# GSEnotes

April 8, 2022

1 Fitting the Gaia Sausage Enceladus Abundances with One-Zone Models

If we apply the fitting routines that we explored for mock samples to the GSE, what does that imply about the evolutionary history of the GSE progenitor?

We begin with an $N = 472$ sample of GSE stars with no age information (ask Charlie for specifics of sample selection). For this sample we have measurements of [Fe/H] and [α/Fe], with the latter incorporating all of the alpha elements. However, in the wavelength range that H3 operates, Mg has many more spectral lines than other alpha elements, making [α/Fe] essentially a proxy for [Mg/Fe]. We additionally make use of an $N = 189$ sample of GSE stars with higher signal-to-noise, 95 of which have age information available.

We show both samples below in the [α/Fe]-[Fe/H] plane in the left hand panel below, and for the smaller sample (in red everywhere), we additionally show the age-[Fe/H] and age-[O/Fe] relations in the middle and right hand panels. The error bars on each panel denote the median error in each quantity for the corresponding sample.

We show the distribution of both samples in the [α/Fe]-[Fe/H] plane below, with the larger sample in black and the smaller sample in red.
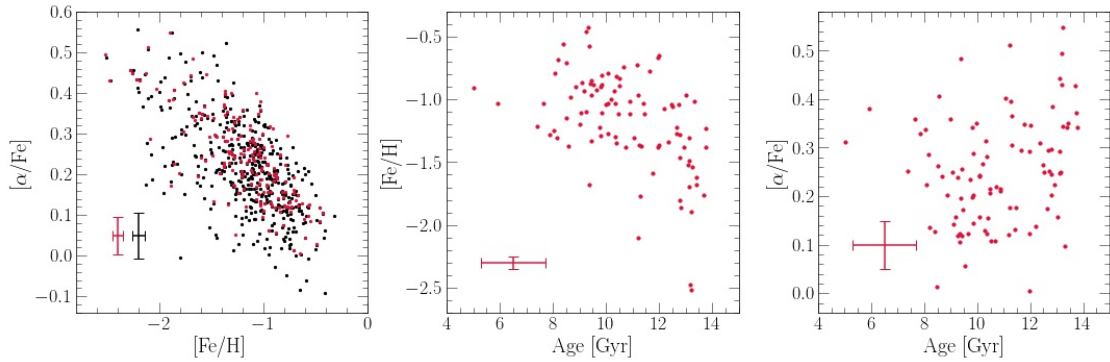

