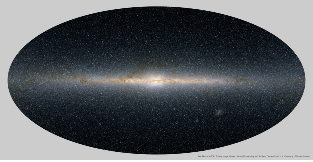
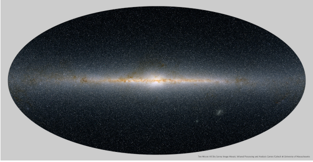


Unraveling the assemblage and evolution history of the Galactic disk with LAMOST

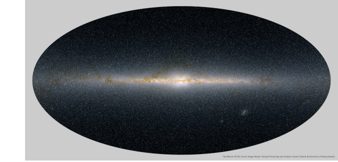
Xiang Maosheng (NAOC)
LAMOST Fellow

On behalf of:
NAOC: Shi Jianrong, Huo Zhiying
Peking Univ.: Liu Xiaowei, Chen Bingqiu, Huang Yang, Wang Chun
Beijing Normal Univ.: Yuan Haibo, Wu Yaqian
Hebei Normal Univ.: Li Ji

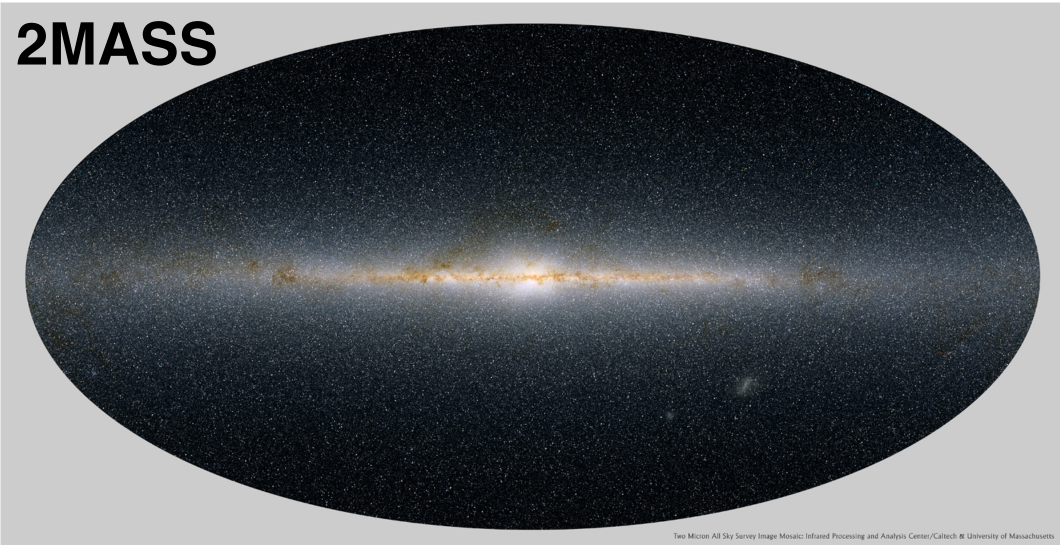


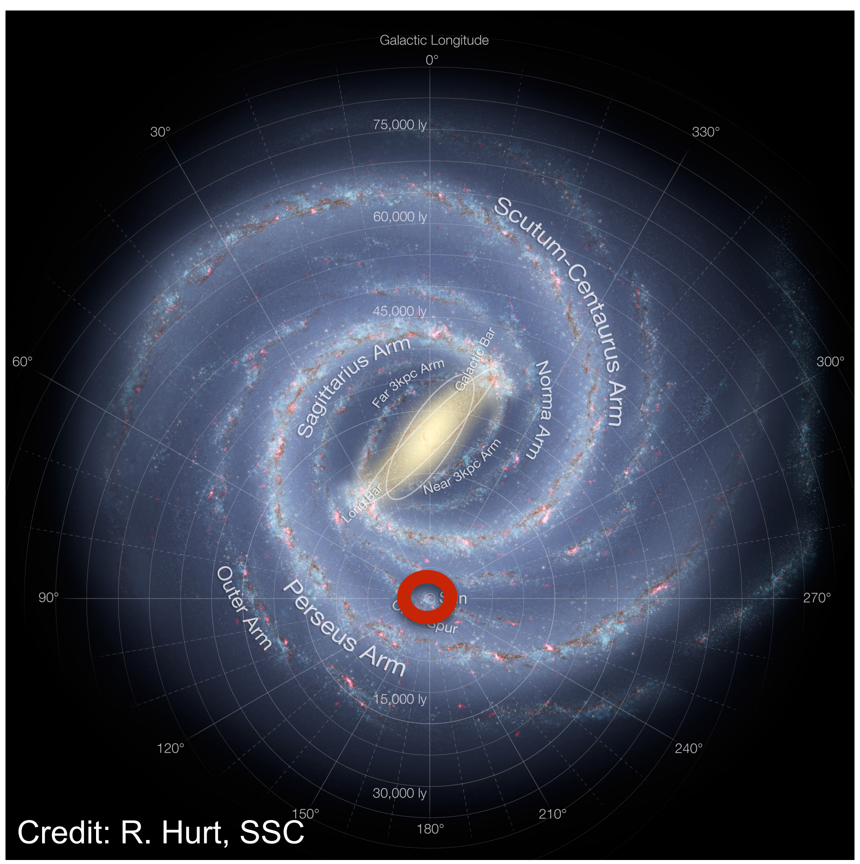
Outline

- Introduction: why Galactic disk
- LAMOST value-added catalogs
- Stellar ages and masses (MSTO, red giants)
- Stellar metallicities for mono-age populations
- Star formation history of the disk
- Summary

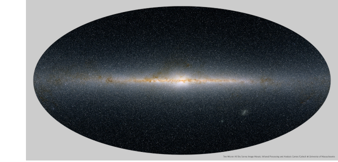


The Galactic Disk





- **The Galactic disk is a unique laboratory for understanding the formation and evolution of disks of spiral galaxies**
- **Scientific issues: thin/thick disk, spiral arms, matter distribution, assemblage & evolution history**
- **Challenge: numerous stars in 4π sky & extinction**
- **LAMOST: 20 sq.deg. FoV, 4000 fibers, good weather in winter (the Galactic anti-center)**

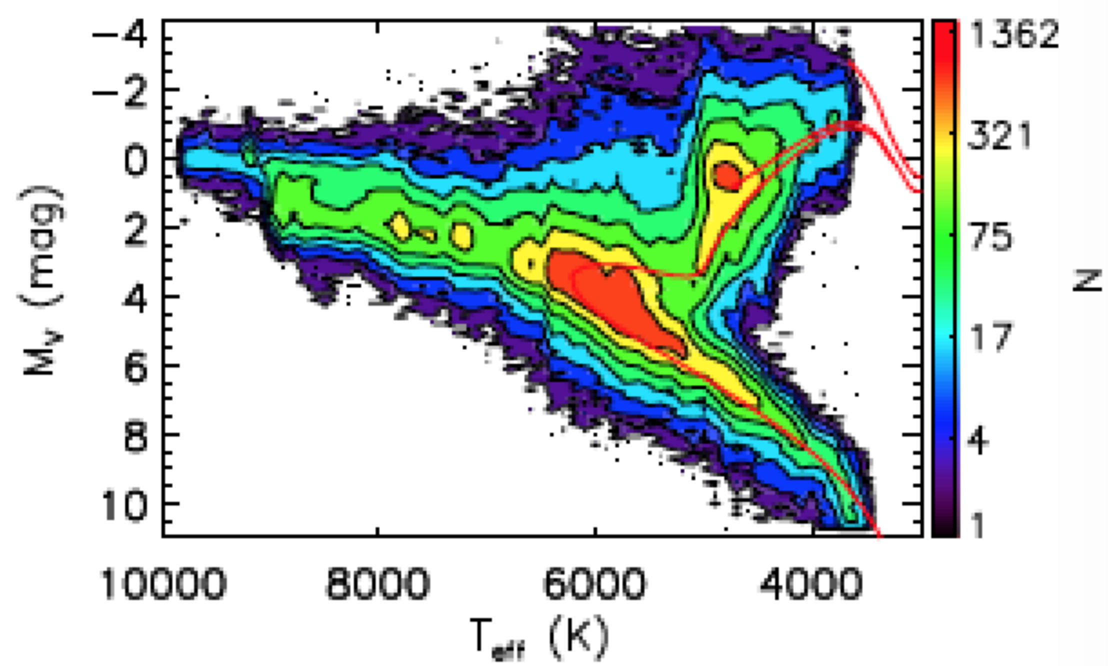


LAMOST value-added catalog for LSS-GAC

http://lamost973.pku.edu.cn/site/data

LSS-GAC DR2

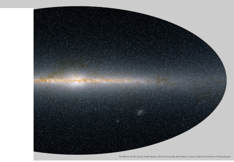
Observation tags, Vr, Teff, log*g*, Mv, [Fe/H], [α/Fe], [C/H], [N/H], E(B-V), distance, 3D positions, 3D velocities yielded by the LAMOST Stellar Parameter Pipeline at Peking University (LSP3) for 1.8 million observations of 1.4 million unique stars from LSS-GAC



