JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

# Cross-NASA Divisional Relevance of an Ice Giant Mission

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*The Johns Hopkins University Applied Physics Laboratory*

# Outline

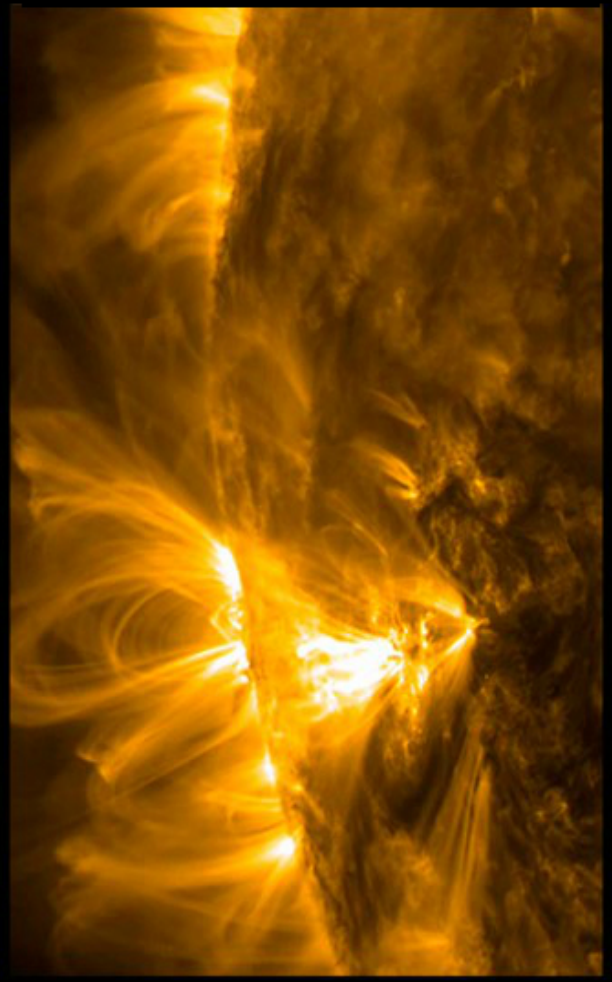
- Overview of NASA Science Divisions
- Voyager: An exemplar
- Cross-disciplinary observations from other missions
- Challenges
- Specific opportunities at the Ice Giants
- Summary

# NASA Science Divisions

# NASA SCIENCE MISSION DIRECTORATE

## EARTH SCIENCE

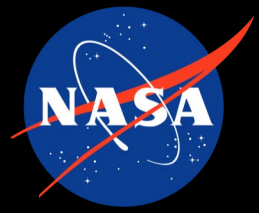
## HELIOPHYSICS



## PLANETARY SCIENCE

## ASTROPHYSICS

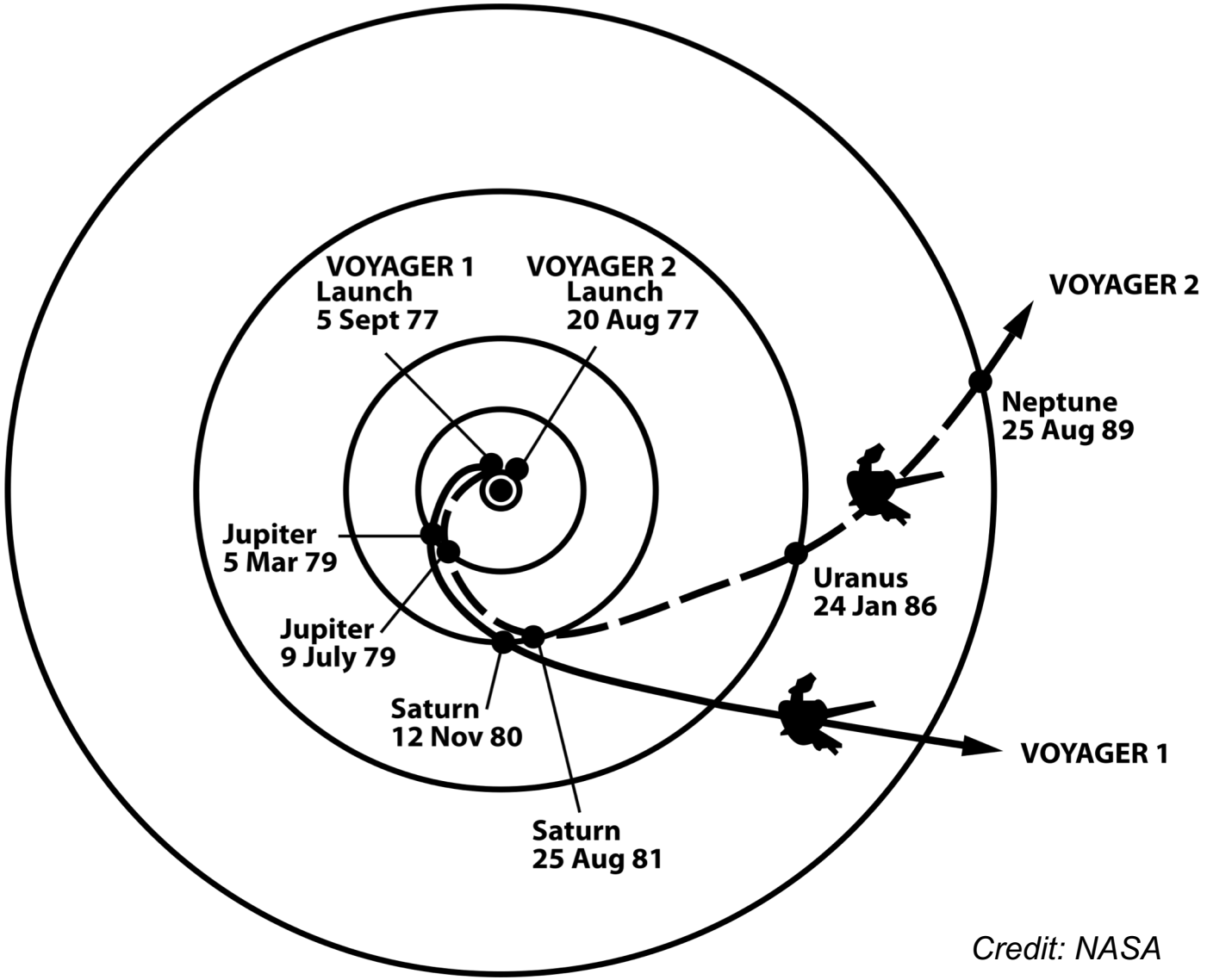
# NASA SCIENCE MISSION DIRECTORATE




| EARTH SCIENCE | HELIOPHYSICS | PLANETARY SCIENCE | ASTROPHYSICS |
|---|---|---|---|
| *Remote Sensing* | | *Remote Sensing* | *Remote Sensing* |
| *Climate* | | *Climate* | |
| | *Plasma Physics* | *Plasma Physics* | *Plasma Physics* |
| | *Acceleration Processes* | *Acceleration Processes* | *Acceleration Processes* |
| | *Exoplanets* | *Exoplanets* | *Exoplanets* |
| | *Star – ISM Interactions* | | *Star – ISM Interactions* |
| | *Planet-SW Interactions* | *Planet-SW Interactions* | |
| | *Space Weather* | *Space Weather* | *Space Weather?* |
| *Surfaces & Interiors* | | *Surfaces & Interiors* | |
| | *Moon-M'sphere Inter.* | *Moon-M'sphere Inter.* | |
| *Atmospheres* | *Atmospheres* | *Atmospheres* | |
| | *Dust Interactions* | *Dust Interactions* | *Dust Interactions* |

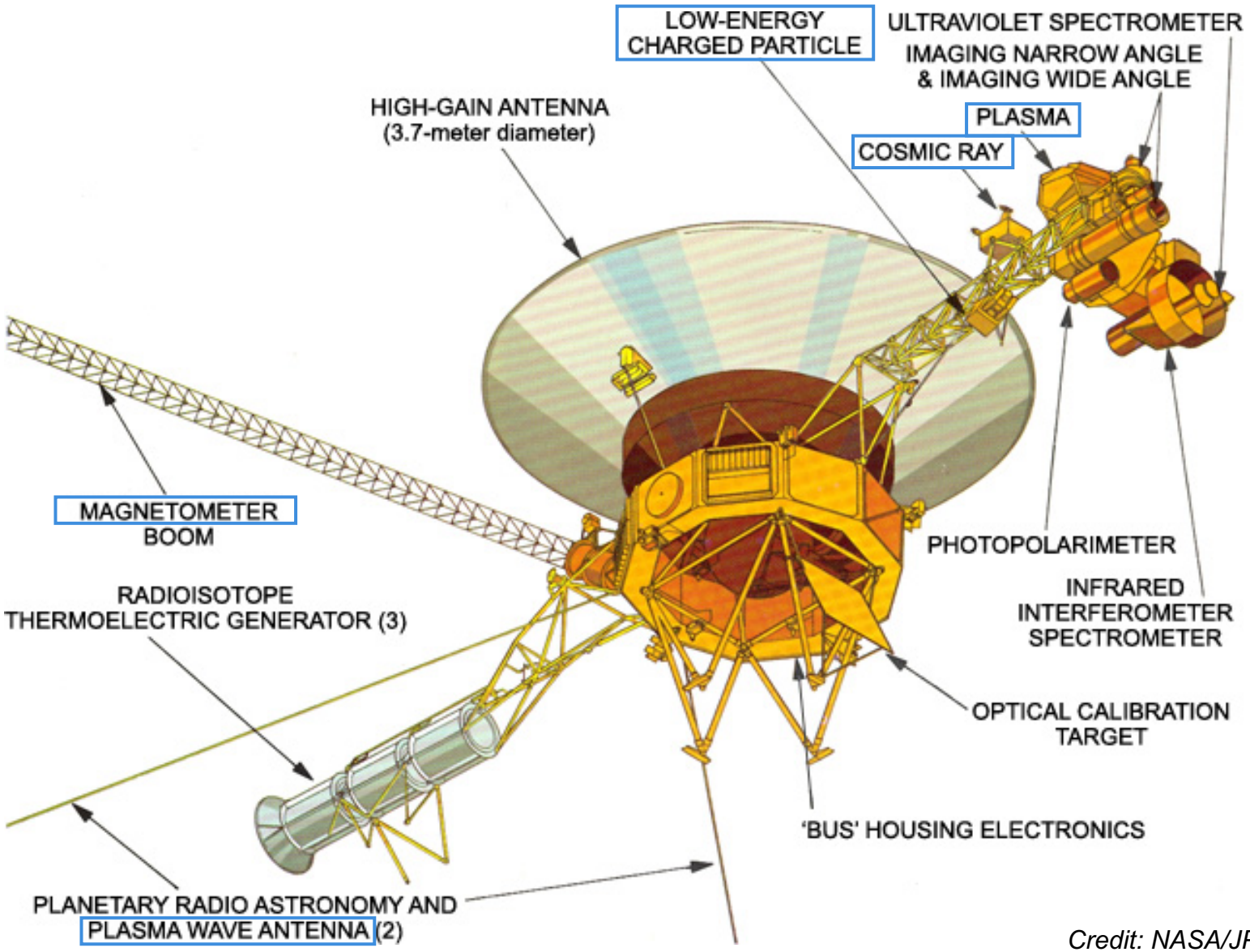
# Voyager:
# The “prototype” cross-divisional mission

