Non-parametric Analysis of Stellar Mass and Star Formation Timescale

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Outline

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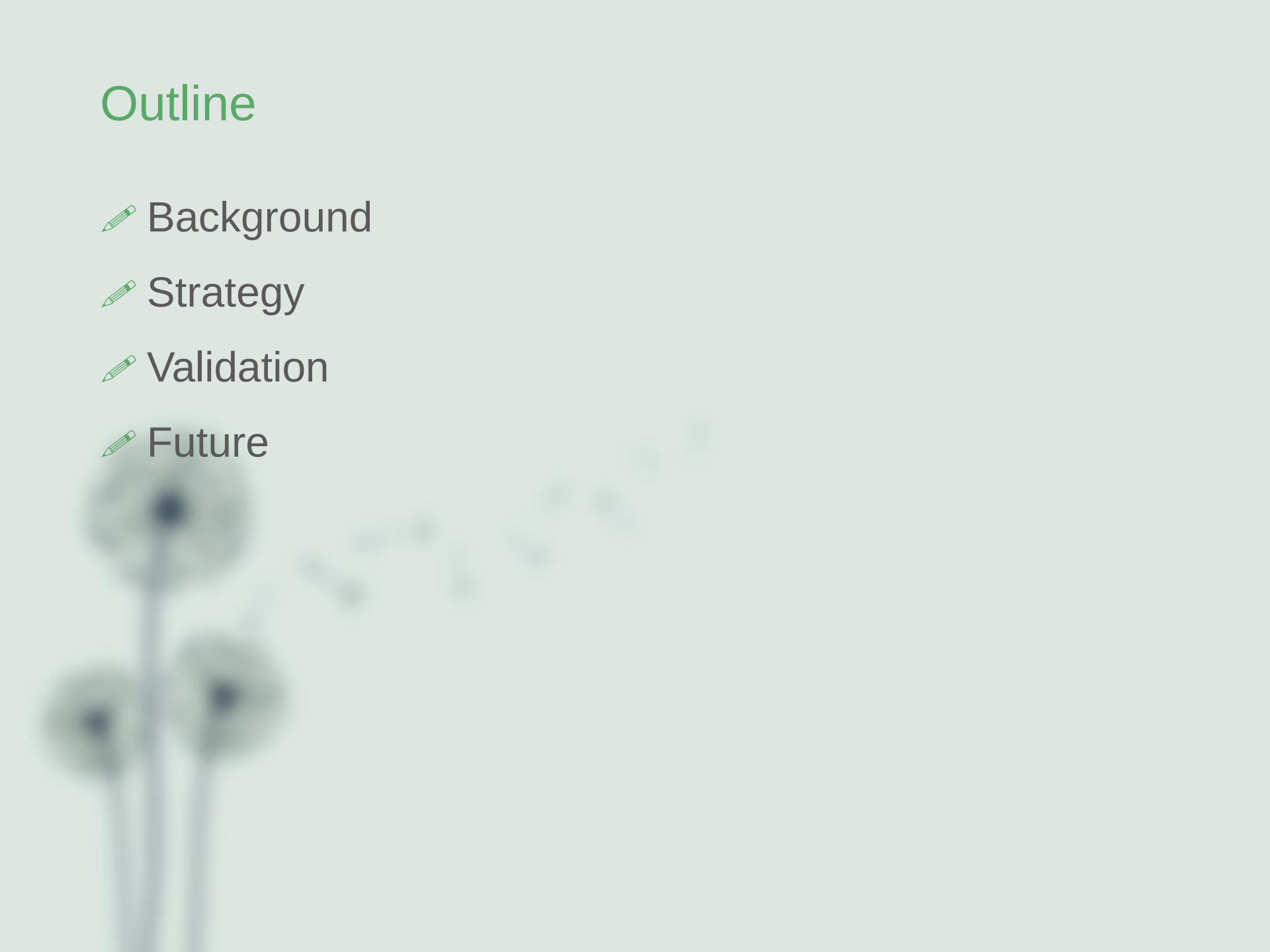
- Strategy
- Validation
- Future



Background

1. Significance

① Total mass in stars (M_*) and star formation history (SFH) contribute to our modern understanding of galaxy formation and evolution.

② The observations now cannot resolve stellar populations in most of galaxies.

③ Stellar population synthesis (SPS) can extract information, such as M_* and SFH, from SEDs by matching observations with composite stellar populations (CSPs) which constructed with different simple stellar populations (SSPs).

Background

2. Stellar population synthesis (SPS)

① Initial mass function (IMF): Chabrier & Salpeter

② Stellar evolution & isochrones: Padova

③ Stellar spectral libraries: theoretical libraries & empirical libraries

④ SFH: $SFR \propto te^{(-t/\tau)}$

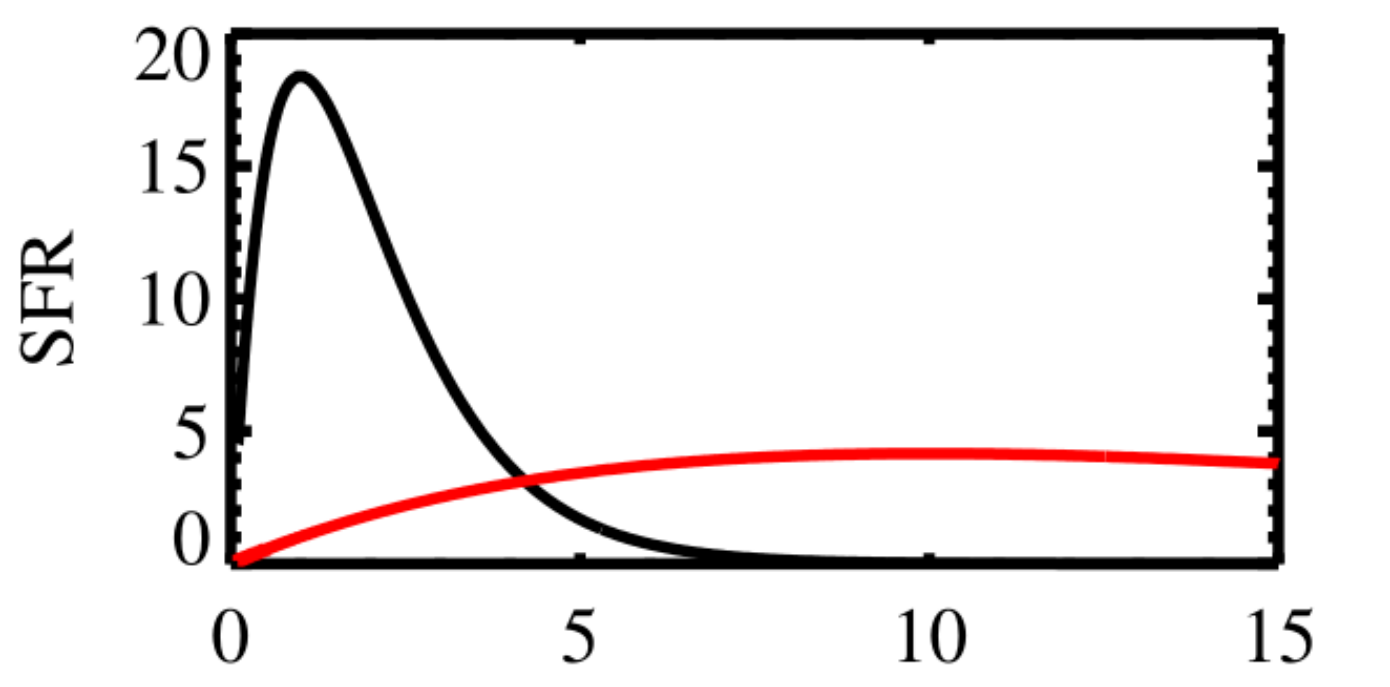
⑤ We can combine different SSPs with SFH to construct CSP, and then fit the CSP to photometric data or spectrum to obtain properties of stellar populations, such as M_*, SFH.

