ABSTRACT

Understanding the dynamical behavior of plasma and energetic particles in Earth's inner magnetosphere requires carefully designed and calibrated instrumentation. The Van Allen Probes Mission included two instruments capable of measuring the proton distribution function in-situ. The Energetic Particle Composition and Thermal Plasma Suite (ECT) – Helium Oxygen, Proton, and Electron (HOPE) spectrometer (Spence et al., 2013; Funsten et al., 2013) used a top-hat detector designed to measure protons from the SC potential through 50 KeV in logarithmic energy steps. The Radiation Belt Storm Probes Ion Composition Detector (RBSPICE) instrument (Mitchell, 2013) used a time of flight and SSD detector design to measure protons from approximately 7 KeV through 650 KeV in logarithmic energy steps. Using the overlap of energy channels between the two instruments, the two instrument teams have worked diligently during the final Phase F of the mission to calibrate the observations so that a continuous distribution function can be resolved on nearly a spin-by-spin basis.

During the life of these two instruments calibration changes have been required both on-board the spacecraft as well as within the final production datasets. Manweiler (2018) provided an early report on the intercalibration factors between HOPE and RBSPICE with a nominal factor of 2 difference between the proton data sets in the energy range between 7 and 50 KeV. With the final production of each of these data sets occurring in Fall 2021, both teams have been worked together to provide for an understanding of the required intercalibration factors to be used so that a full distribution function is available on a spin-by-spin basis. In this poster we report on the final efforts to provide this calibrated set of data products between the two instruments. Details of the intercalibration calculations are presented as well as year by year L by MLT maps of the factors required to match both datasets. Finally, we report on a proposed supplementary data set that is to be made available which contains the spin-by-spin factors required to match the ECT/HOPE and RBSPICE/TOFxPH proton datasets.

Funsten, H.O., et al. Space Sci Rev 179, 2013

Manweiler, J. W., et al., 2018 GEM Summer Workshop.

Mitchell, D.G., et al., Space Sci. Rev., 179, 2013

Spence, H.E., et al. Space Sci Rev 179, 2013

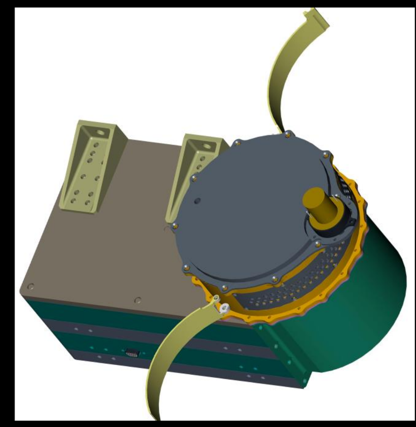
SH35D-2113: Van Allen Probes instrument calibration results for the Energy particle, Composition, and Thermal plasma suite (ECT) – Helium Oxygen Proton and Electron (HOPE) detector and the Radiation Belt Storm Probes Ion Composition Instrument (RBSPICE) energetic particle detectors

Jerry W. Manweiler – Fundamental Technologies, LLC, Lawrence, KS

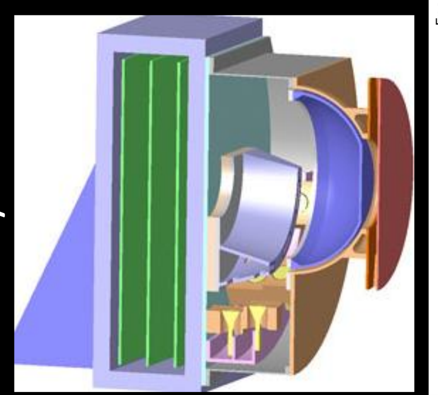
Christopher Mouikis – University New Hampshire, Durham, NH
Alex Boyd – The Aerospace Corporation, El Segundo, CA
Brian Larsen – Los Alamos National Laboratory, Los Alamos, NM
Ruth Skoug – Los Alamos National Laboratory, Los Alamos, NM
Matina Gkioulidou, John Hopkins Applied Physics Laboratory, Laurel, MD
Louis Lanzerotti, New Jersey Institute of Technology, Newark, NJ
Harlan Spence, University New Hampshire, Durham, NH
Geoffrey Reeves, Los Alamos National Laboratory, Los Alamos, NM
Andrew Gerrard, New Jersey Institute of Technology, Newark, NJ

