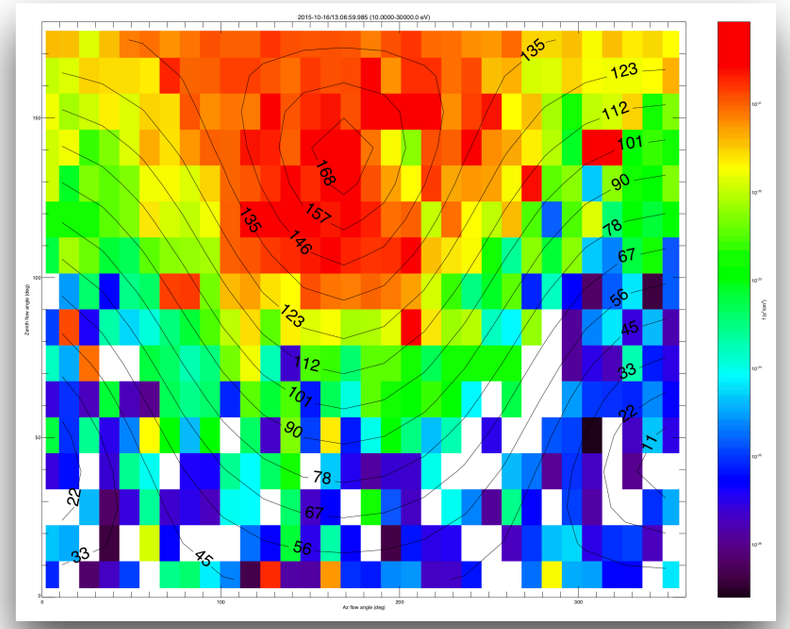
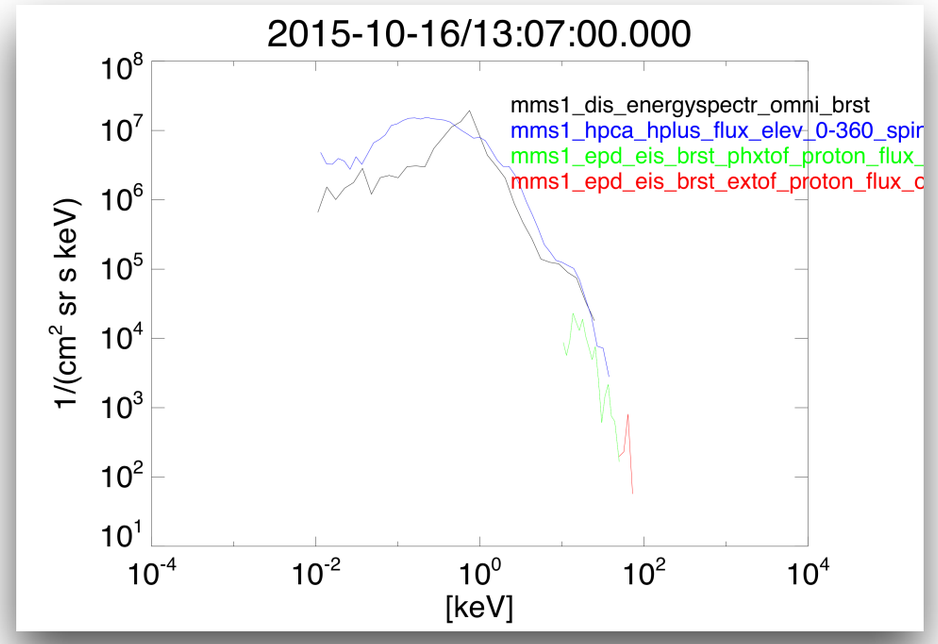
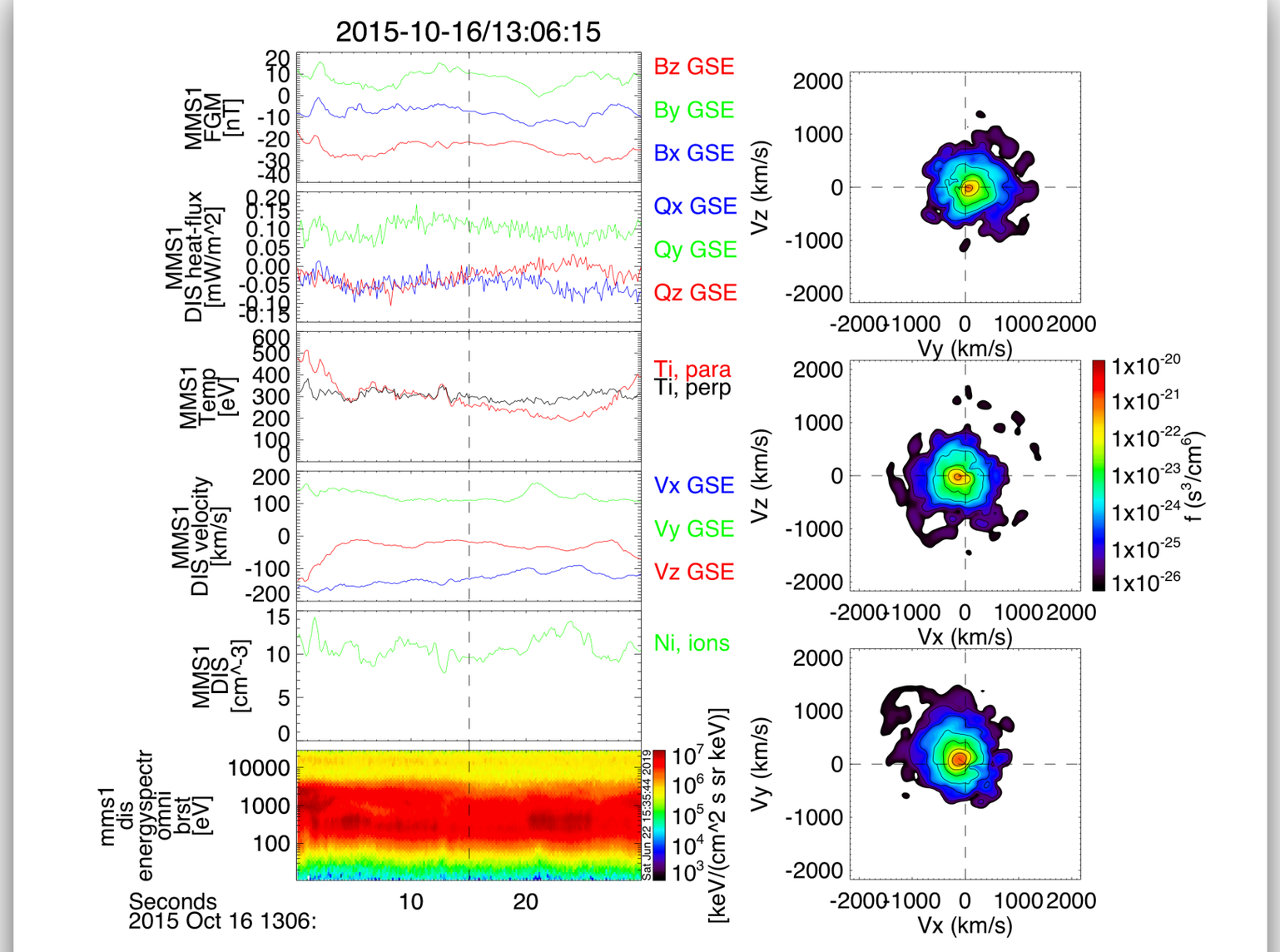






Analyzing MMS Data with SPEDAS and pySPEDAS

Eric Grimes (egrimes@igpp.ucla.edu)

December 8, 2019

Overview

What's New / Plug-in Status

IDL

- Getting Started
- Loading and Plotting Data
- Analysis Tools

Python

- Getting Started
- Loading and Plotting Data
- Analysis Tools

What's New / Plug-in Status

- 500+ unit/regression tests, all passing
- Initial IDL<->Python cross-validation tests
- pySPEDAS
- Wrappers with pythonic function names
- FEEPS, EIS omni-directional spectra
- FEEPS, EIS PADs
- Orbit plots
- Keywords to limit the CDF file versions loaded
- Load data from network mirrors instead of the SDC

Getting Started

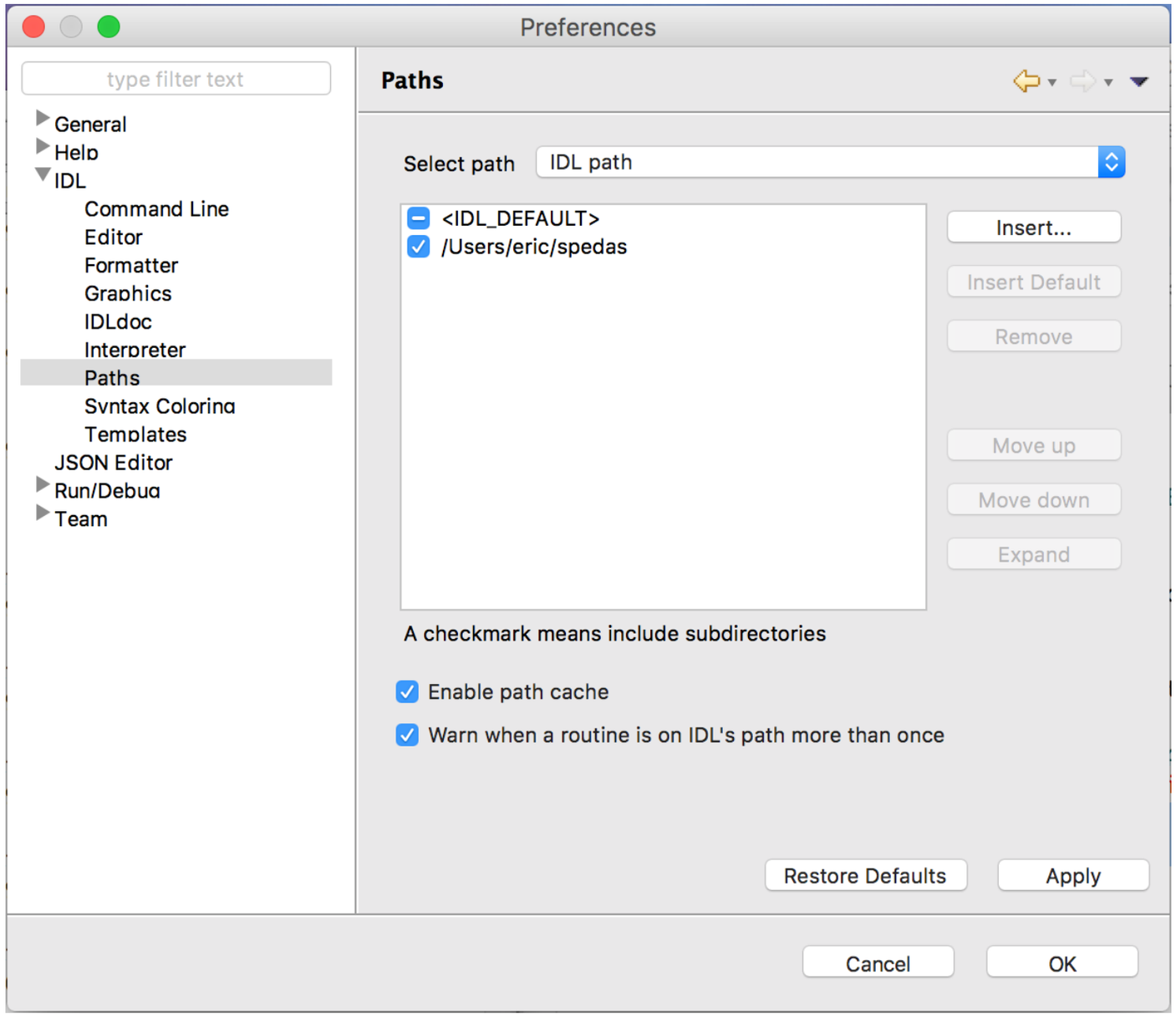
Requirements

- Windows, Linux, or OS X
- IDL 8.4+
- IDL CDF Library 3.6.3+

Getting Started

Installing SPEDAS

http://spedas.org/wiki/index.php?title=Downloads_and_Installation



Getting Started

Organization

spedas_gui: Components of the SPEDAS Graphical User Interface (GUI)

external: Code developed externally, but distributed with SPEDAS (CDAWeb, Geopack, etc.)

projects: Mission specific code

general: General science analysis tools

Getting Started

MMS Load Routines

mms_load_fgm	Fluxgate Magnetometer
mms_load_scm	Search-coil Magnetometer
mms_load_fsm	L3 FGM+SCM
mms_load_mec	Ephemeris and Coordinates
mms_load_fpi	Fast Plasma Investigation
mms_load_hpca	Hot Plasma Composition Analyzer
mms_load_eis	Energetic Ion Spectrometer
mms_load_feeps	Fly's Eye Energetic Particle Sensor
mms_load_edp	Electric-field Double Probe
mms_load_edi	Electron Drift Instrument
mms_load_dsp	Digital Signal Processor
mms_load_aspoc	Active Spacecraft Potential Control
mms_load_tetrahedron_qf	Tetrahedron Quality Factor
mms_load_fast_segments	Fast survey intervals
mms_load_brst_segments	Burst intervals

Getting Started

Standard Keywords

- trange `trange=['2015-10-16', '2015-10-17']`
- probes `probes=[1, 2, 3, 4]`
- level `level='l2'`
- data_rate `data_rate='srvy'`
- datatype `datatype=['des-moms', 'dis-moms']`

Getting Started

Standard Keywords

- suffix `suffix='_burst_mode'`
- time_clip `/time_clip`
- no_update `/no_update`
- spdf `/spdf`
- tplotnames `tplotnames=tvarnames`

Getting Started

Standard Keywords

- cdf_version `cdf_version='4.3.1'`
- min_version `min_version='4.3.0'`
- latest_version `/latest_version`
- major_version `/major_version`

Getting Started

Standard Keywords

For a complete list of keywords and their descriptions, see the header for the load routine you're interested in, e.g.,

```
; PROCEDURE:
;         mms_load_fpi
;
; PURPOSE:
;         Load data from the Fast Plasma Investigation (FPI) onboard MMS
;
; KEYWORDS:
;         trange:       time range of interest [starttime, endtime] with the format
;                       ['YYYY-MM-DD','YYYY-MM-DD'] or to specify more or less than a day
;                       ['YYYY-MM-DD/hh:mm:ss','YYYY-MM-DD/hh:mm:ss']
;         probes:       list of probes, valid values for MMS probes are ['1','2','3','4'].
;                       If no probe is specified the default is probe '3'
;         level:        indicates level of data processing. FPI levels currently include 'l2',
;                       'l1b', 'sitl', 'ql'.
;         datatype:     valid datatypes are:
;                         Quicklook: ['des', 'dis']
;                         SITL: '' (none; loads both electron and ion data from single CDF)
;                         L1b/L2: ['des-dist', 'dis-dist', 'dis-moms', 'des-moms']
;         data_rate:    instrument data rates for MMS FPI include 'fast', 'brst'.
;         local_data_dir: local directory to store the CDF files; should be set if
;                       you're on *nix or OSX, the default currently assumes Windows (c:\data\mms\)
;         source:       specifies a different system variable. By default the MMS mission system
;                       variable is !mms
;         get_support_data: load support data (defined by support_data attribute in the CDF)
;         tplotnames:   returns a list of the names of the tplot variables loaded by the load routine
;         no_color_setup: don't setup graphics configuration; use this keyword when you're
;                       using  this load routine from a terminal without an X server running
;         time_clip:    clip the data to the requested time range; note that if you do not use
;                       this keyword you may load a longer time range than requested
```

Loading and Plotting Data

Simple Example

```
; load the MMS1 FGM data for October 16, 2015
mms_load_fgm, probe=1, data_rate='srvy', trange=['2015-10-16', '2015-10-17']

; list the tplot variables loaded
tplot_names

; get the data out of a tplot variable
get_data, 'mms1_fgm_b_gsm_srvy_l2_bvec', data=bgsm_vec, dlimits=bgsm_metadata

; get basic info on the IDL vars that hold the B-field data
help, bgsm_vec ; structure, x: times, y: data (x, y, z)
help, bgsm_metadata ; plotting and file metadata

; store the data into a different tplot variable
store_data, 'new_var_with_b_gsm', data=bgsm_vec, dlimits=bgsm_metadata
```

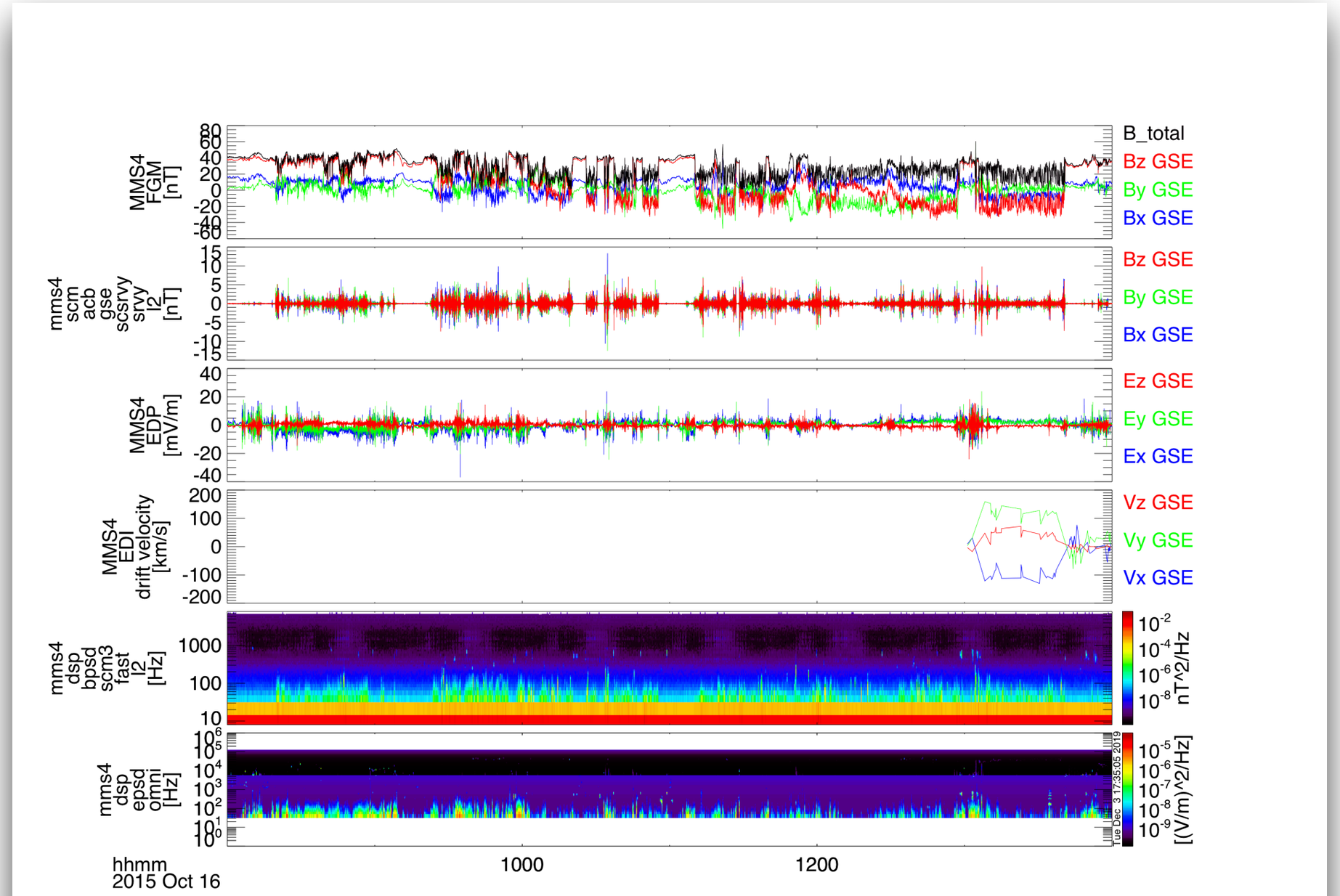
Loading and Plotting Data

FIELDS

```
trange = ['2015-10-16/8:00', '2015-10-16/14:00']

mms_load_fgm, probe=4, trange=trange, /time_clip
mms_load_scm, probe=4, trange=trange, /time_clip
mms_load_edp, probe=4, trange=trange, /time_clip
mms_load_edi, probe=4, trange=trange, /time_clip
mms_load_dsp, datatype=['epsd', 'bpsd'], data_rate='fast', probe=4, trange=trange, /time_clip

tplot, ['mms4_fgm_b_gse_srvy_l2', $
        'mms4_scm_acb_gse_scsrvy_srvy_l2', $
        'mms4_edp_dce_gse_fast_l2', $
        'mms4_edi_vdrift_gse_srvy_l2', $
        'mms4_dsp_bpsd_scm3_fast_l2', $
        'mms4_dsp_epsd_omni']
```

