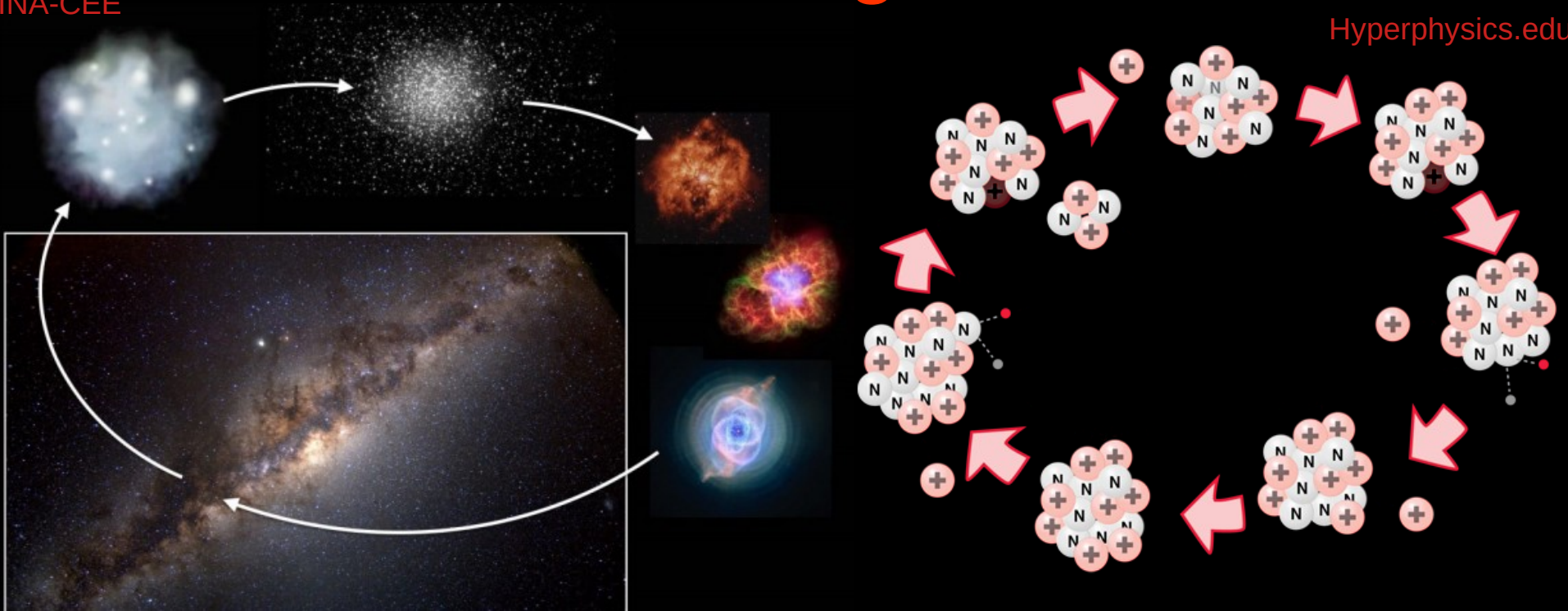


The $^{12}\text{C}/^{13}\text{C}$ isotopic ratio at the dawn of chemical evolution

David Aguado

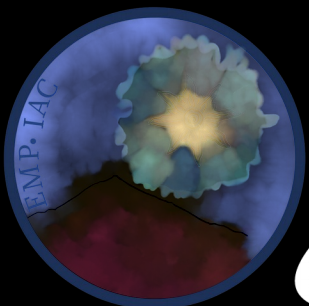
JINA-CEE

Hyperphysics.edu



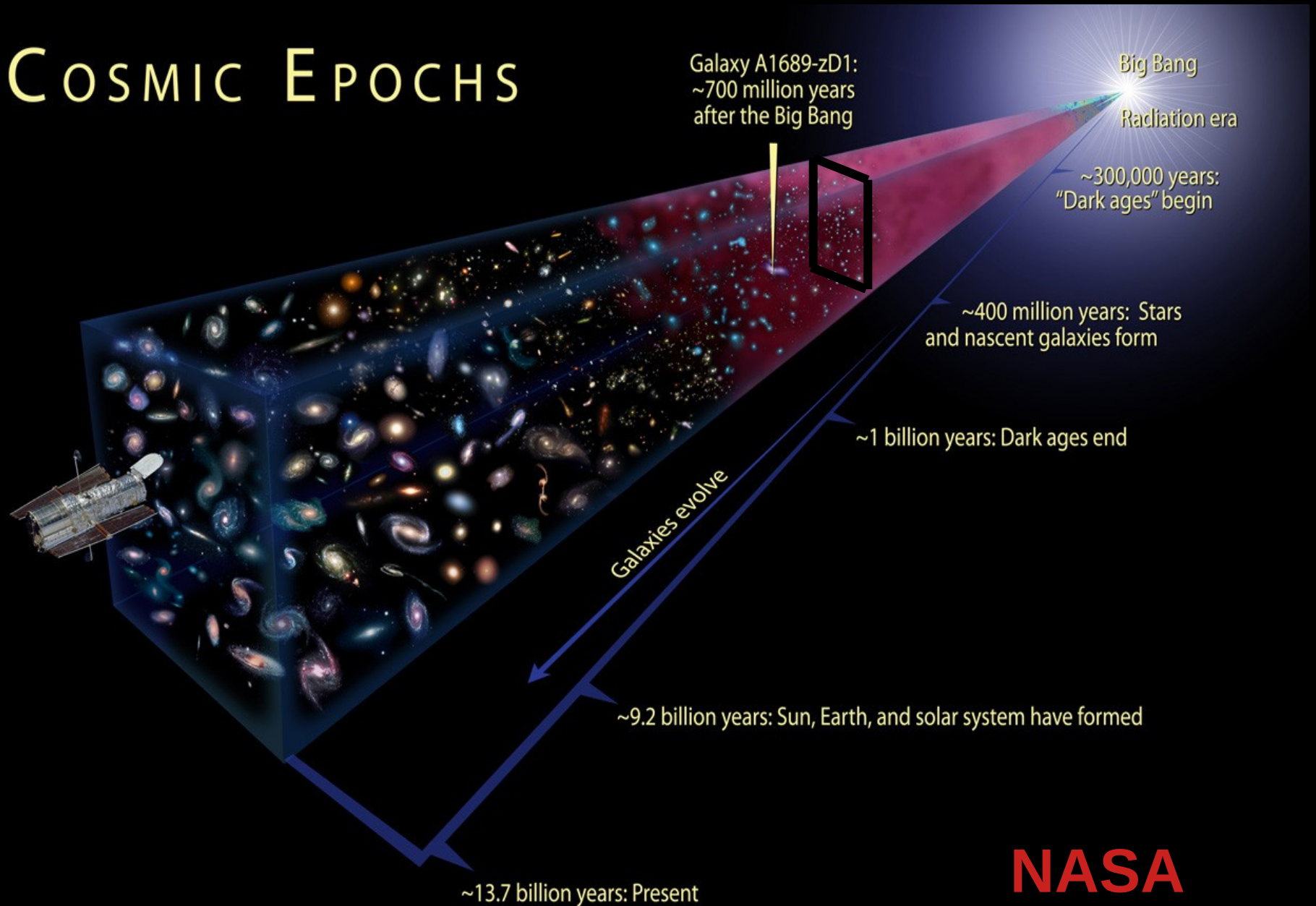
Nuclei in the Cosmos (NIC)

