2022/11/08 Journal club

GOODS-ALMA 2.0: Last gigayear star formation histories of the so-called starbursts within the main sequence

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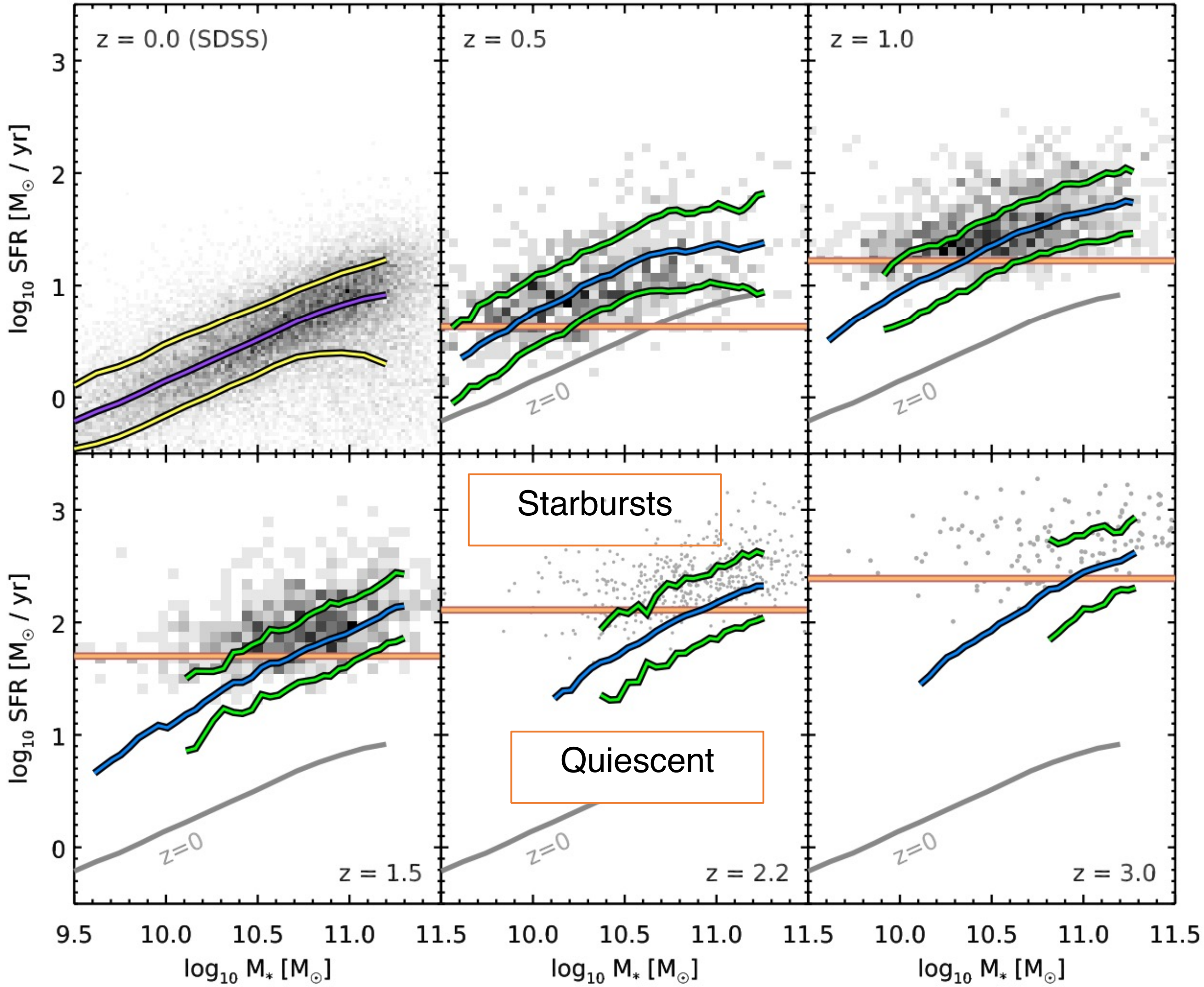
Abstract

Recently, a population of compact main sequence (MS) galaxies exhibiting starburst-like properties have been identified in the GOODS-ALMA blind survey at 1.1 mm. Several evolution scenarios were proposed to explain their particular physical properties (e.g., compact size, low gas content, short depletion time). In this work, we aim at studying the star formation history (SFH) of the GOODS-ALMA galaxies to understand if the so-called "starburst (SB) in the MS" galaxies exhibit a different star formation activity over the last Gyr compared to MS galaxies that could explain their specificity. We use the CIGALE SED modelling code to which we add non-parametric SFHs. To compare quantitatively the recent SFH of the galaxies, we define a parameter, the star formation rate (SFR) gradient that provides the angle showing the direction that a galaxy has followed in the SFR vs stellar mass plane over a given period. We show that "SB in the MS" have positive or weak negative gradients over the last 100, 300, and 1000 Myr, at odds with a scenario where these galaxies would be transitioning from the SB region at the end of a strong starburst phase. Normal GOODS-ALMA galaxies and "SB in the MS" have the same SFR gradients distributions meaning that they have similar recent SFH, despite their different properties (compactness, low depletion time). The "SBs in the MS" manage to maintain a star-formation activity allowing them to stay within the MS. This points toward a diversity of galaxies within a complex MS.

