New plasma observations in highly elliptic orbits

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The Aerospace Corporation

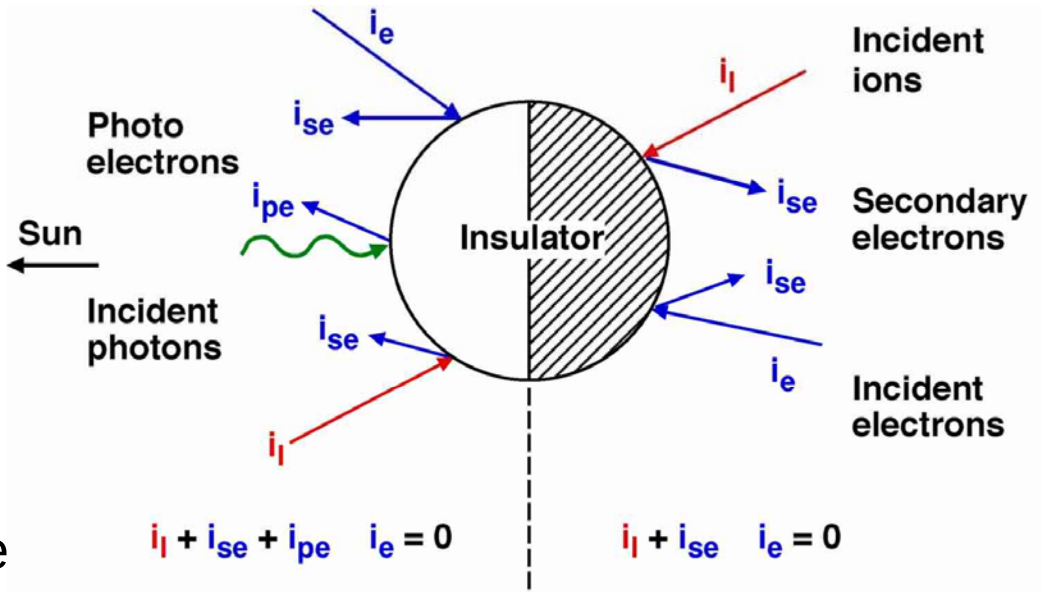
2010 Spacecraft Charging Technology Conference
21 September, 2010

Outline

- Motivation
  - *Surface Charging: Not addressed in this talk*
  - *Surface Dose: These preliminary results*
- New observations in HEO
  - *Surface Charging Monitors on TWINS*
- Previous results
  - *Polar CAMMICE / MICS [Roeder et al., 2005]*
  - *LANL / MPA [Thomsen et al., 2007].*
- Preliminary comparison
- Summary and future work.

Motivation: Surface Charging

- All satellites, in all orbits, have surfaces which charge in response to the space plasma environment.
  - *Space plasma environment defined here as 10 ev < E < 30 keV.*
- Because differential charging carries an associated discharge risk, all satellites must also mitigate surface charging.
- Surface charging environment is fairly well-known near GEO, less well-known in other orbits.
  - *We aim to extend our knowledge of the environment leading to surface charging to orbits beyond GEO.*



Fennell and Mazur, 2007

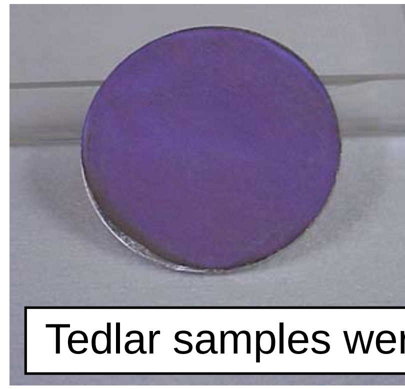
This is future work, and will be discussed at the **NEXT** Spacecraft Charging Technology Conference.

Motivation: Surface Dose

- Certain sensitive satellite surfaces can also degrade due to dose accumulated from that same space plasma environment.
  - *Optical coatings, thin films, and thermal control surfaces.*
- The plasma environment leading to surface dose is fairly well-known near GEO *[Thomsen et al., 2007]*, less well-known in other orbits.

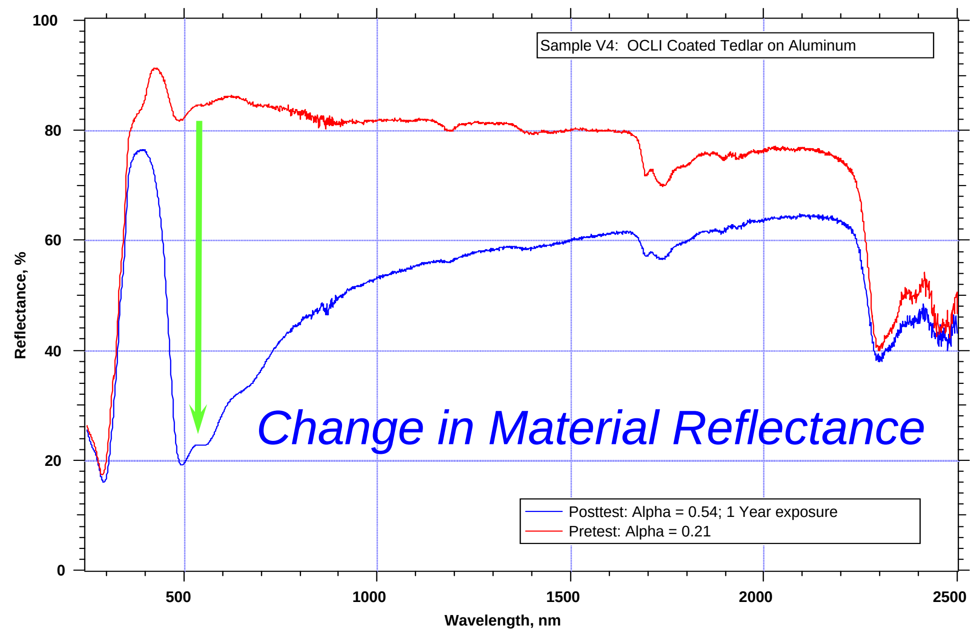
We here present new observations of low energy plasma beyond GEO, and compare them to existing measurements and empirical models of the surface dose environment.

