THE COBE-DMR DATABASE AND HOW TO USE IT *

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Abstract. The anisotropy experiment on board the Cosmic Background Explorer has produced six sky maps of the cosmic microwave temperature at three frequencies: 31.5, 53 and 90 GHz. These data have been the bases for the discovery of the expected anisotropies $\Delta T/T = 1.6 \times 10^{-5}$ left as a signature of primordial density fluctuations at an early hot epoch of the universe. The National Space Science Data Center (NSSDC) has made two releases of COBE-DMR data. A description of these data products and their structure is presented.

1 Introduction

The Differential Microwave Radiometers (DMR) is one of the three experiments on board NASA's Cosmic Background Explorer (COBE) satellite. For a review of the COBE mission see Torres (1994).

The DMR instruments consist of three pairs of differential radiometers at 31.5, 53 and 90 GHz with two independent channels (A and B) at each frequency. The primary signal that comes out of a differential radiometer is a voltage proportional to the temperature difference of two points in the sky at a fixed angular separation of 60°. As the spacecraft rotates along its spin axis at 0.8 rpm and orbits the earth 14 times per day in combination with a 1° precession per day of the orbit's plane, the 7° FWHM horn antennas reach full sky coverage once every 6 months.

2 DMR Data Sets

Difference temperature data is integrated, amplified and digitized at a rate of two data points per second, thus at the end of one year of observation each DMR channel has made $\approx 6.28 \times 10^7$ measurements of temperature differences (ΔT_{ij}) along the directions allowed by its geometry and orbit parameters. These data combined with spacecraft attitude and other housekeeping information defines the TOD record (Time Ordered Data) and constitutes the main raw data archive.

A software pipeline takes the TOD as input and processes these data in order to produce the final scientific database product which is one temperature map of the sky for each channel (Torres *et al.*, 1989). At this stage data is calibrated and corrected for known systematic effets such as the kinematical Doppler ΔT due to the satellite motion arround the Earth and arround the solar system barycenter, magnetic susceptibility, and emission from the Moon and Jupiter.

An intermediate data set is the calibrated and pixelized temperature difference data (Pixel Pair Data) which consists of pixel ordered temperature differences,

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number of observations per pixel, and the sums of the first to fourth powers of the differential temperatures. A Sky Map (i.e. $T_i, i : 0 \rightarrow 6143$) is made from the Pixel Pair Data by minimizing the χ^2 statistic (Jansen and Gulkis, 1992): $\chi^2 = \sum(T_i - T_j - \Delta T_{ij})^2/\sigma_{ij}^2$. A Sky Map is a set of 6144 pixels. Each pixel has an antenna temperature T_i, number of observations, measurement error, Ecliptic longitude, Ecliptic Latitude, Galactic longitude, Galactic latitude, Right Ascension, and Declination (all in degrees).

The Sky Map data sets are written as FITS tables. The Flexible Image Transport System (FITS) format (Wells, 1981) is a standard within the astronomical community. Files in this format have a header followed by data. FITS software is also available from via anonymous FTP from NSSDCA. The documentation provided in the DMR_DATA_PRODUCTS.DOC document (see Table I.) includes a FORTRAN program to read DMR sky maps in FITS tables. Additional documentation on the pixelization scheme can also be found in a FITS file located in the anonymous FTP directory: COBE/GENERAL_INFORMATION/SKYMAP_INFO. Notice that the original Sky Maps are in ecliptic coordinates. The first year Sky Maps included the kinematic dipole, while for the second year Sky Maps the dipole has been subtracted.

In addition to the Project Data Sets, NSSDC has released the Analyzed Science Data Sets (ASDS) which cover the first two years of instrument operation from 1989 December 22 to 1991 December 21. The ASDS consist of Galactic emission and cosmic emission maps. These maps are calibrated, and corrected for satellite velocity, Earth velocity, Sun velocity, magnetic susceptibility, Moon in the sidelobes, instrument memory, and Jupiter, Mars, and Saturn emission. Instrument memory in the time-ordered data refers to the fact that each half-second sample has a 3.2% signal that leaks from the previous sample. This effect is due to the lock-in amplifiers that amplify and integrate the DMR signal. The Galactic Emission maps delivered in this release of the DMR Analyzed Science Data Sets, are the 53 GHz synchrotron model, dust model and free-free maps. Also delivered are two cosmic emission maps resulting from two galaxy subtracting methods (Bennett *et al.*,1992).

