CLUSTERS, ASSOCIATIONS AND GALACTIC STRUCTURE

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Distances to clusters are not more accurately determined today than twenty years ago. Effects of different abundances in different clusters can seriously influence distance determinations. There is, however, no immediate call for a revision of the cluster distance scale as obtained by curve fitting assuming the distance of the Hyades to be known.

Associations and young clusters clearly group in a few features, the positions of which agree with the distribution of H II regions. However, the grand design of spiral structure does not emerge beyond doubt from the young stellar component and we might restrict ourselves to saying that the distribution of clusters and associations supports the spiral structure derived from H II regions. The expected shift of spiral features over a time scale of $20\text{-}100\times10^{6}$ years is not confirmed beyond doubt.

Cluster abundance studies show a gradient with decreasing metallicity outwards in the Galaxy. This gradient seems established in the solar neighbourhood and a few kpc outwards. It supports similar results for gas and stars in the field.

INTRODUCTION

For over fifty years we have known that our stellar system is a galaxy. The structure of this is a particularly intrincate problem since we have to do all the observation from the inside of the disk. There are a number of reasons why the distribution of the stellar component can best be studied by means of clusters and associations:

- Distances can be determined more accurately for clusters than for single stars.
- Clusters and associations contain luminous stars and can thus be studied at large distances.
- Associations and young open clusters are our best tracers of the youngest component of the disk.
- Globular clusters are ideal tracers of the halo system.

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- Ages are better known for clusters than for other objects.
- Composition indices can in certain cases be better determined for clusters than for single stars.

The first comprehensive study of open clusters and their distribution was made by Trumpler (1930). It is particularly exciting that he, already 50 years ago, put the Perseus arm on the map and that one on his diagram can see the positions of the Sagittarius and Carina features. Some characteristics of the apparent cluster distribution led him to place the centre of the Milky Way near the brilliant open cluster NGC 3532. It was the distribution of globular clusters that, at about the same time, showed that the centre of the galaxy was at a larger distance in the direction of Sagittarius. This was done at Harvard by Harlow Shapley and Helen Sawyer.

Twenty years later Morgan, Sharpless and Osterbrock (1952) suggested that the H II regions and the OB associations formed features similar to those typical of the spiral arms in the Andromeda galaxy. While Trumpler had discussed all clusters, it was now the youngest component that was considered and three spiral arms were discussed: the Perseus arm, the local arm and, with some hesitation, the Sagittarius-Carina arm.

During the latest quarter of a century there has been a fruitful interplay between studies of clusters and studies of stellar evolution. Observers continue to provide parameters from cluster studies to stellar models and these models, in return, teach us much about the ages and abundances of clusters, adding interesting aspects to studies of their distribution.

I. STARS IN CLUSTERS AND ASSOCIATIONS

Before discussing what patterns actually come out there are a few issues that must be examined. One concerns the identification of associations, another deals with cepheids and their distribution in the galaxy and the third concerns the distance scale that we use.

I-1. Identification of Associations

There is usually no problem in deciding what is a star cluster. Open as well as globular clusters stand out from the surrounding field because of higher star density per unit area. In exceptional cases the impression of a cluster can be created by the pattern of dark clouds. However, greater problems meet the astronomer, who tries to decide on the extent of an OB association since these systems have few members and can only be recognized when spectral types are known. In some instances (Carina, Cygnus) several associations are seen along the line of sight so that distances are essential for decisions on membership. What we usually mean by an OB association is a collection of a few dozen luminous stars inside a volume of about $10^6 pc^3$. Normally such a space would contain 1 OB star but some 20 A-type stars and hundreds of less luminous stars. The very intrincate problem of assigning high

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luminosity stars as members of associations has recently been treated by Humphreys (1978) who gives memberships for 71 different associations and group, most of these being defined by Ruprecht (1966). I can add that even on this list there are many cases where associations could be considered as parts of one larger association and other cases where some people would divide into several what is defined as one association.

One may define OB associations differently. In the note by Morgan, Sharpless and Osterbrock (1952), it was H II regions and OB star condensations that were compared to those of the Andromeda galaxy. However, those are larger and richer than those of our galaxy (van den Bergh, 1964). To match them we should rightly consider groups of several associations perhaps even the features in Perseus, Carina or Sagittarius.

A third way of defining OB associations would be to require coevality as is usually assumed for clusters. This, however, is a dubious requirement. For one thing, it has been shown by Elmegreen and Lada (1977) that even the traditionally accepted associations contain a spread of stellar ages apparently caused by shockwaves from supernova events inside the same association.

