The Texas/Wisconsin/Oklahoma Early Galactic Nucleosynthesis Program

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in collaboration with many stellar observers, stellar interiors theorists, lab spectroscopists, Galactic evolution modelers

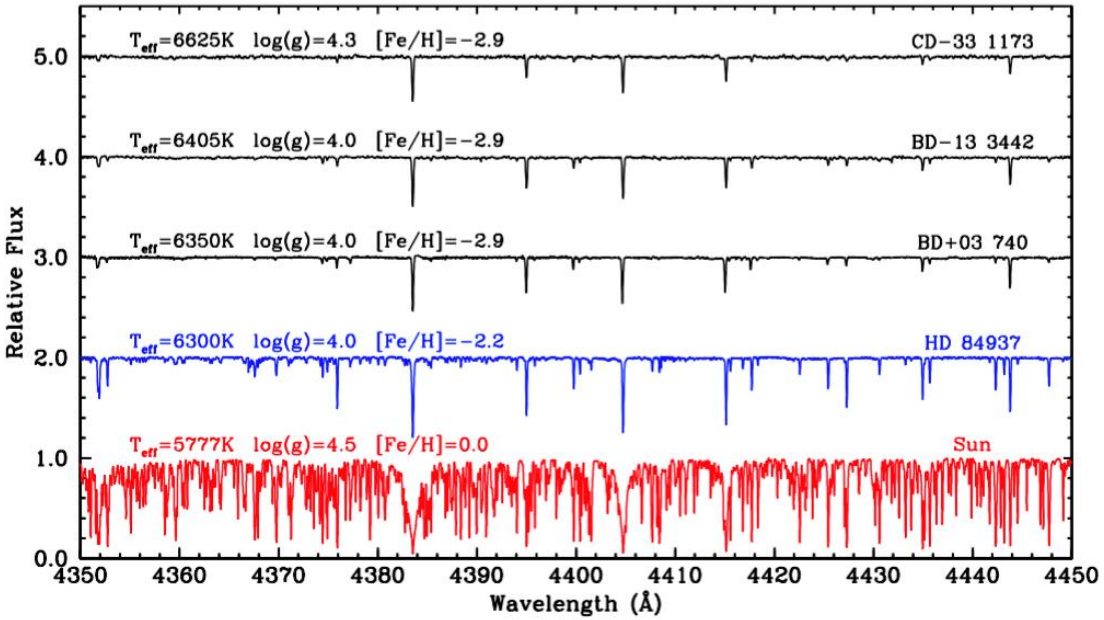
especially Ian Roeder (U Michigan), Tim Beers (Notre Dame), Ann Boesgaard (U Hawaii), Anna Frebel (MIT) …

“No field of science places higher demand on the quantity and accuracy of atomic data than astrophysics” (Nave+2019)

The Texas/Wisconsin/Oklahoma Early Galactic Nucleosynthesis Program

- Featuring spectroscopic analyses of Galactic Halo low-metallicity stars
- Our goal is *NOT* to get good abundances in large stellar samples
- Instead, we want very accurate abundances in a few carefully chosen stars
- Our results should serve as anchors to the large-sample surveys
- To accomplish this, we need:
    - excellent high-resolution spectra covering 2000Å – 1μm
    - good model stellar atmospheres & line analysis techniquge
    - accurate line parameters for:
        - neutral and singly-ionized atoms
        - diatomic molecules
        - including transition probabilities, hyperfine/isotopic substructures
        - preferably laboratory data more than theoretical computations

Good spectra of Low-Metallicity Halo Stars?



optical region:

ground-based spectra from 3100–9000 Å

R = $\lambda/\Delta\lambda \gtrsim$ 40,000

S/N > 100

observational challenge: detection of lines

vacuum ultraviolet region:

HST/STIS spectra from 1800–3050 Å

more commonly 2300–3050 Å

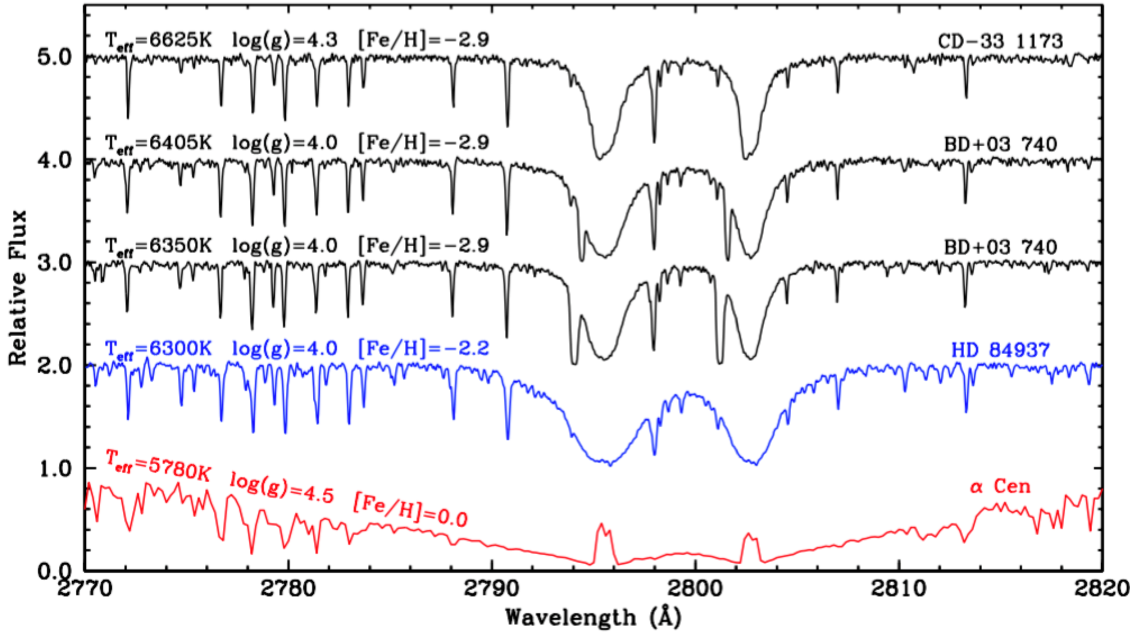
R = $\gtrsim$ 30,000

S/N > 100

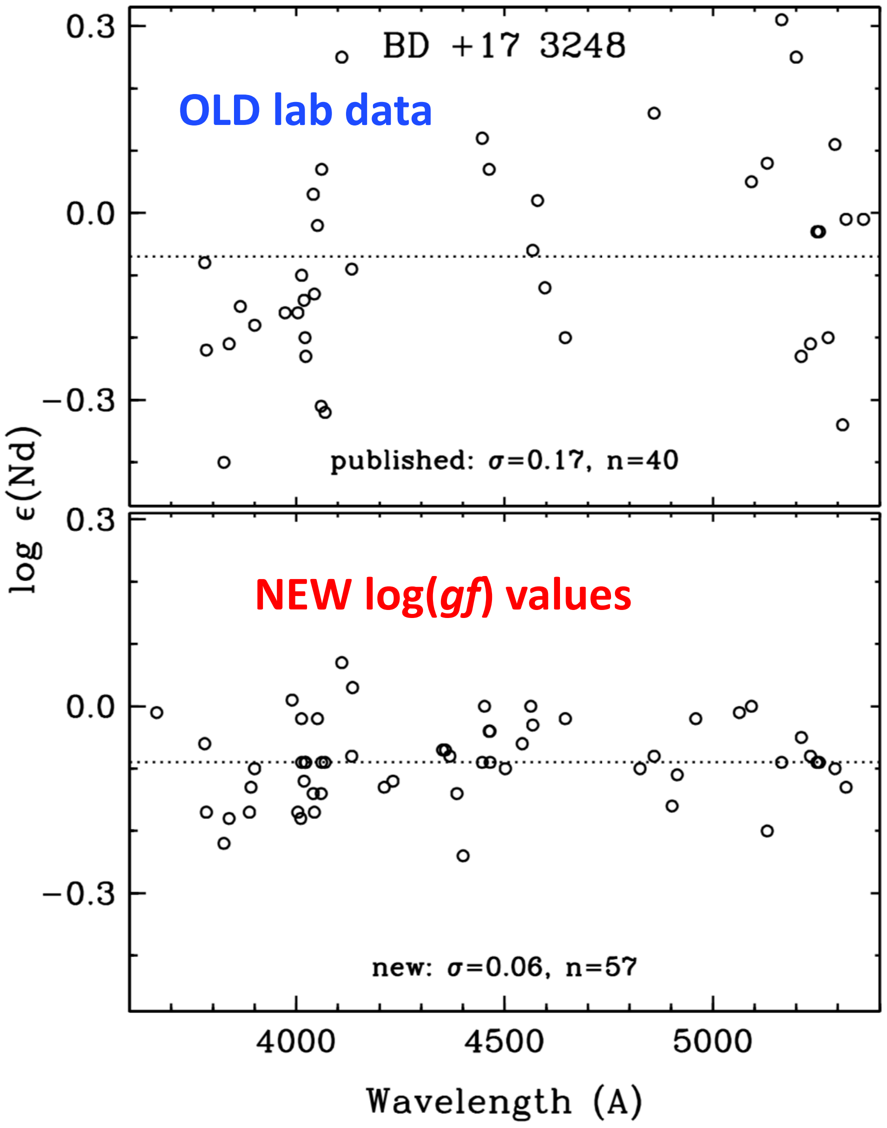
observational challenges:

getting good S/N

getting awarded HST time!



