The Origin of CEMP-no Groups in the Milky Way: Connection to the Satellite Dwarf Galaxies

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Collaboration with
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JINA-CEE
Center for the Evolution of the Elements

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Outline of the talk

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- 1st Identification of Group III CEMP star in dSph. Canes Venatici I
- CEMP Group morphological distribution of stars from satellite dwarf galaxies
- Motivation : Hierarchical assembly history of the halo
  → impact of galactic/natal environments

Follow-up observation of a star in CVn I

Zucker et al. 2006 discovery

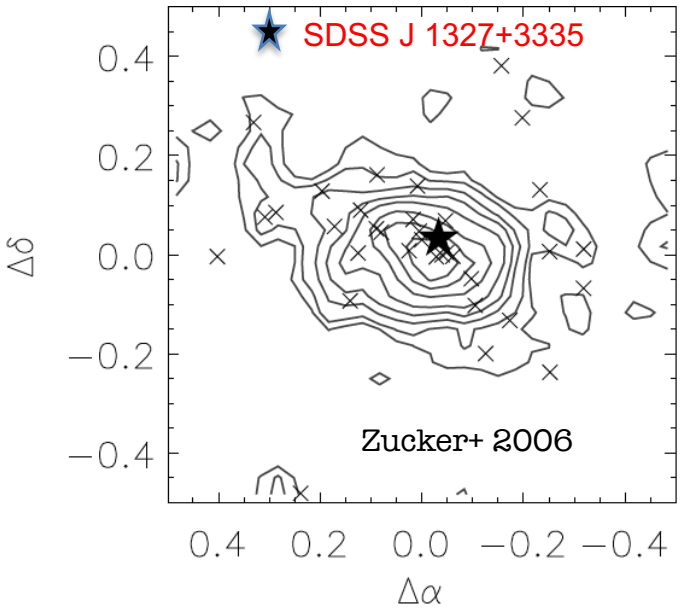
- A Carbon giant, SDSS J 1327+3335
- g ~ 20
- CVn I member

Follow-up observations

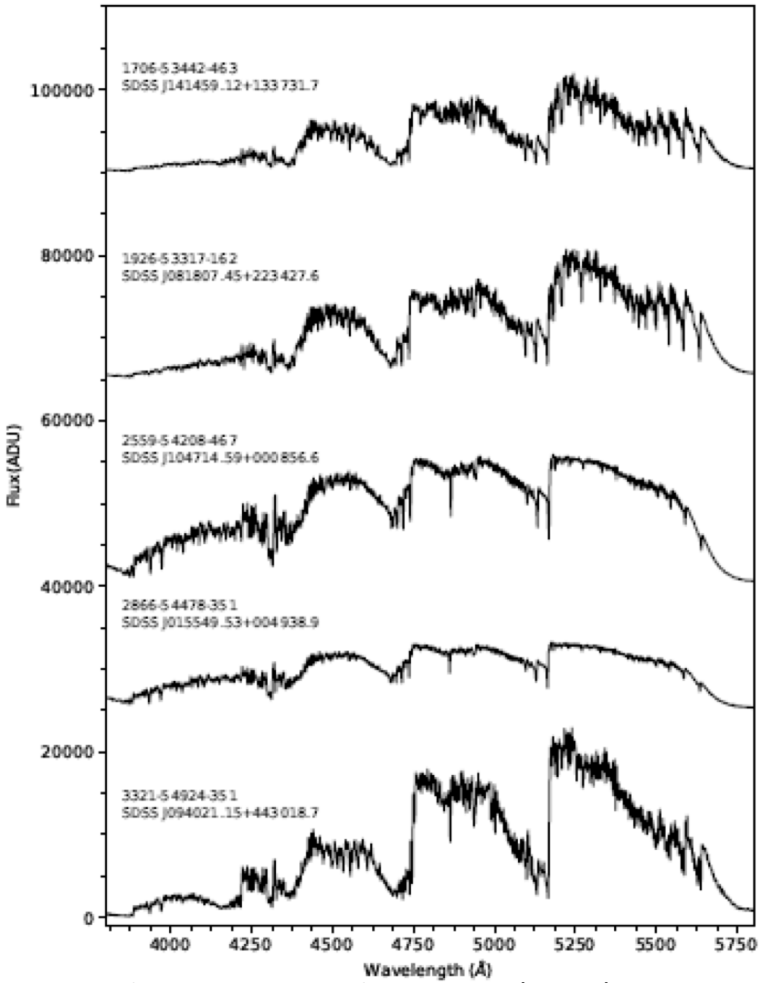
- 5 hrs exposure /w LBT MODS (R ~1800)
- SNR ~20 at 4000A for the CVn I star

