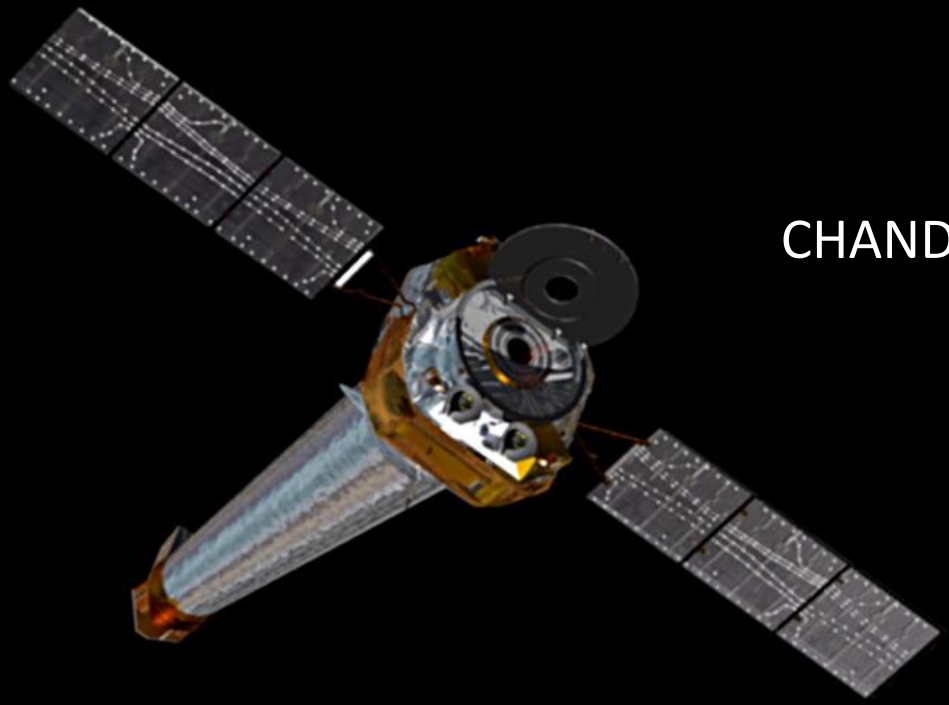

CHANDRA Space Weather Vulnerabilities and Needs Update

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7th NASA Space Weather and Robotic Mission Operations Workshop
NASA GSFC , 29-30 September 2015
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Outline

- Chandra X-Ray Observatory background
- Update on science interruptions due to radiation events
- Status on ACE RTSW data
- ACE Browse Data

Chandra Radiation Team

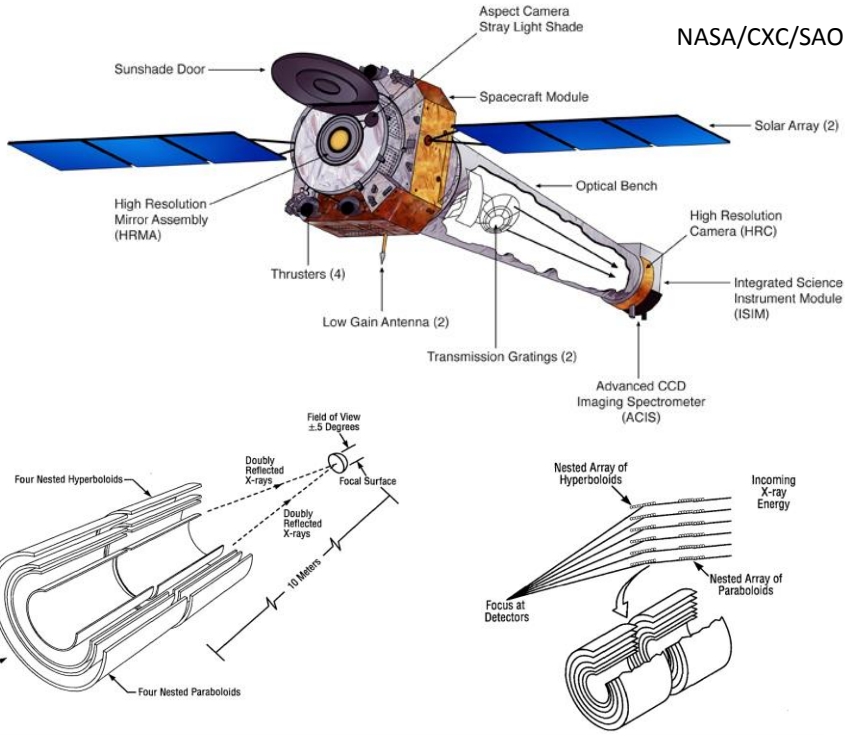
- Steve O'Dell/MSFC
- Linda Parker/Jacobs/MSFC
- Scott Wolk/SAO
- Brad Spitzbart/SAO
- Joe Minow/LARC

Chandra X-Ray Observatory (CXO)

