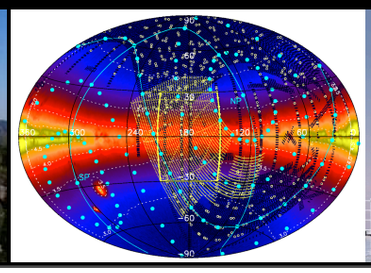
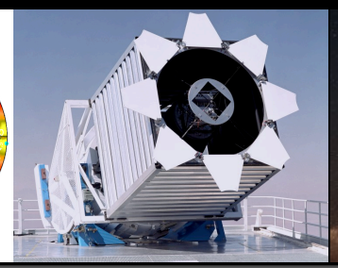
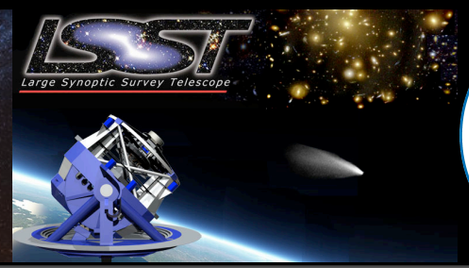
A new method for color calibration to a few mmag accuracy, the recalibration of Stripe 82, and implications on Galactic archaeology

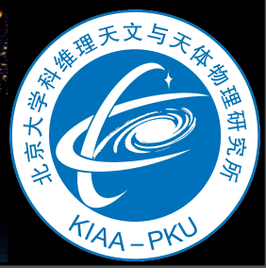
Haibo Yuan (苑海波)

KIAA-PKU; yuanhb4861@pku.edu.cn



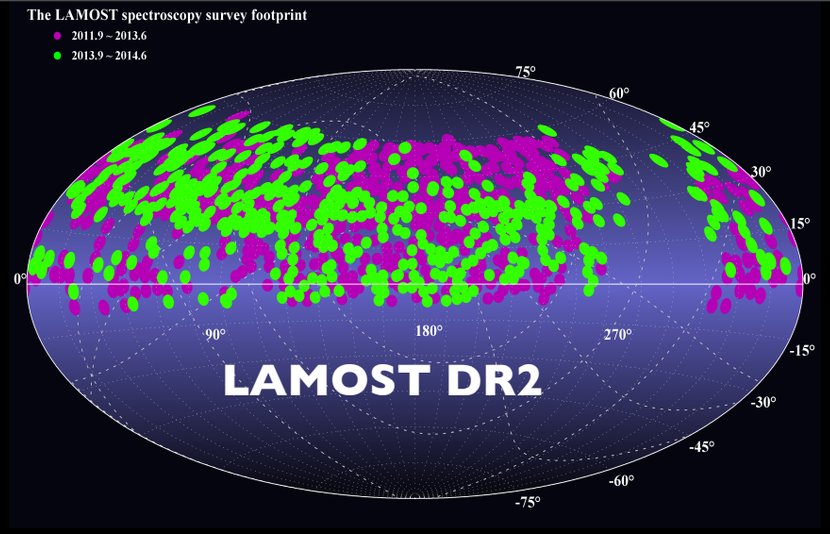







Outline

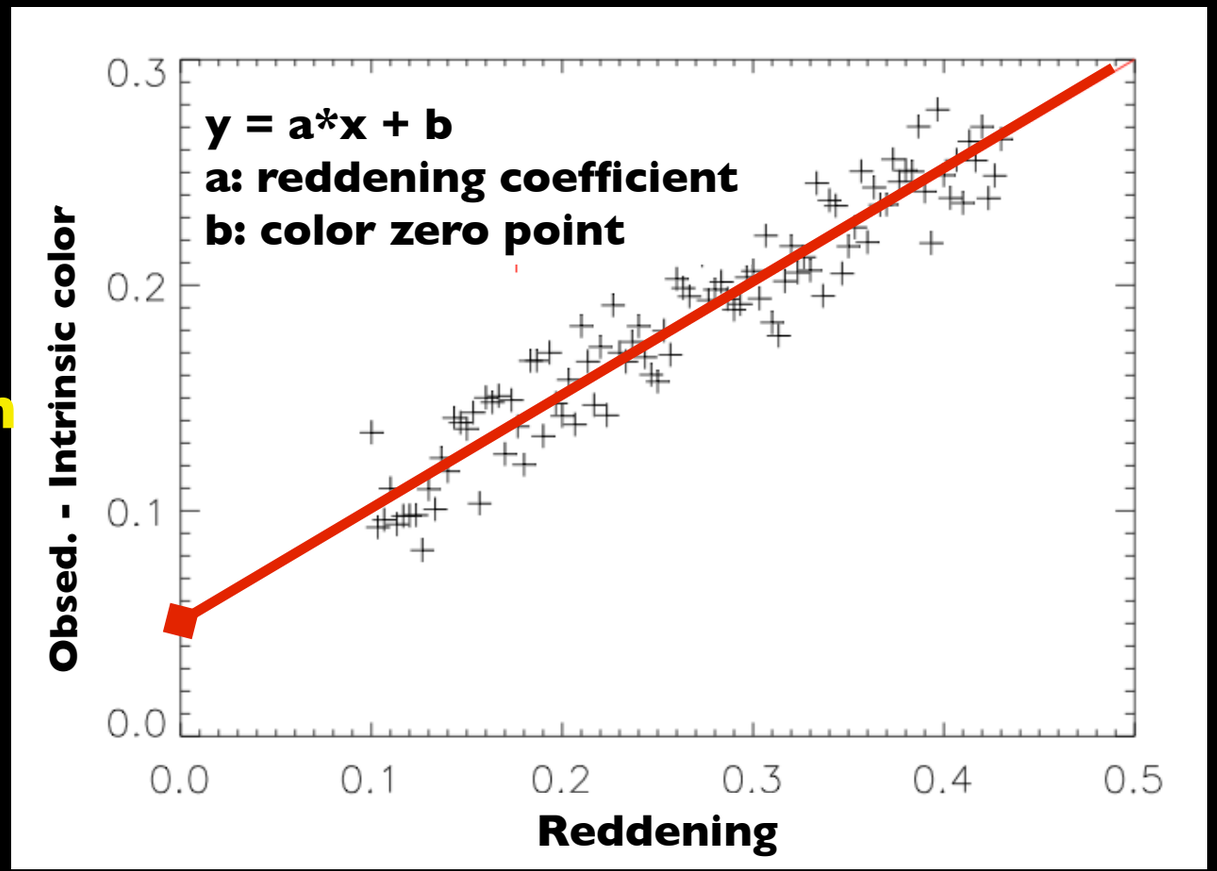
- Stellar Color Regression method & re-calibration of Stripe 82
- [Fe/H]-dependent stellar loci & implications in Galactic archeology
- Summary



The stellar color regression method

-- using millions of spectroscopically observed stars as color standards

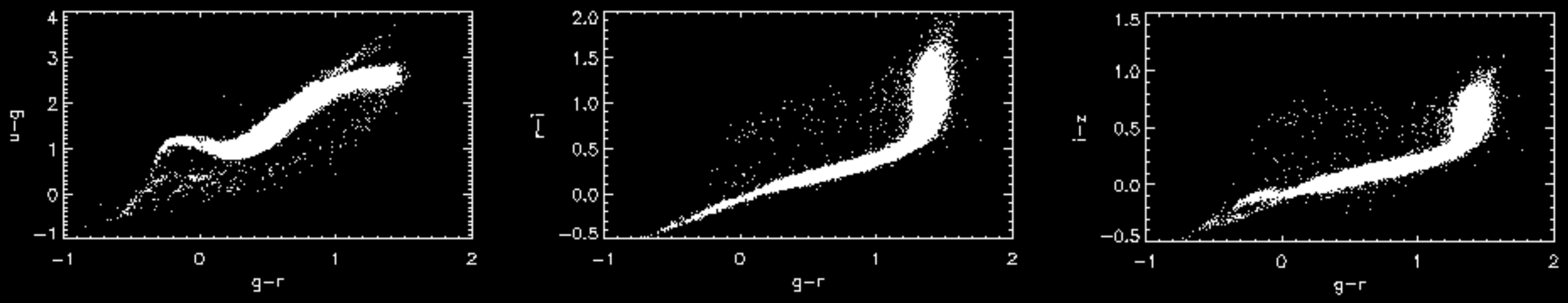
- **Requirements:**
  1) a calibrated field
  2) extinction of stars in target fields
- Zero-point of color by **linear regression**
- **By-product:** reddening coefficient
- **Advantages:**
  straightforward, model-free and can apply to low/high- extinction regions



