HALO STAR ABUNDANCES AND HEAVY ELEMENT NUCLEOSYNTHESIS

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In celebration of Wolfgang's 60th birthday.

Abundance Clues and Constraints

- New observations of n-capture elements in low-metallicity Galactic halo stars providing clues and constraints on:
  1. Synthesis mechanisms for various elements
  2. Suggestions on sites, particularly site or sites for the r-process
  3. Galactic chemical evolution

Most Likely Site(s) for the r-Process

- Supernovae: The Prime Suspects

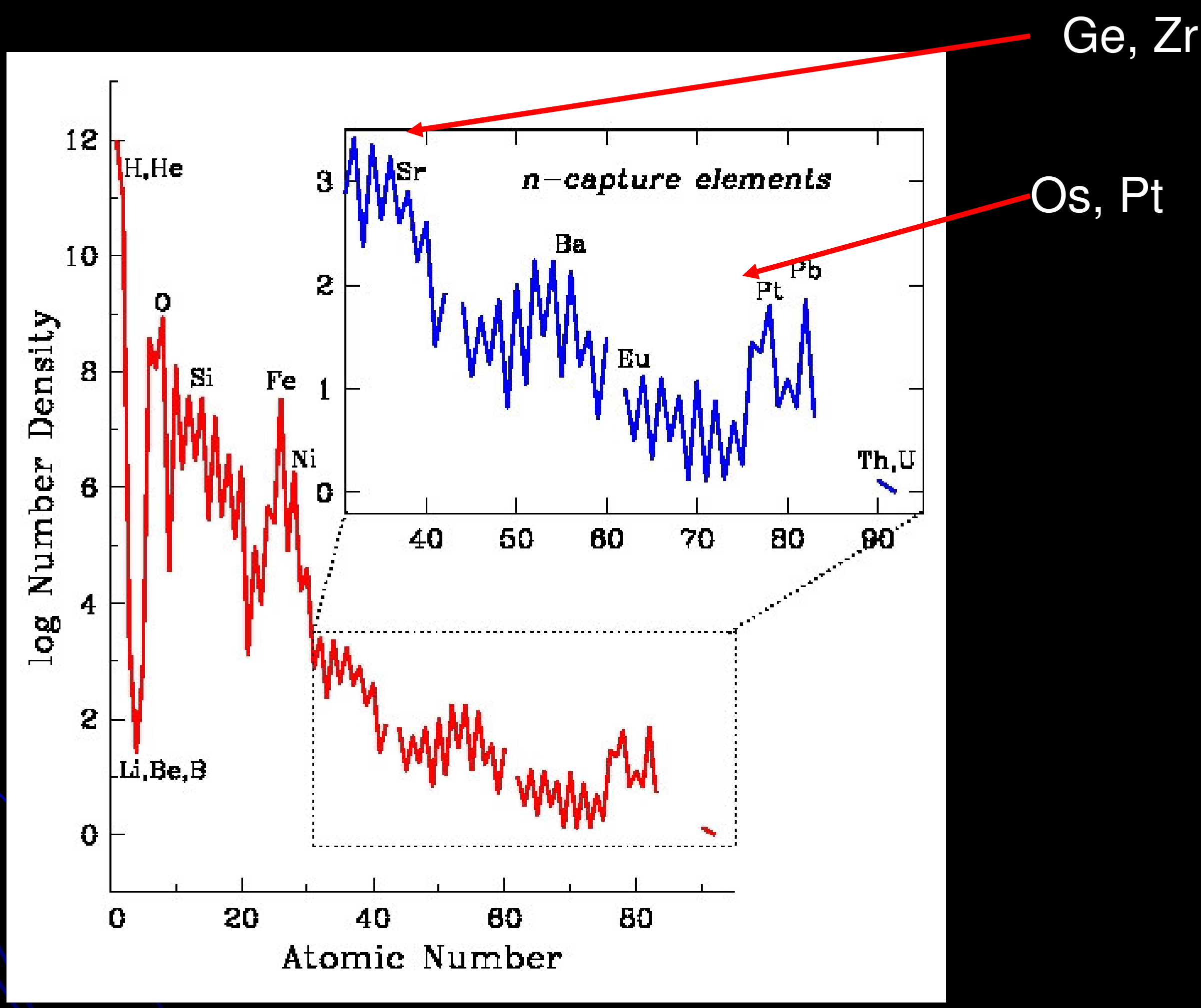
  → Regions just outside neutronized core: (Woosley et al. 1994; Wanajo et al. 2002)

  → Prompt explosions of low-mass Type II SNe (Wheeler, JC, Hillebrandt 1998)

  → Jets and bubbles (Cameron 2001)

- NS & NS-BH mergers (Rosswog et al. 1999; Freiburghaus et al. 1999)

Solar System Abundances



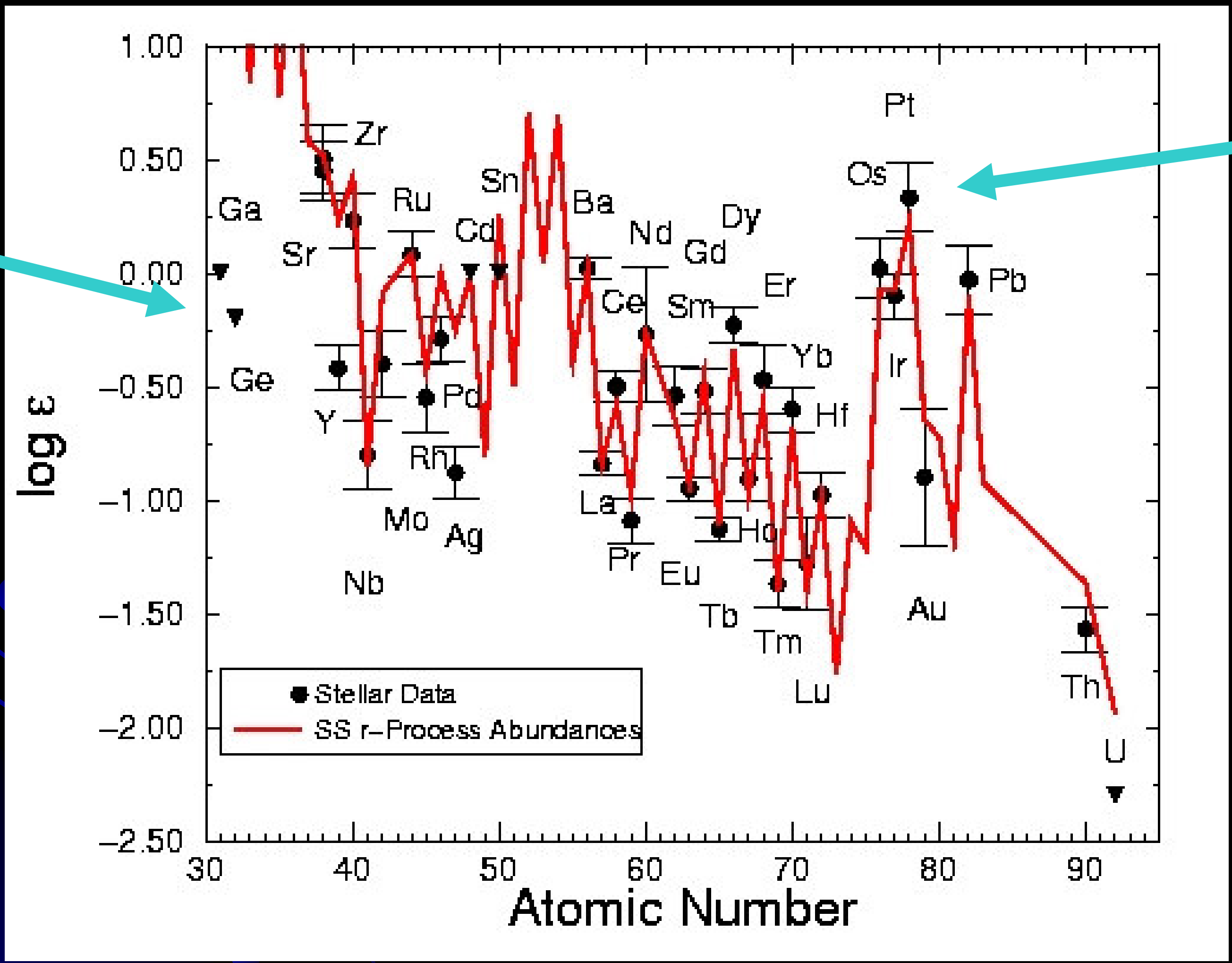
Sneden & JC (2003)

