FORMATION OF POPULOUS CLUSTERS FROM METAL-POOR GAS IN THE MAGELLANIC CLOUDS

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We present the results of low dispersion spectrophotometry (resolution about 5 Å, using IDS at ESO 3.6 m and 1.5 m telescopes) of 80 red supergiants in the Magellanic Clouds: 31 SMC field stars, 26 LMC field stars and 23 suspected members of young populous clusters. From these spectra, spectrophotometric indices have been derived which simulate Strömgren photometry and measure the strengths of the Ca I (4226) line and of the G-band. The indices are calibrated with respect to red giants and provide a set of metallicity indicators.

The results can be summarized as follows: The metallicities of SMC field stars cover a wide range from $-0.5 > [M/H] > -2$. The metallicity of NGC 330 turns out to be -1.4 dex. This low metallicity is in striking contrast to the usual idea of the metal enrichment of the young SMC population (it has been confirmed in a high dispersion study by Spite et. al 1986). The average metallicity of the LMC field stars is higher than that of the SMC stars, occupying the range $0 > [M/H] > -1.2$ (the lower limit may be shifted to a higher value, if individual reddenings for these stars become available). The young clusters show metallicities substancially below those expected for a young population. This leads us to propose that low metallicity is a condition to form globular clusters in the sense that high metallicity promotes the dissolution of previously bound protoclusters. The following possible scenario emerges.

As progenitors, we consider two cold HI-clouds with equal masses and different metallicities. If the clouds are assumed to be in thermal and ionisation equilibrium with the warm intercloud gas, the difference in metallicity corresponds to a difference in pressure (e.g. Talbot 1974). This pressure difference results mainly from an enhanced density for the metal poor cloud (rather than from an increased temperature). Accordingly, the radius of the (spherically symmetric) metal rich cloud is larger than the radius of the metal poor cloud (which we call the initial radii). If we assume that each cloud forms, after its collapse, a stellar cluster of a certain radius, the metal rich cluster obviously would show a larger ratio of the initial to its final radius.

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This ratio is called the compression factor (Hills 1980) and it sets constraints for the stability of the system. Mass loss from the cluster (caused by radiation and stellar winds of luminous stars) also means a loss of binding energy and thus the total energy increases and eventually becomes larger than zero. Hills (1980) has derived a relation between the critical star formation efficiency, i.e. the minimum star formation efficiency to keep the system bound, and the compression factor: $\varepsilon_{min} = 1 - 1/f$ ($f = R_0/R_c$, R_0 and R_c are the initial radius and the radius, at which mass loss occurs, respectively; the mass loss is assumed to take a time short compared to the collapse time). Therefore, a metal poor (and thus dense) protocluster developes a larger stability against mass loss than a metal rich one, where only very little mass loss may be sufficient to dissolve it.

Furtheron, we argue that in the case of a dense and metal poor protocluster the mechanisms which increase the total energy of the system work less efficient than in a metal rich environment. Although the dependence of radiatively driven stellar winds on metal abundance is not yet exactly known, it is clear that the wind luminosity and therefore the energy input in the remaining protocluster gas drops with decreasing metallicity (e.g. Abott 1982). This is also true for the energy input by radiation so far as it is depictable by the concept of Stroemgren spheres. Then the mass which can be ionized by a luminous star is inversely proportional to the density of the ionized medium, so in a metal poor cloud (which is dense) the mass loss through expanding HII-regions is not so effective as in a metal-rich cloud. In reality, the associated stellar wind determines the density profile of the interstellar gas in the star's vicinity and the situation is modified by absorption of ionizing photons in the wind bubble. The principal effect, however, remains unchanged.

To summarize, protoclusters with low metal abundance are difficult to destroy by stellar winds and radiation and are thus expected to form populous, compact clusters like the young globular clusters in the Magellanic Clouds.

REFERENCES

Abbott, D. C. 1982 Astrophys. J. 259, 282.
Hills, J. G. 1980 Astrophys. J. 225, 986.
Spite, M., Cayrel, R., Francois, P., Richtler, T., and Spite, F. 1986 Astron. Astrophys., in press.