# 3.2 The High-Throughput X-ray Spectroscopy Mission (XMM)

## Introduction

The high-throughput X-ray spectroscopy mission, XMM, is under development by the European Space Agency for launch in August 1999. The overall development of XMM is well into the Flight Model (FM) development phase, with most of the experiment deliveries by the Principal Investigators (PIs) expected by June 1998. Although these deliveries are somewhat later than originally foreseen, the overall schedule (and consequently the launch date) remains unchanged.

## Scientific objectives

XMM was designed to investigate, in detail, the spectra of cosmic X-ray sources down to a limiting flux of $10^{-15}$ ergs/cm$^2$/s. XMM's instrument complement has been specifically designed to meet this goal and is capable of detecting weak continuum and X-ray line emission (together with an imaging capability) from many of the emission lines originating in a hot plasma ($10^6$-$10^8$ K). Owing to the high plasma temperature, many of the abundant elements are stripped of all but a few electrons. Consequently, one observes emission lines from elements in H- or He-like states only. Apart from the moderate energy resolution of the imaging cameras, XMM can also perform medium resolution spectroscopy for many of the brighter sources exhibiting a wealth of emission lines. This will reveal the condition of the emitting plasma (temperature, electron density and elemental abundance) in unprecedented detail. These capabilities will ensure that XMM will place the astronomical community at the cutting edge of 21st century X-ray astronomy.

## The XMM payload

The mirror modules are a critical component of the XMM mission in terms of science. Most of the FM mirror modules have been produced and tested extensively and are of excellent quality. The performance of the mirror modules tested to date (FM1, FM2 and FM3) is shown in Table 3.2.1.

These data clearly show that the performance of all XMM mirror modules is excellent. They exceed their original spatial resolution specification by a factor of 2. The effective area of the mirror modules also meets the specification, and provides XMM with the largest X-ray collecting area yet to be flown. A close-up of an integrated mirror module is shown in Figure 3.2.1.

In support of the mirror calibration programme, a full, exact, metrology-based ray-tracing program for the XMM mirrors has been developed as part of an overall XMM Science Simulator (SciSIM). This model has been successfully used to predict the performance of the mirror modules measured so far, and will be used to predict and analyse the in-orbit performance of the XMM mirrors. SciSIM will also be used to tie in the on-ground calibration of the XMM instruments with their in-orbit performance. This approach should allow for a more accurate description of the overall XMM calibration.

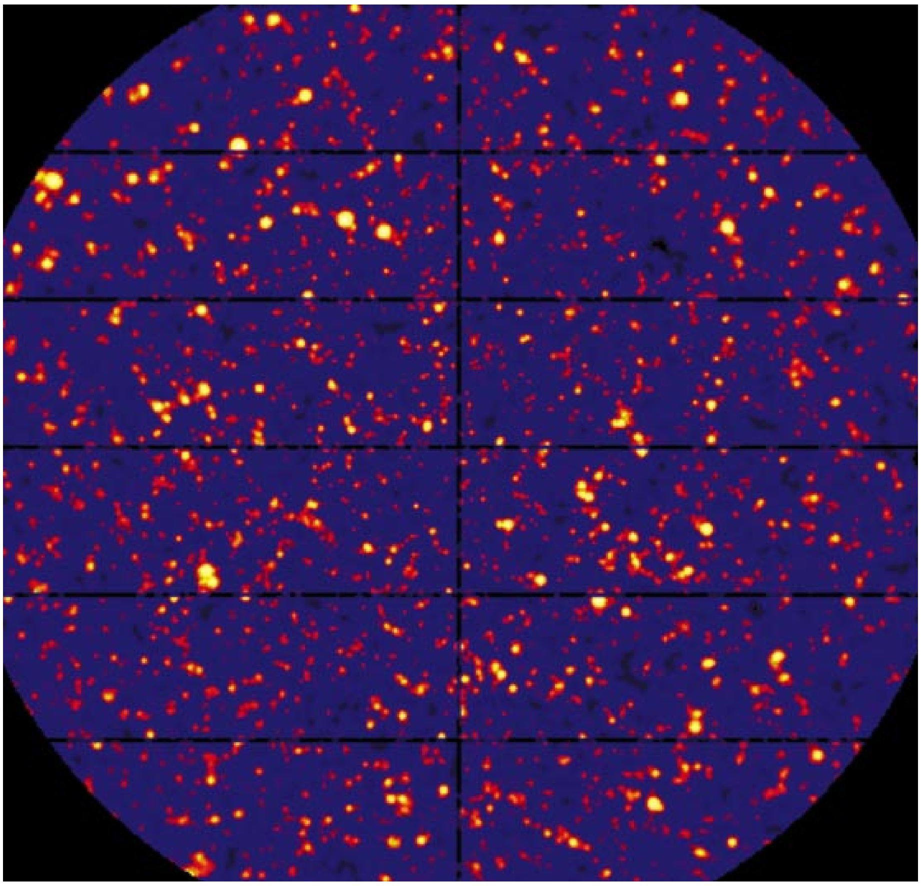
**Figure 3.2.1. A close-up of a fully integrated XMM mirror module. The thickness of the shells ranges from 0.4 mm to 1 mm, while the spacing ranges from 1 mm to 4 mm. The radius of the outer shell is 350 mm.**

