Sounding rocket particle data of Poleward Boundary Intensification aurora

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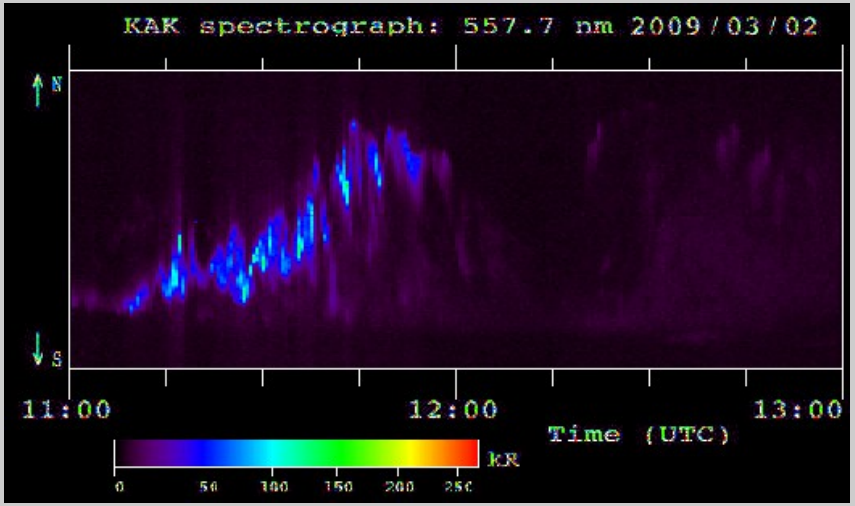
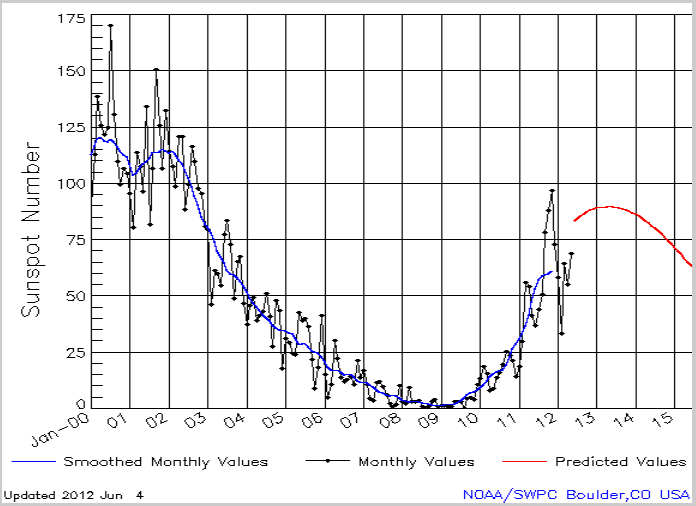
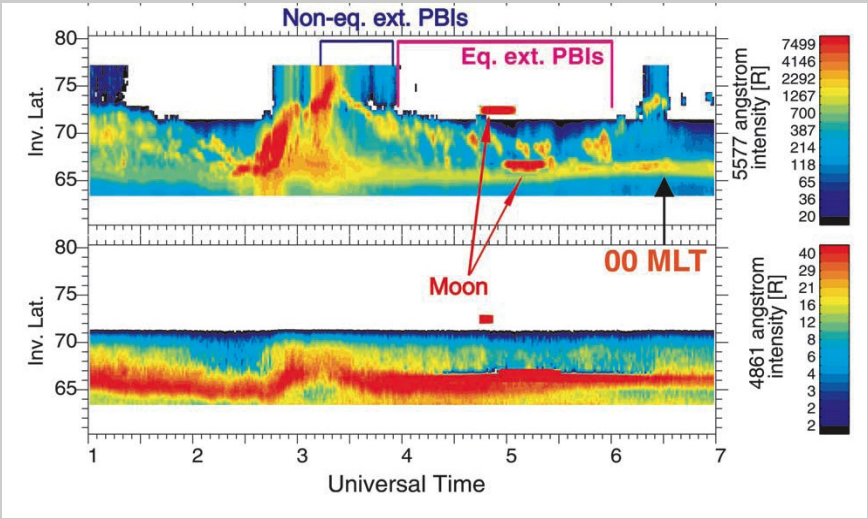
Poleward Boundary Intensification (PBI) aurora

- Second brightest aurora behind the substorm
- Brightens initially at the poleward edge of the auroral oval, and may or may not pull equatorward in time
- Frequently seen during solar minimum
- This study is during solar minimum conditions



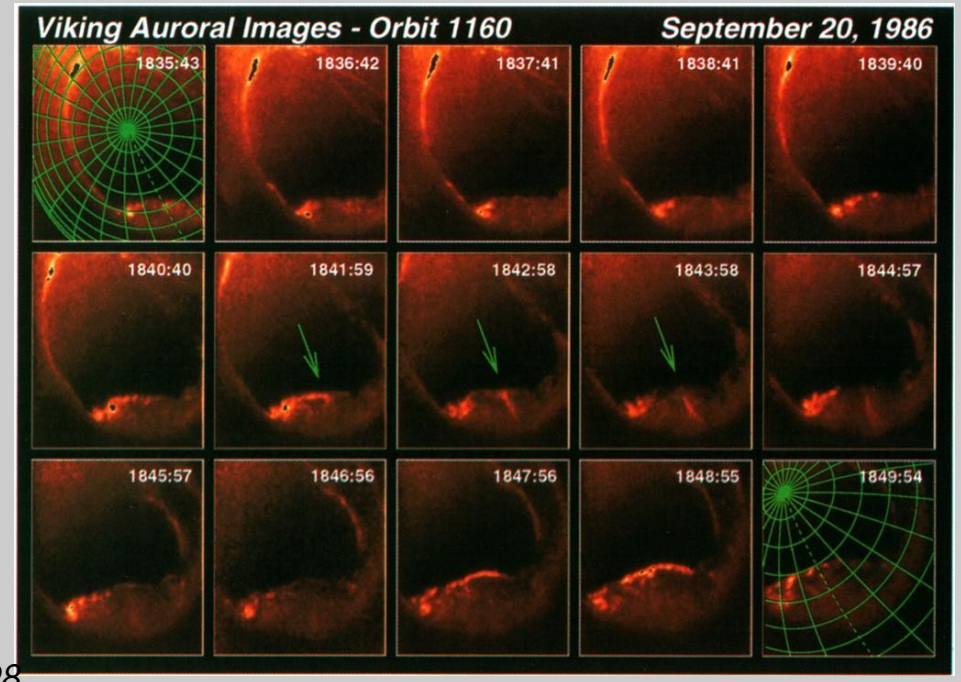


PBIs in general



Zesta et al. 2006

- Term was coined by Lyons in 1998
- This type of aurora had been observed for a long time; there is a clear description in a paper by Davis in 1960
- Classified by its location at the poleward edge of the auroral oval



- PBI includes the term Streamer, which is considered an equatorward-extending PBI
- Many ground-based and satellite studies in the past decade by Zesta

Henderson et al. 98

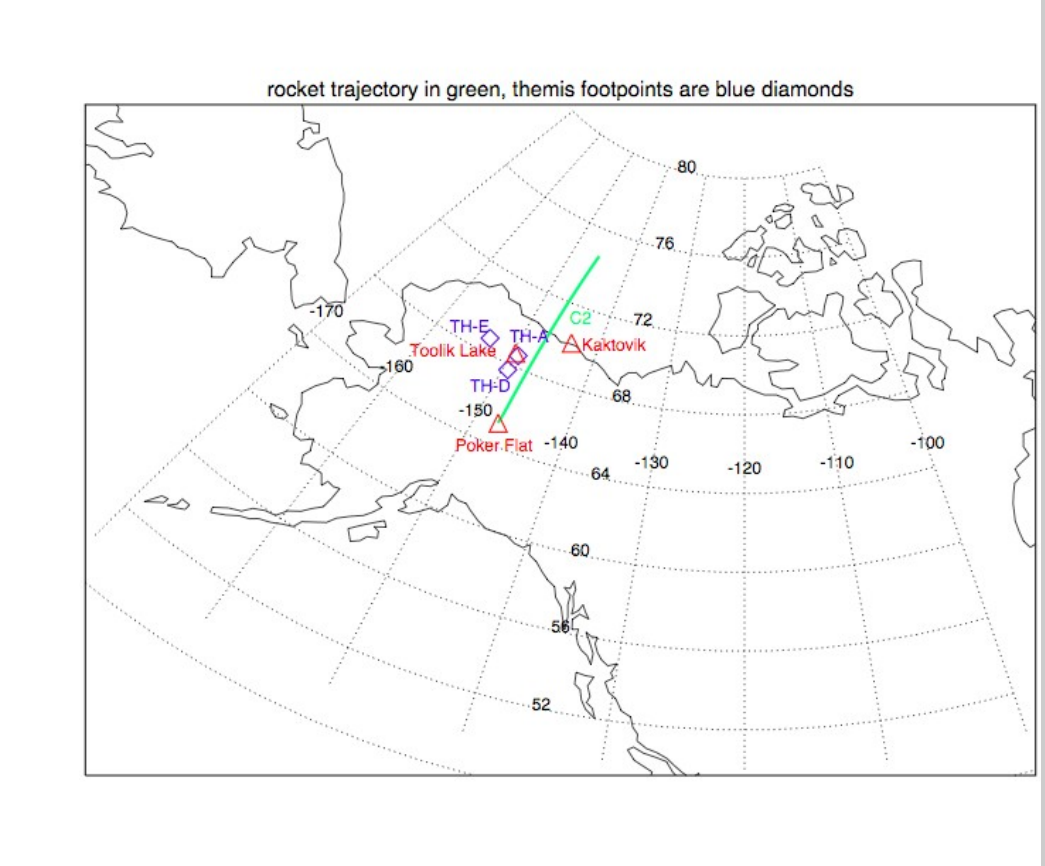
Questions to be addressed:

- What are the sources and acceleration mechanisms that drive the Poleward Boundary Intensifications?

- What information can be obtained from rocket observations of particle dispersions, and how can the in situ particle distributions and dispersions be used to parameterize these mechanisms?

