Basel NewCompStar/Brainstorming and Fun Meeting
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Strontium and barium in VMP stars in the Milky Way and dwarf satellites

INASAN

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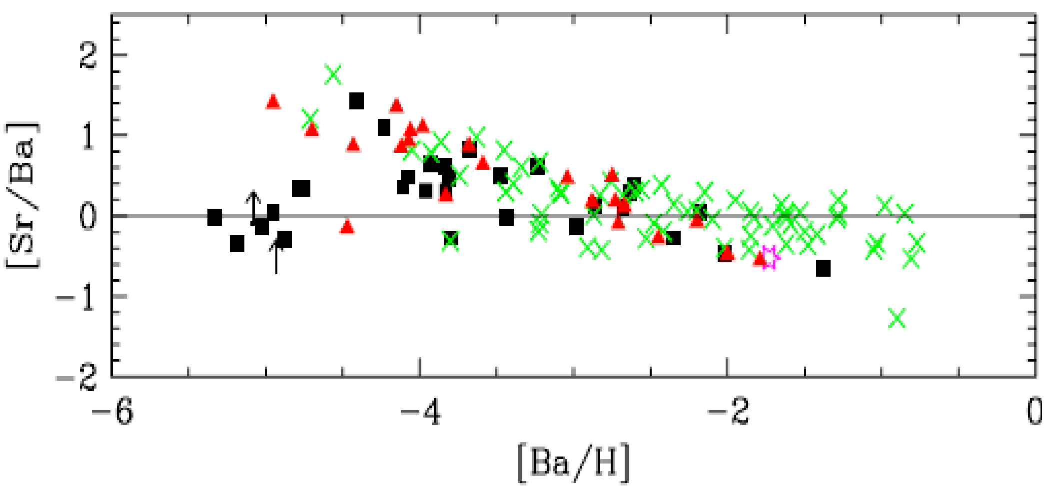
Problem of Sr/Ba

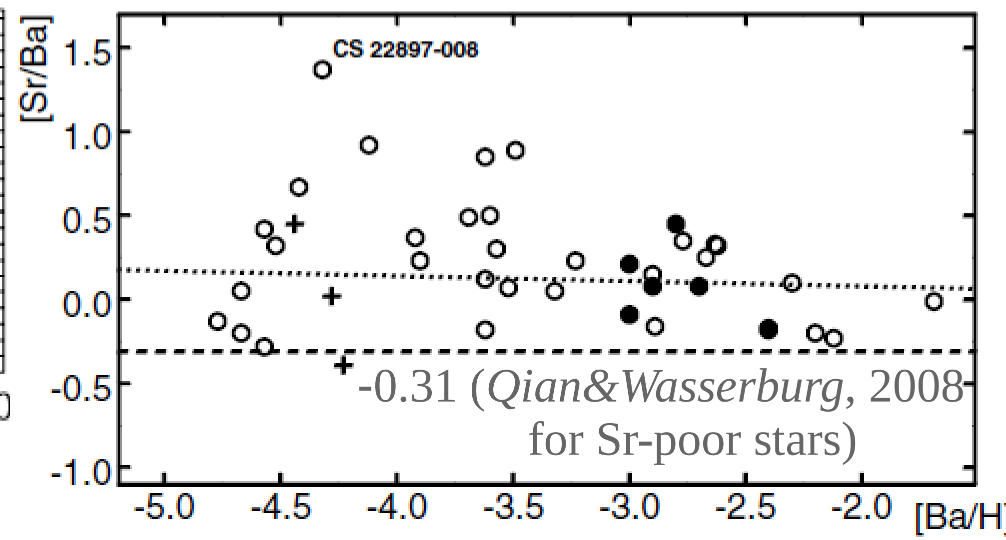
- Solar Sr: 80 % from main + weak s-process (*Travaglio*+2004),
  Ba: 80 % from main s-process (*Travaglio*+1999).

- Stars formed after the onset of s-process in AGB stars: solar Sr/Ba is expected. Observed in MW at [Fe/H] > -2. ☺

- VMP regime: Ba from r-process.
  If Sr would be from the same source, Sr/Ba ≈ constant.
  r-II stars ([Eu/Fe] > 1, [Ba/Eu] < 0): mean $[Sr/Ba]_r = -0.38$.

