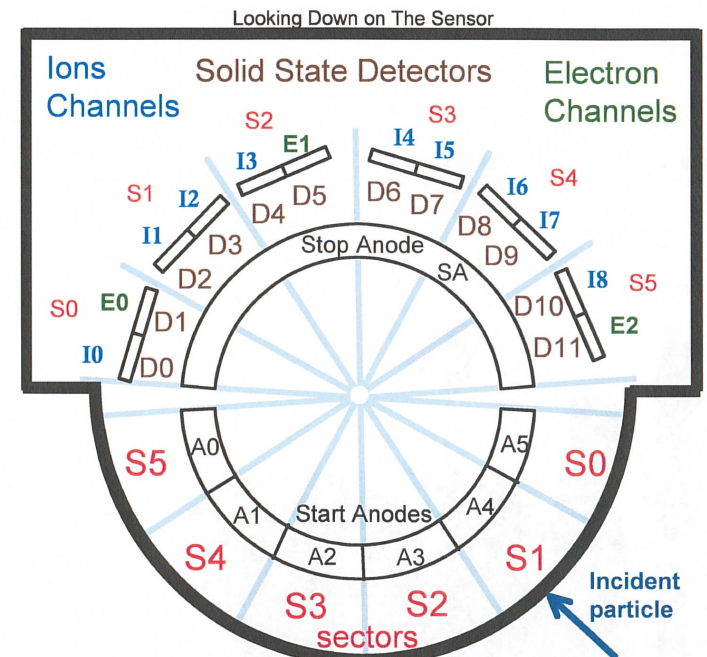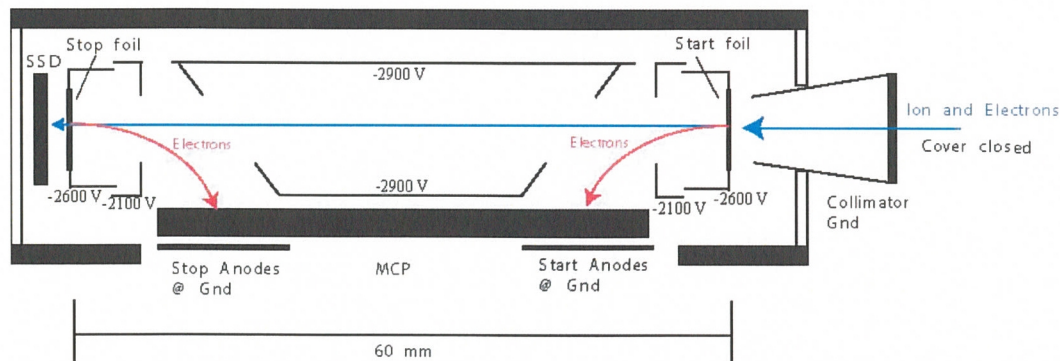# New Horizons
Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)

PRINCIPAL INVESTIGATOR: Ralph McNutt, APL
DESCRIPTION: Medium Energy Particle Spectrometer
ENERGY RANGE: 25-1000 keV (protons)
                          60-1000 keV (atomic ions)
                          25-500 keV (electrons)

FIELD OF VIEW: 160 deg x 12 deg
ANGULAR RESOLUTION: 25 deg x 12 deg
ENERGY RESOLUTION: 0.25 keV
SENSOR SIZE: 7.6 cm dia. x 2.5 cm thick
POWER: 1.4 watt
MASS: 1.5 kg

New Horizons PEPSSI Data Sets

RAW ->

        nh-x-pepssi-2-plutocruise-v2.0
          nh-p-pepssi-2-pluto-v2.0

CALIBRATED ->

        nh-x-pepssi-3-plutocruise-v2.0
          nh-p-pepssi-3-pluto-v2.0

New Horizons PEPSSI Data Set Evaluation Tools

Staging and Evaluation -
    Machine: Dell Precision T3400
    Operating System: Fedora 18 linux

Data Processing -
    Machine: Sun Ultra-350
    Operating System: Sun Solaris OS 5.9

Minor Diagnostics -
    Machine: IBM lenovo T60p ThinkPad
    Operating System: Fedora 25 linux

Documentation Evaluation

All Data Sets in the Top Level Directory aareadme.txt

The Contact Information Lines Shown in the File are:

New Horizons Science Operation Center (SOC):
Joe Peterson
Department of Space Studies

These Should be:

New Horizons Science Operations Center (SOC):
Tiffany Finley
Department of Space Operations

All Data Sets in the Top Level Directory voldesc.txt

The Contact Information Lines Shown in the File are:
```
FULL_NAME          = "JOSEPH PETERSON"
                     DEPARTMENT OF SPACE STUDIES \n
```

These Should be:
```
FULL_NAME          = "Tiffany Finley"
                     Department of Space Operations
```

Also note the extra "\n" characters in the ADDRESS_TEXT line mentioned above and elsewhere in this file. This may be an indication that the termination characters may not be correct. These should be checked in all files as these characters are unseen by the reviewer.

All Data Sets in the catalog Directory nh.cat

This data file is an outdated version. Additional errors have been corrected. Replace this nh.cat file with the version found under SWAPdelta/nh-p-swap-3-pluto-v2.0/catalog

All Data Sets in the catalog Directory nhsc.cat

This data file is an outdated version. Additional errors have been corrected. Replace this nh.cat file with the version found under SWAPdelta/nh-p-swap-3-pluto-v2.0/catalog

For dataset.cat the catalog Directory of nh-p-pepssi-2-pluto-v2.0 and nh-p-pepssi-3-pluto-v2.0
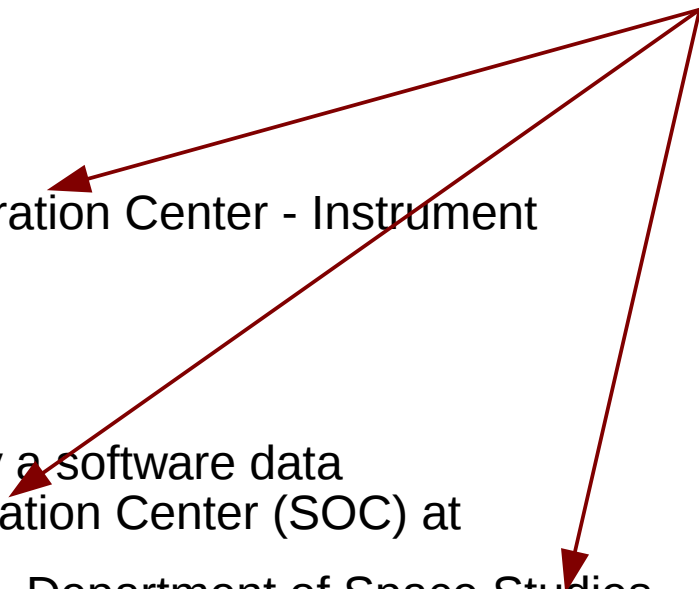
Please update this text:

Operations

files, to the documentation (Science Operation Center - Instrument

Processing
==========

The data in this data set were created by a software data
processing pipeline on the Science Operation Center (SOC) at

the Southwest Research Institute (SwRI), Department of Space Studies.

All Data Sets in the document Directory docinfo.txt

Please remove duplicate line of text:

```
+->NH_MISSION_TRAJECTORY.LBL   Label for mission trajectory;
 |                     please read the label for more detail
 |                     please read the label for more detail
```

All Data Sets in the document Directory aareadme_bu.txt

The Contact Information Lines Shown in the File are:

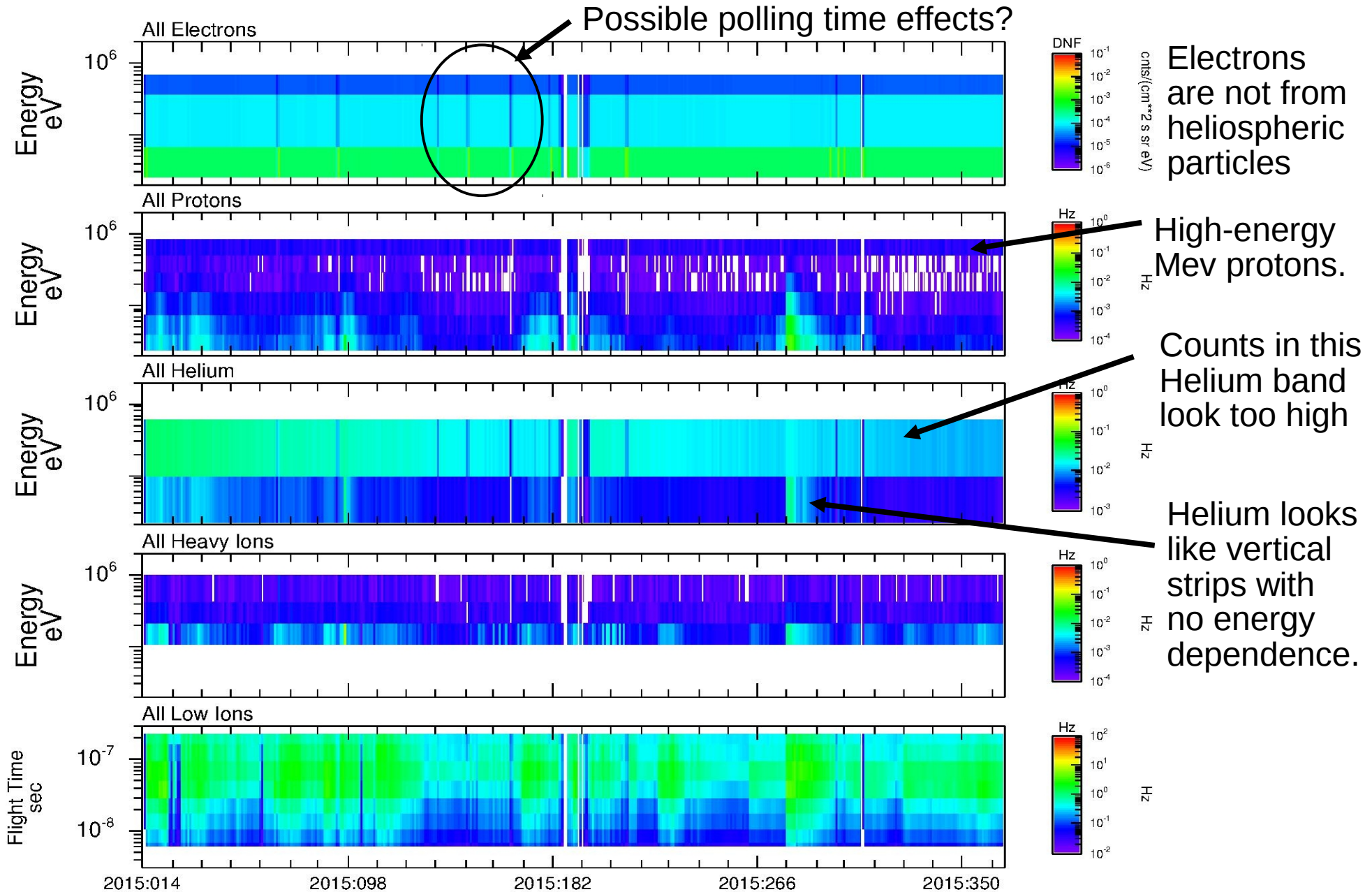New Horizons Science Operation Center (SOC):
Joe Peterson
Department of Space Studies

These Should be:

New Horizons Science Operations Center (SOC):
Tiffany Finley
Department of Space Operations

