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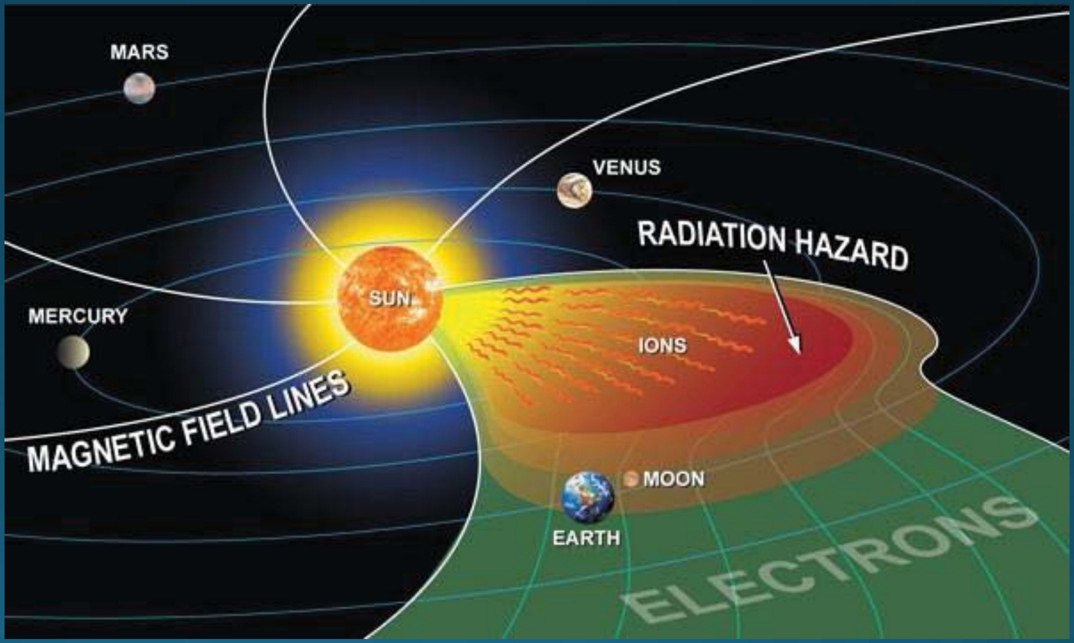
Spacecraft Charging in Geostationary Transfer Orbit

Outline

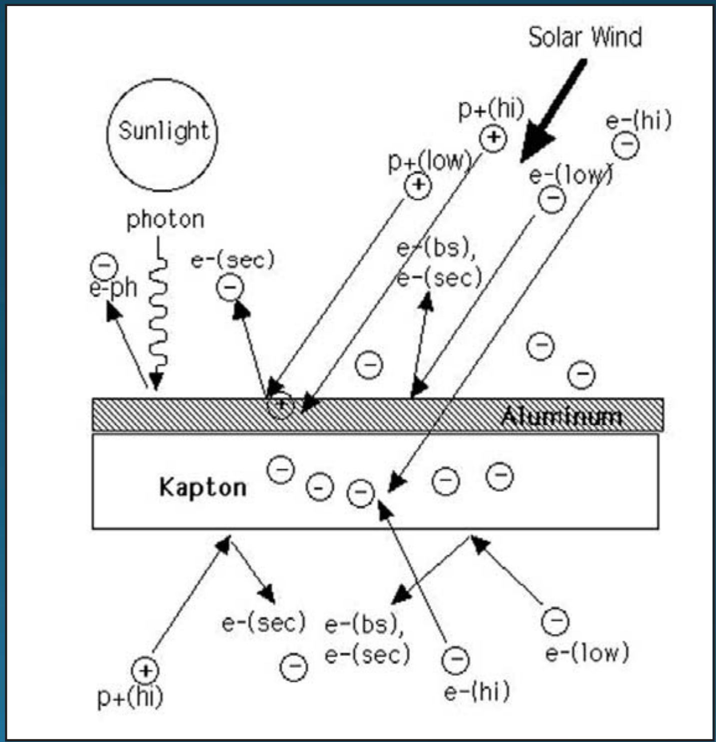
- Background
- Observations
- Model
- Event characteristics
- Future work