대전 20230919



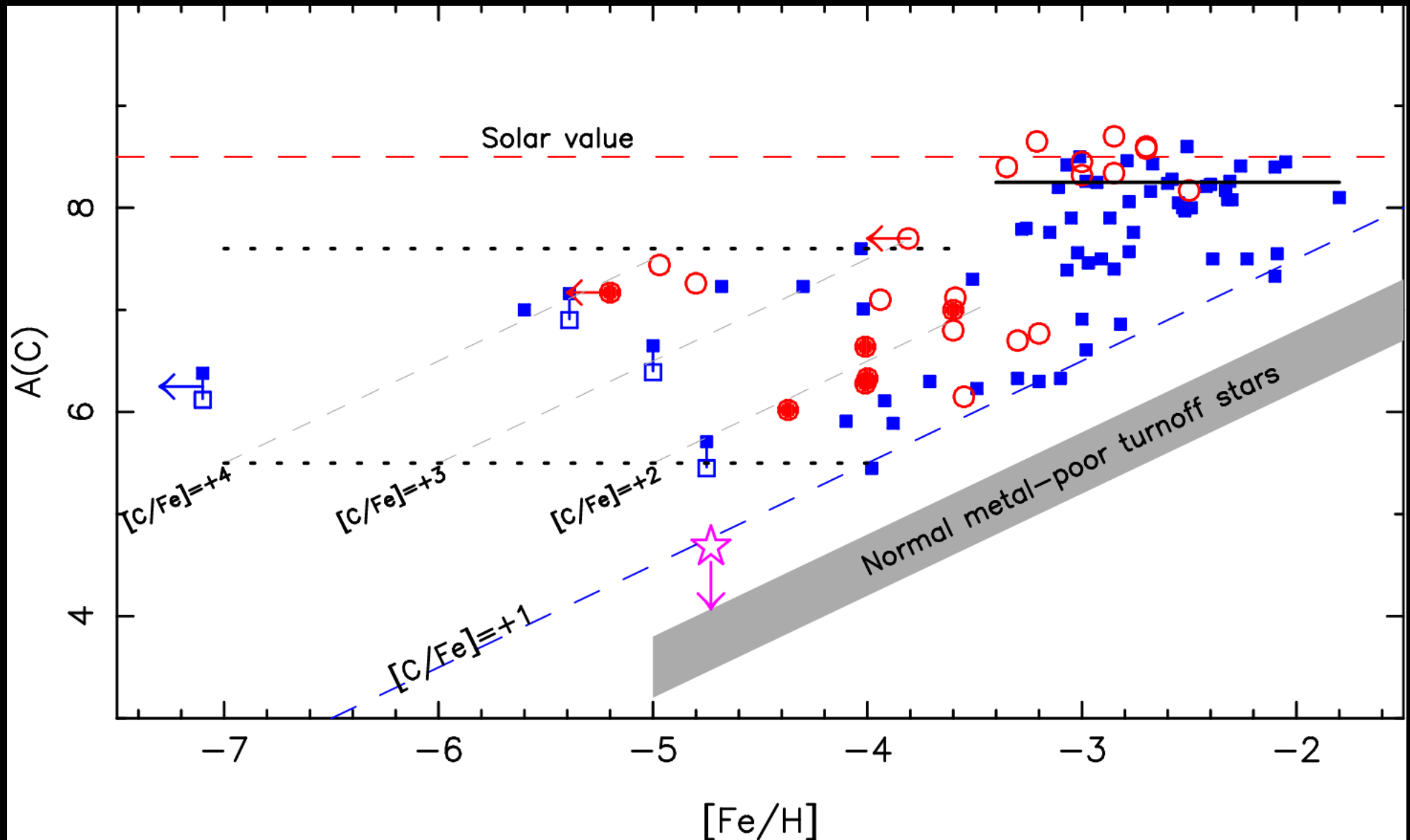
1-Introduction: The First Stars

COSMIC EPOCHS



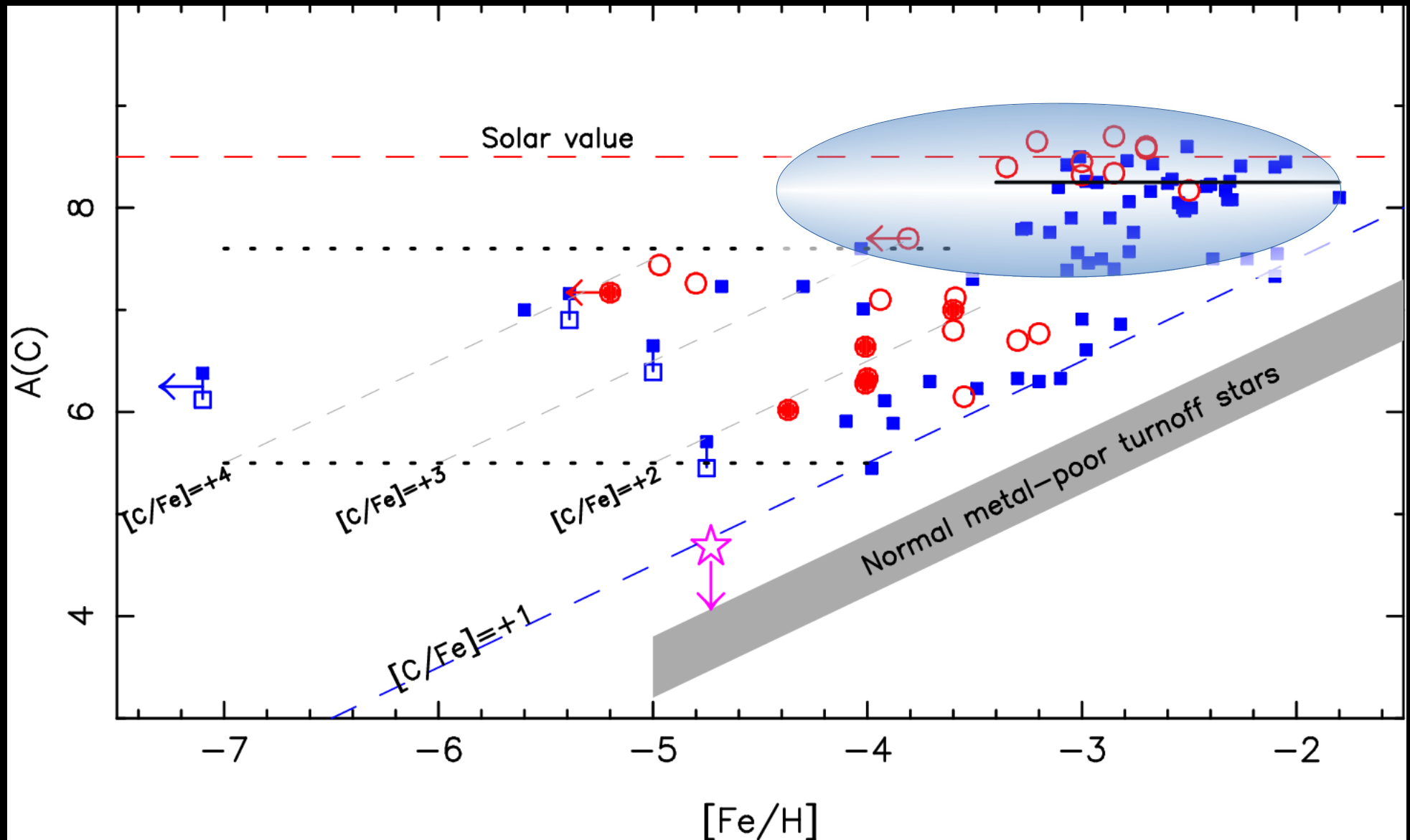
NASA

1-Introduction: The First Stars



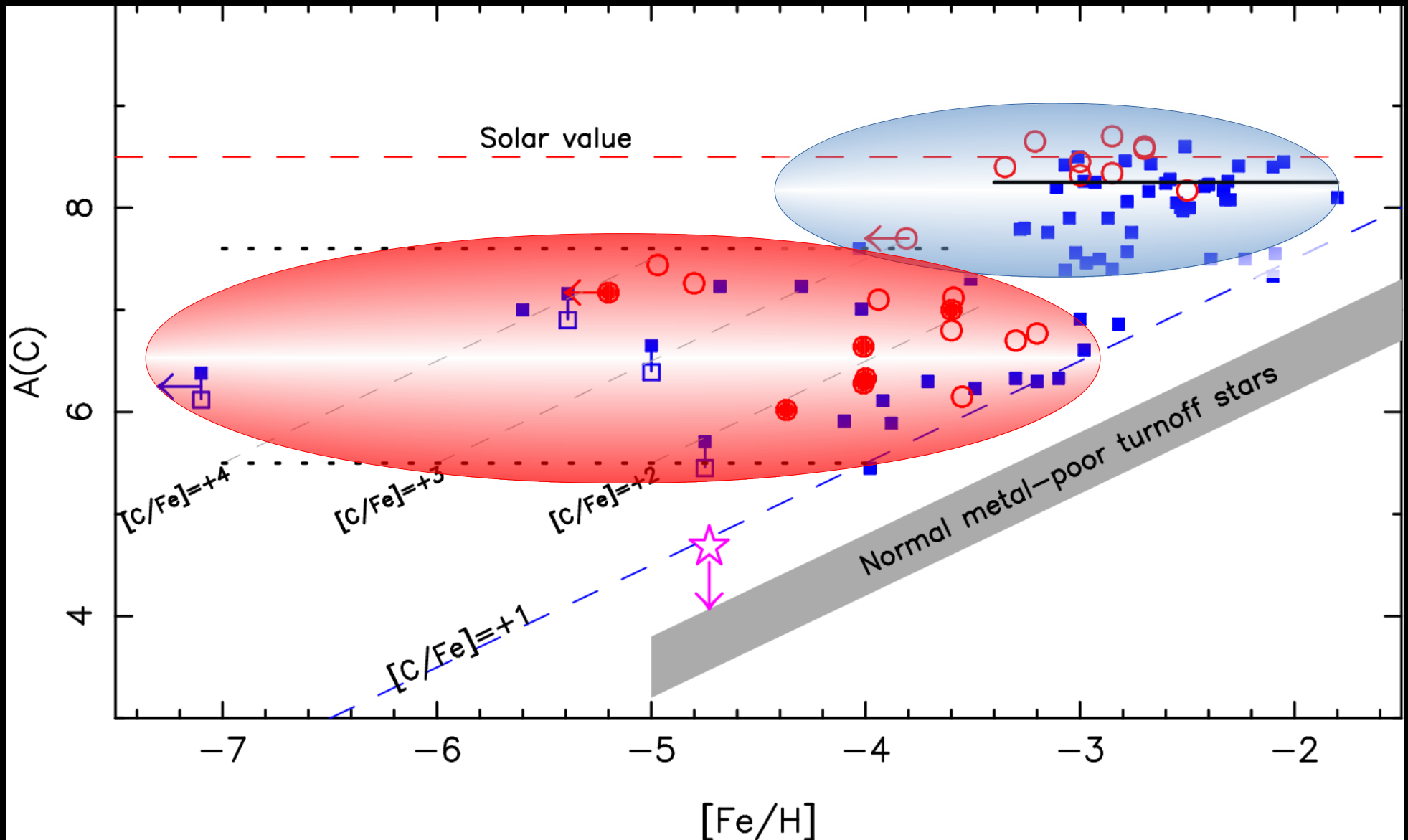
Bonifacio et al. 2015

1-Introduction: The First Stars



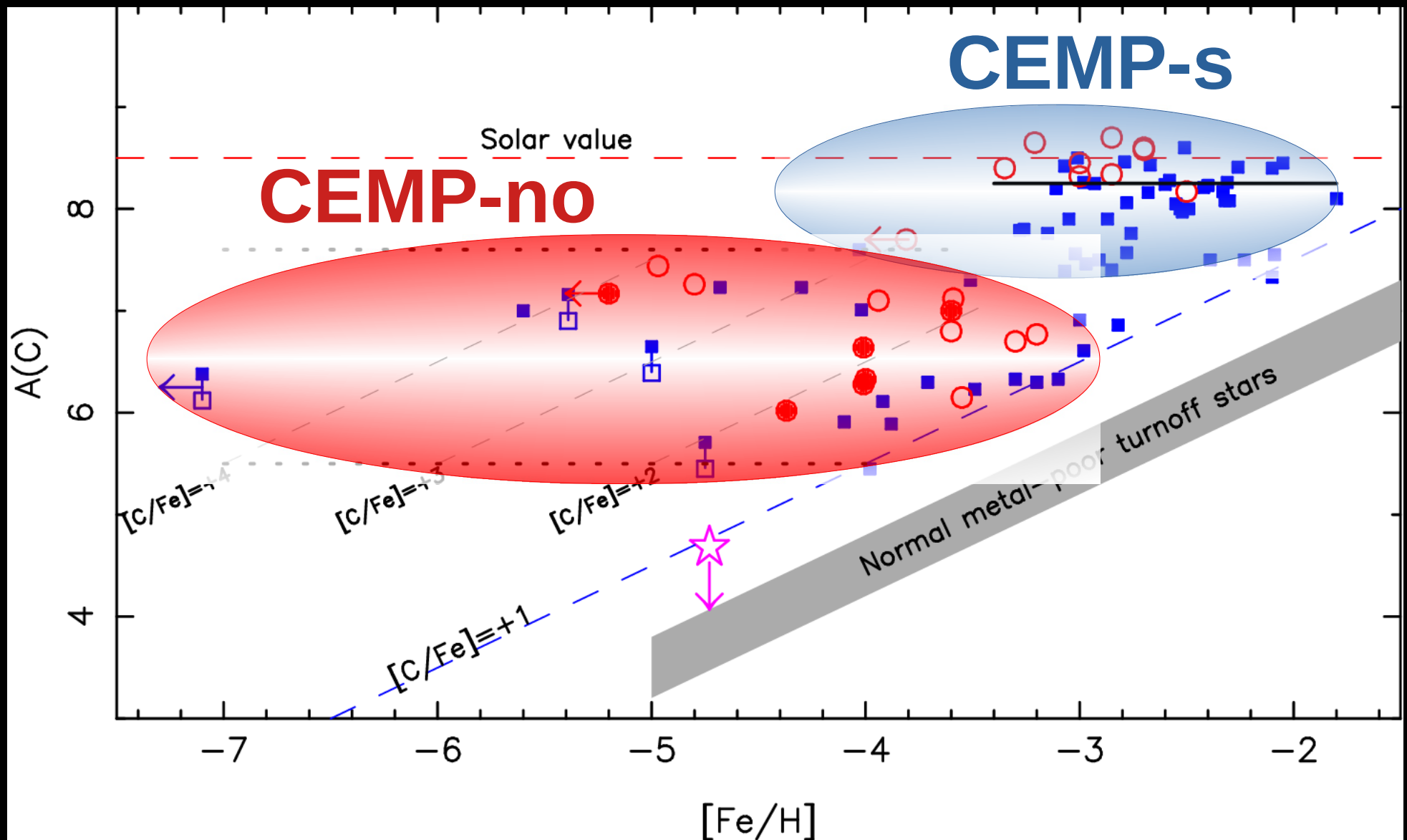
Bonifacio et al. 2015

1-Introduction: The First Stars



