THE COBE DIRBE POINT SOURCE CATALOG

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ABSTRACT

We present the COBE DIRBE Point Source Catalog, an all-sky catalog containing infrared photometry in 10 infrared bands from 1.25 to 240 μm for 11,788 of the brightest near and mid-infrared point sources in the sky. Since DIRBE had excellent temporal coverage (100–1900 independent measurements per object during the 10 month cryogenic mission), the Catalog also contains information about variability at each wavelength, including amplitudes of variation observed during the mission. Since the DIRBE spatial resolution is relatively poor (0.7'), we have carefully investigated the question of confusion and have flagged sources with infrared-bright companions within the DIRBE beam. In addition, we filtered the DIRBE light curves for data points affected by companions outside of the main DIRBE beam but within the "sky" portion of the scan. At high Galactic latitudes (|b| > 5°), the Catalog contains essentially all of the unconfused sources with flux densities greater than 90, 60, 60, 50, 90, and 165 Jy at 1.25, 2.2, 3.5, 4.9, 12, and 25 μm, respectively, corresponding to magnitude limits of approximately 3.1, 2.6, 1.7, 1.3, −1.3, and −3.5. At longer wavelengths and in the Galactic plane, the completeness is less certain because of the large DIRBE beam and possible contributions from extended emission. The Catalog also contains the names of the sources in other catalogs, their spectral types, variability types, and whether or not the sources are known OH/IR stars. We discuss a few remarkable objects in the Catalog, including the extremely red object OH 231.8+4.2 (QX Pup), an asymptotic giant branch star in transition to a proto-planetary nebula, which has a DIRBE 25 μm amplitude of 0.29 ± 0.07 mag.

Subject headings: catalogs — infrared: stars — stars: AGB and post-AGB — stars: variables: other

Online material: machine-readable tables

1. INTRODUCTION

Infrared surveys provide a window on the content and structure of the Galaxy, being relatively free of the interstellar extinction that compromises measurements at shorter wavelengths. Since the nature of the brightest sources in the sky changes with the infrared wavelength and the majority of these objects are variable, measurements over a large wavelength baseline with a fairly dense sampling in time are needed to fully characterize the sources. At optical and near-infrared wavelengths (≤3 μm), the spectral energy distributions of stars are dominated by radiation from the stellar photosphere, while in the mid-infrared (≥6 μm), emission from circumstellar dust becomes important. In the near-infrared (0.9–2.2 μm), the sky was first surveyed by the Two Micron Sky Survey (TMSS; Neugebauer & Leighton 1969), and more recently by the Two Micron All Sky Survey (2MASS; Cutri 2003) and the DENIS survey (Epchtein et al. 1999). The Infrared Astronomical Satellite (IRAS) survey covered almost the whole sky in the 12–100 μm spectral range (Beichman et al. 1988). The small gaps in the IRAS mid-infrared coverage have since been filled in by the Midcourse Space Experiment (MSX) mission (Price et al. 1999). The most complete survey made so far in the intermediate spectral region between 3 and 6 μm was the Air Force Geophysical Laboratory (AFGL) Infrared Sky Survey, which covered 71% of the sky to a sensitivity of 90 Jy at 4.2 μm (Price & Walker 1976). The more sensitive MSX survey (Price et al. 1999) covered only ~15% of the sky (two-thirds of which was within 6° of the Galactic plane) to a point source limit at 4.3 μm of ~20 Jy.

There is another untapped infrared database suitable for the construction of an infrared point source catalog: the archival data from the Diffuse Infrared Background Experiment (DIRBE; Hauser et al. 1998) on the Cosmic Background Explorer (COBE; Boggess et al. 1992). DIRBE operated at cryogenic temperatures for 10 months in 1989–1990, providing full-sky coverage at 10 infrared wavelengths (1.25, 2.2, 3.5, 4.9, 12, 25, 60, 100, 140, and 240 μm). Although DIRBE was designed to search for the cosmic infrared background, the data are also useful for studying point sources, in spite of its relatively poor spatial resolution (0.7'). To date, however, point source fluxes from DIRBE have been little utilized. During the mission, DIRBE stellar fluxes were mainly used for calibration verification (Burdick & Murdock 1997; Cohen 1998). Recently, we used the DIRBE database to extract high-quality 1.25–25 μm time-sequence infrared photometry for 38 known Mira variable stars (Smith et al. 2002) and 207 high Galactic latitude 12 μm—selected sources (Smith 2003), while Knapp et al. (2003) extracted DIRBE 2.2 μm light curves for a few dozen known variable stars. These studies showed that DIRBE provided good stellar photometry in the six shortest wavelengths. At 4.9 μm, the sensitivity per measurement is


10–15 times during the course of a week, and, on the average, C27 about 400–1000 observations over the mission. Near the ecliptic plane, sources were typically observed roughly twice a day for 2 months, then were inaccessible for 4 months before coming back into view. By comparison, IRAS typically provided only two or three independent flux measurements of a star at 12 \( \mu m \) (Little-Marenin & Stencel 1992), while MSX made up to six observations over a 4 month period (Egan et al. 1999).

In this paper, we describe the DIRBE Point Source Catalog, a database of infrared photometry and variability information for the brightest sources in the infrared sky. In the Smith et al. (2002) study, we specifically targeted asymptotic giant branch (AGB) stars that were known to be Mira variables. Consequently, we neglected non-Mira AGB stars, infrared-bright non-AGB stars, Miras not previously classified as Miras, and very dust-enshrouded stars without bright optical counterparts. In Smith (2003), we studied a complete 12 \( \mu m \) flux-limited sample of 207 IRAS sources at Galactic latitudes \( |b| > 5^\circ \). This study neglected bright stars at the shorter DIRBE wavelengths or at 25 \( \mu m \), as well as stars in the Galactic plane. In the current study, we constructed an all-sky DIRBE Point Source Catalog that extends these earlier studies to include all sources above a uniform signal-to-noise (S/N) selection criterion in each of the six shortest wavelength DIRBE bands, as well as sources in the Galactic plane. The present Catalog contains essentially all of the unconfused high Galactic latitude point sources detected by DIRBE in the six shorter wavelength filters with S/N per individual scan greater than 3–9. These levels are sufficient to provide good light curves. In the Galactic plane and at longer wavelengths the Catalog is less complete.

2. SAMPLE SELECTION

Unlike the IRAS and 2MASS Catalogs, the DIRBE Point Source Catalog was not constructed by searching the DIRBE database with a point source template and extracting sources based on S/N and confirmation criteria. The DIRBE Catalog was constructed using a target sample list obtained from other infrared catalogs. Since DIRBE is much less sensitive per scan than IRAS or 2MASS, essentially all of the point sources with high S/N light curves in the DIRBE database are already contained in IRAS, 2MASS, and/or MSX. Thus, for simplicity we used these previous catalogs to select a sample for the DIRBE Point Source Catalog.

Our initial sample included a total of 21,335 sources; the final Catalog contains 11,788 sources. The initial sample was selected from the IRAS Point Source Catalog (1988), the 2MASS Point Source Catalog (Cutri 2003), and/or the MSX Point Source Catalog Version 1.2 (Egan et al. 1999) that satisfied at least one of the following criteria: (a) 2MASS J magnitude \( \leq 4.51 \) (\( F_{12.2} \geq 25 \) Jy), (b) 2MASS K magnitude \( \leq 3.81 \) (\( F_{22} \geq 20 \) Jy), (c) IRAS or MSX\( F_{12} \geq 15 \) Jy, or (d) IRAS or MSX \( F_{25} \geq 27.5 \) Jy. The 1.25 and 2.2 \( \mu m \) limits are equal to the average 1 \( \sigma \) sensitivity per scan in the raw DIRBE light curves of Smith et al. (2002), while the 12 and 25 \( \mu m \) limits are 0.5 times the average noise levels per scan in that study. These low limits were selected in order to avoid missing variable stars that may have been faint during the 2MASS, IRAS, or MSX mission and to improve the completeness at 3.5 and 4.9 \( \mu m \) (see § 6). Since the filtering process improves the average per measurement uncertainty (see § 5), a sensitive selection criterion is warranted to include as many sources as possible.

There are 7872 sources with 2MASS \( J \leq 4.51 \), 20,492 sources with 2MASS \( K \leq 3.81 \), 4969 sources with IRAS \( F_{12} \geq 15 \) Jy, 40 sources in the MSX IRAS Gaps survey with \( MSX\ F_{12} \geq 15 \) Jy, 2753 sources with IRAS \( F_{25} \geq 27.5 \) Jy, and 18 sources in the MSX IRAS Gaps survey with \( MSX\ F_{25} \geq 27.5 \) Jy. Thus, our initial list is dominated by stars selected by the 2MASS criteria. These lists were merged together to make a single target list, containing 21,335 sources. To merge the 2MASS and IRAS/MSX lists, we used a 60" matching radius. If more than one 2MASS source was within 60" of the IRAS position, we assumed the brightest \( K \) band source was the match.

Note that we did not include sources in our input list based on their 60 and/or 100 \( \mu m \) IRAS flux densities, as extended emission from cirrus becomes more significant at these wavelengths. This means that the DIRBE Point Source Catalog is biased against very cold objects, such as galaxies and molecular clouds. Since we only used the point source catalogs of 2MASS, IRAS, and MSX for source selection, our sample is also biased against extended objects. Note also that we are only targeting sources bright enough to detect their possible variability in the DIRBE database (i.e., sources that may be detected in a single DIRBE scan at least once DIRBE wavelength). By co-adding the full light curves, it may be possible to detect fainter objects in the DIRBE database, but without variability information and with a higher likelihood of confusion. Such co-addition is beyond the scope of the current Catalog.

3. EXTRACTION OF THE DIRBE LIGHT CURVES AND THE CATALOG

For all 21,335 sources in our list, we extracted light curves at all 10 wavelengths from the DIRBE Calibrated Individual Observations database. This database contains the individual calibrated 1/8 second samples taken in science-survey mode during each day of the DIRBE cryogenic mission. For all scans that pass within 0.3 of the target position, a linear baseline is fit to the sections \( \pm 1.35 \) from the point of closest approach. The point source photometry is obtained by subtraction of this baseline and correcting for the DIRBE beam response. The uncertainties in the point source photometry are calculated as the root sum square of the rms noise of the baseline, the photometric error produced by a 1’ error in the in-scan and cross-scan directions, an error due to short-term detector gain variations, and signal-dependent detector noise. The number of individual measurements per light curve ranges from 99 to 1932; the average and median number of data points per light curve are 488 and 423, respectively. The average uncertainties per measurement in the raw 1.25–240 \( \mu m \) light curves are 33, 38, 27, 21, 107, 256, 1567, 3207, 8100, and 4510 Jy, respectively.

