SEARCH FOR NEW SINGLE-LINED BINARY SYSTEM (SB1) CANDIDATES USING GAIA DR3 AND GALAH DR3 DATA

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Stars, essential to our understanding of the universe, often exist in binary systems, where two stars orbit each other. Among these, single-lined spectroscopic binaries (SB1) involve one star that cannot be directly seen, and is instead identified through periodic Doppler shifts in the spectrum of its companion. This paper cross-matches Gaia Data Release 3 (Gaia DR3) spectroscopic data with GALAH Data Release 3 (GALAH DR3) spectroscopic data (note that at the time of this study, DR4 was not yet publicly available) to identify potential SB1 candidates. From GALAH, 34 631 objects with more than one radial velocity (RV) measurement are selected, resulting in 9 148 SB1 candidates. When data from the Gaia DR3 catalog are incorporated, the number of objects increases to 502 377, and the number of SB1 candidates rises to 35 537. However, Gaia provides only a single additional RV measurement per star, which limits the number of newly identifiable SB1 systems. Still, this represents the largest catalog of SB1 candidates to date. Based on the data, it is clear that a significant portion of stars are likely SB1 candidates, but precise measurements are necessary for accurate identification. By analyzing key parameters like mass, temperature, luminosity, surface gravity and chemical composition, the study aims to better understand the properties and dynamics of these systems.

ISKANJE NOVIH KANDIDATOV ZA DVOJNE ZVEZDE Z ENO SPEKTRALNO ČRTO (SB1) Z UPORABO PODATKOV IZ KATALOGOV GAIA DR3 IN GALAH DR3

Zvezde, ki so ključne za naše razumevanje vesolja, pogosto sestavljajo dvojne sisteme, kjer dve zvezdi krožita druga okoli druge. Del dvojnic predstavljajo spektroskopski dvojni sistemi z eno samo spektralno črto (SB1), pri katerih ene zvezde ni mogoče neposredno opazovati, temveč jo prepoznamo prek periodičnih Dopplerjevih premikov v spektru njene spremljevalke. V članku so spektroskopski podatki kataloga Gaia Data Release 3 (Gaia DR3) primerjani s spektroskopskimi podatki GALAH Data Release 3 (GALAH DR3) (v času te raziskave izdaja DR4 še ni bila javno dostopna) z namenom identifikacije potencialnih kandidatov za SB1. Iz nabora GALAH je izbranih 34 631 objektov z več kot eno meritvijo radialne hitrosti (RV), kar privede do 9 148 kandidatov za SB1. Ob vključitvi podatkov iz kataloga Gaia DR3 se število objektov poveča na 502 377, število kandidatov za SB1 pa naraste na 35 537. Gaia poda le eno meritev RV, tako da je število novih kandidatov omejeno. Vseeno je to doslej največji katalog kandidatov za SB1. Na podlagi podatkov je razvidno, da nezanemarljiv delež zvezd predstavlja kandidate za SB1, vendar so za zanesljivo identifikacijo potrebne natančnejše meritve. Z analizo ključnih parametrov, kot so masa, temperatura, izsev, površinska gravitacija in kemijska sestava, si študija prizadeva bolje razumeti lastnosti in dinamiko teh sistemov.

1. Introduction to stars

Stars are the luminous building blocks of the universe, transforming hydrogen into helium through nuclear fusion and releasing immense amounts of energy in the process. They range vastly in size, temperature, luminosity and lifespan, with their diversity governed by fundamental properties such as mass, chemical composition and age. Stars are classified using the Morgan-Keenan (MK) spectral classification system, ranging from hot and massive O-type stars to cool and dim M-type stars.

A star's life cycle is dictated by the balance between gravity and the outward pressure of fusion-generated radiation. This equilibrium drives phases of stellar evolution, from the protostar stage to eventual outcomes like white dwarfs, neutron stars or black holes, depending primarily on its initial mass. These objects not only illuminate the universe but also enrich it with heavy elements synthesized in their cores.

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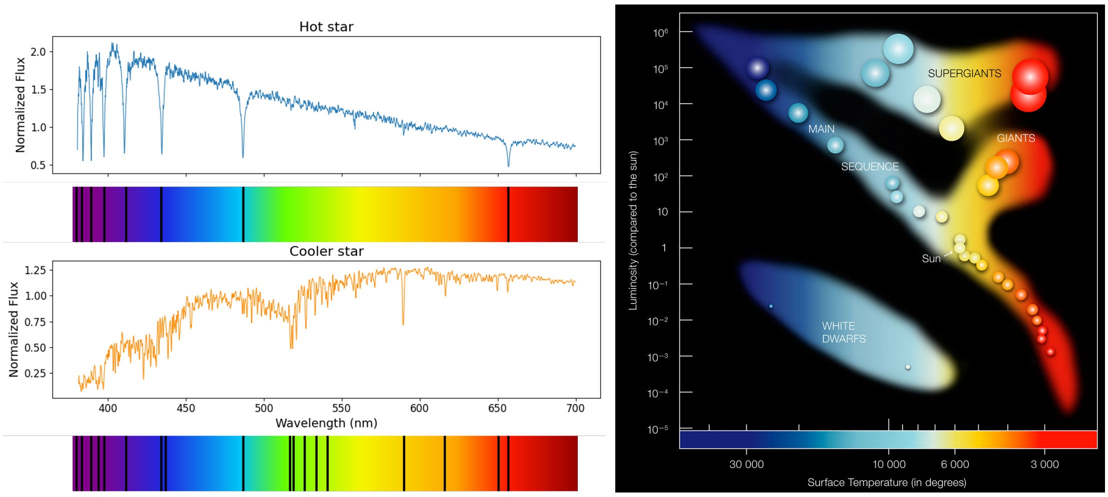

