Real Time Science Displays for the PCA Experiment on the Rossi X-Ray Timing Explorer

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Poster paper at the AAS High Energy Astrophysics Division (HEAD)

meeting at San Diego, April 30th - May 3rd, 1996

& COSPAR, X-Ray Timing (E1.1), Birmingham, UK, July 15 - 16, 1996

Abstract

The NASA Rossi X-Ray Timing Explorer (RXTE) spacecraft was launched successfully on 30th December 1995. Following an initial 30 day In Orbit Checkout (IOC) period routine Guest Observer (GO) observations commenced at the end of January 1996. One of the 3 experiments on board RXTE is the Proportional Counter Array (PCA) developed at GSFC. The telemetry from RXTE is returned via the NASA Tracking and Data Relay Satellite System (TDRSS) which, apart from specific gaps in coverage, provides a steady stream of nearly continuous real time data packets. The PCA has a very large detection area and produces high count rates for many x-ray sources. This provides the opportunity for some serious interpretation and decision making in semi-real time.

The displays developed by the PCA Instrument Team (IT) fall into 4 classes:

- Housekeeping - for Science Operation Facility (SOF) & PCA IT
- General performance (instrumental and calibrating bias) - for SOF & PCA IT
- Spectral (science bias) - for SOF, PCA IT & GO's
- Temporal (science bias) - for SOF, PCA IT & GO's

The displays are used by the Duty Scientist and others to monitor the observation in progress to try and ensure that the observation is proceeding as planned and that modifications to the observing modes are not required. This paper provides some examples of the available display options.

Introduction

Several years ago it was decided to use C++ for all the software associated with the RXTE Science Operation Center (SOC) but this decision was revised for a number of reasons in mid 1993. At this time the Guest Observer Facility (GOF) elected to stay in line with the well established practices of the Office of Guest Investigator Programs (OGIP) and High Energy Astrophysics Science Archive Research Center (HEASARC) activities within NASA at GSFC. The SOF was committed to using C++ and continued with this approach. Since almost all GOF code is written in FORTRAN using FITS & FTOOLS there could be no commonality with the SOF object oriented C++ environment. This fundamental decision meant that the original requirement for an integrated system with extensive analysis capability in the SOF was no longer feasible. Resources did not allow the duplication of the functionality of the analysis tools that the GOF was required to produce.

The RXTE software effort was widely distributed and the Instrument Teams were contracted to deliver much supporting code for their hardware experiment. The principal PCA contributions to the GOF were in the following areas: field of view response maps, energy response matrices, dead time corrections & orbit background model

The PCA C++ code produced for the SOF was developed using Object Center^{tm} from CenterLine Software Inc. The GUI used is TAE+ which is a commercially available NASA product. The delivered code falls mainly in the following SOF subsystems:

- Command Generation (CG)
- Mission Monitoring (MM)
- Health and Safety (HS)
- Science Monitoring (SM)

In this paper we discuss only the PCA contributions to the SOF for the Science Monitoring subsystem. The various software displays are all modular in design and are selected from a main PCA menu. Most modules are fully developed athough a few are still evolving and the need for some additions emerged in the first few weeks after launch. These new options are still being tested on the PCA monitoring and development system at GSFC and may not be available in the SOF immediately. Future SM options may be added as needs arise if resources are available.

The PCA experiment contains 5 similar detectors each of which produces identical housekeeping data packets for the HS display software. These packets contain many detector parameters and some X-ray rates but no spectral information. Most of the science information comes down in data packets from the Electronic Data System (EDS) which is provided by MIT. This sophisticated data selection and compression system allows many pre-programmed data modes to be run simultaneously in the six Event Analyzers (EA's) devoted to the PCA. Extensive details on the PCA/EDS combination can be found in the 1995 RXTE NRA.

RXTE was a fixed price program that was completed within budget and on time with respect to goals set ~4 years prior to the planned launch date of 31st August 1995. Given the practicalities following the GOF/SOF split the PCA team chose to emphasize the following aspects in SOF displays:

- Real Time or near real time graphical displays
- Visual impact and clarity
- Multiple options within a pre-defined (limited) set of constraints
- Limited analysis capability but export of data to external tools such as IDL
- Only a few of the hundreds of EDS modes to be supported with SM concentrating on the EDS Standard Modes 1 & 2 which are always present
- Real Time display or access to SOF Data Base which extends back ~14 days

If Guest Observers (GO’s) are present at the SOF during their observations and really need to do tasks such as background subtraction or spectral fitting in near real time then the GOF’s XFF system can be used. A SOF copy of XFF can be run to produce temporary FITS files on an estimated 15 - 30 minute time frame. The precise time scale depends on the data flow from the NASA PACOR system into GSFC and “fast” FITS files made in this way may be very incomplete. Normally a 24 hour period elapses before all late packets are assumed to have arrived. Once the FITS files are created they can be studied using the GOF FTOOLS.

This paper is intended to give an impression of the PCA displays available. There are too many features and options for a “User Guide” type detailed discussion.

