# CLOSING ADDRESS

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In this workshop, an impressive account has been presented of the scientific capabilities of the X-ray Multi-Mirror mission. This on-orbit X-ray telescope-facility will undoubtedly constitute a major, and partly unique, observing tool for keeping European space science at the forefront of high energy astrophysics in the coming decade. From the various talks that have been given over the past few days, I have tried to extract a number of "salient features" regarding XMM, i.e. characteristics that are rather unique to this mision and which potentially provide significant scientific added value.

•XMM provides **an outstanding spectral grasp:** the *simultaneous* combination of large spectral bandwidth (0.1-15 keV) and spectral resolving power at an unprecedented level of sensitivity owing to the high-throughput imaging optics. This capability is particularly relevant for the spectral diagnostics of multitemperature plasma in the temperature range from five million to one- hundred million Kelvin, residing in supernova remnants in their early evolutionary phase, in active stellar coronae and in cooling flow galaxy clusters. Several interesting cases have been highlighted in this workshop by a.o. J. Schmitt, M. Guedel, R.Pallavicini, H. Tsunemi, and M. Arnaud.

•The XMM replica optics possesses **excellent imaging properties**, **given the demanding requirement on effective X-ray collecting area**, that surpass the design requirement specification by over a factor of two, i.e. an achievement at 8 keV of 5 arcseconds FWHM and a half-power diameter(HPW) of 12 arcseconds respectively (ref. contribution by B.Aschenbach). Moreover this performance also exceeds the design goal of 20 arcseconds HPW at 2 keV for maximising the spectral resolving power of the Reflection Grating Spectrometer. In fact the spectral performance of the RGS is now no longer dominated by the imaging properties of the X-ray collecting optics, but by the intrinsic optical performance of the X-ray dispersive elements in the reflection grating assembly itself, as described by A. Brinkman.

•XMM provides **an unprecedented high-energy imaging response** (up to 15 keV) by virtue of the employment of the novel, thick depletion layer, pn-CCD camera as presented by M.Turner. This will probably turn out becoming a very forceful capability in the diagnostic of the non-thermal (or supra-thermal) radiation morphologies in the hitherto designated "thermal" X-ray sources like shell-type SNR's and clusters of galaxies. Recently, with the the medium-energy X-ray imagers on BeppoSAX, strong evidence has been obtained that synchrotron radiation by TeV-electrons may contribute significantly to the high-energy image of the supernova remnant Cas-A (Vink et al 1999). Also, the X-ray emission from the radial outskirts of the galaxy cluster A2199 may be dominated by the inverse-Compton radiation of energetic cosmic-ray electrons in the intra-cluster medium with the cosmic microwave background (Kaastra et al 1999). Unambiguous assessment of these radiation components requires continuum mapping beyond the the thermal line(continuum) energies,say above 10 keV. XMM is uniquely suited to perform this type of research.

•The XMM **MOS-cameras retain good spectral resolving power near the low-energy end** of the X-ray bandpass, i.e. $E/\Delta E \approx 3$ at 0.2 keV. This is particularly important for conducting carbon-line diagnostics in low-temperature imaging spectroscopy of SNR's with low absorption measure (either nearby galactic or high-latitude extragalactic) and in cooling flow clusters.In addition, this feature is of considerable value in restraining parameter space in Differential Emission Measure (DEM) analyses of coronal plasmas and in accurately assessing the continuum shape of the soft X-ray excess in AGN.

•XMM offers **an order of magnitude improvement in X-ray throughput for Fe-K-line diagnostics**, as compared to other contemporary missions. The important Fe-K-complex diagnostic pertains to almost every class of cosmic X-ray source, be it e.g. X-ray SNR's, diffuse Galactic Ridge emission, X-ray binaries, AGN or galaxy clusters. It is particularly relevant for the study of dynamical phenomena like X-ray flares in active stars and compact objects and for Fe-K-profile reverberation mapping as a probe of gravity in the strong field limit at a few Schwarzschild radii from the supermassive central blackhole in AGN. It is especially in these cases that sheer photon collecting power rules the quality of the result, as was convincingly shown in the video simulation of MCG-6-30-15 presented by Andy Fabian during his talk.

