Galaxies in the local Universe can be split into two broad categories: those that are forming stars and those that have stopped. Gas is the fuel for star formation, while we suspect that interactions between supermassive black holes and their host galaxies are one of the driving forces behind its cessation. Interestingly, those galaxies that are forming stars generally sit on a neatly formed ‘sequence’ which we call the main sequence of star-forming galaxies, or main sequence for short. Higher mass galaxies are forming more stars than lower mass galaxies. Some very energetic starburst galaxies sit above the relation, and those that are shutting down or quiescent sit below it.

As we probe higher redshifts, we might expect the physical conditions of star formation to change, since there was much more gas available in the early Universe and black holes had less time to build up their mass. Indeed, we see the position of the main sequence evolving with ‘normal’ galaxies inhabiting regions occupied by the most energetic starbursts in the local Universe. We might also expect there to be different physical mechanisms regulating star formation at high and low stellar mass. At low stellar mass the energy injected from supernovae can overcome the gravitational potential, temporarily clearing the galaxy of gas, and shutting off star formation. This might change the slope or scatter about the relation at the lowest stellar masses. And finally, although previous studies have taught us a lot about the main sequence and how it evolves, we still don’t know why galaxies follow this relation. Do galaxies evolve along the main sequence, oscillating about it producing the scatter we see? Or could it be that we view the population as a snapshot at different redshifts, with their position on the main sequence encoding information about their past lives, such as when they started forming and how they accreted gas over time? To start to answer these questions we would like to dissect the scatter about the sequence, but constraining the scatter is complicated by measurement errors.

We have developed a Bayesian Hierarchical model to self-consistently take account of complex uncertainties, as well as the possibility that objects sit off the relation, to gain constraints on the evolution of the main sequence and the form of its intrinsic scatter. The *Hubble* Frontier Fields uses massive galaxy clusters (one of them is shown in Figure 1) as nature’s magnifying glasses to image fainter galaxies than can be viewed in blank fields. Applying our model to this data set, we have also taken account of the full variation in galaxies when deriving our masses and star formation rates (SFRs) by using complex models of stellar and nebular light (light emitted from stellar birth clouds).

From our analysis we have constrained the main sequence over 5 Gyrs, from just ~900 Myrs after the Big Bang (z~6.0) to an epoch just less than half the present age of the Universe (z~1). We show the evolution in the main sequence throughout cosmic time using the specific star formation rate (sSFR): the ratio of current to past integrated star formation (SFR / stellar mass; Figure 2, top panel). This is analogous to the normalisation of the star-forming main sequence, and we show good agreement with previous results in the literature. In the bottom panel of Figure 2, we show the measured intrinsic scatter. The uncertainties are large and the measurement sensitive to which objects are considered to be on the relation. We see no strong evidence for redshift evolution in the intrinsic scatter.

We adapted our model to allow for a linear dependence of intrinsic scatter with stellar mass and focussed on the well constrained lowest redshift bin (1.25<z<2.0). Our results provide no evidence for an increase in the scatter at low stellar mass, contrary to a previous study (both shown in Figure 3). However, an overriding theme throughout our analysis was that across all redshifts, the values of stellar mass, star formation rate and redshift were often not well constrained at lower stellar masses. The soon-to-launch James Webb Space Telescope will provide us with considerably improved constraints, enabling us to overcome these difficulties and continue to investigate the evolutionary paths of galaxies across cosmic time.

This work is soon to be submitted to MNRAS.

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Figure 1. *Hubble* Space Telescope image of Abell 2744, the first Frontier Field strong-lensing cluster. (Lotz et al. 2017).

OPTIONAL CAPTION - explained within the text

Figure 2.

*Top panel:* The evolution of log(sSFR) plotted as a function of redshift for galaxies with a stellar mass of ~109.7 M⊙. Our work is shown by the solid red line with shaded 68% credible intervals. Coloured circles show previous observational results from the literature. The grey dotted line is the prediction of the semi-analytical model of galaxy formation of Menci et al. (2014). The dashed grey line represents a simple functional form normalised to our work at z=2.

*Bottom panel:* Scatter around the main sequence as a function of redshift. The results shown are the averages per redshift bin. The intrinsic scatter calculated by our model is shown as a solid red line with shaded 68% credible intervals. Santini et al. 2017 investigated the main sequence scatter for a variety of stellar masses. The solid and dashed black lines show the intrinsic and observed scatter for a stellar mass of ~1010 M⊙. The dotted black lines show their measurements of intrinsic scatter given a stellar mass of ~108.4 M⊙.

OPTIONAL CAPTION - explained within the text

Figure 3.

*Left panel:* Posterior median values of our 435 1.25<z<2.0 cluster galaxies plotted in the stellar mass - SFR plane, colour-coded to show the probability that each object belongs to the star-forming main sequence (redder) or a separate distribution of outliers (bluer). The solid red line shows our fitted main sequence for 1.25<z<2.0, alongside dashed red lines representing the posterior median values for intrinsic scatter. The MS relation, intrinsic scatter and observed scatter from the work of Santini et al. (2017) are shown as solid, dashed, and dotted black lines respectively. The fixed mass at which the sSFR-redshift relation was fitted (109.7 M⊙) is indicated by the vertical grey dashed line.

*Right panel:* Normalised histograms showing the fitted posterior distributions of intrinsic scatter for galaxies with a stellar mass of ~108.5 M⊙ (blue) and ~1010 M⊙ (orange).