Conclusions

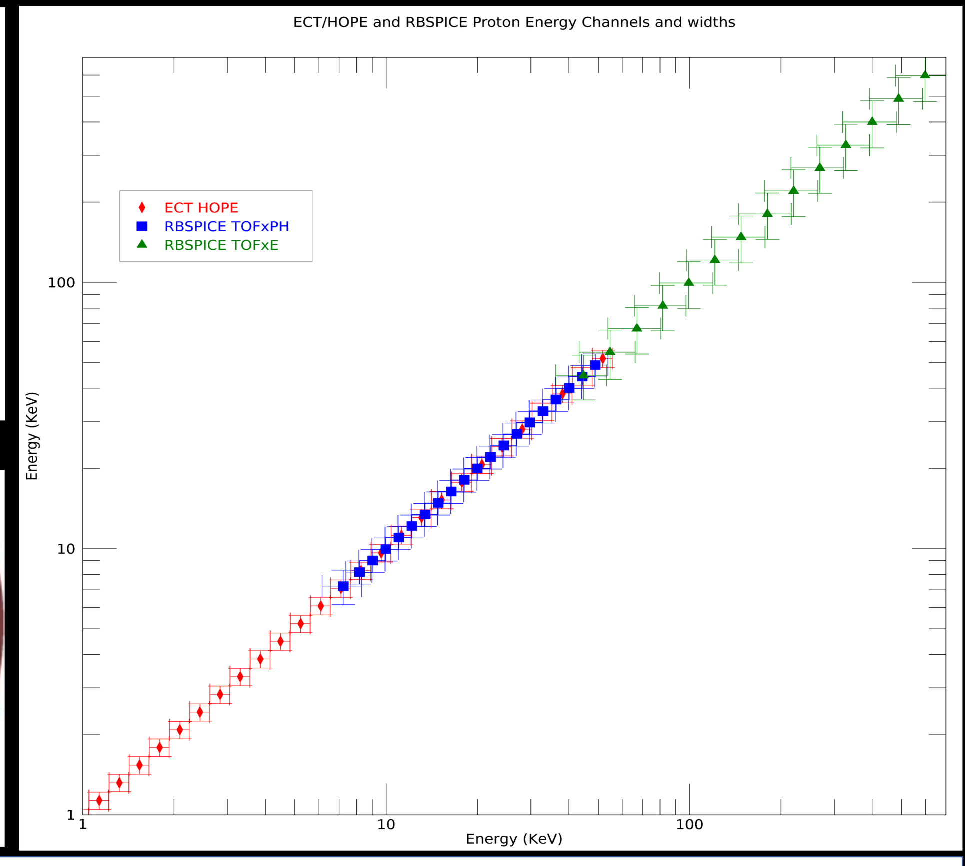
Intercalibration between the Van Allen Probes ECT/HOPE and RBSPICE Instruments requires a systematic analysis of the spectra on an accumulation by accumulation basis. The Ratio (R_{HR}) as described in this poster and in Manweiler, et. al (2022) provides a mechanism for the calculation of an appropriate calibration factor allowing for an unprecedented nearly spin by spin record calibration between the two particle instruments. **A new intercalibration data set** has been proposed to provide the key instrument calibration data that will be available at FTECS.com and SPDF (2022).



