Interstellar Boundary Explorer

Imaging the edge of our solar system and beyond — Discovering the global interaction between the solar wind and the interstellar medium

IBEX

A brief summary of IBEX observations of the heliospheric interaction

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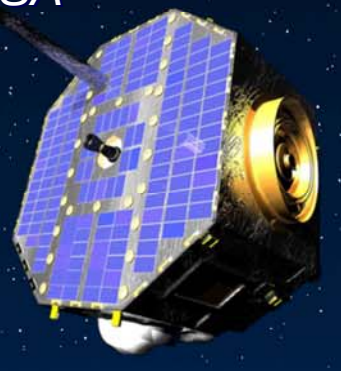
[3] On behalf of the entire IBEX Project and Science Teams

Cosmic Ray Anisotropy Workshop

Madison, WI – 29 October 2011



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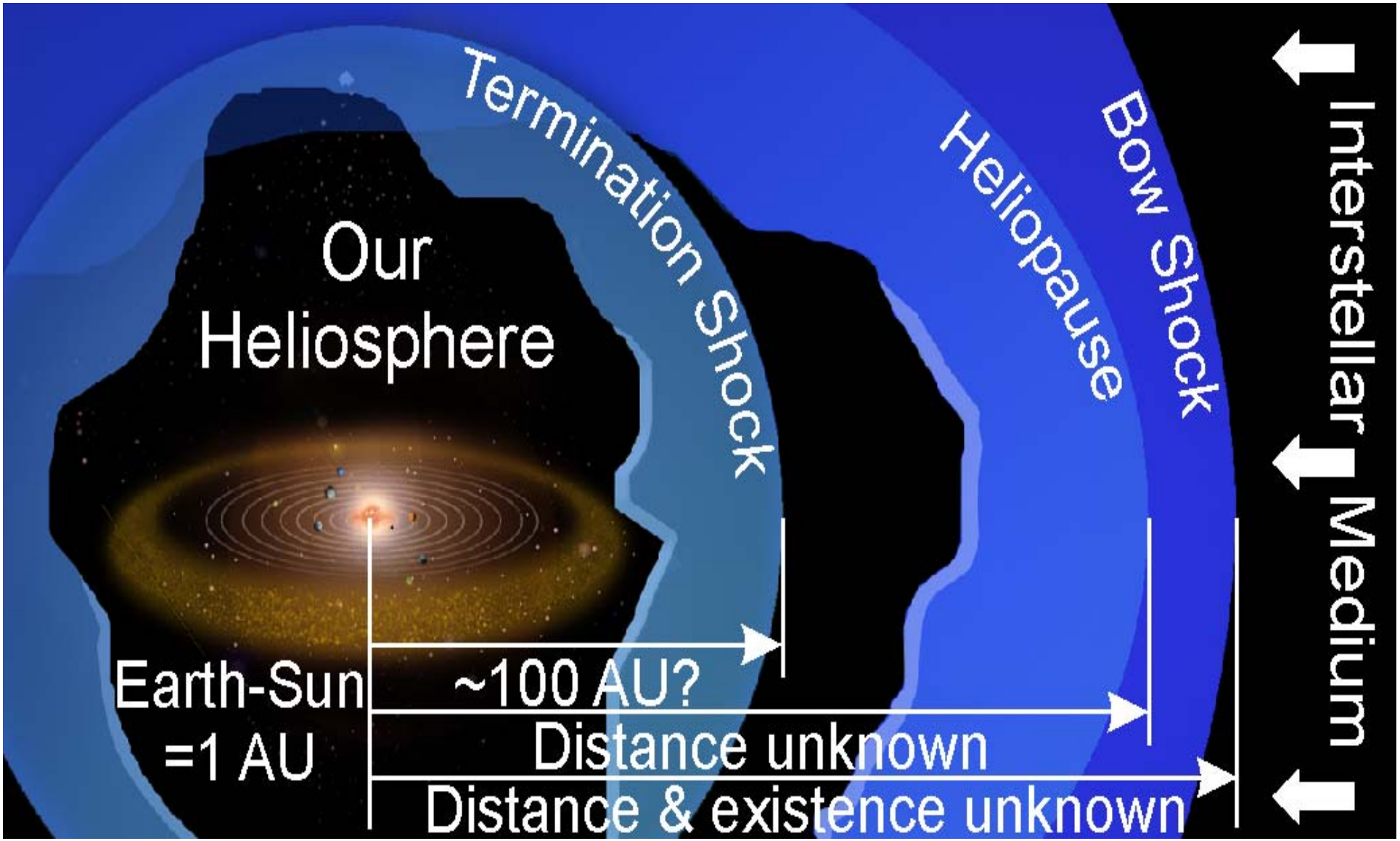
Our Heliosphere



