

FPI Release Notes

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Known features for all FPI data products

Time in all FPI data products mark the beginning of the data interval. In other MMS data products, the time may mark the middle of the data interval. FPI data products after v1.0 include both the time and a "delta +/-" to indicate the time relative to the data interval. That is, for FPI the delta +/- is [10,0] sec for the SITL data product or [0.03, 0] sec for a DES burst product. It is important for users to understand the time conventions of each data product used especially when comparing data sets.

FPI Densities: 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.

Spurious photoelectrons in DES: Internally generated photoelectrons, unaffected by the spacecraft potential in the sun direction produce an effective cold electron component with density ~0.5-1 cm⁻³ and bulk velocity ~750 km/sec in the anti-sunward direction. This component varies with spacecraft spin phase. A model for this signal has been developed and the signal removed for the moment calculations as of software release v2.0. NOTE: These photoelectrons (internal and spacecraft) are not removed from the skymap data product as users need to be aware of this signal for their specific data interval and how its removal might affect analysis and interpretations.

DIS fast survey measurements in the solar wind: Onboard summing of burst counts to form fast survey data products leads to increased numbers of counts/bin in fast survey skymaps. In the solar wind, the maximum number of allowable counts in each bin is exceeded leading to clipping and resulting in a distortion of the plasma moments.

FPI burst data in the solar wind: FPI's field-of-view is binned with 11.25x11.25 deg resolution. In the polar angle direction (+Z to -Z for each sensor), angular space is continually sampled. However, the angular response in the azimuthal direction (X-Y plane) is <10deg. Therefore, as deflection states sweep out the azimuthal plane, there are gaps in the angular sampling of ambient plasma. Sharp angular structure in both DIS and DES can lead to apparent 'spikes' in the plasma moments that are spin-phase dependent. Such a phenomenon occurs often in high Mach number plasmas such as the solar wind.

Some burst segments may appear to look incomplete: Please check the burst status if you are not finding complete information. FPI has processed all available burst segments -- including those with status "DERELICT+FINISHED" (rather than "COMPLETE+FINISHED") -- meaning that some data from one or more spacecraft were not transmitted to the ground. FPI believes that "some data" is more valuable than "no data" and so is making these incomplete segments available. See an [example burst inventory list](#) here; instructions to query for your own list can be found at the [SDC's Web Services instruction page](#).

Some burst segments with status "COMPLETE+FINISHED" do not contain FPI data: While FPI data is available for most segments, there are a small number of burst segments with status "COMPLETE+FINISHED" that do not contain FPI data. Please see the [missing FPI burst segment table](#) for segments in which no FPI data is available.

Reasons spin-periodicities or Vz offsets may be present in the data:

- Compression artifacts, which can be different for Survey and Burst data products
- Imperfect spectrometer response correction tables (e.g., for signals dominating the very lowest or very highest energy channels; for data intervals very near a [FPI macro change](#); and for data intervals for which sufficient burst calibration data was not readily available). Some of these can be addressed with time.
- Imperfect spacecraft potential or photoelectron signal correction. For some data intervals, data users will necessarily need to apply custom corrections.
- In some cases, even when the in-flight calibration tables have reduced the spin-period electron bulk velocity signal amplitude to below 50 km/s, there may appear more significant 20 s oscillations in the current density $n^*e^*(V_i - V_e)$ (comparable to real current densities at the magnetopause). This is a known issue and is currently beyond the scope of our current L2 processing. If such current density oscillations are noticed, please contact the FPI team, and we will address these on a case by case basis until we are able to incorporate a correction into our routine L2 processing.

Helpful info for the use of FPI data products

From the MMS Rules of the Road: "Users should heed the caveats of investigators as to the interpretation and limitations of data or model results. All important caveats should be included in the publication, even if co-authorship is declined. Data and model version numbers should also be specified." The caveats that should be addressed in your presentations/publications include, but are not limited to:

- Moments: presence of DES photoelectrons and the applicability of the nominal mask applied to remove that signal
- Moments: applicability of the nominal spacecraft potential correction applied
- quality of inter-spectrometer calibrations/corrections (<-- an FPI team member can advise for your specific data interval)
- any data condition indicated by the quality flags set in the specific CDF file used.

Know and use the data quality flags present in the CDF files. There are data intervals that will necessarily require the data users to perform additional corrections or alternate moment calculation techniques.