Background

2. Stellar population synthesis (SPS)

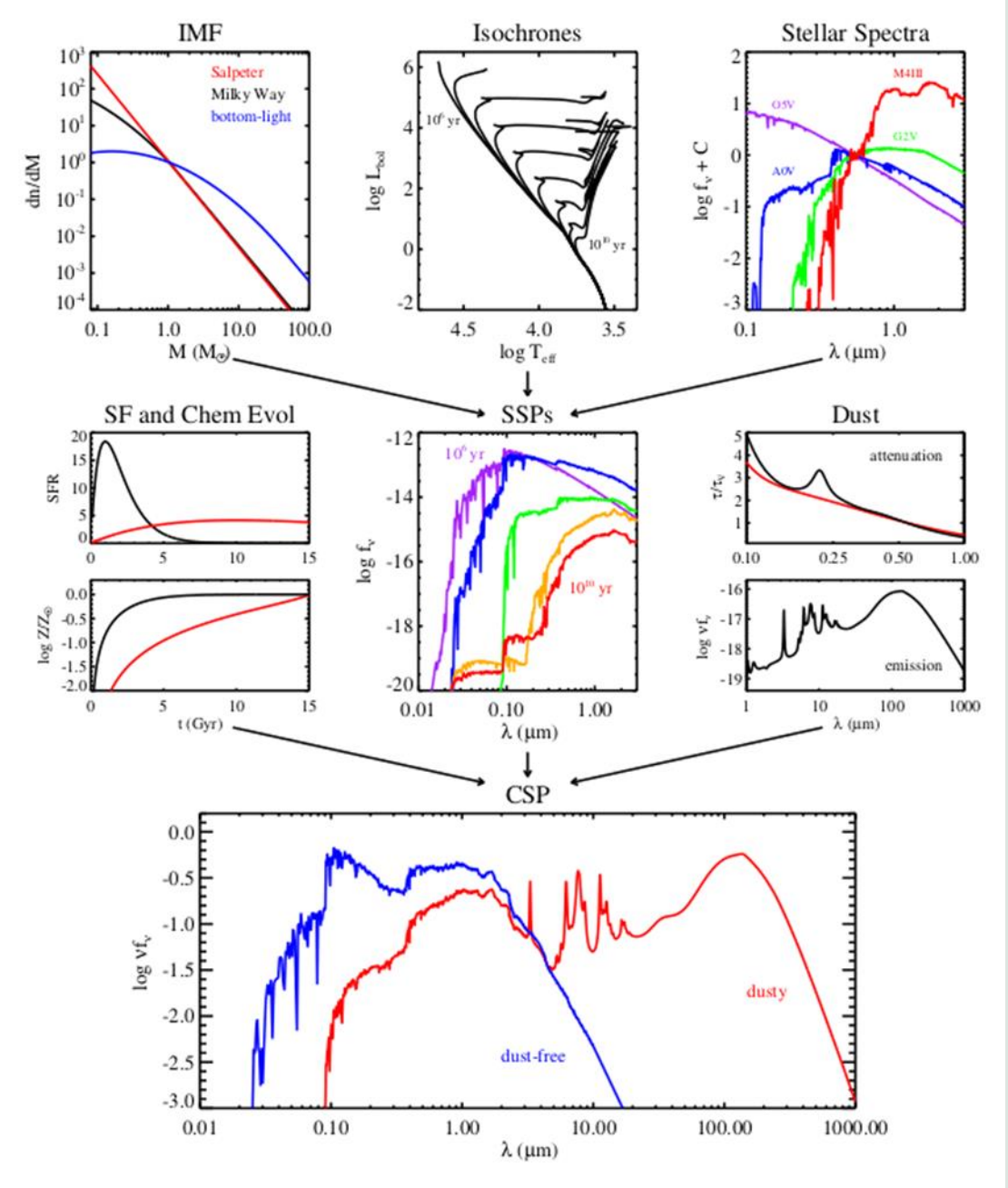
parametric SFH: $\mathrm{SFR} \propto te^{(-t/\tau)}$

The τ of red line is larger than that of black line.



Background

2. Stellar population synthesis (SPS)



Background

3. Status

① With the development of technology, more accurate photometric data and wider coverage in wavelength enable us to fit CSP to multi-colour photometric data.

② With the development of computing power, we can also fit CSP to full spectrum.

