Cluster Hunt in the Southern Milky Way

L. O. Lodén

Most of the known stellar clusters in the Milky Way have been found because they contain conspicuous groupings of relatively bright stars. Nobody doubts, however, that there are many other clusters, in particular very loose ones, which are not known at present. But how to discover them and to prove that they are real physical entities? In this article, Dr. Lars Olof Lodén from the Stockholm Observatory, Sweden, summarizes one aspect of a large investigation that has been underway for nearly two decades: finding new clusters in areas that are densely packed with stars.

In 1962 we began to work seriously with the material from the large spectral survey of the Southern Milky Way that was outlined by the late Bertil Lindblad a few years earlier. This material was secured at the Boyden Observatory in South Africa between 1958 and 1962. It consisted of objective-prism plates obtained with the ADH Baker-Schmidt telescope (widened spectra), direct-photographic plates in blue and yellow taken with the 25 cm Metcalf astrograph, and photoelectric UBV photometry of a large number of standard sequences distributed over the whole investigated part of the sky (obtained with the reflecting telescope). The region covered included a galactic belt between $l = 235°$ and $l = 10°$ with an approximate width of 7°.5.

The intention was to select "interesting" stars from the objective-prism plates by means of visual inspection. These stars should then be subject to subsequent, detailed investigation, maybe also statistical studies with respect to spatial distribution, etc. A problem was that from the beginning of the project it was not clear how to define the concept "interesting stars"! Rather soon, however, it turned out that the quality of the objective-prism exposures was relatively uneven, ranging from excellent to miserable with statistical concentration somewhere between acceptable and good, and it became evident that the objects in question must have the exclusive property of being easily detectable independently of the quality of the plates. In practice this implied that our "targets" should be (a) very early-type stars, (b) very late-type stars, (c) stars with particularly conspicuous spectra (for instance emission-line stars). At that time there was still a lot to be done as far as the mapping and listing of these types of stars were concerned and, in fact, we made a decent contribution to the first-approximation exploration of the Southern Milky Way, particularly its very southernmost parts. My most diligent co-workers at that time were Anita Sundman and Birgitta Nordström.

Close Pairs of Similar Stars

During the inspection of the objective-prism plates, we were immediately surprised by the extremely frequent occurrence of two (sometimes more) spectra of (practically) identical type and magnitude, situated so close together that they formed a very conspicuous configuration for the inspector's eye. Already in the beginning we were convinced that the phenomenon itself was not necessarily a unique astrophysical one, but merely had to do with human perception. In other words: one reacts when two almost equal spectra appear close together on the plate. This concept could also be supported by means of a comparison between the observed frequency of these coincidence phenomena and the one calculated under the assumption that they were produced just by chance. The result of this comparison showed a (not unexpected) clear correlation between the relation between observed and calculated number, as well as the magnitude and angular separation of the components. For stars brighter than about $m = 11$ and with an angular separation less than ten minutes of arc, there was an overwhelming excess of observed coincidences, but the gradients were steep and beyond $m = 13$ and separation $= 12'$ the excess had turned into a corresponding deficit. Thus: when the stars (i.e. their spectra) are bright enough and appear sufficiently close to each other, one discovers the coincidence immediately; otherwise one tends to ignore them. The ultimate separation limit, of course, is set by the diameter of the field of view in the inspection microscope.

Now the question was: how should we explain the excess of coincidences that was actually observed? The phenomenon itself was still an observational one and it would be dangerous to state that there was only one unique physical explanation behind it.

