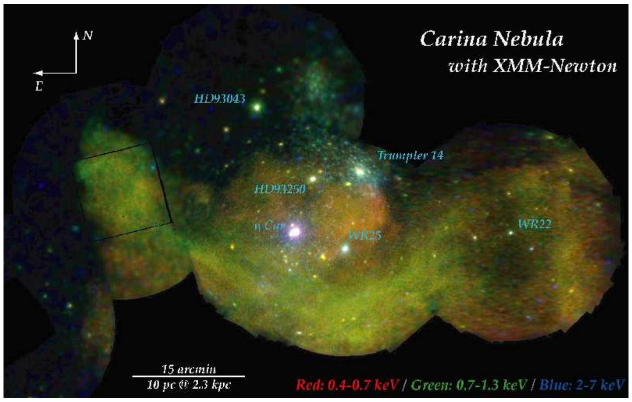

XMM-NEWTON Guest Observer Facility, Guest Observer Funding, US RGS Team, and Education and Public Outreach

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Summary

On behalf of the US *Newton X-ray Multi-Mirror Observatory* (*XMM-Newton*) users community, the US Reflection Grating Spectrometer (RGS) Team, the NASA Goddard Space Flight Center (GSFC) Guest Observer Facility (GOF), and the NASA *XMM-Newton* Education and Public Outreach (E/PO) program, we request funding for the continued support of US participation in the European Space Agency (ESA) *XMM-Newton* mission. *XMM-Newton*'s instruments provide unique data enabling US astronomers to continue to produce high-quality and significant results, at particularly low cost to NASA relative to other Great Observatory-class missions.

Continuing in the seventh Announcement of Opportunity (AO-7), the oversubscription by the world-wide community remains high, even increasing to a factor of 7.8 in time with 586 submitted proposals. The US astronomical community has been a major participant in the Guest Observer (GO) process throughout all AOs. In AO-7, 36% of the accepted proposals had US Principal Investigators (PIs), and an additional 33% had US Co-investigators (Co-Is). ESA has extended the *XMM-Newton* mission through at least 2012, and we anticipate a similar or better US response and success rate in future AOs. Moreover, with over 350 refereed papers per year (417 in 2006, at least 360 in 2007), with a commensurate proportion led by US authors, the scientific output from *XMM-Newton* remains high, and these results are cited four times more often than the average refereed paper in the astronomical literature.

The science goals and achievements of *XMM-Newton* are directly responsive to the 2006 NASA Strategic Plan[1], providing important advances towards the strategic goal of "Discovering the origin, structure, evolution, and destiny of the Universe, and search for Earth-like planets" (Sub-goal 3D). *XMM-Newton* provides unique and necessary data for studies of the fundamental processes of neutron stars and black holes, the creation of the elements in supernovae and their dispersal in supernova remnants and starburst galaxies, the evolution of the elements on the largest scales in clusters and groups of galaxies, and the distribution of dark matter in clusters, groups, and elliptical galaxies. The study of active stars allows direct comparison with models of the early solar system and star forming regions for understanding the origin and evolution of stellar systems. *XMM-Newton* has examined relativistic processes from neutron stars and quasars, and constrained the spin of black holes in Active Galactic Nuclei (AGN). *XMM-Newton* also provides the capability of simultaneous X-ray and optical/ultraviolet (UV) observations. While the science areas of *XMM-Newton*, *Chandra* and *Suzaku* do overlap, each mission has been optimized differently in the six-dimensional space of angular resolution, bandpass, collecting area, spectral resolution, timing ability, and instrumental background.

Why *XMM-Newton*?

The Senior Review panel has been asked to examine the question of "Why are new data from older missions necessary?" As shown below, *XMM-Newton* provides a broad range of exceptional data (from comets to quasars) to a large number of US GOs at low overall cost and has a rich scientific future.

There is no present mission, or any mission planned for launch in the next five years which has *XMM-Newton*'s combination of high through-put X-ray imaging and spectroscopy and broad band (optical and UV) capabilities. *Constellation-X*, the planned successor to *XMM-Newton* as well as *Chandra*, is more than a decade away. The only other relevant mission is *NeXT*, a Japanese-US mission which will have, if approved as a Small Explorer Mission of Opportunity, a spectroscopic capability superior to *XMM-Newton*'s grating spectrometer but will not have the angular resolution or collecting area of *XMM-Newton*. As shown by the response of the US community to both the *Chandra* and *XMM-Newton* AO's, these missions are complementary, with *XMM-Newton*'s wide field and high throughput imaging and *Chandra*'s unique high resolution imaging capabilities. The grating spectrometers of the two missions are also complementary as is *Suzaku*'s broad band ($0.3 - 200$ keV) spectroscopic capability.

Because ESA and its member nations carry the brunt of the costs for *XMM-Newton* operations, software development, and data processing, the US community has access to "Great Observatory" science at a small fraction of the cost of the US operated Great Observatories. The US community receives $\sim \frac{1}{3}$ of the total *XMM-Newton* time and the mission is highly productive. While removing the *XMM-Newton* funding would not, legally, reduce the access of the US community to *XMM-Newton*'s new observations (AOs are open to the entire world), the lack of funding for data analysis and interpretation and the removal of GOF support would have a major impact on the science productivity of the mission by reducing the participation of the US community.

[1] http://www.nasa.gov/pdf/142302main_2006_NASA_Strategic_Plan.pdf

The future for *XMM-Newton* is bright with its unique properties for: 1) Science requiring many counts (but not necessarily high count rates) such as determining the abundance profiles of high-z clusters or the structure of AGN Fe K lines allowing the determination of black hole spin. 2) Science requiring long-looks or monitoring campaigns (i.e., variability studies) such as AGN timing or detailed studies of isolated neutron stars. 3) Science requiring multiwavelength observations using the *XMM-Newton*-unique Optical Monitor (OM), such as detailed studies of star forming regions. 4) Science using large samples of objects (legacy programs) utilizing the high "speed" of *XMM-Newton* observations such as studies of groups of galaxies. 5) Science using *XMM-Newton*'s ability to obtain good signal-to-noise (S/N) spectra for weak sources such as the origin of the X-ray background and binary populations in nearby galaxies.

As new ground-based surveys such as the Sloan Digital Sky Survey (SDSS), the south pole telescope, and VISTA, as well as new space-based surveys from *Spitzer* and *Herschel* become available, *XMM-Newton* is the mission of choice for X-ray spectroscopic and timing follow-ups. In order to accommodate many of these capabilities the ESA project has modified the AO to introduce a new proposal type for very large programs allowing requests for 1–3 Ms of time and increasing the time dedicated to large and very large programs to about 30% of the total. To increase the usefulness of *XMM-Newton* for Targets of Opportunity (ToO) expected to come from *GLAST* and *Swift*, a new AO policy was introduced which allows the GOs to propose ToO observations of targets whose coordinates are not known at the time of submission (e.g., a new supernova)

Mission Overview

XMM-Newton is the second cornerstone of the ESA *Horizon 2000* program. Launched on 1999 December 10, it remains in full operation and is in excellent health. ESA mission support is confirmed through 2012, with a possibility of future extensions. As of 2008 March, nearly 6500 targets have been scheduled for observation. All science data are made public after the expiration of a proprietary period, typically one year after data delivery. The *XMM-Newton* archive had 5600 observations publicly available as of 2008 March.

