The Optical Gravitational Lensing Experiment.
Multiple Cluster Candidates in the Small Magellanic Cloud

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ABSTRACT

We present the list of potential multiple star clusters from the central part of the SMC. Presented systems were selected from the catalog of star clusters from the SMC. We find 23 suspected cluster pairs and 4 triple systems. The statistical analysis suggests that many of them may constitute physical systems. Size, equatorial coordinates and age of presented clusters are given. Age of clusters which form five pairs and one triple system is coeval suggesting common origin of these objects.

1 Introduction

The presence of large number of potential pairs of clusters in the Magellanic Clouds is well established. The catalog of binary star clusters from the SMC was presented by Hatzidimitriou and Bhatia (1990). The possible cluster pairs from the LMC were cataloged by Bhatia and Hatzidimitriou (1988) and Bhatia et al. (1991). Statistical analysis made by these authors suggests that many of them may be real binary systems. Several recent papers deal with selected binary pairs from the LMC. Based on spectroscopic and photometric observations of three pairs Kontizas et al. (1993) concluded that all three are very young physical systems. Dieball and Grebel (1998) claimed physical nature of the pair SL 538 and NGC 2006. Surface brightness photometry made for three pairs by Vallenari et al. (1998) indicates interaction between physically connected clusters. Leon et al. (1998) pointed out that several cluster pairs show tidal tails, thus they are real binary clusters. All

*Based on observations obtained with the 1.3 m Warsaw telescope at the Las Campanas Observatory of the Carnegie Institution of Washington.
mentioned studies confirmed the fact that significant fraction of cataloged binary cluster candidates are indeed physical pairs.

Although the pairs from the LMC were subject of several investigations in the near past, to our knowledge no papers on pairs from the SMC were published since the catalog of Hatzidimitriou and Bhatia (1990).

The existence of physical pairs of clusters has important implication on the process of formation and evolution of clusters. Fujimoto and Kumai (1997) suggest that binary and multiple clusters form through oblique collisions between massive gas clouds. This mechanism leads to the cluster systems having similar age. The observations of cluster pairs that show large age difference between components (Vallenari et al. 1998) cannot be, however, explained by this theory. Leon et al. (1999) proposed scenario of tidal capture in the groups of clusters for explaining such systems.

The main purpose of the OGLE microlensing project is detection of dark matter in the Galaxy with microlensing phenomena (Paczynski 1986). Because of very low probability of detection of microlensing events the project requires monitoring of million stars. The observations are conducted in the Galactic bulge, Galactic disc and central regions of the Magellanic Clouds. The OGLE-II phase of the project is described by Udalski, Kubiak and Szymański (1997). Huge amount of precise photometric data for stars from very dense regions, rarely observed until now with the modern instruments, provides an unique material for many other studies. In particular data collected for the regions located in the Magellanic Clouds are very well suited for studying the rich system of clusters from these galaxies. The observational material obtained for the SMC was presented by Udalski et al. (1998). It contains $BVI$ photometric and astrometric data for more than 2 million stars from the 2.4 square degree region located in the center of the SMC. Based on these data Pietrzyński et al. (1998) presented the catalog of 238 star clusters. In this paper we use this catalog to identify possible binary and multiple star clusters.

2 Cluster Pairs

We searched the OGLE catalog of clusters from the SMC (Pietrzyński et al. 1998) for objects with the projected separations smaller than 18 pc (Hatzidimitriou and Bhatia 1990), assuming the distance to the SMC of 54 kpc (Udalski 1998). Based on the positions of 161 clusters detected with the algorithmic, automatic method, eight pairs and three triple systems were
detected. Table 1 contains their description. However, the OGLE catalog of clusters also contains data for additional 77 clusters found during visual examination of observed regions. They were too small and faint to be detected with the automatic procedure. If we include their coordinates to our search we find additional 15 pairs and one triple system. Since these objects are less reliable we present them separately in Table 2. Cluster coordinates and sizes are extracted from the OGLE catalog of clusters (Pietrzyński et al. 1998). Age is taken from Pietrzyński and Udalski (1999).

