The Sun is moving through the Local Interstellar Cloud of magnetized interstellar matter, composed of ionized and neutral atoms and dust grains. This cloud is one of many similar clouds within the Local Interstellar Medium, which is a ~200 pc remnant of a series of supernova explosions a few million years ago. The Sun emits the solar wind – an ever-evolving, omnidirectional, latitudinally structured, hypersonic outflow of the hot solar coronal plasma. Subjected to the ram and magnetic pressure of interstellar matter, the solar wind slows down through a system of shock waves called the solar wind termination shock and forms the inner heliosheath. Eventually, it flows downstream, forming the heliotail. The interstellar plasma is separated from the inner heliosheath by a contact discontinuity surface called the heliopause, which is transparent for neutral atoms. In front of the heliopause, a region of interstellar matter is disturbed by the heliosphere, just like a bow wave in front of a sailing ship: the outer heliosheath. In this region, the neutral and ionized are no longer in mutual equilibrium and start interacting with each other, producing new populations of atoms and ions.

Interstellar neutral (ISN) atoms, mostly H and He, penetrate the heliopause and enter the heliosphere, forming neutral interstellar wind. Some of these atoms exchange electrons with ions from the solar wind. As a result, the former solar wind ion becomes an Energetic Neutral Atom (ENA) and runs away freely from the reaction site, while the former neutral atom, now ion, is picked up by the flowing plasma and joins an embedded suprathermal ion population. This pickup ion population can be compared to steam from evaporation of the neutral interstellar “drizzle” in the hot solar wind. This "steam" forms a "mist", which is a marker of the solar wind. The ENAs created in the charge exchange reaction are like photons in astronomy: they carry information of the remote regions of the heliosphere.

The ISN atoms inside the termination shock are illuminated by the solar EUV radiation and produce a fluorescent helioglow, which can be used to analyze both the interstellar gas and the solar wind. The ISN atoms can be directly detected by the presently active NASA space probe Interstellar Boundary Explorer (IBEX) and the planned Interstellar Mapping and Accelerating Probe (IMAP). Direct-sampling observations of ISN gas by IBEX resulted in determination of some important parameters of the interstellar matter and magnetic field near the Sun. A global picture is, however, still missing, and the uncertainties of those parameters are relatively large and correlated with each other. Within the project, we will use all existing IBEX observations of ISN He, covering more than the 11-year cycle of the solar activity, and determine self-consistently the intensity and direction of the interstellar magnetic field, the speed and direction of Sun’s motion through the Cloud, the densities of interstellar ionized and neutral components and the content of helium.

The lack of fully consistent image of the interaction of the Sun with the interstellar environment is partly due to the lack of accurate knowledge of the solar plasma and EUV emissions. They had been investigated using two different observation techniques, but the conclusions do not precisely agree with each other. Within the project, we will attempt to determine the latitudinal structure of the solar wind and simultaneously, for the first time, of the solar EUV emissions by combining observations of the Lyman-α helioglow from an ESA space mission SOHO with ground-based observations of interplanetary radio scintillation. We will look for departures of the solar EUV output from spherical symmetry and its evolution during the cycle of solar activity, as well as connections with the anisotropy of the solar wind, hopefully resolving the solar wind enigma.

Another opportunity to improve our understanding of the solar galactic neighborhood and its interaction with the Sun will appear owing to the planned removal of the limitations in the observations geometry of the pioneer IBEX-Lo detector, offered by IMAP. While IBEX was only able to scan great circles in the sky perpendicular to the antisolar directions, IMAP will be able to adjust the elongation angle of its viewing direction and thus scan also small circles in the sky. Within the project, we will explore exactly how to exploit this capability to reduce the uncertainty of the flow velocity and temperature of interstellar matter near the Sun, how to investigate the interaction processes at the heliospheric boundary and how to improve the understanding of the solar EUV emission and the physical state of solar wind electrons, which contribute to ionization losses of ISN gas side the heliosphere and thus modify the ISN gas signal that IMAP will be measuring. This will provide IMAP with an opportunity to optimally schedule its sky coverage during the mission, which is planned to be launched at the end of 2024.