Subaru Telescope 20th Anniversary

LAMOST/Subaru exploration on the early evolution and formation of the Milky Way

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National Astronomical Observatories, CAS (NAOC)
2019/11/19 @ Big Island

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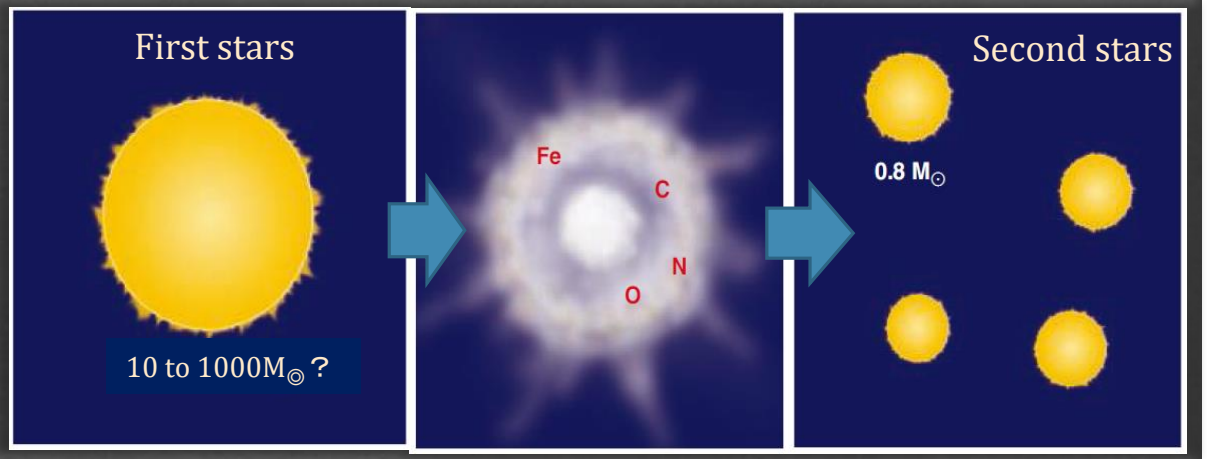
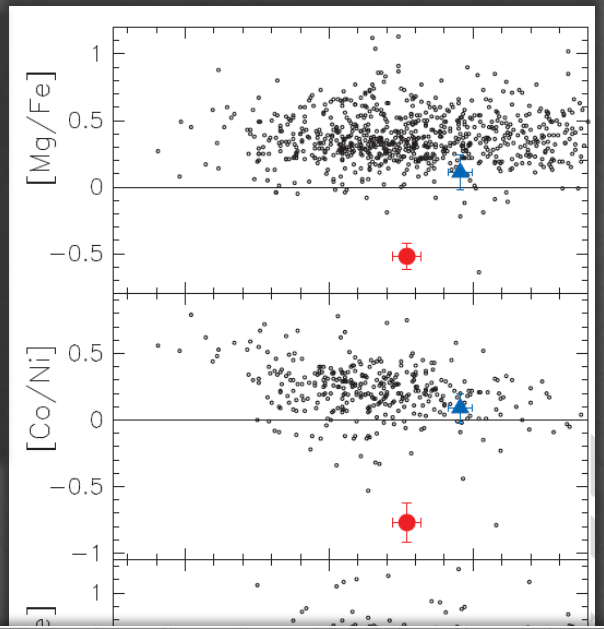
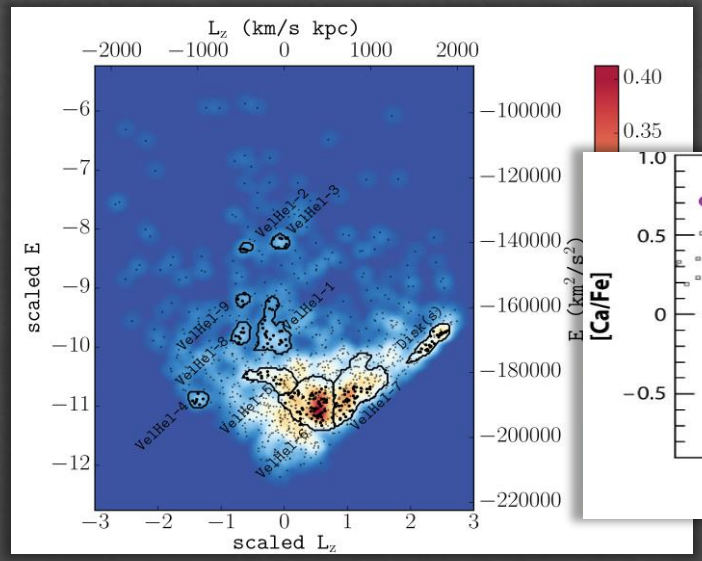
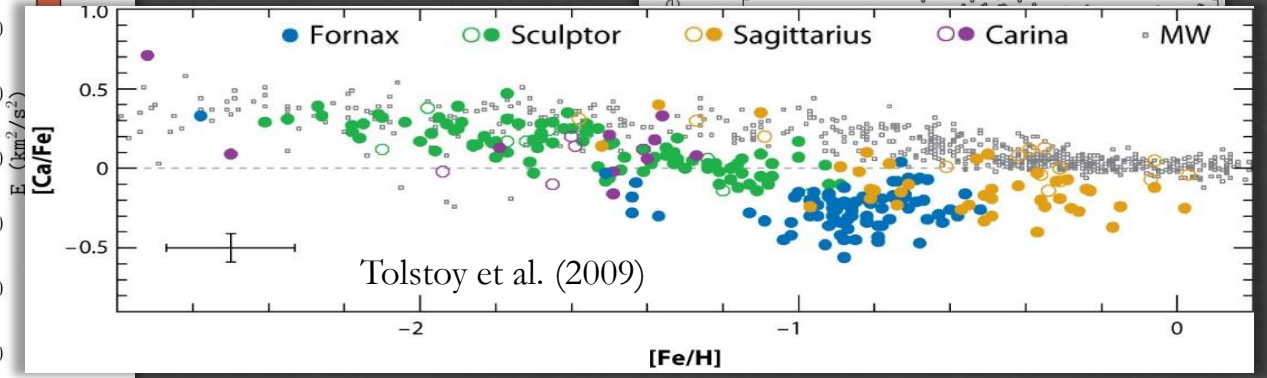
Stellar path to the early Milky Way









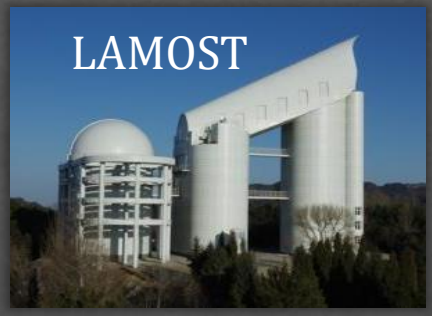
Tolstoy et al. (2009)

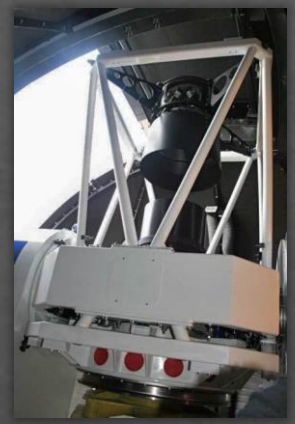
Helmi et al. (2017)

- reveal the early evolution of MW through very metal-poor (VMP) stars
- kinematic (stream/moving group)+ chemical (low-α halo stars) evidence of the merging history
- Rare objects

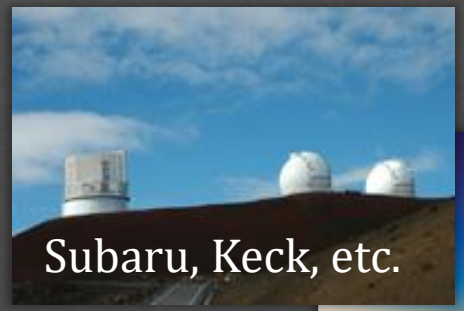
Hunting rare objects

- Extensive searching with wide-field survey
  - Photometry: SDSS, SkyMapper, Pristine
  - Low/medium-resolution spectroscopy: SEGUE, LAMOST, RAVE
  - Astrometry: Gaia
- Follow-up high-resolution spectroscopy
  - 6-10m class telescopes: brighter targets
  - Truly understand their nature/origin
- limited sample

