LAMOST/Subaru project: Searching for metal-poor stars, moving groups and α-deficient stars

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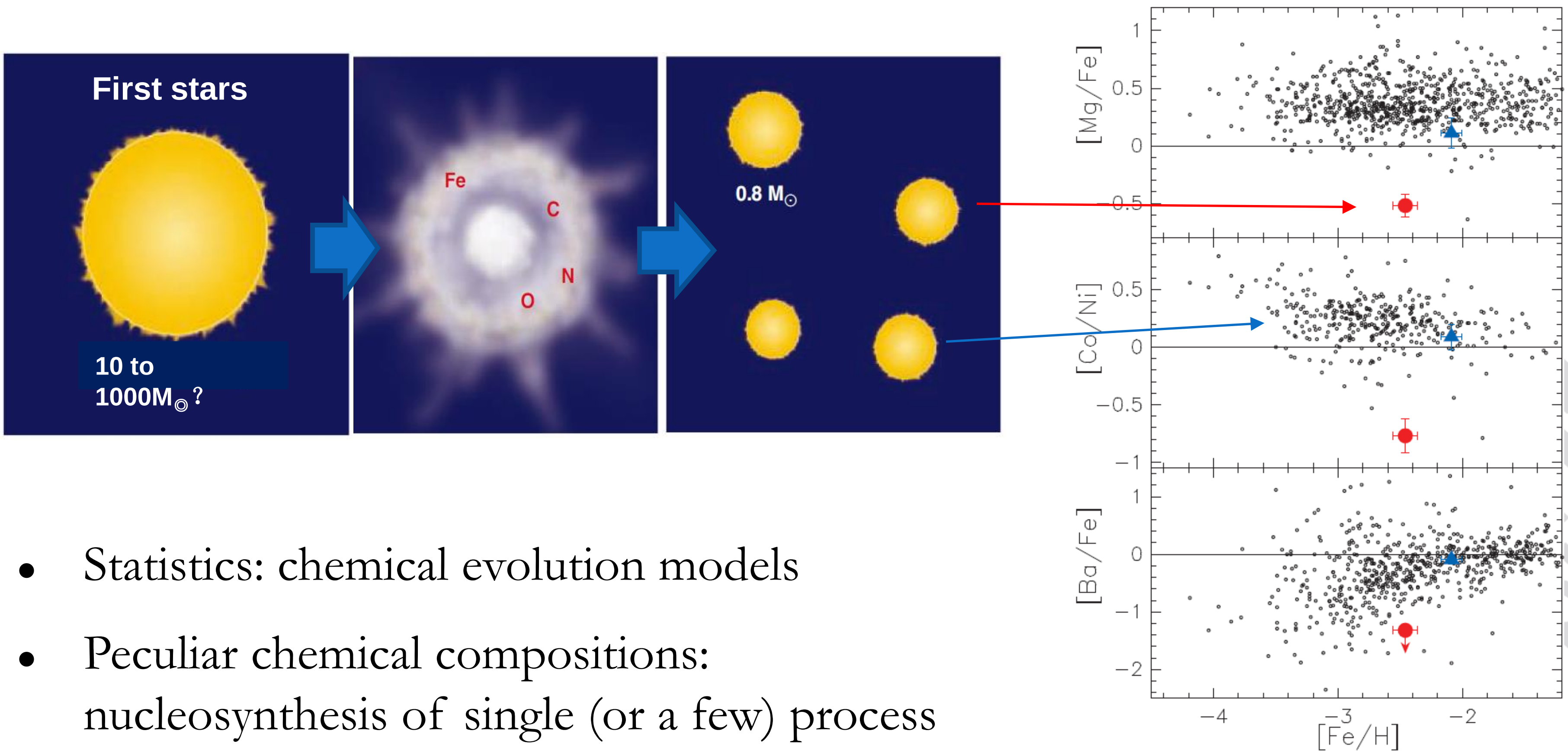
2018-12-03 @ IPMU

Tracing early nucleosynthesis and chemical evolution through very metal-poor stars

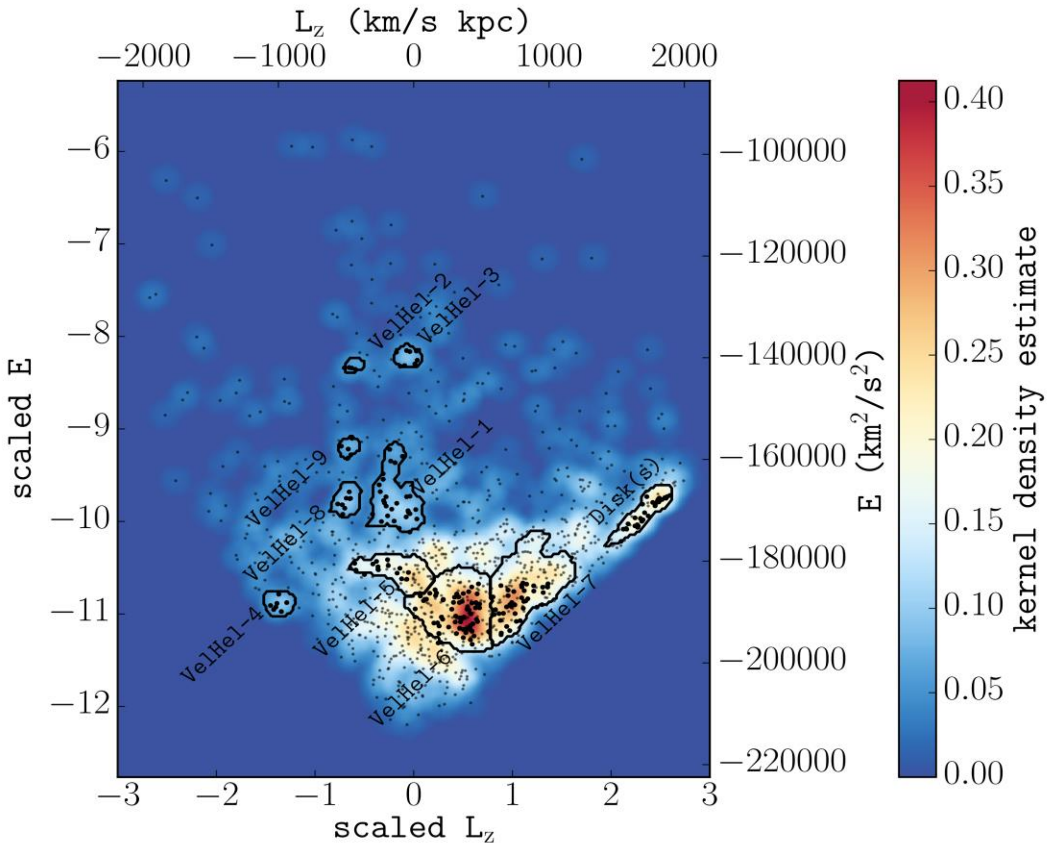


Aoki et al. (2014)

- Statistics: chemical evolution models
- Peculiar chemical compositions: nucleosynthesis of single (or a few) process
- Limited sample + mixed sources

yields of a supernova of a very massive (>100M$_\odot$) star (?)

Relics of ancient accretion events: halo moving groups (MGs)



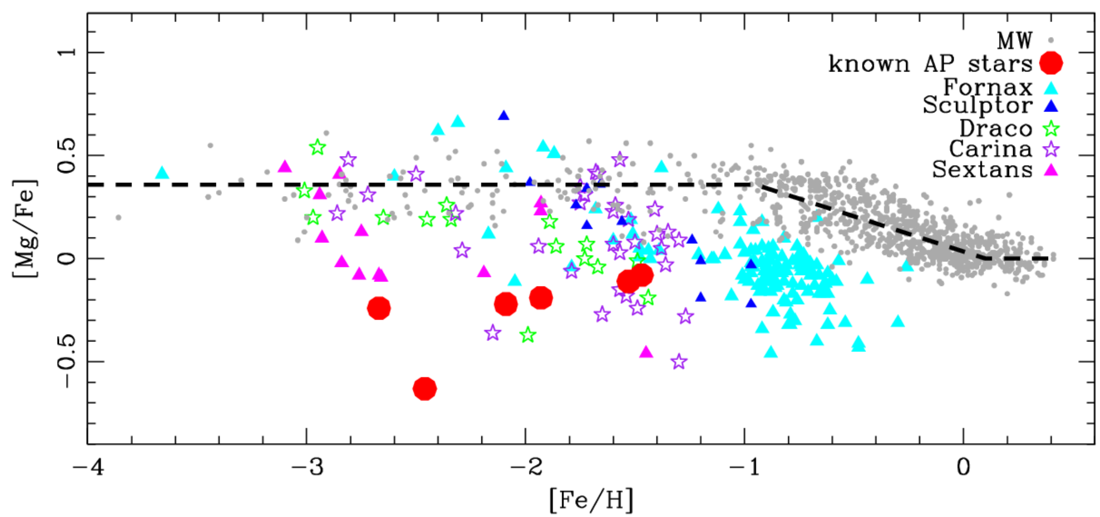
Helmi et al. (2017)

- Limited number of identified MGs + unclear origins

Linking dSphs to MW's Halo with α-deficient stars

Were dSphs the true building blocks of the Galactic halo?

