Astronomical Data Analysis Software and Systems IV
ASP Conference Series, Vol. 77, 1995
R. A. Shaw, H. E. Payne, and J. J. E. Hayes, eds.

Reformatting the Ginga Database to FITS and the Creation of a Data Products Archive

R. H. D. Corbet[1], C. Larkin

Pennsylvania State University, 525 Davey Lab., University Park, PA 16802

J. A. Butcher, J. P. Osborne

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH, UK

J. A. Nousek

Pennsylvania State University, 525 Davey Lab., University Park, PA 16802

Abstract. We present status reports on projects to make both raw data and products from the *Ginga* X-ray astronomy satellite available in FITS formats to the general astronomical community.

1. Introduction

The highly successful *Ginga* X-ray mission was developed in a Japanese/British collaboration under the leadership of the Institute of Space and Astronautical Science (ISAS) in Japan. The main Large Area proportional Counter (LAC) detector had a collecting area of approximately 4000 cm^2 and operated for almost 5 years producing approximately 40 GB of data. The data are, however, stored in a highly non-standard format known as FRF (first reduction file) which closely parallels the telemetry stream from the satellite. This seriously hinders the accessibility of these data to the majority of astronomers. We are therefore undertaking a project to convert these data from the FRF format to FITS. The intention is to thereby enable the data to be analyzed using a variety of existing software such as Xanadu, IDL, and PROS.

The FITS converter is based on software developed at Leicester University known as "`sortac`". The details of the FITS formats to be used are still being debated but will be based on existing formats such as the ASCA GIS MPC mode in order to simply the task of analyzing data using existing software. The FITS conversion software is being developed in close collaboration with the HEASARC at the Goddard Space Flight Center which will be responsible for archiving the FITS files and making these data accessible to the astronomical community. In parallel with the data reformatting project, a database of software products

[1]Now NASA/GSFC, Code 666, Greenbelt, MD 20771

(light curves and spectra) is being produced at Leicester University which will also be made widely available.

2. The Ginga Mission

Ginga was launched on 1987 February 5 and remained operational until reentry on 1991 November 1. The two X-ray detectors carried were a large area proportional counter (LAC) with approximately 4000 cm^2 collecting area (Makino 1987) and an all sky monitor (ASM). The LAC (Turner et al. 1989) was developed by ISAS in collaboration with the University of Leicester and the Rutherford Appleton Laboratory in the UK and the University of Tokyo and Nagoya University in Japan. The LAC consisted of eight identical proportional counters and covered the energy range of approximately 1.5 to 30 keV with a field of view of $1^\circ \times 2^\circ$ (FWHM). Background rejection was obtained from several guard counters and anti-coincidence among individual LAC modules.

During operation the LAC observed approximately 350 targets. To date, over 190 papers in refereed journals have been written based on these observations. Notable highlights include the detection of X-rays from SN1987A, the discovery of six new pulsars, the identification of three new black hole candidates, discovery of cyclotron lines in the spectra of several pulsators, and astrophysically important spectral and timing information on a variety of active galaxies.

The ASM (Tsunemi et al. 1989) collected data typically once per day when *Ginga* executed a 360° rotation. Long term light curves for a large number of bright X-ray sources were thus produced. However, our project does not include the archiving of these data.

The *Ginga* data set totals 40 GB. To date, the principal means of access by US astronomers has been the *Sirius* database system, available only at ISAS. A few investigators from outside Japan and the UK have made use of the *Ginga* data, but this has been limited by the general requirement that U.S. scientists, for example, must undertake the majority of their data reduction in Japan. The *Ginga* data sets provide an opportunity to cross-compare with data from other satellites, but due to the accessibility difficulties, the existing data have not yet been fully exploited.

3. Data Products Archive

The *Ginga* data archive at Leicester is currently held in FRF form, and guest investigators visiting Leicester are supported in their analysis of *Ginga* data on DEC Alpha workstations running OSF. The existing *Ginga* data analysis software at Leicester is being used to produce a products database of spectra and lightcurves. A spectrum and lightcurves in two colors will be available for each observation. The lightcurves will be at the lowest time resolution for each data mode (e.g., 16 s for MPC1 data).

The products will be cleaned and background subtracted. Stringent cleaning criteria and quality control will be applied and a quality assessment will be provided. Background subtraction of *Ginga* observations is not a trivial process. The LAC had no facility for simultaneous background measurement and backgrounds for source observations have to be reconstructed from contemporaneous blank sky observations or from a more general model. Fluctuations in the diffuse X-ray background can, however, cause significant problems. Wherever possible, the products database will provide products produced with the two different methods of background determination to provide the user with an estimate of the importance of these systematic effects.

