Scatter in the star-forming Main Sequence: A remnant of long-term variations in stellar mass growth?

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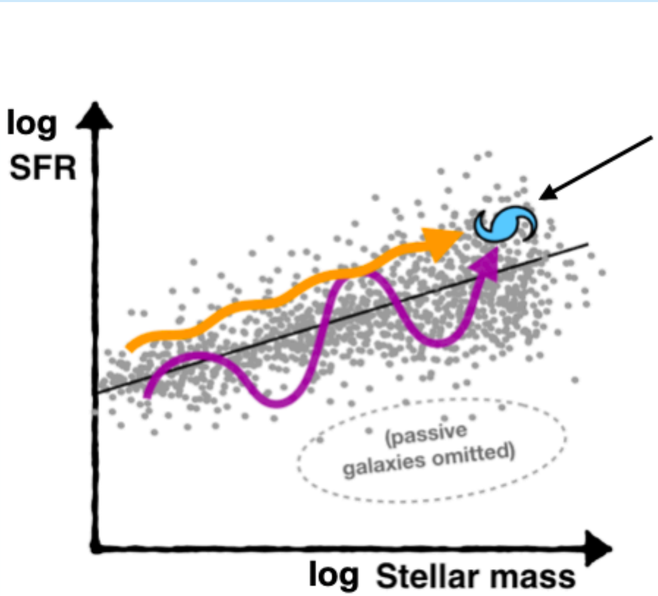
Were today's fastest-growing galaxies always a step ahead?

We constrained the star formation histories of massive nearby galaxies to find out.



Science question:

How did that example galaxy grow?
(Evolution of MS divided out)

Scenario 1: path systematically different from slow growers below the MS

Scenario 2: Stochastic fluctuations span the full scatter

Or a combination of both?

The star-forming Main Sequence (MS) in brief:

- near-linear relation between log $M_\star$ and log SFR (e.g., Brinchmann+ 2004; Noeske+ 2007)
- encompassing 90% of star formation (Rodighiero+ 2011)
- ~constant scatter of 0.3-0.4 dex out to high redshift z~6 (e.g. Salmon +2015)
- Origin of scatter: still under debate! Is it:
  - **Short-term stochastic fluctuations** in growth rate (seen in recent burst/dip)?
  - **Long-term differentiation** on Hubble timescales of galaxies above/below MS?

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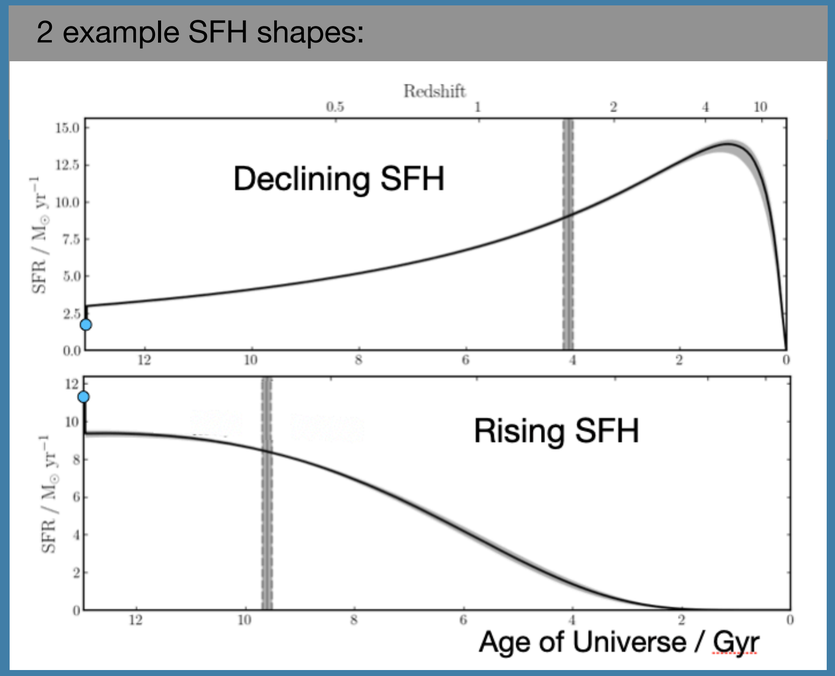
Fitting galaxy spectra as a sum of older + younger stars

