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The XMM-Newton spectral-fit database

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Abstract: The XMM-Newton spectral-fit database is an ongoing ESA funded project aimed to construct a catalogue of spectral-fitting results for all the sources within the XMM-Newton serendipitous source catalogue for which spectral data products have been pipeline-extracted ($\sim$ 120,000 X-ray sources). The fundamental goal of this project is to provide the astronomical community with a tool to construct large and representative samples of X-ray sources by allowing source selection according to spectral properties.

1 Introduction

The XMM-Newton (the ESA Xray Multi-Mirror Mission, launched on 1999) serendipitous source catalogue is the largest catalogue of X-ray sources built to date (see [3]). In its latest version, the 3XMM-Newton Data Release 4 (3XMM DR4[1]), it contains photometric information for more than 500,000 source detections, corresponding to $\sim$ 370,000 unique sources. The people responsible for the construction of the catalogue belong to the XMM-Newton Survey Science Centre (XMM-Newton SSC[2]), a consortium of research institutes in the ESA community.

Only data from the EPIC camera (European Photon Imaging Camera) on board of XMM-Newton are used on the construction of the catalogue. This camera is composed of three detectors: EPIC-pn, EPIC-MOS1, and EPIC-MOS2. These detectors work on photon-counting mode. This implies that from a single observation, images, spectra and time series can be derived for every source detected in the observed field of view. During the construction of the catalogue, photometric data are derived for every source and observation. Besides, spectra and time series are also extracted if the number of source counts collected by the EPIC camera is $>$ 100 counts.

The 3XMM DR4 catalogue is not only an incremental version of the previous catalogue, 2XMM DR3, but also an improved one . The number of public observations used has increased $\sim$ 50% with respect to the previous version. Besides, this latest version benefits from the significant improvements on the XMM-Newton Science Analysis Software and calibration[3]. The key science-driven gains include:

- Improved source characterization and reduced spurious source detections.
- Improved astrometric precision of sources.
- Greater net sensitivity for source detection.
- Extraction of spectra and time series for fainter sources, with improved signal-to-noise.

The resulting catalogue contains spectra for more than 120,000 detections corresponding to $\sim$ 80,000 unique sources. The project described here, is aimed to take advantage of the great wealth of data and information contained within the XMM-Newton source catalogue, to construct a database composed of spectral-fitting results. In this way, large and representative samples of X-ray sources

[1]http://xmmssc-www.star.le.ac.uk/Catalogue/3XMM-DR4/
[2]http://xmmssc-www.star.le.ac.uk/
[3]http://xmm.esac.esa.int/sas/current/documentation/sas_concise.shtml

can be constructed according to spectral properties, and/or sources with interesting properties can be pinpointed.

2 Automated spectral fits

The XMM-Newton spectral-fit database is constructed by using automated spectral fits applied to the pipe-line extracted spectra within the 3XMM DR4 catalogue. The software used to perform the spectral fits is `XSPEC v12.7` (see [1]), the standard package for X-ray spectral analysis. The input files are, for each source and observation, source and background spectra (in counts per spectral channel), and response matrices (that represent the response of each detector as a function of energy) for all EPIC instruments used during the observation. Source and background spectra, as well as the ancillary matrices are included within the catalogue data. Redistribution matrices are the canned matrices provided by the XMM-Newton SOC (Science Operations Centre).

`XSPEC` uses the Tool Command Language (tcl) to process command input. For each spectral model to be fitted, a template fitting-script is written in tcl. These templates are modified for each source and observation, by making use of Perl scripts, and then send to run in `XSPEC` in order to obtain the spectral-fit results.
Three energy bands are considered during the spectral fits:

- Full/Total band: 0.5 - 10 keV.
- Soft band: 0.5 - 2 keV.
- Hard band: 2 - 10 keV.

The statistics used to fit the data is Cash statistics, implemented as C-stat in `XSPEC`. This statistics was selected, instead of the more commonly used χ^2 statistics, to optimise the spectral fitting in the case of low quality spectra. However, even using this statistics, a lower limit on the number of counts in each individual spectrum had to be imposed to ensure a minimum quality on the spectral fits. As a result, only spectra corresponding to a single EPIC instrument, with more than 50 source counts in the full band are included in the spectral fits.

2.1 Spectral models

Five "one-component", and three "two-components" models have been implemented. All these models are applied to the spectral data if the following conditions are fulfilled:

- One-component models: total number of counts (all instruments added together) larger than 50 counts in the energy band under consideration.
- Two-components models: total number of counts larger than 500 counts in the full band.

The one-component models are:

- **Absorbed power-law model (`wa*pow`):** A photoelectrically absorbed power-law model is applied in the three energy bands. The output spectral parameters are the hydrogen column density, the power-law photon index, and the normalizations of the power-law component.
- **Absorbed thermal model (`wa*mekal`):** A photoelectrically absorbed thermal model is applied in the total and soft bands. The output spectral parameters are the hydrogen column density, the thermal plasma temperature, and the normalization of the thermal component.
- **Absorbed black-body model (`wa*bb`):** A photoelectrically absorbed black-body model is only applied in the soft band, and its primary use is to obtain initial input parameters for a more complex model. The output spectral parameters are the hydrogen column density, the black-body temperature, and the normalization of the black-body component.

The two-components models are applied only in the full energy band, and they are:

- **Absorbed power-law model plus thermal model (`wa(mekal+wa*pow)`):** The output spectral parameters are the hydrogen column densities, the power-law photon index, the plasma temperature, and the normalizations of the power-law and thermal components.
- **Double power-law model (`wa*(pow+wa*pow)`):.** The output spectral parameters are the hydrogen column densities, the power-laws photon indices, and the normalizations of both power-law components.
- **Black-body plus power-law model (`wa*(bb+pow)`):.** The output spectral parameters are the hydrogen column density, the power-law photon index, the black-body temperature, and the normalizations of the power-law and black-body components.

