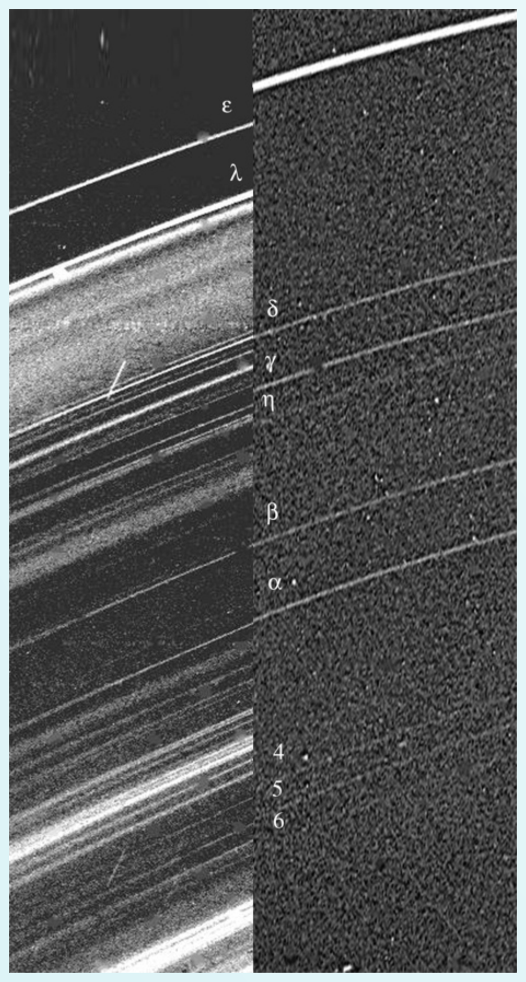
Uranus Magnetosphere and Moons Investigator (UMaMI)

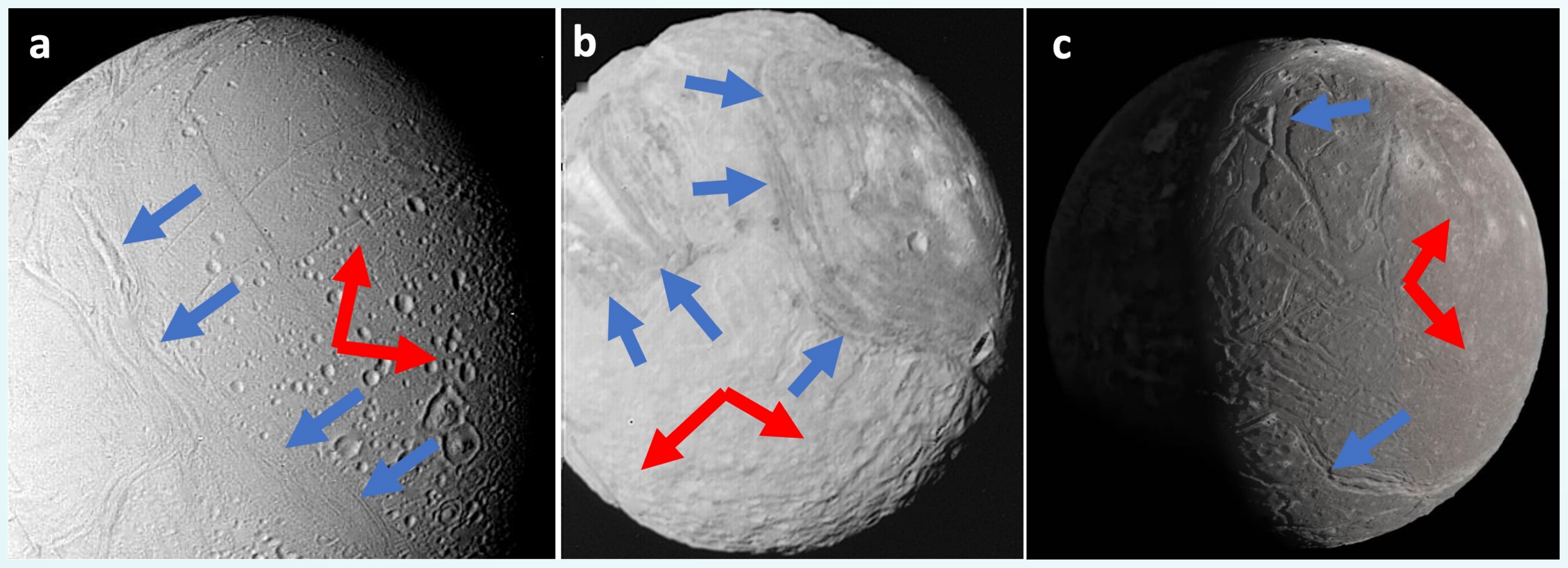
C. M. Elder[1], T. A. Nordheim[1], D. A. Patthoff[2], E. Leonard[1], R. J. Cartwright[3], C. Cochrane[1], C. Paranicas[4], M. Tiscareno[3], A. Masters[5], D. Hemingway[6], M. M. Sori[7,8], H. Cao[9], R. T. Pappalardo[1], B. J. Buratti[1], I. de Pater[10], W. M. Grundy[11], M. Showalter[3], W. Kurth[12], I. Jun[1], J. I. Moses[13], K. L. Aplin[14], J. Casani[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, [2]Planetary Science Institute, [3]SETI Institute, [4]Applied Physics Laboratory, [5]Imperial College, [6]Carnegie Institution, [7]University of Arizona, [8]Purdue University, [9]Harvard University, [10]University of California, Berkeley, [11]Lowell Observatory, [12]University of Iowa, [13]Space Science Institute, [14]Bristol University.

