RNAAS RESEARCH NOTES OF THE AAS

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To cite this article: Diego Godoy-Rivera *et al* 2026 *Res. Notes AAS* **10** 53

Research Notes of the AAS

Draft version March 10, 2026
Typeset using LaTeX **default** style in AASTeX7.0.1

Mining the *Kepler* Field: Atmospheric Parameters, Bolometric Corrections, and Luminosities

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ABSTRACT

The $\sim$ 200,000 stars observed by the *Kepler* mission have provided unprecedented constraints across astrophysics. With the advent of modern spectroscopic and photometric surveys, new limits in stellar characterizations are within reach. In this work, we report a compilation of atmospheric parameters ($T_{\rm eff}$, $\log(g)$, and [M/H]) for the *Kepler* stars by crossmatching with several spectroscopic and spectro-photometric surveys. We use these to calculate bolometric corrections, which combined with color-magnitude diagram (CMD) information from *Gaia* yield self-consistent luminosities on a survey-by-survey basis. These properties will aid in future explorations of *Kepler* data towards new astrophysical insights. We make our catalog publicly available online in Zenodo (doi:10.5281/zenodo.18620911).

Keywords: Hertzsprung Russell diagram (725) — Stellar properties (1624) — Stellar luminosities (1609) — Bolometric correction (173) — Catalogs (205)

1. INTRODUCTION

The light curves from *Kepler* (W. J. Borucki et al. 2010) have enabled discoveries in the fields of exoplanets, asteroseismology, stellar rotation and activity, among others. To fully exploit the *Kepler* data, thorough stellar characterizations are needed. While our knowledge of its targets has increased in the last decade, the advent of modern surveys allows us to push the limits in stellar parameter determinations.

We performed a crossmatch of the $\sim$ 200,000 *Kepler* stars with modern surveys. We gathered atmospheric parameters, computed bolometric corrections, and combined them with *Gaia* DR3 data (Gaia Collaboration et al. 2025) to calculate luminosities, a crucial astrophysical property.

2. METHOD

We defined the target sample as the 196,762 *Kepler* stars with *Gaia* DR3 counterparts from D. Godoy-Rivera et al. (2025). We calculated luminosities and uncertainties as

$$\left(\frac{L}{\rm L_\odot}\right) = 10^{\left(\frac{M_{G_0}+{\rm BC}_G-{\rm M}_{\rm bol,\odot}}{-2.5}\right)}, \quad (1)$$

and

$$\left(\frac{\sigma_L}{L}\right) = \left(\frac{\ln(10)}{2.5}\right)\sqrt{\sigma^2_{M_{G_0}}+\sigma^2_{{\rm BC}_G}}, \quad (2)$$

where M_{G_0} is the de-reddened G-band absolute magnitude, ${\rm BC}_G$ is the G-band bolometric correction, and ${\rm M}_{\rm bol,\odot} =$ 4.74 mag is the solar bolometric magnitude (E. E. Mamajek et al. 2015).