Xiang et al. 2017, MNRAS, 467, 1890

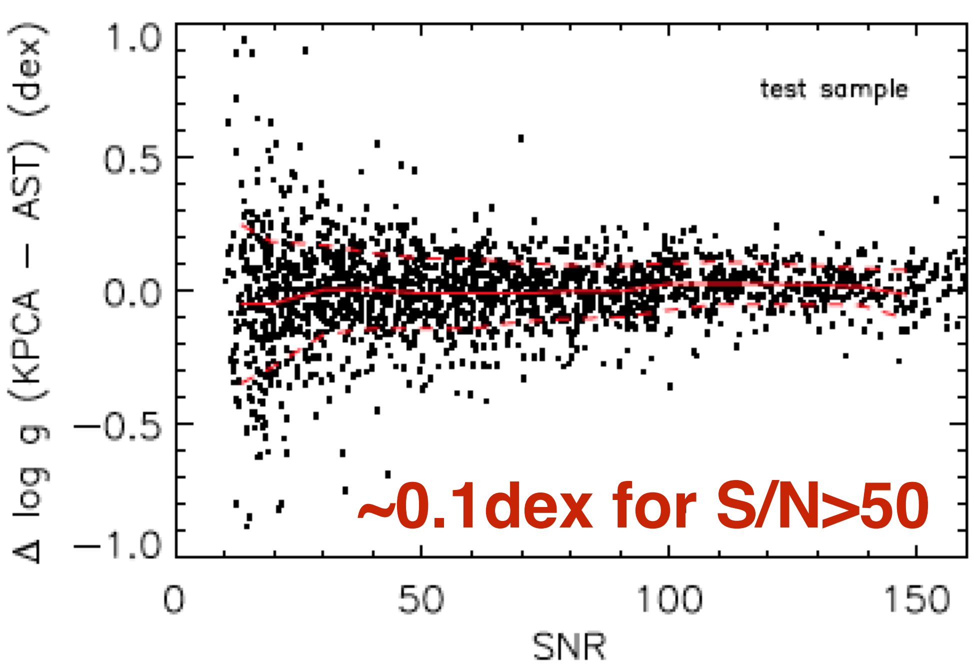
Value-added catalog of LAMOST DR3 will be available soon

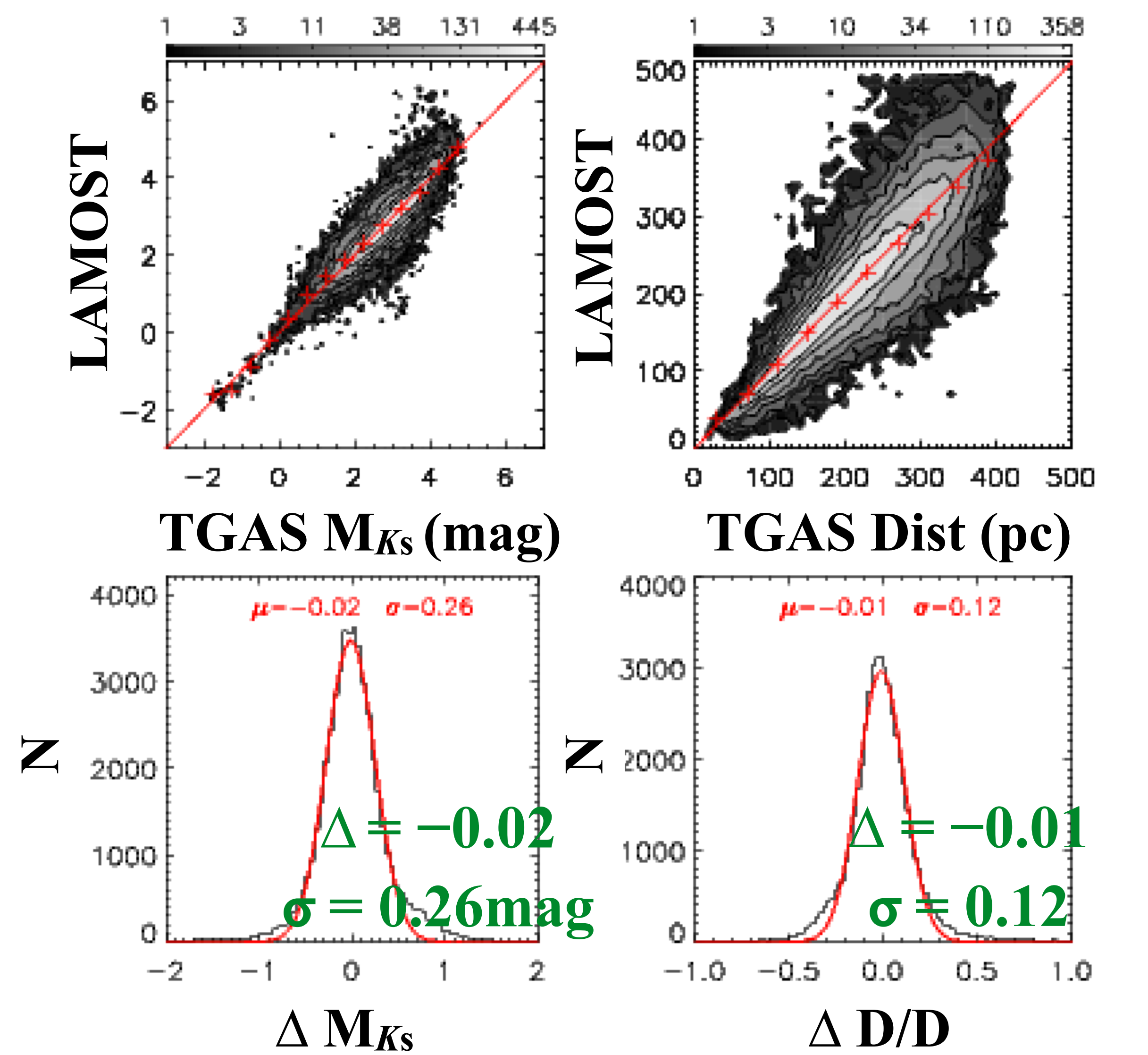
Validations of stellar parameters yielded by LSP3



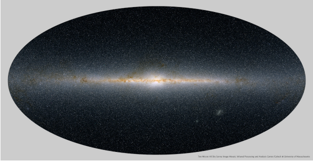
Xiang et al. 2015b, MNRAS, 448, 822
Xiang et al. 2017a, MNRAS, 464, 3657; *ibid*, 467, 1890

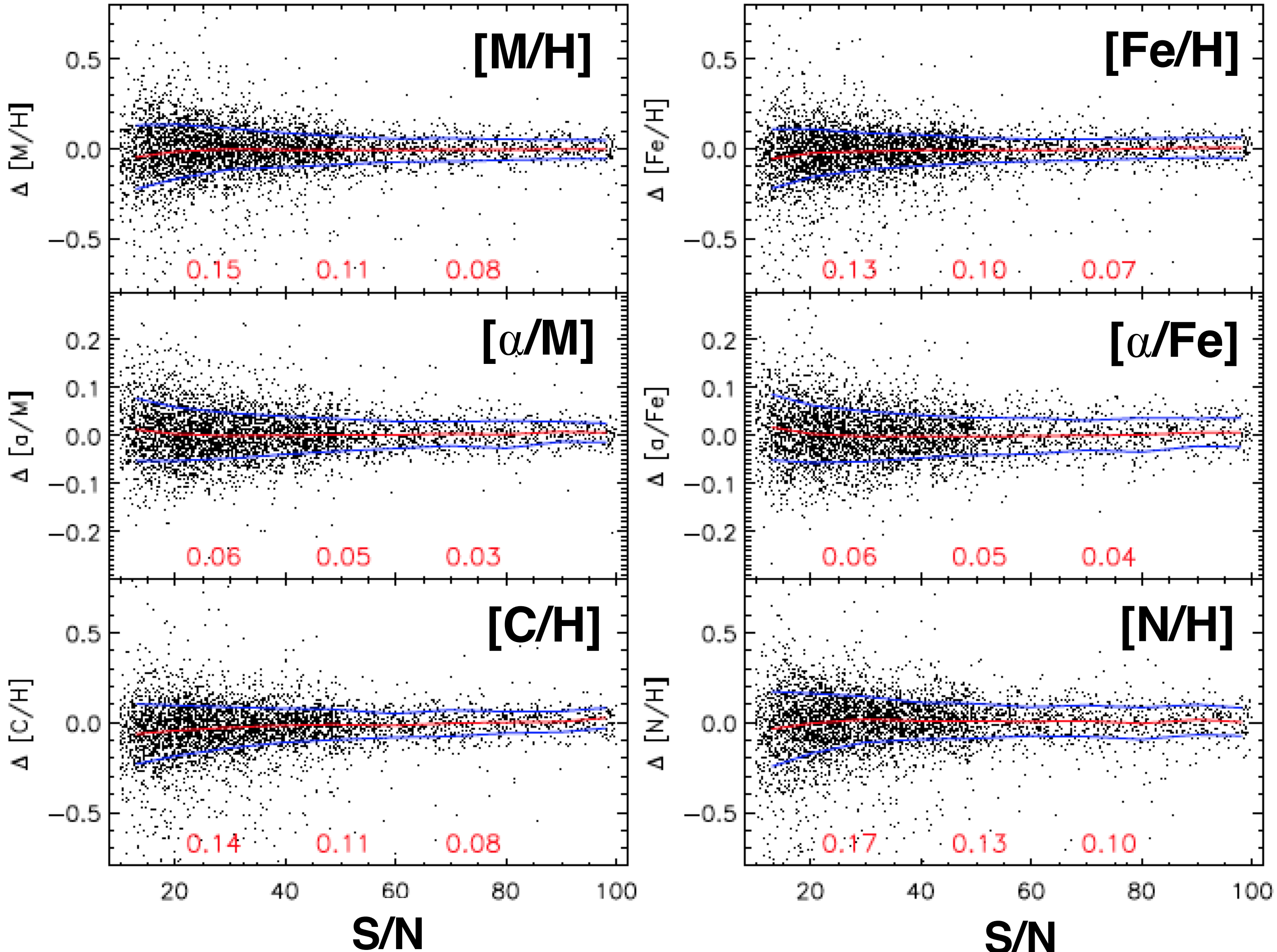
- **V_r (5km/s): APOGEE, RAVE, SDSS, star clusters, LASP, repeat observations**
- **T_{eff} (100K), log *g*(0.1dex), [Fe/H](0.1dex): Photometric temperatures of Huang et al. (2015, MNRAS, 454, 2863), PASTEL, asteroseismology, star clusters, APOGEE, SDSS, LASP, repeat observations**
- **[α/Fe](0.05dex): APOGEE, star clusters, repeat observations**
- **M_V (0.3mag): TGAS, repeat observations**
- **E(B-V)(0.04mag): SFD map, repeat observations**



