CHANDRA
X-ray Center 60 Garden St., Cambridge Massachusetts 02138 USA

MEMORANDUM

Date:	June 3, 2013
From:	Richard J. Edgar
To:	Chandra Operations Team
Subject:	Chandra Radiation Events and Shutdowns, May 22-25, 2013
Cc:	MSFC Project Science, CXC Director's Office
File:	`MAY2213_memo.tex`
Version:	`1.5`

1 Abstract

This memo discusses the thought process that the operations team, especially the ACIS operations team, used during the very high radiation week and events on or about 22 through 25 May, 2013. During this time frame, we experienced two radiation-induced shutdowns, one of which was the first SCS-107 trigger produced by the ACIS radiation monitor. The second was by ground command as a result of exceeding the two-hour ACE P3 fluence limit.

The key decision points to continue or suspend science operations are reviewed. During this time frame, a decision for a manual shutdown was made which resulted in sparing ACIS from a fluence of ACE P3 protons of nearly 2×10^9 and preserved a high priority, coordinated observation of Sgr A*. The ability to resume science operations only 14 hours after a manual shutdown was due to the efficient command load generation process afforded by the "Science-Only Safing (SOSA)" paradigm and, in this case, fortuitous schedule of communication passes.

2 Introduction

The radiation environment for the Chandra satellite during the week starting May 20, 2013 was challenging. An M7 flare and subsequent CME both impacted the satellite, resulting in the first ACIS-triggered SCS 107 run. Two days later, there was a ground-commanded SCS 107 shutdown following the 2-hour fluence alert. By shutting down during the time alotted to two pool targets, we were able to obtain most of a highly constrained observation of Sgr A* without exceeding the orbital fluence limit.

3 Detailed Timeline

- 2013:142 **Wednesday May 22, 2013**
- 2013:142z13:23 First of several alerts from the Space Weather Prediction Center based on GOES data. This one was for an M5 or brighter flare. Our GOES plots were stale at the time, but began updating within about 90 minutes.
- 2013:142z13:38 Flare maximum x-ray intensity at M7.3 (7.3×10^{-5} W m^{-2}). The flare originated from Active Region 11745 near the west limb of the sun. A CME was observed.
- 2013:142z14:05 SWPC alert for 100 MeV protons. The GOES proxy for the Chandra HRC anticoincidence shield counter was over threshold, so it was expected that SCS-107 would have run autonamously.
- 2013:142z14:49 SCS-107 ran autonamously. Subsequent analysis indicated that the ACIS threshold crossing algorithm triggered this action.
- 2013:142z19:38 Early Comm pass shows SCS-107 had indeed run.
- 2013:142z20:00 (Time approx) Radiation telecon. Plan A is to resume day 144 after the radzone passage. Schedule reworked to include ToO of CXOU J072648.3+854549 and the planned observation of Sgr A*.
- 2013:142 evening Several automatic alerts were recieved as various external radiation limits were crossed.
- 2013:143 **Thursday May 23, 2013**
- 2013:143 Replan load MAY2413A was prepared and reviewed. It would resume at 2013:144:11:51. Plan B would resume at 145:05:00 and would include Sgr A* and the other constrained observation from MAY2413A.
- 2013:144 **Friday May 24, 2013**
- 2013:144z11:00 07:00L: Go/No-Go telecon for resuming with MAY2413A. The decision was made to continue. There was an automatic warning of an SCS 107 trip during reactiviation of the loads. This is expected. ACE P3 was about 23,000.
- 2013:144 ACE P3 rates rose through the afternoon (Eastern time).
- 2013:144z18:05 ACE P3 fluence exceeded the 2-hour limit of 3.6×10^8, which is a two-hour average flux of 50,000. A telecon was convened. Next comm: 5:00 pm local, by which time we calculated an orbital fluence of 1.0×10^9, which is the limit for another radiation telecon. Obsid 15648 (a DDT) would be complete by that

time. The possibility of shutting down at the 5PM telecon and resuming at 7AM on Saturday May 25 was discussed.