# A “once-in-a-lifetime” opportunity




*Credit: NASA*

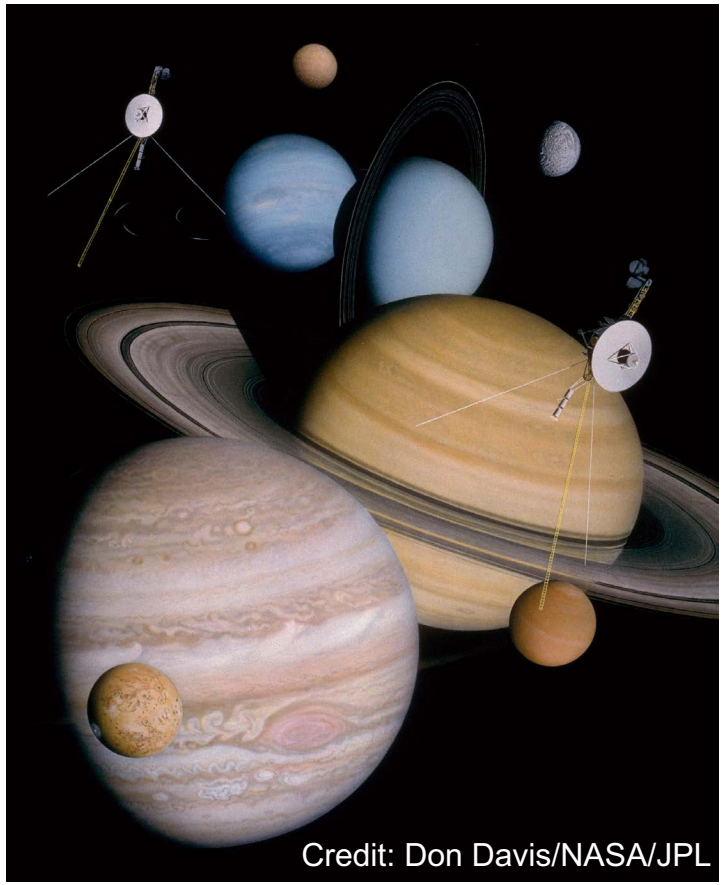
# Voyager's payload included both remote sensing & in-situ instruments



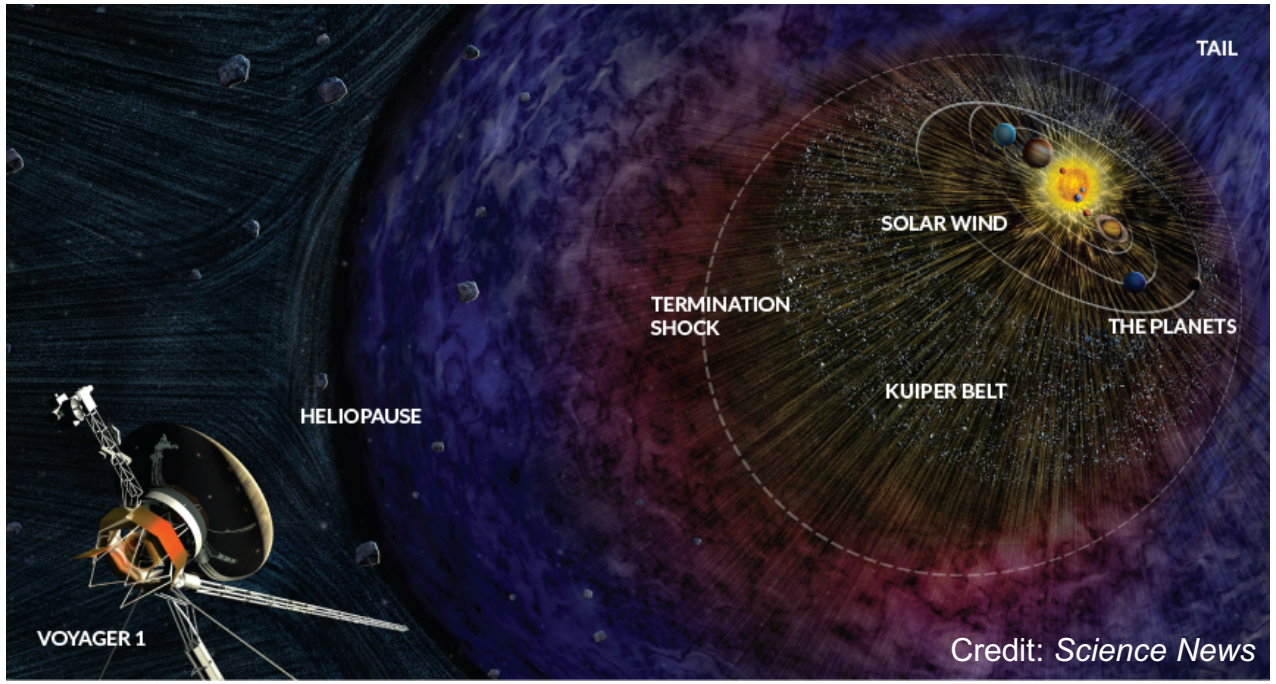

*Credit: NASA/JPL*

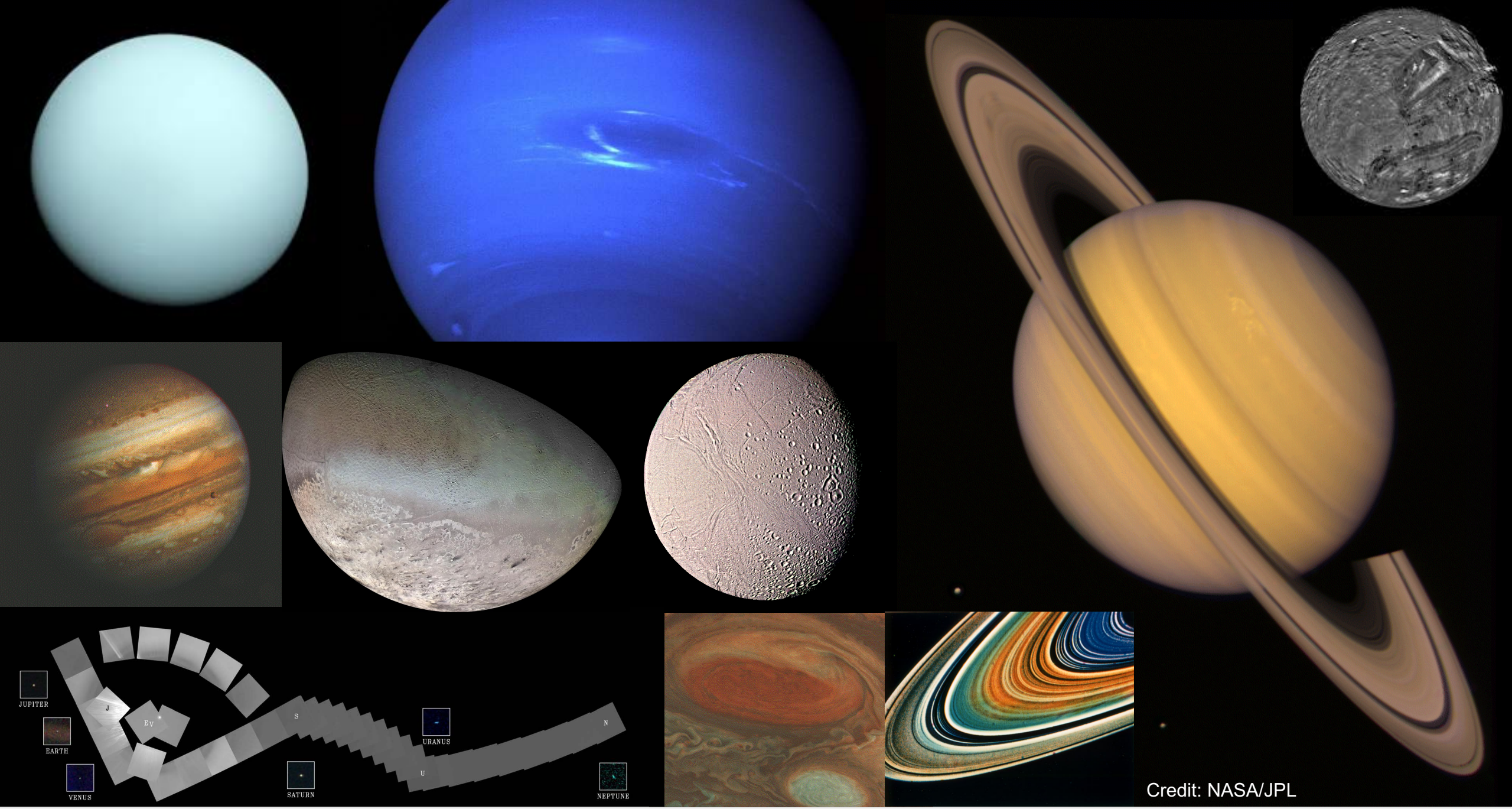
# This enabled foundational contributions to Planetary Science, Heliophysics, & Astrophysics