- MW outer halo: formed through a dissipationless chaotic merging of smaller subsystems (Carollo et al. 2007)



- Limited sample + no systematic search

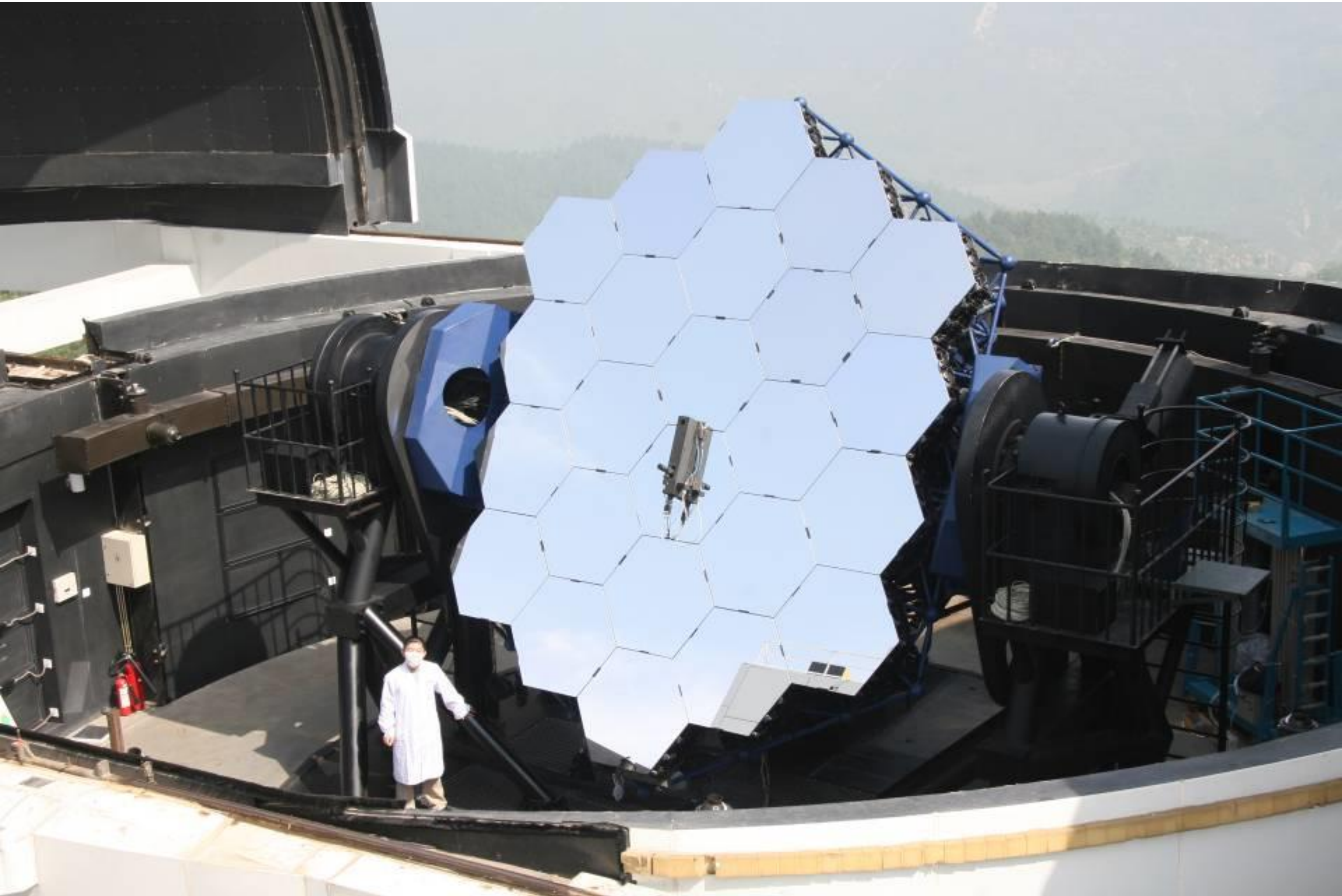
LAMOST (郭守敬望远镜)

- LAMOST (The **L**arge Sky **A**rea **M**ulti-**O**bject Fibre **S**pectroscopic **T**elescope)
  - Commissioning: 2009.9 - 2011.5
  - Pilot survey: 2011.10 - 2012.5
  - Regular survey (Phase I): 2012.9 – 2017.6
  - Phase II: 2018.10 –
- Combination of large aperture (4m) and wide field (5deg)
- High spectra-obtaining efficiency: 3,400 targets at on exposure

LAMOST @ Xinglong, China

- **~4m**
- **4,000 fibers**
- **r ~17.8**
- **370nm – 900nm**

24 sub-mirrors of MA (4.9m)

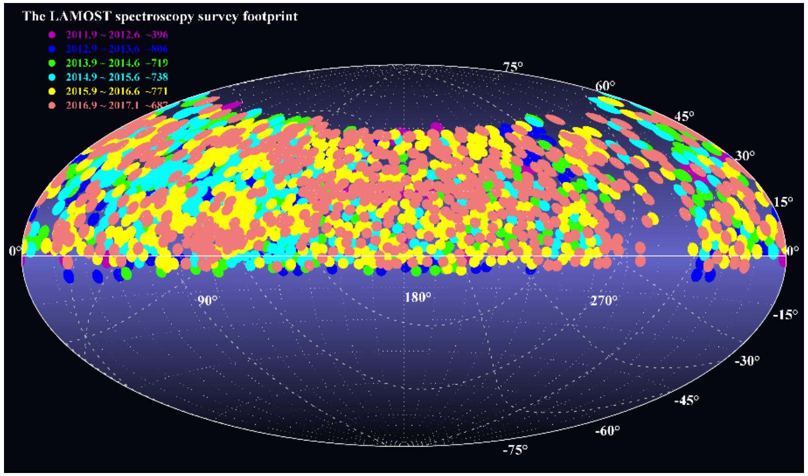



MB
37 sub-mirrors
~ 6.1m

LAMOST data releases

Large survey area
(North 7700 deg^2 + South 3500 deg^2)

> 1.5 million spectra / year

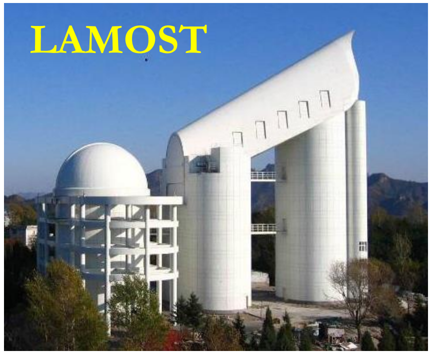


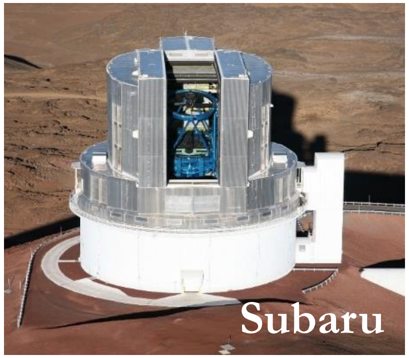
	Ending date	No. of spectra	No. of stellar spectra	Spectra of SNR > 10	No. of spectra with parameters	Release/Public date
DR0	20120617	958,944	812,911	619,151	396,249	2012.08/2012.08
DR1	20130603	2,660,613	2,342,849	1,925,735	1,127,872	2013.09/2015.03
DR2	20140603	4,309,098	3,843,851	3,293,600	2,174,812	2014.12/2016.07
DR3	20150602	5,968,162	5,354,883	4,665,075	3,185,475	2015.12/2017.07
DR4	20160602	7,681,185	7,682,298	6,076,210	4,202,127	2016.12/2018.07
DR5	20170608	9,017,844	8,171,443	7,531,398	5,344,058	2017.12/2019.07

LAMOST provides an unprecedented opportunity to search for more peculiar stars in the Milky Way in large area.

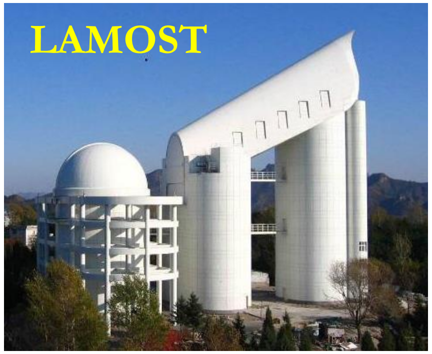
LAMOST-Subaru collaboration

High-resolution spectra are also demanded to understand the nature/origins of these stars



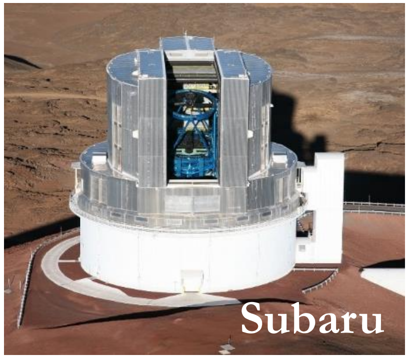


LAMOST-Subaru collaboration



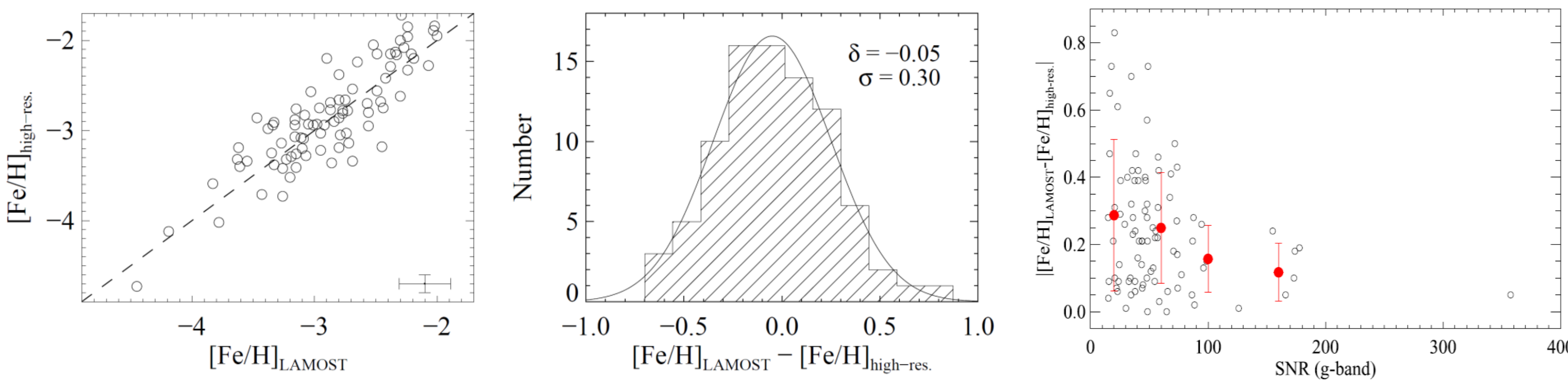
High-resolution spectra are also demanded to understand the nature/origin of these stars

- LAMOST+Subaru joint project since 2014
- Joint proposal for Subaru open-use program
  - Intensive + normal + service programs
- CAS-JSPS joint project (2016.04-2018.12)
- Follow-up with Subaru/HDS runs
  - **About 500 objects (incl. VMP, MGs, low-α stars)**
- More than 10 refereed papers published already