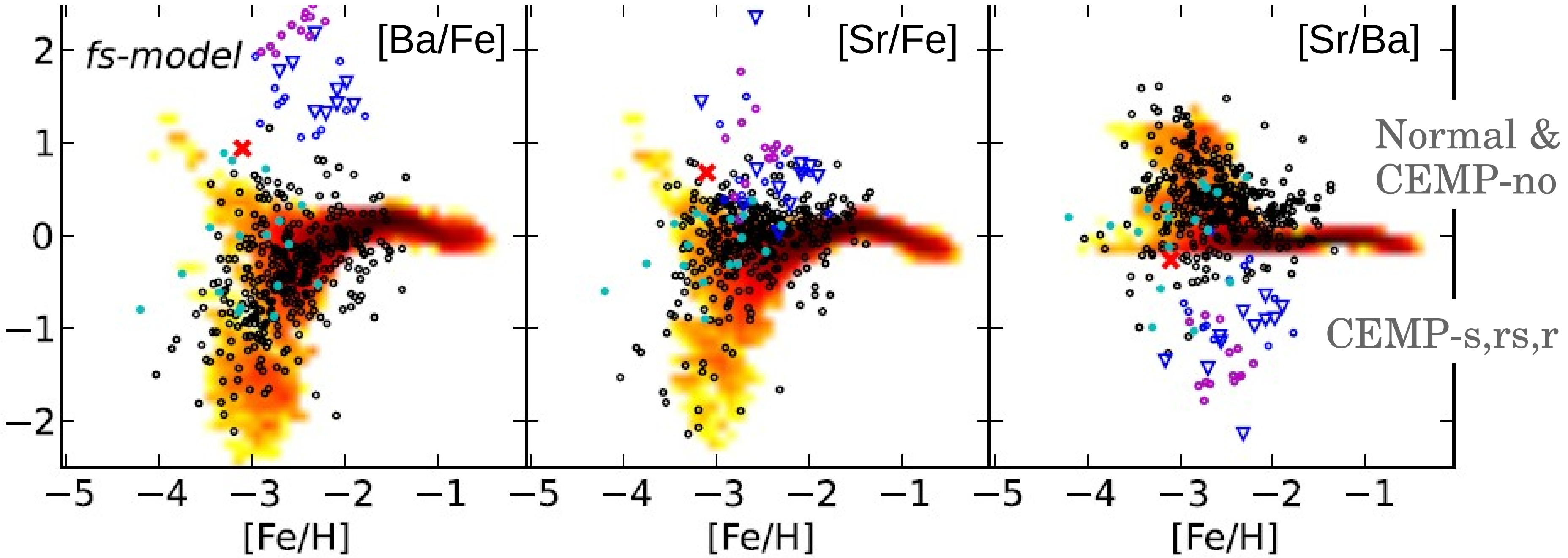


Francois+2007 (■) } upward trend.
Honda+2004 (▲)



After NLTE revision
(*Andrievsky*+2011)

Inhomogeneous model: r-process + s-process (spinstars) reproduces scatter of observed Sr/Ba (*Cescutti*+2013)



Observations for MW from *Frebel* (2010)

Stellar source(s) of Sr and Ba in the primordial environment can be identified using VMP stars in dwarf spheroidal galaxies (dSphs).

What we did.

Stellar sample (-4 ≤ [Fe/H] ≤ -2)

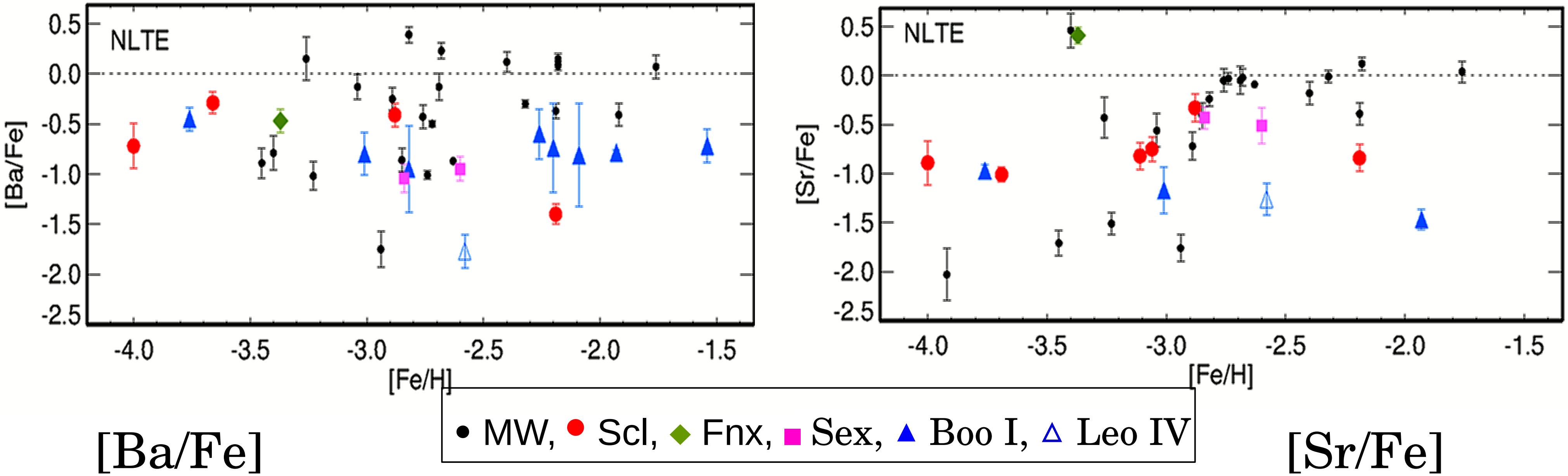
- Classical dSphs: Sculptor, d = 86 kpc, 10 stars,
  Fornax 140 kpc, 1 star,
  Sextans 90 kpc, 2 stars,
- Ultra-faint dSphs (UFD): Boötes I, 60 kpc, 8 stars,
  Leo IV 154 kpc, 1 star,
- MW comparison sample, 23 halo giants.

