NASA-CR-203967

IN-90-CR
021359

1994-01-97-CR

COBE FINAL REPORT: DIRBE CELESTIAL CALIBRATION

FOR WORK PERFORMED UNDER CONTRACT NUMBER NAS5-32475

Dr. Shawn V. Burdick
Dr. Thomas L. Murdock

26 March 1997

5 Cherry Hill Drive
Suite 220
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1 INTRODUCTION

We have completed our study of the traceability of the calibrated COsmic Background Explorer/Diffuse InfraRed Background Experiment (COBE/DIRBE) Photometric Standard Value (PSV) catalog to the "accepted" values as given in Gezari's "Catalog of Infrared Observations" (CIO). This study encompasses nearly 100 celestial sources over a wide range of intensity and temperature. The results provide an independent statistical verification of the DIRBE point source calibration.

The official COBE/DIRBE calibration is based on a single celestial source for each band. The current calibration, called "Mark 3", provides a transformation from linearized DIRBE digital numbers (DNs) to flux as described in the following table:

DIRBE Mark 3 Calibration -- 11 July 1995

Band #	Source	$\frac{(W/m^2 - Sr)}{MJy/Sr}$	$\frac{Jy}{DN}$	$\frac{MJy/Sr}{DN}$	$\frac{\nu I\nu\,(W/m^2 - Sr)}{DN}$	uncertainty %
1	Sirius	2.46468e-007	51.035	0.426	1.0224e-006	3
2	Sirius	8.86400e-008	55.522	0.391	5.3318e-007	3
3	Sirius	7.56593e-008	43.433	0.338	2.8971e-007	3
4	Sirius	2.45934e-008	43.597	0.298	1.8245e-007	3
5	Sirius	1.64531e-007	161.108	1.129	2.8225e-007	4
6	NGC7027	6.15779e-008	212.139	1.457	1.7484e-007	15
7	Uranus	1.17295e-007	722.736	4.780	2.3900e-007	11
8	Uranus	3.91026e-008	556.605	3.906	1.1718e-007	13
9	Jupiter	4.79821e-007	10539.851	76.100	1.6307e-006	11
10	Jupiter	2.09268e-007	5358.150	40.500	5.0625e-007	12

This study reports an independent statistical check on this calibration using an ensemble of celestial sources for each DIRBE band.

2 DIRBE INSTRUMENT DESCRIPTIONS

DIRBE is a 10 band, single element, superfluid He cooled, off-axis Gregorian telescope. Following the Mark3 conventions, the DIRBE wavebands are defined as:

DIRBE Band	Wavelength (microns)	Bandwidth (microns)	Beam Size (steradian)
1	1.25	0.30	1.98E-04
2	2.20	0.37	1.42E-04
3	3.50	0.91	1.29E-04
4	4.90	0.66	1.46E-04
5	12.00	7.00	1.43E-04

6	25.00	8.80	1.46E-04
7	60.00	29.45	1.51E-04
8	100.00	33.37	1.43E-04
9	140.00	41.19	1.39E-04
10	240.00	99.21	1.32E-04

3 METHODOLOGY

We performed a blind test of the new Mark 3 calibrated DIRBE point source PSV catalog obtained from the COBE web site:

http://bolero.gsfc.nasa.gov/astro/cobe_home.html

The PSV catalog contains DIRBE-constructed PSVs in janskys for 92 BEX_COL (DIRBE EXternal Calibrator Object List) sources in all bands for which the source was an approved DIRBE calibrator, and for which an average could be constructed. The catalog also contains the RMS, the backgrounds, and the number of observations. The PSV catalog contains sources useful for calibration from 1-200 microns, covering non-stellar objects and stellar spectral types from A to M over a wide dynamic range. The DIRBE PSV values are produced by averaging over typically 500 single observations of each source, and have been background-subtracted using spatial differencing. The typical RMS for the resulting averages are about 10^{-3} of the source flux.

Our objective was to create a "predicted" PSV catalog from the CIO. We used the 1994 version of the Catalog of Infrared Observations (CIO) from the NSSDC (National Space Science Data Center). NASA Reference Publication 1196, 3rd Edition, 1994, Gezari, Schmitz, Mead. The 1994 version contains more years of data (both earlier and later) from the literature than does the 1987 ADC CD-ROM version. The CIO is an un-edited compilation of values from the literature, with native units spanning many systems from magnitudes, Janskys, W/cm^2 "inband", W/cm^2 "λIλ", radiance, irradiance, spectral, inband, and so on.

We first filtered the CIO into a smaller catalog containing all observations of the 92 BEX_COL objects in bands that overlapped DIRBE bands. We then derived photometric transformations from the various CIO flux units into both janskys (the units of the DIRBE catalog) and W/(cm^2-sr-μm).

Because the CIO only contains effective wavelengths but not bandwidths, we were able to transform the native CIO observations to the proper effective wavelength, but were unable to correct for bandwidth for the CIO inband observations, as that would require manually researching the original CIO source literature which is beyond the scope of this study. No color corrections were attempted with the CIO data, as it would again require manually reviewing the CIO source literature.

We then created the "CIO predicted" PSV catalog by robust averaging all the CIO-observations of each BEX_COL source in each band, keeping the rms and number of observations. Extreme outliers in this distribution were discarded.

We next did a catalog search for the spectral types of all the stellar BEX_COL sources. We were able to find spectral types for over 3/4 of the sources. We assigned an effective blackbody temperature to each star based on its spectral type. Finally we applied a DIRBE-band color correction to the calibrated DIRBE fluxes. Sources, particularly the non-stellar sources, that we could not get a spectral type or temperature for were not color corrected.

As will be discussed more fully later, we used the Sharpless catalog to get the spatial size of several of the longer wavelength sources. Given the source sizes in conjunction with the DIRBE and CIO reported beam sized, we were able to do a primitive spatial extent correction on the appropriate non-stellar data.

