A&A 399, 141–145 (2003)
DOI: 10.1051/0004-6361:20021743

Astronomy & Astrophysics

Merged catalogue of reflection nebulae⋆

T. Yu. Magakian⋆⋆

Byurakan Astrophysical Observatory, Aragatsotn prov., 378433 Armenia and Isaac Newton Institute of Chile, Armenian Branch

Received 21 October 2002 / Accepted 7 November 2002

Abstract. Several catalogues of reflection nebulae are merged to create a uniform catalogue of 913 objects. It contains revised coordinates, cross-identifications of nebulae and stars, as well as identifications with IRAS point sources.

Key words. ISM: reflection nebulae – catalogs

1. Introduction

Since their discovery at the beginning of the Twentieth century and classical works by Hubble (1922a, 1922b) the reflection nebulae (RNe) have become an important target of various studies in astrophysics and galactic astronomy. Many of stars, embedded in RNe, have been found to be objects at early stages of evolution; quite a few Herbig-Haro objects and outflows have been discovered in the vicinity of RNe. Actually, in many cases the presence of RNe is the best indicator of recent or ongoing star formation. On the other hand, the associations of stars in RNe (*R*-associations) were used as tracers of the spiral structure of Galaxy (e.g. van den Bergh 1968), as well as for studies in other areas of galactic astronomy.

The cataloguing of nebulae, including the RNe, was started more than 100 years ago with the creation of the NGC and IC lists. After that many interesting objects were listed in the works of Hubble (1922a, 1922b) and Barnard (1913, 1927). The first attempt to create a comprehensive catalogue of Galactic bright nebulae (215 objects) was made by Cederblad (1946).

Real progress in the searches and cataloguing of RNe was achieved after the First Palomar Sky Atlas (POSS) became available. Soon several catalogues, completely or partly based on POSS, were published. Among them were the lists by Struve & Straka (1962) (74 mostly new objects), by Dorschner & Gürtler (1963, 1966) (192 objects), by van den Bergh (1966) (170 stars, illuminating nebulae; in this work the concept of *R*-associations was introduced), and by Rozhkovski & Kurchakov (1968) (118 nebulae). All these lists have significant overlap and include only the objects with declination greater than −25°. Thus, by the end of the sixties about 300 RNe in the northern hemisphere were catalogued. The large (1125 objects) catalogue of bright nebulae by Lynds (1965) also should be mentioned, but it mixes the emission and reflection nebulae. Subsequently, the southern hemisphere was searched and 136 stars in the nebulae were added (van den Bergh & Herbst 1975).

Since that period no systematic searches, especially devoted to RNe as the class, have been conducted. The interest of the astronomical community shifted to such objects as cometary nebulae (actually a subclass of RNe), Herbig-Haro objects, cometary globules and to the optical identification of IR and radio sources in star-forming regions. The full description of these studies is beyond the scope of the present paper. As a work of more general character the large survey of 75° strip of Southern Milky Way by Brand et al. (1986) should be noted. This survey includes 400 nebulous objects of various sizes and natures.

As a kind of epilogue to the surveys of Galactic nebulae one can consider the atlas and catalogue by Neckel and Vehrenberg (1985, 1987, 1990). Its three volumes contain 1547 bright nebulae of various types (excluding planetary nebulae).

It is evident, however, that a full catalogue of RNe with whole-sky coverage still does not exist. As a first step in this direction we decided to create a merged catalogue of Galactic reflection nebulae, combining and correcting the existing lists.

2. The catalogue

In the process of the work on the catalogue we used as the main resource the digital sky atlases DSS-1 and DSS-2, available through the Internet. For the visualization of the charts and the measurement of coordinates the programs SKYCAT (Brighton et al. 1996) and FITSVIEW v.2.0.2 (Cotton 1999) were used.

As the basis for the merging we chose the catalogues by Dorschner & Gürtler (1963, 1966) (DG), by

⋆ The 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/399/141

⋆⋆ e-mail: tigmag@sci.am

van den Bergh (1966) (VdB) and by Rozhkovski & Kurchakov (1968) (RK) for the northern hemisphere, and the catalogue by van den Bergh & Herbst (1975) (VdBH) for the southern hemisphere. The out-of-date catalogues by Cederblad (1946) (Ced) and by Struve & Straka (1962) (SS) were used only to check the numbering. Also the NGC and IC numbers from the revised versions of these catalogues (Sulentic & Tifft 1973; Sinnott 1988) were checked. After this operation we excluded the objects whose classification was revised according to their morphology in the DSS and/or to references (i.e. objects found to be the planetary nebulae, galaxies, HII regions).

