High-resolution spectroscopy of halo stars with asteroseismic information

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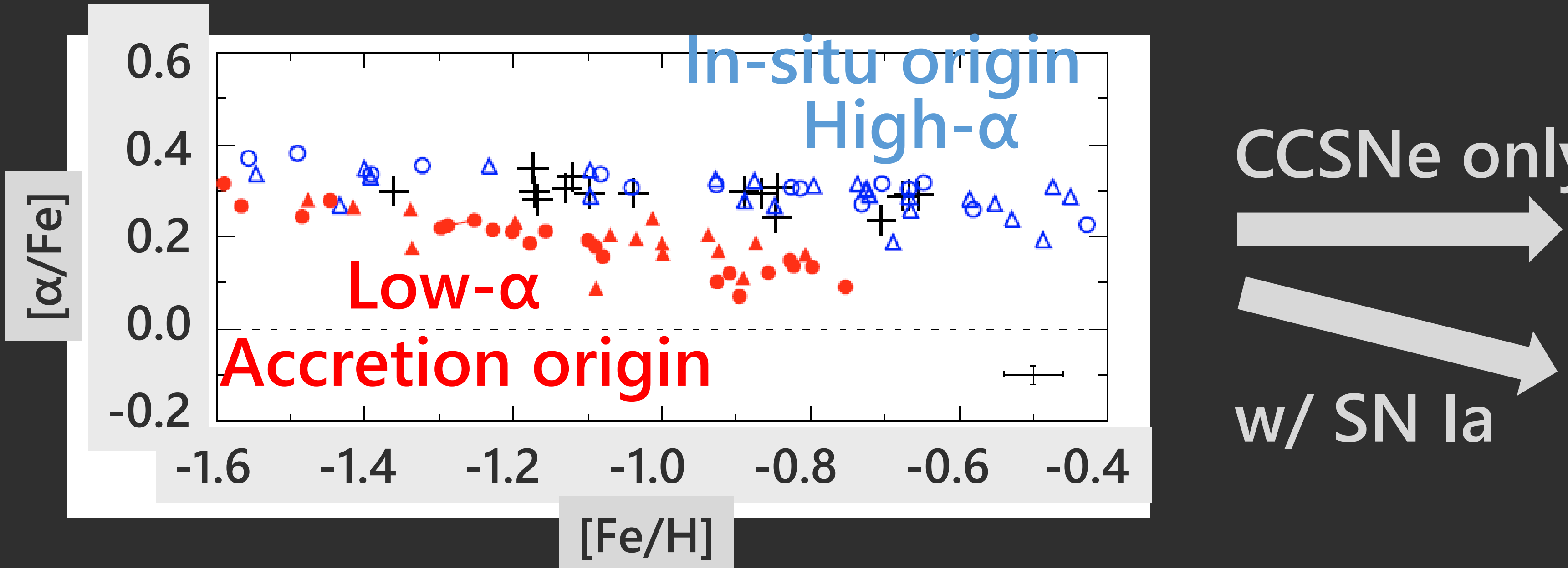
Matsuno+21, accepted, arXiv:2006.03619

Nearby halo populations

Nissen & Schuster 10 (NS10)

See also
e.g., NS11, Fishlock+17, Ishigaki+12,13

High-precision **abundance** study of nearby halo stars



High α: star formation without SN Ia contributions

➡ **short** timescale star formation

➡ star formation **in a massive galaxy** (MW)

Additional information: age

Formation epoch of stellar population

Abundance provides timescale not “epoch”