- Stripe 82, the **defining** stripe of the SDSS photometric system, has been re-calibrated to an accuracy of **5, 3, 2, and 2 mmag** in u-g, g-r, r-i, and i-z colors, respectively, **improved by a factor of 3**

Yuan et al. 2015a, ApJ, 799, 133

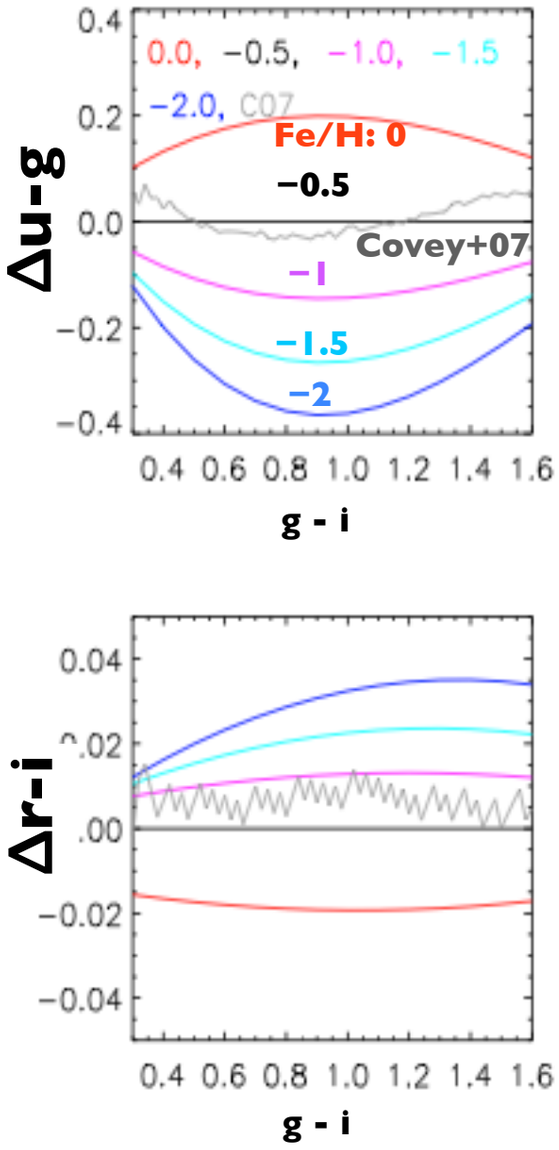
[Fe/H]-dependent stellar locus

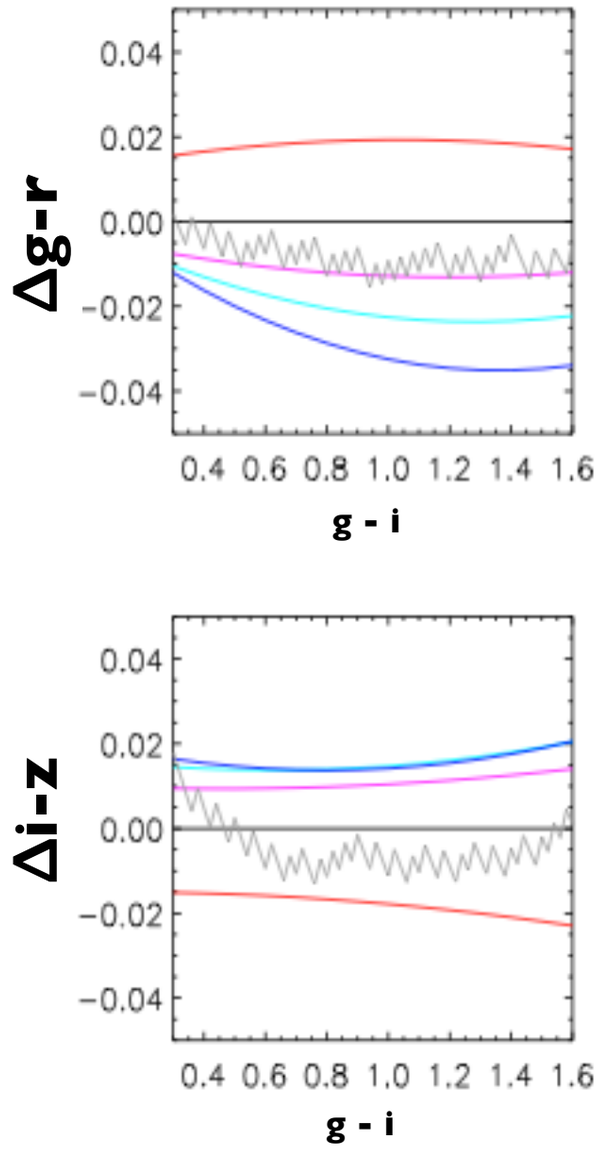


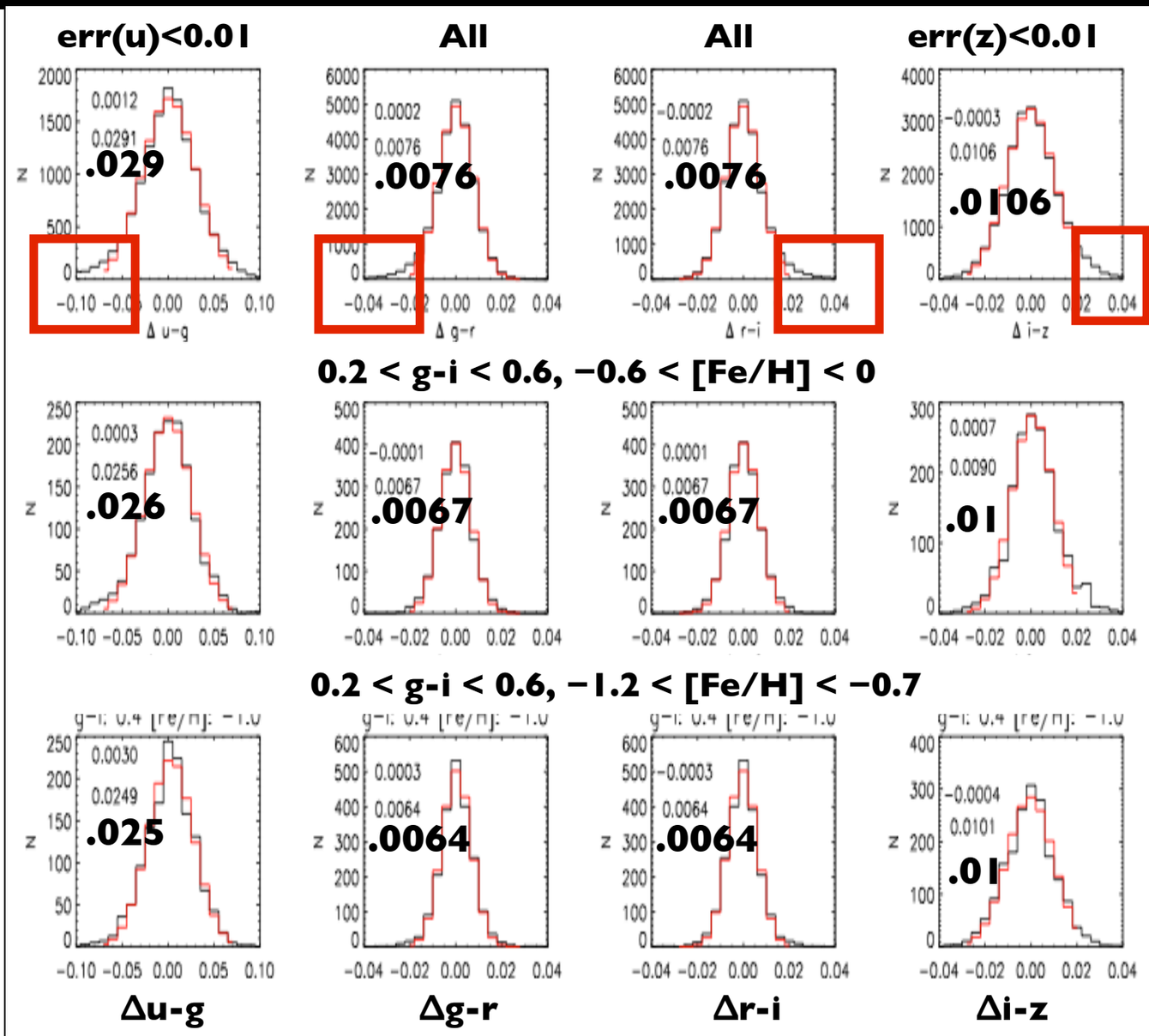
- **Stellar locus is widely used in**
  - **selecting interesting outliers**
  - **reddening determinations (Schalfly+10; Majewski+11; Berry+12; Green+14; Chen+14)**
  - **calibrations (Izevic+07, High+09)**
- **However, no dependences on [Fe/H]/Log g have been considered and the intrinsic widths are unclear.**