The COBE DIRBE Point Source Catalog (Table 1) contains the time-averaged DIRBE flux densities \( F \) in the 10 DIRBE bands for all 11,785 sources in our initial list that had a flux at minimum in the weekly averaged light curve in any of the six shortest DIRBE wavelengths greater than 3 times the average noise per data point, plus three additional sources (see § 6).
| Name | 2MASS Name | IRAS/MSX Name | \( F_{\nu} \) (Jy) | \( \sigma \) (Jy) | \( \langle \text{err} \rangle \) (Jy) | \( \Delta \text{mag} \) | \( \sigma(\Delta \text{mag}) \) | \( N \) |
|------|------------|---------------|-----------------|---------------|----------------|---------------|----------------|-----|
| D00000657P2553112...... | 00000657+2553112 | IRAS 23575+2536 | 162.1 | 47.4 | 12.1 | 0.82 | 0.13 | 180 |
| D00000690P2014145...... | 00000690+2014145 | | 47.8 | 6.9 | 6.2 | 0.35 | 0.22 | 341 |
| D00001353P5541579...... | 00001353+5541579 | | 84.5 | 26.6 | 15.0 | 0.73 | 0.35 | 289 |
| D00001815P6021016...... | 00001815+6021016 | | 324.8 | 52.1 | 25.0 | 0.22 | 0.13 | 265 |
| D00010244P3830145...... | 00010244+3830145 | IRAS 23584+3813 | 83.2 | 11.2 | 7.0 | 0.36 | 0.13 | 378 |

Table 1 is available in its entirety in the electronic edition of the Astrophysical Journal Supplement. A portion is shown here for guidance regarding its form and content.
These flux densities were calculated after filtering the light curves (see §5). The name of the object in the Catalog it was originally selected from is also given (IRAS/MSX and/or 2MASS) in Table 1. Table 1 also contains the number of individual measurements \( N \) available after filtering the light curves, the average uncertainty per measurement (\( \sigma_{\text{err}} \)), and the standard deviation \( \sigma = \sqrt{\sum (F_{\text{err}} - \langle F \rangle)^2 / (N - 1)} \) of the individual flux measurements \( F_i \). Table 1 also gives the observed amplitude \( \Delta\text{mag} \), the uncertainty assigned to that amplitude \( \sigma(\Delta\text{mag}) \) (see §7 for definitions), and the confusion flags (see §§4 and 5 for definitions). The positions given in Table 1 (and the positions used for the extraction) came from either the 2MASS catalog or the IRAS/MSX catalog, with the 2MASS position preferentially used if available. No color corrections have been applied to the data in Table 1 (see Hauser et al. [1998] and Smith [2003] for a discussion of color corrections). The complete filtered light curves for variable sources will be published in a follow-up paper.

4. FLAGGING FOR CONFUSION

For each wavelength, three different confusion flags may be set in the DIRBE Point Source Catalog (see Table 2 for a summary of the flags and Table 3 for some basic statistics on the DIRBE Catalog, including statistics on flagging and number of sources detected above \( \sigma = 3 \) at each wavelength). The first confusion flag is set when a second known infrared-bright source is located within \( 0'5 \) of the target source. We used limits for the brightness of the companion of 25, 20, 20, 10, 30, 55, 320, and 765 Jy for 1.25–100 \( \mu\text{m} \). These are conservative limits, equal to the average per measurement \( \sigma(\Delta\text{mag}) \) (see §7 for definitions), and the confusion flags (see §§4 and 5 for definitions). The positions given in Table 1 (and the positions used for the extraction) came from either the 2MASS catalog or the IRAS/MSX catalog, with the 2MASS position preferentially used if available. No color corrections have been applied to the data in Table 1 (see Hauser et al. [1998] and Smith [2003] for a discussion of color corrections). The complete filtered light curves for variable sources will be published in a follow-up paper.

Table 2

| Flag   | Definition                                                                 |
|--------|-----------------------------------------------------------------------------|
| 1........ | If set to 1, there is another source within 0'5 of the target source above 25, 20, 10, 30, 55, 320, and 765 Jy at 1.25, 2.2, 3.5, 4.9, 12, 25, 60, and 100 \( \mu\text{m} \). This flag is not set at 140 and 240 \( \mu\text{m} \). |
| 2........ | If set to 1, the DIRBE photometry at minimum (in the weekly averaged light curve) is greater than that of 2MASS or IRAS/MSX by more than \( 3 \sigma \), or the DIRBE photometry at maximum is less than that of 2MASS or IRAS/MSX by more than \( 3 \sigma \). This flag is not set at 3.5, 4.9, 140, and 240 \( \mu\text{m} \). |
| 3........ | If set to 1, the rms/err for a two-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering. |

4. FILTERING OF THE LIGHT CURVES

Another issue is the possibility of more distant companions outside of the main DIRBE beam, affecting the "sky" fluxes used in the photometry extraction. Inspection of the DIRBE data showed that, if a second infrared-bright star is between about 0'5–2'5 of the target star and if a scan happened to pass near that second star, flux from the nearby star sometimes contributed to the "sky flux" used to calculate the photometry.
| STATISTIC                                                                 | 1.25 μm | 2.2 μm | 3.5 μm | 4.9 μm | 12 μm | 25 μm | 60 μm | 100 μm | 140 μm | 240 μm |
|--------------------------------------------------------------------------|---------|--------|--------|--------|-------|-------|-------|--------|--------|--------|
| Average uncertainty per data point in raw light curves (Jy)             | 33      | 38     | 27     | 21     | 107   | 256   | 167   | 3207   | 8100   | 4510   |
| Average uncertainty per data point in filtered light curves (Jy)        | 30      | 7      | 17     | 7      | 18    | 32    | 468   | 3207   | 8100   | 4510   |
| Estimated completeness limit for $|b| \geq 5'$ for DIRBE catalog input list (Jy) | 90      | 60     | 60     | 50     | 90    | 165   | ...   | ...    | ...    | ...    |
| Number detected with S/N > 3 per data point                             | 6328    | 8203   | 6338   | 4688   | 894   | 502   | 448   | 395    | 136    | 209    |
| Number flagged for companion in beam                                    | 5943    | 9825   | 1126   | 4848   | 3907  | 3262  | 2513  | 2674   | ...    | ...    |
| Number flagged for discrepancy with other photometry                    | 198     | 152    | ...    | 308    | 173   | 249   | 186   | ...    | ...    | ...    |
| Number flagged for 2 week rms/(err) ≥ 3                                 | 1171    | 1997   | 7274   | 1989   | 2242  | 2325  | 3889  | 3940   | 2774   | 3322   |
| Number unflagged >3 σ detections per data point with $N \geq 100$       | 2521    | 3361   | 3513   | 2352   | 311   | 145   | 56    | 77     | 44     | 47     |
| Number unflagged >3 σ detections per data point with >3 σ amplitudes and $N \geq 100$ | 126     | 223    | 310    | 222    | 85    | 42    | 0     | 2      | 1      | 0      |
### Table 4
2MASS/IRAS/MSX Photometry for DIRBE Catalog Sources

| DIRBE NAME | 2MASS NAME | IRAS NAME | 2MASS Photometry | IRAS Photometry |
|------------|------------|-----------|------------------|-----------------|
|            |            |           | J (mag)         | σ_J (mag)       |
|            |            |           | H (mag)         | σ_H (mag)       |
|            |            |           | K (mag)         | σ_K (mag)       |
|            |            |           | F_12 (Jy)      | F_25 (Jy)       |
|            |            |           | F_60 (Jy)      | F_100 (Jy)      |

- 2MASS Name: 00000657+2553112
- IRAS Name: 23575+2536
- J: 2.225
- σ_J: 0.296
- H: 1.317
- σ_H: 0.158
- K: 0.188
- σ_K: 0.158
- F_12: 53.780
- F_25: 22.560
- F_60: 3.330
- F_100: 1.783

Note.—Table 4 is available in its entirety in the electronic edition of the Astrophysical Journal Supplement. A portion is shown here for guidance regarding its form and content.
for the target source, causing erroneous photometry with large error bars for the targeted star. Fortunately, however, scans in other directions were not affected by the second star. To correct for this problem, we filtered our data to remove scans affected by nearby stars. We searched previous infrared catalogs for objects within 3°2 of each targeted source. At each wavelength, for each DIRBE scan for each targeted source, we scaled the companion’s flux density by a Gaussian with FWHM 0.7°, weighted by the minimum distance between the scan and the companion star. If the weighted flux density of the companion in the respective band was greater than 25, 20, 20, 10, 30, 55, 320, and 765 Jy at 1.25–100 μm, respectively, then the scan was removed from consideration. We also used the IRAS Small Scale Structure Catalog (Helou & Walker 1985) in this filtering process, since extended sources outside the DIRBE beam may also affect the DIRBE photometry.

The remaining measurements with large error bars (≥3 times the average uncertainty) were likely affected by a cosmic-ray hit in the “sky” portion of the measurement. These large deviations were removed from the light curves by an additional filtering process. Generally, only a few DIRBE scans per light curve were removed by this additional filtering processing. A cosmic-ray hit near the star itself may not produce a large error bar, but instead may manifest itself as a very discrepant flux measurement with a small error bar. We also removed these points from the final light curves. No all-sky catalogs are available at the two longest DIRBE wavelengths, thus these light curves were just filtered for measurements with large errors or very discordant photometry.

In some cases, filtering dramatically improved the DIRBE light curves, removing discrepant data points and those with large error bars. Some example DIRBE light curves before and after filtering are shown in Figure 1 and in Smith (2003). The filtered light curves show much less scatter than the originals. In the case of the 1.25 μm light curve of IK Tau (Fig. 1), the data points that were removed by filtering systematically had lower apparent flux densities than those at similar times that were not filtered. The filtering routine found six stars near IK Tau with 2MASS F1.25 μm between 55 and 62 Jy, similar to the deviations seen in the data points that were removed. In the case of the 2.2 μm light curve for CW Leo (Fig. 1), some very discrepant points with large error bars have been removed. These were caused by R Leo, which is 3° away from CW Leo. R Leo has 2MASS F2.2 μm = 5505 Jy, similar to the deviations seen in the unfiltered light curve. In the case of the 12 μm light curve of R Leo, the discrepant points were caused by CW Leo, which is much brighter than R Leo at 12 μm, varying between ~20,000 and ~40,000 Jy. Note that the bad scans occur at the same time for R Leo and CW Leo, as expected. The scans that were not removed by filtering had position angles such that they did not pass directly through both R Leo and CW Leo.

The filtering process somewhat reduces the average noise level in the light curves. Over the entire Catalog, the average noise levels in the filtered light curves are 30, 7, 17, 18, 32, 118, and 468 Jy at 1.25–100 μm, respectively.

Because of incompleteness and photometric uncertainties in the comparison catalogs, and the fact that some of the nearby stars may themselves be variable, the flagging and filtering routines are not always perfect. To test for possible residual effects from companions in the final filtered light curves, we compared the average photometric uncertainty (err) with the rms σ for two-week intervals in the light curves. Since the majority of variable stars in our sample are expected to be long-period variables (see Smith 2003), small timescale variations in the light curves are probably due to a nearby star affecting some scans more than others. If the σ/err was greater than 3 for any 2 week period containing at least 10 measurements, a third confusion flag was set in Table 1. The number of sources with this flag set at each wavelength is given in Table 3. Note that the wavelength with the most sources with this flag set is 3.5 μm, because of the lack of an all-sky catalog for filtering purposes.

If a large fraction of the photometric values in a light curve were removed by filtering, the source may be confused. If the light curve of a source has fewer than about 50–100 measurements in its light curve after filtering, then the photometry and variability parameters in the DIRBE Catalog should be considered somewhat suspect. In some cases, if a source is very confused, all of the scans at a wavelength were deemed affected by nearby companions and so were filtered out. In these cases, no detection is recorded at that wavelength (specifically, the flux density is set to −99.9).