3 Data Base and Pixelization Scheme

Data on the surface of a sphere can be easily accessed and manipulated if it is projected onto an inscribed cube with faces numbered 0 through 5. The faces of the resulting Quadrilateralized Spherical Cube or *Skycube* (Torres *et al.*, 1989) are divided into pixels of equal area when projected onto the sphere. The number of pixels depends on the resolution level. The pixels are addressed by their Cartesian coordinates on the cube face. This method has been successfully used in the analysis of astrophysical data (Chan and O'Neill, 1975; Hon, 1991) where one usually has data on a sphere (galaxy counts, radio temperature, etc).

The number of pixels on the cube is equal to the quantity determined by the formula $6 \times 2^{2(n-1)}$ where n is the level of resolution (6144 pixels for $n = 6$ and 393,216 for $n = 9$). In the case of DMR, the angular resolution of 3.2° can be adequately accommodated with $1024 = 32 \times 32$ pixels per face: 6144 pixels for the full sky ($n = 6$) which corresponds to pixels of angular size $\theta \approx 2.6°$. For the ($n = 6$) level, the (x,y) coordinates of a pixel on a face can be stored on a scalar index (pixel number) by using the even/odd bits of this scalar to store the x/y coordinate. This coordinate information, along with the face number, can be packed in a two-byte integer as follows: PIX_N = $sssfffyxyxyxyxyx$, where the three most significant bits (sss) are spare, the next three (fff) store the face number (0...5) and the other bits correspond to the five bits for each coordinate x and y. A Cartesian coordinate system with origin in the bottom-right corner of each face indicates the directions of increasing pixel number along both axes. By knowing the (x, y) coordinates of a pixel on a face, it is easy to find its coordinates with respect to a three-dimensional coordinate system. All that remains to be done is to choose two points that define the orientation of the 3D coordinate system relative to the faces of the cube. The reference frame for the cube is defined by axes normal to faces 1 and 0. In Geocentric Ecliptic coordinates, these directions correspond to the vernal equinox and the North Ecliptic Pole.

4 Data Releases and Availability

As of the date of this paper, there has been two releases of the DMR data by the NSSDC-Goddard. The first release in July 1993 included the six DMR sky maps and the corresponding Pixel Pair Data for the data accumulated during the first year of observation (1989 day 356 to 1990 day 355). The second data release of June 1994 includes the two year data sets: six DMR Sky Maps, the corresponding Pixel Pair Data and Time Ordered Data, two galaxy reduced cosmic emission sky maps, and galactic emission model maps.

The Sky Map data sets are available via anonymous FTP from the NSSDCA node. Follow the steps below in order to get a copy of these maps:

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establish an FTP connection to NSSDCA.NASA.GOV (or128.183.36.23)
FTP> userid: give 'anonymous' as user id
FTP> password: give your full internet address
FTP> cd cobe/project_data_sets/dmr/dat
FTP> mget *
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These steps should download in the host computer the six Sky Maps corresponding to the two year release. Table I shows the directory structure in the NSSDCA FTP node with the location of data and important documents related to the DMR project.

TABLE I

Location of data and documentation related to the DMR project in the NSSDCA node

Directory	Contents
COBE/GENERAL_INFORMATION	acronyms
	complementary data
	data release schedule
	mission overview
	physical constants
	spacecraft description
	updates
COBE/GENERAL_INFORMATION/SKYMAP_INFO	Skycube information
COBE/GENERAL_INFORMATION/ANALYSIS_SOFTWARE	available software
COBE/GENERAL_INFORMATION/PUBLICATIONS	online copies of COBE papers
COBE/IMAGES/DMR	GIF and JPG image files
COBE/INITIAL_PRODUCTS/DMR/DOC	documentation
	DMR synopsis
	data products
	explanatory supplement
COBE/INITIAL_PRODUCTS/DMR/DAT	first year Sky Maps
COBE/PROJECT_DATA_SETS/DMR/DAT	two year Sky Maps
COBE/ASDS	Cosmic emission maps
	Galactic model maps

References

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