BIBLIOGRAPHY OF SECTION III

1. Blaauw, A. Chapter 20 in Strand: *Basic Astronomical Data* (*Stars and Stellar Systems*, Vol. III) Univ. of Chicago Press, 1963.
2. Voigt, H. H. *Mitt. astr. Ges.* p. 17, 1962.
3. Schmidt-Kaler, Th. *Mitt. astr. Ges.* p. 67, 1962.
4. Strömgren, B. *Quart. J. R. astr. Soc.*, **4**, 8, 1963.
5. Gyldenkerne, K. *Astrophys. J.*, **134**, 657, 1961.
6. Crawford, D. L. *Astrophys. J.*, **137**, 530, 1963.
7. Graham, J. A. IAU/URSI Symposium no. 20 (in press).
8. Ljunggren, B., Oja, T. *Uppsala astr. Obs. Medd.* no. 134, 1961.
9. ,, ,, *Uppsala astr. Obs. Ann.*, **4**, no. 10, 1961.
10. Larsson-Leander, G. *Ark. Astr.*, **3**, 51, 1962.
11. Jaschek, C., Jaschek, M., Kucewicz, B. *Asoc. Argentina Astr. Bol.* no. 4, 37, 1962.
12. Blanco, V. M. *Astr. J.*, **68**, 273, 1963.
13. *Trans. IAU*, **11A**, 376, 1961.
14. Stock, J., Nassau, J. J., Stephenson, C. B. Luminous Stars in the N. Milky Way, Vol. II, *Hamburger Sternwarte and Warner and Swasey Obs.* 1960.
15. Stephenson, C. B., Nassau, J. J. Luminous Stars in the N. Milky Way, Vol. II, *Hamburger Sternwarte and Warner and Swasey Obs.* 1962.
16. Pesch, P. *Astrophys. J.*, **137**, 547, 1963.

IV. THE SPIRAL STRUCTURE OF THE GALAXY

Problems relating to the spiral structure of our Galaxy are fairly evenly distributed over the areas of activity assigned to Commissions 33, 34 and 40. It is obviously our task to limit ourselves here primarily to a Report on stellar distribution, leaving the gas, optically, to the Report for Commission 34 and radioastronomically to that for Commission 40. The only stars and star-groupings that are of interest for the study of the spiral structure of our Galaxy are the youngest stars, clusters and associations, OB stars of spectral class earlier than B2 and clusters and associations with one or more stars earlier than B2. Cepheid variables with periods of 10 days and greater have a marginal interest. Since young stars and clusters and associations have random velocities often as great as 10 km sec^{-1}, they will move from their places of origin by 100 pc in 10^7 years. Hence, stars or clusters with ages greater than 3×10^7 years are of little use for the tracing of spiral arms.

At IAU/URSI Symposium no. 20, several methods were discussed for the tracing of the spiral arms of our Galaxy.

1. The 21 cm line of H I yields the most extensive material, but for the interpretation of the observed profiles one needs a reliable velocity-distance law of circular motion and knowledge about a possible expansion (or contraction) velocity at various distances from the galactic centre (see Report for Commission 40).

2. The most direct approach is through the measurement of distances for individual young stars, clusters and associations—with due attention to the problems of space reddening and interstellar absorption.

3. Studies of optical radial velocities of OB stars and emission nebulae—especially when these are properly correlated with analyses based on 21 cm profiles for the same regions—can provide evidence, *if* one is prepared to accept the most likely form for the law relating distance from the galactic centre and circular velocity of rotation. The interferometric velocities for faint emission nebulae measured by Courtès (1) hold much promise for the future.

4. The study of single and multiple interstellar absorption lines can yield results of great value, since they refer only to the region between the Sun and the star in the spectrum of which they are observed and not beyond (see Report for Commission 34).

5. Studies of surface distribution by optical and radio techniques can provide useful information. The optical data (Elsässer and Haug, for example) are affected by absorption difficulties, which do not influence studies in the radio continuum at wavelengths in the decimeter and centimeter range but which become controlling factors in the decameter and longer wavelength regions (see Reports for Commissions 34 and 40).