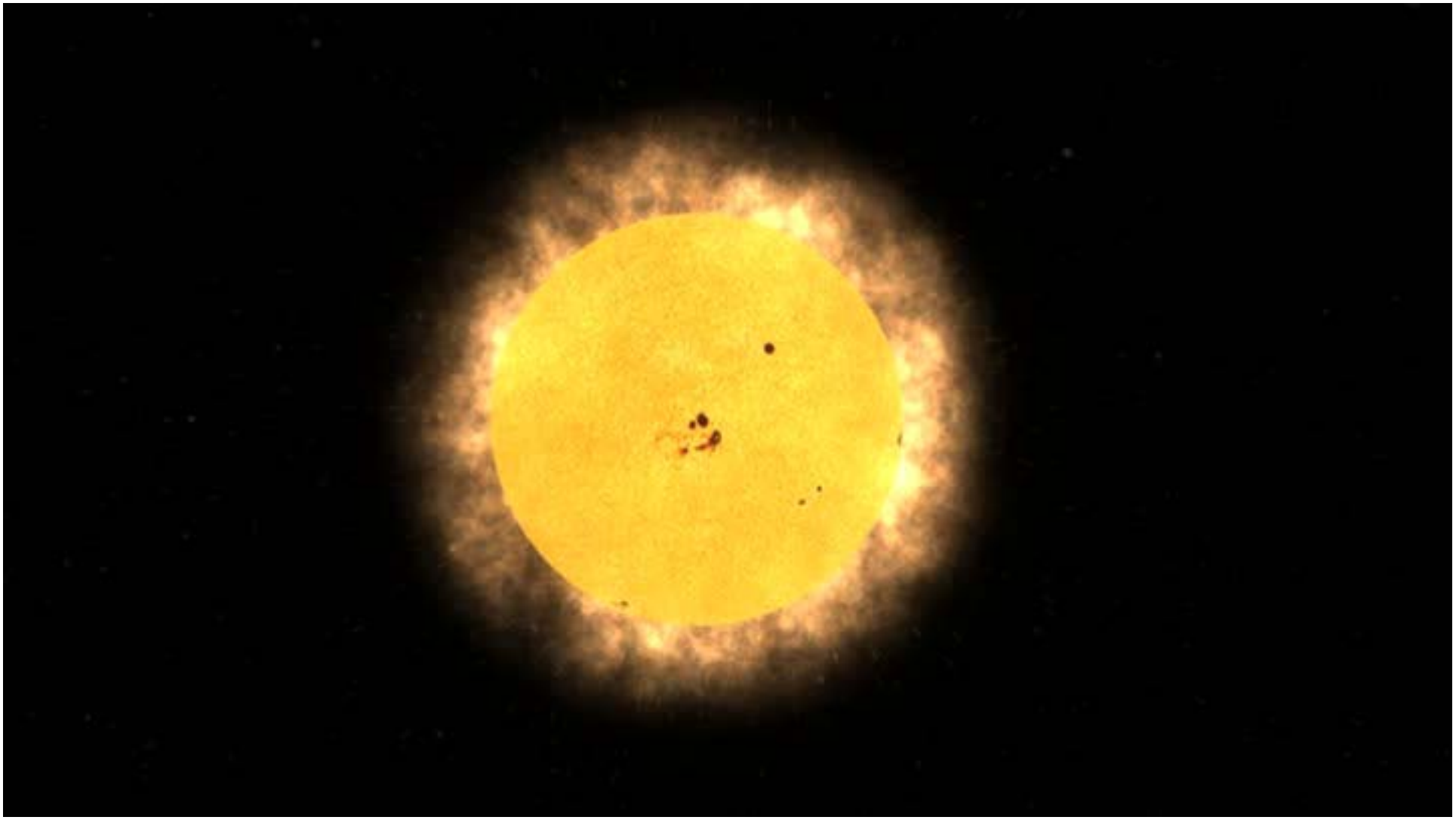
Astrospheres

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

Left image courtesy of R. Casalegno, C. Conselice et al., WIYN, NOAO

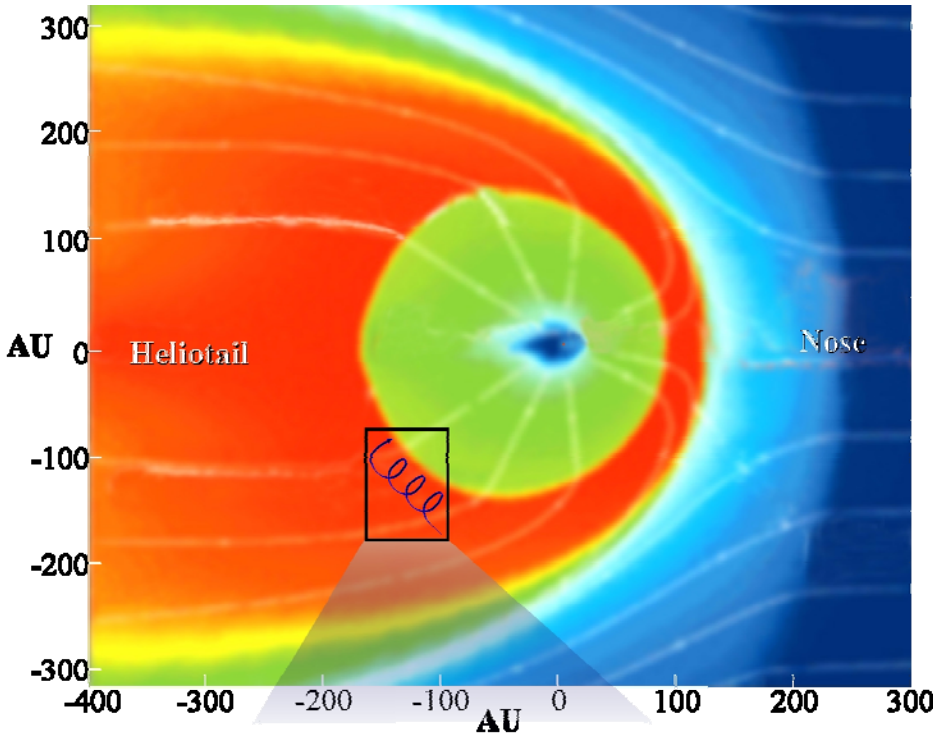
Other images from HubbleSite.org

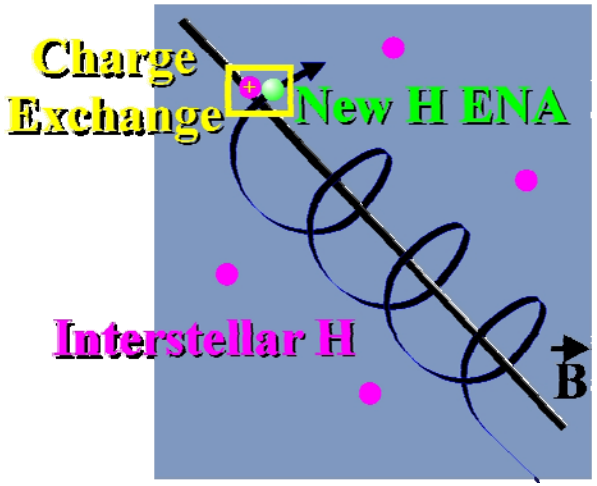
ENAs – From the Sun to IBEX



10 billion mile “hole in one”

ENAs Illuminate the Heliosheath

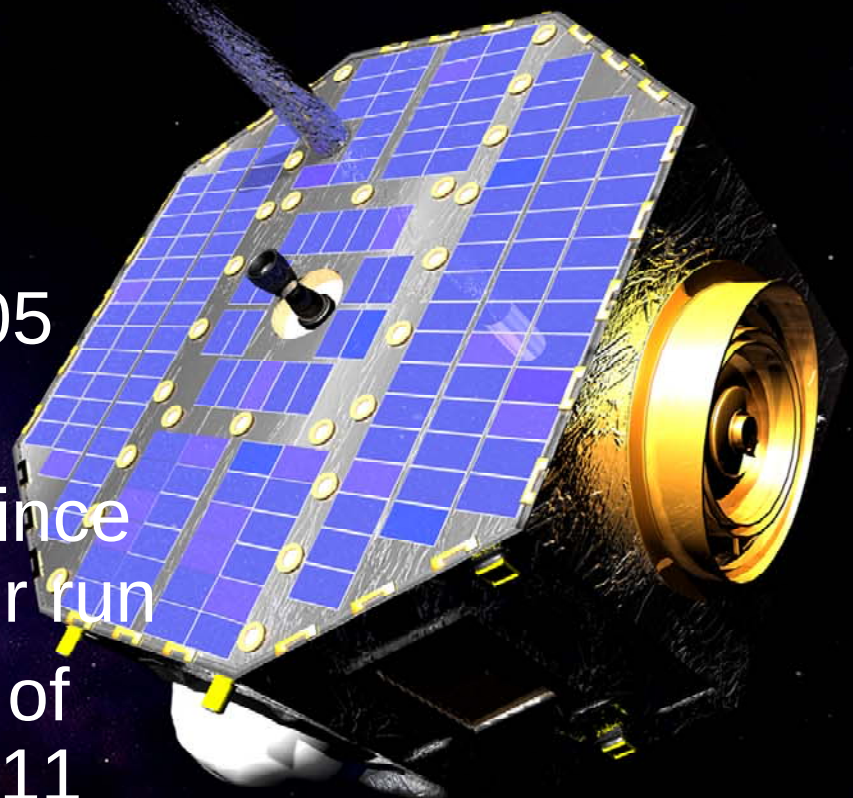




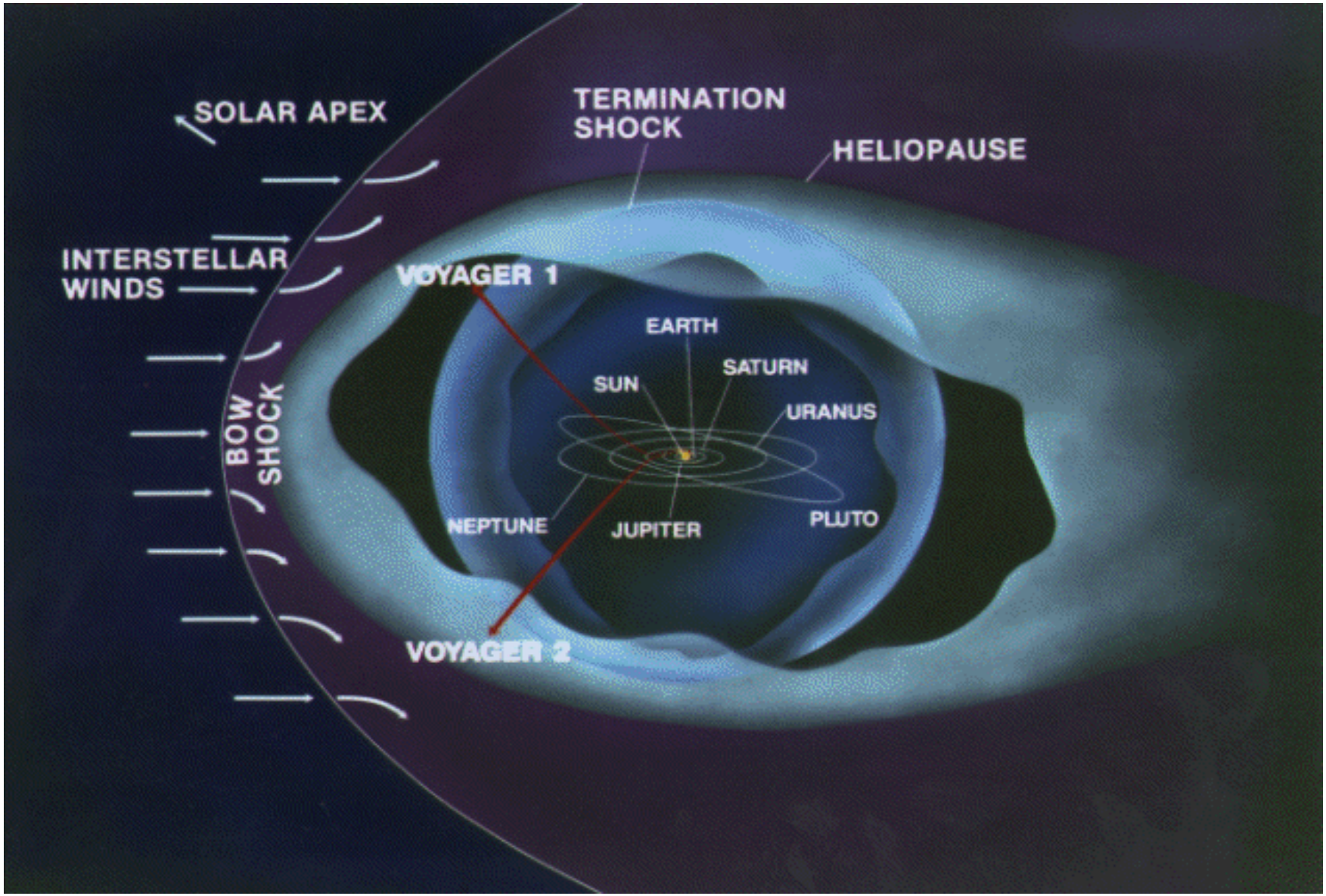
$$J_{ENA} = \int dx\, n_H\, J_{ION}\, \sigma$$