Science Monitoring Requirements

The intention of the science monitoring displays can be summarized in the following list, in approximate order of increasing scientific interest. Remember that “detailed analysis” is not intended with this real time system:

- Do spectra (maybe just background for a weak source) look typical. Are they free of spikes, gaps and noise.
- Are the spectra from all xenon layers in all detectors similar (total of 30 spectra)
- Are all the internal calibration spectra normal
- Has the source been detected
- How does the intensity vary with time
- What sort of spectral shape does the X-ray source have
- How does the spectrum vary with time
- How do the detected intensity & spectrum translate into telemetry loading
- What is the hardness ratio and how does it vary with time
- What sort of “slow” time scale periodic or aperiodic features are visible from Standard Mode 1 data and its derivatives
- What sort of “faster” time scale periodic or aperiodic features are visible from the on-board EDS FFT & Delta Time Binned modes

All the figures displayed in the following pages were “snapped” in real time.

PCA Science Monitoring Displays

The current set of completed or part finished displays is shown in the table below.

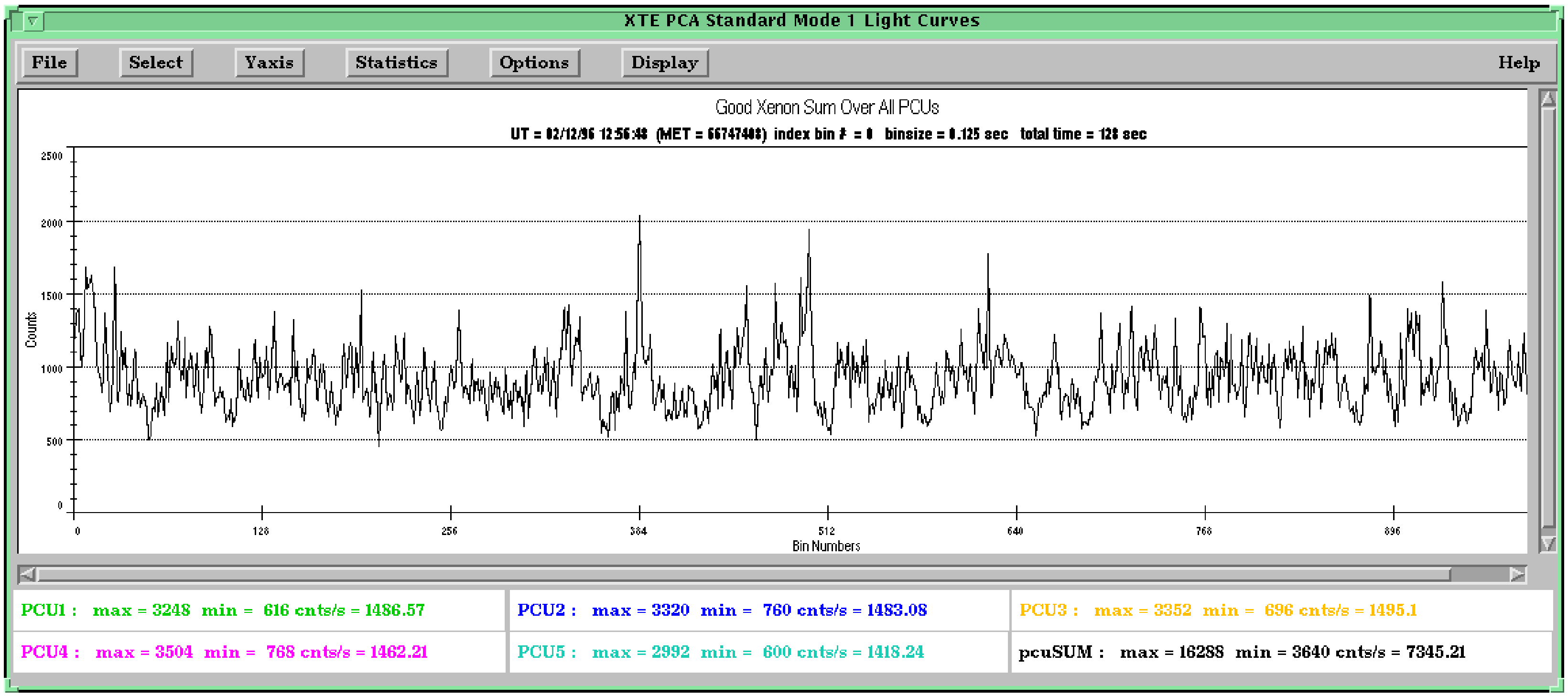
Main Option	Second Option	Description
STD Mode 1	Calibration Spectra	Calibration tagged events, raw 256 channel spectra, every 128 seconds, all PCU's, all layers
	Light Curves (LC)	Eight 1024 point light curves, 1/8 sec samples, every 128 seconds, 5 PCU xenon rates + 3 others. Can bin up data to span ~18 hours with 64 second resolution
Temporal Science	Power Spec.	Derived from STD Mode 1 light curves, plots Power Spectrum (PS) of same data
	PS History	2-D plot, PS frequency (vertical axis) vs. time (horizontal axis) with signal being color coded
	Layer LC's	Light curves (adjustable energy range) from STD Mode 2 data. 16,32,64 sec, all PCU's, all layers
	Energy LC's	Light curves (4 adjustable energy ranges) from STD Mode 2 data. 16,32,64 sec, all PCU's
STD Mode 2	Spectra	16 second updates, xenon spectra - raw 128 channels, all PCU's, all layers, sum of all PCU's propane spectra - 32 channels, each PCU, sum of all PCU's, xenon & propane can be integrated
	Rates	29 rates monitored each 16 seconds, various anticoincidence signals and other veto diagnostics
Spectral Science	Base Summa-tion	Derived from STD Mode 2, all xenon signals can be added raw or with gain & offset corrections applied. Single xenon plot can be integrated
	Recommend	Base summation split into the 6 energy bands defined for the GOF RECOMMD program
	Colors vs. Time	Three definable energy bands on Base Mode, plots of color vs. time
	Spectral History	2-D plot, spectra (vertical axis) vs. time (horizontal axis) with signal being color coded
Others	EDS FFT	On-board EDS FFT spectra mode, time scale dependent on selected EDS mode
	EDS Delta T.	On-board delta time binned mode, time scale dependent on selected EDS mode
	Event Selection	A tool to make selections from PCU, layer, Energy and bin up to produce "special" light curves
	Slew Detection	A derivative of Event Data selection optimized for detection of weak sources during slews

