

## A DEEP NEAR INFRARED OBJECTIVE PRISM SURVEY FOR CARBON STARS TOWARD THE GALACTIC CENTER AND ANTICENTER

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### RESUMEN

La distribución asimétrica de las estrellas de carbono frías y relativamente brillantes a lo largo del ecuador galáctico, se conoce desde hace tiempo, especialmente a través de sondeos de prisma objetivo. Para estudiar este problema cuando se incluye una muestra de estrellas mucho más débiles, se ha llevado a cabo un sondeo profundo de estrellas de carbono hacia el centro y anticentro galácticos, utilizando la técnica de prisma objetivo a muy baja dispersión. Cada región estudiada comprende un área de 322 grados cuadrados y fue observada con telescopios tipo Schmidt, de similar diseño óptico, localizados uno en el hemisferio norte y otro en el sur. Asimismo se aplicaron las mismas técnicas de observación, de identificación y de reducción de datos, haciendo de este modo ambos sondeos comparables estadísticamente. La magnitud límite hasta la cual fue posible identificar estrellas de carbono es  $I = 13$ .

Se presenta un catálogo que contiene las 283 estrellas de carbono observadas, 123 de las cuales representan nuevas identificaciones. Se realizó un análisis estadístico de la distribución superficial y espacial de la muestra de estrellas observadas, llegándose a los siguientes resultados:

1) El número de estrellas de carbono observado hacia el anticentro galáctico es tres veces mayor que el observado hacia el centro galáctico. 2) La asimetría centro-anticentro en la distribución parece ser real y se extiende hasta una distancia aproximada de 8 kpc. 3) Las estrellas de carbono en la muestra se concentran en tres posiciones localizadas a distancias promedio de 5.5 kpc hacia el centro galáctico y a 0.5 y 5.0 kpc hacia el anticentro, medidas desde el sol. La densidad media de estrellas de carbono en estas posiciones es de 15, 20 y 50 estrellas por kpc cúbico, respectivamente.

Los resultados obtenidos en esta investigación se han combinado con aquellos de otros autores para describir el problema global de la distribución de las estrellas de carbono en la Vía Láctea. Existe evidencia de un incremento radial del número de estrellas de carbono desde una distancia de 2 kpc del centro galáctico hacia afuera. Existe una correlación significativa entre la concentración de las estrellas de carbono y la estructura espiral de la Galaxia.

### ABSTRACT

The asymmetric distribution of the cool carbon stars in the Milky Way has been known for some time, mainly from the results of objective-prism surveys. In order to make an assessment of this problem when a fainter sample of stars is included, a deep near infrared objective-prism survey for carbon stars has been carried out in the direction of both the galactic center and the galactic anticenter. Each survey area of 322 square degrees was observed with similar Schmidt type telescopes located in the northern and the southern hemispheres. The same observational procedures and the same identification and reduction technique were applied throughout thus making both surveys statistically comparable. The limiting magnitude to which carbon stars could be identified is  $I = 13.0$ .

A catalogue containing 283 carbon stars is presented, of which 123 have not been previously reported. A statistical analysis of the surface and space distribution of the stars in the sample has been carried out yielding the following results: 1) The number of carbon stars observed toward the galactic anticenter is larger than that observed toward the center by a factor of 3. 2) The center-anticenter asymmetry appears to be real and it seems to reach up to an approximate distance of 8 kpc. 3) The carbon stars in the sample appear to be concentrated at average distances from the sun of 5.5 kpc toward the galactic center, and 0.5 and 5.0 kpc toward the anticenter. The mean space density of carbon stars at these locations is 15, 20 and 50 stars per cubic kpc, respectively.

The results are combined with those obtained in other investigations to discuss the distribution of carbon stars on the galactic plane. There is evidence for an increase in the population of carbon stars

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from a distance of about 2 kpc from the center outwards. The correlation between the location where the cooler carbon stars appear to be concentrated and the spiral structure of our Galaxy seems to be significant.

**Key words:** STARS-CARBON – GALAXIES-MILKY WAY

## I. INTRODUCTION

The study of the surface and space distribution of carbon stars, and of other late-type stars, in our Galaxy, is relevant to the theory of stellar structure and evolution, and to the understanding of galactic structure.

Most of the known carbon stars have been discovered by means of objective-prism techniques, especially the near-infrared and red techniques developed by Nassau, Blanco, and collaborators at the Warner and Swasey Observatory. The infrared techniques allow the identification of the (often cooler) carbon stars of type N, on infrared-sensitive emulsion at the very low dispersions of 1700 and 3400 Å/mm (Nassau and Velghe 1964).

Early surveys of carbon stars showed that they are generally located at low galactic latitudes and continuously distributed in galactic longitude. Thereafter, a number of general and regional infrared objective-prism surveys, covering the whole Milky Way, have been carried out by observers in both the northern and southern hemispheres. These surveys were intended to identify stars of spectral types M, carbon, and sometimes S, and their general limiting infrared magnitude was about 9.5. A list of papers dealing with the carbon stars found in these surveys has been given by Stephenson (1966). Details on all important surveys, and references to others of relative interest, that have been made up to 1970 have been given by Mavridis (1971).

A first study on the distribution of carbon stars in the Milky Way was made by Blanco (1965). Plots of their distribution with galactic longitude show that carbon stars tend to avoid that part of the Milky Way toward the galactic center and to favor the region of the galactic anticenter.

The aim of this investigation is to make a deep near-infrared objective-prism survey of carbon stars in the direction of both the galactic center and anticenter, in order to determine whether the asymmetry just mentioned is local or if it is present on a relatively large scale. I planned to extend the search of carbon stars down to about infrared magnitude  $I = 13$ , a fainter limit than  $I = 9$  reached by most previous surveys.

In order to make both surveys statistically comparable, I carried out the observations using similar Schmidt-type telescopes and prisms, located in the northern and the southern hemispheres. Likewise, the same kind of photographic emulsion was used, and the same observational and reduction techniques were applied throughout.

The results of this study will be discussed and compared to those of other deep infrared surveys of the Milky Way carried out in recent years.

## II. OBSERVATIONS

The 61/91-cm University of Michigan Curtis Schmidt-type telescope of the Cerro Tololo Inter-American Observatory was used on July 1978 to obtain the objective prism plate material for a region surrounding the galactic center. In the same way, the 61/91-cm Burrell Schmidt at the Nassau Station of the Warner and Swasey Observatory, of almost identical design, was used from October 1978 through April 1979 to secure the corresponding observational material for a region surrounding the galactic anticenter. Each survey area was covered photographically by a fifteen-field plate array of about 322 square degrees. The general shape of each array is that of a cross oriented parallel to the galactic system and extended to about  $\pm 20^\circ$  in longitude and  $\pm 10^\circ$  latitude.

A four-degree prism was attached to each telescope. I-N Kodak emulsion was exposed through a 3 mm Schott RG8 filter. This prism-filter combination yields a band pass between 6800 and 8800 Å, with a dispersion of the atmospheric A band of  $1700 \text{ Å mm}^{-1}$ . The plates were exposed for 45 minutes, with the emulsion hypersensitized in a bath of distilled water at  $5^\circ\text{C}$  for 10 minutes and then dried in a strong flow of cool air for 10 minutes. All exposures were guided and the spectra unwidened. This procedure results in a limiting infrared magnitude of 13.0.

Carbon stars are identified on infrared-sensitive spectral plates by the presence of the CN molecule absorption band system at  $\lambda\lambda 7945, 8025, \text{ and } 8320$  (Nassau and Velghe 1964). No attempt was made to classify the carbon stars found in the present survey into subclasses. This has been proven to be unfruitful at the low dispersion involved (Stephenson 1979).

Photographic infrared magnitudes in the Kron system (Kron *et al.* 1953) were obtained for all carbon stars identified in this survey. Apparent magnitudes were estimated on I-N direct plates, taken with the same telescope, with untreated emulsion, exposed for 10 minutes through a RG8 filter. Faint *UBV* properties converted into the *VI* system, established by Hoag *et al.* (1961) in the open clusters NGC 6531 and NGC 209 were transferred via plate overlapping to all the survey fields.

Positions for the carbon stars observed in this survey were obtained from either direct plates or objective prism plates. The plates were measured in the two coordinate machine of the Warner and Swasey Observatory. The mean error in the determination of the position of a star in a direct plate is 1 arc sec in both coordinates.

