JOURNAL OF THE KOREAN ASTRONOMICAL SOCIETY
29: S129 ∼ S131, 1996

THE SURFACE DISTRIBUTION OF CARBON STARS IN THE GALAXY

OMAR M. KURTANIDZE AND MARIA G. NIKOLASHVILI
Abastumani Astrophysical Observatory, 383762 Abastumani, Georgia
e-mail: okur@abao.kheta.ge, mgnik@abao.kheta.ge

ABSTRACT

The results on the deep low dispersion (1250 Å/mm at H_γ, $30° < l < 165°$, $195° < l < 210°$, $|b| < 5°$; 7000Å/mm at A band, $50° < l < 115°$, b=0°, b=±3.5°) spectral surveys of the MILKY WAY are presented. More than 2250 carbon stars were identified among them 1440 new ones. The C/M5$^+$ ratio increases from 0.02 to 0.3 when longitude varies from 30° to 210°. On the basis of A GENERAL CATALOG OF GALACTIC COOL CARBON STARS the surface distribution of carbon stars has been studied.

I. INTRODUCTION

Theoretical models for AGB stars indicate that the Carbon Star (CS) phase may last up to 10^6 years which is strongly limited by rapid mass loss rates up to 10^{-4} $M_\odot$ yr^{-1} (Kleinmann 1989). This lifetime is consistent with the analysis of Claussen *et al.* (1987), who used the space distribution of high luminosity CS and their main sequence progenitors to argue that the lifetime of CS lies between 10^5 and 10^6 years.

CS are promising standard candle tracers of the large-scale Galactic structure. The CS with determined distances and velocities will be powerful indicators of disk dynamics, giving the opportunity to probe evolutionary history of the Galaxy (Weinberg 1993). They can also play important role in the estimation of galaxy dark matter out to $5R_\odot$ (Schechter 1995).

II. OBJECTIVE PRISM SURVEYS

The Henry Draper catalogue was primary source containing data on CS till 1940-ies. Starting with a pioneer work of Lee, *et al.* (1940) the low dispersion objective-prism near-infrared (NIR) spectra have been widely used for identification of cool red stars. Nassau and Velghe (1964) introduced the method of using the near-infrared spectral range 6800-8800Åfor the detection and classification of late-type stars. They showed that CS may be easily identified by their pronounced cyanogen bands. In 1950's Nassau and his collaborators carried out a NIR spectral survey of the galactic belt to a limiting magnitude I=$10^m.5$. Numerous extensive objective prism spectral surveys were conducted later by Westerlund (1971), MacConnell (1988, 1995), Maehara and Soyano (1990), Soyano and Maehara (1993), Fuenmayor (1981), Alksne et al (1989), Aaronson and Blanco et al (1989, 1990), Stephenson (1989) the results of which are summarised in Table 2.

III. YELLOW-RED SURVEY

In the beginning of 1975 we began at Abastumani Astrophysical Observatory a laboratory tests for hypersensitization of the Kodak emulsions (103a-O, IIa-O, D, IIIa-J,F) by baking in dry air for 4-10^h at 50-70°C. Applied to types IIIa-J,F this technique yielded a speed gains from 3 to 5. At first stage, this hypersensitized plates were used for a direct photography of nearby clusters of galaxies ($z < 0.05$, B=$21^m.5$) and later on at the end of 1977 in a low dispersion spectroscopy for identification of the different kind of stars. Namely, CS were identified on this plates to V=$16^m.5$, which is equivalent to the limit of Westerlund for objects having V-I∼3. Therefore, in the middle of 1978 we undertook an extensive low dispersion spectral survey of the northern equatorial belt of the MILKY WAY for identification OB, B8-A3, M and C stars (Kurtanidze, Nikolashvili, 1981). The principal aim was the extension of Westerlund's deep southern galactic belt survey to the northern Milky Way.

The spectra obtained for this survey have a dispersion of 1250Å/mm at H_γ. They were taken with 2° objective prism attached to the 70/98/210 cm meniscus telescope of the Abastumani Observatory. Kodak IIIa-J,F plates hypersensitized in dry air or in nitrogen of 20 and 50 min exposure time yielded B=$18^m.5$ (A0V).

The plate material cover the region of the MILKY WAY from l=30° to l=165° and l=195° to l= 210°, b=0°, ±3.6°. The survey of the region $165° < l < 196°$ was carried out by Fuenmayor (1981) in the near-infrared.

On these plates the group of OB, B8-A3, M and C stars are easily distinguished. CS were identified by the presence of carbon molecular C2 bands at 4737Å, 5167Å(IIIa-J,F) and 5635Å(IIIa-F).

It must be noted that the survey of the region $195° < l < 210°$, $|b| < 5°$ was carried out on Kodak I-N + RG5, but nevertheless included here due to I and J, F surveys limiting magnitude are nearly the same for late type stars as it is stated above.

As a result of the Fitst Abastumani Survey for Early and Late type stars more than 1500 CS were identified among them more than 860 new ones (Nikolashvili 1987; Kurtanidze and Nikolashvili 1981, 1989a,b,c; 1993, 1995). Details are presented in Table 1.

