High-precision abundance analysis of a unique CEMP-no star in Sculptor

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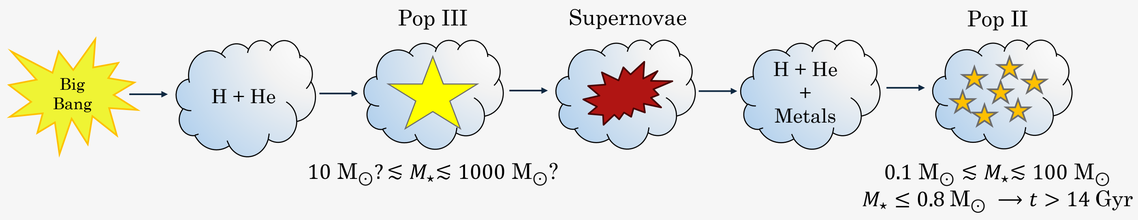
First Stars

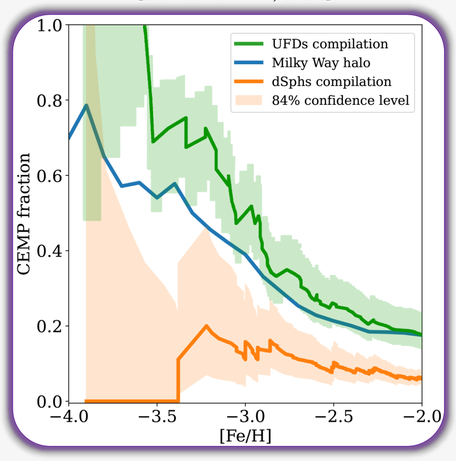


The **first stars** (Pop III) likely had very high masses due to their pristine composition. Their supernovae (SNe) **distributed the first metals in the Universe**. However, these massive stars had short lifetimes, making Pop III unobservable today.
Second-generation stars had lower masses, and those **with $M_\star \leq 0.8$ M$_\odot$ have survived until today**. We can observe these old, metal-poor stars in the local Universe and measure their **chemical abundances**, which they **inherited directly from the first stars**.

[e.g., Hirano et al., 2014, Frebel and Norris, 2015, Rossi et al., 2021]

CEMP-no stars

[Lucchesi et al., 2024]

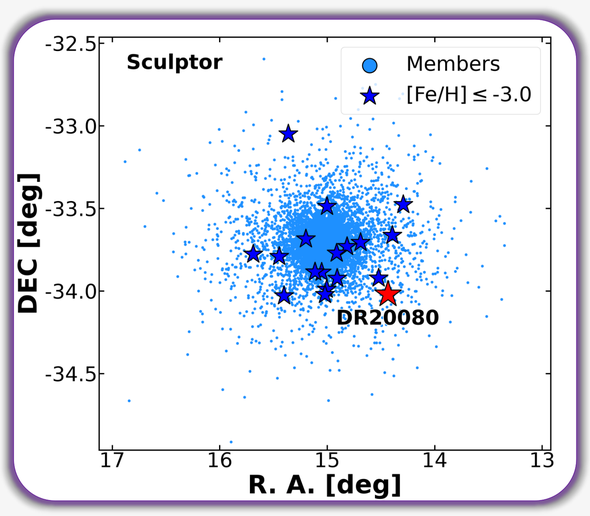


The closest **old and metal-poor environments**:
- Milky Way (MW) stellar halo
- Dwarf galaxy satellites of the MW
  - **Dwarf spheroidal galaxies** (dSphs)
  - **Ultra faint dwarf galaxies** (UFDs)

Carbon-Enhanced Metal-Poor stars not enriched in n-capture elements (**CEMP-no**) are believed to be **direct descendants of Pop III faint SNe**. However, their **population in dSphs** seems to be very **different than in UFDs and in the MW**.

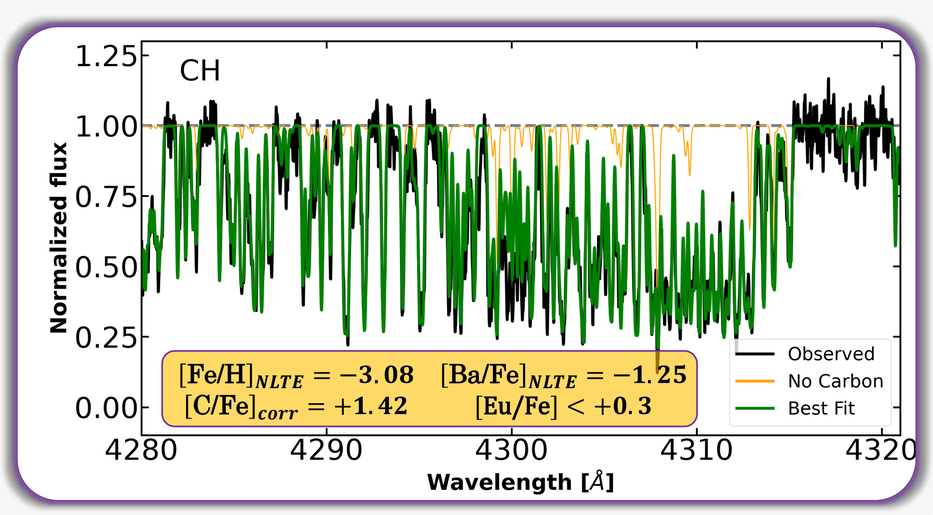
Are Pop III properties dependant on the formation environment?

