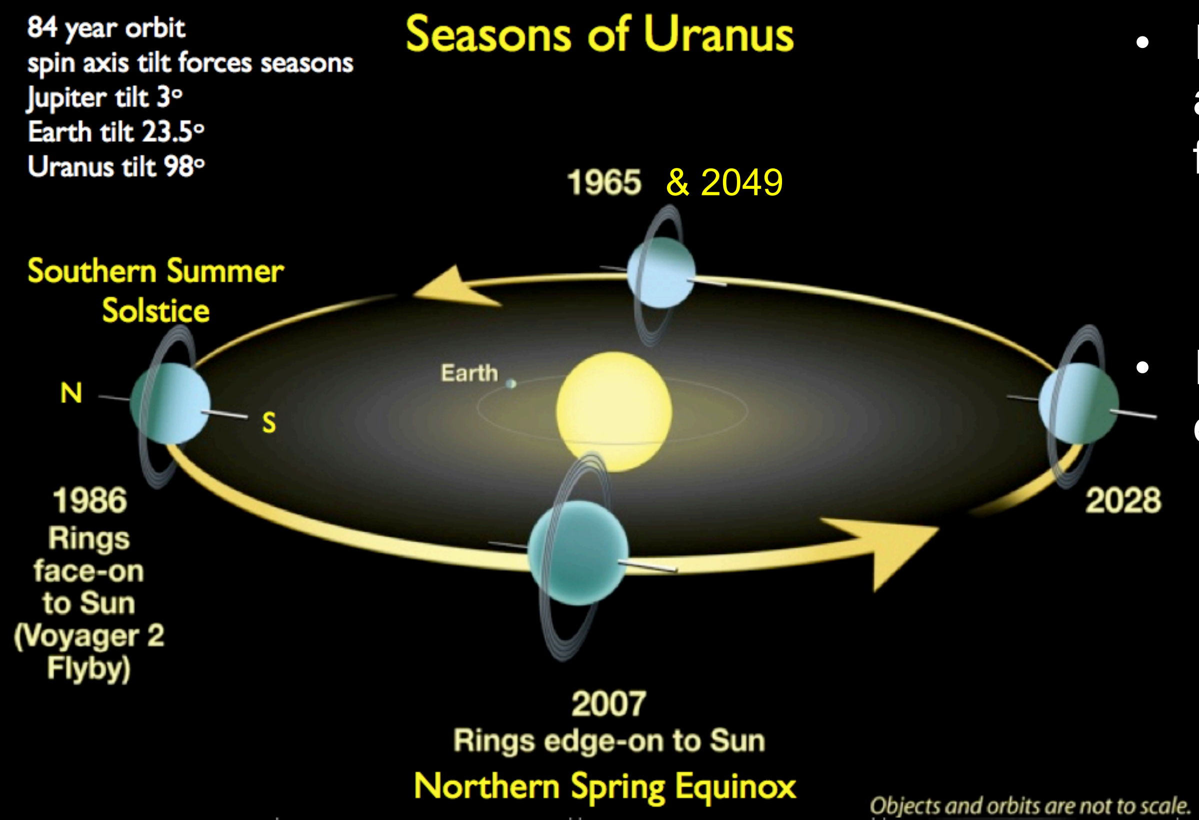
The Missing Link

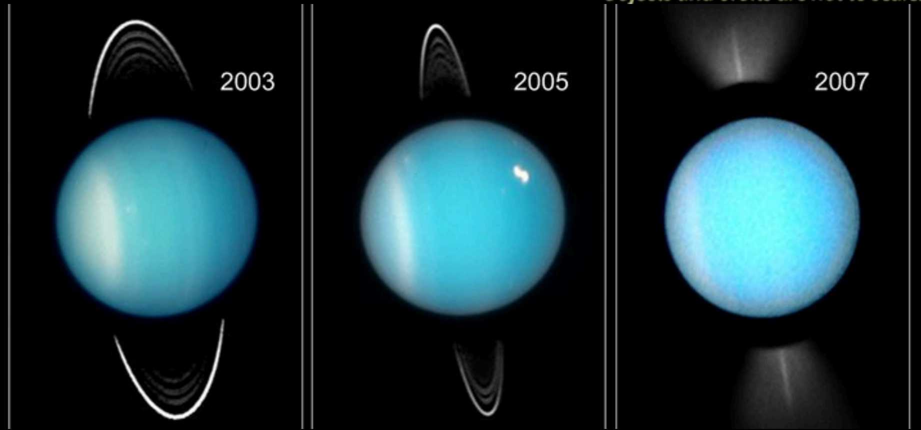
- Missing Link between the giant H_2-rich gaseous worlds and H_2-poor terrestrial planets.
  - Representative of a whole class of astrophysical object.
  - Compositional fingerprints of planetary origins & formation timescales.