Standard Mode 1 - Calibration Spectra

An integrated Am ^{241} spectrum for the 6 Xe anodes in PCU 5. The peak to the right is at 60 keV. The peak to the left in L1 & R1 is contamination due to a bright X-ray source.

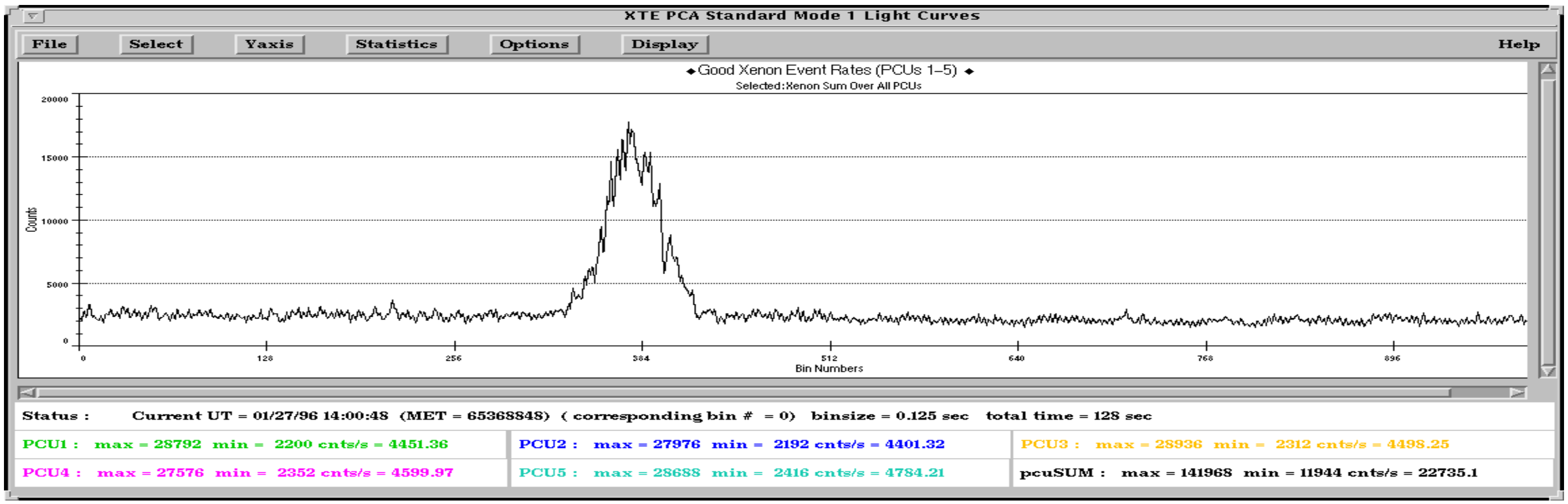
Standard Mode 1 - Light Curves (Cyg X-1)

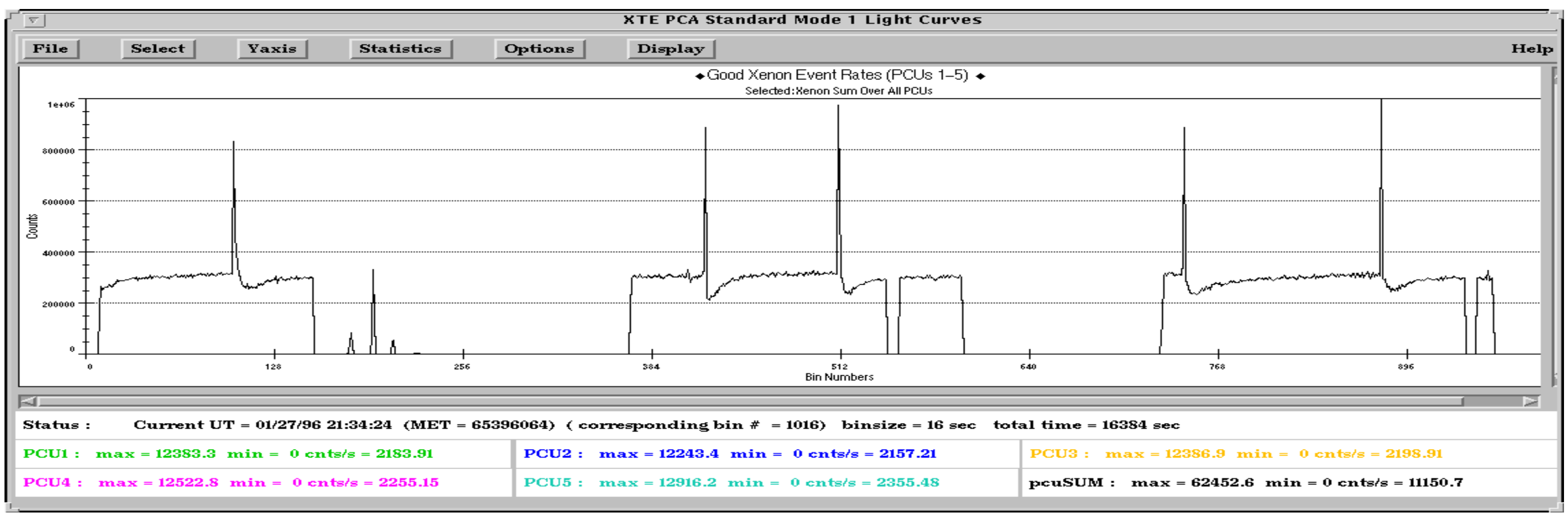
A Light Curve for the summed rate from PCU's 1-5. The temporal resolution shown is 0.125 seconds with 1024 points across the plot. Individual PCU average rates over the 128 second interval are shown in the lower boxes.



