remains are sometimes found in the occupation layers. They used paints, were clever flint workers, and buried their dead. It is obvious that they did not lack inventive powers.

Most of the stone tools which were developed in Upper Paleolithic times by *Homo sapiens* were invented by Mousterian or even by Acheulean peoples. The blade (that is, a blade made through a special technique of *débitage* and not the result of a flaking accident) goes back at least to the end of the Acheulean, and in some Mousterian assemblages blades comprise up to 40 percent of the *débitage*. End scrapers and burins were known in the Middle Acheulean. The backed knife is an Acheulean invention also. But if all these tools already existed in the Acheulean, they were further developed and diversified in the Mousterian. Even the multiple tool is found in the Mousterian (Fig. 1, No. 8); some complex tools—for instance, a burin combined with an end scraper—are also found, but rarely.

The peoples of the Mousterian also experimented with bone tools, but there they fall very short of the achievements of men in the Upper Paleolithic. They never did more than make some bone spear points, and in the main they used only bone splinters, shaping them crudely. But in this respect the first people of the Upper Paleolithic (Périgordian I) appear not to have done much better.

To conclude, it does not seem that, culturally at least, there is any great gap between the Mousterian cultures and the early Upper Paleolithic cultures that followed. One of the latter, at least, has its roots quite clearly in the Mousterian of Acheulean tradition. And even if some anthropologists deny to Neanderthal man (*sensu stricto*) the right to be counted among our direct ancestors, one thing is sure: these ancestors of ours were at a cultural level very like that of the Mousterian peoples. So we come uncomfortably close to the old joke: It was not William Shakespeare who wrote *Hamlet* but another man who lived at the same time and whose name was also William Shakespeare!

CURRENT PROBLEMS IN RESEARCH

Stellar Content of Galaxies

Two parameters which describe the stars that make up any galaxy are age and chemical composition.

Halton Arp

In order to understand how a galaxy is formed, how it evolves, and how different kinds of galaxies are related to each other, it is necessary to understand the kind of stars a galaxy contains. An important impetus to the understanding of the relation of the galaxy to the stars which it contains came in 1944 when Baade originated the concept of population types. According to his original definition, a type II population consists of stars which have the same Hertzsprung-Russell diagram as globular cluster stars, and population-I stars have a color-magnitude diagram like stars in spiral arms, in galactic clusters, and in the neighborhood of the sun. It was quickly realized that population I contains the highly luminous, and therefore young, stars, while population II is an old population.

In the following years galaxies were widely analyzed in terms of the relative number of old and young stars they contained, and the designation of population type became common in astronomical literature. Inevitably this terminology has been modified and extended. The new results, which are just now becoming available, introduce new concepts, reflect our increased knowledge of the kinds of stars galaxies contain, and begin to offer us further insight into the relationships between different kinds of galaxies as well.

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Our Own Galaxy

Advent of the parameter of chemical composition. It became possible to derive an age for a cluster of stars by observing in the color-magnitude diagram the absolute magnitude at which the main sequence broke away to evolve more rapidly (*1*). Systematic observations of clusters of stars led finally to the discovery of a globular cluster, M 3 (*2*), and a galactic cluster, M 67 (*3*), in which the observed main sequences both terminated at the same absolute magnitude. Presumably they were of the same age, but, by definition, they belonged to different populations. The contradiction would only be resolved by attributing the conspicuous differences between their color-magnitude diagrams to differences in the chemical composition of the stars in the two clusters. That such differences exist was borne out by an examination of the spectra (*4*). From this point forward astronomers began to talk less about populations I and II and more about the twin parameters of age and chemical composition. It also became apparent that subdwarfs were associated with the halo regions in which the globular clusters resided (*5*). It was shown that the subdwarfs, like the globular-cluster giants, were extremely metal-poor (*6*). It was obvious now that not only were the globular-cluster stars metal-poor throughout but that the main sequence to which they should be fitted was the subdwarf main sequence.

Revising the calculated ages of the clusters. Sandage and Eggen (*7*) showed that when differential line blanketing was taken into account, the subdwarfs turned out to have lower effective temperatures (T_e) than had been previously indicated by using the color index, effective temperature (B-V, log T_e) relation for metal-rich stars. In computing the age of globular clusters in the bolemetric magnitude (m_{bol}), log T_e diagram, this resulted in termination of the globular-cluster main sequences at fainter luminosities and increased the derived ages. The most recent evolutionary calculations, by Haselgrove and Hoyle (*8*), decreased the importance of the carbon cycle and lengthened the evolutionary ages. Also, these calculations indicate that at a given luminosity the population-I stars are less massive and will therefore evolve faster. On the observational side, very careful work by Baum, Hiltner, Johnson, and Sandage on M 13, and by me on M 5, has yielded very accurate faint main sequences in these globular clusters. Sandage (*9*) has combined the new blanketing corrections, the new observations on the globular-cluster main sequence, and the recent calculations of Hazelgrove and Hoyle. He derives 22×10^9 years as the age of M 13. The age of M 5 turns out to be about 26×10^9 years (*10*). The age of M 67 is only about 9×10^9 years on this new fit, and even the very old galactic cluster NGC 188 (*9, 11*) is only 16×10^9 years old. It should be emphasized that all these globular clusters are now believed to be older because of (i) the lower effective temperatures which differential line blanketing gives the subdwarfs, and (ii) the higher mass which the globular-cluster stars have at the same luminosity.

Chemical composition as a function of date of formation. It is now possible, in the light of this most recent work, to plot out on a time scale the most accurately known ages of aggregates of stars in our own Galaxy. The top scale in Fig. 1 shows the ages of the clusters which have now been accurately dated.

Wallerstein and Carlson (*12*) published the calibration between the metal-hydrogen ratio (M/H) and the excess ultraviolet radiation for subdwarfs. I have established (*10*) the relation between ultraviolet excess on the giant branch and ultraviolet excess on the main sequence. As a result, all the clusters may be plotted at their respective ages against their approximate M/H value. This is shown at the bottom of Fig. 1.

Thus, the first important point has been established: On the average, the oldest clusters are the most metal-poor, and in general, the younger a cluster is, the more metal-rich it is. This is in encouraging agreement with the simplifying theory that stars originally were formed out of pure hydrogen and that the metals are built in the interiors of stars and spread to the interstellar medium. From this theory we would expect only recently formed stars to have been formed out of an interstellar medium appreciably enriched with metals.

Chemical composition as a function of position in the galaxy. There is considerable scatter from the curve in Fig. 1. Although there is a good deal of uncertainty about some of the estimates, we can show that at least some of this scatter is real. For example, regardless of the uncertainties in the absolute age, the recent observational work on M 13 and M 5 leaves no doubt that M 5 is the older cluster. The appearance of the spectra and the ultraviolet excess show definitely that M 5 is also more metal-rich than M 13. It is evident, therefore, that there is no exact relationship between the youth of a cluster and the degree of metal-richness—only the general relationship just outlined. This is very important because it again establishes the fact that age alone is not an adequate parameter for distinguishing kinds of stars. We conclude that stars formed in different parts of the galaxy at the same time must have been, in some cases, of different chemical composition. We suggest that the stratification is a function of halo-disk distance or *z* coordinate, because the metal-rich dust out of which stars are presently being formed in our Galaxy is concentrated in the plane.