2.2 Spectral fitting and spectral-fitting results

Although many sources within the catalogue have been observed multiple times, the spectral-fitting pipe-line has been designed to fit each observation separately. The resulting spectral-fit database contains one row per source and observation, listing source information, and spectral-fit output parameters and errors, as well as fluxes and additional information about the goodness of fit for every model applied.

C-stat statistics lacks an estimate of the goodness of fit. For the spectral-fit database, goodness of fit is estimated by using the `XSPEC` command `goodness`. This command performs a number of simulations and returns the fraction of the simulations that results in a better fit statistic. Therefore, a spectral fit with a N% goodness value, can be rejected at the N% confidence level.

Sometimes, the automated fitting process is unable to constrain all the variable parameters during the error computation. In the case of one-component models, the corresponding parameter is fixed to the value obtained by fitting a model that only includes the corresponding component in the energy band that encompass the maximum contribution of that component. For example, in the case of not being able to constrain the power-law photon index, its value is fixed to the one obtained by fitting a power-law model without absorption in the hard band. The input parameter values for the two-component models, that are also the values the parameters are fixed to in case they cannot be constrained, are the ones obtained from the spectral-fitting results of the one-component models.

3 Application to a scientific case

In order to test the reliability of the automated fits, the spectral-fitting process has been applied to a sample of X-ray sources extracted from the SDSS/XMM-Newton cross-correlation presented in [2]. The sample is composed of the X-ray sources detected in the 2-8 keV energy band, $\sim$ 14,000 sources, many of them with spectroscopic or photometric redshifts. For $\sim$ 8,000 of these sources, there are spectral data available within the XMM-Newton catalogue.
The spectral-fitting pipe-line was modified to include the effect of redshift and Galactic absorption, in the case of sources with either spectroscopic or photometric redshifts, and the results of the spectral fits are already available on the project's web page (**http://xraygroup.astro.noa.gr/Webpage-prodec/index.html**). Examples of spectral fitting results are shown in Fig. 1.

4 Summary

The XMM-Newton spectral-fit database contains spectral fitting results for all the sources within the XMM-Newton serendipitous source catalogue for which spectral data are available, $\sim$ 120,000

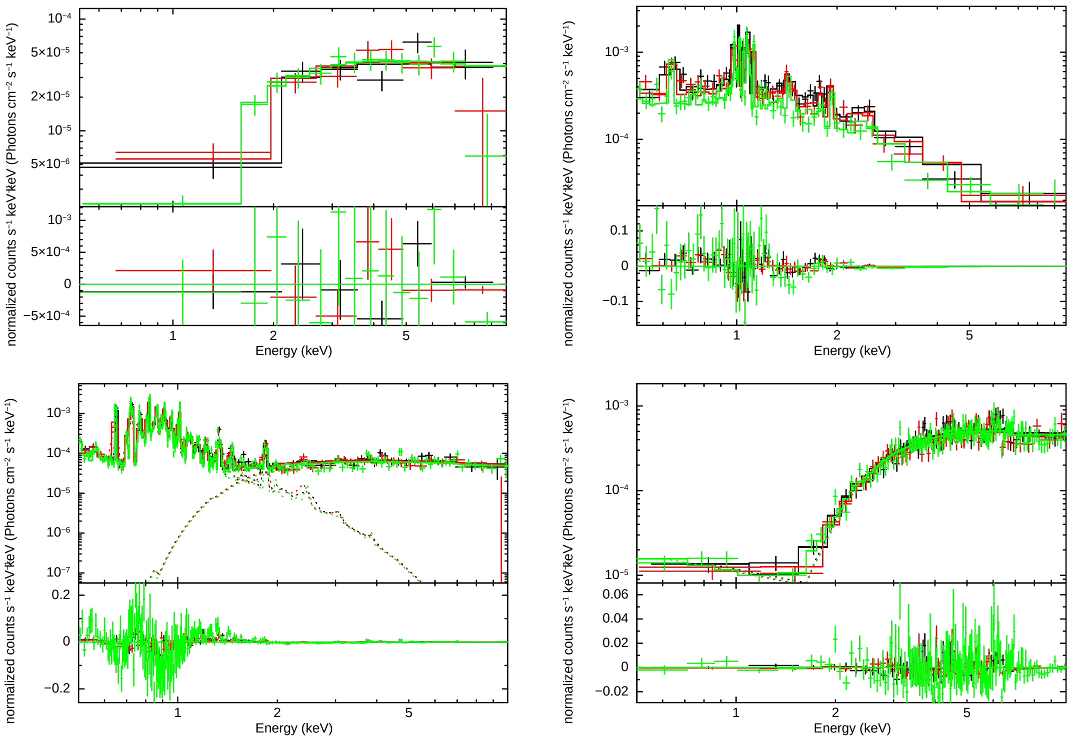

Figure 1: Examples of spectral-fitting results. Top-left: absorbed power-law model. Top-right: absorbed thermal model. Bottom-left: thermal plus power-law model. Bottom-right: Double power-law model.

source detections. The goal of this database is to provide the astronomical community with a tool to construct large and representative samples of X-ray sources by selecting them according to their spectral properties. The full database will be released to the public by the end of 2013. Preliminary results of the automated spectral-fitting procedure applied to a smaller sample are available on the project's web page, and ready to use.

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