SM41D-3265
Speaker Present: 08:30-09:30

Automated Identification of Electron Microinjections in MMS/FEEPS Measurements: Initial Results

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ABSTRACT

The MMS spacecraft routinely observe electron "microinjections" at energies in the 10s-100s keV range across the nightside magnetosphere at distances <20 Re. Microinjections are typically observed in clusters where multiple dispersed injection signatures are recorded in succession over a short time interval (e.g., ~10 in one hour) and may be related to surface wave activity at the magnetopause. Recent work has shown that microinjections have distinctive features in the angular distributions, where field-aligned distributions are observed near dusk, while trapped distributions are observed near dawn. Due to their recent discovery, the origin and generation of microinjections has yet to be conclusively identified and detailed studies thus far have largely been done on a case-by-case basis. In an effort to elucidate more general properties and characteristics of microinjections, we describe an automated routine designed to identify microinjection signatures in the MMS/FEEPS measurements. The algorithm uses image processing techniques (the radon transform) and is based on a similar method developed to identify whistler-mode chorus elements in Van Allen Probes wave observations (Sen Gupta et al., [2017]). We present an initial set of results from a statistical database of microinjection events obtained from the automated algorithm to further our understanding of this intriguing phenomenon.

OUTLINE OF THIS WORK

Question

Is the source location of duskside electron microinjections at or near the magnetopause?