Standard Mode 1 - Light Curves (GRO J1744-28)

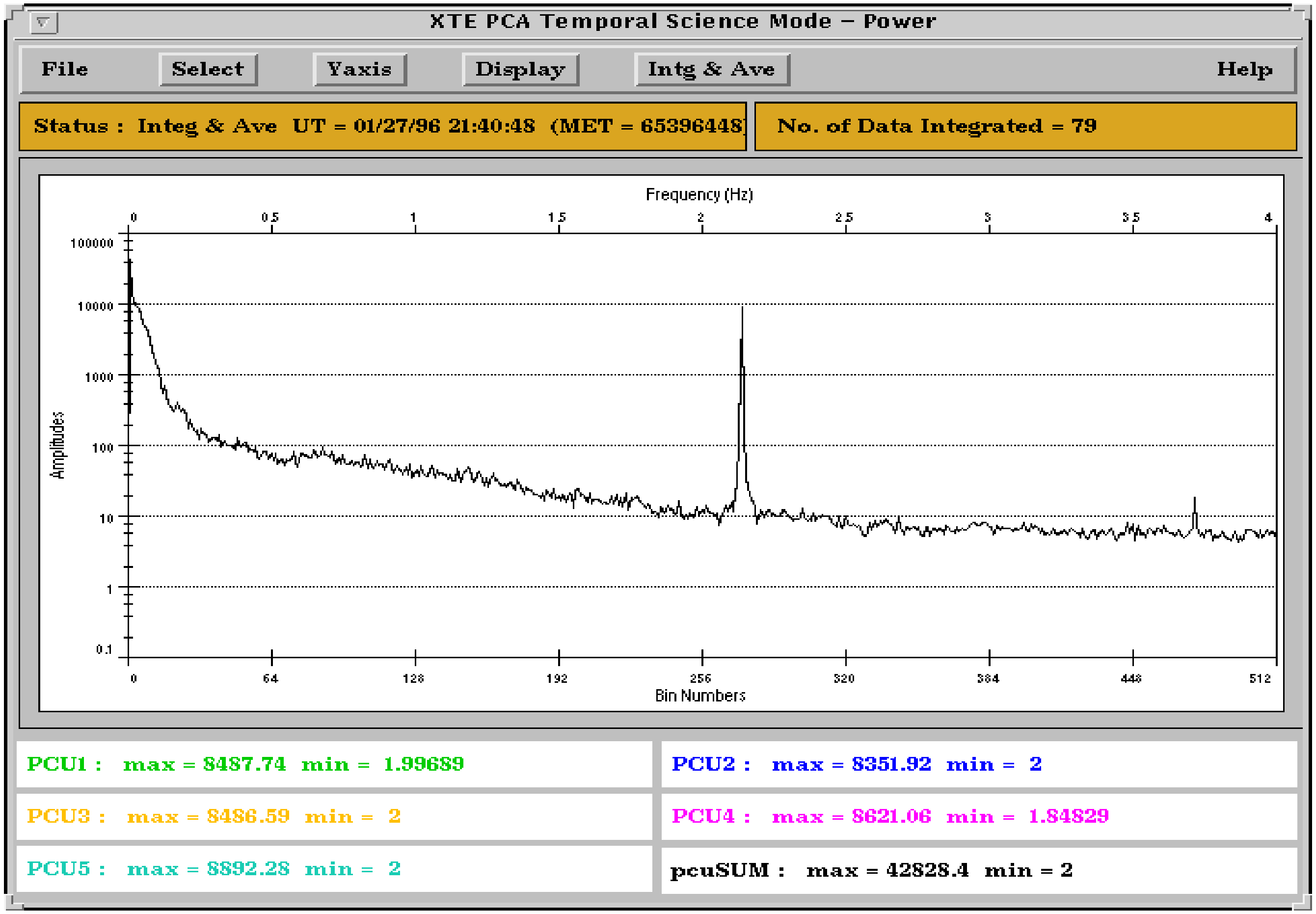
Light curve temporal options. Top 0.125 sec data bins, Bottom 16 sec data bins.