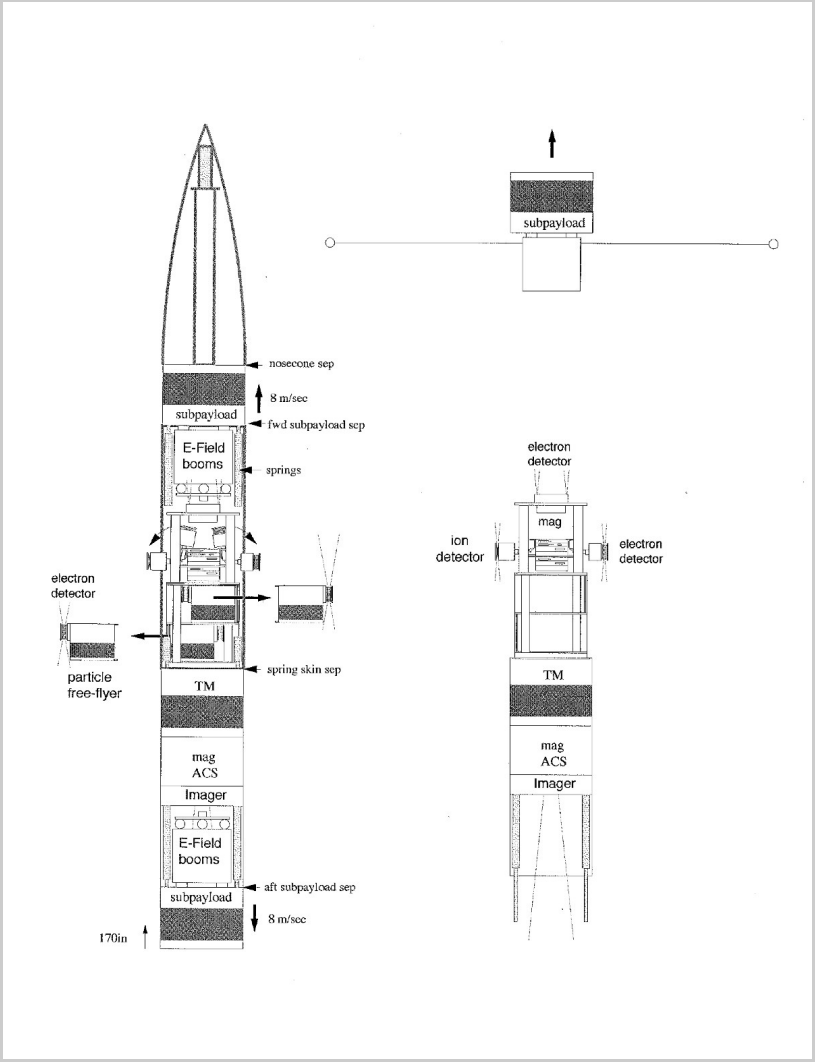
Method

- Nightside auroral sounding rocket
- Cascades-2 was launched on 20 March 2009 from the Poker Flat Research Range in Alaska at 11:04:00 UT (about a half hour pre-midnight)
- Flight time of 12 minutes and 43 seconds
- Reached an apogee of 564 km at 11:11:11 UT

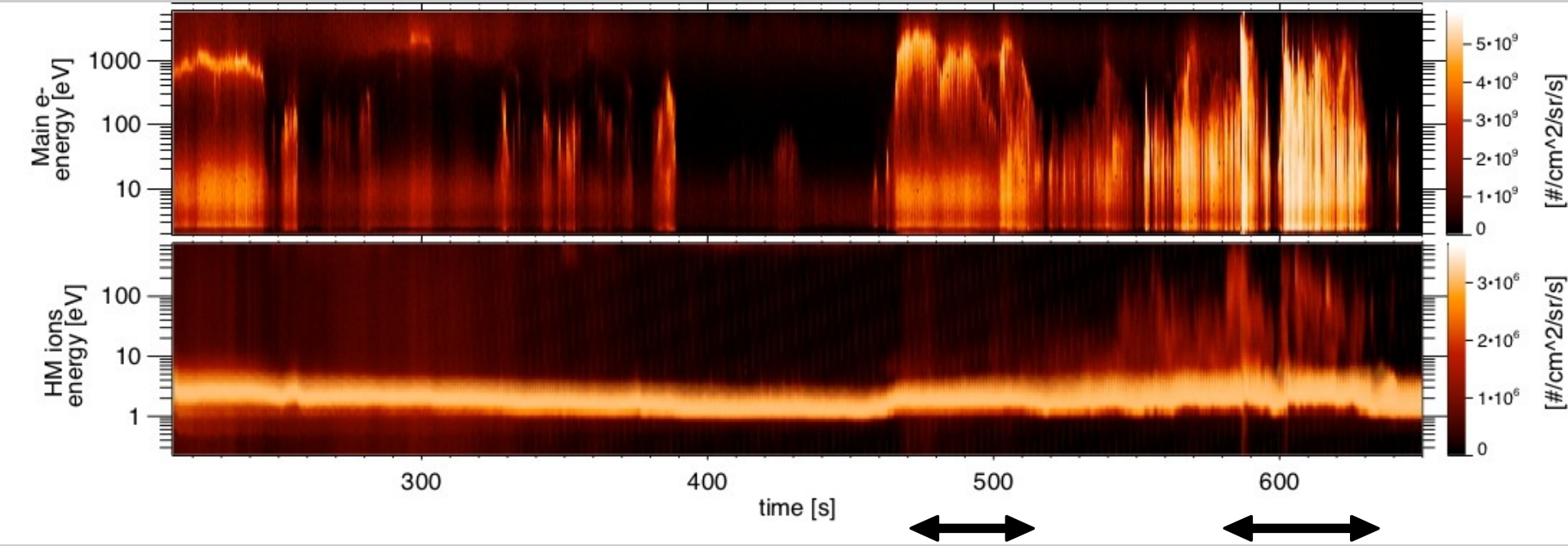


Cascades-2

- 5 payload sounding rocket designed to measure particles and electric and magnetic fields at multiple points
- Included electron tophat detectors (2 eV – 1.5 keV) on three payloads, plus a toroidal electron detector (5 eV – 1 keV) looking at the field-aligned population on the main payload



Full flight data

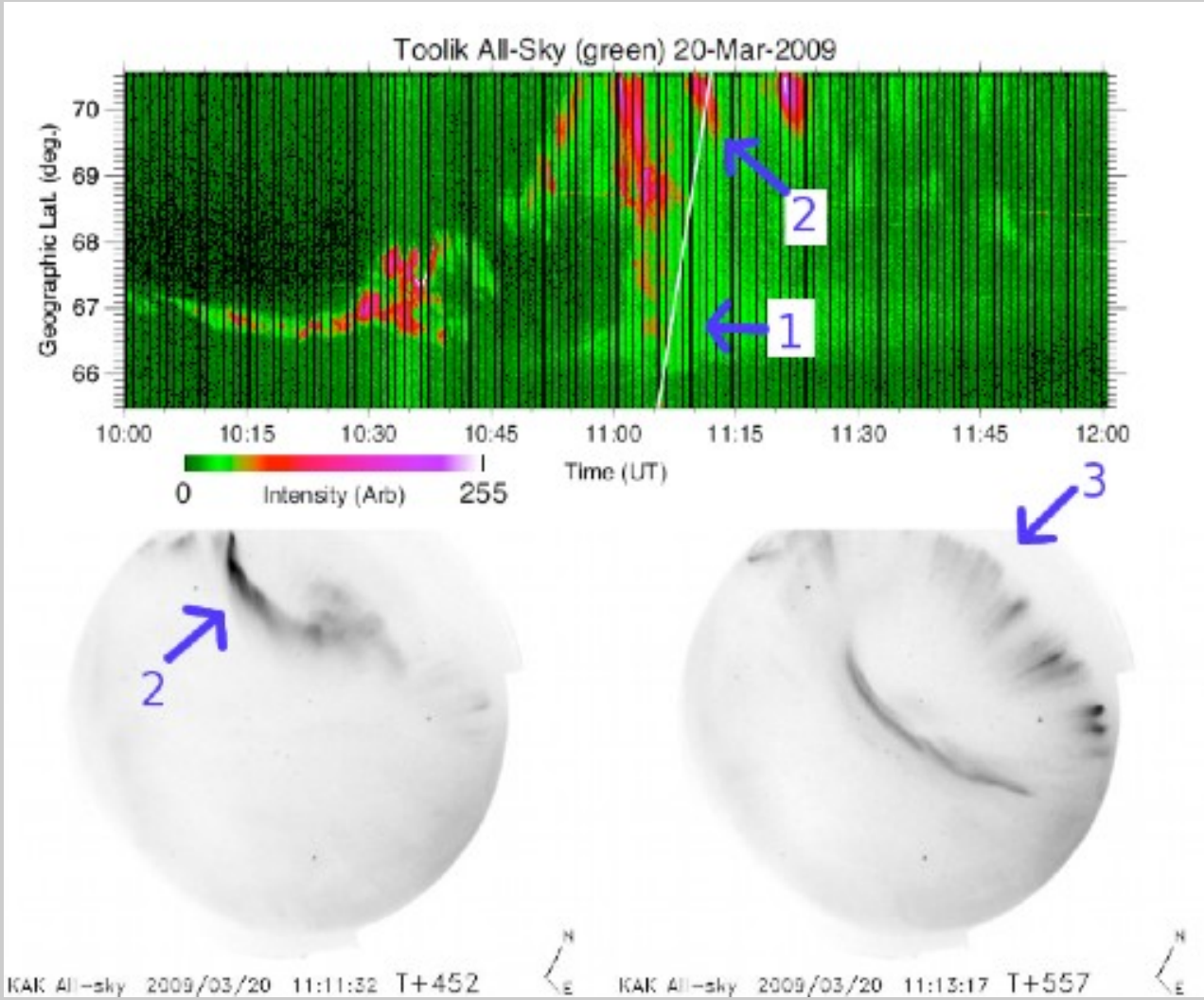


Equatorward-extending PBI (streamer)