[Fe/H]-dependent stellar locus: main-sequence stars

2D polynomial fitting: color (e.g., g-r) = f(g-i, [Fe/H]) using data of Stripe 82 and SDSS DR9







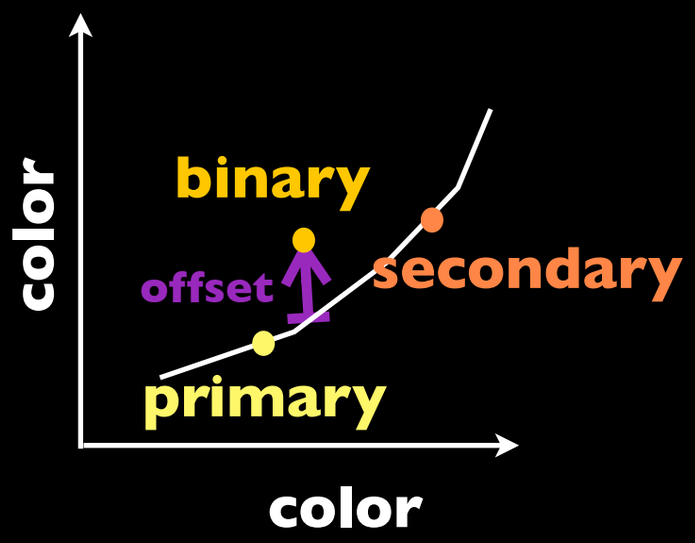
One dex decrease in [Fe/H] causes
0.20 & 0.02 mag decrease in u−g & g−r
0.02 & 0.02 mag increase in r−i & i−z

Residuals are fully accounted by the phot. errors & [Fe/H] uncertainties,
--> intrinsic widths of the loci are ~zero
(Yuan et al. 2015b, ApJ, 799, 134)

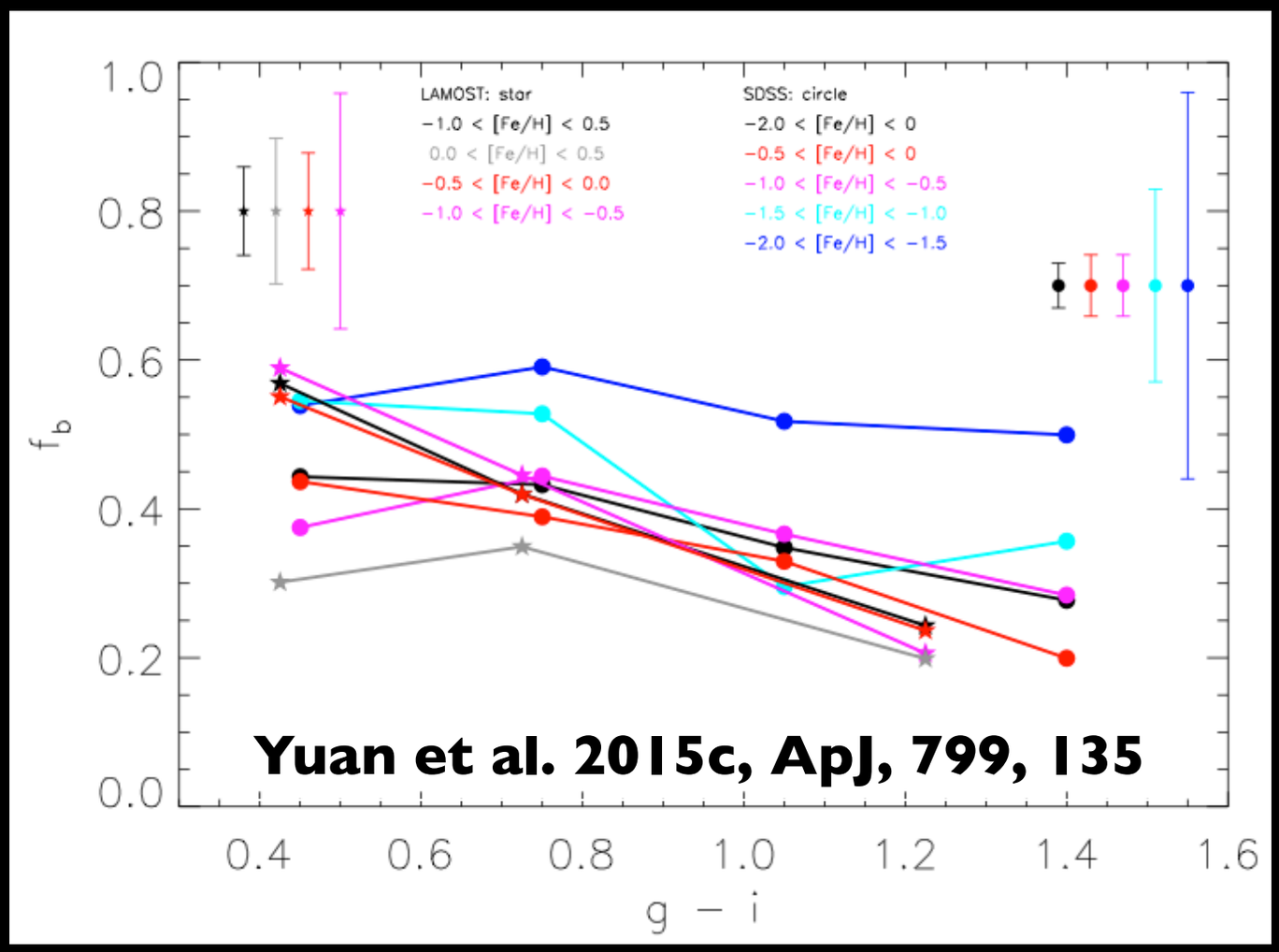
Non-gaussian residuals --> binary stars (Yuan et al. 2015c, ApJ, 799, 135)