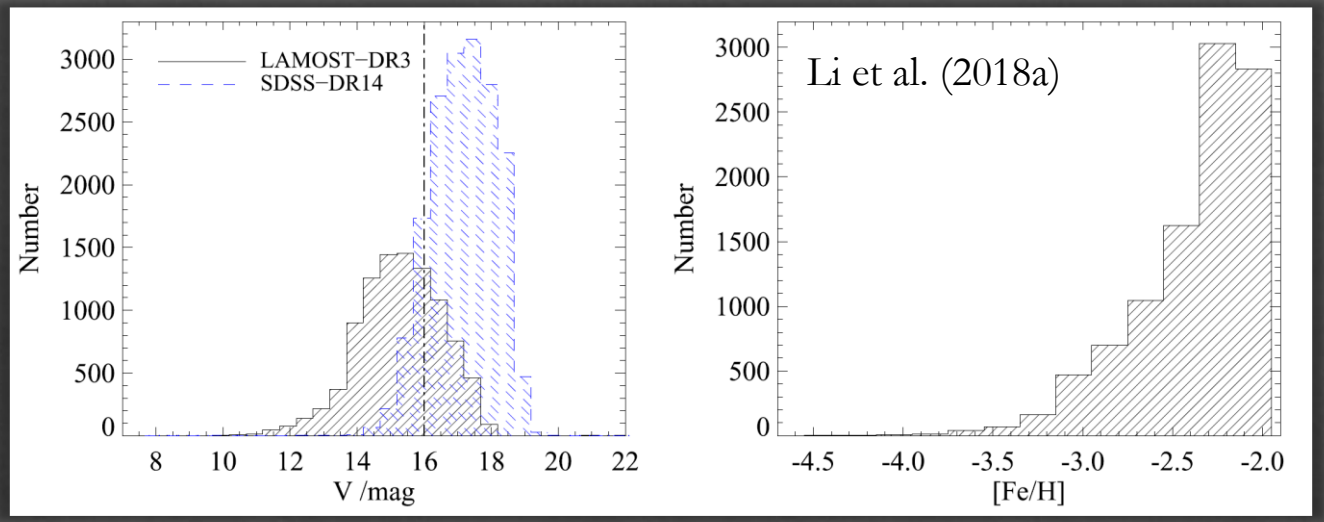


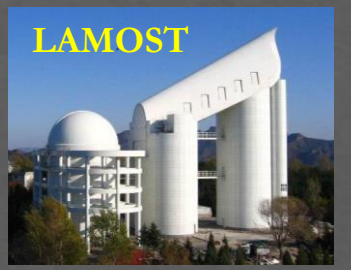


Skymapper

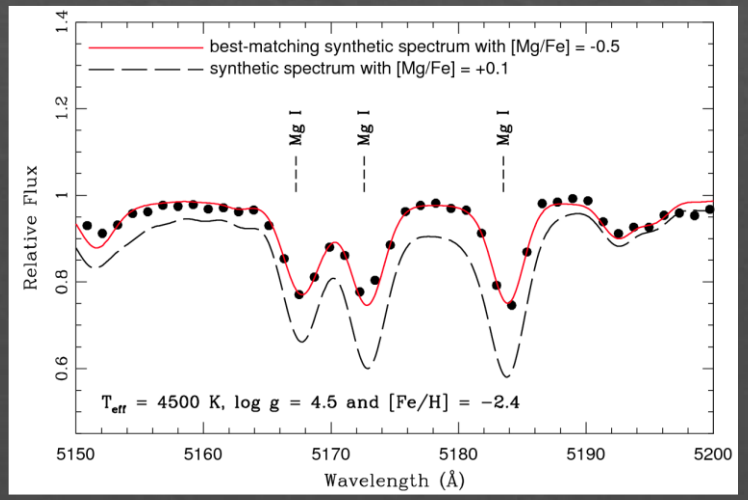


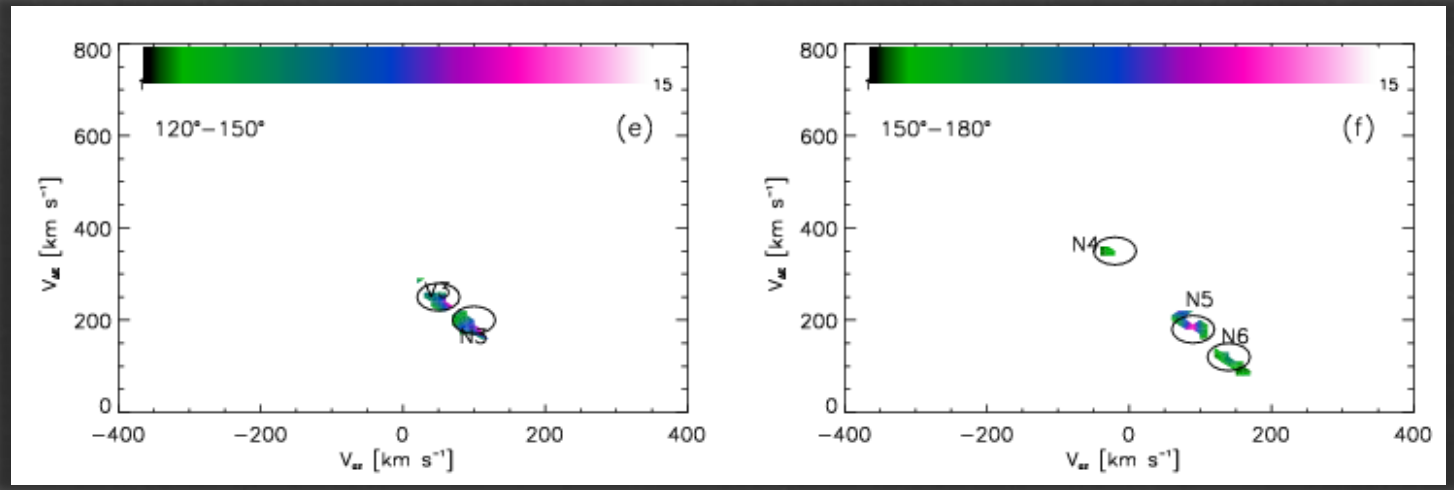
LAMOST-Subaru project: an example





- The largest bright very metal-poor (VMP) star sample (e.g., ~8,000 objects with V < 16.5)
- Over 100 low-α halo star (first systematic search)
- Ten new halo MGs detected in phase space (increased by 50%)