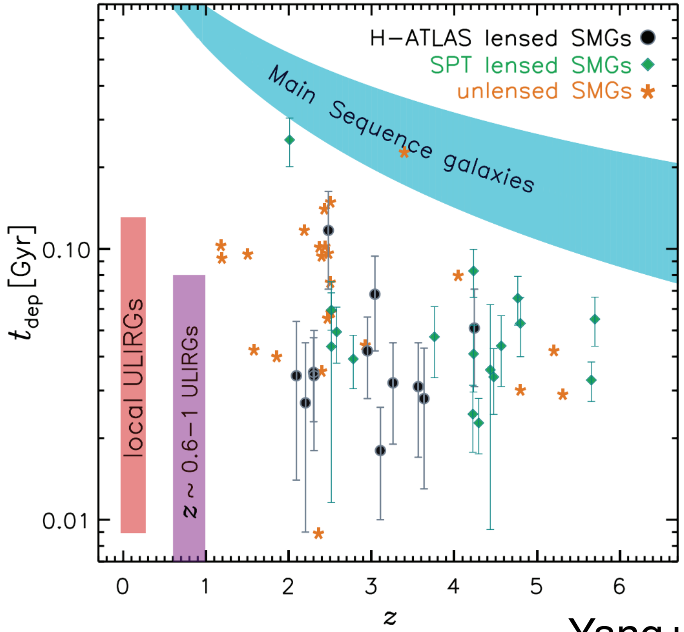
- SBs in the MS do not exhibit any particular SFH that could explain their properties compared to the normal MS galaxies

Main Sequence galaxies (MS)



Schreiber+2015

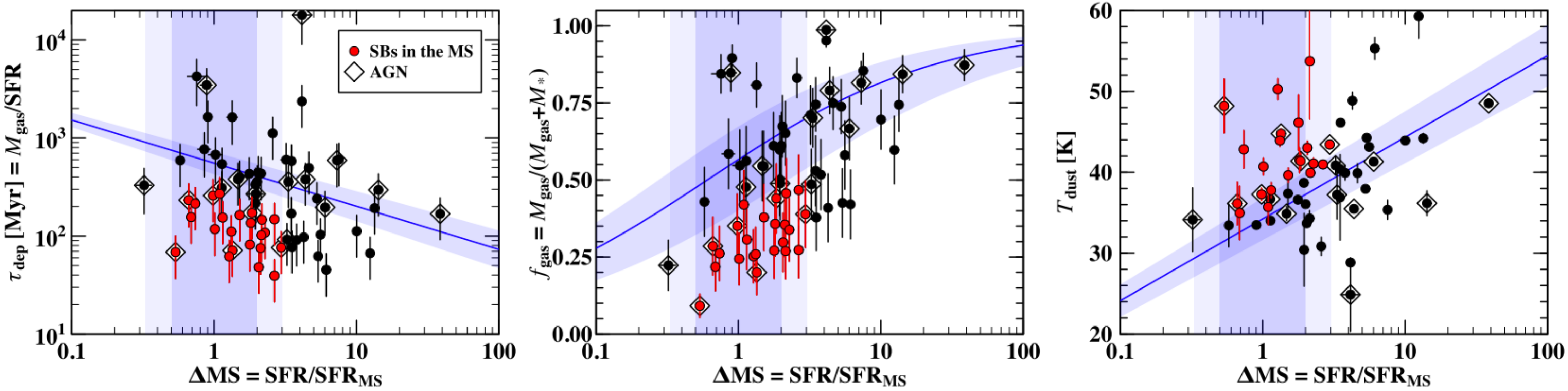
- The small scatter of M*-SFR relation suggests the secular evolution is the dominant mode of stellar assembly
- Star-forming galaxies (SFGs) would spend most of their time evolving as extended star-forming disks



Yang+2019

Starburst galaxies in the main sequence ("SB in the MS")