CS 22892-052 Abundances

Sneden et al. (2003)

Germanium

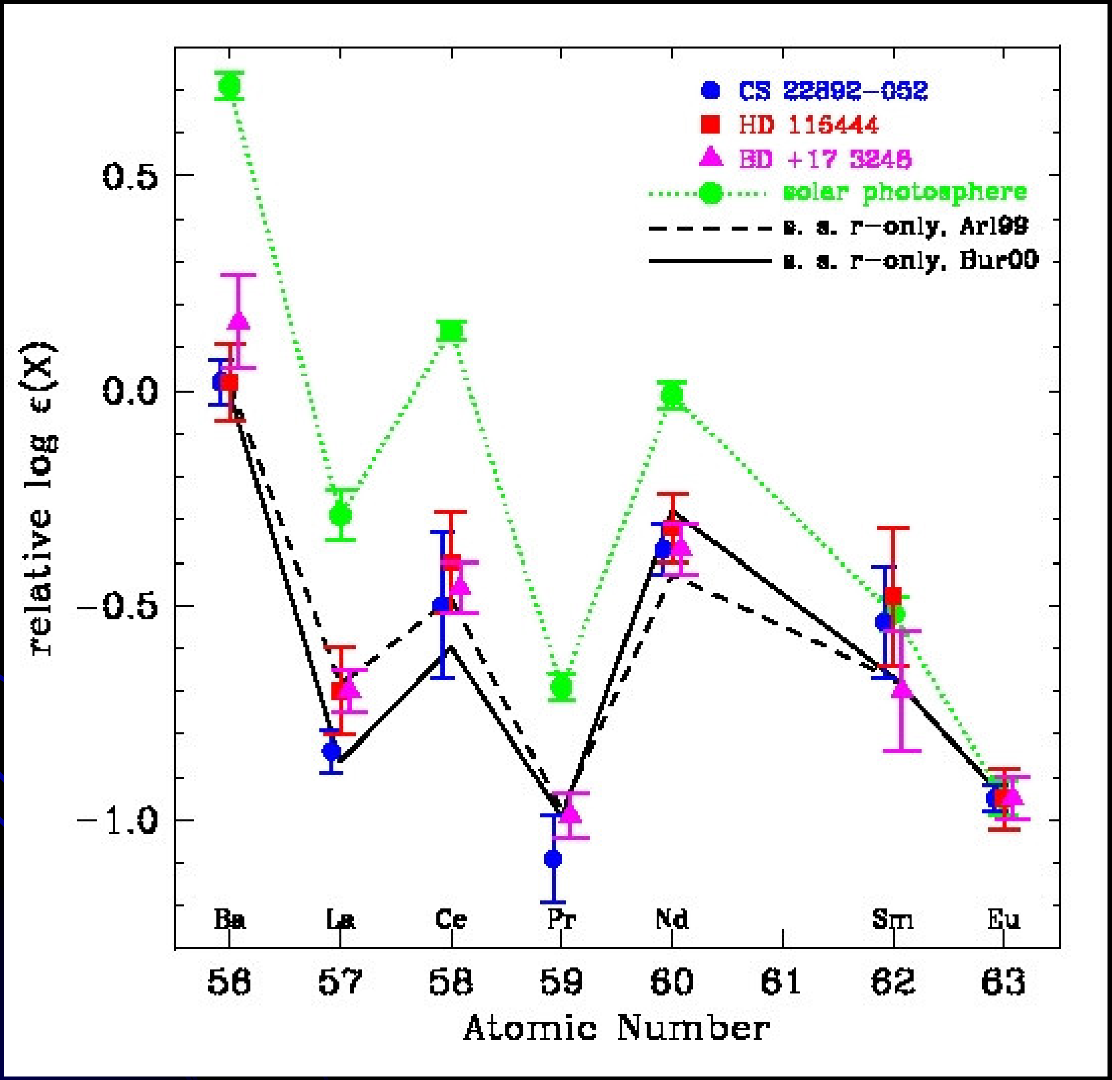
Platinum



57 elements observed. More than any star except the Sun.

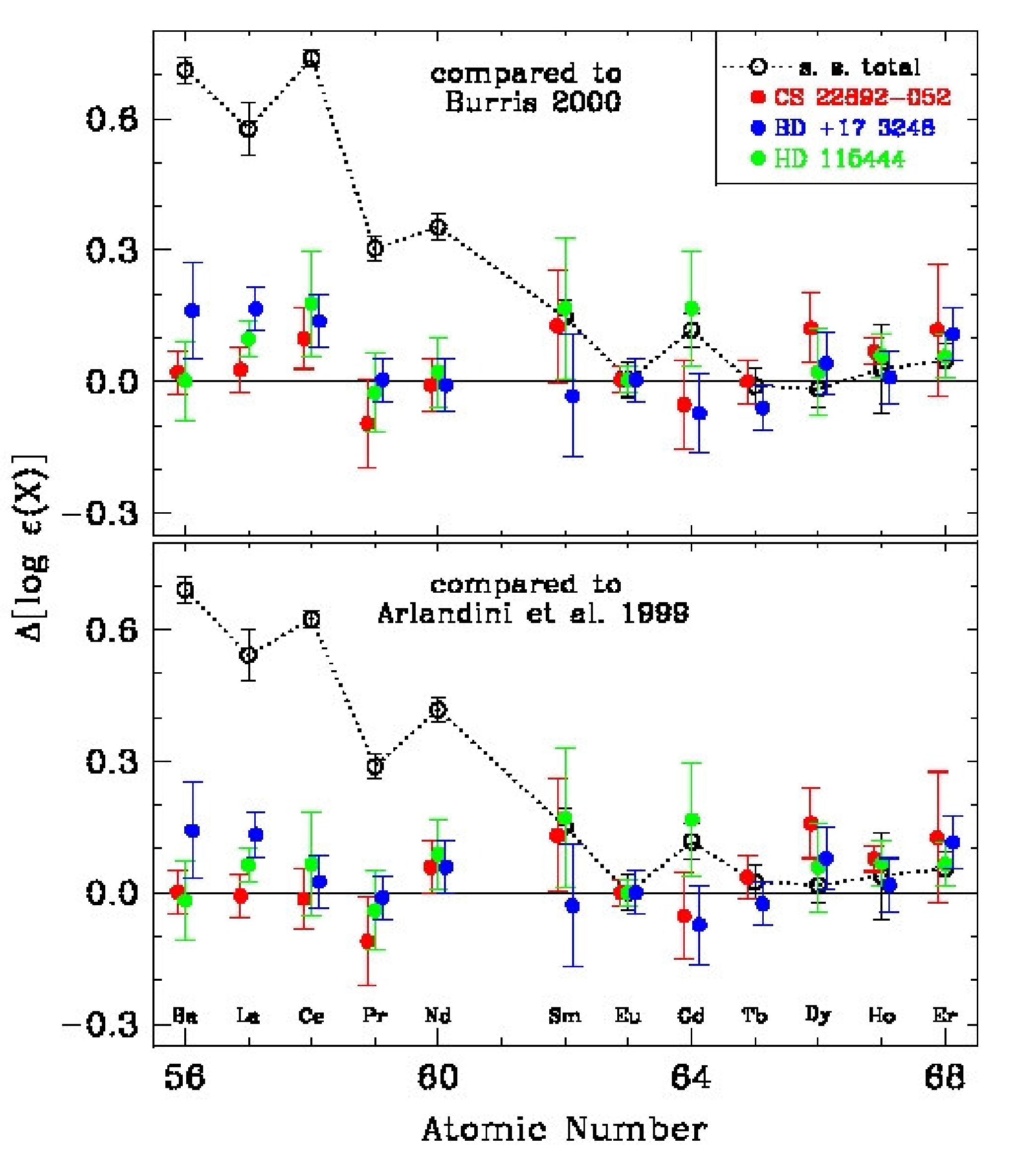
$$\text{Log } \varepsilon(A) = \log_{10}(N_A/N_H) + 12$$