The nuclear globular clusters. There is one class of objects which we have not yet discussed, and that is the important group of globular clusters lying toward the nucleus of our own Galaxy. It had been hoped that we would find these clusters to be the transition cases between the classical globular cluster and the old galactic clusters. Morgan (*13*) shows that the spectra of these clusters are always richer in metals than the spectra of the usual high-latitude globular clusters. Because these clusters are located in the rich galactic center, however, they are obscured by dust and crowded by adjoining star images. Consequently only the bright regions of their color-

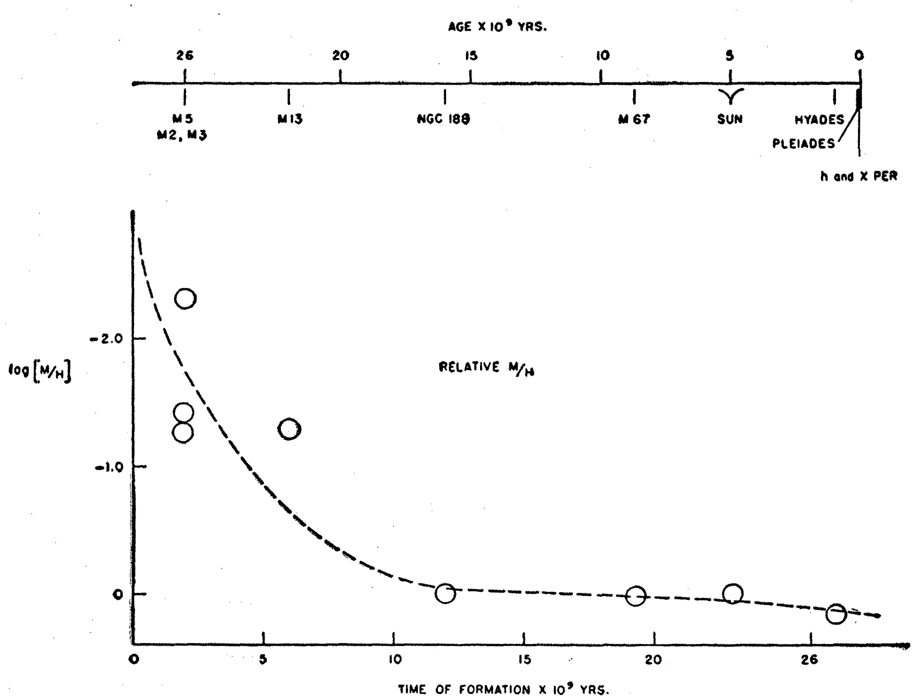


Fig. 1. (Top) Ages of star clusters which are most accurately known at present. (Bottom) The metal-to-hydrogen ratio, relative to that in the sun, as a function of the time at which the star clusters formed.

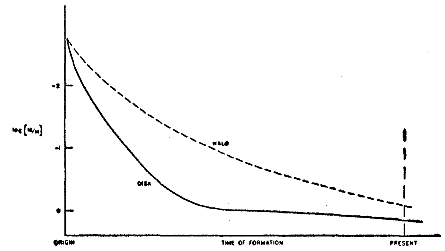


Fig. 2. Metal-richness as a function of the time of formation of a star. A possible difference between disk and halo star formation is shown.

magnitude diagram can be observed. Differences between the color-magnitude diagrams of these nuclear globular clusters and of the halo clusters are observed in NGC 6356 (*14*). Our only means of determining which of these differences are caused by age and which are caused by difference in chemical composition, however, is by observing faint enough regions in the color-magnitude diagram to determine the age from the break-off point on the main sequence.

Cluster NGC 6838. The only one of Morgan's group of nuclear globular clusters which is near enough for us to have a chance of making an age-determination of this kind is NGC 6838. Despite the difficulties involved in observing this cluster, observation for two seasons with the 200-inch telescope (*15*) at Palomar has produced enough results for me to make some preliminary statements. First of all, the ultraviolet excess of the giants in this cluster is between 0 and −0.1 magnitude. The most metal-rich halo cluster observed so far, M 5, has an ultraviolet excess of δ(U-B) = −0.15 for the giants, at B-V of 1.0 magnitude. The result checks very well with Morgan's statement that the cluster, from its integrated spectrum, seems to be much less metal-poor than the halo clusters.

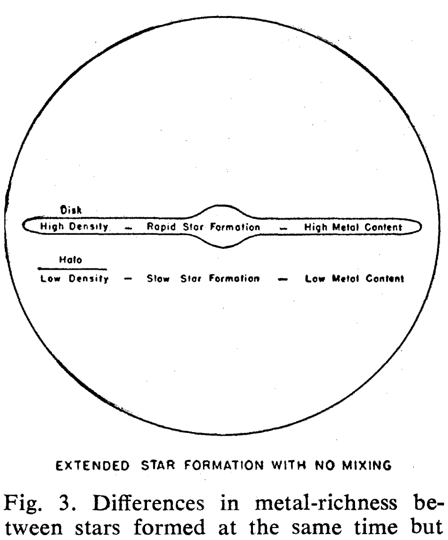


Fig. 3. Differences in metal-richness between stars formed at the same time but over extended regions of a galaxy.

The subgiant sequence in NGC 6838 has been followed down, not yet to the main sequence break-off point, but to a point where it is so blue that we know it cannot be older than 20×10^9 years, at the most. Neither does it appear to be younger than M 67. The final age for NGC 6838 will probably be intermediate between the extremes of 9 and 20×10^9 years.

A closer look at chemical composition as a function of position in the galaxy. Because Morgan's integrated spectra of NGC 6838 and the group show a small but appreciable metal-poorness, and the ultraviolet excess places an upper limit on metal-poorness, we can estimate that $0 > \log M/H > -0.3$. Together with the age estimate given above, this gives another point in agreement with the general relationship in Fig. 1, but one that falls significantly above the curve.

This is an important result and forces us to the conclusion that, instead of a discrete curve, as in Fig. 1, it may now be necessary to draw a band, such as that in Fig. 2. Sandage has shown that NGC 188 is a very metal-rich galactic cluster. The age of this cluster is about the same as that of NGC 6838, discussed above. This implies that the plane of the galaxy at the time NGC 188 was formed was more metal-rich than the region (presumably somewhat out of the plane) in which NGC 6838 was formed.