Background

3. Status

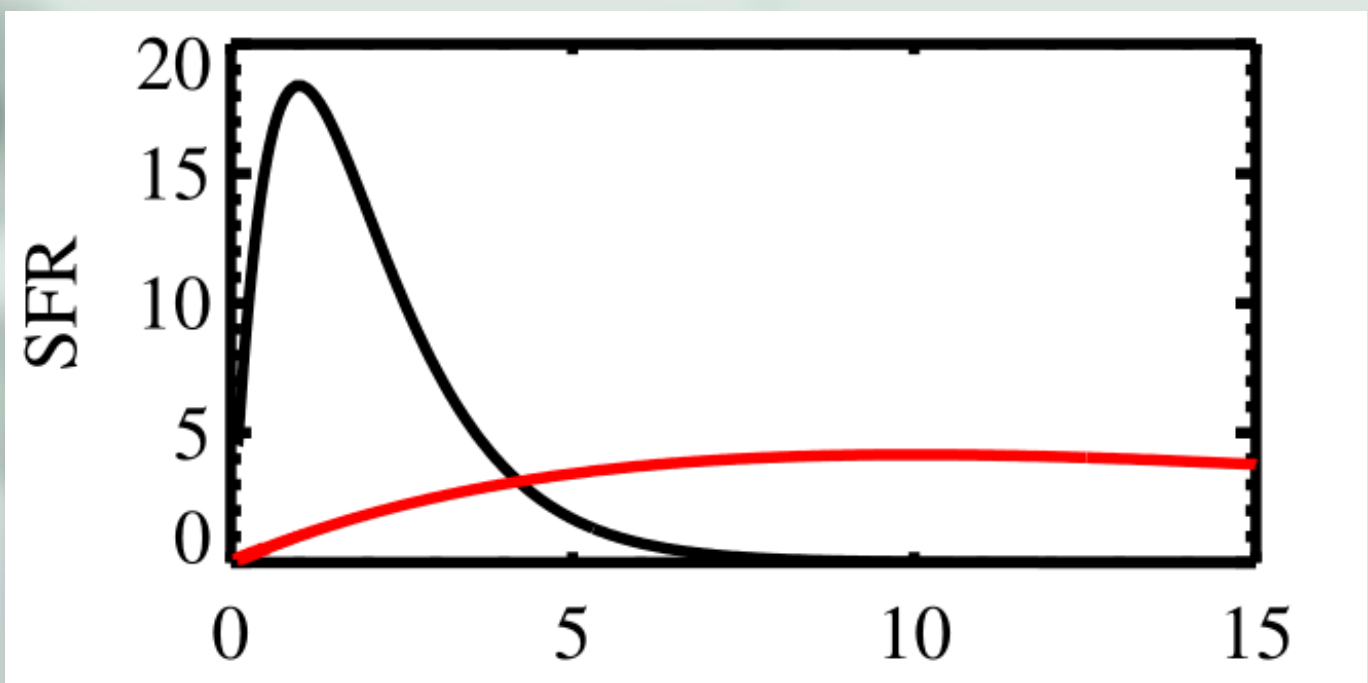
③ Integral field spectrograph (IFS) lets spectrum have spatial resolution such as MaNGA which can obtain the spectrum of the whole galaxy rather than just center of a galaxy. Using SPS, we can analysis relations between stellar populations and structure of galaxies and their coevolution.

Background

3. Status

④ Parametric SFH： $\mathrm{SFR} \propto \mathrm{te}^{-\frac{t}{\tau}}$

The result of fitting depends on the SFH model.



Background

3. Status

⑤ Non-parametric SFH：

we can do not constraint the shape of SFH, but fit masses of different SSPs that is weights of SSPs.

⑥ There are several codes of SPS, in which pPXF and STARLIGHT are most used which perform full spectrum fitting using non-parametric SFH, but they all just obtain a optimum solution of parameters rather than probability density distribution (PDF) of parameters in parameter space.

Strategy

1.Ours

We use SPS with non-parametric SFH and Bayesian statistical method to obtain total mass (M_{tot}) in galaxy and star formation timescale, for example the star formation time of half M_{tot} (t_{50}).

① Non-parametric SFH replacing parametric :

we use n masses of SSP to characterize SFH, that is, we use M_i (i=1,2…n) replacing τ to analysis photometric data of galaxies.

Strategy

1.Ours

② PDF replacing optimum resolution:

we use Bayesian statistical method to obtain PDF of M_i instead of just a optimum resolution.

② Constructing new parameter using PDF:

we can construct a new parameter $Q=f(M_1, M_2, M_3, \ldots M_n)$, and then obtain the PDF of Q from that of M_i. In this way, we can obtain a new parameter with good statistical properties, for example M_{tot} and t_{50}.

