Data Analysis of IBEX-Lo Energy Steps 1, 2, 3 and 4 for Neutral Interstellar He

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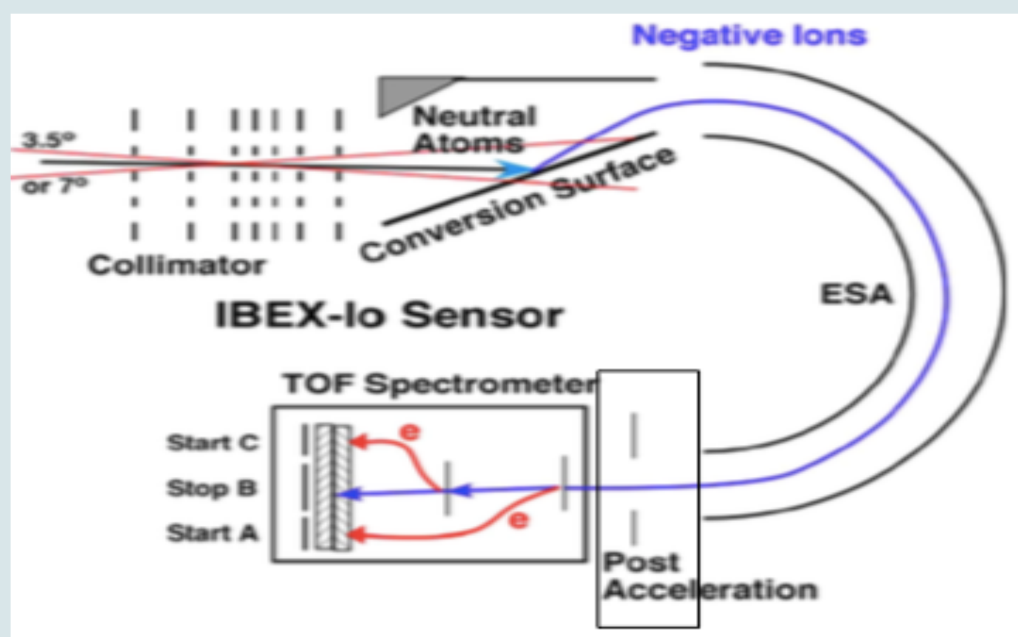
Abstract

We determined the position of the bulk flow (*λpeak)* of interstellar neutral (ISN) Helium (He) at Earth's orbit using observations of the Interstellar Boundary Explorer (IBEX) to analyze sensor efficiency related to ecliptic longitude, and energy steps. *λpeak* was found for energy steps 1, 2, 3, and 4 using the count integrated count rates observed by the IBEX-Lo sensor during the year 2013. The ecliptic longitude of the maximum of these rates determines a fixed relation between the interstellar flow speed and direction through the trajectory of neutral Helium in the Sun's gravitational field. Analyzing these new parameters relating to sensor efficiency can be used to minimization of the chi-square relation between observed and simulated data. This minimization provides better analysis of parameter of the ISN He flow.

IBEX-Lo sensor

The IBEX-Lo detector is designed for the observation of Interstellar Neutral gas flow. It analysis particles in the energy range of 10-2000 eV. The satellite consist of five subsections that combine to provide the identity of the incoming neutral particles.



Above is a schematic of the subsections of the IBEX-Lo detector

- **Collimator and negatively biased rejection rings**
  -The collimator defines the field of view of the instrument which is 7 degrees full width half max. The negatively biased rejection rings reject electrons with energies of 200 eV or less. A positive potential is applied to the collimator to repel all positive ions
- **Conversion surface**
  -Converts incoming neutral particles into negative ions through charge exchange and while also producing sputtered Carbon, Oxygen and Hydrogen ions.
- **Electrostatic analyzer**
  - Filters negative ions in the desired energy range.
- **Post accelerator**
  -A post acceleration is applied to minimize uncertainty in the measurement and give the ions higher energy for proper analysis by the time of flight mass spectrometer.
- **Triple coincidence Time or Flight spectrometer**
  -Analyze the incoming particles speeds while suppressing unwanted events. The known energy range and calculated velocity can then be used to obtain the mass and identity of the particle.