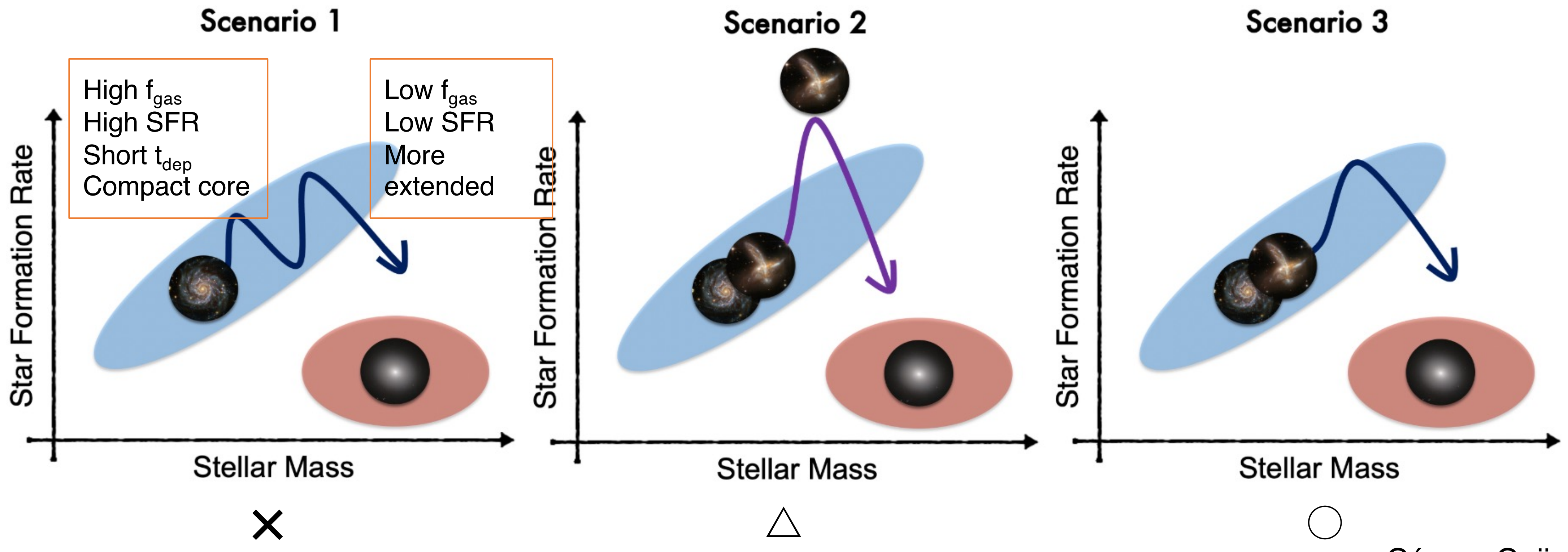
- ALMA have highlighted the existence of a population which have **SB-like properties within MS** (e.g., Elbaz+2018, Gómez-Guijarro+2022)
  - ✓ Short depletion timescale
  - ✓ Compact star formation traced by dust continuum → high dust temperature
  - ✓ High star formation surface density
- They are massive galaxies (~60% of them are M* > 10^11 Msun; Gómez-Guijarro+2022)
- Evolution path of this population is still unknown



Gómez-Guijarro+2022

Starburst galaxies in the main sequence (“SB in the MS”)

- Possible scenarios of galaxy evolution in the MS context



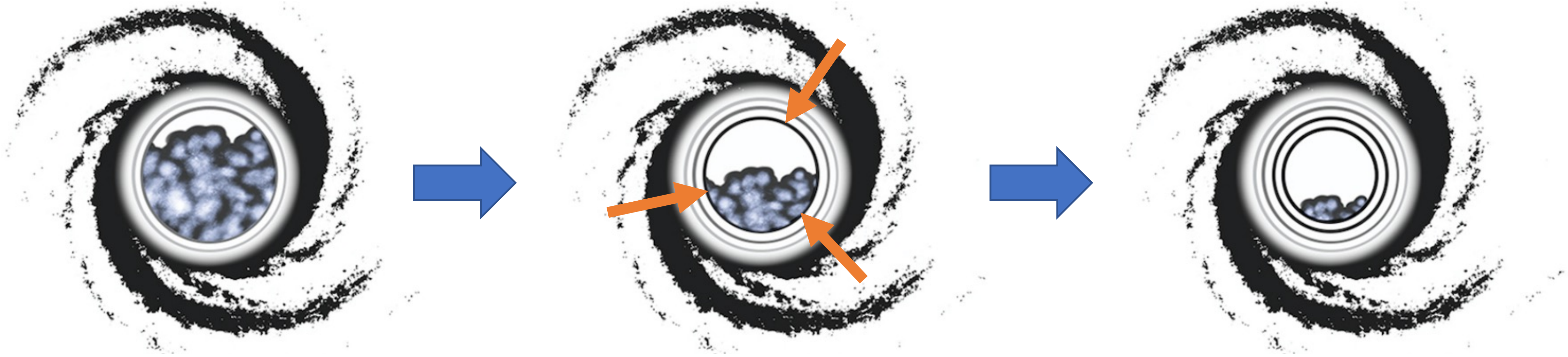
Gómez-Guijarro+2022

- High SFE caused by **compaction** due to mergers or some internal processes

Starburst galaxies in the main sequence (“SB in the MS”)

- Possible scenario of SB in the MS

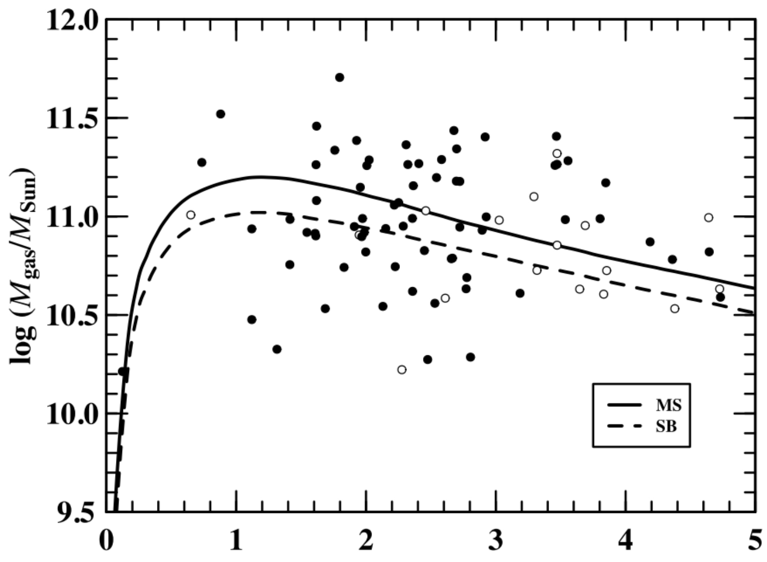
Evolving as extending star-forming disk	Gas transportation to the central region	High SFR in the central **compact** region