Loading and Plotting Data

FIELDS



Loading and Plotting Data

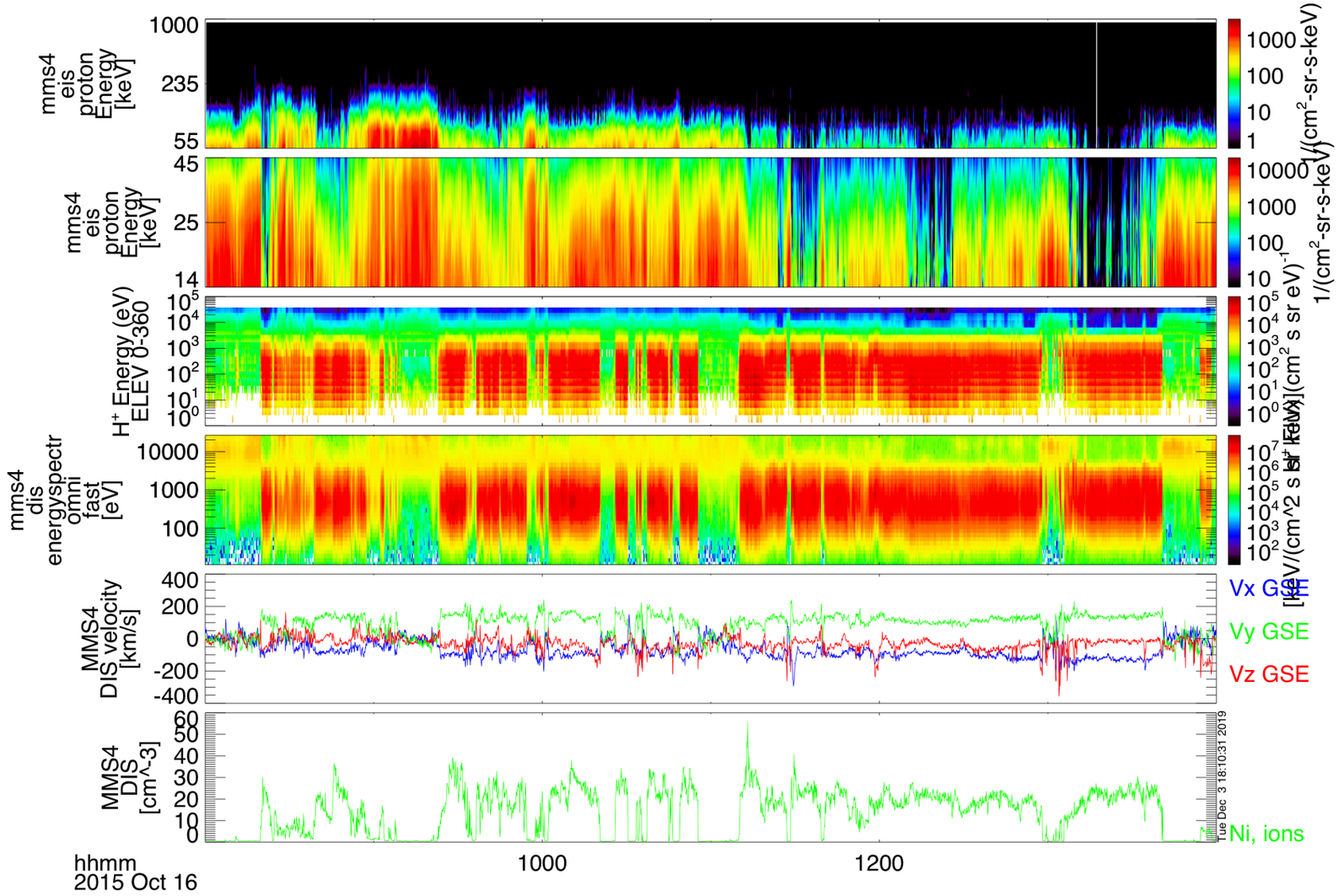
Ions

```
mms_load_eis, datatype=['extof', 'phxtof'], probe=4, trange=trange, /time_clip
mms_load_fpi, /center_measurement, datatype='dis-moms', probe=4, trange=trange, /time_clip
mms_load_hpca, /center_measurement, datatype='ion', probe=4, trange=trange, /time_clip
```

```
mms_hpca_calc_anodes, fov=[0, 360] ; sum over the full field of view
mms_hpca_spin_sum, probe=4, /avg ; spin-average to create the omni-directional data product

tplot, ['mms4_epd_eis_extof_proton_flux_omni', $
  'mms4_epd_eis_phxtof_proton_flux_omni', $
  'mms4_hpca_hplus_flux_elev_0-360_spin', $
  'mms4_dis_energyspectr_omni_fast', $
  'mms4_dis_bulkv_gse_fast', $
  'mms4_dis_numberdensity_fast']
```

Loading and Plotting Data

Ions



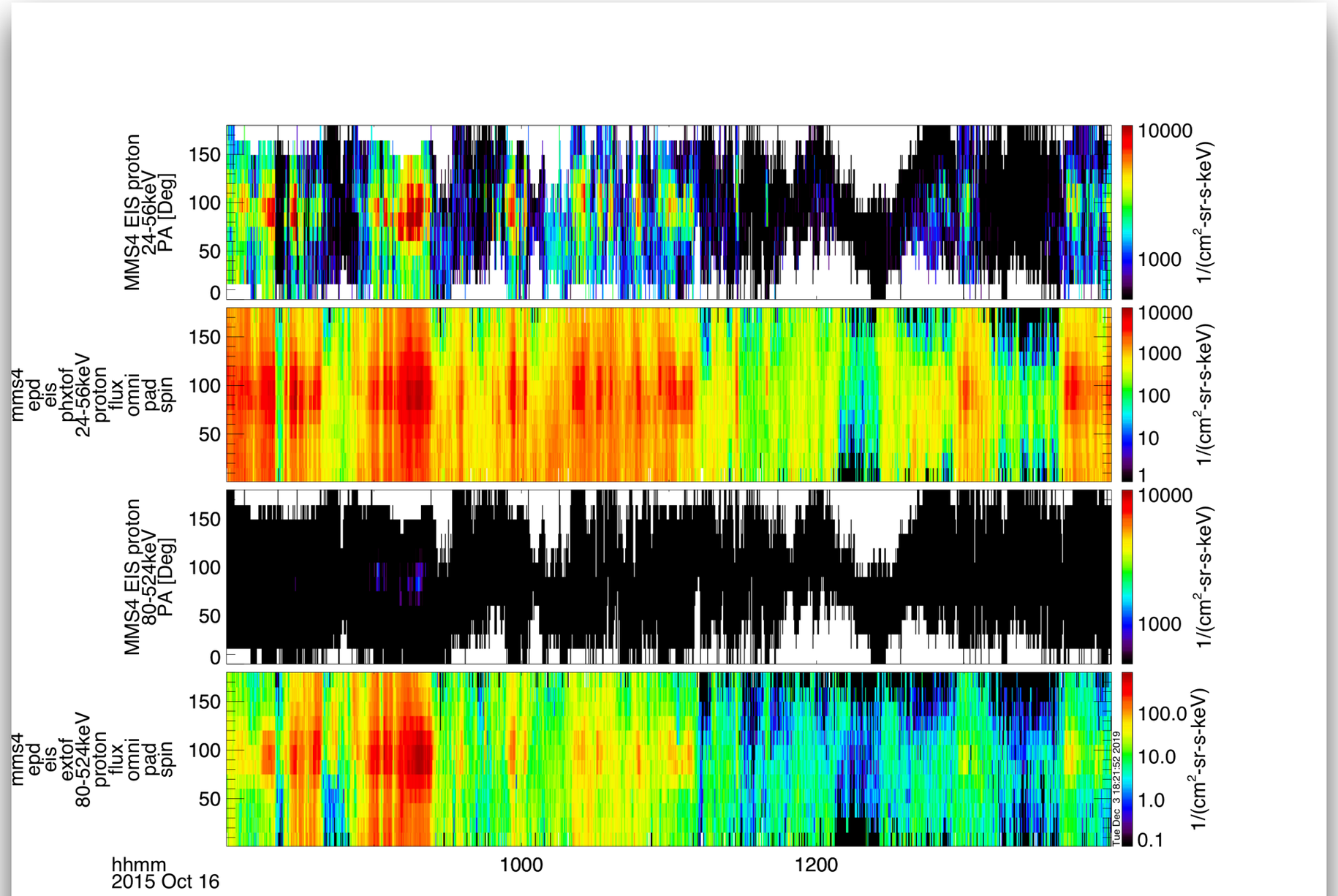
Loading and Plotting Data

Ion pitch angle distributions

```
mms_eis_pad, energy=[20, 60], datatype='phxtof', probe=4
mms_eis_pad, energy=[56, 550], datatype='extof', probe=4

tplot, ['mms4_epd_eis_phxtof_24-56keV_proton_flux_omni_pad', $
        'mms4_epd_eis_phxtof_24-56keV_proton_flux_omni_pad_spin', $
        'mms4_epd_eis_extof_80-524keV_proton_flux_omni_pad', $
        'mms4_epd_eis_extof_80-524keV_proton_flux_omni_pad_spin']
```

Loading and Plotting Data

Ion pitch angle distributions



Loading and Plotting Data

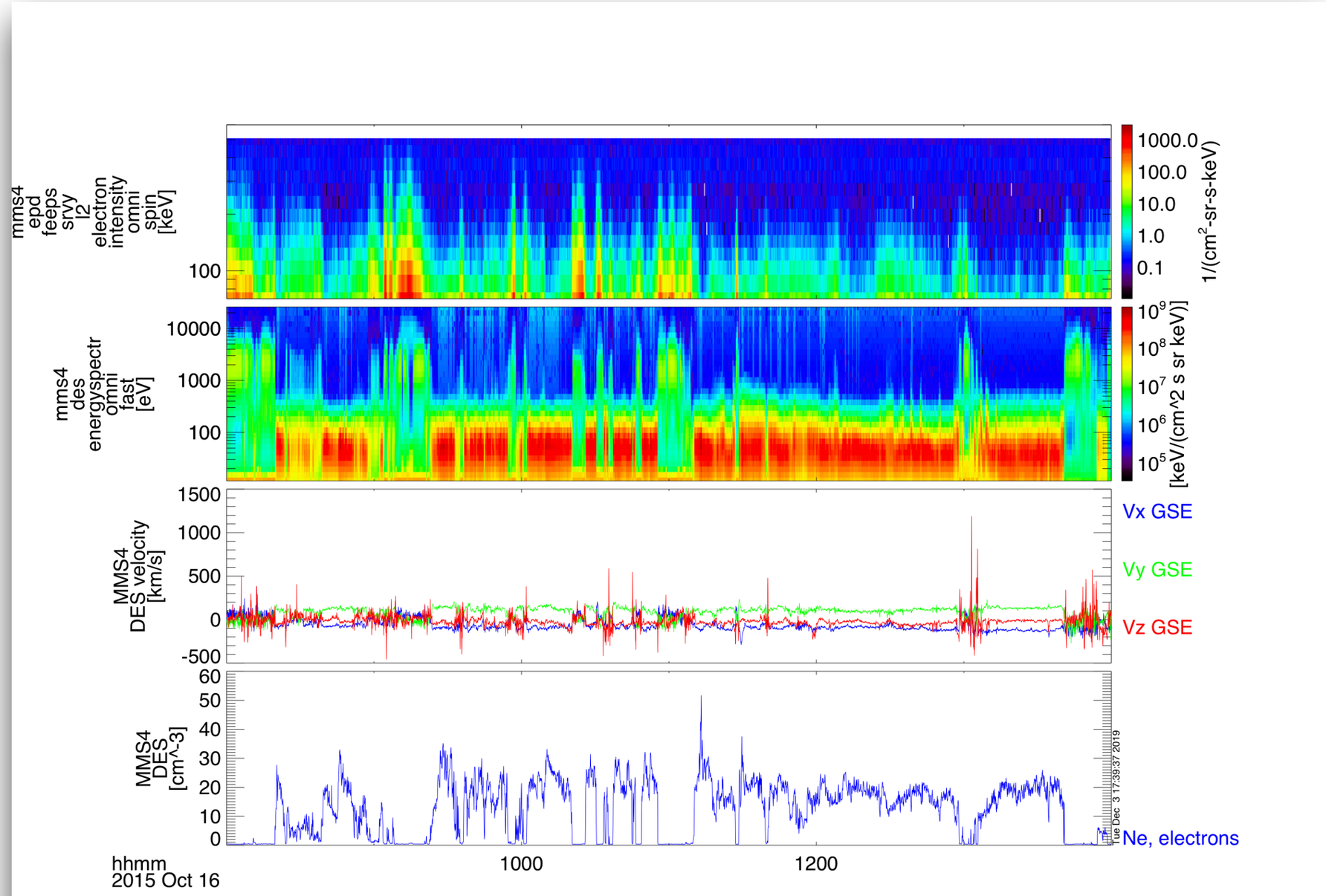
Electrons

```
mms_load_fpi, /center_measurement, datatype='des-moms', probe=4, trange=trange, /time_clip
mms_load_feeps, datatype='electron', probe=4, trange=trange, /time_clip
```

```
tplot, ['mms4_epd_feeps_srvy_l2_electron_intensity_omni_spin', $
  'mms4_des_energyspectr_omni_fast', $
  'mms4_des_bulkv_gse_fast', $
  'mms4_des_numberdensity_fast']
```

Loading and Plotting Data

Electrons



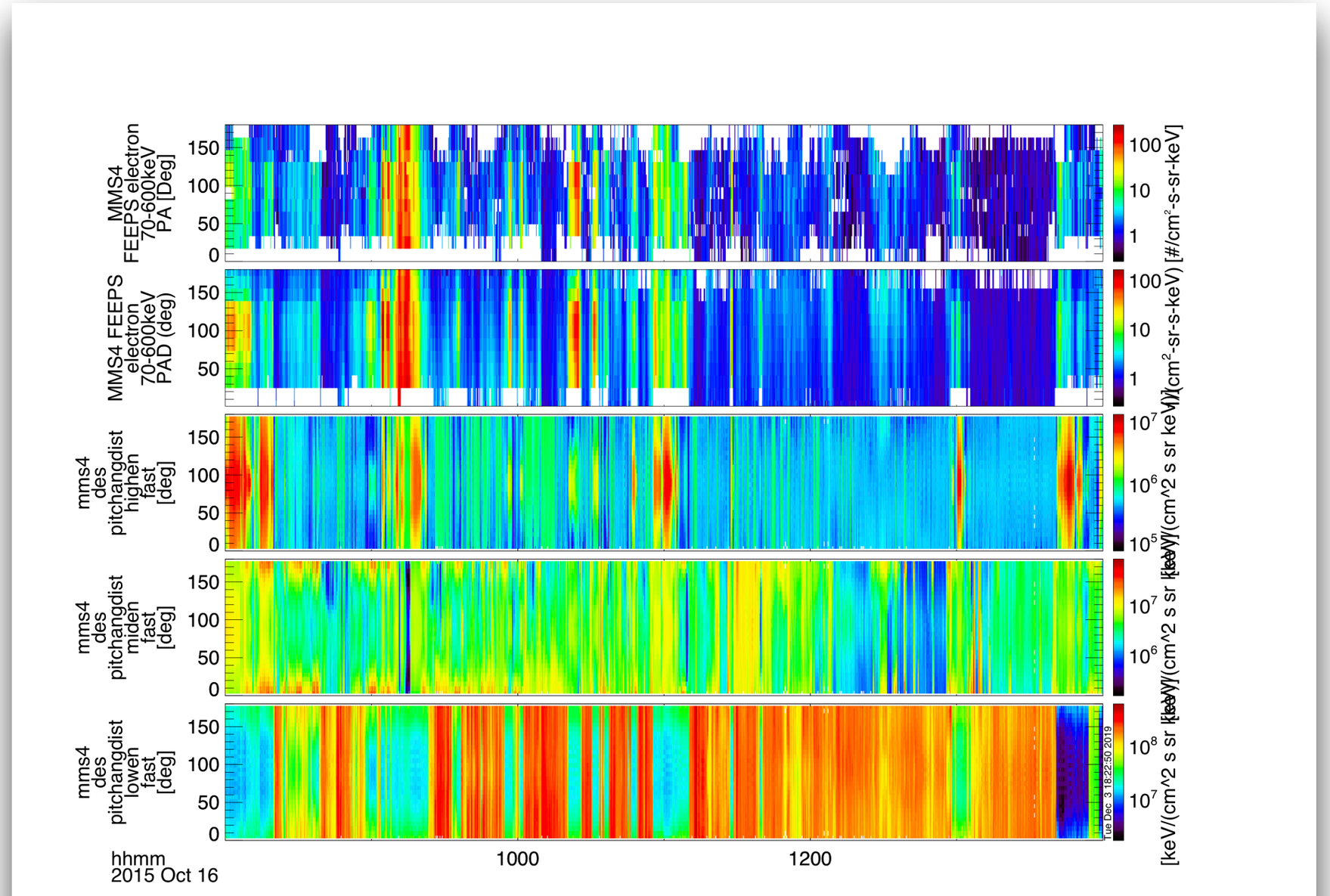
Loading and Plotting Data

Electron pitch angle distributions

```
mms_feeps_pad, energy=[70, 600], datatype='electron', probe=4

tplot, ['mms4_epd_feeps_srvy_l2_electron_intensity_70-600keV_pad', $
        'mms4_epd_feeps_srvy_l2_electron_intensity_70-600keV_pad_spin', $
        'mms4_des_pitchangdist_highen_fast', $
        'mms4_des_pitchangdist_miden_fast', $
        'mms4_des_pitchangdist_lowen_fast']
```

Loading and Plotting Data

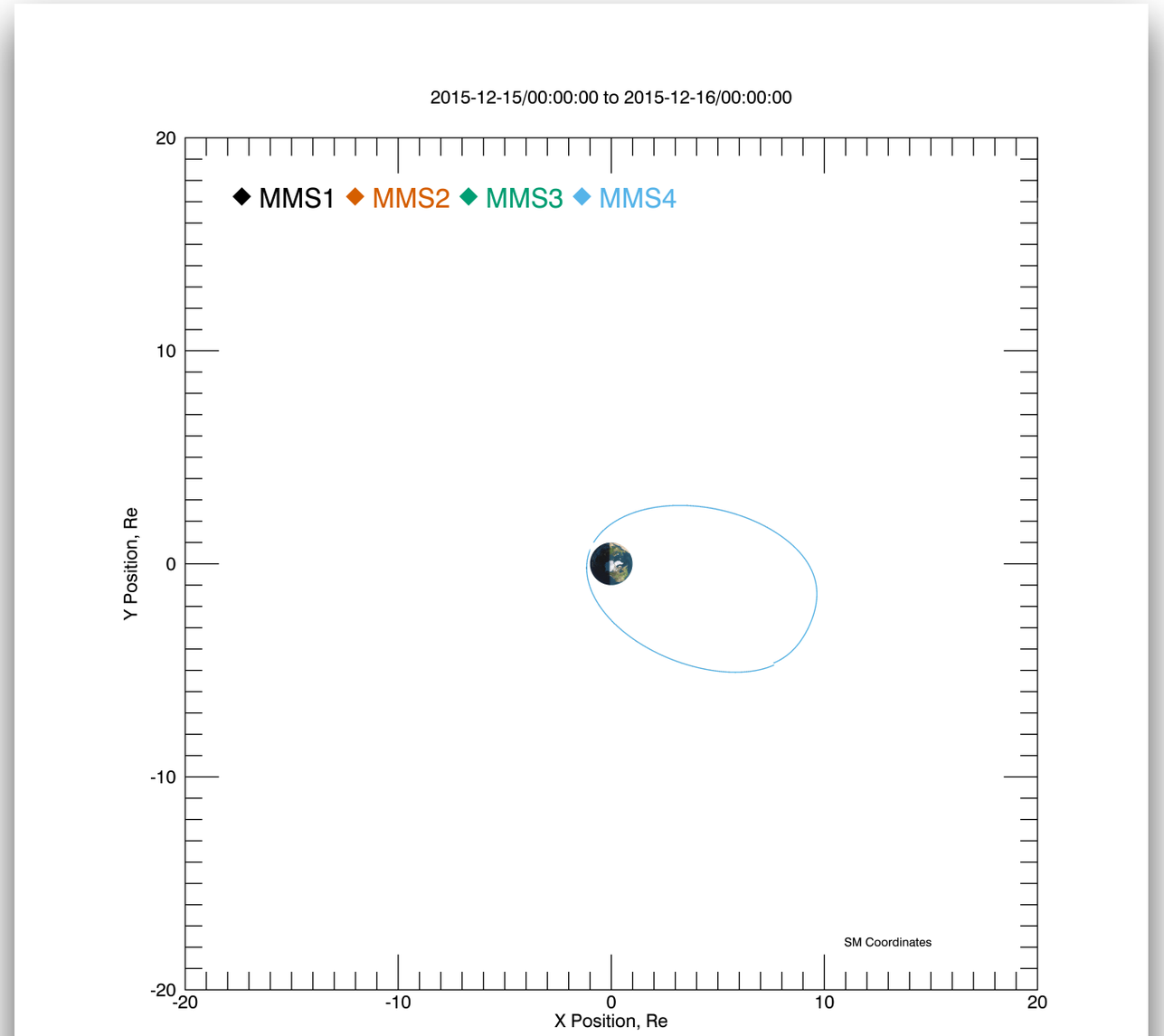
Electron pitch angle distributions



Loading and Plotting Data

Plotting Orbits

```
mms_orbit_plot, coord='sm', probe=[1, 2, 3, 4], trange=['2015-12-15', '2015-12-16'], yrange=[-20, 20], xrange=[-20, 20]
```



