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# Genesis Radiation Environment

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# Overview

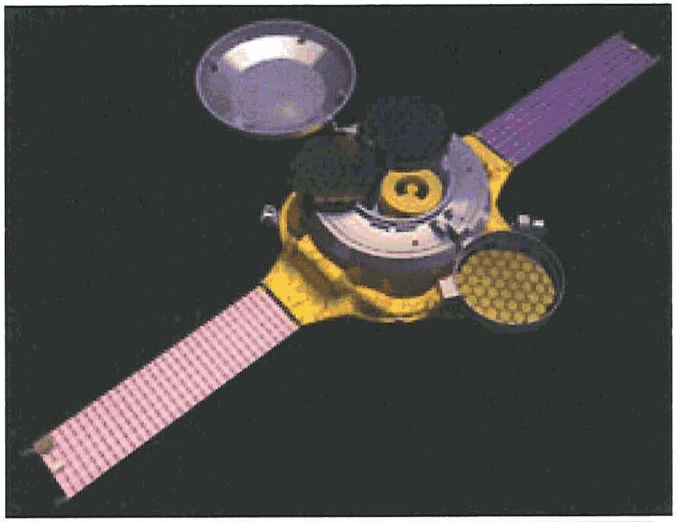
- Survey and Examination of Eroded Returned Surfaces (SEERS) Project
- Genesis spacecraft
- Genesis reference radiation environment
- Summary

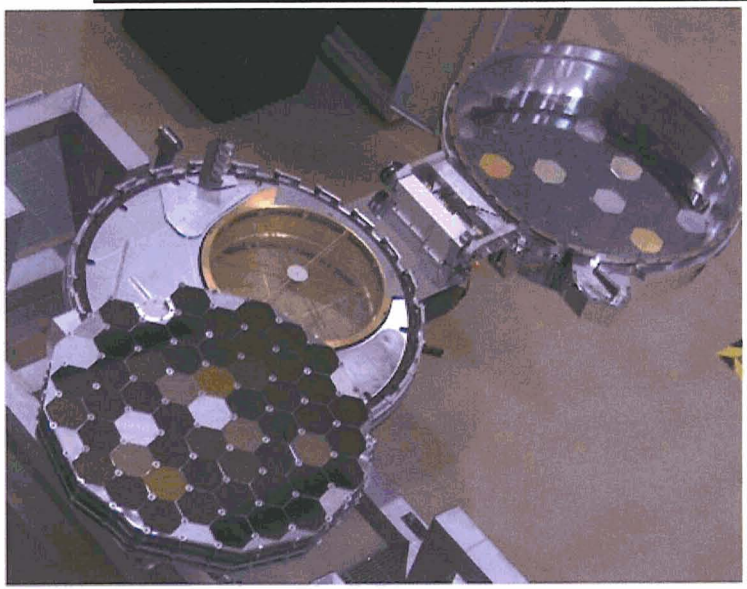
# Overview

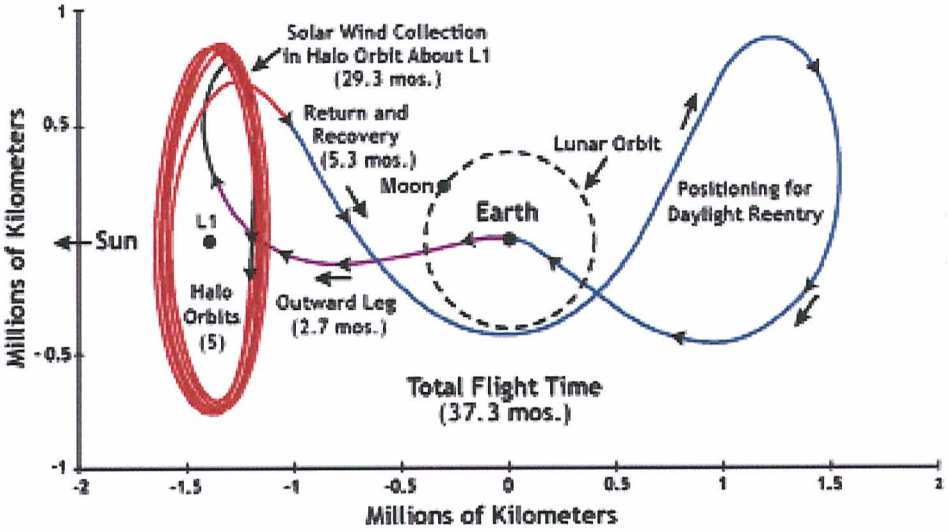
- Unique opportunity learn about L1 charged particle environment interactions with spacecraft from studying Genesis returned hardware:
  - L1 charged particle environments
    - Degradation of surface materials (compaction, erosion, pitting)
    - Radiation damage of materials
    - Validation of solar wind/radiation effects models
  - Spacecraft charging
    - Analysis of arc damage sites
    - Validation of charging models (surface, internal)

- Outline:
  - Genesis spacecraft
  - Solar wind/energetic particle environments
  - Charging/electrical discharge
  - Summary

# Genesis/L1 Radiation Environment







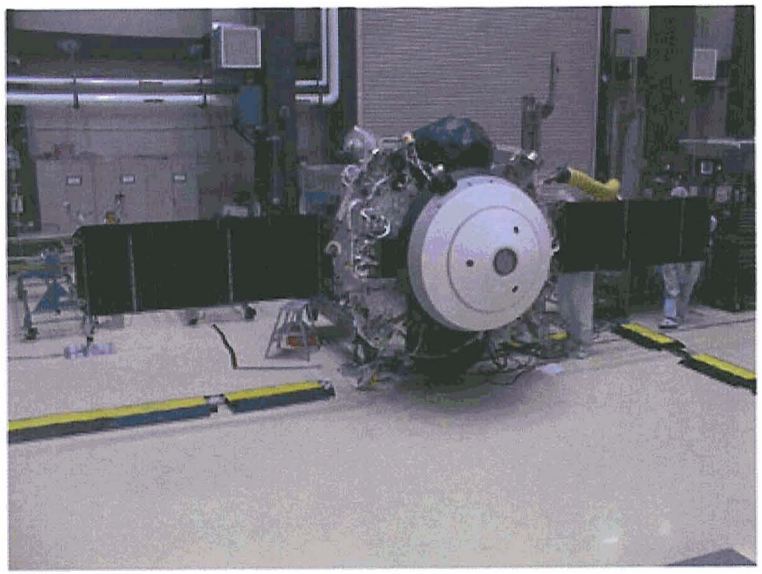

Science Capsule open 1 Dec 2000 to 1 April 2004

--GIM ion moments available on LANL website

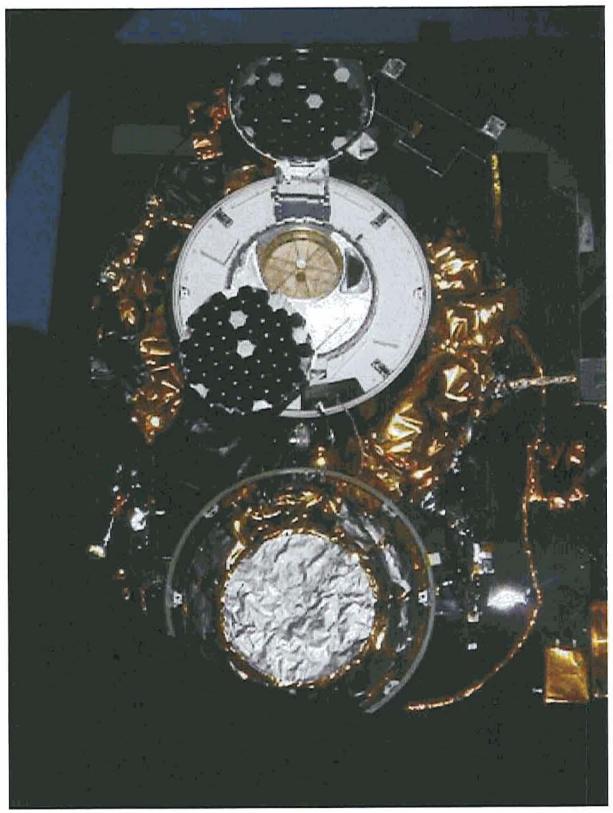
--No electron data

# Genesis Radiation Model

- Differential flux radiation environment for space exposed materials on Genesis spacecraft
- Support materials evaluation of returned hardware for Survey and Examination of Eroded Returned Surfaces (SEERS) program