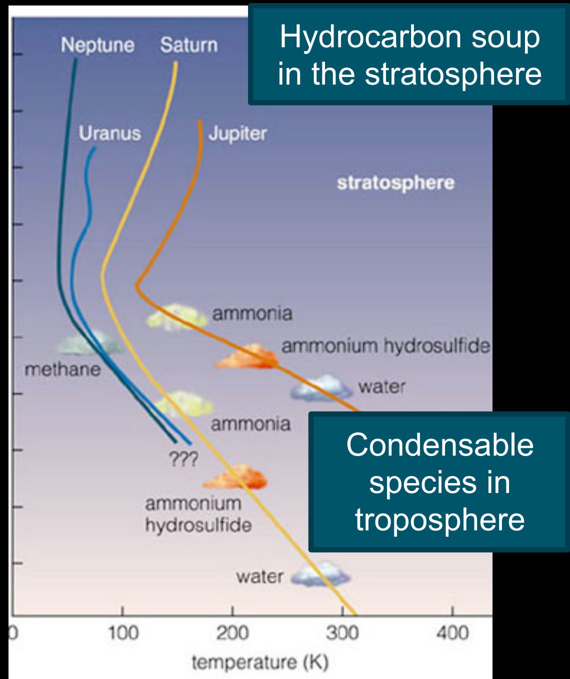


Uranus' Climate & Seasons

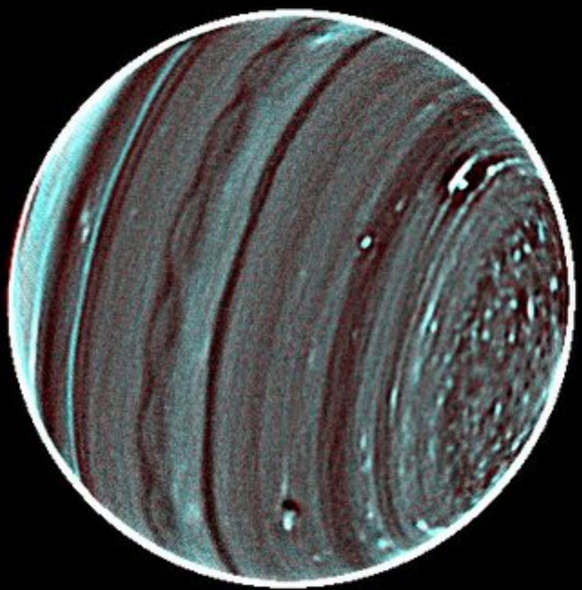




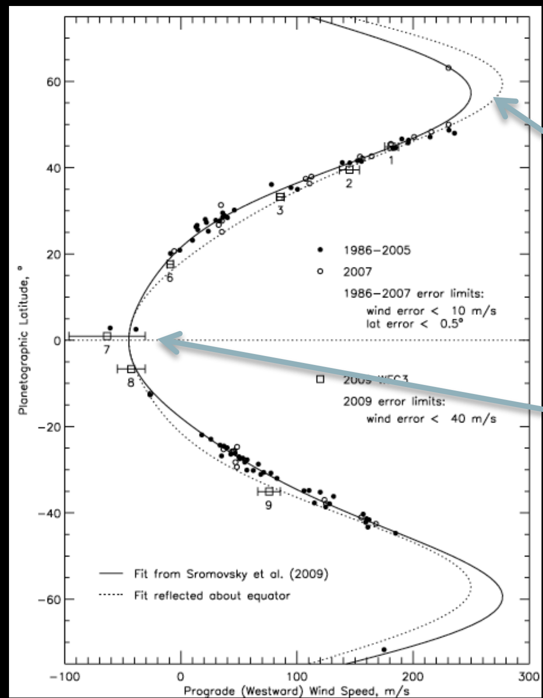
- Extreme tilt subjects atmosphere to unusual forcing.
  - How does the atmospheric circulation/chemistry respond to sunlight?
- Extreme cold means almost everything condenses.
  - What are the dynamics of the cloud-forming region?



Uranus' Weather Activity



- Voyager 2 gave Uranus atmosphere an unfair reputation!
  - Upturn in storm activity since summer solstice.
  - Advances in imaging (i.e., methane bands).
  - Banded structure, equatorial waves, storm activity…
  - How does the meteorology of Uranus compare to the gas giant cousins?
  - What is the driving energy source for convection?

