Introduction

Full sky maps of energetic neutral hydrogen atoms (H ENA) obtained with IBEX, revealed a bright, arc-like Ribbon, which dominates over the heliosheath emission on large swaths of the sky. Potentially, the helium ENA emission could give complementary information about the heliosphere and its environment.

Helium binary interactions

Hydrogen → important charge-exchange with protons (H⁺ + H → H²⁺ + H) → other: almost negligible if the energy is small < 100 keV

Helium:

- three charge-states He²⁺ (α-particles), He⁺ and He⁰
- a number of different reactions that change charge state of He ion or atom, including ionization (ion), charge-exchange (cx), double charge-exchange between He³⁺ and He⁰ (2cx)
- contributions depend on assumed conditions in plasma (different in the inner heliosheath, interstellar medium, and hot interstellar bubbles)

For energy < 10 keV the mean free path (m.f.p.) against He ENA ionization is up to one order of magnitude longer than the m.f.p. of H ENA.

For assumed Local Interstellar Medium (LISM) conditions: 

\[ n_\text{H} = 0.194 \text{ cm}^{-3}, \quad n_\text{He} = 0.056 \text{ cm}^{-3}, \quad n_\text{H} = 0.0153 \text{ cm}^{-3}, \quad n_\text{He} = 0.0096 \text{ cm}^{-3}, \]

where the m.f.p. of He ENA: 7.80 AU; H ENA 870 AU at \( E = 5 \) keV.

Heliosheath signal (Grzedzielski et al. 2013 & 2014)

To assess the inner heliosheath contribution to He ENA fluxes we use a simple axisymmetrical analytical model by Susor & Nerney (1990):

- circular termination shock (TS) at 94 AU (as measured by Voyager 2)
- distance to heliopause at the Voyager 1 trajectory: 121 AU
- plasma density in the inner heliosheath 0.002 cm⁻³
- post-termination-shock bulk plasma velocity 150 km/s
- He ion spectra consist of solar wind particles and pick-up ions (PUI)
  → PUI — assumed = distribution consistent with high energy Voyager data

Results — maps of expected He ENA flux in the two hypotheses

Conclusions — expected properties of the He ENA signal

The expected heliospheric signal is highly concentrated in the direction of the heliospheric tail: Flux(tail)/Flux(nose) \( \sim 10^5 \)

If observed hydrogen atoms from the Ribbon are the secondary ENA then observation of the He ENA signal from the Ribbon is not likely due to too small amount of helium in the neutral solar wind.

If the Ribbon is produced as in the extraheliospheric model then the He ENA signal from the Ribbon dominates over the heliosheath signal except for the heliospheric tail and should be potentially easily detectable.

Outlook

The long mean free path against ionization of keV He ENA in the LISM and low heliosheath signal in large part of the sky make He ENA a good candidate for studies of the LISM structure at distances comparable with the distance to the LIC edge (0.05 pc = 10,000 AU, Redfield & Linsky 2000).

For two-dimensional sources (e.g. interfaces), also secondary ENA, i.e., produced from the ionized and then neutralized primary ENA, should give a non-negligible contribution and be included into future considerations.

References

Sukov & Narrow 1993, JGR, 98, 6403

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http://www.cbk.waw.pl/en

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