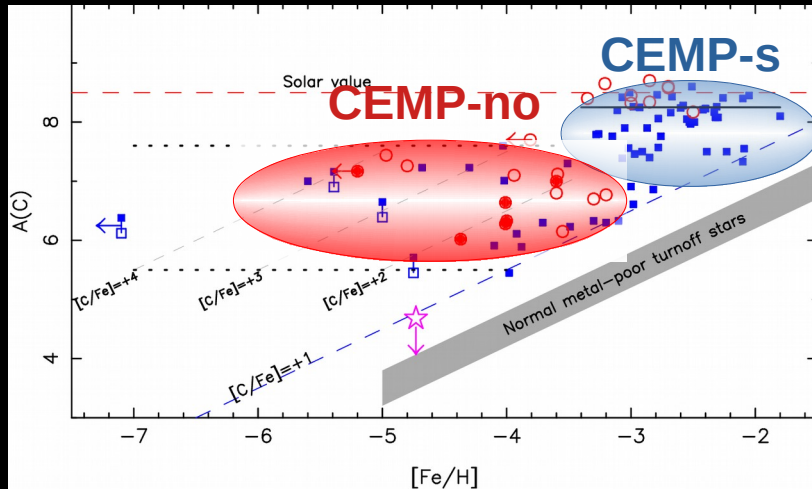
Bonifacio et al. 2015

1-Introduction: The First Stars

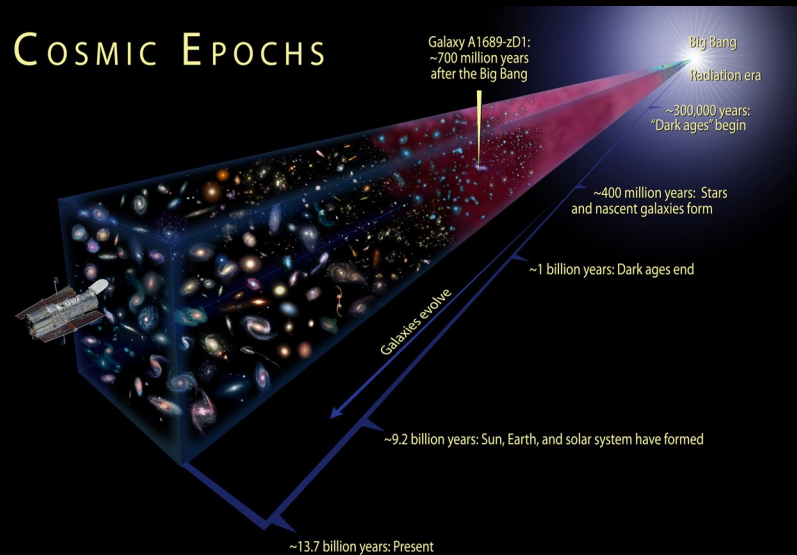


Bonifacio et al. 2015

1-Introduction: The First Stars



Bonifacio et al. 2015



NASA

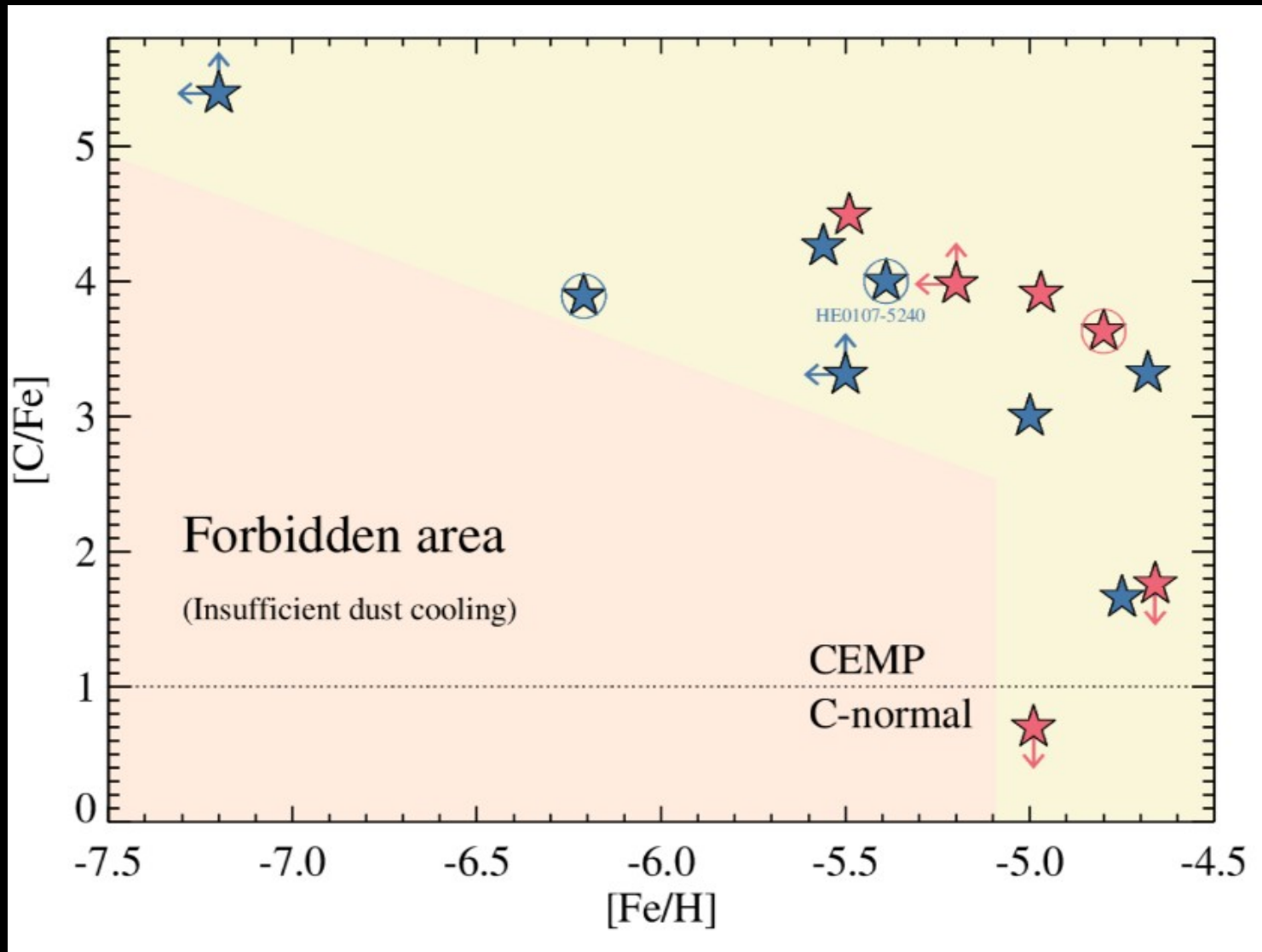
Are CEMP-no stars
pristine descendants
of the First Stars?



별 CEMP-no 는 첫 번째
별의 순수한 후손인가
요 ?