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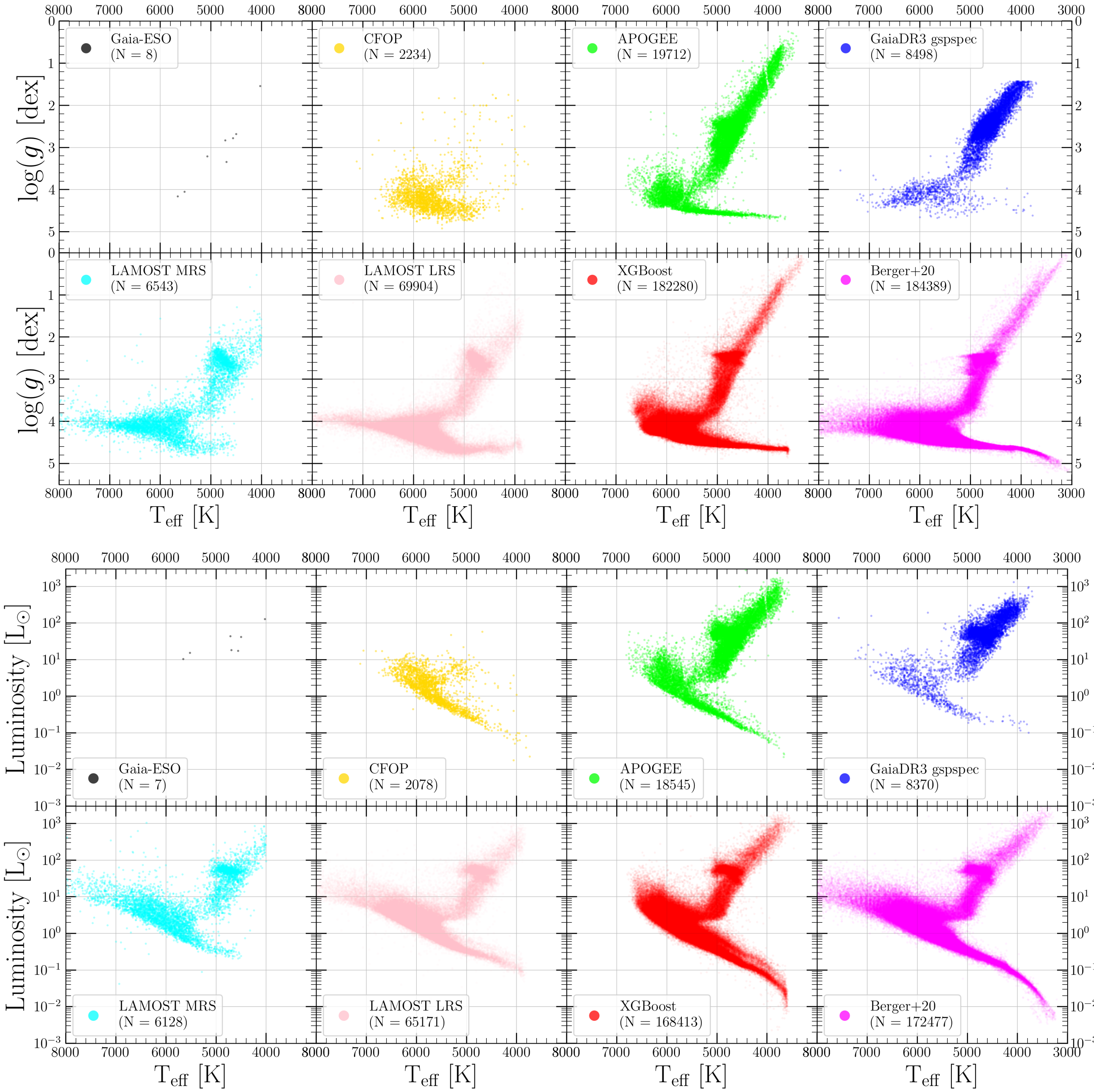

Figure 1. Kiel (top) and Hertzsprung-Russell (bottom) diagram for the *Kepler* stars. Each panel indicates a survey, with the number of stars found in each indicated in the legend.

We took the absolute magnitudes from D. Godoy-Rivera et al. (2025), who used the *Gaia* DR3 parallaxes and extinction-corrected photometry, to place the targets on the absolute and de-reddened color-magnitude diagram (CMD). After quality cuts, their CMD sample comprised 179,295 stars, with a median error of $\sigma_{M_{G_0}} = 0.063$ mag. Bolometric corrections were calculated following O. L. Creevey et al. (2023) with the `gaiadr3_bcg`[1] function, which takes as input the atmospheric parameters ($T_{\rm eff}$, $\log(g)$, [Fe/H], [α/Fe]) and calculates BC_G by interpolating MARCS synthetic spectra (B. Gustafsson et al. 2008).

[1] https://gitlab.oca.eu/ordenovic/gaiadr3_bcg

3. SPECTROSCOPIC COMPILATION

Given the need for atmospheric parameters in the computation of bolometric corrections, we compiled these from surveys. The crossmatch is available online and summarized in the Kiel diagram of Fig. 1.

Sorting by resolution, we crossmatched with: *Gaia*-ESO (v5.1[2], $R \sim 47{,}000$; A. Hourihane et al. 2023), the *Kepler* Community Follow-up Observation Program (CFOP, $R \sim 40{,}000$; E. Furlan et al. 2018), APOGEE (DR17, $R \sim 22{,}000$; Abdurro'uf et al. 2022), *Gaia* DR3 `gspspec` ($R \sim 11{,}500$; A. Recio-Blanco et al. 2023), and LAMOST (DR10 v2.0; X.-Q. Cui et al. 2012) Medium- and Low-Resolution Spectroscopy (MRS, $R \sim 7{,}500$; LRS, $R \sim 1{,}800$). We also queried spectro-photometric catalogs, namely XGBoost ($R \sim 100$, R. Andrae et al. 2023), which was based on the *Gaia* DR3 XP coefficients and trained on the APOGEE data, and T. A. Berger et al. (2020), who reported stellar parameters for the *Kepler* stars based on isochrones, broadband photometry, and *Gaia* DR2 parallaxes.

