THE DISTRIBUTION OF YOUNG STARS, CLUSTERS AND CEPHEIDS IN THE MILKY WAY AND M33 - A COMPARISON

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Ever since the pioneering work by Morgan and his collaborators (1952, 1953), it has been well known that the distribution of the associations of young stars, HII regions, and young clusters defines the optical spiral features. Although considerable progress has been made in spiral structure studies during these past 25 years, the basic picture of optical spiral structure has not been significantly altered. The three spiral features first described by Morgan are still recognized. Modern work on the various optical spiral features has strengthened and improved the definition of the optical features, especially to larger distances. Most of the improvements and any additions to the basic three-arm pattern have resulted primarily from observations of the spiral tracers in the Southern Milky Way. Specifically, the Sagittarius feature is now generally recognized as the Sagittarius-Carina arm which may indeed be a major arm of the Galaxy. It can now be traced optically to very large distances, up to 6 kpc or more in the direction $\ell = 290°$. The Local arm (Cygnus-Orion) probably extends to 4 kpc in the direction of Puppis ($\ell \cong 240°$), and most astronomers would probably agree that our local spiral feature is not a major arm, but an inter-arm feature.

In this paper, I will briefly review the evidence for optical spiral structure as revealed by the distribution of the assocations of young stars, the youngest open clusters and the long-period Cepheids. I will also discuss the distribution of the young stars, associations and Cepheids in our neighboring spiral galaxy M33. A comparison allows some perspective on the problems of spiral structure in the Milky Way.

The first figure shows the distribution of the recognized OB associations and youngest clusters (B2-B3). Considerable work has recently been done on the clusters in the Southern sky by Moffat, Vogt, and FitzGerald (references given at the end) and their new data has been combined with the young clusters from the compilation by Becker and Fenkart (1971). Although considerable recent work has also been done by a number of astronomers (Humphreys 1973, 1975, Walborn 1973, Miller 1972, Jackson 1976, Muzzio and Orsatti 1977a, b, and Garrison,

W. B. Burton (ed.), The Large-Scale Characteristics of the Galaxy, 93–98.

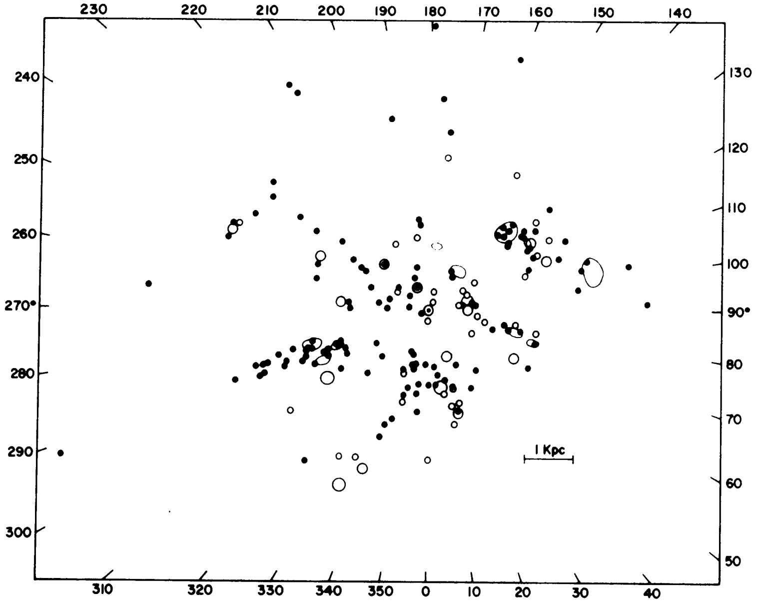

Figure 1 - The space distribution of the associations of young stars, O, and young clusters (B2-B3), ●. The sun's position is indicated by ʘ.

Hiltner and Schild 1977) on the supergiants and OB stars in the Southern sky, I have chosen to show the distribution of the associations of young stars instead of the individual stars to eliminate some of the scatter due to distance errors. The large open circles for the associations are shown in various sizes in the figure in an attempt to weight the associations, first according to their sizes based on their published boundaries (the angular size or extent in figure 1) and secondly by the number of known member stars (radial size in figure 1). Thus in this figure greater weight is given to the largest and most heavily populated associations.