**Table 3.2.1. XMM mirror module measured X-ray imaging performance.**

| | *FM1 (arcsec)* | *FM2 (arcsec)* | *FM3 (arcsec)* |
|---|---|---|---|
| FWHM @ 1.5 keV | 8.4 | 6.6 | 6.0 |
| FWHM @ 8.0 keV | 7.7 | 6.6 | 5.1 |
| HEW @ 1.5 keV | 15.2 | 15.1 | 13.6 |
| HEW @ 8.0 keV | 14.4 | 14.8 | 12.5 |
| W90 @ 1.5 keV | 56.8 | 57.2 | 48.1 |
| W90 @ 8.0 keV | 161.0 | 182.0 | 153.0 |

*For further information on XMM, see http://astro.estec.esa.nl/XMM/xmm.html*

**Figure 3.2.2. A simulated exposure of 100 000 s with XMM using the EPIC-PN camera. From this image, it is clear that XMM will detect a vast number of hitherto-unknown X-ray sources.**



**European Photon Imaging Cameras** (PI: M. Turner, Leicester University, UK)
A European Photon Imaging Camera (EPIC) detector will be placed behind each of the three X-ray mirror modules. Two cameras based on MOS-CCD technology share the mirrors with the grating array, and the detector based on PN-CCD technology is located behind the fully-open telescope position. Although the development of all of the EPIC cameras has met with some delay, the schedule has been reworked so that their delivery to the spacecraft contractor still allows the launch date to be maintained.

The performance expected from the EPIC cameras remains essentially unchanged since the previous report. Given the excellent performance of the XMM mirror modules and the good performance of the EPIC cameras, it is expected that XMM can greatly expand the knowledge on many classes of X-ray sources. It will be particularly powerful for those sources that show weak extended X-ray emission (such as clusters of galaxies).

The combination of mirrors and EPIC X-ray camera also allows XMM to investigate a hitherto-unknown part of the so-called Log N-Log S relation, which relates the surface number density of sources in the X-ray sky to their luminosity. It is not known how this relation extends to the population of weaker sources, especially in the 2-10 keV X-ray band, and this is where XMM will perform best. A SciSIM simulation of a random field in the X-ray sky, as one would expect to observe with an EPIC-PN camera after a $10^5$ s exposure, is shown in Figure 3.2.2.

