Chapter 1

Introduction

1.1 The Experiment: Objectives and Approach

The Diffuse Infrared Background Experiment (*DIRBE*), one of three instruments aboard the Cosmic Background Explorer (*COBE*) satellite, was designed primarily to search for the isotropic cosmic infrared background (CIB) radiation expected to arise from the cumulative emissions of early luminous objects, and to measure the energy distribution of that radiation. This objective was achieved: the CIB was detected at 140 and 240 μm and limits were placed on the CIB brightness over the spectral range 1–100 μm (Hauser *et al.* 1998). Secondary objectives included studies of foreground astrophysical sources arising in the solar system and Milky Way Galaxy. The observational approach was to make absolute brightness maps of the full sky at 10 wavelengths (1.25, 2.2, 3.5, 4.9, 12, 25, 60, 100, 140, and 240 μm), and to map linear polarization at 1.25, 2.2, and 3.5 μm.

The *DIRBE* instrument operated at cryogenic temperatures for 10 months, from 1989 November 24 to 1990 September 21, mapping the full sky with high redundancy during the first six months, and covering most of the sky with similar redundancy during the final four months. The data products described in this *Explanatory Supplement* are based upon the high quality data acquired during the cryogenic period.

A more complete description of the *COBE* mission has been given by Boggess *et al.* (1992).

1.2 The Explanatory Supplement

This document is intended to provide a complete, self–contained description of the *DIRBE* experiment and the products of the *DIRBE* sky survey. The instrument, its calibration, electronics, operating modes, and context within the *COBE* satellite are described in Chapter 2. Flight operations, instrument monitoring tests, anticipated and actual environmental influences, and malfunctions are described in Chapter 3. Chapter 4 discusses attitude determination and data processing, calibration and quality assurance. Some known processing deficiencies were allowed; these are described at the end of Chapter 4. The *DIRBE* data products, their intended use, formats, and limitations, are given in Chapter 5. Chapter 6 lists the references cited in this document; Appendix G contains a bibliography of related *COBE* publications. The *DIRBE* System Spectral Response is tabulated in Appendix A. Appendix B contains Color Correction Tables. Appendix C gives a chronology of events that took place during the cryogenic mission. Appendix D provides information about data retrieval. Appendix E is a list of acronyms. The *DIRBE* Faint Source Model, which was used by Arendt *et al.* (1998) to subtract stellar emission from the *DIRBE* sky maps as part of the search for the cosmic infrared background, is described in Appendix F; the model is available as a data product.

This version of the *DIRBE Explanatory Supplement* supersedes the version released with the Galactic Plane Maps on July 19, 1993 and version 2.0, which was released on May 4, 1995. The next version will describe additional data products and is likely to be released in mid–1997.

1.3 Overview of Data Products

Data from the *DIRBE* sky survey are available in time–ordered and sky map formats. Most of the data products give the sky brightness as observed, including the zodiacal and Galactic components. Some, however, include estimates of the zodiacal light intensity or give residual intensity after zodiacal light subtraction. The data products are described in detail in Chapter 5.

The **Time–Ordered Data (TOD)** product includes calibrated sky brightness values and is the most complete archival record of the *DIRBE* observations. It is necessary to understand the operating modes of the instrument and to recognize various mission events in order to select and interpret the data of interest. The TOD product is not intended for heavy use by the research community. In those rare instances in which individual time–ordered data are needed (*e.g.*, to obtain definitive *DIRBE* point source flux values), the **Calibrated Individual Observations (CIO)** product should be used instead of the TOD. It is expected, however, that one or more of the sky map data products will suffice in most applications.

The maps are distinguished by the time interval over which multiple observations of a single celestial position are coadded. All of the sky maps are presented in FITS binary tables, in which the first column – the independent variable – is pixel number [1]. The following sky map products are available:

Weekly Sky Maps provide weekly–averaged intensity values for each pixel and photometric band, plus Stokes Q and U parameters at 1.25, 2.2 and 3.5 μm, for the period of optimized cryogenic operation, 1989 December 11 to 1990 September 21. Each map covers approximately half of the sky. As a set, the 41 Weekly Sky Maps offer an unprecedented view of the interplanetary dust (IPD) cloud, since each celestial direction was observed by the *DIRBE* along a variety of paths through the cloud. The variable zodiacal light signature can be seen in Figures 1.3-1–1.3-3 and is especially pronounced at 25 μm (Figure 1.3-2) where the emission peaks.

Annual Average Sky Maps provide a single, ten–month averaged intensity value per pixel for each of the 10 *DIRBE* bands. The effect of coaddition is to improve sensitivity to faint emission. Since these maps average over the variable zodiacal light signal, they are useful primarily at wavelengths at which the IPD signature is weak, particularly 140 and 240 μm. The Annual Average Sky Maps also provide information on the depth of sky coverage over the mission. In many applications, the **Zodi–Subtracted Mission Average (ZSMA) Maps** will supersede the Annual Average Sky Maps.

