Background Treatment of Large Solid-Angle Contiguous Surveys

S. L. Snowden[1]
Code 662, NASA/Goddard Space Flight Center, Greenbelt, MD 20771
and

K. D. Kuntz
Henry A. Rowland Department of Physics and Astronomy, The Johns Hopkins University, 366 Bloomberg Center, 3400 N. Charles Street, Baltimore, MD 21218

ABSTRACT

Large contiguous surveys make possible a search for structure in the universe. However, the utility of such surveys is very dependent on proper treatment of the instrumental and time varying cosmic backgrounds. This presentation will discuss the various backgrounds experienced by the *XMM-Newton* EPIC detectors and the various procedures which can be used to eliminate or at least minimize their contaminating effects. The backgrounds considered here are the: 1) instrumental background from penetrating charged particles, 2) fluorescent X-rays which originate within the telescope, 3) soft protons flares, 4) solar wind charge exchange emission, and 5) the Galactic diffuse background which may be the signal of interest or contamination for a study of extragalactic emission.

Subject headings: x-rays: analysis: methods

1. Introduction

The analysis of extended sources and the diffuse X-ray background is made extremely complicated by the angular extent of the source, the similarity in surface brightness of typical signals of interest and instrumental and cosmic backgrounds, and the limited field of view of the available detectors. As opposed to the study of point sources, there may be no off-source region of the detector to use as a local measurement of the background. An observer is then left to use some other mechanism for determining what the background may be. Two methods are typically used in such cases, either a highly accurate cleaning of the data (which may include the use of "blank-sky" fields) and modeling of the residual background or the mosaicking of multiple overlapping observations in order to extend the effective field of view out beyond the boundary of the source. In most cases it is not reliably accurate to use a second off-source observation as the background as both the cosmic backgrounds and instrumental backgrounds will likely be varying either temporarily or spatially. However, this may also be true with the use of blank-sky observations.

We have developed a suite of software which can be used to clean and model various backgrounds experienced by the *XMM-Newton* EPIC detectors. This software, known as XMM-ESAS (*XMM-Newton* Extended Source Analysis Software), both screens the data to eliminate time periods of high background count rates and models the residual backgrounds. It also uses information from spectral fits to provide the best possible results. XMM-ESAS currently only works for MOS data but we are currently extending it to the pn. Snowden et al. (2008) recently published a paper discussing XMM-ESAS and its application to a large catalog of clusters of galaxies.

---

[1] Steven.L.Snowden@nasa.gov

2. EPIC MOS Background Components

The XMM-ESAS package models five separate background components using several different methods. The quiescent particle background is modeled by using both filter-wheel closed data and data from the unexposed (to the sky) corners of the detectors from observations in the public archive. The method for doing this is discussed in Kuntz & Snowden (2008).

Fluorescent line emission is separate from the quiescent particle background in spectral signature but is produced by the same flux of penetrating particles. The dominant lines are Al Kα and Si Kα with additional contributions at higher energies by other elements found in the telescope and detector structure. The Al Kα and Si Kα lines are so bright that attempting to model and subtract them can produce large residuals due to residual gain variations. To avoid this problem we create a smooth bridge in the quiescent particle background model spectrum in the $1.35 - 1.9$ keV band and then add two Gaussians to the spectral fit to represent the lines.

The background from soft protons can be very problematic. The levels of contamination range from low, but not necessarily zero, to a much greater surface brightness than most cosmic extended sources. In the latter case there is no alternative but to exclude the data. In the former case it is up to the observer to decide how to trade off between signal-to-noise and available data. On average roughly 35% of observation data are lost to obvious soft proton contamination but for an individual observation the data loss can vary between 0 and 100%. However, in our experience, most if not all observations are affected by soft protons at some level. This residual contamination can be insignificant, however in pathological cases the flux can be significant but effectively constant over the time period of an observation and so not be obvious in the light curve. We use two methods for the soft proton flares. First, the light curves are screened to remove time periods of obvious contamination. Second, a power law not folded through the instrumental response is fit to the data during the spectral fitting process.

The cosmic background may or may not be the object of the scientific investigation, but in either case it is useful to constrain the spectral fit. Emission from low temperature ($\sim 10^6$ K) Galactic plasmas (Local Hot Bubble or Galactic halo) can contribute significantly in the $\frac{3}{4}$ keV band but the emission measure and temperature are poorly constrained by the *XMM-Newton* data. We therefore simultaneously fit data from the *ROSAT* All-Sky Survey with the *XMM-Newton* spectra. These data are conveniently availably using the X-ray Background Tool of the HEASARC [1].