RBSPICE



ECT/HOPE

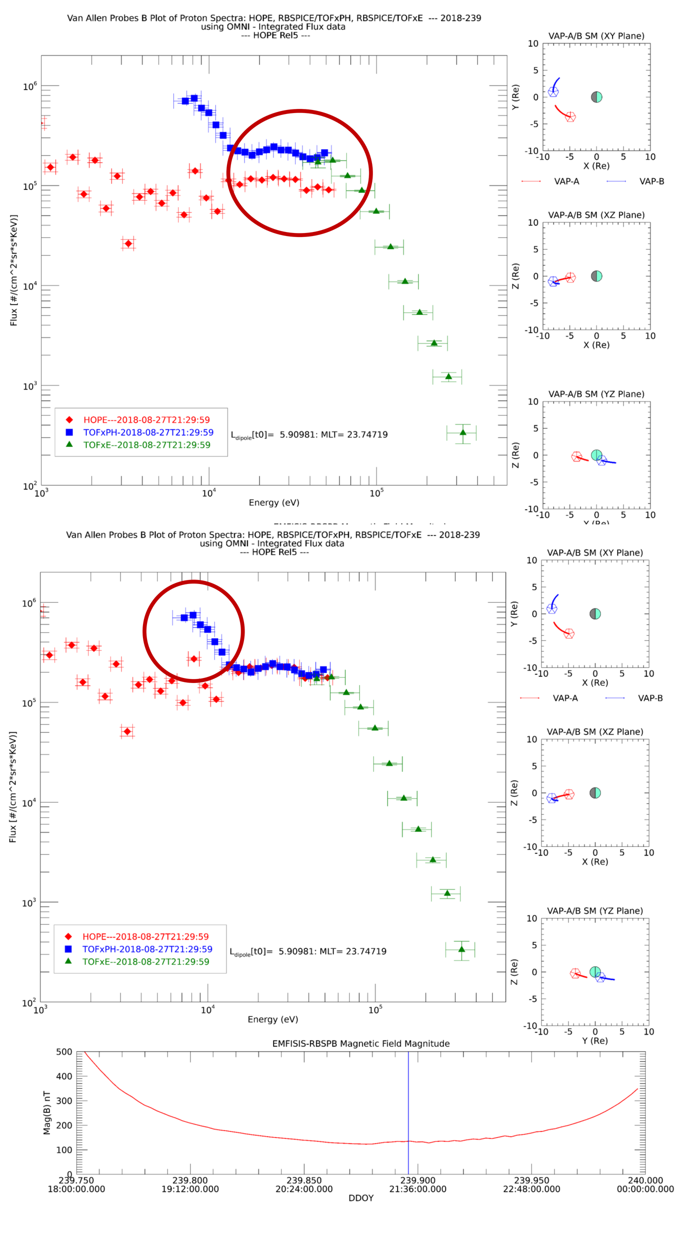


The Problem: Part 1

Spectra derived from a combination of HOPE Proton, RBSPICE/TOFxPH Proton, and RBSPICE/TOFxE Proton data **reveal** a **systematic mismatch** in **flux** between overlapping energy channels in the upper energies of HOPE and RBSPICE/TOFxPH detectors. The plot on the upper right of this poster shows the KeV and above energy channels for each of the three proton data products. The highest energies of the HOPE and TOFxPH energy channels have reasonable equivalency such that we expect the observed HOPE proton flux to have similar values to the RBSPICE/TOFxPH proton flux. The plot below on the left shows a sample spectra from 2018-08-27T21:29:59 with the measured flux color coded the same as in the energy plot. There is a clear mismatch between HOPE proton flux (red) and RBSPICE/TOFxPH proton flux (blue) as shown in the red circled area. RBSPICE/TOFxPH proton flux reasonably matches the RBSPICE/TOFxE proton flux lowest energies (green).

When HOPE proton flux is multiplied by ~2 then the spectra becomes consistent across all three sets of energy channels as seen in the right plot.

Note: The "Cobra" like head on the left of the blue RBSPICE/TOFxPH data rises above the HOPE data is an artifact. This effect occurs when energy equivalent oxygen ions are identified as protons by the RBSPICE TOFxPH logic. These "accidentals" in the lowest RBSPICE/TOFxPH proton energy channels do not always exist in the data but when the Cobra lifts its head then it is a clear indication of "accidentals".



