

Is 12 Enough?

Evaluation of New Filters for the Determination of Stellar Parameters and Chemical Abundances in the S-PLUS Survey

M. A. Menegati¹ & F. Almeida-Fernandes²

¹ Instituto Nacional de Pesquisas Espaciais, Av. dos Astronautas 1758, Jardim da Granja, 12227-010 São José dos Campos, SP, Brazil
e-mail: murilo.menegati@inpe.br

Abstract. The S-PLUS survey (Mendes de Oliveira et al. 2019), with its 12-band photometric system (including seven narrow-band filters centered on relevant spectral features), has demonstrated strong potential for estimating stellar atmospheric parameters and chemical abundances using machine-learning techniques (Ferreira Lopes et al. 2025). This work investigates the feasibility of expanding the S-PLUS narrow-band filter set by testing more than 60 candidates distributed across the optical range, with the goal of improving the recovery of physical parameters and enabling access to new chemical abundances using photometry alone. Using data from S-PLUS iDR5, together with reference spectroscopic catalogs such as Gaia-ESO (Hourihane et al. 2023) and APOGEE DR17 (Abdurro'uf et al. 2022), as well as synthetic photometry generated from Gaia DR3 spectra via *gaiaxy*, we evaluate different filter combinations through Random Forest algorithms. The methodology aims to quantify the precision and robustness of the regression as a function of the adopted photometric set, with the purpose of proposing an optimized configuration for future observations with the T80-South telescope.

Resumo. The S-PLUS survey (Mendes de Oliveira et al. 2019), with its 12-band photometric system (including seven narrow-band filters centered on relevant spectral features), has demonstrated strong potential for estimating stellar atmospheric parameters and chemical abundances using machine-learning techniques (Ferreira Lopes et al. 2025). This work investigates the feasibility of expanding the S-PLUS narrow-band filter set by testing more than 60 candidates distributed across the optical range, aiming to improve the recovery of physical parameters and enable access to new chemical abundances using photometry alone. Using data from S-PLUS iDR5, combined with reference spectroscopic catalogs such as Gaia-ESO (Hourihane et al. 2023) and APOGEE DR17 (Abdurro'uf et al. 2022), as well as synthetic photometry generated from Gaia DR3 spectra via *gaiaxy*, different filter combinations are evaluated through Random Forest algorithms. The methodology seeks to quantify the precision and robustness of the regression as a function of the adopted photometric set, with the goal of proposing an optimized configuration for future observations with the T80-South telescope.

Keywords. Techniques: photometric – Methods: data analysis – Stars: fundamental parameters – Stars: abundances – Surveys – Instrumentation: photometers

1. Introduction

S-PLUS uses the photometric system originally described in Mendes de Oliveira et al. (2019). The optical infrastructure and the development of narrow-band filters follow the technical principles presented in Cenarro (2018). Calibration methods recently implemented in the S-PLUS pipeline are discussed in Almeida-Fernandes et al. (2022).

The system is composed of seven narrow-band filters (J0378, J0395, J0410, J0430, J0515, J0660, J0861), sensitive to spectral features such as [O II], Ca H+K, H δ , the G-band, Mg b, H α , and the Ca triplet; in addition to five broad-band filters (u, g, r, i, z), similar to those of SDSS.

In this work, we evaluate the possibility of expanding the S-PLUS narrow-band filter set by including more than 60 candidate filters distributed across the optical spectrum. The selection was inspired by the strategy of the J-PAS survey, whose narrow-band filter grid is described in detail by Cenarro (2018). Synthetic magnitudes were generated from Gaia DR3 XP spectra using *Gaiaxy* (De Angeli et al. 2022), with transmission curves obtained from the SVO Filter Profile Service.

2. Sample

The sample consists of sources from S-PLUS iDR5 for which we performed a crossmatch with the APOGEE DR17 spectroscopic

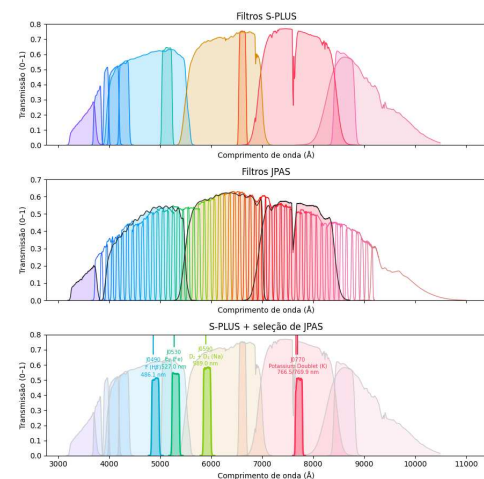


FIGURE 1. Transmission curves of the original S-PLUS filters (colored) and examples of additional narrow-band filters tested (gray). Filters centered on features such as Mg b, H α , and the Ca triplet contribute to increased sensitivity to photometric parameters.

catalog. Detailed chemical characterization and reference stellar parameters were taken from Majewski et al. (2017) and Hawkins