For discussions of galactic structure, my preference is to use the second concept, i.e. we should discuss groups of several associations. Such groups are particularly relevant if we want to compare the structure of our galaxy with that of another galaxy. There are two parallels to this concept. One is interstellar clouds, usually found in sizes of a few parsecs up to 100 parsecs. Lucke (1978) found considerably larger groupings of interstellar clouds. The other parallel is the concept of star complexes among cepheids as described by Efremov (1978b). He gives a mean diameter of 600 pc and ages of several tens of millions of year. Inside these complexes Efremov finds extended periods of star formation.

These types of objects thus seem to group in complexes of several hundred parsecs. Let me make it quite clear that I only discuss the similarity of size distribution between these types of objects. I have earlier pointed out (Lyngå, 1979) the lack of positional agreement between cloud groupings and young stars. Similarly, there is an obvious lack of agreement in position between Efremov's 35 cepheid complexes and the associations of luminous stars. Of course, the main interest of these complexes is that they correspond to the prevailingly patchy appearance of external galaxies.

I-2. Cepheids in the Galaxy

Since the paper by Kraft and Schmidt (1963) the accepted view has been that long-period cepheids are good spiral tracers. The periods considered by Kraft and Schmidt were 10 days or longer which, according to Efremov's (1978a) period-age relation correspond to ages of 30×10^6 years or younger. The open clusters considered by Becker (1963b) to line up spiral structure have ages which on the whole are considerably lower than the cepheids mentioned (cf. Lindoff 1968). Later increase of the number of cepheids studied (Tammann, 1970; Grayzeck, 1978 and 1979) has not significantly improved the agreement between cepheid distribution and structural features of the galaxy. Humphreys (1979) describes a collaborative study with Sandage, in which they establish spiral structure of M33 from associations of blue stars. It turns out that for M33 the distribution of cepheids with periods 13-70 days (Hubble, 1926) is different from the distribution of associations. Humphreys also selects galactic cepheids of periods exceeding 15 days (younger than 23×10^6 years according to Efremov's relation) for distribution study. Even with this more critically selected material a surprisingly poor agreement with the distribution of young clusters is found: only the Carina feature is discernable.

There may still exist a true correlation between cepheid positions and spiral features but if so, the inaccuracies in distance determination have blurred the pattern beyond recognition. This critical attitude can be brought further by considering that the Carina region is quite rich in stars generally and it would indeed have been surprising if there had not been more cepheids than in the less dense parts of the galaxy.

I-3. Distance Scale of Clusters

Recently, there has been a very important reassessment of the Hyades distance which will be commented on later by Hanson. Let me just make some brief remarks on the use of colour-magnitude diagrams for deriving distances assuming that of Hyades to be known.

Blaauw (1963) gave the probable error for the distance modulus of h and χ Per ($11^{m}_{.}8$) as $0^{m}_{.}23$ of which $0^{m}_{.}05$ were due to the inaccuracy of the Hyades distance modulus. The inaccuracies in curve-fitting and in reddening correction are still with us, even if one might surmise that modern technique has slightly improved the photometric accuracy. For determination of cluster distances one has mainly used the calibration tables provided by Blaauw (1963), by Johnson (1963) and by Schmidt-Kaler (1965). Based on these, a homogeneous system of cluster distances has come into existence. Revisions of absolute magnitude calibrations have been made (Walborn 1972, Balona and Crampton 1974 and others) but, by and large, the distances derived from curve-fitting procedures have not changed significantly.

From time to time it has been claimed that in certain directions the interstellar reddening law is different from the generally accepted one, which in the UBV system is expressed by $R=A_V/E_{B-V}\simeq 3.1$ or near that value. If indeed the interstellar medium behaved like that, the distances to open clusters would be very different from the accepted distances, but several recent investigations have shown that apart from circumstellar extinction, which need not concern us today, the value of R is constant to within 5-10 % (cf. Lyngå 1979) and the distances of open clusters are thus not seriously affected.

However, a source of error, to which insufficient account has been paid, is the blanketing effect on photometric colours and thus on the colour-magnitude diagram. This was discussed by van den Bergh (1977) for an open cluster with the metallicity of the solar neighbourhood. Let us similarly estimate the effect on distance determination for distant clusters in the Galaxy and then also consider a gradient of metallicity (cf. Janes, 1979). An open cluster with a galactocentric

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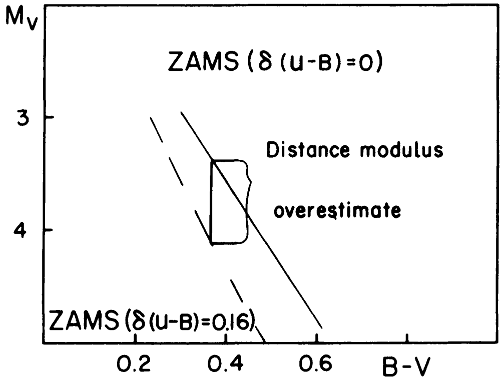

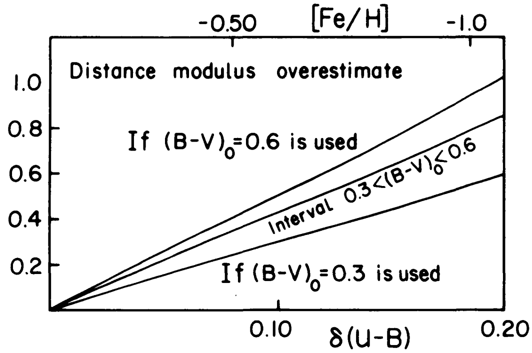

Figure 1a. Effect of blanketing on distance modulus determination by curve fitting.