Surface Charging

- Accumulation of charge on the outer surfaces of a spacecraft
- The net charge is due to the sum of the incident currents

$$\frac{dQ}{dt} = C\frac{dV}{dt} = \frac{d\sigma}{dt}A = \sum_k I_k$$



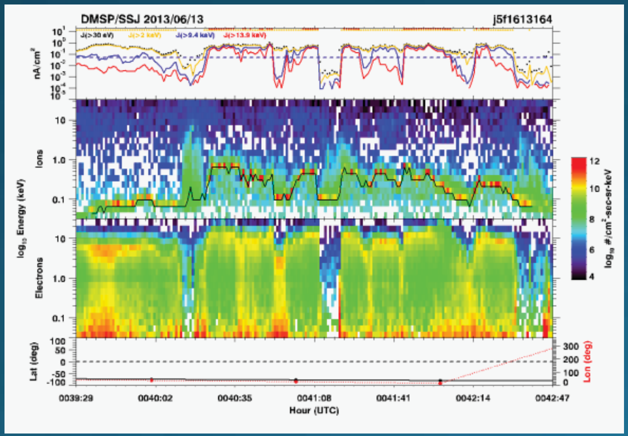
(Garrett and Minow, 2004)

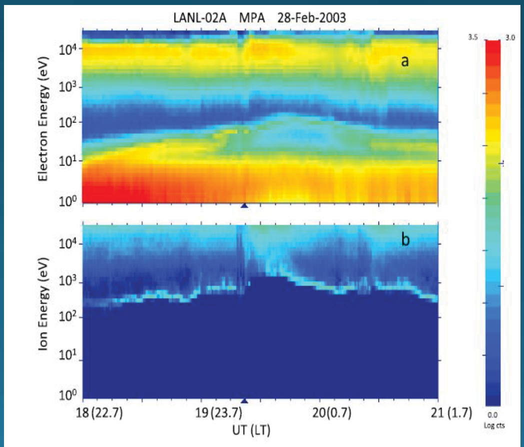
Ion Line Charging Signature

- "Ion line" is due to the low energy (E_o) background ions accelerated to an additional energy ($q\,\phi$) due to the spacecraft potential

$$E = E_o + q\,\phi$$

- Auroral, 1-2 kV, eclipse, low ambient density and high flux for high energy electrons
- GEO, 1-10 kV, midnight through dawn sector

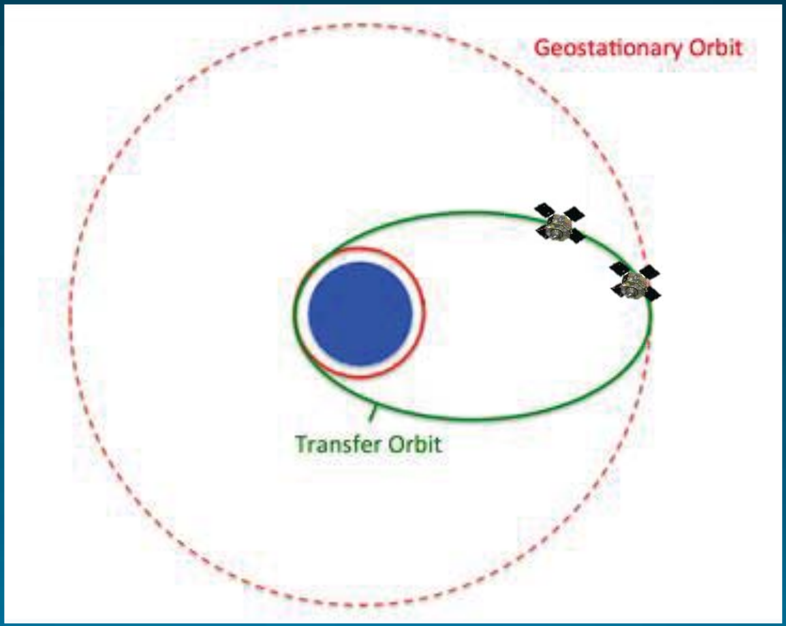




[Thomson et al., 2013]

Van Allen Probes

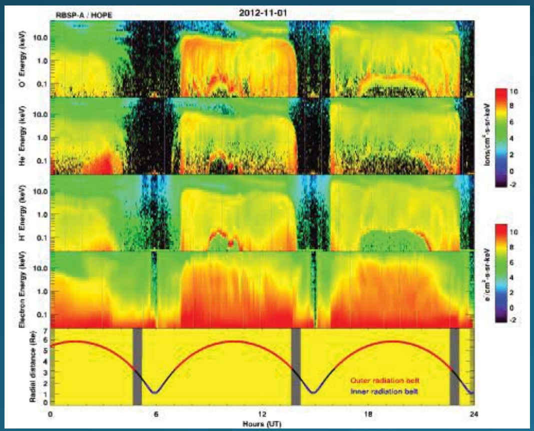
- 700 km x 5.8 R_e orbit, geostationary transit orbit
- Study includes data from the start of mission through December 2013.
- Helium Oxygen Proton Electron (HOPE) plasma spectrometer to identify candidate surface charging events
- Level III moments files