G 77-61 as a comparison star

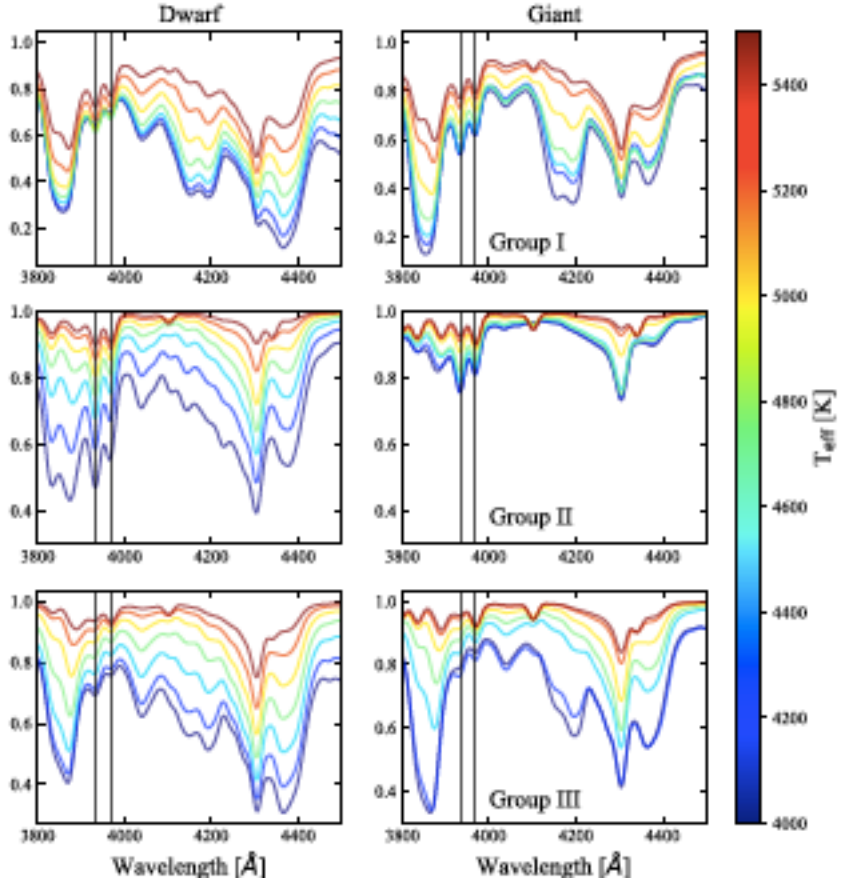
- /w LBT MODS
- SNR ~ 160 at 4000A for G 77-61
- High-res. (Plez & Cohen 2005)



Yoon, Whitten, Beers, Lee, & Placco, 2018c in prep.



Yoon, Whitten, Beers, Placco, Lee (2019) in prep.