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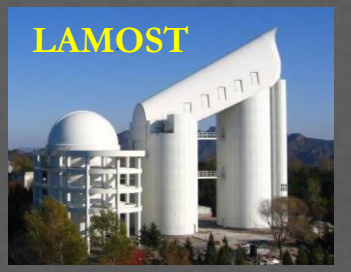
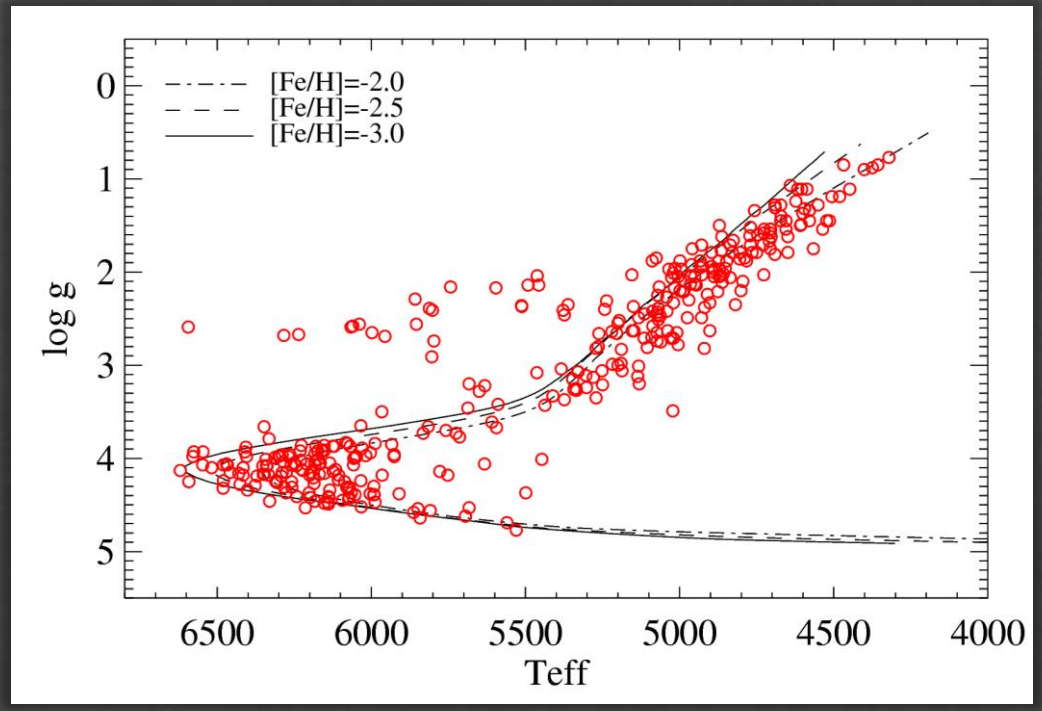


- LAMOST+Subaru joint project since 2014
  - Joint proposal for Subaru open-use program
- Follow-up with Subaru/HDS for about 500 objects (2014-2018)
  - About 450 VMP candidates
  - Bright members from LAMOST-N1 MG
  - A dozen low-α candidates
- CAS-JSPS joint project (2016.04-2018.12; 2019.04-2021.12)

Large sample of VMP stars

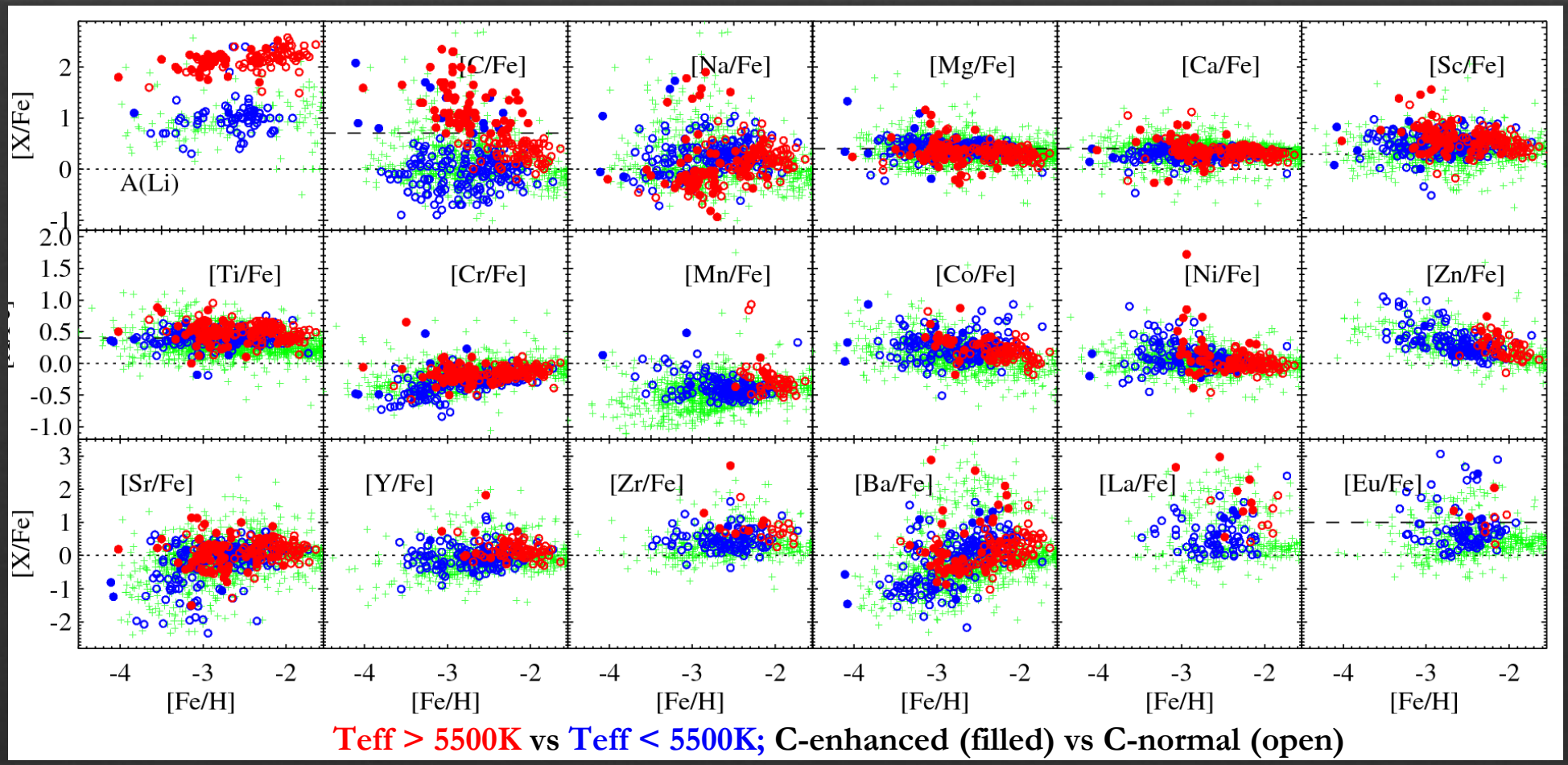
- About 450 VMP candidates observed with Subaru/HDS



Li et al. in preparation

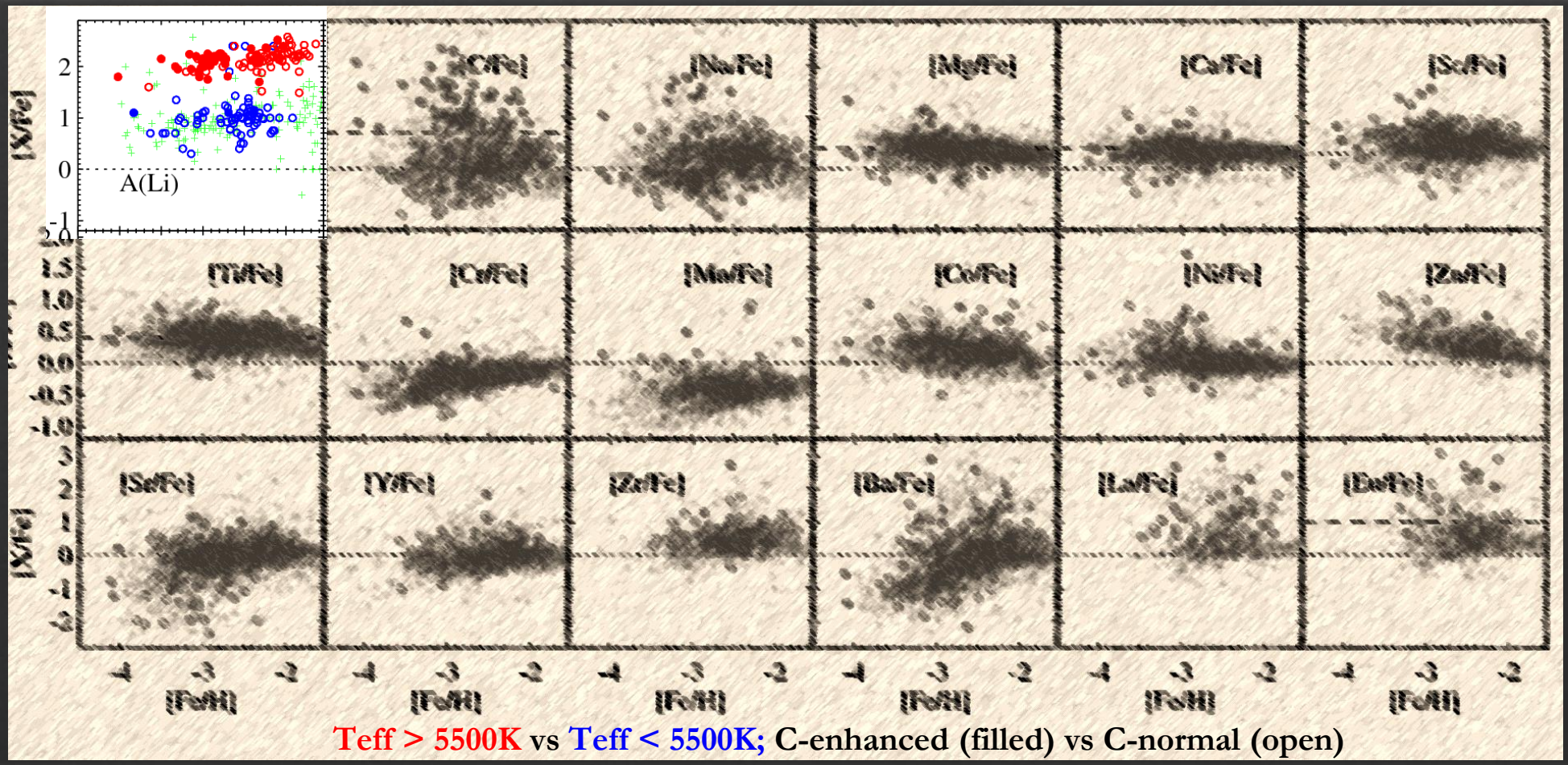
- Over 400 were analyzed;
- wide evolutionary stages
- ~100 extremely metal-poor stars
- three ultra metal-poor stars
- Success rate > 90% for VMP stars

