Sky Background Calculations for the Optical Monitor (Version 6)

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Abstract

Instructions on how to calculate the sky background flux for the Optical Monitor on XMM-Newton, by considering diffuse galactic, zodiacal light, and the average dark count rate of the instrument.

Contents

1 Calculating Sky Background

The total sky background count rate (B_{total}) is calculating by considering the diffuse galactic background (B_{dg}), the background due to zodiacal light (B_{zl}), and the average dark count rate of the instrument (B_{ad}), and is therefore dependent on sky coordinates. B_{total} is calculated using

$$B_{total} = B_{dg} + B_{zl} + B_{ad}, \tag{1}$$

where the diffuse galactic and zodiacal light backgrounds are calculated using

$$B_X = \frac{I_X f_{tp}}{I_{ref}}, \tag{2}$$

where I_X is the intensity of background X at a given coordinate ($X = dg$ - diffuse galactic; $X = zl$ - zodiacal light), f_{tp} is the filter throughput for the background, and I_{ref} is the reference intensity.

2 Diffuse Galactic Light

The diffuse component of the galactic background radiation (B_{dg}) is produced by scattering of stellar photons by dust grains in interstellar space, and effects wavelengths from the far ultraviolet to the near infrared. This scattering process dominants the general interstellar extinction of starlight, and is therefore more intense at low galactic latitudes where the dust column density and integrated stellar emissivity are both high. Typically, diffuse galactic light (DGL) contributes 20% to 30% of total integrated light from the Milky Way [3]. Due to the strongly forward scattering nature of interstellar grains the DGL, intensity generally tracks the LOS* intensity at constant latitude, but large differences of LOS* intensity may occur with galactic longitude, therefore ratios must be used. Table 1 shows the ratio of DGL to LOS* from [3], and shows the variation in the ratios with galactic longitude.

Galactic Longitude (^{o})	DGL/LOS* S10
0 - 5	0.21 ± 0.05
5 - 10	0.34 ± 0.07
10 - 15	0.31 ± 0.03
15 - 20	0.19 ± 0.04
20 - 30	0.25 ± 0.04
30 - 40	0.17 ± 0.04
40 - 60	0.17 ± 0.02
60 - 90	0.12 ± 0.02

Table 1: Ratio of DGL to LOS* from [3] for $\lambda \sim 440$nm based on Toller's data ([9]).

2.1 Background Intensity

The DGL background Intensity (I_{dg}) was calculated using background starlight at 440nm (from [3] Table 35), and the DGL/LOS* ratio in units of S10[1] from Table 1. The final DGL intensity map (after correcting for DGL/LOS* ratio) can be seen in Figure 1.