Strategy

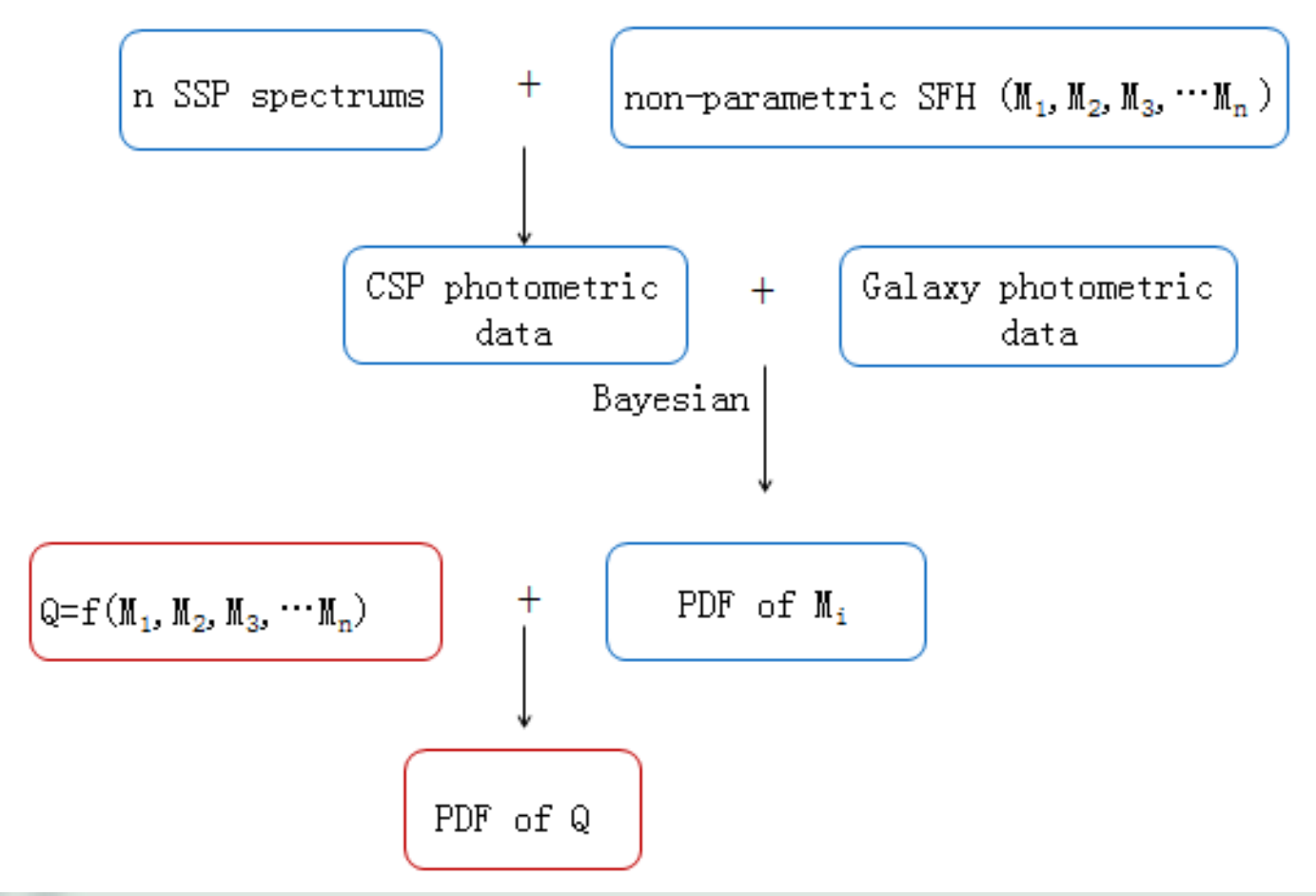
1.Ours

③ Bayesian evidence：

We can also discuss different SSP models, for example BC03 and Mist, or IMF such as Chabrier and Salpeter.

Strategy

1.Ours



Strategy

2.Comparing with pPXF and STARLIGHT

① pPXF obtains the weights of SSPs by resolve matrix equation.

② STARLIGHT obtains the weights by searching the related χ^2_{min} using mcmc.

③ pPXF and STARLIGHT all perform full spectrum fitting, which, however, is very slow. And the SSP models are not enough accurate to resolve spectrum. This may lead to some influences on results, for example too many peaks in parameter space.

Strategy

2.Comparing with pPXF and STARLIGHT

④ Both pPXF and STARLIGHT obtain optimum resolutions rather than PDF of parameters, so they can not obtain PDF of a new parameter from that of fit parameters.

Validation

1. Validating the correctness of likelihood and reliability of mcmc

Mock data：z=0.02，age=2.6Gyr，mass=1$M_{\odot}$

Fit parameters：z，age，mass

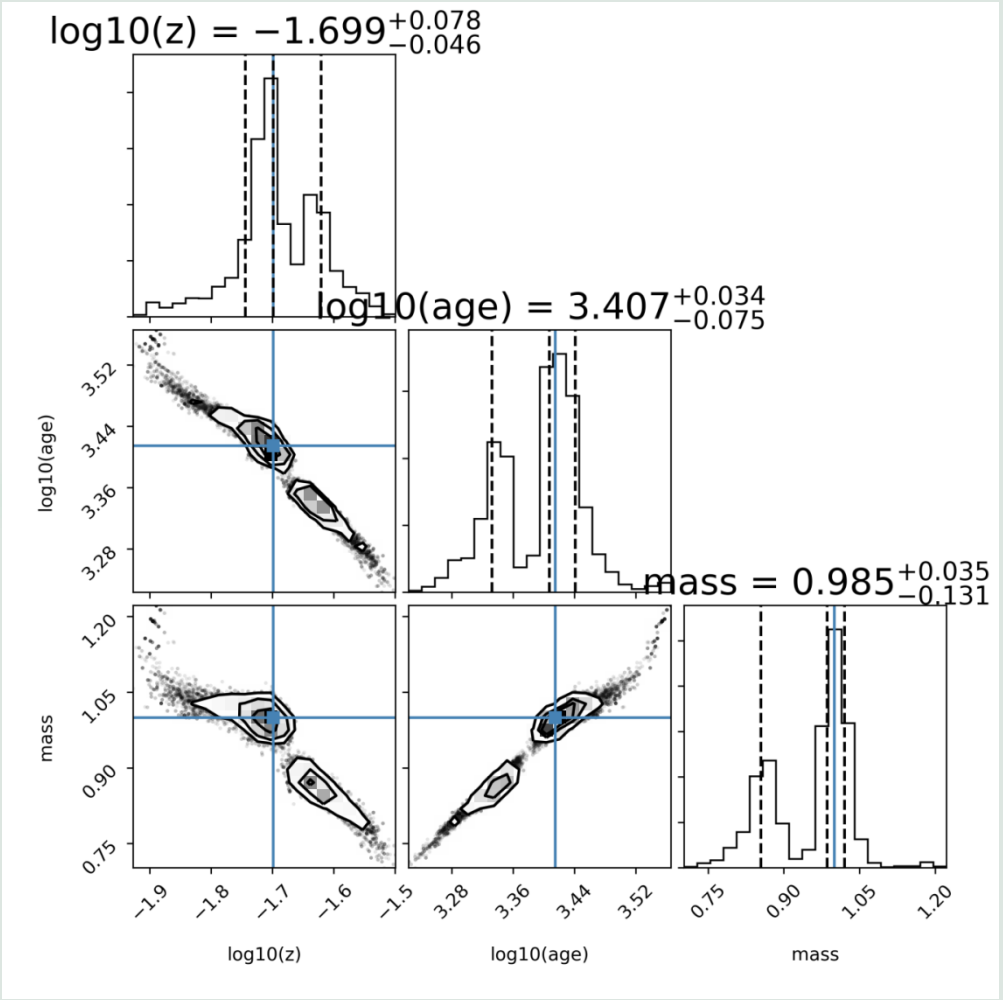
Validation

① Photometric error:

Merr=0.03

From left to right, the dotted lines represent 0.16, 0.5, 0.84 of CDF corresponding to median -1σ, median and median+1σ.

The blue cross represent truth value of parameters.



