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

Interstellar Neutral He Parameters from Crossing Parameter Tubes with the Interstellar Mapping and Acceleration Probe (IMAP) informed by 10 Years of Interstellar Boundary Explorer (IBEX) Observations

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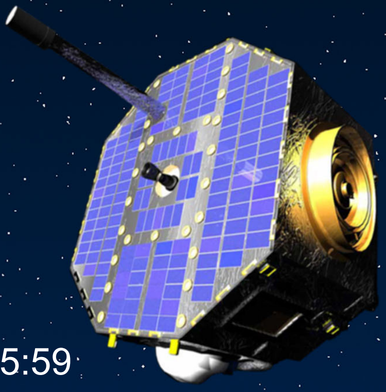
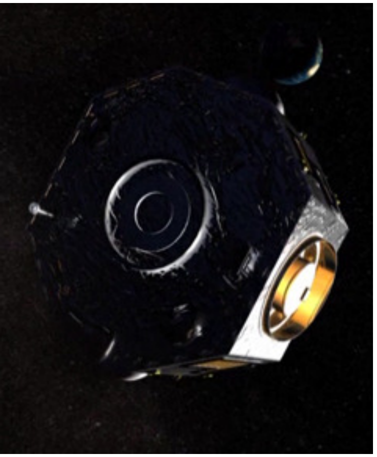
IMAP