Solar Elongation (ε) = 90° Sky Maps provide an estimate of the infrared intensity for each wavelength at each pixel based on an interpolation of the observations made at various times at ε close to 90° . This is the only fixed elongation angle at which the entire sky can be mapped.

Galactic Plane Maps are subsets of the $\varepsilon = 90°$ Sky Maps designed to facilitate studies of the Galaxy. The maps cover Galactic latitudes $|b| < 10°$ at longitudes $30° < \ell < 330°$, and cover $|b| < 15°$ elsewhere.

Figures 1.3-4–1.3-6 show Mollweide projections, in Galactic coordinates, of the $\varepsilon = 90°$ Sky Maps for all 10 *DIRBE* intensity bands. The intensity scales are logarithmic and range from the minima (black) to the maxima (white) listed in Table 1.3-1. Zodiacal emission is evident at wavelengths ranging from 4.9 to 100 μm (an 'S' pattern is made by the ecliptic plane). The Galactic stellar component is clearly visible in the near–infrared (1.25 – 4.9 μm), and interstellar dust emission is prominent at $\lambda \geq 60$ μm.

To illustrate the better sensitivity available when the data are coadded, the 240 μm Annual Average Sky Map is compared with the 240 μm $\varepsilon = 90°$ Sky Map in Figure 1.3-7.

The *DIRBE* **Calibrated Annual File (DCAF)**, a reorganized form of the Weekly Sky Maps, provides convenient access to the weekly–averaged intensities seen in individual pixels as a function of time, facilitating studies of the zodiacal light.

[1] The *DIRBE* convention is to represent the sky as a quadrilateralized spherical cube (see §5.3) in which each cube face ($4\pi/6$ sr) is divided into 256 × 256 pixels of approximately equal area. The area is equivalent to a square $0\overset{\circ}{.}32$ on a side. The *DIRBE* beam (instantaneous field of view) is a square $0\overset{\circ}{.}7$ on a side.