VMP stars: large sample from LAMOST

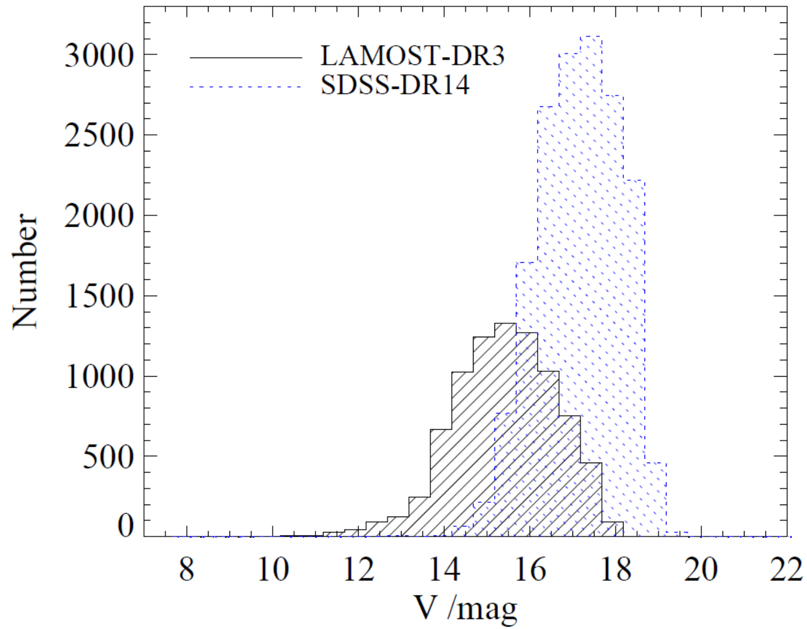
- Over 10,000 very metal-poor (VMP, [Fe/H] < -2.0) stars selected from LAMOST-DR3
  - Quite robust estimation of metallicity based on low-resolution spectroscopy reaching [Fe/H] ~ -4.0
  - Typical uncertainty ~0.30dex for SNR~40, 0.15dex for SNR~80

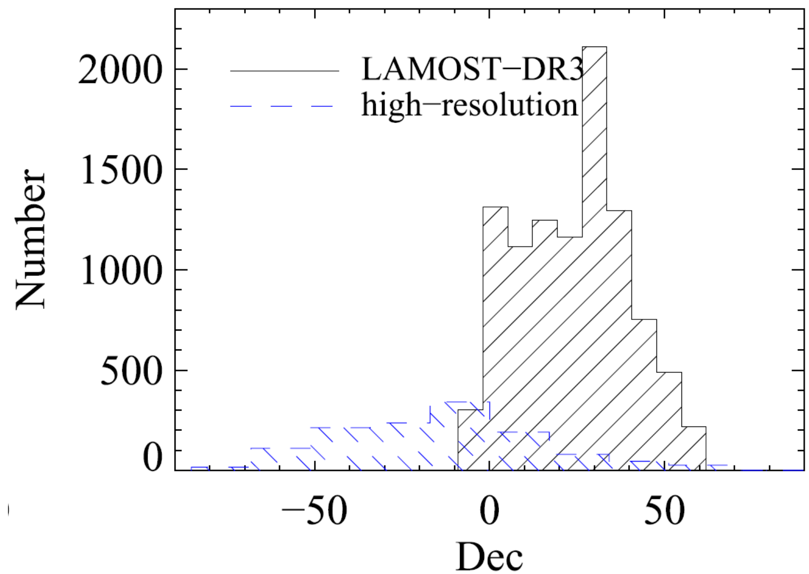


Li et al. (2018a)

VMP stars: large sample from LAMOST

- Valuable resource for high-resolution follow-up
  - The largest bright VMP star sample (e.g., ~8,000 objects with V < 16.5)
  - specially for the northern hemisphere

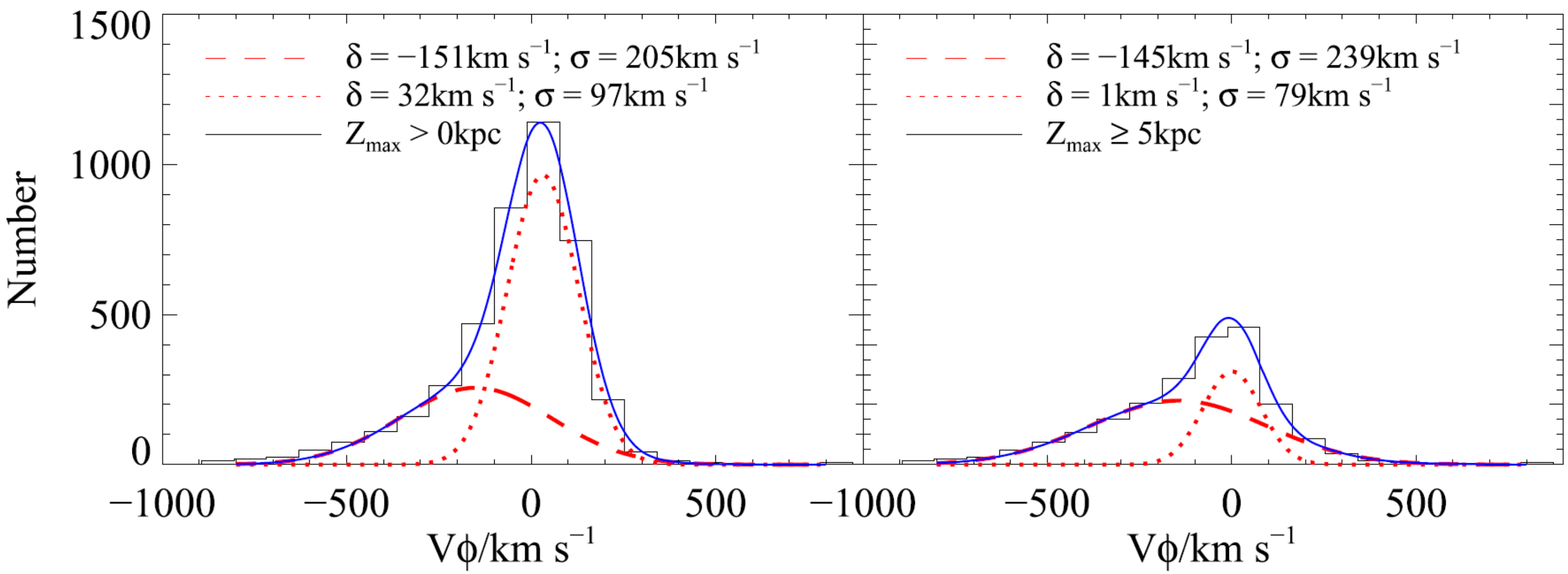




Li et al. (2018a)

VMP stars: large sample from LAMOST

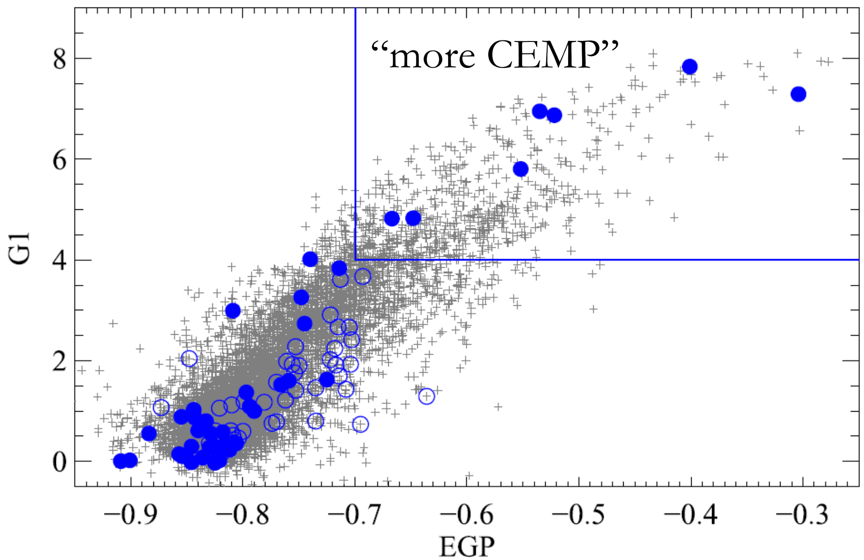
- Dominant by the halo population(s)
- Notable fraction of the retrograde component
  - Further investigation of the nature of the halo components



Li et al. (2018a)

VMP stars: large sample from LAMOST

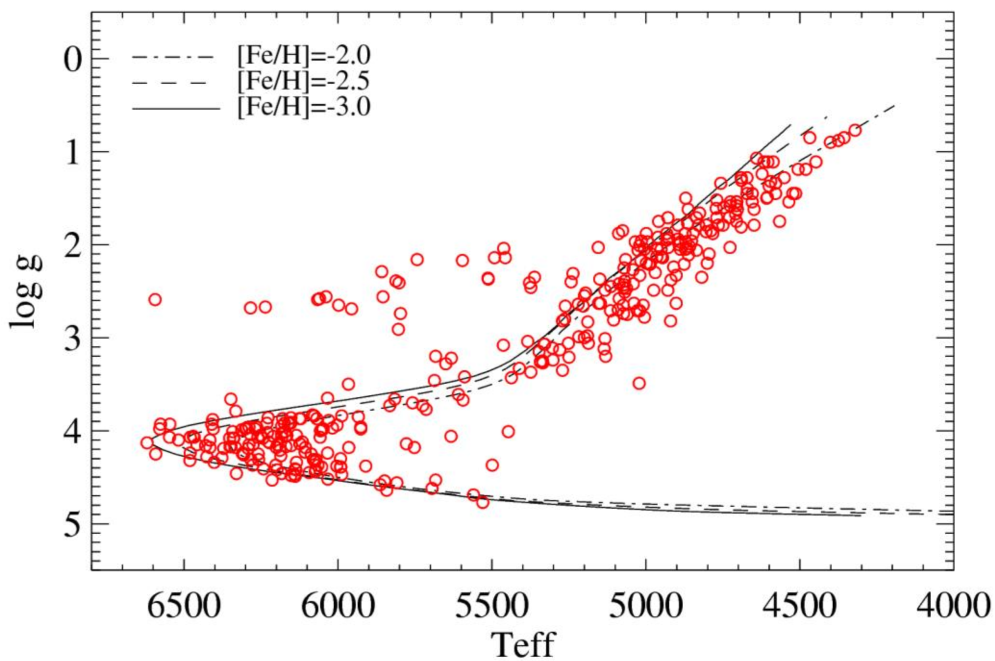
- Reservoir for carbon-enhanced metal-poor (CEMP) stars
  - Over 630 candidate CEMP stars identified using combined line indices
  - v2.0 with carbon abundances estimated



