Sextans Dwarf Galaxy as a Hint to the Evolution of the Milky Way

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ABSTRACT

According to the hierarchical structure formation scenario, small galaxies with various star formation histories have contributed to form larger galaxies, including the Milky Way. Large dispersion in abundance of r-process elements in the metal-poor region of the halo stars is its evidence . Chemical evolution models show that the abundance ratio (e.g., [Ba/Fe]) have different feature depending on the mass of the small galaxy (e.g., Ishimaru, Wanajo, Prantzos 2015). The abundance ratio of neutron-capture elements of dwarf galaxies are expected to be simple, showing clumps instead of smooth dispersion (Bland-Hawthorn et al. 2010). We present the abundance analysis of n-capture elements (e.g., Sr, Ba) of metal-poor stars ([Fe/H]<-2.5) in Sextans dwarf galaxy observed using Subaru Telescope HDS. We discuss the chemical evolution of the dwarf galaxy and the possibility of such small structures building large galaxy by comparing our results to chemical evolution model of the Milky Way.

1. Background

Hierarchical Galactic Formation Scenario

According to the hierarchical galactic formation scenario, the difference in star formation history of each sub-halo cause the observed dispersions in [r/Fe] of metal-poor stars (MPS), if the Galactic halo is formed from multiple of sub-halos[e.g., 3]. Smallest dwarf galaxies may be the remnants of the sub-halos.

Different Sites of r-process Elements

Recent studies suggest two major candidates of r-process sites;

- ◆Neutrino driven winds in core-collapse supernovae (CCSNe) as site of light r-elements (e.g., Sr) [e.g., 4]
- ◆Neutron star mergers (NSMs) as major site of heavy r-elements (e.g., Ba) [e.g., 5,6].

Wanajo et al. (2011) Wanajo et al. (2014)

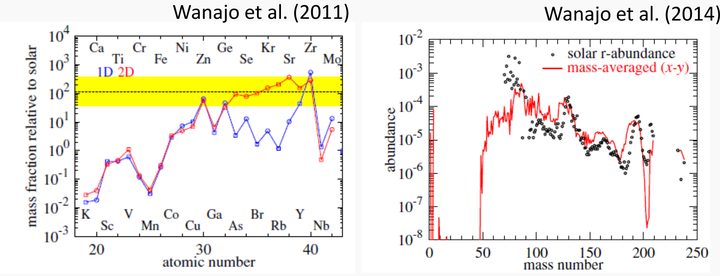

Figure 1: CCSNe as site of light r-elements (left), NSMs as site of heavy r-elements (right)

2. Motivation

In MW halo stars, [Sr/Ba] shows a large dispersion at metal-poor region (Figure 2-right). In smaller galaxies such as Sextans dwarf galaxy, abundance ratio of MPS may show “clump” instead of dispersion.

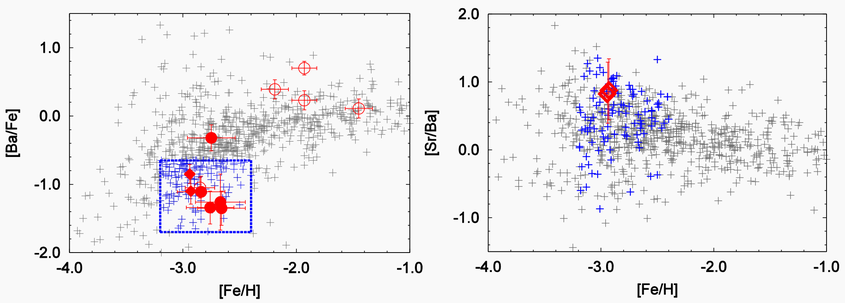

Figure 2: [Ba/Fe] and [Sr/Ba] of MW Galaxy and Sextans dwarf galaxy
＋: MW Halo stars
◇、●、○: Sextans dwarf stars
(Tafelmeyer et al 2010, Aoki et al. 2009, Shetrone et al. 2001)

[Ba/Fe]: Seven out of eight MPS ([Fe/H]<-2.5) of Sextans dwarf show [Ba/Fe] clumped at ～-1.2 dex.

[Sr/Ba]: [9] measured two stars, showing very similar abundance ratio at ～0.8 dex. **⇒Evidence of “clump” in abundance ratio of MPS?**

3. Observation

Target Selection: Three brightest stars with its Ba abundance measured.
Telescope: 8.2m Subaru Telescope High Dispersion Spectrograph.

Table 1: Stellar Parameter

Object	T_{eff} (K)	[Fe/H]	log g	VEL.	Ref. of T_{eff}
S10-14	4620	-2.79	1.1	2.4	[7]
S11-13	4400	-2.91	0.7	2.3	[7]
S49	4325	-3.00	1.4	1.7	[8]

- ◆ We derive Sr and Ba abundances from
  Sr: 4077.7 Å
  Ba: 4934.1 Å and 4554.0 Å
- ◆ Effective temperatures are adopted from the previous studies (Table 1)

- ◆Date of Observation: 2016-04-25, 27
- ◆Wavelength Coverage (nm): 392.32-560.44
- ◆Exposure time/target (s): ～14,400

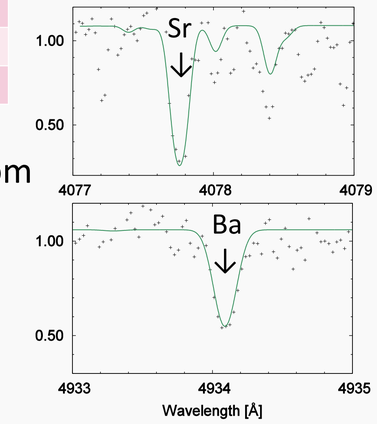

Figure 3: Example of observed Sr and Ba spectra of S10-14.
Dotted line: observations;
Green line: spectra calculated for the adopted abundance

4. Results

Abundance Ratio [Ba/Fe]

The abundance ratio [Ba/Fe] of Sextans dwarf stars are shown in Figure 4 (left). The results of [Ba/Fe] and [Fe/H] are similar to previous studies (Table 2).