DR20080 – A unique star in Sculptor



DR20080 is a **recently discovered** [Skúladóttir et al., 2024] **CEMP-no star in the Sculptor dSph** (left figure), and, by far, **the most metal-poor** among the two CEMP-no stars identified in this galaxy so far.
We performed a **high-resolution ($R \sim 35,000$) follow-up** of DR20080 through the VLT/UVES spectrograph, collecting **8 hours of exposure** across 3 spectral bands (3700 Å – 6625 Å).
The **main goals**:
- **Compare the abundance pattern with other CEMP-no stars and metal-poor stars;**
- **Derive the properties of its Pop III progenitors** (mass, M_{PopIII}, and explosion energy, E_{SN}) .

The only extremely metal-poor CEMP-no star in Sculptor!

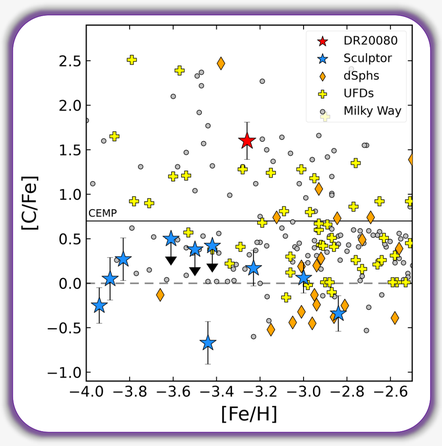


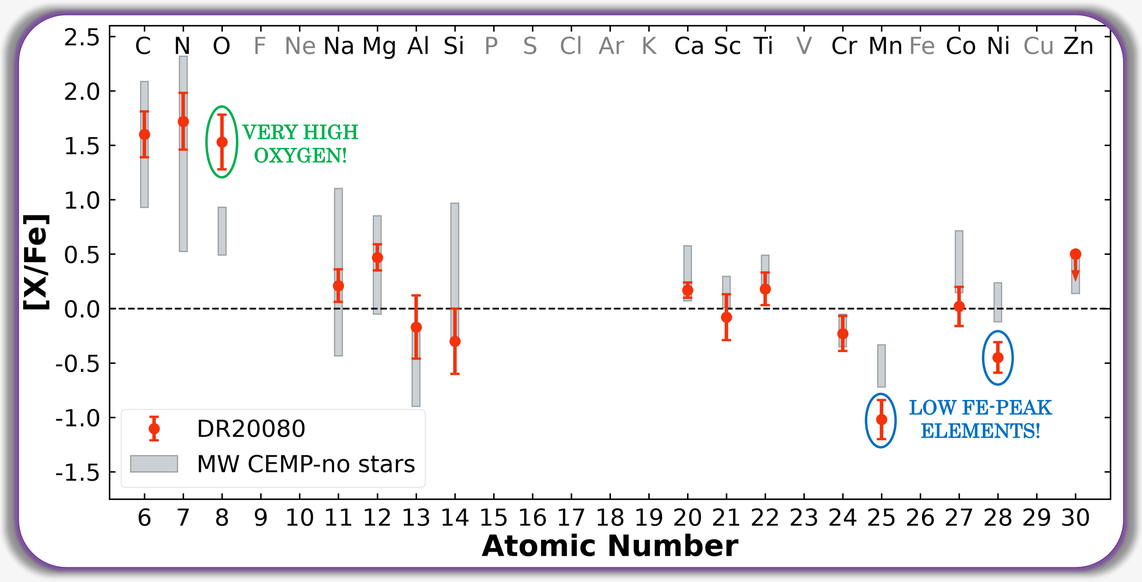
Comparison with other stars

Thanks to these high-quality spectra, we were able to **measure the abundances of 17 elements** (including C, O, Si, Ba, Sr) and the **upper limits of 4 elements** (including Zn and Eu).

One of the most detailed and precise abundance patterns ever obtained for a CEMP-no star in a dwarf galaxy!

