

The r- and s- process contributions to heavy-element abundances in halo star HD 29907.

Sitnova T.¹, Mashonkina L.I.²

¹Moscow State University, Universitetsky pr. 13, 119992, Moscow, Russia, e-mail: sitamih@gmail.com

²Institute of astronomy, RAS, Pyatnitskaya st. 48, 119017, Moscow, Russia, , e-mail: lima@inasan.ru

2011

Neutron capture reactions

R-process

Neutron Capture

Beta Decay

44					
Ru	45				
⁹² Ru	Rh	46			
⁹³ Ru		Pd	47		
⁹⁴ Ru	⁹⁵ Rh		Ag	48	
⁹⁵ Ru	⁹⁶ Rh	⁹⁷ Pd		Cd	
⁹⁶ Ru	⁹⁷ Rh	⁹⁸ Pd	⁹⁹ Ag	¹⁰⁰ Cd	49
⁹⁷ Ru	⁹⁸ Rh	⁹⁹ Pd	¹⁰⁰ Ag	¹⁰¹ Cd	In
⁹⁸ Ru	⁹⁹ Rh	¹⁰⁰ Pd	¹⁰¹ Ag	¹⁰² Cd	
⁹⁹ Ru	¹⁰⁰ Rh	¹⁰¹ Pd	¹⁰² Ag	¹⁰³ Cd	¹⁰⁴ In
¹⁰⁰ Ru	¹⁰¹ Rh	¹⁰² Pd	¹⁰³ Ag	¹⁰⁴ Cd	¹⁰⁵ In
¹⁰¹ Ru	¹⁰² Rh	¹⁰³ Pd	¹⁰⁴ Ag	¹⁰⁵ Cd	¹⁰⁶ In
¹⁰² Ru	¹⁰³ Rh	¹⁰⁴ Pd	¹⁰⁵ Ag	¹⁰⁶ Cd	¹⁰⁷ In
¹⁰³ Ru	¹⁰⁴ Rh	¹⁰⁵ Pd	¹⁰⁶ Ag	¹⁰⁷ Cd	¹⁰⁸ In
¹⁰⁴ Ru	¹⁰⁵ Rh	¹⁰⁶ Pd	¹⁰⁷ Ag	¹⁰⁸ Cd	¹⁰⁹ In
¹⁰⁵ Ru	¹⁰⁶ Rh	¹⁰⁷ Pd	¹⁰⁸ Ag	¹⁰⁹ Cd	¹¹⁰ In
¹⁰⁶ Ru	¹⁰⁷ Rh	¹⁰⁸ Pd	¹⁰⁹ Ag	¹¹⁰ Cd	¹¹¹ In
¹⁰⁷ Ru	¹⁰⁸ Rh	¹⁰⁹ Pd	¹¹⁰ Ag	¹¹¹ Cd	¹¹² In
¹⁰⁸ Ru	¹⁰⁹ Rh	¹¹⁰ Pd	¹¹¹ Ag	¹¹² Cd	¹¹³ In
¹⁰⁹ Ru	¹¹⁰ Rh	¹¹¹ Pd	¹¹² Ag	¹¹³ Cd	¹¹⁴ In
¹¹⁰ Ru	¹¹¹ Rh	¹¹² Pd	¹¹³ Ag	¹¹⁴ Cd	¹¹⁵ In
67					
	68				
		69			
			70		