The *General Catalogue of Cool Stars* (Stephenson 1973) was used as the primary source of information for the identification procedure. The *Merged Infrared Catalogue* (Schmitz *et al.* 1978) and the data file maintained by W. P. Bidelman at the Warner and Swasey Observatory were also consulted.

III. THE CATALOGUE

A list of the carbon stars observed toward the galactic center and the anticenter survey areas is given in the form of a catalogue in Table 1. The information presented here has been obtained from the observations and reduction procedures described in the preceding section. The content of each column is the following:

- Column 1:
- The sequence star number in the present survey. An asterisk indicates that a note is to be found at the end of the table.
- Column 2-3:
- Equatorial coordinates for the mean equinox of 1900.
- Column 4-5:
- Galactic coordinates  $l$  and  $b$ .
- Column 6:
- Photographic infrared magnitude  $I$ .
- Column 7:
- Catalogue number as given by Stephenson (1973).

TABLE 1  
THE CATALOGUE OF THE OBSERVED CARBON STARS

| Num  | R. A.     | Dec.      | $l$   | $b$   | $I$  | CCCS | Num  | R. A.     | Dec.      | $l$   | $b$   | $I$  | CCCS |
|------|-----------|-----------|-------|-------|------|------|------|-----------|-----------|-------|-------|------|------|
| 1    | 4 55 20.0 | +24 9 47  | 178.3 | -10.8 | 10.8 |      | 46   | 5 20 10.7 | +23 57 38 | 181.8 | - 6.3 | 8.5  | 334  |
| 2    | 55 41.2   | 41 48 19  | 164.4 | + 0.1 | 9.4  | 278  | 47   | 20 15.2   | 31 55 20  | 175.2 | - 1.8 | 9.3  | 333  |
| 3    | 56 3.8    | 42 9 50   | 164.1 | + 0.4 | 9.8  | 279  | 48   | 20 16.2   | 36 42 18  | 171.3 | + 0.9 | 10.3 | 335  |
| 4    | 59 34.2   | 40 1 51   | 166.2 | - 0.4 | 9.2  | 283  | 49   | 20 30.6   | 34 3 44   | 173.5 | - 0.5 | 6.8  | 336  |
| 5    | 5 00 31.8 | 40 10 35  | 166.2 | - 0.1 | 10.8 |      | 50   | 20 33.9   | 37 59 17  | 170.3 | + 1.7 | 9.4  | 337  |
| 6    | 5 1 38.5  | +40 18 56 | 166.2 | + 0.1 | 9.9  | 287  | 51   | 5 21 25.2 | +34 25 7  | 173.3 | - 0.2 | 12.1 | 338  |
| 7    | 2 13.1    | 38 52 18  | 167.4 | - 0.7 | 5.0  | 288  | 52   | 21 27.9   | 37 8 14   | 171.1 | + 1.4 | 11.2 |      |
| 8    | 2 39.5    | 39 52 11  | 167.7 | 0.0   | 12.8 |      | 53   | 21 45.1   | 35 24 40  | 172.5 | + 0.5 | 12.2 | 339  |
| 9    | 2 45.6    | 40 36 38  | 166.1 | + 0.5 | 12.8 |      | 54   | 21 49.9   | 30 30 25  | 176.6 | - 2.3 | 12.9 |      |
| 10   | 3 22.7    | 39 15 38  | 167.3 | - 0.3 | 8.6  | 293  | 55   | 22 18.6   | 34 25 50  | 173.4 | 0.0   | 12.1 | 341  |
| 11   | 5 3 24.9  | +39 41 43 | 166.9 | 0.0   | 9.6  | 292  | 56   | 5 22 20.3 | +33 59 24 | 173.8 | - 0.2 | 12.1 | 342  |
| 12   | 3 34.0    | 38 55 53  | 167.5 | - 0.4 | 10.7 |      | 57   | 22 41.4   | 39 4 23   | 169.6 | + 2.7 | 10.4 |      |
| 13   | 6 2.1     | 40 48 7   | 166.3 | + 1.1 | 10.8 | 300  | 58   | 23 28.6   | 35 20 20  | 172.8 | + 0.7 | 11.5 |      |
| 14   | 7 28.5    | 34 40 52  | 171.4 | - 2.4 | 10.0 | 303  | 59   | 23 43.2   | 37 40 0   | 170.9 | + 2.0 | 10.3 |      |
| 15   | 7 38.1    | 41 17 18  | 166.1 | + 1.6 | 10.6 | 304  | 60   | 23 44.2   | 31 54 48  | 175.6 | - 1.2 | 12.6 | 343  |
| 16   | 5 7 54.1  | +40 43 57 | 166.6 | + 1.3 | 9.8  | 305  | 61   | 5 24 1.8  | +31 38 39 | 175.9 | - 1.3 | 10.8 | 345  |
| 17   | 8 29.4    | 21 11 10  | 182.6 | -10.1 | 9.6  |      | 62   | 24 18.4   | 26 57 27  | 179.8 | - 3.8 | 10.2 |      |
| 18   | 9 18.8    | 35 27 49  | 171.0 | - 1.6 | 11.6 |      | 63   | 24 30.9   | 34 35 12  | 173.5 | + 0.5 | 9.1  | 346  |
| 19   | 9 24.1    | 23 53 22  | 180.4 | - 8.3 | 10.8 |      | 64   | 24 37.6   | 31 49 36  | 175.8 | - 1.1 | 9.8  | 347  |
| 20   | 9 47.1    | 36 57 26  | 169.9 | - 0.6 | 10.3 | 306  | 65   | 25 25.9   | 28 12 11  | 178.9 | - 2.9 | 9.5  | 348  |
| 21   | 5 10 52.8 | +27 35 3  | 177.6 | - 5.9 | 8.9  | 309  | 66   | 5 25 32.6 | +23 28 33 | 182.9 | - 5.5 | 9.8  | 349  |
| 22   | 11 24.1   | 32 6 10   | 174.0 | - 3.2 | 11.3 | 310  | 67   | 25 48.0   | 29 28 00  | 177.9 | - 2.2 | 9.4  | 350  |
| 23   | 11 39.1   | 35 8 29   | 171.6 | - 1.4 | 10.8 | 311  | 68   | 26 31.3   | 38 33 41  | 170.4 | + 2.9 | 10.3 |      |
| * 24 | 12 21.1   | 24 27 39  | 180.4 | - 7.5 | 10.3 |      | * 69 | 25 57.3   | 35 35 6   | 172.9 | + 1.3 | 10.1 | 354  |
| 25   | 12 28.4   | 35 41 8   | 171.2 | - 0.9 | 6.2  | 313  | 70   | 26 6.2    | 29 36 24  | 177.8 | - 2.0 | 9.4  | 356  |
| 26   | 5 12 31.5 | +42 57 41 | 165.3 | + 3.3 | 11.2 |      | 71   | 5 26 7.5  | +32 51 55 | 175.1 | - 0.2 | 9.2  | 355  |
| 27   | 13 43.6   | 42 31 5   | 165.8 | + 3.2 | 9.7  | 314  | 72   | 26 17.0   | 28 25 28  | 178.8 | - 2.7 | 10.3 | 353  |
| 28   | 14 31.2   | 37 59 17  | 169.6 | + 0.7 | 9.0  | 317  | 73   | 26 40.9   | 32 6 49   | 175.8 | - 0.5 | 11.3 | 359  |
| 29   | 15 17.9   | 32 24 39  | 174.2 | - 2.4 | 4.5  | 318  | 74   | 26 46.8   | 32 9 56   | 175.9 | - 0.3 | 12.0 |      |
| 30   | 15 31.1   | 38 45 15  | 169.1 | + 1.3 | 10.8 |      | 75   | 26 57.0   | 29 33 47  | 178.0 | - 1.9 | 11.5 |      |
| 31   | 5 16 37.8 | +32 22 37 | 174.4 | - 2.1 | 12.2 | 323  | 76   | 5 27 24.4 | +33 15 53 | 174.9 | + 0.2 | 10.8 | 362  |
| * 32 | 16 38.8   | 29 18 27  | 176.9 | -3.9  | 10.4 |      | 77   | 27 46.4   | 26 2 36   | 181.0 | - 3.7 | 12.2 |      |
| 33   | 16 59.2   | 35 7 17   | 172.2 | - 0.5 | 13.0 |      | 78   | 28 16.7   | 24 47 1   | 182.1 | - 4.3 | 7.3  | 366  |
| * 34 | 17 34.6   | 34 27 19  | 172.8 | - 0.8 | 11.6 | 322  | 79   | 28 25.2   | 33 45 52  | 174.6 | + 0.7 | 10.1 | 367  |
| 35   | 17 52.5   | 29 5 49   | 177.3 | - 3.8 | 10.9 |      | 80   | 28 41.0   | 30 52 19  | 177.1 | - 0.9 | 11.2 |      |
| 36   | 5 17 53.9 | +30 26 23 | 176.2 | - 3.0 | 9.4  | 325  | 81   | 5 30 15.6 | +35 24 48 | 173.5 | + 1.9 | 13.2 |      |
| 37   | 17 58.0   | 39 58 24  | 168.3 | + 2.4 | 11.2 | 326  | 82   | 30 16.7   | 25 47 39  | 181.5 | - 3.4 | 10.3 |      |
| 38   | 18 26.0   | 33 43 55  | 173.5 | - 1.1 | 9.0  | 327  | 83   | 31 22.1   | 30 0 8    | 178.1 | - 0.9 | 9.2  | 372  |
| 39   | 18 30.8   | 42 40 50  | 166.2 | + 4.1 | 10.8 |      | 84   | 32 10.5   | 22 45 34  | 184.3 | - 4.6 | 7.9  | 374  |
| 40   | 18 41.2   | 39 47 4   | 168.6 | + 2.4 | 7.1  | 328  | 85   | 32 29.0   | 30 23 21  | 177.9 | - 0.5 | 10.2 | 376  |
| 41   | 5 18 52.7 | +39 38 59 | 168.7 | + 2.4 | 11.4 |      | 86   | 5 33 24.3 | +33 23 18 | 175.5 | + 1.3 | 9.3  | 377  |
| 42   | 19 1.7    | 36 14 53  | 171.5 | + 0.5 | 11.8 |      | 87   | 33 48.9   | 23 6 37   | 184.2 | - 4.1 | 12.2 |      |
| * 43 | 19 12.4   | 26 48 38  | 179.3 | - 4.9 | 10.8 |      | 88   | 34 0.3    | 26 28 20  | 181.4 | - 2.3 | 13.5 |      |
| 44   | 19 19.6   | 38 17 15  | 169.9 | + 1.7 | 7.8  | 330  | 89   | 34 0.7    | 34 35 37  | 174.5 | + 2.1 | 12.5 |      |
| 45   | 19 39.2   | 32 19 24  | 174.8 | - 1.7 | 10.3 | 332  | 90   | 34 22.1   | 34 34 0   | 174.6 | + 2.1 | 10.0 | 379  |