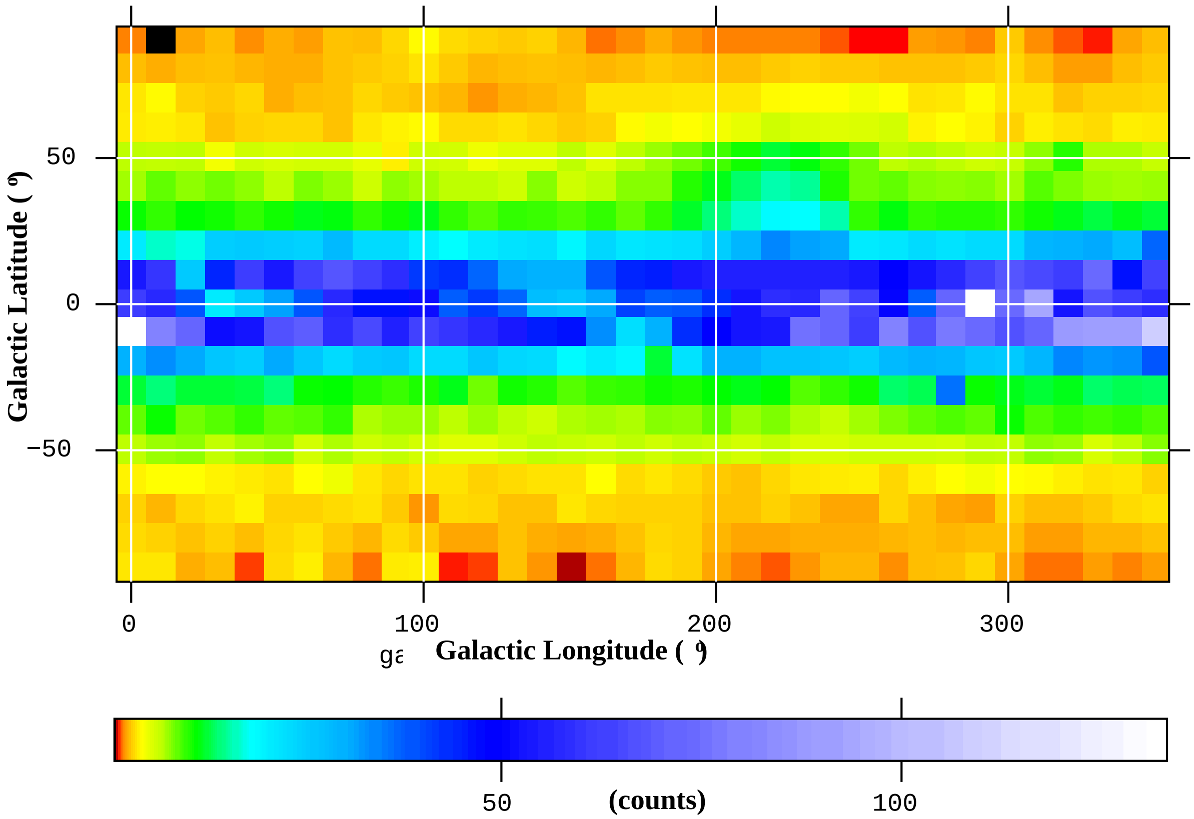

Figure 1: Final DGL intensity map.

2.2 Throughput of filter

To find the throughput (f_{tp}) of each OM filter, the spectrum for DGL needs to be considered. This spectrum was constructed using data from [7], [2] and [8], and has a reference intensity of 43 S10.

Using data from [7], wavelengths from $155 - 435$nm were considered. The flux of these values was calculated by multiplying the DGL intensity ([7], Table 2 units of S10) values by

- a0 spectrum (interpolated at the same wavelengths)
- 1×10^{-4} (to scale by 10 magnitudes)

[1]S10 is units of a standard star with a visual magnitude of 10.

Data from [2] at wavelengths $92.5 - 147.5$nm, and [8] at wavelengths $450 - 1000$nm, were scaled to match the values of [7]. The resulting spectrum can be seen in Figure 2.

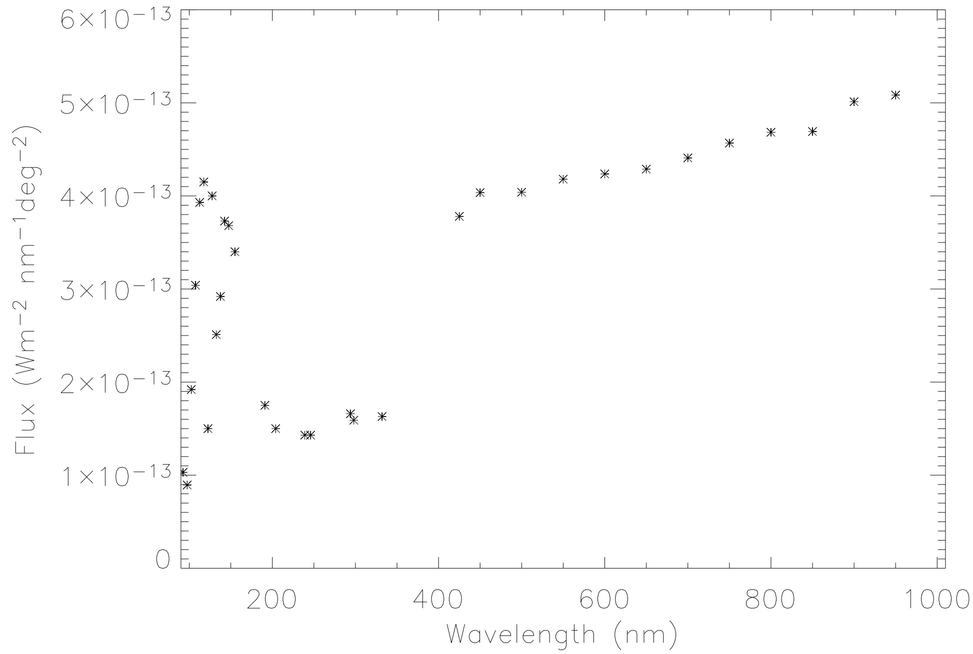

Figure 2: Basic spectrum of galactic light constructed from the data of [7], [2] and [8].

This DGL spectrum was then run through the IDLSimulator to calculate the throughput for each OM filter. The final throughput results can be seen in Table 2.

Filter	Diffuse Galactic ($count.s^{-1}arcsec^{-2}$)
V	0.0127473
U	0.00819123
B	0.0214153
White	0.069187
UVW1	0.00258478
UVM2	0.000496318
UVW2	0.000204369

Table 2: Filter throughput for diffuse galactic spectrum of reference intensity 43 S10.

2.3 Intensity of reference

Intensity of reference spectrum is 43 S10.