Focus On Individual Elements: Nd



New experimental atomic physics data.
Den Hartog et al. (2003).

Focus On Individual Elements: Ho

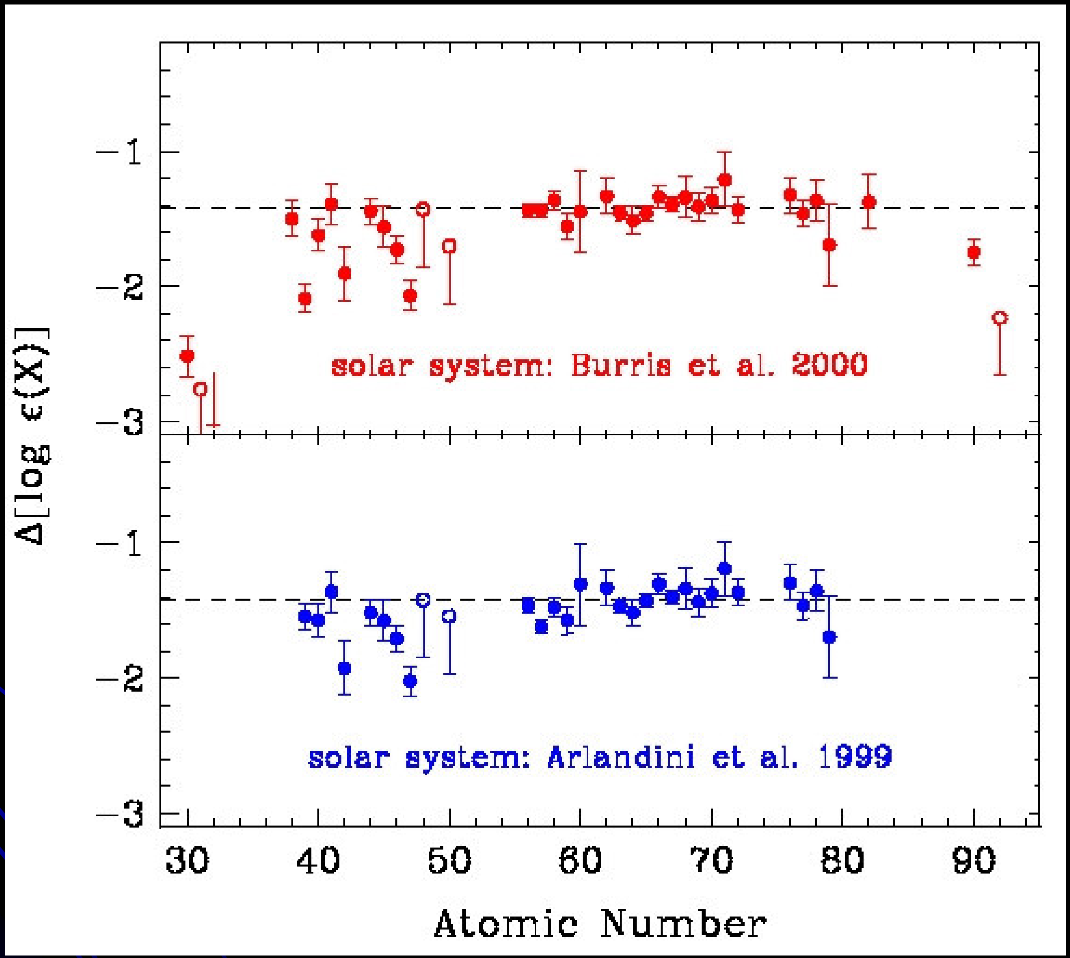


New experimental atomic physics data. Lawler et al. (2004).

Working our way through the Periodic Table!

