2.4 Data Selection

In order to determine accurately the interstellar gas flow vector, the pointing of IBEX-Lo has to be known to ≈0.1^{o} accuracy for the observations used in this analysis. We have demonstrated that the pointing of the IBEX-Lo star sensor and of the spacecraft star tracker agree within this prescribed accuracy for time periods of simultaneous good observations (Hlond et al., 2012). Therefore, we use data from time periods when the IBEX star tracker, which provides precision pointing information for the routine data processing, was operating within its specifications for all analysis that requires exact pointing knowledge, such as the evaluation of the flow distributions in latitude. However, the determination of the ISM flow maximum in ecliptic longitude only requires the use of the count rates, obtained over ±3σ of the angular distribution from the latitude peak position, as a function of longitude, so this requirement can be relaxed.

During the analysis, it was found that the data transfer through the CEU that formats the information for the telemetry slows down because of the total traffic across the interface and the computational load event rates that exceed ≈10 counts/s, as observed during the He ISM flow peak. This slow down produces a modulation in the high-resolution data according to the accumulation scheme into 6^{o} sectors. Therefore, we only use integrated 6^{o} sector data for He in this analysis. In addition, IBEX-Lo detects background electrons, which are easily identified as invalid events by the TOF spectrometer, but they have to be removed by the CEU, which adds to its load and the slow down when electron rates increase. A more detailed description of these instrumental effects that are taken into consideration can be found in Appendix A.

For this analysis, we have compiled a list of valid time periods for the ISM flow analysis that is used throughout this paper and also in the analysis by Bzowski et al. (2012). Excluded from this list are time periods, for which the following conditions apply:

- IBEX is close to the magnetosphere, where IBEX-Lo observes high count rates of magnetospheric ENAs and ions, based on angular ranges outside the ISM flow distribution.
- The Moon is in the IBEX FoV. These times are taken from the ISOC command files, which contain special commanding for the star sensor.
- The electron rates for IBEX-Lo are high. These times are identified in the IBEX-Lo TOF count rates, when the otherwise very stable base count rate outside the ISM flow direction is exceeded by more than a factor of 1.6 (safely above any stochastic fluctuations of the base count rate, but low enough to indicate any significant electron rate increases).
- The star tracker function has been impaired. This affects the determination of the ISM peak location and width in latitude.

No further culling for increased background counts (routinely performed for suprathermal ENA observations (McComas et al. 2009b)) is necessary for ISM flow observations because of the concentrated angular distributions at much higher rates. The time periods used for the analysis of the ISM flow are compiled in Table 1 separately for the total count rate and the angular distribution analysis. The angular distribution analysis, in general, is performed on much shorter 'good' time periods than the count rate analysis because nominal operation of the star tracker is required. Because the rate analysis requires contiguous time sections of fixed length to achieve approximately comparable counting statistics for each data point, very small portions at the beginning or end of the

'good' time intervals may be unused, which accounts for the occasional foreshortening of the 'good' time intervals for the rate analysis at the beginning or the end.

Table 1: IBEX-Lo ISM flow observation periods.

Orbit	SunPt Longit.	Good Times for Rates (year/m:d:h:m:s - m:d:h:m:s) Files: onnnn_ctratedata.csv	Good Times for Angular Distributions Files: onnnn_ angulardata.csv	Other Conditions
2009				
0012	105.24	2009/01:02:18:23:37-01:02:22:26:04		
		2009/01:03:01:27:10-01:06:19:36:05	2009/01:03:15:28:18-01:06:19:39:58	
		2009/01:06:23:36:34-01:08:18:44:31	2009/01:06:21:29:53-01:07:01:51:34	
			2009/01:07:02:53:37-01:08:03:00:48	
			2009/01:08:04:33:38-01:08:05:50:36	
			2009/01:08:10:28:24-01:08:20:13:20	
0013	109.59	2009/01:10:09:39:30 - 01:15:03:45:17	2009/01:14:07:25:58-01:14:20:39:06	Not in $\Psi_p'(\lambda_{Obs})$ Long Extrapol.
			2009/01:14:21:40:53-01:15:09:29:07	
0014	117.47	2009/01:18:05:37:40 - 01:18:21:42:12		Not in $\Psi_p'(\lambda_{Obs})$ Long Extrapol.
		2009/01:20:01:41:16 - 01:20:17:41:58		
		2009/01:21:04:43:26 - 01:21:16:45:39		
		2009/01:21:23:43:20 - 01:23:15:45:07	2009/01:21:22:07:33-01:23:17:44:34	
0015	124.9	2009/01:24:18:44:23 - 01:25:18:44:26	2009/01:24:16:41:34-01:24:18:44:56	
			2009/01:24:19:31:01-01:25:01:55:02	
			2009/01:25:04:44:00-01:25:19:41:38	
		2009/01:29:20:59:53 - 01:31:12:29:36	2009/01:29:19:57:05-01:31:06:36:35	
			2009/01:31:09:56:17-01:31:12:45:15	
0016	132.81	2009/02:01:18:22:37 - 02:03:08:21:38	2009/02:01:17:20:06-02:03:08:18:06	Use Av. Ψ_p', σ'
0017	140.78	2009/02:09:11:57:46 - 02:14:01:58:06	2009/02:09:05:47:14-02:09:08:46:54	Not in $\Psi_p'(\lambda_{Obs})$ Intervals too short
		2009/02:14:16:32:51 - 02:15:02:31:45		
		2009/02:15:02:31:45 - 02:15:19:41:09	2009/02:15:16:32:40-02:15:23:26:39	
0018	148.59	2009/02:17:08:40:02 - 02:18:20:32:18	2009/02:17:00:38:02-02:18:21:44:25	
		2009/02:19:01:31:59 - 02:21:21:23:00	2009/02:18:23:50:04-02:20:17:27:04	
		2009/02:22:13:20:26 - 02:23:17:14:17	2009/02:23:14:23:27-02:23:16:14:16	
0019	156.23	2009/02:24:17:28:44 - 03:02:13:32:48	2009/02:24:18:20:54-02:27:08:09:05	
			2009/02:27:08:39:41-03:01:14:54:08	
2010				
0060	102.61	2010/01:03:00:24:59-01:05:22:27:09	2010/01:04:12:08:30-01:05:23:44:01	
		2010/01:06:02:25:16-01:09:16:27:23	2010/01:06:01:46:55-01:09:17:05:52	
0061	110.46	2010/01:10:17:47:27 - 01:11:11:46:03		
		2010/01:11:19:46:06 - 01:17:07:45:05	2010/01:11:23:13:27-01:17:08:27:08	
0063	125.12	2010/01:26:22:26:52 - 02:01:16:28:30	2010/01:31:21:34:16-02:01:15:31:48	Not in $\Psi_p'(\lambda_{Obs})$ Long Extrapol.
0064	133.8	2010/02:02:11:35:58 - 02:09:00:57:57	2010/02:02:11:35:18-02:02:20:55:56	
			2010/02:07:04:38:34-02:07:19:41:53	
			2010/02:08:18:30:09-02:09:01:57:13	
0065	141.57	2010/02:10:04:14:17 - 02:17:01:18:24	2010/02:10:02:26:10-02:11:01:37:17	
			2010/02:16:14:11:23-02:17:02:24:10	
0066	149.42	2010/02:18:02:46:08 - 02:20:13:05:09	2010/02:19:00:58:36-02:20:12:02:13	
		2010/02:20:17:04:49 - 02:24:09:35:11	2010/02:24:16:00:45-02:24:18:37:39	
0067	156.88	2010/02:25:16:52:17 - 03:04:09:41:59	2010/02:25:14:51:15-02:25:20:12:21	
			2010/02:25:20:43:13-02:28:10:12:03	