The final background component is also very problematic, and is gaining interest as a source in its own right. The solar wind interacts with exospheric material in Earth's magnetosheath and with interstellar neutrals passing through the solar system in charge-exchange reactions. The highly ionized solar wind nuclei can pick up an electron in an excited state which then radiatively decays. Unfortunately this can produce exactly the same lines, e.g., O VII and O VIII, which are used as temperature and density diagnostics for diffuse astrophysical plasmas. While monitoring of the solar wind flux can point to times where solar wind charge exchange emission may be a problem, it is not an entirely accurate indicator. Having multiple observations of the same point or at least having contiguous observations is the best way to determine the level of any contamination, although the method is not absolute.

3. Image Correction

Background modeling must be applied to image correction as well as spectral fitting requiring the capability to cast the background components listed above into sky coordinates. Flat fielding is also required but that function is taken care of by SAS and the creation of exposure maps. Instrument maps for the quiescent particle background are created from the filter-wheel closed data. The $1.35 - 1.9$ keV band is problematic because of the Al Kα and Si Kα fluorescent lines.

The maps are scaled by the number of counts in the model background spectrum over the energy range specified for the image creation. Detector maps have been created for the soft proton component by processing all data in the public archive and differencing the cumulative image for all observations at their nominal low level and when

---

[1] http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/xraybg/xraybg.pl

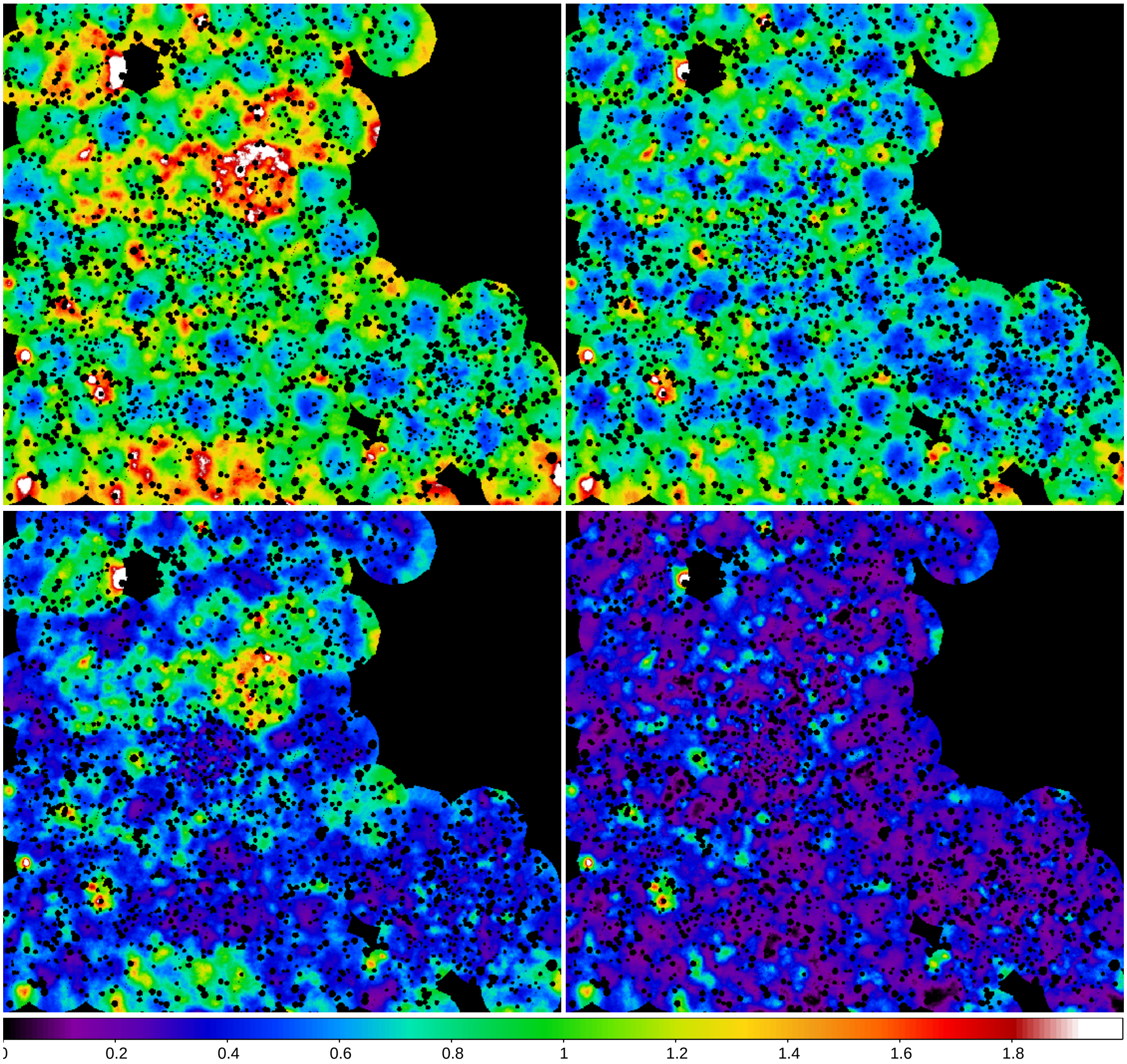

Fig. 1.— Mosaics of the LSS region in the $0.80 - 1.25$ keV band. *Upper Left:* no background subtraction. *Upper Right:* soft-proton background subtracted. *Lower Left:* quiescent particle background subtracted. *Lower Right:* both quiescent particle background and soft-proton background subtracted. Intensity units are counts s^{-1} deg^{-2}, and all plots are linearly scaled between 0 and 2.

the count rate is slightly elevated. Detector maps were created in this manner for a limited number of bands which are then scaled and combined to create final detector maps for an observation in a desired band.