Credit: Devin Whitten

Archetypal fitting to CEMP groups

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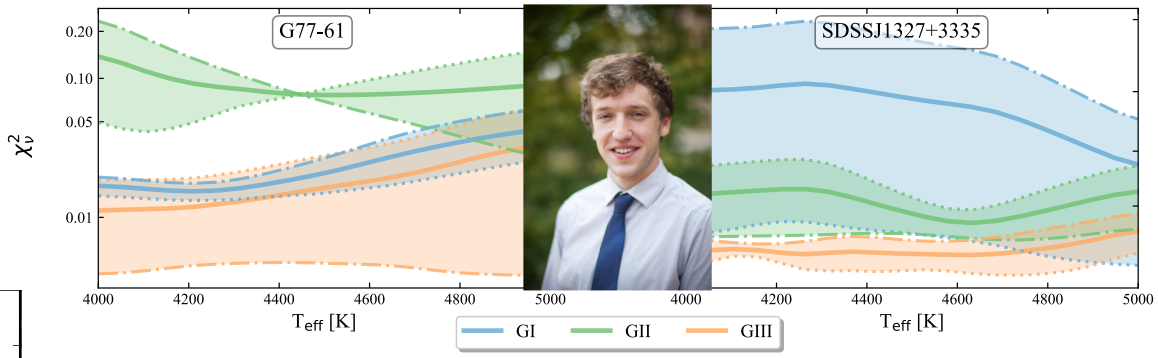
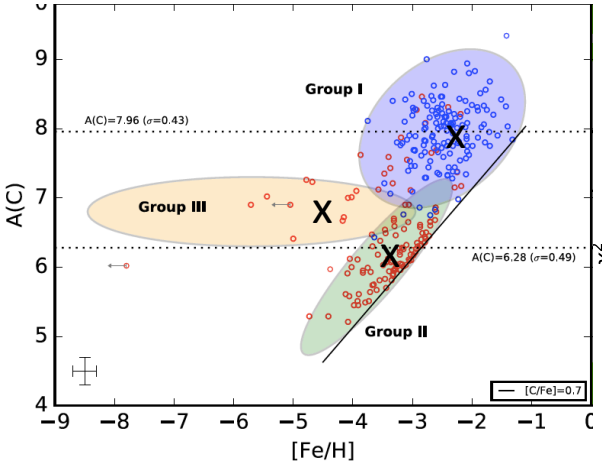
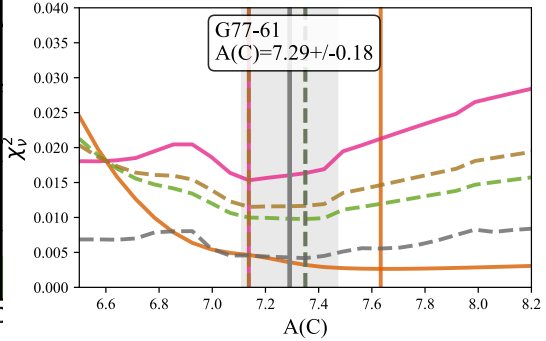
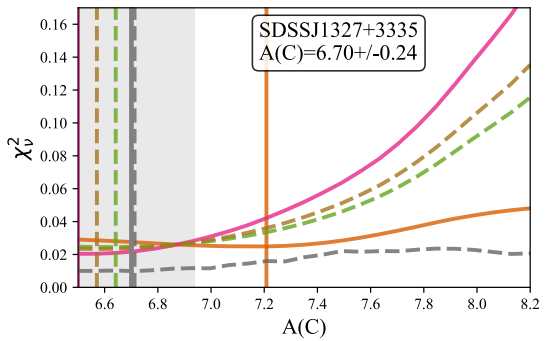
3 archetypes of parameters representing CEMP groups.

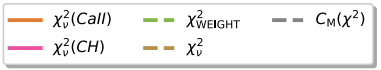
Devin Whitten's Poster







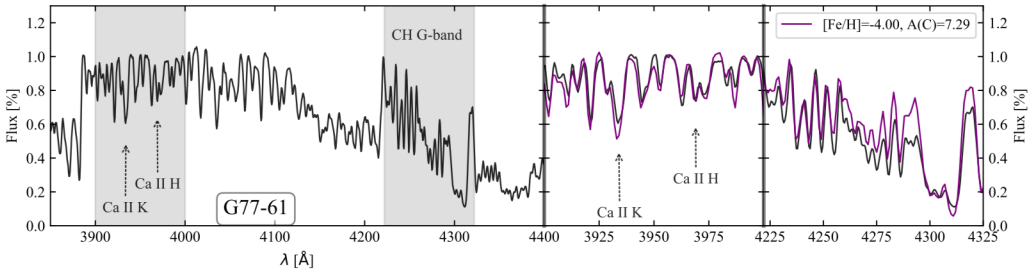




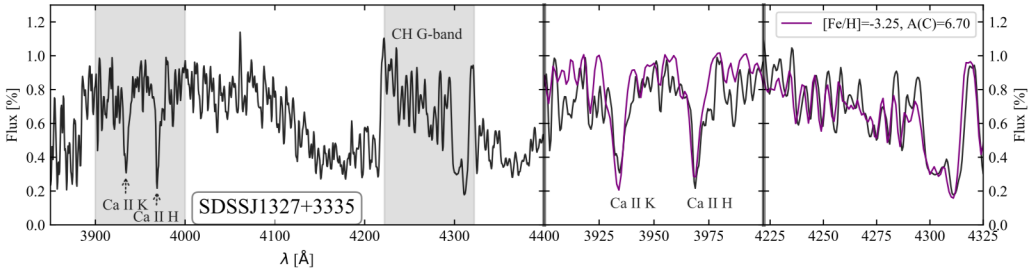
Yoon, Whitten, Beers, Lee, & Placco (2018c) in prep.