After this first stage we decided to also include in the catalogue several other lists, which were oriented to more specific objects (e.g. cometary nebulae), or covered only part of the sky. Thus, we added the list by Bernes (1977) (Be), with exclusion of all HH objects and obvious HII regions, and the list by Brand et al. (1986) (BBWo), which also contained a large number of galaxies, HII regions and very faint nebulous patches of unknown nature.

As a last step we used the Atlas of Galactic Nebulae (GN) by Neckel & Vehrenberg (1985, 1987, 1990). It already contains a large fraction of the objects that were included in the merged catalogue. From this source we added other RNe, which were omitted in the previous surveys, as well as those red nebulous objects (RNO) from the list by Cohen (1980) (this list is nearly fully included in the Atlas), which, according to their appearance and/or subsequent studies, were definitely classified as RNe or cometary nebulae.

Because of our intention to describe in this catalogue the direct connection between nebulae and stars (or stellar groups), we did not include the faint extended nebulae, illuminated by the galactic field or distant luminous stars. Many such objects can be found in BBWo and GN catalogues, mentioned above. The full cataloguing of such nebulae should be considered as a separate task. Faintly glowing rims of the dark clouds and similar objects also were not included. The cometary globules, listed in the GN Atlas, were included (at least all objects which were discernible on the DSS charts), as well as the somewhat similar in morphology and, probably, in origin, RNe in Orion (see Ogura & Sugitani 1998).

To exclude galaxies wrongly identified as Galactic nebulae, we were mainly guided by the object morphology. Difficult cases were checked with the NED database (`http://nedwww.ipac.caltech.edu`). The number of such objects was quite significant, especially in the lists of BBWo, RNO and GN. Several cases are rather complicate and probably could be fully understood only when spectral data become available. For example, in VdB83 we probably see a bright and extended galaxy, which shines through the group of stars, involved in the faint reflection nebula.

For a significant fraction of the objects it was necessary to determine new coordinates from DSS. For the bright illuminating stars, coordinates were taken from the electronic version of the cross-identification catalogue of BD, CD and CPD sky surveys (Roman et al. 1983). For the objects from the VdBH catalogue we took precise coordinates from the work of Rousseau & Périé (1996); it should be noted that the existence of this work itself demonstrates the seriousness of the situation with the faint nebulae coordinates.

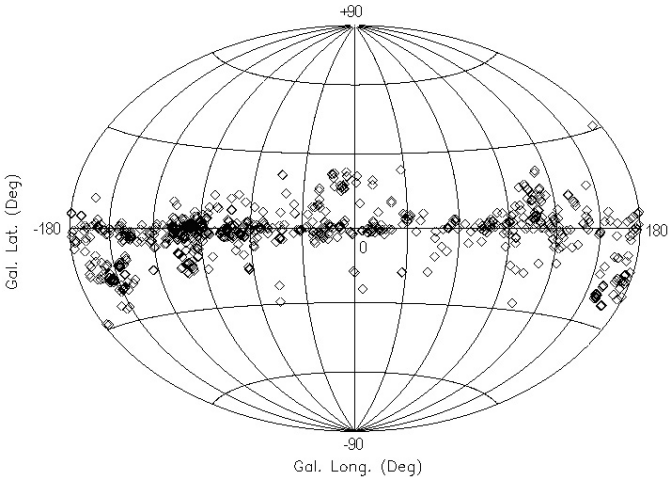

Fig. 1. Plot in galactic coordinates of all the objects of the catalogue. Grid lines are spaced by 30°.

In the final list more than 900 objects were included. The identification of all objects was checked with the SIMBAD database, available via Internet (`http://simbad.u-strasbg.fr/Simbad`). This allowed us in many cases to make additions and corrections. Besides, SIMBAD was used to identify the stars and infrared sources, connected with the nebulae.