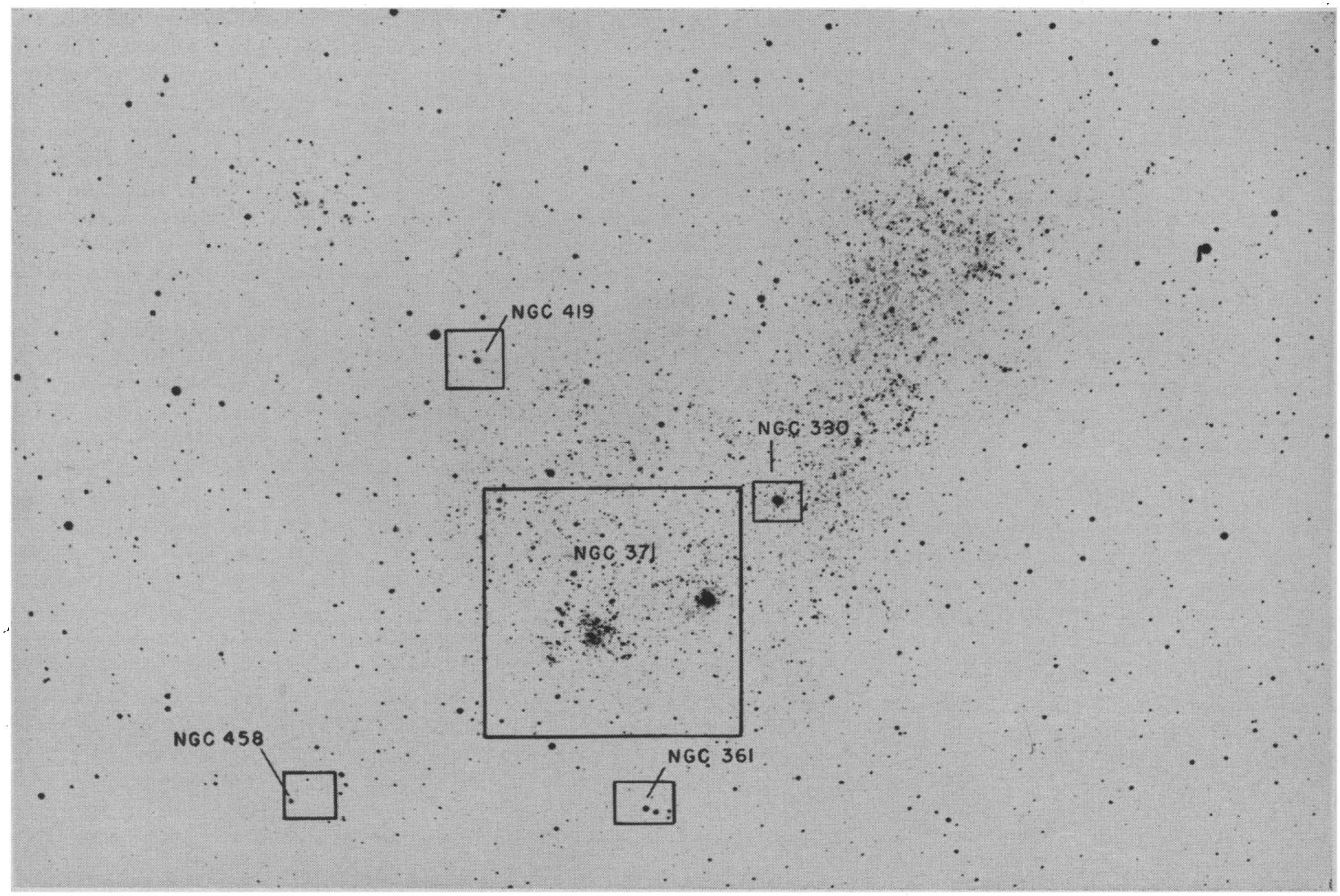
This circumstance is easily pictured in terms of the present theory of metal enrichment. For, even if there was no density gradient in the original galaxy when stars were being formed out of pure hydrogen, a density gradient would soon have been set up as the metal-enriched interstellar material was forced into the plane by galactic rotation. Of course, once the density in the disk is greater than the density in the halo, star formation, which appears to proceed as some positive power of the density (*16*), would be more rapid in the disk. At any given time thereafter the disk would be more metal-rich than the halo, and stars of the same age would show differences in chemical composition, depending on where they were formed. This situation is shown schematically in Fig. 3.

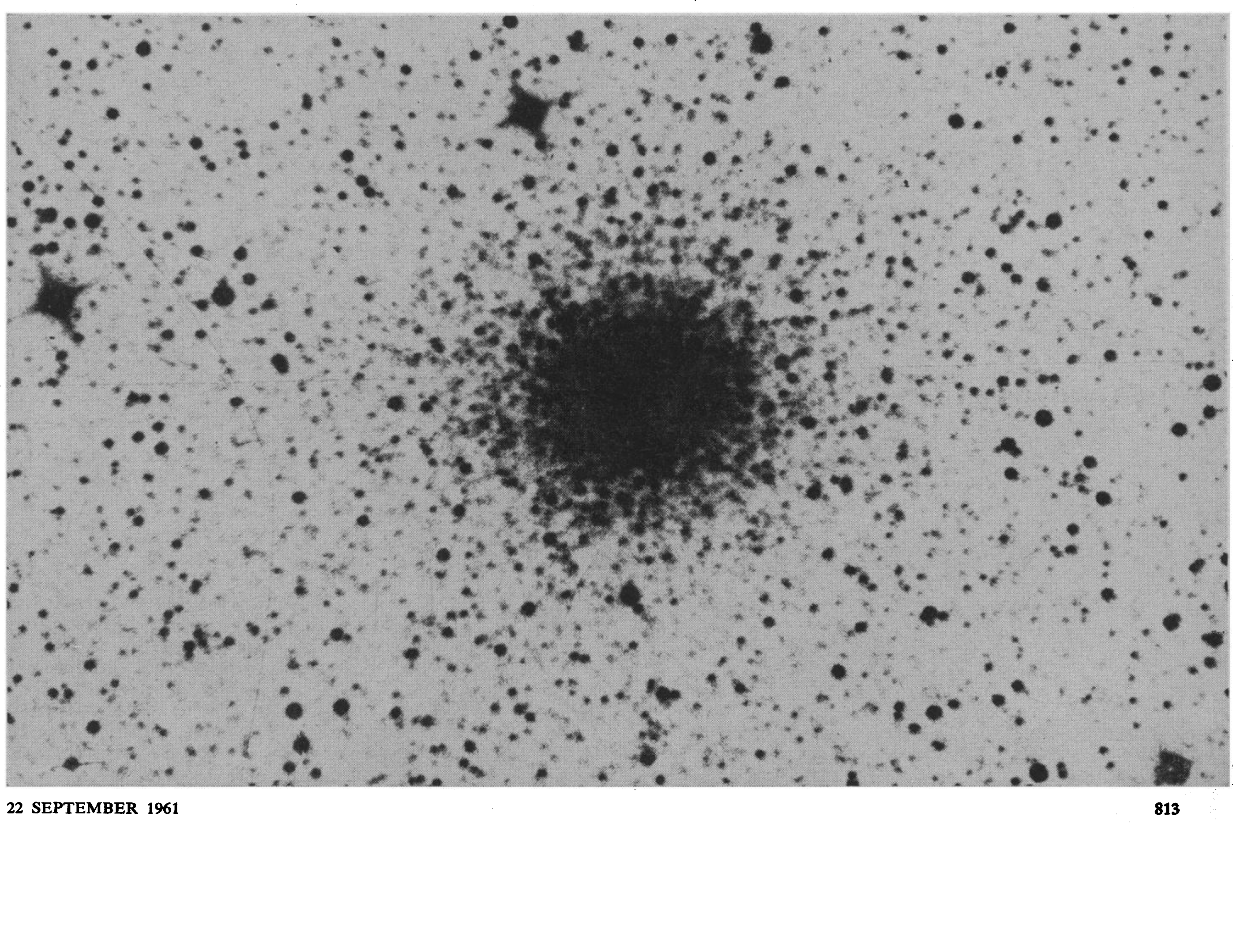
One explanatory note is in order here: The gas and dust in our own Galaxy are presently compressed into narrow spiral arms, where most star formation apparently takes place, to be followed by eventual diffusion into the Galaxy as a whole. Star formation over larger regions, as shown in Fig. 3, is the complementary process, a process which was probably of much greater importance in the earlier stages of our Galaxy. In addition, of course, star formation over extended regions which differ in density is the only possible mechanism in irregular galaxies which lack rotational characteristics.

The preceding analysis of the stellar content of our own Galaxy is a very simple theory which organizes the major facts known at the present time about age and chemical composition. At present a great deal of work is going on to separately measure these parameters in other clusters in our own Galaxy. When those additional results are available they will quickly point up the modifications that are needed in the theory.

Chemical composition and evolutionary tracks. Results on clusters of the same age but of different chemical composition are just beginning to be assembled. The differences between the globular clusters M 2 and M 5 (*10*), of the same age but of different chemical composition, show that there are small but definite differences in the observed color-magnitude diagram. The results on NGC 6838 are preliminary, and I cannot yet state just how the color-magnitude diagram appears, but it is clear that, over-all, the differences between the color-magnitude diagram for NGC 6838 and the diagrams for galactic clusters of the NGC 188 and M 67 type are large. This indicates that only a slight increase in metal content results in a large difference in the appearance of the sequences.

