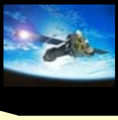
XMM-Newton trainee projects at ESAC



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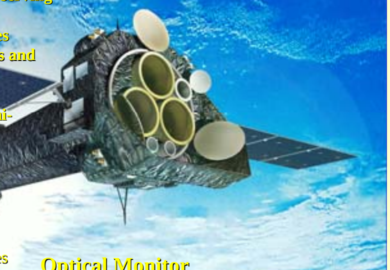
XMM-Newton



- **Launched December 1999**
- **3 Wolter type 1 telescopes**
- **3 instruments: EPIC, RGS, OM**
- **Instruments operated in parallel**
- **48-hour high elliptical orbit**

European Photon Imaging Camera:

- **Spatially resolved spectroscopy over the field-of-view of 30' with moderate energy resolution ($E/\Delta E$=10-50 in 0.1-15 keV)**
- **3 independent cameras (2 MOS & 1 pn), observing simultaneously the same field**
- **3 different light filters for both camera types**
- **Different modes to accommodate brightness and timing**
- **pn: 12 back illuminated pn-junction CCDs**
- **MOS: 7 front illuminated Metal-Oxide Semi-conductor CCDs**

Reflection Grating Spectrometers

- high-resolution spectroscopy of bright sources in the energy range from 0.3 to 2.1 keV

Optical Monitor

- extends the spectral coverage of XMM-Newton into the UV and optical
- six broadband filters
- two grisms, one in the UV and one in the optical

European Space Astronomy Centre — ESAC

- Scientific operation of astronomical missions like XMM-NEWTON, INTEGRAL, ISO, IUE
- Scientific Archives, Community Support
- Satellite tracking station

Gabriele Schönherr

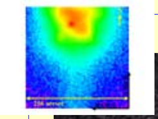
- **Born in Düsseldorf, Germany - studied Physics and Astronomy at the University of Bonn/Germany and Universidad Autonoma de Madrid, Spain - work during diploma thesis at the Research Centre Jülich - 5 months traineeship at ESAC in 2004 - 2005 PhD project started at the Institute of Astronomy and Astrophysics at the University of Tübingen, Germany in collaboration with the University of Warwick, UK, and ESAC, Spain.**
- **The main scientific objective of my project was a pulse phase resolved spectral analysis of observations of the Crab pulsar with XMM-Newton. Since its discovery (Staelin & Reifenstein 1968, Science 162, 1481), the Crab is one of the best studied objects and one of the most luminous sources at the X-ray sky. It consists of a compact object, the so-called Crab pulsar, and a region of nebulosity, the Crab nebula. The pulsar, a spinning neutron star with a period of only 33ms, has been observed over nearly all energy bands. Its pulse profile is characterized by a double-peaked structure with a phase difference of 0.4 between the first and second pulse.**
- **I combined several XMM-Newton observations in EPIC-pn Burst and Small Window mode in order to achieve a two dimensional spatial and a high quality phase resolved spectroscopy of the Crab nebula and pulsar. Moreover, I assessed the pile-up level of the Small Window data by different approaches in order to estimate the effects on the spectral parameters. A spatially resolved analysis of the Crab spectrum was obtained with both types of data sets (one-dimensional results from Burst mode data and two-dimensional analysis of SW mode data).**

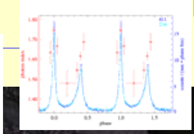
Jenny Carter

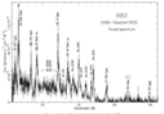
- **Born in Swindon, UK - University of Bristol for four years MSci Physics with Astrophysics – after graduating spent one year working at the National Physical Laboratory in London within the Optical Radiation Measurement department - YGT in 2004 at ESAC, Spain.**
- **During my year as a YGT, I am working as a member of the Reflection Grating Spectrometry (RGS) team, which monitors and continuously calibrates the two Reflection Grating Spectrometers onboard XMM-Newton. One project as part of placement involves the development of a new software task, which will form part of the general XMM-Newton scientific analysis package, SAS.**
- **The motivation behind the project is to be able to look in unprecedented detail at the spectrum of a particular object using an accumulation of data taken for this source of interest. The presence or absence of an ion species will become more apparent. As examples, and due to the wealth of data already collected by XMM-Newton, I have concentrated the development and testing of the software on three specific objects often used for calibration purposes: HR1099, Capella and AB Doradus.**
- **To be able to achieve this, the addition of the individual spectra are added together, along with a combination of the instrument's appropriate response matrices, to give an increasingly clear picture of the nature of the spectra under investigation.**