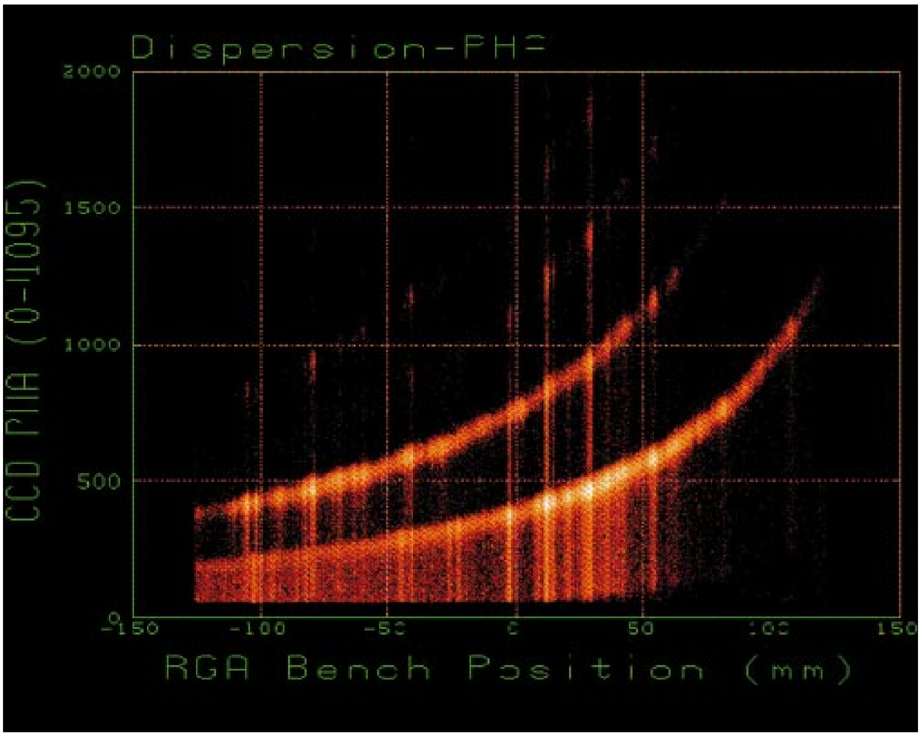


**Figure 3.2.3. A simulated 7000 s exposure of Capella with XMM, using the Reflection Grating Spectrometer (RGS).**

**Reflection Grating Spectrometer** (PI: A. Brinkman, SRON-NL)
The Reflection Grating Spectrometer (RGS) is a powerful, large-area detector that will allow XMM to take X-ray spectra with an E/DE of 300-700 (1st order) in the 5-35 Å (0.35-2.4 keV) soft X-ray band. The effective area for the two grating arrays will be in the range 40-200 $cm^2$ over this wavelength band. Both grating arrays have been manufactured and meet the specification. A SciSIM simulation of a 7000 s XMM observation of Capella is shown in Figure 3.2.3. This complex graph clearly shows the resolved spectral features in the Capella spectrum (the bright vertically-oriented features). It also shows the capability of the RGS to separate 1st and 2nd order reflection from the grating arrays. This is done by using the intrinsic spectral resolution of the CCD detecting element in the RGS. (The 1st and 2nd order spectra are represented by the two bright features running from bottom left to top right in the image).

**Optical Monitor** (PI: K. Mason, Mullard Space Science Laboratory, UK)
XMM's Optical Monitor (OM) is a powerful telescope in the 170-600 nm wavelength band, which can detect sources down to 24th magnitude in a few thousand seconds (depending on spectral type). This camera is powerful enough, both in sensitivity and positional accuracy, to allow for possible identification of counterparts of many of the new X-ray sources that will be detected with XMM. An exciting prospect with XMM would be direct follow-up observations of a gamma-ray burst, since the Optical Monitor would ensure that XMM could track the X-ray and optical afterglow for these objects.

**Figure 3.2.4. The XMM Structural Thermal Model (STM) under integration at Dornier.**

## The XMM spacecraft

XMM's Structural Thermal Model (STM) has successfully completed all environmental tests, and work is continuing on the Flight Model (FM). The STM under integration at Dornier is shown in Figure 3.2.4. The XMM spacecraft weighs 3900 kg and measures almost 10 m long. The tests on the light tightness of the telescope tube went especially well. This is of crucial importance as the X-ray detectors are very sensitive to visible light.

The original XMM orbit required an Ariane-5 option that would not have been qualified in time for the XMM launch. Consequently, the orbit was changed to a 40°-inclination, 48 h southern orbit. This will be covered by the ESA antennas in Perth and Kourou, with only a minor period of no coverage around apogee. This gap divides the useful part of XMM's orbit into two parts, but still allows for uninterrupted observations of 80-90 ks during most of XMM's lifetime. The orbit change also changed XMM's sky visibility, which hitherto had an almost uncovered region in the Large Magellanic Cloud (LMC) – an area of vital importance for instrument in-flight calibration. In the new orbit, most of the sky will become visible over the first two years of the mission, although there will still be a small area around Cygnus X-1 that will remain invisible for the first two years of the mission.

## The XMM ground segment

The XMM ground segment has been defined in a series of user requirements documents on all of the software subsystems. Following the ESA PSS-05 software development cycle, the XMM software subcontractor subsequently translated this into a system requirements document, an architectural design document and a detailed design document; all of these have been fully reviewed. The actual software coding of the XMM ground segment subsystems has started and the first delivery is expected at the end of 1998. The XMM data archive is part of the ground segment and particular effort has been made to make the archive user-friendly, easily accessible and offer data preview products whenever possible.

An important element in the XMM ground segment is the Survey Science Centre (SSC), an Announcement of Opportunity-selected, PI-led (PI M. Watson, Leicester University, UK) consortium of astronomical institutes responsible for:

- performing the routine pipeline processing of all XMM data, providing the general observers with a standard analysis;
- performing detailed follow-up observations for a number of XMM fields.

The XMM SOC (Science Operations Centre) is preparing for the first call for observing proposals. The release will be accompanied by a workshop dedicated to XMM on 30 September to 2 October 1998 at ESTEC.