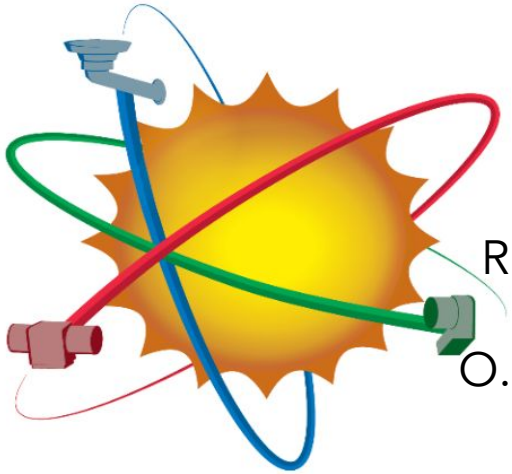
As seen by Parker Solar Probe: The role of wave-particle interactions across generalized discontinuities in the inner heliosphere



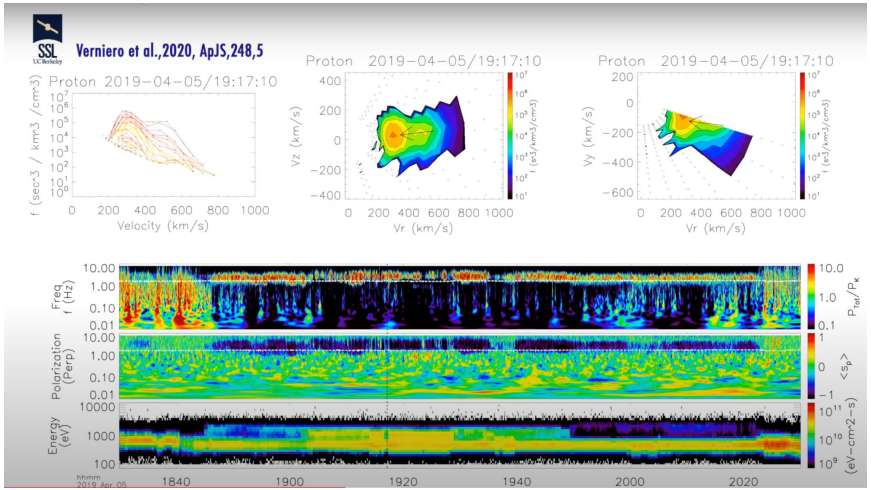
J. L. Verniero[1], T. D. Phan, A. Brosius, A. Szabo, D. E. Larson, R. Livi,P. L. Whittlesey, M. D. McManus, A. Rahmati, O. Romeo, K. W. Paulson, P. S. Pyakurel, C. Cattell, T. A. Bowen, M. Velli, O. Panasenco, B. Lavraud, M. L. Stevens, J. C. Kasper, S. D. Bale, *SWEAP/FIELDS Team*

[1]Code 672,
NASA Goddard Space Flight Center
jaye.l.verniero@nasa.gov
(they/them)

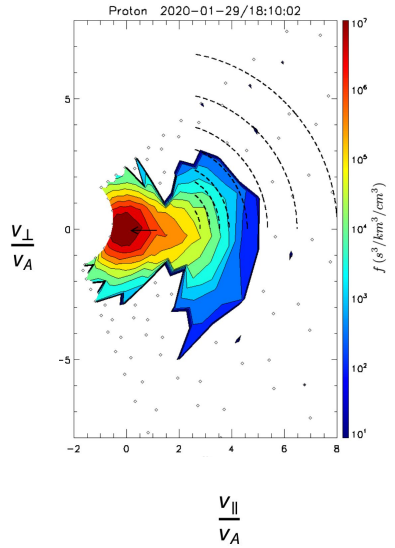
SHINE Workshop
2022 Jun 28

Work supported by NASA contract NNN06AA01C.

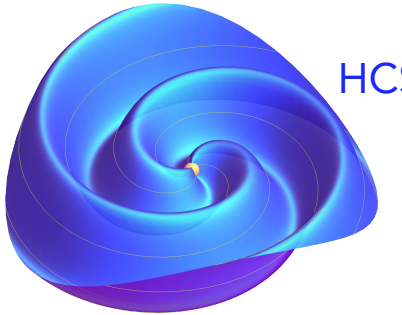
Proton and electron beams (strahls)



Verniero et al., 2020, ApJS, 248, 5
https://doi.org/10.3847/1538-4365/ab86af



[Verniero *et al*. 2022 et al 2022 ApJ 924 112
DOI: 10.3847/1538-4357/ac36d5]

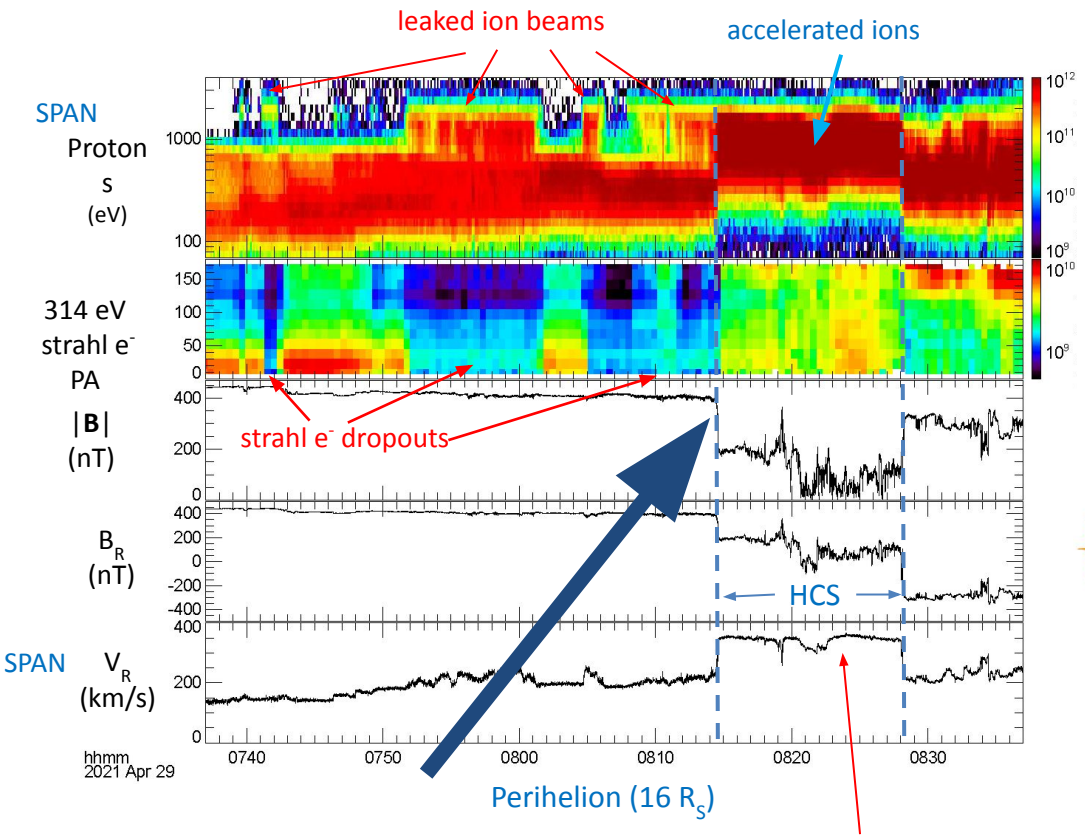


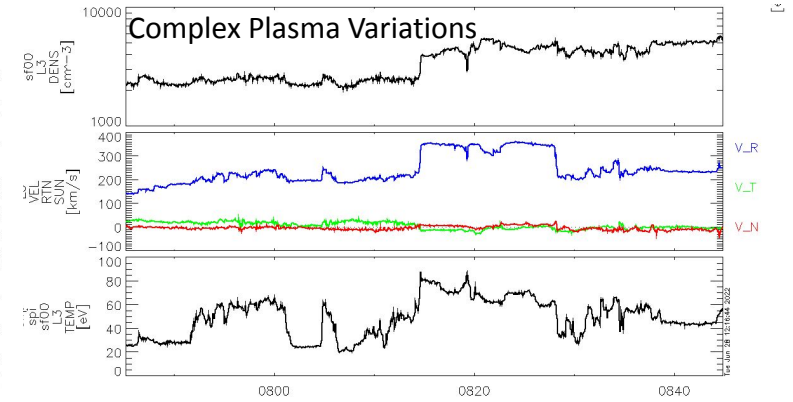
HCS

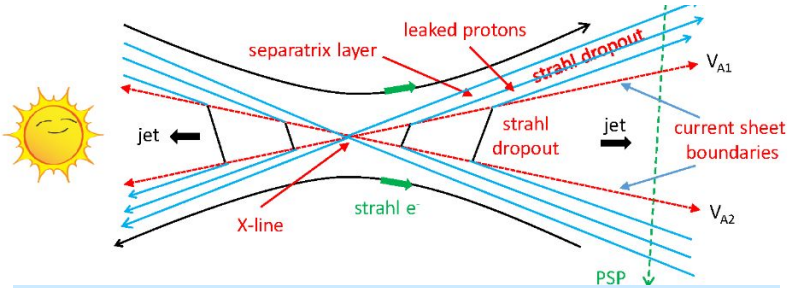
Both the proton and electron VDFs participate in ion-scale and electron-scale wave-particle instabilities, respectively

The evolution of the particle VDFs appear to depend on location from Heliospheric Current Sheet (HCS)

PSP Encounter 08 HCS at 16 R_s: Reconnection producing high-energy proton beams observed around the HCS





