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Observing the Interstellar Medium flow over the past 6 years with IBEX-Lo

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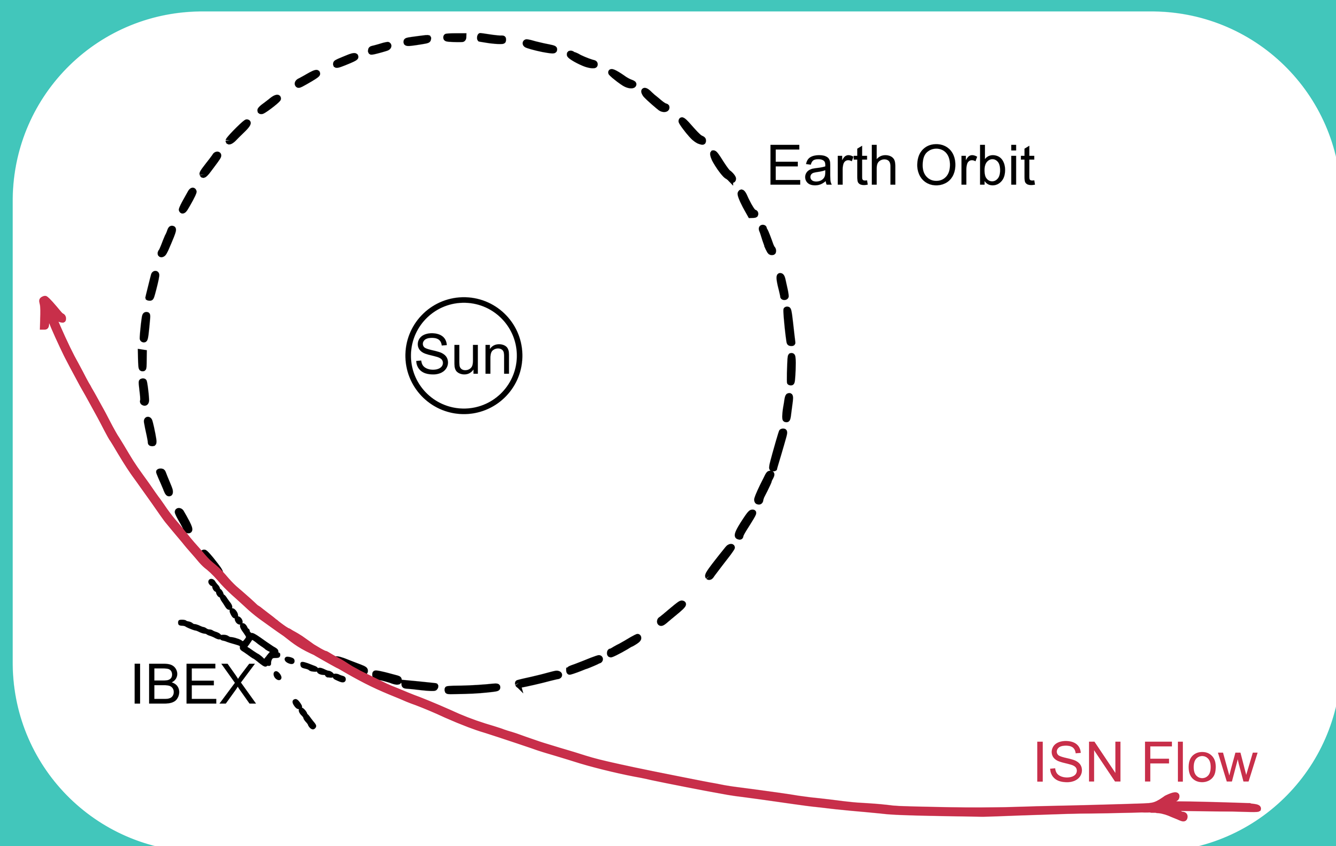
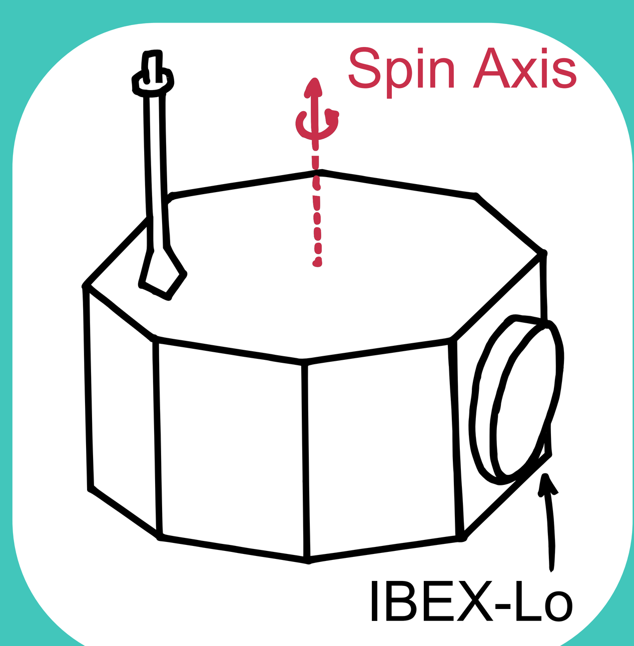
The Interstellar Boundary Explorer (IBEX) has observed the interstellar neutral (ISN) gas flow over the past 6 years during the winter/spring when the Earth's motion opposes the ISN flow direction.