TABLE 1  
(CONTINUED)

| Num   | R. A.     | Dec.      | l     | b     | I     | CCCS | Num   | R. A.      | Dec.       | l     | b     | I     | CCCS |
|-------|-----------|-----------|-------|-------|-------|------|-------|------------|------------|-------|-------|-------|------|
| 91    | 5 34 32.3 | +27 33 1  | 18.6  | - 1.6 | 11.2  |      | 166   | 5 57 51.1  | +19 3 15   | 190.6 | - 1.4 | 10.3  |      |
| 92    | 35 12.6   | 34 32 15  | 174.8 | + 2.3 | 12.0  |      | 167   | 59 30.5    | 18 31 46   | 191.3 | - 1.4 | 8.8   | 448  |
| 93    | 35 47.7   | 22 24 4   | 185.1 | - 4.1 | 10.3  |      | 168   | 6 0 45.1   | 29 12 47   | 182.1 | + 4.2 | 11.9  |      |
| 94    | 35 56.1   | 28 14 21  | 180.2 | - 1.0 | 10.6  | 382  | 169   | 1 9.1      | 22 52 33   | 187.7 | + 1.1 | 12.8  |      |
| 95    | 36 26.5   | 33 37 39  | 175.7 | + 2.0 | 9.8   | 383  | 170   | 2 14.2     | 22 43 15   | 187.9 | + 1.3 | 9.0   | 456  |
| 96    | 5 36 49.7 | +31 55 13 | 177.2 | + 1.2 | 11.0  |      | 171   | 6 2 45.3   | +19 55 10  | 190.4 | - 0.0 | 10.8  |      |
| 97    | 37 1.8    | 22 44 19  | 184.9 | - 3.7 | 10.4  |      | 172   | 3 4.6      | 18 41 7    | 191.5 | - 0.5 | 11.7  |      |
| 98    | 37 20.6   | 29 6 37   | 179.6 | - 0.3 | 12.4  |      | 173   | 3 21.3     | 30 2 43    | 181.7 | + 5.1 | 9.8   | 457  |
| 99    | 38 34.9   | 30 42 55  | 178.4 | - 0.8 | 12.0  |      | 174   | 3 47.1     | 32 4 11    | 179.9 | + 6.2 | 9.8   | 458  |
| 100   | 39 5.9    | 24 22 37  | 183.8 | - 2.4 | 5.0   | 390  | 175   | 3 49.2     | 19 10 25   | 191.2 | - 0.2 | 12.2  |      |
| 101   | 5 39 37.5 | +25 27 13 | 183.0 | - 1.8 | 9.3   | 392  | 176   | 6 4 4.4    | +19 32 57  | 190.9 | + 0.1 | 12.1  |      |
| 102   | 40 02.1   | 25 40 51  | 182.9 | - 1.5 | 10.0  |      | 177   | 4 25.1     | 30 38 46   | 181.3 | + 5.6 | 9.3   | 460  |
| 103   | 40 23.7   | 25 35 44  | 182.9 | - 1.5 | 9.4   | 397  | 178   | 4 36.2     | 16 2 44    | 194.0 | - 1.5 | 11.9  |      |
| 104   | 40 27.4   | 22 45 4   | 185.4 | - 3.0 | 10.8  |      | 179   | 4 40.4     | 26 1 59    | 185.3 | + 3.4 | 5.0   | 461  |
| 105   | 40 39.4   | 23 49 8   | 180.2 | + 0.2 | 11.5  | 399  | 180   | 5 2.2      | 28 33 24   | 183.2 | + 4.7 | 12.5  |      |
| 106   | 5 40 45.9 | +24 9 53  | 184.2 | - 2.2 | 10.3  |      | 181   | 6 5 34.2   | +19 42 52  | 190.9 | + 0.5 | 12.8  |      |
| 107   | 41 24.5   | 30 32 40  | 178.8 | + 1.3 | 9.4   | 401  | 182   | 6 23.9     | 20 3 32    | 190.7 | + 0.8 | 12.6  |      |
| 108   | 41 26.5   | 28 41 37  | 180.4 | - 0.3 | 10.6  |      | 183   | 6 27.0     | 27 40 58   | 184.1 | + 4.5 | 10.4  | 466  |
| 109   | 41 32.2   | 32 1 6    | 177.6 | + 2.1 | 10.8  |      | 184   | 7 47.8     | 21 37 39   | 189.5 | + 1.9 | 12.2  |      |
| 110   | 41 42.0   | 30 35 41  | 178.8 | + 1.3 | 5.0   | 402  | 185   | 7 48.0:    | 13 47 00:  | 196.4 | - 2.0 | 11.9  |      |
| 111   | 5 41 45.8 | +31 19 26 | 178.2 | + 1.7 | 11.6  |      | * 186 | 6 8 4.9    | +33 26 32  | 179.2 | + 7.6 | 10.1  |      |
| 112   | 42 33.7   | 26 11 11  | 182.7 | - 0.8 | 9.9   | 406  | 187   | 8 34.6     | 21 36 47   | 189.6 | + 2.0 | 10.8  |      |
| 113   | 42 34.8   | 32 00 49  | 177.7 | + 2.2 | 10.9  | 405  | 188   | 8 51.1     | 22 44 53   | 188.7 | + 2.6 | 10.2  |      |
| 114   | 43 17.4   | 35 43 26  | 174.6 | + 4.3 | 8.9   | 407  | 189   | 9 24.5     | 21 35 36   | 189.7 | + 2.2 | 10.2  |      |
| * 115 | 43 18.2   | 34 35 27  | 175.6 | + 3.7 | 10.3  |      | 190   | 9 31.6     | 21 9 54    | 190.1 | + 2.0 | 9.2   | 468  |
| 116   | 5 43 29.8 | +23 20 53 | 185.2 | - 2.1 | 10.2  |      | 191   | 6 9 36.9   | +21 53 9   | 189.5 | + 2.4 | 8.9   | 469  |
| 117   | 43 50.1   | 25 15 16  | 183.6 | - 1.1 | 9.4   | 410  | 192   | 9 37.4     | 21 51 59   | 189.5 | + 2.3 | 11.5  |      |
| 118   | 43 58.4   | 22 14 20  | 186.2 | - 2.6 | 9.8   | 412  | 193   | 9 44.8     | 22 25 20   | 189.1 | + 2.6 | 8.6   | 470  |
| 119   | 45 17.8   | 30 43 20  | 179.1 | + 2.1 | 10.9  |      | 194   | 9 45.1     | 14 40 9    | 195.8 | - 1.1 | 10.3  |      |
| 120   | 45 28.7   | 23 35 31  | 185.2 | - 1.6 | 11.4  |      | 195   | 9 56.8     | 22 51 19   | 188.7 | + 2.9 | 11.5  |      |
| 121   | 5 45 55.0 | +29 30 43 | 180.2 | + 1.6 | 11.2  |      | 196   | 6 11 36.8  | +20 8 24   | 191.3 | + 1.9 | 10.0  | 478  |
| 122   | 46 9.1    | 32 10 17  | 178.0 | + 3.0 | 9.4   | 414  | 197   | 11 43.1    | 18 38 7    | 192.6 | + 1.2 | 9.3   | 477  |
| 123   | 46 22.6   | 29 52 54  | 180.0 | + 1.8 | 7.3   | 415  | 198   | 11 43.2    | 34 40 25   | 178.4 | + 8.8 | 12.3  |      |
| 124   | 46 29.1   | 29 48 48  | 180.0 | + 1.8 | 10.1  | 416  | 199   | 11 59.8    | 14 31 1    | 196.2 | - 0.7 | 7.6   | 479  |
| 125   | 46 30.3   | 25 19 54  | 183.9 | - 0.5 | 12.8  |      | 200   | 12 38.0    | 15 20 28   | 195.6 | - 0.2 | 10.8  |      |
| 126   | 5 46 38.0 | +30 37 9  | 179.4 | + 2.3 | 9.5   | 417  | 201   | 6 12 56.2  | +20 10 56  | 191.4 | + 2.2 | 8.4   | 483  |