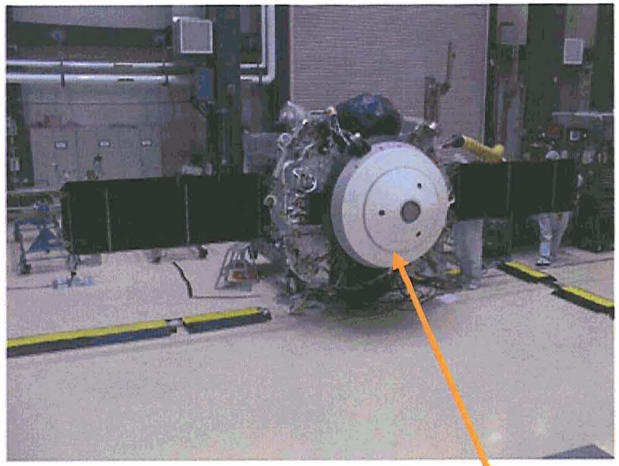


- Model will be completed even though future of SEERS is uncertain

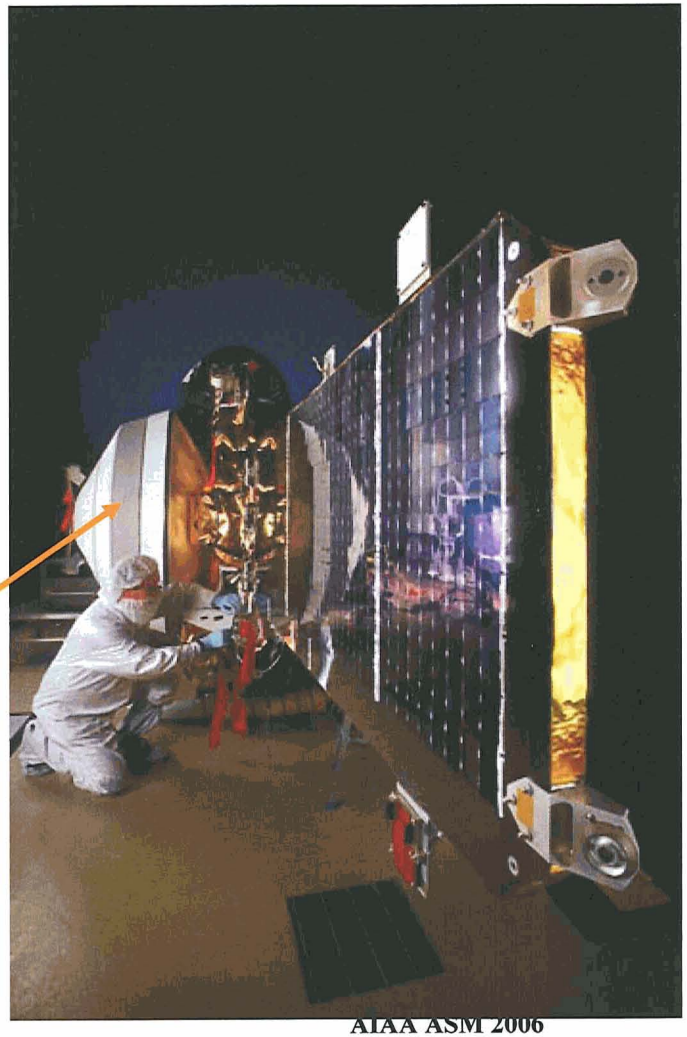


# Genesis Spacecraft

Only the Sample Return Capsule (SRC) will be returned to Earth!



SRC

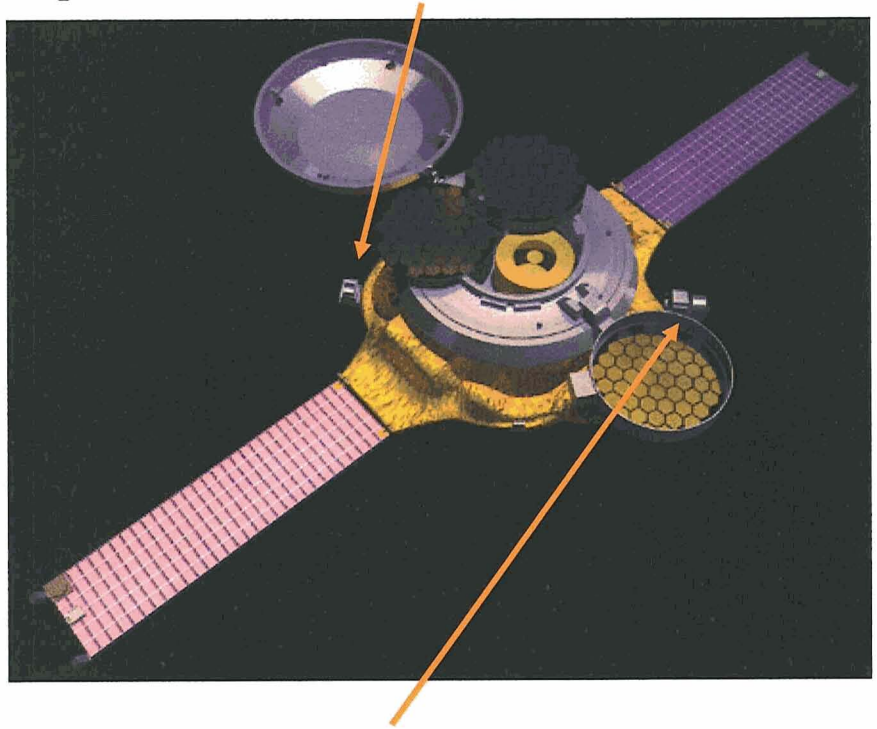


# Genesis Spacecraft

**Genesis Ion Monitor (GIM)**

•40 energy steps, 200 eV – 25 keV

•Complete 3-D ion ($H^+$, $He^{++}$) spectra every 4 spins (at 1.6 rpm)



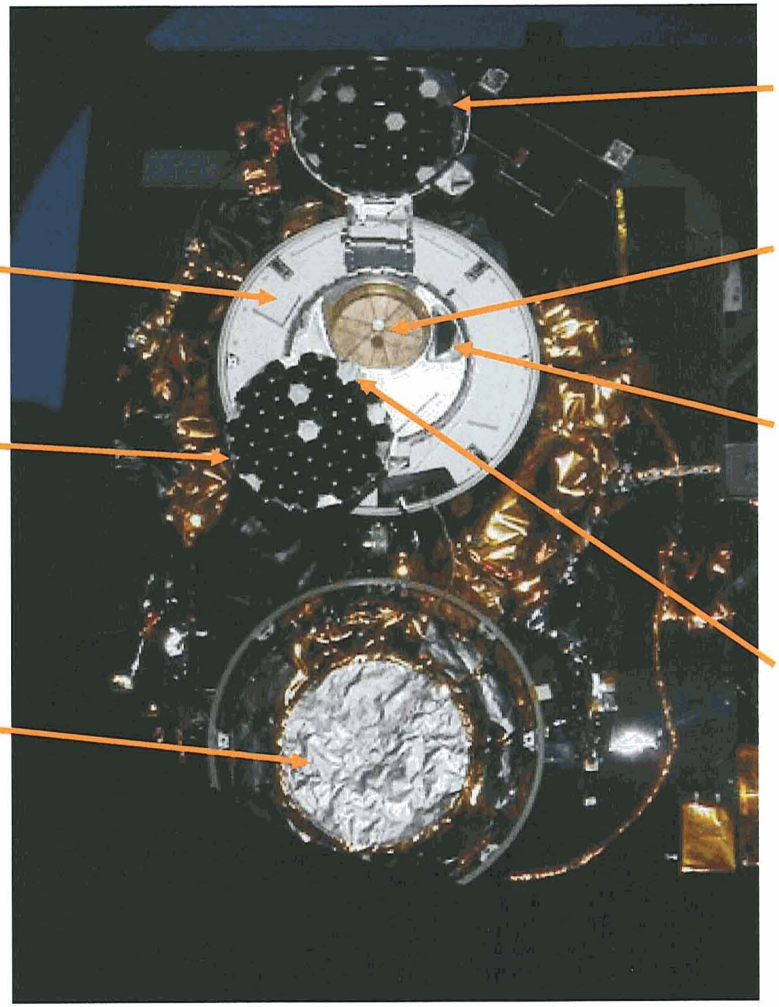
**Genesis Electron Monitor (GIM)**

•24 energy steps, 1.5 eV – 1 keV, 3-D spectra

**GEM/GIM role:**

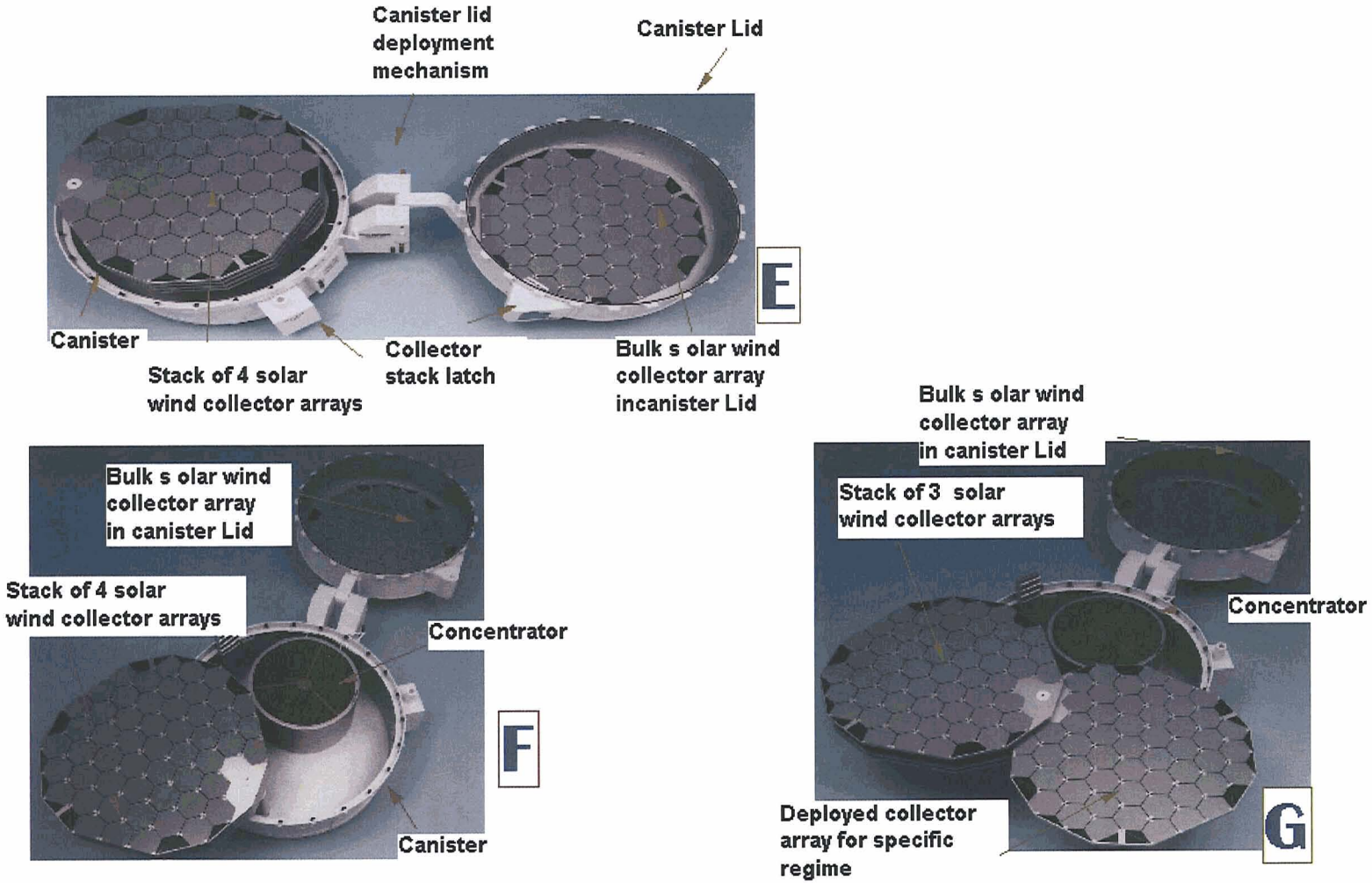
- Provide data to spacecraft control and data handling system to select the appropriate solar wind collector array
  - Algorithm uses data to determine solar wind regime
- Provide solar wind electron/ion data to science community