XMM-Newton observes in the 0.2–12 keV and optical/UV bands. Its highly elliptical orbit allows long, uninterrupted observations. This contiguous coverage (up to $\sim$ 135 ks) is more important now that *Chandra* is limited to $\sim$ 35 ks or less in many orientations. The observatory has three co-aligned high throughput 7.5 m focal length X-ray telescopes with $6''$ full width at half maximum (FWHM) angular resolution. The European Photon Imaging Camera (EPIC) charge-coupled device (CCD) detectors provide X-ray images over a $30'$ field of view (FOV). Higher resolution spectra ($E/\Delta E \sim 200-800$) are provided by the RGS that deflect half of the beam from two of the X-ray telescopes, and these are the only high spectral resolution instruments capable of observing extended sources. The sixth instrument, the OM, is a co-aligned 30 cm optical/UV telescope sensitive in the 1600-6500 Å band with a $17'$ FOV and a wide variety of modes. **All the scientific instruments operate simultaneously, providing exceptionally rich data sets.** The instruments can be run in a variety of modes, allowing them to be tuned for the science needs of a given observation.

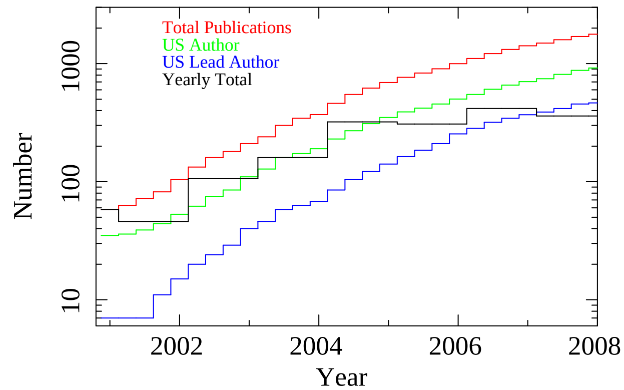

Figure 1: *XMM-Newton* refereed paper publication history.

XMM-Newton excels in providing high throughput X-ray imaging, timing, and spectroscopy for an extremely wide variety of astrophysical sources, from comets and planets to quasars and clusters of galaxies. With the EPIC and OM instruments constantly observing a large FOV, the well-calibrated and very large serendipitous source archive is a vast resource for ancillary research. However, only through the availability of *XMM-Newton*, *Chandra*, and *Suzaku* observations does the world community achieve the full complement of high angular resolution, high throughput, high spectral resolution, and low background in the 0.2–70 keV and optical/UV bands.

By the end of 2007 there were 1775 refereed papers published based on *XMM-Newton* data, with new papers appearing at the rate of one per day (see Figure 1 and the publication list[2]). Over the last two years *XMM-Newton* and *Chandra* have had similar numbers of refereed publications. The character of highly cited *XMM-Newton* papers is changing due to the publication of results from large *XMM-Newton* programs and combined analysis of *XMM-Newton* and other (e.g., *Hubble*, *Chandra*, *Spitzer*) data. We expect these trends to continue in the future and to amplify the impact of *XMM-Newton* results.

The *XMM-Newton* workshop on the future of the mission "*XMM-Newton*: The Next Decade" held in 2007 June in Spain, identified a large number of rich new science areas for *XMM-Newton* including studying the intergalactic medium, the origin of ultraluminous galaxies, the evolution of large scale structure, how AGN have influenced the formation of structure, detailed studies of nearby galaxies including their interstellar medium, constraints on the equation of state of neutron stars and the physics of star forming regions (to mention a few). Some of this new science comes from the release of the 2^{nd} *XMM-Newton* serendipitous source catalog (2XMM) in 2007 October with 191,870 unique sources and the *XMM-Newton* Slew Survey, released in 2007, which is 5 times more sensitive than the best previous

[2]http://xmm.gsfc.nasa.gov/docs/xmm/xmmbib.html

hard (2–8 keV) X-ray large solid angle survey. These catalogs are a major resource for archival research and provide a firm basis for future observation proposals.

XMM-Newton's status as one of the world's pre-eminent astronomical observatories is shown by the high proposal pressure, publication rate, and the frequent citation of refereed papers. In the last 3 years there have been more than 65 *XMM-Newton* papers with more than 25 citations compared to 117 from *Hubble*. US scientists author $\sim \frac{1}{3}$ of the successful proposals and refereed papers, and would be placed at a severe disadvantage in many areas of astrophysical research without continued guest observer funding and support.

Given the health of the instruments and the satellite, the high oversubscription rate, the high fraction of the time going to US guest observers, the large archive and the rich scientific future we believe the continuation of the US *XMM-Newton* program at the present rate of funding is highly justified.

1 XMM-Newton Science

XMM-Newton's research program is peer-review driven with ToO possibilities, and thus it is very difficult to predict the next great discoveries. Every year since *XMM-Newton* was launched has seen major discoveries across many areas of science. One way of documenting the evolving scientific program is via the accepted large projects. Starting in AO-3 these have included surveys of clusters of galaxies across a wide range of redshifts, monitoring of the galactic center, a large solid angle deep X-ray survey, and a survey of the Taurus molecular cloud. AO-4 brought projects to study the intergalactic medium, timing observations of ultra-luminous X-ray sources, time variability of AGN Fe lines, and the spin rate of an isolated neutron star. In AO-5 there were a deep and wide survey of M31, a follow-up of *Swift* BAT sources, a very large but relatively shallow X-ray survey to search for large scale structure, measuring the ionization structure of "dipping" X-ray binaries, and a study of the relativistic double pulsar PSR J0737-3039. AO-6 had an investigation of the outer regions of a galaxy cluster, a study of Orion's population of young stars, deep grating observations of low redshift clusters, and a RGS study of shell-type supernova remnants with X-ray synchrotron radiation. AO-7 large projects include a survey of nearby stars with planets, X-ray timing studies of X-ray pulsars, mass profiles of galaxy clusters, and a survey of the SN 1006 supernova remnant. There have been over 25 press releases on *XMM-Newton* science in the last two years.

The next dedicated *XMM-Newton* Symposium, "The X-ray Universe 2008" to be held in Granada, Spain, is expected to be well-attended (the last such meeting had over 320 participants) with many new results. *XMM-Newton* is also well represented at a wide variety of international and national astronomical meetings.

The future science of *XMM-Newton* is considerably enhanced by the availability of the 2XMM, Slew Survey, and OM catalogs, which provide "finding charts" for future proposals and large samples of all types of objects. These databases enable not only direct archival research but also new GO programs. The phase space for discovery with *XMM-Newton* has increased through the years. For example, continual improvements in calibration and the advent of new software allow diffuse background studies and measurement of the mass profiles of clusters, measurements of the soft X-ray background and the galactic plane emission. The continued development of the basic Science Analysis System (SAS) has made analysis easier and more robust as well as providing new automatic data products, easing the analysis of the large and complex data sets. We believe that the best is yet to come from *XMM-Newton*.

The wealth of *XMM-Newton* results requires a focus on a small fraction of the representative results. With more than 1350 accepted GO proposals and $\sim$ 1800 refereed papers, more than 750 in the last two years, the following is just a taste of what has been accomplished in the last two years, and suggests what the future might hold.

1.1 Active Galactic Nuclei (AGN)

XMM-Newton observations of AGN continue to provide the highest quality spectral and timing data, crucial for understanding the origin of the continuum and the nature and distribution of matter near the black hole. The innermost regions of AGN where the bulk of the energy is produced can be investigated only by sensitive X-ray observations. The intensity and the profile of the iron emission lines near 6.4 keV provide a unique diagnostic tool to understand accretion processes in the vicinity of the black hole where the effects of strong gravity (e.g., gravitational redshift and light bending in curved space-time) are important. One of the most recent highlights is that systematic studies of large (> 100) samples of AGN demonstrate that most of the "well-exposed" objects (i.e., with $> 150,000$ counts) do indeed show broad Fe K profiles (Figure 2; Guainazzi et al. 2006; Nandra et al. 2007) indicating the importance of relativistic processes. Moreover there are a significant number of sources showing transient and/or modulated variations of the Fe K line (see e.g., Tombesi et al. 2007; Petrucci et al. 2007). Such observations offer the opportunity to directly estimate the black hole mass and spin (a), and test theoretical models describing the innermost regions of accretion disks around AGNs. Brenneman & Reynolds (2007), in the first ever survey of black hole spin, analyzed a set of high S/N *XMM-Newton* AGN spectra placing robust constraints on black hole spin from moderate (a$\sim$0:5–0:7) to high (a>0:85). The validity of such observations have been supported by detailed comparisons of *Suzaku* and *XMM-Newton* observations of several AGN (Reeves et al. 2007) which have shown that both sets of data are virtually identical, confirming that the EPIC and the *Suzaku* XIS are extremely well cross calibrated.

