Appendix F

The Faint Source Model

F.1 Introduction

The *DIRBE* Faint Source Model (FSM) was created to simulate the unresolved Galactic emission of stars and other compact sources at wavelengths from 1.25 to 25 μm . The emission predicted by the FSM was subtracted as a foreground component from the observed *DIRBE* intensities in an effort to determine the cosmic IR background (Arendt *et al.* 1998). The main requirements imposed on the FSM were (a) that it yield integrated surface brightnesses at the nominal *DIRBE* wavelengths, (b) that it provide maps of the surface brightness at *DIRBE* resolution, and (c) that it include an adjustable brightness cutoff, enabling exclusion of the brighter stars, which could be detected individually by the *DIRBE* .

The FSM is a statistical model which follows the basic form of the Wainscoat *et al.* (1992) and Cohen (1993, 1994, 1995) "SKY" models, including 5 structural components for the Galaxy (disk, spiral arms, molecular ring, bulge, and halo), 87 source types, each with a dispersion of absolute magnitudes, and interstellar extinction from dust in an exponential (in radius, R, and scale height, z) disk. The formalism of the SKY model allows the FSM to predict source counts in stars per magnitude per steradian. With the application of a zero–magnitude flux to convert magnitudes to flux densities, the FSM transforms the source counts to integrated intensities, in MJy/sr, along each line of sight. Some of the relatively recent modifications to the SKY model (Cohen 1993, 1994, 1995) could also be used to improve the FSM, but many of these changes are either irrelevant at the *DIRBE* wavelengths, or are difficult to implement while maintaining fidelity to the SKY model. Some modifications to the Wainscoat *et al.* version of the SKY model (version 1.0) were included in the FSM, either out of necessity or to produce results that were better suited for comparison with the *DIRBE* data. These changes are as follows:

1. Since source count models cannot accurately represent the brightest point sources, which are unevenly distributed across the sky, the FSM was only integrated over stars fainter than those that were previously blanked from the *DIRBE* maps (see Table F.1-1). The value of the brightness limit at which the bright source blanking of the data stops and the Faint Source Model begins is not a significant source of uncertainty. Changes in the limits by 20% produce <5% changes in the Faint Source Model intensities.

2. The angular resolution of the model was increased; the sky brightness was calculated at the resolution of the *DIRBE* maps.

3. The halo is described by Wainscoat *et al.* (1992) only as an $R^{1/4}$ law in projected surface brightness. Therefore we have adapted the formulation for the volume density presented by Young (1976) for use in the Faint Source Model. At high Galactic latitudes, the halo is the third most important component of the Faint Source Model after the disk and the spiral arms.

4. We omitted the extragalactic component of the SKY model, which contributes mainly at faint magnitudes at 25 μm (Cohen 1994).

5. The position of the Sun was set at 18 pc North of the midplane of the Galactic disk. This was determined during preliminary trials, by requiring equal brightnesses at the north and south Galactic poles after subtraction of the FSM from the *DIRBE* maps in the near IR bands. This value is independently supported by analysis done with the SKY model (Cohen 1995), and by direct analysis of the *DIRBE* maps (Weiland *et al.* 1994).

6. For 3.5 and 4.9 μm magnitudes, which are not represented in the Wainscoat *et al.* (1992) source table, we obtained approximate magnitudes for the various source types by extrapolating from the J magnitudes using $V-J, V-L$, and $V-M$ stellar colors from Johnson (1966).

7. Wainscoat *et al.* (1992) made adjustments to their model in certain Galactic latitude–longitude zones. These changes were not specified exactly in terms of magnitude and location, and thus could not be included in the FSM.

