COBE-DMR Project Data Sets (PDS), Analyzed Science Data Sets (ASDS), and Galactic Coordinate Data Sets Explanatory Supplements

Preface

This document is a concise description of the delivered Data sets for the first two years of operation of the Differential Microwave Radiometers (DMR) experiment on board the *COBE* spacecraft. It is intended as an overview of the delivered data sets and as a description of the specific quantities contained in the DMR time-ordered data. Detailed descriptions of the instrument and data reduction methods have been described in publications that are referenced in Section 4 of this document.

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1.1 The Differential Microwave Radiometers Experiment

The purpose of the Cosmic Background Explorer (COBE) Differential Microwave Radiometers (DMR) experiment is to measure large angular scale anisotropies of the cosmic microwave background (CMB) radiation. This release of the DMR Project Data Sets covers the first two years of instrument operation, specifically the time range from 1989 December 22 to 1991 December 21. The DMR Project Data Sets are (i) maps of the full sky at three microwave frequencies, (ii) the corresponding differential data coadded by sky position, and (iii) the time-ordered raw differential temperatures. Data sets (i) and (ii) are in the Flexible Image Transport System (FITS) format, and (iii) are in the DMR native data format.

Smoot et al. (1990) and Bennett et al. (1992a) provide detailed descriptions of the DMR instrument. The instrument consists of six differential microwave radiometers, two nearly independent channels (labelled A and B) at each of three frequencies: 31.5, 53, and 90 GHz (wavelengths 9.5, 5.7, and 3.3 mm). Each radiometer measures the difference in power, expressed as a differential antenna temperature, between two regions of the sky separated by 60°. The combined motions of spacecraft spin (73 s period), orbit (103 m period) and orbital precession ($\sim 1°$/day) allow each sky position to be compared to all others through a highly redundant set of all possible difference measurements spaced 60° apart.

The DMR has three separate receiver boxes, one for each frequency, that are mounted 120° apart on the outside of the *COBE* cryostat containing the Far Infrared Absolute Spectrophotometer (FIRAS) and the Diffuse Infrared Background Experiment (DIRBE). There are ten horn antennas, all of which have an approximately Gaussian main beam with a 7° FWHM. The pair of horns for each channel are pointed 60° apart, 30° to each side of the spacecraft spin axis and are designated as Horn 1 and Horn 2. The differential temperature is always in the sense Horn 1 minus Horn 2. For each channel, the switching between Horns 1 and 2 is at a rate of 100 Hz, and the switched signals undergo amplification, detection, and synchronous demodulation with a 0.5 s integration period. Table 1 describes the noise level per measurement (0.5 sec being the duration of a measurement) for each DMR channel in units of antenna temperature.

Table 1: Noise Level (per 0.5 sec measurement) for Each DMR Channel

DMR Channel	31A	31B	53A	53B	90A	90B
Flight RMS (mK)	58.6	60.4	23.2	27.1	39.7	30.2

The 53 and 90 GHz channels use two separate linearly polarized horn pairs, while the 31 GHz channels receive opposite circular polarizations in a single pair of horns. The polarization of the 53 and 90 GHz receivers is such that the E-plane of each horn is perpendicular to the plane of the two horns of a given channel. A shield surrounding the aperture plane protects all three instruments from solar and terrestrial emission. As the spacecraft spins, a point 30° from the spin axis is swept successively, at about 12.5 second intervals, by 31 GHz Horn 1, by 90 GHz A and B Horns 2, by 53 GHz A and B Horns 1, by 31 GHz Horn

2, by 90 GHz A and B Horns 1, and 53 GHz A and B Horns 2 respectively. See Figure 8 of Bennett at al. (1992a) for a schematic illustration of the *COBE* aperture plane.

1.2 The Software System

The purpose of the DMR software system is to take the raw telemetry data from the instrument and produce calibrated maps of the sky that have systematic effects (instrumental and environmental) reduced below well specified levels. The techniques used and resulting systematic error limits for the initial product dataset release of July 1993, covering the first year of DMR data, are described by Kogut et al. (1992). A description of the more detailed analysis and lower systematic error limits that apply to the two years of data covered by this release is described by Bennett et al. (1994). The software system and data processing algorithms are also described by Janssen & Gulkis (1991) and Jackson et al. (1992).

1.2.1 Data Reduction

The DMR telemetry consists of uncalibrated differential temperatures, taken every 0.5 second for each of the six channels, plus housekeeping data (voltages, temperatures, relay states, etc). These are merged with spacecraft attitude data into a time-ordered dataset. Various algorithms are used to check data quality and flag bad data in this dataset (Keegstra et al. 1992). For these DMR datasets, the data from a channel are flagged as bad when either horn was within 21° of the Moon, or when the limb of the Earth was higher than 1° below the plane of the shield (3° at 31 GHz).

The instrumental offset was removed by fitting a smooth baseline to the uncalibrated time-ordered data. As a cross-check, baselines were routinely fitted three different ways: a running mean, a slowly varying cubic spline, and a more rapidly varying cubic spline fitted to the data after correction for magnetic susceptibility. The averaging period for the running mean is two orbit periods (the orbit period is 103 minutes); the slowly varying cubic spline has a knot every 52 minutes; and the fast spline has a knot every 9 minutes. The aim is to use the longest baseline consistent with instrument stability in order to reduce the influence of possible systematic errors. The fast baseline retains information only over the 73-second spin period; the slower spline retains information over the roughly 15-minute time period where the orbital motion is less than the 60° separation between the horns; and the mean baseline retains information over the *COBE* orbital period. The sky maps for this data release use the mean baseline.

Calibration of the data to antenna temperature is achieved by turning on noise sources of known antenna temperature for two minutes every two hours. Long-term stability of the noise sources is checked by observations of the Moon and by the amplitude of the modulation of the CMB signal over the course of a year caused by the Earth's 30 km/sec orbital motion. See Bennett et al. (1992a, 1994) for a detailed description of DMR calibration techniques.

In the preparation of the DMR Pixelized Differential Data and Sky Maps Project Data Sets, the calibrated time-ordered data were corrected for known instrumental and systematic effects: the Doppler effect from the *COBE* velocity about the Earth ("satellite velocity") and the Earth's velocity about the solar system barycenter ("Earth velocity"); the susceptibility of the instrument to the Earth's magnetic field; emission from the Moon in the antenna sidelobes; the slight 3.2% 'memory' of the previous observation (arising in the lock-in amplifier); and emission from the planets Jupiter, Mars, and Saturn. In order to reduce the errors inherent in pixelizing over the non-uniformly sampled sky, the calibrated time-ordered data were also corrected for a nominal CMB dipole ("Sun velocity") assuming a dipole of 3.35623 mK (in thermodynamic temperature) directed towards 2000 R.A. = 11^h 11^m $41^s.5$, Dec =-7° 30′ 32″.5 .

1.2.2 Pixelization

The time-ordered data are pixelized according to the quadrilateralized spherical cube projection (White & Stemwedel 1992), which projects the entire sky onto six cube faces. Each face is pixelized into $2^{2(N-1)}$ approximately equal-area pixels. For these DMR Project Data Sets, we use $N = 6$, which divides the sky into 6144 pixels; each pixel subtends 6.7 square degrees. (For the actual solutions of the maps, we used a smaller pixel size of 1.7 square degrees, corresponding to $N = 7$, for all data within 20° of the Galactic plane in order to minimize the effects of gradients in the Galactic disk emission. These pixels were then block-averaged to form the $N = 6$ maps).

1.3 DMR Project Data Sets

1.3.1 Pixelized Differential Data

The baseline-subtracted, calibrated and corrected time-ordered data were sorted according to the pixel number seen by Horn 1, and then by the pixel number seen by Horn 2. All such data for a given pixel pair were then combined into four statistics: the sums of the first to fourth powers of the differential temperatures. These sums, the Horn 1 and 2 pixel numbers, and the number of occurrences of each pixel permutation comprise the DMR Pixelized Differential Data. Note that linear polarization information for 53 and 90 GHz is retained since the E-plane is perpendicular to the great circle joining the two pixels. For each channel, there are over a million pixel permutations of the 6144 pixels. Tables 2 and 3 describe, respectively, the parameters of the Data Set and the information given for each pixel permutation.

A simple program, PIXPRM, listed in Appendix A, can be used to read the FITS binary table from the DMR Pixelized Project Data set. This FORTRAN example uses the FITSIO library and should run, as written, on all platforms on which the library is supported. FITSIO was written by William Pence of NASA GSFC HEASARC, and is available by anonymous FTP from tetra.gsfc.nasa.gov. For illustrative purposes, the example calculates some simple statistics from the data sets; users may wish to substitute their own code to perform the calculations in which they are interested.

1.3.2 DMR Sky Maps

A sky temperature is derived for each pixel by simultaneously fitting (i.e. minimizing the chi-squared) a linear system of equations to the DMR observations and the coefficients of systematic error models (see Janssen & Gulkis 1992). Since the instrument only measures temperature differences between different sky directions, these maps of the sky only represent differences of the sky temperature. Tables 2 and 4 describe, respectively, the parameters of the Data Set and the information given for each pixel.