The three major spiral features, Sagittarius-Carina, the Local feature, and the Perseus feature, are clearly defined, and there are significant gaps between the three features. The outer edge to the Sgr-Car arm occurs at ℓ = 30°-40° in the North and ℓ = 280°-285° in the South. With the addition of supergiants and HII regions this arm can be traced optically to more than 6 kpc from the sun. In addition there is evidence for an inner spur in the direction ℓ = 305°. A spiral feature, Norma-Scutum, interior to Sgr-Car is also present at 3 to 4 kpc from the sun.

The Local feature can now be traced to large distances towards ℓ = 240° and it is possible it may be a spur or bifurcation of the Perseus arm. The Perseus feature or outer arm is not very well-defined at larger distances, although it may extend through Cam OB3 and Aur OB2 towards ℓ = 210°.

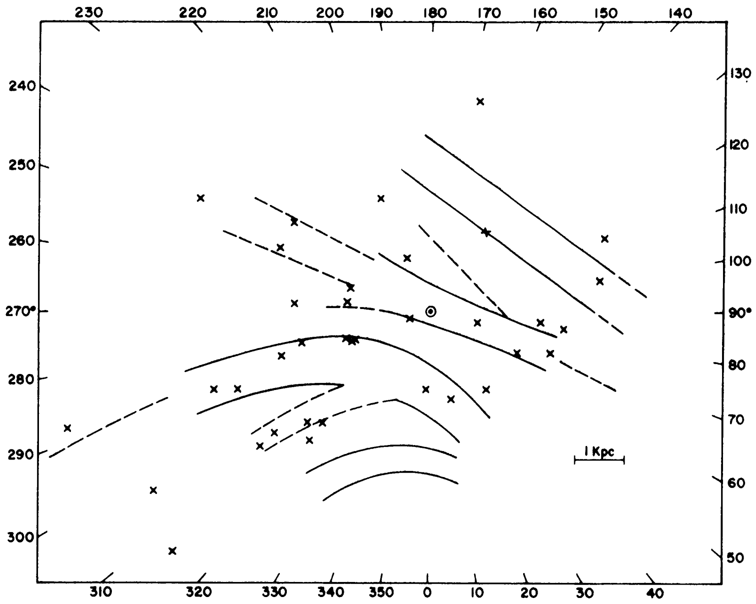

Figure 2 - The space distribution of the long-period Cepheids, P $\geq$ 15^d, with the outlines of the spiral features as shown by the objects in Figure 1.

Figure 2 shows the distribution of the longest period Cepheids (P $\geq$ 15^d), selected from Tammann (1970) and Grayzeck (1974). This limit was selected because a period of 15^d corresponds to a visual luminosity of $M_V \simeq -5^m$ and most of the supergiants and OB stars are even brighter than this. It was felt that shorter period and consequently less luminous Cepheids might belong to a somewhat older population. It is clear from this figure that there are too few Cepheids of longest period to be used alone as spiral tracers. However the outlines of the spiral features as revealed by the associations and young clusters are also included with the Cepheids, and it is apparent that most of the longest period Cepheids lie in or near the spiral features. From this comparison it is reasonable to conclude that in future spiral structure studies the most luminous Cepheids should serve as beacons or signposts to places which should be studied for other more abundant tracers. However we shall see in M33 that the presence of a Cepheid does not always mean that a spiral arm is present.

The following discussion of M33 is based on the first results of a study of the population I stars in that galaxy. This work is in collaboration with Allan Sandage. The brightest blue and red stars have been identified in M33 by blinking blue, visual and red (IV-N) plates of that galaxy, and the associations of the blue stars have been mapped based on deep blue photographs. A photograph of M33 shows the outlines of the associations of blue stars. 141 associations have been identified and it is clear from this picture that the associations follow the basic spiral pattern of M33. The spiral structure of M33 is rather complex as is obvious from any photograph of that galaxy. Although one has the impression of an underlying two-arm pattern it is complicated by the extensive fragmentation of the arms which begins quite near the nucleus. It was hoped that the distribution of the brightest blue and red stars and particularly the associations would make the basic pattern clearer, and they do to some extent.