Data Evaluation

nh-p-pepssi-3-pluto-v2.0/data

New Data from Pluto

The new PEPSSI data from the Pluto phase is shown on the next slide. The time period covers the entire Pluto Phase. The color bar is enhanced to increase the visibility of fluctuations in the data, but the data is very much the same at this time scale.
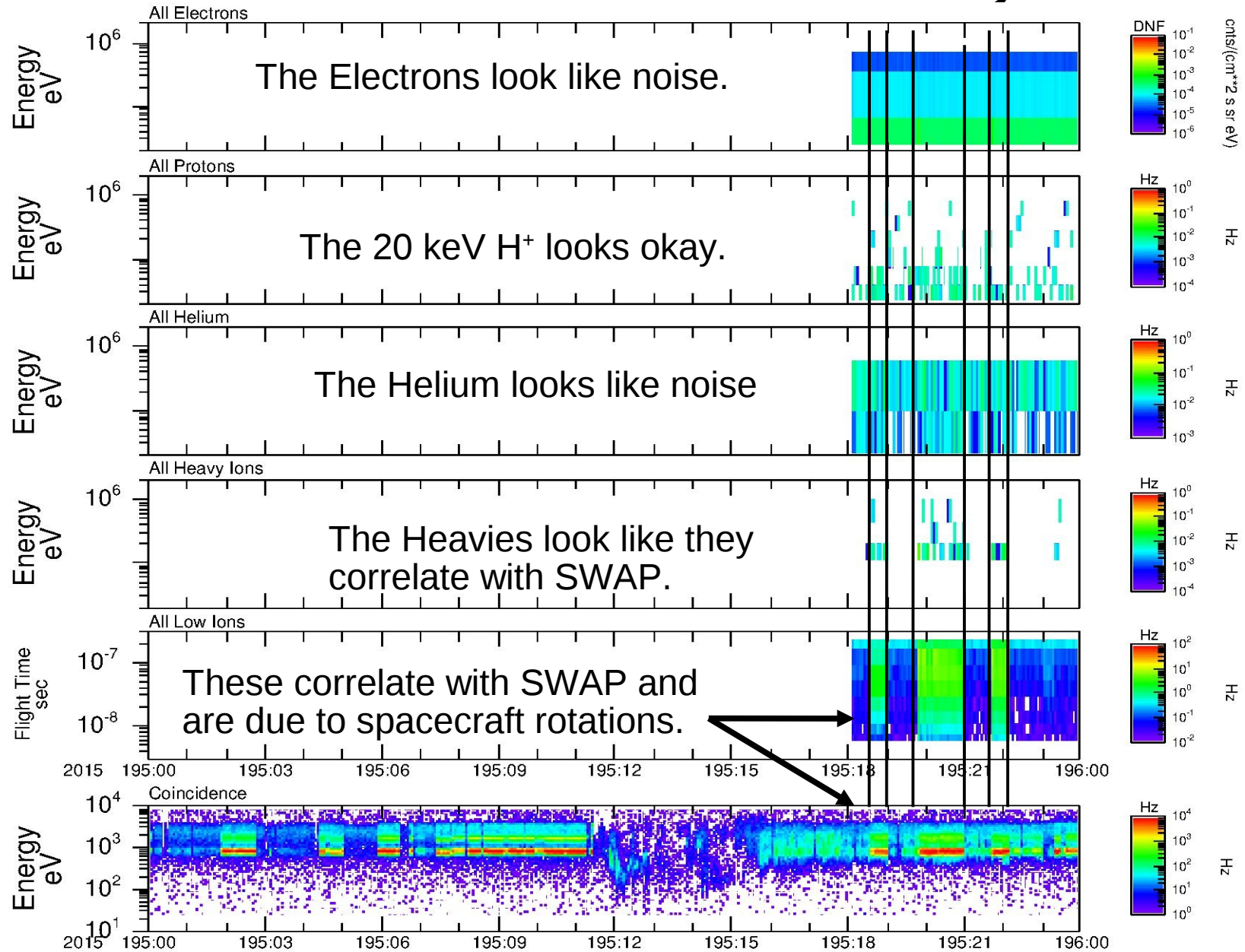
New nh-p-pepssi-3-pluto-v2.0/data
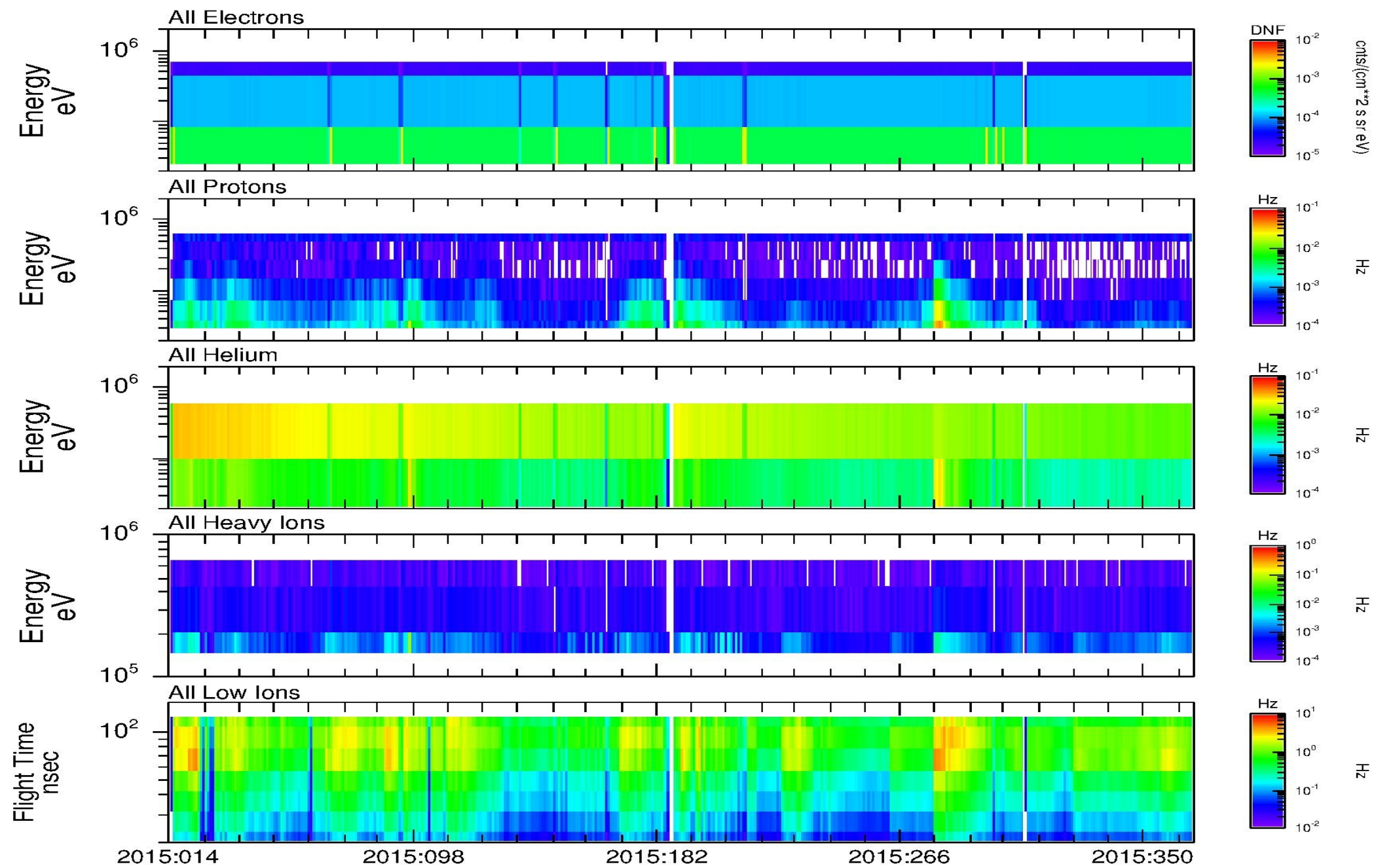
Pluto Encounter Day

On the next slide shows the original data from the Pluto Encounter Day.
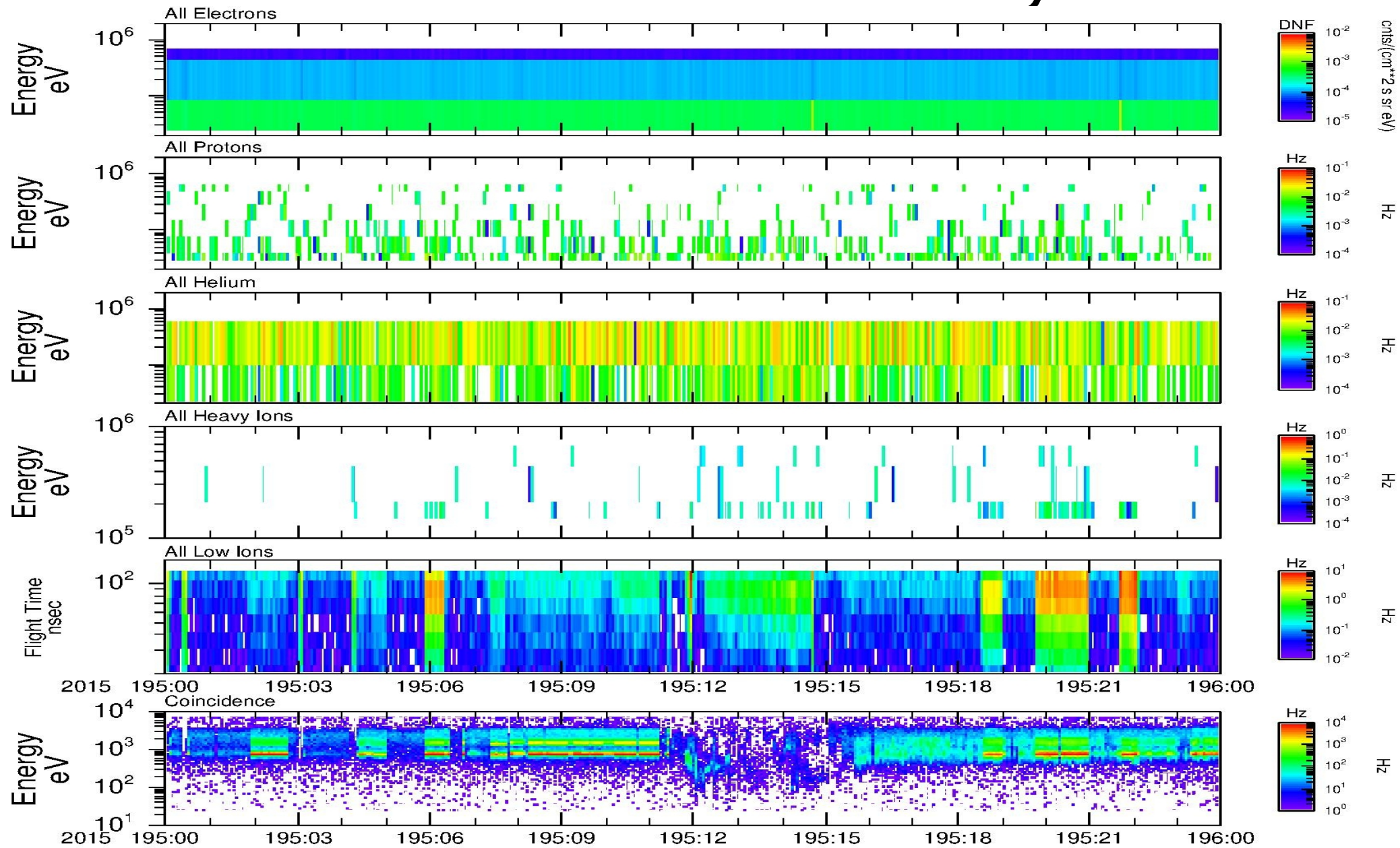
nh-p-pepssi-3-pluto-v2.0/data Pluto Encounter Day

New Data for the Pluto Encounter Day

On the next slide shows the new data from the Pluto Encounter Day. The missing data has been recovered.

nh-p-pepssi-3-pluto-v2.0/data
Pluto Encounter Day
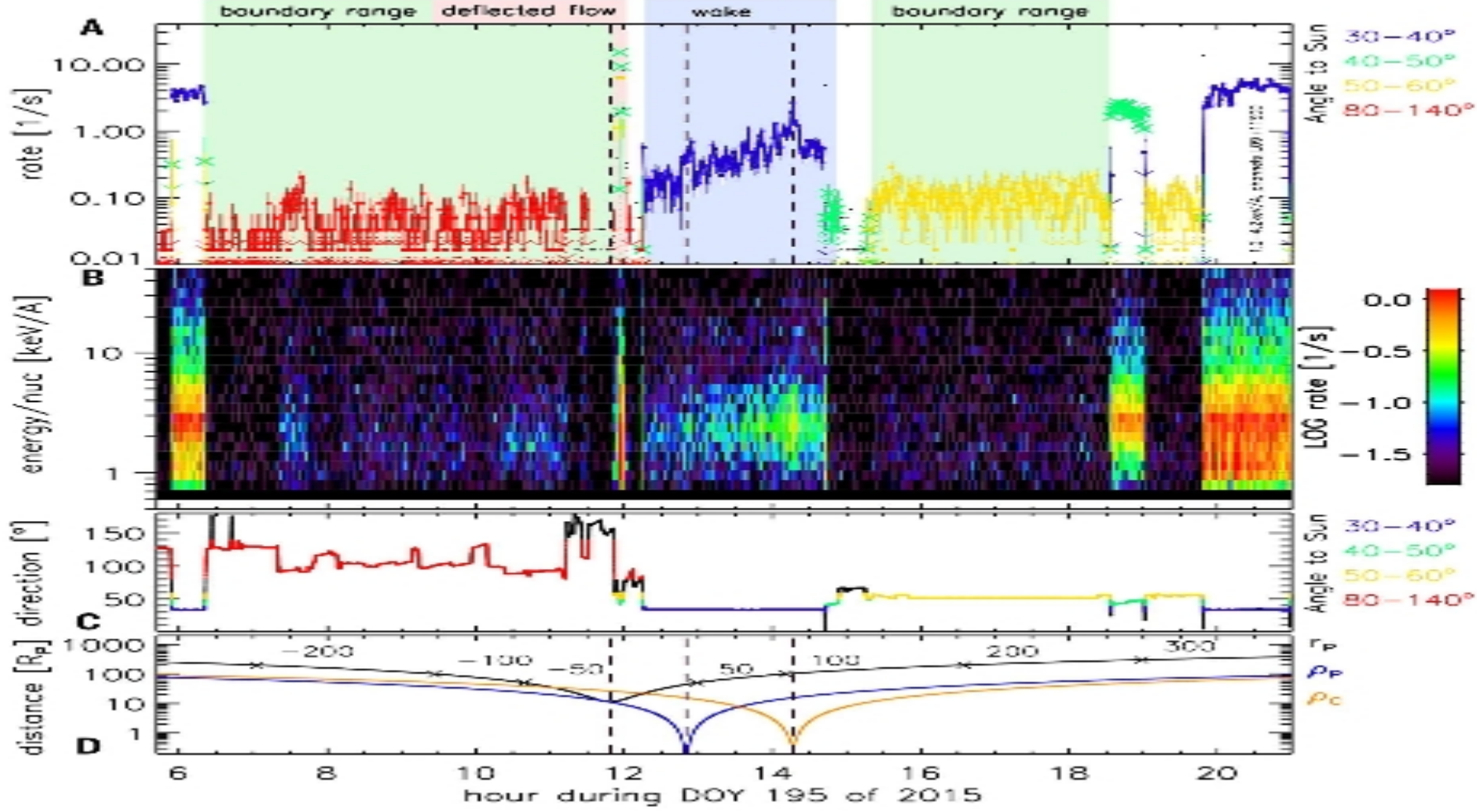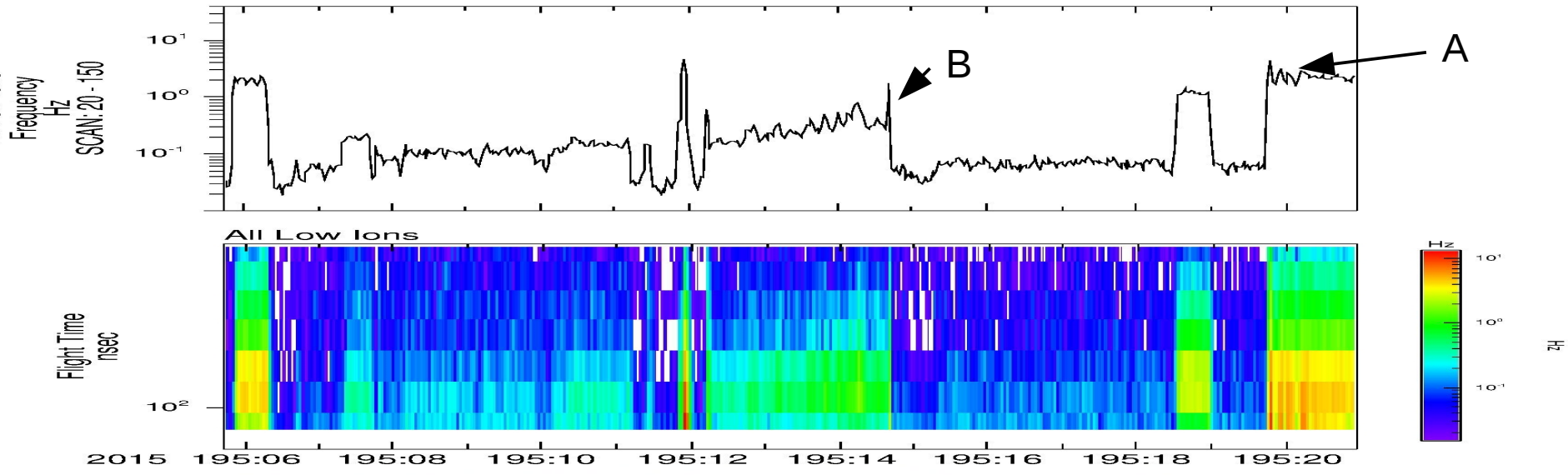
Comparison with the Published PEPSSI TOF data

Comparisons were made to the PEPSSI figures published in Bagenal *et al*., Pluto's interaction with its space environment: Solar wind, energetic particles, and dust, Science, **351**(6279), 1282 (aad9045 1-8). 2016. Bagenal *et al*. figures are below, figures matching data times from this data are shown above.

Time coverage of the published plots was set to match those locally produced and the horizontal axes are aligned.