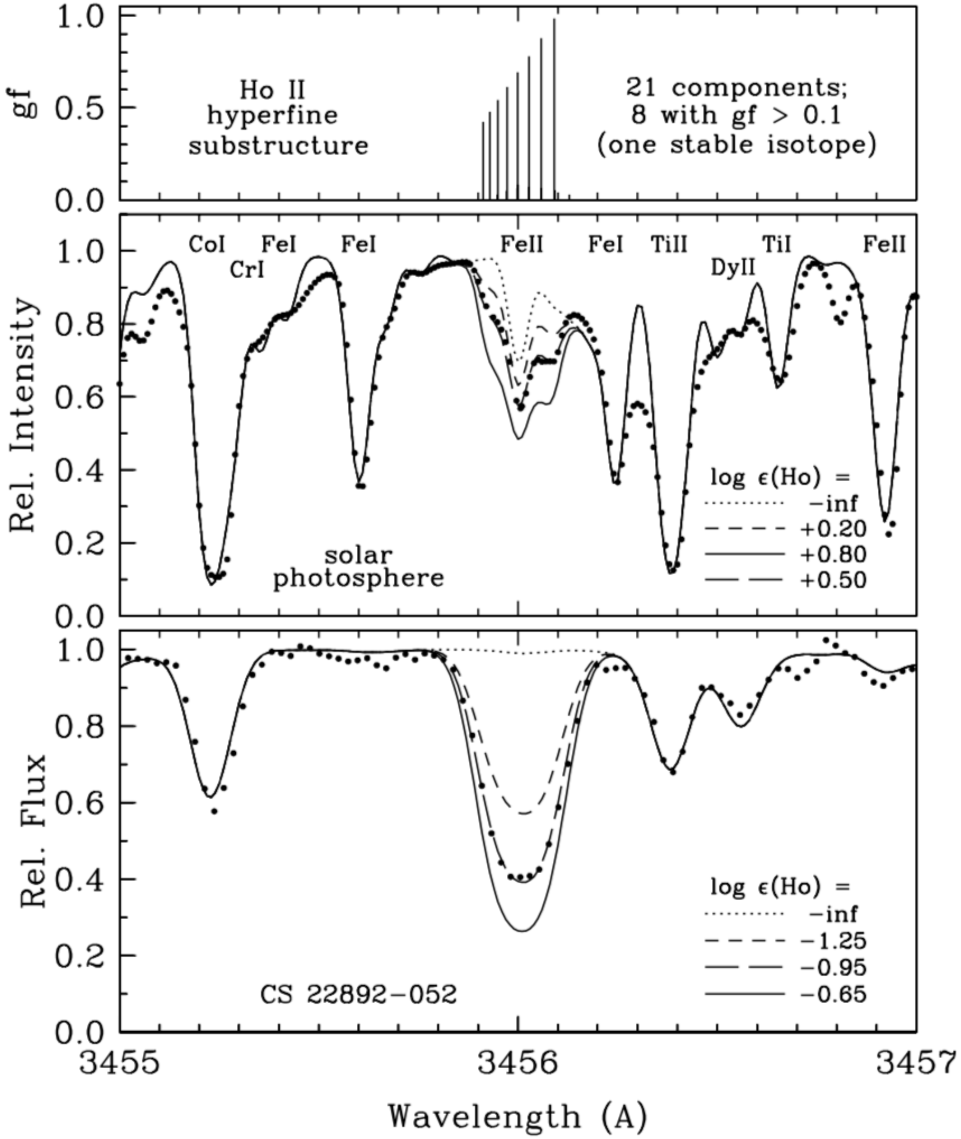
Needing accurate lab data?
It must be ≪ astronomical/analytical error sources