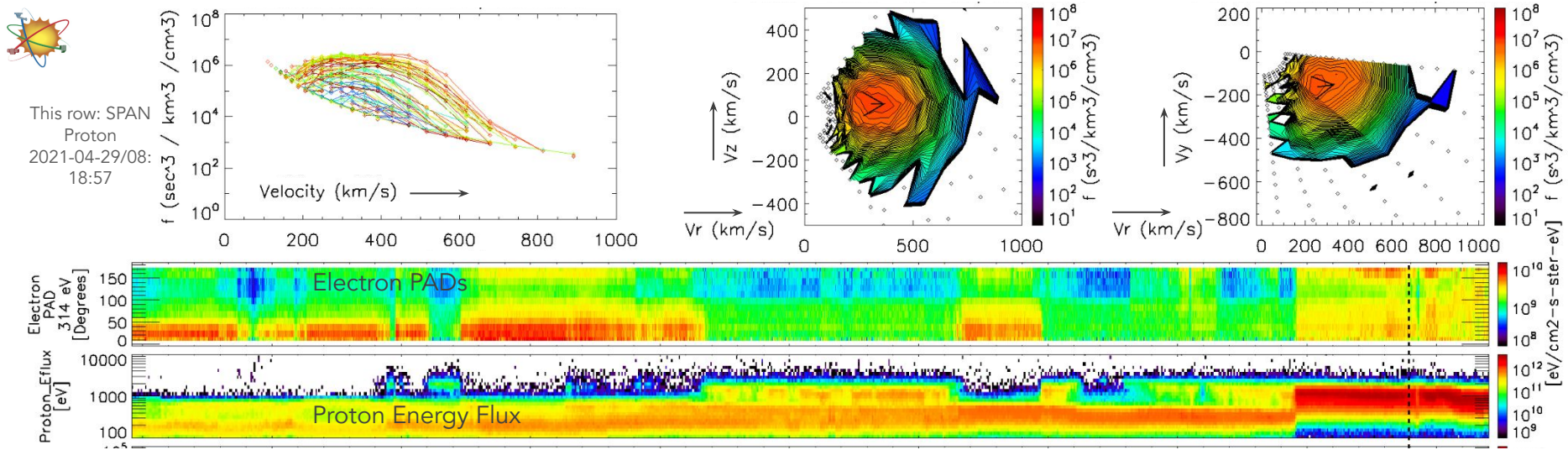


"sharp slow-shock-like exhaust edge (Petschek, 1964) "

Evidence for proton beams originating from the HCS exhaust: (1) Same upper energy; (2) Energy dispersion; (3) Strahl electron dropouts implying disconnection from Sun

Phan, T. D. et al. 2022 https://doi.org/10.1029/2021GL096986

PSP Encounter 08 HCS at 16 R_s: reconnection



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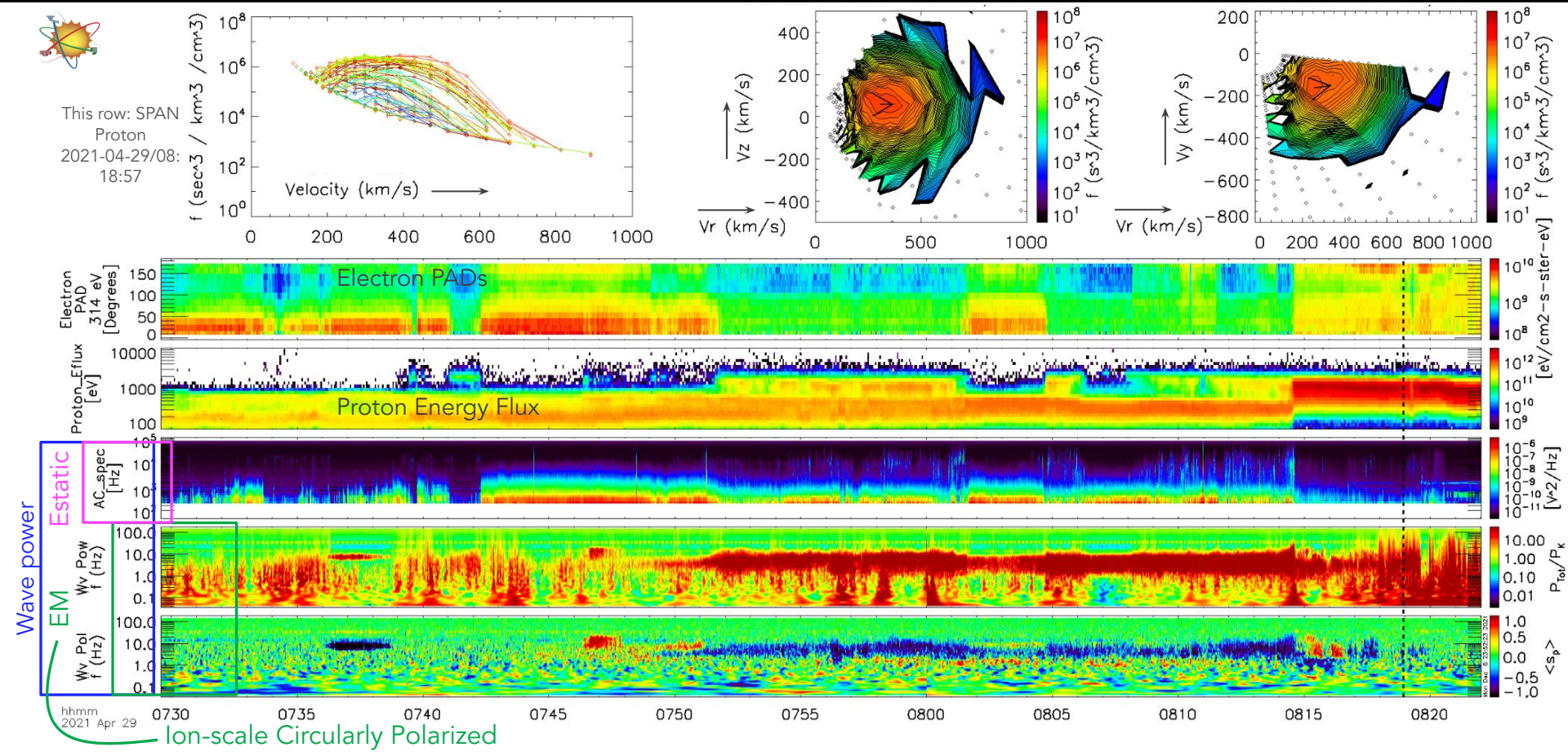

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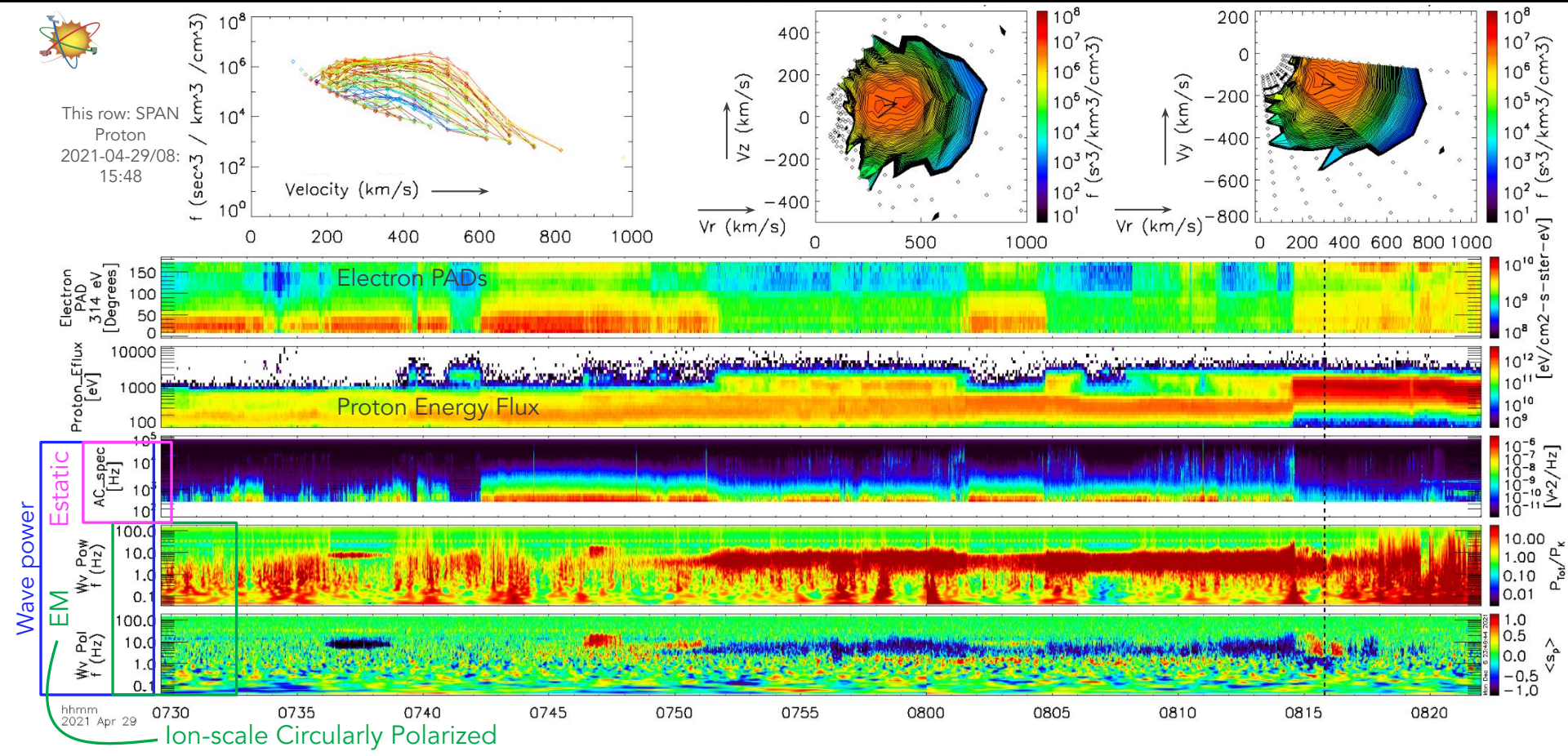