EGU 2022 ST1.7-03 Schwadron ISN Xing Tubes Thur May 26 15:59

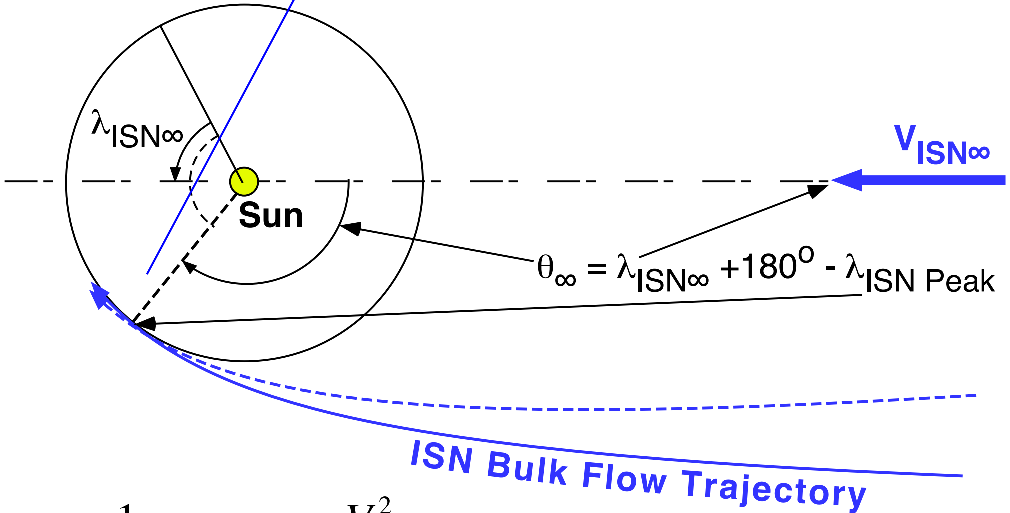
TA007367_IBEX

IBEX-Lo: Degeneracy from fixed orientation

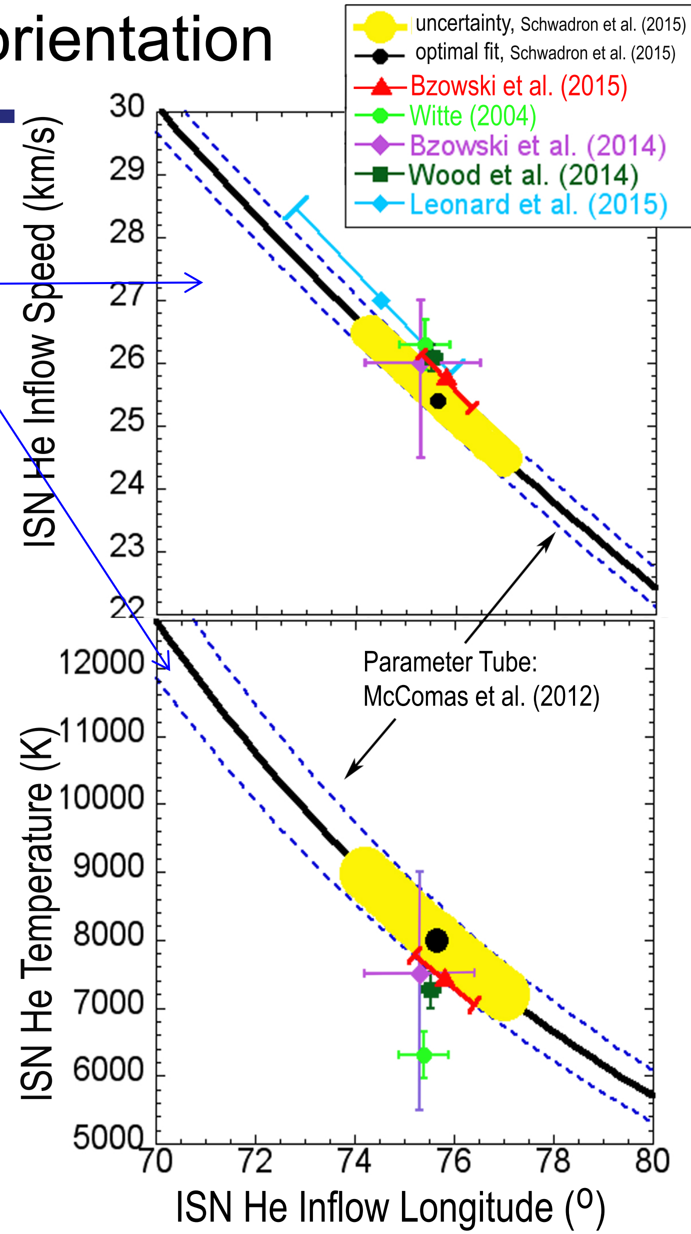


Degeneracy:
ISN parameter tube

IBEX sweet-spot
from IBEX-Lo
fixed orienation
90° to spin-axis



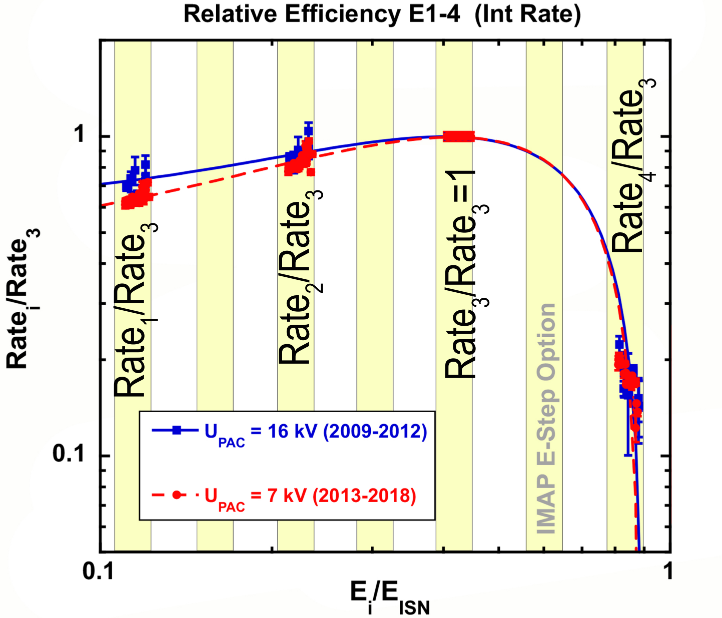
$$\frac{-1}{\cos(\theta_\infty)} = 1 + \left(\frac{r_E V_{ISN\infty}^2}{GM_s}\right)$$



Schwadron et al. 2015

Breaking the Degeneracy Variation with Elongation

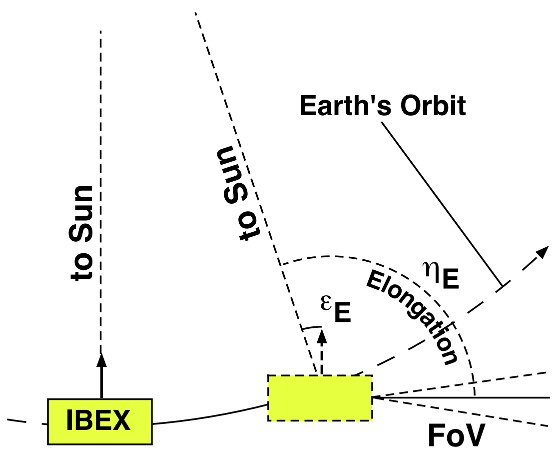
Schwadron et al., ApJ, In Press 2021

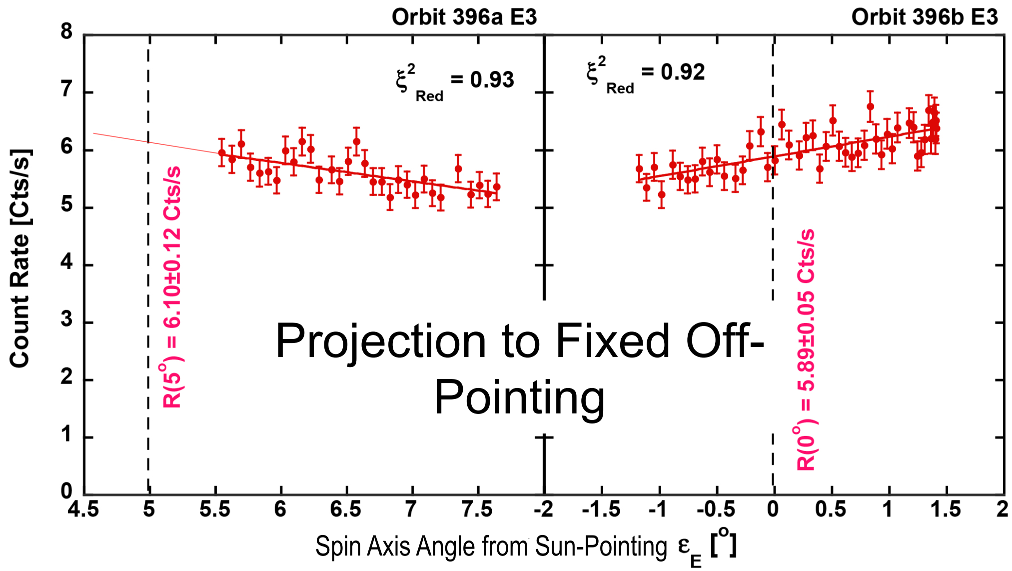


Steeper variation of efficiency with energy in E-Step 1 and 2 after the PAC reduction connected to two sputtered populations

- **knock-on sputtering:** encounter of He atom w surface atom (or molecule), sputter products with **energies near incident particle** concentrated in angle around specular reflection of incoming ISN atom on conversion surface
- **Sputtering due to excitation** of the surface lattice leads to **boil-off of atoms with very low energy** and almost isotropic angular distribution (Sigmund 1981).

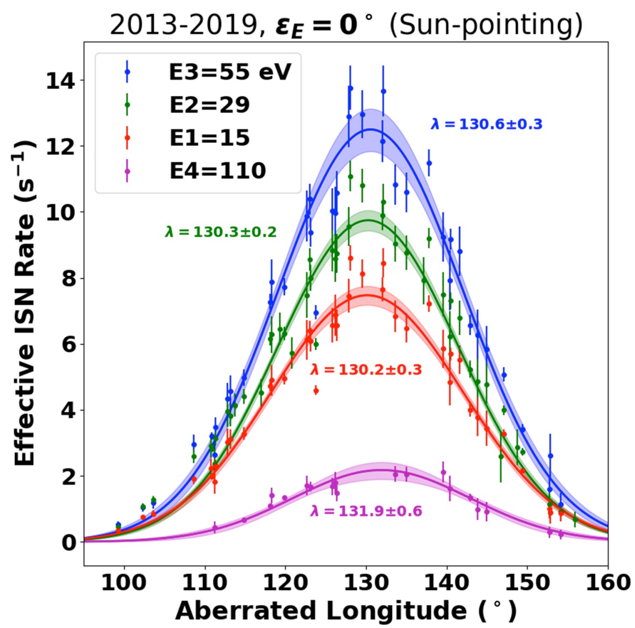
Focusing of angular distribution of ions from the conversion surface and thus the effective collection of these ions improves with increasing PAC voltage (Wieser et al. 2007).