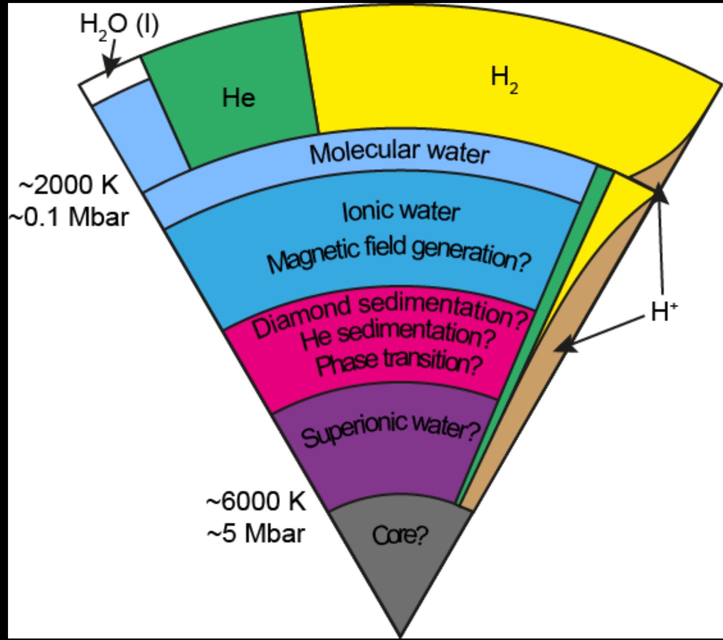


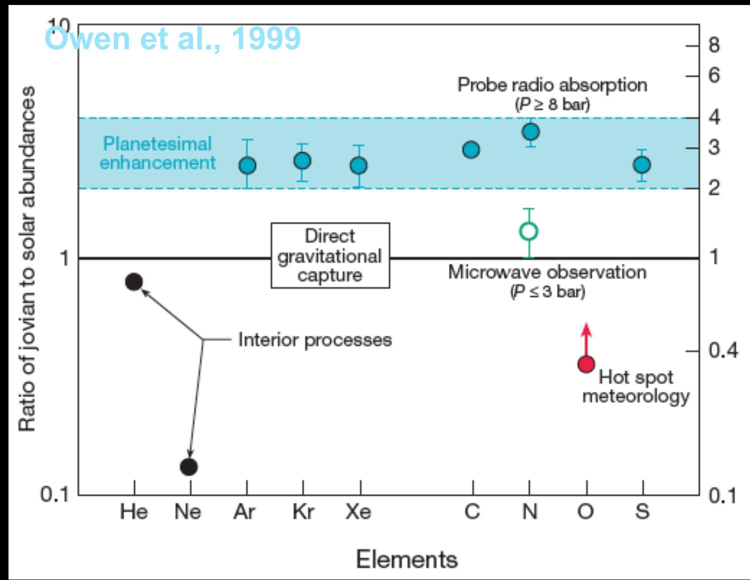
250 m/s prograde maxima

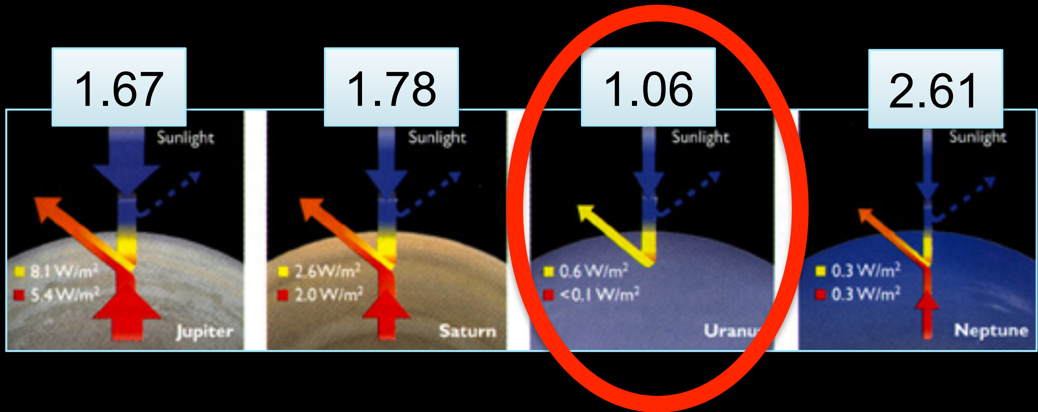
-50 m/s retrograde maxima

Beneath the Clouds: Uranus’ Interior

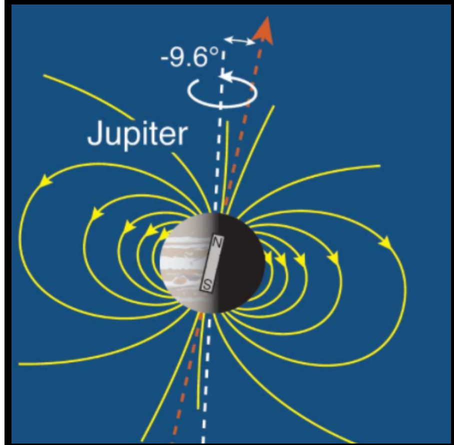
- Lower troposphere and interior hidden from view, rely on spacecraft to provide indirect constraints:
  - Bulk composition (in situ probe).
  - Gravitational and magnetic fields.
  - Magnitude of the heat flux.
  - Rotation rate of interior.
  - Depth of zonal flows (shallow or deep)
  - Planetary oscillations (seismology).
- The composition, energy balance and structure of Uranus’ deep interior will reveal the origins of this ice giant

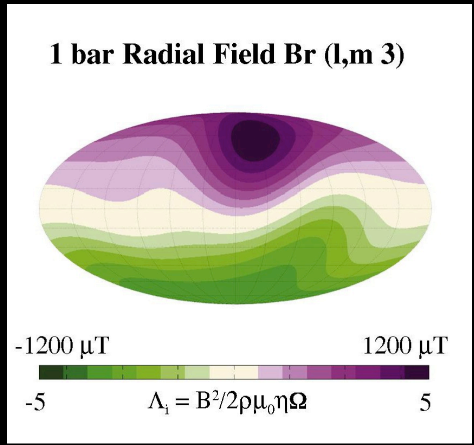






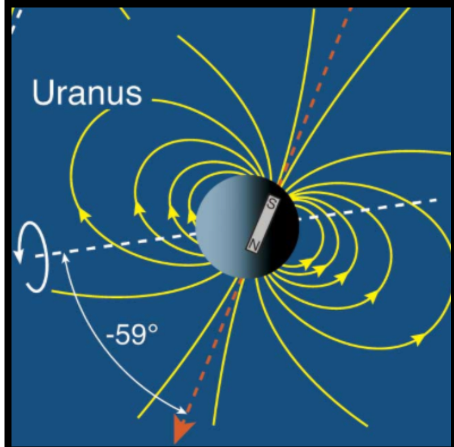
Internal magnetic field and magnetosphere