Finally, we compared the CIO-predicted and observed PSVs, calculating RMS delta_flux, and flagging all those observations which did not fit into each others RMS (root-mean-square) uncertainties. We did this in both janskys and W/(cm^2-sr-μm). We plotted a flux vs. flux correlation plot for all the sources in each DIRBE band. We calculated two statistical metrics: The correlation coefficients:

$$k = \frac{\sum x_i y_i}{\sqrt{\sum x_i^2 \sum y_i^2}}$$

and the band-averaged percent differences:

$$d = \frac{\sum |x_i - y_i|}{\sum \left(\frac{x_i + y_i}{2} \right)}$$

Where the x_i and y_i are the DIRBE and CIO measurement sets respectively. There were typically ~500 measurements in the DIRBE ensemble for each source for each band. The CIO in contrast typically contained only ~10 measurements in an equivalent ensemble.

4 RESULTS

The enclosed plots and table in Appendices A & B respectively give the CIO-predicted and observed flux in W/(cm^2-sr-μm) (abbreviated as "wcsu"), RMSs, number of observations, and DIRBE-derived backgrounds for all CIO observations of DIRBE BEX_COL sources for all bands in which the source is an approved calibrator. Where sources or bands are missing it is because either the CIO did not contain relevant observations, or DIRBE was unable to construct a PSV. The final four columns contain the absolute and percent differences between the predicted and observed RMS PSVs, as well as a flag for those RMS observations which did not fit into each others RMS uncertainties (0:agree, 1:disagree). The last column gives the assigned source spectral type where available.

There was no overlapping data between the CIO and DIRBE for band 10.

The figures in Appendix A are correlation plots between DIRBE and CIO flux. If DIRBE and the various CIO observations were all in perfect agreement, all the points would fall on the 1:1 line indicated. The CIO errorbars (horizontal) are from the RMS of the various CIO measurements of that star in that band. The DIRBE errorbars (vertical) are the DIRBE RMS error. The DIRBE errors are typically too small to show up on the plots, though they are tabulated below.

The "band-average-percent difference" d is a measure of how well the DIRBE points agree with the CIO points on average, over each DIRBE band.

The correlation coefficient k is a measure of how well the data fits the 1:1 line.

5 CONCLUSIONS

5A GENERAL CONCLUSIONS

DIRBE was able to construct internal PSVs that agree with the literature, especially in the shorter wavelengths (bands 1-6). Longer wavelengths (bands 7-9) are not as good. Remember that we did not typically color correct the non-stellar fluxes. There are only 3 overlapping sources in each of the bands 7-9. and they are all extended sources. This leads to possible systematic errors that will be discussed later.

The agreement between the predicted and observed PSV over many bands and many sources is encouraging. Almost all the disagreement (deltas of more ~5 %) we attribute to beam size effects due to bright backgrounds, or the source having extended IR structure. Some of the remaining anomalies may be related to unknown or uncorrected bandwidths. Many of the CIO observations are ground-based, so errors in the original investigators' atmospheric corrections may also contribute to the differences.

This current work represents a significant improvement over the preliminary version that we reported last year. The previous version used the older CIO database, the older "mark 2" DIRBE calibration, and performed no color or beam size corrections. With these improvements, the typical percent difference between the cio-derived predicted PSVs and the actual DIRBE PSVs has been significantly reduced.

5B SHORT WAVELENGTHS

As expected, in DIRBE bands 1-4 (1-5 microns), we have many clean stellar point sources, typically with good temperature/spectral type corrections. The correlations and percent differences are excellent.

5C MEDIUM WAVELENGTHS

In DIRBE bands 5 and 6 (12 and 25 microns) we begin to have several non-stellar sources in the comparison. Because the zodiacal light is integrated over a large field of view, the point sources are typically 10-100 times fainter than the average background. The pipeline processing algorithm which generated the PSV catalog subtracted an *average* background over the 10 months of observations. Because the Zodiacal Light is a strongly time dependent background, this leads to a residual systematic background error. This average background can be corrected in principle by re-creating a point-source average value from the real data, but this time subtracting the zodiacal signal for the appropriate position and date prior to averaging, but this effort is beyond the scope of this study.

There are numerically fewer comparison sources in the statistical samples for the medium wavelength regime. Even with these limitations, the correlations and percent errors are still good.

5D LONG WAVELENGTHS

In the longer 60-140 micron wavelength bands (DIRBE bands 7-9) There are many possible systematic and random errors. One of the biggest limitations is the very small number of sources available: only 3 sources in each band. This makes the statistics inherently poor. In addition, *every* source in these bands is an extended cool object, typically much larger than the CIO beam sizes. The Sharpless catalog reports the angular sizes to be:

Source Name	Angular Size (arcmin)	# Assoc Stars	Typical CIO_beam Size (arcsec)
S140	30	1	120
S184	40	1	30
S222	6	0	37
S235	10	0	180
S254-257	~15	1	50

Remember that the DIRBE beam size was about 1.5e-4 sr, or about 0.7 deg.

In addition the Sharpless catalog indicates that all these sources are morphologically "elliptical/filamentary", i.e. exhibit strong spatial structure. We did only a rudimentary area-ratio correction to the CIO flux, essentially calculating what the CIO measurement should have been if it spanned the entire spatial extent of the structure, and assuming that the source was spatially uniform. This is expected to be a gross overcorrection, so we assigned the resulting CIO uncertainties to be 100%.

The band 7-9 plots show two sets of points: the beam-uncorrected data are the standard boxes with solid CIO errorbars. The beam-corrected data are the * symbols with the dashed CIO errorbars. Before the angular size corrections, the DIRBE data is systematically higher than the CIO data, but still roughly parallel to the ideal 1:1 correlation line. As expected, because the CIO beams are typically much smaller than the sources, while DIRBE typically integrates the entire spatial extent.

