



A software library for space science data analysis, modelling and space weather forecasting

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1 – Los Alamos National Laboratory

2 – University of Michigan

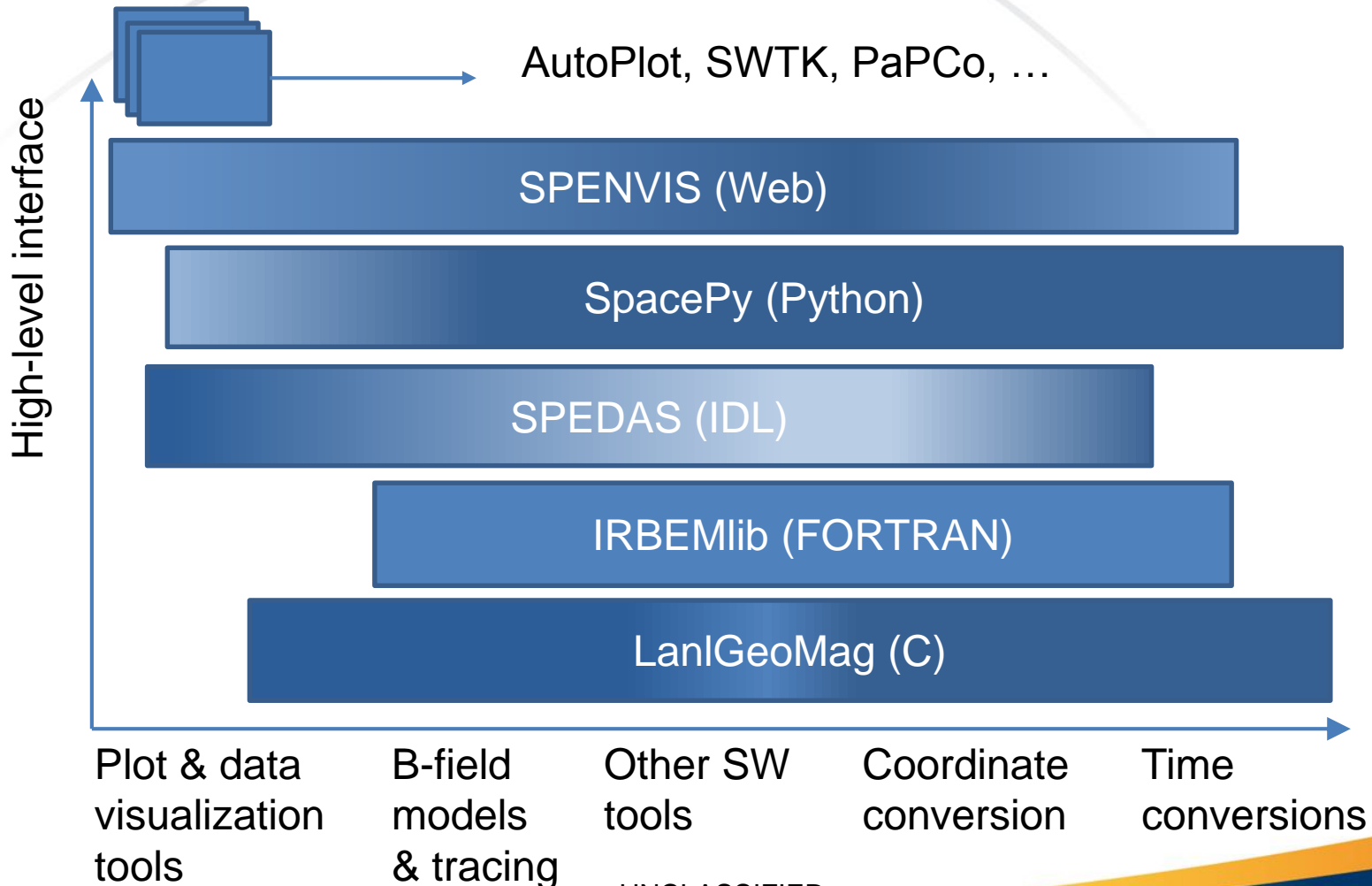
3 – University of New Hampshire

Additional contributions to SpacePy from more people than I have space here...

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Intended Audience

Who is it for?



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Why Open Source?

