The global statistical response of the outer radiation belt during geomagnetic storms

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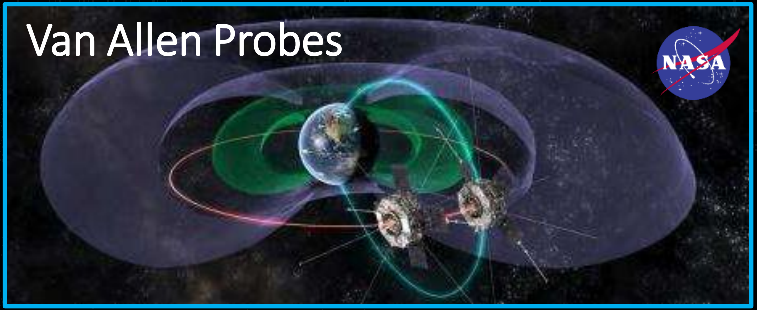
Can we identify a characteristic sequence of events during storms?

To do this we need:

- Total Radiation Belt

Content (TRBEC) and

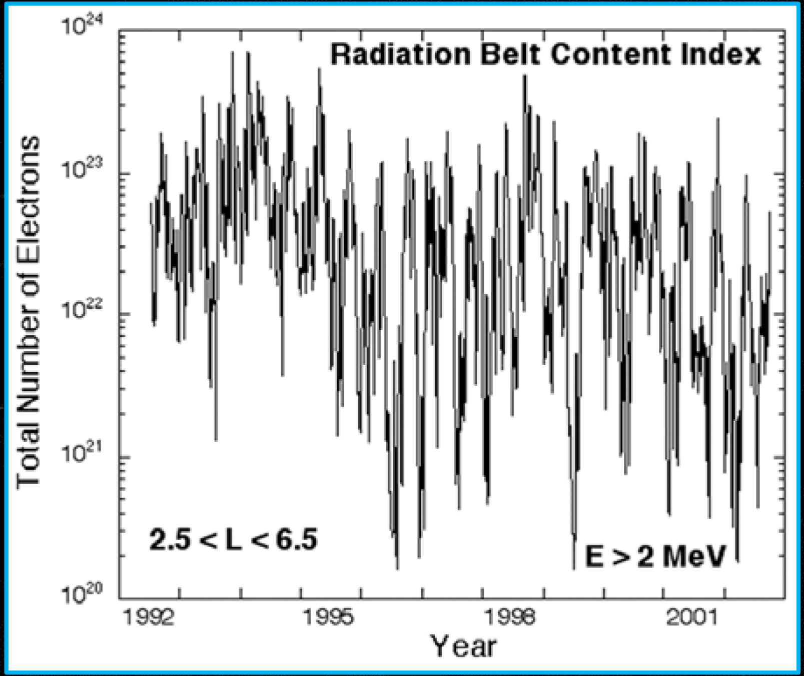
Phase Space Density (PSD)



- Van Allen era geomagnetic storms (2012-2016)
- Superposed epoch analysis of storm-time solar wind, radiation belt, and wave dynamics

Total Radiation Belt Electron Content: Ideal for Statistics

SAMPEX Radiation Belt Content

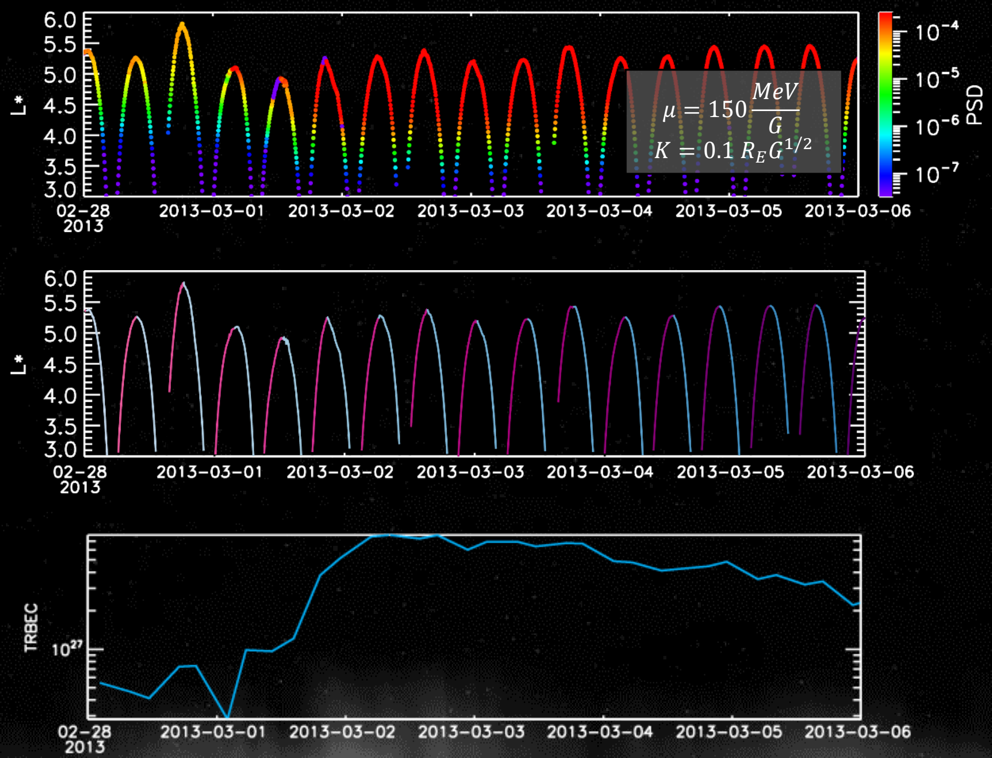


Baker et al. [2004]

- Estimate of total number of electrons within the radiation belt [Baker et al., 2004]
  - TRBEC (aka Radiation Belt Content; RBC)
- Reduces data set dimensions