Discussions include the fact that the orbital fluence was expected to reach 1.0×10^9 before the telecon, and the ACE P3 rates had decreased to 45,000. At 1 day+16.5 hours to RADMON disable, the liklihood of accumulating less than 2.0×10^9 for the orbit seemed remote. We suggested shutting down at the 5 PM pass with the option of restarting at the 7AM pass on Saturday, should the radiation situation permit, to get the high-value HETG observation of Sgr A*. Guesses as to the future of the P3 rate included a decay at a half-life of about 12 hours, or flattening out around 25,000 as had been seen earlier in the week.

- 2013:144z20:20 Early comm and telecon to discuss the radiation situation. We decided to shut down and restart at the morning comm if possible.
- 2013:144z20:39 SCS 107 was run via ground command.
- 2013:144z20:41 Automatically generated SCS 107 alert
- 2013:144 Evening review of MAY2513A command load, continuing the previous load starting with the Sgr A* HETG observation.

  ACIS Ops thought we would re-start the load if ACE P3 was less than about 25,000 at the comm. It was the ACIS Ops assessment that, given that level, the load could continue until the next scheduled RADMON DISABLE.
- 2013:145 **Saturday May 25, 2013**
- 2013:145z09:20 High ACE P3 alerts begin, with ACE P3 above 100,000. P3 was 117,000 at 5:30 AM. This spike was unexpected, and not found in any of the radiation environment models we are aware of.
- 2013:145z09:30 My cat is absolutely thrilled that I'm giving him breakfast at 5:30AM on a Saturday morning.
- 2013:145z10:10 Early comm obtained.
- 2013:145z10:30 Go/No-Go telecon. Rates were very high (c. P3 $\sim 38,000$) at the start of the telecon, but trending downwards. After ascertaining that a Go/No-Go decision could be made as late as 07:05L, we discussed the nature of the science case for priority, and the radiation budget. As we talked, the P3 rate decreased to about 26,000, at which level we would have an orbital fluence of $\sim 1.8 \times 10^9$ before the next comm (at 4:50L Saturday afternoon). The attenuation of the HETG (a factor of 5) was absolutely necessary to come to this conclusion.

  In a difficult decision, we chose to press forward with the MAY2513A load, resuming observations with Sgr A*.

- 2013:145z21:00 "Continue the Load" telecon. The ACE P3 rates were dropping fast, so there was no reason to stop the load. We projected an orbital fluence of $\sim 1.9 \times 10^9$ if rates held steady at that level. The loads were continued.

4 Discussion

Note that the flexibility of scheduling, including the 14-hour shutdown on the evening of May 24, was greatly enhanced by a number of factors:

- Separate vehicle and science instrument loads. The Science-Only Safing (SOSA) paradigm makes it possible to resume science operations quickly, in the event that the schedule does not need to be reshuffled. This permitted skipping pool targets and resuming the load when a high-priority target occurred.
- Communication opportunities just before, and not long after, the Sgr A* observation, which was deemed a high science priority. This was a wonderful coincidence, and may not happen in future situations of this type.
- The use of the HETG for the Sgr A* observation, which attenuates the proton flux by a factor of five. Without this ACIS Ops would have argued forcefully for continuing the shut down.
- Skillful OC and CC who were able to quickly upload and enable the MAY2513A load after the "GO" decision was made.

Because of the second shutdown, on Friday afternoon at 2013:144z20:39, the orbital fluence was limited to a value of about 1.42×10^9.

If we had elected not to take this action, we compute that the orbital fluence would have reached 3.38×10^9, a factor of 2.4 higher. This represents 17% of the annual dose of 2×10^{10}.

Another alternate scenario is as follows: We elect not to shut down Friday night, and come up to the (early) comm at 06:30 local on Saturday morning. By this time the orbital fluence would already be 3.03×10^9. The ACIS team would have argued forcefully for shutting down, and missing the Sgr A* observation (especially in light of the very large spike in the P3 flux then in progress).