Survey articles on spiral structure have been published by Whiteoak (**2**) and by Schmidt (**3**) and there is a series of papers on the subject by Oort, Schmidt, Thackeray, Becker, Weaver and Bok in the volume (in press) reporting of the proceedings of IAU/URSI Symposium no. 20. Semi-popular articles on spiral structure have been written by Tassoul (**4**), Rossiger (**5**) and Bok (**6**); references should also be made to a survey article by Elsässer (**6a**). The distribution of galactic star clusters has been considered by W. Becker (**7**) and by Johnson, Hoag, Iriarte, Mitchell, Hallam and Sharpless (**8**); see also the forthcoming chapter by Sharpless. W. Becker and Fenkart (**9**) have studied the distribution of 55 H II regions; Kraft and Schmidt the distribution of the cepheid variables. Beer (**10**) has examined the distribution of southern B stars.

The time has not yet arrived when we can draw a definitive diagram for the spiral structure of our Galaxy. The 21 cm picture is not clear because of uncertainties in the law relating circular velocity with distance from the galactic centre and the related problem of a possible general galactic expansion or contraction—at least for the gas associated with spiral arms near the Sun (Kerr and others). There is fair agreement as to the places where spiral concentrations are found within 3 kpc from the Sun, but there is no agreement as yet as to what these observed concentrations imply for the overall spiral structure of our Galaxy. Roberts (**11**) has discussed the distribution of Wolf-Rayet stars over the sky and its bearing upon the spiral structure of the Galaxy. He finds evidence for strong concentrations of WR stars near $l^{II} = 75°$ (Cygnus), $l^{II} = 290°$ (Carina) and $l^{II} = 350°$ (Scorpius), and a remarkable void in the range $140° < l^{II} < 230°$. The presence of the Cygnus-Carina arm, the Sagittarius arm, the Vela spur and the Perseus region are clearly shown, but the Orion spur—with many OB stars—is not shown in WR stars.

Figure 7 in W. Becker's paper (**7**) and Figure 1 of the paper by W. Becker and Fenkart (**9**), together with the earlier diagram by Bok (**12**) show the situation from the optical point of view. The composite diagram shown by Whiteoak (**2**) relates the optical and radio data. Briefly summarized, one can represent the available *optical* data quite well by the Morgan-Osterbrock-Sharpless picture of three parallel sections of spiral arms, inclined by 55° to 60° to the radius vector from the galactic centre to the Sun. There are several gaps in the observed sections of the spiral arms, notably in the range $300° < l^{II} < 325°$, where there is only a thin string of small and distant H II regions. Bok and others, however, favour a basic optical pattern of more nearly circular spiral arms, a point of view that coincides more nearly with that of the Sydney and Parkes radio astronomers. We note here that the data from the 210-foot radio telescope at Parkes indicate that a typical spiral arm is patchy in form with the patches on the average 500 to 1000 pc in diameter. They point to the depth of the spiral features in Carina (near $l^{II} = 290°$), which seem severely bounded in longitude on either side, and in which young galactic clusters have been located in the whole range of distance from the Sun 1000 to 5000 pc. In a similar manner, the feature near $l^{II} = 327°$ appears to have considerable depth—as though it marks the edge of an inner spiral arm. The Orion—Puppis—Vela section would then mark a spur protruding from the more nearly circular spiral arms, a picture that apparently fits reasonably well with the radio-astronomical spiral array. To complicate the situation, Beer (**10**) finds that some of the southern B stars studied at Radcliffe Observatory fall between the radio spiral arms. Reference to some of these features will be made in the detailed summary of regional surveys to follow.

I. I. Pronik and V. I. Pronik (**13**) hold the view that there exist in our galaxy two massive and roughly annular zones of O – B0 stars, the outer one coinciding with the Orion Arm, the inner

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one with the Sagittarius Arm. Genkin (**14**) has investigated the spiral structure of the Galaxy from the contour of the 21 cm line, taking account of the K effect. For K = -2 km sec^{-1} kpc^{-1}, the arms turn out to be almost symmetrical logarithmic spirals with a characteristic angle of 72°. Analyses of spiral structure and related problems based on radio-astronomical data have also been made by Agekian and Klosovskaya (**15**) by Sorochenko (**16**) and by Lozinskaya and Kardashev (**17**), who find that the thickness of the H I disk increases continuously from the center outward. Schöneich and Nikolov (**18**) have found that 25 galactic clusters with diffuse two-colour diagrams tend to fall in the regions of the Perseus, Orion and Sagittarius Arms.