PDS Data

Sensor Data
All Low Ions
Frequency
Hz
SCAN·20 - 150

B

A

All Low Ions

Hz

Flight Time
nsec

Hz

2015 195:06   195:08   195:10   195:12   195:14   195:16   195:18   195:20

Bagenal et al. Published Data

A

boundary range   deflected flow   wake   boundary range

rate [1/s]

Angle to Sun
30−40°
40−50°
50−60°
80−140°

B

energy/nuc [keV/A]

LOG rate [1/s]

C

direction [°]

Angle to Sun
30−40°
40−50°
50−60°
80−140°

D

distance [R_P]

r_P
ρ_P
ρ_C

hour during DOY 195 of 2015

Bagenal *et al*. Figure 3

The line plot comparison replicates to the degree as can be seen. The details in marking the average points are masked due to the error bars in the Bagenal *et al*. figure; however, there are two differences which are easily picked out:

A: after 1930 UT, there are higher levels of PDS data values at the the angle transition boundary and the PDS data appears to be flatter until the end of the spectrogram,

B: there are several data values in the PDS data which appear to be missing in the published figure.

The spectrogram compares a time scale and an energy scale, but ere appear to be more pixels represented in the vertical direction. The general shapes are shown to be the same. Differences exist the vertical scale, but can not account for the number of pixels. The color intensity is also different due to the ranges of the color bar values. However, matching the color scales saturates the PDS data plot. This suggests that the top of the color scale shown on the Bagenal *et al*. figure may have been inadvertently cut off.

Bagenal *et al*. Figure 4

The line plot comparison is the total sum (the label is incorrect) of the Low Ion PHA for each entry in the PDS data file. The overall structure seems to replicate, but not the details of the PHA sum. It is possible that in the Bagenal *et al.* figure, the Level 2 data was binned differently to achieve different values.

The spectrogram compares a time scale and an energy scale on the vertical axis; however the time resolution on the horizontal axis shows that the time resolution of the PDS data is greater that the time resolution of the published data. The details of the TOF are not adequate to determine that there are indeed multiple TOF peaks within the Pluto encounter. The number of pixels in the vertical direction appears to be the same.

PDS Data

Bagenal *et al* Published Data
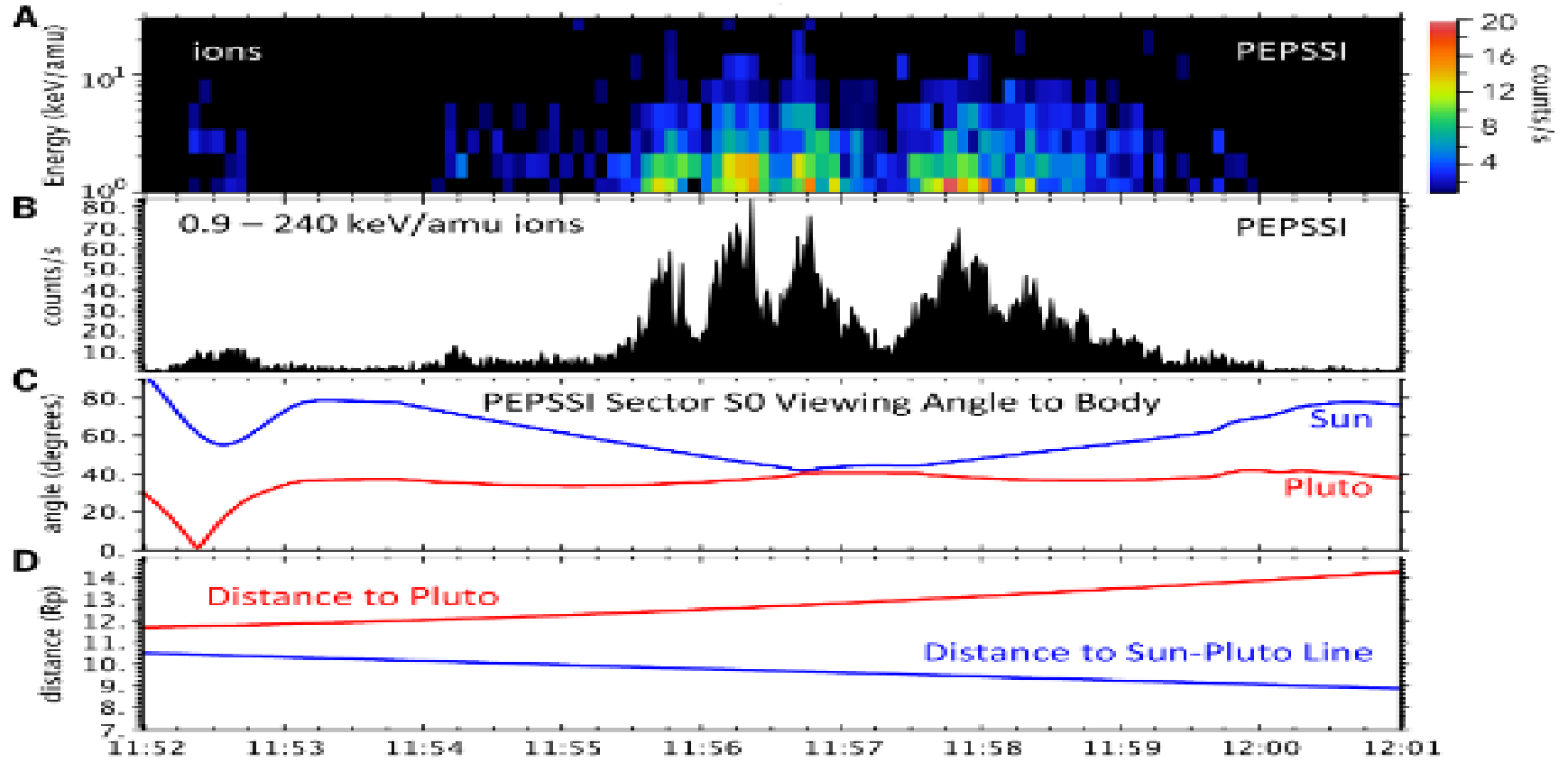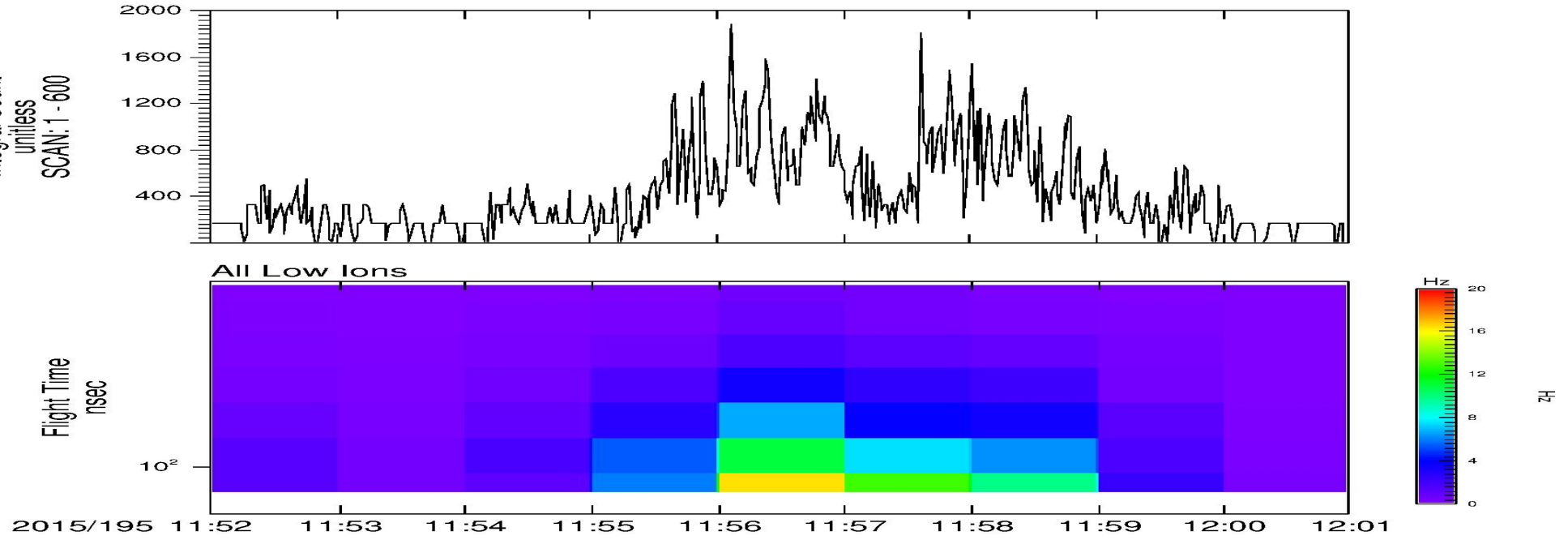
Polling Time Check

Has the Polling Time effect been removed?

First, the original slides:

nh-p-pepssi-3-pluto-v2.0/data Polling Time Effect?

A polling time effect could caused when counts for multiple species become disjointed so that the ability to statistical sample is influenced by the count. If you have two input sources with both generating a number at a constant rate, then the probability of polling is constant. However, if the rate of one source increases, then the polling will find that the increased source occurs more frequently due to the increased rate. During this time, the constant source count would look depressed if this is not taken into account.

nh-p-pepssi-3-pluto-v2.0/data Polling Time Effect?

Electrons are probably generating signals at a constant rate, but the rate of ion generation increases causing a polling time effect. In this case, the electron count would seem to decrease, caused only by the frequency at which the electrons are polled and not because their flux decreased.

Change of New Data vs. Old Data

The next slide shows that there is no change in the new data set.
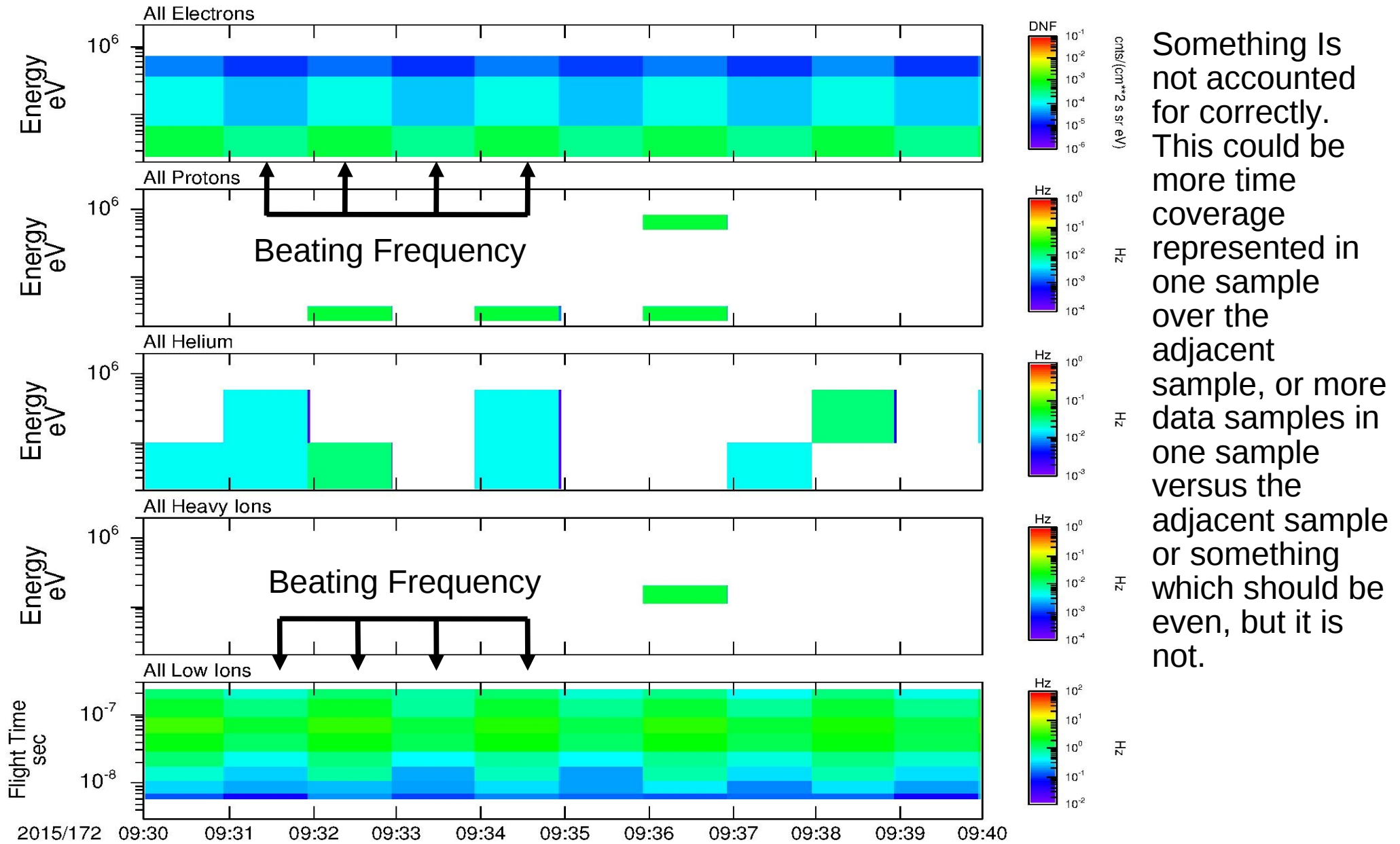
New Data showing
Polling Time Issue
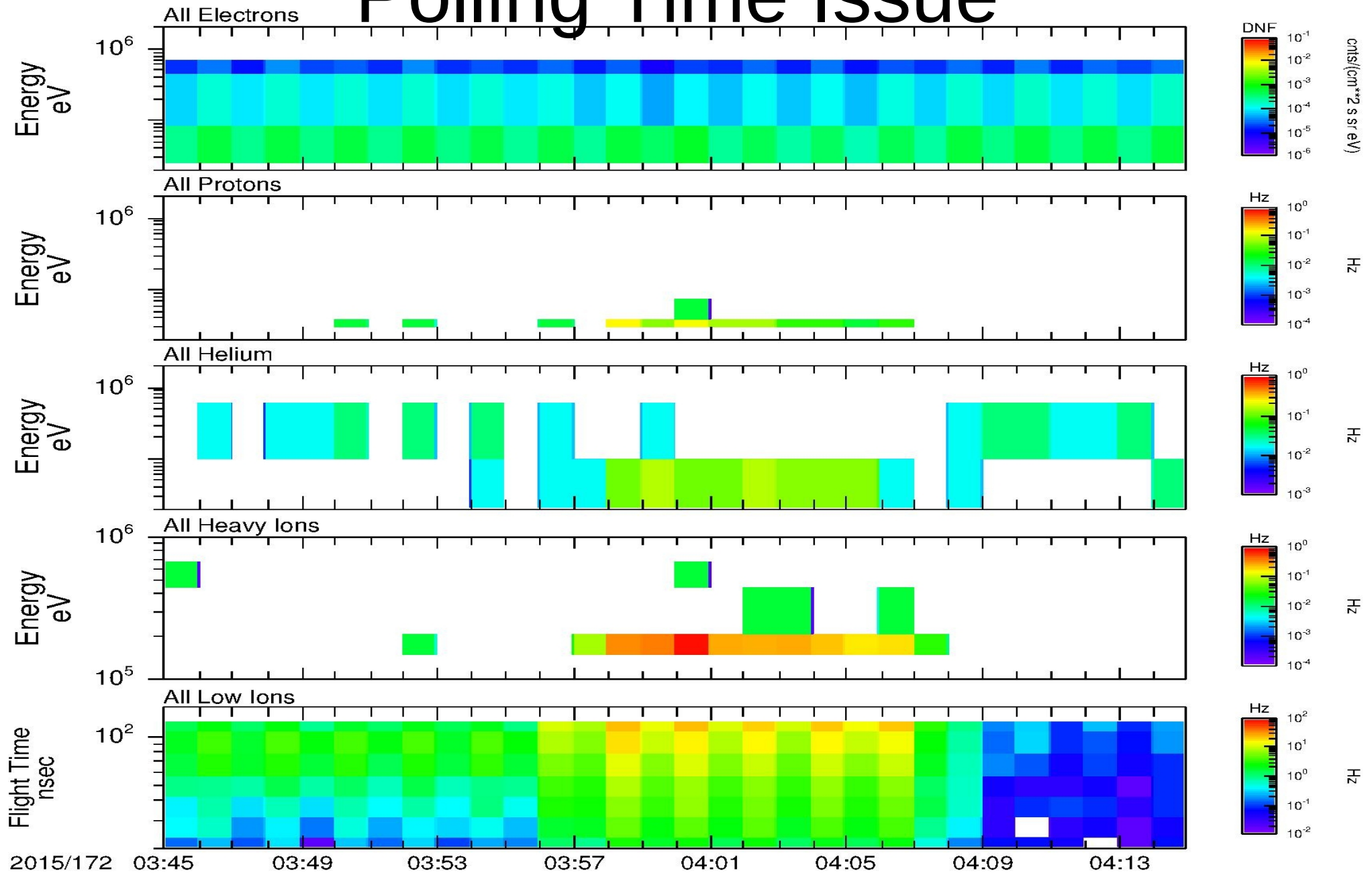
Oscillations in the Data

The next slide illustrated periodic beating, or oscillations in the original data.

nh-p-pepssi-3-pluto-v2.0/data Unequal Sampling Time Effect?

