# Spectroscopy of pre-CV candidates in open cluster M 67

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**Abstract** The systematic study of selected open clusters by our team, has lead to the production of the best set of Strömgren photometry ever obtained of the old open cluster M 67. Its analysis has shown a previously unknown clump of more than 50 stars in the HR diagram, located below the cluster MS. The spatial distribution of these stars indicates that most of them could be cluster members. Two alternative hypothesis would explain their photometry: (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 by our team using the PMAS/PPAK at 3.5m telescope in Calar Alto[1] will show the composite or single nature of the objects, and will allow to deblend the spectral contributions from the white and the red dwarfs, if the pre-CV hypothesis would turn out to be true. Also good spectrophotometric calibration will allow to determine precise spectral types, luminosities, surface temperatures and gravities, thus providing a preliminary astrophysical characterization of these systems. The same spectrophotometric calibration will yield separate and accurate synthetic photometry for both components, if present, in different broad and Intermediate band systems.

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[1] Based on observations collected at the German-Spanish Astronomical Center, Calar Alto, jointly operated by the Max-Planck-Institut für Astronomie Heidelberg and the Instituto de Astrofísica de Andalucía (CSIC).

## 1 Astrophysical Context

The class of Cataclysmic Variable stars (CVs) comprises dwarf novae, classical novae and Ia-type supernovae. All these objects are semi-detached binary systems composed by a late red dwarf feeding matter onto a white dwarf. CVs represent advanced stages in an evolutionary process in which the components have undergone previous stages of mass interchange and a common-envelope phase. Models predict, and observation reveals, that after the common-envelope phase, and before the semi-detached status (active or quiescent CV), the pairs have to traverse a detached phase in which these objects are known as pre-CV systems.

Most known CVs are field stars. Theory predicts that they should be numerous in globular clusters, but such findings are well below the theoretical expectations. In spite of intensive searches, only three CVs are known in open clusters (one of them in M 67). Even smaller is the census of known pre-CVs: not showing outbursts, they are more difficult to identify.

Our previous photometric work on the open cluster NGC 2682 = M 67 has revealed a peculiar clump of stars in the colour-magnitude diagram, non previously reported. The spatial distribution of the stars indicates that most probably they belong to the cluster, and their photometry can be explained if they are composed by white dwarf-red dwarf detached pairs: the combinations corresponding to the observed colours are physically feasible.

Other authors have found that five stars in this clump are variables of kinds compatible with the pre-CV status, but they did not perceive the relevance of this concentration because of the small size of their data set. We have perceived this feature in the colour-magnitude diagram due to the unusually wide field covered by our photometry.

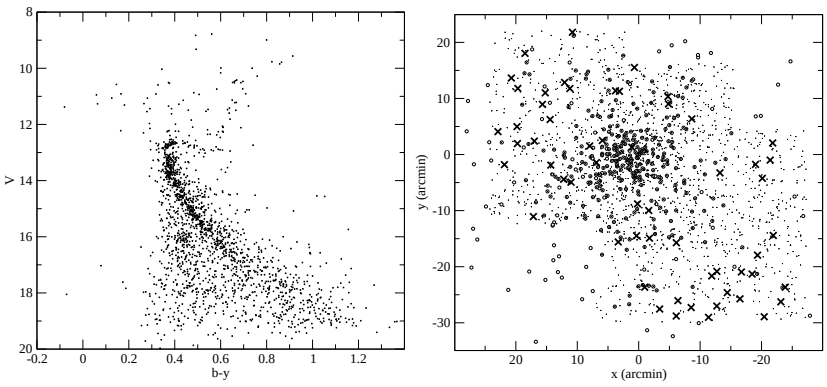


**Fig. 1** The colour-magnitude diagram of the NGC 2682 (M 67) area on the left and the spatial distribution on the right. Clump stars are crosses, members from our astrometric study in empty circles and dots represent the stars present in our CCD photometric sample: their spatial coverage does not reach the lower right nor the upper left corners. North is up, East is left.

Confirming the existence of a significant population of pre-CV stars in such a well studied open cluster (and thus, of known distance, age and metallicity) would have very deep implications for the understanding of the nature and evolution of these binary systems.

## 2 Photometric Data

The photometric analysis of our Strömgren data showed a clump of around 65 stars, very outstanding in the V vs (b–y) diagram (see Fig. 1 left). The clump concentrates around: V=16, (b–y) = 0.45.