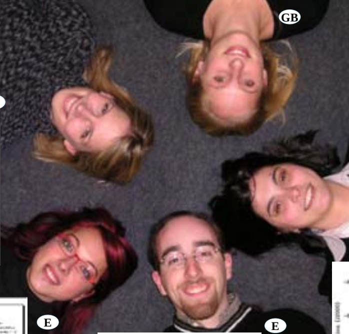
M. Pilar Esquej

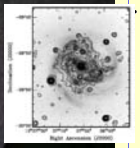
- **Born in Zaragoza, Spain - studied Physics at the Universidad de Zaragoza and Madrid - graduated in September of 2004 - Pre-Graduate Trainee Program at XMM-Newton Science Operations Centre/ESAC in 2004**
- **For the EPIC-pn extended Full Frame (eFF) mode a special energy calibration assessment was performed, which showed an over correction of the energy with respect to the Full Frame (FF) mode for the internal calibration source at aluminium and manganese energies. A dedicated calibration observation of Cas-A performed in revolution 836 was analysed, and spectra of the target have been extracted using the XMM-Newton Science Analysis System (SAS), in order to assess the energy differences in a wider energy range than given by the internal calibration source. Using the standard X-ray spectral fitting tool XSPEC line positions of the prominent Cas-A lines were determined. Ratios of line positions between the two modes were used to derive a smooth correction Boltzmann function of the energy that was implemented in the CAL (version 3.172.5), and corresponding parameters were added to the EPN_CTI_0014.CCF in the extension eFF_Gain.**
- **After reprocessing the data with the updated SAS (6.1.0), accuracy in line energy determination in eFF mode is supposed to be better than 0.1 % with respect to the FF mode.**

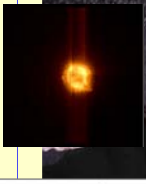


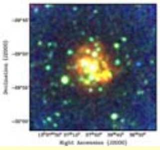


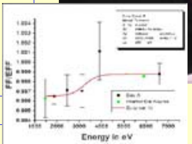


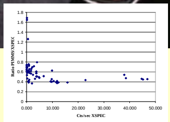












Florencia Jimenez Luján

- **Born in Alcorcón/Madrid, Spain - studied Physics at Universidad Complutense de Madrid - Pre-Graduate Trainee Program at XMM-Newton Science Operations Centre/ESAC in 2004**
- **My project consisted of analysing the nearby spiral galaxy M 83, also called NGC 5236. M83 is a bright barred spiral galaxy with an active starburst nucleus. It has been the target of numerous astrophysical investigations because of its proximity. Its distance was recently estimated to be 4.5 Mpc but it is still very uncertain. Since it is seen almost face-on and lies in a direction of the southern sky with low Galactic absorption, M 83 is an ideal candidate to study X-ray emission components.**
- **We obtained X-ray images for different energy bands and created a false colour image as a combination of three of these bands.**
- **We detected the point-like sources in the field of view and performed spectral analysis of selected sources and extended emission. Our models confirmed the expectation that one observes a superposition of a soft halo and hard disk emission in face-on galaxies.**

We also calculated light curves to see the variability of the sources in the X-ray regime and hardness ratio diagrams to study how soft or hard the X-ray emission of the sources is. With this information, we could classify the brightest sources.

