FPI L2 DES/DIS Moments -- Methodology

FPI plasma moments are calculated as follows:

Quantity		Additional Notes
Number Density:	$n = \int(f\, d^3v)$	
Bulk Velocity Vector:	$\mathbf{U} = \int(f\, \mathbf{v}\, d^3v) / n$	
Pressure Tensor:	$\underline{\mathbf{P}} = m\int(f\, (v-\mathbf{U})\, (v-\mathbf{U})\, d^3v)$	
Temperature Tensor:	$\underline{\mathbf{T}} = \underline{\mathbf{P}} / (n\, k_B)$	
Parallel Temperature:	$T_{\|\|} = (\mathbf{b}^T\, \underline{\mathbf{T}}\, \mathbf{b})$	
Perpendicular Temperature:	$T_{perp} = (Tr(\underline{\mathbf{T}}) - T_{\|\|}) / 2$	
Heat Flux Vector:	$\mathbf{q} = m * \int(f\, \mathbf{v}\, v^2\, d^3v) / 2 - (nmU^2)*\mathbf{U} / 2 - ((Tr\, \underline{\mathbf{P}}/2)\, \underline{\mathbf{I}} + \underline{\mathbf{P}}) \bullet \underline{\mathbf{U}}$	

where **b** is the unit vector of the magnetic field averaged over the measurement interval

FPI uses a trapezoidal triple integration scheme for its calculation of plasma moments. First, phase space density skymaps are integrated with respect to spacecraft azimuth (32 11.25o bins from 0-348.75o). Second, skymaps are integrated with respect to spacecraft elevation (16 11.25^o bins from 5.625 to 174.375^o). Finally skymaps are integrated with respect to energy (32 bins from 10eV to 30keV). Energy and angle targets for a particular skymap are included as record varying entries in FPI distribution function CDFs. The reported energies are energy setpoints and do not include the effects of spacecraft potential which are obtained separately from EDP's L2 FAST SCPOT CDF files.

Energies are rescaled from E to U following U = E/(E+ E0) where E0 is a constant (set to 100eV for FPI). This maps U(E->0) = 0 and U(E->inf) = 1. Velocity integrands are modified accordingly. Before being sent to the integration routine, skymaps are preprocessed as follows:

1. f(phi = 0) is repeated as f(phi = 360) to ensure that the periodic boundary condition is incorporated to the azimuthal integration.
2. f(theta=0) = 0 and f(theta=180) = 0 data points are added to ensure the polar integration goes from 0 to 180. The sin(theta) dependence of the polar integration force the integrand at theta = 0 and theta = 180 to zero regardless of the value of the phase space density
3. f(U = 0) = 0 and f(U=1) =0 data points are added to ensure the integration goes from E->0 to E->infinity. V = 0 forces the integrand equal to zero regardless of the phase space density. The extrapolation in polar angle and energy is appropriate for most magnetosheath and magnetospheric plasmas. However, when plasmas have a significant hot or cold component, this approach may need to be adjusted by the user. The extrapolated cold (<10eV) and hot (>30keV) contributions to the density integral are included as 'x' and 'y' in the FPI moment CDFs, respectively. When these estimated densities become large (>25%) compared to the total density, corresponding flags are set in the FPI errorflags variable.

Because FPI energy stepper performance was not fully characterized at very low energies during laboratory calibration, low energy (<10eV) electron and ion data are not included in Level 2 FPI moment integration. Low energy data should not be treated quantitatively without consultation with the instrument team.

Number Density

In v2.0 and greater L2 files, Ne and Ni are generally reliable. Exceptions include:

1. periods for which internally generated DES photoelectrons could not be completely removed;
2. periods when the spacecraft potential is very high and the spacecraft potential correction needs individual work; and
3. at very low DES densities, when the spurious photoelectron signal is removed, the resulting density value can be obviously nonphysical; do not use FPI density moments when the corresponding quality flag is 1. (Quality Flag bit 7). <-- this is a known limitation that will be addressed in the next software release.

For L2 data, FPI densities were initially scaled by an overall factor to match those of plasma waves (fpi_waves_cmp.pdf). The overall sensitivity of DES and DIS can change with each FPI macro load in which the voltages applied to the MCP detector stack for each sensor are adjusted. In Phase 1a, the relative sensitivity of DIS across spacecraft has not been observed to change. The sensitivity of DES with respect to DIS has changed by ~10-20% over the course of commissioning and Phase 1a. A correction factor for DES densities is derived from observations of DES and DIS in the magnetosheath. The minimum time-scale for which a correction factor can be applied is an *entire orbit,* though in practice the same correction factor is typically used for *all orbits for which the MCP voltage is unchanged*. Periods where changes in DES and DIS densities are correlated and have the same ratio as in adjacent quiet magnetosheath (where there are unlikely to be 'hidden' cold ions <10eV and the entire distribution is likely within FPI's energy range) intervals suggest that the entire relevant ion and electron distribution functions are being sampled.

Parallel and Perpendicular Temperature

The parallel and perpendicular temperatures are computed as follows: 1) the eigenvalues of the DBCS temperature tensor T are computed, 2) T is projected onto the DBCS magnetic field unit vector (obtained from the magnetometer data) to compute the parallel temperature Tpar, 3) the perpendicular temperature is computed as Tperp = (Tr(T) – Tpar)/2