Figure 1b. Overestimate of distance modulus as a function of cluster abundance.

radius of 11 kpc is typically slightly metal poor with an UV excess of between $0^{m}.01$ and $0^{m}.02$. Applying the blanketing values given by Wildey et al. (1962) on the main sequence from $B-V=0^{m}.3$ to $B-V=0^{m}.5$ one finds that the curve fitting procedure would overestimate the distance modulus by almost $0^{m}.1$. Figure 1a shows, for reasons of clarity, an extreme case where the UV excess $\delta(U-B)=0^{m}.16$. Towards the inner parts of our galaxy a slight underestimate of distances may be expected although not many clusters are known to have a higher metallicity than the Hyades. The Basel (Becker, 1963a) method of using two colour-magnitude diagrams does not avoid this particular problem since the effects are about the same on both diagrams.

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I-4. Cepheids and Cluster Distances

It is essential for galactic structure studies as well as for the extragalactic distance scale that there is a good tie between cepheid and cluster distances. Considerable effort has lately been made to examine the problem and to determine period-luminosity and period-colour relations for cepheids in clusters. The most reliable list of such cepheids seems to be the one given by van den Bergh (1977). This list contains 14 cepheids which are members of well studied galactic open clusters and associations. Madore (1977) and Pel (1978) both find that about a quarter of all cepheids belong to binary systems. This might have given a systematic shift of the period-luminosity relation but, as Madore points out, the effect is fortunately small, and one may expect that the relations derived by van den Bergh should still be valid. What happens if one applies them on cepheids of other galaxies, where some binary rate might prevail, is outside my topic.

II. THE GALACTIC STRUCTURE AS DISPLAYED BY CLUSTERS AND ASSOCIATIONS

This discussion will be divided into the following subjects:

II-1. Globular clusters in the halo
II-2. The galactic structure in the disk
II-3. Age effects in the positions of galactic features
II-4. Longitude distribution of clusters of different ages
II-5. The distribution of elements in the disk
II-6. Comparison with the open cluster system of M31

II-1. Globular clusters in the Halo

Searle (1977) has discussed the globular cluster system and particularly the distribution of heavy elements in the halo. His main reference is the investigation by Searle and Zinn (1978) which shows that clusters with metal abundance up to 0.1 of the solar value can be found between 8 and 30 kpc from the galactic centre without any gradient. Similarly, Kraft (1979) has studied RR Lyrae stars in the halo and does not find compelling evidence for an abundance gradient. Since the subject will be reviewed during this symposium I shall not add more at this stage.

II-2. The Galactic Structure in the Disk

Becker (1963b) pointed out the similarity between the distribution of young open clusters in our galaxy and the appearance of the spiral structure in NGC 1232. Since then many discussions have aimed at getting a better picture of our galactic spiral arms by adding more young clusters to the material and by including other types of objects. Papers by Lyngå (1964), Sharpless (1965), Bok (1971), Moffat and Vogt (1973a), Humphreys (1976), Quiroga (1977) and many more have used clusters, associations, cepheids, supergiants, WR Stars, H II regions and even

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other objects to obtain spiral arms of a few hundreds parsecs' width and of several kiloparsecs' length. Inclinations are in the range $8^{o}-15^{o}$ against galactic circles and arms are trailing. This has become known as the grand design and I feel it necessary to make some heretical statements about it:

- During the last fifteen years we have not improved on the picture given by Becker (1963b); in many cases new data have rather blurred it.
- The grand design referred to in other spiral galaxies generally consists of no more than a few very large pieces (Toomre, 1977).
- Very often the evidence for such spiral features is slight. One finds a few young clusters in approximately the same direction and immediately part of a spiral arm is invoked. Considering that the total absolute magnitude of a galactic open cluster is below -8^{m}, corresponding to about 16^{m} in the Andromeda galaxy, that is not very realistic. In fact the average association in external galaxies is rather brighter than $M_V=-10^{m}$, and has a size of several hundred pcs.
- It seems increasingly evident, in our galaxy as well as in external galaxies, that stars and clusters can form between the established spiral features; even at some distance from the galactic plane, there is evidence of on-going star formation.

