EVIDENCE FOR MULTIPLE PROGENITORS OF CEMP-NO STARS

Jinmi Yoon

Postdoctoral Research Associate
Department of Physics and JINA-CEE
University of Notre Dame, IN, USA

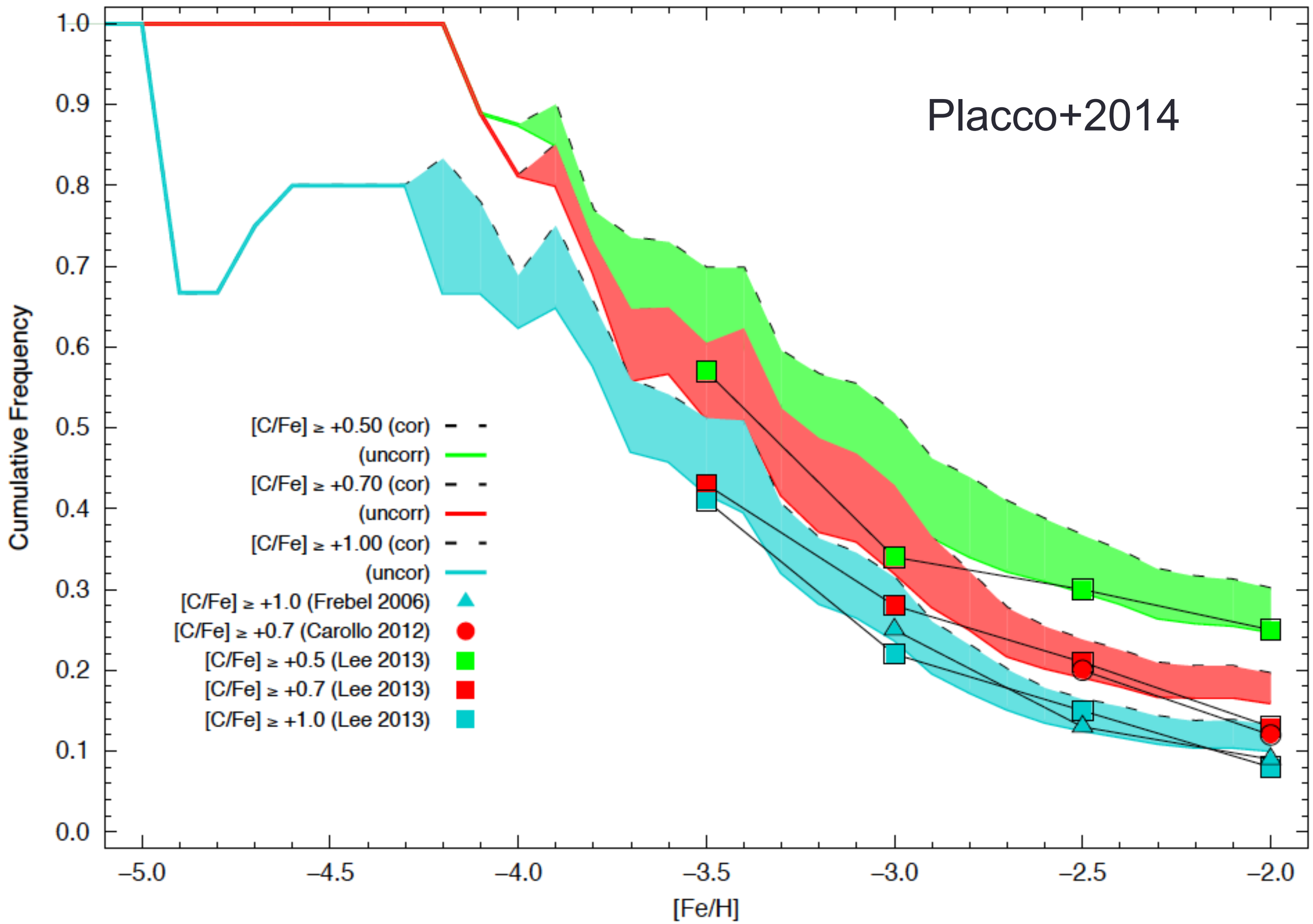
09/21/2016
Precision Spectroscopy Workshop, Porto Alegre, Brazil

ND Galactic Archeology group

Overview of the talk

- Carbon-Enhanced Metal-Poor (CEMP) stars
  - A Critical probe to study the chemical environment for the early universe (near-field cosmology)
- Recent results about CEMP stars
  - First star Nucleosynthesis:
    - Based on A(C) and Light elements signatures
  - Binary statistics
  - Application of bi-modal A(C) distribution