The data on cepheid variables summarized by Kraft and Schmidt (**19**) favour the presence of a Carina Arm, stretching from the Sun in a direction $l^{II} = 295°$ between 1000 and 5000 pc, but no further clear spiral pattern is distinguishable. There are two useful new lists of colours and magnitudes of cepheid variables, one by Irwin (**20**) for 145 southern cepheids, the other by Bahner, Hiltner and Kraft (**21**) for 45 northern cepheids.

Data on OB stars have been accumulating in the southern hemisphere through the efforts of the Radcliffe observers (**22**) and the H-gamma measurement of Beer (**10**). He has in press a list of 461 new OB star distances derived from H-gamma intensities, which are being used as a basis for further studies of spiral structure. Upgren shows (**23**) that measurements of H-gamma total intensities provide a good measure for separating OB +, OB and OB − stars ($M = -5\cdot9$, $-4\cdot6$ and $-2\cdot5$ respectively) to $m = 13$.

Considerable difficulties arise in the analysis of observational data on the surface brightness of the Milky Way. Elsässer reports that he and Th. Neckel are analysing the data gathered for the southern Milky Way by Elsässer and Haug and they find that the results depend critically on the model for the spatial distribution of absorbing material—which appears very highly concentrated in a local dust cloud with a diameter of the order of 500 pc. Kostyakova (**24**) reports spectrophotometric observations of seven southern Milky Way regions from a research vessel in the Indian Ocean; analysis and discussion will follow shortly.

The present section obviously is not the place to discuss problems of the interpretation of the spiral structure of our Galaxy. We must note, however, that the recent trend has been to lower the estimates of the magnetic field in our Galaxy. The situation is reviewed in two survey papers by McNally (**25**) and there was much discussion on the subject at IAU/URSI Symposium no. 20. The general conclusion appears to be that in the interstellar medium in our Galaxy the average field is not likely to exceed 5×10^{-6} gauss, and that the values quoted earlier—as high as a few times 10^{-5} gauss—are definitely too large. In view of the decreasing emphasis on the galactic magnetic field as controlling the spiral pattern of our Galaxy, it becomes all the more important to consider gravitational factors; the paper presented by Lindblad at IAU/URSI Symposium no. 20 surveys the gravitational approach.

BIBLIOGRAPHY OF SECTION IV

1. Courtès, G. IAU/URSI Symposium no. 20 (in press).
2. Whiteoak, J. B. *Publ. astr. Soc. Pacif.*, **75**, 103, 1963.
3. Schmidt, M. *J. Roy. astr. Soc. Can.*, **55**, 169, 1961.
4. Tassoul, J. *Ciel et Terre*, **77**, 1, 1961.
5. Rossiger, S. *Die Sterne*, **38**, 174, 1962.
6. Bok, B. J. *Proc. R. Inst. G.B.*, **38**, 552, 1961. *Mt. Stromlo Reprint* no. 45.
6a. Elsässer, H. *Mitt. astr. Ges.*, 1960, 34, 1961.
7. Becker, W. *Z. Astrophys.*, **57**, 117, 1963. *Mitt. Basel* no. 28.
8. Hoag, A. A., Johnson, H. L., Iriarte, B., Mitchell, R. I., Sharpless, S. *Publ. U.S. Nav. Obs.*, **17**, 347, 1961. See also: Johnson, H. L., Hoag, A. A. Iriarte, B., Mitchell, R. I., Hallam, K. L. *Lowell Obs. Bull.*, **5**, 133, 1961. (*Lowell Obs. Bull.* no. 113).

https://doi.org/10.1017/S0251107X00015017 Published online by Cambridge University Press