The Project

- In 2004 five young scientists participated in a pilot trainee programme taking place at the European Space Astronomy Centre (ESAC) and contributing to the XMM-Newton project.
- The trainees were from the University Complutense of Madrid (Spain), the University of Bonn (Germany) and from the ESA Young Graduate Trainee Programme.
- The idea behind the project is to build up a group of 3-5 people at different stages in their scientific or technical careers, with membership rotating on timescales of three months to one year, who contribute to the work of the XMM-Newton Team. Moreover, all participants benefit from this work by developing new skills and building up knowledge in a space science related environment.
- Additionally, due to the cooperation of several universities in the project, students have the possibility to build up networks also outside of ESA, benefiting their future careers.

- A Web page describing the XMM-Newton SOC Trainee Project is available, offering further information, at

  http://xmm.vilspa.esa.es/external/xmm_links/trainee/

Diego Aguado

- **Born in Madrid, Spain - studied Mathematics at the Universidad Complutense de Madrid and Liverpool - Pre-Graduate Trainee Program at XMM-Newton Science Operations Centre/ESAC in 2004**
- **The observation proposals for XMM-Newton must be checked for certain sky environment parameters in order to guarantee the best possible scientific output. These checks are carried out by special software called Proposal Handling System (PHS) tools.**
- **The PHS Tools include 19 different software tools. We were interested in one of them: the "EPIC specific expected x-ray count rate tool".**
- **The PIMMS tool needs certain input parameters, such as flux of target, energy range and mathematical model for the spectrum (out of these four: Black Body, Power Law, Thermal Bremsstrahlung, or Raymond-Smith). With these, PIMMS estimates the expected count rate. We checked if this works correctly by comparing the theoretical predictions made by PIMMS with real sky data, processed by ourselves. For this, we used about 50 ODF (Observation Data Files) covering different combinations of cameras, modes, filters and models.**

The Tutors

Marcus Kirsch has been working since 2002 for ESA as the Calibration Scientist of the European Photon Imaging Camera (EPIC) that operates in the energy range 0.2-15 keV and provides spatial, energy and timing information for the detected X-ray photons. The European EPIC Consortium carries out the calibration of the EPIC camera where major calibration development is performed by the University of Leicester (UK) , by MPE and the University of Tübingen (Germany). The EPIC Instrument Dedicated (EPIC-IDT) team at ESAC, coordinated by MK, participates in the calibration efforts and transfers all important calibration information into Current Calibration Files (CCF) and/or software products.

MK is the local trainee contact of ESAC coordinating the student placements at ESAC with local universities.

Andy Pollock’s job for XMM is RGS Calibration Scientist, which means that he is responsible for making sure everything is in place for astronomers to be able to understand as well as possible the data collected by the high-resolution gratings aboard XMM.

Andy occupies the seat between the experts who built the instrument, on one hand, and the people who want to use it, on the other. Since growing up and studying physics in England, his career has been spent in the shadowy lands between astronomy and software engineering for projects like COS-B, EXOSAT, ISO and XMM. He especially likes hot stars, such as Wolf-Rayet stars and O stars, which do all sorts of interesting things in X-rays, both by themselves and in binary systems.

Mathias Ehle is a staff astronomer in the XMM-Newton Science Operations Centre. Besides his EPIC calibration support tasks, he is a member of the Users Community Support and Mission Planning Team. As such, he is (amongst other duties) responsible for the helpdesk, documentation and observing proposal handling.

Before moving to Spain, he was research assistant in the X-ray astronomy group at the Max-Planck-Institut für Extraterrestrische Physik (MPE) in Garching near Munich. His major research interests are: X-ray and radio emission from galaxies, star-bursts and AGNs, the formation of galactic radio and X-ray halos and the study of cosmic magnetic fields. Some of these topics were already part of his PhD thesis undertaken at the Max-Planck-Institut für Radioastronomie (MPIfR) in Bonn. As a post doc he also spent 1.5 years at the Australia Telescope National Facility (ATNF) in Sydney.