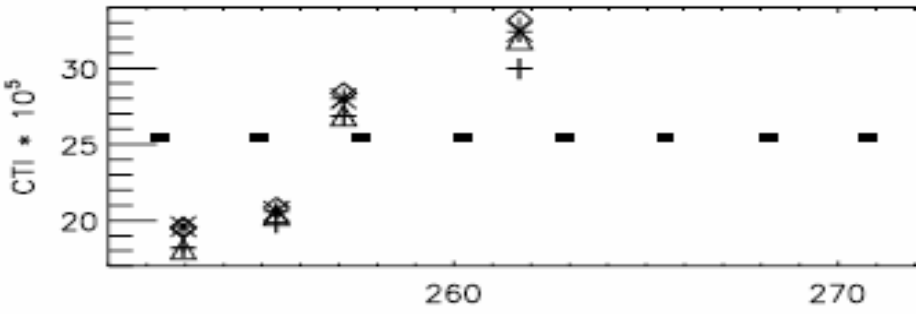
- Launched 23 July 1999 by STS-93
- Current orbit:
  ~1.5 Re x 22 Re x 67°, ~64.5 hour period
- Mission
  - 5-year primary science mission
  - Currently in 2nd 5-year extension
  - Planning for 3rd to 2019

- Advanced CCD Imaging Spectrometer (ACIS) is CXO's premier science most often requested in observatory proposals
  - Degradation of the 8 front illuminated ACIS CCD detectors was observed to be much worse than expected soon after launch, 2 back illuminated CCD's immune to damage
  - ~5 years worth of degradation in a single perigee passage
  - Damage mechanism identified as soft protons (~100 to 200 keV) depositing energy in CCD substrate

- ACIS can't be operated in high flux, soft proton environment within the magnetosphere and solar particle events



http://chandra.harvard.edu/about/top_ten.html



CXO Radiation Mitigation Strategy

- Schedule science operations to avoid high soft proton flux in the Earth's ring currents using Chandra Radiation Model, AP-8/AE-8
- Real time radiation monitoring using in-situ (autonomous) and other data sources (manual), move ACIS to protected position during periods of high particle flux
- CXO Monitoring and Trends Analysis (MTA) Team utilizes data from a variety of sources for real-time monitoring of CXO radiation environment:

Satellite	Instrument	Species	Energy	Notes
CXO (NASA)	EPHIN rates	H^+, e^-	H^+ 25 – 41 MeV e^- 2.6 – 6.2 MeV	In-situ, autonomous ACIS safing
	HRC rates	H^+	>10's MeV	In-situ, autonomous ACIS safing
	ACIS rates	H^+	>10's MeV	In-situ, autonomous ACIS safing
GOES (NOAA)	EPS P2 (P4GM proxy)	H^+	4 – 8 MeV	NOAA real time (5 min), manual
	EPS P5 (P41GM proxy)	H^+	38-80 MeV	NOAA real time (5 min), manual
	EPS E	e^-	>2 MeV	NOAA real time (5 min), manual
ACE (NASA)	P3'	H^+	115 – 195 keV	NOAA real time (5 min), manual
XMM (ESA)	Radiation Monitor	H^+, e^-	H^+ >1 MeV e^- > 130 keV	ESA real time (2 to 60 minutes), manual

Chandra Radiation Environment Monitoring

Chandra Radiation Environment Summary

See about rad_summ for the definition and origin of the values below.