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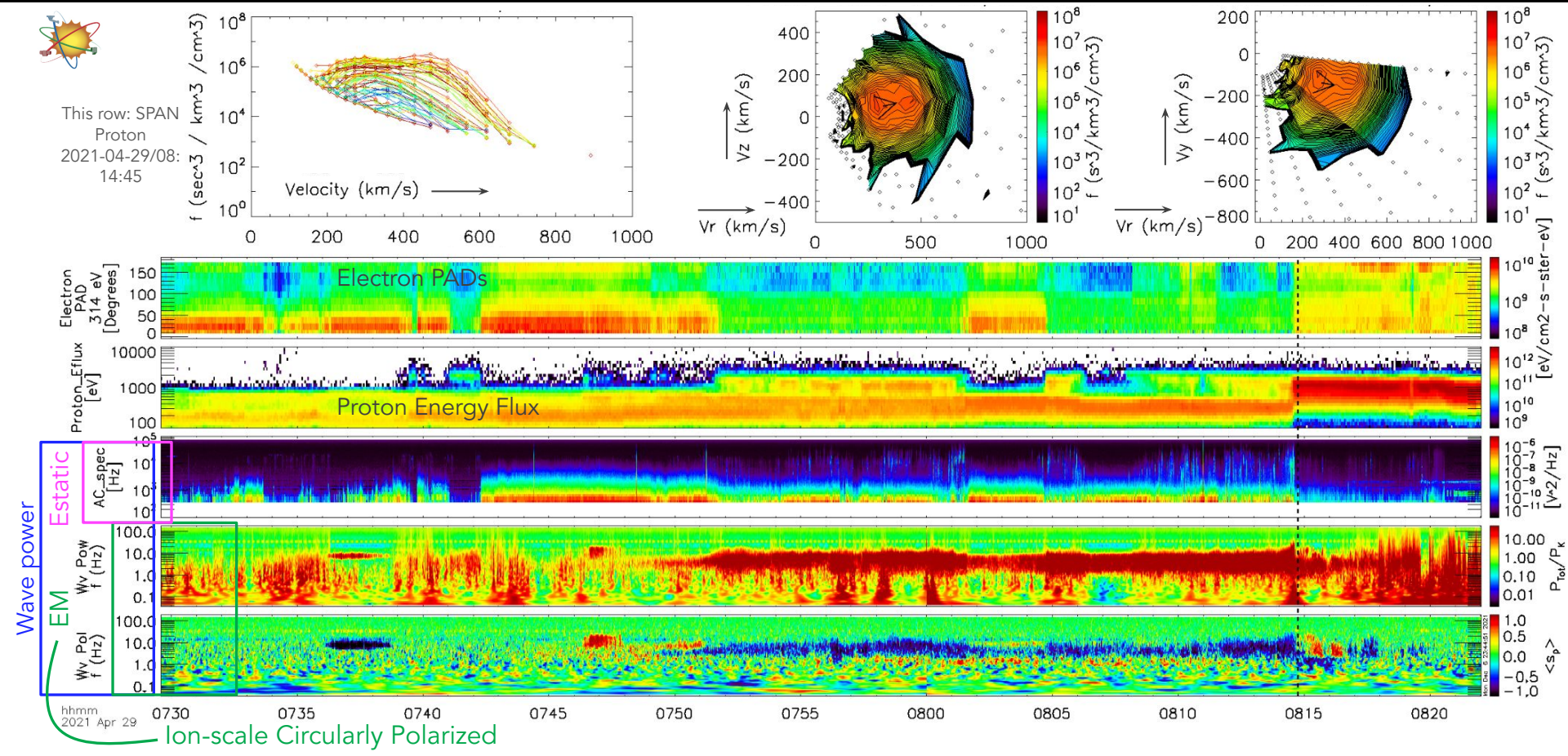

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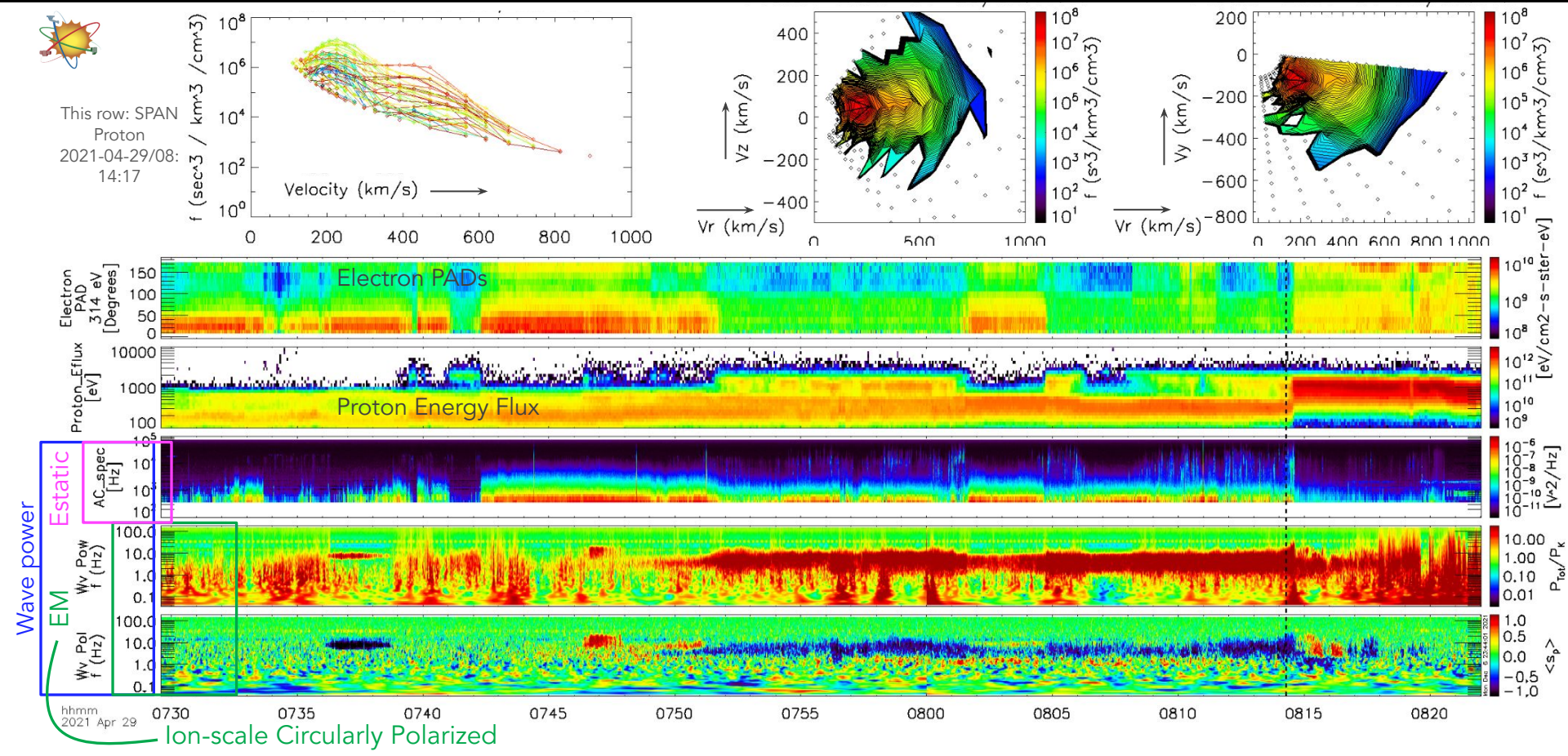

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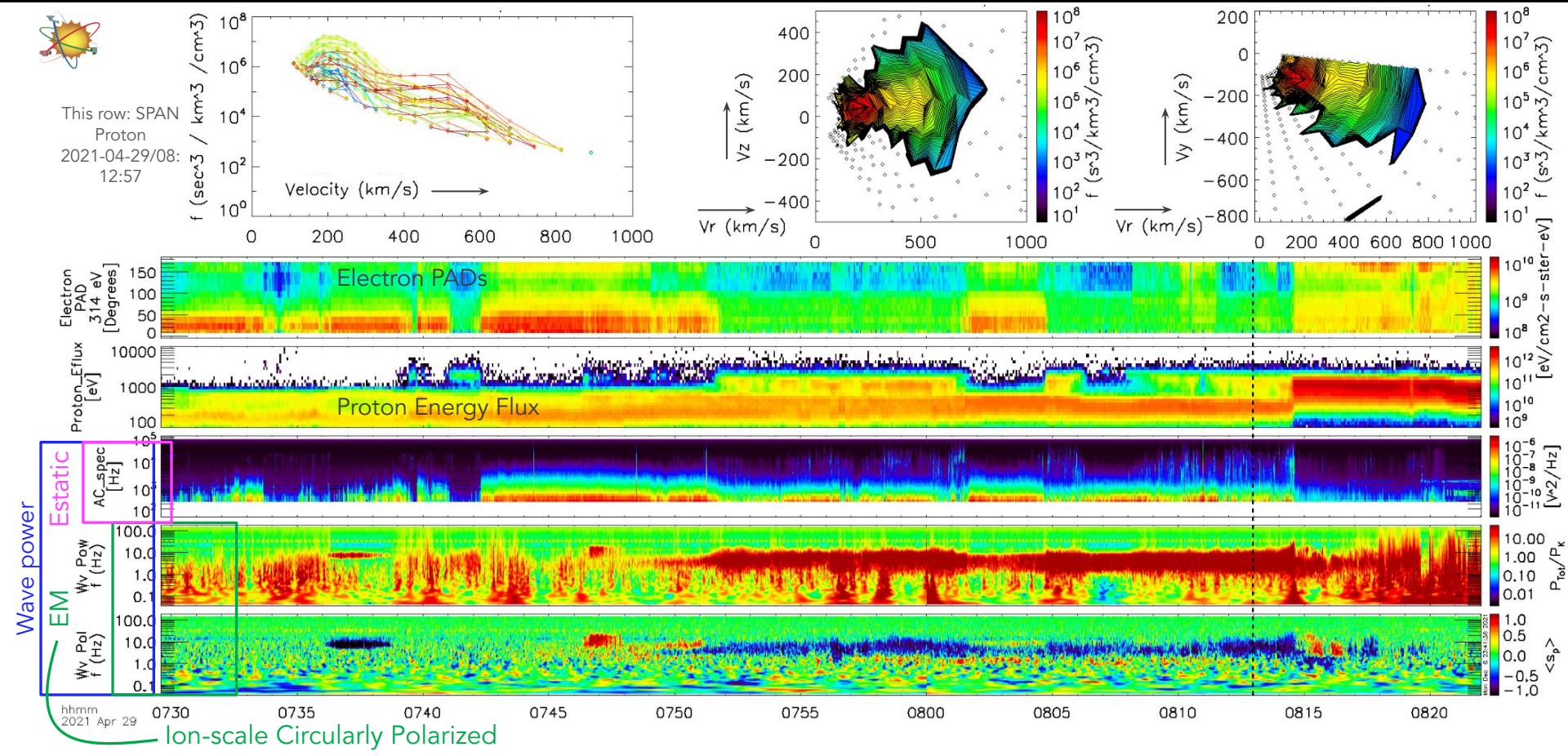