$N_n > 10^{22} \text{ cm}^{-3}$

SN II

r- process began earlier than the main s-process

S-process

Neutron Capture

Beta Decay

Ag	48				
	Cd				
⁹⁹ Ag	¹⁰⁰ Cd	49			
¹⁰⁰ Ag	¹⁰¹ Cd	In	50		
¹⁰¹ Ag	¹⁰² Cd		Sn	51	
¹⁰² Ag	¹⁰³ Cd	¹⁰⁴ In		Sb	52
¹⁰³ Ag	¹⁰⁴ Cd	¹⁰⁵ In			Te
¹⁰⁴ Ag	¹⁰⁵ Cd	¹⁰⁶ In	¹⁰⁷ Sn		¹⁰⁹ Te
¹⁰⁵ Ag	¹⁰⁶ Cd	¹⁰⁷ In	¹⁰⁸ Sn		
¹⁰⁶ Ag	¹⁰⁷ Cd	¹⁰⁸ In	¹⁰⁹ Sn	¹¹⁰ Sb	¹¹¹ Te
¹⁰⁷ Ag	¹⁰⁸ Cd	¹⁰⁹ In	¹¹⁰ Sn	¹¹¹ Sb	¹¹² Te
¹⁰⁸ Ag	¹⁰⁹ Cd	¹¹⁰ In	¹¹¹ Sn	¹¹² Sb	¹¹³ Te
¹⁰⁹ Ag	¹¹⁰ Cd	¹¹¹ In	¹¹² Sn	¹¹³ Sb	¹¹⁴ Te
¹¹⁰ Ag	¹¹¹ Cd	¹¹² In	¹¹³ Sn	¹¹⁴ Sb	¹¹⁵ Te
¹¹¹ Ag	¹¹² Cd	¹¹³ In	¹¹⁴ Sn	¹¹⁵ Sb	¹¹⁶ Te
¹¹² Ag	¹¹³ Cd	¹¹⁴ In	¹¹⁵ Sn	¹¹⁶ Sb	¹¹⁷ Te
¹¹³ Ag	¹¹⁴ Cd	¹¹⁵ In	¹¹⁶ Sn	¹¹⁷ Sb	¹¹⁸ Te
¹¹⁴ Ag	¹¹⁵ Cd	¹¹⁶ In	¹¹⁷ Sn	¹¹⁸ Sb	¹¹⁹ Te
¹¹⁵ Ag	¹¹⁶ Cd	¹¹⁷ In	¹¹⁸ Sn	¹¹⁹ Sb	¹²⁰ Te
¹¹⁶ Ag	¹¹⁷ Cd	¹¹⁸ In	¹¹⁹ Sn	¹²⁰ Sb	¹²¹ Te
¹¹⁷ Ag	¹¹⁸ Cd	¹¹⁹ In	¹²⁰ Sn	¹²¹ Sb	¹²² Te
¹¹⁸ Ag	¹¹⁹ Cd	¹²⁰ In	¹²¹ Sn	¹²² Sb	¹²³ Te
¹¹⁹ Ag	¹²⁰ Cd	¹²¹ In	¹²² Sn	¹²³ Sb	¹²⁴ Te
¹²⁰ Ag	¹²¹ Cd	¹²² In	¹²³ Sn	¹²⁴ Sb	¹²⁵ Te
¹²¹ Ag	¹²² Cd	¹²³ In	¹²⁴ Sn	¹²⁵ Sb	¹²⁶ Te

$N_n > 10^8 \text{ cm}^{-3}$

During hydrostatic He burning. Main component in AGB stars of 2-4 M_{\odot}

s-process contribution to solar abundance (*Arlandini et al. 1999*)

X	Sr	Y	Zr	Mo	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Ho	Er	Tm	Yb
S-, %	85	92	83	50	81	62	77	49	56	29	5.8	15	15	7.8	17	13	33

For example, Ba is called as s-process element,
Eu is called as r-process element.

Beers and Christlieb (2005):

r-I stars, if $0.3 < [\text{Eu}/\text{Fe}] < 1$ and $[\text{Ba}/\text{Eu}] < 0$,

r-II stars, if $[\text{Eu}/\text{Fe}] > 1$ and $[\text{Ba}/\text{Eu}] < 0$ (12 stars are known,
all have $-3 < [\text{Fe}/\text{H}] < -2.5$).

When the s-nuclei synthesis began in AGB stars?