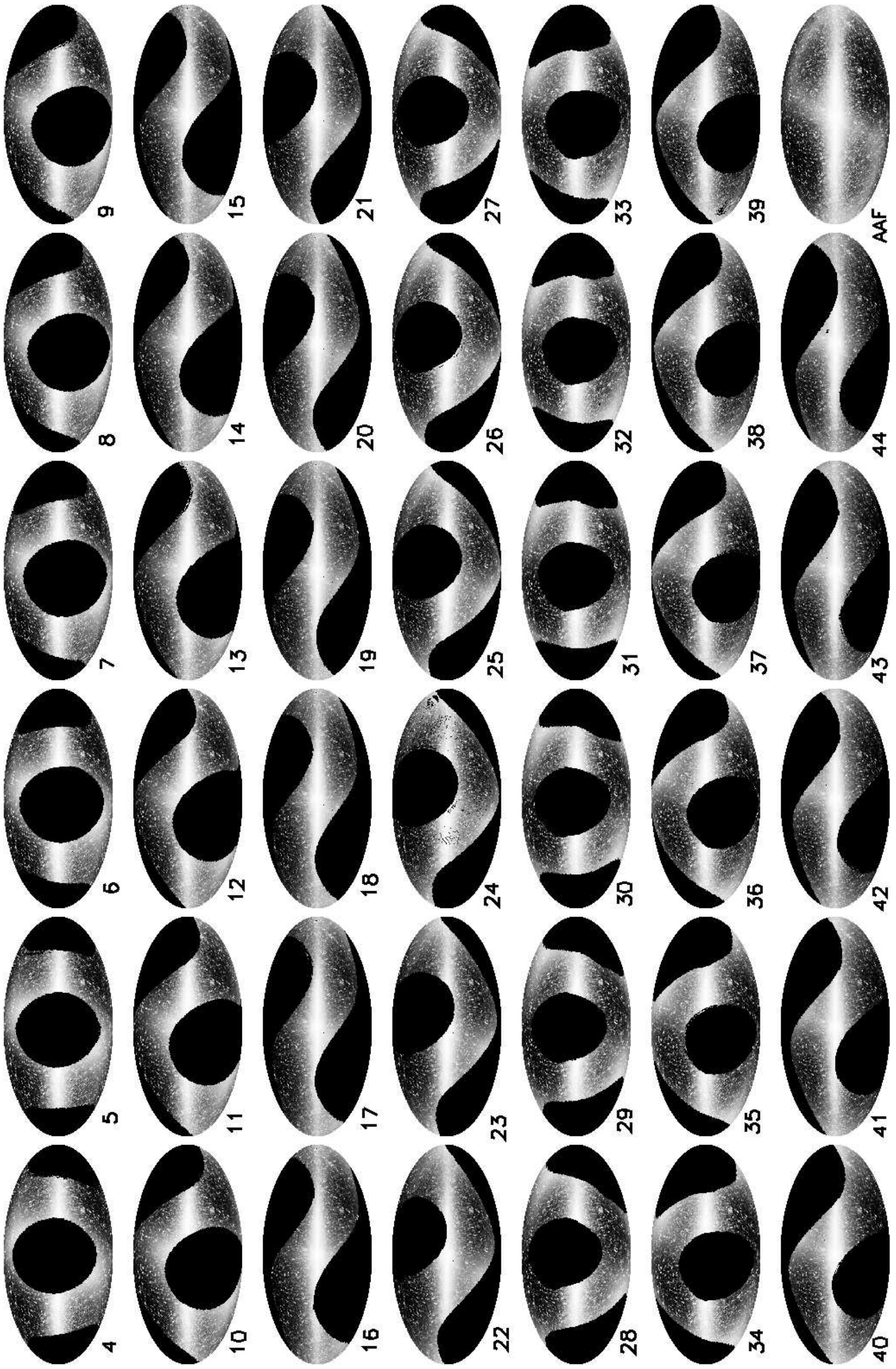

Figure 1.3-1: Weekly Sky Map mosaics at 3.5 μm. Each map is an all–sky Mollweide projection in Galactic coordinates with the Galactic center in the middle. Maps are labeled by mission week number beginning 1989 November 18 (*e.g.*, map 4 shows data from 1989 December 11 – December 17). The map labeled AAF is the Annual Average Sky Map.