EPIC Consortium Meeting
11 – 13 April , 2005, Schloss Ringberg, Tegernsee , Germany

XMM-Newton (cross-)calibration

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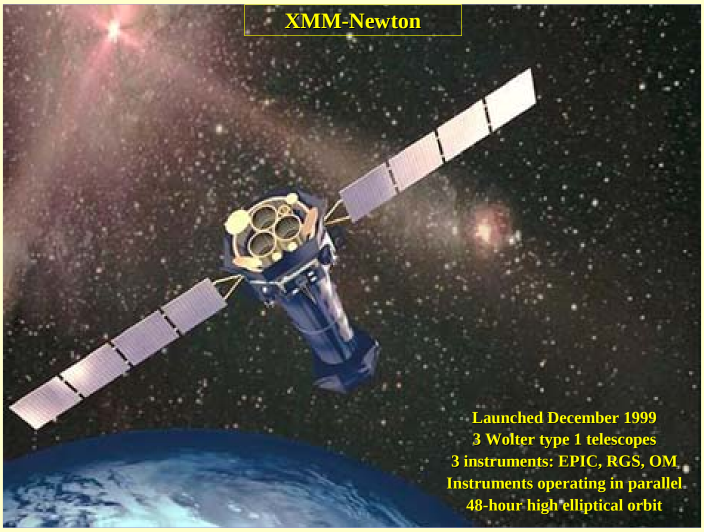
XMM-Newton



Launched December 1999
3 Wolter type 1 telescopes
3 instruments: EPIC, RGS, OM
Instruments operating in parallel
48-hour high elliptical orbit

Calibration status: SAS 6.1

Improvements in EPIC calibration

- **pn telescope effective area:** the effective area around the gold edge at 2.2 keV has been altered resulting in the improvement of the residuals around that edge in the pn-spectra.
- **Point Spread Function (PSF):** the best model of the point spread function (PSF) of the EPIC cameras is provided by a King function model, which parameters were calculated early in the mission. This parameterisation was good, however it was noticed that the energy dependence of the King model was not quite correct and extracting the spectrum of a point source using circles and annuli of different radii gave inconsistent results. With the acquisition of long, clean observations of bright, but not piled-up, point sources (Fig. 1), the modelling of the energy dependence has been significantly improved. The release of the CCF elements, (described in XMM-CCF-REL-167) now allow spectral parameters to be reliably calculated independent of the extraction region (Fig. 2).
- **pn CTI:**

  - Small Window (SW) and Large Window (LW) modes: the effect of the under-correction of the CTI of 2-3% for the pn SW mode between 550 and 700 eV has been reduced. The LW mode CTI was adjusted to this SW CTI for energies below 500 eV, which improves the residuals in the fitted spectra.

  - Extended Full Frame (eFF) mode: the extended Full Frame mode showed an over-correction of the energy for the internal calibration source by up to 15 eV for the Mn-K line position with respect to the Full Frame (FF) mode related to imperfect Gain/CTI correction. A special calibration observation of the SNR Cas-A was analysed and used to derive a correction function of the energy for the eFF mode which leads to the agreement of energy line positions between eFF and FF modes with an accuracy of 0.1%.

  - Long-term correction: The long-term CTI behaviour of all modes is now modelled with an additional quadratic pn term to tail off the time dependence, affecting all modes.

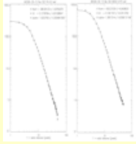


Fig 1. Surface brightness radial profiles (crosses) plus fitted. King profiles (lines) for two examples: (left) MCG-06-30-15 rev. 303 pn at 6 keV (right) MCG-06-30-15 rev. 302 MOS at 0.475 keV.

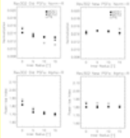


Fig 2. Plots showing how the fitted normalisation (top) and power-law index (bottom) vary as a function of extraction region (left to right: 0-30" circle, 5-40" annulus, 10-50" annulus, 15-60" annulus), using the older PSF CCFs (left) and the new PSF CCFs (right panel) for the MCG-06-30-15 revolution 302 dataset.

Low-energy flux with SAS 6.1

EPIC flux stability on SNRs

The flux of the SNR N132D in the soft band 0.4-0.8 keV was computed for all EPIC cameras, giving the following results for that energy range (see Fig 3).