Theory (*Travaglio et al. 1999*): $[\text{Fe}/\text{H}] \approx -1.5$

Observations (*Burris et al. 2000, Roederer et al. 2010*): $[\text{Fe}/\text{H}]$ from -2.6 to -1.4.

$$[\text{X}/\text{Fe}] = [\text{X}/\text{H}] - [\text{Fe}/\text{H}]$$

$$[\text{Fe}/\text{H}] = \log(N_{\text{Fe}}/N_{\text{H}})_{*} - \log(N_{\text{Fe}}/N_{\text{H}})_{\text{o}}$$

The purpose of this work is to find traces of the enrichment of Galactic matter with s-nuclei from precise analysis of chemical abundances of halo star with metallicity of -1.55

HD29907 – halo star

$T_{\text{eff}}=5500$ K, $\text{Log}(g) = 4.64$, $[\text{Fe}/\text{H}]=-1.55$, $\xi= 0.6$ km/c

(Mashonkina et al. 2003)

Observations (project no. 67.D-0086A, PI – T. Gehren):

$\lambda/\Delta\lambda=60000$ $\text{S}/\text{N}>200$

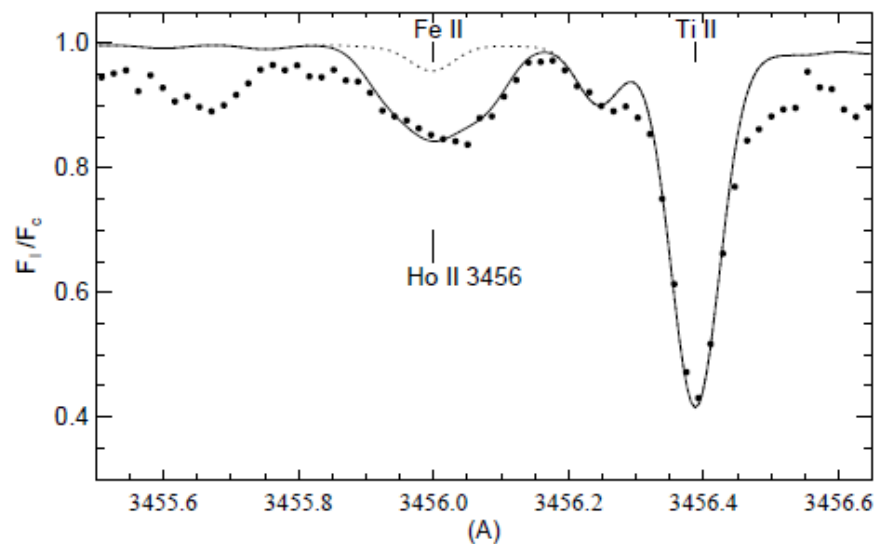
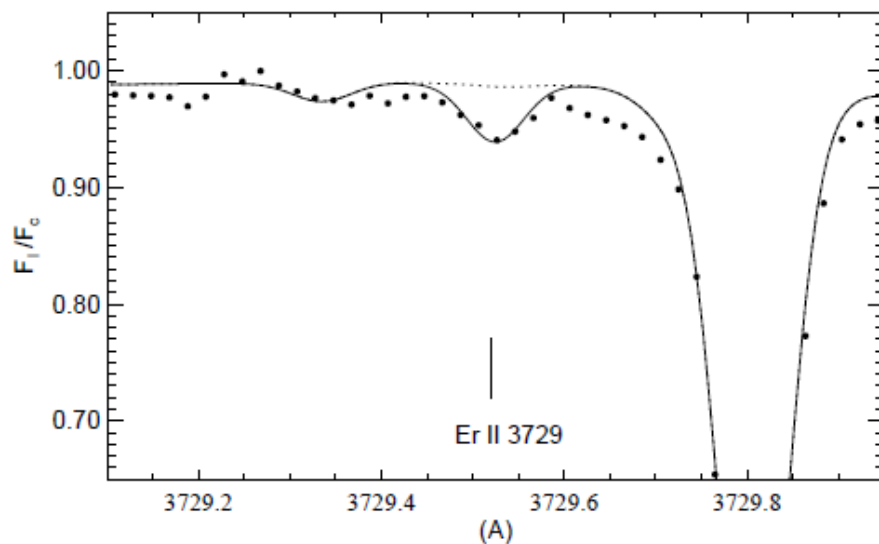
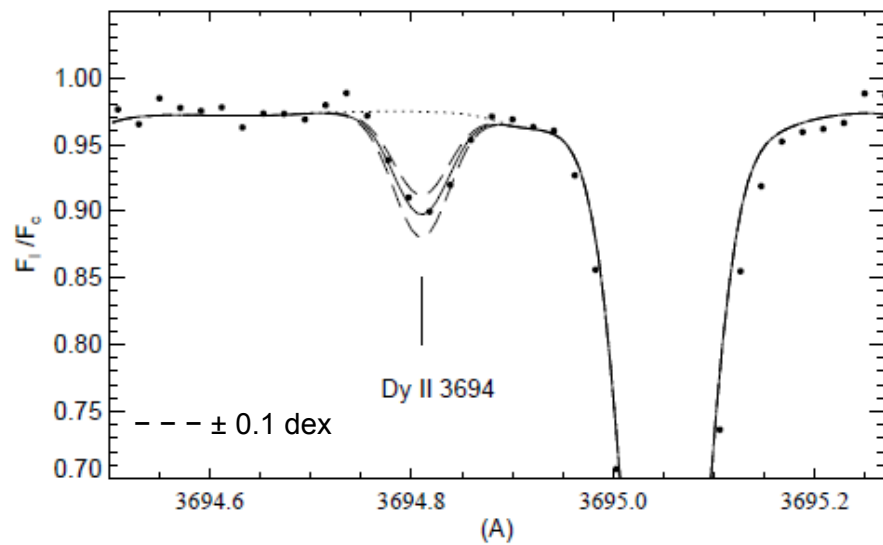
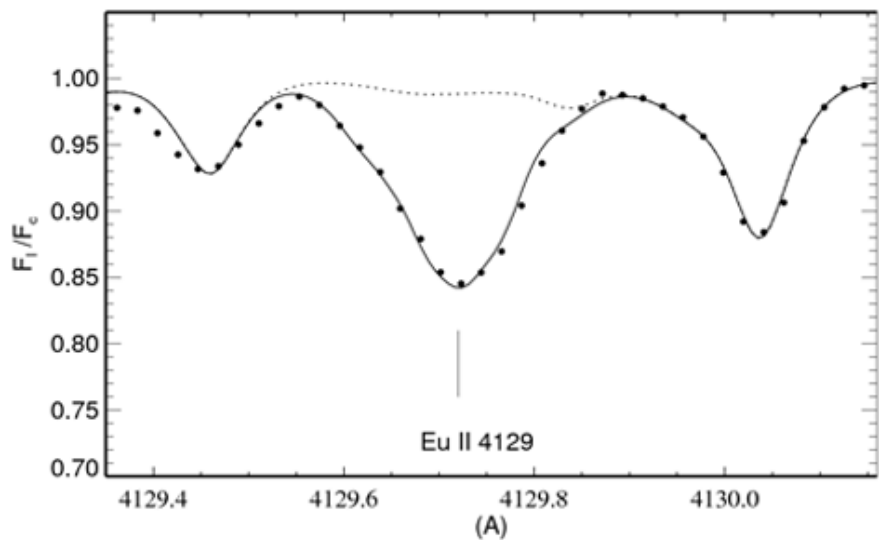
VLT2/UVES (Chile)