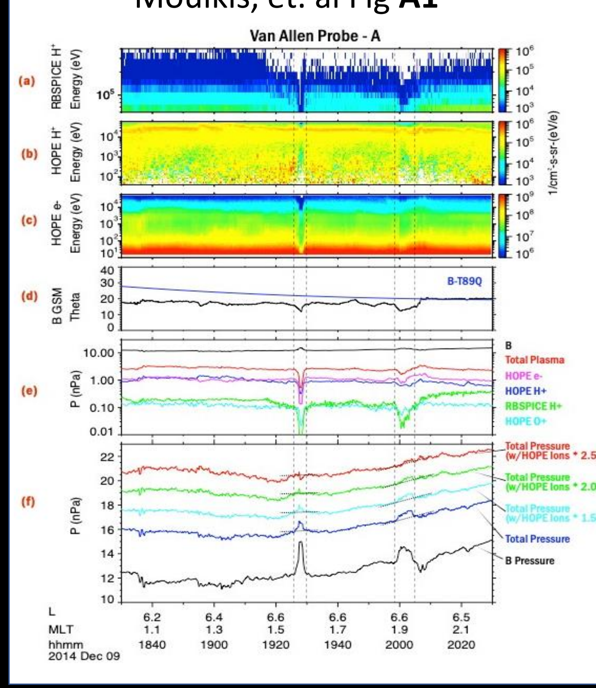
The Problem: Part 2

Mouikis, et. al (2019) (in appendix A) examined specific quiet times where a relatively small "bump" or "dip" occurs in the measured magnetic field. Assuming adiabatic conditions, the total pressure ($P_T = P_B + P_K$) should remain a constant in that changes in the magnetic field pressure (P_B) have corresponding changes in total kinetic particle pressure (P_k). In this paper, the pressure balance test as originally described in Kistler et al. (2013), was used to examine three different times with small scale semi-isolated events. The left figure is figure A1 from the Mouikis paper for two small pressure events that occur on 2014-12-09. Each event displays **drop-outs** in the higher energy particles of the **proton and electron particle distributions** – top three panels (RBSPICE protons, HOPE protons, and HOPE electrons) **reflecting** a **decrease** in the **particle kinetic pressure**. At the **same time**, there is an **increase** in the **magnetic field** and associated increase in the **magnetic field pressure** (black curve in bottom panel).

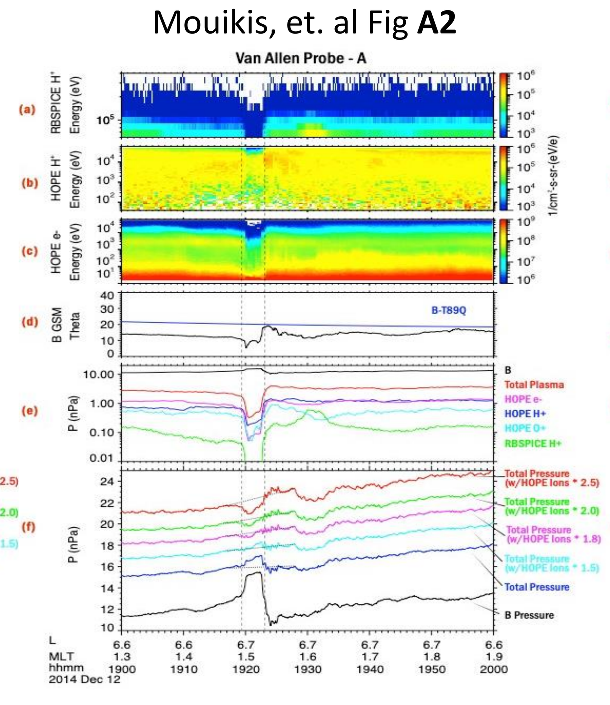
The **total pressure** is also **calculated** with an **alternative** set of curves each **utilizing** a **multiplicative factor** for the **HOPE flux** for an alternative **total pressure** curves. The total pressure becomes nearly constant when the multiplicative factor is approximately 2.0.

