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Photometric calibrations of M-dwarf metallicity with Markov Chain Monte Carlo and Bayesian inference

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Abstract

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≤[Fe/H]≤+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.

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