Systematic effects are also expected due to the lack of color corrections in either these non-stellar objects or the backgrounds, though the spatial corrections dominate.

It should be noted that the detectors in these long wavelength bands also exhibited extreme non-linear behavior, with uncorrected residuals typically near 10-20 percent.

Appendix A:

Presentation given at session 51.03 of AAS 189, 14 January 1997, Toronto, Ontario, Canada.

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Center for Science and Phenomenology

COBE/DIRBE Point Source Photometry Comparison

Session 51.03, AAS 189
14 January 1997
Toronto, Ontario, Canada

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Abstract

We report the results of a comparative study of the COsmic Background Explorer/Diffuse InfraRed Background Experiment (COBE/DIRBE) photometric calibration over ~100 selected stellar and non-stellar calibration objects across a wide range of the DIRBE instrument dynamic range, wavelength coverage, and source temperature. A statistical comparison of the DIRBE-reported flux to the accepted values from the literature (as summarized in the CIO) provides an independent verification of the DIRBE point source calibration.

The DIRBE Instrument

- 10 band Radiometer

Band	Wavelength (microns)	Bandwidth (microns)	Beam Size (steradian)
1	1.25	0.30	1.98E-04
2	2.20	0.37	1.42E-04
3	3.50	0.91	1.29E-04
4	4.90	0.66	1.46E-04
5	12.00	7.00	1.43E-04
6	25.00	8.80	1.46E-04
7	60.00	29.45	1.51E-04
8	100.00	33.37	1.43E-04
9	140.00	41.19	1.39E-04
10	240.00	99.21	1.32E-04

- Single element He cooled detectors
- Off-axis Gregorian telescope

Methodology: Overview

- We compare the DIRBE observed flux to the accepted literature:
  - Wide wavelength range (1-200 microns)
  - Wide temperature range (A-M spectral type stars...)
  - Multiple sources (~100)
  - Wide dynamic range
- DIRBE:
  - The 92 source DIRBE Photometric Standard Values (PSV) obtained from the COBE web site:
    - » http://bolero.gsfc.nasa.gov/astro/cobe/cobe_home.html
    - » Typically
      - ~ 500 observations of a given calibration object
      - Background subtracted and averaged
      - RMS ~ 10^{-3} of source flux
- Accepted Values:
  - The Catalog of Infrared Observations (CIO), NASA Reference Publication 1196, 3rd Edition, 1994. Gezari, Schmitz, Mead.

Methodology: DIRBE Processing

- Transform the DIRBE catalog entries from Janskys to W/(cm^2-sr-μm).
- Look up spectral type and/or temperatures for most DIRBE sources.
- Apply DIRBE instrument color corrections to observations.

Methodology: CIO Processing

- Filter the CIO electronic catalog for all entries containing DIRBE PSV sources that overlap the DIRBE wavelength bands.
- Transform the selected CIO entries to W/(cm^2-sr-μm).
- Calculate weighted robust average & RMS of all CIO values:
  - For each DIRBE source
  - For each DIRBE wavelength
- Create a "predicted" DIRBE PSV catalog subset from resulting CIO database.
- No color corrections done with CIO data.
  - Not possible without going to original source literature
  - Little expected gain for large effort

Methodology: Comparison

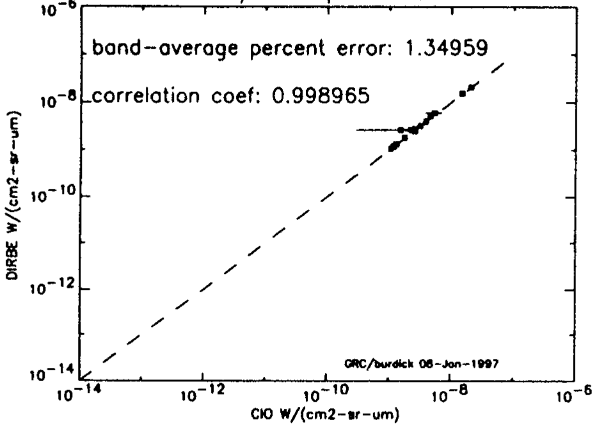
- Correlation plots by DIRBE band for overlapping data.
- Error bars in both DIRBE & CIO axes from the RMS of multiple observations.
- Calculate correlation coefficients:
  $k=\mathrm{sum}(x_i * y_i)/\mathrm{sqrt}(\mathrm{sum}(x_i^2) * \mathrm{sum}(y_i^2))$
- Calculate band-average percent errors:
  $d=\mathrm{sum}(\mathrm{abs}(x_i - y_i))/(\mathrm{sum}(x_i + y_i)/2)$

Cautions

- Possible systematic errors for longer wavelengths:
  - Temperature/color correction errors:
    - Background
    - Source
  - Beam size effects:
    - Extended sources
    - Background effects
- CIO is a "metacatalog" of mixed quality.