2-CEMP-no stars

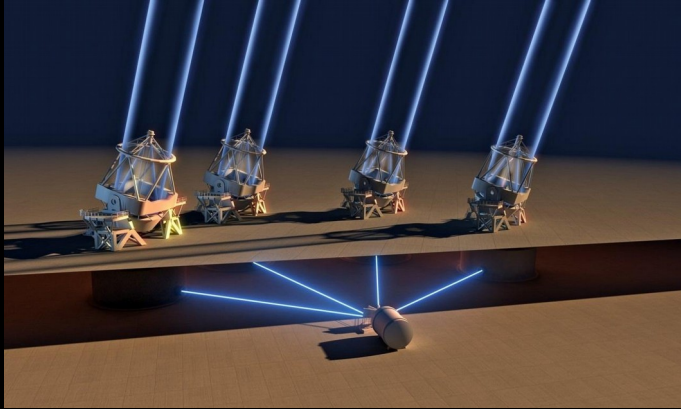
Follow-up with ESPRESSO



DA, Molaro, et al. 2022

2-CEMP-no stars

Follow-up with ESPRESSO



lower Efficiency

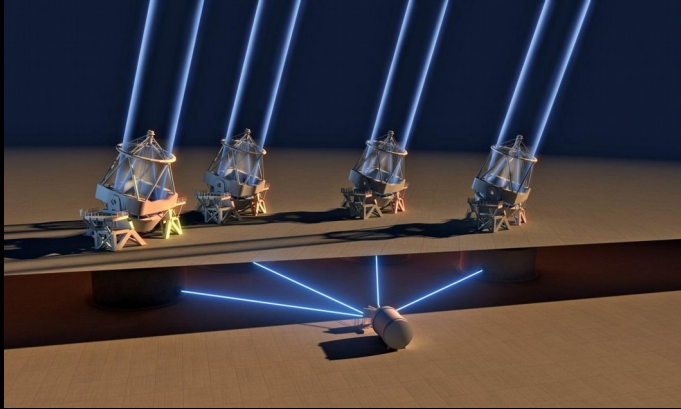
$R \sim 140,000$

λ coverage 3800-7000Å

$RV \sim 10 \text{ cm/s}$

2-CEMP-no stars

Follow-up with ESPRESSO

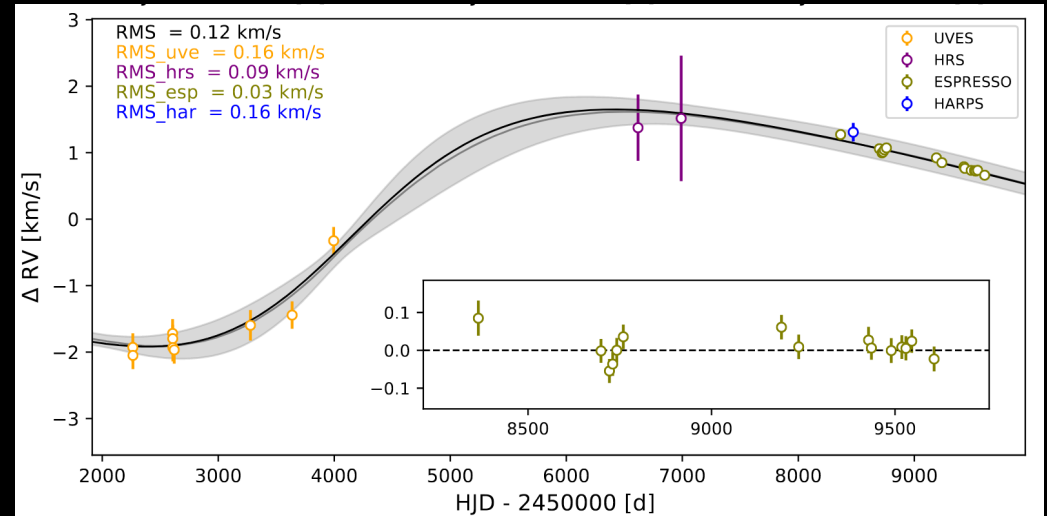


lower Efficiency

$R \sim 140,000$

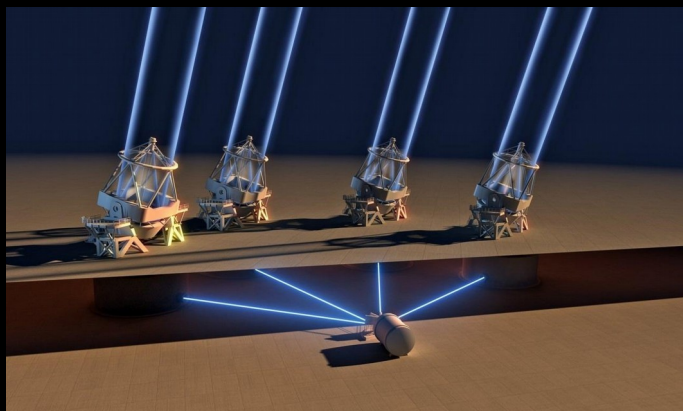
λ coverage 3800-7000Å

$RV \sim 10 \text{ cm/s}$



HE0107-5240 **DA+2022**
[Fe/H]=-5.4 [C/Fe]=+4.0

2-CEMP-no stars Follow-up with ESPRESSO



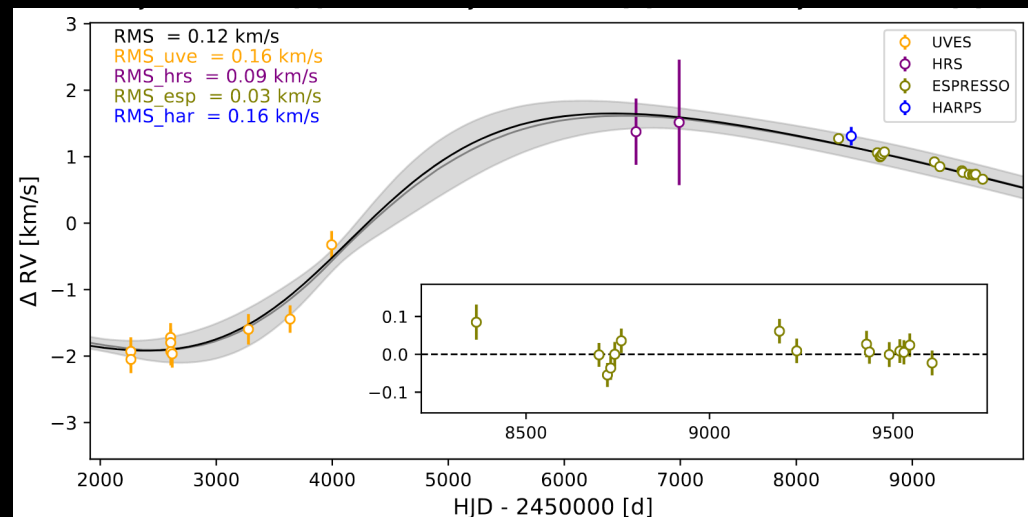
lower Efficiency

$R \sim 140,000$

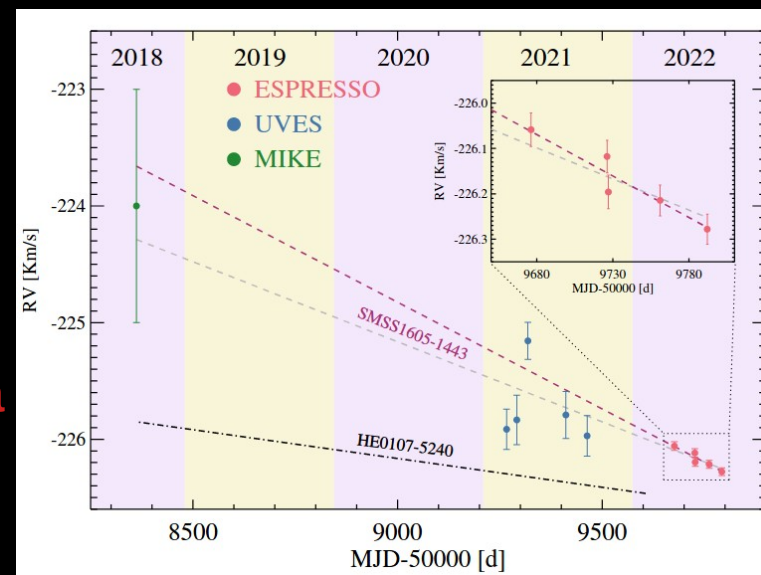
λ coverage 3800-7000Å

$RV \sim 10$ cm/s