Table 1. Yellow-Red Spectral Survey

Region	New	All	N/S	C/M5$^+$
30-50	85	111	0.56	0.02
50-70	145	217	1.09	0.04
70-90	156	264	1.32	0.06
90-115	146	278	1.11	0.09
115-130	115	181	1.12	0.09
130-145	79	122	0.81	0.14
145-165	83	172	0.86	0.25
195-210	53	158	1.05	0.30
$\sum$	862	641	1503	

Table 2. Deep Spectral Surveys

*	S	I	All	New
W	1,320	12.5	1,124	950
F	644	13.0	283	123
McC	1,200	13.0		600
MS	869	13.0	523	200
SM	456	13.0	361	59
AA	1,200	14.5(V)	318	
KN	1,500	16.5(V)	1,503	862
KN	350	15.5	496	384
NK	150	15.5	256	194
AB	400	15.0	921	423
S	2,400	14.0	2,100	

IV. NEAR-INFRARED SURVEY

To probe the farthest outer part of the Galaxy in the galactic plane we initiated in the middle of 80's a new deepest spectral survey. It covers the region from l=50° to l=115° and b=0°, ±3.5°. The area covered by plates with size 12×12 cm is equal to ~12 sq. degrees. All observations have been carried out with 70-cm meniscus telescope equipped by 2° prism giving reciprocal linear dispersion about 7000Å/mm at A band. Fine grain Kodak IV-N plates hypersensitized in silver-nitrate solution ($AgNO_3$) were used in combination with 2mm Schott RG8 filter yielded a passband λλ6800-8800Å.

CS are identified on the infrared-sensitive spectral plates by presence of the easily noticeable deep located in the middle of the spectra, originated due to an unresolved CN bands at λλ 7945, 8025, 8320Å. Despite the very low dispersion used, consequantly the low resolution ~200Å (R=40), CS are easily distinguished from M-type stars, TiO bands of which are well separated on these spectra. On plates obtained with 1° prism (~15000Å/mm at A-band, Δλ=400) CS are indistinguishable from other late type stars. As a result of the survey of about 500 sq.degrees 752 CS were revealed to a limiting NIR magnitude $15^m.5$, among them 580 new ones (Kurtanidze, Nikolashvili 1988; Nikolashvili, Kurtanidze 1989). The limiting magnitude was estimated on spectral plates of IC5146 (Forte, Orsatti 1984).

V. SURFACE DISTRIBUTION

The data on all the surveys described were compiled by Stephenson (1989) in A General Catalogue of Cool Carbon Stars containing 5987 entries the faintest of which are as faint as **$15^m.5$** in the NIR. Thanks to all these low dispersion spectral surveys carried out in the NIR and Yellow-Red spectral regions, the equatorial ten degree belt of the MILKY WAY is now uniformly covered to a NIR magnitude $13^m.0$.

Fig.1 displays the longitude distribution of about 3900 carbon stars in the galactic plane ($|b| < 5°.0$, $I < 13^m$). The number of CS was counted in bins of size 5° with an area of 50 sq.deg. It is clearly seen, that the longitude distribution of CS is strikingly nonuniform. The surface density of CS increases outside the directions of galactic center and reaches it's maximum values in the direction of CARINA (l=290°) and CYG-CAS (l=100°), which are equal to 2.7 and 2.3 carbon stars per sq.deg. The average surface density of CS in the region 50° − 0° − 310° is two times lower than in the direction of 130° − 180° − 230°, while M-type stars are more numerous in the direction of galactic center. The latitude distribution of CS within ±5° is more or less uniform.

The C/M5$^+$ has been determined in more than a hundred fields located at b=0°, ±3.5°. The numbers of M5$^+$ were counted in a square of 2° × 2°. The results are given in Table 1. There is a pronounced insrease of this ratio from l=0° to l=180°. As it well known this ratio is correlated with metal content of galaxies. It is equal to 0.7 and 4.4 for LMC AND SMC respectively (Richer 1989).

We have applied nearest neighbour statistics to study a pairing tendency of CS and their probable conection with galactic star clusters, bright and dark nebulae. The probability distribution for the distance r to the nearest neighbour is given by

$$P(r \leq r_0) = 1 - e^{-\pi r_0^2 \sigma}$$

where σ is the surface density of objects.