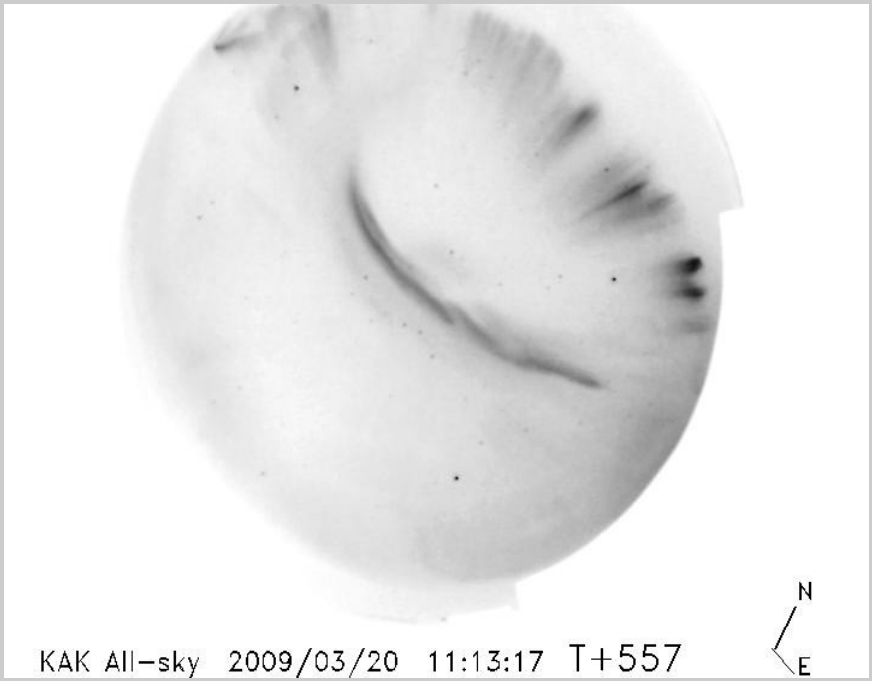
Non-equatorward-extending PBI

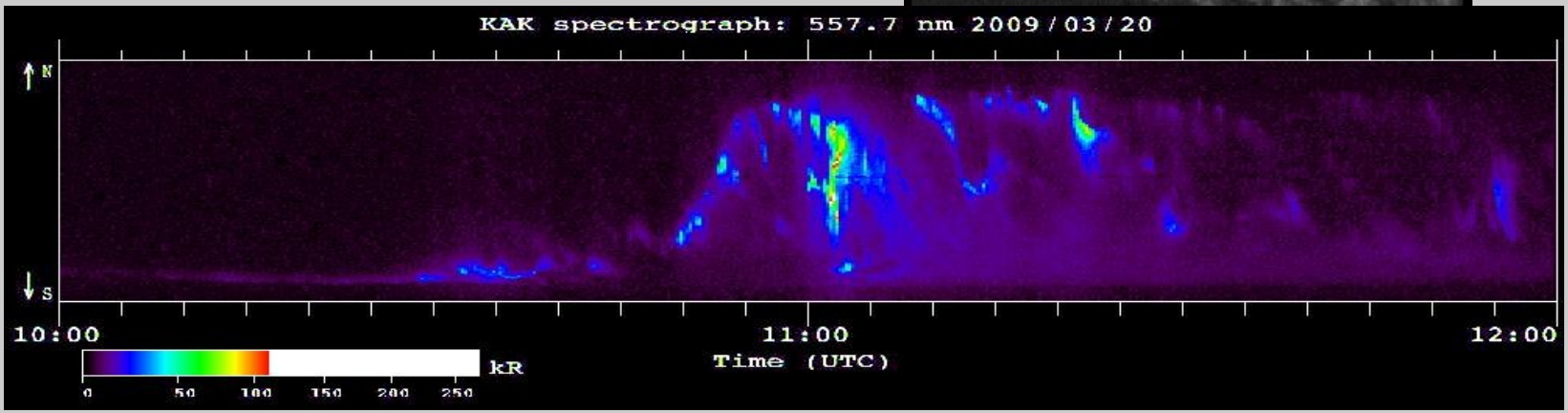
Ground optics from two sequential PBI events

- Equatorward extending PBI (streamer) marked 2
- Non-equatorward-extending PBI marked 3

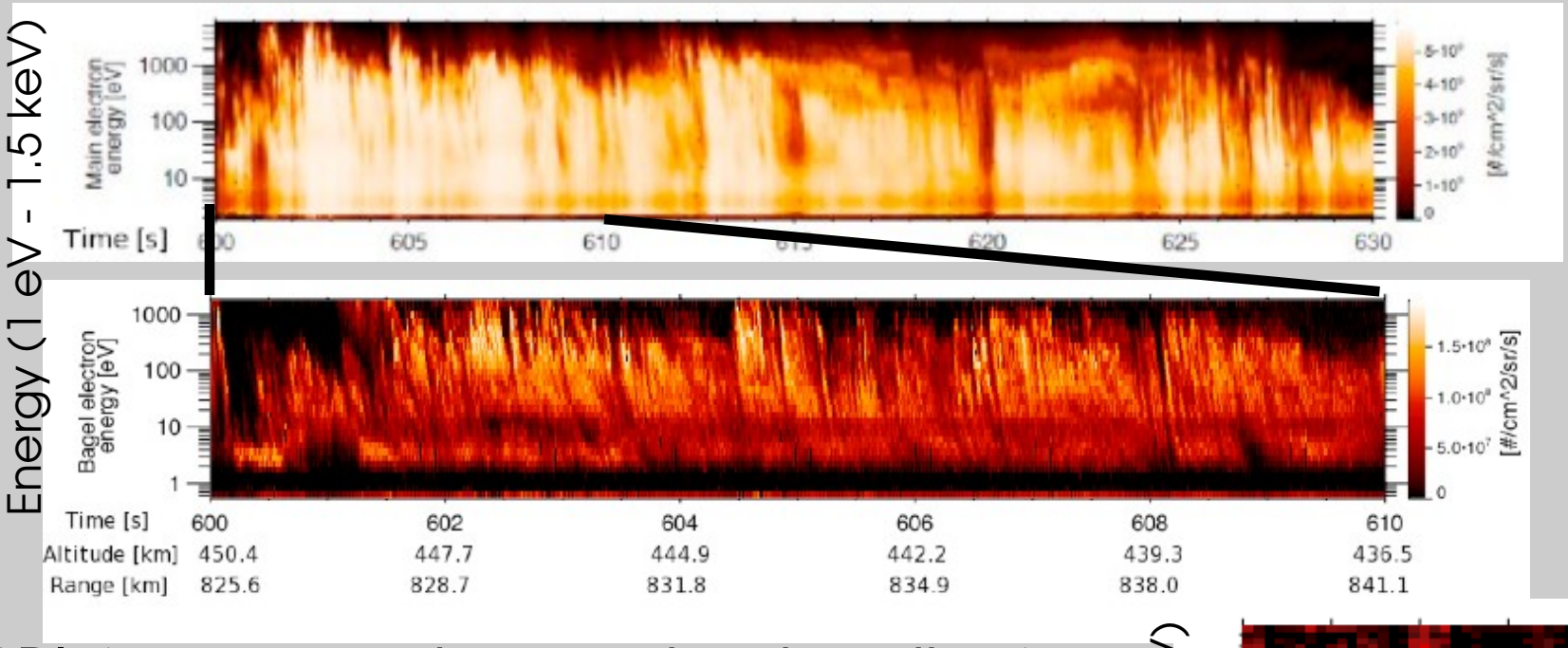


Non-e-e PBI – ground optics

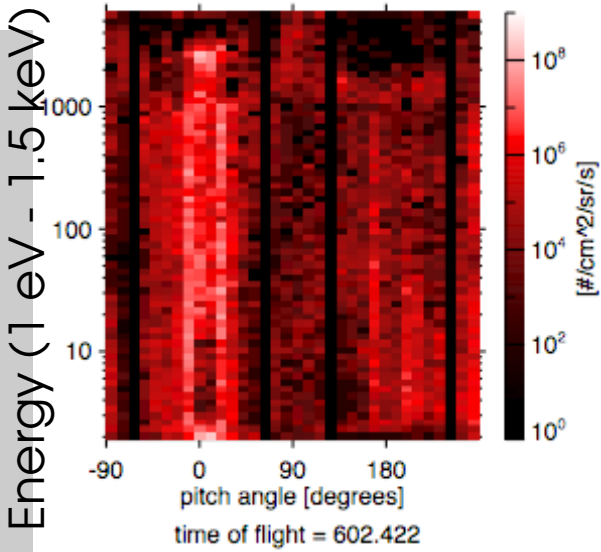




Non-e-e PBI - in situ electron data

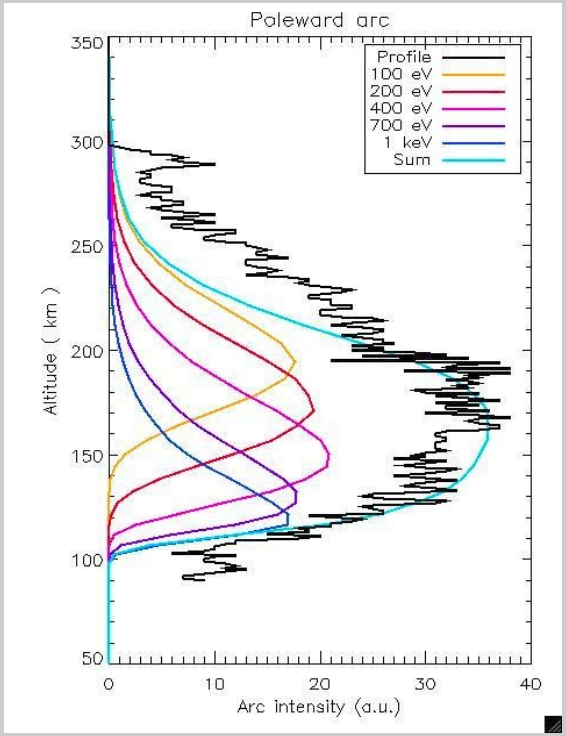


- PBI (non-equatorward-extending)
- Time-energy spectrogram shows wide spread in energy
- Strong dispersion signatures
- Pitch energy image shows population is field-aligned