VMP stars: general abundance trend



Characterize the first star/supernovae (see M. Ishigaki's talk)

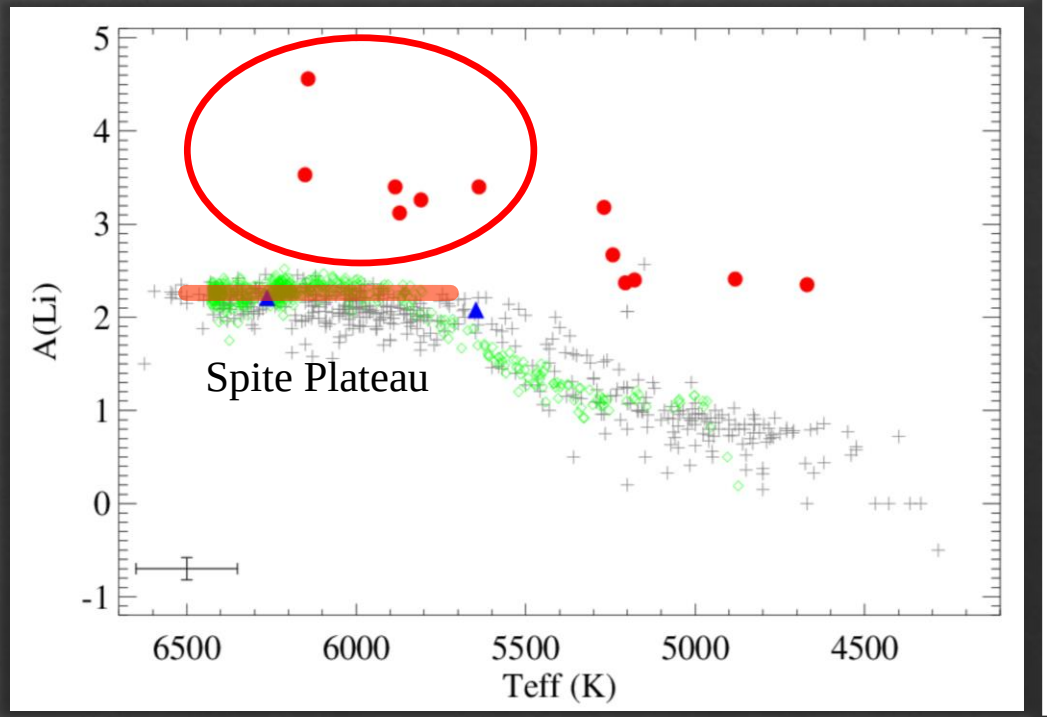
VMP stars: Li evolution in low-mass stars

