RESIDENT ARCHIVE SERVICES OF THE YOHKOH LEGACY DATA ARCHIVE

A. Takeda[1]*, L. Acton[1], D. McKenzie[1], K. Yoshimura[1], and S. Freeland[2]

*[*1]Department of Physics, Montana State University, Bozeman, MT 59717, USA*
Email: takeda@solar.physics.montana.edu
[2]Lockheed-Martin Solar and Astrophysics Laboratory, 3251 Hanover Street, Palo Alto, CA 94304, USA

ABSTRACT

The Yohkoh Legacy Data Archive (YLA) is one of the first group of Resident Archives (RAs) selected for funding for NASA's Virtual Observatories for the Heliophysics Data program. YLA provides the best corrected data set of solar X-ray images and spectra from the Yohkoh satellite with a user-friendly web interface. As a RA, we take responsibility to keep our products well maintained and easily accessible. In addition, we have launched the 'E-consultant service', an e-mail based support to individual users regarding data handling to bolster access and use from a wide range of communities.

Keywords: Resident Archive, Virtual Observatories, Yohkoh, Yohkoh Legacy Data Archive, YLA, Solar corona, X-ray images

1 THE YOHKOH MISSION

Yohkoh is a Japan/US/UK space mission investigating high-energy phenomena in the solar corona. Yohkoh was in operation for more than ten years (September 1991 through December 2001), which covered almost an entire solar activity cycle. Yohkoh carried four scientific instruments: Soft X-ray Telescope (SXT), Hard X-ray Telescope (HXT), Bragg Crystal Spectrometer (BCS), and Wide Band Spectrometer (WBS). Technical details of those instruments are found in the following papers; Tsuneta, et al., 1991, Kosugi, et al., 1991, Culhane, et al., 1991, and Yoshimori, et al., 1991. Yohkoh brought considerable progress in understanding the dynamic aspects of the solar corona by:

- Discovering new active phenomena, e.g. transient brightenings (Shimizu, et al., 1994), X-ray jets (Shimojo, et al., 1996), and sigmoid eruptions (Canfield, et al., 1999).
- Confirming magnetic reconnection as the fundamental mechanism of energy release in flares by revealing evidence such as cusp-shaped loops (Tsuneta, 1996), separate hard-X-ray and soft-X-ray sources (Masuda, et al., 1994), X-ray plasmoids (Ohyama & Shibata, 1998), supra arcade structures (McKenzie & Hudson, 2001), and velocity fields (Culhane, et al., 1994).

Yohkoh data are valuable as a steady source of coronal images over the whole solar cycle. In particular, due to the fact that Yohkoh was the only coronal imager in orbit in the early 1990s, the data for this period are unique and invaluable. The data processing environment developed for the Yohkoh project forms the foundation of the current data handling system, integrated as SolarSoft in the Interactive Data Language (IDL) and widely used in the solar physics community.

2 THE YOHKOH LEGACY DATA ARCHIVE

The Yohkoh Legacy Data Archive project was kicked off in July 2002, with the following founding philosophy: *Provide a fully-calibrated archive of the Yohkoh mission data, with easy access, so that any scientist can perform reliable analysis even when removed by distance and time from the core team of `Yohkoh experts`.*

The main feature of YLA is the improved quality of the soft X-ray images and high accumulation of value-added products and documentation:

Table 1. Basic data of the Yohkoh Legacy Data Archive.

SXT products :	
Level_0	weekly files in XDA format
Level_1	corrected data in XDA and FITS formats
Level_2	scientific composites (XDA, FITS), browse (movie) images (FITS), aspect sensor (white light) corrected movie images (FITS), synoptic maps.
HXT, WBS, and BCS products :	
Level_0	weekly files in XDA format
Level_1	N/A
Level_2	flare catalogs in HTML and ASCII formats
Documents :	operation reports, calibration notes, analysis guides, the Science Nuggets, operational procedures, SXT observation tables.
User interface :	data search (YLA, VSO), SXT Movie Maker, SXT Quick Look, observing log inquiry.
Web URL :	http://solar.physics.montana.edu/ylegacy

1. Providing corrected data sets: We classify our products into three types, i.e., levels 0, 1, and 2. Level_0 data are those of the most basic level, essentially reformatted raw telemetry data. Level_1 data are the best corrected version of level_0 data. The further processed products, e.g., composite images, synoptic maps, and event catalogs, are classified as level_2. Table 1 is a summary of the contents of the YLA as of December 2008. During more than ten years of operation, Yohkoh had trouble in the SXT entrance filter and satellite attitude control system. The former caused a significant increase in stray light level, while the latter caused alignment and roll problems in SXT images. We have spent much time correcting those effects and improving the quality of our images. A part of these efforts is still in progress.

2. Providing FITS files as well as the Yohkoh original format: Yohkoh data handling has long depended on the specific data format called XDA, which requires IDL software to handle. However, the FITS format is now commonly used in many solar projects after Yohkoh. Providing FITS data therefore gives a common basis with recent data and improves manageability and accessibility of our products.

3. Developing a user-friendly web interface: We set up our web interface on a domain of Montana State University, Department of Physics. Figure 1 shows the top page of our archive. We developed our own data search system, in which users can access by specifying the observed time range and optional parameters. YLA has had linkage with the Virtual Solar Observatory (VSO) since 2005. Our level_0 and level_1 products are accessed through the VSO data search, while the accommodation of level_2 data to VSO is now in preparation. A quick-look service of our daily observation is available as SXT Quick Look (see Figure 2). We also provide a web interface for creating customized movies called the SXT Movie Maker.

4. Accumulating value-added data and documents: Examples of our value-added products are our two kinds of flare catalogs. One is for the events detected with HXT/WBS instruments, and the other is for flares detected with the BCS instrument (see Figure 3). The processing of the former catalog was initiated by the former HXT group in Japan (Sato, et al., 2006), while the latter is the contribution of the former BCS group in the UK. Our documentation archive is rich in both amount and quality. It ranges from records of daily operation to short scientific articles.

The major part of the work has been achieved at Montana State University, with technical support from Lockheed Martin Solar and Astrophysics Laboratory. As already demonstrated in the above, we have data contributions from the former Yohkoh teams in Japan and the UK and in some cases from individual researchers.

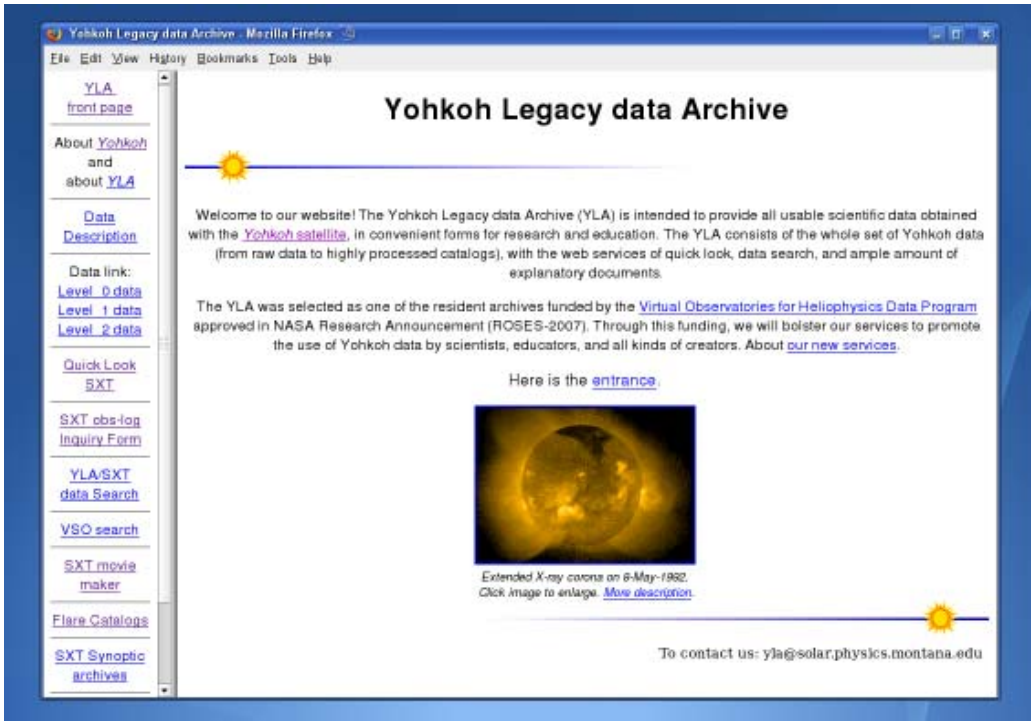

Figure 1. The front page of the Yohkoh Legacy Data Archive web interface. The URL is http://solar.physics.montana.edu/ylegacy.

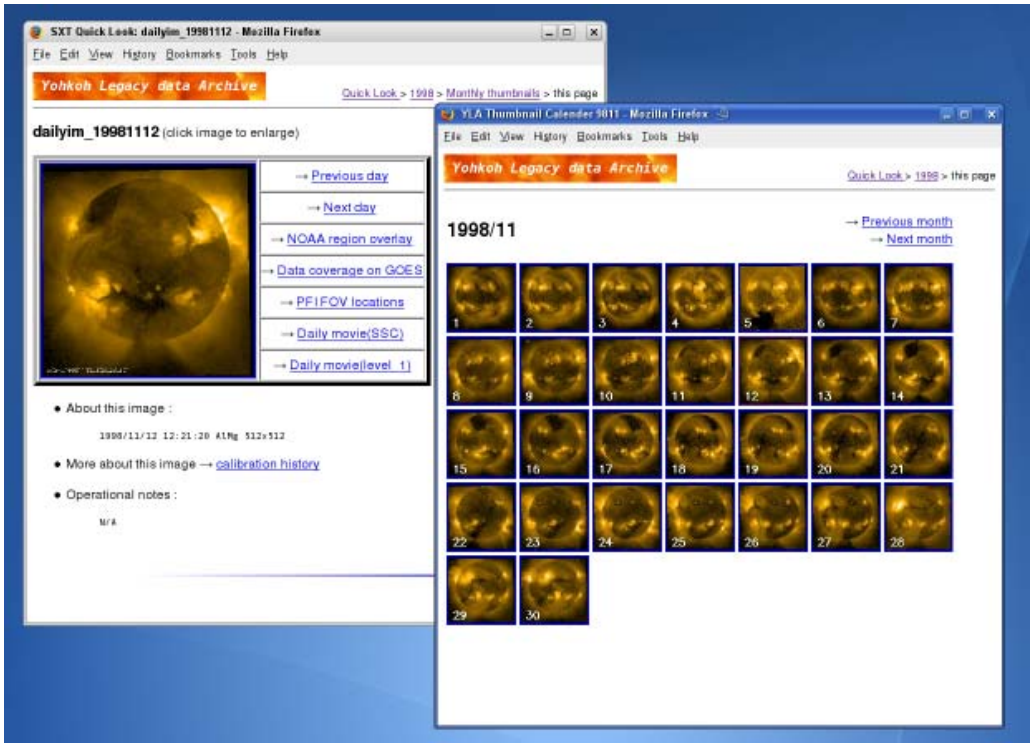

Figure 2. Sample pages from the SXT Quick Look service: a daily page (left) and a clickable monthly thumbnail images (right).

