RHESSI

Reuven Ramaty High Energy Spectroscopic Imager

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Mission Archive Plan

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1. Mission Overview

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1.1 Science Objectives

The primary scientific objective of RHESSI is to understand particle acceleration and explosive energy release at the Sun using high-resolution imaging spectroscopy of solar flare X-rays and gamma-rays.

1.2 Instrumentation Overview

RHESSI was launched in February 2002 into a ~600 km circular orbit. The spacecraft rotates at ~15 rpm about an axis that normally points at the Sun. RHESSI's single instrument performs high-resolution imaging spectroscopy at hard X-ray and gamma-ray energies from 3 keV to 15 MeV with spectral resolution of ~1 keV, and spatial resolution down to 2.3 arcsec. The imager is comprised of nine Rotating Modulation Collimators (RMCs), each consisting of a pair of widely separated grids which time-modulate the X-ray flux detected by a corresponding set of nine mechanically cooled germanium detectors (GeDs), one behind each RMC. Each GeD is electrically divided into independent front and rear segments to optimize the response to low- and high-energy photons, respectively. As the spacecraft rotates, the RMCs transmit a time-modulated fraction of the incident flux with imaging information encoded as rapid time-variations in the observed count rates. Telemetry includes the precise arrival time and energy of each detected photon and high-cadence pitch-yaw aspect information from a Solar Aspect System (SAS) and roll aspect from two redundant side-looking star scanners (PMTRAS and RAS). SAS data are also used for high-precision measurements of the solar radius as a function of position angle and time. The detectors are unshielded so that transient non-solar phenomena such as gamma-ray bursts and terrestrial gamma-ray flashes are observed and scientifically exploited.

A full description of the instrumentation can be found in Lin et al. (2002) and references therein.

1.3 Operations Overview

RHESSI operations are largely autonomous with data acquisition on an 85% duty cycle. The remaining 15% corresponds to passages through the South Atlantic Anomaly during which science data acquisition is suspended. Operationally, the only difference between day and night is the nighttime absence of SAS aspect data and (optionally) of front-segment detector data.

The spacecraft is pointed a few degrees off the Sun for observations of the Crab Nebula for a few days once a year. During solar minimum, offpointing by ~1 degree is also commanded a few times per year in support of special quiet Sun observing campaigns. Solar flares are not well observed during offpointing observations.

Spacecraft operations are centered at the Missions Operations Center (MOC) at the Space Science Lab, University of California, Berkeley. Although largely automated, operations require a routine daily command upload containing the telemetry schedule and occasional adjustments to instrument parameters. This includes changes to the individual detector high voltages and the selection of one of several preset decimation modes in order to match memory usage to current levels of solar activity and/or downlink availability. To accommodate the large dynamic range in flare intensity, one or two X-ray attenuators are automatically inserted between the lower grids and detectors when the count rates exceed preset levels. As an additional measure during large flares, on-board instrument logic applies increasingly stringent energy criteria (decimation modes) to favor the retention of high-energy photons, along with an unbiased subset of the more numerous low-energy photons.

1.4 Data Acquisition Overview

The primary science data are returned in event data packets in the VC3 data stream. The contents of these packets include the time, energy and detector-segment identification for each event. Aspect data from SAS are provided with sufficient time resolution that the instantaneous aspect associated with each detected event can be inferred. The instantaneous roll aspect can be determined from one of two redundant side-looking star scanners (PMTRAS or RAS). The former is used for most analysis although its data are included in the VC1 rather than the VC3 data stream. In all cases, Monitor Rates with lower time resolution are available to provide an overview of detector performance.

Data acquisition averages about 2 GBytes per day and is based on a store-and-dump system using a 4 Gbyte on-board memory. There are typically ~11 prescheduled downlink passes per day, half of which use the Berkeley Ground Station (BGS), adjacent to the MOC. The other half uses the NASA Wallops Ground Station (WGS). Additional telemetry support is provided by ground stations at Waldheim Germany and Santiago, Chile (AGO).

The received telemetry is automatically converted to FITS files and made available online for scientific analysis along with catalog data products (described below) within an hour of receipt at the MOC.

