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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 at: https://zenodo.org/records/18620911.

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

1. INTRODUCTION

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

In this work, we performed a crossmatch of the $\sim$ 200,000 stars observed by *Kepler* with numerous modern surveys and catalogs. We gathered atmospheric parameters, computed bolometric corrections, and combined them with *Gaia* Data Release 3 (DR3; Gaia Collaboration et al. 2023) data to calculate luminosities, a crucial astrophysical property.

2. METHOD

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

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

and

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

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

We took the absolute magnitudes from D. Godoy-Rivera et al. (2025), who used the *Gaia* DR3 parallaxes and photometry, as well as the J. L. Vergely et al. (2022) extinction map, to place the *Kepler* targets on the absolute and de-reddened color-magnitude diagram (CMD). After applying a series of 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) by employing the `gaiadr3_bcg`[1] function. For a given star, this takes as input the atmospheric parameters (T_{eff}, $\log(g)$, [Fe/H], [α/Fe]) and calculates the BC_G value by interpolating MARCS synthetic stellar spectra (B. Gustafsson et al. 2008).

3. SPECTROSCOPIC COMPILATION

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

Sorting by survey resolution, we crossmatched the target sample with: *Gaia*-ESO (v5.1[2]; A. Hourihane et al. 2023), the *Kepler* Community Follow-up Observation Program (CFOP; E. Furlan et al. 2018), APOGEE (DR17; Abdurro'uf et al. 2022), *Gaia* DR3 `gspspec` (A. Recio-Blanco et al. 2023), and LAMOST (DR10 v2.0; X.-Q. Cui et al. 2012; G. Zhao et al. 2012) Medium-Resolution-Spectroscopy (MRS) and Low-Resolution-Spectroscopy (LRS). We also queried spectro-photometric catalogs, namely XGBoost (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.

To add reliability, we applied the following quality cuts. For CFOP, we removed a couple of stars with Kiel diagram locations unpopulated by other surveys (KIC 8823868 and KIC 9552608) or with unphysical values (KIC 2437209). For APOGEE, we only considered the targets without the `ASPCAPFLAG STAR_WARN`, `STAR_BAD`, or `M_H_WARN` quality flags set (e.g., C. Boettner et al. 2024). For *Gaia* DR3 `gspspec`, we took the calibrated best-quality sample from D. Godoy-Rivera et al. (2025) (see their Appendix B). For LAMOST MRS and LRS, we only considered targets with measured (T_{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 the R. Andrae et al. (2023) 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 (GOF) > 0.99. These quality cuts did not significantly impact the amount of successful crossmatches.

For every survey, we adopted the uncertainties reported in the respective catalogs. For *Gaia* DR3 `gspspec`, we averaged the (largely symmetric) lower and upper error bars to streamline the propagation of uncertainties. For XGBoost, no star-by-star uncertainties were reported, and we adopted the overall mean precisions from R. Andrae et al. (2023) as uncertainties (50 K in T_{eff}, 0.08 dex in $\log(g)$, and 0.1 dex in [M/H]).

As shown in Figure 1, the fraction of the *Kepler* stars found in the crossmatches varies strongly on a survey-by-survey basis. We performed global inter-survey comparisons, finding varying degrees of agreement between them (e.g., median $\Delta T_{\mathrm{eff,(LAMOSTLRS\text{-}APOGEE)}} \approx +6$ K and $\Delta T_{\mathrm{eff,(GaiaDR3gspspec\text{-}APOGEE)}} \approx -34$ K; see also T. Tang et al. 2025). While it would be preferable to homogenize the stellar parameters across surveys, this task is non-trivial (e.g., G. F. Thomas et al. 2024; A. Turchi et al. 2025), and beyond the scope of this work.

4. BOLOMETRIC CORRECTIONS

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

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

[2] The few stars found in the *Gaia*-ESO crossmatch correspond to members of NGC 6791 cluster (e.g., E. L. Hunt & S. Reffert 2023).