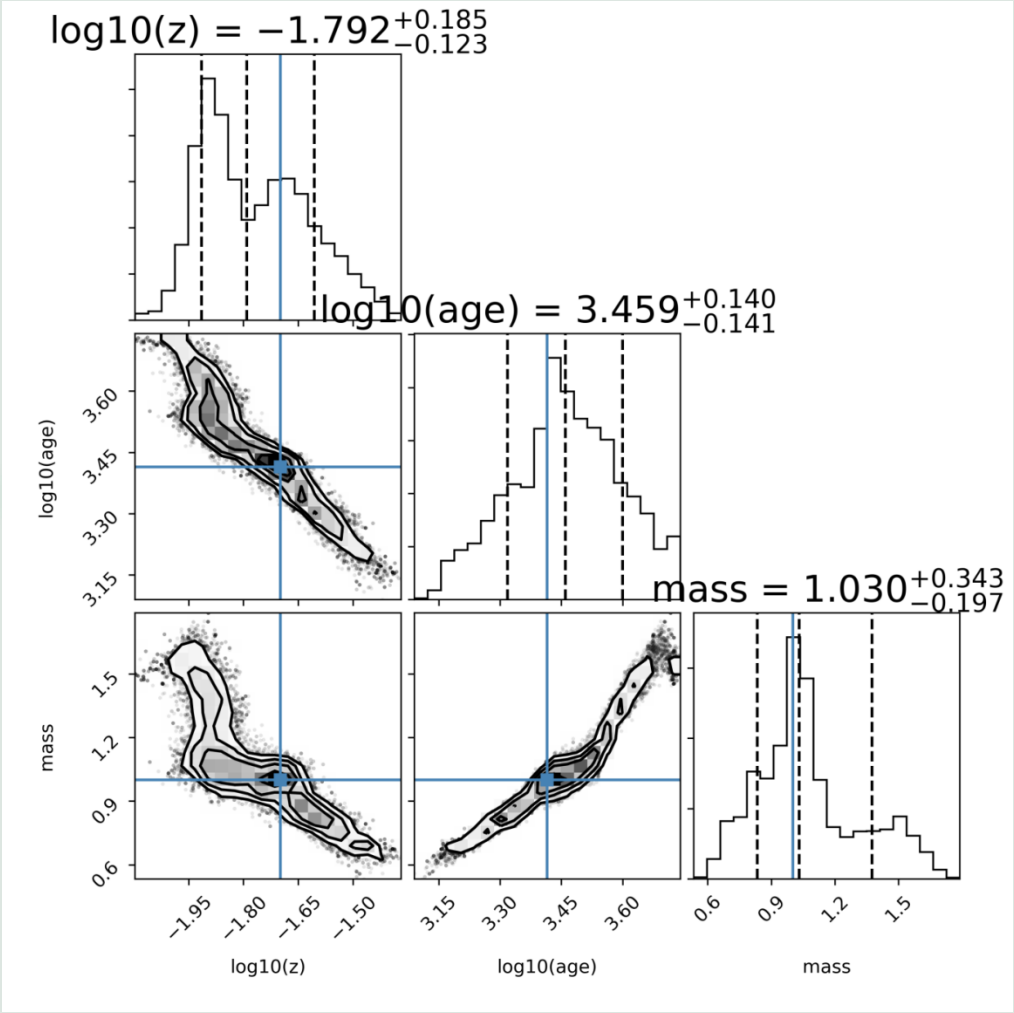
Validation

① Photometric error:

Merr=0.1

From left to right, the dotted lines represent 0.16, 0.5, 0.84 of CDF corresponding to median -1σ, median and median+1σ.

The blue cross represent truth value of parameters.