Correlation Plots

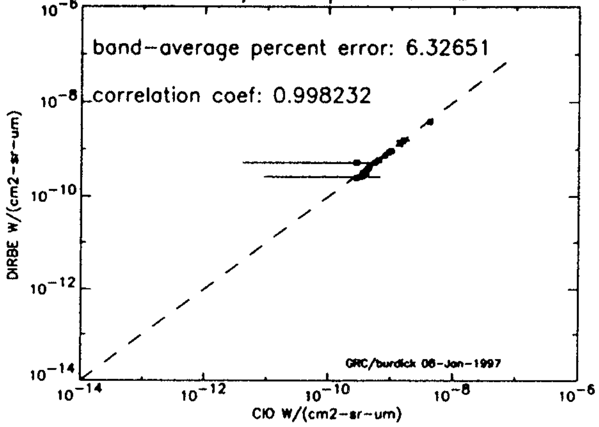
DIRBE/CIO Comparison: Band 1



band-average percent error: 1.34959

correlation coef: 0.998965

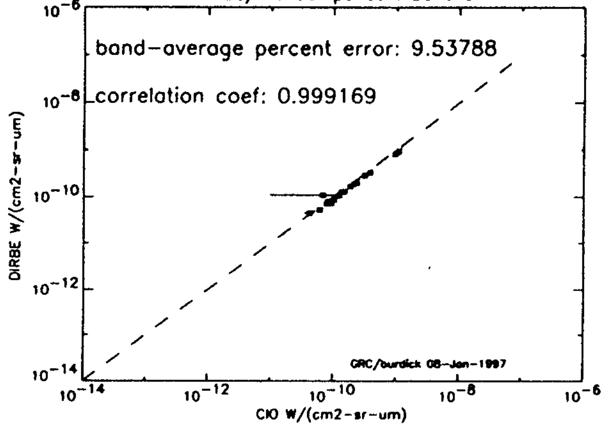
DIRBE/CIO Comparison: Band 2



band-average percent error: 6.32651

correlation coef: 0.998232

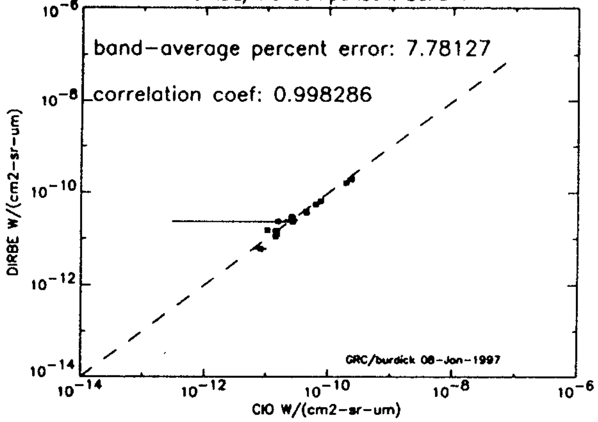
DIRBE/CIO Comparison: Band 3



band-average percent error: 9.53788

correlation coef: 0.999169

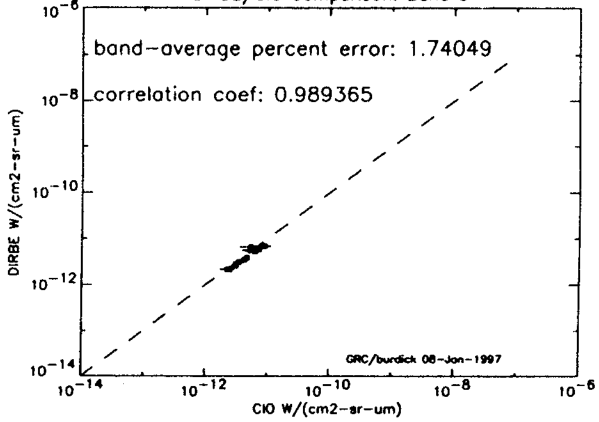
DIRBE/CIO Comparison: Band 4



band-average percent error: 7.78127

correlation coef: 0.998286

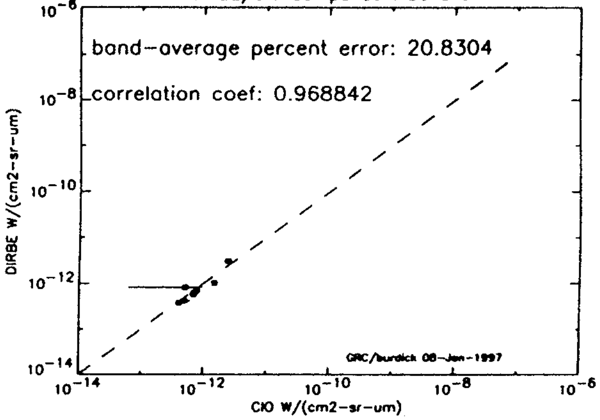
DIRBE/CIO Comparison: Band 5



band-average percent error: 1.74049

correlation coef: 0.989365

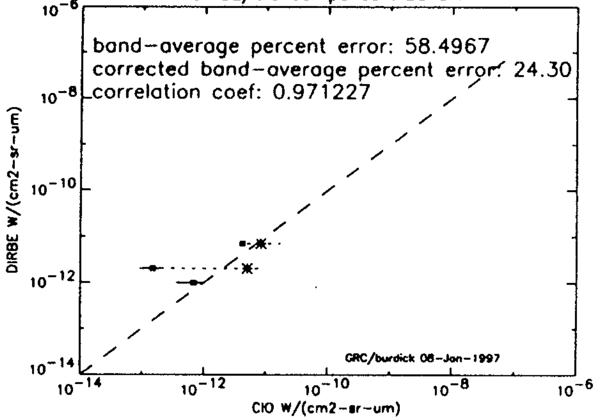
DIRBE/CIO Comparison: Band 6



band-average percent error: 20.8304

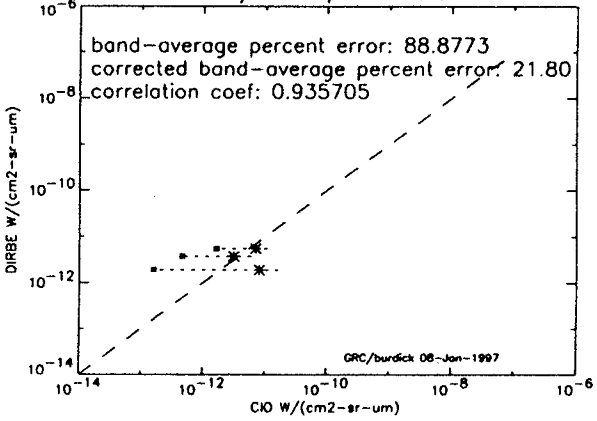
correlation coef: 0.968842

DIRBE/CIO Comparison: Band 7



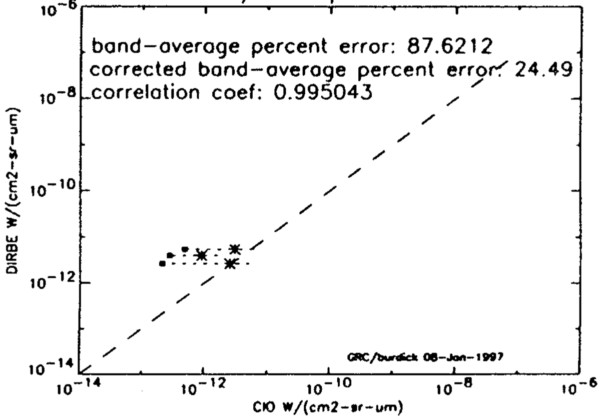
band-average percent error: 58.4967
corrected band-average percent error: 24.30
correlation coef: 0.971227

DIRBE/CIO Comparison: Band 8



band-average percent error: 88.8773
corrected band-average percent error: 21.80
correlation coef: 0.935705

DIRBE/CIO Comparison: Band 9



band-average percent error: 87.6212
corrected band-average percent error: 24.49
correlation coef: 0.995043

Discussion: Shorter Wavelengths

- DIRBE bands 1-4 (1.25 - 4.9 µm):
  - Stellar sources:
    - Point-like sources
    - Good temperature/spectral type data
  - Many sources per waveband: good statistics.
  - Excellent correlation & good calibration.

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Discussion: Medium Wavelengths

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- DIRBE bands 5 & 6 (12 - 25 µm):
  - Some non-stellar sources
  - Sources typically 10-100 times fainter than background
  - Not as many common DIRBE/CIO sources
  - Good correlations & reasonable calibration

Discussion: Longer Wavelengths