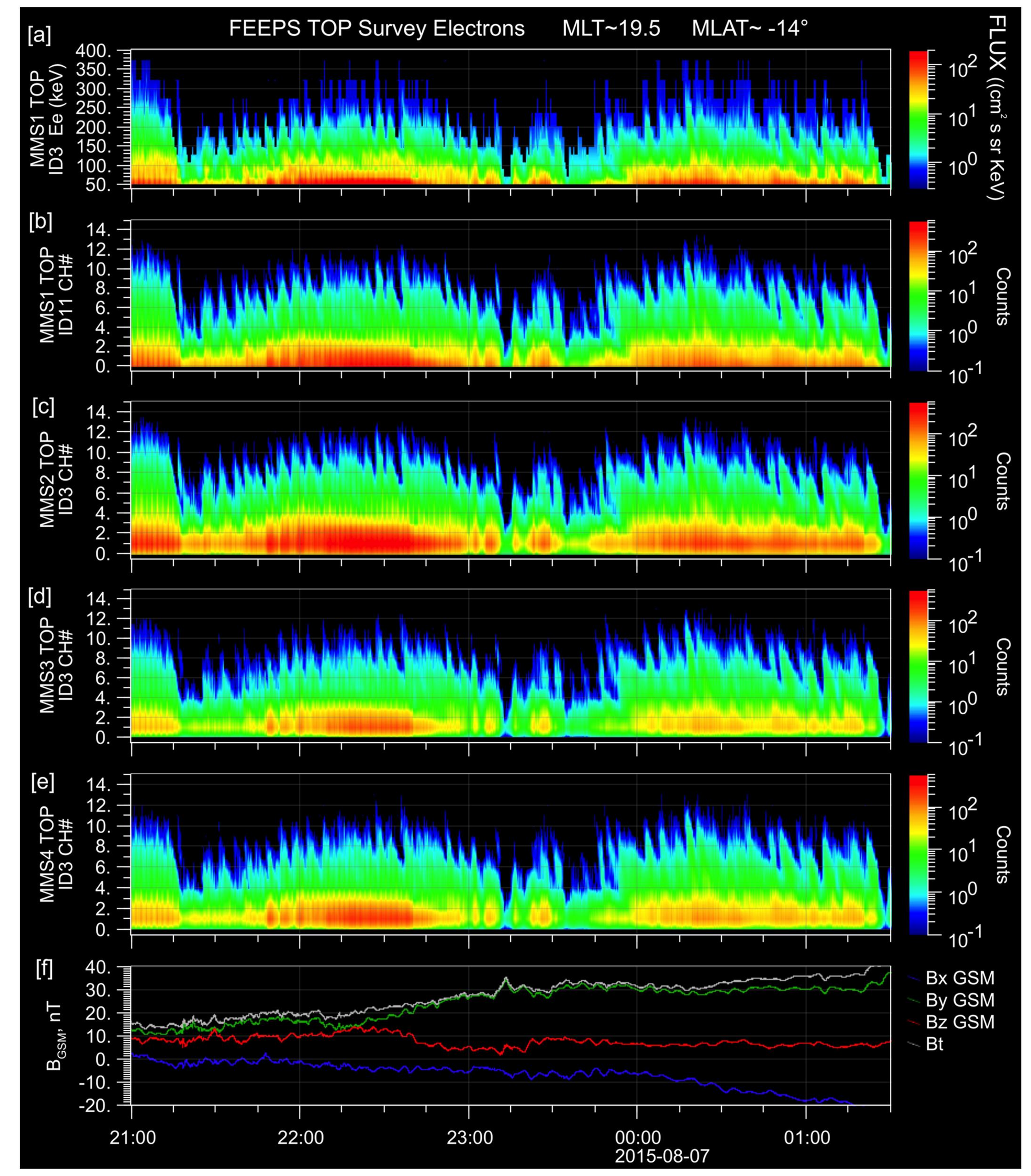
Goal

Compute the energy dispersion (dE/dt) for a large number of duskside microinjection elements

Methods

Automatically identify microinjection elements and analyze statistically (spatial distribution, dE/dt, etc.)

ELECTRON MICROINJECTIONS OBSERVED BY MMS: *FENNELL ET AL., [2016]*



Microinjections appear to be a distinctly different phenomenon from classic substorm injections and unrelated to nightside processes

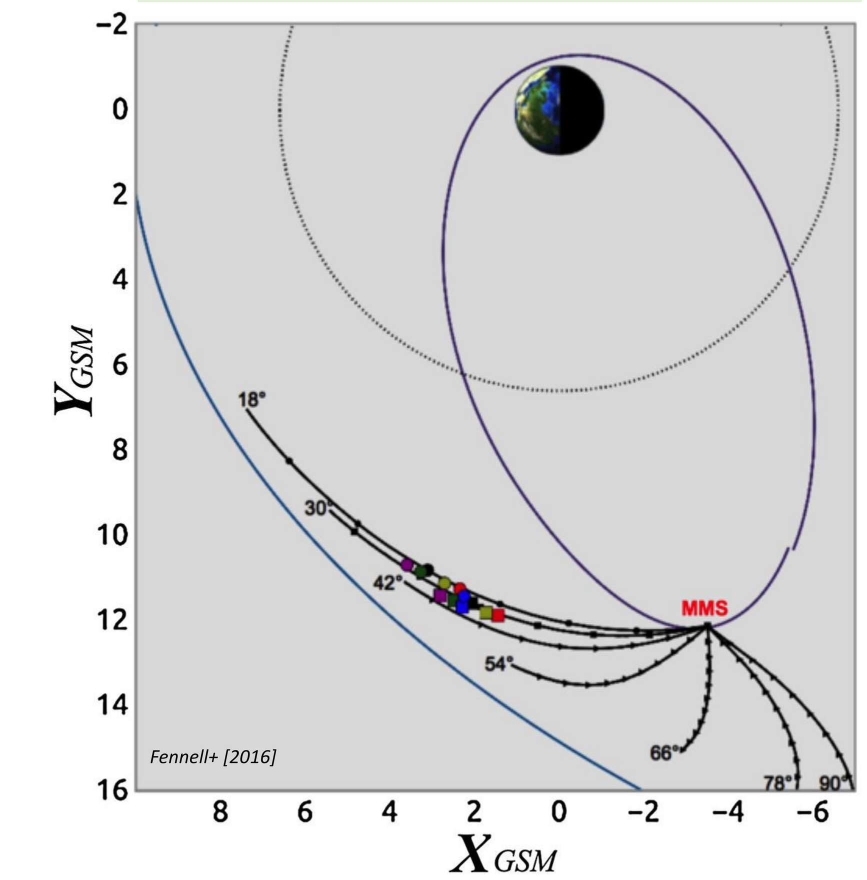
Characteristics
- *Energy range: ~50-400 keV*
- *Spatial distribution: ~8 - 12 Re on nightside (16 to 0 to 9 MLT)*
- *At dusk, energy dispersion suggests an origin at earlier MLT*
- *Occur in clusters in rapid succession (~10 per hour)*
- *Bidirectional field-aligned angular distributions*
- *Often accompanied by ULF perturbations*
- *Possibly observed in ions as well*