# SRC Interior



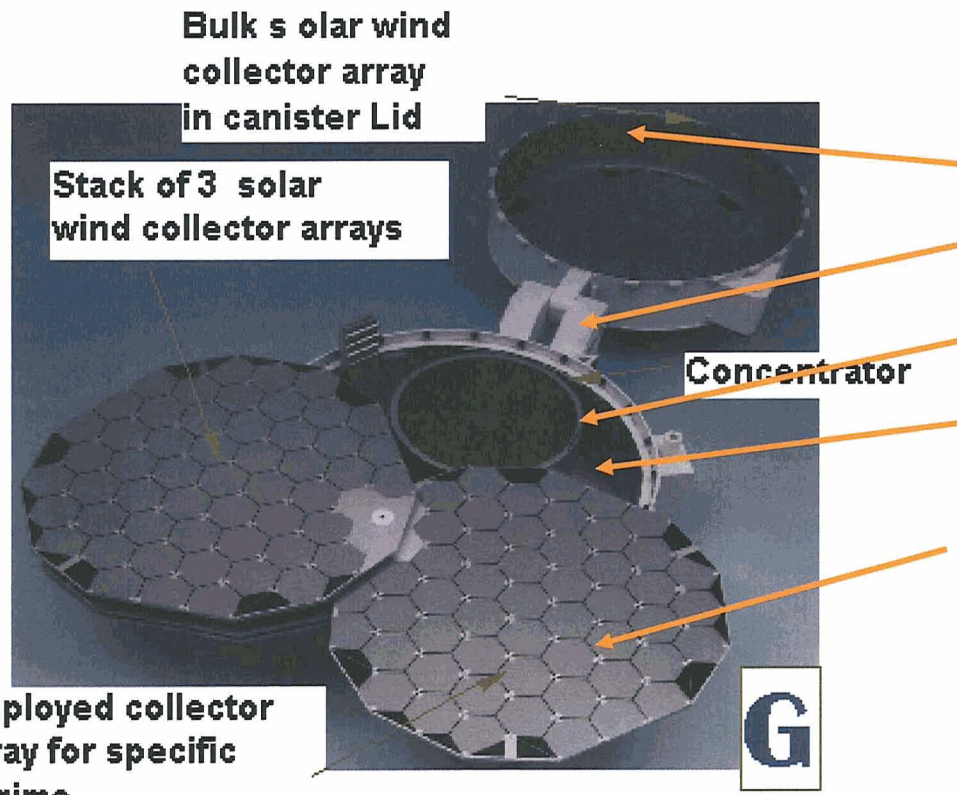
- Polished Al side collector
- Deployable collector arrays
- Mb coated foils
- Canister lid collector array
- Concentrator
- Au foil mounted on side collector
- Metallic glass collector (on top of array deployment mechanism

# Collector Array Deployment




(from http://www.gps.caltech.edu/genesis/fig2-2.html)

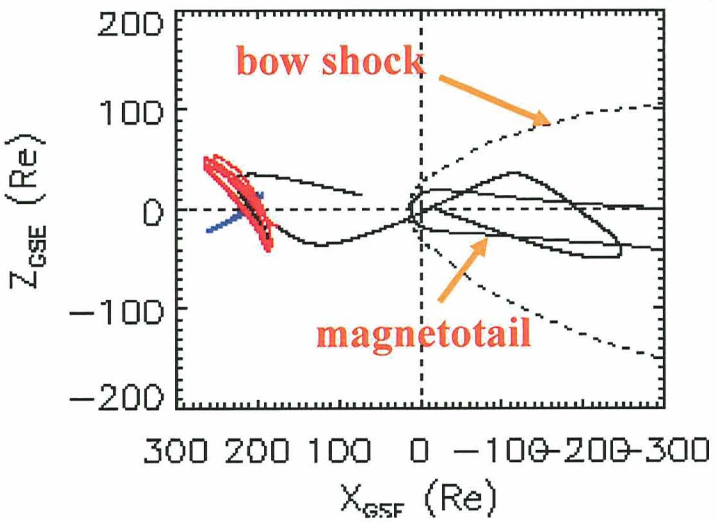
# Arrays During Science Operations

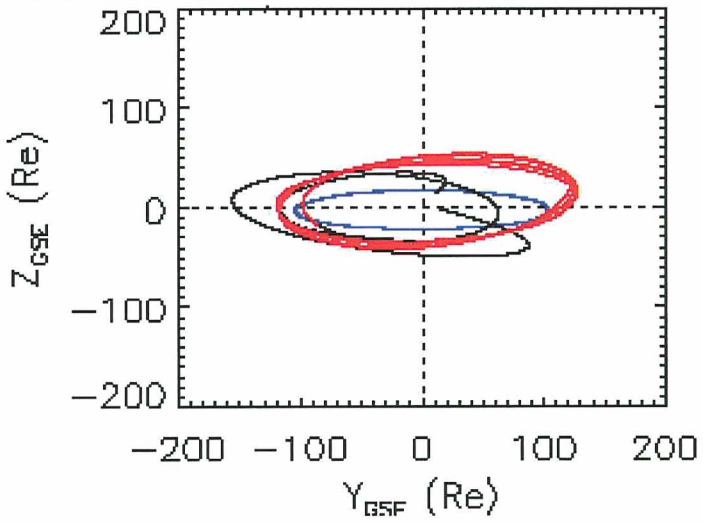


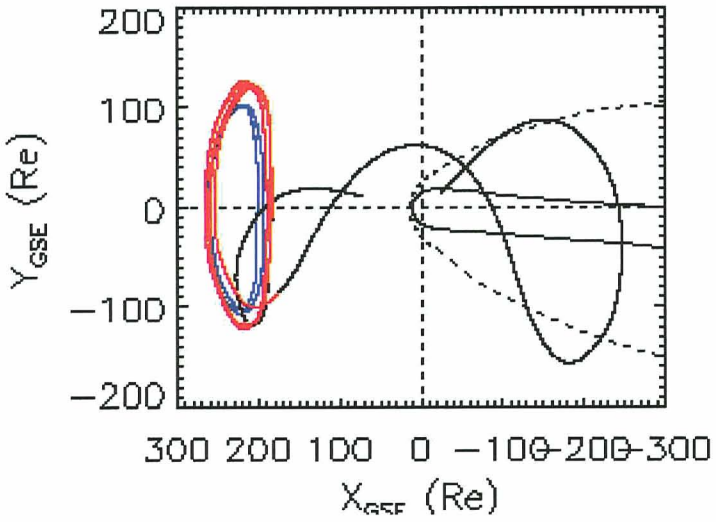

**Sites for solar wind impingement studies:**

- Inner surface of canister lid
- Hinge
- Edges of concentrator
- Inner surface of canister not covered by collector array
- Collector coupon support structures

# Genesis, SOHO L1 Orbits




Genesis:
12 Sep 2001 – 7 Sep 2004

Genesis:
30 Nov 2001 – 1 Apr 2004

SOHO:
30 Nov 2001 – 28 Feb 2003

# Solar Wind Statistics

Only the integrated effect of bulk solar wind is of interest to us!