Voyager Mission




Voyager Interstellar Mission



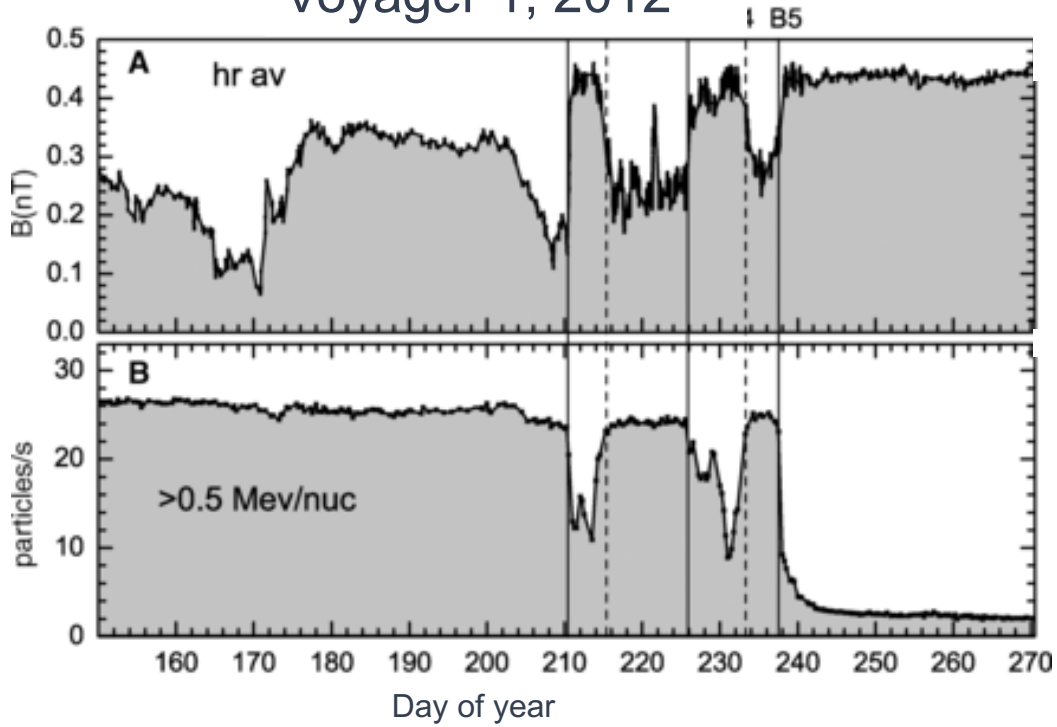

JUPITER
EARTH
VENUS
J
Ev
S
SATURN
URANUS
U
N
NEPTUNE
Credit: NASA/JPL

# Boldly going where no spacecraft have gone before…

Magnetic Field

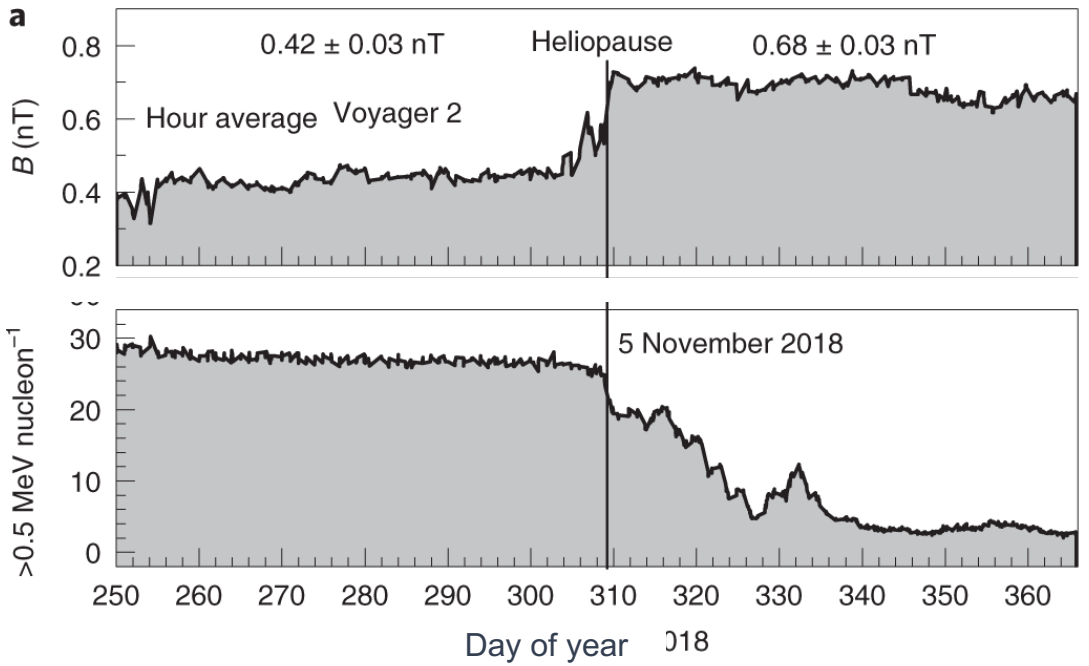
Anomalous Cosmic Rays

## Voyager 1, 2012




Burlaga et al., *Science,* 2013

## Voyager 2, 2018



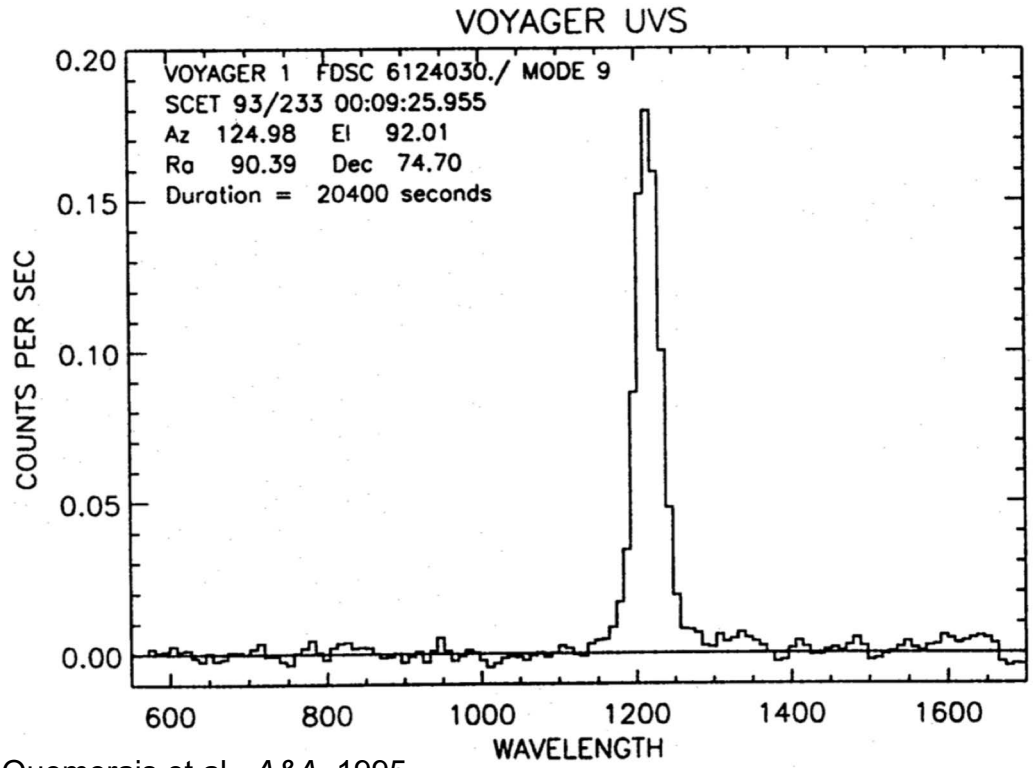

Burlaga et al., *Nature Astro.,* 2019

**The Voyagers provided our first (and only) in-situ observations of the termination shock, heliosheath, heliopause, and local interstellar medium**

