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NEAR-INFRARED SPECTRAL EVOLUTION OF BLUE LMC CLUSTERS: A COMPARISON WITH GALACTIC OPEN CLUSTERS

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RESUMEN. Se comparan las propiedades espectrales integradas de cúmulos jóvenes de la Nube Mayor de Magallanes agrupados en clases de edad con los diagramas HR compuestos de cúmulos abiertos Galácticos de Mermilliod (1981a, b). Hay una fuerte correspondencia entre estas sequencias evolutivas con fases en la evolución estelar, como estrellas supergigantes rojas, gigantes con progenitores de masa intermedia y estrellas Be.

ABSTRACT. We compare the spectral properties of young LMC clusters classified in age groups with the composite HR diagrams of Galactic open clusters from Mermilliod (1981a, b). There is a strong correspondence between these evolutionary sequences in terms of phases in the stellar evolution, such as red supergiants, giants with origin in intermediate mass progenitors and Be stars.

Key words: CLUSTERS-OPEN — GALAXIES-MAGELLANIC CLOUDS

I. INTRODUCTION

Recently Bica, Alloin and Santos Jr. (1989; hereafter BAS89) have analyzed near-infrared integrated spectra of 36 blue LMC clusters and found evidence of 8 spectral evolutionary stages in the age range 5 < t(Myr) < 500.

Blue Magellanic clusters with globular appearance are extremely populous in stars, and have small angular size which makes them ideal targets for integrated spectra. On the other hand, Galactic open clusters are suitable for detailed classification of individual stars and the relatively small stellar content, which would otherwise cause statistical fluctuations in the occurrence of some stellar types, can be overcome by grouping clusters of similar age. Mermilliod (1981a, b) created composite HR diagrams for Galactic open clusters and studied in detail their stellar content.

As the young clusters in the LMC have almost solar metallicity (Cohen, 1982), we compare in the present study the near-infrared spectral stages for the blue LMC clusters with Mermilliod's composite HR diagrams for open clusters.

II. OBSERVATIONS AND AGE CALIBRATION FOR THE BLUE LMC CLUSTERS

We have observed the blue Magellanic clusters in the ESO/La Silla 1.52-m telescope with a CCD detector. We employed a long slit oriented in the E-W direction and scanned the clusters in the N-S direction in the range 15" to 60" according to the cluster size, in order to have a good sampling of their stellar content. The spectral range was 5600 to 10000A with 14A of resolution. The cluster sample, complemented with observations from our previous studies (Bica and Alloin 1986, 1987), amounts to 36 among the brightest and largest young clusters in the LMC.

The age calibration, which is described in detail in BAS89, consists of relations between blue-violet colours and turn-off ages for the blue Magellanic clusters possessing HR diagrams. Blue-violet colours are available for the whole sample and are essentially free of contamination from cool stars, which on the other hand are important flux contributors in the near-infrared spectra. The cluster spectra were grouped according to similar age and spectral properties. Eight evolutionary stages were obtained between 5 < t(Myr) < 500 (Figure 1). The cluster members in each group and age range are listed in Table 1.