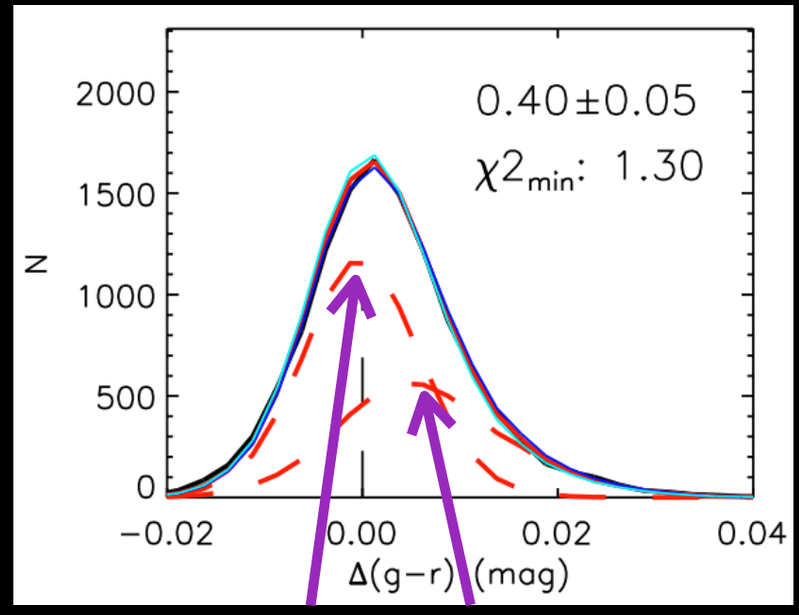
Binary fraction of field FGK stars

- **Stellar Locus OuTiler (SLOT) method:**
  - **Model-free**: independent of orbital period, insensitive to mass ratio distribution assumed
  - Applicable to a large sample of **different populations**



Maximum offset: 0.15 mag in u-g and 0.035 mag in others

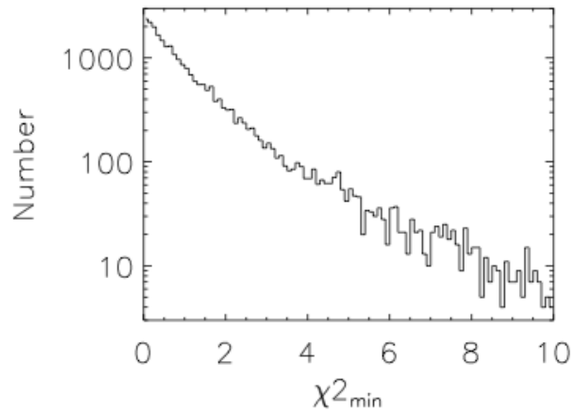


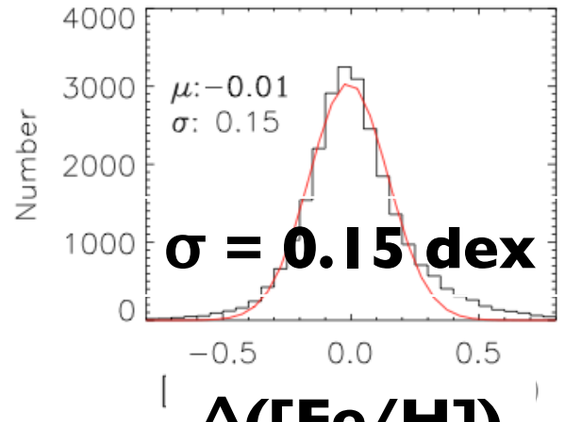


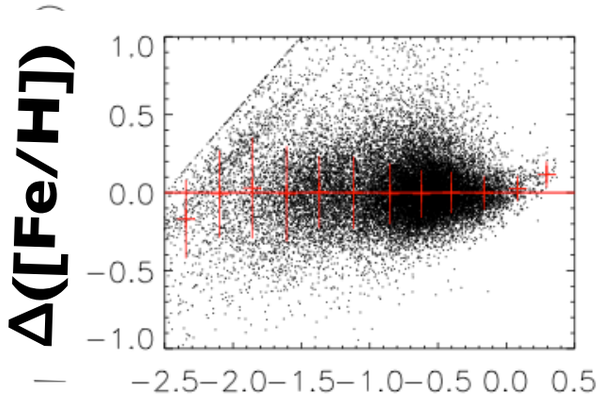
Binary fraction in field stars is 41±2%, decreasing towards stars of red colors & high metallicities

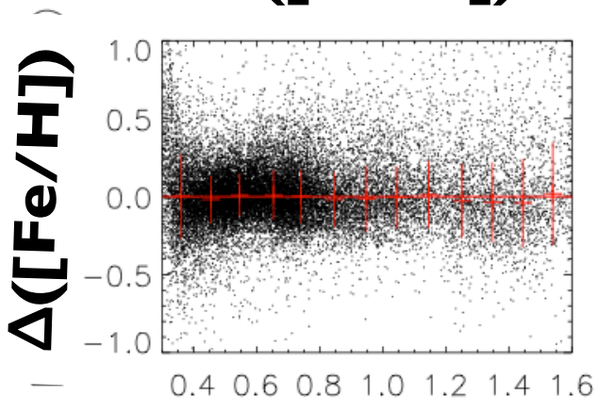
Photometric [Fe/H]s of 0.5M FGK stars in Stripe 82

$$\chi^2([\mathrm{Fe/H}], g-i) = \sum_{i=1}^{4} \frac{[c^i_{\mathrm{obs}} - R^i_c \times E(B-V) - c^i_{\mathrm{int}}([\mathrm{Fe/H}], g-i)]^2}{(\sigma^i_c)^2 \times (4-2)},$$