2.4 Results

The total background intensity of DGL can be found for a given galactic longitude and latitude in an OM filter, using Equation 3 derived from Equation 2

$$B_{dg} = \frac{I_{dg} f_{tp}}{I_{ref}}, \tag{3}$$

where I_{dg} is the intensity of DGL background given by the intensity map in Figure 1, f_{tp} is the filter throughput for the DGL background given in Table 2, and I_{ref} is 43. Results of the minimum and maximum count rates can be seen in Table 3, where the minimum DGL is found using the UVW2, and the maximum using the White filter.

	filter	B_{dg} (count.s^{-1}arcsec^{-2})	longitude (^{o})	latitude (^{o})
minimum	UVW2	7.985×10^{-6}	10	90
maximum	white	0.214	290	0

Table 3: Results of the DGL background.

3 Zodiacal Light

Zodiacal light (B_{zl}) is due to sunlight scattered by interplanetary dust particles, and is seen at ultraviolet, optical and near infrared wavelengths. Its brightness is a function of wavelength, heliocentric distance, and position of the observer relative to symmetry plane of interplanetary dust. In general zodiacal light (ZL) is smoothly distributed with small scale structures appearing only at the level of $\sim$ few %; its brightness does not vary with the solar cycle to within 1% ([1] and [4]).

3.1 Background Intensity

The ZL background Intensity (I_{zl}) was produced using the smoothed brightness values from [6] (Table 2 - in units of S10) for eliptic longitudes of $50 - 130^o$. The ZL intensity map can be seen in Figure 3.

3.2 Throughput of filter

To find the throughput (f_{tp}) of each OM filter, the spectrum for ZL needs to be considered. The spectrum used in this case was a G2 type star (as the Sun is a G2V star). The spectrum used can be seen in Figure 4.

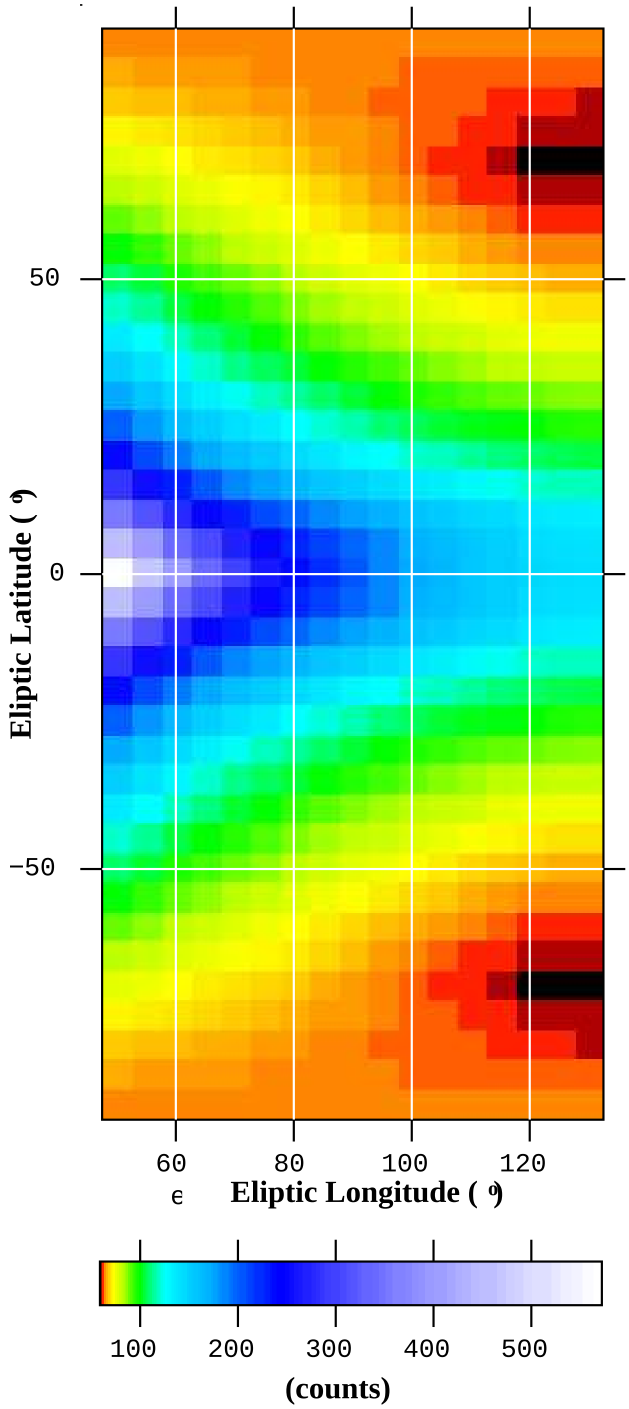

Figure 3: ZL intensity map.