Energy Distribution and Sputtering

Conversion surface

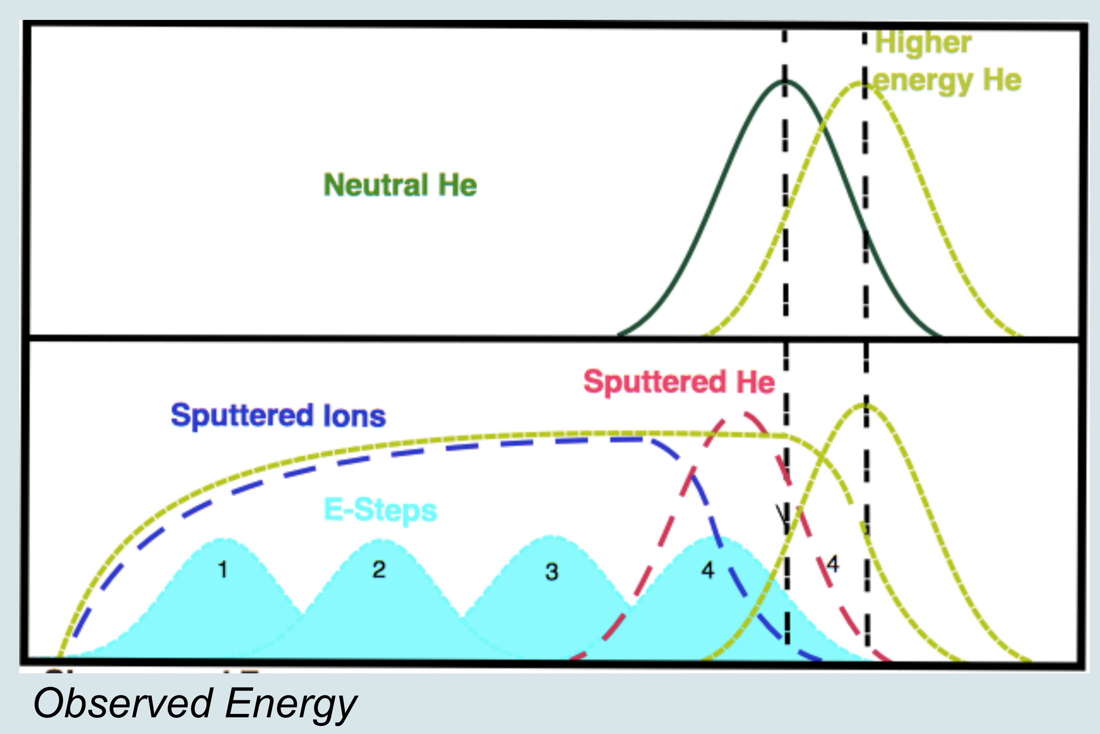
- Before the electrostatic analyzer can sort the incoming neutrals into different energy steps they must first be ionized by the conversions surface

Sputtering

- Certain Neutral particles, like He, are not ionized due to their stable electron shell. Their interaction with the conversion surface produces negatively charged Oxygen, Carbon and Hydrogen.

Energy Distribution

- Sputtered ions, produced by He, have an energy distribution spanning over energy steps 1-4. The higher the energy He has the larger the distribution.



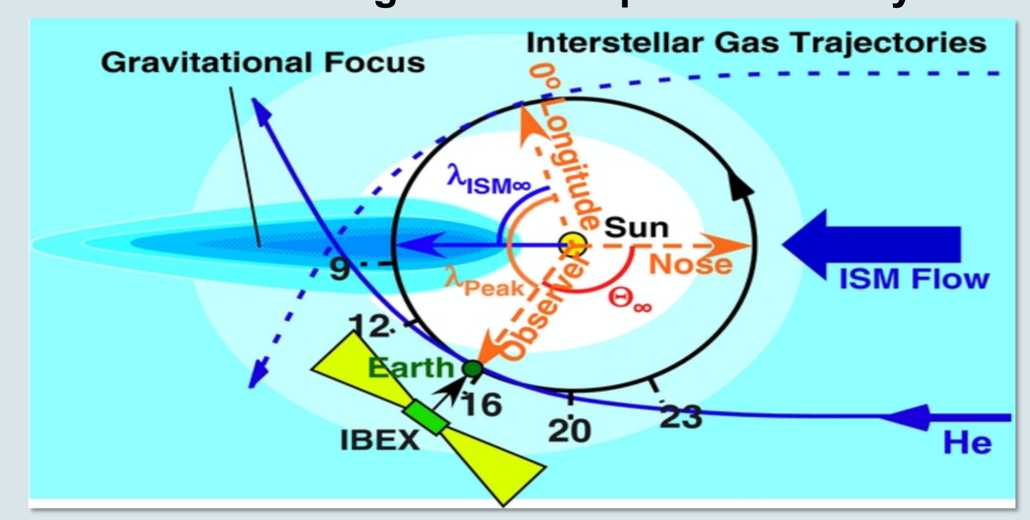
- The graph above is an image of the energy distributions of ISN He and it's resulting energy distributions before and after interaction with the conversion surface. The red line shows the energy distribution of He which lost because in cannot be analyzed because its neutral.

