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MEMORANDUM

December 22, 2004

From: Nancy Adams-Wolk
To: ACIS Operations Team
Subject: MARX Simulations of the Crab Nebula Pulsar On Axis
File: `/data/acis34/MARX_archive/Crab/RESULTS/crab_onaxis.tex`
Version: 1.0

Abstract

This memo summarizes the damage that can be expected to the ACIS instrument when observing the Crab Nebula Pulsar on axis. While most observations of the Crab Pulsar are NOT on axis, we often use this object as a standard of the brightness of an X-ray source. Here, the damage to the detectors examined with both aim points, with the HETG gratings in and out and with dither turned on and off.

1 Introduction

The Crab Nebula is one of the brightest X-ray sources in the sky and it is often used as a standard of the brightness of an X-ray source. To protect ACIS from excess radiation damage, we wish to know how much damage the detector will receive from the Crab Pulsar in different circumstances. From these numbers, we can scale other observations to determine if that observation is safe for ACIS.

I have conducted MARX simulations for the Crab Pulsar for various ACIS configurations. In all cases, the Crab Pulsar is on-axis, allowing us to assess maximum damage.

These data are similar to the June, 2002 memo by Virani, except that his simulations were for a specific observation that placed the Crab Pulsar off-axis.

2 Simulated Data-XSPEC spectral model and MARX simulations

Using the HEASARC package XSPEC, I created a spectral model for the Crab Pulsar. After a literature search, the best values available for the pulsar are still from Willingale *et al.*, 2001. This paper found a spectral index for the pulsar of 1.63 ± 0.09. Using the scaled normalization from Virani (0.49 photons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{keV}^{-1}$), and a neutral hydrogen density, nH, of $3.0 \times 10^{21}\ \mathrm{cm}^{-2}$, I created a spectral model using the phabs and pow models. I also used the AO6 proposal files for ACIS-I and ACIS-S for the rmf/arf files when calling the XSPEC *fakit* program.

To use these XSPEC files in MARX 3.0, the script *xspec2marx* was run on the model files. Then I ran 8 simulations in MARX. Table 1 describes the set up of the simulations. All observations were set to 10 ks to lower the size of the output files and to allow an easy scaling for future comparisons. Following Virani, I used MARX QE files created by Joe DePasquale that assumes an ideal quantum efficiency. MARX 3.0 allows us to separate out the filter transmissions and the quantum efficiency. By using the ideal quantum efficency, we are recording the number of photons actually incedent on the CCDs, once those photons get past the filters. This is done to determine the maximum damage, as opposed to what is detected. Cases with the DITHER set to OFF where simulated in case of an error that prevents the spacecraft dither.

Simulation	Aim point	HETG	Dither	Exposure
1	ACIS-I	NO	ON	10 ks
2	ACIS-I	NO	OFF	10 ks
3	ACIS-I	YES	ON	10 ks
4	ACIS-I	YES	OFF	10 ks
5	ACIS-S	NO	ON	10 ks
6	ACIS-S	NO	OFF	10 ks
7	ACIS-S	YES	ON	10 ks
8	ACIS-S	YES	OFF	10 ks

Table 1: MARX setup for simulations

After the MARX simulations completed, *marx2fits* was executed to convert the MARX data to FITS files. Using CXC Data System, version: 7.4.0 data system, the FITS files were copied to only include the aim point ccd (*dmcopy*), then converted to an image from the event list (*dmcopy*) and finally a statistical summary of the image was performed to find the maximum counts in a pixel (*dmstat*).

3 Results of Simulations

To determine the damage to ACIS, I used the total budgeted dose of radiation for the mission, the Mission Dose (MD). This is described in Butt's memo. Table 2 shows the limits used in the calculations.

CCD	MD(krad)	cts/pix : rad/pix
FI	25	135:1
BI	625	100:1

Table 2: Mission Dose limits

In table 3, the results of these simulations are shown with the maximum number of counts in the peak pixel, the location of the peak pixel, the dose and the percentage of mission dose.

Simulation	Aim point	HETG/Dither	Pixel (x,y)	Max Counts (Peak pixel)	Dose krad	%MD
1	ACIS-I	NO/ON	(944,936)	19228	0.142	0.57%
2	ACIS-I	NO/OFF	(960,952)	1396084	10.341	41.37%
3	ACIS-I	YES/ON	(944,936)	3220	0.0239	0.095%
4	ACIS-I	YES/OFF	(960,952)	229002	1.69	0.42%
5	ACIS-S	NO/ON	(279,523)	17496	0.175	0.028%
6	ACIS-S	NO/OFF	(263,507)	993911	9.939	1.59%
7	ACIS-S	YES/ON	(279,523)	2951	0.295	0.0047%
8	ACIS-S	YES/OFF	(263,507)	159204	1.592	0.25%

Table 3: ACIS-I and ACIS-S simulation results

4 Discussion

Given the results in table 3, ACIS-S is fairly safe unless it is left on a bright source for a very long time. For ACIS-I, the percentage of mission dose can be achieved in a very short time if we have bare ACIS and a failure to dither.

These values are for the on-axis observations. Since many objects measure their output in terms of crabs (ie 1/3 crab), these values can be used to help determine the potential damage from other bright objects.

To assist in assessing potential damage, a script,*dose_in_crabs.pl* was written to scale the values presented in this memo for any source that can be described in terms of "crabs". For example, a source that is 1/3 of a Crab and 40 ks long would present the following information:

```
xcanuck> dose_in_crabs.pl
Please enter the estimated flux in terms of crab (.5 for half crab) .33
What is the exposure time in ksec? 40


AIMPT   GRATING DITHER  Max Counts      Dose(krad)      % MD
------  ------- ------  ----------      ----------      -----
ACIS-I  NONE    ON      25380.96        0.19            0.75
ACIS-I  NONE    OFF     1842830.88      13.65           54.61
ACIS-I  HETG    ON       4250.40        0.03            0.13
ACIS-I  HETG    OFF     302282.64       2.23            0.55
ACIS-S  NONE    ON      23094.72        0.23            0.04
ACIS-S  NONE    OFF     1311962.52      13.12           2.10
ACIS-S  HETG    ON       3895.32        0.39            0.01
ACIS-S  HETG    OFF     210149.28       2.10            0.33
```

It is clear that this is a dangerous observation for the case of ACIS-I if dither failed. This script is stored in /home/acisdude/bin/ and if the numbers in this memo are superseded, the script should be modified with the new values.

5 References

1. S. Virani, "MARX Simulations of the AO4 Crab Nebula/Saturn-Titan Conjunction Proposals", CXC Memo, 27, June 2002
2. Y. Butt, "Operational Limits for X-ray Photon Dose On ACIS", CXC Memo, 3 May 2002
3. Willingale, R., et al. A & A 365, L212-L217 (2001).