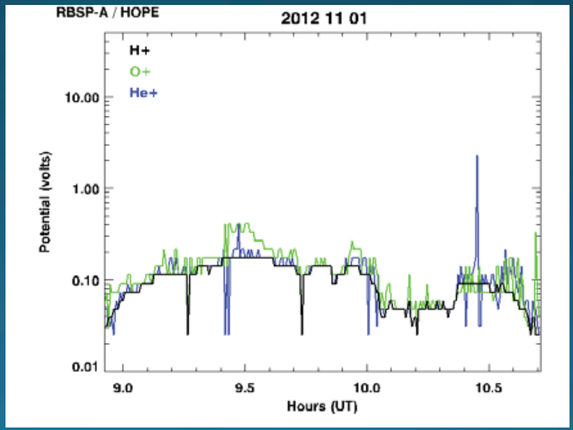


HOPE data courtesy of
http://www.rbsp-ect.lanl.gov/rbsp_ect.php

Charging Line Extraction Program

- Read in RBSP HOPE data
- Look for ion charging line in the proton differential energy flux channel
- Program automatically extracts the H+, He+, O+ charging lines
  - Plots charging line
  - Prints variables to file including t_o, t_f, ϕ, ephemeris, moments.



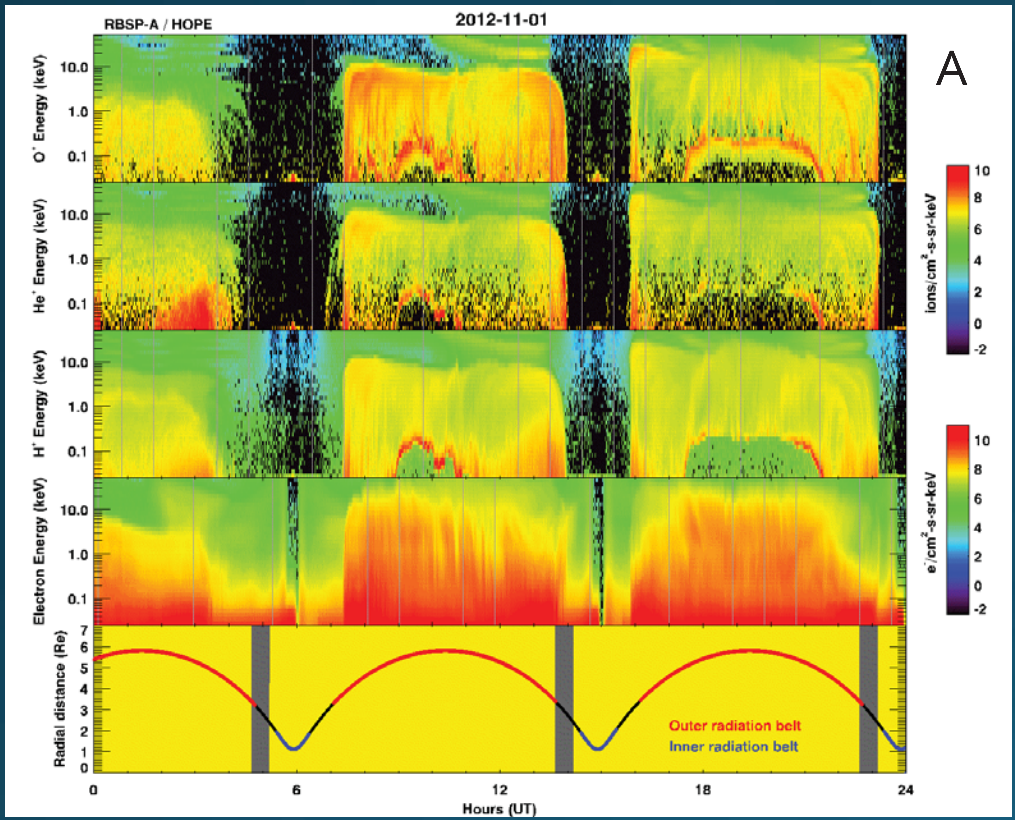


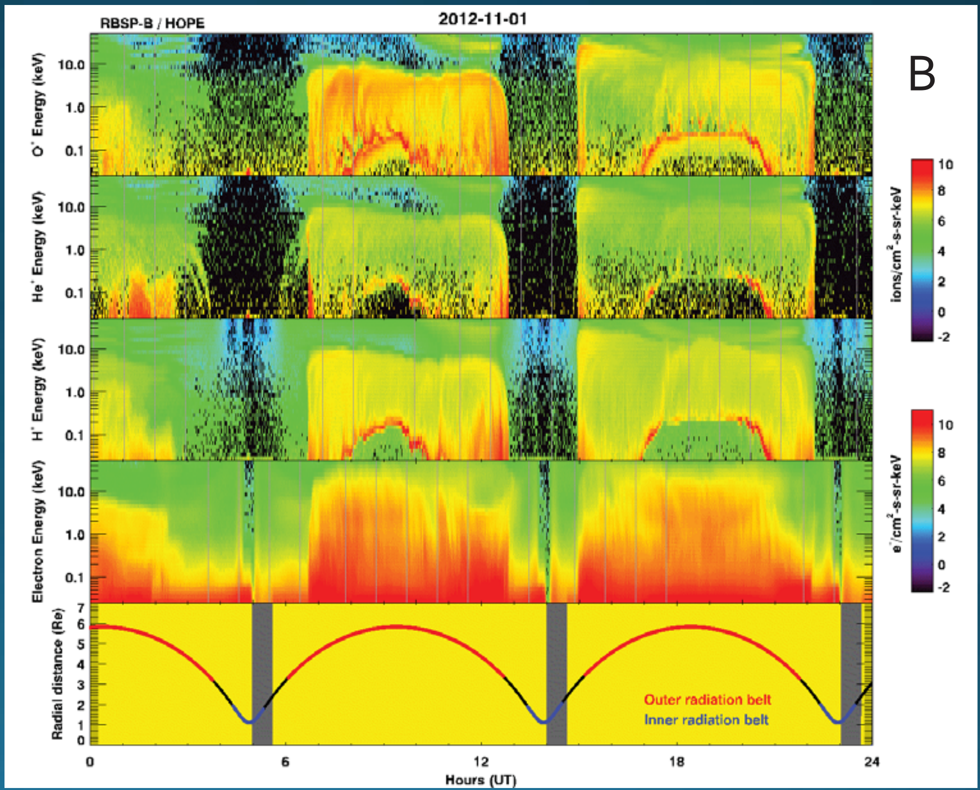
Extracted ion lines.