Li et al. (2018a)

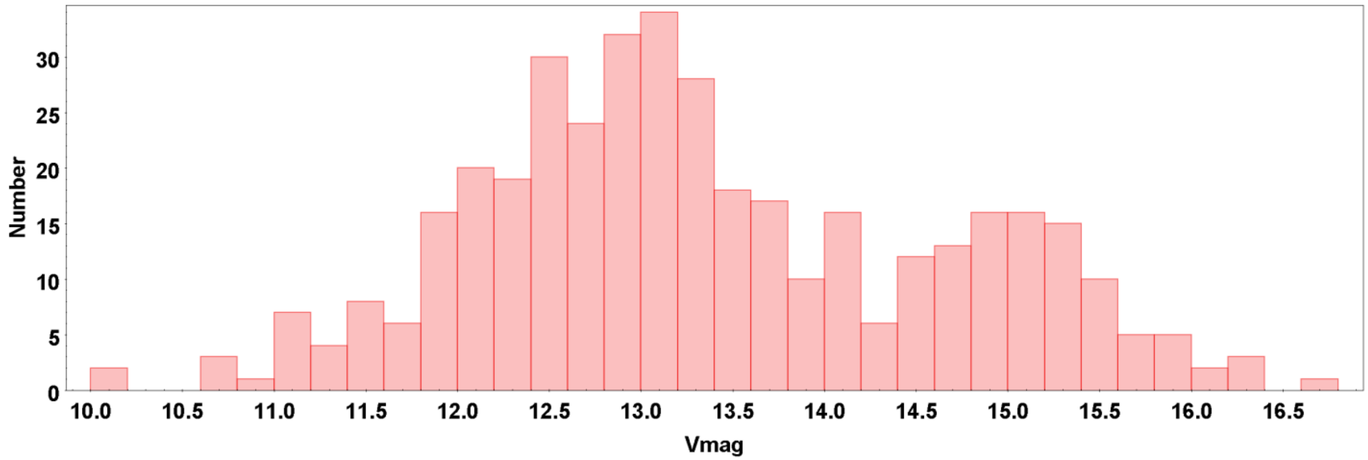
VMP stars: follow-up with Subaru

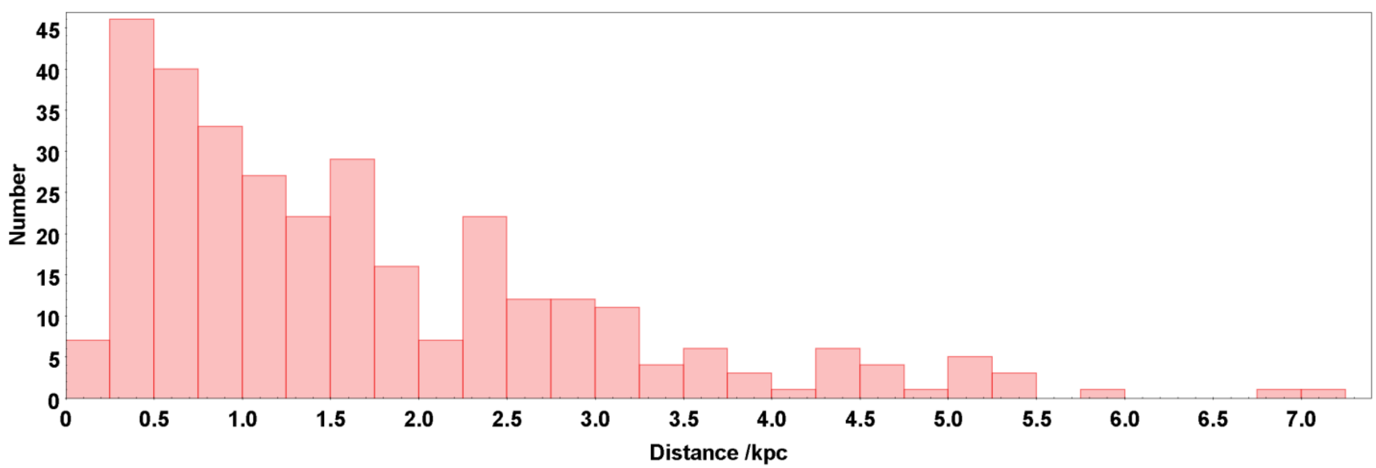
- About 450 VMP candidates from LAMOST were follow-up observed with Subaru/HDS (in "snapshot" mode)



- Over 400 were analyzed;
- Covering wide evolutionary stages
- ~100 EMP stars
- 3 UMP stars
- Searching efficiency > 90% for VMP stars

VMP stars: follow-up with Subaru

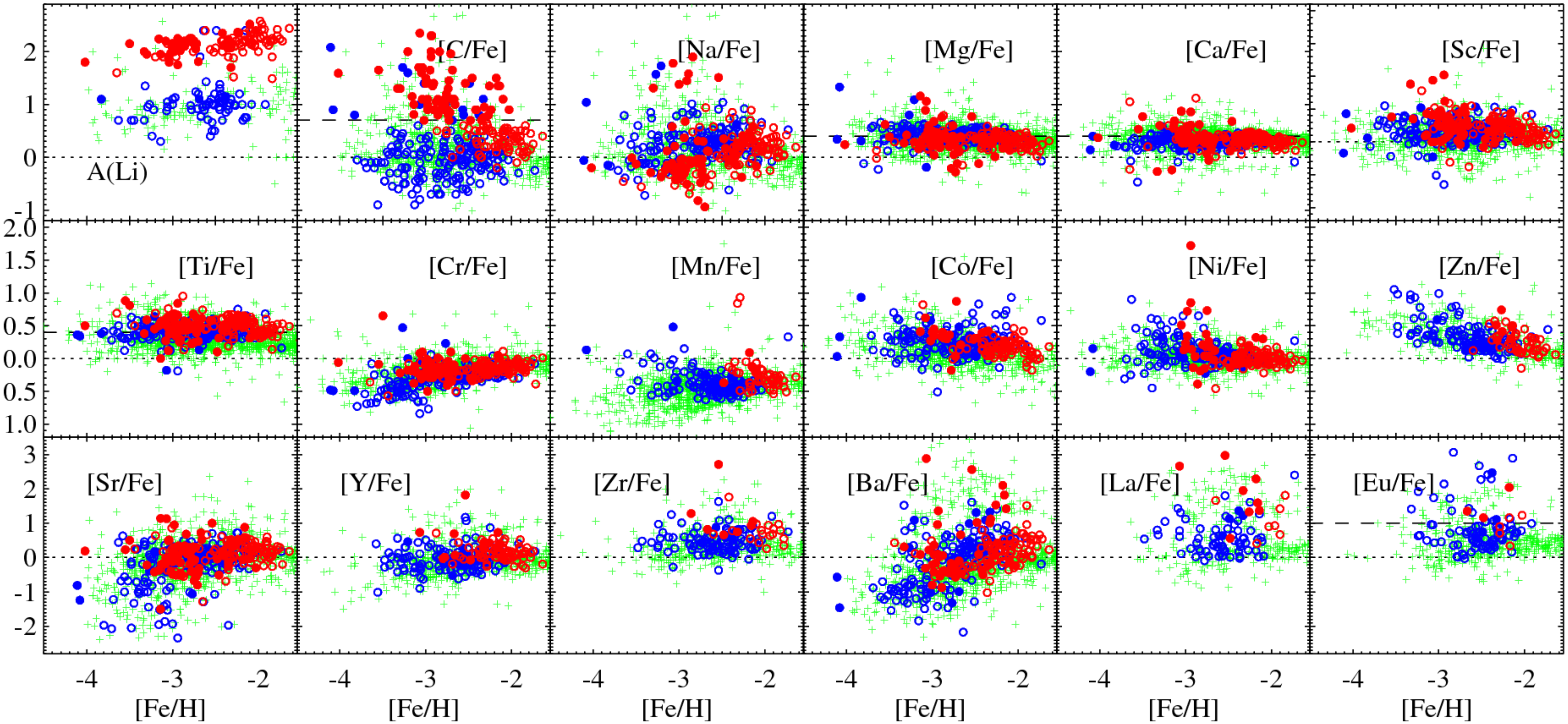




- Relatively bright + reliable kinematics (e.g., plx/err_plx>5.0 for ~80% of the sample)