| 127   | 46 49.4   | 29 3 18   | 180.7 | + 1.0 | 11.6  |      | 202   | 13 15.0    | 21 39 28   | 190.1 | + 3.0 | 8.8   | 485  |
| 128   | 47 33.0   | 24 25 17  | 184.8 | - 0.8 | 11.8  |      | 203   | 13 52.2    | 18 17 46   | 193.1 | + 1.5 | 9.5   | 488  |
| 129   | 47 40.9   | 22 14 21  | 186.7 | - 1.9 | 10.8  |      | 204   | 15 19.2    | 16 18 36   | 195.0 | + 0.8 | 10.3  |      |
| 130   | 47 46.3   | 28 37 30  | 181.2 | + 1.4 | 9.4   | 418  | 205   | 16 29.7    | 14 28 9    | 196.8 | + 0.2 | 9.5   |      |
| 131   | 5 47 54.4 | +24 8 40  | 185.1 | - 0.8 | 12.2  |      | 206   | 6 16 50.4  | +15 21 52  | 196.0 | + 0.7 | 9.8   |      |
| 132   | 48 14.2   | 30 10 20  | 179.9 | + 2.3 | 10.7  | 419  | 207   | 19 13.3    | 17 3 26    | 194.8 | + 2.0 | 12.2  |      |
| 133   | 48 35.6   | 31 26 41  | 178.9 | + 3.0 | 9.9   | 421  | 208   | 19 34.7    | 15 19 43   | 196.4 | + 1.3 | 10.0  |      |
| 134   | 48 35.9   | 34 1 42   | 176.6 | + 4.4 | 9.1   | 420  | 209   | 19 45.9    | 14 46 37   | 196.9 | + 1.1 | 5.0   | 508  |
| 135   | 49 24.3   | 32 01 18  | 178.5 | + 3.5 | 9.6   | 423  | 210   | 19 49.5    | 16 8 44    | 195.7 | + 1.7 | 11.4  |      |
| 136   | 5 49 36.7 | +33 51 33 | 176.9 | + 4.5 | 9.0   | 424  | 211   | 6 20 54.6  | +18 29 57  | 193.8 | + 3.1 | 12.2  |      |
| 137   | 49 52.5   | 22 50 53  | 186.4 | - 1.1 | 11.6  |      | 212   | 21 34.4    | 15 50 14   | 196.2 | + 1.9 | 10.8  | 516  |
| 138   | 50 12.9   | 28 47 41  | 181.3 | + 2.0 | 10.8  |      | 213   | 23 2.5     | 16 53 24   | 195.4 | + 2.7 | 10.9  |      |
| 139   | 50 21.3   | 30 49 15  | 179.6 | + 3.0 | 11.5: |      | 214   | 23 6.1     | 35 45 15   | 178.5 | +11.4 | 8.5   |      |
| 140   | 50 26.1   | 30 6 3    | 180.2 | + 2.7 | 9.4   | 425  | 215   | 25 53.9:   | 16 11 00:  | 196.4 | + 3.0 | 8.0:  | 523  |
| 141   | 5 50 49.9 | +22 44 28 | 186.6 | - 1.0 | 8.7   |      | 216   | 6 27 06.0: | +16 33 30: | 196.2 | + 3.5 | 11.5  |      |
| 142   | 50 53.1   | 25 43 59  | 184.0 | + 0.5 | 12.6  |      | * 217 | 16 53 8.2  | -24 18 30  | 357.9 | +11.1 | 11.4  |      |
| 143   | 50 57.1   | 22 29 59  | 186.8 | - 1.1 | 10.7  |      | 218   | 16 53 24.8 | -21 13 13  | 0.4   | +12.9 | 11.5  |      |
| 144   | 51 51.6   | 28 27 21  | 181.8 | + 2.1 | 7.5   | 429  | * 219 | 16 53 44.8 | -24 12 5   | 358.0 | +11.0 | 10.5  |      |
| 145   | 52 3.2    | 32 20 42  | 178.5 | + 4.1 | 10.8  |      | 220   | 16 55 36.7 | -41 0 47   | 345.0 | + 0.4 | 11.7  |      |
| * 146 | 5 52 23.1 | +34 59 37 | 176.2 | + 5.5 | 12.2  |      | 221   | 17 1 54.8  | -43 38 30  | 343.6 | - 2.2 | 11.2: | 2398 |
| 147   | 52 43.3   | 26 48 7   | 183.3 | + 1.4 | 11.9  |      | 222   | 4 7.8      | 40 18 33   | 346.5 | - 0.5 | 12.7  | 2403 |
| 148   | 52 54.9   | 22 4 48   | 187.4 | - 0.9 | 12.4  |      | 223   | 5 38.1     | 39 24 57   | 347.4 | - 0.2 | 12.6  | 2404 |
| 149   | 53 41.1   | 24 47 24  | 185.2 | + 0.6 | 11.6  |      | 224   | 6 59.3     | 35 48 11   | 350.5 | + 1.8 | 8.8   | 2409 |
| 150   | 54 25.3   | 30 45 3   | 180.1 | + 3.8 | 9.5   | 434  | 225   | 7 37.1     | 42 7 21    | 345.5 | - 2.1 | 9.5   | 2411 |
| * 151 | 5 54 33.3 | +20 51 29 | 188.7 | - 1.2 | 10.3  |      | 226   | 17 10 37.3 | -35 21 44  | 351.2 | + 1.4 | 12.2  | 2418 |
| 152   | 54 53.0   | 18 59 8   | 190.3 | - 2.1 | 12.8  |      | 227   | 11 53.5    | 38 4 9     | 349.2 | - 0.4 | 10.8  | 2423 |
| 153   | 55 1.9    | 21 5 5    | 188.5 | - 1.0 | 9.0   | 435  | 228   | 13 47.2    | 40 17 0    | 347.6 | - 2.0 | 7.2   | 2429 |
| 154   | 55 12.6   | 27 39 59  | 182.9 | + 2.4 | 11.9  |      | 229   | 14 30.1    | 40 22 44   | 347.6 | - 2.1 | 11.0  |      |
| 155   | 55 17.9   | 21 20 47  | 188.3 | - 0.8 | 12.2  |      | 230   | 15 27.0    | 36 40 1    | 350.8 | - 0.1 | 10.0  | 2431 |
| 156   | 5 55 20.8 | +29 27 2  | 181.3 | + 3.3 | 7.5   | 436  | 231   | 17 17 10.9 | -40 7 53   | 348.1 | - 2.4 | 9.5   | 2435 |
| 157   | 55 34.1   | 24 33 47  | 185.6 | + 0.9 | 12.2  |      | 232   | 17 24.7    | 28 15 1    | 357.9 | + 4.4 | 8.8   | 2436 |
| * 158 | 55 36.0   | 20 11 41  | 189.4 | - 1.3 | 9.7   |      | 233   | 17 39.4    | 29 13 50   | 357.1 | + 3.8 | 6.5   | 2438 |
| 159   | 55 51.6   | 27 31 21  | 183.1 | + 2.4 | 7.9   | 439  | 234   | 17 42.8    | 39 3 44    | 349.1 | - 1.9 | 12.0: |      |
| 160   | 56 22.5   | 29 38 39  | 181.3 | + 3.6 | 9.8   | 441  | 235   | 18 42.5    | 29 39 45   | 356.9 | + 3.4 | 10.2  | 2439 |
| 161   | 5 56 52.0 | +24 6 21  | 186.1 | + 0.9 | 11.7  |      | 236   | 17 19 20.6 | -31 45 20  | 355.2 | + 2.0 | 12.0  |      |
| 162   | 57 19.1   | 26 0 1    | 184.5 | + 1.9 | 8.8   | 443  | 237   | 19 24.5    | 32 20 6    | 354.8 | + 1.7 | 12.0: | 2441 |
| 163   | 57 42.6   | 20 7 9    | 189.7 | - 0.9 | 11.5  |      | 238   | 20 6.8     | 31 29 59   | 355.5 | + 2.0 | 11.1  | 2443 |
| 164   | 57 45.3   | 26 52 30  | 183.8 | + 2.5 | 9.6   | 440  | 239   | 20 6.9     | 39 19 19   | 349.1 | - 2.4 | 11.5  | 2444 |
| 165   | 57 50.7   | 19 56 16  | 189.8 | - 1.0 | 10.7  |      | 240   | 22 55.0    | 30 51 7    | 356.4 | + 1.9 | 12.0  |      |