Rationale for SpacePy

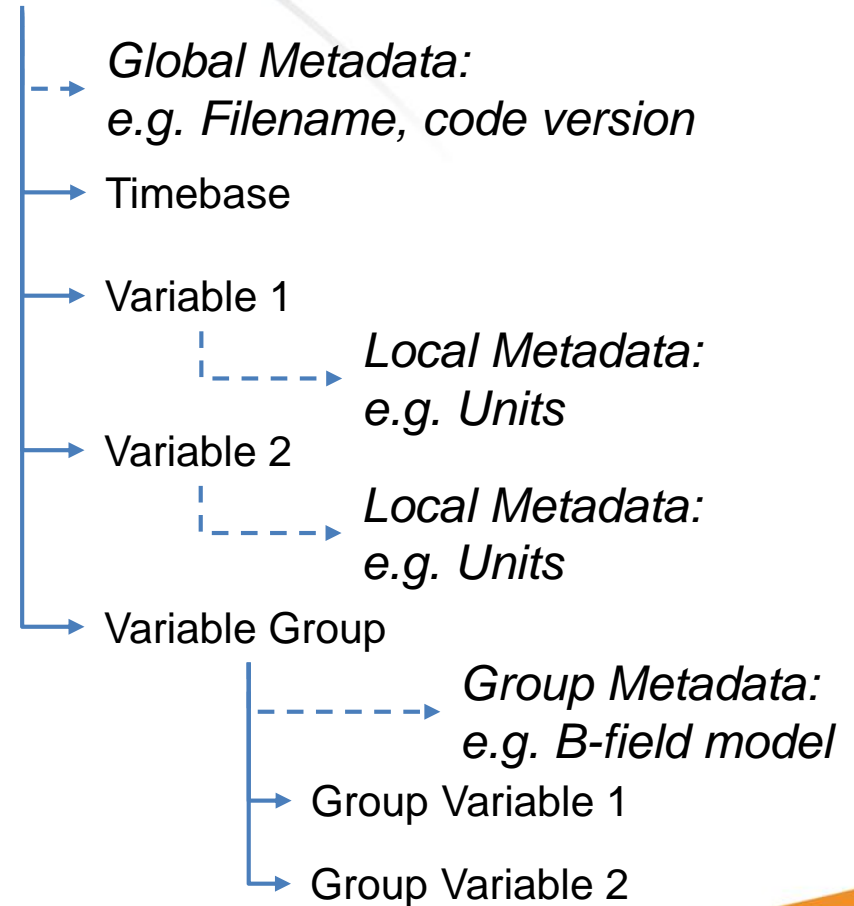
- Free software
 - No licence required
 - Widely used programming language
- Source code available under version control
 - No “black box” routines
 - Bug trackers, feature requests, quick feedback
- Common routines available to whole community
 - Work is reproducible
 - Public unit test framework
- Good for scripted jobs
 - Python has easy multi-processing capabilities

