Galactic Archaeology with the WFMOS high-resolution mode

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Purposes and goals:
Determining chemical abundances for individual stars to reveal (1) the evolutionary history of stellar components and substructures, and (2) the nature of clusters that have contributed to structure formation.

Contents:
• Separations of groups by $\alpha$/Fe
  - thick disk stars
  - halo stars
• other useful elements for chemical tagging
• other possible (PI-type) projects
An extreme case: stars with low abundances of $\alpha$ elements


A goup of stars may be identified from elemental abundances
Origins and implications of individual elements

- **O, Mg**: SN II (M ≥ 20 Msun)
- **Si, Ca, Ti, Cr** (even-Z): SN II (not only massive ones)
- **Fe, Ni**: “metallicity”. SN Ia contribution (determination of atmospheric parameters)
- **Mn, Co**: SN II, metallicity dependent, explosion energy dependent
- **Eu**: r-process. Low-mass SN II?
- **Y, Zr, Ba, La**: s-process (+r-process at low metallicity)
$\alpha$/Fe ratios of Galactic field stars

Simplified view

Observational results

inner/outer halo + thick disk

Thick disk

Thin disk
Elemental abundance studies for disk stars

  - 181 F & G dwarfs
  - 27 elements
  - stellar space motion

  - 176 stars → 95 thick disc stars
  - 22 elements
\( \alpha / \text{Fe} \) ratios in thick/thin disk stars

- Thick/thin disks are distinguished by kinematics
- There is metallicity overlap, but alpha/Fe is different
- A fraction of thick disk stars have similar elemental abundances to thin disk stars

Reddy et al. (2003)
$\alpha/\text{Fe}$ ratios in thick/thin disk stars

A scenario to explain the abundance ratios in the disk stars:
- enrichment by SNe and dilution by metal-poor gas

Reddy et al. (2003)

- Enrichment by SN II
- Infall of metal-poor gas?
- Enrichment by SN II + SN Ia
Stars having kinematics of the thick disk but abundances of the thin disk: the second component scattered from the thin disk?

Reddy et al. (2003)
\( \alpha / \text{Fe} \) ratios in halo stars

- Galactic halo consists of at least two components: outer and inner halos
- alpha/Fe ratios of halo stars show some variations
Stars having large Rapo (=outer halo) show low alpha/Fe?

$\alpha/Fe$ in outer halo stars: a new result

Outer halo stars show decrease of $\alpha/Fe$ in $[\text{Fe/H}]>-2$. →See Ishigaki et al. for details.

Filled symbols: outer halo stars ($Z_{\text{max}} > 5 \text{kpc}$)

*Ishigaki et al., in prep.*
Low $\alpha$/Fe in outer halo stars $\rightarrow$ connection to dwarf galaxies?

Tolstoy et al. (2006, ESO messenger)
Other elements for chemical tagging

1. Odd elements Mn and Cu

Stars in Sgr dwarf have lower Cu/Fe and Mn/Fe than in field stars... such dwarf galaxies are not the origin of field stars near the sun.
Other elements for chemical tagging
2. neutron-capture elements

[Y/Eu]  
[Ba/Eu]  
[La/Eu]  
[Ba/Y]  

Field stars
Dwarf galaxies

Venn et al. (2004)
An example of survey program

• A large sample of stars is required to study *individual* stellar components
• The survey must be extended to cover the range beyond the solar neighborhood

A survey program optimized for thick disk studies:
- High resolution mode (R=30,000, limited wavelength coverage)
- Area surveyed: 1000 sq. deg.
- Total number of spectra: 600,000
  thin disk: 300,000
  thick disk: 250,000
  halo: 10,000
- Observing time: 300 nights
Possible PI-type programs

• Searches for population III stars and their evidence
  - searches for metal-free or hyper metal-poor stars
  - searches for stars showing evidence of pair instability SNe
  - surveys for the outer halo and the bulge

• Astrophysical sites of explosive nucleosynthesis (r-process)
  → see Honda et al.
  - searches for r-process-enhanced stars
  - intensive studies for globular clusters and dwarf galaxies

• Dwarf galaxies, clusters, and streams
  → see Okamoto et al.
  - enrichment history of individual galaxies
  - chemical nature of disrupted clusters and streams