TABLE 1  
(CONTINUED)

| Num | R. | A.   | Dec.     | l         | b     | I     | CCCS | Num  | R.  | A.    | Dec.      | l         | b     | I     | CCCS  |
|-----|----|------|----------|-----------|-------|-------|------|------|-----|-------|-----------|-----------|-------|-------|-------|
| 241 | 17 | 25   | 5.1      | -35 11 58 | 353.1 | - 0.9 | 12.0 | 266  | 17  | 54    | 28.8      | -33 53 28 | 357.4 | - 5.3 | 10.3  |
| 242 | 26 | 48.4 | 34 28 18 | 353.9     | - 0.8 | 10.0  | 2454 | 267  | 54  | 41.3  | 29 5 11   | 1.6       | - 3.0 | 9.0   | 2511  |
| 243 | 26 | 52.5 | 36 11 5  | 352.5     | - 1.7 | 9.0   | 2455 | 268  | 56  | 20.3  | 24 45 58  | 5.5       | - 1.1 | 11.3  | 2520  |
| 244 | 27 | 59.6 | 34 6 36  | 354.3     | - 0.8 | 10.5  | 2458 | 269  | 56  | 34.4  | 19 10 22  | 10.4      | + 1.6 | 6.6   | 2521  |
| 245 | 28 | 9.8  | 32 53 43 | 355.3     | - 0.2 | 12.5  |      | 270  | 57  | 21.2  | 32 13 20  | 359.1     | - 5.0 | 10.1  |       |
| 246 | 17 | 29   | 7.4      | -33 38 56 | 354.9 | - 0.7 | 10.0 | 2459 | 271 | 18    | 0 42.3    | -19 8 23  | 10.9  | + 0.8 | 13.3: |
| 247 | 29 | 40.4 | 34 32 42 | 354.1     | - 1.3 | 10.0  | 2461 | 272  | 0   | 53.9  | 33 17 9   | 358.6     | - 6.2 | 10.2  |       |
| 248 | 32 | 11.0 | 28 41 39 | 359.3     | + 1.4 | 10.5  | 2463 | 273  | 1   | 8.8   | 28 31 15  | 2.8       | - 3.9 | 8.0   | 2529  |
| 249 | 35 | 41.7 | 35 11 41 | 354.3     | - 2.7 | 8.0   | 2473 | 274  | 3   | 2.5   | 27 39 39  | 3.7       | - 3.9 | 9.0   | 2535  |
| 250 | 35 | 44.6 | 32 8 18  | 356.8     | - 1.1 | 11.5  |      | 275  | 3   | 28.2  | 21 40 41  | 9.0       | - 1.0 | 9.3   | 2537  |
| 251 | 17 | 38   | 52.0     | -26 50 51 | 1.7   | + 1.2 | 12.5 | 276  | 18  | 4     | 5.4       | -32 39 10 | 359.5 | - 6.5 | 9.5   |
| 252 | 43 | 32.9 | 27 26 33 | 1.7       | 0.0   | 12.2  |      | 277  | 4   | 12.8  | 26 53 1   | 4.5       | - 3.7 | 9.2   | 2540  |
| 253 | 46 | 55.0 | 28 48 35 | 0.9       | - 1.4 | 10.0  | 2490 | 278  | 08  | 06.0: | 14 54 12: | 15.4      | + 1.4 | 8.5   | 2551  |
| 254 | 47 | 17.5 | 23 15 21 | 5.7       | + 1.4 | 10.0  | 2491 | 279  | 10  | 12.4  | 16 30 52  | 14.3      | + 0.1 | 8.9   | 2554  |
| 255 | 48 | 41.8 | 32 3 3   | 358.4     | - 3.4 | 9.6   |      | 280  | 10  | 42.9  | 20 36 58  | 10.7      | - 2.0 | 12.8  |       |
| 256 | 17 | 48   | 55.9     | -27 57 34 | 1.9   | - 1.3 | 10.8 | 281  | 18  | 11    | 16.1      | -21 56 50 | 9.6   | - 2.7 | 12.5  |
| 257 | 49 | 13.7 | 27 9 44  | 2.6       | - 1.0 | 11.3  | 2496 | 282  | 13  | 37.1  | 15 39 10  | 15.4      | - 0.2 | 6.2   | 2567  |
| 258 | 49 | 29.8 | 25 26 49 | 4.1       | - 0.1 | 11.0  | 2498 | 283  | 16  | 17.0  | 19 3 55   | 12.7      | - 2.4 | 9.2   | 2569  |
| 259 | 49 | 38.0 | 28 0 49  | 1.9       | - 1.5 | 7.0   | 2499 |      |     |       |           |           |       |       |       |
| 260 | 50 | 20.0 | 23 12 22 | 6.1       | + 0.9 | 9.5   | 2500 |      |     |       |           |           |       |       |       |
| 261 | 17 | 50   | 51.4     | -24 5 20  | 5.4   | + 0.3 | 12.2 |      |     |       |           |           |       |       |       |
| 262 | 51 | 7.1  | 23 27 18 | 6.0       | + 0.6 | 10.5  | 2503 |      |     |       |           |           |       |       |       |
| 263 | 53 | 4.7  | 30 27 24 | 0.2       | - 3.4 | 11.4  |      |      |     |       |           |           |       |       |       |
| 264 | 53 | 36.3 | 27 34 43 | 2.8       | - 2.0 | 11.7  |      |      |     |       |           |           |       |       |       |
| 265 | 53 | 45.9 | 31 3 16  | 359.8     | - 3.8 | 10.4  |      |      |     |       |           |           |       |       |       |

(\*) Notes to Table 1  
24 BC 63  
32 BC 64  
34 CCCS position 1<sup>m</sup>0 off in R A.  
43 BC 65  
69 BC 11  
115 BC 13  
146 BC 15  
151 BC 34  
158 BC 36  
186 BC 71  
192 Fainter visual companion of 191. Separation ~1'.5, ΔI = 2.5.

