Nonstorm-time Acceleration and Transport of Radiation Belt Electrons

Physical Mechanisms & Favored Conditions

Zhenpeng Su
University of Science and Technology of China
Representative radiation belt storm events

[Brautigam and Albert, 2000; Summers et al., 2002] [Baker et al., 2004; Shprits et al., 2006] [Reeves et al., 2013; Thorne et al., 2013]
Storms can either increase or decrease the radiation belt relativistic electron fluxes

Neither acceleration nor loss mechanisms scale with storm intensities
Solar and magnetospheric conditions for Van Allen Probes

- Weakest solar cycle in 100 years, infrequent occurrence of strong storms
- Nonstorm-time radiation belt dynamics

[Pande et al., 2017]
Nonstorm-time acceleration and transport of radiation belt electrons

- Physical mechanisms: two representative events
  - Local acceleration during 2-7 Aug. 2014
  - Radial diffusion and adiabatic transport during 16-17 Jan. 2013
- Favored conditions: statistical analysis
Event I: 3-month overview of radiation belt environment

- ~70 days without storms
- Most prominent event during 2-7 Aug. 2014 (shadow)
- Intense and sustained substorms
- Continuous injection of seed electrons
- Enhancement of relativistic electrons
Event I: local acceleration characteristics

- Pre-event radiation belt centered at L=4.3
- New radiation belt formed at L=5.5 within 5 days
- Flat-top pitch angle distributions
- Peaked phase space densities
Event I: Plasma wave characteristics

- Substorm injections destabilized chorus waves outside L=4.5
- Chorus might be responsible for the local electron acceleration, similar to the storm situation [e.g., Horne et al., 2003, Reeves et al., 2013]
- Enhanced substorm activities favored the local acceleration
Event II: 3-month overview of radiation belt environment

- ~50 days without storms
- Interesting event during 16-17 Jan. 2013 (shadow)
- Enhanced SYM-H (solar wind dynamic pressure)
- Enhanced substorm injections before the event
Event II: radial transport characteristics

- Pre-event radiation belt centered at \( L = 3.6 \)
- New radiation belt formed at \( L = 5.2 \) within 2 days
- Very weak substorm activities
- Quasi-periodic oscillations of electron fluxes, drift resonance [e.g., Mann et al., 2013]
- Inward radial diffusion of phase space density
Event II: Magnetic field configurations

- Enhanced solar wind dynamic pressure
- Earthward movement of magnetic field lines
- Steep radial profiles of electron phase space density
- Fully adiabatic transport could contribute to the flux enhancement
Precondition for Event II

- Enhanced substorm activities before Event II
- Generation of the phase space density peaks
- Allowing the subsequent radial transport
Intense and continuous substorm activities were important for the radiation belt electron acceleration

- Causing the local acceleration
- Creating phase space density peaks to favor the subsequent radial transport (radial diffusion and adiabatic transport)
Correlation between daily RBC (log10) and AE* over ~5 years

- Daily radiation belt content
  \[ RBC(t) = \int_{L=3}^{L=6} j(t, L)L^2 dL \]

- Averaged AE in the preceding \( \Delta t \) days
  \[ AE^*(t) = \frac{1}{\Delta t} \int_{t-\Delta t}^{t} AE(t)dt \]

- Linear correlation (0.67) peaks at \( \Delta t = 17 \) days

- Scatter dot plot shows a positive correlation between RBC and AE*
Physical interpretation of optimal averaging time $\Delta t$ for AE*

- Gradual decay of accelerated electrons
- $\Delta t$ comparable to electron lifetime
Correlation between daily RBC (log10) and SYM-H* over ~5 years

- Daily radiation belt content
  \[ RBC(t) = \int_{L=3}^{L=6} j(t, L) L^2 dL \]

- Averaged SYM-H in the preceding \( \Delta t \) days
  \[ SYMH^*(t) = \frac{1}{\Delta t} \int_{t-\Delta t}^{t} SYMH(t) dt \]

- Linear correlation (0.48) peaks at \( \Delta t = 14 \) day

- Scatter dot plot shows a triangle-shaped distribution, and particularly when SYM-H* \( \sim 0 \), RBC varies over a wide range
Conclusions

- Frequent observations of nonstorm radiation belt dynamics by RBSP
- Nonstorm mechanisms: local acceleration and/or radial transport, similar to the storm situation
- Importance of substorm activities: causing local acceleration and producing PSD peaks to allow subsequent radial transport
- Positive correlation (0.67) between daily RBC and AE* (averaged AE in preceding 17 days)