It appears that the tactic we stumbled upon is a good one: shut down during pool targets on the schedule in times of high radiation in favor of high-value targets that may occur later.

We attach plots of a number of relevant quantities, showing the autonomous shutdown, in HRC antico shield rates and ACIS threshold crossings; the GOES proton rates, a graphical event timeline (ACE P3 rates, notable events, and the ACIS attenuation factor); ACE electron and proton rates; and the SOHO solar wind velocity and density plots.

Time	Event
2013:142	Wednesday May 22, 2013
2013:142:13:38	M7.3 Solar Flare
2013:142:14:49	ACIS-triggered SCS 107
2013:142:20:00	Radiation telecon
2013:144	Friday May 24, 2013
2013:144:11:00	Go/No-Go telecon. Start MAY2413A load.
2013:144:18:05	ACE 2-hour fluence exceeded.
2013:144:20:39	SCS 107 run by ground command.
2013:145	Saturday May 25, 2013
2013:145:09:20	ACE P3 rates exceed 100,000
2013:145:10:30	Go/No-Go telecon. Start May 2513A load.
2013:145:11:22	Sgr A* observation begins

Table 1: Abbreviated Timeline

Note especially the graphical timeline in figure 3, superimposed on the ACE P3 flux for reference.

5 Notes

Many of us have phones set up to issue audible alarms based on text in subject lines of e-mails, such as "sot_red", "alert", "SCS 107" (with space or dash or nothing between), "Safe", and "Radiation telecon". If you're not actually calling an urgent situation, for example replying to such a call, please change the subject line of the e-mail.

ACE fluxes are given in units of particles s^{-1} cm^{-2} MeV^{-1} sr^{-1}, and ACE fluences are in particles cm^{-2} MeV^{-1} sr^{-1}.

Thanks to the ACE, GOES, and SOHO data centers for solar wind and particle flux data.

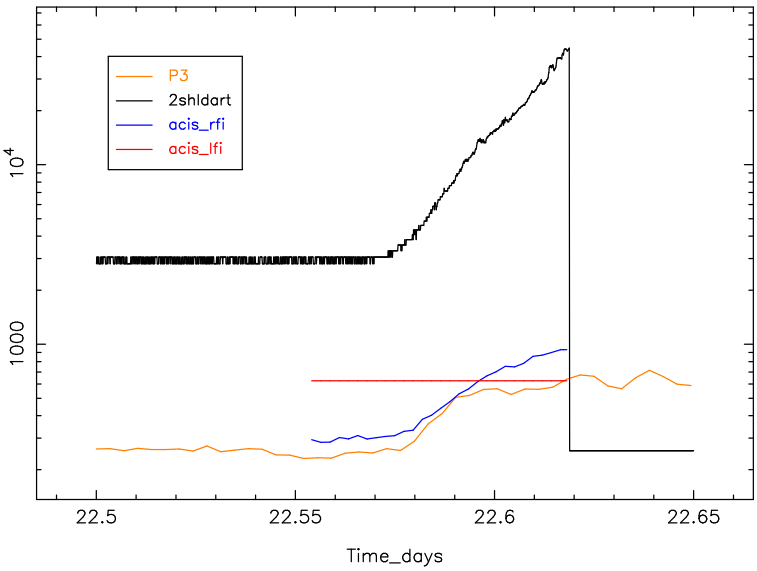


Figure 1: HRC Anticoincidence Shield rates (counts s^{-1}, and ACIS threshold crossings (units: events/sec/100 rows) for the event of May 22. The ACE P3 rates are included for reference. The horizontal red line is the RADMON trip threshold for FI threshold crossings. The HRC RADMON threshold is 62729 counts s^{-1}, so the HRC was about 2/3 of the way to its limit when ACIS triggered SCS 107. The horizontal axis on this and subsequent plots is in days of May, 2013 (add 120 for day of year).

