Chandra Operations

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Chandra X-ray Observatory Center

Operations

Radiation-related Operations:

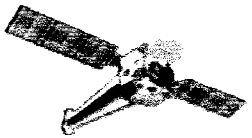
The objective: protecting the Science Instruments, while maximizing the science observing time on Chandra.

The tasks:

- Implement autonomous radiation protection on Chandra
- Implement a radiation monitoring and alert system for the Science Operations Team and Flight Operations Team
- Improve radiation prediction models for mission planning

The groups involved:

- Science Operations Team. Leader: Dan Schwartz
- Radiation Working Group. Leader: Steve O'Dell
- Flight Operations Team, Mission Planning. Leader: Dan Shropshire



SI Safing Enhancements

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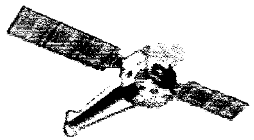
- Implemented in November 1999.
- Provided an autonomous safing capability for protection of Science Instruments. This does not replace scheduling of Science Instrument protection activities through perigee passages, but provides backup protection in case of schedule failures (e.g. if the mission schedule is incorrectly built or stops running).
- Extended the spacecraft safing capabilities to include safing of the science instruments in the event of spacecraft failures interrupting the science mission.
- Provided better use of EPHIN energy ranges, for detecting low energy protons, and adjusted the particle count rate thresholds to prevent false triggers outside perigee while providing reliable detection of potentially damaging proton events.
- Accompanied by improved Flight Operations Team monitoring of science instrument safety, and improved ground-based science instrument safing procedures (including an OCC script-based version of the autonomous procedure).
- Accompanied by improved review of mission command loads to check correct science instrument safing command sequences and times for radiation belt passages.



SI Safing Enhancements

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A universal instrument safing response applies to all SI safing triggers. For autonomous safe operation, the mission command loads must be stopped. The same safing thresholds are applies during ACIS and HRC observations. There is no autonomous recovery from instrument safing.

<u>SI safing triggering events:</u>

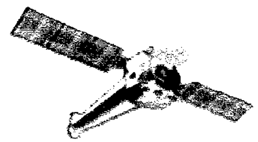
- Observatory Safe Mode
- Normal Sun Mode transition
- Bright Star Hold
- RADMON high radiation detection
- EPHIN failure
- On-board computer Standby Timeout

SI Safing Enhancements

CHANDRA

SI safing actions, implemented in Stored Command Sequence 107:

1. Disable RADMON Process
2. Terminate Mission SCSs
3. Disable Momentum Unloading; disable VDE MUPS valve power
4. Disable Spacecraft Momentum Monitor Safing
5. Disable RW Momentum Bias
6. Retract OTGs
7. Move SIM Translation Table to midpoint
8. Safe ACIS: stop science; power down VBs and FEPs; dump system configuration
9. Safe HRC: stop I&S HV ramp up and HRC dither control; I&S HV rampdown; A&B shield HV turnoff; retract focus shutters; open HRC door; mostly close HRC door
10. Move SIM Translation Table to HRC-S Position
11. Enable Momentum Unloading
12. Enable Spacecraft Momentum Monitor Safing
13. Enable RW Momentum Bias
14. Disable SCS 107



SI Safing Enhancements

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SI Safing Events

17 February 2000: Chandra Safe Mode; ground command error.

5 June 2000: SCS 107 executed by ground command, because of incorrect command timing in mission load.

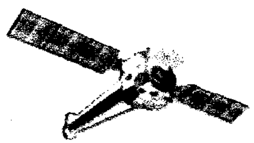
8 June 2000: Autonomous; high radiation.

13 July 2000: SCS 107 executed by ground command; high radiation.

13 September 2000: Autonomous; high radiation.

8 November 2000: Autonomous; high radiation.

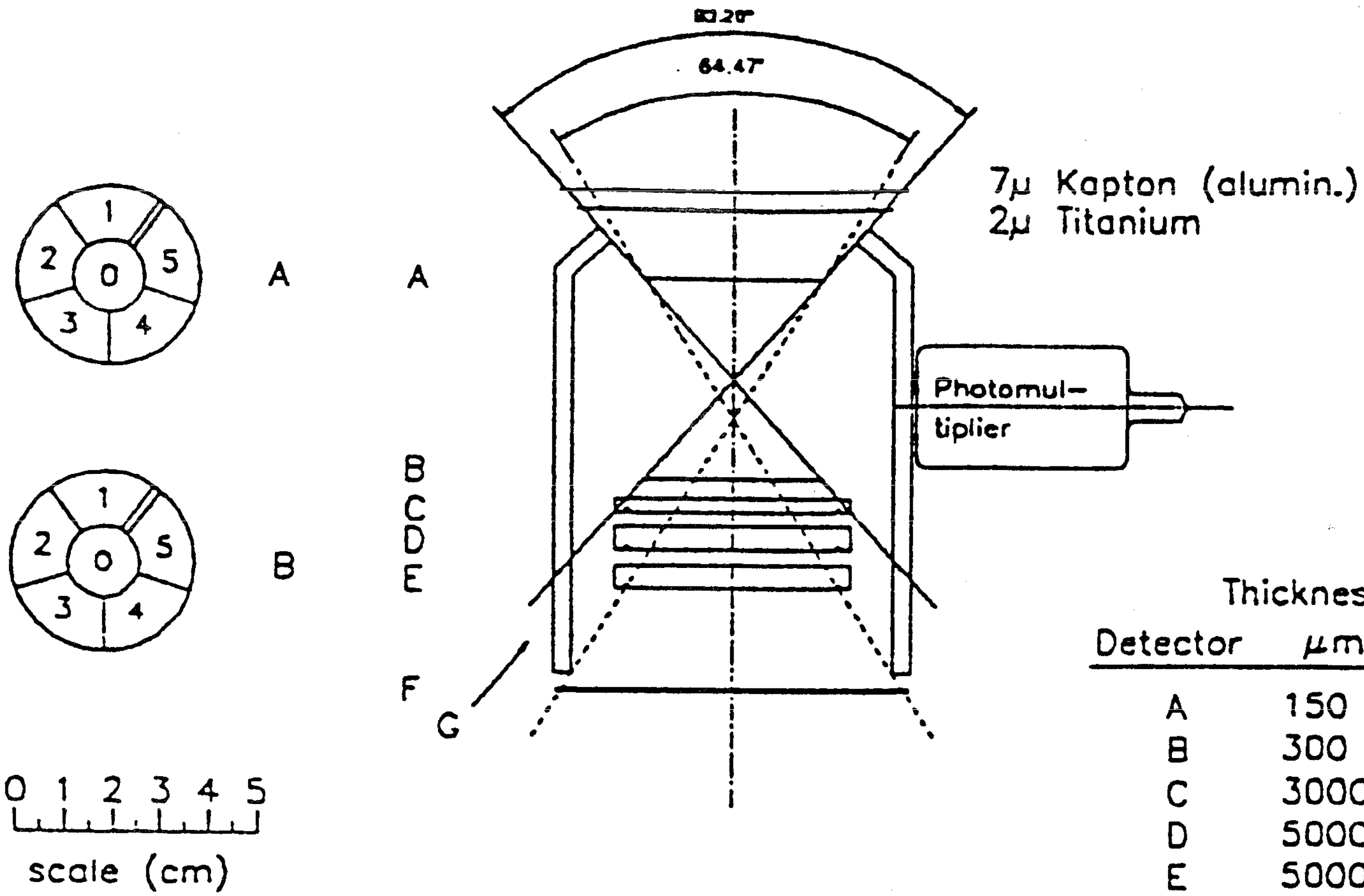
26 November 2000: Autonomous; high radiation.



EPHIN

Electron Proton Helium Instrument (EPHIN)

- Designed for the Solar and Heliospheric Observatory (SOHO), by University of Kiel. Principal Investigator: Reinhold Mueller-Mellin.
- Stack of 5 Si detectors + plastic anti-co shield + sixth Si detector (for penetrating particles).
- 83 degree field of view.
- 5.1 cm2-sr geometric factor.
- A and B detectors have switchable geometry, for high count rates. Geometric factor changes by 24x, which allows flux measurements up to 200000 cts/cm2-s-sr without significant dead time losses.
- Telemetry update period: 65.6 seconds.
- Chandra uses electron and proton rates for on-board radiation monitor.



EPHIN

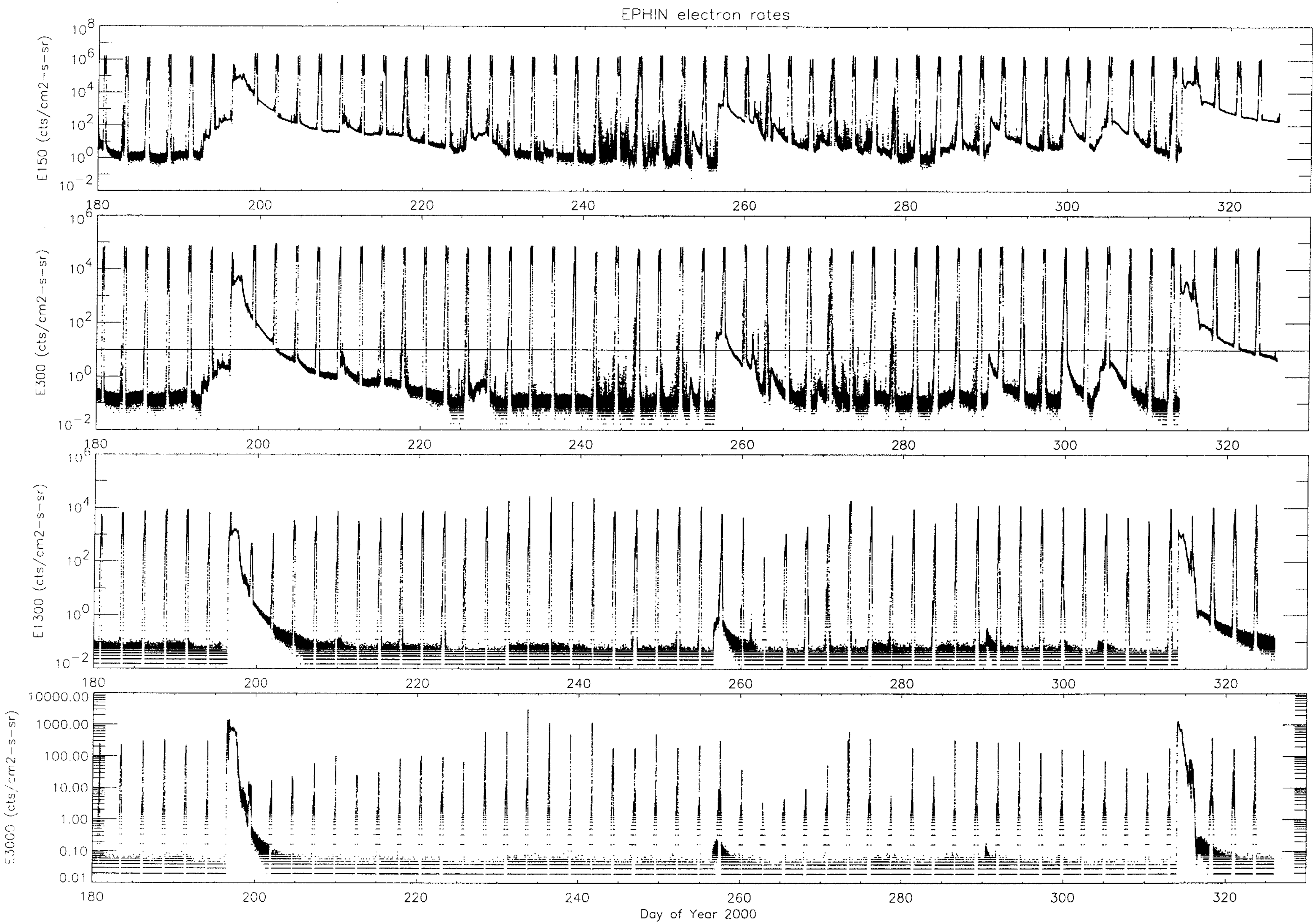
Detector	Thickness µm	Active Area cm^2	Type
A	150	11.3	ion-implanted
B	300	11.3	ion-implanted
C	3000	15.2	lithium-drifted
D	5000	15.2	lithium-drifted
E	5000	15.2	lithium-drifted
F	700	50.0	ion-implanted
G	4000		plastic scintill.