White Tedlar after 1 Year exposure to combined particle & UV environment in GEO



Tedlar after 3 Year Exposure

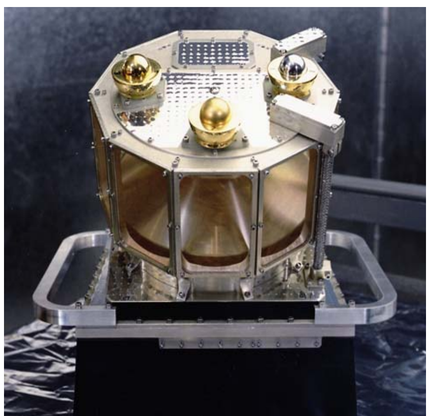
Tedlar samples were white before exposure



Fennell and Mazur, 2007

New observations in highly elliptical orbits: TWINS

- The NASA TWINS mission of opportunity (Two Wide-angle Imaging Neutral-atom Spectrometers) consists of two spacecraft in high inclination, high altitude orbits (7.2 RE apogee).
- Both spacecraft have identical energetic neutral atom (ENA) imagers provided by SwRI and *in-situ* plasma analyzers provided by Aerospace.
- This paper will present preliminary data from the plasma analyzers.



FM1=DOS/SCM

SCM: Surface Charge Monitor
DOS: Dosimetry measurement.

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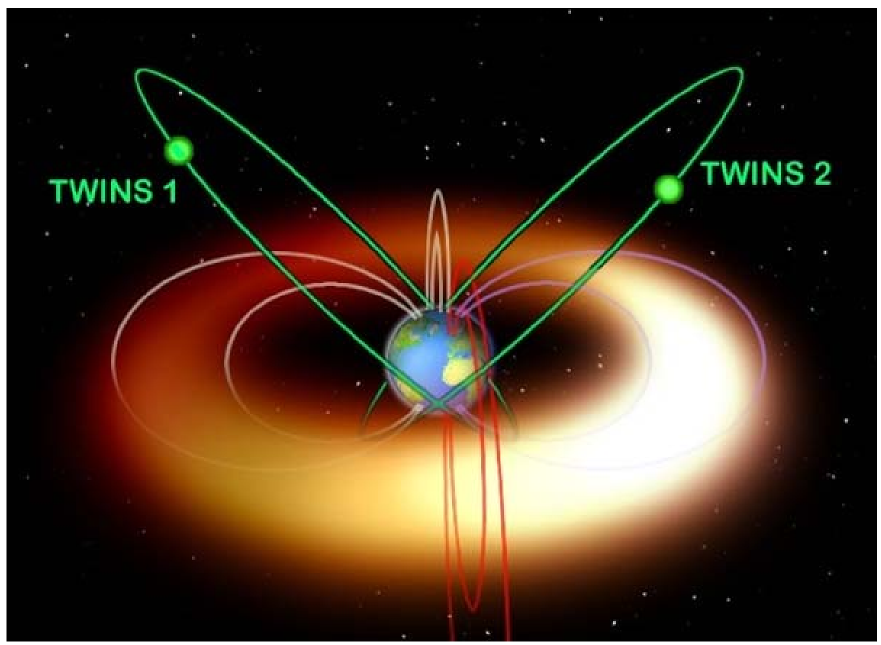

