Precise Stellar Ages: Calibrating Theoretical Isochrones Using Non Local Thermodynamic Equilibrium Conditions

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Isochrones are the most common tool used to calculate the age of stellar clusters, and they subsequently provide valuable insight into processes such as stellar evolution. Current isochrones are created through the assumption of Local Thermodynamic Equilibrium (LTE) in stars, which is not valid for older stars with lower metallicities as well as stars with extended atmospheres such as giant and supergiant stars. For such stars, assuming Non Local Thermodynamic Equilibrium (NLTE) is considerably more accurate, as NLTE represents realistic conditions of radiative transfer. Despite it's accuracy, NLTE has never before been used to create isochrones due to its computational complexity. Using NLTE stellar atmospheric models, a calibration routine was created to transform LTE stellar parameters to NLTE. After running the NLTE calibration on test stars, we observed that the NLTE effective temperature is cooler than in LTE, while the surface gravities in NLTE are systematically higher than their LTE values. The NLTE calibration routine was run on curve defining points of the 11 Gyrs, [Fe/H] = -1.0 and 11 Gyrs, [Fe/H] = -1.5 LTE, and the 9 Gyrs, [Fe/H] = -1.0 isochrones to create the first-ever NLTE theoretical isochrones. This resulted in a gravity shift up to 0.6 dex and a temperature shift up to 180K between LTE and NLTE points. The magnitude of the shift between the LTE and NLTE isochrones indicates that stellar cluster ages calculated using LTE isochrones could be overestimated by up to a few Gyrs, with the [Fe/H] = -1.5 isochrone experiencing the greatest overall shift. Additionally, we obtain a correlation between the NLTE gravity correction and the original LTE gravity as predicted by previous observational studies.