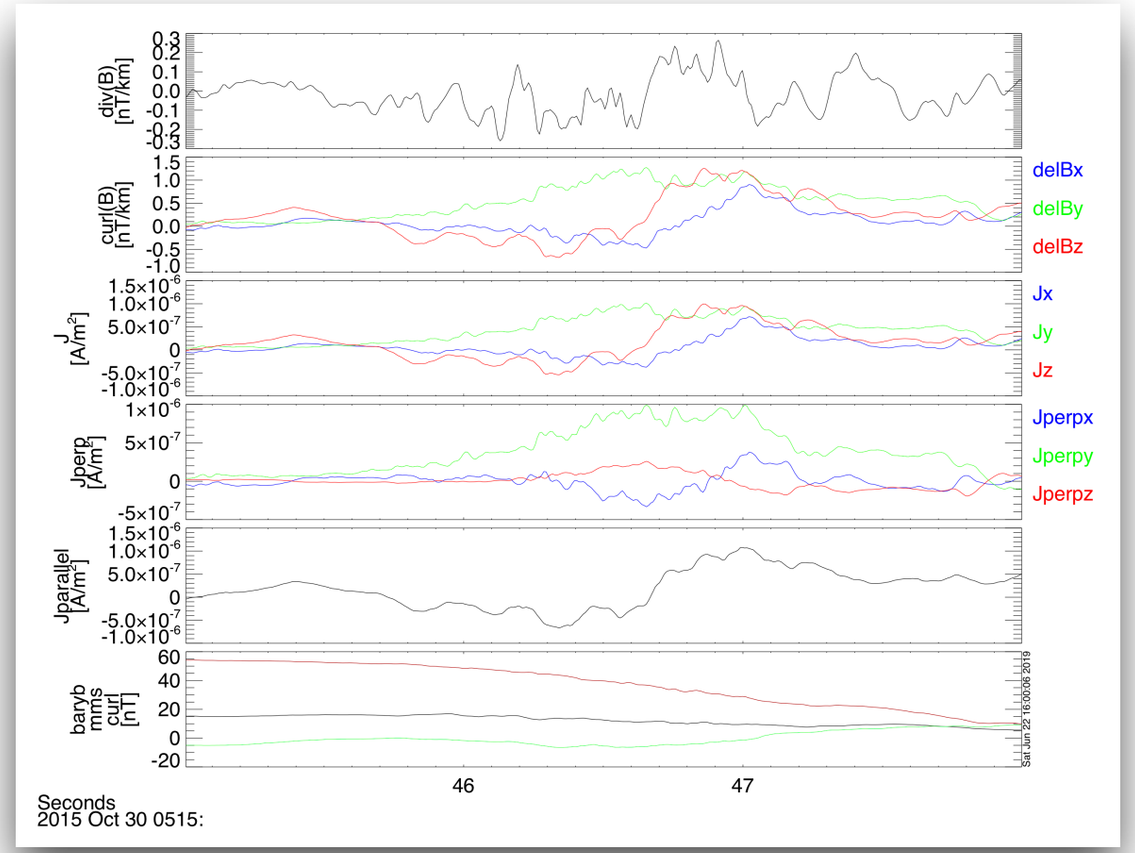
Analysis Tools

mms_curl	Curlometer technique
tdpwrspc	SCM dynamic power spectra
mms_part_getspec	Calculate spectra from FPI/HPCA distributions
mms_part_slice2d	Plot 2D slices of FPI/HPCA distributions
mms_part_isee3d	Plot FPI/HPCA distributions in 3D
mms_flipbookify	Combine FPI/HPCA 2D slices with tplot windows
eis_ang_ang	Create EIS angle-angle plots
mms_fpi_ang_ang	Create FPI angle-angle plots
mms_hpca_ang_ang	Create HPCA angle-angle plots

Analysis Tools

Curlometer technique

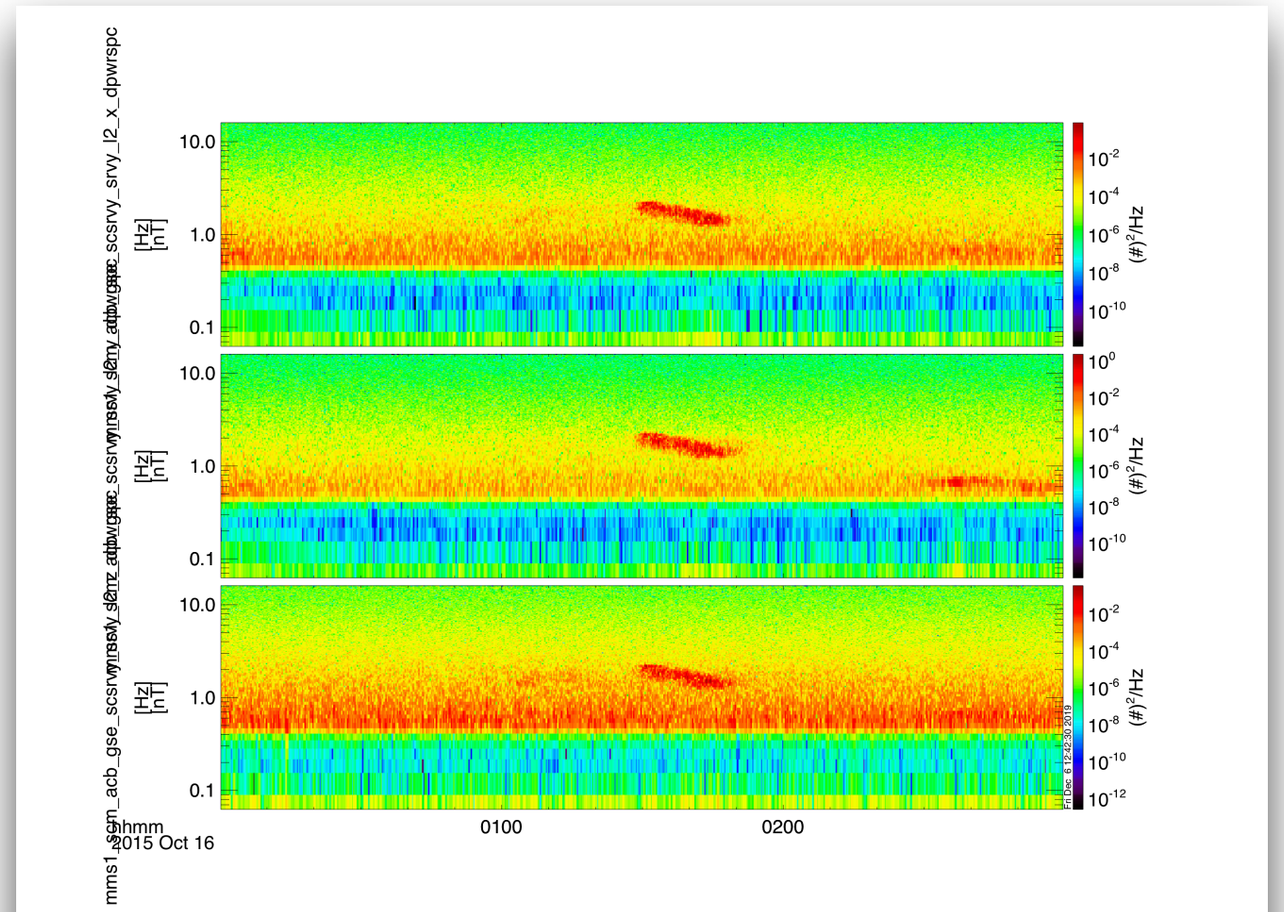
```
trange = ['2015-10-30/05:15:45', '2015-10-30/05:15:48']

mms_load_fgm, trange=trange, /get_fgm_ephemeris, probes=[1, 2, 3, 4], data_rate='brst'

fields = 'mms'+['1', '2', '3', '4']+'_fgm_b_gse_brst_l2'
positions = 'mms'+['1', '2', '3', '4']+'_fgm_r_gse_brst_l2'

mms_curl, trange=trange, fields=fields, positions=positions, suffix='_mms_curl'

tplot, ['divB','curlB','jtotal','jperp','jpar','baryb']+'_mms_curl'
```



Analysis Tools

SCM dynamic power spectra

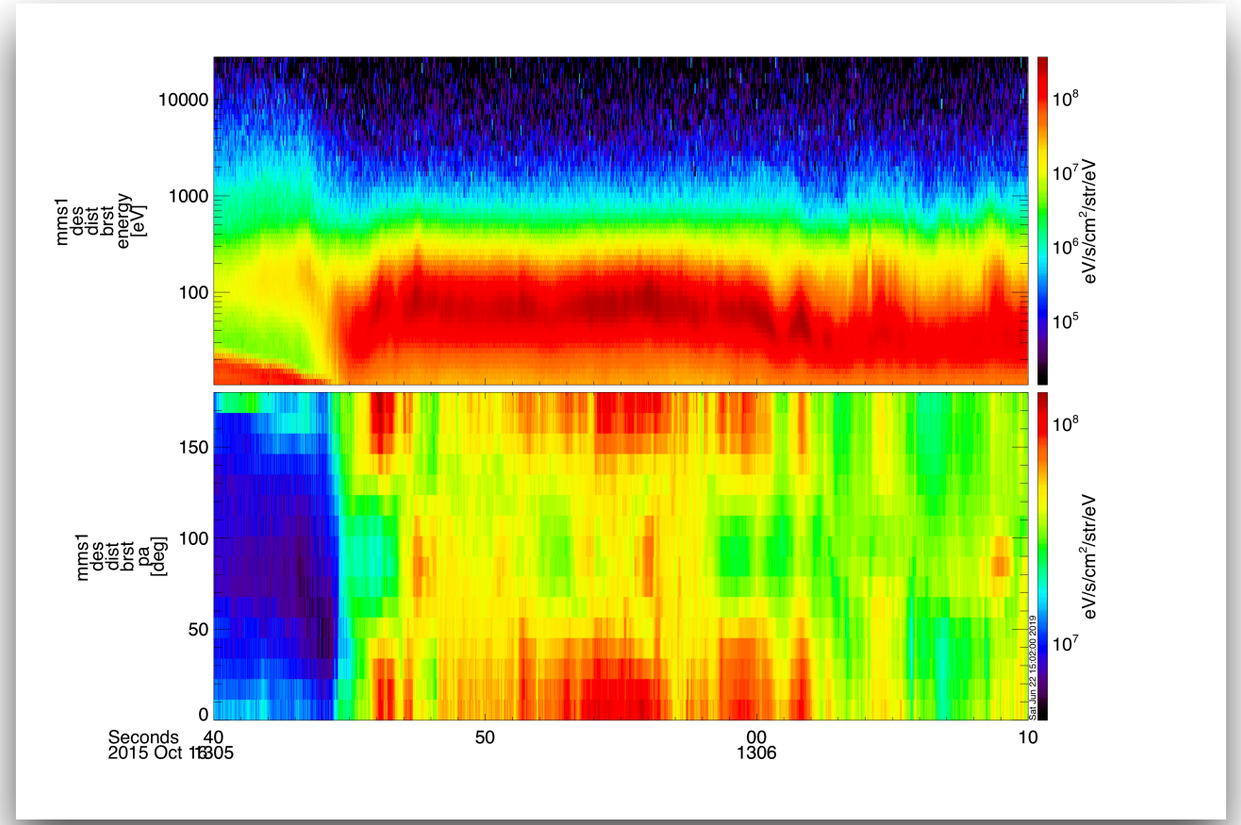
```
mms_load_scm, trange=['2015-10-16', '2015-10-16/03:00'], /time_clip

tdpwrspc, 'mms1_scm_acb_gse_scsrvy_srvy_l2', nshiftpoints=512, nboxpoints=512, bin=1

tplot, ['mms1_scm_acb_gse_scsrvy_srvy_l2_x_dpwrspc', $
        'mms1_scm_acb_gse_scsrvy_srvy_l2_y_dpwrspc', $
        'mms1_scm_acb_gse_scsrvy_srvy_l2_z_dpwrspc']
```



Analysis Tools

Calculate spectra from FPI/HPCA distributions

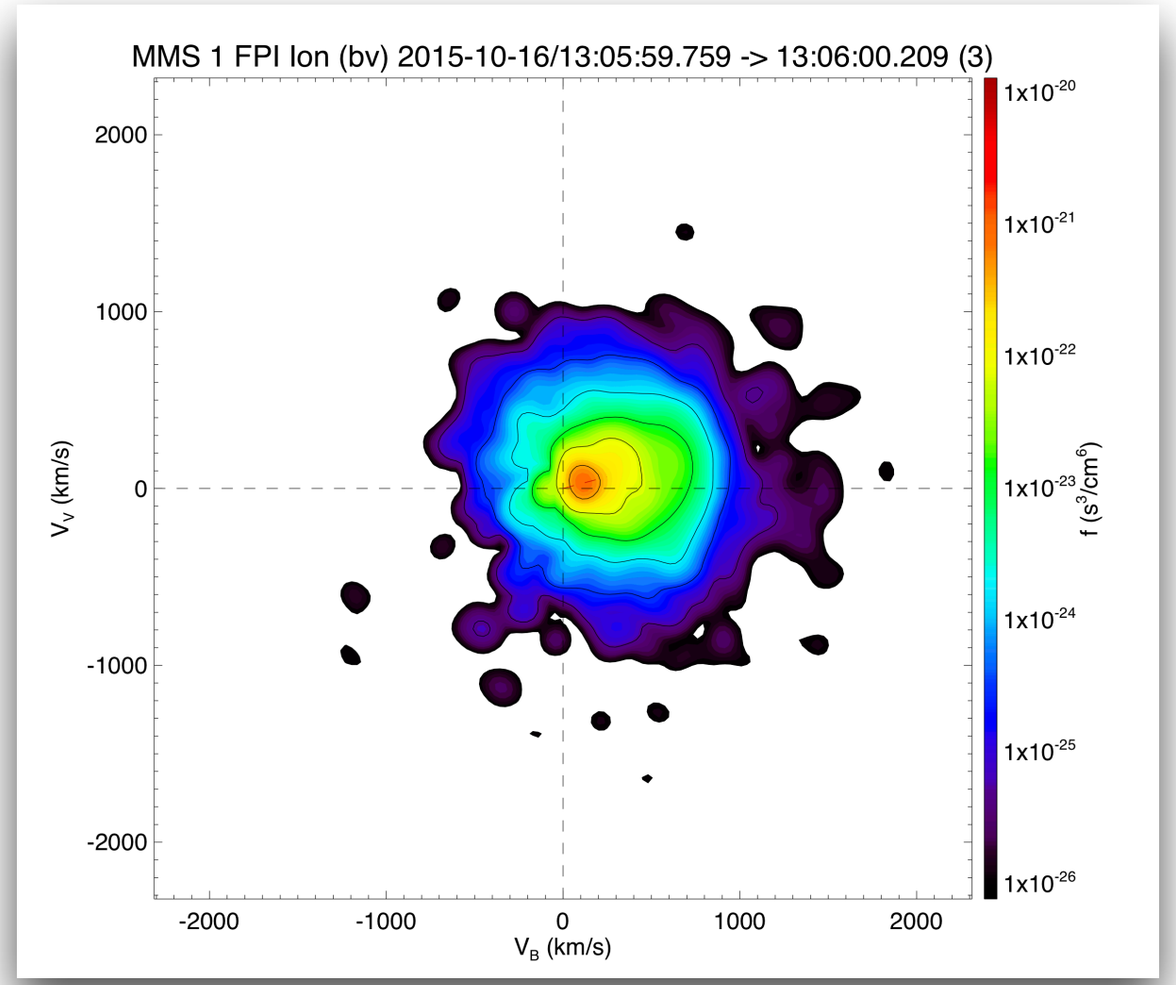
```
; use short time range for data due to high resolution
timespan, '2015-10-16/13:05:40', 30, /sec

; generate products
mms_part_getspec, instrument='fpi', probe='1', species='e', data_rate='brst', level='l2', outputs=['energy', 'pa']

; plot spectrograms
tplot, 'mms1_des_dist_brst_'+['energy', 'pa']
```



Analysis Tools

Plot 2D slices of FPI/HPCA distributions

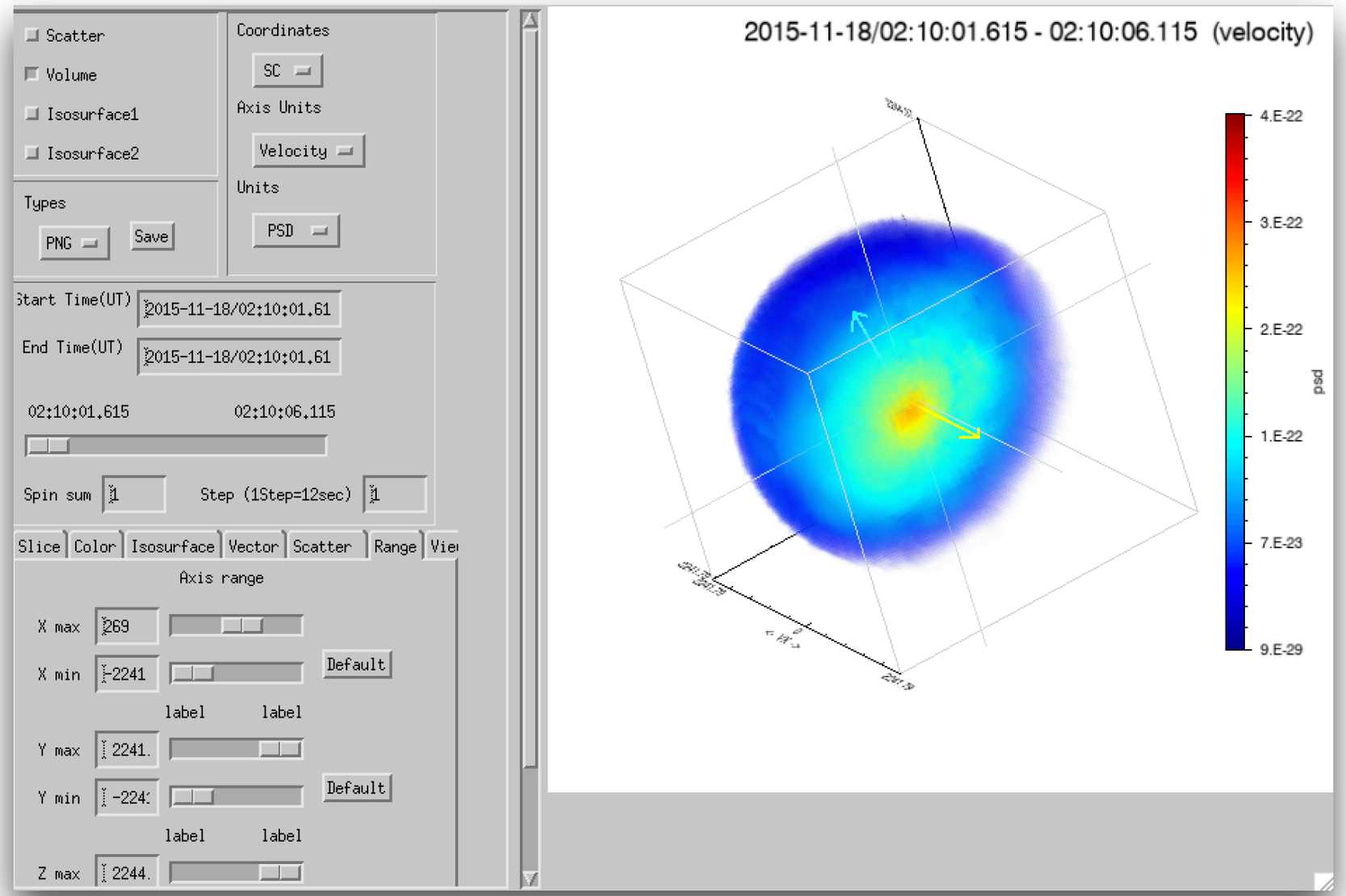
```
;field/velocity aligned slice
;  -the plot's x axis is parallel to the B field
;  -the plot's y axis is defined by the bulk velocity direction
;-----------------------------------------
mms_part_slice2d, rotation='bv', samples=3, time='2015-10-16/13:06:00', probe=1, species='i', data_rate='brst'
```



Analysis Tools

Plot FPI/HPCA distributions in 3D

```
timespan, '2015-11-18/02:10:00', 10, /sec

mms_part_isee3d, probe='1', species='i', data_rate='fast', level='l2'
```



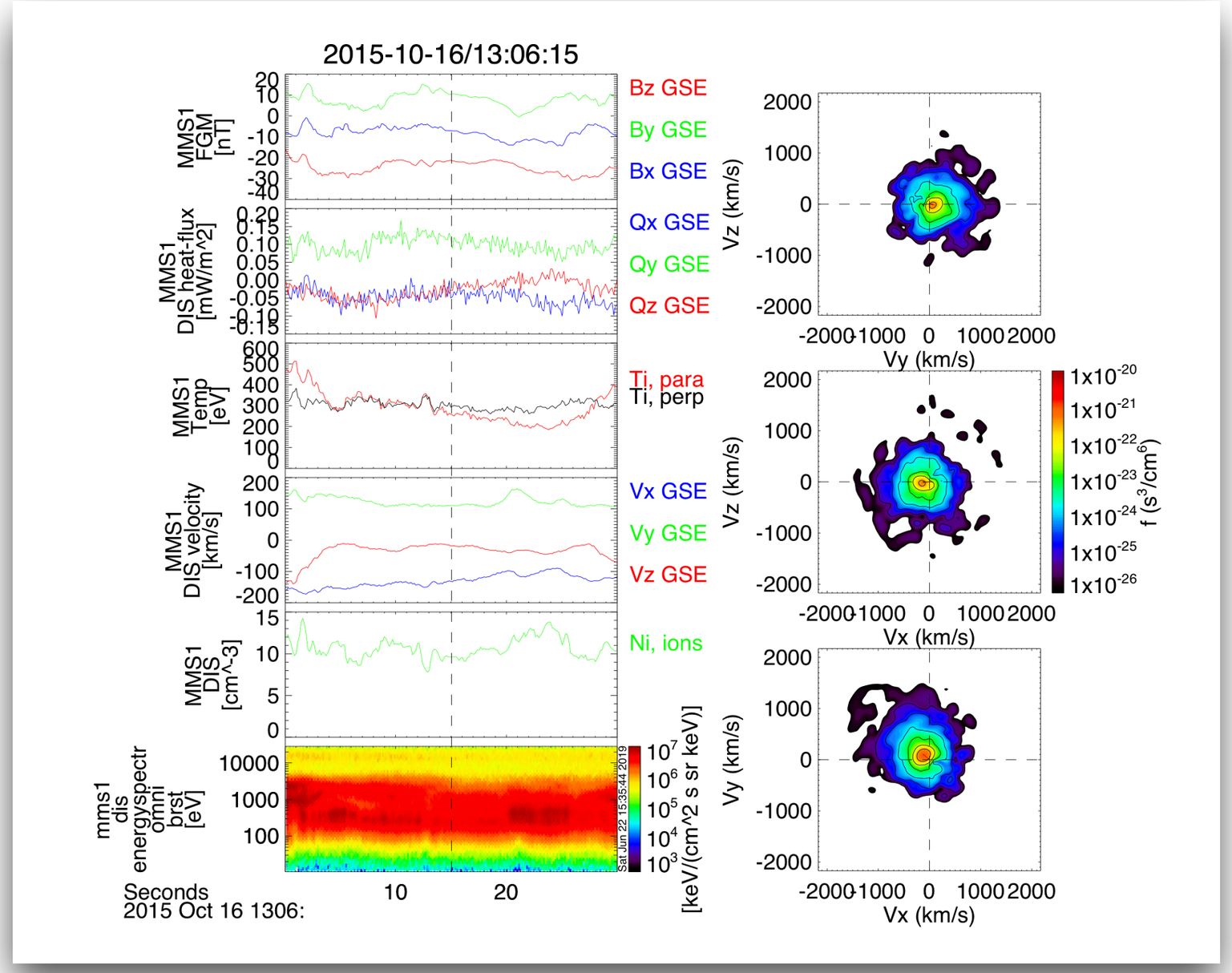
Analysis Tools

Combine FPI/HPCA 2D slices with tplot windows

```
trange=['2015-10-16/13:06:00', '2015-10-16/13:06:30']
probe=1
data_rate = 'brst'
species = 'i'

mms_load_fgm, trange=trange, probe=probe, /time_clip
mms_load_fpi, trange=trange, probe=probe, datatype='d'+species+'s-moms', /time_clip, data_rate=data_rate

window, xsize=1000, ysize=650

; store the temperature in the same panel
store_data, 'temp', data='mms1_d'+species+'s_temppara_brst mms1_d'+species+'s_tempperp_brst'

tplot, ['mms1_fgm_b_gse_srvy_l2_bvec', 'mms1_dis_heatq_gse_brst', 'temp', 'mms1_d'+species+'s_bulkv_gse_brst', $
  'mms1_d'+species+'s_numberdensity_brst', 'mms1_d'+species+'s_energyspectr_omni_brst']

mms_flipbookify, time_step=10, probe=1, species='i', /postscript
```

