

# CHANDRA

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## MEMORANDUM

Date: July 24, 2024  
From: Jack Steiner  
To: Chandra Operations Team  
Subject: Chandra Radiation Shutdown in May 2024  
Cc: MSFC Project Science, CXC Director's Office  
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## 1 Abstract

During the week of May 6, 2024, an Earth-directed sunspot cluster from Active Region 3664 released a sequence of four X-class along with a large number of M-class flares within  $\approx 48$  hours. At least three CMEs were seen to merge into one major shock front. This was forecast to impact Earth on the evening of May 10 (ET). In advance of its arrival, there was team-wide consensus to perform a manual SCS-107 for radiation safety. This “cannibal” CME event produced the highest ACE P3 flux seen in many years. The decision to shut down saved an attenuated ACE-P3 fluence of  $9.7 \times 10^9$ , to be compared with an annual budget of  $2 \times 10^{10}$  and per-orbit budget of  $2 \times 10^9$  (all values in standard ACE units of particles  $\text{cm}^{-2} \text{MeV}^{-1} \text{sr}^{-1}$ ). The accumulated fluence was  $8.5 \times 10^8$ . This memo discusses the event timeline and the merged CME's impact, and describes the team's thought process at decision points.

## 2 Introduction

Solar activity has increased with the ramping up of the Solar Cycle, and the activity growth over the past 1.5 years has been more drastic than the previous cycle. This suggests a more active cycle than several models had predicted. The confluence of activity in early May 2024 resulted in a “cannibal” CME which was a merger of at least three smaller ejections into a single shock front. The CME impact produced the highest ACE-P3 rates seen in many years (550,000, in standard units; see § 5), and also resulted in the largest geomagnetic storm in decades. All this activity was driven by a single highly-active region, AR3664. Under the circumstances, i.e., multiple CMEs directed to Earth and a multitude of X- and M-class flares in the offing, the manual shutdown decision was clear and unanimously supported at the time the call was made.

### 3 May 2024 Detailed Timeline, from May0624A load to MAY1424B RTS Load

- 2024:126:22:06:38 **Sunday, May 5, 2024** Start of MAY0624 load.
- 2024:127:05:28 **Monday, May 6, 2024** M1.3 class solar flare.
- 2024:127:06:35 X4.5 class solar flare.
- 2024:127:21:48 M1.2 class solar flare.
- 2024:127:22:27 M4.3 class solar flare.
- 2024:128:06:16 **Tuesday, May 7, 2024** M5.1 class solar flare.
- 2024:128:11:50 M2.4 class solar flare.
- 2024:128:16:30 M8.2 class solar flare.
- 2024:129:01:41 **Wednesday, May 8, 2024** X1.0 class solar flare.
- 2024:129:06:53 M7.1 class solar flare.
- 2024:129:11:22 M4.1 class solar flare.
- 2024:129:12:04 M8.6 class solar flare.
- 2024:129:17:53 M7.9 class solar flare.
- 2024:129:21:40 X1.0 class solar flare.
- 2024:130:03:17 **Thursday, May 9, 2024** M4.0 class solar flare.
- 2024:130:08:40 M2.1 class solar flare.
- 2024:130:09:13 X2.2 class solar flare.
- 2024:130:13:23 M3.7 class solar flare.
- 2024:130:17:44 X1.1 class solar flare.
- 2024:130:22:15 M1.0 class solar flare.
- 2024:130:22:41 M2.6 class solar flare.
- 2024:131:03:29 **Friday, May 10, 2024** M1.4 class solar flare.
- 2024:131:06:54 X3.9 class solar flare.