•The Reflection Grating Spectrometers on XMM possess a truly **unique capability for high-resolution spectroscopy,including 1D/2D imaging capability, of extended thin plasma sources with limited angular extent** (≤2 arcminutes). This possibility arises from the characteristically high dispersive power of a reflection grating irradiated at grazing incidence. This feature allows a detailed study of the physical properties of strong astrophysical shocks, like the primary blast wave and reverse-shock heating in young SNR's and, potentially, in the interaction between cooling flows and the underlying galaxies. A simulation of this capability on N132D, a supernova remnant in the LMC of a few arcminutes in size, shows that for relatively isolated spectral lines like OVIII a full two-dimensional image in the line can indeed be recovered (courtesy J.Spodek).

•A major asset of XMM is its ability to provide **simultaneous optical coverage** of the observed X-ray sources with the aid of a highly sensitive boresighted Optical Monitor.The large value of multi-spectral correlations regarding source positioning, identification, and X-ray/optical lightcurves has been amply logged in the literature and was also touched on in this meeting by a.o. K.Mason and A.Parmar.

Let me now make a few comments on the exploitation of the XMM observatory.
First and foremost I like to emphasize once more that high quality measurements do not only require the availability of a sophisticated instrument package, but also adequate exposures as to fully exploit the high resolution capabilities of XMM.. We are all aware of several examples in past observations of marginal exposures, which in the end did not really deliver the new insights originally aimed for. A detailed assessment of high resolution spectra with XMM will require at least ten thousand source photons and in some cases considerably more. I want to urge everybody to run proper simulations with the SCISIM tools to make sure that we use XMM in the scientifically most (and by implication

cost) effective way. In this respect I wish to express a word of concern about the feasibility of properly measuring the radiation morphologies of extended sources with very low surface brightness, like e.g. a fluctuation analysis to assess the presence of large scale structures in the universe. With full acknowledgement of this exciting topic, the residual leakage of the X-ray baffle in front of the grazing incidence mirrors may nevertheless severely corrupt the measurement results and a fully representative simulation, to bring out potential artifacts, is in this case absolutely mandatory.
Also, considerable effort is still required to bring the physical modelling tools up to the standard required for the detailed spectral work that XMM can do. Frits Paerels has presented us with an important overview of what is really involved in performing spectroscopic analyses with the XMM instruments and we should all be (or become) very aware of this. I like to highlight a few model aspects that deserve some attention in the near future:

- The analyses of optically thin plasma sources
  - Establishing accurate wavelengths through laboratory and solar benchmarking.
  - Large uncertainties still exist (50-100%) regarding the collision strengths for high values of the principal quantum number n in He- and H-like ions.
  - More accurate computation of the L-complexes for the heavier elements Mg, Si, S etc. are required, except for the case of the Fe-L-complex, which has recently been upgraded.
  - More accurate computations of the ionisation balance for the same elements, again with the exception of iron.

- More in-depth modelling of the spectroscopic line-features of X-ray photo-ionised nebulae, the so-called XPN-models, most relevant for accretion driven sources.

Looking ahead, the next decade promises to be very rewarding for X-ray astronomy. With missions like ASCA, RossiXTE and BeppoSAX still operational and healthy, and with AXAF, ABRIXAS, XMM, and ASTRO-E to be launched in the upcoming two years, we may actually slightly face an *embarassment of richess*. Given the fact however, that there is a large degree of complementarity to these various observatories, we are in a unique position to capitalize on their mutual synergy! We should explicitly see to it, as our responsibility, that the exploitation of this synergy indeed takes shape with focussed, well-coordinated observation programmes, to reap the richest possible scientific harvest from an extremely exciting next decade in (X-ray) astronomy.