6. COMPLETENESS OF THE DIRBE CATALOG INPUT LIST AND THE CATALOG ITSELF

Our procedure of selecting sources from the IRAS, 2MASS, and MSX databases ensures that the input list for the DIRBE Catalog should be as complete as these catalogs for bright objects at high Galactic latitudes. At |b| > 5°, we estimate completeness limits of approximately 90, 60, 90, and 165 Jy at 1.25, 2.2, 12, and 25 μm, respectively, corresponding to magnitude limits of ~3.1, 2.6, −1.3, and ~3.5. These are 3.3, 8.6, 5.0, and 5.1 times the average noise level per scan in the filtered light curves, and are 3.6 times our 1.25 μm 2MASS selection criterion, 3.0 times our selection criterion at 2.2 μm, and 6 times our selection criterion at 12 and 25 μm. This means that all sources with amplitudes ≤1.4 mag at 1.25 μm, ≤1.2 mag at 2.2 μm, and ≤1.9 mag at 12 and 25 μm are
included in our sample, even if they were observed at minimum by 2MASS or IRAS/MSX and at maximum by DIRBE. These amplitude limits are larger than typical values for Miras (see §12 and Table 17).

The DIRBE Catalog input list should also be complete at high Galactic latitudes at 3.5 μm to about 60 Jy, 3.5 times the average noise level in the filtered light curves. The reddest stars in $K - L$ (i.e., $F_{2.2}/F_{3.5}$) in the Smith (2003) sample are the Mira carbons, with $F_{2.2}/F_{3.5} \sim 0.45$, $F_{3.5}/F_{4.9} \sim 0.61$, and $F_{4.9}/F_{12} \sim 0.88$. If these stars have $F_{12} = 60$ Jy, they will have $F_{2.2} \sim 27$ Jy ($K \sim 3.47$) and thus would be included in the sample based on the 2.2 μm criterion ($K \leq 3.81$). Carbon Miras fainter than $\sim 44$ Jy at 3.5 μm will not meet the 2.2 μm selection criterion; however, they are expected to be selected by the 12 μm criterion down to $F_{12} = 10$ Jy. Thus, the DIRBE catalog input list should be complete at high Galactic latitudes at 3.5 μm to at least 60 Jy for sources with amplitudes $\leq 1.9$ mag. All of the sources in the DIRBE Catalog have smaller 3.5 μm amplitudes than this limit (see §12).

At 4.9 μm, we estimate a high-latitude completeness limit of 50 Jy, 5 times the average noise level at this wavelength. A carbon Mira with $F_{4.9} = 50$ Jy has an expected $F_{12} = 57$ Jy, well above our IRAS 12 μm selection cutoff of 15 Jy. Thus, all sources with 4.9 μm amplitudes of $\leq 1.4$ mag would be included in our sample to a limit of 50 Jy.

To confirm these estimates of the completeness limits of our input list, we performed three tests. First, to search for missing sources, we cross-correlated our input list of 21,335 sources with the 4.3 μm sources in the MSX IRAS Gaps survey (the 4% of the sky missed by IRAS with $|b| \geq 6^\circ$; Egan et al. 1999), the synthetic 4.2 μm catalog of Egan & Price (1996), and the Catalog of Infrared Observations at 3.5 and 4.2–4.9 μm. There were no sources in the MSX IRAS Gaps survey with MSX band B1 (4.22–4.36 μm) or band B2 (4.24–4.45 μm) flux densities greater than our nominal completeness limit of 50 Jy which were not in our DIRBE input list, and only eight with flux densities $\geq 30$ Jy. All of these sources had very low quality detections in MSX band B1 (quality flag = 1; see Egan et al. 1999) with $F_{B1} \leq 41$ Jy and were not detected in MSX band B2. We extracted DIRBE photometry for these eight sources. None of them were detected at any wavelength by DIRBE.

Only 16 sources in the synthetic Egan & Price (1996) catalog have estimated 4.2 μm flux densities greater than 50 Jy, $|b| \geq 5^\circ$, and are not in our initial source list for the DIRBE Catalog. We extracted DIRBE photometry for these 16 sources. None were detected by DIRBE at 4.9 μm.

At 3.5 μm, all but four of the high-latitude ($|b| \geq 5^\circ$) sources in the Catalog of Infrared Observations with $F_{3.5} > 50$ Jy are included in our sample.

Fig. 1.—Some examples of light curve filtering: (a) the raw 1.25 μm DIRBE light curve of IK Tau; (b) the filtered 1.25 μm DIRBE light curve of IK Tau; (c) the raw 2.2 μm light curve for CW Leo; (d) the filtered 2.2 μm light curve for CW Leo; (e) the raw 12 μm light curve of R Leo; (f) the filtered 12 μm light curve of R Leo.
included in our sample. At 4.9 μm, the DIRBE catalog input list does not include 181 of the 4.2–4.9 μm high-latitude sources in the Catalog of Infrared Observations brighter than 50 Jy. Nearly all of these apparent “missing” sources are low S/N unconfirmed detections in the AFGL or TMSS, and thus may be spurious or extended sources, or have large positional errors. We extracted the DIRBE light curves for these positions and found only one unconfused detection above 50 Jy at 4.9 μm. This source, the very bright star θ Cnc, was missed by 2MASS because it was strongly saturated. This star was also detected by DIRBE above our nominal completeness limits at 1.25, 2.2, and 3.5 μm. Another source, the semiregular variable V1888 Cyg, was only detected at 4.9 μm by DIRBE, with a time-averaged flux density of 34.6 Jy, below our nominal Catalog completeness limit. These two sources were added to the DIRBE Point Source Catalog.

We also added RAFGL 2688 (the Egg Nebula) to the Catalog. This very dusty source lies in the small part of the sky not observed by either IRAS or MSX but was strongly detected by DIRBE (see § 14 and Fig. 9b). These three additions bring the number of sources in the Catalog up to 11,788.

We note that infrared-bright transient objects would be missed by our sample selection criteria. For example, the Catalog of Infrared Observations contains three novae with 3.5 μm flux densities greater than our nominal completeness limit of 60 Jy, and two with 4.2 μm flux densities greater than our nominal 4.9 μm completeness limit of 30 Jy. In addition, SN 1987A was detected at 4.2 μm above 30 Jy in the months following its appearance (Bouchet et al. 1989), but it had faded significantly by the time of the DIRBE mission (Wooden et al. 1993) and was not detected by DIRBE.

As a second test of the completeness of the DIRBE Catalog input list, for a selected region of the sky we extracted DIRBE light curves for a much more sensitive sample of 2382 2MASS sources, covering ~2% of the sky. This deeper sample had a 2MASS K band limit of $F_{2.2} = 1.4$ Jy ($K \leq 6.7$) (0.02 times the average noise level in the filtered DIRBE light curves) or $F_{1.25} = 12$ Jy ($J \leq 5.3$) (0.4 times the DIRBE per point uncertainty), R.A. $\leq 0^h 30^m$, $|b| \geq 5^\circ$, and all declinations. None of these additional sources have unconfused DIRBE time-averaged flux densities greater than our nominal completeness limits. This indicates that our initial selection criteria provides a very complete sample above these limits.

To further investigate the completeness levels of the Catalog, in Figure 2 we have plotted log N–log S at each wavelength for high Galactic latitudes ($|b| \geq 5^\circ$). At 1.25–25 μm, clear turnovers are visible in these plots at flux levels of ~40, 40, 40, 25, 65, and 110 Jy, respectively. These are somewhat lower than our nominal completeness limits, showing that our completeness estimates are reasonable. The log N–log S plots for 60–240 μm do not show turnovers, showing that, as expected, the Catalog is not complete at those wavelengths.

![Fig. 2.—log N–log S plots made from the DIRBE Point Source Catalog, for high Galactic latitude sources ($|b| \geq 5^\circ$).](image_url)
Our estimated completeness limits only pertain to unconfused sources; as noted earlier, in some cases all of the measurements in a light curve are filtered out (see § 5 and Table 6). Since filtering does not depend upon the brightness of the target source, the lack of photometry for these sources in the Catalog will lower the log N−log ∆S curve but should not strongly affect the turnover flux density. To investigate the incompleteness of the Catalog itself caused by this filtering, we searched the DIRBE Catalog input list for sources with 2MASS or IRAS/MSX photometry brighter than our nominal completeness limit at a given wavelength, which had all their measurements at that wavelength removed by filtering. In Table 6, we provide statistics on the resulting incompleteness of the Catalog. Approximately one-quarter of the photometry is lost at 1.25, 2.2, and 12 µm as a result of filtering, about half at 25 µm, about three-quarters at 60 µm, and ~85% at 100 µm.

This removal of all measurements by filtering is a strong function of Galactic latitude, in that it is more likely to happen at lower latitudes. In Figure 3, using equal sky-area bins, we plot, as function of Galactic latitude, the fraction of sources in our input list with 2MASS/IRAS/MSX fluxes above our nominal completeness limits that have had all their measurements removed by filtering. The worst cases are for 1.25 and 2.2 µm, where ~65% of the photometry is lost at |b| ≤ 5°, decreasing to less than 10% at |b| > 30°.

The resulting incompleteness of the Catalog at 1.25 and 2.2 µm is also visible in Figure 4, where we plot a histogram of the number of sources in the Catalog as a function of Galactic latitude in equal sky-area bins. There are clear turnovers of the 1.25 and 2.2 µm source counts at |b| > 20°, showing incompleteness below these latitudes.

In Figure 4, we also plot the number of flagged sources as a function of latitude, while in Figure 5, we give the fraction of Catalog sources that are flagged as a function of Galactic latitude. At 1.25–4.9 µm, this fraction decreases with increasing latitude. The most extreme case is that of 2.2 µm, where 95% of sources with |b| < 5° are flagged, and ~40% at |b| ≥ 45°. At 12 and 25 µm, the percentage of flagged sources is highest at |b| ≤ 5°, but there is little correlation with latitude otherwise.

### 7. THE DIRBE VARIABILITY PARAMETERS

As noted in § 3, in addition to the time-averaged infrared flux densities, Table 1 also includes both the standard deviation σ of the individual flux values in the light curve of the object (after filtering) and the mean uncertainty ⟨err⟩ of the individual data points in the light curve. The comparison of these two values provides an estimate of the likelihood of variability of the object. In addition, for each light curve with minimum flux density greater than 3 times the average uncertainty per measurement, Table 1 also includes the total observed amplitude of variation during the DIRBE observations.

Δmag = 2.5 log (F_{max}/F_{min}), where F_{min} and F_{max} are the minimum and maximum flux densities after averaging over 1 week time intervals. Table 1 also lists σ(Δmag), the uncertainty on Δmag, calculated from σ(Δmag) = 2.5σ_{F_{max}/F_{min}}, where σ_{F_{max}/F_{min}}/(F_{max}/F_{min}) = (σ_{F_{max}}/F_{max}^2 + σ_{F_{min}}/F_{min}^2)^{1/2} and σ_{F_{max}} and σ_{F_{min}} are set equal to the average uncertainty per measurement ⟨err⟩. If the S/N at minimum in the weekly averaged light curve was less than 3, then an amplitude and amplitude uncertainty were not calculated (that is, they were set to −99.9 in Table 1). We note that the observed changes in brightness given in the DIRBE Catalog may not represent the full range of variation for these stars, because many of the light curves are not complete and may not cover a full pulsation period. In these cases, the observed variations are a lower limit to the true amplitudes of variation. In Table 3, we list the numbers of unflagged sources at each wavelength with at least 100 measurements in their filtered light curves and Δmag/σ(Δmag) ≥ 3.

The largest unconfused DIRBE amplitudes are 2.2 mag at 1.25 µm for the oxygen-rich Mira star IK Tau (see Fig. 1), 1.8 and 1.6 mag at 2.2 and 3.5 µm, respectively, for the carbon star CW Leo (see Fig. 1), 1.5 mag at 4.9 µm for the Mira star IR Peg (see Fig. 6), and 1.2 and 1.0 mag at 12 and 25 µm, respectively, for the OH/IR star OH 348.2–19.7 (see Smith 2003).

