EPSC Abstracts
Vol. 13, EPSC-DPS2019-826-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Interstellar Probe: The First Explicit Step in to the Galaxy

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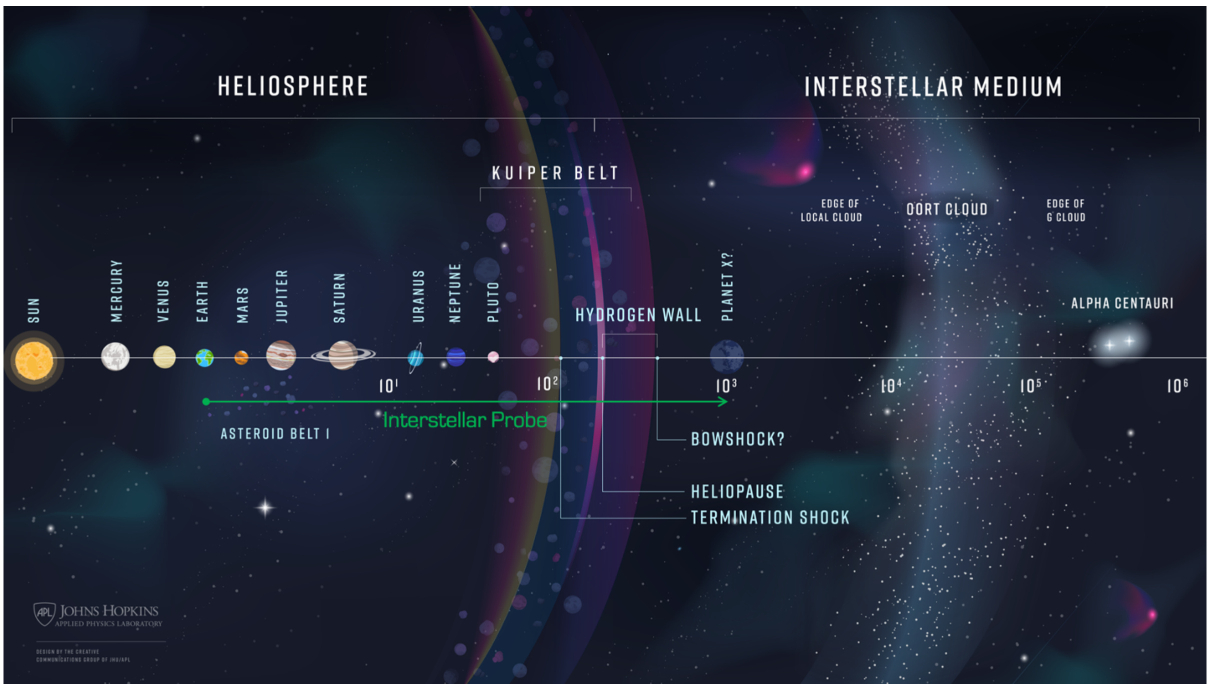

Figure 1: An Interstellar Probe would represent humanity's first explicit step in to the galaxy to explore our heliosphere, outer solar system, debris disk and the extra-galactic background light.

Abstract

Inevitably humanity seeks to expand across the sea of space to other Suns. The Interstellar Probe represents humanity's first deliberate step in to the galaxy on that journey. From just after the establishment of NASA, such an interstellar mission has been under discussion. It would open remarkable possibilities across disciplines and would represent perhaps the boldest move in space exploration.

This trade study focuses on a pragmatic Interstellar Probe up to 1000 AU to assess its technical readiness for a launch in 2030 to help support the Decadal Surveys (2023-2032). An international science team is analyzing the compelling science goals, iterated with a study of mission architectures led by a team at JHU/APL to find realistic solutions that close technically and scientifically. Building on the decades of previous studies, three cross-disciplinary science goals have been identified.

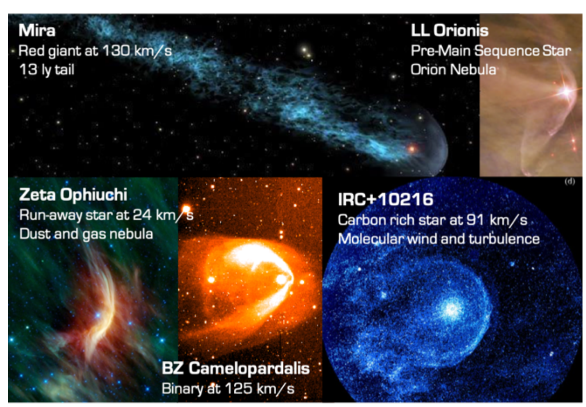

Figure 2: From its external vantage point an Interstellar Probe would uniquely capture the global nature of our habitable astrosphere for the first time.