- DIRBE bands 7-9 (60 - 140 μm):
  - Few overlapping sources: poor statistics
  - Roughly parallel with ideal 1:1 line
  - DIRBE systematically higher than CIO values
  - Systematic errors:
    - Temperature/color corrections
    - Beam size/source size
- DIRBE band 10 (240 μm):
  - No overlapping data

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Band 7, 8, 9 Systematics

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- 6 sources: 5 Sharpless HII regions & M82.
- Estimate beam size correction factors & errors:
  - 42 min DIRBE beam vs typically ~30-120 sec CIO beams
  - Sharpless sources typically:
    - 10-50m angular size
    - Elliptical, filamentary shape
  - Implies DIRBE values up to ~50 times greater than CIO
  - The correction factors are upper bounds
  - Apply Corrections to CIO data:
    - Plotted as * symbols
    - Corrected CIO uncertainty taken as 100% (dashed lines)

Appendix B:

The Following table is the result of the IDL analysis routines used to process the data in this study. The columns contain:

bex#	DIRBE BEX_COL (EXternal Calibrator Object List) number
bex_name	DIRBE BEX_COL source name
band	DIRBE band
CIO_wcsu	CIO average flux in w/(cm^2-sr-μm)
CIO_rms	CIO rms uncertainty
CIO_#obs	number of observations in CIO ensemble for this source in this band
psv_wcsu	DIRBE average flux in w/(cm^2-sr- μm)
psv_rms	DIRBE rms uncertainty
psv_bkg	DIRBE constructed background flux
psv_#obs	number of observations in DIRBE ensemble for this source in this band
delta	the difference between the CIO and DIRBE flux in w/(cm^2-sr- μm)
frac	the ratio between the CIO and DIRBE flux
flag	a flag to indicate top-level agreement: 0:agree, 1:disagree
spctyp	source spectral type if known

Detailed Table of DIRBE/CIO Source Comparison Results:
Comparison of DIRBE calibrated PSC vs CIO average values: run date: 29-Dec-1996 20:42:29.00
Predicted DIRBE JYs (avg of CIO BEX_COL obs w/ mark3 cal) GRC/burdick 19-Dec-1996