Validation

2. Validating practicability of strategy by fitting 3 SSPs to Mock data with non-parametric SFH

Mock data：z=0.02，age=2.6Gyr，mass=1，

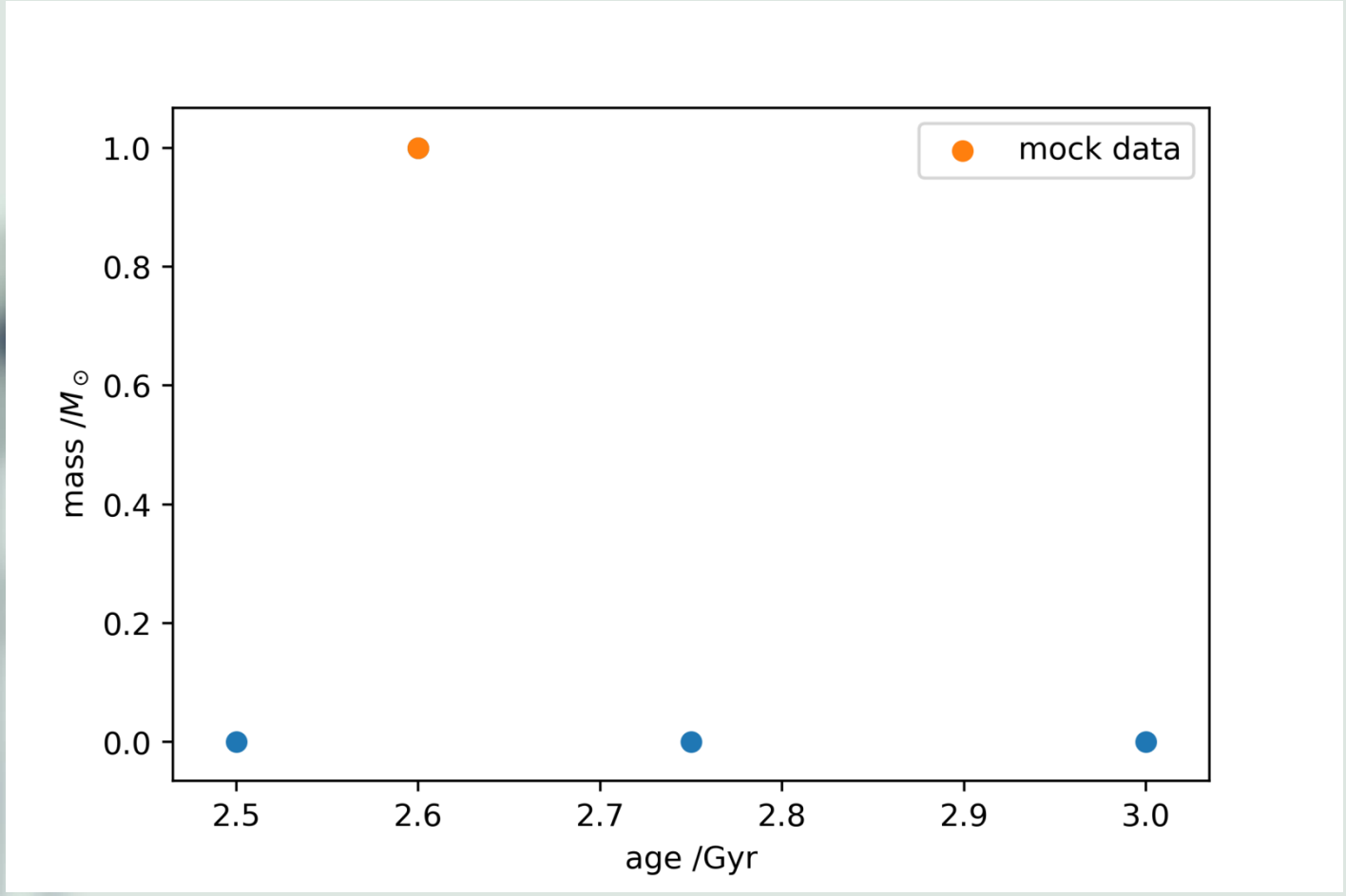
Merr=0.03

Fit parameters(3 weights of SSPs): mass1, mass2,

mass3

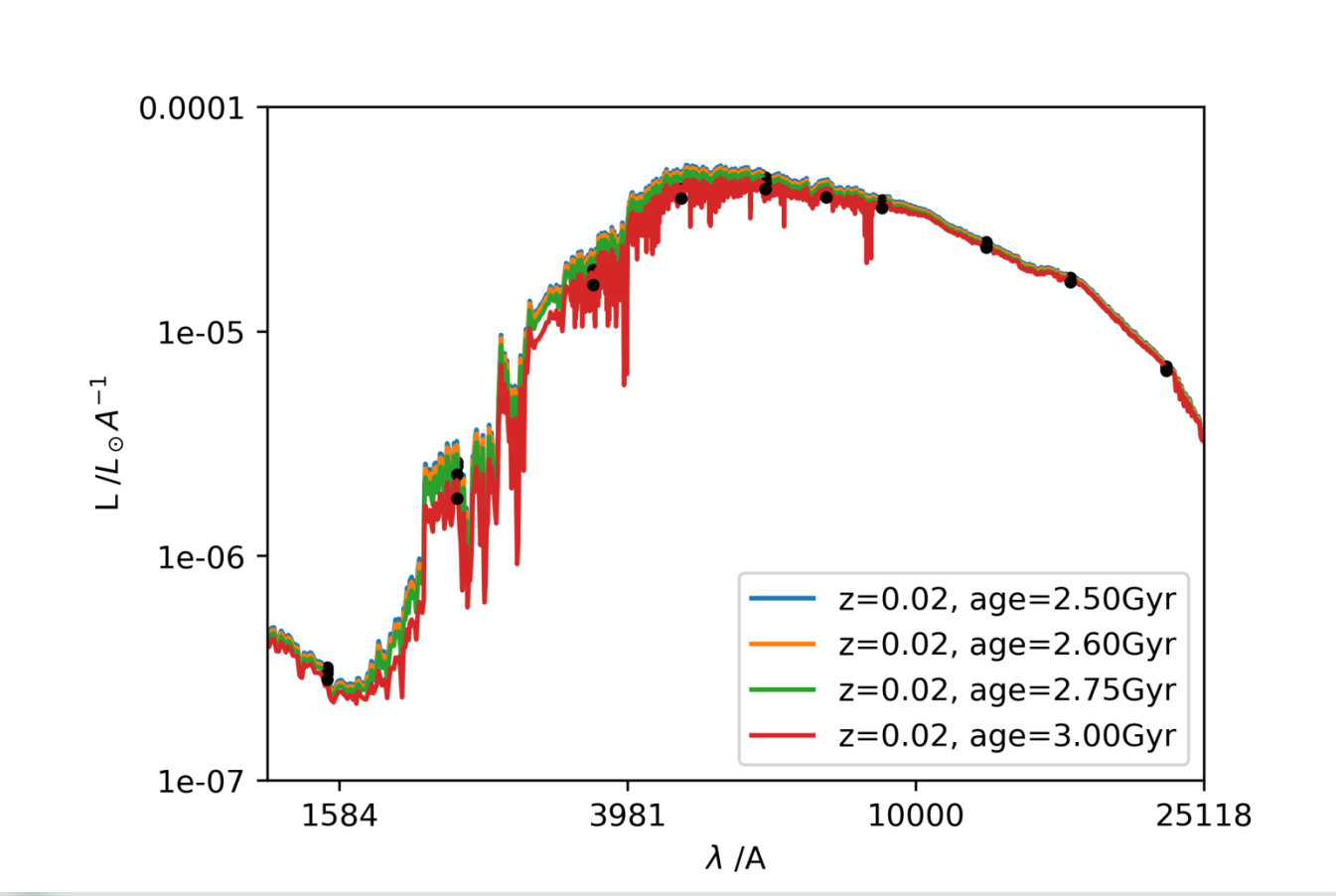
Validation