Total Radiation Belt Electron Content: Van Allen

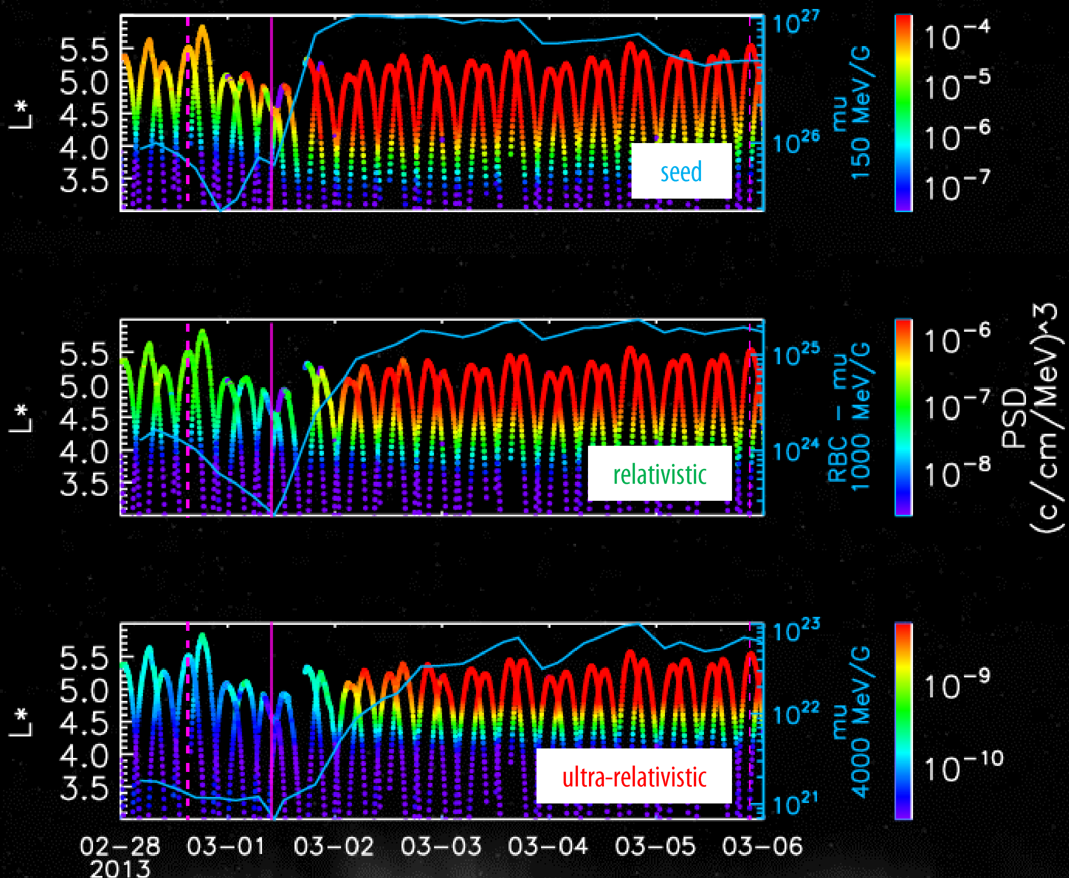
$$N = \iiint (2\pi)^3 f(\mu, K, L^*) \frac{8\sqrt{2}\pi^2 m_0^{3/2} \mu_0}{R_E} \frac{\sqrt{\mu}}{L^{*2}} d\mu dK dL^*$$



- Use Phase Space Density
  - Removes adiabatic effects
  - Boyd et al. [2016]
- Integrate over each half orbit
- Integrate over fixed μ, K

$$N = N(\mu, K)$$

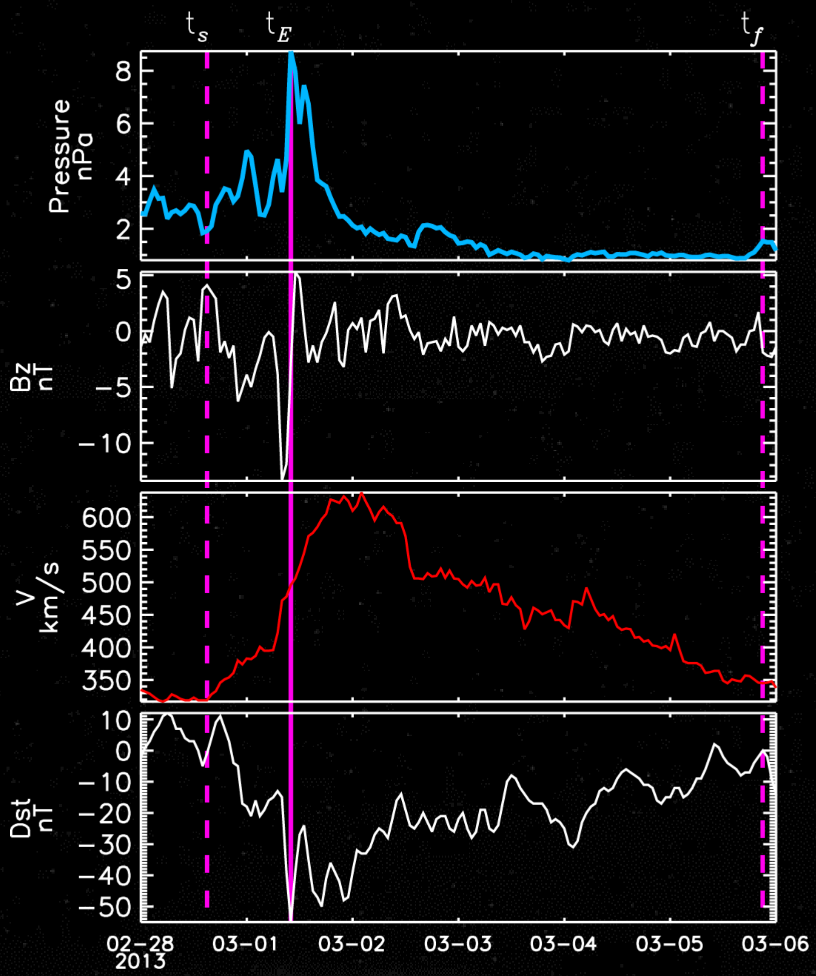
Total Radiation Belt Electron Content: Van Allen



Three μ values

- Seed Population
  $\mu = 150\ MeV/G$
- Relativistic Population
  $\mu = 1000\ MeV/G$
- Ultra-relativistic Population
  $\mu = 4000\ MeV/G$