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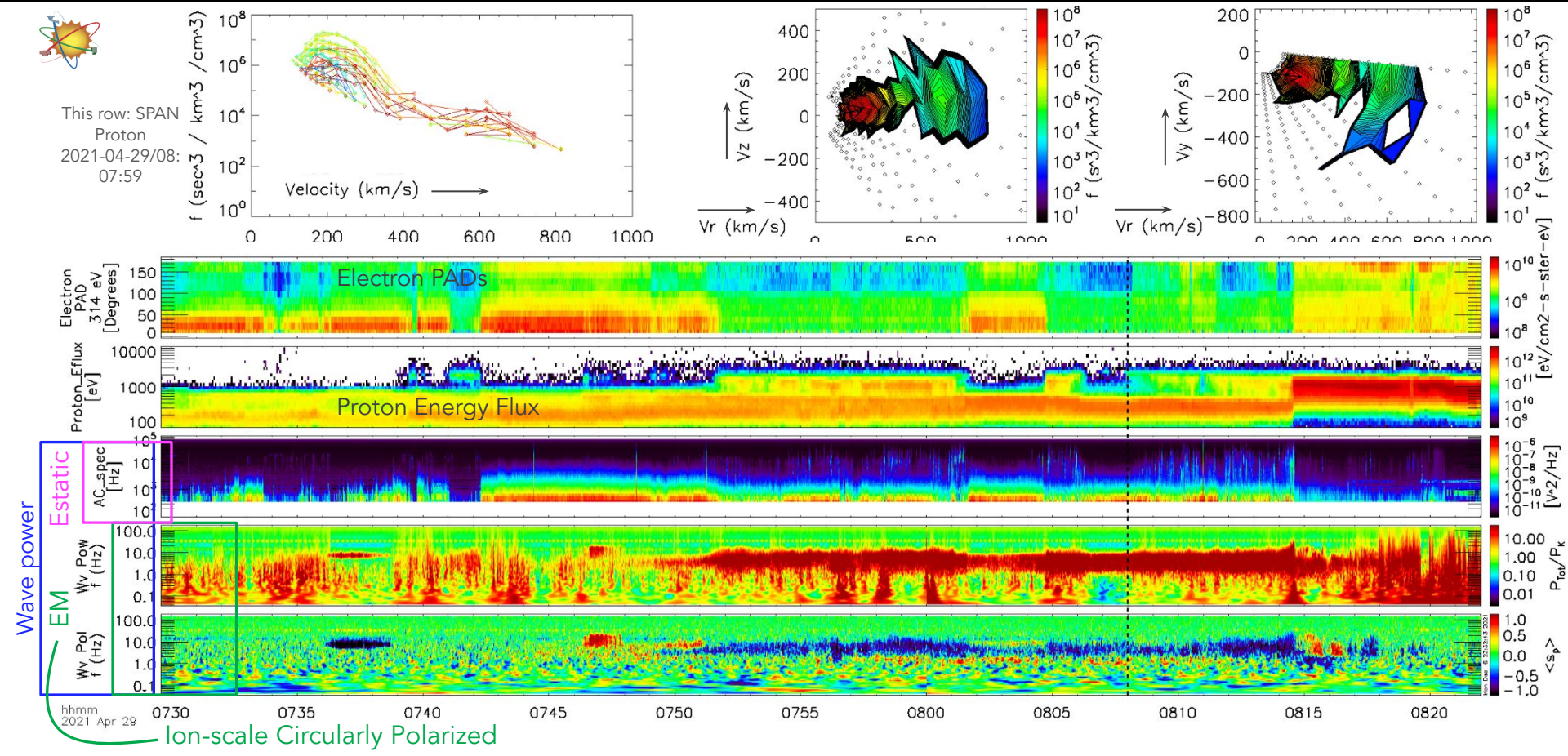

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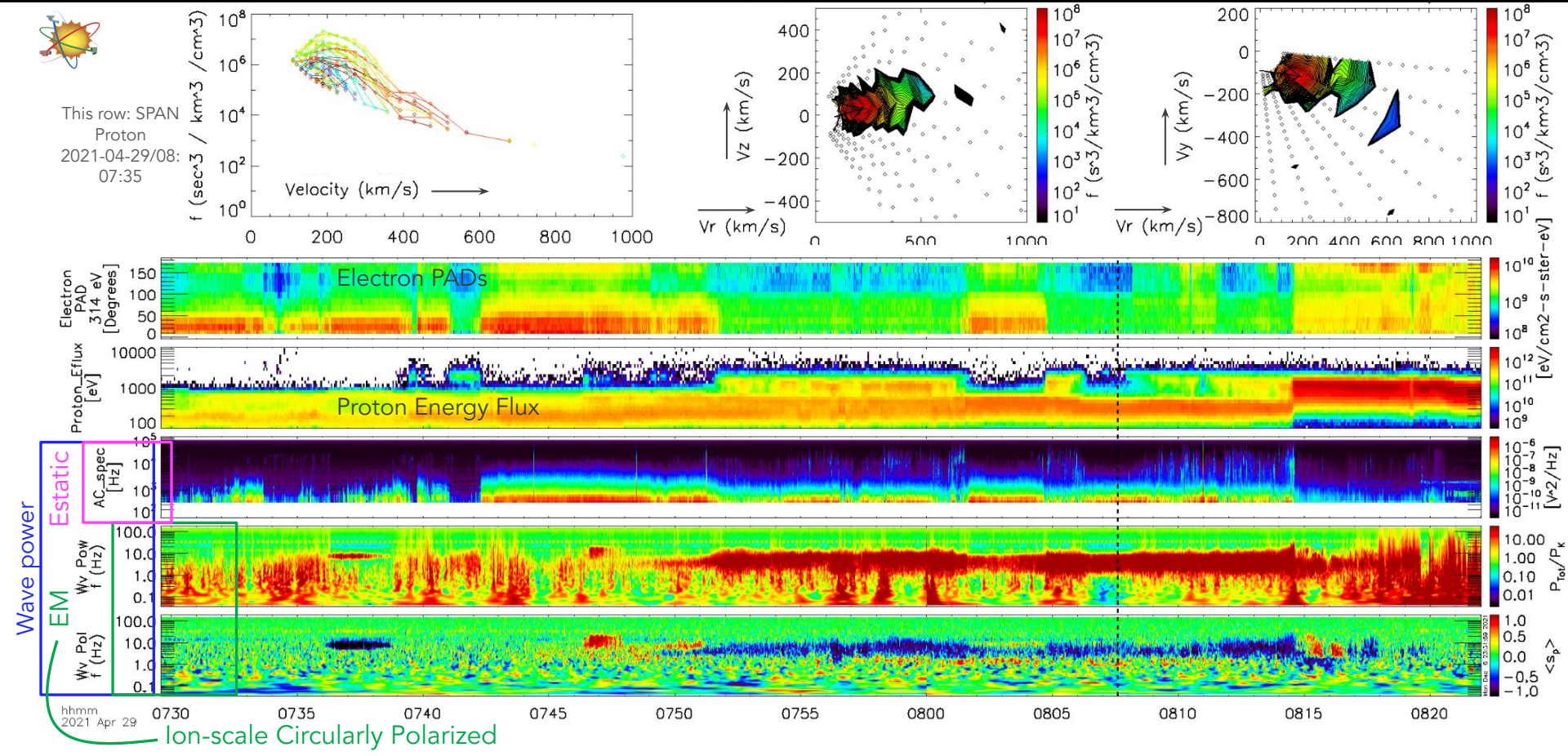