Figure 1. *Left:* the spectrum of a star is, to a first approximation, the Planck spectrum of blackbody radiation. A hotter star (above) emits more radiation at shorter wavelengths, while a cooler star (below) emits light predominantly at longer wavelengths. Superimposed on this continuous spectrum are absorption lines, which differ between different stars depending on their temperature, composition, and atmospheric conditions. Image produced from SDSS spectra [1]. *Right:* the Hertzsprung–Russell (HR) diagram represents the luminosity of stars as a function of their color or effective temperature. Stars distribute into distinct groups: most stars align along the diagonal main sequence, giant and supergiant stars appear in the upper-right and white dwarfs are located in the lower-left. Source: ESO [2].

1.1 Physical properties

Stars, which can be approximated as black bodies, emit light across a spectrum described by the Planck law of black body radiation. This spectrum is determined by the star's surface temperature, with hotter stars emitting more energy at shorter wavelengths (blue), and cooler stars emitting more at longer wavelengths (red) (Figure 1, left). Spectral lines, formed by the absorption of specific wavelengths of light by elements in the star's outer layers, further provide unique chemical fingerprints. The depth and shape of these lines reveal details about the abundance of elements and surface temperature. Additionally, line broadening, caused by effects like pressure, rotation, or turbulence, provides insights into the star's dynamics. The Doppler shift of spectral lines enables the measurement of a star's radial velocity — its motion toward or away from us. This is essential for studying binary systems, exoplanet detection, and mapping galactic motions.

The Hertzsprung-Russell (HR) diagram is useful tool for classifying stars based on their luminosity and surface temperature, highlighting their evolutionary stages. Figure 1 (right) illustrates the distinct groups of stars distributed on the HR diagram. Most stars lie along the main sequence, where their position reflects a balance between gravity and nuclear fusion. Giants and supergiants, which are typically cooler but more luminous, represent later evolutionary stages, while white dwarfs are compact, hot remnants of stellar cores. Source: [3].

The mass-luminosity relation describes how the luminosity of a star depends on its mass, stating that for main-sequence stars, luminosity (L) is approximately proportional to a power of the mass (M), often expressed as $L \propto M^n$, with n typically around 3.8 [4] for stars similar to the Sun, as determined empirically from observations of stellar populations. However, the value varies for stars of different masses. This relation highlights that more massive stars are much brighter than their less massive counterparts.

1.2 Binary and multiple star systems

Many stars are part of binary systems or even multiple star systems, where two or more stars orbit a common center of mass due to their gravitational interaction. Binary systems are incredibly common, comprising more than half of all stellar systems in the Milky Way. They range from wide binaries, with stars far apart, to close binaries that interact through mass transfer. Studying binaries provides vital insights into stellar masses, evolution, and dynamics, since the orbital motion of binary stars allows direct determination of stellar masses through Kepler's laws and radial velocity measurements, which can then be compared with theoretical models. This in turn helps us understand how stars evolve, enrich the interstellar medium, and shape the structure and formation of galaxies and the universe.

Depending on the system's intrinsic and extrinsic factors, such as orbital radius, orbital period, stellar radii, orientation relative to Earth (inclination) and the observational method used, binary stars can be categorized into distinct types: visual binaries, eclipsing binaries, spectroscopic binaries, and astrometric binaries. Each type offers unique observational opportunities and scientific insights.

Visual binaries are systems where both stars can be resolved as distinct points of light through telescopes. These binaries have wide angular separations, making them suitable for direct observation. This means the orbital period must be very long, which requires prolonged observations. The stars also need to be relatively close to us for the angular separation to be measurable. Consequently, this method is effective only for the stars in our neighborhood, although the limits are being pushed with better telescopes. By tracking their orbital motion over time, astronomers can calculate their orbital parameters, including the semi-major axis and period. Measuring the angular separation and distance to the system allows the determination of the true physical separation, which is critical for calculation of the masses of the components.

