Spectroscopy of a stream of G-stars in the area of the open cluster M67

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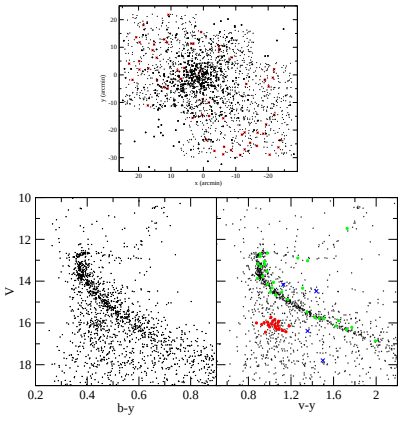
ABSTRACT

The systematic study of selected open clusters by our team lead to the production of the best set of Strömgren photometry ever obtained of the old open cluster M67. Its analysis showed a previously unknown clump of more than 50 stars in the HR diagram, located below the cluster main sequence. The spatial distribution of these stars suggested that most of them could be cluster members and two alternative hypothesis were proposed: (1) if members, they would be binary systems composed by a white dwarf and a red dwarf, i.e. pre-cataclysmic variable systems; (2) if non-members, they would constitute a stream of G-type stars placed behind the cluster. Medium dispersion spectra taken using the PMAS/PPAK spectrograph at 3.5m telescope in Calar Alto lead to the conclusion that all stars are F-G main sequence stars, and therefore the first hypothesis can be discarded. We are acquiring new uvby-Hβ photometric data with the Wide Field Camera of INT and, in addition, we are carrying out an astrometric study with the Meridian Circle of San Fernando CMASF at El Leoncito (Argentina) to derive properties of stars fainter than our previous survey and covering a wider area in the cluster region. The new data will yield proper motions of the stars in the clump as well as allow to study the properties of the corona of M67.

Astrophysical Context

In the last decade, large scale surveys have demonstrated the existence of extended tidal streams and overdensities. One possibility for their origin could be the disruption of massive systems such as dwarf galaxies as they merge with our Galaxy. These structures' formation has direct implications on the history of the assembly of the Galaxy. Our wide-field photometric work on the open cluster NGC 2682 = M67 (Balaguer-Núñez et al. A&A 470. 585, 2007) has revealed an overdensity of stars in the colour-magnitude diagram, non previously reported. From the two alternatives originally proposed, the analysis of the spectra taken shows that all stars studied are F-G stars and form a stream of some sort.

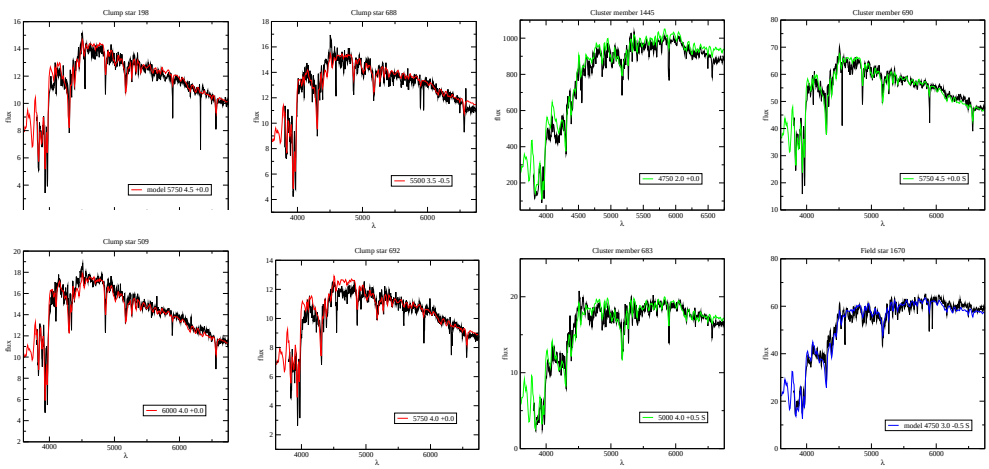


Photometric and Astrometric Data

The photometric analysis of our Strömgren data showed a stellar overdensity of around 65 stars, very outstanding in the *V* vs (*b*--*y*) diagram (see left figure). The clump concentrates around: *V*=16, (*b*--*y*) = 0.45. The field population in this region of the HR diagram shows that we could expect approximately 25 of the 65 clump stars (38%) to be field stars. To evaluate the reliability of the clump, we have also checked the data from the Sloan Digital Sky Survey (SDSS) where it can also be distinguished in some filters (Balaguer et al, SEA2008).
We have performed further wide-field photometry of the area (2007, 2008 and 2009 runs, reduction now under process) to perform a detailed analysis of this feature as well as a more complete variability study.
The spatial distribution of the stars (seemingly in a corona around the cluster centre) led us to believe that this population could be related to the cluster. The stars are too faint to have reliable proper motions (and thus astrometric membership) determined on the existing surveys. We are carrying out an astrometric study with the Meridian Circle of San Fernando CMASF at El Leoncito (Argentina), to derive properties of stars fainter than our previous survey and covering a wider area in the cluster region. The new data will yield proper motions of the stars in the clump as well as allow to study the properties of the corona of M67.