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A Data Model

Similar to HDF5 Model

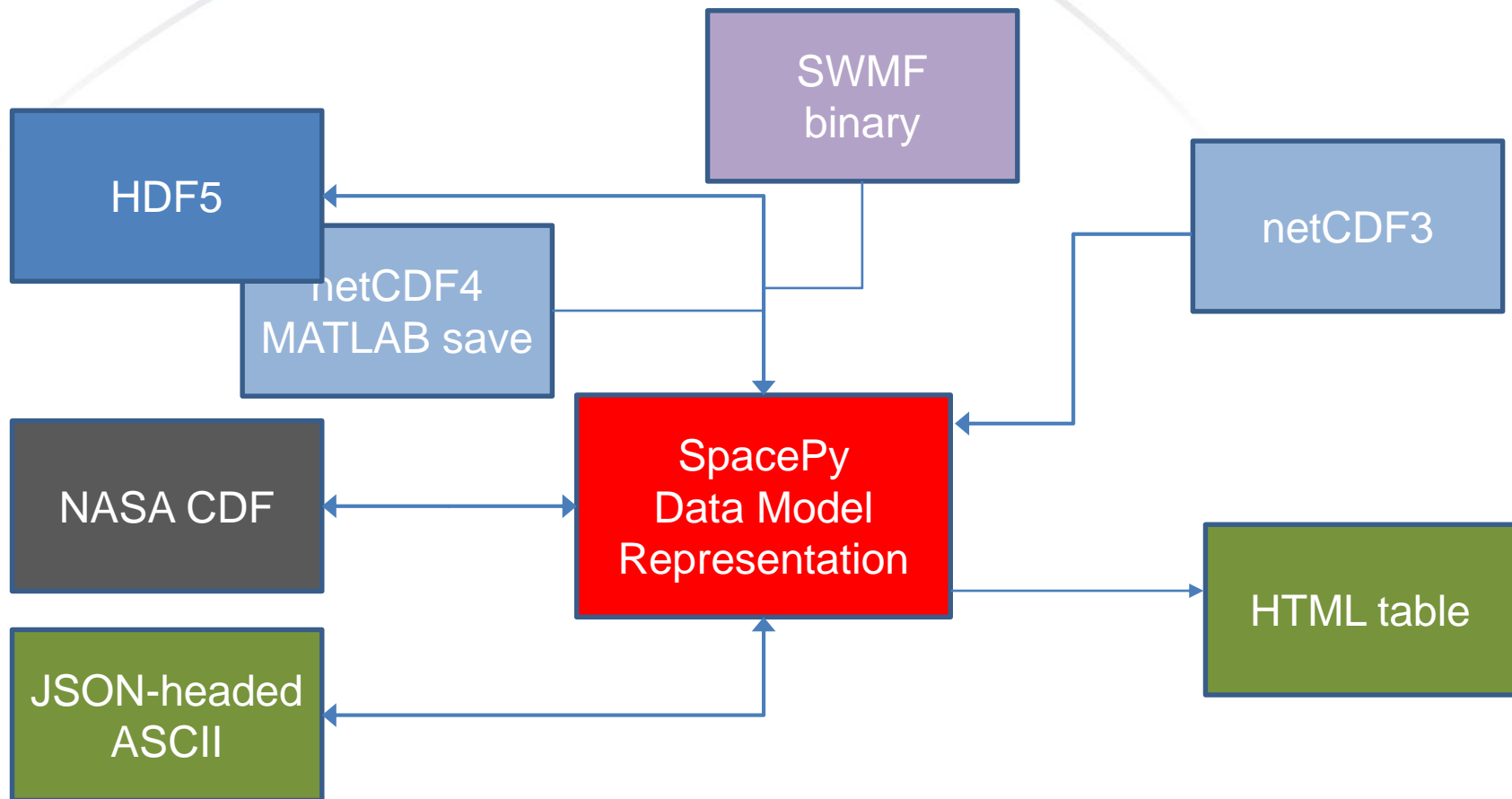
- Two basic datatypes:
 - Group
 - Dataset
- Both have metadata
- Groups can contain groups or datasets
- Datasets are array-like
- Supports many metadata standards



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File Types

Conversion via a common data model



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JSON-headed ASCII

Self-describing ASCII data files



```
# "Pmin_gsm":      { "DESCRIPTION": "Location of minimum-|B| point (in GSM coords).",
#                   "NAME": "Pmin_gsm",
#                   "TITLE": "Minimum-|B| point (in GSM Coordinates)",
#                   "LABEL": "T01S Pmin_gsm [R_E]",
#                   "UNITS": "R_E",
#                   "DIMENSION": [ 3 ],
#                   "START_COLUMN": 100,
#                   "ELEMENT_NAMES": [ "Pmin_gsm_x", "Pmin_gsm_y", "Pmin_gsm_z" ],
#                   ELEMENT_LABELS": [ "T01S Pmin_gsm_x [R_E]", "T01S Pmin_gsm_y
[R_E]", "T01S Pmin_gsm_z, R_E" ],
#                   "FILL_VALUE": -1e31 }
```

JSON-headed ASCII working group:

Jeremy Faden (Autoplot), Steve Morley (SpacePy), Brian Larsen (SpacePy)