Fig. 4 (top). The Small Magellanic Cloud. Blue-sensitive emulsion, exposed with the 3-inch telescope of the Royal Obesrvatory, Capetown. Objects and regions investigated are identified by NGC numbers. Fig. 5 (bottom). Star cluster NGC 419 in the Small Magellanic Cloud, photographed with the 74-inch reflector of Radcliffe Observatory, Pretoria, South Africa.


NGC 419
NGC 330
NGC 371
NGC 458
NGC 361



Draco

As for galaxies other than our own, it is possible to announce a preliminary result on the sparse dwarf galaxy Draco. The system is at 85,000 parsecs distance, has a low surface brightness, and is about 1000 parsecs in diameter (1 parsec ≅ 3.26 light years). The ultraviolet excess [δ (U-B)] of its giants of B-V near 1.0 magnitude is about −0.34 magnitude. Cluster M 92, the most metal-poor globular cluster known, has the same ultraviolet excess. This, then, is another finding in support of the theory that old, low-density systems contain the most metal-poor stars.

The details of the color-magnitude diagram are not final. When they become so, however, it will be of great interest to compare the diagram with the diagrams of standard globular clusters, to see whether the system is even more extreme in this aspect.

Small Magellanic Cloud

I shall now discuss a completely different extragalactic system, the Small Magellanic Cloud (SMC). Originally it was thought that this system contained exactly the same kinds of stars as the Galaxy. A study of the Cloud was only intended as a sorting out of these stars—a means of fixing the modulus by, say, the Cepheids and thus calibrating all the remaining kinds of stars. In this process of calibration, which was started about 5 years ago, observers have turned up a number of unexpected differences between the Small Magellanic Cloud and the Galaxy. For clarity I shall start with my own investigations and shall include other results later.

Completeness of the sample. First of all, however, we must assure ourselves that the regions investigated in the Small Magellanic Cloud are truly representative of the system as a whole.

Figure 4 is a photograph of the Cloud taken with the 3-inch camera of the Royal Observatory, Capetown. I have indicated the four regions in which colors and magnitudes of clusters, stars, and field stars were obtained. In a fifth region, centered on NGC 371, 69 Cepheid light curves were obtained. It is clear that a representative sample of regions in the Cloud has been investigated. The dense regions in the bar and the sparse regions on either side of the bar are all represented.

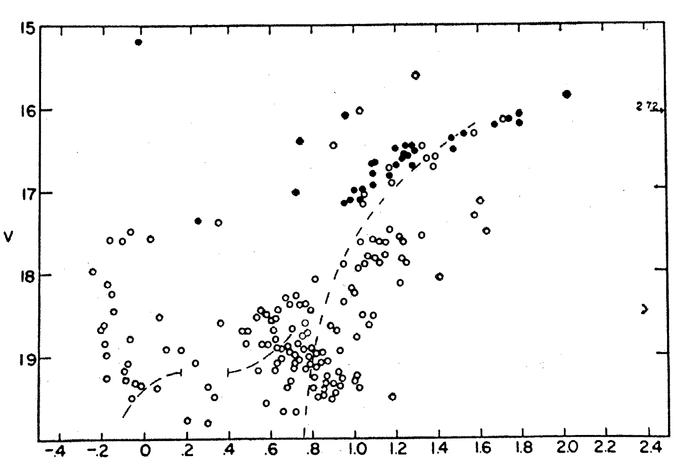
Figure 5 shows NGC 419, a rich spherical star cluster in the Cloud. Figure 6 shows the color-magnitude diagram of this cluster, with the schematic of a normal globular cluster in our own Galaxy (dashed lines) shown for comparison. Figure 7 shows the color-magnitude diagram of a much sparser cluster, NGC 361. The two clusters are very similar, and they have giant branches roughly like those of globular clusters in our own Galaxy but with some distinct differences.

Cluster NGC 458, a so-called "blue globular cluster," is shown in Fig. 8. Its color-magnitude diagram is shown in Fig. 9. Finally, the color-magnitude diagram for NGC 330, a large young cluster in the center of the bar, is shown in Fig. 10. Notice the characteristic difference between these clusters and clusters of comparable age in our own Galaxy. Both Cloud clusters show gaps between the main sequence and the evolved giants. Both show well-populated giant branches, filled in very close to the blue side of the Cepheid gap.

But now let us superpose the three characteristic color-magnitude diagrams NGC 419, NGC 458, and NGC 330, all on the same plot (Fig. 11). Notice the characteristic regions which each cluster fills in the color-magnitude diagram. Note the similarity between Fig. 11 and the color-magnitude diagram of a comparable number of stars in the field near NGC 419 (Fig. 12). Notice how it is possible to pick out the regions filled by stars from clusters of certain age. With slightly different ratios of old to young stars, the field color-magnitude diagram of each region investigated was similar to Fig. 11. In Fig. 13 all the color-magnitude diagrams from all over the Cloud are superposed. We get the same accurately defined regions, boundaries, and mass of concentration of stars.

We may conclude from all of these data that we now do know quite a bit about the stellar composition of the Small Magellanic Cloud. We have an excellent survey of the stellar content, and we are now ready to compare the data with what we know of stars in our own Galaxy. We will look for differences between the stars in the two systems and will list them under ten major headings, as follows:

1) *Differences in color-magnitude diagrams of clusters, SMC–Galaxy.* Cluster NGC 330–h and χ Perseus



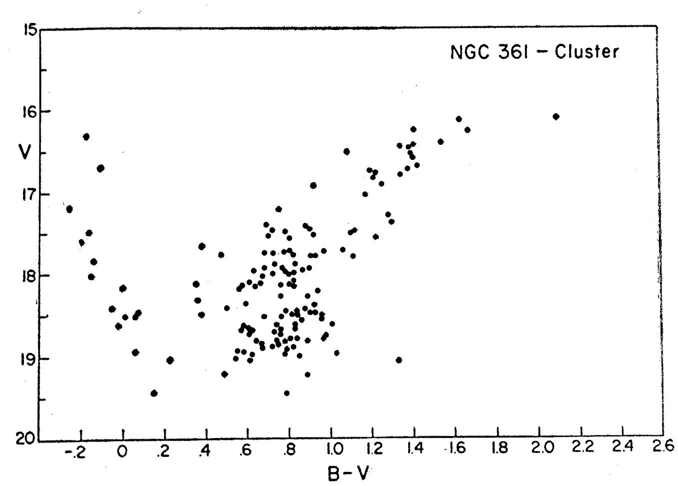


Fig. 6 (left). Color-magnitude diagram for the cluster (NGC 419) shown in Fig. 5. The curve for a globular cluster in our own Galaxy (M 3) is shown (dashed line) for comparison. Fig. 7 (right). Color-magnitude diagram for the Small Magellanic Cloud cluster NGC 361. Although the cluster appears geometrically much sparser than NGC 419, the two diagrams are essentially the same.