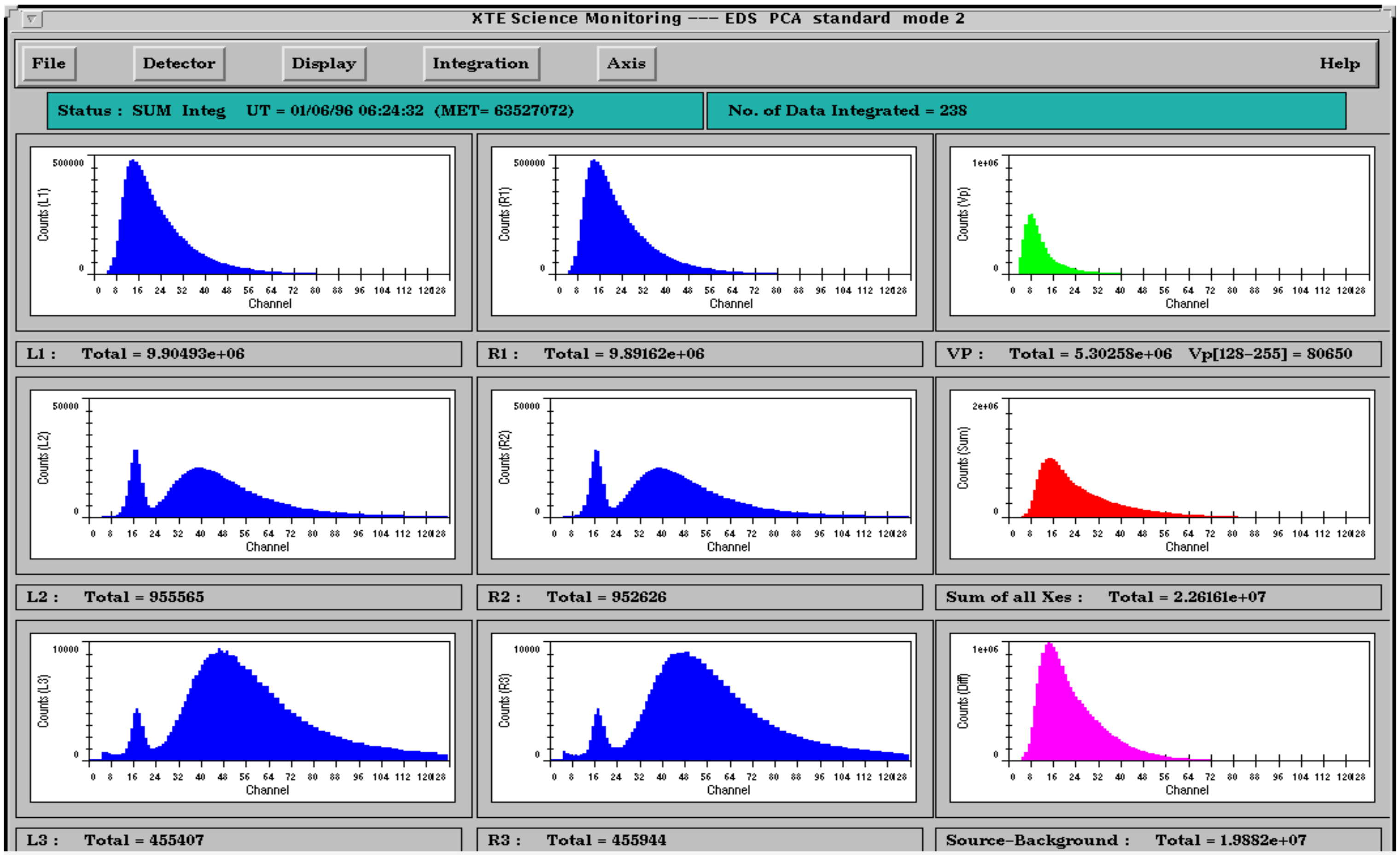
Standard Mode 1 - Power Spectrum (GRO J1744-28)

An integrated power spectrum of the new bursting pulsar. Note the huge sinusoidal power at a frequency of ~2.14 Hz. The small peak to the right is a harmonic (reflected). The low frequency power is due to a large burst like those shown on page 10.