Specification at: github.com/JSONheadedASCII

Reader/writer in: `spacepy.datamodel`

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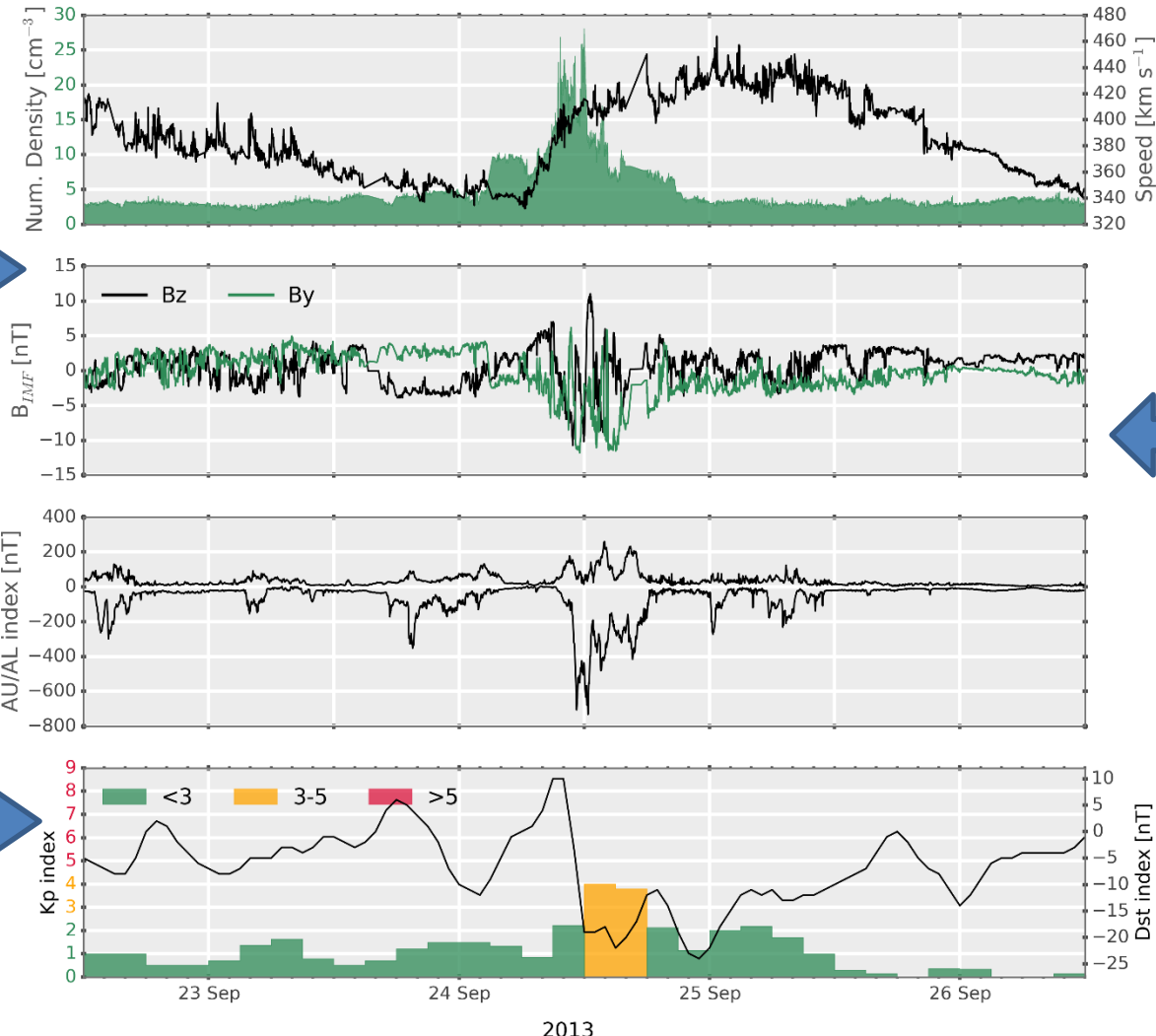


In use: Plot

Solar wind data and indices



plot module provides new plot styles



Solar wind data and indices through omni module

Kyoto WDC data (Dst, Kp, AE) can be retrieved and parsed

“Traffic light” plot routine in plot module

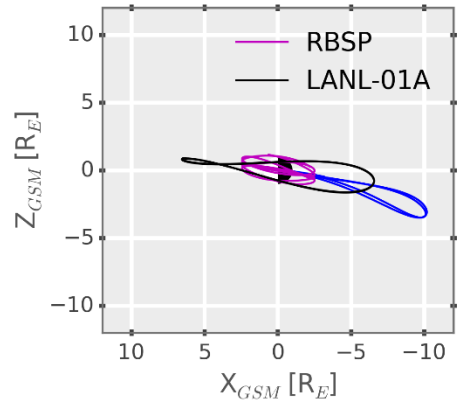
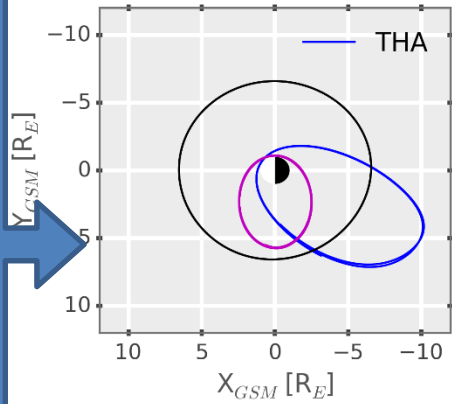
In use: Plot

