To Boldly Go

By mid-century, we may have sent a craft to look back at ourselves from beyond the solar system.

In the last decade, the notion of interstellar travel went from fiction to reality. In 2012, after 35 years of interplanetary travel across 122 astronomical units, Voyager 1 left the solar system and crossed into interstellar space. In 2018, Voyager 2 did the same.

But the only other transmitting spacecraft on a trajectory to interstellar space, New Horizons, is not even halfway there. The scientific community's tenuous connection to this unexplored region therefore depends on the 44-year-old Voyagers staying alive or the New Horizons craft surviving another couple decades.

Unless we send a dedicated mission to interstellar space.

U.S. astronomers have proposed interstellar missions since 1960; since then, NASA and the European Space Agency (ESA) have entertained a couple dozen interstellar mission concepts, none coming to fruition. But a few ideas persist today. Interstellar Probe, a mission proposed by the Johns Hopkins University Applied Physics Laboratory and funded by NASA as a concept study, is one of them. Interstellar Probe could travel to 200 a.u. in 30 to 40 years — beyond where the Voyagers are now — and answer some of the biggest open questions about our star's relationship with the galaxy.

Seeing the Heliosphere

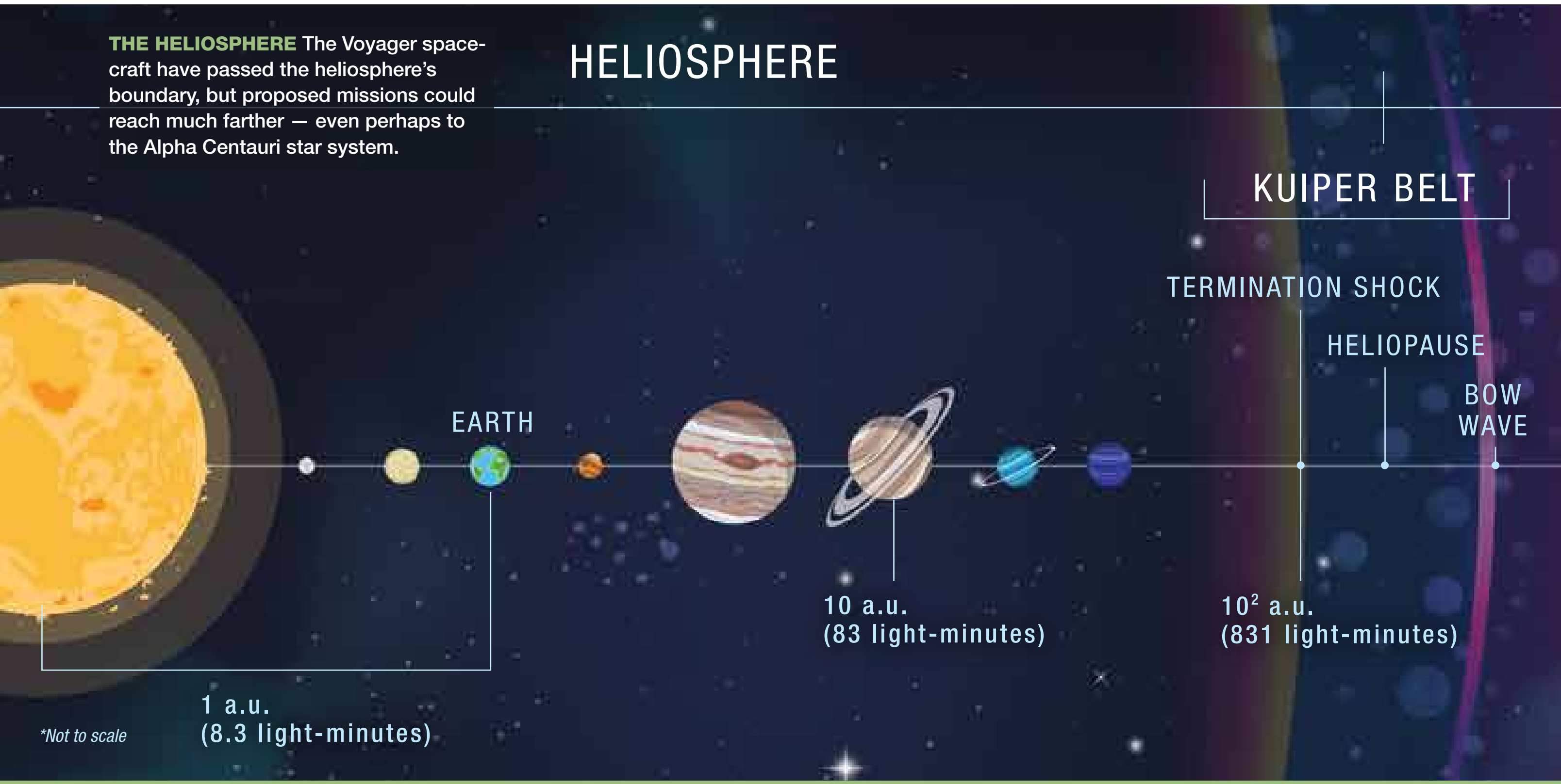
The Sun produces a wind, full of particles and magnetic fields, that carves out a magnetic bubble in space. This *heliosphere* envelops the solar system and protects us from high-energy galactic particles. But data from the Voyager spacecraft as they left the heliosphere raised more questions than answers (*S&T:* Sept. 2020, p. 16). What does the heliosphere look like? What is the material composition of interstellar space? And what happens at the boundary where these two meet?

