Interstellar Probe: Pushing the Boundaries in a New Decade for Heliophysics

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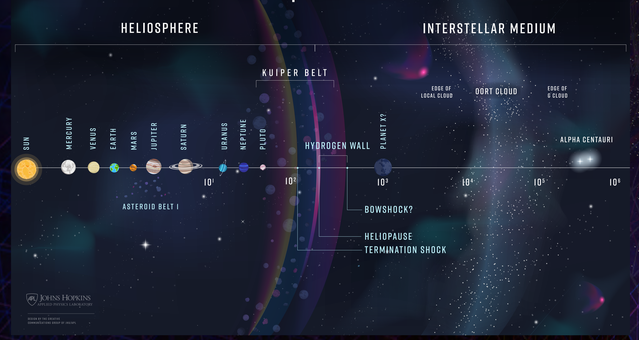
The Interstellar Probe Concept

The Interstellar Probe is a mission concept with the capability to operate at a maximum distance of 1000 AU, achieving a nominal lifetime of 50 years with 85% probability of success. Interstellar Probe would represent the first explicit step of Humanity step in to the Interstellar Medium. Its high-speed escape trajectory out of the solar system offers historic discoveries in the exotic physics at work in the ISM and allows us for the first time to look back at our own habitable astrosphere.

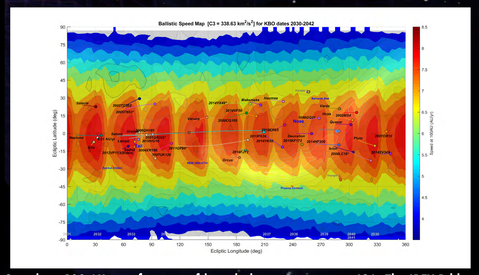


JHU/APL leads a NASA-funded study of a Pragmatic Interstellar Probe focused on designing a mission with technology, propulsion and launch vehicles available today or by a no-later launch date 2030. The Interstellar Probe concept builds on more than five decades of various studies(Holzer+1990; Liewer+2000; McNutt+2001; Mewaldt+2001; Fiehler+2006; Wimmer-Schweingruber+2009; KISS Workshops 2014, 2015).

Mission Study Status

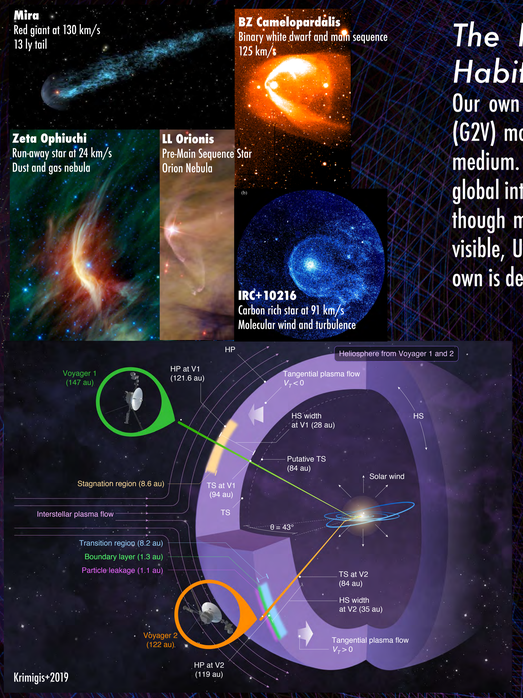
Centaur-Atlas Centaur-D

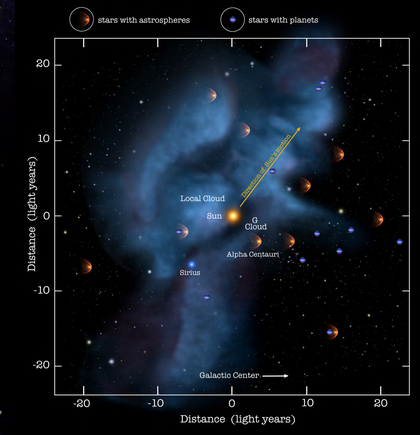
- Multiple stage configurations analyzed assuming the SLS-1B
- Three payload masses assumed: 40, 80, 120 kg
- Passive JGA
- Powered JGA
- Solar Oberth Maneuver: High risk with marginal gain



Speeds at 100 AU as a function of launch date using passive JGA. The IBEX Ribbon is contoured in the background.

Through the Heliospheric Boundary in to the Unexplored Interstellar Cloud





The New Physics Regimes of a Habitable Astrospheres

Our own star, The Sun, is a G-type main-sequence star (G2V) moving at 26.4 km/s through the local interstellar medium. When its expanding solar wind meets the LISM, a global interaction boundary is formed - The Heliosphere. Although many other "Astrospheres" have been detected in visible, UV and IR, it is unlikely that a type similar to our own is detectable at those distances.

Voyager 1 and 2 have uncovered a new regime of plasma interactions leaving us with an expanding list of mysteries:

- Heliosheath pressure is upheld by energetic ("suprathermal") ions
- Interstellar Magnetic Field stronger than expected and solar like
- The Heliopause is not a surface
- Acceleration of Anomalous Cosmic Rays not at the Termination Shock
- Solar disturbances still detected at Voyager 1
- Where/what is the Bow Shock?