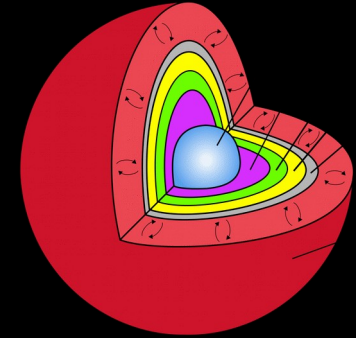
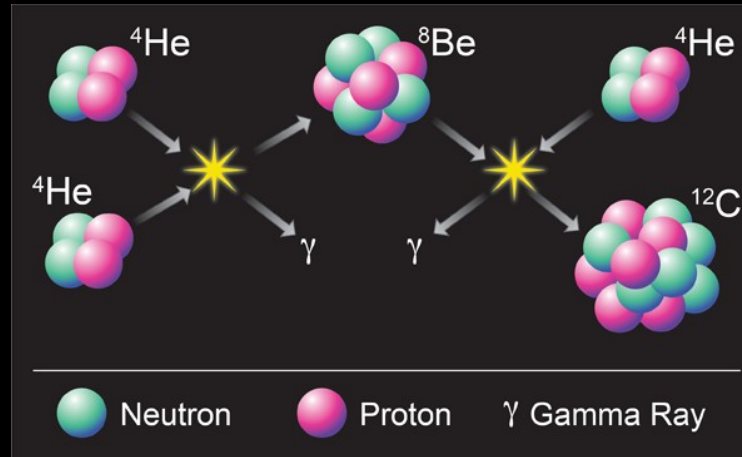
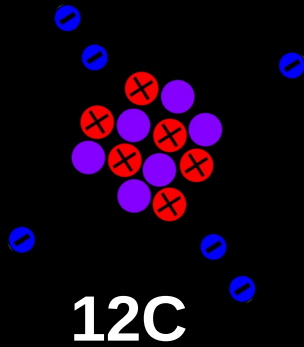
SMSS1605-1443 **DA+2023a**
 $[Fe/H] = -6.2$ $[C/Fe] = +3.9$



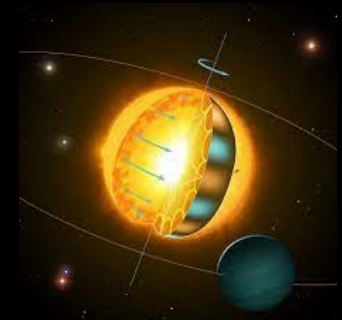
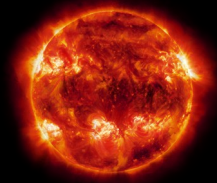
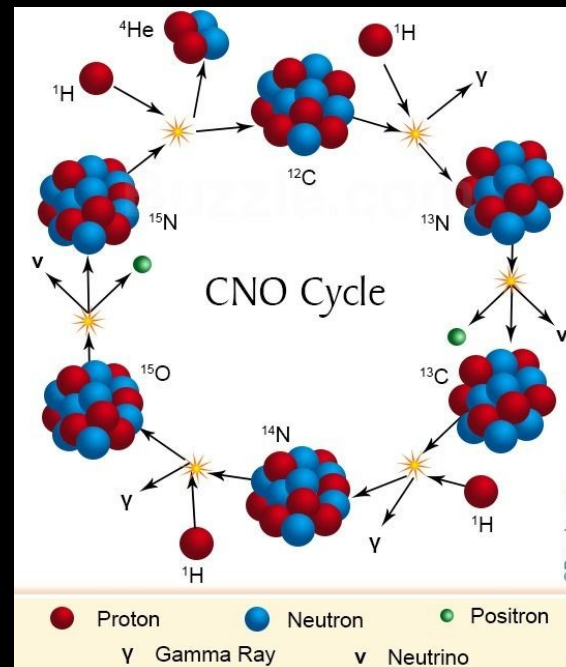
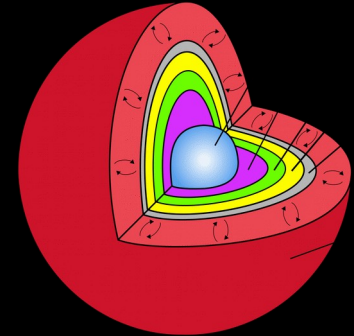
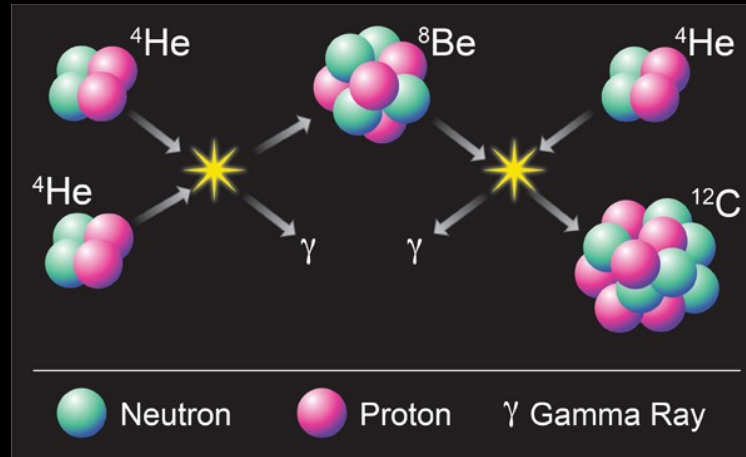
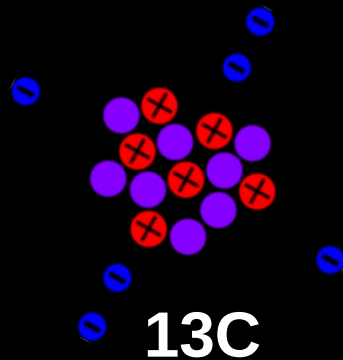
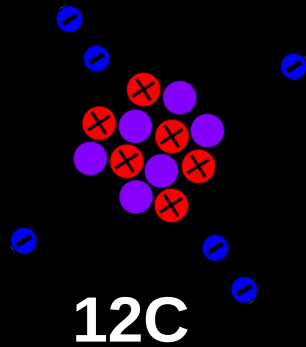
HE0107-5240 **DA+2022**
 $[Fe/H] = -5.4$ $[C/Fe] = +4.0$



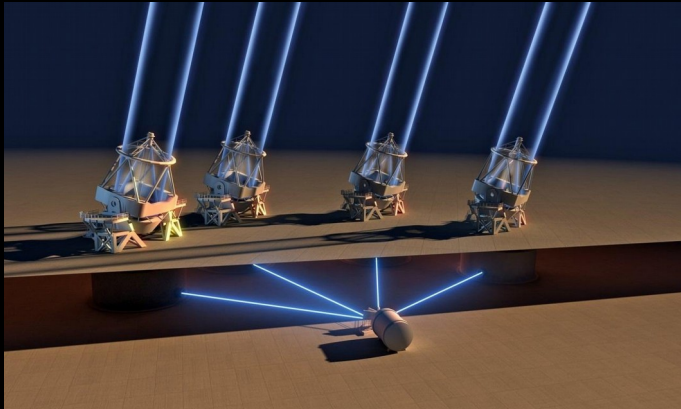
3- The carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$



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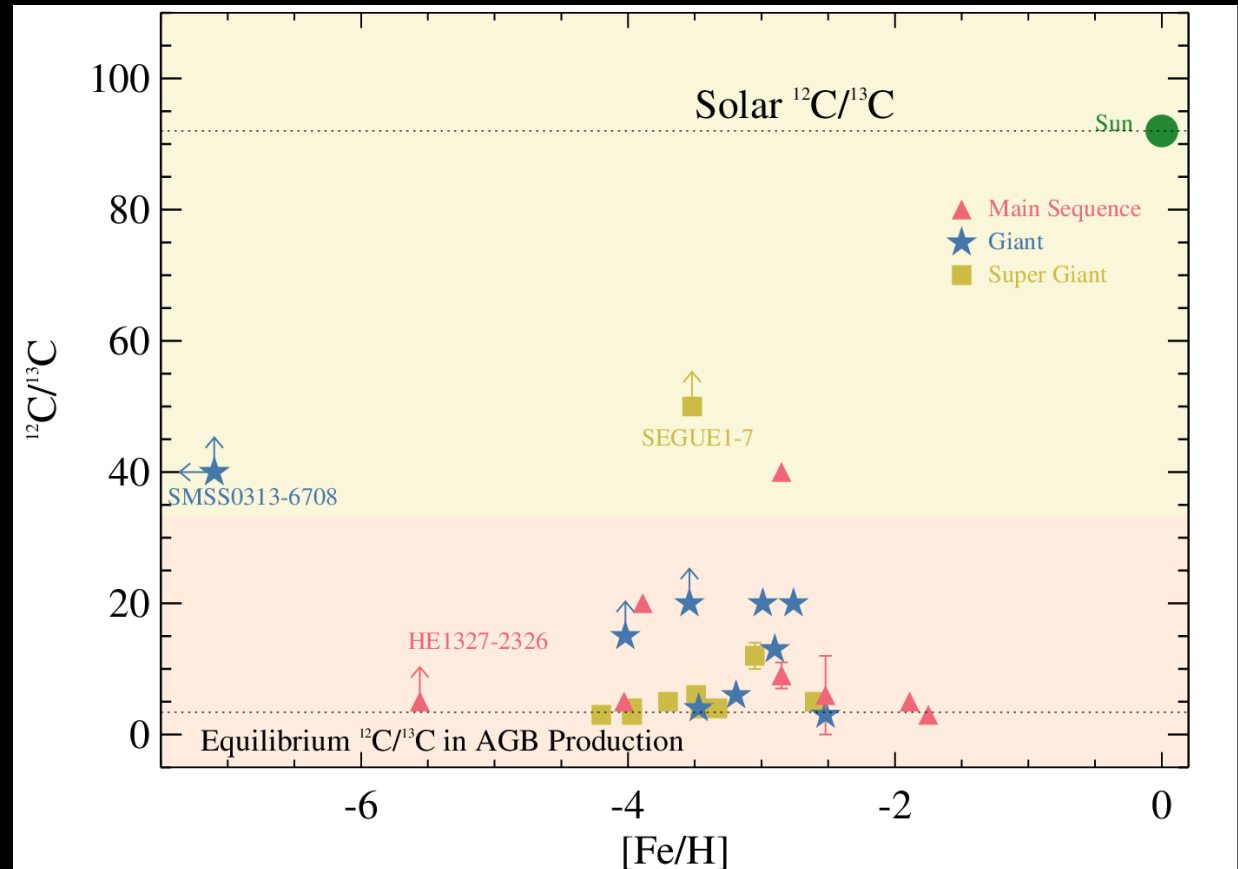