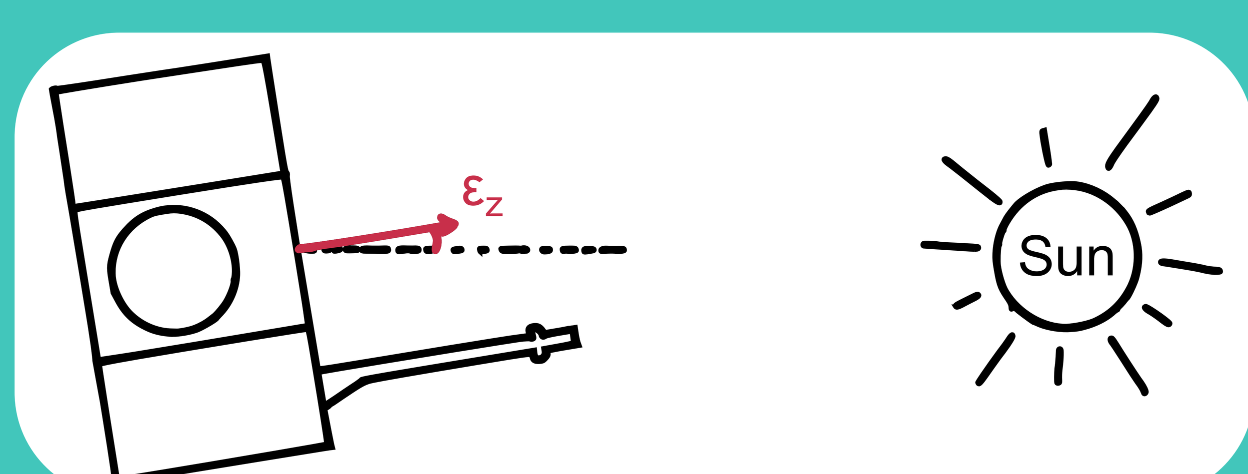


Since IBEX observes the interstellar atom trajectories near their perihelion, we can use an analytical model (Lee et al. 2012) based upon orbital mechanics to determine the interstellar parameters, inflow longitude (λ_∞) and latitude (β_∞).