VMP stars: abundance trend

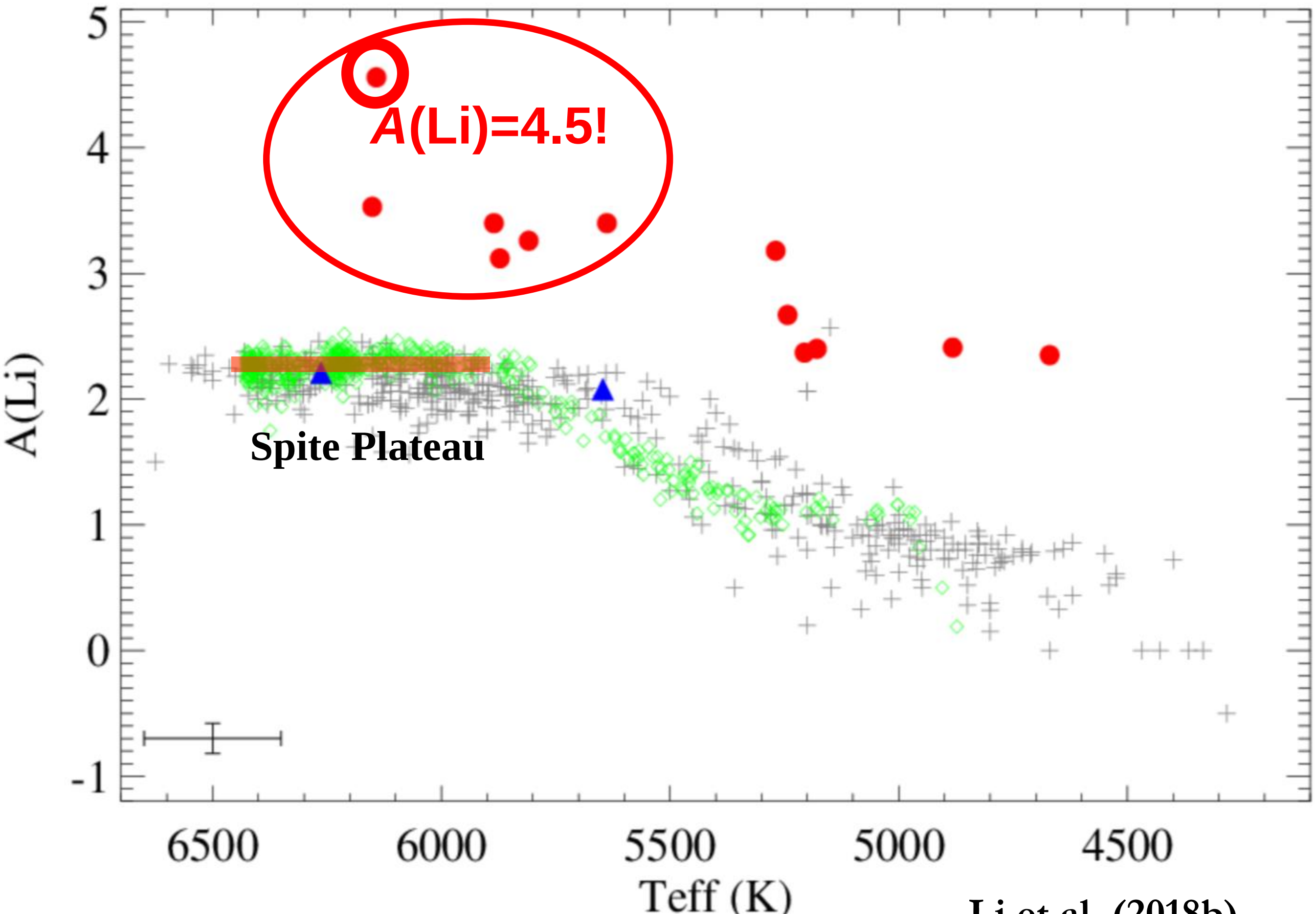
- Largest uniform very metal-poor sample to date



Teff > 5500K vs Teff < 5500K; CEMP (filled) vs C-normal (open)

VMP stars: Li-rich VMP stars

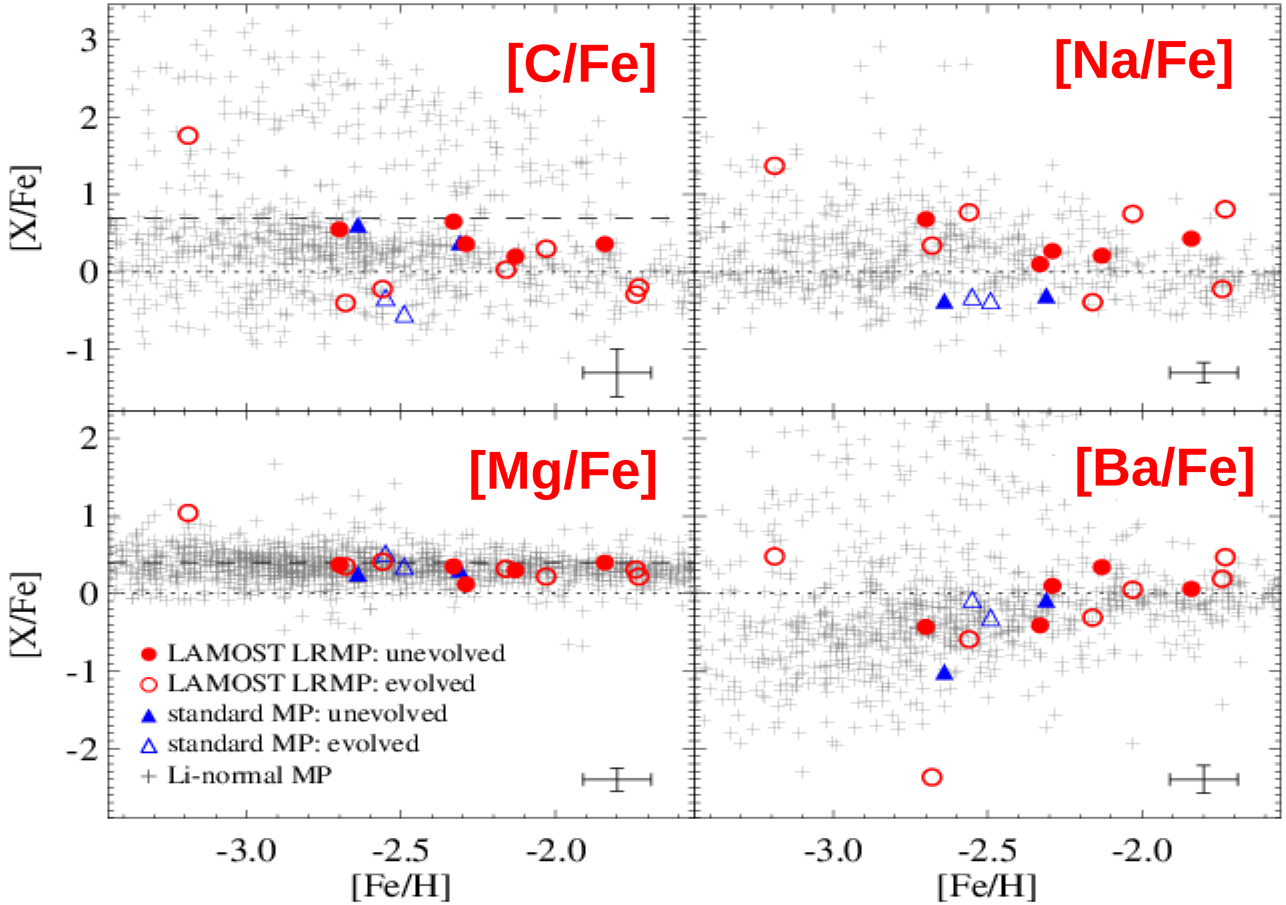
Subaru follow-ups confirm 12 Li-rich very metal-poor star



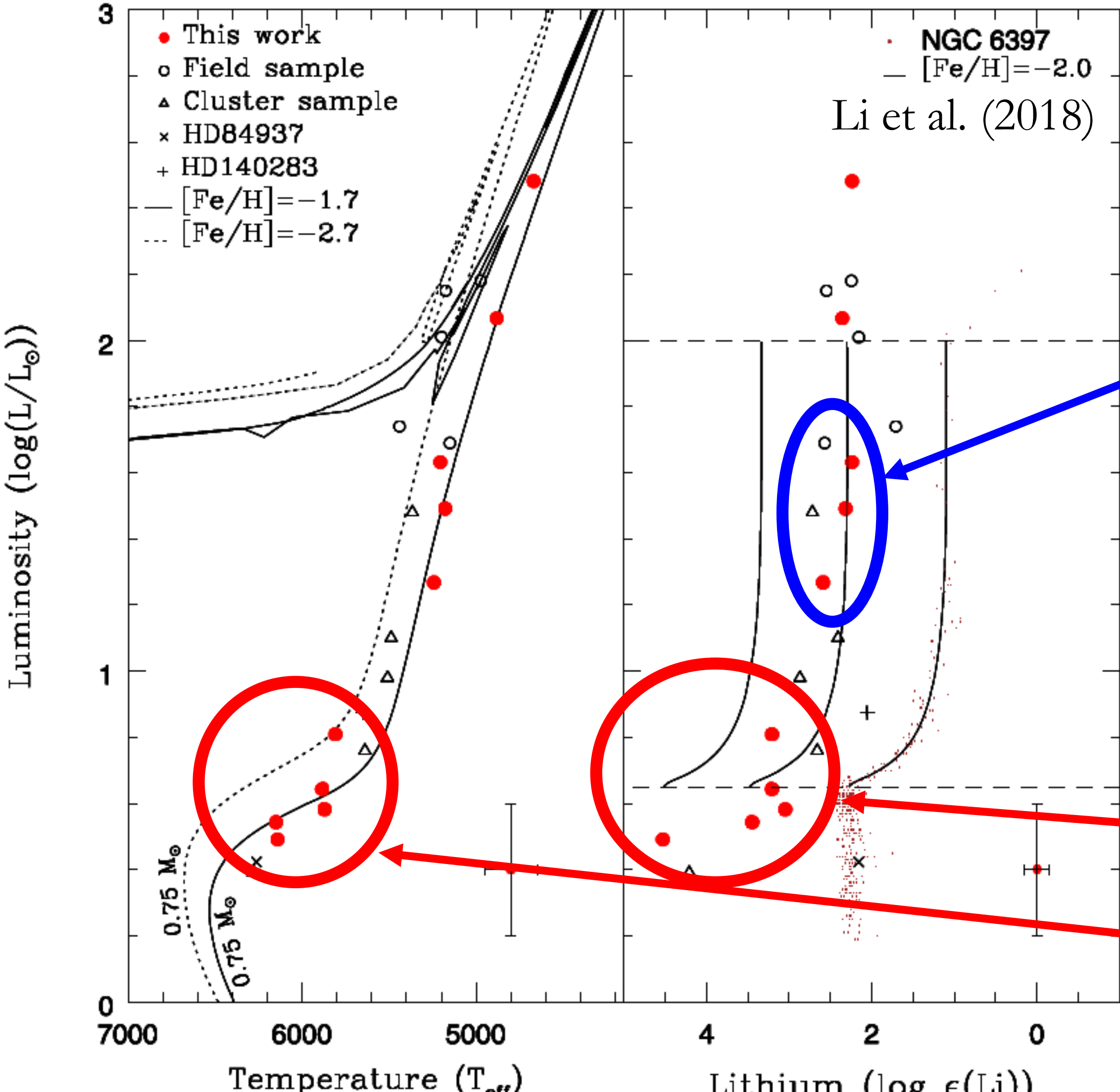
Li et al. (2018b)