Project:

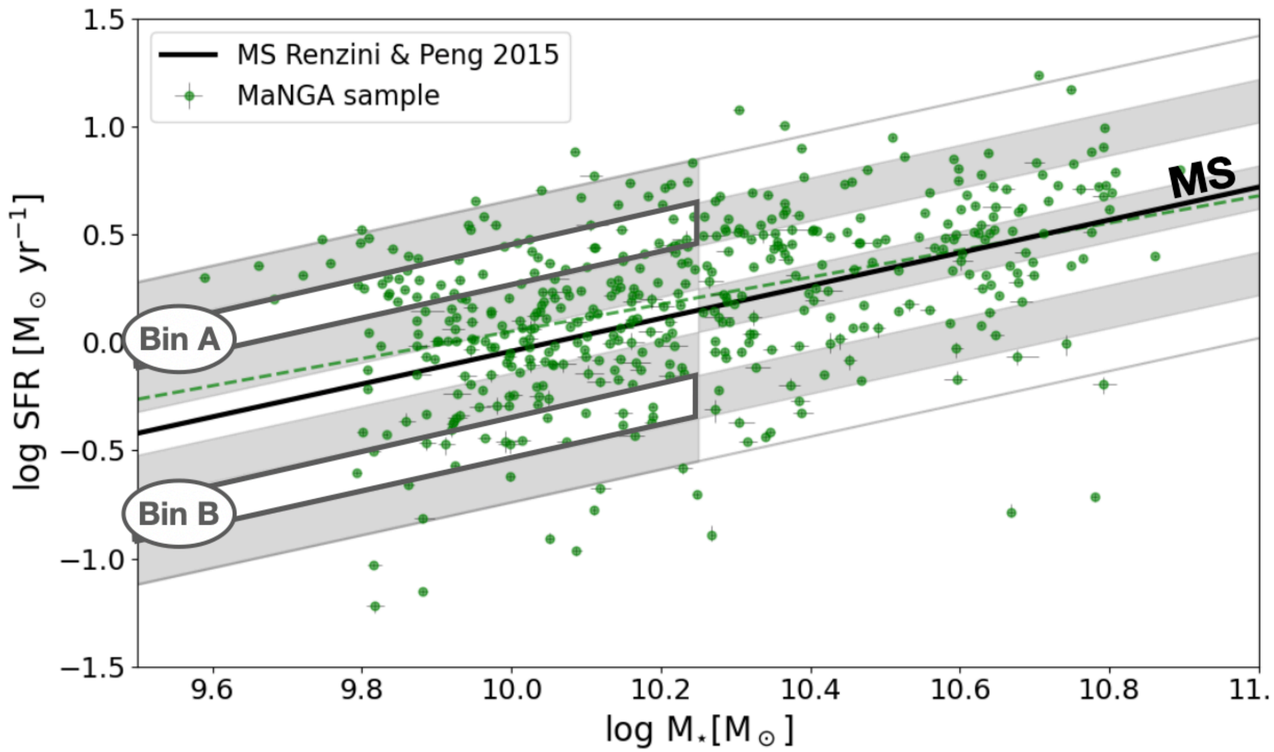
- Fit a 2-component star formation history (SFH) to the spectra of massive star-forming MaNGA (z~0.04) galaxies:
  lognormal + recent burst (using Bagpipes [Carnall+18])

