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Position of the IBEX ribbon as a key to understand its origin

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Observations of the energetic neutral atom (ENA) emission by the Interstellar Boundary Explorer (IBEX) allow for remote sensing of the plasma properties in heliosheath. The first IBEX results revealed an unexpected arc-like enhancement of the ENA flux in the sky, dubbed the IBEX ribbon. This discovery led to formulation of more than a dozen hypotheses on its origin. The emission source region proposed in these hypotheses span the heliospheric termination shock up to a hypothetical nearby interface between the Local Interstellar Cloud and a local bay in the Local Bubble. Among these hypotheses is the concept that the ribbon is produced by the secondary ENA mechanism, operating in the outer heliosheath.

The observational strategy of IBEX allows observation of the same part of the sky from the opposite sides of the Sun every six months and thus provides parallax viewing with a baseline of 2 AU. After correcting the observations for the Compton-Getting effect and for gravitational deflection and radiation pressure, we use this parallax viewing to precisely determine the apparent position of the maximum flux associated with the ribbon. We find that the ribbon peak position differs semi-annually by an angle of 0.41 ± 0.15 deg, which we interpret as the parallax effect. This angle corresponds to a distance of 140^{+84}_{-38} AU, and thus suggests that most likely the ribbon's source is located just beyond the heliopause.

Comparison of the IBEX ribbon position in five energy steps of IBEX-Hi shows a systematic shift, which changes the position of the ribbon center by $\sim$10 deg. We find that it can be explained using an analytic model of the secondary ENA mechanism with the neutralized supersonic solar wind as the source of the primary ENAs, which are ionized in the outer heliosheath, picked up by the ambient magnetic field, and eventually re-neutralized (as originally conceived, McComas et al. 2009). We use a realistic model of the solar wind evolution dependent on heliographic latitude, calculated the neutral solar wind flux and averaged it over the solar cycle, which was then used as the input in the analytic model of the secondary ENAs. The modeled ENA emission signal as observed at IBEX reproduces the observed features of the IBEX ribbon: the relative signal intensity along the ribbon in each energy channel and the shift of the ribbon center.

The combination of the distance to the ribbon source obtained from parallax and the energy progression of the ribbon center location suggest that the secondary ENA mechanism is a plausible explanation for the ribbon origin. A better resolution of the ENA detectors expected on the IMAP mission will enable a more accurate determination of the ribbon's position and will extend observations to higher energies. In consequence, a better determination of its parallax should be possible, and time-dependent effects resulting from the evolution of the supersonic solar wind structure with time will provide additional, critical signatures of the ribbon origin.