Something Is not accounted for correctly. This could be more time coverage represented in one sample over the adjacent sample, or more data samples in one sample versus the adjacent sample or something which should be even, but it is not.

New Data Showing Oscillations

The next slide shows that this issue still exists with the new data. The color bars were changed to enhance the contrast. No adjustment has been made between the old and new data to fix this effect.
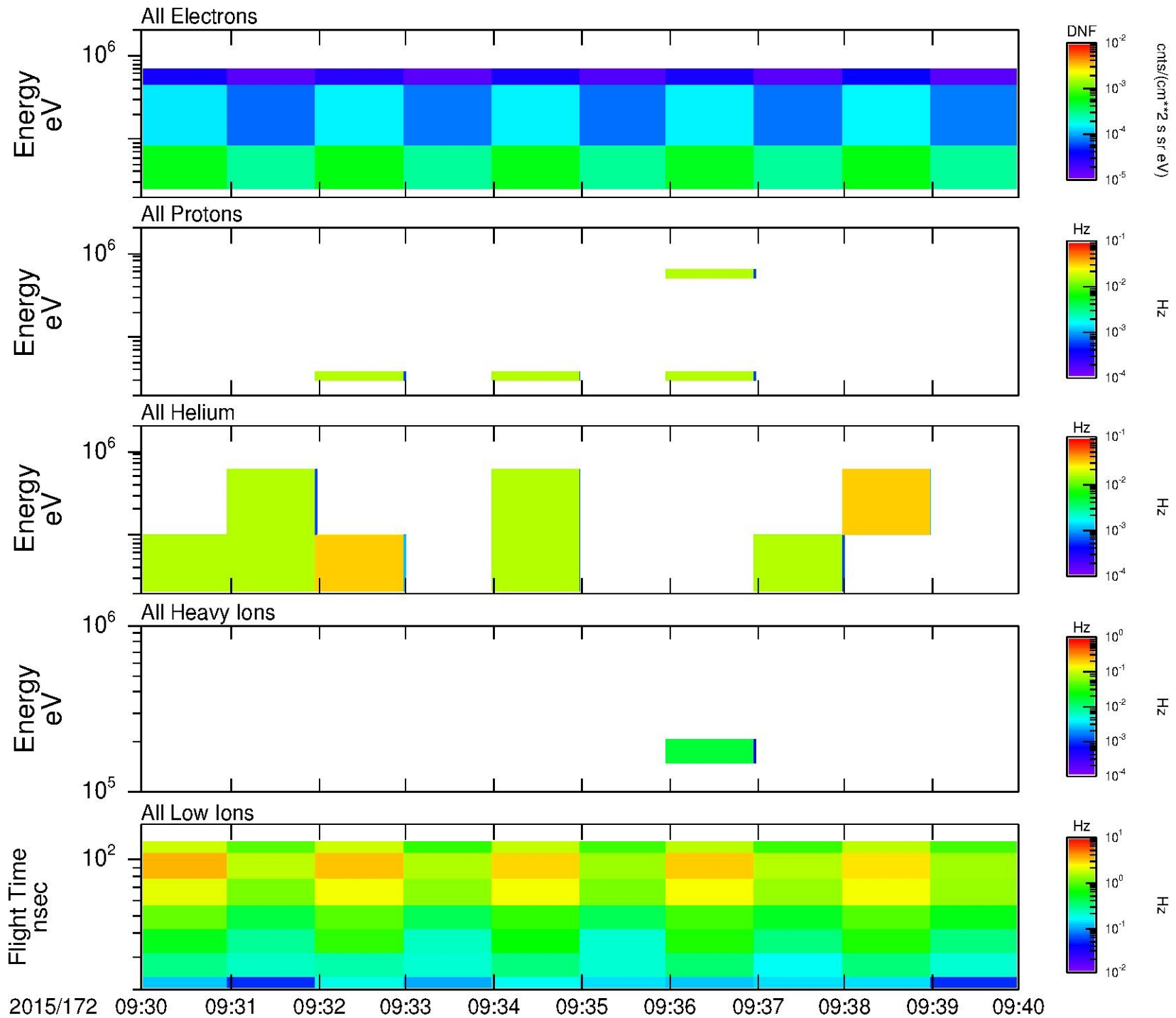
Spacecraft Motion

At the bottom of the SWAP summary plots is information about the spacecraft attitude. This is showing that the spacecraft was not spinning, but did change its orientation with respect to the Sun. The polling effect occurs during the motion of the spacecraft so this could be an effect of the spacecraft motion. However, this does not explain the oscillation effect which seems to occur throughout this time period.

New Horizons Solar Wind Around Pluto (SWAP) Data
06/20/2015 (171) 23:59:42 to 06/22/2015 (173) 00:00:02 UTC

Software Version: ' 3.00000' Processed: 2016-09-17T05:04:43
Plot Created: Wed Oct 12 22:02:15 2016
Files: 0297129600_0x584_sci.fit to 0297302400_0x584_sci.fit

Spectrogram Timing Accurate to Within: 20.00 [sec]
Plot Width:: 0.754545 [norm]
Plot Width: 8.3000 [in]
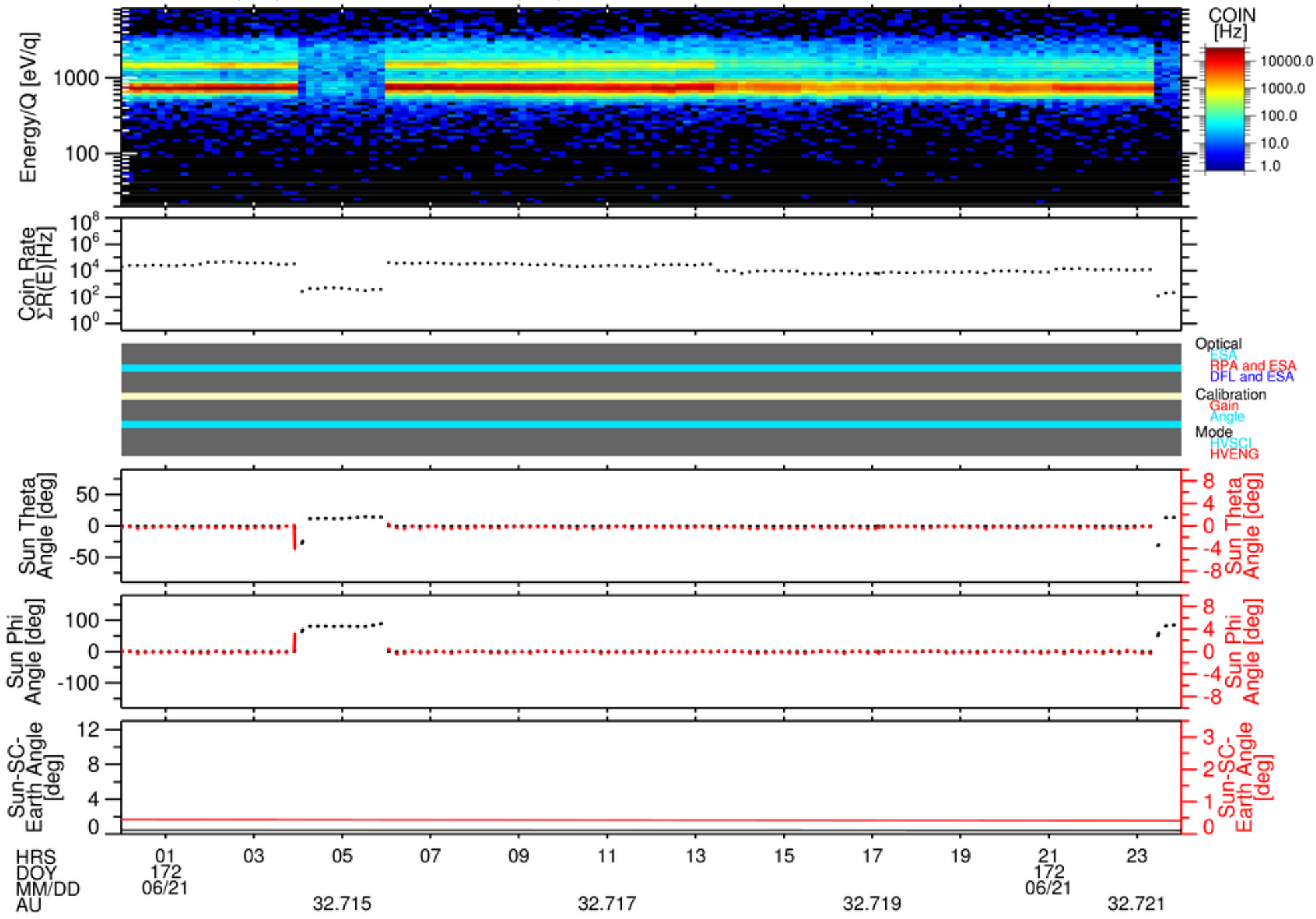
Time After Pluto Encounter Without Spin and Direct Sun Pointing
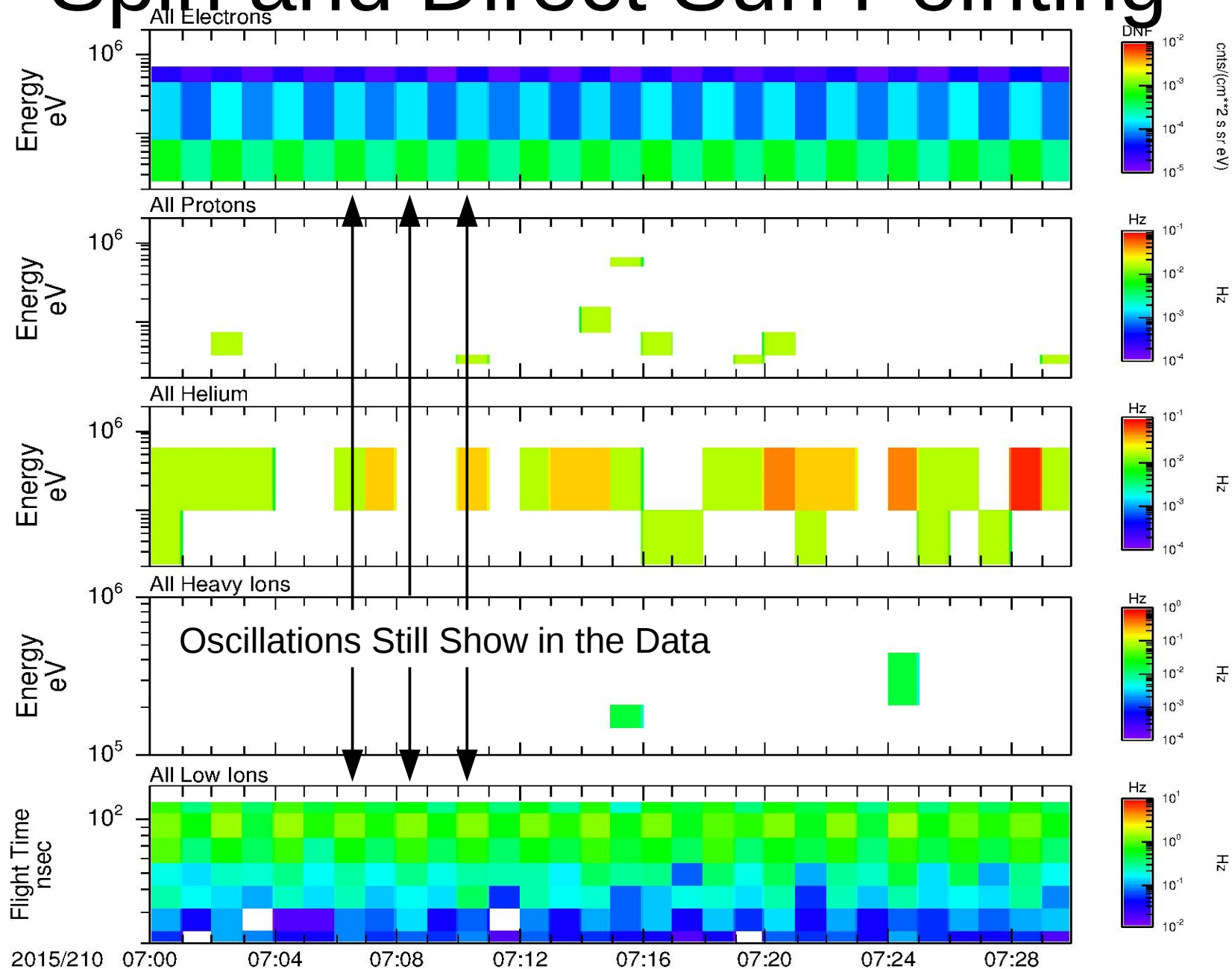
GCRs as a noise source in the Electron SSDs

The PEPSSI documentation cited Galactic Cosmic Rays (GCRs) as a possible effect showing up in the electron SSDs. PEPSSI has no anticoincidence hardware to eliminate hard particles and relies on the falling spectral shape to limit their effect. GCRs are powerful enough to penetrate the detector and a small fraction could cause a signal in the electron detector. However, one would think that the Al covering is not a significant barrier to GCRs and the GCR influence should occur in all SSDs simultaneously. It is not clear why there is no corresponding signal in the ion SSDs.