The central figure (A2 from Mouikis) for 2014-12-12 and the right figure (A3 from Mouikis) for 2013-07-06. Each displays a set of **calculated total pressure curves** for **various factors** used to **multiply the HOPE proton flux data**. **Total pressure** remains a **constant** value when the **factor** used is somewhere **between 1.5 and 2.5**.

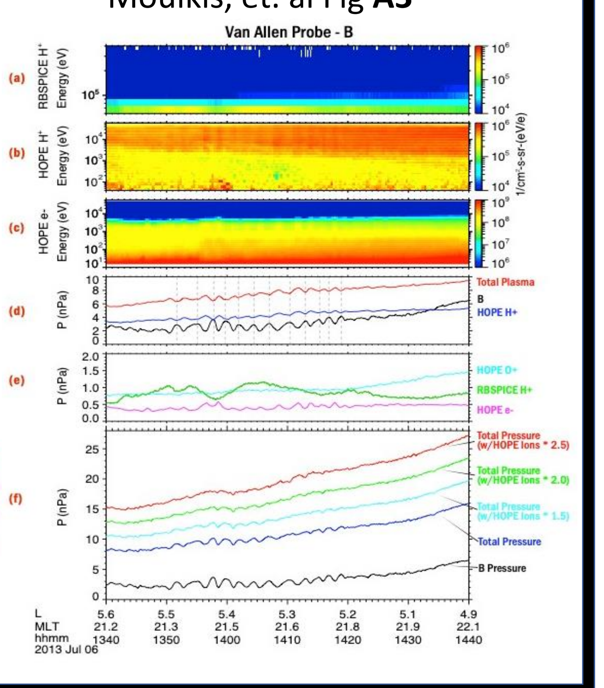
Mouikis, et. al Fig **A1**



Mouikis, et. al Fig **A2**



Mouikis, et. al Fig **A3**



References

- Funsten H.O. et al. (2013) Helium, Oxygen, Proton, and Electron (HOPE) Mass Spectrometer for the Radiation Belt Storm Probes Mission. In: Fox N., Burch J.L. (eds) The Van Allen Probes Mission. Springer, Boston, MA. https://doi.org/10.1007/978-1-4899-7433-4_13
- Manweiler, J.W., A. Breneman, J. Niehof, B. Larsen, et. al, Science of the Van Allen Probes Operations Centers, Space Science Reviews, In Review, 2022.
- Mitchell, D.G., Lanzerotti, L.J., Kim, C.K. et al. Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE). Space Sci Rev 179, 263–308 (2013). https://doi.org/10.1007/s11214-013-9965-x
- Mouikis, C. G., Bingham, S. T., Kistler, L. M., Farrugia, C. J., Spence, H. E., Reeves, G. D., et al. (2019). The storm-time ring current response to ICMEs and CIRs using Van Allen Probe Observations. Journal of Geophysical Research: Space Physics, 124, 9017– 9039. https://doi.org/10.1029/2019JA026695
- Spence H.E. et al. (2013) Science Goals and Overview of the Radiation Belt Storm Probes (RBSP) Energetic Particle, Composition, and Thermal Plasma (ECT) Suite on NASA's Van Allen Probes Mission. In: Fox N., Burch J.L. (eds) The Van Allen Probes Mission. Springer, Boston, MA. https://doi.org/10.1007/978-1-4899-7433-4_10