9. Becker, W., Fenkart, R. *Z. Astrophys.*, **56**, 257, 1963. *Mitt. Basel* no. 26.
10. Beer, A. *Mon. Not. R. astr. Soc.*, **123**, 191, 1961.
11. Roberts, M. S. *Astr. J.*, **67**, 79, 1962.
12. Bok, B. J. *Observatory*, **79**, 58, 1959.
13. Pronik, I. I., Pronik, V. I. *Astr. Zu.*, **40**, 94, 1963.
14. Genkin, I. L. *Astr. Zu.*, **39**, 15, 1962.
15. Agekian, T. A., Klosovskaya, E. V. *Vestnik Leningrad. Univ.*, **13**, 103, 1962.
16. Sorochenko, R. L. *Astr. Zu.*, **38**, 478, 1961; *Trudy fiz. Inst. AK. N. SSSR*, **17**, 128, 1962.
17. Lozinskaya, T. A., Kardashev, N. S. *Astr. Zu.*, **39**, 840, 1962: **40**, 209, 1963; *Contr. Sternberg astr. Inst.*, no. 131, 37, 1964.
18. Schöneich, W., Nikolov, N. S. *Astr. Zu.*, **40**, 534, 1963.
19. Kraft, R. P., Schmidt, M. *Astrophys. J.*, **137**, 249, 1963.
20. Irwin, J. B. *Astrophys. J. Supp.*, **6**, 253, 1961.
21. Bahner, K., Hiltner, W. A., Kraft, R. P. *Astrophys. J. Supp.*, **6**, 319, 1962.
22. Feast, M. W., Stoy, R. H., Thackeray, A. D., Wesselink, A. J. *Mon. Not. R. astr. Soc.* **122**, 239, 1961.
23. Upgren, A. R. *Astr. J.*, **67**, 588, 1962.
24. Kostyakova, E. B. *Astr. Zu.*, **40**, 771, 1963; **41**, 505, 1964.
25. McNally, D. *Science Progress*, **51**, 60 and 239, 1963.

V. STELLAR DISTRIBUTION IN LOW GALACTIC LATITUDES

General Surveys

To supplement the surveys noted in other Sections of this Report and in Dr Elvius' Report on Selected Areas, we list here briefly a few General Surveys otherwise not fully reported.

1. The Uppsala Milky Way Survey (**1**) is continuing. The results for the range $40^\circ < l^{I} < 60^\circ$ have been published as Part II of the series (**2**). Ljunggren is now investigating the adjoining sector at lower longitudes ($10^\circ < l^{I} < 40^\circ$) and Oja that at higher longitudes ($80^\circ < l^{I} < 100^\circ$). The limiting magnitude (m_{4400}) is now 10·5.

2. The extensive three-colour photometry undertaken at Basel which includes stars to $m = 19$, and which uses as a basis mostly 48-inch Palomar-Schmidt plates in the *R*, *G*, *U* system, includes in addition to the nine Selected Areas, fields as follows: Small and Large Sagittarius Cloud, and fields in Scutum, Aquila, Cepheus, Cassiopeia, Taurus, Lacerta and the region of the Hyades. The progress of the work has been slowed down by the unavailability of suitable photo-electric standards.

3. Boulon reports that at the Observatoire de Haute-Provence, ten fields are being investigated in the range $55^\circ < l^{II} < 192^\circ$, and that in each field spectral-luminosity classes and colours are being determined together with objective prism radial velocities; approximately 1000 stars are included in the survey. One result is that the width of the Orion arm is found to be of the order of 550 pc.

4. Useful compilations of radial velocities, magnitudes and colours and spectral-luminosity data have recently been published for OB stars. The work for the northern hemisphere was performed by Mrs Rubin and associates (**3**), that for the southern hemisphere by Buscombe (**4**). Iwanowska reports that a 'Spectral Sky Atlas', consisting of objective prism plates photometrically calibrated, is in preparation at Toruń Observatory.

5. Infra-red surveys are more and more coming to the fore. Westerlund (**5**) has completed an infra-red survey for M, S and carbon stars for the range $230^\circ < l^{II} < 10^\circ$, including the galactic centre, complete to infra-red magnitude 10·5. He finds that the M2 – M4 stars tend to cluster along spiral arms, and that the later M stars are more evenly distributed. The distribution of 1326 carbon stars and 87 S stars shows these stars to be connected with spiral

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