The *XMM-Newton* high count rate for AGN studies combined with long and uninterrupted observations has allowed a direct comparison of properties of Galactic and extragalactic black holes. Summons et al. (2007) and Arévalo et al. (2006) have shown that the timing properties of AGN can be well modeled by the same processes seen in Galactic black holes making a fundamental connection between black holes across a mass range of 10^6 in mass. *XMM-Newton*'s unique properties

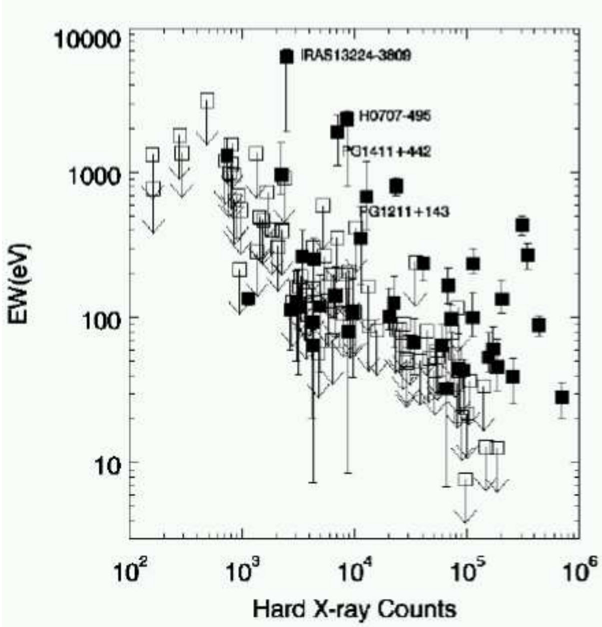

Figure 2: *XMM-Newton* measurements of the equivalent width of the Fe Kα relativistically broadened component as a function of the total net counts in the 2-10 keV band. Filled squares are detections. Empty squares are upper-limits. Broad lines are found in 50% of spectra with $> 1.5 \times 10^5$ counts, emphasizing the need for high-quality data (Guainazzi et al. 2006).

have allowed the detections of lags and leads between different spectral bands (McHardy et al. 2007) giving unique insight into the physical mechanisms producing the X-ray photons.

The high S/N of *XMM-Newton* RGS spectra from a long observation of NGC4051 (Krongold et al. 2007) was used to determine the total power in an AGN's wind for the first time, and thus provided the first constraints on the ability of AGN to control the formation of structure in the Universe. *XMM-Newton* observations of the cavities produced in clusters by radio sources (Gitti et al. 2007) have revealed the enormous power in relativistic AGN winds, while an *XMM-Newton* follow-up of hard X-ray selected sources from *Integral* and *Swift* (Winter et al. 2008) has shown a wide variety of X-ray spectral types which have challenged the unified model of AGN and models for the origin of the X-ray background. The availability of the *XMM-Newton* archive has made available the first large sample of the average high resolution spectra of AGN (Kaastra 2008) revealing a wealth of previously unknown spectral features.

Future AGN research: This will concentrate on high S/N Fe K line studies to determine black hole spin and the origin of variable Fe K lines, detailed follow-up studies of "new" highly obscured AGN discovered by *Spitzer*, *Swift* BAT, SDSS, and *Integral*, and deep exposures of a sizable sample with the RGS to understand the energetics of AGN outflows and the possible existence of broad low energy lines. Reverberation studies will require three or four well-sampled sources, each with about 1 Ms exposure, showing the size of potential programs.

1.2 Clusters of Galaxies and Dark Matter

The intracluster medium (ICM) in clusters of galaxies comprises most of the baryons in the cluster. *XMM-Newton*'s large collecting area, good spatial resolution and large FOV (15′ radius), and a better high-resolution spectrometer for extended sources than *Chandra* make it the premier instrument for cluster spectroscopy. Recent *XMM-Newton* results have shed new light on the complex physics that governs the evolution of the baryonic components in clusters. Zhang et al. (2007) established that the gas entropy exceeds the value attainable through gravitational heating not only in the core but throughout the whole ICM. This is direct evidence that physics other than gravity has had a major impact of the formation of groups and clusters and is key to the understanding of the effects of feedback on the formation of structure. Studies of distant clusters are measuring the size of the feedback through cosmic time. Two recent *XMM-Newton* studies of distant clusters, surprisingly show no significant departure from the evolution expected in the standard self-similar model up to $z \sim 1$ which assumes, incorrectly, that all the entropy comes from gravitational physics.

One of the most surprising recent *XMM-Newton* cluster discoveries was that of a candidate "fossil cluster" (Gastaldello et al. 2007) at $z = 0.29$. It has normal X-ray properties with a temperature of 3.6 keV and bolometric luminosity of 2×10^{44} erg s^{-1} – but only one very bright elliptical galaxy. This object is thought to be the long-term dead end of gravitational evolution where the central galaxy has assimilated the stellar content of the member galaxies into a huge extended halo. Given that in most systems there is a strong relationship between the galaxy content and the cluster mass this result was quite unanticipated. The best interpretation is that this system was formed at very high redshift and thus is a "true" fossil of the Universe.

The evolution of clusters can provide crucial information about the nature of the "dark energy." But in order for cluster cosmology to achieve its promise, an improvement in the understanding of cluster physics is needed; understanding the relationship between a cluster's mass and its X-ray luminosity, its temperature, and its gas mass. Significant progress was made in this area including the first precise calibration of the mass-temperature relation in the local Universe (Croston et al. 2008). Studies of these crucial scaling relations are just now beginning with the availability of large samples over an interesting range of redshifts and X-ray luminosities. Early results show that the cluster masses and gas mass fractions measured for an unbiased, flux-limited and nearly volume-complete sample of 13 clusters at $z \sim 0.3$ and Zhang et al. (2006) are consistent with self-similar behavior for the gas fractions at radii larger than $0.2 - 0.3\ r_{500}$.

A major breakthrough in the understanding of the *XMM-Newton* EPIC detector background allowed Snowden et al. (2008) to derive robust temperature, density and abundance profiles and maps for large clusters providing the data for detailed comparison with cluster models.

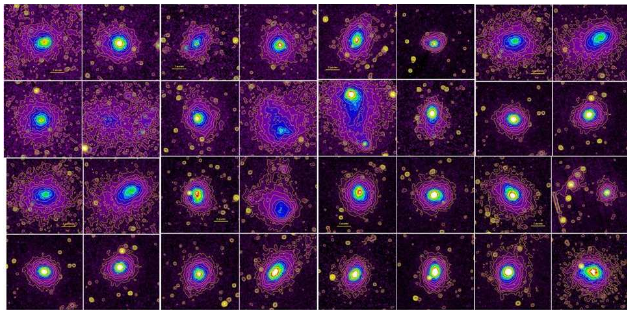

Figure 3: *XMM-Newton* EPIC images of 32 clusters from the XMM-LP sample (Böhringer et al. 2007). They form a representative sample of cluster morphologies with only L_x as the selection criteria in the redshift range $z = 0.055$ to 0.183. This sample made optimal use of the large *XMM-Newton* FOV, and provides nearly homogeneous X-ray luminosity coverage for the full range from poor clusters to the most massive objects in the Universe

Galaxy Formation and X-ray Cluster Science: Observations of metal and entropy distributions constrain the two most prominent processes in galaxy formation: star formation and AGN formation. Tozzi (2008) measured the distribution and level of iron enrichment to $t_{lookback} = 9$ Gyr and claimed a factor of two evolution in the Fe abundance consistent with a burst from massive ellipticals at $z > 2$ and slower enrichment from disks later on.

