are exactly the same ones as for galactic star clusters of early type. The scattering is larger for the HII regions because the accuracy of the distances is lower than for clusters.

The three spiral arms shown by the young star clusters and by the HII regions do not coincide with the spiral arms shown by the HI clouds.

References

BECKER, W. (1961).—*Zs. f. Ap.* **51**: 151–62.

HOAG, A. A., JOHNSON, H. L., IRIARTE, B., MITCHELL, R. I., HALLAM, K. L., and SHARPLESS, S. (1961).—*Publ. U.S. Naval Obs.* **17**: 345–542.

Discussion

Bok: The distances for galactic clusters in the range $260° < l^{II} < 270°$ and $300° < l^{II} < 325°$ can be checked with the aid of radial velocities for $m = 9$ to 12. The gaps will be filled in shortly. Combining results from luminosity classifications and Hβ absolute magnitudes will provide anchor points in distance for the interpretation of radial velocities and the reflex of galactic rotation.

Perek: Ruprecht has determined distances of a number of faint early-type clusters. (Slide shown.) The spiral structure derived by Professor Becker was confirmed.

Kerr: The diagram comparing cluster and hydrogen spiral arms is hard to understand, as the published hydrogen diagrams show arms that are much more circular in form.

Westerhout: Dr. Becker used an artist's impression to compare the cluster distribution with that of neutral hydrogen whereas an actual contour diagram would have been the correct one to use. Also one should realize that in the neighbourhood of the Sun the method used in the 21-cm line work for determining distance from radial velocity is extremely uncertain; small deviations from circular motion give very large deviations in distance.

Regarding Professor Bok's remark about the work with the nebular spectrograph, one should bear in mind that at those places where the velocity model does not have much influence his combination of photometric and radial velocity observations will not be of much use in giving anchor points for the neutral hydrogen distribution.

Arp: In Professor Becker's final slide he showed a disagreement between the hydrogen arms and the galactic cluster arms in the anticentre region. Regardless of the distance of the HI material at that longitude it was shown at a longitude where there is a break in distribution of clusters. Would one of the radio astronomers present state whether the HI material is indeed observed primarily at this longitude or whether the discrepancy does not exist as was implied by several of the foregoing remarks?

Kerr: This question can be discussed in more detail tomorrow.

4. STUDIES OF NGC 6067 AND IC 2944

A. D. THACKERAY
Radcliffe Observatory

NGC 6067 is a very rich cluster free of nebulosity in the Norma Cloud, whose colour-magnitude array has been published by Thackeray, Wesselink, and Harding (1962). The choice of stars for measurement was highly restricted to a square approximately $10' \times 10'$ of arc near the centre, so that above $B = 13 \cdot 0$ only 10% are expected to be field stars, and between $B = 15 \cdot 0$ and $16 \cdot 0$ some 20–30%.

The radial velocity is -43 km/sec and this forms a useful criterion for membership among the stars bright enough for spectroscopy; spectra of 30 stars are available.

https://doi.org/10.1017/S0074180900052153 Published online by Cambridge University Press

The colour-magnitude array shows the usual blue sequence deviating upwards in a way which suggests a conventional age similar to that of the Pleiades, but NGC 6067 is 15–20 times richer. The cluster has red supergiants brighter than those in the otherwise similar cluster M11. A few supergiants straddle across a very well-defined Hertzsprung gap, including the brighest central star which is classified G0 Ib. There can be no doubt about the membership of these stars. NGC 6067 resembles in some respects Hodge's "young populous clusters" in the Clouds (e.g. NGC 1866).

The great spread in colours near the limit of the survey must be due in part to the presence of field stars. If, despite the crowded field, one regards this branch as containing an appreciable number of cluster members in a state of Kelvin contraction, then the "Kelvin point" occurs at $(B-V)_0=+0\cdot3$, suggesting a gravitational contraction time of about 30 million years.