Goal 1: Understand our heliosphere as a habitable astrosphere: The solar system is encased in a magnetic bubble spanned by the expanding solar wind. As it plows through galactic space, the properties of the solar wind and the interstellar environment shape this "heliosphere". The complex processes at its interface shield the solar system from the very high energy cosmic rays that otherwise would have bombarded and affected the chemical evolution of the planetary atmospheres. Despite its crucial importance for understanding the physics and habitability of our "astrosphere" and others out there, its global structure and astrophysical processes continue to be mysteries that only can be solved by flying a probe with comprehensive plasma and fields measurements through the interface region and image the heliosphere from the outside in UV and Energetic Neutral Atoms (ENA).

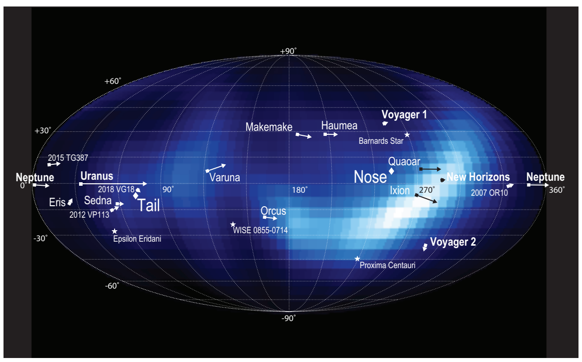

Figure 3: Flybys of KBOs and dwarf planets would offer new discoveries on the early state of the solar system.

Goal 2: Understand the evolutionary history of the planetary systems: The solar system was formed by a nebula of dust and gas, where gravitational accretion and collisions formed planets and moons, but also a wide range Kuiper Belt Objects that are all immersed in a debris disk. This disk extends well beyond the solar system and is a fossil of the formation processes. Multiple debris disks have been observed around other stars and hold immense information on how exoplanetary systems form and evolve. However, almost nothing is known about the large-scale structure of our own debris disk since its foreground infrared emissions are obscuring the overall structure. Therefore, there is no ground truth for the critical interpretation of other circum-stellar disks. By relatively modest instrumentation, the structure of our disk can be captured. Flybys of KBOs and dwarf planets would greatly expand our knowledge of their properties that provide direct insight in to the detailed formation processes of the Kuiper Belt itself.

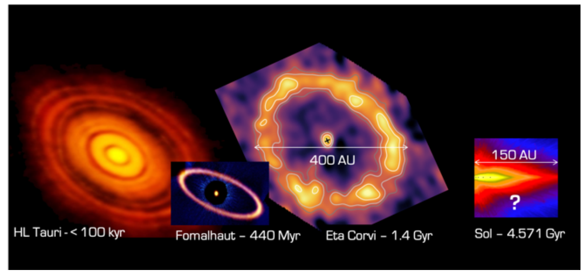

Figure 4: IR measurements from outside the zodiacal cloud would reveal the unknown large-scale structure of the circum-solar debris disk.

Goal 3: Open the observational window to early galaxy and stellar formation: The IR emissions from our debris disk, or "Zodiacal" cloud completely overwhelms the remnant light from the time when galaxies are formed. This may be the biggest stumbling block in experimental astrophysics today since it leaves theories of galaxy and stellar formation without any constraints. An Interstellar Probe traveling past the Zodiacal cloud would eliminate the foreground emissions and unveil the early universe by using the same relatively simple IR detector used for retrieving the disk structure.

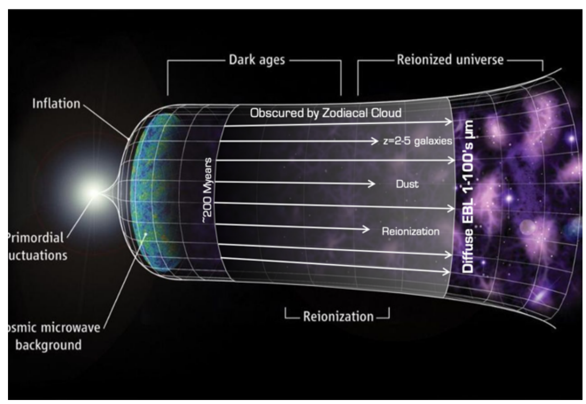

Figure 5: Traveling beyond the Zodiacal cloud would uncover EBL to provide unprecedent insight in to early galaxy formation.

Here, the compelling science cases enabled by an Interstellar Probe are presented. An overview of different mission architectures is given. Possible measurement approaches, science operations and trade-offs between mission scenarios and science are discussed.