Observational data: VLT, Magellan, Keck, CFHT, $R \geq 25\,000$.

✓ Determination of homogeneous set of atmospheric parameters,

✓ NLTE abundances.

NLTE abundance trends: Ba/Fe, Sr/Fe



[Ba/Fe]

MW: scatter at [Fe/H] < -2.5, with the floor at [Ba/Fe] ≈ -1.

dSphs:

✓ subsolar Ba/Fe,

✓ similar in different galaxies, except ET0381 in Scl, Leo IV-S1,

✓ close to Ba/Fe floor of MW.

Boötes I: [Ba/Fe] = -0.73±0.15

[Sr/Fe]

MW: scatter at [Fe/H] < -2.8, with [Sr/Fe] down to -2.

Different behaviour in

✓ UFD: [Sr/Fe] ≈ -1.2,

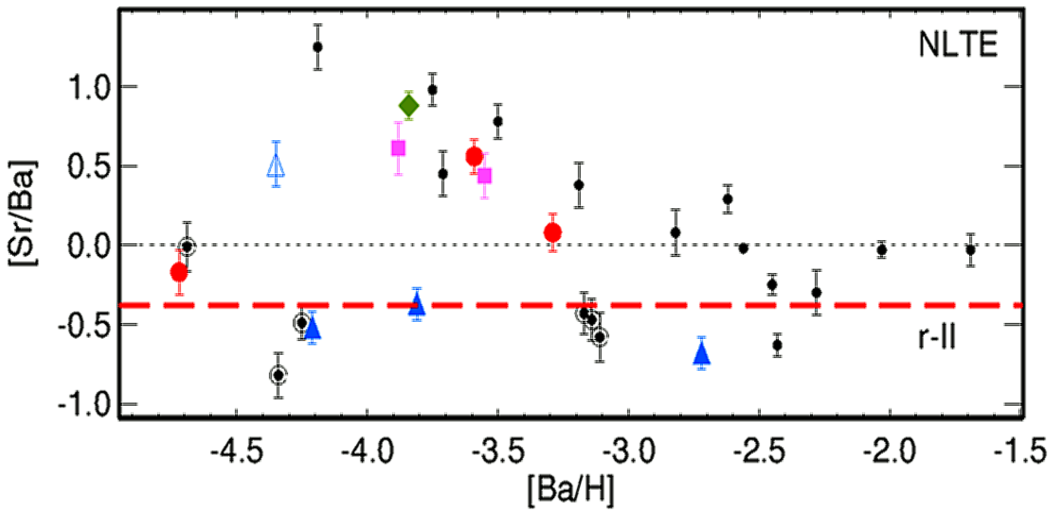
✓ classical dSphs:

- follow UFD at [Fe/H] < -3,
- hint of upward trend at higher metallicity.

NLTE abundance trends: Sr/Ba

MW, two groups depending on Sr/Fe.

- Sr-poor, [Sr/Fe] < -0.4: Sr/Ba close to $[\mathrm{Sr/Ba}]_r = -0.38$, Sr, Ba from r-process.
- [Sr/Fe] > -0.4: upward trend with Ba/H. r-process + s-process (spinstars)?