### 8. DIRBE VERSUS 2MASS PHOTOMETRY

Stars brighter than J ~ 4.5 (F_{1.25µm} ~ 25 Jy) and K ~ 3.5 (F_{2.2µm} ~ 26 Jy) were saturated in 2MASS; thus, their 2MASS photometry is somewhat uncertain (σ ~ 0.2–0.3 mag; Cutri 2003). This means that for the brightest stars in the sky, DIRBE provides more accurate photometry at these wavelengths for unconfused sources. In Figure 7, we plot the distribution of the 2MASS and DIRBE 1.25 and 2.2 µm uncertainties for the subset of 791 sources in the DIRBE Catalog with 2MASS K < 1.0 (i.e., F_{2.2} > 266 Jy). There is a dramatic difference, with the median 1.25 µm uncertainty in DIRBE being 0.03 mag, and the median in 2MASS being 0.26 mag. At 2.2 µm, the median DIRBE uncertainty is 0.02 mag, and the median 2MASS uncertainty is 0.23 mag. Thus, for the brightest near-infrared sources, the DIRBE photometry is ~10 times more precise than that of 2MASS.

In Figure 8a, we plot the 2MASS J magnitudes against the DIRBE 1.25 µm magnitudes for all unflagged |b| ≥ 5° sources in the DIRBE Catalog. In Figure 8b, we compare the 2MASS K magnitudes with the unflagged DIRBE photometry. For the unflagged sources in the K < 1 subset, the best-fit relationships between the 2MASS and DIRBE photometry are J_{DIRBE} = (1.011 ± 0.010)J_{2MASS} − 0.019 ± 0.016 (χ^2 = 220 with N = 373) and K_{DIRBE} = (1.010 ± 0.012)K_{2MASS} + 0.085 ± 0.011 (χ^2 = 154 with N = 389). For the full Catalog, the best-fit relationships for the unflagged sources are J_{DIRBE} = (0.937 ± 0.003)J_{2MASS} + 0.077 ± 0.012 (χ^2 = 4304).
Fig. 3.—Distribution with Galactic latitude of the fraction of 1.25, 2.2, 12, and 25 µm sources with flux densities from 2MASS, IRAS, or MSX above the Catalog input list nominal completeness limits that have all their DIRBE measurements removed by filtering. The bins cover equal sky area.
Fig. 4.—*Solid line*: A histogram of the number of sources in the DIRBE Catalog with DIRBE photometry above the Catalog input list nominal completeness limits. *Dotted line*: A similar histogram for the flagged sources. The bins cover equal sky areas.
Fig. 5.—Fraction of flagged sources above the nominal completeness limits as a function of Galactic latitude. The bins cover equal sky area.
with \( N = 4691 \) and \( K_{\text{DIRBE}} = (0.982 \pm 0.004) K_{\text{2MASS}} + 0.109 \pm 0.004 \left( \chi^2 = 3542 \text{ with } N = 5169 \right) \). No sources were flagged for discrepant photometry from 2MASS that were not already flagged for a companion in the beam or \( \sigma / \text{err} \geq 3 \) in a two-week period.

DIRBE also provides information about near-infrared variability, which is unavailable from 2MASS. In Table 7, we provide statistics on the DIRBE light curves and flagging for the 791 sources in the 2MASS \( K < 1.0 \) sample. Of the 791 sources, 570 survive the filtering process at 2.2 \( \mu \)m (i.e., do not have all their measurements removed by filtering) and are detected in a single DIRBE scan at S/N \( \geq 3 \). Of these 570 sources, 271 are unflagged at 2.2 \( \mu \)m and have more than 100 points left in their light curves after filtering. Of these, 90 (33\%) are observably variable at 2.2 \( \mu \)m (\( \geq 3 \sigma \) DIRBE amplitudes).

In Figure 9, we plot histograms of the observed DIRBE amplitudes at the six shortest DIRBE wavelengths for the sources in the \( K < 1.0 \) subset. This plot only includes unflagged sources with high S/N light curves (\( \geq 3 \sigma \) per scan) with at least 100 measurements remaining after filtering. The sizes of the bins at each wavelength are equal to the median uncertainty in the amplitude at that wavelength. These histograms, along with Table 7, show that the majority of the sources in this subset are not observably variable in the DIRBE data. For the sources that are variable, the observed amplitudes are all less than 2.5 mag at 1.25 \( \mu \)m, less than 2 mag at 2.2 and 3.5 \( \mu \)m, and less than 1.5 mag at 4.9, 12, and 25 \( \mu \)m.

9. IRAS VERSUS DIRBE VARIABILITY

In Figure 10a, we plot the DIRBE 12 \( \mu \)m flux density against that from \( \text{IRAS} \), for the unflagged \( |b| \leq 5^\circ \) sources. The DIRBE 25 \( \mu \)m flux densities for unflagged \( |b| \geq 5^\circ \) sources are plotted against the \( \text{IRAS} \) 25 \( \mu \)m flux density in Figure 10b. The error bars plotted on the DIRBE flux densities are the standard deviations in the filtered light curves; thus, they include both measurement errors and intrinsic variations.

![Fig. 6.—Some example light curves. Top row: DIRBE light curves at 3.5, 4.9, and 25 \( \mu \)m for IZ Peg. Middle and bottom rows: DIRBE light curves at 2.2, 3.5, 4.9, 12, 25, and 60 \( \mu \)m for W Hya.](image)

![Fig. 7.—Distribution of uncertainties in the J (1.25 \( \mu \)m) and K (2.2 \( \mu \)m) magnitudes in DIRBE and 2MASS for the 791 brightest 2.2 \( \mu \)m sources in the sky [2MASS \( K \leq 1.0 \) (\( F_{22} \geq 266 \text{ Jy})]].](image)
Because of the good temporal coverage of COBE, the DIRBE variability parameters, particularly the amplitude of variation compared to the uncertainty on the amplitude, are expected to be more reliable indicators of variability for high S/N unconfused objects. DIRBE has the extra advantage of additional shorter wavelength bands than IRAS.

In Figures 11a–11f, we compare the IRAS VAR parameter with the DIRBE amplitude of variation at the six shortest DIRBE wavelengths for the sources in the Smith (2003) sample (IRAS $F_{12} \geq 150$ Jy; $|b| \geq 5^\circ$). We have excluded sources with less than 5 $\sigma$ DIRBE flux densities at minimum light at the given wavelength, sources that were flagged as possibly confused in the DIRBE database, and sources that were flagged in the IRAS Point Source Catalog as possibly being confused or in a region dominated by cirrus. We have only included sources with high-quality IRAS fluxes at both 12 and 25 $\mu$m.

These plots show considerable scatter. In particular, a number of stars that have low IRAS VAR parameters have large amplitudes of variation in the DIRBE database (>0.5 mag).

As expected, the IRAS satellite was unsuccessful in detecting variability for some strongly variable stars. DIRBE is also better at finding smaller variations than IRAS. This figure shows a number of sources that are variable in DIRBE ($\Delta(mag)/\sigma(\Delta(mag)) > 3$) with low amplitude (<0.4 mag) but have low IRAS VAR. The DIRBE light curves of the stars variable in DIRBE but with low IRAS VAR have been inspected by eye and confirmed that they are indeed variable in the DIRBE database. Most of these stars are well-known variable stars, including Mira, which has an IRAS VAR parameter of only 3.

Note, however, that the majority of VAR = 99 sources are strongly variable in the DIRBE database. In fact, most sources with VAR $\geq 80$ are also variable in DIRBE. Thus, using the IRAS VAR parameter to select highly variable sources (as in, e.g., Allen et al. 1993) appears to be reasonably reliable (albeit incomplete).

10. ASSOCIATIONS WITH OTHER CATALOGS AND SPECTRAL TYPES

To obtain associations with known optical sources and sources at other wavelengths, the DIRBE Catalog was cross-correlated with the SIMBAD database (Wenger et al. 1996). The results are given in Table 8. The closest source listed in SIMBAD within 1$^\prime$ was assumed to be the same source, and the spectral type and object type of this source are given in Table 8. SIMBAD sometimes has more than one listing for the same source, if the source appeared in two different catalogs with slightly different positions and different names. Therefore, if a second SIMBAD source is listed within 5$^\prime$ of the first source, that second source and its SIMBAD object type and spectral type are also given in Table 8. We also cross-correlated our list with the General Catalog of Variable Stars (GCVS; Kholopov et al. 1985–1988), the New Catalog of Suspected Variables (NSV; Kukarin et al. 1982), and the NSV Supplement (NSVS; Kazarovets & Durlevich 1998), using search radii of 60$^\prime$, 30$^\prime$, and 5$^\prime$, respectively. If a match occurred, the variability type and period are included in Table 8, if available.

Table 8 also includes IRAS spectral types from Kwok et al. (1997) for the IRAS sources. In addition, we compared our list with the Chen et al. (2001) OH/IR star compilation, which is listed by IRAS name. DIRBE Catalog sources that are in that list are noted in Table 8, and the OH expansion velocity is included.
| Statistic                                                                 | 1.25 \( \mu \)m | 2.2 \( \mu \)m | 3.5 \( \mu \)m | 4.9 \( \mu \)m | 12 \( \mu \)m | 25 \( \mu \)m | 60 \( \mu \)m | 100 \( \mu \)m | 140 \( \mu \)m | 240 \( \mu \)m |
|---------------------------------------------------------------------------|-----------------|----------------|----------------|----------------|-----------|----------|----------|----------|----------|----------|
| Number detected with S/N > 3.......................................................... | 462             | 570            | 765            | 699            | 279       | 98       | 14       | 14       | 1        | 2        |
| Number flagged for companion in beam.............................................. | 153             | 252            | 20             | 138            | 120       | 52       | 22       | 18       | 0        | 0        |
| Number flagged for discrepancy with other photometry.......................... | 4               | 1              | 0              | 0              | 63        | 18       | 7        | 12       | 0        | 0        |
| Number flagged for 2 week rms/(err) \( \geq 3 \)................................| 45              | 92             | 213            | 98             | 106       | 89       | 139      | 165      | 62       | 63       |
| Number unflagged \( \geq 3 \sigma \) detections with \( N \geq 100 \)........ | 215             | 271            | 540            | 435            | 149       | 52       | 5        | 1        | 1        | 1        |
| Number unflagged \( > 3 \sigma \) detections with \( > 3 \sigma \) amplitudes and \( N \geq 100 \)... | 57              | 90             | 123            | 77             | 20        | 11       | 0        | 0        | 0        | 0        |
Although the SIMBAD classifications are inhomogeneous and incomplete, they provide some rudimentary statistical information about the types of sources contained in the DIRBE Catalog. In Table 9, we provide statistics on types as a function of wavelength, for the sources with S/N per scan per wavelength. The sources have been divided into 18 groups, based on their SIMBAD spectral type and object type, as well as their variability type from the GCVS, NSV, or NSVS, if available. Stars with optical types M, K, S, and C are divided into two groups: those with variability types associated with the AGB (Mira, SRa, SRb, Lb) and those not previously classified into one of those variability types. Objects identified in SIMBAD, the GCVS, the NSV, or the NSVS as young stellar objects, Orion variables, Herbig Ae/Be stars, T Tauri stars, H ii regions, or Herbig-Haro objects are lumped together as star formation sources. Sources listed in SIMBAD as post-AGB objects are also separated out, as are planetary nebulae, possible planetary nebulae, and galaxies. Stars with optical types of O, B, A, F, and G not included in one of these sets are tabulated separately. A similar listing for the 2MASS K < 1.0 subsample is presented in Table 10. This near-infrared-bright subset has no known star formation sources, post-AGB objects, or planetary nebulae, but contains mainly late-type stars.