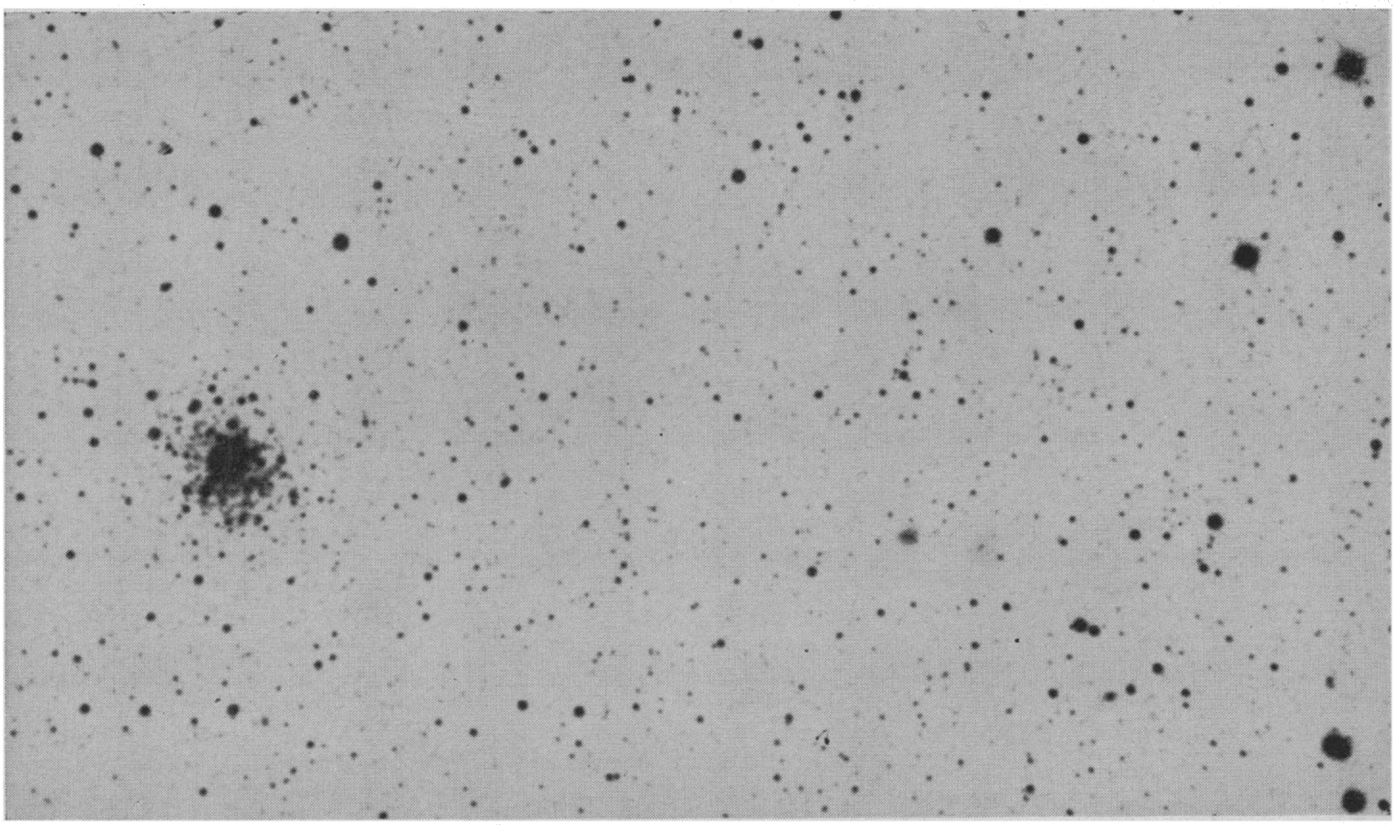


Fig. 8. Cluster NGC 458, a Small Magellanic Cloud cluster containing many bright blue and white stars.

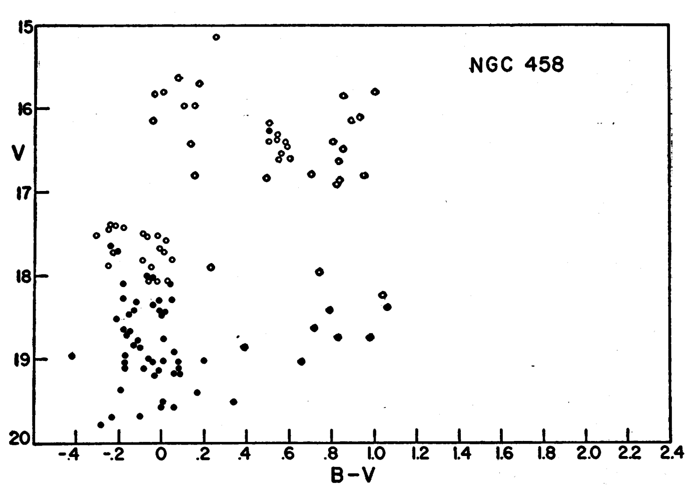
(gap in sequence, place, and number of giants).

2) *Differences in color-magnitude diagrams of clusters, SMC–Galaxy.* Cluster NGC 458–Pleiades or NGC 6664 (gap in sequence, place, and number of giants).

3) *Differences in color-magnitude diagrams of clusters, SMC–Galaxy.* Cluster NGC 419 and NGC 361–globular clusters M3, M5, M2, and so on (shape of giant branch, and breaks).

4) *Distribution of stars in field.* In the field color-magnitude diagram, B-V for the Small Magellanic Cloud stars ranges between 0.4 and 1.0 at absolute visual magnitudes (M_v) around 0 and brighter. In the Galaxy, there are few stars of these magnitudes and colors (*17*). Another difference is shown in Fig. 12. In that star diagram for the Cloud there is a well-defined limit in the red which is well above the plate limit (horizontal dashed line). The red limit in the neighborhood of the sun in our own Galaxy is also well determined (see Fig. 12, vertical dashed line and solid-line continuation, for red limit and NGC 188), but it is very different from the limit for the Cloud.

5) *Cepheid period-amplitude diagram.* There is unquestionably a physical difference represented by the fact that Cepheids in the Cloud with periods of less than 10 days have much larger amplitudes than Cepheids of the same period in the neighborhood of the sun (*18*). Figure 14 shows this, where the lines have been drawn as upper envelope lines to the amplitude distributions.



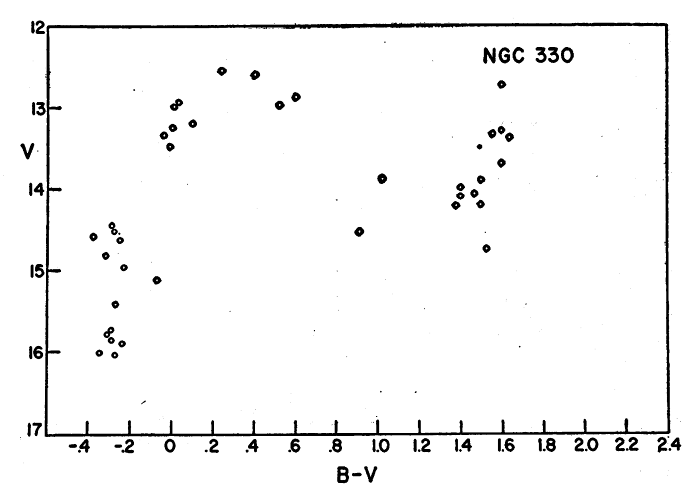
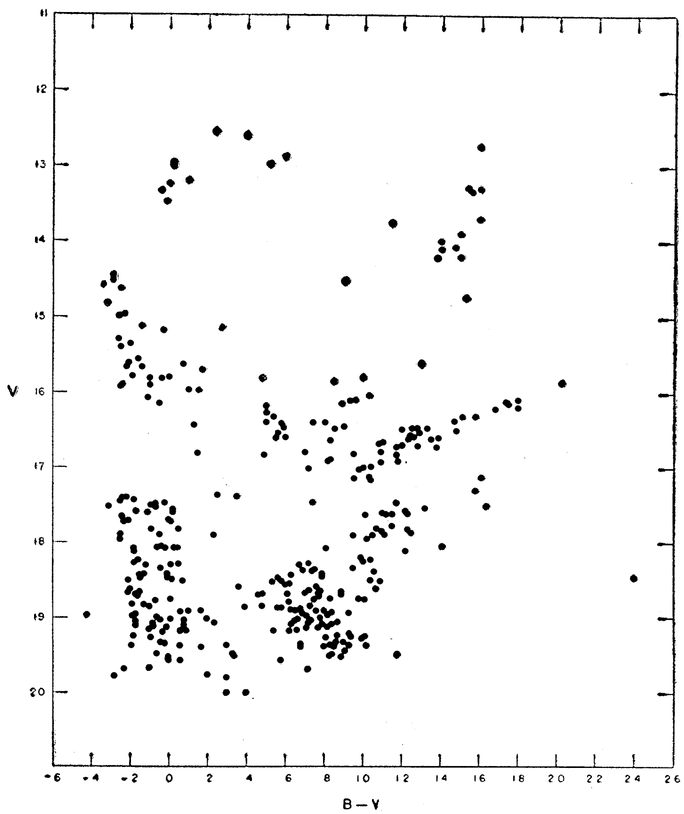


Fig. 9 (left). Color-magnitude diagram for cluster NGC 458. The latter is a young rich cluster containing many bright stars. It is located in the bar of the Small Magellanic Cloud.