217 McC 79  
219 McC 79  
255 McC 79  
  
Sources of Information  
  
Symbol      References  
CCCS      Stephenson 1973.  
BC      Alksne and Ozolina 1972, 1974, 1976.  
         Alksnis *et al.* 1976, 1979, 1978.  
         Daube and Ozolina 1974.  
McC      MacConnell 1979.

IV. STATISTICAL ANALYSIS

Results for the surface and space distribution of the carbon stars observed in this survey are derived below, based upon the information provided in the catalogue described in §III.

a) Surface Density

Surface distribution plots for all the carbon stars observed toward the galactic center and anticenter are presented in Figures 1 and 2. Comparison of these figures indicates that the number of cool carbon stars observed toward the anticenter is 3.2 times larger than the number observed toward the center.

Surface distribution plots of the fainter carbon stars, I ≥ 10.5, are shown in Figures 3 and 4. Both distributions look remarkably flatter than the distribution

showing all the stars in the samples. The number ratio in this case is also 3.2. These results confirm previous evidence of a center anticenter asymmetry based only upon surveys of bright carbon stars (Blanco 1965). Furthermore, they provide new evidence for an asymmetry extending to a larger distance.

Wolf diagrams showing the surface density distribution of carbon stars as a function of apparent infrared magnitude corrected for interstellar extinction were constructed (Figure 5). Values of the infrared interstellar extinction, A<sub>I</sub>, were derived assuming a 1/λ absorption law and a ratio A<sub>V</sub>/A<sub>I</sub> = 1.82 (Sharpless 1963). The dependence of A<sub>I</sub> with distance was then derived from photometric observations of young open clusters located close to the galactic plane (Becker and Fenkart 1971). The diagrams for the galactic center and anticenter are remarkably alike. Both distributions run almost parallel to each other for a wide range in magnitudes both show



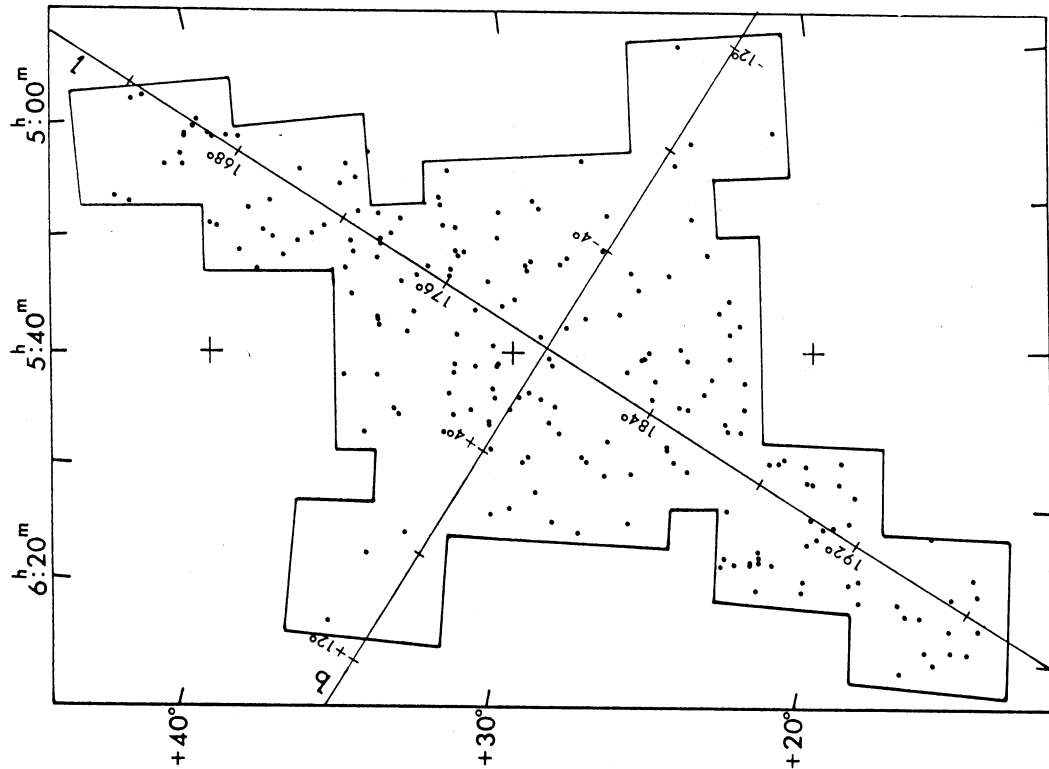


Fig. 1. The surface distribution of the carbon stars observed toward the galactic center. The outline shows the area covered by the survey. Equatorial coordinates for the mean equinox 1900 and galactic coordinates are also included in the diagram.

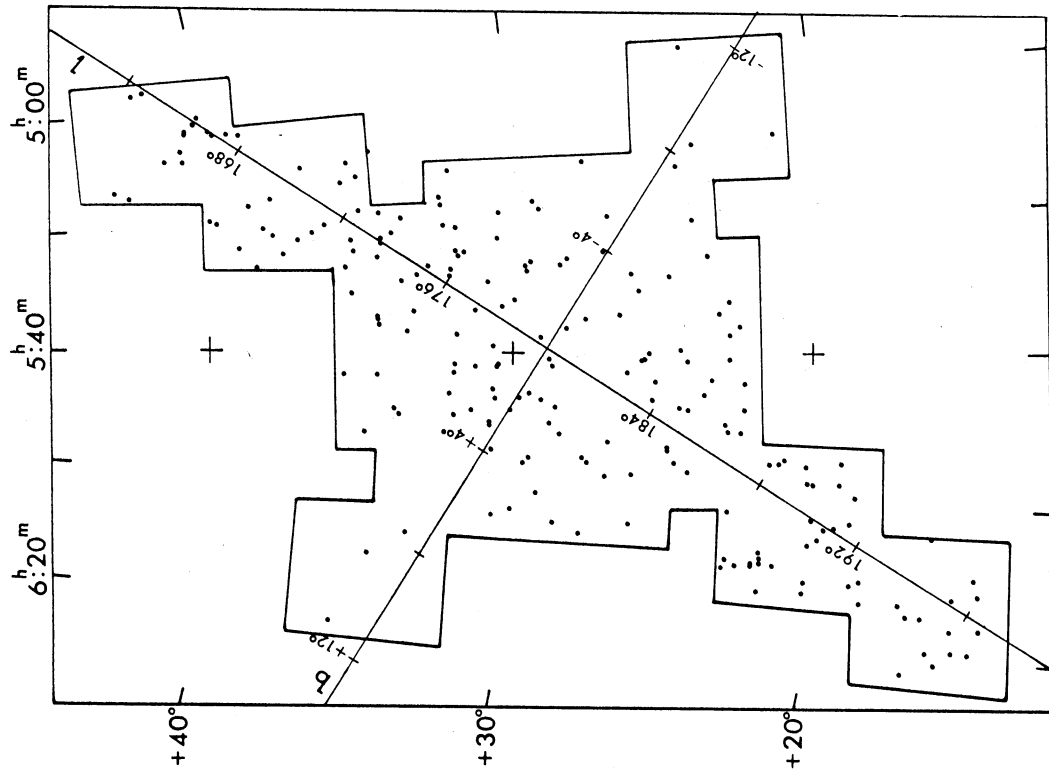


Fig. 2. The same as in Figure 1, but for the galactic anticenter.