Appendix A: Instrumental Effects Related to the Data Selection

- Data Selection Related to Pointing Issues

As pointed out in Section 2, the analysis of the flow distributions in latitude require precision knowledge of the IBEX-Lo pointing at any time. However, during time periods when the operation of the IBEX star tracker is impaired by intense light sources (such as the Earth and the Moon) in its FoV over a substantial fraction of its spin scan, the spin pulse (which signals that IBEX-Lo points 3^o before passing the southern ecliptic pole) is missing. During these times, the pulse height events of the two IBEX sensors are time-tagged by the central electronics unit in a free running mode using the last reliable spin period. This value is not precisely correct over long intervals, and, as a result, the IBEX coordinate system drifts slowly in spin phase over time. Using the ISM flow or bright stars as observed with the IBEX-Lo star sensor as markers, the coordinate system is de-spun. Small uncertainties in the de-spinning process do not influence the ISM flow count rate that is obtained over $\pm 3\sigma$ of the angular distribution from the peak position in latitude. For the analysis of the angular flow distributions, used in sections 4 and 5, however, we are currently only selecting time periods, when the star tracker performs within specifications. In addition to some uncertainties about the accuracy of the de-spinning to better than 0.2^o, there are reasons to adhere to time periods that do not require post-processing of the spin phase, as discussed below.

- Data Selection Related to CEU Data Transfer Issues

By concentrating on heliospheric ENAs, IBEX is a mission with rather low count rates. Therefore, the full information for individual ENAs is transmitted as the highest resolution data. Each such event is time-tagged so that its arrival direction in spin phase

can be known with a precision of 0.04^{o}. This data product would be ideal for the ISM flow analysis. However, for magnetospheric ENAs (e.g., Fuselier et al. 2010; McComas et al. 2011a; Petrinec et al. 2011) and the ISM flow, the count rates are so high that they affect data onboard data processing. Specifically, the transmission between the IBEX-Lo sensor and the central electronics unit (CEU) that formats the information for the telemetry slows down both owing to the total traffic across that interface and the computational load on the CEU. This load also includes generating histograms of counts accumulated in 6^{o} angle bins. The transmission speed is modulated by this histogram accumulation scheme.

As anticipated, the number of counts accumulated in the peak of the ISM flow distributions (and magnetospheric emissions) exceeds the telemetry allocation. Thus, in order to avoid filling of the telemetry buffer with high rates of peaked distributions, telemetry slots are allocated within each 6^{o} sector. This scheme leads to a drop in the transmitted event rate towards the end of each 6^{o} sector in the center of the ISM flow peak. However, by design, these events are still accumulated in internal histograms. For the current analysis, we restrict our analysis to 6^{o} data that are readily corrected for these effects in the histograms.

The collimator bias voltages of IBEX-Lo were supposed to provide additional protection against electrons and ions. However, the IBEX-Lo positive collimator voltage could not be brought to operational values, and thus the negative voltage is kept at a low value. As a result, on average IBEX-Lo counts 22 electrons/s. These electrons do not produce ENA background because the triple coincidence system can easily remove these events that have very short TOFs. However, these electrons contribute to the load on the CEU, which removes them from the event stream. During times when IBEX-Hi observes substantial

solar wind related background (Schwadron et al. 2011) the electron rate increases in IBEX-Lo, which in turn reduces the throughput of valid ENA events, which, in turn, results in a noticeable reduction in the ISM flow data. These time periods can be easily identified in the IBEX-Lo TOF rates and in the IBEX-Hi background signals and are also removed from analysis.