8. The FSM includes the split local spur as one of the spiral arm features, according to Cohen's (1994) description.

Table F.1-1: Faint Source Model Parameters

Wavelength (μm)	Zero–Magnitude Flux Density (Jy)	Bright Source Cutoff (Jy)	Extinction (τ kpc^{-1})
1.25	1547.	15	0.1610
2.2	612.3	15	0.0639
3.5	285.0	15	0.0331
4.9	153.5	15	0.0131
12	31.65	85	0.0274
25	12.23	110	0.0029

F.2 Calibration

The SKY model as described in Wainscoat *et al.* (1992) is used to predict source counts as a function of magnitude. In order for the FSM to calculate intensities, the stellar magnitudes need to be converted to fluxes, using adopted values of the apparent flux density for a 0^{th}–magnitude star at each *DIRBE* wavelength. The zero–magnitude flux densities used in the FSM (see Table F.1-1) were chosen to be consistent with the absolute calibration of the *DIRBE* data (see Chapter 4). The zero–magnitude flux density of the FSM at 2.2 μm was reduced by a factor of 0.963 to account for differences between the color corrections of Sirius (which was used as the absolute calibrator) and those of K and M giants which dominate the emission of the FSM and have a CO absorption band partially within the 2.2 μm *DIRBE* band. There exist uncertainties of 10 – 15% in the model arising from details of the absolute calibration of the model and the differences and treatment of the various broadband filter responses (Cohen 1993, private communication).

The extinction at each wavelength (specified as optical depth per kpc in the vicinity of the Sun) is listed in Table F.1-1. The extinction law was chosen to match that of Rieke & Lebofsky (1985), and normalized to $A_V = 0.62$ mag/kpc (Wainscoat *et al.* 1992).

F.3 Verification

To check the FSM, we compared the results of our calculations at 1.25 - 25 μm to the average surface brightnesses, calculated using the SKY model, of 238 large zones covering the entire sky (Cohen 1993, private communication). Wainscoat *et al.* (1992) give a table and map of the zone boundaries. The Faint Source Model reproduces the mean intensities calculated with the SKY model to within $\sim$5% over most of the sky. The zones that are not well matched are all at low latitudes, below $|b| = 20^\circ$, except a zone containing the LMC and another near the Taurus region. Cohen (1994) made adjustments for various localized features in the Galaxy, but no such adjustments were made in the FSM.

We also compared the star counts expected from the FSM with star counts from the prototype 2MASS survey in 7 fields at J and K_S (Skrutskie *et al.* 1996, private communication). The fields are all in the first Galactic longitude quadrant and span the latitude range $8° < b < 87°$. The FSM star counts are similar to the 2MASS star counts, although statistically significant differences were found in about half of the fields, mostly at magnitudes $J > 12$ and $K_S > 12$. Because such faint stars contribute a small fraction of the total emission from these fields, the FSM predictions are consistent with the 2MASS observations in integrated brightness. This comparison is limited by the small sizes of the fields ($0.122 - 6.9$ deg^2) and the corresponding large statistical uncertainties in the star counts.

Discontinuities in the surface brightness of the FSM are due to the sharp edges (in galactocentric radius) in the geometric representation of the spiral arms. These edges are obscured at the resolution of the large zones used by Wainscoat *et al.* (1992). One edge of the local spur passes through the solar neighborhood and causes a discontinuity in the model at high Galactic latitudes.

F.4 Comparison with the *DIRBE* Data

Residual maps generated by subtracting the FSM from the *DIRBE* data are presented by Arendt *et al.* (1998). At wavelengths ≤ 3.5 μm and low Galactic latitudes ($|b| < 10°$), the FSM tends to overestimate the actual sky brightness, leading to negative residuals. A longitudinally anti–symmetric residual is present at the location of the Galactic bulge, which suggests that improvements could result if a bar–like model were used for the bulge (*e.g.,* Blitz & Spergel 1991, Weiland *et al.* 1994, Dwek *et al.* 1995, Freudenreich 1998). Some relatively large differences between the model and the data are found at locations where the Faint Source Model has omitted particular adjustments for specific disk and spiral arm features (Cohen 1994).

F.5 Warnings

The FSM data product described in §5.8 incorporates the bright source limits listed in Table F.1-1. It will not properly represent the diffuse sky brightness if the bright stars are blanked at a different level, or if they are not blanked at all. Furthermore, the FSM is intended to be a reproduction of, rather than an improvement upon, the SKY model of Wainscoat *et al.* (1992). Its sole purpose was to enable subtraction of the contribution from faint stars to the near–IR sky brightness in order to search for the cosmic infrared background (Hauser *et al.* 1998). In other applications, one should not use the FSM as a substitute for the SKY model, which has been extensively compared with existing source counts.

F.6 References

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