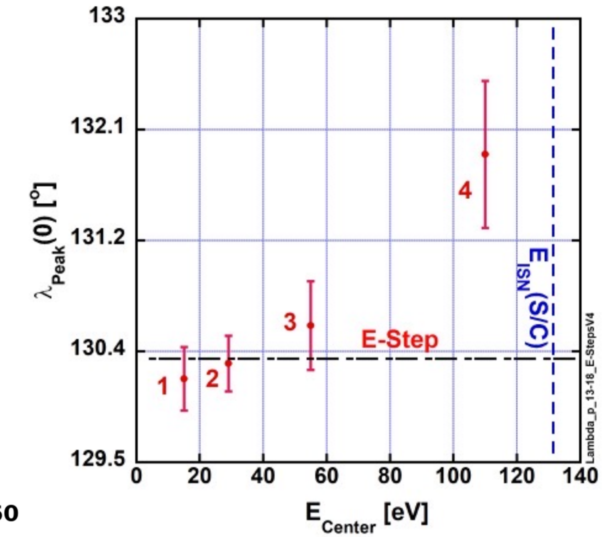




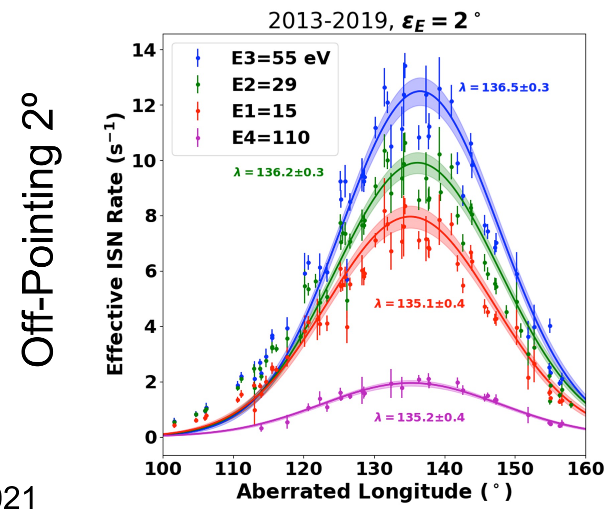
Variation with Aberrated Longitude

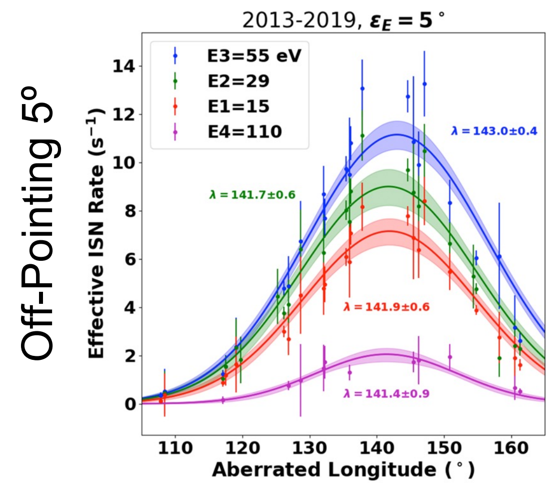
Sun-Pointing Case





Off-Pointing Cases





Schwadron et al., ApJ, In Press 2021

Average LISM Conditions

Table 1. Local Interstellar Conditions

Method/instrument	$V_{\rm ISN\infty}$ [km s^{-1}]	$\lambda_{\rm ISN\infty}$ [°]	$\beta_{\rm ISN\infty}$ [°]	$T_{\rm ISN\infty}$ [K]	Reference
Neutral Gas/Ulysses-GAS	26.3 ± 0.4	75.4 ± 0.5	-5.2 ± 0.2	6300 ± 340	Witte (2004)
Neutral Gas/Ulysses-GAS	26.08 ± 0.21	75.54 ± 0.19	-5.44 ± 0.24	7260 ± 270	Wood et al. (2015)
Neutral Gas/Ulysses-GAS	26	75.30		7500	Bzowski et al. (2014)
Neutral He/IBEX	25.4	75.7	-5.1	7500	McComas et al. (2015b)
Neutral He/IBEX	25.8 ± 0.4	75.8 ± 0.5	-5.16 ± 0.1	7440 ± 260	Bzowski et al. (2015)
Neutral He/IBEX[a]	$25.4 \pm^{0.8\rm fit}_{1.1\rm tot}$	$75.6 \pm^{1.0\rm fit}_{1.4\rm tot}$	$-5.12 \pm^{0.04\rm fit}_{0.27\rm total}$	$8000 \pm^{900\rm fit}_{1300\rm tot}$	Schwadron et al. (2015b)
Neutral He/IBEX	25.82 ± 0.33	75.62 ± 0.36	-5.19 ± 0.06	7673 ± 225	Swaczyna et al. (2018)
UV backscatter/EUVE	24.5 ± 2	74.7 ± 0.5	-5.7 ± 0.5	6500 ± 2000	Vallerga et al. (2004)
UV backscatter/Prognoz 6		74.5 ± 1	-6 ± 1		Lallement et al. (2004)
Pickup Ions/ACE-SWICS		74.43 ± 0.33			Gloeckler et al. (2004)
Pickup Ions/STEREO-PLASTIC		75.41 ± 0.34			Taut et al. (2018)
Average[b]	25.99 ± 0.18	75.28 ± 0.13	-5.200 ± 0.075	7496 ± 172	This study
Param Tube Intersection[c]	$25.99^{+1.86}_{-1.76}$	$75.28^{+2.27}_{-2.21}$	$-5.200^{+0.093}_{-0.085}$	7496^{+1274}_{-1528}	This study
Absorption/Haute-provence	25.7 ± 1[c]			7000 ± 1000[d]	Lallement & Bertin (1992)
Absorption/Hubble				7000 ± 200[d]	Linsky et al. (1993)

[a] We state both fit uncertainties (in superscript) and the total uncertainty (in subscript). The total uncertainty is the root-mean-square sum of the fit, statistical and systematic uncertainties.