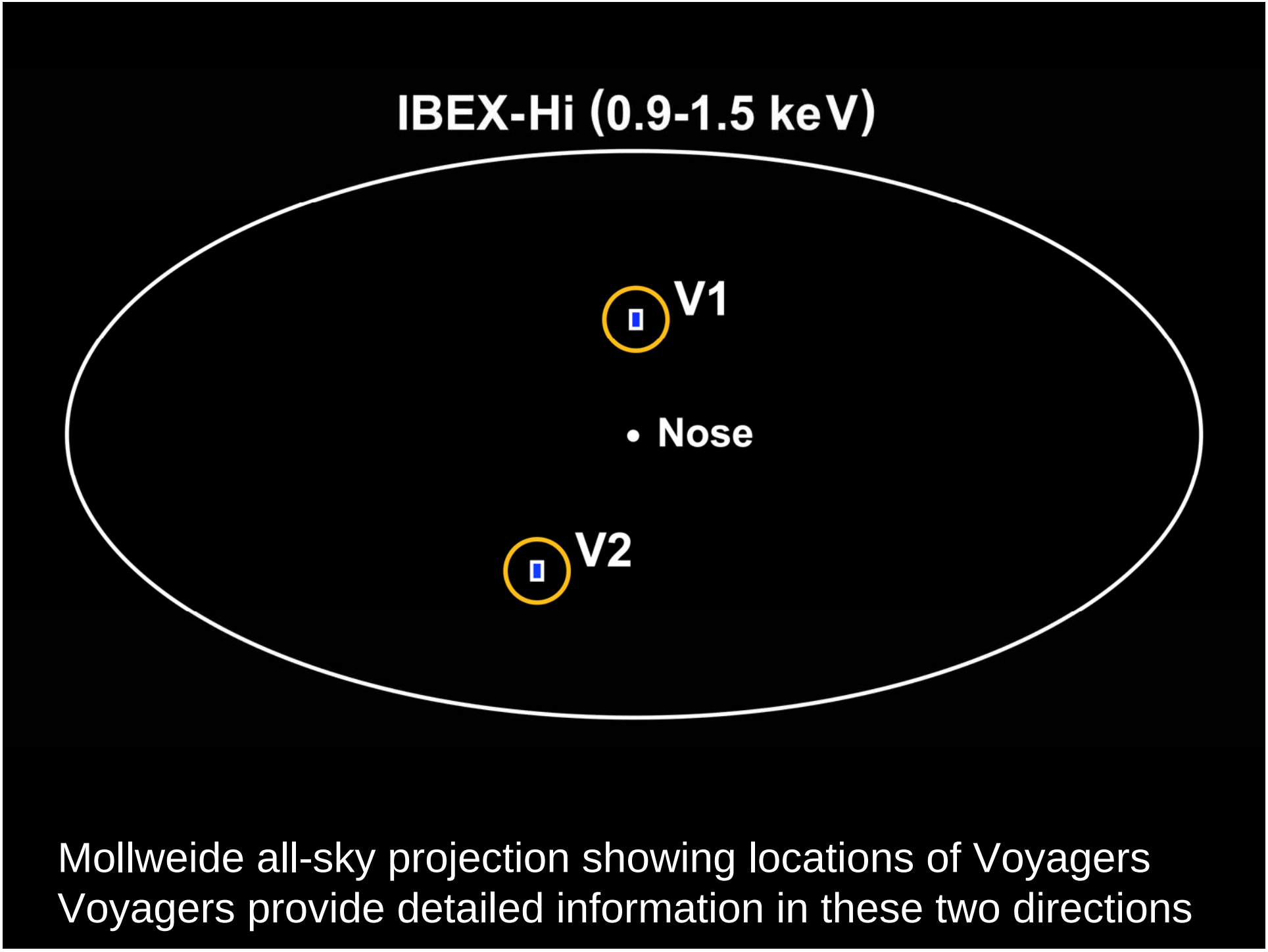
IBEX Mission Summary

- 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

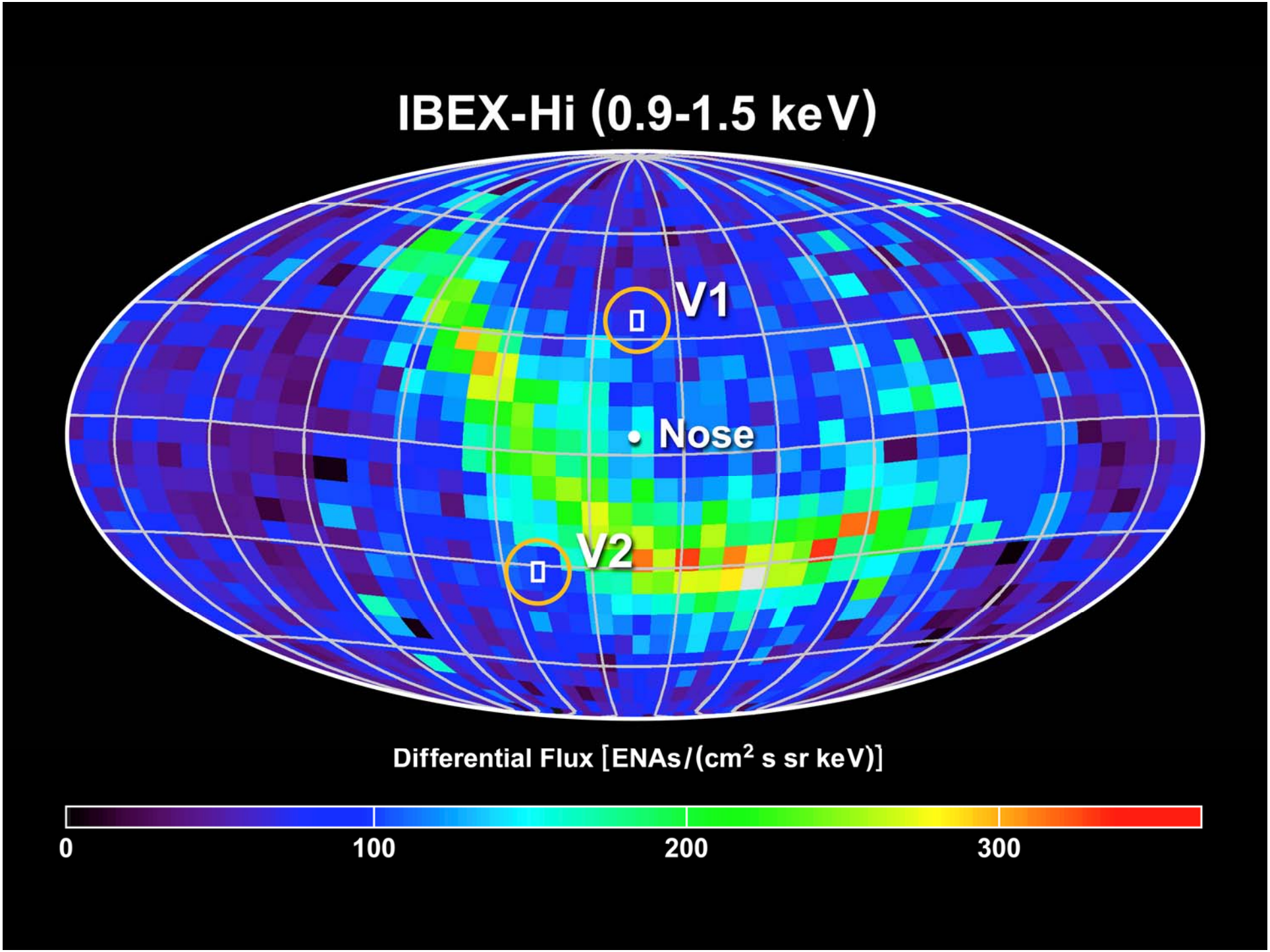


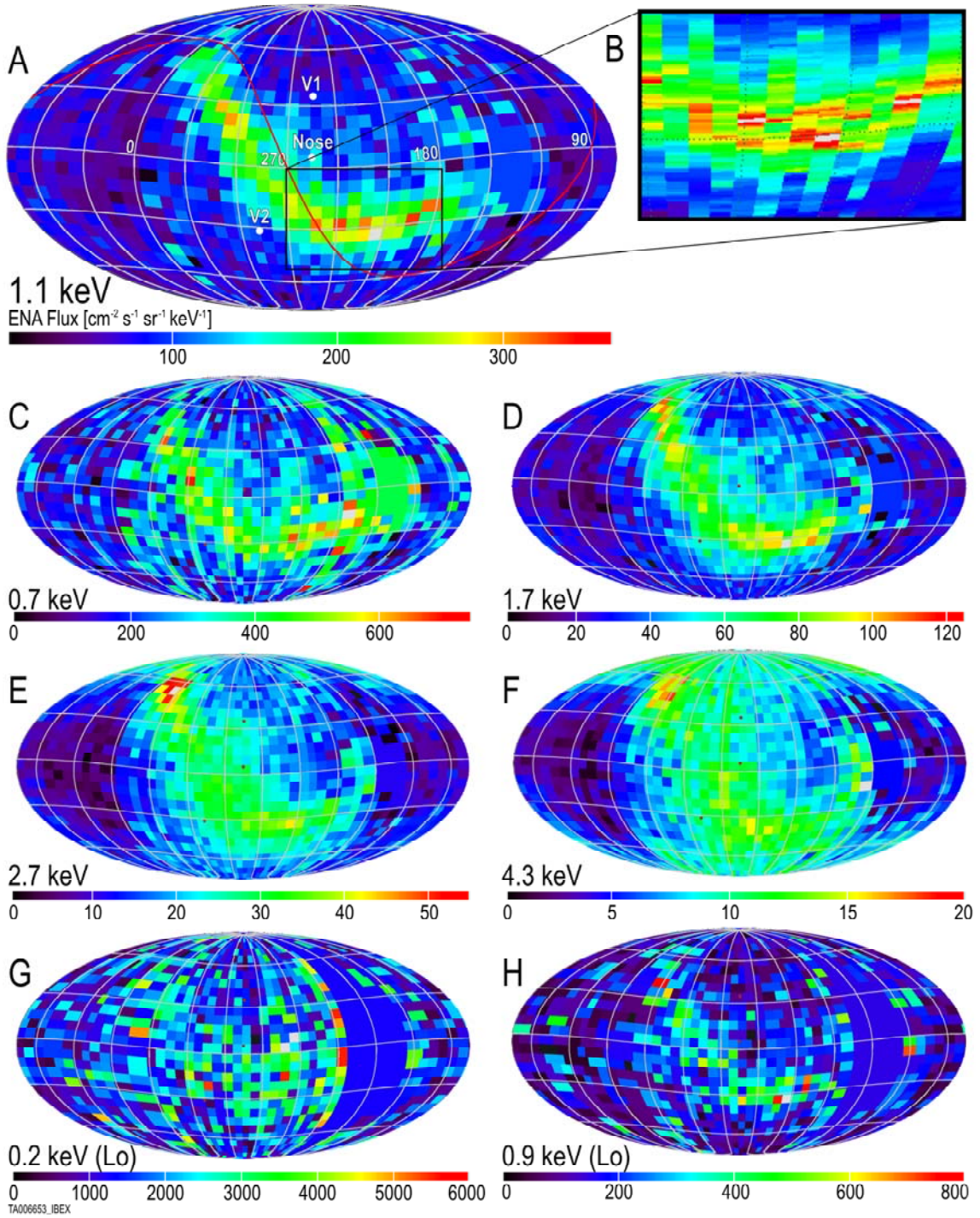
Voyager 1 & 2 in Heliosheath





Mollweide all-sky projection showing locations of Voyagers
Voyagers provide detailed information in these two directions


IBEX-Hi (0.9-1.5 keV)
V1
Nose
V2
Differential Flux [ENAs/(cm² s sr keV)]
0
100
200
300



