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UPPER MAIN SEQUENCE AND BLUE STRAGGLERS IN GALACTIC OPEN CLUSTERS

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RESUMEN

Se presentan resultados preliminares de un estudio fotométrico CCD multicolor de ocho cúmulos abiertos galácticos. La fotometría previa de varios de los objetos es antigua o escasa. Mediante el examen de la secuencia principal superior en los diagramas color-magnitud de los cúmulos se trata de identificar posibles *blue stragglers.*

ABSTRACT

The preliminary results of a multicolor CCD photometry of eight galactic open clusters are reported. Several of these objects have rather old or little previous photometric information. The upper main sequences in the cluster color-magnitude diagrams are examined in order to identify blue straggler candidates.

Key words: **OPEN CLUSTERS AND ASSOCIATIONS: GENERAL — STARS: BLUE STRAGGLERS**

1. INTRODUCTION

On cluster color-magnitude diagrams, blue stragglers are stars which appear above and blueward the cluster turnoff. That is, they are located on areas not allowed by the standard theory of stellar evolution, provided they are cluster members. Relatively recent accounts of the present knowledge on this subject, as well as many references, may be found in Stryker (1993), Saffer (1993), and Part IV-D of Milone & Mermilliod (1996).

Through the inspection of color-magnitude diagrams, blue straggler candidates have been identified in open and globular clusters, OB associations, and dwarf galaxies. This report deals with blue stragglers in open clusters; a catalog of such objects was published recently (Ahumada & Lapasset 1995). Stragglers appear in clusters of all ages though there are very few in young clusters and lots of them in old ones. In general, every old cluster seems to have some stragglers. Another noticeable and general feature of these stars is that they appear centrally concentrated. In the rare cases when there is a blue straggler in a young cluster, it is usually a hot star just in the middle of the cluster.

The more popular theories put forward to explain the existence of blue stragglers propose that they may be (i) stars formed after the bulk of the cluster members (Eggen & Iben 1988), (ii) stars with anomalously long lives (Finzi & Wolf 1968), (iii) close binaries that have undergone mass transfer, maybe a complete merger (McCrea 1964), or (iv) the result of stellar collisions (Hills & Day 1976). Today there is little doubt that binarity plays a fundamental role in the formation of stragglers in open clusters. There are individual examples that support this assertion (see, e.g., Lapasset & Ahumada 1996), but perhaps the most striking evidence comes from the well-known population of blue stragglers of M67. It shows a very high frequency of spectroscopic binaries (Latham & Milone 1996) with such a range of properties that different cases of mass transfer and stellar collisions must apparently be at work simultaneously to explain them (Leonard 1996). Of course, other mechanisms are not excluded. For instance, internal mixing has been invoked to account for spectral peculiarities observed among blue stragglers in OB associations and young clusters (Mermilliod 1982; Abt 1985).

In the context of a Ph.D. project, I am observing a number of open clusters, most of them with old or little previous photometry, in order to obtain new, accurate color-magnitude diagrams. A primary interest of mine is the identification of blue straggler candidates. In this contribution I report the preliminary results for eight open clusters.

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2. OBSERVATIONS AND REDUCTIONS

The open clusters included in this work are listed in Table 1. The data are from Lyngå (1987). In general, a selection has been made of objects relatively rich (N) and rather small (D). The observations were carried

TABLE 1

LIST OF CLUSTERS

Cluster name	α (2000.0)	δ (2000.0)	l	b	N	D
NGC 2311	$06^h57^m.8$	$-04°35'$	297°.57	1°.17	45	6′
NGC 2204	$06^h15^m.7$	$-18°39'$	226°.01	−16°.07	80	10′
Haffner 5	$07^h18^m.1$	$-22°34'$	236°.08	−4°.58	50	7′
NGC 2509	$08^h00^m.7$	$-19°04'$	237°.06	5°.83	70	12′
NGC 2627	$08^h37^m.2$	$-29°56'$	251°.58	6°.65	60	9′
NGC 2658	$08^h43^m.4$	$-32°39'$	254°.56	6°.07	80	10′
Melotte 105	$11^h19^m.4$	$-63°30'$	292°.89	−2°.45	70	5′
NGC 4103	$12^h06^m.7$	$-61°15'$	297°.57	1°.17	45	6′

out with the 2.15-m telescope at CASLEO (Argentina), and the 0.60-m Helen Sawyer Hogg telescope of the University of Toronto Southern Observatory (Chile). The dates of observations and instrumentation are listed in Table 2. The reduction of the observations was performed with tools available in the IRAF[4] package. The procedures followed in the frame processing and photometry (e.g., star finding, PSF generation and fitting, calibration) were all standard (Stetson 1987; Da Costa 1992). The observed color-magnitude diagrams were "cleaned" through the analysis of the errors returned by the DAOPHOT code, and the comparison with diagrams of stellar fields taken near the clusters (see, for example, Kałużny & Masur 1991).

