MIT Kavli Institute

ARCUS

MEMORANDUM
November 16, 2017

To:	*Arcus* Simulations & Calibration Team
From:	David P. Huenemoerder, Moritz Günther
Subject:	Technical Note: *Arcus* sky background rate estimate
Revision:	1.0
URL:	`http://space.mit.edu/home/dph/arcus/background_sky_sim.pdf`
File:	`background_sky_sim.tex`

1 Summary

Based on a ray-trace simulation, the diffuse sky background rate in the region of primary interest is about $0.2\,\mathrm{counts\,Ms^{-1}\,pix^{-1}}$, for a cross-dispersion extraction width of $50\,\mathrm{pix}$ and an order-sorting energy width of $340\,\mathrm{eV}$. This corresponds to an incident rate on one side (2 channels) of about $2.4 \times 10^{-8}\,\mathrm{counts\,s^{-1}\,eV^{-1}\ mm^{-2}}$.

2 Diffuse Sky Simulation

We use a ray-trace simulation of a diffuse sky field to estimate the cosmic background rate in the spectral region of primary interest. We have assumed that the cosmic background has a uniform surface brightness over the central 1 square degree and is zero otherwise. The reason for field truncation is that the current mirror model has no off-axis vignetting; the result for a uniform off-axis response will thus be an overestimate.

The cosmic background definition can be found in the *Athena* X-IFU site[1] We show the model flux in Figure 1 and list the model and parameters in Table 1.

The simulation had about $30,000$ rays which project to a detector (out of millions of input rays), and 40% of those remained after applying efficiencies for mirror, grating, filter, and detector. The simulation used all 4 channels. Given the model flux, the effective exposure time was about $52\,\mathrm{ks}$.

Figure 2 shows the event distribution on the detector. Each side has 8 CCD detectors, and the blank region is the gap in between arrays. The coordinates are projections onto a flat plane; $proj\_y$ is the cross-dispersion direction, and $proj\_x$ is along the dispersion. For a diffuse source, the events from the two

[1] Athena IFU background reference:
`http://x-ifu-resources.irap.omp.eu/PUBLIC/BACKGROUND/X-IFU%20background%20files.docx`.

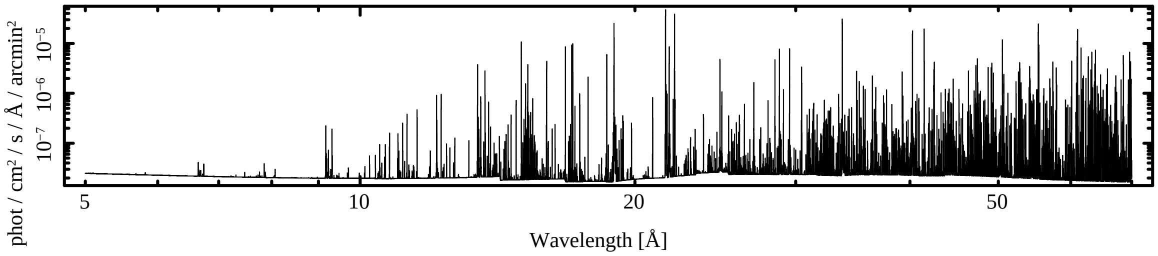

Figure 1 – Cosmic background spectral model. The flux is about $7.5 \times 10^{-6}\,\mathrm{photons\,cm^{-2}\,s^{-1}\,arcmin^{-2}}$, or $4.3 \times 10^{-15}\,\mathrm{ergs\,cm^{-2}\,s^{-1}\,arcmin^{-2}}$.

Table 1 – Cosmic Background Model Parameters

`apec(1)+wabs(1)*(apec(2)+powerlaw(1))`		
param	value	unit
apec(1).norm	1.76e-06	
apec(1).kT	0.099	keV
wabs(1).nH	0.018	$10^{22}\,\mathrm{cm^{-2}}$
apec(2).norm	7.3e-07	
apec(2).kT	0.225	keV
powerlaw(1).norm	2e-07	
powerlaw(1).PhoIndex	1.52	