*Similar from *Pioneer Venus, Galileo, Cassini, MESSENGER, etc.*

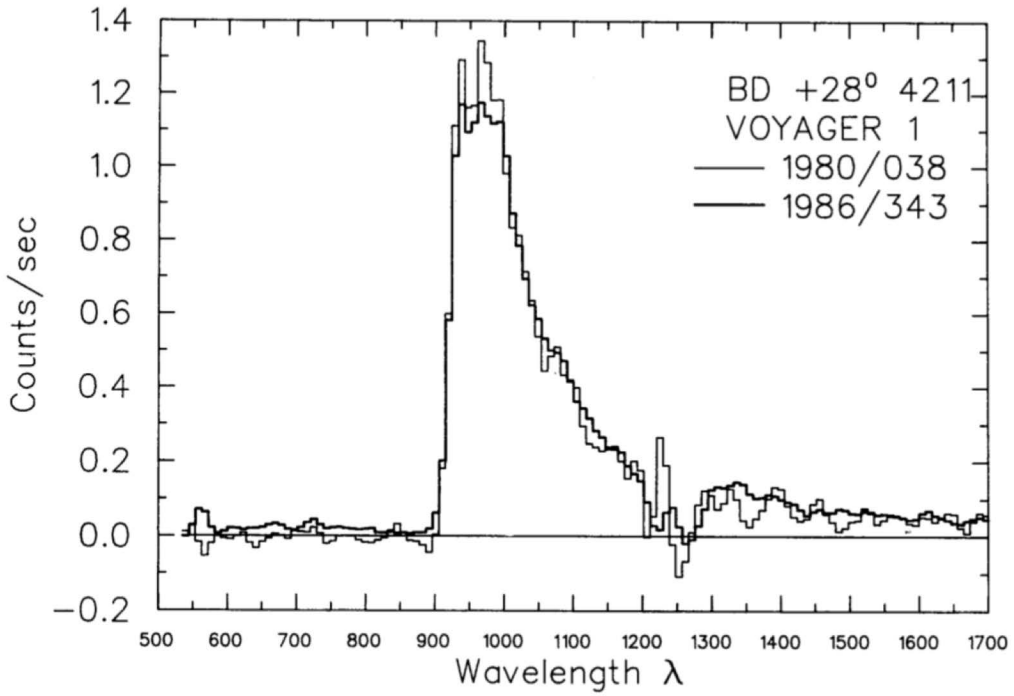
# Astronomy from Voyager

## Interstellar Hydrogen*



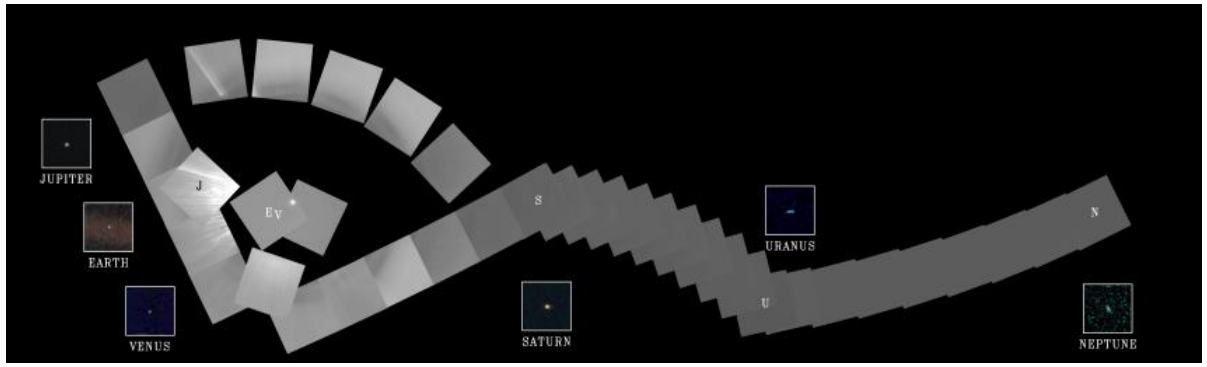

Quemerais et al., *A&A,* 1995

## Stellar Occultations

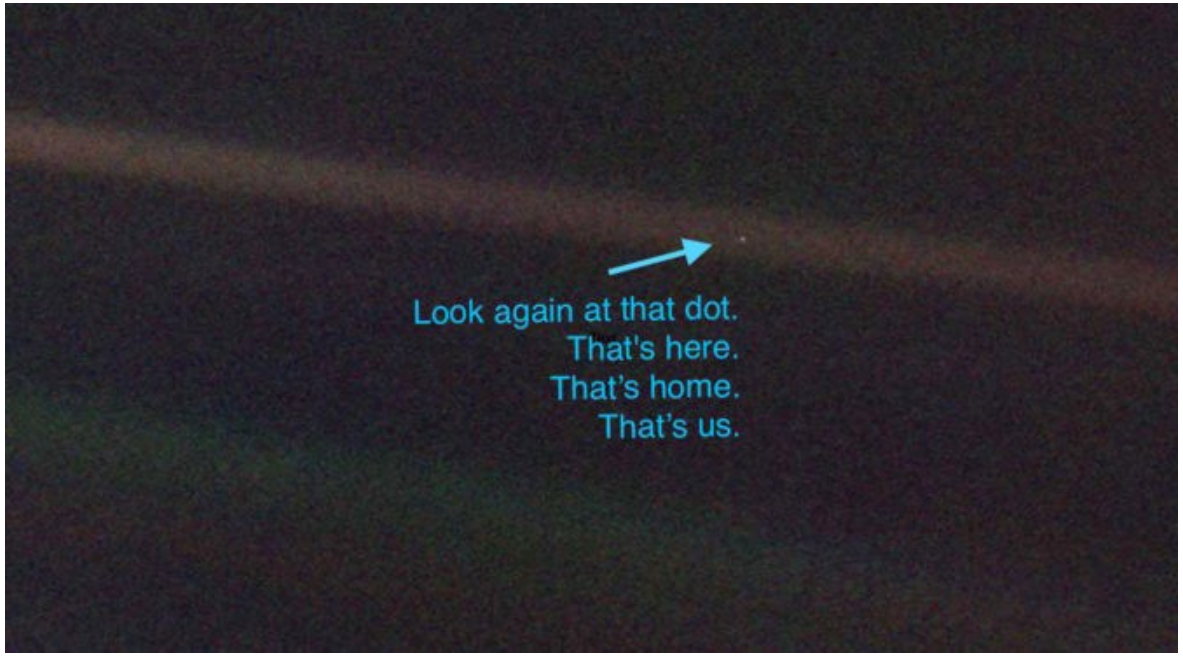



Holberg et al., *ApJ,* 1991

# And also put humanity into universal perspective




*Credit: NASA/JPL*

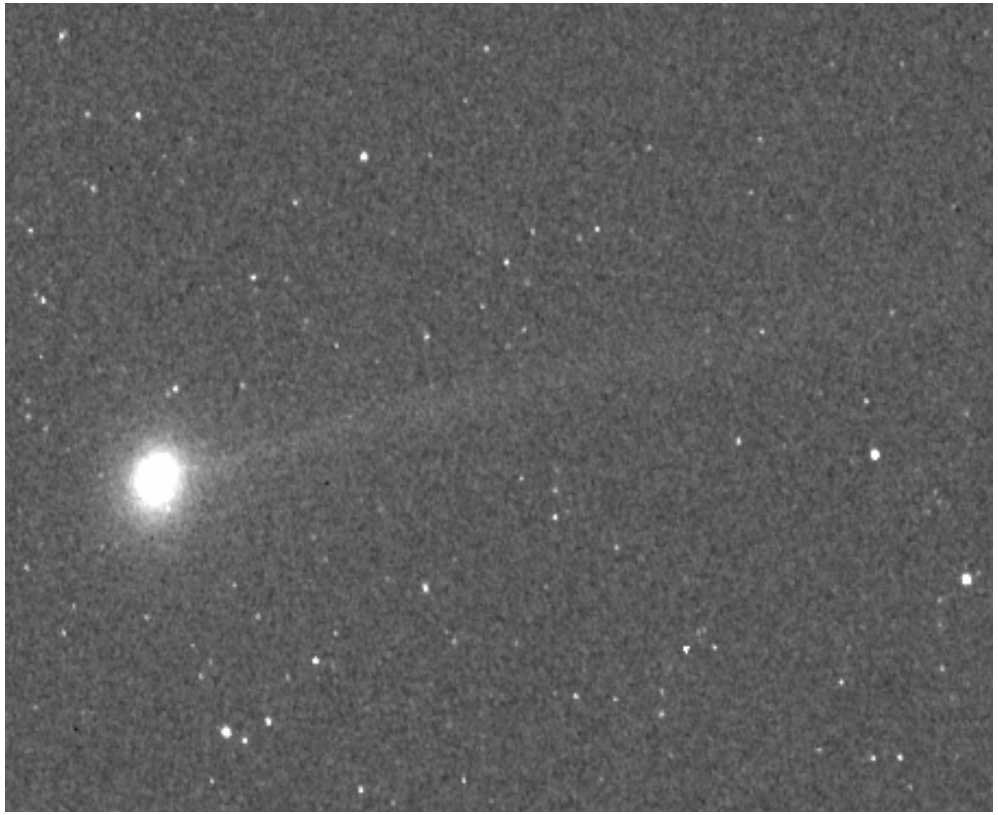



*Credit: NASA/JPL*

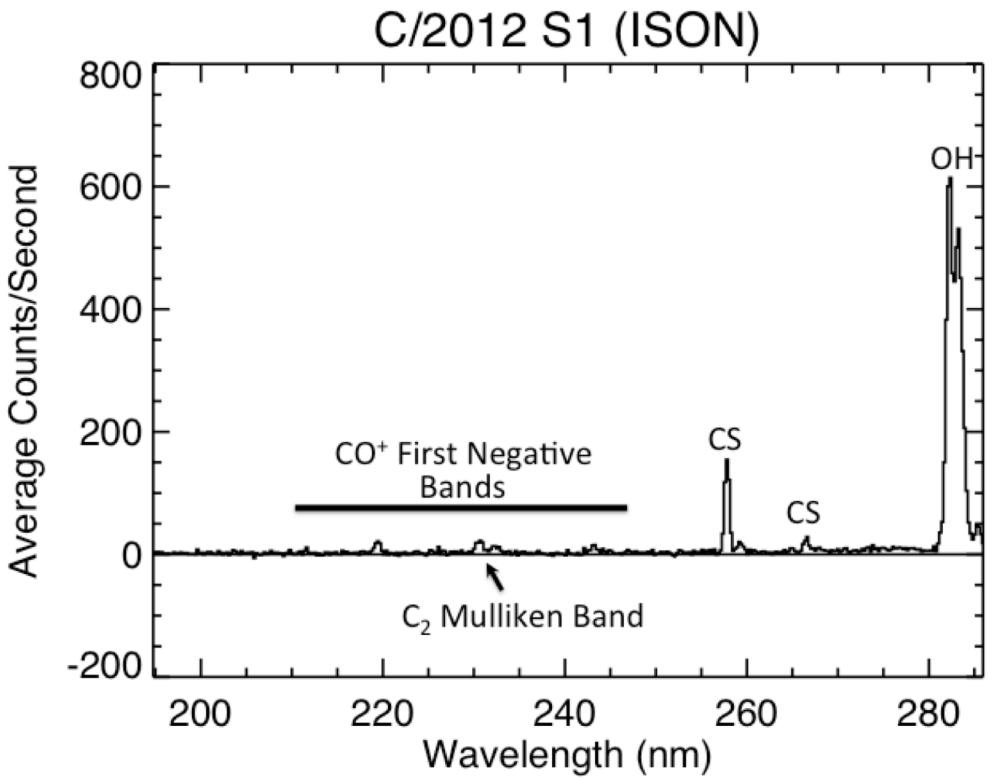
**The Voyagers were designed for planetary encounters, not the solar wind, interplanetary space, or astronomy – *what could/would we do if we consciously planned for cross-disciplinary science*?**

# Cross-divisional research from other missions

# MESSENGER UV imaging



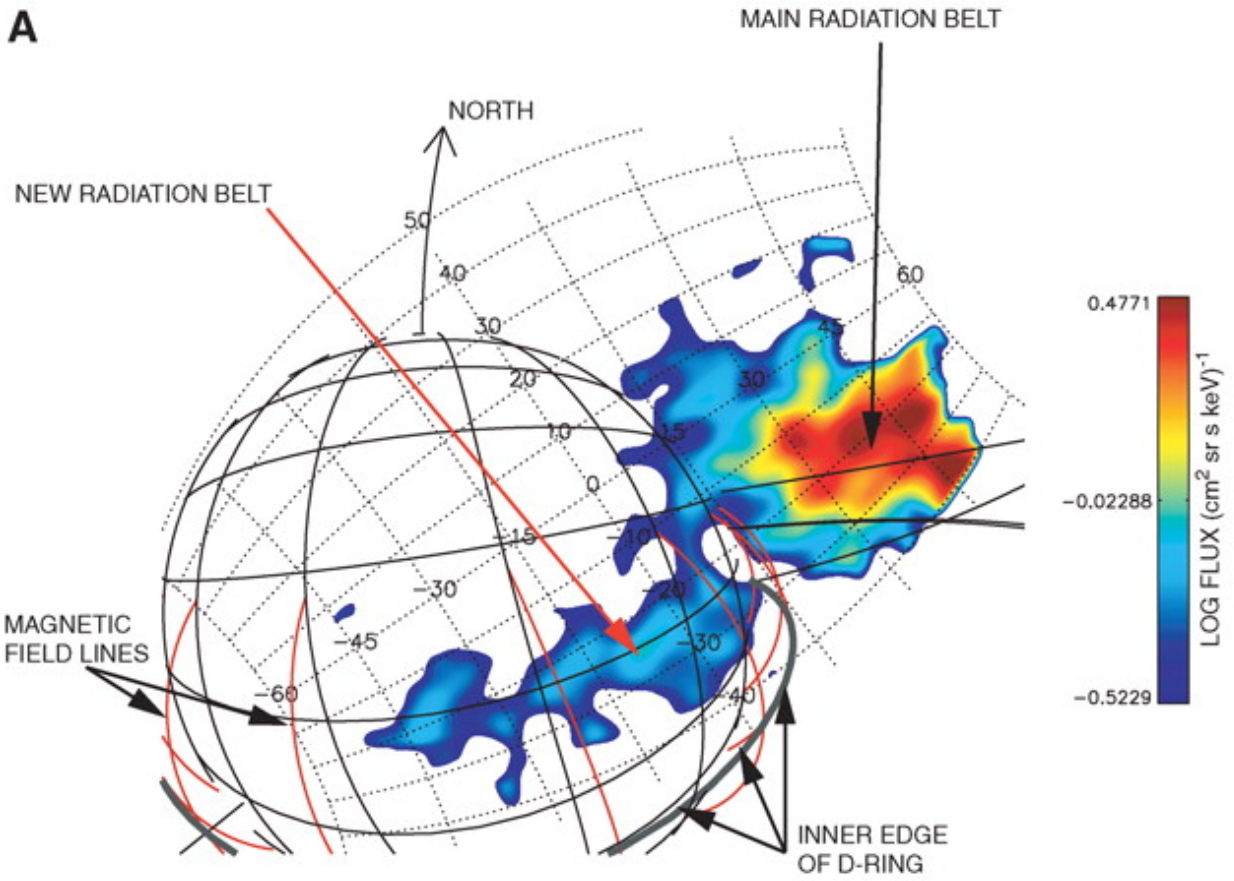
*Courtesy: R. Vervack, JHU/APL*

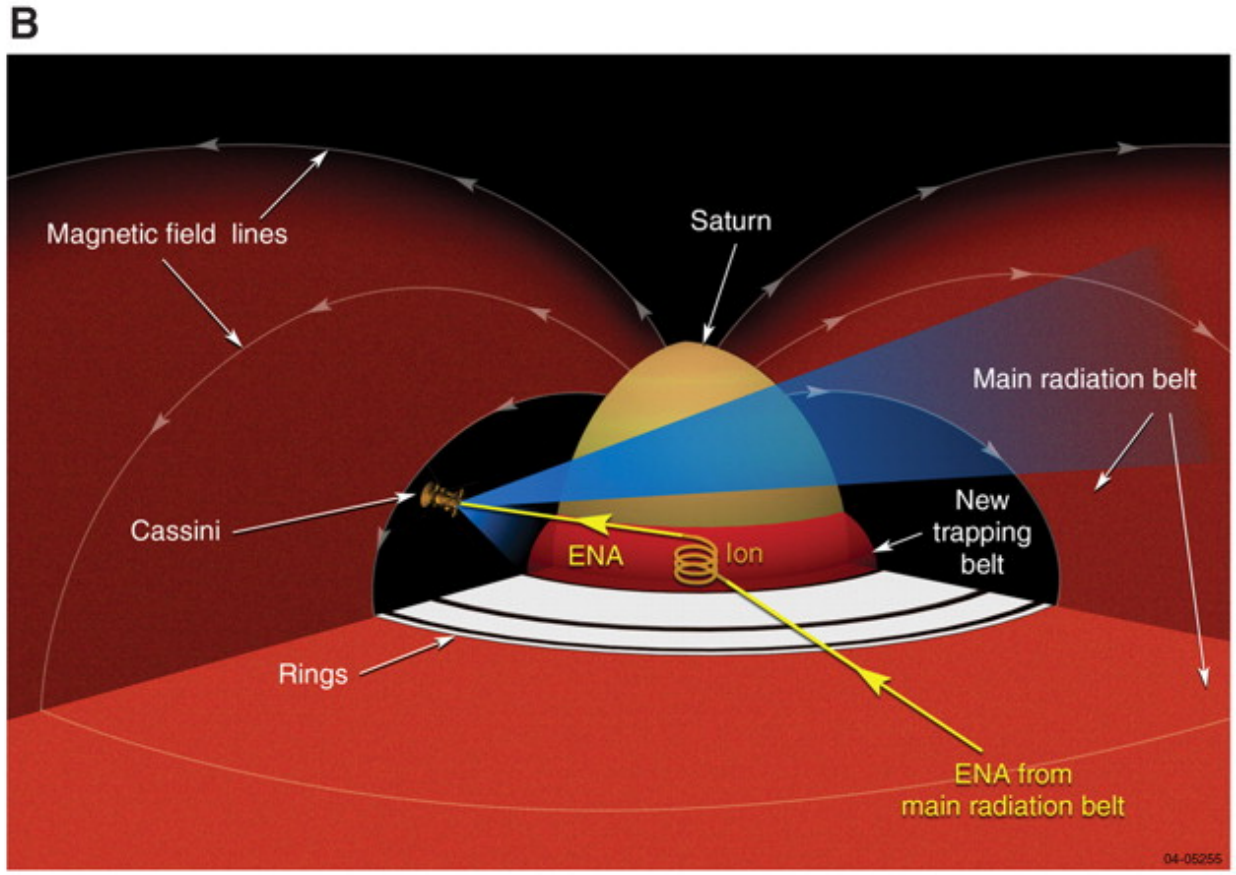



*Courtesy: R. Vervack, JHU/APL*

**MESSENGER's highly elliptical orbit provided long periods away from Mercury when serendipitous comet imaging could be obtained**