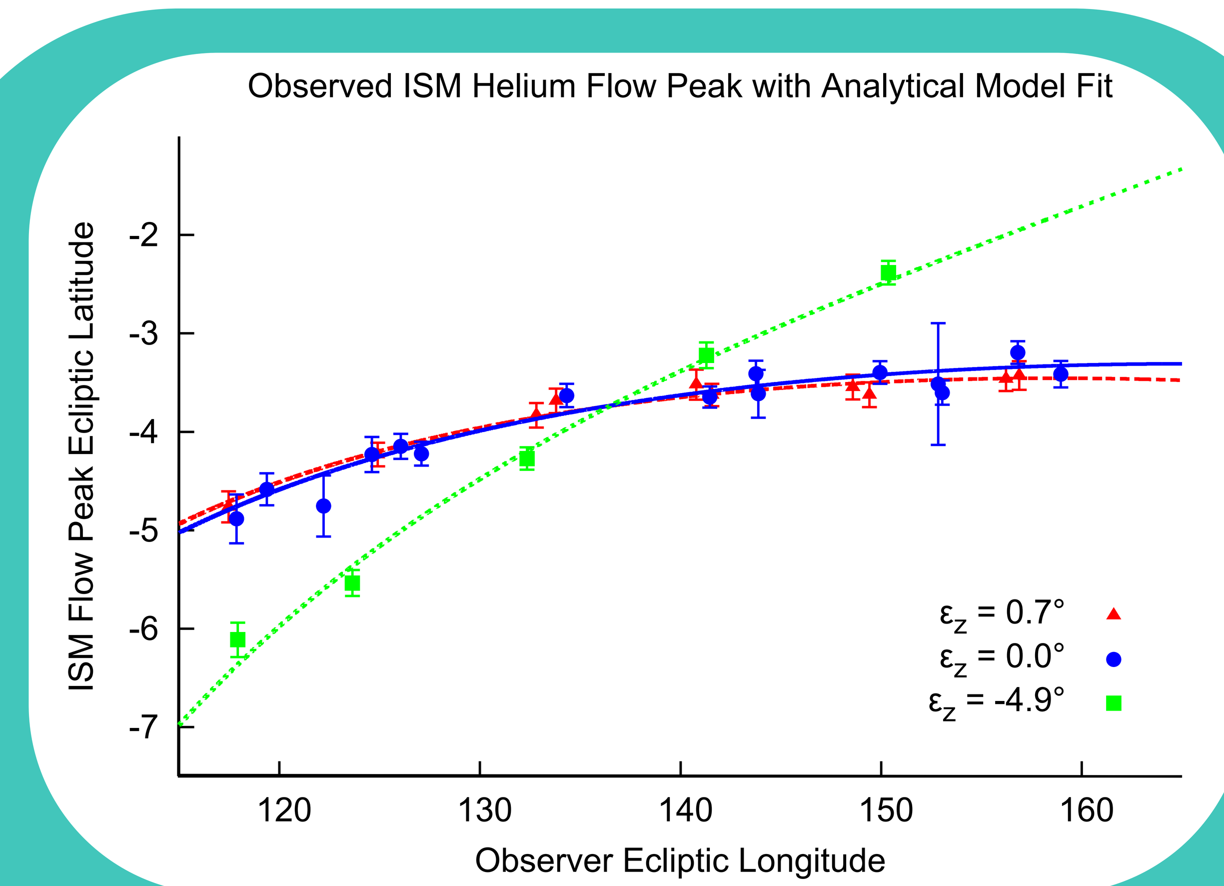


IBEX is a spinning spacecraft with two ENA cameras, IBEX-Lo and IBEX-Hi, both pointing perpendicular to the spin axis.

In our original analysis (Möbius et al. 2012) we found that a slight out of the ecliptic plane pointing (ε_z) of the spacecraft spin axis significantly influences the ISN flow vector determination.