In addition to providing the number of sources of each type detected at each wavelength at S/N ≥ 3 per scan, in Tables 9 and 10 we give statistics on the number of these that are unflagged and have at least 100 measurements left after
filtering. We also include the number of unflagged sources with \( \geq 100 \) measurements that are variable with amplitude/\( \sigma \)-amplitude \( \geq 3 \). Table 9 shows that, of the 2352 unflagged high S/N 4.9 \( \mu \)m sources, 984 were previously classified as Mira, SRa, SRb, or Lb. Of these, 152 (15\%) are observably variable in the DIRBE database. Of the remaining 1368 not previously classified as one of these variability types, 70 (5\%) are variable in DIRBE at the 3 \( \sigma \) level. At 12 \( \mu \)m, 85 of 311 (27\%) unflagged high S/N sources are variable; 42 of these (49\%) are not previously classified as Mira, SRa, SRb, or Lb. Note that, of the unflagged carbon stars not previously classified as one of these variability types, more than half of the stars that are detected at 4.9, 12, or 25 \( \mu \)m are variable at these wavelengths.

11. THE BRIGHTEST CATALOG SOURCES

In Tables 11, 12, 13, 14, 15, and 16, the brightest 10 sources in the DIRBE Catalog at each of the six shortest wavelengths are given. Although these are the brightest sources in the Catalog, they are not necessarily the brightest sources in the sky because filtering eliminates some sources and because of incompleteness in the Galactic plane. The characteristics of the brightest sources change with wavelength. At the shortest wavelengths, optically bright semiregulars and nonvariable K and M stars dominate. At the longer wavelengths, more evolved dusty stars and star formation regions become more important.

Some of these extremely bright sources are clearly variable in DIRBE. For some examples, see the 2.2–60 \( \mu \)m DIRBE light curves for W Hya shown in Figure 6 and the DIRBE light curves of CW Leo, \( \alpha \) Ori, VY CMa, and L2 Pup presented in Figure 1 and Smith (2003).

At 12 and 25 \( \mu \)m there is considerable confusion in the vicinity of star formation regions, such as that in Orion. This demonstrates the need for caution in using flagged photometry from the Catalog.

12. DIRBE VARIABILITY OF AGB STARS

As shown in Table 9, the vast majority of objects in the DIRBE Catalog with known optical spectral types are late-type stars (spectral types M, K, S, and C). Of these, more than half are known variables with variability types associated with the AGB. In Smith et al. (2002) and Smith (2003), we showed that the amplitudes of variation for these types of stars tend to decrease with increasing wavelength. Further, the amplitudes increased along the sequence SRb/Lb--SRa--Mira. The DIRBE Catalog contains a significantly larger number of sources than these earlier studies, so we have repeated these analyses with the full Catalog sample.

In Table 17, we provide the mean DIRBE amplitudes of variation at each wavelength \( \Delta \) (mag) for the known Miras, SRa, SRb, and Lb stars in the DIRBE Catalog. We have separated the stars into groups according to whether they are oxygen-rich (M stars and/or IRAS LRS types E or A; see Kwok.
### Table 8

**DIRBE Catalog Associations and Other Information**

| DIRBE Name        | 2MASS Name | IRAS Name | First SIMBAD Name | SIMBAD Object Type | SIMBAD Spectral Type | SIMBAD Offset (arcsec) | Second SIMBAD Name |
|-------------------|------------|-----------|-------------------|--------------------|----------------------|------------------------|--------------------|
| D00000657P2553112 | 00000657+2553112 | IRAS 23575+2536 | V* Z Peg          | Mi*                | M7e                  | 0.2                    |                    |
| D00000690P2014145 | 00000690+2014145 | V* EP Peg       | sr*               | M...               | 0.1                  | IRAS 23575+1957       |                    |
| D00001353P5541579 | 00001353+5541579 | HD 224719       | *                 | M...               | 0.1                  |                        |                    |
| D00001815P6021016 | 00001815+6021016 | HD 224754       | *                 | M2                 | 0.1                  |                        |                    |
| D00010244P3830145 | 00010244+3830145 | IRAS 23584+3813 | DO 22623          | *                  | M0                   | 5.4                   |                    |

**Note.**—Table 8 is available in its entirety in the electronic edition of the *Astrophysical Journal Supplement*. A portion is shown here for guidance regarding its form and content.
| Type                          | Subtype                     | Band       |
|-------------------------------|-----------------------------|------------|
|                               |                             | 1.25 µm    |
|                               |                             | 2.2 µm     |
|                               |                             | 3.5 µm     |
|                               |                             | 4.9 µm     |
|                               |                             | 12 µm      |
|                               |                             | 25 µm      |
|                               |                             | 60 µm      |
|                               |                             | 100 µm     |
|                               |                             | 140 µm     |
|                               |                             | 240 µm     |
| Mira/SRa/SRb/Lb               | S/N ≥ 3 per data point      | 1353       |
|                               | Unflagged with N ≥ 100      | 612        |
|                               | ≥3 σ amplitude              | 94         |
|                               | Percent variable            | 15         |
| Other/unspecified             | S/N ≥ 3 per data point      | 1394       |
|                               | Unflagged with N ≥ 100      | 517        |
|                               | ≥3 σ amplitude              | 6          |
|                               | Percent variable            | 1          |
| K Mira/SRa/SRb/Lb             | S/N ≥ 3 per data point      | 57         |
|                               | Unflagged with N ≥ 100      | 28         |
|                               | ≥3 σ amplitude              | 1          |
| Other/unspecified             | S/N ≥ 3 per data point      | 2054       |
|                               | Unflagged with N ≥ 100      | 57         |
|                               | ≥3 σ amplitude              | 1          |
| Star formation                | S/N ≥ 3 per data point      | 6          |
|                               | Unflagged with N ≥ 100      | 1          |
| Planetary nebulae             | S/N ≥ 3 per data point      | 1          |
|                               | Unflagged with N ≥ 100      | 1          |
| Galaxies                      | S/N ≥ 3 per data point      | 1          |
|                               | Unflagged with N ≥ 100      | 1          |
| Other/unspecified             | S/N ≥ 3 per data point      | 3          |
|                               | Unflagged with N ≥ 100      | 1          |
| B other/unspecified           | S/N ≥ 3 per data point      | 64         |
|                               | Unflagged with N ≥ 100      | 29         |
| A other/unspecified           | S/N ≥ 3 per data point      | 131        |
|                               | Unflagged with N ≥ 100      | 53         |
| F other/unspecified           | S/N ≥ 3 per data point      | 147        |
|                               | Unflagged with N ≥ 100      | 62         |

**Note:** The table above provides statistics on associations categorized by various types and subtypes, along with specific data points for each category.
et al. 1997), carbon-rich (optical types C, N, or R, or IRAS type C), optical type S (C/O ratio ∼1), or known OH/IR stars (often also optical type M and/or IRAS type A or E). We also include the average uncertainty in the amplitude, \( \langle \sigma \Delta \text{mag} \rangle \). In constructing Table 17, we only included unflagged stars with \( \geq 5 \sigma \) DIRBE flux densities at minimum light.

In Table 18, we provide the mean ratios of the amplitudes at adjacent wavelengths for the different classes of objects. The quoted uncertainties in this table are the standard deviations of the ratios for each class. Table 18 excludes flagged stars and stars with flux densities less than 5 \( \sigma \) at minimum and \( \Delta \text{mag} / \langle \sigma \Delta \text{mag} \rangle < 5 \) at either wavelength. These results are shown graphically in Figure 12, where we plot the mean amplitude ratio for two adjacent wavelength bands as a function of the shorter wavelength. Table 18 and Figure 12 show that, on average, there is a decrease in amplitude with wavelength, with the exception of the 4.9 \( \mu \text{m} \)/12 \( \mu \text{m} \) amplitudes for the oxygen-rich Miras, the 2.2 \( \mu \text{m} / 3.5 \mu \text{m} \) amplitudes for the carbon Miras and the oxygen-rich SRb stars, and the 1.25 \( \mu \text{m} / 2.2 \mu \text{m} \) amplitudes for the oxygen-rich SRa stars.

There is, however, a lot of scatter in the amplitude ratios from star to star; although the average ratio tends to decrease with wavelength, for some individual stars the ratio increases or remains constant. This general trend is consistent with earlier DIRBE results with a smaller sample (Smith 2003) as well as ground-based studies (Harvey et al. 1979).

Such amplitude decrements with wavelength are predicted by theoretical models of AGB stars (Le Bertre 1988; Winters et al. 1994; Winters et al. 2000). A decrease in amplitude with wavelength means that the dust shell is redder at stellar minimum than at maximum. At any given radius in a circumstellar shell, the average dust temperature is expected to be highest at stellar maximum, and the radii that dust condensation and evaporation occur are largest at stellar maximum. Assuming a roughly 1/r\(^2\) density distribution for the dust in the shell and integrating over all of the dust in the shell, the optical depth of the shell is therefore highest at minimum, while the average effective dust temperature for the shell is lowest. This produces a redder infrared spectrum at minimum.

13. MASSIVE EVOLVED STARS

In Smith (2003), we presented the DIRBE light curves of the supergiants \( \alpha \) Ori and VY CMa. The dusty object VY CMa, the fourth brightest object in the DIRBE Catalog at 25 \( \mu \text{m} \) (Table 16), is variable in the mid-infrared, but not as variable as a typical Mira. Another object that may be similar to VY CMa is NML Cyg (V1489 Cyg) (Neugebauer et al. 1965), also an OH/IR star and the thirteenth brightest 25 \( \mu \text{m} \) DIRBE Catalog source. NML Cyg may also be a supergiant (Johnson 1967; Morris & Jura 1983). NML Cyg is clearly variable in the DIRBE database (see Fig. 13a), with observed amplitudes of 0.30 ± 0.03, 0.23 ± 0.06, and 0.20 ± 0.06 mag at 3.5, 12, and 25 \( \mu \text{m} \), respectively. These amplitudes are somewhat larger than those of VY CMa, but smaller than typical values for Miras (see Table 17).

Monnier et al. (1997) published a 10.2 \( \mu \text{m} \) light curve for 1980–1995 for NML Cyg and found a period of \( \sim 940 \) days. Their photometry is consistent within the uncertainties with that of DIRBE for the time period in common. The DIRBE photometry and amplitudes are also reasonably consistent with the older data of Harvey et al. (1974) and Strecker (1975), as well as the IRAS time-averaged flux densities (from the xscani software) of \( F_{12} = 5461 \) Jy and \( F_{25} = 4065 \) Jy, and the MSX photometry (Egan et al. 1999).

14. PLANETARY NEBULAE AND POST-AGB OBJECTS

Only eight sources detected by DIRBE at the \( \geq 3 \sigma \) level per measurement at 4.9 \( \mu \text{m} \) are classified in SIMBAD as post-AGB objects, while four are listed as planetary nebulae or suspected planetary nebulae. None of these sources were found to be unconfused and variable at the \( \geq 3 \sigma \) level in DIRBE at any wavelength (Table 9). In Figure 13b, we show a few light curves for the post-AGB object RAFGL 2688 (the Egg Nebula), which is not variable in DIRBE.