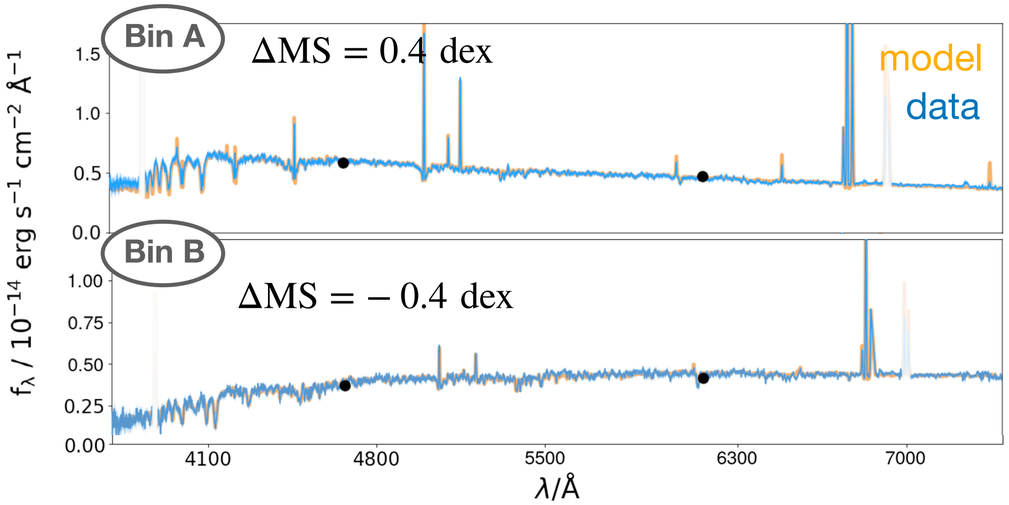
2 example SFH shapes:



→ NOTE: In principle, code could adjust the recent burst only & use the same lognormal for all objects.

- Compare recovered SFHs from different bins around the Main Sequence. → Bins and 2 example fits are shown on the right



