

Detection of pulsating white dwarfs through the S-PLUS data

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Abstract. The project proposes the search for short-period stellar variability, mainly of pulsating white dwarfs (WDs), through data obtained in the context of the Southern Photometric Local Universe Survey (S-PLUS), which is currently observing the southern hemisphere sky in 12 optical photometric bands. For the search for variability, we applied a general extension of the Lomb–Scargle algorithm for multiband astronomical time series to recover periodograms. The analysis was performed by applying the method to 1169 fields of the internal Data Release 4 (iDR4), which resulted in the selection of 42 objects as candidates to be observed in time-series format by the S-PLUS T80-South telescope (T80S) to confirm the variability.

Resumo. O projeto propõe a busca da variabilidade estelar de curto período, principalmente de anãs brancas pulsantes (WDs), através de dados obtidos no contexto do Southern Photometric Local Universe Survey, que está atualmente observando o céu do hemisfério sul em 12 bandas fotométricas do espectro óptico. Para a busca por variabilidade, aplicamos uma extensão geral do algoritmo de Lomb-Scargle para séries temporais astronômicas multibanda para recuperar periodogramas. A análise foi realizada aplicando o método a 1.169 campos do internal Data Release 4 (iDR4), resultando na seleção de 42 objetos como candidatos a serem observados em série temporal pelo telescópio S-PLUS T80-South (T80S) para confirmar a variabilidade.

Keywords. white dwarfs – Stars: variables: general – Methods: data analysis

1. Introduction

It is possible to detect several types of variability, but the targets of this project are pulsating white dwarfs, which are objects of great interest in the study of stellar structures. The reason is that they can provide important clues about the evolution of the progenitor stars during the main sequence phase or later phases, already entering the end of the active life of these astronomical sources, or even to study asteroseismology.

Although white dwarfs are quite common objects given that most stars end their evolution as an object of this class, pulsating WDs are difficult targets to find. This is due to their low luminosity and because they generally have low amplitude variability, which means that only a few hundred of them are currently known.

2. Objectives

In this context, the project proposes the detection and study of pulsating white dwarfs using the data obtained under the S-PLUS (Mendes de Oliveira 2019) project, in which variability detection methods are applied in order to select a sample of candidates that could be studied in more detail in the future.

As the S-PLUS is observing more than 3000 degrees of the southern sky with a 12-band photometric system, composed of 5 broad and 7 narrow bands distributed along the optical spectrum, we can scan a large area of the sky looking for these objects.

3. Methodology

The methodology involves exploring the cadence created by the observational strategy of the Main Survey (MS) of S-PLUS, whose images are obtained sequentially with 3 exposures for

each of the 12 filters, that is, 36 individual images of each field, allowing the analysis of the light curve for each star using a Fourier Transform (FT) in the search for possible signs of variability.

The range of the S-PLUS observation window of approximately 1.5 hours and the filter cadence allows us to search for variability in WDs, which are found in very specific regions of an H-R diagram, offering the possibility for a selection of pulsating candidates.

Thus, a general extension of the Lomb-Scargle (LS; Vanderplas & Ivezić (2015); Vanderplas (2018)) algorithm is applied, in order to recover the periodograms that can indicate the presence of variability, as shown in Figure 1.

4. Analysis

A preliminary analysis was carried out in 16 fields with MS and time series data obtained by Follow-up, as a process of evaluating the method and its delimitations. Applying the method to the selected fields, analyses were carried out and from there, some criteria were established:

- candidates must present a signal with LS power greater than 0.65 in the multiband MS;
- amplitude of variation at some point in the light curve must be greater than 0.03 magnitudes in multiband MS;
- periods must be longer than 200 seconds to avoid false positives due to filter changes.

It was considered that, based on these imposed criteria, it is possible to largely separate the most likely candidates for variables from data that contain many spurious signals that can generate false positives.

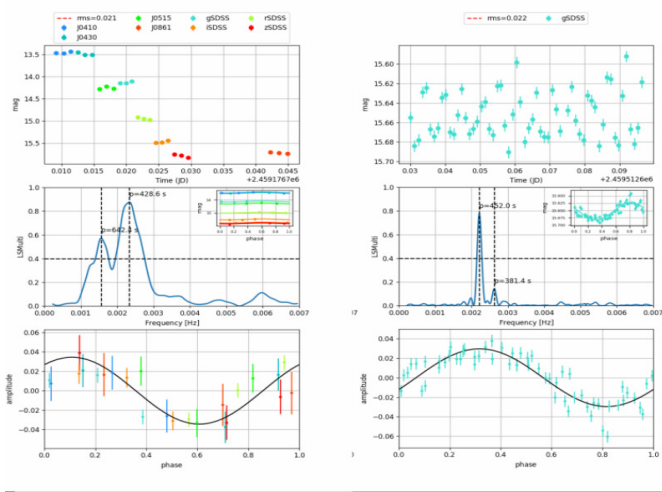


FIGURE 1. Light curves, periodograms and phase diagrams obtained for the pulsating white dwarf star ZZB, known as EC 04207-4748, in S-PLUS MS and Follow-up data. At the top left of the figure is the light curve (LC) for MS instrumental magnitudes of the 8 S-PLUS bands (some filters were removed as they did not contribute to the detection in the range of selected periods), colored according to the legend. In the middle left panel is the periodogram obtained using the multiband LS method applied to the LC. The lower left panel of the figure shows the phase curves for the period corresponding to the highest peak of the respective periodogram. The right panels are the results of the same method applied to the Follow-up data.

Thus, it was possible to create a table of possible pulsating white dwarfs. For this, data from the S-PLUS iDR4 was used, such that the method was applied to 1169 fields, resulting in a total of 67,921 variable star candidates.

5. Results

The selection of candidates for pulsating white dwarfs was made considering an H-R diagram, shown in Figure 2, resulting from the match of 67,921 candidate stars to variables from the S-PLUS iDR4 fields with GAIA’s External Data Release 3 (EDR3; Gaia Collaboration et al. (2021)), to recover parallax and parallax errors for the sample.

With this, stars that are in the white dwarf region are selected, resulting in 42 candidates, as two of the 44 stars in the region are already known pulsating white dwarfs, called ZZA VY Hor and ZZB EC 04207-4748, such that they do not make up the final sample.

These stars were placed as targets in the time order applied to the S-PLUS T80S telescope. By observing S-PLUS fields that contain these stars classified as candidates using time series, more accurate light curves will be obtained to determine variability and establish whether the signal found through the method applied to MS is true or a false positive.

6. Conclusions

The analysis performed on the S-PLUS iDR4 fields resulted in 42 pulsating white dwarf candidates. With the acceptance of the time request proposal to S-PLUS, the table of candidates was sent for observation, and time series data from these stars will be obtained to validate whether there is any variation.

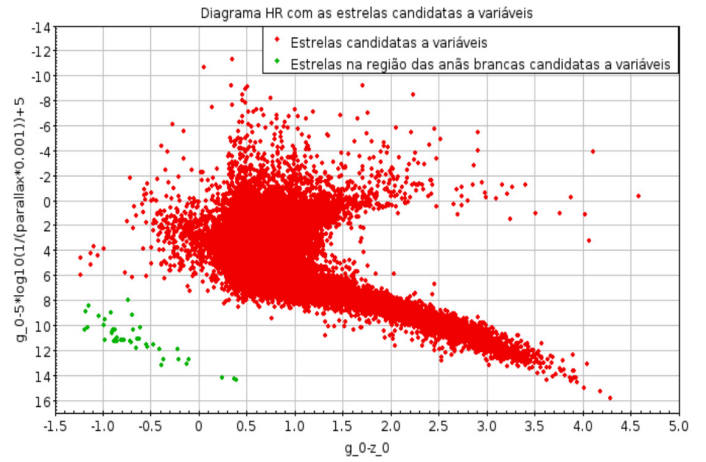


FIGURE 2. H-R diagram of candidate variables for S-PLUS fields when applying the method. The region with candidate stars for pulsating white dwarfs is highlighted in green, corresponding to 44 stars.

As the number of candidates for observation is considerable, a process of screening the best stars for observation is still necessary, to place them as priority targets. This will be done considering the instability range of white dwarfs and the use of classification methods such as principal component analysis (PCA).

After the selected targets have their time series data obtained, the presence of variability can be confirmed and, if there is no confirmation, the causes and justifications for this will be analyzed.

References

- Gaia Collaboration, Brown, A. G. A., Vallenari, A., et al. 2021, *A&A*, 649, A1
- Mendes de Oliveira, C., et al., 2019, S-PLUS, *MNRAS*, v. 489, p. 241–267, out. 2019.
- Vanderplas, J. T., & Ivezić, Ž. 2015, *ApJ*, 812, 18
- Vanderplas, J. T. 2018, *ApJS*, 236, 16