Carbon Enhanced Metal-Poor stars



CEMP sub-classes

- CEMP ([C/Fe] >=+0.7)

- CEMP-r (rI: +0.3<[Eu/Fe]<+1.0, rII: [Eu/Fe]>1.0)
  - Enhancement in rapid n-process (r-process) elements (Eu)
  - Supernova, neutron star mergers, magnetars

- CEMP-s ([Ba/Fe]>+1.0, [Ba/Eu]>+0.5)
  - Enhancement in slow n-process (s-process) elements (Ba)
  - Binary mass transfer from low mass AGB stars (eg., Bisterzo+)

- CEMP-r/s → CEMP-i (0.0<[Ba/Eu]<+0.5)
  - Intermediate process (i-process, Hempel+2016)
  - Intermediate mass or massive AGB stars (+mass transfer)

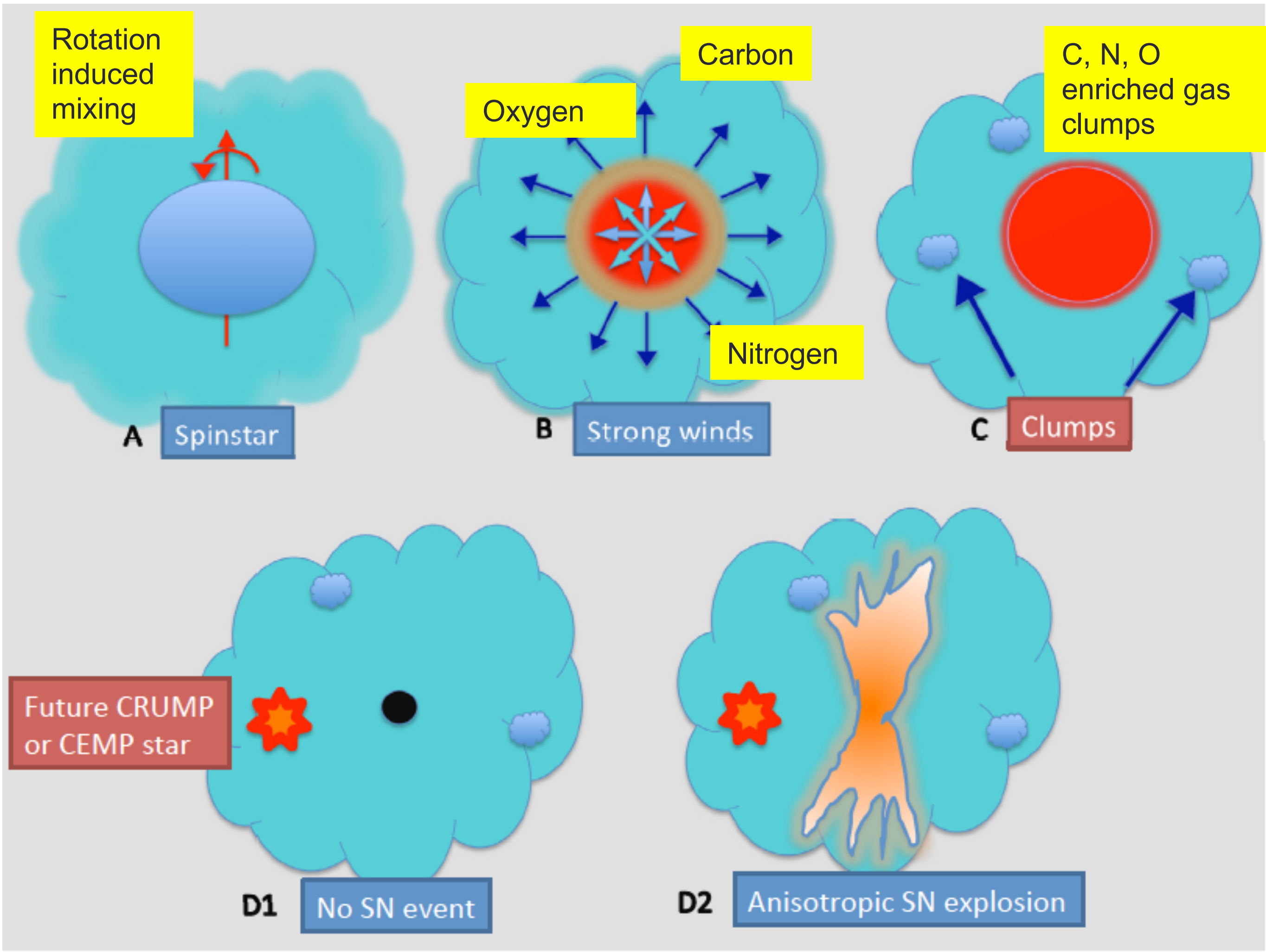
- CEMP-no ([Ba/Fe]<0.0)
  - No enhancement in n-capture elements
  - Born out of Metal free (or very low metallicity) massive stars remnants