# Cassini/INCA – Saturn magnetospheric science

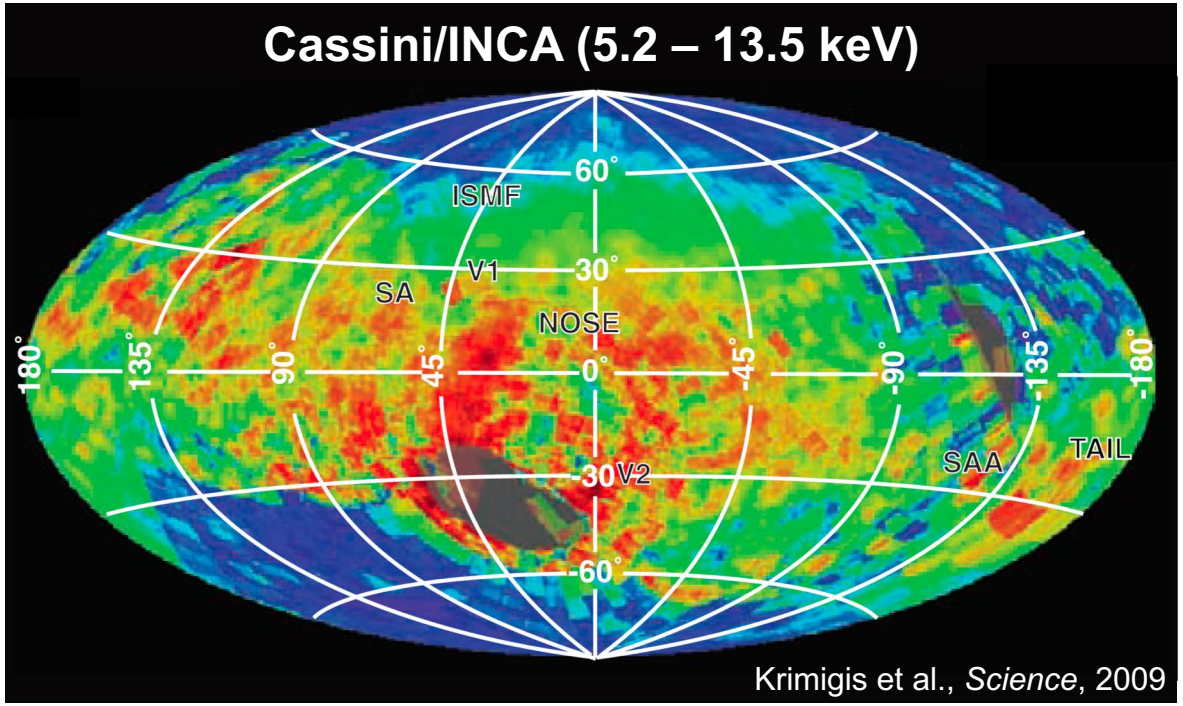


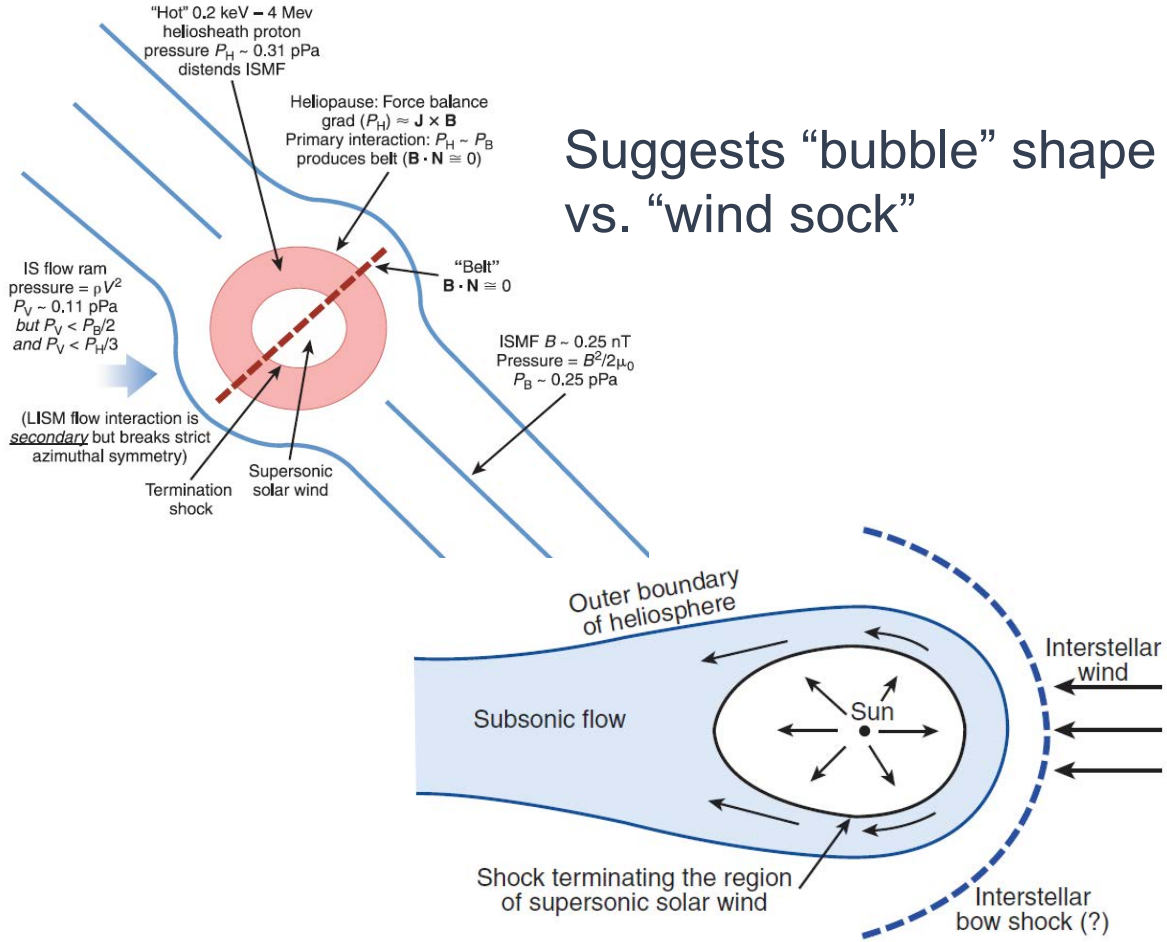

Krimigis et al., *Science,* 2005

**INCA was designed to image energetic neutral atoms (ENAs) within Saturn's magnetosphere**

# Cassini/INCA – critical heliospheric contributions




"INCA Belt"

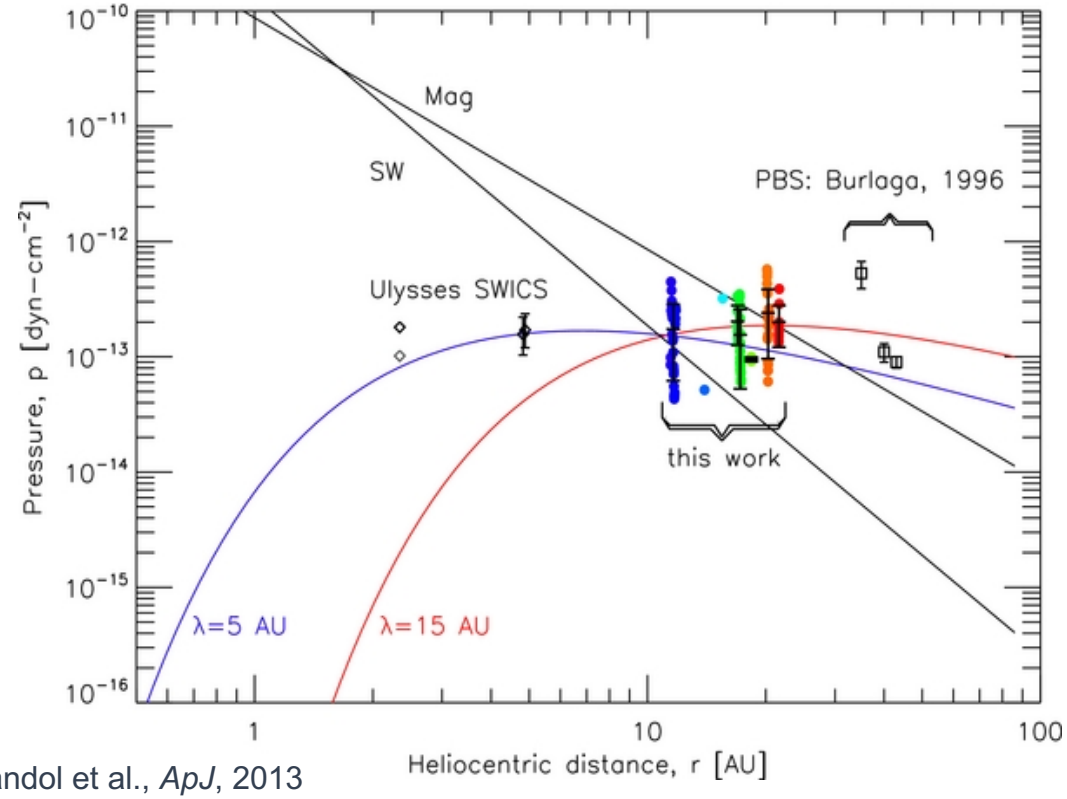



Suggests "bubble" shape vs. "wind sock"

**INCA's high-energy imaging of the heliospheric boundary reignited debate within the Heliophysics community regarding the shape of the heliosphere**

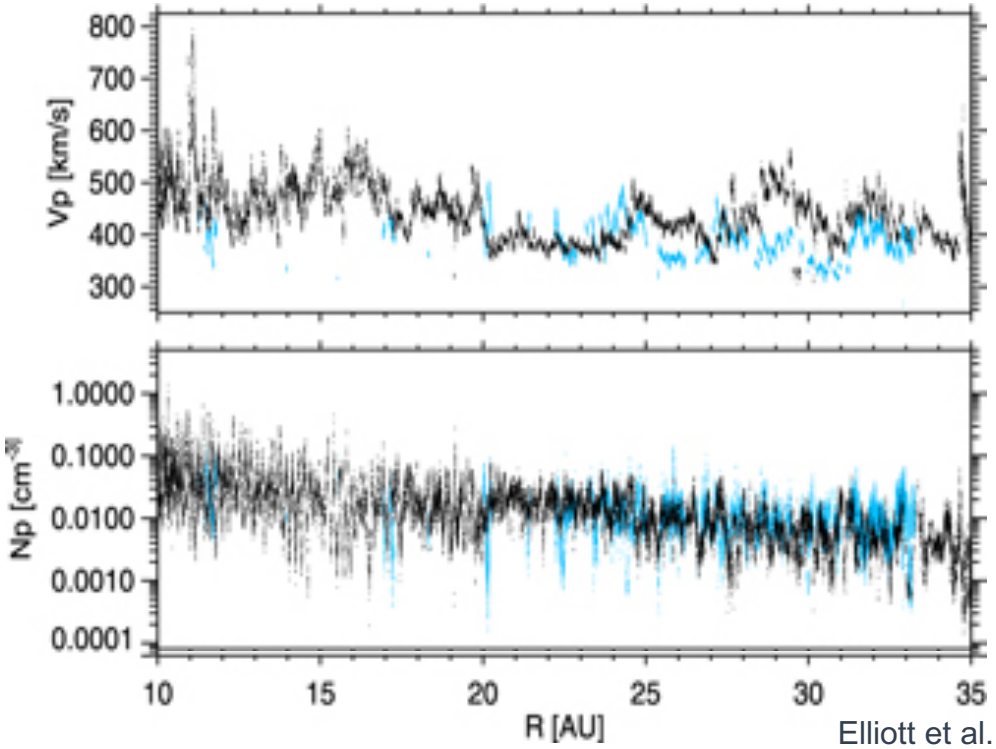
# New Horizons - solar wind studies

***Study of pickup ionization vs. distance***



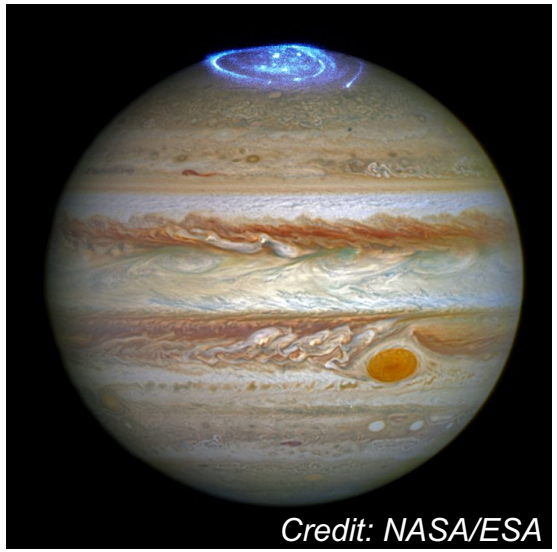

Randol et al., *ApJ*, 2013

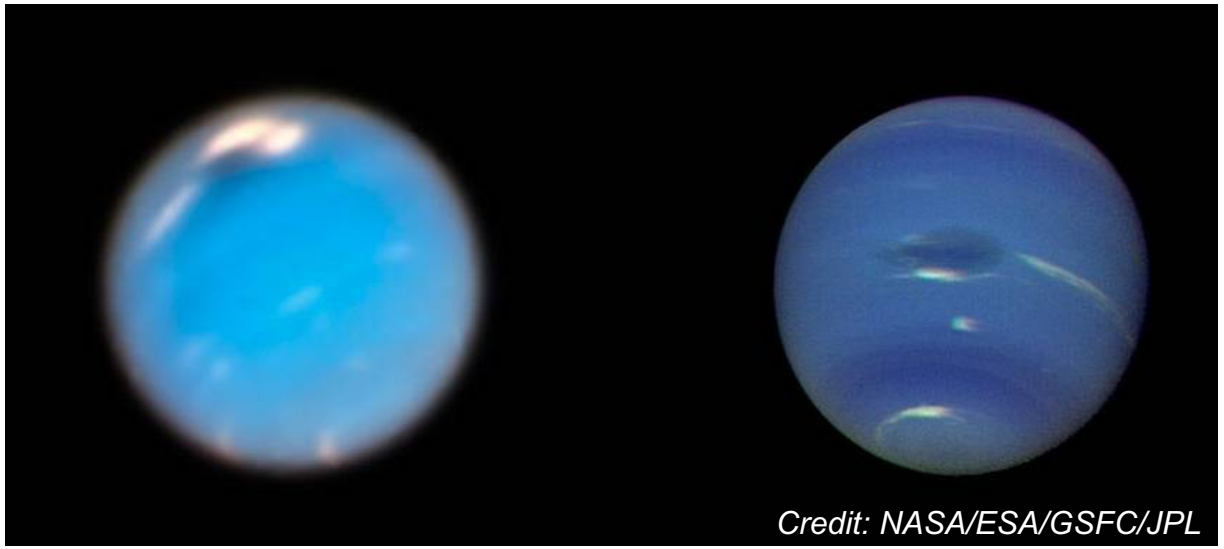
***Study of solar wind evolution vs. distance***