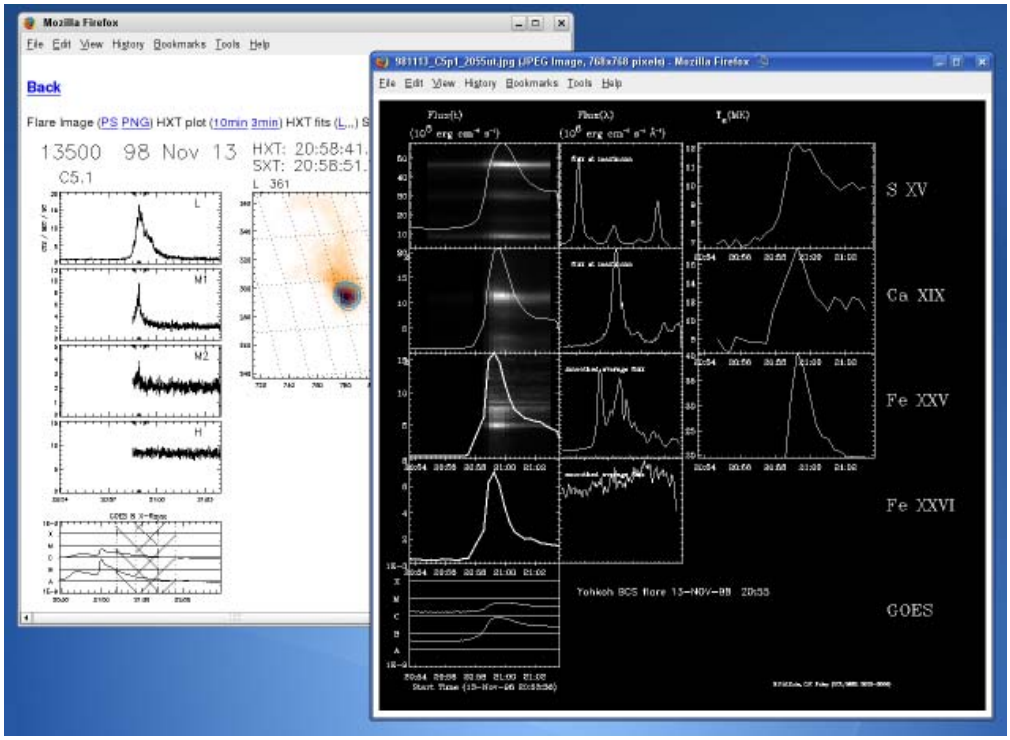

Figure 3. Sample pages of our flare catalogs: from the HXT/WBS flare catalog (left) and from the BCS flare catalog (right).

3 RESIDENT ARCHIVE SERVICES

The Resident Archive is a new category of archives defined in NASA's Helio Physics Data Environment (HPDE) beginning in 2007 (Fisher, 2007). Placed between Mission Archives and Final Archives, Resident Archives will provide continued access and maintenance to post-mission data products, with optional expert support to users. In 2008, YLA was selected for funding as one of the resident archives for HPDE's Virtual Observatories for the Heliophysics (VxO) Data Program. Our proposed tasks as one of the resident archives are as follows.

1. Keep our products well maintained and avoid permanent loss.
2. Provide convenient and comfortable access to users.
3. Provide users with individual assistance for accessing and handling data (E-consultant service).
4. Enhance the connection with the Virtual Solar Observatory (VSO) data search.
5. Improve analysis software, mainly to accommodate FITS users.
6. Prepare a `transplant package` of our products for any group or individual who would like to have it.

Our greatest emphasis here is the E-consultant service. This service is provided as an effort to promote the use of our products. In analogy with pharmacists at a drug store, we will assist users when they need support. We provide consultation through e-mail, via our contact address, yla@solar.physics.montana.edu. We will keep this service for at least two years beyond fiscal year 2009 or as long as funded.

We are delighted to kick off our new services concurrently with the two anniversaries related to geo- and astro-physics: fifty years after the International Geophysical Year (1957-1958) and four hundred years after the first use of an astronomical telescope by Galileo Galillei in 1609 (celebrated as the International Year of Astronomy in 2009).