Calibration

- The IBEX-Lo sensor was calibrated with controlled beam of Neutral He at different energy level. The ratios of the production of different sputtered ions allows for the identification of He.

Inflow Speed Related to Ecliptic Longitude

Determining the Flow Speed at Infinity



- Sputtering in the IBEX-Lo instrument results in an energy distribution too broad to be used in the calculation of the particles energy and ultimately the speed. Instead Keplerian trajectories are used to obtain the speed and energy of the particles analytically .

Trajectory equations

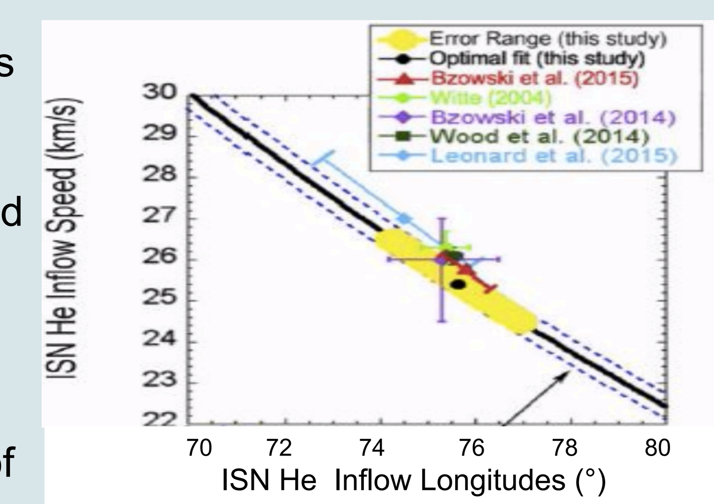
$$\theta_\infty = \lambda_{ISM\infty} + 180^\circ - \lambda_{Peak}$$

$$\frac{1}{\cos(\theta_\infty)} = 1 + \left(\frac{r_E V_{ISM\infty}^2}{GM_S}\right)$$

$$V_{ISM\infty} = \sqrt{\frac{GM_S}{r_E} * \left(\frac{-1}{\cos(\theta\infty)} - 1\right)}$$

Parameter Tube

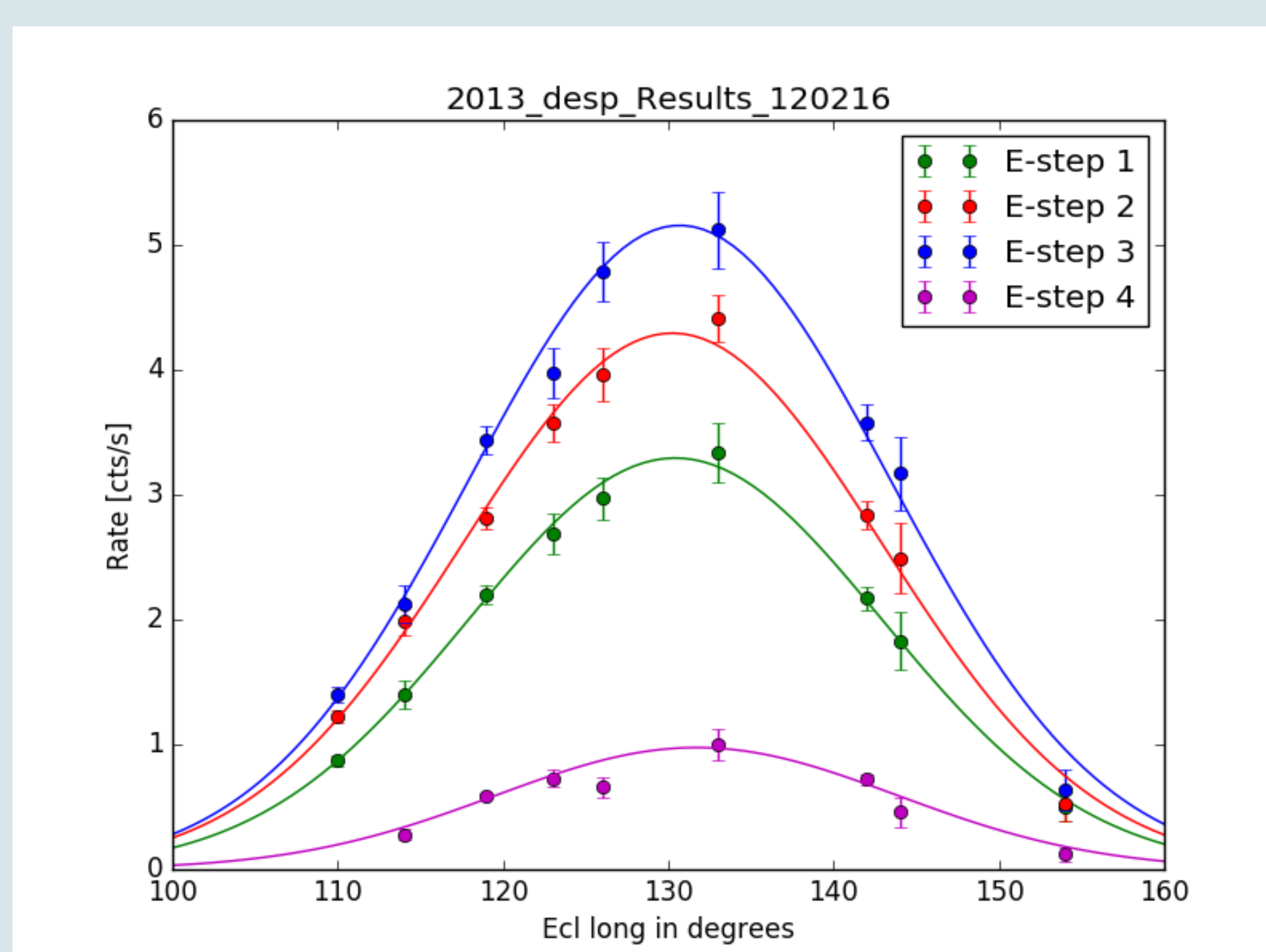
- The particle trajectories defined by the Ecliptic longitude and latitude, speed, temperature and density result in a parameter tube. The error bars for the parameter tube are large due to coupling of different parameters.



