PHOTOMETRIC CALIBRATION OF M-DWARF METALLICITY USING BAYESIAN INFERENCE

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Metallicity has remained as a challenging parameter when characterizing M-type dwarf stars due to difficulties in the analysis of their spectra, dominated by molecular features, but it is required in multiple areas of astrophysics, for example to constrain theoretical stellar models or guide exoplanet searches. In order to estimate the metallicity of these cool stars, we have carried out **multi-band photometric calibrations for early and intermediate M dwarfs** using the precision, accuracy, and homogeneity of both astrometry and photometry from **Gaia DR3**, complemented by near- and mid-IR photometry from **2MASS** and **CatWISE2020** surveys. These catalogs, combined with a sample of 5453 M dwarfs with additional parameters determined by APOGEE high-resolution spectroscopy, allow us to study **the effect of the chemical composition in color-color and color-magnitude diagrams**. We train calibrations using Bayesian statistics and Markov Chain Monte Carlo (MCMC) techniques using Stan to derive several photometric calibrations applicable to M dwarfs with metallicities in the range of $-0.45 \leq [\mathrm{Fe/H}] \leq +0.45$ and spectral types down to M5.0V, obtaining **estimations reliable to 0.10 dex**. Finally, we compare our results with previous photometric studies of metallicity found in the literature for an additional sample of 46 M-dwarf common-proper-motion companions of FGK-type primary stars with well-defined spectroscopic metallicities, finding a great predictive performance.

The sample of 5453 stars selected from Birky et al. (2020) is randomly divided into two sets: 932 stars are used to train the calibrations with MCMC and the remaining 4521 stars to test the accuracy of the estimations using Leave-One-Out Cross Validation (LOO-CV). Our best estimations rely on the three-dimensional diagram using the $W1-W2$ and $G_{BP}-G_{RP}$ colors and the M_G absolute magnitude.

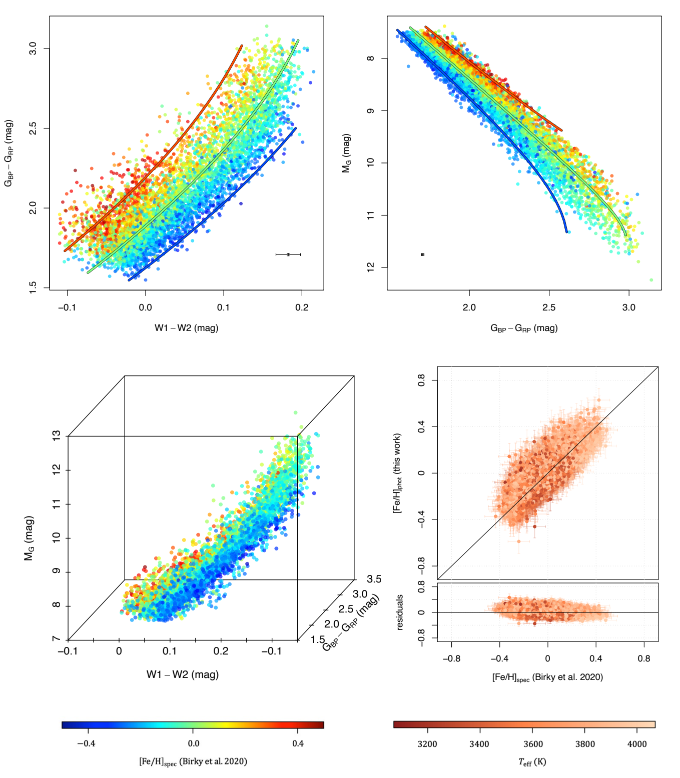
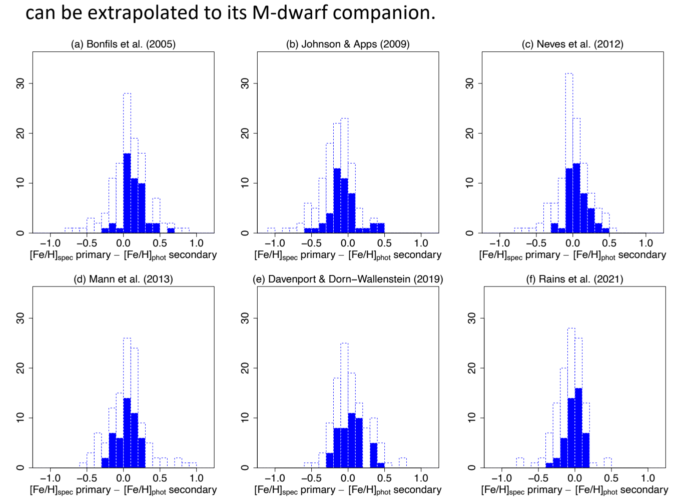


Fig. 1: *Upper panels*: Color-color and color-magnitude diagrams of the stars from Birky et al. (2020), color-coded by spectroscopic [Fe/H] and with the calibrations given by this work. *Bottom panels*: Three-dimensional color-color-magnitude diagram of the stars from Birky et al. (2020), and the comparison between the spectroscopic metallicity values and the corresponding photometric estimations given by this work, and respective residuals (color-coded by effective temperature).

Then, we select 46 M-dwarf companions from the wide binary systems with high-quality photometric and astrometric data presented by Montes et al. (2018). Since binaries are assumed to be born at the same time and from the same molecular cloud, the composition of the primary FGK star can be extrapolated to its M-dwarf companion.



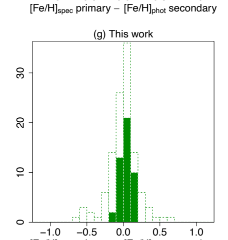


Fig. 2: Histograms of the difference between primary's spectroscopic [Fe/H] and the photometric metallicity values estimated by several authors (blue) and by this work (green). The dashed histograms refer to the whole sample, while the solid ones refer to the stars with high-quality astrometric and photometric data.

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