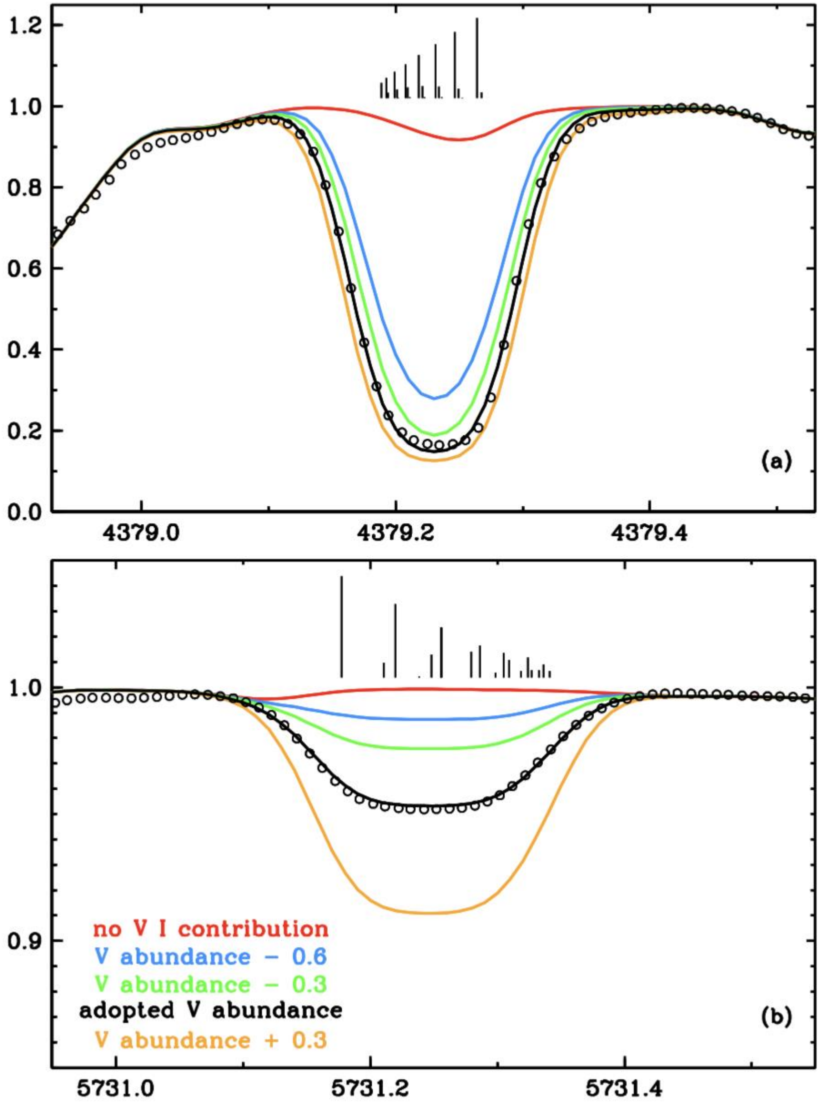
Den Hartog et al. 2003:

- lab study of 168 Nd II transitions
- application to Sun, and a metal-poor halo star
- log ε(Nd) = log10(N_{Nd}/N_H) + 12
- more lines can be used
- line-line scatter reduces hugely
- the σ value approaches the achievable minimum
- the new lab *gf* uncertainties do not matter in the overall abundance error budget