VMP stars: Li-rich VMP stars

- No correlation with abundances of other elements
- No signature of high binary frequency
- No clear excess of line broadening due to rapid rotation



VMP stars: Li-rich VMP stars

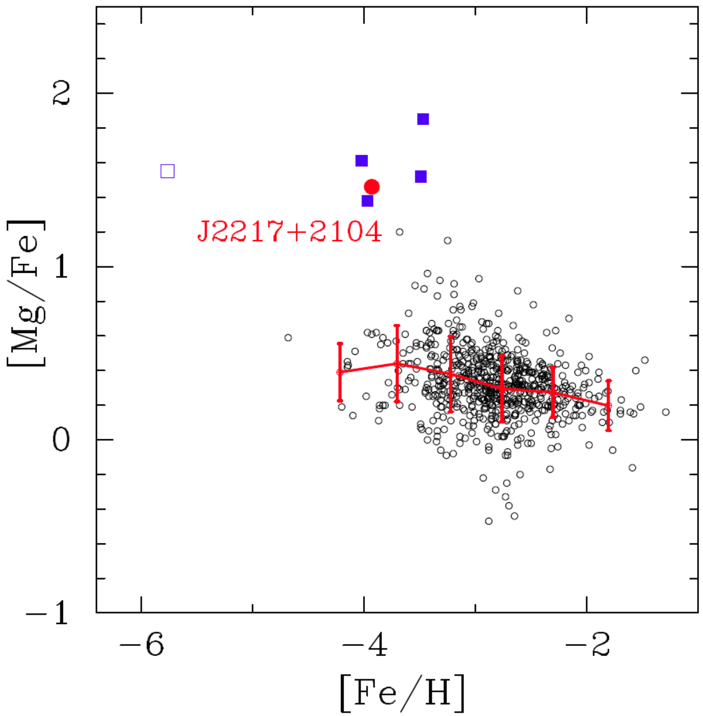


First systematic search

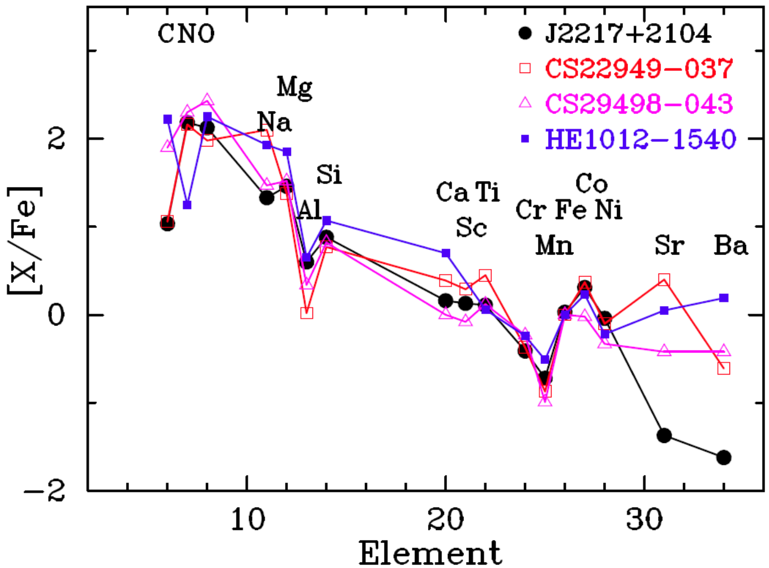
Li-rich giants (before RGB bump) can be explained by dilution by 1st dredge-up

First discovery of super Li-rich sub-giants in the field, raising challenges to low-mass stellar evolution model

VMP stars: J2217

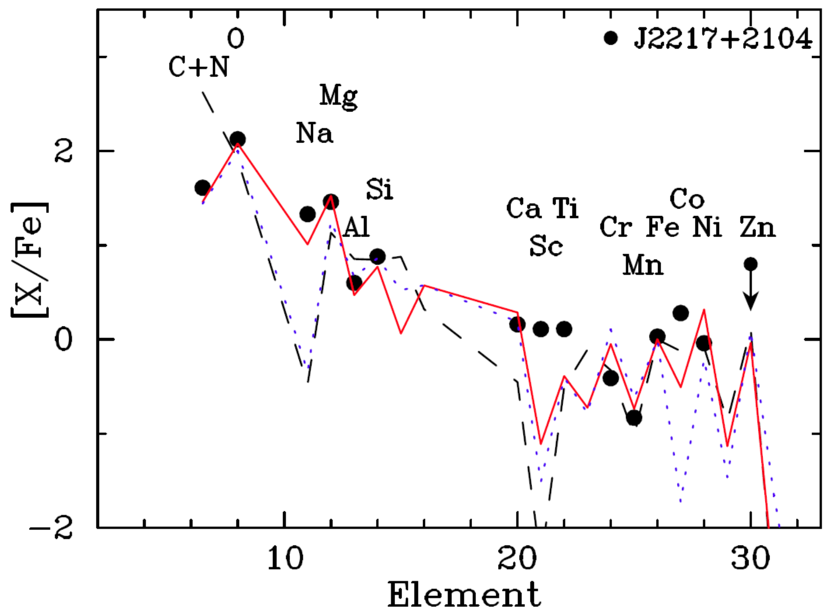


Aoki et al. (2018)



- Very similar pattern from O to Zn (including similar (C+N)/O): similar progenitor in the early universe
- Discrepancy of heavy elements: no connection between their origin and the excess of lighter elements

VMP stars: J2217

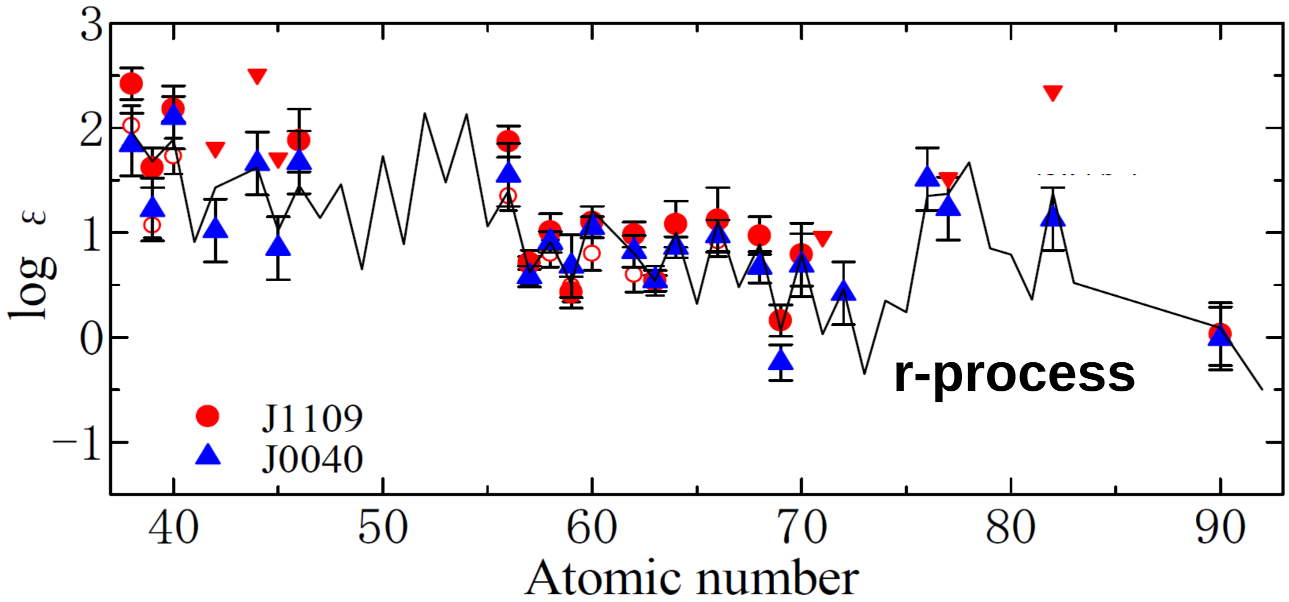


Aoki et al. (2018)

- The abundance pattern from C + N to Ca is well reproduced by the model of 25Msun
  - Typical mass for normal EMP stars
  - Different abundance pattern would be some property of progenitors other than their mass

VMP stars: r-II stars

- Two new bright r-II stars (Vmag~11.2/12.4)
  - important to understand the site for the universal r-process
  - UV spectra obtained