Know and use the statistical error information provided in the CDF files. The error associated with the inherent spectrometer counting statistics is provided in the CDF files for both the moments and for the distributions. The actual counts can be recovered from the distErr variable from $C = (f/\text{distErr})^{**2}$ with distErr from the dist CDFs.

Be aware of the CDF file version # and keep your data files up-to-date: The first year of any mission is marked equally by scientific discovery and by better understanding of the experimental apparatus in flight. Ensure you have based your presentation graphics and interpretations on the latest software release.

Plotting distributions:

- For 30ms electron distributions, use the corresponding burst B data and document the degree to which B changes during the 30ms. Be cautious about distributions that appear non-gyrotropic in regions of rapidly varying B, such as the magnetopause.
- Ensure the cuts in the two perpendicular velocity planes are in the bulk frame. Do this by shifting the time of FPI to center time and then average the higher resolution burst B data onto the same time intervals as for DIS and DES. Interpolation should not be done.

Script to compare E with $-V \times B$ and V_{perp} with $E \times B / B^2$ (available in SPEDAS under FIELDS EDP):

- In general, the comparison of E with $-v \times B$ is thought to be more useful than comparing V_{perp} with $E \times B / B^2$.
- although not always convincing, this is useful for detecting the presence or absence of reconnection jets
- do comparison in DBCS coordinates to NOT mix in axial E.

See the [FPI Data Products Q&A Page](#)

Release 3.2.z (pending)

New Features

- Processing of slow survey
- DES spintone estimator
- Cold plasma density estimator
- Flag for penetrating radiation in DIS

Bug Fixes

- Clarify particle direction in spectrogram and skymap metadata and labels

Release 3.1.z

Delta release to correct one inconsistency across data products

- imposed uniformity on the application of the energy sweep tables across all data types and products
 - As you know, each FPI data quantity supplied in our CDFs consists of contributions from eight spectrometers. The energy band sampled by each spectrometer at each step is a function of applied voltages (each with their own ground-calibrated error) and great care is spent in balancing the operation of each set of eight spectrometers to yield a uniform energy sweep for the ensemble. This release ensures all products and types are processed using the same tables, as updated for Phase 1B operations.
 - This fix should not affect data quality. Any differences between this and previous releases (e.g., v3.0z) should not be discernible within the error margins already inherent to the system. Please report instances that appear otherwise.

Previous Limitations Corrected

Some Phase 1A FPI L2 DES/DIS v 3.1.0 fast survey moments (des-moms and dis-moms) inadvertently did not include optimal spacecraft potential correction. These data have been replaced (as of 15Nov2016) and are designated as v. 3.1.1 files. The dates of the affected moments files are:

- 2016-01-01 - 2016-01-12
- 2016-02-01 - 2016-02-15
- 2016-03-01 - 2016-03-08

Known Limitations to be addressed in future data release

GSE-Referenced Directional Spectrograms: The data for the six directional spectrogram variables in the FPI DES/DIS v3.1.0 burst and fast survey moments files (des-moms and dis-moms) do not match their respective VAR_NOTES descriptions nor do they match the data standard released with the v2.1 CDF files. The issue is "plasma flow" direction versus "detector look" direction; that is, the VAR_NOTES descriptions and the FPI data standard set with v2.1 dictate flow direction, while the v3.1 spectrograms are detector look direction with respect to GSE. In order to maintain consistency with FPI v.2.1 you may switch the `_px` (plus x) variable with that labeled `_mx` (minus x), `_py` with `_my`, and `_pz` with `_mz`, where `px` indicates the plus GSE x direction, `mx` indicates the minus GSE x direction and similarly for `py`, `my`, `pz`, `mz`. This applies for Release 3.1.z only. These are less frequently used variables and will be corrected in release (v3.2). We thank Ali Varsani for bringing this to our attention. The affected variables are:

- `energyspectr_px`
- `energyspectr_mx`
- `energyspectr_py`
- `energyspectr_my`
- `energyspectr_pz`
- `energyspectr_mz`

Note that the pitch-angle distributions (`*_pitchangdist_*`) are *not* similarly affected.