A study of M87 (Forman et al. 2007) revealed that shocks may be the most significant channel for AGN energy input into cluster cooling cores. A violent outburst of the central AGN may also play a fundamental role in shaping the global properties of clusters as seen in MS 0735+7421 (Gitti et al. 2007).

Considerable progress was made in understanding the effects of relativistic particles in providing pressure and heating the gas. The combination of radio and X-ray observations provides a measure of the magnetic field independent of equipartition or minimum energy assumptions. Chen et al. (2008) found that *XMM-Newton* data give a lower limit to the magnetic field which is larger than equipartition. Belsole et al. (2007) showed that 60% of powerful radio galaxies in the redshift range from $z = 0.45 - 1$ lie in a luminous X-ray cluster, and all but one narrow-line radio galaxy are in a cluster environment. Therefore there is no strong evidence that the presence of a radio source requires a peculiar environment.

The unique power of RGS spectroscopy of extended sources was demonstrated by Sanders et al. (2007) who detected strong N VII emission, indicating supersolar N abundance in the central regions of clusters, a strong constraint on the nature of the stars that have produced the metals. They also showed that the lack of RGS detections of cool gas in other clusters could be due to their relatively short, $\sim 30-40$ ks, exposures, indicating that longer *XMM-Newton* exposures, possible with the new large programs, will strongly constrain the emission measure distribution of the cooling gas in clusters.

Future of cluster research: A major step forward in our understanding of dark matter structure formation and dark energy is expected by combining *XMM-Newton* surveys, e.g., the XMM Cluster Survey (XCS; Pierre et al. 2007) with more than 2000 cluster candidates, more than 300 with measured redshift including the most distant cluster ever known at $z = 1.45$, and the forthcoming *Planck* data. The *Planck* whole sky survey will increase by two orders of magnitude the number of known very massive ($T > 7$ keV) clusters at $z > 0.6$, the best objects for precise cosmology with clusters. *XMM-Newton* follow-up will be crucial to fully exploit this sample, allowing constraints on the dark energy equation of state from the gas mass fraction (used as standard candle) and from cluster abundance (which requires a precise calibration of the mass Sunyaev-Zeldovich observable relation). In addition, these observations will allow a full test of dark matter collapse models from detailed studies of the mass profiles and their evolution with redshift.

1.3 Diffuse X-ray Emission in Galaxies

XMM-Newton observations of edge-on early-type disk galaxies have confirmed the detection of hot gas in extended halos. The diffuse X-ray emission from the edge-on Sa galaxy M104 (Sombrero) has two components, one distributed like the stellar K-band light (due primarily to residual emission from discrete sources), and diffuse hot gas extending to ∼20 kpc from the galactic center with $kT \sim 0.6 - 0.7$ keV (Li et al. 2007). However, in NGC 2613 the diffuse emission is distributed in discrete bubble-like features extending from the disk out into the halo (Li et al. 2006), unlike the smooth hot gas halo of M104. In NGC 6810 the extraplanar diffuse X-ray emission is spatially associated with diffuse Hα emission and Hα filaments, suggesting the presence of a “disk-wide” superwind (Strickland 2007).

XMM-Newton observations of the X-ray-bright elliptical galaxy NGC 4649 detected “fingers” similar to radial features seen in hydrodynamic simulations of cooling flows in elliptical galaxies, and might be due to convective motions of hot outflowing gas and cooler inflowing gas (Randall et al. 2006). Recent results on NGC7619 in the Pegasus group shows the first clear pictorial evidence of the process of metal enrichment of the ICM as a result of galaxy-cluster dynamical interaction (Kim et al. 2007). In M87, Simionescu et al. (2007) have, for the first time, found evidence that cold, metal-rich gas is being transported outwards, possibly through bubble-induced mixing as the radio lobes rise along the short axis of the elliptical pressure distribution, following the steepest gradient of the gravitational potential, and contain a nonthermal pressure component. In a parallel result, deep RGS observations of M87 (Werner et al. 2006) determined, for the first time, accurate abundance values for C and N in the hot gas. The comparison of the abundance ratios of C, N, O, and Fe in the intersellar medium (ISM) of M 87 with those in the stellar population of our Galaxy shows that the relative contribution of core-collapse supernovae to the enrichment of the ISM in M 87 is significantly less than in the Milky Way, and indicates that the enrichment of the ISM by Fe through Type Ia supernovae and by C and N is occurring in parallel.

1.3.1 *Diffuse Hot Gas in the Milky Way*

Recent X-ray observations of distant quasars have detected O VII absorption at near-zero redshift, which could originate from a hot gas halo of the Galaxy or the ICM in the Local Group. Archival *XMM-Newton* RGS observations of 25 AGNs and LMC X-3 were analyzed to measure the O VII Kα absorption line strength. The data are in conflict with a purely Local Group model but support the Galactic halo model since the O VII absorption equivalent width is well correlated with the Röntgensatellit (*ROSAT*) measurements of the background emission in the R45 band (0.4–1 keV), for which O VII emission makes the largest single contribution (Bregman & Lloyd-Davies 2007; Fang et al. 2006). These observations prove that the Milky Way has a moderate scale height hot gas halo whose mass is considerably less than that predicted by cold dark matter (CDM) models

Archival *XMM-Newton* observations of 11 galaxy clusters have been used to measure the oxygen abundance of the Milky Way's ISM by analyzing the K-shell X-ray photoionization edge in the X-ray spectra (Baumgartner & Mushotzky 2006). It is found that at high Galactic columns above $\sim 10^{21}$ cm^{-2} the X-ray columns are generally 1.5–3.0 times greater than the 21-cm H I columns, indicating that molecular clouds become an important contributor to $N_{\rm H}$ and that the average ISM O abundance (O/H) is $(4.85\pm0.06)\times10^{-4}$, or 0.99 solar when using the most recent solar photospheric values. Since X-ray observations are sensitive to the total amount of oxygen present (gas+dust), these results indicate a high gas-to-dust ratio. Also, the oxygen abundances along lines of sight through high Galactic columns are the same as abundances through low columns, suggesting that the composition of denser clouds is similar to that of the more diffuse ISM.

The X-ray spectrum of the Local Bubble was studied by analyzing spectra from two *XMM-Newton* pointings on and off an absorbing filament in the southern Galactic hemisphere (Henley et al. 2007). This Local Bubble emission is consistent with that from a plasma in collisional ionization equilibrium with a temperature $\log(T/K) = 6.06^{+0.02}_{-0.04}$ and an emission measure of 0.018 cm^{-6} pc. This temperature is in good agreement with that derived from the *ROSAT* All-Sky Survey.

Future Programs: Studies of the diffuse X-ray emission from the disk, bulge, and nucleus of the Milky Way and other nearby normal galaxies will be considerably enhanced by the new background subtraction software allowing the statistical limits of the data to be reached. This will allow analysis of the vast archive of "effective" ISM pointings for a detailed map of the diffuse emission in the Milky Way.

1.4 Supernova Remnants and Neutron Stars

1.4.1 *Supernova Remnants (SNR)*

Supernovae (SNe) produce the heavy elements and SNR distribute these elements throughout the ISM and disturb and compress the material in the ISM producing the conditions which are necessary to form the next generation of stars. As extended objects with high temperatures and a complex set of abundances and ionization conditions, SNRs are prime objects for study with *XMM-Newton* providing rich spectra on physically important spatial scales. Spatially resolved SNR spectra separate thermal from non-thermal emission, identify stratification of ejecta, separate the forward and reverse shock regions, measure variations in temperature and ionization conditions.