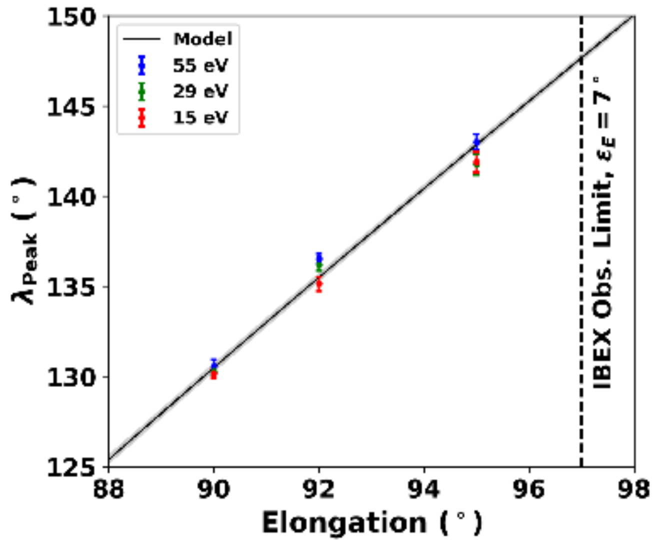
[b] Averaging is done using inverse variance weighting with independent values where available including results from Wood et al. (2015), Swaczyna et al. (2018), Vallerga et al. (2004), Lallement et al. (2004), Gloeckler et al. (2004), and Taut et al. (2018). We exclude the bottom two rows that apply to the Local Interstellar Cloud.

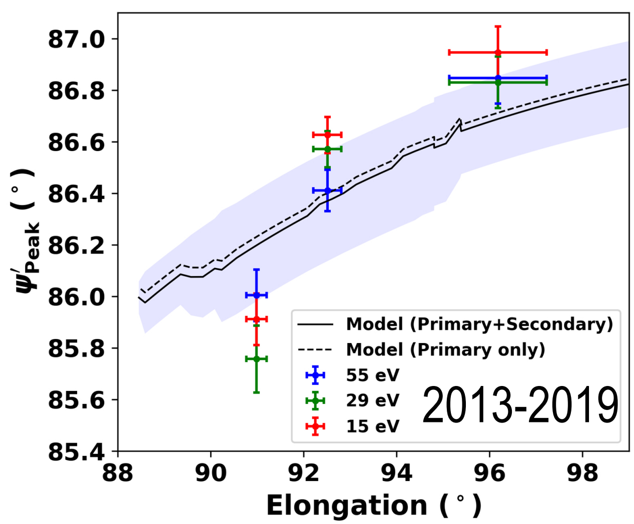
[c] Intersection in Parameter Tubes provides an outer range of uncertainties associated with longitudinal inflow direction and ISN He bulk flow speed. We use similar relations detailed by McComas et al. (2012b) to derive uncertainties for temperature $T_{\rm ISN\infty}$ and latitudinal inflow direction $\beta_{\rm ISN\infty}$ along the parameter tube: $T_{\rm ISN\infty}(\lambda_{\rm ISN\infty}) = 258.645 \cdot V^2_{\rm ISN\infty}(\lambda_{\rm ISN\infty})/(-13.5 + 0.489 \cdot \lambda_{\rm ISN\infty})$, and $\tan(\beta_{\rm ISN\infty}) = -0.03 - 0.073|\sin(\lambda_{\rm ISN\infty} + 48°.04)|$.

[d] Local Interstellar Cloud bulk parameters.

Derived Peak Longitudes & Latitudes

Schwadron et al., ApJ, In Press 2021



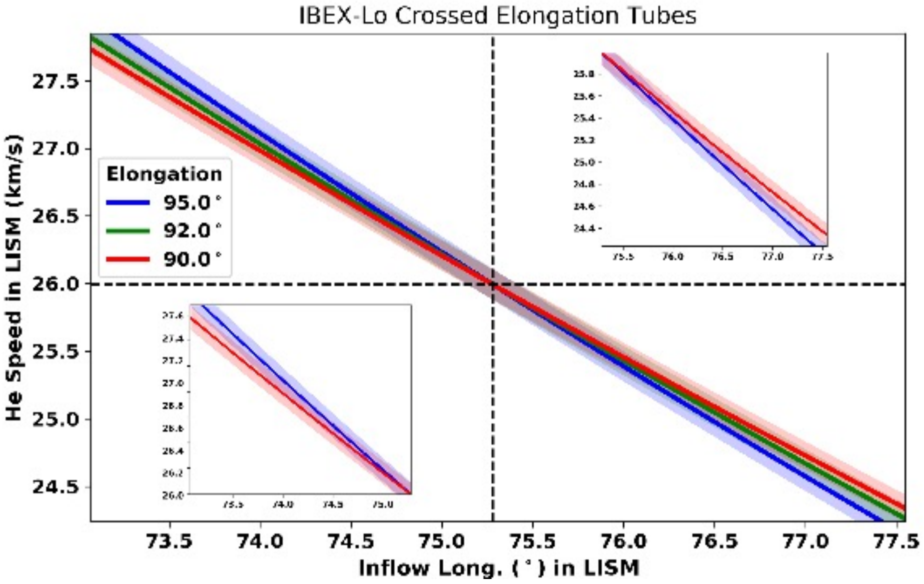


- Model based on Lee et al (2012) ISN Kinematic Eq.
- ISN params (Swaczyna et al., 2018)