Satellite data and orbits



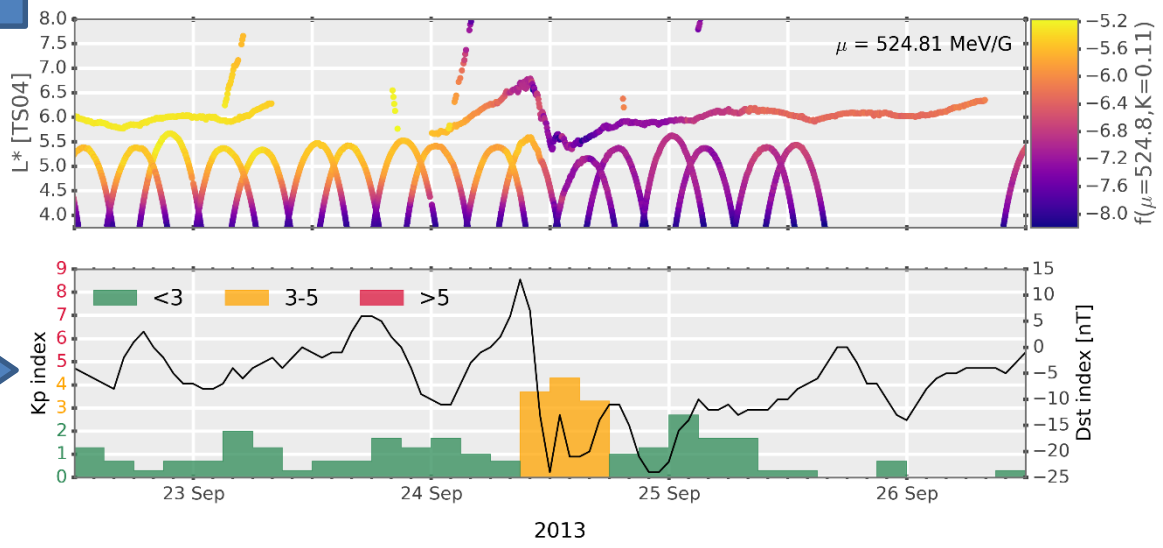
Coordinate conversion in coordinates module

Black/white planet in plot module



Ephemeris and particle data read using `pycdf` and `datamodel` modules

“Traffic light” plot routine in SpacePy `plot` module



plot module provides colour blind-friendly colourmaps (from new matplotlib)