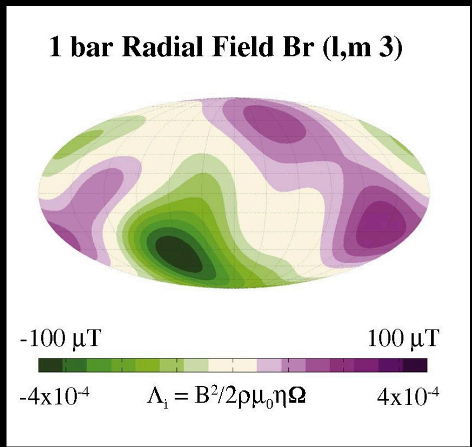


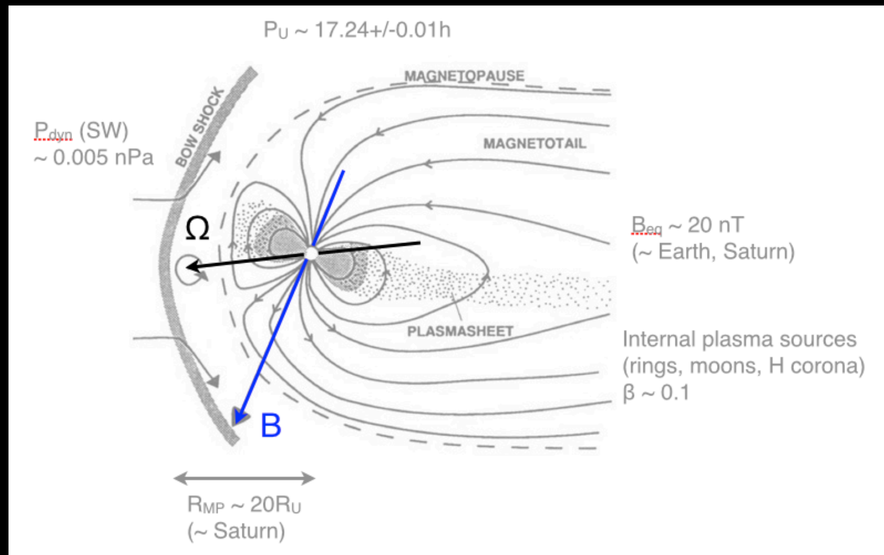


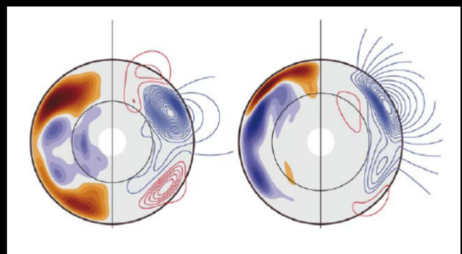
- Unique magnetic field:
  - Unusually tilted/offset magnetic field
  - Origin, secular variations? Rotation rate ?

  - Asymetric magnetosphere with large tilt, fast rotation ~17h, large distance from sun
  - Plasma circulation and magnetospheric dynamics from a rotation to seasons ?







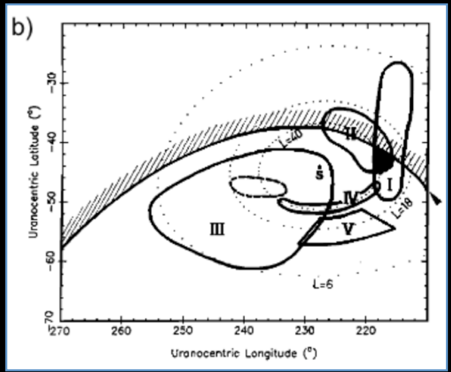


Sun 

1986 : Solstice
2007 : Equinox
2040 : Solstice to equinox

Aurorae and aeronomy

Zarka et Lecacheux, 1987



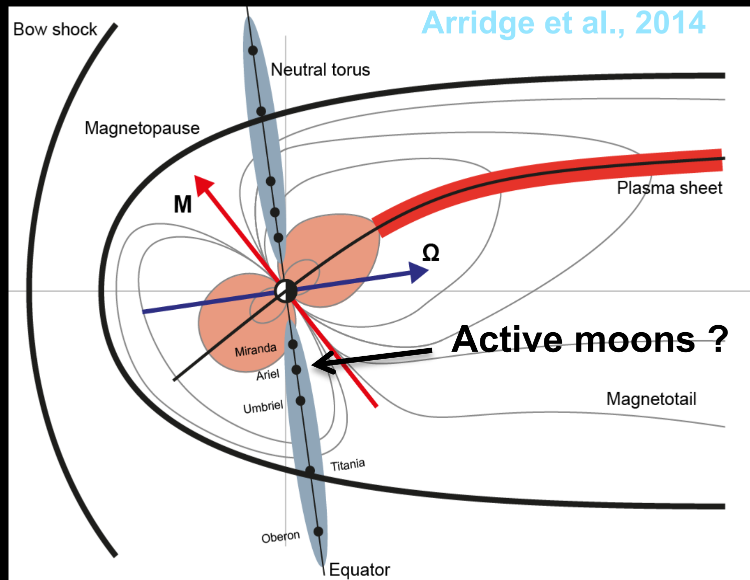
1986 : solstice

2011:
near-equinox

Lamy et al., 2012

2028 :
next solstice

- Magnetosphere-ionosphere coupling :
  - Radio emissions unique to Ice giants (time-stationnary, variety of sources)
  - What makes Uranus a radio source?
  - Auroral features strongly vary with time, auroral forcing unknown, hot thermosphere
  - Auroral acceleration mechanisms and energy transfer ? Interaction with solar wind and moons ?