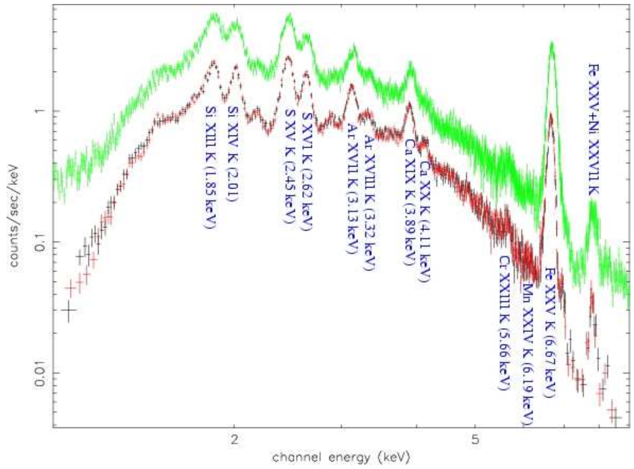

Figure 4: *XMM-Newton* pn and MOS total spectra of the galactic SNR W49B. Note the strong K shell lines of Si, S, Ar, Ca, and Fe and the weak but significant detections of Cr and Mn (Miceli et al. 2006).

The extraordinarily high quality of the *XMM-Newton* EPIC spectral data have provided the relative ratios of the elements Si, S, Ar, Ca, Cr, Mn and Fe in several remnants which, for the first time, can test detailed explosion models for Type Ia SNe (Badenes et al. 2006; Kosenko 2006). Another example of *XMM-Newton*'s spectral capabilities is SNR W49B (Figure 4) for which Miceli et al. (2006) concluded that the abundances are not consistent with a γ-ray burst progenitor. *XMM-Newton* spectra of the LMC SNRs DEM L238 and L249 detected a surprisingly large abundance of Fe at high ionization timescales interior to the remnant (Borkowski et al. 2006). Such a large amount of Fe near to ionization equilibrium is at odds with models of Type Ia SNe and may indicate that there is new class of these explosions. *XMM-Newton* data from clusters were used by de Plaa et al. (2007) to derive average nucleosynthetic yields from Type Ia SNe which favor the delayed detonation models.

SNRs are thought to be primarily responsible for the acceleration of cosmic-rays up to energies of 10^{15} GeV. The observational evidence for this phenomenon has only been acquired recently and *XMM-Newton* has contributed significantly to these discoveries via detailed measurements of particle spectra and the magnetic fields. Vink & Kuiper (2006) separated thermal and non-thermal emission in the galactic SNR RCW 86 using *XMM-Newton* spectral and imaging capabilities (Figure 5). Analysis of the non-thermal emission indicated a magnetic field of B =24 μG and a shock velocity of $v_s = 2700$ km s^{-1} supporting the association of RCW 86 with SN 185. Importantly, the broad band high S/N *XMM-Newton* spectrum reveals that a simple power-

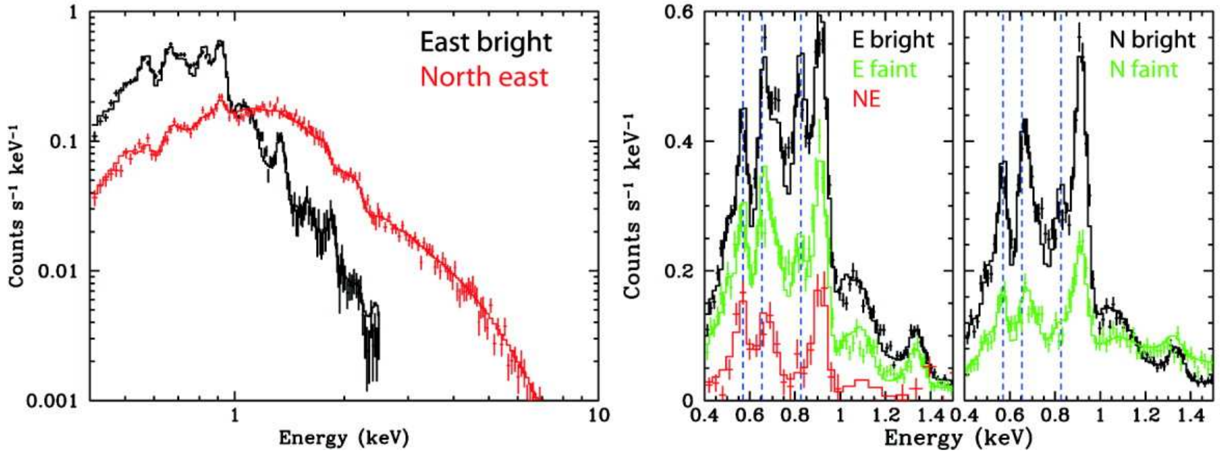

Figure 5: *XMM-Newton* MOS spectra of East and NE rims of the SNR RCW 86 showing the ability of *XMM-Newton* to obtain spatially resolved high S/N spectra even in regions of low surface brightness and detect weak spectral features in continuum dominated spectra. The left panel shows the total spectrum. The right panel shows the line emission after the continuum has been subtracted.

law cosmic-ray electron spectrum with an exponential cutoff cannot explain the broadband synchrotron emission. Instead, a concave electron spectrum is needed, as predicted by nonlinear shock acceleration models.

The shape and spectra of pulsar wind nebulae (PWNe) depend on the angular distribution, magnetization, and energy spectrum of the wind streaming from the pulsar magnetosphere, as well as on the pulsar velocity and the properties of the ambient medium. *XMM-Newton* observations have detected new PWN in G337.2+0.1, DEM L241, and around PSR B0355+54. The PWN in G328.4+0.2 has been studied in detail by Gelfand et al. (2007) who conclude that the X-ray emission is consistent with a 10^4 yr old PWNe formed by a low magnetic field (10^{12} G) neutron star, spinning rapidly (<10 ms), in an undetected SNR with a high explosion energy ($> 10^{51}$ ergs) and a relatively low amount of ejecta (< 5 M$_\odot$).

Future Prospects: Thanks to its high sensitivity, reasonable angular resolution, and large field of view, there are a large number of projects to be carried out on SNRs. These include the study of nucleosynthesis products in nearby or middle-aged SNRs and shock physics using deep RGS observations of specific remnants or regions. The study of electron acceleration using deep spatially resolved spectroscopy in extended SNRs (e.g., SN 1006, G347.3-0.5, Vela Junior) can be used to search for the maximum energy of accelerated particles, azimuthal variations in particle acceleration, and to determine the density of the thermal plasma. The followup of High Energy Stereoscopic System (HESS), *Integral*, and *GLAST* sources with *XMM-Newton* will constrain proton acceleration from a detailed comparison of the X-ray and the TeV emission.

1.4.2 Neutron Stars (NS)

XMM-Newton observations of the "bursting" behavior of the Anomalous X-ray Pulsars (AXPs) have been essential in characterizing the complicated processes by which a NS relaxes after the burst. In AXP 1E 2259+586 (Zhu et al. 2008) and AXP 4U 0142+61 (Gonzalez et al. 2008) the flux and hardness ratio are correlated (both increasing) after the burst, and this behavior can be explained by both the "twisted magnetosphere" model of Thompson et al. (2002) and the surface thermal emission model of Özel & Güver (2007). Phase-resolved spectroscopy with high statistical precision data (Rea et al. 2007) show significant variations with phase but none of the spectral features expected from an atmosphere of a highly-magnetized NS. The detection in the isolated NS RX J1856-3754 of a 7 s period by Tiengo & Mereghetti (2007) at the extremely low level of only 1.2% modulation, is a testament to the sensitivity of *XMM-Newton* observations and confirms that RX J1856-3754 belongs in the class of the nearby, thermally-emitting NS with soft X-ray spectra. Continued *XMM-Newton* observations of another member of this class, RX J07204-3125, which does show broad spectral features which vary significantly in time (Haberl et al. 2006a), suggest that the time-variable spectral features can be explained by the precession of the NS if there are two hotspots which rotate into view at different times. In each of these cases, repeated observations of the same source with *XMM-Newton* was the key to making the discovery.