PEPSSI Electrons - Updated

Why are the fluxes from PEPSSI abnormally high?

PEPSSI Electrons

2014/041 23:59:57.000   2016/001 00:00:57.000
2014/042 16:38:57.000   2016/001 16:39:57.000

Solar Wind Electrons at 1 AU

WIND

STEREO-A

$\sim E^{-1.88}$

PEPSSI Electrons (28 AU)

$\sim E^{-2.44}$

STEREO-B

$\sim E^{-2.26}$ WIND

Wang et al, ApJ Lett. 2012
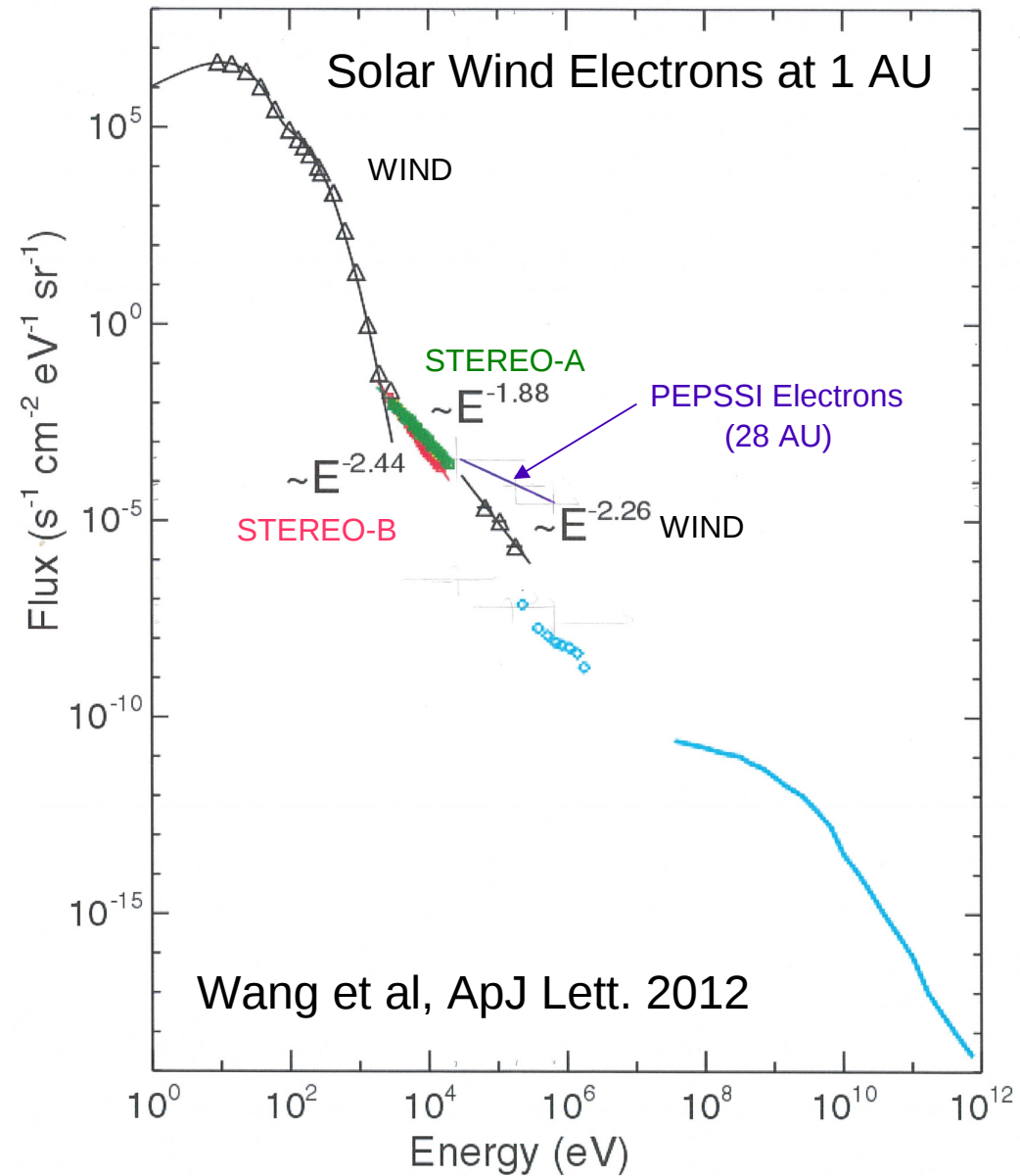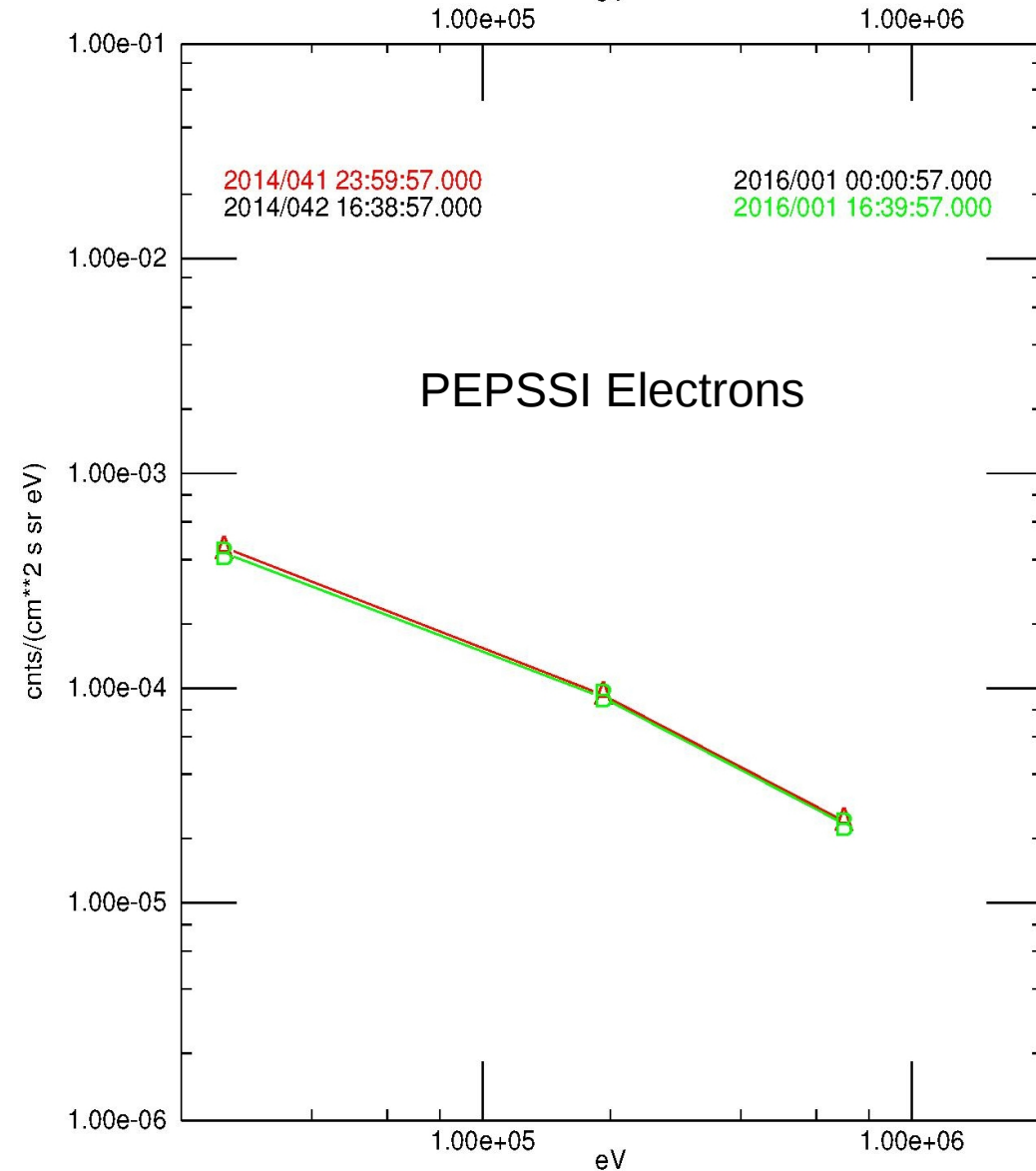
Ions During a Solar Wind Shock
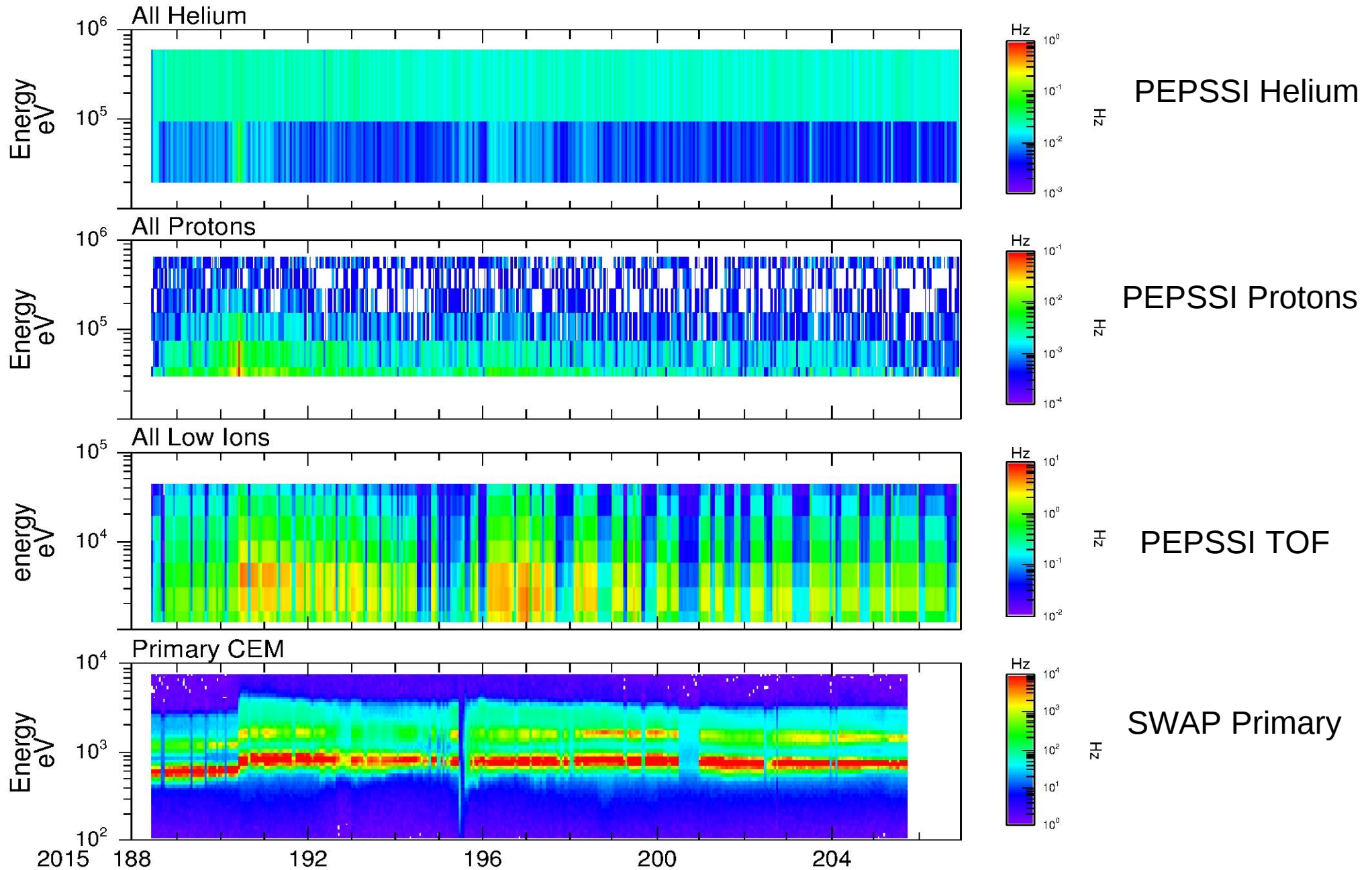
Solar Wind at a Heliospheric Shock

PEPSSI Electrons (not shown) are constant throughout this time period, an unrealistic result.

PEPSSI Low Ions show a peak at about twice the energy as the He++ peak in SWAP. This is correct since their velocities are the same, the He++ mass is 4 times the H+ mass, and the He++ charge is twice the H+ charge.

PEPSSI Protons show a decrease count rate with an increasing energy and penetration of shock protons into the PEPSSI energy range. This is also correct.

PEPSSI Helium still does not seem correct. Voyager results report rare time periods of anomalous He++ peaks in the 10-100 MeV energy range, but not continually. The He++ spectrum intensity should still be decreasing with increasing energy. The PEPSSI helium data seems incorrect. Is it possible that the Helium energy channels are swapped?

