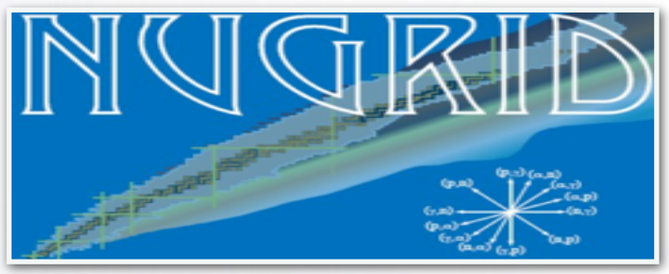

Galactic Chemical Evolution

Using NuPyCEE and JINAPyCEE to connect stellar yields to astronomical data

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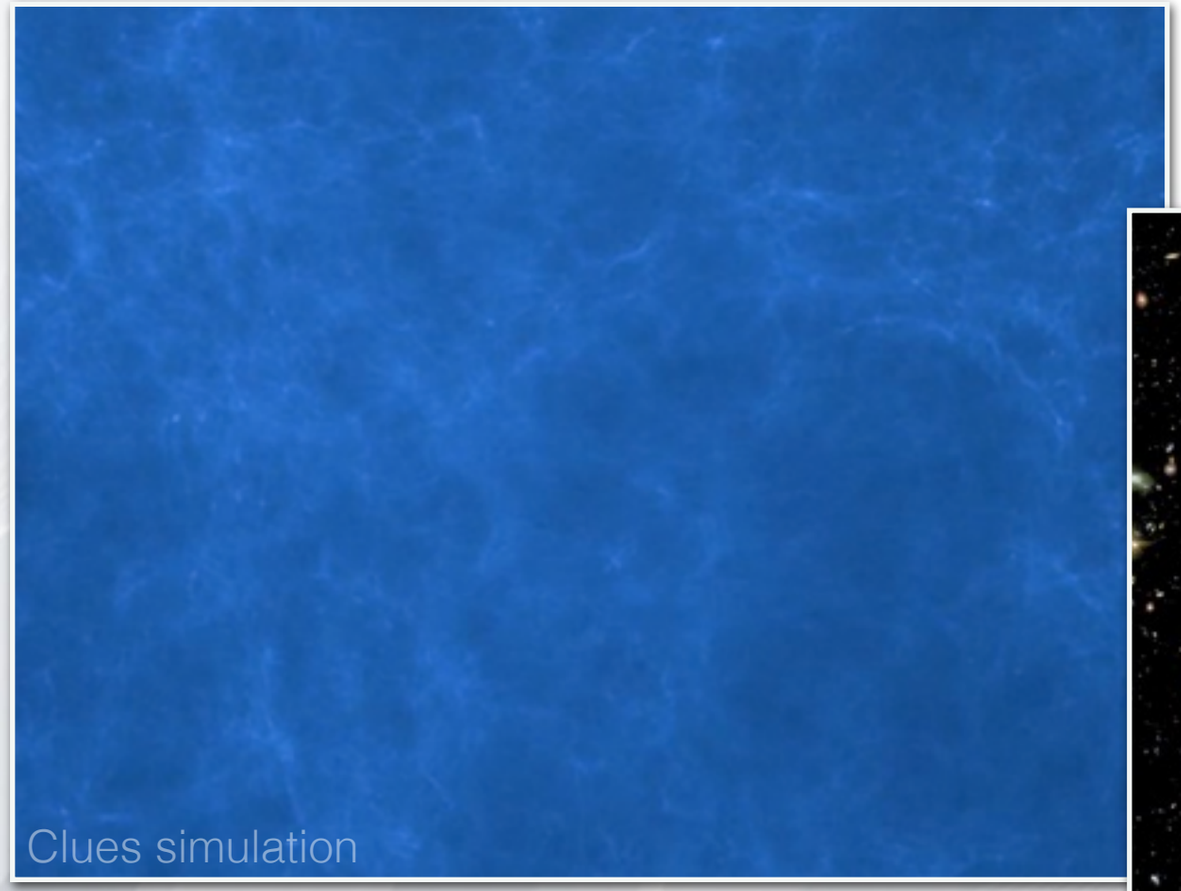
Benoit Côté
Postdoctoral Fellow

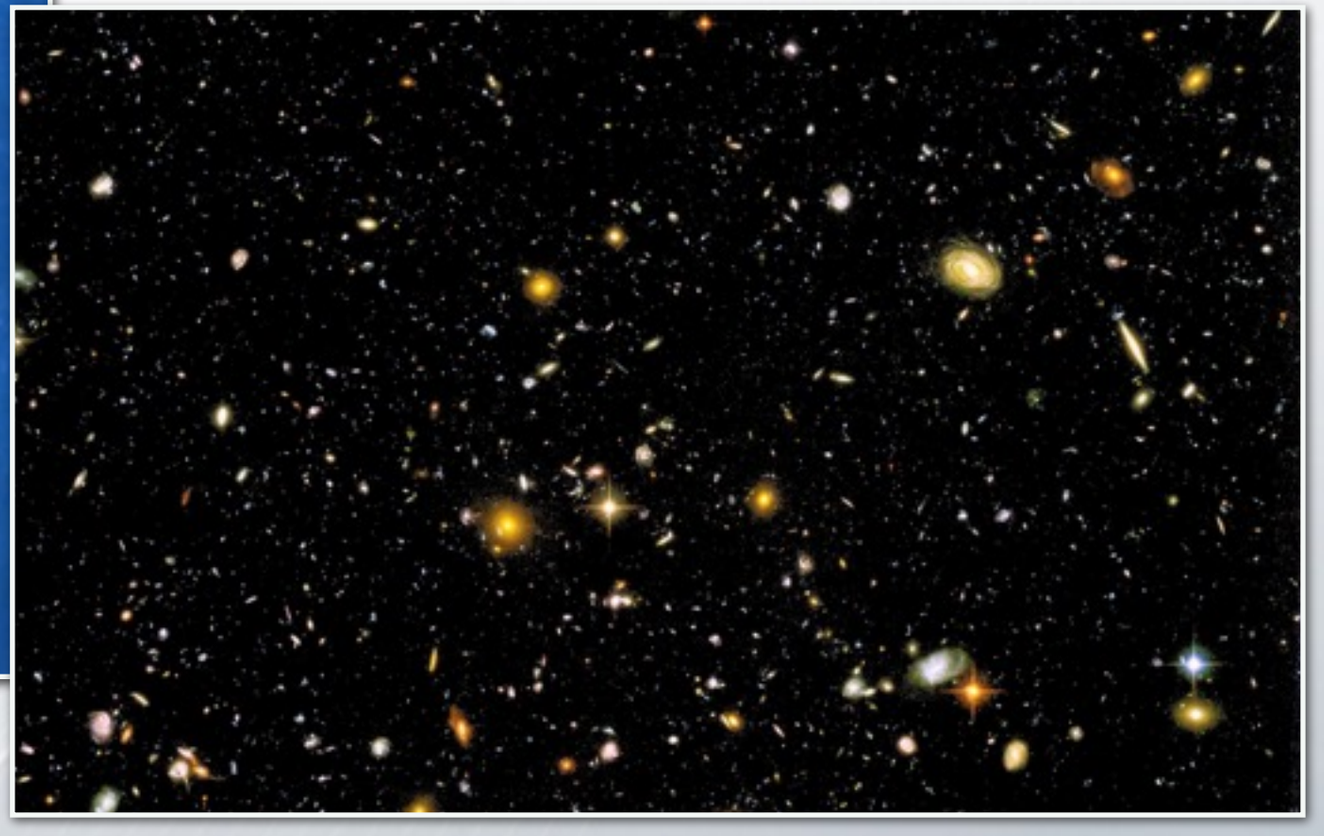
Software Tools for Simulations in Nuclear Astrophysics
Hull University, UK
September 19th 2018

ORIGIN OF THE ELEMENTS

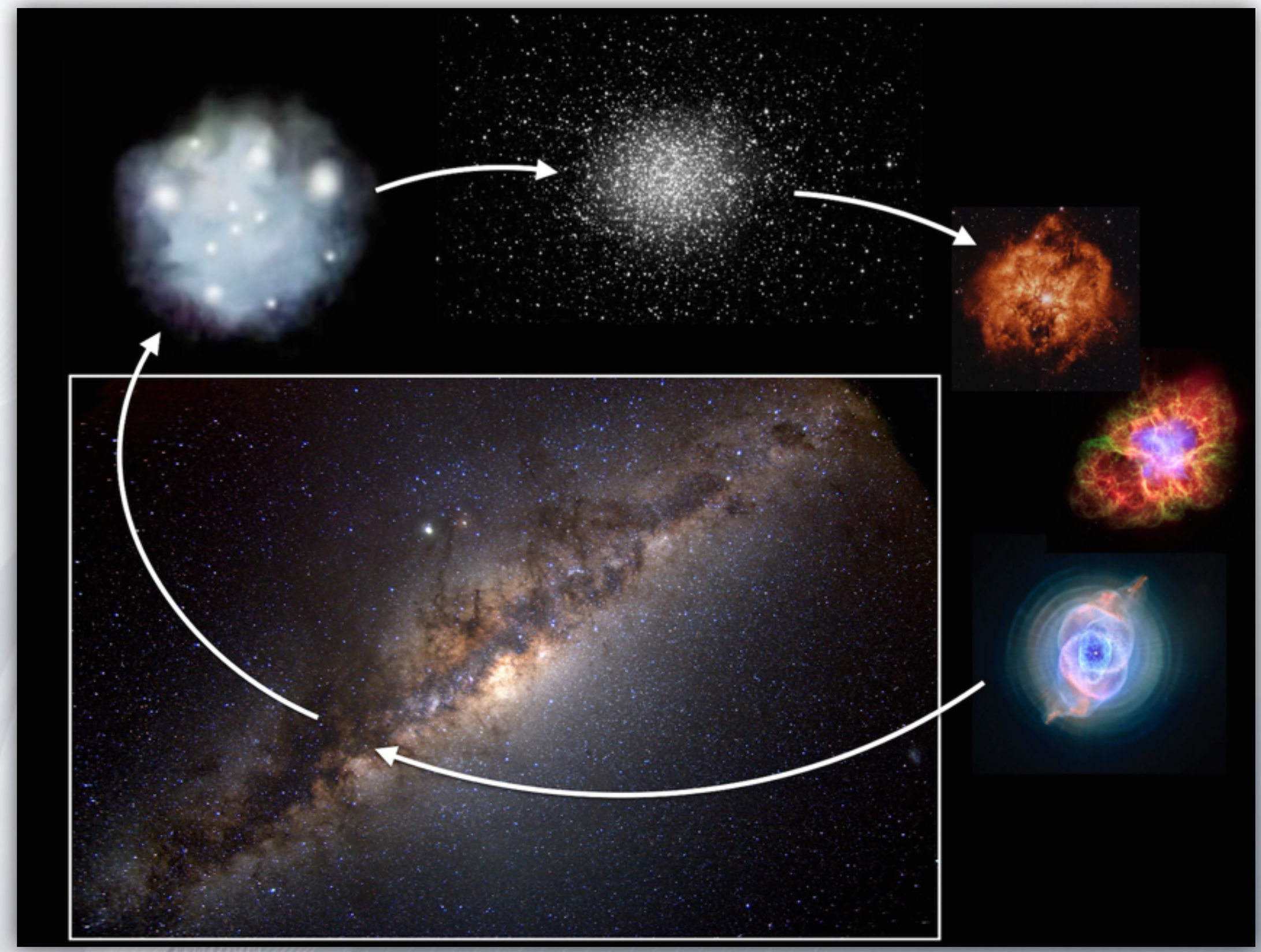
Early universe (Big Bang nucleosynthesis)
H, He, Li



Current universe (~13 Gyr later)
H, He, Li, C, N, O, Fe, Ni, Sr, Y, Ba, Eu, Ir, Hf, …



