Basel, Switzerland
September 29-30, 2014

Observational constraints to models of heavy-element production in the early Galaxy

I. Ba/Eu ratio in the *r*-process.

II. Ba isotope ratios in MP stars.

III. Light vs. heavy n-capture elements in VMP stars.

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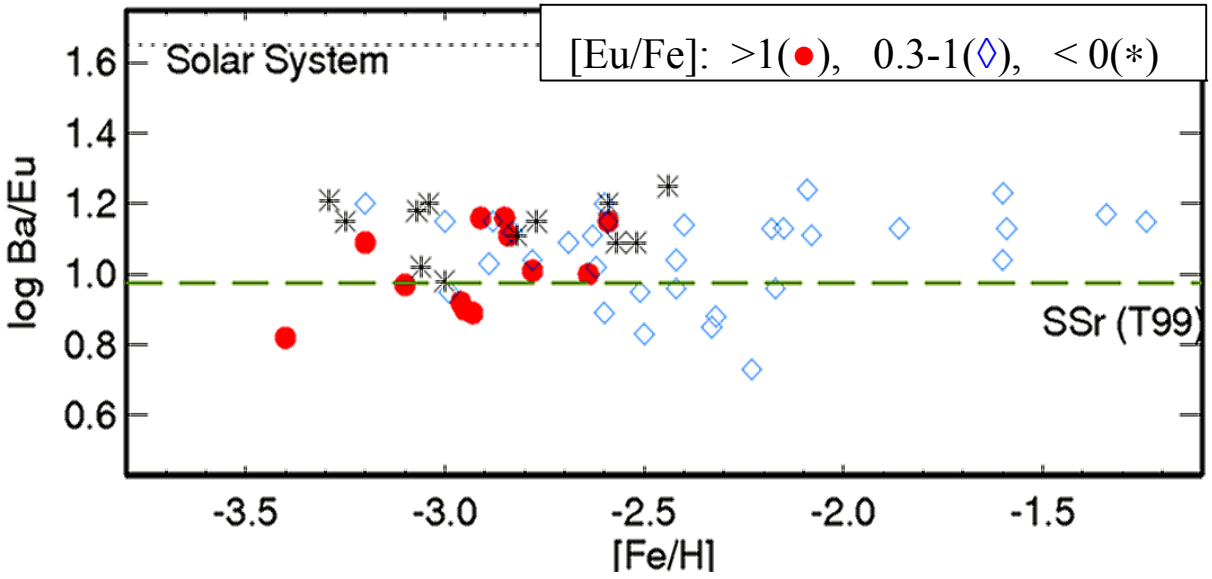
I. Stellar Ba/Eu abundance ratios

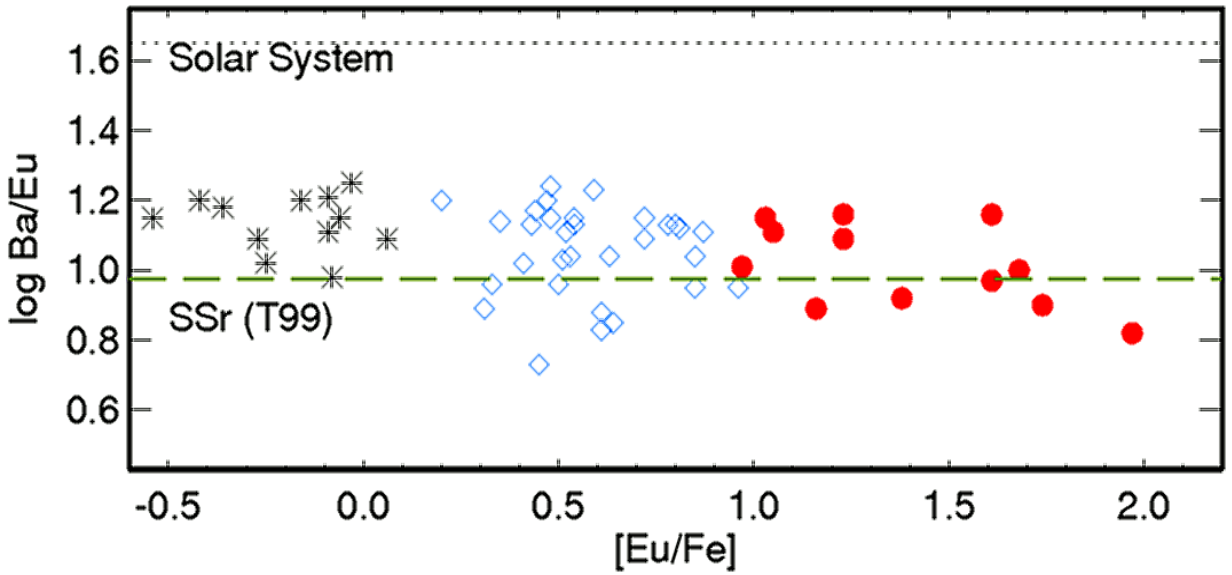


Selected from 14 studies, high-resolution spectra.