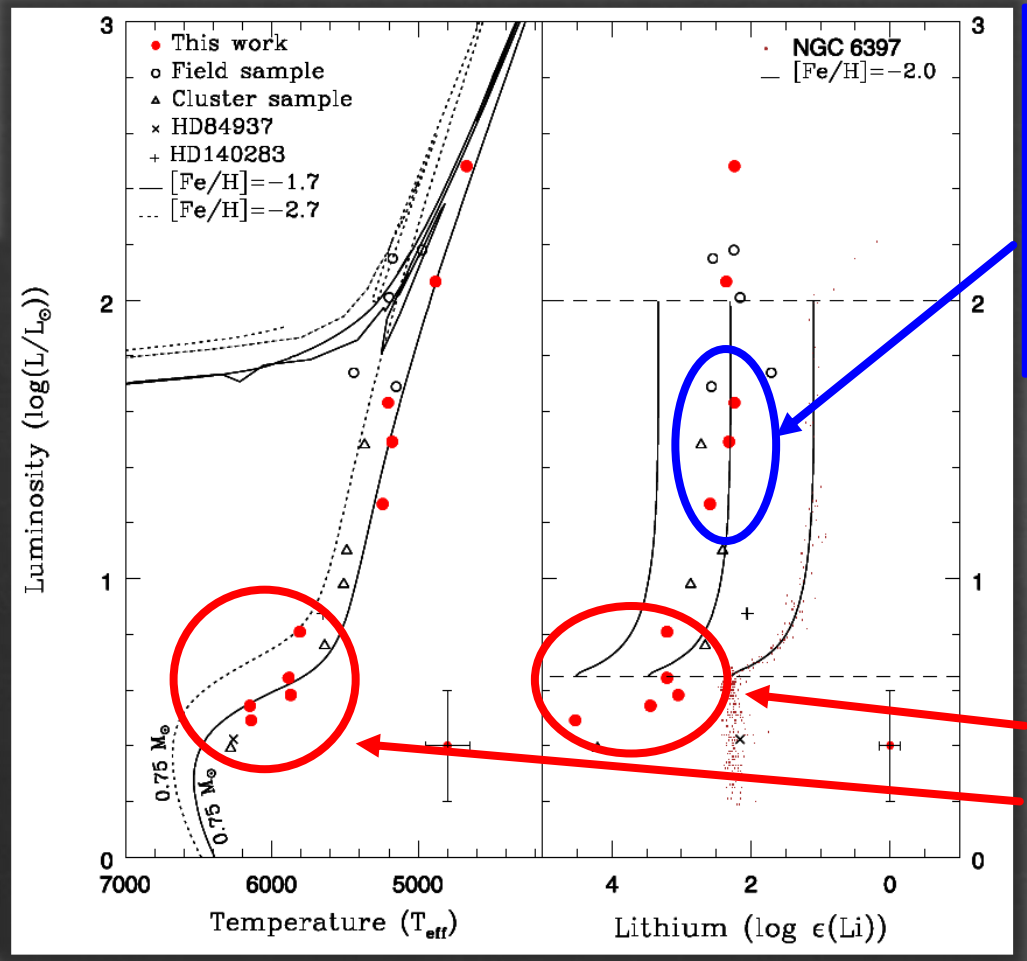


Investigate evolution/depletion of lithium

Li evolution in low-mass stars: extreme case

- First systematic search of Li-rich VMP stars: 12 were confirmed



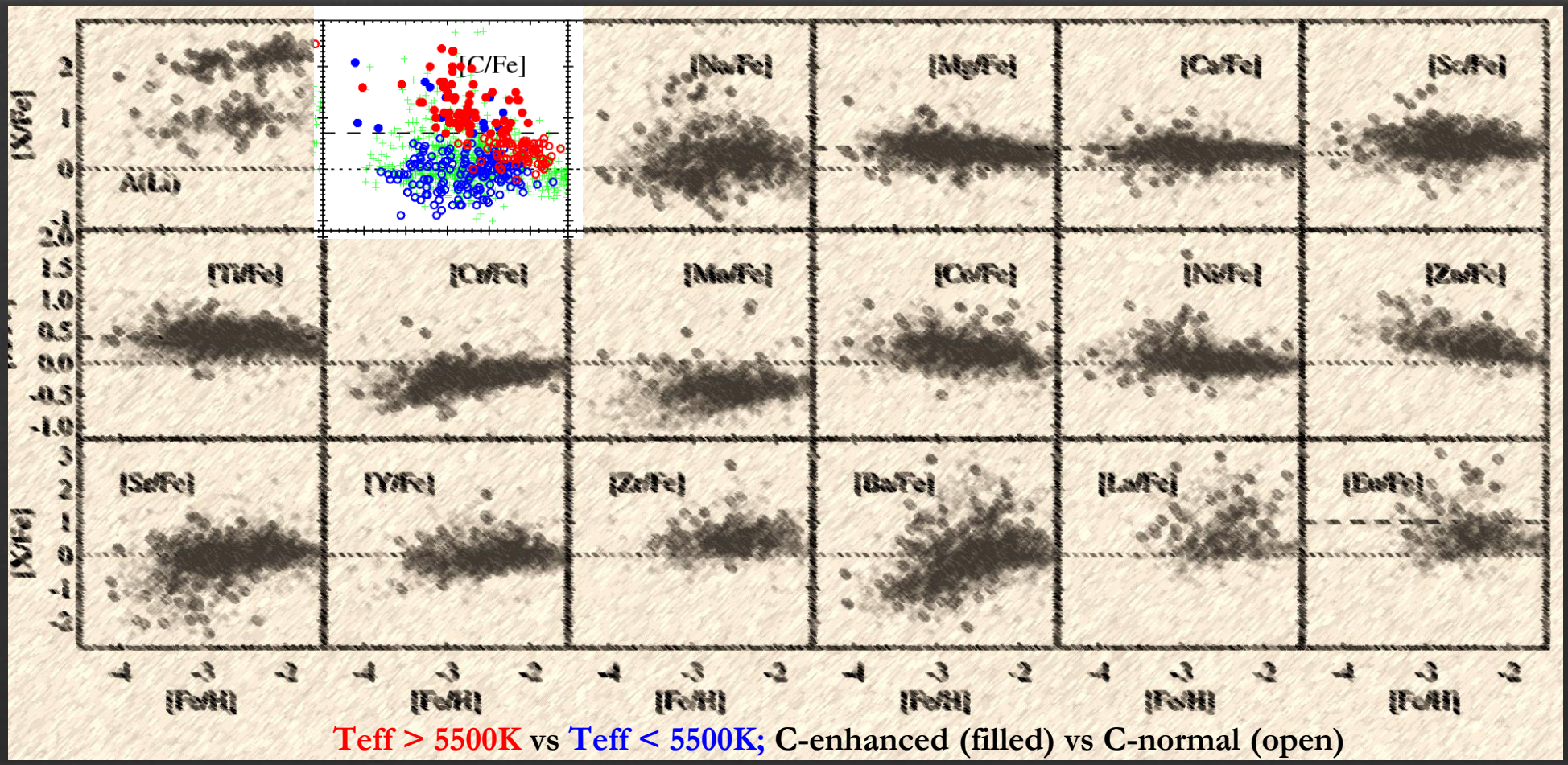


Li-rich giants (before RGB bump) can be explained by dilution by 1st dredge-up

Discovery of super Li-rich sub-giants in the field raises challenges to low-mass stellar evolution model

Li et al. (2018b)

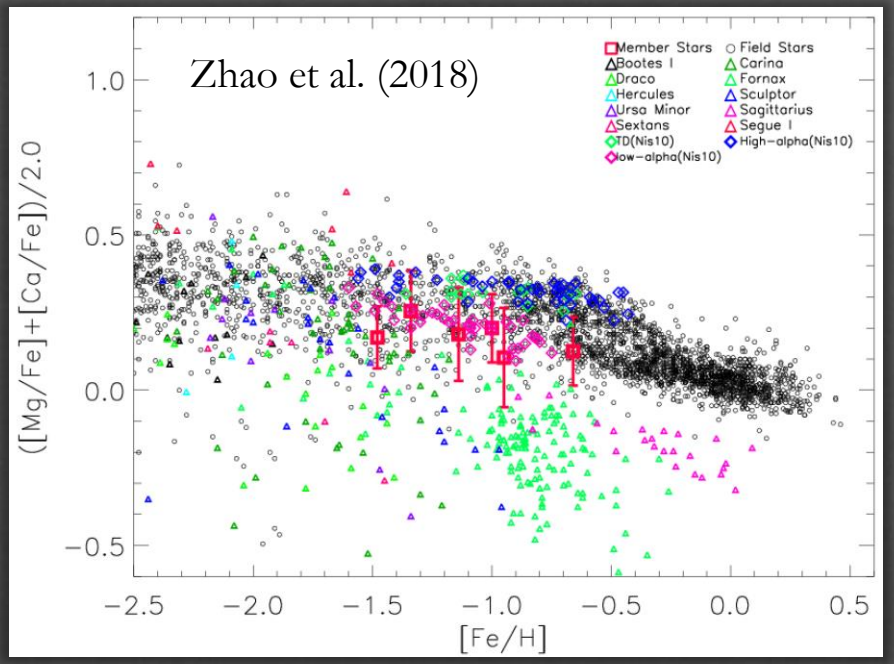
VMP stars: Carbon-enhance metal-poor (CEMP) stars

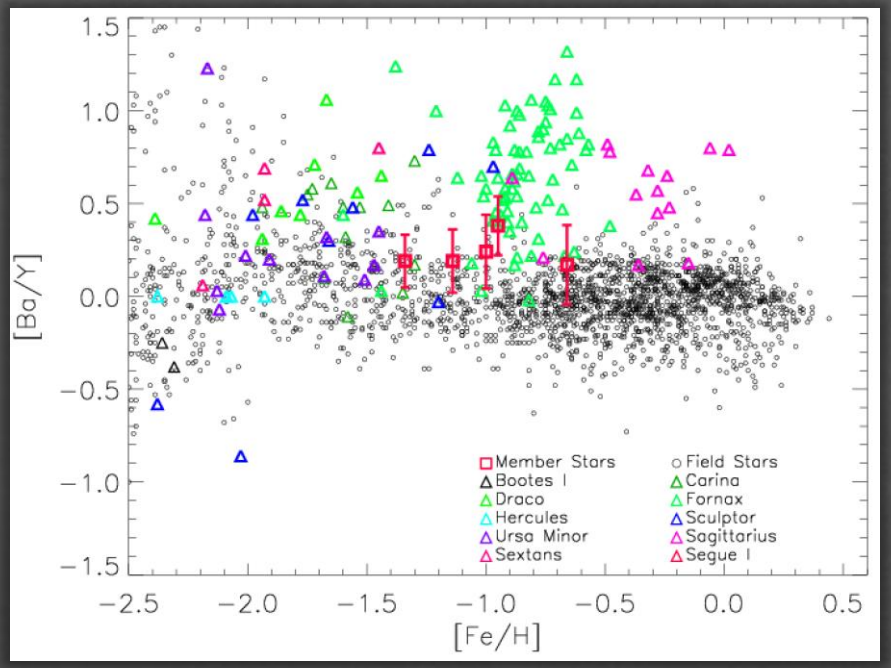


Among the most pristine objects (see W. Aoki's talk)