Dual Satellite Observations

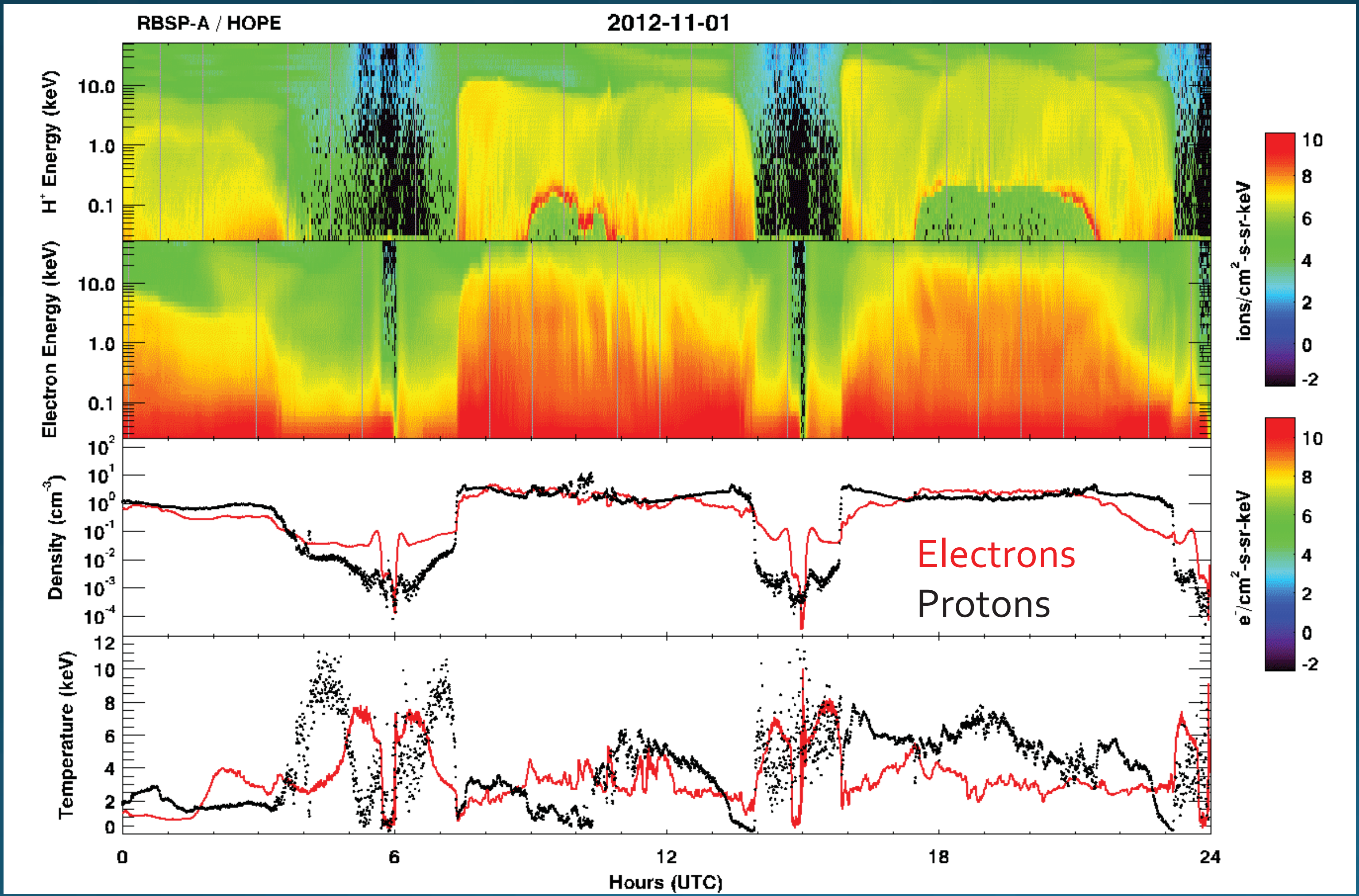
- By looking at RBSP-A and -B, we can explore the temporal and spatial information of the charging events
- Satellites exhibited charging on the same day in 12 out of 30 days
- When both satellites exhibit charging on the same day, the charging was of similar magnitude

