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# A catalogue of dust clouds in the Galaxy*

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**Abstract.** In this study 21 catalogues of dust clouds in the Galaxy were cross-identified by taking into account available properties such as position, angular dimensions, opacity class and velocity. An initial list of ≈6500 entries was condensed into a cross-identified all-sky catalogue containing 5004 dust clouds. In particular, the transition zone between high and low Galactic latitude studies was also cross-identified. The unified catalogue contains 525 high-latitude clouds. The catalogue deals primarily with optical dark nebulae and globules, but it includes as well substantial information from their molecular counterparts. Some previously uncatalogued clouds were detected on optical images and FIR maps. Finally, we address recent results and prospective work based on NIR imaging, especially for clouds detected in the 2MASS $K_s$ Atlas.

**Key words.** ISM: clouds – catalogs

## 1. Introduction

Dust clouds are fundamental to understand many issues in the Galaxy. Optical obscuration is an obstacle to the study of Galactic structure from the perspective of star clusters and H II Regions. However, dust association to molecular gas, and velocity determinations (e.g. Blitz et al. 1982; Dame et al. 1987) make them excellent tracers of related structures in the Galaxy. Since some clouds are actively forming stars, with protostellar objects and/or embedded clusters (e.g. Lawson et al. 1996; Lada et al. 1996), clouds are interesting targets to search for new IR clusters. Near infra-red (NIR) surveys such as the Two Micron All Sky Survey (2MASS – Skrutskie et al. 1997) are opening this possibility (e.g. Dutra & Bica 2000a).

Much information on dust clouds remains strewn throughout many catalogues, and subsequent studies often refer to a particular designation. A unified catalogue would be useful for searches of new clouds, especially for surveys in wavelengths other than optical. Similar to catalogue efforts in other fields, such as those dealing with galaxies, open clusters or globular clusters, the present study aims at providing a step forward to an overall catalogue of dust clouds. In Sect. 2 input catalogues are gathered. In Sect. 3 merging and cross-identification procedures are given, and results are presented. In Sect. 4 some catalogue properties and prospective work are discussed.

## 2. Input catalogues

The acronyms and number of entries Input catalogues dealing mostly with low-latitude clouds ($|b| < 25°$), (prior to cross-identifications) are given in Table 1. Barnard (1919, 1927) first catalogued clouds in the northern and equatorial zones. Lynds (1962) built the largest set of dark clouds (LDN) north of $\delta = -33°$ using the Palomar Sky Survey (PSS), including some high-latitude clouds. Sandqvist & Lindroos (1976) detected clouds in the PSS for $-33° < \delta < -46°$. Sandqvist (1977) found clouds south of $\delta = -42.5°$ using the ESO (B) Atlas. Bernes (1977) looked for bright nebulae mainly related to LDN's, and reported some new dust clouds. Zealey et al. (1983) compiled cometary globules – as a rule "bright dark" nebulae with reflection and absorption components. Feitzinger & Stüwe (1984) inspected ESO/SERC plates and provided two catalogues: (i) extended clouds, and (ii) globules (≈6′ or less). Hartley et al. (1986) presented the largest southern set of clouds from a search on ESO/SERC $J$ plates for $\delta \leq -35°$.

Some Table 1 catalogues deal with dense cloud cores and isolated small clouds. Myers et al. (1983) identified small clouds using the PSS for low-mass star formation studies by means of CO. Clemens & Barvainis (1988) used

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* The unified catalogue is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/ cgi-bin/qcat?J/A+A/383/631

**Table 1.** Input catalogues: mostly low latitudes.

| Catalogue | Acronym | Entries |
|---|---|---|
| Barnard (1919, 1927) | B | 349 |
| Lynds (1962) | LDN | 1806 |
| Sandqvist & Lindroos (1976) | SLDN | 42 |
| Sandqvist (1977) | SDN | 95 |
| Bernes (1977) | BDN | 81 |
| Zealey et al. (1983) | CG | 34 |
| Myers et al. (1983) | MLB | 90 |
| Feitzinger & Stüwe (1984)[a] | FeSt1- | 489 |
| Feitzinger & Stüwe (1984)[b] | FeSt2- | 331 |
| Hartley et al. (1986) | HMSTG | 1101 |
| Clemens & Barvainis (1988) | CB | 248 |
| Parker (1988) | P | 147 |
| Vilas-Boas et al. (1994) | VMF[c] | 101 |
| Bourke et al. (1995) | BHR | 169 |
| Lee & Myers (1999) | LM | 406 |
| Vilas-Boas et al. (2000) | [d] | 104 |