Timing the last major merger

When a larger galaxy accreted,

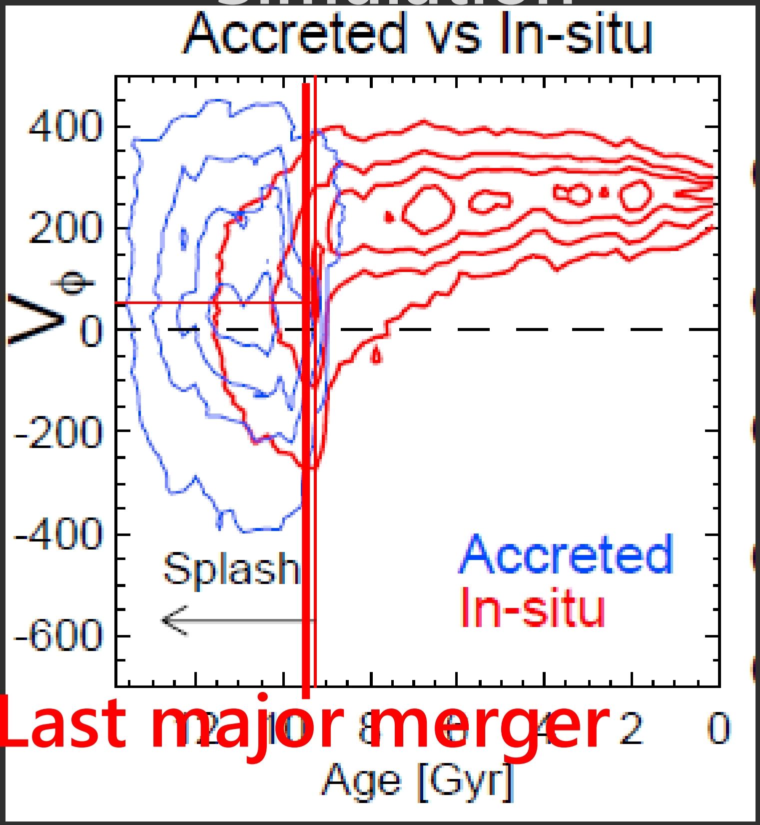
accreted stars

Star formation stops

In-situ stars

Stellar Kinematics changes

Simulation

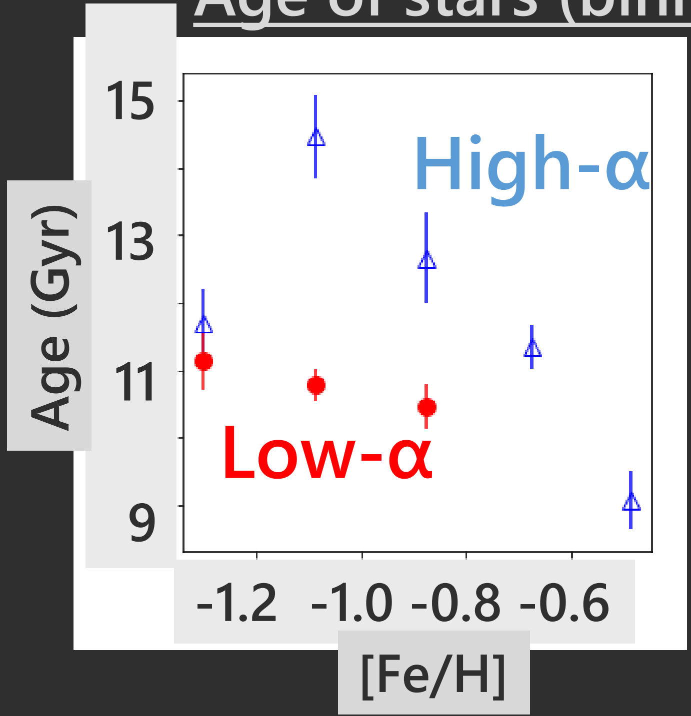


Belokurov+19

Milky Way halo

Schuster+12
age study of NS10 stars

Age of stars (binned)