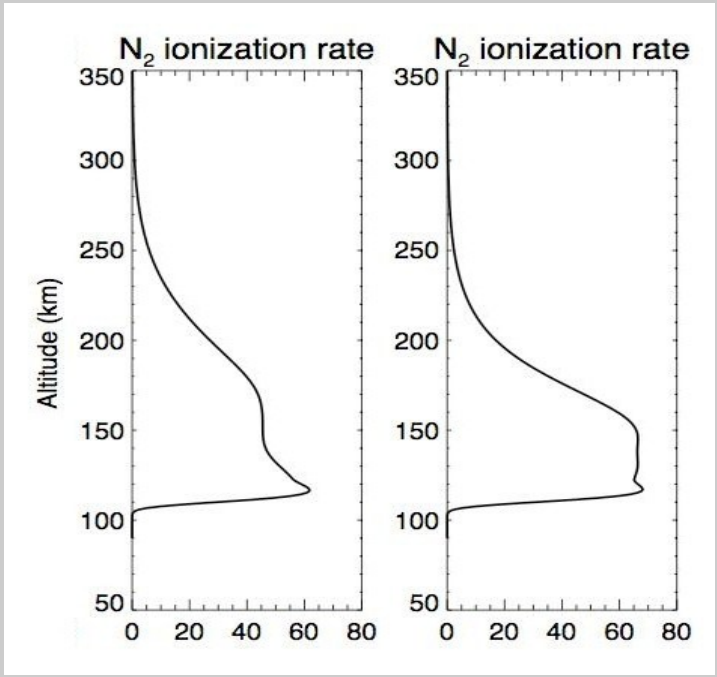


Collisional Transport Code

Lummerzheim and Lilensten, 1994

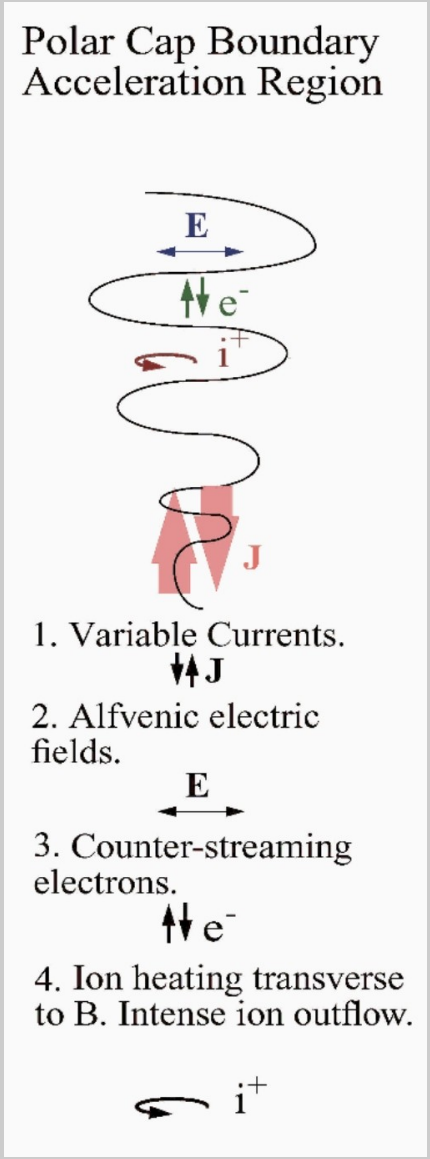


For a non-equatorward-extending PBI, modeled profiles match reasonably well

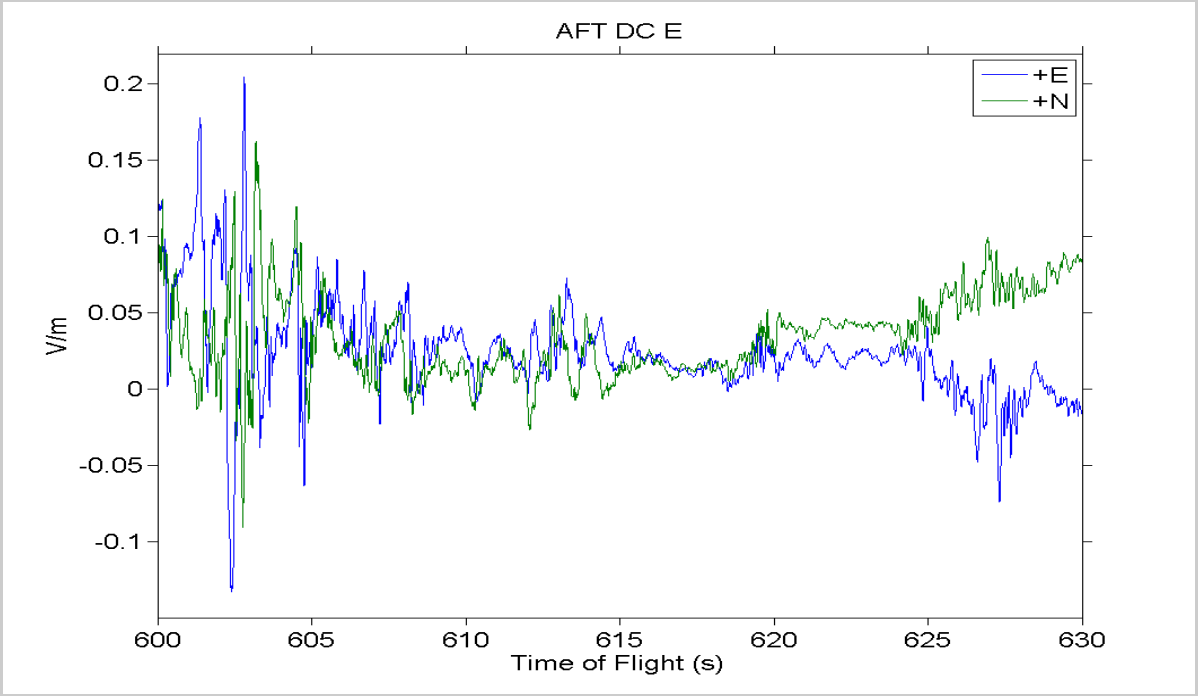


- Use ground camera data to compare arc altitude profile to a modeled N2 first-positive emission rate profile
- Use electron data from the rocket to calculate the expected N2 ionization rate profile

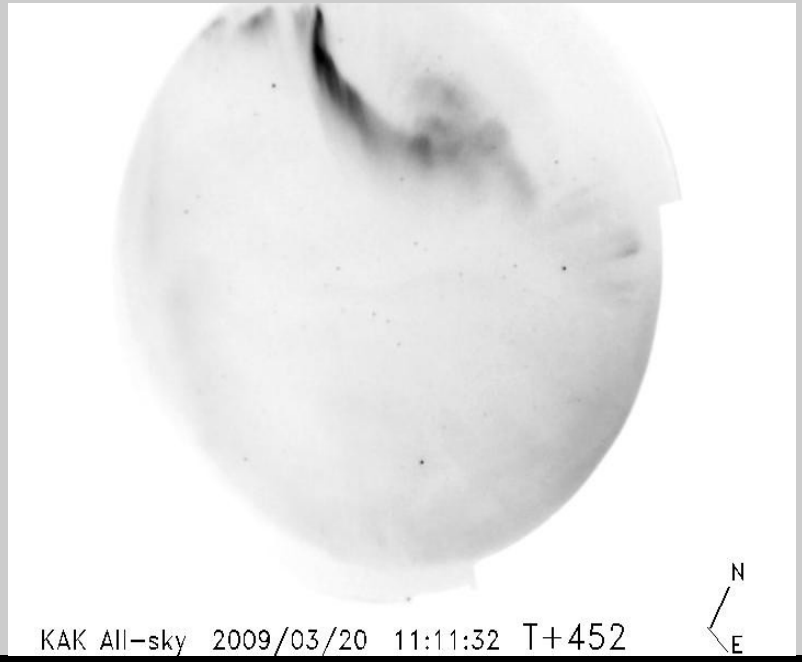
Non-e-e PBI - Alfvénic acceleration

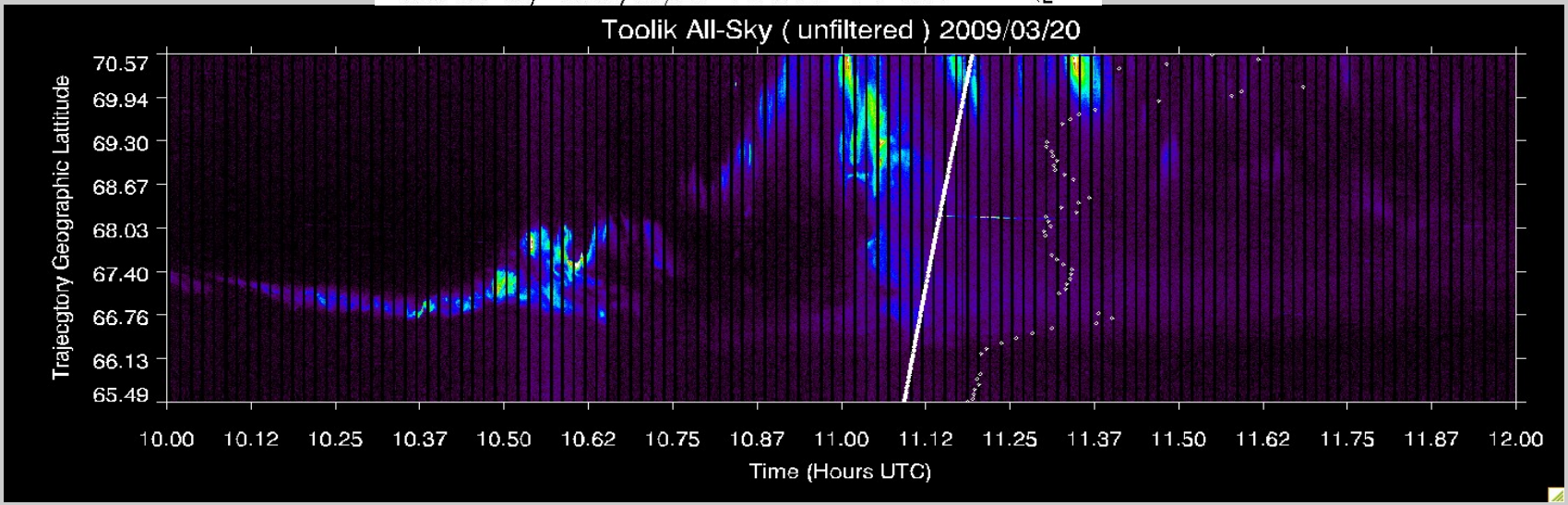


- Electron signatures on the rocket, plus ground camera data, along with strong DC E-field fluctuations indicate acceleration by Alfvén waves