Notes: [a] Extended clouds; [b] globules; [c] additional designation is the related dust complex abbreviation plus running number; [d] designation as in [c].

the PSS for small cloud searches and studied their optical, IR and millimeter properties. Vilas-Boas et al. (1994) investigated small clouds from ESO/SERC J plates, extinction maps and previous studies, located in nearby clouds or complexes such as Coalsack and Vela. Bourke et al. (1995) analysed clouds with opacity class A from Hartley et al., two of them new. Dense clouds can harbour embedded cores of Young Stellar Objects (YSO) or Pre-Main-Sequence (PMS) stars. Parker (1988) provided accurate positions for 147 Lynds' clouds with opacity class 6. Lee & Myers (1999) listed the largest set of dense cores, with opacity classes 5 and 6 from Lynds and A from Hartley et al. Parker (1988) and Lee & Myers (1999) studied the relation of dense cores to IRAS sources, and in turn to YSO and PMS. Finally, Vilas-Boas et al. (2000) studied cores in Lupus, Corona Australis, Scorpius and Vela.

The input data were complemented with objects from individual studies or small lists: (i) 21 nearby clouds and complexes (Cambrésy 1999) with extinction maps from star counts; (ii) 23 nearby clouds and complexes as studied in CO (Dame et al. 1987); (iii) molecular clouds from individual studies such as TMC-1 and TMC-2 (Churchwell et al. 1978), OMC-1 (Ziurys et al. 1981), OMC-2 and OMC-3 (Chini et al. 1997), Heiles 2 (Heiles 1968) and MT 1 (Maddalena & Thaddeus 1985); (iv) 2 cometary globules – CG – and 7 Gum Nebula Dark Clouds – GDC (Reipurth 1983); and finally, (v) a pre-cometary globule (Lefloch & Lazareff 1995). The total number of entries from catalogues and lists preferentially including low-latitude clouds is 5654.

**Table 2.** Input catalogues: mostly high latitudes.

| Catalogue | Acronym | Entries |
|---|---|---|
| Magnani et al. (1985) | MBM | 57 |
| Keto & Myers (1986) | KM | 18 |
| Désert et al. (1988) | IREC | 516 |
| Magnani et al. (1996) | various | 120 |
| Reach et al. (1998) | DIR | 141 |

The acronyms and number of entries of the input catalogues dealing mostly with high-latitude clouds are given in Table 2. Most of them deal with CO studies, but searches based on far infra-red (FIR) dust emission atlases such as IRAS provided most entries. High-latitude clouds present low visual extinction (translucent – van Dishoeck et al. 1991) and are therefore difficult to detect on photographic surveys. Magnani et al. (1985) and Keto & Myers (1986) studied high-latitude clouds in CO (the latter study includes some lower-latitude clouds). Magnani et al. (1996) compiled list of clouds taken from the literature, providing properties and references for clouds with the acronyms UT, ir, HSVMT, G, Stark and 3C. The acronym HRK stands for clouds in regions studied in HI, CO and IR (Heiles et al. 1988). FIR emission excess with respect to H I indicates cold clouds where hydrogen appears in molecular form (de Vries et al. 1987). Désert et al. (1988) used the IRAS 100 $\mu$m data coupled to the Berkeley H I survey (Heiles & Habing 1974) to detect 516 infrared excess clouds (IREC) for $|b| > 5°$. Reach et al. (1998) used DIRBE/COBE in conjunction with the Leiden-Dwingeloo H I survey (Hartmann & Burton 1997) to create higher resolution maps. From the IR excesses they retrieved 60 previous clouds and found 81 new ones (DIR – Diffuse Infrared Clouds). Also included were 2 new clouds studied in CO by Hartmann et al. (1987), and the absorption component of the Draco Nebula (Goerigk et al. 1983).

## 3. Catalogue construction and contents

The procedures for catalogue construction and cross-identifications follow those outlined for the LMC and SMC extended objects (Bica & Schmitt 1995; Bica et al. 1999). Available electronic catalogues were retrieved from CDS and remaining ones were typed. The original coordinates (usually either B1950.0 $\alpha, \delta$ or in $l$, $b$) were transformed to J2000.0 $\alpha, \delta$ and to homogeneous $l$, $b$ values. All catalogues were merged into one file and sorted by $l$. Equivalent objects were merged into a single line considering positions and angular dimensions. This was complemented with available properties such as optical opacity class. Previous cross-identifications were examined. Revisions occurred and many new equivalences were found. Doubts on optical clouds were inspected on Digitized Sky Survey (DSS and XDSS) images and/or sky charts generated by means of the Guide Star Catalogue. Recent catalogues dealing with small nebulae (Sect. 2) and that by Hartley et al. (1986) produced accurate coordinates, which is not always the case of early works.