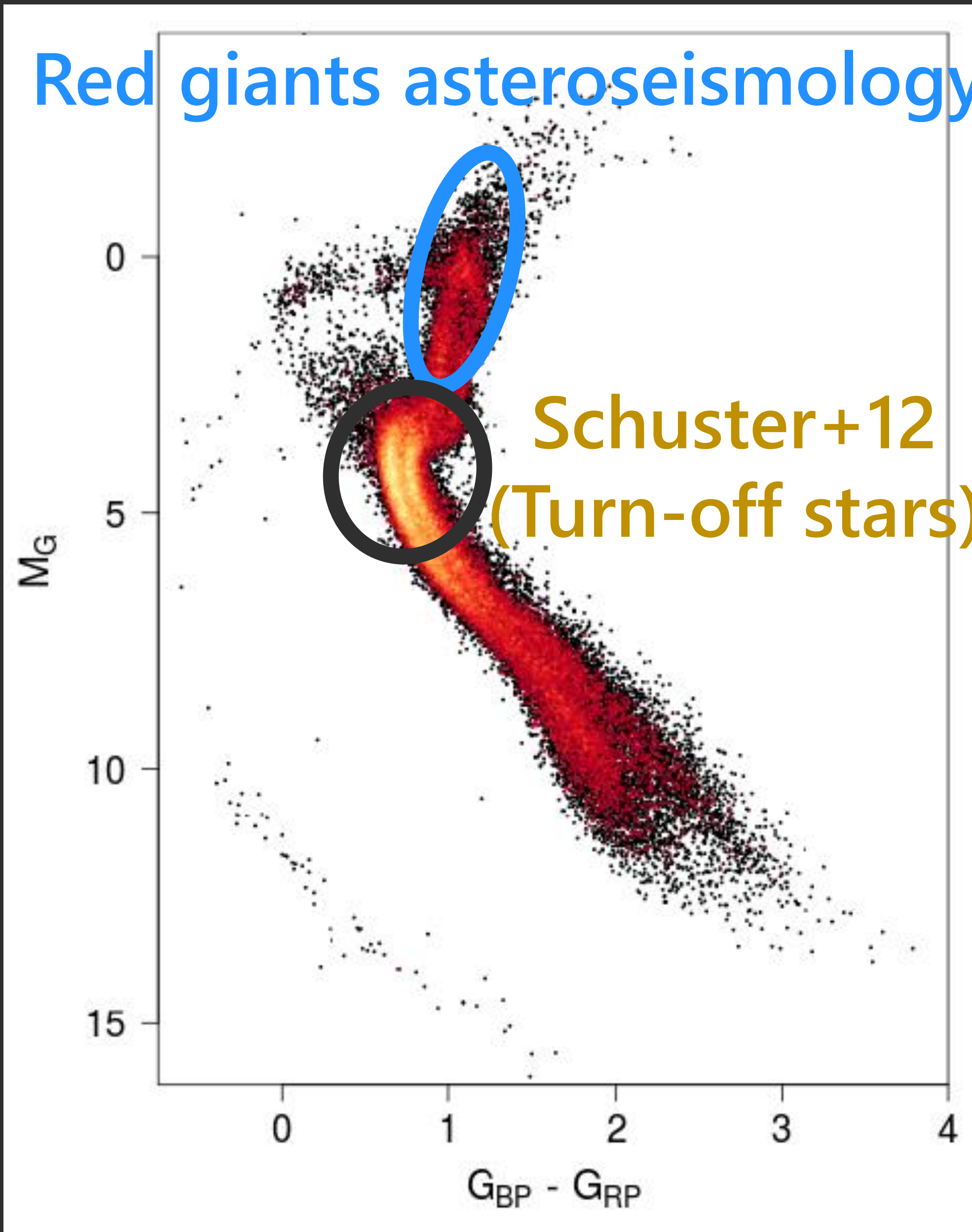


High-α stars are older
i.e., less time since Big Bang
consistent with abundance

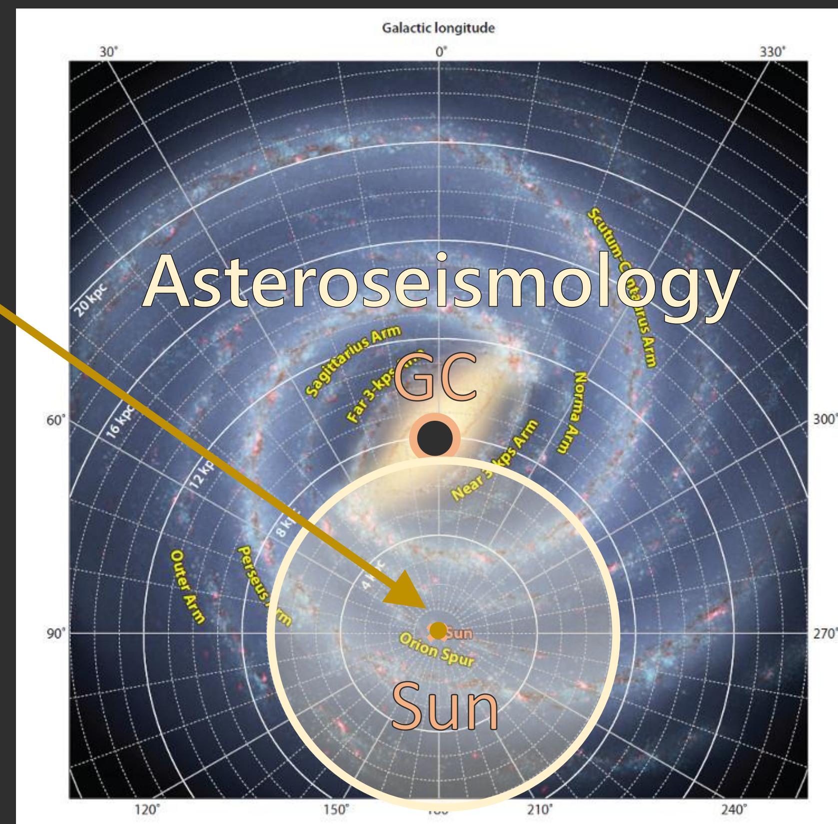
Both are older than ~10 Gyr
the last major merger would be quite ancient
(see e.g., Belokurov+19)

Most of these results are mainly from nearby stars (<300pc)

Asteroseismology: age of red giants



Red giants are bright!



Gaia Collaboration+18

Our observation

Instrument

High Dispersion

Spectrograph on Subaru

Setting

R~80000 (~4 km/s)

