Early Enrichment Mechanisms of the Heaviest and Lightest Elements

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The Element Patterns in Very Early Stars

The early element pattern is best seen in stars from first Gyr

- Ages hard, but determined from [U/Th] chronology etc.
- These stars are Extremely Metal-Poor (EMP: [Fe/H] $\lesssim$ -3)

⇨ Iron-peak spectral line forest greatly reduced

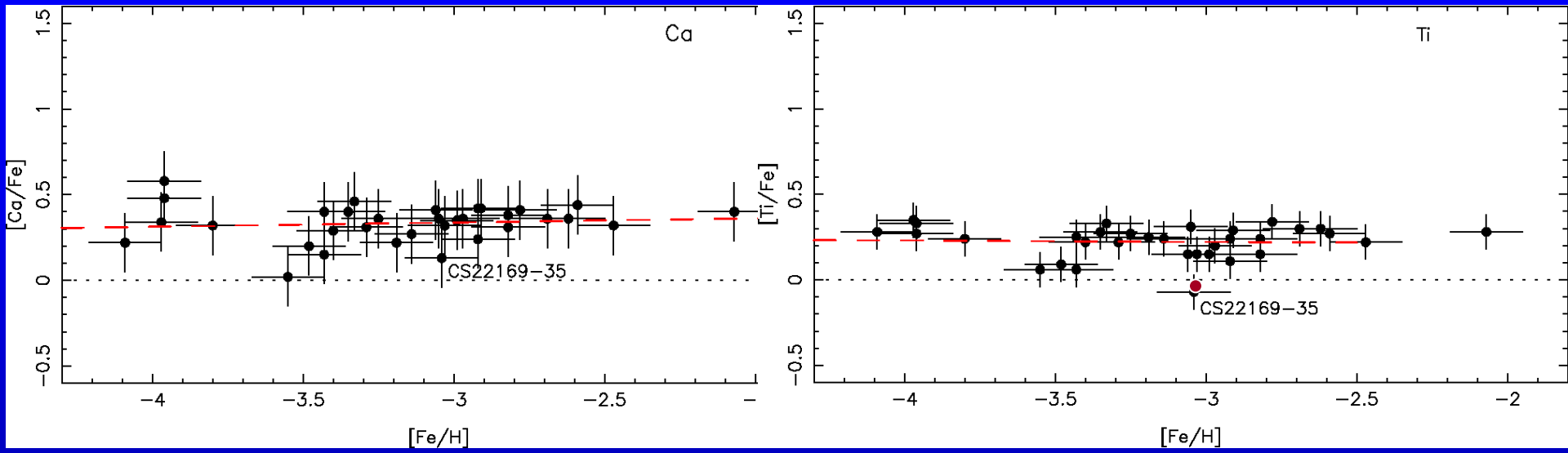
⇨ Significant individual chemical anomalies stand out

- Galactic Archaeology becomes easier

Insight in:

- Structure of and enrichment processes in primitive ISM
- Production sites of key element groups (*r*-process; C)

Results So Far (from VLT/UVES Spectra):



- B^2FH pattern + α-enhancement (< SNe Ia) holds up well
  [X/Fe] ratios have extremely small scatter(!)
- Two prominent element groups stand out:
  - *r*-process elements either (very) strong or weak (~3%)
  - C (strongly!!) enhanced in 20-40% of EMP giants
- What can we learn from this?

(Cayrel et al. 2004++)