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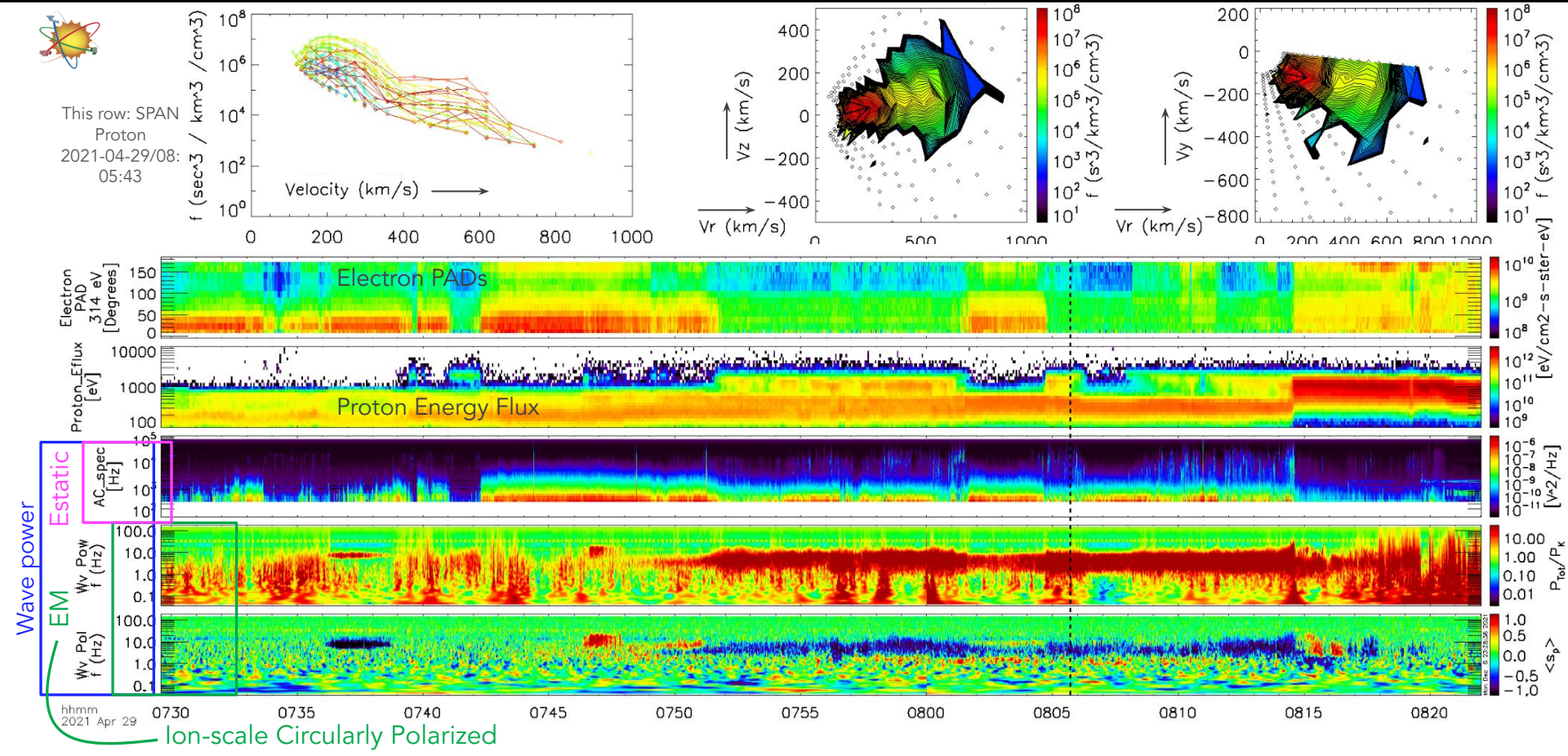

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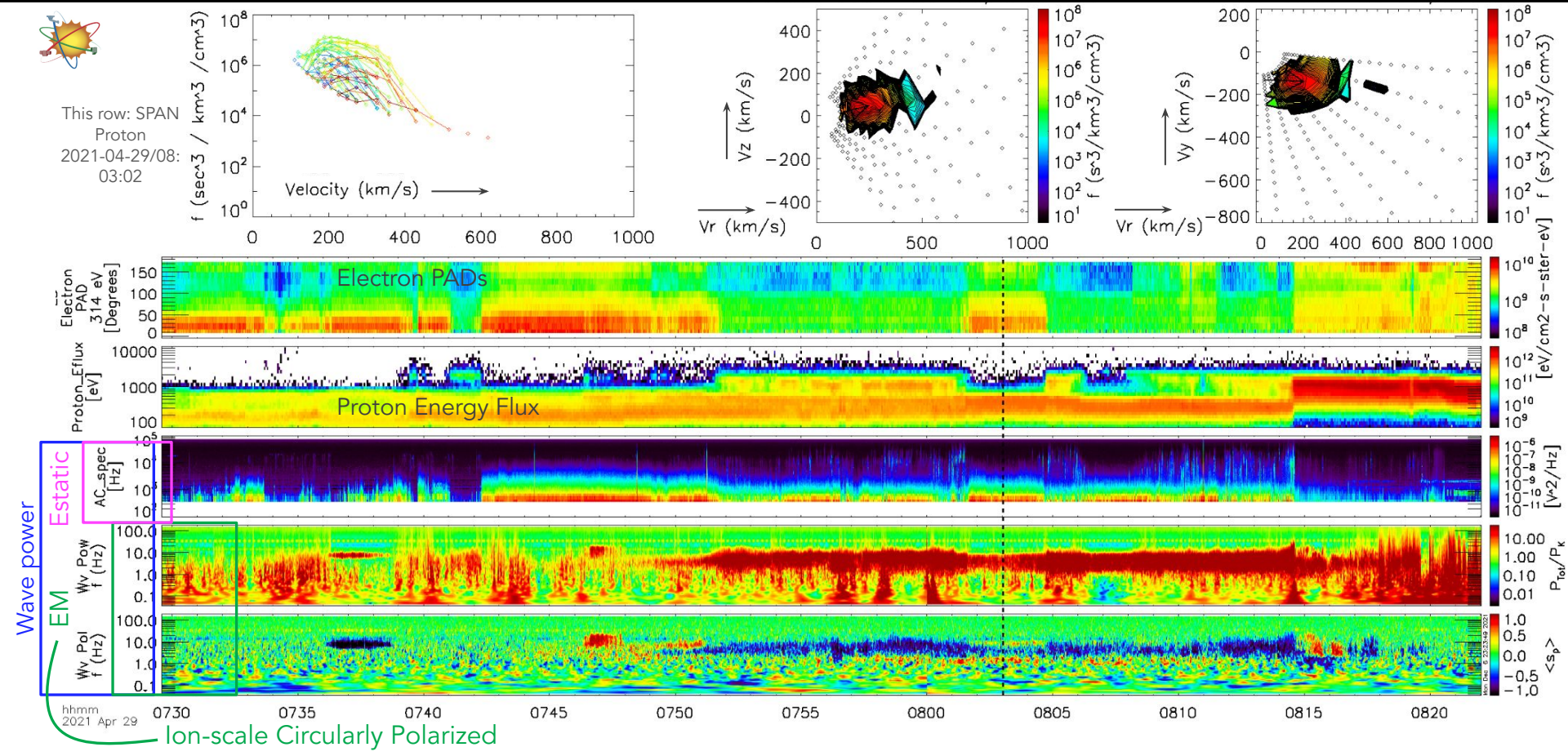

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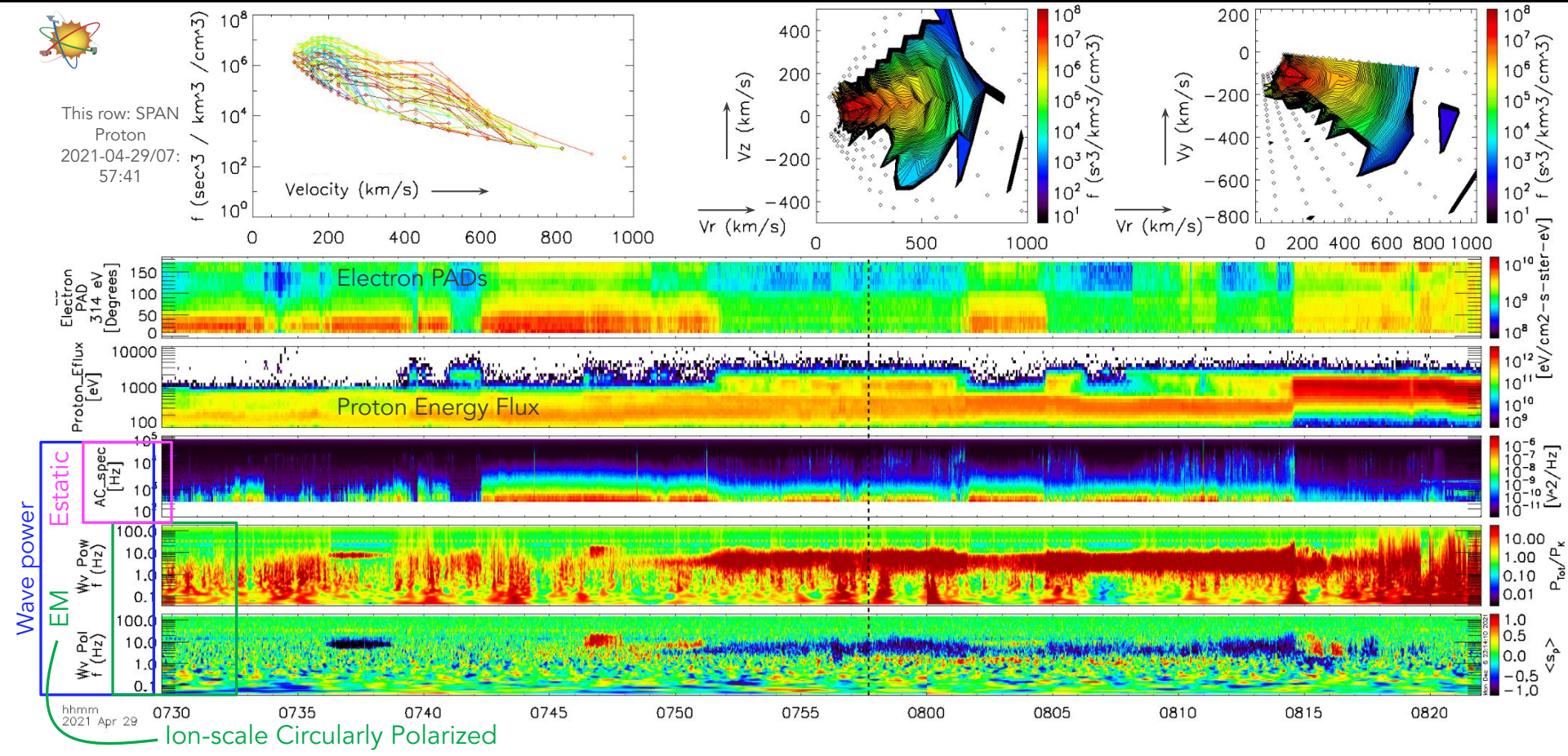