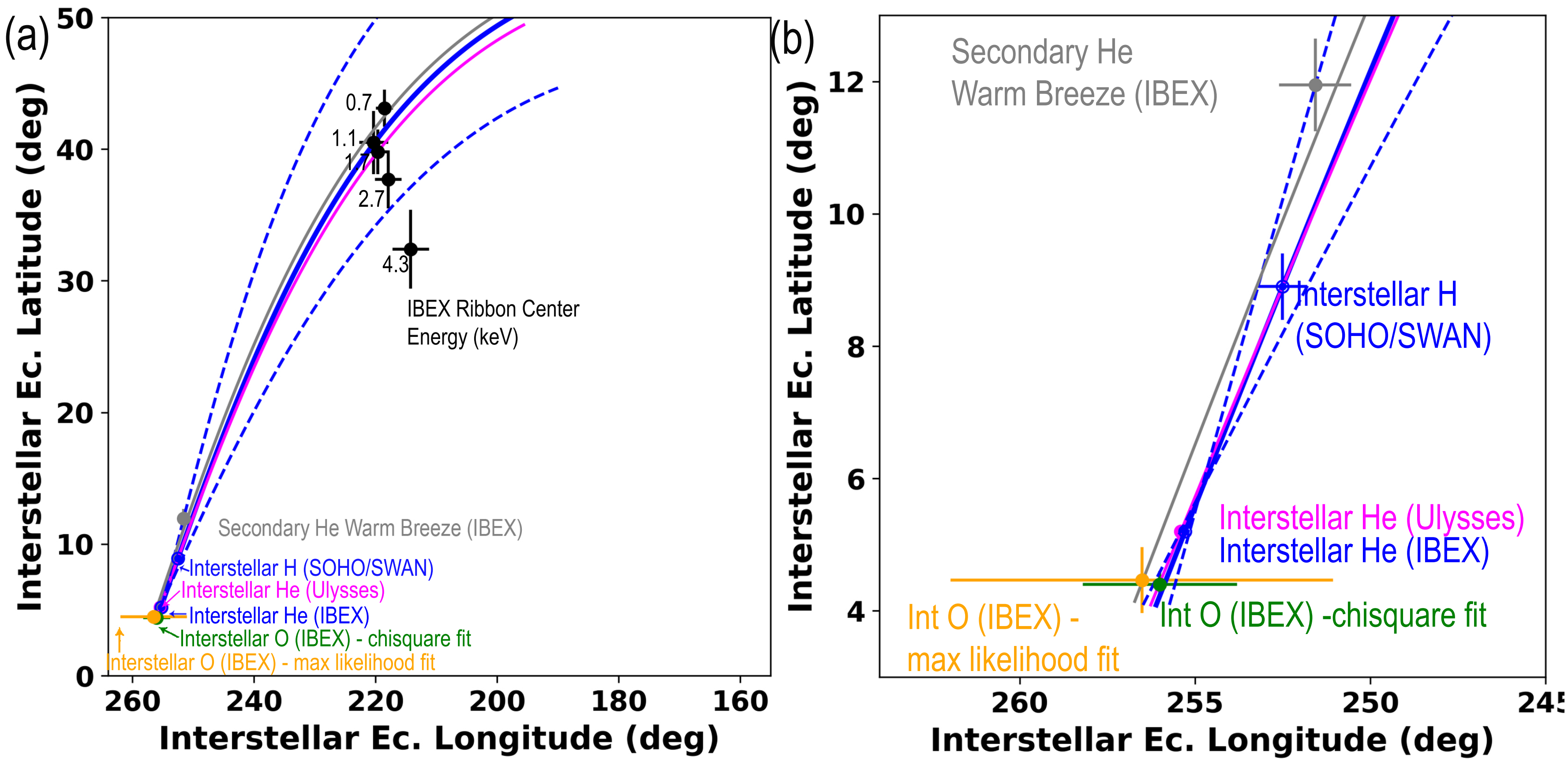
$V_{ISN\infty}$=25.99±0.18 km s^{-1}

$\lambda_{ISN\infty}$=75.28°±0.13°

$\beta_{ISN\infty}$= -5.200°±0.075°

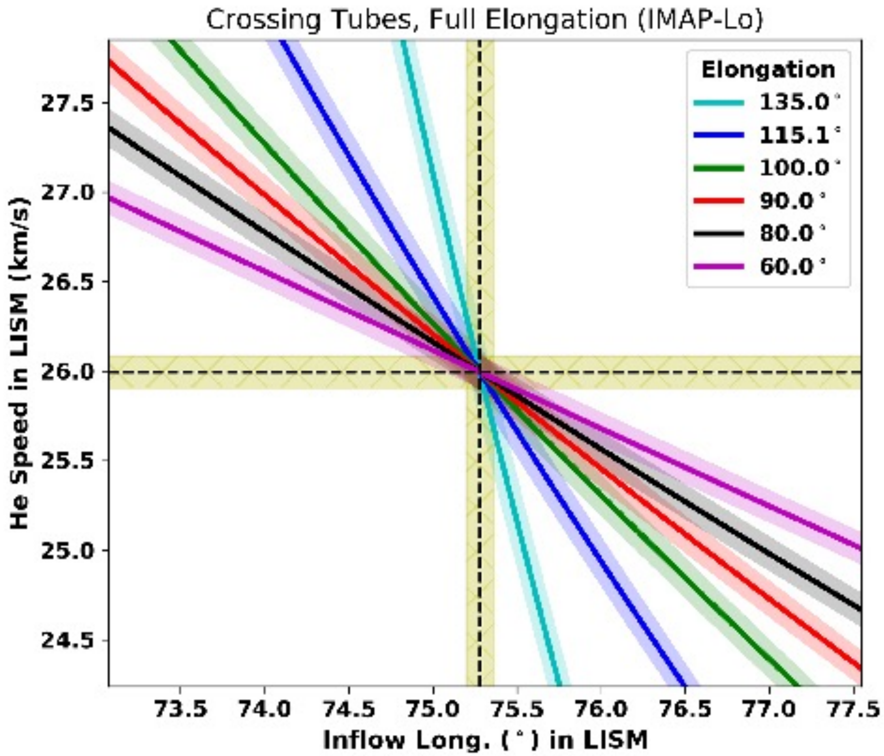


Refined B-V plane



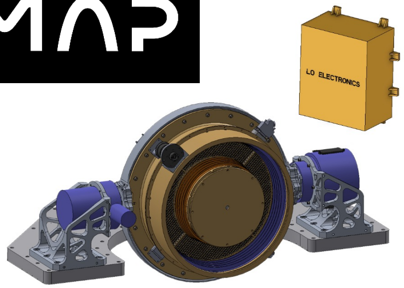
Prelude to Coming Attractions (IMAP!!)

- Since 2009, observations of the neutral wind at 1 AU with IBEX have returned a precise 4-dimensional parameter tube
  - ISN flow observations only nearly perpendicular to the Earth-Sun line limits the range of observations in ecliptic longitude to 130º±30º
- Expansion of IBEX viewing helps break the degeneracy of the ISN parameters, weakly crossing the 4D IBEX parameter tubes -- enhances the full χ^2 minimization
- Next generation, IMAP-Lo, mounted on a pivot platform, observations for He, and for O, Ne, and H that cross at varying angles in full ISN parameter space
  - mitigates systematic uncertainties .. ionization effects and secondary components