Table 2: DMR Pixelized Differential Data and Sky Maps Project Data Sets

Time range 53,90 GHz	0 UT Dec 22, 1989 to 0 UT Dec 22, 1991
31 GHz Channel A	0 UT Dec 22, 1989 to 0 UT May 21, 1990 plus
	0 UT July 25, 1990 to 0 UT May 21, 1991 plus
	0 UT July 25, 1991 to 0 UT Dec 22, 1991
31 GHz Channel B	0 UT Dec 22, 1989 to 0 UT May 21, 1990 plus
	0 UT July 25, 1990 to 0 UT May 21, 1991 plus
	0 UT July 25, 1991 to 0 UT Sept 23, 1991
Temperature Unit	milliKelvin antenna temperature
Ecliptic Latitude	-90° to + 90°
Ecliptic Longitude	0° to 360°
Frequencies	31.5, 53, and 90 GHz
Channels	two independent channels, A and B at each freq
Wavelengths	9.5, 5.7, and 3.3 mm
Pixelization	2.59°, ecliptic coordinates
Beamwidth	7° FWHM Gaussian, circular
Corrections	Satellite velocity, Earth velocity, Sun velocity,
	Magnetic susceptibility, Moon in sidelobes,
	Instrument Memory, Jupiter, Mars, Saturn

Table 3: Data Fields in DMR Pixelized Differential Data Project Data Set

Data field	Description
PIX_PLUS	Pixel number (0 to 6143) for horn 1
PIX_MINU	Pixel number (0 to 6143) for horn 2
N_OBS	Number of observations for differential temperatures ΔT
SUM	$\Sigma\ \Delta T$ (mK)
SUM_2	$\Sigma\ \Delta T^2$ (mK^2)
SUM_3	$\Sigma\ \Delta T^3$ (mK^3)
SUM_4	$\Sigma\ \Delta T^4$ (mK^4)

Table 4: Data Fields in DMR Sky Maps Project Data Set

Data field	Description
PIXEL	Pixel number (0 to 6143)
SIGNAL	Sky antenna temperature (mK)
N_OBS	Number of observations
SERROR	Estimate of uncertainty as RMS/SQRT(N_OBS) (mK)
ECLON	Ecliptic longitude of pixel center (degrees)
ECLAT	Ecliptic latitude of pixel center (degrees)
GALON	Galactic longitude of pixel center (degrees)
GALAT	Galactic latitude of pixel center (degrees)
RA	Right ascension of pixel center (degrees)
DEC	Declination of pixel center (degrees)

Table 5: DMR Sky Map Coverage and Sensitivity Limits

DMR Channel	31A	31B	53A	53B	90A	90B
Max obs/pixel	72499	63157	81890	82550	81247	81130
Noise level(mK)	0.218	0.241	0.081	0.094	0.139	0.106
Mean obs/pixel	29727	24484	35672	35681	35655	35643
Noise level(mK)	0.340	0.386	0.123	0.143	0.210	0.160
Min obs/pixel	11622	8108	21535	21489	21499	21560
Noise level(mK)	0.544	0.671	0.158	0.185	0.271	0.205

Table 6: DMR Time-Ordered Data Project Data Set

Time range	16 UT Nov 19, 1989 to 0 UT Jan 1, 1992
Temperature Unit	"Telemetry" units, integers from 0 to 4095
Ecliptic Latitude	-90° to + 90°
Ecliptic Longitude	0° to 360°
Frequencies	31.5, 53, and 90 GHz
Channels	two independent channels, A and B at each freq
Wavelengths	9.5, 5.7, and 3.3 mm
Beamwidth	7° FWHM Gaussian, circular
Data Rate	Every 0.5 sec for each of 6 DMR channels
Corrections available	Satellite velocity, Earth velocity, Sun velocity, Magnetic susceptibility, Moon in sidelobes, Instrument Memory, Jupiter, Mars, Saturn

The noise level of the DMR Sky Maps Project Data Set varies by more than a factor of two over the sky owing to differences in sky coverage during the mission. The greatest redundancy is on rings of 60° diameter centered at the North and South ecliptic poles since those regions are sampled on every orbit. The least redundancy is near the ecliptic plane owing to the presence of the Moon (we do not use data when either DMR horn is within 21° of the Moon). For channels 31A and 31B, the more stringent limits on the position of the limb of the Earth relative to the shield, and the rejection of data during the two months when there is an 'eclipse' of *COBE* by the Earth (see below) also reduce coverage considerably for certain pixels.

Table 5 gives the maximum, mean, and minimum coverages and the corresponding pixel-to-pixel rms noise levels. Note that since the DMR beam covers several pixels, the rms uncertainty in the determination of the strength of a point source is about 0.6 that of the pixel-to-pixel rms noise. Of course, the DMR was designed to be insensitive to point sources: a 1,000 Jy point source would yield peak antenna temperatures of 1.55 mK, 0.54 mK, and 0.19 mK at 31.5, 53, and 90 GHz respectively.

The DMR Sky Maps Project Data Set are in units of mK antenna temperature which have been calibrated to correct for any losses in the instrument and antenna system. To scale these to maps of the differential thermodynamic temperature of the cosmic microwave background, multiply by the frequency-dependent scaling factors given in Table 1 of Bennett et al (1992a), which are based on an assumed background thermodynamic temperature of 2.735K.

A simple program, SKYMAP, listed in Appendix B, can be used to read the FITS binary table from the DMR Sky Maps Project Data Set. This FORTRAN program also uses the FITSIO library described above.

1.3.3 DMR Time-Ordered Data

The DMR telemetry, merged with spacecraft attitude data, comprise the DMR Time-Ordered Data (TOD) Project Data Set. Included in the TOD are various warning flags and indicators of data quality. Table 6 gives the basic parameters of the data set, Appendix C describes its structure, and Appendix D provides more details.

Before the DMR Sky Map and Pixelized data sets were made, the Time-Ordered Data were corrected for the following systematic effects:

- emission from the Moon when it lies between 21 and 90 degrees from the axis of either of the two DMR horns
- emission from Jupiter, Mars, and Saturn when they lie within 15 degrees of the axis of either of the two DMR horns
- susceptibility of the instrument to the ambient magnetic field
- instrument "memory"
- the Doppler velocities of *COBE* around the Earth and the Earth around the Sun, and
- a dipole of 3.356 mK thermodynamic temperature considered to be produced by the Doppler velocity of the Sun with respect to the cosmic microwave background.

Correction algorithms coded in VAX Fortran, and the reference datasets that they use, are available to Guest Investigators. An IDL routine, which converts the Time-Ordered Data from its native format to an IDL save set but does not apply the corrections, is also available.

1.4 Warnings and Limitations

Bennett et al. (1992a) present the DMR calibration and its uncertainties and Kogut et al. (1992) give a summary of upper limits on residual systematic errors affecting the DMR Initial Product (first year of data) released in July 1993. A summary of the calibration and systematic errors affecting the two-year Project Data Sets is described by Bennett et al. (1994). Our maps of systematic errors are available on request to the NSSDC. Scientific conclusions based on the DMR Project Data Sets should take proper account of the systematic error limits and the calibration uncertainties.

Near the time of the summer solstice, the *COBE* spacecraft enters the Earth's shadow during a portion of each orbit and is thus 'eclipsed'. This causes changes in the spacecraft temperature and electrical systems. Systematic errors during the eclipse season significantly affect the DMR 31 GHz channels. Hence, these DMR Project Data Sets do not include 31 GHz data for the period 0 UT on 1990 May 21 through 0 UT on 1990 July 25; and from 0 UT on 1991 May 21 through 0 UT on 1991 July 25.

On 1991 October 4, the 31B channel suffered an increase in receiver noise by more than a factor of 2. Data following this event are not included in the Sky Maps and Pixelized Differential Data Project Data Sets; however, these data are included in the Time-Ordered Data Project Data Set.

Scientific results based on the first year of DMR data have been published by Smoot et al. (1992, 1994), Bennett et al. (1992b, 1993), Wright et al. (1992, 1994a), Kogut et al. (1993), and Hinshaw et al. (1994). Smoot et al. (1992) review the overall results. Bennett et al. (1992b) analyze the Galactic emission and derive a value for the cosmic quadrupole.

Wright et al. (1992) intepret the DMR anisotropy in terms of cold dark matter cosmological models. Bennett et al. (1993) search for evidence of noncosmological source contributions. Kogut et al. (1993) analyze the dipole anisotropy and derive the Solar velocity, relative to the cosmic background radiation, implied by the observed dipole. Wright et al. (1994a) comment on the power spectrum normalization implied by the excess variance in the first-year maps. Hinshaw et al. (1994) analyze the 3-point correlation function to search for evidence of non-Gaussian fluctuations. Smoot et al. (1994) search for evidence of non-Gaussian fluctuations by analyzing the third and fourth moments and the genus of the first year maps. Scientific results based on the first two years of data have been published by Bennett et al. (1994), Wright et al. (1994b), and Kogut et al. (1994). Bennett et al. (1994) review the overall results of the first two years of data. Wright et al. (1994b) analyze the angular power spectrum. Kogut et al. (1994) search for unresolved point sources in the two-year maps.

2 DMR Analyzed Science Data Sets (ASDS) Explanatory Supplement

2.1 Introduction

The purpose of the *COBE* Differential Microwave Radiometers (DMR) experiment is to measure the large angular scale anisotropies of the cosmic microwave background (CMB) radiation. Smoot et al. (1990) and Bennett et al. (1992a) provide detailed descriptions of the DMR instrument. This release of the DMR Analyzed Science Data Sets covers the first two years of instrument operation, specifically the time range from 1989 December 22 to 1991 December 21. The data sets are in the Flexible Image Transport System (FITS) format. The detailed analysis and systematic error limits that apply to the two years of data covered by this release are described in Bennett et al. (1994).

2.2 DMR Analyzed Science Data Sets

The DMR Analyzed Science Data Sets consist of Galactic emission and cosmic emission maps. Bennett et al. (1992b) discuss the separation of the Galactic foreground emission from the cosmic emission. Four components are important at microwave wavelengths: CMB anisotropies, synchrotron emission, free-free emission, and thermal emission from dust. The latter three compose the Galactic foreground.

Tables 7 and 8 describe, respectively, the parameters of the Data Sets and the information given for each pixel.

Table 7: DMR Analyzed Science Data Sets

Time range	0 UT Dec 22, 1989 to 0 UT Dec 22, 1991
Temperature Unit	milliKelvin thermodynamic temperature for CMB maps milliKelvin antenna temperature for Galactic maps
Ecliptic Latitude	-90° to + 90°
Ecliptic Longitude	0° to 360°
Pixelization	2.59°, ecliptic coordinates
Beamwidth	7° FWHM Gaussian, circular
Corrections	Satellite velocity, Earth velocity, Sun velocity, Magnetic susceptibility, Moon in sidelobes, Instrument Memory, Jupiter, Mars, Saturn

2.2.1 Galactic Emission Maps

The 53 GHz synchrotron model, dust model and free-free maps are delivered in this release of the DMR Analyzed Science Data Sets (ASDS). The details about deriving these Galactic emission maps are described in Bennett et al. (1992b).

Synchrotron emission arises from relativistic electrons accelerated in the Galactic magnetic field. We use the observed local electron spectrum in conjunction with 408 MHz and 1420 MHz radio data to model the synchrotron radiation at the DMR frequencies.

Table 8: Data Fields in DMR Analyzed Science Data Sets

Data field	Description
PIXEL	Pixel number (0 to 6143)
SIGNAL	Sky temperature (mK)
N_OBS	Number of observations
SERROR	Statistical uncertainty (mK, 68% confidence level)
ECLON	Ecliptic longitude of pixel center (degrees)
ECLAT	Ecliptic latitude of pixel center (degrees)
GALON	Galactic longitude of pixel center (degrees)
GALAT	Galactic latitude of pixel center (degrees)
RA	Right ascension of pixel center (degrees)
DEC	Declination of pixel center (degrees)

Thermal emission from dust is also important at microwave wavelengths. We utilize the full sky measurements of the dust intensity and spectrum at higher frequencies from the *COBE*-FIRAS experiment and extrapolate these to the DMR frequencies.