4000 < λ (A) < 6800

Targets

26 halo stars in the Kepler field

from LAMOST and APOGEE

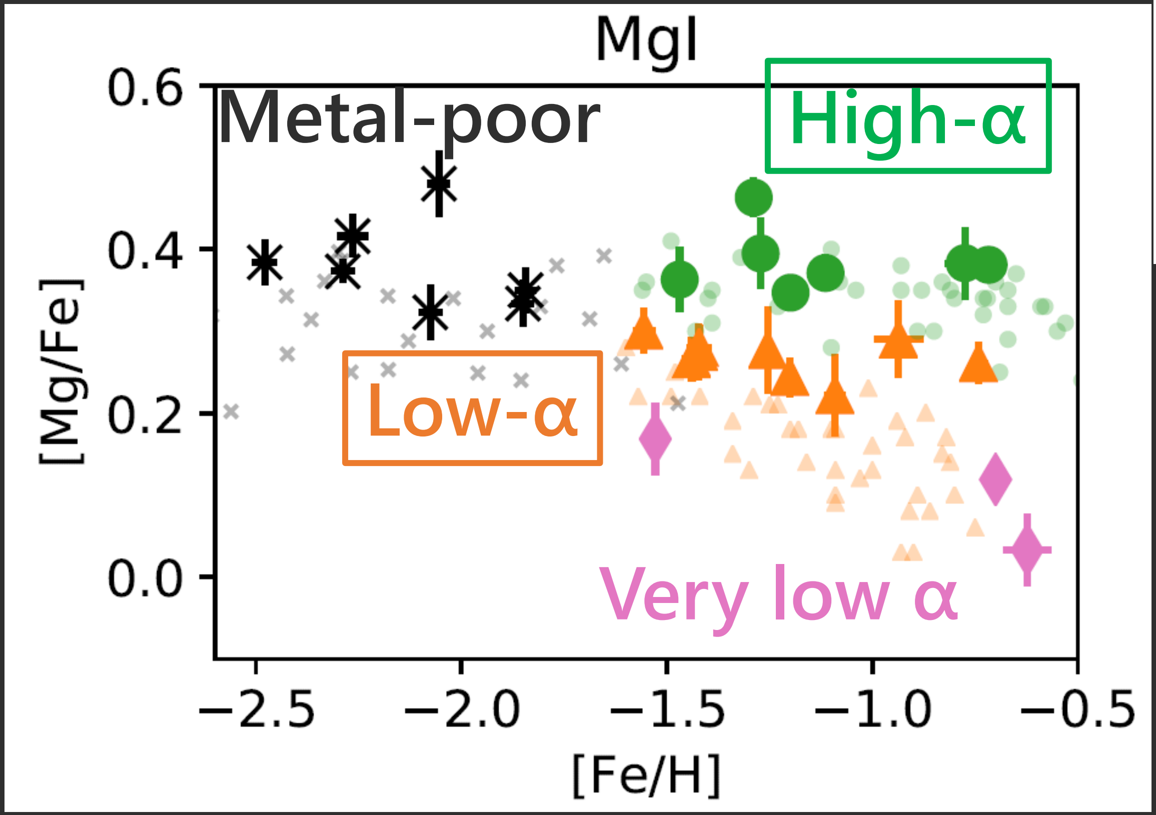
Use of high-resolution spectra

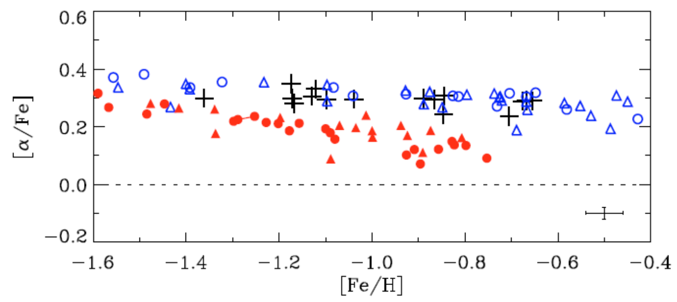
- Teff determination
- Classifying the targets into low-α/high-α
- Additional constraints on formation timescales