Gómez-Guijarro+2022

- High SFE caused by **compaction** due to mergers or some internal processes

Objective and Data



Gómez-Guijarro+2022

Objective

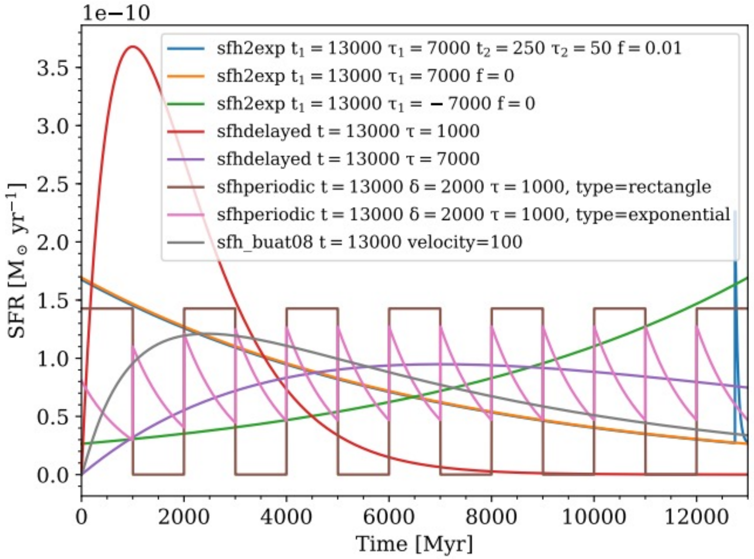
- To disentangle between evolutionary scenarios **by investigating SFH**

Data

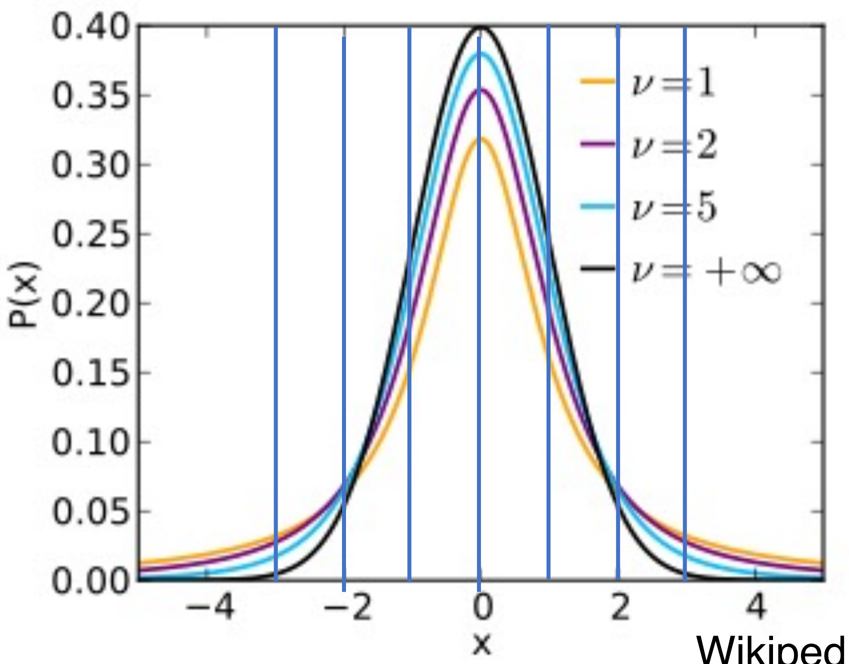
- GOODS-ALMA: blind 1.1 mm survey toward GOODS-South field
  - ✓ Covers a continuous area of 72 arcmin^2
  - ✓ Band 6 observations using two array configurations
  - ✓ GOODS-ALMA 1.0 (Franco+2018): high resolution dataset
  - ✓ GOODS-ALMA 2.0 (Gómez-Guijarro+2022a): combined dataset, beam size~0.4", RMS~68 uJy/beam
  - ✓ Total 88 sources → have Herschel counterpart: 69 → discard HST-dark: 65
- UV and NIR photometry are from ASTRODEEP-GS43
  - ✓ 43 bands from U-band to IRAC 8 um
- Mid-IR: Spitzer/MIPS/24 um
- FIR: GOODS-Herschel (PACS/70, 100, 160 um) and HerMES (SPIRE/250, 350, 500 um)