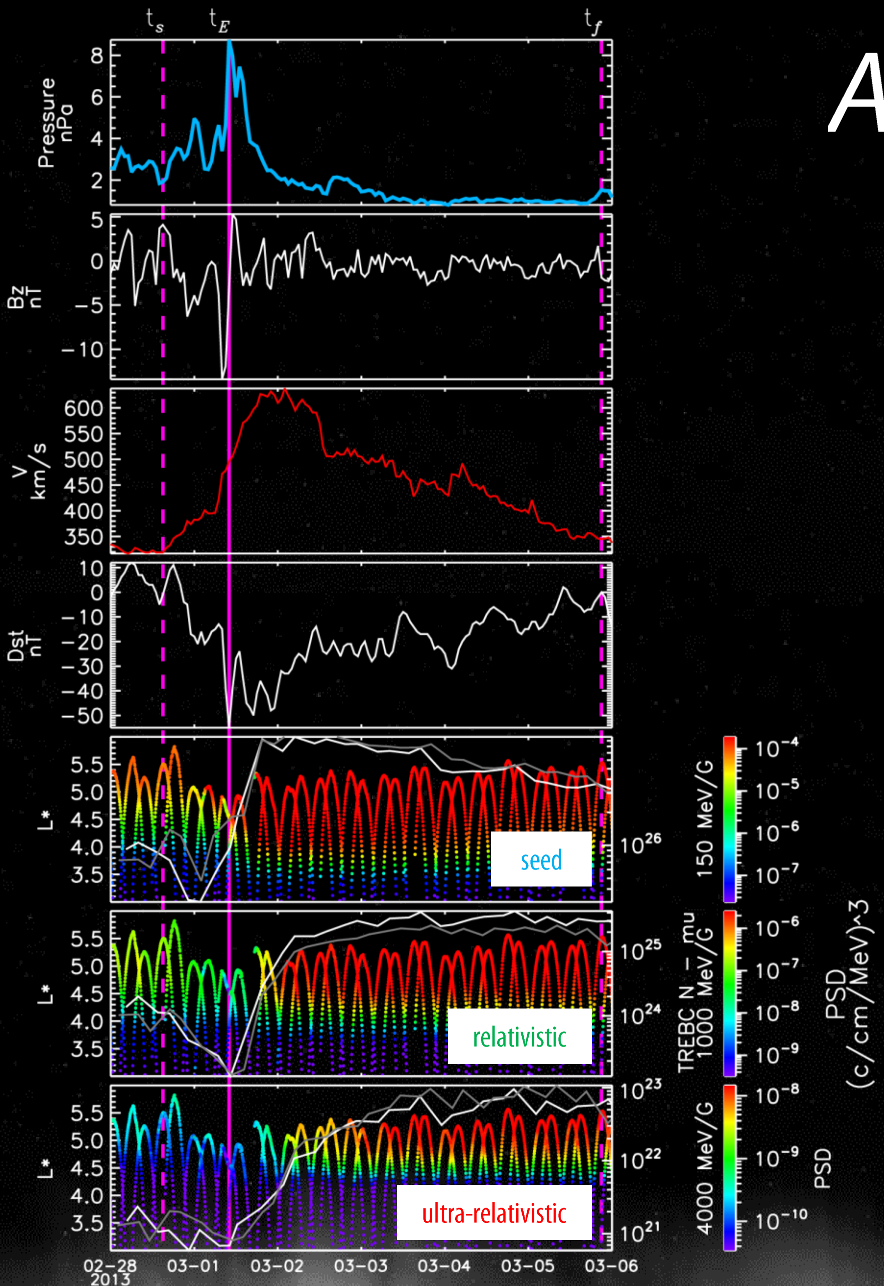
A novel Superposed Epoch Analysis



Murphy et al. [2018, *submitted*]

- Three physical epoch times
- Use *enhanced solar* wind driving to define start t_s
  - V_{SW}↑, *Pressure*↑
- Use *solar wind driving* and *Dst recovery* to define end, t_f
  - V_{SW}↓, *Pressure*↓, *Dst*↑,
- Epoch defined as minimum *Dst*, t_E

A novel Superposed Epoch Analysis

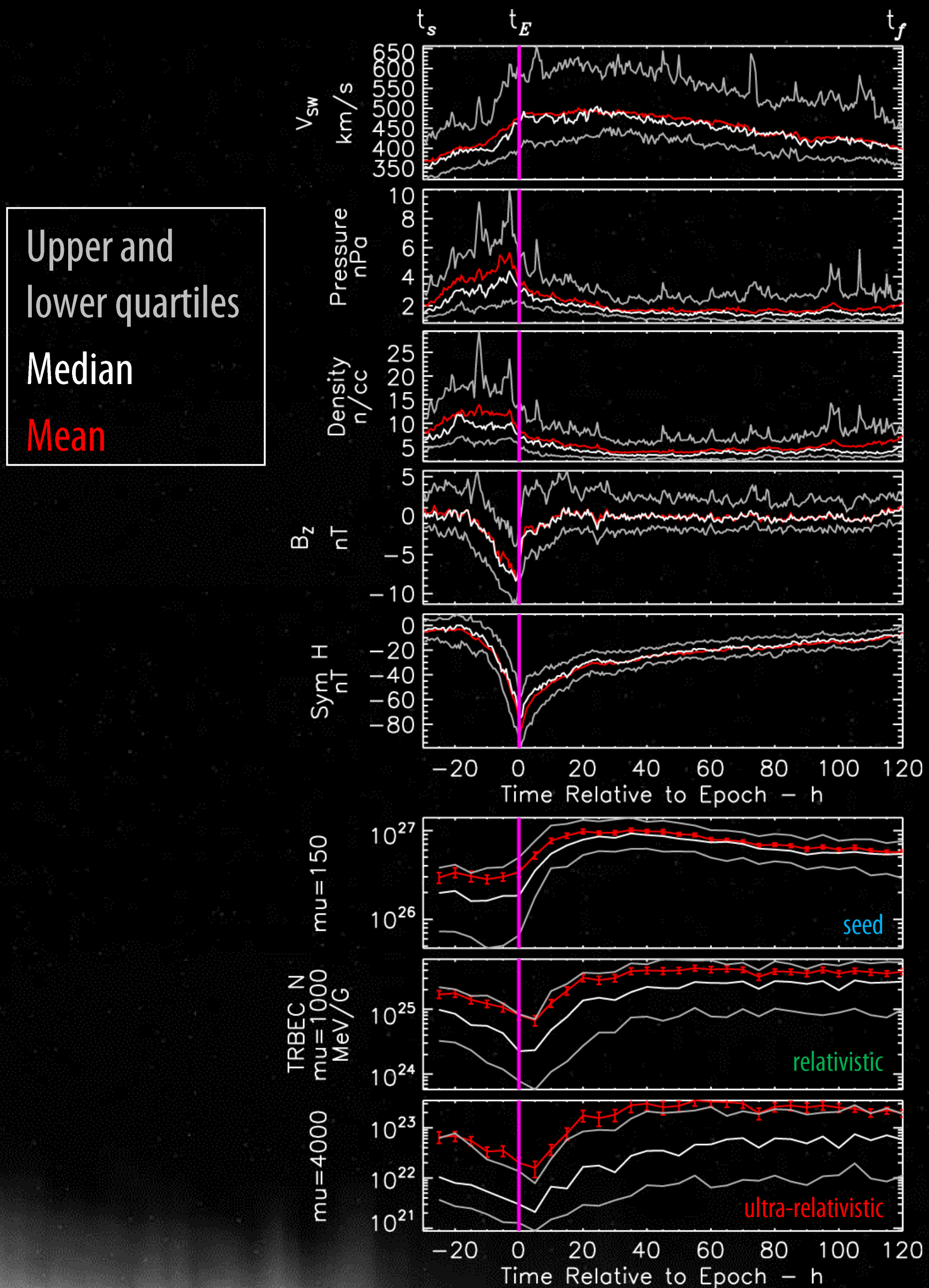


Murphy et al. [2018, *submitted*]

- Three physical epoch times
- Three μ values
  - seed, relativistic, and ultra-relativistic populations
- Solar wind and geomagnetic dynamics
  - *V_{SW}, Pressure, Density, B_Z, Sym-H, Magnetopause and Plasmapause location, ULF and VLF wave power*