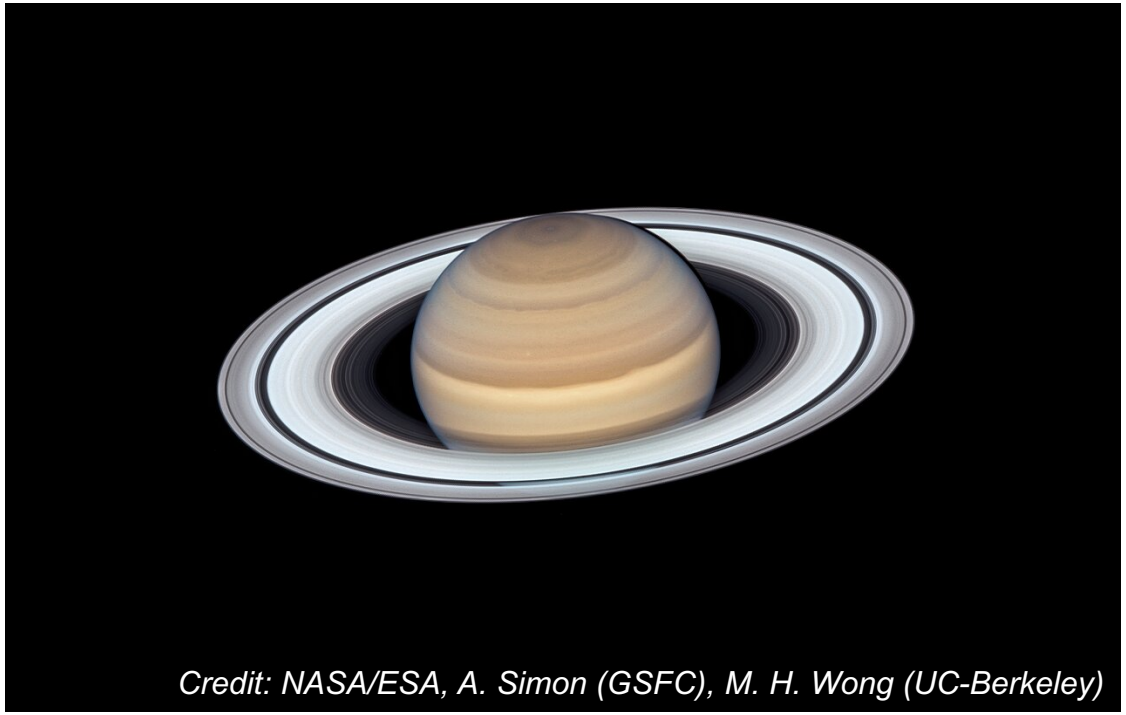


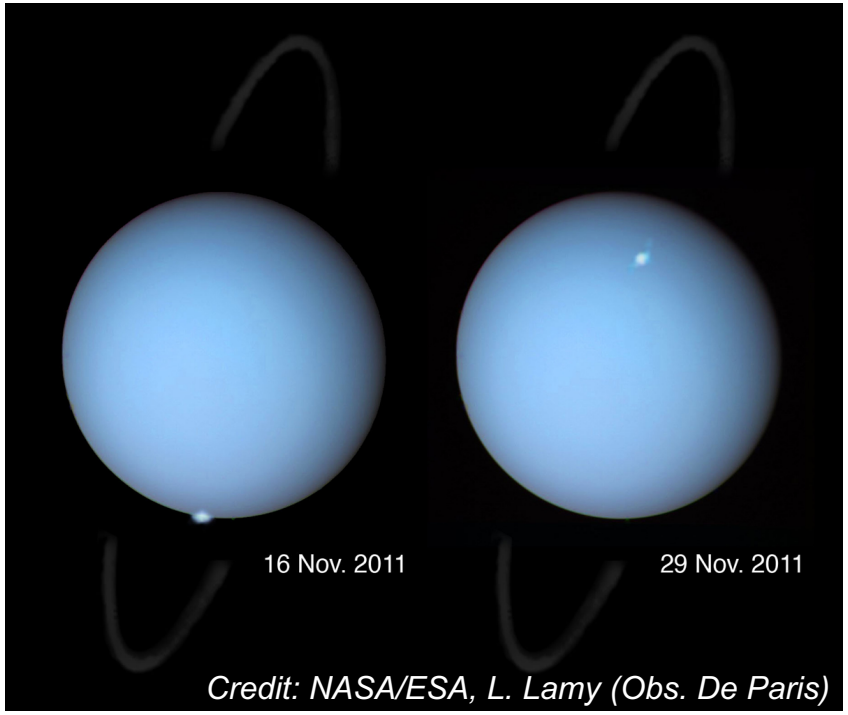

Elliott et al., *ApJS*, 2016

# Hubble


Credit: NASA/ESA


Credit: NASA/ESA/GSFC/JPL

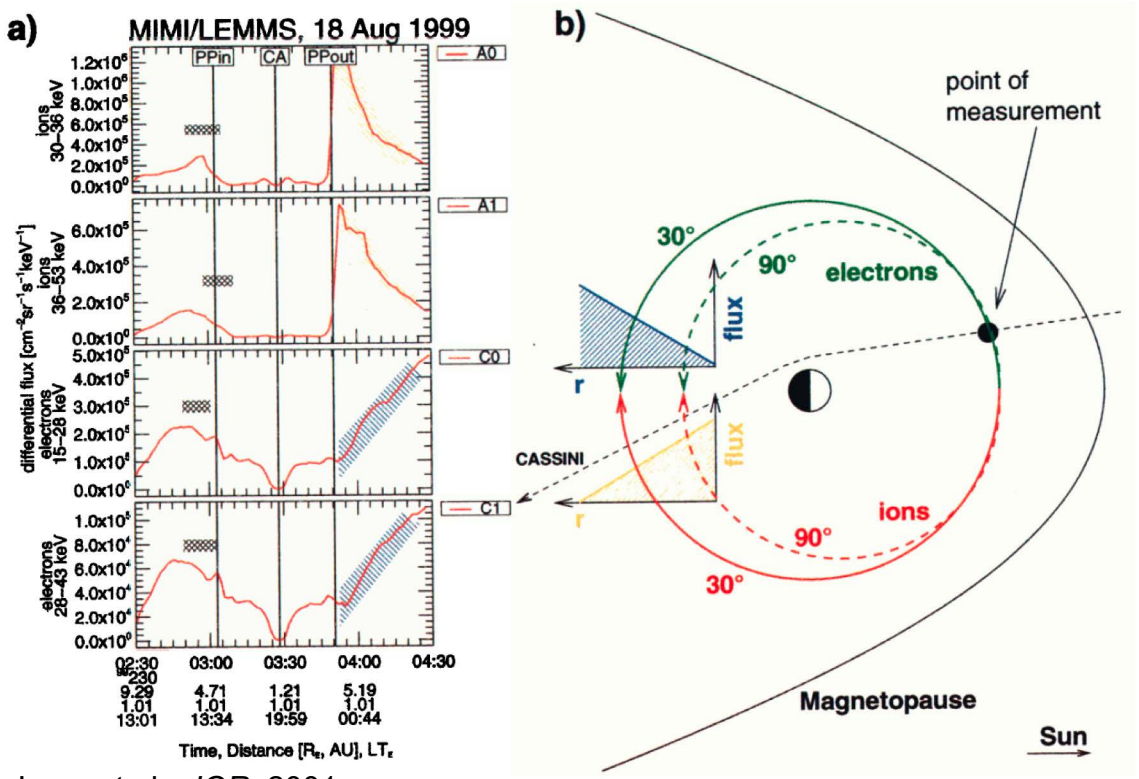

Credit: NASA/ESA, A. Simon (GSFC), M. H. Wong (UC-Berkeley)



Credit: NASA/ESA, L. Lamy (Obs. De Paris)

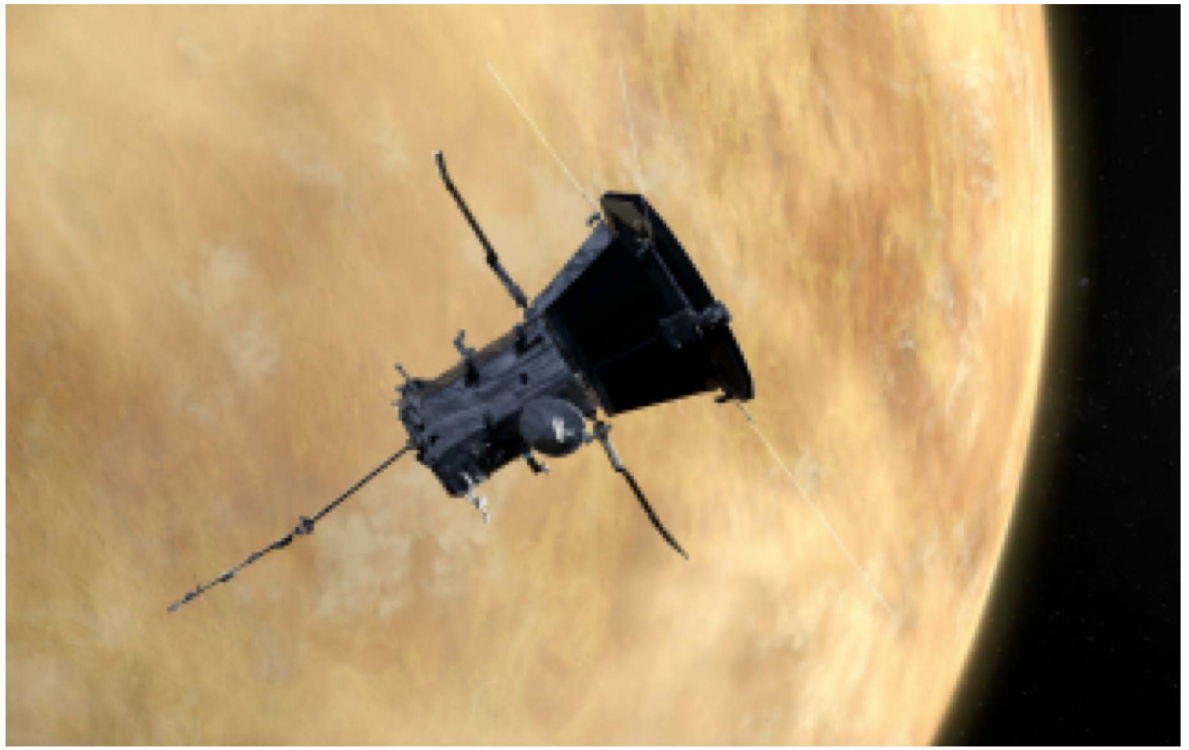
# Flyby opportunities

## *Cassini @ Earth*




Lagg et al., *JGR*, 2001

## *Parker Solar Probe @ Venus (TBD)*



Credit: NASA/JHU-APL

**Flyby opportunities can be doubly beneficial –**
**allowing for crucial calibration points as well as providing potentially new science**

# Challenges

# Why don’t we do more of this?

**Logistics**:

- Historically rather stove-piped structuring of funding within divisions
- Lack of support for science outside of mission scope/discipline – selected missions are vulnerable to descope which makes advocating to broaden mission scope post-selection particularly challenging

