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# Determining Star Formation Histories And Age-Metallicity Relations With Convolutional Neural Networks

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# Abstract

**Context.** Recovering the star formation and chemical enrichment histories of galaxies is essential for understanding the physical processes that govern their formation and evolution. Classical full spectral fitting techniques have enabled major advances in this field, but the inversion problem remains highly degenerate, particularly when the available data have limited wavelength coverage and moderate signal-to-noise ratios.

**Aims.** We aim to develop a state-of-the-art tool to infer detailed star formation histories (SFHs) and age-metallicity relations from realistic observational data, while mitigating classical degeneracies and substantially reducing computational cost. In particular, we seek to exploit the complementarity of spectroscopic and photometric data to improve constraints on the spatially resolved SFH and metallicity evolution of nearby galaxies in the PHANGS collaboration.

**Methods.** We construct and train a convolutional neural network (CNN) that combines convolutional layers, attention mechanisms, and a shared latent space to jointly predict SFHs and metallicities in 16 age bins. The network simultaneously processes integral-field spectroscopic data from PHANGS-MUSE and five-band photometric fluxes from PHANGS-HST. Training is performed on a dataset of 165 000 synthetic spectra and photometric measurements spanning a broad range of SFH shapes, metallicity evolution, dust attenuation, and signal-to-noise ratios representative of the observations.

**Results.** The CNN accurately recovers SFHs and age-metallicity relations over a wide range of evolutionary scenarios. The inferred luminosity- and mass-weighted mean ages and metallicities show negligible bias, with dispersions of  $\sim 0.12$  dex in age and  $\sim 0.03$  dex in metallicity. When applied to real PHANGS-MUSE and PHANGS-HST data for NGC 3627, the network produces smooth, spatially coherent maps of stellar age and metallicity that recover physically meaningful structures, including younger populations tracing the spiral arms and star-forming regions. The CNN is approximately  $5 \times 10^3$ – $2 \times 10^4$  times faster than traditional full spectral fitting codes, providing a powerful and efficient alternative for the analysis of large spectro-photometric surveys.