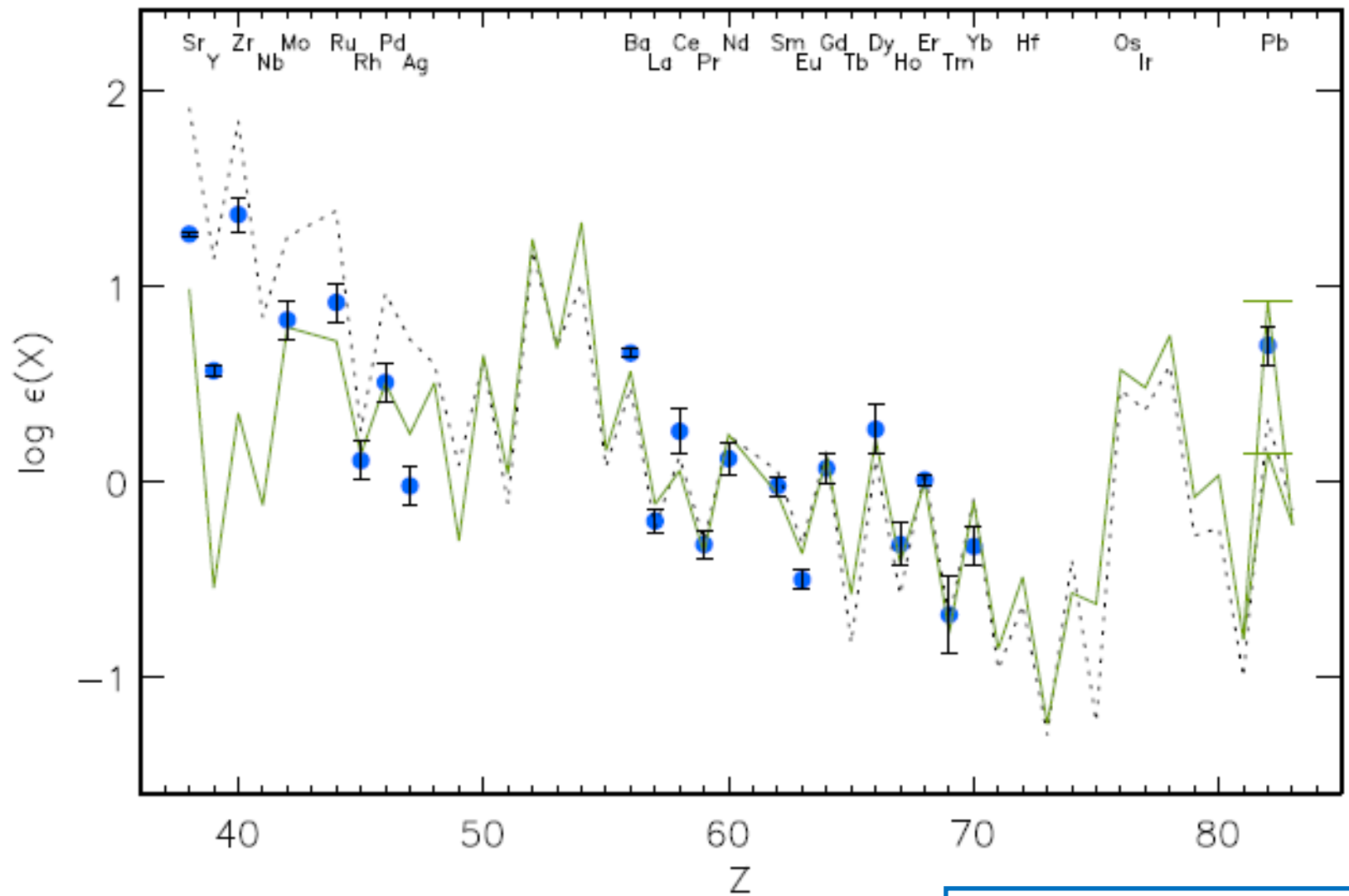
$\lambda = 3350\text{-}4450$ A, $4600\text{-}5550$ A, $5650\text{-}6650$ A