A repeatable result

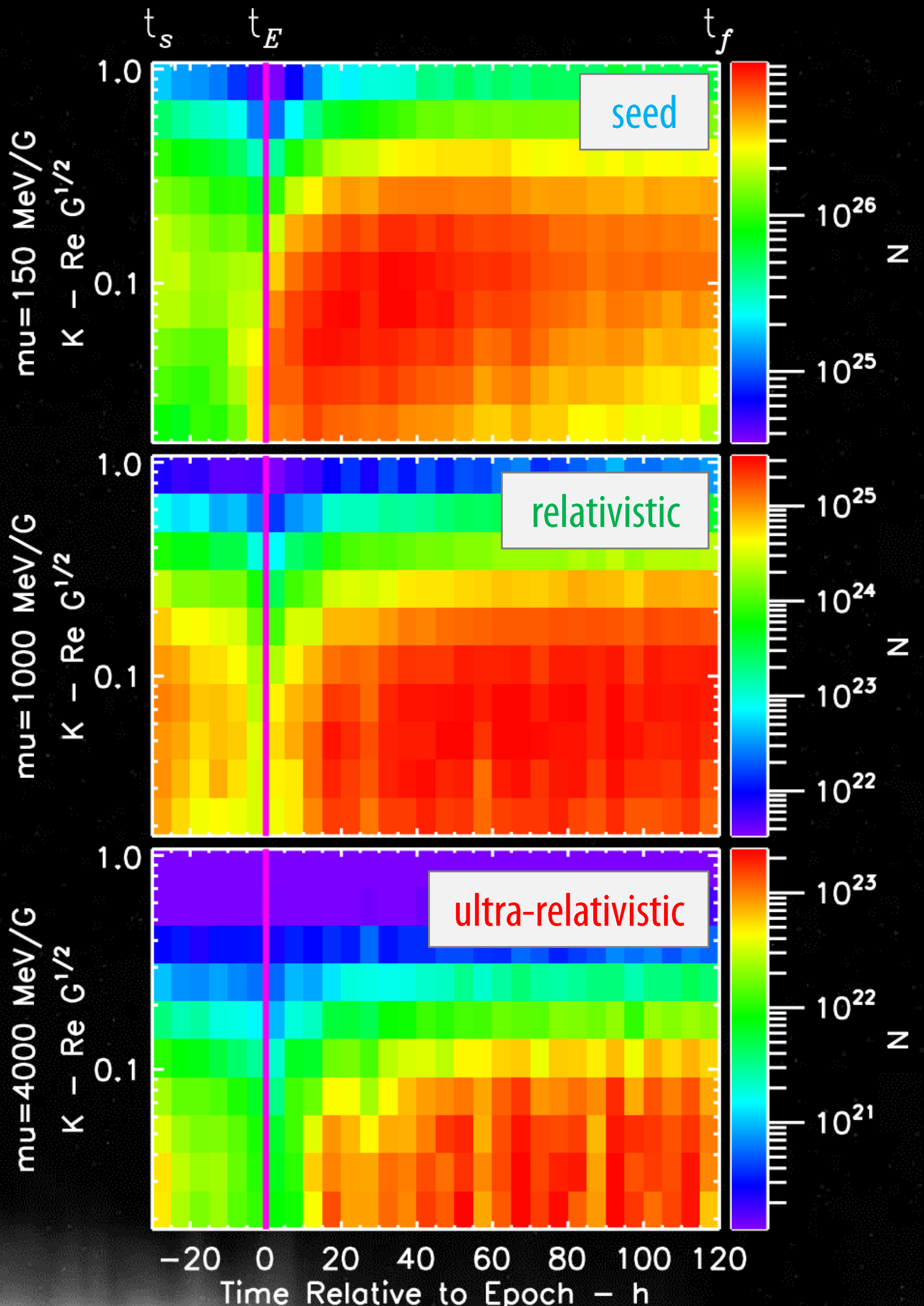
- Solar wind and geomagnetic activity
  - Rapid enhancement
  - Slow retreat toward quiet values
- Radiation belt dynamics
  - Initial phase dominated by loss
  - Second phase dominate by acceleration/transport



Murphy et al. [2018, *submitted*]

A global net loss followed by net acceleration

- Seed populations
  - Some evidence of loss
  - Rapid enhancement following epoch
- Relativistic and Ultra-relativistic
  - Initial period dominated by loss
  - Followed by acceleration
- Acceleration is K dependent



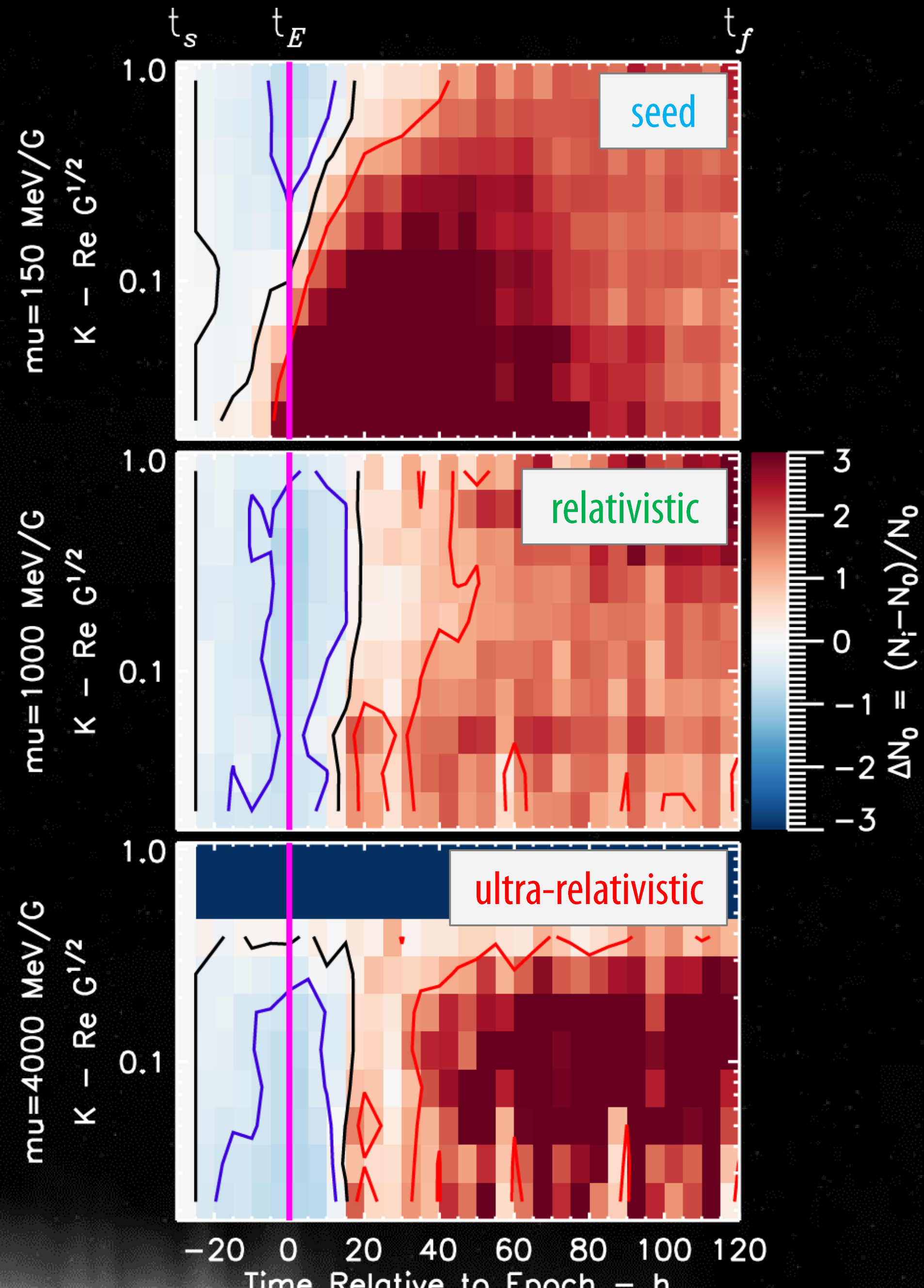
Murphy et al. [2018, *submitted*]

Emphasizing Rapid Losses

Fractional change relative to t_s

$$\Delta N_0 = (N_i - N_0)/N_0$$

- $t_s \rightarrow t_E$ dominated by *loss*
- $t_E \rightarrow t_f$ dominated by *acceleration*
- Transition from loss to acceleration is μ *dependent*