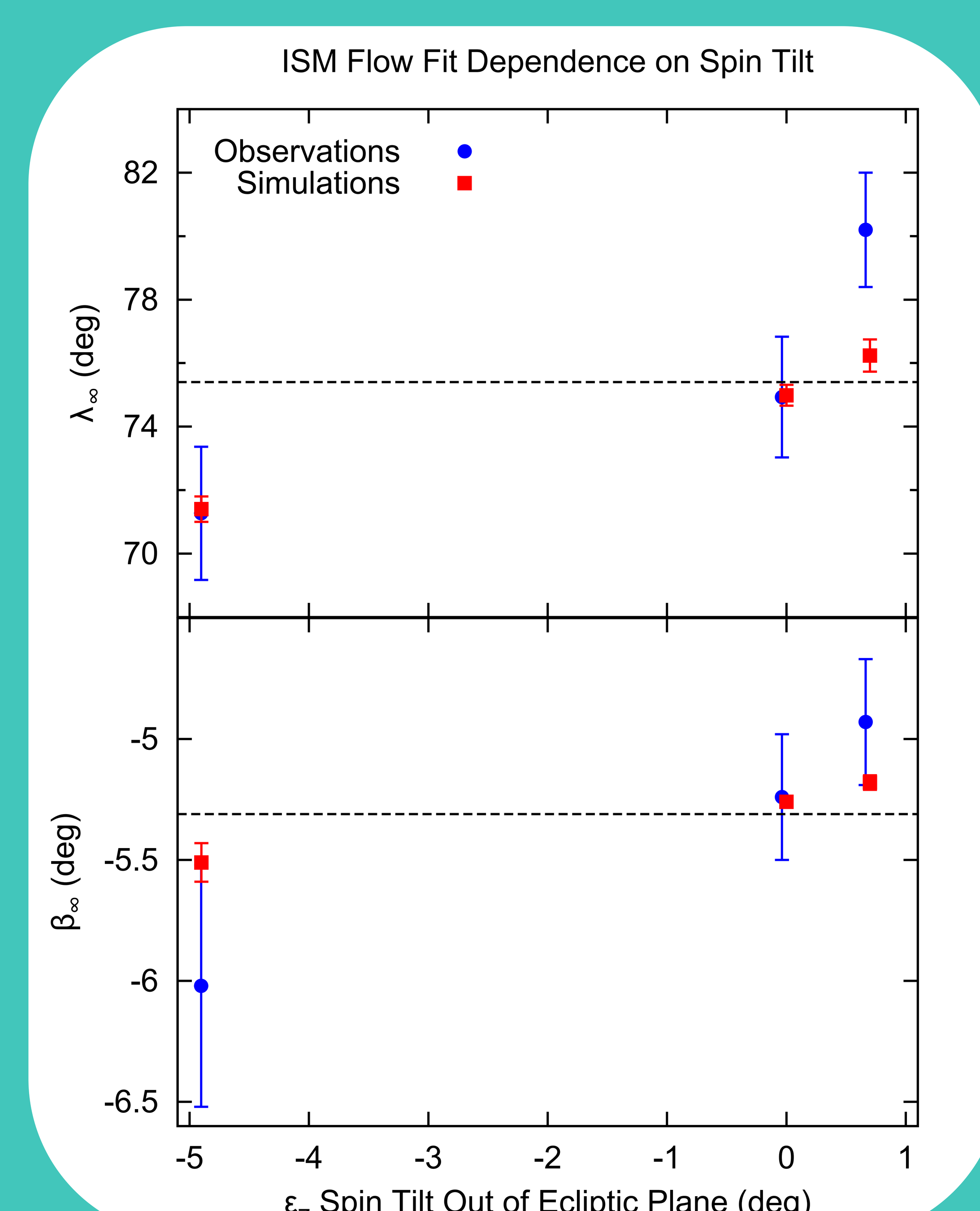
Introducing ε_z into the analytical model has shown that IBEX observations with various ε_z can substantially reduce the range of acceptable solutions to the ISN flow parameters as a function of inflow longitude.