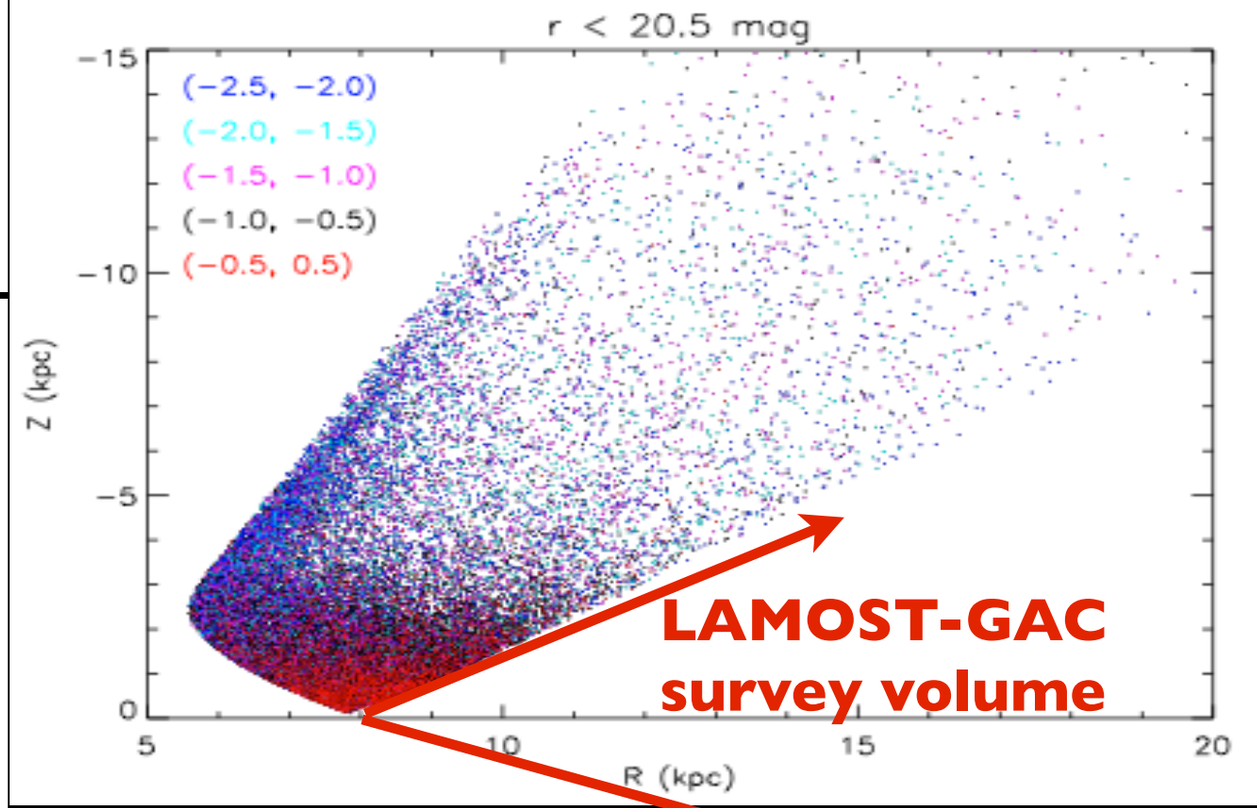








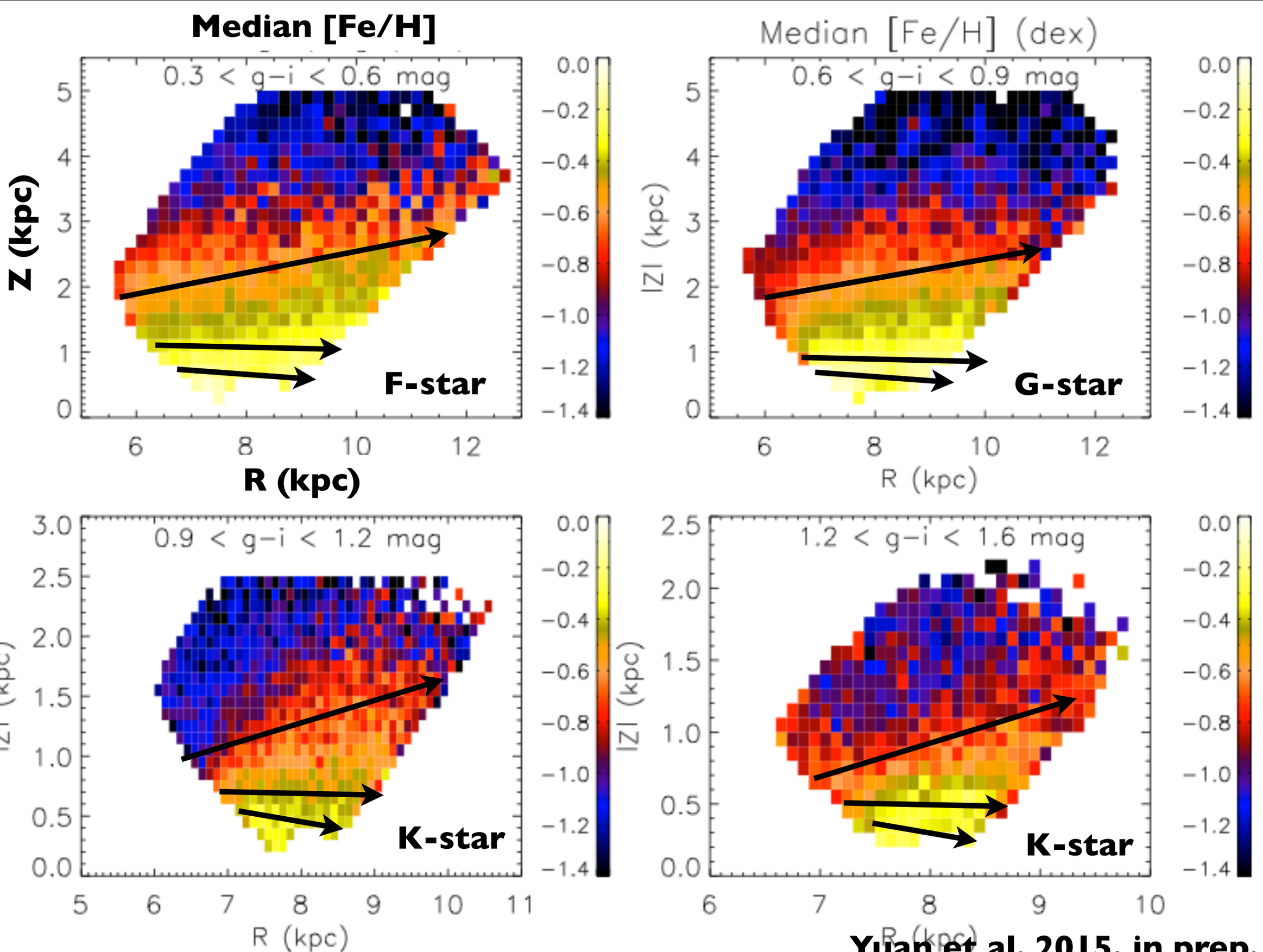
Advantages: more precise, applicable to wider metallicity and color ranges



	Num. of stars	median [Fe/H] err.	median distance. err.
r < 20.5	0.45M	0.16 dex	5.6%
r < 19.5	0.35M	0.11 dex	4.6%
r < 18.5	0.25M	0.085 dex	3.8%

A mag. limited sample to study the structure & chemistry of the Galactic disk and inner halo