The observed number of CS-CS, CS-SCl, CS-BN and CS-DN pairs are equal to the expected ones with the 0.05 confidence level, i.e. there is no pronounced pairing tendency of CS or their location in SCl, BN and DN,

VI. FURTHER PROSPECTS

Thanks to very faint limiting magnitude K=14 reached by DENIS and 2MASS, they will play a very important role to study the Space Distribution of CS and the variations of their characteristics with galactocentric distances, as well as in other galactic problems. Practically most of galactic CS will be detected by them

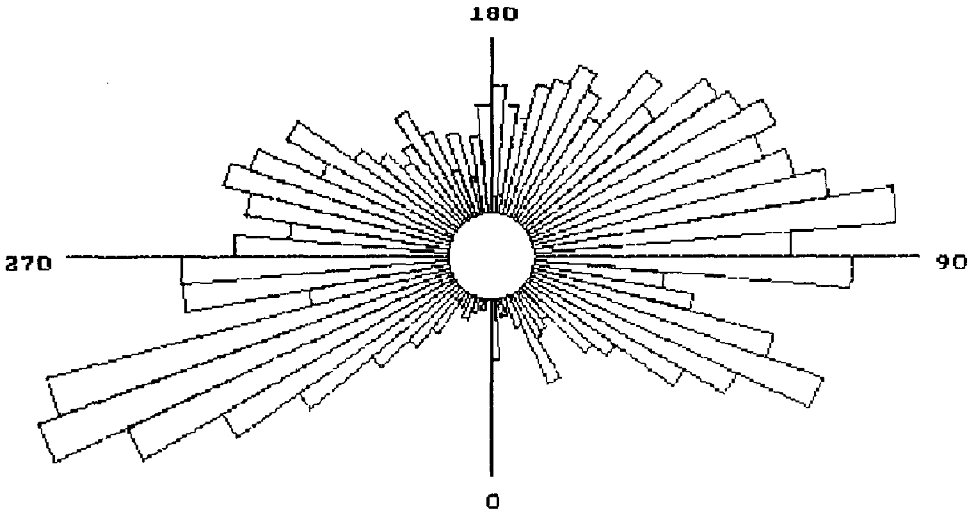

Fig. 1.— The longitude distribution of carbon stars in the galactic plane. The diameter of the circle is equal to 25 stars per bin.

including the warmer ones, although the separation of the later ones having $J - K < 1.5$ from other kind of objects will be impossible (Wood 1994).

Therefore, the spectral surveys in optical region for identification and classification of warmer CS will still play an important role . These surveys might be carried out at 10Å resolution and should be as deep as possible.

ACKNOWLEDGEMENTS

It is great pleasure to thank the SOC for invaluable financial support to attend the meeting.

REFERENCES

Aaronson, M., Blanco, V.M., Cook, K.H., E.W., Schechter, P.L., 1989, ApJS, 70, 637.

Aaronson, M., Blanco, V.M., Cook, K.H., Olszewski, E.W., Schechter, P.L., 1990, ApJS, 73, 841.

Alksne, Z., Alksnis, A., et al., 1989, The Investigation of the Sun and Red Stars, 30, 40.

Claussen, M.J., Kleinmann, S.G., Joyce, R.R., Jura, M., 1987, ApJ, 65, 385.

Forte, J.C., Orsatti, A.M., 1984, ApJS, 56, 211.

Fuenmayor, F., 1981, Rev. Mex. Astron. y Astrofis., 6, 83.

Kleinmann, S.G., 1989, in IAU Coll.106, p.13.

Kurtanidze, O.M., Nikolashvili, M.G., 1981 Astrophysica, 17, 576.

Kurtanidze, O.M., Nikolashvili, M.G., 1988, Reports of the Georgian Sci. Res. Institute of the Sci. and Technical Information, no.430-G88, 1.

Kurtanidze, O.M., Nikolashvili, M.G., 1989a, in IAU Coll.106, p.63.

Kurtanidze, O.M., Nikolashvili, M.G., 1989b, Astrophysics, 31, 507 (paper IV).

Kurtanidze, O.M., Nikolashvili, M.G., 1989c, unpublished, (paper V, VI, VII, VIII).

Kurtanidze, O.M., Nikolashvili, M.G., 1994, IAU Symp.161, p.467.

Kurtanidze, O.M., Nikolashvili, M.G., 1995, IAU Coll.148, p.337.

Lee, O., Gore, G., Bartlett, Th., 1940, Ann. Dearborn Observ., 4, 16.

MacConnell, D.J., 1988, AJ, 96, 354.

MacConnell, D.J., 1995, IAU Coll.148, p.323.

Maehara, H., Soyano, T., 1988, Ann. Tokyo. Astron. Obs., 2nd ser. 22, 59.

Nassau, J.J., Velghe, A.G., 1964, AJ, 139, 190.

Nikolashvili, M.G., 1987, Astrophysica, 27, 197 (paper II).

Nikolashvili, M.G., Kurtanidze, O.M., 1989, unpublished.

Risher, H.B, 1989, in IAU Coll.106, p.35.

Schechter, P.L. 1993, in Back to the Galaxy, S.S. Holt et al. (eds), AIP CP v.278, p.571.

Soyano, T., Maehara, H., 1993, Publ. Nat. Astron. Obs. Japan, 3, 259.

Stephenson, C.B., 1989, ıPubl. Warner and Swasey Obs., 3, 53.

Weinberg, M.D., 1993, in Back to the Galaxy, S.S.Holt et al. (eds), AIP CP v.278, p.347.

Westerlund, B., 1971, A&AS, 4, 51.

Wood, P.R., 1994, in Science with Astronomical Near-Infrared Sky Survey,

Epchtein N., Omont A., Burton B., Persi P., (eds), p.121.