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IBEX Data Release 9 – Direct Sampling the Local Interstellar Medium

Dave McComas (Southwest Research Institute and University of Texas at San Antonio)

The interstellar medium arises from material ejected as stellar winds and from cataclysmic phenomena such as novae and supernovae. The Interstellar Boundary Explorer (IBEX) directly observes neutral atoms from the local interstellar medium surrounding the Sun that penetrate our heliosphere and survive into Earth's orbit. This material is partially ionized and the ions and neutrals interact with each other, coupling these components together and allowing various aspects of the plasma interactions between the interstellar medium and heliosphere to also imprint themselves onto the observed neutral atom distributions.

IBEX interstellar neutral observations now span six years (2009-2014) and provide a wealth of new information about the very local interstellar medium and its heliospheric interaction. In this *Astrophysical Journal Supplement* special issue, we collect together 14 new studies that describe the IBEX interstellar neutral results over this interval and provide other supporting and relevant observational and theoretical results. The first paper in this issue, McComas et al. 2015, lists the titles and first authors of each of the contributions; that paper also provides an overview and summary of the entire special issue and recommends the best combined interstellar parameters currently available for other researchers to use for theory and modeling studies. Each of the papers in this special issue provides great insight into various detailed aspects of the observations, interpretations, and theories related to IBEX's unique interstellar neutral data set.

Collectively, the 14 studies in this special issue, along with the prior papers, open a completely new window on the local interstellar medium in terms of its composition, properties, and even the processes at work in the interstellar region around our heliosphere. These observations provide the ground truth for understanding the interstellar medium more generally, which is critical for stellar and planetary system formation. They also inform the formation of astrospheres around other stars and a deeper understanding of the tenuous material throughout our galaxy and the other galaxies beyond.

[Level 3 Interstellar Neutral Data by Heirtzler](#)

- Includes data product: IBEX-Lo Interstellar Neutral Histogram Counts and Direct Event Counts
- The analyses of the IBEX He and H ISN flow distributions within this release are based on these data sets

Publications

[Local Interstellar Medium: Six Years of Direct Sampling by IBEX by McComas et al](#)

- Presents an overview of the 14 studies in the Astrophysical Journal Supplement Series Special Issue
- Provides the community with a set of recommended interstellar parameters based on recent work

[Determination of Interstellar He Parameters Using 5 Years of Data From IBEX: Beyond Closed-form Approximations by Schwadron et al](#)

- Includes data product: IBEX Data Used to Compute Interstellar He Parameters
- Uses a comparison between simulated results and IBEX measurements to determine interstellar neutral He parameters
- Varies these parameters along the IBEX parameter tube to minimize the chi-square difference between observations and simulations
- This analysis results in values for ISN He flow longitude, latitude, speed, and temperature

[Interstellar Neutral Helium in the Heliosphere from IBEX Observations. III. Mach Number of the Flow, Velocity Vector, and Temperature from the First Six Years of Measurements by Bzowski et al](#)

- Includes data product: Covariance Matrix of Inflow Parameters
- Presents the results of the Warsaw analysis of IBEX ISN He observations from 2009-2014
- Shows the temperature and velocity vector of ISN He using these methods
- Discusses the scatter of the ISN He parameters obtained for individual observation seasons

[Interstellar Flow and Temperature Determination with IBEX: Robustness and Sensitivity to Systematic Effects by Möbius et al](#)

- Includes data product: IBEX Data Used in Interstellar Neutral Temperature Analysis
- Compares the ISN flow analysis results between all 4 different models
- Provides the absolute pointing uncertainty of IBEX-Lo
- Evaluates systematic effects on the ISN flow parameter determination and their contribution to the uncertainty budget
- Determines the interstellar neutral He temperature based on six years of IBEX data, along with the associated statistical and systematic uncertainties

[Interstellar Neutral Helium in the Heliosphere from IBEX Observations. II. The Warsaw Test Particle Model (WTPM) by Sokół](#)

- Includes data product: Total Ionization Rates for Interstellar Neutral Helium
- Provides a detailed description the Warsaw Test Particle Model used to determine ISN He parameters

- Presents the analytical formulae for connecting the local state vector of an individual He atom at IBEX with its state vector in the source region of ISN gas
- Discusses the effect of the ionization losses on the shape of the ISN He flux reaching IBEX

[Interstellar Neutral Helium in the Heliosphere from IBEX Observations. I. Uncertainties and Backgrounds in the Data and Parameter Determination Method by Swaczyna et al](#)