$-3.3 \leq [Fe/H] < -1.2$,

$[Ba/Eu] < 0$,

$-0.5 < [Eu/Fe] \leq 1.9$



Constant Ba/Eu independent of Eu abundance.

r-II stars are best candidates for learning about *r*-process

r-II stars: [Eu/Fe] > 1, [Ba/Eu] < 0 (*Christlieb et al.* 2004)

✓ n-capture element abundances of r-II stars are dominated by influence of single (few) r-process event(s).

✓ 12 discovered stars: $1.0 \leq [Eu/Fe] \leq 1.9$, $-3.4 \leq [Fe/H] \leq -2.8$ | (*Sneden et al.* 1994, ..., *Aoki et al.* 2010)

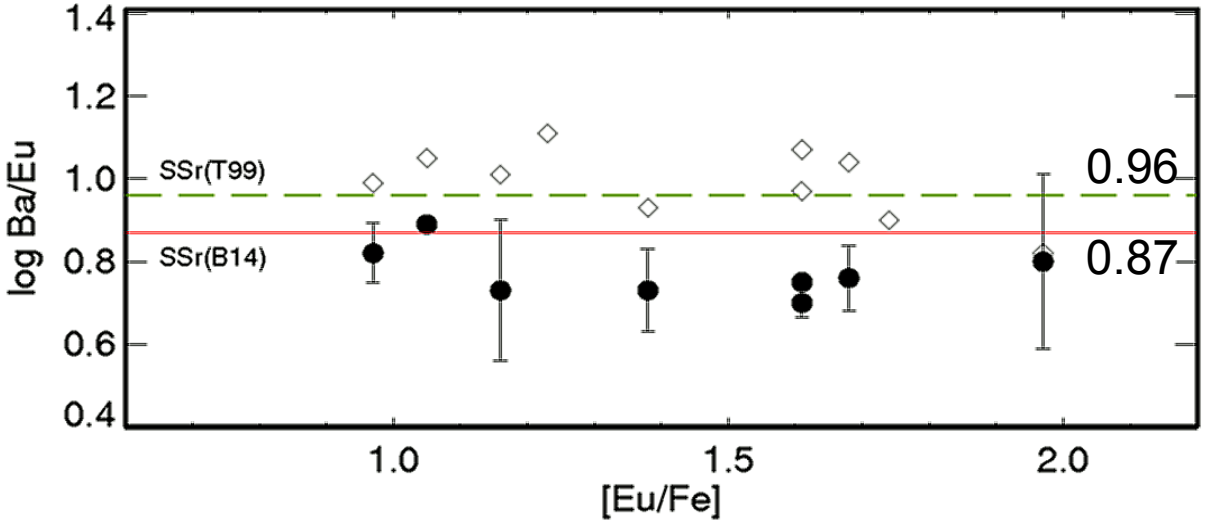
✓ r-II: ~ 5 % of stars at [Fe/H] < -2.5 (*Barklem et al.* 2005)

Ba and Eu abundances were revised for 8 stars.

- Use Ba II subordinate lines (nearly free of HFS),
- 4 stars: only Ba II resonance lines are available, derived abundances depend on Ba odd isotope fraction f_{odd}, check f_{odd} = 0.5 (A99, T99, S96) and 0.66 (B11),
- non-LTE.

(*Mashonkina & Christlieb,* 2014, A&A, 565, A123)

Ba/Eu of r-II stars



◊ LTE,
● non-LTE, $f_{odd} = 0.5$

Solar system r-process
T99 = *Travaglio et al.* 1999
B14 = *Bisterzo et al.* 2014

LTE, mean log Ba/Eu = 0.99±0.09 (10 stars)
non-LTE, $f_{odd} = 0.5$ 0.78±0.06 (8 stars)
non-LTE, $f_{odd} = 0.66$ 0.75

Consistent with recent estimate of SSr

r-process models?
WP: $\log (Ba/Eu)_r = 1.0$ (*Kratz et al.* 2007),
HEW: 0.8 (*Farouqi et al.* 2010)

Neutron star mergers ??