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

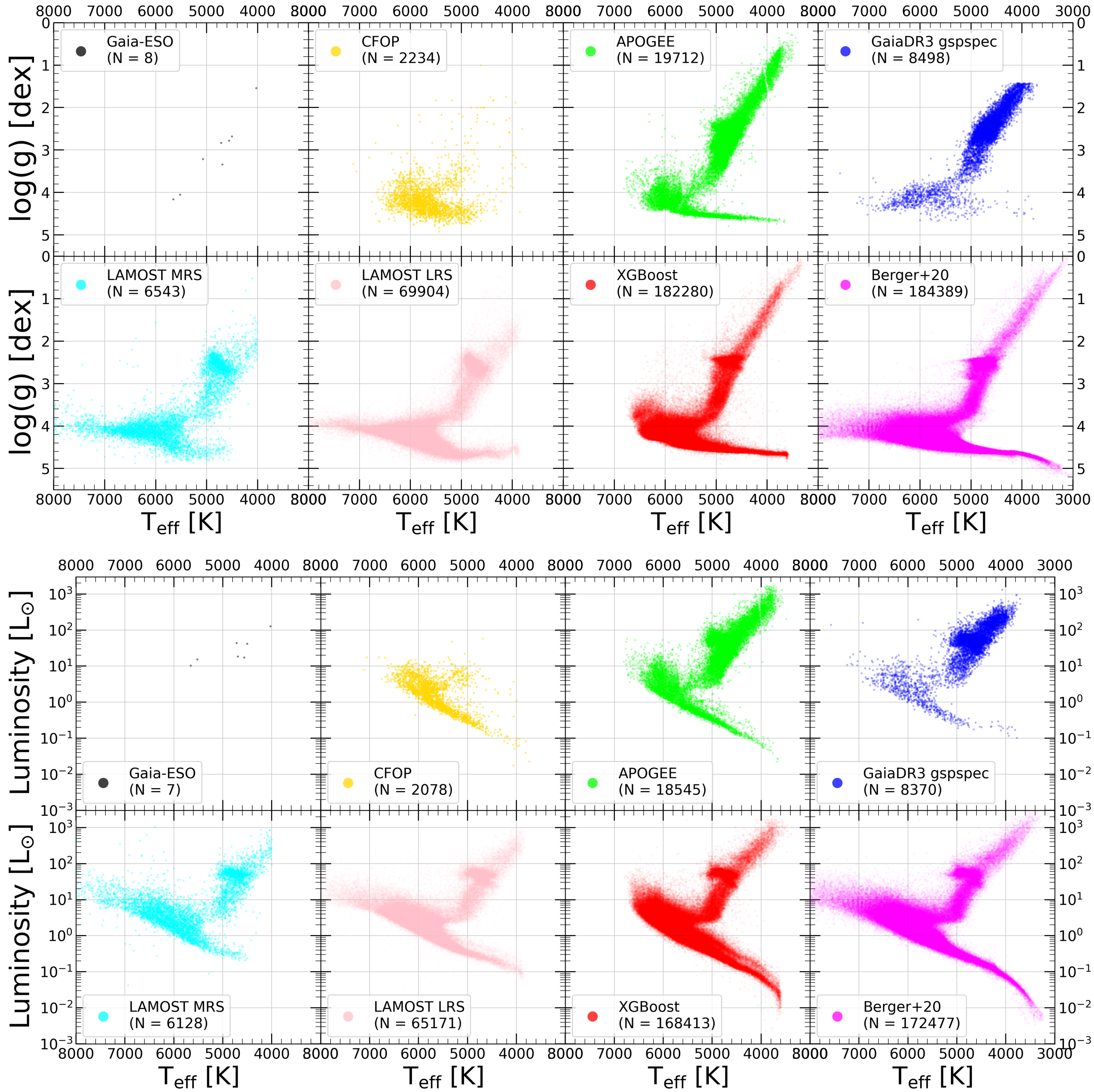

Figure 1. Kiel (top) and Hertzsprung-Russell (bottom) diagram for the *Kepler* stars with atmospheric parameters in surveys. Each panel indicates a survey, with the number of stars found in the respective crossmatch indicated in the legend.