Kinematics + chemistry: origin of moving groups

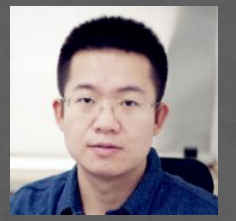
J.K. Zhao



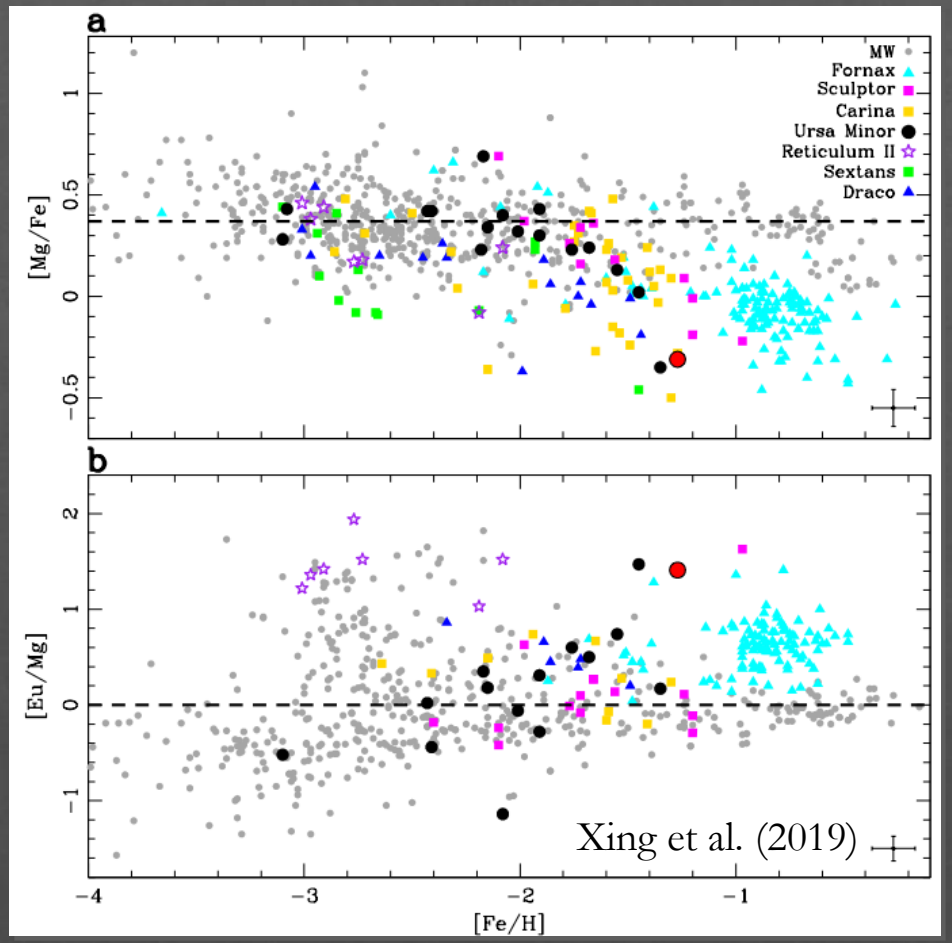


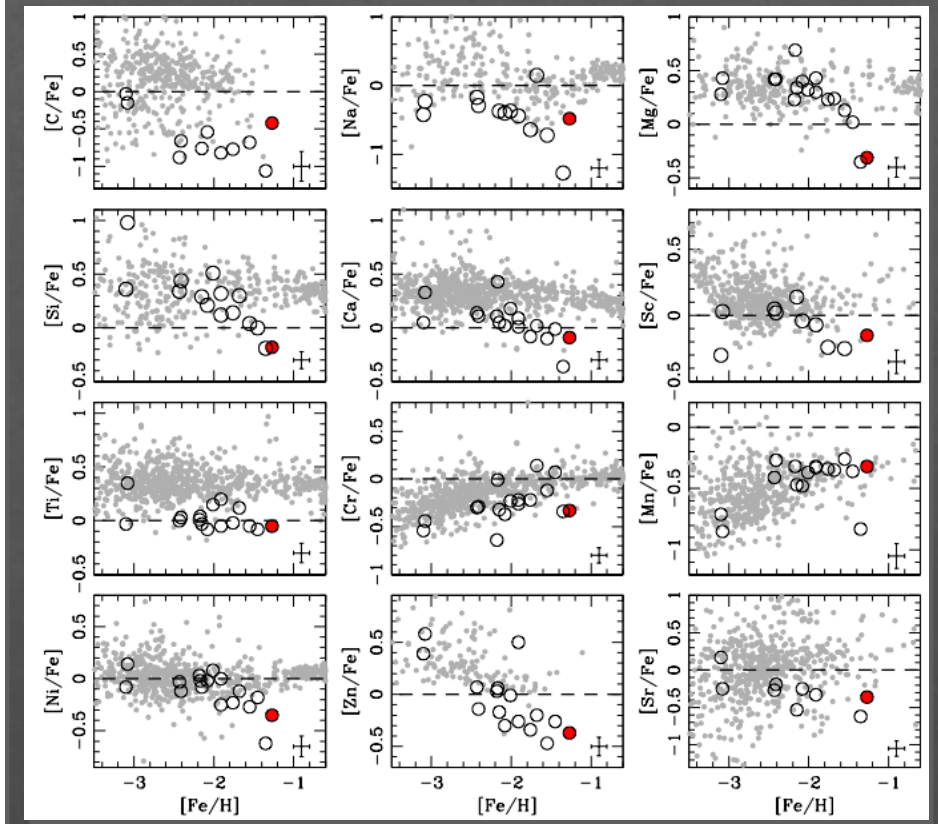
- LAMOST-N1: α abundance pattern similar to that of low-α halo population in Nissen & Schuster (2010)
- most likely originate from systems with a slower chemical evolution

A r-II low-α halo star: tracking the early merging



Q.F. Xing





Comparison with halo field stars and UMi

First discovery of r-II low-α star in the halo: accretion origin of r-process elements