Checking the spatial distribution of the stars, we saw that they are preferentially organised in a corona around the cluster center, at an average distance of 20 arcmin (see Fig. 1 right). This implies that this population is related to the cluster. The stars are too faint to have reliable proper motions (and thus astrometric membership) determined. 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.

We have checked the data from the Sloan Digital Sky Survey (SDSS) in our aim to evaluate the reliability of the clump. Sloan photometry is taken in 5 filters: ugriz with effective wavelengths 3540, 4750, 6222, 7632 and 9049 A, selected to avoid the strongest night-sky lines. We have chosen a similar spatial area than in our INT- WFC Strömgren photometry (30 arcmin). In all graphs (see Fig. 2) the main sequence of the cluster is clearly distinguished and in some filters the clump can also be appreciated.

## 3 Spectroscopic Data

Medium dispersion spectra have been obtained, with the aim to show the composite or single nature of the objects, and they would allow to deblend the spectral contributions from the white and the red dwarfs, if this would be the case. The ob-

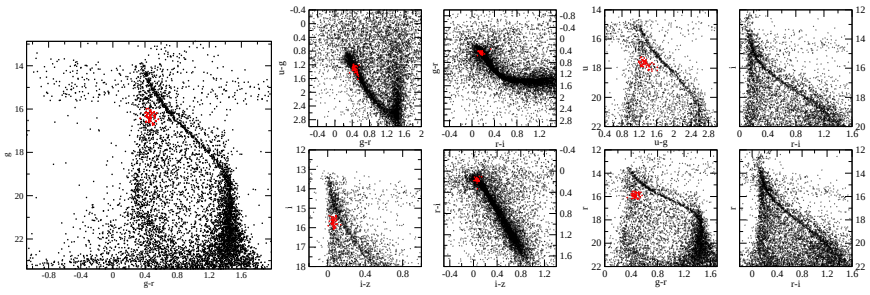

**Fig. 2** SDSS. The colour-magnitude and colour-colour diagrams of the NGC 2682 (M 67) area.

servations were done in the 28 Oct 2006 and 11-12 Dec 2007 with Calar Alto 3.5 m telescope and the PMAS/PPAK spectrograph. More than 20 pre-CV candidates were observed and the data are being reduced and treated right now. Here we show preliminary results for three of the candidates, and for one non-candidate late-type star, member of the cluster (see Fig. 3). All these three candidates turn out to be single, main sequence F-G type stars.

A good spectrophotometric calibration will allow to determine precise spectral types, luminosities, surface temperatures and gravities, thus providing a preliminary astrophysical characterization of the observed stars. The same spectrophotometric calibration will yield separate and accurate synthetic photometry for both components in different broad and intermediate band systems, for the candidates that will show a composite nature. Repeated observations of the same fields would display variations in radial velocity that will be compared with those expected for pre-CV systems (few hours period, hundreds of km/s amplitude).

Average radial velocities should be compatible with cluster membership, providing additional confirmation that the systems belong to M 67. According to our scheme, we have also obtained the spectra of several tens of surrounding non-clump stars with high probability of being members of M 67. This will be used for the spectrophotometric calibration, and also will yield relevant data on these stars: discordant radial velocities will improve the membership assignation, and metallicities and spectral types will be computed and assigned, enlarging the amount of well-characterised members of M 67.

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 more than 20 fields, all of them containing inside the PPAK field of view at least one clump star, plus at least one (often more) other member suitable for precise spectrophotometric calibration. In two cases, two clump stars are contained simultaneously in the PPAK field. Also, probable non-member stars enter the field of view serendipitously in several cases.

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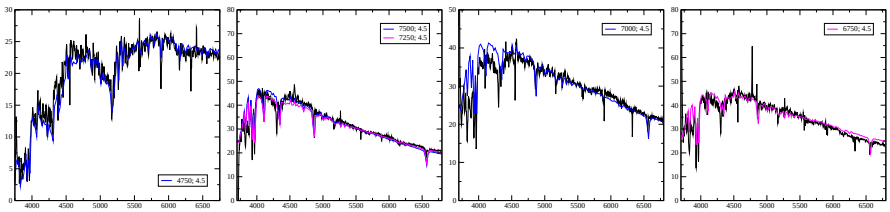


**Fig. 3** Medium dispersion spectra of stars in M 67 area. Right to left: 0963, cluster member; 1024, candidate pre-CV star; 1080, candidate pre-CV; 1288. candidate pre-CV. Temperatures and gravities of the fitted spectra in boxes.