Best-fit Spectra

G77-61 (High-res.)
Teff=4000K
[Fe/H] =-4.0
log *g* = 5.05
A(C) = 7.00



From Green sample
8 dwarfs
12 giants



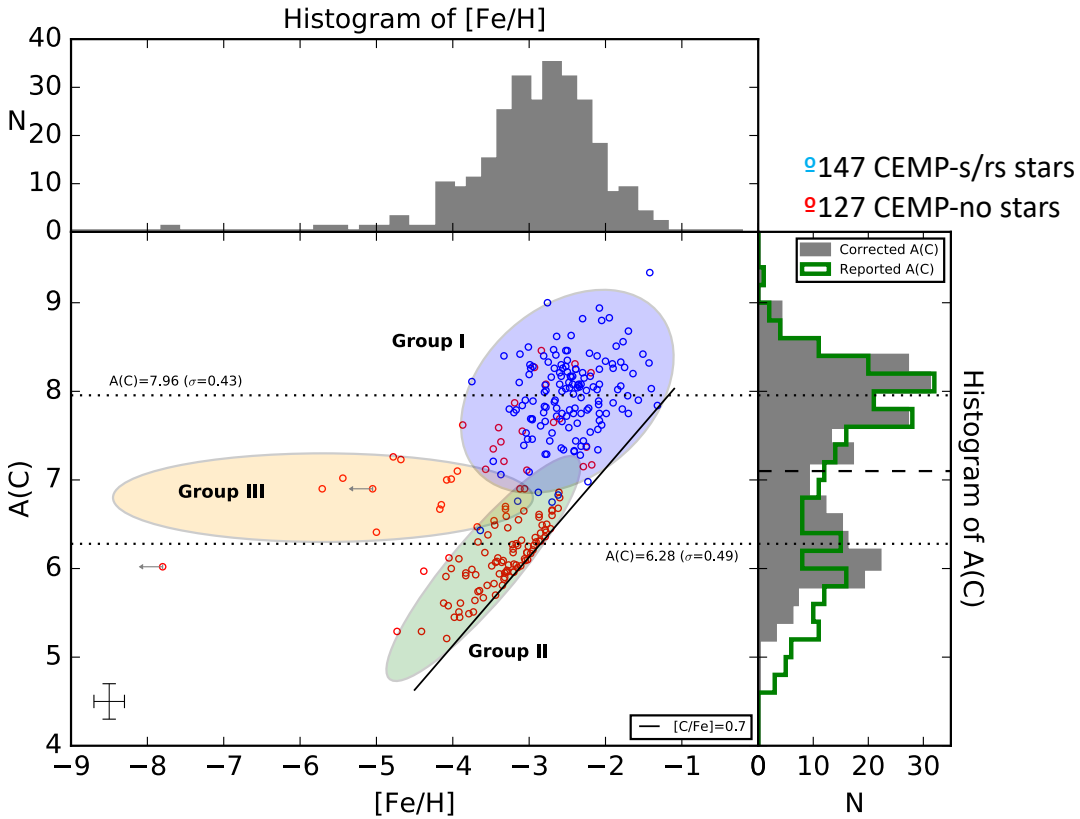
MODS results

G77-61
Teff=4000K
[Fe/H] =-4.0
log *g* = 5.00
A(C) = 7.29

SDSS J1327+3335
Teff=4250K
[Fe/H] =-3.25
log *g* = 0.10
A(C) = 6.70

Yoon, Whitten, Beers, Lee, & Placco, (2018c) in prep.