Finally, there is the curious vertical branch at $B-V=+1\cdot1$; some of these stars probably belong to the field, but one may ask whether some correspond to a very much older generation of stars. This observation seems to support Herbig's (1962) proposal of a spread in ages within one cluster. It is planned to extend work on NGC 6067 and also to study a neighbouring field in the Norma Cloud.

IC 2944 (originally a nebula discovered near λ Cen) has come to be adopted as the designation of a cluster near the centre of a large HII region which embraces both IC 2944 and IC 2948. As a cluster it differs in two important respects from NGC 6067; it is immersed in a combined field of bright nebulosity and dark matter, and it is dominated by a few bright stars and definition of the faint cluster members in a rich field is difficult. The two brightest stars in the cluster (HD 101205, 101131) are both early-type O stars (despite HD classification as B2) and Radcliffe spectra have revealed 10 stars of type O9·5 and earlier, strongly concentrated in the cluster, as the chief source of excitation of the main HII region. HD 99897 excites another HII region nearby. Figure 1 shows these O stars as large circles within the HII regions. Dots show the distribution of the other known B0 to B1·5 stars in the region. This may represent the strongest known concentration of O stars in the sky, exceeding even the well-known "elephant-trunk" nebula and cluster NGC 6611 which IC 2944 resembles in several respects. Both are undoubtedly very young clusters, younger than NGC 6067.

The cross indicates HD 101712 discovered spectroscopically as a peculiar symbiotic star in the course of this Radcliffe work, which is quite possibly within the HII region. It has a supergiant M spectrum, with remarkably strong [FeII] emission, while beyond 3900 Å an early-type spectrum appears. The luminosity appears to be similar to that of the M supergiants near h and χ Persei. Antares forms an obvious parallel, but HD 101712 is not known as an optical double.

In the immediate neighbourhood of the cluster there is a remarkable family of small and highly irregular globules with bright rims — perhaps the most remarkable group of these curious objects known (Thackeray 1950). They show a tendency to be lengthened and distributed along an easterly, slightly northerly, direction. The smallest of them measured has an estimated linear diameter of about 2000 astronomical units. The bright nebula itself has a streaky structure in this region roughly perpendicular to the direction of the globules. There is evidence that the globules are actually within the nebula and not merely superposed.

Spectral classification of 29 stars in the central regions combined with Wesselink's photometry yield a mean reddening in $B-V$ of $+0\cdot33$, with a total range from $0\cdot24$ to $0\cdot47$. Both reddening and variation in reddening are small compared with other similar clusters (e.g. NGC 6611). Despite the presence of globules we are apparently free from serious absorption problems. Correcting V magnitudes by $3\cdot0\ E_{B-V}$ (and by a further $0^m_\cdot5$ for stars with variable velocity) we plot V_0 against spectral type for the HR diagram shown in Figure 2. Blaauw's zero-age main sequence is shown fitted to the observations from O8 to B3. This yields a corrected distance modulus $11\cdot0$ and a true distance of $1\cdot6$ kpc. This is probably to be regarded as a minimum distance. A straight mean of distances computed from MK luminosity classes gives the larger distance of $2\cdot2$ kpc.

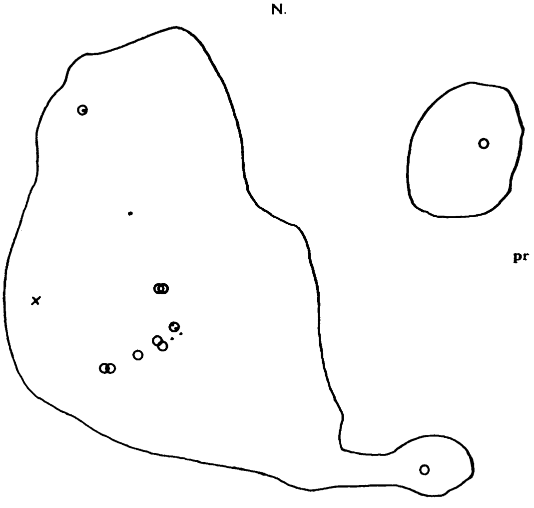

Fig. 1.