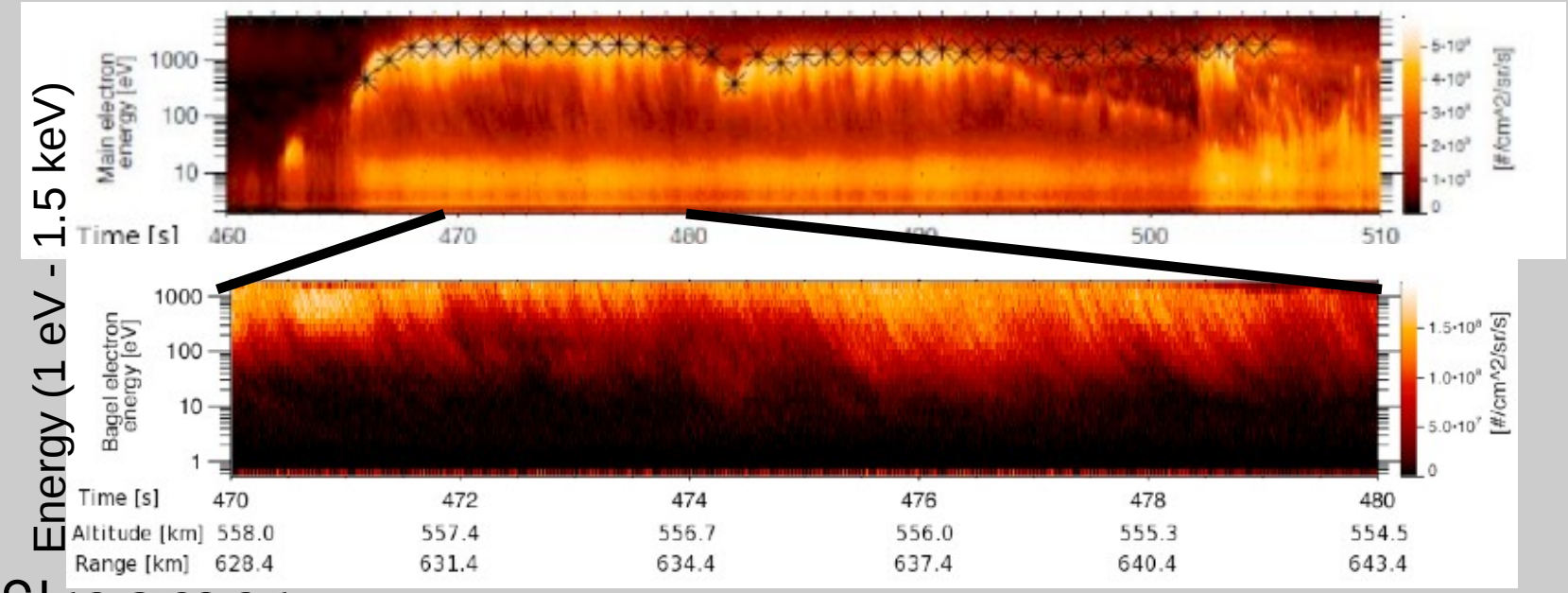


Streamer aurora (e-e)

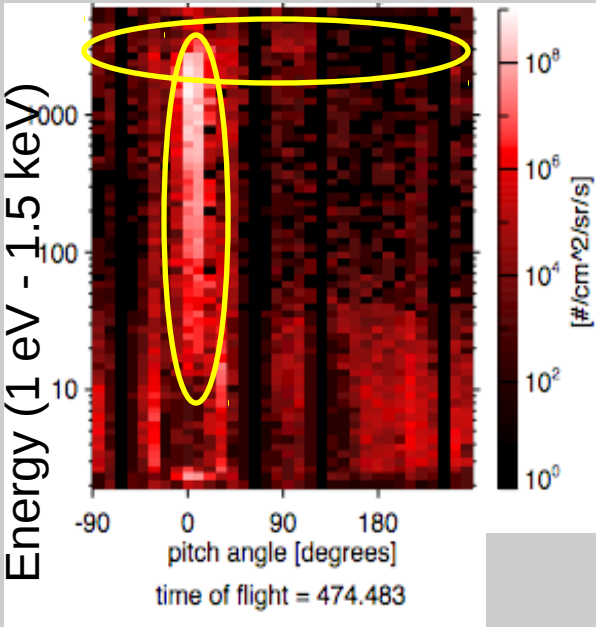




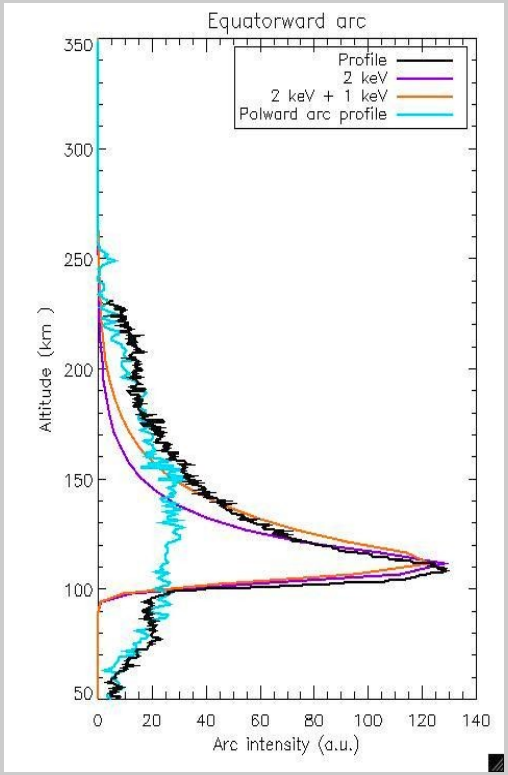
In situ electron data from event 2



- Streamer
- Time-energy spectrogram shows electrons slightly spread in energy
- Dispersion still present
- Pitch-energy image shows even more narrowly field-aligned population plus an isotropic with loss cone population

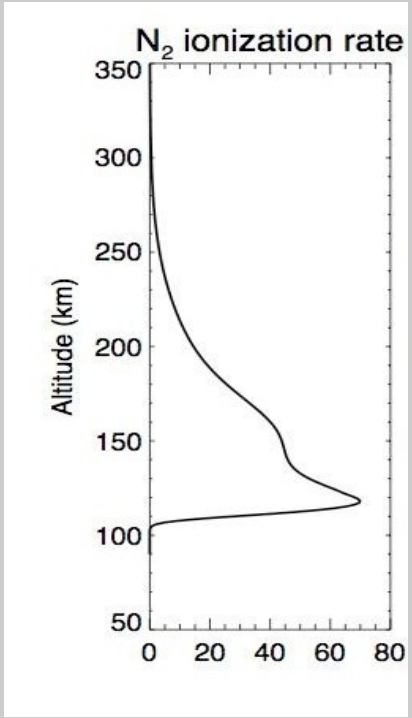


Collisional Transport Code



Modeled profiles do not match

Lummerzheim and Lilensten, 1994



- Use ground camera data to compare arc altitude profile to a modeled N2 first-positive emission rate profile
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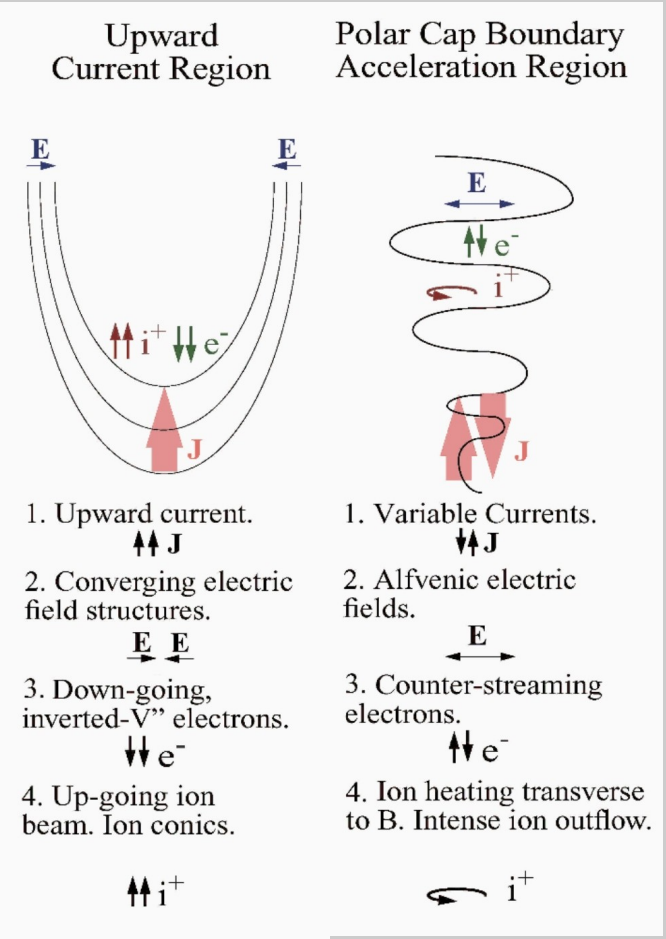
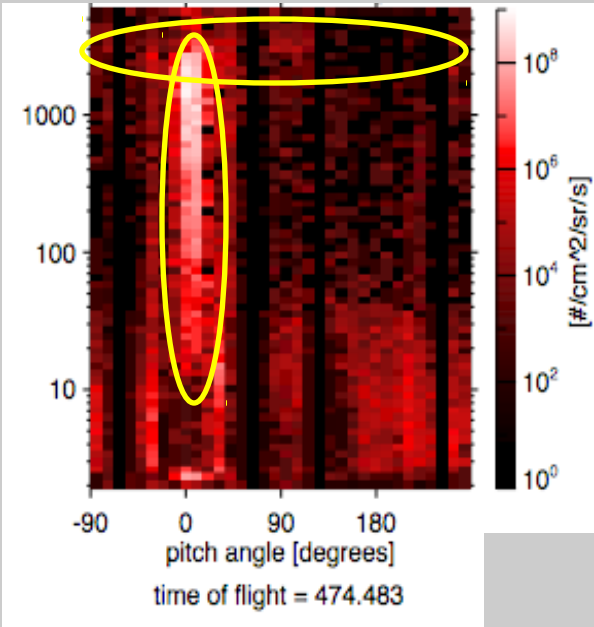
Streamer has two electron populations

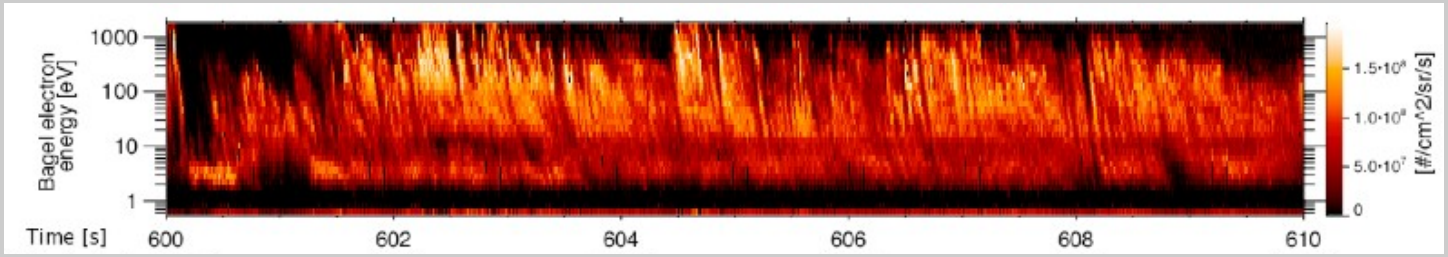


- Higher energy, isotropic with a loss cone population typical of acceleration in an upward current region
- Narrow in pitch angle, spread through a range of energies population typical of Alfvenic acceleration
- Cascades-2 observations show a mixture of two populations, indicating a mixture of two separate acceleration mechanisms