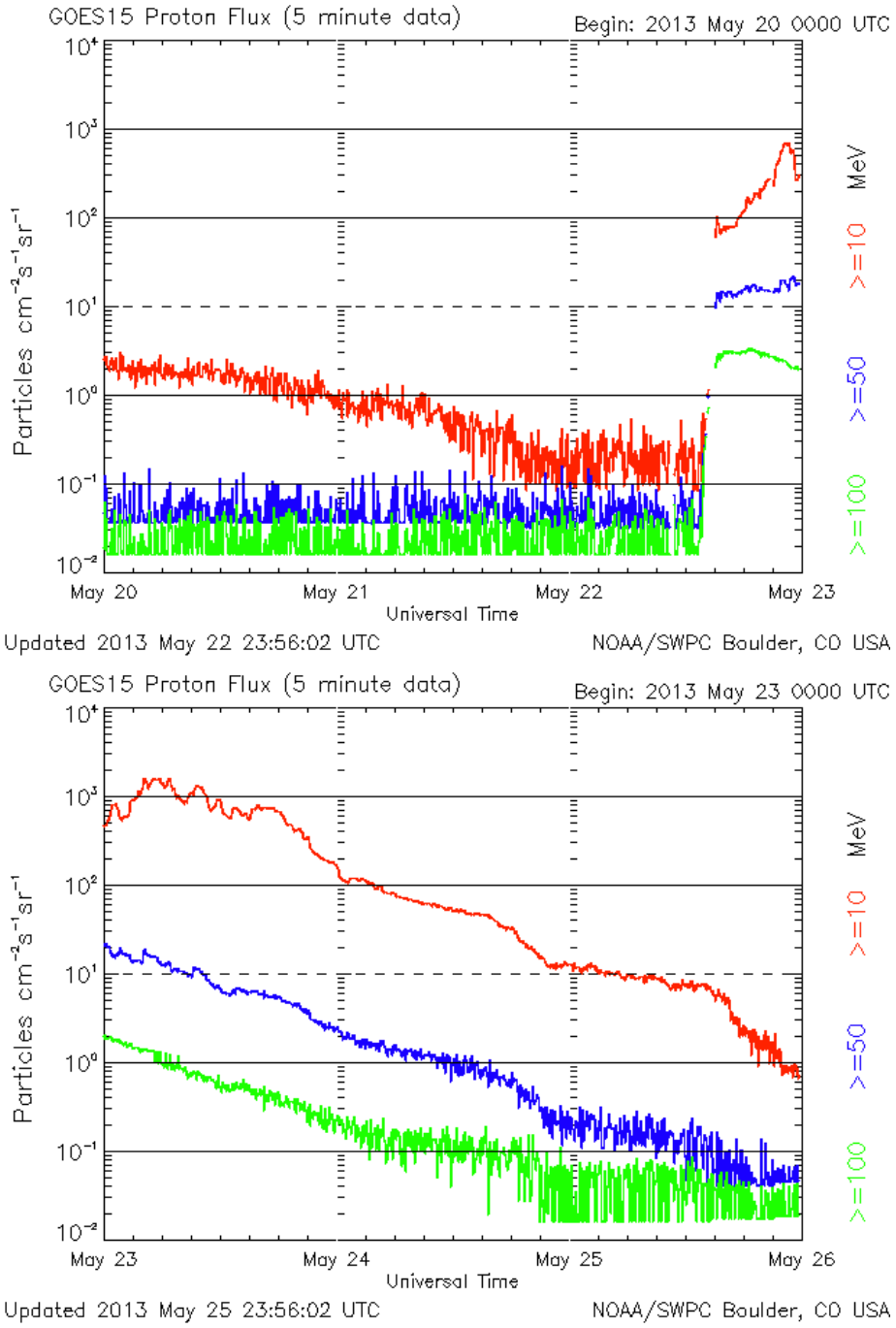


Figure 2: GOES-15 proton data

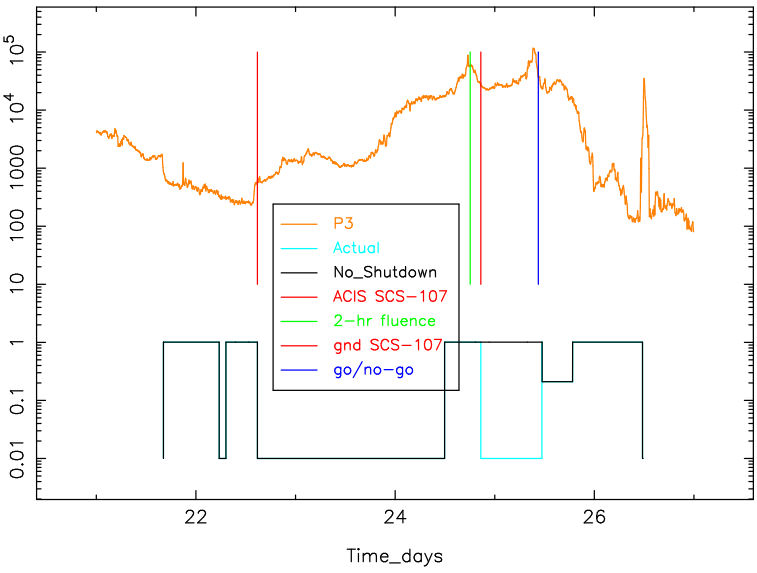
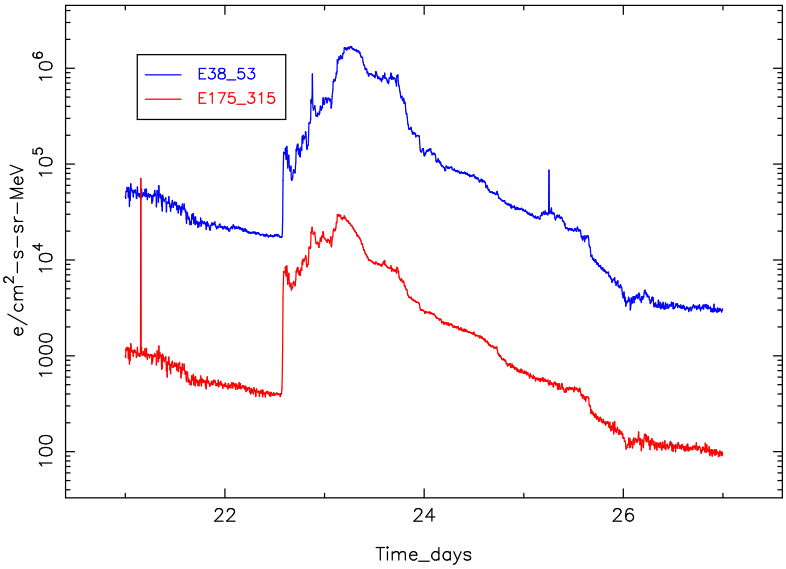


Figure 3: ACE P3 rates, and ACIS attenuation factors (1=unshielded ACIS, 0=HRC in focal plane, 0.2=HETG/ACIS), for two scenarios: the actual history, and the case of no shutdown on May 24.