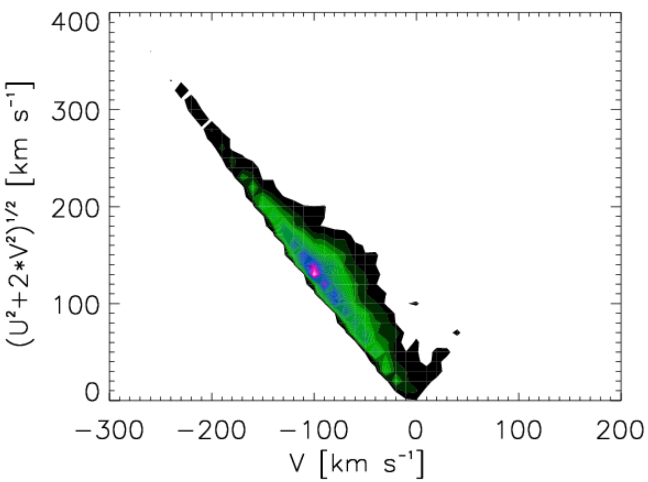


Li et al. (2015); Honda et al. in preparation

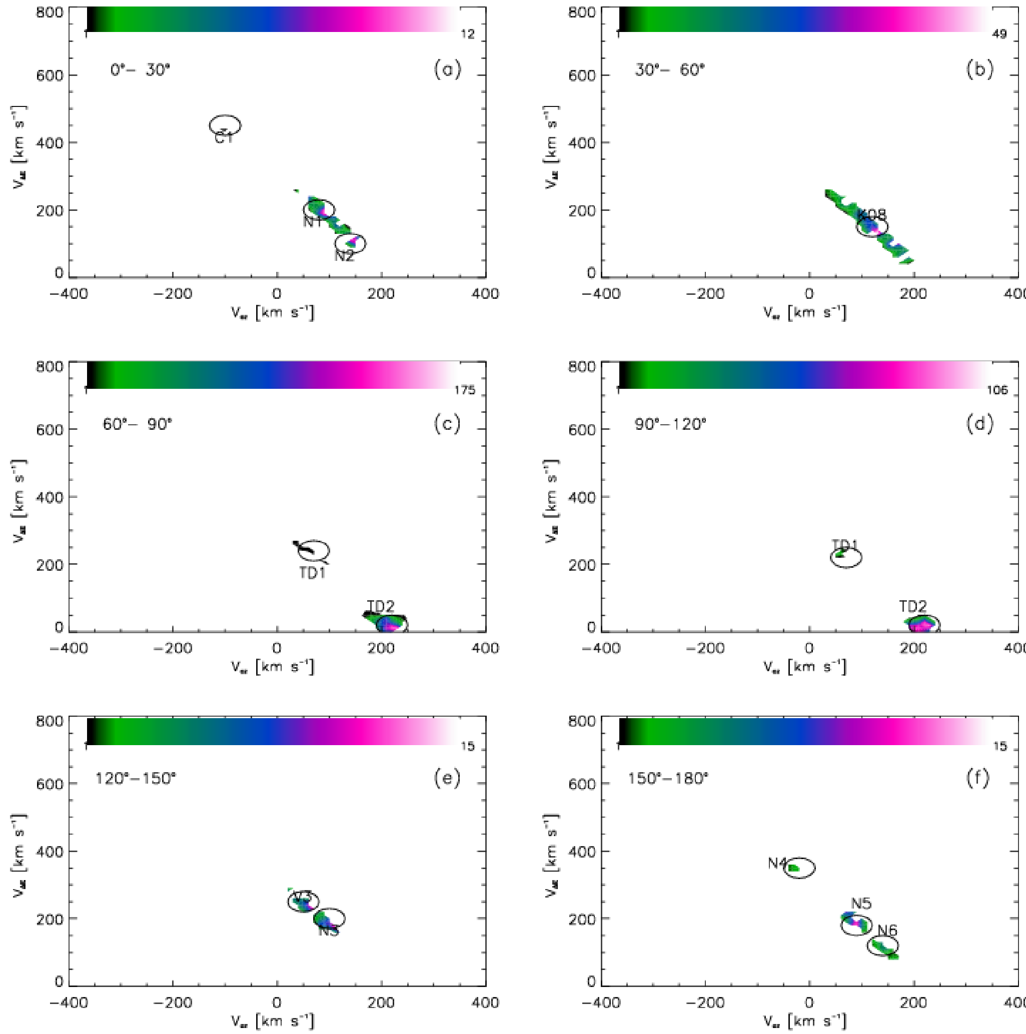
Halo MGs: LAMOST detection

J.K. Zhao

Ten new halo MGs in phase space were detected with LAMOST. The number increased by 50% (14->24).



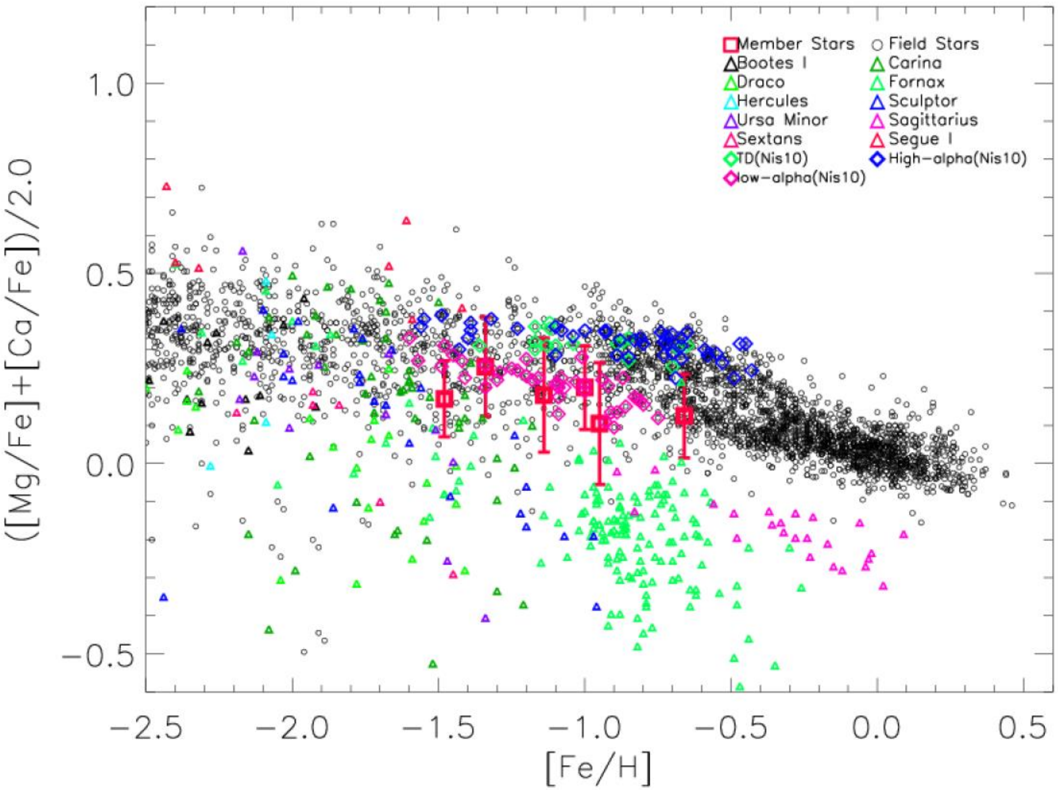
Zhao et al. (2014)



Zhao et al. (2015)

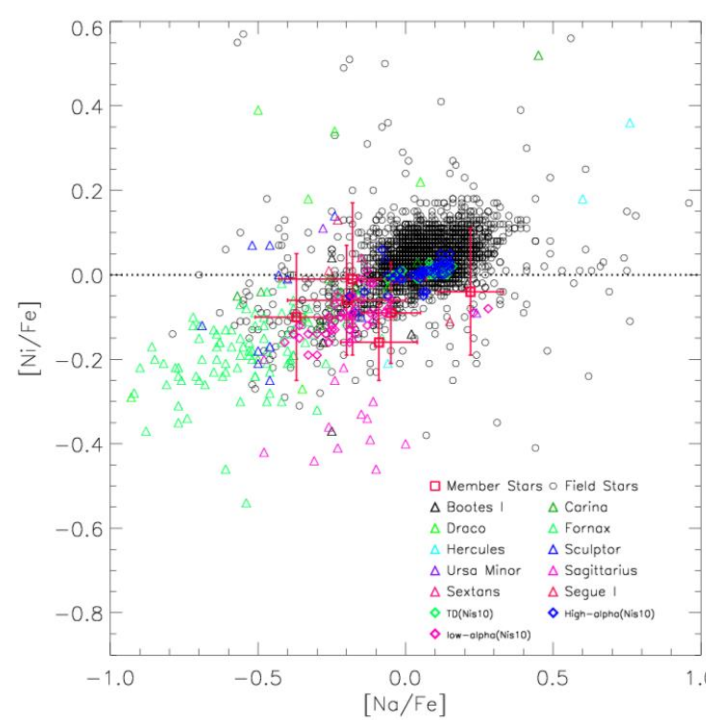
Halo MGs: origin of LAMOST-N1

J.K. Zhao



Na and Ni values show similar distribution with the low-α halo population

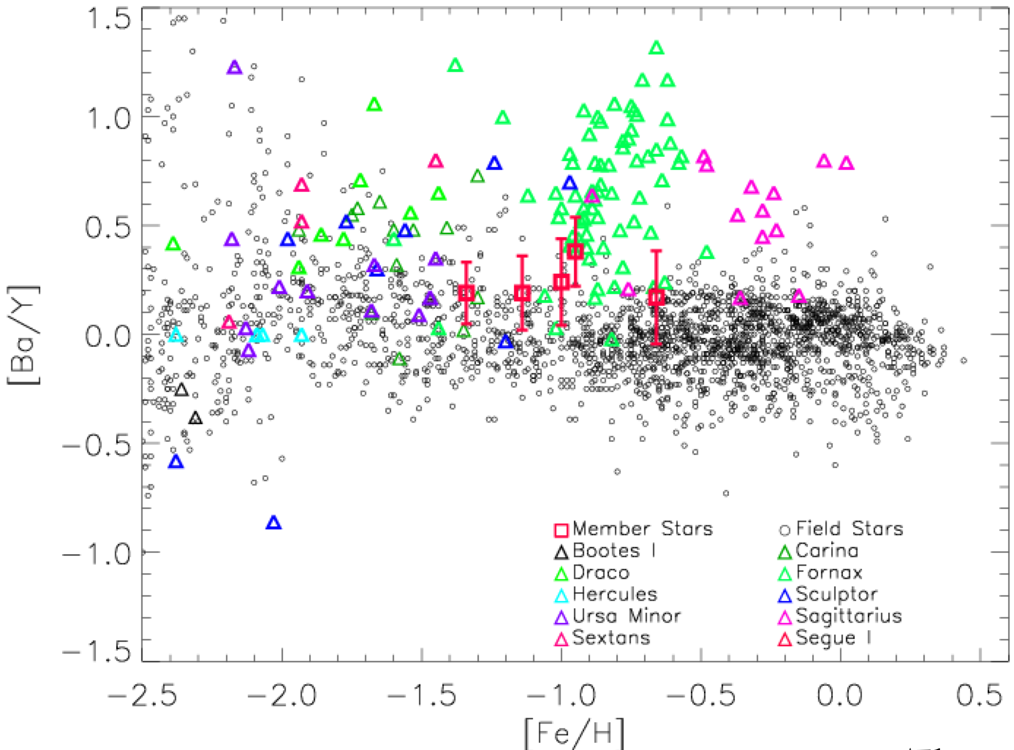
Zhao et al. (2018)



