Chemo-Dynamical evolution of dwarf spheroidal galaxies

Yutaka Hirai
(The University of Tokyo, NAOJ)
Jun Hidaka (NAOJ), Takayuki R. Saitoh (Titech),
Michiko Fujii (NAOJ), Shota Shibagaki (UTokyo),
Grant J. Mathews (U. Notre Dome),
and Toshitaka Kajino (NAOJ, UTokyo)
Dwarf Galaxies

Leo II dwarf galaxy

Tolstoy et al. 2009

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Galaxy Formation

Dwarf Galaxies might be building blocks of the Milky Way

We can observe each star in nearby dwarf galaxies to estimate star formation histories and metallicity.

Dwarf galaxies are useful tool to study galaxy formation and evolution
Observation

Star Formation Histories of dwarf galaxies

Each dwarf galaxies might experience different evolution. Star formation histories affect the chemical abundance pattern of galaxies.

Starkenburg et al. 2013
Elemental Abundance Pattern of dwarf galaxies

Systematically different chemical abundance pattern from Milky Way
Present dwarf galaxies and building blocks of the Milky Way are different?

We need detailed simulation of dwarf galaxy evolution.
Physical Processes inside a galaxy

We need to simulate dynamical and chemical evolution of galaxies at the same time!

Chemical and Dynamical Evolution = Chemodynamical evolution

Massive Stars
Type II Supernovae
Type Ia Supernova
Our Ultimate Goal

to reveal the chemo-dynamical evolution of dwarf galaxies in order to construct a comprehensive picture of the formation and evolution of the Milky Way in terms of the origin and evolution of atomic elements!
Today’s goal

• to construct a “chemo-dynamical evolution code”
• to find important physics on star formation histories

Next Goal

• to implement “supernova nucleosynthesis yields” which we are calculating in our Tokyo Group into the present chemo-dynamical code
• to study the “chemical evolution” and “dynamical evolution” of dwarf spheroidal galaxies simultaneously as building blocks of understanding the Milky Way
Importance of star formation for chemical enrichment inside a galaxy

Star Formation

Chemical Enrichment

Type II Supernova

Type Ia Supernova
Chemo-Dynamical Evolution Code

- Dark Matter (Gravity, Tree method)
- Gas (Hydrodynamics, SPH method, ASURA (Saitoh & Makino, 2013))
- Star (Feedback)
Star Formation Law and Supernova Feedback

- Radiative Cooling
- Low Temperature ($T < 3 \times 10^4 \text{ K}$)
- High Density ($\rho > 0.1 \text{ cm}^{-3}$)
- Collapsing
- Gas Particles
- Star Formation
- Supernova
- $E = \eta \times 10^{51} \text{ erg}$
  - $\eta$: Feedback Energy Efficiency
Past Studies (Revaz & Jablonka 2012)

Star Formation History  Chemical Abundance Pattern

Successfully reproduce star formation histories and chemical abundance patterns

But… they reduce the energy of the supernova explosion ($10^{49}$ erg)
Initial Condition

Density Profile: pseudo-isothermal profile

Radial Density Profile

Density Distribution

Total Number of Particles: $2^{16}$

Mass of One Gas Particle: $10^3 M_\odot$
Star Formation Histories

Bursty early phase star formation due to the initial collapse of the model galaxy.

Total mass of the model galaxy: $5 \times 10^8 \, M_\odot$

Sculptor dwarf galaxy seems to evolve isolated.
Importance of supernova feedback

- Supernova feedback strongly affects the star formation rate
- Strong feedback blew away the gas inside the galaxy
- Chemical abundance pattern may be affected by supernova feedback

For near future
We need to check more massive galaxy and effects of merger with feedback
Next Prospects

Constraining the sites of r-process elements

Origin of r-process elements: Type II supernovae? Neutron Star Mergers?

The answer might be in chemodynamical simulation of dwarf galaxies!
Summary

- Dwarf spheroidal galaxies is useful tool to study galaxy formation and evolution.
- We constructed chemical and dynamical evolution code.
- Supernova feedback is an important process to derive star formation histories.
- We will include chemical feedback such as r-process elements to deeply study evolution of dwarf galaxies and origin of elements.