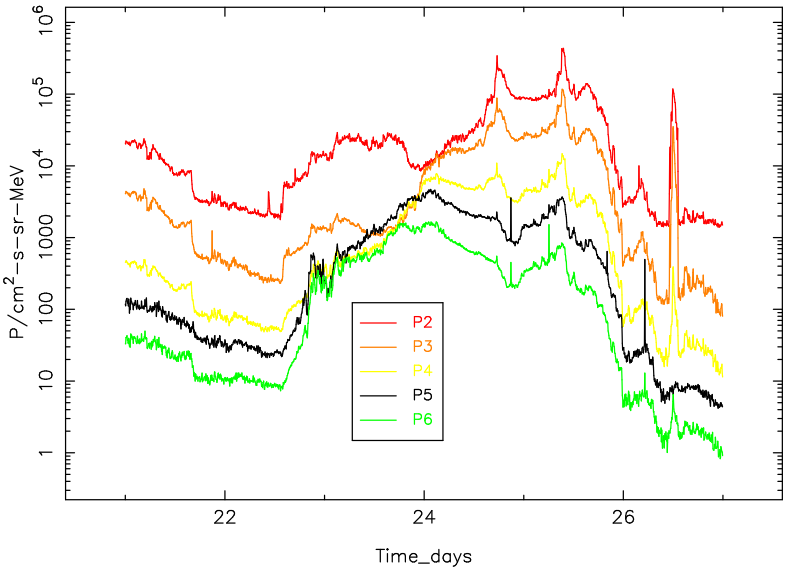


Figure 4: ACE electron and proton rates

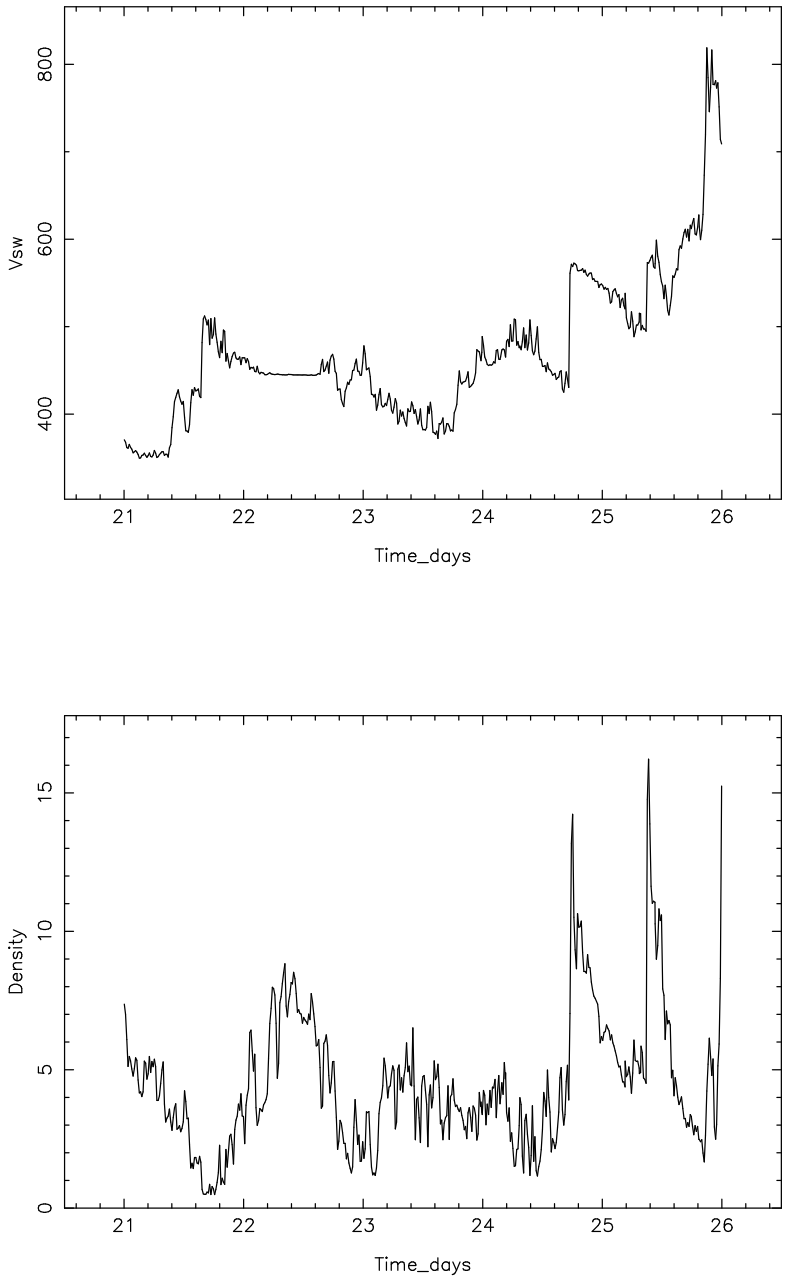


Figure 5: SOHO CELIAS/MTOF solar wind velocity and density