I have considered it important to adopt this rather critical attitude initially and yet I shall try to maintain that we by studying associations and young clusters can say something and that what we can say weights heavier than the results from studies of positions of single stars like cepheids, WR stars and supergiants. This would already be so because of the increased accuracy for determination of distance and reddening to clusters. However, one may also seriously doubt the positional correlation between cepheids and spiral features (section I-2) although such has often been assumed in the past.

Returning to open clusters, particularly young ones, the table by Becker and Fenkart (1971) form a homogeneous material of about 90 objects. The material has recently been augmented by Fenkart and Binggeli (1979) and now consists of over 150 open clusters with an earliest spectral class of B2 or earlier. The increase in observational data is largely due to efforts of Moffat and Vogt (1973b, 1975a, b, c). A plot of these clusters is given in figure 2. As already pointed out, most of these clusters would look insignificant from outside our galaxy and to evaluate the spiral structure we ought to give most weight to the most luminous clusters of the largest diameters. The total luminosity is not readily available for most clusters while the linear diameter is. In figure 2 the clusters with diameters of 2 pc or more have been marked by dots and smaller clusters by crosses. It would be possible to discern the three spiral arms +I, 0 and -I, of which Becker (1963b) writes, but one may also take the more critical view that only regions where several large clusters are present should be considered. Then there appear to be three strong concentrations (features) corresponding to what have been termed the Perseus, the Sagittarius and the Carina spiral features. They have been outlined in figure 3. In addition there are some less

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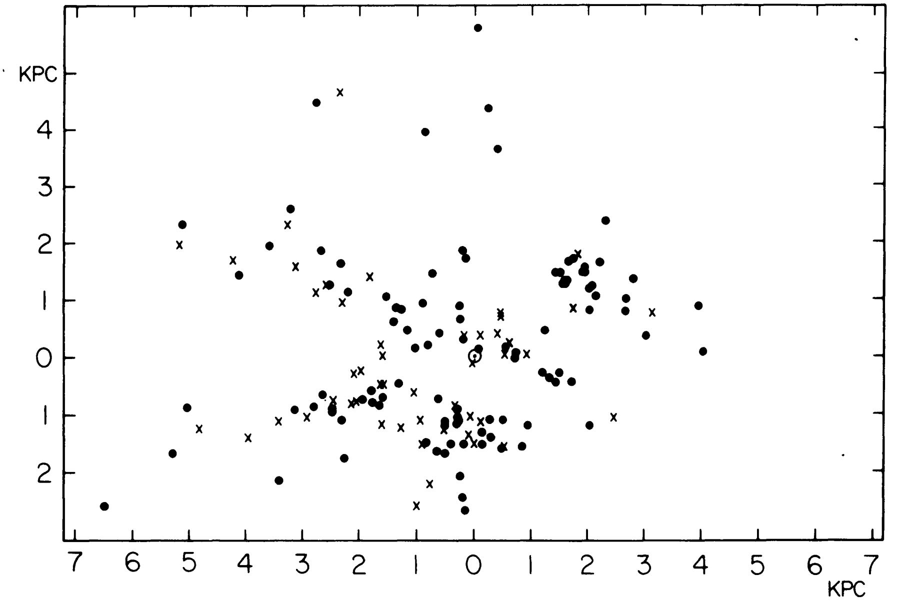

Figure 2. Distribution in the galactic disk of open clusters larger then 2 pc (●) and smaller than 2 pc (x). Place of sun:⊙