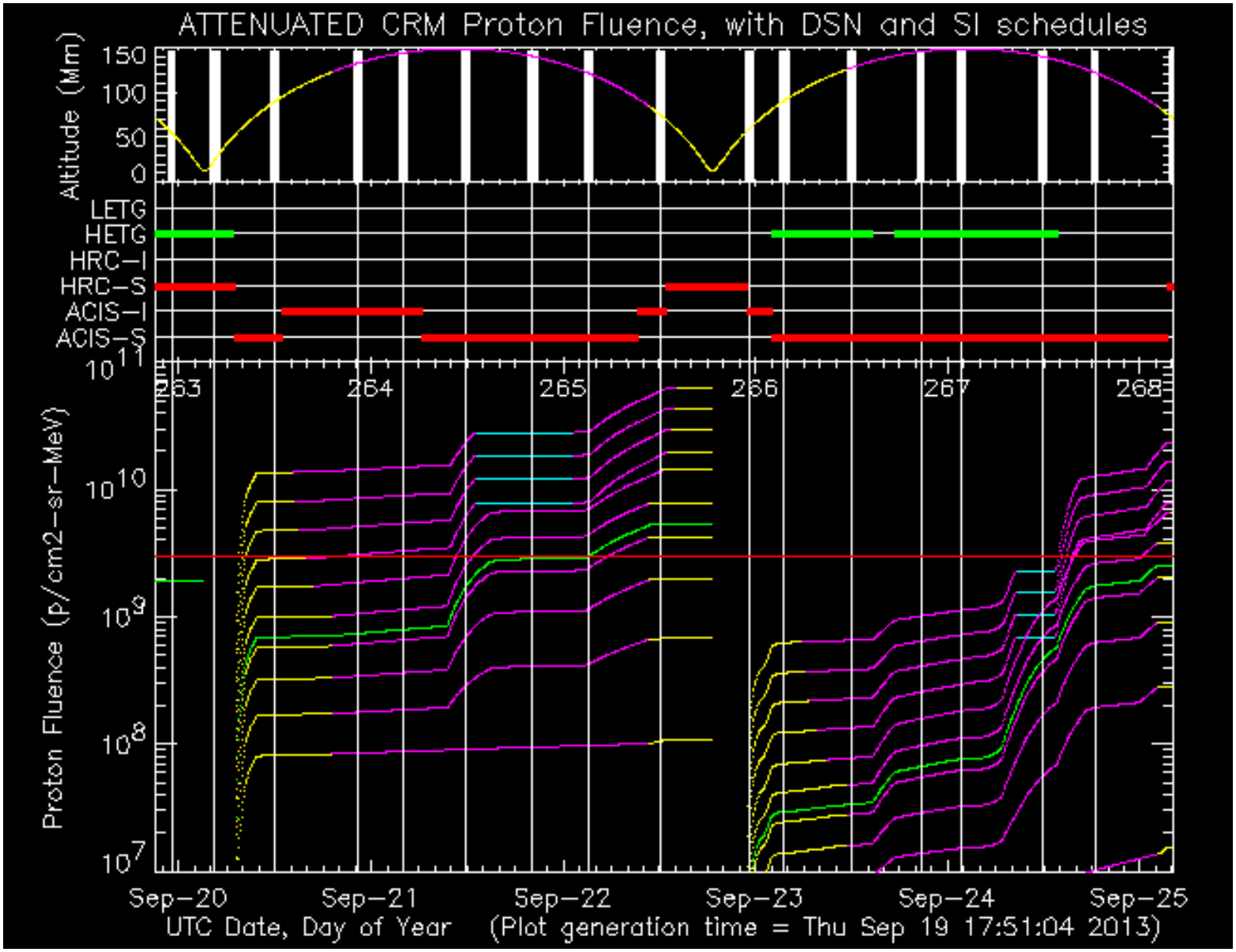
Orbit start: 2013:260:11:49:16 (all times on this page are UTC)
Current altitude (km) and orbit leg: 63602 D
Current configuration: HRC-S HETG
Next comm: 2013:262:22:45:00 (0.5 hours)
Next rad zone: 2013:265:12:56:00 (62.7 hours)
Last updated: Thu Sep 19 22:12:10 2013

Chandra Science Operations Team
Chandra X-ray Center, SAO
http://asc.harvard.edu/mta/
http://asc.harvard.edu/mta/alerts/rad_summ.html

	Attenuated - projects fluences based on upcoming SI and grating configuration ACIS effective exposure times (ks) Until next radzone: 193.4 Until next comm: 0.0					
	Current Flux	Current fluence (total so far in current orbit)	Projected fluence until next rad zone	Projected fluence	Projected fluence	Limits
	(p/cm^2-s-sr-MeV)	(p/cm^2-sr-MeV)	at current flux (at 2X flux) *at 10X flux*	until next comm.	until second comm.	
CRM	0.000E+00	2.573E+08	1.073E+10 (2.120E+10) *1.050E+11*	2.573E+08	2.573E+08	working yellow limit: 1.000E+09 (fluence)
ACE P3	0.000E+00	1.980E+06	1.107E+07 (2.016E+07) *9.287E+07*	1.980E+06	1.980E+06	alert trigger: 1.000E+09 (fluence)
GOES-13 (P2)	0.000E+00	2.746E+04	1.203E+05	2.746E+04	2.746E+04	
GOES-13 (P5)	0.000E+00	6.293E+03	2.756E+04	6.293E+03	6.293E+03	
GOES-13 (E > 2.0 MeV)	0.000E+00	1.688E+07	7.392E+07	1.688E+07	1.688E+07	

	External - does not take into account the instrument configuration					
	Current Flux	Current fluence (total so far in current orbit)	Projected fluence	Projected fluence		Limits
	(p/cm^2-s-sr-MeV)	(p/cm^2-sr-MeV)	until next radzone (total for current orbit)	until next comm.	until second comm.	
CRM	5.415E+04	9.453E+08	1.317E+10	1.052E+09	2.076E+09	
ACE P3	4.780E+01	3.808E+10	3.810E+10	3.808E+10	3.809E+10	3.6e8 (2 hr fluence, red)
GOES-13 (P2)	4.800E-01	1.009E+05	2.093E+05	1.018E+05	1.109E+05	30.0/90.9 (flux, yellow/red)
GOES-13 (P5)	1.100E-01	2.312E+04	4.796E+04	2.334E+04	2.541E+04	0.25/0.70 (flux, yellow/red)
GOES-13 (E > 2.0 MeV)	2.950E+02	6.200E+07	1.286E+08	6.258E+07	6.816E+07	
EPHIN E150 *	********	N/A	N/A	N/A		8.0e5 (radmon safing)
EPHIN E1300 *	1.0	N/A	N/A			1000 (radmon safing)