2.0 Current RHESSI Data Archive, Software and Documentation

2.1 RHESSI Data Archive

The current RHESSI data archive contains the full Level-0 telemetry data, the RHESSI flare list, and a number of quicklook (or catalog) data products including mission-long light curves, flare spectra, and images, and summaries of housekeeping data. The full archive (~4.5 TB as of February 2008) resides on servers at SSL and is automatically mirrored at GSFC and the HESSI Experimental Data Center (HEDC) at ETHZ, Zurich. It is online and accessible by anyone with an Internet connection.

The Level-0 data files contain the full raw telemetry data in packed time-ordered format. All of the quicklook product generation and detailed analyses of RHESSI data start with the Level-0 files. These files are in FITS format and usually cover an orbit (~1.5 hours), but during periods of high activity are limited to ~110 MB each. The files are contiguous in time and contain the data for all times, day and night, whether quiet or during a flare. The files contain

- Science data - packed 4-byte 'photon-tagged events' that encode the detector ID, arrival time, and energy for each detector count,
- Monitor rates - one-second readouts showing detector status and environment,
- Solar aspect system and roll aspect system data, and
- Housekeeping data – voltages, temperatures, and general state-of-health measurements.

Even though these files are in standard FITS format, they are meaningful only through the RHESSI SSW software due to the complicated unpacking algorithms. The calibration information needed to interpret these data is distributed with and accessed by the analysis software. The entire Level-0 database is currently being backed up into a deep archive at the NSSDC with a latency of a few months. As of February 2008, it contains data through October 2007.

The flare list contains the time, duration, size, and location of >40,000 events automatically identified in the RHESSI data. It also contains flags indicating the quality of the data during the flare, instrument status, possible non-solar origin, orbital status (SAA, night, etc), and reliability of the position information. The full flare list is available in the archive (and viewable through a browser) as one large text file. In addition, monthly flare list files are stored in FITS format, as well as text files for easy direct viewing. The RHESSI software reads the FITS files, automatically merging the monthly files, and provides options for selecting analysis time intervals based on flare parameters.

The quick-look products (QLP) allow the RHESSI observations to be surveyed using near-continuous lightcurves with sample spectra and images for each flare. Also referred to as catalog or summary data, the QLP are created automatically from the Level-0 data using the same software used for higher-level analysis. They are created both as FITS files and browser-viewable image formats such as GIF, PNG, or text files. The FITS files can be read by any FITS file reader, but are most easily read and handled using the RHESSI-provided software. The GIF, PNG and text files can be read by any web browser.
The FITS QLPs include:

- Daily observing summary data files – pre-binned data from the Level-0 files. From these files, analysts can quickly generate plots of the following quantities for any time period:
    - spin-averaged, 4-second resolution count rates averaged over all nine detectors, binned into nine standard energy bands covering the range from 3 keV to 20 MeV,
    - spacecraft ephemeris, roll period, and roll angle every 20 seconds,
    - pointing location every 4 seconds, and
    - modulation variance every 4 seconds.
- Spectrum and image FITS files for most flares. Images at the peak time of the flare are generated in several energy bands, and the spectrum for the flare time is analyzed with approximately 1-minute time resolution. The results are stored in FITS files. Users can read the image and spectrum FITS files and display or analyze them further. However, these quick-look products are generated autonomously using parameters optimized for most flares, so are intended to be used only as a starting point. Detailed analysis of a flare is usually done using the Level-0 data, where the user can select the times, energies, detectors, etc. that are best suited to the scientific objectives and the event under study.

The prepared plots are online in the archive and can be viewed directly by accessing the archive metadata directories, or more easily through the versatile RHESSI Quick-Look Browser at http://sprg.ssl.berkeley.edu/~tohban/browser/. The Quick-Look Browser allows users to display more than 20 different products for a selected time or flare, and easily navigate in time by day, orbit, or flare. The currently available quick-look plots are listed below.

