The Gaia DR2
and
the Database of Metal-Poor Stars

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Good memories of stars

Stars remember their birth conditions

**Stellar kinematics**

- negligible stellar interactions
- slowly changing gravitational potential with symmetry

There are should be conserved quantities

Stellar chemical abundances

abundance of 10Gyr-old stars = abundance of ISM 10Gyr ago, reflecting star formation before

Stars $\rightarrow$ the Galaxy
To understand the halo formation from chemo-dynamical analysis of (very) metal-poor stars

Why metal-poor stars?

How do we study and where can we get chemical abundances and kinematics?
Metal-Poor Stars

metal-poor = old
(the Universe started without metals)

Very Metal-poor stars ([Fe/H] < -2.0)
- almost as old as the Galaxy (~10Gyr old)
- mostly found in the Galactic stellar halo

Tell us about the very beginning of the Galaxy/halo formation

Note: $[X/Y] = \log \frac{N_X}{N_Y} - \left( \log \frac{N_X}{N_Y} \right)_\odot$
Chemical Abundances

How do we get chemical abundance of stars?

Absorption lines in stellar spectra

Requirements
- high resolution (R > 20,000)
- high S/N (S/N > 20)

Expensive observation

SAGA database


Stellar Abundances for Galactic Archaeology Database

- Compilation of abundance measurements for very metal-poor stars in literatures
- >1300 very metal-poor stars in >300 literatures
Stellar kinematics

Gaia: space telescope for astrometry

We are now able to explore chemo-dynamics of very metal-poor stars for the first time
Kinematics and abundances in halo

Stellar kinematics in the halo
5Gyr after satellite accretion in N-body simulation by Jean-Baptiste et al. (2017)

Stellar chemical abundances

Mg: α-element
Ba: r-process element

E

All stars
in-situ stars
accreted stars

[Lz]

Milky Way data from SAGA database

[fainter satellites]

[Fe/H] [Mg/Fe] [Ba/Fe] [Fe/H]
Results

Global property

Two components

Substructures
Global property of metal-poor stars

- No overdensity associated with the disk
- There would be a metallicity above which disk formation has started

[Fe/H] < -1.5

disk stars

disk rotation

prograde

retrograde
Abundances of prograde/retrograde halo halo

Metallicity difference

Lack of abundance difference at \( [\text{Fe/H}] < -2 \)
The metal-poor component has formed in a similar way between prograde/retrograde halo.
Known Substructures in the Halo

What are the origins of the substructures?

Helmi+17
Mg abundance of substructures

All stars in the database / stars in a substructure

Prograde substructures have higher [Mg/Fe], meaning they have formed in Milky Way

Similar picture in Nissen&Schuster 10
Ba abundance of substructures

Large scatter at low metallicity

A possible signature of “[Ba/Fe]” jump

Similar feature in a dwarf galaxy

Tsujimoto, Matsuno, et al. (2017)
Conclusion

First chemo-dynamical analysis for a large number of very metal-poor stars are conducted

**Indications to the early phase of the Galaxy formation**
- Disk formation has started above a certain metallicity
- The metal-poor component of the prograde/retrograde haloes seems to have formed in a similar way
  - The most prograde kinematic substructure might be a mixture of stars formed in Milky Way and those formed in a dwarf galaxy
Future

Gaia DR2 are excellent!!
we could utilize a large potion of stars in SAGA database

Still, any chemical signatures are, at most, week

Limitations:

**Abundance precision**
Systematic errors could have blurred signatures

[LAMOST-Subaru survey of 400 metal-poor stars](H.-N. Li, W. Aoki, T. Matsuno et al.)

**Number of stars**
cf. 400 stars in 20 Subaru nights
abundance determination from lower-res. spectra