Analysis Tools

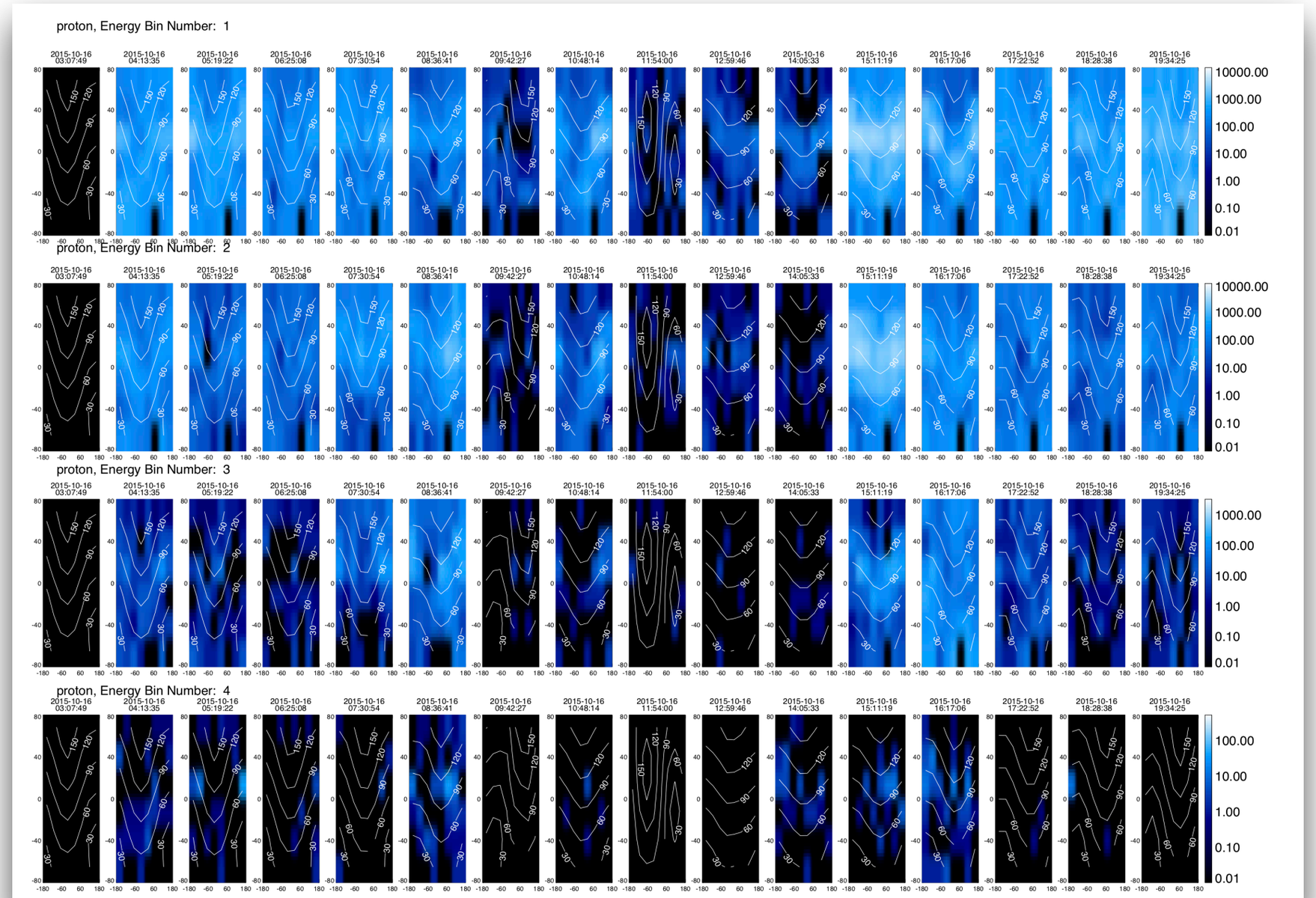
Combine FPI/HPCA 2D slices with tplot windows



Analysis Tools

Create EIS angle-angle plots

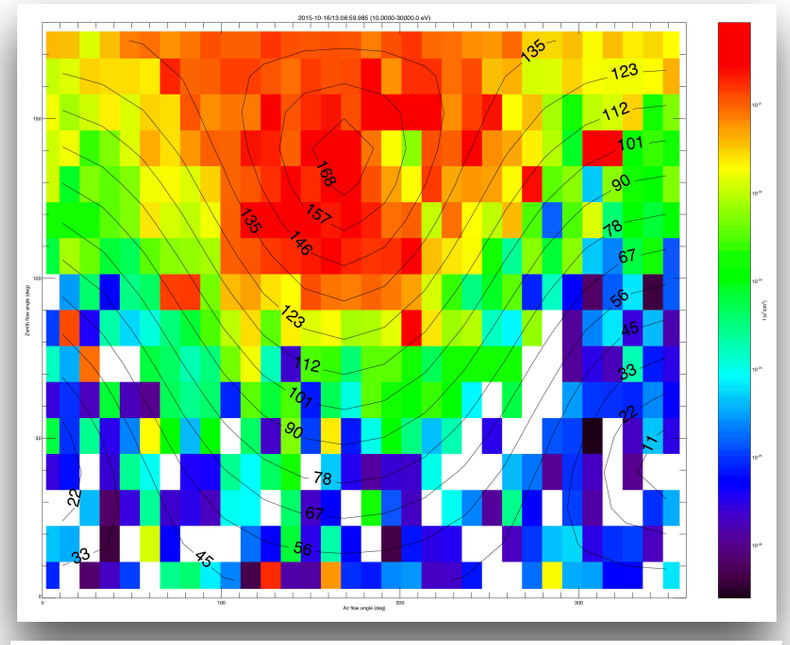
```
eis_ang_ang, trange=['2015-10-16', '2015-10-17'], level='l2', probe=3, datatype='extof'
```

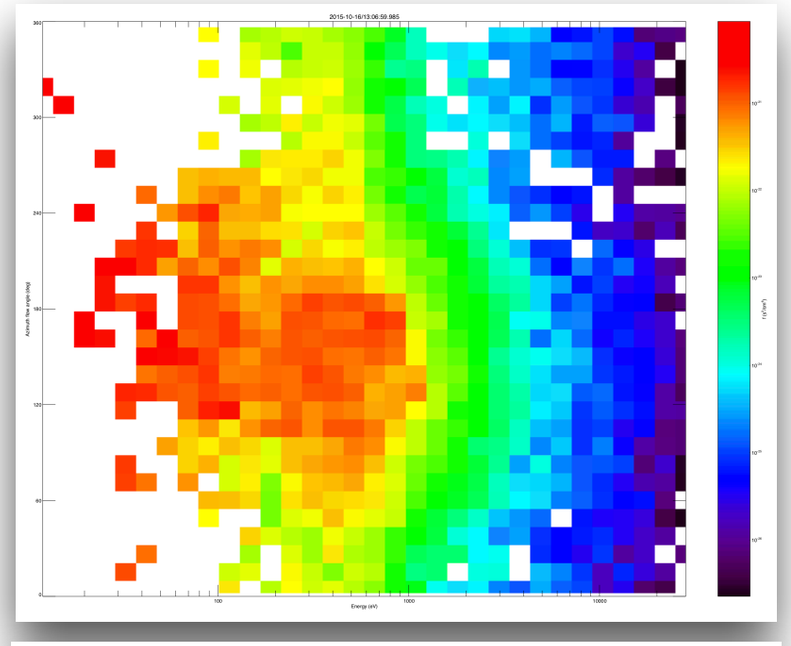


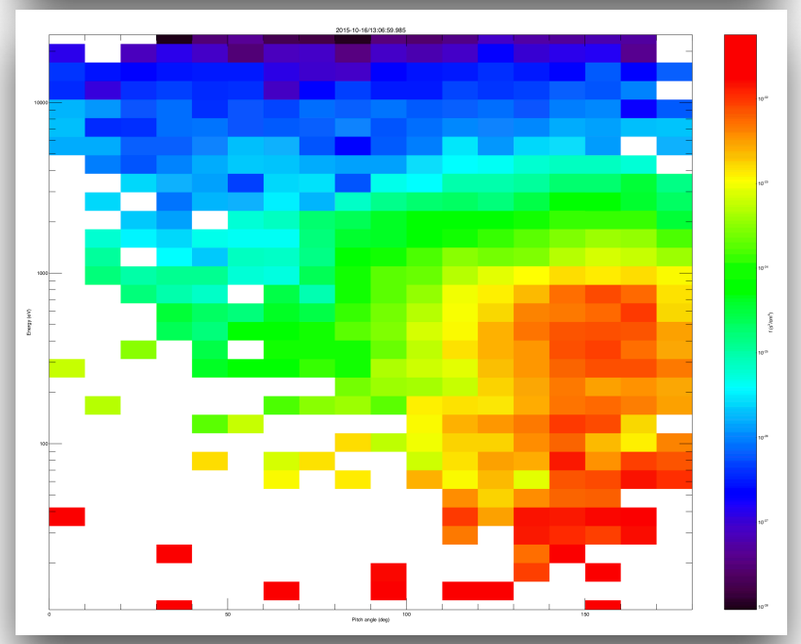
Analysis Tools

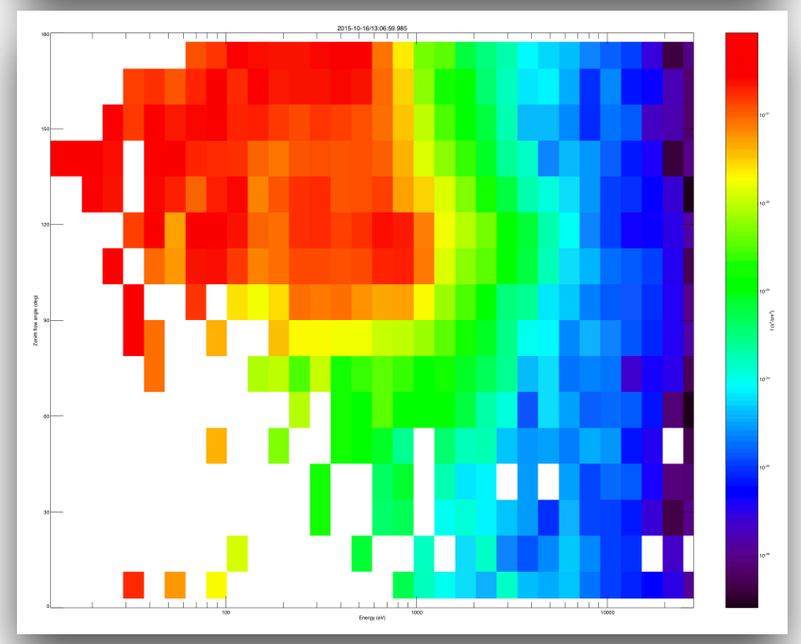
Create FPI angle-angle plots

```
mms_fpi_ang_ang, '2015-10-16/13:06:59.985', species='i', data_rate='brst'
```



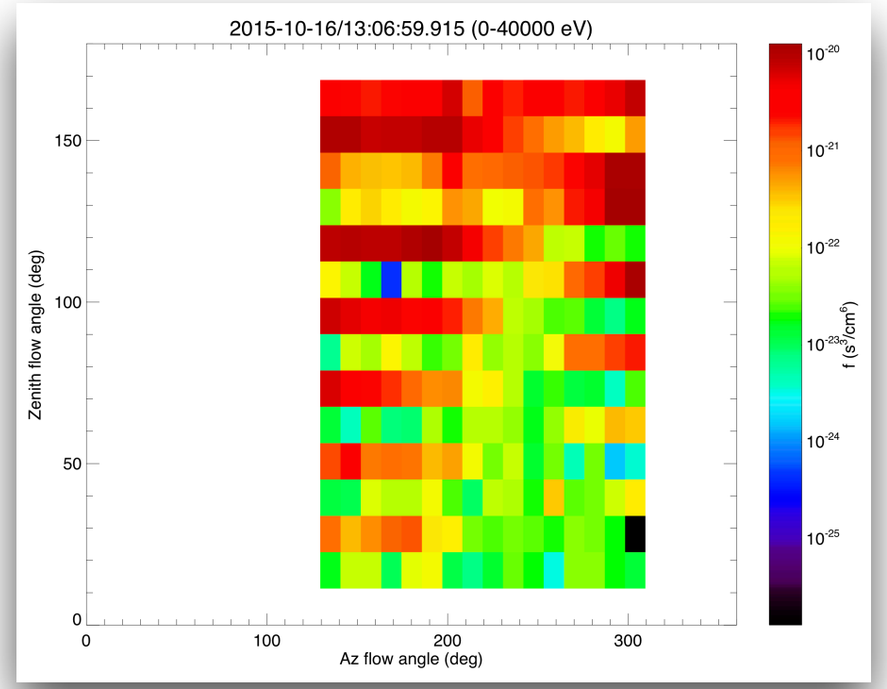


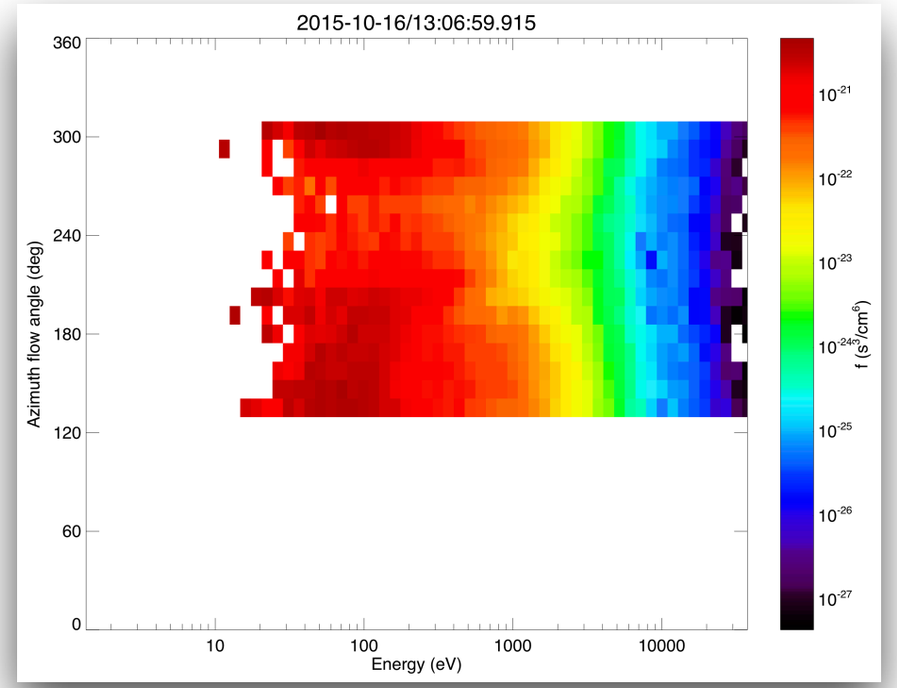


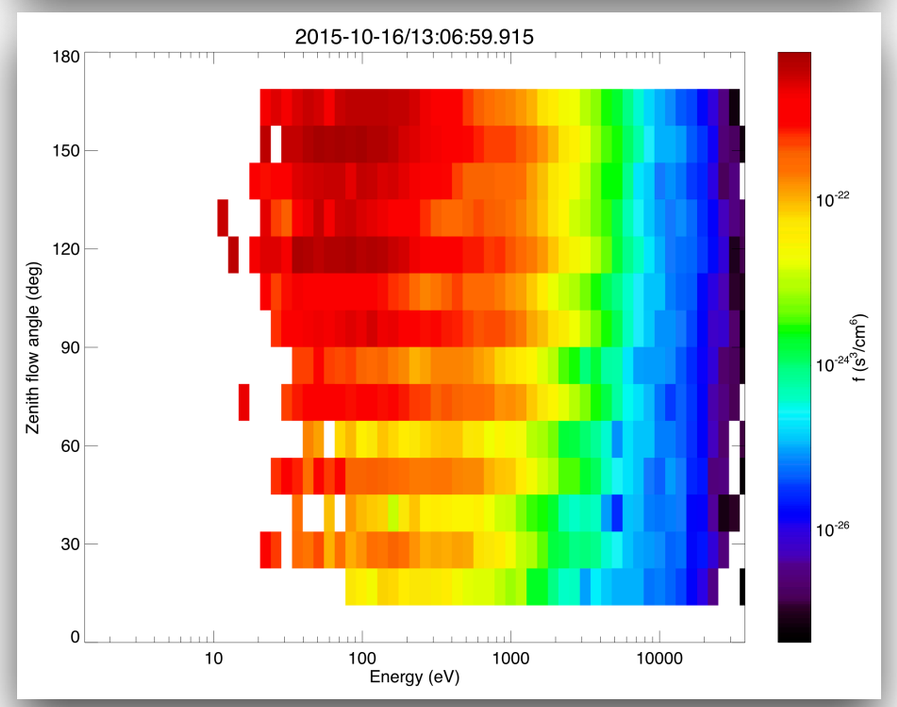


Analysis Tools

Create HPCA angle-angle plots







Analysis Tools

More Examples

Basic:
projects/mms/examples/basic/

Advanced:
projects/mms/examples/advanced/

Getting Started

Requirements

Python 3.5+

Required packages:

pytplot
cdflib
pyqtgraph
xarray
numpy
requests
dateutil

BETA

Getting Started

Installing pySPEDAS

Bleeding edge: https://github.com/spedas/pyspedas

Config settings (e.g., local_data_dir) are set in the hash table stored in mms_config.py

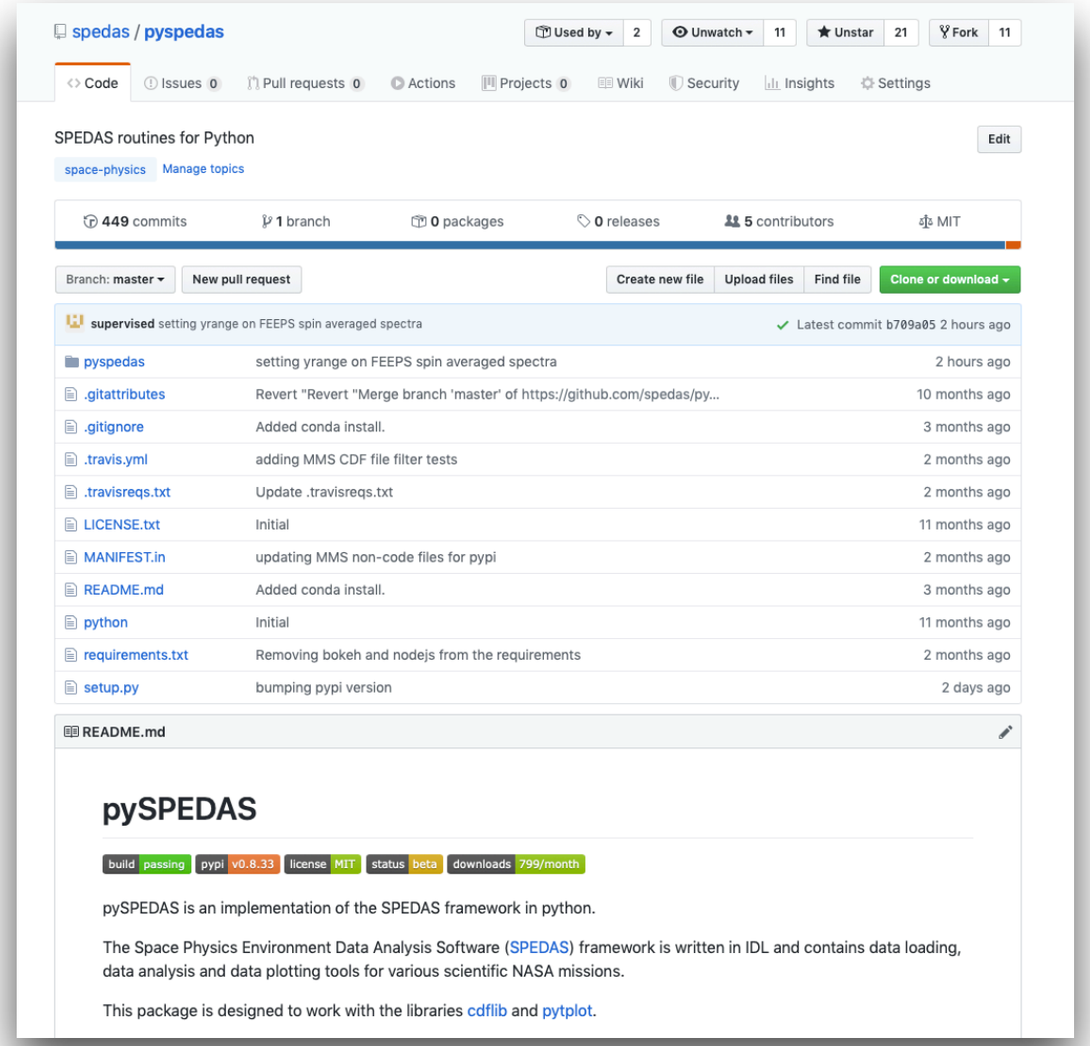
pip install pyspedas

or

pip install pyspedas --upgrade

to get the latest version

BETA



Getting Started

Configuring MMS in pySPEDAS

```python
import os

CONFIG = {'local_data_dir': 'pydata',
          #'local_data_dir': '/Users/eric/data/mms', # example of setting your local data directory on macOS
          #'local_data_dir': 'c:\users\eric\data\mms', # and Windows
           'mirror_data_dir': None, # e.g., '/Volumes/data_network/data/mms'
           'debug_mode': False,
           'download_only': False,
           'no_download': False}

# override local data directory with environment variables
if os.environ.get('ROOT_DATA_DIR'):
    CONFIG['local_data_dir'] = os.sep.join([os.environ['ROOT_DATA_DIR'], 'mms'])

if os.environ.get('MMS_DATA_DIR'):
    CONFIG['local_data_dir'] = os.environ['MMS_DATA_DIR']
```