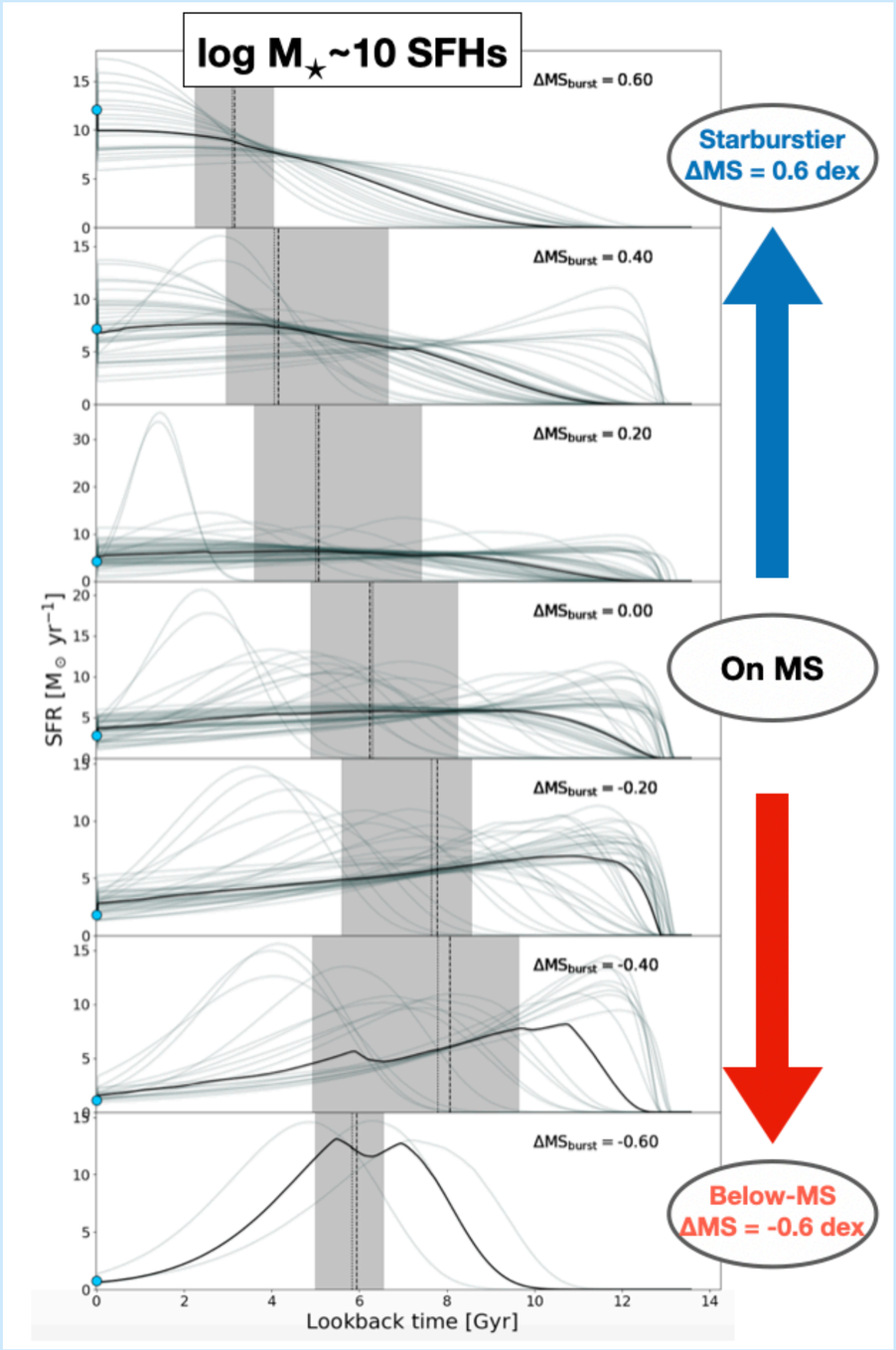


Do the star formation histories in bins A & B differ? 🤔

Result 1: A link between present-day MS offset & early star formation history (SFH)

Classifying our recovered SFHs into bins of different Main Sequence (MS) offset shows:

Today's below-MS galaxies are further into the declining phase of their SFH.



Recovered SFHs for star-forming galaxies of log $M_\star$ ~10, classified into bins of different Main Sequence offsets ΔMS_{burst} = log SFR_{burst} - log SFR_{RP15} = 0.6, 0.4, ..., -0.6 dex.

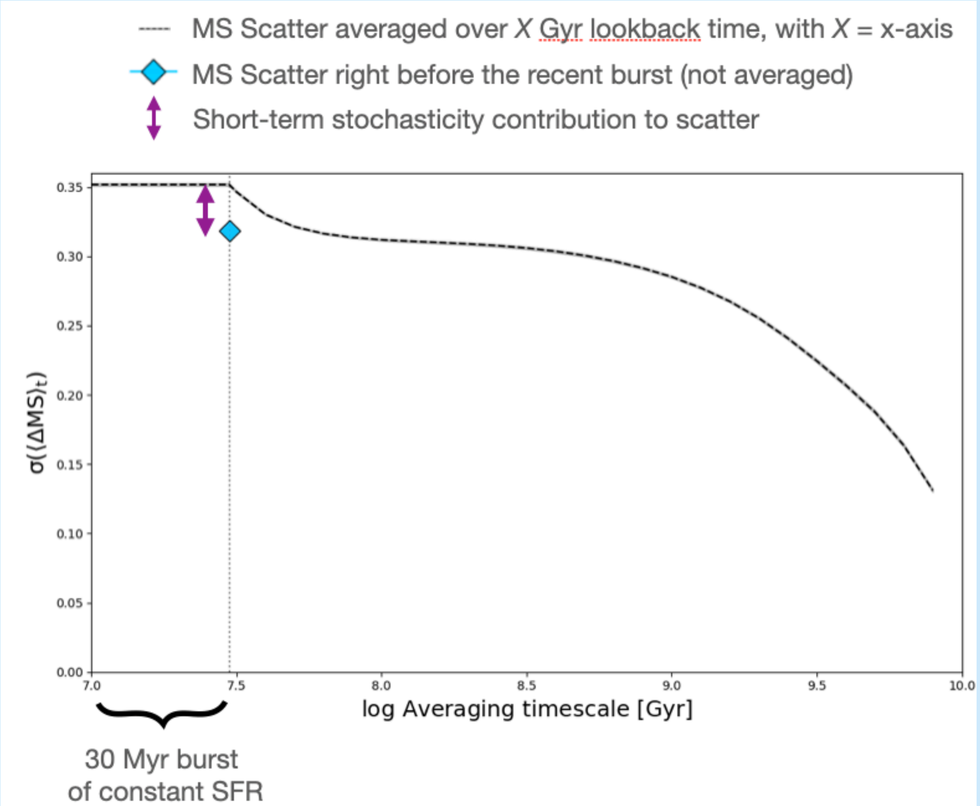
The median SFH in each panel is show by a black line. The SFR of the recent burst is highlighted by a blue dot, and vertical lines represent t_{50}= time at which 50 % of a galaxy was assembled.