Back-Up Slides

Useful Table for PEPSSI
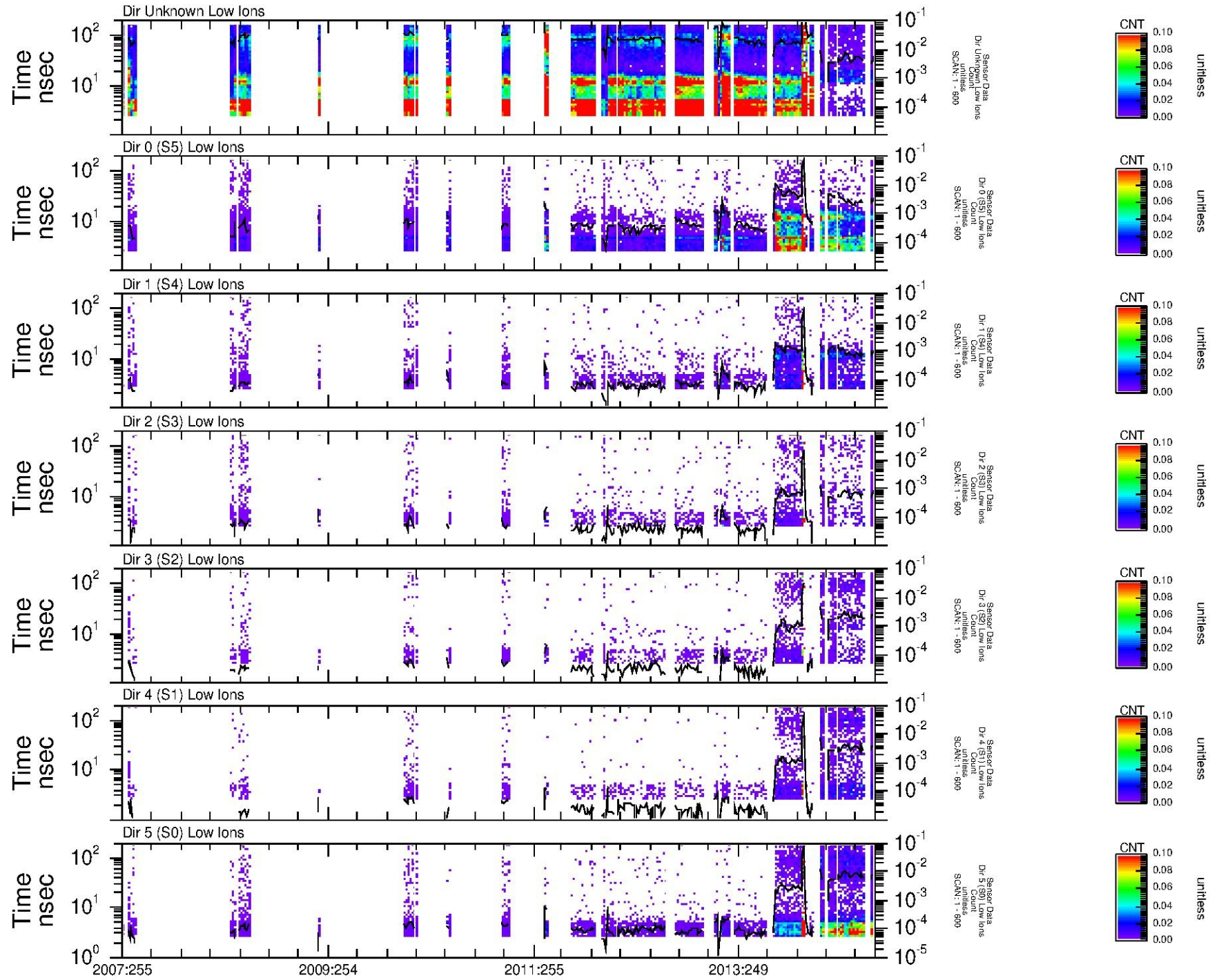
Flight Distance is 6 cm (ICD Section 11.4.5.4)

Time	Velocity	H+ Energy
1 ns	60,000 km/s	18.76 MeV
2 ns	30,000 km/s	4.69 MeV
5 ns	12,000 km/s	750.6 keV
10 ns	6,000 km/s	187.6 keV
20 ns	3,000 km/s	46.9 keV
50 ns	1,200 km/s	7.506 keV
100 ns	600 km/s	1.876 keV
200 ns	300 km/s	469 eV
500 ns	120 km/s	75 eV

nh-x-pepssi-3-plutocruise-v2.0/data

New Data

Ion PHA From Pluto Cruise Phase

Original Slide
nh-x-pepssi-3-plutocruise-v2.0/data

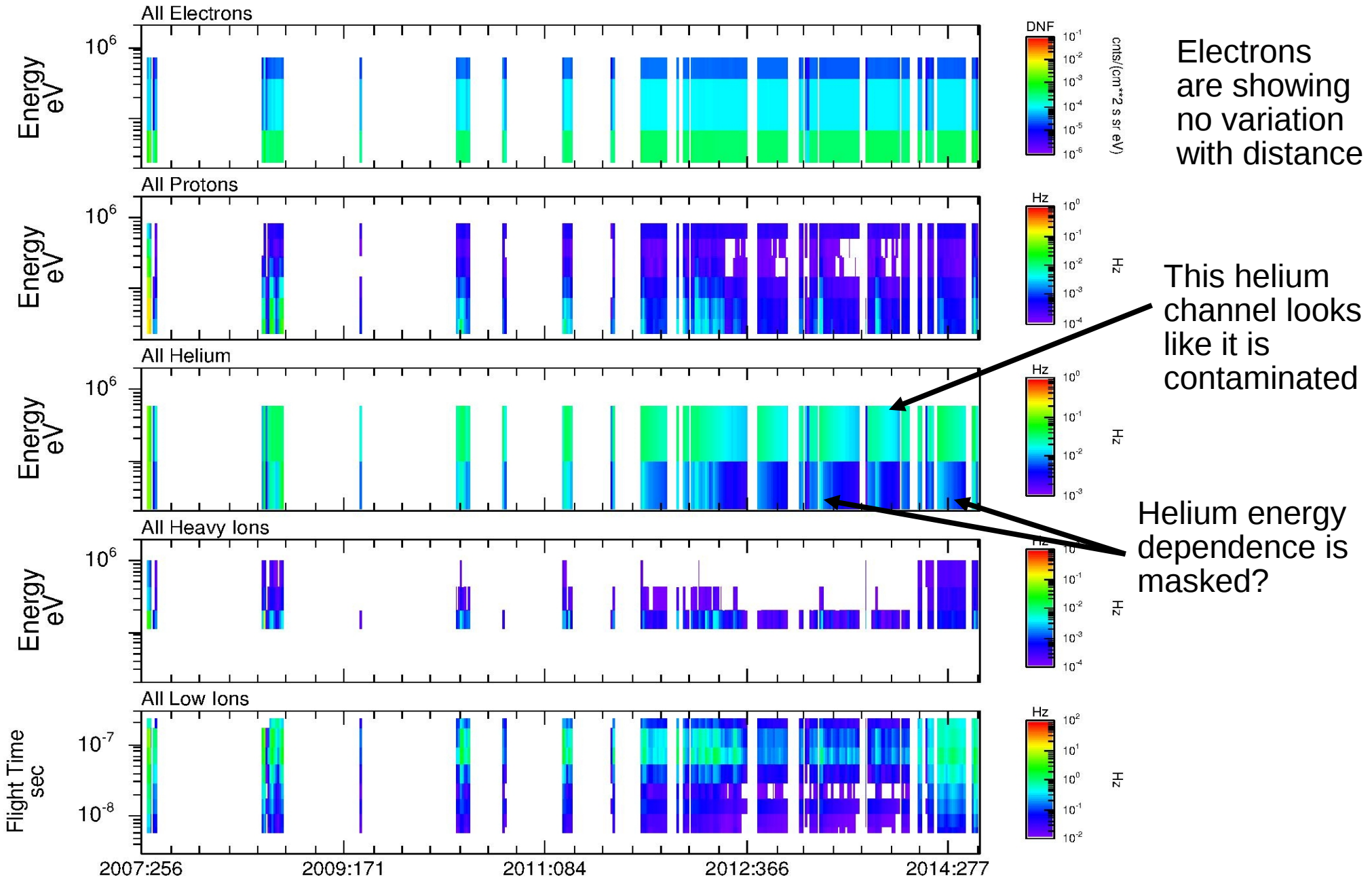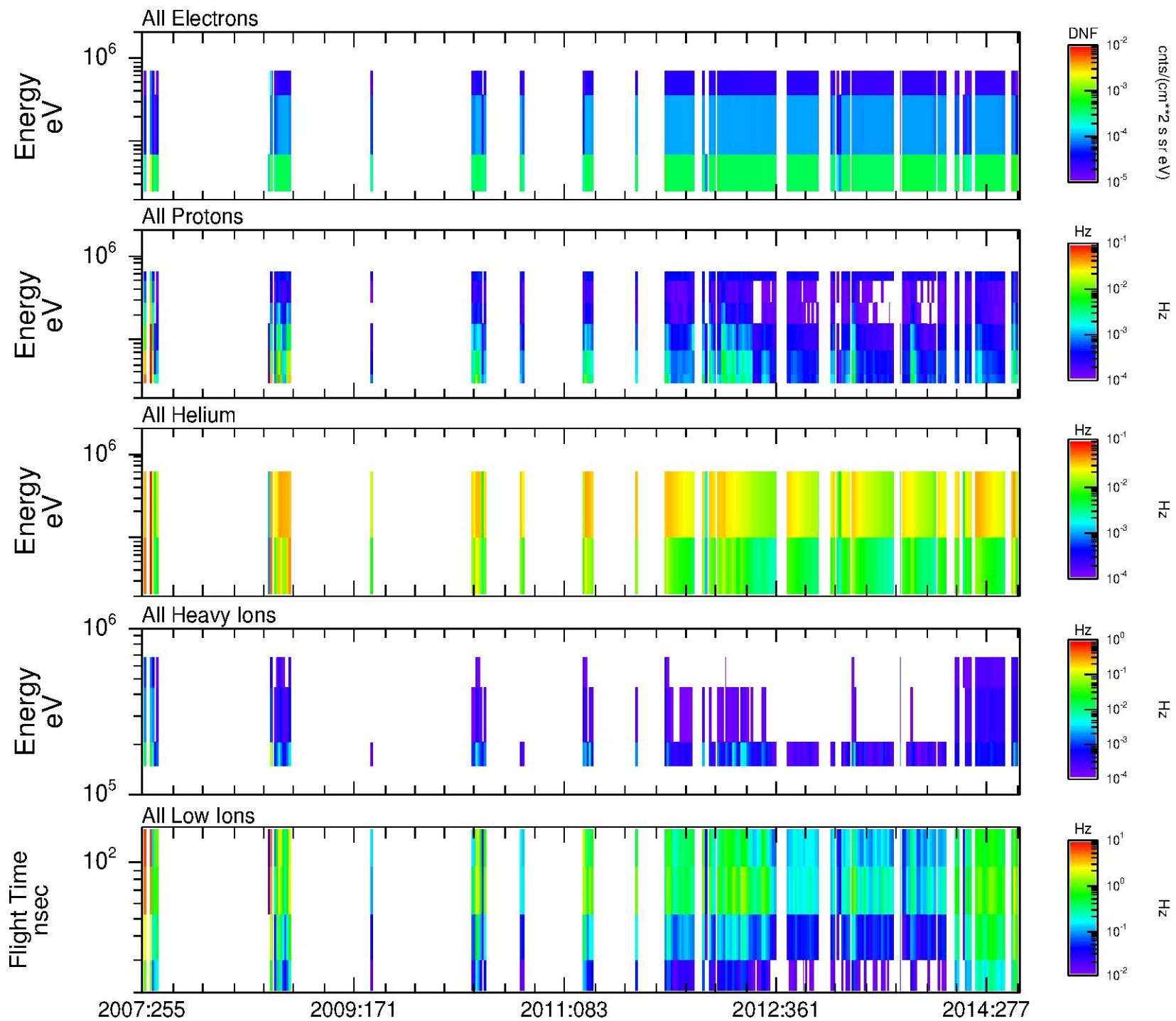# New Data