XMM-Newton detected a 6.67 hr period of 1E 161348-5055 at the center of SNR RCW103 which has an age of 2000 years (De Luca et al. 2007). This period is much too long for a 2000 year old star, which should be rotating thousands of times faster. This could be the first example of a low-mass X-ray binary (LMXB) associated with a SNR, and thus the first LMXB for which we know the precise birth date, just 2000 years ago. Alternatively, if it is an isolated NS, the unprecedented combination of age, period and variability may only fit in a very unusual scenario, featuring a peculiar magnetar, dramatically slowed-down over 2000 years, possibly by a supernova debris disc.

XMM-Newton has provided new evidence that some pulsars are born spinning relatively slowly with relatively low values of the magnetic field. Gotthelf & Halpern (2005) placed an upper limit on the period derivative of 1E 1207-5209 suggesting a magnetic field of 3.3×10^{11} G and a characteristic age of 27 Myr assuming a dipole spin-down, inconsistent with the age of the remnant and suggesting the pulsar was born spinning close to its current period of 424 ms. Mori & Hailey (2006) have shown that the spectral features in 1E 1207-5209 can be explained by an atmosphere which contains O and Ne and has a characteristic magnetic field of $\approx 1 \times 10^{12}$ G. Another NS which shows evidence for a weak magnetic field and a slow, stable rotation is J1852+40 in the SNR Kes 79. Halpern et al. (2007) use a similar technique to estimate a magnetic field strength of 1.5×10^{11} G and a characteristic age of 8 Myr, which is again wildly inconsistent with the age of the remnant. They suggest that this might point to a scenario for the formation of radio-quite Compact Central Objects (CCOs). The key to these discoveries was again repeated observations of the same source with the high sensitivity of *XMM-Newton*. The coming years promise more such discoveries as *XMM-Newton* will be able to make repeated observations of more sources.

For the milli-sec pulsars PSRs J0030+0451 and J2124-3358 (Bogdanov et al. 2007) the relatively large pulsed fractions observed require the existence of a light-element atmosphere and cannot be reproduced by a blackbody model for realistic NS radii. Modeling of their spectra placed constraints on their compactness of $R > 9.4$ km and $R > 7.8$ km (68% confidence) assuming $M = 1.4$ M. or more generally $R/R_{Schwarzschild} > 2.3$ and > 2, a major constraint on the equation of state of NSs.

Future Prospects: AGILE and *GLAST* will certainly discover more Geminga-like NSs and *Integral* will find new candidate neutron stars. Deep observations of black hole sources in quiescence will constrain the physics of advection-dominated accretion flow (ADAF) models and high S/N observations of quiescent systems will allow the determination of the inclination of the system from the X-ray light curve.

1.4.3 X-Ray Sources in Other Galaxies

The deep *XMM-Newton* survey of M31 is a major milestone allowing the detailed study of the source populations and individual sources (Stiele et al. 2007, 2008; Figure 6). This survey revolutionized our study of extragalactic X-ray binaries providing data of the quality that were previously only possible for X-ray binaries in the Milky Way and the Magellanic Clouds. Stiele et al. (2008) have matched supersoft sources discovered in the *XMM-Newton* survey with optical novae observed in M31 . The*XMM-Newton* spectra of an X-ray transient suggests that it is a black-hole X-ray nova. Two of the supersoft sources are periodic (at 865 s and 217 s; Osborne et al. 2001; Trudolyubov & Priedhorsky 2008) suggesting that they are rotating, magnetic white dwarfs.

Trudolyubov et al. (2007) have discovered a transient accreting X-ray pulsar in NGC 2403. This remarkable system shows an extremely high luminosity during its outburst of 1.2×10^{39} erg s^{-1}, 10× the Eddington limit for a neutron star and a very fast decrease in its pulsation period during the outburst. Its X-ray luminosity is high enough to account for the observed spin-up rate, assuming that the X-ray source is powered by disk accretion onto a highly magnetized neutron star. Optical follow-up (Zepf et al. 2007) of a luminous time variable *XMM-Newton* source in the elliptical NGC4472 showed [O III] emission, sealing the case for it being a black hole in a globular cluster, the first ever found.

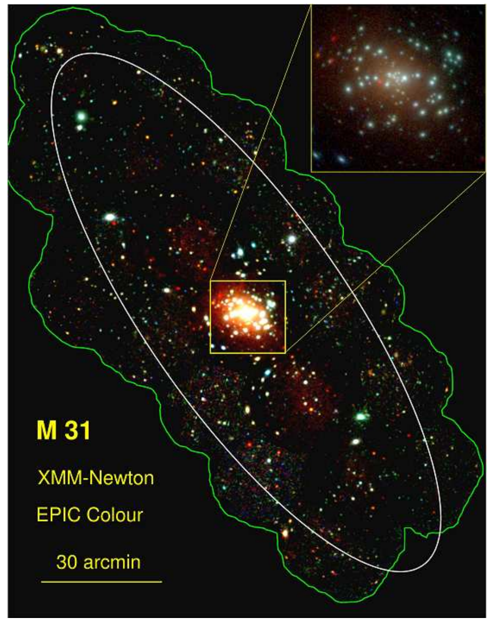

Figure 6: Multi-color mosaic produced from the deep *XMM-Newton* survey of M31. The RGB colors represent energies of $0.2 - 1$ keV, $1 - 2$ keV, and $2 - 10$ keV respectively. The green outline shows the limits of the survey area. The white ellipse represents the D_{25} contour. All sources have X-ray spectra and light curves.

1.4.4 Ultraluminous X-Ray Sources (ULXs)

These sources have an X-ray luminosity, $L_X > 2.5 \times 10^{39}$ erg s^{-1}, which exceeds the Eddington limit of black holes with masses of order 15 $M_\odot$, and are suspected to either have "super-stellar" mass black holes or to beam their emission towards us. Only *XMM-Newton* can deliver light curves and spectra with the very high S/N needed to find indirect indicators of the mass, such as breaks and quasiperiodic oscillations (QPOs) in their X-ray power spectra. These observations have led to the identification of QPOs in several ULXs (e.g., Strohmayer et al. 2007; Dewagan et al. 2006) as well as measurements of the slope of their low-frequency power spectra suggesting that the masses of the compact objects in these ULXs are of the order of 100 $M_\odot$ or greater, consistent with a new type of object. The high-S/N *XMM-Newton* spectra allowed Winter et al. (2007) to probe their immediate gaseous environments by measuring the oxygen (and sometimes the iron) abundance in the host galaxy. They found that the abundances are similar in all ULXs and comparable to the abundances of H II regions, despite the fact that their host galaxies have very diverse properties. Moreover the column

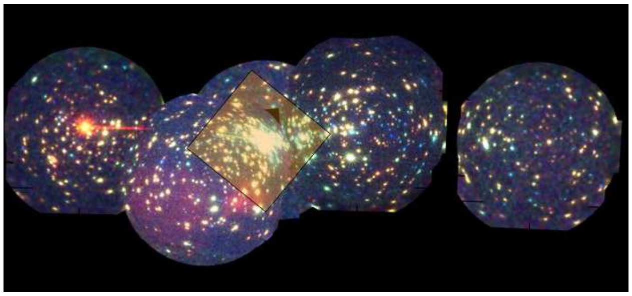

Figure 7: *XMM-Newton* observations of the Orion region illustrating the ability of *XMM-Newton* to survey large solid angles to sensitive limits and obtain large samples of objects. The highlighted square is the *Chandra* COUP field.

density along the line of sight can be attributed to the intervening interstellar medium.