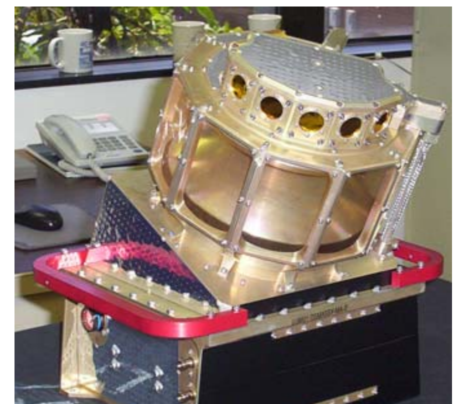

FM2=HiLET/SCM

SCM: Surface Charge Monitor
HiLET: High LET measurement

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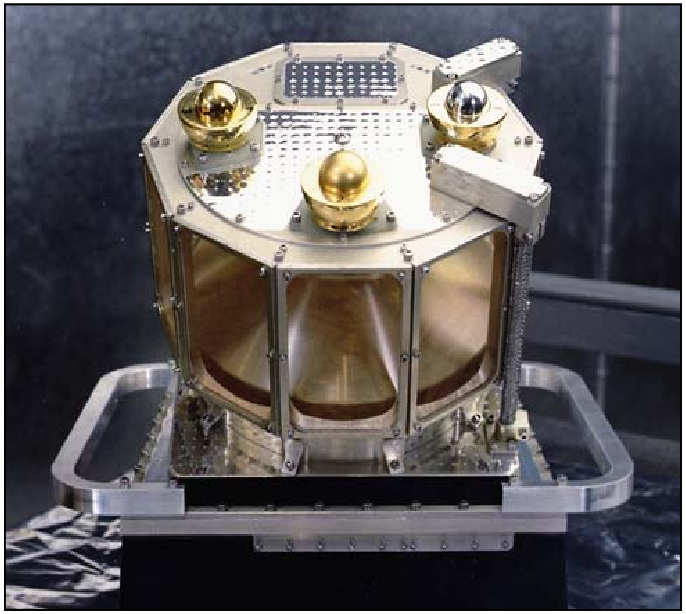
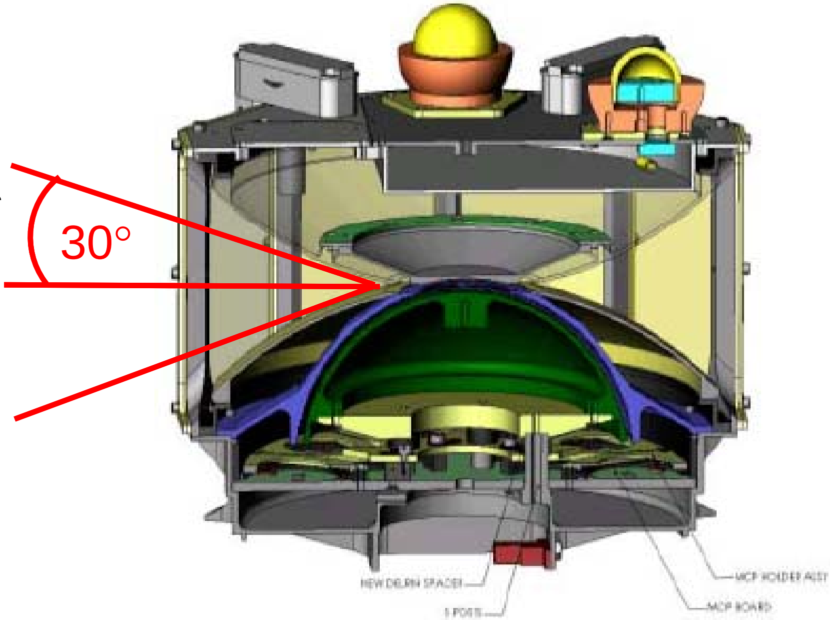
New Plasma Observations in HEO orbit

Surface Charging Monitors (SCM)

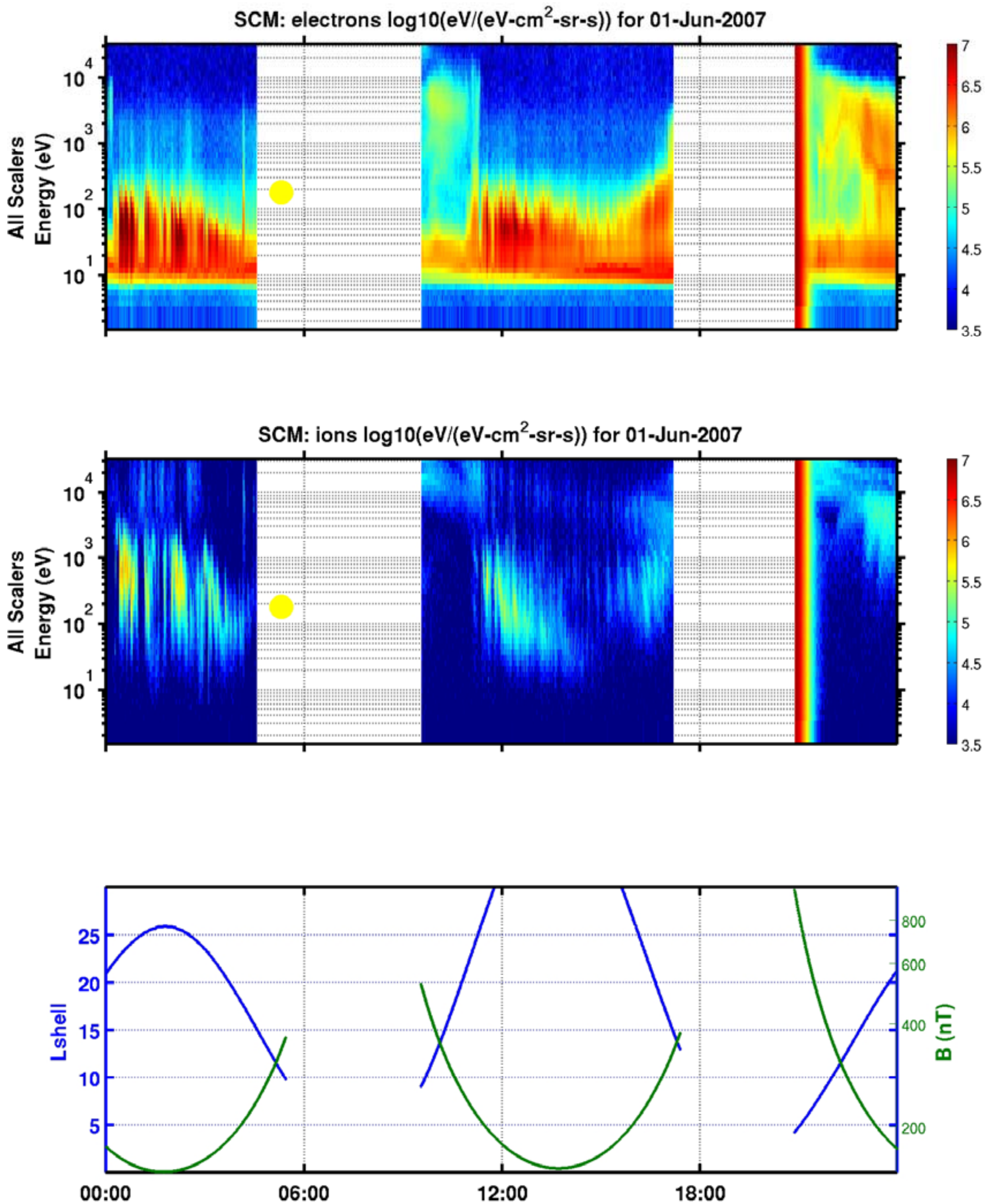


- The surface charging monitor (SCM) is a top-hat plasma analyzer which
  - *measures electrons and ions from ~10 eV-30 keV on each TWINS vehicle*
    - dE/E ~ 0.17.
  - *In 20 azimuthal look-directions*
    - Each 12° wide
  - *Currently 3 polar angles within 30° of the instrument azimuth plane.*
  - *Analyzer and deflector potentials stepped to accumulate ~2π steradians of coverage every 2 seconds.*
- One significant limitation of these measurements is that the spacecraft have <u>no magnetometer.</u>