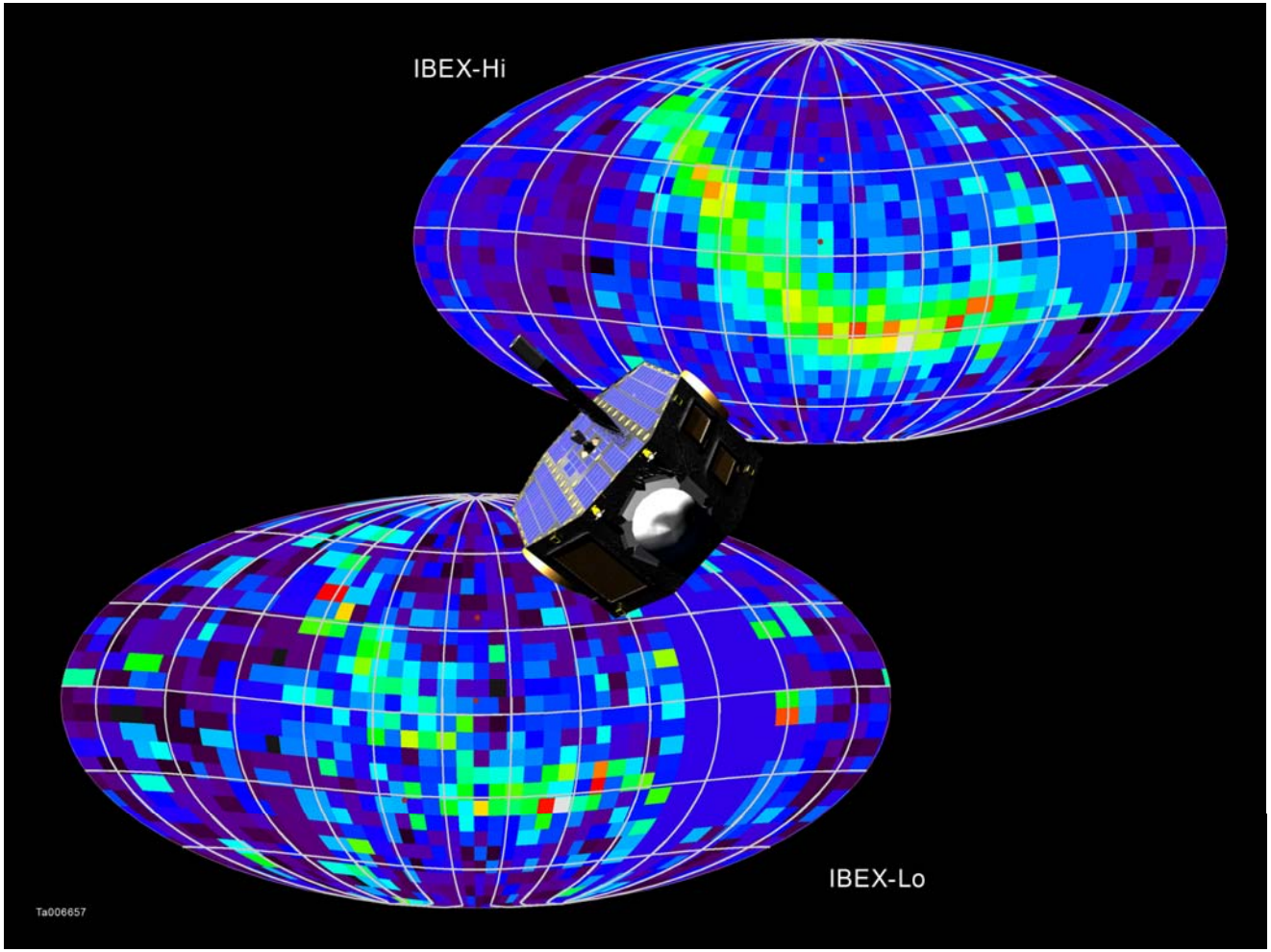
McComas et al., *Science* 2009

Science - IBEX Special Section

- 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

13 November 2009 Issue

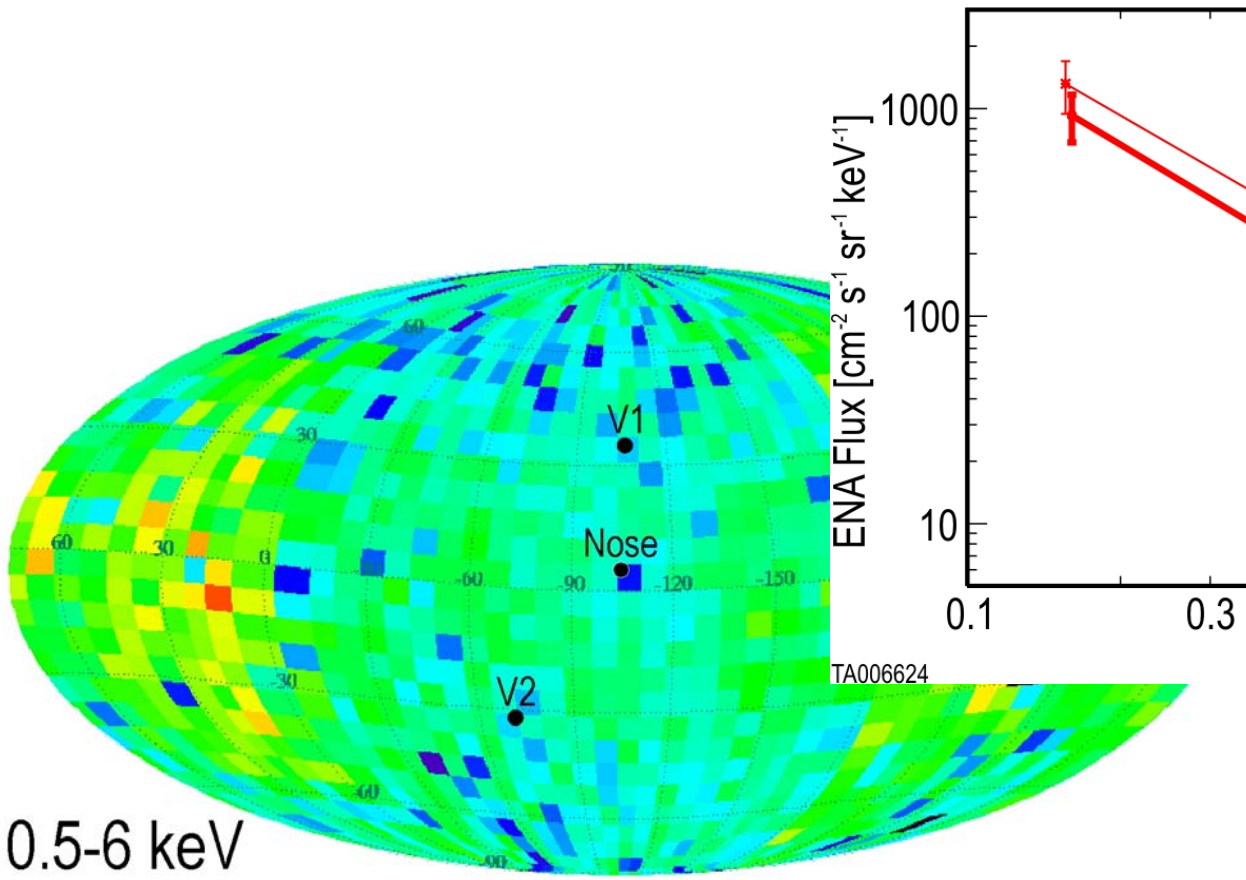
Independent Confirmation

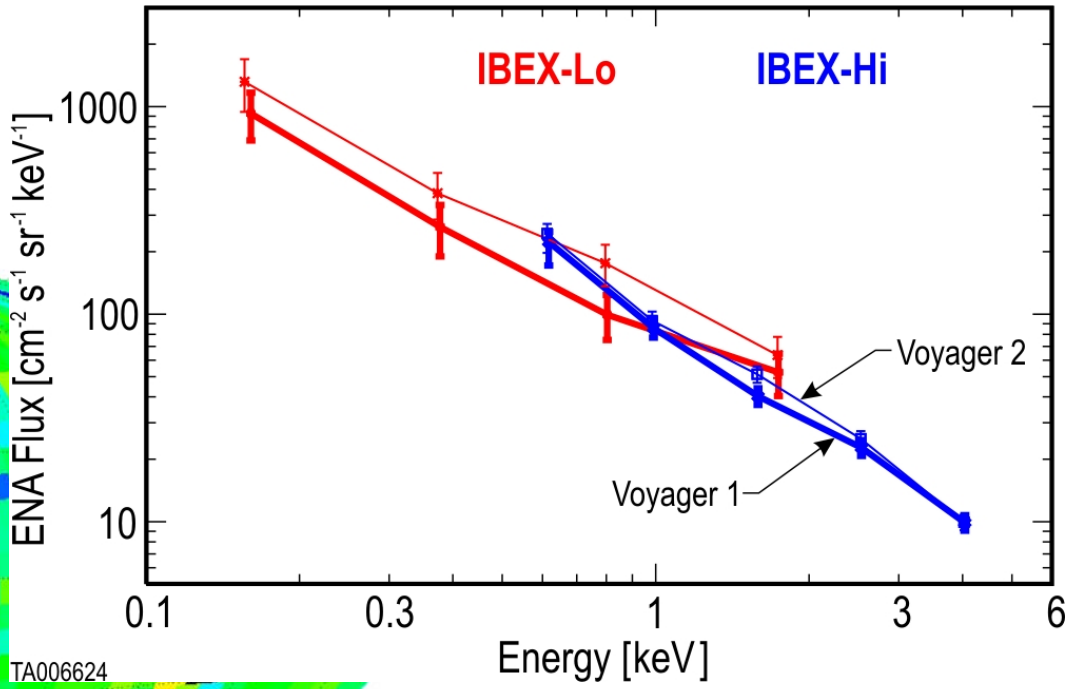


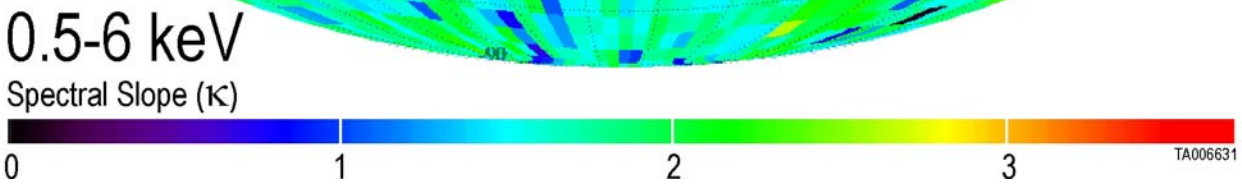
IBEX-Lo & Hi observations independently confirm ribbon (Hi at ~1.1 keV and Lo at ~0.9 keV shown)