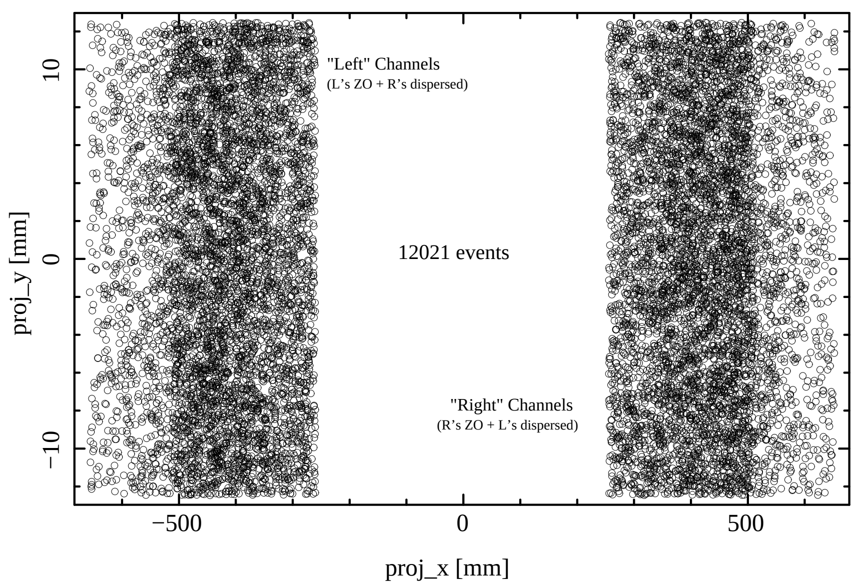

Figure 2 – Detector view of the event distribution. The exposure time of the simulation is $51.823\,\mathrm{ks}$.

channels on each side overlap and cannot be distinguished. Optical axes (4 of them) are near coordinates $(-300, 0)$ and $(300, 0)$ (two on each side).

The dispersion position vs. energy view is shown in Figure 3. Events have been color-coded by order (as known *a priori* in the simulation), and the model energy has been Gaussian-blurred by the approximate CCD energy redistribution of $70\,\mathrm{eV}$ (1σ). The rectangular feature at higher energies is the zeroth order; the 1° input image has a width of about $210\,\mathrm{mm}$. The general hyperbolic shape of diffracted orders in these coordinates is apparent in the colored bands.

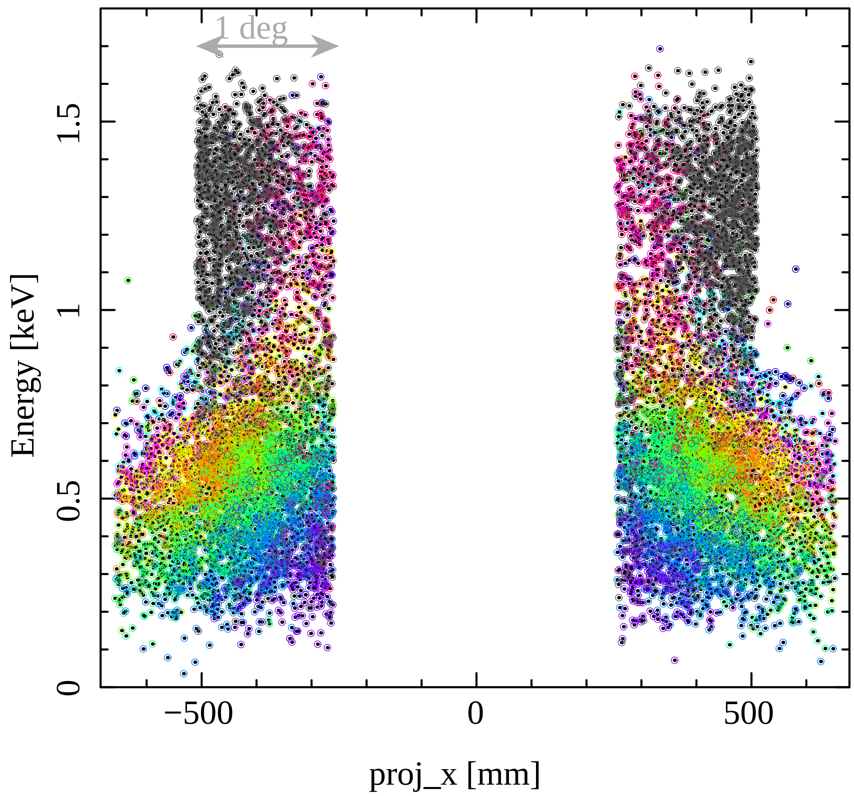

Figure 3 – Events in a position-energy view. Events have been colored by their *a priori* known diffraction orders. Model spectral energies have been blurred by $70\,\mathrm{eV}$, the approximate CCD energy redistribution scale.