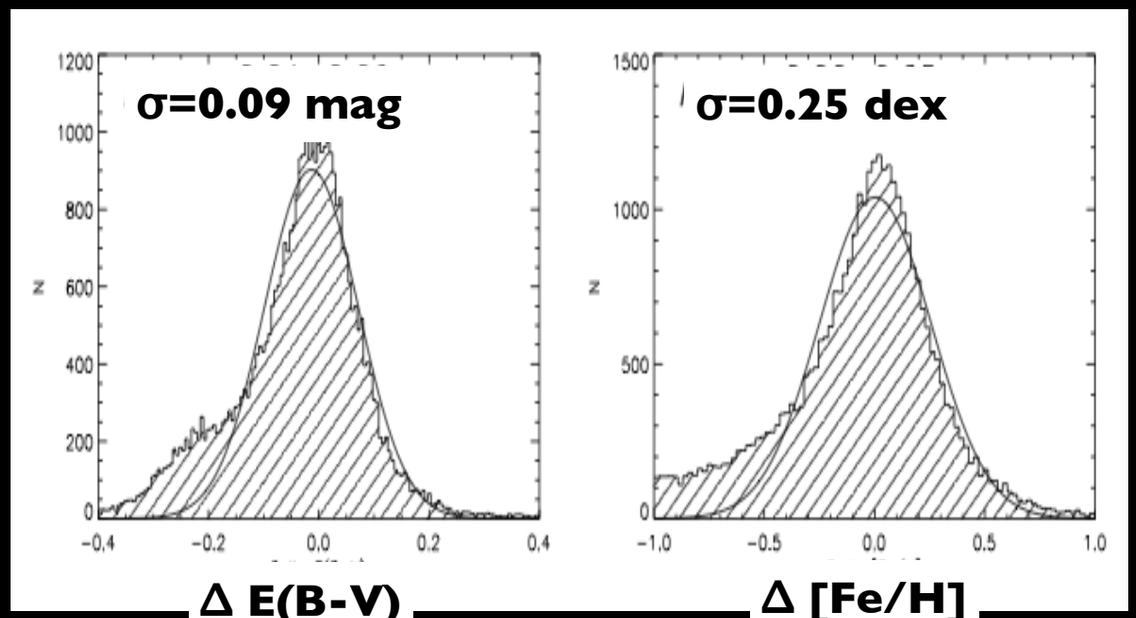
Yuan et al. 2015d, ApJ, in press



Median metallicity as a function of R and Z for different stellar types

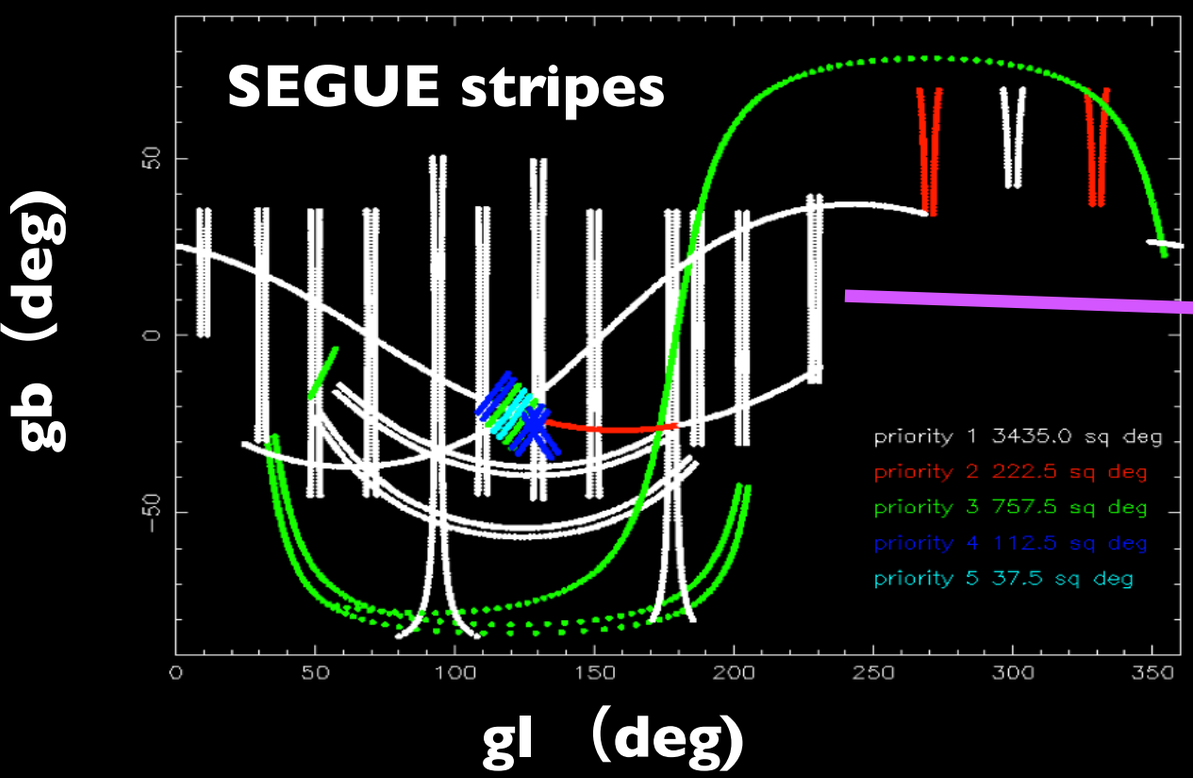
What if E(B-V) is unknown?

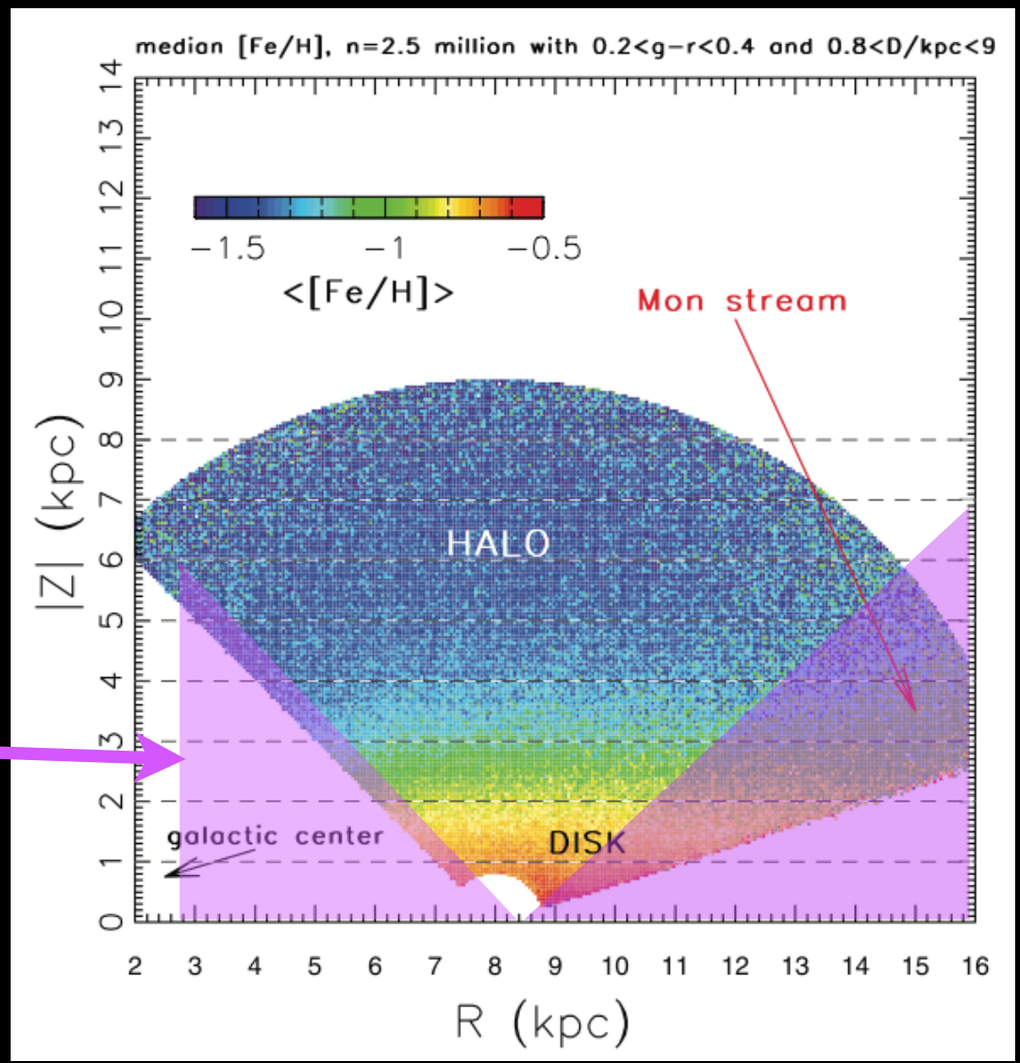
Combining 2MASS/WISE data,



Yuan et al. 2015, in prep.

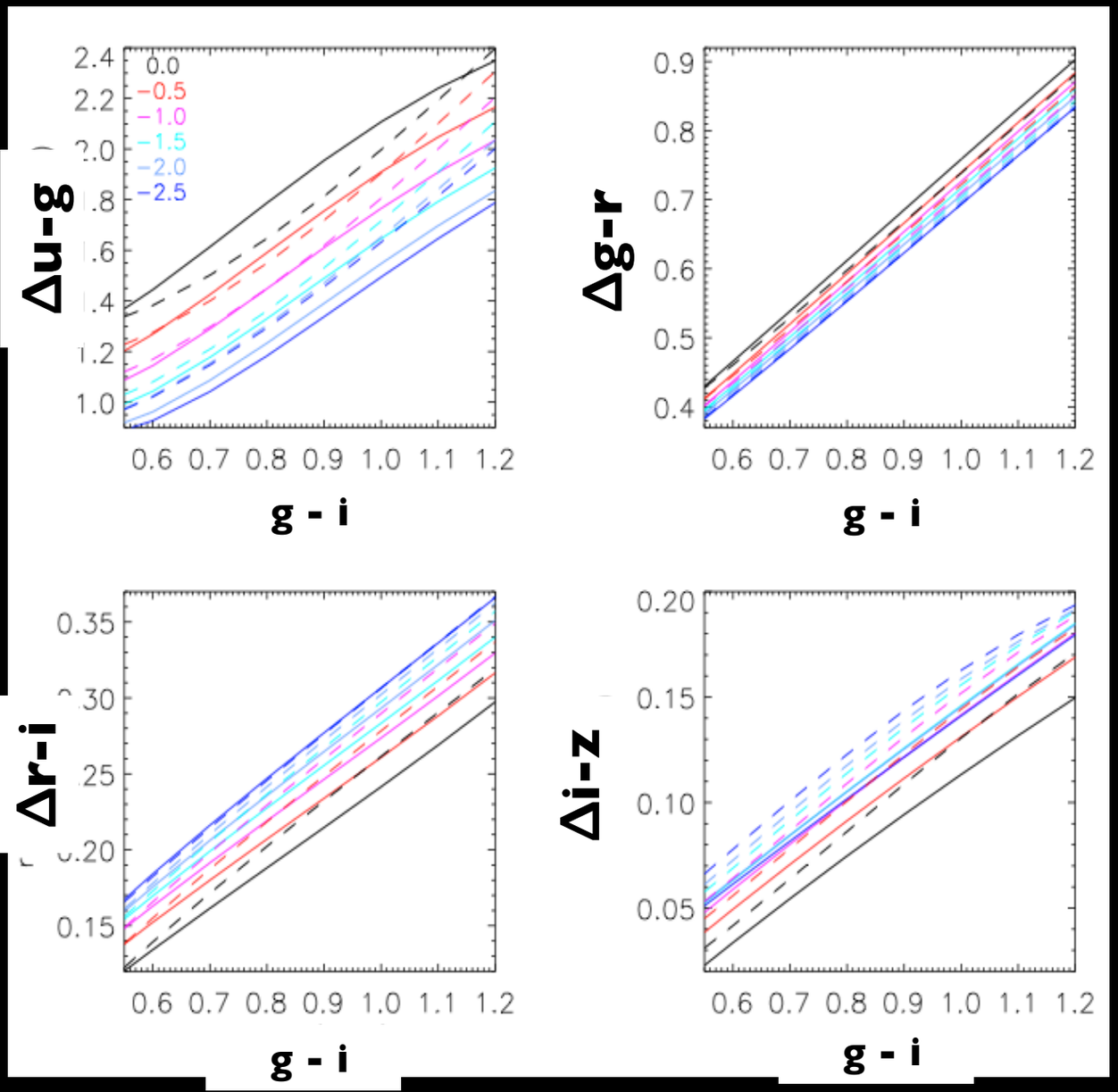
A great opportunity for Galactic thin disk tomography