Method: line profile analysis (program SIU),
model atmosphere (program MAFAGS)

Abundances of 22 elements were determined: Sr-Pb and C,N.

Quality of line profile fitting



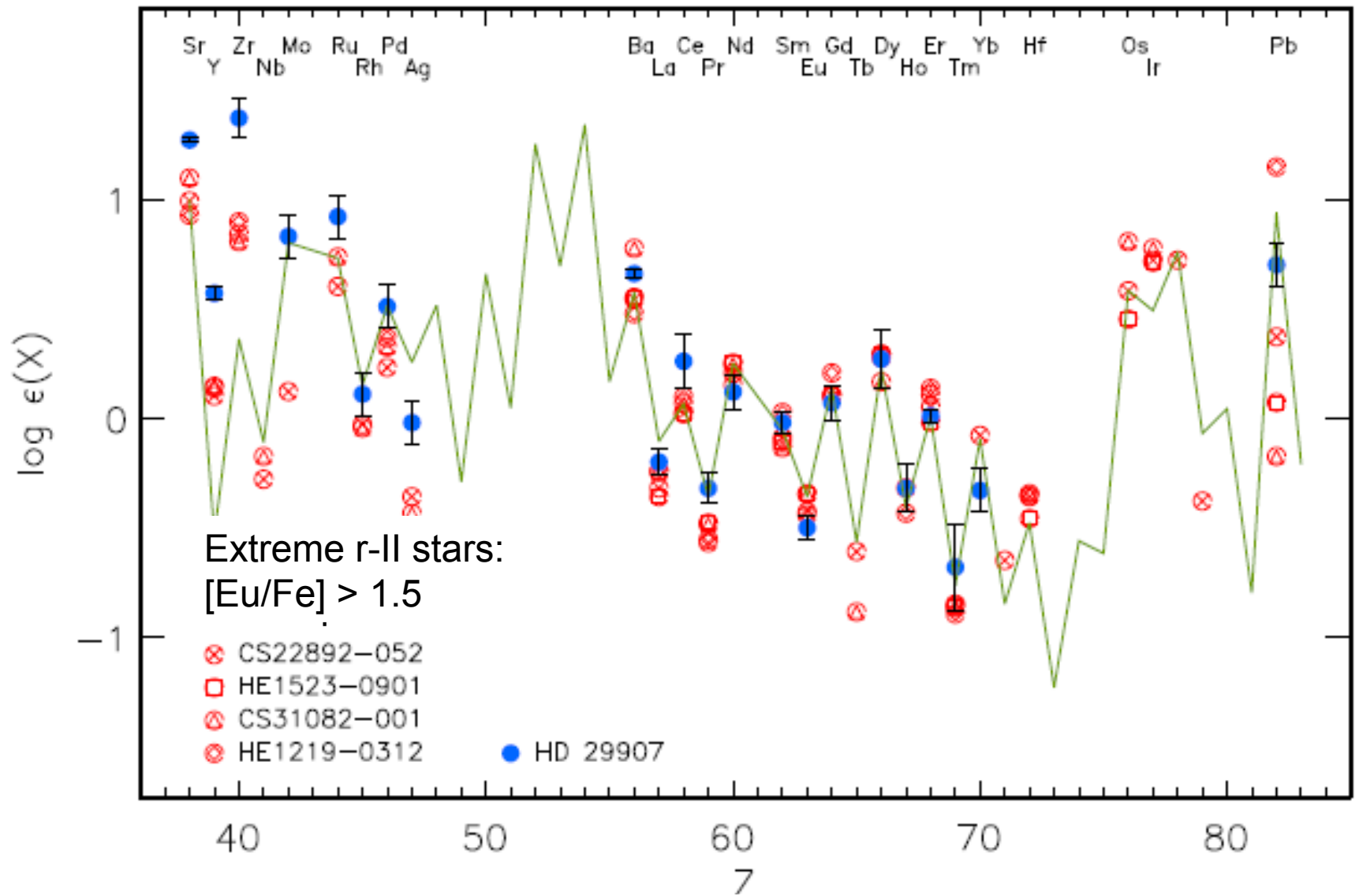