In use: PyBATS

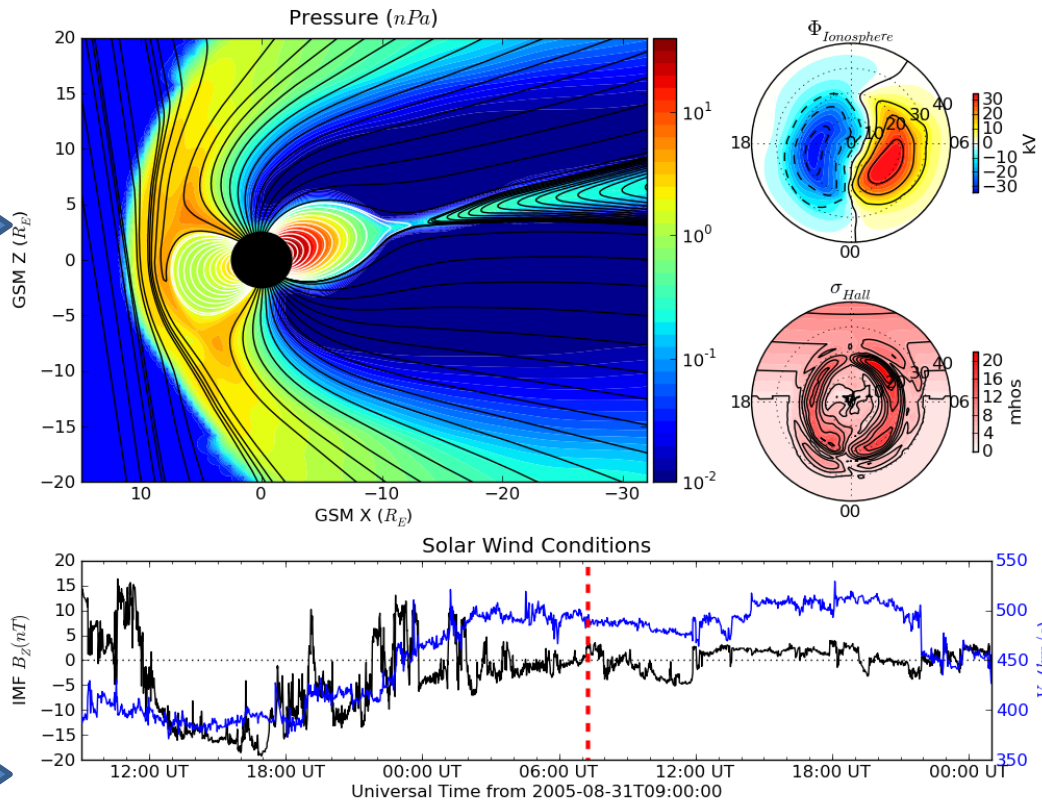


Space Weather Modeling Framework

BATS-R-US
output read
with
pybats

Tracing
done in
pybats

Smart
date/time
labelling
through
SpacePy
plot
module



pybats also
manages
other SWMF
data:
rim
rampy
pwom

Solar wind
data through
SpacePy
omni module

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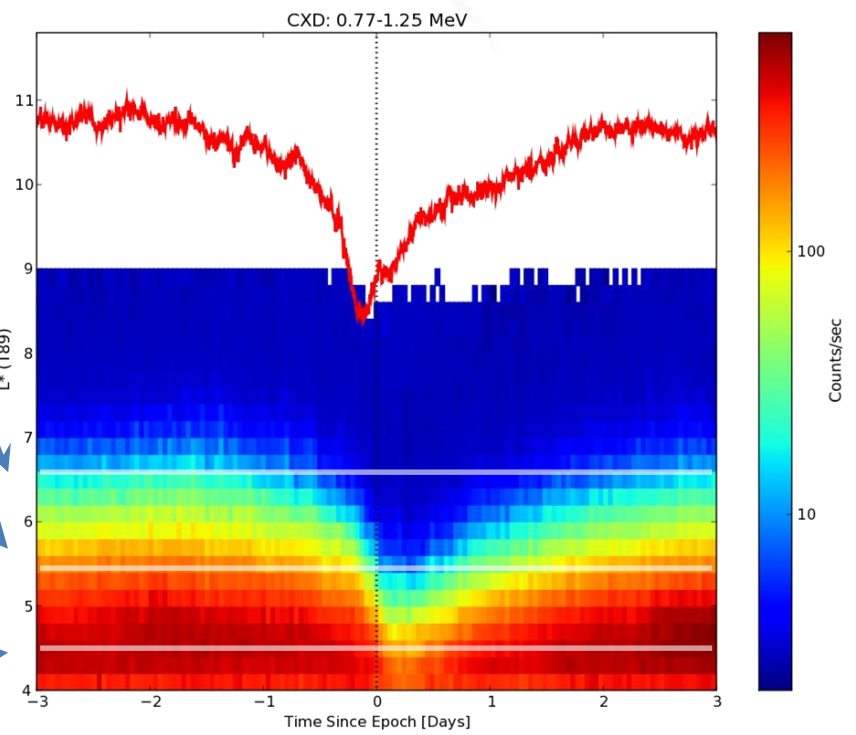
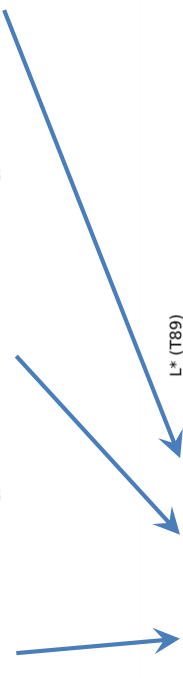
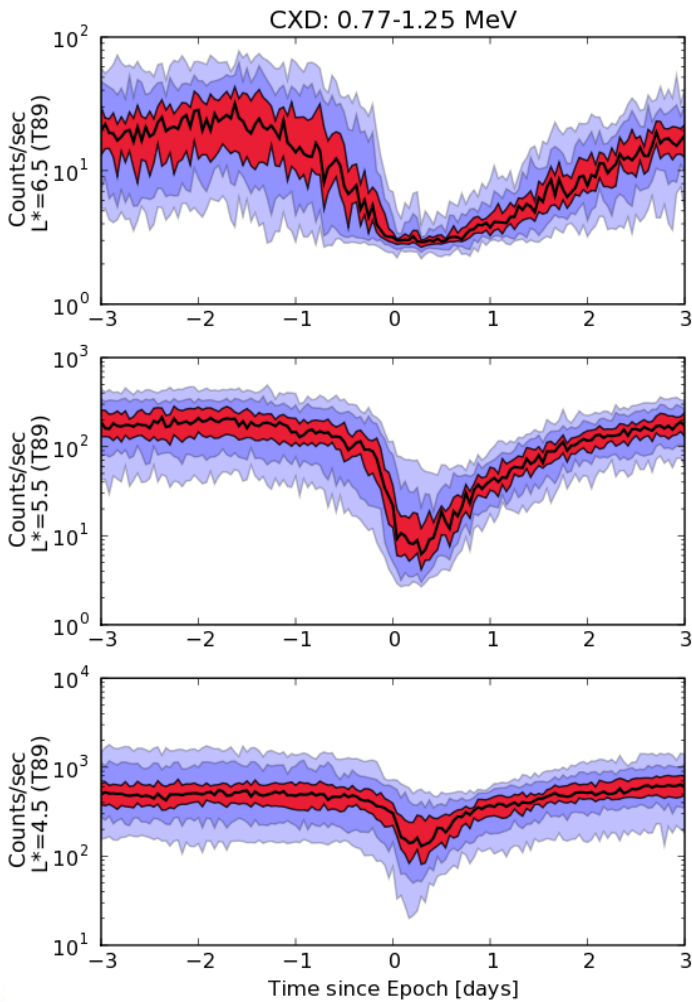