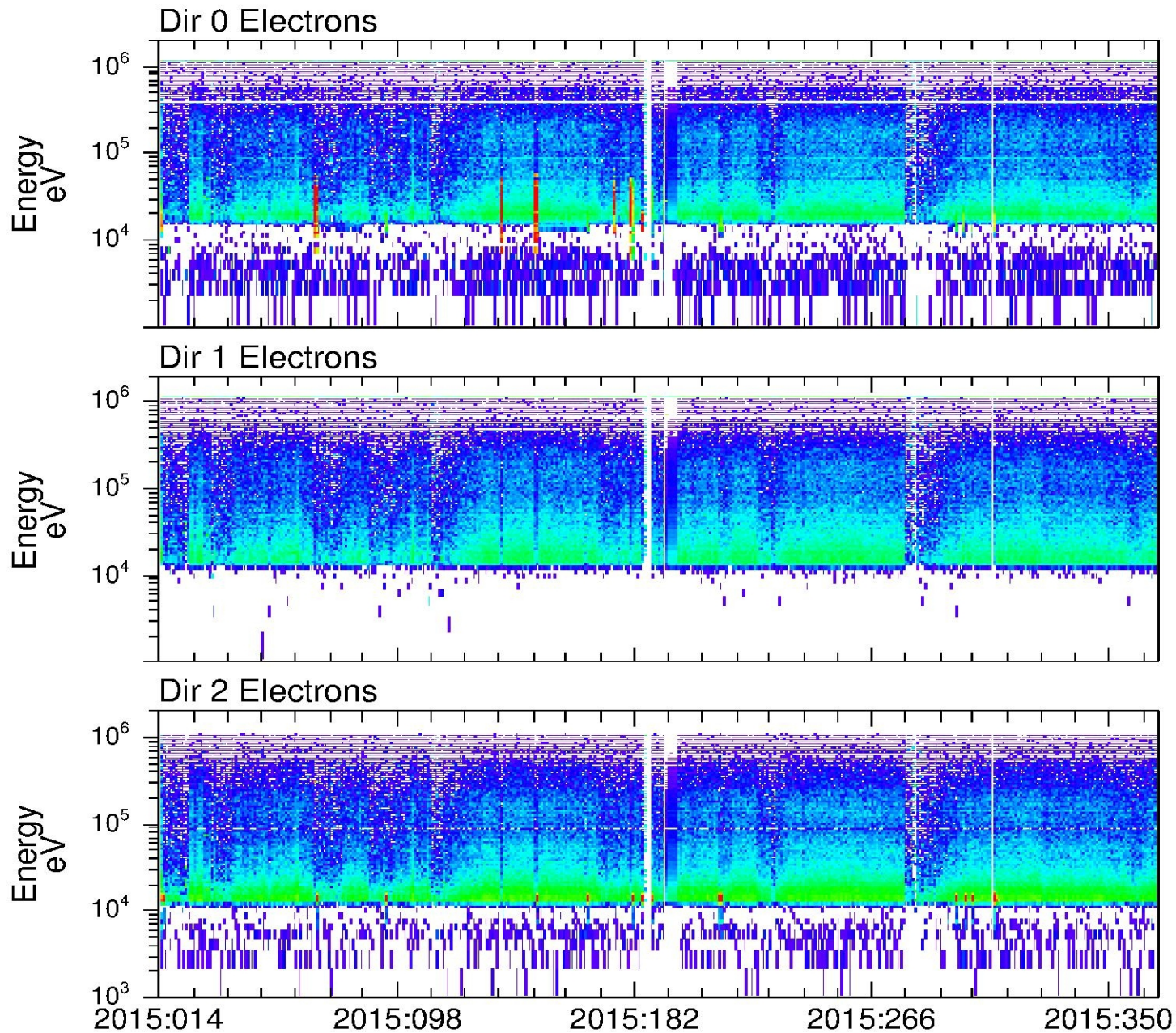## Electron PHA from Pluto Cruise Phase

nh-x-pepssi-3-plutocruise-v2.0/data

Electrons are showing no variation with distance

This helium channel looks like it is contaminated

Helium energy dependence is masked?
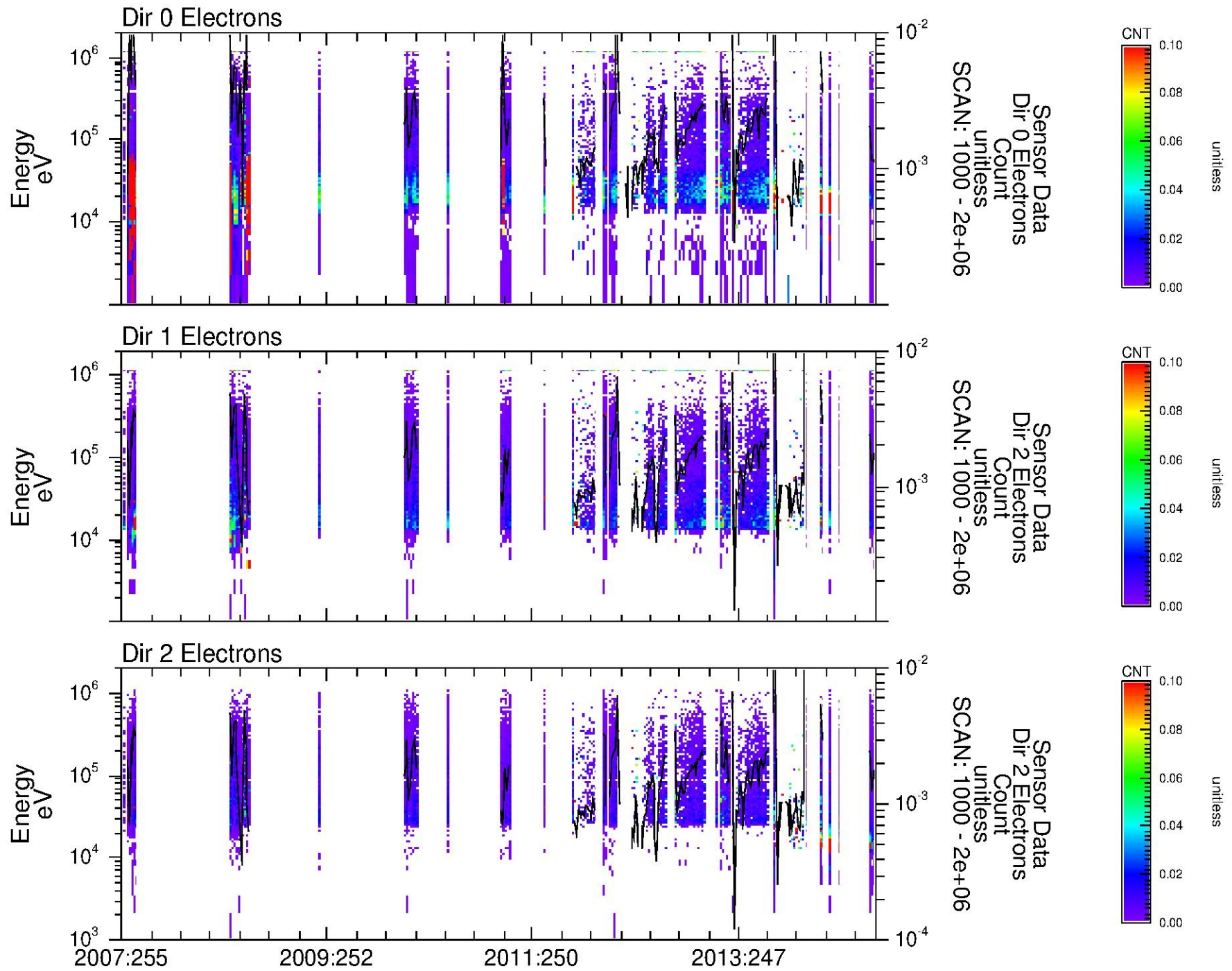
Spectrograms from the Pluto Cruise Phase

nh-p-pepssi-3-pluto-v2.0/data

high-energy MeV ions.

killovolt solar wind ions

high-energy MeV ions.

New Data

Ion PHA From Pluto Phase

The electron PHA data signifies the spectral shape, but not its Intensity. The electrons here could have the same shape, but the variation could be in the sampling rate.
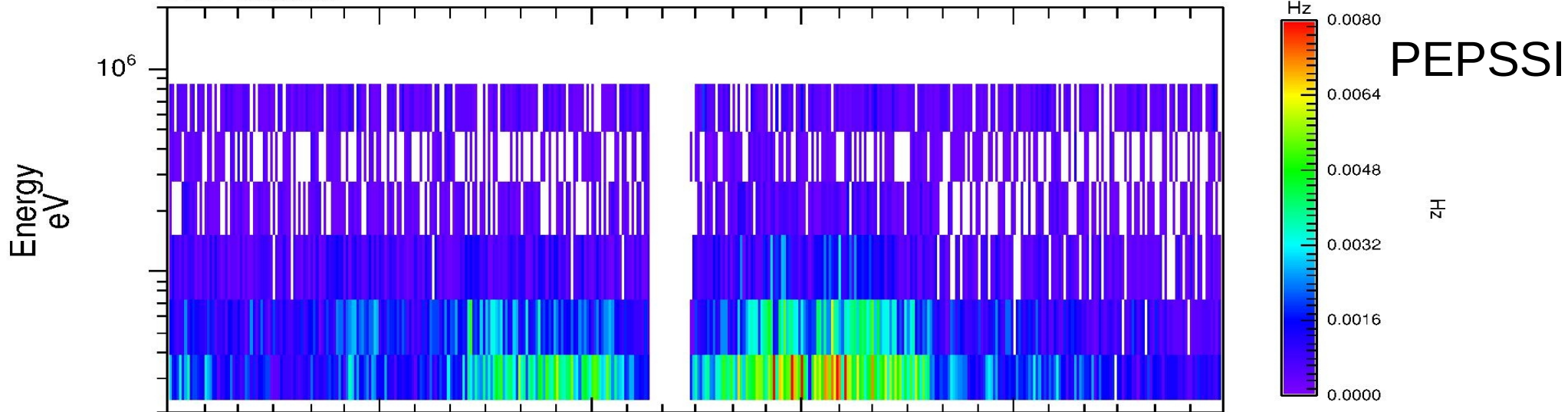
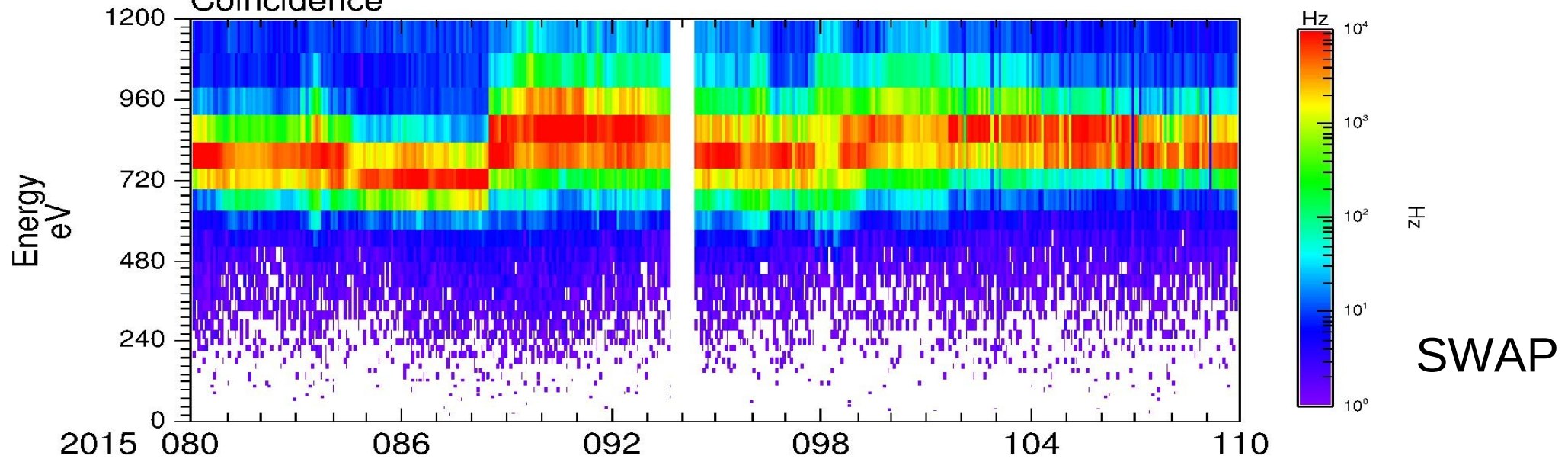# New data