McComas et al., *Science* 2009

Spectral Slopes of ENAs

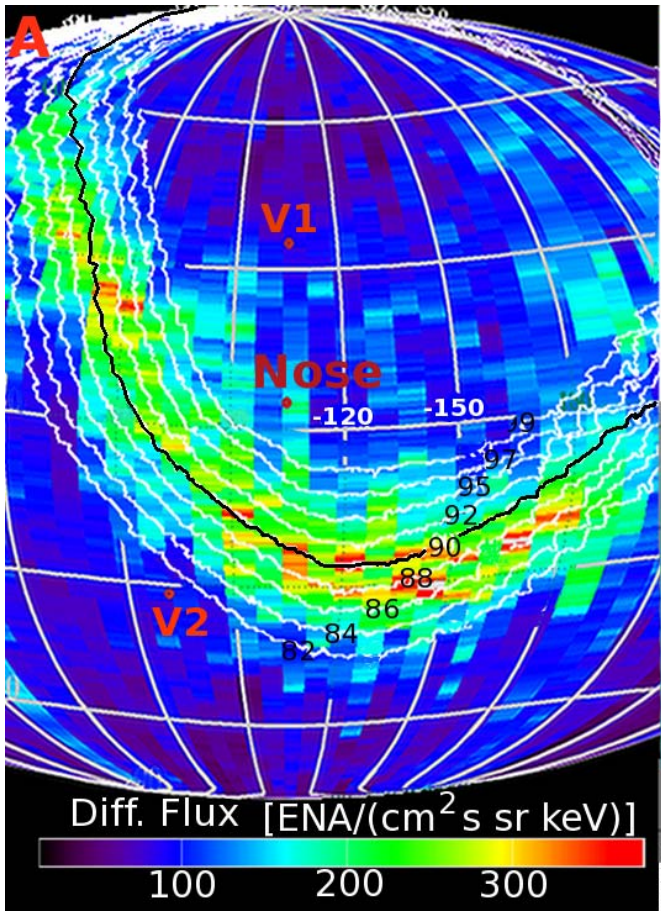






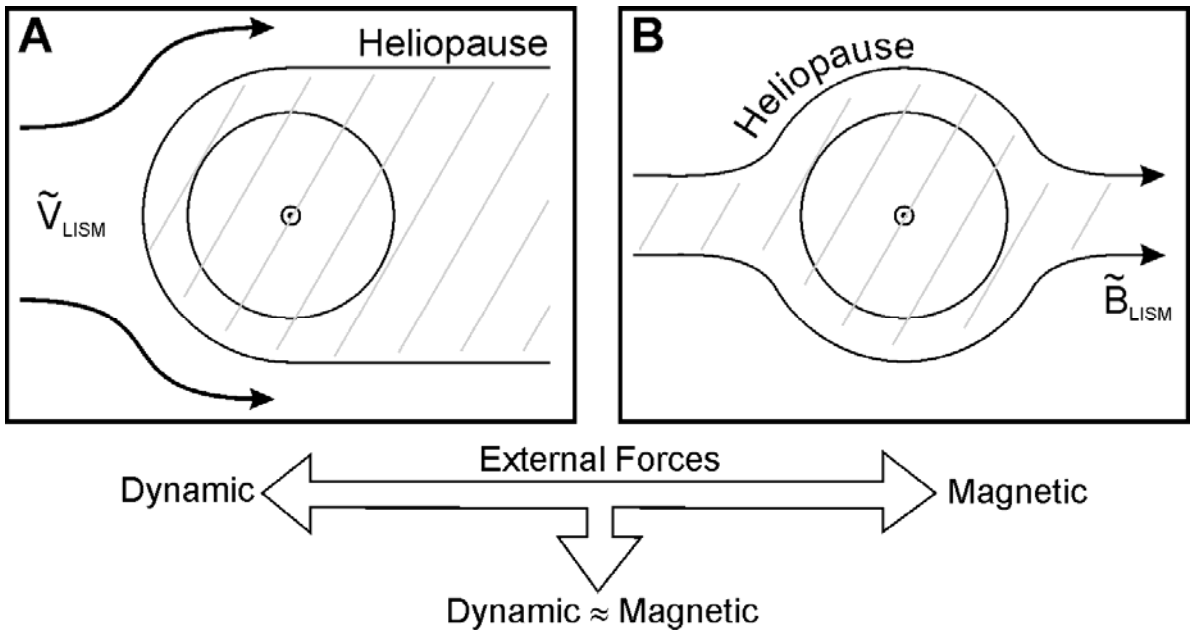
McComas et al., *Science* 2009

Ribbon Correlates with **B•r=0**



Schwadron et al., *Science* 2009

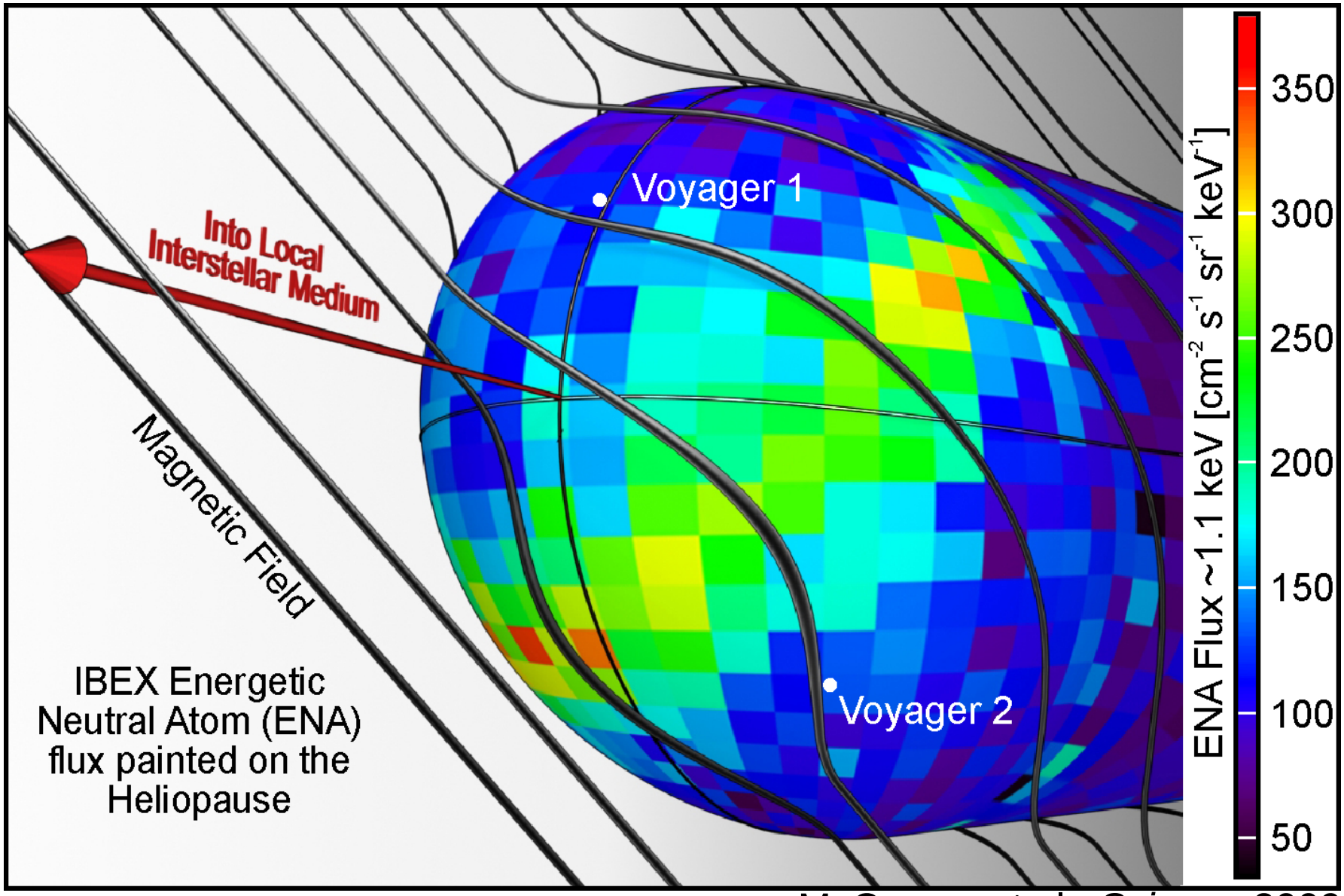
Parker [1961] Interactions



IBEX results indicate both external forces are important!

