

# Characterization of embedded stellar clusters in the Sh2-296 nebula based on SOAR: SPARTAN and SAM data

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**Abstract.** Investigating the Canis Major R1/OB1 (CMa) association of young stars, distant about 1 kpc from the Solar System, has played a significant role in the study of star formation. The region is characterized by hundreds of B-type stars, some O-type stars, other emission nebulae and young star clusters immersed in dust and gas. This work aims the analysis of images of three of these clusters in the direction of the Seagull nebula (Sh2-296), a main component of CMa, focusing on the methodology used for detection and identification of members, also covering observations focused on the gas surrounding these clusters for studying the formation environment. Early results of the data analysis are presented, such as the detected sources and cross-match relations with 2MASS and GAIA DR3 for one of the clusters (HD 53456).

**Resumo.** A investigação da associação de estrelas jovens Canis Major R1/OB1 (CMa), distante por volta de 1 kpc do Sistema Solar, tem contribuído significativamente no estudo de formação estelar. A região é caracterizada por centenas de estrelas do tipo B, algumas estrelas tipo O, nebulosas de emissão e aglomerados estelares jovens imersos em poeira e gás. Este trabalho se refere à análise de imagens de três destes aglomerados na direção da Nebulosa da Gaivota (Sh2-296), com destaque à metodologia empregada para detecção e identificação de membros, abrangendo ainda observações do gás ao redor dos aglomerados para estudo dos ambientes de formação. Resultados iniciais da análise das imagens são apresentados, como as fontes detectadas e relações obtidas pelo cruzamento de catálogos 2MASS e GAIA DR3 para um dos aglomerados (HD 53456).

**Keywords.** Stars: formation – Stars: pre-main sequence – Techniques: photometric

## 1. Introduction

The Seagull Nebula is a research target with multiband literature indicating large structures with morphological links to events that triggered star formation in the region. The analysis of the spatial and kinematic distribution of gas clouds around the three target clusters seeks to contribute to understanding context and survey their history.

In particular, they are targets located on the inner edge of a bubble-shaped structure, or shell, with a diameter of approximately 60 pc, known as the “CMa Shell”, which refers to shock fronts of probable recent supernova events (Fernandes *et al.* 2019).

The objective of this paper is to describe the analysis of three clusters observed with the SOAR telescope by the SAM optical ( $R$ ,  $H\alpha$ ,  $[OIII]$  and  $[SII]$ ) and SPARTAN infrared ( $J$ ,  $H$ ,  $K$ ,  $H_2$ ,  $Br\gamma$  and  $Cont3$ ) modules, contributing to the census of the stellar population and characterization of its environment, searching for gas condensations, substructures and other elements linked to star formation in CMa.

## 2. Methodology

The SPARTAN infrared images are mainly used for identifying the stars in the field in order to build a reference catalog. Then, by combining different band images ( $J$ ,  $H$  and  $K$ ), color-color and color-magnitude diagrams can be elaborated in order to highlight star candidates for cluster membership. Parameters such as age and mass will be estimated by fitting PARSEC isochrones (Bressan *et al.* 2012). Once these stars are characterized, particular aspects of their emissions will be analyzed.

The star identification is done using the IDL software *starfinder*, which basically trains the searched PSF with some reference stars of the field. The list of found targets allows cross-

matching with other literature catalogs (2MASS, WISE, GAIA DR3). From these comparisons, a new multi-survey catalog was built so new color-color and color-magnitude diagrams of the clusters can be made, further characterizing its stars and properties. In order to do so, as SPARTAN and 2MASS cover on similar wavebands, a relation between the star sample on each survey is done for establishing a conversion expression, so it can extend the comparison to other reference catalogs based on 2MASS “corrected” values for the star’s brightness.

The cross-matching with the GAIA DR3 catalog allows for a cinematic study, contributing to the search for clustering patterns. Maps of position and proper motion were done to search for the stars members of the cluster and possible candidates.

With optical images from SAM, the main target is the emission surrounding the stars, which can be used to observe the diffuse gas distribution of the star’s nest in order to study the environment conditions and its relations with the member stars themselves. The observations with narrow filters  $H\alpha$ ,  $[OIII]$  and  $[SII]$  allow inferring ionization aspects of the gas by interpreting the ratios between the emission intensity of those lines, working as a tool to analyze virial conditions of the cluster. This procedure is described in Loh *et al.* (2011).