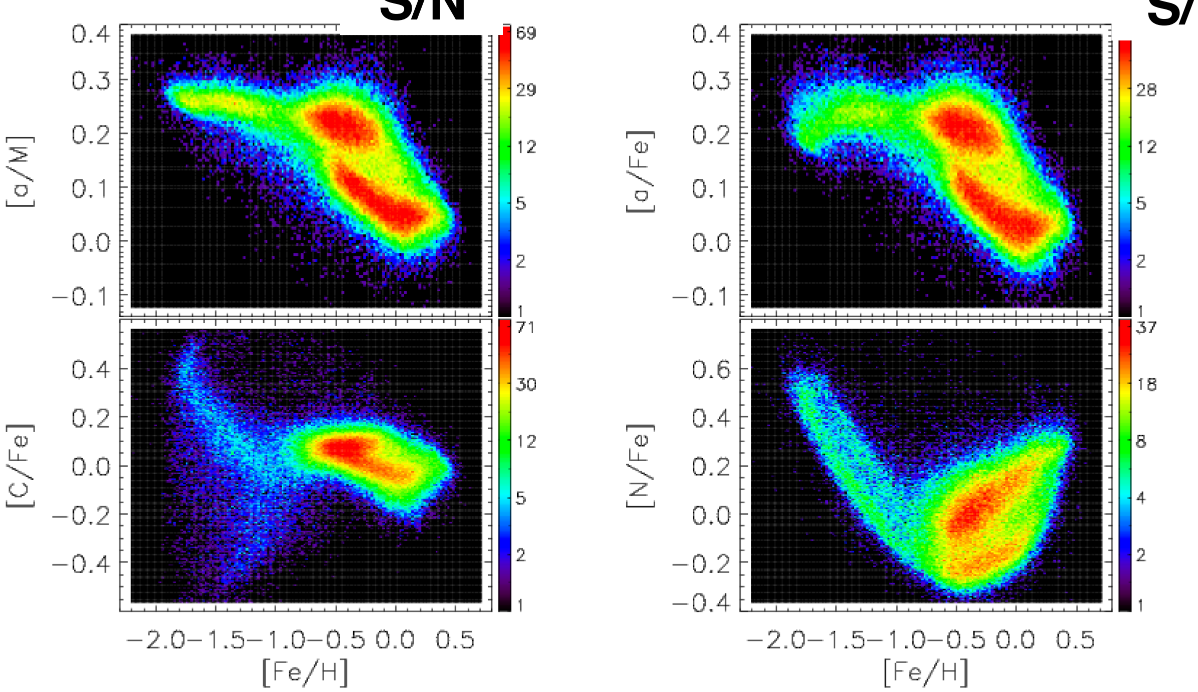


Chemical abundance





Xiang et al. 2017a, MNRAS, 464, 3657

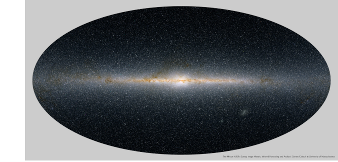


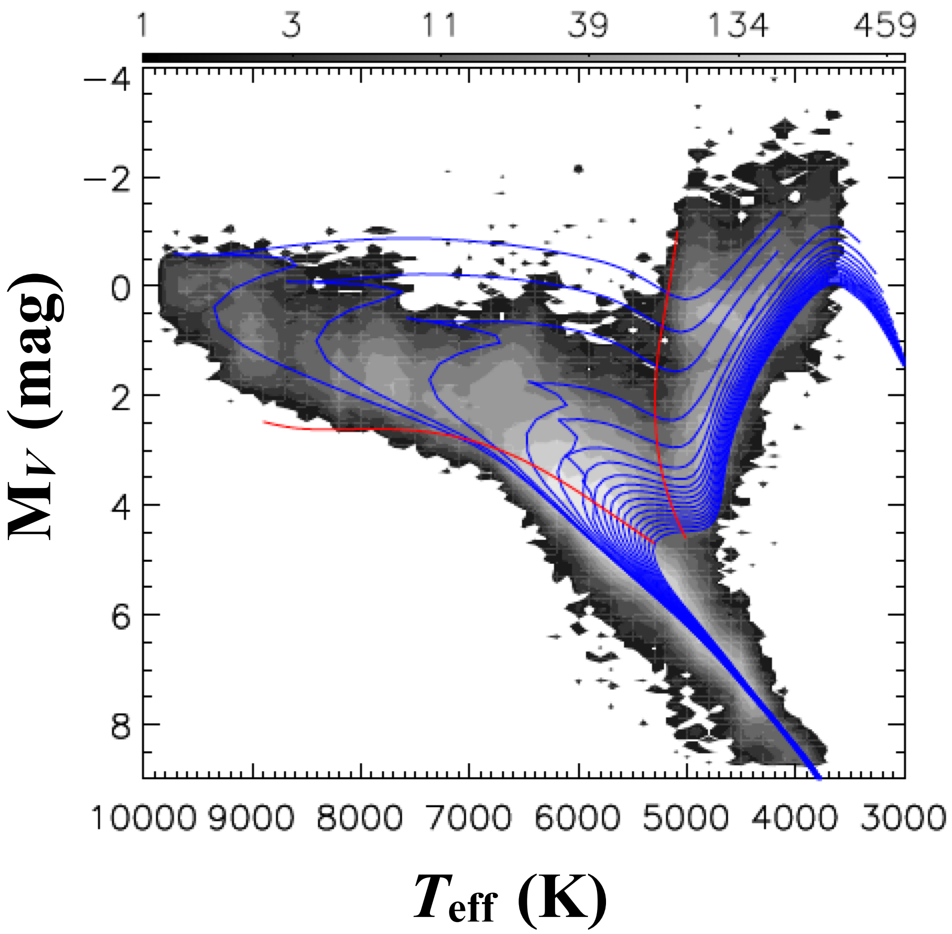
|b|>30°

Precise abundances are derived from the LAMOST spectra

For S/N>30: [Fe/H], [C/H],[N/H]: ~0.1dex [α/Fe]: ~0.05dex

The MSTO-SG sample



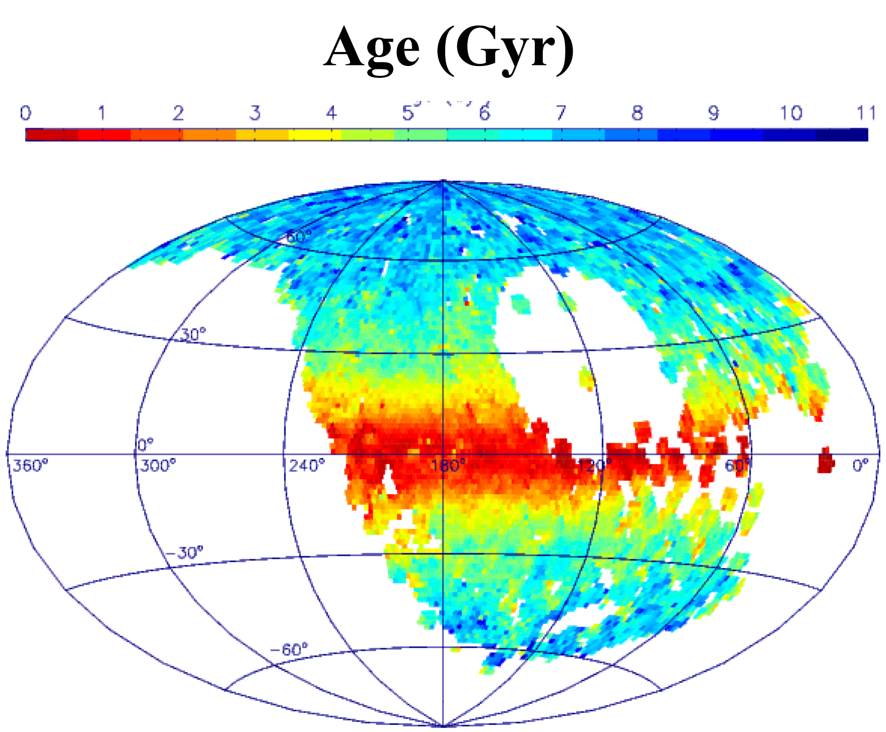


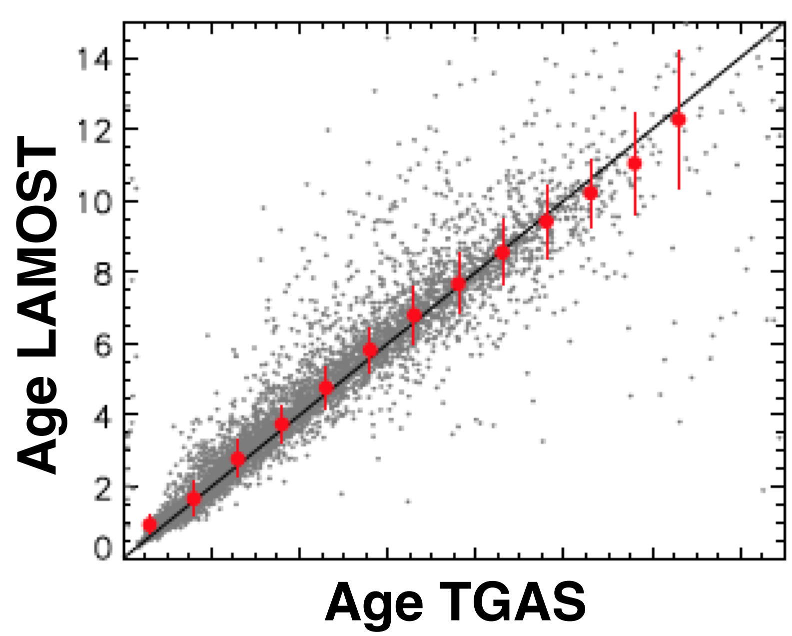
Xiang et al. 2017c, ApJS, in press, ArXiv:1707.06236