CEMP-no stars :2nd generation stars

- CEMP-no stars
  - Lowest metallicity ([Fe/H]<-2.5)
  - Intrinsically enhanced C abundance
    - [Sr/Ba]>0.0
    - Normal binary fraction ~20%
  - C, N, O enhancement with low n-capture elements abundances
  - Lower A(Li) than Spite Li plateau ← dilution due to the ISM.
  - Their space velocity is high and retrograde and thought to be the outer halo population.
  - They are thought to be born in first galaxies (ultra faint dwarf galaxies).
  - Damped Lyman alpha forest (C enhancement)

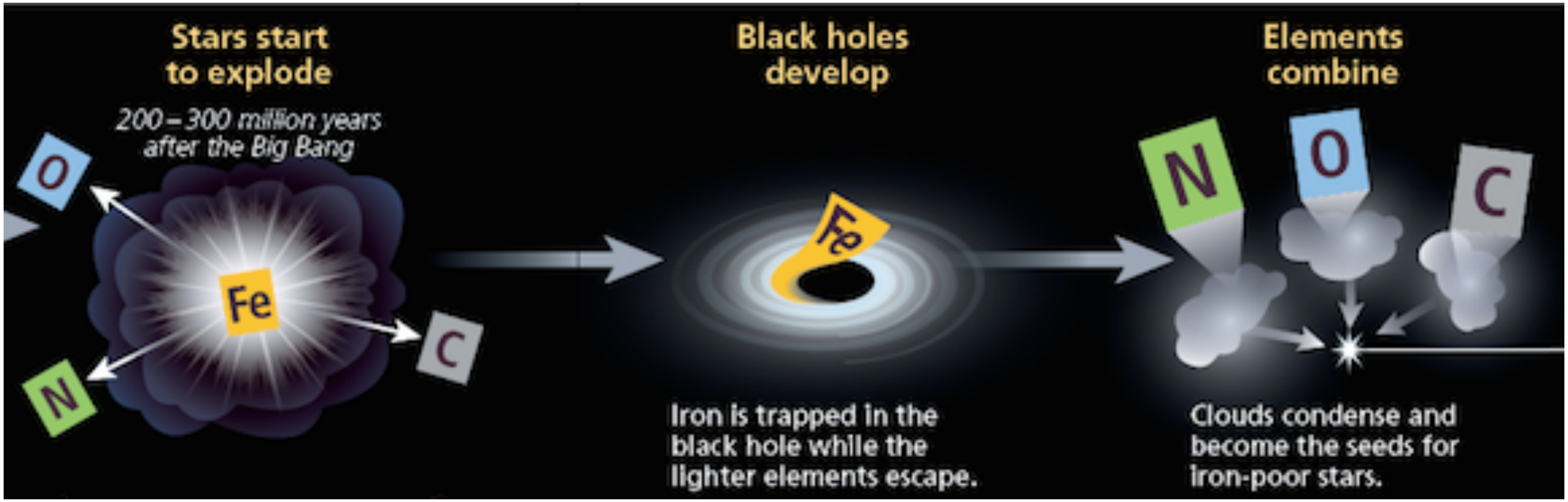
- Progenitor models
  - Massive rapidly rotating stars with a very low metallicity (Meynet+ 2006)
  - Mixing & Fallback Supernovae (Umeda+Nomoto 2003, Nomoto+2013)
  - Non-rotating metal free massive stars supernovae (Heger & Woosly 2010)

Spinstars (50-100M$_\odot$) -Rapidly rotating massive stars



Meynet+2010

Mixing & fallback faint supernova (10-50 $M_\odot$)



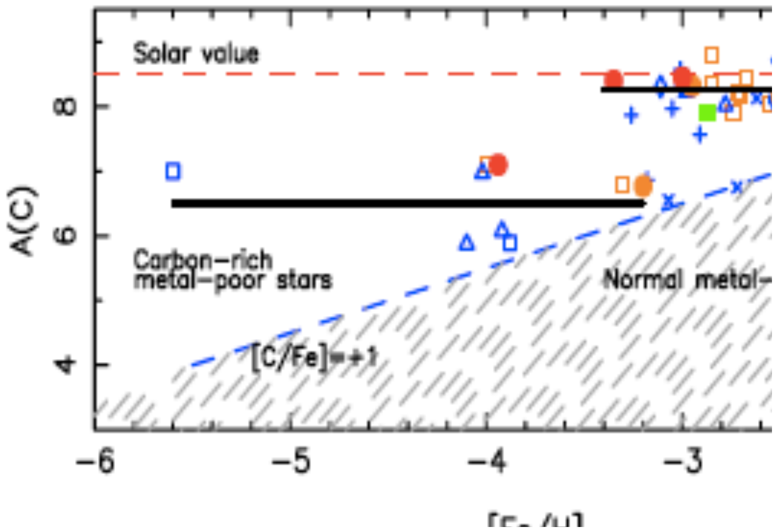
Discovery (2015)