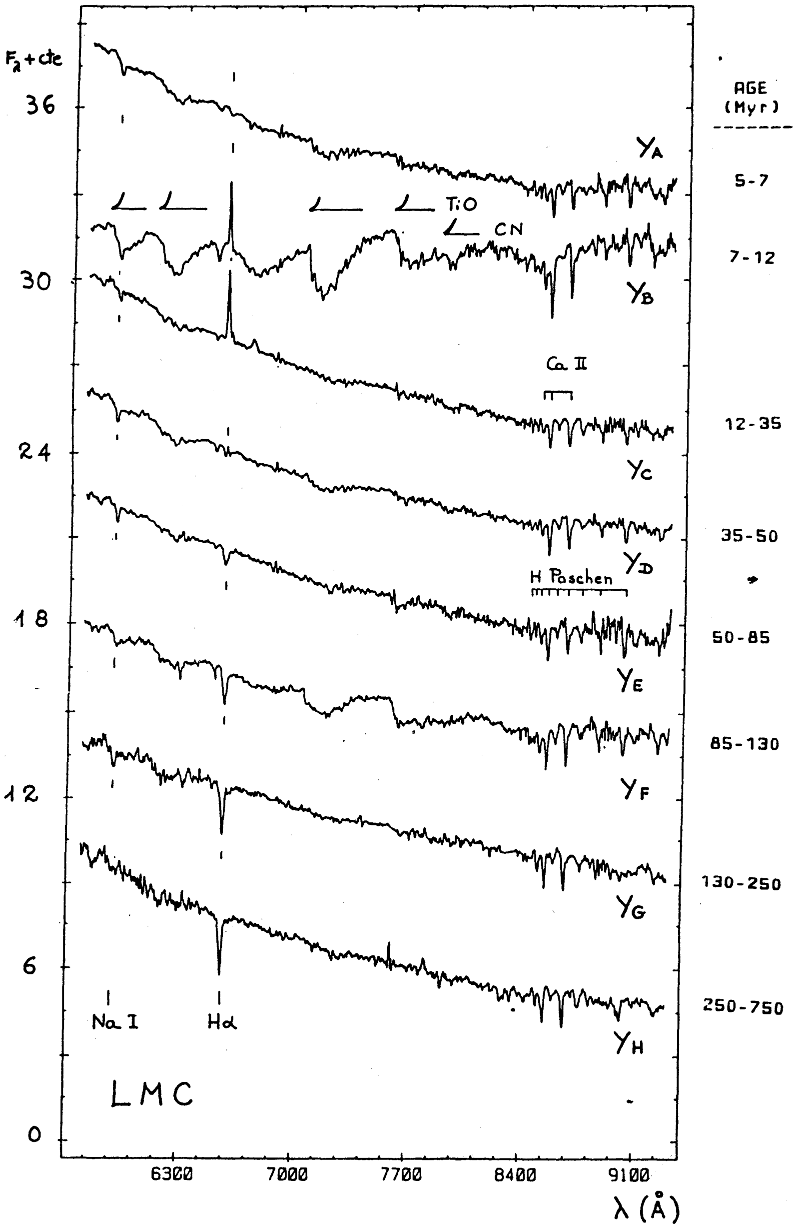

Figure 1.- Spectral evolutionary stages for LMC clusters between ages 5 < t(Myr) < 500. The star clusters which were grouped in each stage are indicated in Table 1.

TABLE 1. DATA ON LMC AND GALACTIC CLUSTER GROUPS

LMC GROUP	MEMBERS NGC	AGE (MYR)	MERMILLIOD GROUP	MAIN CLUSTER	TURN-OFF
YA	1767 2003 2006 SL538 2011	5-7	13	NGC2362	B0
YB	1805 1994 2002 2004 2098 2100	7-12	12	NGC884	B0.5
			11	NGC457	B1
			10	NGC3766	B2
YC	1711 1735 1818 1847 1850 1854	12-35	9	IC4665	B3
YD	1774 1782 1903 1951 2157 2164 2214	35-50	8	α PER	B5
YE	1755 2025 2041 2058 2065 2136	50-85	7	PLEIADES	B6
YF	1866 2031 2134	85-130	6	NGC2516	B8.5
YG	1831 1856	130-250	5	NGC2287	B8.5/B9
			4	NGC6475	B9
YH	1868	250-750	3	NGC3532	A0
			2	NGC2281	A1
			1	HYADES	A2

III. COMPARISON WITH GALACTIC OPEN CLUSTERS

We also show in Table 1 data on Mermilliod's (1981a) groups. We show in Figure 2 Mermilliod's average stellar sequences for his cluster groups in the Mv vs (B-V)o plane, where we indicate the correspondence with the 8 spectral stages for the LMC (Figure 1). We describe the common properties of the LMC and the Galactic cluster groups:

YA in the LMC corresponds to the NGC2362 group in the Galaxy, just after the HII region phase and before red supergiants appear. The absence of evolved stars implies that the CaII triplet arises from the lower main sequence. Be stars are essentially absent in these Galactic clusters in agreement with the integrated spectrum of the LMC group, for which H+ in emission hardly fulfils the absorption.

YB consists of clusters with a strong contribution of red supergiants of spectral type M, as denoted by strong TiO bands, the strong CaII triplet and the flat continuum (Figure 1). These luminous red stars occur only in Mermilliod's groups NGC884, NGC457 and NGC3766 (the clump of stars at (B-V) ≈ 1.8). These late type red supergiants appear only in a very limited age range around 10 Myr.Also from the stellar evolution theory this is a natural result, when the integrated light evolution of a star cluster is computed with a fine age step using an evolutionary code (Arimoto and Bica, 1989). We conclude that there is no doubt about a red supergiant phase, producing a "red flare" in the spectral evolution of a star cluster. These stars are certainly the result of the evolution of those around 15 Mo or at most 25 Mo depending on the mass loss rate. It is interesting that stars with M > 40 Mo do not reach during their evolution effective temperatures low enough to produce M type stars according to the models of Maeder and Meynet (1989). Thus the late type red supergiant phase around 10 Myr should not be confused with red supergiants which are the product of the evolution of very massive stars in a time scale of less than 5 Myr, which are expected to be of spectral types K, G or hotter as they evolve in their path to the red or back to the blue in the HR diagram. This might explain why Terlevich and collaborators (this meeting), who observed a giant HII region near the nucleus of NGC3310 which presents CaII triplet, do not detect TiO bands. Another explanation is also possible. We point out that giant HII regions near the central parts of galaxies are situated in crowded regions where several stellar generations in