CS 22892-052: n-Capture Element Abundance Distribution

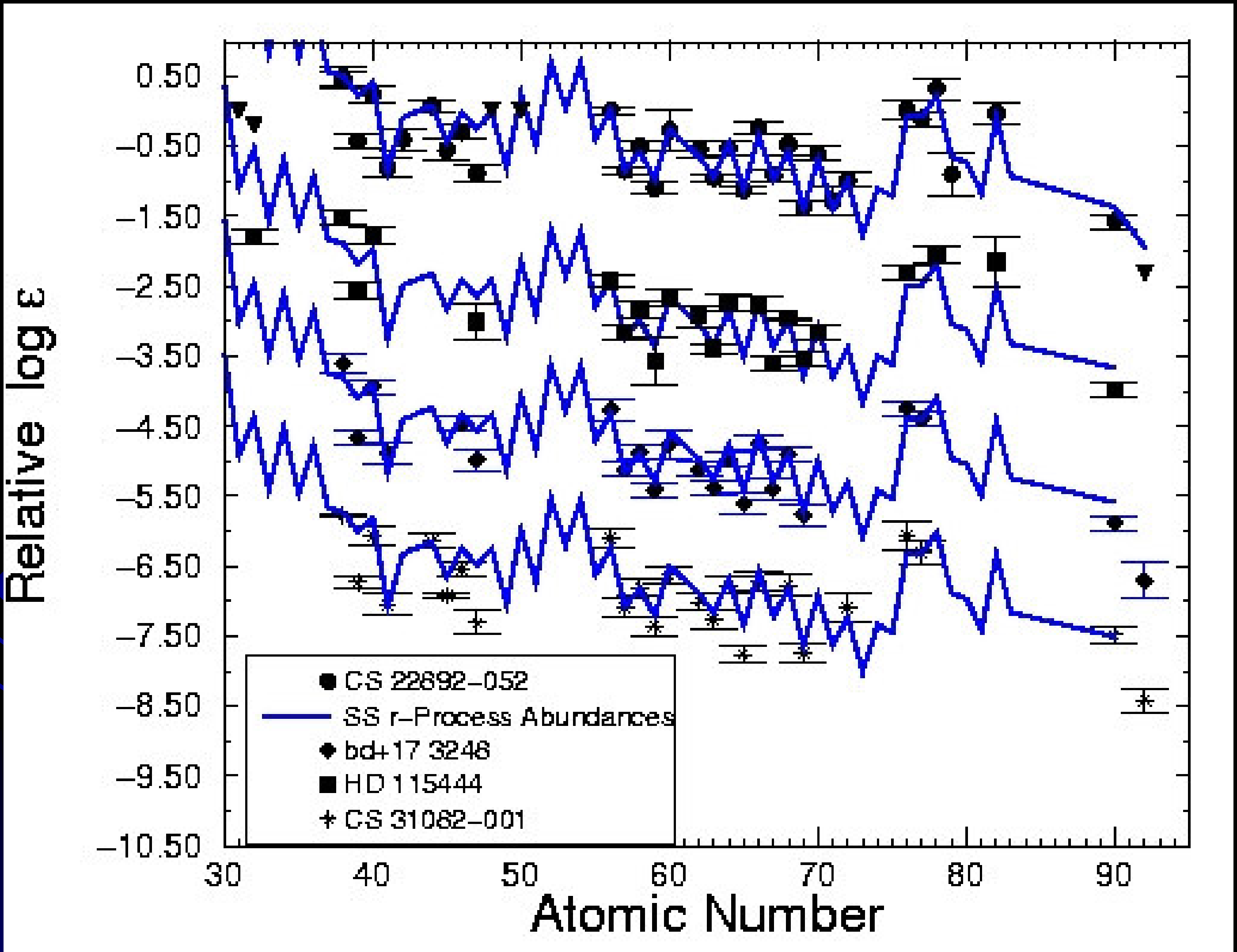
Lower end



Upper end

Sneden et al. (2003).

Halo Star Abundances



4 r-process rich stars

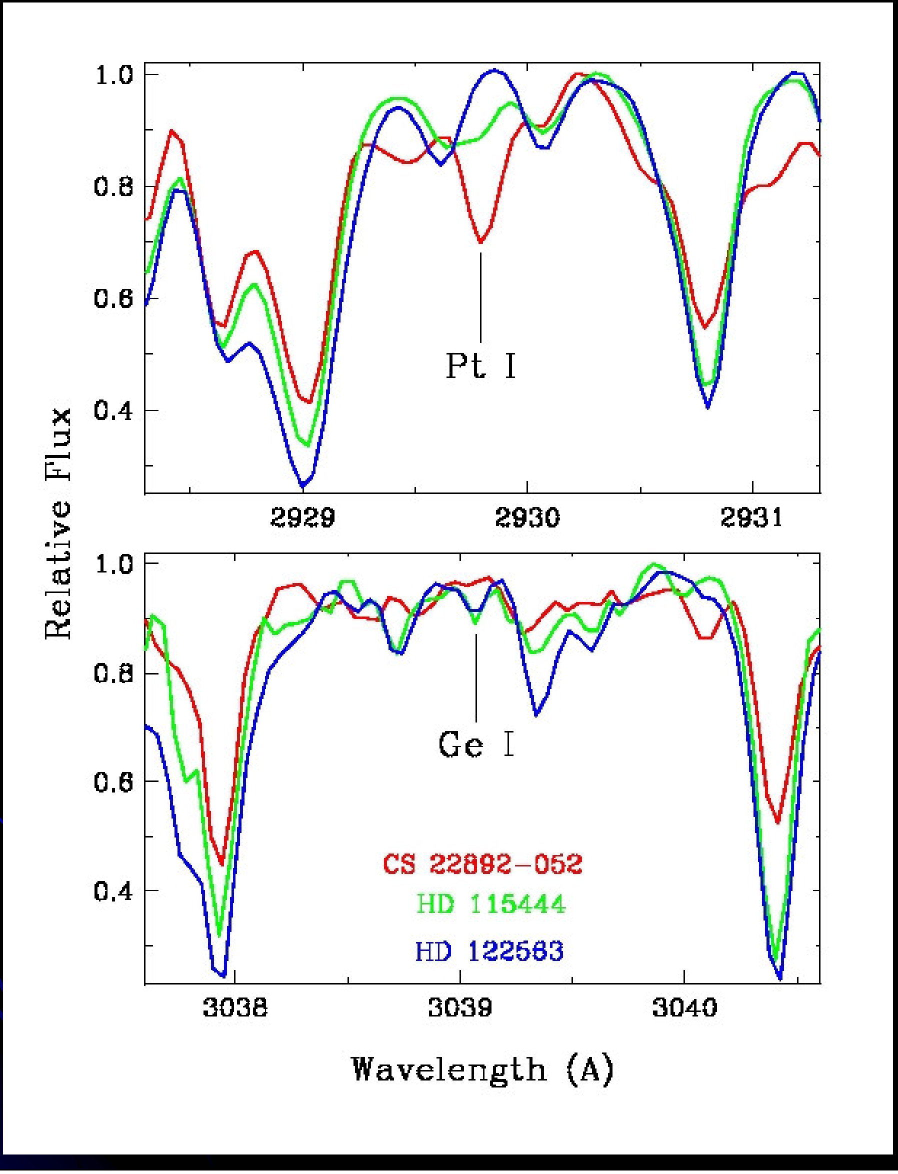
Light n-Capture Elements: Evidence for a Second r-process ?

- Only recently any detections of elements, Z = 40-50
  → Best evidence CS 22892-052
- Heavier element (Z ≥ 56) abundances seem to follow SS r-process curve, not so for the lighter elements
  → Same pattern appears in several other r-process rich stars
- Two separate sites (Wasserburg, Busso & Gallino): strong and weak r-process (2 types of SNe or SNe and NS mergers) or
- One site (different epochs or regions)