Example: Nov 1, 2012





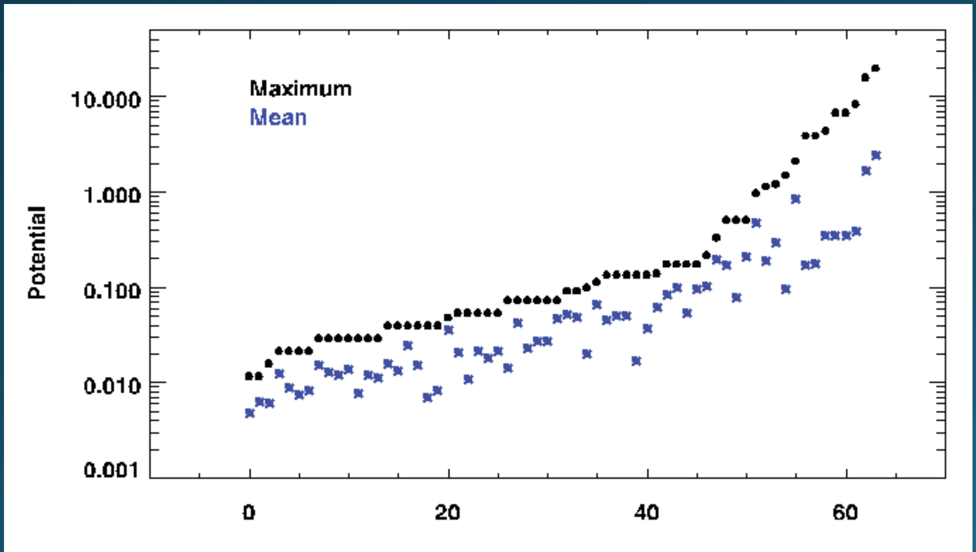
Moments

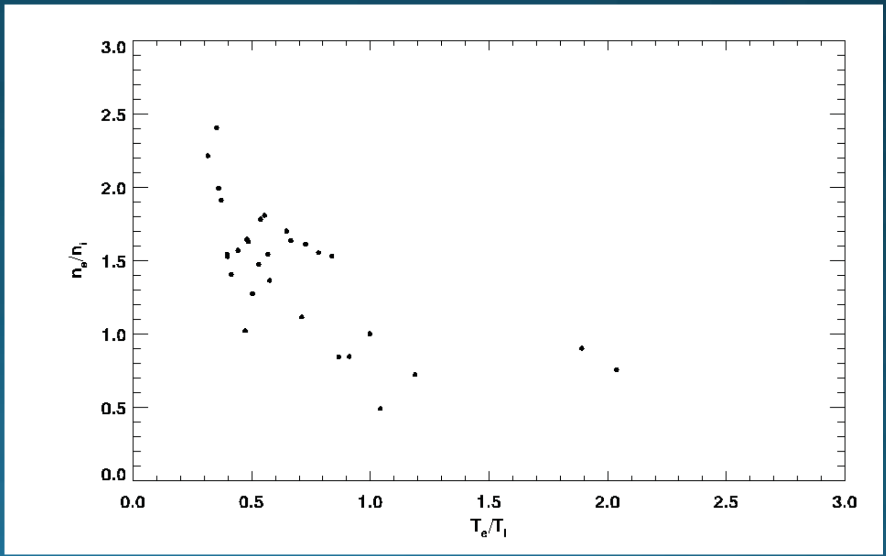


RBSP-A / HOPE
2012-11-01
H+ Energy (keV)
10.0
1.0
0.1
Electron Energy (keV)
10.0
1.0
0.1
Density (cm-3)
Temperature (keV)
12
10
8
6
4
2
0
6
12
18
24
Hours (UTC)
ions/cm2-s-sr-keV
e-/cm2-s-sr-keV
Electrons
Protons

Charging Levels

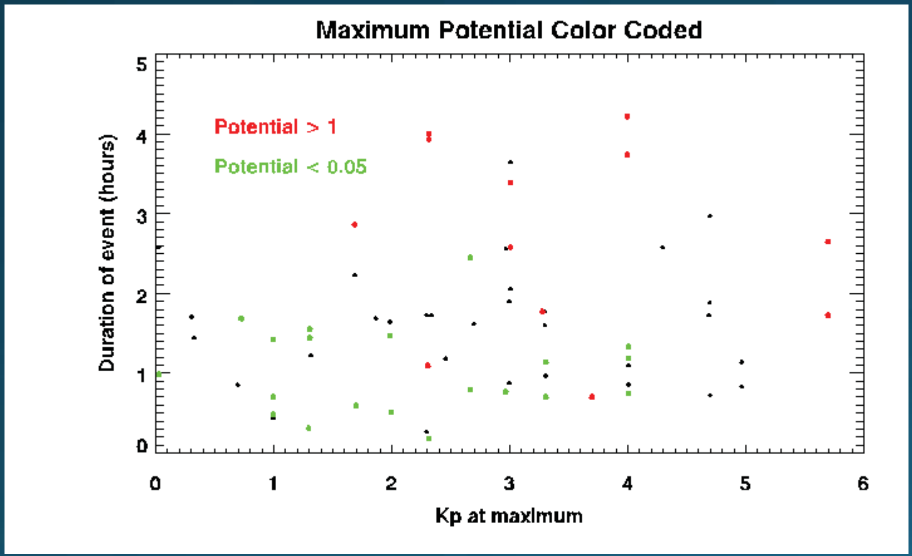
- Peak potentials exceed the mean of the charging events by an approximate order of magnitude or less
- In general, more charging events occurred at times when $n_e > n_i$ and when $T_i > T_e$