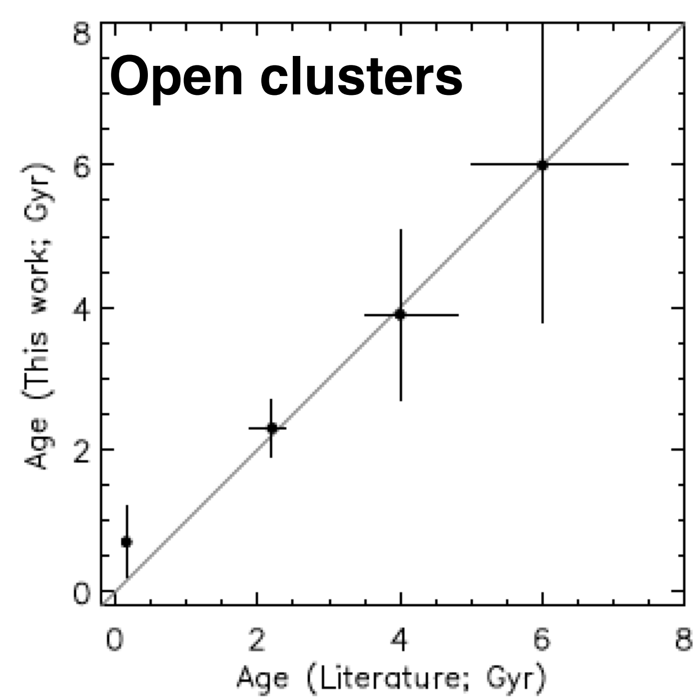
By June, 2016:
6.5M spectra of 4.4M stars

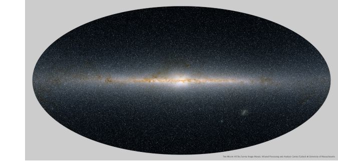
Age & mass for 1M MSTO-SG stars with isochrone matching

Median error: 30% in age, 8% in mass

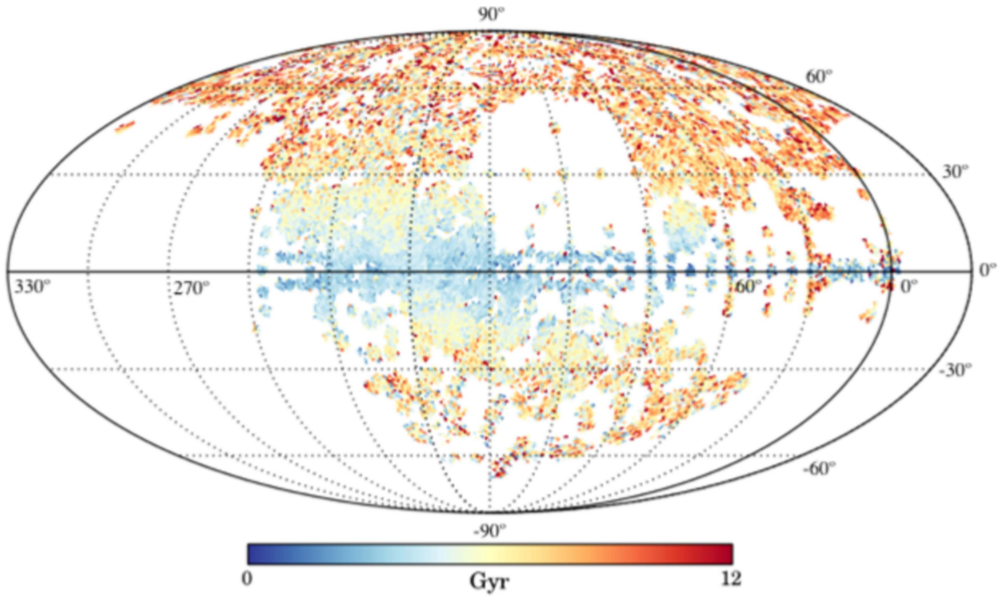








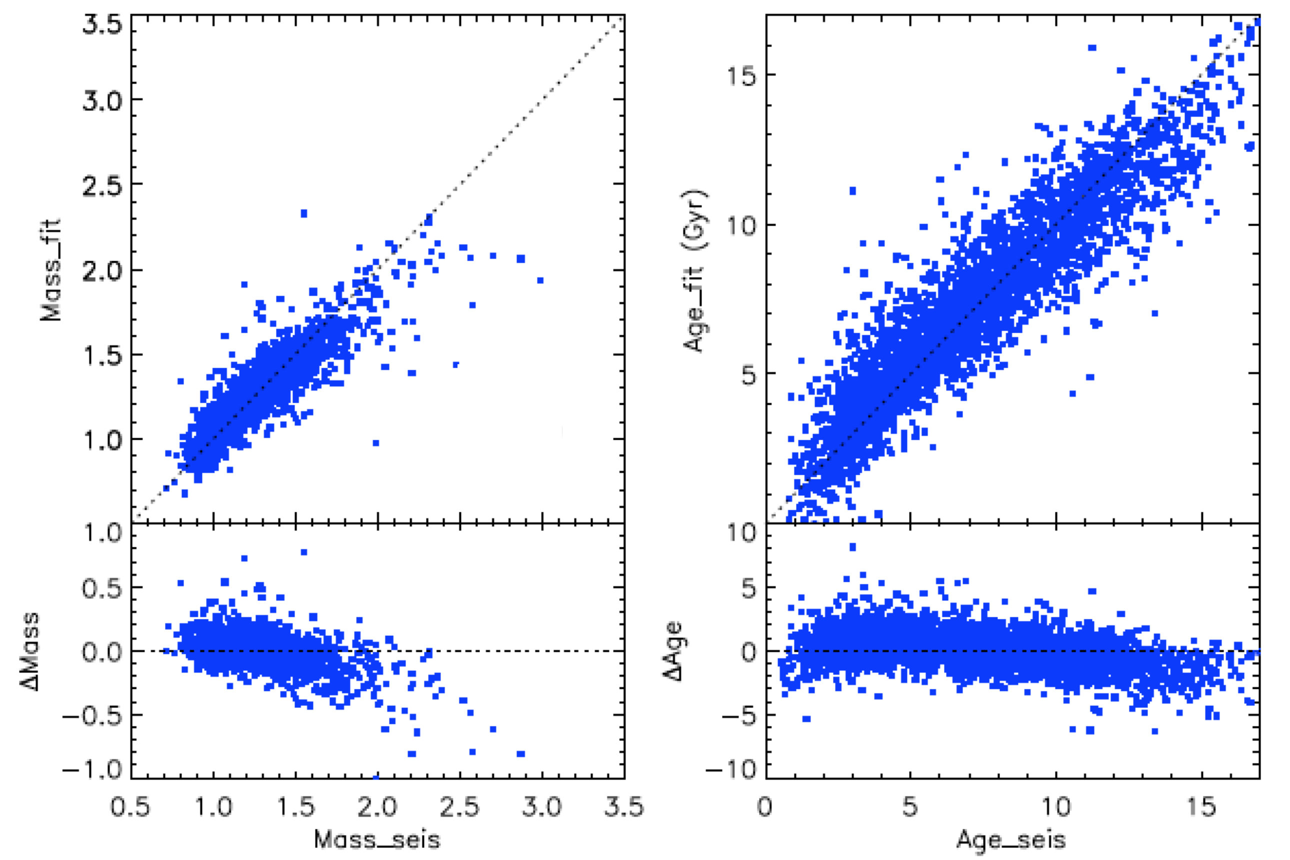
Age of red giant stars



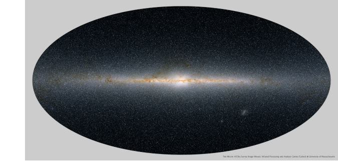
Ho et al. 2017, ApJ, 841, 40
Stellar ages of 230,000 giant stars from C and N abundance, with age error of ~46 per cent (0.2dex)

