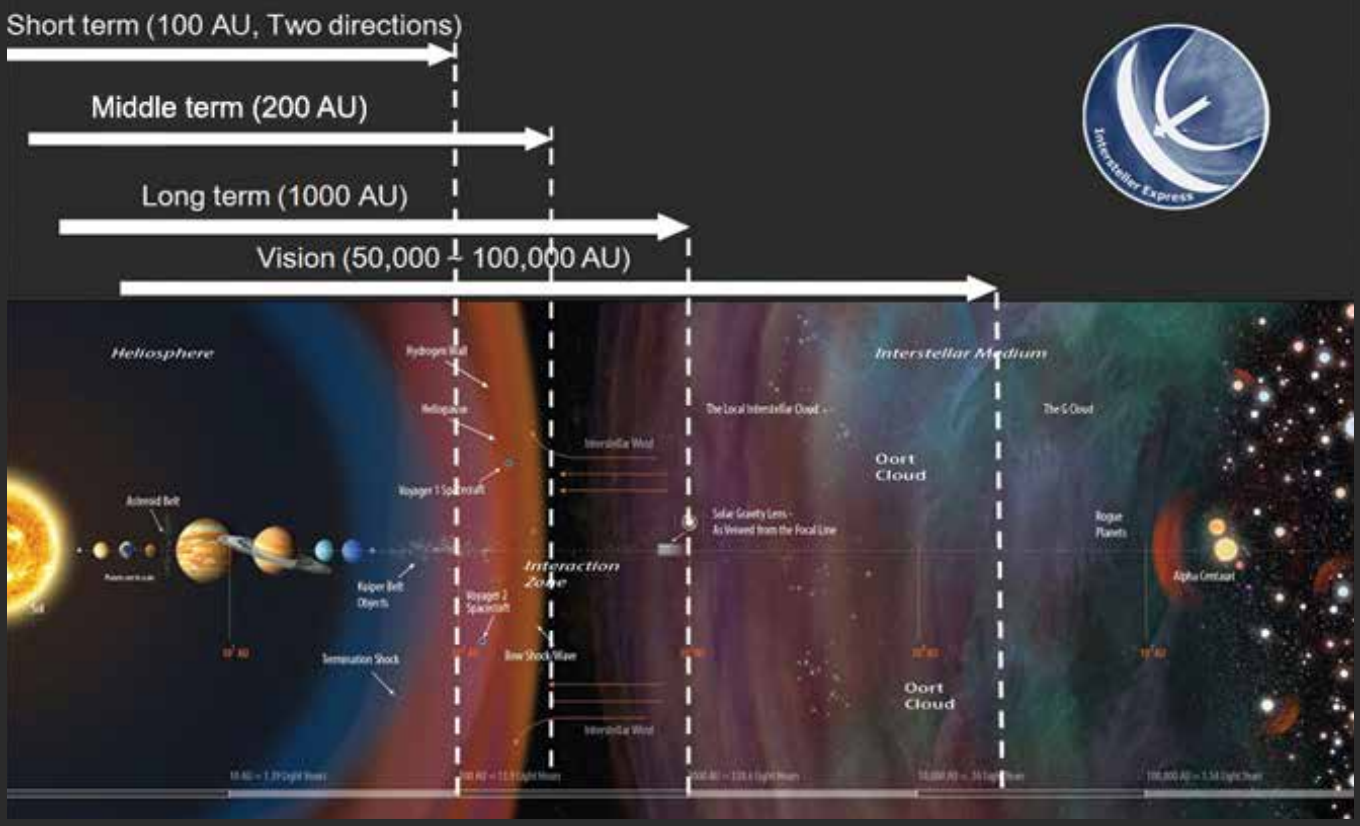
“Interstellar Express”: A Possible Successor to Voyagers

By SONG Jianlan (Staff Reporter)

When the world is celebrating the one-year anniversary of Voyager 2’s crossing the boundary of the heliosphere – the farthest reach of the solar wind as universally agreed, scientists at the Chinese Academy of Sciences are defining future journeys into this open cosmic water. Named “Interstellar Express”, this plan is to launch two probes in the near term, one going to the “nose”, and the other the “tail” part of the presumed comet-shape envelop of the heliosphere, which extends far beyond the realm of Pluto.