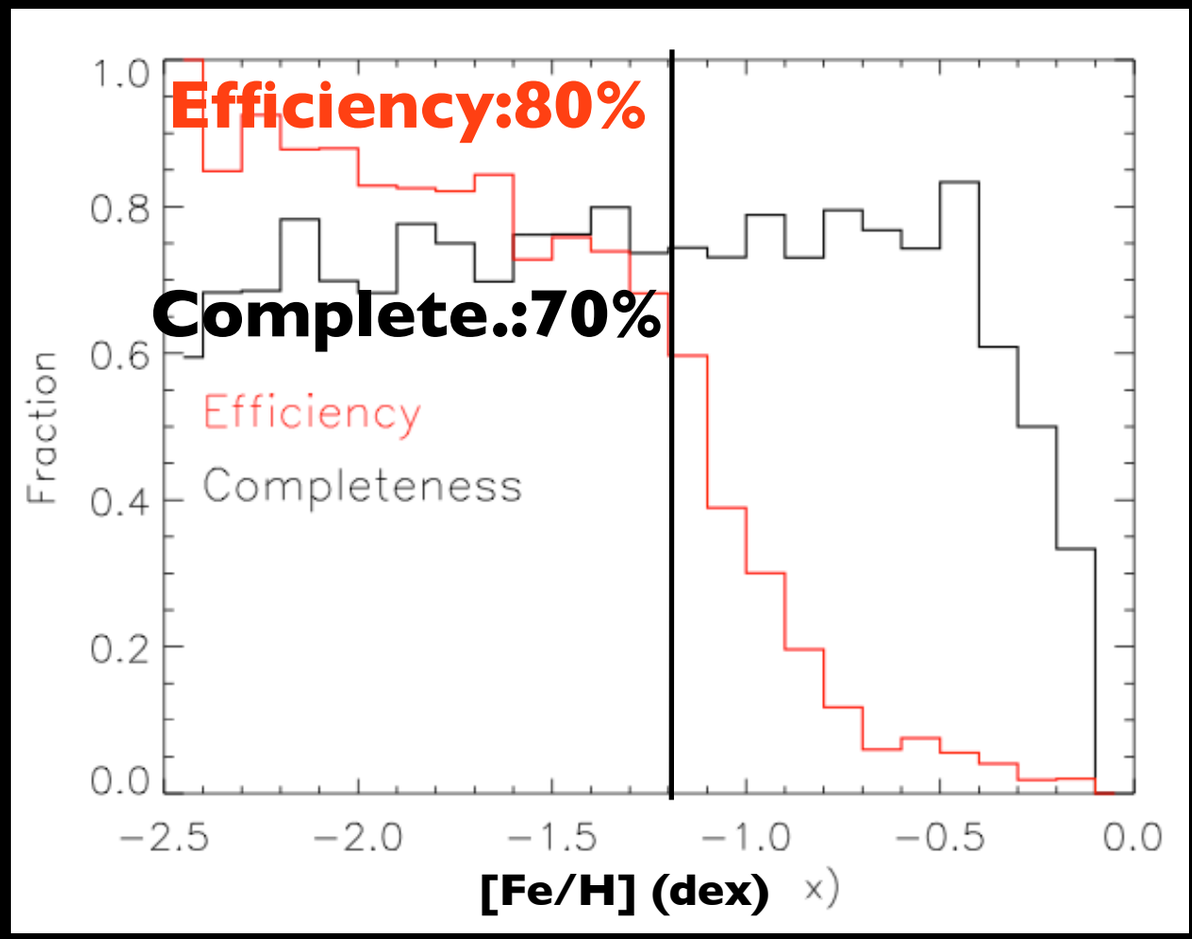
[Fe/H]-dependent stellar loci: red giant stars

Yuan et al. 2015e, ApJ submitted



Systematic discrepancies exist between loci of dwarfs (solid lines) and giants (dashed lines)

Candidates of red giants are selected as those whose colors fit the loci of giant stars better



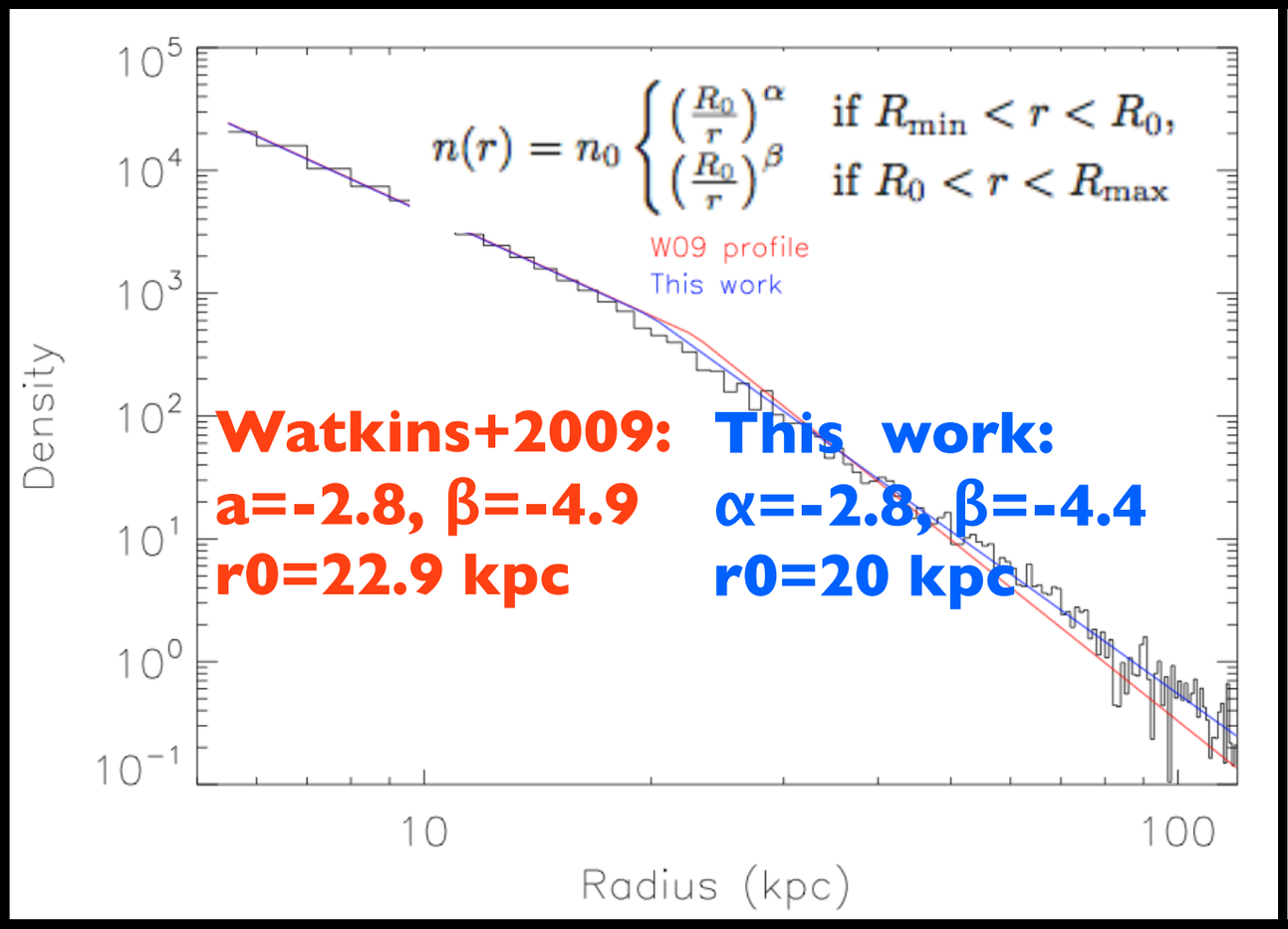
~10,000 candidates of halo red giants ([Fe/H] < -1.2) are selected from Stripe 82