Release 3.0.z

Second major release of research-grade L2 data products

New Features

- Added temp/pres matrices and bulkv/heatq vectors. Removed individual component variables.
- Adjust existing spectrograms to make them non-overlapping
- Addition of omni-directional differential energy flux variable
- Population of GSE coordinate variables to complement DBCS
- Population of CDF global attributes
- Increased compliance with MMS CDF Format Guide
- Record varying step energy tables
- Removal of spherical vectors (azimuth, elevation, bulkspeed, heat flux)
- Delta plus and minus variables for energies and angles

- Addition of density extrapolation values
- Properly set Z variable of CDF file version

Bug Fixes

- Fixed bit-11 of errorflags to properly reflect compression error. Noted in metadata.
 - Fixed DES bursts occasional missing maps at end of segment
 - Compression loss variable to properly reflect FPI-IDPU-SPEC-0008
 - Capped relative moments statistical errors at 100%
 - Ensure absolute moment statistical errors are positive
 - Fixed DES burst phi targets
 - Corrected tpara and tperp in fast survey DES moments occasionally appearing as all zeros
 - Metadata corrections (units, SI conversion, valid min/max, variable description, etc.)
 - Removal of coordinate system references for number density and bulk speed
 - Properly interpolate spacecraft potential for DES burst
 - Ensure that density extrapolation values are not negative
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Release 2.1.z

Delta release to correct two errors in L2 data products

- The function converting counts to differential flux for the L2 spectrograms has been corrected.
- The occasional nonphysical density values resulting from the removal of the DES photoelectron signal has been resolved.

Known Limitations to be addressed in a future data release

- The temppara and tempperp fields in the DES Fast Survey files are set to zero. The temperature tensor fields (e.g., Txx, Txy, etc...) are unaffected. The tensor can be transformed into magnetic coordinates in order to recover estimates of temppara and tempperp.
 - 'GSE' quantities are reported as zero. Use of 'DBCS' should be sufficient for scientific analysis as it differs by ~1-2deg from true GSE.
 - Scalar quantities such as density and heatFlux have a coordinate system associated with them. These will be removed for the next release. The 'DBCS' quantity should be used.
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Release 2.0.z

First release of research-grade L2 data products

New Features

- [Data Quality Flags](#) added
- L2pre Fields data are used for PAD spectrograms and field-aligned moment parameters
- Improvements to moment calculations:
 - spacecraft potential correction applied using L2 spacecraft potential data
 - spurious DES photoelectron signal (internal) removed
 - NOTE: these are not applied to the skymap data product
- Updated, time-dependent spectrometer response correction tables
 - intra-spectrometer responses balanced
 - inter-spacecraft responses balanced
 - DES/DIS absolute density correction
- Statistical errors are provided for the moment quantities (systematic errors are not yet included).

- Significant development to CDF structures, metadata, attributes, and variable names
- Units of measure now compliant with [MMS Units of Measure Standard](#)
- Spectrogram data products are now in units of Differential Energy Flux (eV/cm² s sr eV).

Previous Limitations Corrected

- Missing 10s of burst at the end of burst CDFs has been addressed
- Directional energy-time burst spectrograms are now despun consistent with all other spectrograms

Known Limitations to be addressed in a future data release

- **The unit field for spectrogram data products is blank and the var_notes in the CDF incorrectly states the unit is counts.**
- Statistical errors are erroneously reported with signs. Until resolved, take the absolute value of the reported uncertainties.
- Burst compression status is currently listed as a 1 or 3 instead of a 1 or 0. Until resolved, consider 1 as lossless compression and 3 as lossy compression.
- The temppara and tempperp variables in the Fast Survey moments CDFs are set to zero. This issue does not impact the full temperature tensor. Users should manually project the full tensor onto the magnetic field to recover parallel and perpendicular temperatures from the 4.5 s Fast Survey maps.
- 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).
- Not all SI conversions are populated in the metadata
- Not all planned Global Attributes are populated
- The bug remains that causes missing (≤ 5) DES skymaps at the end of some burst files
- The function that converts counts to differential flux for the L2 spectrograms was hard-coded for electron mass. The DIS numbers are therefore a factor of $\sqrt{(1.67e-27/9.11e-31)^4}$ too high (~3360440 too high). Users of this data parameter will need to divide by this scale factor. This was corrected in v2.1.
- The moment values in GSE coordinates are not yet populated. The values are instead given in separate variables in a despun body coordinate system. True GSE values will be provided in the next data release. As MMS maintains the positive spin axis within ~3 degrees from ecliptic normal during science operations, DBCS may nominally be considered 'near GSE'. When this is corrected, only vector quantities will be associated with a coordinate system; scalar quantities will not, as would be expected.