A step-wise layout of the programme, with the near-term goal of exploration set within a distance of 100 astronomical units (1 astronomical unit = 93 million miles) from the Sun. At this distance, the outer heliosphere ends and transits to the nearby interstellar medium. On the interface, the solar wind and the interstellar wind “bump” into each other, and radical disturbances burst out in the plasma soup of energetic particles. Illustrated in the chart are the possible interactions occurring between the two regions and the equilibrium achieved on the enveloped surface – the boundary of the heliosphere where the solar wind pauses and hence named the “heliopause”. Seen on the upper right is the LOGO for the “Interstellar Express”. (Credit: NSSC)

Interstellar Express: A Chinese Messenger

The notion of the interstellar adventure came to light at a forum convened on November 7 and 8, 2019 by the International Space Science Institute-Beijing (ISSI-BJ). As a partner institution of the International Space Science Institute (ISSI) in Bern, Switzerland, this institute is jointly established by ISSI and the National Space Science Centre (NSSC) under the Chinese Academy of Sciences (CAS) and operates as an independent entity.

At the forum, representative of the programme's science team introduced the layout of the "Interstellar Express", and experts from top science institutions around the world were invited to give advice to define further the science questions and objectives for this plan.

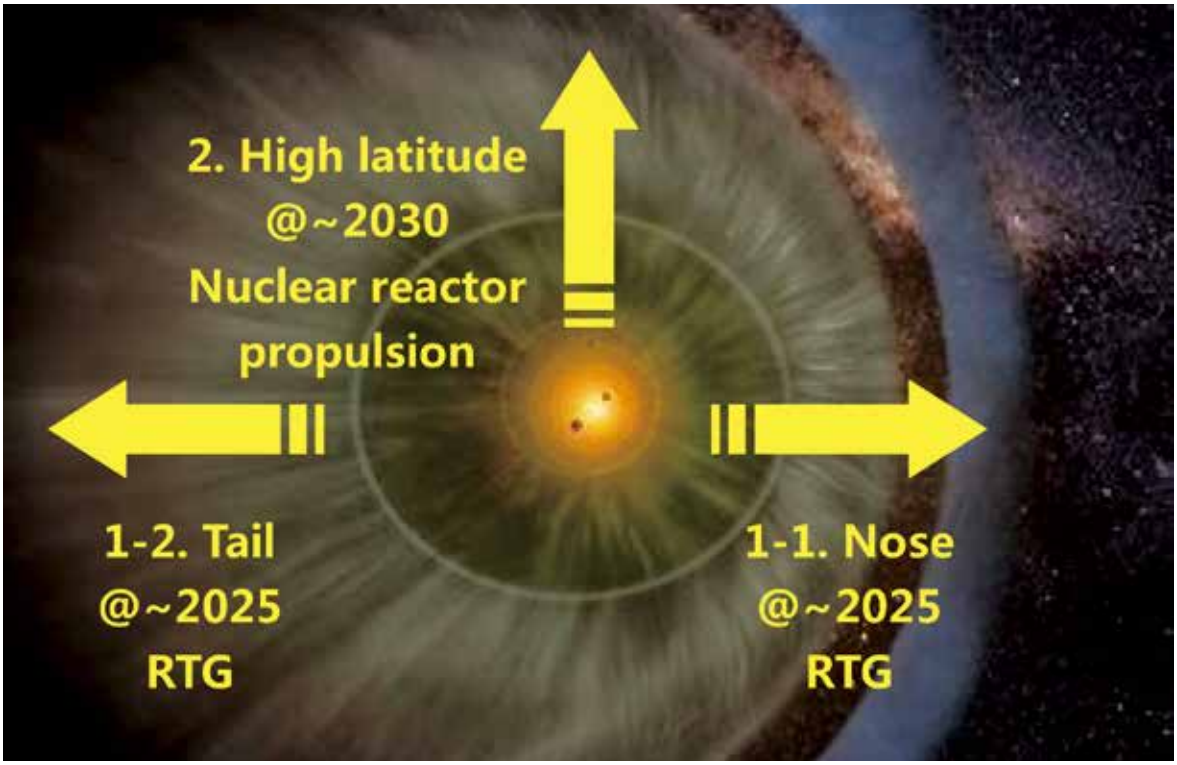
Prof. WANG Chi, expert in space physics and director of NSSC, outlined the proposed programme. First initiated in 2014, the notion of Interstellar Express has evolved into an initial proposal after five years of concept and feasibility studies. Formulated in its roadmap are missions to be implemented in three stages, namely near/middle-, long-term stages, and the vision. For the near-term, two probes will be sent in the first mission, heading in two opposite directions of the heliosphere. The two probes are expected to fly in 2025 if possible, and the one sent on the nose path is to arrive in the outer heliosphere by 2049, disclosed WANG. Another probe for high altitude exploration in the heliosphere will be sent in 2030 as the second mission.