But the demands are also for hyperfine substructures



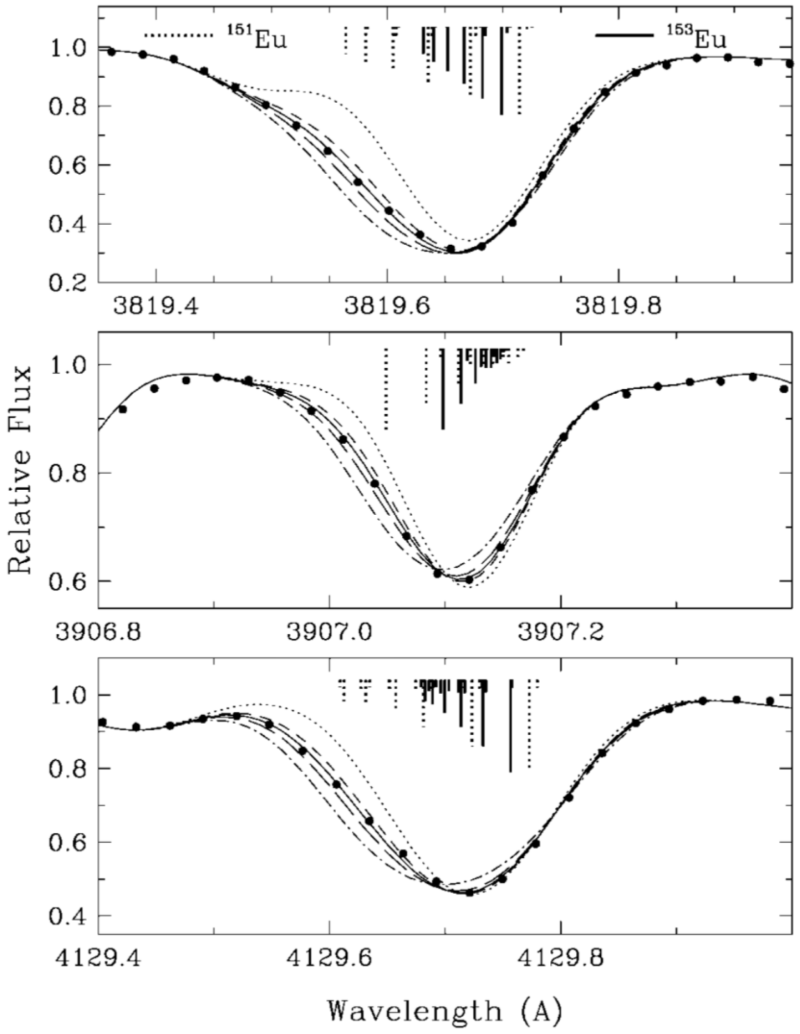
Lawler et al. 2004



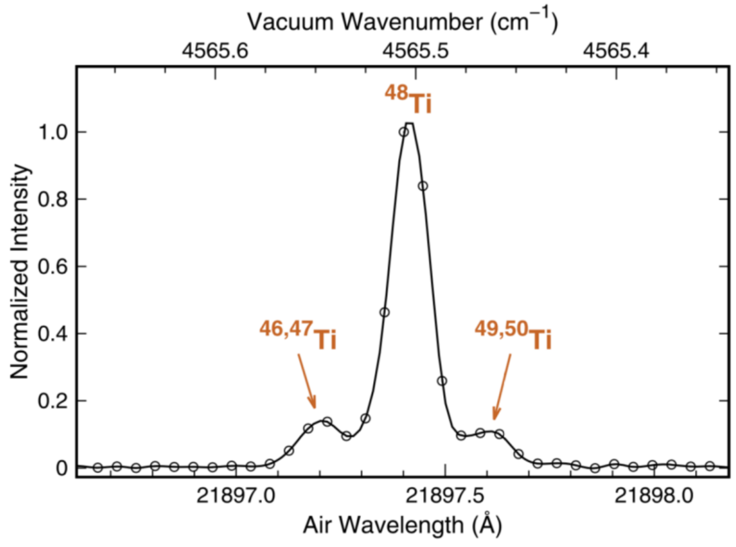
Lawler et al. 2014

it is impossible to obtain accurate abundances for many elements without including hfs