1.4.5 Cataclysmic Variables (CVs) and Related Objects

In a recent paper Ramsay et al. (2006a) present sensitive observations of a system with one of the shortest orbital periods, RX J1914+24, determining that the orbit is decaying at a rate of 3.2×10^{-12} s s^{-1} consistent with the emission of gravitational waves from this system. In a separate study of the X-ray properties of a sample of seven AM CVn stars Ramsay et al. (2006b) discovered a strong anti-correlation between the UV luminosity, measured by the OM, and the orbital period, which provides a strong test of models for the accretion process in these systems. Using the *XMM-Newton* X-ray spectra, these authors discovered a strong overabundance of N, a test of the evolutionary processes that led to their formation.

1.5 Stars

1.5.1 X-ray emission from Pre-Main-Sequence Stars

The XMM-Newton Extended Survey of the Taurus molecular cloud (XEST) (Güdel 2008 and 14 papers in a special feature of 2007, A&A, 468) significantly improved the sampling of X-ray emission from young stars in the Taurus-Auriga star formation region (SFR). It is the closest and best-studied large SFR and has served as a test-bed for low-mass star formation theory for decades. *XMM-Newton* provided unprecedented spectroscopic results from nearly every observed T Tauri star, and from $\sim 50\%$ of the studied brown dwarfs and protostars. The survey includes the first coherent statistical sample of high-resolution spectra of T Tauri stars, and is accompanied by a U-band/UV imaging photometric survey with the OM. XEST led to the discovery of new, systematic X-ray features, not possible before with smaller samples and lower S/N, in particular the X-ray soft excess in classical T Tauri stars indicative of accretion and the two-absorber X-ray spectra of jet-driving T Tauri stars. In an on-going program, Wolk et al. (2008) surveyed the X-ray emission from young stars in Orion (Figure 7) over a far greater spatial area than covered by the *Chandra* COUP observations.

The wide field imaging of the EPIC cameras provides efficient X-ray sampling of young stellar clusters, with the RGS providing grating spectra for studies of the coronal temperature and density distributions.

Accretion-induced X-ray emission is indicated by high electron densities, unusual patterns of elemental abundances, and low temperatures. The XEST survey confirms that the soft excess is certainly confined to accreting stars, the densities in the plasma are often too low for the X-rays to originate in the accretion shock itself (Telleschi et al. 2007abc; Güdel et al. 2007), and that the accreting material produces an excess of cool 1 MK plasma, rather than suppressing the coronal heating process that produces the typical 10^7 K hot plasma (Güdel & Telleschi 2007).

Stelzer et al. (2006) detected a dramatic (30× increase in X-ray count rate and 6 magnitudes at V using the OM) flare on the older (300 Myr), ultracool M8 dwarf LP 412-31. This flare showed physical evolution compatible with a single impulsive injection of 3×10^{32} ergs of energy into the corona of this very low mass star over a 4 minute time interval, which was then reradiated as X-rays for the next 30 minutes.

1.5.2 High Mass OB and Wolf-Rayet Stars

Changes in the X-ray luminosity, temperature, and absorption in colliding wind binaries (CWB) allow the wind properties of both components of the systems to be investigated. Skinner et al. (2007) used spectral fits with a constant-temperature plane-parallel shock model to derive a shock temperature $kT_{shock} = 2.7$ keV ($T_{shock} \sim 31$ MK), hotter than can be accounted for using 2D numerical colliding wind shock models based on nominal mass-loss parameters. Hamaguchi et al. (2007) observed η Car through its 2003 X-ray minimum and found a large $(5 - 10\times)$ increase in the hydrogen absorption column towards the star. These variations were qualitatively consistent with emission from the wind-wind collision plasma entering into the dense wind of the massive primary star. They also discovered an additional X-ray component that exhibited no variation on timescales of weeks to years which is probably produced by the collision of high-speed outflows at $v \sim 1000 - 2000$ km s^{-1} from η Car with ambient gas within a few thousand AU from the star. Phase-dependent X-ray variability was also found for a similar star, the massive SMC binary HD5980 (Nazé et al. 2007).

The X-ray emission from single O stars is thought to arise from shocks within the massive winds and emission generated in magnetic structures. The observation of N VI and C VI resonance lines in RGS spectra (Leutenberger et al. 2007) allowed the examination of evidence for resonance scattering which can alter the He-like triplet resonance line profiles. Inclusion of this effect in spectral fitting has the potential to reduce discrepancies between the mass loss rates derived from UV and X-ray data. Pollock (2007) used *XMM-Newton* spectra of ζ Ori to study the role of collisionless shocks far out in the wind as the source of the observed X-ray emission; such shocks would be magnetically controlled and should behave significantly differently than cooling shocks in the wind acceleration region.

Future: XMM-Newton has the capability of providing high S/N grating spectra for moderate-sized samples of many types of stars, drastically increasing the present sample size. In addition, detailed studies of the hosts of planets will provide information of the X-ray radiation fields around these stars that will allow far more refined simulation of the high energy processes affecting the atmospheres of these planets. Surprisingly, out of over one hundred stars (as of early 2007) known to harbor extrasolar planets, about 35 are known to emit X-rays and studies of volume limited samples of field stars yield detection rates approaching 100%. *XMM-Newton* is ideally suited to study the X-ray emission of very young open clusters containing a large number of O-type stars (e.g., NGC6231; Sana et al. 2006) and there are at least eight more clusters that are rich in O-type stars and have not yet been observed with *XMM-Newton* or *Chandra*.

1.6 Cosmology, Surveys, Serendipitous Science

The *XMM-Newton* serendipitous data provide a deep, large area sky survey with an extended energy range, allowing detection of large numbers of obscured and hard-spectrum objects absent in earlier surveys. The survey catalog, 2XMM, was released in 2007 August and is the largest catalog of X-ray sources containing $\sim 247,000$ detections of $\sim 192,000$ unique sources drawn from 3491 public *XMM-Newton* observations covering more than 500 deg^2. The catalog is accompanied by X-ray spectra and time series for the brighter sources (amounting to $\sim 14\%$ of the total); these associated data products are a major resource in their own right.

This catalog complements deeper Chandra and *XMM-Newton* small-area surveys, probing a large sky area at the flux limit corresponding to the objects that contribute to bulk of X-ray background. It provides a rich resource for generating large, well-defined samples since X-ray selection is a highly efficient technique for selecting AGN, clusters of galaxies, interacting compact binaries, and active stellar coronae. As an example, Page et al. (2007) have explored the properties of the harder sources, finding that their average spectra are harder than that of the X-ray background, and that they are absorbed AGN.

The ESA *XMM-Newton* project has developed a *Slew Survey* (Saxton et al. 2008) in which the X-ray data are recorded while the spacecraft slews across the sky from one target to another. This has produced the best ever hard band (2–8 keV) X-ray survey with ~ 0.45 sources deg^{-2}. One of the more spectacular results from this survey has been the discovery of two new candidate giant amplitude X-ray flares which are thought to be due to the tidal disruption of a star by a quiescent supermassive black hole at the center of the galaxy (Esquej et al. 2007). The survey has, so far, 4700 relatively bright X-ray sources with positions better than $8''$ over 14% of the sky (Saxton et al. 2008). The slew survey should cover most of the sky over the next few years and is a great source of rare, X-ray bright objects suitable for further study. The *XMM-Newton* GOF (Kuntz et al. 2008) has produced the OM source catalog with over 3.7×10^6 sources in 3 UV filters and 3 optical filters in 4950 fields producing optical counterparts for many of the 2nd XMM source catalog. This catalog is also a good resource for comparison with SDSS and *GALEX* data.