lower Efficiency

$R \sim 140,000$

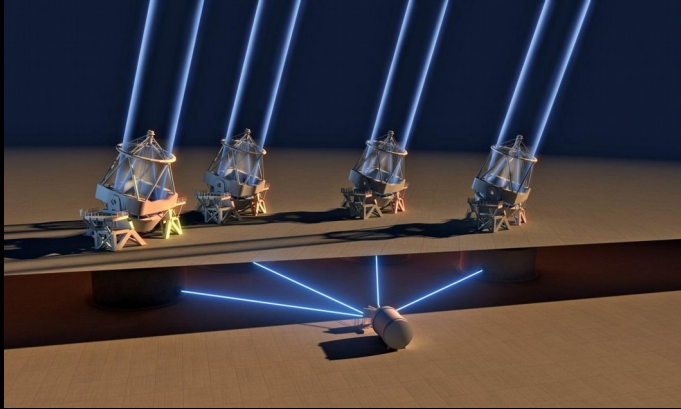
λ coverage 3800-7000Å

$RV \sim 10 \text{ cm/s}$



DA+ 2023a

3- The carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$

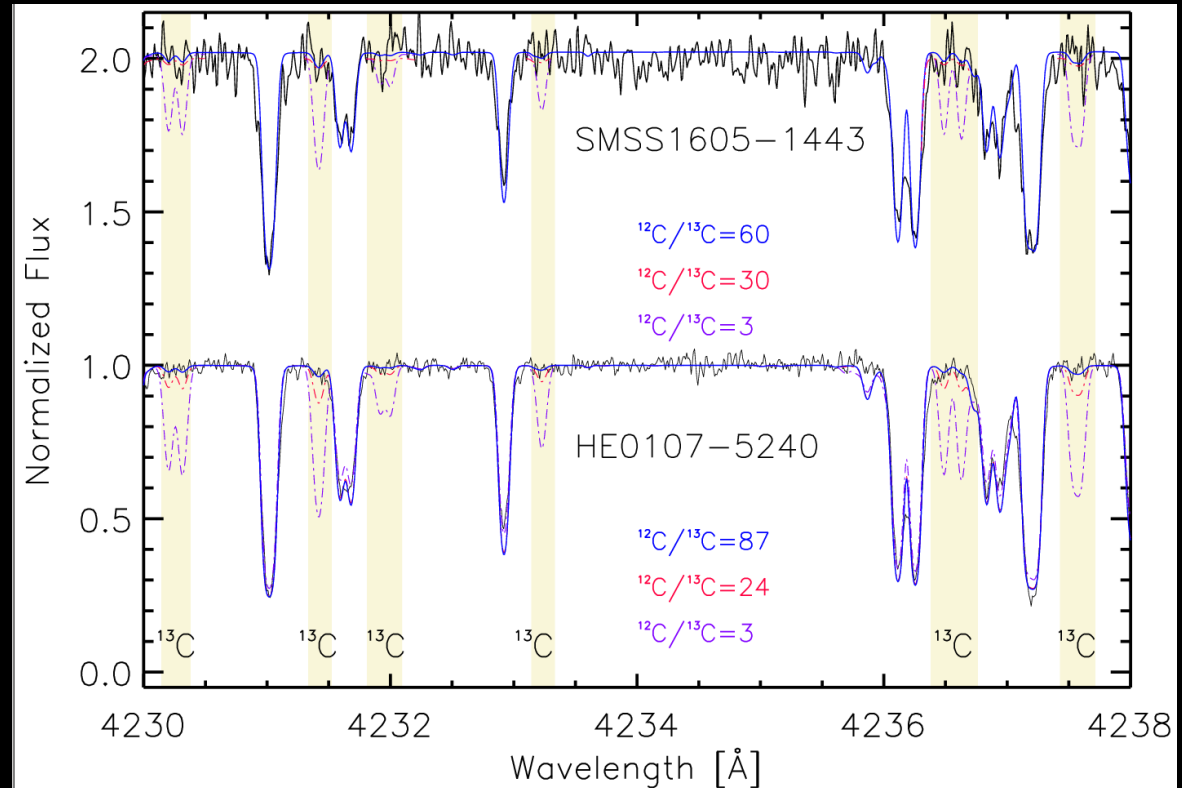


lower Efficiency

$R \sim 140,000$

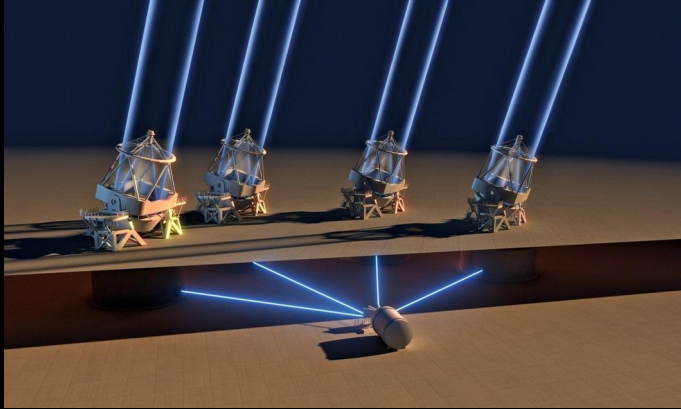
λ coverage 3800-7000Å

$RV \sim 10 \text{ cm/s}$



DA+ 2023a

3- The carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$

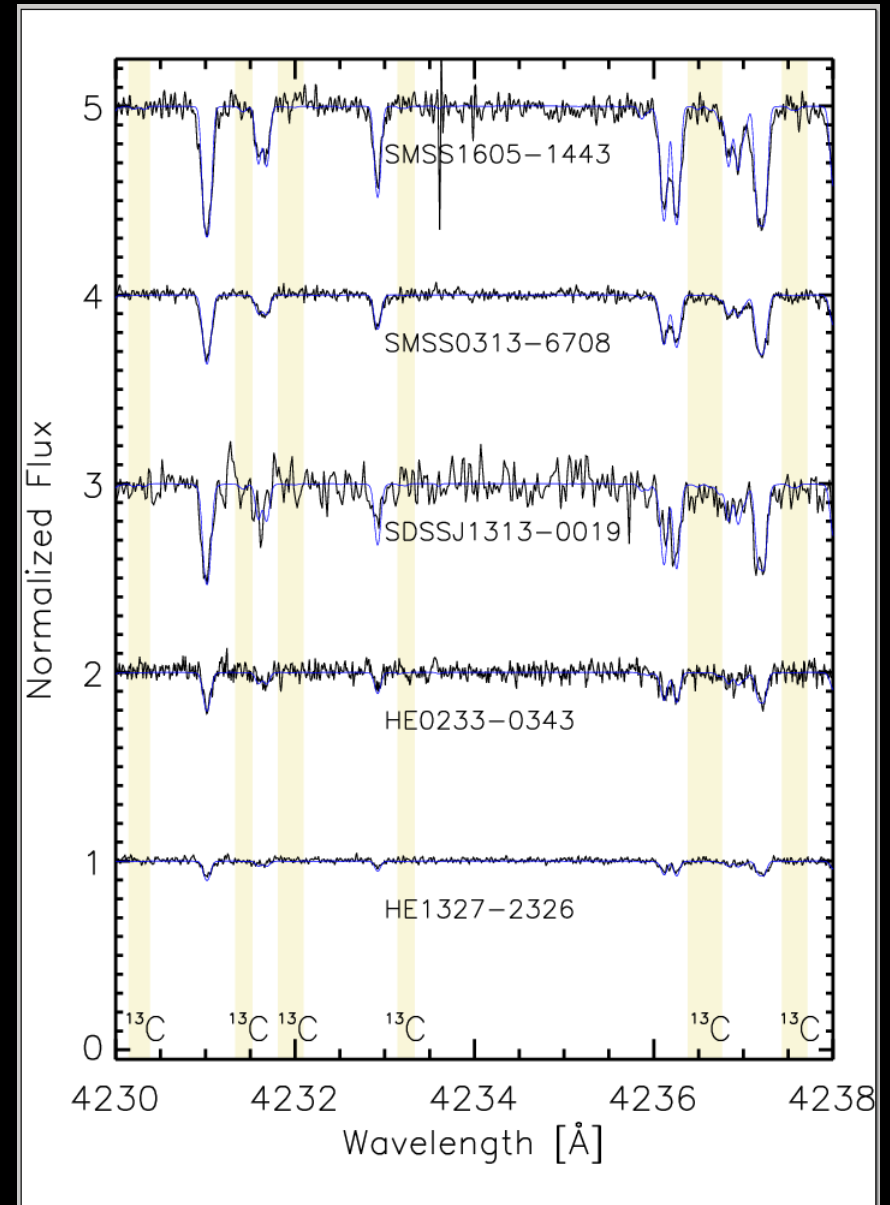


lower Efficiency

$R \sim 140,000$

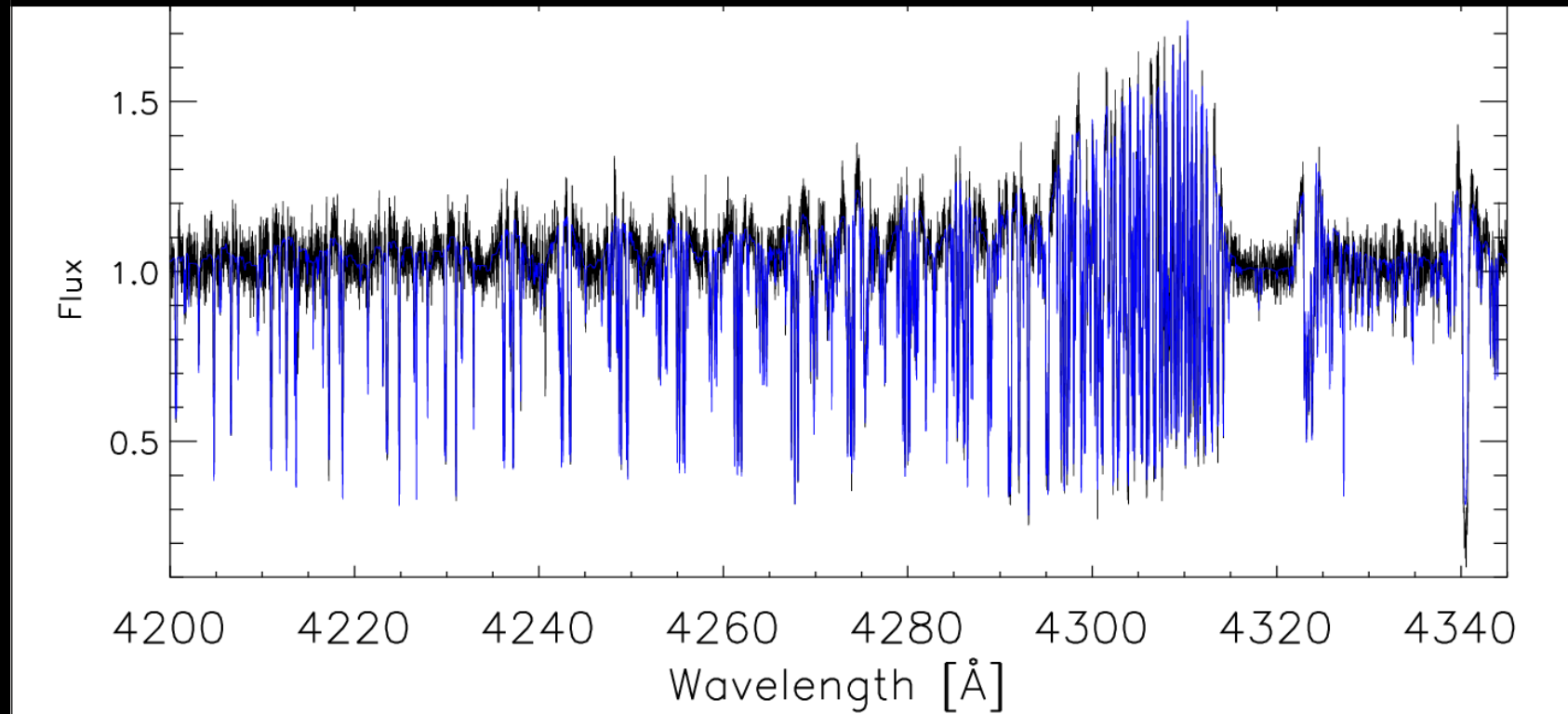
λ coverage 3800-7000Å

$RV \sim 10 \text{ cm/s}$



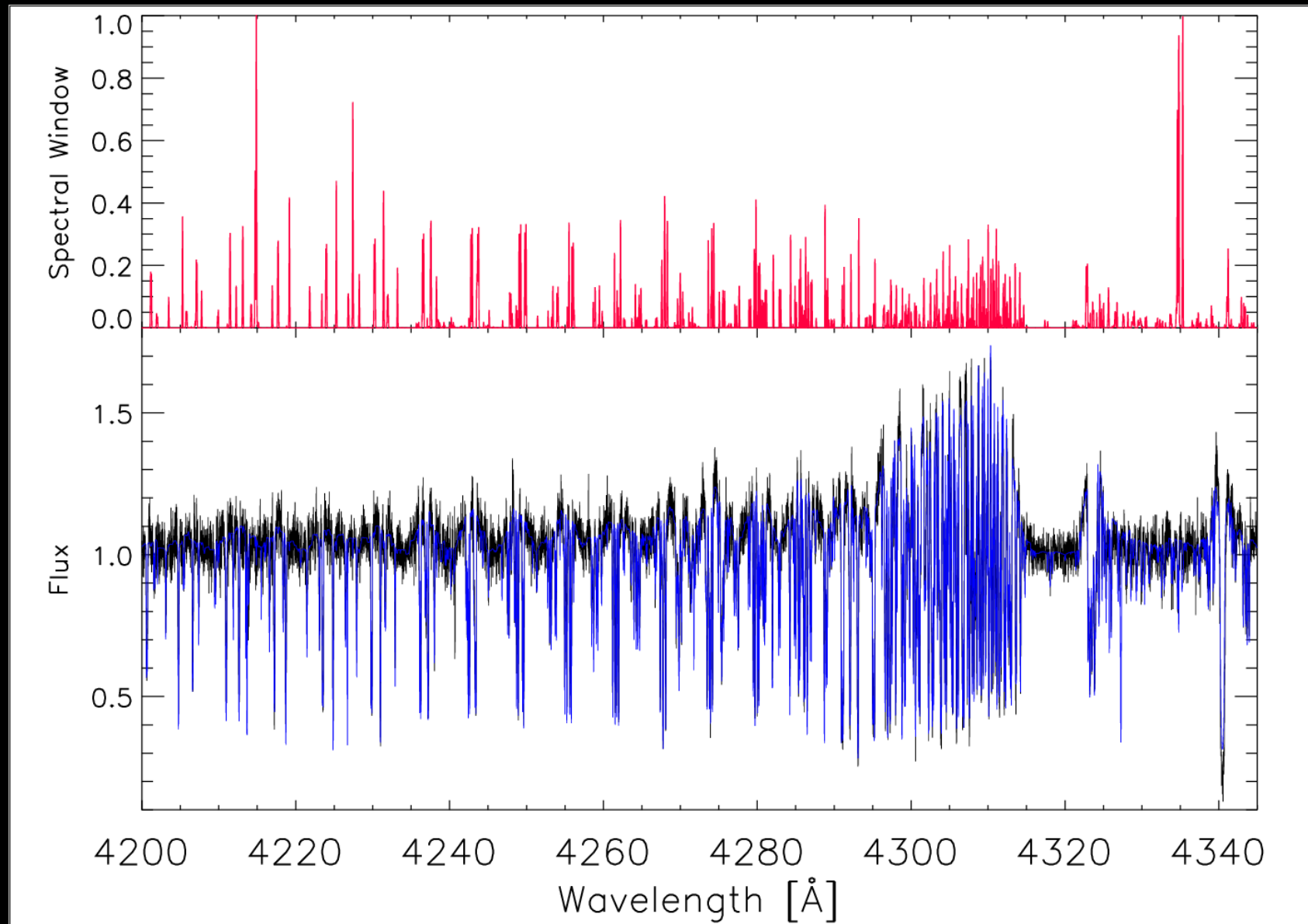
Molaro et al. (submitted)

3- The carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$



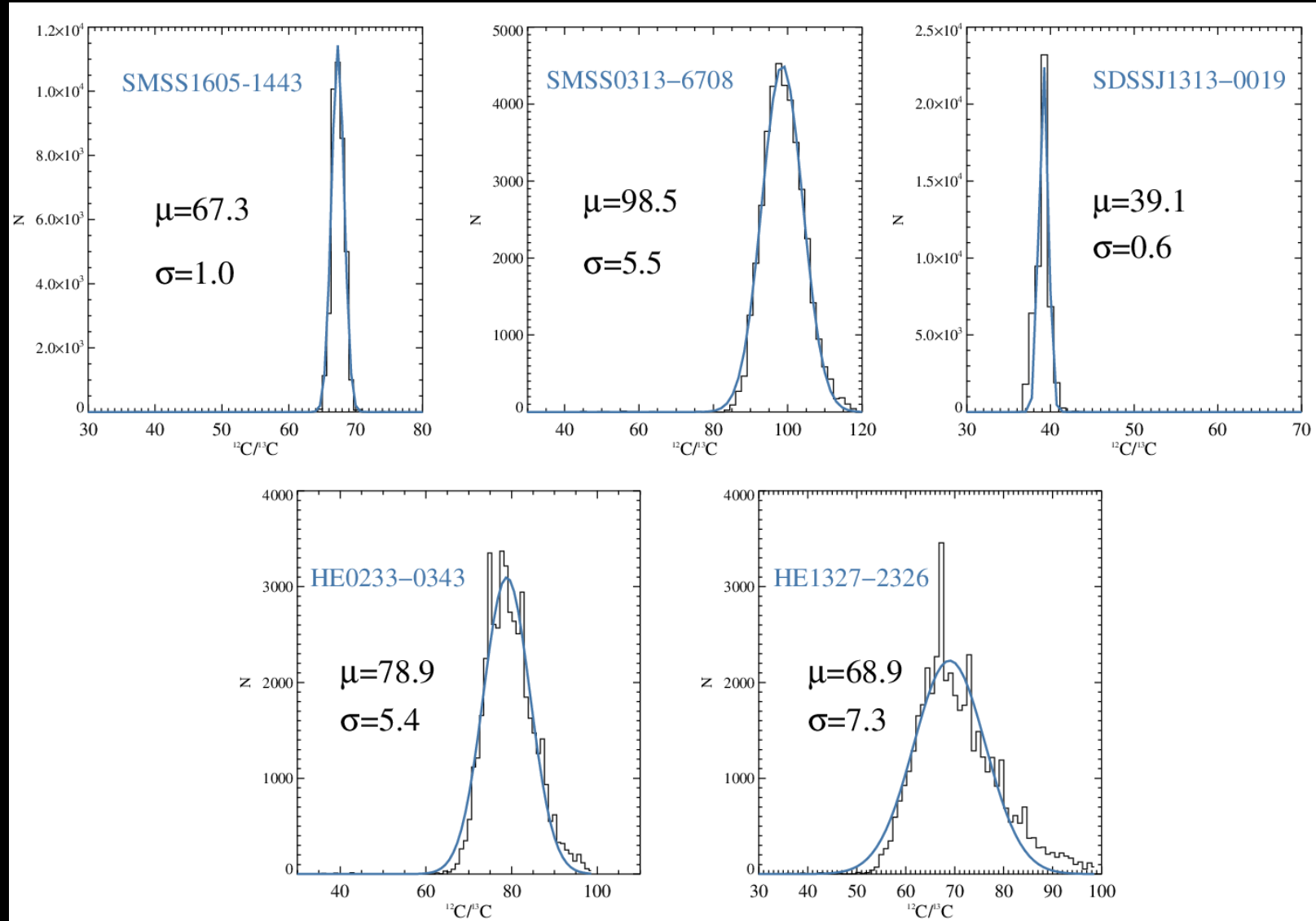
DA+ 2023a

3- The carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$



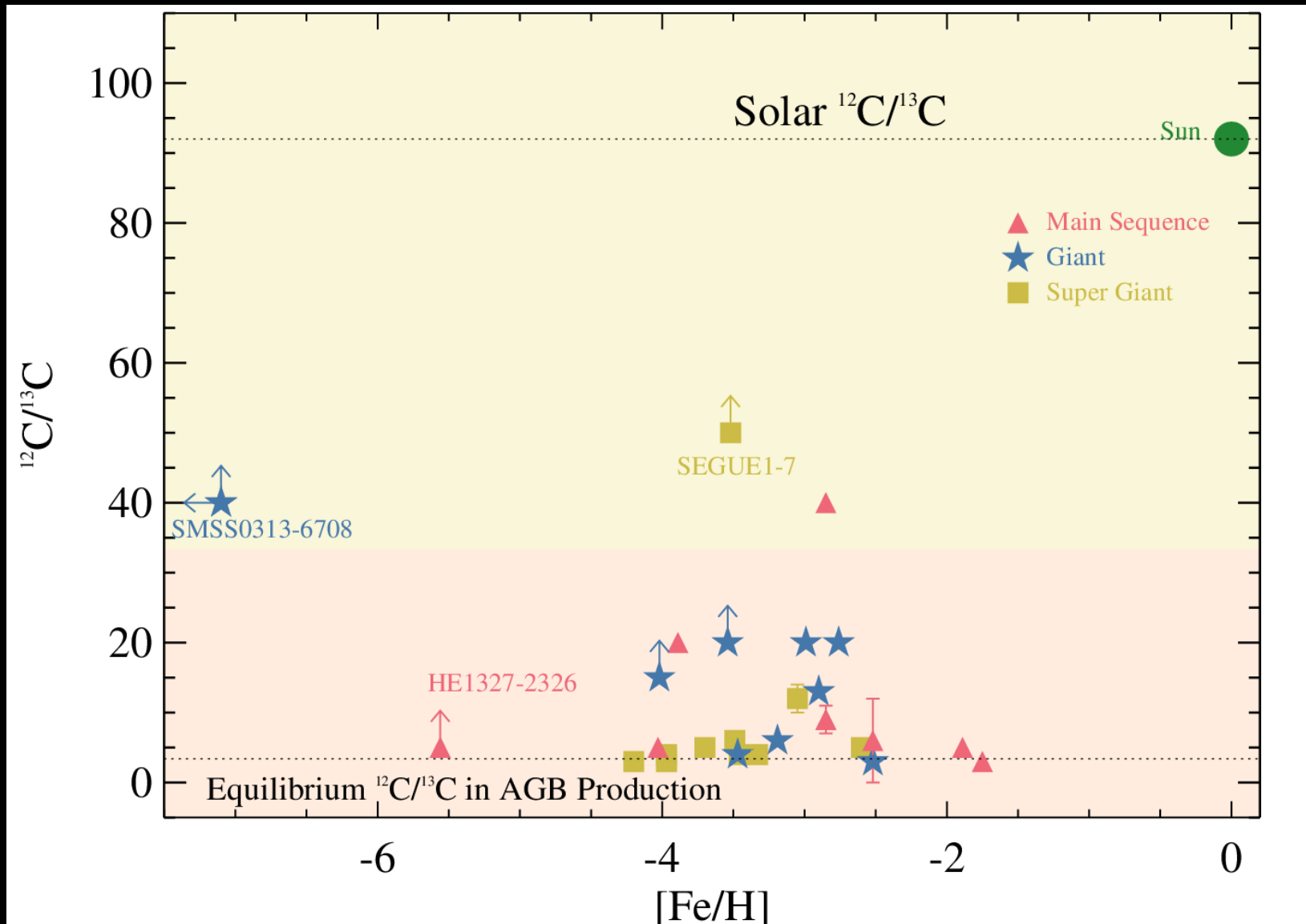
DA+ 2023a

3- The carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$



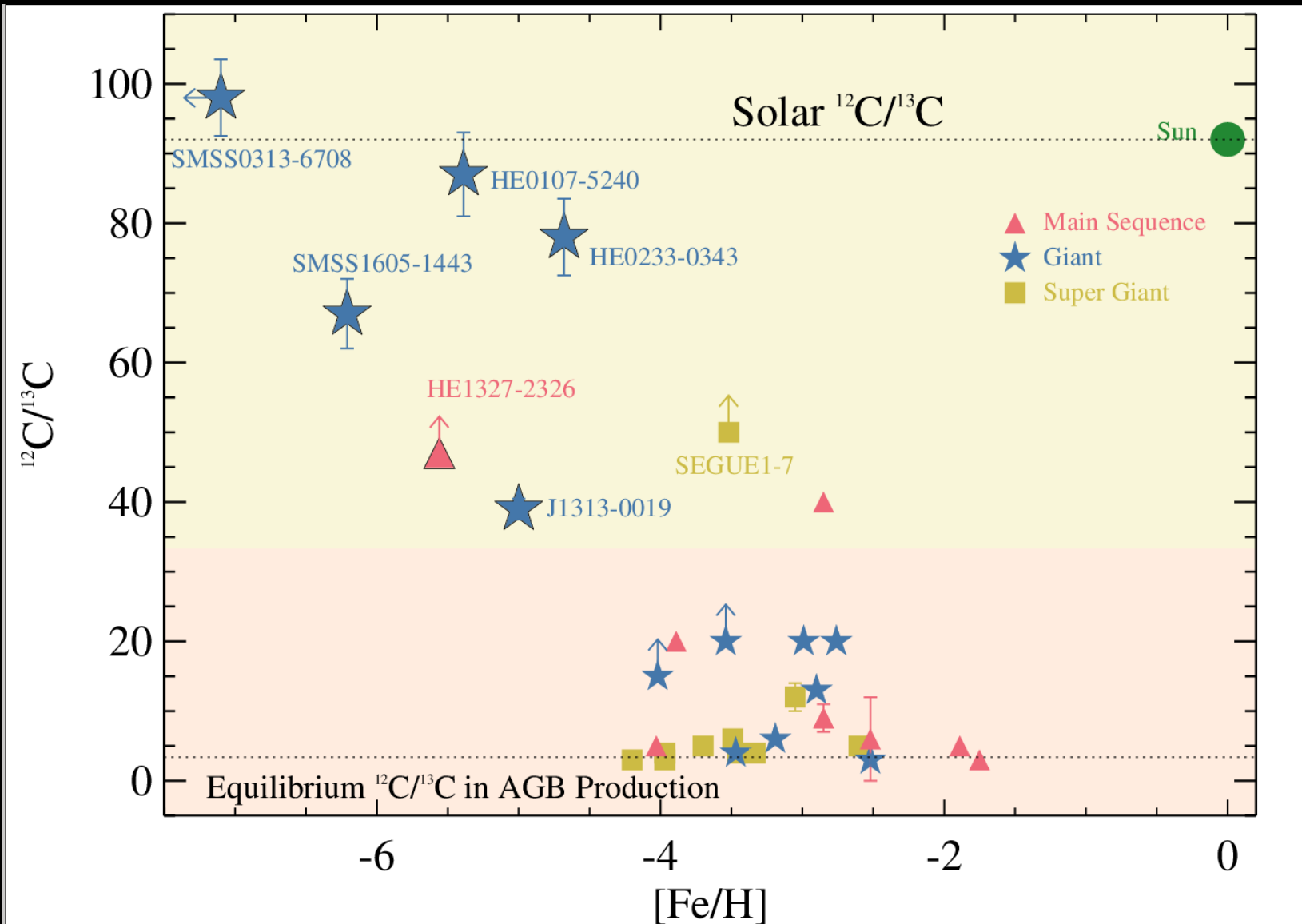
Molaro et al. (submitted)

4- Results: a new picture on $^{12}\text{C}/^{13}\text{C}$



Molaro et al. (submitted)

4- Results: a new picture on $^{12}\text{C}/^{13}\text{C}$



Molaro et al. (submitted)

5- Summary

We probed the early universe through CEMP-no stars to comprehend chemical evolution.

We employ the unique ESPRESSO instrument for binarity testing and carbon-13 measurements.

We have shown that CEMP-no stars, regardless of their binary nature, exhibit high $^{12}\text{C}/^{13}\text{C}$ ratios when they possess lower metallicity.

We conclude that these stars manifest the original composition of the molecular clouds from which they originated.

Thank You!

감사합니다 !

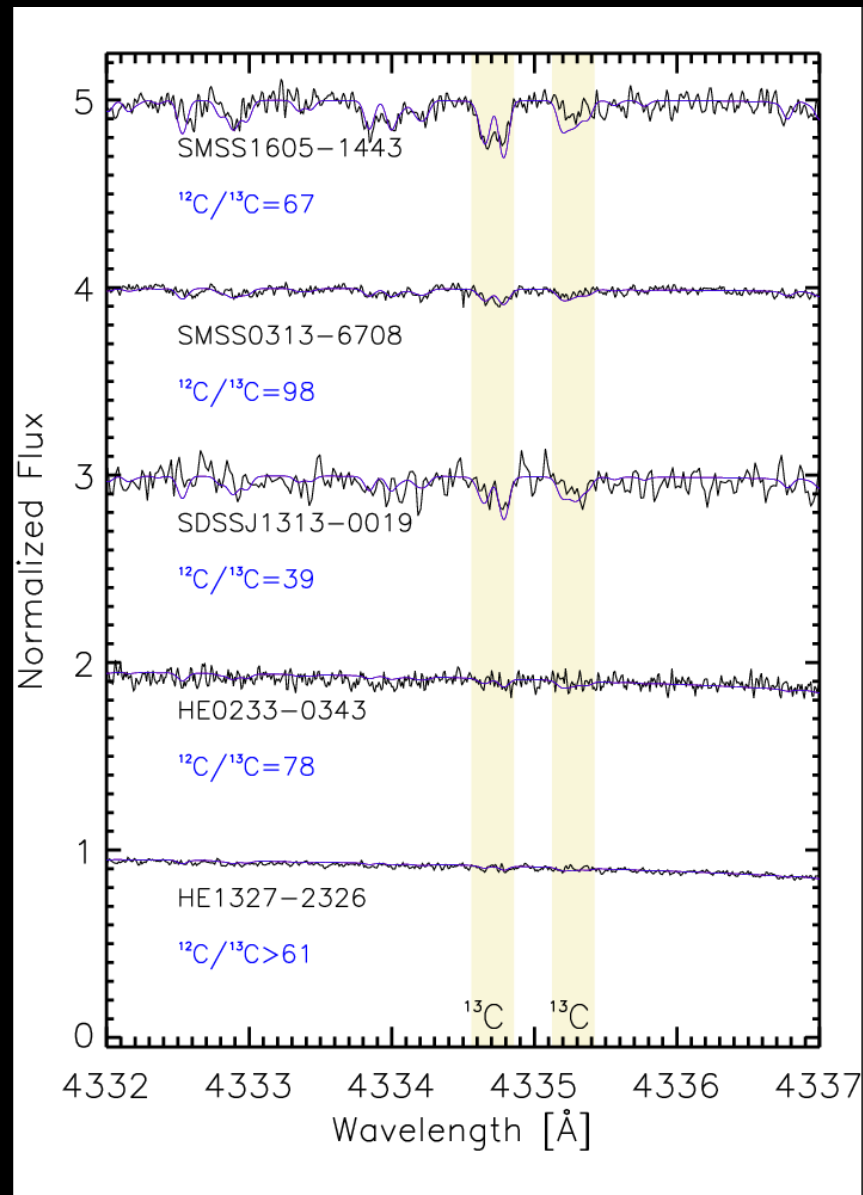
DA acknowledges financial support from the Spanish Ministry of Science and Innovation (MICINN) under the 2021 Ramón y Cajal program MICINN RYC2021-032609.