Eclipsing binaries occur when the orbital plane of two stars is aligned with the observer's line of sight, causing one star to periodically block the light of the other. This creates a distinctive light curve with dips in brightness (eclipses), from which astronomers can determine key parameters such as stellar radii[1], orbital inclination[2], and period[3]. By combining photometric and spectroscopic data, it is also possible to measure the stars' temperatures. Eclipsing binaries are particularly valuable because they allow for direct measurement of stellar radii, which are difficult to obtain for single stars. However, because of the precise alignment needed, only a small percentage of binary star systems are detected as eclipsing binaries. The detection is further complicated by the fact that the duration of the eclipse is much shorter than the total orbital period of the stars, meaning that for most of the time, the stars do not overlap and the eclipse is not observed. Source: [4].

Spectroscopic binaries are stellar systems identified through periodic Doppler shifts in their spectral lines, which occur as a result of the orbital motion of the stars. These shifts, manifesting as periodic variations in the wavelengths of light emitted by the stars, allow astronomers to detect the movement of the stars. By analyzing the amplitude and periodicity of these shifts, astronomers can determine the radial velocities of the stars and consequently estimate their masses and orbital radii, although the precise masses require knowledge of the orbital inclination. Spectroscopic observations are particularly crucial for detecting close binary systems where the stars are too close to be resolved by direct imaging. An advantage of spectroscopic binaries is also that the detection does not require the orbital plane to be precisely aligned with our line of sight, as is the case with eclipsing binaries. This allows spectroscopic binaries to be observed even when the system's orientation is not ideal for an eclipse (though systems oriented nearly face-on still produce very small radial velocity shifts, making them difficult to detect). As a result, spectroscopic binaries can be identified across a wider range of orbital configurations. Source: [4].

[1] Stellar radius is defined as the distance from star's center to its surface – the point where the star becomes optically thin and the majority of its light escapes freely into space.

[2] The inclination of a binary star is the angle between the normal vector to the orbital plane and the direction of our line of sight.

[3] The orbital period of a binary system is the time it takes for the two stars to complete one full orbit around their common center of mass.

Astrometric binaries are systems in which the presence of an invisible companion is detected by observing the periodic wobble in the motion of a visible star. This wobble occurs because the unseen companion, which could be another normal star or a compact object such as a white dwarf, neutron star or black hole, exerts a gravitational pull on the visible star. As a result, the visible star's motion deviates from a straight path, revealing the presence of the unseen object. This type of binary system is challenging to detect using other methods since the companion does not emit light that can be directly observed, especially if viewed face-on.

1.3 Spectroscopic binary stars

Spectroscopic binaries can be classified into two main types based on the number of components whose spectral lines are observable. These are single-lined spectroscopic binaries (SB1) and double-lined spectroscopic binaries (SB2).

SB2 systems are a type of spectroscopic binary in which the spectral lines of both stars are observable, meaning that the periodic Doppler shifts in the light emitted from both components can be detected. This allows astronomers to directly measure the radial velocities of both stars, which provides more detailed information about the binary system, including the relative motion of the stars and their orbital parameters. SB2 systems are particularly valuable for studying binaries with more equal mass components, as both stars are visible and their motions can be measured. However, SB2 systems can be challenging to study, as they require distinguishing the spectral lines of both stars, which may be more complicated when the stars have similar spectral features.

In contrast, in SB1 systems, only the spectral lines of one star are detectable, typically because it is much brighter than its companion. The presence of the unseen companion is revealed through periodic Doppler shifts in the visible star's spectrum, allowing astronomers to study the system's dynamics and estimate the companion's mass even when it contributes little to the system's light.

This study will focus on the search and detection of SB1 binaries through observations combining different sky surveys.

2. Gaia and GALAH observations

The Gaia[4] mission, launched by the European Space Agency (ESA) in December 2013, is a groundbreaking space observatory dedicated to mapping the Milky Way galaxy with unparalleled precision. Equipped with two 1.45 m $\times$ 0.5 m aperture telescopes, Gaia is designed to capture images of billions of stars, as well as other celestial objects. The telescope features three main systems: an astrometry instrument, a broadband photometric instrument, and a radial-velocity spectrometer, which are essential for measuring the positions, distances, velocities, and physical properties of stars. The radial velocity spectrometer collects medium-resolution spectra (resolving power R $\simeq$ 11 500) in the near-infrared wavelength range of 845–872 nm, primarily targeting the calcium triplet absorption features (Ca II) used for Doppler-shift measurements. This enables measurements of stellar radial velocities, detection of spectroscopic binaries, and estimation of basic stellar parameters such as effective temperature and surface gravity. Gaia's astrometric measurements have an accuracy of a few tens of microarcseconds [5], enabling the detection of very small angular motions of stars. It is equipped with a large camera with almost 1 billion pixels spread across 106 charge-coupled device (CCD) detectors, arranged in a two-dimensional array. This configuration allows Gaia to capture high-resolution images of a large portion of the sky and thus many stars simultaneously. Source: [6].