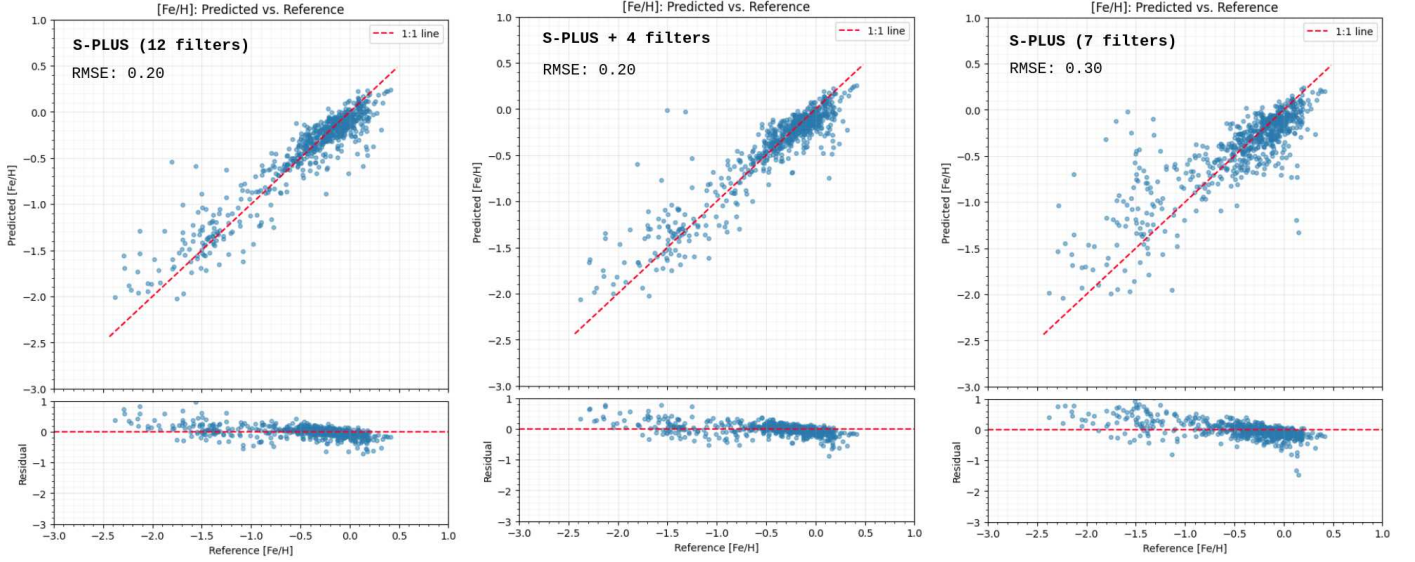


FIGURE 2. Root mean square error (RMSE) obtained for T_{eff} , $\log g$, and $[\text{Fe}/\text{H}]$ in three photometric configurations: (1) the original 12 filters; (2) S-PLUS + 4 additional narrow-band filters; (3) an optimized subset of 7 filters. The reduction in RMSE for $[\text{Fe}/\text{H}]$ indicates consistent improvement when adding narrow-band filters centered on chemical features.

et al. (2017). The inclusion of this information allows us to evaluate the photometric performance of each filter set in recovering physical parameters.

Synthetic magnitudes were generated for all S-PLUS filters and candidate filters using Gaia DR3 XP spectra, following the methodology described in De Angeli et al. (2022). The resulting dataset combines observed photometry, spectroscopy, and simulated photometry, ensuring statistical robustness in the comparison between different photometric systems.

2.1. Validation of Synthetic Photometry

Synthetic magnitudes were directly compared with real S-PLUS observations, showing small systematic deviations consistent with the results of Montegriffo et al. (2023) for photometric transformations between different systems. This validation ensures that XP spectra can be reliably used to test new filters.

2.2. GaiaXPpy

As a validation step, we compared synthetic magnitudes generated with GaiaXPpy to observed S-PLUS magnitudes. This comparison demonstrated consistency between them, confirming the reliability of using synthetic photometry in the analysis.

3. Methodology

We used the Random Forest algorithm (Breiman 2001) to regress stellar parameters under three configurations:

1. the 12 original S-PLUS filters;
2. the expanded set including four additional narrow-band filters inspired by J-PAS;
3. an optimized subset of 7 filters with the highest statistical importance.

The adopted metric was the RMSE for T_{eff} , $\log g$, and $[\text{Fe}/\text{H}]$. Additional filters centered on narrow spectral lines showed a stronger impact on $[\text{Fe}/\text{H}]$ recovery and a moderate effect on T_{eff} .

4. Discussion

Additional filters reduced the RMSE of $[\text{Fe}/\text{H}]$ by up to 25%, demonstrating that narrow spectral features provide additional chemical information. The 7-filter subset achieves performance comparable to the original system, suggesting redundancy and indicating that an optimized filter-wheel configuration is feasible.

5. Conclusions

We expect that the addition of strategically selected narrow-band filters will increase the precision of S-PLUS in determining stellar parameters and enhance its sensitivity to chemical abundances, opening new opportunities for Galactic archaeology.

Acknowledgements. M.A.M. acknowledges support from FAPESP grant 2025/03403-6; F.A.-F. acknowledges support from FAPESP grants 2024/00822-5 and 2024/22842-8.

References

- Abdurro'uf, H., et al. 2022, *ApJS*, 259, 35
 Almeida-Fernandes, F., et al. 2022, *MNRAS*, 512, 1234
 Breiman, L. 2001, *Machine Learning*, 45, 5
 Cenarro, A. J. 2018, *RMxAC*, 50, 110
 De Angeli, F., et al. 2022, *A&A*, 658, A91
 Hawkins, K., et al. 2017, *A&A*, 605, A104
 Majewski, S. R., et al. 2017, *AJ*, 154, 94
 Mendes de Oliveira, C., et al. 2019, *MNRAS*, 489, 241
 Montegriffo, P., et al. 2023, *A&A*, 670, A123