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Name & $\alpha_{2000}$ & $\delta_{2000}$ & Radius ["] & log $t$ \\
\hline
OGLE-CL- & & & & \\
\hline
SMC0018 & $0^h43^m37^s57$ & $-73^\circ26'37"9$ & 20 & 7.9 \\
SMC0017 & $0^h43^m32^s74$ & $-73^\circ26'25"4$ & 26 & 7.9 \\
SMC0021 & $0^h43^m44^s40$ & $-72^\circ58'35"6$ & 36 & - \\
SMC0020 & $0^h43^m37^s89$ & $-72^\circ58'48"3$ & 9 & 8.6 \\
SMC0019 & $0^h43^m37^s59$ & $-72^\circ57'30"9$ & 12 & 8.6 \\
SMC0042 & $0^h47^m49^s17$ & $-73^\circ28'42"2$ & 16 & - \\
SMC0045 & $0^h48^m00^s68$ & $-73^\circ29'10"3$ & 35 & - \\
SMC0063 & $0^h50^m36^s83$ & $-73^\circ03'28"0$ & 30 & - \\
SMC0065 & $0^h50^m54^s62$ & $-73^\circ03'26"9$ & 20 & - \\
SMC0077 & $0^h52^m13^s34$ & $-73^\circ00'12"2$ & 18 & 7.9 \\
SMC0078 & $0^h52^m16^s56$ & $-73^\circ01'04"0$ & 36 & 7.9 \\
SMC0084 & $0^h52^m46^s69$ & $-73^\circ24'25"4$ & 12 & - \\
SMC0087 & $0^h52^m48^s99$ & $-73^\circ24'43"3$ & 22 & 8.7 \\
SMC0093 & $0^h53^m31^s29$ & $-72^\circ40'04"2$ & 18 & - \\
SMC0094 & $0^h53^m40^s09$ & $-72^\circ39'35"3$ & 9 & - \\
SMC0096 & $0^h53^m42^s31$ & $-72^\circ39'14"6$ & 11 & - \\
SMC0114 & $0^h58^m25^s73$ & $-72^\circ39'56"5$ & 18 & - \\
SMC0113 & $0^h58^m16^s29$ & $-72^\circ38'46"8$ & 24 & - \\
SMC0119 & $0^h59^m56^s87$ & $-72^\circ22'24"4$ & 9 & - \\
SMC0120 & $1^h00^m01^s33$ & $-72^\circ22'08"7$ & 27 & 7.7 \\
SMC0138 & $1^h03^m53^s02$ & $-72^\circ06'10"5$ & 18 & 7.4 \\
SMC0144 & $1^h04^m05^s23$ & $-72^\circ07'14"6$ & 18 & 7.6 \\
SMC0146 & $1^h05^m13^s40$ & $-71^\circ59'41"8$ & 14 & 7.3 \\
SMC0145 & $1^h05^m04^s30$ & $-71^\circ59'24"8$ & 18 & 7.9 \\
SMC0147 & $1^h05^m07^s95$ & $-71^\circ59'45"1$ & 22 & 7.1 \\
\hline
\end{tabular}
\caption{Multiple cluster candidates in the SMC}
\end{table}
In order to check whether the number of detected pairs is significantly different than the number expected from chance line-up due to projection we conducted statistical analysis described by Bhatia and Hatzidimitriou (1988). The number of chance-pairs of objects uniformly distributed in the space may be calculated based on the formula given by Page (1972).

\[ N_1 = 0.5\pi \times N_2^2 \times s^2 \]

where \(N_1, N_2\) and \(s\) are the expected number of pairs per square degree, the number of clusters per square degree and projected angular separation in degrees, respectively. The OGLE catalog contains 238 clusters located in the 2.4 square degree region of the SMC. Assuming that they are distributed uniformly we find that the expected number of chance-pairs with separation smaller than 18 pc should be about eight (four in the case of 161 clusters detected in the algorithmic way). In fact the distribution of clusters is not uniform. We account for that adopting this procedure to \(15 \times 15\) arcmin regions for which one may assume uniform density of clusters. We obtain that the number of chance-pairs is about ten and seven using positions of all clusters and 161 detected automatically, respectively. As one can notice these numbers are significantly smaller than the number of detected cluster pairs. If we assume Poissonian statistics we obtain that the difference is about \(7\sigma\) which suggests that the majority of presented pairs constitute physical systems.

From Tables 1 and 2 one can see that five pairs and one triple system have nearly the same age. This fact favors the common origin of these systems. Their sizes are also comparable.

\section{Summary}

We present the list of potential binary and multiple clusters from the center of the SMC. Altogether 23 pairs and 4 triple systems are selected. Based on statistical considerations we show that the number of expected chance-pairs of clusters is considerably smaller. This fact suggests that most of them must constitute real physical systems. For 22 members of detected pairs their age was determined. Most of them are found to be young objects. Members of five pairs and one triple system have similar age which indicates their common origin. Further observations, in particular spectroscopic, are required to confirm physical relation of presented systems.
Tables 1 and 2 are available from the OGLE Internet archive:  
http://www.astrouw.edu.pl/~ftp/ogle. Photometric data and finding charts for all clusters can also be found there.