Since the system is symmetric in the dispersion direction, we will "fold" it over about $proj\_x = 0$. We will define an approximate wavelength coordinate, $m\lambda$, from the simple grating equation ($m\lambda = P\sin(\theta) \sim P \times proj\_x/X$), using a grating period, $P = 2000$ Å, and an approximate Rowland spacing, $X = 12000\,\mathrm{mm}$. We can further define the real-valued diffraction order by dividing our high-resolution $m\lambda$ by the blurred CCD "wavelength", $\lambda_{\mathrm{ccd}} \sim hc/\mathtt{ENERGY}$. (These approximations would not be sufficient for fully calibrated high-resolution analysis, but they will suffice for the diffuse source rate assessment here.) Figure 4 shows the events in these coordinates.

3 Analysis

In Figure 5 we show the counts as a grayscale intensity image (white represents zero counts) in both the spatial-energy and the dispersion-order coordinates. The prime region of interest is roughly 19–28 Å, orders 4–7. We have selected events in this region to evaluate the cosmic background rate (there are about 1700 events in this locus, which are shown as cyan points in the figure).

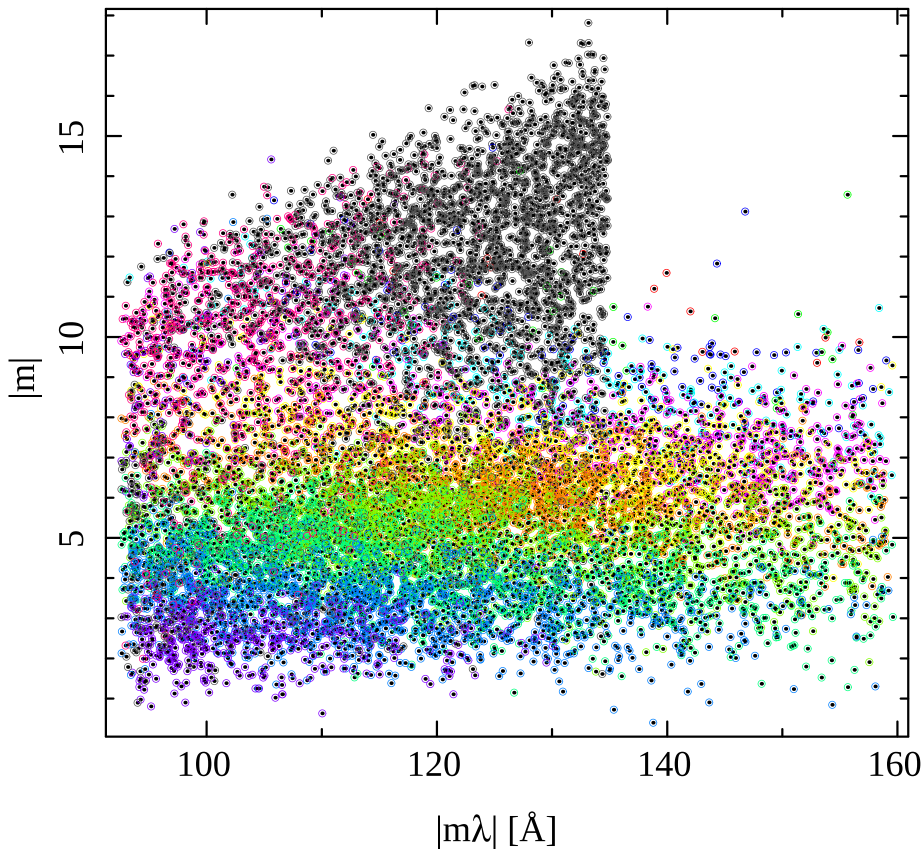

Figure 4 – The events in the $m\lambda$ vs m system, left and right channels folded together. (Note: this mis-represents the spatial relationship of the zeroth orders to dispersed events, but that is not relevant to the analysis of the rate.)