LTE: 0.93±0.19 (*Roederer et al.* 2014, 13stars)

II.

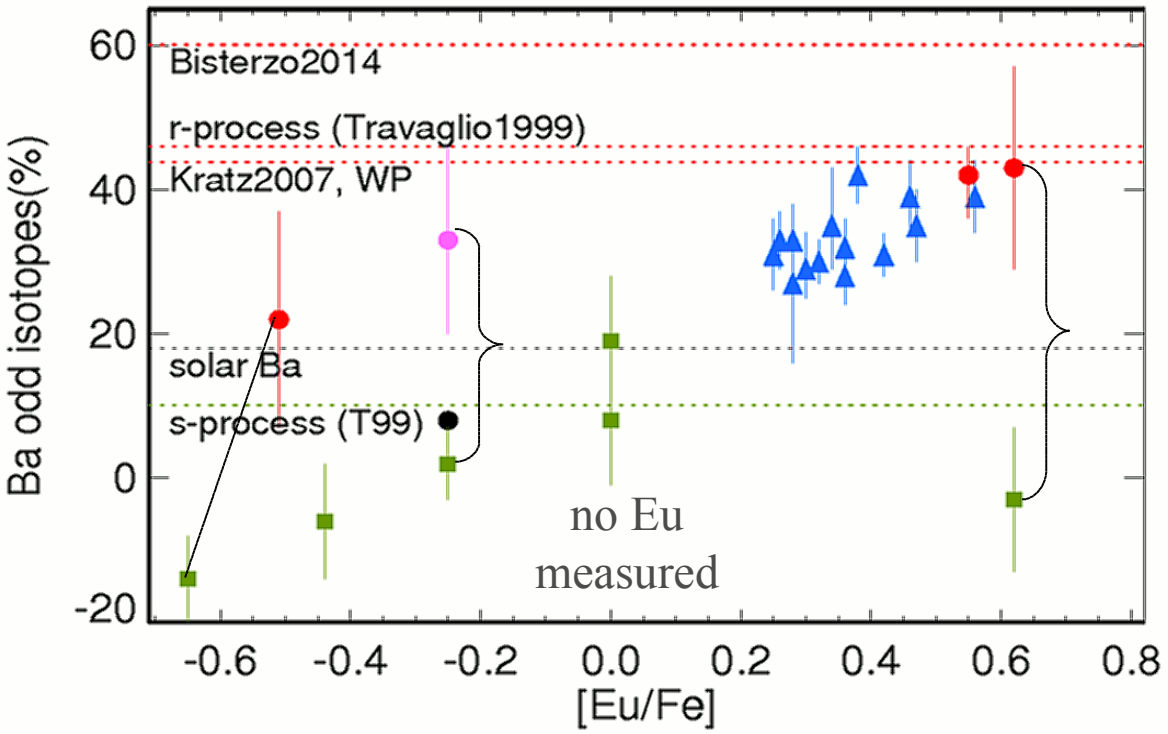
Cescutti & Chiappini (2014, A&A, 565, A51): predict contribution of **s-process** in spinstars at low Ba/Fe (or high Sr/Ba) and [Fe/H] < -2 to explain scatter in Sr,Y/Ba,Eu.

Lower fraction of Ba odd-A isotopes, f_{odd}, compared with pure r-process?

Mashonkina & Christlieb (2014, A&A, 565, A123): suspect that f_{odd} is related to the r-process abundances of the star.

- r-process enhanced stars, with [Eu/Fe] = 0.24 to 0.70, reveal high f_{odd}
- Eu-poor stars HD 122563 and HD 140283, with [Eu/Fe] = -0.51 and < -0.2, reveal low f_{odd}.

Stellar fractional abundance of odd-A isotopes of Ba



▲ thick disk, ● halo

r-process enhanced stars,
[Eu/Fe] = 0.24-0.62:
f_{odd} = 0.27 to 0.43.