A Recent Study of A(C) of CEMP stars

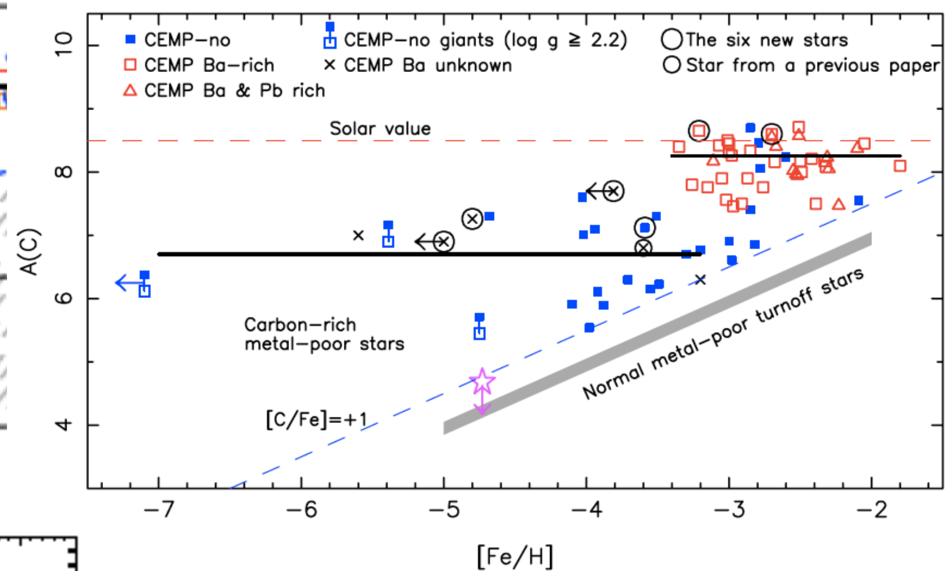
Yoon, Beers, Placco, et al, 2016, ApJ submitted
arXiv:1607.06336

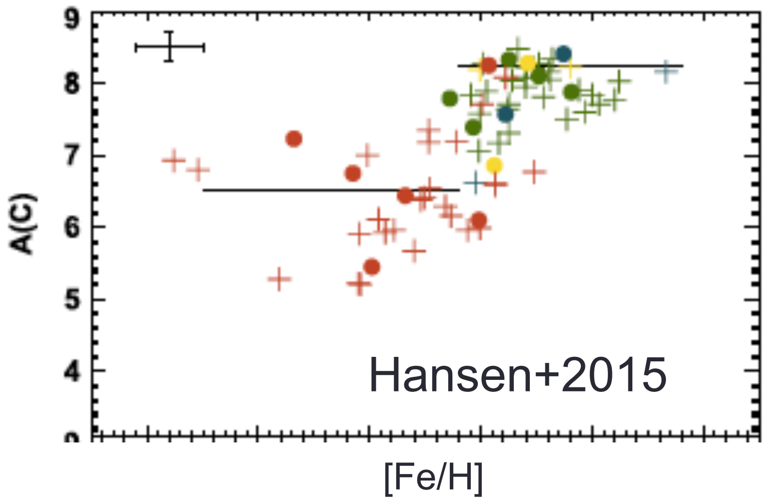
Bi-modal distribution of A(C)