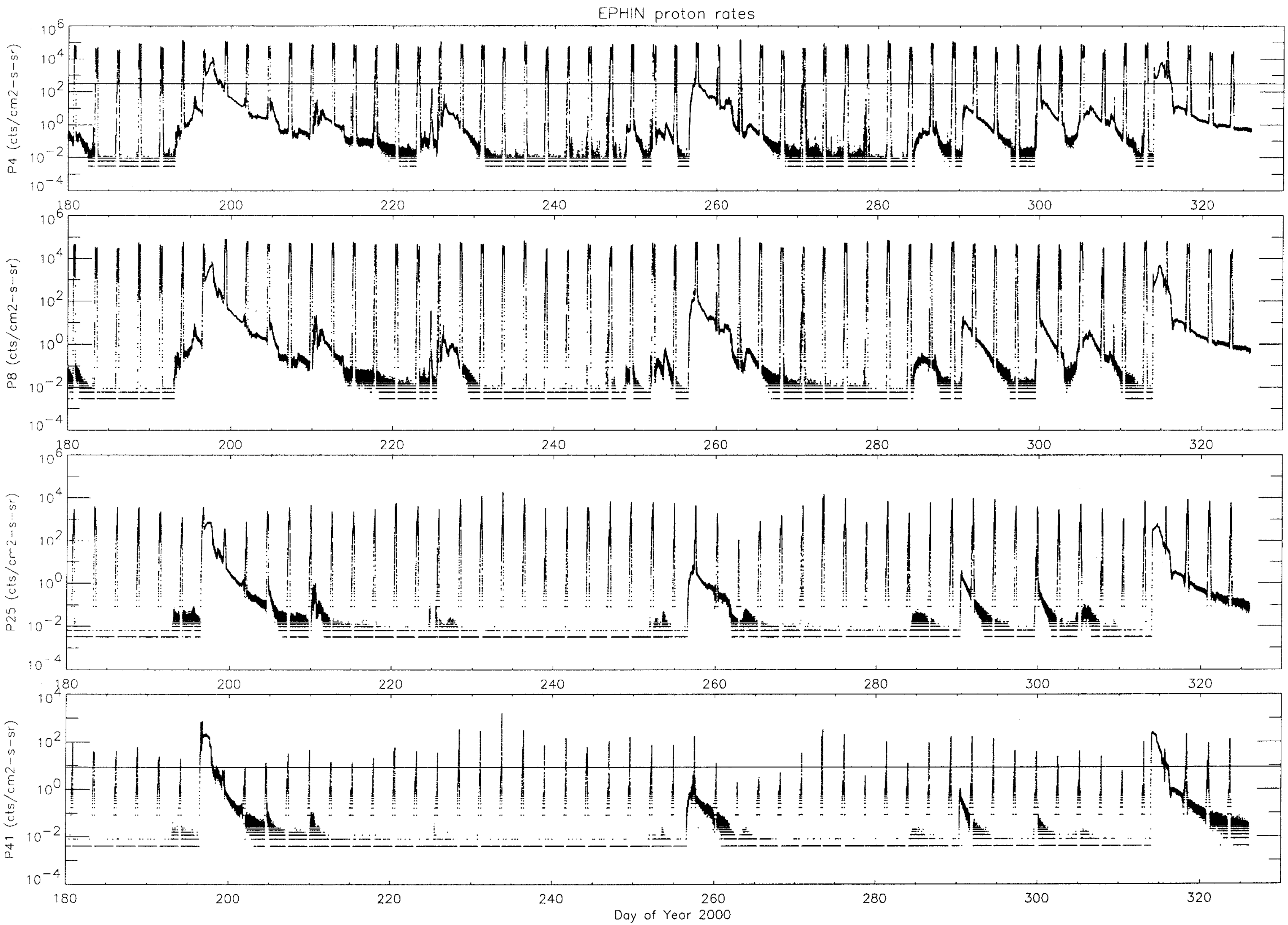
EPHIN Channels

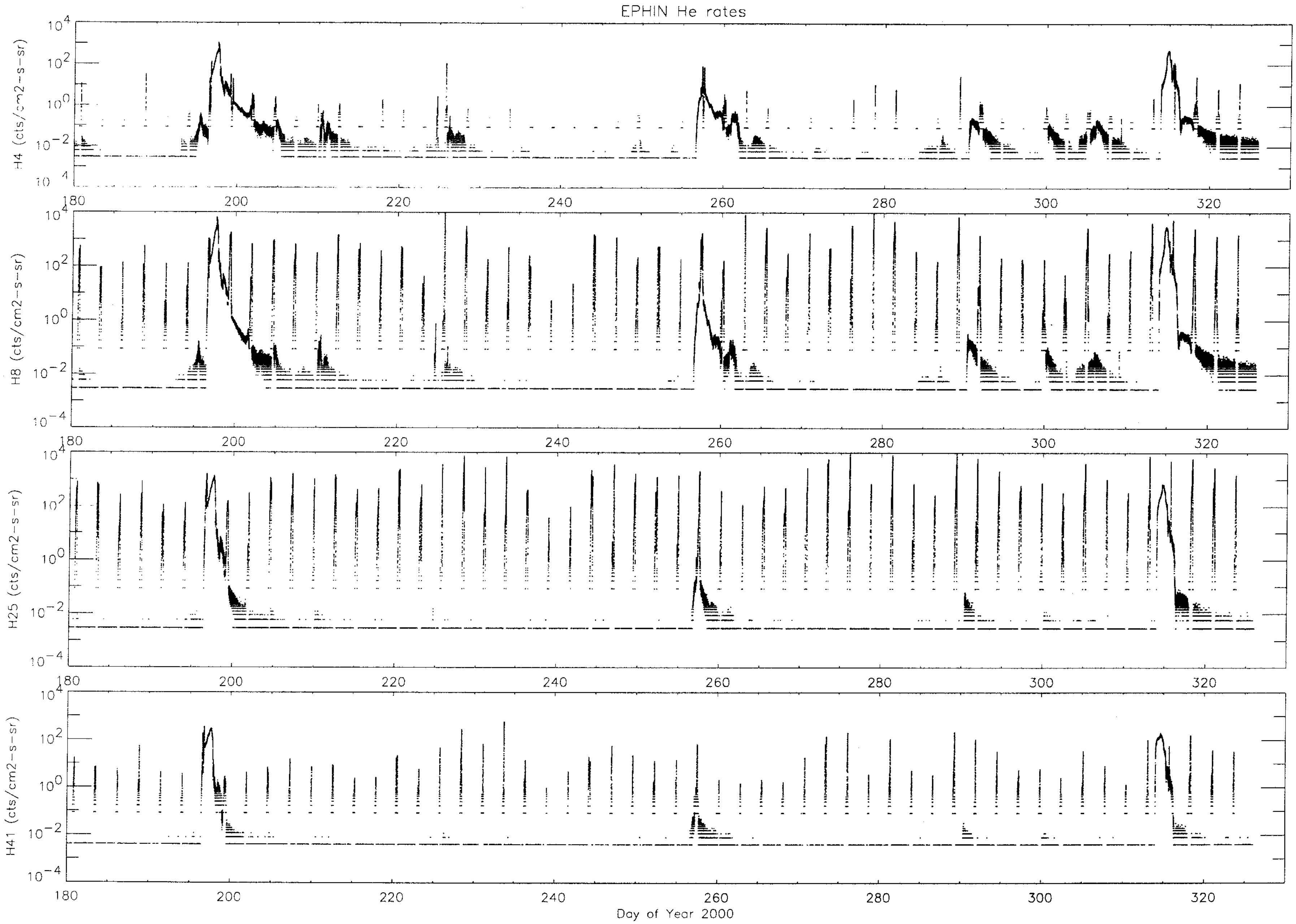
Type	Name	Energy Range (MeV)	Energy Width (MeV)
Electron	E150	0.25 – 0.70	0.45
	E300	0.67 – 3.00	2.3
	E1300	2.64 – 6.18	3.6
	E3000	4.80 – 10.4	5.6
Proton	P4	5.0 – 8.3	3.3
	P8	8.3 – 25.0	16.7
	P25	25.0 – 41.0	16.0
	P41	41.0 – 53.0	12.0
Helium	H4	5.0 – 8.3	3.3
	H8	8.3 – 25.0	16.7
	H25	25.0 – 41.0	16.0
	H41	41.0 – 53.0	12.0
Integral	INT	e>8.7, p>53, He>53	

EPHIN Channels and RADMON Trigger Thresholds

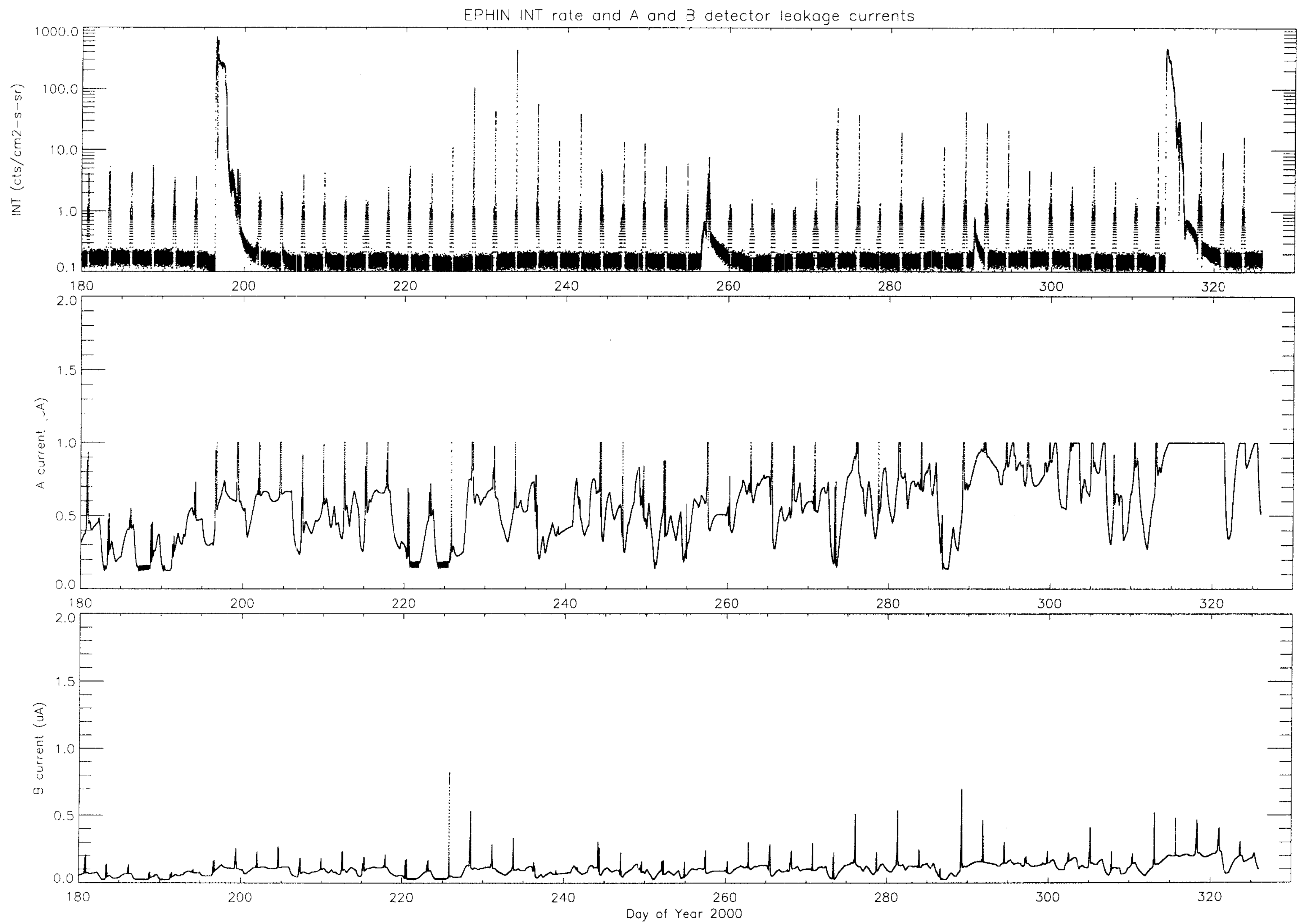
Type	Name	Energy Range (MeV)	RADMON Threshold (cts/cm^2-s-sr)
Electron	E150	0.25 – 0.70	
	E300	0.67 – 3.00	
	E1300	2.64 – 6.18	10.0
	E3000	4.80 – 10.4	
Proton	P4	5.0 – 8.3	300.0
	P8	8.3 – 25.0	
	P25	25.0 – 41.0	
	P41	41.0 – 53.0	8.47
Helium	H4	5.0 – 8.3	
	H8	8.3 – 25.0	
	H25	25.0 – 41.0	
	H41	41.0 – 53.0	
Integral	INT	e>8.7, p>53, He>53	