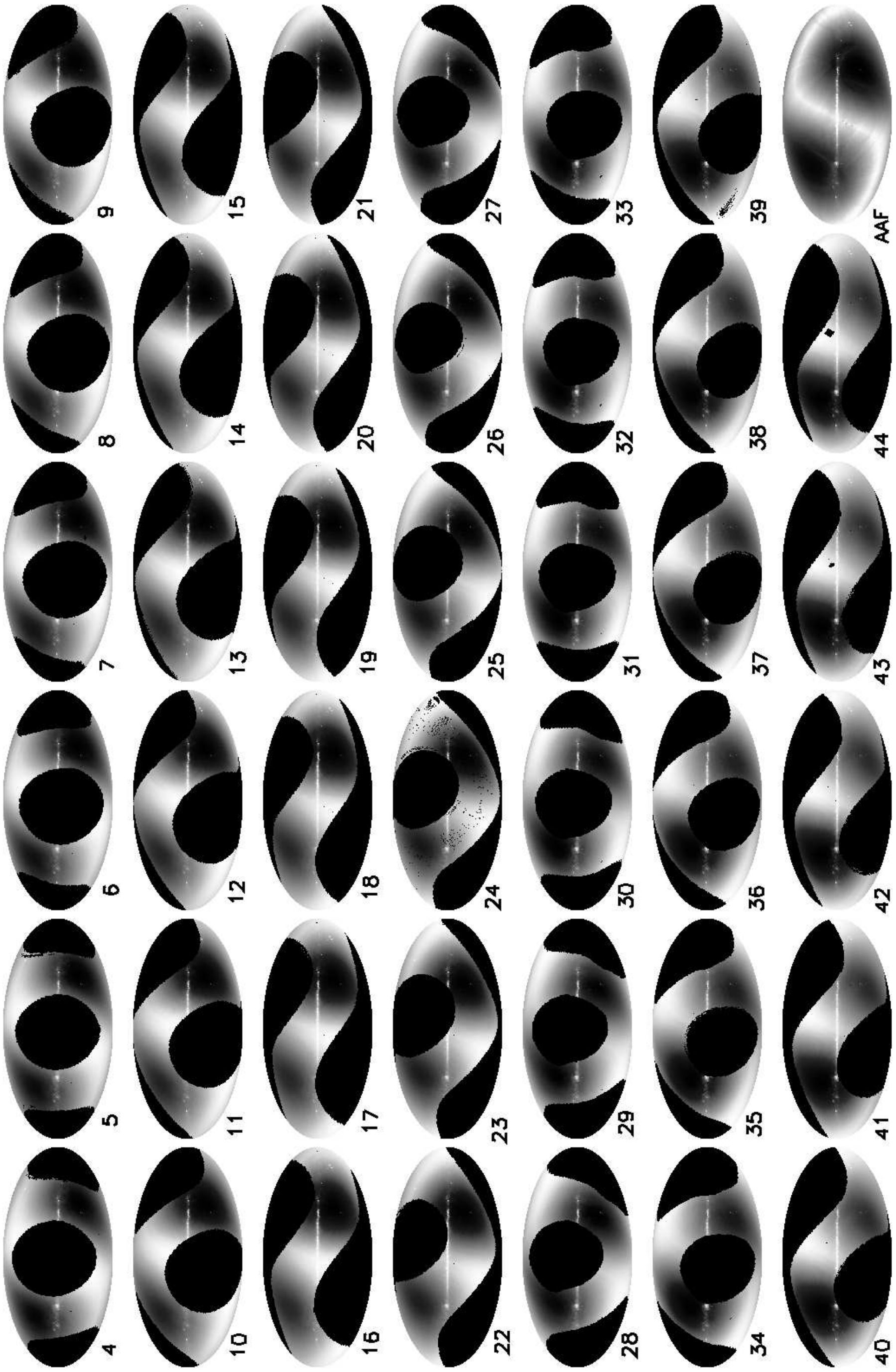

Figure 1.3-2: Same as Fig. 1.3-1 except at 25 μm.

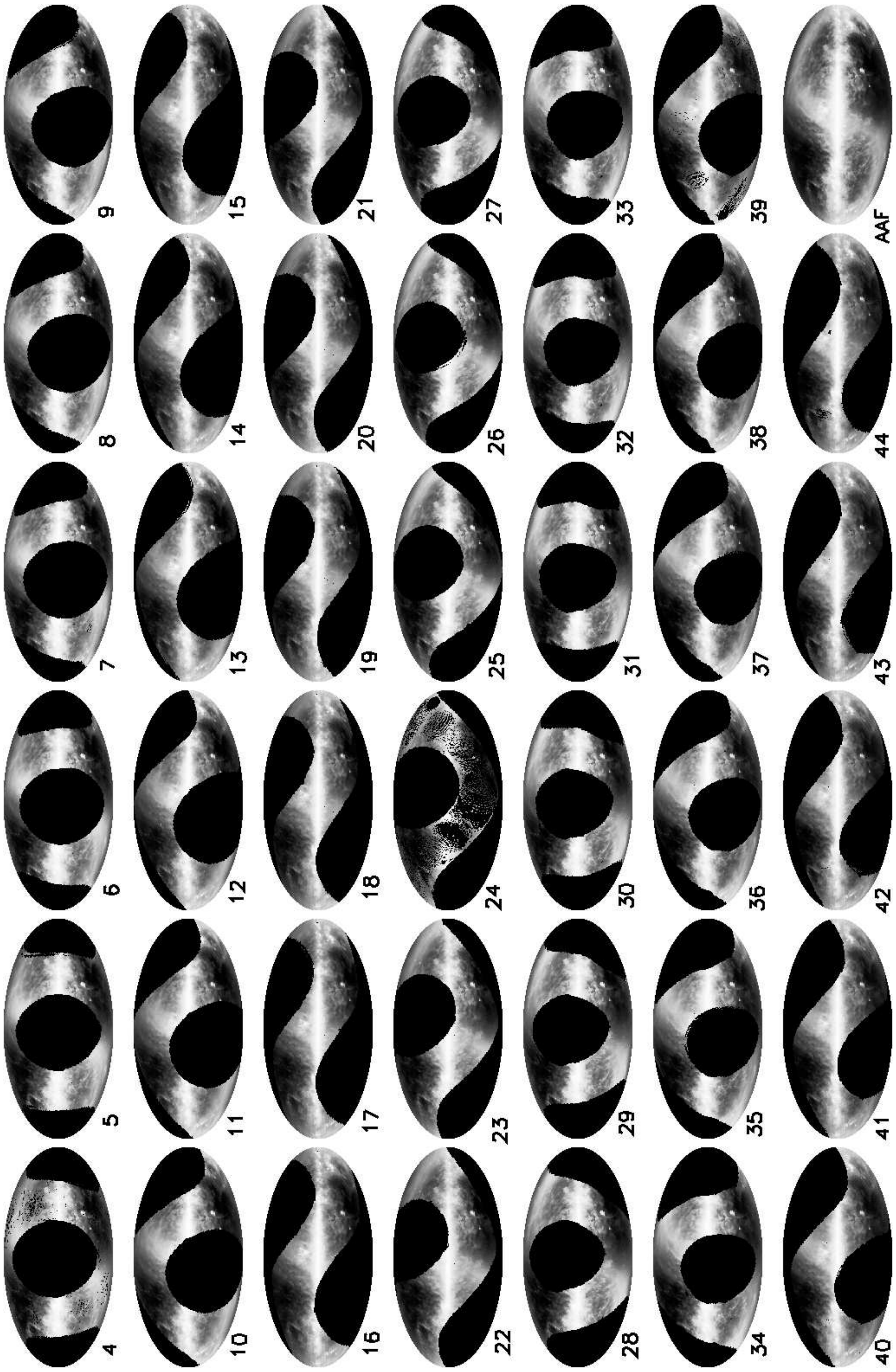

Figure 1.3-3: Same as Fig. 1.3-1 except at 100 μm.