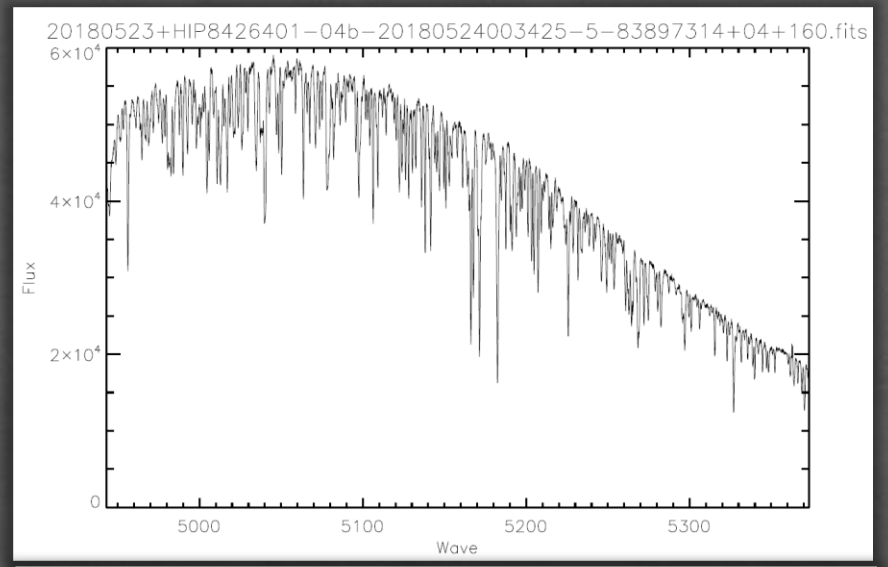
LAMOST-II

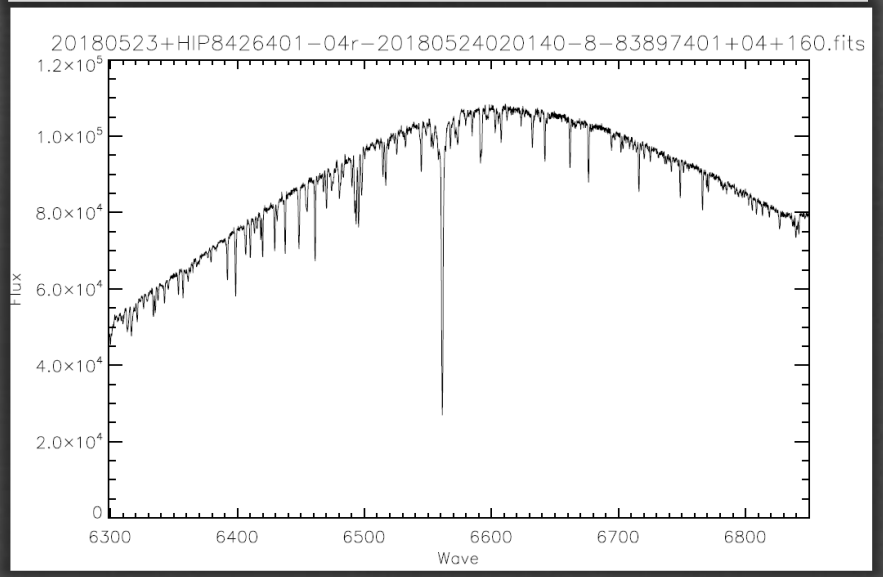
- Updated spectrographs
  - Gratings are updated and able to switch to R~7500
  - Blue arm: 496-533 nm + Red arm: 630-680 nm
- 5-year survey: Oct. 2018-Jun. 2023
  - Dark/gray nights (14 nights/month): LRS mode

  - ~3 million (stars + galaxies+ QSOs), r<18
  - Bright/gray nights (13 nights/month): MRS mode

  - ~200 K stars for time-domain, G<14

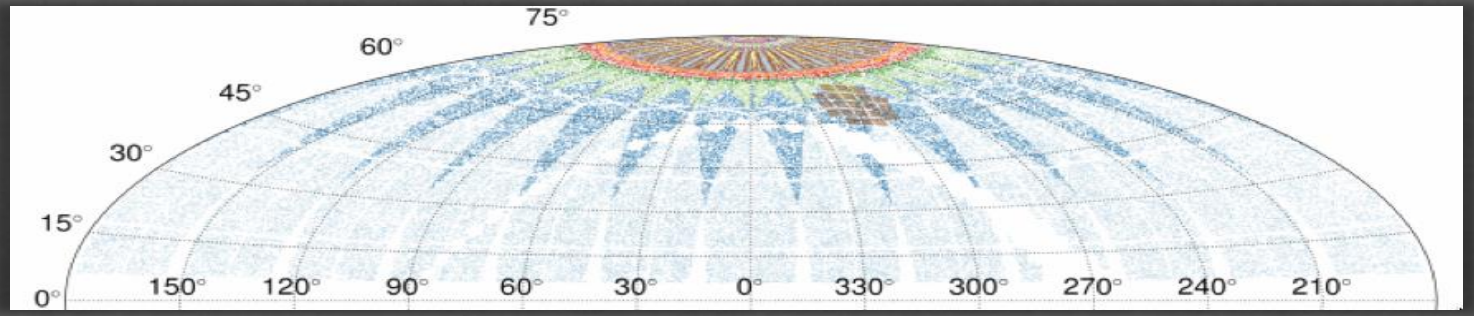
  - ~2 million, G<15

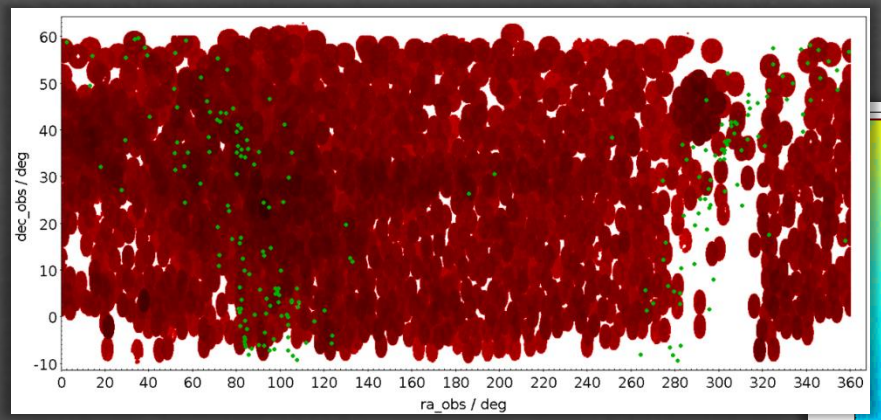


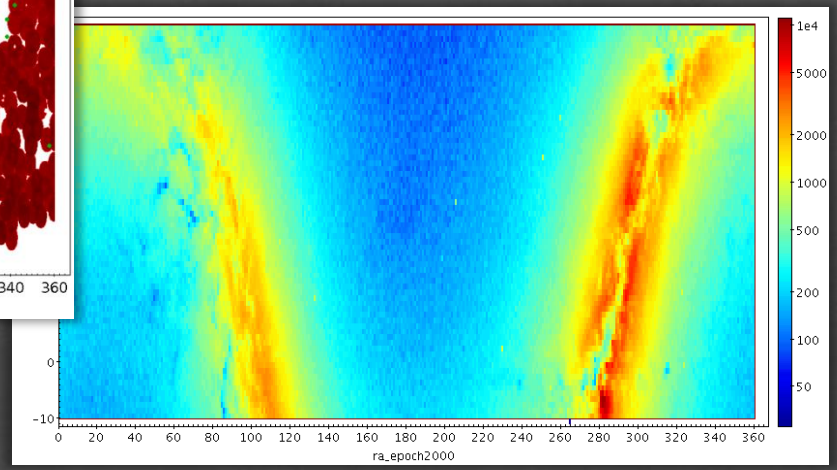


LAMOST-II: MRS science cases

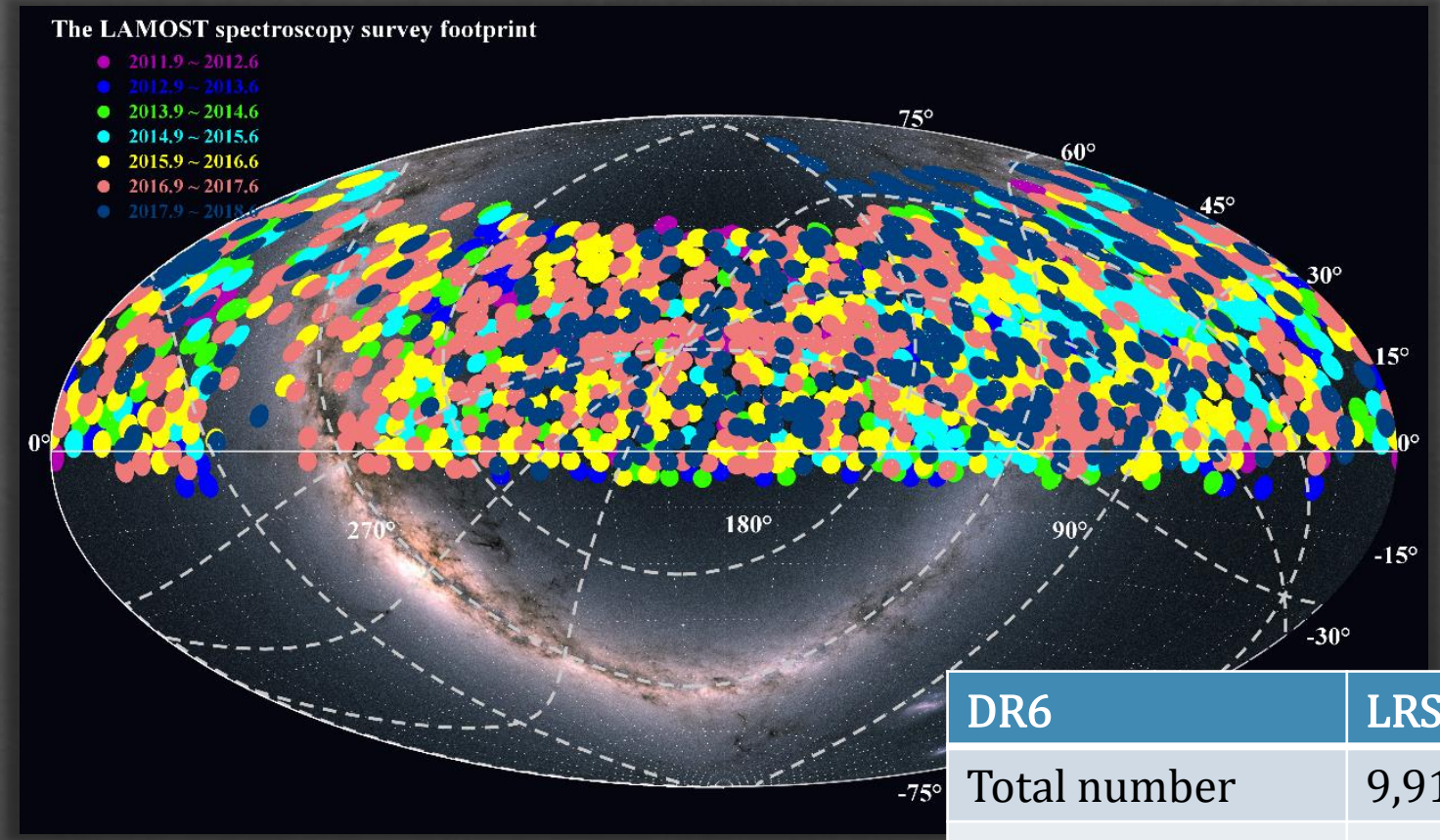
- Time domain science
  - TESS north pole including Kepler region: ~100,000 objects (~1,000 planetary systems)
  - Binarity and variability
- Chemical tagging
- Star-forming region
  - 3,000 deg^2
- Open clusters
  - 50-100 OCs within 2kpc