The cosmic background is an integral part of the signal and should probably treated as such even in cases where it is not the signal of interest. Other mechanisms such as comparisons with interstellar absorption can possibly be used to separate structure in the cosmic background from structure of the extended source of interest. This will be a very complicated task, however. In most cases away from the Galactic plane and distinct features such as Loop I the cosmic background does not show great structure over angular scales of a few degrees in extent above 0.5 keV.

Emission from solar wind charge exchange will be flat over the instrumental field of view. If an observation is contaminated then it will appear as a surface-brightness offset.

4. Examples

The LSS region has a very large number of pointings which have been processed through an early version of XMM-ESAS. Figure 1 displays the region for different levels of background subtraction. All observations were screened to exclude times of soft-proton flaring The image in the upper right shows the field with only exposure correction. The enhancements around the rims of all of the observations is due to the quiescent particle background which is not significantly vignetted. This is a standard signature that is caused by the unvignetted background being corrected by the vignetted exposure map. This effect is shown more clearly in the upper-right image where the model soft-proton background has been subtracted.

The image in the lower left of Figure 1 shows the image with the quiescent particle background subtracted. Some observations stand out as bright regions because of soft-proton contamination. The image in the lower right shows the field after both the model soft proton and model quiescent particle background subtracted. Figure 2 repeats the LSS image with the model soft proton and model quiescent particle background subtracted scaled to better show the structure, at least some of which is probably real.

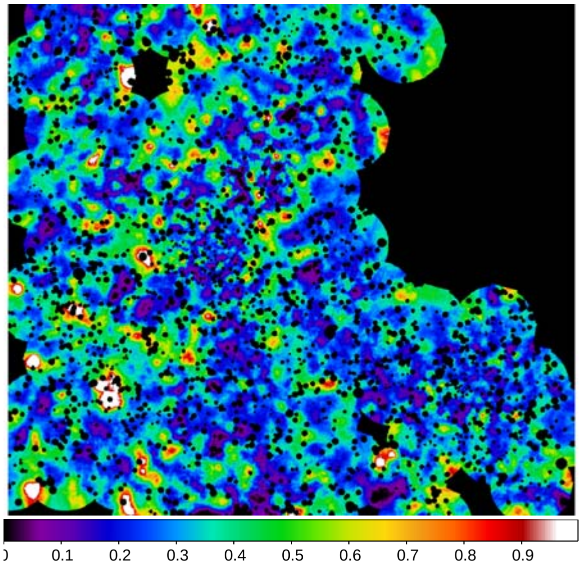

Fig. 2.— Mosaic of the LSS region in the 0.80 – 1.25 keV band with both the quiescent particle background and soft-proton background subtracted. Intensity is in counts s^{-1} deg^{-2} and the data are linearly scaled between 0 and 1.

Figure 3 shows a set of images for the Coma Cluster. With a very bright source the details of background subtraction are not as critical, but they can still be very important as the source drops its intensity near its edge. This can be seen in the observation just south of the center of the cluster which even after cleaning using the light curve still has a strong residual soft-proton contamination.