PSP Encounter 08 HCS: key results

314eV electron PADs (strahl)

Proton Energy Flux

AC Power

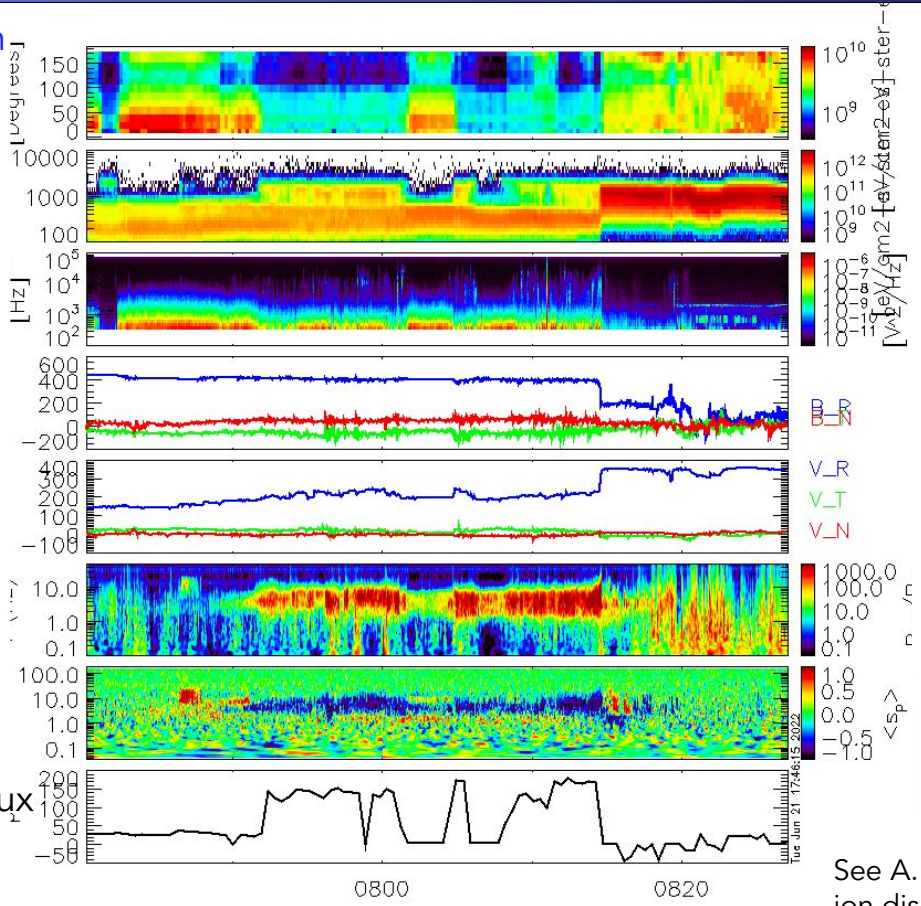
B (RTN)

V (RTN)

Ion Wave Power

Polarization

Proton Heat Flux



Proton Heat Flux

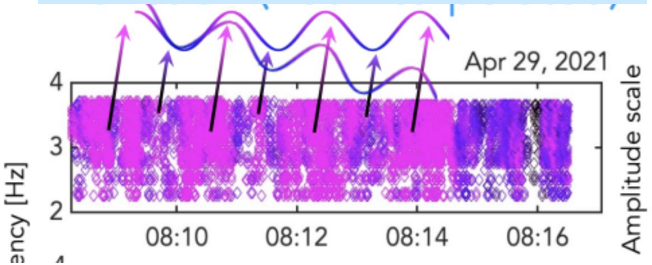
(derived from preliminary proton core-beam maxwellian fitting)

correlates with:

Ion-scale wave activity

Electron Strahl Dropout

Electrostatic wave activity



See A. Brosius's Poster #196 for further characterization of ion dispersion with novel adaptive MVA algorithm

Shocking Questions/Revelations from E8 Reconnection Event

- What exactly is a “slow shock-like exhaust” ? What is the difference between “shock-like” and “shock”?
- “Death” of slow shocks turn into Tangential Discontinuities close to HCS crossings. Candidates for magnetic holes?
- How do we exactly determine whether it is a shock, given that the RK conditions require the assumption of steady state? Observed temperature anisotropy makes this a more nuanced problem.
- How much of a role is this particular shock mediating for observed cross-scale energy transfer? Is the shock affecting the HCS dynamics and instabilities?
- PSP may be revealing a new regime to study shocks - Shocks driven by shear flows around the HCS, or other generalized discontinuities such as the Alfven Critical Surface

E10: Beams Breaking Boundaries

Alfven Crossing

B (RTN)

V (RTN)

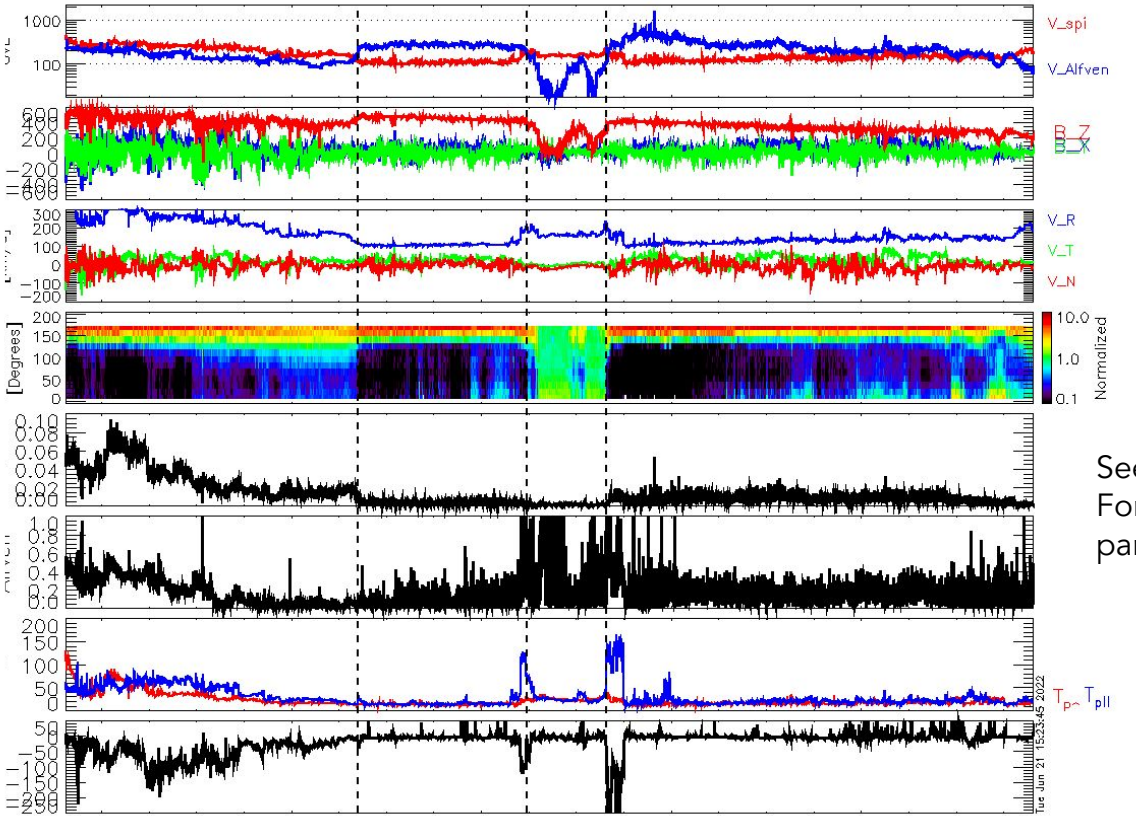
Electron PAD (normalized)

NA/NP

|a-p drift|/vA

Proton Temp Anisotropy

Proton Heat Flux



See Mostafavi et al 2022 (in prep) For more information about alpha particles close to the Sun