Assigning populations

We need to understand the population of our sample

halo has (at least) two major populations





Nissen & Schuster 10

In-situ

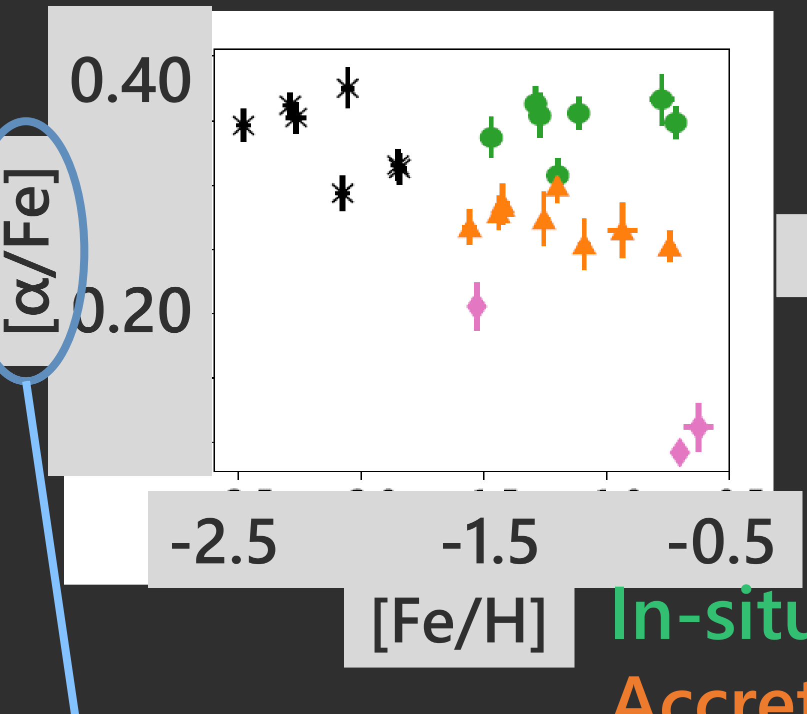
Accreted

Mg- based classification

Background: NS10, Reggiani+17

Timescale of high-α/low-α populations

from α abundances



Decreases with time thanks to delayed Fe enrichment by SN Ia

[α/Fe] difference

Less Ia contribution in high-α

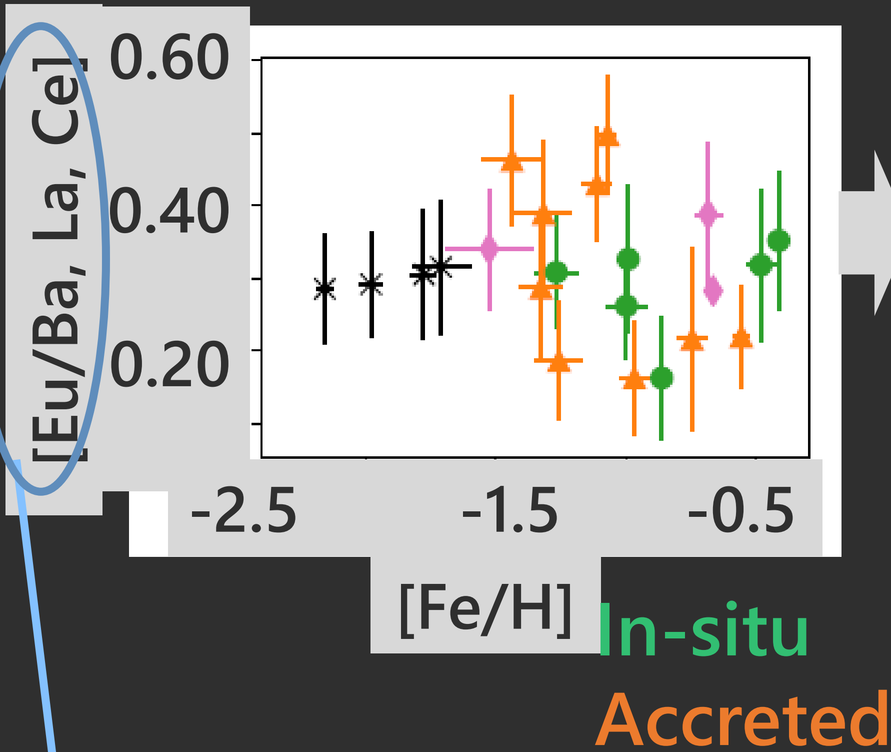
$$\tau_{\mathrm{high-\alpha}} < \tau_{\mathrm{low-\alpha}}$$

SN Ia should contribute at least to the low-α population

$$\tau_{\mathrm{low-\alpha}} > 100\ \mathrm{Myr}$$

* High-α population has, if any, little Ia contribution

Timescale of high-α/low-α populations
from neutron capture abundances



Consistent [Eu/s]

If either of the two populations is enriched by 1-3 Msun stars, the timescale difference would make a difference

