Ionization and neutralization processes in the heliosphere

M. Bzowski, M. Wachowicz, S. Grzedzielski

Space Research Centre PAS, Bartycka 18A, 00-716 Warsaw, Poland

Ionization and neutralization are key processes shaping the heliosphere and creating the plethora of heliospheric charged and neutral populations. The most important include charge exchange between solar wind ions and neutral interstellar gas atoms, ionization by the solar EUV radiation, and (inside a few AU from the Sun and most probable within the inner heliosheath) ionization by electron impact. The newly ionized atoms are immediately picked up by the solar wind, slowing it down by mass-loading, and eventually transfer some of their quasi-thermal energy to the thermal energy of the solar wind. Consequently, ionization of interstellar gas atoms is a coupling process responsible for deposition of energy and momentum of interstellar gas in the solar wind. The other charge exchange products – Energetic Neutral Atoms being mainly the neutralized solar wind protons – manage to escape from the heliosphere to the Local Interstellar Cloud in significant numbers, where they again enter into charge exchange reaction with the LIC plasma, and deposit energy and momentum from the solar wind into the regions in front of the heliospheric bow shock. Charge exchange with interstellar gas is not limited to solar wind protons – it operates in the case of heavy ions as well. The most abundant of them include fully stripped nuclei of oxygen, carbon, nitrogen, silicon, magnesium, and iron. These ions become gradually decharged and eventually, close to the heliopause, may even become completely neutralized and – according to very recent hypothesis – form a significant population of neutral atoms in the heliosphere that might be responsible for the “inner source” of pickup ions and for the presence of heavy nuclei in ACR. While the rate of EUV ionization is almost spherically symmetric (with deviations on the order of 10%), the spatial distribution of rates of plasma-related reactions is fully 3D and strongly depends on the regime of the solar wind (fast/slow, CME/CIR) and consequently on the phase of the solar cycle. In anticipation of the forthcoming NASA mission IBEX, devoted entirely to in-situ detection of heliospheric neutral atoms at 1 AU, understanding and precision modeling of these processes is a prerequisite for appropriate interpretation of such observations. With this in sight, we will show the 3D spatial structure of the relevant processes in the heliosphere and its evolution during the solar cycle, taking into account newly available cross sections and solar wind data. We will also address some aspects of statistical treatment of underlying parameters of the solar wind available from in-situ observations.