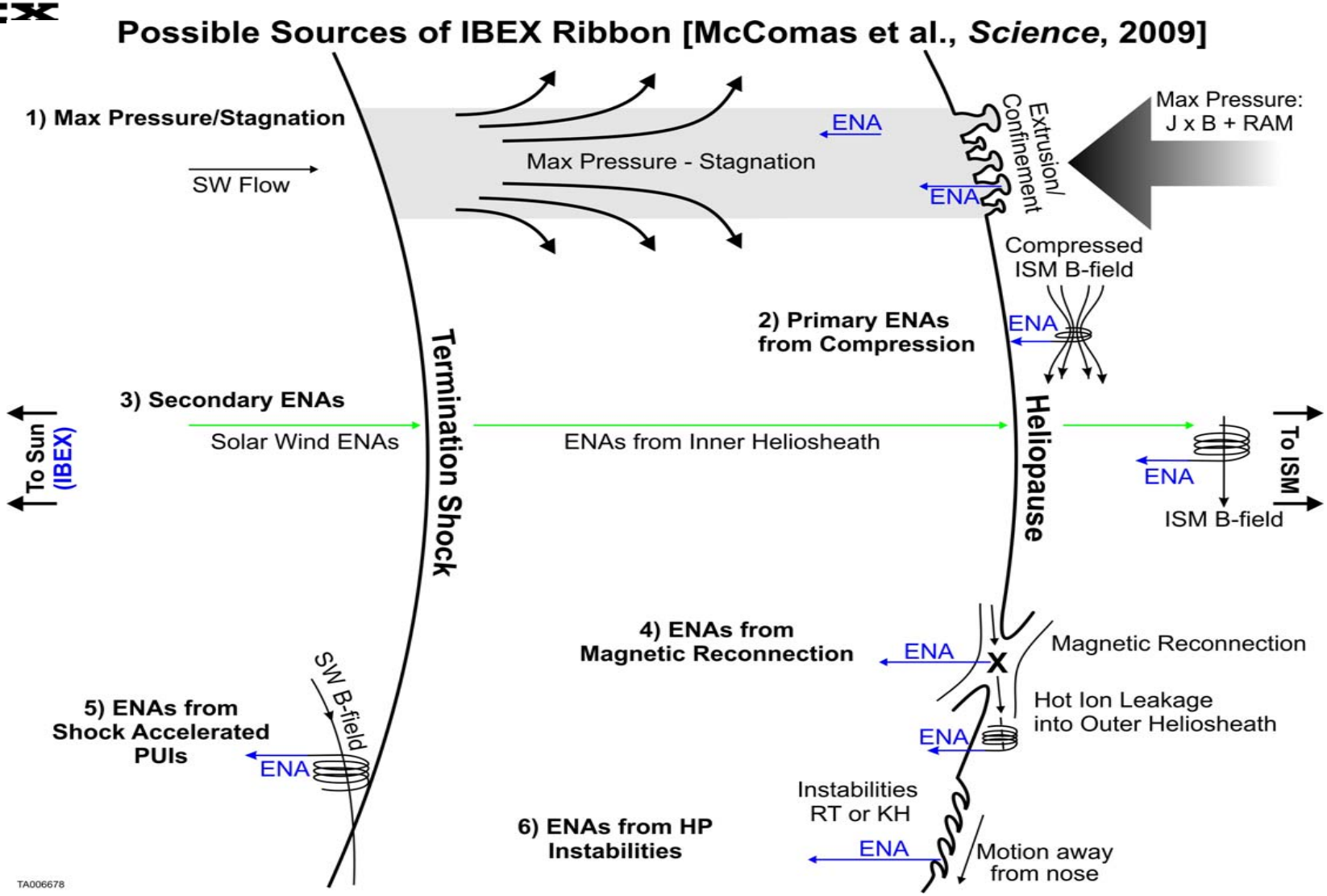
McComas et al., *Science* 2009

A New Paradigm



McComas et al., *Science* 2009

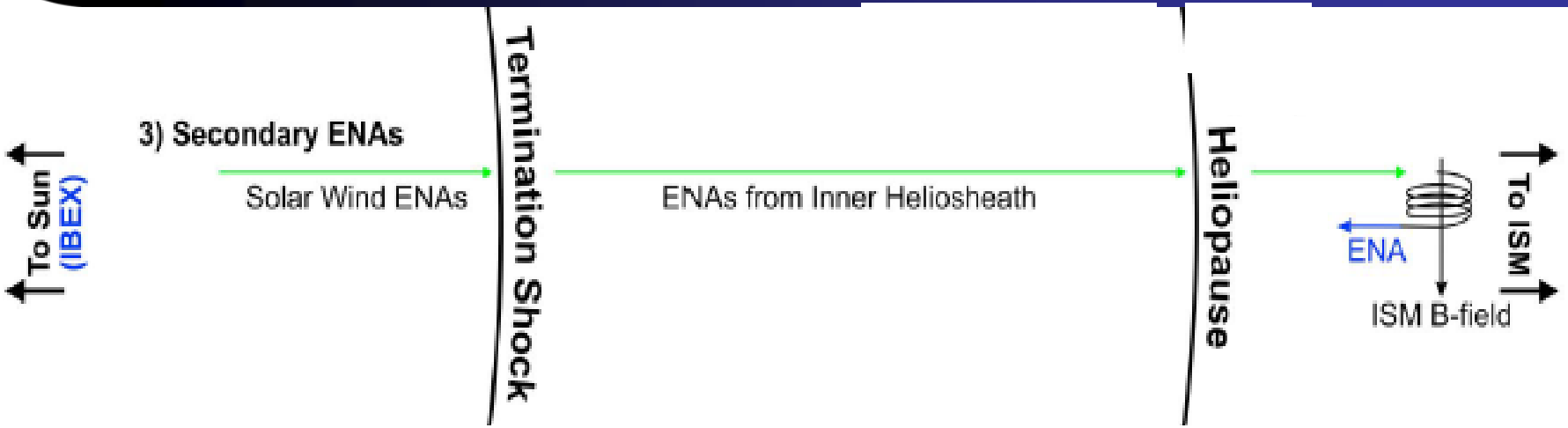
Six+ Possible Ribbon Sources



3 more possible mechanisms published since Science papers

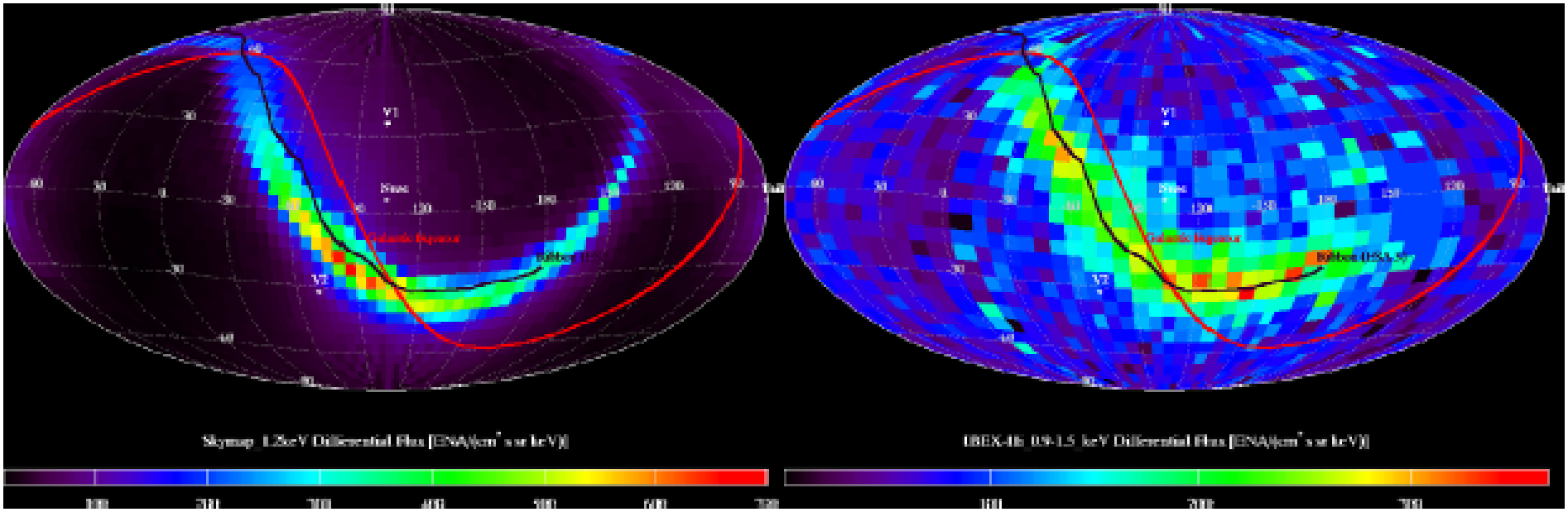
McComas et al., *JGR* 2010

Secondary ENAs



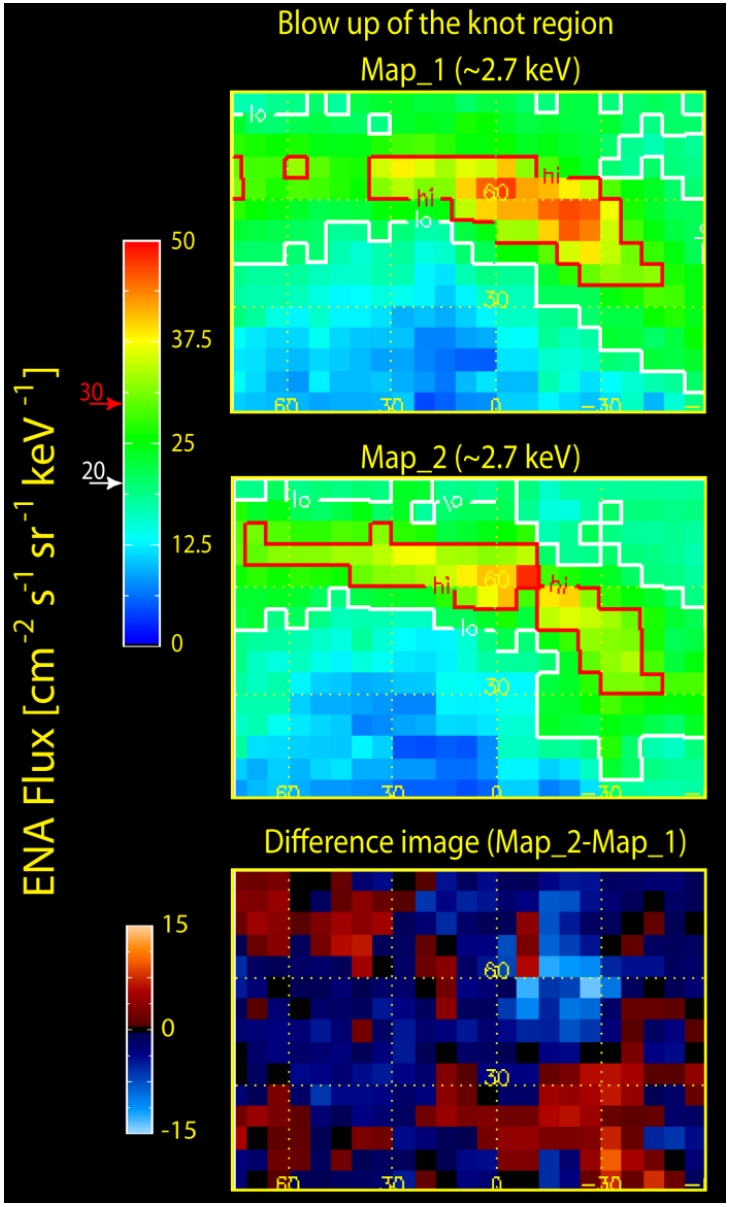
Simulated

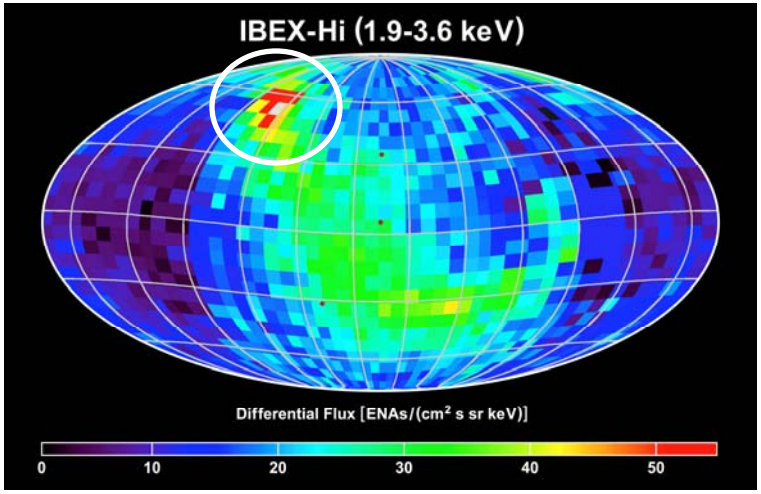
IBEX Data



Heerikhuisen et al., *ApJ* 2010

Time Variations over 6 Months





- Evolution of “knot” in high latitude ribbon
- Overall reduction in global ENA emissions

