Observations of New CEMP Stars with the South African Large Telescope

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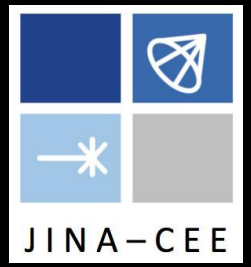


overview:

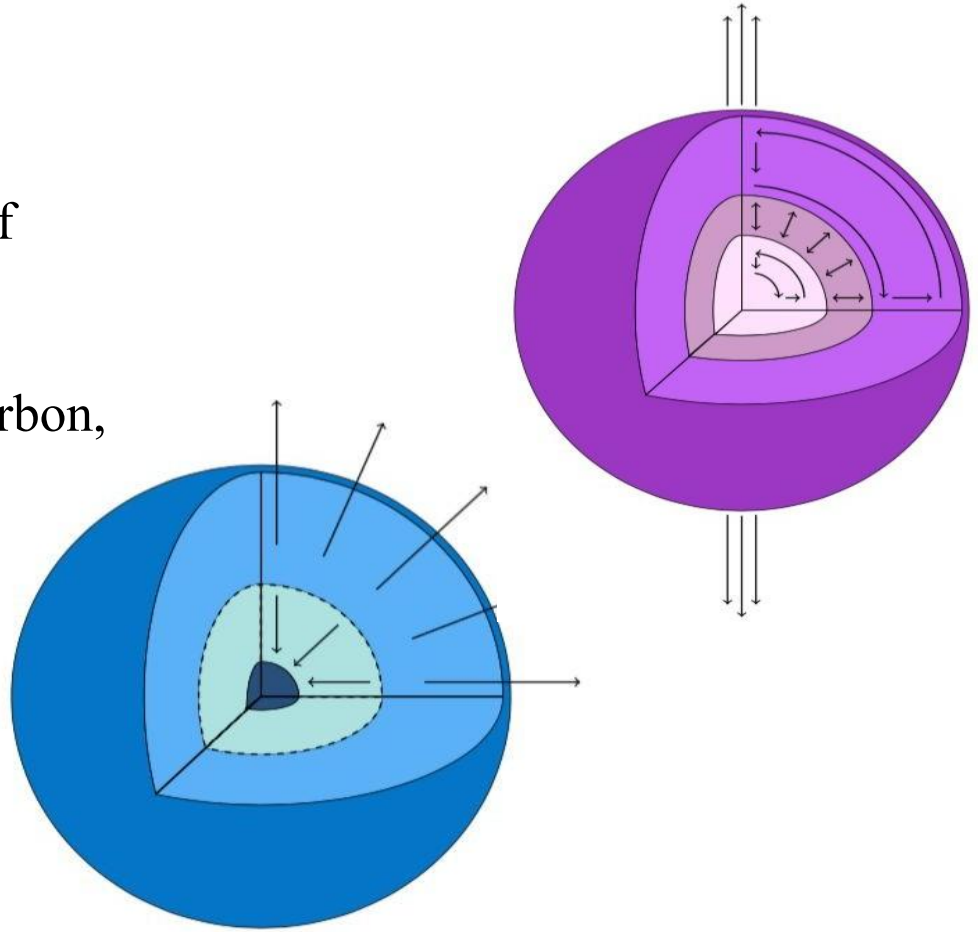
With the South African Large Telescope, we have observed ~220 new metal-poor stars, ~60 of which are CEMP. The first 50 have been analyzed as a part of Paper 1.

background

first stars:

Rapid rotation (spinstar model) of metal-free star creates unique conditions for both creation and expulsion of large quantities of carbon, nitrogen, and oxygen

Low SN explosion energy (mixing & fallback) leads to "mass cut"; light elements are ejected while heavy elements are not

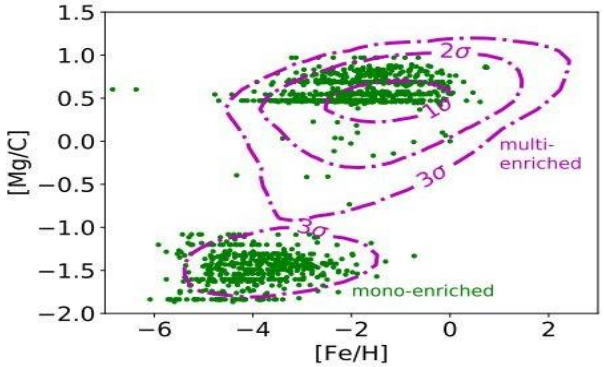


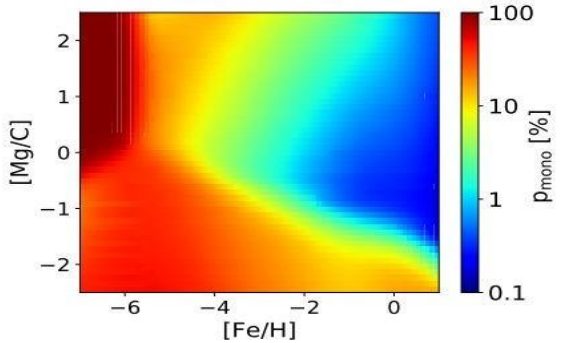
first stars:

Exotic Supernovae:

1. Pair-Instability
2. Hypernovae
3. Magneto-rotational
4. Aspherical
5. Collapsars

primordial mini-halos:





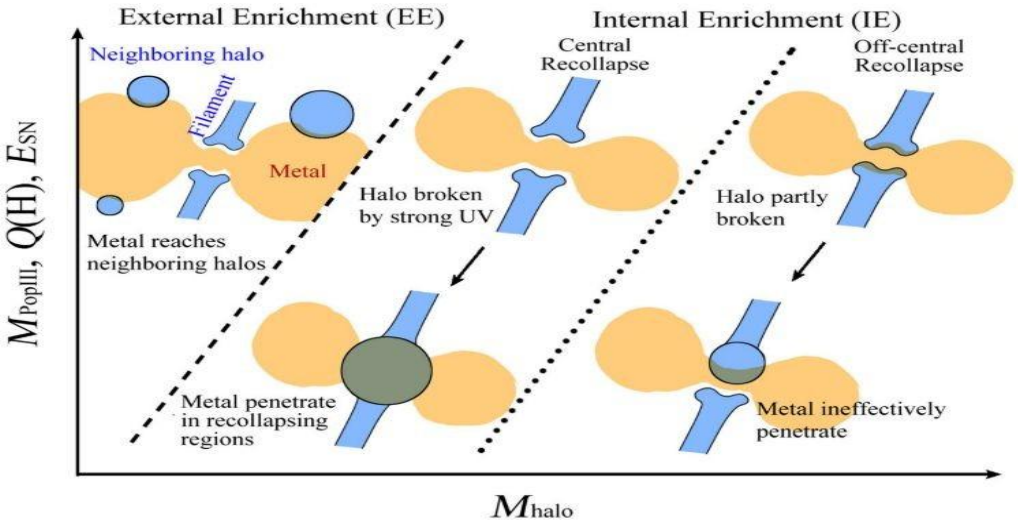
Mono- vs. Multi-enriched halos:

→ 1% of stars come from halos with single enrichment progenitor event (supernova, neutron star merger, etc)

→ We can differentiate between mono- and multi-enriched halos by their respective [Mg/C] ratios

Hartwig et al. (2018)

primordial mini-halos:



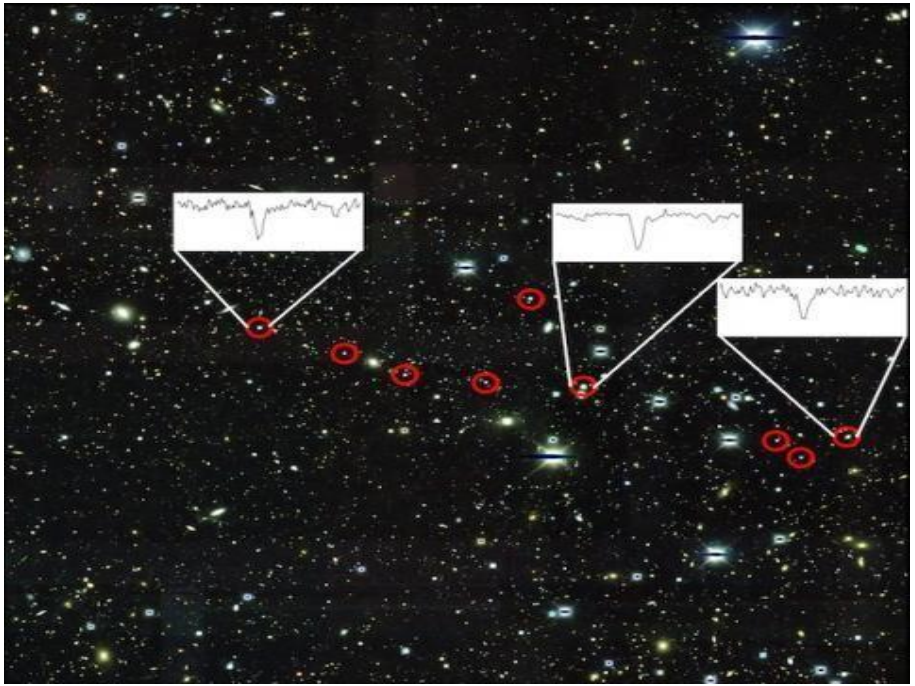
Chiaki et al. (2018b)

Internal vs. External Enrichment:

External → Low metallicity, high carbon

Internal → higher metallicity, lower carbon

primordial mini-halos:



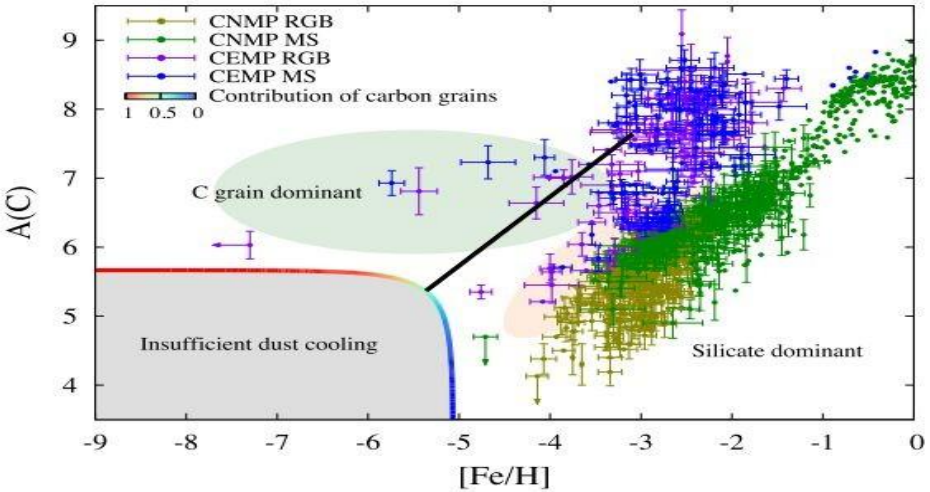
R-process events

- Surviving mini-halos called “Ultra-Faint Dwarf Galaxies” (UFDs) today
- UFDs can be r-process enriched with (Ret II) or without (Tuc III) carbon enhancement

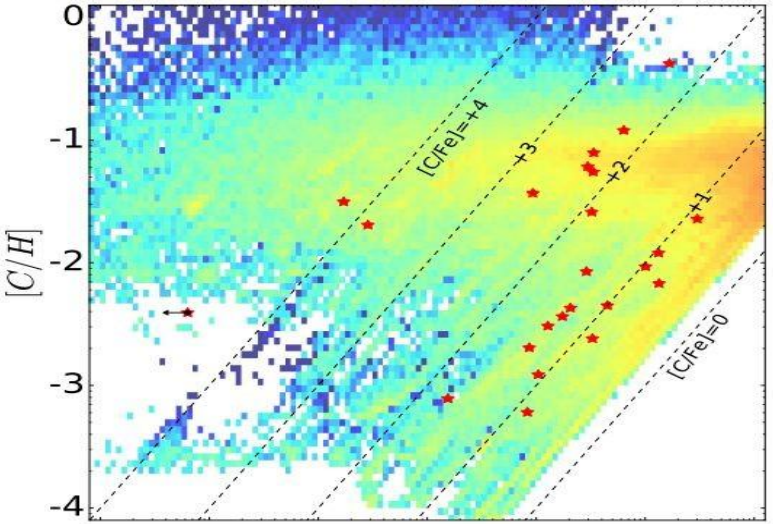
Ji et al. (2016)

galactic chemical evolution

- Concerned with *early* GCE: origins and rise of the elements
- Successful models must be able to reproduce patterns observed in A(C)-[Fe/H] space



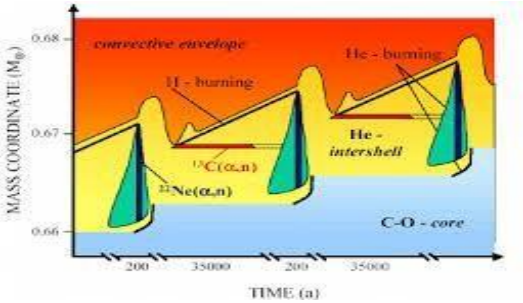
Chiaki et al. (2018a)

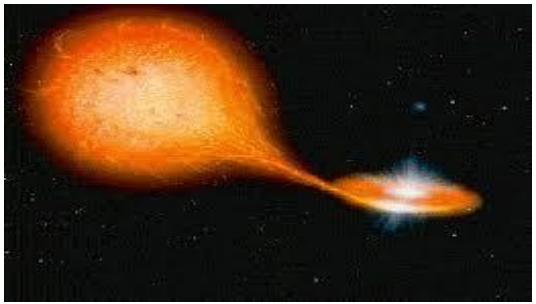


Sarmento et al. (2017)

i-process

→ “intermediate” neutron capture process which occurs in conjunction with carbon-enrichment, leading to CEMP-i stars



