r-process enhanced stars in the Milky Way halo and its satellites

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Hirschegg 2017

r-process enhanced stars

Metal-poor ($[\mathrm{Fe/H}] < -1$) stars showing an enhancement in r-process elements.

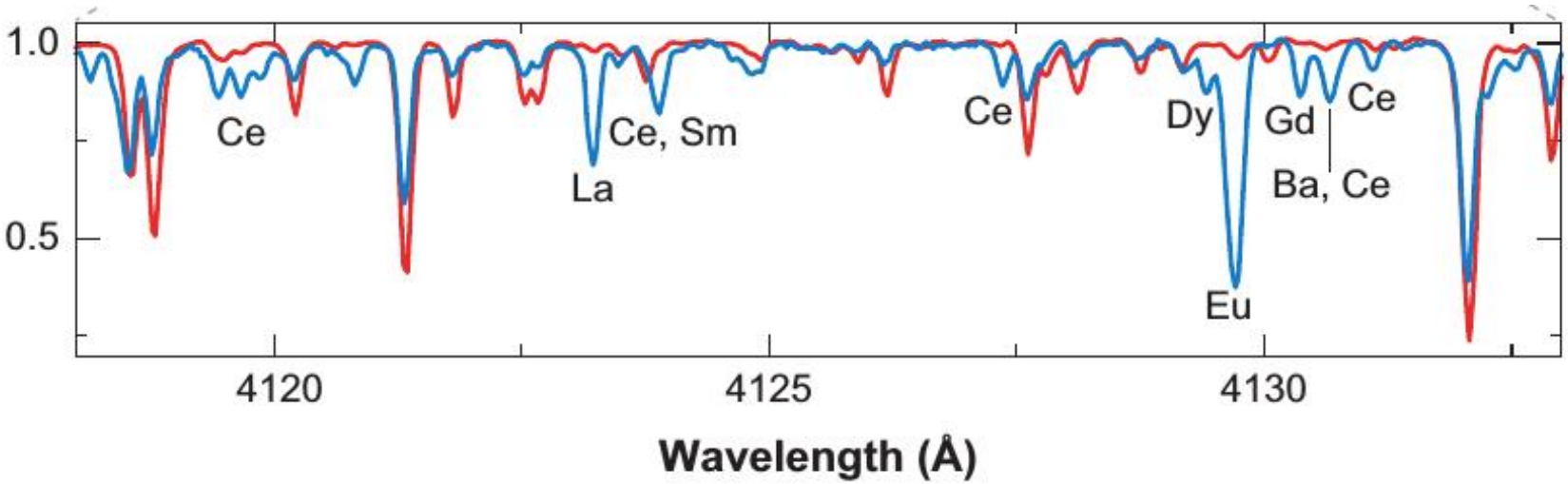
- r-I : $0.3 < [\mathrm{Eu/Fe}] < 1.0$ and $[\mathrm{Ba/Eu}] < 0$
- r-II : $[\mathrm{Eu/Fe}] > 1.0$ and $[\mathrm{Ba/Eu}] < 0$

Reminder of bracket notation:

$$[\mathrm{X/Y}] = \log\left(\frac{N_X}{N_Y}\right)_* - \log\left(\frac{N_X}{N_Y}\right)_\odot$$