- Prepared lightcurves generated from the observing summary data files for every orbit (~ 1.5 hours) of the mission are available as PNG files. Two versions of these plots have been generated – one showing the measured count rate, and one showing ‘corrected’ count rate (includes an approximate correction for the changes in attenuator and decimation state).
- Images and spectra in PNG files for most flares, created from the quick-look spectrum and image FITS files described above.
- GOES lightcurves with RHESSI observing time intervals overlaid.
- Various Monitor rates for the front and rear detectors.
- Stacked plots of GOES and RHESSI lightcurves and WIND/WAVES and WIND/3DP spectrograms all on the same time axis.

In addition, RHESSI housekeeping data for the entire mission are available in the archive and can be accessed at http://hessi.ssl.berkeley.edu/hessidata/metadata/hsi_1day_sohdata/.
Text files and GIF plots provide a record of the average daily values for ~100 state-of-health parameters including spacecraft bus voltages and currents, imager aspect sensor parameters, spectrometer cryocooler power and temperature, and more.

Access to the data archive is almost transparent. Users located at a site hosting the full data archive (Goddard, Berkeley, or ETHZ) share the data directories from a local file server. Remote users set a feature in the software to enable network searching and copying of files from an archive to their own computer. In either case, the software automatically determines the files needed for the selected time interval and after either sharing or copying them, reads them and retrieves the requested data for processing.

Another, separate, extensive source of quick-look products is an archive at the Swiss-funded HESSI Experimental Data Center at ETHZ in Zurich - http://www.hedc.ethz.ch/www/quick_dp_search.html. It provides a large array of pre-processed images, spectra, spectrograms, and more for each RHESSI flare.

2.2 Software

Almost all the RHESSI software package (Schwartz et al. 2002) is written in Interactive Data Language (IDL licensed from ITT Visual Data Solutions). It contains all procedures necessary to read and unpack the FITS data files, prepare and plot light curves, reconstruct images, and accumulate, display, and analyze spectra. Analysis procedures can be invoked from the IDL command line, from user-generated scripts building on these commands, or from a graphical user interface (GUI) that forms a user-friendly shell around the basic analysis routines. The software is fully compatible with both UNIX-like (including Mac OS X) and Windows operating systems and is freely available as part of the Solar Software (SSW) tree.

The RHESSI data analysis software is a robust system that allows any analyst with access to Level-0 files, calibration data, and the QLPs to generate and analyze RHESSI lightcurves, spectra, and images. The available capabilities include the following:

- browsing the RHESSI flare list and making flare selections based on flare parameters,
- generating observing summary (quick-look) lightcurves for any time interval,
- generating spectra and lightcurves from the Level-0 data at any time and energy resolution for any detectors,
- reconstructing images using one of five image reconstruction algorithms (Back Projection, Clean, Maximum Entropy, Forward Fit, and Pixon) for any selection of detectors, any time and energy intervals, and any spatial resolution,
- displaying and manipulating plots in an interactive plot manager (PlotMan) window,
- generating image cubes containing images at multiple time and energy intervals,
- generating movies from image cubes,
- subtracting background and performing spectral analysis on RHESSI data,
- performing feature-based imaging spectroscopy,
- enabling and disabling a variety of software corrections (for decimation, pileup, etc) and options (detector weighting, flat fielding, etc), and
- performing joint analysis of many different observations of the same events by other observatories.

The software can be downloaded to any user's computer as part of the SolarSoft (SSW) installation following instructions provided on the RHESSI web site. The only requirement is that the user has a license for IDL Version 5.6 or higher.

The RHESSI data analysis software is based on object-oriented design concepts. The use of objects has three significant advantages: it provides identical access methods for getting/setting processing options and generating/displaying a wide range of data products; it speeds processing by automatically reusing intermediate products when possible; and the reuse of functional modules within objects simplifies software maintenance.

Analysts use the RHESSI software either by typing commands through IDL's command-line interface (CLI), or by entering the RHESSI graphical user interface (GUI). The CLI offers the full power and flexibility of the tools, while the GUI provides a convenient interface for the more frequently used options. Provision is also made for combined CLI/GUI analyses. For repetitive or computation-intensive tasks, many users find it convenient to combine CLI commands into a batch script to run in the background.

2.3 Documentation and Support

Extensive documentation describing the mission, instrumentation, analysis techniques, software, and data access can be found via a single RHESSI web site: http://hesperia.gsfc.nasa.gov/rhessidatacenter/. Support personnel at SSL, GSFC and ETH are also available to provide guidance as needed in using the software and interpreting the results.