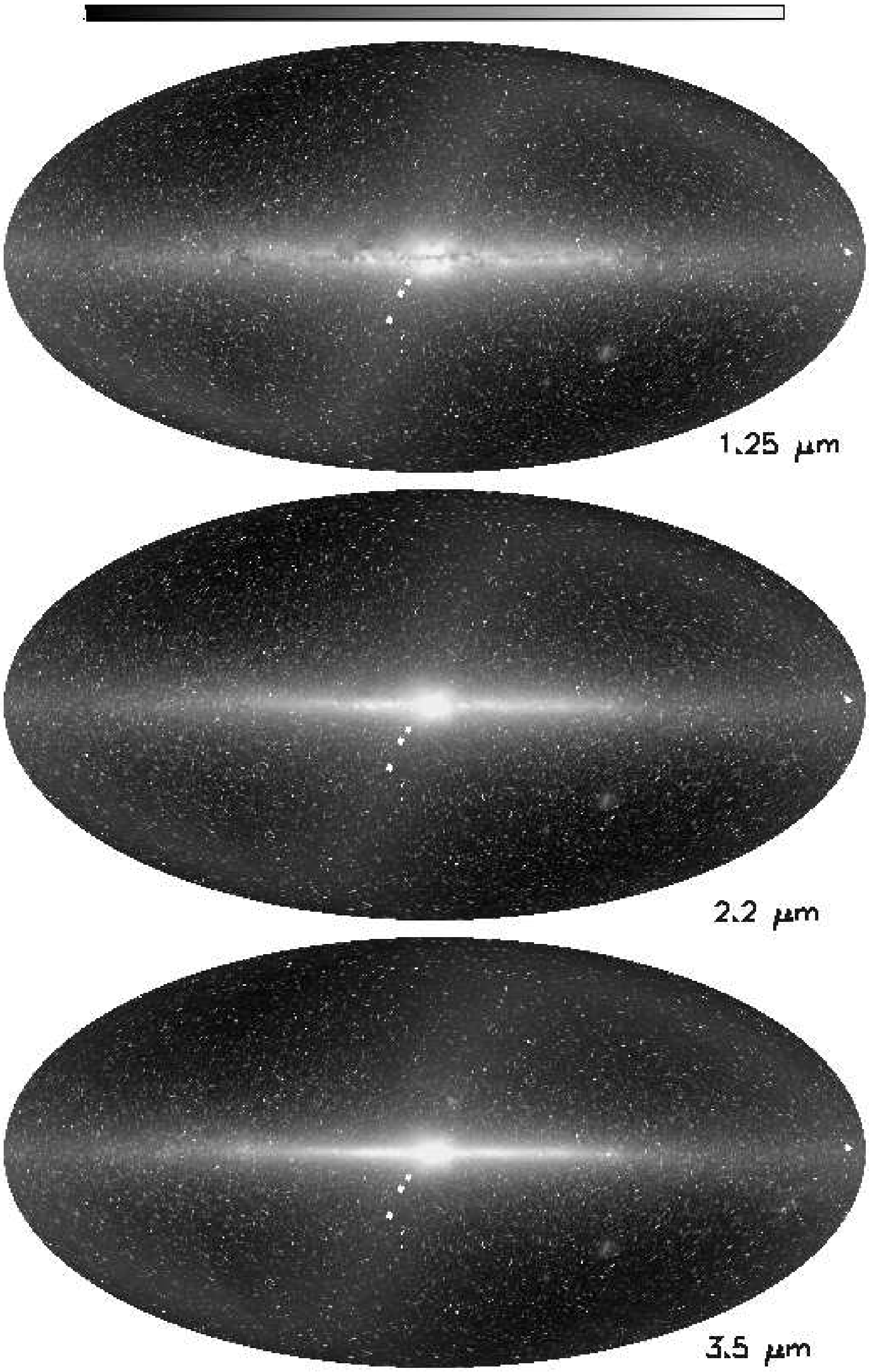

Figure 1.3-4: Solar elongation = 90° Sky Maps at 1.25, 2.2, and 3.5 μm . Each map is a Mollweide projection in Galactic coordinates with the Galactic center in the middle. Holes in the maps in the ecliptic plane (south of the Galactic center and near the Galactic anti–center) are due to exclusion of data near bright planets (see §5.6.2). The wavelength–dependent intensity scale is given in Table 1.3-1