Free-free emission occurs when free electrons are accelerated by interactions with ions. The free-free emission map is obtained by the simultaneous fitting of the DMR 31 and 53 GHz maps for the free-free and cosmic emission after subtracting the model synchrotron and dust maps. This is the first all-sky map of the Galactic free-free emissions.

2.2.2 DMR Cosmic Emission Sky Maps

Two techniques are used for separating the cosmic emission from the foreground Galactic emission. The details are described in Bennett et al. (1992b, 1994). The resulting cosmic emission maps from both techniques are delivered in this release of the DMR Analyzed Science Data Sets (ASDS). The combination factors for the three DMR channels are slightly different in the FITS headers than in Bennett et al (1992b, 1994) owing to the use of ecliptic coordinate maps for these ASDS Data Sets.

1. Subtraction technique. We first subtract the Galactic emission maps from the DMR maps, where Galactic emission is based on maps of synchrotron and dust emission derived from measurements at frequencies where these type of emissions are strong. The free-free galactic emission is then separated and subtracted from the remaining cosmic signal by making a linear combination, based on the assumed free-free spectral index, of the 31 GHz map with the 53 GHz map.

2. Combination technique. We form a linear combination of the DMR maps to 1) cancel the Galactic emission for $|l| > 30$ degrees and $|b| < 6$ degrees, 2) cancel the free-free emission based on the assumed free-free spectral index, and 3) normalize the cosmic emission map in thermodynamic temperature.

3 DMR Galactic Coordinate Data Sets Explanatory Supplement

3.1 Galactic versus Ecliptic Pixelization

The delivered Project Data Sets (PDS) and Analyzed Science Data Sets (ASDS) from all three instruments on the Cosmic Background Explorer (COBE) have been pixelized in ecliptic (J2000) coordinates. However, for the Differential Microwave Radiometers (DMR) experiment, the Milky Way Galaxy is the chief source of foreground emission. The accurate characterization of this galactic emission is the main challenge for the determination of the quadrupole and other largest-scale aspects of the cosmic microwave background (cmb) from the DMR data. When we select a portion of the skymap for analysis, based on a cut at a certain value of galactic latitude, the boundary of the selected portion of the sky will be smooth when we use galactic pixelization and jagged when we use ecliptic pixelization. For these reasons, the DMR team has consistently performed their primary analyses of the cmb structure based on maps and other datasets which are pixelized in galactic coordinates.

As other researchers have performed analyses on the PDS and ASDS, it has become apparent that some small differences between their analyses and those of the DMR team may arise from the different pixelizations (ecliptic vs galactic). In order for the scientific community to be able to more accurately estimate what the effects of a particular pixelization may be on their analyses, we have prepared DMR skymaps which are completely equivalent to the PDS and ASDS skymaps, except that they are pixelized in galactic coordinates.

3.2 DMR Two-year Galactic Coordinate Skymaps

These galactic coordinate skymaps are based on exactly the same time-ordered data (December 1989 to December 1991) as the PDS skymaps. All details of the observations and, except as otherwise described in this report, all details of the data reduction and analysis are the same as described in the 'DMR Project Data Sets (PDS) Explanatory Supplement'. Full details of the determination of the cmb structure based on the galactic skymaps are given in Bennett et al. (1994).

Owing to the different pixelization, there are slight modifications to Table 5 (DMR Sky Map Coverage and Sensitivity Limits) of the PDS Explanatory Supplement. A revised version of Table 5 which applies to these galactic skymaps is given in Table 9:

Table 9: DMR Galactic Sky Map Coverage and Sensitivity Limits

DMR Channel	31A	31B	53A	53B	90A	90B
Max obs/pixel	71145	62839	81271	81400	81490	81669
Noise level(mK)	0.220	0.241	0.081	0.095	0.139	0.106
Mean obs/pixel	29728	24484	35672	35681	35655	35643
Noise level(mK)	0.340	0.386	0.123	0.143	0.210	0.160
Min obs/pixel	11506	7988	21526	21471	21579	21557
Noise level(mK)	0.547	0.676	0.158	0.185	0.270	0.205

3.3 DMR Two-year Galactic Coordinate Analyzed Science Data Sets

These are analogous to the DMR Analyzed Science Data Sets (ASDS) which were released in ecliptic coordinates; and consist of three galactic emission maps (for 53 GHz synchrotron emission, free-free-emission, and thermal emission from dust) and (two) maps of the cosmic microwave background emission resulting from removal of the galactic foreground using two techniques - the subtraction technique and the combination technique. See the DMR Analyzed Science Data Sets (ASDS) Explanatory Supplement for more details.

Owing to the use of galactic versus ecliptic pixelization, there are small differences between the weights used to combine the 31, 53, and 90 GHz skymaps when forming the cosmic emission maps using the combination technique; and the weights for the corresponding map in the ASDS. See the FITS headers and Bennett et al 1994 for more details.

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A FORTRAN Source Code to Read the DMR Pixelized Differential Data

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      program pixprm

C     A simple program to read the FITS binary table from the DMR
C     Pixelized Project Data Set.

      integer maxdim
      parameter (maxdim = 20)
      character*30 errtxt, extnam,
     &             ttype(maxdim),
     &             tform(maxdim),
     &             tunit(maxdim)
      logical simple,extend,anyflg
      integer iunit,status,bitpix,naxis,naxes(maxdim),pcount,gcount
      integer group,fpixel,nelem,nrows
      integer i,j,nobs,nperm,npoint
      integer tfield,rwstat,bksize,vardat
      integer colnum,frow,felem
      integer hdutyp,inull
      real    sum,sum2,enull
      doubleprecision sumsum,sum_sq

      status=0
      iunit=15
C     open the existing FITS file with readonly access
      rwstat=0
      call ftopen(iunit,'dmr_pixperm_31a.fits',rwstat,bksize,status)
      if (status .ne. 0) goto 99

C     read the required primary array keywords
      call ftghpr(iunit,maxdim,simple,bitpix,naxis,naxes,
     &            pcount,gcount,extend,status)
      if (status .ne. 0) goto 99

C     now move to the binary table extension
      call ftmahd(iunit,2,hdutyp,status)
      if (status .ne. 0) goto 99

C     get the binary table parameters
      call ftghbn(iunit,maxdim,nrows,tfield,ttype,tform,tunit,
     &            extnam,vardat,status)
      if (status .ne. 0) goto 99

C     test that this is a DMR pixperm dataset, and its fields
```

```
C       are as expected.
        if (extnam .ne. 'DMR_PIXPERM' .or.
     &      ttype(4) .ne. 'SUM'   .or.
     &      ttype(5) .ne. 'SUM_2' .or.
     &      ttype(3) .ne. 'N_OBS') then
          print *, 'extnam   = ', extnam
          print *, 'ttype(4) = ', ttype(4)
          print *, 'ttype(5) = ', ttype(5)
          print *, 'ttype(3) = ', ttype(3)
          stop 'Not a DMR pixperm dataset.'
        endif

C       initialize statistical accumulators
        nperm  =  0
        npoint =  0
        sumsum =  0.0d0
        sum_sq =  0.0d0
C       read each pix-perm and process
        do 10 frow = 1, nrows
          felem=1
          nelem=1
          inull=0
          colnum=4
          call ftgcve(iunit,colnum,frow,felem,nelem,enull,sum,
     &                anyflg,status)
          if (status .ne. 0) goto 99
          colnum=5
          call ftgcve(iunit,colnum,frow,felem,nelem,enull,sum2,
     &                anyflg,status)
          if (status .ne. 0) goto 99
          colnum=3
          call ftgcvj(iunit,colnum,frow,felem,nelem,inull,nobs,
     &                anyflg,status)
          if (status .ne. 0) goto 99

          if (nobs .gt. 0) then
            nperm  = nperm  + 1
            npoint = npoint + nobs
            sumsum = sumsum + sum
            sum_sq = sum_sq + sum2
          endif
10      continue

C       print out statistics
        print 1000, nperm, npoint, sumsum/dble(npoint),
     &              sqrt(sum_sq/dble(npoint))
```

```
1000    format(' Pix-perms read in  = ',i9/
     &         ' Total observations = ',i9/
     &         '          Data mean = ',2x,f14.6/
     &         '           Data RMS = ',2x,f14.6)

C       now close the table and quit
        call ftclos(iunit,status)

99      if (status .le. 0)then
                print *,'*** Program completed successfully ***'
        else
C          get the error text description
           call ftgerr(status,errtxt)
           print *,'*** ERROR - program did not run successfully ***'
           print *,'status =',status,': ',errtxt
        end if

100     continue
        end
```

B FORTRAN Source Code to Read the DMR Sky Maps

```
      program skymap

C     A simple program to read the FITS binary table from the DMR
C     Sky Maps Project Data Set.

      integer maxdim
      parameter (maxdim = 20)
      real    d2r
      parameter (d2r = 0.017453292e0)
      character*30 errtxt, extnam,
     &             ttype(maxdim),
     &             tform(maxdim),
     &             tunit(maxdim)
      character*80 fname
      logical simple,extend,anyflg
      logical sunv
      integer iunit,status,bitpix,naxis,naxes(maxdim),pcount,gcount
      integer group,fpixel,nelem,nrows
      integer i,j,nobs,npseen,tfield,rwstat,bksize,vardat
      integer colnum,frow,felem
      integer hdutyp,inull
      real    temp,enull,tmax,tmin
      real    dt,elat,elon,dtd,elatd,elond
      doubleprecision sum,sum_sq,sumd,sumd_sq

      status=0
      iunit=15
C     open the existing FITS file with readonly access
      rwstat=0

      print *,'Enter the name of the FITS sky map to read:'
      read(*,'(a80)') fname
      call ftopen(iunit,fname,rwstat,bksize,status)
      if (status .ne. 0) goto 99

C     read the required primary array keywords
      call ftghpr(iunit,maxdim,simple,bitpix,naxis,naxes,
     &            pcount,gcount,extend,status)
      if (status .ne. 0) goto 99

C     if dipole has been supressed, get dipole to add back in.
      call ftgkyl(iunit,'VEL_SUN',sunv,comment,status)
      if (status .ne. 0) goto 99
```

```
      if (sunv) then
        call ftgkye(iunit,'DIP_MAG', dtd, comment,status)
        if (status .ne. 0) goto 99
        call ftgkye(iunit,'DIP_ELAT',elatd,comment,status)
        if (status .ne. 0) goto 99
        call ftgkye(iunit,'DIP_ELON',elond,comment,status)
        if (status .ne. 0) goto 99
        elond = d2r*elond
        elatd = d2r*elatd
      endif