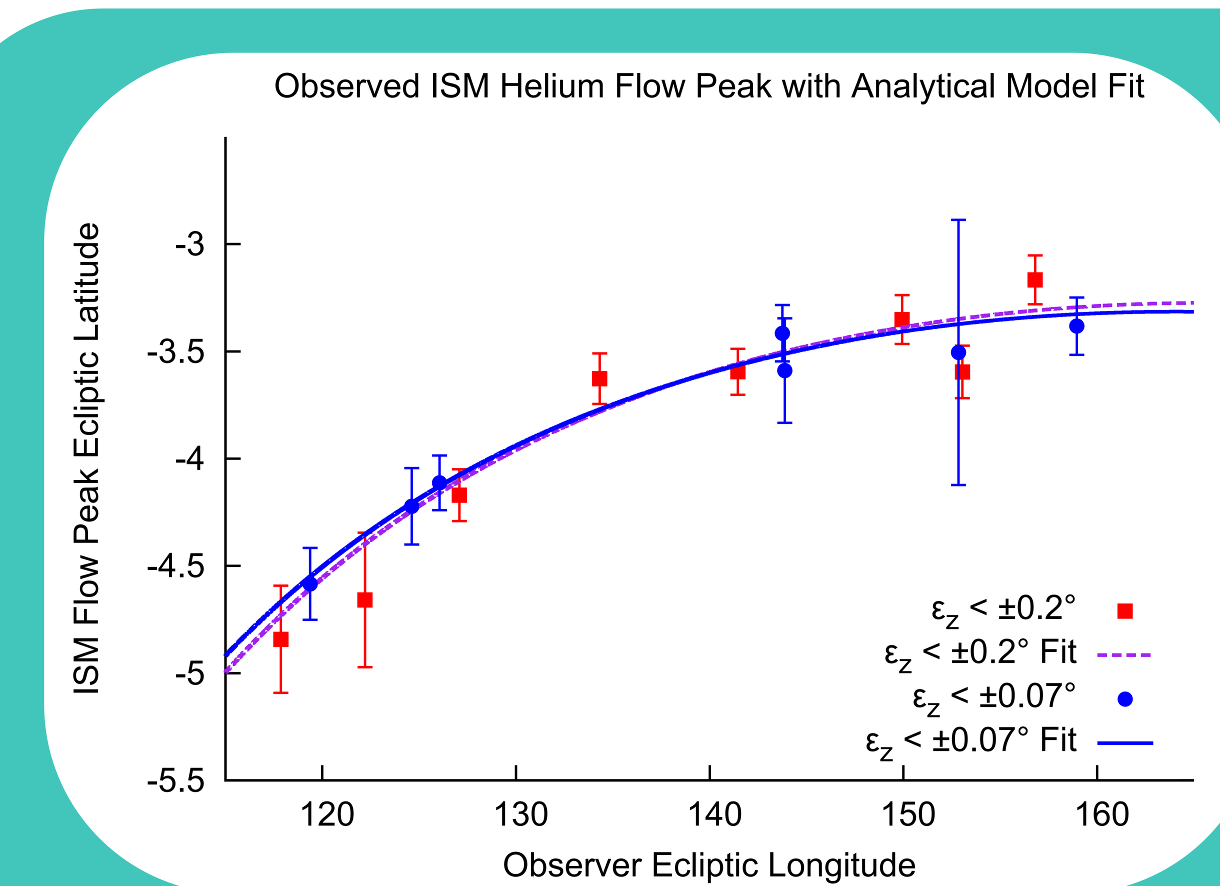
Three observation groups organized by ε_z such that all orbits are within ±0.2° of each group average. The analytical model fit to each of the three groups of orbits demonstrates the influence of ε_z on the observed peak location of the ISN He latitude distribution.

Year	ε_z	$\bar{\chi}^2$	λ_∞	β_∞
2009-2010	0.7°	0.4	80.2° ± 1.8°	−4.9° ± 0.3°
2012-2014	0.0°	0.9	74.9° ± 1.9°	−5.2° ± 0.3°
2014	-4.9°	1.6	71.3° ± 2.1°	−6.0° ± 0.5°

Surprisingly, λ_∞ and β_∞ are different for each ε_z group which indicates an apparent dependence on ε_z. The reduced chi-squared for the $\varepsilon_z = -4.9°$ group is substantially larger than unity, which demonstrates that the current implementation of the analytical model is not adequate for large ε_z. Furthermore, since the 2014 observations include orbits with $\varepsilon_z = 0.0°$ and $\varepsilon_z = -4.9°$ we can eliminate the possibility of a large change in λ_∞ and β_∞ between these groups and this change is an artifact of the current analysis method.