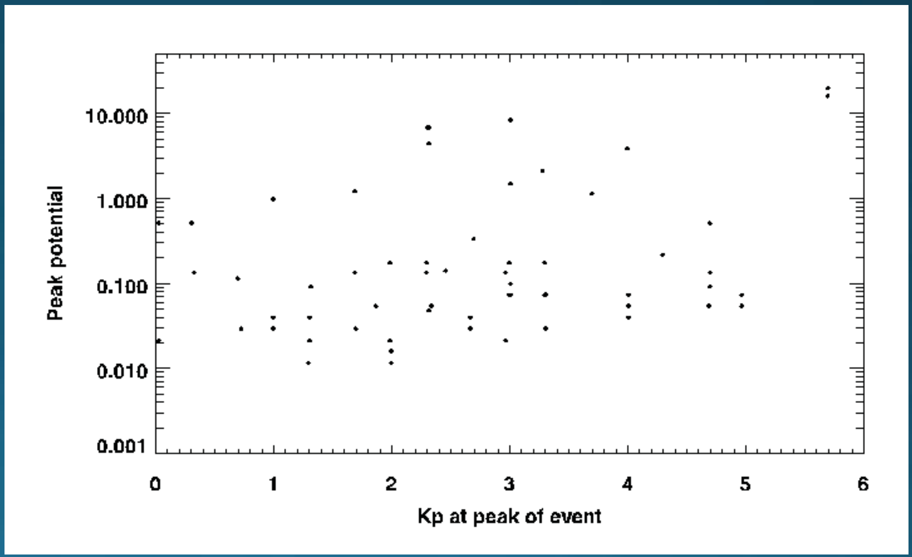




Relationship to K_p

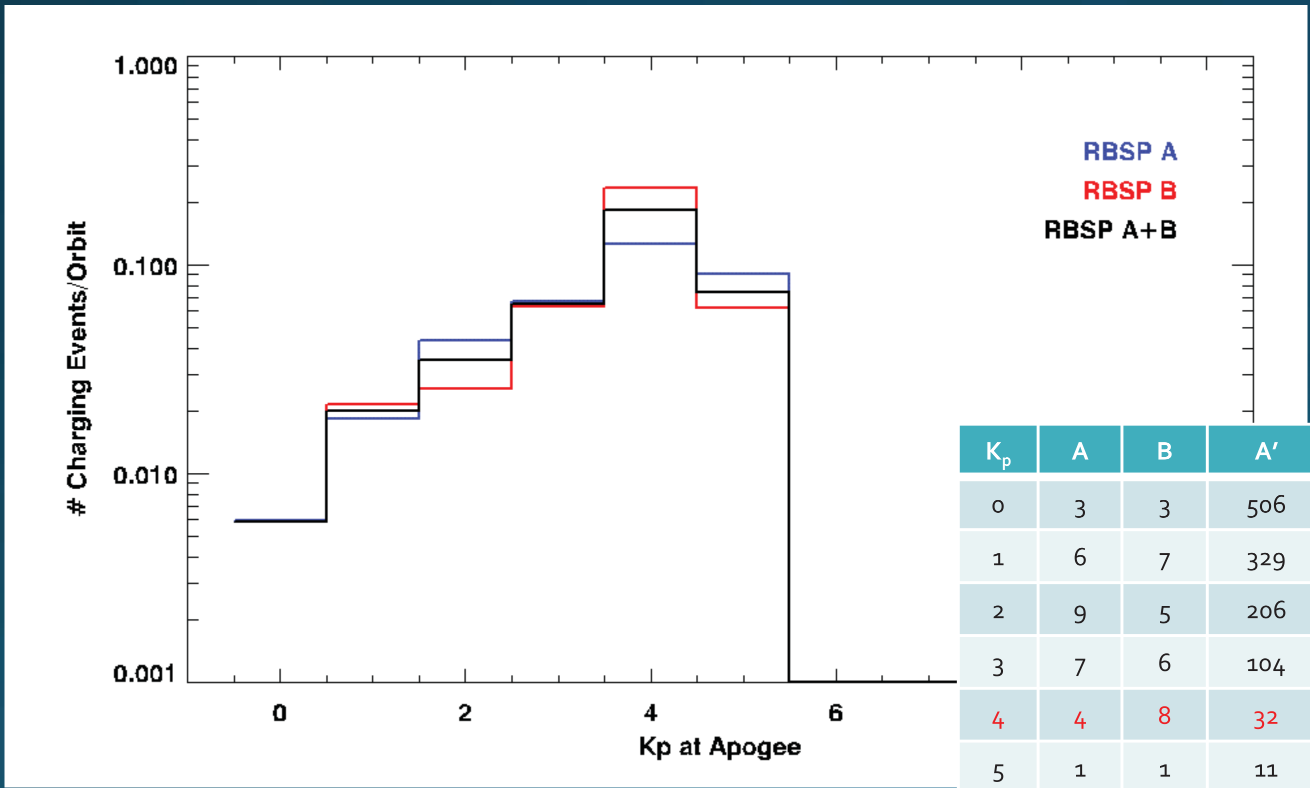
- Weak correlation between the longer the event, higher Kp, higher charging levels