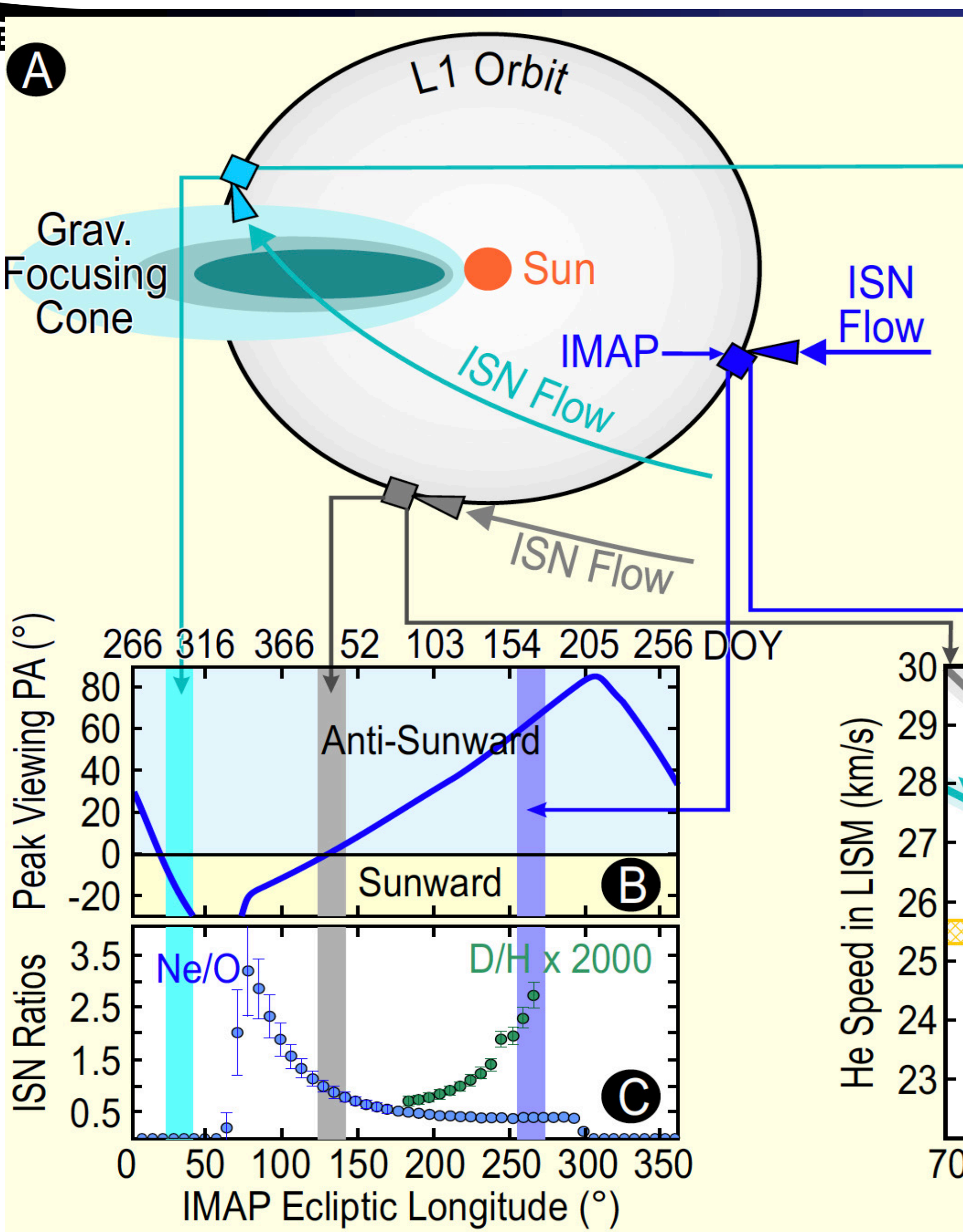


Schwadron et al., ApJ, In Press 2021

→ IMAP will probe interstellar neutral gas flow in even greater detail than IBEX to derive precise parameters of interstellar primary and secondary flow of the local interstellar plasma