Observed fairly regularly in the MMS/FEEPS duskside data
- *First observed only at dusk, but that was largely related to MMS orbit/operation*
- *MMS orbit rearrangement and FEEPS operation change has permitted observation of microinjections in local morning MLT as well*

The character of the morningside microinjections is different from those on the duskside (see related poster by Fennell, SM41D-3275, just down the hall)
- *They do not tend to occur as large clusters of microinjections.*
- *The angular distributions in the morningside microinjections are predominantly peaked near 90⁰*

There is some evidence (e.g., Kavosi+ [2018]) that microinjections are related to dayside magnetopause boundary dynamics (KH waves/FTEs)

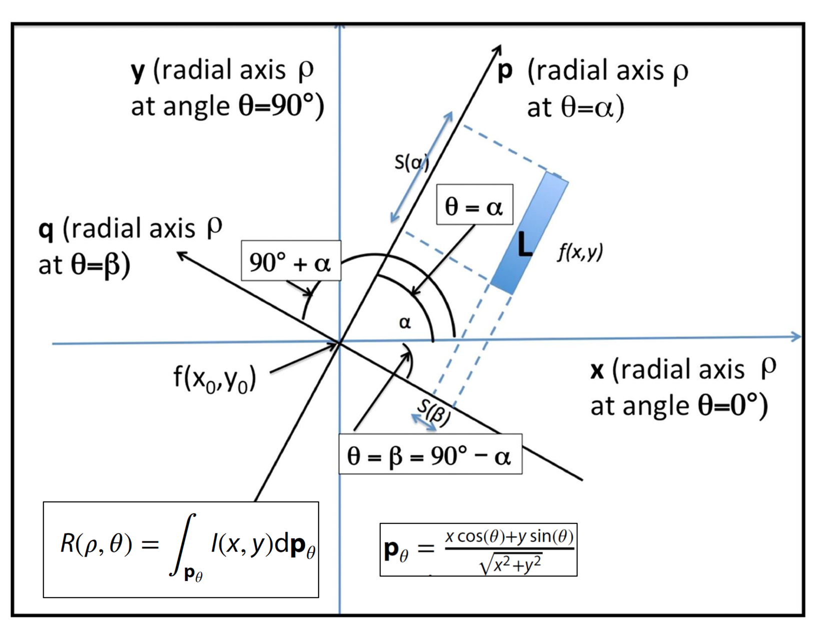
Particle Tracing Suggesting a Source near the Magnetopause