For reliability we applied quality cuts. For CFOP, we removed stars with Kiel diagram locations unpopulated by other surveys or unphysical values (KIC 8823868, KIC 9552608, and KIC 2437209). For APOGEE, we removed targets with the `ASPCAPFLAG` `STAR_WARN`, `STAR_BAD`, or `M_H_WARN` quality flags. For *Gaia* DR3 `gspspec`, we took the calibrated best-quality sample from D. Godoy-Rivera et al. (2025). For LAMOST, we only considered targets with measured ($T_{\rm eff}$, $\log(g)$, [M/H]) parameters and uncertainties. For XGBoost, we did not consider the targets with *Gaia* color $(BP - RP) \leq 0.5$ mag, or with $(BP - RP) \geq 2.5$ mag and $\log(g) > 3.6$ dex, as in those regimes their training set had limited coverage and their data did not follow the expected color-temperature relation. For T. A. Berger et al. (2020), we only kept targets with goodness-of-fit > 0.99. These quality cuts did not significantly impact the amount of successful crossmatches.

We adopted the uncertainties reported in the respective surveys. For *Gaia* DR3 `gspspec`, we averaged the (largely symmetric) lower and upper error bars to streamline the uncertainty propagation. For XGBoost, no star-by-star uncertainties were reported, and we adopted their overall mean precisions as uncertainties (50 K in $T_{\rm eff}$, 0.08 dex in $\log(g)$, and 0.1 dex in [M/H]).

As shown in Fig. 1, the fraction of the *Kepler* stars found varies strongly on a survey-by-survey basis. We performed inter-survey comparisons, finding varying degrees of agreement (e.g., median $\Delta T_{\rm eff,(LAMOSTLRS\text{-}APOGEE)} \approx +6$ K and $\Delta T_{\rm eff,(GaiaDR3gspspec\text{-}APOGEE)} \approx -34$ K). While preferable, homogenizing parameters across surveys is non-trivial (G. F. Thomas et al. 2024) and beyond the scope of this work.

4. BOLOMETRIC CORRECTIONS

We calculated bolometric corrections using the compiled atmospheric parameters[3]. While some surveys reported [Fe/H] and others [M/H], we took both of them to represent metallicity. We assumed $[\alpha/\mathrm{Fe}]=0$ as this parameter is scarcely available and tests showed it has little impact on the resulting BC_G values. For each star we performed 1000 Monte Carlo simulations of the atmospheric parameters assuming Gaussian distributions (R. A. García et al. in preparation), and adopted the median and its 1σ range of the resulting distribution as BC_G and σ_{BC_G}. The median error is $\sigma_{\mathrm{BC}_G} = 0.010$ mag, although with significant survey-dependent trends.

5. LUMINOSITIES

For stars with available absolute magnitudes and bolometric corrections, we used Equations (1) and (2) to calculate luminosities. The median luminosity uncertainty is $\left(\frac{\sigma_L}{L}\right) = 5.7\%$. The resulting Hertzsprung-Russell diagram is shown in Fig. 1. The sample includes the upper main-sequence (MS), solar-like stars, and evolved phases (e.g., red giant branch and red clump). Heterogeneities can be seen due to the inherited atmospheric parameters from different surveys. This is particularly evident along the MS for XGBoost, and we thus caution about its use in this regime. Our luminosities are in good agreement with the literature (e.g., 93% of the LAMOST LRS values are within 3σ of *Gaia* DR3 FLAME). We make our catalog publicly available as a resource to the community.

DATA AVAILABILITY

The catalog is available in electronic form on Zenodo at doi:10.5281/zenodo.18620911 and reports the atmospheric parameters, bolometric corrections, and luminosities.

[2] All crossmatches found are members of NGC 6791 (E. L. Hunt & S. Reffert 2023).

[3] ~ 100 stars with atmospheric parameters fall outside the input range of the `gaiadr3_bcg` function and lack bolometric corrections.

ACKNOWLEDGMENTS

We thank Santi Cassisi, Alejandro Martín Escabia, Travis Berger, and Thomas Masseron for helpful discussions.

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