- 2024:131:13:05 Radiation discussion following the 9am tagup in which tentative shutdown decision was made for 4pm, with a 2pm plan to discuss and confirm.
- 2024:131:14:11 M5.9 class solar flare.
- 2024:131:14:55 sot\_ace\_alert from S. Wolk suggesting a shutdown at 11:35. ACE-P3 rates at 50,000. There was quick concurrence from ACIS, HRC, and Steve O'Dell.
- 2024:131:15:37:02 manual SCS-107 executed; 2pm radiation discussion canceled; return-to-science targeting May 13 (MAY1324C).
- 2024:131:17:00 Merged CME impacted Earth around this time.
- 2024:132:01:23 **Saturday, May 11, 2024** X5.8 class solar flare.
- 2024:132:11:44 X1.5 class solar flare.
- 2024:132:16:27 SpaceWeather Alert received - more CME impacts expected over 24-48 hours.
- 2024:132:23:41 MAY1324C loads delayed owing to inbound CME and high radiation levels.
- 2024:133:01:33 **Sunday, May 12, 2024** M1.2 class solar flare.
- 2024:133:09:33 M4.9 class solar flare.
- 2024:133:09:44 M6.6 class solar flare.
- 2024:133:16:26 X1.0 class solar flare.
- 2024:133:17:18 Owing to radiation concerns with inbound CME, MAY1324C loads canceled, MAY1424 to be targeted, interrupting the MAY1324B vehicle load.
- 2024:133:17:47 M1.0 class solar flare.
- 2024:133:21:59 M1.5 class solar flare.
- 2024:134:01:48 **Monday, May 13, 2024** M2.5 class solar flare.
- 2024:134:02:09 X1.7 class solar flare.
- 2024:134:12:55 X1.2 class solar flare.
- 2024:134:13:05 Radiation replan discussion following the 9am tagup, tentatively targeting evening upload of the MAY1424B load.
- 2024:134:16:51 X8.7 class solar flare.

- 2024:135:00:59 **Tuesday, May 14, 2024** A 10pm ET science-resumption go/no-go discussion announced on `sot_red_alert`.
- 2024:135:02:00 MAY1424B science resumption load discussion, approved given low HRC proxy and sufficiently-low ACE P3 rates. No further CME impacts anticipated.
- 2024:135:03:57:00 MAY1424B RTS load begins execution.

## 4 May 2024 Shutdown Overview

Given both the extreme solar activity in the week preceding the radiation shutdown, and the corresponding concern about the magnitude of the cannibal CME, there were no dissenting views in the call for a manual shutdown in advance of the CME arrival. At the end of the 9am tagup on Friday May 10, there was consensus to proceed with a manual SCS-107 targeting the 4pm comm (ET) given that the CME impact was anticipated in the evening. However, during the next several hours, P3 rates increased sharply by more than an order of magnitude. In response to this increase, a `sot_ace_alert` discussion was called, and an earlier manual SCS-107 was agreed upon, targeting the 11:35am (ET) comm instead. This was successfully executed at 2024:131:15:37:02, marking the fourth radiation shutdown of 2024. Previous shutdowns were in January and February (both manual) and March (autonomous).

Figure 1 shows the ACE P3 rate over the week in question, and a corresponding plot of the other ACE proton rates is shown in Figure 2. The magnitude of the rise in P3 rates is apparent, and upon close inspection, the shutdown (red line in Fig. 1) is seen to have occurred just prior to a final 10-fold rise to the peak-intensity of the event (an exceptionally high P3 rate of  $\sim 550,000$ ).

Science resumption loads were initially planned as updates to the (regularly scheduled) MAY1324 science load to use the same date. However, within 24 hours of the shutdown, two additional X-class flares were produced with associated CME impacts expected to follow shortly thereafter, and so the loads were postponed, targeting MAY1424 (to interrupt the MAY1324 vehicle load). This plan was in some jeopardy as well, as between May 12th and 14th, 4 additional X-class flares were produced. However, by late Tuesday May 14th, no further Earth-directed CMEs were expected and so a go/no-go discussion was convened in the evening. Despite the ongoing large solar flares, the ACE rates had declined more than 100-fold from the event peak, and no CME impacts were imminently expected. The decision was to go ahead and so the MAY1424B loads were uploaded and began executing later that evening (local time).

The total science orbit time unavailable for science due to the radiation shutdown was  $\sim 266$  ks. The attenuated ACE P3 fluence avoided by shutting down was  $9.7 \times 10^9$ . For comparison, the attenuated ACE P3 fluence for the orbit at the point of shutdown was  $8.5 \times 10^8$ .