UMaMI Synopsis

- New Frontiers mission concept.
- Observe the magnetosphere, moons, and rings of Uranus. These three systems interact and require a similar payload.
- We would optimize instruments and the orbital tour for the magnetosphere, moons, and rings but would observe Uranus when possible.

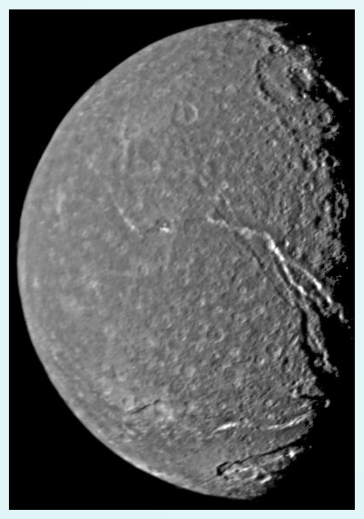




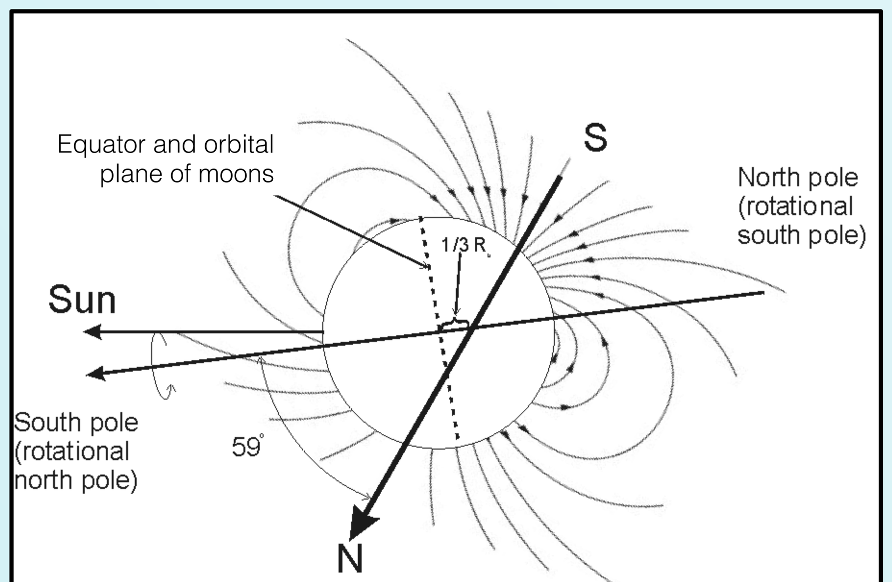
Above: Voyager 2 image mosaics of (a) Enceladus (d=504 km), (b) Miranda (d=472 km), and (c) Ariel (d=1158 km) including night-side illumination by Uranus shine [1]. Cratered regions (red arrows) and boundaries of isolated recent resurfacing (blue arrows) highlighted in each figure. **Miranda and Ariel show evidence of partial resurfacing, similar to Enceladus.** Image credit: NASA/JPL/Caltech/USGS.
Left: Voyager 2 images of the rings. The epsilon ring (brightest) is approximately 100 km wide. **The image on the left revealed Uranus's dusty rings and is the only Voyager 2 occultation image.**

Why New Frontiers?