To ensure maximum utility of the products database, we intend that users will be able to extract spectra from different time intervals. Thus, although access to the raw data will be required to answer detailed questions, the non-expert user, and users requiring answers to basic questions, will not need to go back to the raw data.

The data products will be written in OGIP FITS format and will be made available through the Leicester Data Archive Service (LEDAS), which incorporates the HEASARC BROWSE database system. In this way they will be easily accessible over the Internet. The raw FRF data are now held in a CD-ROM jukebox, and will very shortly also be available over the net to expert users (until the FITS-converted data become available). Up to date information on the status of the *Ginga* products archive project can be obtained via the LEDAS[1] World Wide Web home page.

4. Reformatting to FITS

To minimize the amount of code that needs to be written the FITS reformatter takes *sortac* as the starting point. In parallel with creating hypercube format data products, the output routines are being rewritten to write FITS files as well. These routines make heavy use of the FITSIO library written by Pence (1992). The status of the *sortac* modifications is that header information is now written to FITS files and we have created a parameter file interface (cf. IRAF parameter files and the ASCA reformatter) which facilitates running in batch mode.

Science information will be stored in a binary table extension similar to that used with ASCA (cf. Corbet et al. 1992). The precise FITS formats will be defined in close collaboration with a project to reformat the HEAO-1 data base to ensure maximum compatibility. It has not yet been decided whether to store house keeping information as separate files or as separate extensions within science files. It is expected that the FITS creation software will be run once on the entire *Ginga* data set. The resulting FITS files will then be made available to the community by the HEASARC[2] at the Goddard Space Flight Center.

The *Ginga* LAC could be operated in several modes. These made trade-offs between time resolution and detector information (which affects the accuracy with which spectra can be measured). The FITS formats for the various modes will be similar, with the principal difference being the number of columns in the binary tables.

[1] http://darc-www.star.le.ac.uk/public

[2] http://heasarc.gsfc.nasa.gov/

MPC1 mode: mainly used for spectral studies of faint sources. Events are accumulated in sixteen separate spectra of 48 channels each. The sixteen spectra comprise the top and middle layers from each of the 8 detectors. The separation of top and middle layers improves the signal to noise ratio for weak sources and helps the background estimation.

MPC2 mode: provides compression of data by a factor of eight enabling better time resolution. Combines top and middle layers from four detectors into one and gives two separate spectra. The combination of layers decreases the signal to noise ratio and background estimation is less precise.

MPC3 mode: carries the process further by combining the 48 energy channels into twelve and grouping all eight detectors together, giving a further factor of eight compression.

PC mode: used for timing studies; it by-passes the ADC to avoid dead time effects. Signals are divided into two energy bands by three discriminators (lower, middle and upper) and no other energy information is retained. In this way the dead time is reduced to 16.5μs/event and time resolution down to 976.6μs ($= 1/1024$) is obtained from two energy bands per detector group. The lower discriminator is the same as that used for the pulse height spectra, while the other two discriminators have two commandable levels.

5. Other Tools

In addition to the reformatting work tools will be required to make the *Ginga* data useful to astronomers. The main additional software that is required is: (1) Response matrix generator, and (2) Background subtraction. It is envisaged that these will be provided as "FTOOLS" (e.g., Pence et al. 1993). Response matrix generation has already been implemented by K. Ebisawa for use with XSPEC and it is expected that this software will be converted to an FTOOL. Background subtraction for *Ginga* is either done making use of source free regions of sky observed close to the target or by making use of relations between parameters such guard counter rates, time since SAA-passage and other factors which are correlated with the non-X-ray background (e.g., Hayashida et al. 1989).

Acknowledgments. This work is funded in part by NASA contract NAS5–32489.

References

Corbet, R. H. D., Larkin, C., & Nousek, J. A. 1992, in Astronomical Data Analysis Software and Systems I, ASP Conf. Ser., Vol. 25, eds. D. M. Worrall, C. Biemesderfer, & J. Barnes (San Francisco, ASP), p. 106

Hayashida, K., et al. 1989, PASJ, 41, 345

Makino, F., and the Astro-C Team 1987, Astrophys. Let. Commun., 25, 223

Pence, W. D. 1992, in Astronomical Data Analysis Software and Systems I, ASP Conf. Ser., Vol. 25, eds. D. M. Worrall, C. Biemesderfer, & J. Barnes (San Francisco, ASP), p. 22

Pence, W., Blackburn, J. K., & Greene, E. 1993, in Astronomical Data Analysis Software and Systems II, ASP Conf. Ser., Vol. 52, eds. R. J. Hanisch, R. J. V. Brissenden, & J. Barnes (San Francisco, ASP), p. 541

Tsunemi, K., et al. 1989, PASJ, 41, 373

Turner, M. J. L., et al. 1989, PASJ, 41, 739