• The response of the pn camera is extremely stable, there is no variation of the observed flux for a given mode (~5% lower flux for the LW mode with respect to the SW due to a pile-up effect).

• The MOSs response shows a decreasing trend of ~5% up to revolution 800.

• The MOS1 flux is lower than that of MOS2 by ~5%.

• The lower flux of the MOSs with respect to that of the pn is probably due to pile-up in the MOS LW mode (all MOS observations plotted here have been performed in this mode).

Relative flux trend analysis with AGNs

Data from a sample of AGNs were analysed with SAS 6.1 and fluxes were computed. The relative long-term trend obtained from Fig 4 has evidence that MOSs and RGSs lose sensitivity over time in the soft energy band 0.4-0.8 keV with respect to pn. This trend leads to a deficit of 15% for MOS2 and 15-20% for MOS1 and RGSs after 800 revolutions (5% of deficit at launch), which is consistent with SNR studies.

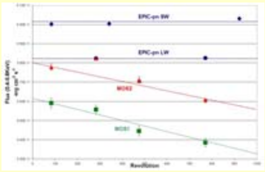


Fig. 3 Flux of N132D in the soft band from 0.4 to 0.8 keV for all EPIC cameras as a function of time (revolution). Blue diamonds: pn (SW mode), blue circles: pn (LW mode), red: MOS2 (LW mode), green: MOS1 (LW mode).

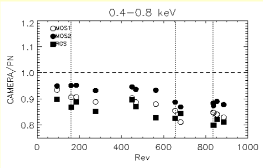


Fig. 4.Camera/pn flux ratios in the 0.4-0.8 band (vertical dotted lines show the exposures performed in SW/Thin filter). Open circles: MOS1, closed circles: MOS2, closed squares: RGS1+2.

Conclusions

The spectral response of the MOS detectors has been now discovered to be spatially dependent, and not uniform as believed previously.

The only explanation consistent with this evidence is that a small patch on each detector has degraded over time in a way which broadens the redistribution function at energies around 0.5 keV. Using the SNR as a torchlight the position of the patch on the detector can be identified (Fig 6). It is seen to be oval in shape and be coincident with the nominal position of sources when placed at the PN and RGS boresights. In fact it is coincident with the peak in received photon dose of the detectors.

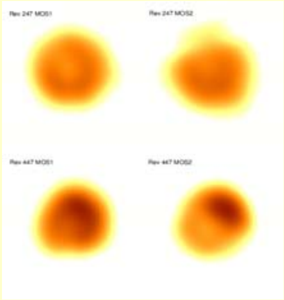


Fig 5. 0.1-0.35 keV smoothed images of the remnant for MOS1 and MOS2 for an off-boresight (247) and an on-boresight (447) pointing.

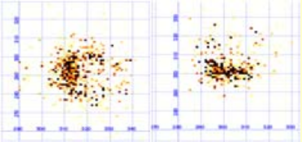


Fig 6. Patch position in RAW coordinates, MOS-1 (left), MOS-2 (right)

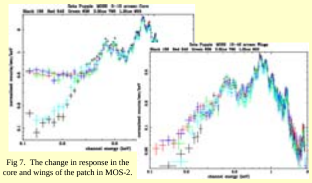


Fig 7. The change in response in the core and wings of the patch in MOS-2.

Latest improvements

MOS redistribution

Due to the discovery of the existence of the patch in the MOSs, the redistribution function of the MOS has already been modified in order to solve the effect that this patch produces at low energies. This updated redistribution, modelled in 8 different epochs, must now be extended to cover different areas of the detector. At present, the response may be divided into three discrete areas: a core, of radius 15", centred upon the observed patch whose response degraded gradually with time but stabilised around rev 700, a wings area, modelled as an annulus about the core region of outer radius 40", which is not as strongly affected as the core but whose response continues to evolve and an outer area, defined as the rest of the detector which has experienced a slow and still changing evolution.

