SpectroAge: A Model-Driven Ensemble of Multi-Layer Perceptron Neural Networks for High-Precision Estimation of Stellar Ages

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Determining stellar ages at the scale of modern spectroscopic surveys is hindered by the extreme computational cost of professional Bayesian isochrone-fitting pipelines, which limits large-scale galactic and planetary science. I designed SpectroAge, a stellar age estimation tool that uses a heterogeneous ensemble of ten multilayer perceptron neural networks trained directly on five stellar evolutionary model grids: BaSTI, MIST, PARSEC, Dartmouth, and Geneva, using three inputs: scaled metallicity, absolute Gaia G magnitude, and Gaia BP-RP color index. Applied to the GALAH DR3 survey, SpectroAge achieved a mean absolute error of 0.82 Gyr and a Pearson correlation of r = 0.86 against professional reference ages, while running at 9.1 milliseconds per star, 4,400 times faster than the reference pipeline on a consumer laptop with no GPU. SpectroAge decomposes uncertainty into three components: observational, epistemic, and inter-grid systematic, and attains near-perfect 1s calibration coverage of 69.4%. Applied to 2.3 million LAMOST DR10 stars, SpectroAge shows that confirmed ultra-short-period planet hosts have a median age 1.7 Gyr older than matched field stars (p = .003), providing the first spectroscopic-age-based evidence favoring secular dynamical migration as their dominant formation channel, replicated across all five grids. Additionally, SpectroAge identifies 847 stellar rejuvenation candidates, 70% of which show elevated barium consistent with asymptotic giant branch (AGB) binary mass transfer. SpectroAge, therefore, makes million-star age studies feasible on free hardware, enabling new discoveries in galactic archaeology and planetary science.

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