r-Elements: Enhancements *and* Deficiency

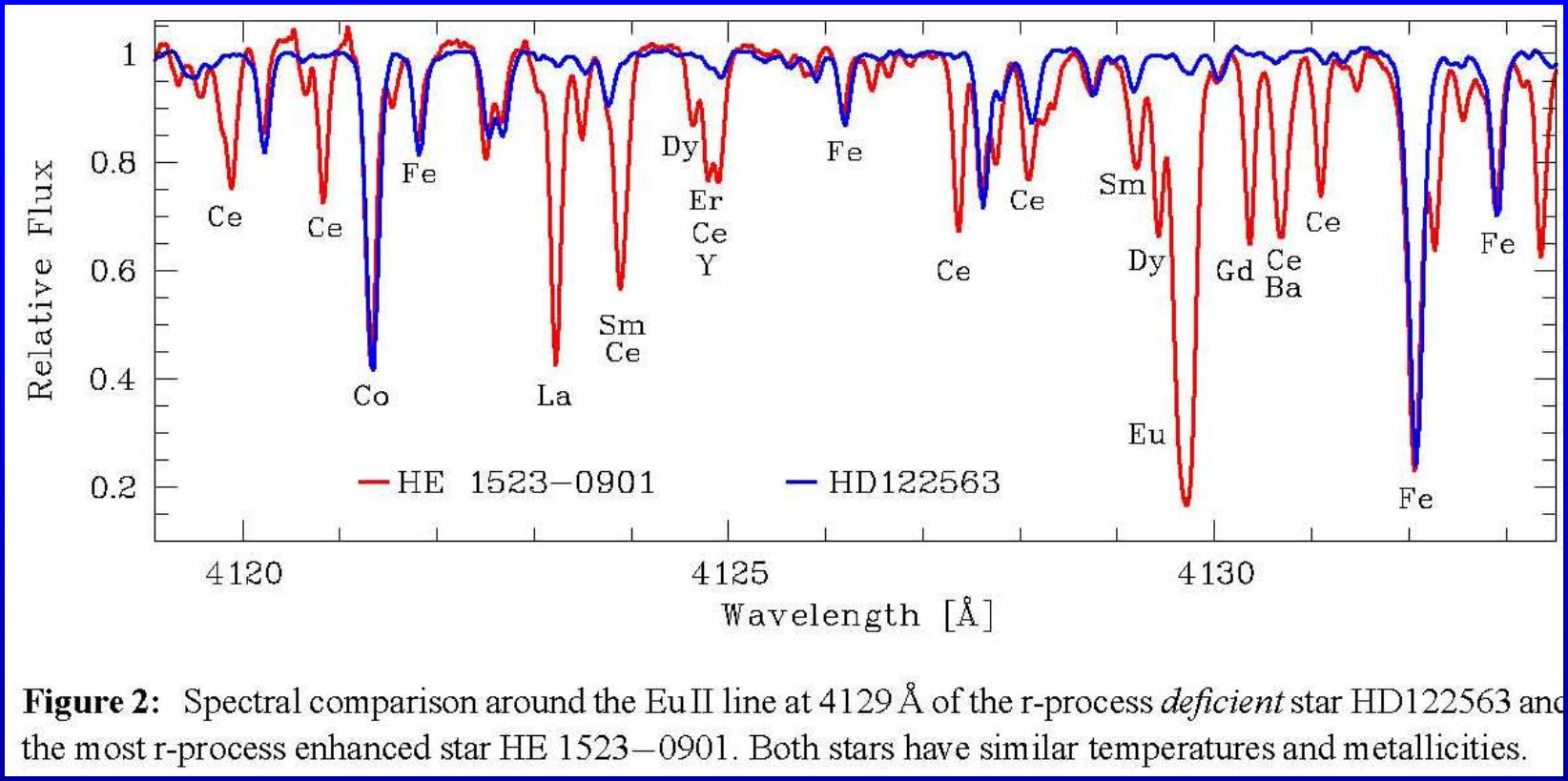


Figure 2: Spectral comparison around the Eu II line at 4129 Å of the r-process *deficient* star HD122563 and the most r-process enhanced star HE 1523−0901. Both stars have similar temperatures and metallicities.

(Frebel+ 2007)

Alternative explanations:

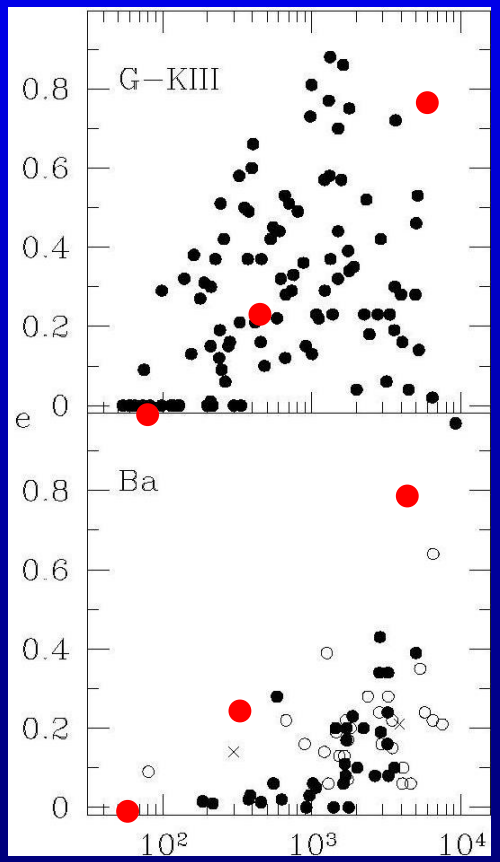
Intrinsic: Surface was polluted by binary companion (but deficiency??)

Extrinsic: Spotty enrichment of parental cloud by distant sourcd

Key to answer: Precise long-term RV monitoring w. FIES@NOT

14 r-I and II Stars are Single; 3 (17%) are SB

Binary frequency is completely normal
Orbital properties like open cluster dGK



P-*e* diagram:

Pop I giant SBs

Ba/CH/S stars:

SBs for $P > 200$d

e=0 for $P \lesssim 10^3$d

CEMP-no & CEMP-s Binary Properties

CEMP-no stars: Normally *single!*

Orbital phase

CEMP-s stars: Normally/all binaries, but the jury is out for another 20-30 years(!)

THANK YOU !

Points for Discussion:

- How could the early halo ISM be so clumpy when the detailed chemical composition is so uniform in general?
- Is the different SF histories of dSph galaxies a solution?
- Can very early EMP AGB stars have produced the C seen in DLA systems from early galaxy disks (*s*-element production; stellar lifetimes @ z ~ 2-3)?
- What progress to expect from Gaia distances & velocities?
- What are the spectral diagnostics of *r*-process nucleosynthesis in SNe II with jets vs. runaway merged NS-NS binaries?
- What are the diagnostics of C production in spinning massive zero-metal stars vs. 'faint' SNe II with fallback & mixing?