SED modeling with non-parametric SFH

- Implement a new SFH module SFHNLEVELS to CIGALE
- Assume a given number of time bins in which the SFRs are constant
  - ✓ The first bin age is fixed to an input value
- Use a prior which weights against sharp transitions between SFH bins
  - ✓ “bursty continuity” (Tacchella+2021): Student-t distribution (v=2)



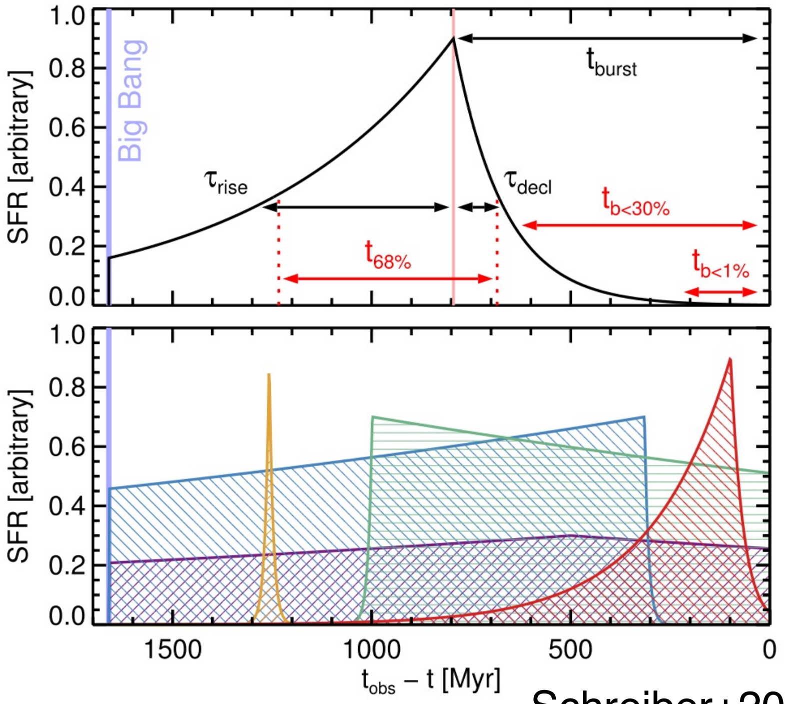
Boquine+2019



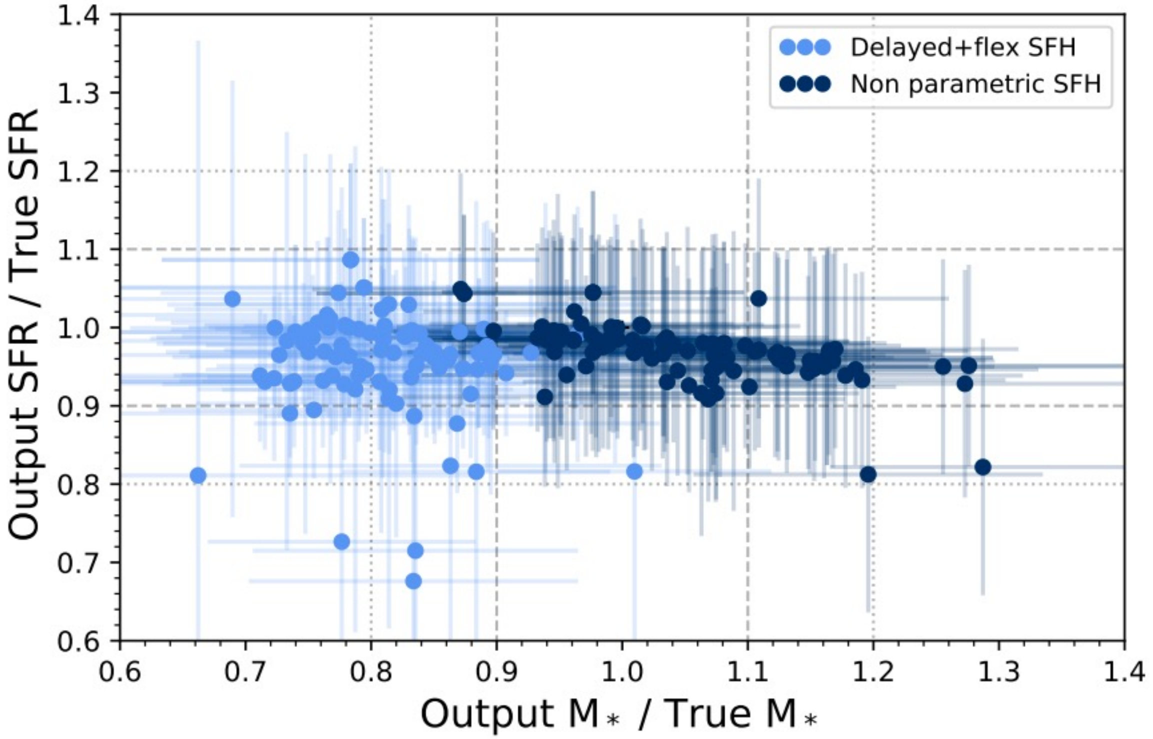
Wikipedia

Accuracy of the non-parametric SFH modeling

- Test the ability of non-parametric SFH to model the SEDs of mock MS galaxies obtained by semi-analytical code GALFORM
- τ-delayed + flexibility SFH vs. non-parametric
- The former model tend to underestimate stellar mass
    - ✓ Parametric SFH is rigid and in order to provide good fit, the resulting SFH is younger