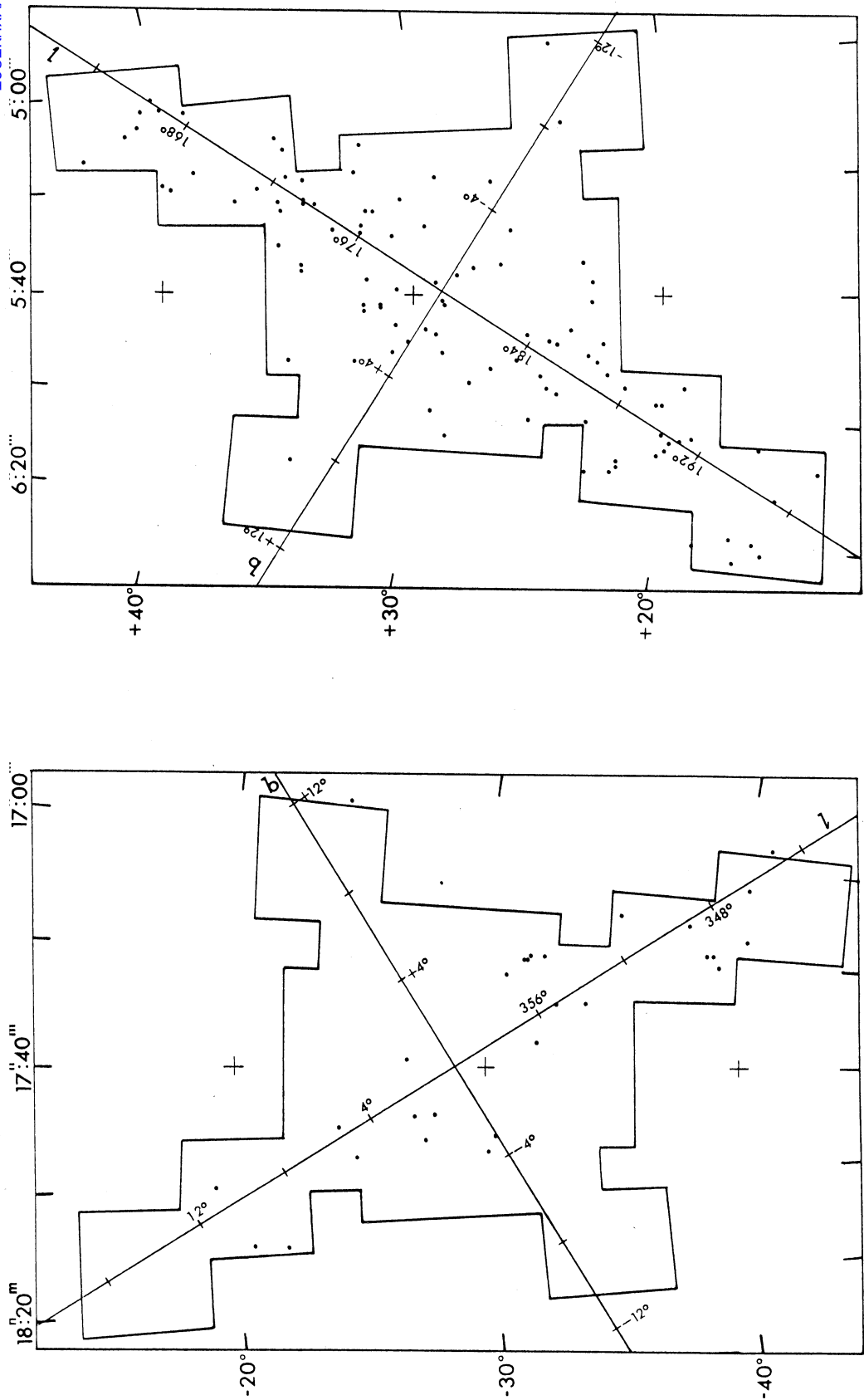


Fig. 3. The surface distribution of the carbon stars fainter than magnitude  $I=10.5$  observed toward the galactic center. The outline shows the area covered by the survey. Equatorial coordinates for the mean equinox 1900 and galactic coordinates are also included in the diagram.

Fig. 4. The same as in Figure 3, but for the galactic anticenter.

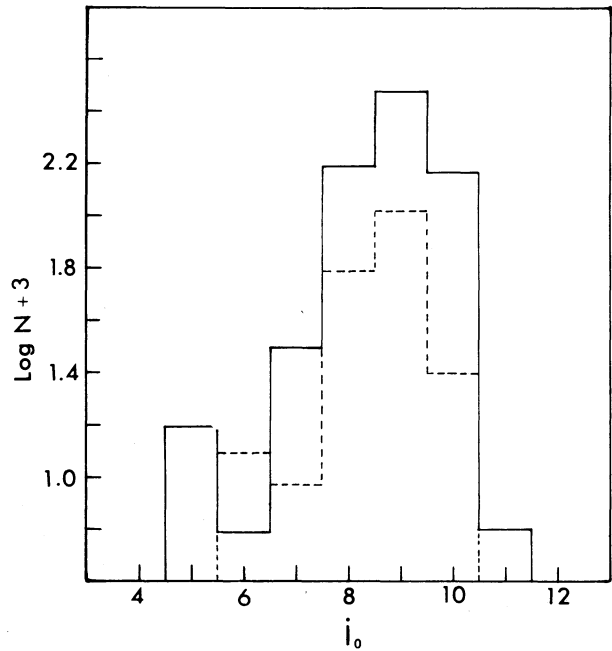


Figure 5. The Wolf diagrams for the carbon stars with apparent infrared magnitudes.  $i_0$ , corrected for interstellar absorption observed toward the galactic center survey area (dashed lines), and the galactic anticenter survey area (solid lines).

an excess of bright stars, and both distributions fall off a about the same value of apparent magnitude. The Wolf diagrams also show that the present survey appears to be complete up to apparent infrared magnitude 11.0.

b) Space Density

A space density function for carbon stars toward the galactic center and anticenter can be obtained provided an assumption is made as to the value of their mean

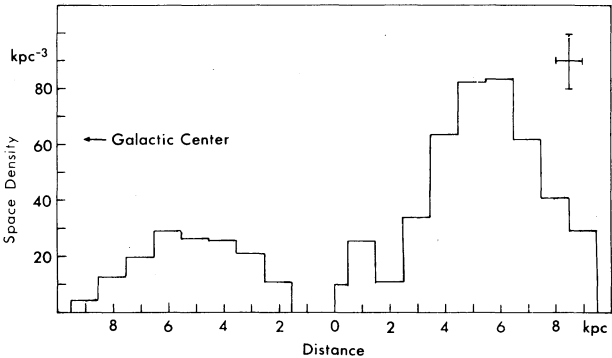


Fig. 6. The space density function for the cool carbon stars toward the galactic center and anticenter, as observed from the sun. Estimated error bars are indicated.

infrared absolute magnitude. Independent determinations of the distances to several carbon stars, and recent infrared photometric observations of galactic carbon stars (Walker 1980), point to a mean value of  $M_V = -2.5$  and an intrinsic color in the range  $V - I \sim 2-3$ . Therefore, it seems reasonable to adopt a value of  $M_I = -5$  as the average infrared absolute magnitudes for these stars. The space density function was computed applying the Malmquist's method. It is given in Table 2, in units of stars  $\text{kpc}^{-3}$  and is plotted in Figure 6.

Since both objective prism surveys are statistically comparable the mean and the relative values of the space density function are meaningful. The conclusions derived from this analysis are the following:

- 1. The ratio anticenter-center between the mean values of the space density is 3.3, close to the ratio derived from star counts on the surface distribution plots.
- 2. The cool carbon stars appear to be concentrated at the average distances from the sun of 0.5 and 5.0 kpc, toward the galactic anticenter, and at 5.5 kpc toward the

TABLE 2

SPACE DENSITY FUNCTION

| d(kpc) | $V \times 10^3$ | Galactic Center |       | Galactic Anticenter |       |
|--------|-----------------|-----------------|-------|---------------------|-------|
|        |                 | $N \times 10^3$ | D     | $N \times 10^3$     | D     |
| 0.5    | 0.305           | —               | —     | 3.1                 | 10.16 |
| 1.0    | 0.609           | —               | —     | 15.5                | 25.45 |
| 2.0    | 1.218           | 12.5            | 10.26 | 13.2                | 10.84 |
| 3.0    | 1.828           | 39.8            | 21.77 | 62.0                | 33.92 |
| 4.0    | 2.437           | 62.1            | 25.48 | 155.2               | 63.68 |
| 5.0    | 3.046           | 79.4            | 26.07 | 251.2               | 82.47 |
| 6.0    | 3.655           | 105.6           | 28.89 | 304.3               | 83.26 |
| 7.0    | 4.264           | 83.2            | 19.51 | 263.0               | 61.68 |
| 8.0    | 4.874           | 62.0            | 12.72 | 199.5               | 40.93 |
| 9.0    | 5.483           | 24.0            | 4.38  | 158.5               | 28.91 |



galactic center. The mean space density at those distances is 15, 20 and 50 stars  $\text{kpc}^{-3}$ , respectively.