bex#	bex_name	band	CIO_wcsu	CIO_rms	CIO _#obs	psv_wcsu	psv_rms	psv_bkg	psv_#obs	delta	frac	flag	spctyp
27	ALP-CAS	1	1.76e-009	0.00e+000	2	1.812e-009	1.476e-012	1.408e-010	674	2.230e-011	0.012	1	K0
27	ALP-CAS	2	3.98e-010	3.74e-011	3	3.476e-010	2.555e-013	3.620e-011	613	5.491e-011	0.160	1	K0
27	ALP-CAS	3	9.29e-011	0.00e+000	2	7.211e-011	5.818e-014	8.900e-012	654	2.059e-011	0.285	1	K0
27	ALP-CAS	4	1.04e-011	0.00e+000	1	1.499e-011	1.630e-014	7.127e-012	716	4.823e-012	0.316	1	K0
115	S184	7	1.49e-013	5.70e-014	2	2.012e-012	9.121e-015	1.075e-012	342	2.753e-012	0.949	1	M0
115	S184	8	1.59e-013	0.00e+000	1	1.892e-012	9.233e-015	6.476e-013	300	2.104e-012	0.930	1	M0
71	BET-AND	1	5.36e-009	1.54e-009	14	5.996e-009	3.992e-012	6.808e-011	364	5.602e-010	0.095	0	M0
71	BET-AND	2	1.57e-009	3.66e-010	23	1.553e-009	5.295e-013	1.563e-011	366	3.372e-011	0.022	0	M0
71	BET-AND	3	3.88e-010	2.84e-011	15	3.353e-010	1.486e-013	3.998e-012	350	5.231e-011	0.156	1	M0
71	BET-AND	4	7.44e-011	7.95e-012	14	6.458e-011	2.551e-014	6.424e-012	463	8.745e-012	0.133	1	M0
71	BET-AND	5	3.04e-012	3.01e-013	38	2.588e-012	1.229e-014	3.693e-011	345	4.372e-014	0.015	0	M0
88	GAM-AND	1	2.61e-009	1.37e-010	4	2.776e-009	1.460e-012	8.250e-011	479	1.239e-010	0.045	0	K3
88	GAM-AND	2	6.38e-010	2.76e-011	5	5.963e-010	2.141e-013	1.912e-011	481	4.815e-011	0.082	1	K3
88	GAM-AND	3	1.34e-010	1.01e-011	6	1.276e-010	5.896e-014	4.678e-012	488	6.440e-012	0.050	0	K3
88	GAM-AND	4	2.52e-011	0.00e+000	1	2.505e-011	1.666e-014	6.263e-012	573	2.326e-013	0.009	1	K3
113	ALP-CET	1	4.61e-009	3.03e-010	11	4.978e-009	3.425e-012	6.707e-011	346	3.117e-010	0.063	1	M2
113	ALP-CET	2	1.39e-009	7.28e-011	13	1.318e-009	4.535e-013	1.458e-011	340	8.514e-011	0.065	1	M2
113	ALP-CET	3	3.19e-010	2.53e-011	17	2.885e-010	1.596e-013	4.139e-012	338	3.033e-011	0.105	1	M2
113	ALP-CET	4	6.24e-011	6.21e-012	8	5.469e-011	2.516e-014	7.022e-012	432	6.874e-012	0.124	1	M2
93	RHO-PER	5	3.41e-012	6.65e-013	9	3.142e-012	1.162e-014	3.998e-011	419	2.081e-013	0.057	0	M4
120	S222	3	4.15e-011	7.15e-012	5	4.392e-011	8.019e-014	7.730e-012	255	2.392e-012	0.054	0	
120	S222	4	2.59e-011	3.04e-012	4	3.000e-011	4.678e-014	7.753e-012	355	4.061e-012	0.135	1	
120	S222	8	4.60e-013	9.09e-013	12	3.708e-012	1.015e-014	6.880e-013	163	3.247e-012	0.876	1	
112	ALP-TAU	1	1.49e-008	1.03e-009	15	1.551e-008	1.633e-011	1.126e-010	262	4.174e-010	0.027	0	K5
112	ALP-TAU	2	4.13e-009	3.89e-010	28	3.854e-009	1.690e-012	2.649e-011	261	3.165e-010	0.083	0	K5
112	ALP-TAU	3	9.56e-010	3.85e-011	29	8.263e-010	6.706e-013	8.104e-012	244	1.287e-010	0.156	1	K5
112	ALP-TAU	4	1.89e-010	1.29e-011	29	1.615e-010	7.052e-014	8.101e-012	308	2.504e-011	0.153	1	K5
112	ALP-TAU	5	7.21e-012	4.70e-013	82	5.998e-012	1.967e-014	4.542e-011	319	2.438e-013	0.035	0	K5
122	S235	9	2.76e-013	0.00e+000	1	3.925e-012	3.123e-014	1.539e-012	304	3.475e-012	0.926	1	K5
125	S254-257	6	2.42e-012	2.87e-013	2	3.077e-012	1.028e-014	2.198e-011	283	6.601e-013	0.215	1	
125	S254-257	9	2.11e-013	0.00e+000	1	2.621e-012	3.461e-014	1.404e-012	211	2.411e-012	0.920	1	