Figure 3 shows the *txings* rate leading up to the shutdown. A significant increase is observed during the last hour of ObsID 28699, during which the FI rate increases by  $\sim 50\%$ , although still below threshold at the time of manual shutdown. From this plot it appears likely, though not certain, that a *txings* autonomous SCS-107 may have occurred if the observation had been run for longer.

## 5 Notes

ACE data was obtained from <ftp://mussel.srl.caltech.edu/pub/ace/browse/>.

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

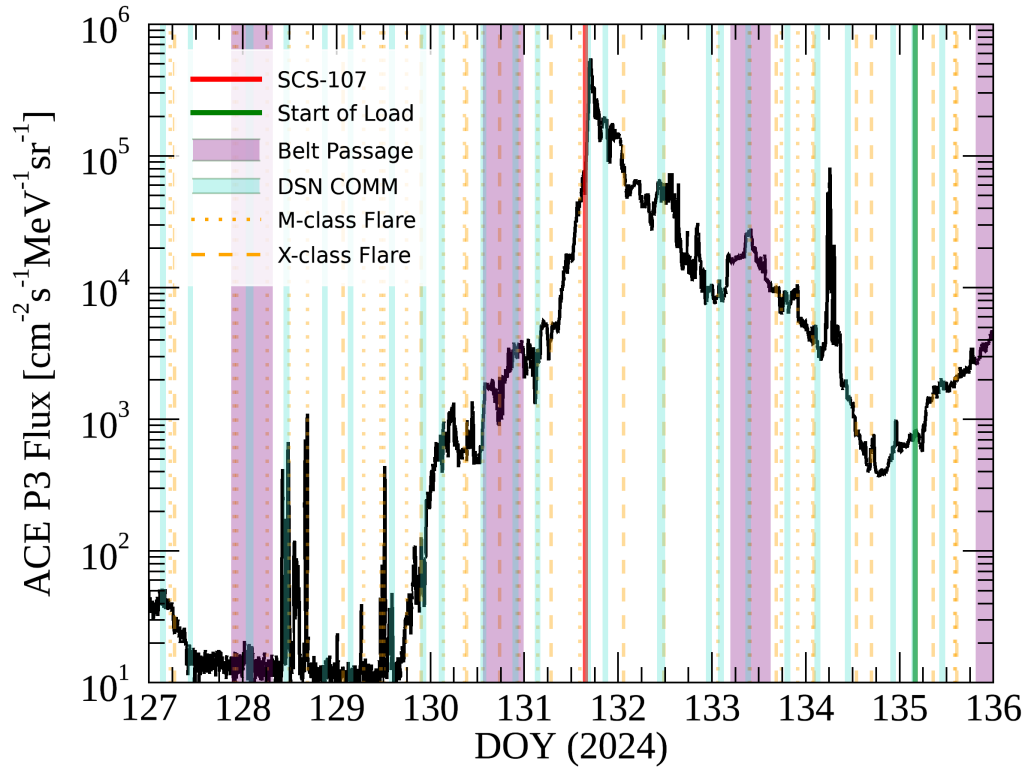


Figure 1: The ACE P3 flux during the storm, with time markers indicating the start of the science-resumption load (dark green), the manual SCS-107 (red), and the times of flares (orange). Shaded regions indicate belt passages (purple) and DSN comms (blue).