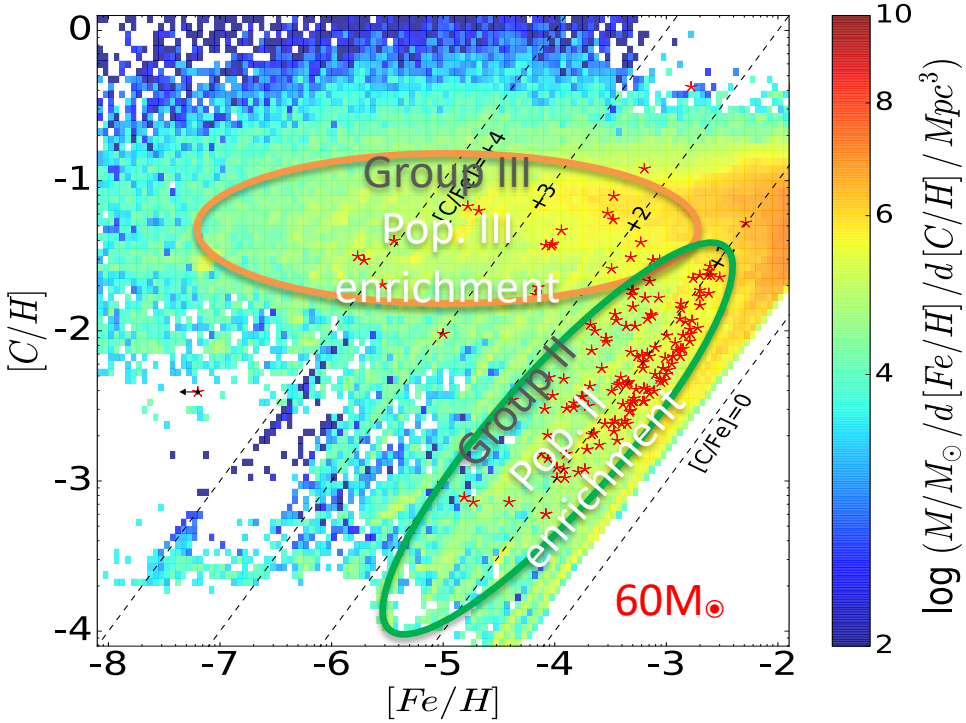
Halo CEMP Morphology



Yoon, Beers, Placco,+ 2016

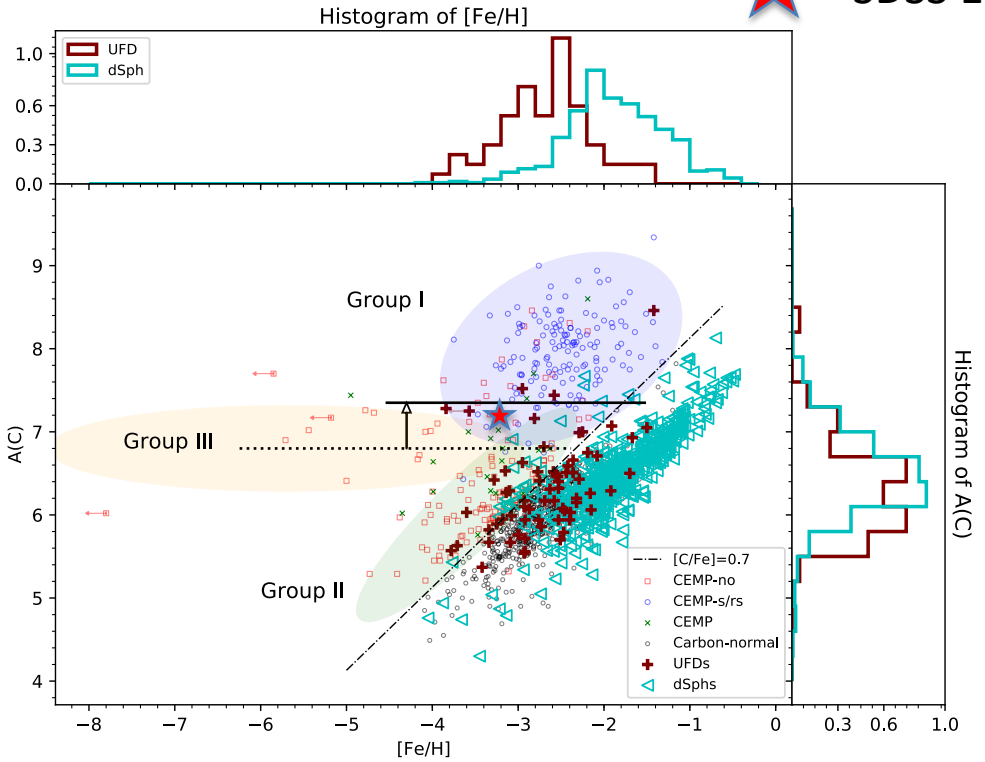
- Distinct 3 groups
  - Group I: CEMP-s+Anomalous CEMP-no (high A(C) but low Ba)
  - Group II : CEMP-no (A(C) dependence on [Fe/H])
  - Group III : CEMP-no (A(C) no relation on [Fe/H])
- Origin of 3 groups
  - Different progenitor masses✓
  - Different mixing process with ISM ✓
  - Different SFH (external vs. internal pollution) ✓
  - Dust cooling (Chiaki+2017) ✓
  - Stochastic star-formation