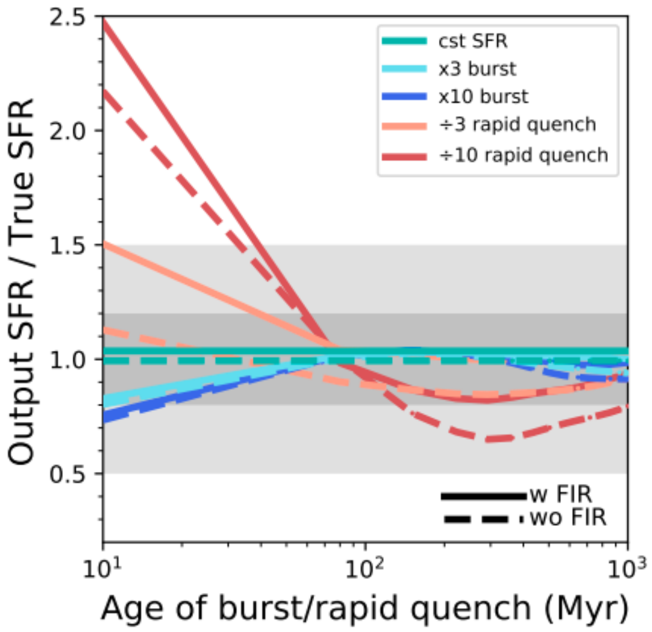
Schreiber+2018

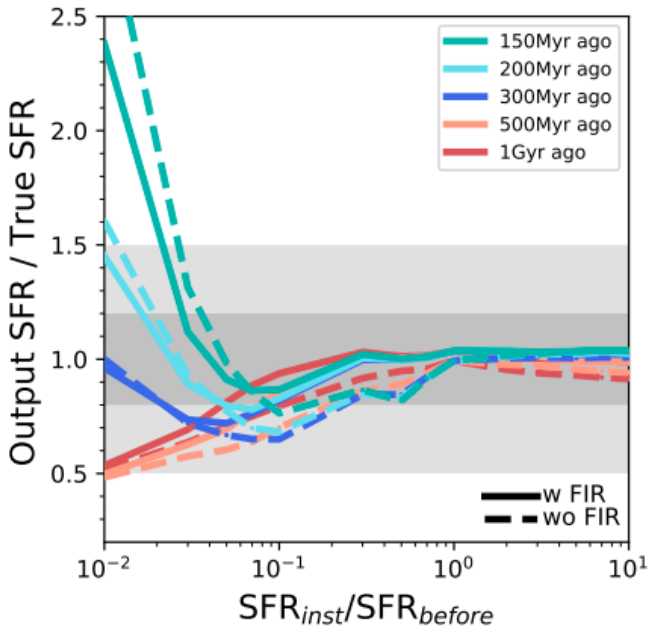


Sensitivity of the non-parametric modeling

- Need to assess the ability to recover any recent variation of SF activity in the last hundreds of Myr
- Simulate a set of mock SEDs assuming a final instantaneous burst or quenching
  - ✓ The time when the variation occurs varies from 10 Myr to 1 Gyr
  - ✓ Its strength (SFR_{inst}/SFR_{before}) is set between 0.01 to 10