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 (HRD) is shown in Figure 1. The sample spans the entirety of the HRD, including the upper main-sequence (MS), solar-like stars, and evolved phases such as the red giant branch (RGB) and red clump (RC). As expected, some heterogeneities can be seen due to the inherited atmospheric parameters from different surveys. This is particularly evident along the MS for the XGBoost values, and we thus caution about their use in this regime. Our luminosities are in good agreement with the literature, for example with 93% of the LAMOST LRS sample falling within 3σ of the *Gaia* DR3 FLAME values. We make our catalog publicly available as a resource to the community.

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REFERENCES

Abdurro'uf, Accetta, K., Aerts, C., et al. 2022, ApJS, 259, 35, doi: 10.3847/1538-4365/ac4414

Andrae, R., Rix, H.-W., & Chandra, V. 2023, ApJS, 267, 8, doi: 10.3847/1538-4365/acd53e

Berger, T. A., Huber, D., van Saders, J. L., et al. 2020, AJ, 159, 280, doi: 10.3847/1538-3881/159/6/280

Boettner, C., Viswanathan, A., & Dayal, P. 2024, A&A, 692, A150, doi: 10.1051/0004-6361/202451537

Borucki, W. J., Koch, D., Basri, G., et al. 2010, Science, 327, 977, doi: 10.1126/science.1185402

Creevey, O. L., Sordo, R., Pailler, F., et al. 2023, A&A, 674, A26, doi: 10.1051/0004-6361/202243688

Cui, X.-Q., Zhao, Y.-H., Chu, Y.-Q., et al. 2012, Research in Astronomy and Astrophysics, 12, 1197, doi: 10.1088/1674-4527/12/9/003

Furlan, E., Ciardi, D. R., Cochran, W. D., et al. 2018, ApJ, 861, 149, doi: 10.3847/1538-4357/aaca34

Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al. 2023, A&A, 674, A1, doi: 10.1051/0004-6361/202243940

Godoy-Rivera, D., Mathur, S., García, R. A., et al. 2025, A&A, 696, A243, doi: 10.1051/0004-6361/202348735

Gustafsson, B., Edvardsson, B., Eriksson, K., et al. 2008, A&A, 486, 951, doi: 10.1051/0004-6361:200809724

Hourihane, A., François, P., Worley, C. C., et al. 2023, A&A, 676, A129, doi: 10.1051/0004-6361/202345910

Hunt, E. L., & Reffert, S. 2023, A&A, 673, A114, doi: 10.1051/0004-6361/202346285

Mamajek, E. E., Torres, G., Prsa, A., et al. 2015, arXiv e-prints, arXiv:1510.06262, doi: 10.48550/arXiv.1510.06262

Recio-Blanco, A., de Laverny, P., Palicio, P. A., et al. 2023, A&A, 674, A29, doi: 10.1051/0004-6361/202243750

Tang, T., Qin, S., Zhong, J., Jiang, Y., & Chen, L. 2025, A&A, 698, A295, doi: 10.1051/0004-6361/202451807

Thomas, G. F., Battaglia, G., Gran, F., et al. 2024, A&A, 690, A54, doi: 10.1051/0004-6361/202450198

Turchi, A., Pancino, E., Avdeeva, A., et al. 2025, A&A, 700, A195, doi: 10.1051/0004-6361/202555695

Vergely, J. L., Lallement, R., & Cox, N. L. J. 2022, A&A, 664, A174, doi: 10.1051/0004-6361/202243319

Zhao, G., Zhao, Y.-H., Chu, Y.-Q., Jing, Y.-P., & Deng, L.-C. 2012, Research in Astronomy and Astrophysics, 12, 723, doi: 10.1088/1674-4527/12/7/002