We next apply the same fitting routines explored in the context of mock samples with an exponential infall history characterized by an e-folding timescale $\tau_{\rm in}$, constant star formation timescale $\tau_\star$, constant mass loading factor η, and some duration of star formation $\tau_{\rm tot}$. Below we show the corner plot with the 2-dimensional cross sections of the likelihood function for the $N = 472$ sample with no age information.
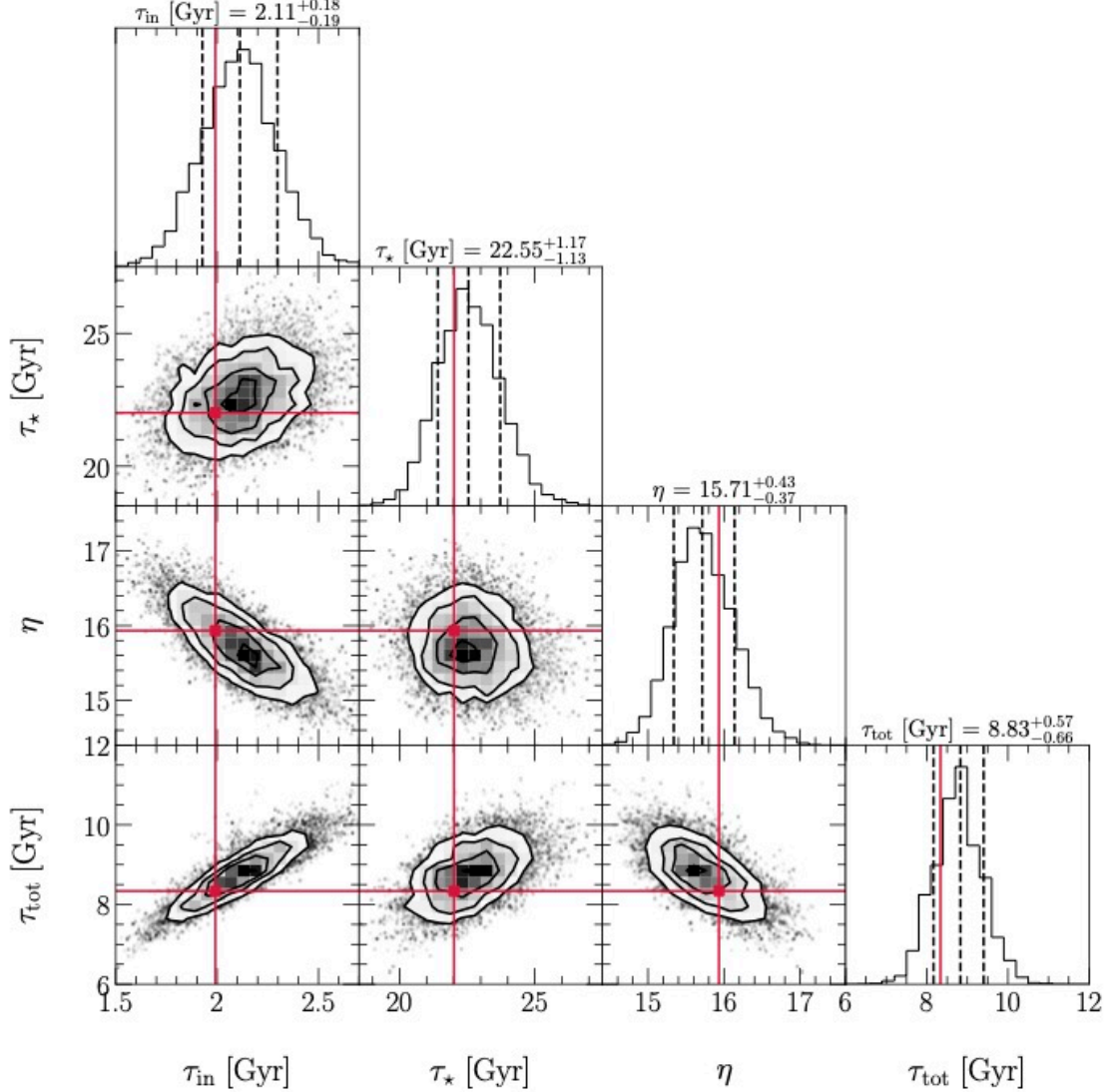
This fit suggests an ~ 8.8 Gyr duration of star formation in the GSE, and an e-folding timescale of the infall history of ~ 2.1 Gyr. Star formation was relatively inefficient ($\tau_\star \approx 22.5$ Gyr), and outflows relatively strong ($\eta \approx 15.71$). Weak star formation and strong outflows are expected for a dwarf galaxy since a small fraction of its gas reservoir will be able to shield itself against the cosmic UV background, and strong outflows are also expected because of the weak gravitational potential. It is more or less necessitated by the requirement of a low equilibrium abundance suggested by the data.