From Schwadron et al.. 2015 APJ 220:15

- Measurements of the location of the *λpeak* in different energy steps will provide a more accurate value for the efficiency of the IBEX-Lo sensor

Data Analysis



E-Step 1

	value	Error
Rate [cts/s]	3.29	0.05
λpeak In ecliptic longitude	130.42	0.14
Width of Gaussian	12.52	0.15

Efficiency = 0.99864

E-Step 2

	values	Error
Rate [cts/s]	4.29	0.11
λpeak In ecliptic longitude	130.24	0.28
Width of Gaussian	12.72	0.30

Efficiency =0.99389

E-Step 3

	values	Error
Rate [cts/s]	5.16	0.16
λpeak In ecliptic longitude	130.69	0.32
Width of Gaussian	12.72	0.34

Efficiency= 0.99435

E-Step 4

	values	Error
Rate [cts/s]	0.98	0.09
*λpeak*In ecliptic longitude	131.71	0.71
Width of Gaussian	12.16	1.22

Efficiency= 0.95196

Analysis

Efficiency
-count rate per energy

Sensor Efficiencies related peak location
-E-steps 1-3 have similar peak positions in ecliptic longitudes and a similar efficiency
-E-step 4 has a higher peak position in ecliptic longitude and the lower sensor efficiency

Efficiency related to E-step 1-3
-E-steps 1-3 have a small angular difference in the location of the *λpeak*. This results in similar energies of neutral He.
-Energy steps 1-3 have similar efficiencies because as the energy steps increase so does the count rate.
-*λpeak* appears to be independent of energy steps

Efficiency related to E-step 4
-E-step 4's position of *λpeak* is shifted to higher position in ecliptic longitude. At this position the energy distribution is shifted to the right.
-E-step 4 has a lower expected efficiency do to it's lower count rate at higher energies

Difference in efficiency in E-step 3 and 4
- E-step 3 has a high efficiency do to the production of sputtered ions by the incoming Neutral He. Estep 4 has a lower efficiency because of low count rates at higher energies do to the shifted *λpeak.*

Conclusion

-The analysis of the position of *λpeak* ,related to Energy steps, provided us with the observation of an independence in the position of the *λpeak* for Esteps 1-3 and a shift in the *λpeak* for energy step 4. This shift is do to the inability to observe sputtered ions at high energies. The location of *λpeak* was shifted for Estep 4 because the energy distribution for Estep 1-3 didn't provide the proper amount of counts for a peak location to be observed for Estep 4. A shift in ecliptic longitude provided a increase in the energy of ISN He enough to provide Estep 4 with a small increase in count rate. This observed of *λpeak* is do to over compensation of energy loss due to the conversion surface.

References & Acknowledgements

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