[4] Initially, GAIA was an acronym for Global Astrometric Interferometer for Astrophysics. However, as the mission design evolved, it moved away from using interferometry as its core technology. Despite the technical changes, the name was kept for continuity, though it is now written in lowercase as Gaia.

The Gaia satellite is positioned in a unique orbit around the second Lagrange point (L2) of the Earth-Sun system, located about 1.5 million kilometers from Earth. This location provides a stable environment for continuous observations, as it allows the spacecraft to remain in line with Earth and the Sun, ensuring minimal interference from both.

The data Gaia provides is revolutionizing our understanding of the universe by allowing astronomers to probe the structure and evolution of our Galaxy and expanding our knowledge about stellar populations, stellar dynamics, star formation and thus contributing significantly to many fields of astrophysics. Gaia Data Release 3 (Gaia DR3), released on June 13, 2022, provides astrometric solutions for around 1.46 billion sources, including positions, parallax, and proper motion. Additionally, photometric data for 1.8 billion sources was made available. Source: [7].

Gaia's radial velocity data is useful for detecting SB1 binaries as it measures the radial motion of the visible star. However, a limitation is that, for now, Gaia publicly provides only one measurement per star, which requires additional observations. Detection of SB1 systems is still possible by combining Gaia's radial velocities with measurements from other surveys, such as GALAH, to reveal periodic Doppler shifts.

The GALAH survey (Galactic Archaeology with HERMES)[5] is an ongoing large-scale spectroscopic survey that aims to map the Milky Way's stellar population in great detail. It uses the HERMES spectrograph (High Efficiency and Resolution Multi-Element Spectrograph), installed at the 3.1-meter Anglo-Australian Telescope (AAT), located at the Siding Spring Observatory in New South Wales, Australia. The survey is primarily focused on studying the chemical composition, kinematics, and ages of stars across our Galaxy, which, in turn, helps to reconstruct the history and evolution of the Milky Way. HERMES is a four channel fiber-fed spectrograph with four channels covering blue, green, red, and infrared ranges, each around 20–30 nm wide. It can simultaneously acquire up to 392 spectra across a two-degree field, enabling the survey to measure a vast array of stellar parameters, such as metallicity, temperature, and elemental abundances for nearly a million stars [8]. Through these observations, the GALAH survey provides essential data for understanding the formation of stars, stellar clusters, and the structure of the Galaxy. The survey's comprehensive data set allows for a deeper exploration of galactic archaeology, tracing the processes that led to the current configuration of the Milky Way.

The Third Data Release (DR3) of the GALAH survey (note, at the time of this study, DR4 was not yet publicly available) includes one-dimensional spectra, stellar atmospheric parameters, and elemental abundances for 678 423 spectra of 588 571 nearby stars, observed at the ATT from November 2013 to February 2019. I use this spectra to get additional and possibly multiple radial velocity measurements of stars [9]. The later release of DR4, which includes a larger sample and additional observations, would likely increase the number of detectable SB1 candidates.

The GALAH survey measures radial velocities (RV) with significantly higher precision than the Gaia mission, achieving accuracies of around 0.1 km/s compared to Gaia's typical uncertainties of 1–2 km/s for bright stars.

3. The method

In order to identify SB1 candidates we need to compare multiple radial velocity (from now on RV) measurements of their brighter components. If these velocities exhibit significant variation over time, it is highly likely that the system is an SB1 binary, although other causes for such variations cannot just be ruled out.

[5]The GALAH survey's name stands for GALactic Archaeology with HERMES, reflecting its focus on unraveling the Milky Way's formation history through stellar spectroscopy. It also nods to the Galah, an iconic Australian cockatoo, linking the project to its Australian origins.