LANL 30 March 2003

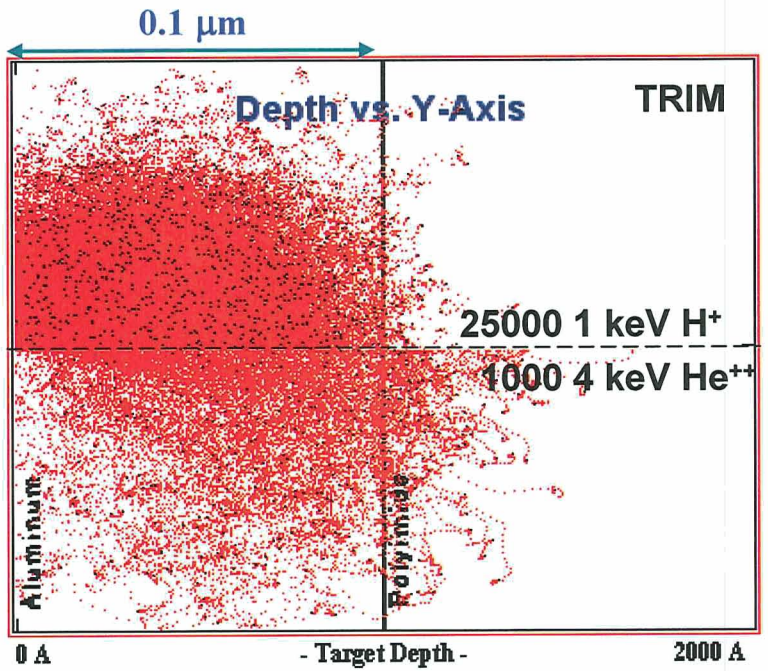
| | Bulk | CME | CH (fast) | Slow | SRC Lid | Conc |
|---|---|---|---|---|---|---|
| Total exposure time (days) | 485.09 | 122.84 | 98.20 | 254.00 | 501.76 | 467.19 |
| Proton Fluence ($x10^{16}$ #/cm$^2$) | 1.2034 | 0.2847 | 0.1993 | 0.6868 | 1.2268 | 0.2281 |
| Fluence other regimes | | 0.0013 | 0.0010 | 0.0049 | | |
| He/H ratio | 0.0399 | 0.0469 | 0.0381 | 0.0378 | 0.0401 | 0.0398 |
| Array changes | | 145 | 80 | 97 | | |

(adapted from http://genesismission.jpl.nasa.gov/)

SOHO estimate was $1.3855x10^{16}$

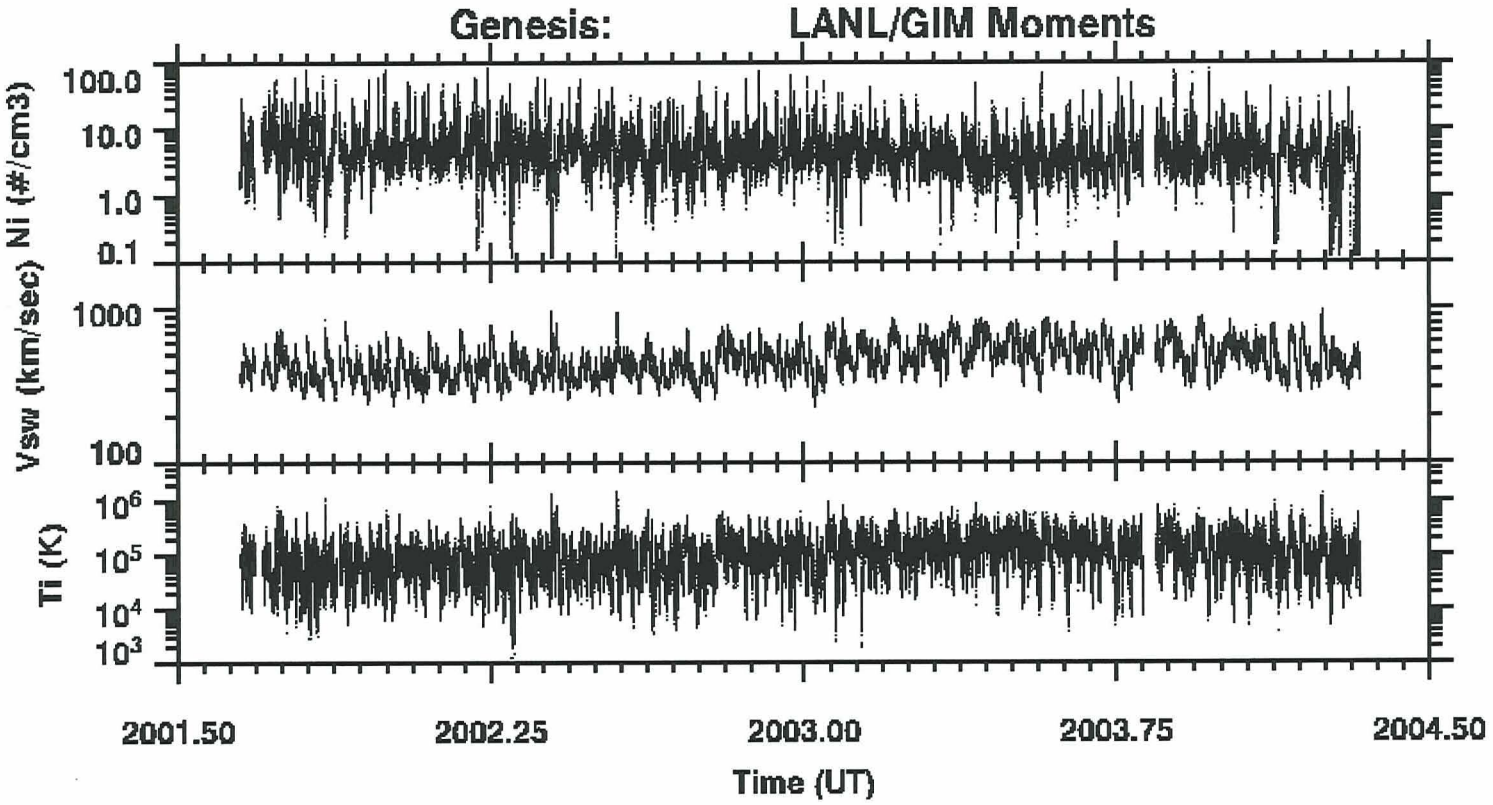
# Solar Wind as Radiation Environment

- Solar wind is generally considered a benign radiation environment
  - Solar wind velocity ~400 km/sec to 800 km/sec, mean ~450 km/sec
    - Kinetic energy of $H^+$ ~ 0.21 keV to 3.3 keV, mean 1.1 keV
    - Kinetic energy of $He^{++}$ ~ 0.84 keV to 13 keV, mean 4.2 keV
  - $H^+$ flux ~ NV ~ (7 $H^+/cm^3$)(450 x$10^3$ m/s) ~ 3.2x$10^8$ $H^+/cm^2$-sec
  - $He^{++}/H^+$ ~ 0.038 $He^{++}$ flux ~ 0.12x$10^8$ $H^+/cm^2$-sec
  - Fluence
    - $H^+$ ~ 9.9x$10^{15}$ $H^+/cm^2$-year
    - $He^{++}$ ~ 3.8x$10^{14}$ $H^+/cm^2$-year
- Solar wind penetration depths are only fractions of a micron
  - Bulk materials impacted only on "surfaces"
  - 1000 Å (0.1 μm) coating is impacted throughout the material



# Genesis Radiation Model

- Genesis Ion Monitor (GIM) provides ion flux in-situ measurements
- Los Alamos National Laboratory provides ion moments on web site
- Reconstruct differential flux from moments



# Differential Flux Reconstruction Technique

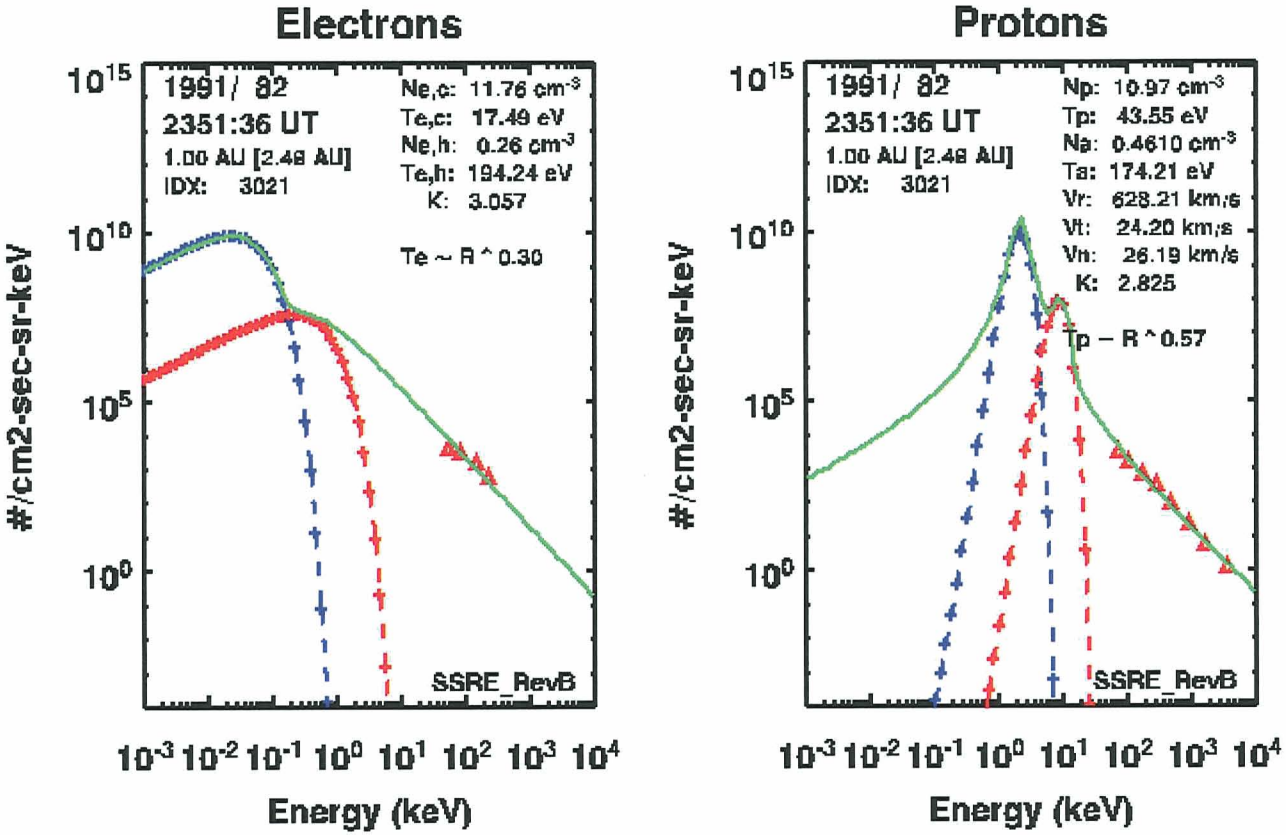
**Ulysses SWOOPS plasma moments and LEFS, LEMS energetic particle flux**