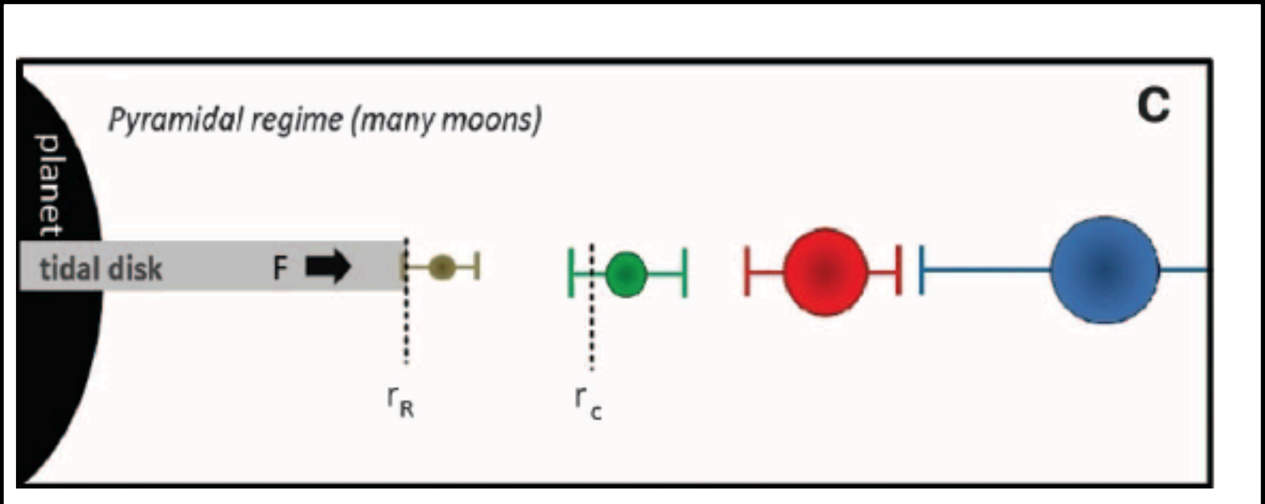
Arridge et al., 2014

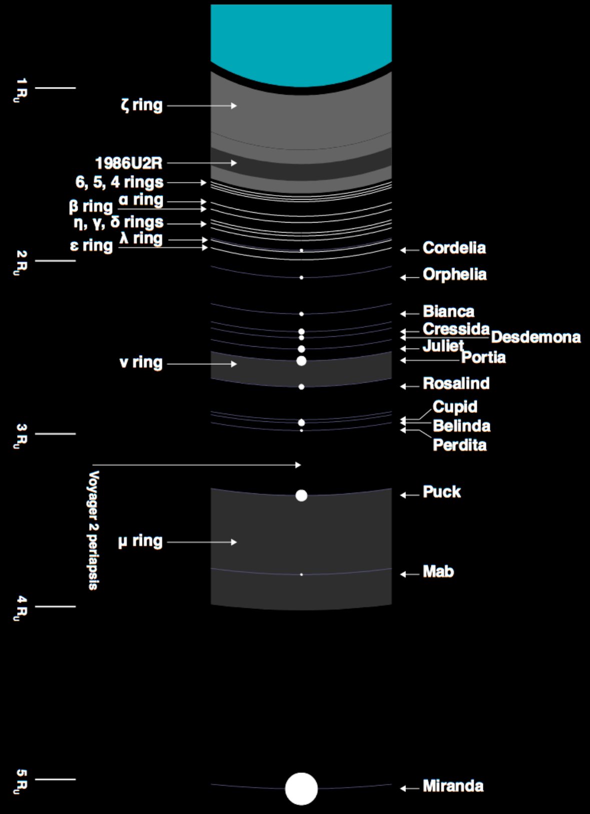
Architecture of the Uranian planetary system