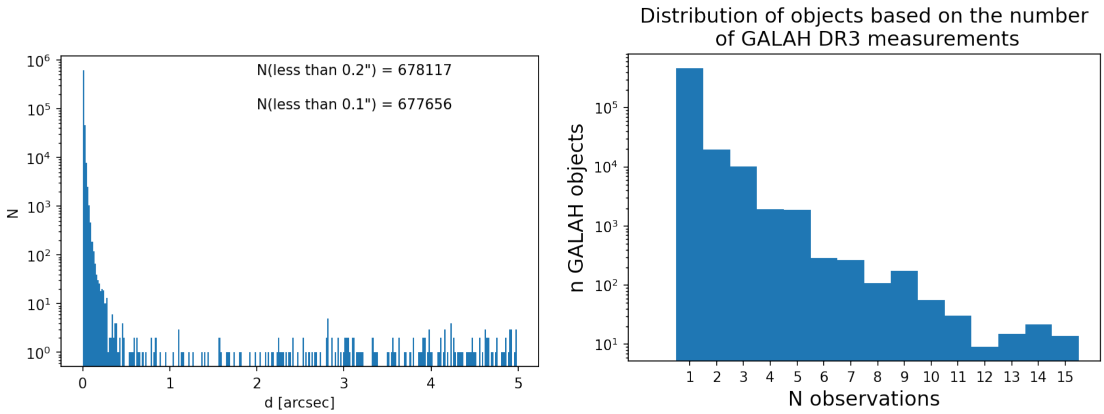

Figure 2. *Left:* The histogram shows the number of GALAH DR3 measurements in relation to the angular distance of the nearest match from Gaia DR3. Most measurements (678 117) deviate by less than 0.2 arcseconds, which I have taken as the acceptable limit. *Right:* Our final sample includes 502 377 distinct objects. Each object has one Gaia DR3 measurement and one or more GALAH DR3 measurements of radial velocity (RV). The histogram shows the distribution of objects in our sample based on the number of RV measurements available from GALAH.

The GALAH DR3 catalog [10] provides 678 423 spectra for 588 571 distinct stars, which means that some stars have multiple measurements, while many have only a single observation. To enhance the dataset, I combine the GALAH DR3 measurements with those from the Gaia DR3 catalog [11]. This way, we add an additional measurement for each object. This cross-match is achieved using the X-Match service [12], which matches the corresponding observations with both sky surveys based on the precise celestial coordinates of the stars.

I set X-Match service to return all Gaia DR3 objects within an angular separation of 2 arcsec for each object in the GALAH DR3 catalog. For each measurement, I select only the nearest object if it lies within an angular distance of 0.2 arcsec. Otherwise, as a precaution, I establish that the cross-match has failed and discard the object. As shown in Figure 2 (left), we get 678 117 good matches, which means that we lost 306 data points or 0.045 % of all measurements. Now we can group multiple data points with the same Gaia DR3 match. This leaves us with 541 808 stars with a single GALAH DR3 measurement and a single Gaia DR3 measurement, 25 008 stars with two GALAH DR3 measurements, 14 155 with three and 7 999 with four or more.

Of course, we should not just blindly believe every RV measurement. GALAH DR3 provides various flags to indicate potential issues (more explained in [13]), and I proactively remove all objects marked with the following flags: 8, 32, 64, and 512. Flag 8 indicates issues with data reduction for the spectrum, resulting in incorrect velocity measurements. Flags 32 and 64 correspond to SB2 (double-lined spectroscopic binary) stars, while flag 512 denotes that the multi-parameter fitting process failed to converge. Doing this results in further reduction of sample size to final 502 377 objects; 467 746 with a single GALAH DR3 measurement, 19 640 stars with two, 10 230 with three and 4 761 with four or more (Figure 2, right). In the end we are left with 85.36 % of initial star sample, each object with total of 2 to 16 measurements (GALAH DR3 and Gaia DR3 combined).

We now need to identify potential SB1 candidates by comparing multiple RV measurements. Ideally, we would have enough data points to search for periodicity, but with only 2 to 16 measurements, this is not possible. Consequently, I focus on detecting significant deviations between measurements to infer changes in velocity.

From the Matijevič et al. (2012) [14], one can derive the probability that the second radial velocity RV_2 is greater than the first RV_1, based on the measurements and their associated uncertainties. The equation

$$P(2 > 1) = \frac{1}{2}\left[1 + \text{erf}\left(\frac{\text{RV}_2 - \text{RV}_1}{\sqrt{2(\sigma_1^2 + \sigma_2^2)}}\right)\right], \quad (1)$$

used for this calculation was already developed in Birko et al. (2019) [15]. RV_1 and RV_2 represent two radial velocities for the same star, while σ_1 and σ_2 are their respective uncertainties. Error function in denoted by erf. For objects with very significant RV variability, P value can be very close to 1, therefore it is better to introduce a logarithm

$$p_{\log} = -\log_{10}(1 - P).$$

Probability $p_{\log} < 1$ implies RV differences smaller than $1.8\,\sigma_i$ and $p_{\log} < 2$ corresponds to RV values less than $3.3\,\sigma_i$ apart. Pourbaix et al. (2005) [16] use $p_{\log} = 2.87$ as a lower limit for RV variability detection, which corresponds to RV values that are $4.24\,\sigma_i$ apart. Similarly to Birko et al. (2019) [15], I use this value as a threshold. When more than two measurements are available, $p_{\log}$ is calculated for each pair of measurements, and the maximum value is taken as the probability. We note that this simple pairwise method may be sensitive to individual large (possibly erroneous) measurements and does not fully account for all measurement uncertainties; more sophisticated approaches such as global modeling with MCMC could be explored in future work.

4. SB1 candidates from GALAH DR3 data only

First, I identify candidates for SB1 based solely on the GALAH DR3 data. By applying the lower detection limit of $p_{\log} = 2.87$, I obtain 9 148 potential SB1 candidates (Table 1). GALAH has made more than one measurement on 34 631 different objects, which means that 26.42 % of all observed objects are strong candidates for SB1 binary star systems (Figure 3). Of course, these candidates may include some other objects, although they have been largely excluded when checking for important flags. According to Birko et al. (2019) [15], very few false positives were encountered during this selection.