Radial scaling

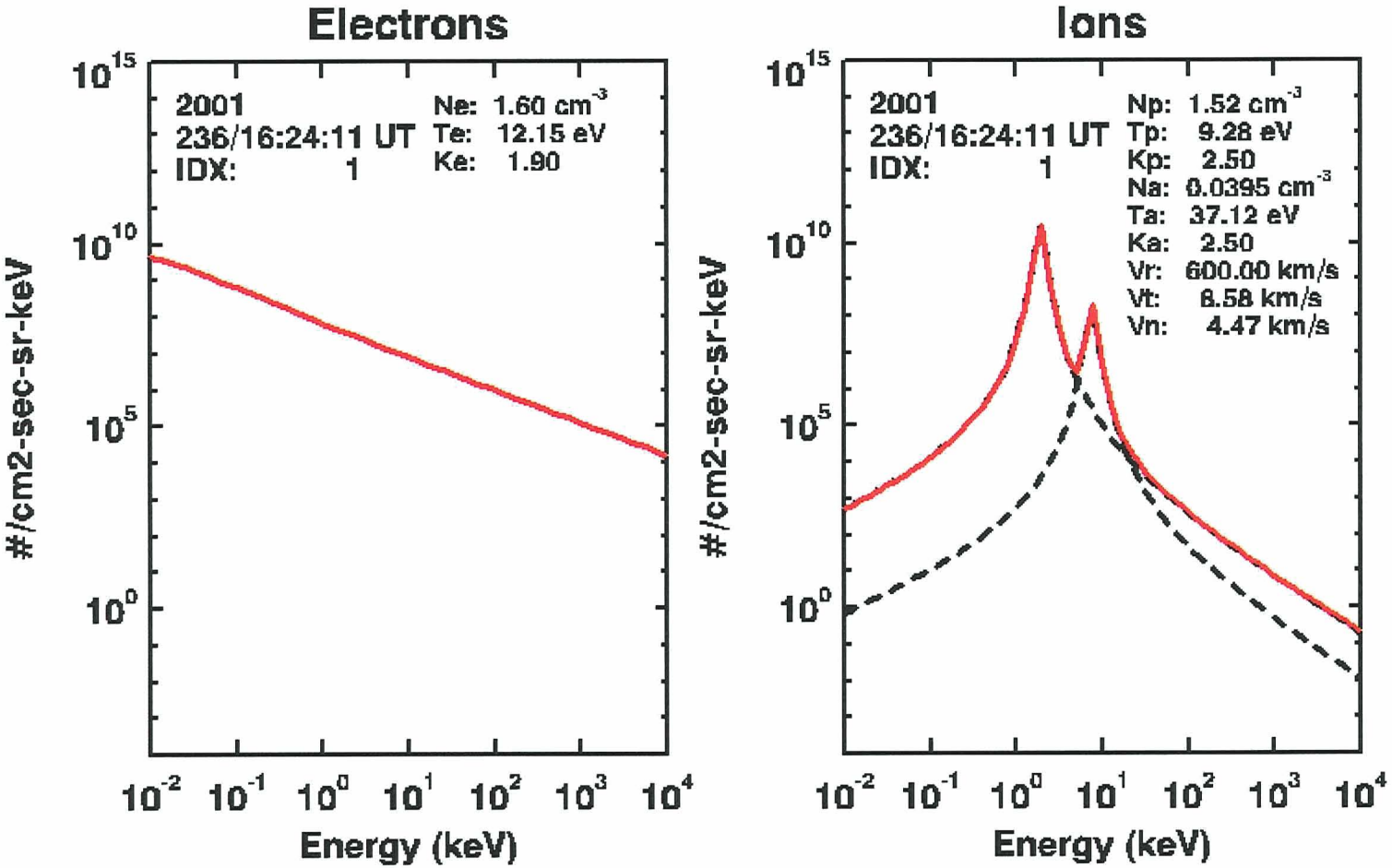
$N_p \sim R^{-2}$

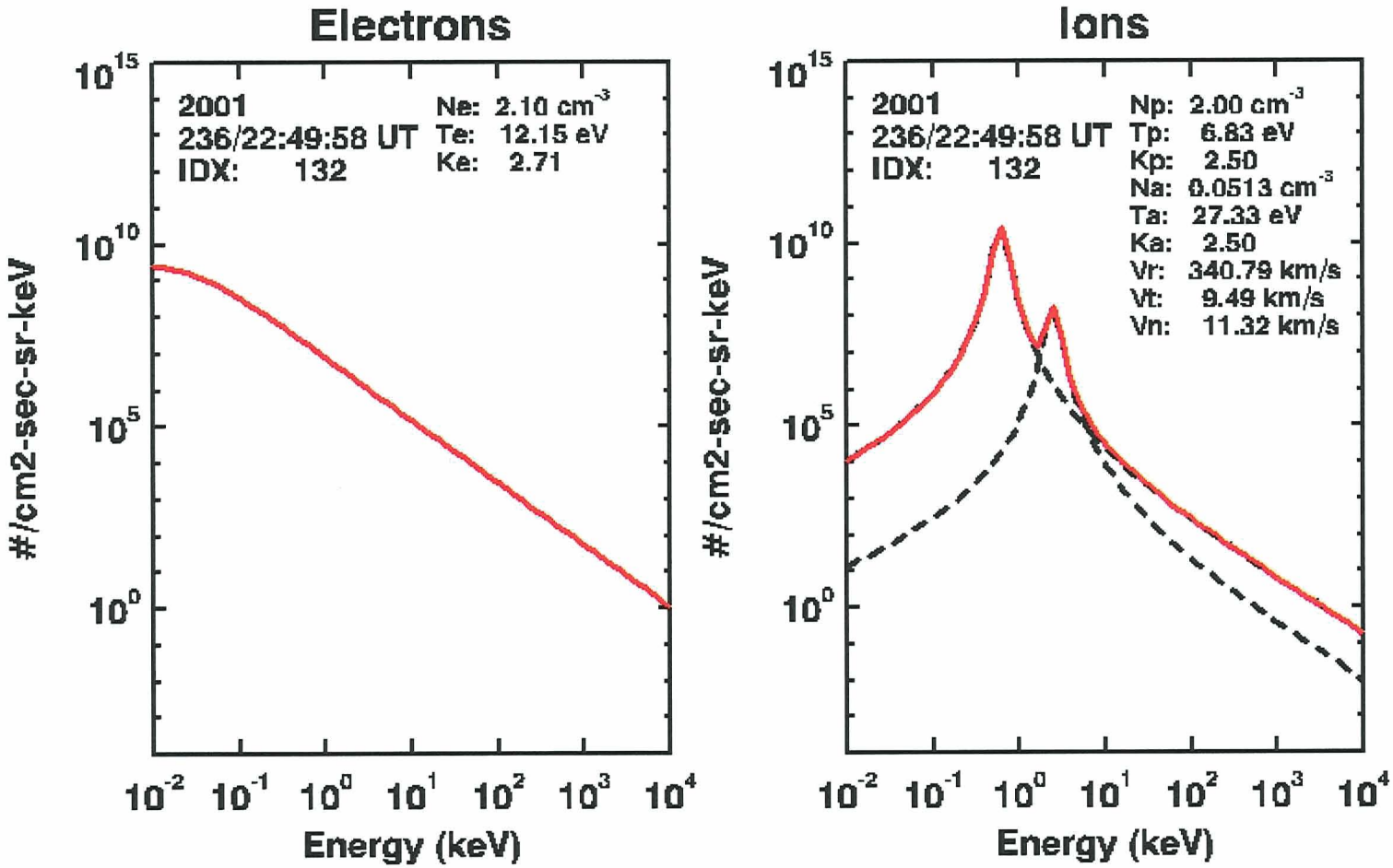
$T_p \sim R^{-0.57}$

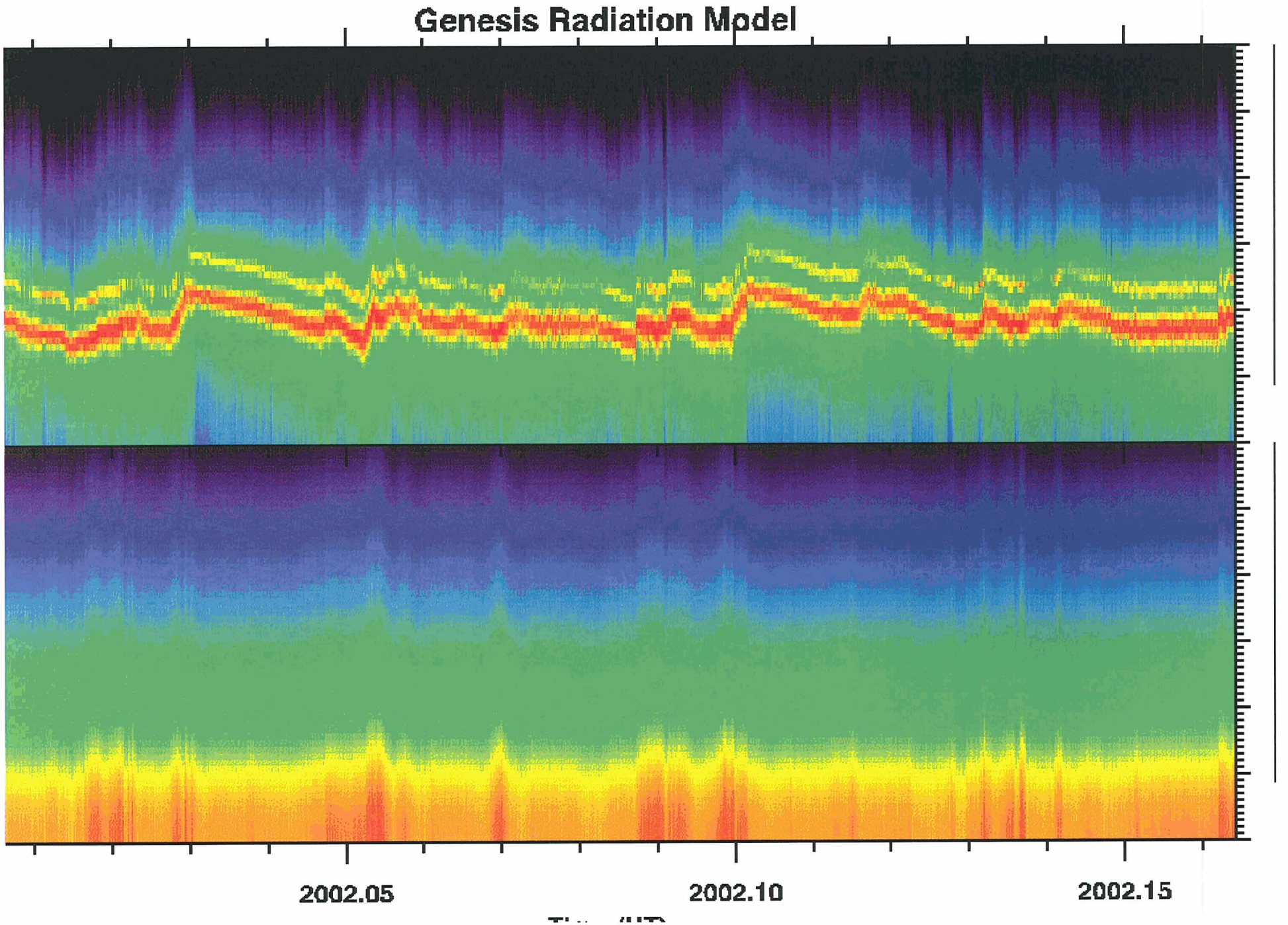
$V_p \sim R^{0}$

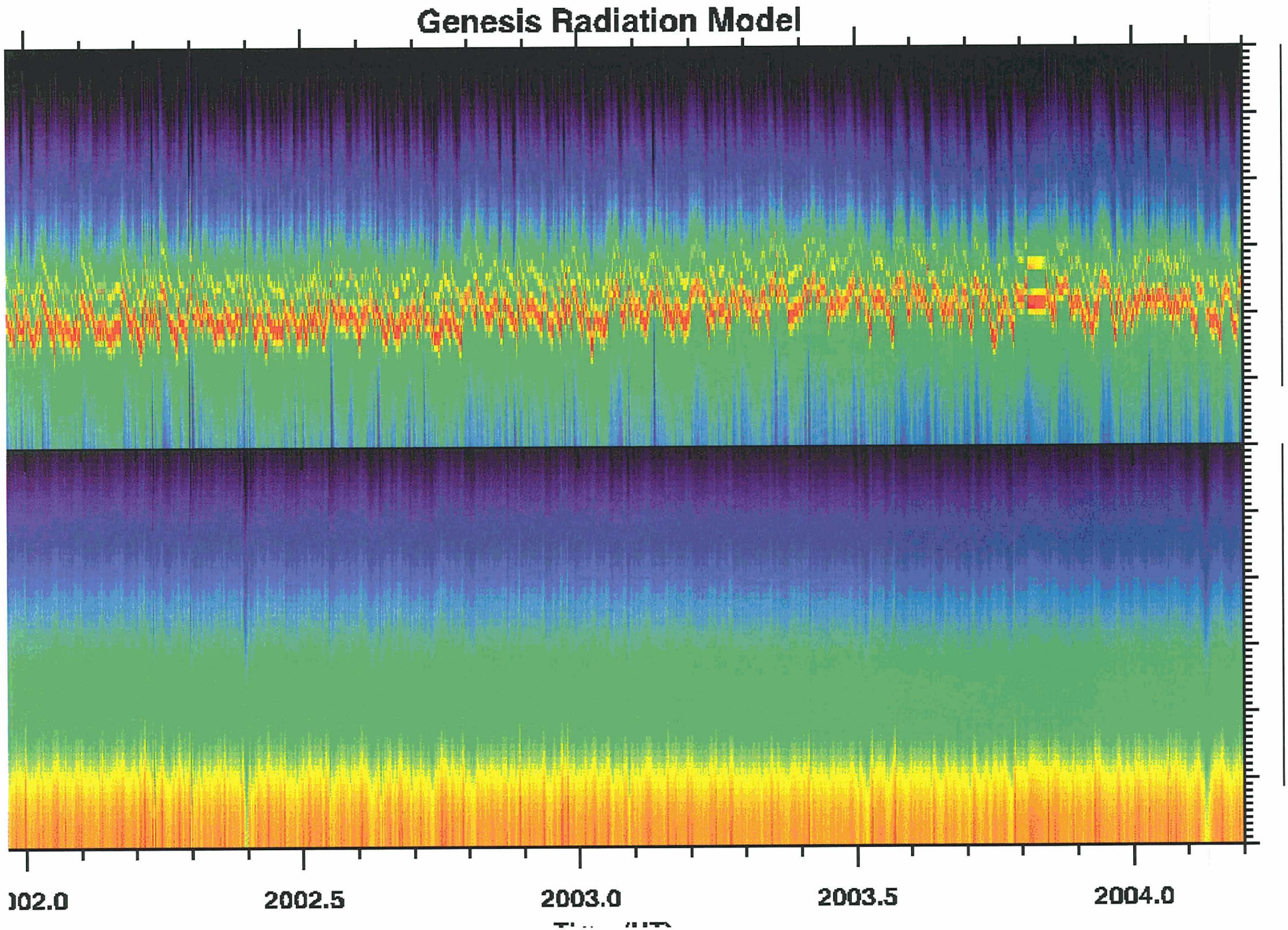



**Minow et al., 2005**


Electrons
2001
236/16:24:11 UT
IDX: 1
Ne: 1.60 cm-3
Te: 12.15 eV
Ke: 1.90
#/cm2-sec-sr-keV
Energy (keV)
Ions
2001
236/16:24:11 UT
IDX: 1
Np: 1.52 cm-3
Tp: 9.28 eV
Kp: 2.50
Na: 0.0395 cm-3
Ta: 37.12 eV
Ka: 2.50
Vr: 600.00 km/s
Vt: 6.58 km/s
Vn: 4.47 km/s
#/cm2-sec-sr-keV
Energy (keV)


Electrons
2001
236/22:49:58 UT
IDX: 132
Ne: 2.10 cm-3
Te: 12.15 eV
Ke: 2.71
#/cm2-sec-sr-keV
Energy (keV)
Ions
2001
236/22:49:58 UT
IDX: 132
Np: 2.00 cm-3
Tp: 6.83 eV
Kp: 2.50
Na: 0.0513 cm-3
Ta: 27.33 eV
Ka: 2.50
Vr: 340.79 km/s
Vt: 9.49 km/s
Vn: 11.32 km/s
#/cm2-sec-sr-keV
Energy (keV)