With improved performance and aimed at measuring some neglected properties of the heliosphere, for example populations of energetic neutral atoms (ENA), the mission aims to fill in the large gaps in heliospheric physics and interstellar space observation.

The programme is open to international cooperation in terms of optimization of scientific objectives, payload contributions, and mission-level synergetic observations.

The Only Mission to Fill the Gap

Past the edge of the heliosphere, the solar wind and the interstellar wind bump into each other and stir up a



An illustration showing different layers of the heliosphere, a protective bubble formed by plasma particles sprayed by the Sun that envelops the planets in the solar system. The structure and dynamics of the heliosphere are largely unknown. Under "Interstellar Express", a probe sent as part of the first mission will traverse the boundary (heliopause) of the bubble from its "nose", whilst the other will go opposite way – to its tail. Another probe, for exploration into the high-latitude heliosphere, is set to be launched around 2030 as the second mission under its umbrella. (Credit: Adapted from an image by NASA/IBEX/Adler planetarium)

violent disturbance in the outer heliosphere – a "soup of plasma particles". The rivals reach some dynamic equilibrium on the interface and in doing so form a stagnant boundary. The solar/interstellar winds "pause" here, and hence the boundary is named the heliopause. What exactly is happening on this interface is not well known, and hence has greatly interested scientists.

It took Voyagers, two probes sent into space by NASA in 1977, respectively 35 and 41 years to get to the heliopause. They traversed the boundary from two different points on the "nose" of the heliosphere envelope. The probes were originally expected to work for only five years; however, they well outlived the expectations, won over continued support for their maintenance and operation, and dramatically flew beyond the reach of the solar wind. The two probes, the very first man-made spacecraft without protection from "the womb of humanity", are still flying in nearby interstellar space, where every inch of journey means discovery and surprise.

Their power systems are fading out, though; and their thrusters are degrading. Experts are worried that they might not last long. "Voyagers might not last beyond 2025," warns Prof. Robert Wimmer-Schweingruber, University of Kiel, Germany. His team just submitted in last August a white paper to ESA's Voyage 2050 Initiative, a long-term plan to define this agency's future space explorations. In the white paper his team urged the Agency to launch during the time between 2030 and 2050 a mission termed "Interstellar Probe" for *in-situ* measurement of the interstellar medium, citing the importance of understanding this part of the cosmos and the vast knowledge gap.

"After 2025, there might be nothing working in interstellar space," says Dr. Ralph L. McNutt, Jr., chair of the Panel on Interstellar Research under COSPAR, the Committee on Space Research under the International Science Council (ISC, formerly the International Council of Scientific Unions, ICSU). Dr. McNutt also works as Chief Scientist for Space Science for the Space Exploration Sector of the Applied Physics Laboratory (APL) at Johns Hopkins University, USA. His team has been working on the concept of an interstellar probe, which is expected to be launched by January 1, 2030, if funding agencies give it a green light.

"Interstellar Express" is the only one designed to launch in the next five years or so to fill the vast gap. "I know no other mission flying there about the same time," Dr. McNutt said when asked of possible candidate interstellar probes to come.

It will take "Interstellar Express" less time than Voyagers to fly past the heliopause, if the proposal gets approved by Chinese authorities. Still, however, it will take it about 25 years to traverse the heliosphere – Far long enough to beat any other space mission in China to become the longest of the country.

"It would be exciting if the Chinese Government supports a science mission lasting for decades," comments Dr. Maurizio Falanga, Executive Director of ISSI-BJ, who is one of the conveners of the forum. "It takes great patience to sow a seed and take care of the sprout that will not bear fruits in decades."