5. SB1 candidates from combined GALAH and Gaia data

In combination with Gaia RV measurements, I obtain 502 377 distinct objects, which is 14.5 times more than from the GALAH DR3 data alone. Using the combined data, I get 35 537 (7.2 % of all measurements) SB1 candidates with $p_{\log} > 2.87$, which is less than four times more than from using GALAH data alone (Table 1). This means that the proportion of detected SB1 candidates has significantly decreased. Since GALAH selects stars randomly and avoids any biases, the reason lies elsewhere. The radial velocity measurements made by Gaia, on average, have nearly 10 times larger errors (Figure 4) and thus contribute significanty less compared to the GALAH measurements. The calculated value of $p_{\log}$ is strongly influenced by the measurement errors, and in many cases, Gaia data is simply not precise enough to provide reliable RV measurements.

6. Analysis of stellar parameters

With spectral fitting, GALAH and Gaia determine many stellar properties: mass, surface temperature, luminosity, abundance of heavier elements, and many others. Now we can analyze our set of SB1 candidates and compare their data to those of the full set of observed stars. Figure 6 shows the distributions of six different parameters. There are two peaks in the temperature distribution: one for sun-like dwarfs (on the right) and another for red giants (on the left). Sun-like stars are slightly underrepresented among SB1 candidates, while both hotter and unexpectedly colder stars are more

Table 1. Number and fraction of SB1 candidates for different values of $p_{\log}$. Similar to Matijevič et al. (2012) [14], I use $p_{\log} = 2.87$ as the detection threshold. The top row shows candidates based solely on GALAH DR3 data, while the bottom row displays candidates based on the combined GALAH DR3 and Gaia DR3 data. When I add Gaia data, I obtain 14.5 times more objects, but the number of candidates is only about four times larger. This is due to the significantly larger errors in the radial velocity measurements from Gaia in comparison to GALAH.

	$p_{\log} > 2.87$		$p_{\log} > 4$		$p_{\log} > 6$	
	N	%	N	%	N	%
GALAH	9 148	26.4	7 088	20.5	5 371	15.5
GALAH + Gaia	35 537	7.2	25 712	5.2	17 522	3.6

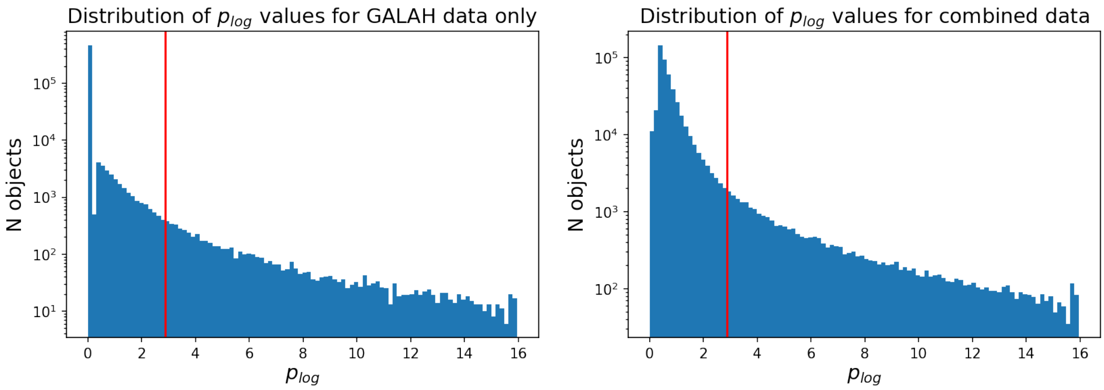

Figure 3. *Left:* Out of the 34 631 objects with at least two GALAH measurements, 9 148 have a $p_{\log} > 2.87$ (red line). The histogram shows the distribution of $p_{\log}$ values, calculated only from GALAH DR3 data. *Right:* out of the 502 377 objects, 35 537 have a $p_{\log} > 2.87$ (red line). The histogram shows the distribution of $p_{\log}$ values, calculated from combined GALAH DR3 and Gaia DR3 data.