More Results: Dividing up the scatter

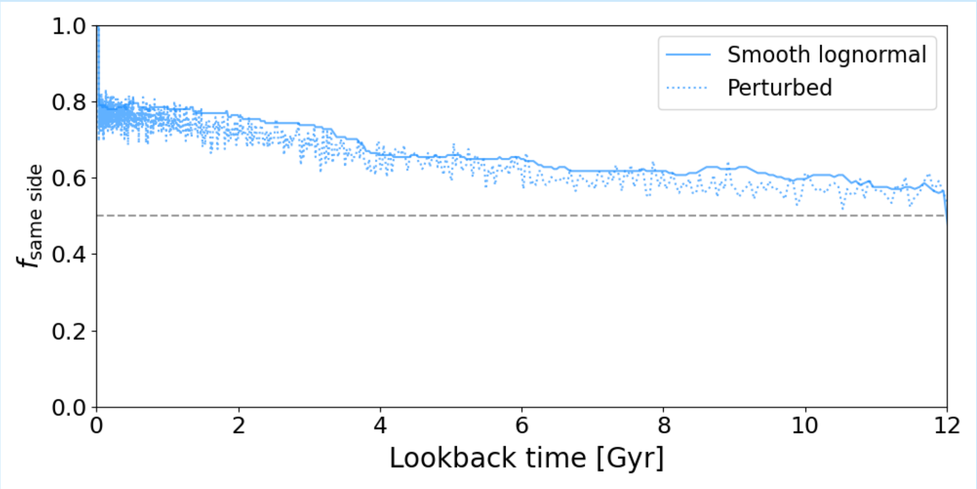
Now, we throw together all recovered star formation histories (SFHs)
→ get MS scatter averaged over different lookback times (top Fig)

→ Conclusion: Scatter is predominantly due to Hubble timescale processes (e.g. due to differences in halo formation redshifts - see Matthee&Schaye 2019)

→ Further: At any given $t_{lookback}$, a majority of galaxies are found on the same side of the MS as they inhabit today (bottom Fig)



Evolution of the MS scatter, based on SFR(t) averaged over the period in lookback time indicated on the x-axis.
The blue marker shows the MS scatter derived at the recent end of the log-normal SFH component (i.e., not averaged over time).



Fraction of galaxies that, at a given lookback time, maintain the same above/below-MS status as they do today.
The dotted line displays the fraction recovered when perturbing the backtracked MS offset values within 0.12 dex to approximately account for the contribution of stochasticity.

References: Brinchmann et al., 2004, MNRAS Carnall et al., 2018, MNRAS Matthee & Schaye, 2019, MNRAS Noeske et al., 2007, ApJ Rodighiero et al., 2011, ApJ Salmon et al., 2015, ApJ