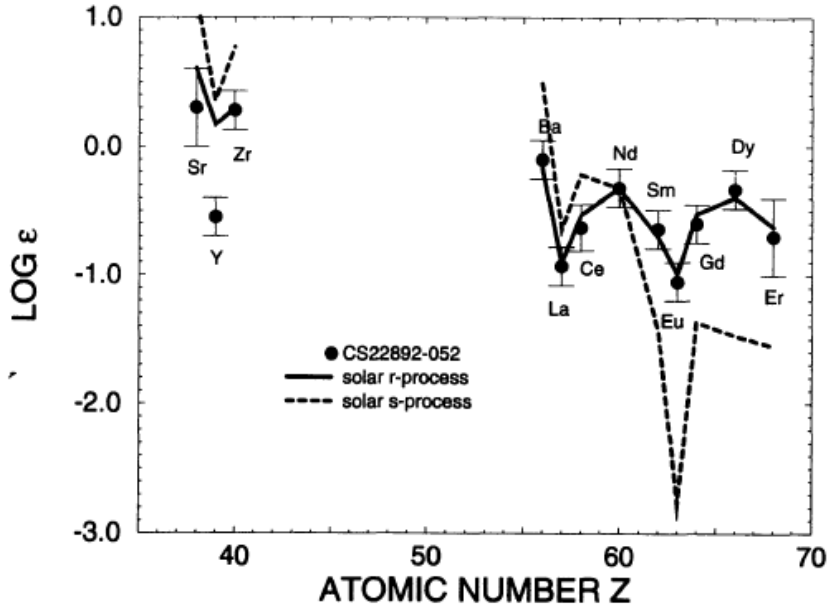
The first r-process enhanced star

CS 22892−052 with $[\mathrm{Fe/H}] = -3.10$ and $[\mathrm{Eu/Fe}] = 1.64$ (Sneden+ 1994).

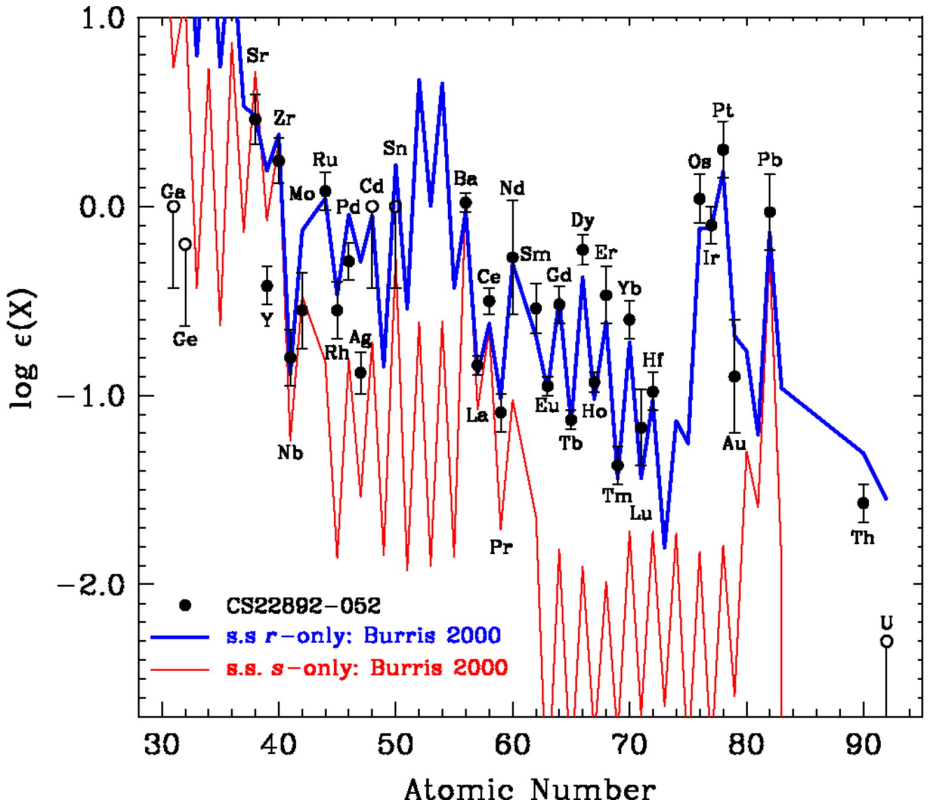


CS 22892−052 (blue) and HD 122563 (red), Sneden+ 2008

The first r-process enhanced star



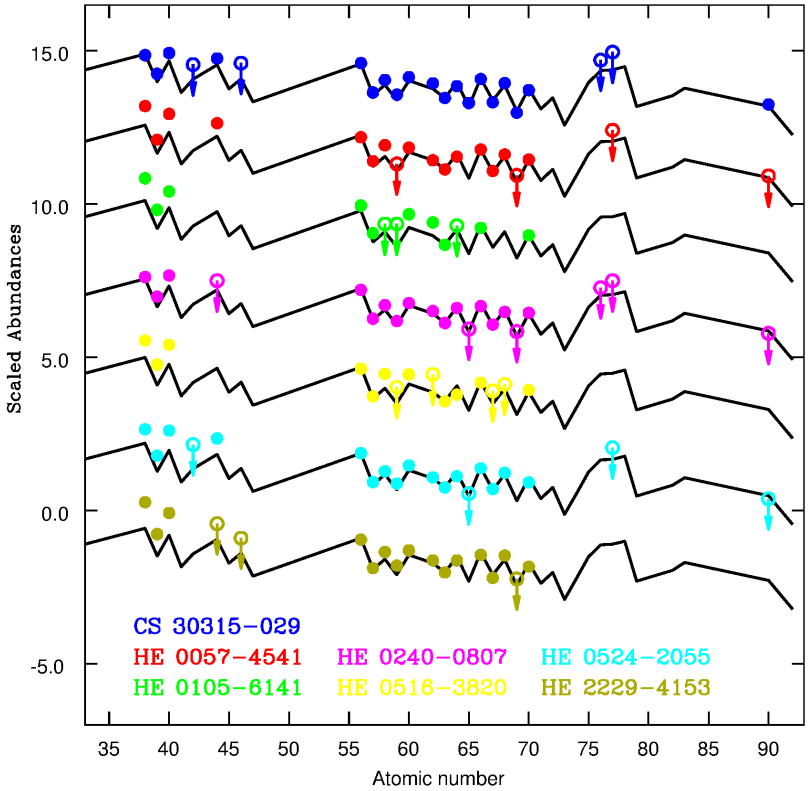
Cowan+ 1995



Sneden+ 2003

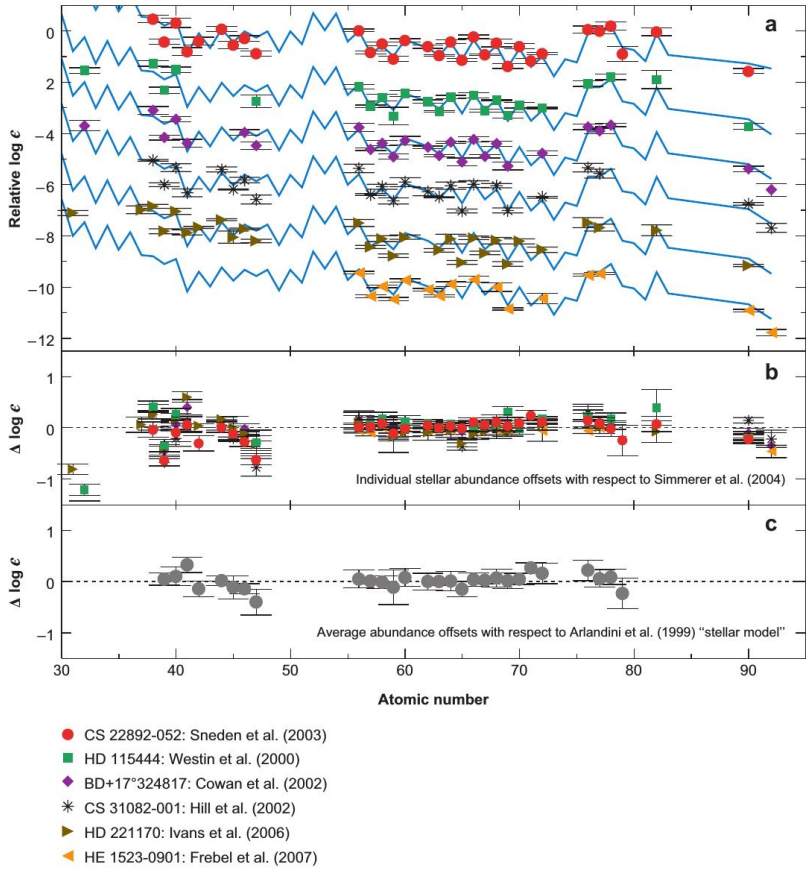
Abundance pattern of r-process enhanced stars

r-I stars



Siqueira Mello+ 2014

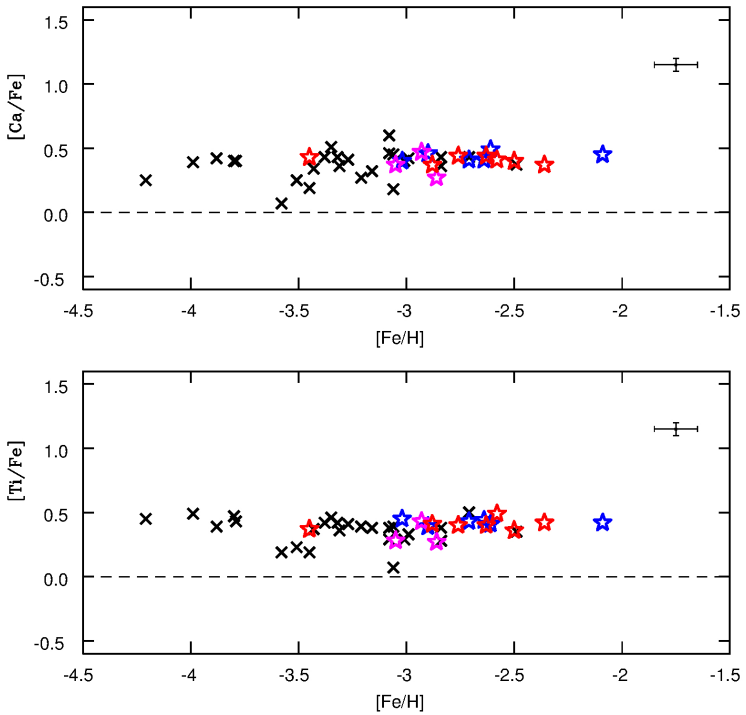
r-II stars



Sneden+ 2008

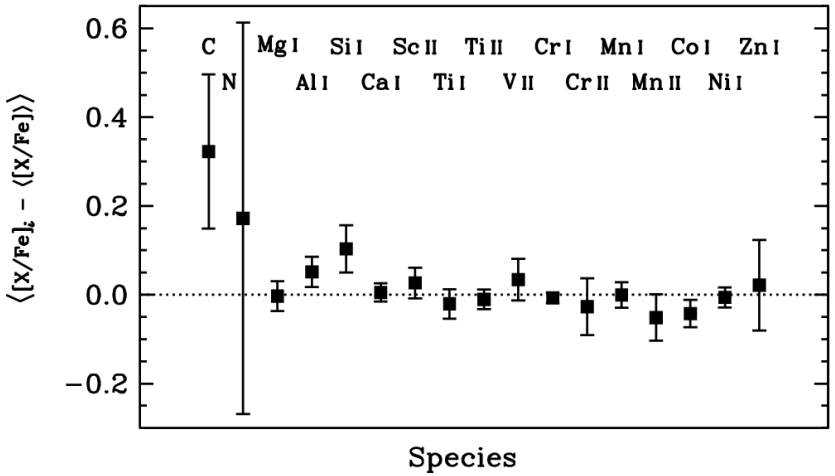
Abundance pattern of r-process enhanced stars

r-I stars



Siqueira Mello+ 2014

r-II stars

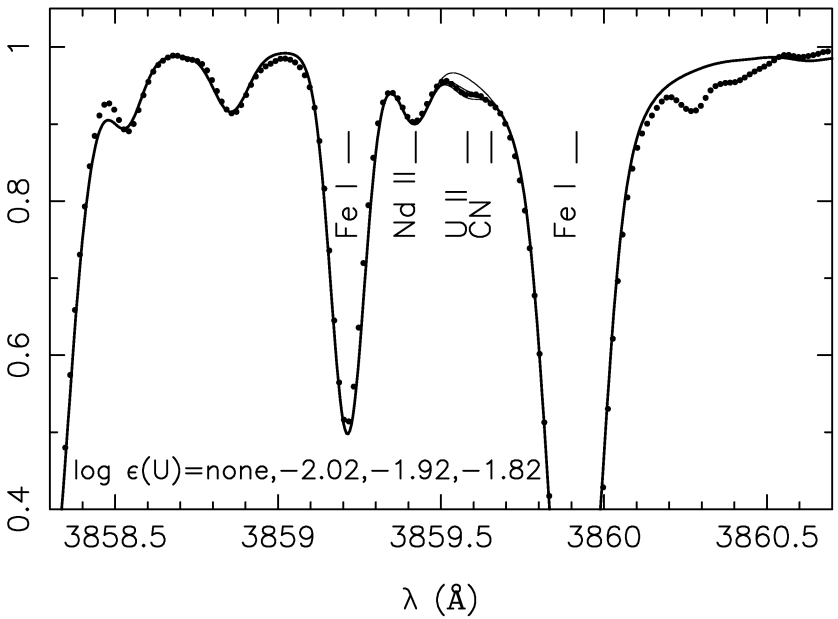


Roederer+ 2014

Actinide boost stars

One r-I and five r-II stars are enhanced in Th (and U where detected) relative to second and third peak r-process elements.

CS 31082−001
$[\mathrm{U/Fe}] = 1.49$



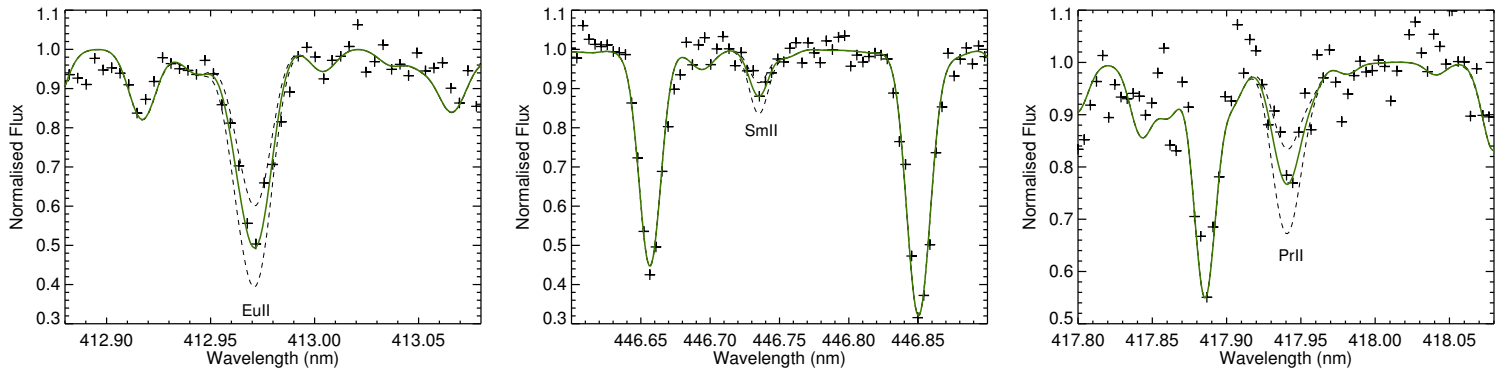
Hill+ 2002

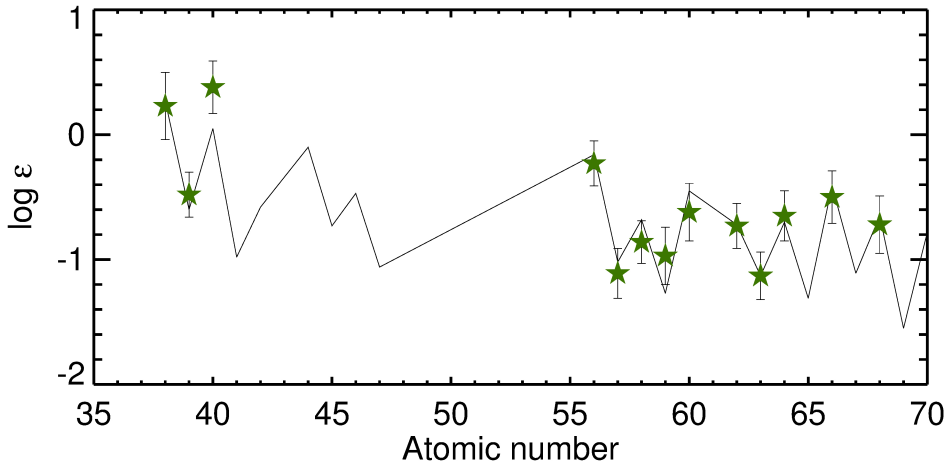
normal r-II
CS 22892−052: $[\mathrm{Eu/Th}] = 0.28$