C     now move to the binary table extension
      call ftmahd(iunit,2,hdutyp,status)
      if (status .ne. 0) goto 99

C     get the binary table parameters
      call ftghbn(iunit,maxdim,nrows,tfield,ttype,tform,tunit,
     &            extnam,vardat,status)
      if (status .ne. 0) goto 99

C     test that this is a DMR sky map dataset, and its fields
C     are as expected.
      if (extnam .ne. 'DMR_SKYMAP' .or.
     &    ttype(2) .ne. 'SIGNAL' .or.
     &    ttype(3) .ne. 'N_OBS') then
        print *, 'extnam   = ', extnam
        print *, 'ttype(2) = ', ttype(2)
        print *, 'ttype(3) = ', ttype(3)
        stop 'Not a DMR sky map.'
      endif

C     initialize statistical accumulators
      npseen =  0
      sum    =  0.0d0
      sum_sq =  0.0d0
      tmax   = -1e30
      tmin   =  1e30
C     read each pixel and process
      do 10 frow = 1, nrows
        felem=1
        nelem=1
        inull=0
        enull=0.0
        colnum=2
        call ftgcve(iunit,colnum,frow,felem,nelem,enull,temp,
     &              anyflg,status)
```

```
      if (status .ne. 0) goto 99
      colnum=3
      call ftgcvj(iunit,colnum,frow,felem,nelem,inull,nobs,
     &            anyflg,status)
      if (status .ne. 0) goto 99
      colnum=5
      call ftgcve(iunit,colnum,frow,felem,nelem,enull,elon,
     &            anyflg,status)
      if (status .ne. 0) goto 99
      elon = d2r*elon
      colnum=6
      call ftgcve(iunit,colnum,frow,felem,nelem,enull,elat,
     &            anyflg,status)
      if (status .ne. 0) goto 99
      elat = d2r*elat

      if (nobs .gt. 0) then
        npseen = npseen + 1
        sum    = sum + temp
        sum_sq = sum_sq + temp*temp
        tmax   = max(tmax,temp)
        tmin   = min(tmin,temp)

C     add dipole term
        if (sunv) then
          temp = temp
     &         + dtd*( sin(elatd)*sin(elat) +
     &                 cos(elatd)*cos(elat)*cos(elond-elon) )
          sumd    = sumd + temp
          sumd_sq = sumd_sq + temp*temp
          tmaxd   = max(tmaxd,temp)
          tmind   = min(tmind,temp)
        endif

      endif
10    continue

C     print out statistics
      if (sunv) then
        print 1020
        print 1010, npseen, npseen,
     &            tmax, tmaxd,
     &            tmin, tmind,
     &            sum/dble(npseen),
     &            sumd/dble(npseen),
     &            sqrt( (dble(npseen)*sum_sq - sum*sum)
```

```
     &                      /dble(npseen)/dble(npseen-1) ),
     &                sqrt( (dble(npseen)*sumd_sq - sumd*sumd)
     &                      /dble(npseen)/dble(npseen-1) )
        else
          print 1000, npseen,
     &                tmax,
     &                tmin,
     &                sum/dble(npseen),
     &                sqrt( (dble(npseen)*sum_sq - sum*sum)
     &                      /dble(npseen)/dble(npseen-1) )
        endif
1000    format(' Observed Pixels = ',2x,i5/
     &         '             Max = ',f14.6/
     &         '             Min = ',f14.6/
     &         '             Avg = ',f14.6/
     &         '           Sigma = ',f14.6)
1010    format(' Observed Pixels = ',2x,i5,12x,i5/
     &         '             Max = ',f14.6, 3x,f14.6/
     &         '             Min = ',f14.6, 3x,f14.6/
     &         '             Avg = ',f14.6, 3x,f14.6/
     &         '           Sigma = ',f14.6, 3x,f14.6)
1020    format(18x,'       Without           With'/
     &         18x,'       Dipole           Dipole'/
     &         18x,'       As Read         Restored')

C       now close the table and quit
        call ftclos(iunit,status)

99      if (status .le. 0)then
                print *,'*** Program completed successfully ***'
        else
C          get the error text description
           call ftgerr(status,errtxt)
           print *,'*** ERROR - program did not run successfully ***'
           print *,'status =',status,': ',errtxt
        end if

100     continue
        end
```

C DMR Time-Ordered Data Project Data Set Structure

```
                RECORD DT04_TOD/DURATION="00:00:32"

Offset Length Description
------ ------ -----------
(Bytes)(Bytes)
             !
             !   ****** DMR TIME ORDERED DATA (TOD) FILE STRUCTURE ******
             !
             !         Record Size 2048 Bytes [4 x 512 Byte Blocks]
             !
             !----------------------------------------------------------
   0   8       Scalar/ADT             TIME
             !----------------------------------------------------------
   8  22       STRUCTURE      COBETRIEVE_HEADER
   8   4       Scalar/Long            MAJOR_FRAME_NUMBER
  12   4       Scalar/Long            ORBIT_NUMBER
  16   1       Scalar/Byte            SPIKE_LEVEL
             !                      ( x RMS X 10 for spike flagging )
  17   1       Scalar/Byte            WRITE_HIST
             !                      ( Last Write: 0=DSA,2=DTO,4=DCA )
  18   1       Scalar/Byte            DSA_FLAG
             !                      ( 1=Derived From a Simulated Archive )
  19   2       Scalar/Word            FRAME_FLAG          !Bits 0 to 15 set for
             !                      Not_clear, Gap, Eng, Dump, Bad_att, Prev_cal,
             !                      Cal_up, Cal_dn, All_bad, 31A -> 90B_bad,spare
             !                      ( Major-Frame Quality Flag )
  21   1       Scalar/Byte            SEARCH_FLAG
  22   1       Scalar/Byte            CELESTIAL_OBJECTS   !Bits 0 to 7 for
             !                      Moon, Earth (31,53,90),
             !                      Jupiter, Mars, Saturn, Galaxy
  23   1       Scalar/Byte            ATTITUDE_TYPE
             !                      ( 0=None, 1=SunEarth, 2=Definitive )
  24   1       Scalar/Byte            Galaxy_Cut_Angle   ! Degrees
  25   1       Scalar/Byte            Planet_Cut_Angle   ! Degrees
  26   1       Scalar/Byte            Moon_Cut_Angle     ! Degrees
  27   3       Array/Byte/Dim=3       Earth_Cut_Angle    ! Degrees for 31, 53, 90
               ENDSTRUCTURE  ! COBETRIEVE_HEADER
             !----------------------------------------------------------
  30 518       STRUCTURE      SPACECRAFT_INFORMATION
  30 144       Array/Float/Dim=(4,9)  ATTITUDE_QUATERNION
             !                      ( 9 quaternions per frame to interpolate )
 174 224       Array/Byte/Dim=(4,56)  ATTITUDE_RESIDUAL
```

```
        !                       ( Residuals for the interpolator )
398  12   Array/Float/Dim=3      SPACECRAFT_VELOCITY ! meters / sec
410  12   Array/Float/Dim=3      SPACECRAFT_POSITION ! Celestial coord J2000
422  12   Array/Float/Dim=3      EARTH_VELOCITY      ! meters / sec
434   4   Scalar/Float           Orbit_Angle         ! Degrees
438   4   Scalar/Float           DIPDUATH_Orbit_Var         ! D.U.
442   4   Scalar/Float           DP28VRUA_Orbit_Var         ! D.U.
        ! MPA_BRACKET_THERM_31A  Major frame average
446   4   Scalar/Float           MPA_BRACKET_THERMISTOR_31  ! DMT31MAA
        ! ABSOLUTE_PRT_53A and ABSOLUTE_PRT_90A Major frame averages
450   4   Scalar/Float           CRITICAL_REGION_53         ! DAP53MAA
454   4   Scalar/Float           CRITICAL_REGION_90         ! DAP90MAA
        !
        ! Fields from spacecraft archive NSB_SCDB_CS
        ! Torquer bar currents
458   2   ARRAY /BYTE /DIM= 2      AMABI    !MODULO 64 MMA A BAR CURRENT
460   2   ARRAY /BYTE /DIM= 2      AMAXBI   !MODULO 64 MMA AX BAR CURRENT
462   2   ARRAY /BYTE /DIM= 2      AMBBI    !MODULO 64 MMA B BAR CURRENT
464   2   ARRAY /BYTE /DIM= 2      AMBXBI   !MODULO 64 MMA BX BAR CURRENT
466   2   ARRAY /BYTE /DIM= 2      AMCBI    !MODULO 64 MMA C BAR CURRENT
468   2   ARRAY /BYTE /DIM= 2      AMCXBI   !MODULO 64 MMA CX BAR CURRENT
        ! Magnetometer field components, 4 per major frame in NSB_SCDB_CS
        !(For each set of six values,the first value is the last value from
        ! NSB_SCDB_CS for the previous major frame, and the sixth value
        ! is the first value from NSB_SCDB_CS for the next major frame)
470   6   ARRAY /BYTE /DIM= 6  ATAMA  !MODULO 32 TAM A  FIELD
476   6   ARRAY /BYTE /DIM= 6  ATAMAP !MODULO 32 TAM AP FIELD(PERPENDICULAR)
482   6   ARRAY /BYTE /DIM= 6  ATAMAX !MODULO 32 TAM AX FIELD
488   6   ARRAY /BYTE /DIM= 6  ATAMB  !MODULO 32 TAM B  FIELD
494   6   ARRAY /BYTE /DIM= 6  ATAMBP !MODULO 32 TAM BP FIELD
500   6   ARRAY /BYTE /DIM= 6  ATAMBX !MODULO 32 TAM BX FIELD
506   6   ARRAY /BYTE /DIM= 6  ATAMC  !MODULO 32 TAM C  FIELD
512   6   ARRAY /BYTE /DIM= 6  ATAMCP !MODULO 32 TAM CP FIELD
518   6   ARRAY /BYTE /DIM= 6  ATAMCX !MODULO 32 TAM CX FIELD
        ! Momentum and Reaction Wheels
        ! (For each set of six reaction wheel values, the first value is the
        ! last value from NSB_SCDB_CS for the previous major frame, and the
        ! sixth value is the first value from NSB_SCDB_CS for the next major
        ! frame)
524   1   SCALAR/BYTE       AMW1WSP  !ACS MOMENTUM WHEEL 1 WHEEL  SPEED.RPM.
525   1   SCALAR/BYTE       AMW1SPER !ACS MOMENTUM WHEEL 1 SPEED  ERROR.RPM.
526   1   SCALAR/BYTE       AMW2WSP  !ACS MOMENTUM WHEEL 2 WHEEL  SPEED.RPM.
527   1   SCALAR/BYTE       AMW2SPER !ACS MOMENTUM WHEEL 2 SPEED  ERROR.RPM.
528   6   ARRAY/BYTE/DIM=6  ARWASP   !ACS REACTION WHEEL A SPEED. RPM.
534   6   ARRAY/BYTE/DIM=6  ARWBSP   !ACS REACTION WHEEL B SPEED. RPM.
540   6   ARRAY/BYTE/DIM=6  ARWCSP   !ACS REACTION WHEEL C SPEED. RPM.
```