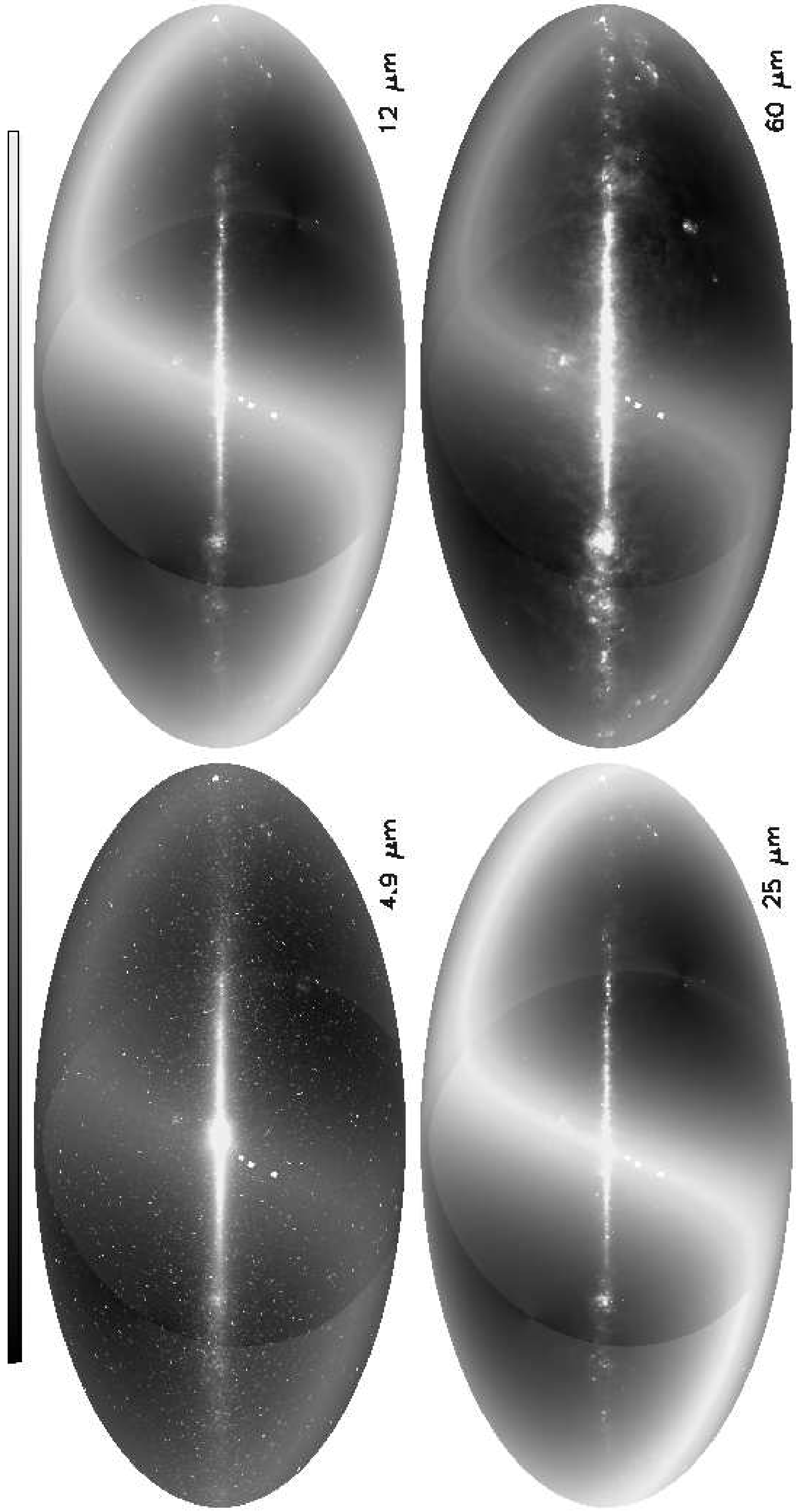

Figure 1.3-5: Same as Fig. 1.3-4 except at 4.9, 12, 25, and 60 μm.

