University of Oklahoma

Galactic Archaeology and the Formation of the Elements

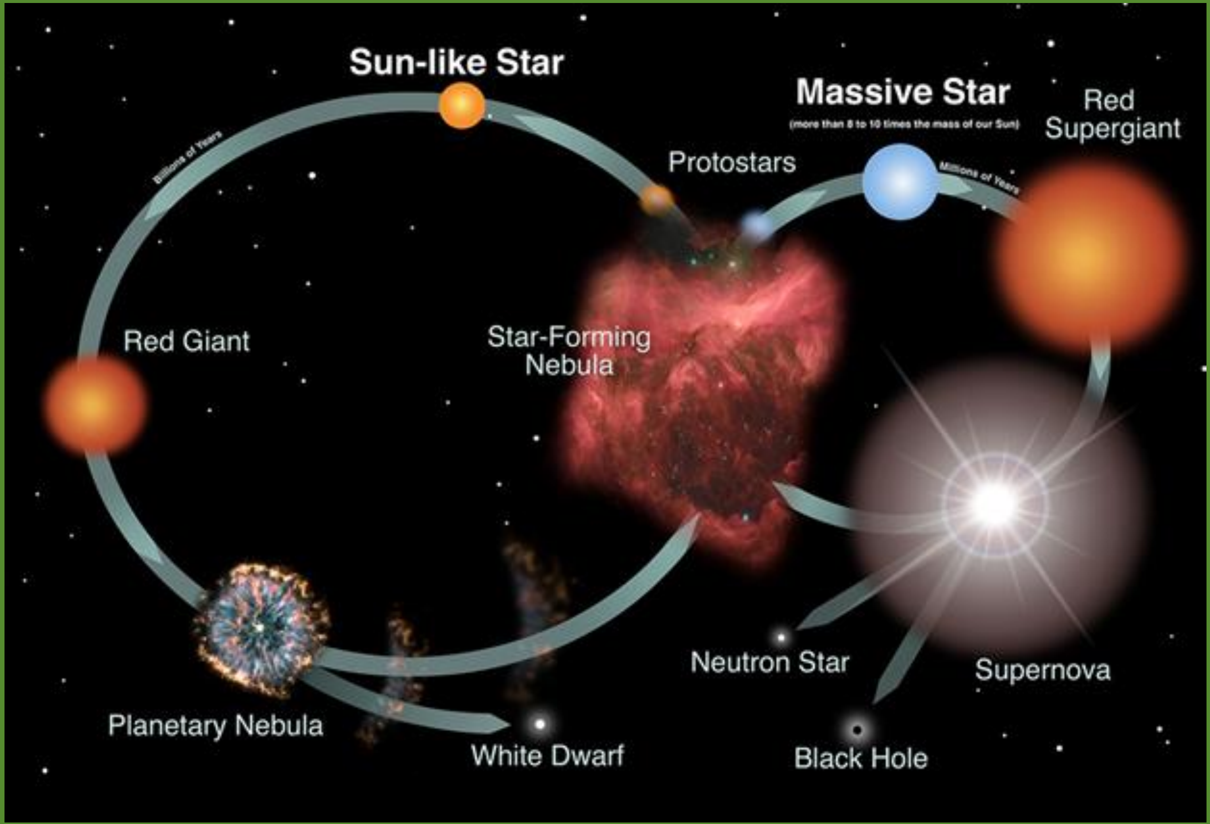
The cosmos is within us. We are made of star-stuff. We are a way for the Universe to know itself.
-Carl Sagan

Madeline van Staveren

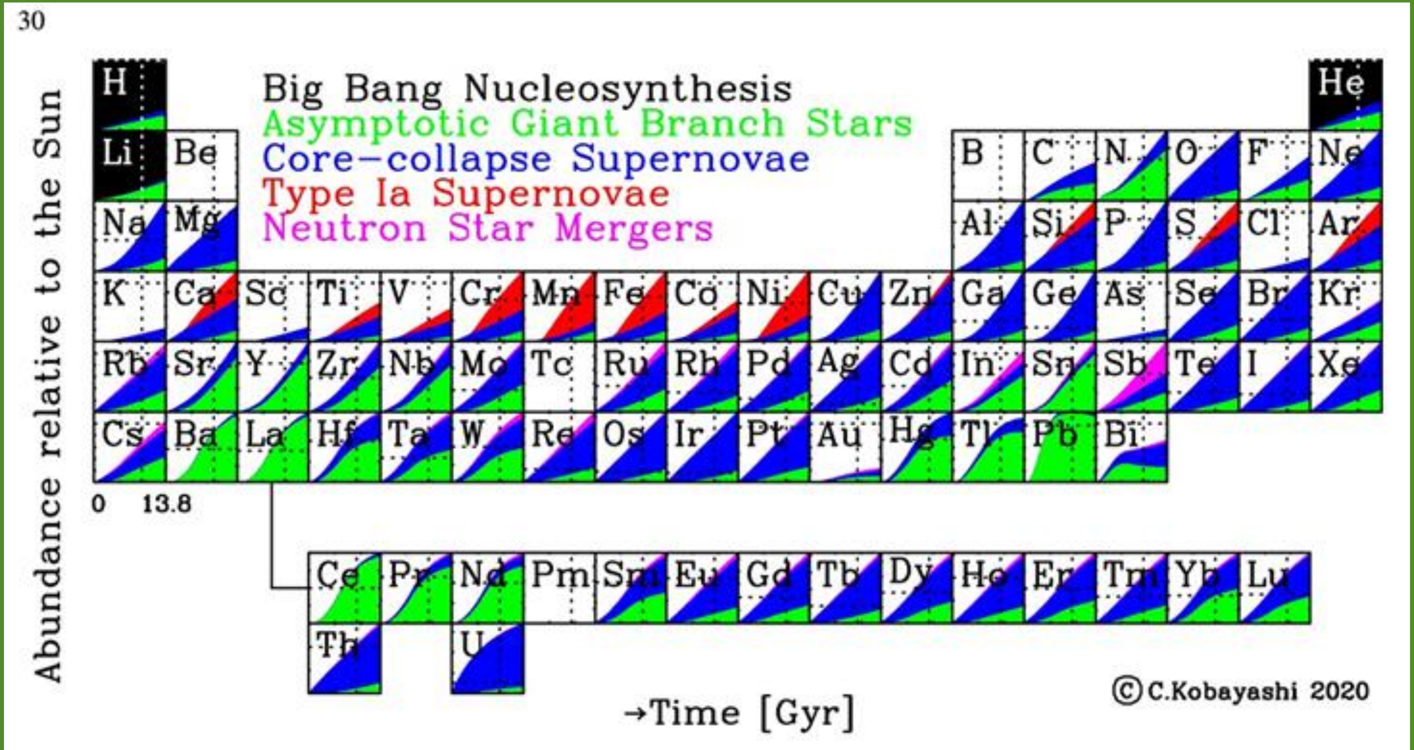
Michael Hayden

- Galactic Archaeology is the study of the history and formation of galaxies using data collected from their stars.
- Stars function as a “time machine”

Credits: NASA, ESA and the Hubble Heritage Team (STScI/AURA)



Galactic Archaeology surveys data revealing the chemo dynamical structure (the galaxy's "fossil record") of the Milky Way and the Local Group.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Big Bang Nucleosynthesis
Asymptotic Giant Branch Stars
Core-collapse Supernovae
Type Ia Supernovae
Neutron Star Mergers
H He Li Be B C N O F Ne Na Mg Al Si P S Cl Ar K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th U
0 13.8
Abundance relative to the Sun
→Time [Gyr]
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- x-axis is time, y-axis is element abundance per our model
- Cross section is measured abundance in our sun when it was born

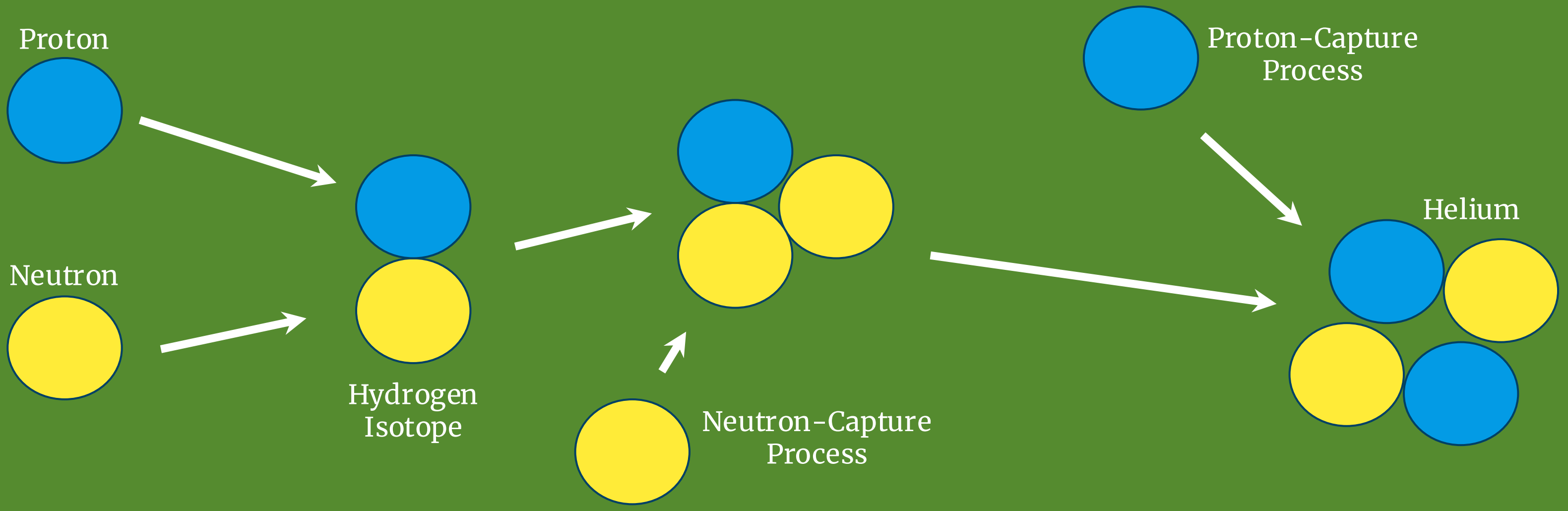
- Colors correspond to various production sites
- Some elements better fitted than others

AGB Stars
1a SN
CC SN

- Different production sites producing elements on different time scales

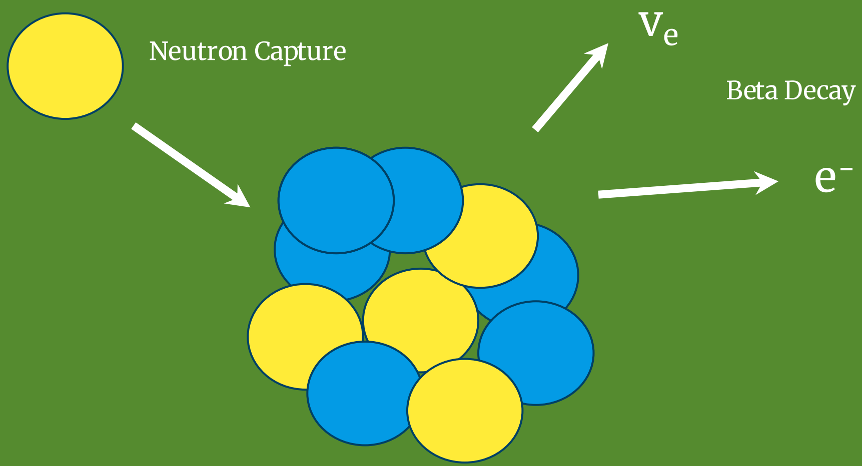
Nucleosynthesis

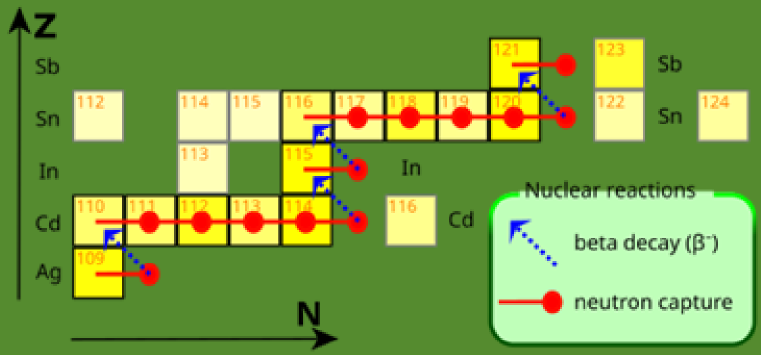
The mechanisms through which new elements are created with events like Neutron/Proton capture process, Radioactive decay, and Electron capture process.



Neutron Capture Process

Slow and Rapid neutron capture process (s-process, r-process) is the primary event for creating elements heavier than iron in stars.



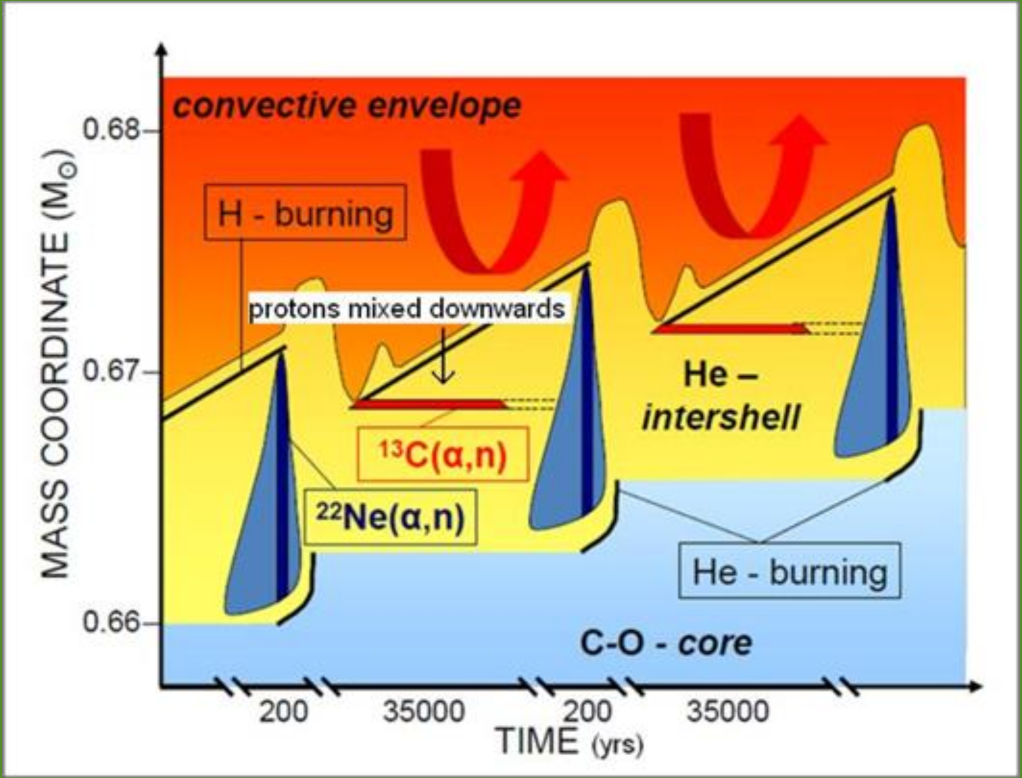


S-Process Production

Asymptotic Giant Branch Stars

Low-Intermediate Mass Stars: .9 - 8 Solar Masses
Super AGB Stars: 8 - 10 Solar Masses

- Alpha particles smash into stable ^{13}C and ^{22}Ne molecules, resulting in heavier metals and a lone neutron.
- Occurs between the H and He shell during thermal pulsing.



Talwar, R. (2015). Stellar Neutron Sources and s-Process in Massive Stars

R-Process Production

Type II Supernovae: Core-collapse Supernovae

10-25M⊙

- A star runs out of fuel and collapses due to the imbalance of degeneracy pressure and gravity. This will either result in a neutron star or a black hole, depending on the mass.

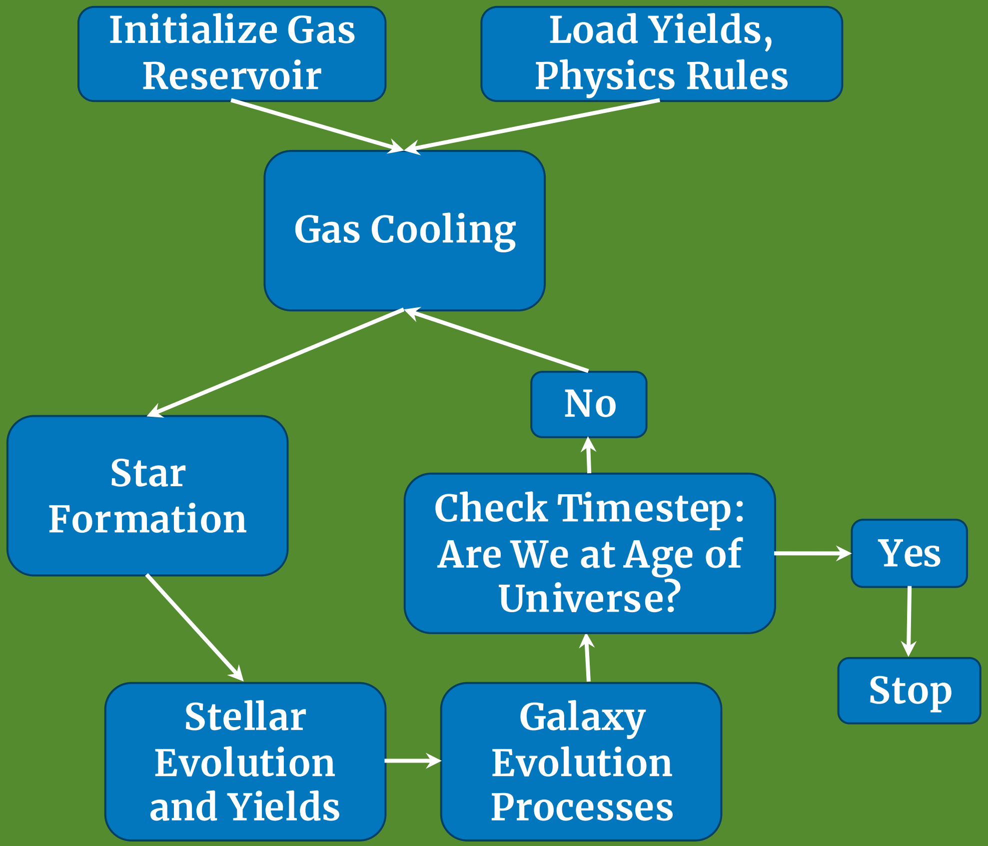
How do all of these work together?

Galactic Chemical Evolution Model

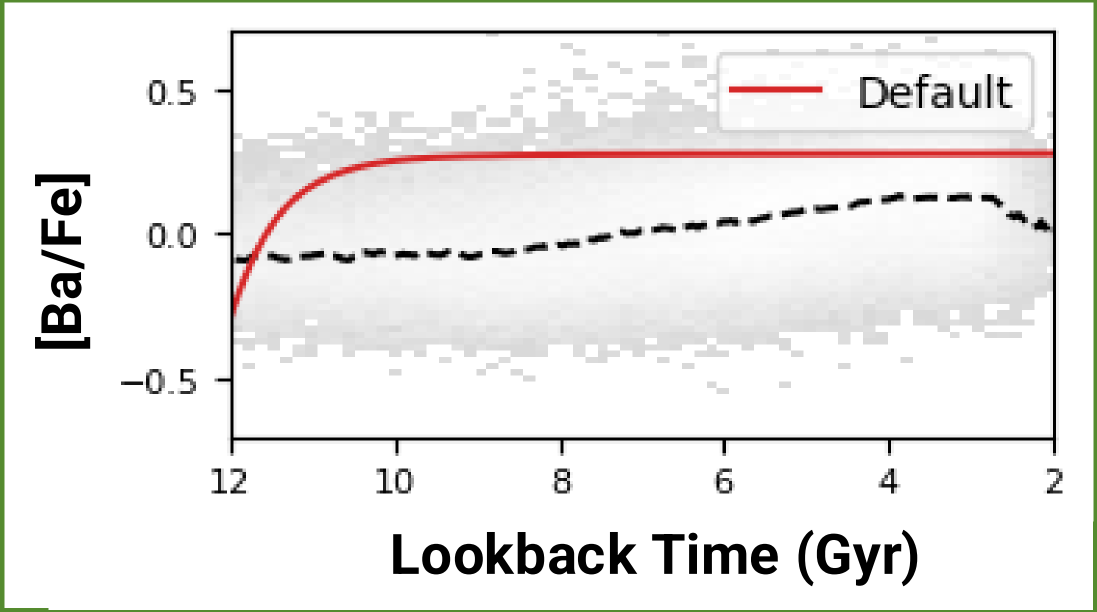
A Galactic chemical evolution model traces how elements evolve with time in a Galaxy

The model contains warm and cold gas (cold gas forms stars), stars, and tracks the abundance of elements for each of these components

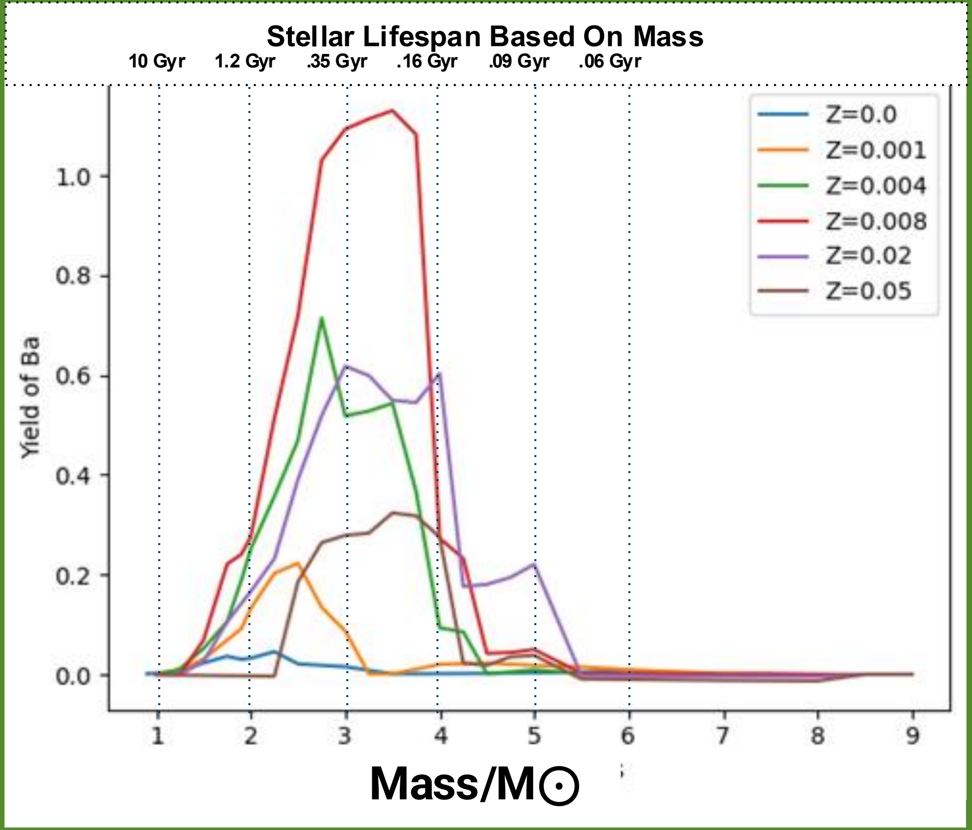
The model has physical rules for star formation, stellar yields, gas cooling and heating, and galaxy evolution properties like gas accretion and the movement of gas and stars around the galaxy



Understanding Barium

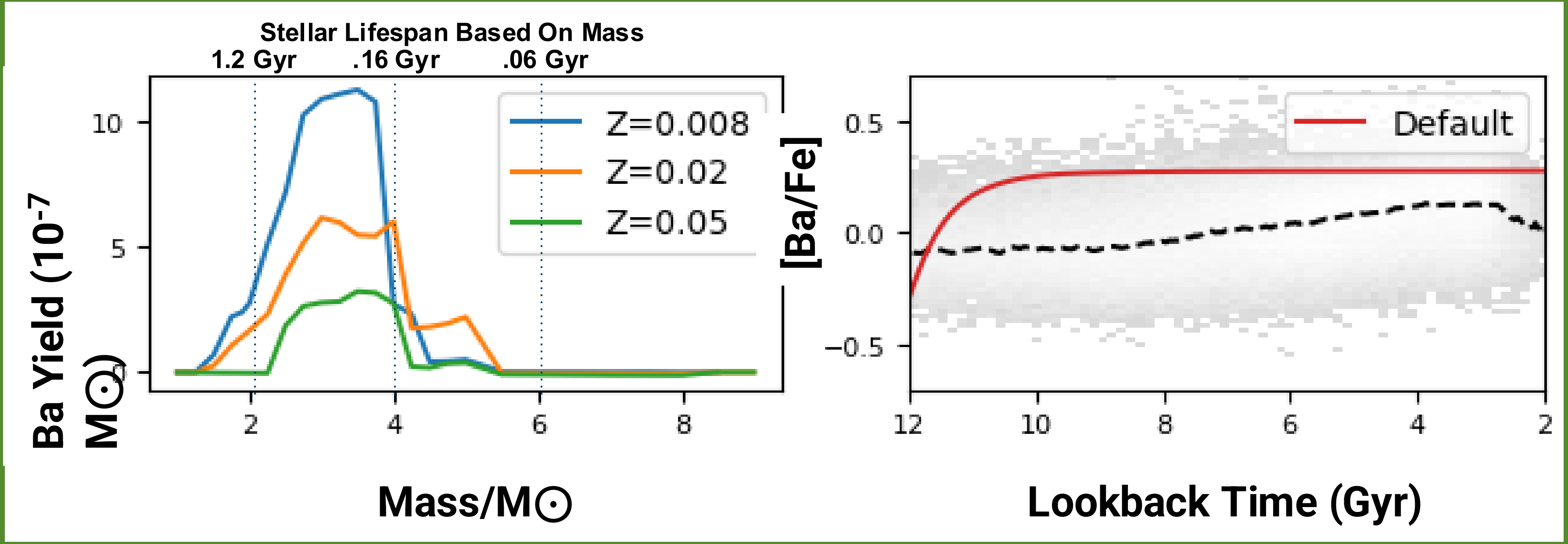


Galactic Chemical Evolution models simulated changes in the chemical composition of galaxies over time.

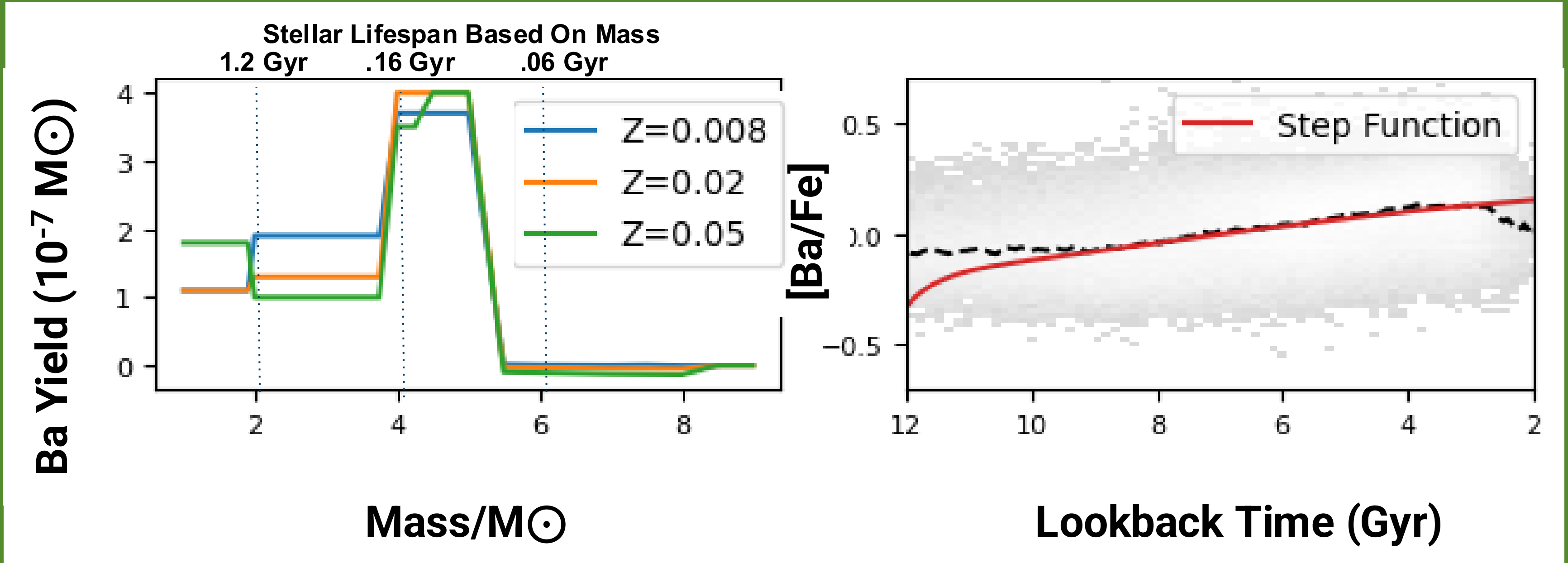


- Z is the mass ratio of elements heavier than Helium to the total mass of the star.
- Stars under Z = 0.008 don't exist in the Milky Way.

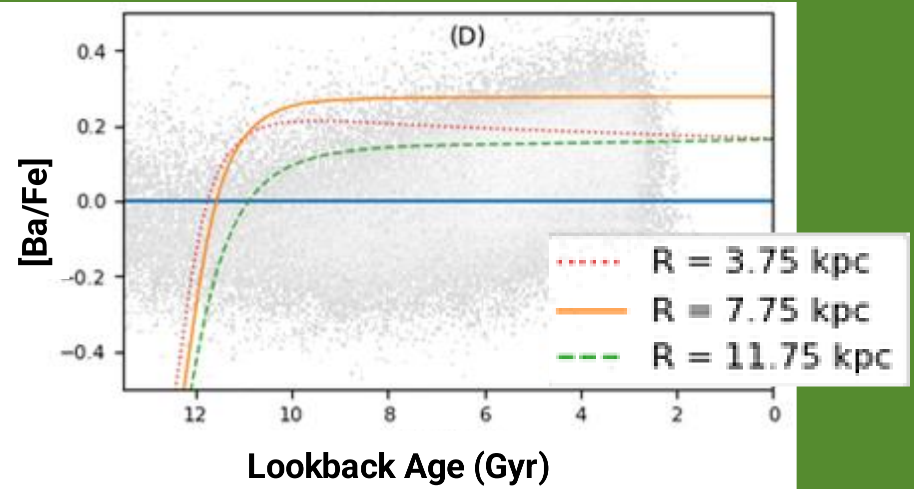
Default Yields



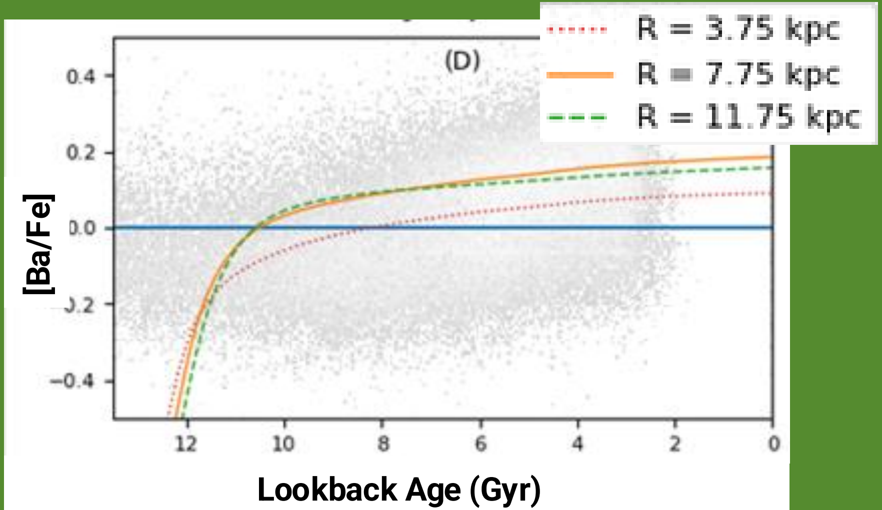
Adjusted Yields



- Adjusted 3 different metallicities
- Masses between .9 - 5.5 M⊙



Default Yields



Adjusted Yields

Conclusion:

- Higher Barium yields for low mass stars across all tested metallicities lead to a better agreement between our model and the data

Future:

- Write up our findings and look into s-process production in low mass stars