- UMaMI would be complementary to a variety of outer solar system Flagship class missions.
- UMaMI could study a primordial ice giant satellite system at Uranus, while a Flagship class mission to Neptune addressed questions related to ice giants and Triton (Triton's capture from the Kuiper Belt destroyed much of Neptune's native satellite system [e.g. 2]).
- Alternatively, if a Flagship mission to an ice-giant were not recommended for the next decade, UMaMI would address a focused subset of the science objectives of a Flagship class mission.



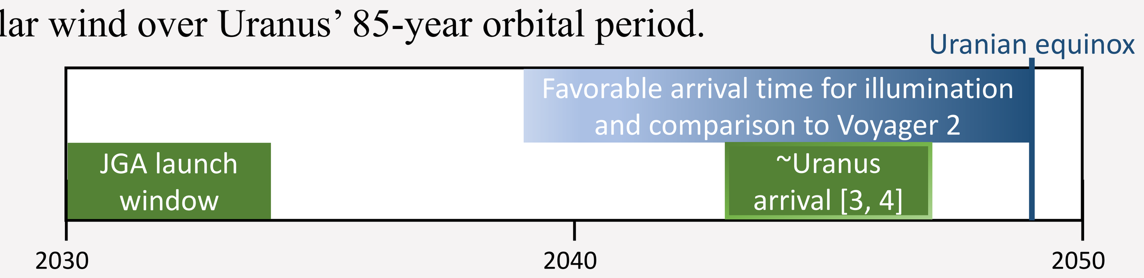
Above: Voyager 2's highest resolution image of Titania. Image credit: NASA/JPL



Left: Uranus's magnetic field during the Voyager 2 flyby. N and S are the magnetic north and south poles.

Why decade 2023-2032?

- Uranus' large obliquity (97.9º) results in extreme variations in insolation conditions of the moons and in interactions between the magnetosphere and the solar wind over Uranus' 85-year orbital period.



- Launching between 2030 and 2034 would provide an opportunity for a Jupiter gravity assist (JGA) and would enable arrival at Uranus just before equinox [3].

Payload

- High-resolution camera with color filters
- Magnetometer
- Visible and Infrared (VIR) spectrometer
- Plasma spectrometer
- Energetic particle detector

Science Background

- Moons
  - Fractures, ridges
  - Relaxed craters
  - Volatiles that should not be stable
  - Regions with relatively few craters
  - Possible cryovolcanism
  - Could host subsurface oceans
  - *Northern hemispheres of moons were dark during Voyager 2 flyby*
- Magnetosphere
  - Relatively low plasma densities
  - *Voyager 2 sampled only the inner plasma sheet*
  - Interaction between magnetosphere and solar wind is highly variable over both diurnal and seasonal timescales due to the large obliquity of Uranus (97.9º) and the tilt (-59º) of the dipole magnetic field
  - *Voyager 2 was a single flyby (could not observe temporal variability)*
- Rings
  - Dense and sharp edged unlike other ring systems
  - Dusty rings must be continuously replenished, if old
  - Dusty rings may have moved since Voyager flyby
  - μ ring is blue in color (small uniform grain size), with moon Mab embedded in the center. Only known ring with similar characteristics is the E ring at Saturn
  - *Voyager did not measure ring composition*

UMaMI Science Goals

1. Moons: Determine whether the Uranian satellites host subsurface oceans, search for signs of ongoing endogenic activity, and determine to what extent the surfaces are modified by exogenic processes (e.g. charged particle bombardment and irregular satellite dust accumulation).
2. Rings: Understand the formation and evolution of the Uranian rings and their interactions with the satellites.
3. Magnetosphere: Characterize the structure and dynamics of the Uranian magnetosphere, including its interaction with the solar wind and the Uranian moons.