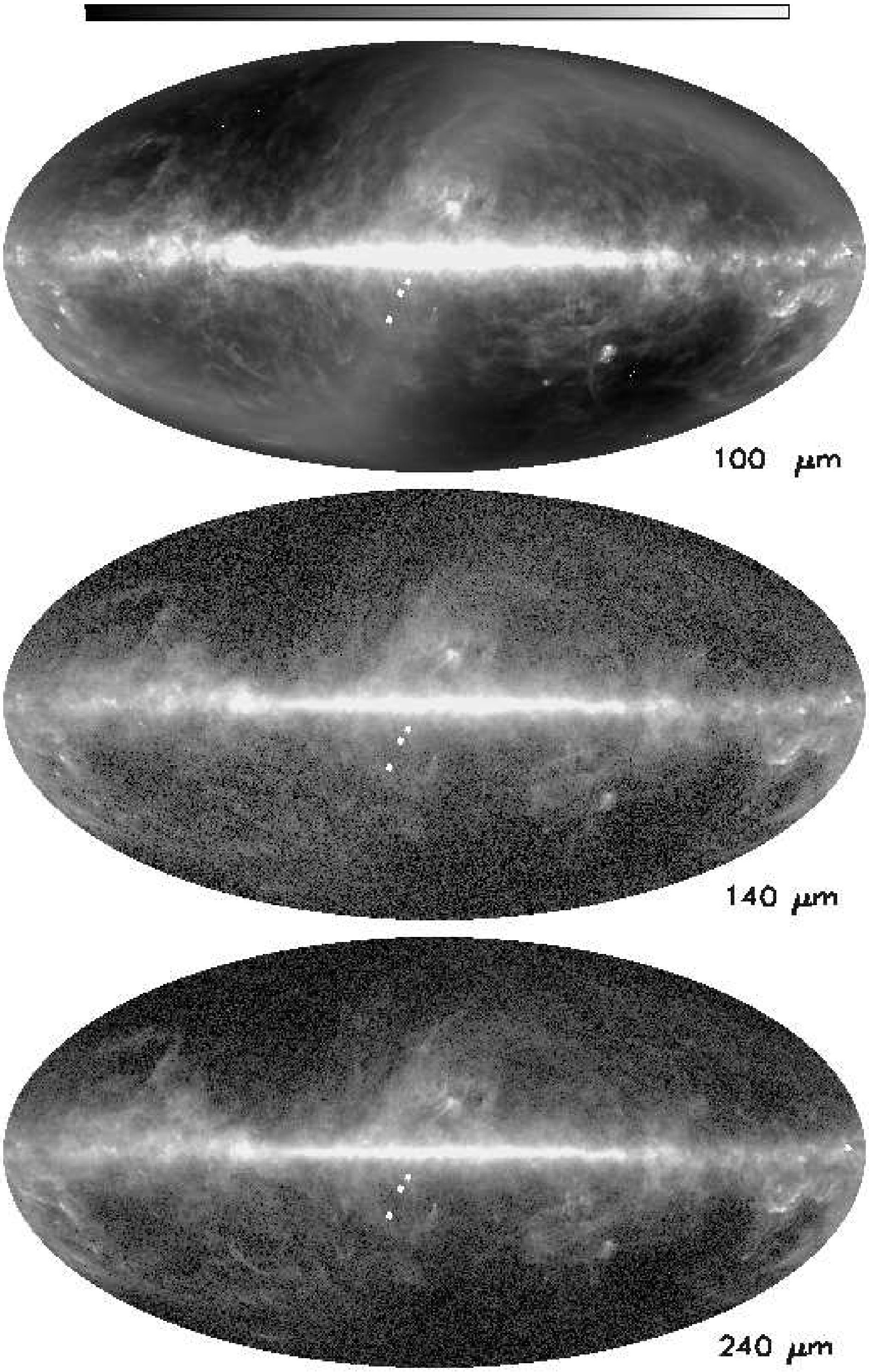

Figure 1.3-6: Same as Fig. 1.3-4 except at 100, 140, and 240 μm.