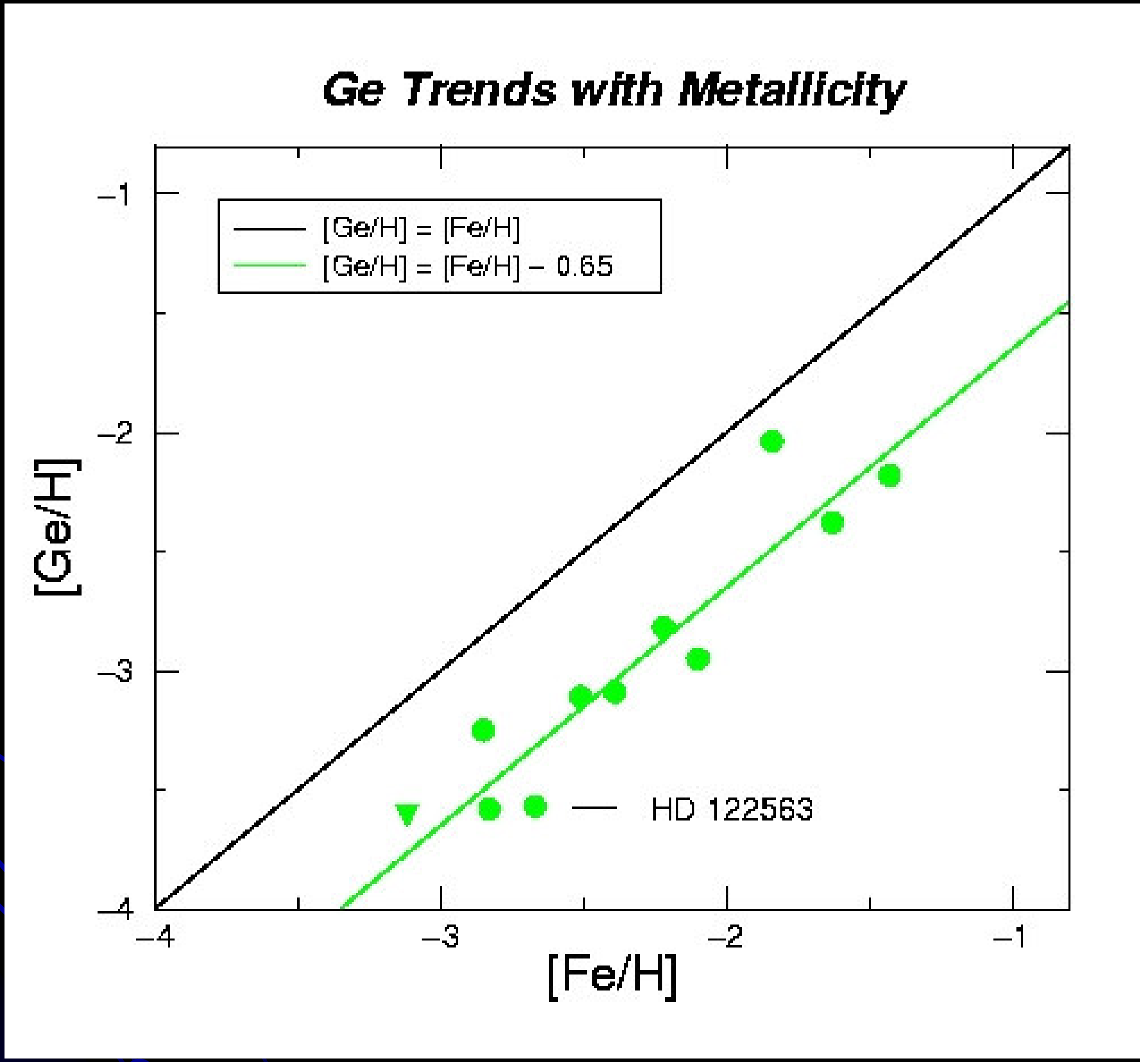
New HST Abundance Observations

- Dominant transitions for elements such as Ge, Os and Pt in NUV requires HST
- New abundance determinations of these elements (and Zr) in 11 metal-poor halo stars
- Attempt to identify abundance trends and correlations

NUV HST STIS Spectra



Ge Abundances in Halo Stars

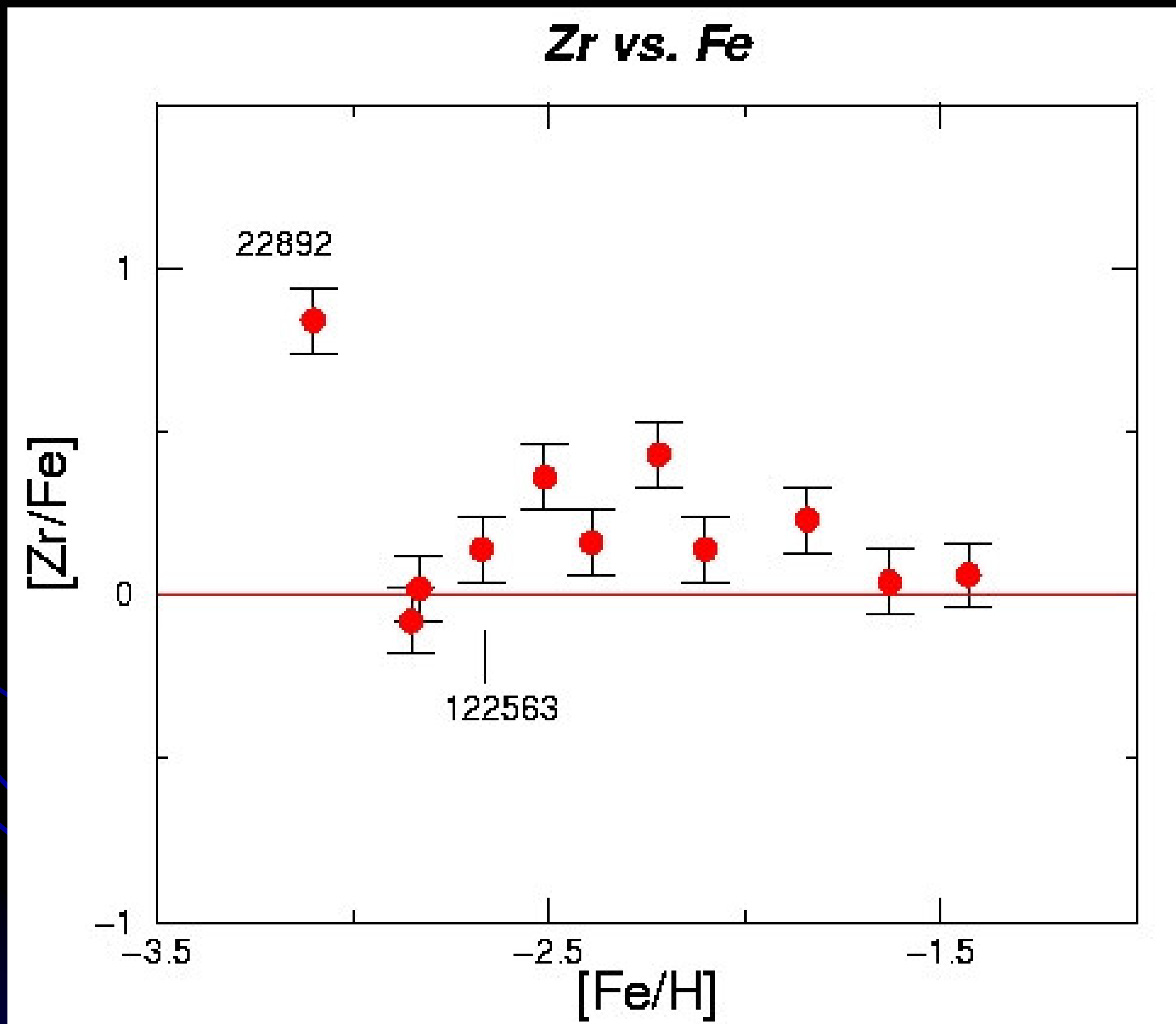


Ge ∝ Fe

JC et al. (2004)