15. AN OBJECT IN TRANSITION: OH 231.8+4.2 (QX PUP)

One of the most intriguing objects in the DIRBE Catalog is OH 231.8+4.2 (QX Pup), which apparently is in the process of changing from an AGB star to a post-AGB object (Meakin et al. 2003). OH 231.8+4.2 is a bipolar reflection nebula (Reipurth 1987) with an embedded M9 III star (Cohen 1981). This star is known to be variable with an amplitude of approximately 2 mag at 2.2 \( \mu \text{m} \) and a pulsation period of 700 days (Kastner et al. 1992), typical of Miras. This is thus a very unusual source, in a brief and rarely observed stage of development: a pulsating AGB star inside of a proto–planetary nebula.

OH 231.8+4.2 is variable in the DIRBE database, with an amplitude of \( 0.29 \pm 0.07 \) mag at 25 \( \mu \text{m} \) (see Fig. 13c). This confirms the high IRAS VAR of 99 for this source. The DIRBE 25 \( \mu \text{m} \) amplitude for OH 231.8+4.2 is less than the average for the known Miras in the DIRBE Catalog (Table 17), which
| Type                        | Subtype                  | $\text{S/N} \geq 3$ per data point | Unflagged with $N \geq 100$ |
|-----------------------------|--------------------------|-------------------------------------|-----------------------------|
| M Mira/SRa/SRb/Lb....       | $\geq 3 \sigma$ amplitude | 41                                  | 41                           |
|                             | Percent variable         | 32                                  | 32                           |
| M other/unspecified ....... | $\geq 3 \sigma$ amplitude | 3                                  | 3                            |
|                             | Percent variable         | 9                                  | 9                            |
| K Mira/SRa/SRb/Lb....       | $\geq 3 \sigma$ amplitude | 1                                  | 1                            |
|                             | Percent variable         | 50                                 | 50                           |
| K other/unspecified ....... | $\geq 3 \sigma$ amplitude | 0                                  | 0                            |
|                             | Percent variable         | 0                                  | 0                            |
| S Mira/SRa/SRb/Lb....       | $\geq 3 \sigma$ amplitude | 1                                  | 1                            |
|                             | Percent variable         | 100                                | 100                          |
| C Mira/SRa/SRb/Lb....       | $\geq 3 \sigma$ amplitude | 10                                 | 10                           |
|                             | Percent variable         | 71                                 | 71                           |
| B other/unspecified ....... | $\geq 3 \sigma$ amplitude | 0                                  | 0                            |
|                             | Percent variable         | 0                                  | 0                            |
| A other/unspecified ....... | $\geq 3 \sigma$ amplitude | 0                                  | 0                            |
|                             | Percent variable         | 0                                  | 0                            |
| F other/unspecified........ | $\geq 3 \sigma$ amplitude | 0                                  | 0                            |
|                             | Percent variable         | 0                                  | 0                            |
| G other/unspecified........ | $\geq 3 \sigma$ amplitude | 0                                  | 0                            |
|                             | Percent variable         | 0                                  | 0                            |
| Other/unspecified .......... | $\geq 3 \sigma$ amplitude | 0                                  | 0                            |
|                             | Percent variable         | 100                                | 100                          |
| Total                       | $\geq 3 \sigma$ amplitude | 57                                 | 57                           |
|                             | Percent variable         | 27                                 | 27                           |

| Type                        | Subtype                  | $1.25 \mu m$ | $2.2 \mu m$ | $3.5 \mu m$ | $4.9 \mu m$ | $12 \mu m$ | $25 \mu m$ | $60 \mu m$ | $100 \mu m$ | $140 \mu m$ | $240 \mu m$ |
|-----------------------------|--------------------------|-------------|------------|------------|------------|------------|------------|------------|-------------|-------------|-------------|
| M Mira/SRa/SRb/Lb....       |                          | 266         | 316        | 417        | 387        | 173        | 62         | 8          | 8           | 0           | 0           |
|                             |                          | 129         | 161        | 302        | 251        | 98         | 34         | 4          | 1           | 0           | 0           |
| M other/unspecified ....... |                          | 76          | 98         | 138        | 121        | 39         | 17         | 4          | 2           | 1           | 1           |
| K Mira/SRa/SRb/Lb....       |                          | 35          | 42         | 93         | 72         | 15         | 7          | 1          | 0           | 1           | 1           |
| K other/unspecified ....... |                          | 2           | 2          | 5          | 4          | 0          | 2          | 0          | 0           | 0           | 0           |
| S Mira/SRa/SRb/Lb....       |                          | 1           | 2          | 5          | 2          | 1          | 2          | 0          | 0           | 0           | 0           |
| C Mira/SRa/SRb/Lb....       |                          | 1           | 1          | 1          | 0          | 0          | 0          | 0          | 0           | 0           | 0           |
| B other/unspecified ....... |                          | 1           | 2          | 2          | 2          | 0          | 0          | 0          | 0           | 0           | 0           |
| A other/unspecified ....... |                          | 1           | 1          | 1          | 0          | 0          | 0          | 0          | 0           | 0           | 0           |
| F other/unspecified........ |                          | 1           | 1          | 1          | 0          | 0          | 0          | 0          | 0           | 0           | 0           |
| G other/unspecified........ |                          | 1           | 2          | 9          | 9          | 0          | 0          | 0          | 0           | 0           | 0           |
| Other/unspecified .......... |                          | 1           | 1          | 1          | 0          | 0          | 0          | 0          | 0           | 0           | 0           |
| Total                       |                          | 462         | 570        | 765        | 699        | 279        | 98         | 14         | 12          | 1           | 2           |

TABLE 10

Statistics on Associations: 2MASS $K < 1.0$ Subsample

- **S/N** per data point
- **Unflagged with N ≥ 100**
- **≥3 σ amplitude**
- **Percent variable**

**Band**

- $1.25 \mu m$
- $2.2 \mu m$
- $3.5 \mu m$
- $4.9 \mu m$
- $12 \mu m$
- $25 \mu m$
- $60 \mu m$
- $100 \mu m$
- $140 \mu m$
- $240 \mu m$
| DIRBE NAME             | 2MASS NAME        | IRAS NAME       | $F_\nu$  | $\sigma$ | (err) | $\Delta$mag | $\sigma$(Δmag) | $N$   | Flags* | SIMBAD NAME | SPECTRAL TYPE | VAR. TYPE |
|-----------------------|-------------------|-----------------|---------|---------|-------|-------------|--------------|------|--------|-------------|---------------|-----------|
| D05551028P0724255 ...... | 05551028+0724255  | 05524+0723      | 30122   | 922     | 510   | 0.08        | 0.03         | 99   | 000    | α Ori       | M1            | SR        |
| D04364544M6204379 ...... | 04364544−6204379  | 04361−6210      | 16977   | 642     | 386   | 0.02        | 0.04         | 26   | 000    | R Dor       | M8 III        | SR        |
| D17143885P1423253 ...... | 17143885+1423253  | 17123+1426      | 13590   | 362     | 388   | 0.02        | 0.04         | 26   | 000    | α Her       | M5 Ib–II      | SR        |
| D14153968P1910558 ...... | 14153968+1910558  | 14133+1925      | 12763   | 247     | 248   | 0.04        | 0.03         | 229  | 000    | α Boo       | K1.5 III      |           |
| D22424003M4653044 ...... | 22424003−4653044  | 22396−4708      | 11397   | 398     | 234   | 0.06        | 0.03         | 123  | 001    | β Gru       | M5 III        |           |
| D13490199M2822034 ...... | 13490199−2822034  | 13462−2807      | 7331    | 1753    | 123   | 0.11        | 0.02         | 29   | 000    | W Hya       | M7e           | SR        |
| D05164138P4559525 ...... | 05164138+4559525  | 05130+4556      | 5451    | 72      | 105   | 0.04        | 0.03         | 61   | 000    | α Aur       | G5 IIIe+…     |           |
| D23034644P2804580 ...... | 13490199−2822034  | 13462−2807      | 4781    | 109     | 93    | 0.05        | 0.03         | 297  | 000    | β Peg       | M2.5 II–III   |           |
| D09473348P1125436 ...... | 09473348+1125436  | 09448+1139      | 4421    | 835     | 86    | 0.37        | 0.03         | 50   | 101    | R Leo       | M8 IIIe       | M         |
| D07133229M4438233 ...... | 07133229−4438233  | 07120−4433      | 4019    | 269     | 113   | 0.17        | 0.04         | 102  | 000    | L2 Pup      | M5 IIIe       | SR        |

* If the first confusion flag is set to 1, there is another source in the DIRBE beam with a 2MASS $J$ band flux density above 25 Jy. If the second confusion flag is set to 1, the DIRBE photometry at minimum (in the weekly averaged light curve) is greater than that of 2MASS by more than 3 $\sigma$, or the DIRBE photometry at maximum is less than that of 2MASS by more than 3 $\sigma$. If this flag is set, this may mean a second source in the beam, extended emission, or large variations not observed in DIRBE. If the third flag is set, the rms/(err) for a 2-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering.
| DIRBE NAME         | 2MASS NAME         | IRAS NAME         | $F_v$   | $\sigma$ (err) | $\Delta$mag | $\sigma$($\Delta$mag) | N   | Flags* | SIMBAD NAME | SPECTRAL TYPE | VAR. TYPE |
|-------------------|--------------------|-------------------|---------|----------------|-------------|-----------------------|-----|--------|-------------|---------------|-----------|
| D05551028P0724255 | 05551028+0724255    | 05524+0723        | 29995   | 889            | 210         | 0.07                  | 72  | 100    | $\alpha$ Ori | M1            | SR        |
| D04364544M6204379 | 04364544-6204379    | 04361-6210        | 25601   | 1898           | 163         | 0.19                  | 0   | 119    | 000         | M8 IIIe       | SR        |
| D16292443M2625549 | 16292443-2625549    | 16262-2619A       | 23270   | 179            | 143         | 0.01                  | 44  | 100    | $\alpha$ Sco | M1.5 Ib       | SR        |
| D17143885P1423253 | 17143885+1423253    | 17123+1426        | 15614   | 229            | 107         | 0.04                  | 13  | 100    | $\alpha$ Her | M5 II         | SR        |
| D22242003M4653044 | 22242003-4653044    | 22396-4708        | 12123   | 107            | 78          | 0.02                  | 19  | 000    | $\beta$ Gru  | M5 III        | SR        |
| D12310993M5706474 | 12310993-5706474    | 12283-5650        | 11710   | 82             | 97          | 0.00                  | 35  | 100    | $\gamma$ Cru | M3.5 III      | SR        |
| D13490199M2822034 | 13490199-2822034    | 13462-2807        | 11442   | 2506           | 85          | 0.50                  | 160 | 000    | W Hya       | M7e           | SR        |
| D14153968P1910558 | 14153968+1910558    | 14133+1925        | 10073   | 61             | 62          | 0.01                  | 299 | 000    | $\alpha$ Boo | K1.5 III      | SR        |
| D04355524P1630331 | 04355524+1630331    | 04330+1624        | 8739    | 42             | 49          | 0.00                  | 40  | 000    | $\alpha$ Tau | K5 III        | SR        |
| D09473348P1125436 | 09473348+1125436    | 09448+1139        | 7680    | 976            | 52          | 0.26                  | 70  | 101    | R Leo       | M8 IIIe       | M         |