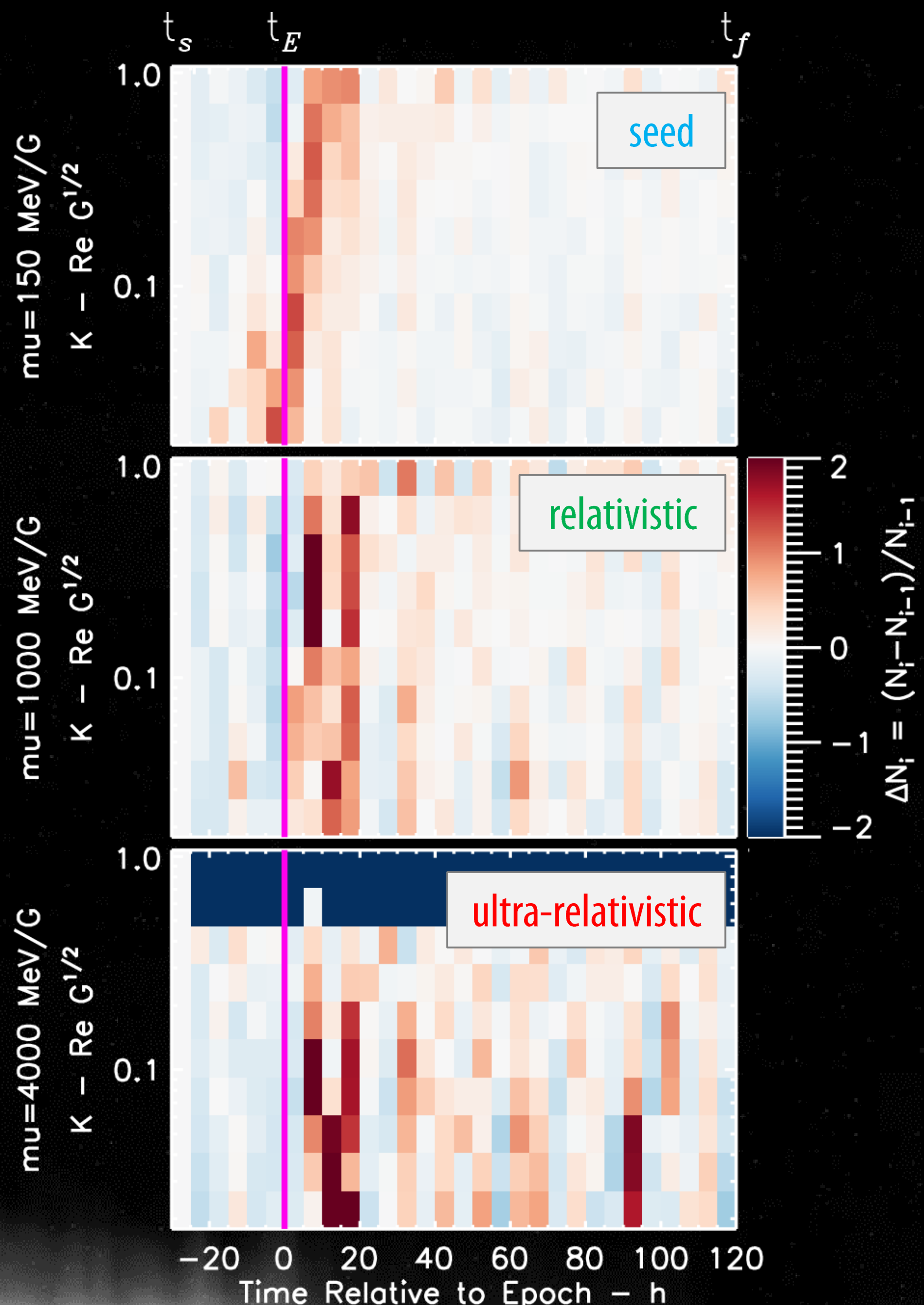
Murphy et al. [2018, *submitted*]

Emphasizing Rapid Acceleration

Fractional change relative to t_i

$$\Delta N_i = (N_i - N_{i-1})/N_{i-1}$$

- Short period of *rapid acceleration*
- Evidence of extended acceleration at relatvistic energies



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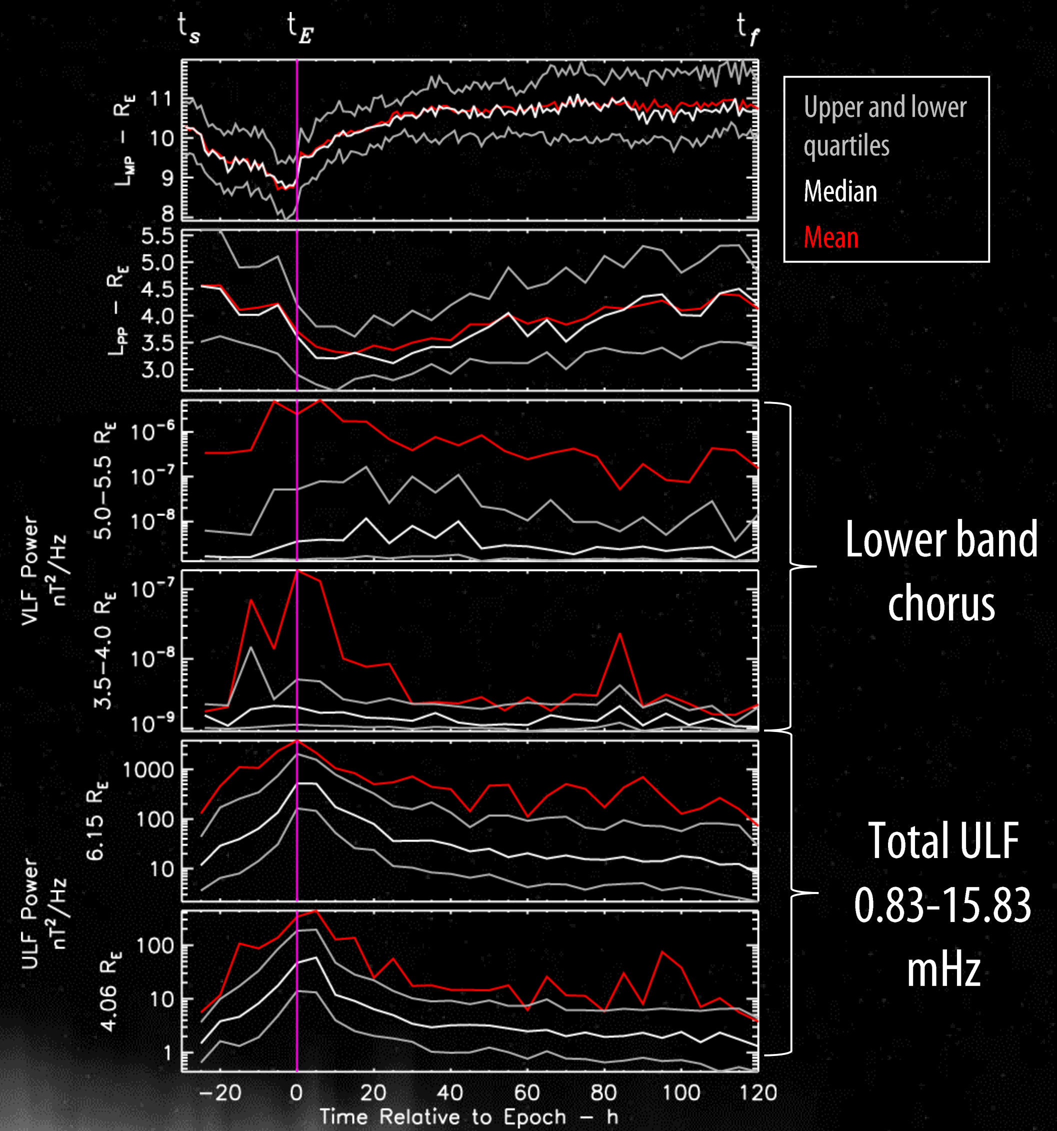
Storm-time Drivers