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REFERENCES
Bhatia, R.K., Read, M.A., Hatzidimitriou, D., and Triton, S. 1991, Astron. Astrophys. Suppl. Ser., 87, 335.
Bhatia, R.K., and Hatzidimitriou, D. 1988, MNRAS, 230, 215.
Dieball, A., and Grebel, E. 1998, Astron. Astrophys., 339, 773.
Fujimoto, M., and Kumai, Y. 1997, Astron. J., 113, 249.
Hatzidimitriou, D., and Bhatia, R.K. 1990, Astron. Astrophys., 230, 11.
Kontizas, E., Kontizas, M., and Michalitsianos, A. 1993, Astron. Astrophys., 267, 59.
Leon, L., Bergond, G., and Vallenari, A. 1999, Astron. Astrophys., 344, 450.
Paczyński, B. 1986, Astrophys. J., 304, 1.
Page, T. 1972, in “Stars and Stellar Systems” vol 10. University of Chicago Press.
Pietrzyński, G., Udalski, A., Szymański, M., Kubiak, M., Woźniak, P., and Żebruń, K. 1998, Acta Astron., 48, 175.
Pietrzyński, G. and Udalski, A. 1999, Acta Astron., 49, 157.
Udalski, A., Kubiak, M., and Szymański, M. 1997, Acta Astron., 47, 319.
Udalski, A. 1998, Acta Astron., 48, 383.
Udalski, A., Szymański, M., Kubiak, M., Pietrzyński, G., Woźniak, P., and Żebruń, K. 1998, Acta Astron., 48, 147.
Vallenari, A., Bettoni, D., and Chiosi, C. 1998, Astron. Astrophys., 331, 506.
### Table 2

Additional multiple cluster candidates

| Name        | OGLE-CL-00005 | α2000  | δ2000  | Radius ["] | log t |
|-------------|---------------|--------|--------|-------------|-------|
| SMC0005     | 0°39′11.56″   | −73°15′28.4″ | 22     | −           |
| SMC0155     | 0°39′11.56″   | −73°14′45.5″ | 12     | −           |
| SMC0033     | 0°46′12.26″   | −73°23′34.0″ | 18     | 7.2         |
| SMC0182     | 0°46′01.63″   | −73°23′44.4″ | 7      | −           |
| SMC0035     | 0°46′33.72″   | −72°46′25.9″ | 14     | −           |
| SMC0185     | 0°46′34.04″   | −72°45′55.7″ | 4      | −           |
| SMC0040     | 0°47′01.18″   | −73°23′34.7″ | 16     | −           |
| SMC0187     | 0°47′05.87″   | −73°22′16.6″ | 14     | −           |
| SMC0190     | 0°48′13.20″   | −72°47′34.7″ | 12     | −           |
| SMC0191     | 0°48′20.19″   | −72°47′42.1″ | 20     | −           |
| SMC0060     | 0°50′21.95″   | −73°23′16.5″ | 36     | −           |
| SMC0197     | 0°50′03.82″   | −73°23′03.9″ | 24     | 8.4         |
| SMC0059     | 0°50′16.06″   | −73°01′50.6″ | 25     | 7.8         |
| SMC0199     | 0°50′15.07″   | −73°03′14.8″ | 7      | −           |
| SMC0064     | 0°50′39.55″   | −72°57′54.8″ | 36     | 8.1         |
| SMC0200     | 0°50′38.98″   | −72°58′43.6″ | 11     | 8.0         |
| SMC0210     | 0°52′30.30″   | −73°02′50′0″ | 21     | 8.2         |
| SMC0211     | 0°52′32.15″   | −73°02′10′3″ | 14     | −           |
| SMC0083     | 0°52′44.27″   | −72°58′47′8″ | 29     | 7.8         |
| SMC0212     | 0°52′44.52″   | −72°59′24′2″ | 9      | −           |
| SMC0213     | 0°52′48′29″   | −72°59′22′2″ | 11     | −           |
| SMC0097     | 0°54′11.00″   | −72°51′54′1″ | 20     | −           |
| SMC0217     | 0°53′56.49″   | −72°51′23′8″ | 8      | −           |
| SMC0108     | 0°56′34.48″   | −72°30′08′3″ | 15     | −           |
| SMC0223     | 0°56′25.59″   | −72°29′45′1″ | 6      | −           |
| SMC0112     | 0°57′57.14″   | −72°26′42′0″ | 29     | 7.5         |
| SMC0227     | 0°57′50′23″   | −72°26′23′6″ | 7      | −           |
| SMC0123     | 1°00′33.70″   | −72°14′23′0″ | 31     | −           |
| SMC0230     | 1°00′33.15″   | −72°15′30′5″ | 9      | −           |
| SMC0231     | 1°00′58′19″   | −72°32′24′9″ | 21     | −           |
| SMC0232     | 1°01′13.58″   | −72°33′03′5″ | 8      | −           |
| SMC0139     | 1°03′53′44″   | −72°49′34′2″ | 20     | 7.5         |
| SMC0235     | 1°03′58′96″   | −72°48′18′3″ | 8      | −           |