The Solution: Part 1 – HOPE Efficiencies

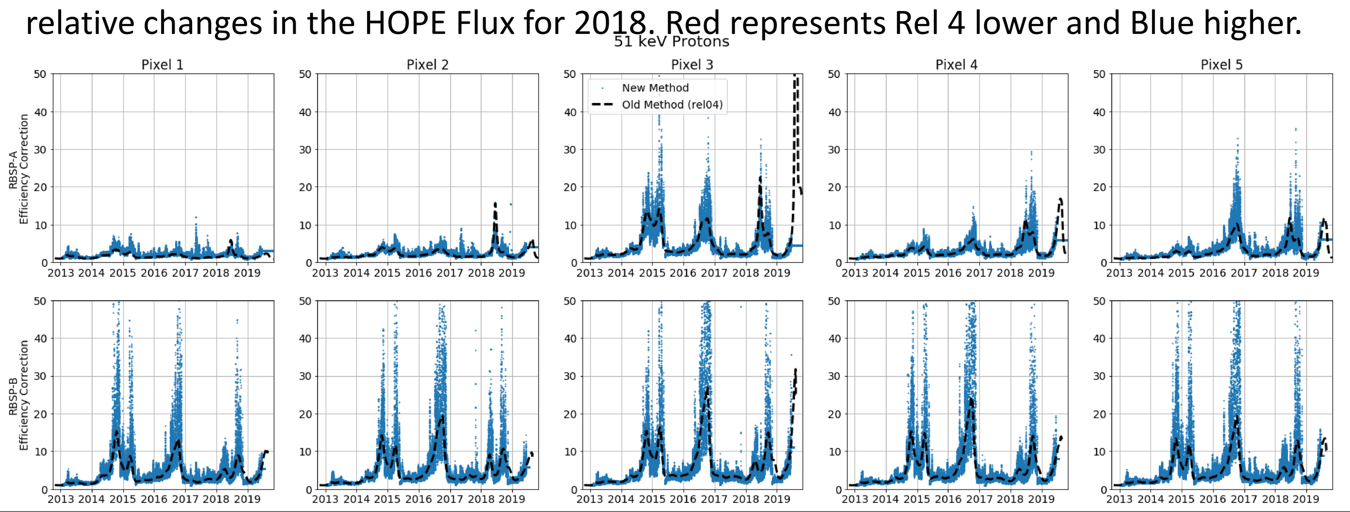
The HOPE data includes a correction for the time-dependent instrument detection efficiency. This correction is based on the measured singles rates in each of the 5 HOPE pixels. The ECT/HOPE team recently made significant updates to the efficiency correction algorithm to account for high frequency changes.

Old Method (rel04)	New Method
Computed Daily	**Computed Hourly**
Single correction value for all energies	**Correction computed independently for each energy***
Smoothed based 21-day running average	**Low count times (<3600 counts) smoothed based on dynamic window**

*Ions with Energy < 200 eV use the correction at 200 eV

The new correction generally increases the HOPE fluxes, giving better agreement with RBSPICE proton measurements and MagEIS electron measurements.

The figures below shows the Old Method correction factors (black dashes) compared to the new method (blue dots) where it is easy to see that the new method is much more responsive to magnetospheric variations. The L x MLT plots to the right display the relative changes in the HOPE Flux for 2018. Red represents Rel 4 lower and Blue higher.



The Solution: Part 2 – The Algorithm:

Align HOPE OMNI and RBSPICE OMNI proton spectra

Manweiler, et. al (2022-in review) developed an **algorithm** to **calculate** a Spin by spin **Factor** for **HOPE OMNI proton spectra** upper energy channels and **RBSPICE TOFxPH** upper energy channels.

1) $< f_{HOPE} > = \sum_{i=68}^{i=70} E_i / 3$:

$E_{range} = [30.3\ \text{KeV} - 47.8\ \text{KeV}]$

$\Delta E = 17.5\ KeV$

$E_{68} = 32.7 \pm 2.5\ KeV$

$E_{69} = 38.1 \pm 2.8\ KeV$

$E_{70} = 44.4 \pm 2.5\ KeV$

2) $< f_{RBSPICE_{TOFxPH}} > = \sum_{i=15}^{i=18} E_i / 4$

$E_{range} = [31.2\ \text{KeV} - 46.5\ \text{KeV}]$

$\Delta E = 15.3\ KeV$

$E_{15} = 32.9 \pm 3.3\ KeV$

$E_{16} = 36.3 \pm 3.6\ KeV$

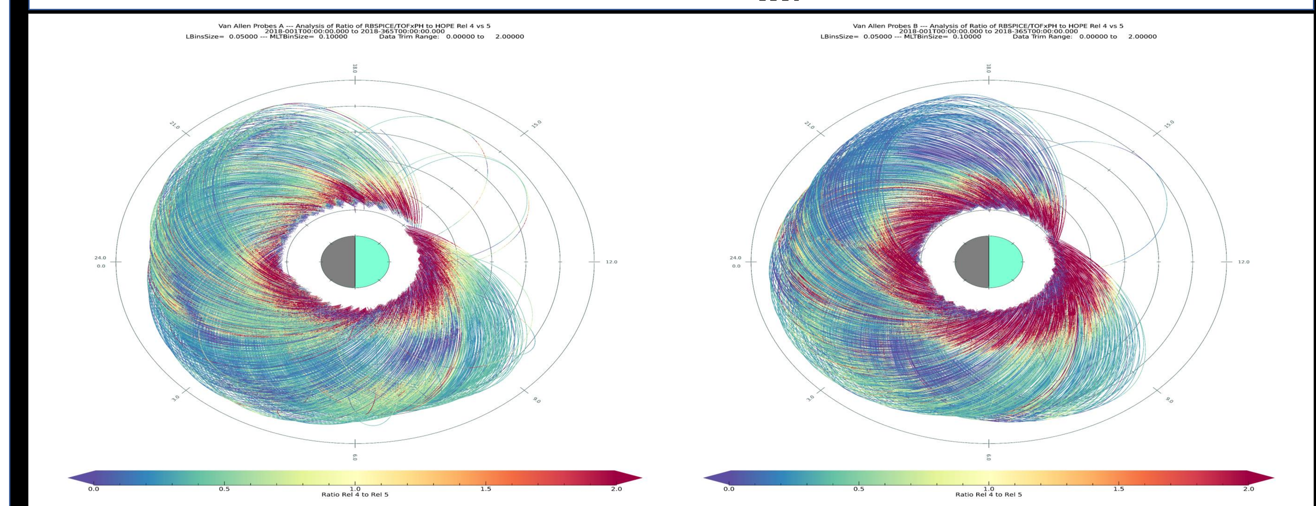
$E_{17} = 40.1 \pm 3.9\ KeV$

$E_{18} = 44.3 \pm 4.4\ KeV$

3) $R_{HR} = \frac{<f_{RBSPICE_{tofxph}}>}{<f_{HOPE}>}$

4) $f_{HOPE_{ch}} = R_{HR} * f_{HOPE_{ch}}$

This algorithm was used to modify spectra in the image on the right of Problem: Part 1 with a calculated factor: $R_{HR} = 1.94$



The Results

The algorithm was applied to the HOPE (rel5) and RBSPICE proton data for the entire Van Allen Probes Mission. It is seen that the factor R_{HR} varies significantly throughout the mission. While some variations are systematic such as perigee passes other variations have no obvious explanation. The **leftmost figure** below displays a time series of the calculated R_{HR} factors before, during, and after the Aug 27, 2018 storm. The **middle frame** shows SYM-H clearly indicating a storm occurring during 2018-238. The R_{HR} factors show almost no dependency upon storm onset but show strong orbital dependencies. The bottom left figure is an example histograms of R_{HR} at midnight (2014-2015). The Inset plot identifies the peaks of the histogram for each particular $\Delta L = 0.5$ along with errors derived from width of the peak. These peaks have been extracted and plotted into the panels on the right (3x3 – Top Right A and Bottom Right B). These plots display the variation of the factor over time. The first panel in each 3x3 set is the overall value of R_{HR} independent of L. The rest of the 8 panels displays R_{HR} as a function of L with $\Delta L = 0.5$. These plots display the strong time dependence of the factor over the life of the mission.