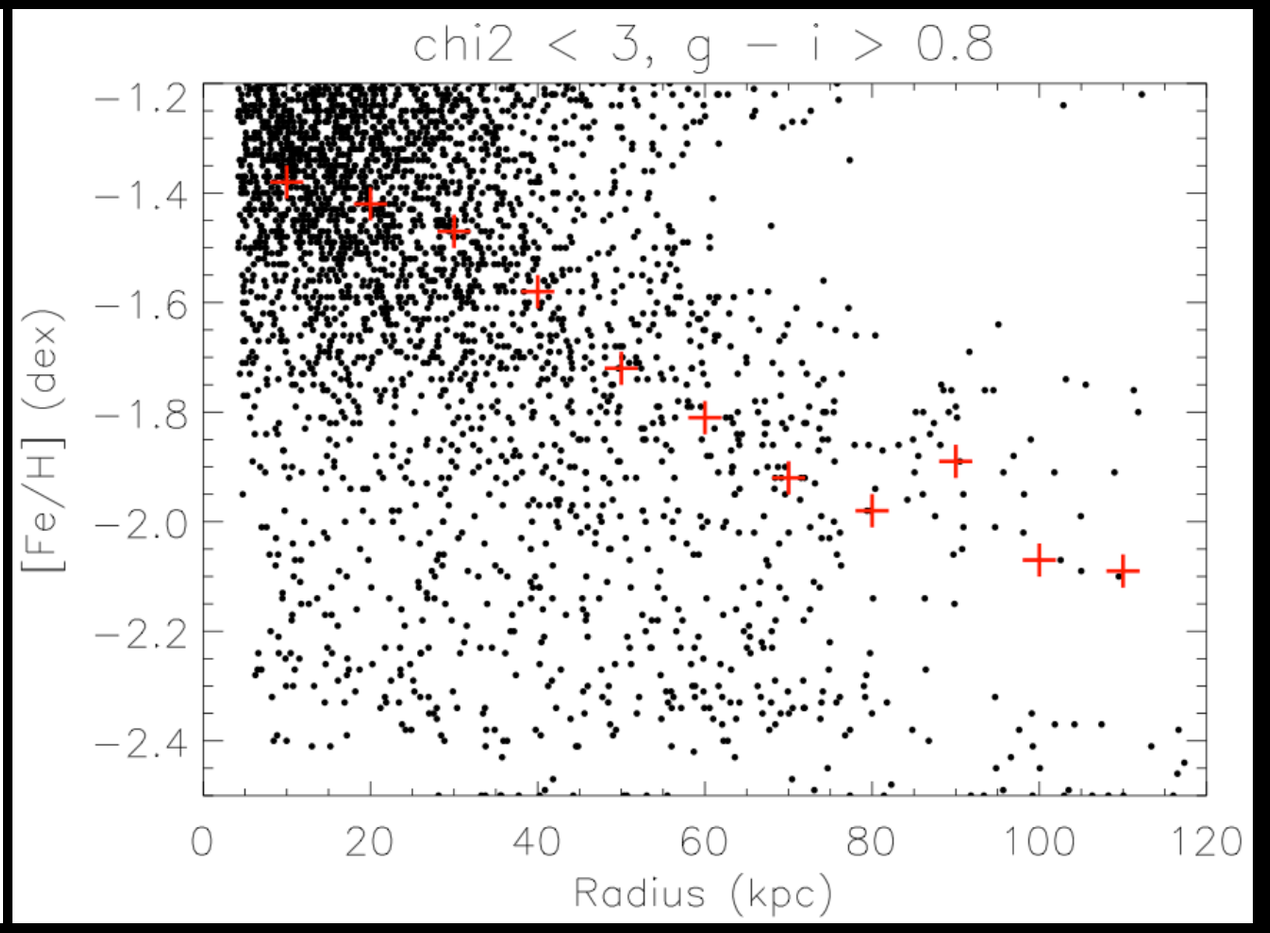
A direct evidence of dual Galactic halos

Carollo et al. 2007: Halo --> Halos, based on a local sample

Inner Halo: Dominant at R < 10-15 kpc
Highly eccentric orbits
Metallicity peaks at [Fe/H] = -1.6
Likely associated with major/major collision of massive components early in galactic history

Outer Halo: Dominant at R > 15-20 kpc
More uniform distribution of eccentricity,
Metallicity peaks around [Fe/H] = -2.2
Likely associated with accretion of low-mass galaxies over an extended period up to now

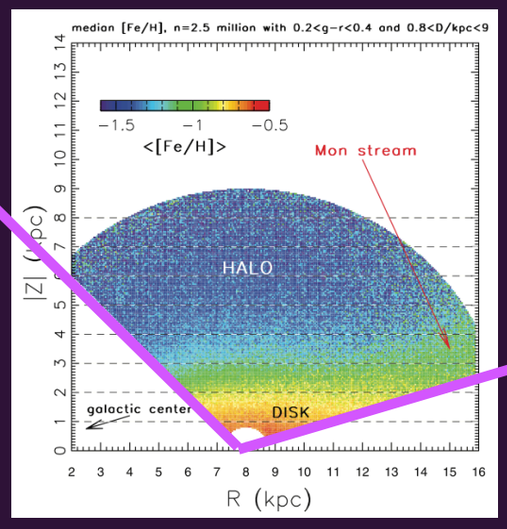




Yuan et al. 2015, in prep.

With ~ a few x 10^5 red giants from the whole SDSS footprint, shapes, substructures, chemistry of the Galactic halos can be well studied

~50 kpc with SDSS



~300 kpc with LSST, Chinese Space Station

Touching the intergalactic stars

Summary

- **The SCR method: Calibrate colors to a few mmag precision**
- **Stripe 82 is re-calibrated to 2-5 mmag accuracy**
- **Intrinsic widths of [Fe/H]-dependent stellar loci are zero**
- **The tools of metallicity-dependent stellar loci**
  - **Measure photometric [Fe/H] to 0.1 dex (dwarfs) and 0.2 dex (giants), comparable to low-resolution spectroscopy**
  - **Measure [Fe/H] (0.20 dex) and E(B-V) (0.09 mag) of disk stars**
  - **Select halo red giants (70%, 80%)**
- **New opportunities in Galactic archeology (tomography) with high-precision photometry**

Pls contact me if your are interested

yuanhb4861@pku.edu.cn

@KIAA

Thanks