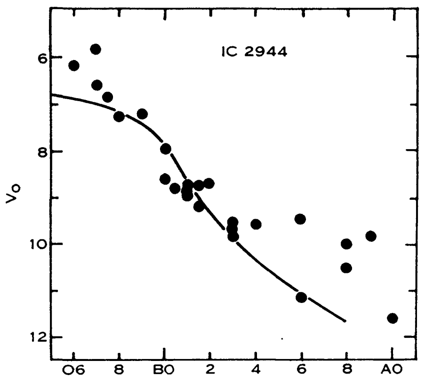

Fig. 2

Fig. 1.—Distribution of early-type stars with the HII region IC 2944. Open circles are stars of type O9·5 and earlier, points are stars of type B0 to B1·5.

Fig. 2.—HR diagram of bright stars in the cluster IC 2944. Blaauw's zero-age main sequence is fitted at O8 to B3.

In Figure 2 a small deviation from the zero-age main sequence appears to begin at O8, thus indicating a very young cluster indeed. According to current estimates the age should be less than 10^7 years. Here it should be noted that, since $B-V$ colours change very little from B0 to O5, any evolutionary deviation can be determined in this range far more accurately from a true HR diagram (when spectral classifications are available) than from a colour-magnitude array.

Turning to the reddest stars in Figure 2 we note several stars lying a full magnitude or more above the main sequence. These look like the stars studied by Walker (1961) in very young clusters. It is easy enough to dismiss these stars as foreground and in fact statistics suggest that in the area investigated some three or four foreground stars could be found. However, there are two stars above the main sequence whose presence either in nebulosity or proximity to a globule definitely suggest membership; and it is after all just such an environment where one might most expect to witness the birth of a star. If, following Walker, these stars are taken as defining a group of stars contracting on to the main sequence at type B3, their age should be only 6×10^5 years, according to the Henyey formula, i.e. *less* than the age of the brightest stars. It is not unreasonable that in a young cluster like this one may find stars with ages ranging from order 10^7 years to less than 10^6 years. The very presence of the globules suggests that star formation is still active, despite the presence of several O stars. Are these O stars gradually halting star formation and in the process dissipating mass from the surface of the globules, and thus changing the "initial luminosity function" of the last generation of stars?

The problem of a spread in ages in IC 2944 can best be studied by pushing the observations to fainter limits and this will be done, despite the photometric difficulties associated with the bright nebulosity.

In the analogous but more distant cluster, NGC 6611, Walker (1961) found many very faint variables at 20 to 21 magnitude. Nine years ago one faint variable of about visual magnitude 16 was found at the very edge of the largest globule in IC 2944 (Thackeray 1955). Another variable has been found at about the same magnitude and the search is being continued. The absolute magnitudes are roughly equal to that of the Sun, i.e. considerably brighter than Walker's variables in NGC 6611. It is also of interest that close to the centre of IC 2944 there are two β Lyr eclipsing binaries LW Cen and BH Cen. Further, at least 25% of the members studied spectroscopically have variable radial velocity, and we have already mentioned the peculiar symbiotic star HD 101712. It is an unfortunate fact that the formation of binary stars, so widespread a phenomenon, is to such a large extent ignored in the present-day theory of stellar evolution.

References

HERBIG, G. H. (1962).—*Ap. J.* **135**: 736–47.

THACKERAY, A. D. (1950).—*M.N.* **110**: 524–30.

THACKERAY, A. D. (1955).—"Les particules solides dans les astres." [Liège 1954.] *Mém. Soc. Roy. Sci. Liège* (4) **15**: 437–40.

THACKERAY, A. D., WESSELINK, A. J., and HARDING, G. A. (1962).—*M.N.* **124**: 445–58.