abundant. The higher fraction of hotter stars makes sense because they are brighter and more likely to hide a weaker companion. In the surface gravity distribution, we can observe an excess of stars with greater mass. Since higher mass typically corresponds to higher luminosity, this can be explained by the fact that more massive stars are brighter and more easily detectable and their higher luminosity helps them mask the weaker signal of a companion star. It is also generaly known that more massive stars are more likely to be in a binary system than less massive stars. SB1 candidates tend to have, on average, lower metallicity compared to the overall stellar population because the spectral signal of the companion star is superimposed on the spectrum, reducing the relative depth of absorption lines, which is interpreted as a lower metallicity measurement. SB1 candidates are often somewhat more massive and luminous, which is again explained by the fact that more massive stars are more often in a binary system. It is often useful to also examine correlations between different star parameters. In Section 1.1, we already encountered the HR diagram, which shows the relationship between effective temperature T_{eff} and bolometric luminosity L_{bol}. A similar diagram is the Kiel diagram, which shows the correlation between effective temperature T_{eff} and surface gravity $\log g$ for a set of stars. Surface gravity is important because it reflects a star's size relative to its mass, allowing us to distinguish evolutionary stages: stars with similar temperatures can have very different $\log g$ values depending on whether they are main-sequence dwarfs, subgiants, or red giants. It is particularly useful for visualizing stellar populations and their properties. In both plots in Figure 5, we observe that SB1 candidates cover all regions of the diagrams, with a slight lack of red giants for example. Two distinct clumps are visible: one near 6000 K, representing Sun-like main-sequence stars, and another at temperatures between 4500 K and 5000 K, corresponding to red giants.

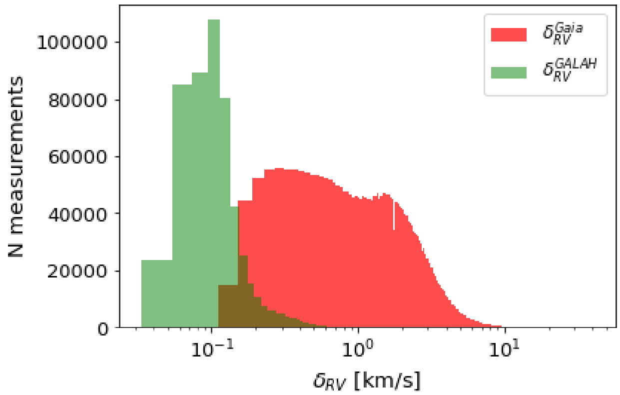

Figure 4. The histogram displays the distribution of radial velocity measurement errors from the GALAH DR3 catalog (green) and the Gaia DR3 catalog (red). The GALAH errors are, on average, smaller by an order of magnitude, as expected, since GALAH is a dedicated spectrograph designed for high-precision radial velocity measurements.

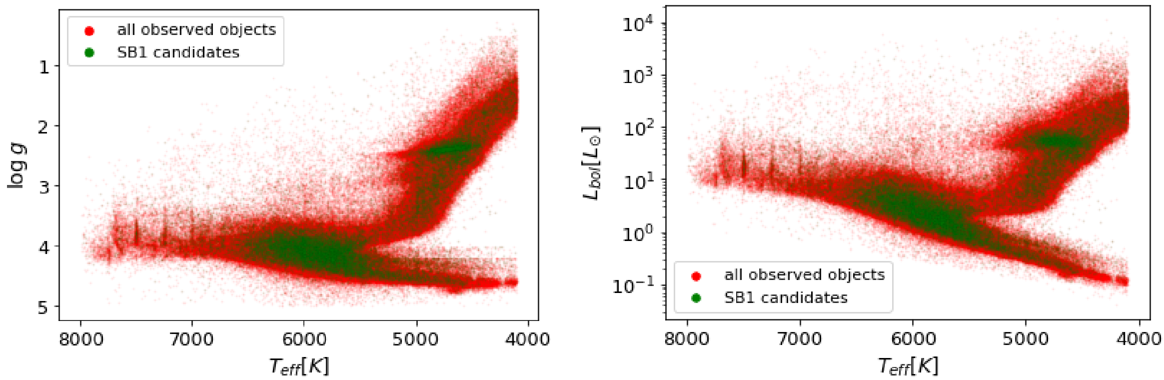

Figure 5. *Left:* Kiel diagram of all observed objects (red) and SB1 candidates (green). Surface gravity generally decreases with increasing mass. Surface temperature is closely related to the color of stars; hotter stars appear blue, while cooler stars are red. Our sample of SB1 candidates does not significantly deviate from the overall set of observed objects, with only a moderate underrepresentation of red supergiants. *Right:* The HR diagram shows the total (bolometric) luminosity of stars as a function of their surface temperature. It is evident that the Kiel and HR diagrams are similar, due to the strong correlation between stellar mass and luminosity.

7. Conclusions

The paper presents a complete list of SB1 candidates based on radial velocity measurements from the GALAH DR3 and Gaia DR3 catalogs. Using the probability function (1) from Matijevič et al. (2012) [14], I identified 9,148 SB1 candidates with $p_{\log} > 2.87$ ($4.24\,\sigma$ significance), which accounts for 26.4 % of all 34 631 studied objects. When Gaia measurements are added, the number of SB1 candidates increases to 35 537, representing just 7.2 % of all observed objects. The smaller percentage of detected SB1 candidates can be attributed to the approximately 10 times larger average measurement error in Gaia's radial velocity data compared to GALAH. Nevertheless, this represents the largest catalog of SB1 candidates compiled to date.