Mock data & Model data（ z=0.02 ）

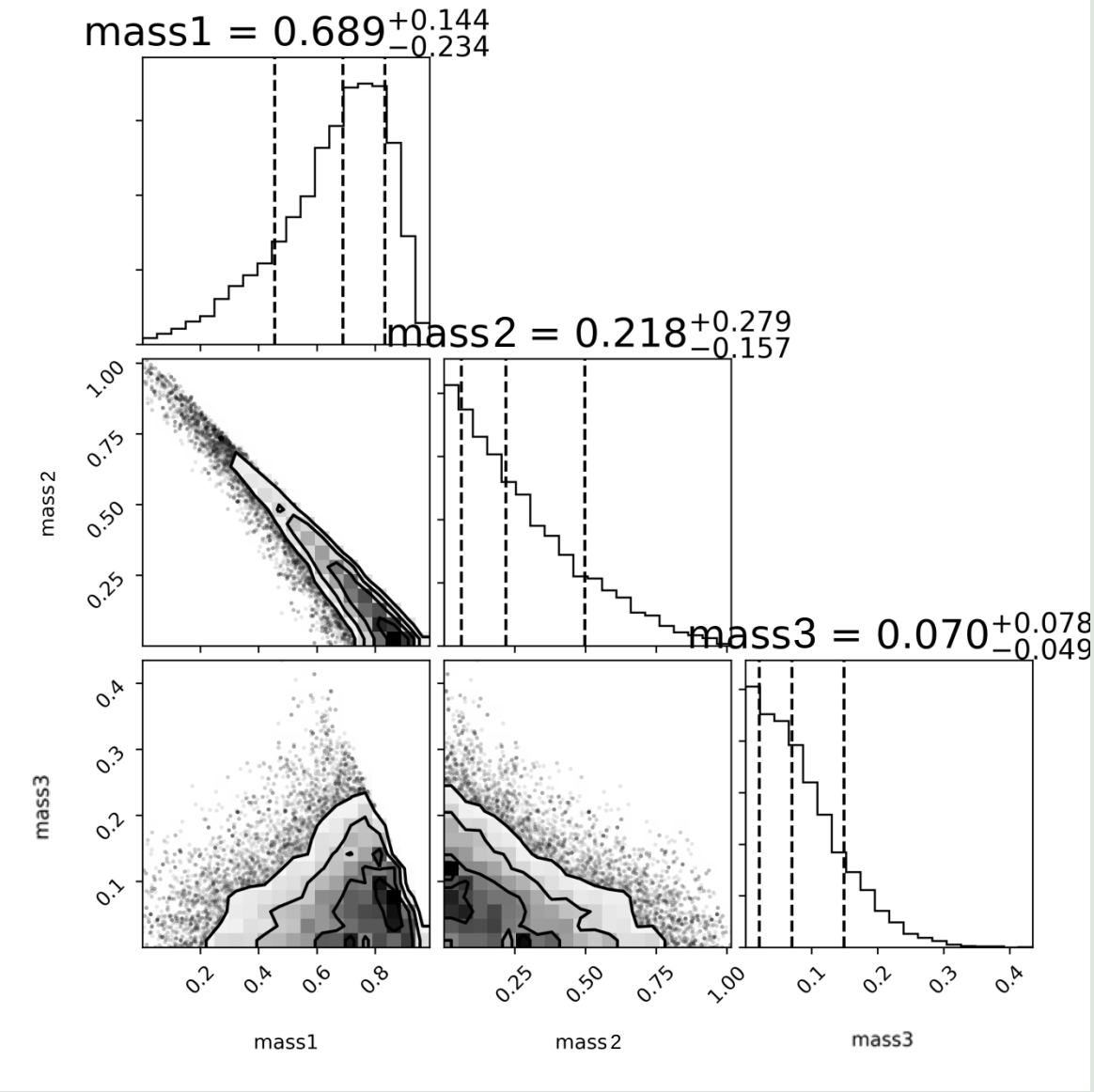


Validation

Mock data & Model data（ z=0.02 ）

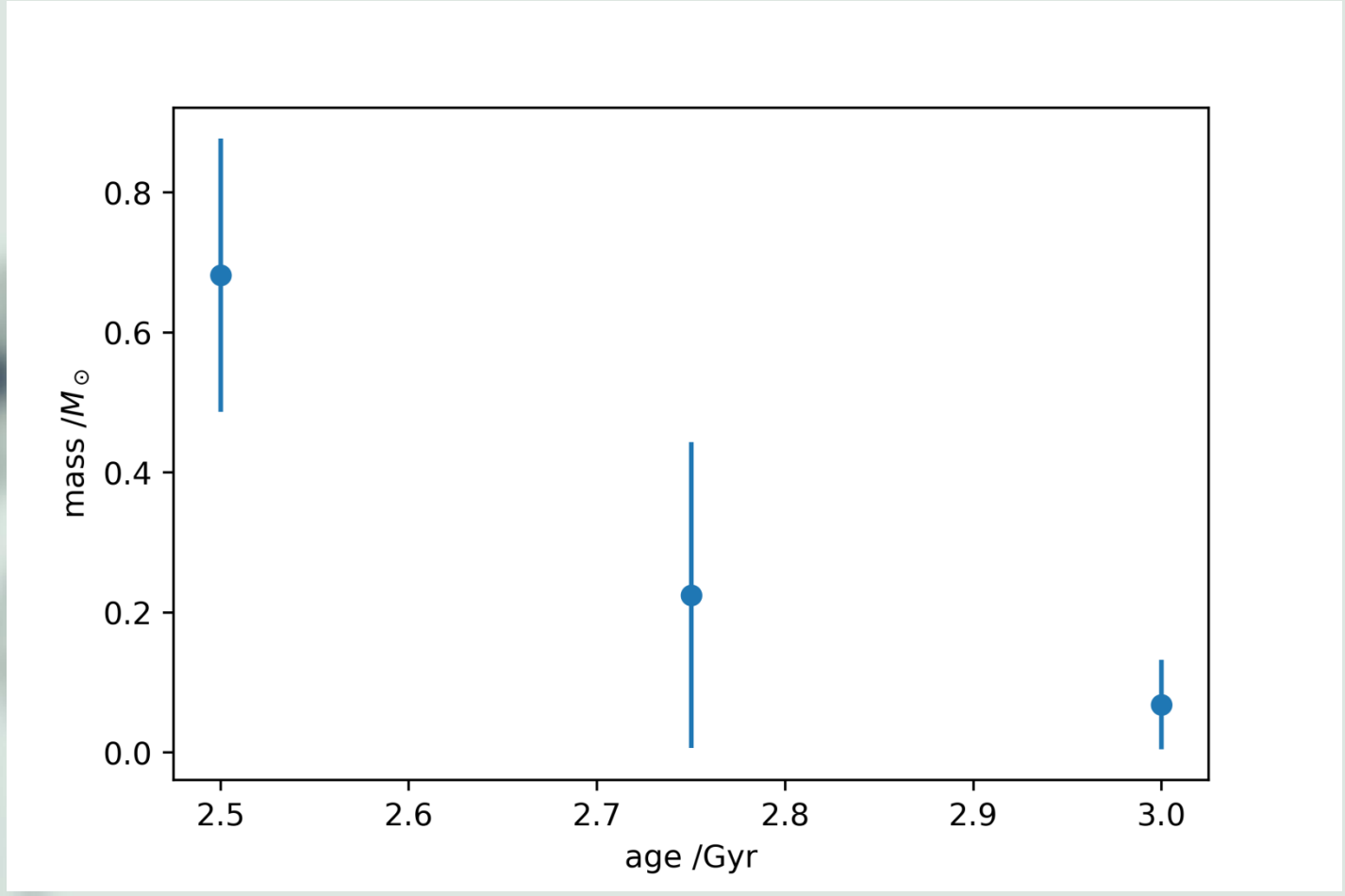


Validation


mass1 = 0.689$^{+0.144}_{-0.234}$
mass2 = 0.218$^{+0.279}_{-0.157}$
mass3 = 0.070$^{+0.078}_{-0.049}$
mass1
mass2
mass3

