

# Detailed diagnostic of absorption lines in solar twin stars

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**Abstract.** Solar twins are stars with physical properties remarkably similar to those of the Sun, including mass, temperature, composition, luminosity, and magnetic activity. These objects are key to understanding stellar evolution and assessing the Sun's representativeness within the local population, in addition to their astrobiological importance as potential hosts of Earth-like planets. We analyzed 22 solar twin candidates observed with the high-resolution FEROS spectrograph ( $R = 47\,000$ ,  $S/N \geq 350$ ), performing automatic line measurements with IRAF to obtain equivalent widths, full width at half maximum, and line depths. A refined list of reliable Fe I lines was established after rejecting contaminated or inconsistent features. The comparison with the solar spectrum identified HD 71334, HD 88072, HD 98649, HD 138573, HD 146233, HD 164595, and BD+15 3364 as solar analogs and potential solar twins, while HD 8291 and HD 216436 are proposed here for the first time as new solar analog candidates. The resulting line list provides a solid basis for future modeling and spectral synthesis studies.

**Resumo.** Gêmeas solares são estrelas com propriedades físicas notavelmente semelhantes às do Sol, incluindo massa, temperatura, composição química, luminosidade e atividade magnética. Esses objetos são fundamentais para compreender a evolução estelar e avaliar a representatividade do Sol na população estelar local, além de possuírem importância astrobiológica por poderem abrigar planetas semelhantes à Terra. Analisamos 22 candidatas a gêmeas solares observadas com o espectrógrafo FEROS ( $R = 47\,000$ ,  $S/N \geq 350$ ), realizando medições automáticas de linhas no IRAF para obter larguras equivalentes, larguras à meia altura e profundidades. Foi estabelecida uma lista refinada de linhas de Fe I confiáveis, após a exclusão de feições contaminadas ou inconsistentes. A comparação com o espectro solar identificou as estrelas HD 71334, HD 88072, HD 98649, HD 138573, HD 146233, HD 164595 e BD+15 3364 como análogas e potenciais gêmeas solares, enquanto HD 8291 e HD 216436 são aqui propostas, pela primeira vez, como novas candidatas a análogas solares. A lista resultante de linhas espectrais fornece uma base sólida para estudos futuros com modelos atmosféricos e síntese espectral.

**Keywords.** solar-type – spectroscopic – statistical

## 1. Introduction

Solar twins are stars that closely resemble the Sun in parameters such as mass, temperature, and chemical composition. Studying their evolution helps to assess the Sun's representativeness within the local stellar population and their astrobiological potential as hosts of Earth-like planets.

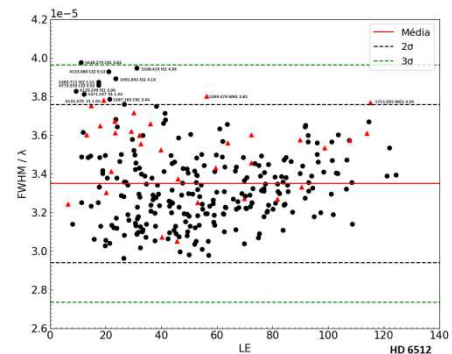
## 2. Objective

We analyzed 22 solar twin candidates previously identified by Porto de Mello et al. (2014) with the aim of improving the selection of spectral lines by refining the criteria established by Di Bartolo (2005), using high-resolution data and the principles of line formation. To this end, we performed a direct comparison between the solar spectrum and those of the sample stars, focusing the analysis on Fe I lines in order to identify analogs and potential solar twins.

## 3. Methodology

Automatic line measurements were performed using the IRAF software, employing the task `bp1ot` with a customized cursor originally adapted from Di Bartolo (2005). Gaussian profiles were fitted to each spectral line to determine the line center, equivalent width (EW), line depth, and full width at half maximum (FWHM).

A statistical analysis of the measured lines was carried out by examining the relation between  $FWHM/\lambda$  and EW (Fig. 1). Significance tests were applied to identify and remove outliers.

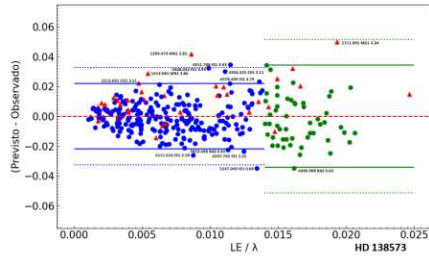


**FIGURE 1.** Test of  $FWHM/\lambda$  versus EW for HD 6512, corresponding to the fifth and final iteration. The plot shows the mean,  $2\sigma$  and  $3\sigma$  limits, and red triangles marking lines affected by hyperfine structure.