$t_s \rightarrow t_E$

- Magnetopause and Plasmapause inward
- VLF/ULF increase

$t_E \rightarrow t_f$

- Magnetopause retreats
- Plasmapause minimum
- Both VLF/ULF peak and rapidly decay



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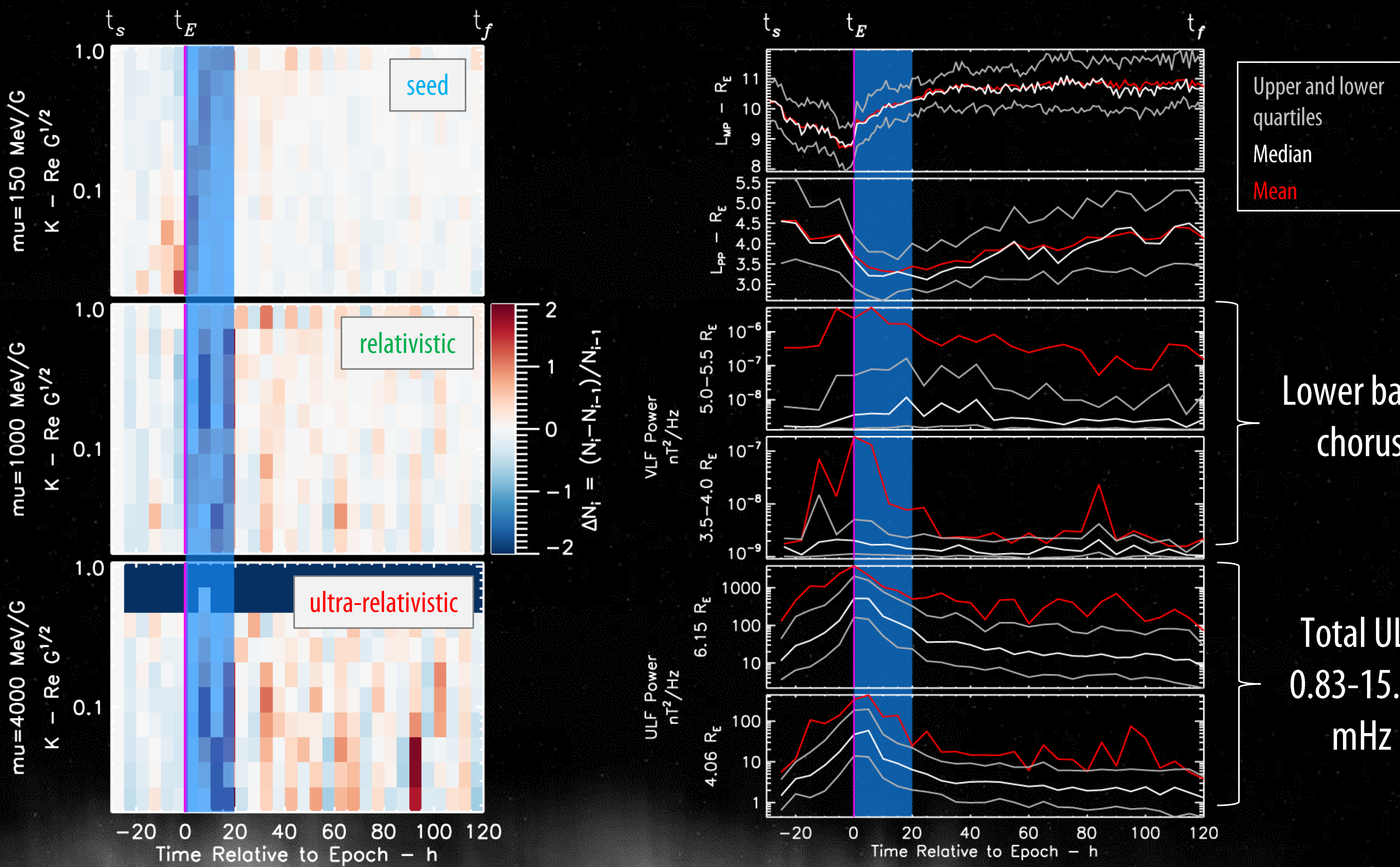
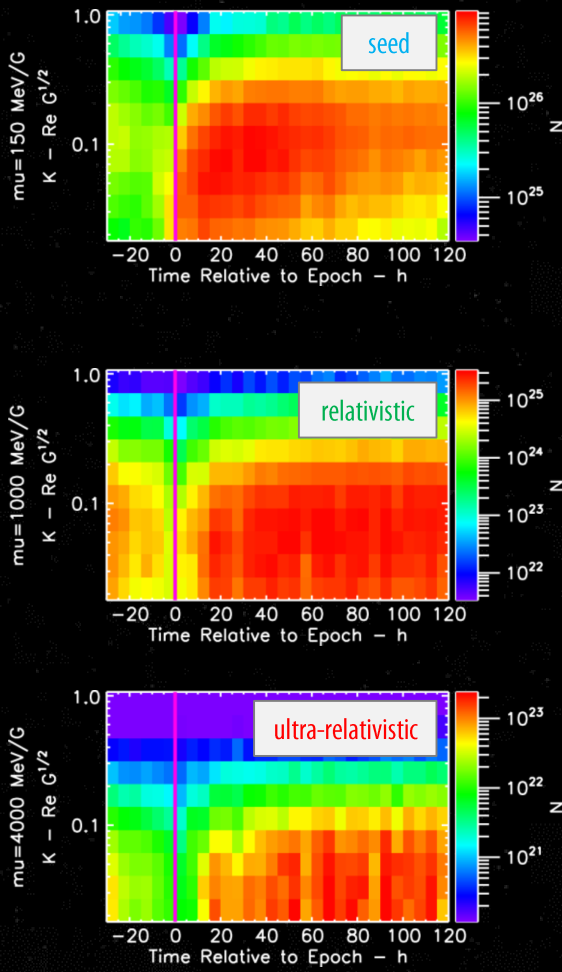


Murphy et al. [2018, *in prep*]

Storm-times may be more repeatable than you think

- Physical drivers define three epoch times to define a storm framework
- Seed, relativistic, and ultra-relativistic electrons have an initial period of net loss followed by net enhancement.
- Loss phase is characterized by enhanced wave power and inward motion of the magnetopause.
- Acceleration phase is quick and occurs when wave power in ***both*** VLF and ULF waves peak
- Both phases need to be taken into account independently