Electron PHA from Pluto Phase
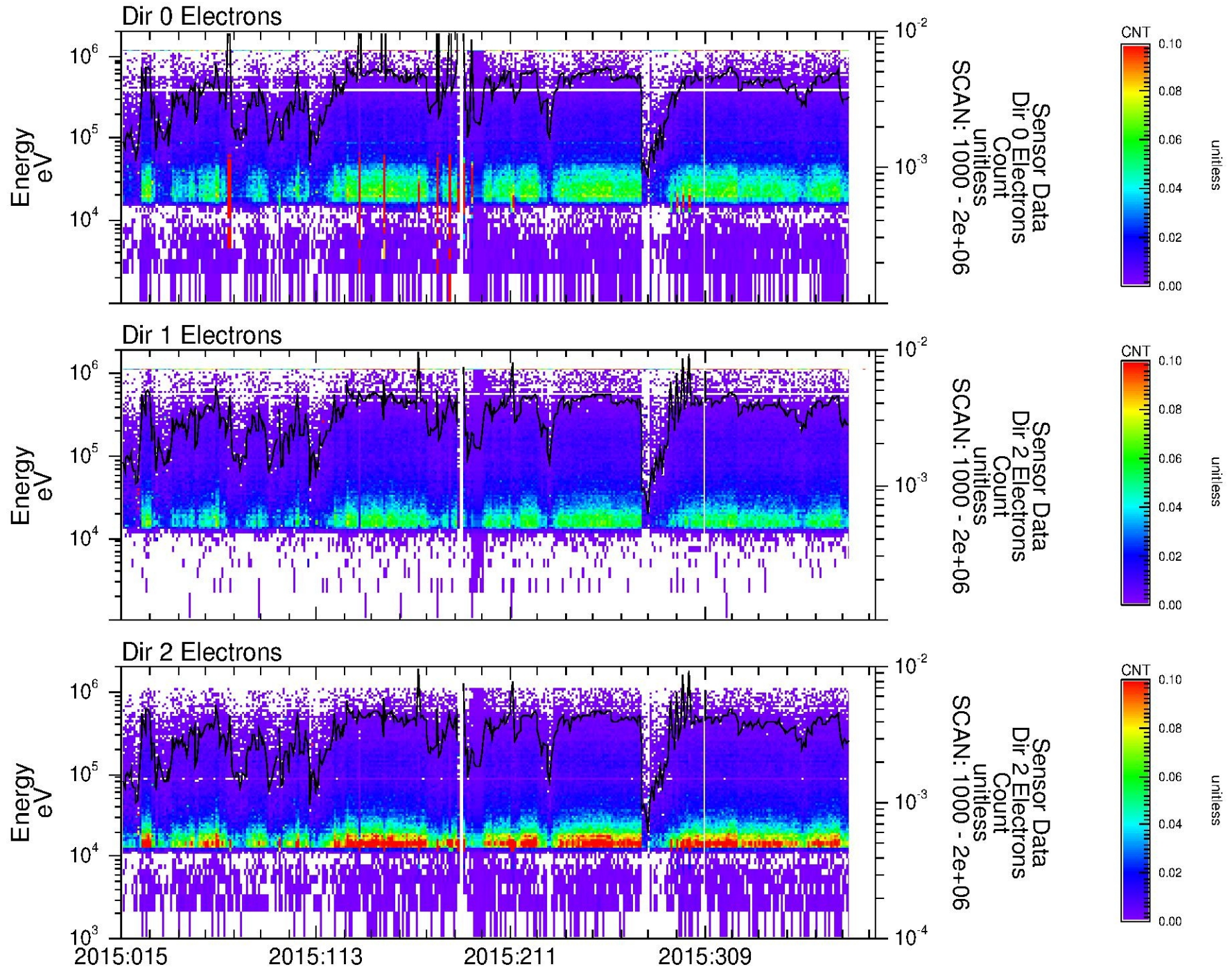
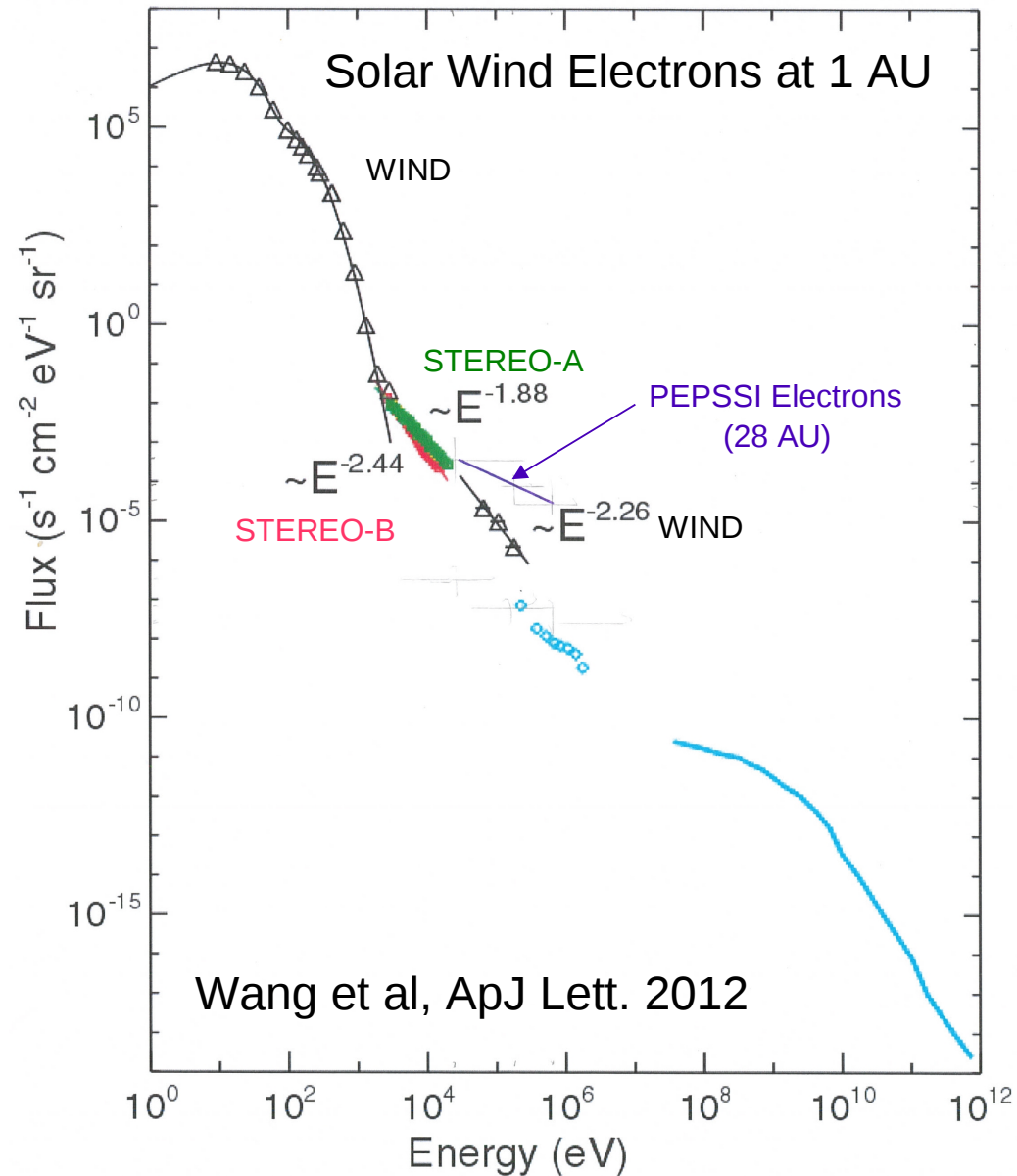# Heliospheric Shock or Heated Region in the Solar Wind - Updated
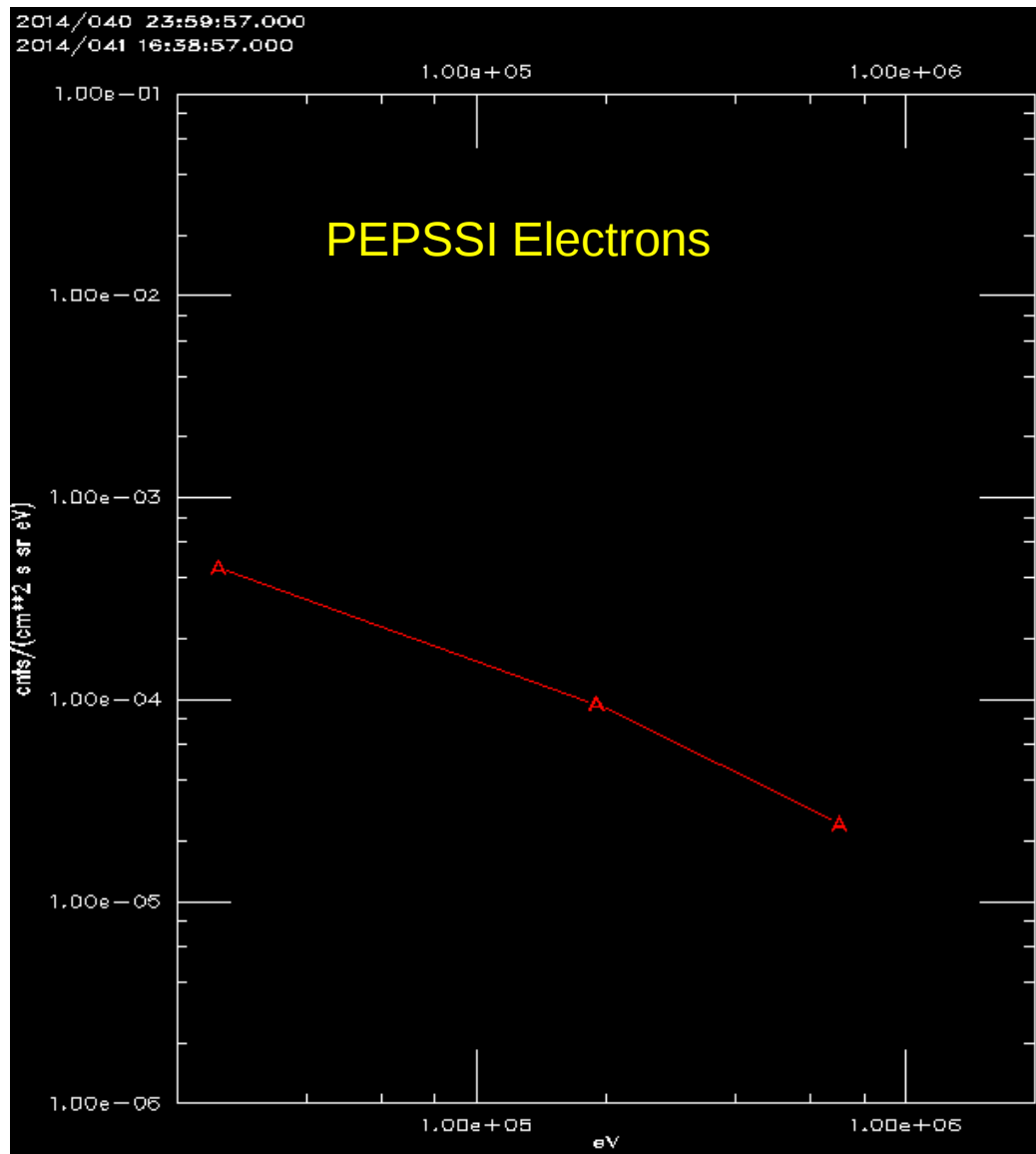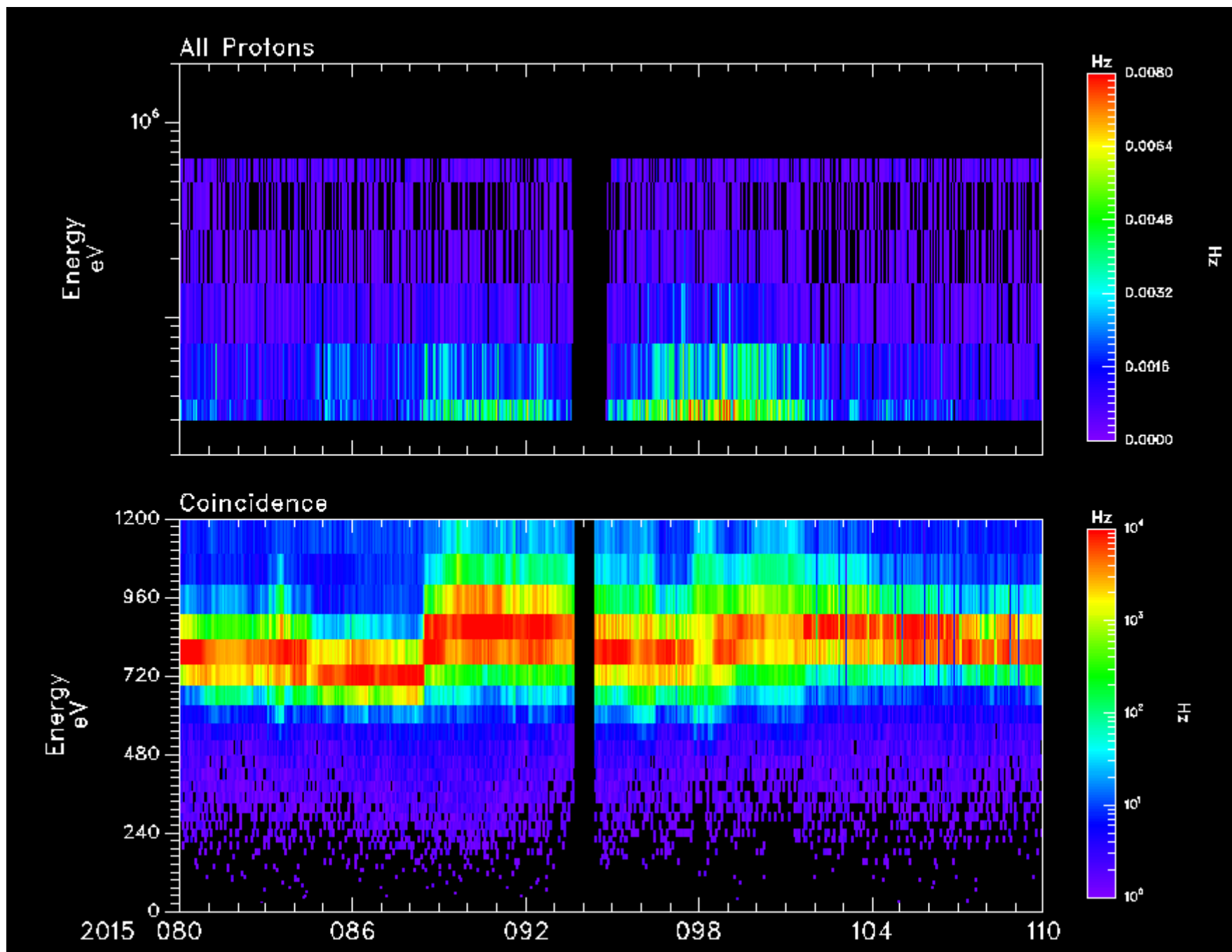
PEPSSI Electrons - 3

Why are the fluxes from PEPSSI abnormally high?

Heliospheric Shock or
Heated Region in the Solar Wind

So is this really a heliospheric shock or just heated plasma from the Sun. Attached is a blow-up on the SWAP H+ region on a linear scale. The PEPSSI data resembles more of an extension of the SWAP H+.

All Data Sets in the catalog Directory ref.cat

GOOD

All Data Sets in the catalog Directory pepssi.cat

GOOD

For dataset.cat the catalog Directory of nh-x-pepssi-2-plutocruise-v2.0 and nh-x-pepssi-3-plutocruise-v2.0

GOOD

All Data Sets in the index Directory indxinfo.txt

GOOD

All Data Sets in the index Directory
index.lbl

GOOD

All Data Sets in the index Directory checksum.lbl & checksum.tab

GOOD

All Data Sets in the index Directory slimindx.lbl

GOOD

For calinfo.txt in the calib Directory of
nh-p-pepssi-3-pluto-v2.0 and
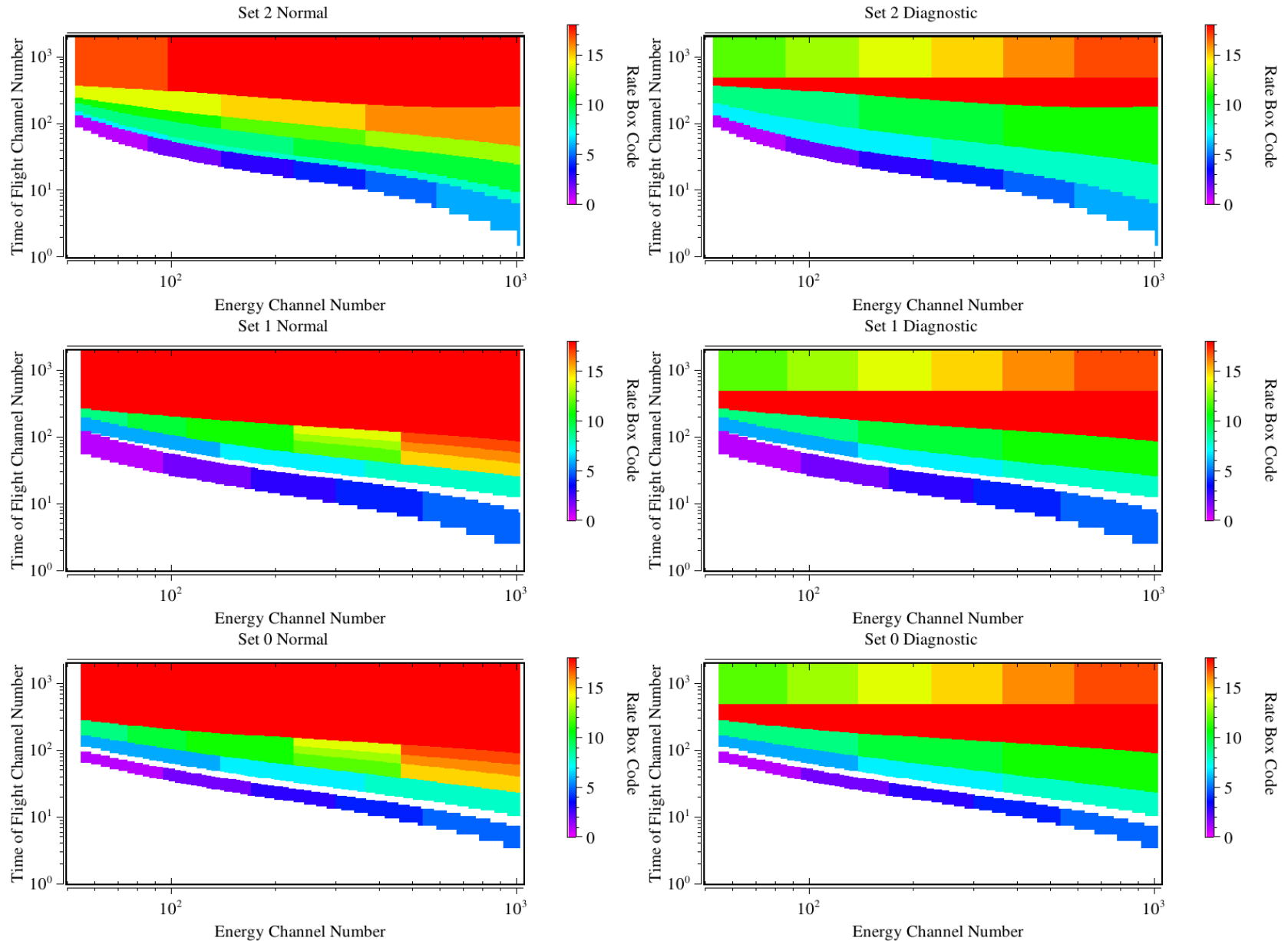nh-x-pepssi-3-plutocruise-v2.0

GOOD

For calinfo.txt in the calib Directory of
nh-p-pepssi-2-pluto-v2.0 and
nh-x-pepssi-2-plutocruise-v2.0

GOOD

All Data Sets in the index Directory rateboxdefinitionplanes.lbl

GOOD

All Data Sets in the calib Directory rateboxdefinitionplanes.fit - GOOD

Plot created by SDDAS/gPlot - J. Mukherjee, et al. Generated on Sun Mar 19 17:33:40 2017.

All Data Sets in the calib Directory
hk_n1_input_20050228.lbl and hk_n1_input_20050228.tab

GOOD

All Data Sets in the calib Directory
hk_stat_input_20041016.lbl and
hk_stat_input_20041016.tab

GOOD

For calpar_columns.fmt in the calib/calpars Directory of nh-p-pepssi-3-pluto-v2.0 and nh-x-pepssi-3-plutocruise-v2.0

GOOD

All Data Sets in the document Directory codmac_level_definition.lbl and codmac_level_definitions.pdf

GOOD

All Data Sets in the document Directory
nh_mission_trajectory.lbl
nh_mission_trajectory.tab

GOOD

All Data Sets in the document Directory lunineetal1995.lbl & lunineetal1995.pdf

GOOD

All Data Sets in the document Directory
nh_fov.lbl & nh_fov.png

GOOD

All Data Sets in the document Directory nh_met2utc.lbl & nh_met2utc.tab

GOOD

All Data Sets in the document Directory payload_ssr.lbl & paload_ssr.pdf

GOOD

All Data Sets in the document Directory nh_pepssi_v110_ti.txt

GOOD

All Data Sets in the document Directory
quat_axyz_instr_to_j2k.lbl
quat_axyz_instr_to_j2k.asc

GOOD

All Data Sets in the document Directory pepssi_ssr.lbl & pepssi_ssr.pdf

GOOD

nh-p-pepssi-2-plutocruise-v2.0/document
nh-p-pepssi-3-plutocruise-v2.0/document
seq_pepssi_plutocruise.lbl
seq_pepssi_plutocruise.pdf

GOOD

nh-p-pepssi-2-pluto-v2.0/document
nh-p-pepssi-3-pluto-v2.0/document
seq_pepssi_pluto.lbl & seq_pepssi_pluto.pdf

GOOD

All Data Sets in the document Directory pep_bti.txt & pep_bti.tab

GOOD

All Data Sets in the document Directory soc_inst_icd.lbl & soc_inst_icd.pdf

GOOD for Section 11.