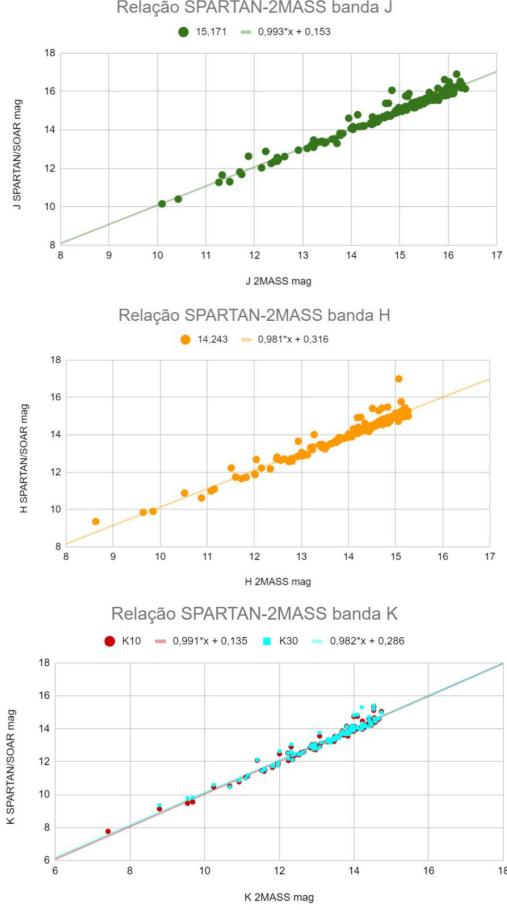
## 3. Preliminary results

In Tab. 1, each cluster is identified by the main object of the image field, showing its coordinates and the number of sources detected using *starfinder*.

The first cluster chosen for cross-match with other surveys was HD 53456. There were 246 sources with 2MASS counterparts. For establishing photometric correlation, the sample of SPARTAN sources with detection in the six filters and their 2MASS counterparts with the best acquisition quality was selected. Then, a linear fit was performed to find the magnitude

**TABLE 1.** Clusters identification with number of detected H band sources in the image field (for G224.36-01.90 the source number refers to the R band, as this field was only observed in optical).

ID	$\alpha, \delta$ (J2000)	$l, b$ ( $^\circ$ )	N $^\circ$ sources
HD 53456	07:04:38, -11:31:27	224.69, -2.34	619
G224.36-01.90	07:05:39, -11:01:36	224.36, -1.90	240
G224.28-00.82	07:09:21, -10:28:29	224.28, -0.82	215



**FIGURE 1.** Linear fit for conversion of SPARTAN J, H and K magnitudes for the 2MASS reference system.

conversion between the catalogs for each band, in order to extend 2MASS magnitude values to the SPARTAN sources without counterparts. These relations are shown in Fig. 1.

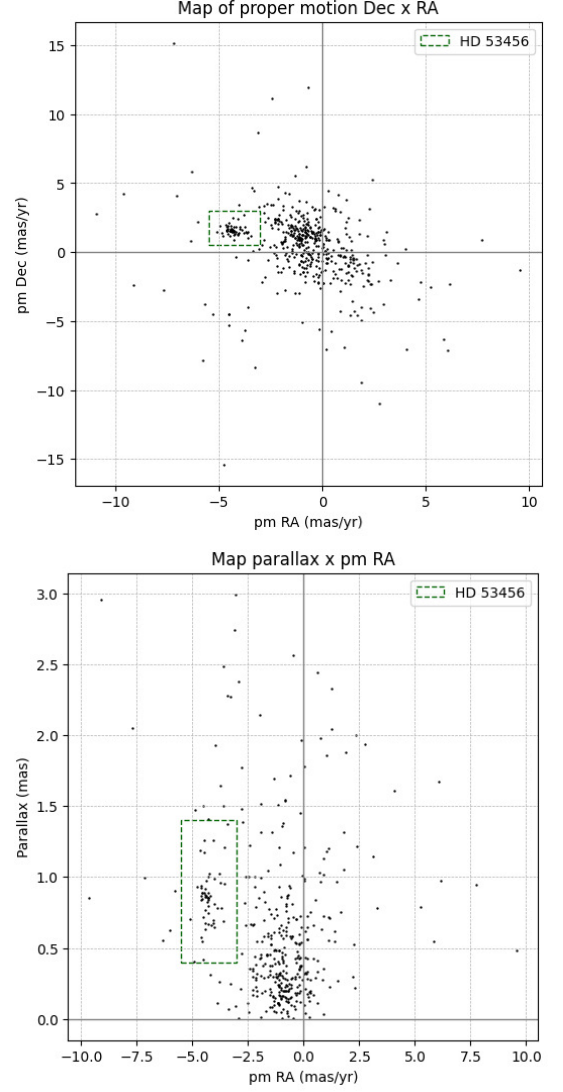
The search for Gaia counterparts provided 409 objects for kinematic analysis. The preliminary results are shown in Fig. 2. We are currently working on the selection criteria for refining the sample and estimate the cluster membership.

For the other two clusters, the search for counterparts in WISE, Gaia DR3 and 2MASS catalogues is ongoing. The same relations done for 2MASS magnitude conversion in HD 53456 are going to be executed for consistency check.

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## References

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**FIGURE 2.** Distribution of Gaia DR3 counterparts in parallax and proper motion for the field of the star HD 53456, narrowing the cluster of interest.

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