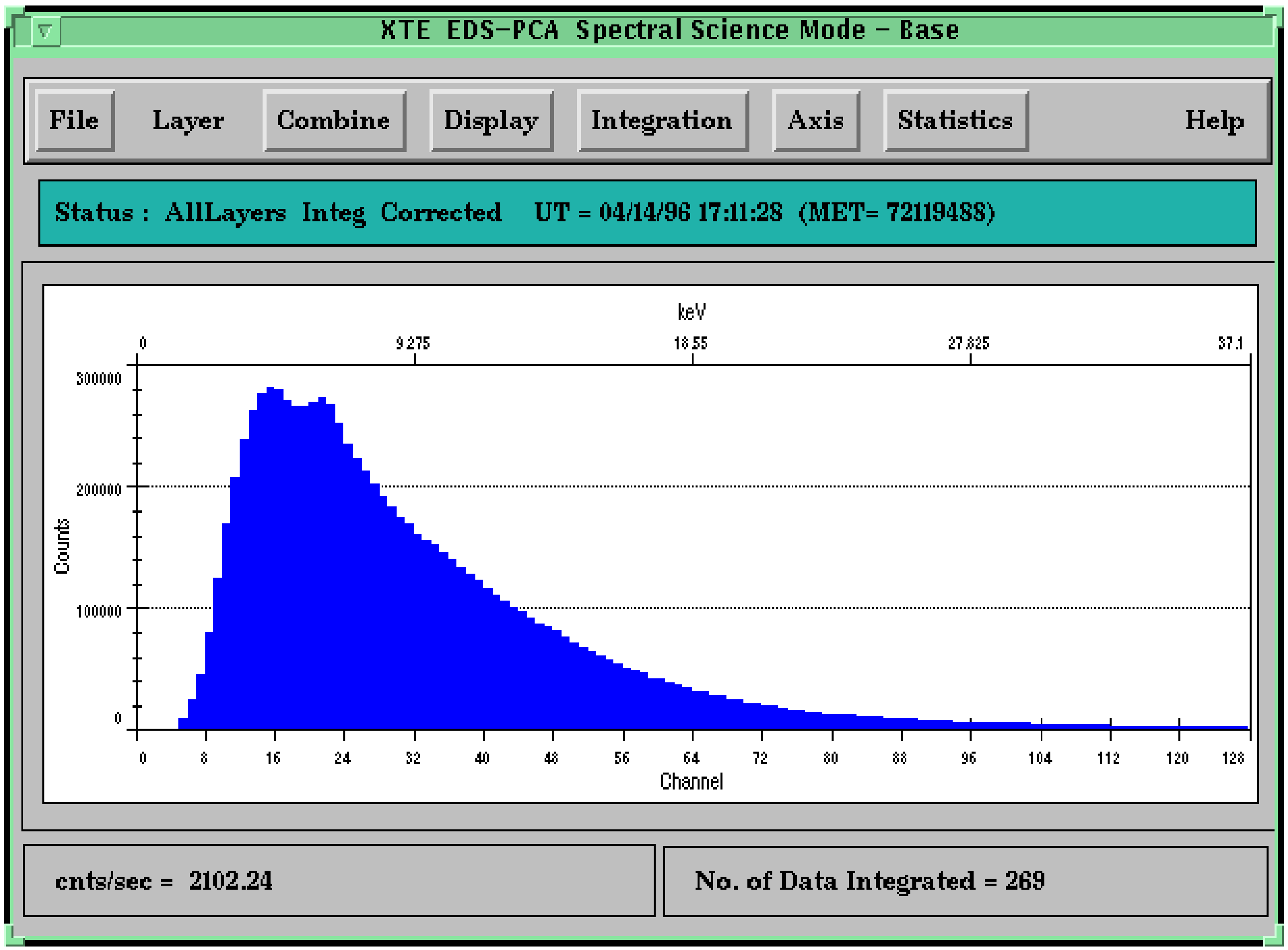
Standard Mode 2 - Spectra (Crab)

An integrated spectrum of the Crab for PCU's 1-5. The X axis has been "zoomed" to ~32 keV. The lower right box shows a crude source minus background difference [L1+R1+L2 +R2 - 2x(L3+R3)]. The sharp peak in L2, R2, L3 & R3 is a Xenon L escape feature.



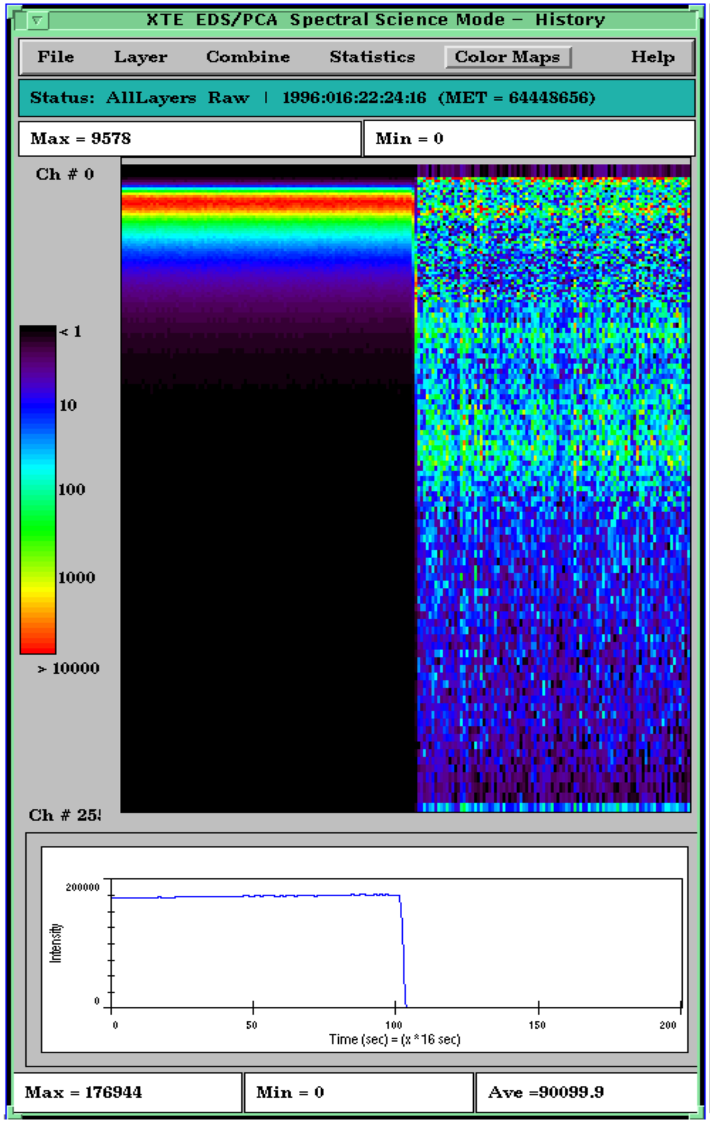
Spectral Science - Base (GRO J1744-28)