Through the good maintenance and support services as a resident archive, we ambitiously aim to ensure the usefulness of the Yohkoh data over decades or even centuries, similar in spirit to the enduring accessibility and utility of the sunspot data recorded by Galillei in the 17th century. Although YLA is designed primarily to serve

the solar and terrestrial physics communities, many of our products are suitable for public use. Access from a wide range of communities is greatly encouraged.

4 REFERENCES

Canfield, R.C., Hudson, H.S., & McKenzie, D.E., (1999) Sigmoidal Morphology and Eruptive Solar Activity, *Geophysics Research Letters* 26, 627-630.

Culhane, J.L., Hiei, E., Doschek, G.A., & et al., (1991) The Bragg Crystal Spectrometer for Solar-A, *Solar Physics* 136, 89-104.

Culhane, J.L., Phillips, A.T., Inda-Koide, M., & et al., (1994) YOHKOH observations of the creation of high-temperature plasma in the flare of 16 December 1991, *Solar Physics* 153, 307-336.

Fisher, R.R., (2007) NASA Heliophysics Science Data Management Policy, Retrieved December 19, 2008 from the World Wide Web: http://hpde.gsfc.nasa.gov/HPDP.html .

Freeland, S.L., (2000) SolarSoft, Retrieved December 19, 2008 from the World Wide Web: http://www.lmsal.com/solarsoft/sswdoc/index_menu.html.

Kosugi, T., Makishima, K., Murakami, T., & et al., (1991) The Hard X-ray Telescope for the Solar-A Mission, *Solar Physics* 136, 17-36.

Masuda, S., Kosugi, T., Hara, H., Tsuneta, S., & Ogawara Y., (1994) A Loop-Top Hard X-ray Source in a Compact Solar Flare as Evidence for Magnetic Reconnection, *Nature* 371/6497, 495-497.

McKenzie, D.E., & Hudson, H.S., (2001) Downflows and Structure above LDE Arcades: Possible Signatures of Reconnection?, *Proceedings of The University of Tokyo Symposium in 2000 on Magnetic Reconnection in Space and Laboratory Plasmas*, M. Hoshino, R. L. Stenzel, and K. Shibata, eds., Earth Planets Space 53, 577-580.

Ohyama, M., & Shibata, K., (1998) X-Ray Plasma Ejection Associated with an Impulsive Flare on 1992 October 5: Physical Conditions of X-Ray Plasma Ejection, *Astrophysical Journal* 499, 934-944.

Sato, J., Matsumoto, Y., Yoshimura, K., & et al. (2006) YOHKOH/WBS Recalibration and a Comprehensive Catalogue of Solar Flares Observed by YOHKOH SXT, HXT and WBS Instruments, *Solar Physics* 236, 351-368.

Shimizu, T., Tsuneta, S., Acton, L.W., Lemen, J.R., Ogawara, Y., & Uchida, Y., (1994) Morphology of Active Region Transient Brightenings with the YOHKOH Soft X-ray Telescope, *Astrophysical Journal* 422, 906-911.

Shimojo, M., Hashimoto, S., Shibata, K., Hirayama, T., Hudson, H.S., & Acton, L.W., (1996) Statistical Study of Solar X-Ray Jets Observed with the YOHKOH Soft X-Ray Telescope, *Publ. of the Astronomical Society of Japan*, 48, 123-136.

Tsuneta, S., Acton, L.W., Bruner, M.E., & et al., (1991) The Soft X-ray Telescope for the Solar-A Mission, *Solar Physics* 136, 37-67.

Tsuneta S., (1996) Structure and Dynamics of Magnetic Reconnection in a Solar Flare, *Astrophysical Journal* 456, 840-849.

Yoshimori, M., Okudaira, K., Hirasima, Y., & et al., (1991) The Wide Band Spectrometer on the Solar-A, *Solar Physics* 136, 69-88.

(Article history: Received 2 January 2009, Accepted 25 May 2009, Available online 6 June 2009)