Neither of the populations is enriched by 1-3 Msun stars

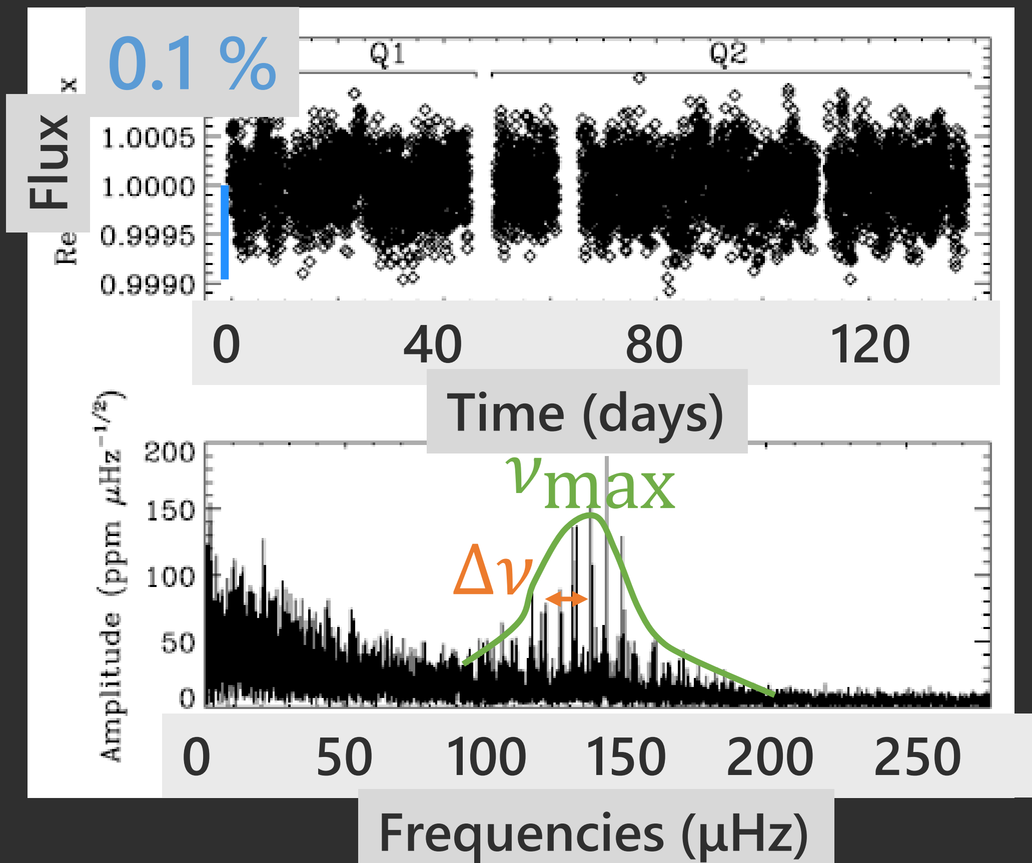
$\tau_{\mathrm{high}-\alpha}, \tau_{\mathrm{low}-\alpha} < 300\ \mathrm{Myr}$

Decreases with time thanks to delayed Ba, La, Ce enrichment by 1-3 Msun stars

See also Fishlock+17

Age estimates from asteroseismology

Age is based on mass estimates



Huber+10

Scaling relations of asteroseismology

$$\begin{cases} \nu_{\mathrm{max}} \propto \dfrac{g}{\sqrt{T_{\mathrm{eff}}}} \propto \dfrac{M}{R^2\sqrt{T_{\mathrm{eff}}}} \\ \Delta\nu \propto \sqrt{\bar{\rho}} \propto \sqrt{M/R^3} \end{cases}$$