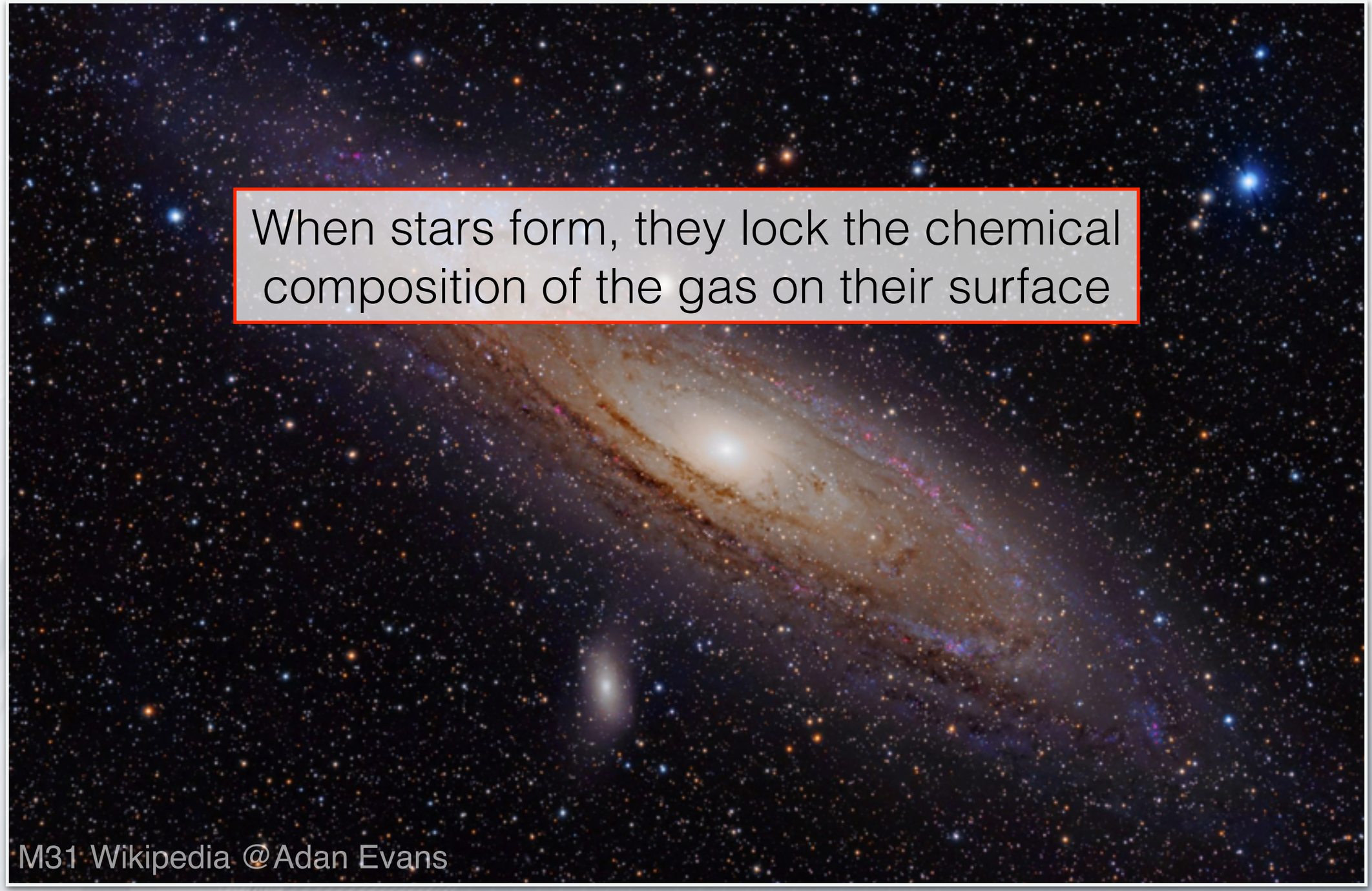
LIFE CYCLE OF STARS



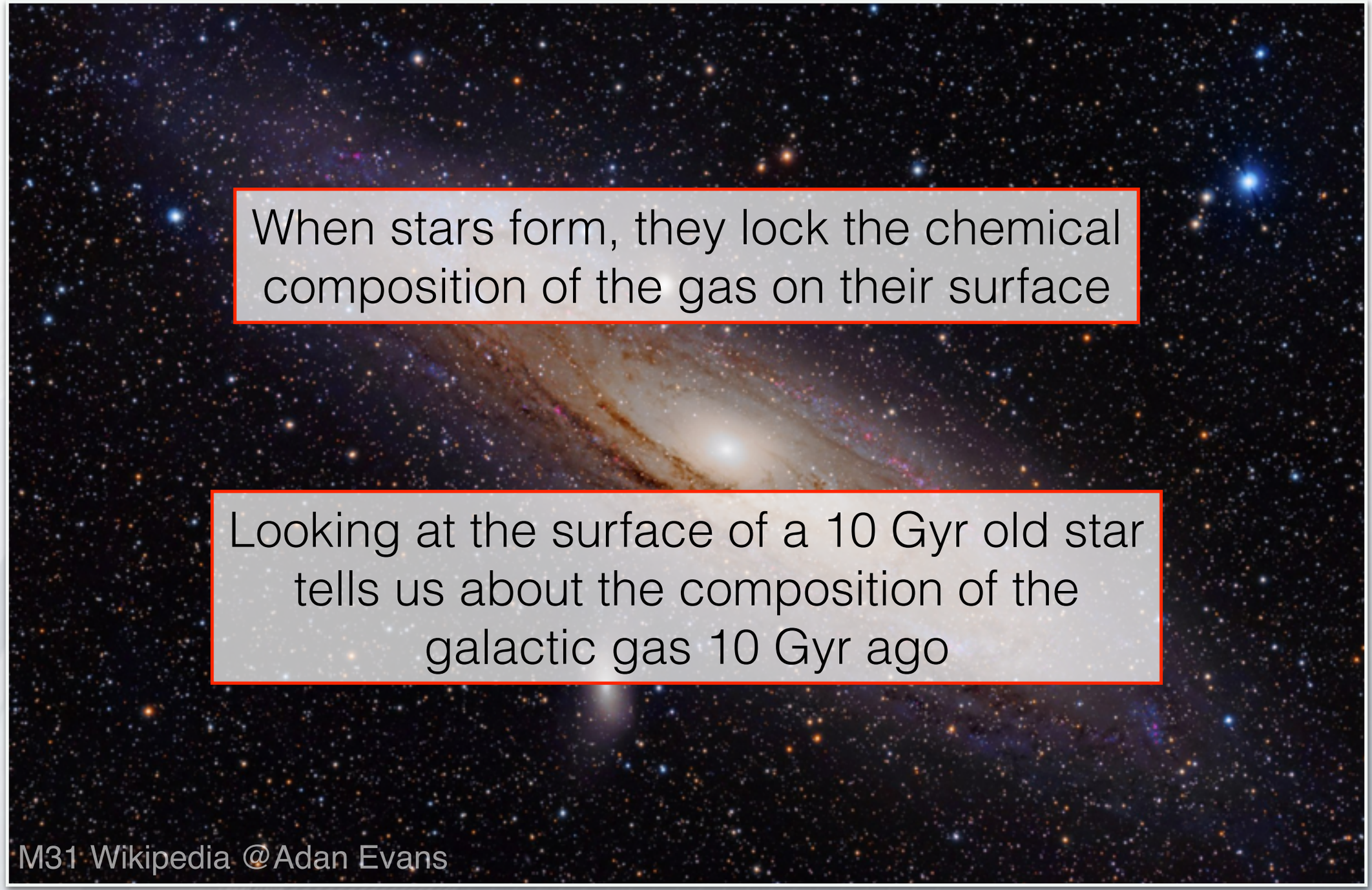
OBSERVING CHEMICAL EVOLUTION

M31 Wikipedia @Adan Evans

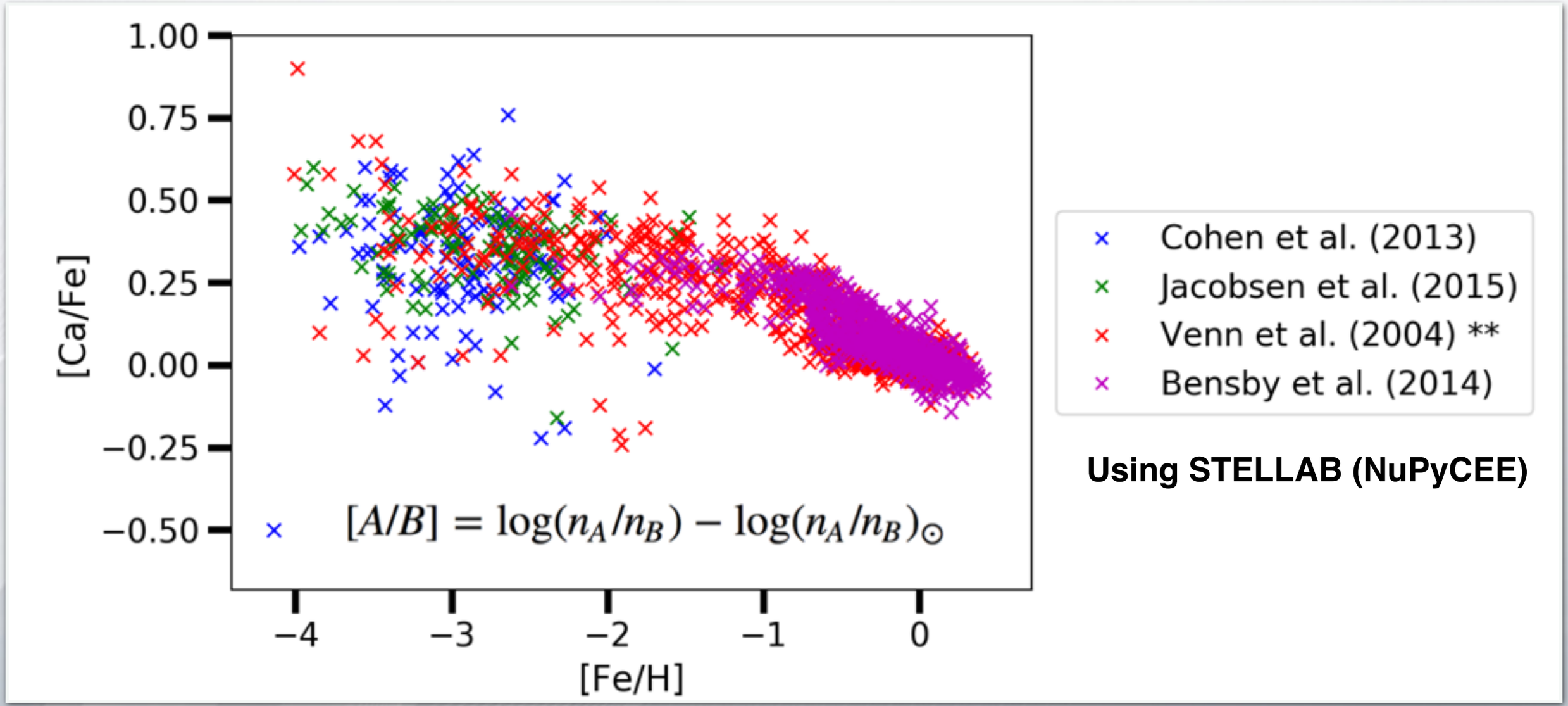
OBSERVING CHEMICAL EVOLUTION



OBSERVING CHEMICAL EVOLUTION

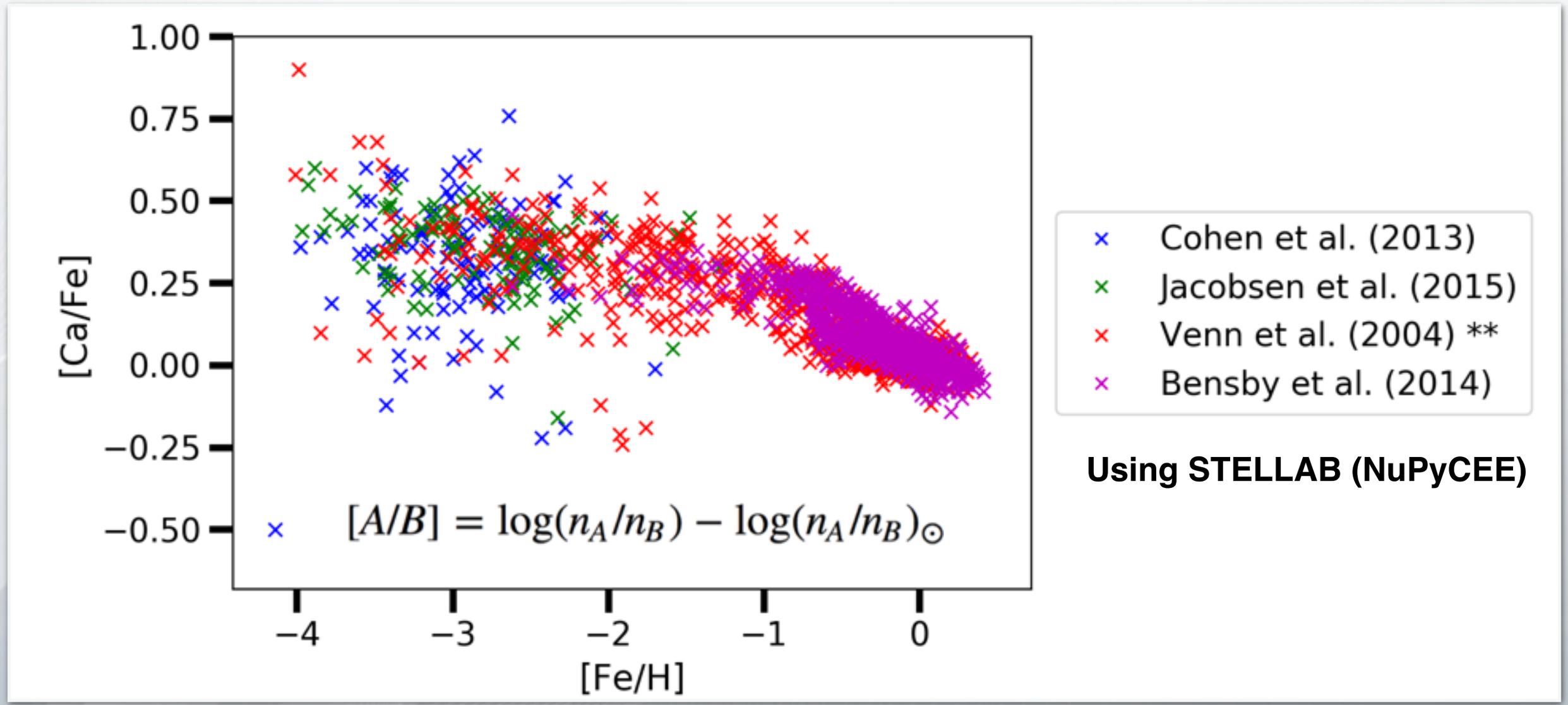


STELLAR ABUNDANCES



Using STELLAB (NuPyCEE)