The extensive online RHESSI documentation provides both background and explanatory material on the RHESSI mission, as well as instructions for almost every aspect of the software, from installation through use of the objects and the GUI. Detailed descriptions of every data product and warnings about misinterpreting data are available. There are 'First Steps' instructions for imaging and spectroscopy to guide users through sample GUI sessions. There are also explanations of the use of the objects, the connections between the many intermediate data product objects, and the methods and parameters available for each object. A software FAQ is available to provide solutions to common questions or problems.

There is a dedicated email address (hessibugs@hesperia.gsfc.nasa.gov), monitored by one of the team members, for RHESSI software bug reports and questions. Queries are answered promptly either by the monitor or by core members of the RHESSI group who can be called upon as needed to address more specialized issues. All bug reports and their solutions are archived for user access.

3.0 Plans for Resident Archive and Permanent Archive

3.1 Introduction

In general, the data products, software and documentation discussed in Section 2 will be incorporated into the Resident and Permanent archives. This section emphasizes those tasks related to adapting those data sets to make them effective with a reduced (or eliminated) level of support from the instrument team, and includes a discussion of additional archive material not discussed above.

In broad terms, there are four classes of data products to be provided in the Resident and Permanent Archives:

1. Catalog data, providing basic Level-1 data products with predetermined parameterization to provide an overview of the data and to support relatively undemanding applications;
2. Level-0 plus documented software to provide maximum analysis flexibility;
3. Calibrated visibility data to provide considerable flexibility in time and energy resolution for flare analyses using either a simplified subset of existing software or external analysis packages;
4. Secondary databases to support exploitation of the high-precision solar radius measurements; and to support non-solar analyses.

3.2 Data Products

3.2.1 Catalog Data

The catalog data products serve the needs of those requiring a convenient overview of the data and basic X-ray data products (light curves, representative images, and spectra, etc.). The catalog data to be archived for post-mission use will be similar in form and content to that described in Section 2.1. These data products are being generated on a continuing basis. During the Resident Archive phase, the number of quick look images will be increased to reduce the need for post-mission image reconstruction. Automated tools for creating such products exist. We now outline the specifics of the catalog data products.

The RHESSI Observing Summary contains:

- Light curves, 9 energy bands, ranging from 3 keV to approximately 20 MeV, with 4-second time resolution. Light curves are provided for each detector segment. Light curves corrected for decimation and attenuation will also be provided.
- Pointing (arcseconds from Sun-center) and pointing quality (a measure of the uncertainty in arcseconds) with a few seconds time resolution.
- Roll angle and roll period with 64-second time resolution.
- Data flags, including flags for: SAA passage, eclipse, flare occurrence, IDPU version control number (needed for interpretation of decimation state), on-board SSR state, attenuator state, front/total counts ratio, non-solar event identification, data gaps, decimation energy and weights for front and rear detectors, flags for passage in high-latitude regions, flag for front detector turn-offs, flag for bad telemetry packets. Engineering data will also be included here, with such items as cold-plate and cold-tip temperatures, high-voltage supply status and cryocooler power and efficiency.
- Spacecraft ephemeris: Position and velocity in Earth-Centered Inertial coordinates, with 20-second time resolution.
- Spacecraft monitor rates: particle detector rates, preamp reset rates, rates over upper level discriminator, delay line rates, live time. These are accumulated for each detector segment, with 20-second time resolution.

The RHESSI flare list contains a listing of solar flares, possible flares, and non-solar 'events' for the mission. Events are found by automatically checking for peaks in the 6- 12 keV count rates, and confirmed as flares by successfully imaging the source. Each entry in the list includes: A unique ID number, start, end, and peak times, the highest energy band of successfully imaged data, the energy range used to find the flares, the peak count rate, the background count rate, the total number of counts, correction factors in the peak and total counts, for decimation and attenuation, flare position in arcsec from Sun center (if applicable), a list of the detectors used to find the flares, also flags for, SAA, eclipse, data gaps, decimation and attenuator state(s), presence of particles, data quality, position solution quality, confirmed solar flare, possible solar flare, and non-solar event.