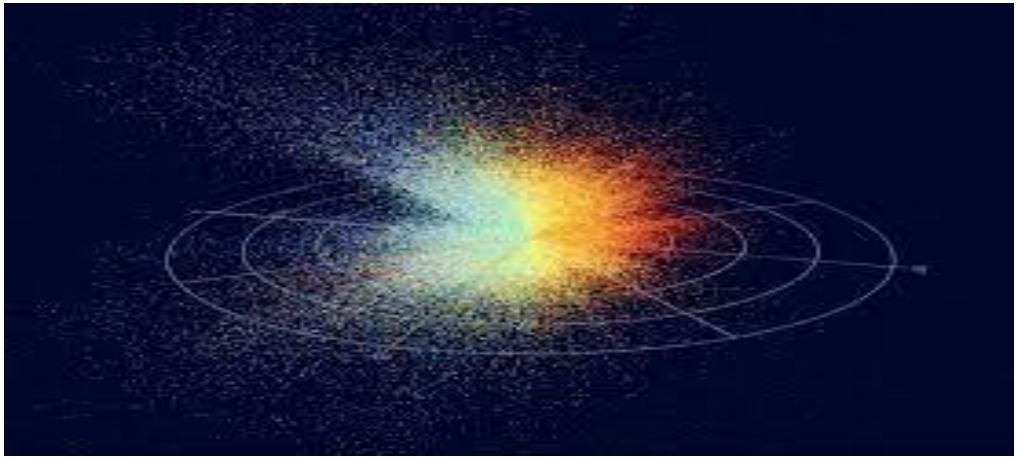


1. Thermally-Pulsing Asymptotic Giant Branch Stars (Hampel et al. 2016)
2. Rapidly Accreting White Dwarfs in close binary systems (Denisenkov et al. 2017)
3. CEMP-r stars in mass-transfer binary systems

methods

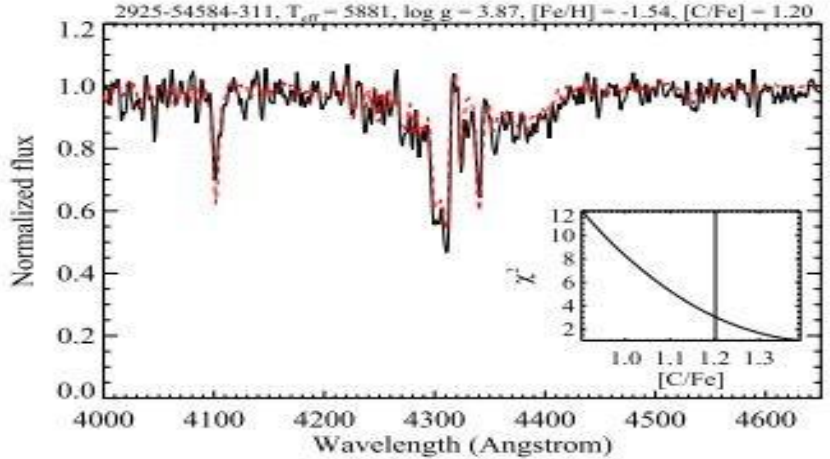
source list:

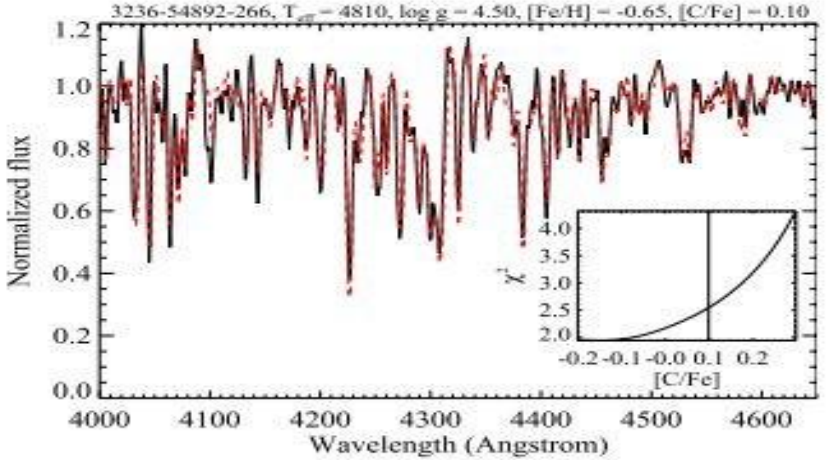
- **Ra**dial **Ve**locity Survey (RAVE)
- Moderate resolution (R ~ 7,500) of NIR Ca triplet region of ~500,000 stars
- Data Release 5 provides stellar parameter estimates (Temperature, metallicity, surface gravity)



target selection:

- Modified non-SEGUE Stellar Parameter Pipeline (n-SSPP) used to make C determinations and identify CEMP candidates

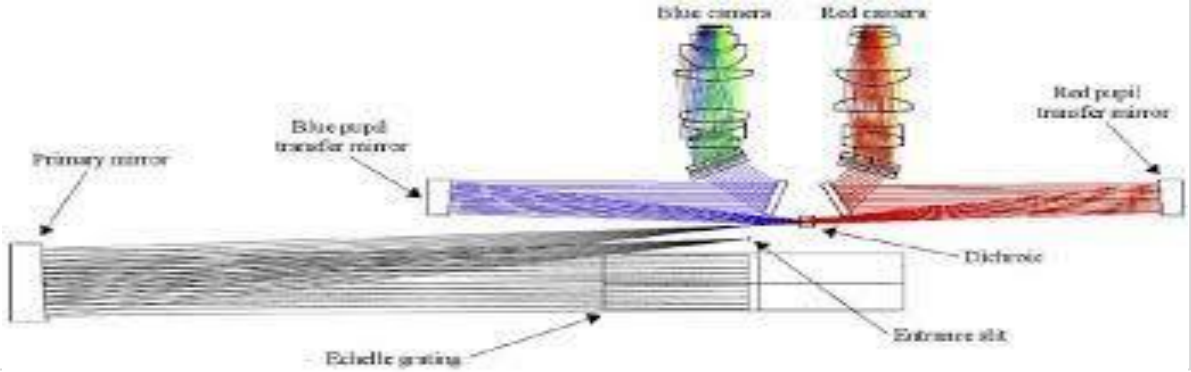




Lee et al. (2013)

telescope:

- South African Large Telescope (SALT) (10-m)
- HRS R ~ 34,000
- S/N ~ 30



observing program:

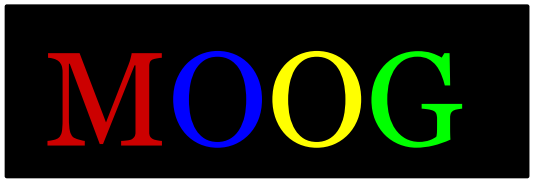
- Time allotment: 200,000 s of “official” Priority 3 time under SALT Long Term Proposal 2017-1-MLT-012, “Detailed Study of CEMP Stars Identified in the RAVE Survey”
- Spanned four semesters from April 2017 - March 2019
- Were able to use much more than officially granted by utilizing poor observing conditions (Priority 4 time)

223 stars were ultimately observed with this program!

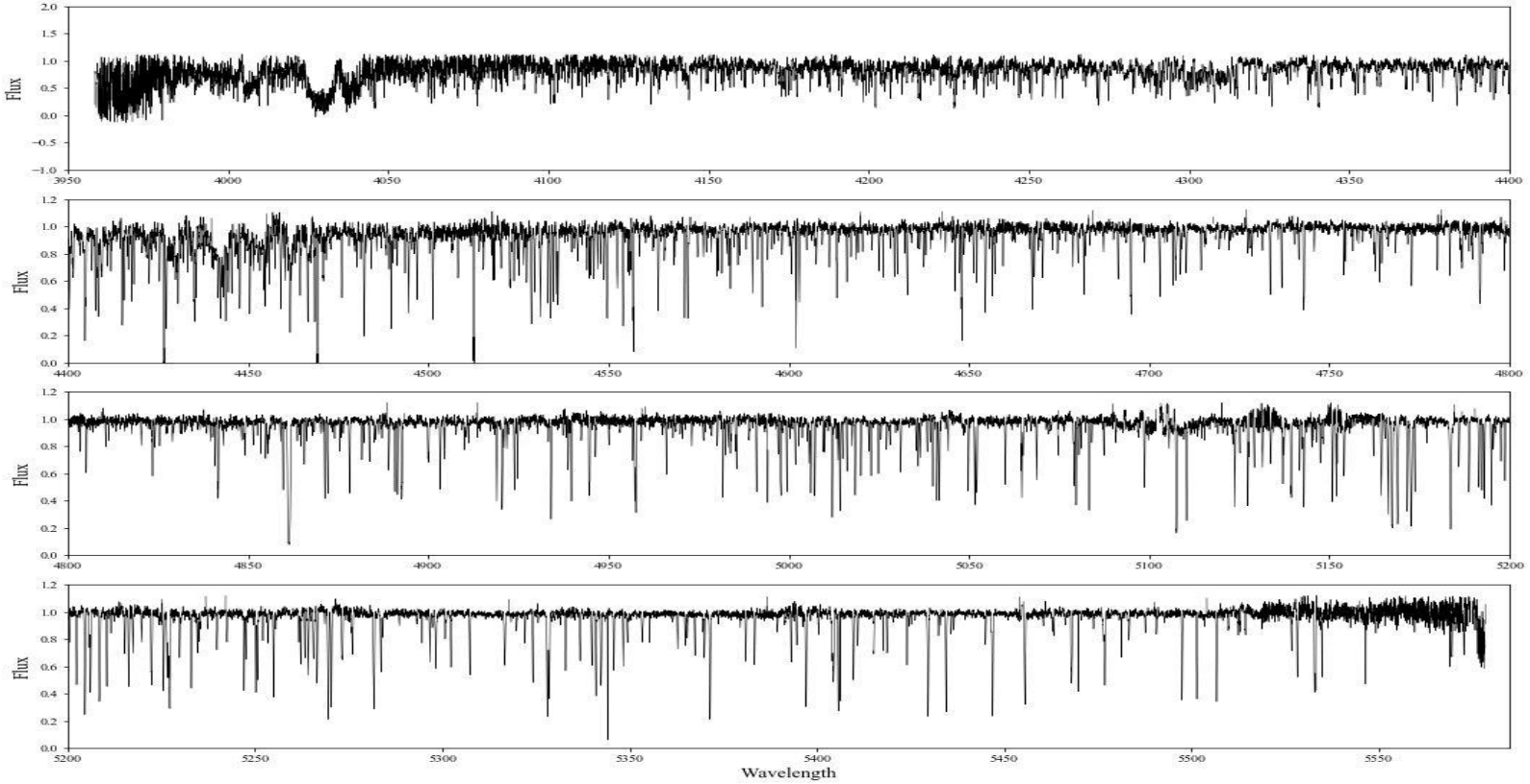
data analysis:

1. reduction
2. wavelength calibration
3. normalization & stitching
4. stellar parameter determination
5. spectral synthesis

Spectroscopy Made Hard



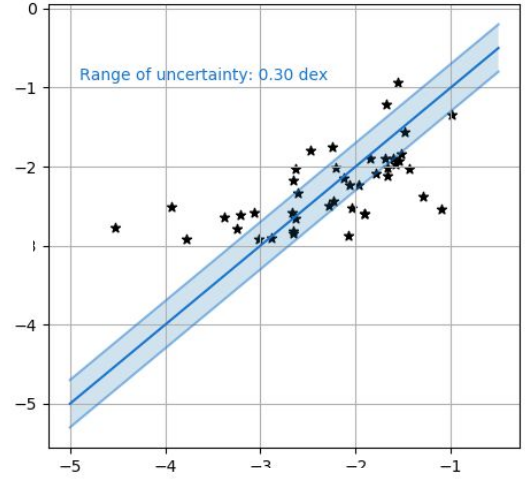
data analysis:



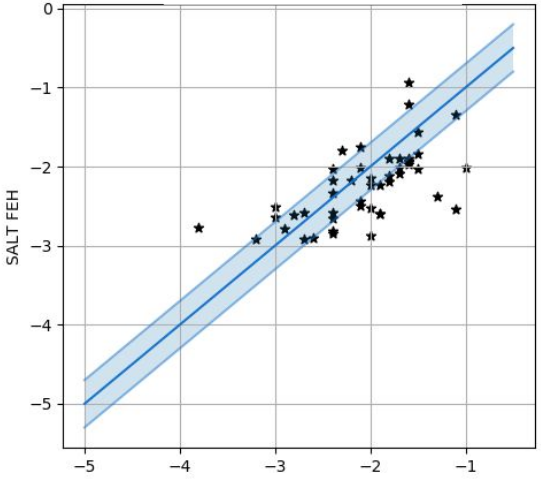
results

science products: a test of stellar parameters

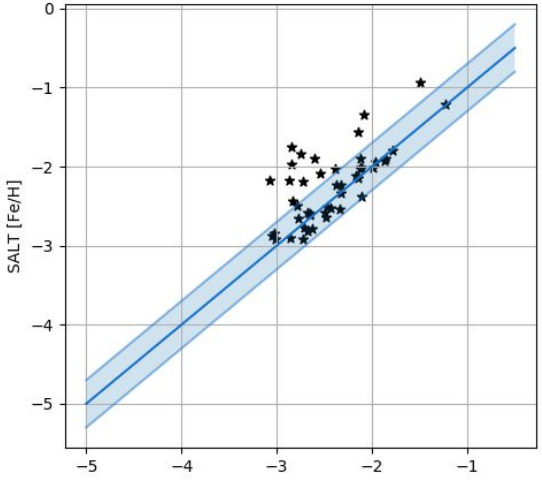
SALT



[Fe/H]
RAVE DR4