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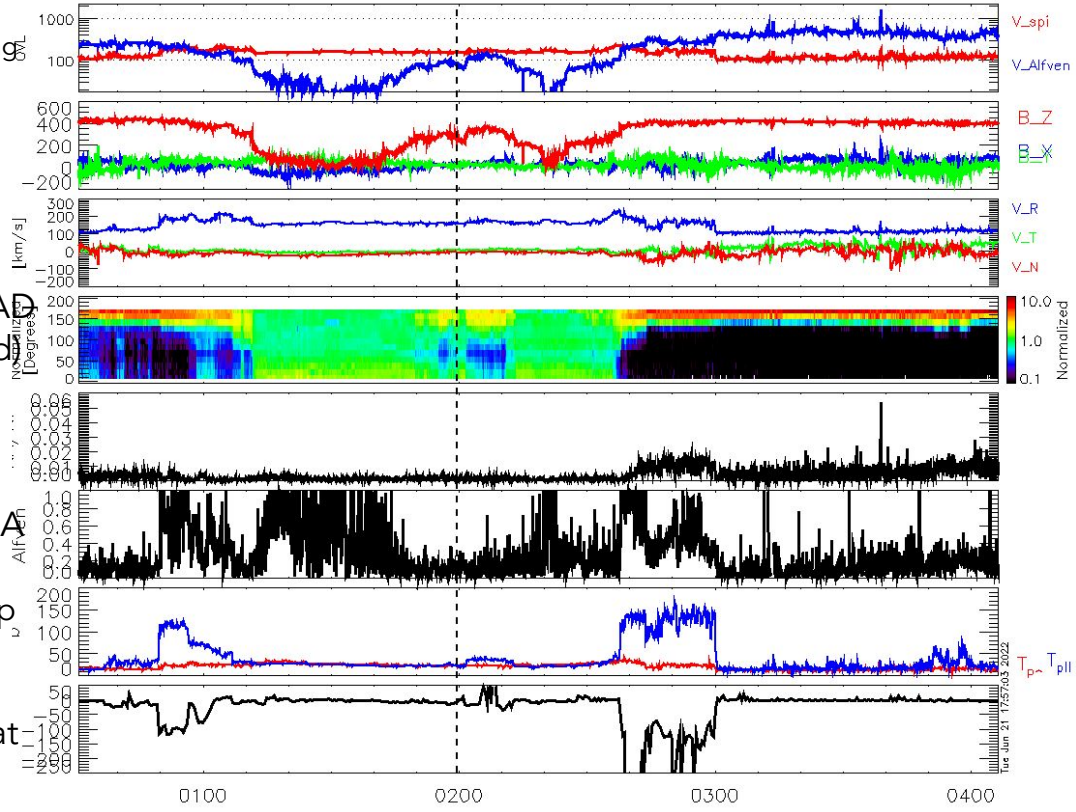
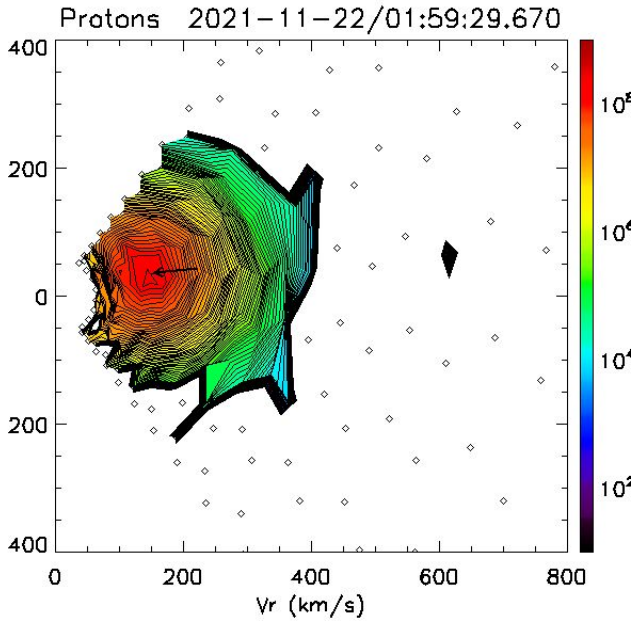
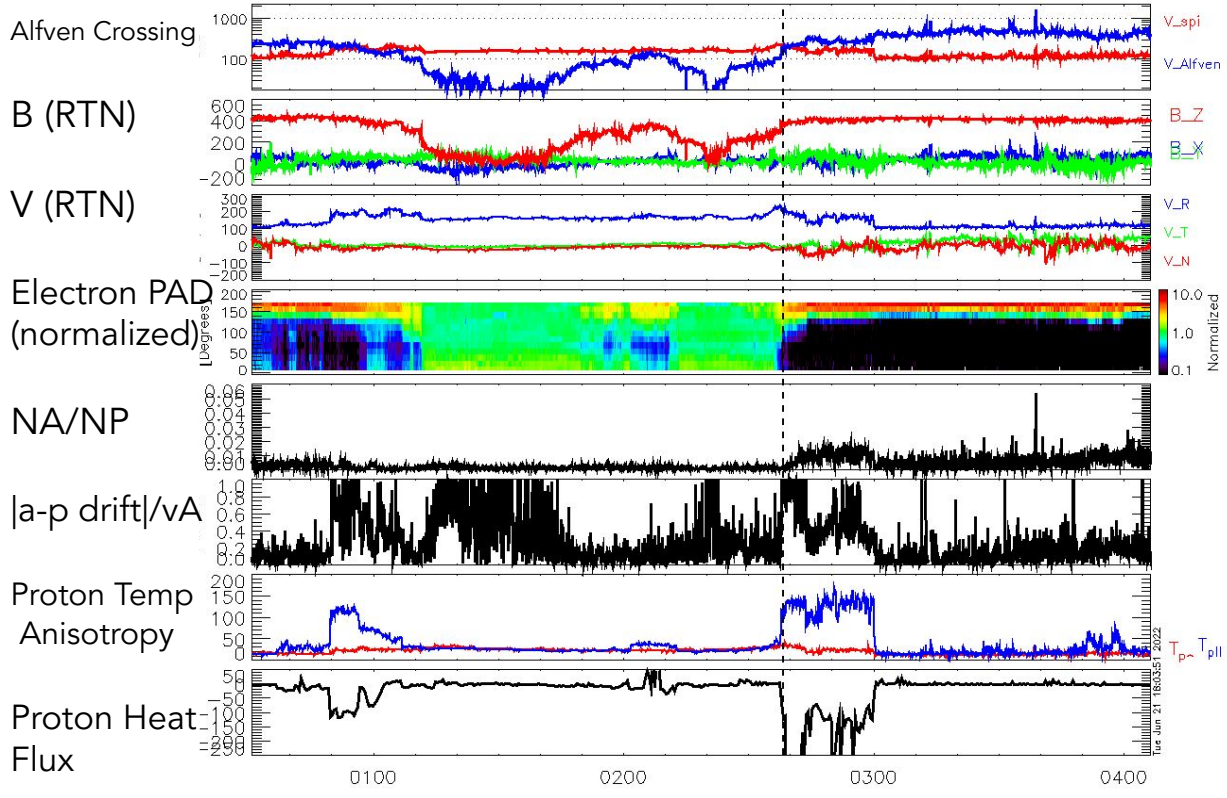
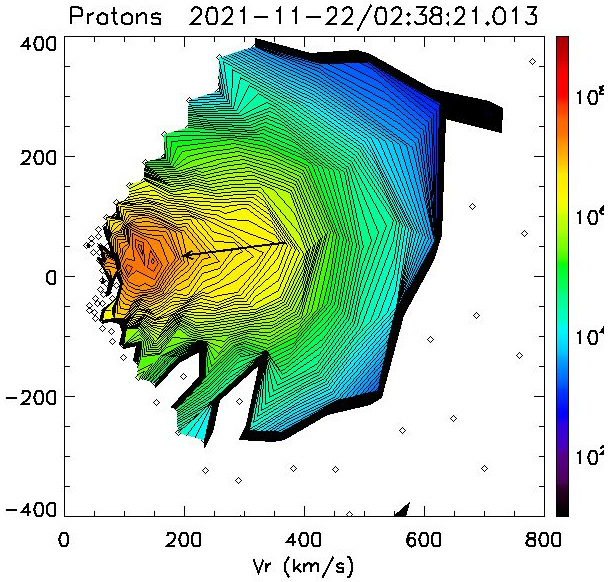




E10:Beams Breaking Boundaries





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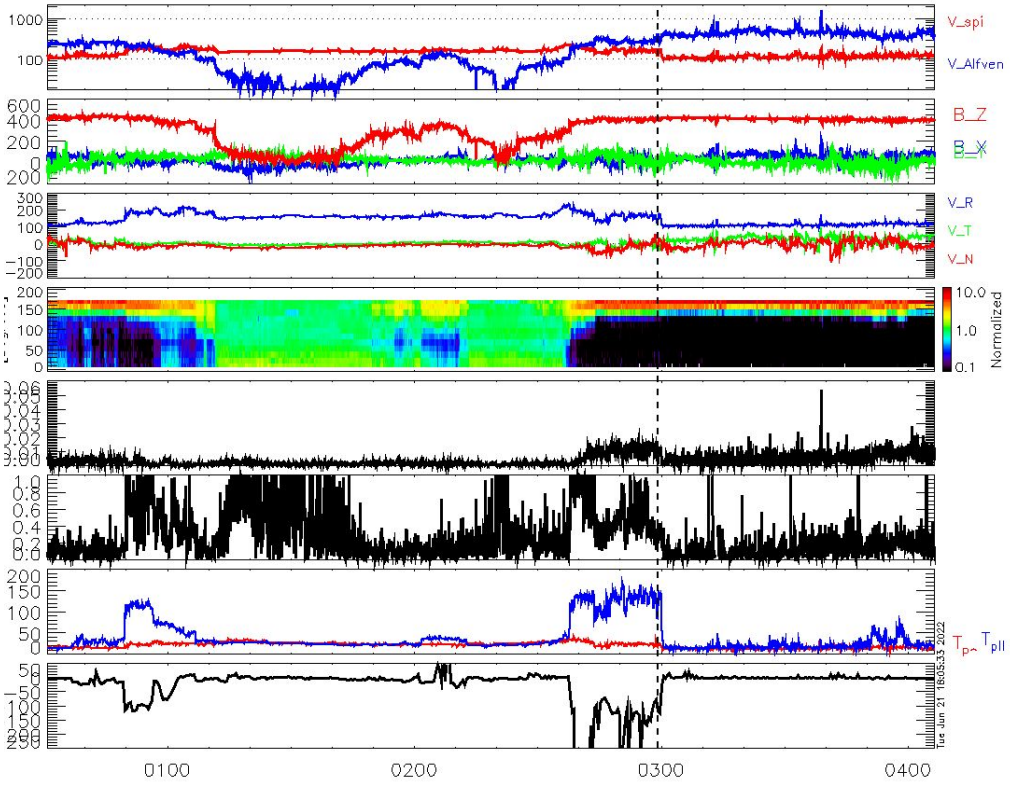