THANK YOU
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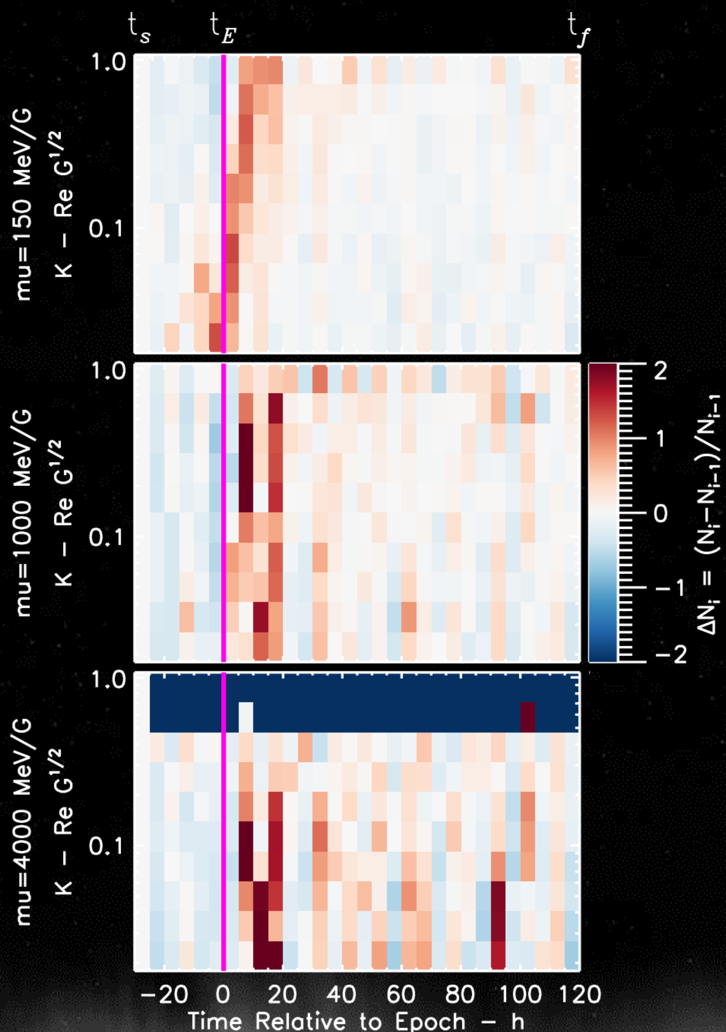
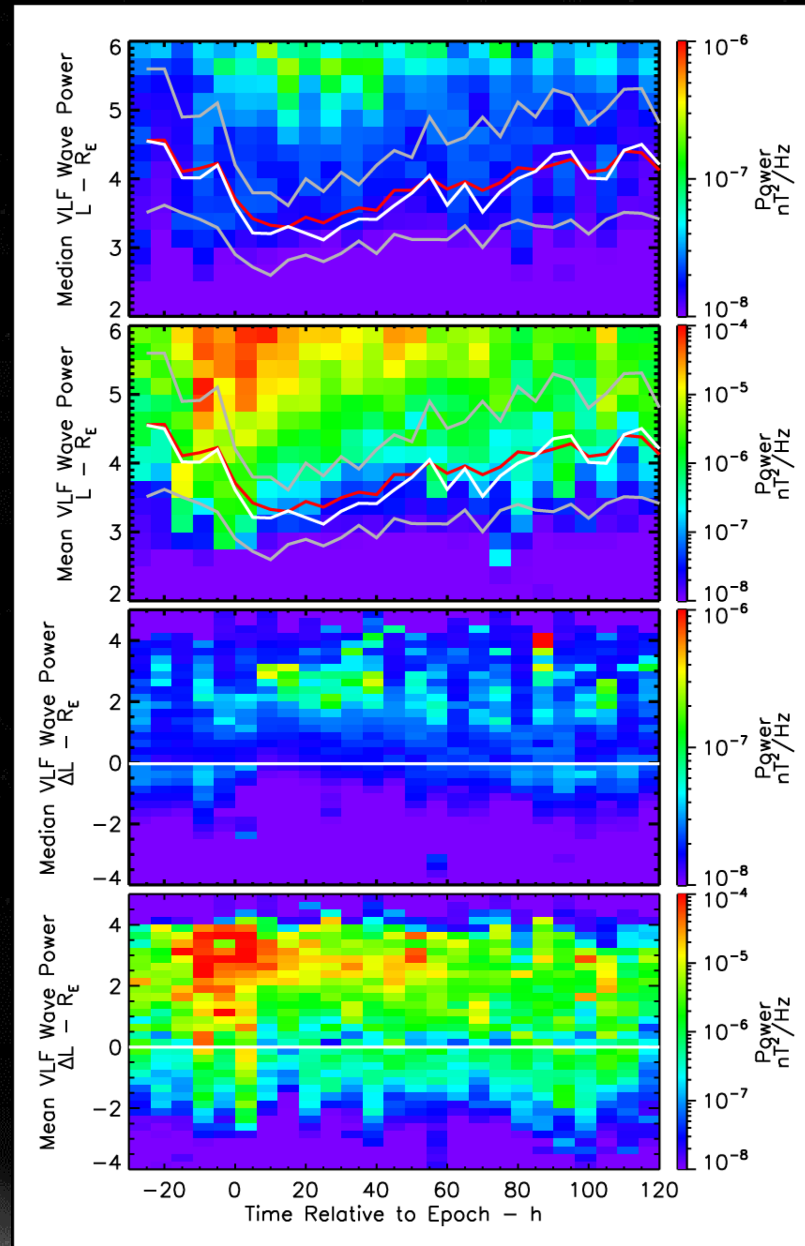
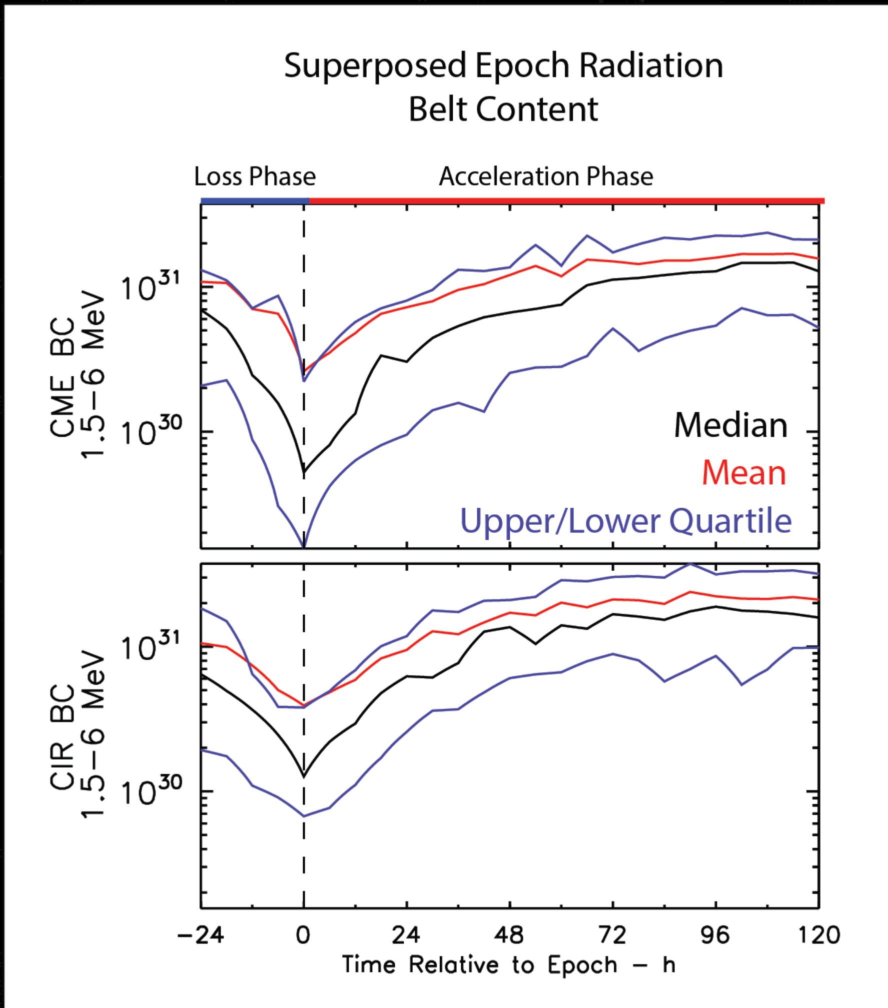
VLF Chorus vs L