V. DISCUSSION

The results for the surface and space distribution of the cool carbon stars toward the galactic center and anticenter, as presented in this study, are discussed here in the light of those obtained from several other deep surveys carried out recently in different regions of Milky Way. An up-to-date picture of the distribution of carbon stars along the galactic equator as seen from the sun is also discussed.

a) Deep Surveys in the Milky Way

Since 1970 several deep objective-prism surveys for carbon stars have been carried out in different regions of the Milky Way, using either red or infrared sensitive emulsions. Westerlund (1971) has made an extensive infrared survey of the southern Milky Way covering about 135 degrees in longitude. Nandy and Smriglio (1970) and Nandy, Smriglio and Buonans (1978), have carried out a series of small-area surveys in the northern Milky Way. The surveys mentioned so far have a limiting magnitude  $I = 12.0$ . Alksnis and Alksne (1977), and Daube and Duncans (1977) have made a series of red surveys and follow-up photometric investigations of carbon stars in several regions in the northern Milky Way. These surveys have an average limiting magnitude of  $V = 14.0$  and produced identifications for about 200 new carbon stars. MacConnell (1979) has carried out a somewhat less deep survey using red-sensitive plates. This survey has a limiting magnitude of  $V = 12.0$ , and overlaps almost all of Westerlund's survey area, thus yielding a relatively small number of new carbon stars. Blanco *et al.* (1978), using a recently introduced non-objective-prism spectral technique (Hoag 1976), have made an exploratory infrared survey of the galactic bulge up to a limiting magnitude  $I = 18.0$ . Only one

carbon star was detected in a small clear area around Baade's window.

A list with the characteristics of some important objective-prism surveys as known to the author, carried out recently is given in Table 3. These surveys, except for Westerlund's survey, were published at a more recent date than the Cool Carbon Stars Catalogue (Stephenson 1973).

b) A Picture of the Distribution of Carbon Stars on the Galactic Plane

Figure 7 summarizes the results obtained from an analysis of the infrared surveys listed in Table 3. The diagram represents the known distribution of carbon stars and shows the number of stars per  $10^\circ$  interval in longitude and within a belt  $4^\circ$  wide along the galactic equator. All numbers were normalized to the scale shown on the diagram. The original distribution as presented by Blanco (1965) is included; those are stars found in infrared objective-prism surveys.

Some conclusions may be drawn from this diagram: 1) The main features of the original distribution as given by Blanco are confirmed, and emphasized by the new results. This indicates that the center-anticenter asymmetry of the distribution of carbon stars is real, despite the influence of the interstellar absorption at the implied larger distance. 2) The observed number of carbon stars increases significantly at certain particular directions which roughly coincide with tangents to known spiral features around the Sun as traced by young open star clusters, emission stars of type OB and B, late-type supergiants, and other objects considered as spiral tracers (Moffat and Vogt 1973). This correlation is apparent at the longitudes  $240^\circ$  (Carina),  $285^\circ$  (Sagittarius), and  $90^\circ$  (Cygnus). On the other hand, the depletion of carbon stars in the tangential direction toward the Centaurus spiral feature at  $\ell = 315^\circ$ , in the general direction toward the galactic center is noticeable.

TABLE 3  
RECENT DEEP SURVEYS FOR CARBON STARS IN THE MILKY WAY

| No. | Region                      | l               | b              | Area<br>(sq dg) | No. of<br>C Stars | Limiting<br>Magnitude | References                |
|-----|-----------------------------|-----------------|----------------|-----------------|-------------------|-----------------------|---------------------------|
| 1   | Cygnus                      | $88^\circ$      | $0^\circ$      | 12              | 26                | $m_i = 12.0$          | Nandy and Smriglio 1970   |
| 2   | S. Milky Way                | $235-7^\circ$   | $+5^\circ$     | 1350            | 1124              | $m_i = 12.0$          | Westerlund 1971           |
| 3   | Cygnus                      | $90^\circ$      | $\pm 9^\circ$  | 81              | 45                | $V = 14.0$            | Alksnis and Alksne 1977   |
| 4   | Anticenter                  | $174^\circ$     | $\pm 9^\circ$  | 81              | 27                | $V = 14.0$            | Daube and Duncans 1977    |
| 5   | Cassiopeia                  | $118^\circ$     | $0^\circ$      | 15              | 20                | $m_i = 12.0$          | Nandy <i>et al.</i> 1978  |
| 6   | Baade's Window <sup>a</sup> | $0^\circ$       | $-5^\circ$     | 0.1             | 1                 | $I = 18.0$            | Blanco <i>et al.</i> 1978 |
| 7   | S. Milky Way                | $230-20^\circ$  | $\pm 15^\circ$ | 4500            | 494               | $V = 12.0$            | MacConnell 1979           |
| 8   | Cygnus                      | $80-90^\circ$   | $-5^\circ$     | 48              | 20                | $V = 16.5$            | Kurtanizde and West 1980  |
| 9   | G. Center                   | $348-16^\circ$  | $\pm 10^\circ$ | 322             | 67                | $I = 13.0$            | Present Survey            |
| 10  | Anticenter                  | $168-196^\circ$ | $\pm 10^\circ$ | 322             | 216               | $I = 13.0$            | Present Survey            |

a. A non-objective-prism survey: a prism-grating combination (grism) at the prime-focus plane of a large reflecting telescope was used.

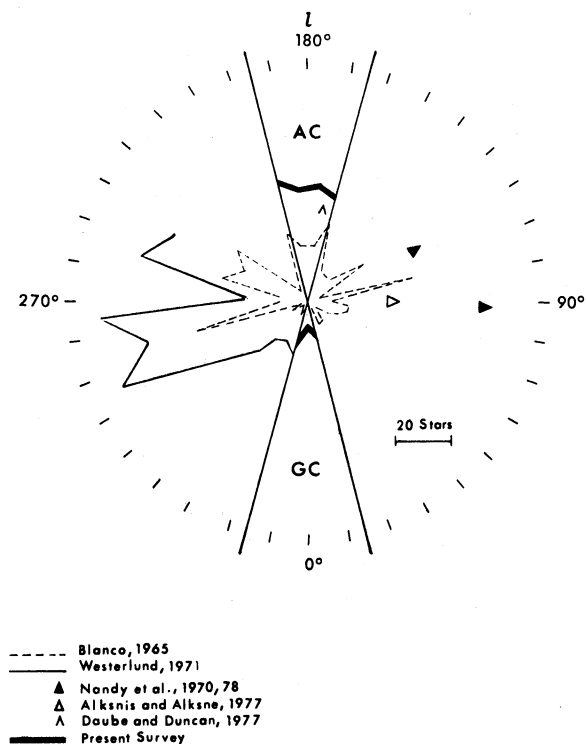


Fig. 7. Distribution of the cool carbon stars near the galactic planes as derived from infrared objective-prism surveys. The diagram shows the number of stars per  $10^\circ$  interval located within  $2^\circ$  of the galactic equator. The sources of information utilized are indicated at the lower-left side of the diagram.

3) The number of carbon stars observed toward the galactic anticenter is relatively small as compared to the number observed toward the tangential directions just mentioned. This may be interpreted as an effect arising from viewing across the main body of the outer spiral arms.

The main result of this investigation is that there is evidence of a gradual increase in the number of cool carbon stars, on the galactic plane, from a distance of about 2 kpc from the galactic center outwards. This evidence is in agreement with a radial gradient of the space density obtained for the carbon stars observed in this survey.

I would like to thank Dr. C.B. Stephenson for suggesting this research. I am also grateful to the faculty

staff and students of the Warner and Swasey Observatory for their kind hospitality during my stay as a graduate student. This work was supported by a scholarship granted to me by the Universidad de Los Andes, Mérida, Venezuela.

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## DISCUSSION

*Sofia:* ¿Did you find enough stars of spectral type S on your plates to be able to say whether they show the same asymmetries between center and anti-center as the carbon stars?

*Fuenmayor:* No, I did not look for S stars.

*Niemela:* ¿Existe entre las estrellas de carbono de las nubes de Magallanes el mismo tipo de asimetría entre el centro y periferias que en nuestra Galaxia?

*Fuenmayor:* Sí, Blanco y otros han encontrado resultados que apuntan en esa dirección.

*Sofia:* ¿Puede usted dar una explicación teórica, aunque especulativa, de la razón por la cual estrellas de carbono trazan los brazos espirales?

*Fuenmayor:* La tasa de formación de estrellas de carbono puede estar conectada con el contenido inicial de metales en el material estelar primigenio.

*Mendoza E.:* Deseo comentar que se podría llegar a magnitudes más débiles en el descubrimiento de estrellas de carbono, combinando la cámara Schmidt con filtros UV e IR, ya que estas estrellas tienen una fuerte deficiencia en el UV y un exceso infrarrojo.

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