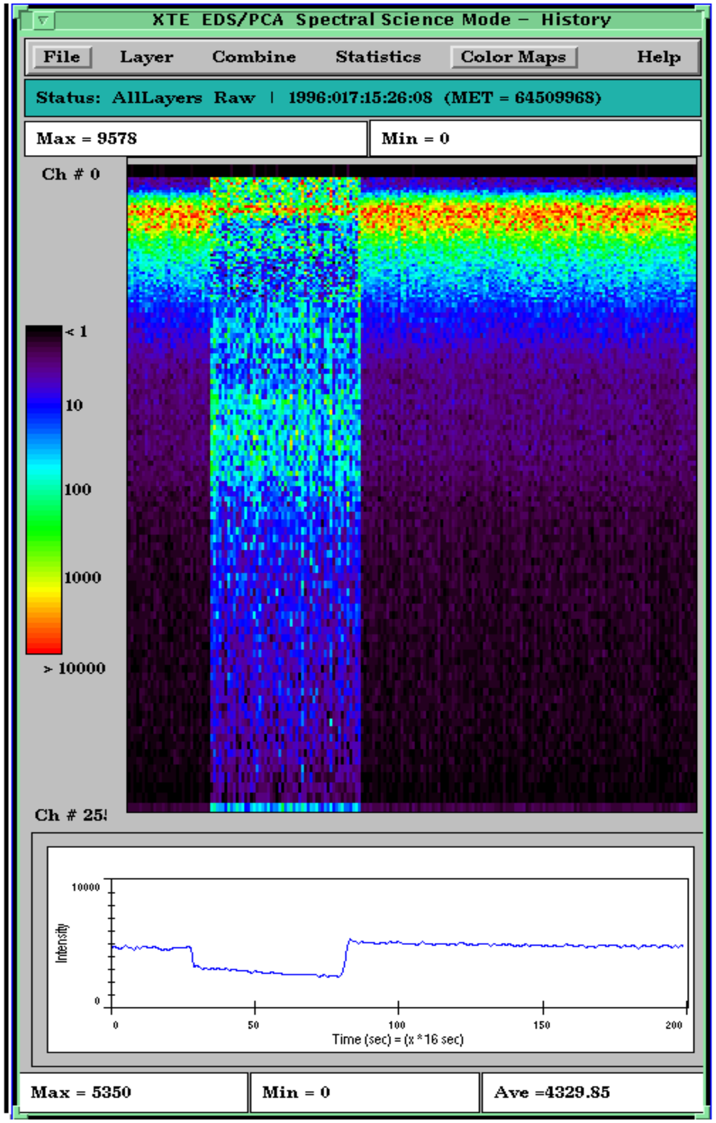
An integrated spectrum of GRO J1744-28 for PCU's 1-5. This mode is used as the "base" for several other display modes. The spectrum is dominated by the front layer L1 & R1 signals and the X axis is again "zoomed" (~37 keV). The PCU's have been gain corrected and a keV scale added. Note the emission feature.



Spectral Science - History (Crab, Earth, NGC4151)

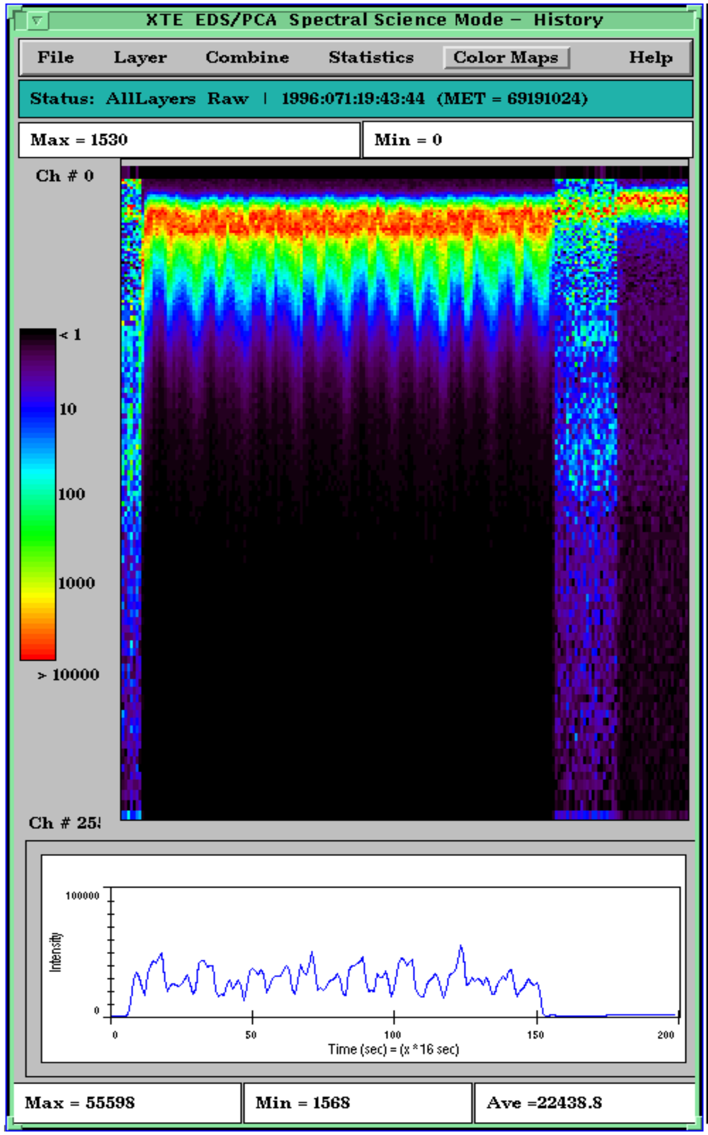
Incoming 16 second spectral stripes have been height color coded. Low keV at top.