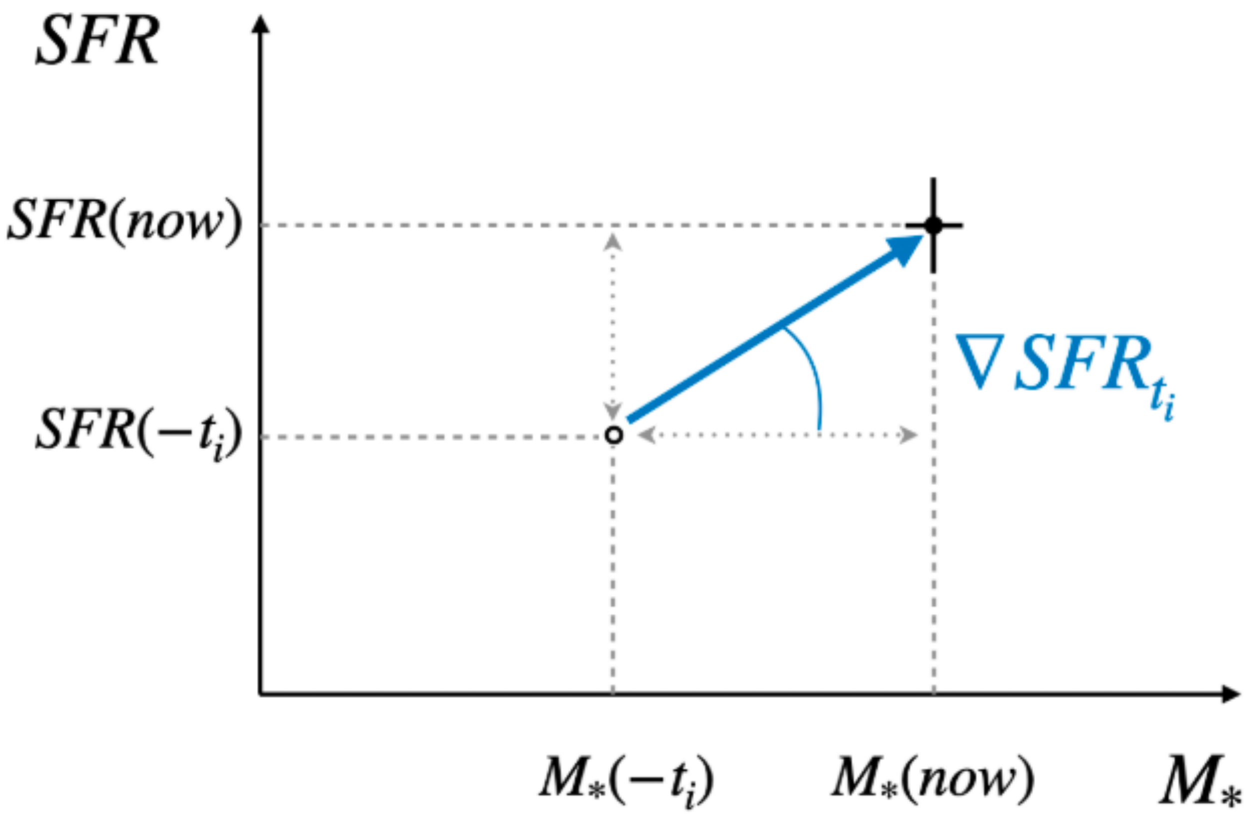
- Burst event:
  - ✓ Well recovered, even a factor 10 case
- Quenching event:
  - ✓ Overestimated by 50% where the age of variation is 40 Myr





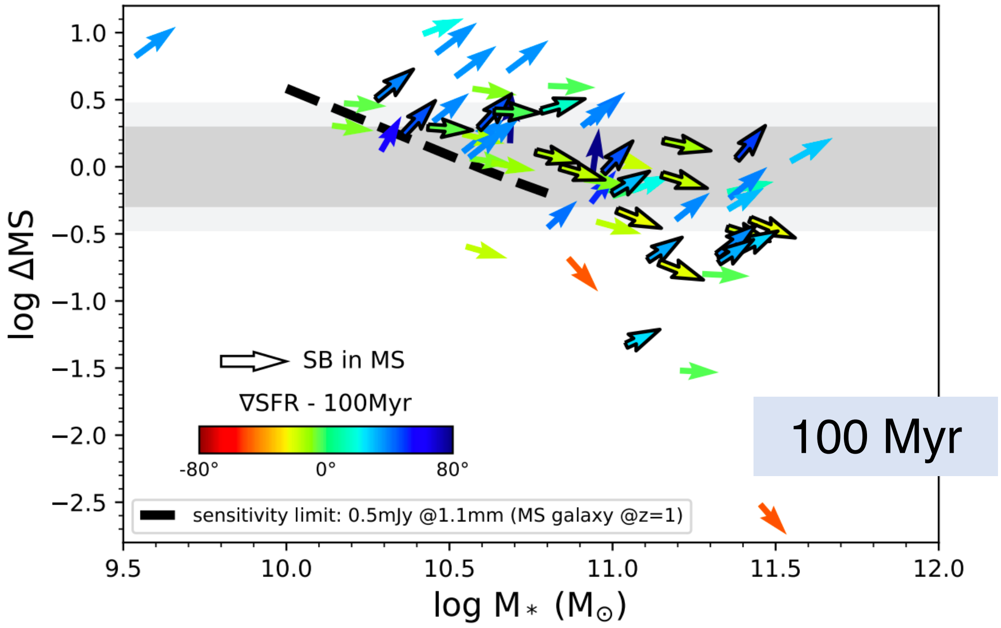
Definition of SFR gradient

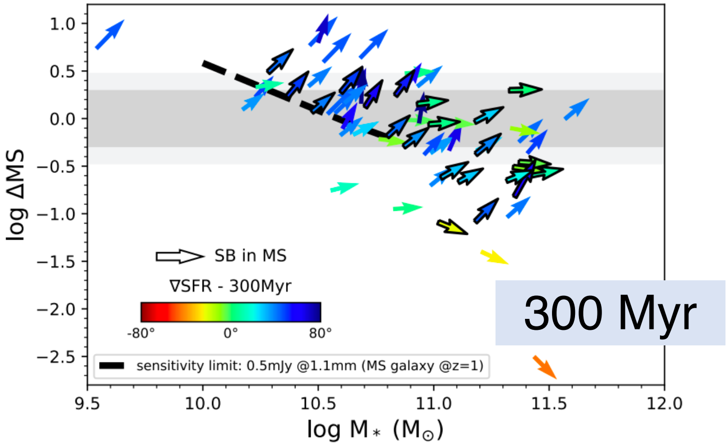
- ∇ SFR = 0°: recent SFH is overall constant
- |∇ SFR | >> 0°: undergoes a starburst/quenching phase