Normalized to K_p

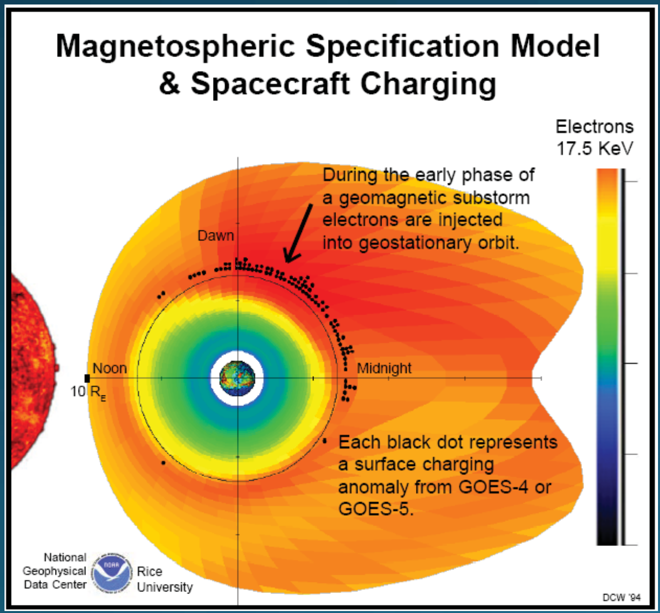
- RBSP-A saw charging 12.5% of the orbits when K_p=4
- 2.5% of the total time (orbits) saw charging

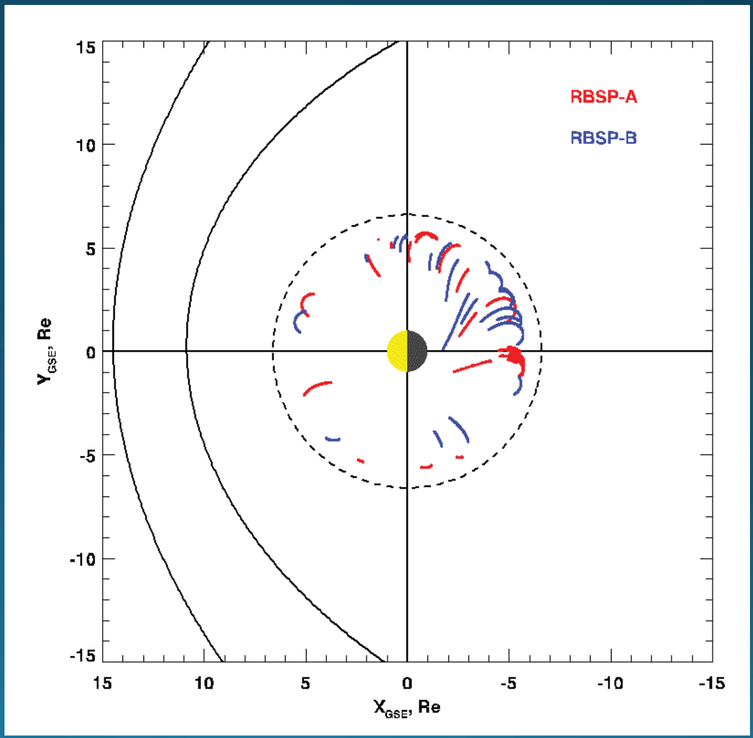


K_p	A	B	A′	B′	A/A′	B/B′	A+B/A'+B'
0	3	3	506	512	0.006	0.006	0.006
1	6	7	329	327	0.018	0.021	0.02
2	9	5	206	196	0.044	0.026	0.035
3	7	6	104	95	0.067	0.063	0.065
4	4	8	32	34	0.125	0.235	0.185
5	1	1	11	16	0.091	0.063	0.074
6	0	0	2	2	0	0	0
7	0	0	1	2	0	0	0

Surface Charging Locations

- GEO charging is more prevalent in the midnight to dawn sector
- GTO, larger number in midnight-dawn sector, but sizable number at other local times





Summary

- 63 candidate surface charging events in both RBSP-A and B
- All events are in the outer radiation belt
- Charging rates increase with K_p
- Most (55) are in sunlight, however 8 are in eclipse or partial eclipse condition
- Minimum duration charging event ~20 minutes
- Maximum duration charging event ~4 hours
- Maximum potential ~ few kilovolts