Pop. III vs. Pop. II enrichment



Credit: Rick Sarmento

CEMP Populations



SDSS 1327+3335, CVn I Group III CEMP star

	UFDs	dSphs
<[Fe/H]>	-2.69	-1.88
<A(C)>	6.33	6.49
CEMP frequency	~28%	~3%

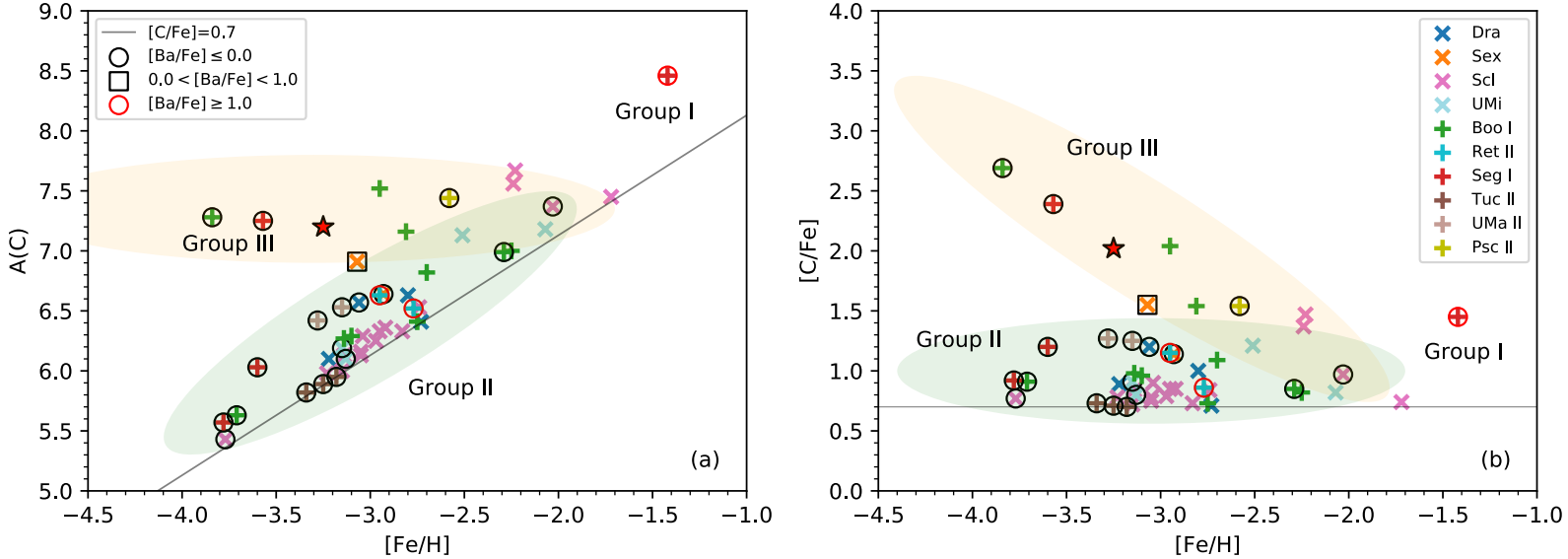
See e.g., Salvadori+15, Salvadori's talk

Data: literature data, SAGA database

Yoon, Beers, Whitten, & Tian (2018b, to be submitted)