Fig. 10 (right). Color-magnitude diagram for cluster NGC 330.



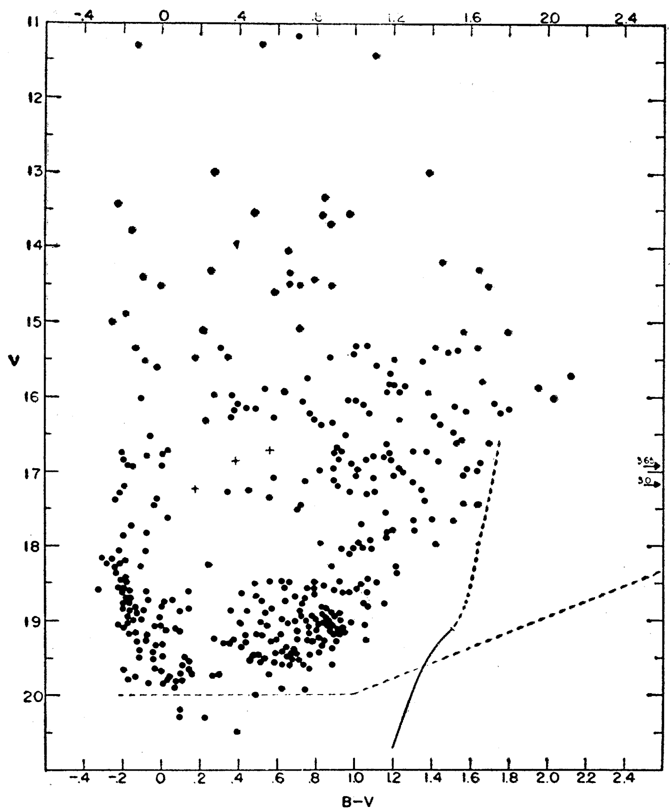
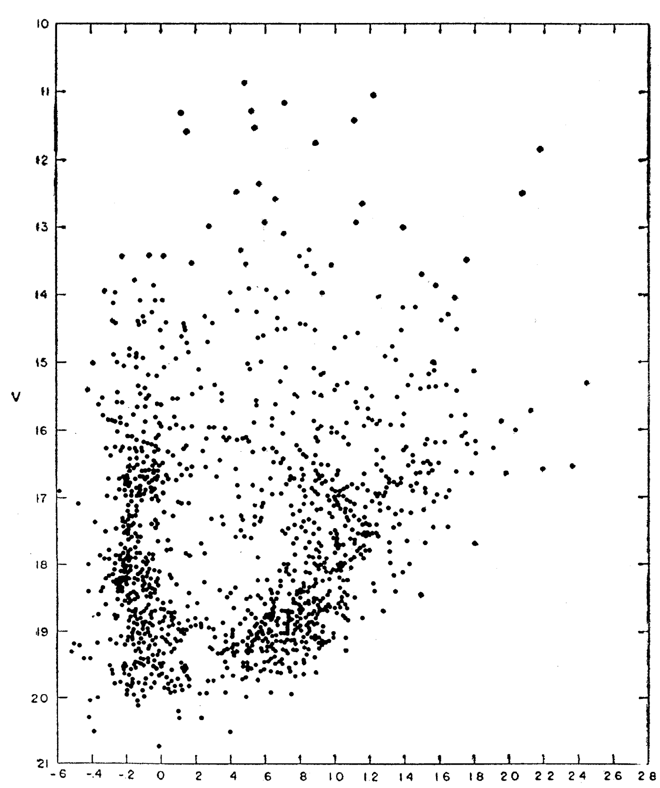


Fig. 11 (left). Color-magnitude diagrams of clusters NGC 419, 458, and 330, superposed. Fig. 12 (right). Color-magnitude diagram for stars in the vicinity of cluster NGC 419. Note the similarity of Figs. 11 and 12. (Vertical dashed line) The limit of nonvariable stars in our own Galaxy [after Wilson (*25*)]; (solid continuation of vertical dashed line) the oldest galactic cluster in our own Galaxy, NGC 188 (Sandage); (horizontal dashed line) the plate limit, which shows that the difference between the red limit for Small Magellanic Cloud and galactic stars is observationally significant.



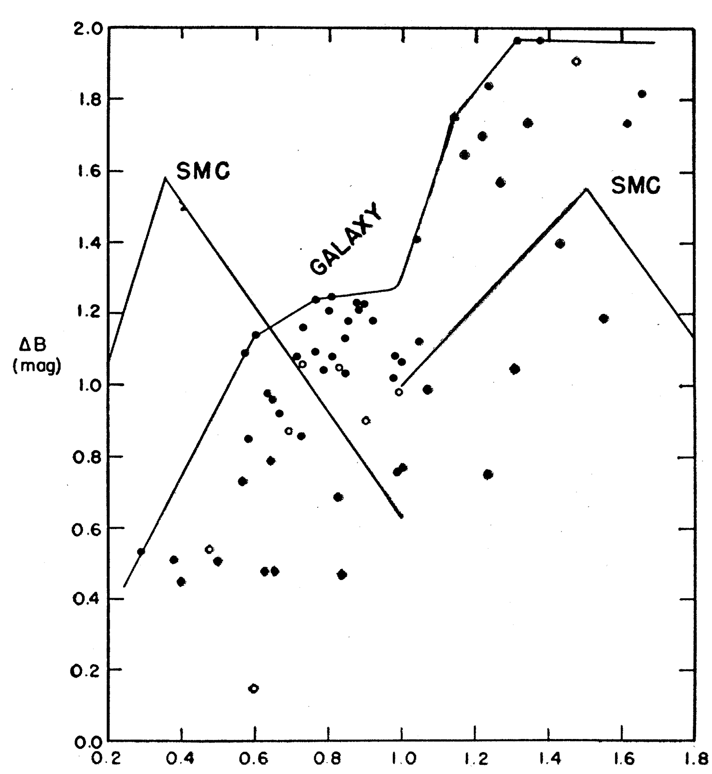


Fig. 13 (left). Color-magnitude diagrams for all the regions investigated in the Small Magellanic Cloud, superposed. Note the close similarity to Figs. 11 and 12. Fig. 14 (right). Period-amplitude relation for galactic Cepheids and Small Magellanic Cloud Cepheids. (Solid lines) Upper-envelope lines; (solid circles) galactic Cepheids; (open circles) Small Magellanic Cloud Cepheids.