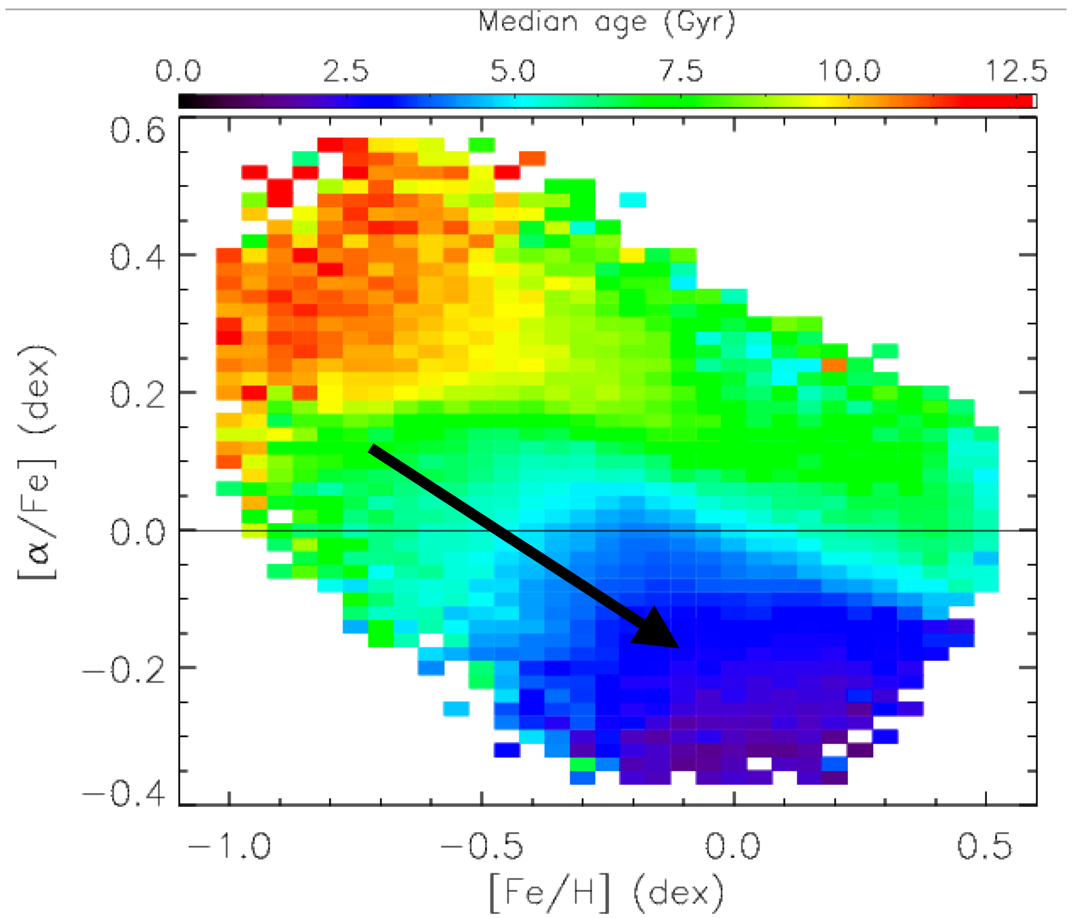
- **Yu's seismic sample + LAMOST DR4 13,500 spectra + Modified scaling relations of Sharma et al. (2016)**
- **Stellar mass for 7000 LAMOST-*Kepler* red giant branch stars, precise to 0.1M。**
- **Stellar ages accurate to 20–30 per cent for 0.5 million red giant branch stars**

Wu et al. to be submitted



Age—[Fe/H]—[a/Fe]