The final catalogue contains 913 objects. In the table their equatorial coordinates, precessed to the Epoch 2000.0, and numbers according to the DG, RK, VdB, VdBH, Be, NGC-IC, GN, BBWo, Ced, SS catalogues, are given. Other names by which these objects or their related stars are known are also given. For the stars belonging to the BD, CD (or CPD) and HD surveys these numbers are included. If the illuminating star can be definitely identified, but it is too faint to be included in these surveys, its existence is denoted by asterisks. Many such stars are included in deeper surveys, such as SAO, PPM, GSC. We did not insert their numbers in the table to keep its size within reasonable limits. If necessary, these numbers can be easily obtained from SIMBAD. We give also the identifications of the objects in the Point Sources Catalogue from IRAS database (`http://space.gsfc.nasa.gov/astro/iras/`). In most cases, but not always, these sources coincide with illuminating stars. A significant fraction of these identifications were made by us for the first time. In the last column the probable types of nebulae (reflection, reflection+emission, cometary) are given. In Table 1 we present the beginning of the catalogue (0th hour in RA) to illustrate its structure.

The differentiation between various types of nebulae was made on the basis of their morphology and brightness on the blue and red plates of DSS-2. We tried to exclude all the pure emission nebulae: the remaining ones were divided into the types “C” (reflection), “C+E” (nebulae with combined spectrum) and “CN” (cometary nebulae). The last type we understand in a broad sense, i.e. it embraces nebulae which have classic cometary shapes (fans, commas, semi-rings) and other nebulae with morphological evidence of circumstellar disks, as

Table 1. Merged catalogue of reflection nebulae.

RA(2000)	Dec(2000)	DG	RK	VdB	VdBH	Be	NGC	GN	Brand	Ced	SS	Other des.	DM	HD	IRAS	Class	Comments
00 07 03.4	+65 38 38							00.04.4				PP1, MacCH1	*	*	00044+6521	CN	
00 07 11.5	+65 39 13	2	1					00.04.6			1		*	*		C	
00 10 46.3	+58 46 11		2	1a-d				00.08.0					57°9, 18, 19, 22	470, 594, 236327, 627	00081+5829	C	4 stars in nebula
00 11 26.6	+58 49 28							00.08.8				LkHα198	*	*	00087+5833	CN	
00 13 23.5	+65 36 46	3	3	2				00.10.6		1	2		64°13			C	
00 23 24.3	+56 09 53							00.20.6					*	*	00206+5553	C	
00 28 58.9	+56 42 05							00.26.1				Kr3-1				C	edge of globule
00 34 37.2	+69 26 02	5		3				00.31.6			4		68°34	3037	00315+6909	C	
00 35 47.2	+58 54 14							00.32.9					*	*	00329+5837	C	
00 36 05.5	+66 17 30							00.33.2				GM3-1	*	*	00331+6600	C	
00 36 52.3	+63 29 29							00.34.0				GM1-33, RNO1	*	*		CN	
00 43 18.4	+61 54 40		4	4				00.40.4				V594 Cas	61°154		00403+6138	C	
00 44 57.2	+55 46 53	4						00.42.0				NS2	*	*	00420+5530	C,CN?	several stars?
00 49 24.7	+50 44 53							00.46.3				RNO3			00465+5028	CN	inside globule
00 56 42.0	+60 43 02			5			IC59, IC63			4a,b		γ Cas	59°144	5394	00536+6026	C+E	
00 58 09.3	+56 30 21	6	5					00.55.3				Kr3-2?	*	*	00551+5613	C, gal?	4 nebulae

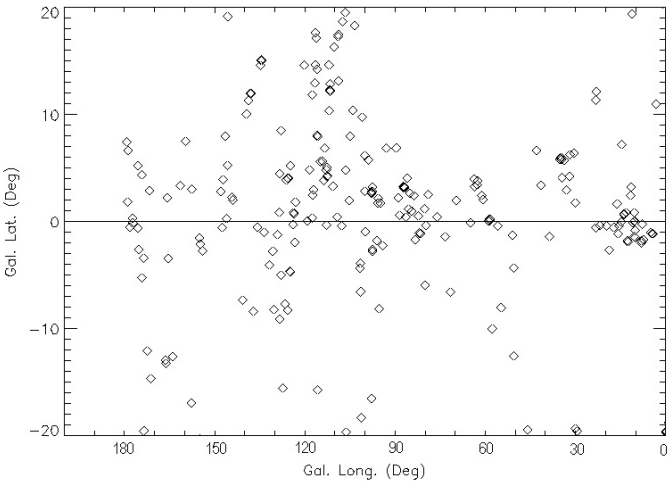

Fig. 2. Distribution of objects along the Northern Milky Way.