In Use: SeaPy

Analysis of GPS particle data



Morley et al., Proc. Roy. Soc. A, 2010



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In Use: SeaPy

Analysis of GPS particle data

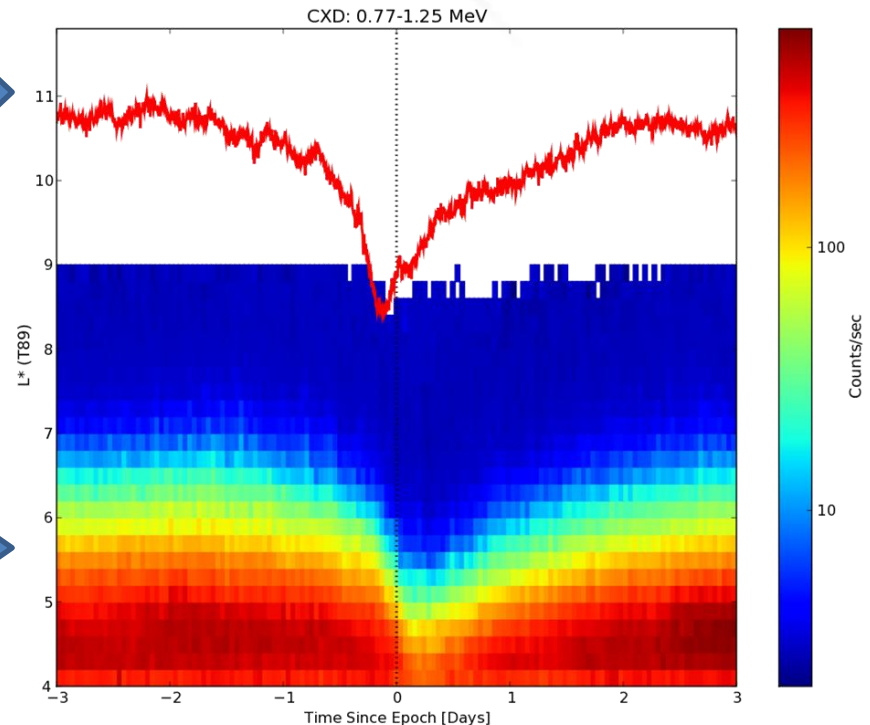


Magnetopause Standoff:

SW data through `omni` module
Shue et al. model in `empiricals` module

L^* calculation:
IRBEM library interface (`irbempy`), or neural net (`lanlstar`)