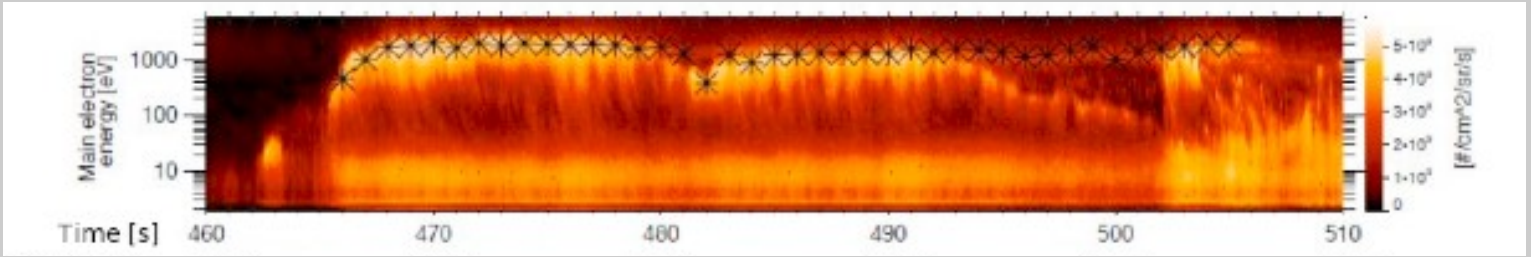


The main idea

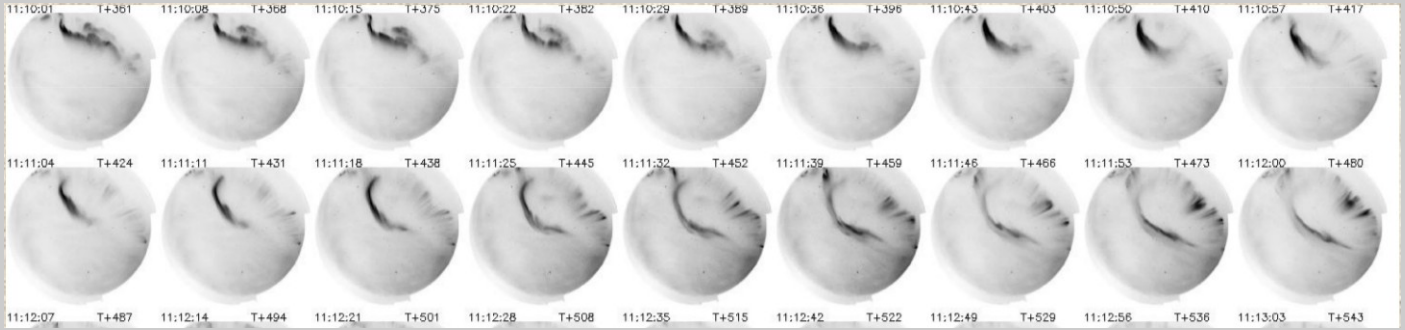
- Non-e-e PBI is quite clearly Alfvenic aurora



- E-e PBI (streamer) has aspects of both Alfvenic aurora and inverted-V aurora



- From the ground cameras, it is obvious that the streamer started just like the non-e-e PBI

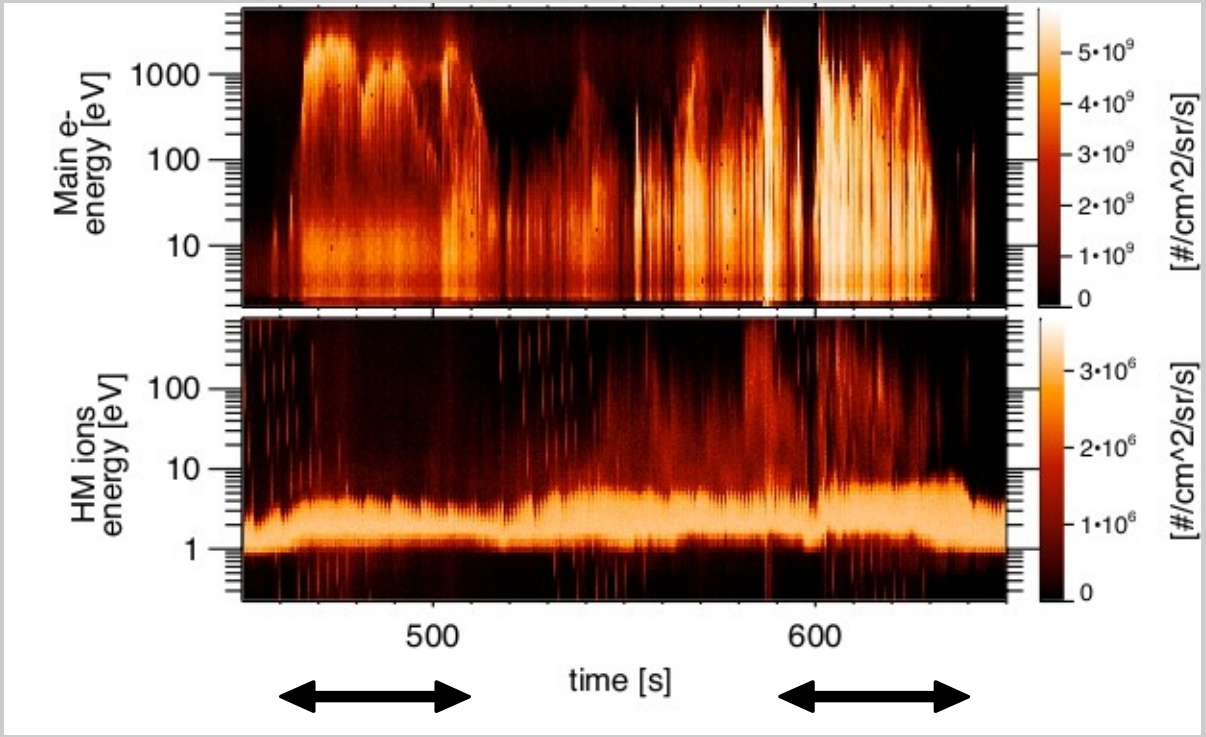


What are the acceleration mechanisms that drive the Poleward Boundary Intensifications?

- We show that PBIs will be purely Alfvenic if they do not extend equatorward, whereas streamers will be a mixture of Alfvenic and quasi-static
- This work is in agreement with previous studies which suggest quasi-static acceleration regions can develop out of Alfvenic acceleration regions, namely Hull et al. 2010

Ion data during PBIs

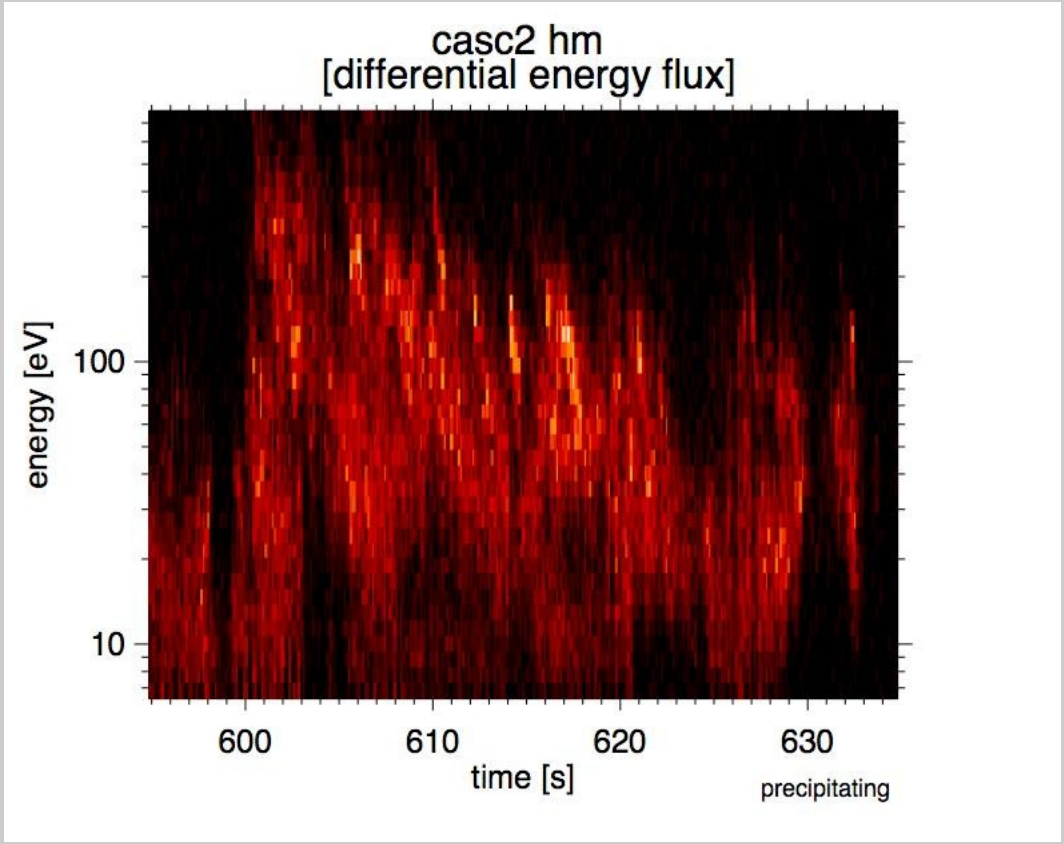
- Ions between 10 - 800 eV are not present at the time of the streamer
- Structured ion signatures occur around 600 s



Equatorward-extending PBI (streamer)