6) *Cepheid period-frequency diagram.* There is some evolutionary mapping function which presumably, as stars evolve, transforms main-sequence stars into Cepheids. What the initial M_V of a star which becomes a Cepheid of a certain period is, and how long the star remains a Cepheid, depends on this mapping function—that is, on the nature of the evolutionary tracks and on how fast a star moves along them. We observe a certain frequency of periods in the neighborhood of the sun. In the Cloud, as I shall show, the luminosity function is such that there are more bright stars than there are in the vicinity of the sun. Therefore, if the Cepheid mapping function were the same for the two regions, we would expect *more* long-period Cepheids in the Cloud than in the neighborhood of the sun. The observations are quite the reverse. We conclude that there is a strong intrinsic physical difference between the evolutionary mapping function in the two systems. We reached a similar conclusion earlier about the color-magnitude diagrams of NGC 458 and NGC 330 (*19*). The fact that the period-frequency function of the Large Magellanic Cloud is intermediate between that of the Small Magellanic Cloud and that of stars in the neighborhood of the sun indicates that the evolutionary properties of the Large Magellanic Cloud are also intermediate. This is borne out by a preliminary color-magnitude diagram of the star cluster NGC 1866 in the Large Magellanic Cloud. This cluster is, in my opinion, of the same age as the Small Magellanic Cloud cluster, NGC 458, but its giants are placed more to the red, more like clusters of this age in the Galaxy.

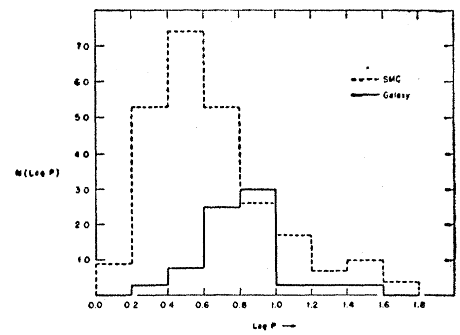
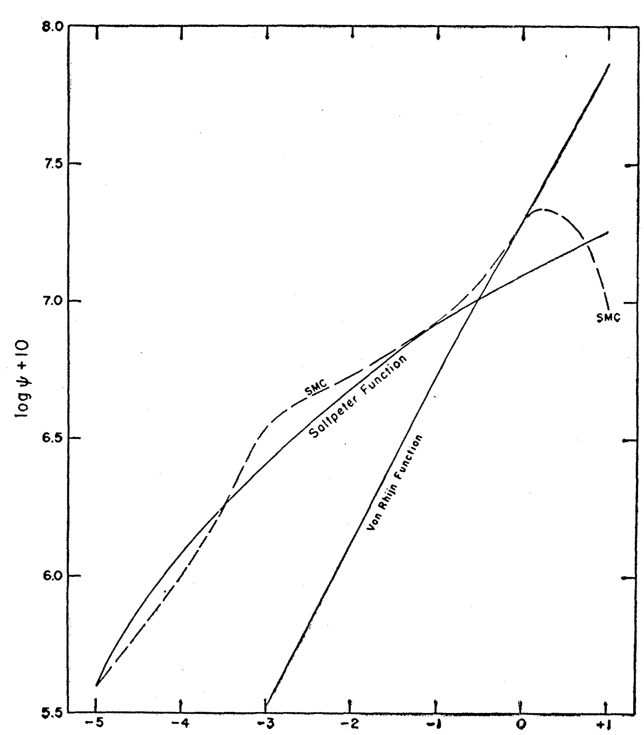


Fig. 15. Period-frequency diagram for Small Magellanic Cloud Cepheids (dashed line) and Cepheids in the vicinity of the sun (solid line).

The Cepheid period-frequency function (Fig. 15) seems to be a sensitive function of the evolutionary properties of the stellar system. The luminosity function, or the relative numbers of bright and faint stars in the Cepheid region, can easily be divided out in most cases. This gives us a powerful empirical tool with which to select and reject galaxies with identical physical properties.

7) *Star clusters.* In our own Galaxy and in Andromeda all the bright, rich, spherical star clusters have red integrated colors (*20*) and contain old stars. As a matter of course we call such objects globular clusters. In the Small and Large Magellanic Clouds, however, we have geometrically globular star clusters which contain young stars. This gave rise to the semantically confusing term *blue globular cluster.* How can we explain such a difference between the galaxies and the Magellanic Clouds? It seems clear that in small, high-density, turbulent regions of spiral arms, primarily where star formation is now going on in our Galaxy, young, very rich, spherical objects such as NGC 1866 and NGC 458 are not usually formed or maintained. In more quiescent, low-density regions such as exist in the Magellanic Clouds, clusters such as were formed in our own halo can form. The major difference between the Clouds and the Galaxy is that these clusters are forming *now* in the Small Magellanic Cloud.

8) *Lack of dust.* Contrary to findings for our own or other spiral galaxies, there is no conspicuous dust and there are no conspicuous absorption lanes and patches in the Small Magellanic Cloud. This finding is supported by the low mean absorption found for the Cepheids around NGC 371. The average reddening for those Cepheids was only 0.06 magnitude (*21*). In ordinary spirals, reddenings of 0.5



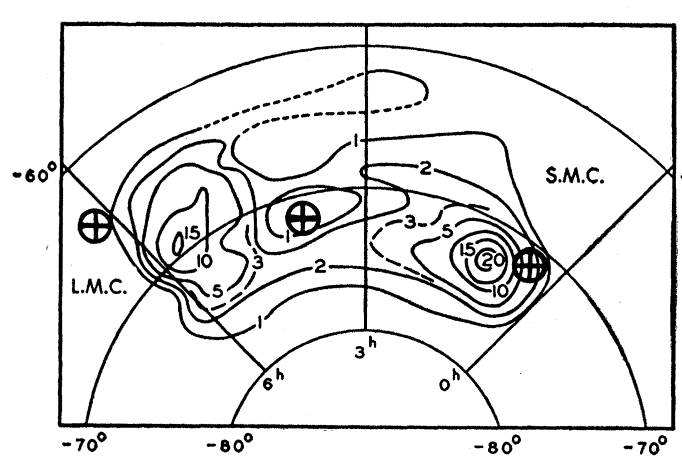


Fig. 16 (left). Luminosity function for Small Magellanic Cloud stars (for all areas investigated) compared to luminosity function for the neighborhood of the sun (Van Rhijn) and initial luminosity function for our own Galaxy (Saltpeter function). The latter two curves include an arbitrary normalization. Fig. 17 (above). Radio observations of Large and Small Magellanic Clouds, showing the common envelope of hydrogen gas [Courtesy Radio Physics Laboratory, Sydney, Australia]. The three globular clusters (NGC 121, 1466, and 2257) known to contain numbers of RR Lyrae stars are plotted as circled crosses.

magnitude are usual in regions where there is dust. Again, the absence of dust points to a low metal content for the Small Magellanic Cloud.

9) *Ratio of gas to stars.* Elsasser (*22*), working with his own data for star counts in the Small Magellanic Cloud and with Kerr and Hindman's data (*23*) for hydrogen masses in the Cloud and in the Galaxy, computes that the mass ratio of hydrogen to stars varies from about 15 percent at the center of the Cloud to 52 percent at the edge. In our own Galaxy the ratio is only 6 percent at the distance of the sun and decreases toward the center. Because so much less of the gas of the Cloud has turned into stars, Elsasser concludes "that the state of evolution of the SMC is far behind the evolution of the galaxy."