CRM Situational Awareness



http://asc.harvard.edu/mta/alerts/rad_summ.html

Solar Cycle 24 Radiation Interventions

Event	Start	End	Lost Science time	Auto/Manual	Cause
3 *(+1)*	**2011**		**406 ks (113 hr)**	**2/1**	
1**	Jun 7 15:23 UT	Jun 8 12:50 UT	74.9 (20.8)	Auto	HRC (hard)
2	Aug 4 07:03	Aug 7 10:25	270.4 (75.1)	Auto	HRC (hard)
3	Oct 24 18:27	Oct 25 22:35	61.1 (17.0)	Manual	ACE P3' (soft)
4	*Oct 26 11:40*	*Oct 28 12:33*	*154 (42.8)*	Auto	*Command Telemetry Unit (SEU)*
10	**2012**		**1,246 ks (346 hr)**	**7/3**	
5	Jan 23 06:00	Jan 26 08:27	192.1 (53.4)	Auto	HRC (hard)
6	Jan 27 19:39	Jan 30 02:20	163.4 (45.4)	Auto	HRC (hard)
7	Feb 27 03:24	Feb 27 20:23	61 (16.9)	Manual	ACE P3' (soft)
8	Mar 7 05:30	Mar 13 05:14	440 (122.2)	Auto	HRC (hard)
9	Mar 13 22:41	Mar 14 13:57	53.3 (14.8)	Auto	HRC (hard)
10	May 17 02:18	May 18 04:52	93.8 (26.1)	Auto	E1300 (hard)
11	Jul 12 19:59	Jul 14 00:09	61.7 (17.1)	Auto	E1300 (hard)
12	Jul 14 21:08	Jul 16 05:16	80.1 (22.3)	Manual	ACE P3' (soft)
13	Jul 19 11:44	Jul 20 04:09	56.5 (15.7)	Auto	HRC (hard)
14	Sep 3 12:57	Sep 4 12:41	44.5 (12.4)	Manual	ACE P3' (soft)