Heavy element abundance pattern of HD 29907

— «solar r-process» = total – s

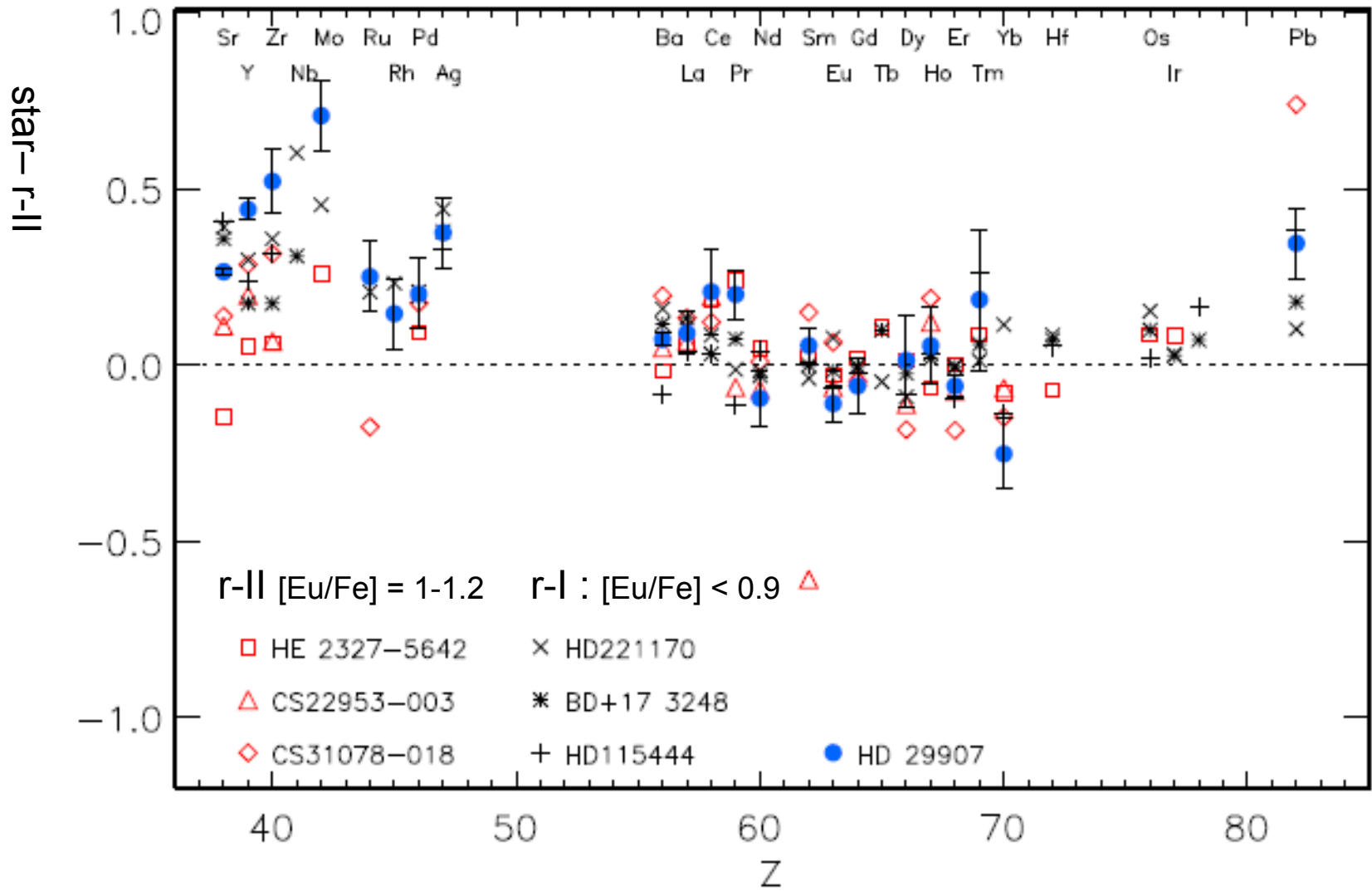
..... r-process model HEW (Farouqi et al. 2010)

Ba – Yb match
solar and theoretical
r-process. r-l star
[Eu/Fe]=0.53
[Ba/Eu]=-0.49