α abundance pattern is similar with that of low-α halo population

Halo MGs: origin of LAMOST-N1

J.K. Zhao



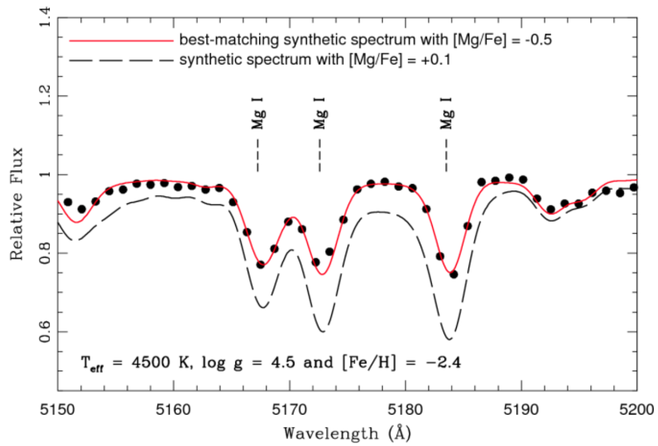
Zhao et al. (2018)

N1 most likely originate from systems with a slower chemical evolution

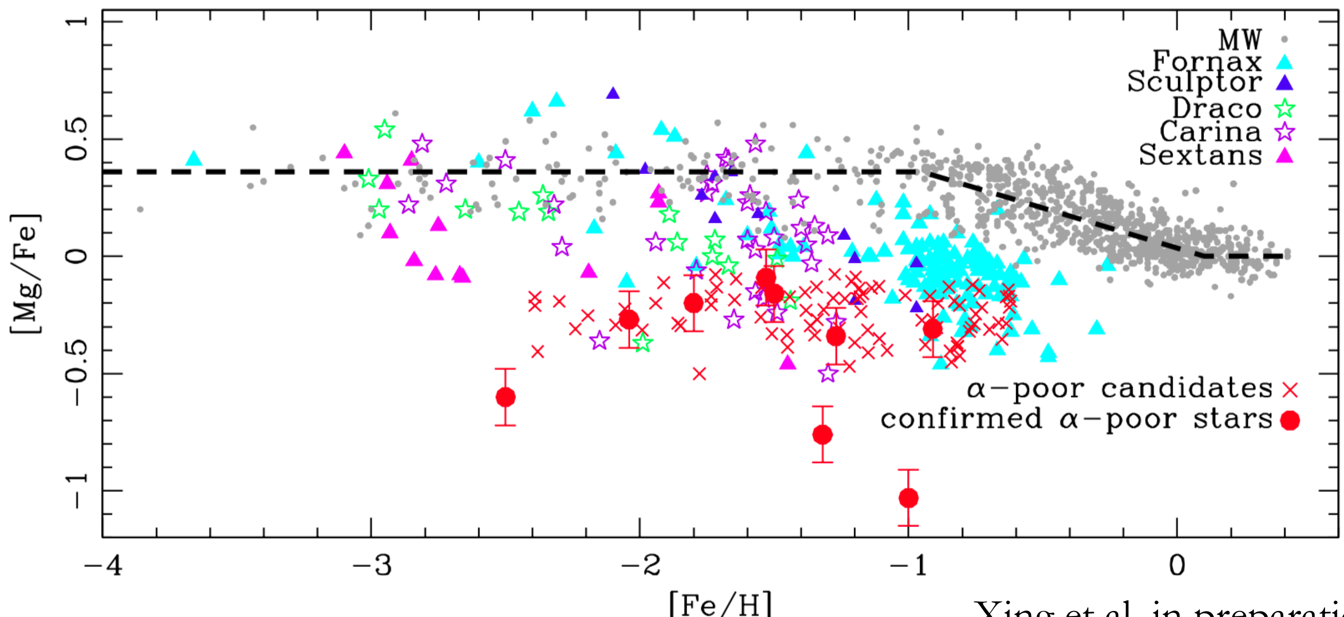
A possible identification of relic of such systems in the phase space
The possibility to disintegrate the "low-α" class into individual groups

α-deficient stars

Q.F. Xing



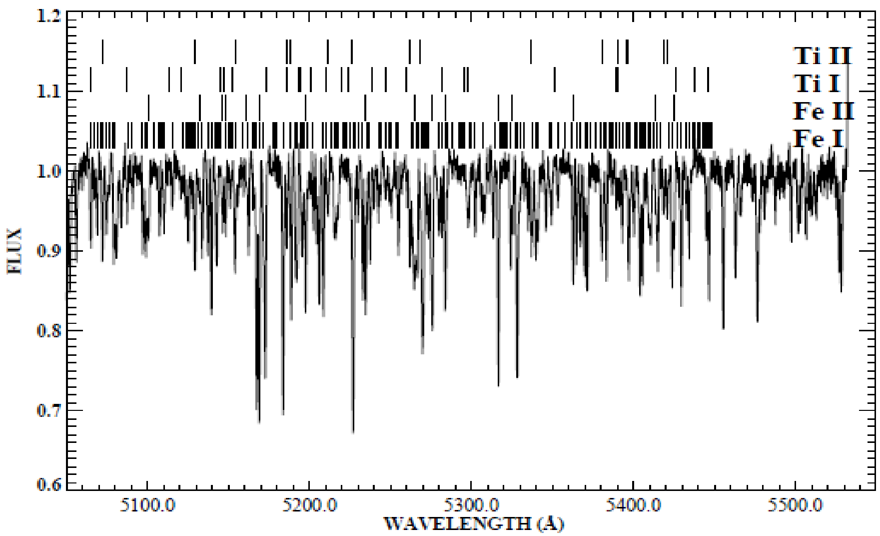
- Detection of over 100 candidates
- Nine (out of 11) confirmed by Subaru/HDS follow-up observations

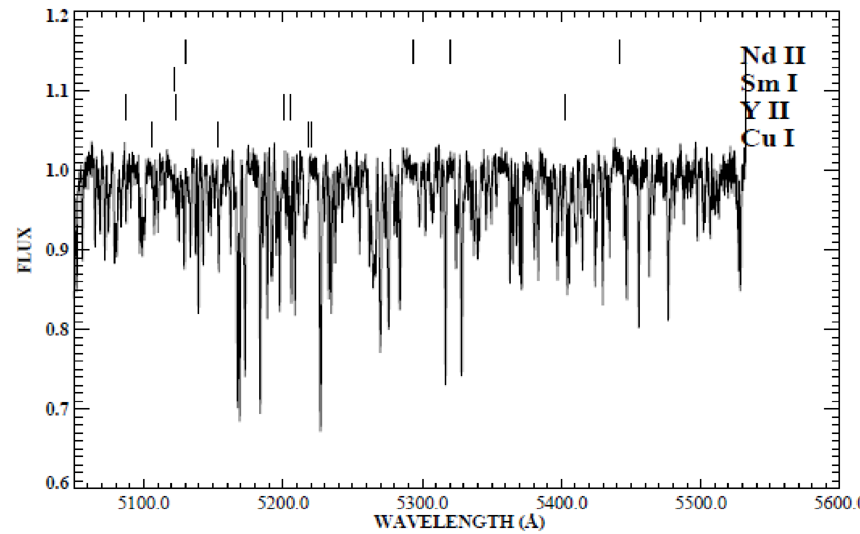


Xing et al. in preparation

LAMOST-II

- Updated spectrographs
  - Gratings are updated and able to switch to R~7500
  - Blue arm: 496-533 nm (Mg Triplet, metallic lines) ;
  - Red arm: 630-680 nm (Hα, Li)



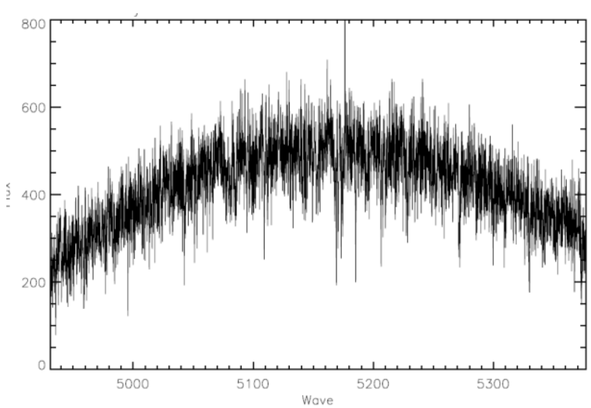


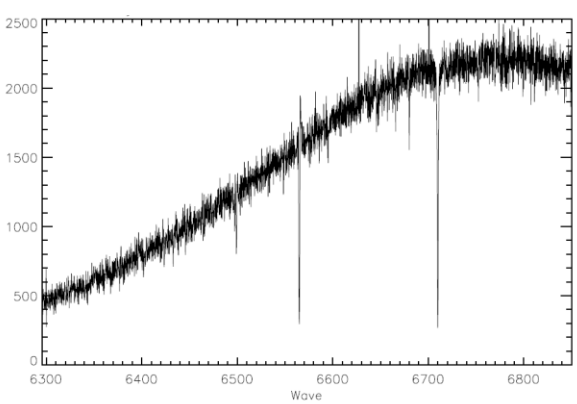
LAMOST-II

- 5-year survey: Oct 2018-Jun 2023
  - Dark/gray nights (14 nights/month): LRS survey
  - Bright/gray nights (13 nights/month): MRS survey
- Scientific goals
  - Galactic archaeology
  - Star formation
  - Stellar physics (time domain)
  - Stellar clusters, etc.

LAMOST-II

- Expected numbers of spectra
  - LRS: ~3 million more spectra with 1.5h exposure (stars + galaxies+ QSOs), r<18
  - MRS: ~200 K stars with time-domain spectra (20min x n_epoch, <n_epoch>~60), G<14
  - MRS: ~2 million stellar spectra (20min x 3),G<15





Summary

- Large sample of peculiar stars detected in LAMOST
  - Over 10,000 very metal-poor stars
  - Ten new halo moving groups in the solar neighborhood
  - Over 100 α-deficient halo stars
- Detailed investigations with Subaru
  - Uniform abundance analysis of over 400 VMP stars: ultra metal-poor (UMP) stars, r-II stars, Li-rich VMP stars, etc.
  - Origin of MGs: LAMOST-N1 as remnants of a massive dwarf galaxy
  - Nine α-deficient stars confirmed
- LAMOST-II + Subaru: stay tune

Thanks !

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