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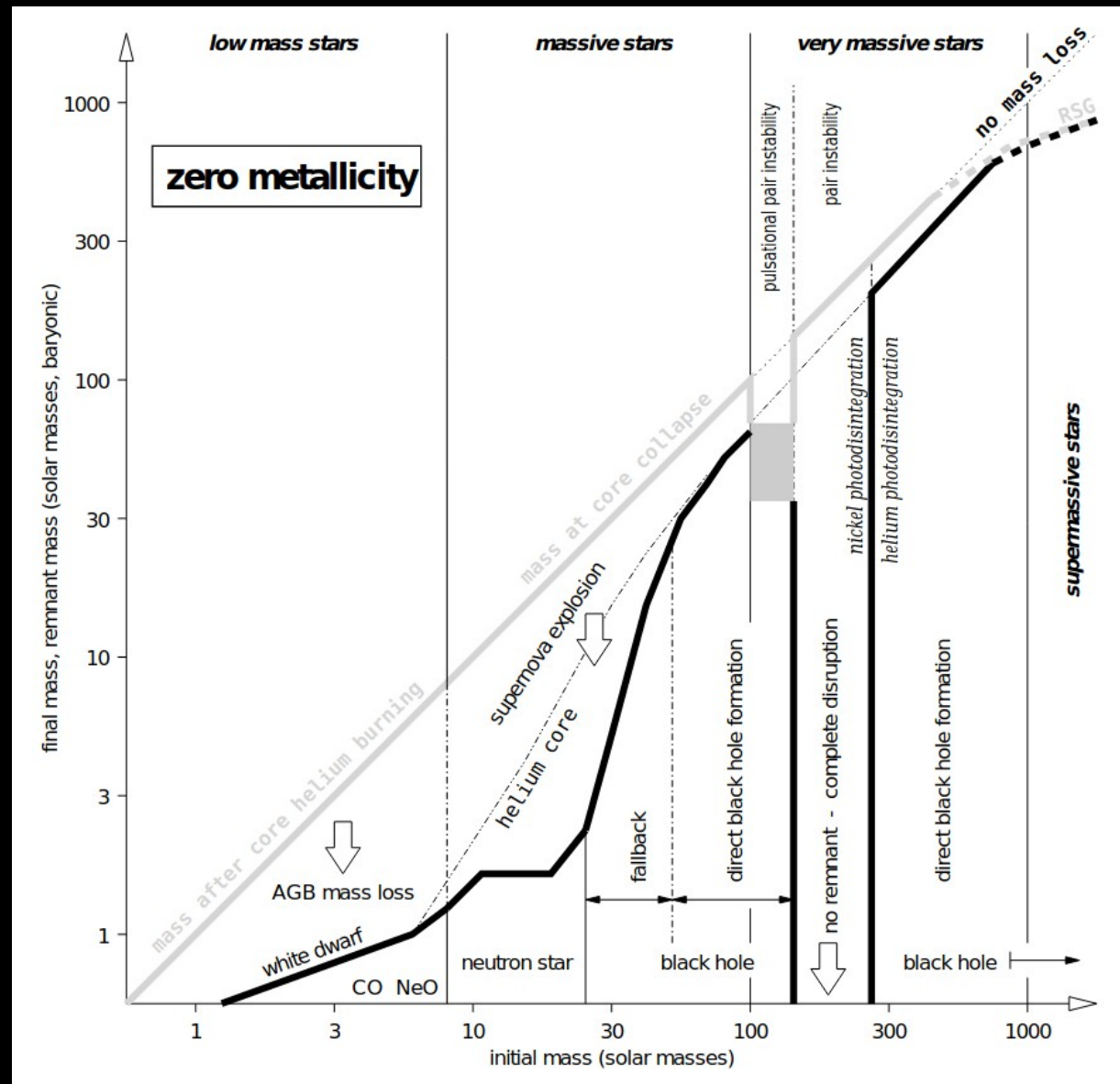


Extra material



Molaro et al. (submitted)

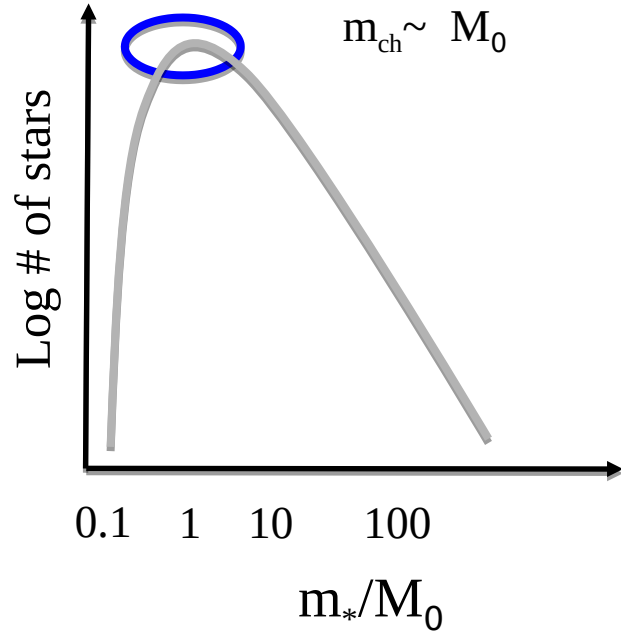
The First Stars



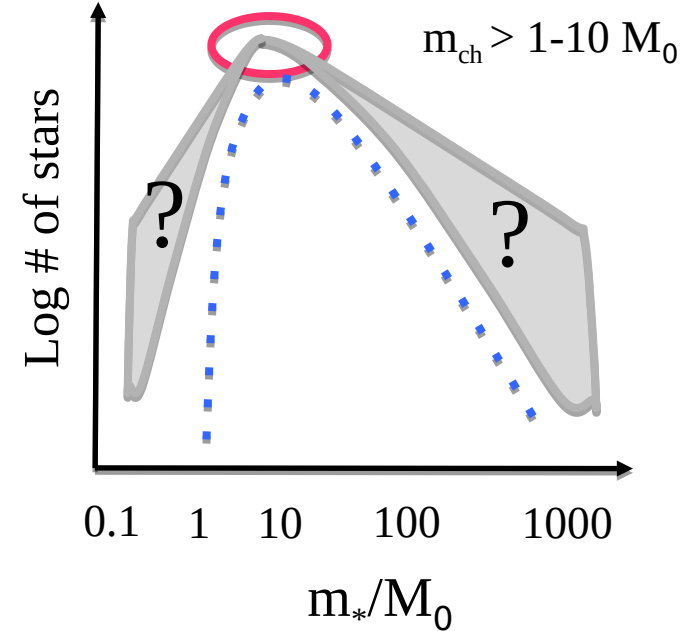
Heger & Woosley 2002

The First Stars

PRESENT-DAY STARS (PopII/I)

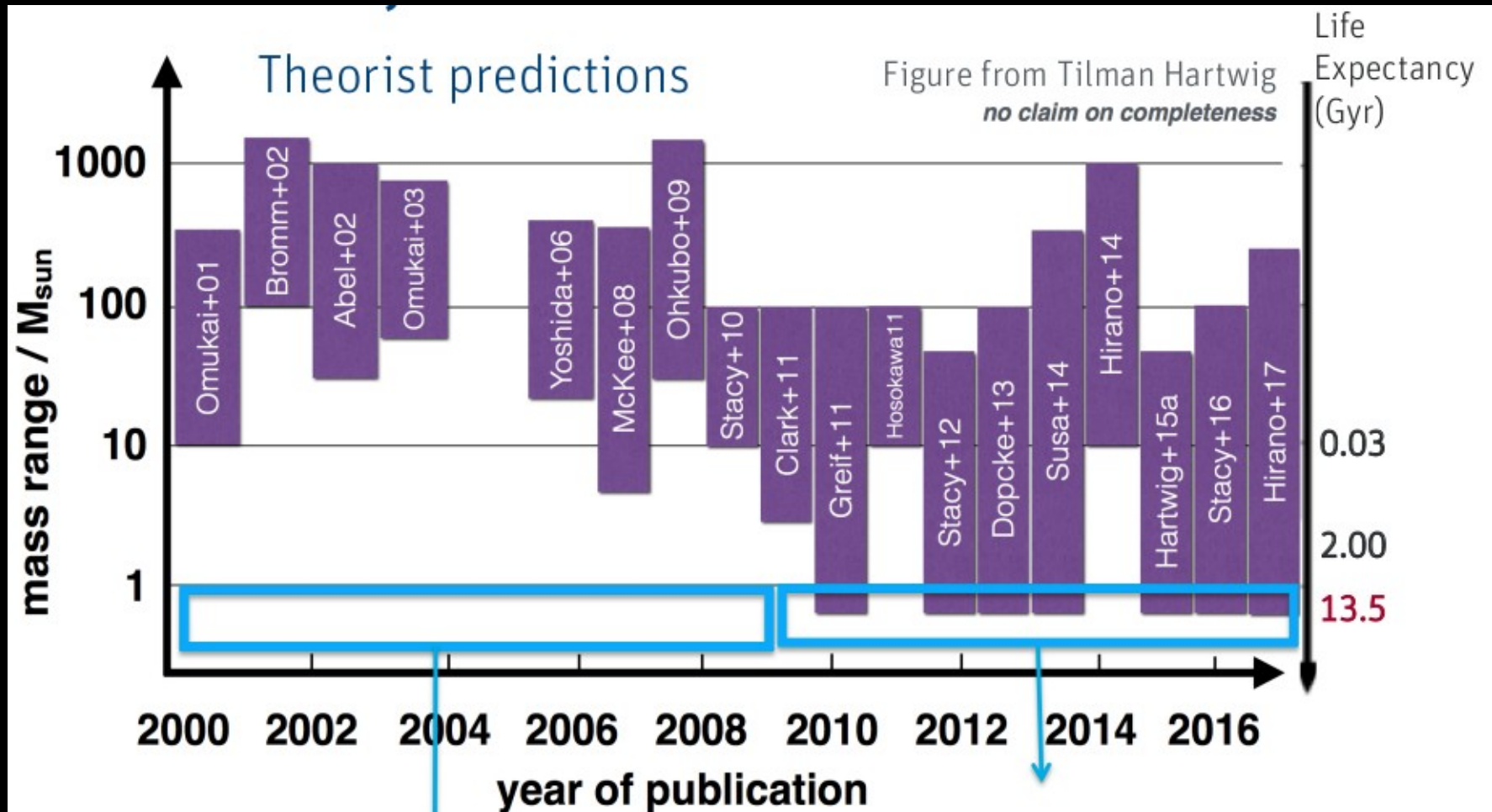


FIRST STARS (PopIII)



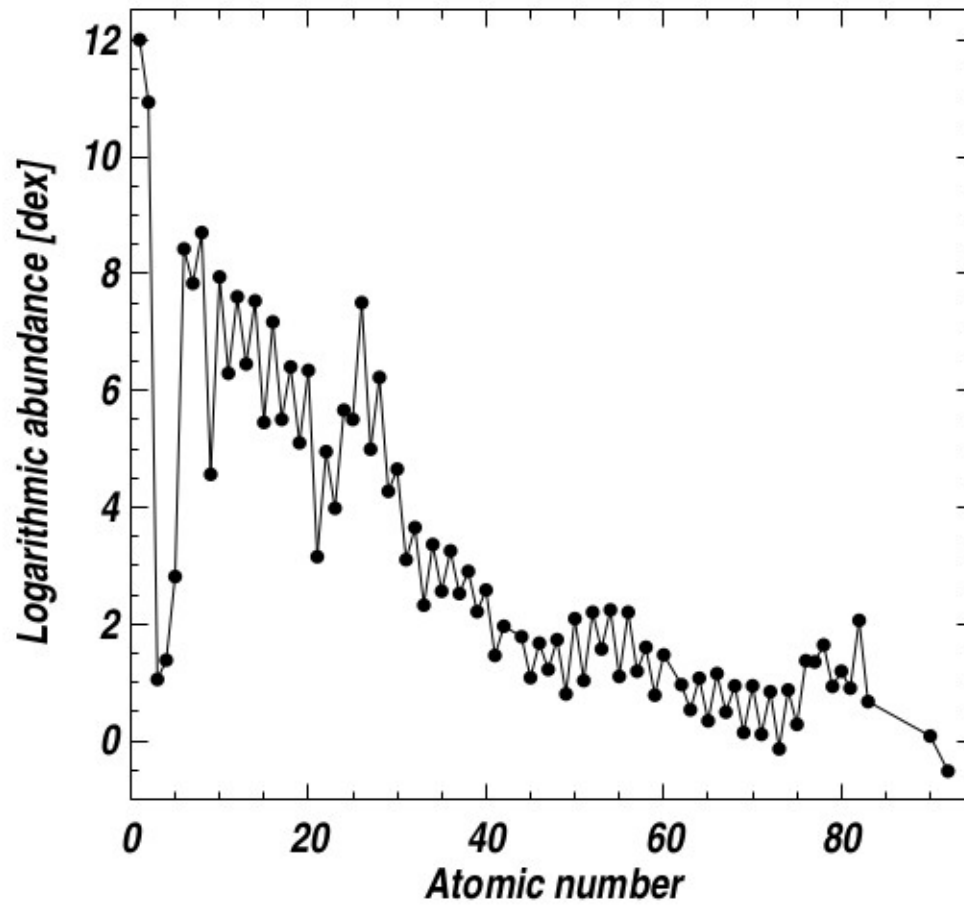
from S. Salvadori

The Early Universe



Hartwig, Starkenburg

The solar composition



Asplund+ 2009