TABLE 2

OBSERVATIONS

Cluster name	Instrument+Detector	Filters	Dates of observations
Haffner 5	CASLEO 2.15-m+CCD TEK1024	*UBVRI*	13, 14 Jan 1997
NGC 2204	"	"	4 Feb 1994, 22 Feb 1995
NGC 2311	"	"	8, 9 Jan 1997
NGC 2509	"	"	9, 13 Jan 1997
NGC 2627	"	"	24 Feb 1995, 8 Jan 1997
NGC 2658	"	"	9, 13 Jan 1997
NGC 4103	"	"	24 Feb 1995, 18 Jan 1996
Melotte 105	HSHT(LCO) 0.60-m+CCD PM512	"	13, 15 Apr 1996

3. DISCUSSION

On each corrected V vs. $B-V$ diagram we fitted a theoretical isochrone from Meynet, Mermilliod, & Maeder (1993). At the same time, the fitting of the standard sequence of Schmidt-Kahler (1982) was performed on the $U-B$ vs. $B-V$ diagrams, in order to make a discrimination of possible cluster members from non-members, according to the position of the stars relative to both sequences. Next, blue straggler candidates were looked for following the criteria discussed in Ahumada & Lapasset (1995).

[4]IRAF is distributed by the National Optical Astronomy Observatories which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

Some comments on each cluster follow; where t is the cluster age in years, $m_{\rm TO}$ is the apparent V magnitude of the turnoff, and R stands for $D/2$, where D is the cluster diameter listed in Table 1. The errors in the reddenings are about 0.03. In some cases (e.g., Haffner 5, NGC 2658) the derived parameters are very preliminary:

NGC 4103 & Haffner 5: With $\log t \sim 7.7$, these are the youngest clusters of the sample. NGC 4103 has a well-defined sequence and is quite bright ($m_{\rm TO} \sim 11.5$, $< E(B-V) >\sim 0.30$). Haf 5 is well fainter ($m_{\rm TO} \sim 15.5$), richer, and quite reddened ($< E(B-V) >\sim 0.85$). No obvious blue straggler candidates appear.

NGC 2311 & Melotte 105: These are intermediate-age clusters ($\log t \sim 8.5$). NGC 2311 has a nicely defined sequence, it is not very rich and is relatively bright ($m_{\rm TO} \sim 12.5$, $< E(B-V) >\sim 0.30$). There is a slightly evolved straggler at $0.9R$ from the cluster center. Mel 105 is fainter and somewhat richer ($m_{\rm TO} \sim 13.3$, $< E(B-V) >\sim 0.5$) than NGC 2311. Two evolved stragglers (at $0.03R$ and $0.29R$) appear on the diagram.

NGC 2658: This cluster appears to be a bit older ($\log t \sim 8.6$) and richer than NGC 2311 and Mel 105. It is rather faint ($m_{\rm TO} \sim 14.7$, $< E(B-V) >\sim 0.25$) and the upper main sequence shows dispersion. Apparently, there are no stragglers.

NGC 2509: This is a rather old ($\log t \sim 9.0$) and faint ($m_{\rm TO} \sim 14.2$, $< E(B-V) >\sim 0.20$) cluster, with a very well defined turnoff; some dispersion is present in the upper main sequence. There are three blue straggler candidates, two ($0.10R$ and $0.40R$) evolved and a third ($0.60R$) located on the ZAMS.

NGC 2627: An old cluster ($\log t \sim 9.4$), less rich and brighter ($m_{\rm TO} \sim 14.2$, $< E(B-V) >\sim 0.05$) than the following, NGC 2204. The diagram shows a nice main sequence and a well-defined turnoff. Only one evolved, straggler candidate appears at $0.40R$ from the cluster center.

NGC 2204: The oldest ($\log t \sim 9.5$) and perhaps the best known cluster in the sample ($m_{\rm TO} \sim 16.1$, $< E(B-V) >\sim 0.07$). The turnoff shows dispersion, but at least three blue straggler candidates can be clearly identified, two (at $0.25R$ and $0.38R$) evolved and near the turnoff, and the third and brighter (more than two magnitudes above the turnoff) is just at the center of the cluster.

Further elaboration of the data of these and other clusters is currently under way.

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