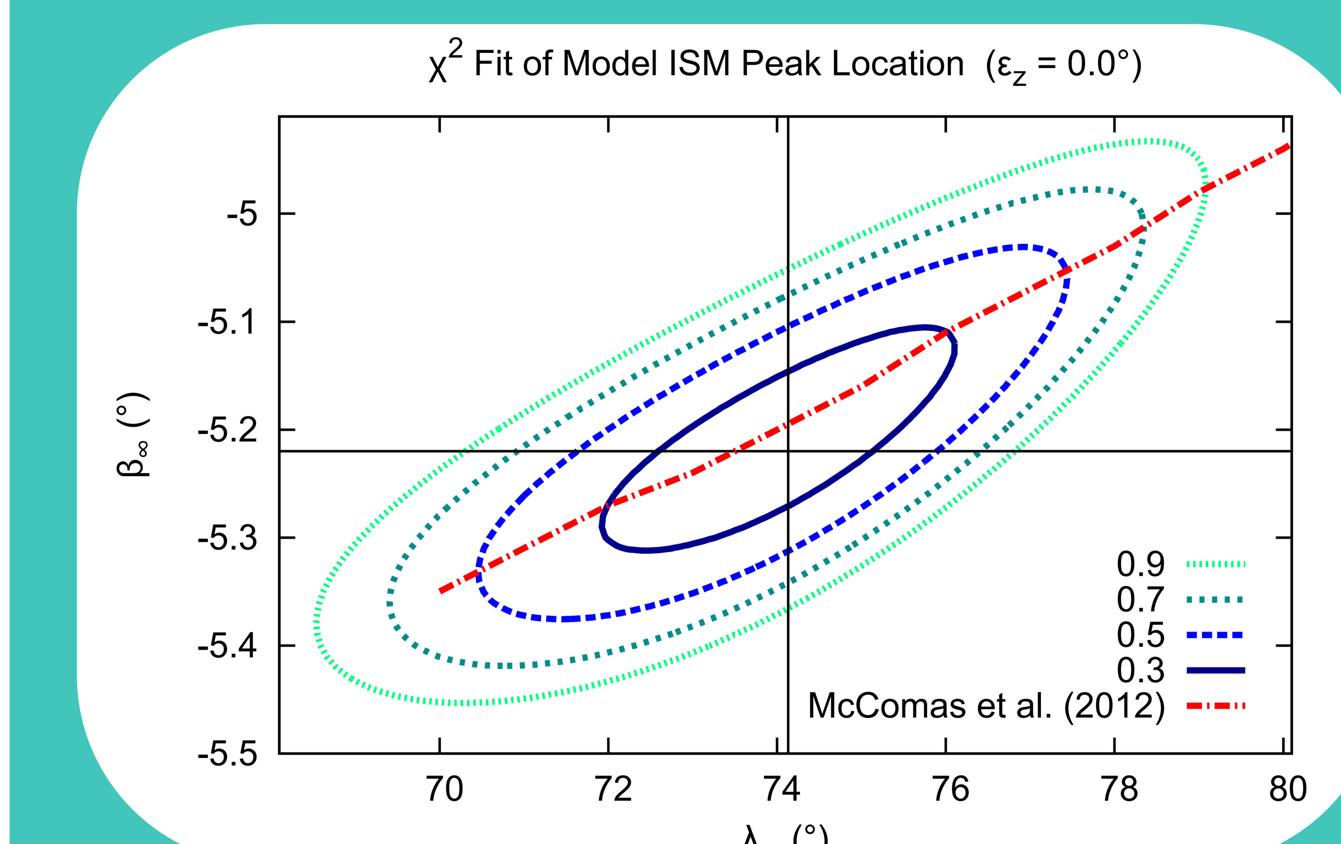


The Warsaw Test Particle Model (Bzowski et al. 2012) was used to simulate the three observation groups to test the ε_z dependency in the analytical model. Again, a trend between the fit parameters (λ_∞, β_∞) and ε_z emerges. This confirms the ε_z dependence for fitting with the analytical model and thus the observations considered in this study are restricted to minimal ε_z. When $\varepsilon_z = 0.0°$, the spin tilt approximation vanishes from the current implementation of the analytical model.



An iterative chi-squared minimization of the analytical model to two observation groups with ε_z restricted to the ecliptic plane. The robustness of the fit results is demonstrated with the two groups. We created a final set of ISN parameters through a weighted average of the fit parameters and by combining the uncertainties of these two data selections.

Group	λ_∞	β_∞
$\varepsilon_z < \pm0.07°$	74.1° ± 1.5°	−5.2° ± 0.2°
$\varepsilon_z < \pm0.2°$	75.1° ± 1.8°	−5.2° ± 0.3°
Final	74.5° ± 1.7°	−5.2° ± 0.3°



The reduced chi-squared landscape as a function of λ_∞ and β_∞ of the final fit to observations close to $\varepsilon_z = 0.0°$ with the central curve of the parameter tube presented in McComas et al. (2012).

Conclusions

Using the current implementation of the analytical model in the analysis of ISN flow observations with multiple spin axis orientations exposes a dependence on the spin axis tilt out of the ecliptic plane (ε_z). A comparison of the analytical model with the Warsaw Test Particle Model simulations for various spin axis orientations shows the best agreement in the case without spin axis tilt. The analytical model involves very few approximations and requires no expansion when observing the ISN flow with $\varepsilon_z = 0.0°$. The analytical model fit of the IBEX observations close to $\varepsilon_z = 0.0°$ results in a new parameter set on the previously determined narrow tube in 4D parameter space which couples the ISN He inflow vector, relative speed, and temperature. The new parameter set becomes more similar to the past results from the Ulysses observations but with the added consequence of a much higher temperature (Möbius et al. 2014).

References

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IBEX

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