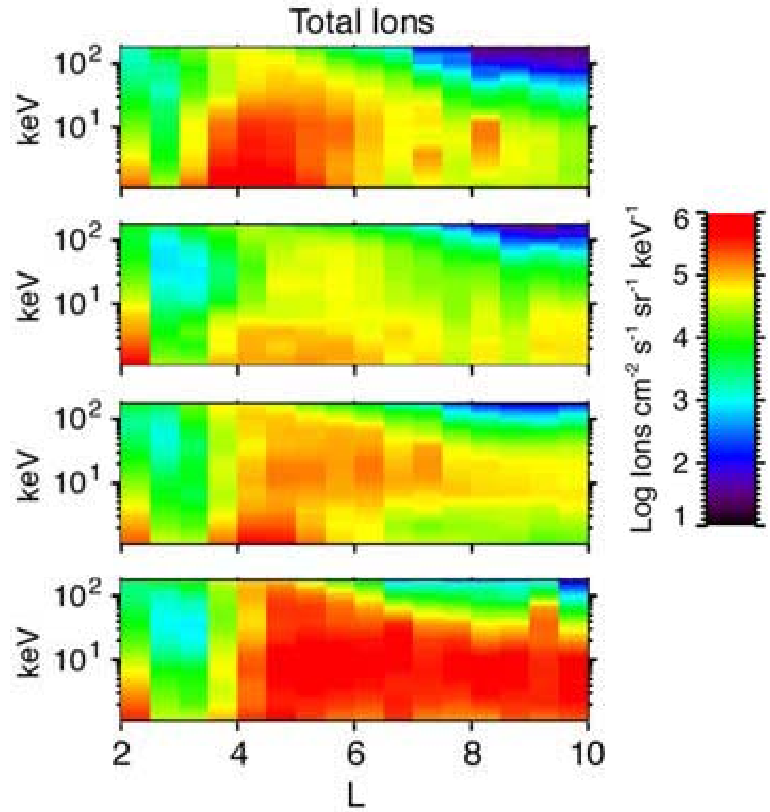
Example Observations

- One day of observations
  - *Electrons at top*
  - *Ions in middle*
  - *L value (blue) and the magnitude of the magnetic field (green), both derived from IGRF.*
- Two perigee passes per day limit observations to L > 5.
- At the lowest Ls, observations are overwhelmed by penetrating background.

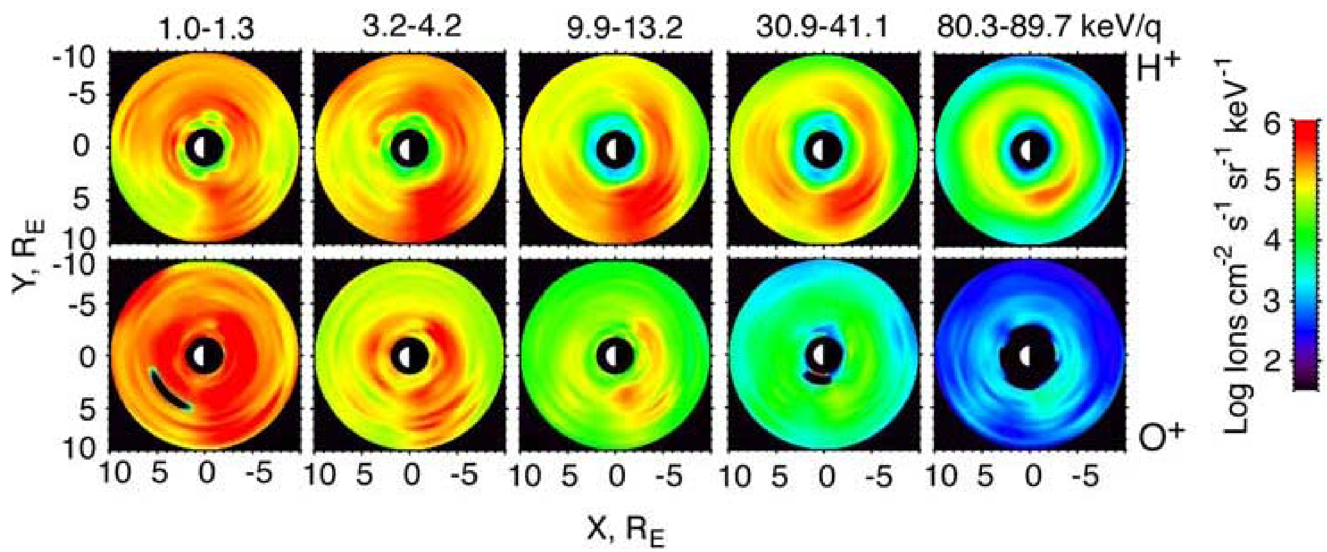


Previous work: Part 1

Roeder et al., 2005



- Roeder et al., 2005 used Polar CAMMICE / MICS observations to construct an average model of the plasma environment.
  - *Data from March, 1996 – September, 1999.*
  - *Energies from 1-200 keV/charge.*
  - *Composition: H+, He+, He++, O+, etc.*
  - *2 < L < 10*
  - *All local times.*



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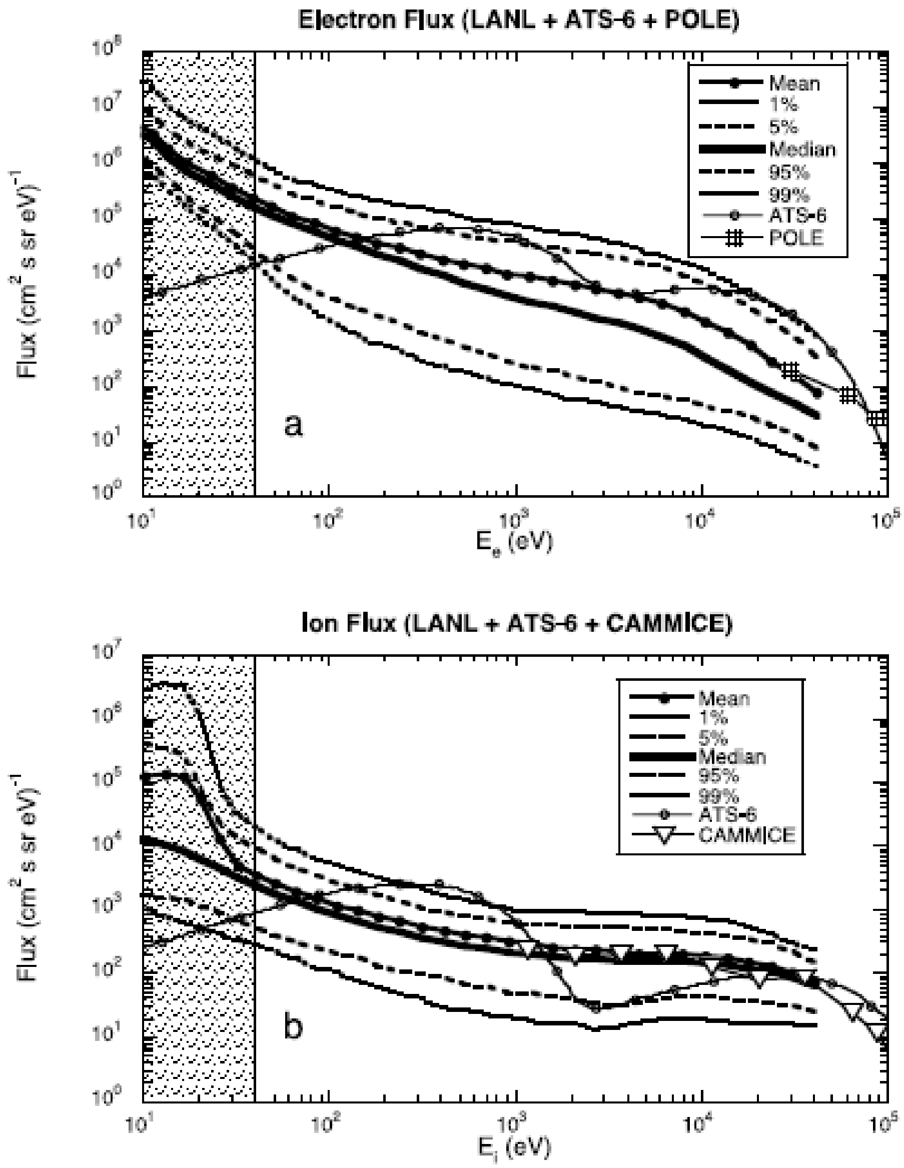
Previous work: Part 2

Thomsen et al., 2007

- Thomsen et al., 2007 used LANL/MPA observations to construct an average model of the plasma environment at GEO.
  - *Data from 1990-2004*
  - *Ions and electrons with energies from 1-45 keV.*
  - *No ion composition.*
  - *Geosynchronous orbit*
  - *Aggregate all data into a mean energy spectrum and percentiles on that mean.*



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Preliminary Results: TWINS-1 / SCM data for 1 year

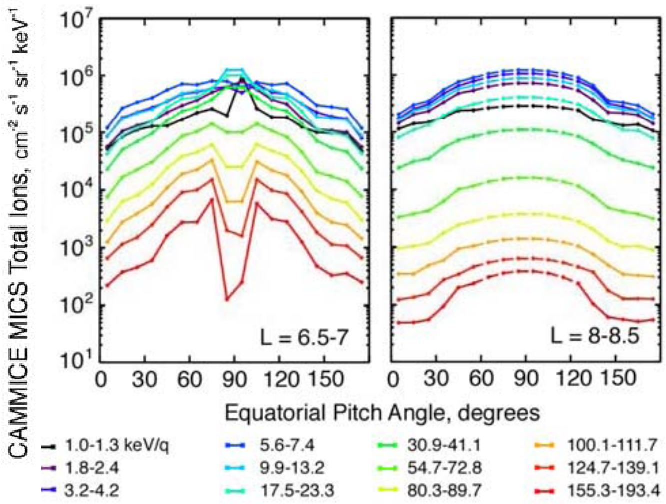
- We have taken observations from TWINS-1 / SCM from 2009 and aggregated it into bins similar to those used by Roeder et al., 2005.
  - *4 < L < 10, 13 steps*
  - *12 steps spanning all local times*
  - *10 eV < E < 30 keV, 15 steps*
  - *0 < Equatorial Pitch Angle < 180, 18 steps.*
- Using only ion observations for these results.
- Only using data in the azimuthal plane (polar angle = 0°).
- The remainder of the slides illustrate preliminary, TWINS-1 plasma observations compared with similar depictions of the Roeder et al., 2005 and Thomsen et al., 2007 datasets.

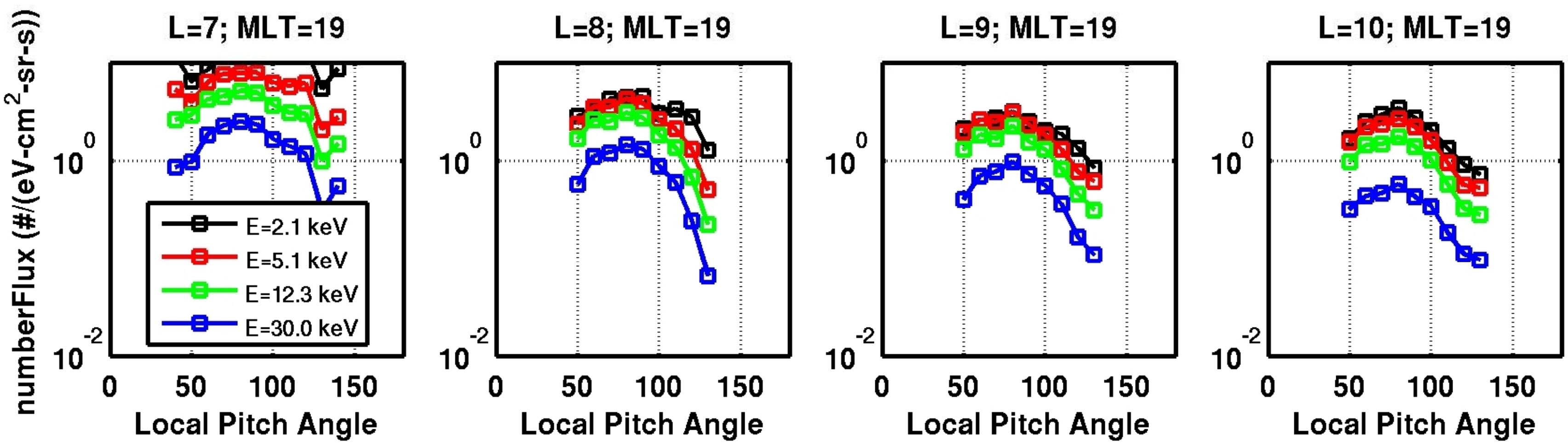
Preliminary Results: SCM Pitch Angle Distributions

- Pitch angle distributions derived from SCM data, **<u>without a magnetometer</u>**, qualitatively reproduces distributions from Polar.
  - *Model magnetic field (IGRF) used to assign local, compute equatorial pitch angles.*
  - *Local pitch angles peaked at 90° for all energies L's shown*
  - *Equatorial pitch angles at these high latitudes are much nearer the loss cone.*
  - *Fluxes fall off with energy*
- This lends confidence to the results, but much more validation is required
  - *Pitch angle assignment less reliable at high L.*