De-spun Body Coordinate System Definition

Component	Definition
Origin	Center of mass
Fundamental Plane	X-Y Plane
X Axis	Completes the right-handed coordinate system
Y-Axis	Perpendicular to the Z-axis, and perpendicular to the line pointing from the spacecraft toward the sun, positive in the direction from the Earth dawn to Earth dusk.
Z-Axis	Aligned with the Observatory Coordinate System Z-Axis, which extends through the S/C structure along the center line of the thrust tube

Release 1.1.z

Delta release to correct an error

- Fixed a bug in the calculation of heat flux in DES/DIS moments data
 - Special corrections for 2015-Oct-16 fast survey and burst data
 - Burst files are now packaged as single segments. Start date/time is in the file name.
-

Release 1.0.z

Improved, scientifically useful products; not research grade quality (no L2 products)

Changes/Updates:

- SITL FS: Corrected use of Epoch_FS in fpjob_fast_procsitl.pro line 209, which resulted in pseudo moments appearing saturated or as constants rather than varying in the expected manner.
 - Correction table updates, including processing architecture for handling versioning and time-referenced tables
 - Update file names and sizes
 - SITL and QL FS contains full ROI, breaking only at day boundaries
 - L1B and L2 FS are 2 hour files, beginning at even 2 hr boundaries
 - QL, L1B, and L2 bursts are 5 minute files, beginning at even 5 min boundaries
 - Modified L1B/L2 CDF file names to better match the SDC file storage structure. Modified other files not stored at SDC with same convention.
 - Upgrade to CDF version 3.6
 - "time_resolution" attribute values are corrected
 - CDF structure changes – compliance with MMS / SPDF conventions
 - Add Energy and angle tables
 - Add the spacecraft potential (set to 0 for release #3) and the file it came from
 - Add Quality flags, including improvements to compression status word
 - Add Delta +/- ; for FPI Minus will be zero and Plus is the interval, 10 on SITL, 4.5 on FS
 - Add labels for units
 - Implemented QL product for first time
 - Applied release #1 and #2 changes to QL codes
 - QL burst moments produced using Fast Survey accumulation times.
 - Add antiparallel and parallel spectrograms; PAR (all within 30deg PA), ANTIPAR (all from 150-180 PA inclusive), PERP (all from 60-120 PA inclusive)
 - Fix units for pressure moments
 - Add statistical errors for sky maps
 - Correct energy tables
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Release 0.2.z

delta release to correct an error

- Deleted correction for spurious photoelectrons in DES/DIS Moment calculations – DID NOT AFFECT BURST PRODUCTS.
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Release 0.1.z

First scientifically useful browse products; not research grade quality (no L2 products)

Cautions

- **Temporary correction for spurious photoelectrons in DES:** A temporary correction was applied to the electron moments: v0.1.0 cuts out energies below 100 eV for electrons but includes the point at zero, so that low energies are not completely excluded. The low energy contribution is represented as an interpolation from 100 eV to zero. For the plasma sheet this works well; for the magnetosheath, it introduces errors in the electron density

and bulk velocity. The moments should not be interpreted as partial moments between 100 eV and the highest channel, due to the interpolation between [0, 100] eV and between [30, Infinity] keV. This correction was inadvertently applied to the ion moments as well.

Changes since last release

- Spectrometer-specific correction tables applied; corrections are based on in-flight data gathered during May-July special calibration orbits.
- Produces sky maps in near GSE with preliminary corrections (FS and Burst), including sun pulse offset correction
- Preliminary corrections incorporated into moments calculations (Burst, FS, and SITL), data below 100 eV excluded due to internally generated photo electrons
- Correct spacecraft name appears in all fields
- Table Parity field – bursts only
- Fast Survey epoch times agree between DES and DIS

Release 0.0.z

products for health and safety checks only, first viable SITL product, not scientifically valid data

Cautions

- **Corrections and Calibrations:** Version 0.0.x of the data files have only crude ground-testing calibrations/corrections applied. While the data may look quite ordered and the moment quantities somewhat reasonable, none should be used for scientific analysis.