For each confirmed solar flare, the RHESSI team will provide a series of images in the energy bands used for the Observing Summary, to the highest energy that can be successfully imaged. An algorithm is being developed to optimize choices for image time intervals for a given event. (Currently in the archive, there is only one image per flare per energy band.) Images will be 128x128 with 2-arcsecond pixels, and will use all available detectors.

For each confirmed solar flare, the RHESSI team will provide a series of full-Sun spectra for each front detector segment in anticoincidence with the corresponding rear segment. These spectra will cover the energy range from 3 keV to the highest energy observed with energy resolution of 1/3 keV at the low end of the spectral range, increasing to 20 keV, and with approximately 1-minute time resolution. For large flares, which have noticeable rear detector count rates, rear segment and front plus rear segment spectra will be supplied.

3.2.2 Level-0 Data

To meet the needs of solar and non-solar analyses without compromising the potential of the data, the Level-0 data will be made part of the resident and permanent archives, along with the corresponding analysis tools and documentation.

3.2.3 Visibility Data

To date, many analysts have exploited the photon-based nature of the RHESSI data to create images, light curves and spectra with the specific time, spatial, and energy resolution that best matches their scientific objectives and/or parameters of other simultaneous datasets. This contrasts with the situation in other imaging and/or spectroscopy data sets for which the parameters are predetermined. Maintaining this flexibility has been a key driver in the design and implementation of the RHESSI data analysis approach. To achieve this, however, it is necessary for users to start from Level-0 data and use the RHESSI-specific IDL software package. While this continues to be effective, it may become more problematic without the occasional one-on-one interaction with experienced users. For the long-term therefore, it would be desirable to identify a way by which most of the flexibility can be maintained without necessarily resorting to the Level-0 data.

Visibilities provide a natural way to accomplish this. A RHESSI visibility is a fully calibrated measurement of a specific Fourier component of the source spatial distribution for a given time interval and (count) energy bin. Each visibility corresponds to a single uv point in radio parlance. Such visibilities are the most direct output of RHESSI's time-modulated measurements of X-ray flux. While RHESSI's 'normal' imaging algorithms bypass the explicit calculation of visibilities, within the last two years, the basic software to convert RHESSI's photon-based data to a set of fully-calibrated visibilities has been implemented. These can then be combined and/or used as the input to imaging algorithms. While making some compromises in time and/or energy resolution, the use of visibilities has several distinct advantages.

- Visibilities are an inherently compact representation of the RHESSI data, preserving the essence of the spatial and temporal characteristics in a form that is typically ~2 orders of magnitude more compact than photon-based data.
- Unlike reconstructed images, visibilities are a *linear* representation of the data so they can be combined across different time/energy ranges to meet the user's needs.
- For each detected energy range, visibilities are fully calibrated, thus relieving the user of subsequent instrument-related calibration tasks.
- Visibilities provide a much more robust method of determining accurate source sizes as compared to inspection of reconstructed images.
- Measured visibilities include well-determined statistical errors whose propagation supports quantitative assessment of the significance of derived results.
- Calibrated X-ray visibilities have the identical significance as visibilities obtained from radio interferometers. Thus, a set of X-ray visibilities can be manipulated and converted to an image using any of several existing radio interferometer analysis packages, *independent of RHESSI-specific software.*

These considerations suggest that, in addition to the catalog and Level-0 data products discussed above, the inclusion of an extensive set of calibrated flare X-ray visibility data would provide a flexible option to meet the needs of users well into the future.

To do so, the following tasks remain to be accomplished:

- While the basic software for visibility calculation has been implemented, there are several important areas in which it needs to be refined.
- Automated algorithms need to be developed to optimally choose statistically significant time and energy intervals within which to calculate visibilities. Such algorithms are currently under development for other missions (e.g. Solar Orbiter) and can be re-parameterized for the present purpose.

- Scripts need to be developed and executed to apply these algorithms to the mission-long RHESSI data set.
- The optimum data format for the calculated visibilities needs to be identified to support long-term use and to ensure compatibility with radio software packages.
- More extensive documentation needs to be developed for use by unsupported users in the Resident and/or Permanent archive phases.