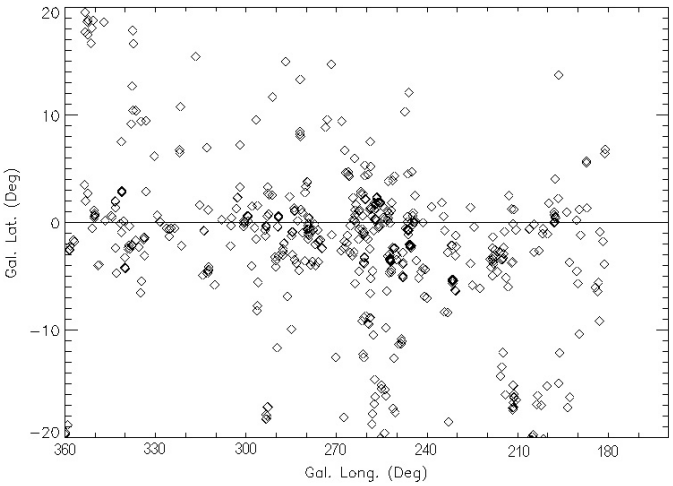

Fig. 3. Distribution of objects along the Southern Milky Way.

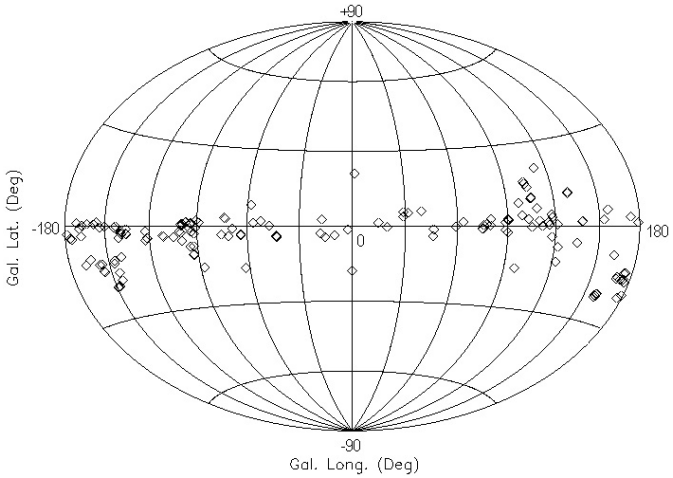

Fig. 4. Distribution of cometary nebulae in galactic coordinates. Grid lines are spaced by 30°.

well as other nebulous objects in the dark clouds, which can be (or probably are) associated with young stellar populations (these last ones are classified as "CN?"). Possible galaxies are noted as "gal?"

It should be noted that as the work on the digitization of blue plates of the DSS-2 is not finished yet, the morphology in the blue part of the spectrum for many of the southern objects has not yet been checked; thus, the classification of certain objects, especially the southern ones, could be changed in the future. Of course, subsequent observations also could change the content of the catalogue, because certain faint objects could be classified afterward as emission nebulae or galaxies. However, we hope, that the classifications of the majority of the objects in the catalogue will prove to be reliable enough.

3. Discussion and conclusion

As one can see from Fig. 1, the objects listed in the catalogue are uniformly distributed along the Galactic plane, which suggests that the sample is reasonably complete. Their high concentration towards the Galactic plane is, of course, expected, because most of these objects are associated with extreme population I objects, and because their distances are low (usually they are nearer than 1–1.5 kps). One can also easily distinguish the nearby groupings of the nebulae in Orion, Taurus, Ophiuchus and other ones, located outside of the Galactic plane.

We also plotted the distributions of RNe for the Northern and Southern Milky Way separately (Figs. 2 and 3). They can be compared with the similar data in the paper of VdBH. One can see the certain similarities as well as differences, which are produced by the much larger volume of the sample. Particularly, the tendency of the greater "clumpiness" of the distribution in the southern hemisphere still persists. However, in general, it is possible to come to conclude that the band of Milky Way is more-or-less uniformely covered by a "diffuse" field of the objects, on which the individual "condensations", i.e. *R*-associations, are scattered. If faint high-latitude nebulae were included in the catalogue, this "diffuse" field would be even more pronounced. The obvious overabundance of the nebulae in the southern hemisphere is probably real.