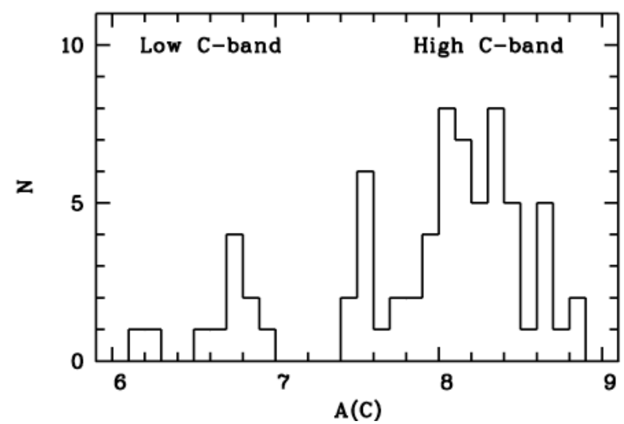
Spite+2013

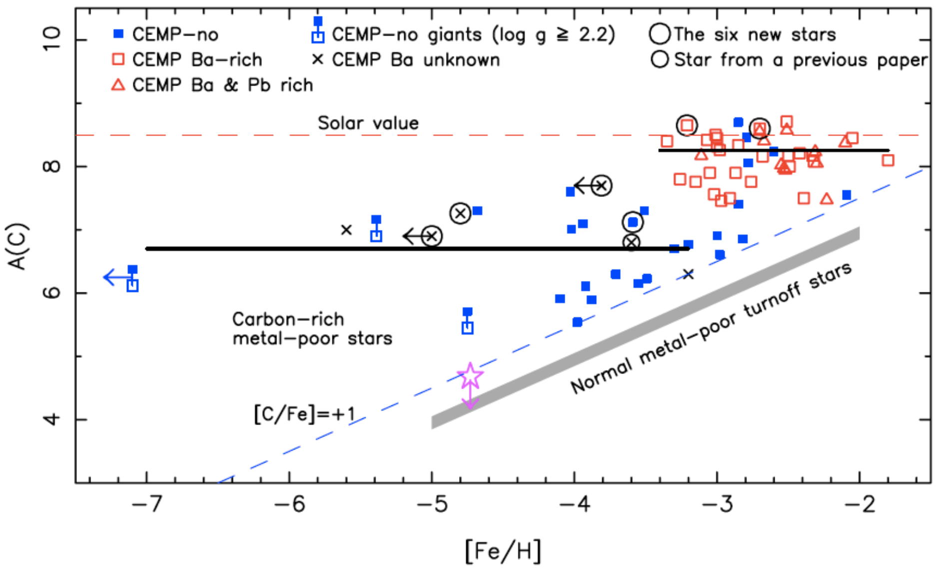


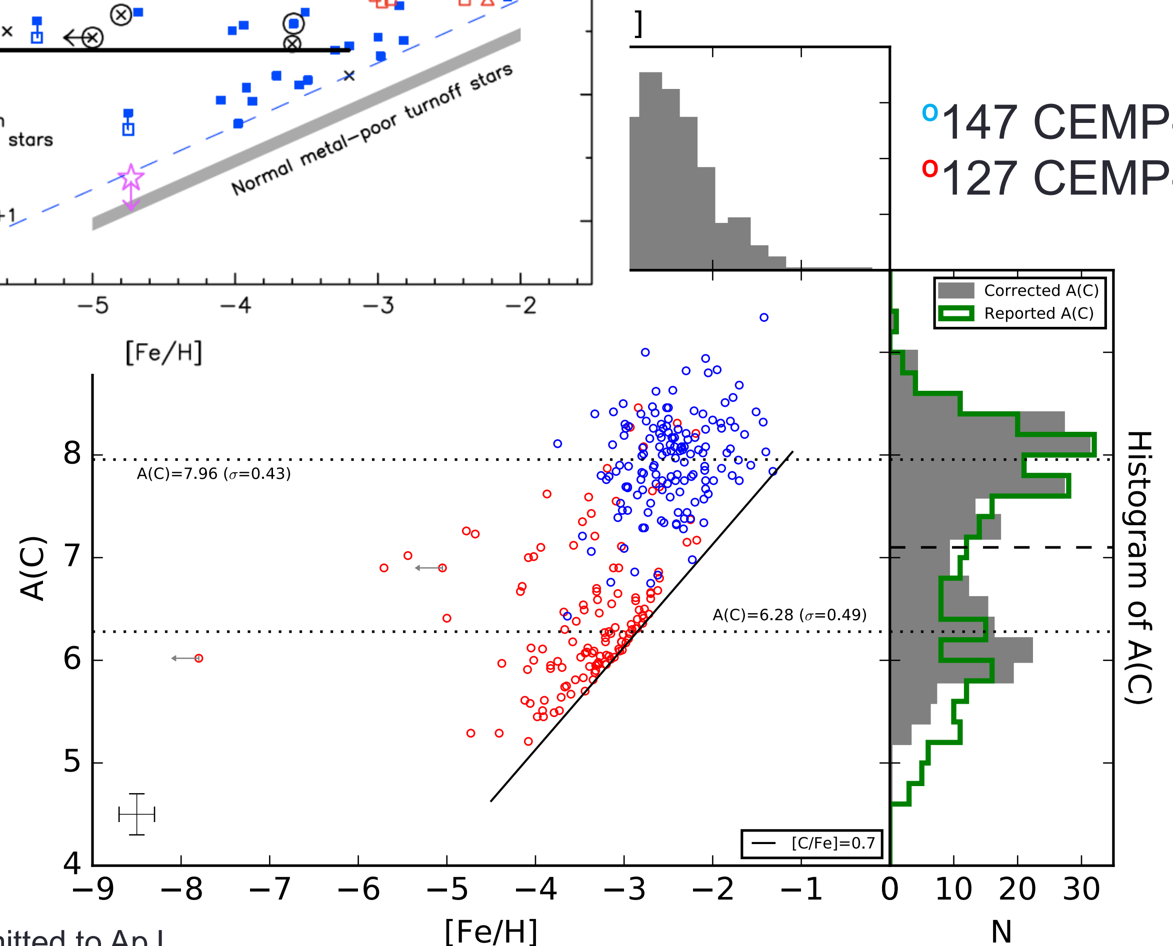
Bonifacio+2015









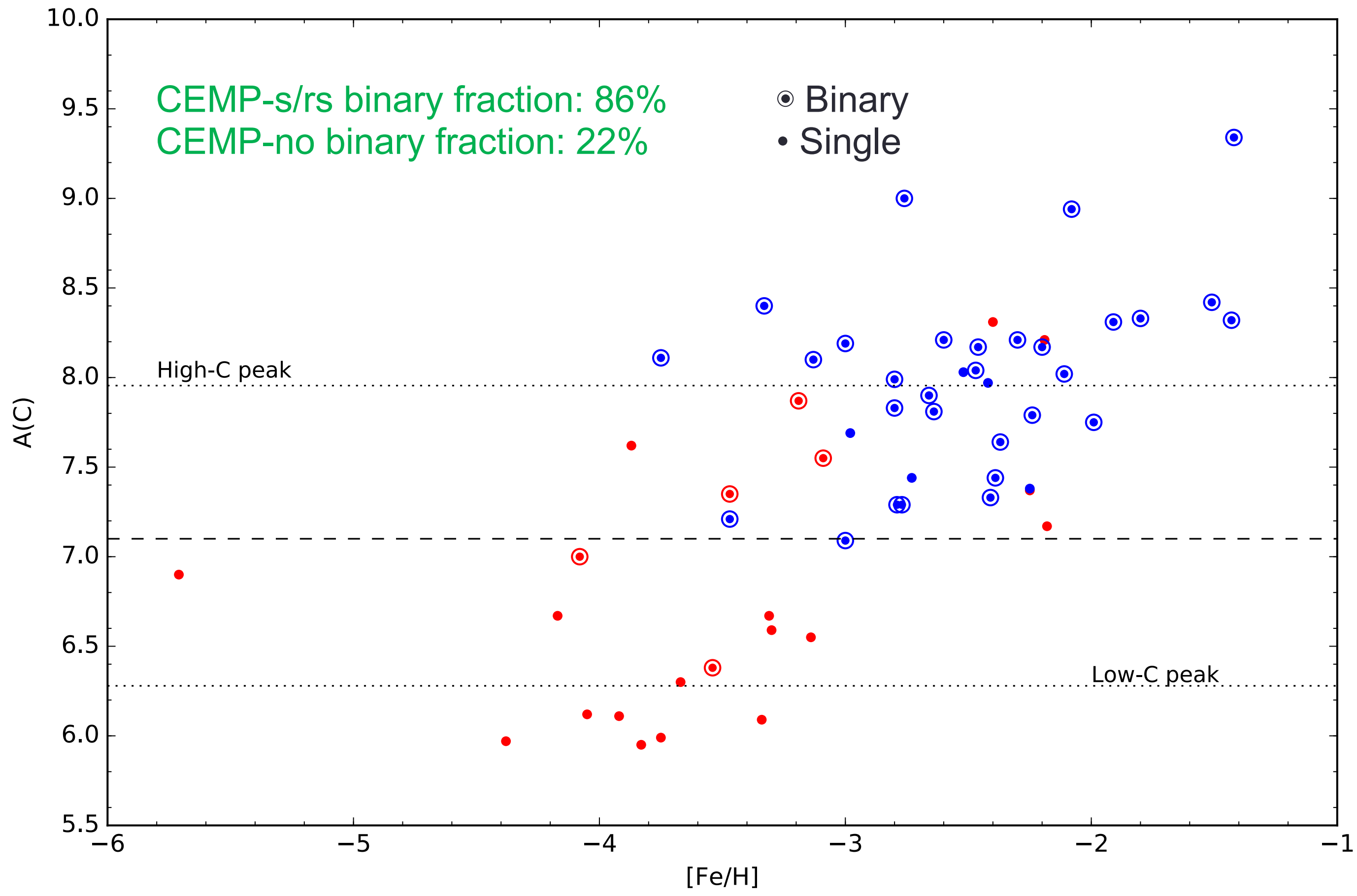


147 CEMP-s/rs stars

127 CEMP-no stars

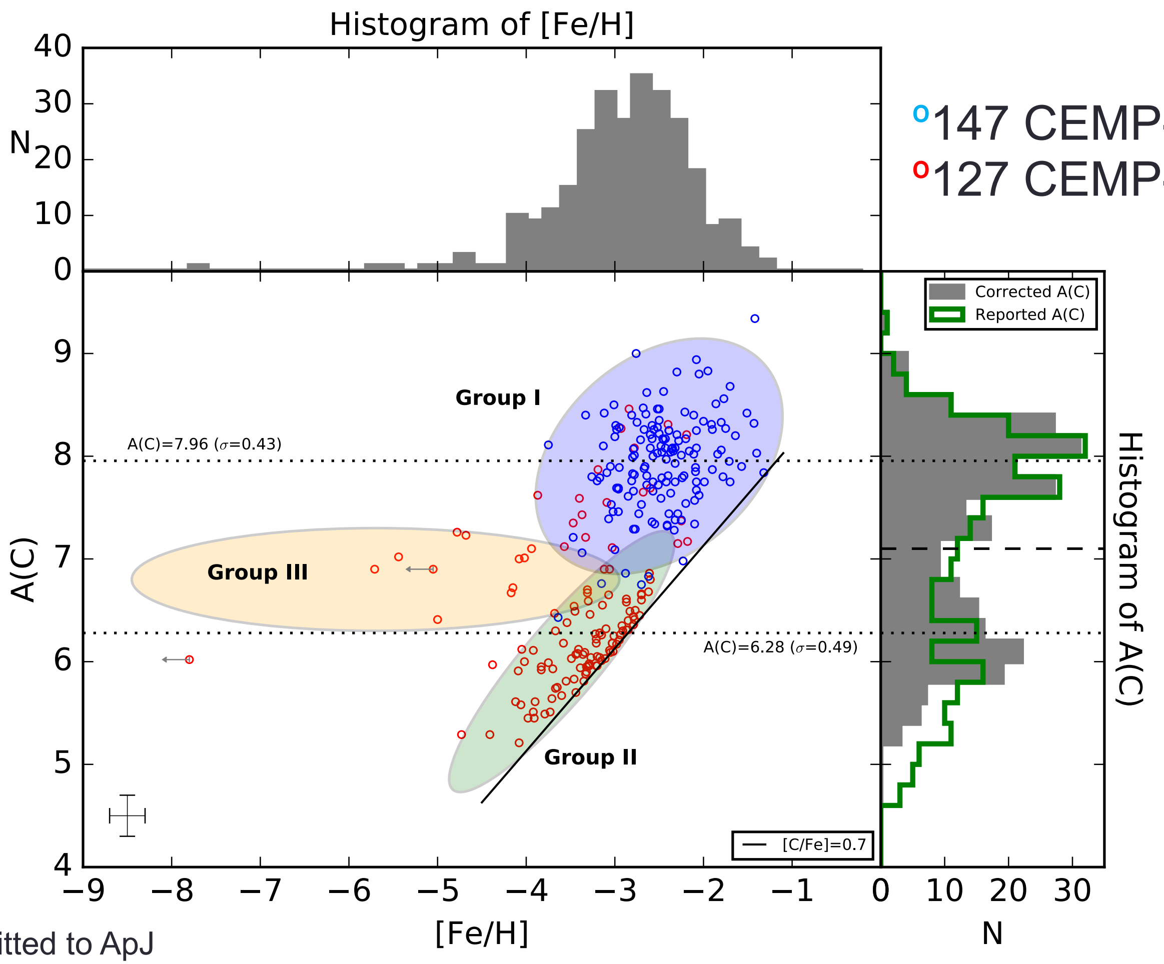
Yoon+2016,submitted to ApJ

Binary status of 57 CEMP stars



Yoon+2016,submitted to ApJ

3 distinct groups

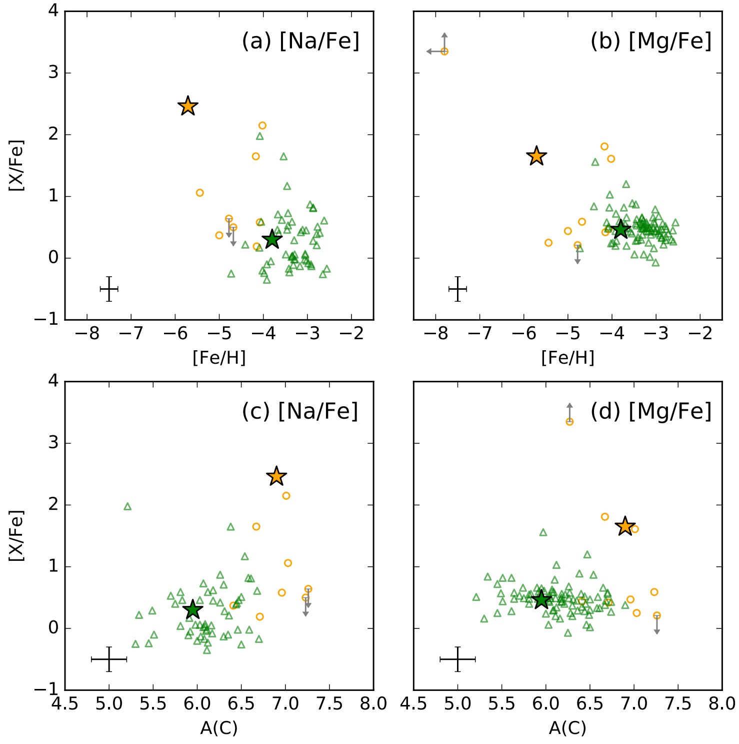


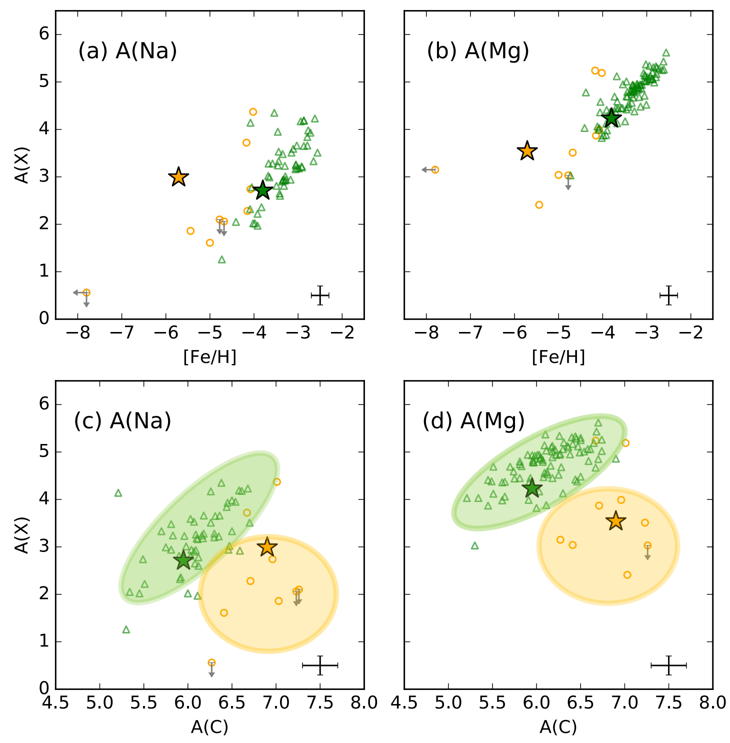