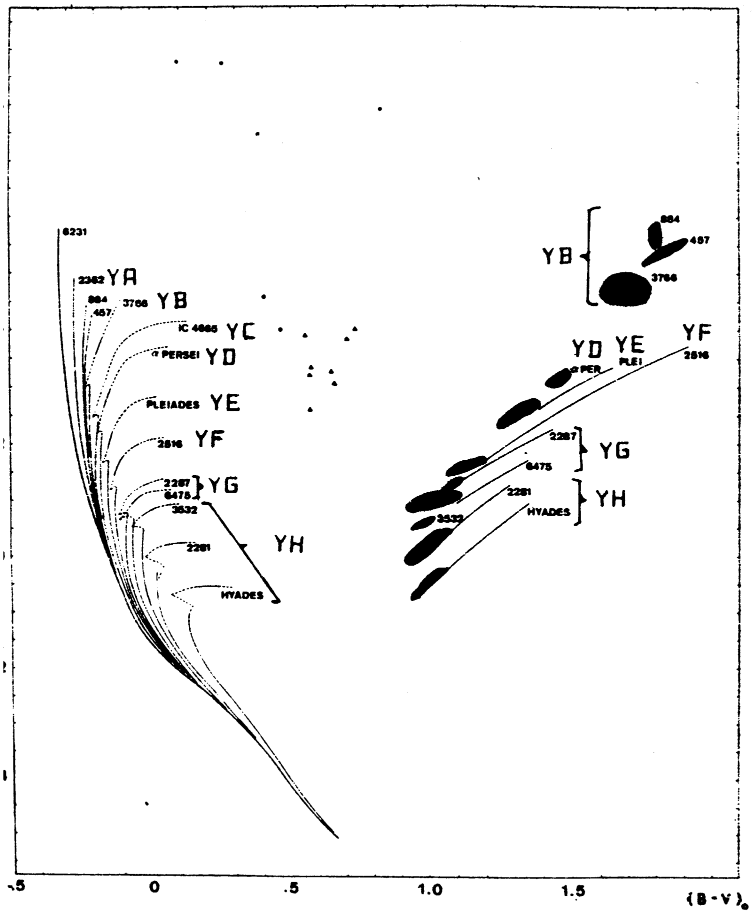

Figure 2.- Correspondence of LMC cluster groups with Mermilliod's groups of galactic open clusters, evolved stars: Black zones and lines denote respectively observed zones of high and low concentration of stars. For details see Mermillliod (1981a).

time scale of 100 Myr might coexist with a superimposition of various ectral stages from Figure 1 plus an HII region event. An extreme case of is kind is the accumulation of populations in hot-spot galaxy nuclei like C5236 (Bica, 1988).

YC at t ≈ 30 Myr corresponds to the Galactic group IC4665, aracterized by an absence of red evolved stars. Indeed the integrated ectrum has no TiO while Paschen lines from B-A type stars are prominent. It s as well CaII triplet, which should arise from the lower main sequence. is blue phase corresponds to a gap in the HR diagram where red supergiants more exist and giants from intermediate mass progenitors (IMP) have not yet veloped. The Be stars are responsible for the strong emission in YB and YC an analogy with Mermilliod's corresponding groups which are very rich in ose stars.

In YD and YE the giants from IMP appear, as denoted by some TiO and ronger CaII than in YC (Figure 1). In YF, which contains clusters like C1866, an important phenomenon takes place by the presence of strong TiO nds denoting M type stars. This is also seen in the HR diagrams of group C2516 in the Galaxy, where the tip of the giant branch (Figure 2) is almost 25 magnitudes redder in (B-V)o than in the previous group Pleiades. Thus in ch cases there is evidence of a second red phase which seems to be due to M pe AGB stars. In YG the integrated spectrum has almost no TiO in agreement ch the HR diagram of Galactic clusters where the tip of the red giant branch comes considerably hotter (e. g. the groups NGC2287 and NGC6475). These ants have an important contribution to CaII triplet although not as much as the lower main sequence, according to the spectral synthesis of the integrated spectrum of the very rich Galactic open cluster M11 of similar age (Santos Jr., Bica and Dottori 1989). The YH group has an integrated spectrum very similar to YG (Figure 1) in the near-infrared. Indeed the giant branch has similar colours in the HR diagram of Galactic open clusters in the corresponding groups (Figure 2). However they differ considerably in the blue spectral region (Bica and Alloin 1986), because of different turn-off colour (Figure 2).

IV. CONCLUSIONS

There is a striking correspondence between evolutionary stages identified in the integrated spectra of blue LMC clusters and Mermilliod's composite HR diagrams for Galactic open clusters. Red and blue phases alternate, in particular there is no doubt about a late type red supergiant phase around 10 Myr and there is evidence of an AGB phase around 100 Myr. An absence of evolved stars is observed after the last red supergiants and the first appearance of giants from intermediate mass progenitors. Strong H+ emission from Be stars occurs from 10 < t(Myr) < 30. The spectral stages obtained are of major importance for population synthesis of star forming regions in galaxies, in particular for dating and determining the age dispersion of star bursts.

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