It can be seen in Figure 5 that the region of interest maps to the highest intensity of the diffuse sky image. The event selection in this region yields a rate of $2.4 \times 10^{-8}\mathrm{counts\,s^{-1}\,eV^{-1}\ mm^{-2}}$ (for a single side), which is equivalent to $1.4 \times 10^{-11}\mathrm{counts\,s^{-1}\,eV^{-1}\,pix^{-2}}$. For an extraction region which is $50\,\mathrm{pix}$ high in the cross dispersion, and for a generous order-sorting region of $340\,\mathrm{eV}$, the rate is $\sim 0.2\,\mathrm{counts\,Ms^{-1}\,pix^{-1}}$. (This is about $10\times$ smaller than our estimate of the non-X-ray rate. See TBS Technical Note.)

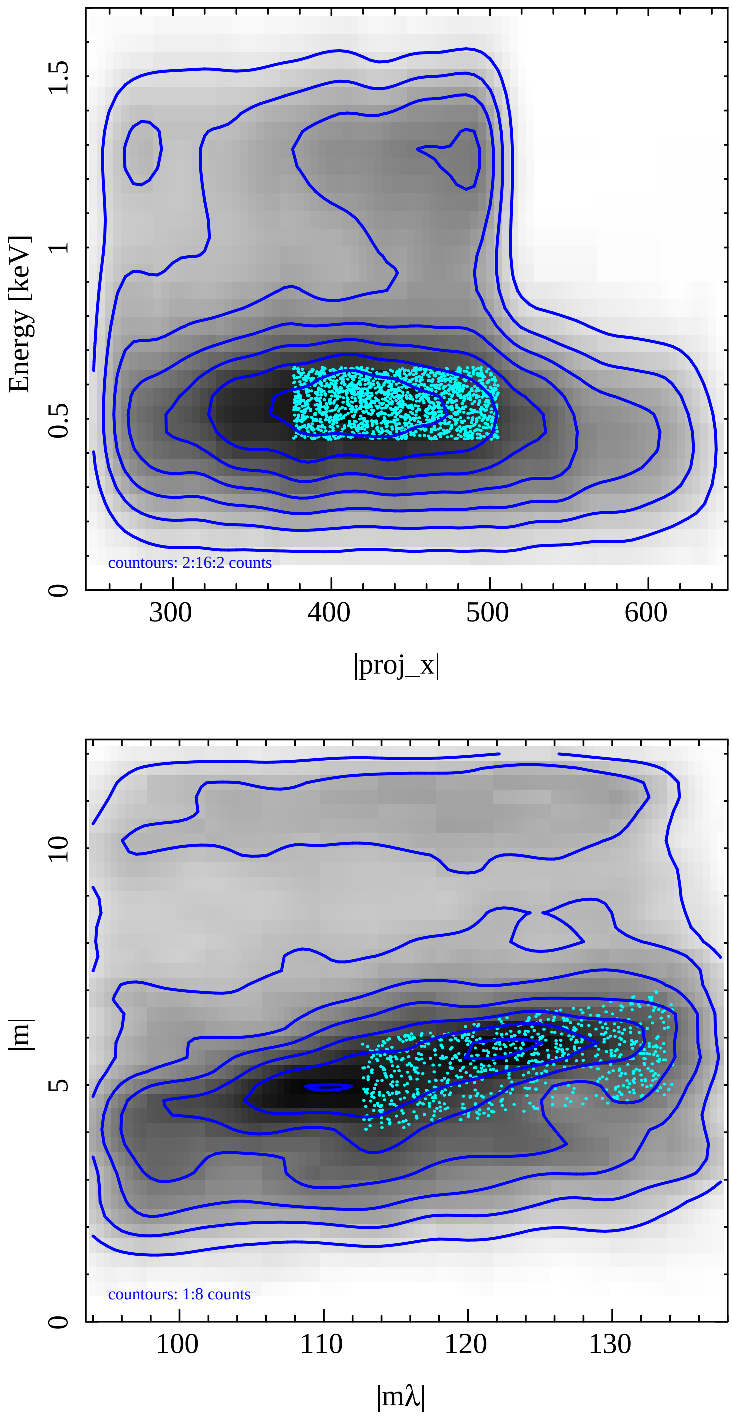

Figure 5 – Intensity image (inverse grayscale), contours (blue), and events in the prime region of interest (cyan points), in two coordinate systems, spatial-energy (top), and dispersion-order (bottom).