Non-equatorward-extending PBI

Structured ion signatures

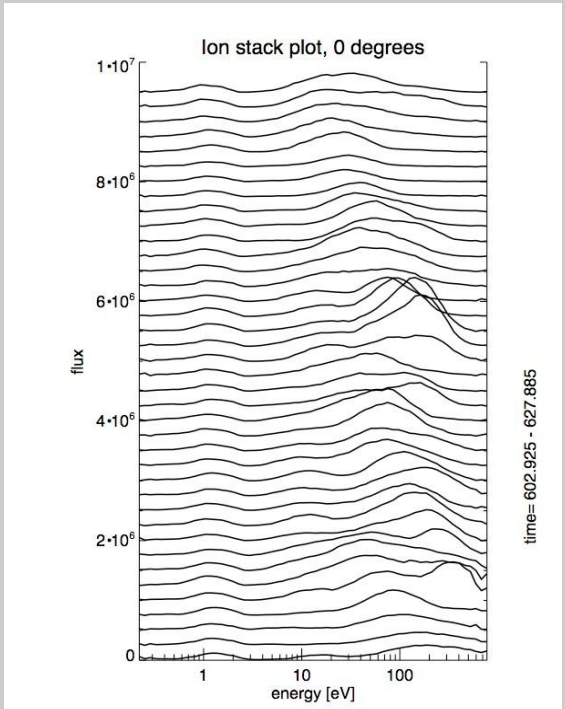


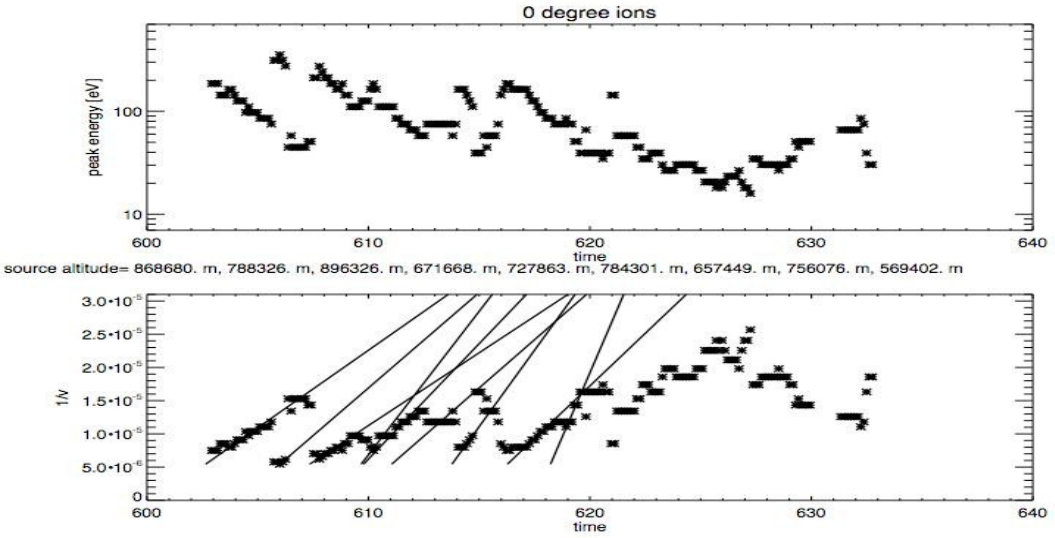
- Precipitating ions are dispersed in energy with time
- Energy decreases with time of flight, corresponding to increasing latitude

Ion dispersion

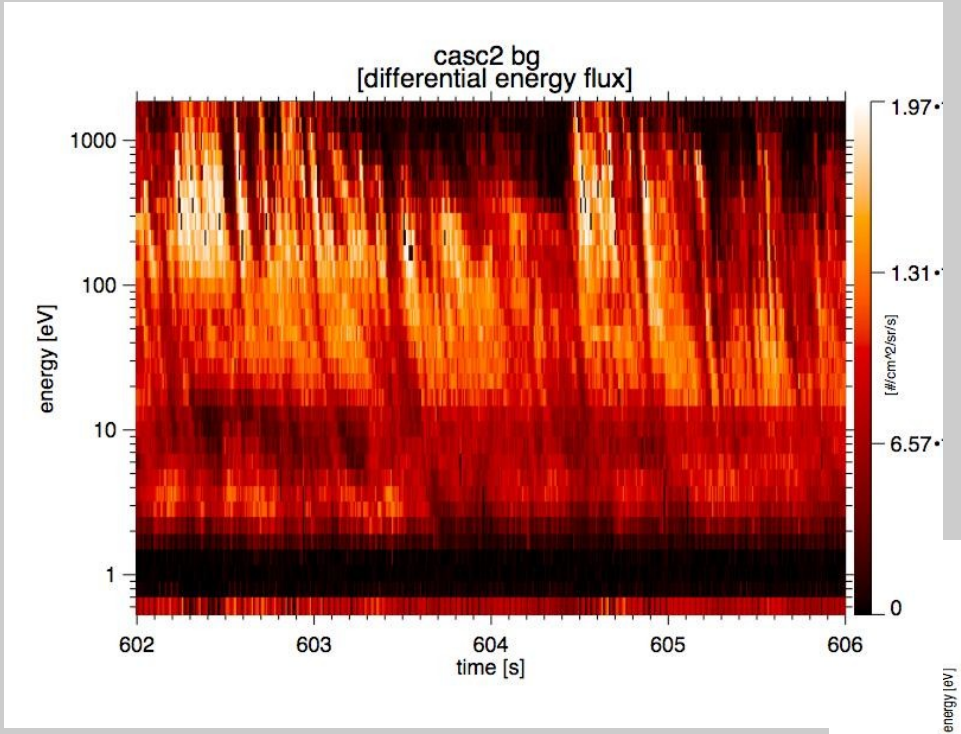
- Taking vertical line cuts through the spectrogram picks out the peaks
- Change from an energy scale to a 1/velocity scale to fit points to a straight line, which gives a calculated minimum acceleration altitude

  t = d * (1/v)
- Source altitudes range from 570 – 870 km, as measured from the ground

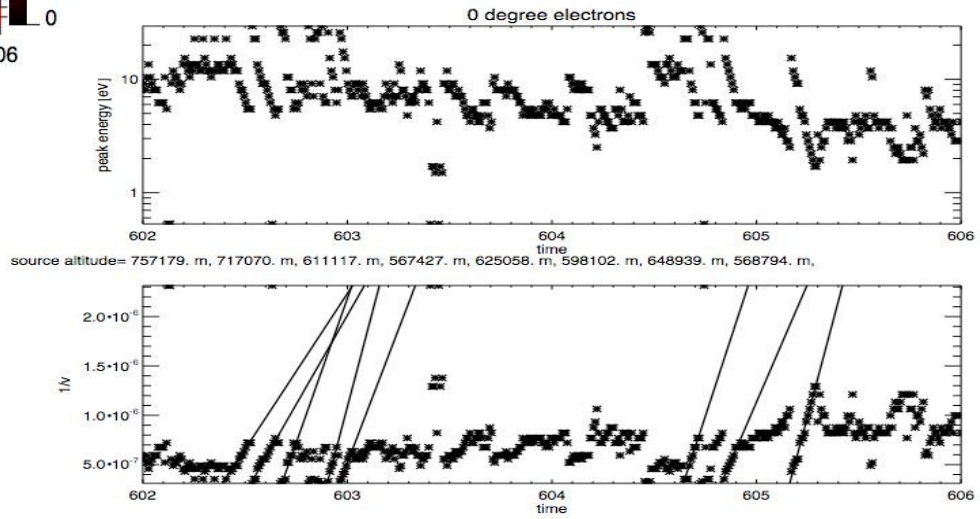




Compare to electron dispersion

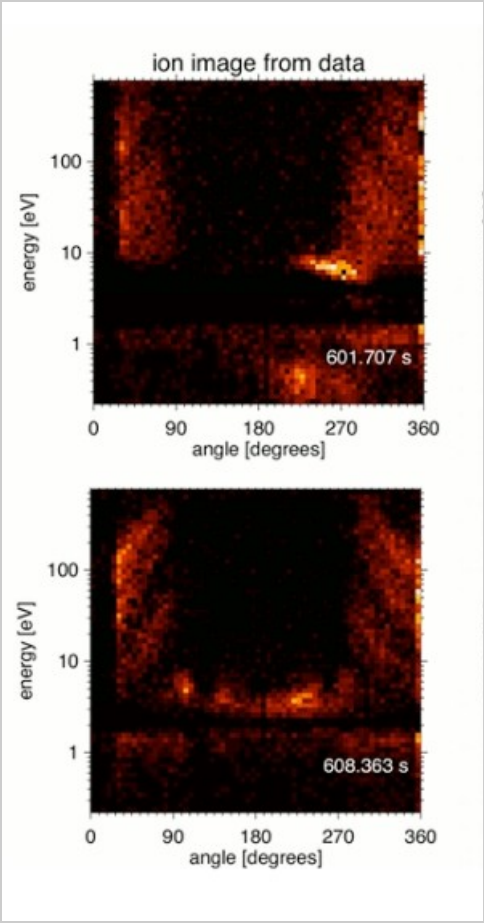


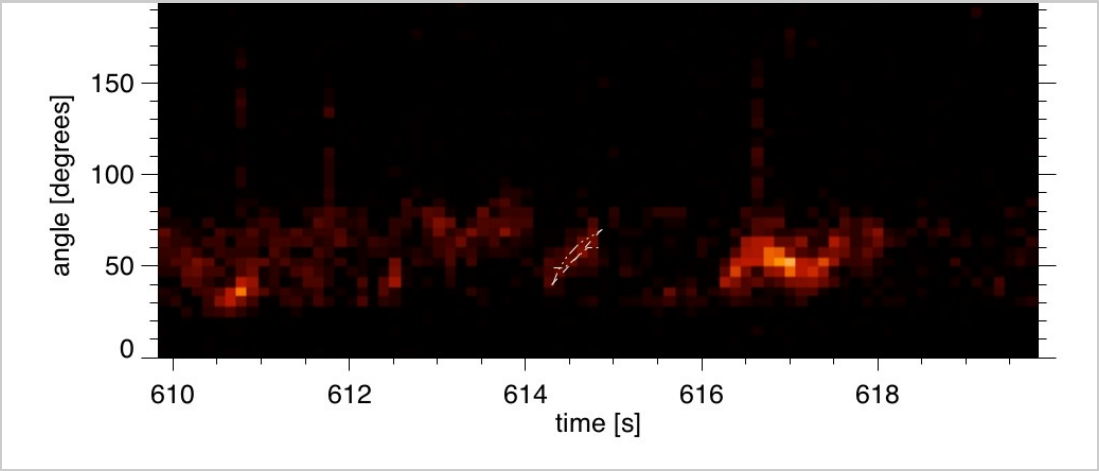
- Electron minimum acceleration altitude ranges from 560 - 760 km