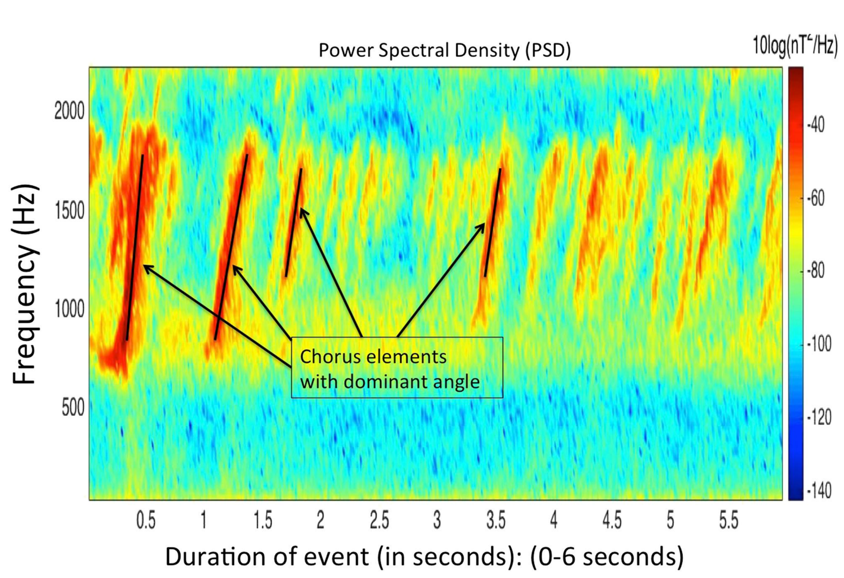


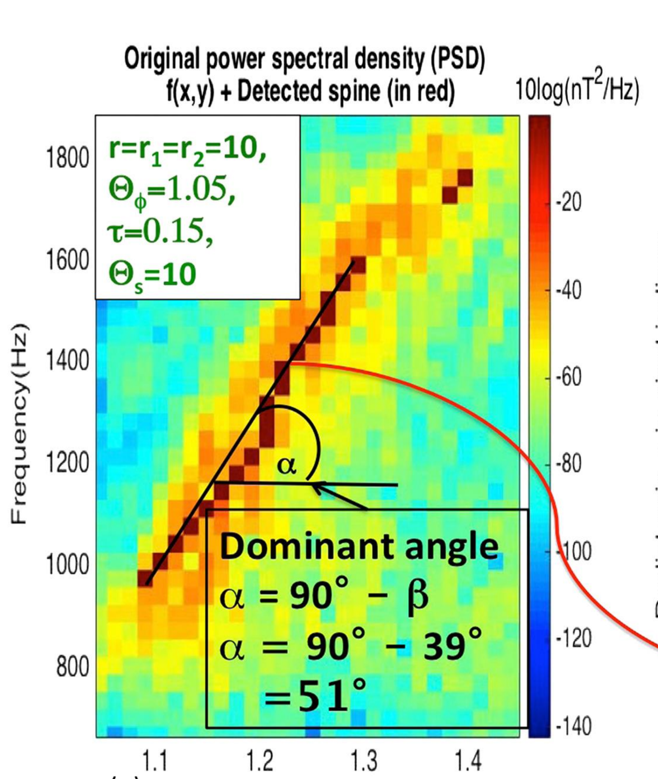
Impact/Importance

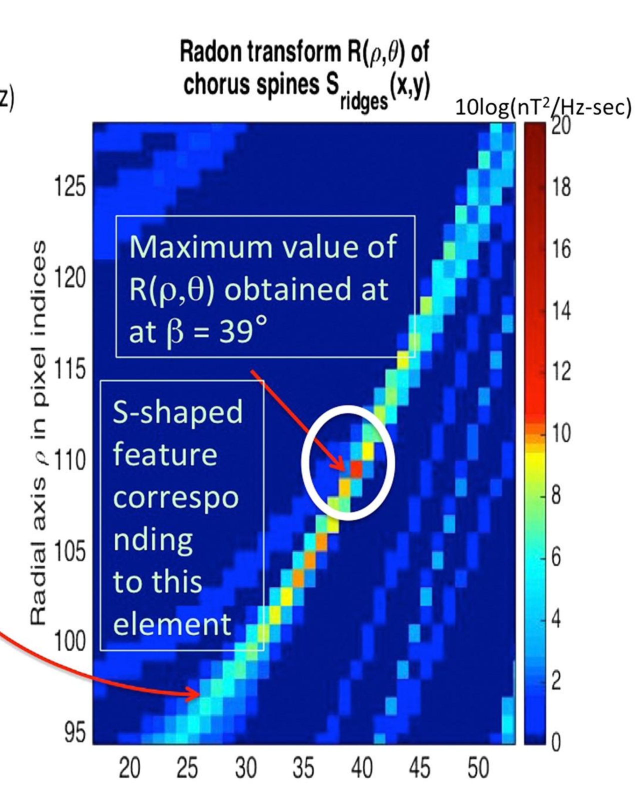
Microinjections could provide an additional source of seed electrons that has not yet been considered in radiation belt dynamics