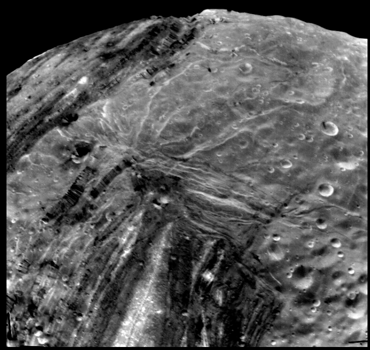
Uranus Pathfinder

Origin and evolution of the ring-satellite system

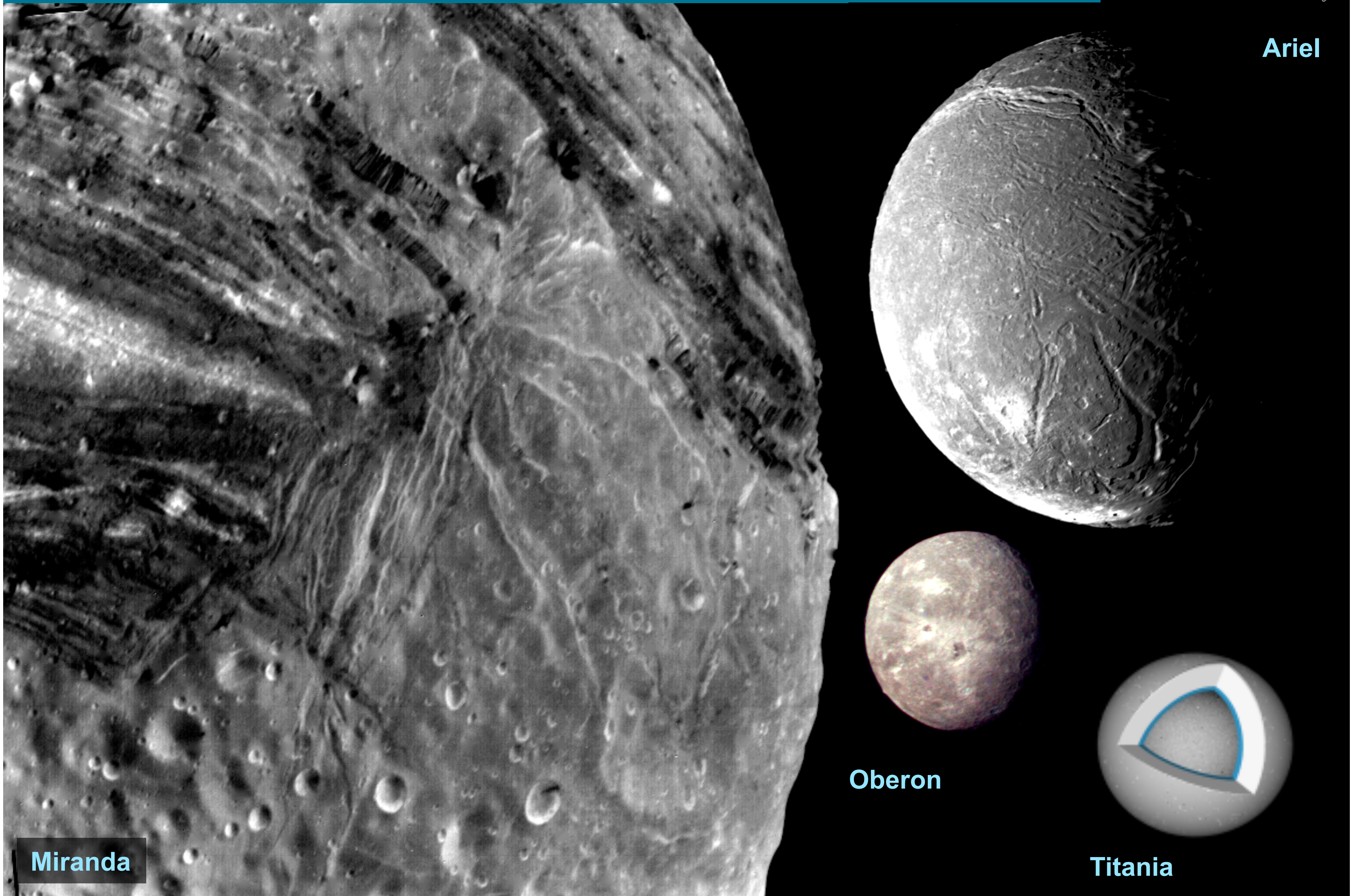
- Dense packing – **co-evolution and origin**?
- Giant impact theory for Uranus' obliquity disrupted original satellite system and formed the rings.
- Cometary impacts.
- Disruption of satellites.
- Re-accretion of ring material.