Completion of these tasks will require ~ 2 to 3 man years. Some of the work has been initiated as part of the ongoing software support for the active RHESSI mission. The tasks specifically associated with the Resident and/or Permanent archive phases will depend on when these phases are initiated.

3.2.4 Other Databases

The additional databases described in this section have the common feature that the data itself is distributed throughout the multi-terabyte Level-0 data. As a result, it is convenient to extract and process the relevant material into compact, standalone databases for subsequent analysis.

Solar Radius Data

In addition to providing essential pitch and yaw aspect data for X-ray image reconstruction, the solar aspect system (SAS) data constitute a unique database of highly precise measurements of solar radii (Fivian et al. 2005). The data are extensive: over the entire Sun-lit portion of the multi-year RHESSI mission, they represent about 100 radius measurements per second (totaling $>10^{10}$ measurements to date), each with a statistical error of a few milli-arcseconds. Because of RHESSI's rotation, the measurements are distributed around the limb and so provide an excellent tool for measuring the shape of the Sun and its time variations, with applications to fundamental solar properties such as solar oblateness and p-modes, to name but a few.

SAS data require elaborate analyses to remove diverse systematic effects in order to obtain their inherent precision. As a result, this data lends itself to the creation of secondary databases, both to isolate the SAS data set itself and to reflect the application of internally derived calibration parameters. There is a preliminary example of such a database, from a three-month period in 2004, with IDL data structures containing reduced radius measurements plus diagnostic information helpful in their analysis. This particular database should be considered preliminary since the format of the secondary SAS database is likely to evolve and there is no user software or documentation available yet. However, the data are transparently useable from the IDL command line in SSW. The creation of such SAS databases is a necessary byproduct of the on-going scientific analysis of the SAS data and it is anticipated that mission-long, documented secondary databases will have been produced by the Resident Archive phase.

Radiation Studies

Mission-long examination of nuclear radiation data is useful for studies of galactic Al^{26}, galactic positron annihilation, novae, and quiet-Sun 2.2 MeV neutron-capture-line emission. As the mission progresses a database of accumulated 1-minute spectra from the rear detector segments is being amassed and will be added to the Permanent Archive. Documentation will be generated during the Resident Archive Phase.

Terrestrial Gamma-Ray Flashes

A catalog of transient events identified by an automated TGF triggering algorithm is being assembled as the mission progresses. During the Resident Archive phase, this will be finalized and documented for use as part of the Permanent Archive.

3.3 Analysis Tools for Level-0 data

The basis for all Mission Archive analysis tools is the software routinely used during the mission for the creation of scientific data products and the interpretation of those products as described in Section 2.2. It is important that the integrity of the software be preserved into the future so that it can remain viable without the continuing support of the current team.

As discussed above, the core of the RHESSI analysis software is written in IDL and distributed as part of the SSW tree. Since the SSW environment is dynamic, it is conceivable that as routines in the SSW evolve after the end of the RHESSI mission, incompatibilities with the RHESSI software may arise. To circumvent this we will archive a snapshot of all the elements of the SSW tree necessary for RHESSI analysis, specifically the GEN, X_RAY, and SPEX branches. This will ensure that the software that was working at the end of mission will continue to work into the future.

Another consideration is that RHESSI software is written in IDL, a proprietary package, which may disappear as a commercial product at some point in the future. At this time IDL is a very healthy product with a large user community in the science and engineering fields. Additionally, existing IDL licenses can be used on any computer as long as the platforms exist. RHESSI software runs on all IDL platforms and so it can be expected that the capability to use IDL will exist for at least another 10-20 years at a minimum. Also, free IDL compilers such as GDL provide an alternative to IDL, if it is discontinued. The core components of the RHESSI analysis software have already been run successfully using GDL.

3.4 Documentation

While an extensive range of documentation is available via the RHESSI website, it needs to be carefully reviewed so that it can effectively serve its purpose during the Resident and Permanent Archive phases with reduced (or absent) one-on-one support. Specifically, obsolete or conflicting material needs to be identified and updated or removed, perceived gaps need to be identified and a robust stand-alone guide to the material generated. While on-going at a low level, this task will be completed during the Resident archive phases, requiring an estimated 2-4 months of effort by a combination of experienced RHESSI personnel.