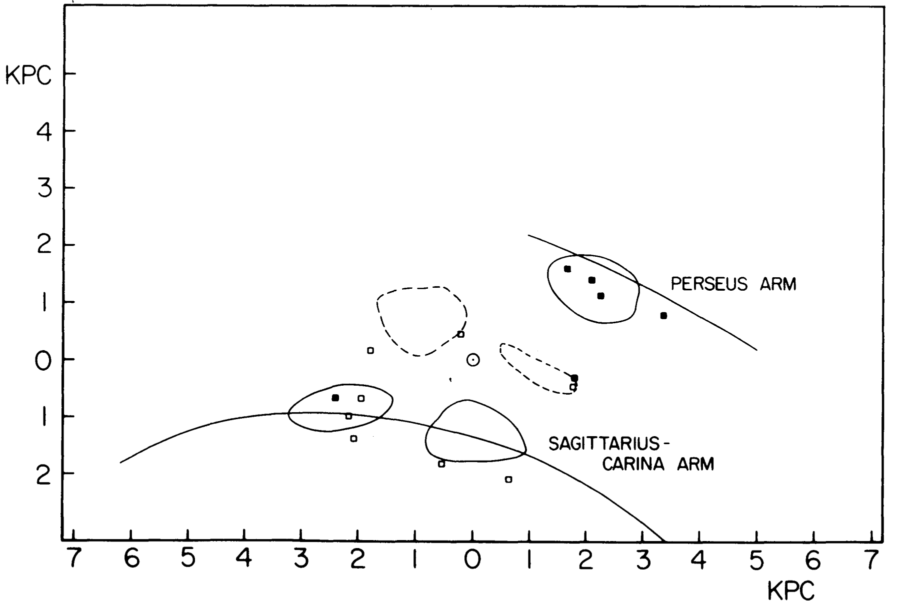

Figure 3. Outlines of the concentrations of figure 2 compared to H II spiral structure and to associations with total magnitude brighter than -9.5 (□) and brighter than -10.0 (■). Place of sun: ⊙

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pronounced concentrations (dashed outlines in figure 3) of open clusters towards Cygnus and towards Vela; these have often been connected and termed the local arm. Recently Moffat, FitzGerald and Jackson (unpublished) have found a number of clusters outside the Perseus feature. Whether this represents another concentration of significance is difficult to judge at this stage.

The most recent and also the most detailed examination of associations of high luminosity stars is given by Humphreys (1978). She also assigns the associations to spiral arms according to the established nomenclature. It is interesting to see that 30 out of the 71 associations are assigned to the local arm and 14 to the Perseus arm; yet, if associations with a total visual magnitude brighter than -10 are considered, only 2 of these are in the local arm (Cyg OB1 and Cyg OB2) against 4 in the Perseus arm. Obviously, selection effects will emphasize the importance of nearby features. In the present discussion I prefer to concentrate on the most luminous associations - even they are less luminous than associations in the spiral structure of external galaxies. Figure 3 thus contains positions of associations with $M_V^{tot}<-9.5$ as squares, those with $M_V^{tot}<-10.0$ as filled squares. The four most luminous associations known in our galaxy are all situated in the Perseus feature while another group of luminous associations are found in the Carina feature.

So far clusters and associations where the features found do agree. Turning to OB stars in the field we find that

- The accuracy in distance determination is low.
- These stars to a large extent form outside the spiral features.

They will thus only add slightly to the picture derived from clusters and OB associations.

The last fruitful comparison is with galactic distribution of H II regions and this is because of two reasons: Firstly, these objects are the most prominent characteristics of spiral arms of external galaxies and, secondly, a very thorough study of the distribution of H II regions has recently been made by Georgelin and Georgelin (1976). They used both optical and radio measurements and, although the model rests mainly on distance determinations of exciting stars, kinematic distances were also used. One important principle employed by Georgelin and Georgelin was a weighting of the objects such that H II regions near the sun do not obtain a higher importance because of their position. The model achieved has a major spiral arm in the position where earlier the Sagittarius--Carina arm was discussed. The exterior Perseus arm and the interior Norma arm are also prominent and one can imagine the Scutum-Crux feature as an intermediate arm. Of the local arm, however, very little is to be seen, once the perspective effect is removed.

In figure 3 I have for comparison entered the positions of the Perseus and the Sagittarius-Carina arms according to Georgelin and Georgelin. The fit between these and the three most prominent concentrations of young clusters is excellent, the associations adding even more credibility to the picture.

Let us, however, note a couple of differences between these arms.

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Firstly, the most prominent OB associations are situated in the Perseus feature, whereas Sagittarius and Carina are richer in H II regions. Secondly, Hartwick (1970) and Humphreys (1978) both find that the ratio between blue and red supergiants decreases with increased galactocentric distance, i.e. this ratio is significantly higher in the Sagittarius and Carina features than in the Perseus feature.

It would have been interesting to compare all this with the distribution of neutral hydrogen from the extensive 21 cm surveys that are available. However, as shown by Burton (1973) and by Wielen (1975), any interpretation requires detailed knowledge about the kinematical behaviour of the gas, a subject that is still controversial. I would thus prefer to postpone such a comparison.

II-3. Age Effects in the Positions of Galactic Features

Since the galactic features discussed are characterized by nebulae, associations and clusters of 20×10^6 years and younger, one would expect slightly older objects to be shifted systematically with respect to those features. The individual motions of clusters of ages 100×10^6 years and older would already have mingled these with the general background but those of intermediate ages ought to be systematically displaced. The expected amount of displacement depends on the parameters of the theory of spiral structure. For instance, the density wave theory as described by Roberts (1969) with a pattern velocity of 12.5 km/s/kpc and an inclination angle of $8\overset{\circ}{.}2$ would leave these clusters on our side of the Sagittarius and Carina features, a few hundred parsecs from them for ages of 50×10^6 years, and smaller shifts for younger clusters. I have tried to look for this effect among the hundred or so clusters of intermediate ($20-100 \times 10^6$y) ages which would be expected to show this shift but nothing stands out very clearly. B. Balázs has pointed out to me that effects of prolonged creation periods of the clusters would alter the expected shifts and at the present time we are reassessing the material with this in mind.