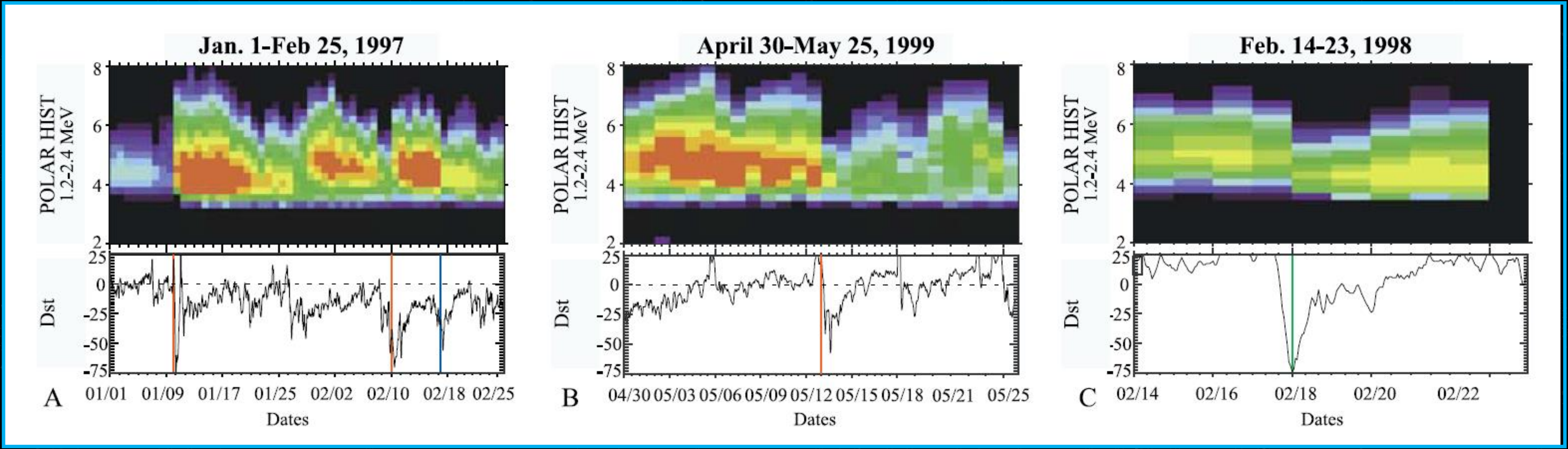


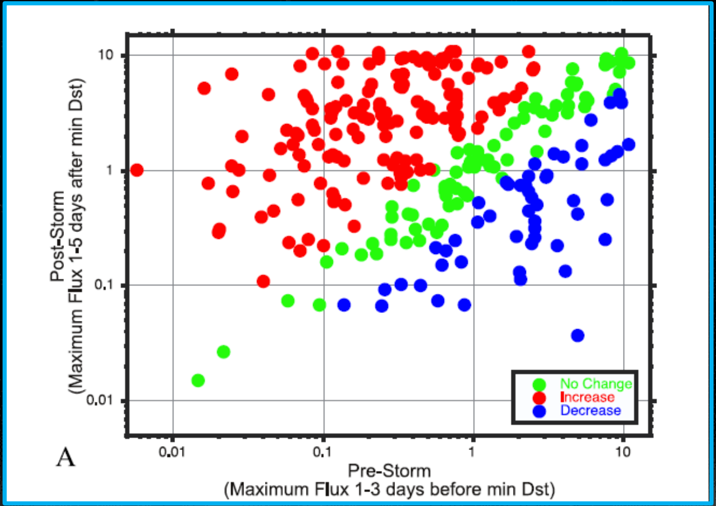
Superposed Epoch



- SAMPEX
  - 1994 - 2004
  - 45 CIR driven storms
  - 39 CME driven storms
- All storms show two distinct phases
  - Initial phase dominated by loss
  - Subsequent phase dominated by acceleration

Geomagnetic Storms

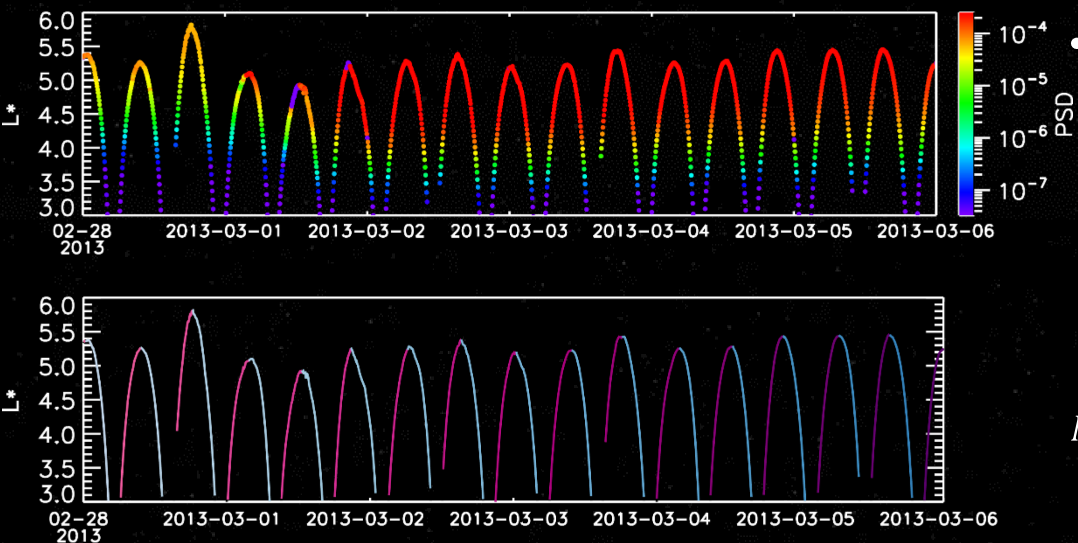




Reeves et al. [2003]

Total Radiation Belt Electron Content

$$\mu = 150 \frac{MeV}{G}, K = 0.1\ R_E G^{1/2}$$



Van Allen Era TRBEC

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  - Removes adiabatic effects
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