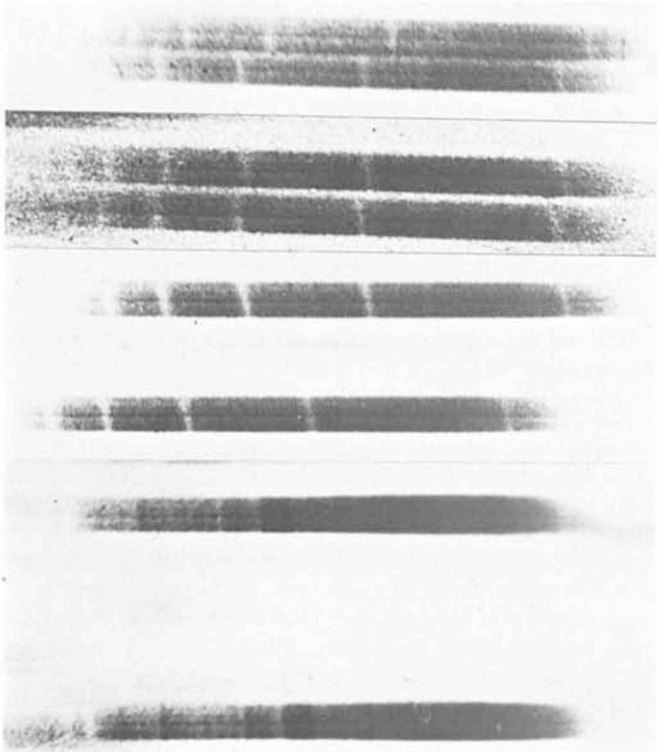

Fig. 1: *Some examples of close pairs of objective-prism spectra of nearly the same spectral class and magnitude. The three upper pairs are all early type; the strong lines are the hydrogen (Balmer) lines. The lower pair is of late (K) type and shows the prominent G band at the centre.*

Our working hypothesis was that within a cluster (or better: clustering) of stars there is an enhanced probability for accidental appearance of two equal stars close to the same line of sight and that therefore a certain fraction of the coincidences would probably belong to open clusters or associations, many of which are too loose or poor to be discovered directly by "conventional" methods. One might call these objects "cluster traitors". The coincidence phenomenon is thus accidental but it facilitates the detection of the cluster. One may think of a pair of identical twins in a gang wanted for crime. If they appear far apart in the mob, their risk of being captured is appreciably smaller than if they show themselves close together.

Observations at ESO

Our first step was to check the relationship between the components of the candidate objects. For that purpose we used UBV photometry and slit spectra. The observations were carried out at La Silla during 1969, 1973, 1974, and 1975 and the results showed that a considerable majority of the coincidences were definitely situated so close to each other in space that there was very little doubt about their mutual relationship. Next step was to study a selection of stars in their immediate neighbourhood in order to discover other presumptive cluster members. This was appreciably more difficult. The only "standard methods" available were analysis of radial velocity or proper motion data—under ideal conditions both. Unfortunately, none of them could be used with any chance of success in this case. Therefore we started desperate attempts to find a physical criterion for cluster membership, preferably a photometrically measurable one. Perhaps a certain metallic peculiarity would be characteristic for a particular cluster or association? We investigated the use of the metal index m_1 in the Strömgren four-colour system for discrimination of mutually associated members from stars in the general field, and uvby observations were made at La Silla between 1976 and 1979, together with UBV photometry, of a large number of stars in the immediate surrounding of some representative candidate objects.

Unfortunately it turned out that the metal index in question was considerably more sensitive to temperature and interstellar reddening than to subtle spectral details, particularly for spectral types A and earlier which predominated in our material. For this reason we are now trying to find a new criterion as a most urgent part of our present research project.

Although we did not find any convenient, elegant, and reliable discrimination method, we could, by means of clumsy classical procedures, get a satisfactory answer to our principal question concerning the suspected objects: more than 80 % of the investigated objects are physically real. A certain number turned out to be situated in or in close connection with more or less ordinary clusters (some of them already known or even well known). A majority of the other ones are very loose open clusters or clusterings, well in accordance with the working hypothesis. There is also a significant number of very small and very poor clusters which we prefer to call "microclusters" or "miniclusters", possibly some sort of cluster remnants. In a few cases our candidate objects have more the appearance of a binary or multiple system with extreme separation between the components. It may be reasonable to assume that such a configuration represents the ultimate state of a cluster in dynamic decomposition. The last stars leaving the cluster should be the most massive ones. The most massive star and the second most massive one are expected to have nearly the same magnitude and spectral type.