Genesis Radiation Model
2002.05
2002.10
2002.15


Genesis Radiation Model
)02.0
2002.5
2003.0
2003.5
2004.0

# Genesis/L1 Radiation Environment

**"Interim" Model**

$N_e \sim N_p + 2N_{He}$

$N_{He} = \chi N_p$

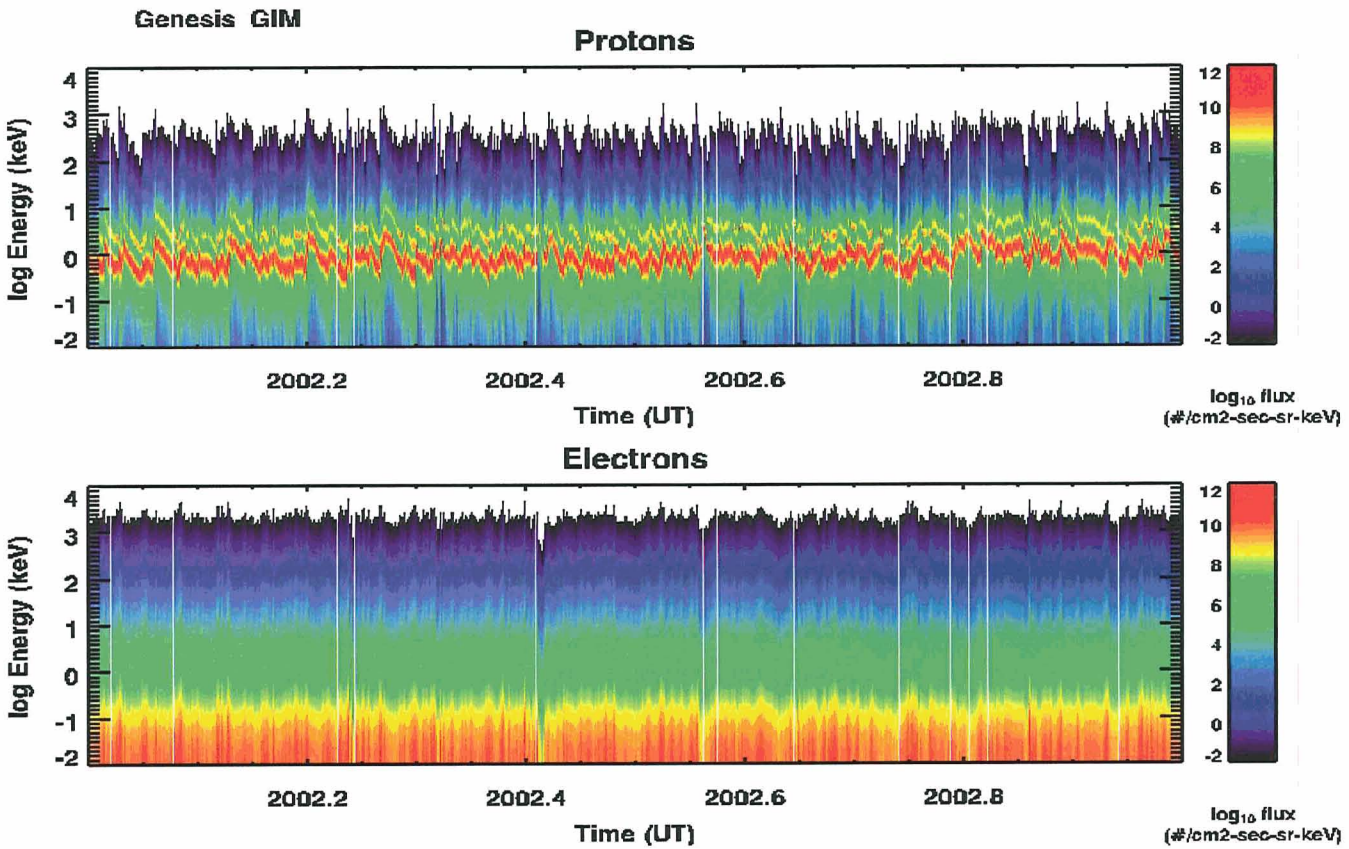
$Te = 1.41 \times 10^5$ K

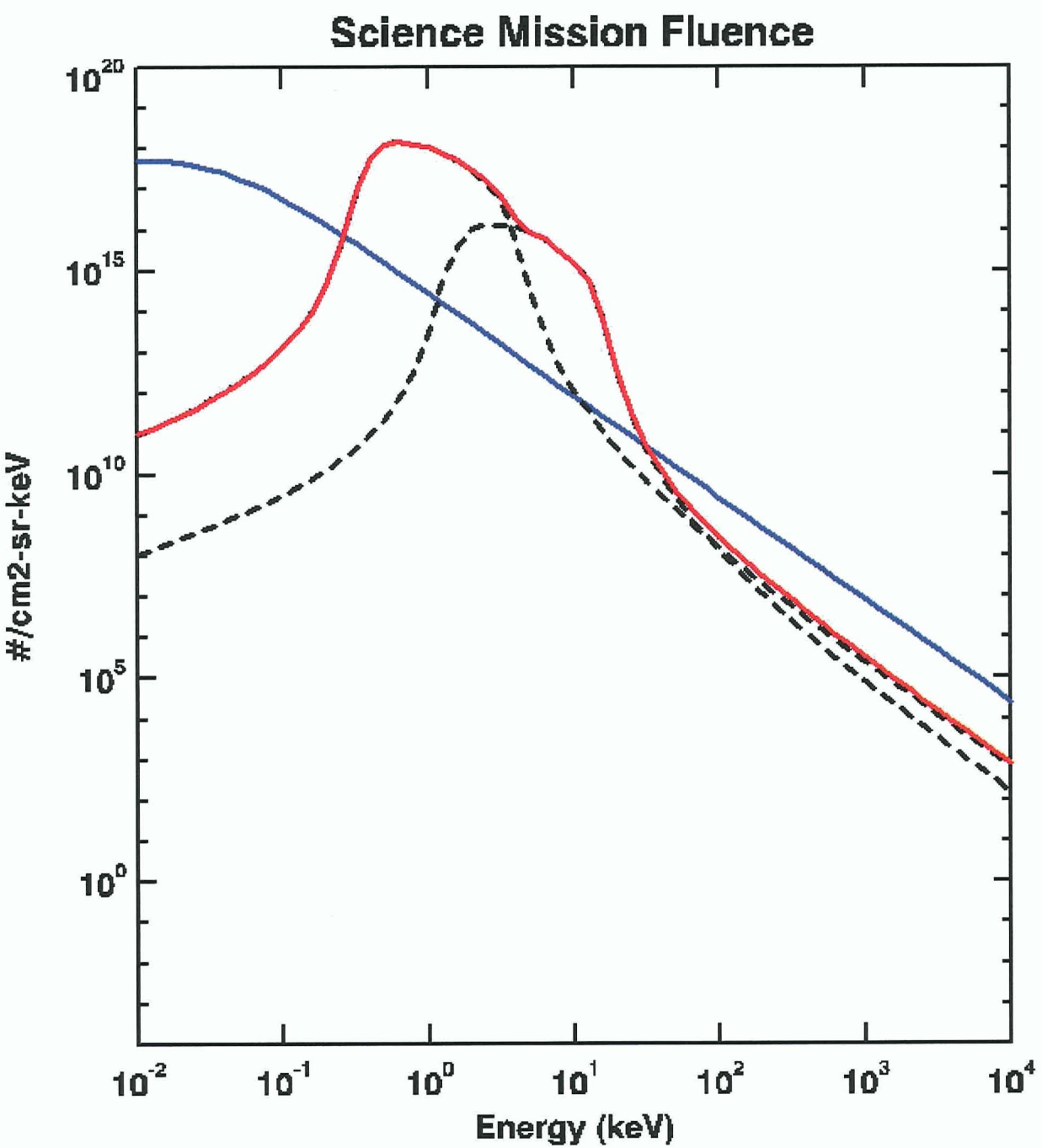
[Newberry et al., 1998]