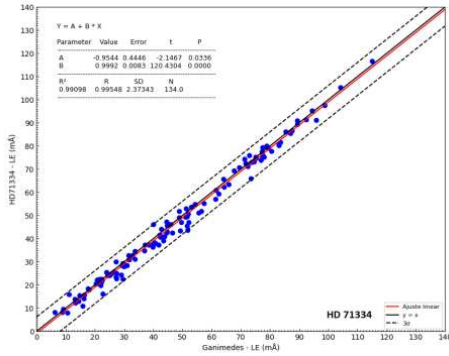
These tests were first performed on the spectrum of Ganymede, used as the solar reference.

The physical consistency of the results was then verified through the relation between line depth and  $EW/\lambda$ . For weak lines, a linear behavior is expected, while strong lines exhibit saturation, requiring a double linear fit to describe both regimes. The transition point was found at  $EW/\lambda \approx 0.014$ , indicating the change from the linear to the saturation regime. Residual plots were generated for Ganymede and all stellar spectra to evaluate deviations between measured and theoretical trends (Fig. 2).

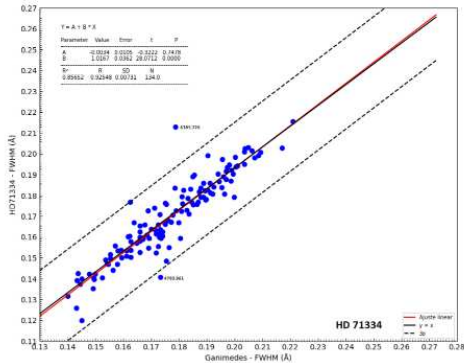
The final comparison with the solar reference spectrum prioritized Fe I lines due to their high abundance in stellar spectra and



**FIGURE 2.** Difference between predicted and observed values as a function of  $EW/\lambda$ , highlighting outliers for HD 138573.



**FIGURE 3.** Comparison between equivalent widths measured in the solar spectrum (Ganymede) and in HD 71334.

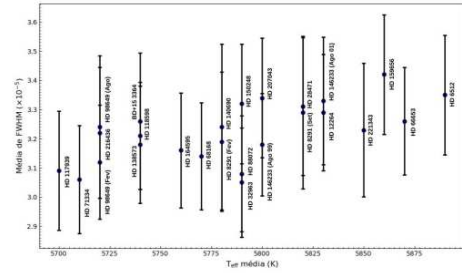


**FIGURE 4.** Comparison between FWHM values measured in the solar spectrum (Ganymedes) and in HD 71334.

sensitivity to excitation potential, which provides valuable information about the effective temperature. Linear regressions were performed between the measured quantities (EW, FWHM, and depth) of each star and the corresponding solar values (Figs. 3 and 4). This approach allowed the evaluation of spectral similarity between the candidate stars and the Sun, serving as the main criterion to identify potential solar twins.

#### 4. Results and discussion

The mean  $FWHM/\lambda$  values were obtained with small uncertainties ( $0.02\text{--}0.03 \times 10^{-5}$ ), although the actual dispersion is larger and reflects intrinsic differences between stellar spectra. Significant deviations were considered only when  $\Delta(FWHM/\lambda) \geq 0.2 \times 10^{-5}$ . Some stars, such as HD 6512, HD 12264, HD 28471, HD 150248, HD 159656, and HD 207043, exhibited average line broadening larger than that of the Sun, while HD 71334 and HD 88072 stood out for their smaller  $FWHM/\lambda$  ratios.



**FIGURE 5.** Mean  $FWHM (\times 10^{-5})$  as a function of the mean effective temperature ( $T_{\text{eff}}$ ) for each spectrum. Error bars represent the standard deviation of the measurements.

The analysis of Fe I line parameters (EW, FWHM, and depth) allowed classifying the stars according to their spectral similarity to the Sun. The most solar-like spectra were found for HD 71334, HD 88072, HD 98649, HD 138573, HD 146233, HD 164595, and BD+15 3364, identified as solar analogs and strong twin candidates. Marginal analogs include HD 8291 and HD 150248, the latter showing slightly broader lines than the solar reference, possibly due to higher rotation or microturbulence.

#### 5. Conclusions and perspectives

We analyzed 26 FEROS spectra, measuring EW, FWHM, and depths of Fe I lines to identify stars similar to the Sun. Differences greater than  $0.2 \times 10^{-5}$  in  $FWHM/\lambda$  allowed us to classify HD 71334, HD 88072, HD 98649, HD 138573, HD 146233, HD 164595, HD 216436, and BD+15 3364 as probable solar analogs, while HD 150248 and HD 8291 were considered marginal cases.

The results confirm the feasibility of identifying stars closely resembling the Sun, though further studies are needed. The clean spectral line list provides a reliable basis for future analyses to refine solar twin identification and improve our understanding of their similarity to the Sun.

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