If s-process contributed to Ba, Ba isotopic ratios are different from that for r-process

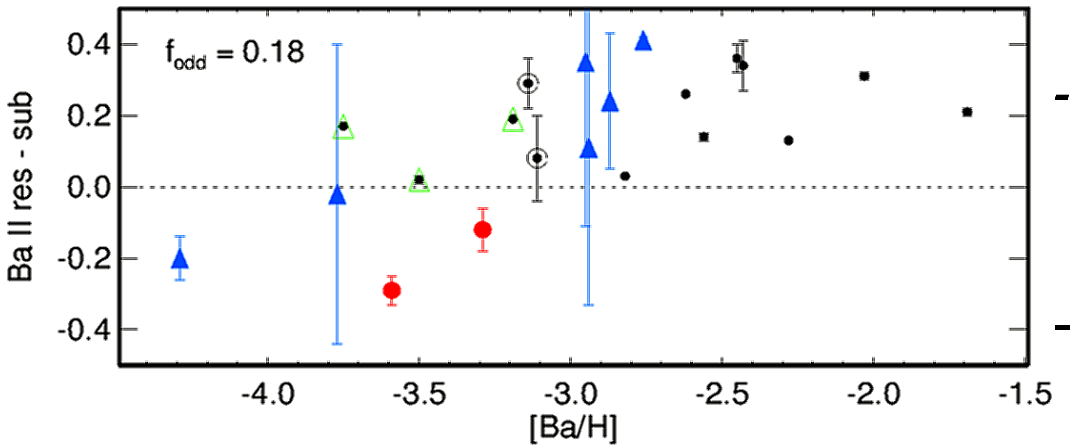
dSphs, different behaviour in

- ✓ Boötes I: Sr, Ba from r-process,
- ✓ Scl, Fnx, Sex: enrichment of Sr, Ba similar to early MW.

- Ba isotopes: A = 134-138. HFS levels in ^{135}Ba, ^{137}Ba.
- Abundance from Ba II 4554, 4934 Å depends on used
  $f_{odd} = (^{135}\mathrm{Ba}+^{137}\mathrm{Ba})/\mathrm{Ba}$. The greater f_{odd}, the lower abundance is.
- Solar Ba, $f_{odd} = 0.18$ (*Lodders*+2009), s : r = 80 : 20.
- s-process, $f_{odd} = 0.11$,
- r-process, f_{odd} = 0.44 to 0.72 (*Kratz*+2007, *Travaglio*+1999, *McWilliam* 1998)
- HFS effects are minor for Ba II subordinate lines.
- Stellar f_{odd} can be derived from requirement:
  abundances from different Ba II lines must be equal.

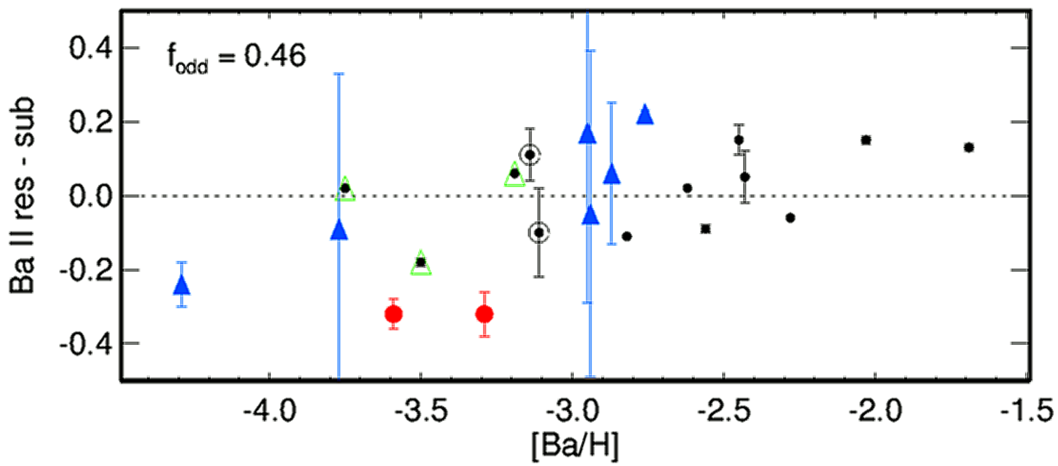
Fraction of Ba odd-*A* isotopes

Abundance differences: Ba II resonance - subordinate lines



MW:

- $f_{odd} \simeq 0.5$ fits most stars, including two on Sr/Ba upward trend (△) ⇨ Ba from r-process.
- HD122563 ($f_{odd} = 0.18$) may have s-process contribution.



Boötes I:

$f_{odd} \simeq 0.5$, r-process.

Sculptor:

low f_{odd}, s-process?

Questions ?

Observations:

Sr/Ba in MW and classical dSphs
— trend like in *Francois*+2007, this study ?
— or scatter ?

Need in larger statistics of homogeneous determinations.

Theory:

how to understand upward trend of Sr/Ba with Ba/H,
if it exists in early MW and classical dSphs ?