Science Goal	Science Objective	Measurement	Instrument
Magnetosphere	1. To what extent are the structure and dynamics of the Uranian magnetosphere driven by the solar wind vs internal process?	Particles and fields measurements with radial and lat/lon sampling in magnetosphere.	mag/plasma/energetic particles
Magnetosphere; Moons	2. Are the major moons sources of magnetospheric plasma?	Mag and plasma measurements in vicinity of moons.	mag/plasma
Magnetosphere; Moons	3. To what extent are the major moons weathered by magnetospheric particles?	Particles and fields measurements in regions of magnetosphere associated with moons.	mag/plasma/energetic particles
Magnetosphere; Moons	4. Do any of the major moons have an exosphere? If so, how do they interact with the magnetosphere?	Magnetic field draping, exospheric pick-up ions.	mag/plasma
		Energetic particle absorptions due to interaction with exosphere.	energetic particle
Magnetosphere; Moons	5. Do the major moons have conducting subsurface oceans? If so, how does this affect moon-magnetosphere interactions?	Magnetic field measurements near the moons. Search for induced fields.	mag/plasma/energetic particles
Moons	6. Are any of the major moons currently geologically active? What are their geologic histories? What are the relative ages among the moons and among different units on each individual moon?	Determine whether NH_3-rich materials are associated with geologic landforms.	VIR spectrometer
		Surface changes compared to Voyager images.	camera
		If actively venting material: search for magnetic field draping, pick-up ions, energetic particle absorptions.	mag
		Limb images to search for plumes.	camera
			VIR spectrometer
		Image moons at better than 500 m/pixel.	camera
Moons	7. What are the internal structures of the major moons?	Measure the degree of flattening and tidal elongation in the shapes of the moons through limb pofile analysis.	camera
		Measure the moons low order gravity coefficients, where possible.	radio science
Moons	8. What are the endogenic and exogenic process that modify the surfaces of the moons? Is the low-albedo spectrally red material on the moons similar to other known materials such as the organics-rich material in the Saturnian system or prebiotic material possibly brought to the Earth by comets and asteroids?	Map the distribution of CO_2 ice and determine whether it is spatially associated with geologic landforms or whether its distribution is consistent with magnetospheric interactions.	camera and VIR spectrometer
		Map the distribution of spectrally red material on the major moons and determine whether it is spatially associated with geologic features.	camera and VIR spectrometer
		Determine the compositions of the irregular satellites and the spectrally red material on the major moons.	VIR spectrometer
Moons; Rings	9. What is the origin of the μ ring?	Measure the size and albedo of Mab (embedded in center of μ ring).	camera
		Determine the composition of Mab and the μ ring.	VIR spectrometer
		Image μ ring to search for gradients.	occultations
		Determine whether μ ring material spirals inward and mantles Puck and/or spirals outward and mantles Miranda.	Camera (color filters) and VIR spectrometer
Moons; Rings	10. Do the rings have the same composition as the nearby moons/moonlets?	Composition of both.	VIR spectrometer
Rings	11. What are the ring dynamics governing the Uranian rings?	Structure within the rings (propellers) for ring dynamics and clumping (embedded masses), within and outside the ring (scalloped edges), varying ring textures.	camera
Rings	12. What causes the structure of the narrow, dense rings? Are they self-sustaining?	Eccentricity gradients, azimuthal structure, occultations, normal modes on the edges.	camera

Table 1 – Science objectives for the UMaMI mission and the corresponding measurements and instruments. "Major moons" refers to Miranda, Ariel, Umbriel, Titania, and Oberon; "mag"=magnetometer; "plasma"=plasma spectrometer; "energetic particles"=energetic particle detector.

References: [1] Stryk, T. and Stooke, P.J. (2008) *LPSC, 39,* Abstract #1362. [2] Agnor, C.B. and Hamilton, D.P. (2006) *Nature, 441*, 192. [3] Hofstadter, M. et al. (2017) *Ice giants pre-decadal survey mission study report*, JPL D-100520. [4] Jarmak, S. et al. (2020) *Acta Astronautica*. [5] Elder, C.M. et al. (2018) *Acta Astronautica, 148,* 1-11.

Part of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.