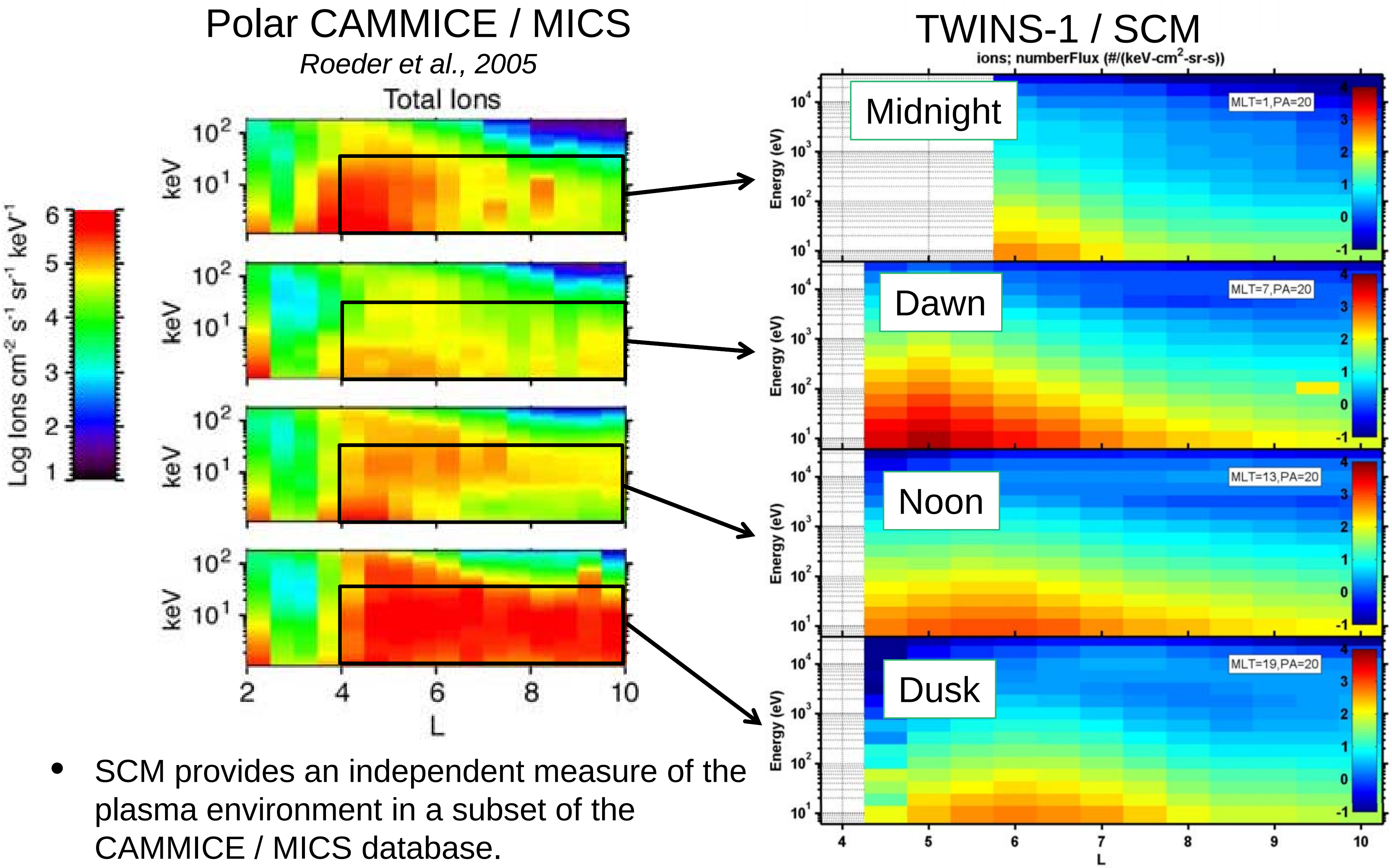
Polar CAMMICE / MICS

Roeder et al., 2005





Preliminary Results: Spectra as a function of L



- SCM provides an independent measure of the plasma environment in a subset of the CAMMICE / MICS database.
- Some features are reproduced, some are not.

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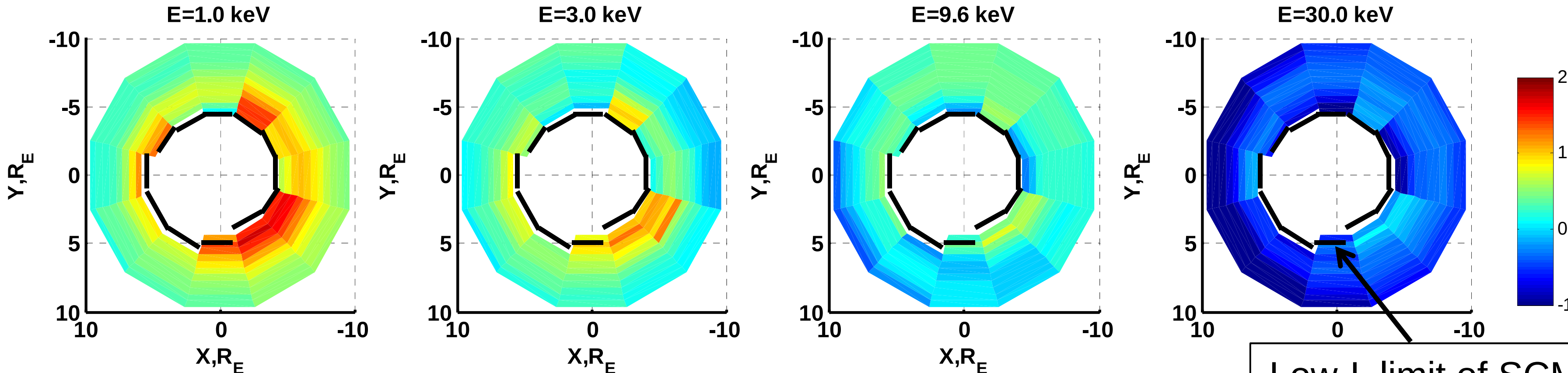
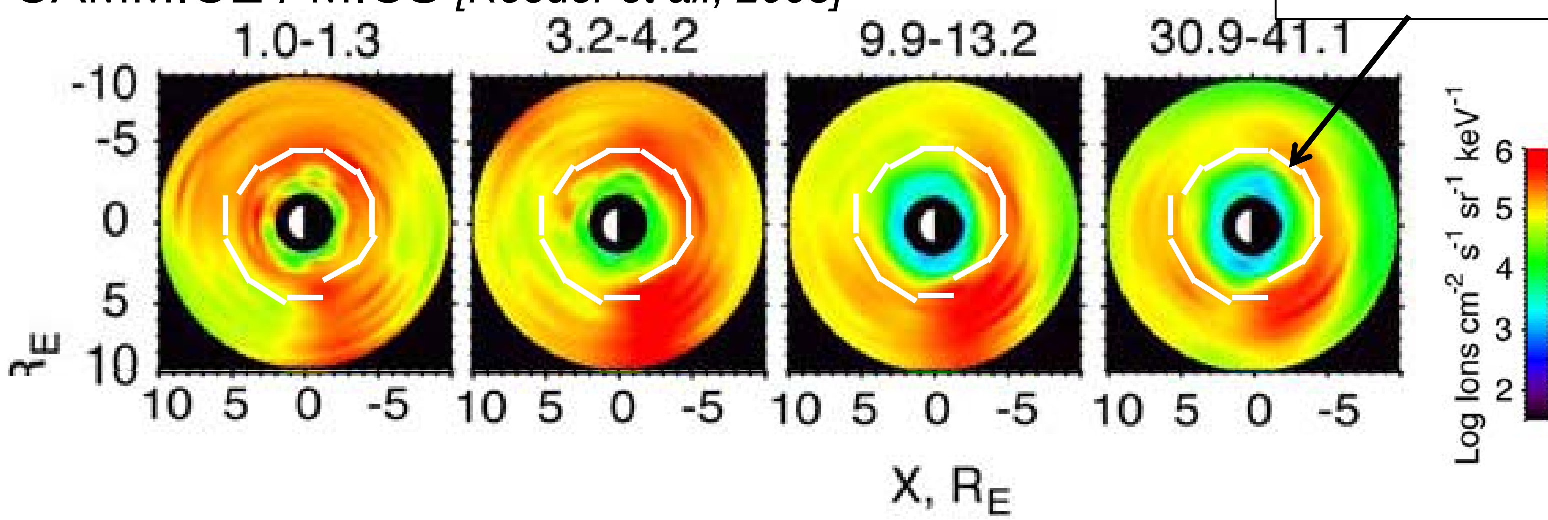
Preliminary Results: Equatorial maps