actinide boost stars:
CS 30315−029: $[\mathrm{Eu/Th}] = -0.23$
CS 30306−132: $[\mathrm{Eu/Th}] = -0.36$
CS 31078−018: $[\mathrm{Eu/Th}] = -0.24$
CS 31082−001: $[\mathrm{Eu/Th}] = -0.20$
HE 1219−0312: $[\mathrm{Eu/Th}] = -0.30$
HE 2252−4225: $[\mathrm{Eu/Th}] = -0.11$
(Sneden+2003, Siqueira Mello+2014, Lai+2008, Hill+2002, Honda+2004, Mashonkina+ 2014, Roederer+ 2009)

Dwarf Galaxies

r-I star in Tucana III with $[\mathrm{Eu/Fe}] = 0.6$





Hansen+ submitted

r-process enhanced stars in other dwarf galaxies

Dwarf galaxy	r-I	r-II	Total stars with Eu and Ba
Ursa Minor	6	1	17
Draco	4	1	17
Sculptor	1	0	21
Fornax	6	4	147
Carina	2	0	14
Reticulum II	0	7	9

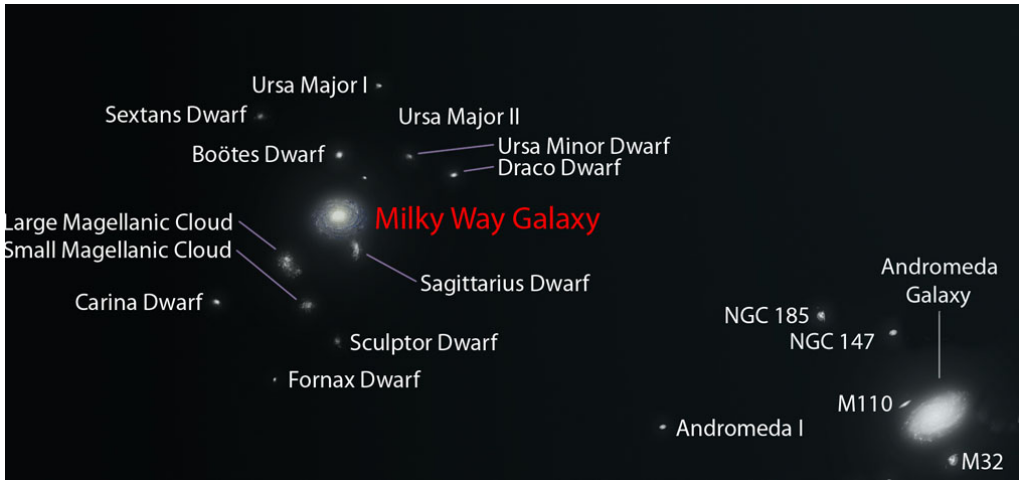
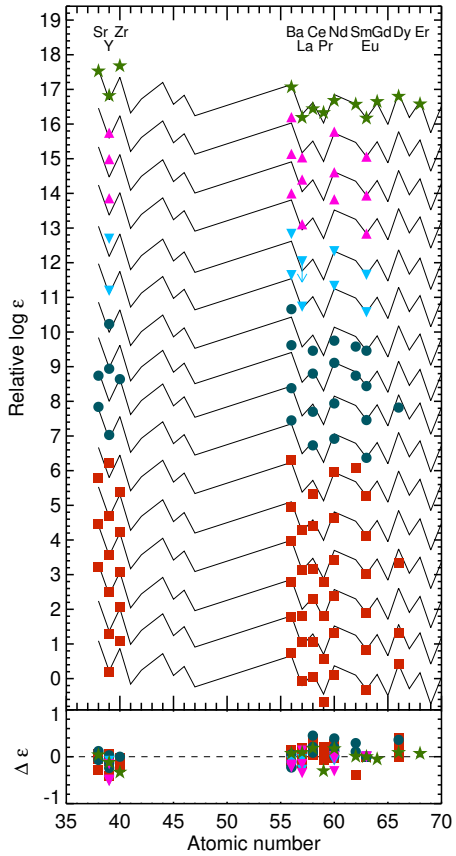


Image credit: Andrew Colvin

Abundance pattern of r-process enhanced stars in dwarf galaxies



Hansen+ submitted

Surveys

Dedicated search for r-process enhanced stars in the halo

First search:

- Barklem+ 2005 took snapshot of 253 stars and discovered 8 r-II and 35 r-I stars $\rightarrow$ r-II stars are very rare!