* First radiation interruption since 2006 December 13 **First ACIS trigger event

Source: Chandra Radiation Central http://asc.harvard.edu/mta/RADIATION/

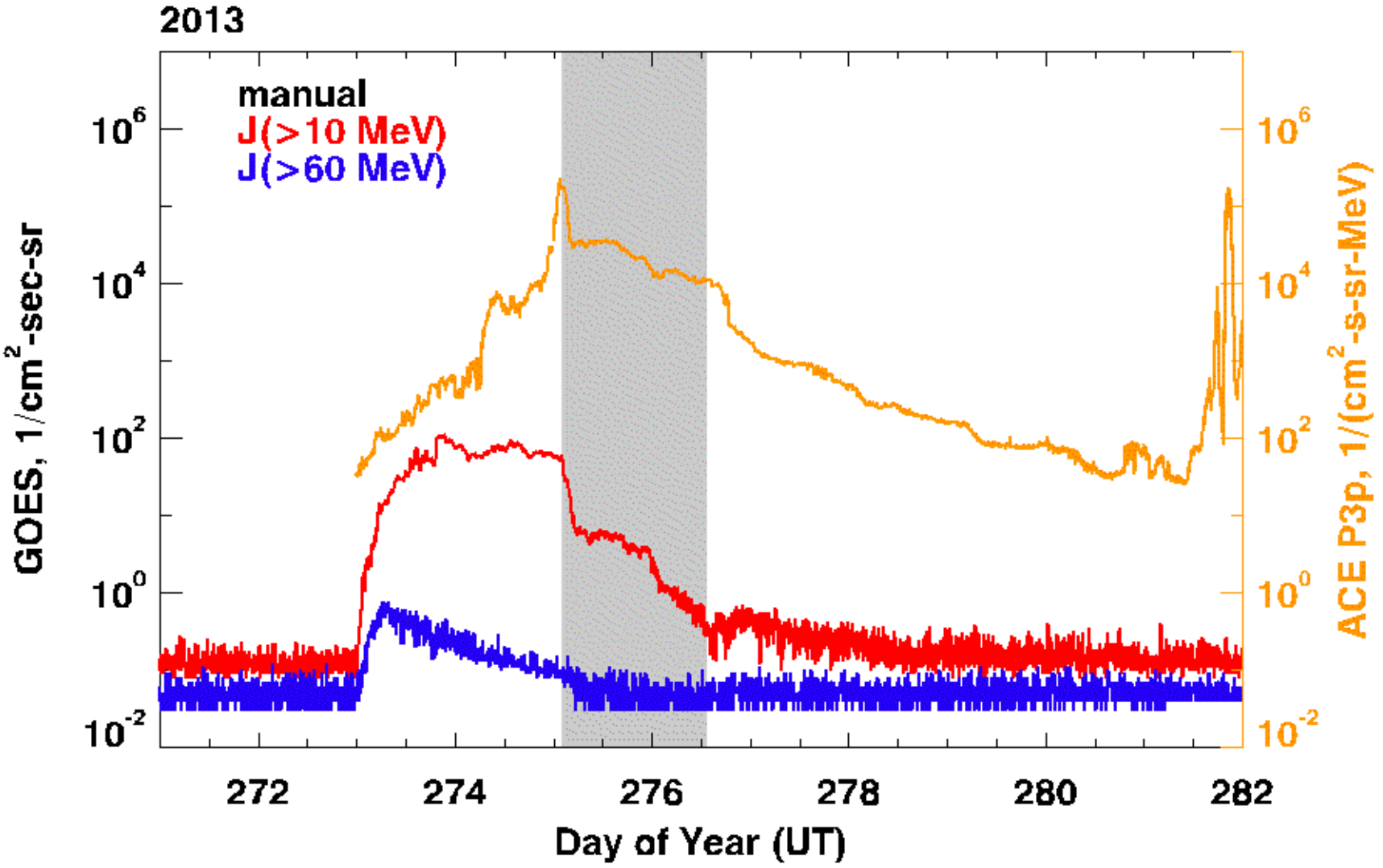
Solar Cycle 24 Radiation Interventions

Event	Start	End	Lost Science time	Auto/Manual	Cause
3	**2013**		**367 ks (102 hr)**	**1/3**	
15	Mar 17 12:32	Mar 19 05:58	105.7 (29.4)	Manual	ACE P3' (soft)
16	May 22 14:49	May 24 12:22	123.6 (34.3)	Auto	ACIS (hard)**
17	May 24 20:41	May 25 11:56	54.0 (15.0)	Manual	ACE P3' (soft)
18	Oct 02 02:04	Oct 03 13:27	83.3 (23.1)	Manual	ACE P3' (soft)
3	**2014**		**545 ks (151 hr)**	**2/2**	
19	Jan 07 20:39	Jan 12 01:54	364.5 (101.3)	Auto	SCS-107
20	Sep 12 11:51	Sep 13 12:48	89.0 (24.7)	Manual	SCS 107
21	Dec 22 04:52	Dec 22 23:26	65.1 (18.1)	Manual	ACE P3' (soft)
22	Dec 23 11:33	Dec 23 18:59	26.0 (7.2)	Manual	ACE P3' (soft)
3	**2015 (through Q3)**		**132 ks (37 hr)**	**0/2**	
23	Mar 17 04:34	Mar 19 08:04	131.8 (36.6)	Manual	ACE P3' (soft)
24	Jun 22 22:40	Jun 23 21:40	82.0 (22.8)	Manual	ACE P3' (soft)
25					

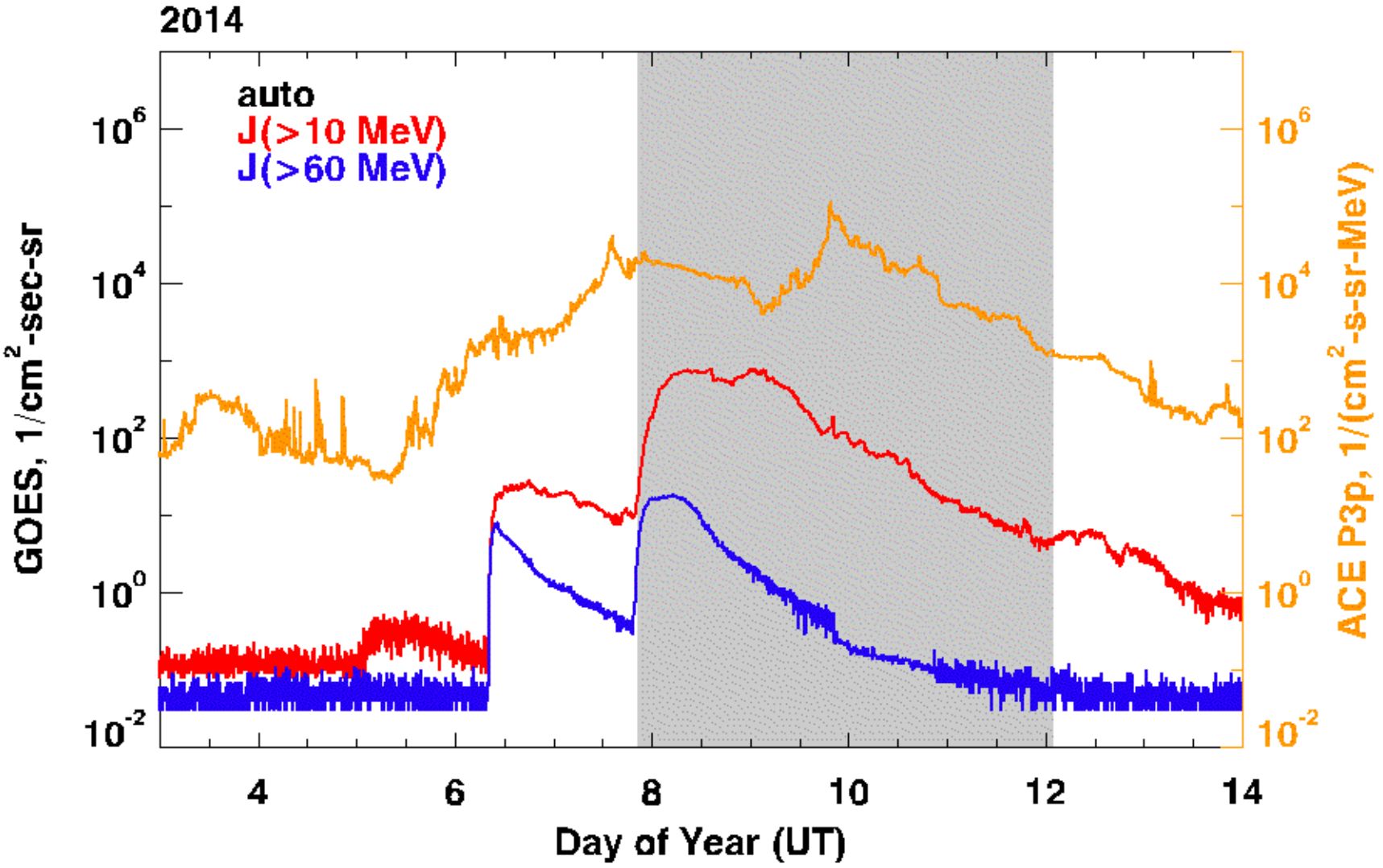
* First radiation interruption since 2006 December 13 **First ACIS trigger event