* If the first confusion flag is set to 1, there is another source in the DIRBE beam with a 2MASS $K$ band flux density above 20 Jy. If the second confusion flag is set to 1, the DIRBE photometry at minimum in the weekly averaged light curve is greater than that of 2MASS by more than 3 $\sigma$, or the DIRBE photometry at maximum is less than that of 2MASS by more than 3 $\sigma$. If this flag is set, this may mean a second source in the beam, extended emission, or large variations not observed in DIRBE. If the third flag is set, the rms/(err) for a 2-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering.
| DIRBE NAME | 2MASS NAME | IRAS NAME | $F_\nu$ | $\sigma$ | $\langle \sigma(\text{err}) \rangle$ | $\Delta \text{mag}$ | $\sigma(\Delta \text{mag})$ | N | Flagnameres | SIMBAD NAME | SPECTRAL TYPE | VAR. TYPE |
|-----------|------------|-----------|--------|--------|-----------------|---------------|----------------|---|-------------|--------------|---------------|------------|
| D05551028P0724255 | 05551028+0724255 | D04364544M6204379 | 04364544-6204379 | D16292443M2625549 | 16292443-2625549 | 17065 | 546 | 228 | 0.08 | 0.02 | 312 | 000 | $\alpha$ Ori | M1 | SR |
| D04364544M6204379 | 04364544-6204379 | D16292443M2625549 | 16292443-2625549 | 17143885P1423253 | 17143885+1423253 | 15611 | 955 | 233 | 0.21 | 0.02 | 684 | 000 | R Dor | M8 IIIe | SR |
| D13490199M2282034 | 13490199-2282034 | D17143885P1423253 | 17143885+1423253 | 13490199M2282034 | 13490199-2282034 | 7945 | 1107 | 105 | 0.34 | 0.02 | 366 | 000 | $\alpha$ Her | M5 II | SR |
| D13490199M2282034 | 13490199-2282034 | D17143885P1423253 | 17143885+1423253 | 12231099M5706474 | 12231099-5706474 | 5920 | 90 | 89 | 0.03 | 0.02 | 803 | 000 | W Hya | M7e | SR |
| D22424003M4653044 | 22424003-4653044 | D12310993M5706474 | 12310993-5706474 | 12283-2807 | 12283-2807 | 6248 | 124 | 89 | 0.04 | 0.02 | 317 | 001 | $\beta$ Gru | M5 III | |
| D09473348P1125436 | 09473348+1125436 | D09473348P1125436 | 09473348+1125436 | 09448+1139 | 09448+1139 | 5104 | 589 | 72 | 0.33 | 0.02 | 179 | 000 | R Leo | M8 IIIe | M |
| D14153968P1910558 | 14153968+1910558 | D14153968P1910558 | 14153968+1910558 | 14133+1925 | 14133+1925 | 4868 | 73 | 73 | 0.04 | 0.02 | 549 | 000 | $\alpha$ Boo | K1.5 III | |
| D04355524P1630331 | 04355524+1630331 | D04355524P1630331 | 04355524+1630331 | 04330+1624 | 04330+1624 | 4339 | 70 | 68 | 0.02 | 0.02 | 354 | 000 | $\alpha$ Tau | K5 III | |

* If the first confusion flag is set to 1, there is another source in the DIRBE beam with a 3.5 $\mu$m flux density above 20 Jy in the Catalog of Infrared Observations. The second confusion flag is not set at 3.5 $\mu$m. If the third flag is set, the rms/\langle \sigma(\text{err}) \rangle for a 2-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering.
| DIRBE Name     | 2MASS Name   | IRAS Name   | $F_\nu$ | $\sigma$ | $(\Delta V)$ | $\sigma(\Delta V)$ | N   | Flags* | SIMBAD Name | Spectral Type | Var. Type |
|---------------|--------------|-------------|--------|----------|--------------|---------------------|-----|--------|-------------|--------------|-----------|
| D09475740P1316435 .......... | 09475740+1316435 | 09452+1330 | 9011   | 5742     | 61           | 1.37                | 0.01 | 89     | 001         | CW Leo       | C         |
| D04364544M6204379 .......... | 04364544-6204379 | 04361-6210 | 8729   | 256      | 41           | 0.11                | 0.01 | 530    | 000         | R Dor        | M8 IIme    |
| D05551028P0724255 .......... | 05551028+0724255 | 05524+0723 | 7142   | 326      | 31           | 0.11                | 0.01 | 67     | 000         | $\alpha$ Ori | M1        |
| D16292443M2625549 .......... | 16292443-2625549 | 16262-2619A | 5650   | 31       | 25           | 0.01                | 0.01 | 71     | 100         | $\alpha$ Sco | M1 Ib+     |
| D13490199M2822034 .......... | 13490199-2822034 | 13462-2807 | 5378   | 326      | 25           | 0.18                | 0.01 | 297    | 001         | W Hya        | M7e        |
| D17143885P1423253 .......... | 17143885+1423253 | 17123+1426 | 3616   | 54       | 17           | 0.04                | 0.01 | 135    | 100         | $\alpha$ Her | M5 II      |
| D09473348P1125436 .......... | 09473348+1125436 | 09448+1139 | 3459   | 364      | 17           | 0.28                | 0.01 | 91     | 101         | R Leo        | M8 IIIe    |
| D02192081M0258393 .......... | 02192081-0258393 | 02168-0312 | 3221   | 812      | 17           | 0.70                | 0.01 | 148    | 001         | $\alpha$ Cet | M7 IIIe    |
| D22424003M4653044 .......... | 22424003-4653044 | 22396-4708 | 2684   | 17       | 14           | 0.02                | 0.01 | 294    | 000         | $\beta$ Gru  | M5 IIIe    |
| D07133229M4438233 .......... | 07133229-4438233 | 07120-4433 | 2646   | 67       | 14           | 0.12                | 0.01 | 1278   | 001         | L2 Pup       | M5 IIIe    |

* If the first confusion flag is set to 1, there is another source in the DIRBE beam with a 4.9 $\mu$m flux density above 10 Jy in the Catalog of Infrared Observations or in the Egan & Price (1996) synthetic 4.2 $\mu$m catalog. The second confusion flag is not set at 4.9 $\mu$m. If the third flag is set, the rms/$\sigma$ for a 2-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering.
**TABLE 15**

**Brightest 12 μm Sources in DIRBE Catalog**

| DIRBE NAME            | 2MASS NAME             | IRAS NAME             | F*   | σ       | (εrr) | Δmag  | σ(Δmag) | N  | Flags* | SIMBAD NAME | SPECTRAL TYPE | VAR. TYPE |
|-----------------------|------------------------|-----------------------|------|---------|-------|-------|---------|----|--------|-------------|---------------|-----------|
| D09475740P1316435      | 09475740+1316435       | 09452+1330            | 31773| 7661    | 356   | 0.33  | 0.02    | 51 | 110    | CW Leo      | C             | M         |
| D05351646M0523230      | 05351646-0523230       | 19690                 | 491  | 266     | 0.03  | 0.02  | 59      | 100| θ Ori C | θ Ori C     | θ Ori C       | θ Ori C   |
| D0535020M0515490       | 05330-0517             | 19114                 | 1205 | 254     | 0.08  | 0.02  | 74      | 111|       |             |               |           |
| D05351000M0527470      | 05327-0529             | 18596                 | 1321 | 284     | 0.05  | 0.02  | 48      | 110|       | LP Ori      | B1.5 Vp      | Orion     |
| D05353430M0514520      | 05331-0515             | 17565                 | 2292 | 253     | 0.09  | 0.02  | 35      | 111|       |             |               |           |
| D11142900M6118000      | 11123-6101             | 9518                  | 847  | 166     | 0.16  | 0.03  | 82      | 111|       | OH CSI-61-11124 | WR            |           |
| D07225830M2546030      | 07225830-2546030       | 9278                  | 299  | 88      | 0.07  | 0.01  | 66      | 110|       | VY CMa      | M3/M4 II      |           |
| D11155060M6113420      | 11136-6056             | 8676                  | 516  | 136     | 0.10  | 0.02  | 78      | 111|       |             |               |           |
| D08590440M4730370      | 08573-4718             | 5378                  | 201  | 84      | 0.02  | 0.02  | 89      | 111|       | Maser 267.94-01.06 |               |           |
| D05413870M0151190      | 05391-0152             | 4897                  | 261  | 82      | 0.08  | 0.03  | 93      | 111|       | NGC 2024    |               |           |

* If the first confusion flag is set to 1, there is another source in the DIRBE beam with an IRAS 12 μm flux density above 30 Jy. If the second confusion flag is set to 1, the DIRBE photometry at minimum is greater than that of IRAS by more than 3 σ, or the DIRBE photometry at maximum is less than that of IRAS by more than 3 σ. If this flag is set, this may mean a second source in the beam, extended emission, or large variations not observed in DIRBE. If the third flag is set, the rms/(err) for a 2-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering.
| DIRBE NAME | 2MASS NAME | IRAS NAME | $F_c$ | $\sigma$ | $\langle$err$\rangle$ | $\Delta$mag | $\sigma$(∆mag) | N | Flags* | SIMBAD NAME | SPECTRAL L TYPE | VAR. TYPE |
|------------|------------|-----------|------|---------|----------------|-------------|----------------|---|--------|-------------|----------------|----------|
| D08590440M4730370 .......... | 08573-4718 | 28682 | 951 | 200 | 0.00 | 0.01 | 24 | 111 | Maser 267.94-01.06 |
| D09475740P1316435 .......... | 09475740+1316435 | 09452+1330 | 28611 | 4508 | 230 | 0.18 | 0.01 | 47 | 110 | CW Leo | C | M |
| D10463100M6003470 .......... | 10445-5947 | 17092 | 3716. | 642 | 0.01 | 0.06 | 23 | 110 | |
| D07225830M2546030 .......... | 07225830-2546030 | 07209-2540 | 12346 | 345 | 96. | 0.10 | 0.01 | 397 | 110 | VY CMa | M3/M4 II: |
| D18172538M1145416 .......... | 18172538-1145416 | 18146-1146 | 10368 | 2143 | 677 | 0.06 | 0.10 | 26 | 110 | |
| D10482740M5951210 .......... | 10464-5935 | 8540 | 4059 | 829 | 0.28 | 0.16 | 32 | 110 | |
| D20350950P4113180 ........... | 20343600+4105541 | 20343600+4105541 | 6394 | 591 | 806 | 0.04 | 0.21 | 36 | 100 | HD 196241 | K5 |
| D18312470M0205320 .......... | 18288-0207 | 6162 | 229 | 79 | 0.03 | 0.02 | 46 | 111 | W40 |
| D20381718P4204251 .......... | 20381718+4204251 | 5962 | 1065 | 1090 | 0.27 | 0.29 | 101 | 000 | HD 196819 | K2.5 IIb |

