THE COSMIC BACKGROUND EXPLORER (*COBE*): MISSION AND SCIENCE OVERVIEW

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Ever since the discovery in 1964 of the Cosmic Microwave Background (CMB), scientists have tried to make accurate measurements of its spectrum and anisotropies. With the successful *COBE* mission, major advances in our understanding of the very early universe have been achieved.

COBE's complement of instruments are the Far Infrared Absolute Spectrophotometer (FIRAS), the Differential Microwave Radiometers (DMR), and the Diffuse Infrared Background Experiment (DIRBE). FIRAS and DIRBE are located inside a ^{4}He dewar to operate at 1.5 K. DMR receivers are located around the outside of the dewar. The instruments and mission plan have been described by Gulkis et al. (1990). Essential for the cosmological objectives are the all-sky observing strategy, periodic absolute calibrations of the instruments, high sensitivity, and extensive care to minimize potential systematic errors.

The FIRAS was designed to measure the spectrum of the CMB over the wavelength range 0.1 to 10 mm, with an accuracy of 0.1% of the peak brightness. FIRAS has a spectral resolution of 0.2 cm^{-1} (6 GHz) and an angular resolution of 7°. The DMR was designed to search for spatial anisotropies with a sensitivity of 0.15 mK at frequencies of 53 and 90 GHz, and 0.3 mK at 31 GHz, per 7° pixel on the sky. The frequencies were chosen to allow separation of galactic emission from the CMB. Each DMR channel has two radiometers for redundancy. See Smoot et al. (1990) for the DMR design. The DIRBE was designed to make a sensitive search for the cosmic infrared background, resulting from the cumulative emissions of luminous objects formed after the universe cooled sufficiently to permit the first galaxies and stars to form. DIRBE measures the spectrum and angular distribution of this diffuse background radiation to a sensitivity of 10^{-13} W cm^{-2} sr^{-1}, in 10 photometric bands from 1 to 300 μm, and linear polarization from 1 to 3 μm to help distinguish the zodiacal dust contribution to the diffuse IR background by measuring the sunlight scattered by interplanetary dust. DIRBE has a field of view of 0.7°.

COBE was launched on November 18, 1989 into a 99° inclination, 900 km altitude circular orbit. The oblateness of the Earth causes the orbit plane to precess so that the entire sky was surveyed in six months. The spin axis of the satellite always points away from the Earth and about 94° away from the Sun. The orbital period is about 103 minutes. *COBE* rotates at 0.8 rpm which helps reduce potential systematic errors in the DMR and provides DIRBE, canted 30° from the spin axis, a range of solar elongation angles from which to view scattering and emission from interplanetary dust.

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On September 21, 1990, the 600 liters of Helium were depleted. This ended the operation of the FIRAS which had surveyed the sky 1.6 times. The DMR continues to operate normally in all six channels. The DIRBE continues to operate in the four near infrared bands, even though by July 1992 the inside of the dewar had warmed up to 45 K. Continued data taking is important to further understand systematic errors and to gather data on the interplanetary cloud, which must be modeled and removed to search for a cosmic infrared background.

The FIRAS results have confirmed the Big Bang model's prediction that the CMB would have a thermal spectrum. At the present level of data processing, no deviation is seen from a blackbody spectrum to 0.25% of the peak intensity. The temperature of the CMB was found to be 2.735±.06 K (Mather et al. 1990, 1991). FIRAS results also include the first all-sky far infrared spectral line survey and mapping of the spectra of the galactic dust distribution at wavelengths >100 μm. Nine lines from interstellar [C I], [C II], [N II], and CO are all clearly detected, and [C II] at 158 μm and [N II] at 205.3 μm were sufficiently strong to be mapped (Wright et al. 1991).

The DMR has obtained the most precise all-sky maps to date of the microwave background, and no cosmic anisotropies have been found. At the present level of data processing, the 95% CL upper limit to the rms quadrupole amplitude is $\Delta T/T < 3x10^{-5}$, and anisotropies on all angular scales larger than 7° are smaller than $4x10^{-5}$. See Smoot et al. (1991a, 1991b). The noise level in the DMR data continues to integrate down as this instrument gathers data, showing that the sensitivity limits from this instrument have not yet been reached.

DIRBE data provide the most extensive infrared absolute sky brightness measurements and maps to date, providing new views of the Milky Way and permitting the first serious search for cumulative light from the first objects in the universe. A preliminary spectrum determined from data in one of the darkest areas of the sky show that the faintest levels of foreground emissions are at 3.4 μm, and at 240 μm. See Hauser et al. (1991). Careful modeling of the zodiacal and galactic emissions are underway, and with these results much improved limits on or detection of an infrared brightness of cosmic origin.

The development and operation of *COBE* and the processing of its data have been carried out by the NASA Goddard Space Flight Center under the guidance of the COBE Science Working Group.

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