Extended CCFs, constructed to define the multi-parameter response space, are being constructed and will be interfaced with SAS 6.5. Naturally a typical extraction region will overlap more than one of the response areas and so rmfgen will be upgraded to calculate a flux averaged RMF in SAS 6.5.

pn redistribution

For SAS 6.1, values of the pn redistribution close to the ground calibration measurements were adopted. As a result, in SAS 6.1 the agreement between EPIC-pn and MOSs (and RGSs) at low energies was improved, and analysis of Zeta Puppis also showed a good modelling of its spectral lines. However, analysing the very soft source RX1856.5-3754, the pn spectrum showed a soft excess with respect to the MOS model below 0.4 keV, and the column density derived from that pn spectrum was $7 \cdot 10^{19}$ cm^{-2} lower than that obtained from a 500 ksec Chandra LEGTS high resolution spectrum. In addition, analysis of a set of Blazer spectra, which are expected to be fit well with broken power-law models, actually show a consistent set of residuals (Fig 10 top) indicating that the modelling of the redistribution function is still not perfect.
Using these residuals as a starting point, an energy-dependent re-working of the RMF has been made which flattens the residuals (Fig 10 bottom). These new RMFs improve the fit to other continuum sources such as RX J1856,5-3754 (giving a fitted N_H closer to that of Chandra) and importantly bring the pn and MOS cameras into better agreement.

These latest MOS and pn redistributions have been used to analyse data from different objects (AGNs, INS). These studies (see Figs 8-11. Upper panel: analysis with SAS 6.1 redistributions, lower panel: new MOS and pn redistributions) show a better agreement between MOSs and pn and also flatten the residuals for pn observations with the new redistributions than using the older ones given by SAS 6.1.

SAS 6.1

Expected for SAS 6.5

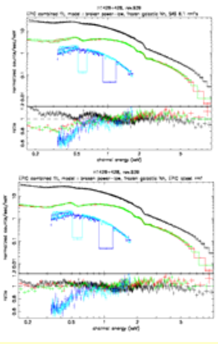


Fig. 8 Analysis of the BL Lac H1426+428. Black: pn, red/green: MOSs, blue/light blue:RGSs. Top: SAS 6.1, bottom: new rmfs

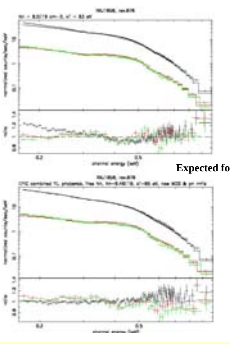


Fig 9. Analysis of the isolated neutron star RX J1856,5-3754. Black: pn, red/green: MOSs. Top: SAS 6.1, bottom: new rmfs

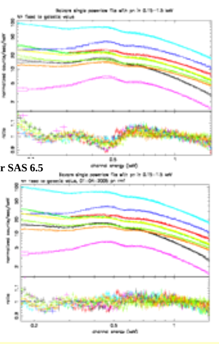


Fig 10. Analysis of a set of Blazer using old rmfs (top panel) and new rmfs (bottom panel). Black: pn, red/green: MOSs. Top: SAS 6.1, bottom: new rmfs

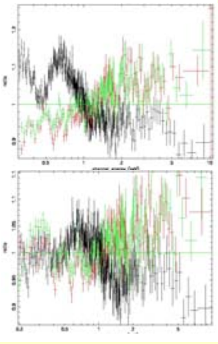


Fig 11. Ratio of data and model for simultaneous spectral fits of PKS 2155-304 using old rmfs (top panel) and new rmfs (bottom panel). Black: pn, red/green: MOSs. Top: SAS 6.1, bottom: new rmfs

Open problems

• EPIC–pn observations with very high statistical precision show residuals at the silicon edge around 1.8 keV.

• Analysis of the pattern distributions in EPIC-pn has shown that charge is more often observed to be split along readout direction than perpendicular to it, which may introduce a systematic error in the energy.

• EPIC-MOSs show more flux than pn at high energies (>5 keV)

EPIC consortium meeting
11-13 April 2005, Schloss Ringberg, Germany