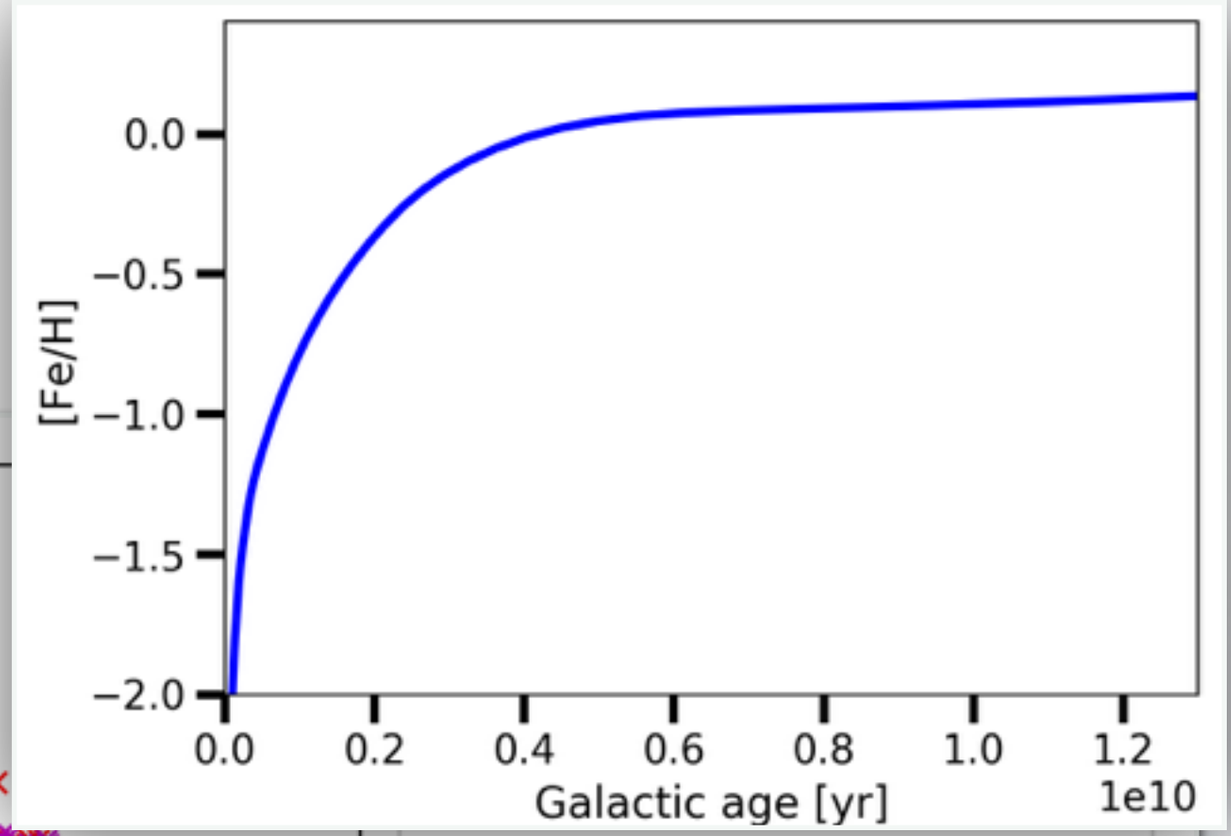
STELLAR ABUNDANCES



Using STELLAB (NuPyCEE)

Past → **Present**

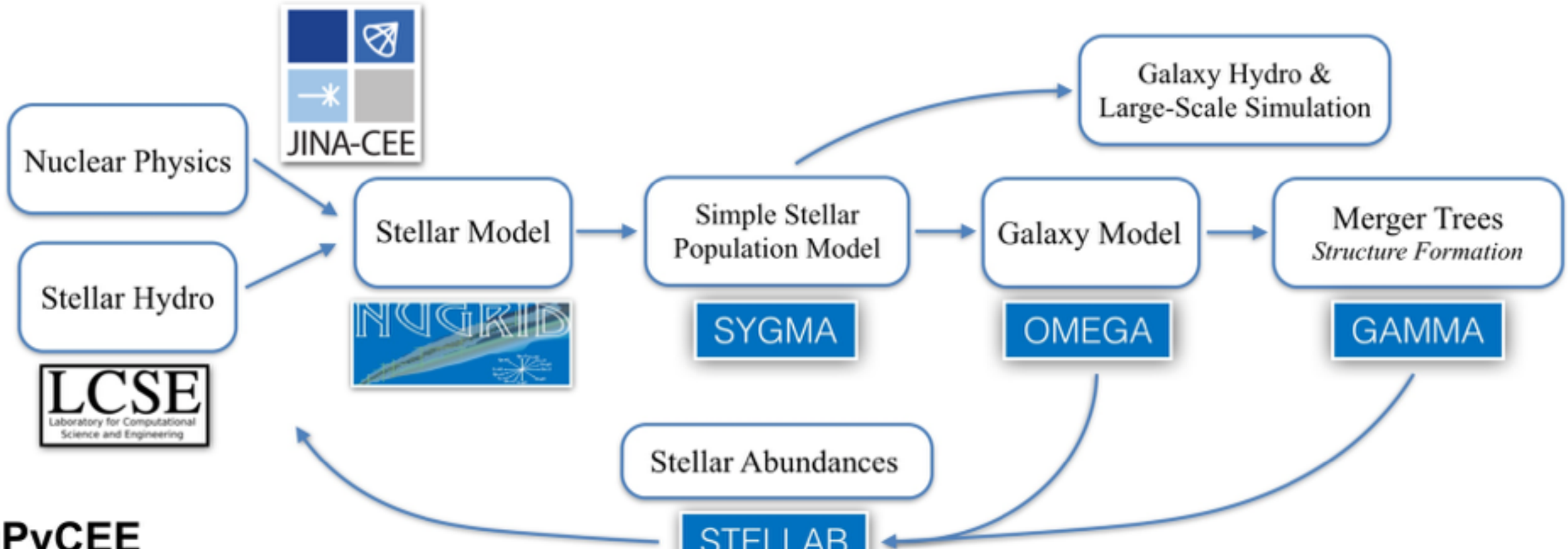
STELLAR ABUNDANCES



Past → **Present**

JINA-NUGRID CHEMICAL EVOLUTION PIPELINE

Côté, Ritter, Herwig, et al. (2017)



NuPyCEE

NuGrid Python Chemical Evolution Environment
https://github.com/NuGrid/NuPyCEE

SYGMA (Ritter, Côté, Herwig, et al. 2018)
Stellar Yields for Galactic Modeling Applications

OMEGA (Côté, O'Shea, Ritter, et al. 2017)
One-zone Model for the Evolution of Galaxies

STELLAB for high-Z (Côté & Ritter 2016)
JINABase for low-Z *(Abohalima & Frebel, 2017, submitted)*
http://jinabase.pythonanywhere.com/plot

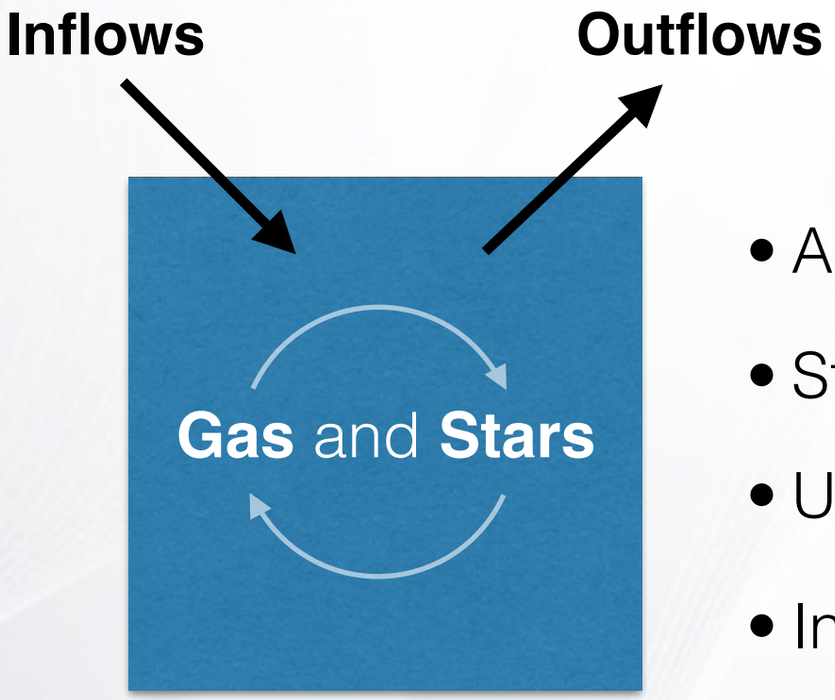
JINAPyCEE

JINA Python Chemical Evolution Environment
https://github.com/becot85/JINAPyCEE

OMEGA+ (Côté, Silvia, O'Shea, et al. 2018)
Two-zone model based on OMEGA

GAMMA (Côté, Silvia, O'Shea, et al. 2018)
Galaxy Assembly with Merger-trees for Modeling Abundances, based on OMEGA+

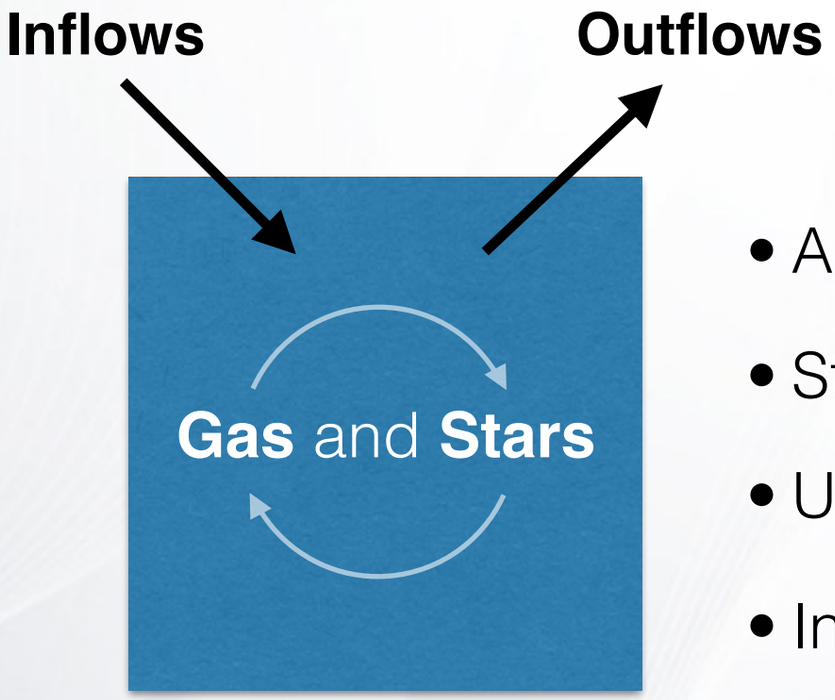
ONE-ZONE MODEL



OMEGA

- A fraction of gas is converted into stars
- Stars evolve, die, and return metals in the gas
- Uniformly mixed
- Interactions with the surrounding

ONE-ZONE MODEL



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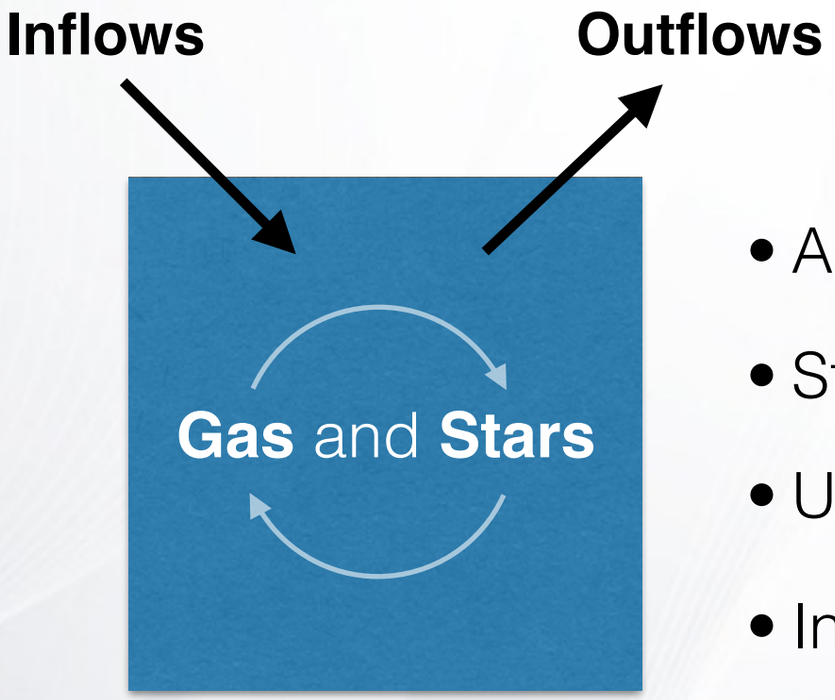

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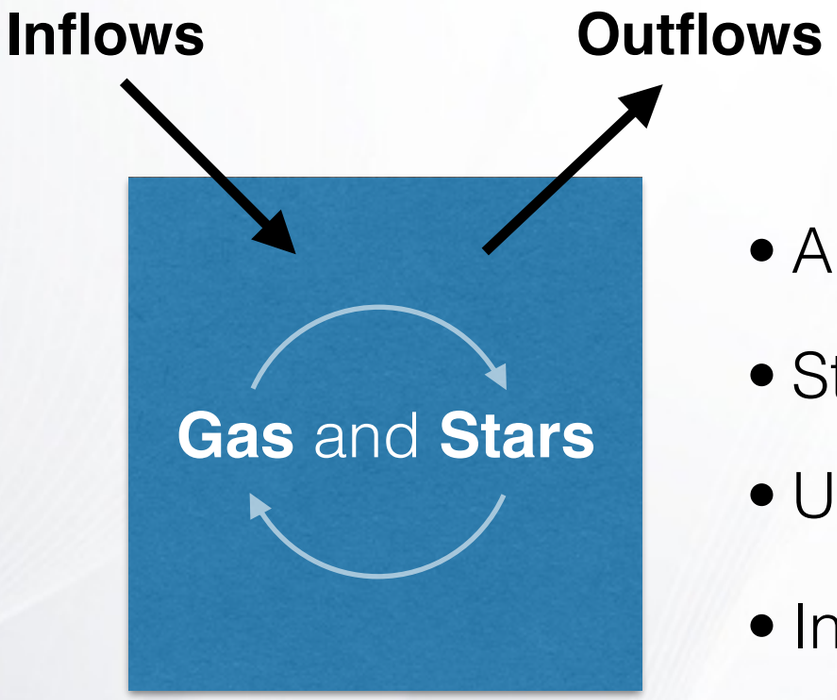

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Fast to compute!

Easy to use for learning the basics of chemical evolution.

Capture the essential to efficiently connect nuclear astrophysics to astronomical data (stellar abundances).

SIMPLE STELLAR POPULATION

SYGMA

A group of stars that form *simultaneously*

SIMPLE STELLAR POPULATION

SYGMA

A group of stars that form *simultaneously*

Input parameters

- Total stellar mass
- Stellar yields

  Mass and composition ejected by stars as a function of **stellar initial mass** and **initial composition (metallicity)**

SIMPLE STELLAR POPULATION

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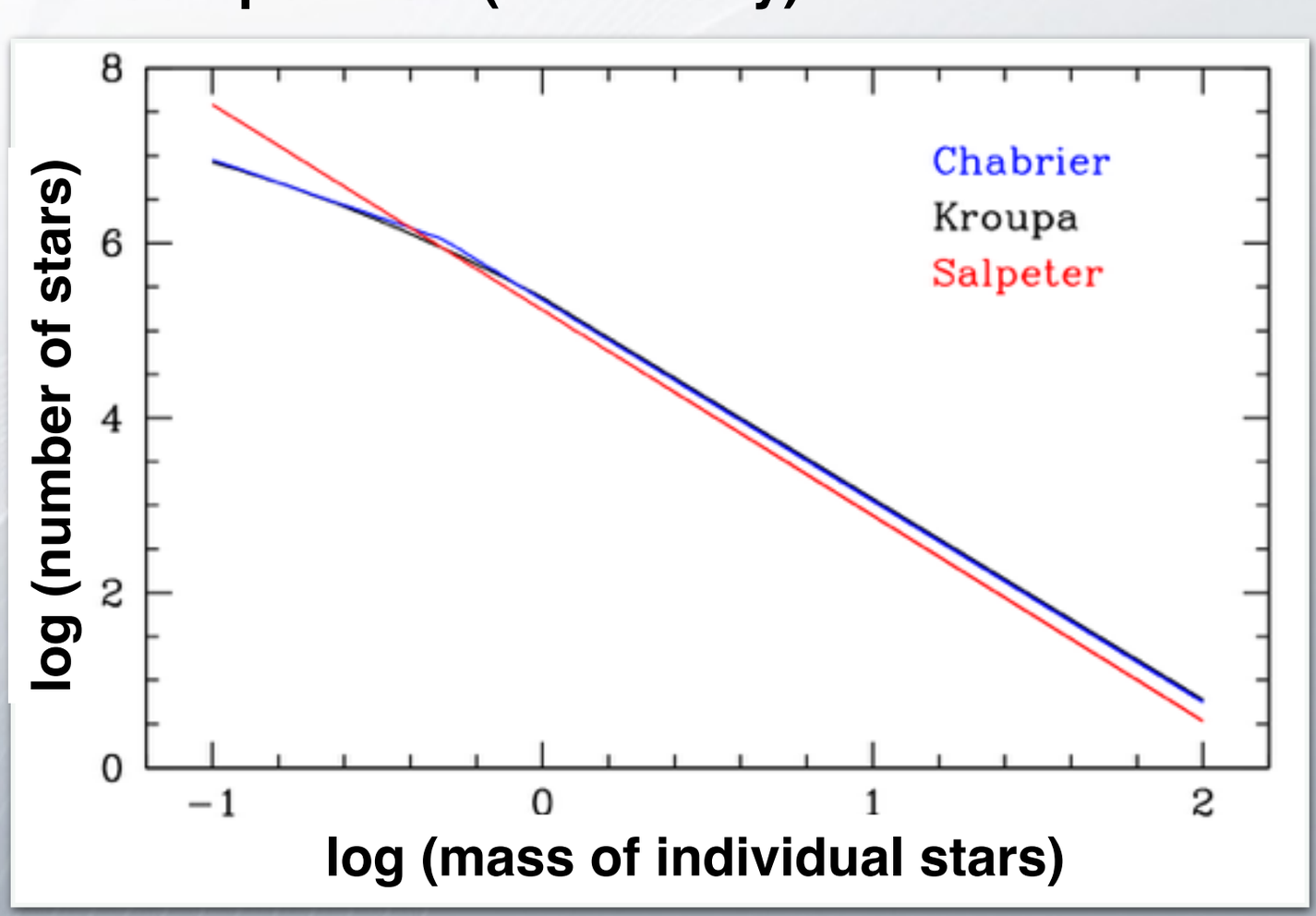
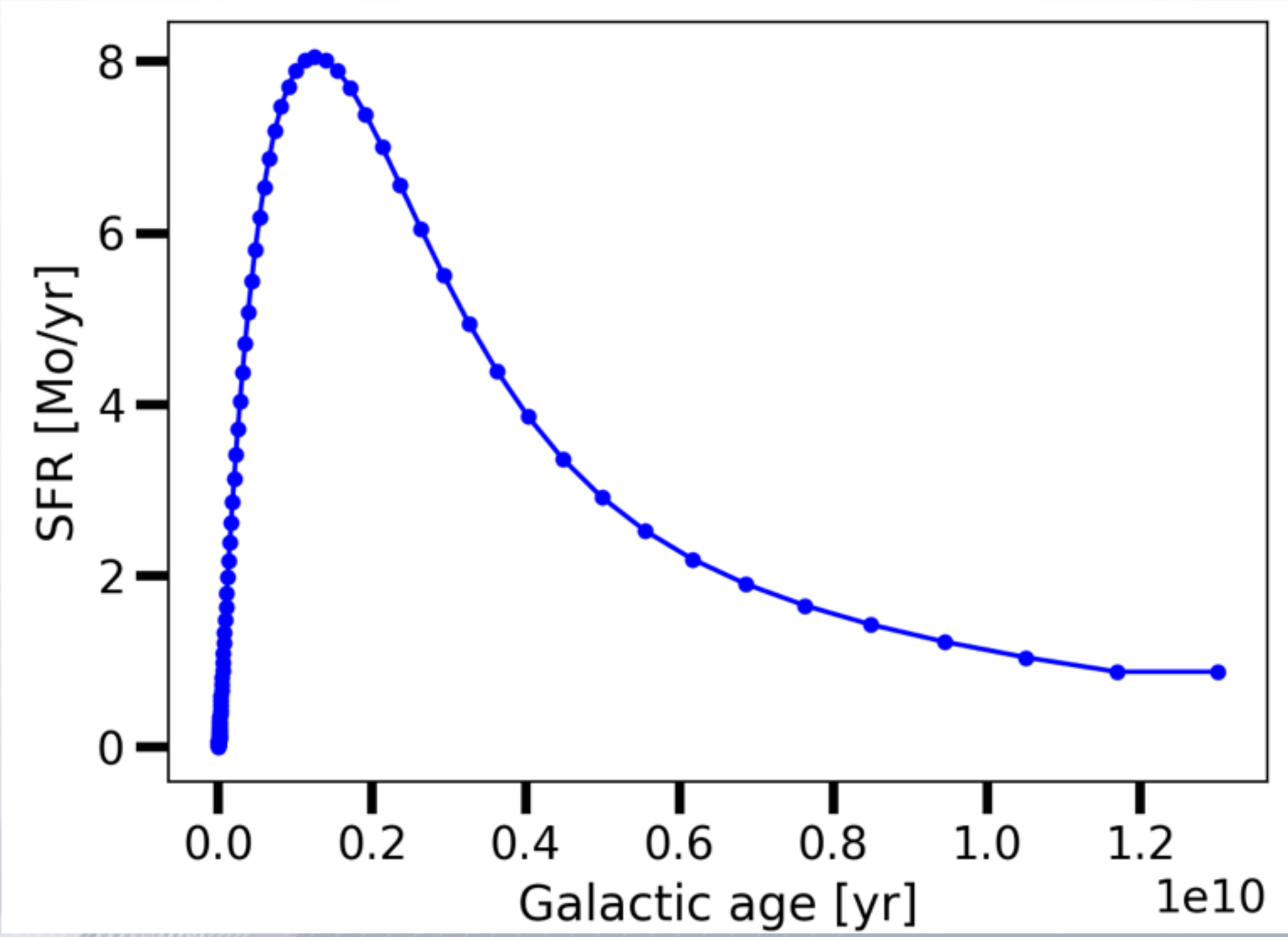
  Mass and composition ejected by stars as a function of **stellar initial mass** and **initial composition (metallicity)**

- Initial mass function (IMF)



STAR FORMATION HISTORY

OMEGA



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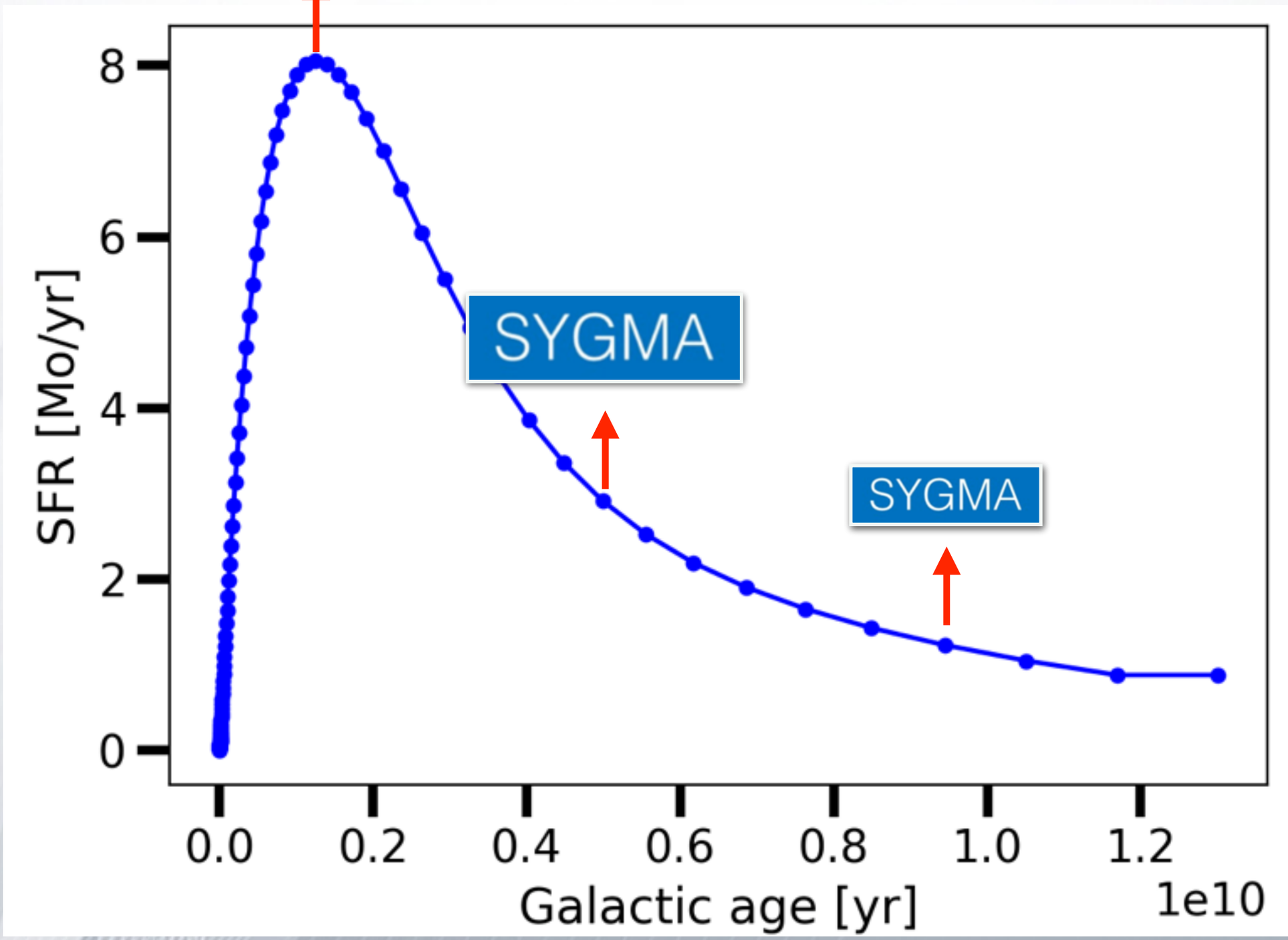

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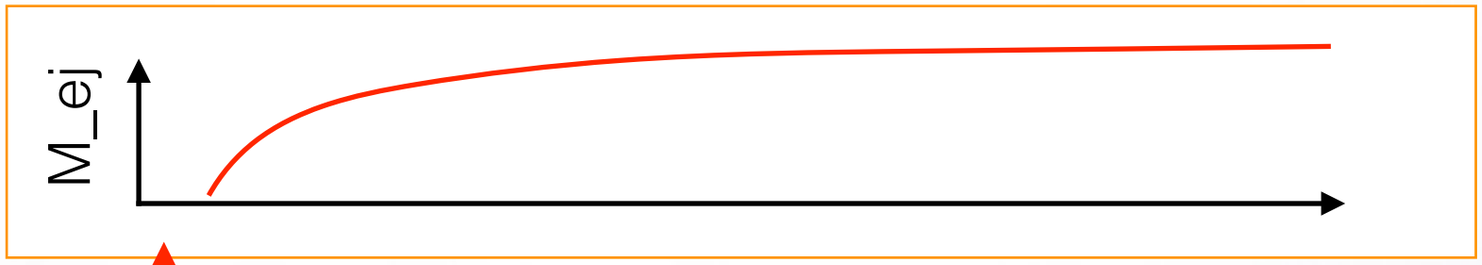

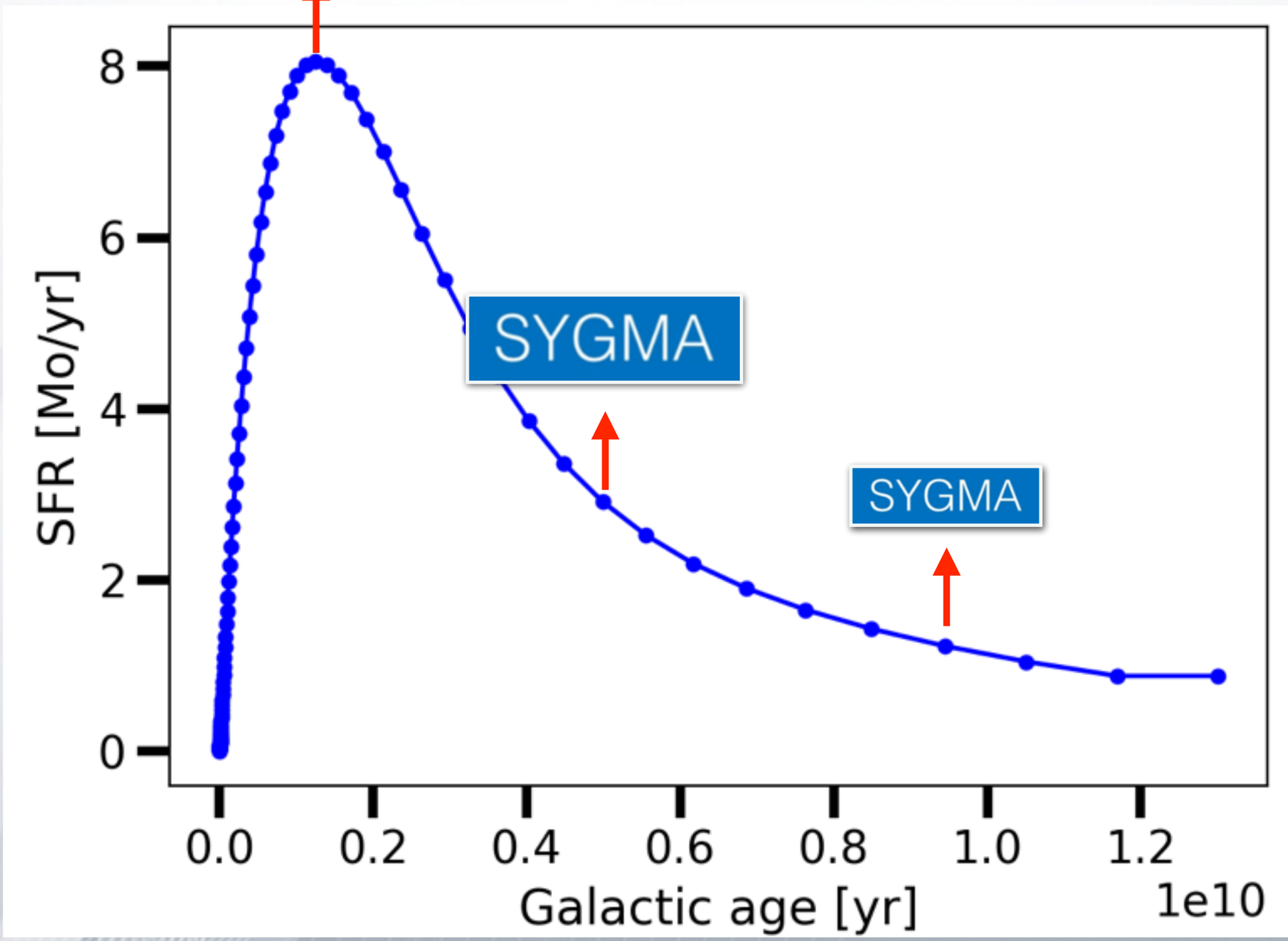

STAR FORMATION HISTORY

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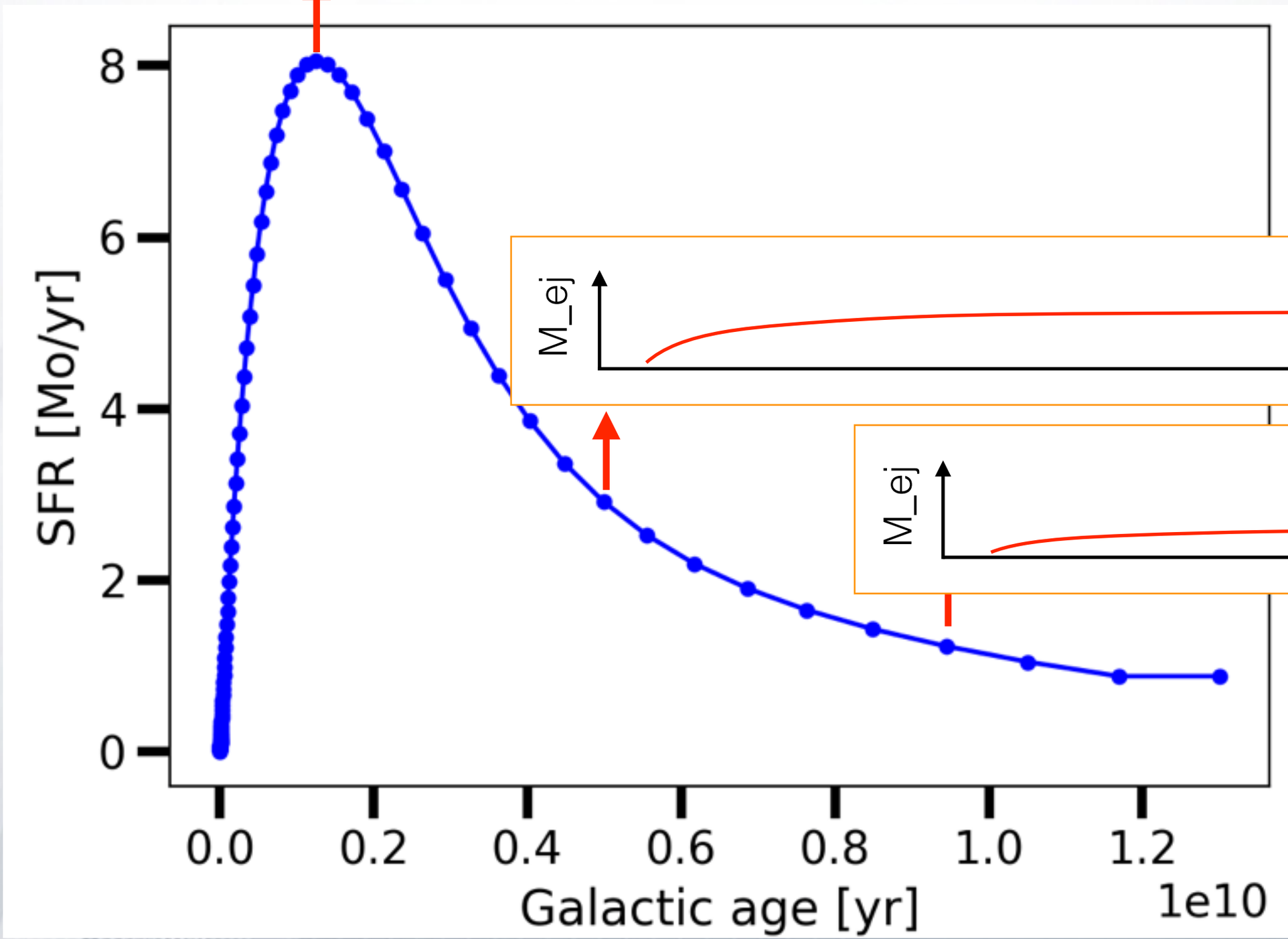
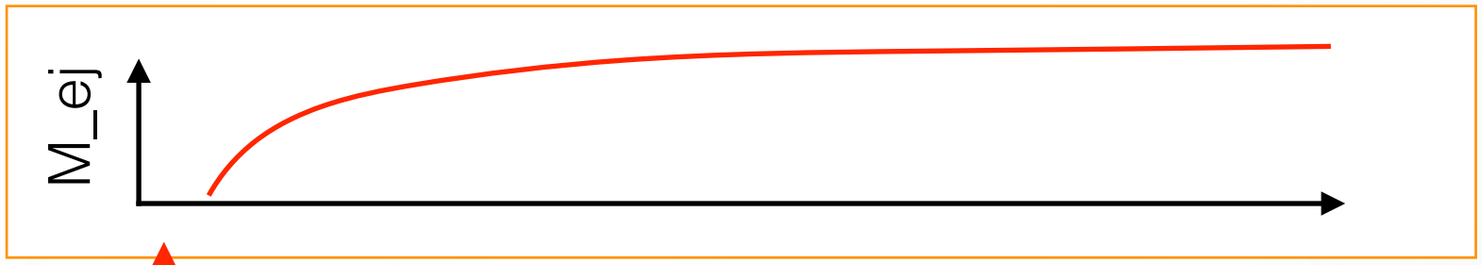
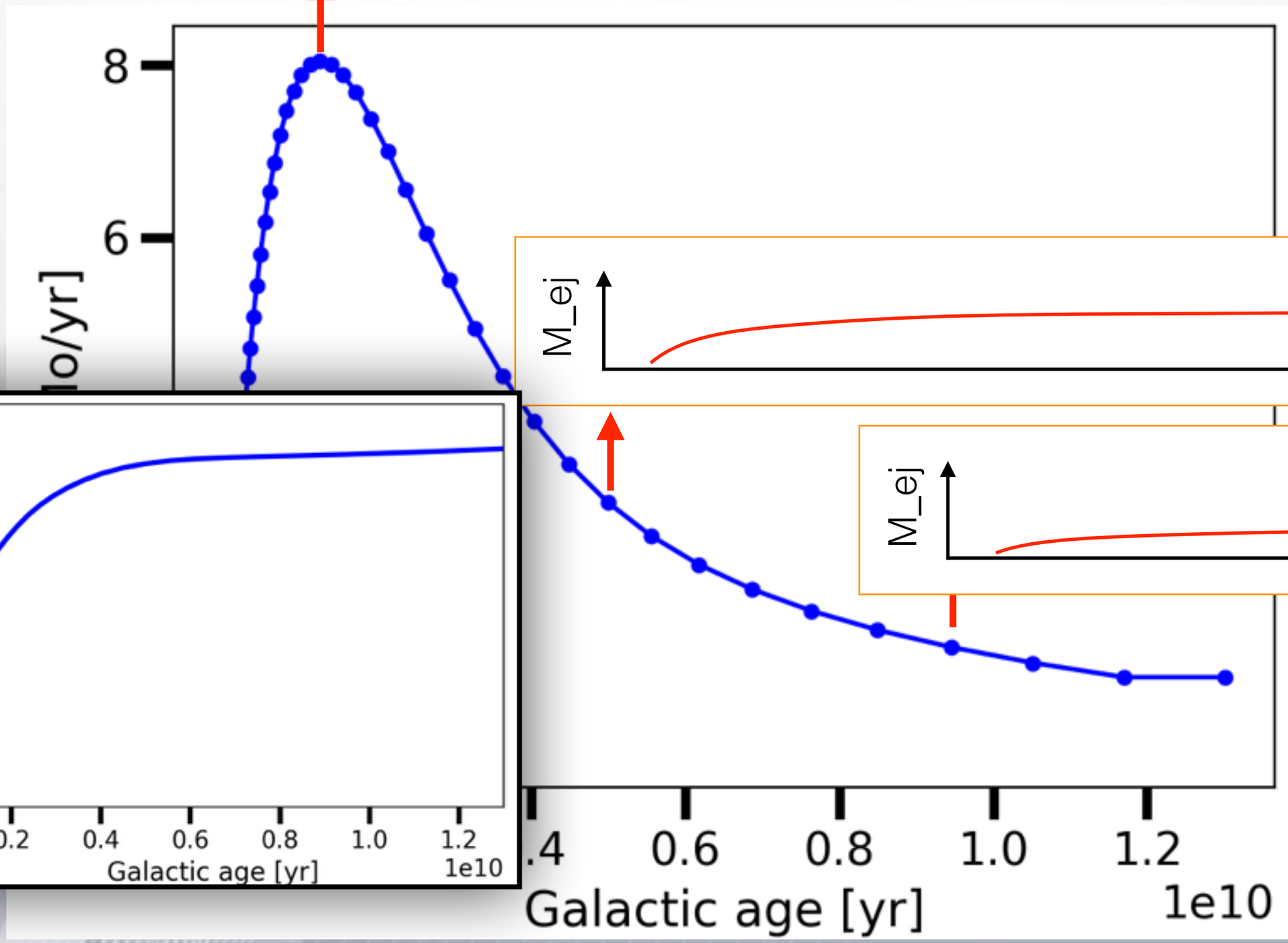


STAR FORMATION HISTORY

OMEGA



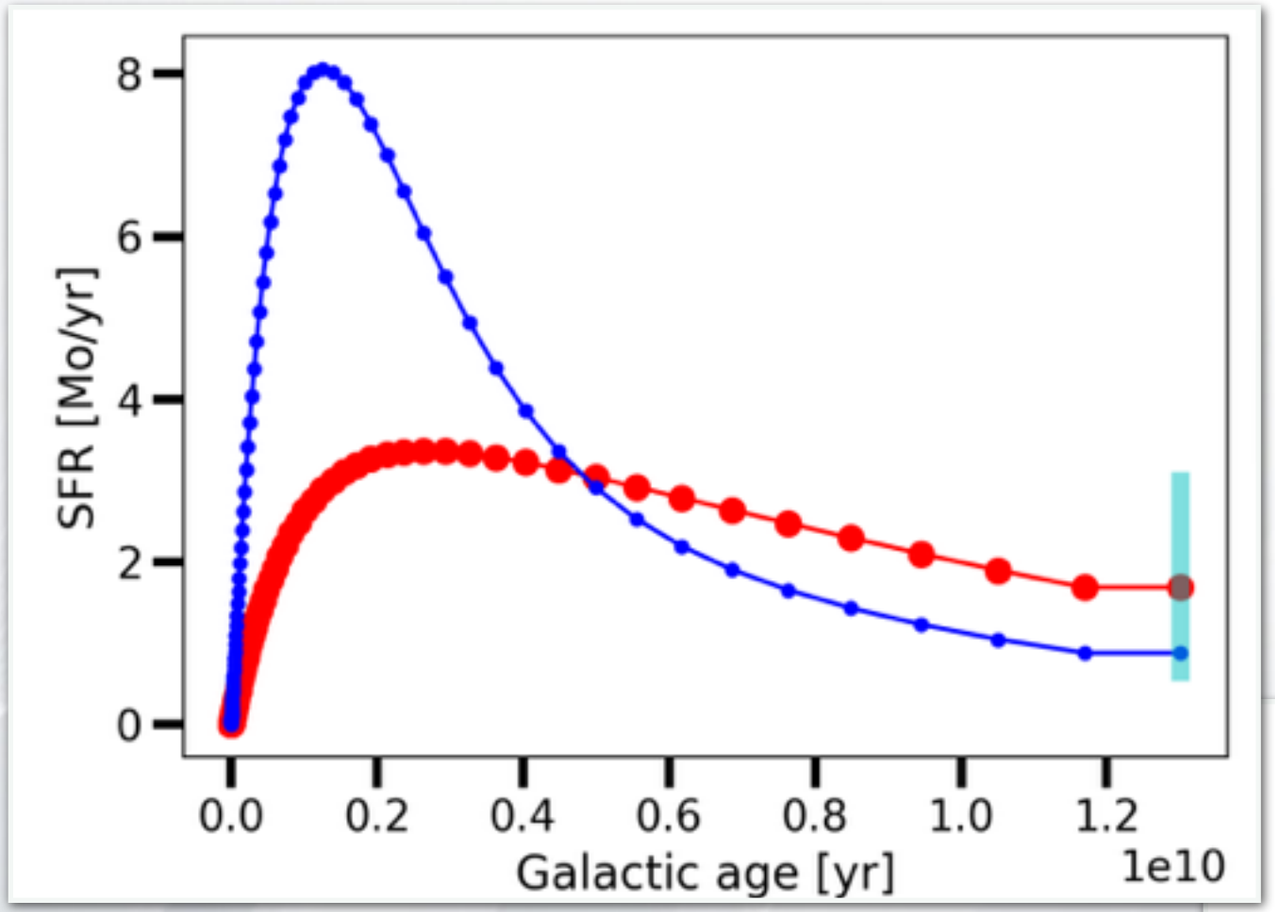


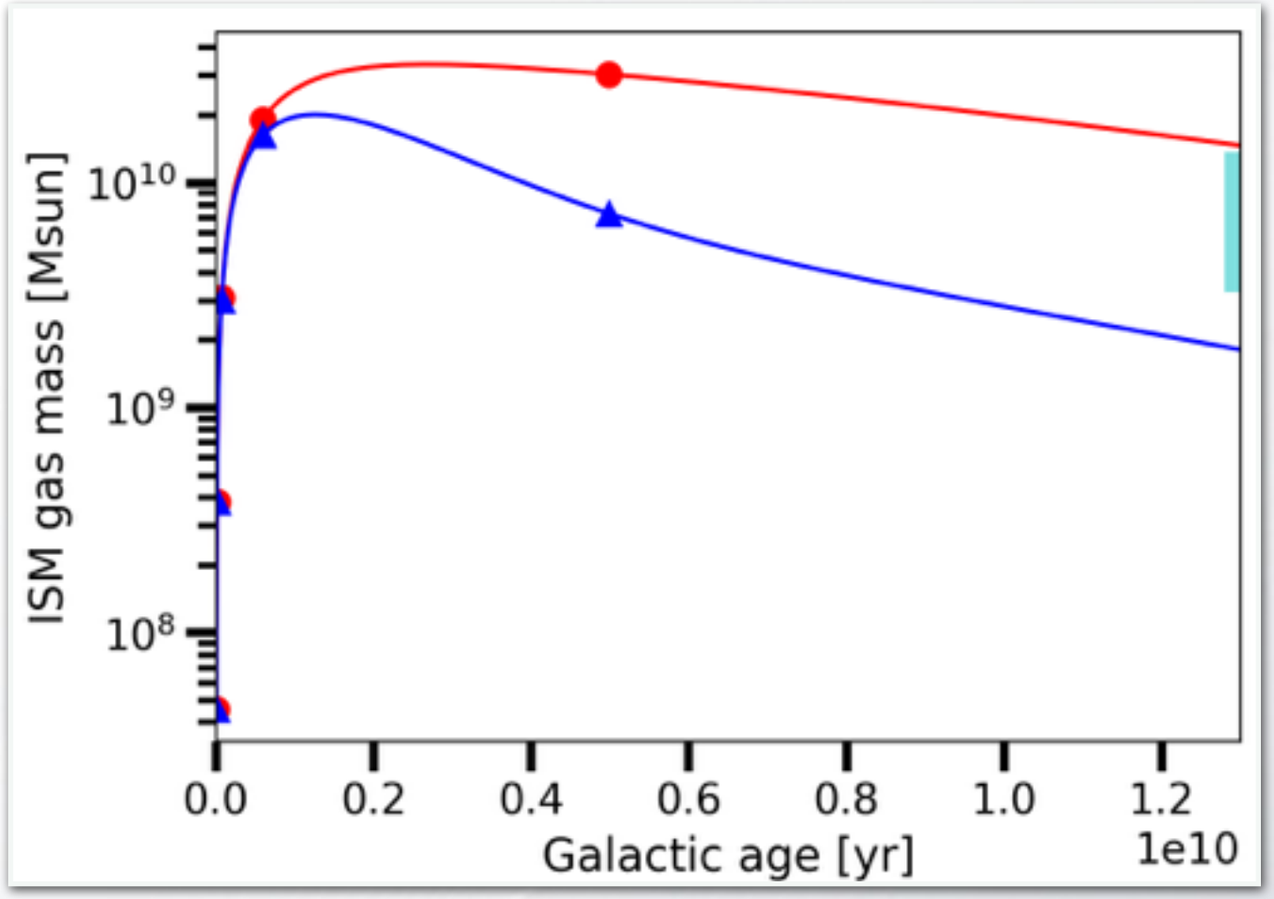
THE ACTIVITIES

- HS_GCE_Step_1_Constrain_MW_model.ipynb
- HS_GCE_Step_2_Evolution_of_the_elements.ipynb
- HS_GCE_Step_3_Stellar_abundances.ipynb
- HS_GCE_Step_4_Chemical_evolution_trends.ipynb
- HS_GCE_Step_5_Solar_composition.ipynb

STEP 1

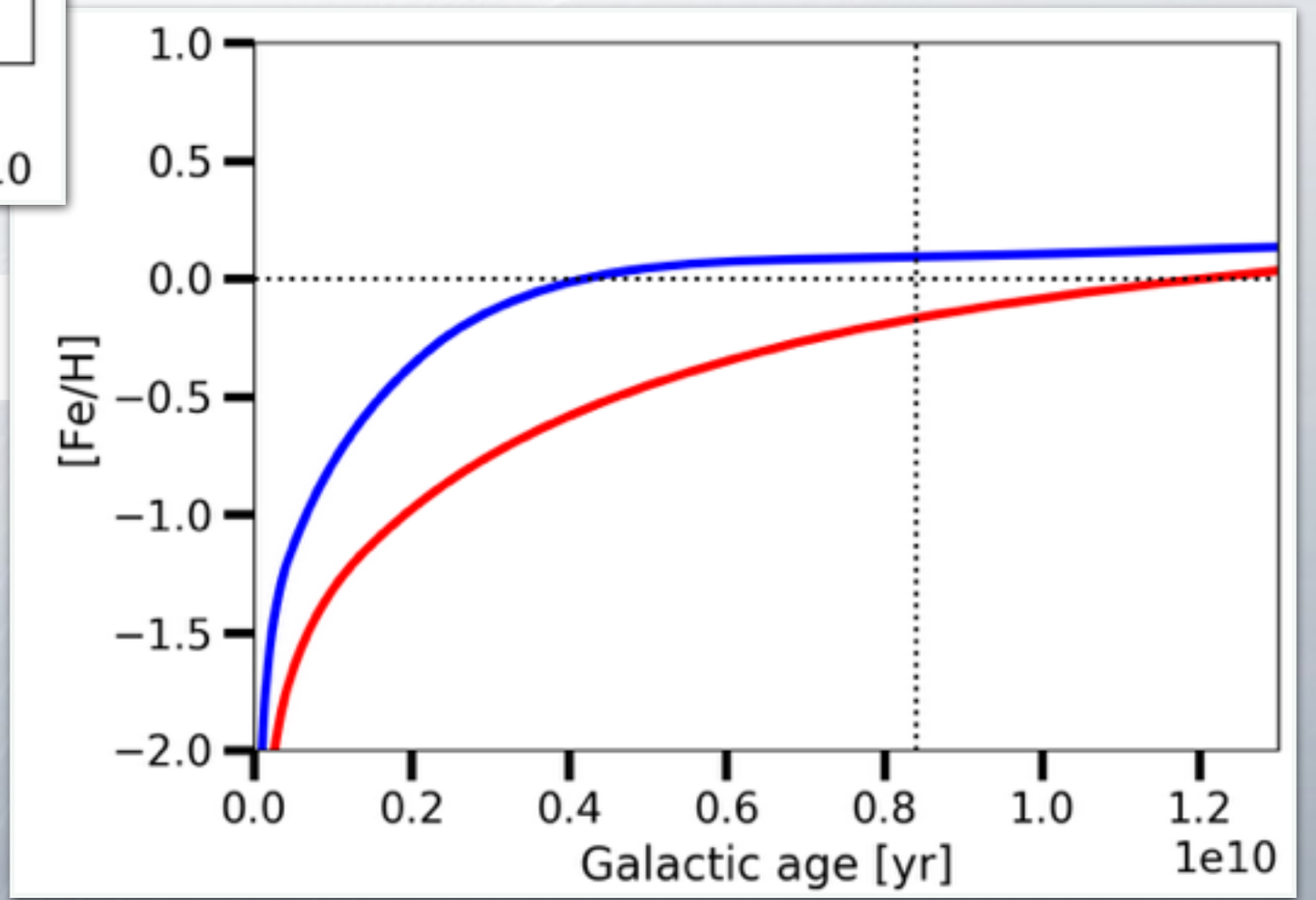
OMEGA





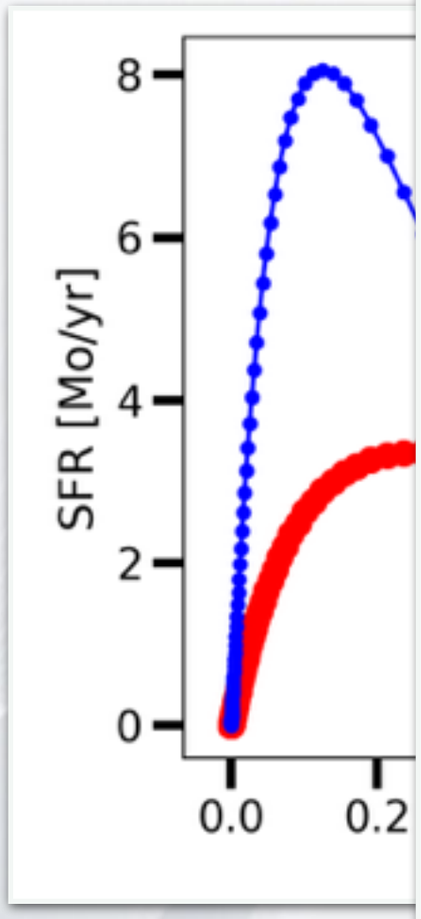

```
# Star formation efficiency (f_\star) -->
sfe = 0.01
```

```
# Galactic inflow rate
# Magnitude (strength) of the inflow rate
in_mag = 1.0
```



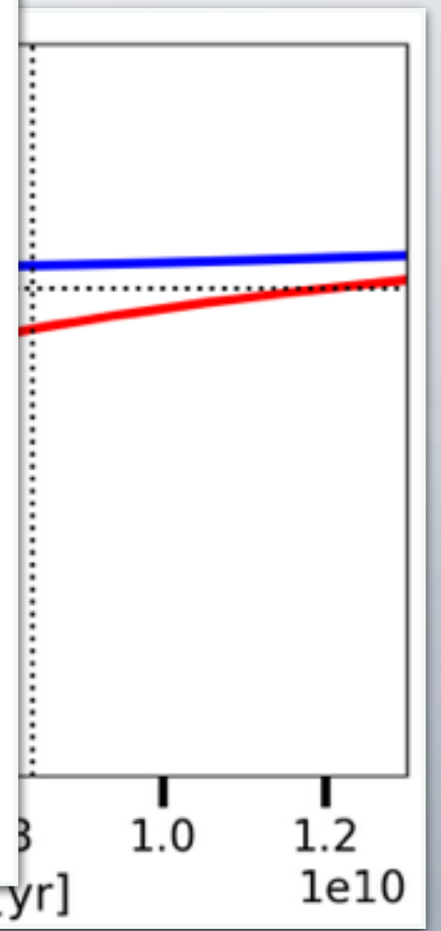
STEP 1

OMEGA

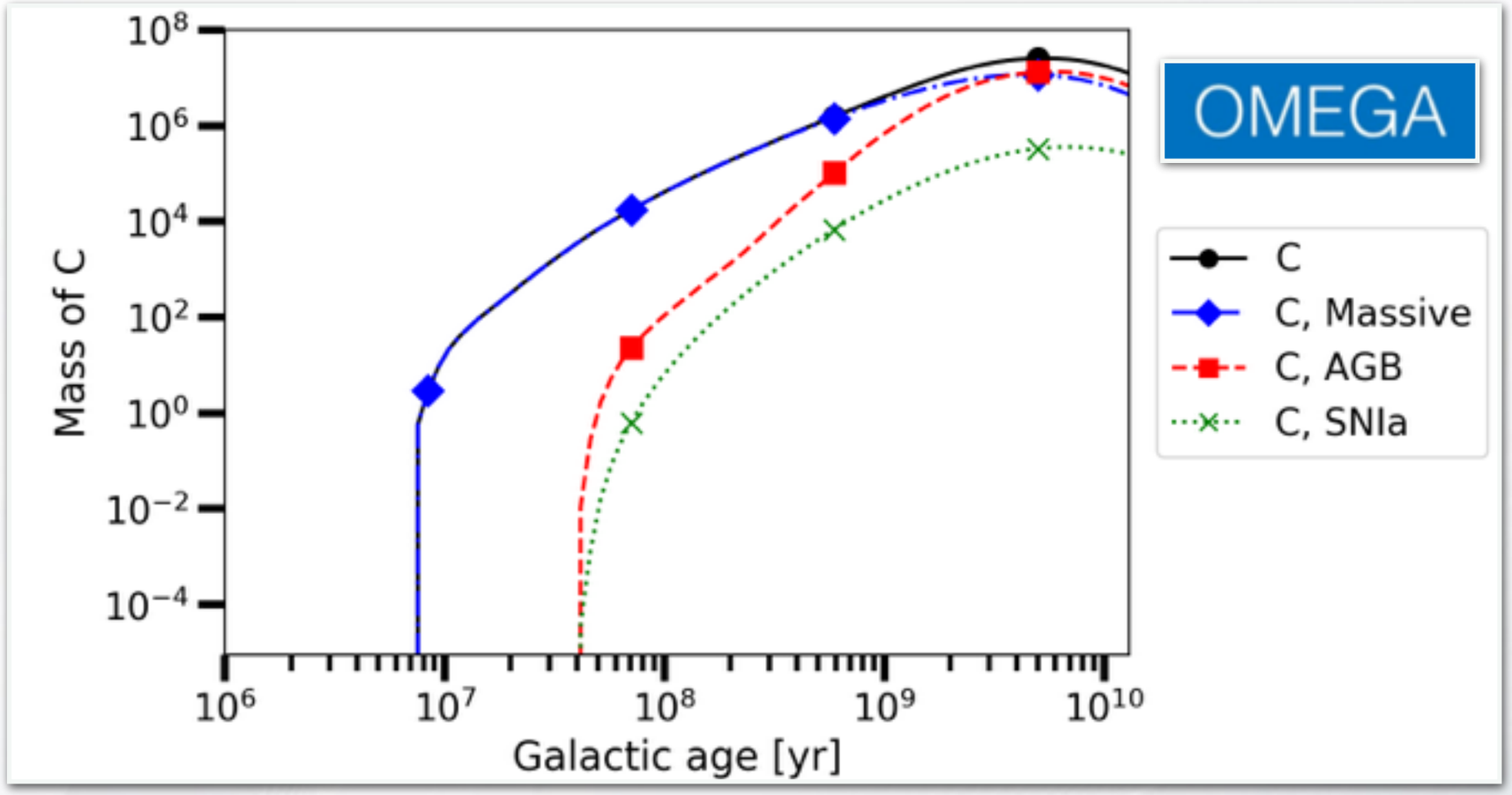



```
# Star forma
sfe = 0.01

# Galactic in
# Magnitude (
in_mag = 1.0
```

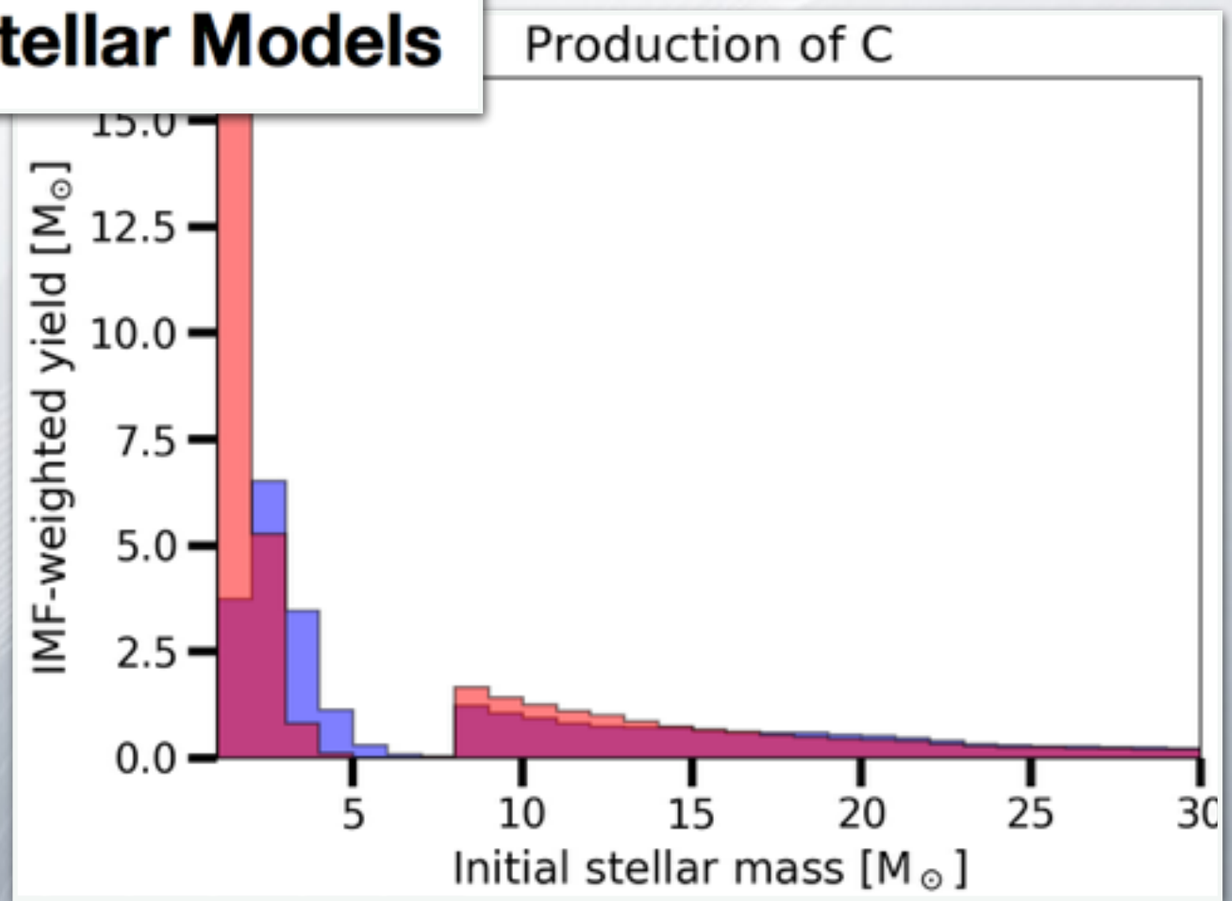


STEP 2



Identify the Important Stellar Models

SYGMA



THE ACTIVITIES

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- HS_GCE_Step_5_Solar_composition.ipynb

THE ACTIVITIES

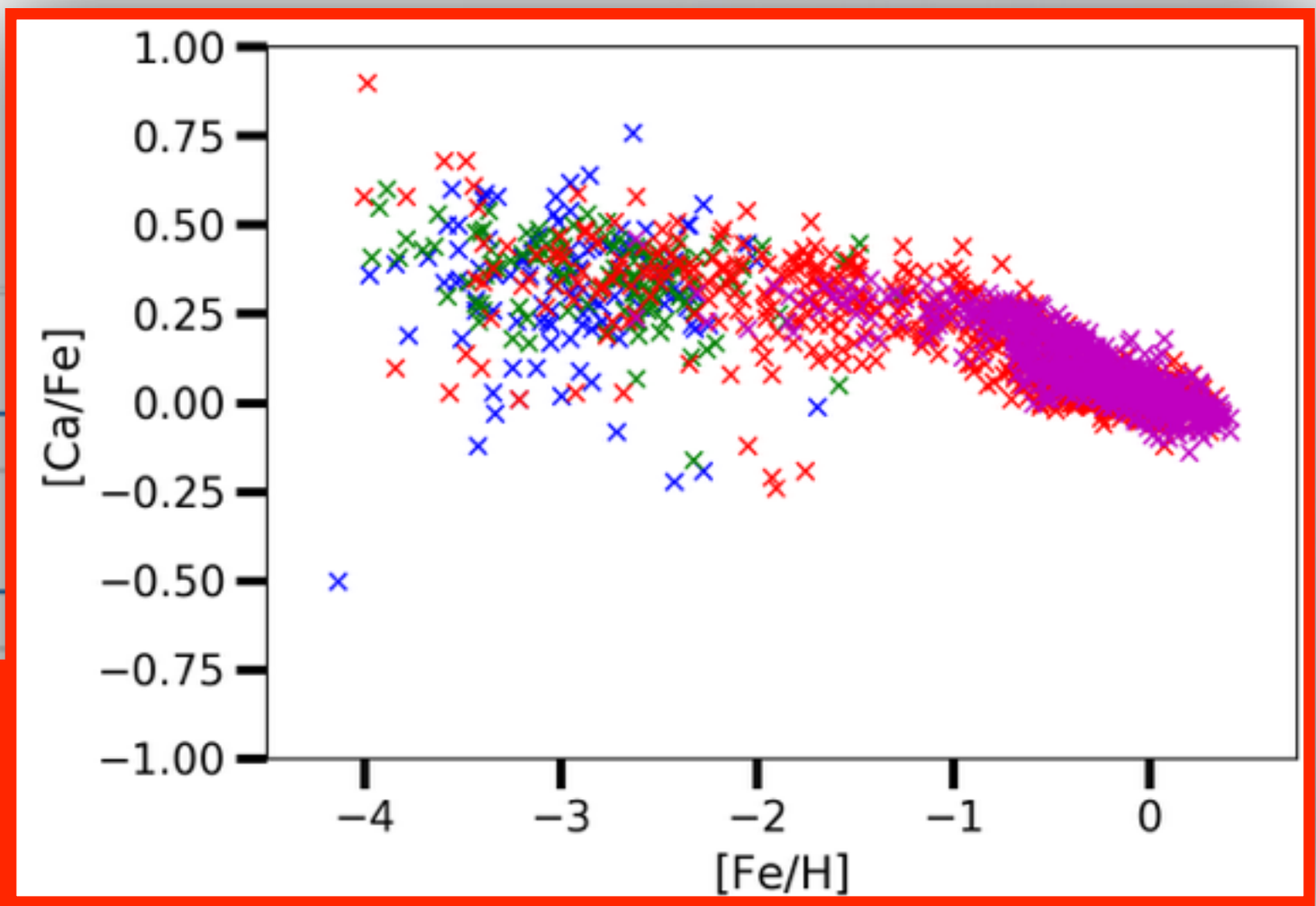
HS_GCE_Step_1_

HS_GCE_Step_2_

HS_GCE_Step_3_

HS_GCE_Step_4_Chemical_evolution_trends.ipynb

HS_GCE_Step_5_Solar_composition.ipynb



THE ACTIVITIES

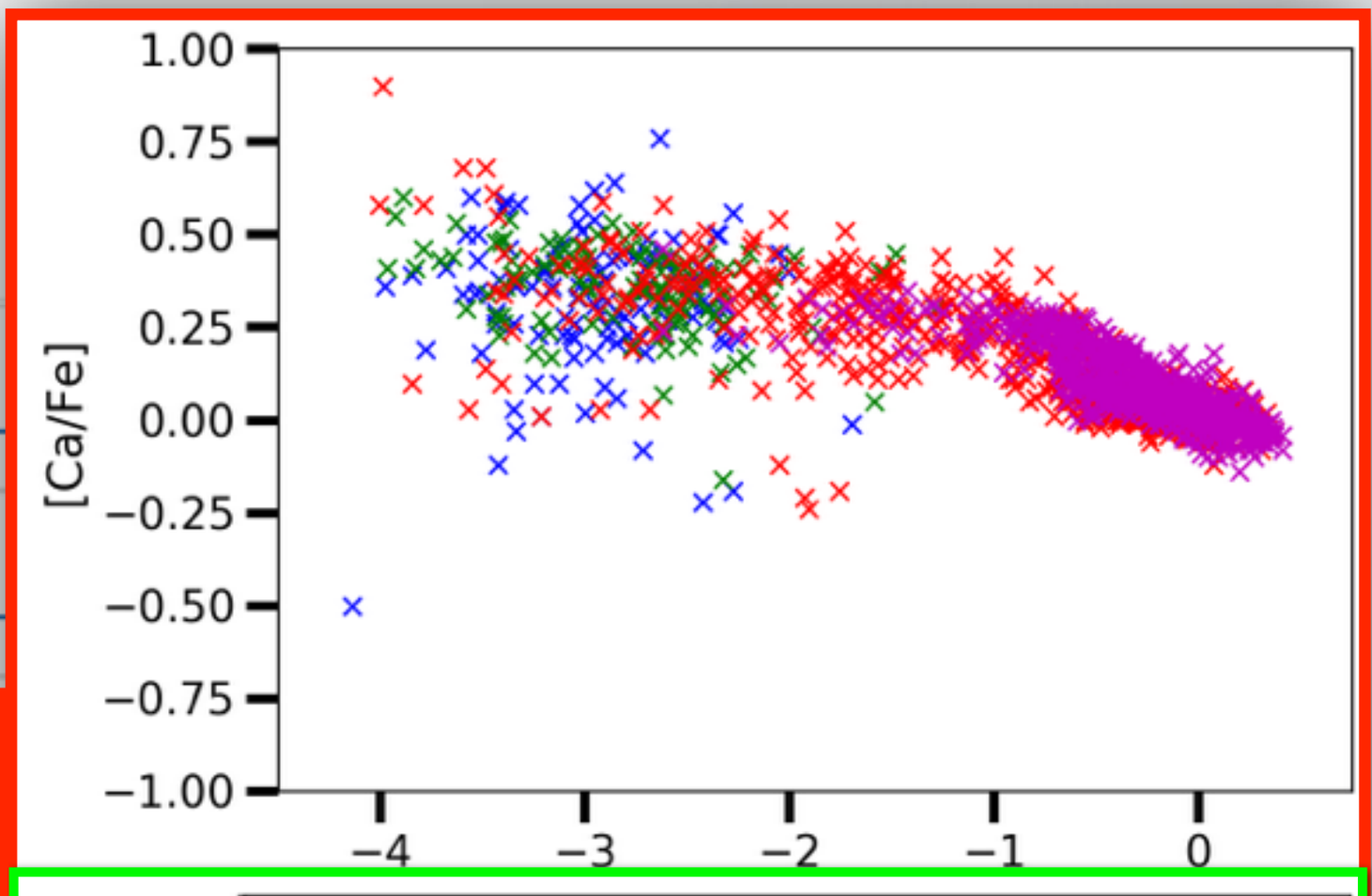
HS_GCE_Step_1

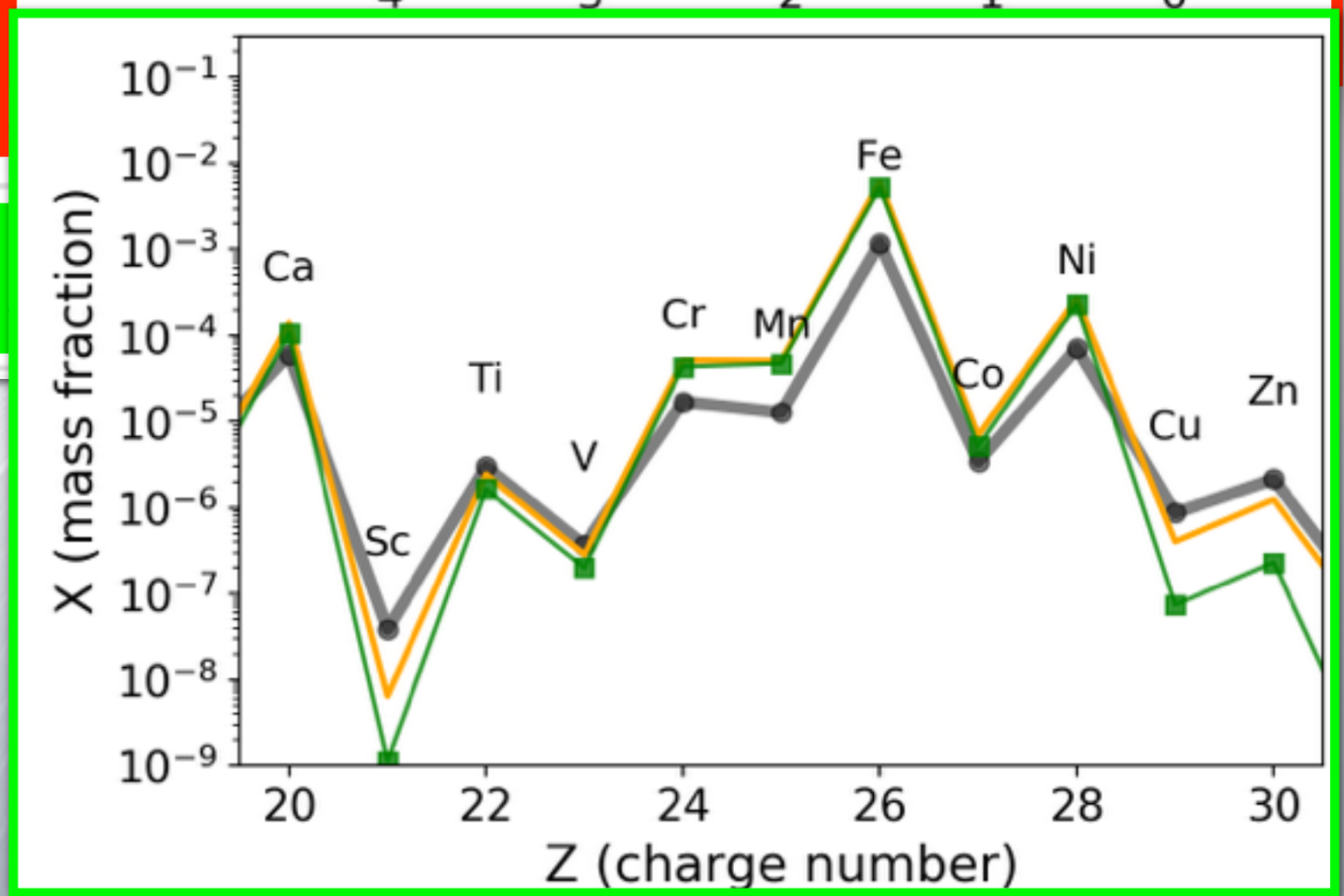
HS_GCE_Step_2

HS_GCE_Step_3

HS_GCE_Step_4

HS_GCE_Step_5

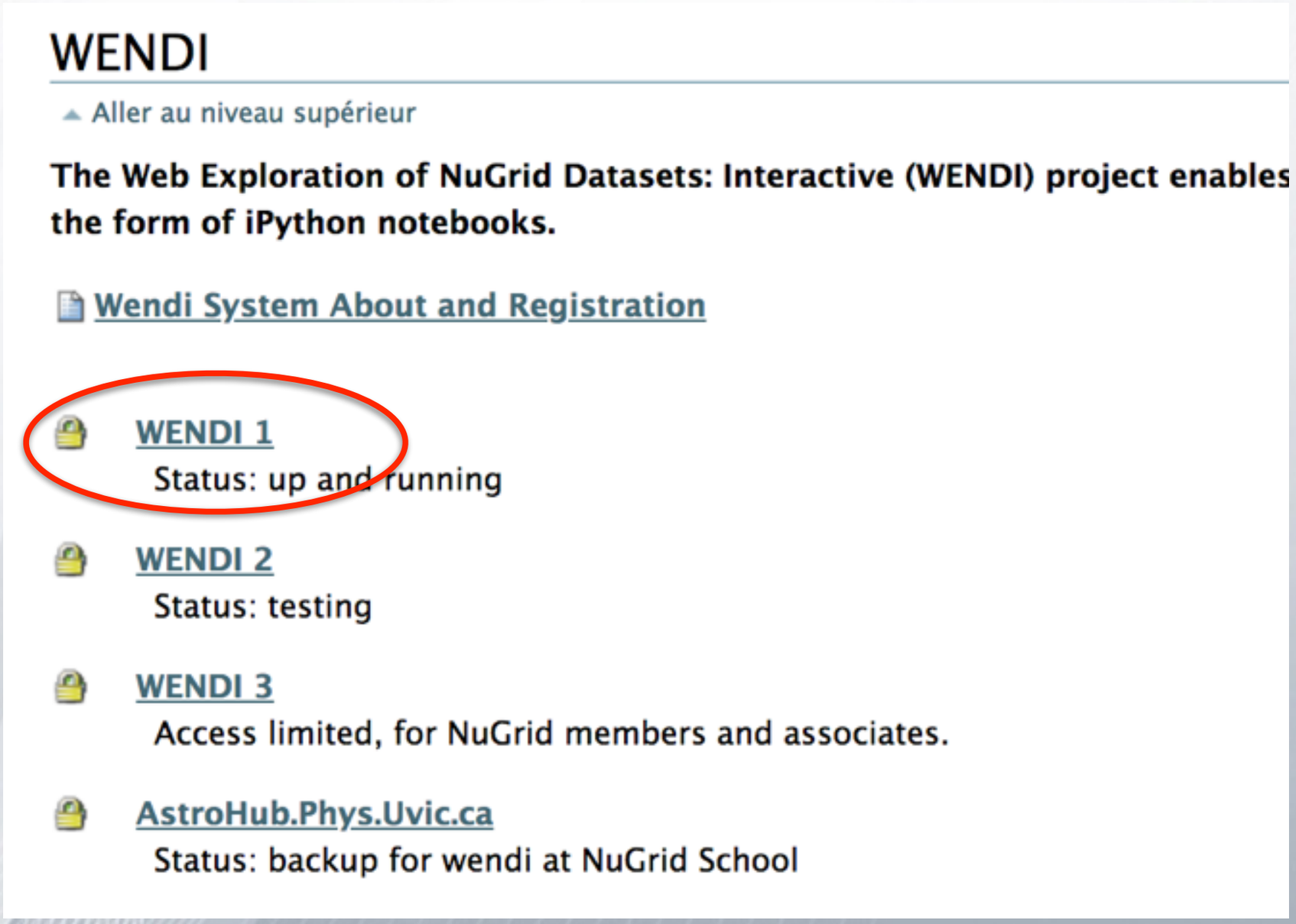




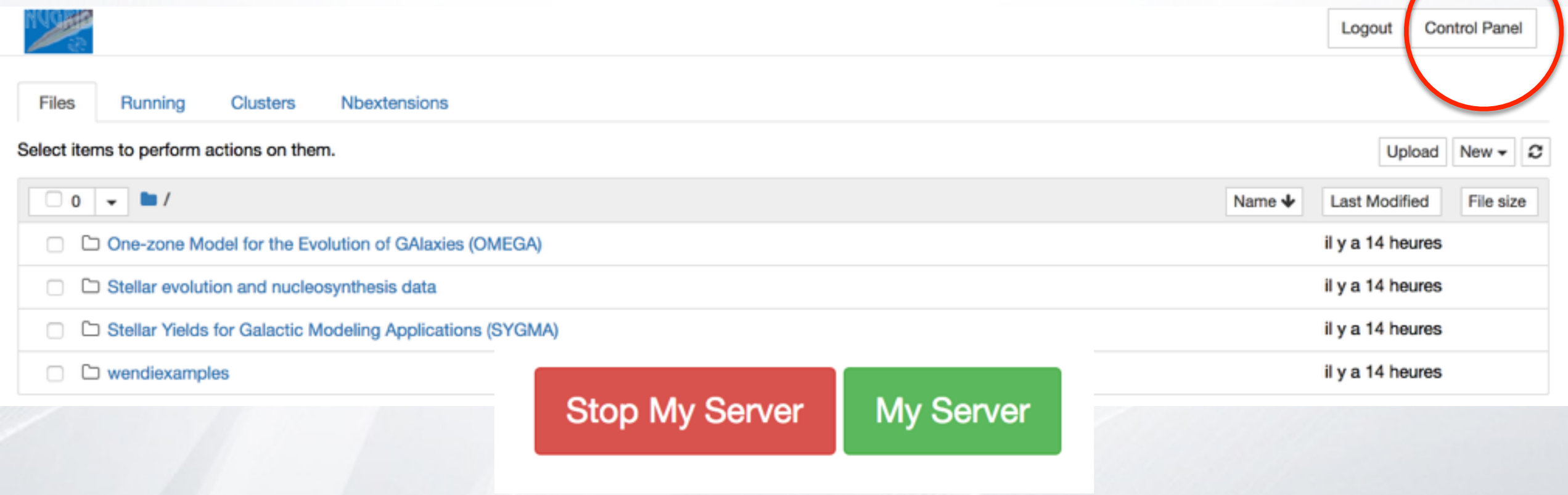
GET STARTED

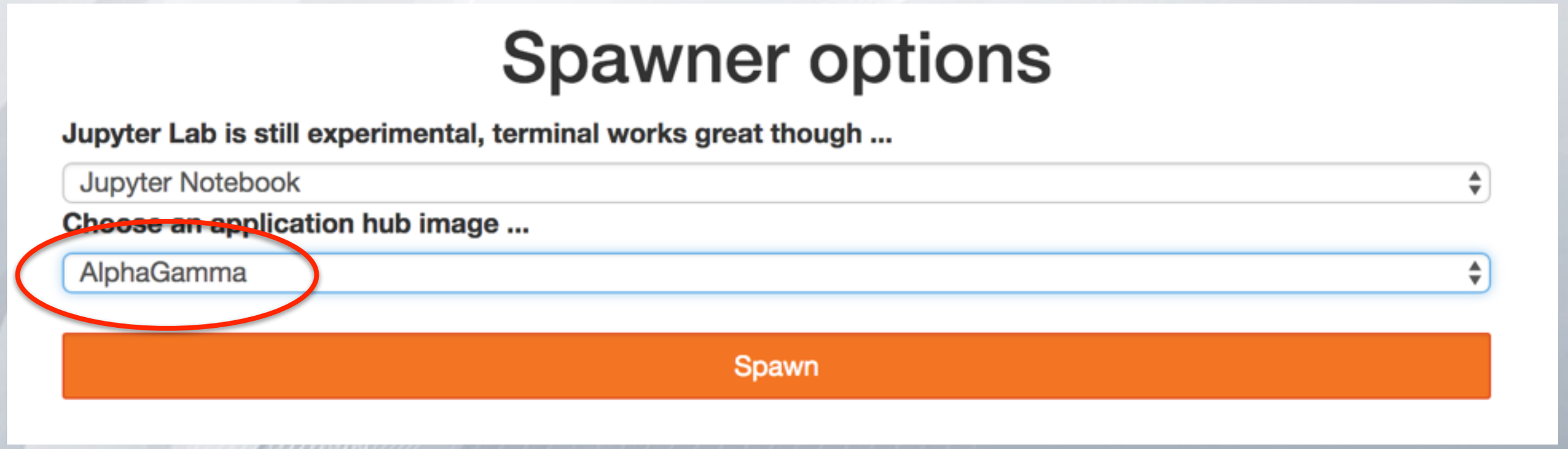
http://wendi.nugridstars.org/

Click on **WENDI 1**

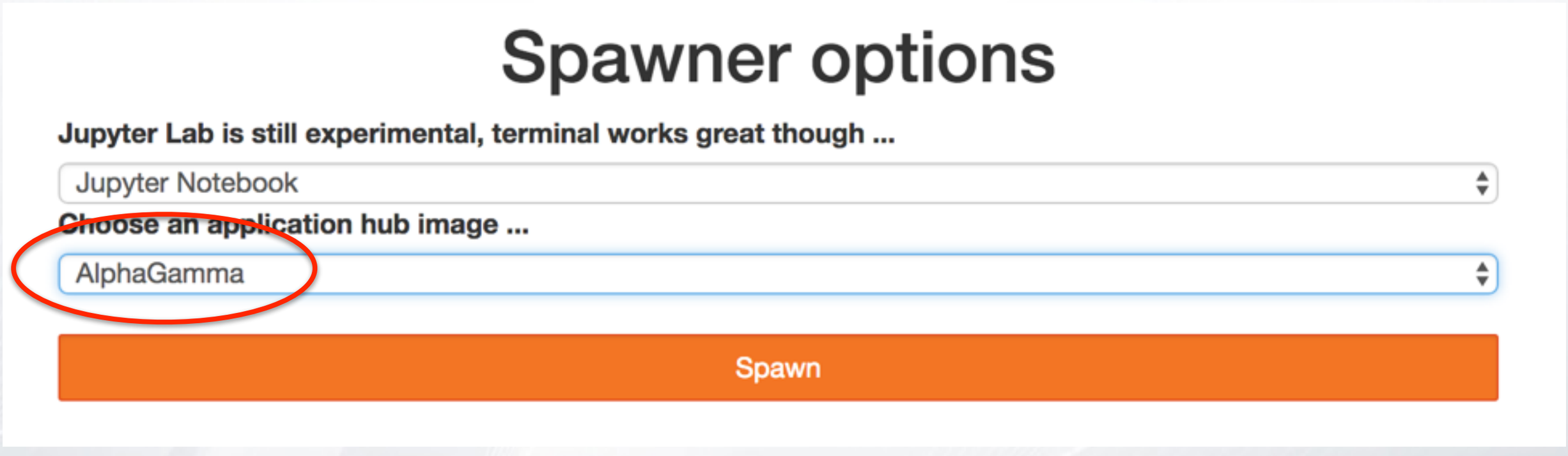


GET STARTED


Logout
Control Panel
Files
Running
Clusters
Nbextensions
Select items to perform actions on them.
Upload
New
0
/
Name
Last Modified
File size
One-zone Model for the Evolution of GAlaxies (OMEGA)
il y a 14 heures
Stellar evolution and nucleosynthesis data
il y a 14 heures
Stellar Yields for Galactic Modeling Applications (SYGMA)
il y a 14 heures
wendiexamples
il y a 14 heures
Stop My Server
My Server


Spawner options
Jupyter Lab is still experimental, terminal works great though ...
Jupyter Notebook
Choose an application hub image ...
AlphaGamma
Spawn

GET STARTED



Folder to the 5 notebooks

EXTRA MATERIAL

GAS CIRCULATION AND RECYCLING

Tumlinson, Peeples & Werk (2017)