Abundance Ratio [Sr/Ba]

The abundance ratio [Sr/Fe] of Sextans dwarf stars are shown in Figure 4 (right). S11-13 and S49 show relatively similar [Sr/Ba] value, but S10-14 is ～0.3 dex higher. Two stars measured by [9] is ～0.8 dex higher.

Table 2: Abundance Ratio of this study and Previous Study

Object	[Fe/H]	[Ba/Fe]	[Sr/Fe]	[Sr/Ba]	[Fe/H]	[Ba/Fe]	Ref
S10-14	-2.79	-1.39	-0.81	0.58	-2.7	-1.35	[7]
S11-13	-2.91	-1.45	-1.26	0.19	-2.8	-1.34	[7]
S49	-3.00	-1.06	-0.83	0.23	-2.85	-1.05	[8]

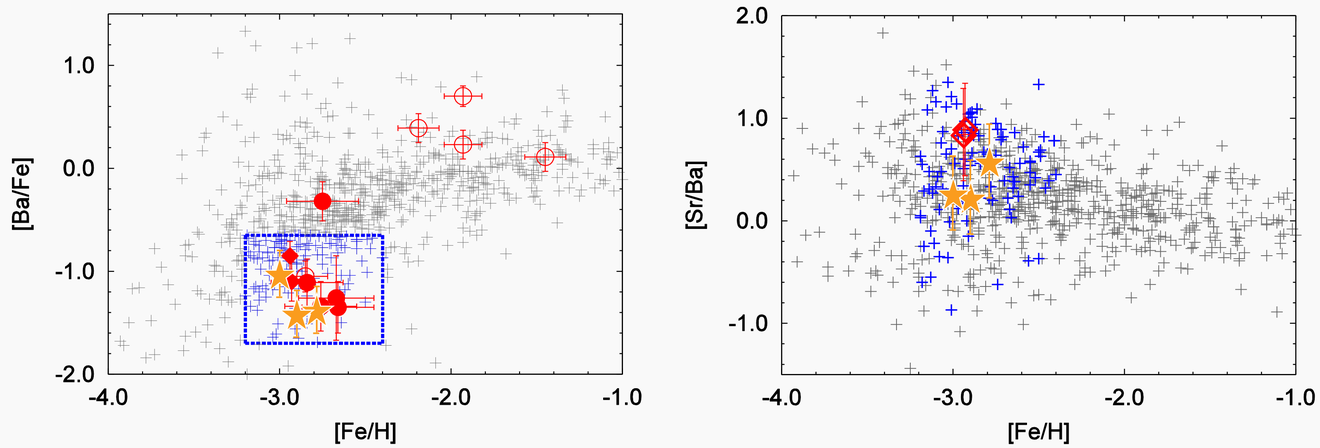

Figure 4: [Ba/Fe] (left) and [Sr/Ba] (right) of MW Galaxy and Sextans dwarf galaxy
＋: MW Halo stars
◇、●、○: Sextans dwarf stars (Tafelmeyer et al 2010, Aoki et al. 2009, Shetrone et al. 2001)
★: [Ba/Fe] and [Sr/Ba] of this study

Clump or Dispersion at [Sr/Ba]?

The error bar is large due to uncertainty in parameters such as microturbulence.

⇒ Difficult to draw a conclusion

5. Discussion

Why we expected clump at MPS

- ◆Small galaxies should have formed from small number / single sub-halo(s)
- ◆Element producing events such as CCSNe and NSMs should affect most of the interstellar gas in small galaxies

In smaller galaxy…

In smaller galaxy such as Ret II measured by [10], Ba in MPS show high abundance and "clumped" at [Ba/Fe]～1.0 dex (Figure 5).
"Ret II might have been contaminated by a **single NSM**" [10]

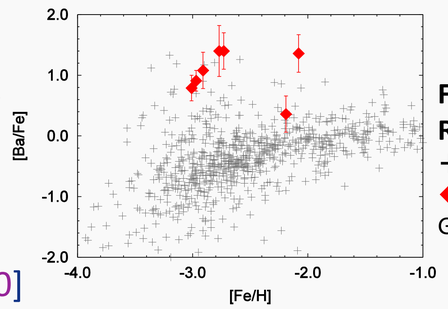

Figure 5: [Ba/Fe] of Ret II UfD Galaxy
＋: MW halo stars
◆: Reticulum II UfD Galaxy (Ji et al. 2016)

Possible Reasons for Dispersion in [Sr/Ba] of MPS

Dispersion in [Sr/Ba] suggest that there are different origins of elements in MPS of Sextans dwarf galaxy.

- ◆ **Evidence of different sub-halo have formed Sextans Dwarf?**
  ⇒It is more likely that [Ba/Fe] would also have variation
- ◆ **Galaxy experiencing CCSN producing light r-elements?**
  ⇒Can explain the abundance of [Ba/Fe]
  ⇒CCSN affect most of the interstellar gas in small galaxies?
- ◆ **Evidence of several CCSNe or inhomogeneity?**

References

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