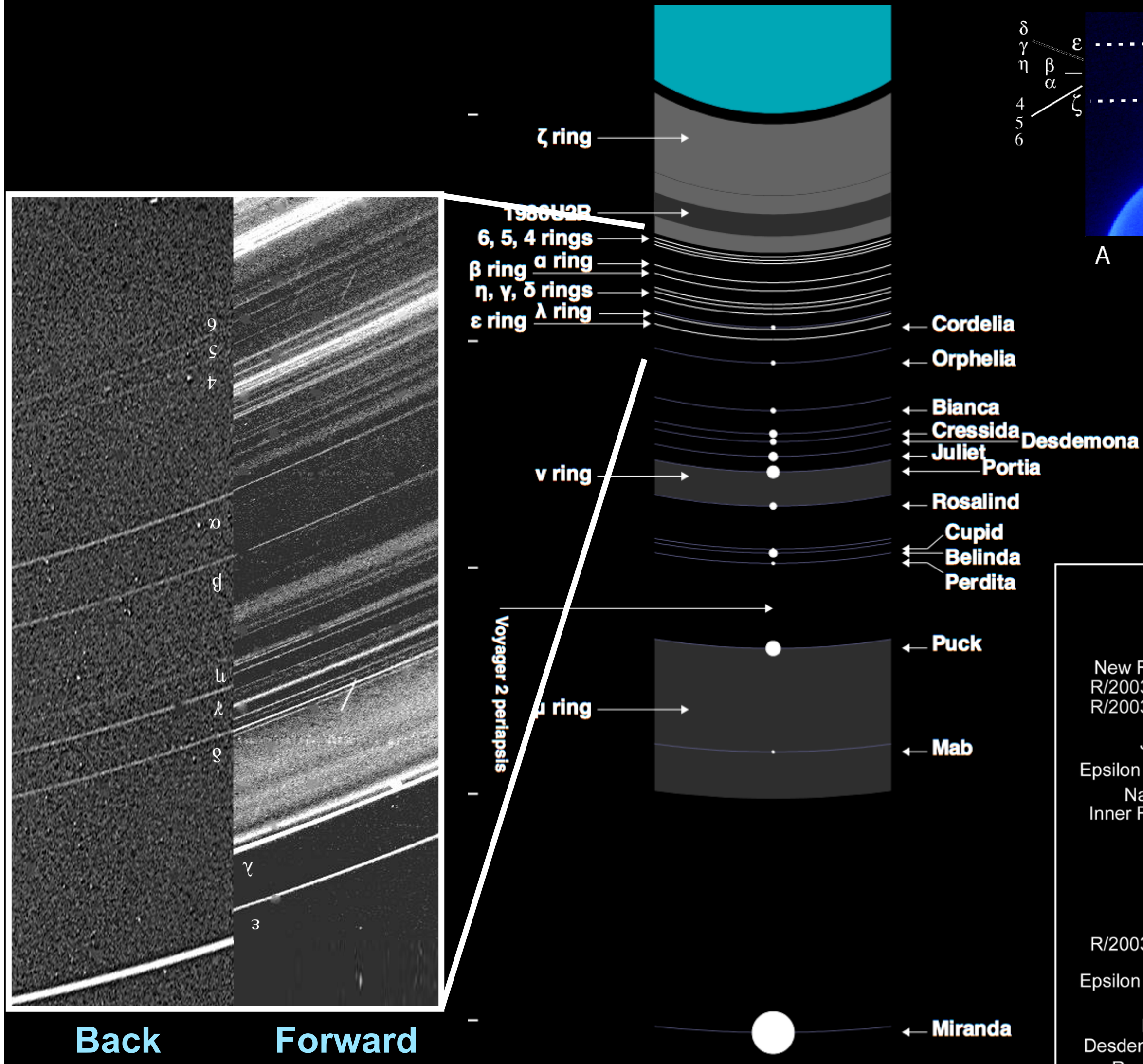


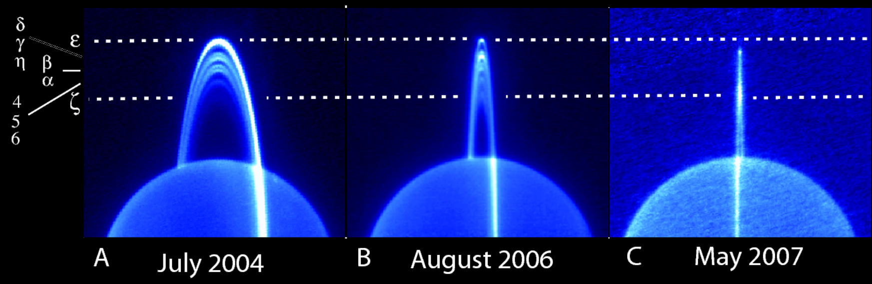


Surfaces and composition of the main satellites

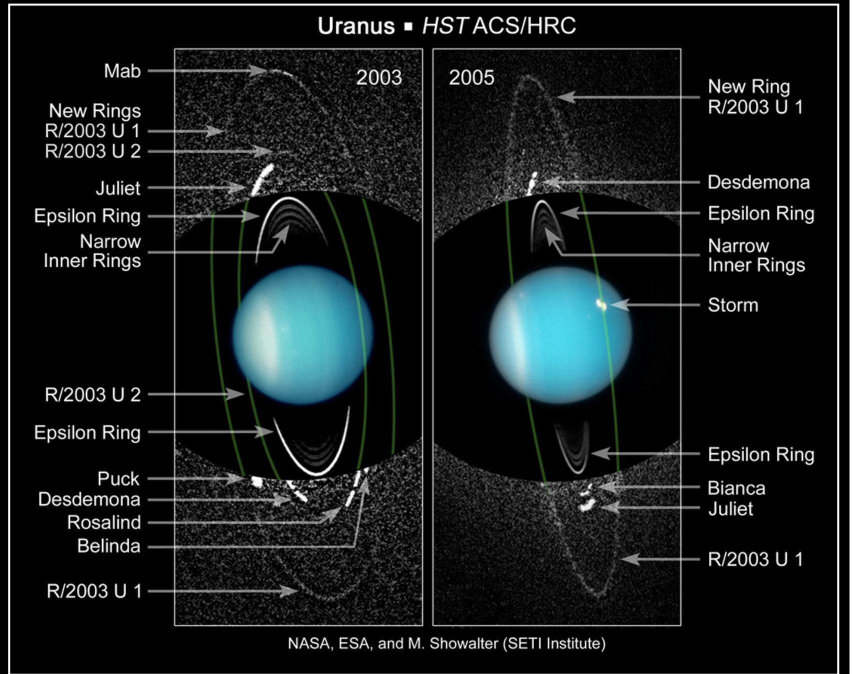


Ring system



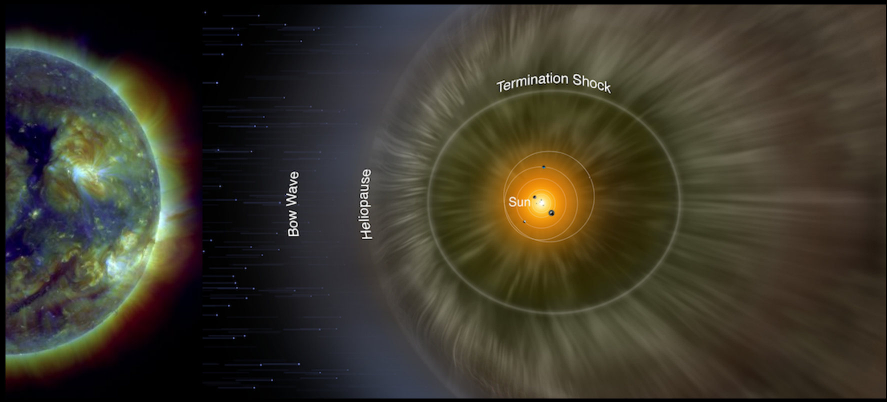


De Pater et al., 2007



Science in the outer heliosphere

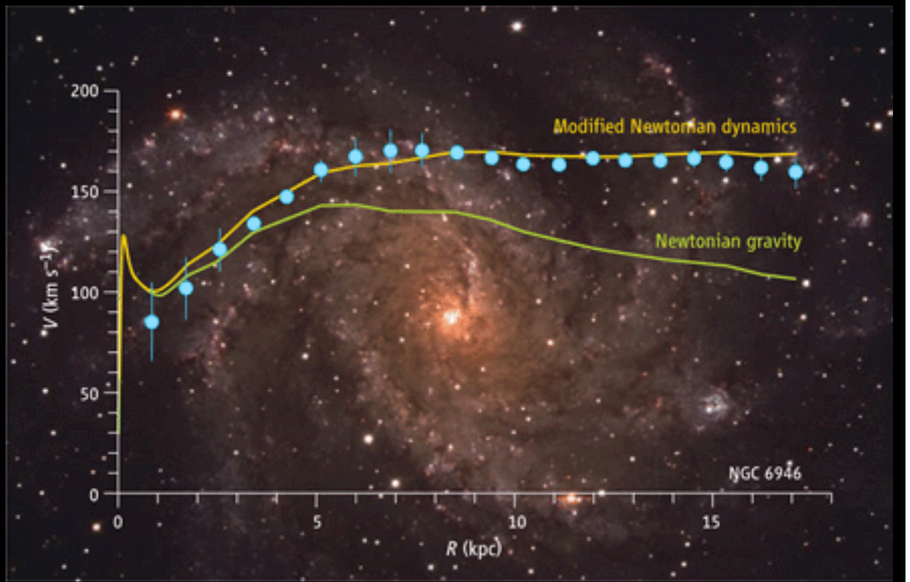
- Very few spacecraft have travelled beyond 10 AU. Mission to Uranus provides an opportunity to study unique physics during the cruise phase.



1- Test gravity at the largest possible length scales to search for deviations from General Relativity (modified Newtonian gravity / dark matter).

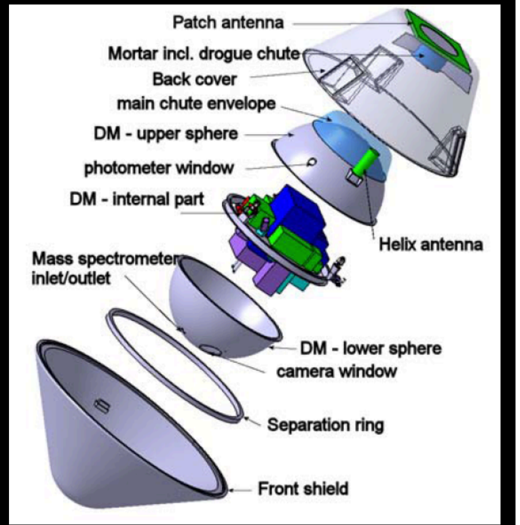
2- Study of structures and processes beyond 10 AU: corotating and merged interaction regions, specific heating processes (role of pick-up ions) …

3- Directly flyby debris from the formation of the solar system.

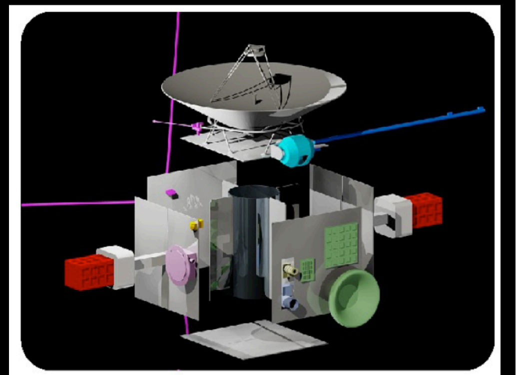


Mission Concepts

- Majority of science goals best addressed by an **orbiter** and **atmospheric entry probe**.
- **Flyby/multipoint** concepts can be competitive.
- Under study: **Airbus D&S** and **Thales Alenia Space**.



- **Constraints**
  - Ring plane hazards are poorly understood.
  - Polar orbits are highly favourable.
  - Modest planetary protection/radiation requirements.