WALKER, M. F. (1961).—*Ap. J.* **133**: 438–56.

Discussion

Aller: The age of 10^7 yr was derived from the turn-off point of the O stars, whilst the age of 10^6 yr corresponds to the contraction age of the B5 stars which are interpreted as approaching or just reaching the main sequence. Would the prior formation of the O stars have rendered the subsequent contraction of the B5 stars unlikely or at least more difficult to understand?

Thackeray: My rough estimate was 10^7 yr from the turn-off point, but this is most uncertain owing to the application of a bolometric correction to O8 stars. Also the whole time scale is a bit uncertain.

With regard to the discrepancy between the two ages, perhaps I could ask Professor Oort how long it would take an O star to dissipate a globule?

Eggen: The surprising thing seems to be that there is only 3^m between the top of the main sequence and the contraction stage.

Hogg: Does the star suspected of being in the stage of contraction exhibit emission lines in its spectrum?

Thackeray: None have been detected.

Oort: In answer to the question by Dr. Thackeray, one could say that the disruption of a large cloud complex by O-type stars could easily take longer than a million years. With expansion velocities of 10 km/sec the gas would move a distance of the order of 10 pc in a million years. But if the mass of gas in the association is sufficiently large the expansional velocities might become very small before the density boundary is reached, so that a spread of star formation over a period of, say, 10^7 yr appears easily possible.

5. A DISCUSSION OF NGC 4755 AND SOME OTHER YOUNG CLUSTERS IN THE GALAXY AND THE MAGELLANIC CLOUDS

M. W. Feast
Radcliffe Observatory

A study of the cluster NGC 4755 (κ Crucis) was begun as a result of the several interesting problems raised by an earlier study of NGC 3293 (Feast 1958). Determinations of radial velocity and spectral type have been made in NGC 4755 from 102 spectra of 35 stars. Full details are published elsewhere (Feast 1963). These results were combined with the three-colour photometry of Arp and van Sant (1958). The cluster has a nearly-vertical evolved main sequence at spectral type B1. The spectral types and B, V measures for giants and dwarfs yield a mean reddening of $+0^{\mathrm{m}}.48$ and a distance of 2·36 kpc. These values are considerably greater than those deduced by Arp and van Sant but they have been confirmed from an analysis of the three-colour measurements alone.

NGC 4755 contains an M-type supergiant, four B-type supergiants, and possibly also an A-type supergiant. This is a valuable addition to the number of clusters known to contain such stars and thus to be of known absolute magnitude and intrinsic colour. The available data for B-type supergiants in clusters have been examined. In the mean the absolute magnitudes agree well with Blaauw's (1963) calibration, but the intrinsic colours are about $0^{\mathrm{m}}.04$ bluer than those given by Johnson (1958). Two clusters in Cygnus give anomalous results, probably due to an abnormal reddening law in this direction.

The HR diagrams of NGC 4755, NGC 3293, and h and χ Per are very similar and these three clusters must be of nearly the same age. A composite HR diagram for the three clusters together contains a sufficient density of points for certain of the finer details to be seen. There is a conspicuous gap between the top of the evolved main sequence and the supergiant branch. A gap in an analogous position was first discovered in the rich somewhat-older clusters NGC 458 and NGC 330 in the SMC by Arp (1959). At the time, this gap seemed to constitute an important difference between clusters in the Galaxy and those in the SMC. However, the present results make it quite clear, as had been suspected from the results on h and χ Per alone (Feast 1960), that the gap is also a feature of clusters in the Galaxy. Indeed, a recent theoretical investigation (Hayashi and Cameron 1962) predicts that such a gap should exist.

NGC 4755, NGC 3293, and h and χ Per contain M-type supergiants but no supergiants of intermediate type. On the other hand, the evidence from other clusters

https://doi.org/10.1017/S0074180900052153 Published online by Cambridge University Press