BETA

Getting Started

MMS Load Routines

Instrument	Wrapper with Pythonic name	IDL syntax
Fluxgate Magnetometer	pyspedas.mms.fgm	mms_load_fgm
Search-coil Magnetometer	pyspedas.mms.scm	mms_load_scm
L3 FGM+SCM	pyspedas.mms.fsm	mms_load_fsm
Ephemeris and Coordinates	pyspedas.mms.mec	mms_load_mec
Fast Plasma Investigation	pyspedas.mms.fpi	mms_load_fpi
Hot Plasma Composition Analyzer	pyspedas.mms.hpca	mms_load_hpca
Energetic Ion Spectrometer	pyspedas.mms.eis	mms_load_eis
Fly's Eye Energetic Particle Sensor	pyspedas.mms.feeps	mms_load_feeps
Electric-field Double Probe	pyspedas.mms.edp	mms_load_edp
Electron Drift Instrument	pyspedas.mms.edi	mms_load_edi
Digital Signal Processor	pyspedas.mms.dsp	mms_load_dsp
Active Spacecraft Potential Control	pyspedas.mms.aspoc	mms_load_aspoc

BETA

Getting Started

MMS Load Routines

```python
# if you prefer the IDL syntax:
from pyspedas import mms_load_fgm
mms_load_fgm(probe=1, data_rate='srvy', trange=['2015-10-16', '2015-10-17'])

# if you prefer the pythonic syntax:
from pyspedas.mms import fgm
fgm_vars = fgm(probe=1, data_rate='srvy', trange=['2015-10-16', '2015-10-17'])

# you can also do:
import pyspedas
fgm_vars = pyspedas.mms.fgm(probe=1, data_rate='srvy', trange=['2015-10-16', '2015-10-17'])
```

BETA

Getting Started

Standard Keywords

- trange
```
trange=['2015-10-16', '2015-10-17']
```
- probe
```
probes=[1, 2, 3, 4]
```
- level
```
level='l2'
```
- data_rate
```
data_rate='srvy'
```
- datatype
```
datatype=['des-moms', 'dis-moms']
```

Getting Started

Standard Keywords

- suffix `suffix='_burst_mode'`
- time_clip `time_clip=True`
- no_update `no_update=True`
- notplot `notplot=True`
- varformat `varformat='*_fgm_*'`

Getting Started

Standard Keywords

- cdf_version `cdf_version='4.3.1'`
- min_version `min_version='4.3.0'`
- latest_version `latest_version=True`
- major_version `major_version=True`

Getting Started

Standard Keywords

For a complete list of keywords and their descriptions, use the ‘help’ command, e.g., help(mms_load_fgm):

```
Help on function mms_load_fgm in module pyspedas.mms:

mms_load_fgm(*args, **kwargs)
    This function loads FGM data into tplot variables

    Parameters:
        trange : list of str
            time range of interest [starttime, endtime] with the format
            'YYYY-MM-DD','YYYY-MM-DD'] or to specify more or less than a day
            ['YYYY-MM-DD/hh:mm:ss','YYYY-MM-DD/hh:mm:ss']

        probe : str or list of str
            list of probes, valid values for MMS probes are ['1','2','3','4'].

        data_rate : str or list of str
            instrument data rates for FGM include 'brst' 'fast' 'slow' 'srvy'. The
            default is 'srvy'.

        level : str
            indicates level of data processing. the default if no level is specified is 'l2'

        datatype : str or list of str
            no datatype for FGM instrument (all science data are loaded)

        get_support_data: bool
            Data with an attribute "VAR_TYPE" with a value of "support_data"
            will be loaded into tplot.  By default, only loads in data with a
            "VAR_TYPE" attribute of "data".

        time_clip: bool
            Data will be clipped to the exact trange specified by the trange keyword.

        varformat: str
            The file variable formats to load into tplot.  Wildcard character
            "*" is accepted.  By default, all variables are loaded in.

        suffix: str
            The tplot variable names will be given this suffix.  By default,
            no suffix is added.

        notplot: bool
            If True, then data are returned in a hash table instead of
            being stored in tplot variables (useful for debugging, and
            access to multi-dimensional data products)

        available: bool
            If True, simply return the available data files (without downloading)
            for the requested paramters

        no_update: bool
            Set this flag to preserve the original data. if not set and newer
            data is found the existing data will be overwritten

        cdf_version: str
            Specify a specific CDF version # to load (e.g., cdf_version='4.3.0')

        min_version: str
            Specify a minimum CDF version # to load

        latest_version: bool
            Only grab the latest CDF version in the requested time interval

        major_version: bool
            Only open the latest major CDF version (e.g., X in vX.Y.Z) in the requested time interval

        keep_flagged: bool
            If True, don't remove flagged data (flagged data are set to NaNs by
            default, this keyword turns this off)

    Returns:
        List of tplot variables created.
```

Getting Started

Note on trange

The **trange** keyword accepts a wide range of different formats:

```
trange=['2015-10-16', '2015-10-17']

trange=['2015-10-16/14:00', '2015-10-16/15:00']

trange=['2015-10-16/14:30:45.553321', '2015-10-16/14:30:46.224322']

trange=['October 16, 2015', 'October 17, 2015']

trange=['Oct 16, 2015', 'Oct 17, 2015']

trange=['October 16, 2015 at 4:00AM', 'October 16, 2015 at 5:00AM']

from datetime import datetime as dt
trange = [dt(year=2015, month=10, day=16), dt(year=2015, month=10, day=17)]
```

Loading and Plotting Data

Simple Example

```python
from pyspedas.mms import fgm
from pytplot import tplot_names, get_data, store_data

# load the MMS1 FGM data for October 16, 2015
fgm_vars = fgm(probe=1, data_rate='srvy', trange=['2015-10-16', '2015-10-17'])

# list the tplot variables loaded
tvars = tplot_names()

# get the data out of a tplot variable
times, bgsm = get_data('mms1_fgm_b_gsm_srvy_l2')

# store the data into a different tplot variable
store_data('new_var_with_b_gsm', data={'x': times, 'y': bgsm})
```

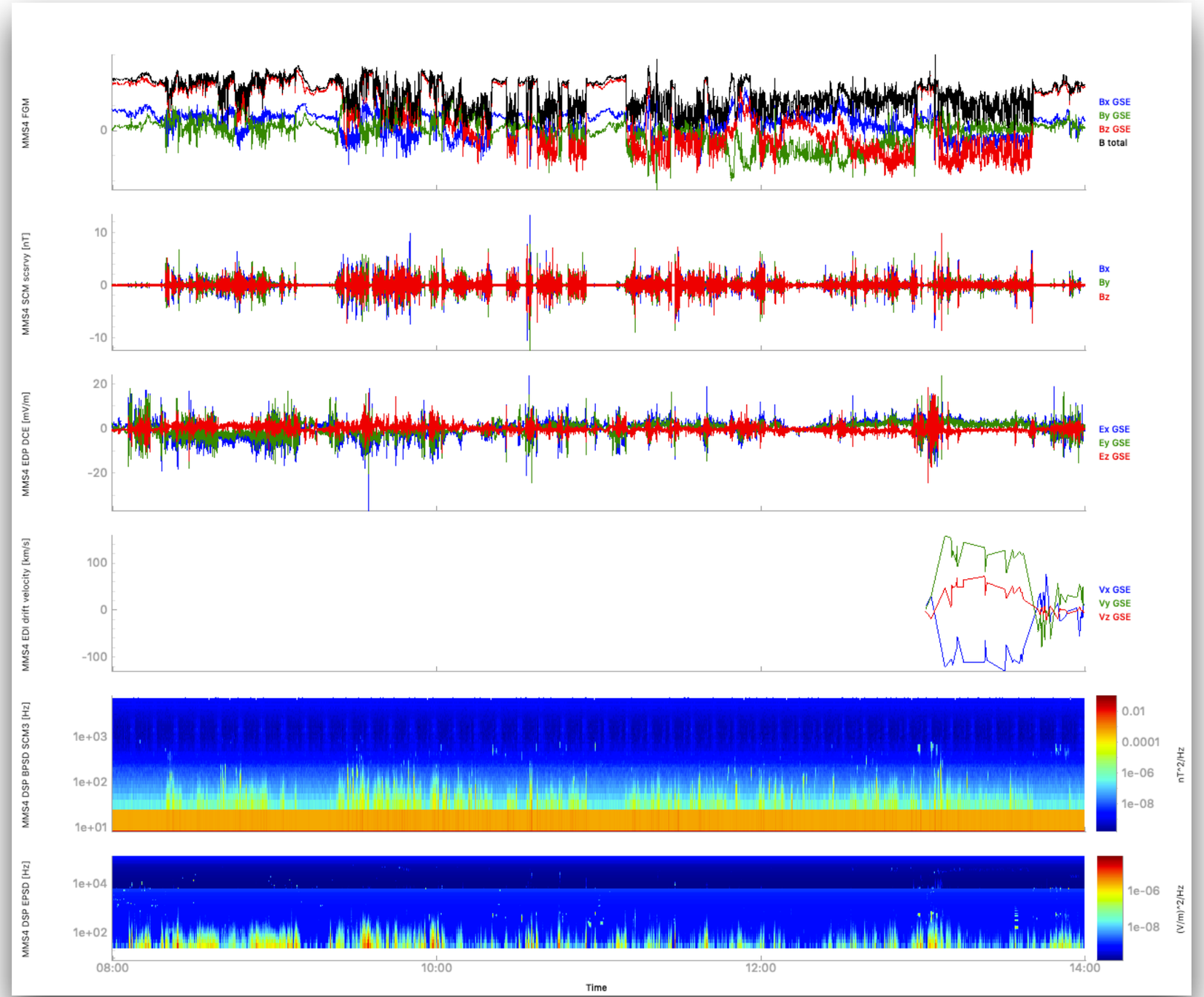
Loading and Plotting Data

FIELDS

```
from pyspedas.mms import fgm, scm, edp, edi, dsp

trange = ['2015-10-16/8:00', '2015-10-16/14:00']

fgm(probe=4, trange=trange, time_clip=True)
scm(probe=4, trange=trange, time_clip=True)
edp(probe=4, trange=trange, time_clip=True)
edi(probe=4, trange=trange, time_clip=True)
dsp(datatype=['epsd', 'bpsd'], data_rate='fast', probe=4, trange=trange, time_clip=True)

tplot(['mms4_fgm_b_gse_srvy_l2',
       'mms4_scm_acb_gse_scsrvy_srvy_l2',
       'mms4_edp_dce_gse_fast_l2',
       'mms4_edi_vdrift_gse_srvy_l2',
       'mms4_dsp_bpsd_scm3_fast_l2',
       'mms4_dsp_epsd_omni'])
```

Loading and Plotting Data

FIELDS



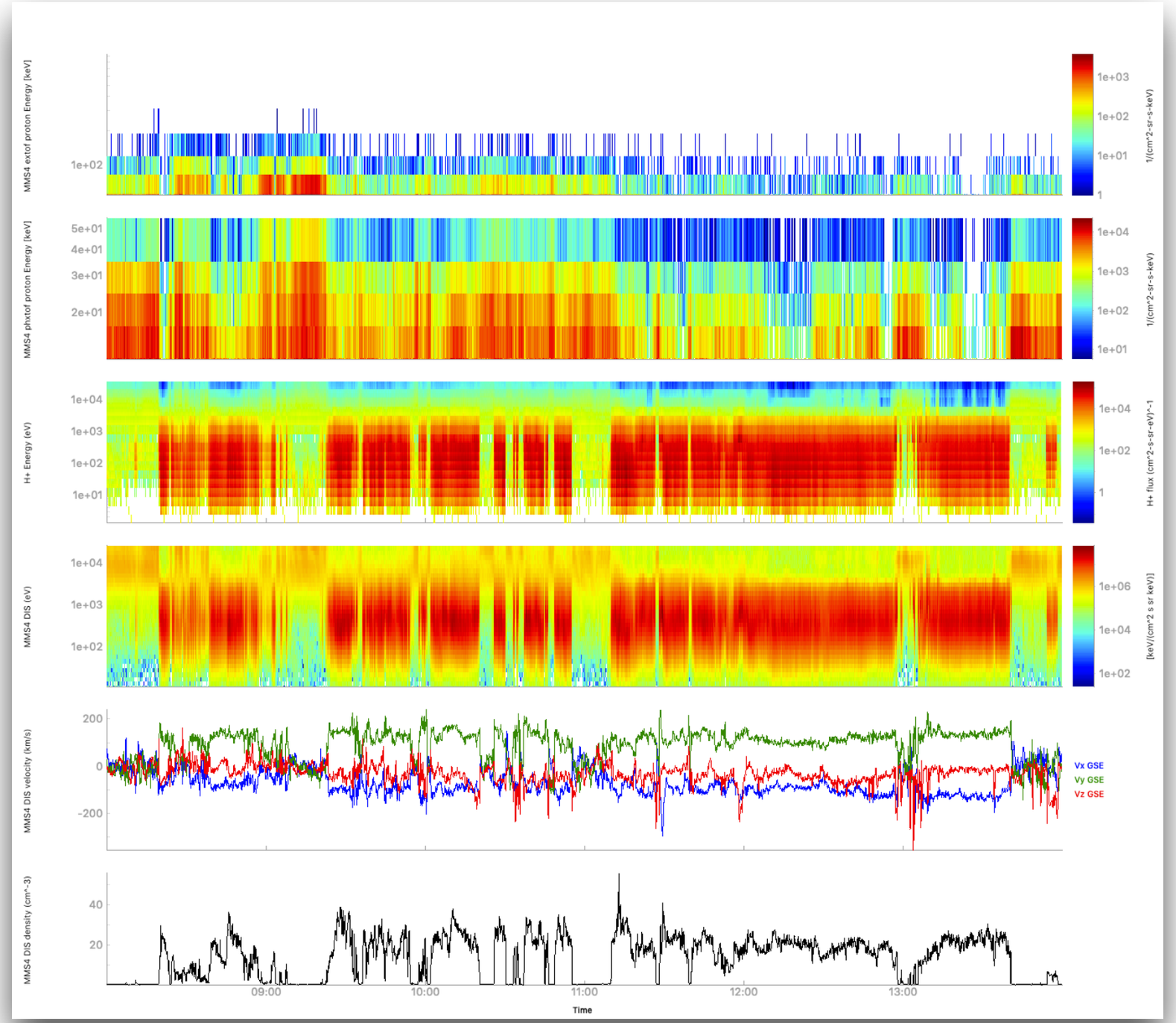
Loading and Plotting Data

Ions

```
from pyspedas.mms import fpi, hpca, eis

eis(datatype=['extof', 'phxtof'], probe=4, trange=trange, time_clip=True)
fpi(center_measurement=True, datatype='dis-moms', probe=4, trange=trange, time_clip=True)
hpca(center_measurement=True, datatype='ion', probe=4, trange=trange, time_clip=True)

from pyspedas import mms_hpca_calc_anodes, mms_hpca_spin_sum

mms_hpca_calc_anodes(fov=[0, 360])
mms_hpca_spin_sum(probe='4', avg=True)

tplot(['mms4_epd_eis_extof_proton_flux_omni',
  'mms4_epd_eis_phxtof_proton_flux_omni',
  'mms4_hpca_hplus_flux_elev_0-360_spin',
  'mms4_dis_energyspectr_omni_fast',
  'mms4_dis_bulkv_gse_fast',
  'mms4_dis_numberdensity_fast'])
```

Loading and Plotting Data

Ions



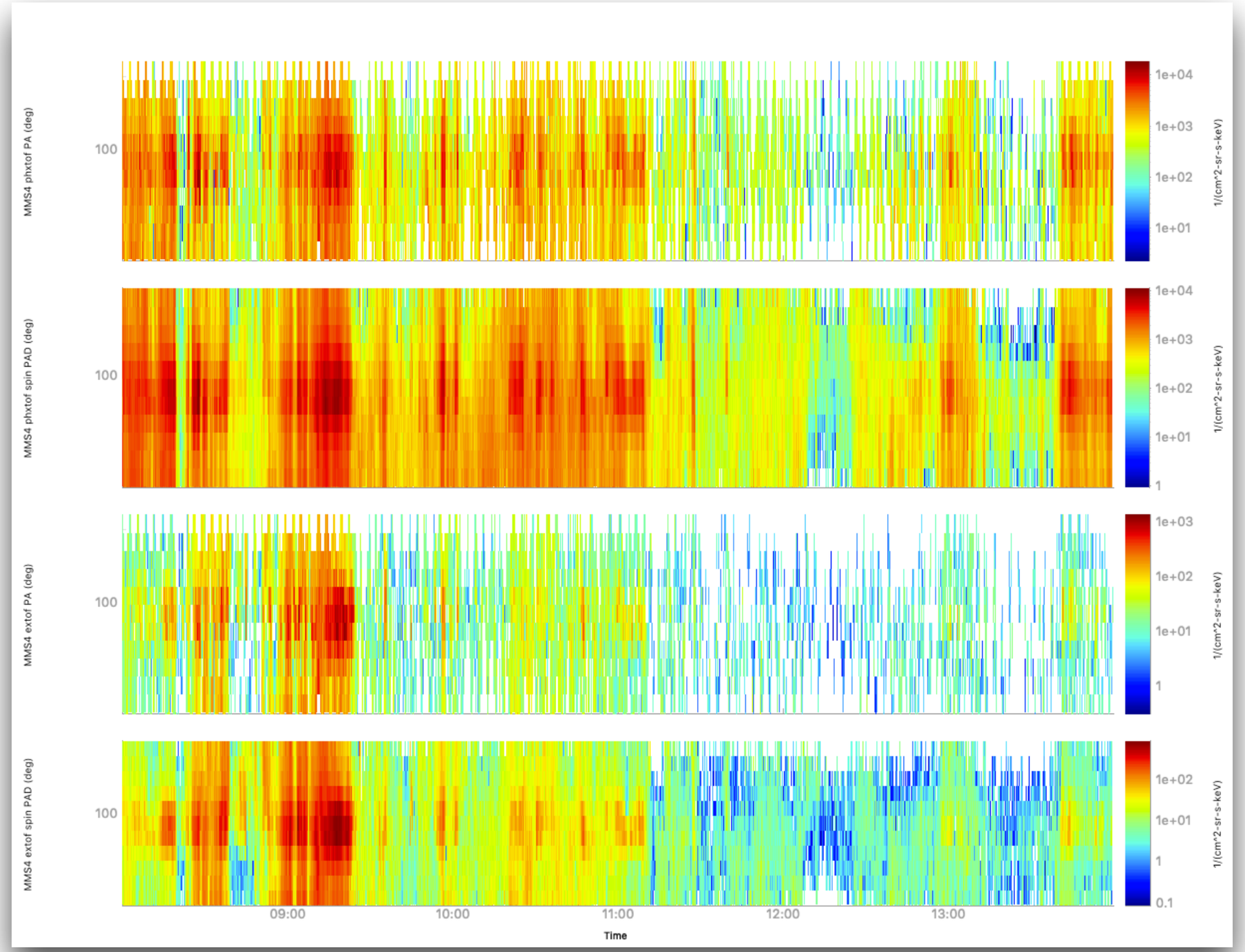
Loading and Plotting Data

Ion pitch angle distributions

```
from pyspedas import mms_eis_pad

mms_eis_pad(energy=[20, 60], datatype='phxtof', probe=4)
mms_eis_pad(energy=[56, 550], datatype='extof', probe=4)

tplot(['mms4_epd_eis_phxtof_24-56keV_proton_flux_omni_pad',
       'mms4_epd_eis_phxtof_24-56keV_proton_flux_omni_pad_spin',
       'mms4_epd_eis_extof_80-524keV_proton_flux_omni_pad',
       'mms4_epd_eis_extof_80-524keV_proton_flux_omni_pad_spin'])
```

