# Open binaries search in the Southern Celestial Hemisphere using $SPM4$

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## 1. Introduction

Open binaries' weak gravitational binding makes them vulnerable to any perturbation, turning them into excellent probes of the gravitational field where they are located. Currently there are only a few hundreds of known or suspected open binaries, therefore a search for more of these systems is highly encouraging by looking for pairs of stars with common proper motions in an extensive, deep and high quality astrometric catalog as $SPM4$. Results presented here are part of an initial evaluation of $SPM4$'s capability to detect open binaries.

By searching within $SPM4$ for a list of known open binaries candidates in the galactic halo taken from [1], we found this catalog can easily detect open binaries with apparent separations in the sky above 10" and both components brighter than magnitude $V = 13$. Therefore, it is possible to obtain a large list of open binaries candidates all over the southern hemisphere from $SPM4$. Since $SPM4$ does not have parallaxes to convert the observed angular separation into a physical separation between the candidate binaries, it is imperative to use other observables as apparent magnitudes and colours, to make an assessment of the distance to each binary. Additional information like spectral type and radial velocity can also help to judge if the candidate open binaries are real or just the result of an apparent alignment. In this sense and as a first step, we have used the Besançon Model [2] of the Galaxy to identify and characterize the various populations of the Milky Way as observed in colour-magnitude and colour-colour diagrams. Results obtained so far show that the observed sequences in these diagrams follow trends in stellar surface gravity (therefore luminosity class) and distance, and therefore it is possible to broadly estimate such values from them.

## 2. Common proper motions to find open binaries

The main tool used to find open binaries is common proper motions. This is based on the fact that the stars in such system have a much smaller velocity within their internal orbit due to their large physical separation as compared to the center-of-mass motion of the system in the field. Therefore the observed proper motion of each component star is dominated by the center-of-mass velocity, which is common to both.

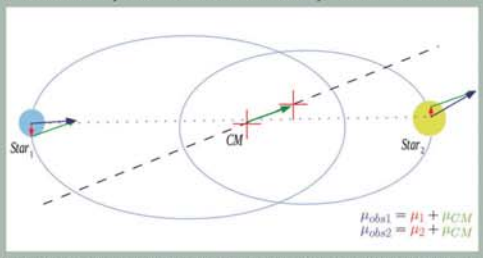


**Figure 1:** *Components of an open binary system sharing a common proper motion $\mu_{obs}$ (blue vector) dominated by the center-of-masss motion $\mu_{CM}$ (green vector).*

## 3. Evaluation of $SPM4$'s capability to detect open binaries

An initial evaluation was done of the capability of $SPM4$ catalog to detect already known and characterised open binaries taken from [1]. This list of candidates located in the galactic halo has 241 systems (10 of them triple), with all but two primaries identified in the New Luyten Two Tenths (NLTT) catalogue. The secondaries have identifiers from several sources including some from catalogues Giclas (G), Bonner Durchmusterung (BD), Luyten Palomar (LP), etc., and all were verified against the SIMBAD database to search for their NLTT identifier if available. For most of these stars we were able to obtain an NLTT id and we also took this chance to fix some typos in the table. This study was limited to the 239 systems with NLTT primaries, of which only 44 are within the $SPM4$ coverage area in the sky.

$$\begin{array}{l} 42 \text{ double} \\ +2 \text{ triple systems in } SPM4 \end{array} \Longrightarrow \begin{cases} \text{Caso 0:} & 10 \text{ double systems} \times 1 \star = 0 \star \\ \text{Caso 1:} & \begin{cases} 24 \text{ double systems} \times 1 \star = 24 \star \\ 1 \text{ triple systems} \times 1 \star = 1 \star \end{cases} \\ \text{Caso 2:} & \begin{cases} 8 \text{ double systems} \times 2 \star = 16 \star \\ 1 \text{ triple systems} \times 3 \star = 3 \star \end{cases} \end{cases}$$

The results, represented by the above cases, is illustrated in figures 2, 3 y 4. Each shows a small area in the sky in (RA,DEC) coordinates where the $SPM4$ and the primary NLTT stars are located. Vectors and open circles sizes represent proper motion and magnitudes, respectively, of each star.