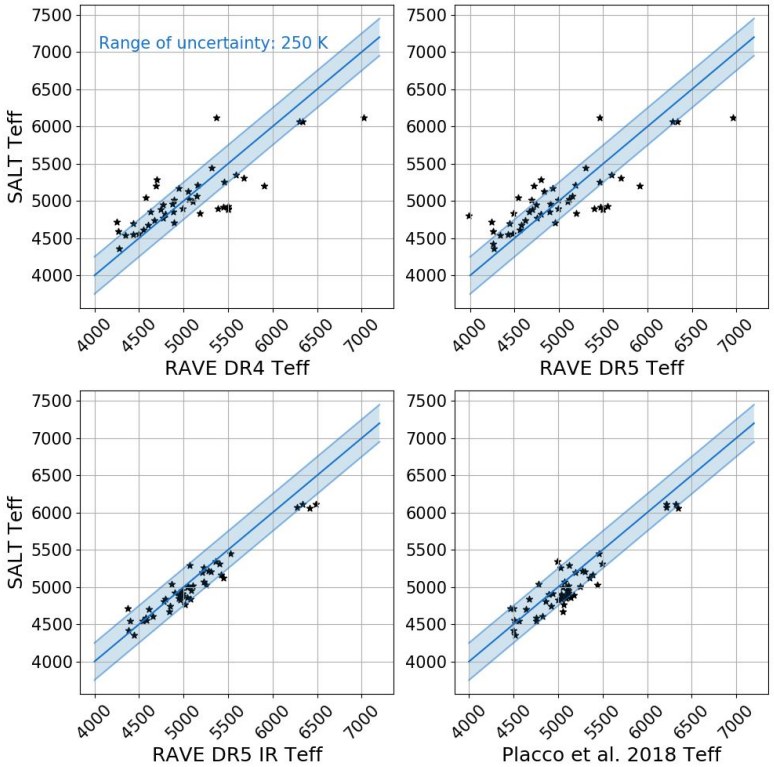


[Fe/H]
RAVE DR5

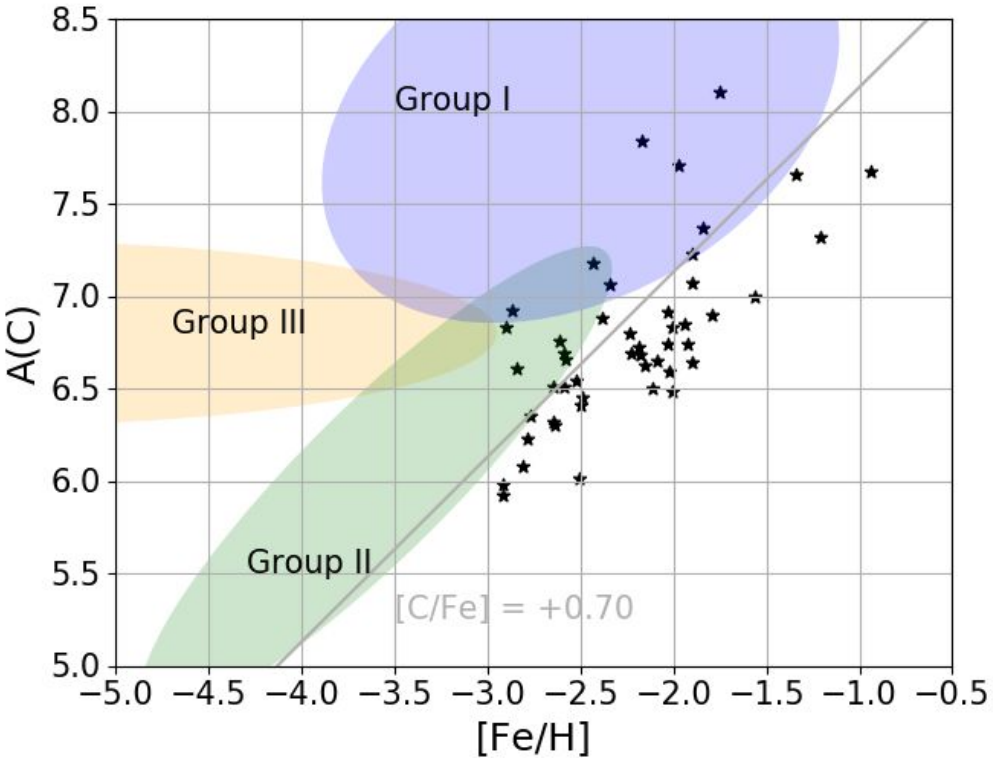


[Fe/H]
Placco et al. 2018

science products: a test of stellar parameters

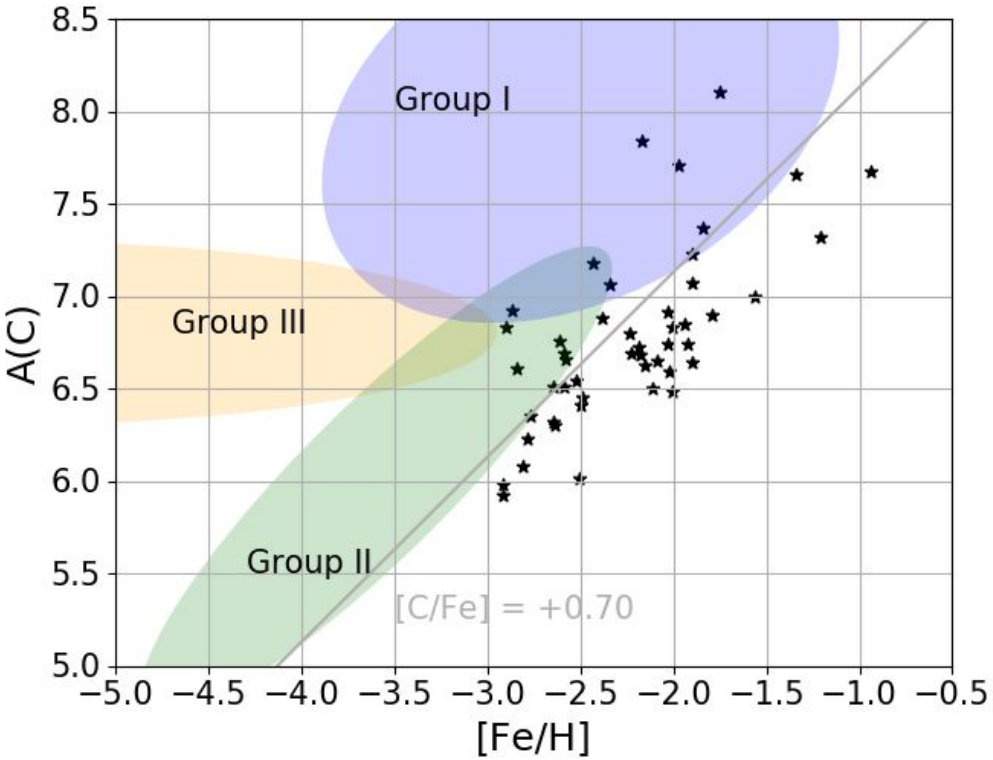


science products: Abundances



Carbon
Magnesium
Calcium
Scandium
Titanium
Vanadium
Chromium
Manganese
Iron
Cobalt
Nickel
Zinc
Strontium
Barium
Europium