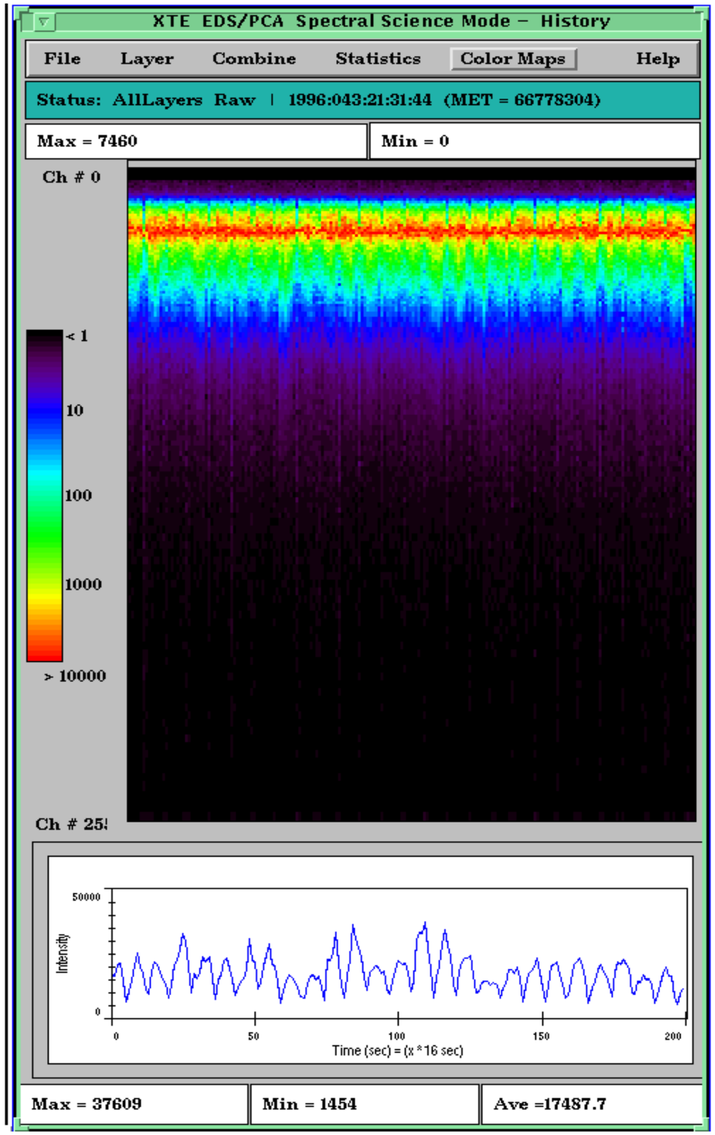




Spectral Science - History (Vela X-1, Sky, GX1+4)

The height is auto scaling (to red) to show low rate Earth occult / Sky data periods.





Acknowledgments

The design of these software systems has benefited from much comment and input from my fellow scientists in the PCA Instrument Team. The actual subsystem coding for HS has been written by Ramesh Ponneganti & Vikram Savkoor, for CG & MM by Vikram Savkoor and for SM by Hwa-Ja Rhee. All these programmers are with the Hughes STX Corporation working under contract at GSFC. David Hon, also with STX but located with the main SOF programming team, has provided the real time client interface to the SOF system.

I thank Thomas Prince for permission to display the data on Vela X-1 and Richard Klein, Garrett Jernigan & Jon Arons for permission to display the data on GX1+4

The entire EDS system is the responsibility of MIT and they have provided us with code to unpack data packets for a few of their many Event Analyzer modes.

References

1st XTE NRA, release January, 1995. The Technical Appendix has many chapters provided by the IT's on their respective experiments.

X-ray Timing Explorer - Instrument Operations User's Guide, Ver. 1.0, May 1995.

PCA Science Monitoring, Design Concepts, Screen Functions, User SOC Interface, Barry Giles, V6.1, Dec 5th 1995.

PCA Science Monitoring User's Guide, Hwa-Ja Rhee, V4.1.1, August 1995.