- Includes data products: IBEX Ephemeris, IBEX Spin Axis Pointing, IBEX Good Times, IBEX Spin-Angle Bin Counts, and Covariance Matrix of Spin-Angle Data.
- Presents a method of fitting the temperature and velocity of ISN He
- Presents the resulting ISN He parameters with an accompanying parameter covariance matrix
- Discusses the magnitude of the parameter uncertainties and identifies the Warm Breeze as the main contributor to the uncertainty

[Statistical Analysis of the Heavy Neutral Atoms Measured by IBEX by Park et al](#)

- Includes data product: IBEX-Lo Heavy Neutral Maps
- Describes the generation of combined heavy neutral maps
- Examines three statistical analysis methods: the signal-to-noise filter, the confidence limit method, and the cluster analysis
- Discusses two notable observed features: the ISN O& Ne flow and the extended tail

[The Analytical Structure of the Primary Interstellar Helium Distribution Function in the Heliosphere by Lee et al](#)

- Presents a new analytical model for the distribution of interstellar helium in the heliosphere
- The model is tailored for comparison with IBEX-Lo observations in order to determine the bulk velocity and temperature of interstellar He
- For specified interstellar parameters, the model predicts the latitudinal and longitudinal structure of the helium distribution
- The model is in reasonable agreement with IBEX observations and the predictions of the other available models

[The Interstellar Neutral He Haze in the Heliosphere: What Can We Learn? by Sokół et al.](#)

- Presents the dependence of the ISN He signal on the magnitude of the lower energy threshold in sensitivity
- Illustrates and explains the differences in the expected ISN He signals during the Fall and Spring ISN He observation seasons
- Presents simulated full-sky maps of neutral He for two different theoretical scenarios for the signal observed by IBEX
- Uses observations to determine the most likely scenario: signal is due to separate ISN He and Warm Breeze populations

[Can IBEX Detect Interstellar Neutral Helium or Oxygen from Anti-ram Directions? by Galli et al.](#)

- Analyzes IBEX-Lo data for October and November when ISN inflow of He and O from anti ram directions is most likely
- Interprets observations using the combined model of ISN flow and Warm Breeze presented by Sokol et al. 2015
- Concludes that the fall signal of ISN He from anti-ram directions cannot be observed by IBEX-Lo

[Exploring the Possibility of O and Ne Contamination in Ulysses Observations of Interstellar Helium by Wood et al.](#)

- Shows that a significant contribution of neutral O and Ne to the observed Ulysses signal could lead to an underestimate of ISM temperature
- This could explain why Ulysses data seem to imply lower ISM temperatures than IBEX
- The amount of O/Ne required to explain this discrepancy is about an order of magnitude higher than the expected ISM abundances

[3D Kinetic-MHD Model of the Global Heliosphere with the Heliopause-surface Fitting by Izmodenov & Alexashov](#)

- Provides a detailed description of a 3D kinetic-MHD model of the interaction between the solar wind and LISM used to analyze IBEX data
- Describes the effects of the heliospheric and interstellar magnetic fields and latitudinal variations on the shape of the termination shock and heliopause
- Develops a set of interstellar parameters that provide reasonable model agreement to the different observational diagnostics of the heliospheric boundaries

[Impact of the Solar Radiation Pressure on Fluxes of Interstellar Hydrogen Atoms Measured by IBEX by Katushkina](#)

- Models the interstellar hydrogen fluxes measured by IBEX-Lo in 2009 using the 3D kinetic-MHD model developed by Izmodenov and Alexashov (2015)
- Finds that the ratio of count rates in the first and second energy bins of IBEX-Low is sensitive to the solar radiation pressure
- Fits the observational data to obtain best fit model parameters for the solar radiation pressure and the hydrogen ionization rate at 1 AU
- The resulting solar radiation pressure is significantly larger than that derived from measurements of the solar Lyman-alpha irradiance

[Impact of Planetary Gravitation on High-precision Neutral Atom Measurements by Kucharek et al.](#)

- Investigates the impact of gravitational effects from the Earth, Moon and Jupiter on ENA measurements performed in Earth orbit

- Shows that the current analysis of ISN parameters by IBEX is not significantly affected by planetary gravitation effects
- Concludes that future instruments with higher angular resolution at lower energies could observe these effects
- Examines the possibility of IBEX measuring the He focusing cone of the Sun/Jupiter and using these observations to determine the temperature of interstellar He