and for isotopic wavelength shifts

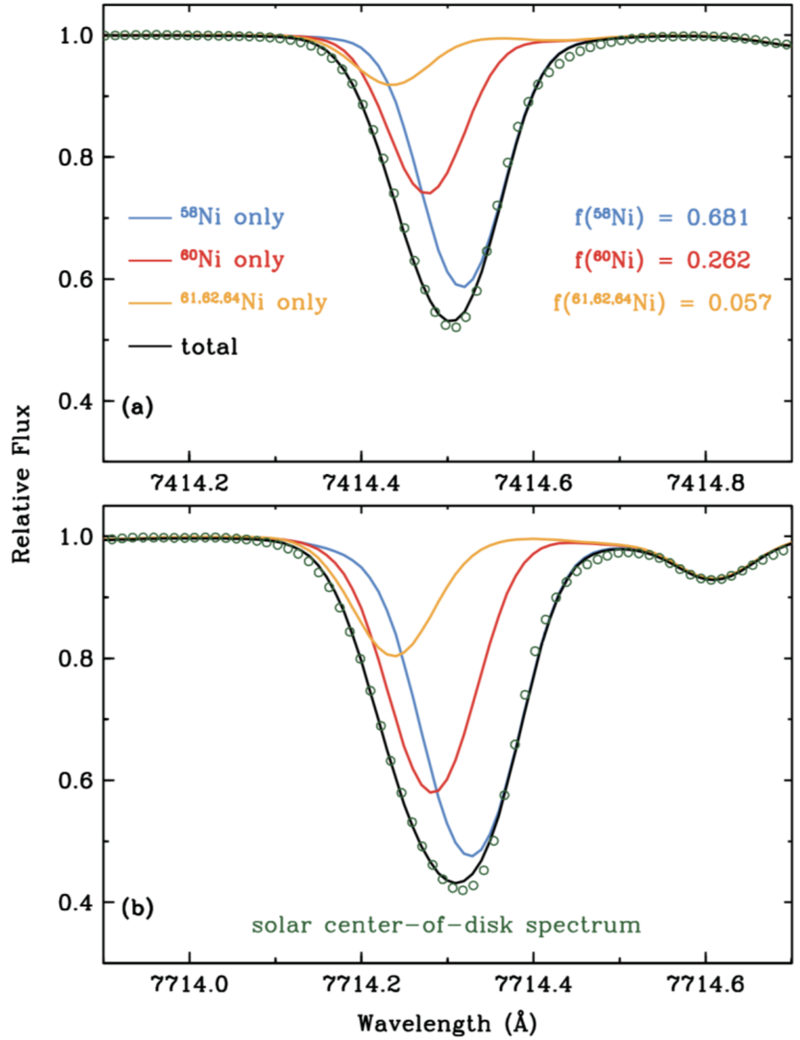


Sneden et al. 2002



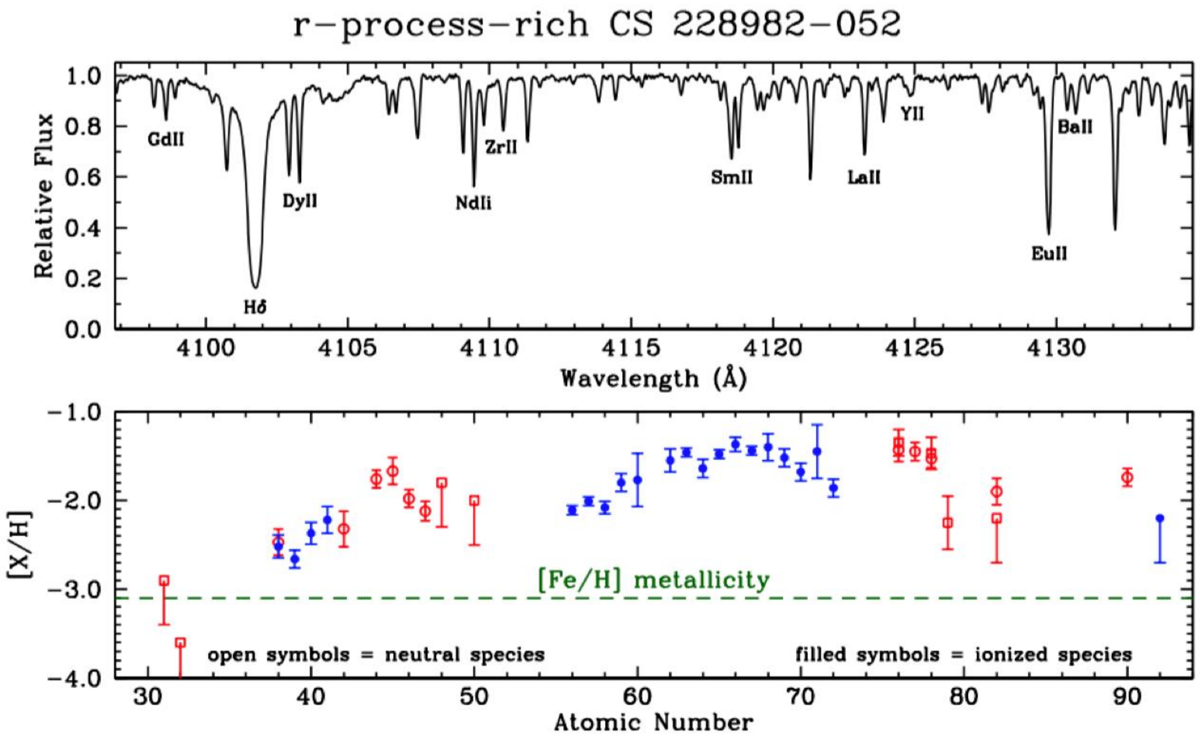
in the red and IR spectral regions, increased attention must be paid to isotopic splitting in transitions