$$M \propto \nu_{\mathrm{max}}^3 \Delta\nu^{-4} T_{\mathrm{eff}}^{1.5}$$

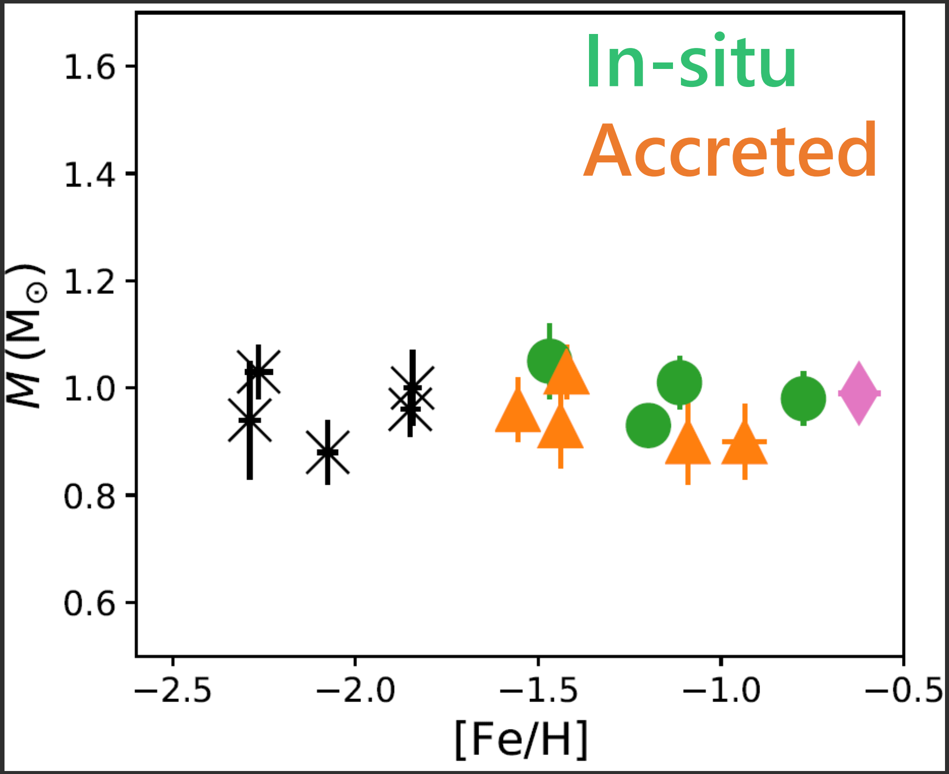
↓ Stellar evolution

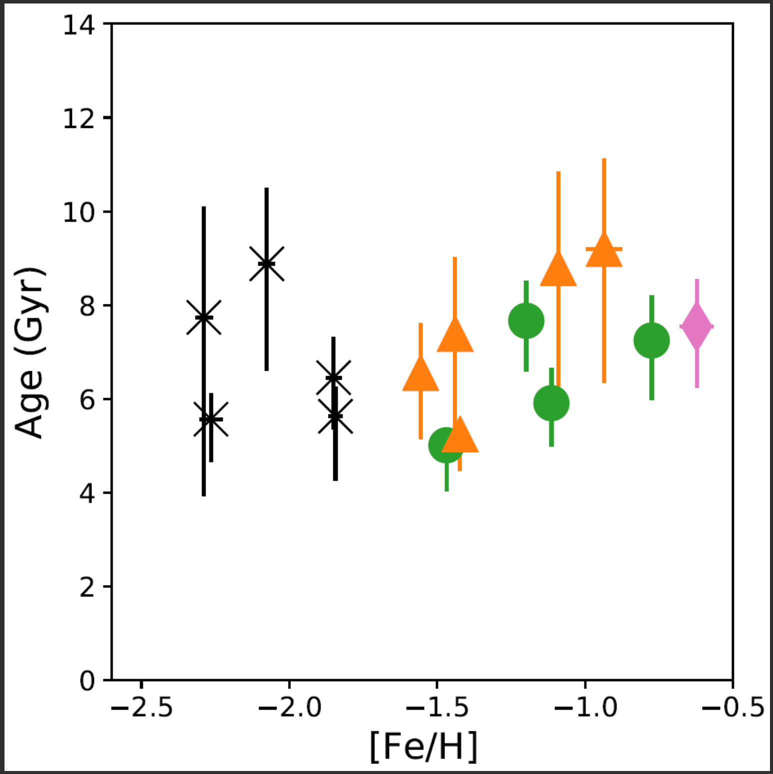
Stellar age

Can be applied to red giant stars

We use $\Delta\nu, \nu_{\mathrm{max}}$ measured by Yu et al. (2018)

Relative mass/age of the populations





The age difference is no greater than 1.5 Gyr (1σ)
The two populations are formed at similar epoch

The absolute age could not be constrained due to large systematic error

Summary of the results

Halo stars with asteroseismic information are divided into two from precise chemical abundance obtained from HDS spectra

We estimate the formation timescale of the low-α population as $100\ \mathrm{Myr} < \tau < 300\ \mathrm{Myr}$ from precisely-measured chemical abundance

We constrain the formation epoch difference between low-α / high-α populations as <1.5 Gyr from asteroseismology