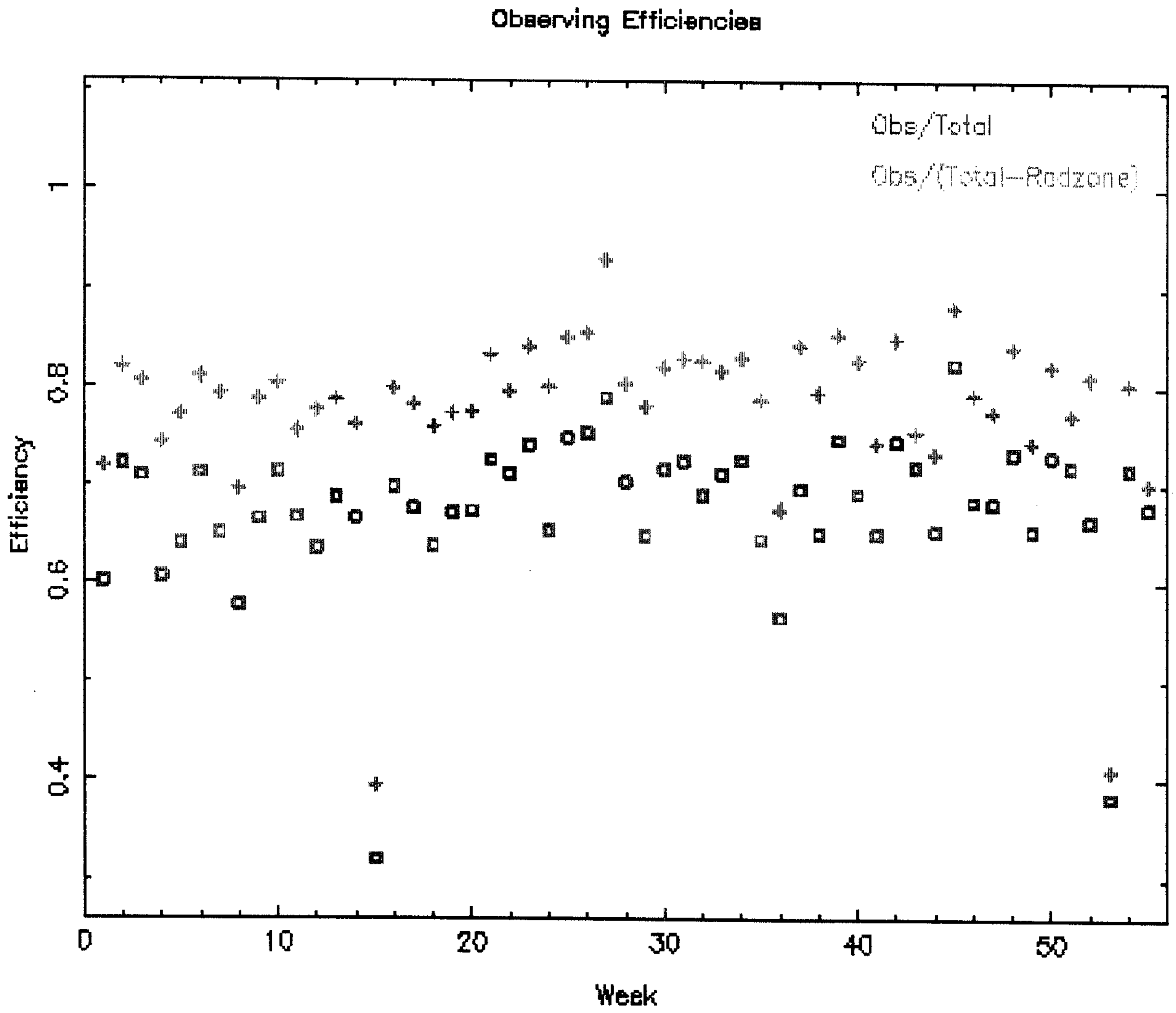

EPHIN electron rates
E150 (cts/cm2-s-sr)
E300 (cts/cm2-s-sr)
E1300 (cts/cm2-s-sr)
E3000 (cts/cm2-s-sr)
Day of Year 2000


EPHIN proton rates
P4 (cts/cm2-s-sr)
P8 (cts/cm2-s-sr)
P25 (cts/cm2-s-sr)
P41 (cts/cm2-s-sr)
Day of Year 2000

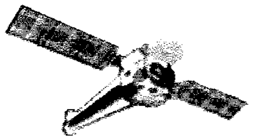


EPHIN He rates
H4 (cts/cm2-s-sr)
H8 (cts/cm2-s-sr)
H25 (cts/cm2-s-sr)
H41 (cts/cm2-s-sr)
Day of Year 2000


EPHIN INT rate and A and B detector leakage currents
INT (cts/cm2-s-sr)
A current (uA)
B current (uA)
Day of Year 2000



Observing Efficiencies
Obs/Total
Obs/(Total-Radzone)
Efficiency
Week
1
0.8
0.6
0.4
0
10
20
30
40
50



Science Operations Team

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The Chandra Science Operations Team maintains a series of proton fluence monitors.

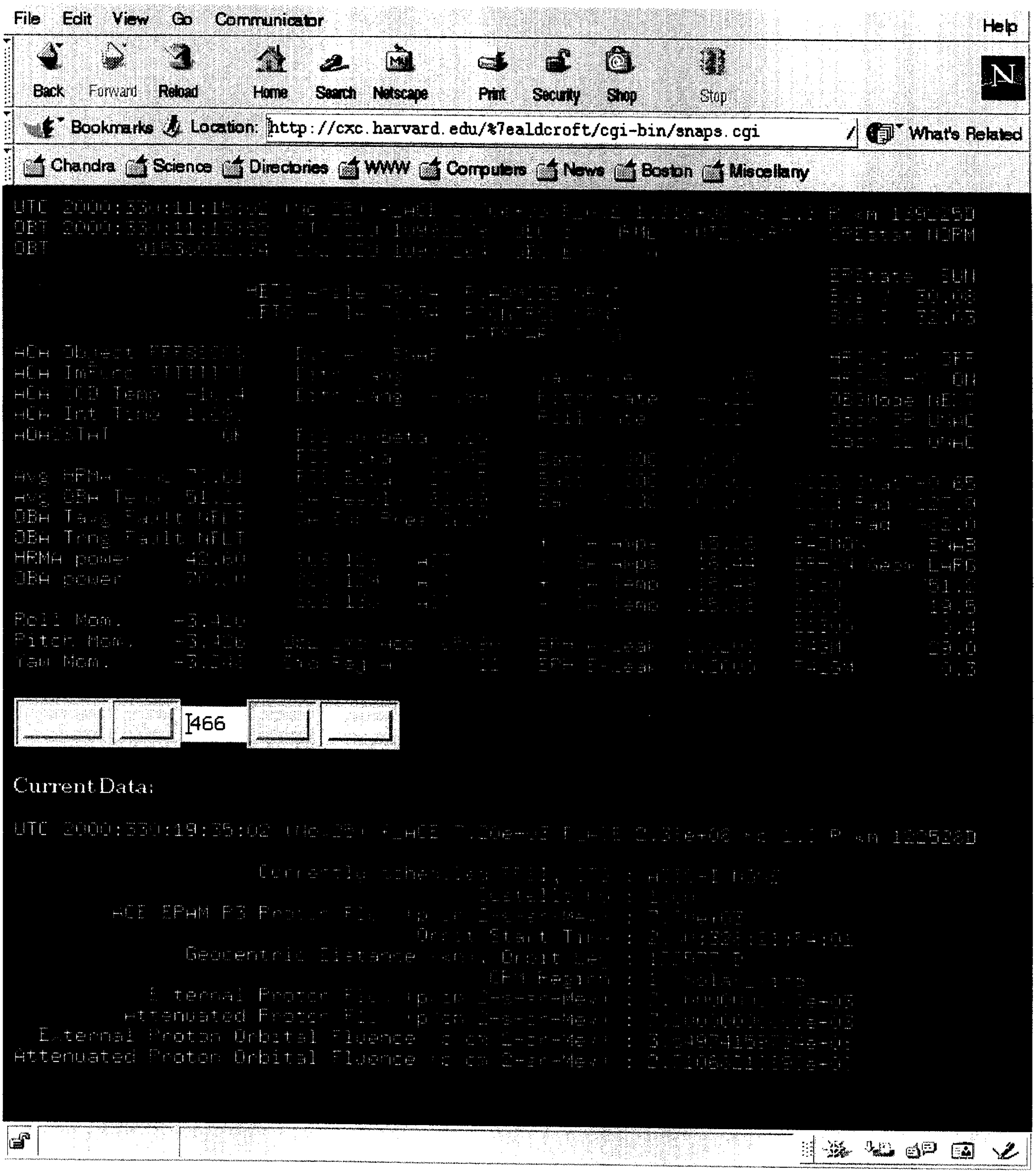
Source data:

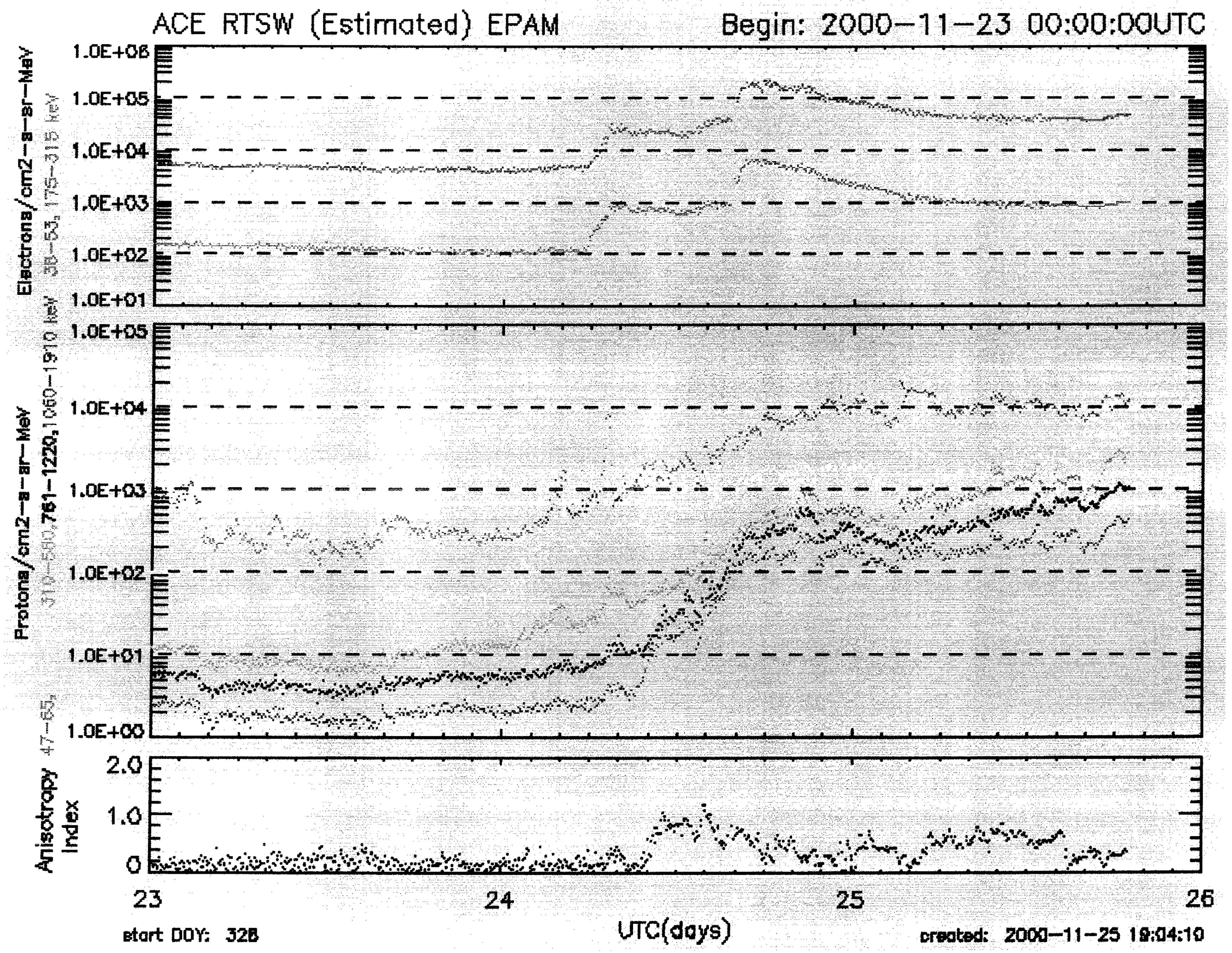
- Advanced Composition Explorer (ACE): Electron, Proton and Alpha Monitor (EPAM) P3 channel: 112 – 187 keV protons.
- Chandra Radiation Model (CRM)
- Air Force and Costello Kp

Monitors:

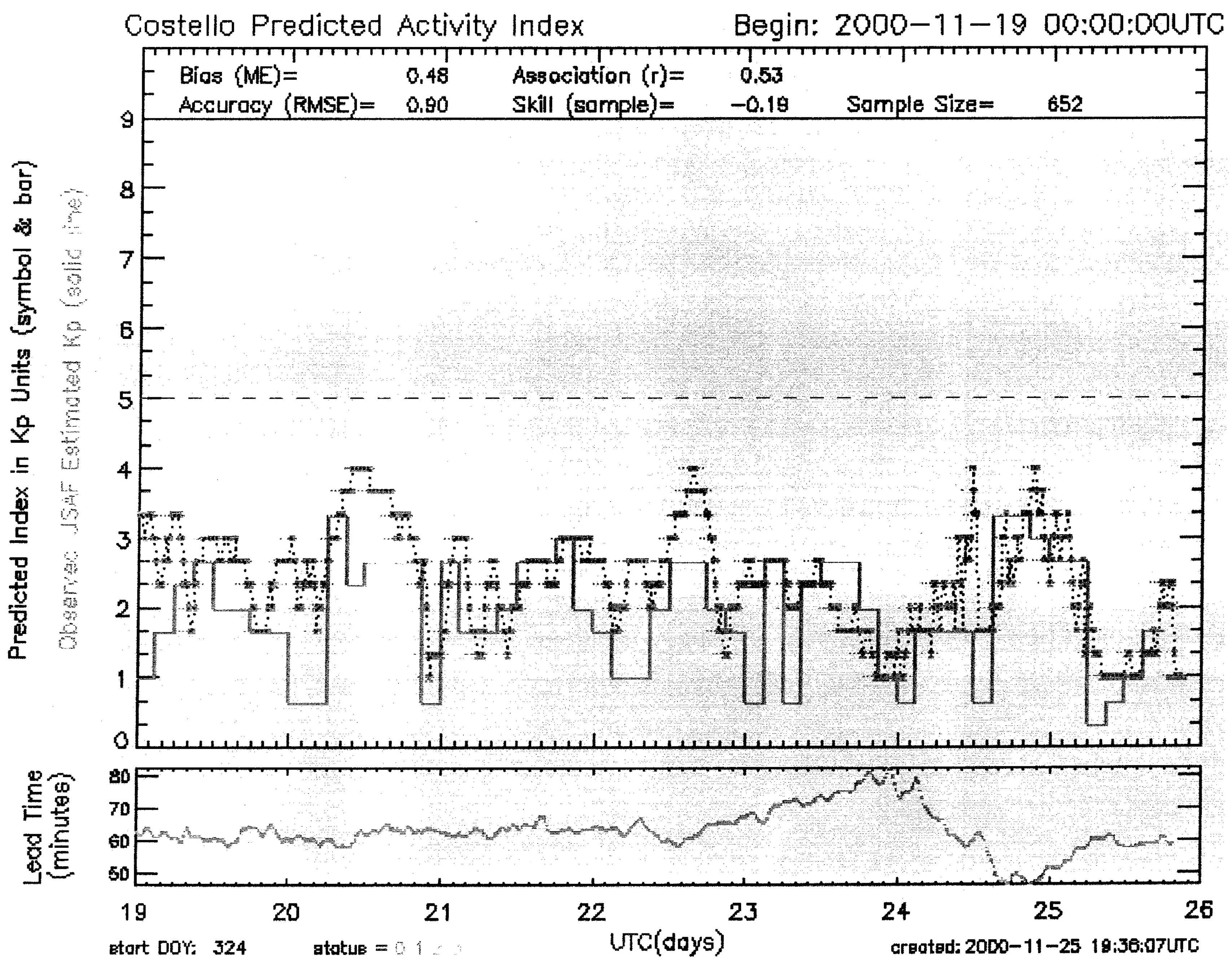
- 2 hour ACE P3 average flux. Alert threshold = 5E4 cts/cm2-s-sr.
- Chandra orbital fluence. Alert thresholds = 1E9, 3E9, 9E9... cts/cm2-s-sr. ACE EPAM P3 and CRM fluxes are integrated for the duration of each Chandra orbit. ACIS flux estimate is attenuated by SIM and OTG transmission factors (TF):
    - SIM translation table. ACIS: TF = 1, HRC: TF = 0.
    - LETG inserted: TF = 0.5
    - HETG inserted: TF = 0.2
- Air Force and Costello Kp estimates. Variable threshold matrix.