```
 546   2      ARRAY/BYTE/DIM=2  SPARE    !Spares
              ENDSTRUCTURE  ! SPACECRAFT_INFORMATION
            !------------------------------------------------------------
 548  12      STRUCTURE       MOON_DATA
 548   4      Scalar/Float           ANGLE_SPIN_MOON  ! Degrees
 552   4      Scalar/Float           PHASE            ! Radians
 556   4      Scalar/Float           POLARIZATION     ! Radians
              ENDSTRUCTURE  ! MOON_DATA
            !------------------------------------------------------------
 560 1392     STRUCTURE/Dim=(3,2)        SIGNAL   !Signal Name  6 x 232 bytes
 560 128      Array/Word/Dim=64      DIFFERENTIAL_TEMPERATURE
 688   8      Array/Word/Dim=4       TOTAL_POWER
 696  16      STRUCTURE       AVERAGE
 696   4      Scalar/Float           DIFFERENTIAL_TEMPERATURE
 700   4      Scalar/Float           ABSOLUTE_STEP
 704   4      Scalar/Float           LOCK_IN_AMP_THERM
 708   4      Scalar/Float           LOCAL_OSC_THERM
              ENDSTRUCTURE  ! AVERAGE
 712   4      Scalar/Float           DIODE_GAIN                ! (du/mK)
              UNION
               MAP
 716  12        Array/Float/Dim=3  BASELINE             ! Alias for baselines
               ENDMAP
               MAP
 716   4        Scalar/Float  MEAN_BASELINE     !Long time constant running mean
 720   4        Scalar/Float  SPLINE_BASELINE   !Medium time constant baseline
 724   4        Scalar/Float  FAST_CTD_BASELINE !Short time constant corrected
                                                !baseline
               ENDMAP
              ENDUNION
 728  64      Array/Byte/Dim=64      FLAG          ! Bits 0 to 7 set for
            !                          Bad_data, Moon, Spike, Offscale,
            !                          Planet, Galaxy, (spare), Bad_att
            !                          (Minor-Frame (Science) Quality Flag)
            !
              ENDSTRUCTURE  ! SIGNAL
            !------------------------------------------------------------
1952  96      STRUCTURE       HOUSEKEEPING_DATA    ! 96 bytes
            !From SUBCOM_99
1952   1      Scalar/Byte              DSCRBY       !S/C REG BUS VOLT
1953   1      Scalar/Byte              DNESBI       !S/C NON-ES BUS CURR
1954   1      Scalar/Byte              DP28VRUA     !IPDU +28 V MON
1955   1      Scalar/Byte              DP5VMRUA     !IPDU +5 V MON
1956   1      Scalar/Byte              DP15VRUA     !IPDU +15V MON
1957   1      Scalar/Byte              DN15VRUA     !IPDU -15V MON
1958   1      Scalar/Byte              DIPDUVMA     !IPDU BUSV MON
```

1959	1	Scalar/Byte	DIPDUIMA	!IPDU BUSI MON
1960	1	Scalar/Byte	DIICBIMA	!IPDU CONV BUSI
1961	1	Scalar/Byte	DIPHBVMA	!IPDU HEAT BUSV
1962	1	Scalar/Byte	DIPHBIMA	!IPDU HEAT BUSI
1963	1	Scalar/Byte	DPR1OVMA	!IPDU PR1V MON
1964	1	Scalar/Byte	DPR2OVMA	!IPDU PR1V MON
1965	1	Scalar/Byte	D31MIVMA	!31 MPA/IPA PRVM
1966	1	Scalar/Byte	D531PRTA	!53 GHz 1K PRT
1967	1	Scalar/Byte	D901PRTA	!90 GHz 1K PRT
1968	1	Scalar/Byte	DIPDUTHA	!IPDU BOX THERM
1969	1	Scalar/Byte	DIPLMTHA	!IPWR LMAC THERM
1970	1	Scalar/Byte	DHPLMTHA	!HPWR LMAC THERM
1971	1	Scalar/Byte	DPRGTH1A	!PRE-REG 1 THERM
1972	1	Scalar/Byte	DPRGTH2A	!PRE-REG 2 THERM
1973	1	Scalar/Byte	DINTCTHA	!IPDU INT CONV T
1974	1	Scalar/Byte	D53NSVMA	!53 GHz NSIV MON
1975	1	Scalar/Byte	D90MIVMA	!90 MPA/IFA PRVM
1976	1	Scalar/Byte	D90NSVMA	!90 GHz NSIV MON
1977	1	Scalar/Byte	DDEP5VMA	!DE +5V IV MON
1978	1	Scalar/Byte	D31TCM1A	!31 GHz TCVM #1
1979	1	Scalar/Byte	D53TCM1A	!53 GHz TCMV #1
1980	1	Scalar/Byte	D90TCM1A	!90 GHz TCMV #1
1981	1	Scalar/Byte	DDEUTCMA	!DATA ELEC TCVM
1982	1	Scalar/Byte	D31NSVMA	!31 GHz NSIV MON
1983	1	Scalar/Byte	D53MIVMA	!53 MPA/IFA PRVM
1984	1	Scalar/Byte	DP28VRUB	!+28 IPDU IV MON
1985	1	Scalar/Byte	DP5VMRUB	!+5 IPDU IV MON
1986	1	Scalar/Byte	DP15VRUB	!+15 IPDU IV MON
1987	1	Scalar/Byte	DN15VRUB	!-15 IPDU IV MON
1988	1	Scalar/Byte	DIPDUVMB	!IPDU I BUSV MON
1989	1	Scalar/Byte	DIPDUIMB	!IPDU I BUSI MON
1990	1	Scalar/Byte	DIICBIMB	!IPDU IC BUSI MON
1991	1	Scalar/Byte	DIPHBVMB	!IPDU HBUSV MON
1992	1	Scalar/Byte	DIPHBIMB	!IPDU HBUSI MON
1993	1	Scalar/Byte	DPR1OVMB	!IPDU PR1 OV MON
1994	1	Scalar/Byte	DPR2OMVB	!IPDU PR2 OV MON
1995	1	Scalar/Byte	D31MIVMB	!31 MPA/IFA PRVM
1996	1	Scalar/Byte	D531PRTB	!53 GHz 1K PRT
1997	1	Scalar/Byte	D901PRTB	!90 GHz 1K PRT
1998	1	Scalar/Byte	DIPDUTHB	!IPDU BOX THERM
1999	1	Scalar/Byte	DIPLMTHB	!IPWR LMAC THERM
2000	1	Scalar/Byte	DHPLMTHB	!HTRP LMAC THERM
2001	1	Scalar/Byte	DPRGTH1B	!PRE-REG 1 THERM
2002	1	Scalar/Byte	DPRGTH2B	!PRE-REG 2 THERM
2003	1	Scalar/Byte	DINTCTHB	!IPDU INT CONV T
2004	1	Scalar/Byte	D53NSVMB	!53 GHz NSIV MON

```
2005   1     Scalar/Byte            D90MIVMB     !90 MPA/IFA PRVM
2006   1     Scalar/Byte            D90NSVMB     !90 GHz NSIV MON
2007   1     Scalar/Byte            DDEP5VMB     !DE +5V INSV MON
2008   1     Scalar/Byte            D31TCM2B     !31 GHz TCVM #2
2009   1     Scalar/Byte            D53TCM2B     !53 GHz TCVM #2
2010   1     Scalar/Byte            D90TCM2B     !90 GHz TCVM #2
2011   1     Scalar/Byte            DDEUTCMB     !DATA ELEC TCVM
2012   1     Scalar/Byte            D31NSVMB     !31 GHz NS IVM
2013   1     Scalar/Byte            D53MIVMB     !53 MPA/IFA PRVM
2014   1     Scalar/Byte            DIPDUATH     !IPDU-A BOX S/CT
2015   1     Scalar/Byte            DIPDUBTH     !IPDU-B BOX S/CT
2016   1     Scalar/Byte            DDEUABTH     !DEU-A BOX S/CT
2017   1     Scalar/Byte            DDEUBBTH     !DEU-B BOX S/CT
2018   1     Scalar/Byte            DI8NSCA      !NS CALIBRATE
2019   5     Array/Byte/Dim=5       DRELA99A     !RelayA group

            !Byte 1
            !Bit0 = DI7DEVRA  Bit1 = D690LIAA  Bit2 = DI590DSA  Bit3 = D453LIAA
            !DE VOLT REG      90 GHz LI AMP    90 GHz DK SW     53 GHz LI AMP
            !Bit4 = DI353DSA  Bit5 = D231LIAA  Bit6 = DI131DSA  Bit7 = DK831CCA
            !53 GHz DK SW     31 GHz LI AMP    31 GHz DK SW     31 GHz CH CNV
            !Byte 2
            !Bit0 = D7DETG5A  Bit1 = D690NSDA  Bit2 = DK590MIA  Bit3 = D453NSDA
            !DE TIM GEN +5    90 GHz NS DIS    90 MPA/IFA       53 GHz NS DIS
            !Bit4 = DK353MIA  Bit5 = D231NSDA  Bit6 = DK131MIA  Bit7 = D853FMHA
            !53 MPA/IFA       31 GHz NS DIS    31 MPA/IFA       53 FAIL M HTR
            !Byte 3
            !Bit0 = D731FMHA  Bit1 = D690WBCA  Bit2 = D590CRCA  Bit3 = D453WBCA
            !31 FAIL M HTR    90 CASE T CNT    90 CRIT T CNT    53 CASE T CNT
            !Bit4 = D353CRCA  Bit5 = DH231CCA  Bit6 = D131CRCA  Bit7 = D1290LOA
            !53 CRIT T CNT    31 CASE T CNT    31 CRIT T CNT    90 GHz LO CNV
            !Byte 4
            !Bit0 = D1153LOA  Bit1 = D10DETCA  Bit2 = D990FMHA  Bit3 = DK12DECA
            !53 GHz LO CNV    DE TEMP CNT      90 FAIL M HTR    DATA ELEC CNV
            !Bit4 = D1131LOA  Bit5 = D1090CCA  Bit6 = DK953CCA  Bit7 = D31MODEA
            !31 GHz LO CNV    90 GHz CH CNV    53 GHz CH CNV    31A INST MODE
            !Byte 5
            !Bit0 = D53MODEA  Bit1 = D90MODEA  Bit2 = D90GAINA  Bit3 = D53GAINA
            !53A INST MODE    90A INST MODE    90 GHz GAIN      53 GHz GAIN
            !Bit4 = D31GAINA  Bit5 = D31BWTHA  Bit6 = DILMACOA  Bit7 = DHLMACOA
            !31 GHz GAIN      31 GHz BANDWD    LMAC OVTP OVR    HPWR OVTP OVR