* If the first confusion flag is set to 1, there is another source in the DIRBE beam with an IRAS 25 μm flux density above 55 Jy. If the second confusion flag is set to 1, the DIRBE photometry at minimum is greater than that of IRAS by more than 3 $\sigma$, or the DIRBE photometry at maximum is less than that of IRAS by more than 3 $\sigma$. If this flag is set, this may mean a second source in the beam, extended emission, or large variations not observed in DIRBE. If the third flag is set, the rms/$\langle$err$\rangle$ for a 2-week period is greater than 3, suggesting confusion from an unknown source that is not completely corrected by filtering.
| Var. Type | Spectral Type | 1.25 μm Band | 2.2 μm Band | 3.5 μm Band | 4.9 μm Band | 12 μm Band | 25 μm Band |
|-----------|---------------|--------------|--------------|--------------|--------------|------------|------------|
|           |               | ⟨Δmag⟩      | ⟨σ⟩         | N            | ⟨Δmag⟩      | ⟨σ⟩         | N          | ⟨Δmag⟩      | ⟨σ⟩         | N          | ⟨Δmag⟩      | ⟨σ⟩         | N          | ⟨Δmag⟩      | ⟨σ⟩         | N          |
| Mira      | OH/IR         | 0.82 ± 0.58  | 0.15         | 12           | 0.58 ± 0.31  | 0.13         | 36         | 0.68 ± 0.29  | 0.11         | 31         | 0.55 ± 0.28  | 0.13         | 37         | 0.66 ± 0.23  | 0.13         | 13         | 0.61 ± 0.16  | 0.12         | 9          |
| Mira      | Oxygen        | 0.53 ± 0.33  | 0.11         | 93           | 0.45 ± 0.25  | 0.12         | 160        | 0.50 ± 0.23  | 0.12         | 152        | 0.37 ± 0.21  | 0.13         | 174        | 0.60 ± 0.27  | 0.15         | 26         | 0.64 ± 0.22  | 0.18         | 12         |
| Mira      | Carbon        | 0.56 ± 0.26  | 0.18         | 4            | 0.64 ± 0.42  | 0.12         | 17         | 0.77 ± 0.35  | 0.11         | 20         | 0.45 ± 0.35  | 0.10         | 38         | 0.59 ± 0.18  | 0.14         | 18         | 0.52 ± 0.19  | 0.14         | 7          |
| Mira      | S             | 0.46 ± 0.27  | 0.13         | 3            | 0.34 ± 0.23  | 0.14         | 7          | 0.67 ± 0.23  | 0.11         | 9          | 0.38 ± 0.19  | 0.14         | 9          | 0.92 ± 0.10  | 1            |            | 0.88 ± 0.23  | 1            |            |
| SRa       | OH/IR         | ...          | 0.13         | 0            | 0.74 ± 0.24  | 1           | ...        | ...         | 0.11        | 0          | ...         | 0.14        | ...        | 0.61 ± 0.09  | 1            | 0.70 ± 0.22  | 1            |            |
| SRa       | Oxygen        | 0.22 ± 0.21  | 0.13         | 39           | 0.19 ± 0.13  | 0.12         | 46         | 0.26 ± 0.16  | 0.12         | 36         | 0.17 ± 0.12  | 0.12         | 30         | 0.22 ± 0.09  | 0.15         | 4           | 0.22 ± 0.17  | 1            |            |
| SRa       | Carbon        | 0.45 ± 0.41  | 0.10         | 5            | 0.24 ± 0.20  | 0.10         | 5          | 0.30 ± 0.16  | 0.10         | 7          | 0.29 ± 0.17  | 0.11         | 5          | 0.16 ± 0.03  | 1            | ...         | 0.17 ± 0.06  | 1            |            |
| SRb       | OH/IR         | ...          | 0.19         | 0            | 0.24 ± 0.17  | 1           | 0.35        | 0.24        | 1           | ...        | 0.11        | 0          | ...        | 0.03 ± 0.03  | 0            | ...         | 0.17 ± 0.07  | 0            |            |
| SRb       | Oxygen        | 0.12 ± 0.10  | 0.11         | 345          | 0.12 ± 0.10  | 0.09         | 380        | 0.18 ± 0.10  | 0.11         | 333        | 0.15 ± 0.08  | 0.13         | 264        | 0.24 ± 0.09  | 0.19         | 24         | 0.22 ± 0.07  | 0.17         | 10         |
| SRb       | Carbon        | 0.16 ± 0.15  | 0.10         | 20           | 0.11 ± 0.10  | 0.06         | 19         | 0.17 ± 0.09  | 0.08         | 27         | 0.15 ± 0.11  | 0.10         | 27         | 0.27 ± 0.07  | 0.21         | 7           | 0.17 ± 0.03  | 1            |            |
| SRb       | S             | 0.16 ± 0.06  | 0.11         | 3            | 0.13 ± 0.14  | 0.10         | 5          | 0.23 ± 0.16  | 0.11         | 6          | 0.25 ± 0.28  | 0.12         | 3          | ...        | 0.21 ± 0.20  | 0            | 0.47 ± 0.09  | 1            |            |
| SRc       | OH/IR         | ...          | 0.11         | 0            | ...         | 0.10        | 0          | ...        | 0.23        | 0.14        | 0          | 0.27        | 0.08        | 1          | 0.38 ± 0.18  | 0.16         | 2           | 0.47 ± 0.26  | 0.21         | 2           |
| SRc       | Oxygen        | 0.10 ± 0.08  | 0.08         | 16           | 0.09 ± 0.08  | 0.08         | 15         | 0.18 ± 0.17  | 0.09         | 22         | 0.14 ± 0.08  | 0.11         | 18         | 0.20 ± 0.05  | 0.19         | 4           | 0.19 ± 0.03  | 0.17         | 3           |
| Lb        | Oxygen        | 0.12 ± 0.10  | 0.12         | 393          | 0.12 ± 0.10  | 0.11         | 436        | 0.20 ± 0.12  | 0.13         | 322        | 0.17 ± 0.11  | 0.14         | 260        | 0.26 ± 0.03  | 0.21         | 6           | 0.20 ± 0.06  | 0.20         | 2           |
| Lc        | Carbon        | 0.19 ± 0.18  | 0.11         | 14           | 0.15 ± 0.22  | 0.11         | 24         | 0.26 ± 0.21  | 0.12         | 26         | 0.28 ± 0.32  | 0.12         | 24         | 0.50 ± 0.23  | 0.17         | 2           | 0.69 ± 0.24  | 1            |            |
| Le        | Oxygen        | 0.07 ± 0.08  | 0.09         | 15           | 0.04 ± 0.05  | 0.06         | 17         | 0.18 ± 0.13  | 0.12         | 25         | 0.11 ± 0.10  | 0.12         | 21         | 0.35 ± 0.01  | 0.21         | 2           | ...         | 0.24 ± 0.00  | 1            |            |
typically have amplitudes of 0.5 mag at 25 μm, however, DIRBE may not have observed a full pulsation cycle for this star. OH 231.8+4.2 is also variable at longer wavelengths, with a measured amplitude of approximately 0.32 mag at 850 μm (Jenness et al. 2002).

OH 231.8+4.2 is one of the reddest evolved stars in the DIRBE Catalog. In Figure 14, we plot the IRAS flux ratios for the 43 unconfused sources in the DIRBE Catalog with IRAS colors $F_{25}/F_{12} \geq 1.2$ and $F_{60}/F_{25} \leq 2.5$, and high-quality IRAS fluxes at 12, 25, and 60 μm. These colors are in the range expected for very late AGB stars and post-AGB objects (van der Veen & Habing 1988). Using types from SIMBAD and additional information from the literature, in Figure 14 we use different symbols to identify young stars, post-AGB objects, planetary nebula, and OH/IR stars not identified as post-AGB objects. For comparison, we also mark the location of the post-AGB Egg Nebula (RAFGL 2688), based on its DIRBE data, and the variable supergiant NML Cyg, based on IRAS xscani results. Of these 43 objects, eight were found to be variable in the DIRBE database. These are distinguished by filled symbols in Figure 14.

In Figure 14, we also plot the regions defined by van der Veen & Habing (1988). As discussed by van der Veen & Habing (1988), sources in regions II, IIIa, and IIIb are mainly AGB stars, with increasing circumstellar shell optical depth along this sequence. Region IV contains very late-stage AGB stars as well as some planetary nebulae. We also plot the theoretical evolutionary track for AGB stars of Bedijn (1987) in Figure 14. Stars get redder as they evolve, moving to the upper right on the IRAS color-color plot. After the stars evolve into region IV of the IRAS color-color plot, they move into region V, which contains mainly nonvariable objects, including planetary nebulae and post-AGB objects (van der Veen & Habing 1988). OH 231.8+4.2 is the reddest source in this plot, lying in the extreme upper right of the color-color plot, to the right of region V, far from the standard AGB evolutionary track, and far from the other sources found to be variable in DIRBE.

16. STAR FORMATION REGIONS AND OTHER O, B, A, F, AND G STARS

As shown in Table 9, 47 of the sources detected at the 3 σ level at 4.9 μm in a single DIRBE scan are associated with star formation regions. Confusion is a major problem for the star formation sources in the Catalog; only nine of these sources are unflagged. None of these are variable in DIRBE at a $\geq$3 σ level.

Table 9 shows that 150 of the high S/N unflagged 4.9 μm sources in the DIRBE Catalog are O, B, A, F, or G stars but are not previously identified as associated with star formation regions or post-AGB objects. Of these sources, none are variable in DIRBE.

17. GALAXIES

As noted above, the DIRBE Catalog selection criteria are biased against galaxies, since we are only selecting sources at wavelengths ≤25 μm and are biased against extended objects. Only two galaxies are included in the final DIRBE Catalog: M82 and NGC 253. Their IRAS flux densities fit our selection criteria, and they are detected at $\geq$3 σ in a single DIRBE scan at 12 and 25 μm. As expected, their light curves show no evidence for variations. NGC 253 is also detected at 1.25 and 2.2 μm with average flux densities of 20 ± 4 and 19 ± 6 Jy per measurement, consistent with values in the 2MASS Large
Fig. 13.—Some more example light curves. (a)–(c) DIRBE light curves at 3.5, 12, and 25 μm for NML Cyg. (d)–(f) DIRBE light curves at 12, 25, and 60 μm for the Egg Nebula (RAFGL 2688). (g)–(i) DIRBE light curves at 12, 25, and 60 μm for QX Pup (OH231.8+4.2).

Fig. 14.—IRAS color-color plot for the 43 unconfused objects in the DIRBE Catalog with a high S/N (≥3) DIRBE light curve with at least 100 unfiltered data points at at least one wavelength, with $\text{IRAS} F_{12}/F_{13} \geq 1.2$ and $F_{60}/F_{100} \geq 2.5$, and with high-quality IRAS Point Source Catalog fluxes at 12, 25, and 60 μm. Sources at all Galactic latitudes are included. Filled symbols represent objects that are variable in the DIRBE database; open symbols are objects that are not variable. The filled triangle in the upper right is QX Pup (OH 231.8+4.2). The cross marks the location based on the DIRBE data of the Egg Nebula (RAFGL 2688), a post-AGB object not variable in DIRBE, while the filled square shows the location of the supergiant NML Cyg, based on IRAS xscanpi results. The regions labeled with Roman numerals are from van der Veen & Habing (1988). The dashed line is the Bedijn (1987) evolutionary track for AGB stars.
Galaxy Atlas$^2$ (Jarrett et al. 2003). By co-addition over the entire DIRBE mission, it is possible to detect additional galaxies at wavelengths of $\geq 60$ $\mu$m (see Odenwald et al. 1998). Such co-addition is beyond the scope of the current Catalog.

18. SUMMARY

From the archival COBE DIRBE database, we have constructed a DIRBE Point Source Catalog containing 11,788 sources detected at the $3\sigma$ level per measurement at least one DIRBE wavelength. This catalog was created using an input list of 21,335 IRAS/MSX and 2MASS sources. We have flagged sources likely to be confused, based on other infrared catalogs and inspection of the DIRBE light curves, and have collected information about the DIRBE sources from other catalogs. We compare the DIRBE photometry with that of 2MASS for the near-infrared–bright sources in the DIRBE Catalog and show that the DIRBE photometry is more precise. We compare the DIRBE variability parameters with the IRAS VAR parameter and show that DIRBE detected variability in a number of sources with low IRAS VAR. We also discuss a few unusual objects in the Catalog, including the peculiar bipolar nebula OH 231.8+4.2, likely evolving from the AGB into a post-AGB object.

2 Available at http://irsa.ipac.caltech.edu/applications/Gator/.

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