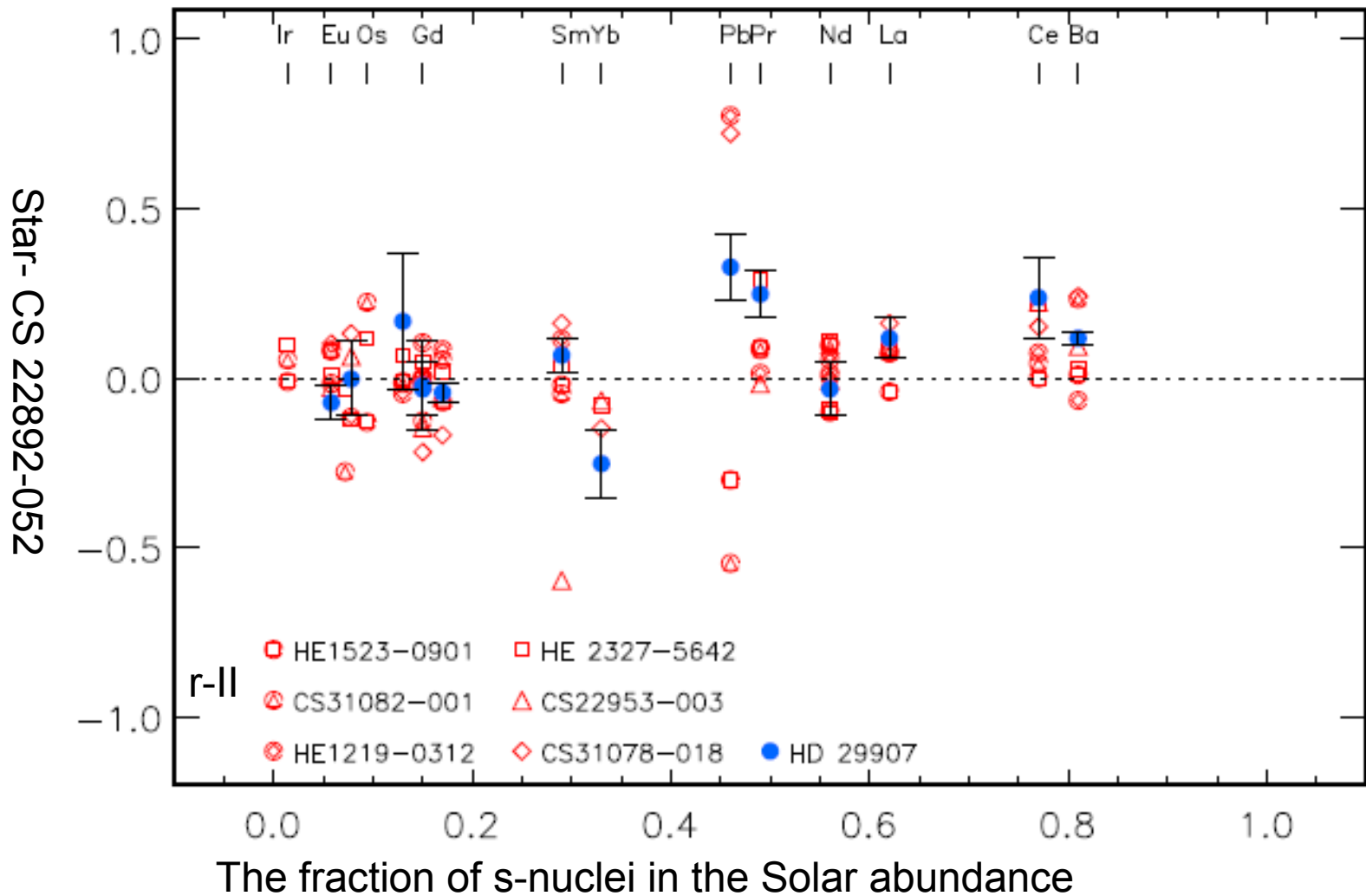


Ba-Yb in HD 29907 match “empirical” r-process based on r-II stars.

Sr-Zr : higher abundances



r-I stars: Sr-Ag are higher than in r-II, but not due to s-process !
 Additional source of their synthesis in early Galaxy was discussed
 (Truran et al. 2002, Travaglio et al. 2004)



Pr, La, Ce, Ba : the fraction of s-nuclei >49 % ,
 (HD 29907 – CS 22892-052) > 0, but no trend in their behavior.
 We didn't found convincing evidence for s-nuclei presence in HD 29907.

Conclusions

- HD 29907 is a r-I star ($[\text{Fe}/\text{H}] = -1.55$ and $[r / \text{Fe}] = 0.63$).
- Ba to Yb in this star match the scaled Solar r-process and empirical r-process abundance pattern very well, their origin is connected with a pure r-process
- HD 29907 shows enhanced abundance of Sr to Zr supporting the idea of the existence of LEPP in the early Galaxy.
- Even if there was a contribution of AGB stars to Galactic heavy elements at the epoch $[\text{Fe}/\text{H}] = -1.55$, it was small, at the level of the abundance errors.