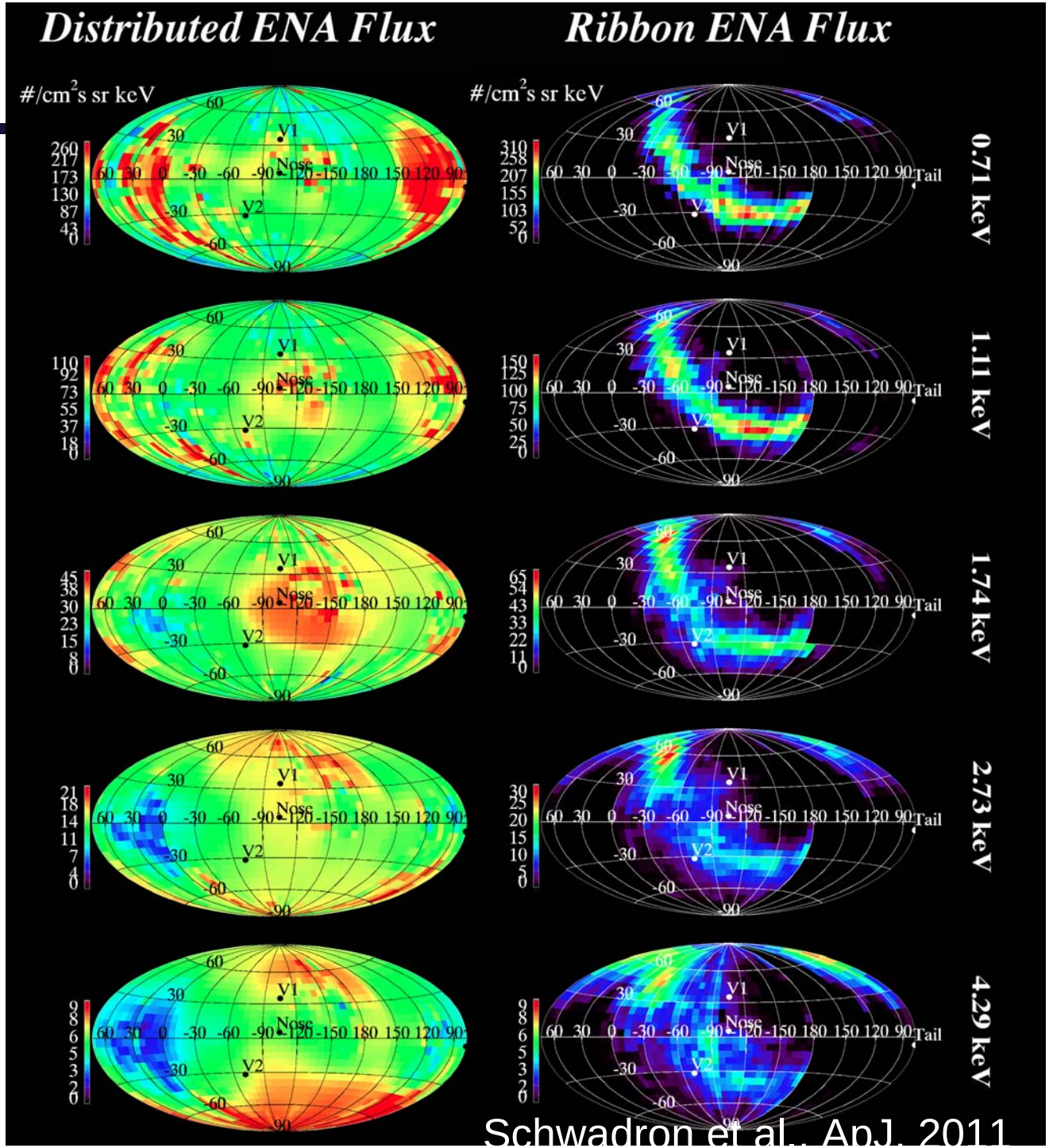
  ←→ likely linked to general reduction in SW flux and pressure

McComas et al., *JGR* 2010

Ribbon Separation

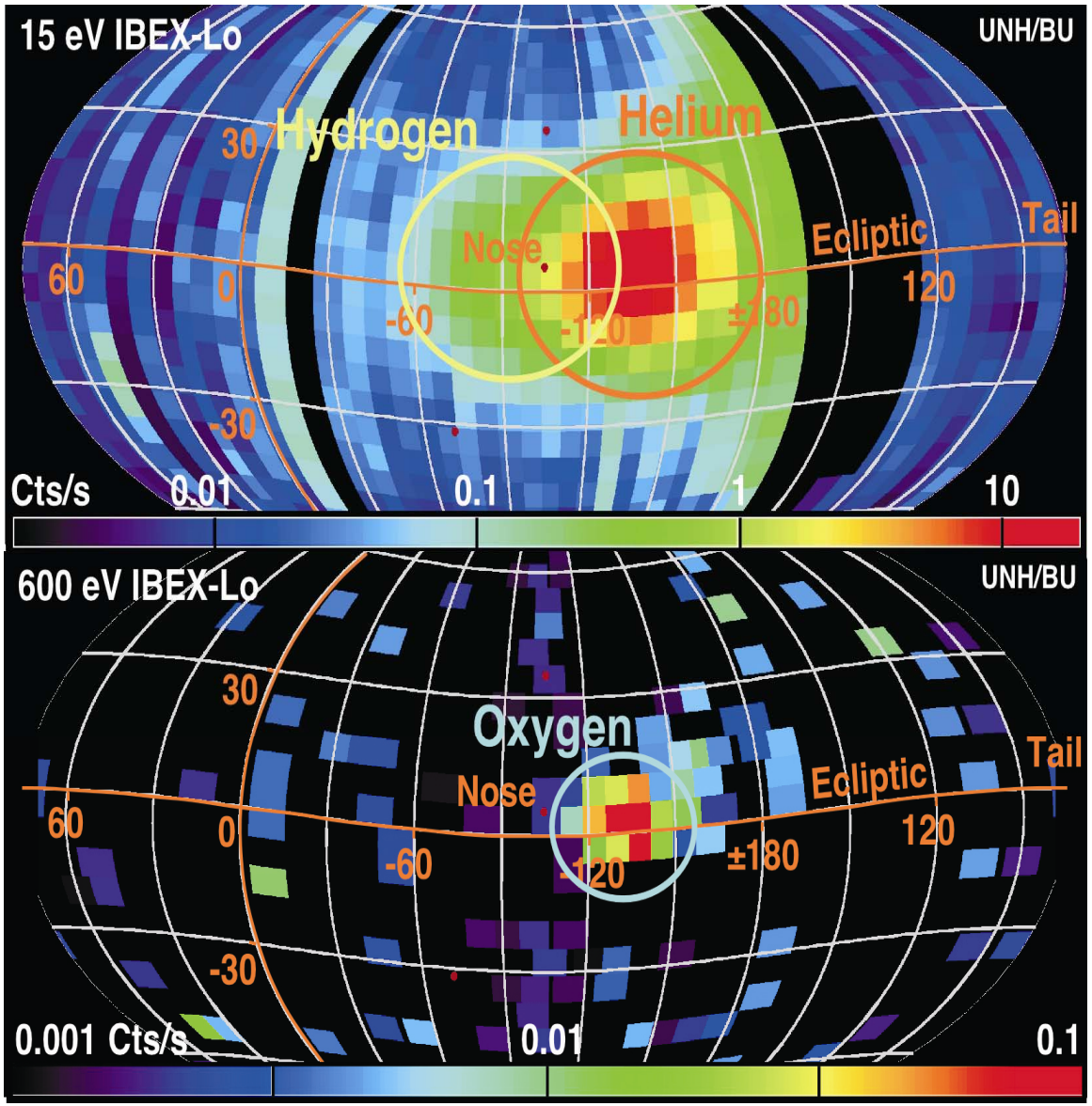
- Based on combination of Maps 1 and 2
- CG corrected
- Sophisticated iterative separation solvers

