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Near-infrared study of regions associated with young star clusters

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Abstract. Star clusters are characterized as group of stars formed from the same cloud of gas and dust within the same period of time. For this reason, the stars in a cluster share common characteristics, making them essential objects for the study of stellar evolution. The aim of this work is to use infrared imaging, obtained with the SOAR telescope and the Spartan camera, for the study of young clusters associated with Canis Major OB1 (CMa OB1), which is a Galactic stellar association with a very intriguing star-formation scenario. We use ancillary data from Gaia DR3, 2MASS and WISE to obtain astrometric and photometric parameters from the star population on the field next to the Z CMa star. In addition, we create a catalogue with the 46 member stars identified.

Resumo. Aglomerados estelares são caracterizados como grupos de estrelas formadas da mesma nuvem de gás e poeira dentro de um mesmo período de tempo. Por esta razão, estrelas de um aglomerado compartilham características em comum, os tornando objetos essenciais para o estudo de evolução estelar. O objetivo deste trabalho é utilizar imageamento no infravermelho, usando o telescópio SOAR e a câmera *Spartan*, para o estudo de aglomerados jovens associados com Canis Major OB1 (CMa OB1), que é uma associação estelar Galática com um cenário intrigante de formação estelar. Nós utilizamos dados auxiliares dos catálogos *Gaia* DR3, 2MASS e WISE para obter parâmetros astrométricos e fotométricos da população estelar no campo próximo à estrela Z CMa. Adicionalmente, nós criamos um catálogo com as 46 estrelas identificadas.

Keywords. Stars: formation - Stars: evolution – Stars: pre-main sequence – Stars: fundamental parameters

1. Introduction

The field observed with SOAR/Spartan is part of the star cluster CMa06 previously identified by (Santos-Silva et al. 2021), among other stellar groups associated with CMa OB1 (see Fig 1). Our objectives are to identify the stars detected by Spartan, perform an astrometric and a photometric calibration, identify the cluster members by using proper motion and parallaxe and finally perform a cross-match with public data bases aiming to construct a catalogue of the member stars.

In Sec. 2, 3 and 4, we describe the methodology developed for extracting the cluster data, deriving its astrometric parameters and determining stellar membership. In Sec. 5 we summarize the conclusion and results.

2. Identifying Stars in Observed Field

We combined the use of the software Aladin and Starfinder to perform an astrometrical calibration through Gaia DR3 positions (Gaia Collaboration et al. 2023) and a PSF extraction to identify the stars on the Spartan images obtained with the H2, Brγ and Cont3 filters. By deriving the physical positions of these stars through this method, we achieved their transformation into astronomical coordinates (RA, DEC) utilizing the XYAD task in IDL. Additionally we overlaid the 2MASS (Skrutskie et al. 2006) sources with the stars detected by the Spartan images using Aladin (see Fig. 1), in order to validate the effectiveness of the astrometric calibration.

3. Photometric Calibration

In order to apply the methodology to determine the physical parameters for the cluster, we needed to perform a cross-match of our data with different astronomical catalogues. Using TopCat, a 4.25 arcmin region was extracted for each catalogue data used in this work, and then we applied the cross-match, considering

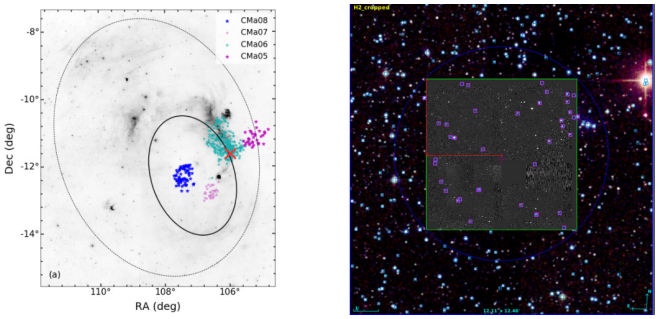

Figure 1. Left: Spatial distribution of clusters associated with the CMa region that were identified by (Santos-Silva et al. 2021), the position of the Spartan field analyzed in this work is shown by the red cross. Right: Spartan H2 image (green square of size ~ 6'x 6', center RA=106.017^o Dec=-11.592^o) overlaid on the 2MASS image (JHK). The blue circle shows the extraction area adopted for the cross-match with different catalogues. Small magenta squares are used to indicate the Gaia DR3 counterparts of Spartan sources. Z CMa is the bright star appearing to the NW of the 2MASS image.

only the counterparts with a maximum difference in position of 1.0 arcsec. Our aim is to use K-band magnitude from 2MASS (Skrutskie et al. 2006) to perform future photometric analysis. In order to do that we needed to perform a photometric calibration, which enable us to transform the instrumental magnitudes obtained from the PSF photometry into K-band magnitudes.