REFERENCES

Kuntz, K. D., & Snowden, S. L. 2008, A&A, in press

Snowden, S. L., Mushotzky, R. F., & Davis, D. S. 2008, A&A, in press

---

This 2-column preprint was prepared with the AAS LATEX macros v5.2.

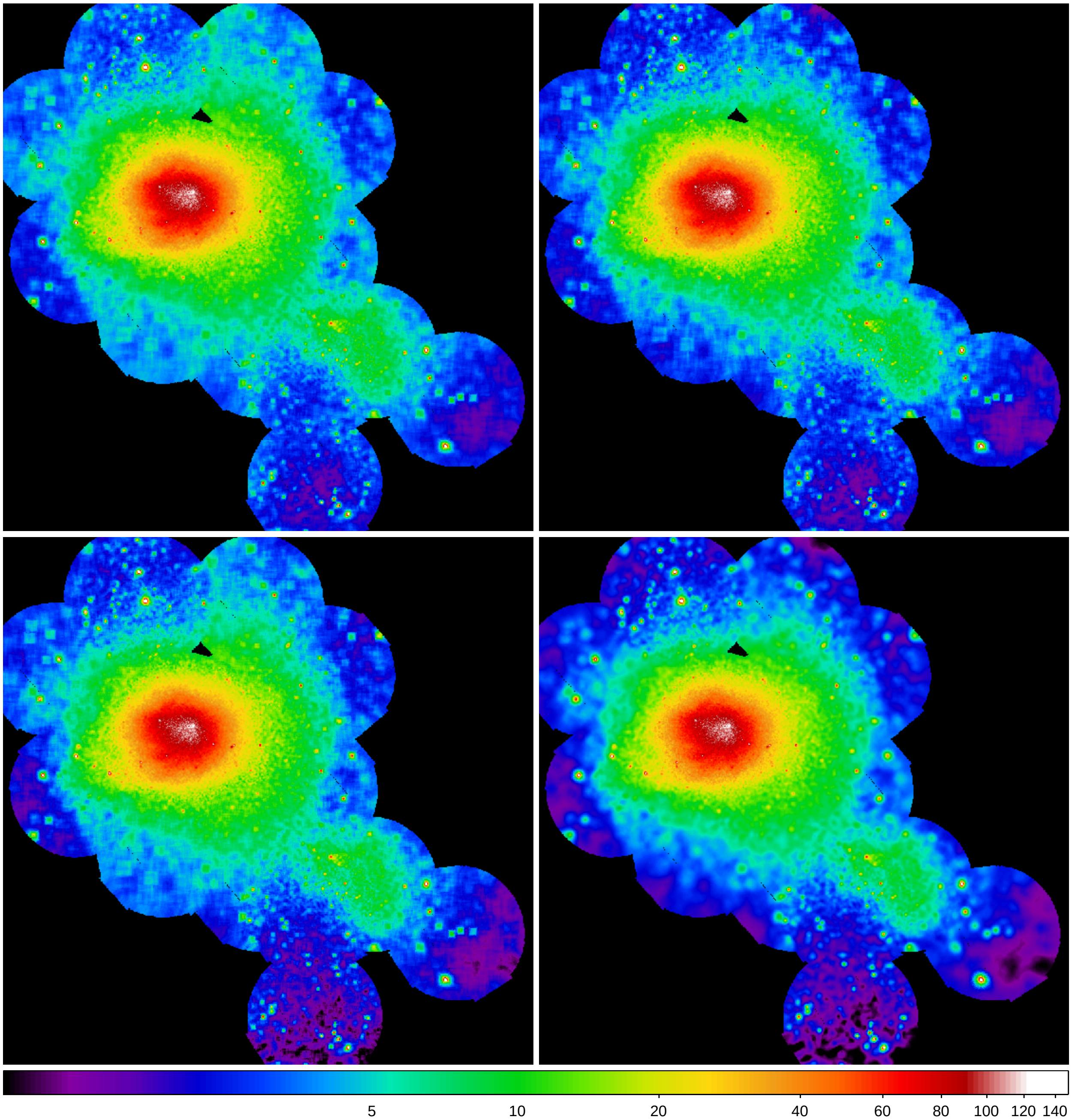

Fig. 3.— Mosaics of the Coma cluster observations in the $0.35 - 0.80$ keV band. *Upper Left:* no background subtraction. *Upper Right:* soft-proton background subtracted. *Lower Left:* quiescent particle background subtracted. *Lower Right:* both quiescent particle background and soft-proton background subtracted. Intensity is in counts s^{-1} deg^{-2}.