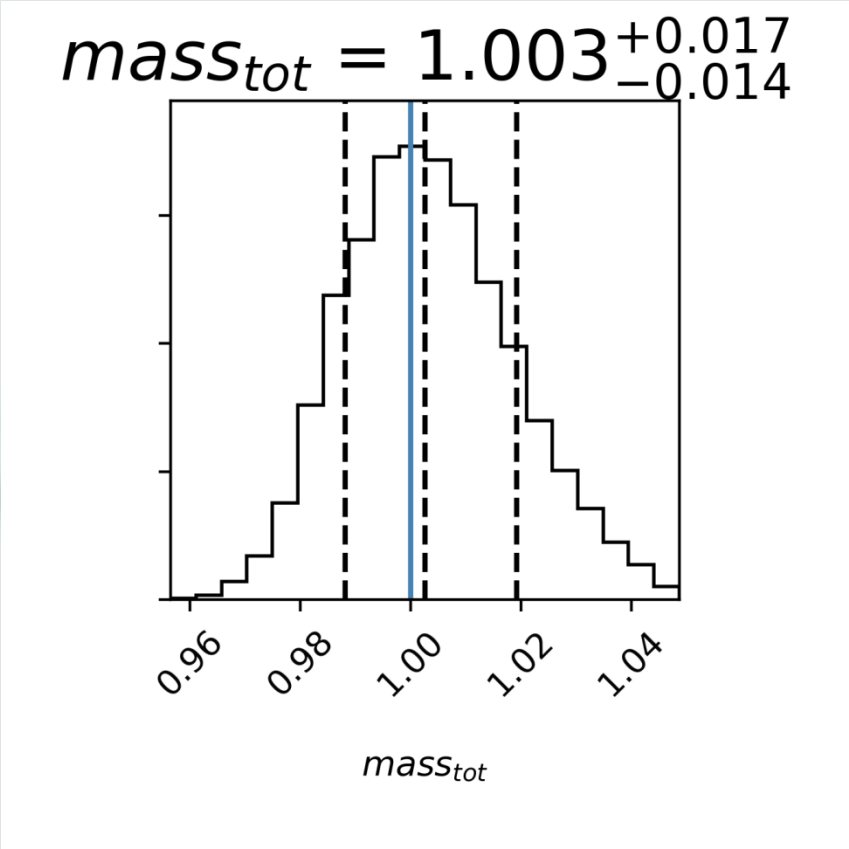
Validation

The length of error bar represents 2σ.



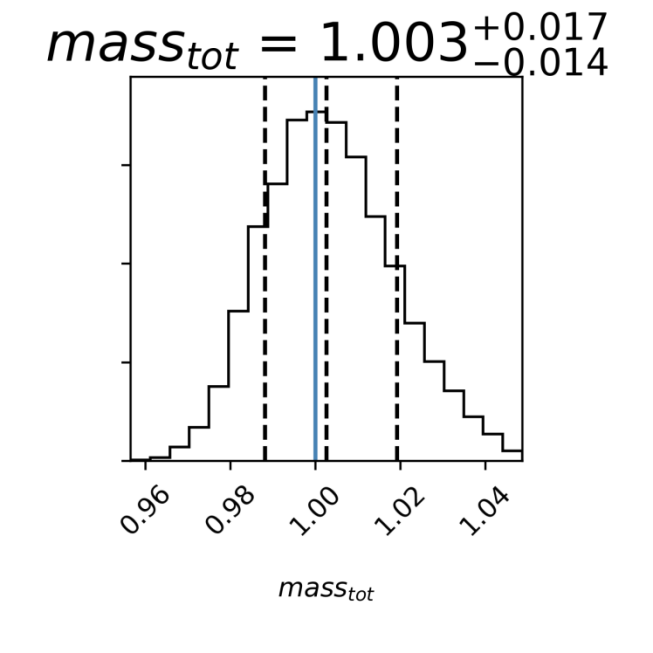
Validation

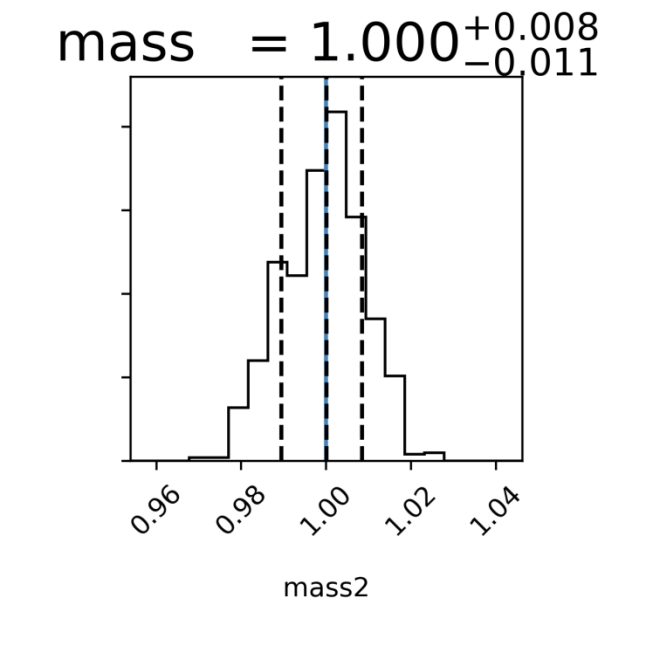
$mass_{tot}$=mass1+mass2+mass3



Validation

Compared with single SSP fitting.





Validation

3. We used non-parametric SFH and Bayesian statistical method to obtain the PDF of mass1, mass2 and mass3, and then obtain the PDF of $mass_{tot}$ = mass1 + mass2 + mass3.

Although the dispersion of each fit parameter is large, the dispersion of $mass_{tot}$ is pretty small, which validates the practicability of our strategy.

Future

① Constructing a mock galaxy with SFH instead of a single star burst

② Fitting SED+lick index

③ Comparing different SSP models or IMF by using Bayesian evidence

④ Constructing new parameters with good statistical properties, for example M_{tot} and t_{50}

⑤ Comparing with parametric SFH to estimate if there is a star burst recently

Future

⑥ Discussing the variation of stellar population with radius and influences of extinction using data from MaNGA, and then obtain some maps of new parameters in MaNGA