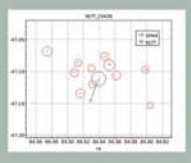

**Figure 2:** *Case 0: no component of the open binary is detected*

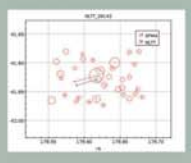

**Figure 3:** *Case 1: only one component of the open binary is detected*

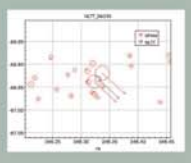

**Figure 4:** *Case 2: all components of the open binary are detected*

We conclude that $SPM4$ can detect open binaries more efficiently at apparent angular separations over 10" and with both components brighter than magnitude $V = 13$. Due to $SPM4$'s $V = 17.5$ limiting magnitude, detection was less efficient for open binaries where the apparent magnitude of one or both components was faint.

## 4. Photometric analysis

Common proper motion is not enough to assure the physical binarity of the chosen candidates. Additional information like distance (or other data like spectral type etc. to estimate it) or radial velocity of the components, allow to gauge better their condition of being a real physical binary. $SPM4$ does not offer such information, nonetheless we can estimate ranges of luminosity class (e.g. dwarfs vs giants) and distance to selected populations of the Galaxy, from colour-magnitude and colour-colour diagrams. This apparent drawback on the other hand could be turned around to search possible effects of the gravitational field of each selected population on the physical separation of open binaries.

To identify these populations in $SPM4$, we studied their (J,J-K) colour-magnitude diagrams in 19 one-square-degree fields located strategically along different galactic longitudes and latitudes. These diagrams showed clear sequences that were more notable towards the galactic plane. Figure 5 shows results from one field at the disk.

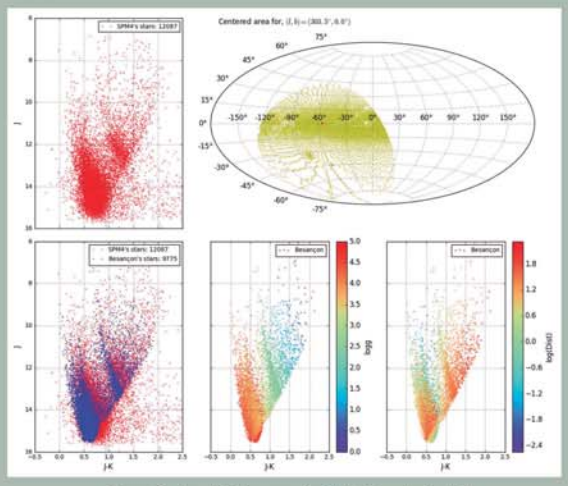

**Figure 5:** *J vs. J-K diagram of a field in the galactic disk*

To identify what population correspond to each observed sequence, we simulated the same fields with the Besançon Model of the Galaxy. After comparison we noted that:

- Most stars belong the disk and have ages of 2-10 Gigayears.
- Simulated data fit well the real stars, except for extinction effects which were not explicitly included in the simulation. As a result, when compared to $SPM4$, the simulation has more stars at fainter magnitudes and in general, simulated stars are bluer than the observed ones.
- Observed sequences are directly related to the stellar surface gravity. The bluer sequence corresponds to dwarf stars with high values of $log(g)$, while the redder one corresponds to giant stars with low $log(g)$.
- As for distance distribution, it is possible to estimate ranges of values according to the star's position in the colour-magnitude diagram, especially for giant stars and the brighter dwarfs, while this is more complicated for faint dwarfs.

We conclude from this analysis that by using colour-magnitude diagrams we can make a good guess of luminosity class and distance to our open binaries candidates selected by proper motion, for stars brighter than $J = 13$. This study was performed in infrared magnitudes $JHK$ (from 2MASS) which are of better quality than the optical BV measured by $SPM4$.

## 5. Conclusion and next steps

- Astrometric catalogue $SPM4$ has properties that make it a good source of open binaries candidates selected by common proper motion.
- Such capability is limited to bright stars mainly. On the other hand proper motions of faint stars have higher errors which make them unsuitable for the proposed search. Despite this limitation, the large area on the sky covered by $SPM4$ will allow us to increase significantly the number of open binaries candidates.
- For each open binary candidate obtained from $SPM4$, we will cross-match its components with the SIMBAD and the Virtual Observatory databases, to obtain as much additional information as possible, that can be used to ascertain the physical binarity of the candidate.
- It is of the uttermost importance to quantify of many possible false candidates can be generated by this search. In this regard, the next step in to perform an statistical estimate that allows us to infer the fraction of false binaries in the final list.

## References

[1] Christine Allen and Miguel A. Monroy-Rodríguez. An improved catalog of halo wide binary candidates. *The Astrophysical Journal*, 790(2):158, 2014.

[2] A. C. Robin, C. Reylé, S. Derrière, and S. Picaud. A synthetic view on structure and evolution of the Milky Way. *Astronomy & Astrophysics*, 409:523–540, oct 2003.

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