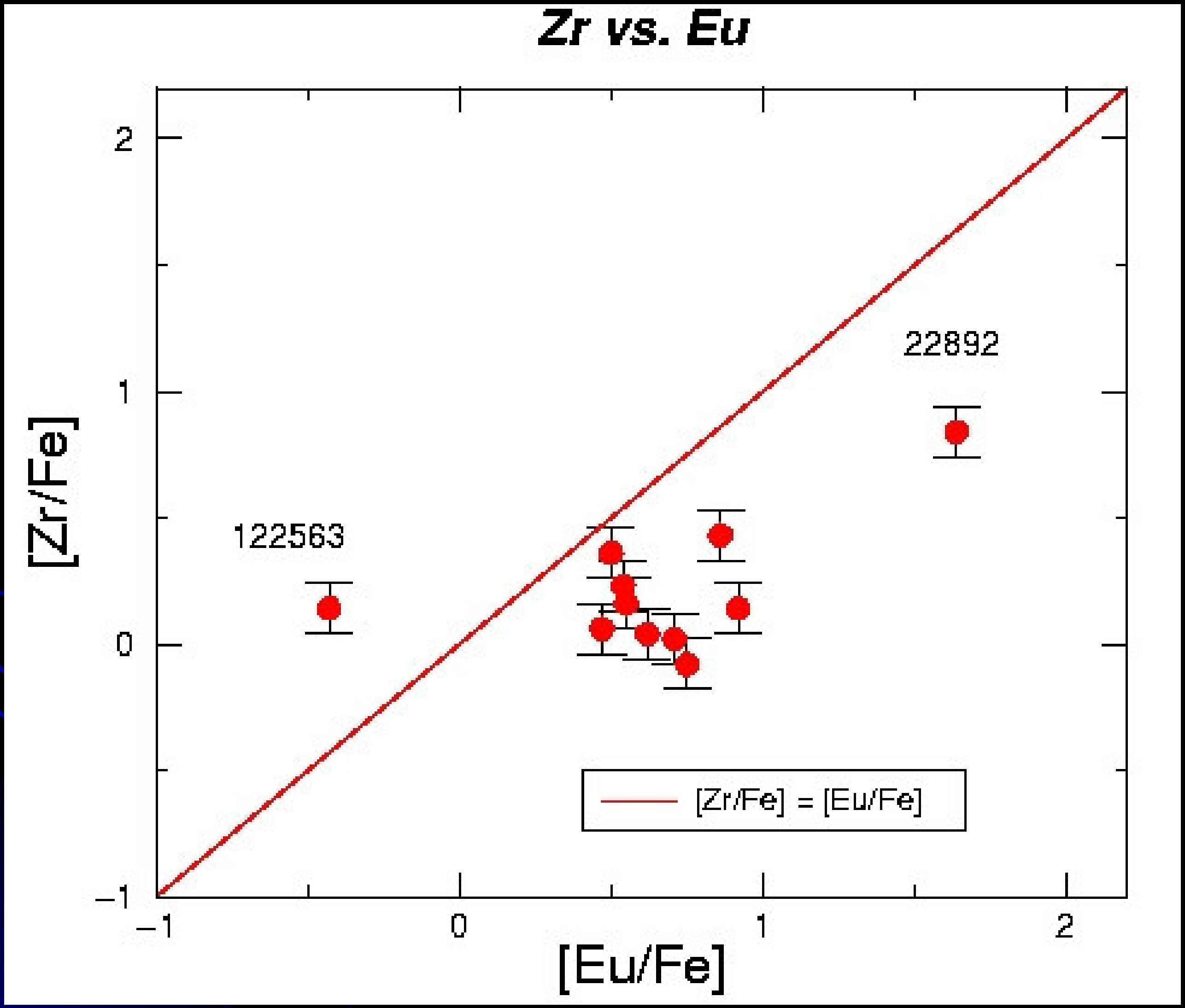
$$[A/B] = \log_{10}(A/B)_{star} - \log_{10}(A/B)_{sun}$$

Zr as a Function of Metallicity



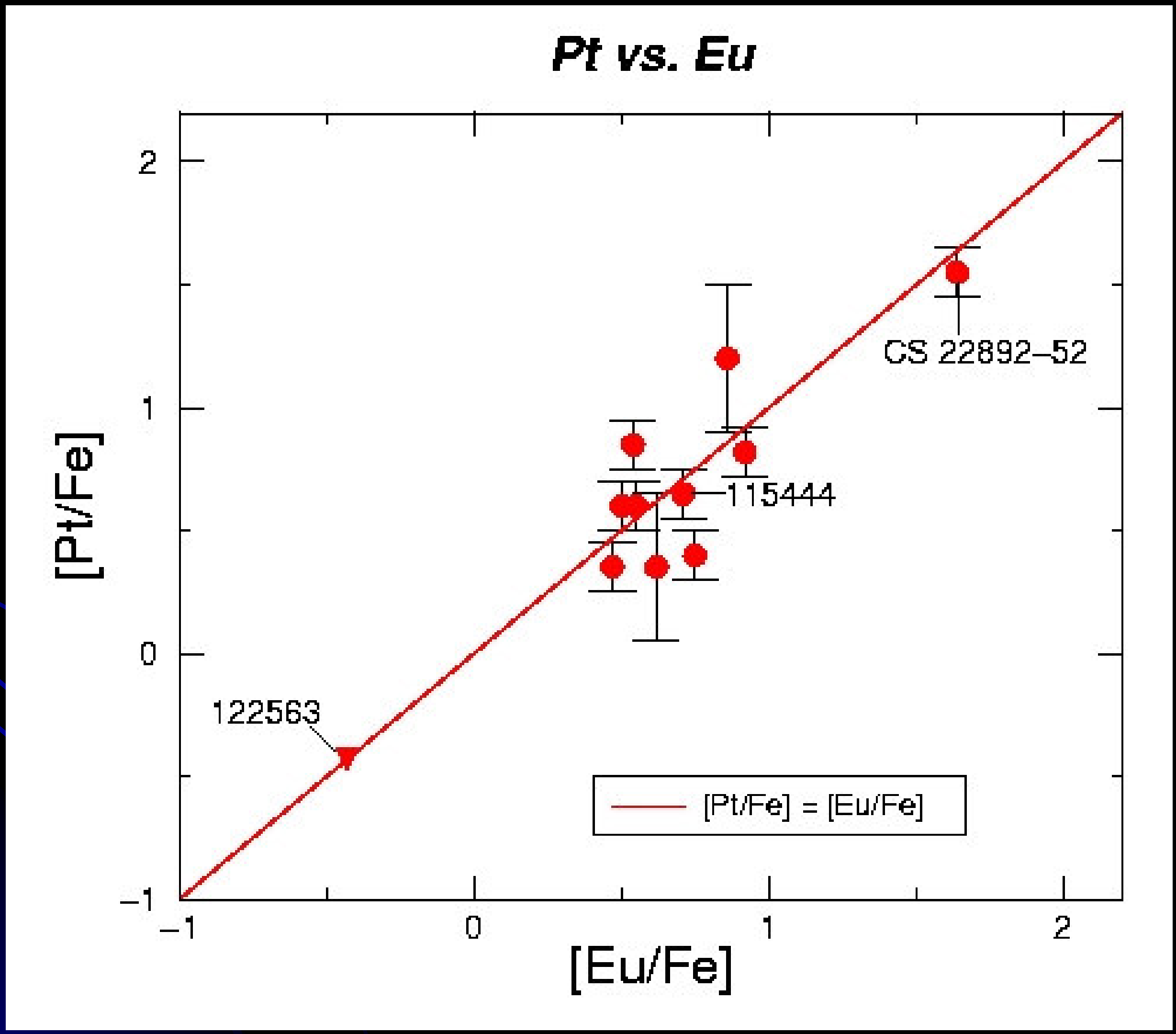
Zr independent of [Fe/H], as shown already by Travaglio et al. (2004).