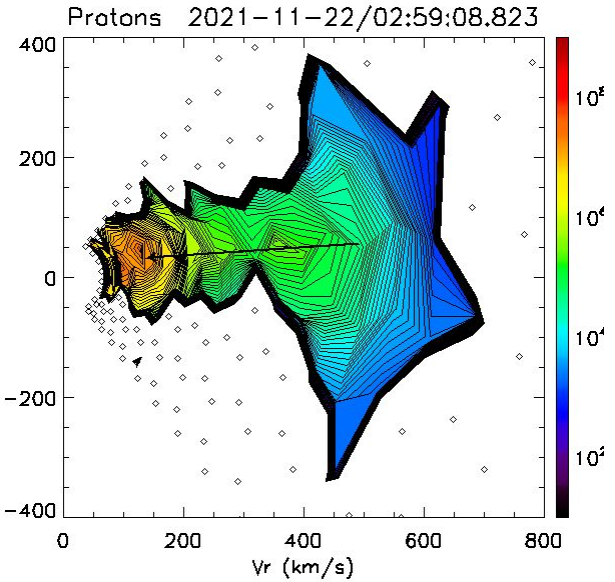

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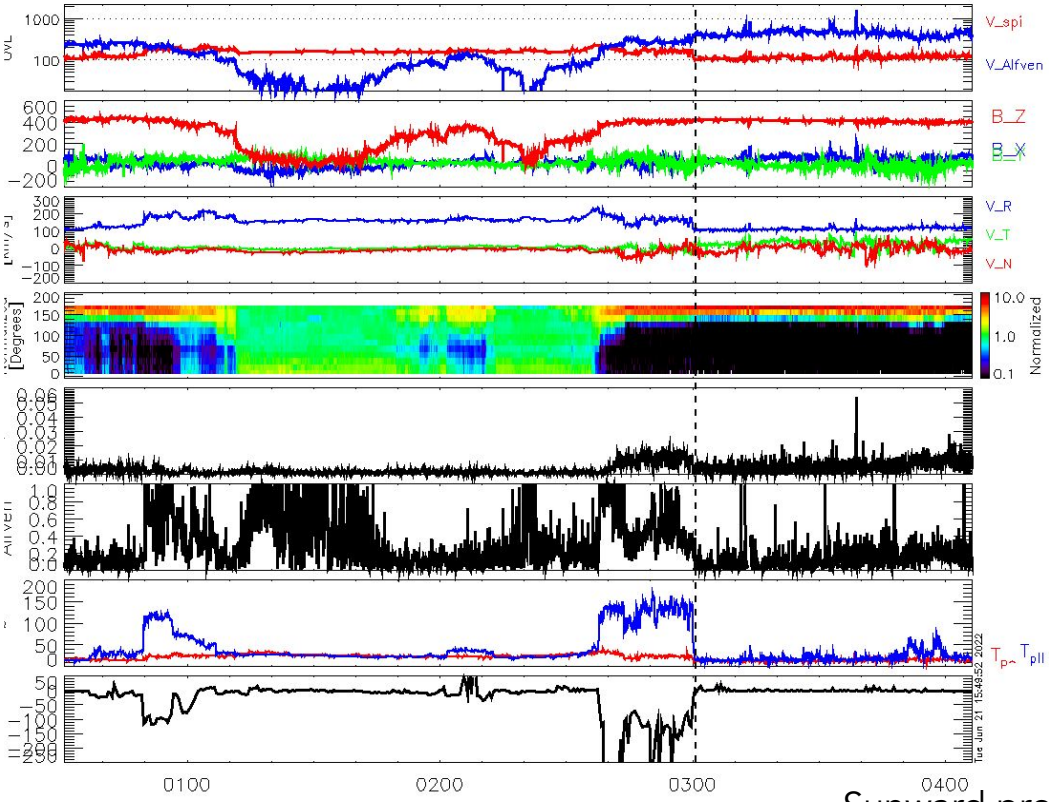
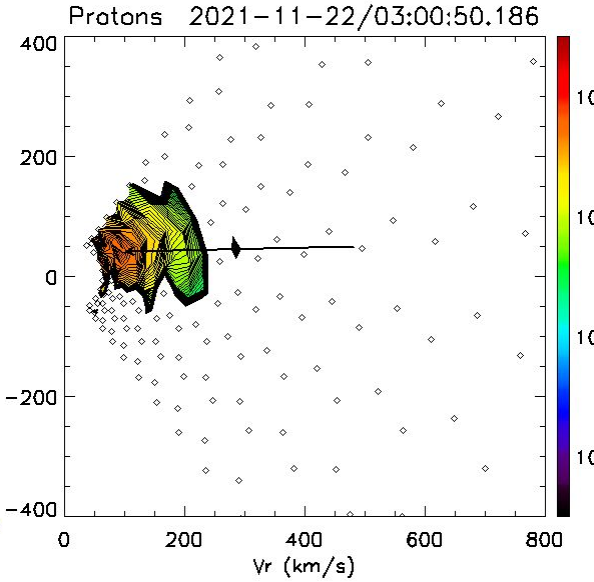




Sunward propagating ion-scale wave event found here? Paulson et al 2022 (in prep)

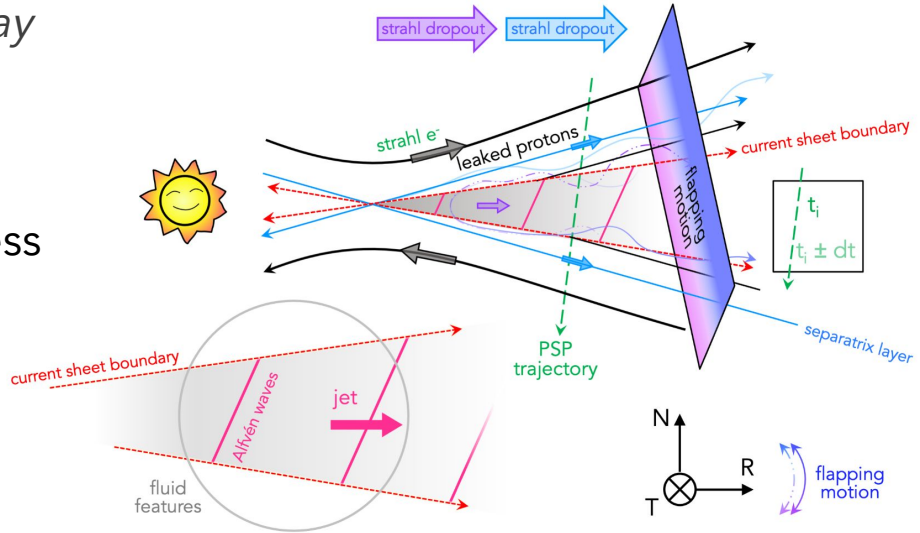
Alfven Critical Surface (E10, 15 Rs) and Information Flow

- At the Alfven surface, streams transition from supersonic to subsonic
- What happens when we cross in and out of multiple boundaries of the ACS? When we transition back out from subsonic region to supersonic, do we expect to see large shocking signatures? If so, what are they? What type of discontinuities should we be looking for?
- The proton beams are moving faster than the Alfven speed during these crossings. What is the implication for the effect of this extra stream changing direction of information flow? When crossing the Alfven Surface, the plasma doesn't know it's going through it, only knows its expanding. Once plasma is behind region, can't "hear" waves. →Traffic analogy to a green light?

Mysteries and opportunities await us

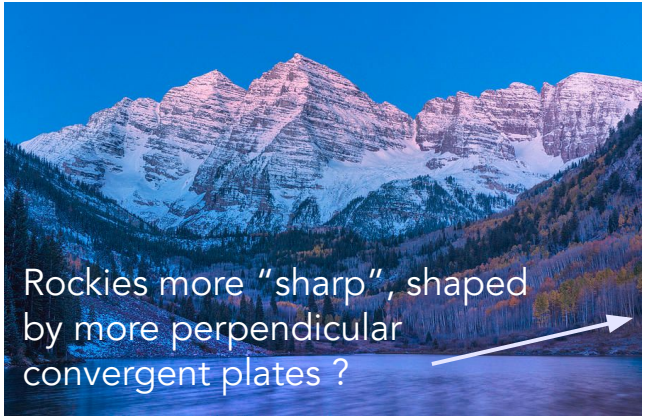
Associated HCS and Alfven Critical Point dynamics appear similar to the *magnetotail and other planetary environments where shocks play a role in energy transfer*

PSP data provides ample opportunities to assess the universality of shocks across the *ocean of plasma regimes...*

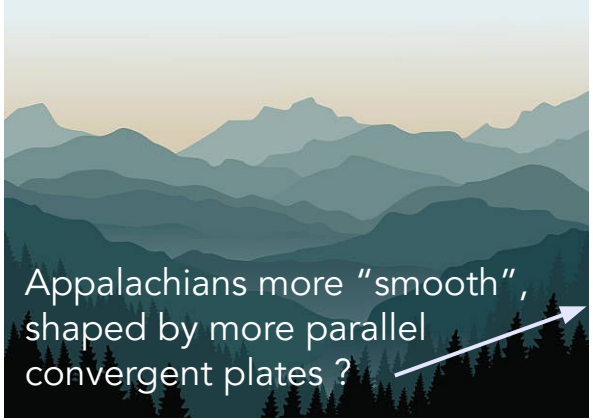


bonus

Mountain Analogy?



Bow shock, quasi-perpendicular shocks?



HCS, quasi-parallel shocks?

- On Earth, we associate shocks with earthquakes which produce mountains.
- Appalachian and Rocky Mountains Differ Shape Morphology due to difference in formation via convergent tectonic plate geometries
- What is the analogous "mountain" in the heliosphere?
- Do the shape of these "mountains" show signatures of the shock waves?