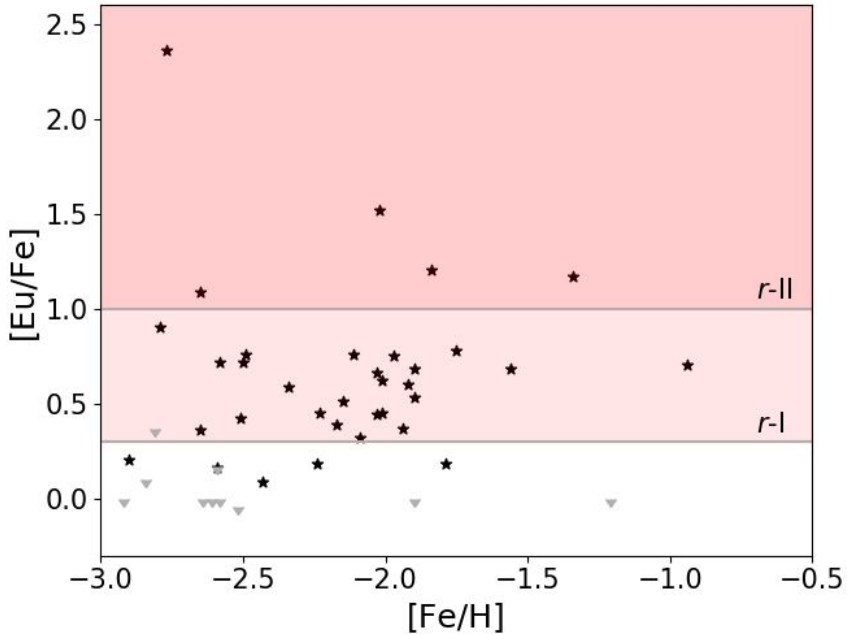
science products: CEMP stars



15 CEMP stars

- **6 CEMP-no**
- **2 CEMP-r/s**
- **1 CEMP-rI**
- **2 CEMP-rII**
- **4 CEMP-s**

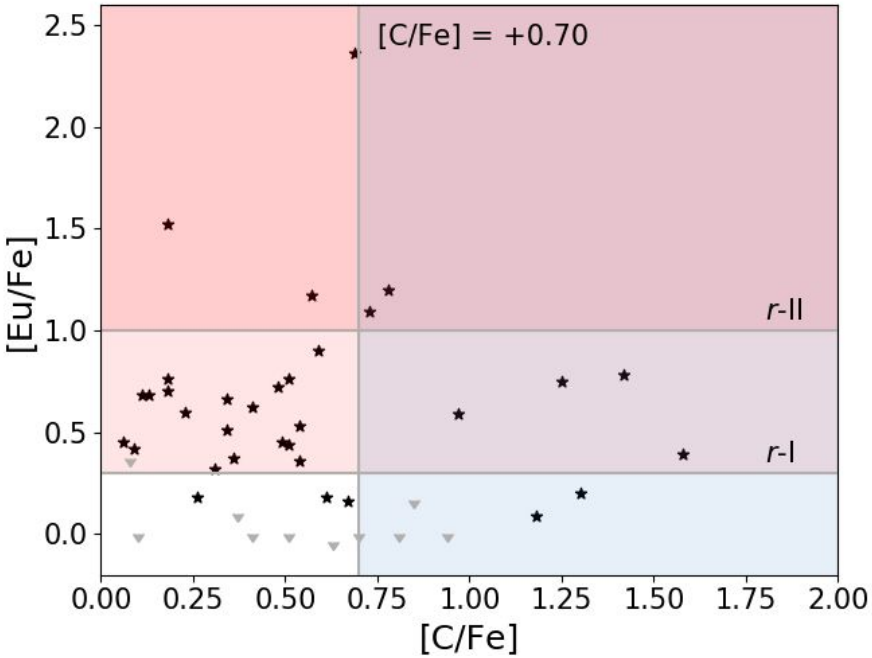
science products: r-process stars



25 r-process stars

- **5 rII (two new)**
- **20 rI**
- **25 not enhanced in r-process elements**

science products: r-process stars



25 r-process stars

- **5 rII (two new)**
- **20 rI**
- **25 not enhanced in r-process elements**

Based on these numbers, we expect:

- **67 CEMP stars**
  - **→ 27 CEMP-no**
  - **→ 18 CEMP-s**
  - **→ 9 CEMP-r/s**
  - **→ 13 CEMP-r**

- **112 r-process metal-poor stars**
  - **→ 22 rII**
  - **→ 90 rI**

In conclusion:

Statistically significant sample of carbon-enhanced and carbon-normal metal-poor stars

→ CEMP frequencies as function of [Fe/H]
→ Abundance trends toward solar metallicity
→ Interesting candidates for in-depth follow-up (CEMP-rII, CEMP-i, etc)

conclusion:

15 new CEMP stars + more to come!

thanks for listening!

Coming to an arXiv near you!