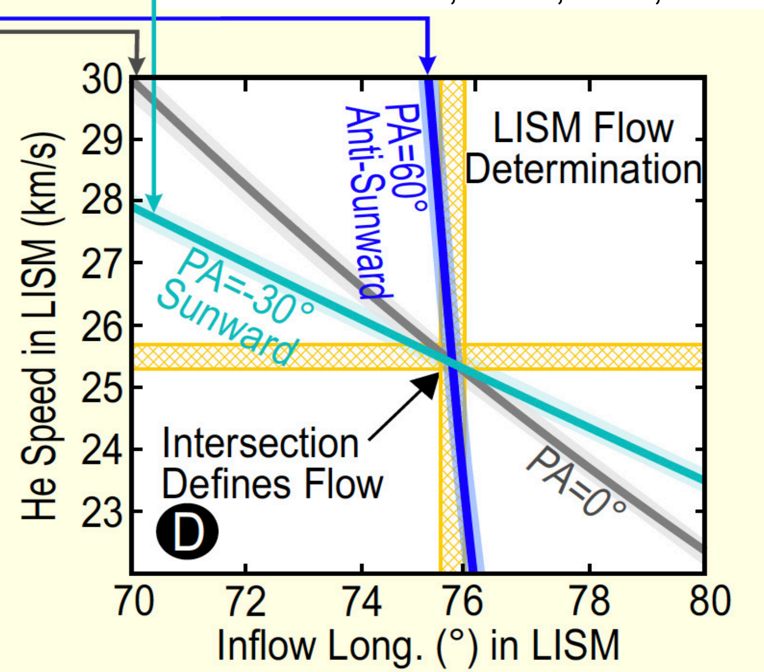


Precise ISN Measurements on IMAP-Lo

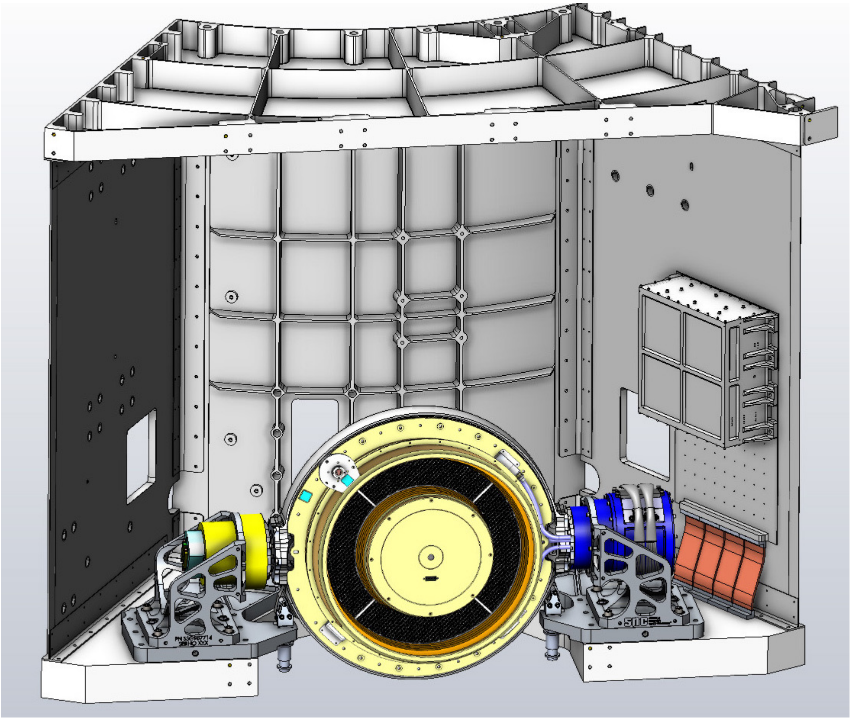


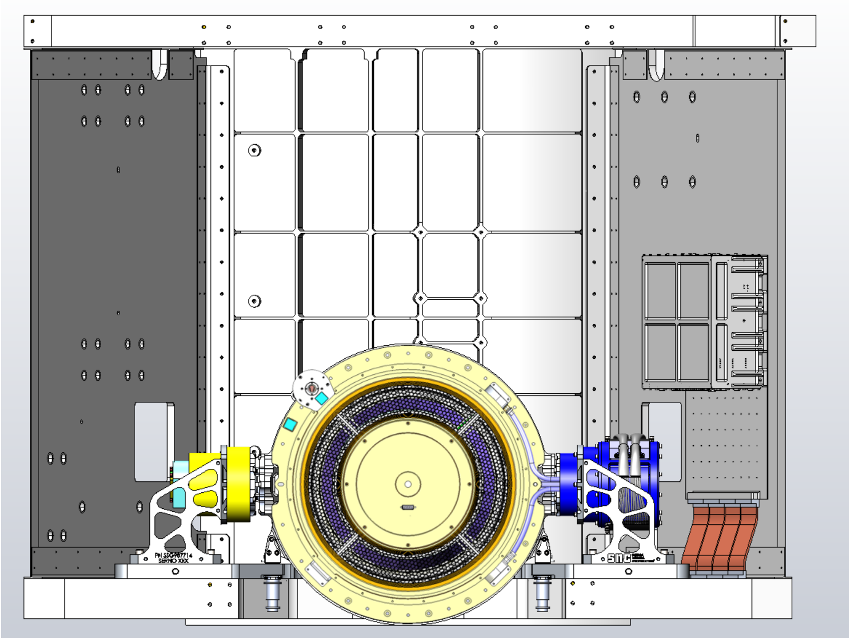
- Complimentary ionization measurements and radiation pressure from GLOWS
- Complimentary dust composition observations for ISN inventory of elemental processing by grains

McComas et al., IMAP, SSR, 2018



IMAP-Lo in Development!






IBEX
Interstellar
Boundary Explorer
NASA
IMAP
Thanks to all the People who have made
IBEX and are making IMAP s Great Success!
TA006660_IBEX

Abstract

The Sun's motion relative to the surrounding interstellar medium leads to an interstellar neutral (ISN) wind through the heliosphere. For several species, including He, this wind is moderately depleted by ionization and can be analyzed in-situ with pickup ions and direct neutral atom imaging. Since 2009, observations of the wind at 1 AU with the Interstellar Boundary Explorer (IBEX) have returned a precise 4-dimensional parameter tube for the flow vector (speed V_{ISN}, longitude λ_{ISN}, and latitude β_{ISN}) and temperature T_{ISN} of interstellar He in the local cloud, which organizes V_{ISN}, λ_{ISN}, and T_{ISN} as a function of λ_{ISN}, and the local flow Mach number (V_{th-ISN}/V_{ISN}). We refer to this functional dependence as the 4D IBEX parameter tube. On IBEX, the limitation of measuring the ISN flow observations to nearly perpendicular to the Earth-Sun line limits the range of observations in ecliptic longitude to ~ 30º. This limitation results in large uncertainties along the IBEX parameter tube and relatively small uncertainties across the parameter tube. Over the past three years, IBEX operations were modified to let the spin axis pointing of IBEX drift to the maximum offset (7º) west of the Sun, which is the limit for the IBEX spacecraft. This expansion of the IBEX viewing helps break the degeneracy of the ISN parameters along the 4D IBEX parameter tube. It complements the full χ-square-minimization to obtain the ISNs parameters through comparison with detailed models of the ISN flow. The next generation IBEX-Lo sensor on IMAP will be mounted on a pivot platform, enabling IMAP-Lo to follow the ISN flow over almost the entire spacecraft orbit around the Sun. A near-continuous set of 4D parameter tubes on IMAP will be observed for He, and for O, Ne, and H that cross at varying angles in the full ISN parameter space. This analysis substantially reduces the flow parameter uncertainties for these species and mitigating systematic uncertainties, such as those from ionization effects and the presence of secondary components. Thus, IMAP will probe the interstellar neutral gas flow in detail to derive the precise parameters of the interstellar primary and secondary flow of the local interstellar plasma.

Relative Efficiencies

Schwadron et al., ApJS, In Press 2021

- Variation in relative rates observed before and after PAC change
- Larger relative efficiencies for higher PAC, particularly at lower energy steps

Steeper variation of efficiency with energy in E-Step 1 and 2 after the PAC reduction connected to two sputtered populations