- **Key enabling technology**
  - Nuclear power sources (MMRTG or ESA ^{241}Am).
  - Limited telemetry rate (~10 kbit/s).
  - Thermal control.
- **International collaboration**: ESA spacecraft, NASA launch vehicle/RTGs.
- **Costs: orbiter fits within ESA M4 cost cap** and is compatible with ESA L2/L3 cost evaluation (including international contribution).

Model payload

High TRL with substantial European flight heritage.

Instrument	Consortia and funding agencies	Heritage
Narrow angle camera (NAC)	JHU/APL, USA [NASA] INAF, Italy [ASI]	New Horizons/LORRI JUICE/JANUS
Visual and near-IR spectral imager (VIRTIS)	INAF, Italy [ASI] Luleå U. T., Sweden [SNSB]	Rosetta/VIRTIS DAWN/VIR
Thermal Infrared Bolometer (UTIRM)	U. Oxford, UK [UKSA]	LRO/Diviner
Magnetometer (MAG)	Imperial College, UK [UKSA]	Rosetta/MAG Cassini/MAG
Electron/ion plasma detector (PLS)	MSSL, UK [UKSA] **IRAP, France [CNES]**	Solar Orbiter/SWA Cassini/CAPS/ELS
Radio and plasma wave experiment (RPW)	**LESIA, France [CNES]** IAP, Czech Rep. [MEYS]	JUICE/RPW BepiColombo/MMO/PWI
Accelerometer (GAP)	**ONERA, France [CNES]**	CHAMP/STAR

The Next Step: Uranus Pathfinder

- Beyond Galileo/JUNO/JUICE and Cassini for gas giants, and after New Horizons for the Kuiper Belt, Ice Giants are **the next and last step** to complete the detailed exploration of the Solar System.