2-D Superposed Epoch (and 1-D) in `seapy` module

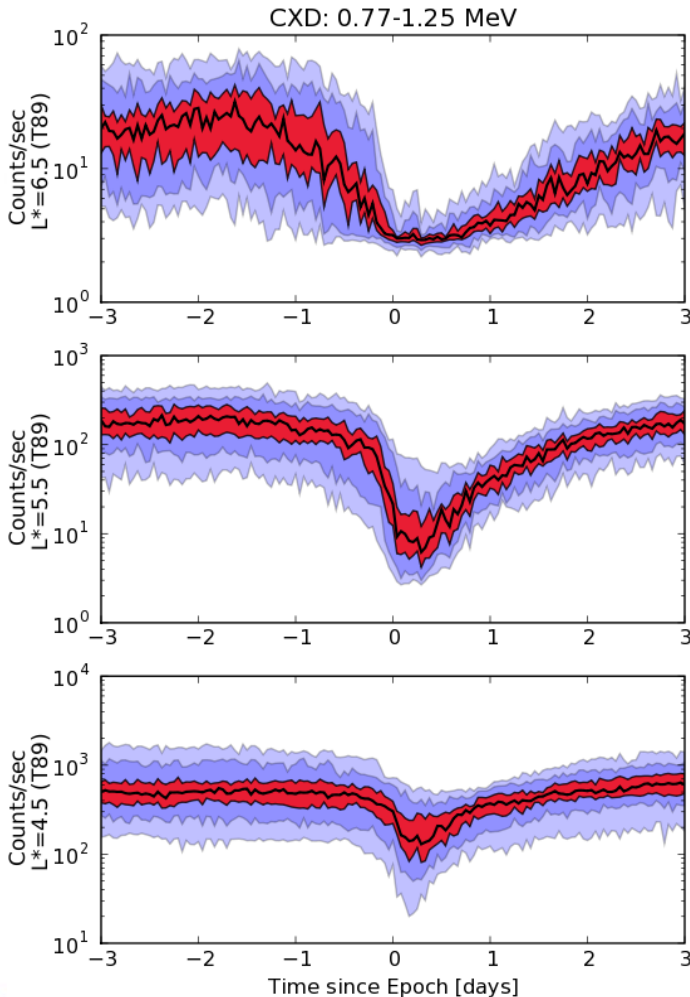


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In Use: SeaPy

Analysis of GPS particle data



1-D Superposed Epoch Analysis in
`seapy` module

Bootstrap confidence intervals
calculated using SpacePy's `poppy`
module

`empiricals` module also provides:

- Pressure-corrected Dst calculation
 - Burton et al. (1975)
 - O'Brien & McPherron (2002)
 - Borovsky and Denton (2010)
- Empirical plasmopause models
 - Carpenter & Anderson (1992)
 - Moldwin et al. (2002)

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Models Included

An Incomplete Selection

SpacePy

- B-field models from IRBEM library
- AE-8/AP-8 (IRBEM)
- Plasmapause
 - Carpenter & Anderson
 - Moldwin et al.
- Magnetopause standoff
- L* neural network
- 1-D RB diffusion model
 - Ensemble Kalman filter

IRBEM

- CDip; IGRF; Jenson & Cain; *Chen & Schulz*
- T87s; T87l; T89c; T96; T02; TSK03; TS04; TS07
- Ostapenko & Maltsev; Alexeev
- Olsen-Pfitzer
 - Static; Dynamic
- Mead-Fairfield

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Tools Included

A Very Incomplete Selection



- Tracing
 - Field lines; Drift shells
- Superposed epoch analysis
 - 1D; 2D
- Bootstrap CI
- Association analysis
- Windowing mean (time based, points based)
- Time & Coordinate conversions
- Quaternion Math
- Full interface to NASA CDF library
- Interface to IRBEM library
 - LANLGeoMag in future versions (hopefully)
- Plot "helper" routines
 - add logo
 - automated time tick formatting
 - rebinning/spectrograms
 - plot styles

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Where to get code and help...

And what's coming next?

- SpacePy (current v0.1.5; new release imminent)
 - We support Linux, Mac and Windows
 - On Mac, Linux we recommend installing from one of our repositories
 - Code repository (git) on SourceForge
sourceforge.net/projects/spacepy
 - Mirrored repository (git) on GitHub
github.com/spacepy/
 - Some Python/SpacePy/PyBATS resources:
www-personal.umich.edu/~dwelling/python/