NOTE - when using the G2 spectrum provided in the IDLSimulator, a scaling of the spectrum of 0.01 is required to obtain the intensity of 100 S10 (i.e. $1 \times 10^{-4} * 100$), as the visual magnitude of the G2 spectrum is 0 .

This spectrum was then run through the IDLSimulatior to calculate the throughput for each OM filter, with a reference intensity of 100 S10. The final throughput results can be seen in Table 4.

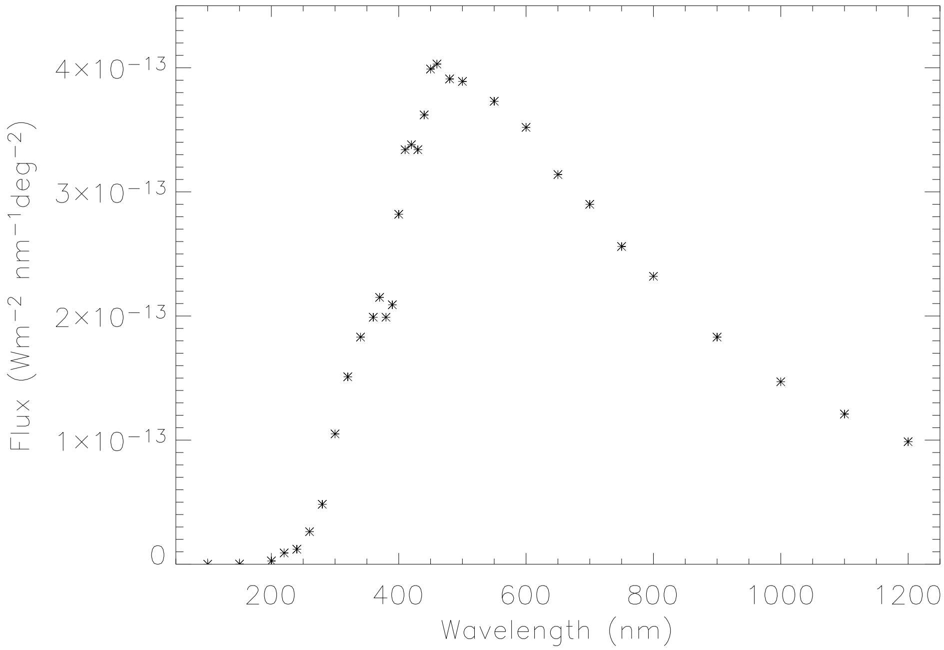

Figure 4: Corrected spectrum of G2 type star used for ZL.

Filter	Zodiacal Light (count.s^{-1}arcsec^{-2})
V	0.0115465
U	0.00737317
B	0.0198009
White	0.057095
UVW1	0.00139419
UVM2	0.0000425153
UVW2	0.00000864731

Table 4: Filter throughput for Zodiacal Light spectrum of reference intensity 100 S10.

3.3 Intensity of reference

Intensity of reference spectrum is 100 S10.

3.4 Results

The total background intensity of ZL can be found for a given eliptic longitude and latitude in an OM filter, using Equation 4 derived from Equation 2

$$B_{zl} = \frac{I_{zl} f_{tp}}{I_{ref}}, \tag{4}$$

where I_{zl} is the intensity of ZL background given by the intensity map in Figure 3, f_{tp} is the filter throughput for the DGL background given in Table 4, and I_{ref} is 100. Results of the minimum and maximum count rates can be seen in Table 3, where the minimum ZL is found using the UVW2, and the maximum using the White filter.

	Filter	background (count s^{-1} $arcsec^{-2}$)	longitude (^{o})	latitude (^{o})
min	UVW2	5.275×10^{-6}	105	70
max	White	0.169	70	0

Table 5: Longitude

4 Average Dark Count rate

The mean OM detector dark count rate (B_{ad}) is 2.56×10^{-4} count.s^{-1}pixel^{-1}. Converting this into arcsec[2], produces a value of 0.001024 count.s^{-1}arcsec^{-2}.

References

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[3] Leinert, C. *et al.,* 1998, *Astr. & Astrophys. Suppl.,* **127**, 1.

[4] Leinert, C., & Pitts, E., 1989, *Astr. & Astrophys.,* **210**, 399.

[5] Leinert, C., Richter, I., Pitz, E., & Hanner, M., 1982, *Astr. & Astrophys.,* **110**, 355.

[6] Levasseur-Regourd, A. C., & Dumont, R., 1980, *Astr. & Astrophys.,* **84**, 277.

[7] Lillie, C. F., & Witt, A. N.,1976, *Astrophys. J.,* **208**, 64.

[8] Mattila, K., 1980, *Astr. & Astrophys.,* **82**, 373.

[9] Toller, G. N., 1981, Ph.D. Thesis, State University of New York at Stony Brook.

[2] 1pixel = 0.5× 0.5 arcsec = 0.25 arcsec