Current studies: correlation of EPHIN P4 with GOES P2 (protons: 4 – 9 MeV).

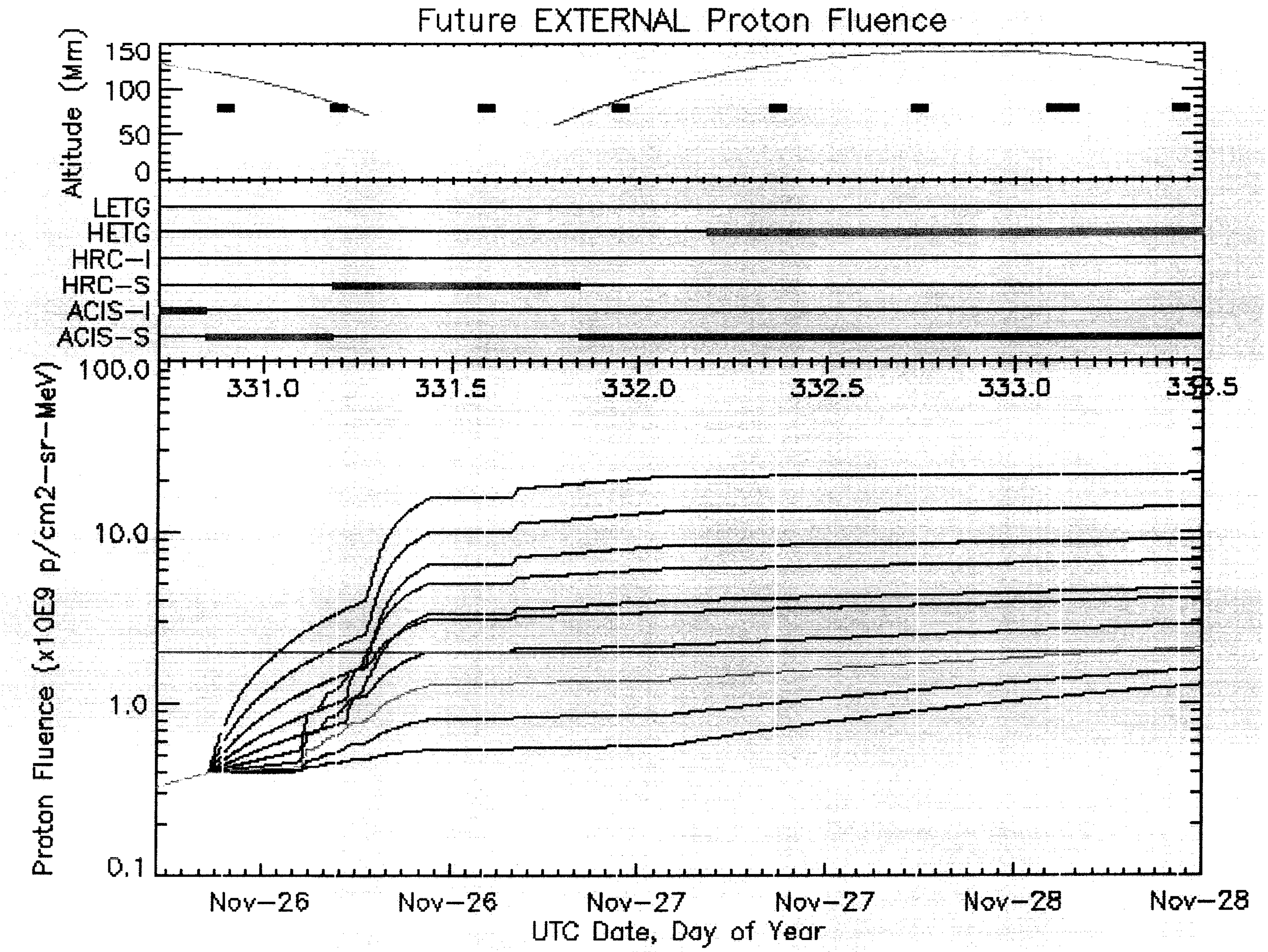

File Edit View Go Communicator
Help
Back Forward Reload Home Search Netscape Print Security Shop Stop
Bookmarks Location: http://cxc.harvard.edu/%7ealdcroft/cgi-bin/snaps.cgi
What's Related
Chandra Science Directories WWW Computers News Boston Miscellany
466
Current Data:



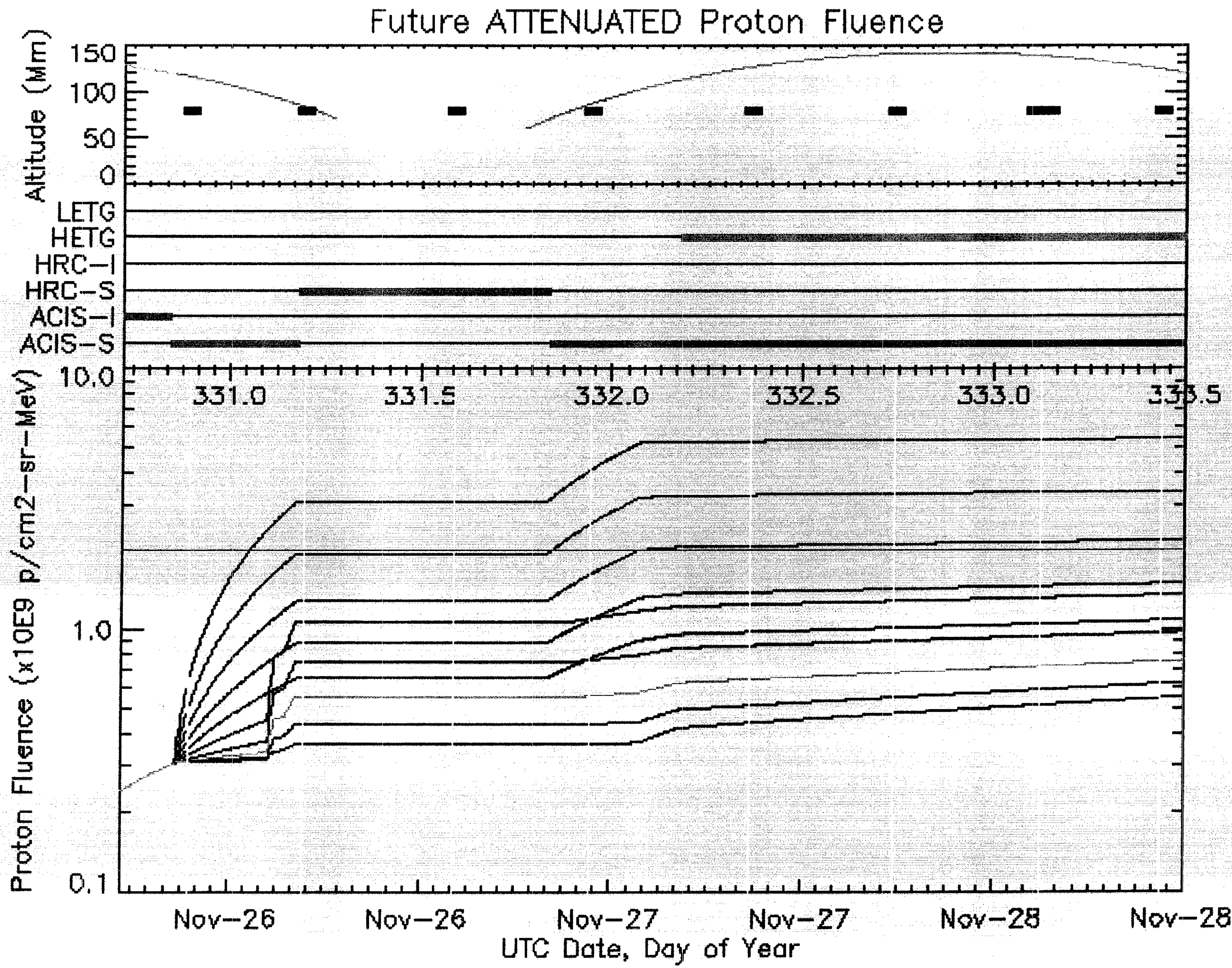
ACE RTSW (Estimated) EPAM
Begin: 2000-11-23 00:00:00UTC
Electrons/cm2-s-sr-MeV
38-53, 175-315 keV
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
Protons/cm2-s-sr-MeV
47-65, 310-580, 761-1220, 1060-1910 keV
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
Anisotropy Index
2.0
1.0
0
23
24
25
26
UTC(days)
start DOY: 328
created: 2000-11-25 19:04:10



Costello Predicted Activity Index
Begin: 2000-11-19 00:00:00UTC
Bias (ME)= 0.48
Association (r)= 0.53
Accuracy (RMSE)= 0.90
Skill (sample)= -0.19
Sample Size= 652
Predicted Index in Kp Units (symbol & bar)
Observed USAF Estimated Kp (solid line)
Lead Time (minutes)
UTC(days)
start DOY: 324
status =
created: 2000-11-25 19:36:07UTC



Future EXTERNAL Proton Fluence
Altitude (Mm)
150
100
50
0
LETG
HETG
HRC-I
HRC-S
ACIS-I
ACIS-S
100.0
331.0
331.5
332.0
332.5
333.0
333.5
10.0
1.0
0.1
Proton Fluence (x10E9 p/cm2-sr-MeV)
Nov-26
Nov-26
Nov-27
Nov-27
Nov-28
Nov-28
UTC Date, Day of Year



Future ATTENUATED Proton Fluence
Altitude (Mm)
150
100
50
0
LETG
HETG
HRC-I
HRC-S
ACIS-I
ACIS-S
Proton Fluence (x10E9 p/cm2-sr-MeV)
10.0
1.0
0.1
331.0
331.5
332.0
332.5
333.0
333.5
Nov-26
Nov-26
Nov-27
Nov-27
Nov-28
Nov-28
UTC Date, Day of Year

Chandra Radiation Model

Chandra Project Science is leading a team to develop and implement an improved model for low energy proton fluxes in the Chandra orbit: the Chandra Radiation Model (CRM). Model development is led by Bill Blackwell (Sverdrup Technology Inc.) and the Chandra Radiation Working Group.

Objectives:

- Improve Chandra science observing efficiency, with low risk of RADMON triggers from trapped radiation.
- Improve real time predictions of Chandra proton fluence, for health and safety decision making.
- Refine understanding of the effects of Chandra particle environment on ACIS, for improved budgeting and control of lifetime accumulated damage.

Current Chandra mission planning and scheduling uses the NASA AP-8/AE-8 radiation models. AP-8 provides poor fidelity above geosynchronous orbit and poor modeling of 100keV protons. AE-8 is used for scheduling science operations in each Chandra orbit. Mismatches between AE-8 predictions and observed EPHIN rates have resulted in required 10ksec "padding" on both the predicted radiation entry and exit times.