Firstly, using only the sample with the 2MASS counterparts, we implemented a filtering algorithm to exclude the sources with low quality K-band magnitude data (see Fig. 2 (b)). Subsequently, with this refined sub-sample, we conducted a linear regression between the K-band magnitude and the instrumental magnitude (see Fig. 2 (a)). The uncertainties associated with the linear fit were determined using the bootstrap algorithm

(Efron 1979), implemented within the R programming language. This methodology increased the number of sources with K-band magnitude (not detected by 2MASS) and extended the dataset by obtaining new measurements for sources that initially had low-quality.

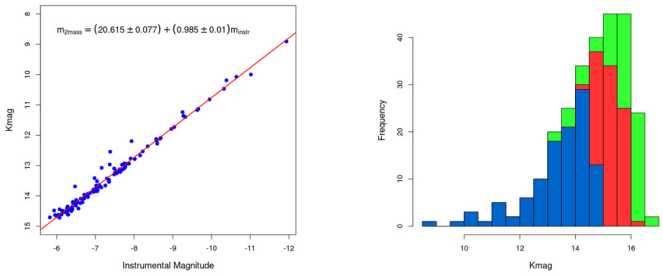

Figure 2. (a) Linear fit for K-band magnitude vs H2 Spartan decontaminated instrumental magnitude. (b) K-band magnitude histogram determined for 3 datasets. (Green): Full sample of sources with Spartan data (264 sources). (Red): Sample restricted to Spartan sources with 2MASS counterparts (195 sources). (Blue): After decontamination excluding 2MASS counterparts with low photometric quality (110 sources).

4. Cluster Membership

With the aim of determining important astrophysical parameters of the cluster, we conducted different astrometric analysis using the 5-dimensional data from the Gaia DR3 catalogue (Gaia Collaboration et al. 2023).

Firstly a Vector Point Diagram (VPD) was generated using all stars in the region aiming to select a set of stars within a 1.5 mas/yr range around the mean value of proper motion found for the cluster. Then, we generated histograms to determine the mean proper motion and parallax, along with their respective mean deviations (σ). The analysis of errors in proper motion is presented in Fig. 3, showing that stars defined as members have significantly smaller errors compared to stars that do not belong to the cluster. The error analysis was performed to establish the selection criteria adopted to define the cluster membership which consisted of: restricting the analysis to stars with parallax in the 0.412 mas to 1.286 mas range, if their proper motion are inside 2σ of the mean value found for the cluster, the stars were considered possible members. By adopting the fraction between parallax and parallax error as an indicator of "signal-to-noise ratio" (S/N), we defined sources with S/N >3 as "members", while those with S/N<3 were defined as candidates (see Fig. 4). The final sample consisted of 34 stars characterized as members and 12 as candidates.

5. Conclusion & Results

The methodology was effective and the final catalogue of members was validated by the error analysis performed.

The first result from this work was the new determination of K-band magnitude for 154 stars detected by Spartan . Secondly, we were able to determine the mean value for the cluster astrometric parameters (see Tab. 1). This values agree very well with data from (Santos-Silva et al. 2021).

Lastly, we created a catalogue of clusters members and candidates stars, consisting of the 2MASS and AllWise infra-red photometric data, the newly determined K-band magnitudes, the Gaia DR3 astrometric and photometric data and the magnitudes derived from the Spartan filters.

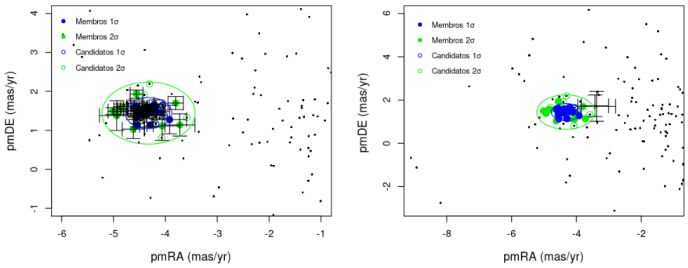

Figure 3. VDP of proper motion used to identify members of the cluster. In the left panel, the individual error bars show that all the selected members and candidates are well contained in the ellipse defined by 2σ of the mean value (green line), and most of than are inside the 1σ ellipse (blue line). The extended plot of the VDP (right panel) demonstrates that sources around the green ellipse could not be considered candidates due to their large error bars.

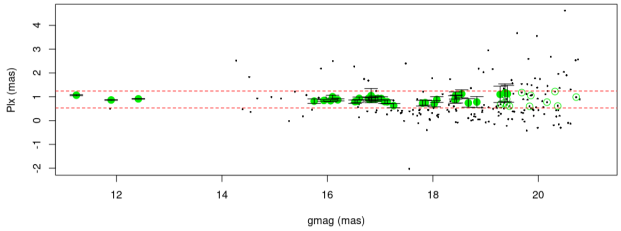

Figure 4. Error analysis perfomed on parallax with the 2σ set of stars from the VPD. The filled green circles represent the determined member stars and the open green circles represent the candidates.

Table 1. Mean values of the cluster astrometric parameters.

μ_α (mas/yr)	μ_δ (mas/yr)	ϖ (mas)
-4.47 ± 0.24	1.57 ± 0.16	0.875 ± 0.089

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