Loading and Plotting Data

Ion pitch angle distributions



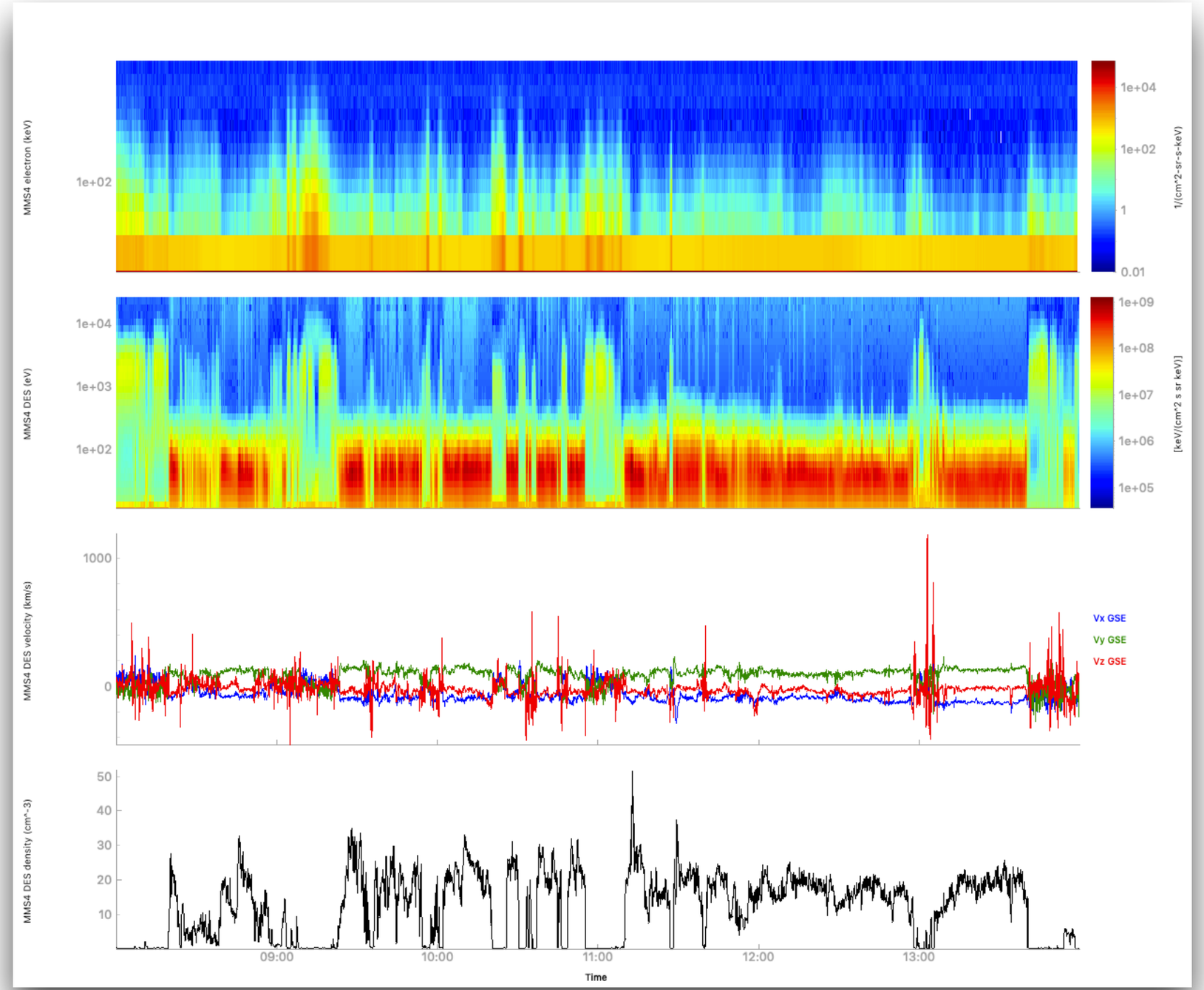
Loading and Plotting Data

Electrons

```
from pyspedas.mms import fpi, feeps

trange = ['2015-10-16/8:00', '2015-10-16/14:00']

fpi(datatype='des-moms', probe=4, trange=trange, time_clip=True, center_measurement=True)
feeps(datatype='electron', probe=4, trange=trange, time_clip=True)


tplot(['mms4_epd_feeps_srvy_l2_electron_intensity_omni_spin',
  'mms4_des_energyspectr_omni_fast',
  'mms4_des_bulkv_gse_fast',
  'mms4_des_numberdensity_fast'])
```

Loading and Plotting Data

Electrons



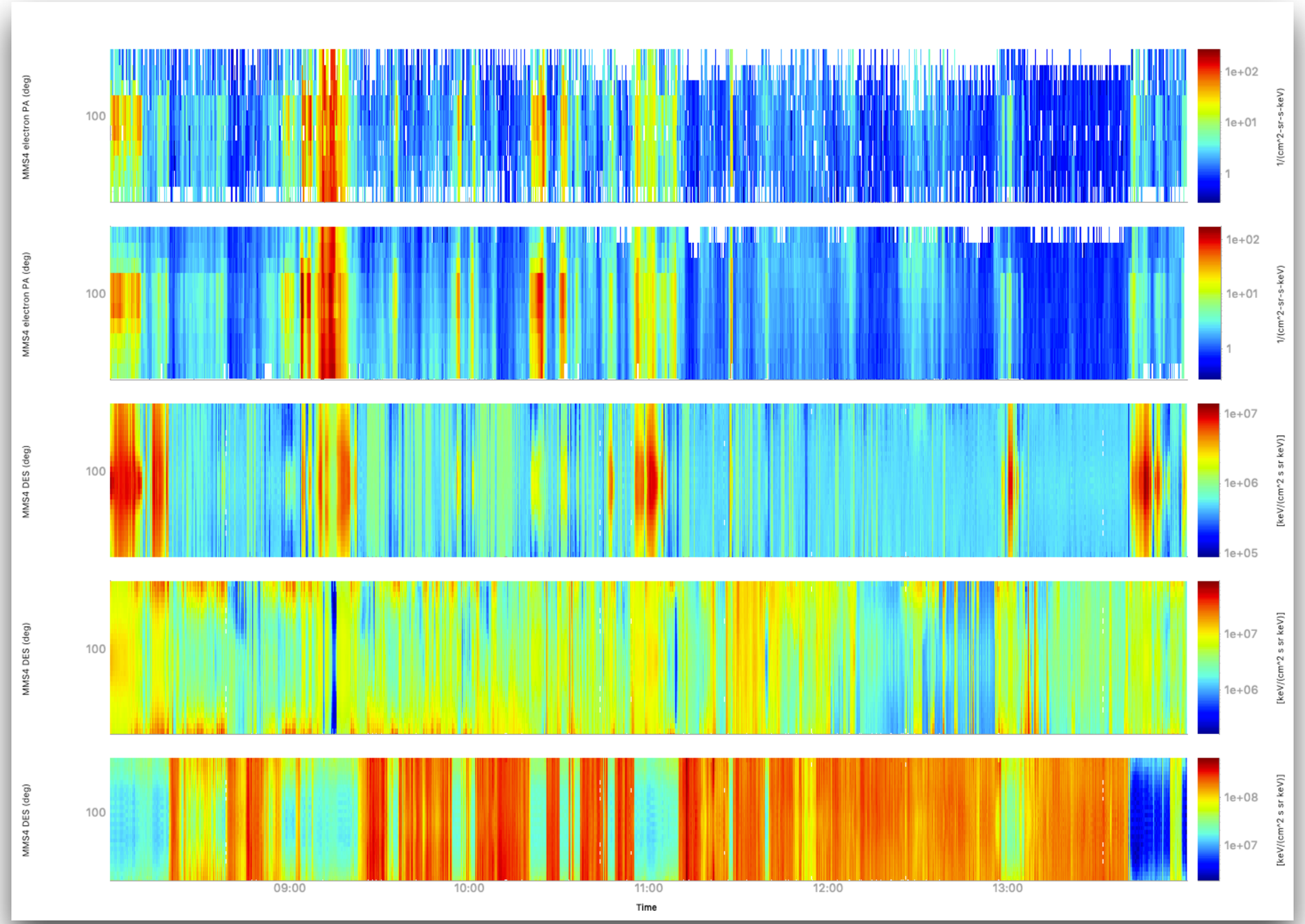
Loading and Plotting Data

Electron pitch angle distributions

```
from pyspedas import mms_feeps_pad

mms_feeps_pad(energy=[70, 600], datatype='electron', probe=4)

tplot(['mms4_epd_feeps_srvy_l2_electron_intensity_70-600keV_pad',
       'mms4_epd_feeps_srvy_l2_electron_intensity_70-600keV_pad_spin',
       'mms4_des_pitchangdist_highen_fast',
       'mms4_des_pitchangdist_miden_fast',
       'mms4_des_pitchangdist_lowen_fast'])
```

Loading and Plotting Data

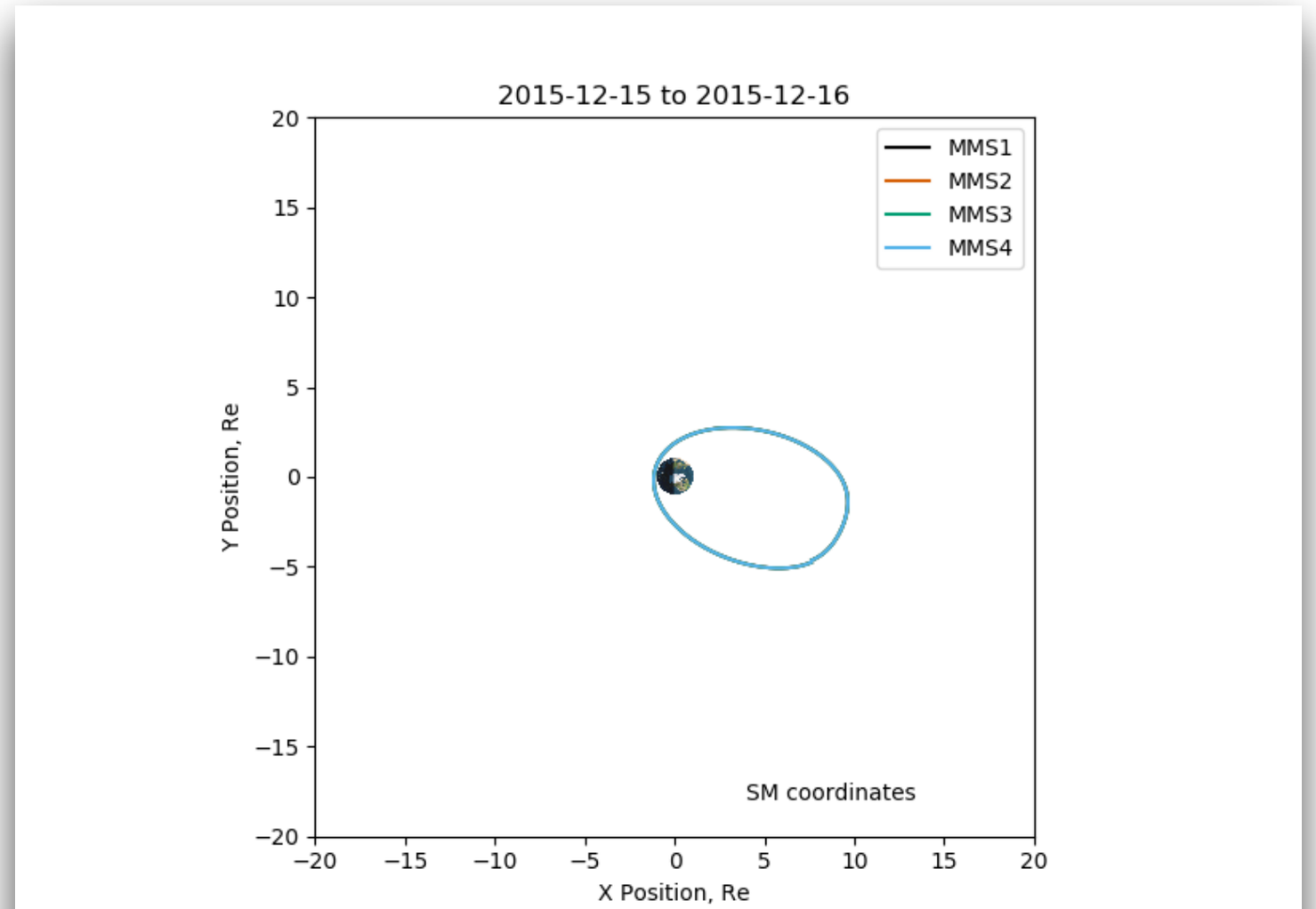
Electron pitch angle distributions



Loading and Plotting Data

Plotting Orbits

```
from pyspedas.mms.mms_orbit_plot import mms_orbit_plot

mms_orbit_plot(coord='sm', probes=[1, 2, 3, 4], trange=['2015-12-15', '2015-12-16'], xr=[-20, 20], yr=[-20, 20])
```



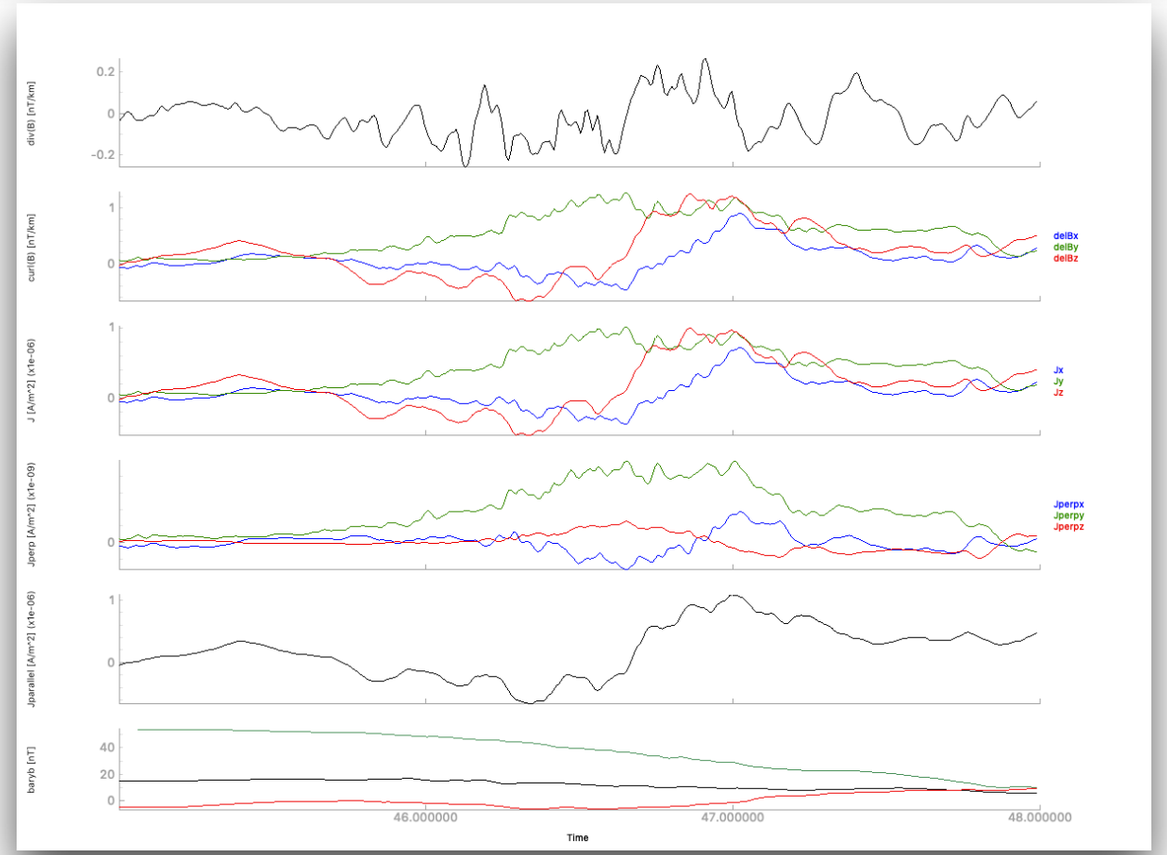
Analysis Tools

pyspedas.mms.curlometer	Curlometer technique
tdpwrspc	SCM dynamic power spectra

Analysis Tools

Curlometer technique

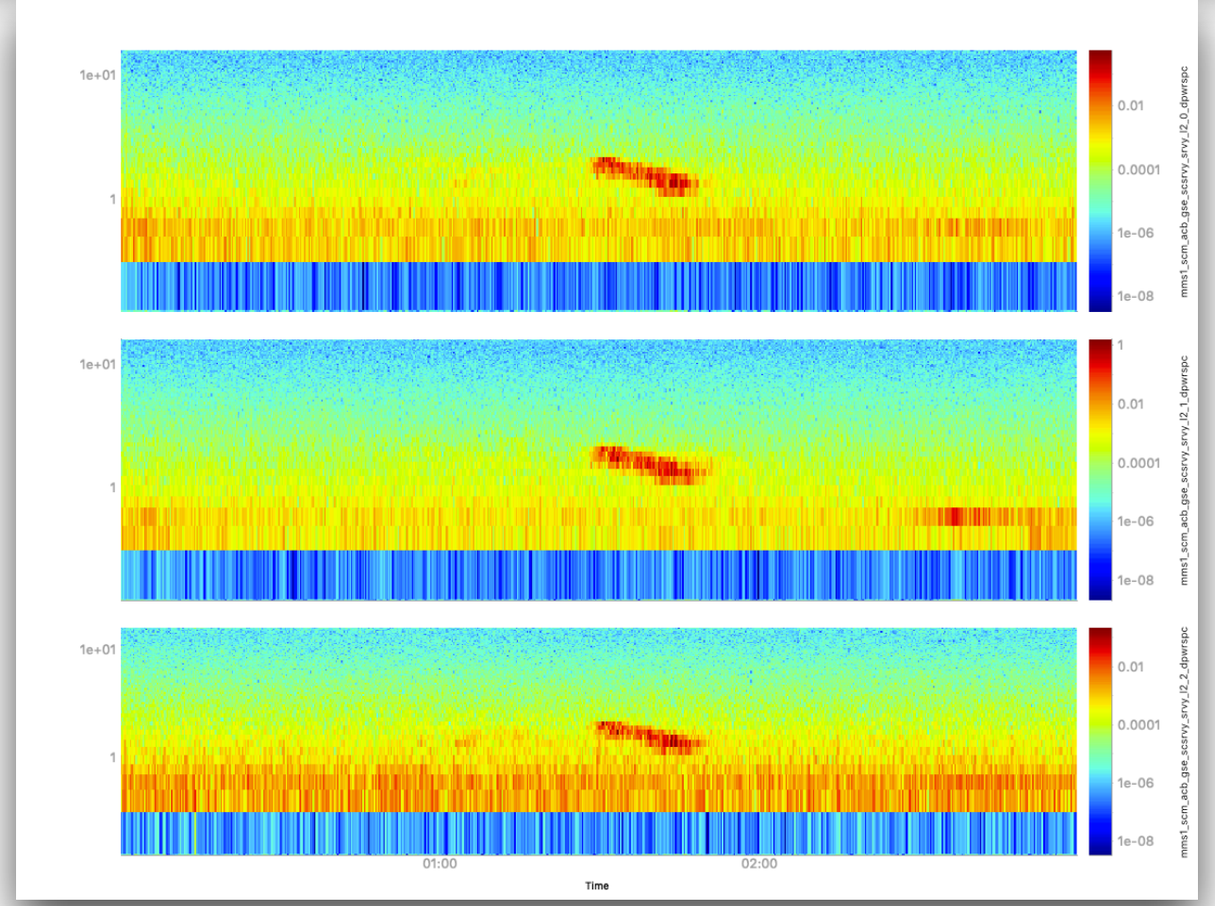
```
from pyspedas.mms import fgm, curlometer

trange = ['2015-10-30/05:15:45', '2015-10-30/05:15:48']

fgm_vars = fgm(trange=trange, probe=[1, 2, 3, 4], data_rate='brst', time_clip=True)

fields = ['mms1_fgm_b_gse_brst_l2', 'mms2_fgm_b_gse_brst_l2', 'mms3_fgm_b_gse_brst_l2', 'mms4_fgm_b_gse_brst_l2']
positions = ['mms1_fgm_r_gse_brst_l2', 'mms2_fgm_r_gse_brst_l2', 'mms3_fgm_r_gse_brst_l2', 'mms4_fgm_r_gse_brst_l2']

curl_vars = curlometer(fields=fields, positions=positions)

tplot(['divB','curlB','jtotal','jperp','jpar','baryb'])
```



Analysis Tools

SCM dynamic power spectra

```
from pyspedas.mms import scm

scm_vars = scm(trange=['2015-10-16', '2015-10-16/03:00'], time_clip=True)

from pyspedas import tdpwrspc

ps = tdpwrspc('mms1_scm_acb_gse_scsrvy_srvy_l2', nshiftpoints=512, nboxpoints=512, binsize=1)

tplot(['mms1_scm_acb_gse_scsrvy_srvy_l2_0_dpwrspc',
       'mms1_scm_acb_gse_scsrvy_srvy_l2_1_dpwrspc',
       'mms1_scm_acb_gse_scsrvy_srvy_l2_2_dpwrspc'])
```



Analysis Tools

More Examples

https://github.com/spedas/mms-examples

Backup slides

Loading and Plotting Data

Find available files

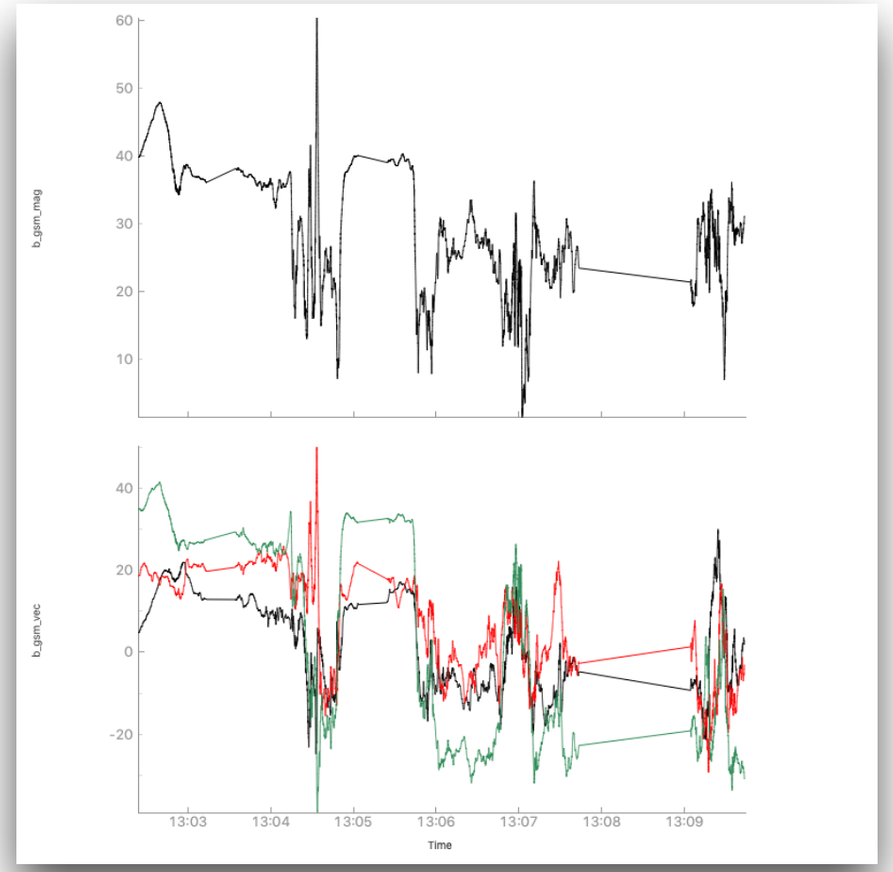
```
tr = ['2015-10-16/13:00', '2015-10-16/13:10']
files = mms_load_fpi(probe='4', data_rate='brst', datatype='dis-moms', trange=tr, available=True)
```

```
25-Jun-19 14:20:19: mms4_fpi_brst_l2_dis-moms_20151016125604_v3.3.0.cdf (1.3 MB)
25-Jun-19 14:20:19: mms4_fpi_brst_l2_dis-moms_20151016130224_v3.3.0.cdf (0.5 MB)
25-Jun-19 14:20:19: mms4_fpi_brst_l2_dis-moms_20151016130334_v3.3.0.cdf (0.8 MB)
25-Jun-19 14:20:19: mms4_fpi_brst_l2_dis-moms_20151016130524_v3.3.0.cdf (1.3 MB)
25-Jun-19 14:20:19: mms4_fpi_brst_l2_dis-moms_20151016130904_v3.3.0.cdf (0.4 MB)
>>>
>>> files[0]
'mms4_fpi_brst_l2_dis-moms_20151016125604_v3.3.0.cdf'
>>>
```

