Stellar Migration and Chemical Enrichment in the Milky Way Disc: The Two-Infall Model

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Simulation Parameters

Recently, Spitoni et al. (2021) parameterized the two-infall model for three bins in radius in the Galactic disk. The infall history is given by:

$$\dot{M}_{\text{in}} = N_1 e^{-t/\tau_1} + H(t - t_{\text{max}}) N_2 e^{-(t-t_{\text{max}})/\tau_2} \tag{1}$$

where N_1 and N_2 are coefficients describing the normalization of the two exponentials, τ_1 and τ_2 are the associated e-folding timescales, t_{max} is the time of onset of the second exponential, and H is the Heaviside step function. They used MCMC methods to obtain best-fit values for these parameters; however, they instead report the present-day surface denisities of high- and low-α stars σ_1 and σ_2 (or rather the ratio thereof σ_2/σ_1). The first three can be taken directly as inputs to a `VICE` simulation, but N_2/N_1 is required rather than σ_2/σ_1. Spitoni et al. (2021) report σ_x as the time-integral of the infall history from one of the two exponentials:

$$\sigma_x = \int_0^T N_x e^{-t/\tau_x} dt \tag{2}$$

The ratio N_2/N_1 is then related to σ_2/σ_1 in the following way:

$$\frac{N_2}{N_1} = \left(\frac{\sigma_2}{\sigma_1}\right)\left(\frac{\tau_1(1 - e^{-T/\tau_1})}{\tau_2(1 - e^{-(T-t_{\text{max}})/\tau_2})}\right) \tag{3}$$

where T is the age of the Galaxy (or the amount of time the simulation runs for: 13.2 Gyr in our original paper). Although such a procedure neglects correlated errors, an estimate of the uncertainties in N_2/N_1 can be obtained from the uncertainties in each of σ_2/σ_1, τ_1, τ_2, and t_{max}, adding them in quadrature. Since we're only looking for a simple scaling of N_2/N_1 with Galactocentric radius R_{gal}, such a simple uncertainty estimate is likely fine for our purposes.

Fig. 1 plots the Spitoni et al. (2021) fit parameters as a function of R_{gal}, with a by-eye description of the trends shown in a dotted line. They are given by:

$$\frac{\tau_1}{\text{Gyr}} = 0.1 + e^{(R_{\text{gal}} - 13\text{ kpc})/1\text{ kpc}} \tag{4a}$$

$$\frac{\tau_2}{\text{Gyr}} = 3.7 + e^{(R_{\text{gal}} - 10\text{ kpc})/1\text{ kpc}} \tag{4b}$$

$$\frac{t_{\text{max}}}{\text{Gyr}} = 5.4 - \frac{R_{\text{gal}}}{5\text{ kpc}} \tag{4c}$$

$$\frac{N_2}{N_1} = 0.13 + 0.1 e^{(R_{\text{gal}} - 10\text{ kpc})/1.2\text{ kpc}} \tag{4d}$$

In general, all parameters except t_{max} are relatively constant within ∼10 kpc, beyond which they increase very quickly. The high values of τ_1 and τ_2 at large R_{gal} mean that at these radii, the SFH will resemble a step function more so than a double exponential. The high values of N_2/N_1 indicate that the in-situ population there will overwhelmingly consist of young stars formed during the second infall episode. The negative slope of the t_{max}-R_{gal} relation means that the second infall episode started earlier at large R_{gal} and propogated inward.

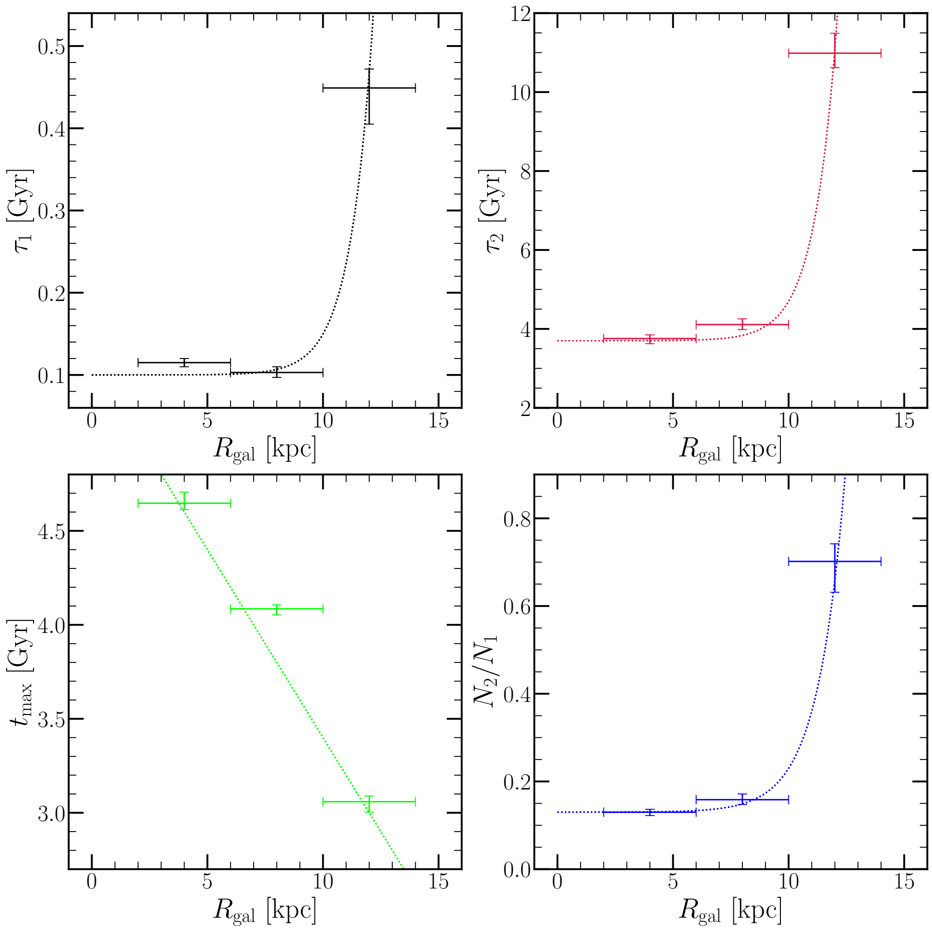

Figure 1: Two-infall model fit parameters from Spitoni et al. (2021). Error bars denote the width of the annulus in their multi-zone model (x-direction) and the uncertainties on the parameter fit (y-direction). Dotted lines denote by-eye descriptions of the trends with $R_{\rm gal}$. The fit parameters are the e-folding timescale of the first infall episode (upper left), the e-folding timescale of the second infall episode (upper right), the time of onset of the second infall episode (lower right), and the ratio of amplitudes of the second to the first exponential describing the infall history (lower right).

Bibliography

Spitoni E., et al., 2021, A&A, 647, A73