Studies in Sect. 2 and Hilton & Lahulla's (1995) provided distances from several methods (e.g. related stars or OB complexes, background and foreground stars, kinematical). Studies in Sect. 2 and Otrupcek et al.'s (2000) provided LSR CO (in a few cases H I) velocities. Velocity and distance estimates were additional contraints for the definition of clouds and their physically related groups.

Opacity classes were reduced to Lynds' (1962) scale. Internal variations in some clouds were averaged. For detailed values we refer to the original studies. Optical opacity class has been a useful parameter for cloud classifications and selections. We provide FIR contrast parameters for similar purposes. Schlegel et al. (1998) built an all-sky reddening $(E(B-V))_{\rm FIR}$ map based on 100 $\mu$m dust thermal emission with resolution of $\approx 6'$, and temperature corrections based on lower resolution DIRBE maps. We extracted the reddening central value in the direction of each cloud and 4 background surrounding positions distant 1.3× the cloud's major axis dimension for those larger than $10'$. For smaller clouds the background distance was 2× the major axis dimension. We computed the background average value, its fluctuation, and 2 contrast parameters. $\Delta$ is defined as the difference between centre and background values, and $\rho$ as the ratio of these quantities. Note that $\Delta$ can present negative and $\rho < 1$ values, since background contributions can be substantial, especially as one approaches the Plane (Dutra & Bica 2000b). Neighbouring clouds, position uncertainties, irregular shapes and extensions can also disturb. Although clouds are concentrated to the Plane ≈3750 clouds present positive FIR contrast ($\Delta > 0$ and $\rho > 1$). Selections for a variety of studies can be obtained from such parameters, from candidates to line-of-sight near projections to isolated dense clouds. As cautionary remark, the present discrete cloud FIR values and parameters should not be taken as true dust column densities and their combinations, especially for small clouds owing to the low resolution of the temperature maps, coupled to other limitations.

Some newly identified clouds are included: (i) Magnani et al. (2000) detected CO along 133 directions for $b < -30°$, 58 were new detections and 75 were related to 26 previous clouds. We compared Reach et al.'s (1998) FIR maps with CO detections by Magnani et al. (2000). As a result we found evidence of 16 new clouds indicated by the acronym CODIR (one additional cloud turned out to be IREC 267); (ii) We were not particularly searching for new clouds in the present study, but during the cross-identification process and inspections of optical images and FIR maps we found 15 uncatalogued clouds (DBDN). They are 2 low-latitude globules, 10 high-latitude and 3 transition zone extended clouds. (iii) The dust clouds recently reported by Dutra & Bica (2001) using the 2MASS Atlas. These 5 clouds (DBIRDN) are opaque in the $K_{\rm s}$ band and are projected onto the central bulge. Some of them are probably giant molecular clouds near the Centre.

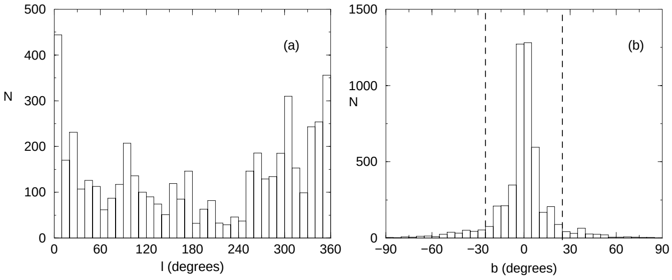


**Fig. 1.** Histograms of dust clouds for Galactic longitudes (Panel **a)**) and latitudes (Panel **b)**). Dashed line separates adopted high and low latitude zones.

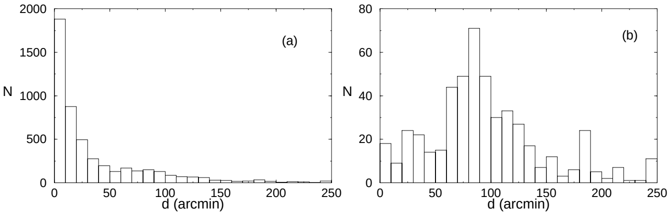


**Fig. 2.** Angular size histograms for low (left panel) and high (right panel) latitude dust clouds. Major axis dimension is used. The plots are limited to $250'$.