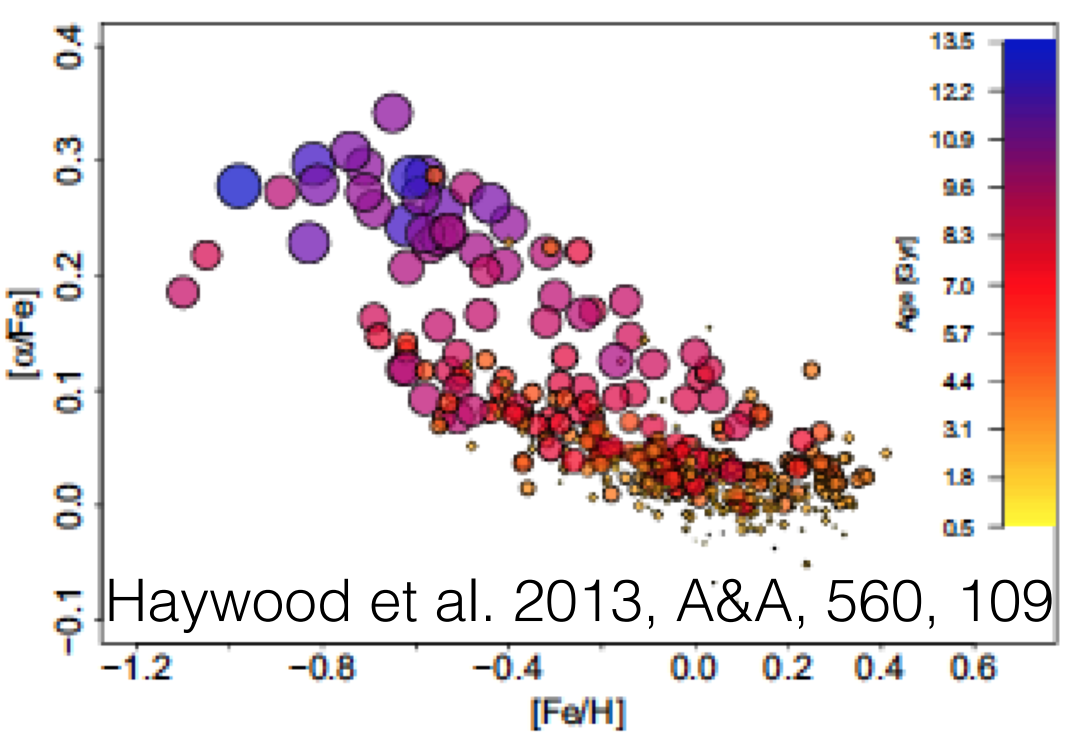


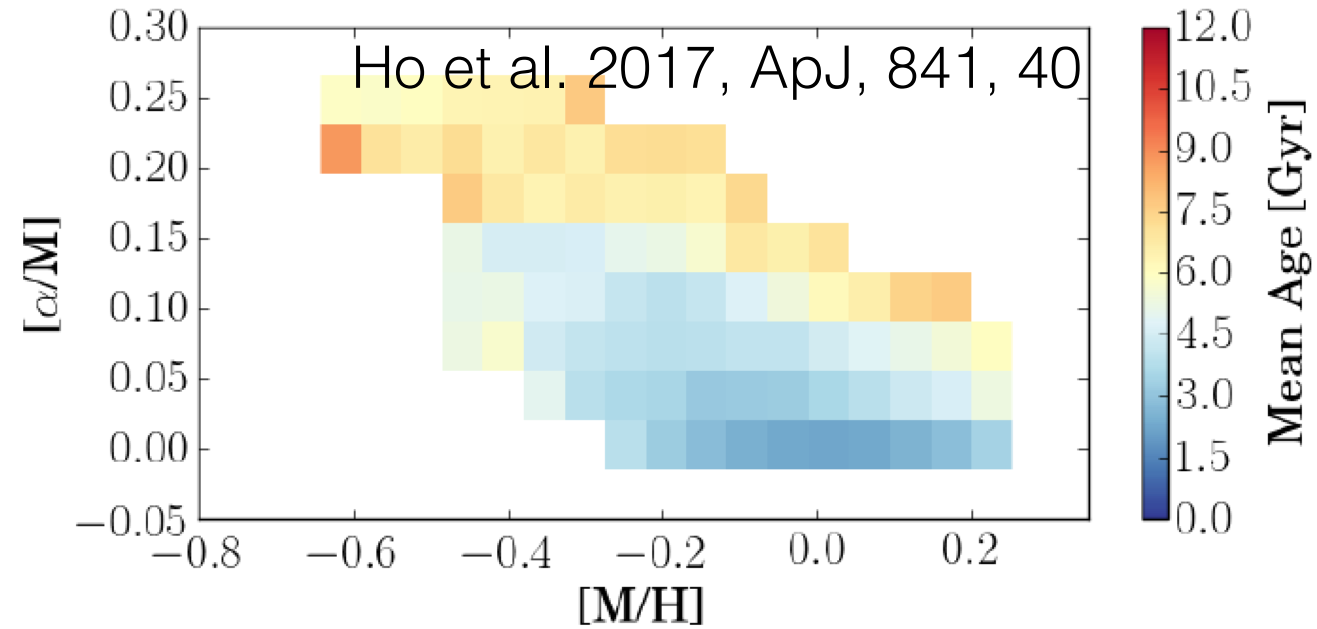


Xiang et al. 2017c, ApJS, in press, ArXiv:1707.06236

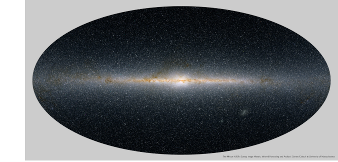
[Fe/H]-poor, [α/Fe]-rich stars are old

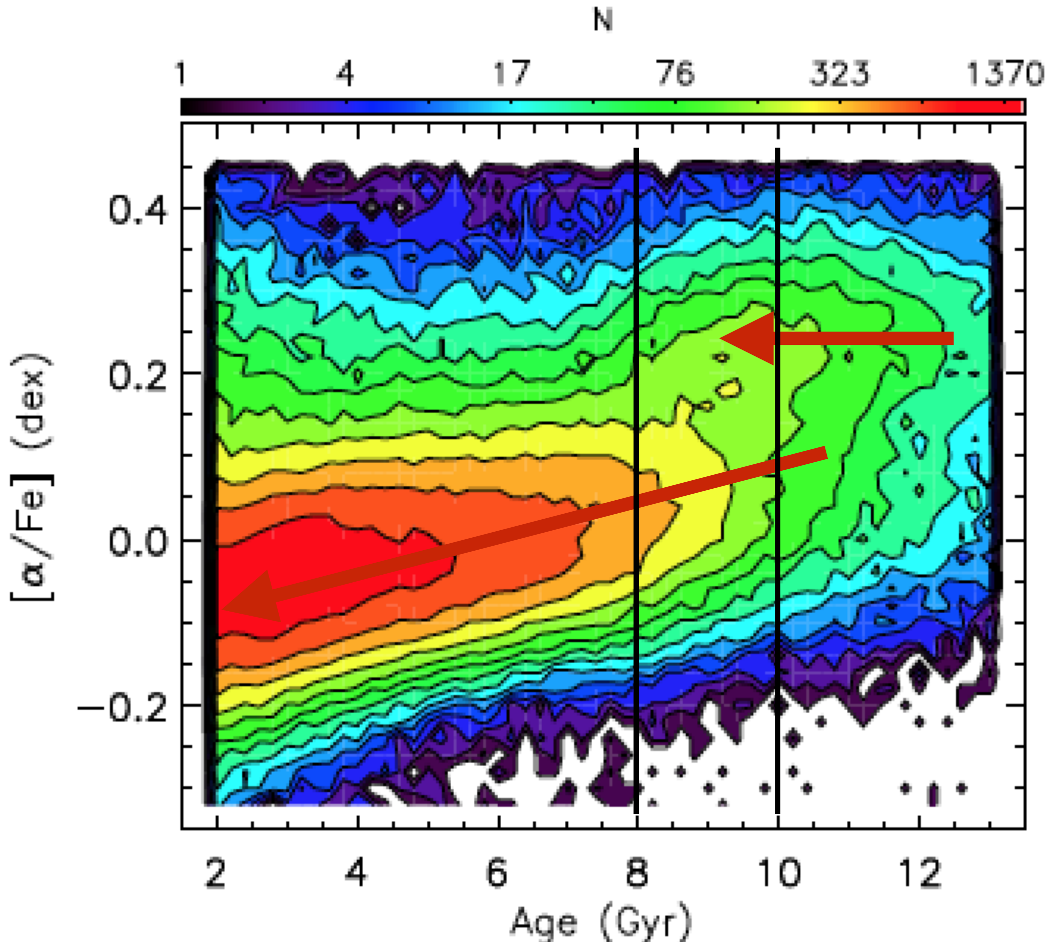
Decreasing trend of age with [Fe/H] for young stars





Age—[Fe/H]—[a/Fe]





Xiang et al. 2017c, ApJS, in press, ArXiv:1707.06236

Double sequence of age—[α/Fe]

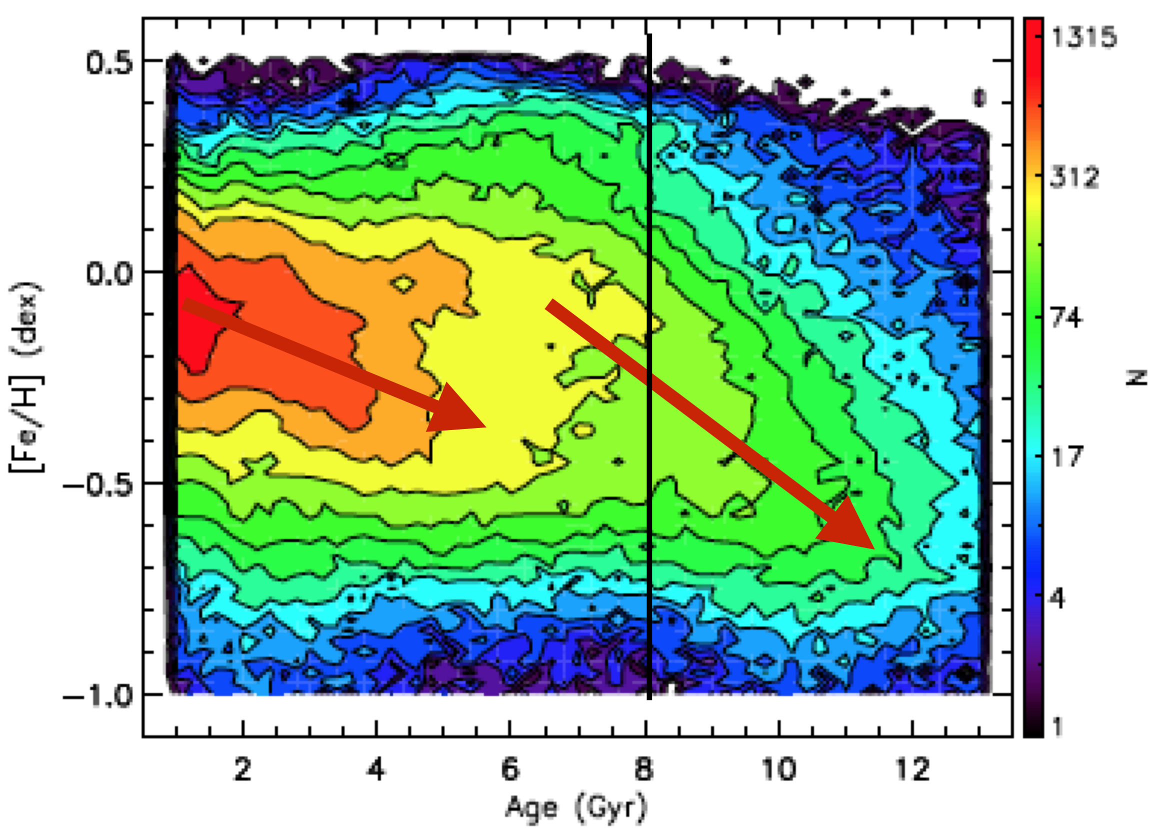
High-α sequence: flat [α/Fe] for stars older than 10Gyr; decreasing [α/Fe] for stars of 8—10Gyr (SN Ia)

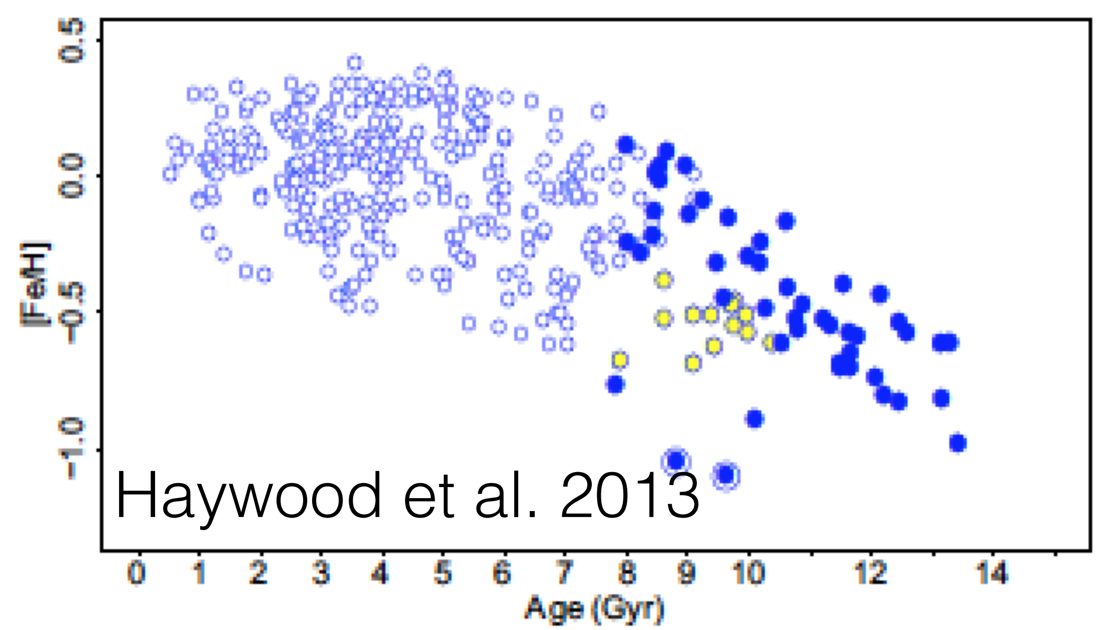
Low-α sequence: stars older than 10Gr

Double sequence of age—[Fe/H]:

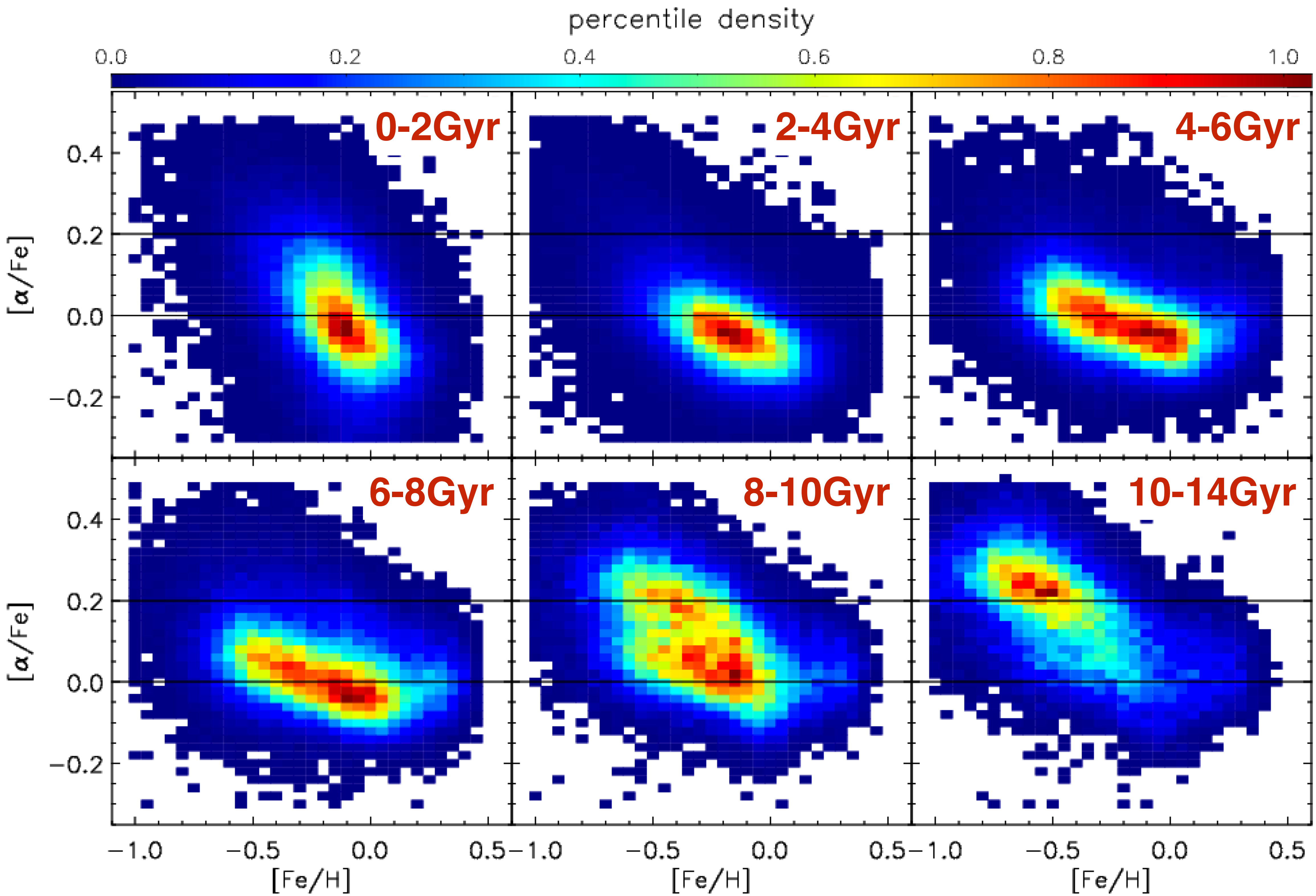
Two global chemical enrichment paradigm?

Young, metal-poor stars —> sustained star formation process



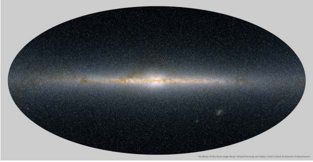


[Fe/H] — [α/Fe] of mono-age stellar populations



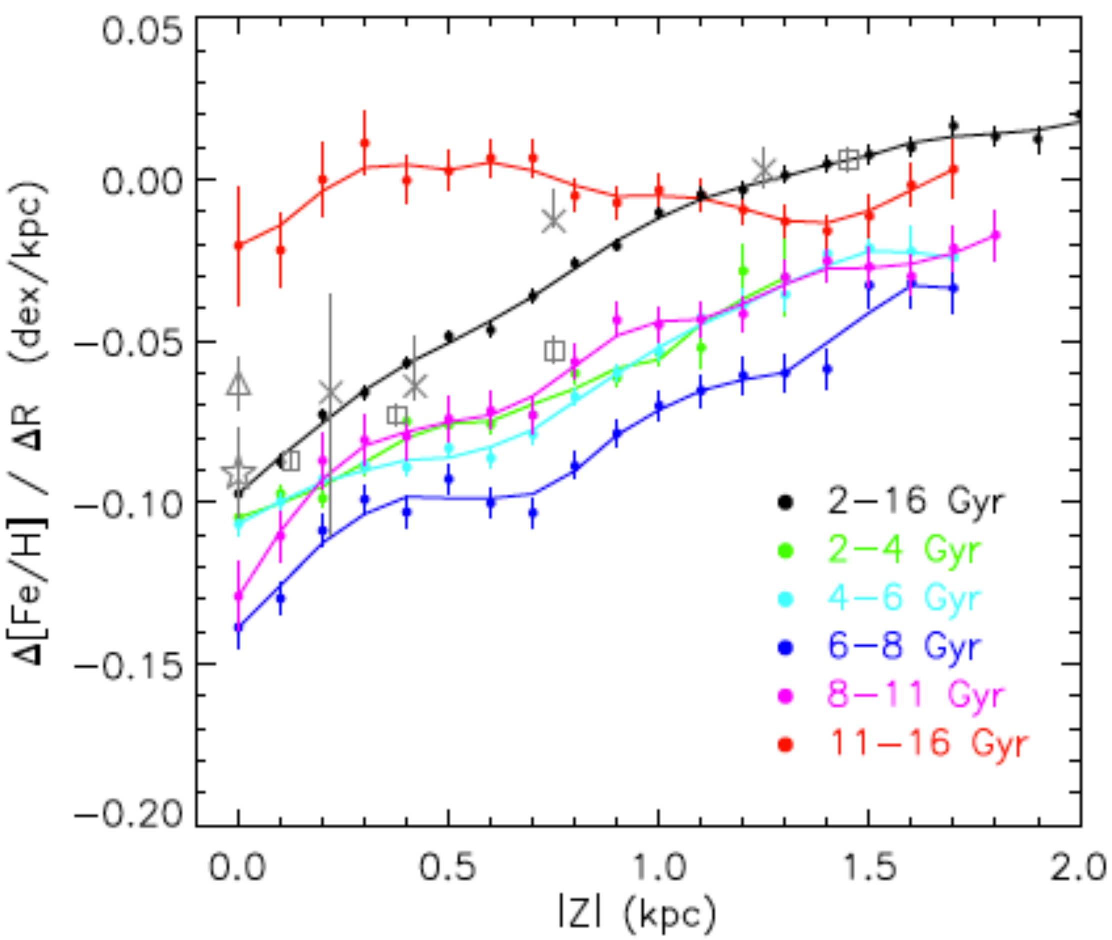
The thick disk formation quenched 8 Gyr ago
The thin disk occurred 8-10 Gyr ago

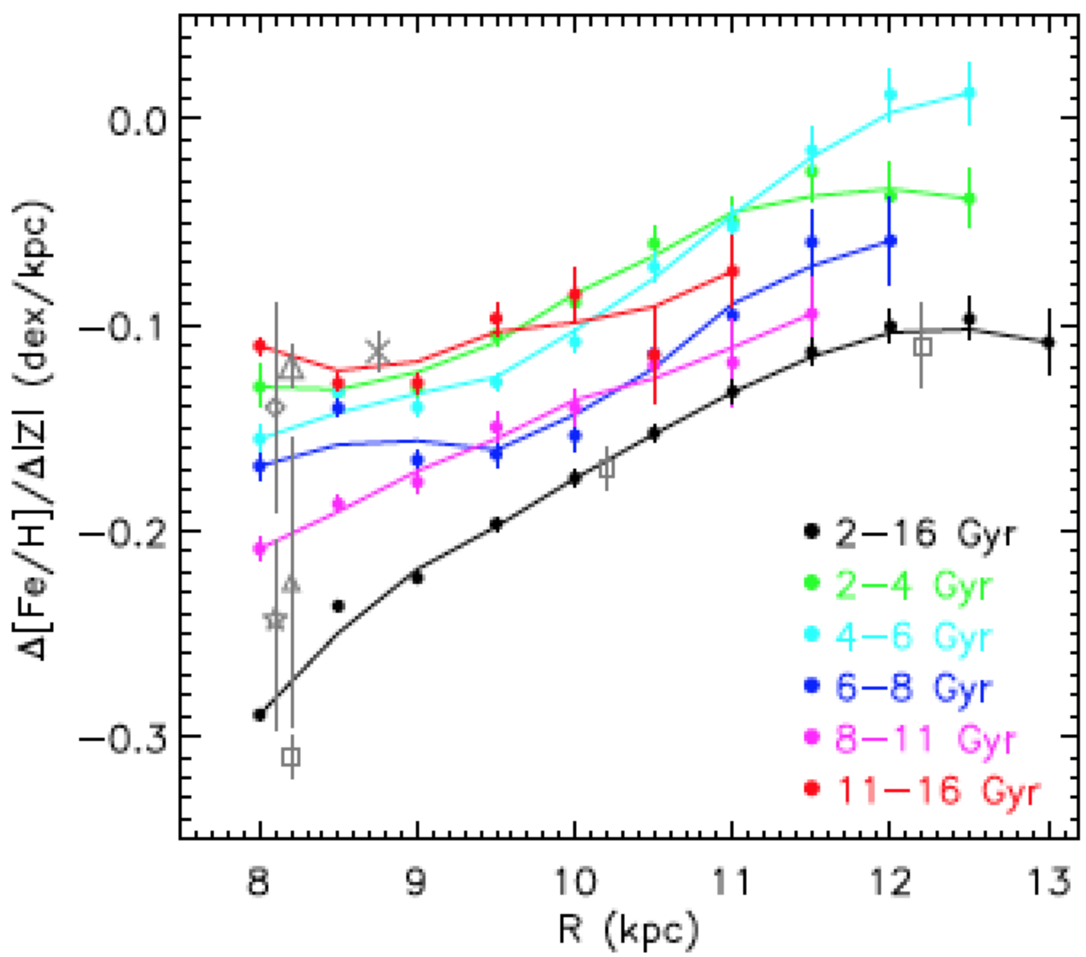
[Fe/H]/[α/Fe] gradients of mono-age populations