o147 CEMP-s/rs stars

o127 CEMP-no stars

Yoon+2016,submitted to ApJ

Light elements signature for CEMP-no





△ Group II CEMP-no
★BD+44 493
○ Group III CEMP-no
★HE 1327-2326

Yoon+2016,submitted to ApJ

Summary

- Carbon-enhanced metal-poor stars are great tools to study chemical environment of the early universe
  - CEMP-s/rs are low-mass and intermediate AGB progenies (Group I stars).
  - CEMP-no stars are true 2nd generation stars still alive in our galaxy.
- There are multiple progenitors for CEMP-no stars
  - Two distinct behaviors are seen in A(C)-[Fe/H] space (Group II and Group III stars)
  - These distinct trends continue from Na/Mg to Zn.
  - The progenitors are likely both faint supernova and spinstars.
  - The ejected CNO enriched gas mixes with the interstellar medium.
  - The 2nd generation of stars, CEMP-no stars are formed out of this gas.

Thank you!

Group II -- faint SNe ?
Group III – Spinstars ?

- In a simplistic view,

  If both spinstars and faint SNe were the progenitors,

  - Spinstars are more massive than faint SNe
  - CNO gas ejected during the lifetime of spinstars vs end of life for faint SNe
  - FIMF top heavy : Spinstars are less frequenty formed than Faint Sne.
  - Spinstars cannot produce Fe while Faint SNe can eject a bit of Fe.

- But, need to think other factors.
  - Dilution with ISM, mass range in each progenitor, Spinstar+ faint SNe, source of Fe
  - → further study of detailed abundance analyses.