Interstellar Probe could answer these questions by turning around and taking a picture of our home star's heliosphere, like the dusty Pale Blue Dot image of Earth taken by Voyager 1. In fact, it could take three.

The first picture would show the heliosphere's shape. Astronomers know that the heliosphere shelters us from harmful, high-energy particles, and similarly protected environments may harbor life elsewhere. But what it actually looks like remains unclear.

To solve this mystery, astronomers can use *energetic neutral atoms*, particles that arise when the solar wind bumps into the interstellar medium, to map the boundary of the heliosphere. While the Interstellar Boundary Explorer (IBEX) is making these maps from vantage points near Earth, it measures atoms at energies too low to probe the entire heliosphere. The future Interstellar Mapping and Acceleration Probe (IMAP) will make similar maps with an even larger energy range and thus reach farther distances.

However, both these missions only measure energetic neutral atoms that travel within the heliosphere, not the ones



THE HELIOSPHERE The Voyager spacecraft have passed the heliosphere's boundary, but proposed missions could reach much farther — even perhaps to the Alpha Centauri star system.

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from interstellar space. Mapping the heliosphere with these data is akin to determining the shape of a house by tracing the inside walls. Interstellar Probe could obtain the first complete view of the heliosphere from a vantage point in interstellar space. Together with IBEX and IMAP, these three probes will provide a definitive picture of the shape of the heliosphere.

The second picture would show how interstellar material piles up at the solar system's boundary. By measuring sunlight scattered off interstellar hydrogen, the Voyager and New Horizons craft detected a wall of hydrogen surrounding the heliosphere. Images from multiple space telescopes show similar walls surrounding the magnetic bubbles, or *astrospheres*, of other Sun-like stars. But astronomers don't know how similar the heliosphere is to these astrospheres. Interstellar Probe could make the first map of the hydrogen wall surrounding the heliosphere as seen from the outside. Then astronomers could compare this picture to other astrospheres to identify Sun-like stars that may, in turn, host habitable planets.

The third picture would show interstellar dust from the outside. Almost 30 years ago, the Ulysses satellite detected interstellar dust *inside* the heliosphere. Since then, the Cassini mission detected 36 grains, Stardust detected seven, and upcoming missions DESTINY+ and IMAP will detect some more. Along with the debris from interstellar visitors like Comet Borisov, these scant grains are the only particulate matter from other stars that astronomers can measure directly inside the solar system. By directly measuring and

◀ **LL ORIONIS** This young star in the Great Nebula in Orion is creating a bow shock around itself as it plows through the interstellar medium. The bow shock forms where the star's vigorous stellar wind hits the slower-moving gas in the nebula.

NASA / HUBBLE HERITAGE TEAM (STSCI / AURA)

imaging dust outside the solar system, Interstellar Probe could illuminate where these particles come from and how they seep into the heliosphere.

Daring Adventures

Interstellar Probe is not the only mission concept on the table. The Chinese Academy of Sciences is discussing Interstellar Heliosphere Probes, twin spacecraft that could travel to 100 a.u. by 2049. And the privately funded Breakthrough Initiative is proposing Breakthrough Starshot, which plans to go 3,000 times farther — to Alpha Centauri — in 20 years.

Regardless of which idea makes it to launch, a craft must travel quickly to get to interstellar space in our lifetime. One possible plan would employ the Sun as a gravitational slingshot to accelerate Interstellar Probe to about 110,000 kilometers per hour (70,000 miles an hour) — nearly twice as fast as the Voyagers. The Breakthrough Starshot team, on the other hand, plans to use a ground-based laser beam to propel an army of tiny spacecraft to more than *160 million* kph.

These plans are both risky and expensive. But the reward, the teams argue, is worth it.

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