3.5 Distribution

During the year after the end of the mission, RHESSI data products will continue to be accessible from servers at SSL and GSFC (and possibly through the Swiss-funded mirror site at ETHZ). The archive will then be transitioned to the Resident Archive at the Solar Data Analysis Center (SDAC) at Goddard. The Permanent Archive will be hosted by the National Space Science Data Center (NSSDC) at Goddard.

Access of RHESSI data through the VSO involves three approaches. The first is to include the Catalog data into the VSO. This will make it possible on one hand, to display quick-look products in VSO query results, and on the other, to download pre-calculated images or image cubes (as presented in Section 3.2.1) for comparison with data sets from other instruments. This requires no RHESSI specific software.

The second approach is to implement event-based queries, i.e. queries based on the flare list and the observing summary in addition to queries based on a time range. This means that the RHESSI archive can be searched, for example, on flares of specific characteristics such as size, duration, or location on the limb.

The third approach is to provide an indexed database of flare visibilities, a subset of which can be identified and provided in response to user time, energy, location or other criteria. These can be manipulated and/or converted to images at the user’s institution using either a simplified subset of IDL software or by external radio interferometric packages such as Miriad.

To allow correct inclusion of the RHESSI data into the VSO, the Catalog data will be annotated in the FITS headers with keywords defined by the SPASE consortium. Adopting SPASE keywords will guarantee that SPASE data analysis programs can use RHESSI Catalog data. The visibility data will also be described by SPASE-compatible keywords. The Level-0 database, however, does not need to be SPASE annotated, as it requires the RHESSI-specific software to generate science ready products.

3.6 Summary

It is anticipated that the RHESSI solar X-ray data will be provided in three different forms: Level-0 plus software and documentation to support maximum flexibility for both solar and non-solar applications; catalog data products requiring no specific analysis software to provide a data overview and to support less demanding applications; and calibrated visibilities to support imaging-spectroscopy with analyst-selected time and energy resolution with the use of external radio analysis packages. In addition, secondary databases supporting future analyses of the high-precision solar radius data and non-solar studies will also be provided.

Acknowledgments

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References

Fivian, M. D., Hudson, H. S. and Lin., R. P., 2005 in *Proc 11th European Solar Physics Meeting*, ESA SP- 600, 41.
Lin, R. P., et al., 2002, Solar Physics 210, 3.
Schwartz, R. S., et al., 2002, Solar Physics, 210, 165.

Acronym List
{ TC "Appendix A- Acronym List" \l 1 }

CLI	- Command Line Interface
ETHZ	- Eidgenössische Technische Hochschule (Zentrum)
FAQ	- Frequently Asked Questions
FITS	- Flexible Image Transport System
GB	- Gigabytes
GeD	- Germanium Detectors
GDL	- Geometric Description Language
GIF	- Graphics Interchange Format
GOES	- Geostationary Operational Environmental Satellite
GSFC	- Goddard Space Flight Center
GUI	- Graphical User Interface
HEDC	- HESSI Experimental Data Center
IDL	- Interactive Data Language
IDPU	- Instrument Data Processing Unit
MB	- Megabytes
MOC	- Mission Operations Center
NSSDC	- National Space Science Data Center
PMTRAS	- PhotoMultiplier Tube Roll Aspect System
PNG	- Portable Network Graphics
QLP	- Quick Look Product
RAS	- Roll Angle System
RHESSI	- Reuven Ramaty High Energy Solar Spectroscopic Imager
RMC	- Rotating Modulation Collimator
SAA	- South Atlantic Anomaly
SAS	- Solar Aspect System
SDAC	- Solar Data Analysis Center
SPASE	- Space Physics Archive Search and Extract
SSL	- Space Sciences Lab (University of California, Berkeley)
SSR	- Solid State Recorder
SSW	- Solar SoftWare
TB	- Terabytes
TGF	- Terrestrial Gamma-ray Flashes
VCn	- Virtual Channel n
VSO	- Virtual Solar Observatory