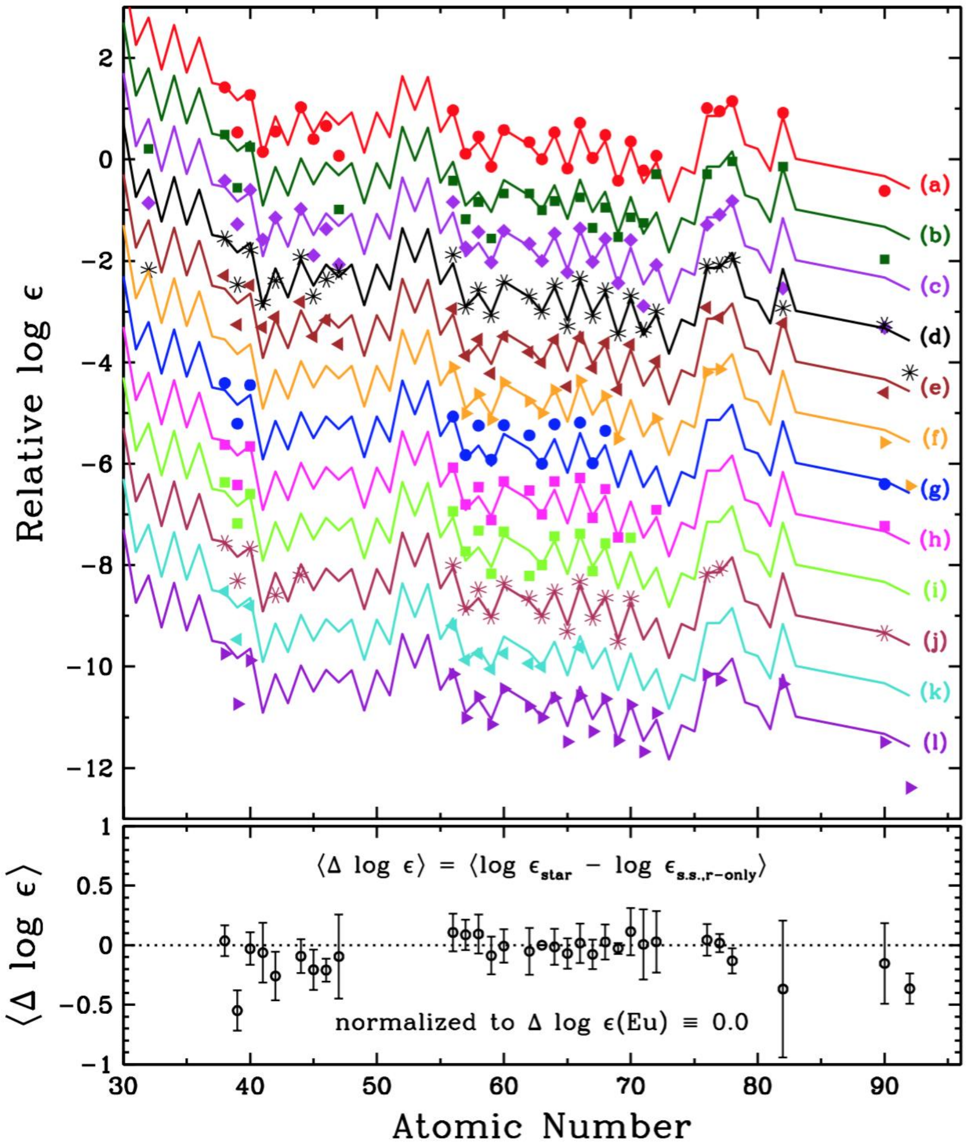
Afșar et al. 2018



Wood et al. 2014

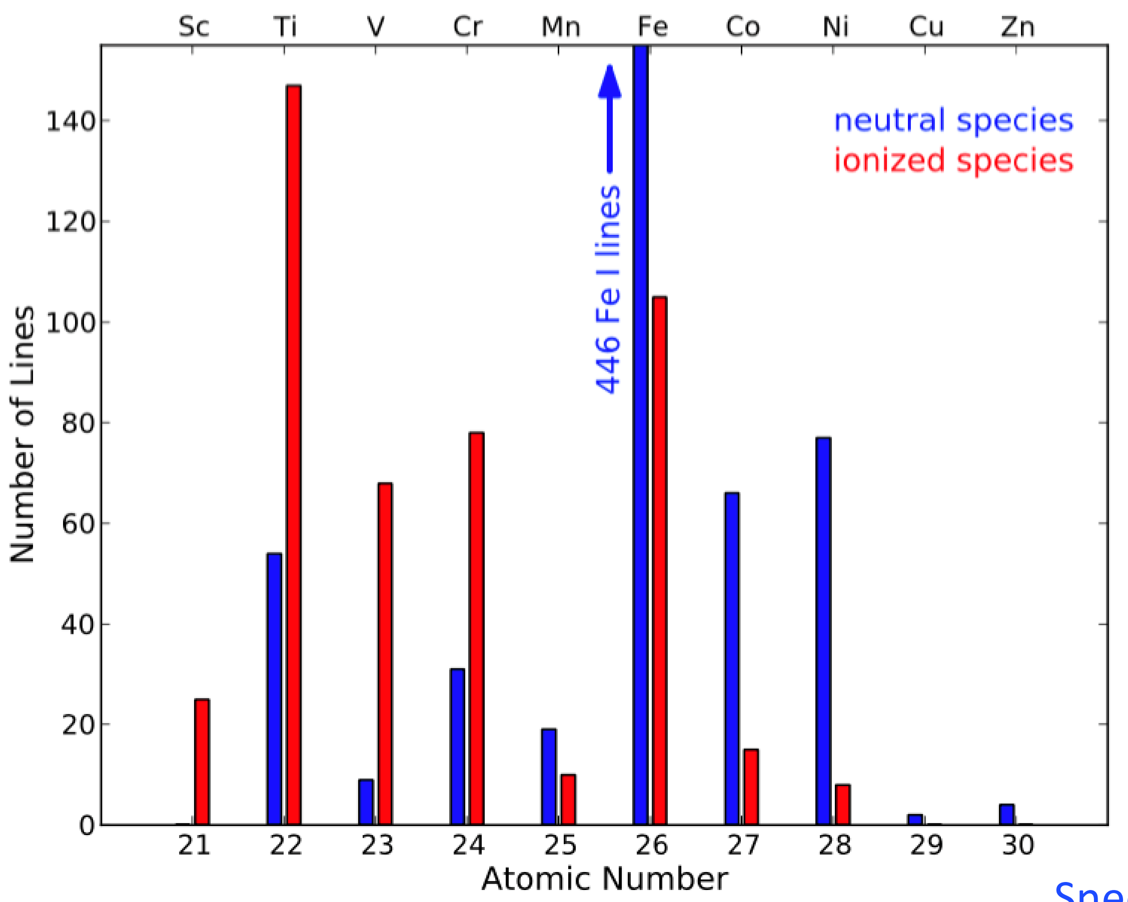
This effort does lead to abundance victories

