Heavy element abundances of cool dwarf stars as a constraint to s- and r-process nucleosynthesis

(proposed study)

Lyudmila Mashonkina, Tatyana Sitnova
Institute of Astronomy, RAS, Russia

Moscow, September 10, 2013

Motivation

- Astrophysical sites for the r-process?

- The onset of the main s-process in AGB stars?

  s-process calculations

  Travaglio et al. (1999): [Fe/H] ≈ -1.5.

  Karakas (2010), *Lugaro* (2011): [Fe/H] ≈ -2.3.

  Observations

  Burris (2000), *Simmerer* (2004) from (Ba, La, Nd)/ (Eu, Dy):
  [Fe/ H] ≈ -2.3 to -2.6,

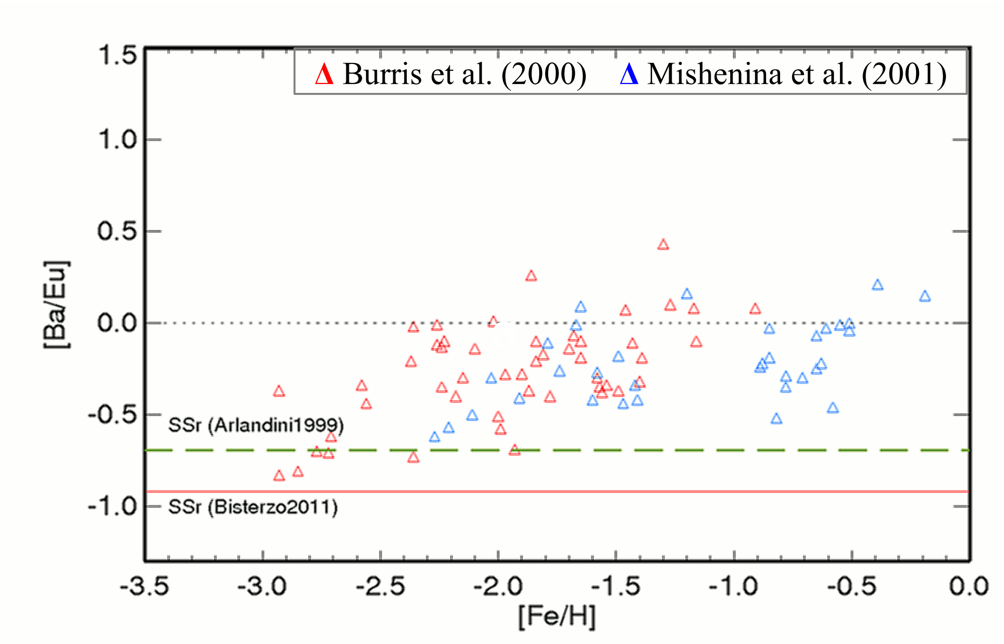
  Roederer et al. (2010) from Pb/Eu: [Fe/H] ≈ -1.4.

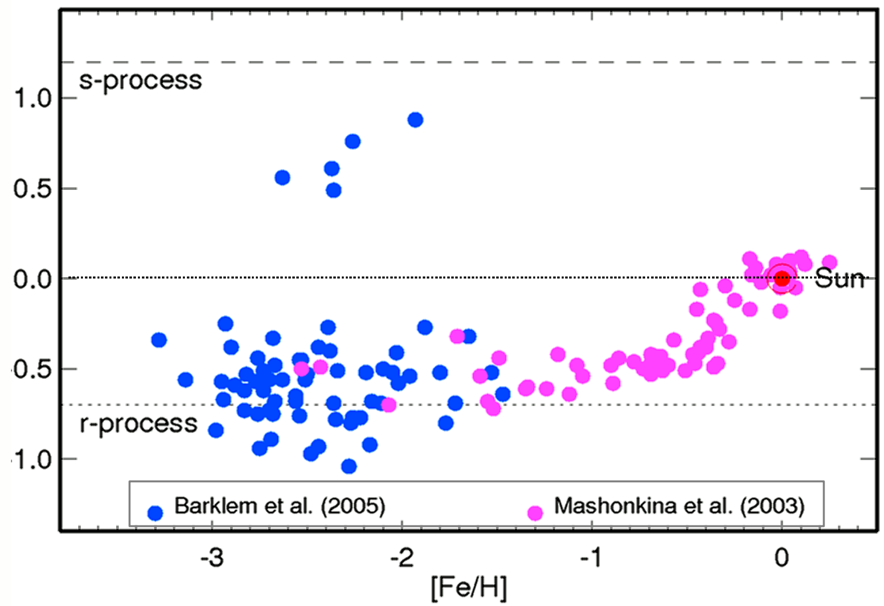
- Origin of light trans-Fe elements in the early Galaxy?