Source: Chandra Radiation Central http://asc.harvard.edu/mta/RADIATION/

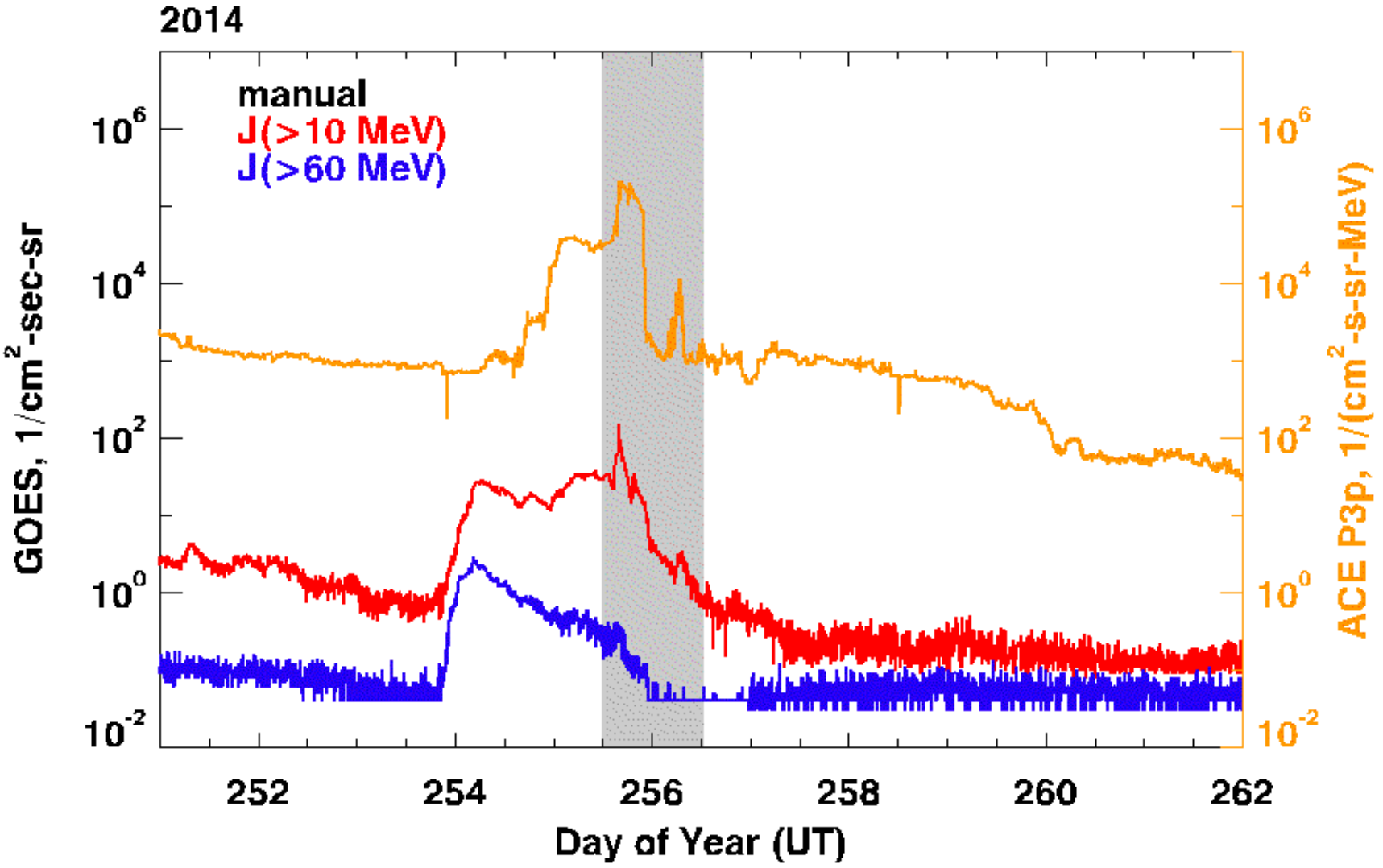
Manual ACE P3’