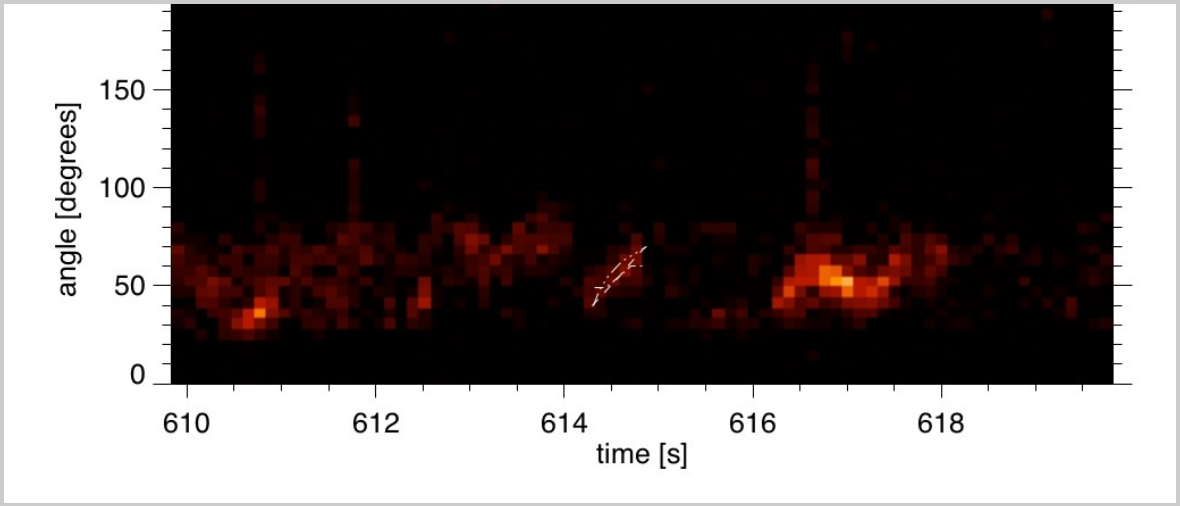
Ion pitch angle dispersion

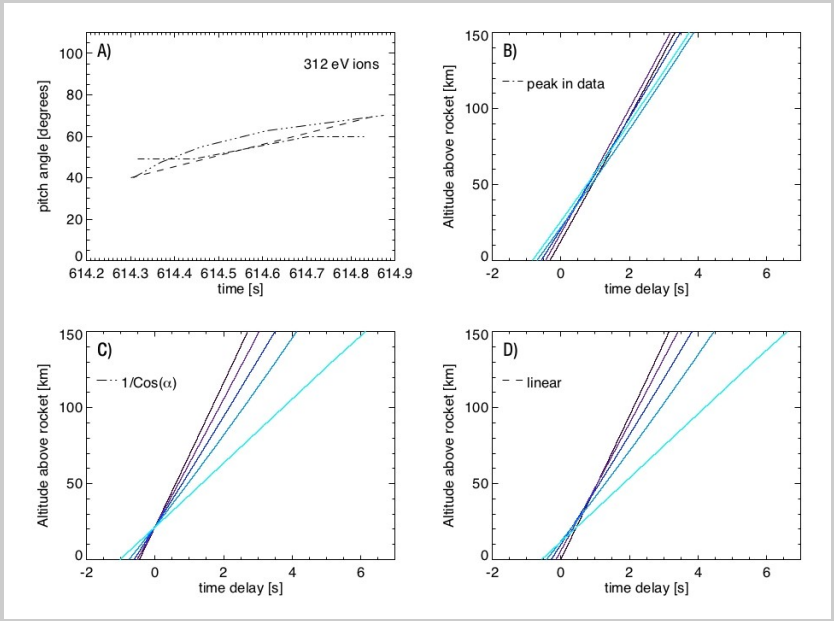
- Ions are also dispersed in pitch angle with time
- Given the pitch angle and the time of arrival of the ions along a dispersion curve, the altitude from which they were precipitated can be determined





Ion pitch angle dispersion



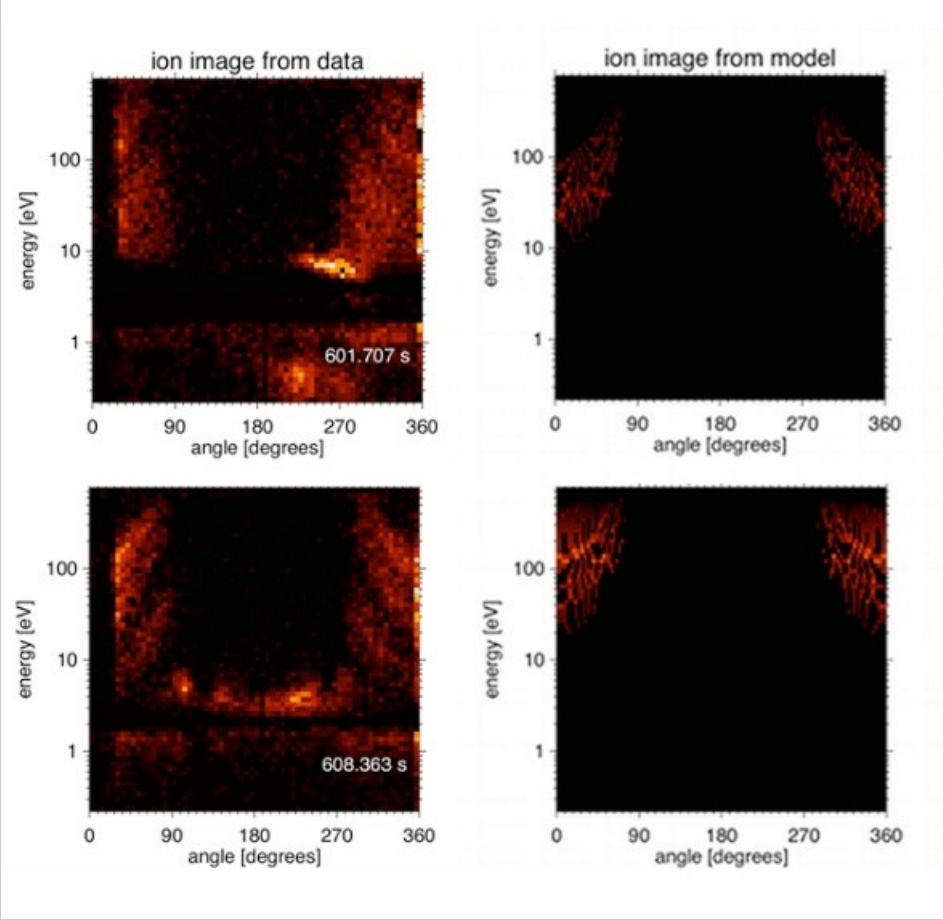


- Ions are also dispersed in pitch angle with time
- Given the pitch angle and the time of arrival of the ions along a dispersion curve, the altitude from which they were precipitated can be determined
- Method indicates precipitation over a range of altitudes of 50 km ranging from 675 - 750 km

Precipitation altitude inconsistency

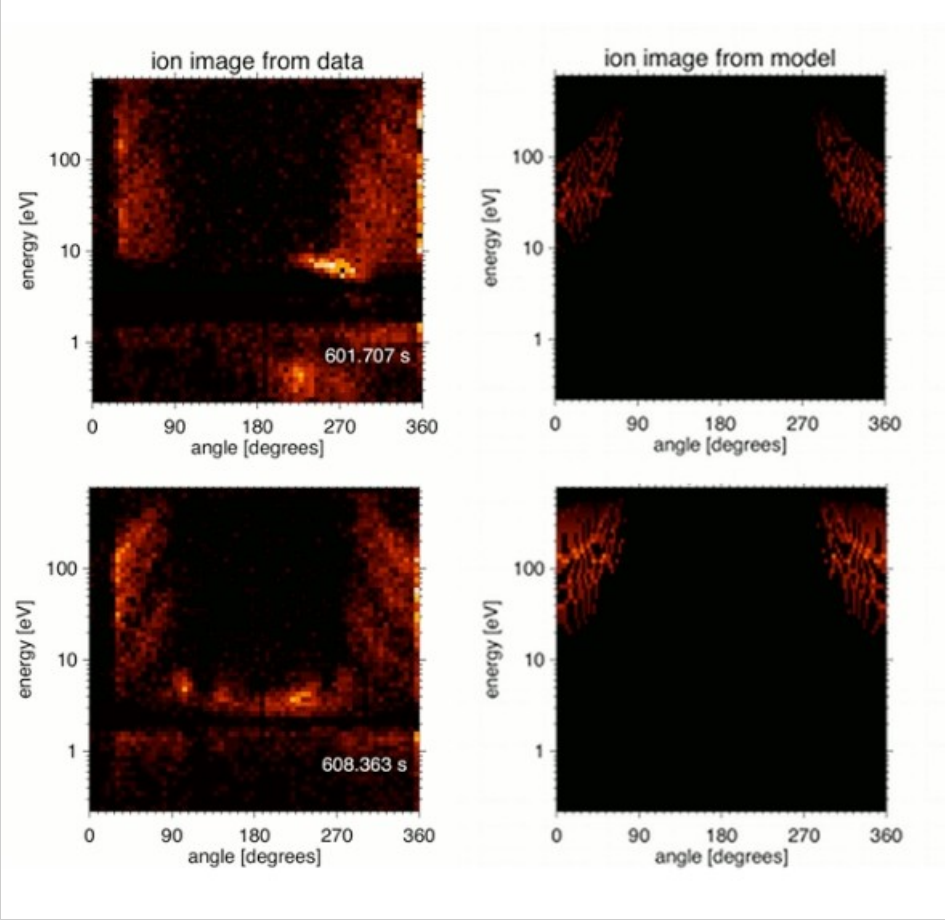
- Separate analysis of pitch angle dispersion and energy dispersion of ion population does not give consistent results
  - Range of altitudes of 50 km between 475 – 550 km, compared to a localized altitude in the range of 570 – 870 km
- Requires analysis of both signatures simultaneously

A simple model



- Choosing an altitude (or range of altitudes) a time delay is calculated based on the initial energy and pitch angle values of a population
- Parameters that can be adjusted:
  - Altitude range of precipitation region
  - Collection time
  - Temperature(s) of initial population
  - Number of initial populations

A simple model



- Best fit to data:
  - Three Maxwellians with different temperature (10, 15, and 60 eV for the top right panel; 15, 50, and 100 eV for the bottom right)
  - An acceleration region spread over 50 km
  - Include multiple populations separated by 1 second in order to get multiple dispersions at one pitch for one time

What information can be obtained from rocket observations of particle dispersions, and how can the in situ particle distributions and dispersions be used to parameterize these mechanisms?

- In the non-equatorward-extending PBI, electrons are observed to have an ionospheric source, which is accelerated by Alfven waves at an altitude of 500 – 1000 km
- Ion dispersions indicate a precipitation altitude of 500 – 550 km, with a source that is comprised of three Maxwellians of differing temperature

Photo by Robert Michell

Questions?