Loading and Plotting Data

Create pyTplot Variables

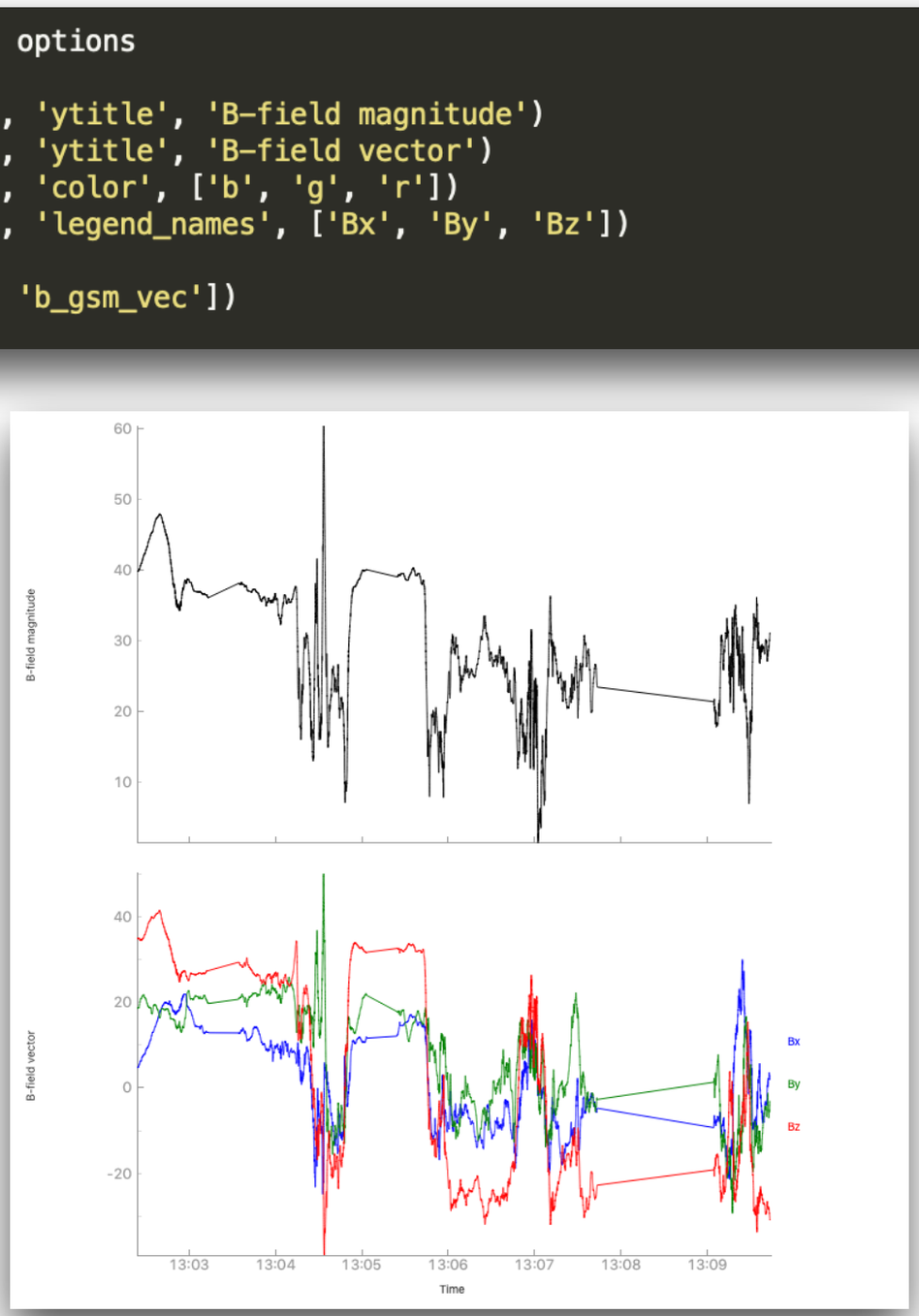
```
mms_load_fgm(probe='1', data_rate='brst', trange=tr, time_clip=True)

times, data = get_data('mms1_fgm_b_gsm_brst_l2')

store_data('b_gsm_vec', data={'x': times, 'y': data[:, 0:3]})

store_data('b_gsm_mag', data={'x': times, 'y': data[:, 3]})

tplot(['b_gsm_mag', 'b_gsm_vec'])
```



Loading and Plotting Data

Modify Variable Metadata

```
from pytplot import options

options('b_gsm_mag', 'ytitle', 'B-field magnitude')
options('b_gsm_vec', 'ytitle', 'B-field vector')
options('b_gsm_vec', 'color', ['b', 'g', 'r'])
options('b_gsm_vec', 'legend_names', ['Bx', 'By', 'Bz'])

tplot(['b_gsm_mag', 'b_gsm_vec'])
```



Loading and Plotting Data

Modify Variable Metadata

```
Help on function options in module pytplot.options:

options(name, option, value)
    This function allows the user to set a large variety of options for individual plots.

    Parameters:
        name : str
            Name of the tplot variable
        option : str
            The name of the option.  See section below
        value : str/int/float/list
            The value of the option.  See section below.

    Options:
        ================== ==========   =====
        Options            Value type   Notes
        ================== ==========   =====
        Color              str/list     Red, Orange, Yellow, Green, Blue, etc.
        Colormap           str/list     https://matplotlib.org/examples/color/colormaps_reference.html.
        Spec               int          1 sets the Tplot Variable to spectrogram mode, 0 reverts.
        Alt                int          1 sets the Tplot Variable to altitude plot mode, 0 reverts.
        Map                int          1 sets the Tplot Variable to latitude/longitude mode, 0 reverts.
        link               list         Allows a user to reference one tplot variable to another.
        ylog               int          1 sets the y axis to log scale, 0 reverts.
        zlog               int          1 sets the z axis to log scale, 0 reverts (spectrograms only).
        legend_names       list         A list of strings that will be used to identify the lines.
        xlog_interactive   bool         Sets x axis on interactive plot to log scale if True.
        ylog               bool         Set y axis on main plot window to log scale if True.
        ylog_interactive   bool         Sets y axis on interactive plot to log scale if True.
        zlog               bool         Sets z axis on main plot window to log scale if True.
        line_style         str          scatter (to make scatter plots), or solid_line, dot, dash, dash_dot, dash_dot_dot_dot, long_dash.
        char_size          int          Defines character size for plot labels, etc.
        name               str          The title of the plot.
        panel_size         flt          Number between (0,1], representing the percent size of the plot.
        basemap            str          Full path and name of a background image for "Map" plots.
        alpha              flt          Number between [0,1], gives the transparancy of the plot lines.
        thick              flt          Sets plot line width.
        yrange             flt list     Two numbers that give the y axis range of the plot.
        zrange             flt list     Two numbers that give the z axis range of the plot.
        xrange_interactive flt list     Two numberes that give the x axis range of interactive plots.
        yrange_interactive flt list     Two numberes that give the y axis range of interactive plots.
        ytitle             str          Title shown on the y axis.
        ztitle             str          Title shown on the z axis.  Spec plots only.
        plotter            str          Allows a user to implement their own plotting script in place of the ones
                                        herein.
        crosshair_x        str          Title for x-axis crosshair.
        crosshair_y        str          Title for y-axis crosshair.
        crosshair_z        str          Title for z-axis crosshair.
        static             str          Datetime string that gives desired time to plot y and z values from a spec
                                        plot.
        static_tavg        str          Datetime string that gives desired time-averaged y and z values to plot
                                        from a spec plot.
        t_average          int          Seconds around which the cursor is averaged when hovering over spectrogram
                                        plots.
        ================== ==========   =====
    Returns:
        None
```

Loading and Plotting Data

Return the data without creating pyTplot variables

```
tr = ['2015-10-16/13:00', '2015-10-16/13:10']
data = mms_load_fpi(probe='4', data_rate='brst', datatype='dis-moms', trange=tr, notplot=True)
```

```
25-Jun-19 14:26:14: Loading pydata/mms4/fpi/brst/l2/dis-moms/2015/10/16/mms4_fpi_brst_l2_dis-moms_20151016125604_v3.3.0.cdf
25-Jun-19 14:26:14: Loading pydata/mms4/fpi/brst/l2/dis-moms/2015/10/16/mms4_fpi_brst_l2_dis-moms_20151016130224_v3.3.0.cdf
25-Jun-19 14:26:14: Loading pydata/mms4/fpi/brst/l2/dis-moms/2015/10/16/mms4_fpi_brst_l2_dis-moms_20151016130334_v3.3.0.cdf
25-Jun-19 14:26:14: Loading pydata/mms4/fpi/brst/l2/dis-moms/2015/10/16/mms4_fpi_brst_l2_dis-moms_20151016130524_v3.3.0.cdf
25-Jun-19 14:26:14: Loading pydata/mms4/fpi/brst/l2/dis-moms/2015/10/16/mms4_fpi_brst_l2_dis-moms_20151016130904_v3.3.0.cdf
>>>
>>> data.keys()
dict_keys(['mms4_dis_errorflags_brst', 'mms4_dis_compressionloss_brst', 'mms4_dis_startdelphi_count_brst', 'mms4_dis_startdelphi_angle_brst', 'mms4_dis_sector_despinp_brst', 'mms4_dis_energyspectr_px_brst', 'mms4_dis_energyspectr_mx_brst', 'mms4_dis_energyspectr_py_brst', 'mms4_dis_energyspectr_my_brst', 'mms4_dis_energyspectr_pz_brst', 'mms4_dis_energyspectr_mz_brst', 'mms4_dis_energyspectr_omni_brst', 'mms4_dis_spectr_bg_brst', 'mms4_dis_numberdensity_bg_brst', 'mms4_dis_numberdensity_brst', 'mms4_dis_densityextrapolation_low_brst', 'mms4_dis_densityextrapolation_high_brst', 'mms4_dis_bulkv_dbcs_brst', 'mms4_dis_bulkv_spintone_dbcs_brst', 'mms4_dis_bulkv_gse_brst', 'mms4_dis_bulkv_spintone_gse_brst', 'mms4_dis_prestensor_dbcs_brst', 'mms4_dis_prestensor_gse_brst', 'mms4_dis_pres_bg_brst', 'mms4_dis_temptensor_dbcs_brst', 'mms4_dis_temptensor_gse_brst', 'mms4_dis_heatq_dbcs_brst', 'mms4_dis_heatq_gse_brst', 'mms4_dis_temppara_brst', 'mms4_dis_tempperp_brst'])
>>>
>>> data['mms4_dis_energyspectr_omni_brst'].keys()
dict_keys(['x', 'y', 'v'])
>>>
>>> data['mms4_dis_energyspectr_omni_brst']['x']
array([1.44500016e+09, 1.44500016e+09, 1.44500016e+09, ...,
       1.44500098e+09, 1.44500098e+09, 1.44500098e+09])
>>>
>>> data['mms4_dis_energyspectr_omni_brst']['v']
array([[1.206000e+01, 1.549000e+01, 1.989000e+01, ..., 1.715373e+04,
        2.203368e+04, 2.830189e+04],
       [1.064000e+01, 1.366000e+01, 1.755000e+01, ..., 1.513542e+04,
        1.944119e+04, 2.497188e+04],
       [1.206000e+01, 1.549000e+01, 1.989000e+01, ..., 1.715373e+04,
        2.203368e+04, 2.830189e+04],
       ...,
       [1.064000e+01, 1.366000e+01, 1.755000e+01, ..., 1.513542e+04,
        1.944119e+04, 2.497188e+04],
       [1.206000e+01, 1.549000e+01, 1.989000e+01, ..., 1.715373e+04,
        2.203368e+04, 2.830189e+04],
       [1.064000e+01, 1.366000e+01, 1.755000e+01, ..., 1.513542e+04,
        1.944119e+04, 2.497188e+04]], dtype=float32)
>>>
```

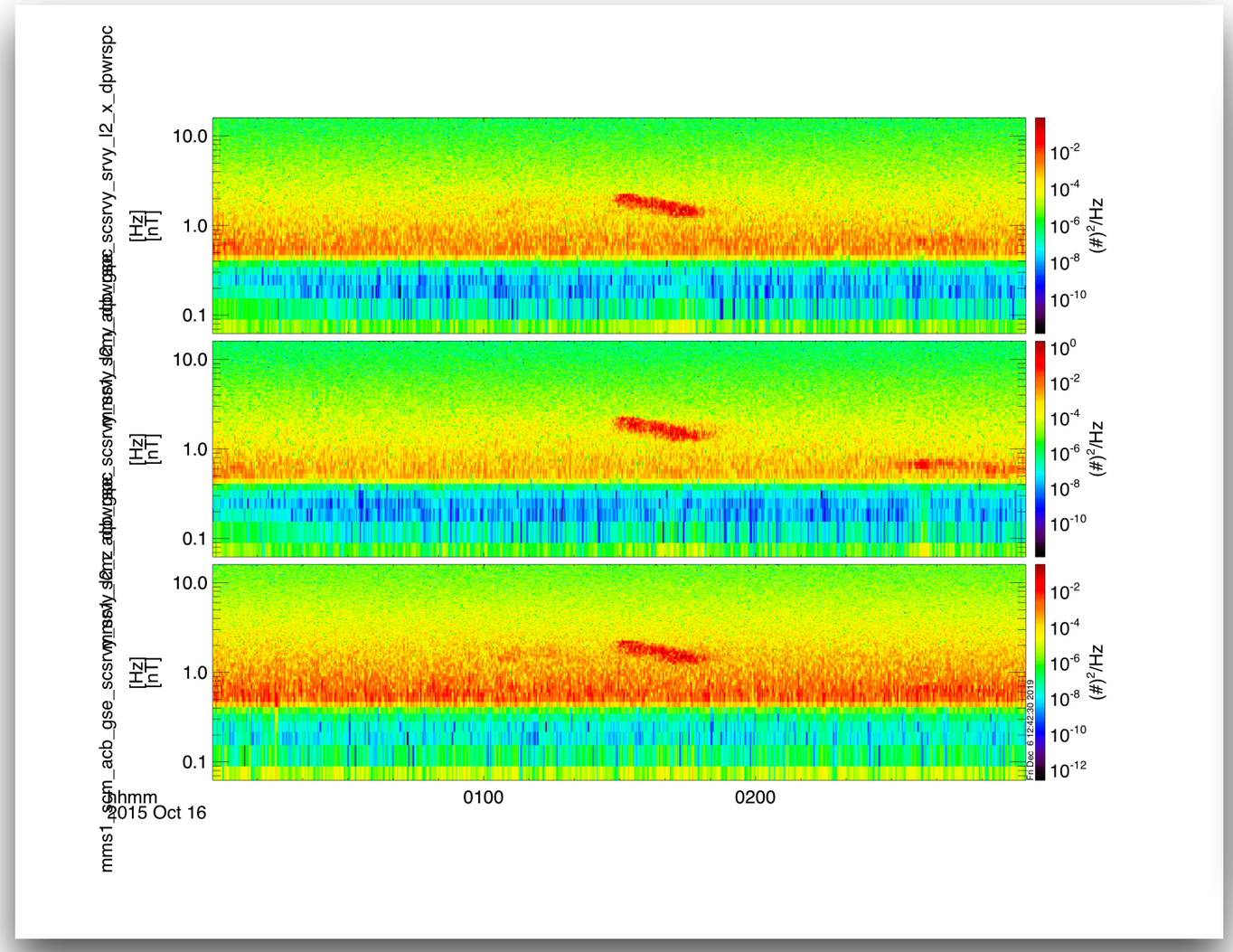
Loading and Plotting Data

Time Conversions

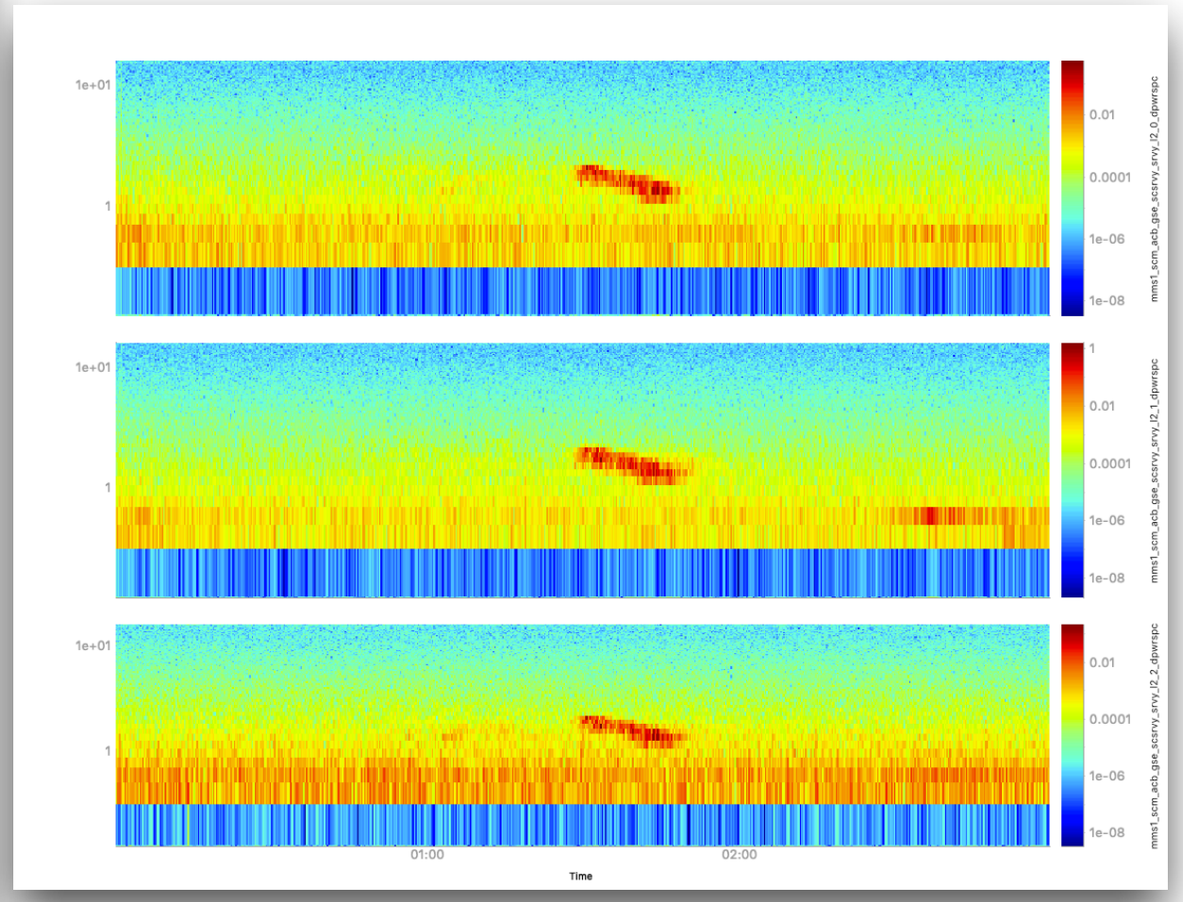
```
from pyspedas import time_string, time_double

print(time_string(1445000544.86188))

print(time_double('2015-10-16 13:02:24.861880'))
```

```
>>> times[0]
1445000544.86188
>>>
>>> from pyspedas import time_string, time_double
>>>
>>> print(time_string(1445000544.86188))
2015-10-16 13:02:24.861880
>>>
>>> print(time_double('2015-10-16 13:02:24.861880'))
1445000544.86188
```