10) *Luminosity function.* Elsasser (*22*) found that the luminosity function in the Cloud differed from the luminosity function in the neighborhood of the sun in the sense that the Cloud had a larger proportion of young stars. He found that the proportion of young stars increased toward the center. It is difficult to tell to exactly what region in the Cloud his luminosity function refers, but I myself have done extensive work on the luminosity functions in the regions described in the beginning of this section. The luminosity functions for all these regions agreed very exactly. They have been superposed and are shown in Fig. 16 as curve *SMC*. The Van Rhijn function for the neighborhood of the sun, with an arbitrary normalization, is shown for comparison. Actually, if the Van Rhijn function were normalized with respect to the total number of stars, the curve would fall much further below the *SMC* luminosity-function curve than it does in the figure. There are simply very many more young, bright stars in the Cloud than in the neighborhood of the sun. In the same figure the Saltpeter (*24*) initial luminosity function is shown to coincide quite closely with the *SMC* luminosity function. If this agreement were significant and implied that what we are seeing now is the initial luminosity function in the Small Magellanic Cloud, this would in turn imply that the majority of stars which we see in in the Cloud are in the process of being formed.

It is undeniable that the Small Magellanic Cloud consists predominantly of bright, and therefore young, stars. This can be seen by looking at a short photographic exposure of the Andromeda nebula. All one sees is the fuzzy red halo of old stars which comprise the bulk of our intermediate-type spiral nebula. In contrast, a short exposure of the Cloud reveals only the region of bright blue stars. A very long exposure is needed to bring out the small contribution of faint old stars, a red background which extends for many degrees around the Cloud.

But it is difficult to accept the view that there is a sudden burst of star formation at this particular time in the Small Magellanic Cloud. Instead, it may be wise to consider the possibility that the coincidence of the *SMC* and Saltpeter luminosity functions is accidental. Remember that the Saltpeter initial luminosity function was obtained by transforming inversely the Van Rhijn function with the evolutionary tracks which apply to stars in our own Galaxy. We have seen that the sequences in the color-magnitude diagram, and hence the evolutionary tracks, are different for stars in the Cloud. It may simply be that the evolution of the initial main sequence is slower and that the evolutionary depletion of the initial main sequence is less in the Cloud. Then the observed main-sequence luminosity function in the Cloud would contain more bright stars than that in the Galaxy. A theory of slow initial evolution of bright stars is supported by the large number of evolved giants, relative to main-sequence stars, which are observed in Small Magellanic Cloud clusters. It is conceivable that this mechanism, with a more or less steady rate of star formation, would give the observed excess of young stars in the Cloud luminosity function.

Of course the question of whether star formation is now proceeding faster in the Small Magellanic Cloud than it has in the past is an important one. Consider the Magellanic Cloud system as outlined by the beautiful new radio observations of the Radio Physics Laboratory at Sydney, Australia. As shown in Fig. 17, not only has a bridge of hydrogen gas been discovered, connecting the two Clouds, but between the sharp optical and radio edges on the preceding side of the Small Magellanic Cloud and the following side of the Large Magellanic Cloud there is a wash of hydrogen gas. The only globular clusters in this region which are known to contain numerous RR Lyrae stars (Cepheids with periods from 5 to 18 hours) are shown by circled crosses in Fig. 17. It is clear that the Clouds form a single extended system and that they are condensations within a common envelope.

By analogy with our own Galaxy we assume that RR Lyrae stars in the Clouds are representative of the oldest stars. The three globular clusters containing RR Lyrae stars show the same distribution as the hydrogen gas. It seems, therefore, that stars in the beginning started to form throughout the extended region of the Clouds. Subsequently there must have been some density concentration to the present nuclei, which we call the Large and Small Magellanic Clouds (the ratio of old to young stars increases away from the center). If star formation is proceeding at a roughly steady rate, then it must be that gas is being fed into the two nuclei, and we can expect the gas to be turned gradually into an envelope of old red stars. If star formation is proceeding much faster now than in the past, however, the whole system will become much brighter before fading into the old, red-star stage. It is also fascinating to conjecture as to whether the Large and Small Magellanic Clouds will become more distinct entities as time passes or whether they will merge again into a single system.

There are a number of exciting observations which can be made now or in the near future to determine which of these various possibilities are the most likely. Some of these are:

1) Observations in young Magellanic Cloud clusters to derive the initial luminosity function.

2) Observations to apparent magnitudes of about $V = 23$ (either through full use of such present techniques as simultaneous star-sky photometry or through use of the more powerful telescopes projected for the Southern Hemisphere). Observations to these faint apparent magnitudes will give a direct observation of the ages of the stars involved in various parts of the Clouds.

3) Three color photoelectric (U, B, V) measures of red giants with color indices around B-V = 1.0. If the expected metal deficiency is found in these giants and if it gives rise to an ultraviolet excess, as in our own Galaxy, the variation of chemical composition can be investigated over the whole system.

Regardless of the future form of the

Magellanic Clouds, all the data presented here combine to show that the rate of processing interstellar material through stars is less for the small Magellanic Cloud than for the Galaxy. This fact is in agreement with the low metal content inferred from the other available data. Most encouraging of all, however, is the fact that, so far, results on the Magellanic Clouds confirm the picture presented in the beginning of this article for our own Galaxy. We must expect in the future, it seems, that wherever we encounter low densities we will encounter stars of low metal content. High-density regions produce stars of high metal content, and therefore the stellar content can be quite different from galaxy, and can even be different from region to region within one extragalactic system.

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Poliomyelitis Immunization

Mass use of oral vaccine in the United States might prevent definitive evaluation of either vaccine.

David Bodian

The apparent unfolding of two unprecedented phenomena in the field of poliomyelitis this summer in the United States highlights the problem of policy making with respect to the use of killed poliovirus vaccine and live oral attenuated poliovirus vaccine. Unfortunately, widespread misconceptions concerning the potentialities of both vaccines, published in scientific journals and in the lay press, have made policy making by medical and public health agencies difficult, if not dangerous. An example is the Summary Statement of the Council on Drugs, American Medical Association, concerning the present status of poliomyelitis vaccination in the United States—a statement recently approved by the House of Delegates, AMA, which has received wide publicity (*1*). This document contains assumptions concerning the effects of killed and oral attenuated poliovirus vaccines which in some instances are unproved, and in others have been proved to be erroneous. In addition, the document does not present an adequate picture of the present status of poliomyelitis immunization in this country, at least as far as our major source of information is concerned, the Surveillance Reports of the U.S. Public Health Service.

The first of the phenomena in question is the new order of magnitude of reduction of incidence of paralytic poliomyelitis in the United States. At the date of writing, the absence of the early summer seasonal rise of cases constitutes a phenomenon unknown in this country since epidemic poliomyelitis began to take its heavy toll in 1916. The second phenomenon is the indication this summer that the dissemination of poliovirus types I and II has been radically reduced in the country as a whole. The only reasonable explanation for these phenomena is the ecological effect of the killed poliovirus vaccine program, instituted only 6 years ago.

Proposed Oral Vaccine Program

By far the most serious step taken by the AMA Council on Drugs has been to propose that a mass vaccination program, involving previously vaccinated as well as unvaccinated individuals, is needed in this country in order to eliminate poliomyelitis as a significant public health problem. Whether poliomyelitis is now a significant health problem in the United States is debatable in itself, but the Council also appears to have overlooked the fact that there is not available enough oral attenuated poliovaccine of all three types to back up this proposal of the AMA at this time, and that the proposal thus contains the seed of futility and embarrassment. In a field where public disappointment has been more frequent than necessary, a premature proposal is worse than none.

Moreover, there are many with long experience in this field who do not feel that mass immunization programs with oral poliovirus vaccines are desirable in this country at this time, even if such vaccines were available. In view of the fact that paralytic poliomyelitis has been eliminated as a major public health problem with the use of inactivated poliomyelitis vaccine, and that residual case incidences are in the range of what may be an irreducible minimum, it would appear sensible to await definitive results of programs with oral attenuated vaccines in other countries rather than to superimpose a new program upon a currently successful one. Proposals for country-wide mass vaccination programs appear to ignore the fact that we do not as yet have defini-

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