The distribution of the brightest blue stars reflects the basic spiral structure of M33, as well as all of the smaller spiral features and branches. Their distribution clearly illustrates the problems one would encounter in mapping the structure from inside M33. There are not as many red stars, so that the spiral structure is not so apparent and contamination from foreground stars is serious for the red stars. When most of the field stars have been removed, the spiral pattern may be more obvious. Those red stars in the associations and the spiral arms are presumably the M supergiants.

The 35 Cepheids from Hubble's (1926) original paper are shown on an outline of the spiral structure in M33. The Cepheids appear to be concentrated towards the nucleus of M33, however this is probably a selection effect since Hubble's plates were of good quality only over the central regions of M33. These Cepheids have periods between 13^d and 70^d. Approximately one third of these long-period Cepheids are in or near the associations and another third in spiral features. The remaining Cepheids including those that appear to be in the nuclear region are clearly <u>not</u> in spiral arms. This result supports the earlier suggestion that Cepheids in the Milky Way should be used in combination with other spiral tracers and as beacons of where possible spiral features might exist.

A comparison of the distribution of the sizes of the associations in the Milky Way and in M33 shows that what we call associations in our galaxy are smaller than those in M33. This is probably not real, but instead due to observational selection. In our galaxy we recognize smaller groupings of stars than in a distant galaxy. It is important to consider what we would call a spiral feature or recognize as a spiral tracer, that is an association of young stars, if the Milky Way were at the distance of M33. Looking at Figure 1 again it is obvious that there are large clumpings of associations, young stars, and clusters - in Carina, Perseus, Cygnus and Sagittarius. These clumps are what we would call spiral tracers in more distant galaxies.

The linear sizes or extent of the associations in our galaxy were determined from their published boundaries and their distances, and the mean linear size of 57 associations is 125 parsecs. In M33 the tangential size refers to the linear size parallel to the spiral arm and the radial size refers to the perpendicular direction. There is a tendency for the associations to be larger in the tangential direction than in the radial. The mean tangential size is 251 parsecs while the mean radial size is 203 parsecs. Thus the associations in M33 appear

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to be pulled out or stretched parallel to the arm.

In conclusion the optical spiral tracers in our region of the Galaxy reveal wide spiral arms with considerable evidence for branching and fragmentation. Sgr-Car may be a major arm of our galaxy particularly since it may be traced to such large distances towards $\ell = 290°$. It would be very worthwhile to study the spiral structure along the northern edge of this arm $\ell = 30°-40°$ to test this hypothesis. It is possible that the local feature is an inner arm spur branching perhaps from the Perseus arm, or that these two features may be due to a bifurcation of the other major arm. We know that considerable branching of the spiral arms occurs in other galaxies particularly in the outer parts. We see such a small part of our galaxy that it is difficult to extrapolate, but if our region is any indication, the spiral structure of the Milky Way may be quite complex.

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DISCUSSION

Bok: 1. How do you intend to eliminate the galactic red stars from your statistics for M33? 2. Have you corrected the discussions of your M33 HII regions for the most probable tilt of M33?

Humphreys: 1. Sandage is measuring true colors and magnitudes for the brightest blue and red stars in M33. A color-magnitude diagram will be produced; we will then be able to eliminate most of the foreground stars. 2. We will be determining the tilt of M33 from the spiral structure diagram; we will then be able to correct the dimensions for tilt.

Kerr: There is still an important difference between the radio and optical pictures. The radio continuum and recombination-line data show a very clear gap between the Sagittarius and Carina features, unlike the Sagittarius-Carina arm described by Sivan and by Humphreys.

Humphreys: Optical spiral tracers show the Sagittarius-Carina feature very strongly. There is no optical gap between the two regions.

Yuan: Could you explain how you arrived at such a high pitch angle for the Perseus arm?

Humphreys: The Perseus arm location is based on the associations and clusters with $r > 2 - 2.5$ kpc between $\ell \simeq 100°$ and $180°$. Actually the pitch of this arm could have been even higher. I tried to be rather conservative in drawing the outline of this feature.