32	PI-PUP	2	7.95e-010	3.66e-012	2	7.426e-010	2.233e-013	2.295e-011	730	6.072e-011	0.083	1	MA
32	PI-PUP	3	1.87e-010	0.00e+000	1	1.692e-010	8.334e-014	5.939e-012	723	1.822e-011	0.108	1	MA
74	M82	6	5.09e-013	4.48e-013	12	8.140e-013	4.056e-015	1.149e-011	516	3.048e-013	0.374	0	
74	M82	7	6.83e-013	3.29e-013	12	9.916e-013	1.514e-015	6.592e-013	546	3.090e-013	0.312	0	
12	GAM1LEO	1	1.50e-009	1.22e-009	5	2.607e-009	2.555e-012	6.245e-011	226	1.068e-009	0.416	0	K0
12	GAM1LEO	2	2.79e-010	2.75e-010	8	5.301e-010	3.108e-013	1.381e-011	236	2.449e-010	0.467	0	K0
12	GAM1LEO	3	6.83e-011	5.85e-011	7	1.100e-010	7.940e-014	3.596e-012	245	4.199e-011	0.381	0	K0
12	GAM1LEO	4	1.53e-011	1.50e-011	2	2.334e-011	2.339e-014	6.718e-012	304	8.422e-012	0.355	0	K0
36	MU-UMA	2	6.36e-010	5.85e-011	14	6.020e-010	2.693e-013	1.130e-011	332	4.119e-011	0.069	0	M0
36	MU-UMA	3	1.51e-010	6.23e-012	10	1.302e-010	8.648e-014	3.022e-012	339	2.054e-011	0.158	1	M0
36	MU-UMA	4	2.49e-011	5.43e-012	9	2.526e-011	1.984e-014	5.595e-012	409	7.389e-013	0.029	0	M0
14	VY-LEO	4	2.65e-011	4.94e-012	3	2.540e-011	2.481e-014	7.449e-012	265	7.002e-013	0.027	0	M5
37	R-CRT	5	5.38e-012	1.92e-012	3	6.537e-012	1.498e-014	3.877e-011	297	2.245e-012	0.295	1	K0
37	R-CRT	6	7.81e-013	1.15e-013	2	6.877e-013	6.293e-015	1.709e-011	301	5.341e-013	0.406	1	K0
15	ALP-UMA	1	2.62e-009	1.45e-010	2	2.707e-009	1.305e-012	4.571e-011	559	4.323e-011	0.016	0	K0
5	ALP-UMA	2	5.51e-010	3.40e-011	4	5.217e-010	1.542e-013	9.335e-012	579	3.567e-011	0.069	1	K0
15	ALP-UMA	3	1.24e-010	2.68e-012	6	1.080e-010	4.796e-014	2.531e-012	605	1.588e-011	0.147	1	K0
15	ALP-UMA	4	2.65e-011	9.70e-013	4	2.303e-011	1.311e-014	4.851e-012	722	3.070e-012	0.131	1	K0
16	LAM-DRA	3	8.09e-011	0.00e+000	2	7.074e-011	5.267e-014	2.480e-012	886	1.016e-011	0.144	1	M0
38	OMEG-VIR	1	1.18e-009	1.63e-011	2	1.177e-009	1.056e-012	7.611e-011	340	1.682e-011	0.014	0	M4
38	OMEG-VIR	2	3.87e-010	1.45e-011	3	3.463e-010	2.118e-013	1.626e-011	340	4.485e-011	0.131	1	M4
38	OMEG-VIR	3	8.24e-011	0.00e+000	1	7.787e-011	6.211e-014	4.494e-012	331	4.697e-012	0.060	1	M4
38	OMEG-VIR	4	1.40e-011	0.00e+000	1	1.472e-011	1.878e-014	8.935e-012	384	9.449e-013	0.063	1	M4
65	Y-UMA	5	2.27e-012	5.70e-013	9	2.171e-012	6.705e-015	2.837e-011	725	2.153e-013	0.087	0	M8
44	TU-CVN	1	1.06e-009	1.46e-011	2	1.041e-009	9.709e-013	4.207e-011	511	2.563e-011	0.025	1	M5
44	TU-CVN	2	3.49e-010	1.66e-011	3	3.140e-010	2.072e-013	9.489e-012	501	3.842e-011	0.124	1	M5
44	TU-CVN	3	7.83e-011	1.80e-012	2	7.115e-011	5.739e-014	2.759e-012	540	7.398e-012	0.104	1	M5
44	TU-CVN	4	1.47e-011	2.03e-013	2	1.381e-011	1.417e-014	6.064e-012	695	7.093e-013	0.051	1	M5
45	DEL-VIR	1	3.16e-009	1.90e-010	9	3.218e-009	3.542e-012	9.571e-011	339	2.630e-011	0.008	0	MA
45	DEL-VIR	2	9.03e-010	9.65e-011	12	8.678e-010	4.972e-013	2.110e-011	333	4.488e-011	0.052	0	MA
45	DEL-VIR	3	2.16e-010	7.12e-012	8	1.920e-010	1.682e-013	5.813e-012	343	2.424e-011	0.127	1	MA
45	DEL-VIR	4	4.43e-011	2.82e-012	3	3.643e-011	2.233e-014	1.508e-011	427	7.376e-012	0.200	1	MA
46	RT-VIR	5	5.30e-012	1.41e-012	7	5.502e-012	1.520e-014	7.499e-011	382	1.033e-012	0.163	0	MA
46	RT-VIR	6	6.76e-013	5.63e-014	2	5.892e-013	5.454e-015	3.478e-011	374	4.379e-013	0.393	1	MA
48	CU-DRA	1	1.13e-009	4.46e-011	3	1.158e-009	5.981e-013	4.375e-011	1099	1.111e-011	0.010	0	M3
48	CU-DRA	2	3.49e-010	1.92e-011	4	3.208e-010	9.438e-014	9.403e-012	1048	3.125e-011	0.098	1	M3
50	BY-BOO	1	1.25e-009	4.75e-011	5	1.315e-009	7.223e-013	4.373e-011	688	5.580e-011	0.043	1	M4
50	BY-BOO	2	4.17e-010	1.95e-011	6	3.848e-010	1.197e-013	9.693e-012	661	3.585e-011	0.094	1	M4
50	BY-BOO	3	1.04e-010	5.23e-012	4	8.624e-011	4.167e-014	3.034e-012	696	1.780e-011	0.207	1	M4