2024   1     Scalar/Byte            D31NSSTA     !31A NS STATUS
2025   1     Scalar/Byte            D53NSSTA     !53A NS STATUS
2026   1     Scalar/Byte            D90NSSTA     !90A NS STATUS
2027   1     Scalar/Byte            D31NSSTB     !31B NS STATUS
```

```
2028   1      Scalar/Byte             D53NSSTB     !53B NS STATUS
2029   1      Scalar/Byte             D31SCBTH     !31 GHz BOX TH
2030   1      Scalar/Byte             D90NSSTB     !90B NS STATUS
2031   1      Scalar/Byte             D53SCBTH     !53 GHz BOX TH
2032   1      Scalar/Byte             D90SCBTH     !90 GHz BOX TH
2033   1      Scalar/Byte             DI8NSCB      !NS CALIBRATE
2034   5      Array/Byte/Dim=5        DRELA99B     !RelayB group

             !Byte 1
             !Bit0 = DI7DEVRB  Bit1 = D690LIAB  Bit2 = DI590DSB  Bit3 = D453LIAB
             !DE VOLT REG      90 GHz LI AMP    90 DICKE SW      53 GHz LI AMP
             !Bit4 = DI353DSB  Bit5 = D231LIAB  Bit6 = DI131DSB  Bit7 = DK831CCB
             !53 DICKE SW      31 GHz LI AMP    31 DICKE SW      31 GHz CH CNV
             !Byte 2
             !Bit0 = D7DETG5B  Bit1 = D690NSDB  Bit2 = DK590MIB  Bit3 = D453NSDB
             !DE TIM GEN +5    90 GHz NS DIS    90 MPA/IFA       53 GHz NS DIS
             !Bit4 = DK353MIB  Bit5 = D231NSDB  Bit6 = DK131MIB  Bit7 = D853FMHB
             !53 MPA/IFA       31 GHz NS DIS    31 MPA/IFA       53 FAIL M HTR
             !Byte 3
             !Bit0 = D731FMHB  Bit1 = D690WBCB  Bit2 = D590CRCB  Bit3 = D453WBCB
             !31 FAIL M HTR    90 CASE T CNT    90 CRIT T CNT    53 CASE T CNT
             !Bit4 = D353CRCB  Bit5 = DH231CCB  Bit6 = D131CRCB  Bit7 = D1290LOB
             !53 CRIT T CNT    31 CASE T CNT    31 CRIT T CNT    90 GHz LO CNV
             !Byte 4
             !Bit0 = D1153LOB  Bit1 = D10DETCB  Bit2 = D990FMHB  Bit3 = DK12DECB
             !53 GHz LO CNV    DE TEMP CNT      90 FAIL M HTR    DATA ELEC CNV
             !Bit4 = D1131LOB  Bit5 = D1090CCB  Bit6 = DK953CCB  Bit7 = D31MODEB
             !31 GHz LO CNV    90 GHz CH CNV    53 GHz CH CNV    31B INST MODE
             !Byte 5
             !Bit0 = D53MODEB  Bit1 = D90MODEB  Bit2 = D90GAINB  Bit3 = D53GAINB
             !53A INST MODE    90A INST MODE    90 GHz GAIN      53 GHz GAIN
             !Bit4 = D31GAINB  Bit5 = D31BWTHB  Bit6 = DILMACOB  Bit7 = DHLMACOB
             !31 GHz GAIN      31 GHz BANDWD    LMAC OVTP OVR    HPWR OVTP OVR

2039   1      Scalar/Byte             Spare
             !
             !From  SUBCOM_98
2040   1      Scalar/Byte             DRELA98      !Relay group

             !Byte1
             !Bit0 = DIPIC28A        Bit1 = DIPIC28B        Bit2 = DHSC28VA
             !+28V IPDU INT CONV A   +28V IPDU INT CONV B   +28V HEATER SWITCH A
             !Bit3 = DHSC28VB        Bit4 = DIPPR28A        Bit5 = DIPPR28B
             !+28V HEATER SWITCH B   +28V IPDU PRE REG  A   +28V IPDU PRE REG  B

2041   1      Scalar/Byte             D31BOXSH     !31 GHz BOX SURV HEATER
```

```
2042   1      Scalar/Byte              D53BOXSH     !53 GHz BOX SURV HEATER
2043   1      Scalar/Byte              D90BOXSH     !90 GHz BOX SURV HEATER
2044   1      Scalar/Byte              DDEUABSH     !DEU-A BOX SURV HEATER
2045   1      Scalar/Byte              DDEUBBSH     !DEU-B BOX SURV HEATER
2046   1      Scalar/Byte              DIPDUBSH     !IPDU BAY SURV HEATER
2047   1      Scalar/Byte              DBUSVOLT     !DMR BUS VOLTAGE
             !
              ENDSTRUCTURE  ! HOUSEKEEPING_DATA
             !-----------------------------------------------------------
2048          END_RECORD


 TOTAL LENGTH OF RECORD:   2048 BYTES
 TOTAL NUMBER OF FIELDS:    161
```

D Comments for the Related Data Fields in DMR Time-Ordered Data Project Data Set

```
Offset Length     Description
------ ------     -----------
   0      8       Scalar/ADT                 TIME
```

This time field is of primary use by the COBE archiving database system (COBETRIEVE). In VAX ADT format, it is defined as the number of 100 nanosecond intervals that have elapsed since 0 UT on November 17, 1858 (not counting leap-seconds), and so currently has values of order 4×10^{16}. It is conceptually an 8-byte signed integer, and can be handled as such on certain 64-bit systems, e.g. DEC Alpha with OSF/1. For systems without such luxuries it may be thought of as (e.g., in C) a structure combining a signed long and an unsigned long. Unfortunately, VAX Fortran does not provide unsigned integer types, so using ADT times in Fortran is quite cumbersome.

It is evaluated in VAX Fortran as two INTEGER*4 numbers, but the sign bit of the first number is used so that it is not straightforward to reconstruct the value. Here is a method of evaluating the ADT time as a REAL*8 number:

```
      INTEGER*4 ADT(2)
      REAL*8 I4MAX/4.294967296D+9/, TADT
         IF (ADT(1) .GE. 0)
     &         TADT = DBLE(ADT(1)) + I4MAX*DBLE(ADT(2))
         IF (ADT(1) .LT. 0)
     &         TADT = I4MAX + DBLE(ADT(1)) + I4MAX*DBLE(ADT(2))
```

In the COBE ingest system, the ADT time is calculated from the UTC (Coordinated Universal Time) for each major frame. Hence, the ADT time increases by exactly 320,000,000 for each 32 second major frame, except for those major frames which follow a 'leap second', in which case the ADT time increases by exactly 310,000,000 from the previous frame. Hence, to convert ADT time back to UTC or to T81 (seconds of UTC or IAT that have elapsed since 0 UTC on Jan 1, 1981), specialized routines are necessary that can make the adjustments at the leap-second times, and these routines will be available to the COBE guest investigators. In case this documentation survives the availability of such routines, the following table will allow a user to make the conversion. The table gives values of UTC, TADT, and T81 for the four leap-seconds that occurred during the COBE mission (UTC times are expressed in the format YYDDDHHMMSS):

```
Leap-second number  1   (Dec 31, 1989)
                      Previous Second    Leap Second    Following Second
              UTC       89365235959      89365235960      90001000000
              T81       283,996,804      283,996,805      283,996,806
       TADT/10**7     4,137,868,799      -----------    4,137,868,800

Leap-second number  2   (Dec 31, 1990)
                      Previous Second    Leap Second    Following Second
```

UTC	90365235959	90365235960	91001000000
T81	315,532,805	315,532,806	315,532,807
TADT/10**7	4,169,404,799	-----------	4,169,404,800

Leap-second number 3 (June 30, 1992)

	Previous Second	Leap Second	Following Second
UTC	92182235959	92182235960	92183000000
T81	362,793,606	362,793,607	362,793,608
TADT/10**7	4,216,665,599	-----------	4,216,665,600

Leap-second number 4 (June 30, 1993)

	Previous Second	Leap Second	Following Second
UTC	93181235959	93181235960	93182000000
T81	394,329,607	394,329,608	394,329,609
TADT/10**7	4,248,201,599	-----------	4,248,201,600

Note that since the ADT time is not definable for leap-seconds, TADT can be thought of as being 'frozen' during the entire leap-second.

Each of the records of this time-ordered data set spans 32 seconds and is called a 'Major Frame'. The major frame contains data for 64 half-second DMR integration periods, called 'DMR Minor Frames'. The TIME field of the major frame corresponds to the time at the end of the first of these 64 integration periods. (The times in the DMR time-ordered dataset are one-eighth second [0.125 sec] less than the times in the ingested COBE telemetry in order to compensate for a time delay in the DMR instrument).

```
Offset Length     Description
------ ------     -----------
   8      4       Scalar/Long                MAJOR_FRAME_NUMBER
```

Integer giving the current major frame number. This number was reset to zero at the beginning of each new ingest tape. Normally each tape had more or less one day's data or 2700 frames and started between 0900 and 1000 UTC.

```
Offset Length     Description
------ ------     -----------
  12      4       Scalar/Long                ORBIT_NUMBER
```

Integer giving the current orbit number. The origin of this number was apparently arbitrary and the COBE mission starts at about orbit number 7232. There are slightly more than 14 orbits per day. A new orbit begins near orbit angle 310° which is between the South Pole and the equator moving northward.