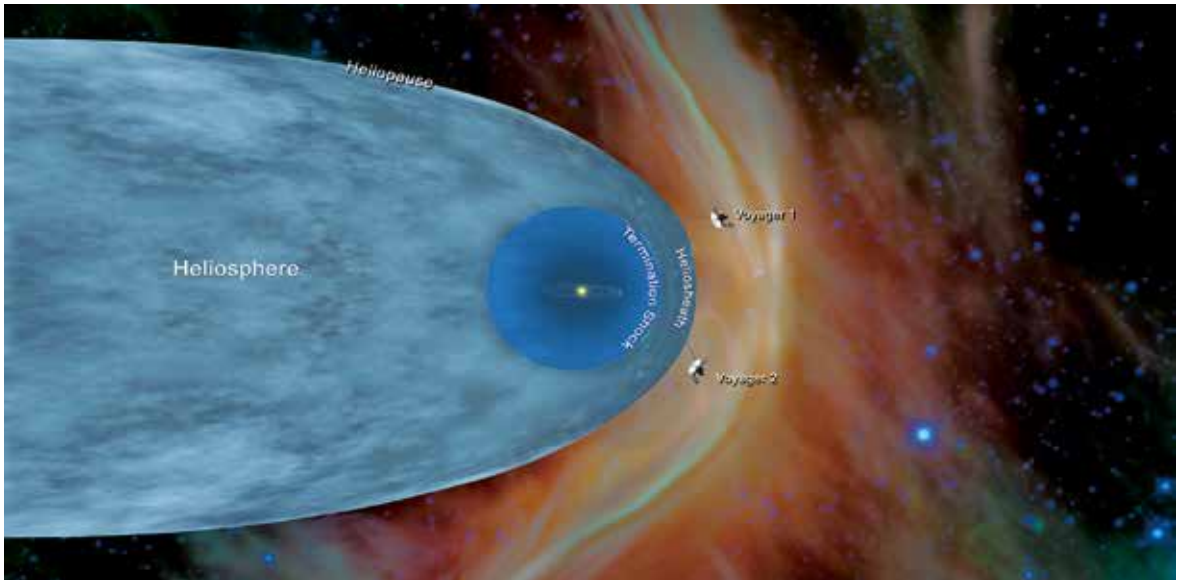
"ISSI-BJ runs the forum as an open platform where excellent experts across the world can exchange their ideas and work together to improve a research project," he added. "We encourage worldwide cooperation to advance research in the field of space science."

Understanding the Heliosphere

An important goal of the forum is to define the most valuable scientific objectives respectively for the probes heading to the two opposite directions in the first mission. On the other hand, experts were consulted with what the binary probe could do on its journey to the destinations to maximize its scientific outputs. Also, the forum sought proposals on payload specifications and design.

The mission is to perform *in-situ* observations on the dynamics of solar plasma particles in the outer heliosphere. Although pioneer *in-situ* measurements made and to be made by the Voyagers, as well as remote observations by the Interstellar Boundary Explorer (IBEX) and Cassini have yielded very valuable and inspiring data, still lots of questions remain open to investigation by human beings. Actually, the new data has raised new questions. For example, the sharply dropped counts of solar particles detected by the Voyagers indicate a clear boundary existing between the heliosphere and the interstellar space outside; however, it remains an enigma what this envelope looks like globally.

It could look like a croissant, comments Prof. Merav Opher from Boston University, USA. She reviewed different models predicting the shape of this shield of our solar system and concludes that data from IBEX and Cassini's observation favors shapes other than the classical comet-like envelope. She also gave the results



NASA's voyager 1 and 2 crossed the edge of the heliosphere in Aug 2012 and November 2018, respectively. Depicted on the map are the positions of the two spacecraft as of December 2018. They both penetrated the boundary (heliopause) of the bubble near the "nose" part of the heliosphere. (Credit: NASA/JPL-Caltech)

from her team's calculation: the magnetic field of the Sun confines the solar wind in a croissant-shape sheath.

This makes the journey to the "tail" necessary and interesting. Interstellar Express, which seeks to explore the heliosphere in different directions, stands out to fill the knowledge gap concerning the basic structure of this shield.

A clearer mapping of the outer heliosphere will help scientists better understand the origin and evolution of the solar wind, which ultimately affect the everyday life of human beings.

Looking at Interstellar Space

How the particles in the two regions interact with each other has intrigued many scientists. "Could it be a hole on the heliosphere envelope?" comments Prof. Vladimir Florinski, University of Alabama at Huntsville, USA, when reporting his simulation of magnetic trapping of local interstellar medium particles, based on the data from Voyagers. He has identified a region on the "nose" where galactic cosmic rays might have direct access to the heliosphere, and suspects it could be a possible "opening" on the heliosphere allowing the interstellar wind to penetrate in. "This could be a promising direction to explore with the Interstellar Express," he suggested when concluding his talk.

Also, the scientists are curious about the nature of the interstellar medium, which contains lots of dust particles alien to the solar system — Where have all these particles come from? What physical processes are responsible for their origin?

All this has made the dynamics of these particles an important objective of the mission. Future observations on the local interstellar medium might also provide clues for some far-reaching science issues of fundamental importance.

"Plasma physics is fundamental, because as you know, 99% of the visible universe is in the state of plasma," says Prof. Wimmer-Schweingruber, when talking about how the *in-situ* investigation of the interstellar medium might inform research in fundamental physics. Meanwhile he reminded everyone of the importance of *in-situ* observations. "The observed could be very different from what we thought before. It is very important to go there!"