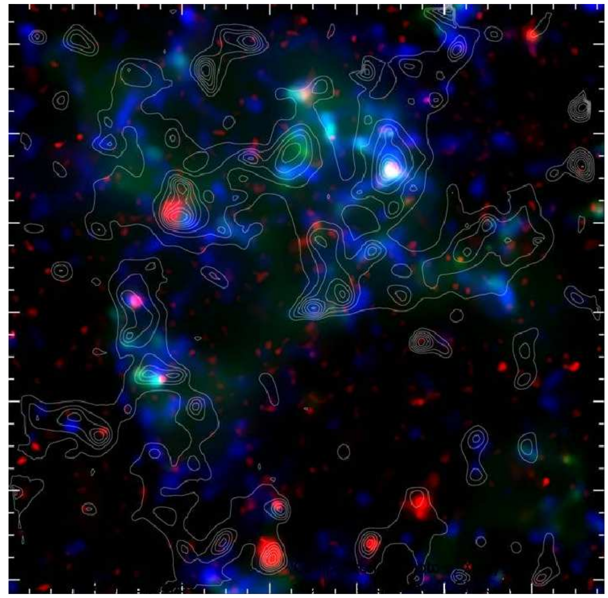

Figure 8: *XMM-Newton* EPIC image of the COSMOS field. The total projected mass from weak lensing, dominated by dark matter, is shown as contours. Independent baryonic tracers comprise (i) stellar mass (blue), (ii) galaxy number density (yellow) seen in optical and near-IR light (adjusted to the redshift sensitivity function of the lensing mass), and (iii) hot gas (red) seen in X-rays after removal of point sources two approaches for surveying large scale structure (Massey et al. 2007).

COSMOS Survey: XMM-Newton surveyed the COSMOS HST 2 deg^2 field (Figure 8), the largest survey undertaken with HST. This combined with ground-based redshifts from the VLT has resulted in the first 3-dimensional map of dark matter across the COSMOS field and extending back in time by about six billion years. The 3-D X-ray map has shown that normal matter, as evidenced by X-ray emitting clusters of galaxies, accumulates along the densest concentrations of dark matter which are shown by weak gravitational lensing.

Future: Results from the approved large program on a wide angle survey will soon be forthcoming as will the results on a deep observation of the Chandra deep field south approved in AO-7. The workshop on “An XXL Extragalactic Survey: Prospects for the XMM Next Decade” will be held 2008 April 14–16 in Paris France and will consider a wide variety of future options for *XMM-Newton* surveys.

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Appendix 2: List of Acronyms

2dF	Two Degree Galaxy and Quasar Survey
AAVSO	American Association of Variable Star Observers
AAS	American Astronomical Society
ACS	Advanced Camera for Surveys
ADP	Astrophysics Data Program
AGN	Active Galactic Nuclei
AO	Announcement of Opportunity
ASCA	Advanced Satellite for Cosmology and Astrophysics
AXP	Anomalous X-ray Pulsar
BAL	Broad Absorption Line
BAT	Burst Alert Telescope
CCD	Charge-Coupled Device
CCF	Current Calibration Files
CCO	Compact Central Object
CDM	Cold Dark Matter
CLEA	Contemporary Laboratory Experiences in Astronomy
CMU	Carnegie Mellon University
Co-I	Co-Investigator
CSM	Circumstellar Matter
CTI	Charge Transfer Inefficiency
CU	Columbia University
CV	Cataclysmic Variable
CWB	Colliding Wind Binaries
DPU	Digital Processing Unit
EA	Educator Ambassadors
EPIC	European Photon Imaging Camera
E/PO	Education and Public Outreach
ESA	European Space Agency
ESOC	European Space Operations Center
FOV	Field of View
FTE	Full Time Equivalent
FWHM	Full Width at Half Maximum
FY	Fiscal Year
GALEX	Galaxy Evolution Explorer
GBH	Galactic Black Hole
GLAST	Gamma-ray Large Area Space Telescope
GO	Guest Observer
GOF	NASA/GSFC Guest Observer Facility
GPG	Public domain version of Pretty Good Privacy
GRB	Gamma-Ray Burst
GSFC	Goddard Space Flight Center
GT	Guaranteed Time
GTN	Global Telescope Network
HEASARC	High Energy Astrophysics Science Archive Research Center
HESS	High Energy Stereoscopic System
HETG	High Energy Transmission Grating
HPD	Half Power Diameter
HST	*Hubble* Space Telescope
ICM	Intracluster Medium
IGM	Intergalactic Medium
INS	Isolated Neutron Stars
INTEGRAL	International Gamma-Ray Astrophysics Laboratory
IR	Infra Red
IRAS	Infra Red Astronomical Satellite
ISM	Interstellar Medium
ITEA	International Technology Education Association
JPL	Jet Propulsion Laboratory
LANL	Los Alamos National Laboratory
LETG	Low Energy Transmission Grating

LMC	Large Magellanic Cloud
LMXB	Low Mass X-ray Binary
LTI	Learning Technologies, Inc.
LTSA	Long Term Support in Astrophysics
MAST	Multimission Archive at Space Telescope
MESA	Math, Engineering, Science, Achievement
MOO	Mission of Opportunity
MOS	MOS style EPIC CCD detector
MSSL	Mullard Space Science Laboratory
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NLS1	Narrow Line Seyfert 1
NPS	North Polar Spur
NRC	National Research Council
NS	Neutron Star
NSF	National Science Foundation
NVO	National Virtual Observatory
OM	Optical Monitor
OSS	Office of Space Science
PDS	Power Density Spectrum
PGP	Pretty Good Privacy
PI	Principal Investigator
PIMMS	Portable, Interactive Multi-Mission Simulator
PN	PN style EPIC CCD detector
PNe	Planetary Nebulae
PSD	Power Spectral Density
PSF	Point Spread Function
PV	Pointing Verification
PWN	Pulsar Wind Nebula
QPO	Quasi-Periodic Oscillation
QSO	Quasi-Stellar Object
RASS	*ROSAT* All-Sky Survey
RGS	Reflection Grating Spectrometer
RMS	Root Mean Square
ROSAT	Röntgen Satellite
RPS	Remote Proposal System
RRC	Radiative Recombination Complexes
RTRD	Real Time Raw Data
RUP	Roseland University Prep
RXTE	Rossi X-ray Time Explorer
SAS	Science Analysis System
SDSS	Sloan Digital Sky Survey
SEU	Structure and Evolution of the Universe
SGR	Soft Gamma-ray Repeater
SMD	Science Mission Directorate
SMEX	Small Explorer
SN	Supernova
S/N	Signal to Noise
SNR	Supernova Remnant
SOC	Science Operations Center
SRON	Netherlands Institute for Space Research
SSB	Space Studies Board (of the NRC)
SSC	Survey Science Centre
SSU	Sonoma State University
STEM	Science, Technology, Engineering and Math
STScI	Space Telescope Science Institute
SWCX	Solar Wind Charge Exchange
SWIRE	*Spitzer* Wide-area Infrared Extragalactic Survey
TAX	Two-Absorber X-ray
TAXP	Transient Anomalous X-ray Pulsar
TOO	Target of Opportunity

UC	University of California
UCB	University of California, Berkeley
UCR	University of California, Riverside
UCSB	University of California, Santa Barbara
UK	United Kingdom
ULX	Ultra-Luminous X-ray source
US	United States
UV	Ultra Violet
VLT	Very Large Telescope
WR	Wolf-Rayet
XCS	X-ray Cluster Survey
XDINS	X-ray Dim Isolated Neutron Stars
XEST	XMM-Newton Extended Survey of Taurus
XID	X-ray source IDenfication program
XMM-Newton	Newton X-ray Multi-Mirror Observatory
XMM-ESAS	*XMM-Newton* Extended Source Analysis Software
XRB	X-ray Binary
XSA	*XMM-Newton* Science Archive