49	ALP-BOO	1	2.04e-008	2.02e-009	15	2.077e-008	1.484e-011	7.557e-011	320	6.576e-011	0.003	0	K2
49	ALP-BOO	3	1.08e-009	6.47e-011	31	9.275e-010	4.654e-013	5.481e-012	336	1.519e-010	0.163	1	K2
49	ALP-BOO	4	2.28e-010	1.62e-011	26	1.920e-010	5.068e-014	1.371e-011	427	3.295e-011	0.169	1	K2
49	ALP-BOO	5	8.81e-012	2.42e-012	82	6.885e-012	1.095e-014	5.403e-011	476	8.048e-013	0.100	0	K2
49	ALP-BOO	6	4.98e-013	1.12e-013	11	4.169e-013	4.195e-015	1.979e-011	336	2.970e-013	0.373	1	K2
51	BET-UMI	1	3.93e-009	0.00e+000	1	3.977e-009	2.206e-012	4.180e-011	544	1.016e-011	0.003	1	K4
51	BET-UMI	2	9.95e-010	6.86e-011	2	9.336e-010	2.670e-013	9.993e-012	561	7.155e-011	0.078	1	K4
97	ALP-SER	1	1.30e-009	4.11e-011	5	1.315e-009	1.041e-012	8.867e-011	449	8.522e-012	0.007	0	K2
97	ALP-SER	2	2.79e-010	7.69e-012	6	2.525e-010	1.957e-013	1.970e-011	448	2.967e-011	0.119	1	K2
97	ALP-SER	3	6.12e-011	7.32e-013	4	5.244e-011	4.796e-014	6.553e-012	465	8.696e-012	0.166	1	K2
97	ALP-SER	4	1.39e-011	0.00e+000	1	1.091e-011	1.417e-014	1.623e-011	500	2.778e-012	0.251	1	K2
70	ST-HER	5	2.43e-012	4.00e-013	3	2.124e-012	6.482e-015	3.023e-011	772	2.894e-015	0.001	0	M8
84	2-HER	4	7.99e-012	2.05e-012	2	5.963e-012	1.772e-014	5.502e-012	78	1.940e-012	0.321	0	M3
66	X-HER	5	6.25e-012	1.67e-012	8	5.223e-012	7.823e-015	3.072e-011	900	2.677e-013	0.045	0	M8
66	X-HER	6	7.06e-013	1.00e-013	3	5.785e-013	3.356e-015	1.193e-011	893	3.805e-013	0.350	1	M8
53	G-HER	6	4.07e-013	4.97e-014	3	3.771e-013	2.587e-015	1.268e-011	669	3.031e-013	0.427	1	M6
110	ALP-HER	6	1.50e-012	8.49e-014	6	1.019e-012	5.244e-015	2.011e-011	443	4.277e-013	0.222	1	M5
54	GAM-DRA	1	3.91e-009	1.55e-010	4	3.899e-009	3.208e-012	5.972e-011	596	7.134e-011	0.019	0	K5
54	GAM-DRA	2	1.02e-009	6.09e-011	7	9.229e-010	3.798e-013	1.335e-011	594	1.086e-010	0.119	1	K5
54	GAM-DRA	3	2.35e-010	9.09e-012	6	1.993e-010	1.148e-013	3.888e-012	619	3.542e-011	0.178	1	K5
54	GAM-DRA	4	4.34e-011	4.00e-013	2	3.841e-011	1.630e-014	7.351e-012	797	4.405e-012	0.113	1	K5
20	ALP-LYR	1	2.58e-009	6.07e-011	27	2.434e-009	1.530e-012	1.058e-010	736	1.743e-010	0.072	1	A0
20	ALP-LYR	2	3.40e-010	3.31e-010	52	2.674e-010	2.279e-013	2.356e-011	608	7.551e-011	0.286	0	A0
20	ALP-LYR	3	6.02e-011	3.16e-012	43	5.124e-011	5.189e-014	6.425e-012	621	8.551e-012	0.166	1	A0
20	ALP-LYR	4	1.47e-011	2.77e-013	32	1.231e-011	1.417e-014	1.025e-011	741	2.167e-012	0.173	1	A0
21	R-LYR	5	4.12e-012	8.32e-013	7	3.458e-012	6.929e-015	3.318e-011	1172	1.437e-013	0.036	0	M5
132	CH-CYG	6	5.08e-013	8.93e-014	3	8.224e-013	3.636e-015	1.153e-011	880	1.049e-012	0.674	1	M3
22	EPS-PEG	1	2.23e-009	4.23e-010	5	2.648e-009	2.237e-012	9.816e-011	274	3.778e-010	0.145	0	K2
22	EPS-PEG	2	6.12e-010	4.08e-011	5	5.931e-010	3.154e-013	2.229e-011	280	2.567e-011	0.044	0	K2
22	EPS-PEG	3	1.45e-010	3.99e-012	2	1.296e-010	9.356e-014	7.308e-012	282	1.479e-011	0.114	1	K2
22	EPS-PEG	4	2.69e-011	4.96e-013	2	2.473e-011	2.233e-014	1.664e-011	331	1.776e-012	0.071	1	K2
76	S-140	7	4.12e-012	3.64e-013	3	7.065e-012	1.701e-014	2.330e-012	614	6.064e-012	0.596	1	M3
76	S-140	8	1.62e-012	1.28e-013	4	5.503e-012	2.525e-014	2.222e-012	542	4.963e-012	0.754	1	M3
76	S-140	9	4.79e-013	0.00e+000	1	5.394e-012	2.109e-014	2.293e-012	929	4.677e-012	0.907	1	M3
58	BET-PEG	5	4.54e-012	4.42e-013	82	3.856e-012	1.274e-014	4.640e-011	381	8.613e-014	0.019	0	M2
72	GZ-PEG	2	4.47e-010	0.00e+000	1	4.191e-010	2.578e-013	2.143e-011	201	3.261e-011	0.079	1	M4
73	HW-PEG	2	4.00e-010	0.00e+000	1	3.277e-010	2.440e-013	1.661e-011	336	7.624e-011	0.235	1	M5

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
3/26/97

3. REPORT TYPE AND DATES COVERED
Final Report 4/1/95-3/31/97

4. TITLE AND SUBTITLE
COBE Final Report DIRBE Clestial Calibration

5. FUNDING NUMBERS
Contract:
NAS5-32475

6. AUTHOR(S)
Dr. Shawn V. Burdick
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
General Research Corporation
5 Cherry Hill Drive, Suite 220
Danvers, MA 01923

8. PERFORMING ORGANIZATION REPORT NUMBER
1994-01-97-CR

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Goddard Space Flight Center

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

We report the results of a comparative study of the COsmic Background Explorer/Diffuse InfraRed Background Experiment (COBE/DIRBE) photometric calibration over about 100 selected stellar and non-stellar calibration objects across a wide range of the DIRBE instrument dynamic range, wavelength coverage, and source temperature. A statistical comparison of the DIRBE-reported flux to the accepted values from the literature (as summarized in the CIO) provides an independent verification of the DIRBE point source calibration.

14. SUBJECT TERMS

15. NUMBER OF PAGES
24

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
unclassified

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std Z39-18
298-102