Real Time Space Weather Support for Chandra X-ray Observatory Operations

Abstract

NASA launched the Chandra X-ray Observatory in July 1999. Soon after first light in August 1999, however, degradation in the energy resolution and charge transfer efficiency of the Advanced CCD Imaging Spectrometer (ACIS)-x ray detectors was observed. The source of the degradation was quickly identified as a radiation effect known as channeling of the front-illuminated CCDs, by weakly penetrating “soft”, 100–500 keV protons as Chandra passed through the Earth’s radiation belts and ring currents. As soft protons were not considered a risk to spacecraft health before launch, the only on-board radiation monitoring systems (Passive, Electron, and Helium instrument (PEHIN), which was included on Chandra with the primary purpose of monitoring energetic solar particle events. Further damage to the ACIS detector has been successfully mitigated through a combination of careful mission planning, autonomous on-board radiation protection, and manual intervention based upon real-time monitoring of the soft-proton environment.

ACIS

The Advanced CCD Imaging Spectrometer (ACIS) is CNO’s premier science instrument, most often used for Chandra’s scientific operations. The 8 front-illuminated ACIS CCD detectors were observed to be much worse than expected. - Initially observed “5 years worth of degradation in a single pique passage” - Damage mechanism identified as “soft” protons (≥ 100 keV) depositing energy in CCD substrate (the two back-illuminated CCDs are immune to the same damage mechanism)

The graining incidence optics used to focus the soft wavelength x-rays photons are also either at focusing the soft photons from the space environment onto the observatory focal plane which degrades the energy resolution and charge transfer efficiency of the Advanced CCD Imaging Spectrometer front-illuminated CCD’s.

Damage to the ACIS detector has been successfully mitigated through a combination of careful mission planning, autonomous on-board radiation protection, and manual intervention based upon real-time monitoring of the soft-proton environment.

Overview

- The most often requested science instrument onboard CNO (ACIS) cannot be operated in high flux, soft proton environment within the magnetosphere and solar particle events due to a C0 damage mechanism from “100–200 keV” protons.

- The ACIS EPAM instrument monitors the only data source available for directly measuring the soft protons in interplanetary space that damage ACIS C0’s.

- No other users of ACIS EPAM RTSW data have been identified to date, it appears that Chandra is the only program using the EPAM (via the CNO’s RTSW) to monitor the real-time energy required to protect the ACIS detector.

- The loss of this real-time data stream could cause a significant impact to the science lifetime and data quality for this Great Observatory.

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Manual intervention for soft proton events in interplanetary space is based on monitoring 115–195 keV proton fluence using data from the P3-channel of the Electron, Proton, and Alpha Monitor (EPAM) instrument on the Advanced Composition Explorer (ACE) spacecraft.

NOAA Space Weather Prediction Center (NWPC) currently provides ACIS/EPAM as a component of the Real Time Solar Wind (RTSW) data stream. ACIS/EPAM is the only data source for real-time measurements of the "100–200 keV" proton environment primarily responsible for damage to ACIS C0's in interplanetary space.

Objectives

- Chandra requires real-time ACIS data for monitoring and implementing manual interruptions of Chandra science operations if necessary. CNO Science Center Level 2 (verified) and Browse (unverified) science products are not updated often enough to be useful for operational support.

- Access to 5-minute average ACIS EPAM RTSW data products (status quo) is the preferred option for Chandra since it allows continuous monitoring of our radiation mitigation strategies to minimize the proton damage in the ACIS CCD detectors and the importance of real-time data sources that are used to protect the ACIS detector system from space weather events.

- However, data rates are negotiable as ACIS radiation damage is a fluence issue, with long exposure periods to soft proton flux required for significant damage to C0’s.

- Lower real-time data rates are acceptable as long as sufficient information is available to estimate soft proton fluence, ACIS EPAM RTSW data rates at upper limits to once per hour can be used by Chandra to monitor soft proton environment.

The Future of ACIS Real-Time Data

The ACE/EPAM RTSW records are the only real-time data currently available for detecting soft "100–200 keV" proton events in interplanetary space that impact the ACIS instrument.

NOAA plans to replace ACE with Deep Space Climate Observatory (DISCOVER) in late 2014

- DISCOVER will become the primary NOAA/ACE space weather plasma data source

- ACE RTSW coverage will be discontinued

- DISCOVER carries a MAG/WEATHER type cold solar wind plasma and magnetic field instrument

- No replacement for non-thermal EPAM, A3 energetic particle instruments on DISCOVER

DISCOVER is planned as an interim solution for an ACE replacement with release of an RFP for a full replacement after DISCOVER’s end of life

- Full ACE replacement satellites could have a more complete set of cold plasma, energetic particle instruments including an EPAM replacement which will be a gap in service for a few years for the real-time energetic particle data.

- None of this has been authorized by Congress so it is all uncertain at best

- The gap could be many years

Loss of ACE/EPAM soft proton data will impact CNO operations.

Are there other spacecraft or space weather users that require the RTSW/ACE/EPAM data for operations that will be similarly impacted?

The CNO Program would like to know...

Joseph.I.minow@nasa.gov

Oxo Solar Cycle 24 Radiation Interruptions

The table above indicates Solar Cycle 24 events where ACIS science data was lost due to radiation events. Autonomous “auto” events are triggered by a high flux of solar energetic particles that generate high count rates in either the anti-coincidence shield of the High Resolution Camera (HRC) or the EPHN E1300 channel. The on-board radiation monitoring system sends a signal to autonomously move the ACIS instrument from the focal plane position to a protected location that cannot be accessed by the soft protons for these events. Manual events require operator intervention based on ground based monitoring of the ACE F3 channel from the NOAA RTSW data stream. In addition, there is one period of solar quiet due to the low solar activity. The CNO Science Center (PDF) document on the Autonomous Command Telemetry Unit that put the spacecraft in safe mode. Of note is that four out of fourteen events that result in lost science observations are manual events due only to soft protons that would have triggered the autonomous protection systems, leaving the ACIS instrument vulnerable to additional radiation degradation.

The above graph presents two examples of periods with low ACIS science observations (gray boxes) and the corresponding temporal variations in the radiation environment measured over a range of energies by GOES and ACE instruments. Radiation interactions during the current solar cycle strongly dominated by a combination of solar events, what is often referred to as an event set up that put the spacecraft in safe mode, and the manual events based on the ACE F3 data. The Autonomous HRC auto event follow high solar particle events and sometimes do not always, from the high flux of soft protons. The ACE F3 instrument is the only source of real time data that can be used to guard against soft proton events that are not accompanied by high energy particles. All of the on-board autonomous systems are driven by high energy particle events.