CEMP groups of dwarf galaxies

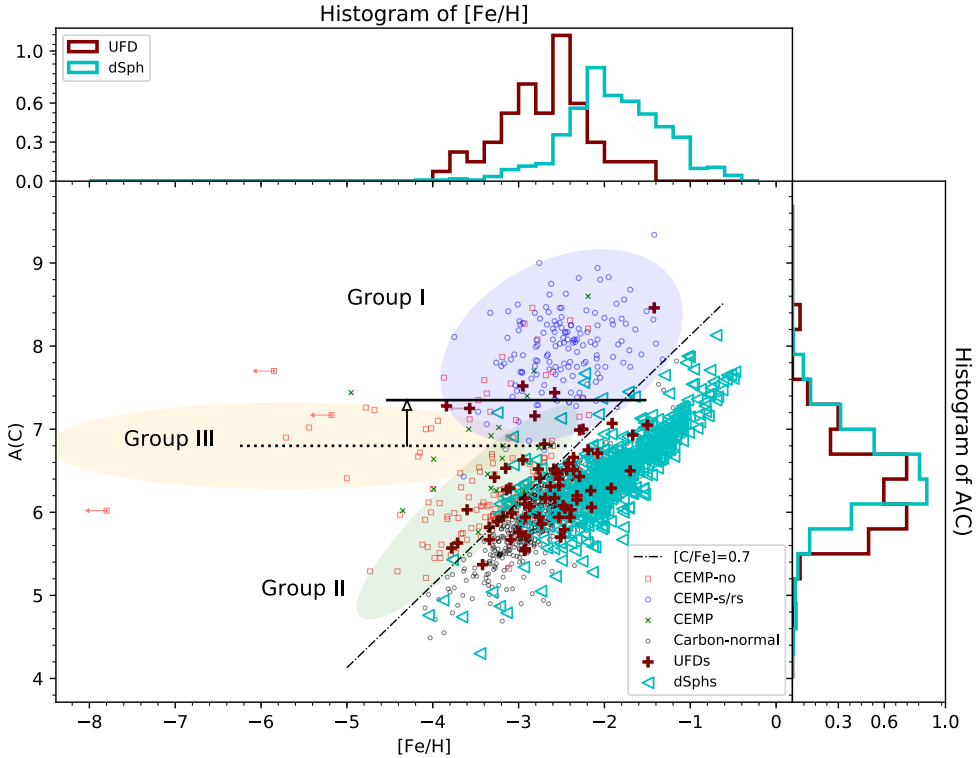
SDSS 1327+3335, CVn I Group III CEMP star



Data: cohen+2010,frebel+2010,tafelmeyer+2010,honda+2011, lai+2011,shetrone+2013, frebel+2014,Kirby+2015,skuladottir+2015, lardo+2016, ji+2016d,chiti+2018a,chiti+2018b, spite+2018

Yoon, Beers, Whitten, & Tian (2018b, to be submitted)