Today:

- Halo: 25 r-II and $\sim$125 r-I stars.
- Dwarf galaxies: 13 r-II and 20 r-I stars.

New survey for r-process enhanced stars

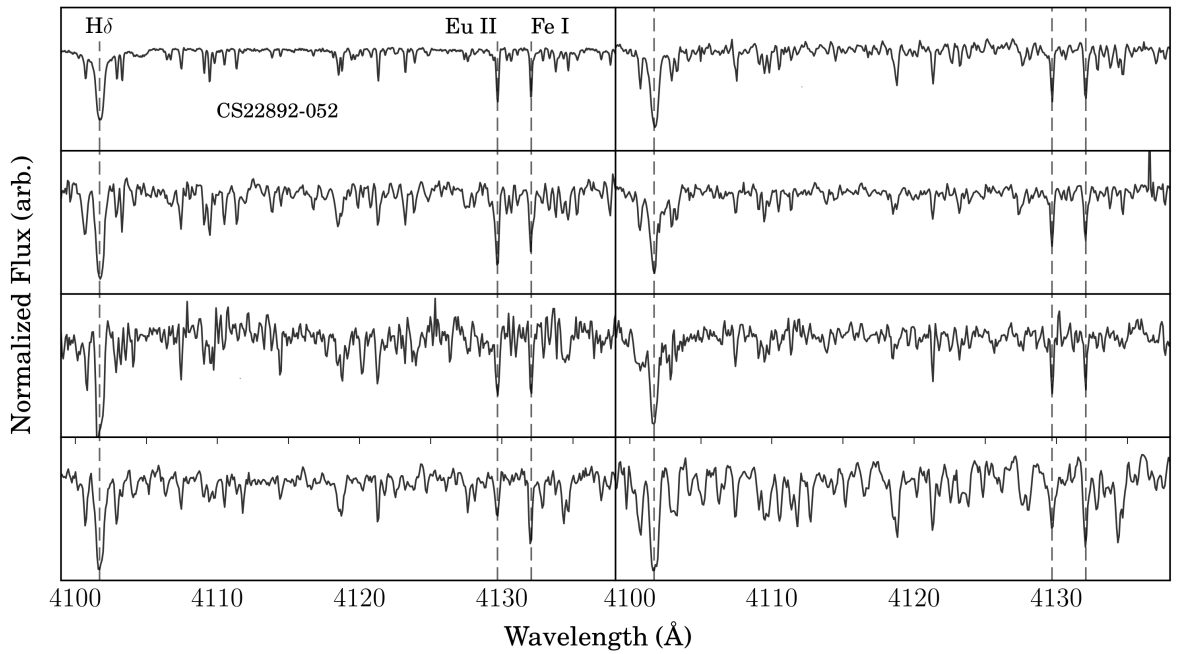
Obtain high resolution spectra for $\sim$2000 stars to find $\sim$75 new r-II stars plus a large number of r-I stars.

Selection:

- Bright $V > 13.5 \rightarrow$ can observe many stars in short time
- Cool $4000 < \mathrm{T_{eff}} < 5500 \rightarrow$ Get Eu abundance or good upper limits
- Metal poor $[\mathrm{Fe/H}] < -2 \rightarrow$ Only few nucleosynthesis events

Pilot run

Six nights on du Pont at Las Campanas Observatory in August 2016, obtained spectra of 110 stars.



Hansen+ in prep.

More data to come

- Large sample with full abundance pattern
- More stars with Th and U detections, possible actinide boost
- HST observations

Summary

- Abundance pattern same for r-I and r-II stars in halo and dwarf galaxies.
- r-process element enrichment is not coupled to light element abundances, but small number show additional enhancement in actinides
- New survey to find more r-process enhanced stars