Eu-poor star:
f_{odd} = 0.22

(*Mashonkina et al.* 2006, 2008):

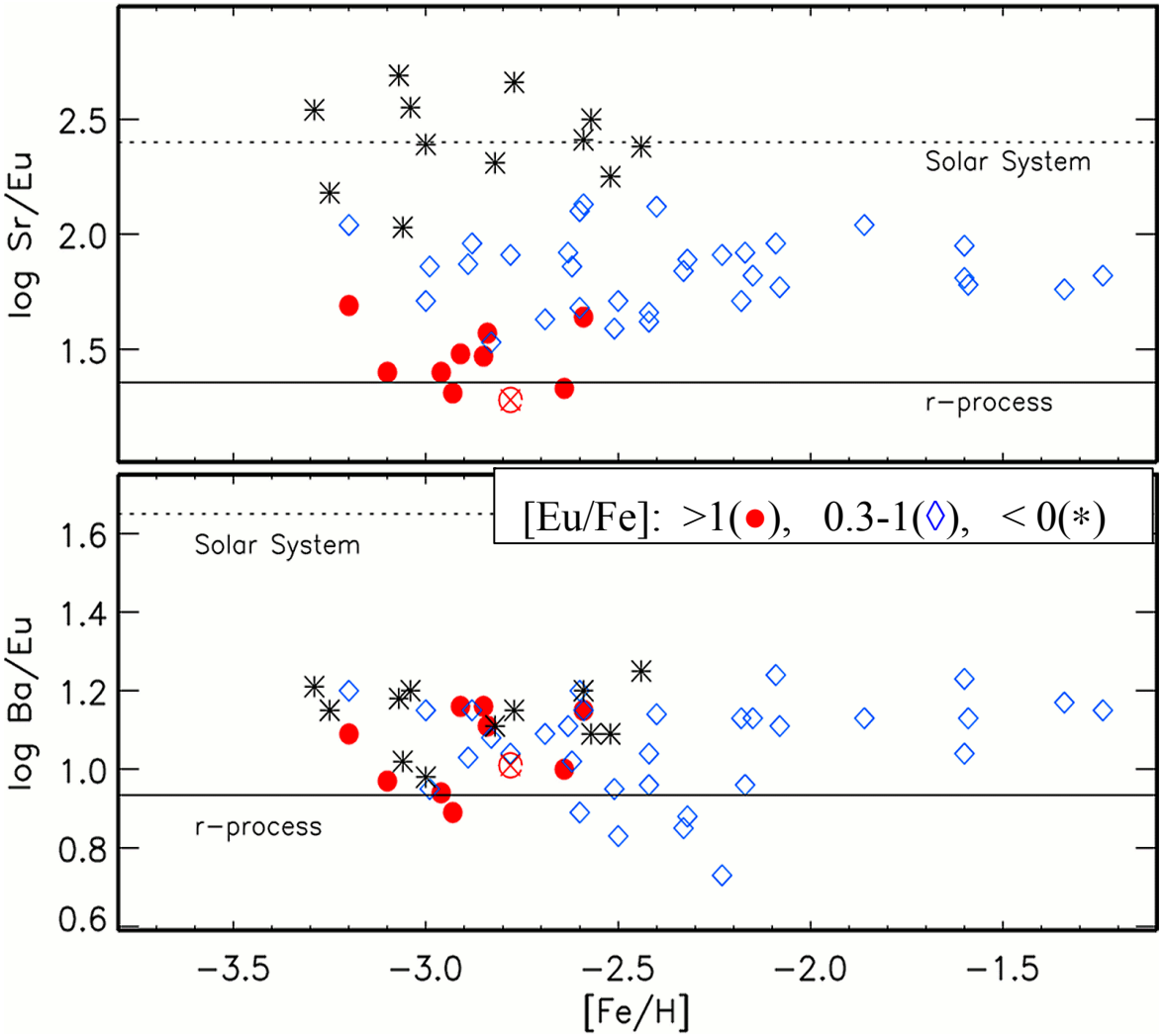
- *Magain* (1995, HD 140283),
- *Gallagher et al.* (2013),
- *Collet et al.* (2009, 3D)

Large scatter of data for common stars.

Non-physical f_{odd}: < 0, < 0.11 (s-process)

HD 122563, [Fe/H] = -2.6, [Ba/Fe] = -1.0, [Sr/Ba] = 0.6, [Ba/Eu] = -0.5
HD 140283, -2.4, -0.8, 0.4, < -0.2
present, probably, signature of s-process in spinstars.

III. Light vs. heavy n-capture elements in VMP stars



Mashonkina et al. (2010)

Eu-poor stars:

[Fe/H] < -2,

[Eu/Fe] < 0,

[Ba/Fe] < -0.5,

[Sr/Ba] > 0.5.

Are their abundances signature of s-process in spinstars?