Another approach was made by Palouš et al. (1977) who made detailed studies of ages as well as of space motions for 20 clusters. They traced each cluster back along its orbit to the place where it was when the member stars were formed. These places were compared with the positions of spiral arms with inclinations $6\overset{\circ}{.}2$. For certain pattern speeds (13.5 and 20.0 km/s/kpc) there are a fair number of these birth places inside the spiral arms. Palouš et al. find a feature of age less than 60×10^6 years in the solar neighbourhood; they identify this with a local interarm feature. Similar results were obtained by Forte and Muzzio (1976) for 10 open clusters. In both of these papers, rather wide spiral arms have been considered, and the results show trends rather than statistically established coincidences between birthplaces and places of present spiral arm patterns. From both papers it appears that at least some clusters are formed outside the spiral features.

II-4. Longitude Distribution of Clusters of Different Ages

Using our computer based cluster catalogue (see Lyngå and Lundström, poster paper at this symposium) I have studied the positions of open clusters as a function of their ages. Clusters younger than 10^8 years have an average distance from the galactic plane of 52 parsecs while the ones that are older than 10^8 years have an average value of 126 parsecs.

The distribution in galactic longitude is shown in figure 4. The young clusters in the top graph show two maxima for longitude intervals corresponding to the two spiral features in Perseus and in Carina. A

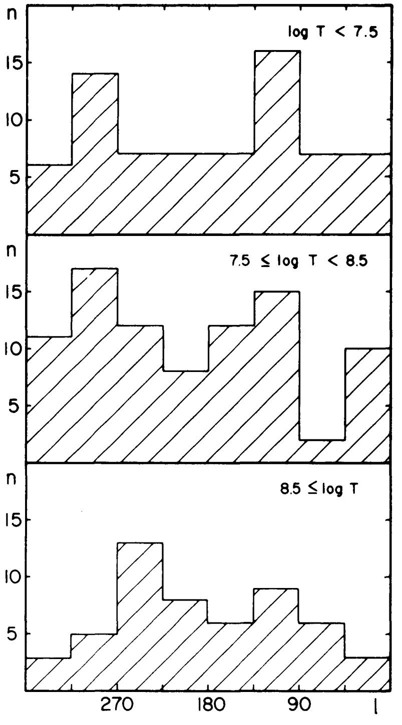

Figure 4. Longitude distribution of open clusters of different ages.

slight tendency is present for a similar distribution among the intermediate age clusters (middle graph).

The older clusters (bottom graph) seem to be much less prevalent in the inner part of the galaxy than towards the outer regions. This curious phenomenon has earlier been commented on by Hawarden (1975) who associates a minimum near $l=80^o$ with a feature of interstellar extinction. The distribution is obviously sensitive to selection effects and it is necessary to compare the different trends in the top and bottom graphs of figure 4. This can be added to the two differences between the inner and outer parts of the galaxy described in section II-2.

II-5. The Distribution of Elements in the Disk

While the globular cluster system and the distribution of elements in the halo of our galaxy seems to be reasonably well known, it is less clear what the status is of open clusters and associations and what conclusions can be made from them about the element distribution in the galactic disk. From studies of K giants in open clusters and by discussing U-B excesses, Janes (1979) has found evidence of a gradient of decreasing metallicity with increasing galactocentric radius. This seems well established for the outer parts of the galaxy, particularly since Christian and Janes (1978) have added the metal poor open cluster Be 21 to the material. The gradient is much less pronounced in the inner parts of the galaxy although some work is in progress. Clariá from Porto Alegre is studying red giants in clusters by DDO phtometry, and I have been observing a few clusters with uvby photometry. However, the scatter in Janes' diagram appears larger than the inaccuracy of abundance determinations and there is probably much more to this than simply an abundance gradient.

Photometric studies of nearby field stars with known space motions have enabled Grenon (1972) and Mayor (1976) to derive abundances typical for stars with different galactic orbits. Orbits with smaller galactocentric radii then belong to stars with relatively high metallicity and both investigations give a gradient in [Fe/H] of -0.05 kpc^{-1} in the solar neighbourhood. This value agrees with the gradient derived by Janes from cluster studies. Similar gradients are found, and mostly with higher accuracy, from studies of the gaseous component as reviewed by Peimbert (1978).