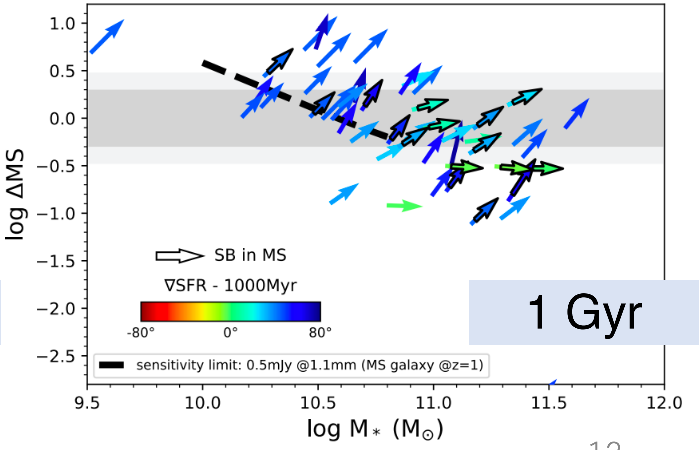


Results

- Lower mass ($M_* < 10^{10.7}$ Msun) galaxies are mostly located above MS
  - ✓ Due to the detection limit
- Lower mass galaxies have a positive gradient
  - ✓ Indicative of an undergoing enhances SF
- SB in MS (defined by Gómez-Guijarro+2022) have a range of SFH
  - ✓ No significant difference between the normal MS
- Higher mass ones lie within MS or below
- Their last 100 Myr SFH do not show any evidence of a rapid decline
- Over the longer timescales, SF activity has increased

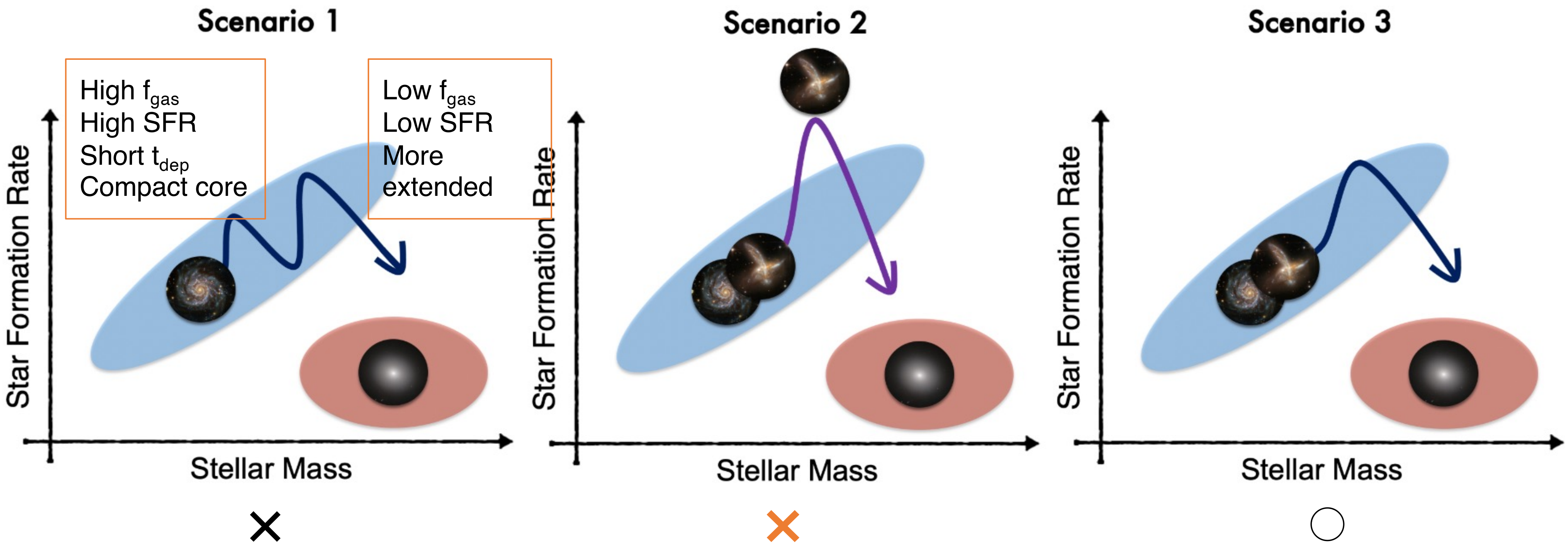






Discussion

- Possible scenarios of galaxy evolution in the MS context



Gómez-Guijarro+2022

- Their last 100-1000 Myr SFH do not show any evidence of a rapid decline

Summary

- This work aimed at constraining the recent SFH of the GOODS-ALMA galaxy sample using non-parametric SFH models
  - ✓ These models provide a better estimate of stellar mass than parametric ones
  - ✓ These models are sensitive to strong burst events
  - ✓ These models are sensitive to strong quenching variations in case of the age is older than 100 Myr
- Define a new parameter ∇ SFR to characterize the SFH
- The SB in MS don't have negative ∇ SFR → decline scenario 2
- Find no differences in the last 1 Gyr SFH between SB in the MS and other galaxies despite their different properties (compactness, low depletion time, …)