AUTOMATED IDENTIFICATION OF CHORUS ELEMENTS: *SEN GUPTA ET AL., [2017]*









Sen Gupta+ [2017] develop the "ridge" transform to enable automated detection of whistler mode chorus elements observed by NASA's Van Allen Probes

The ridge transform makes use of the radon transform, a geometric signal processing technique (Beylkin [1982])

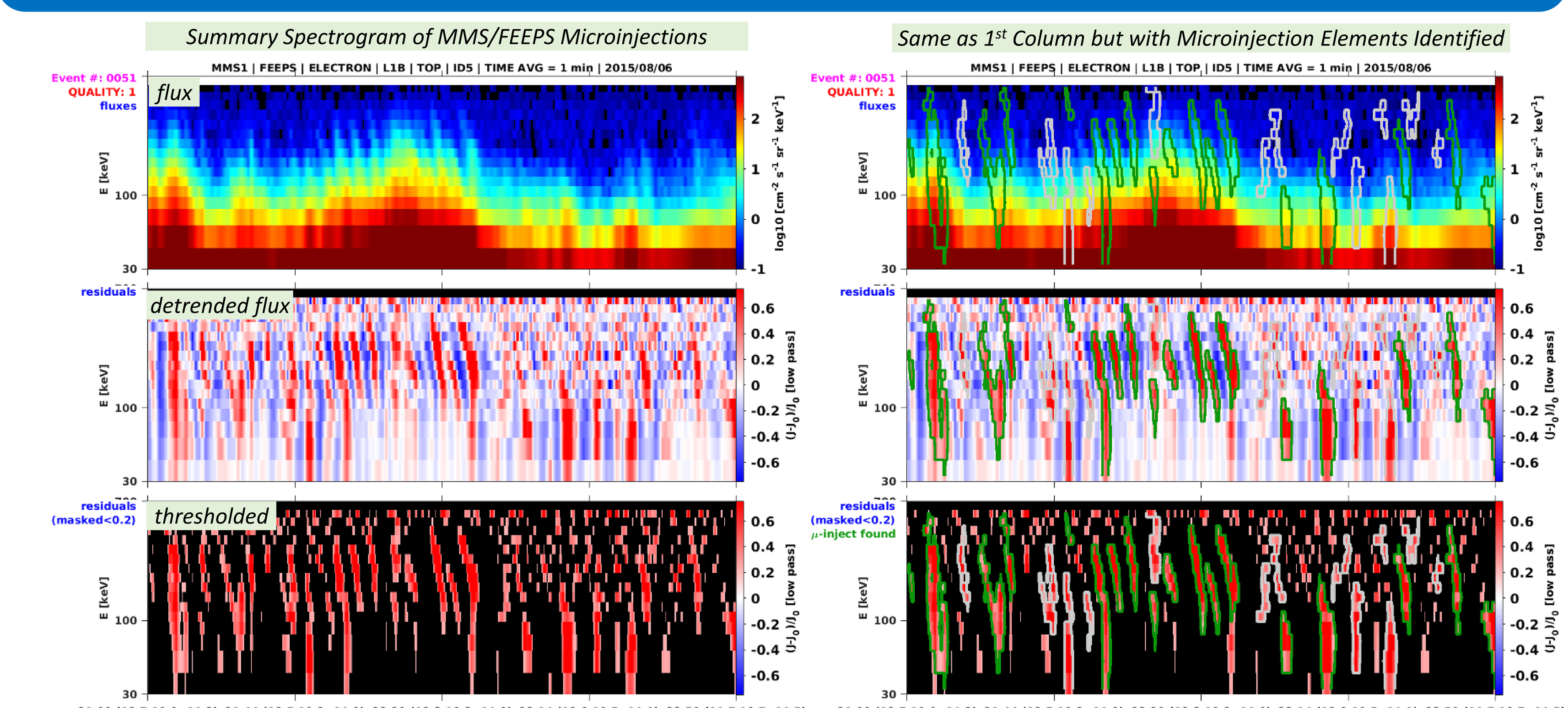
The radon transform is widely used to isolate geometric trends in image processing and is designed to detect angular spread of image features in a dual domain

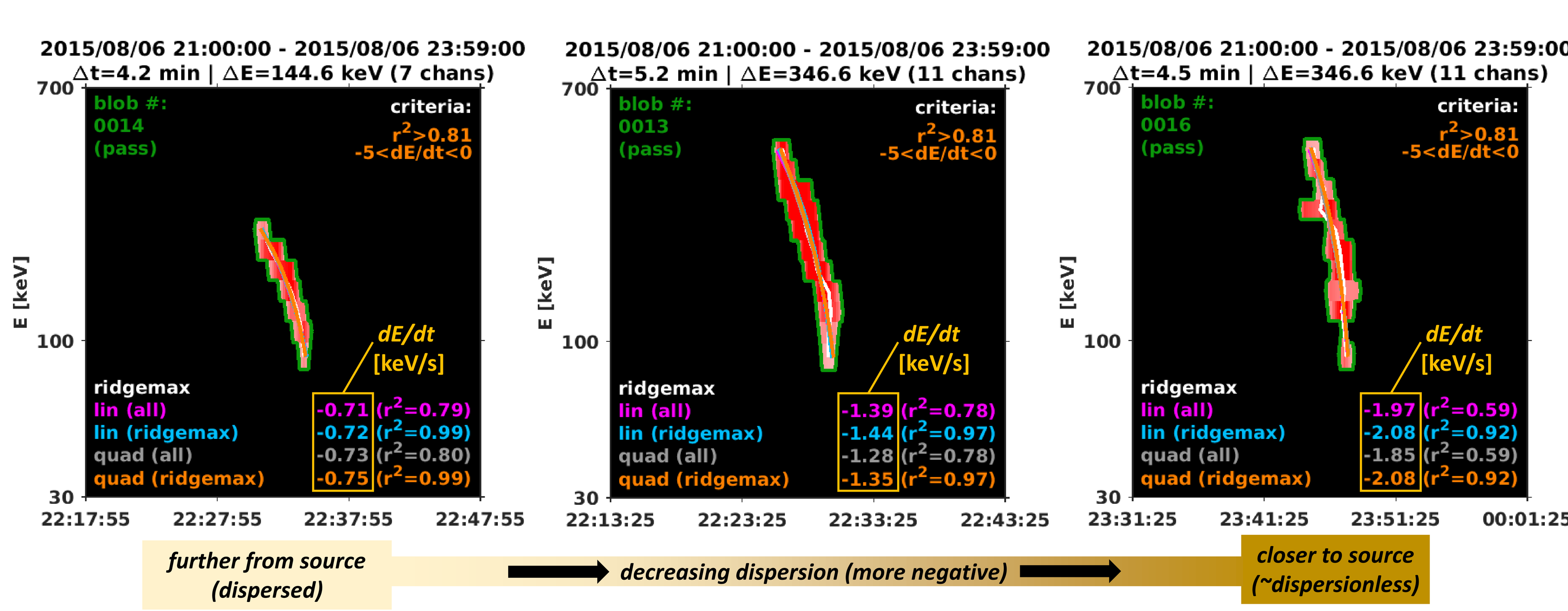
Intuitively, it may be viewed as a parameter-based integration technique for discovering local linearity within a two-dimensional image (see schematic at upper left)

The ridge transform combines elements of various image processing techniques to achieve (1) automatic identification and (2) geometric characterization (sweep rate) of chorus elements by exploiting the dominant geometric feature, the dominant slope of the "spine" (see figures at left and right)

We have adapted the ridge transform of Sen Gupta+ [2017] to automatically identify individual microinjection elements observed by MMS/FEEPS

AUTOMATED IDENTIFICATION OF DUSKSIDE ELECTRON MICROINJECTIONS





We begin with a list of 382 microinjection event "clusters," multiple-hour long intervals where many microinjections are observed (events are identified by a human eye using spectrograms from the MMS-1 FEEPS "TOP ID5" sensor).

We restrict to the event clusters on the duskside only (321 of 382 events), which corresponds to two MMS-1 passes through the duskside region, one from 2015-Jul to 2015-Oct, and the other from 2016-Jul to 2016-Oct.

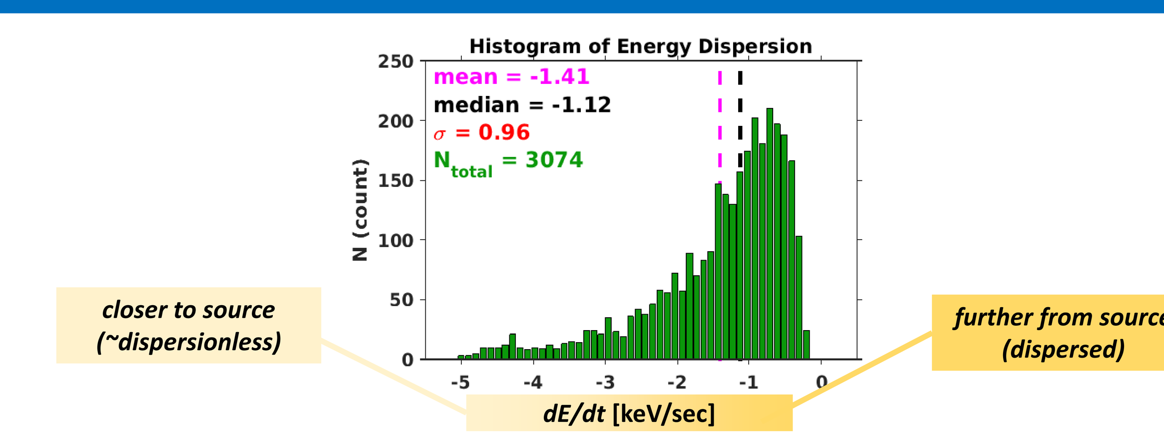
For each of the 321 events in the list, we apply a modified version of the ridge transform to identify and isolate linear features in the spectrograms of detrended+thresholded fluxes. This results in 6532 linear features identified across the 321 events.

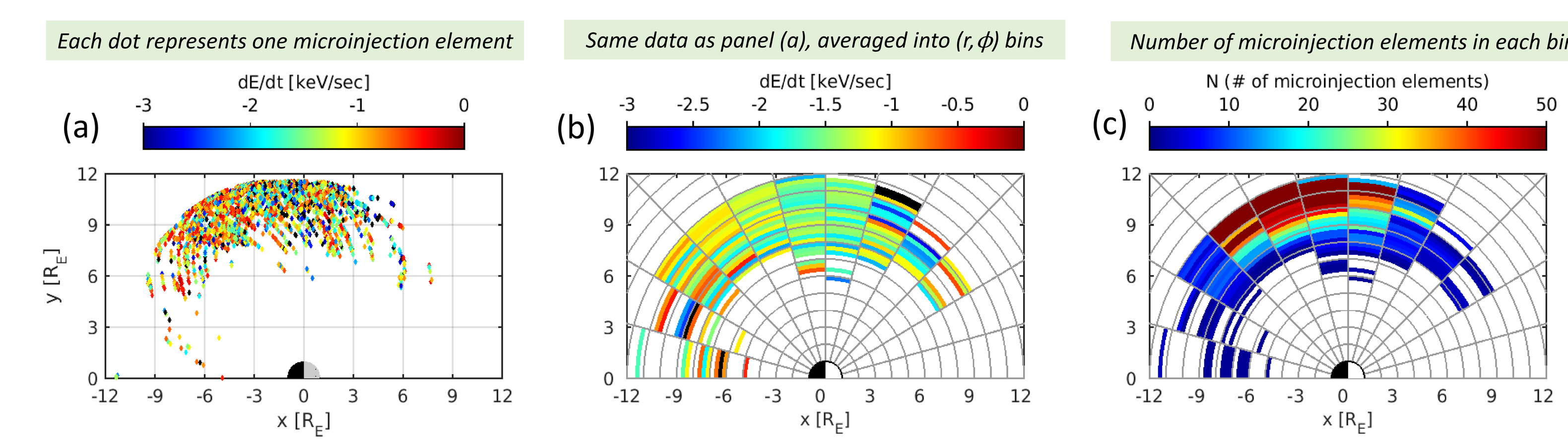
For each linear feature ("element" or "blob") identified, we fit a quadratic function ($E(t) = a_2t^2 + a_1t + a_0$) to the set of points within the element/blob (either all of the points, or just those that lie along the maximum of detrended flux). We then compute *dE/dt* for the element.

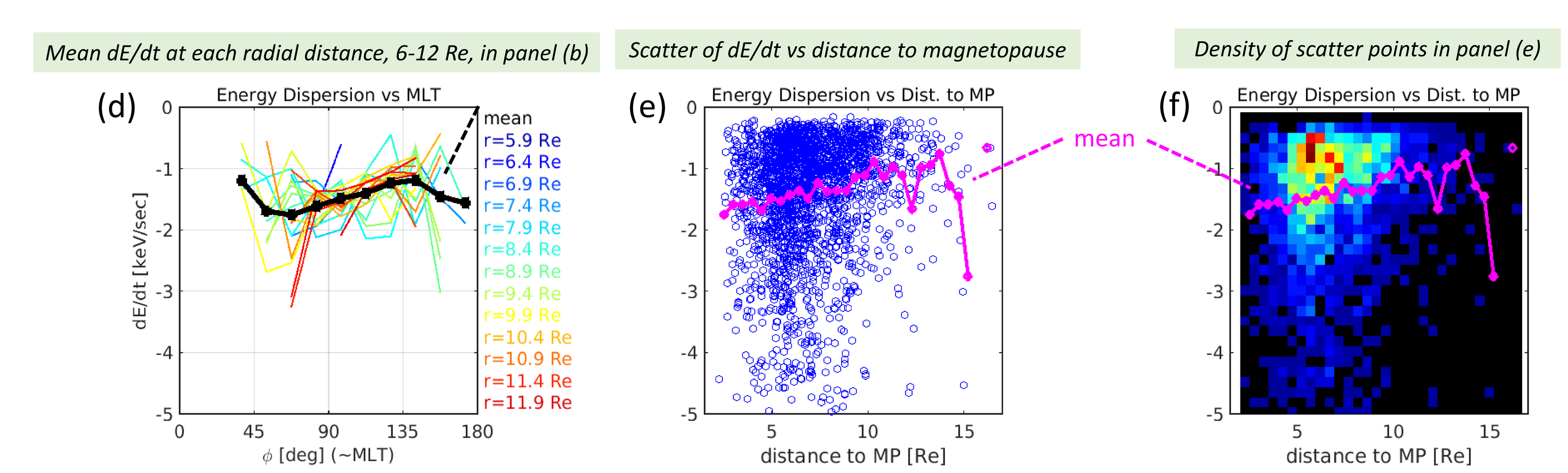
If the r^2 of the fit exceeds some threshold (here $r^2 > 0.81$), then we retain the element as a valid microinjection element (green contours). We also only retain elements with -5 keV/s < *dE/dt* < 0 keV/s, and only those elements that span at least 4 energy channels.

This entire procedure results in 3074 microinjection elements identified, the distribution of which is shown in the figures at the right

STATISTICAL DISTRIBUTION OF DUSKSIDE MICROINJECTIONS







Energy dispersion decreases (more negative) towards magnetopause => microinjection source at/near magnetopause

REFERENCES

Beylkin, G., (1987), **Discrete Radon Transform**, IEEE Trans. Acous., Sp., Sig. Proc., vol. ASSP-35, No. 2.

Fennell, J. F., et al. (2016), **Microinjections observed by MMS FEEPS in the dusk to midnight region**, *Geophys. Res. Lett.*, 43, 6078– 6086, doi:10.1002/2016GL069207.

Kavosi, S., et al. (2018), **MMS/FEEPS observations of electron microinjections due to Kelvin-Helmholtz waves and flux transfer events: A case study**. *J. Geophys. Res. Space Physics*, 123, 5364– 5378. https://doi.org/10.1029/2018JA025244

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