TWINS-1 / SCM



Low-L limit of SCM observations

Polar CAMMICE / MICS *[Roeder et al., 2005]*

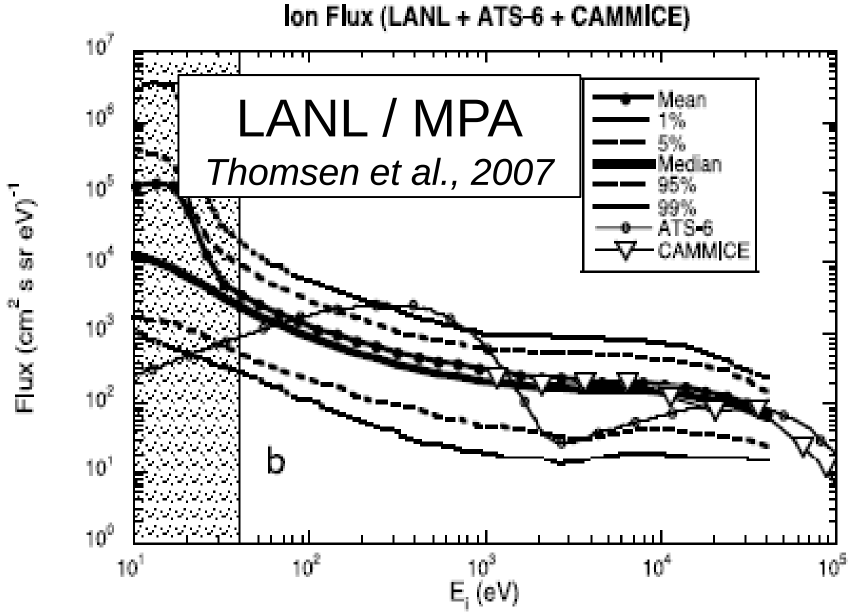


Equatorial maps of SCM data show similar features to the CAMMICE/MICS maps.

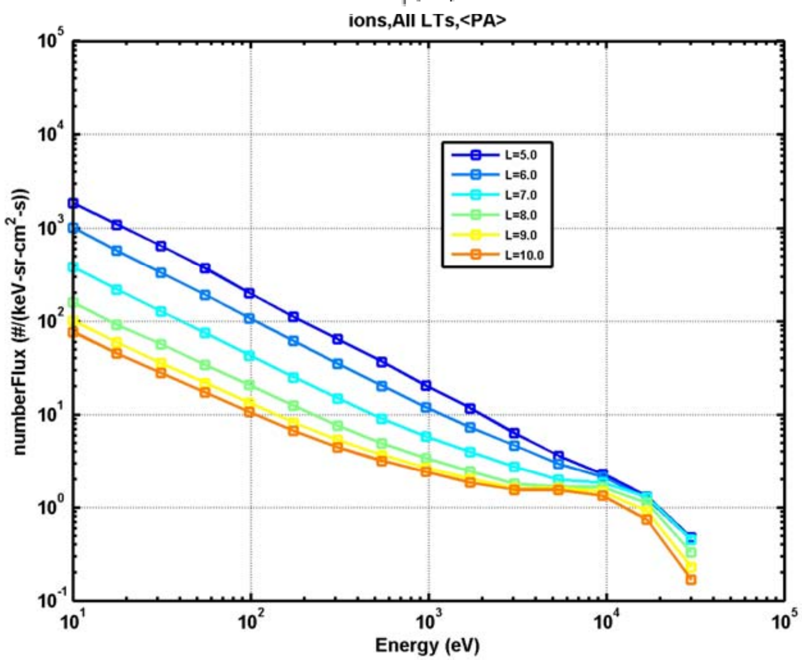
Preliminary Results: Ion spectrum at (and beyond) GEO

- We can directly compare SCM spectra with LANL / MPA measurements over the past ~1.5 solar cycles (Thomsen et al., 2007).
- Though Thomsen et al., 2007 has significantly better statistics, SCM extends beyond GEO.
  - *A comparison can be made at GEO, and the radial dependence of the spectrum can be established using SCM data.*

LANL / MPA



TWINS-1/SCM



Summary

- We report on new observations of the plasma environment from ~10 eV to 30 keV currently being made on two platforms in highly elliptic orbits (TWINS / SCM).
  - *These observations will feed into empirical models of the low energy plasma that is directly applicable to HEO orbits, but can apply to orbits from GPS to beyond GEO.*
  - *These observations can feed into specifications of surface dose expected at such orbits.*
- Preliminary results are qualitatively consistent with previous state-of-the-art empirical specifications of low energy plasma in the inner magnetosphere *[Roeder et al., 2005, Thomsen et al., 2007].*

Future Work

- Far more verification of these preliminary results are required.
  - *Verify and improve the pitch angle calculation by using more detailed, solar wind-driven magnetic field models.*
- Far more data will improve the statistics of these results, improving reliability and comparison with other results.
  - *Include data from off the azimuth plane of the instrument, increasing pitch angle coverage and statistics.*
  - *Include all data from TWINS-1 (late 2006-present) and TWINS-2 (mid-2008-present).*
- Subtract background to improve coverage inside geosynchronous orbit.
  - *This will be challenging.*
- Use TWINS / SCM data to investigate the occurrence distribution and magnitude of surface charging in highly elliptic orbits.

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References

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Acknowledgements

- This research is supported by The Aerospace Corporation's Independent Research and Development program.

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