```
Offset Length     Description
------ ------     -----------
  16      1       Scalar/Byte                SPIKE_LEVEL
```

Individual data points beyond a certain threshhold from the mean are flagged as spikes [see comments for data field DTO4_TOD.SIGNAL(frequency,channel).FLAG(1:64)]. DMR used the threshhold of 5.0 times the daily RMS value, so that SPIKE_LEVEL has the value of 50.

```
Offset Length     Description
------ ------     -----------
  17       1      Scalar/Byte            WRITE_HIST
                  !                      ( Last Write: 0=DSA,2=DTO,4=DCA )
```

The delivered DMR time-ordered data was produced by the DCA (CAlibrate time-ordered data) facility, so that WRITE_HIST has the value of 4.

```
Offset Length     Description
------ ------     -----------
  18       1      Scalar/Byte            DSA_FLAG
                  !                      ( 1=Derived From a Simulated Archive )
```

For the real, non-simulated data, DSA_FLAG = 0.

```
Offset Length     Description
------ ------     -----------
  19       2      Scalar/Word            FRAME_FLAG
                  !                      Bits 0 to 15 set for Not_clear, Gap,
                  !                      Eng, Dump, Bad_att, Prev_cal,Cal_up,
                  !                      Cal_dn, All_bad,31A -> 90B_bad,spare
                  !                      ( Major-Frame Quality Flag )
```

Determines whether the major frame has usable data. Evaluated as a number FRAME_FLAG can have values from 0 to 65535. If all 6 channels have at least some minor frames with usable data, then FRAME_FLAG, evaluated as a number will be 0 or 1.

```
Offset Length     Description
------ ------     -----------
  21       1      Scalar/Byte            SEARCH_FLAG
```

This is a bit-by-bit logical OR of the 384 (6 channels by 64 minor frames) minor frame science FLAGs. See comments for data field DTO4_TOD.SIGNAL(frequency,channel).FLAG(1:64).

```
Offset Length     Description
------ ------     -----------
  22       1      Scalar/Byte            CELESTIAL_OBJECTS
                  !                      Bits 0 to 7 set for Moon,
                  !                      Earth(31,53,90), Jupiter, Mars,
                  !                      Saturn, Galaxy
```

This flag tells the user whether to search the individual minor-frame science FLAGS for occurrence of the particular celestial object. Data flagged as Moon or Earth close are not considered usable. Data flagged for planets were corrected for those planets in the DMR Sky Maps and Pixelized Project Data Sets. The Galaxy flag is a warning only. If bits 0, 4, 5, 6, or 7 were set, then the data for at least one minor frame for at least one channel were affected. If bits 1, 2, or 3 were set, then the data for the respective frequency or frequencies were not used for the entire major frame.

```
Offset Length     Description
------ ------     -----------
  23       1      Scalar/Byte             ATTITUDE_TYPE
                  !                       ( 0=None, 1=SunEarth, 2=Definitive )
```

Usable DMR data must have attitude types of 1 or 2. The Definitive attitude is usually of higher quality and was obtained from analyzing DIRBE observations of stars.

```
Offset Length     Description
------ ------     -----------
  24       1      Scalar/Byte             Galaxy_Cut_Angle   ! Degrees
```

DMR data within 15° of the galactic plane are flagged as Galaxy_close (see comments on DTO4_TOD.COBETRIEVE_HEADER.CELESTIAL_OBJECTS). Such data are usable with this caveat.

```
Offset Length     Description
------ ------     -----------
  25       1      Scalar/Byte             Planet_Cut_Angle   ! Degrees
```

DMR data from within 15° of Mars, Jupiter, or Saturn are flagged (see comments on DTO4_TOD.COBETRIEVE_HEADER.CELESTIAL_OBJECTS). Data so flagged were corrected for planetary emission in the DMR Sky Maps and Pixelized Project Data Sets.

```
Offset Length     Description
------ ------     -----------
  26       1      Scalar/Byte             Moon_Cut_Angle     ! Degrees
```

DMR data from within 21° of the Moon are flagged and were not used in the production of DMR Sky Maps or Pixelized Project Data Sets.

```
Offset Length     Description
------ ------     -----------
  27       3      Array/Byte/Dim=3        Earth_Cut_Angle    ! Degrees
```

Data obtained when the Earth's limb was too close to the COBE ground shield (less than 3° below the shield for 31 GHz data and less than 1° below for 53 and 90 GHz data) were flagged (see comments on DTO4_TOD.COBETRIEVE_HEADER.CELESTIAL_OBJECTS), and not used in the production of DMR Sky Maps or Pixelized Project Data Sets.

```
Offset Length     Description
------ ------     -----------
  30     144      Array/Float/Dim=(4,9)  ATTITUDE_QUATERNION
```

These are the four quaternions describing the spacecraft attitude for nine of the DMR integration periods (DMR minor frames). These are integration periods 1,9,17,25,33,41,49,56,and 65 (which corresponds to the first integration period of the next record or major frame).

```
Offset Length     Description
------ ------     -----------
 174     224      Array/Byte/Dim=(4,56)  ATTITUDE_RESIDUAL
```

These are residuals so that attitude interpolation routine in the DMR software could accurately reconstruct the spacecraft attitude quaternions for the ramaining 56 DMR integration periods. The actual pointings for the ten DMR horns were constructed from the quaternions by adding the vectors defining the offsets of the horns from the spacecraft spin axis.

```
Offset Length     Description
------ ------     -----------
 398      12      Array/Float/Dim=3      SPACECRAFT_VELOCITY ! meters/sec
```

This field contains the Cartesian components (x,y,z) of the spacecraft velocity around the earth in J2000 equatorial coordinates. It is evaluated at the center of the major frame, specifically, at the time 16 seconds later than the timestamp of the frame. (Note that this is the boundary between DMR integration periods 33 and 34.)

```
Offset Length     Description
------ ------     -----------
 410      12      Array/Float/Dim=3      SPACECRAFT_POSITION !Celestial coord
```

This field contains the Cartesian components (x,y,z) of the spacecraft position in J2000 equatorial coordinates. It is evaluated at the center of the major frame, specifically, at the time 16 seconds later than the timestamp of the frame. (Note that this is the boundary between DMR integration periods 33 and 34.)

```
Offset Length     Description
------ ------     -----------
 422      12      Array/Float/Dim=3      EARTH_VELOCITY        ! meters / sec
```

For the preparation of the Sky Maps and Pixelized Project Data Sets, the DMR time-ordered data were corrected for the velocity of the spacecraft around the Earth, the Earth around the Sun, and 'Sun Velocity' (velocity which would produce a nominal CMB Dipole). This field contains the Cartesian components (x,y,z) of the earth velocity about the solar system barycenter in J2000 equatorial coordinates.

```
 Offset Length     Description
 ------ ------     -----------
  434      4       Scalar/Float             Orbit_Angle
```

The spacecraft orbit angle is defined as the angle between the spacecraft and the ascending node of the orbit with vertex at the center of the Earth. Thus the orbit angle is 0 at the ascending node, 90° over the North Pole, 180° at the descending node, and 270° over the South Pole.

```
 Offset Length     Description
 ------ ------     -----------
  438      4       Scalar/Float             DIPDUATH_Orbit_Var         ! D.U.
```

Residual of DIPDUATH (IPDU-A box thermistor) for this frame after subtracting mean value from 2 orbits centered on this frame. See Appendix E for conversion to Kelvin.

```
 Offset Length     Description
 ------ ------     -----------
  442      4       Scalar/Float             DP28VRUA_Orbit_Var         ! D.U.
```

Residual of DP28VRUA (IPDU +28 Voltage monitor) for this frame after subtracting mean value from 2 orbits centered on this frame. See Appendix E for conversion to Volts.

```
 Offset Length     Description
 ------ ------     -----------
  548      4       Scalar/Float             ANGLE_SPIN_MOON  ! Degrees
```

The angle between the spacecraft spin axis and the direction to the moon as seen from COBE at the middle of the major frame.

```
 Offset Length     Description
 ------ ------     -----------
  552      4       Scalar/Float             PHASE            ! Radians
```

The phase of the moon as seen from the COBE satellite. Full = 0, Last Quarter = $\pi/2$, New = π, and First quarter = $-\pi/2$.

```
Offset Length     Description
------ ------     -----------
 556      4       Scalar/Float           POLARIZATION     ! Radians
```

Always zero (not used).

```
Offset Length     Description
------ ------     -----------
 560     128      Array/Word/Dim=64      DIFFERENTIAL_TEMPERATURE
```

Differential temperature telemetry. Each point is an unsigned integer between 0 and 4095 data units (du) representing the difference in input power between the two horns averaged over a half-second. Each half-second interval is called a "minor frame". See DIODE-GAIN (below) to correct to antenna temperature in mK.

```
Offset Length     Description
------ ------     -----------
 688      8       Array/Word/Dim=4       TOTAL_POWER
```

Total power telemetry. Each point is an unsigned integer between 0 and 4095 data units (du) representing the total radiometer output over an eight-second integration period. Note that four 8-second total power samples are taken for every 64 half-second differential temperature samples.

```
Offset Length     Description
------ ------     -----------
 696      4       Scalar/Float           DIFFERENTIAL_TEMPERATURE
```

Average of the differential temperatures measured during this frame. The average is over minor frames 3 to 64 to avoid transients during calibration.

```
Offset Length     Description
------ ------     -----------
 700      4       Scalar/Float           ABSOLUTE_STEP
```

Absolute step is defined as the average absolute difference between successive differential temperatures. It is computed on a frame by frame basis and used as an alternative to the standard deviation because of its greater computational efficiency. It is computed only for minor frames 3 to 64 to avoid transients during calibration.

```
Offset Length     Description
------ ------     -----------
 704      4       Scalar/Float           LOCK_IN_AMP_THERM
```

Average of the lock-in amplifier thermistor telemetry for this frame (du). See Appendix E (DLTH31A) for conversion to Kelvin.

```
Offset Length     Description
------ ------     -----------
 708       4      Scalar/Float             LOCAL_OSC_THERM
```

Average of the local oscillator thermistor telemetry for this frame (du). See Appendix E (DLOT31A) for conversion to Kelvin.

```
Offset Length     Description
------ ------     -----------
 712       4      Scalar/Float             DIODE_GAIN          ! (du/mK)
```

Gain pertaining to this major frame derived from a noise source measurement. Divide the baseline-subtracted differential temperatures in data units by this number to obtain the uncorrected measurement in milliKelvin antenna temperature.

```
Offset Length     Description
------ ------     -----------
 716       4      Scalar/Float         MEAN_BASELINE
                                       ! Long time constant running mean
```

Mean baseline value pertaining to this major frame. This value may be subtracted from the differential temperatures in data units to remove the instrument offset.