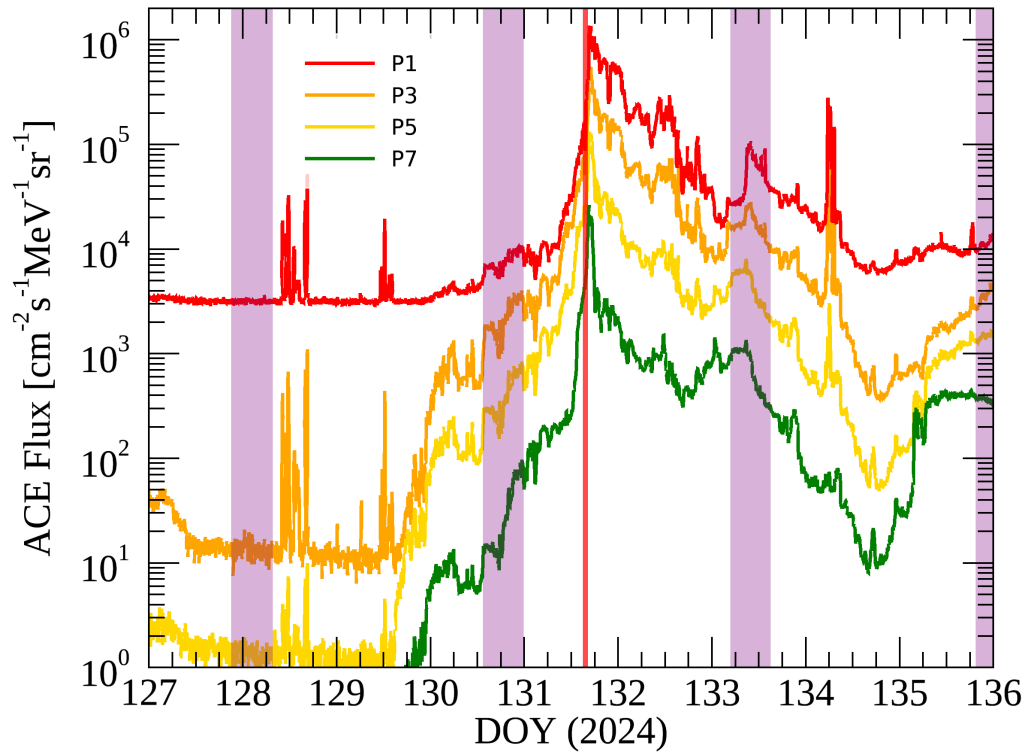


Figure 2: ACE proton bands during the storm event. The red vertical line marks the time of shutdown and purple shaded regions show the belt passages.

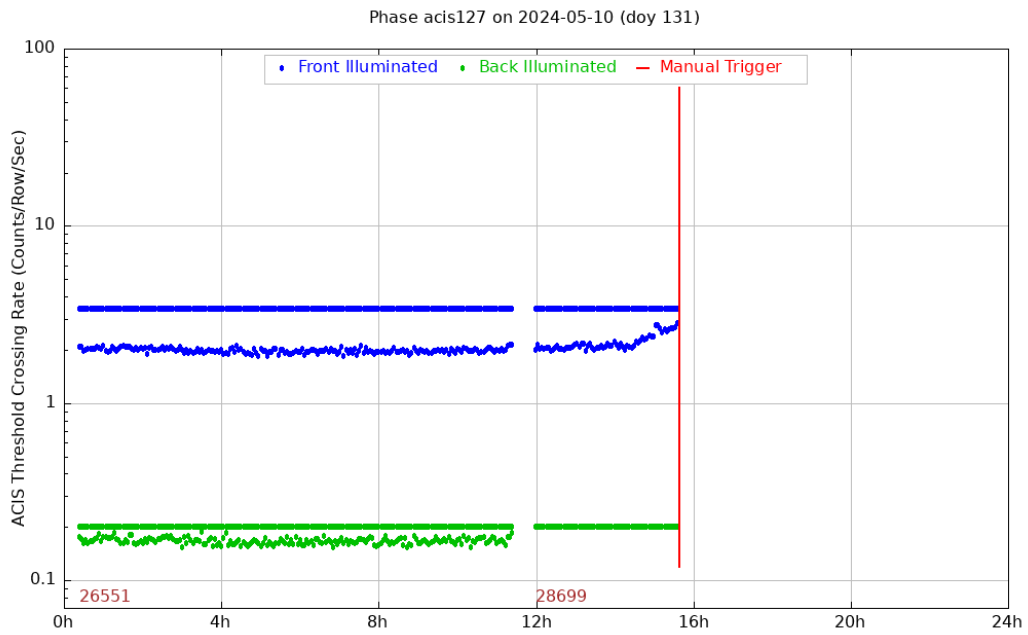


Figure 3: *txings* data for May 10 showing rising FI rates. The manual SCS-107 interrupted observations, but it appears *txings* may have been poised to produce an autonomous trigger shortly afterwards.