A brief summary of IBEX observations of the heliospheric interaction

David J. McComas¹,²,³

¹ Southwest Research Institute, San Antonio, TX 78228, USA
² University of Texas at San Antonio, San Antonio, TX 78249, USA
³ On behalf of the entire IBEX Project and Science Teams

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Astrospheres

Closeup of IRS8, resolving the bow-shock of a fast-moving star

Left image courtesy of R. Casalegno, C. Conselice et al., WIYN, NOAO
Other images from HubbleSite.org
ENAs – From the Sun to IBEX

10 billion mile “hole in one”
ENAs Illuminate the Heliosheath

\[ J_{\text{ENA}} = \int dx \ n_H \ J_{\text{ION}} \sigma \]
IBEX Mission Summary

- NASA Small Explorer (SMEX)
  - PI Mission (~$100M SwRI prime)
  - NASA-provided Pegasus LV
  - Foreign contributions: Swiss (hardware) and many country (science) contributions
- Initial Selection January 2005
- Launched 19 October 2008
- First Heliophysics mission since ACE (13 years ago) to under run
- Fully successful completion of Prime Mission – January 2011 → Now in Extended Mission
Voyager 1 & 2 in Heliosheath

Dave McComas: 7
Mollweide all-sky projection showing locations of Voyagers
Voyagers provide detailed information in these two directions
McComas et al., First Global Observations of the Interstellar Interaction from the Interstellar Boundary Explorer

Fuselier et al., Width and Variation of the ENA Flux Ribbon Observed by the Interstellar Boundary Explorer

Funsten et al., Structures and Spectral Variations of the Outer Heliosphere in the IBEX Energetic Neutral Atom Sky Maps

Schwadron et al., Comparison of Interstellar Boundary Explorer Observations with 3-D Global Heliospheric Models

Möbius et al., Direct Observations of Interstellar H, He, and O by the Interstellar Boundary Explorer

Krimigis et al., Imaging the Interaction of the Heliosphere with the Interstellar Medium from Saturn with Cassini
IBEX-Lo & Hi observations independently confirm ribbon (Hi at ~1.1 keV and Lo at ~0.9 keV shown)

McComas et al., Science 2009
Spectral Slopes of ENAs

McComas et al., Science 2009
Ribbon Correlates with $\mathbf{B} \cdot \mathbf{r} = 0$

Parker [1961] Interactions

IBEX results indicate both external forces are important!

McComas et al., Science 2009
A New Paradigm

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McComas et al., Science 2009
Six+ Possible Ribbon Sources

3 more possible mechanisms published since Science papers

McComas et al., JGR 2010
Secondary ENAs

Simulated

IBEX Data

Heerikhuisen et al., ApJ 2010
Time Variations over 6 Months

- Evolution of “knot” in high latitude ribbon
- Overall reduction in global ENA emissions \(\leftrightarrow\) likely linked to general reduction in SW flux and pressure

McComas et al., *JGR* 2010
Ribbon Separation

- Based on combination of Maps 1 and 2
- CG corrected
- Sophisticated iterative separation solvers
- Deflected tail and other key science

First: Interstellar H and O

Möbius et al., Science 2009
• Bochsler, P., et al., Estimation of the neon/oxygen abundance ratio at the heliospheric termination shock and in the local interstellar medium from IBEX observations (In Press)
• Bzowski, M., et al., Neutral interstellar helium parameters based on IBEX-Lo observations and test particle calculations (In Press)
• Hlond, M., et al., Precision pointing of IBEX-Lo observations (In Press)
• Lee, M. et al., An Analytical Model of Interstellar Gas in the Heliosphere Tailored to IBEX Observations (In Press)
• Saul, L., et al., Local Interstellar Neutral Hydrogen sampled in-situ by IBEX (Positive review; Revisions submitted)
ISN Major Findings

• He atoms show that the speed and direction (the motion of the heliosphere with respect to the interstellar medium) is different than that thought from prior Ulysses observations
• Evidence for a previously unknown and unanticipated secondary population of He
• First direct quantitative measurements of the ISN H parameters
• First direct measurements of interstellar Ne
• First measurements of interstellar Ne/O abundance ratio
  – ratio higher than solar abundance
  – consistent with earlier PUI observations
  – O may be locked up in grains
IBEX is a sun-pointed spinner with radially viewing sensors - Observes the ISM flow at its perihelion
ISN Observations in IBEX Maps

- ISN observed over 3 consecutive years
- H, He, O & Ne
- Observations through focusing cone
- ISN data very similar even in absolute flux → ISN flow well measured and stable at least on short times
Remarkable mission of discovery and exploration...

Thanks to all the Outstanding Men and Women who have made IBEX such a Great Success!