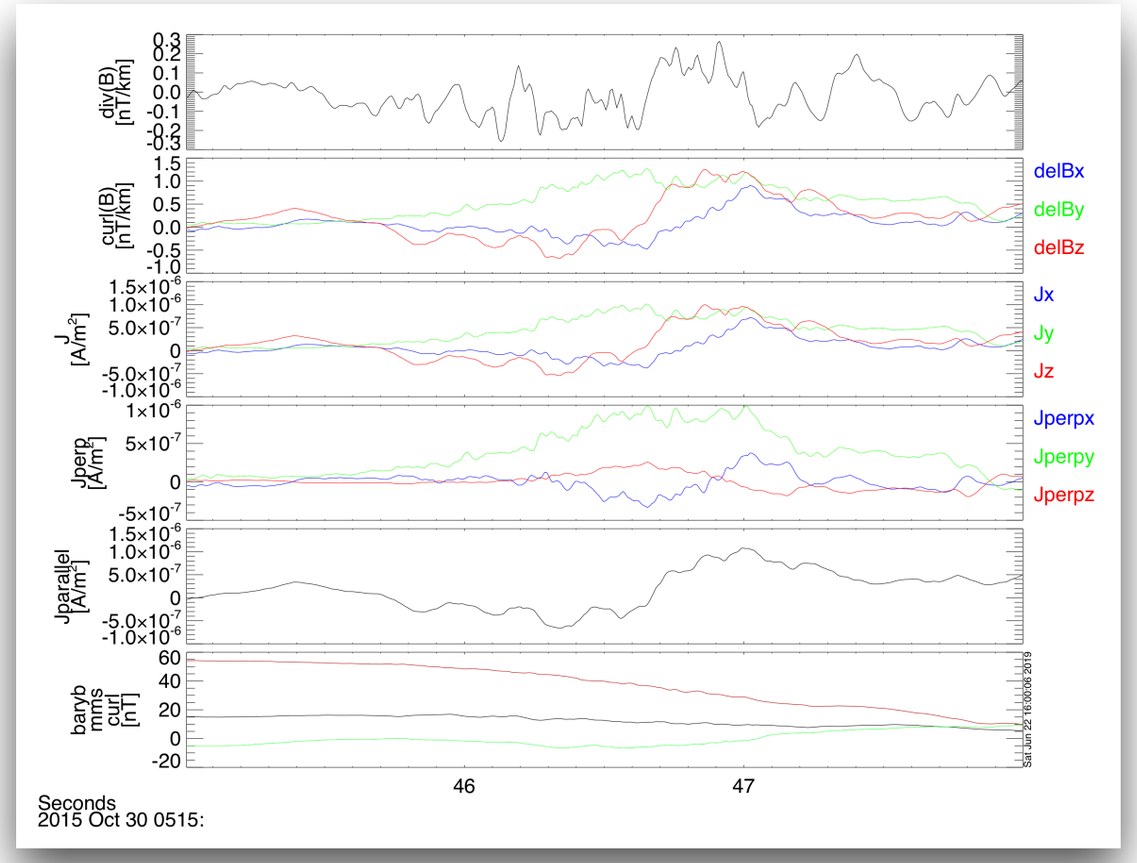
IDL


mms1_scm_acb_gse_scsrvy_srvy_l2_x_dpwrspc
[Hz]
[nT]
10.0
1.0
0.1
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
$(\#)^2$/Hz
10^{0}
10^{-12}
Fri Dec 6 12:42:30 2019
hhmm
2015 Oct 16
0100
0200

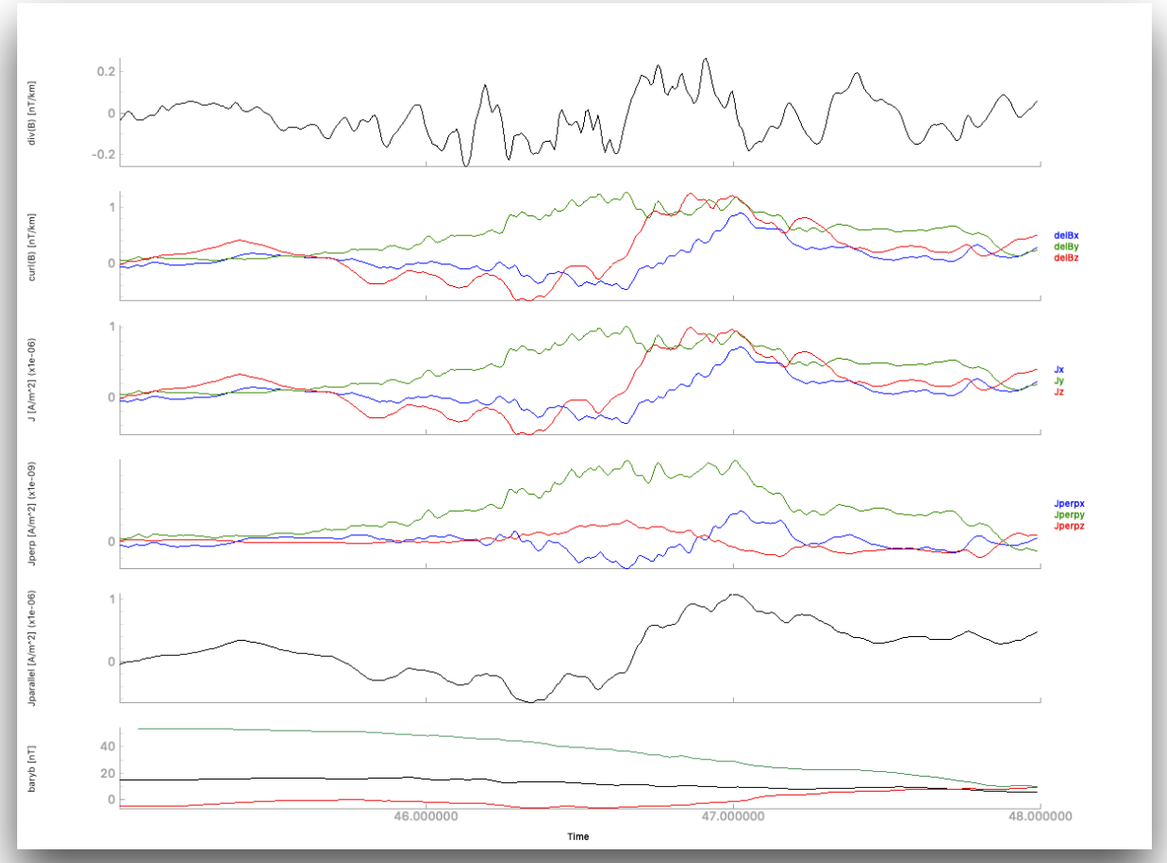
Python


1e+01
1
0.01
0.0001
1e-06
1e-08
mms1_scm_acb_gse_scsrvy_srvy_l2_0_dpwrspc
mms1_scm_acb_gse_scsrvy_srvy_l2_1_dpwrspc
mms1_scm_acb_gse_scsrvy_srvy_l2_2_dpwrspc
01:00
02:00
Time

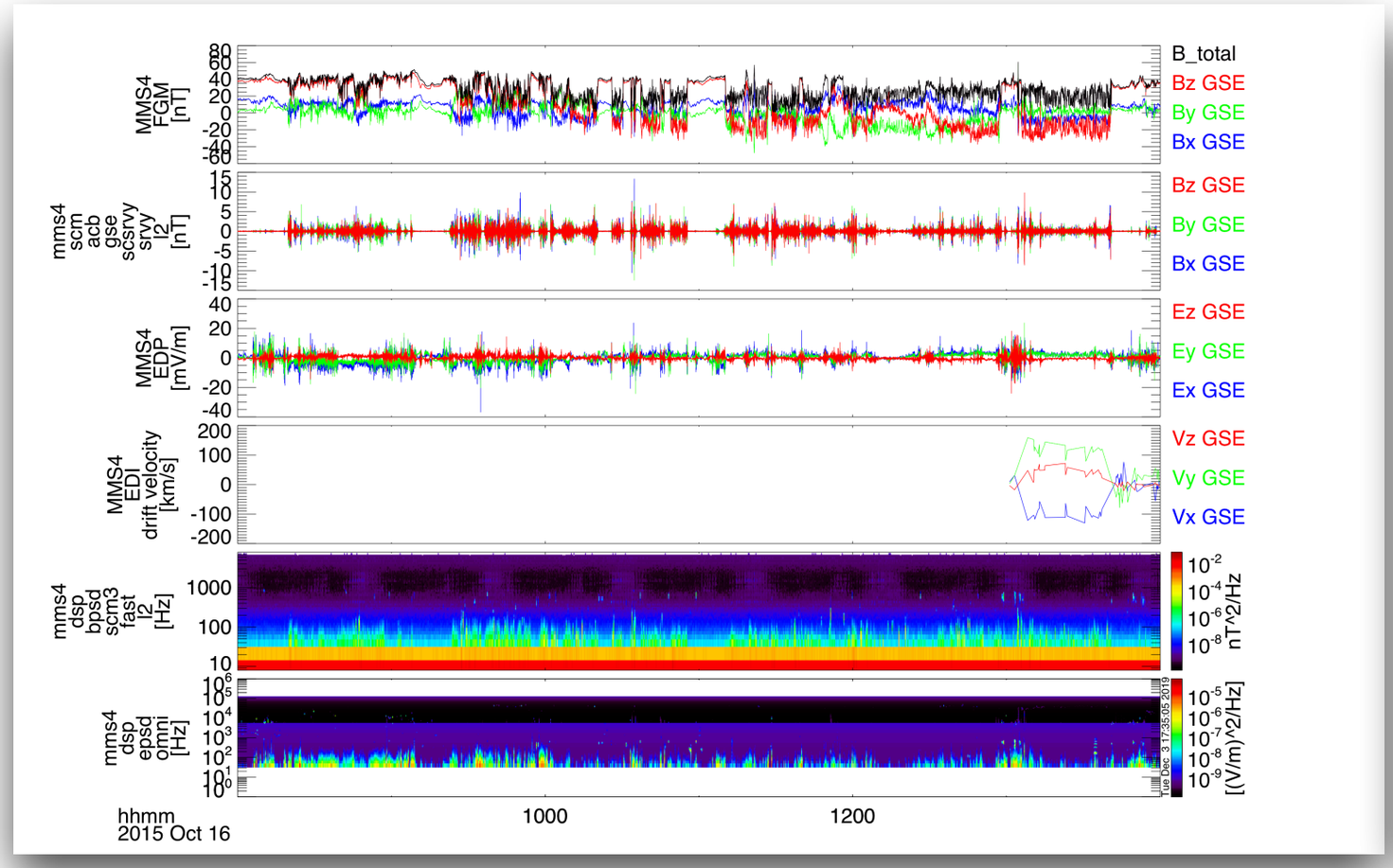
IDL


div(B) [nT/km]
curl(B) [nT/km]
J [A/m^2]
Jperp [A/m^2]
Jparallel [A/m^2]
baryb mms curl [nT]
delBx
delBy
delBz
Jx
Jy
Jz
Jperpx
Jperpy
Jperpz
Sat Jun 22 16:00:06 2019
46
47
Seconds
2015 Oct 30 0515:

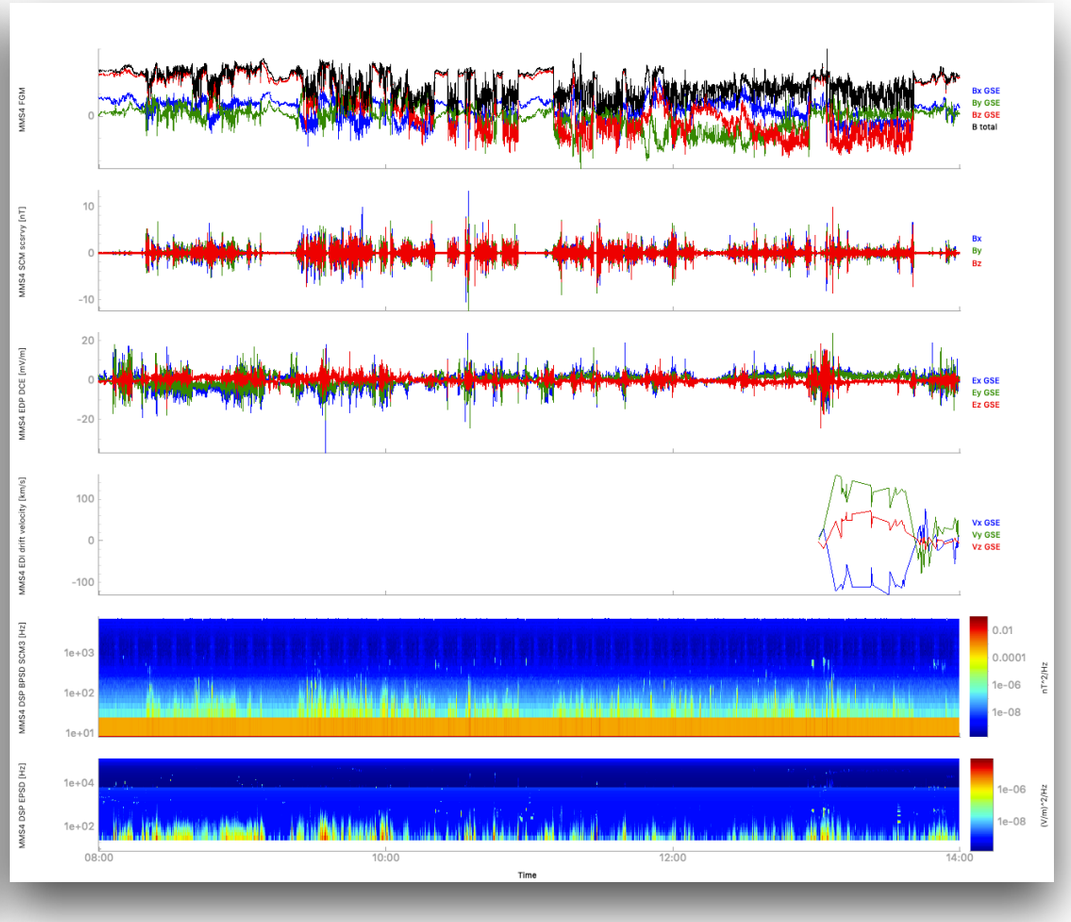
Python


div(B) [nT/km]
curl(B) [nT/km]
J [A/m^2] (x1e-06)
Jperp [A/m^2] (x1e-09)
Jparallel [A/m^2] (x1e-06)
baryb [nT]
delBx
delBy
delBz
Jx
Jy
Jz
Jperpx
Jperpy
Jperpz
46.000000
47.000000
48.000000
Time

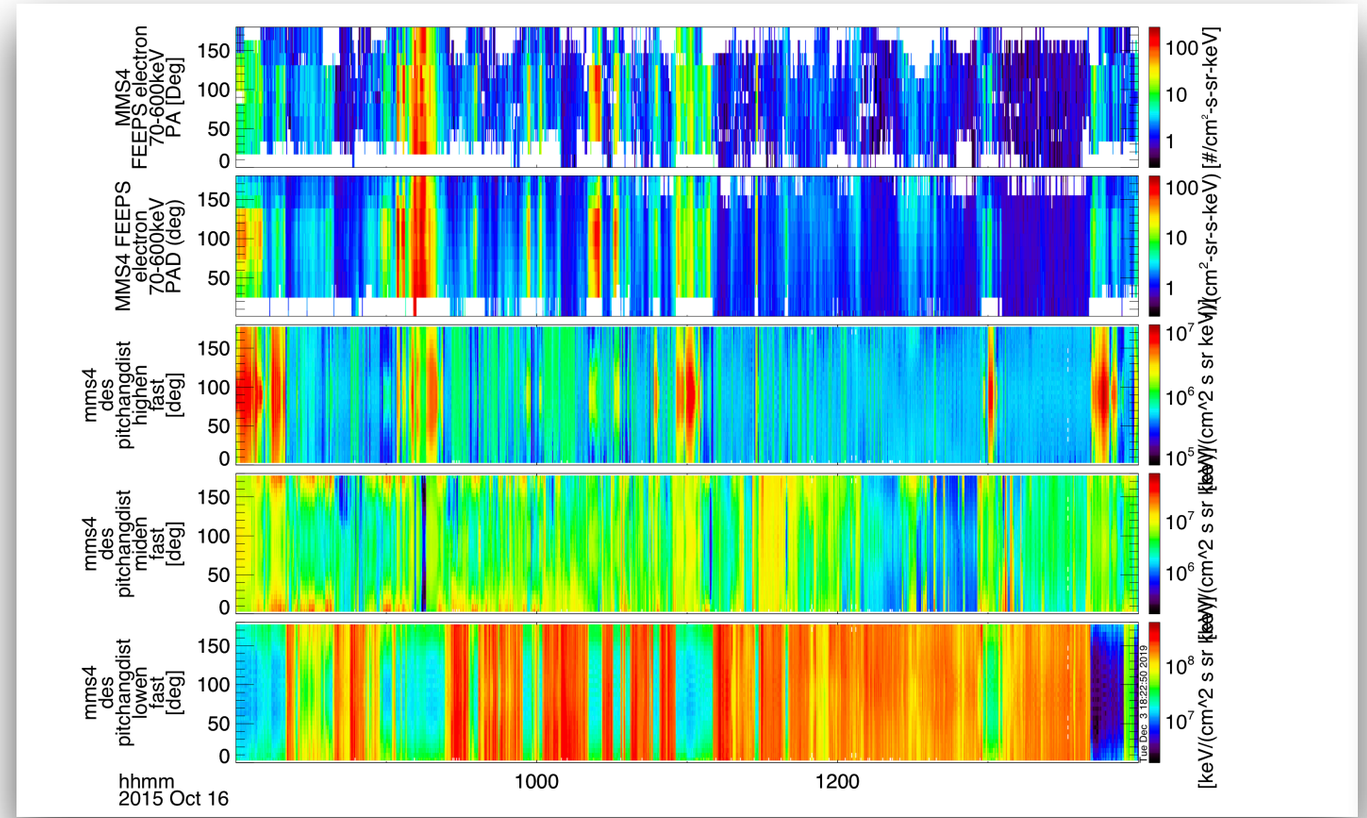
IDL


MMS4 FGM [nT]
B_total
Bz GSE
By GSE
Bx GSE
mms4 scm acb gse scsrvy srvy l2 [nT]
Bz GSE
By GSE
Bx GSE
MMS4 EDP [mV/m]
Ez GSE
Ey GSE
Ex GSE
MMS4 EDI drift velocity [km/s]
Vz GSE
Vy GSE
Vx GSE
mms4 dsp bpsd scm3 fast l2 [Hz]
nT^2/Hz
mms4 dsp epsd omni [Hz]
[(V/m)^2/Hz]
Tue Dec 3 17:35:05 2019
hhmm
2015 Oct 16
1000
1200

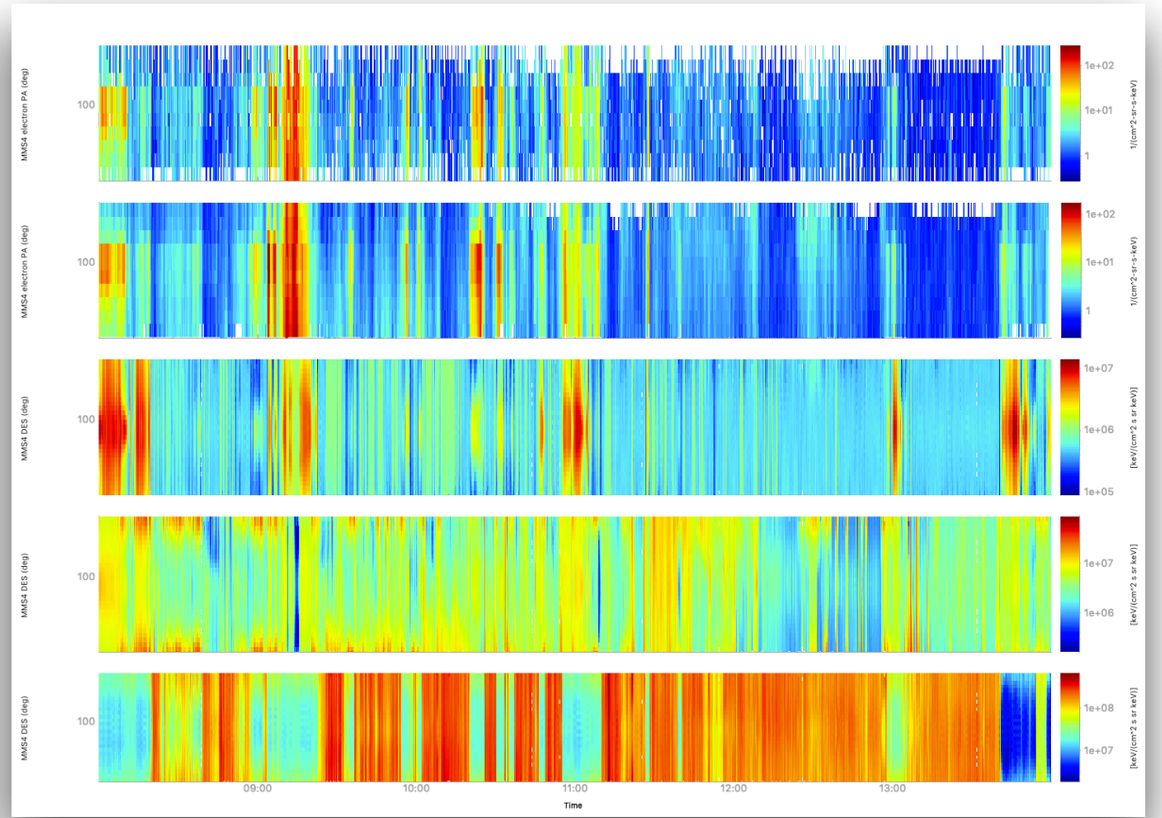
Python


MMS4 FGM
Bx GSE
By GSE
Bz GSE
B total
MMS4 SCM scsrvy [nT]
Bx
By
Bz
MMS4 EDP DCE [mV/m]
Ex GSE
Ey GSE
Ez GSE
MMS4 EDI drift velocity [km/s]
Vx GSE
Vy GSE
Vz GSE
MMS4 DSP BPSD SCM3 [Hz]
nT^2/Hz
MMS4 DSP EPSD [Hz]
(V/m)^2/Hz
08:00
10:00
12:00
14:00
Time

IDL


MMS4 FEEPS electron 70-600keV PA [Deg]
MMS4 FEEPS electron 70-600keV PAD (deg)
mms4 des pitchangdist higher fast [deg]
mms4 des pitchangdist midden fast [deg]
mms4 des pitchangdist lower fast [deg]
[#/cm²-s-sr-keV]
[keV/(cm^2 s sr keV)]
hhmm
2015 Oct 16
1000
1200
Tue Dec 3 18:22:50 2019

Python


MMS4 electron PA (deg)
MMS4 DES (deg)
1/(cm^2-sr-s-keV)
[keV/(cm^2 s sr keV)]
09:00
10:00
11:00
12:00
13:00
Time