DR20080 stands out as an outlier in Sculptor (see right figure), more closely resembling the [C/Fe] of metal-poor stars from UFDs or the MW stellar Halo.
However, **if we compare it with MW CEMP-no stars…**



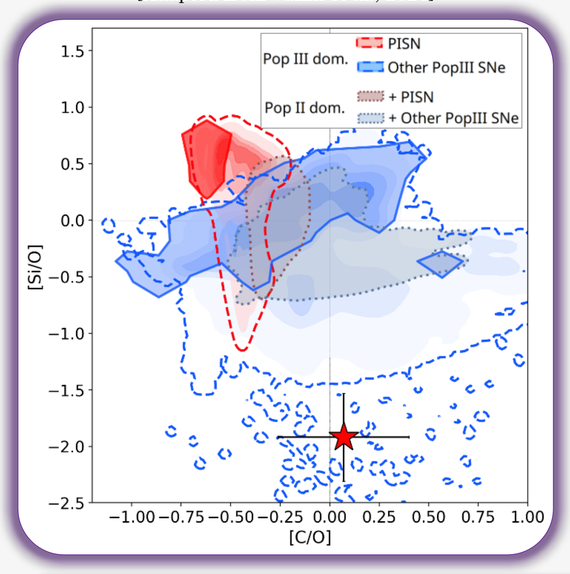


…**clear differences appear**, showing once again that CEMP-no stars in dSphs show peculiar characteristics relative to those belonging to other environments.
The **properties of CEMP-no stars (and thus of their Pop III progenitors) may depend on the formation environment**, although larger samples are needed to confirm this trend.

DR20080: a CEMP-no star with unique properties!

Pop III progenitor(s)

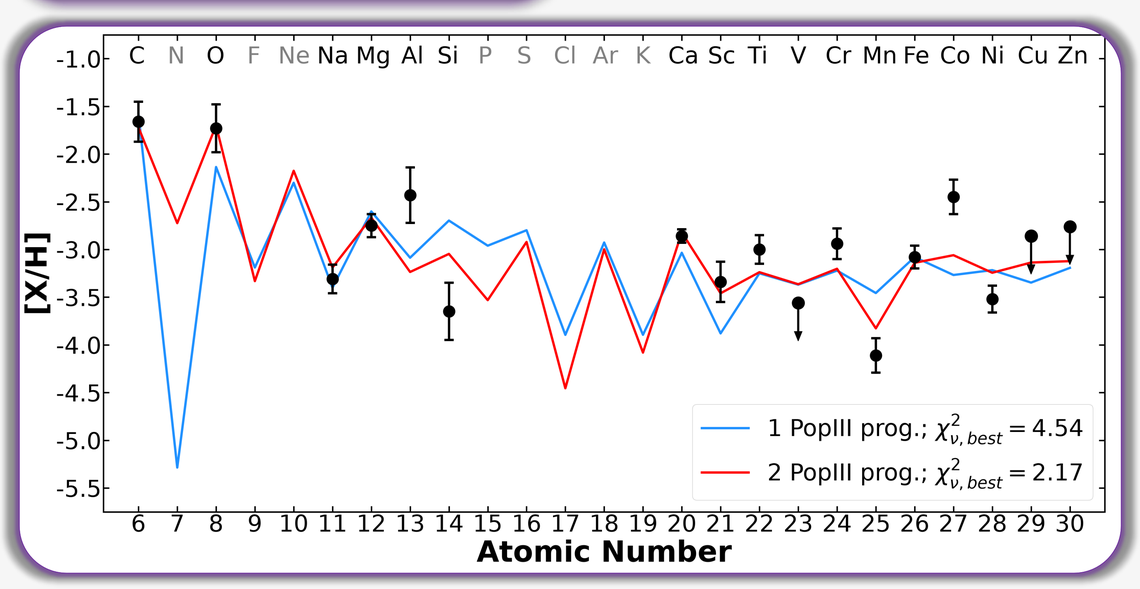
[Adapted from Vanni et al., 2024]



When **comparing with SN yield models**, **DR20080** lies in a chemical space sparsely populated by theoretical yields (see left figure). **Only Pop III models provide a plausible match**.

DR20080 very likely to be a descendant of Pop III stars!

Fitting the full abundance pattern of DR20080 with models considering Pop II and Pop III progenitors, assuming either one or two progenitors (see figure below), favours a **pure Pop III enrichment**, with the **two-progenitor scenario providing the best fit**.



Two Pop III progenitors:
- **95% faint SN: $M_{PopIII} = 43$ M$_\odot$; $E_{SN} = 0.6 \cdot 10^{51}$ erg**
- **5% hypernova: $M_{PopIII} = 19.4$ M$_\odot$; $E_{SN} = 10^{52}$ erg**

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