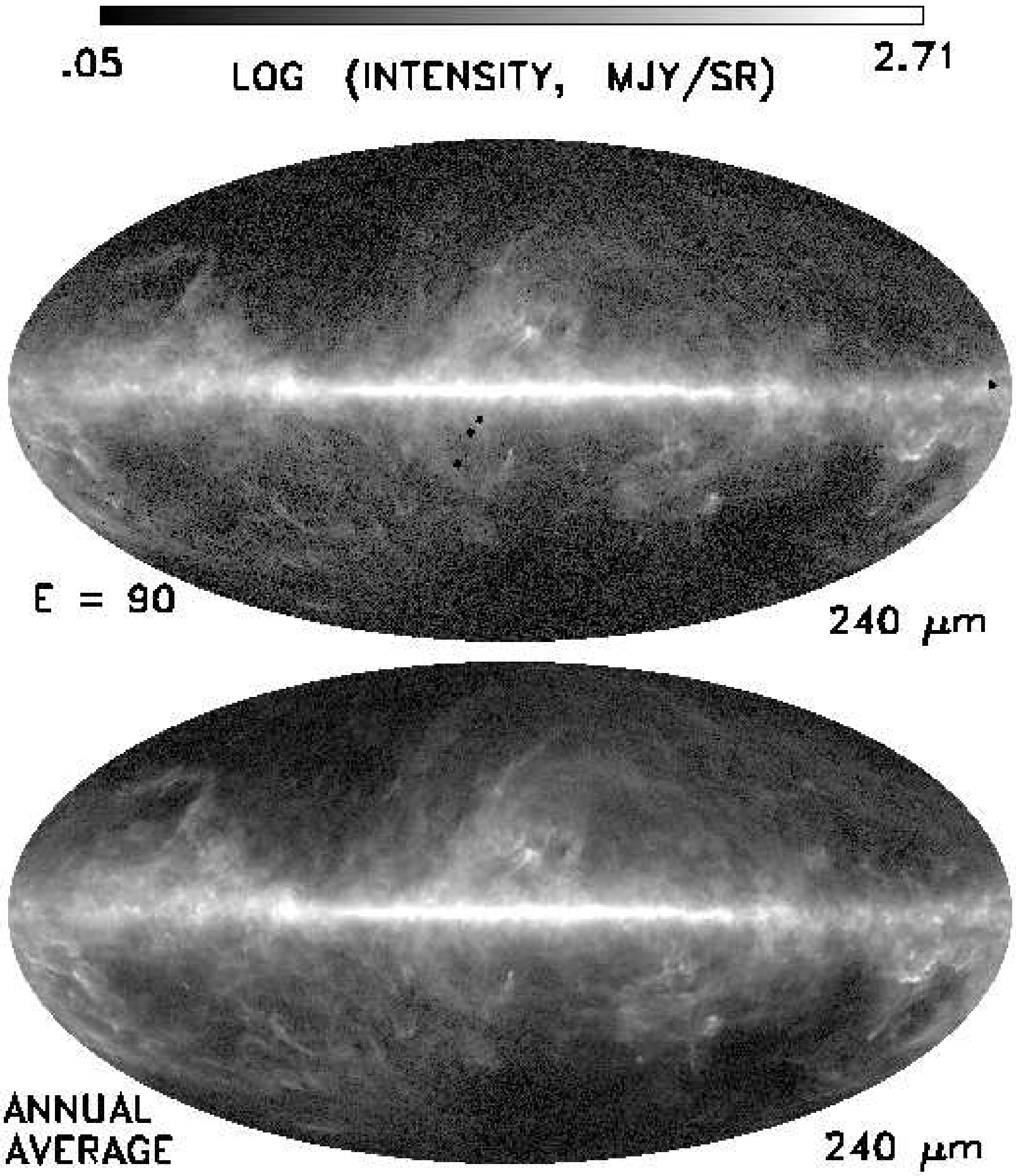

Figure 1.3-7: Comparison of Solar elongation = 90° *(top)* and Annual Average Sky Maps *(bottom)* at 240 μm illustrating the greater sensitivity in the latter. Both maps are Mollweide projections in Galactic coordinates.

Table 1.3-1: Intensity ranges for Figures 1.3-4–1.3-6

Wavelength (μm)	log (I_ν, MJy/sr) corresponding to black	white
1.25	-0.8	1.1
2.2	-0.95	1.3
3.5	-1.1	1.1
4.9	-0.5	0.75
12	1.0	1.7
25	1.2	1.91
60	0.7	1.91
100	0.42	2.0
140	0.05	2.71
240	0.05	2.71

The highest level *COBE* data products are called Analyzed Science Data Sets (ASDS). The **Photometric Standard Values Table** contains photometric data for the 92 objects which were used to establish the baseline relative celestial calibration system. *DIRBE* observations of Mars, Jupiter, Saturn, Uranus, Ceres, Pallas, and Vesta are reported in the **Solar System Object Dataset**; flux densities and relevant ancillary information are included in this product.

Additional ASDS products include estimates of the zodiacal light (ZL) intensity derived from the *DIRBE* interplanetary dust model (Kelsall *et al.* 1998) or have the zodiacal light subtracted. The *DIRBE* **Sky and Zodi Atlas (DSZA)** contains most of the data given in the DCAF, as well as an estimate of the ZL contribution to each of the individual weekly averaged photometric measurements. Finally, the ZL intensities were subtracted week by week and the residual intensity values were averaged to create the **Zodi–Subtracted Mission Average Maps (ZSMA)**, which give the best available picture of the Galactic and extragalactic diffuse infrared emission on degree or coarser angular scales.

The following ancillary products are also available:

Beam Profile Maps provide the effective two–dimensional shape of the *DIRBE* beam for each wavelength as the *DIRBE* instrument scanned the sky.

System Response Functions provide normalized system spectral response functions for each *DIRBE* wavelength band.

Color Correction Tables The *DIRBE* spectral intensity data, I_ν, are expressed in MJy/sr, assuming the source spectrum is $\nu I_\nu = constant$. Where this is not true, color corrections must be applied to obtain an accurate intensity. These files provide the needed color correction factors for a variety of source spectral shapes.