Let me finally recall the differences in the content of the galactic disk inside and outside the sun's position:

	inside the sun	outside the sun	reference
Spiral features	Sag-Car	Per	
OB associations	Less luminous	More luminous	figure 3
H II regions	Larger	Smaller	Georgelin et al. (1976)
Blue/Red SG	Higher	Lower	Humphreys (1978)
Metal content	Higher	Lower	Janes (1979)
Old open clusters	Fewer	More numerous	figure 4

II-6. Comparison with the Open Cluster System of M31

Recently, a particularly relevant comparison became possible through the investigation by Hodge (1979) of the open clusters in M31. Several of the points made above are strongly supported by this, the first detailed study of the open cluster system in an external spiral galaxy:

- Large open clusters have clumpy distribution.
- Some clumps are near spiral features.
- Many large clusters lie between spiral arms.
- Young clusters are more plentiful than old in inner areas.

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DISCUSSION

BOK: Thank you very much, Dr. Lyngå. It might be of interest to mention here that at the administrative meeting of IAU Commission 33 there was a very fervent discussion of the distance scale and the constants of the galaxy. There was even a move on for a while to start setting up a new set of constants of the Galaxy, but by the end of the discussion it was perfectly clear that nobody was ready for it. The biggest worry there was the problem of the distancesto the HII regions. They come, of course, from the distances of the associations. The basic uncertainties there are at large distances (for example, where you determine the rotation curve and you get the values of Oort's A and B), where there seems to be a general indication to cut A down from 15 to 12. We all know that the distance scale plus the distance to the center is perhaps much better fixed than we have the distances of the far outlying HII regions. Therefore, in all the spiral structure there is the basic uncertainty that you have a distance modulus uncertainty which some of us, who are pessimistic, say is about half a magnitude and Adrian Blauuw a little smaller, that may well be; but we do not know the distances. That means at great distances an unbelievable fuzziness begins to set in. Does the speaker have any comments on this sad state of affairs?

LYNGA: I agree.You are, in fact, emphasizing some of the points I tried to make.

BOK: I don't mind telling you that I moved out of our own Galaxy and came to star formation where things are much sweeter and nicer than in this business, but the outlying spiral structure in our Galaxy we have now pretty well to about 7 or 8 kpc; there are a few spots like the ones Fitzgerald has worked on, and Herbst that we will hear about later on, where things have been done beautifully. But there is a definite law of diminishing returns at work . . . Amen. (Laughter).

KING: I have a small comment about numbers of clusters as a function of longitude. You've emphasized a great number of uncertainties; I think maybe there is one more that one should add and that is that our list of clusters is very incomplete. As you well know, when one looks at photographs of the Milky Way . . .

BOK: What clusters do you mean?

KING: Open clusters. One sees new clusters and there are a number with your name which you found because no one ever catalogued them before. Number as a function of longitude I think is a dangerous thing because of that incompleteness. I wonder if the larger number in the anticenter direction could simply indicate a somewhat larger completeness both because there is less obscuration and because the general star density is lower and it is easier to see clusters?

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LYNGA: The clusters that I had were those that people had decided to determine the ages of, so that perhaps is even more of a selection effect, but it's a different one because I think all clusters for which it would be possible to determine the ages would be pretty well known, so I don't think that is due to incompleteness.

CHRISTIAN: If you take a look at absorption vs. numbers of open clusters, as catalogued by the Alter Catalog, there is a strong anti-correlation between high absorption and number of clusters. What I mean is that areas where you have high absorption you have very few clusters catalogued; and galactic longitudes (for example, 240°) where you have strong numbers of clusters of all ages you have very little reddening. The reddening has been studied in that direction, and, in fact, very close to the plane there are galaxies seen there. So these places where you have large numbers of clusters are really strongly correlated with where the absorption is, so I think you have to be really careful about saying . . .

LYNGA: Could we please have that slide back again? What I want you to look at is the relation between the young clusters and the old clusters, because this sort of selection effect would hit both the same. If there were a selection effect because of the extinction, then no doubt we've got fewer clusters inside the Sun's direction, and then I would expect all these diagrams to be the same.

CHRISTIAN: Yes, except the enhancement in between 180° and 270° may result from the very low absorption there, so that you have things coming in like more luminous clusters seen at much larger distances, and that sort of thing. I think that the sample is really incomplete.

LYNGA: Be21, or something like that, is that around here?

CHRISTIAN: Oh no, that's at 180°.

LYNGA: 180°, yes. I do expect that there is quite a lot of extinction close to here, the Vela region, and there still I've got quite a few clusters. I think that there are these selection effects, but what selection effect would cause the young clusters to be more numerous here and the old clusters more numerous there?

CHRISTIAN: I feel very strongly that a lot of it is just incomplete sampling.

LYNGA: All right.

BOK: Barry Madore pointed out to me very strongly that Roberta Humphrey's diagram was far too pessimestic. Since he's here, would he wish to comment on this Cepheid result?

MADORE: No. (Laughter). Not without a slide - you can't see it.

BOK: Unhuh, well would you give briefly your conclusions? No? OK.