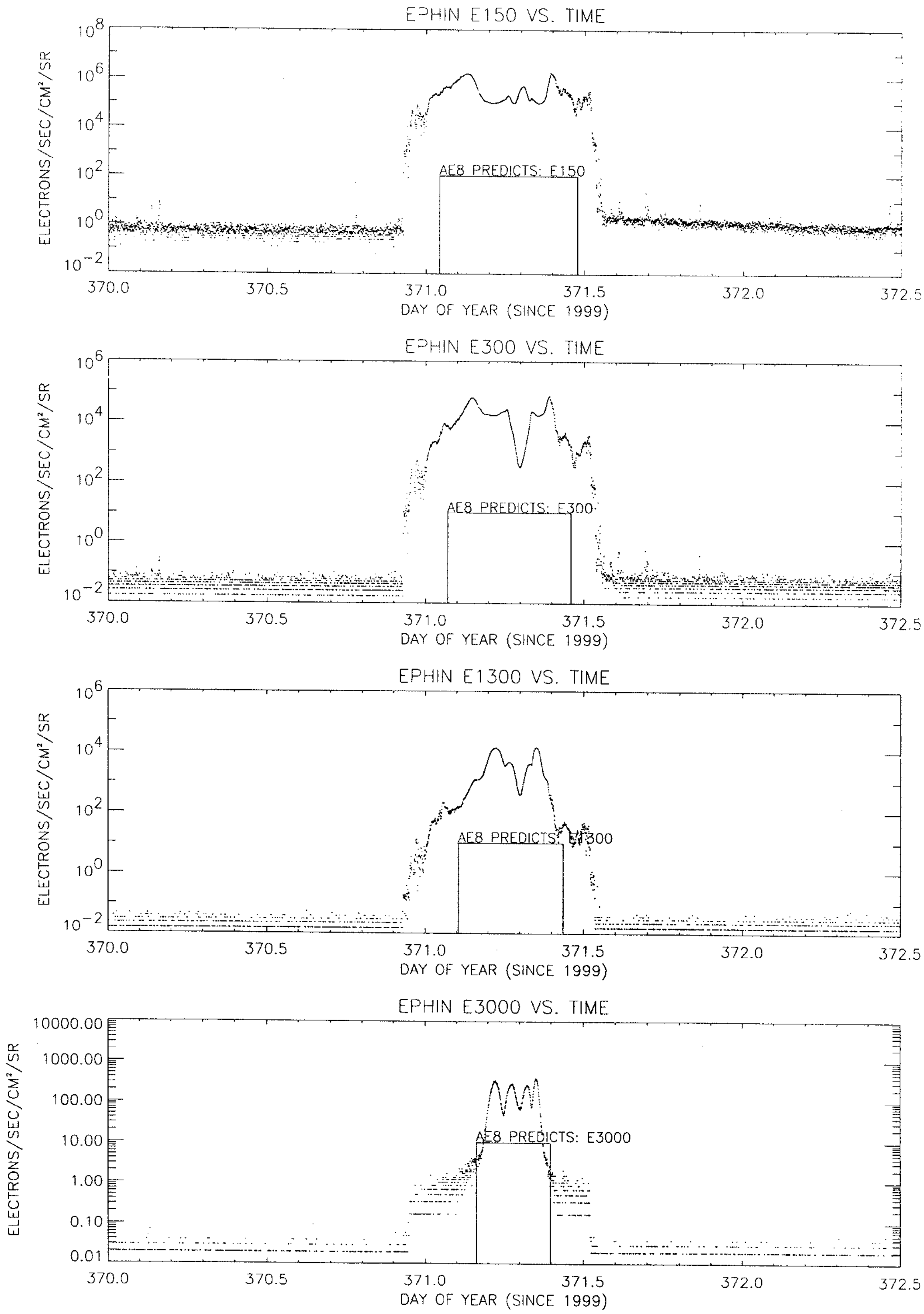
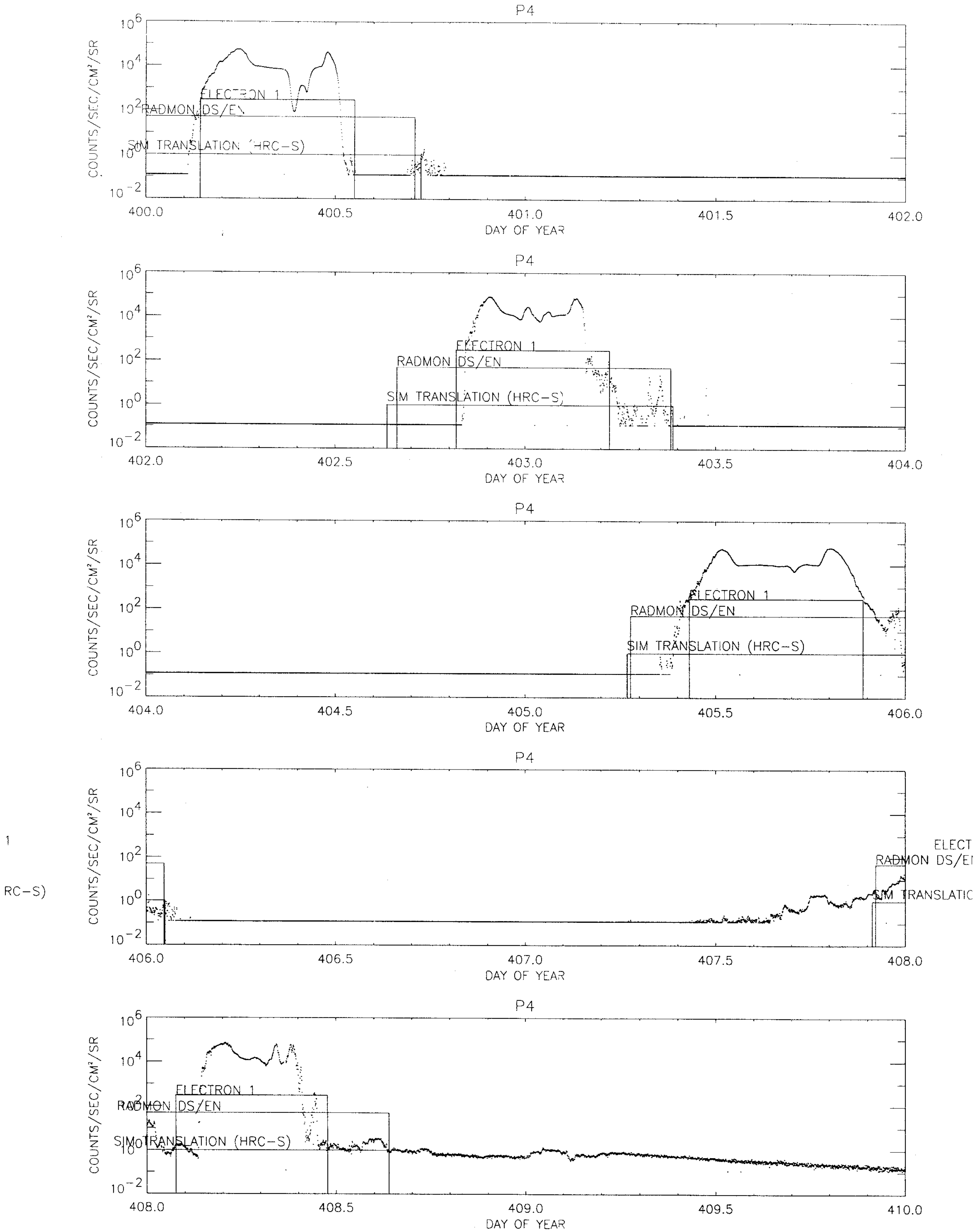
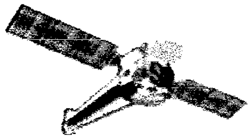


Figure 5. AE-8 radiation belt model predictions against EPHIN data on Day 371. Note AE-8 predictions are based on an integral above an energy threshold (specified within the text) whereas the EPHIN electron channel has a much narrower energy window.


P4
COUNTS/SEC/CM²/SR
DAY OF YEAR
ELECTRON 1
RADMON DS/EN
SIM TRANSLATION (HRC-S)
400.0 400.5 401.0 401.5 402.0
402.0 402.5 403.0 403.5 404.0
404.0 404.5 405.0 405.5 406.0
406.0 406.5 407.0 407.5 408.0
408.0 408.5 409.0 409.5 410.0



Chandra Radiation Model

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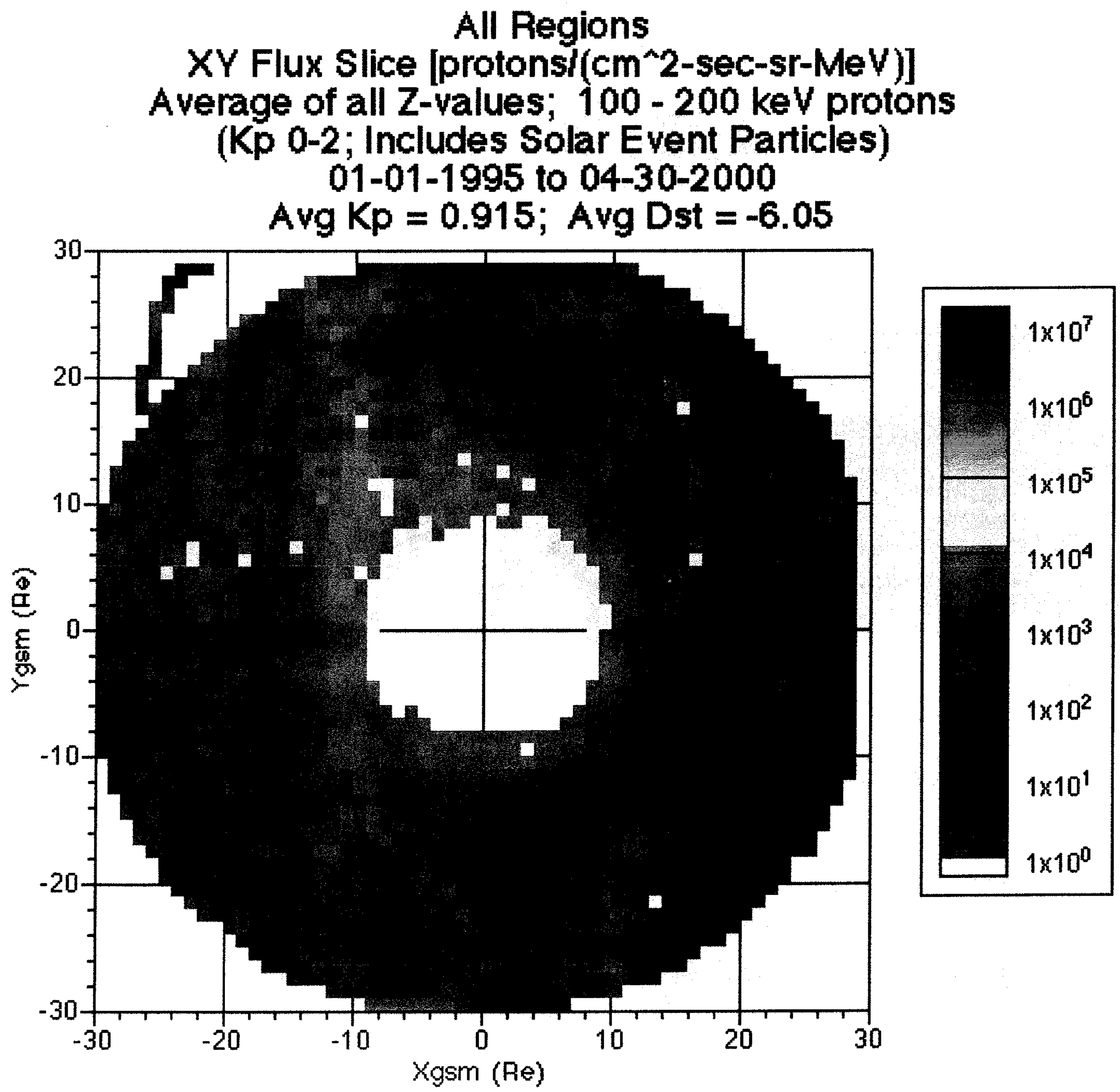
The CRM is a data-drive model. CRM characteristics:

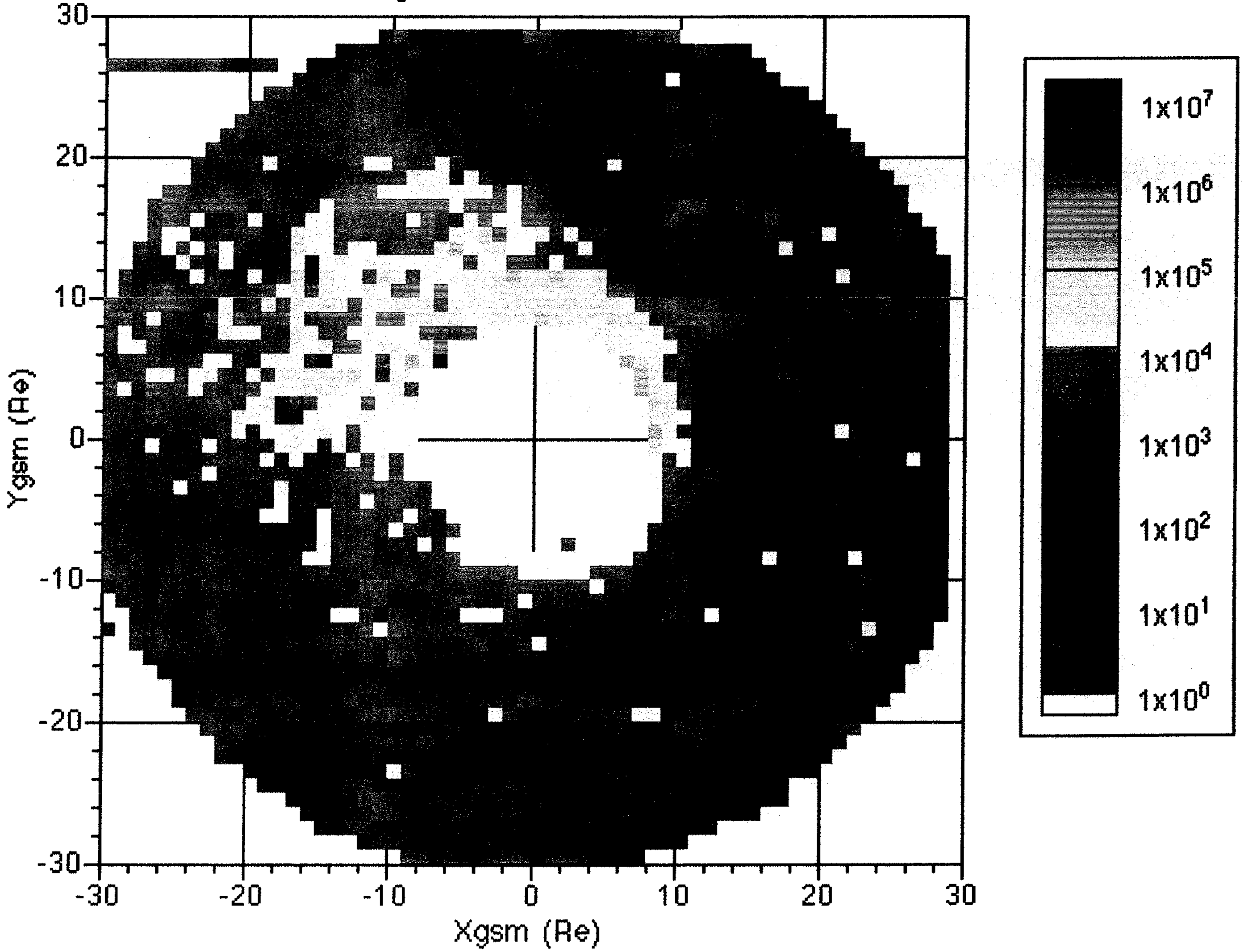
- Model for 100 – 200 keV protons, compatible with ACE EPAM P3 data.
- 9 – 30 Re geocentric altitude coverage.
- Indexed by Geocentric Solar Magnetospheric (GSM) coordinates and Kp.
- Flux predictions identified by region: magnetosphere, magnetosheath, solar wind for improved estimation of Chandra global radiation environment.
- Probabilistic flux estimates: mean, 50%, 95% estimates.
- Multiple species and energies: p: 100 – 200 keV, p > 1 MeV, He, CNO.

CRM data source: 5 year dataset (1995 – 2000) from the Ion Composition Subsystem (ICS) of the Energetic Particles and Ion Composition (EPIC) instrument on the Japan ISIS/NASA Geotail satellite. Ion and electron spectrograms from the Comprehensive Plasma Instrument (CPI) Hot Plasma Analyzer (HPA) provided the region identification.

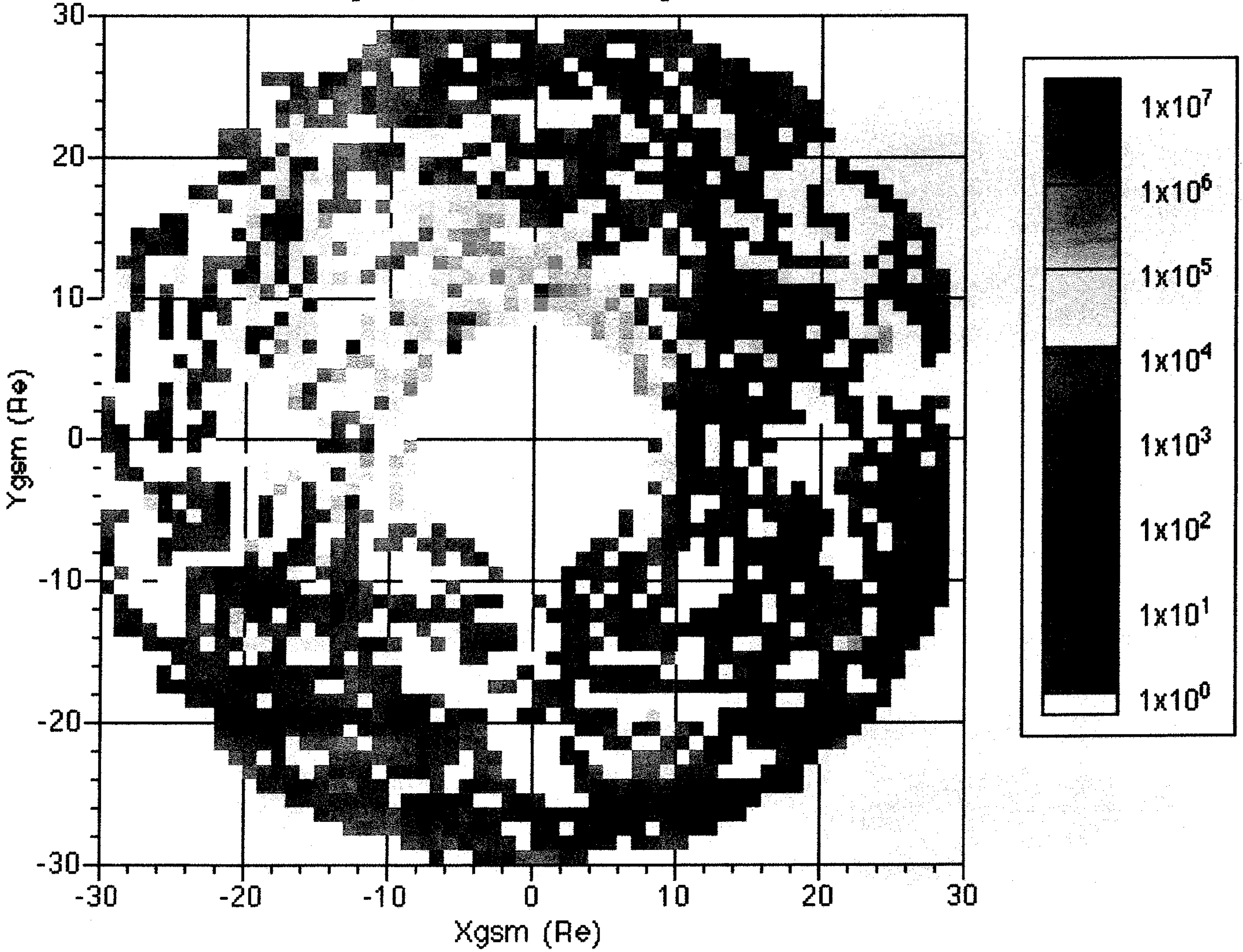


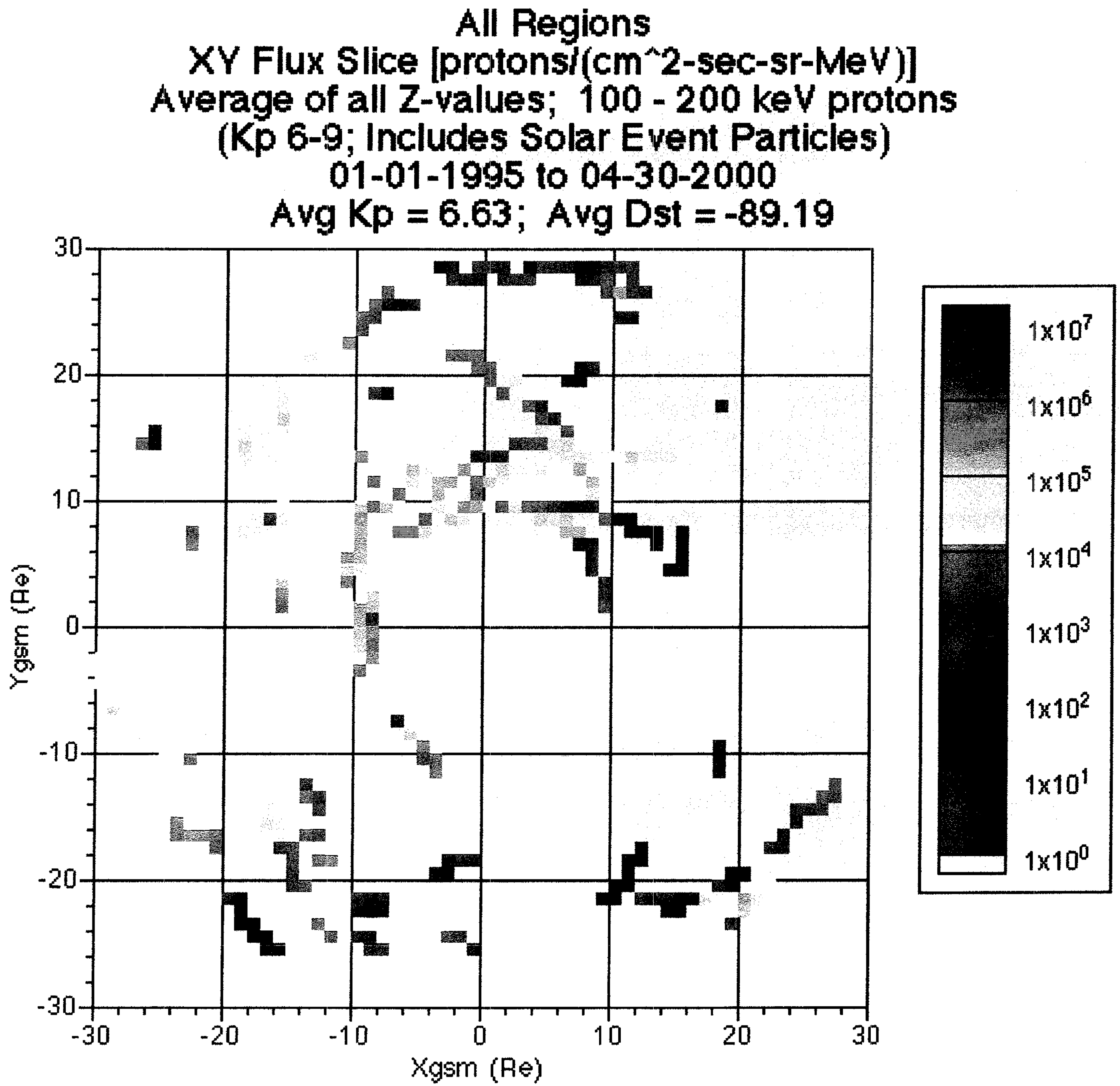
All Regions
XY Flux Slice [protons/(cm^2-sec-sr-MeV)]
Average of all Z-values; 100 - 200 keV protons
(Kp 0-2; Includes Solar Event Particles)
01-01-1995 to 04-30-2000
Avg Kp = 0.915; Avg Dst = -6.05
Ygsm (Re)
Xgsm (Re)
30
20
10
0
-10
-20
-30
1x10^7
1x10^6
1x10^5
1x10^4
1x10^3
1x10^2
1x10^1
1x10^0

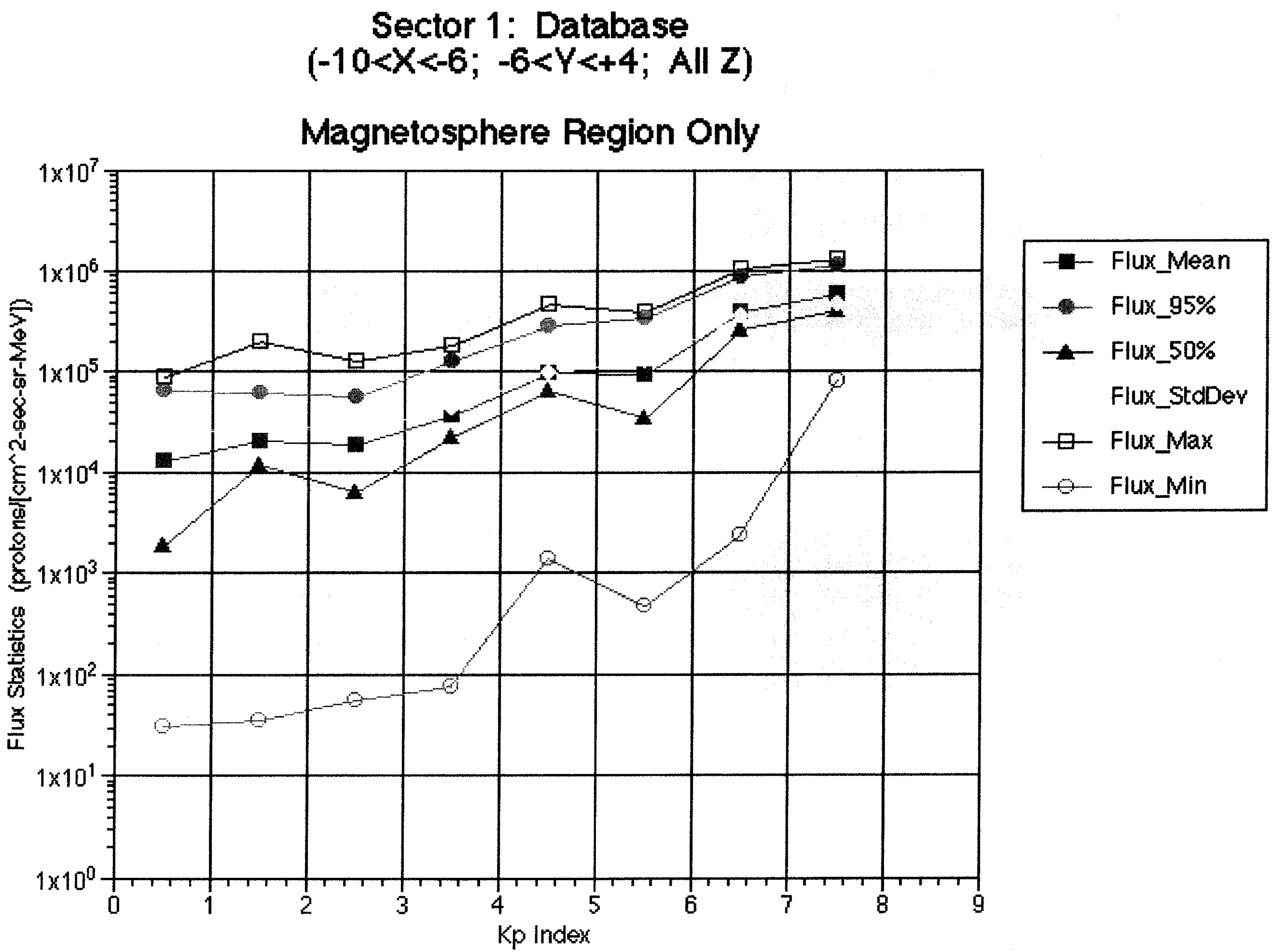
All Regions
XY Flux Slice [protons/(cm^2-sec-sr-MeV)]
Average of all Z-values; 100 - 200 keV protons
(Kp 2-4; Includes Solar Event Particles)
01-01-1995 to 04-30-2000
Avg Kp = 2.63; Dst = -17.33