- **knock-on sputtering:** encounter of He atom w surface atom (or molecule), sputter products with **energies near incident particle** concentrated in angle around specular reflection of incoming ISN atom on conversion surface
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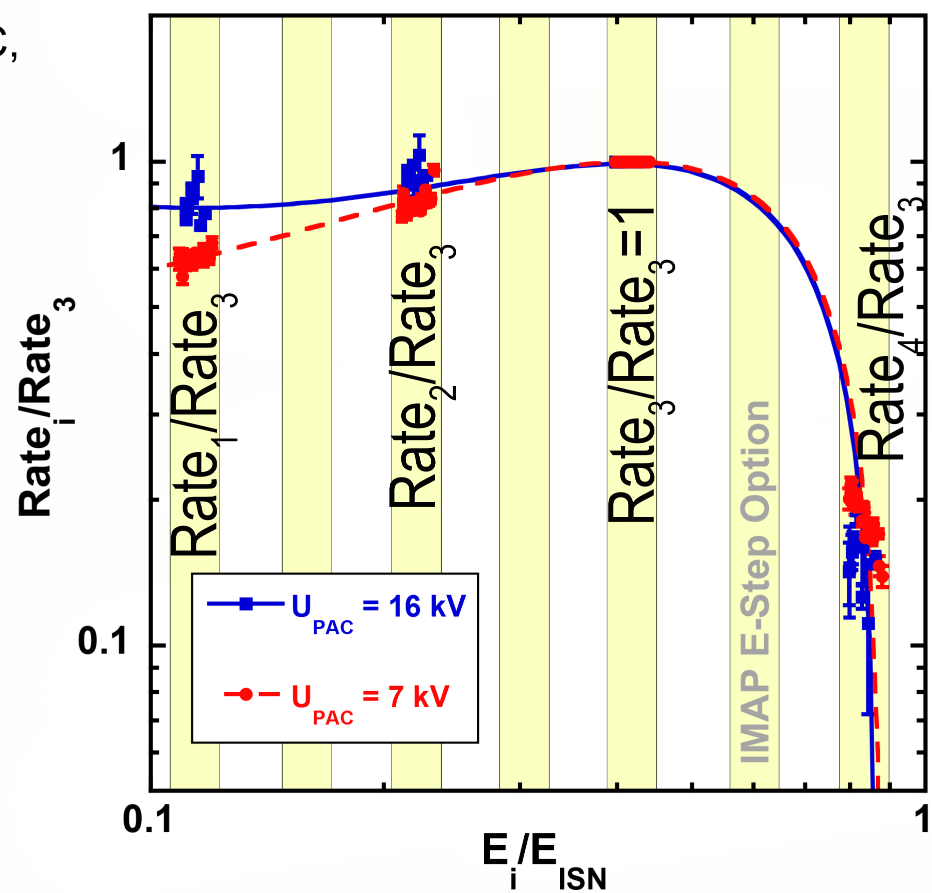
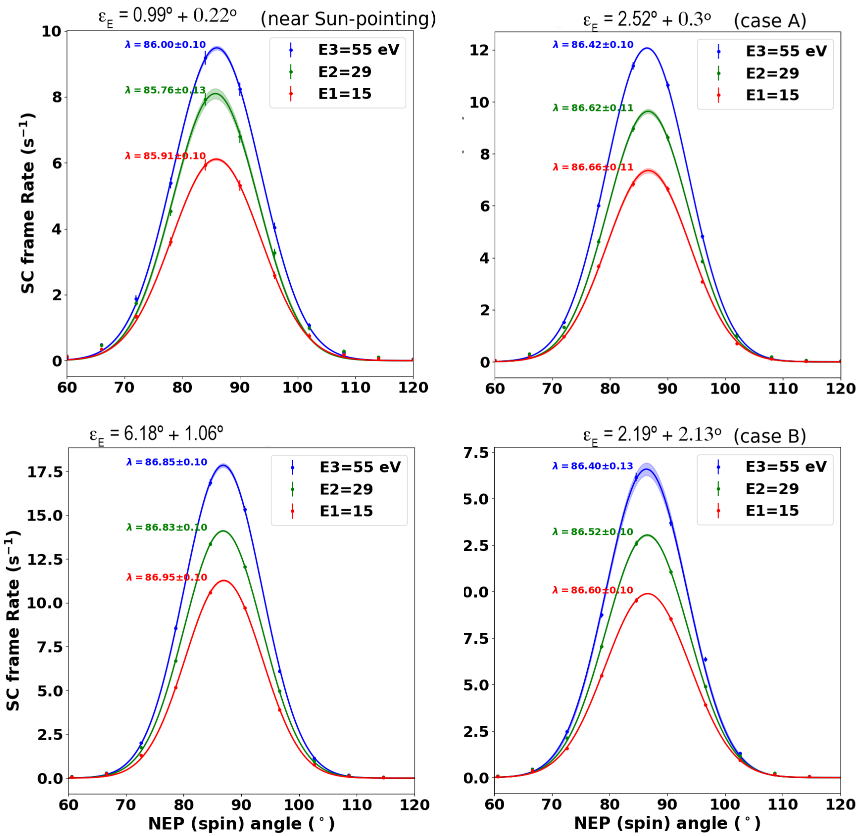
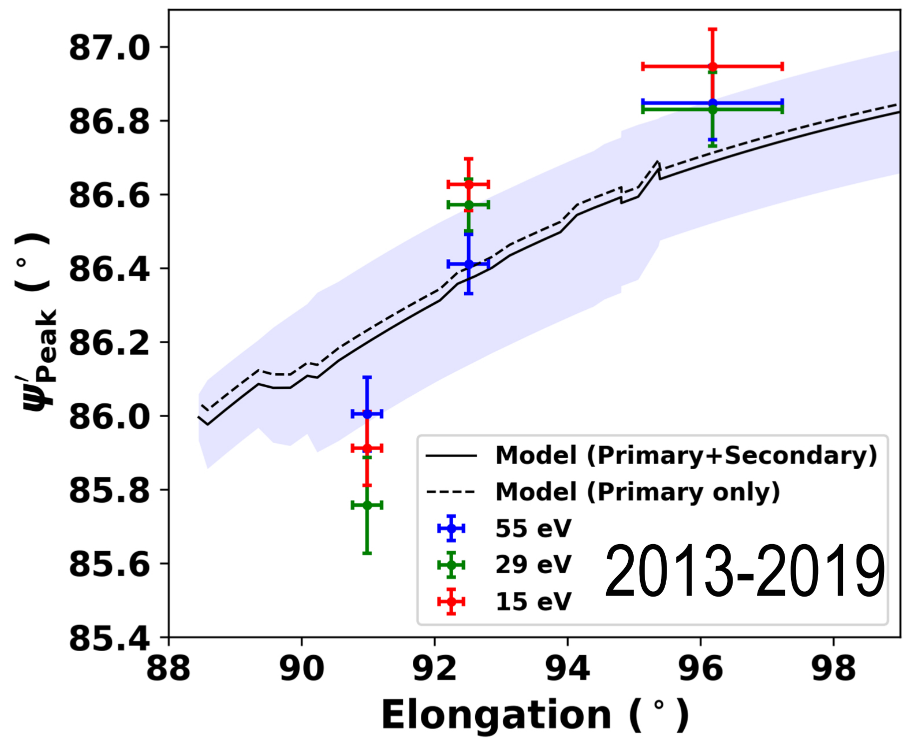


Latitudinal Fits (NEP/Spin-Phase)





Schwadron et al., ApJ, In Press 2021