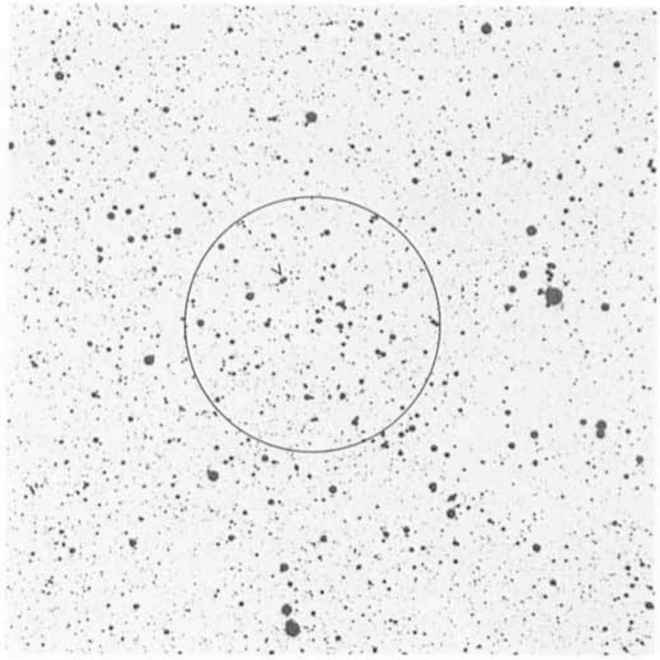

Fig. 2: *A small part of the Milky Way in the constellation Carina. Many groupings of stars are seen. The circle encloses a possible, very loose cluster. A very close pair of stars (indicated with an arrow) first drew attention to this area because of equal spectral type and magnitude.*

How Many Clusters are there?

Next we come to the astrophysical implication of the observed phenomenon. If we consider the spectral type coincidence to be more or less accidental, we are forced to believe that there are many loose stellar clusterings which are less conspicuous and consequently remain undetected. It is even possible that we detect only a very small minority of the clusterings and that the true number is several orders of magnitude larger than the number of ordinary clusters and associations catalogued thus far. There still would be a majority of free stars without dynamical connection to any particular cluster, but no more an overwhelming one. The concept "general stellar field" or "general stellar background" should in that case be used with a certain caution. What we see when we carelessly talk about this background field might as well be a puzzle created by a successive superposition of a manifold of various clusterings and associations. Some of them are visible; others disappear in the crowd. The denser and richer a cluster is, the higher is its chance of being detected.

If, on the other hand, stars of various magnitudes are randomly distributed in space there is also a high degree of probability that a few of them accidentally will form apparent groupings that are erroneously considered as clusters. In other words: You don't see all real clusters in your Milky Way region and all clusters you see are not real. And there is no reason to believe that the two processes cancel out.

With respect to the general structure of the Milky Way, we can make two different models, each one representing an extreme case. To begin with we forget the time parameter. In the first one the stars are completely homogeneously distributed—except for some random groupings. In the second one there are no "free" stars at all, only clusters and associations of clusters in some sort of hierarchic organization. Observations tell us that none of the models is correct but that the real situation is somewhere in between these extreme cases. The natural question then is: *Where* in between? Here we must introduce the time parameter; the relation between "free" and "bound" stars is definitely correlated to the stage of evolution of the Galaxy—unless we believe that the processes of creation and disintegration of clusterings are in perfect equilibrium.

Personally I do not think that it would be realistic to use the number of cluster(ing)s as a criterion of the age of a galaxy but, more probably, it could be used in an empirical check of the theories for the dynamical stability of these clusters and that is interesting enough.