Spectroscopic Data: CAHA 3.5 m with PMAS/PPAK

From our list of 65 stars in the photometric clump, we have carefully selected those spatially placed close to other stars of similar apparent brightness, having previous multicolour photometry, and considered probable cluster members from our photometric and astrometric studies. This leads to a list of 24 fields, all of them containing inside the PPAK field of view at least one clump star, plus at least one (often more) other members suitable for precise spectrophotometric calibration. In two cases, two clump stars are contained simultaneously in the PPAK field. Care was taken to include the known variables from Stassun et al. (2002). Also probable non-member stars enter the field of view serendipitously. 81 medium dispersion spectra have been obtained, with the aim to investigate the composite or single nature of the objects. The observations were done in the 28 Oct 2006 and 11-12 Dec 2007 with Calar Alto 3.5 m telescope and the PMAS/PPAK spectrograph. A total of 25 clump stars (in red) were observed, as well as 32 probable members of the cluster (in green) and 4 probable non-member stars (in blue). From a set of theoretical spectra (Munari et al. 2005, from 3500 to 47500 K in T_{eff}, -2.5 dex to +0.5 dex in metallicity and 0.0 to 5.0 in log g) we have found the best chi-square fitting to our observations. All spectra have been successfully fitted to single star spectra and the results are in the table at the right side. Preliminary astrophysical characterization: surface temperature, metallicity and gravity are given for each of the single spectra fitted. The four Stassun variables (509,1048,1610,1613 in darker red) were also fitted to single spectra. The resolved spectra indicates that the overdensity is formed by an accumulation of late-F and early-G type stars placed at approximately twice the distance of M67. It remains the question about the origin of such an odd feature in the stellar population, and why this group of stars seems to avoid (by chance?) the direction towards central area of M67.



Near future and Gaia

We have a spectroscopic catalogue of 61 stars in M67 area. Our astrometric and photometric studies will shed more light on the nature of this strange feature in the colour-magnitude of the galactic population towards Cancer. Gaia will allow to clarify the nature of those stars. Parallaxes for these stars will be resolved by Gaia with a precision better than 4%. Proper motions uncertainties of 18 μas/yr will allow accurate cluster membership analysis, representing an error of 0.5% for members of the cluster.

Id	V	b - y	v - y	T	[Fe/H]	log g
174	13.208	0.364	0.952	6000	+0.0	4.5
487	15.738	0.517	1.422	5000	+0.0	4.5
546	13.066	0.427	0.950	6000	+0.0	3.0
554	14.149	0.403	0.978	6000	+0.0	5.0
655	15.482	0.514	1.350	5000	+0.0	3.5
683	15.786	0.546	1.465	5000	+0.5	4.0
690	14.527	0.408	1.008	5750	+0.0	4.5
704	17.084	0.796	2.231	3750	-1.0	4.0
758	12.654	0.394	0.980	5750	-0.5	4.5
777	13.530	0.425	0.974	6000	+0.0	4.0
866	14.662	0.418	1.055	5750	+0.0	5.0
871	13.872	0.363	0.884	6250	+0.0	5.0
907	15.888	0.603	1.646	5000	+0.5	4.0
942	13.176	0.370	0.890	6000	+0.0	3.5
963	16.312	0.639	1.721	4500	-0.5	4.0
978	16.863	0.677	1.992	4250	+0.0	3.5
1008	13.023	0.532	1.355	5250	+0.0	4.0
1010	16.143	0.593	1.623	4750	+0.0	4.5
1034	14.327	0.408	1.022	6000	+0.0	5.0
1061	14.059	0.421	1.033	5500	-1.0	4.5
1077	13.297	0.373	0.916	6000	-0.5	4.5
1095	14.338	0.513	1.309	5250	-0.5	5.0
1108	12.827	0.367	0.909	6500	+0.5	3.5
1114	15.790	0.576	1.510	5000	+0.0	4.5
1121	14.525	0.440	1.113	5750	+0.0	5.0
1207	12.694	0.401	0.913	6250	+0.0	4.5
1383	13.768	0.397	0.933	6000	+0.0	3.5
1389	16.810	0.770	2.256	4000	-0.5	3.0
1445	11.475	0.630	1.727	4750	+0.0	2.0
1634	12.896	0.512	1.264	5250	+0.0	4.0
1667	14.875	0.460	1.170	5500	+0.5	3.5
1781	16.210	0.667	1.772	4750	+0.5	3.5
198	16.171	0.411	1.052	5750	+0.0	4.5
509	16.001	0.345	0.875	6000	+0.0	4.0
553	16.443	0.363	0.961	5500	-0.5	4.5
688	16.091	0.414	0.990	5500	-0.5	3.5
692	16.301	0.465	1.067	5750	+0.0	4.0
763	16.150	0.477	1.182	5500	+0.0	4.5
873	16.280	0.435	1.087	5750	+0.0	2.5
917	15.984	0.434	1.077	5750	+0.0	5.0
1024	16.099	0.438	0.988	5750	-0.5	4.5
1048	15.838	0.437	1.048	5500	-0.5	4.5
1080	16.193	0.425	1.000	5750	-0.5	4.5
1230	16.359	0.477	1.119	5250	-1.0	4.5
1243	16.360	0.454	1.120	5500	+0.0	4.0
1288	15.728	0.435	1.012	5500	-0.5	3.0
1405	16.046	0.419	1.018	5500	-0.5	4.5
1459	15.965	0.401	0.979	5750	-0.5	4.5
1610	16.087	0.399	1.046	6000	+0.0	5.0
1613	16.076	0.373	0.925	6250	+0.0	5.0
1614	16.308	0.484	1.086	5750	-0.5	5.0
1628	-	-	-	5000	+0.0	5.0
1658	15.985	0.376	0.948	5500	-1.0	4.5
1662	16.422	0.523	1.153	5250	-0.5	4.0
1666	16.142	0.436	1.077	5750	+0.0	4.5
1671	15.915	0.450	1.083	5500	-0.5	4.0
1768	15.922	0.448	1.031	5500	-0.5	4.0
177	17.169	0.861	-	3750	-1.0	4.0
1125	14.171	0.445	1.128	6000	+0.0	5.0
1213	17.796	0.573	1.499	4500	-1.5	3.5
1670	14.482	0.574	1.438	4750	-0.5	3.0