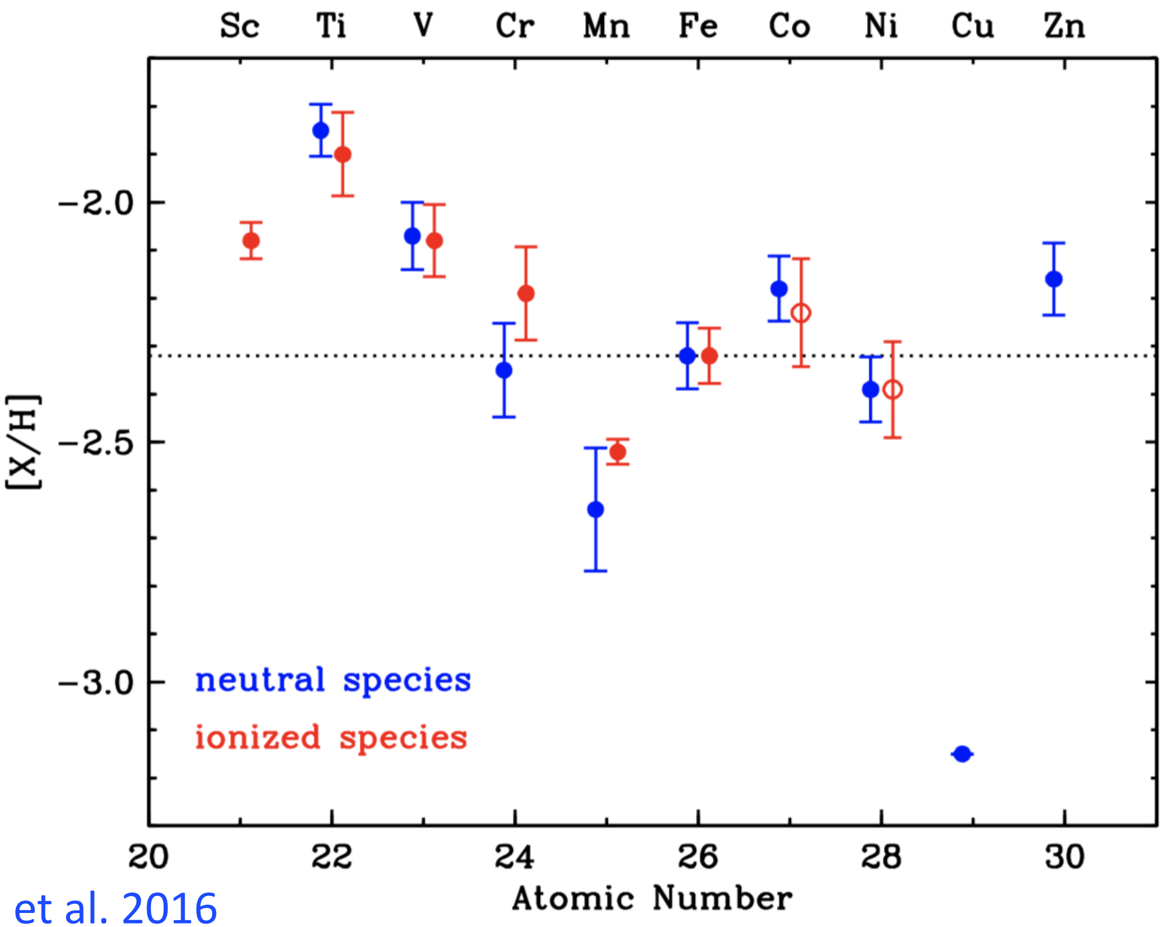




Cowan et al. 2020

and in believable Fe-group abundance distributions





Sneden et al. 2016

about 1200 transitions, individual synthetic spectra

neutrals & ions agree in abundance

new: correlated Sc-Ti-V abundances

It would be very good to have …

new laboratory attacks on “neglected” species detectable in metal-poor stars

the “alpha” elements:

Mg I, Mg II, Si I, Si II, S I, Ca I, Ca II

odd-Z light elements

especially Na I, Al I

ANY laboratory transition work on transitions in the near-IR

0.9 – 4.0 μm

light and Fe-group elements dominate the near-IR spectra

new efforts to at least provide accurate wavelengths for near-IR lines

(lots of unidentified features in this wavelength domain