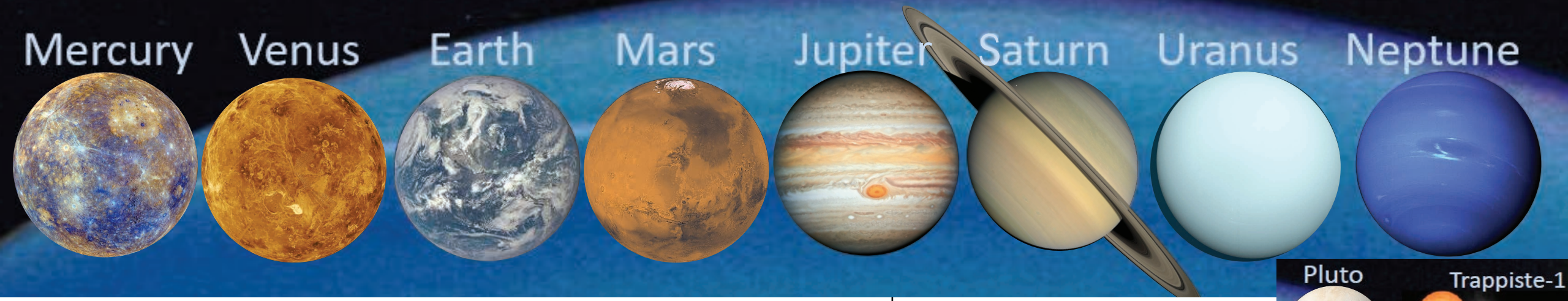
**Culture**:

- Logistics above lead to lack of confidence in the community to conceive of or strongly advocate for cross-divisional concepts
- Community resistance/perception of “us” versus “them”
- “Stay in your lane” mentality
  - These are improving and the community would be well-served to encourage and advocate for progress

# How do we overcome these?

1. Communicate across divisions & disciplines/communities
2. Speak up and support cross-disciplinary opportunities & studies
3. Take advantage of existing infrastructure that could be leveraged (i.e. technology demonstration opportunities, rideshares, missions of opportunity, etc.)
4. Push for including (and funding!) cross-disciplinary "measurements of opportunity" or augmentation on future missions *from the start*

# ‘It Takes a Village.’ Collaborative Outer Planet Missions.





WHITE PAPER FOR THE
HELIOPHYSICS SCIENCE DECADAL SURVEY, 2013-2023.

**The Case for Exploring Uranus’ Magnetosphere.**

This White Paper is endorsed by 66 scientists (listed at the end) from the USA and Europ
of whom are early career scientists representing the driving force of the heliophysics con

WHITE PAPER FOR EXOPLANET SCIENCE STRATEGY 2018

**Solar System Ice Giants: Exoplanets in our Backyard.**

(Cover page)

Co-authors and endorsers:
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**Advancing Space Science Requires NASA Support for Coordination Between the Science Mission Directorate Communities**

*White paper submitted as a State of the Profession paper to the Astro2020 Decadal Survey. It will be submitted next to the Planetary and Heliophysics Decadal Surveys.*

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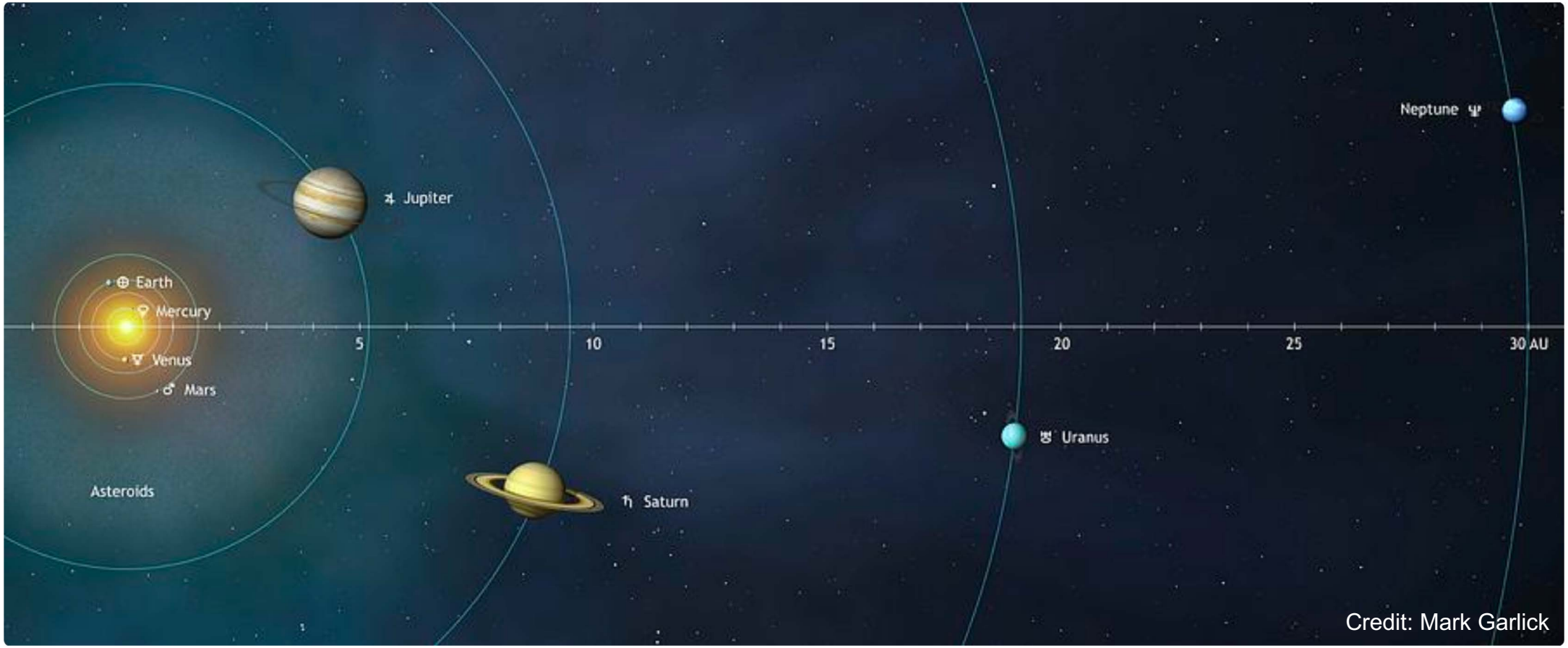
Abigail Rymer[1], Jason Kalirai[1], Robert Allen[1], Alice Cocoros[1], Kevin Stevenson[2], Dana Hurley[1],

Using the Interstellar Probe to Decipher Exoplanet Signatures of Our Planets from the Very Local Interstellar Medium

Pontus C. Brandt, Ralph McNutt, Michael Paul, Carey Lisse, Kathleen Mandt, Abigail Rymer