From ≈6500 input entries, cross-identifications led to 5004 clouds and complexes in the unified catalogue, which will be available in electronic form at CDS (Strasbourg) via anonymous ftp to `cdsarc.u-strasbg.fr` `(130.79.128.5)`. Each entry occupies 2 catalogue lines. The first line shows by columns: (1) and (2) Galactic coordinates, (3) and (4) J2000.0 $\alpha, \delta$, (5) and (6) major and minor axes dimensions in arcmin, (7) optical opacity class, (8) designation(s). In line 2 Cols. (1) to (5) list FIR central reddening, background reddening, fluctuation and contrast parameters $\Delta$ and $\rho$. Subsequent fields are distances in kpc preceded by "d=", and CO or H I LSR velocities preceded by "vCO=" or "vHI=", respectively. Finally, comments occupy the last part of line 2: (i) further designations (preceded by "&") with respect to Col. (8) of line 1; (ii) hyerarchical relations among dark and/or bright nebulae (e.g. LBN for Lynds 1963 and Sh2- for Sharpless 1959), as indicated by *in* (within), *inc* (includes) or *rel* (related). Note that dust cloud designations are not mixed to those of bright clouds, since such possible relations are given only in line 2. Concerning IREC clouds we include the remarks by Désert et al. (1988) on those disturbed by bad IR or HI pixels. Dust cloud acronyms in the catalogue other than those indicated in the present references, are taken from the references themselves.

## 4. Some catalogue properties and prospective work

Figure 1 shows $l$ and $b$ histograms for the resulting 5004 dust clouds. The $l$ histogram presents a minimum towards the Anticentre and maximum in the Galactic Centre direction. In the $b$ histogram the clouds are strongly concentrated to the Plane, 89% located in the low-latitude zone. In the high-latitude zone there occur 525 clouds. A few clouds populate the Polar Caps. The present sample of high-latitude clouds is a factor ≈2 larger than that recently compiled by Bhatt (2000) in a study of possible connection of part of them to the Per OB3/CasTau and Sco OB2 associations.

Angular size histograms are shown in Fig. 2 in terms of cloud major axis dimension. Each histogram is limited to 250′, but some clouds and complexes exceed 1000′. For the total sample (Panel a) the distribution is exponential, dominated by globules and cloud cores. For the high-latitude sample (Panel b) the distribution is ≈Gaussian, and the peak occurs for clouds of size 80′–90′.

The present effort to merge and cross-identify dust cloud catalogues allows one to conclude that ≈1500 have a previously reported equivalent object. Chronology (Tables 1 and 2) and usage help decide which acronym(s) to adopt. Just to mention a few examples: (i) Barnard's early catalogue has some clouds overlapping with those of large southern catalogues, e.g. B 232, FeSt1-252 and HMSTG 343.7+4.0 are equivalent objects; (ii) the northern/equatorial and southern largest catalogues have an overlapping zone, e.g. the small cloud LDN 1701 = HMSTG 354.0+3.5 = Sc16, the latter designation is from Vilas-Boas et al. (2000); (iii) the small dust cloud in the Gum Nebula GDC 6 has counterparts in HMSTG 267.6–6.4 and BHR 40, but its neighbour GDC 3 remains to date with a single designation; (iv) at high latitudes MBM 2 = IREC 155 originate from 2 different methods (CO and IR/H I excess); (v) IREC and DIR clouds have many equivalences, e.g. IREC 7 = DIR 009-30; (vi) catalogues typical of high and low latitude zones have clouds in common, e.g. LDN 317 = IREC 10, and FeSt1-223 = IREC 445. The catalogue is not intended to be complete, but it includes all cross-identified acronyms, and provides a tool to converge information. Doubt on any cross-identification or parameter can be analysed by accessing the original catalogues.

Finally, we address prospective work. A promising approach is the identification of dust clouds in the $K_{\rm s}$ band with 2MASS (Dutra & Bica 2001). The present catalogue is a tool to verify whether NIR clouds have an optical counterpart or not. Recently, 2MASS reported in `http://www.ipac.caltech.edu/2mass/gallery/fest1-457atlas.jpg` a 3-band image and description of a cloud identified as FeSt1-457 (Feitzinger & Stüwe 1984). This was a near-position match. A detailed cross-identification with all available information shows that one is dealing with 2 different objects. The 2MASS object (included as 2MASS-DN1.7+3.6 in the present catalogue) has a small angular size (≈4′ × 3′) with no optical counterpart on DSS or XDSS images, while FeSt1-457 is a large cloud (≈70′) with medium optical opacity (class 4). If both clouds are nearby, that in 2MASS may be a related globule, but it may turn out to be a more distant object. This application shows the importance of a unified catalogue for searches of new clouds.

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