Below we show the predicted tracks in [O/Fe]-[Fe/H] as well as distributions in age, [Fe/H], and [O/Fe] in comparison to the sample shown in black. The best fit model is shown in red along with 200 additional one-zone models drawn from the posterior and plotted as high-transparency lines to give a sense of the uncertainty in the fit. We additionally draw 10^4 stars from the star formation history in this model, perturb their ages and abundances by drawing from gaussian distributions with the same width as the median uncertainties in the model, then rebinning and plotting the distributions in light blue.
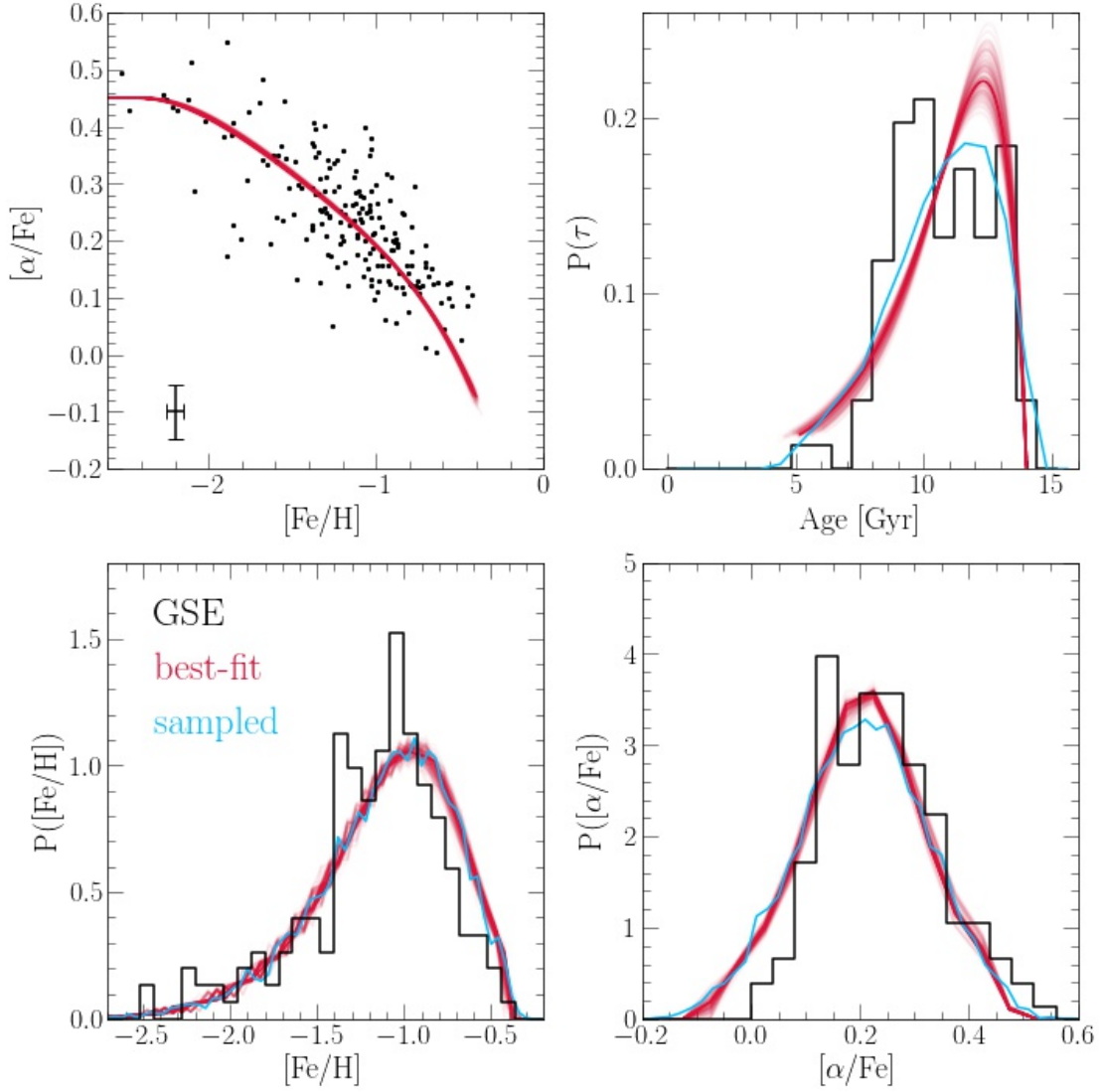
Below we show the same figures but for the smaller $N = 189$ sample where 95 stars have age information. We include this age information in the fit, still basing the likelihood calculation on abundances for all stars, but including age information where available.
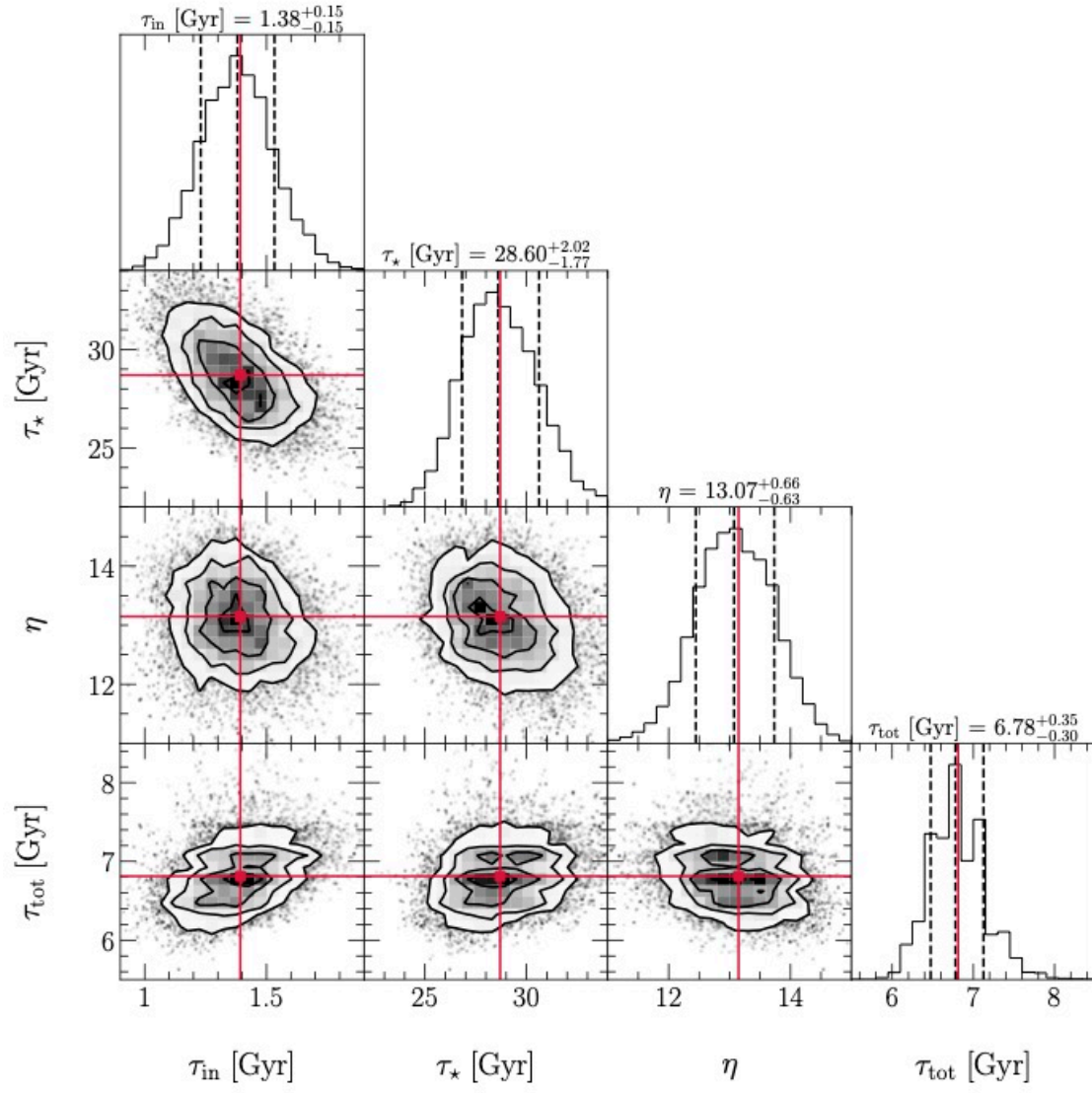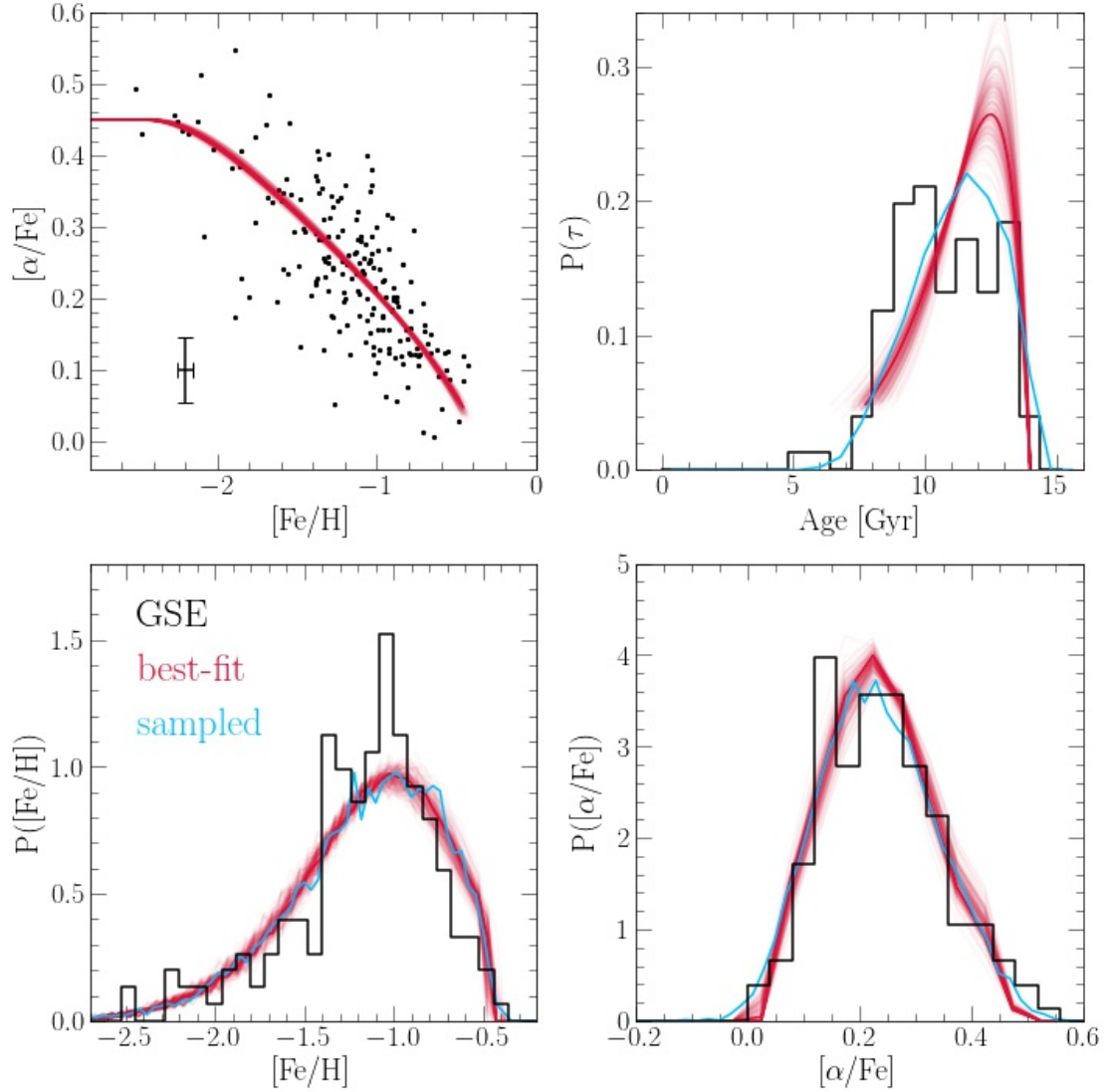
As we've seen in the mock samples, including age information gets rid of much of the degeneracy between $\tau_{\rm in}$ and $\tau_{\rm tot}$. Interestingly, this fit favors a shorter duration of star formation (~ 6.8 versus 8.8 Gyr) and a shorter e-folding timescale on the accretion history (~ 1.4 versus 2.1 Gyr).

In the mock samples, sample size appears to affect the accuracy of fits, but having only explored a handful of mock samples, it remains to be seen if we should be worried about the small sample size of the $N = 189$ sample or the lower signal-to-noise of the $N = 472$ sample. $\tau_{\rm tot} = 6.78$ Gyr puts the accretion of the GSE progenitor at a lookback time of ~ 7.22 Gyr (taking 14 Gyr as the age of the universe as in the H3 stellar age prior), which is more in line with the direct stellar age measurements of the GSE placing it at ~ 8 Gyr ago.

[ ]: