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DOCUMENT

XMM-Newton Post-Operation Requirements

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1 INTRODUCTION

A significant amount of astronomical research is based on measurements collected by facilities which are not any longer operational. The conservation of X-ray measurements is of special scientific importance as the majority of X-ray sources are variable. Therefore, data collected by future X-ray missions will not supersede measurements taken by XMM-Newton. On the contrary, observations of future X-ray missions will resurrect the scientific interest on XMM-Newton observations as variability provides powerful constraints for the physical interpretation. In addition, the standard XMM-Newton observation is deeper and more detailed than any planned X-ray survey mission. Therefore XMM-Newton archive data will be the most important source of information on X-ray properties of sources over a large area for many multi-wavelengths studies of astronomical objects to come.

In order to estimate the dimension and requirements of post-operation research for XMM-Newton I had a look to previous European UV and X-ray missions. In the appendix I provide some parameters for EXOSAT, IUE, BeppoSAX and ROSAT. All considered missions show aspects (data, spectra, and lifetime) which can also be found in XMM-Newton. They all share the same user community and the performed analysis shows common patterns.

Based on the above study I estimate the number of refereed articles that will be published in the decade after operations-end to be five or more times the number of refereed article per year, i.e. for XMM-Newton, based on the current rate of 300 papers per year, we can expect about 1500 refereed articles. This number may increase significantly depending how much the source catalogues will be used for "catalogue" research and data mining.

We have to expect that the majority of the post-operations-end articles will be based on:

- archived meta data, especially spectra and light curves and especially meta-data of the on-axis targets
- source catalogues, supporting selection of meta data samples or catalogue research
- raw data in combination with the XMM-Newton specific analysis software, where the availability of the XMM-Newton specific analysis software will be the critical bottleneck.

ESA prepares the data collected by its missions and the corresponding auxiliary information for future scientific research, within a post-operations phase.
In the following chapter the requirements for the XMM-Newton post-operation phase will be specified. The scientific productivity and especially the long-term usability of XMM-Newton observations strongly depend on the quality and completeness of the data preparation during the post-operations phase.

2 REQUIREMENTS

Many of the listed requirements were based on considerations from L. Metcalfe and M. Santos-Lleo in 2006 \& 2007 and considering Herschel Science Centre Post-Operations Phase Plan. (Herschel-HSC-DOC-1087).

With two exceptions the requirements specify what should be provided at the end of the post-operations phase to the scientific community for public access. All provided material has to be tested, validated and ready for direct scientific usage. In addition it is necessary that all required auxiliary data are provided.

- Final Bulk Reprocessing of all XMM-Newton data using the final consolidated calibration:

  The Final Bulk Reprocessing should be designed assuming astronomers with no access to XMM-Newton specific analysis software, e.g. XMM-Newton Science Analysis System (SAS).

  All data products should be VO-compliant and easy to use by non-X-ray astronomers. The data format should be defined as late as possible in order to take the latest developments into account.

  - Final ODFs (if required)
    - Screening of problematic observations and repair if possible
  - Pipeline products for observations
    - Linearized event files
    - Exposure maps (in different energy bands)
    - Exposure corrected images (in different energy bands)
    - Background subtracted and exposure corrected images (in different energy bands)
    - Supporting special observations like processing moving targets in their own reference frame
  - Enhanced EPIC & RGS meta-data for on-axis point sources
    - EPIC: Spectra & light curves (including sources observed in timing and burst mode)
    - EPIC: Pile-up corrected spectra & light curves where applicable
    - EPIC: Upper-limits if no on-axis point source is detected
    - RGS: RGS1, RGS2 and combined RGS spectra \& light curves with modelled and with measured background
    - RGS: Pile-up corrected spectra \& and light curves where applicable
    - RGS: RGS1, RGS2 and combined RGS fluxed spectra and light curves with modelled and measured background
    - Common good time ranges and related products (RGS & EPIC) if on-axis source is variable above a given variability threshold
    - Flux over the time-energy plane for RGSs and EPIC

        - Supporting special observations like processing moving targets in their own reference frame or auxiliary files for observations with pn in modified timing mode.
    - Enhanced meta-data for extended sources
        - Hardness-Ratio background-subtracted and exposure corrected images
    - Serendipitous EPIC source catalogue (& source products)
    - Serendipitous EPIC source catalogue of merged observations (& source products)
    - Slew catalogue
    - Slew images and catalogue upon merged slews (depending on the success of eROSITA)
    - OM source catalogue (& source products)
    - Consistency of all final products avoiding duplications (i.e. between standard pipeline products and catalogue products)

- Final Scientific Archive
    - Allow ingestion and search of all final products and catalogues (from ODF & SDF to pipeline products and catalogue products)
    - Scientifically enhanced presentation of EPIC and RGS spectra (e.g. Bird)
    - Advanced storage of catalogues and source products anticipating increasing computer memory and band-widths
    - Data and data produces should be linked to all refereed scientific publications that made use of them (at the time of the production of the archive)

- Analysis Software
    - Upper-limit server: should provide within seconds upper-limits (count rate and flux in different energy bands) for any given sky-position observed by XMM-Newton (pointing & slew), or return that it was not observed
    - Analysis support level I: should support the analysis of arbitrary (but simple) spatial and temporal selected areas of individual targets providing all required diagnostics, corrections and auxiliary files. The emphasis is on analysis of an individual astronomical object in greater detail than supported by provided standard source products, e.g. light curves for user specified energy ranges, generation of phase-resolved spectra of a piled-up source, generation of spectrum of a source for certain count-rate ranges, certain area of an extended source.
    - Analysis support level II: should support major processing of XMM-Newton observations in combination with external data analysis tools & data providing all required diagnostics, corrections and auxiliary files (e.g. alternative good-time interval selection, alternative background subtraction, definition of complex extraction regions based on XMM-Newton measurements in combination with other data, user provided complex extraction areas of a sample of extended sources).
    - User-friendly and detailed documentation

- Calibration
  - Final consolidation of calibration and instrument characterization
  - Cross-calibration with other missions
  - Generic instrument description as part of the XMM-Newton Handbook
    Description of instrument, observing modes, data, calibration (status, assumptions, limitations, caveats) and usage of data

- Documentation (including web)
  - XMM-Newton Handbook
    A synthesising of available documentation, descriptive and technical, into a single, accessible, broad but detailed description of the Mission, its data products, and their access and use.
  - Explanatory Library
    Evaluation and sorting of public and internal documentation and transfer to an online Explanatory Library supporting and underpinning the Handbook
  - Image Gallery
    The image gallery should be updated and completed as far as possible.

- Helpdesk (during post-operations phase)

- XMM-Newton Legacy Conference (during post-operations phase)

3 APPENDIX

European Space Agency's X-ray Observatory, EXOSAT, was operational from May 1983 to April 1986. During the 3 years of operations EXOSAT made 1780 observations. ADS shows 132 refereed EXOSAT articles[1] published before and 520 after mission operations end, i.e. a ratio 1 to 4 of pre to post operations-end papers. There are 4 EXOSAT articles published in 2012 and 2013. Three of them analyse pre-prepared spectra (2) or light curves (1) which were obtained from archives (2) or privately (1) stored. No EXOSAT specific software is currently publicly available.

The International Ultraviolet Explorer (IUE) was launched in January 1978 and was switched off in September, 1996. During the 18.5 years operation 104,470 spectra were taken. ADS shows 2421 refereed IUE articles[2] published before and 793 after mission operations end, i.e. a ratio 3 to 1 of pre to post operations-end papers. ADS shows 25 IUE articles published in 2012 and 2013. 16 of them analyse IUE spectra. All studies use extracted and processed spectra from the archive where the majority was obtained from INES (W. Wamsteker, 2000). No IUE specific software is currently available.

The Italian Space Agency with participation of the Netherlands Agency for Aerospace programs "Satellite per Astronomia X", BeppoSAX, was operated from April 1996 to April 2002. During the 6 years of operations about 1500 observations were performed. ADS shows 625 refereed BeppoSAX articles[3] published before and 532 after mission operations-end, i.e. a ratio 1 to 1 of pre to post operations-end papers. There are 25 BeppoSAX articles published in 2012 and 2013. 16 of the papers report about the analysis of spectra. 5 of the authors analyse pre-prepared spectra (4) or light curves (1) 10 use mission specific software to analyse the archival data. (Limited) software and support is available online at ASI and GSFC.

The X-ray observatory, Röntgensatellit, ROSAT, developed through a cooperative program between the Germany, the United States, and the United Kingdom, was in operations from June 1990 to February 1999. During the 8.75 years of operation about 11,000 observations were taken of which about half with the High Resolution Imager and half with the Position Sensitive Proportional Counters. In addition ROSAT performed an all sky survey (RASS). ADS shows 2065 refereed ROSAT articles[4] published before and 1950 after mission operations end, i.e. a ratio 1 to 1 of pre to post operations-end papers. There are 118 ROSAT articles published in 2012 and 2013. 73 of the papers use data of which 44 refer to the RASS and 31 to pointed observations, 31 of the authors use ROSAT sources catalogues, 16 use pre-prepared pipeline products and 31 analysed data with mission specific software. The majority of users refer to software provided at GSFC.

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[1] Articles which according to ADS mention EXOSAT either in the title or in the abstract
[2] Articles which according to ADS mention IUE either in the title or in the abstract
[3] Articles which according to ADS mention BeppoSAX either in the title or in the abstract
[4] Articles which according to ADS mention ROSAT either in the title or in the abstract

4 BIBLIOGRAPHY

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