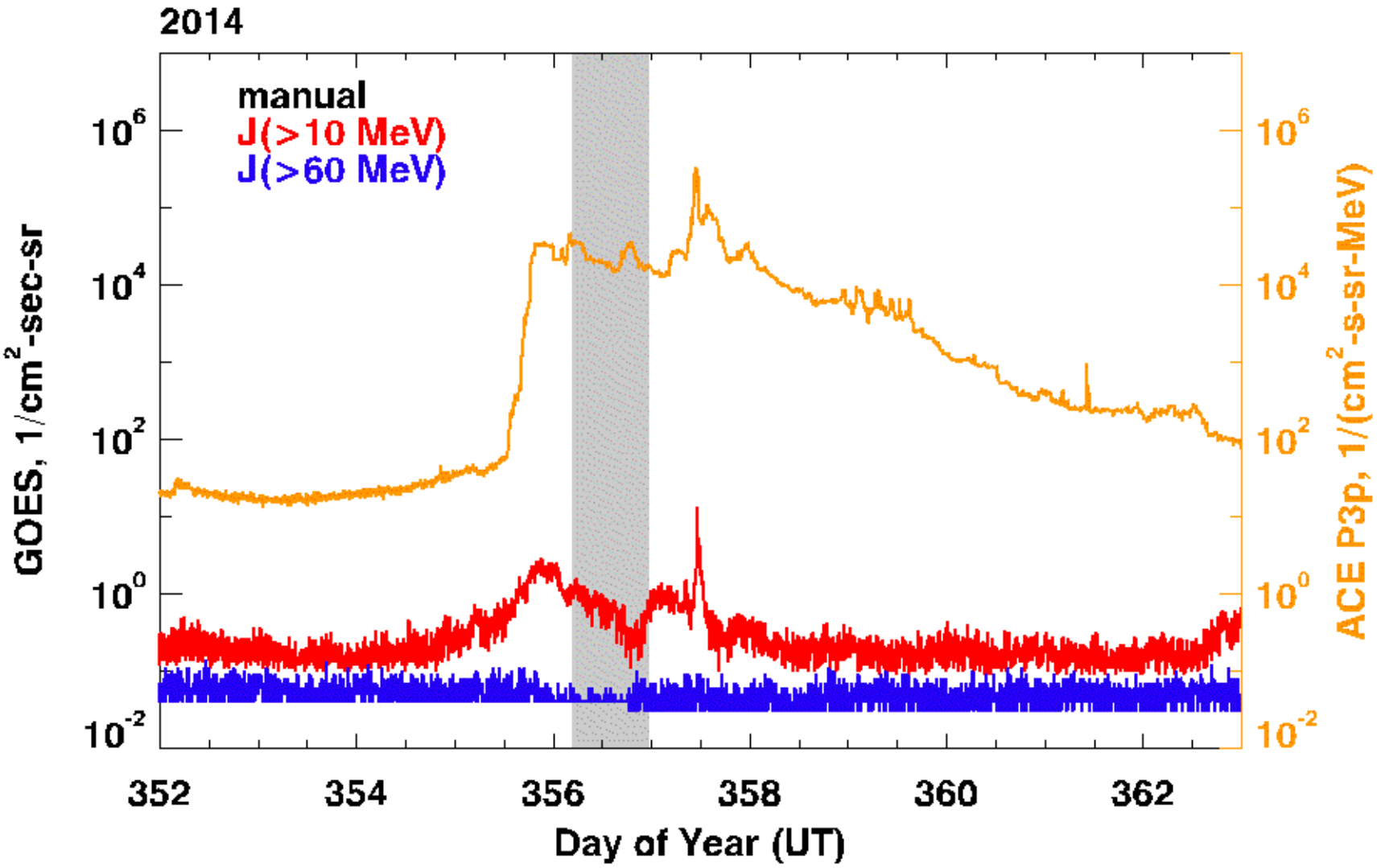
Auto


2014
auto
J(>10 MeV)
J(>60 MeV)
GOES, 1/cm²-sec-sr
ACE P3p, 1/(cm²-s-sr-MeV)
10⁶
10⁴
10²
10⁰
10⁻²
4
6
8
10
12
14
Day of Year (UT)