300,000 MSTO stars selected in T_{eff} — log g diagram of LSS-GAC DR1

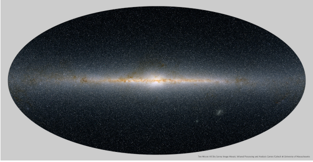
Xiang et al., 2015, RAA, 15, 1209





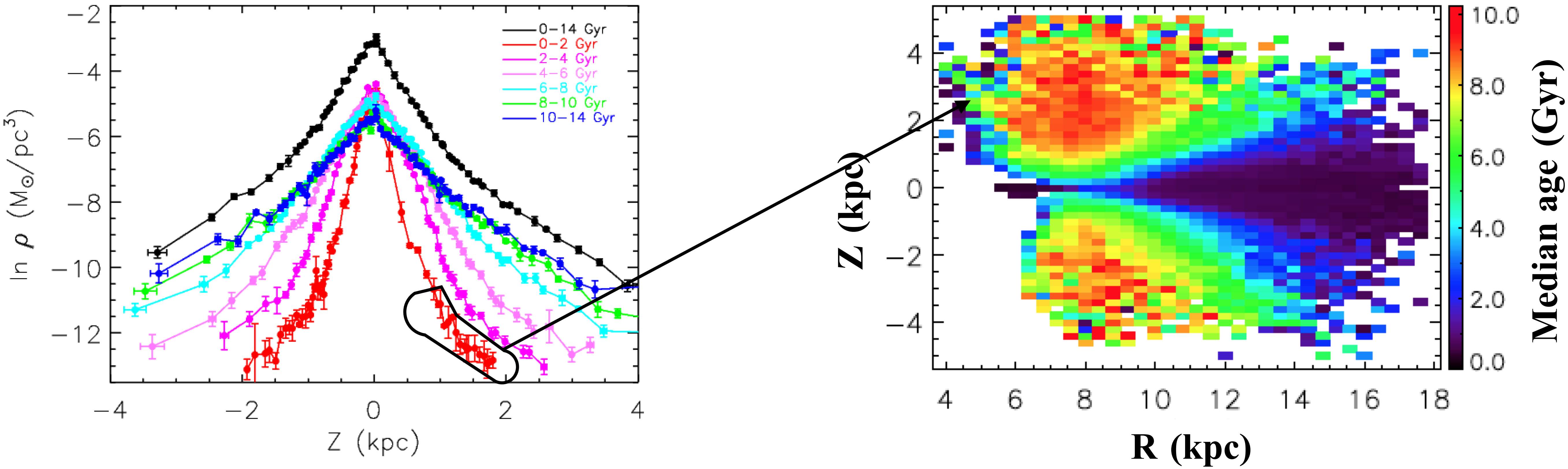
Different behaviors between oldest stars (thick disk) and younger ones (thin disk) indicate different disk formation mechanisms

Old (thick) disk: pressure-supported gas collapse
Younger disk: gas accretion

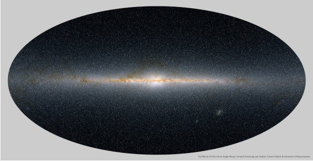


Disk structures from mono-age populations

Xiang et al. to be submitted

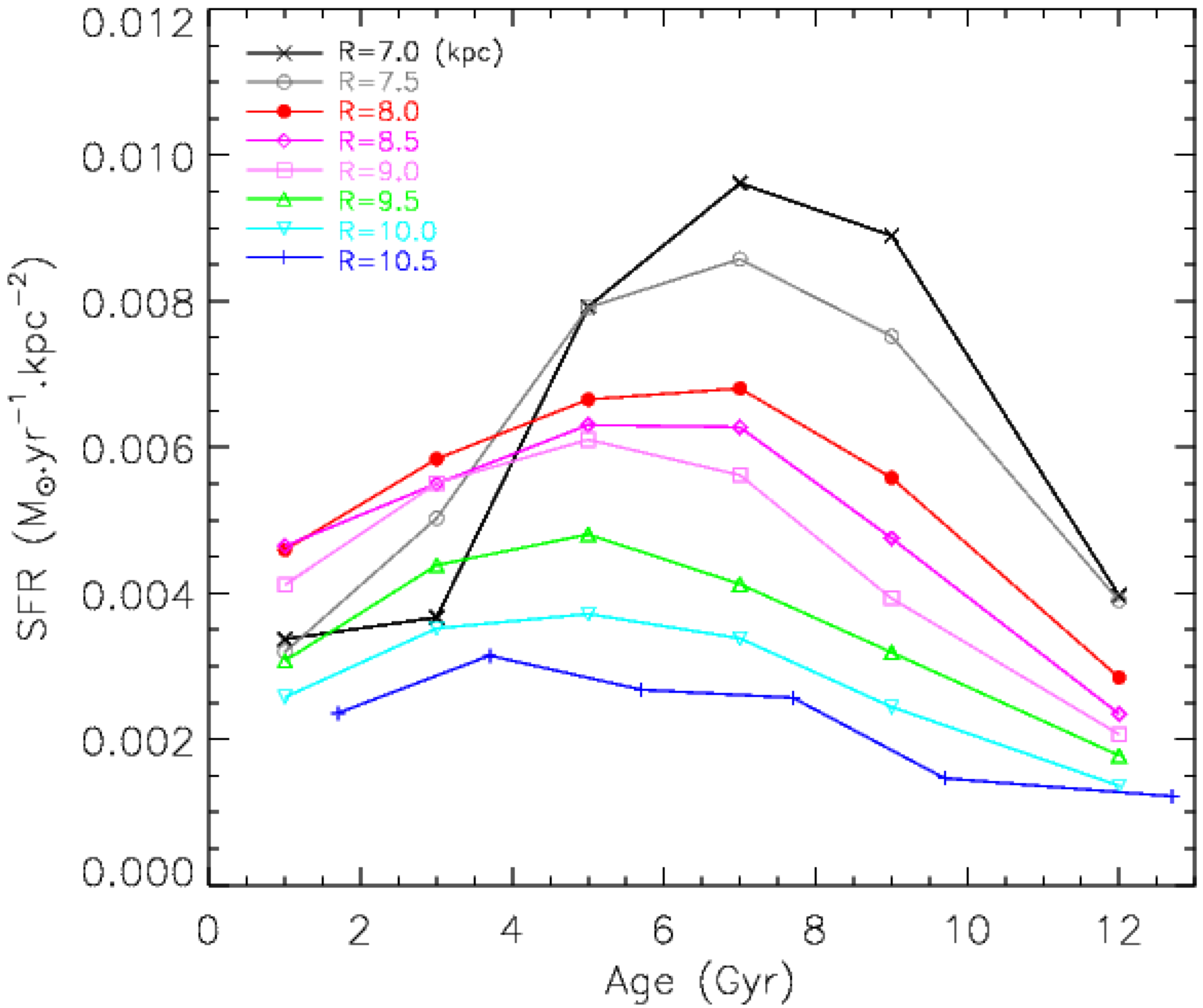


Older —> thicker
Non-single exponential for all populations
Flaring age distribution of the outer disk



Disk star formation history

Xiang et al. to be submitted

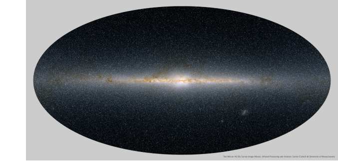


IMF: MSTO—> whole stellar population of given age & [Fe/H]

7—8.5kpc: peak at ~6-8 Gyr ago

8.5—10.5kpc: peak at ~4-6 Gyr ago

Inside-out growth



Summary

- Accurate & precise stellar parameters have been derived from the LAMOST low-resolution spectra
- Reliable ages for a large sample field stars (MSTO & red giants) are obtained with LAMOST, APOGEE and coming large-scale sky surveys (e.g. Gaia …)— new era of Galactic Archaeology
- The age-[Fe/H] -[α/Fe] correlations, as well as metallicity gradients, indicate different phases of disk formation, which are responsible to the thin and (old) thick disks
- The thin disk has become prominent 8-10Gyr ago; the thick disk formed at early epoch and almost quenched ~8Gyr ago
- Direct measurement of the disk star formation history
- The LAMOST-*Kepler* data have an significant impact on Galactic archaeology: accurate stellar parameters (age, logg) for a huge number of giant stars