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MADORE: Upon Bart Bok's insistence I shall make just a few remarks about the distribution of long period Cepheids in our Galaxy and their relevance to spiral structure. While the continued addition of long-period Cepheids appeared to be confusing the spiral picture rather than strengthening it, I do not believe that it is necessarily the fault of the Cepheids. There are several reasons for this. First and foremost are the very grave uncertainties in the correct reddenings for long-period Cepheids. Related but somewhat independent of the reddening is the question of the appropriate calibration of the intrinsic PLC: lack of a coherent spiral picture in the Cepheid data *may* in fact be pointing to a calibration error. However, even in the presence of a perfect calibration, Cepheids, by their very nature, are indicators of recent star formation. If those locations prove to be ragged in distribution it does not mean that Cepheids are to be mistrusted or abandoned but that star formation of a general nature can and does go on outside of grand-design spirals. Any other indicator of star formation should, of course, be consistent with this but we should not make the mistake of looking for, or only trusting, *spiral* patterns in the data.

SCHMIDT-KALER: Well, I have a few remarks. Number 1, we made a test on the distribution of the Cepheids and conclude there is no spiral structure you can delineate by the Cepheids. Second, the picture of the Georgelins' is mostly considered to be very reliable as regarding spiral structure. I'm a little bit concerned about the fact that he gets much better aligned spiral structure features if you get farther out, but of course that's known. Point three, you mention the objects which are grouping on a large scale, several hundred parsecs; I think that's an important point, since we see many galaxies with not a global grand spiral structure, but kind of a global spiral structure broken up into parts. Broken up into pieces of that size. There is a whole group of galaxies, which I think is NGC 2841, that is the best example of that. If you look at these groups of galaxies you see they're mostly also inclined to the galactic plane. The Carina group is another example, and the Sagittarius Group is obviously inclined to the galactic plane in some particular way. I call this phenomenon "shingles", because it's just like tiles or shingles inclined and building together a kind of secondary instability on the instability which is the spiral feature itself.

LYNGA: I think its very nice, your third point here; the angles to the plane will be something like a few degrees, one or two, three degrees - something like that. The second point, the Georgelin one, I think their method of weighting is a very nice one. They're weighting the results, or the HII distances, so that the nearby features will not be emphasized like they will be if you plot out what you know.

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SCHMIDT-KALER: No, that was not the point. The point was that you get a very fine alignment at very large distances, 10 kpc, from the Sun; and this is due to the way they determine the distances, while you get just a mess around the Sun.

BOK: Professor Blaauw - who, by the way, had the age gradient of Lada and Elmegreen about 15 years before Lada and Elmegreen had it.

BLAAUW: Just a question. I wanted some clarification on that table you put there with HII regions and associations where you give some differences between the outer arm and the inner arm. Now I think you said that you find that the associations in the outer arm, the Perseus arm, are brighter than the ones in the inner arm. Now, what do you mean by this? Do you mean that, on the average, in the outer arm the associations are more luminous than in the inner arm? Or do you mean to say they are so much more numerous that, therefore, there will be more luminous ones than in the inner arm, but even then the average brightness per association might be the same? So is this effect an effect of numbers per cubic parsec or kiloparsec, or is it some intrinsic difference in the associations? Could you clarify that?

LYNGA: I would have thought that it would be an intrinsic difference. I think you might remember the slide showing about four very luminous associations in Perseus and one or two in Sagittarius. If you take all the associations that are known and determine distances and absolute magnitudes of them, you get many more in Sagittarius than in Perseus; so, in relation to the total number of associations, those in the outer arm seem to be more luminous.

BLAAUW: So what you say is the average association is more luminous in the outer arm than in the inner arm? That is what you really mean?

LYNGA: No, not necessarily. There are certainly several more luminous associations in the outer arm than in the inner arm. Yes. And if you take the mean value, yes, you would get that. But whether the median of luminosity would be different, I don't know.

BLAAUW: But that's just what you say. You say the average one is more luminous in the outer arm than in the inner arm . . .

LYNGA: Yes, if you take the mean value, yes, right.

BLAAUW: But I would like to know how you get to that conclusion, but that is probably a more complicated thing than you can explain here. But it seems to me there is very much a selection effect involved in this whole thing.

LYNGA: Yes, if you have two associations considered as one then you will, of course, get a higher luminosity.

FEAST: Just two quick points on what you said about Cepheids. The recent work on the Large Cloud I think shows such a narrow PLC relation that it is very difficult to believe that binaries are really a terribly important thing in that connection. And, secondly, if you take the best studied clusters in the Galaxy with Cepheids, the zero point they give for the PLC relation all agree so well that it is rather difficult to believe that a *U-B* excess problem is really very important for them either.

LYNGA: But I said this.

FEAST: Well, you said it might be a problem.