Zr and Eu Abundances in Halo Stars



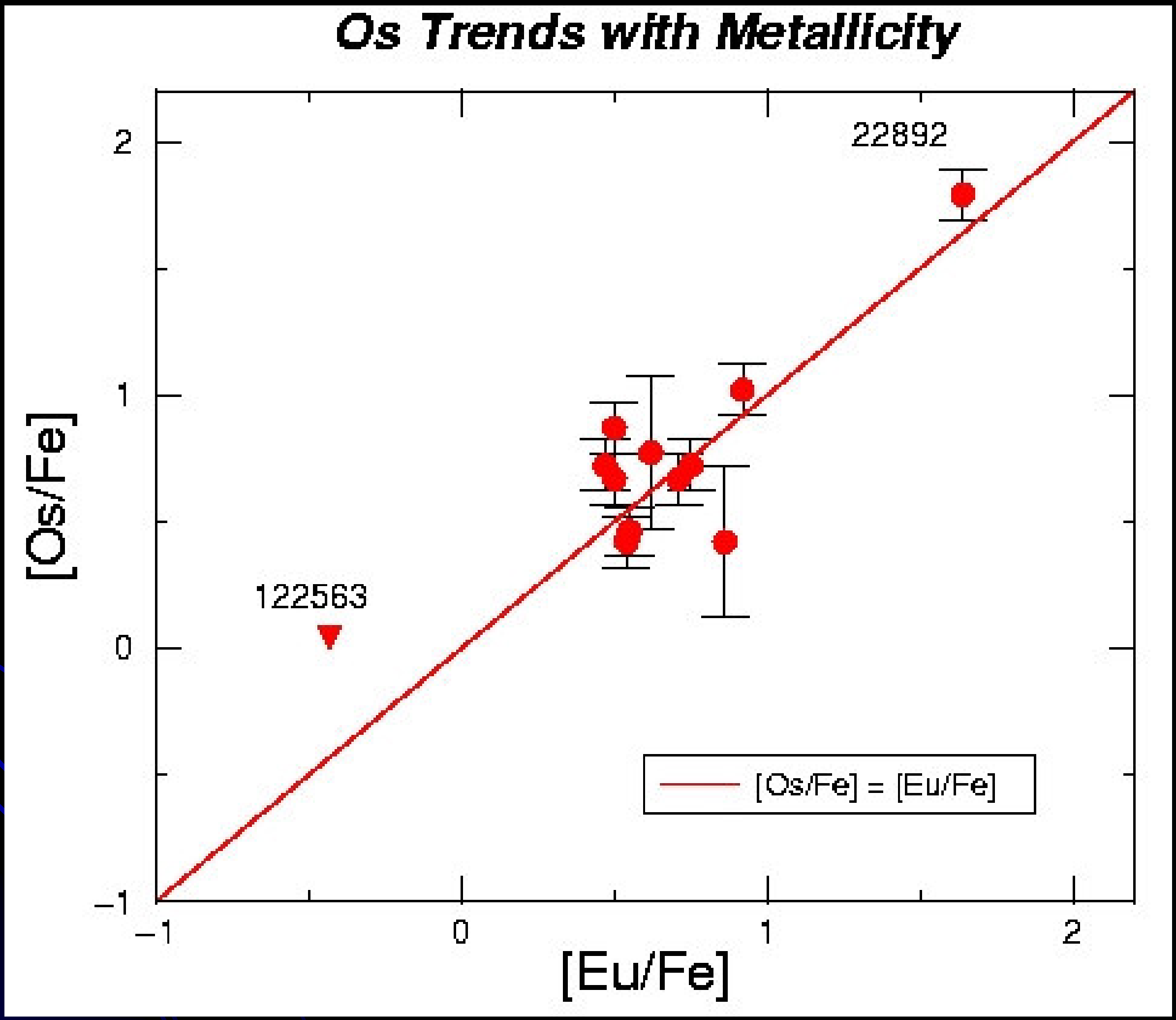
Zr $\not\propto$ Eu

N-Capture Element Correlations



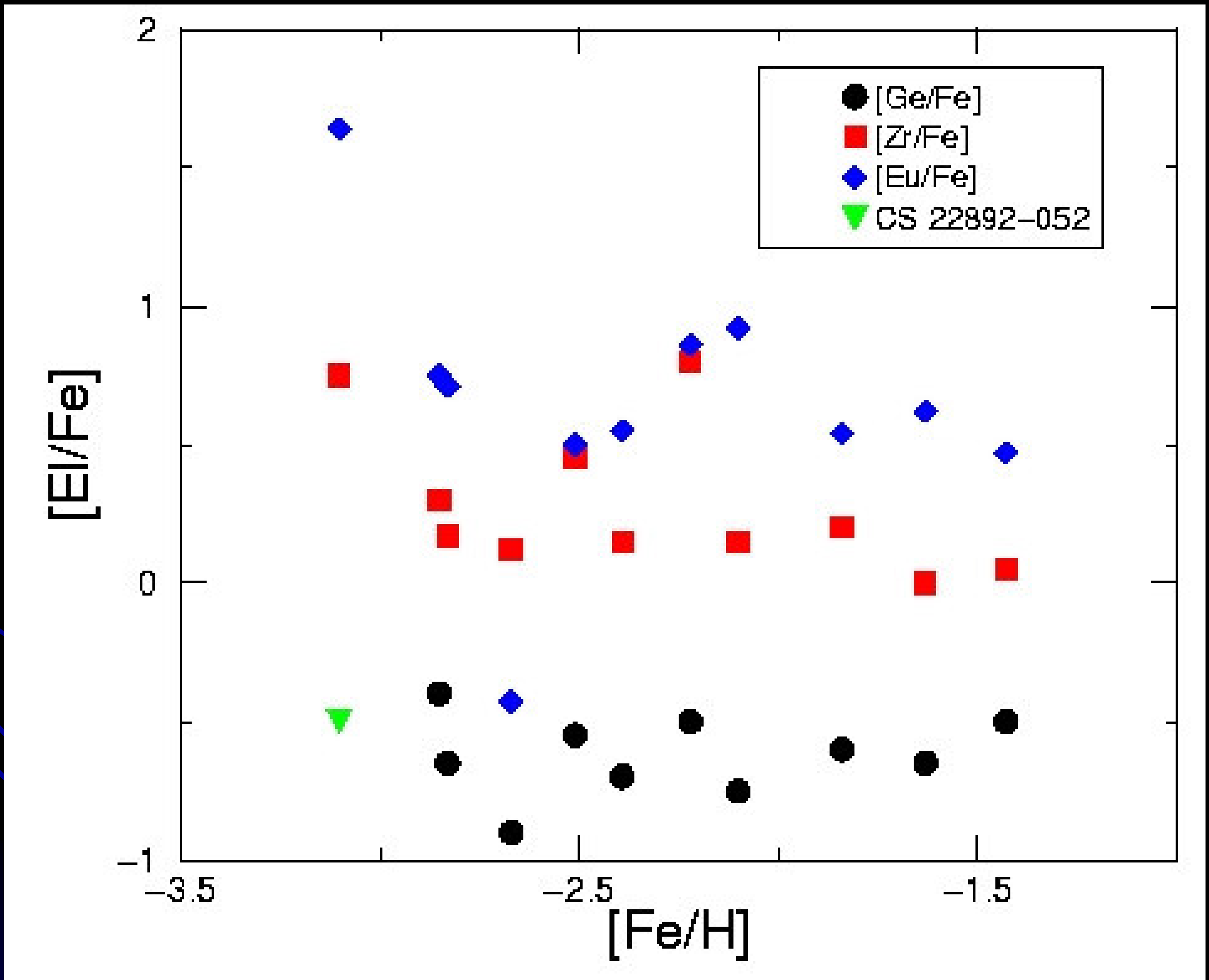
Pt ∝ Eu

N-Capture Element Correlations

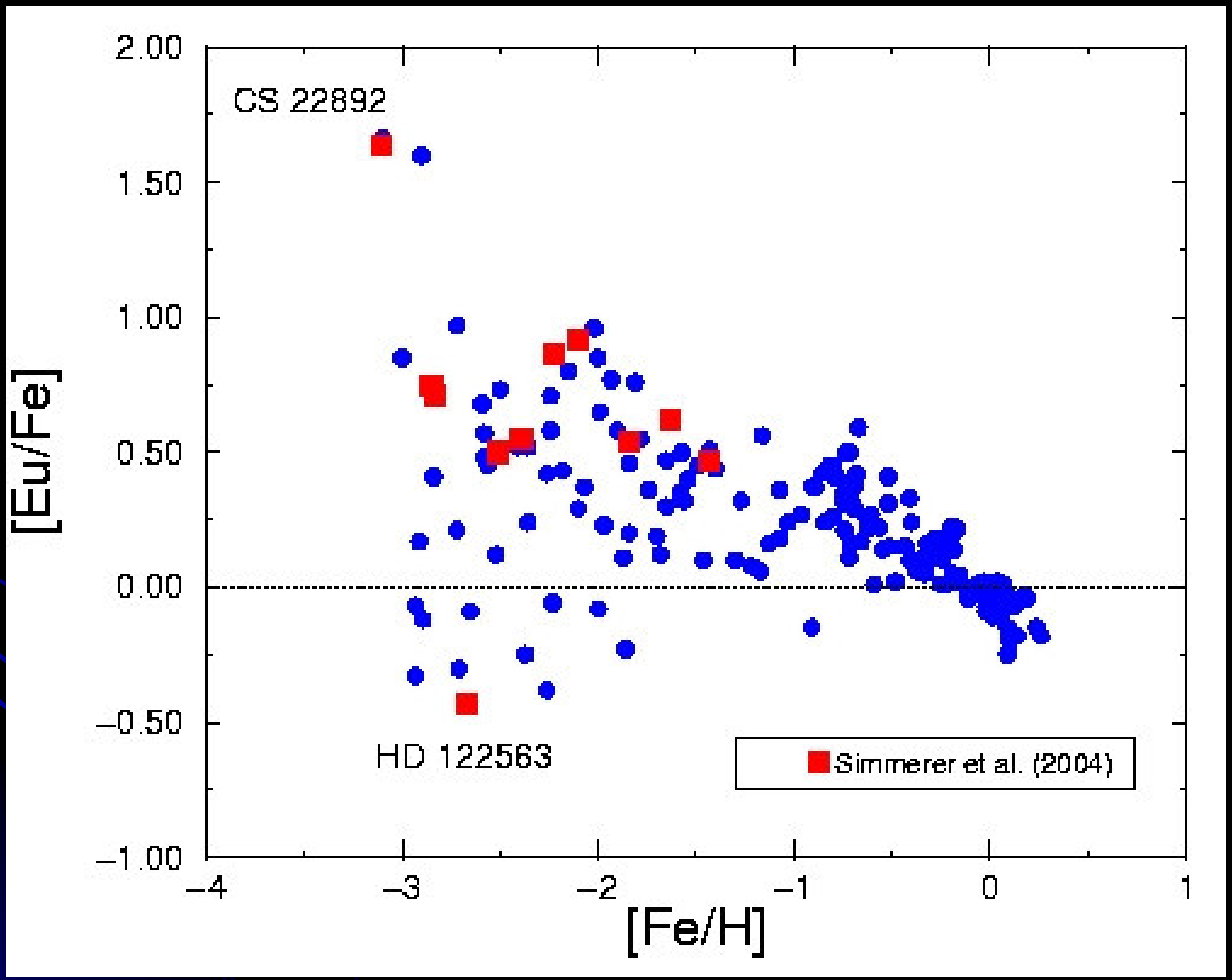


Os ∝ Eu

N-Capture Element Abundance Trends

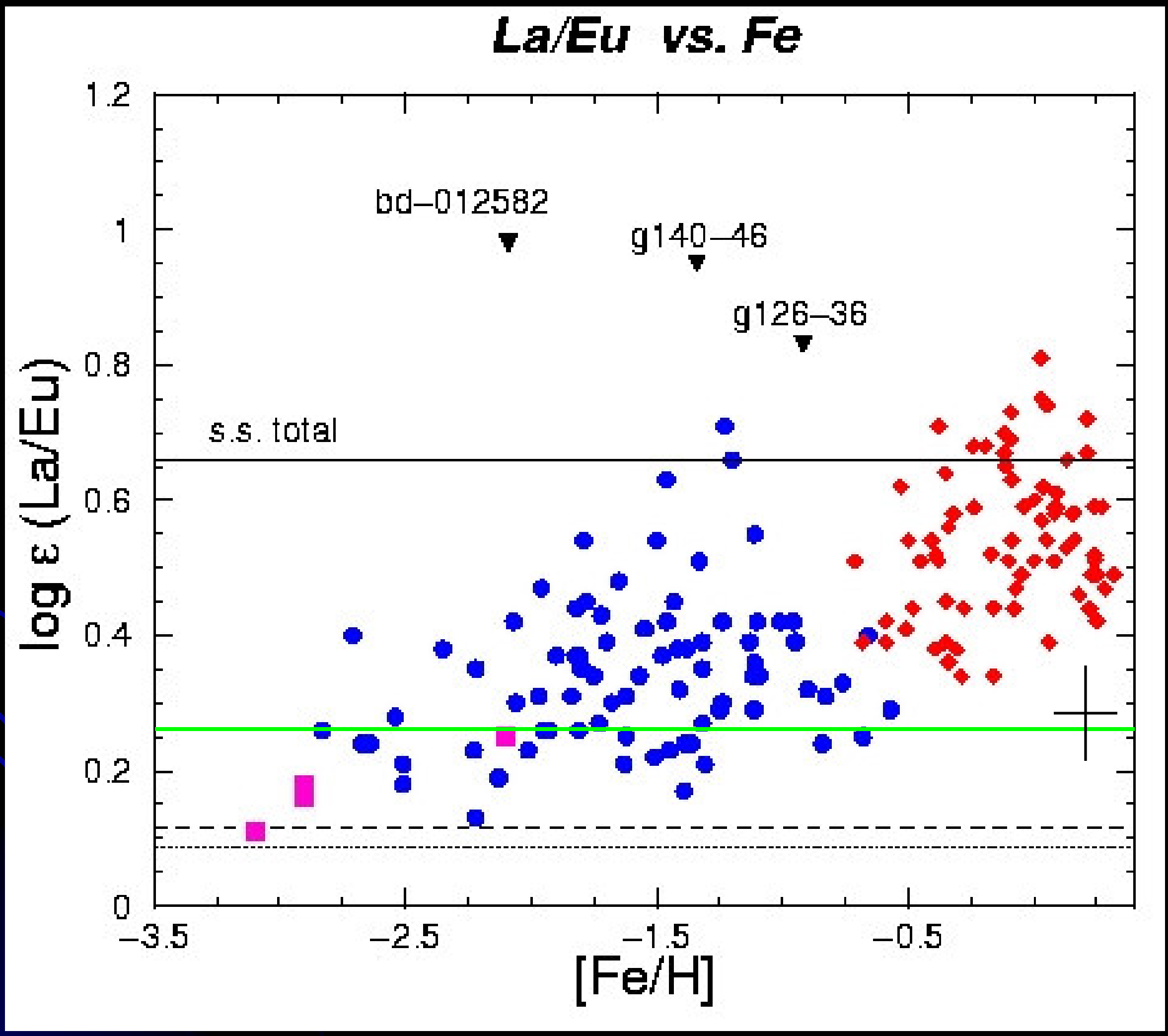


Eu Abundance Scatter in the Galaxy



R- and S-Process Abundance Trends

Simmerer et al. (2004)



O'Brien et al. (2003)

Burris et al. (2000)

r-process only

Some Concluding thoughts on: Element Synthesis

- Ge, thought of as an n-capture element, appears to be correlated with Fe
- Zr (like Sr & Y) complicated:
  - → not correlated with metallicity or with heavier n-capture element abundances
  - → (not same origin as Eu), some primary

    Ask Claudia and Roberto to explain!
- Element abundances from Z = 40-50 may be uniform in r-process rich stars, but below upper end
- Pt & Os correlated with Eu abundances

Some Concluding Thoughts on: Abundance Trends in the Galaxy

- New Eu abundance values confirm early [Eu/Fe] scatter at low metallicity
- New La/Eu ratios more reliable than Ba/Eu:

1. Show scatter
2. Only most metal-poor stars show r-process only ratio
3. Stresses importance of nuclear measurement
4. Some “dusting” of s-process even at [Fe/H] < -2 ?