Remote ENA imaging from IBEX and Cassini reveals unexplained features:

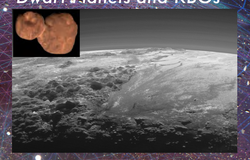
- Is the heliosphere bubble- or comet shaped?
- What is the "Ribbon"?

In to the Unexplored Local Interstellar Cloud (LIC)

The heliosphere, and its neighboring astrospheres plow through ionized clouds of gas (interstellar clouds) made up of the remnants of supernovae explosions. The varying properties of the Clouds dramatically alter the heliospheric interaction and shape. Although the heliosphere currently belongs to the Local Interstellar Cloud (LIC), it is believed that the heliosphere is about leave the LIC towards its neighboring G Cloud. As the Interstellar Probe continues beyond the heliospheric boundaries it would enter the Local Interstellar Cloud (LIC), where it would sample its properties for the first time offering insights in to the heliosphere's location within the LIC, providing direct constraints on the chemical evolution of the galaxy and nucleosynthesis, determining the LIC vector, and other discoveries.

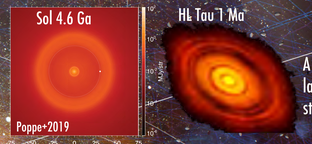
Potential Cross-Divisional Contributions

Dwarf Planets and KBOs



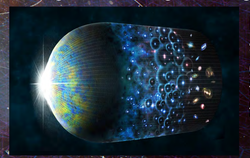
Any direction defined by the Primary Heliophysics Goal offers a giant planet flyby and at least one flyby of a compelling KBO or a Dwarf Planet.

Circum-Solar Debris Disk



A modest IR detector can reveal the large-scale disk structure critical for understanding the evolution of planetary systems.

Extragalactic Background Light



Beyond the obscuring Zodiacal cloud, the same IR detector can uncover the Extragalactic Background spectrum missing from our understanding of early galaxy formation.

Science Traceability Matrix

	Goals	Questions	Specific Questions	Measurements
Primary Goal	The Heliosphere as a Habitable Astrosphere	What is the Global Nature of the Heliosphere?	Structure of Heliopause, Bowshock, H-Wall, Ribbon	Probe boundaries in-situ and image structure in ENAs and UV, radio
			Nature of heliosheath, Energy partitioning	Particle distributions
			Acceleration at astrophysical shocks	
		How do the Sun and the Galaxy Affect the Dynamics of the Heliosphere?	Shock and HP response	In-situ, ENA, UV, radio
			Extent of influence in to ISM	ISM properties
			Effects on inner heliosphere	In-situ
		What is the Nature of the Interstellar Medium?	ISM vs solar system composition	Isotopic composition
			Recent nucleosynthesis in the ISM	
			Interstellar Dust	Dust composition
Supporting Goals	Origin and Evolution of Planetary Systems	How did Matter in the Solar System Originate and Evolve?	Circum-Solar Debris Disk	In-situ dust, IR 10-100 μm
			Current state of evolution, collisional processes of KBO and dwarf planets	VISNIR imaging
			Dynamical and compositional state of the Kuiper Belt	
			Sub-surface oceans and atmospheres of KBOs and dwarf planets	VISNIR, UV, magnetic field, plasma/particles
	The Universe Beyond the Circum-Solar Dust Cloud	How did Galaxies Form and Evolve in the Universe?	Early galaxy and star formation	Diffuse IR measurements of the Extragalactic Background Light (10-100 μm)

v3

Instrument "Menu"

v2.0

Instrument	Mass (kg)	Power (W)	Data rate (bps)	TRL	Reference/Heritage
Vector Helium Magnetometer	1.1-3	3.4-10	2-6	5-9	Szabo Personal Comm., Cassini/MAG
Fluxgate Magnetometer	4.1-5.6	2-5.1	1200	9	PSP, MESSENGER, Voyager
Plasma Wave Instrument	5-15.5	1.3-14.2	240-2800	9	Galileo/PWS, PSP, VAP, Voyager
Solar Wind and PUI	6.1-8	10-10.8	1500-2500	6-9	PSP, IMAP
Suprathermals and Energetic Ions	8	5	500	9	Solar Orbiter, PSP
Cosmic-ray spectrometer	3.6-14.6	6-14.7	200	9	Solar Orbiter, Ulysses, PSP
Dust Detector	1.9-11	5-15	579	6-9	NH, LADEE, Cassini, Europa Clipper
Neutral Ion Mass Spectrometer	3.5-10.3	5-23.3	1-1495	7-9	Luna-Resurs, JUICE, Cassini
Low-Energy ENA	11.5	3.5	100	9	IBEX-Lo
Medium-Energy ENA	7.4	0.7	99	9	IBEX-Hi
High-Energy ENA	7.4	7.6	500	>7	JUICE/JENI
Ly-alpha Spectrograph	13.3	11	200	9	SOHO/SWAN
UV (50-180 nm)	4.5	4.4	600	9	Voyager/UVS, NH/Alice
VisNIR Imager	8.6	15	16	9	NH/LORRI, Europa Clipper/EIS, DART/DRACO
VISIR Spectral Mapper	4	3	10	5-9	Voyager, Galileo, Cassini, Rosetta, NH, CIBER-2
Range	**90-133 kg**	**83-143 W**	**5747-10805 bps**		