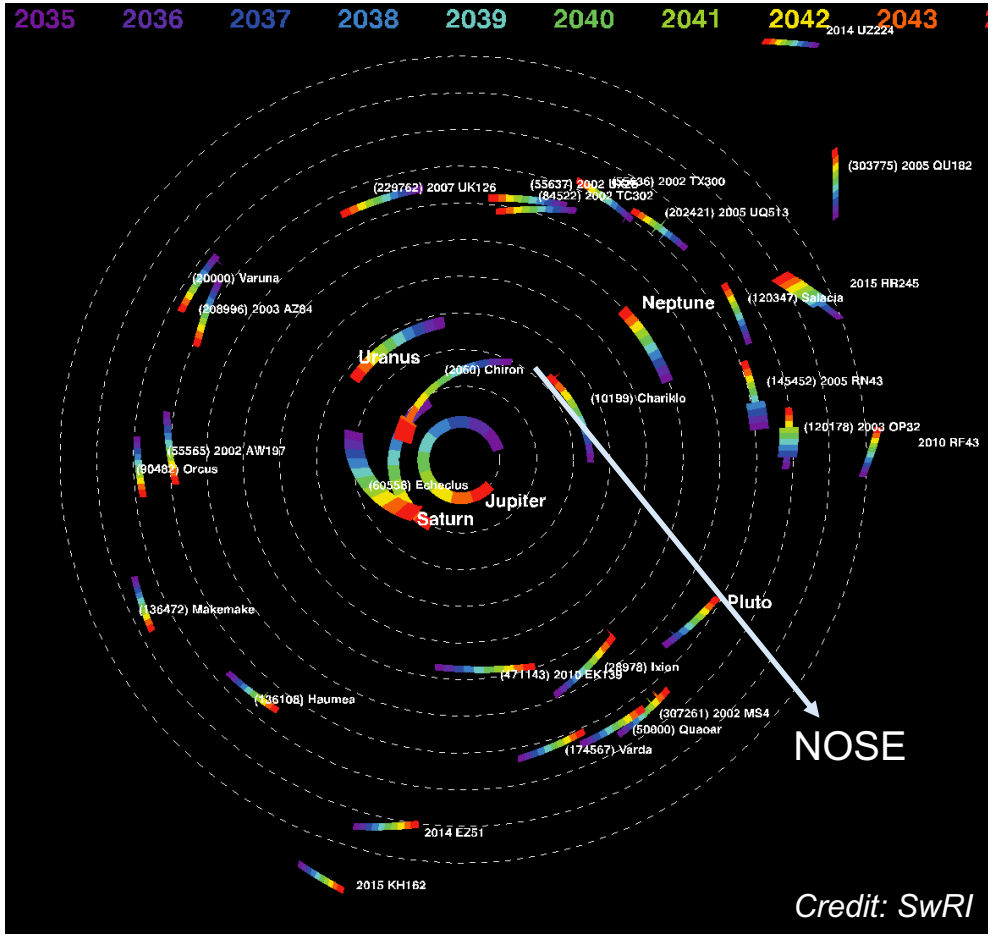
# Opportunities at the Ice Giants

# It’s a long way to the Ice Giants

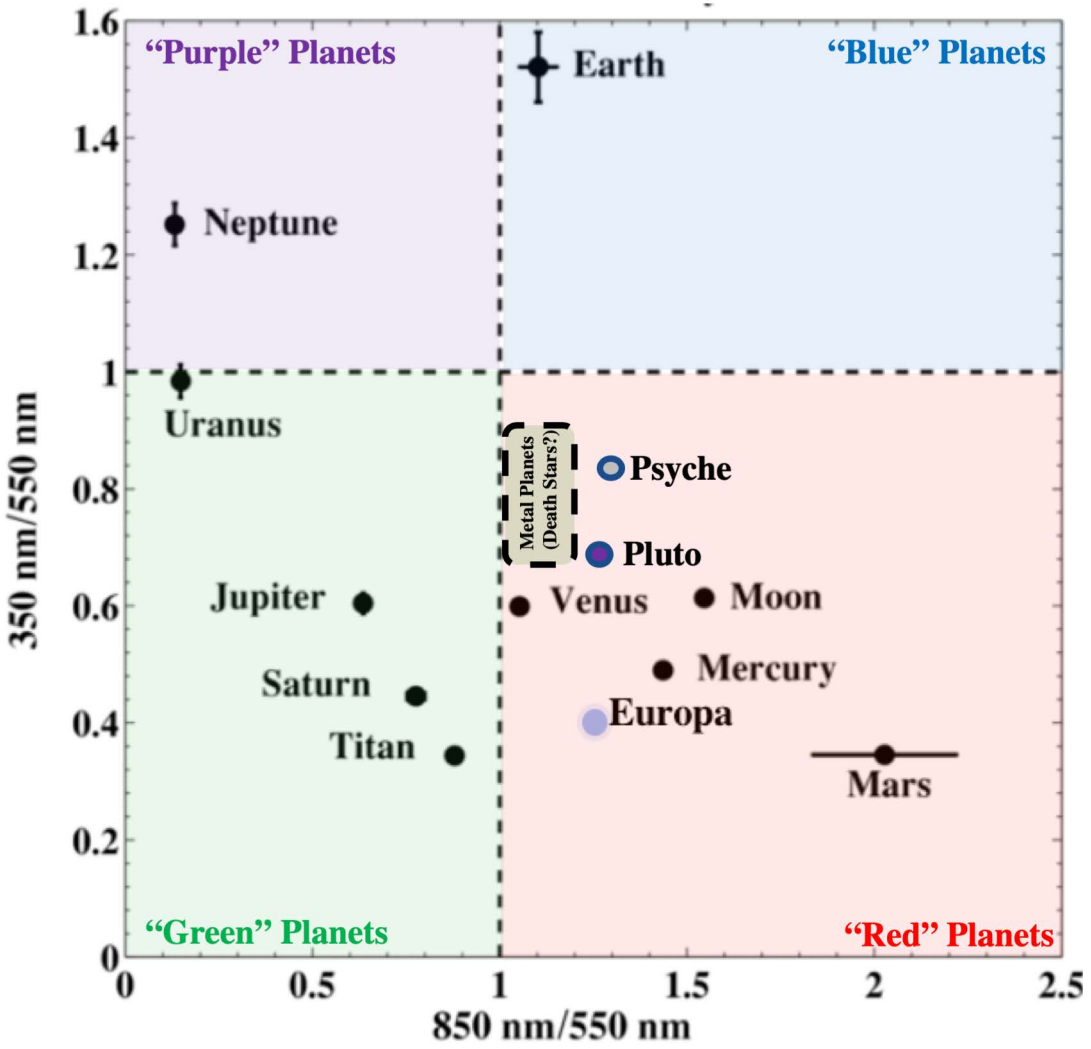


# Advantage 1: Unique Perspective

## *Stereoscopic imaging of the Heliosphere*



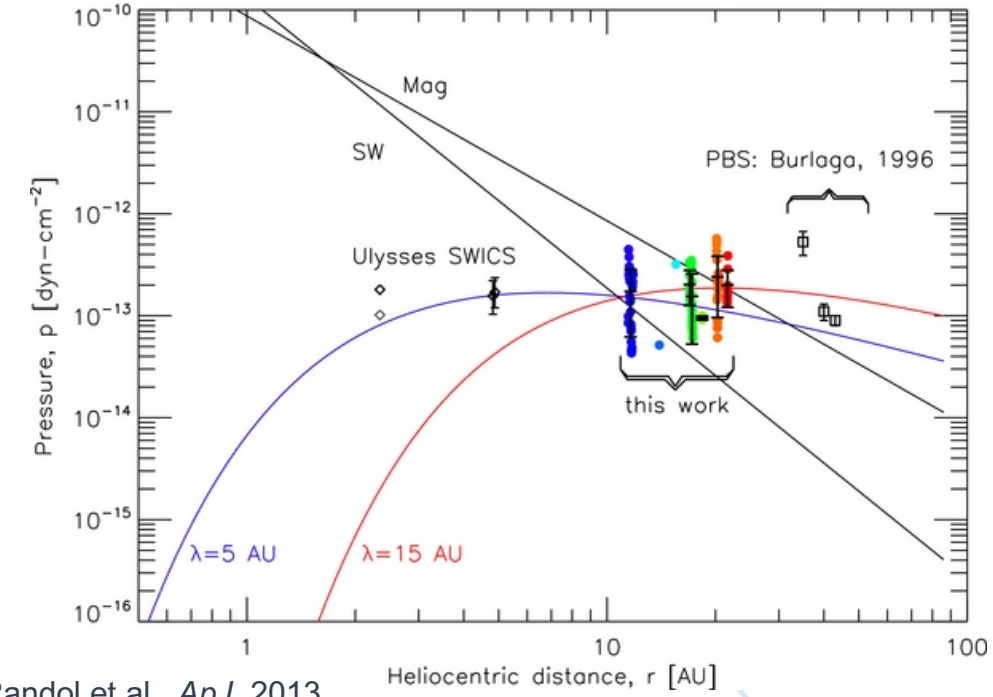

## *Imaging our Solar System as Exoplanets*




*From N. Izenberg, JHU/APL [modified from Crow et al., ApJ, 2011]*

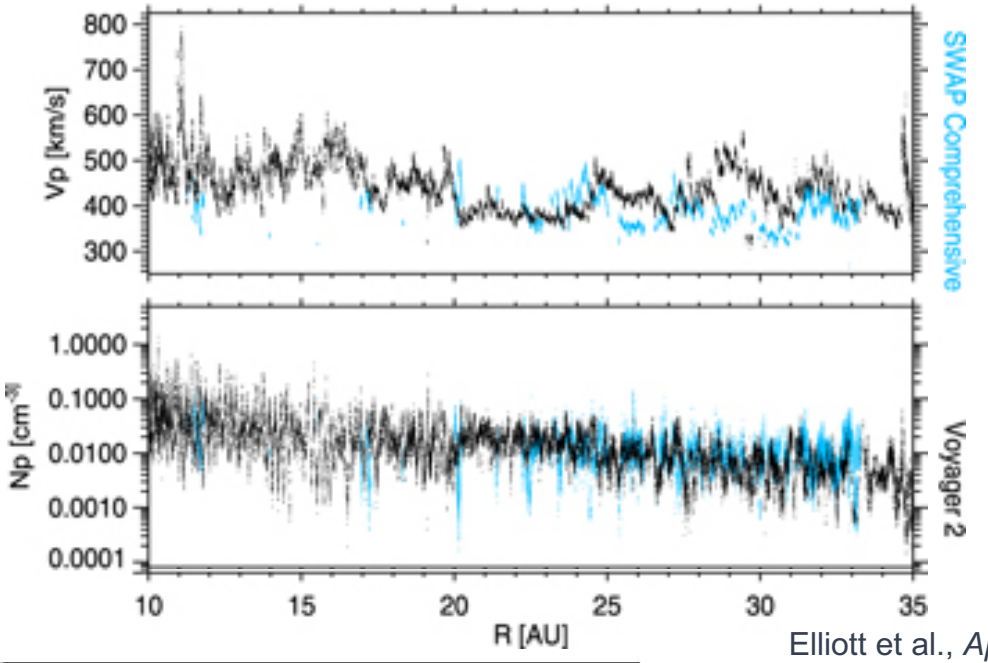
# Advantage 2: Long-cruise duration

## *Study of pickup ionization vs. distance*

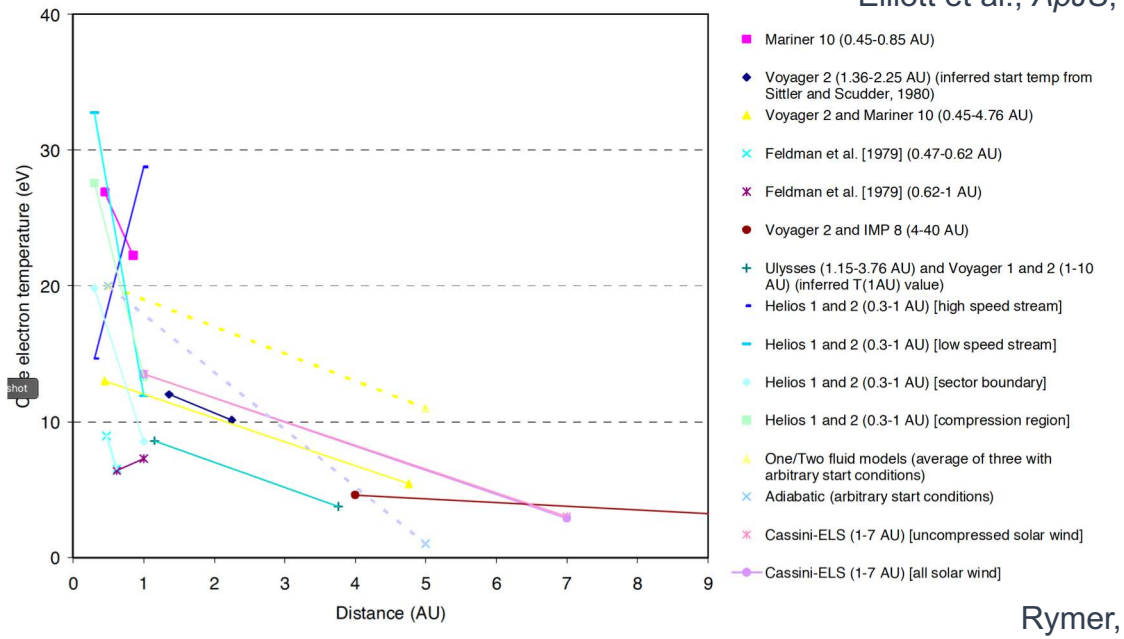



Randol et al., *ApJ*, 2013

## *Study of solar wind evolution vs. distance*

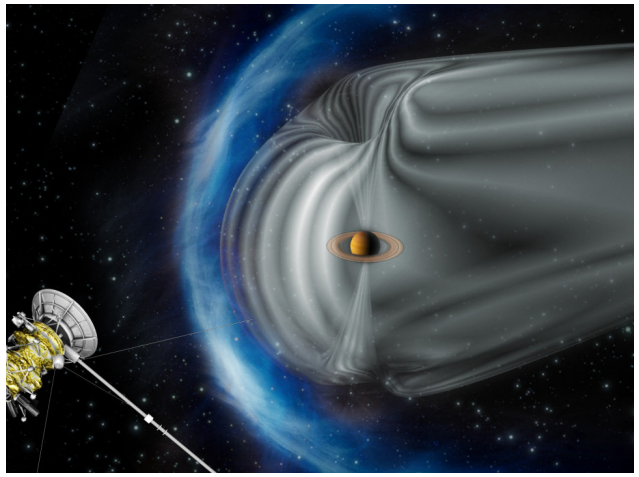



Elliott et al., *ApJS*, 2016



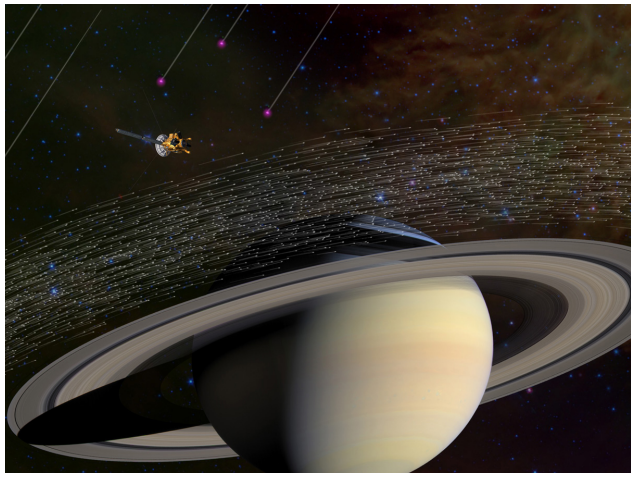

Rymer, 2004

# Include instrumentation beneficial to multiple divisions



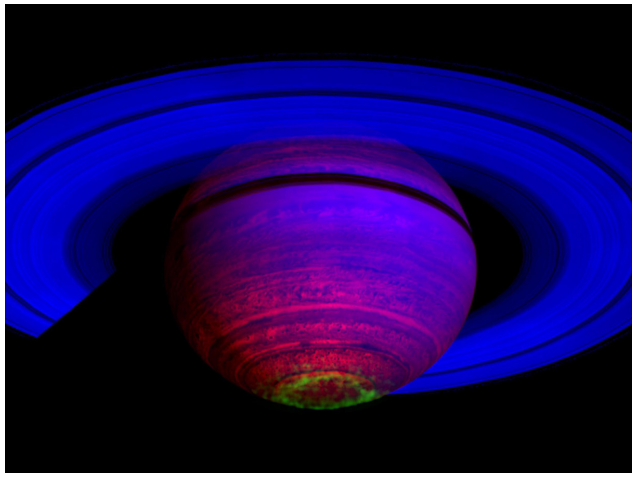
## Particles & Fields

- **Planetary magnetospheres/aurora**
- **Planetary dynamos/interiors**
- **Satellite surface weathering**
- **Planetary rings**
- **Ocean worlds**
- Exoplanets
- Heliophysics



## Dust

- **Planetary rings**
- Comets & small bodies
- Heliosphere-LISM interaction
- Astrophysics
- Solar physics



## UV, IR, Radar, etc.

- **Planetary atmospheres**
- **Satellite surfaces**
- **Aurora**
- **Planetary rings**
- Exoplanets
- Astrophysics

**Many instruments can serve cross-disciplinary purposes if they are included in a payload and are potentially augmented with additional funding from *outside* of Planetary Science**

# Summary and Musings

- Amazing and transformative cross-divisional (i.e. cross-disciplinary) science has been fortuitously achieved from NASA & ESA missions
- We advocate for deliberate, upfront planning to take advantage of the full range of opportunities provided by our relatively few outer solar system missions
- Challenges face such an ideal, but communication, broad advocacy, and forward-thinking planning can overcome them
- The Ice Giants, in particular, are a great opportunity where mutually-beneficial instrumentation can allow for more great interdisciplinary science, especially if cross-divisional augmentation of funding is provided