$V_{r,e} \sim V_{r,p} \sim V_r$

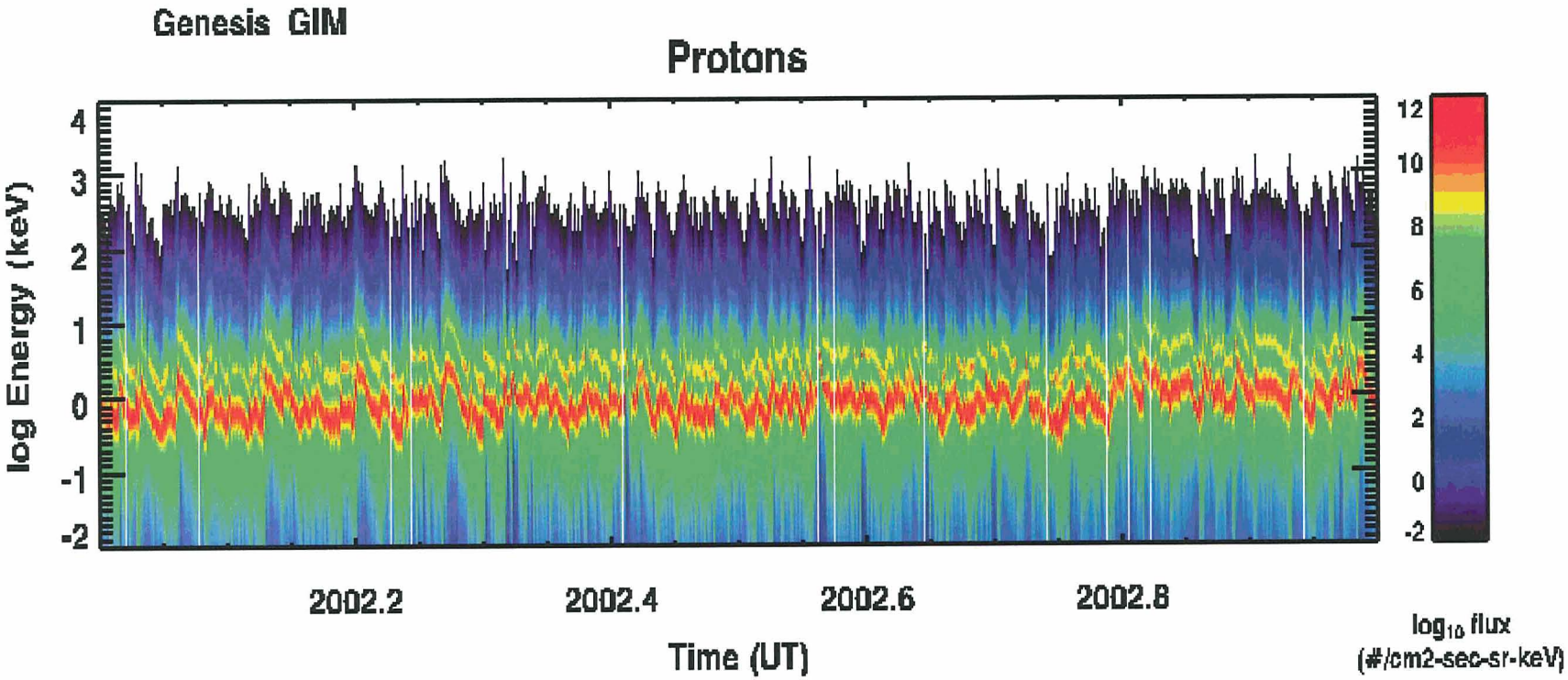
$T_{He} = T_p$

$\kappa = 3.5$ for H, He, $e^-$



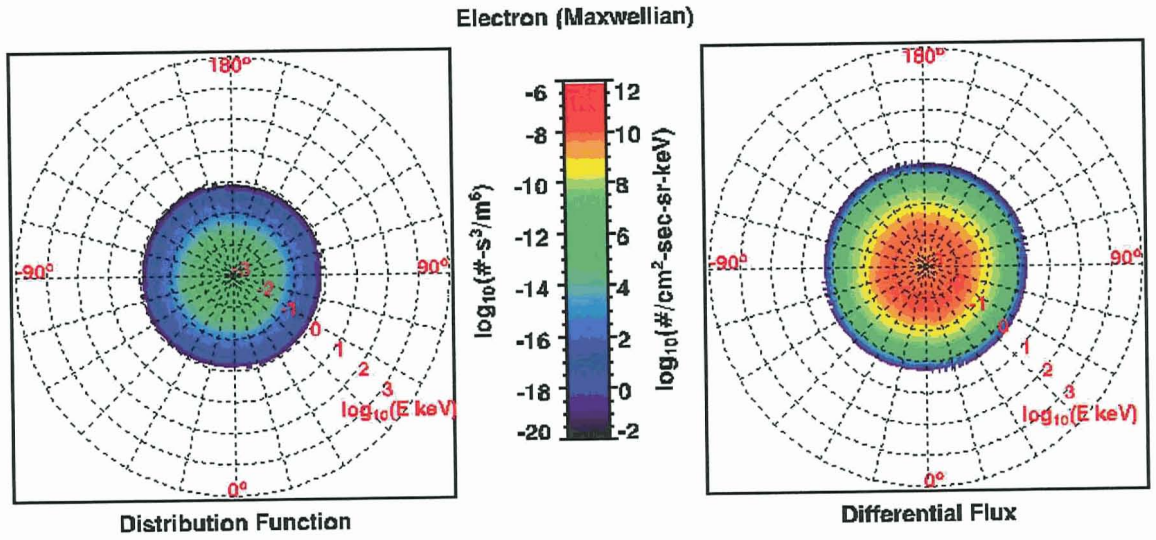

Science Mission Fluence
#/cm2-sr-keV
Energy (keV)
10^20
10^15
10^10
10^5
10^0
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4

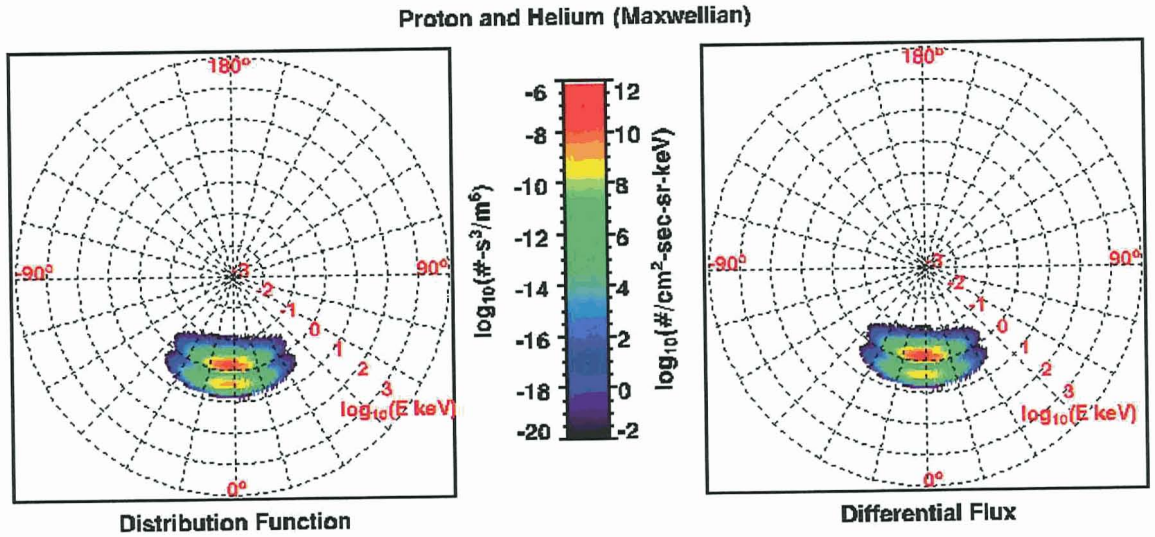
# Reconstructed Genesis Ion Flux




- Reconstructed environment provides energy dependent H, He environments for evaluation of:
  - Energy dependent sputter yields
  - Variation in ion implantation depths

# Reconstructed 2-D Distribution Functions



# Genesis Electron Monitor Data

834 eV

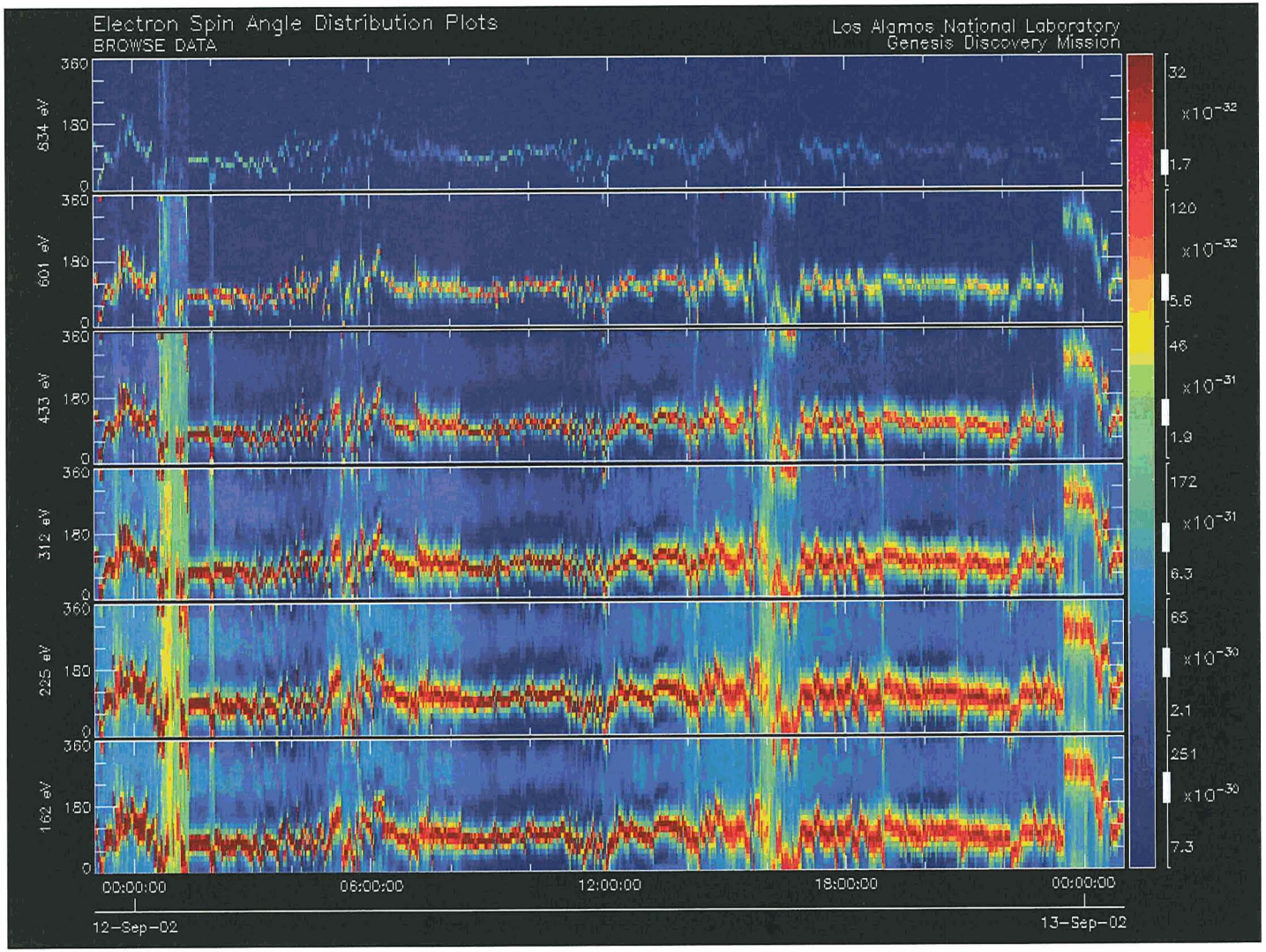
601 eV

433 eV

312 eV

225 eV

162 eV



# Genesis/L1 Radiation Environment

- **Status**
  - Environments analysis
    - Completed database for characterizing environment based on GIM ion moments
    - Collected, merged ACE LEFS, LEMS ion, electron flux measurements for period coinciding with Genesis observations
    - Gap analysis
  - Completed software for preliminary environment based on GIM ion moments, derived electron environments

- **Remaining work**
  - Complete "interim" version using full 1 Dec 2001 to 1 Apr 2004 GIM moments, derived electron environments
  - Kappa fits using ACE Low Energy Foil Spectrometer (LEFS), Low Energy Magnetic Spectrometer (LEMS)
    - Software has been used for Geotail, Ulysses L2-CPE environments
  - Complete ion, electron dose as function of depth
  - Complete documentation

# Genesis/L1 Radiation Environment

- **Summary:**
  - Engineering analysis of Genesis Science Capsule (SC) materials returned from L1 provides a unique opportunity to investigate degradation of materials exposed to the L1 space environment
  - Incorporate Genesis GEM/GIM particle flux measurements with energetic particle observations from other L1 spacecraft to construct ion, electron energy flux spectra, fluence required for materials degradation analysis
  - Adapt results and include as L1 environment for the L2-Charged Particle Environment (L2-CPE) model
  - Products are
    - Charged particle (radiation) environment for use in engineering analyses of Genesis returned hardware,
    - L1 environment for L2-CPE model,
    - Documentation