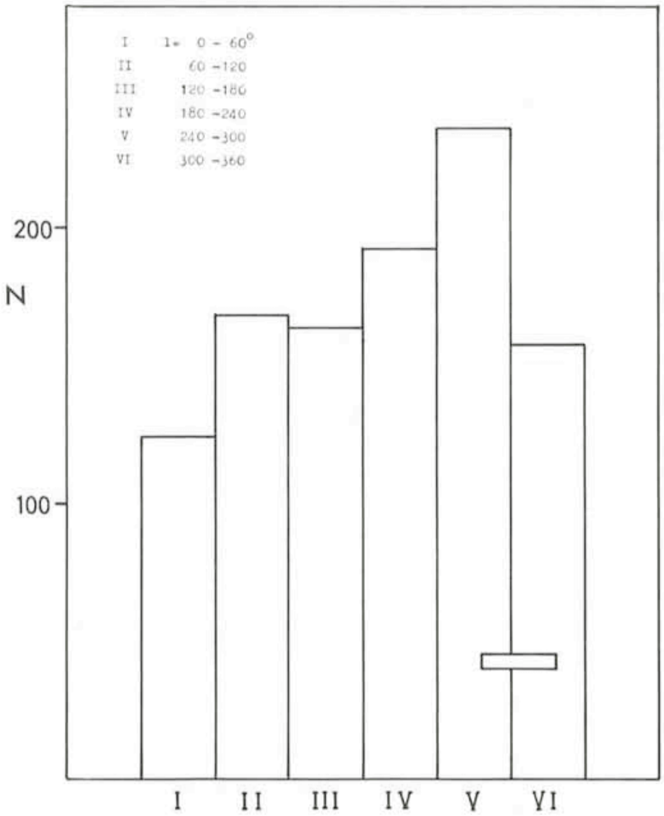

Fig. 3: *The distribution of known open clusters in 60° intervals of galactic longitude. The small rectangle indicates the area investigated by the author and his collaborators at the Stockholm Observatory.* ▸

Discovery of New Wolf-Rayet Stars in the Magellanic Clouds

J. Breysacher and M. Azzopardi

As a result of a thorough search with the ESO GPO astrograph, the number of known Wolf-Rayet stars in the Small Magellanic Cloud has just been doubled (from 4 to 8). Drs. Jacques Breysacher (ESO) and Marc Azzopardi (Observatoire de Toulouse, France) also discovered 17 new WR stars in the Large Magellanic Cloud. Slit spectra of these stars have been obtained with the 3.6 m telescope and there is an indication of a significant difference between the WR stars in the Clouds and those in our own galaxy.

The Magellanic Clouds offer the possibility to study objects of various classes which are at the same distance from us. It is known that some notable differences exist between the stellar populations of the two Clouds, and the Wolf-Rayet (WR) stars do not seem to be an exception to the rule. However, before any comparative study can be undertaken, it is first necessary to make sure that the detection of WR stars in both Clouds is as complete as possible.

The Objective-Prism Search

A systematic search for this kind of star was carried out in October 1977, in March, and in November 1978 with the ESO 40 cm Objective-Prism Astrograph using an interference filter centred at λ 4650 which has a passband of 120 Å wide. WR stars show up strongly in this spectral region due to the emission, mainly from either λ 4650 C III (WC) or λ 4686 He II (WN). This detection technique enabled us to study very crowded regions by reducing the background fog and the length of the spectra, i.e. the number of overlapping images.

Figure 1 reproduces an LMC survey plate. The field has 85′ in diameter. The limiting magnitude of the survey is $m_{pg} = 16.5$ for the Small Cloud and $m_{pg} = 17.5$ for the greater part of the Large Cloud. But due to the poor sensitivity of some of the IIa-O plates used, for a few LMC fields only the continuum of 16.0 m_{pg} stars was reached. The B magnitudes of the WR stars were determined from astrographic plates taken after removing the prisms of the Objective-Prism Astrograph, in combination with a Schott GG385 filter. In order to get an accurate classification of the newly discovered WR stars, slit spectra were obtained for all of them with the Boller and Chivens Cassegrain spectrograph equipped with either the Carnegie image-tube or the Image Dissector Scanner at the ESO 3.6 m telescope.

SMC

In the Small Magellanic Cloud, 4 new WR stars of the WN type ($12.9 \leq m_{pg} \leq 15.3$) were identified (Azzopardi and Breysacher, 1979a) increasing to 8 the number of known WR stars in this system. Considering the distribution among the different WR subclasses, it is remarkable that in