Literature data on heavy element abundances:
either narrow [Fe/H] range
or inhomogeneous in luminosity stellar samples
or LTE.

	[Fe/H]	luminosity	method
McWilliam (1998):	[-4.1, -2.1]	giants $0.4 < \log g < 3.6$	LTE
Burris et al. (2000):	[-3, -1]	giants $0 < \log g < 2.9$	LTE
Mashonkina & Gehren (2000-2003):	[-2, 0]	dwarfs $3.4 < \log g < 4.6$	NLTE
Mishenina et al. (2001,2002):	[-3, -0.5]	dwarfs-giants $0.5 < \log g < 4.6$	LTE
Mishenina et al. (2004-2013):	[-1, 0.3]	dwarfs	NLTE, LTE
Bensby et al. (2005):	[-0.8, 0.4]	dwarfs	LTE
Francois et al. (2007):	[-4.1, -2.7]	giants	LTE
Andrievsky et al. (2009, 2011)	[-4.1, -2.5]	dwarfs-giants $0.7 < \log g < 4.5$	NLTE

Elemental ratios in stars with various metallicities are used for testing chemical evolution models.





✓ Scatter of data for stars of close metallicities is up to 0.7 dex (!)

✓ Differences in average ratios between different studies.

- Uncertainty in stellar parameters?
- LTE?

Which Ba/Eu should be used in comparisons with model predictions?

Aims

- Homogeneous and accurate determination of stellar parameters and heavy element (Sr, Zr, Ba, Nd, Eu, Pb, Th) abundances for homogeneous in temperature and luminosity stellar sample in broad metallicity range $-3 < [Fe/H] < +0.3$.

- Constraining epoch for the onset of the main s-process in the Galaxy from elemental ratio comparisons.

- Improving the statistics of observed data on the LEPP elements Sr and Zr.

- Constraining r-process models by deriving fraction of the odd isotopes of Ba (for selected stars, where possible).

Observational data

Spectral observations: 3-m/Hamilton, Lick Observatory (USA),

3800-9600 A, R ≈ 40000, S/N > 100.

Stellar sample includes 80 stars:

T_{eff} = 4 800 – 6 500 K (IRFM, color calibrations),

log g = 3.4 – 4.6 (literature data, to be checked),

-3 ≤ [Fe/H] ≤ 0.3 (literature data, to be checked).

Method of calculations

Stellar parameters

- T_{eff}: IRFM, color calibrations;
- log g: HIPPARCOS parallaxes, Fe I/Fe II ionization equilibrium
  NLTE for Fe I-Fe II with model atom from *Mashonkina et al.* (2011);
- [Fe/H], ξ_t : from Fe lines.

Chemical abundances

- NLTE for Sr II, Zr II, Ba II, Nd II, Eu II, Pb I, Th II
  (original model atoms: *Mashonkina et al.* 1997-2012)

1D model atmospheres:

MARCS (*Gustafsson et al.* 2008)

Plan for 2014:

1. Testing spectroscopic method of surface gravity determination through NLTE analysis of iron lines in 19 stars with well determined T_{eff} and log g (see yesterday talk of Tatyana Sitnova).

2. Determination of log g, [Fe/H], ξ_t from Fe lines for the remaining stars.

3. r-process enhanced star HE 2252-4225:
determination of stellar parameters and detailed chemical abundances, analysis of heavy-element abundance pattern.

2015:

1. NLTE calculations for Sr II, Zr II, Ba II, Nd II, Eu II, Pb I, Th II for all investigated stars.

2. NLTE and LTE abundance determinations (for Pb and Th, where possible) through line profile fitting.

2016:

1. Analysis of n-capture element abundance pattern in selected stars. Comparison with the s- and r-process predictions.

2. Stellar elemental ratios vs. metallicity.

3. Determination of fraction of the odd isotopes of Ba in selected stars. The s/r-process controversy.