A total of 171 objects from our catalogue were classified as cometary or possible cometary nebulae. As is seen in Fig. 4, they are heavily concentrated towards the Galactic plane; outside of it they are situated mainly in the nearby groups in dark clouds. This could be explained by their proximity to Sun and by their extreme evolutionary youth. The subsample of cometary nebulae is far from complete.

The present merged catalogue is useful by itself as the checked and revised list of the Galactic RNe and related stars. Also, it is sufficiently complete to conduct various studies in stellar astronomy and statistics. For example, it will be interesting to check the existing *R*-associations and to try to find new ones. This catalogue also could serve as a useful tool for the planning of new survey works. Actually, for a significant number of the objects included nothing is known except for their coordinates. Meanwhile many of them coincide with infrared sources, have interesting morphology, and they could, in fact, be young pre-main sequence stars.

Acknowledgements. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. This research also has made use of the SIMBAD database, operated at CDS, Strasbourg, France. The Digitized Sky Survey was produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope in Australia. The plates were processed into the present compressed digital form with the permission of these institutions.

The author also wishes to thank the librarians of European Southern Observatory for providing copies of the tables of the catalogue of Neckel and Vehrenberg. He is grateful to the referee Dr. S. van den Bergh for helpful comments and suggestions.

This work was partially supported by INTAS grant 00-00287 and ANSEF grant No. PS103-01.

References

Barnard, E. E. 1913, Lick Obs. Publ., 11

Barnard, E. E. 1927, A Photographic Atlas of Selected Regions of the Milky Way, ed. E. B. Frost, & M. R. Calvert (Washington, Carnegie Institution of Washington)

Bernes, C. 1977, A&AS, 29, 65

Brand, J., Blitz, L., & Wouterloot, J. G. A. 1986, A&AS, 65, 537

Brighton, A., Herlin, T., Albrecht, M., Durand, D., & Biereichel, P. 1996, ESO, `http://archive.eso.org/skycat`

Cederblad, S. 1946, Medd. Lund Astrophys. Obs., ser.II, No.119

Cohen, M. 1980, AJ, 85, 29

Cotton, W. D. 1999, `http://www.cv.nrao.edu/~bcotton/fitsview.html`

Dorschner, J., & Gürtler, J. 1963, Astron. Nachr., 287, 257

Dorschner, J., & Gürtler, J. 1966, Astron. Nachr., 289, 57

Hubble, E. 1922a, ApJ, 56, 162

Hubble, E. 1922b, ApJ, 56, 400

Lynds, B. 1965, ApJS, 12, 163

Neckel, T., & Vehrenberg, H. 1985, 1987, 1990, Atlas of Galactic Nebulae, Vol I-III (Treugesell Verlag, Düsseldorf)

Ogura, K., & Sugitani, K. 1998, Publ. AS Australia, 15, 91

Roman, N. G., Warren, W. H., & Schofield, N. J. 1983, SAO-HD-GC-DM Cross Index, Astronomical Data Center, NASA

Rousseau, J. M., & Périé, J. P. 1996, A&AS, 117, 379

Rozhkovski, D. A., & Kurchakov, A. V. 1968, Tr. Astroph. Inst. AN Kaz. SSR., 11, 3

Sinnott, R. W. (ed.) 1988, NGC 2000,0 – The Complete New General Catalogue and Index Catalogue of Nebulae and Star Clusters, by J. C. E. Dreyer (Sky Publ. Corp. and Cambridge Univ. Press)

Struve, O., & Straka, W. C. 1962, PASP, 74, 474

Sulentic, J. W., & Tifft, W. G. 1973, The Revised New General Catalogue of Nonstellar Astronomical Objects (Tucson: The Univ. of Arizona Press)

van den Bergh, S. 1966, AJ, 71, 990

van den Bergh, S. 1968, Astrophys. Lett., 2, 71

van den Bergh, S., & Herbst, W. 1975, AJ, 80, 208