LAMOST-II: data release

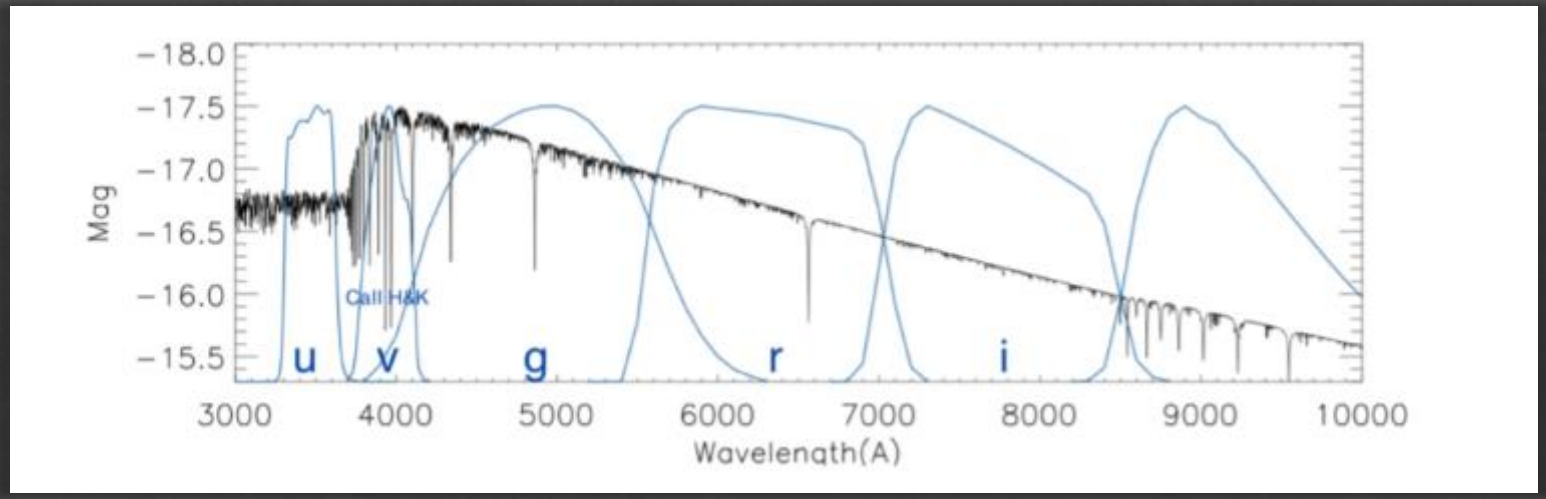


- DR5
  - Dec. 2018: domestically published (external collaborators)
  - Jun. 2019: fully published
- DR6
  - Mar. 2019: domestically published (external collaborators)

DR6	LRS	MRS/non-TD	MRS/TD
Total number	9,910,000	500,000	840,000
S/N > 10	8,560,000	340,000	470,000
Stellar parameter	5,840,000	220,000	300,000

Not only spectra: SAGE Survey

- A photometric survey covering 12,000deg^2 in the north
- Hundreds of millions of stars for 9<V<15 mag
- Filters sensitive to different stellar parameters (Teff, logg, [Fe/H])



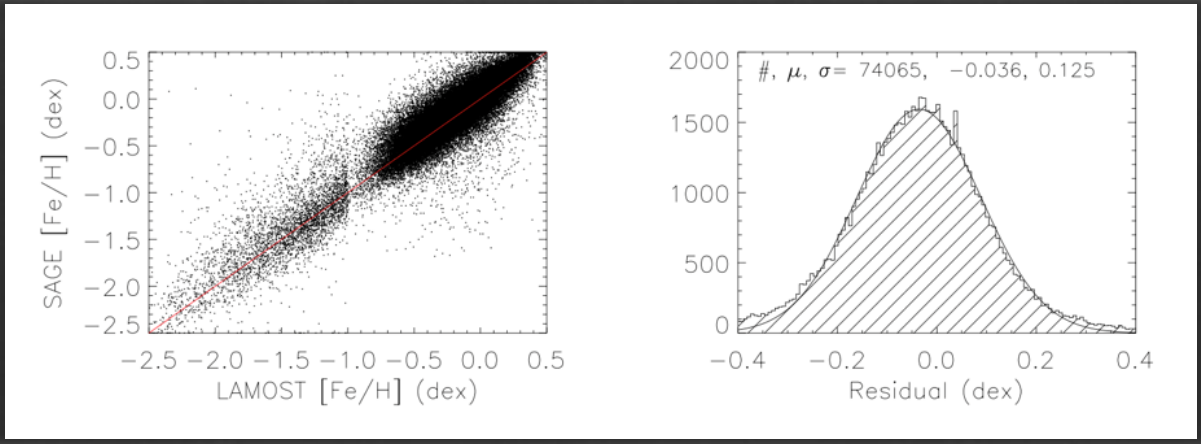
Bok 2.3m: uv

Nanshan 1m: gri

- Galactic science: Searching for EMP stars; MDF of different stellar populations; Galactic substructure; peculiar objects

SAGE Survey: data and VMP candidates

- DR0 (Apr., 2019)
  - 66,079,675 stars in 6,500 deg^2 (uv, photometric accuracy ~ 1.5%)
  - SAGES+Pan-STARRS1: 34,335,989
  - SAGES+Pan-STARRS1+Gaia DR2: 12,733,218
- DR1 (Jan. 2020)
  - ~100 million stars in 9,500 deg^2 (uv, photometric accuracy ~ 1.0%)



- Success rate of 60% (dwarf) and 80% (giant)
- LAMOST add-on project on follow-up of VMP candidates from the SAGE Survey

Summary

- Exploring early Milky Way with LAMOST and Subaru
  - Largest uniform high-resolution VMP sample
  - Relic evidence of early merging
- Synergy for China-Japan collaborations
  - Chinese astronomers need large telescopes (in the north)
    - National key project on the Milky Way (~1.1/5million USD for large telescope follow-up)
    - Exchange/collaboration between LAMOST/FAST and Subaru
  - Already participating in Subaru/PFS and TMT

useful experience and obvious synergy for future China-Japan collaborations (not only) in the local universe

Thanks

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