The analysis of SB1 candidates' properties reveals that, compared to all observed stars, they are on average slightly more massive, more luminous, exhibit slightly lower metallicity, and display more extreme temperatures (either very high or very low).

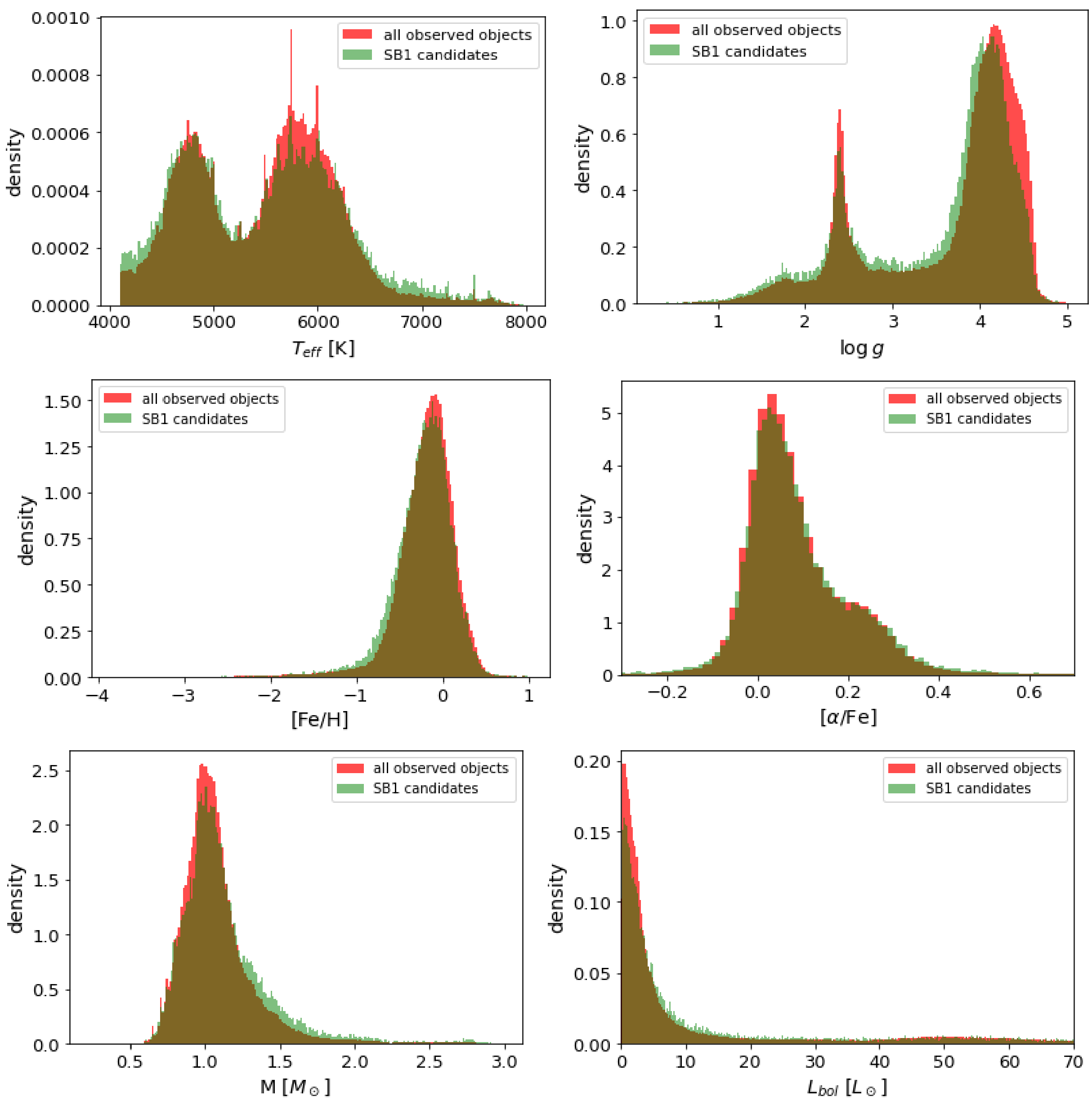

Figure 6. Comparison between the distributions of all observed objects and the extracted SB1 candidates. The two peaks arise because the group of less luminous, lower-mass, and generally hotter stars corresponds to Sun-like main-sequence dwarfs, while the other group represents mainly red giants. In this order, the histograms depict effective temperature T_{eff}, surface gravity $\log g$, metallicity $[Fe/H]$, alpha abundance $[\alpha/H]$, mass M and bolometric luminosity L_{bol}. The data is derived from the multiparametric spectral fits in the GALAH DR3 catalog. $M_\odot$ and $L_\odot$ represent the solar mass and luminosity, respectively.

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