```
Offset Length     Description
------ ------     -----------
 720       4      Scalar/Float         SPLINE_BASELINE
                                       ! Medium time constant baseline
```

Spline baseline value pertaining to this major frame. This value may be subtracted from the differential temperatures in data units to remove the instrument offset.

```
Offset Length     Description
------ ------     -----------
 724       4      Scalar/Float         FAST_CTD_BASELINE
                                       ! Short time constant corrected baseline
```

Fast corrected baseline value pertaining to this major frame. This value may be subtracted from the differential temperatures in data units to remove the instrument offset.

```
Offset Length      Description
------ ------      -----------
 728      64       Array/Byte/Dim=64       FLAG
             !                             Bits 0 to 7 set for Bad_data, Moon,
             !                             Spike, Offscale, Planet, Galaxy,
             !                             (Spare), Bad_att
             !                             (Minor-Frame (Science) Quality Flag)
             !
```

Determines whether the corresponding minor frame datum is usable. Each bad data flag is a single byte whose interpretation is given in the following table.

DTO4_TOD.COBETRIEVE_HEADER.FRAME_FLAG

Bit	Hex	Set Condition	Comments
0	0001	Any bad data	If clear, entire frame is clean (all channels)
1	0002	Gap	If set, frame is gap (data unusable)
2	0004	Engineering	If set, data were taken in engineering mode
3	0008	Dump	If set, frame is in dump mode (data unusable)
4	0010	Bad attitude	If set, no attitude available for this frame
5	0020	Prev Cal	If set, previous frame was calibration and current is not
6	0040	Cal up	If set, calibrating with UP noise source
7	0080	Cal down	If set, calibrating with DOWN noise source
8	0100	Unusable frame	If set, entire frame is unusable (all channels)
9	0200	31A Unusable	If set, there is no usable data for 31A channel
10	0400	31B Unusable	If set, there is no usable data for 31B channel
11	0800	53A Unusable	If set, there is no usable data for 53A channel
12	1000	53B Unusable	If set, there is no usable data for 53B channel
13	2000	90A Unusable	If set, there is no usable data for 90A channel
14	4000	90B Unusable	If set, there is no usable data for 90B channel
15	8000	Spare	(not used)

DTO4_TOD.COBETRIEVE_HEADER.CELESTIAL_OBJECTS

Bit	Hex	Set Condition	Comments
0	01	Moon close	If set, the Moon is within the cut angle of spin axis
1	02	Earth, 31 GHz	If set, the Earth is above the 31 GHz cut angle
2	04	Earth, 53 GHz	If set, the Earth is above the 53 GHz cut angle
3	08	Earth, 90 GHz	If set, the Earth is above the 90 GHz cut angle
4	10	Jupiter close	If set, Jupiter is within cut angle of at least 1 channel
5	20	Mars close	If set, Mars is within cut angle of at least 1 channel
6	40	Saturn close	If set, Saturn is within cut angle of at least 1 channel
7	80	Galaxy close	If set, the Galactic plane is within cut angle

DTO4_TOD.SIGNAL(frequency,channel).FLAG(1:64)

Bit	Hex	Significance of bit value = 1	Comments
0	01	Unusable datum	This datum is unusable. This usually means that there were bad quality flags set in the raw data telemtery for this major frame or that the time range and channel were specified in the 'bad data log' (DQU4_BAD_LOG)
1	02	Moon	Moon is within cut angle of beam center. These data were not used.
2	04	Spike	Datum deviates from local mean by more than threshold These data were not used.
3	08	Off-scale	Datum is off scale (0 or 4095). These data were not used.
4	10	Planet	One or more planets (Jupiter, Mars, and Saturn) are within cut angle of beam center. These data were used after correction.
5	20	Galaxy	Galaxy is within cut angle of beam center. This is a warning only and the data were used.
6	40	Spare	Not used.
7	80	Bad attitude	Residual too large to interpolate attitude for this datum. These data were not used.

E Conversion of DMR Housekeeping Signals and Spacecraft Signals from Telemetry Digital Units to Physical Units

Some of the DMR housekeeping signals and spacecraft signals specified in the Time-Ordered Data Project Data Set are given in Telemetry Digital Units (DU's). For purposes of converting data in Telemetry Digital Units into Physical Units, one of the following type of conversions is applied.

1. Polynomial conversion:

$$Y = C(1) + C(2)X + C(3)X^2 + C(4)X^3 + C(5)X^4 + C(6)X^5$$

2. Reciprocal Logarithm conversion:

$$Y = \frac{1.0}{C(1) \cdot \log[C(4)X + C(5)] + C(2)} + C(3)$$

Where X is given in Telemetry Digital Units (DU) and Y is the corresponding value in Physical Units (Kelvin,Volts or Amps); C(0), C(1),...,and C(5) are coefficients whose values are given in the following table.

Note:

- The type of conversion (given in the table) depends on the type of signal (temperature, voltage or current). Type "0" represents the case where no conversion is applied.
- All mnemonics begining with the letter "D" denote DMR signals, and letter "A" spacecraft signals.
- No conversion is applied for Differential Temperatures, Total Powers, Gains and Baselines.

Signal Name	Coefficients						Type of Conv.
	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	
AMABI	-2.00000E+05	1.60000E+03	3.39897E-02	-2.64241E-04	1.01191E-06	-1.51852E-09	1
AMAXBI	-5.00000E+04	4.00000E+02	3.39897E-02	-2.64241E-04	1.01191E-06	-1.51852E-09	1
AMBBI	-2.00000E+05	1.60000E+03	3.39897E-02	-2.64241E-04	1.01191E-06	-1.51852E-09	1
AMBXBI	-5.00000E+04	4.00000E+02	3.39897E-02	-2.64241E-04	1.01191E-06	-1.51852E-09	1
AMCBI	-2.00000E+05	1.60000E+03	3.39897E-02	-2.64241E-04	1.01191E-06	-1.51852E-09	1
AMCXBI	-5.00000E+04	4.00000E+02	3.39897E-02	-2.64241E-04	1.01191E-06	-1.51852E-09	1
ATAMA	6.39260E-01	-5.15996E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMAP	6.39300E-01	-5.15597E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMAX	6.39920E-01	-5.14403E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMB	6.37350E-01	-5.09684E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMBP	6.38690E-01	-5.19247E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMBX	6.39260E-01	-5.13479E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMC	6.39920E-01	-5.16796E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMCP	6.39510E-01	-5.14272E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ATAMCX	6.40290E-01	-5.15730E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
AMW1WSP	2.03446E+00	-1.28926E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
AMW1SPER	1.27000E+02	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
AMW2WSP	2.03446E+00	-1.28926E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
AMW2SPER	1.27000E+02	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ARWASP	-2.75000E+03	2.20000E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ARWBSP	-2.75000E+03	2.20000E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
ARWCSP	-2.75000E+03	2.20000E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DMBT31A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DPRT31A	2.02037E+01	-9.86502E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRT53A	1.89732E+01	-9.26421E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRT53B	1.89732E+01	-9.26421E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRT90A	1.89732E+01	-9.26421E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRT90B	1.89732E+01	-9.26421E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DASP31B	3.15214E+02	-9.92608E-03	1.48992E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DASP53A	1.54213E+02	-9.38283E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DASP53B	1.54213E+02	-9.38283E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DASP90A	1.54213E+02	-9.38283E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DASP90B	1.54213E+02	-9.38283E-03	2.83949E-08	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DLTH31A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLTH31B	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLTH53A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLTH53B	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLTH90A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLTH90B	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLOT31A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLOT31B	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLOT53A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLOT53B	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLOT90A	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2
DLOT90B	2.09805E-04	1.41211E-03	-3.18000E+01	-1.19150E+01	4.92328E+04	-2.98106E-09	2

Signal Name	Coefficients						Type of Conv.
	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	
DSCRBY	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DNESBI	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DP28VRUA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DP5VMRUA	0.00000E+00	4.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DP15VRUA	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DN15VRUA	-2.04000E+01	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUVMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUIMA	0.00000E+00	2.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIICBIMA	0.00000E+00	4.00000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPHBVMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPHBIMA	0.00000E+00	2.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DPR10VMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DPR20VMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D31MIVMA	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D531PRTA	7.52052E+01	9.69722E-01	2.18727E-04	0.00000E+00	0.00000E+00	0.00000E+00	1
D901PRTA	7.52052E+01	9.69722E-01	2.18727E-04	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUTHA	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DIPLMTHA	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DHPLMTHA	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRGTH1A	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRGTH2A	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DINTCTHA	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
D53NSVMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D90MIVMA	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D90NSVMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DDEP5VMA	0.00000E+00	4.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D31TCM1A	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D53TCM1A	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D90TCM1A	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DDEUTCMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D31NSVMA	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D53MIVMA	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DP28VRUB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DP5VMRUB	0.00000E+00	4.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DP15VRUB	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DN15VRUB	-2.04000E+01	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUVMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUIMB	0.00000E+00	2.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIICBIMB	0.00000E+00	4.00000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPHBVMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPHBIMB	0.00000E+00	2.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DPR10VMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DPR20VMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1

Signal	Coefficients						Type of
Name	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	Conv.
D31MIVMB	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D531PRTB	7.52052E+01	9.69722E-01	2.18727E-04	0.00000E+00	0.00000E+00	0.00000E+00	1
D901PRTB	7.52052E+01	9.69722E-01	2.18727E-04	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUTHB	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DIPLMTHB	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DHPLMTHB	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRGTH1B	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DPRGTH2B	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DINTCTHB	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
D53NSVMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D90MIVMB	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D90NSVMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DDEP5VMB	0.00000E+00	4.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D31TCM2B	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D53TCM2B	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D90TCM2B	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DDEUTCMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D31NSVMB	0.00000E+00	1.60000E-01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
D53MIVMB	0.00000E+00	8.00000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1
DIPDUATH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DIPDUBTH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DDEUABTH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DDEUBBTH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DI8NSCA	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DRELA99A	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D31NSSTA	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D53NSSTA	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D90NSSTA	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D31NSSTB	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D53NSSTB	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D31SCBTH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
D90NSSTB	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D53SCBTH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
D90SCBTH	3.80965E+02	-2.72743E+00	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1
DI8NSCB	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DRELA99B —	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D31BOXSH	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D53BOXSH	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
D90BOXSH	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DDEUABSH	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DDEUBBSH	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DIPDUBSH	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0
DBUSVOLT	0.00000E+00	2.00000E-02	4.18229E-02	-3.75715E-04	1.68846E-06	-2.98106E-09	1