All Regions
XY Flux Slice [protons/(cm^2-sec-sr-MeV)]
Average of all Z-values; 100 - 200 keV protons
(Kp 4-6; Includes Solar Event Particles)
01-01-1995 to 04-30-2000
Avg Kp = 4.46; Avg Dst = -35.82

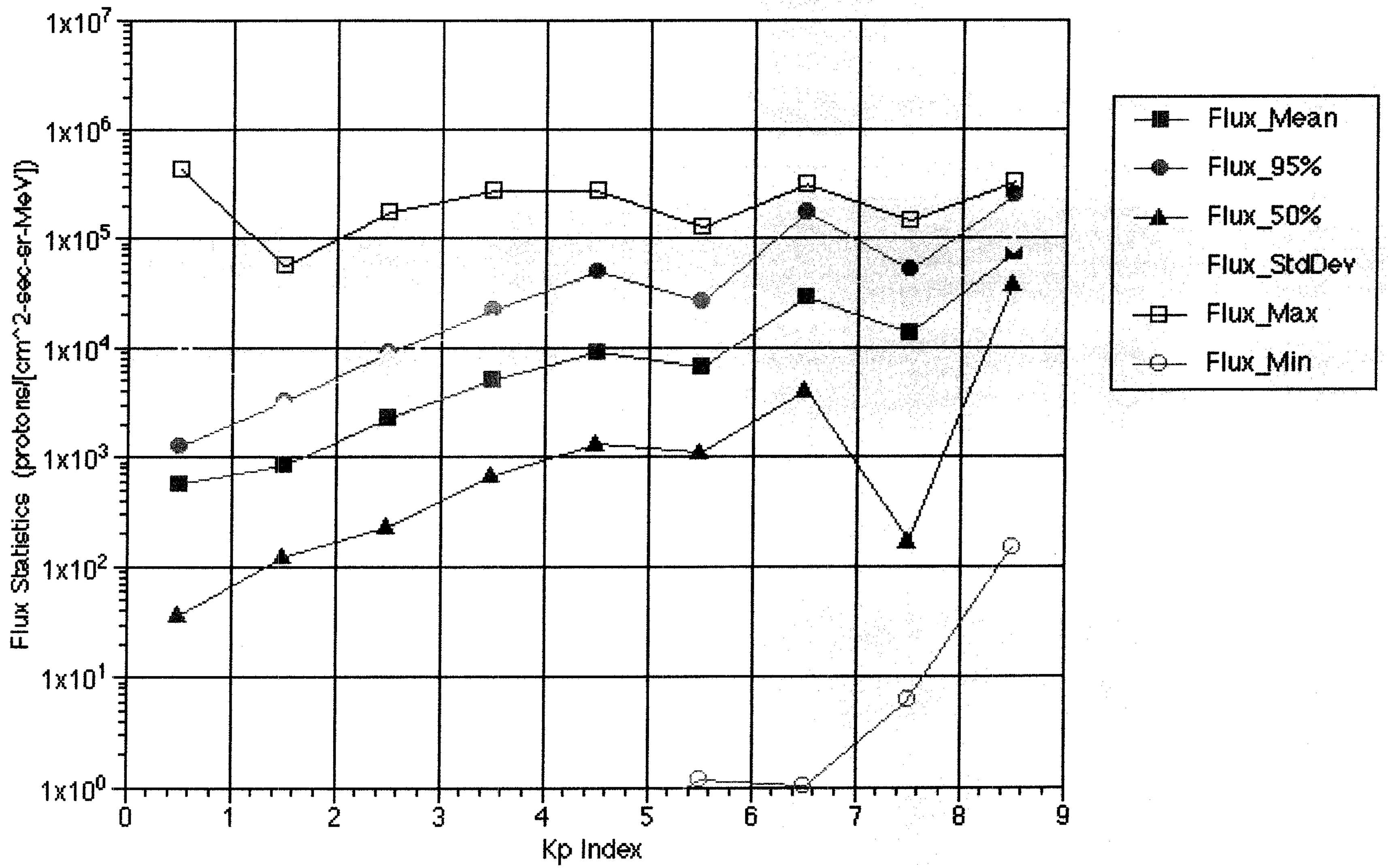


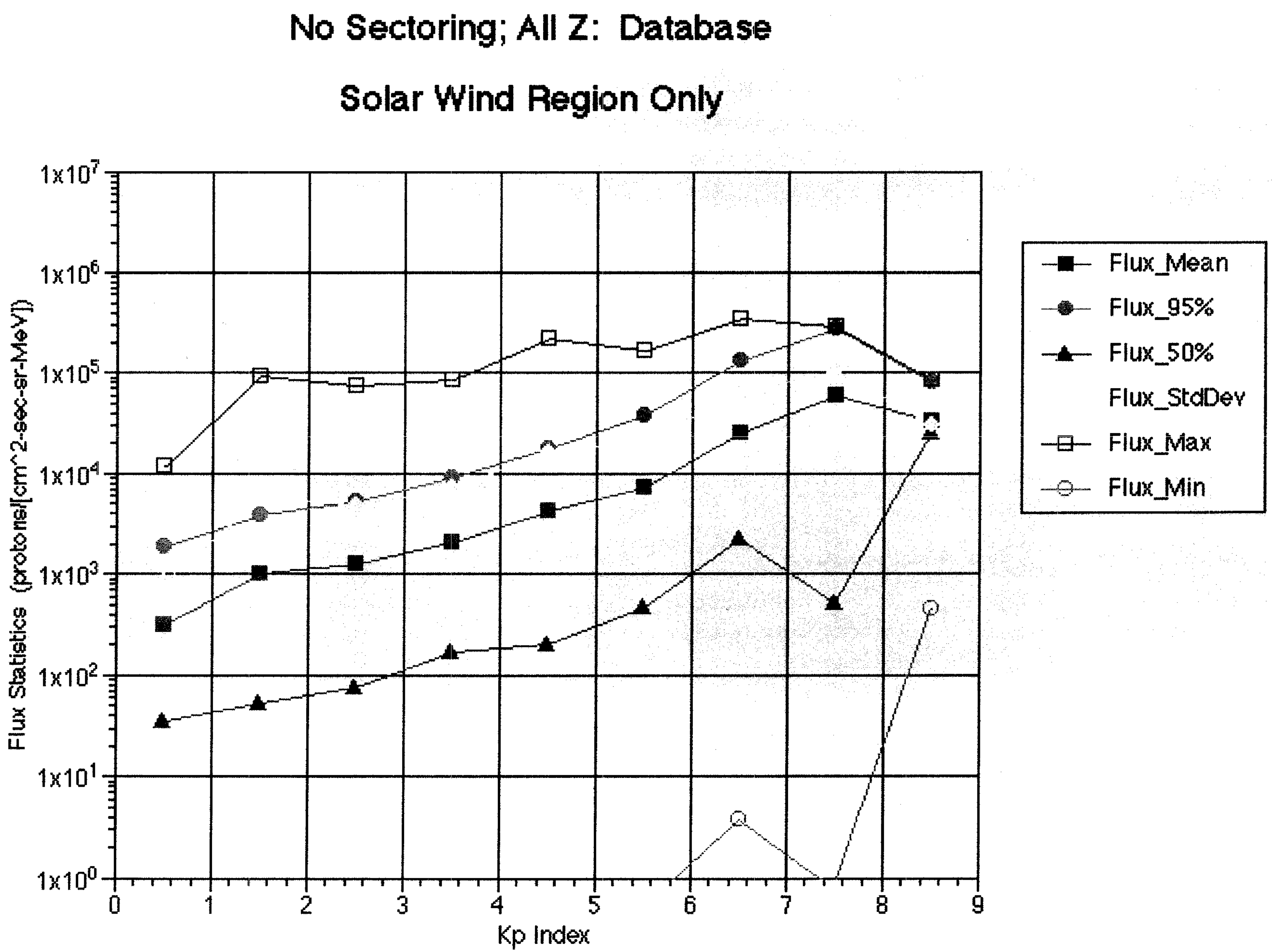

All Regions
XY Flux Slice [protons/(cm^2-sec-sr-MeV)]
Average of all Z-values; 100 - 200 keV protons
(Kp 6-9; Includes Solar Event Particles)
01-01-1995 to 04-30-2000
Avg Kp = 6.63; Avg Dst = -89.19
30
20
10
0
-10
-20
-30
Ygsm (Re)
-30
-20
-10
0
10
20
30
Xgsm (Re)
1x10^7
1x10^6
1x10^5
1x10^4
1x10^3
1x10^2
1x10^1
1x10^0


Sector 1: Database
(-10<X<-6; -6<Y<+4; All Z)
Magnetosphere Region Only
Flux Statistics (protons/[cm^2-sec-sr-MeV])
1x10^7
1x10^6
1x10^5
1x10^4
1x10^3
1x10^2
1x10^1
1x10^0
0
1
2
3
4
5
6
7
8
9
Kp Index
Flux_Mean
Flux_95%
Flux_50%
Flux_StdDev
Flux_Max
Flux_Min

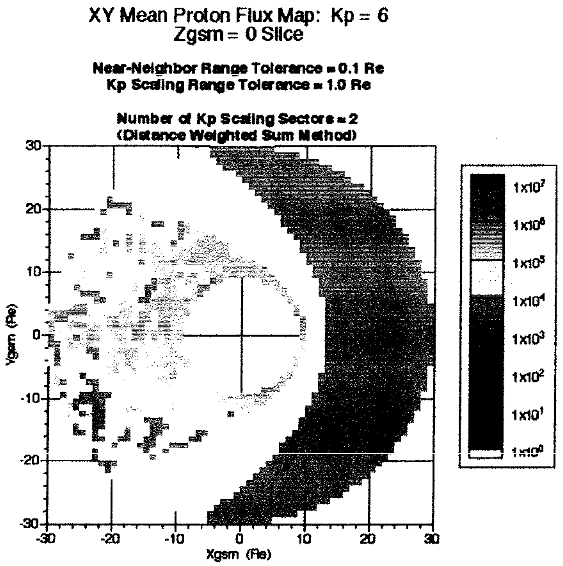
No Sectoring; All Z: Database

Magnetosheath Region Only

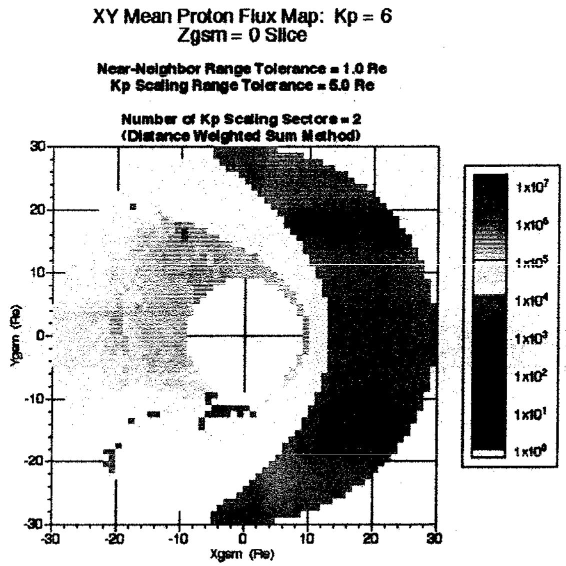



No Sectoring; All Z: Database
Solar Wind Region Only
1x10^7
1x10^6
1x10^5
1x10^4
1x10^3
1x10^2
1x10^1
1x10^0
Flux Statistics (protons/[cm^2-sec-sr-MeV])
0
1
2
3
4
5
6
7
8
9
Kp Index
Flux_Mean
Flux_95%
Flux_50%
Flux_StdDev
Flux_Max
Flux_Min