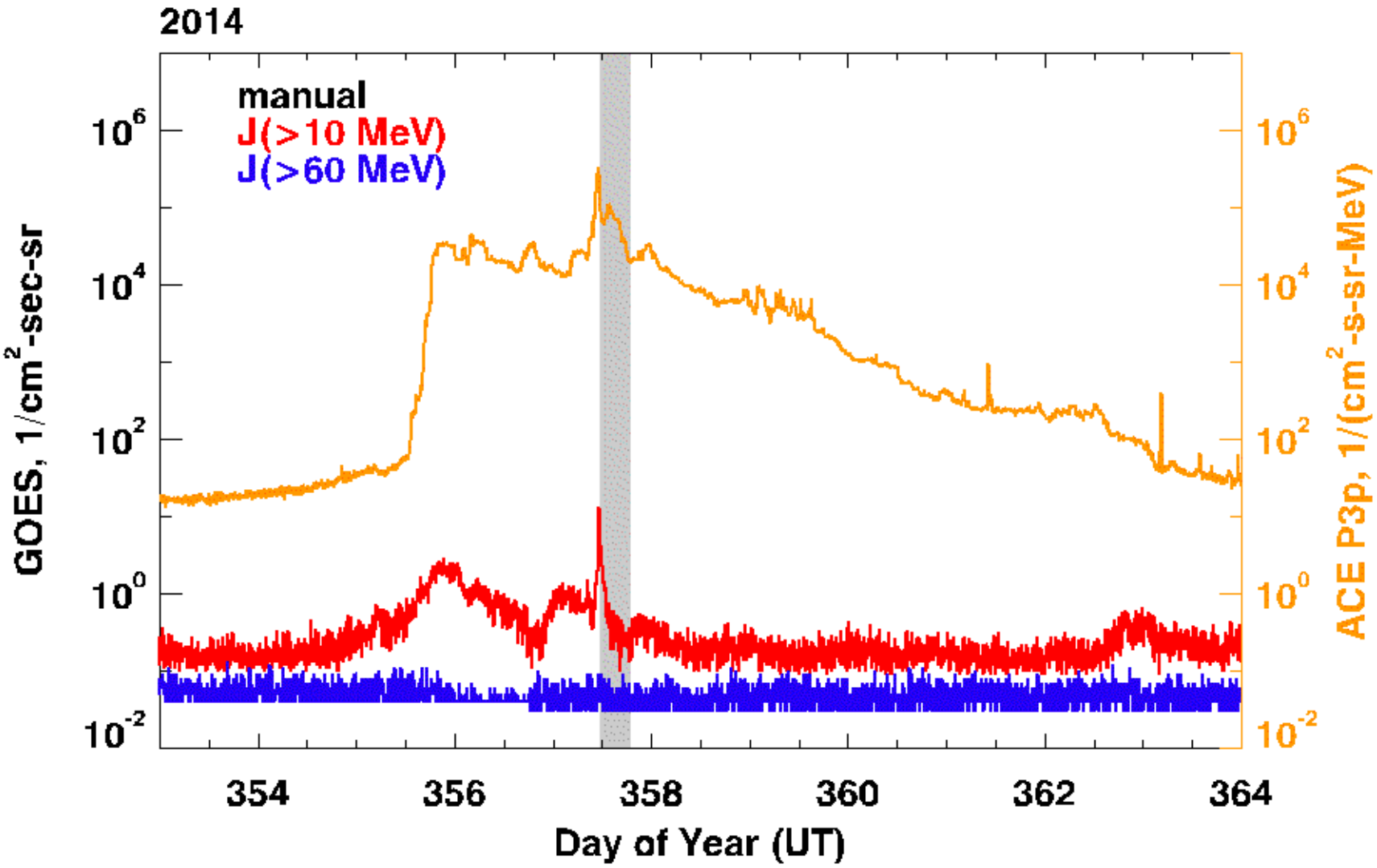
Manual ACE P3’



Manual ACE P3’



Manual ACE P3’



ACE Real Time Data Issue

- Deep Space Climate Observatory (DSCOVR) will replace ACE in late 2015 (no earlier than early Nov)
  - DSCOVR will become the primary NOAA space weather plasma data source from L1
  - ACE RTSW coverage will be discontinued (NASA will continue to downlink science data)
  - DSCOVR carries a MAG/SWEPAM type cold solar wind plasma and magnetic field instrument
  - No replacement for non-thermal EPAM, SIS energetic particle instruments on DSCOVR

- The ACE/EPAM RTSW records are the only real-time data for detecting ~100-200 keV proton events in interplanetary space that impact the ACIS instrument

- CXO strategy is to
  - Develop contingency plans to operate without ACE RTSW data
  - Work with NOAA SWPC for option of continued ACE RTSW data

ACE RTSW Status

- NASA working with NOAA to identify options for continued ACE RTSW data
  - NASA senior management formally requested NOAA continue ACE RTSW data
  - NOAA response:
    - NOAA tracking resources are inadequate to support both ACE and DSCOVR
    - DSCOVR meets their primary requirements
    - NOAA will continue to process and distribute ACE RTSW if NASA can provide the data
  - NASA currently working on request to NOAA for support in identifying additional tracking stations

- ACE Science Center modified Browse Data processing software to provide expedited access to EPAM records
  - EPAM Browse Data now available to CXO ops team same day as science downlink
  - ACE Ops providing DSN downlink schedules to CXO ops for aid in monitoring for incoming Browse Data updates

- Confirmed ACE Science Team will continue to provide RTSW signal to SWPC during science downlink
  - NOAA SWPC will continue to provide some fraction of this data

Questions?