Evolution of the outer heliosphere seen in neutral atom fluxes

The space between planets and stars is filled with a low-density, partially ionized plasma. Close to Earth, the main source of this interplanetary medium is the Sun, which continuously emits fully ionized plasma called the solar wind. The solar wind expands from the Sun with a very high speed of ~400-800 km/s, blowing away the interstellar plasma from the solar system, creating the heliosphere. The heliosphere extends over the entire solar system, reaching more than 100 times further away from the Sun than Earth's orbit. The Sun and the solar wind change over the solar cycle, resulting in dynamic heliosphere changes. The studies of the heliosphere are complex because only a few spacecraft have left the solar system and can detect the particles in the solar wind plasma far away from the Sun. One such spacecraft is New Horizons, which continues its mission through the heliosphere after passing Pluto. Voyagers had measured the heliosphere plasma, but they crossed the heliopause – the heliosphere outer boundary – and continued their journey in the interstellar medium. While in situ measurements from New Horizons and Voyagers are critical for studying the processes operating in the outer heliosphere plasma, the heliosphere is also imaged globally using energetic neutral atoms.

Energetic neutral atoms are created in all regions in the heliosphere from energetic ions that capture electrons from ambient interstellar neutral atoms present in all regions of the heliosphere. As all charged particles, ions are subject to electromagnetic forces, and thus, their dynamic is governed by the plasma's global flow. On the other hand, neutral atoms are only subject to gravitational forces and can travel through the heliosphere on ballistic trajectories. Consequently, energetic neutral atoms detected close to the Sun may inform about the state of the plasma from which they originate. These atoms are detected currently by instruments on NASA's Interstellar Boundary Explorer (IBEX) mission. This small satellite scans through the sky, producing images of the heliosphere every year. The first results of the mission showed that in addition to the predicted broad structure from the heliosphere, there is another narrow circular feature in the sky called the IBEX ribbon. This feature is created outside the heliopause in the local interstellar medium and shows us the orientation of the interstellar magnetic field.

In the project, we plan to analyze the observations of energetic neutral atoms to understand how the heliosphere changes in response to the solar wind evolution caused by the solar cycle and long-term changes. We will try to find the heliosphere's shape from observations of energetic neutral helium atoms, which should reveal the structure of the heliospheric tail. Such observations are not currently available from IBEX but should be possible with the next-generation instruments on the Interstellar Mapping and Acceleration Probe (IMAP) mission. We will carefully investigate those observations with newly developed tools. Moreover, we plan to understand the source of energization of ions in the solar wind as observed by the New Horizons mission.