- Deflected tail and other key science



Schwadron et al., ApJ, 2011

First: Interstellar H and O



Möbius et al., *Science* 2009

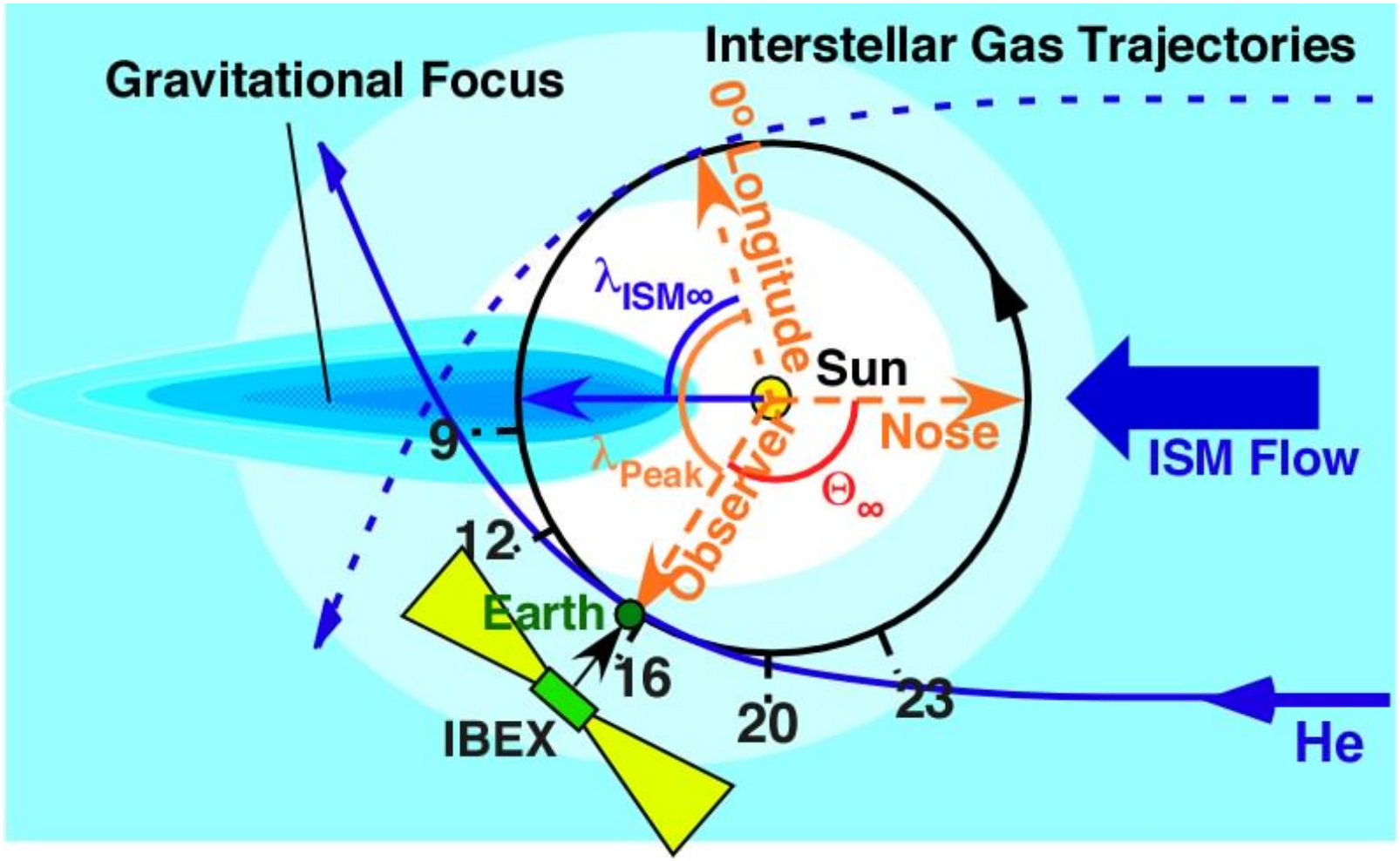
ApJ Special Supplements

- 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)
- Möbius, E. et al., Interstellar Gas Flow Parameters Derived from IBEX-Lo Observations in 2009 and 2010 - Analytical Analysis (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

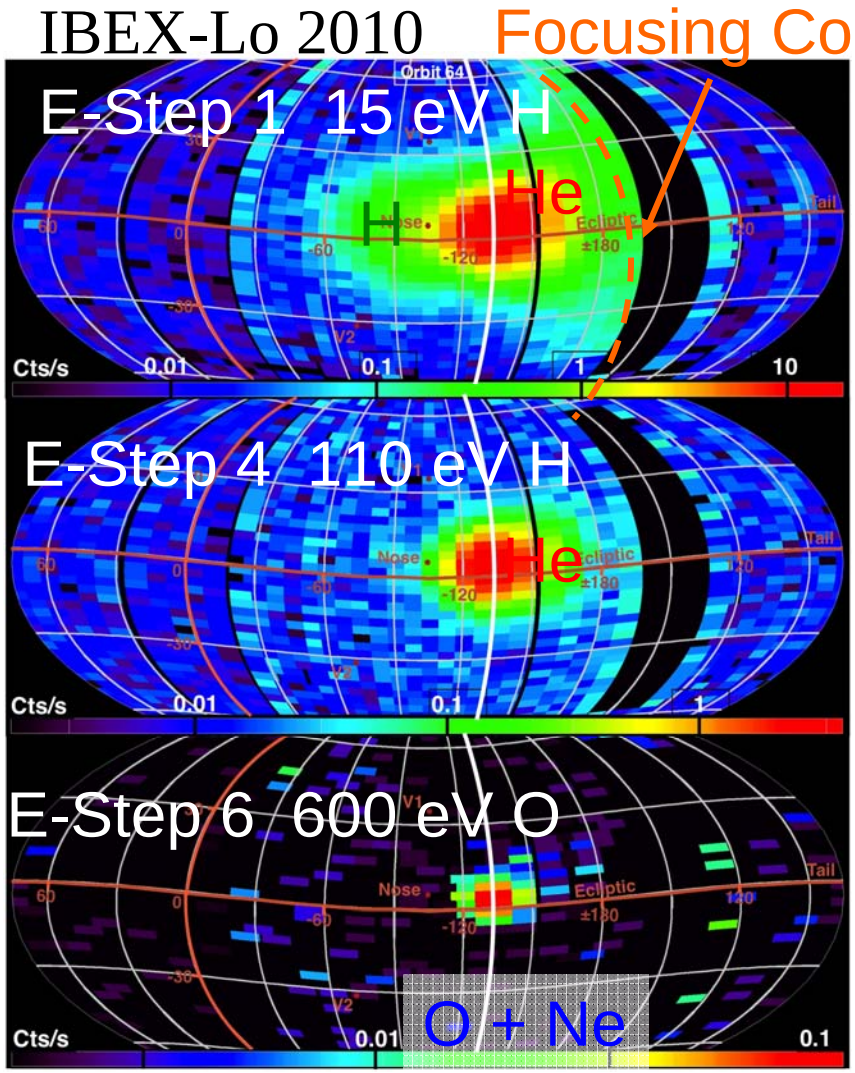
How IBEX Observes the Interstellar Flow

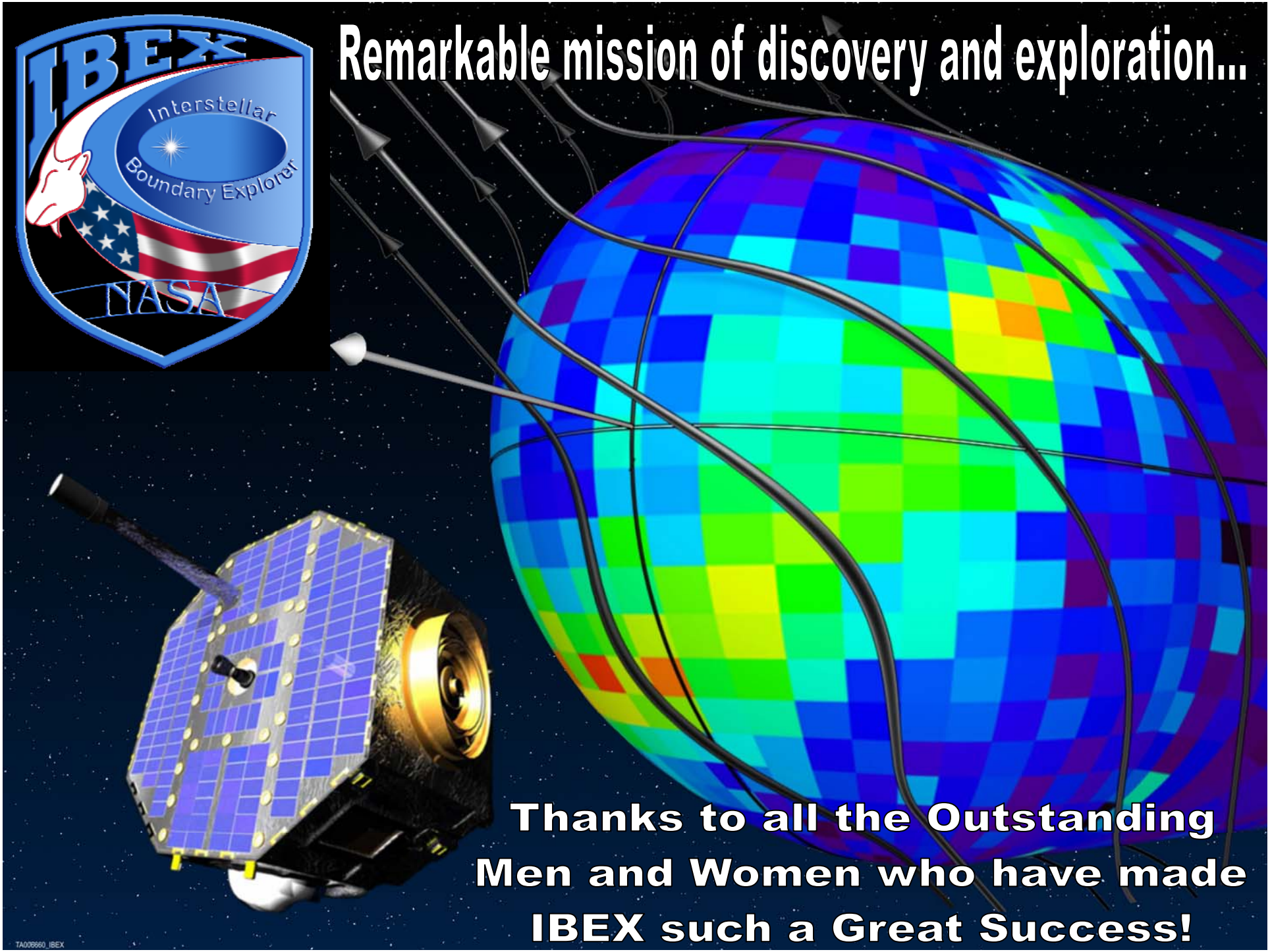


IBEX is a sun-pointed spinner with radially viewing sensors
- Observes the ISM flow at its perihelion

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




IBEX
Interstellar
Boundary Explorer
NASA
Remarkable mission of discovery and exploration...
Thanks to all the Outstanding
Men and Women who have made
IBEX such a Great Success!
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