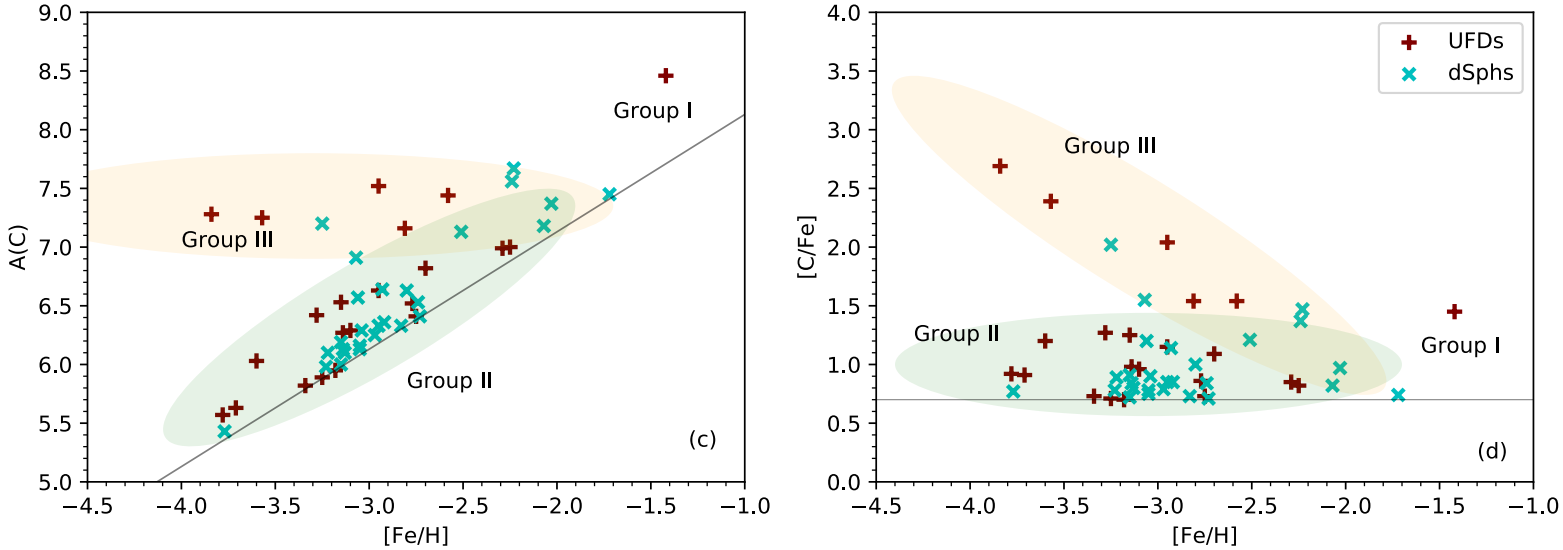
CEMP groups accretion origin 1



Based on the morphological Connection between the halo Group I and dwarf galaxy Group III, the halo Group I CEMP-no Stars could have the same origin with the Group III CEMP-no stars.

Yoon, Beers, Whitten, & Tian (2018b, to be submitted

CEMP groups accretion origin 2



UFDs: Group II and Group III → Halo Group III only from UFD-like systems

dSphs: Group II stars → the majority of halo Group II from dSph-like systems

Yoon, Beers, Whitten, & Tian (2018b, to be submitted

Impact of masses of galactic env.

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Characteristic	Group II	Group III	Reference
	Chemical signatures		
A(C)-[Fe/H] correlation	yes	no & higher A(C)	Yoon et al. (2016), this work
A(C)-A(Na, Mg) correlation	yes	no & lower A(Na,Mg)	Yoon et al. (2016)
	Star-forming environment		
Progenitor SN	normal CCSNe	faint SNe	Chiaki et al. (2017)
Gas cooling agents	silicate grains	carbon grains	Chiaki et al. (2017)
Pop. contribution	Pop. II	Pop. III	Sarmento et al. (2017)
Number of progenitors	multiple (multi-enrichment)	single (mono-enrichment)	Hartwig et al. (2018)
Natal-gas enrichment	internal pollution	external & internal pollutions	Chiaki et al. (2018)
	Galactic environment		
Galaxy type	dSphs & UFDs	UFDs	this work
Host galaxy mass[a]	$\sim 10^9 M_\odot$	$\sim 10^6 M_\odot$	Simon (2019)
Star-formation history	prolonged	truncated	Simon (2019)

Yoon, Beers, Whitten, & Tian (2018b, to be submitted)

Future Work/Prospects

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- Chemical analysis
  - High-resolution spectroscopy for CEMP-no stars, in particularly, halo Group I
  - Carbon measurement for stars from the dwarf galaxies
- Kinematic analysis of Group I, II, III CEMP-no stars
- Cosmological simulations
  - CEMP group morphology → external/internal, stochasticity, local inhomogeneity, gas-to dark matter ratio,
  - The A(C) level of Group III stars → constraining lower mass limit of baryonic mass

  → CEMP frequency as constraints

Summary

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- Identification of the 1st Group III CEMP star in CVn I.
- Compilation of CEMP stars of the satellite dwarf galaxies compared with the halo
  - similar CEMP groups pattern to the halo → strong evidence of accretion history of the halo CEMP-no stars
  - Halo Group I likely have the same origin as halo Group III
  - UFDs have both Group II and Group III stars, while dSphs appear to have only Group II stars → role of baryonic masses of the parent mini-halos on the morphology of the CEMP groups

- JINA-CEE Frontiers Summer school

“Astronomy for Nuclear physicists and Nuclear physics for Astronomers”

May 15 -18, 2019 (prior to JINA-CEE Frontiers meeting)

Michigan State University