What epoch and space region at the heliospheric boundaries are probing IBEX and IMAP observations of interstellar neutral gas populations?

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Interaction between the solar wind and the local interstellar environment has been studied using several observation techniques, including in-situ sampling of the plasma, magnetic field, energetic ions by the Voyager spacecraft; remote-sensing observations of energetic neutral atoms (IBEX, Cassini); and the primary and secondary populations of interstellar neutral gas (IBEX-Lo). Understanding the processes at the heliospheric boundary and of the conditions outside the heliosphere is typically done by fitting parameters used in models of this interaction to various observables, including the Voyager crossing distances of the termination shock and the heliopause, the size of the IBEX ribbon and its center directions, the sky distribution of the Lyman-alpha helioglow, and the flux of interstellar gas at 1 au from direct-sampling observations. Typically, it is expected that all or most of these observables are successfully reproduced. Even though the interaction of interstellar neutral gas with the solar wind and solar EUV output is sometimes taken into account, the global heliosphere is usually simulated as a stationary structure, with the solar wind flux, density, and magnetic field variation ignored. However, solar wind is a dynamic phenomenon, which results in variations in the plasma flow both inside and outside the heliopause and in variations of the distance to the heliopause. Based on in-situ solar wind observations, dynamic pressure of the solar wind may change by a factor of 2, which may result in a heliopause distance change by 50%, counting from the lowest-pressure conditions.

Interstellar neutral atoms reaching detectors at 1 au or contributing to the helioglow observed from 1 au need very different times to travel from the interaction region, typically located at ~1.75 of the heliopause distance to 1 au. While the primary ISN atoms take 3—4 solar cycles to travel from this region to 1 au, with a physical time spread (not an uncertainty!) of about one solar cycle, the atoms from secondary population take as much as 15 solar cycles, with a large spread of 7 solar cycles. This implies that ISN He atoms sampled by IBEX-Lo, as well as those observed as the helioglow, originate from two different and disparate epochs. While it may be expected that the interstellar conditions at a time scale of 200 years are little variable, solar wind is definitely varying, with secular changes superimposed on the solar cycle variation.

Direct-sampling observations provide information on the plasma flow in the OHS inside ~60° around the inflow direction, with well-defined regions of the OHS contributing atoms to individual
pixels observed by IBEX and IMAP at different orbits. However, the information obtained is heavily averaged over time, and the epoch imprinted on these population is very different to the epochs characteristic for in-situ observations from the Voyagers (by 50 to 170 years!) and remote-sensing observations of the much faster-running energetic neutral atoms.