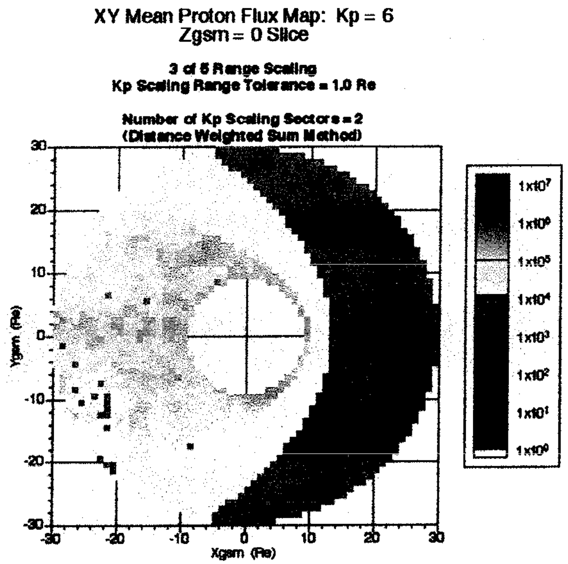
Preliminary CRMFLX Smoothing Results



No Data Smoothing



Spatial Averaging

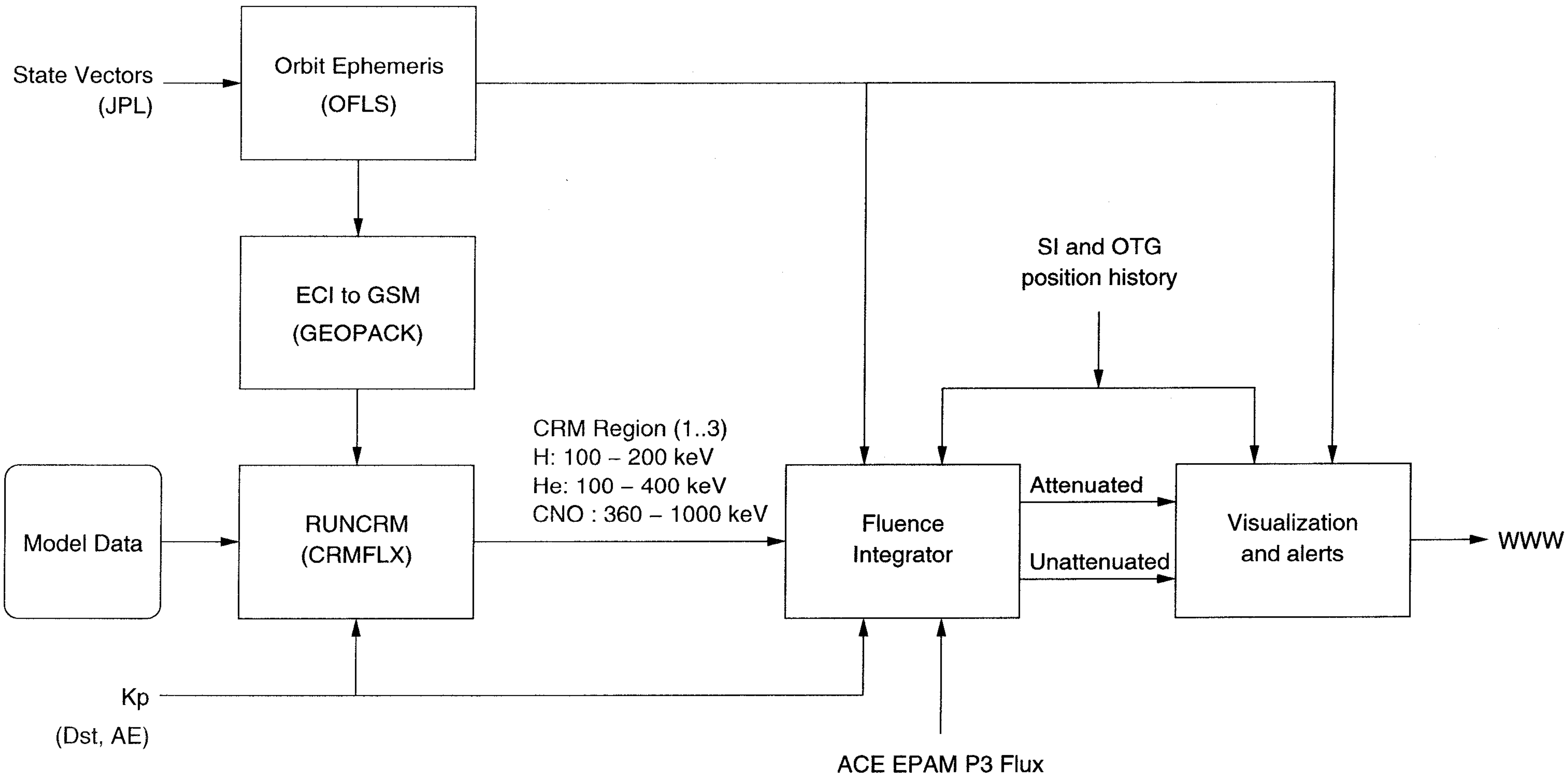


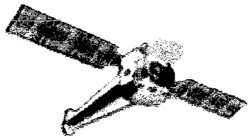
3-of-5 Spike Rejection

- A number of different smoothing algorithms are now being tested in CRMFLX
  - Variations of spatial averaging and spike rejection
  - Care must be taken so to not throw away physical variations
- Much of the data scatter will be removed by performing better data correlation
  - Include solar wind conditions as well as geomagnetic activity (Kp index)
  - Data correlation is next priority task

B. Blackwell/SvT

Chandra Radiation Model (CRM) realtime and predictive system





Chandra Radiation Model

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CRM development status:

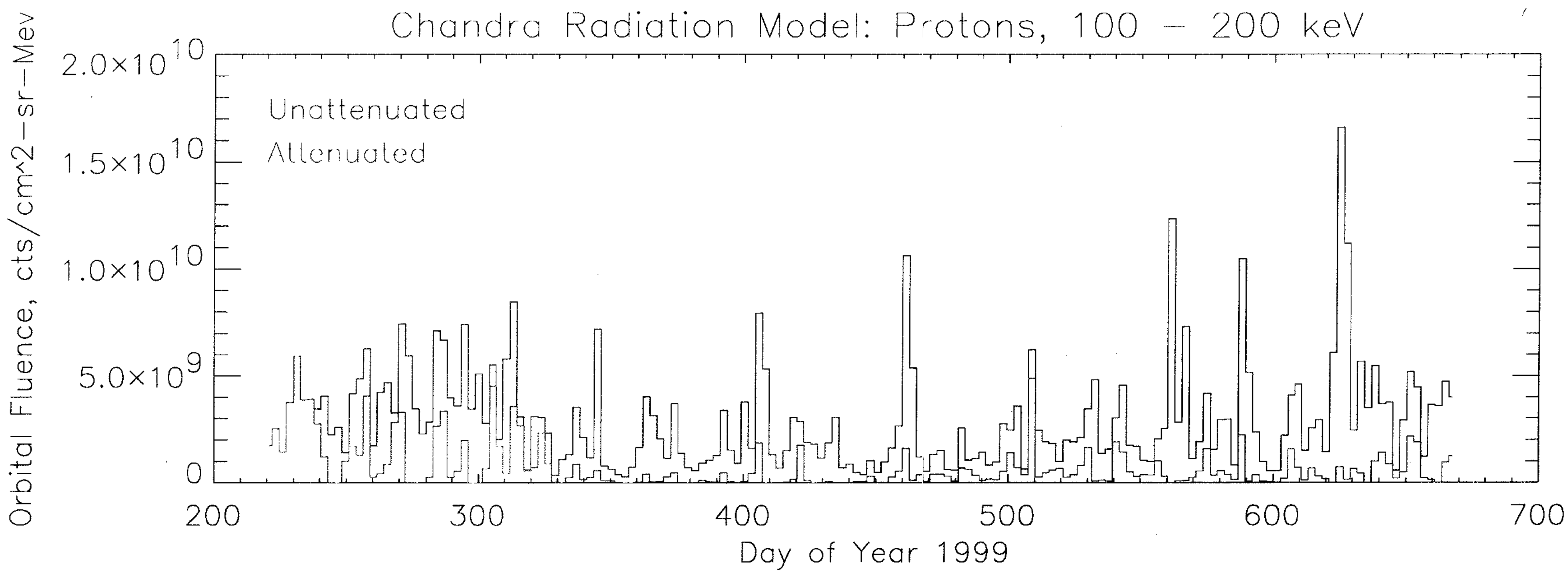
- Version 1.0 released 8 September 2000.
- Version 1.1 released 16 October 2000. Data interpolation errors fixed. 50% and 95% flux estimates corrected.

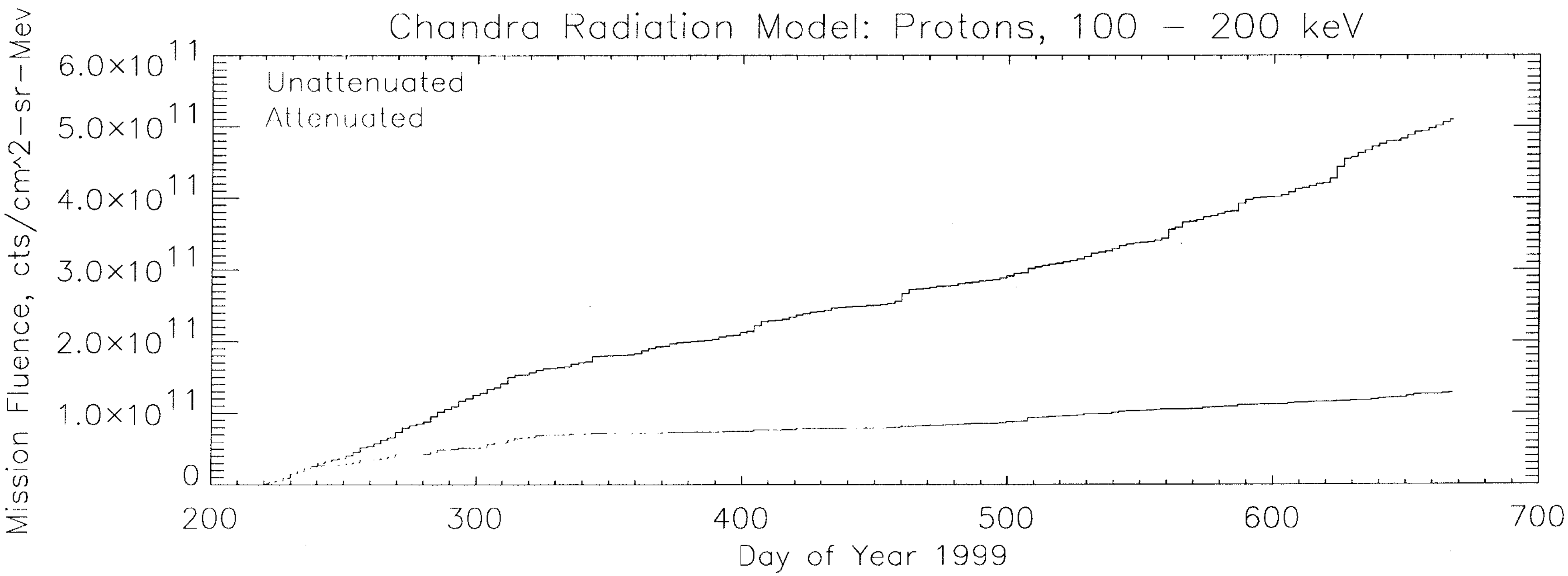
Usage:

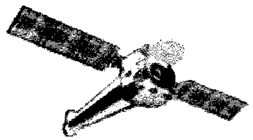
- Version 1.1 implemented by the Science Operations Team for real time integration of Chandra flux and orbital fluence and prediction of future fluence.
- Development in progress of orbital start science and stop science scheduler for Chandra Operations Control Center Off-Line System (OFLS). Objective: optimize science time per orbit while maintaining fluence within specified limits.

Issues:

- Data model empty below 9 Re: incomplete measure of Chandra radiation history.
- Data interpolation; sparse data at high Kp.
- P > 1 MeV proton data are needed to allow OFLS testing based on comparison with existing AE-8 and AP-8 models.
- Devolution of OFLS science time scheduling to CRM.


Chandra Radiation Model: Protons, 100 - 200 keV
Orbital Fluence, cts/cm^2-sr-Mev
Day of Year 1999
Unattenuated
Attenuated
2.0×10^10
1.5×10^10
1.0×10^10
5.0×10^9
0
200
300
400
500
600
700


Chandra Radiation Model: Protons, 100 - 200 keV
Mission Fluence, cts/cm^2-sr-Mev
Day of Year 1999
Unattenuated
Attenuated
6.0×10^11
5.0×10^11
4.0×10^11
3.0×10^11
2.0×10^11
1.0×10^11
0
200
300
400
500
600
700



Data Sources

NASA Space Environment Center:
http://ww.sec.noaa.gov/index.html

ACE:
Data: **http://sec.noaa.gov/ace/ACErtsw_data.html**
ACE Science Center: **http://www.srl.caltech.edu/ACE/ASC**

Geotail:
http://www-spof.gsfc.nasa.gov/istp/geotail

Chandra Project Science:
http://xanth.msfc.nasa.gov/xray/axafps.html
Chandra Radiation: **http://wwwastro.msfc.nasa.gov/xray/ACIS/fluence**

Chandra Science Operations Team:
http://asc.harvard.edu/mta/sot.html