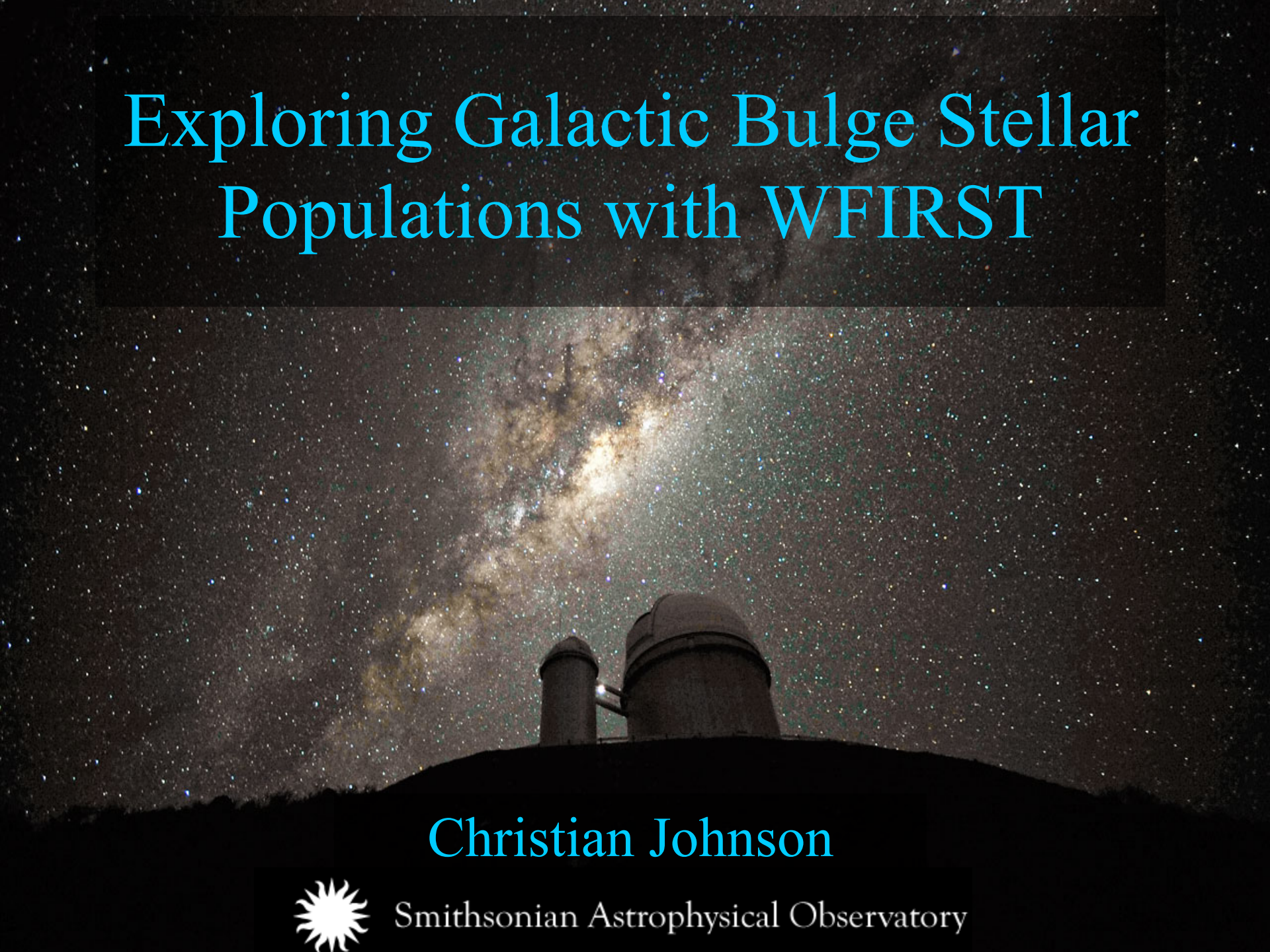
Exploring Galactic Bulge Stellar Populations with WFIRST



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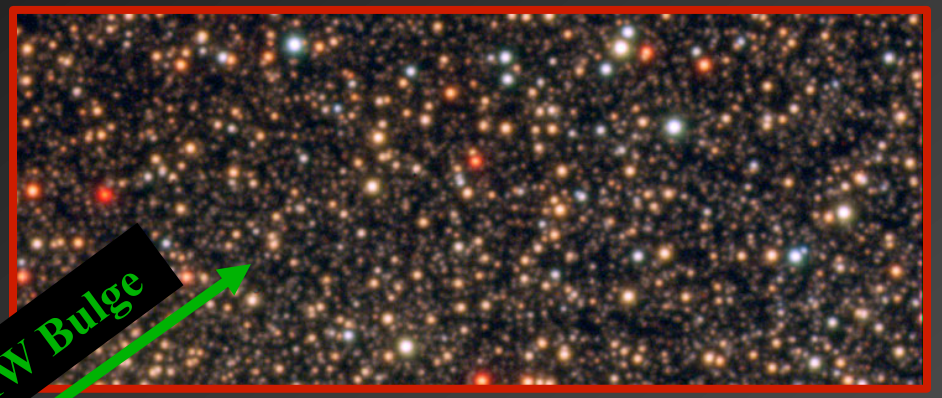
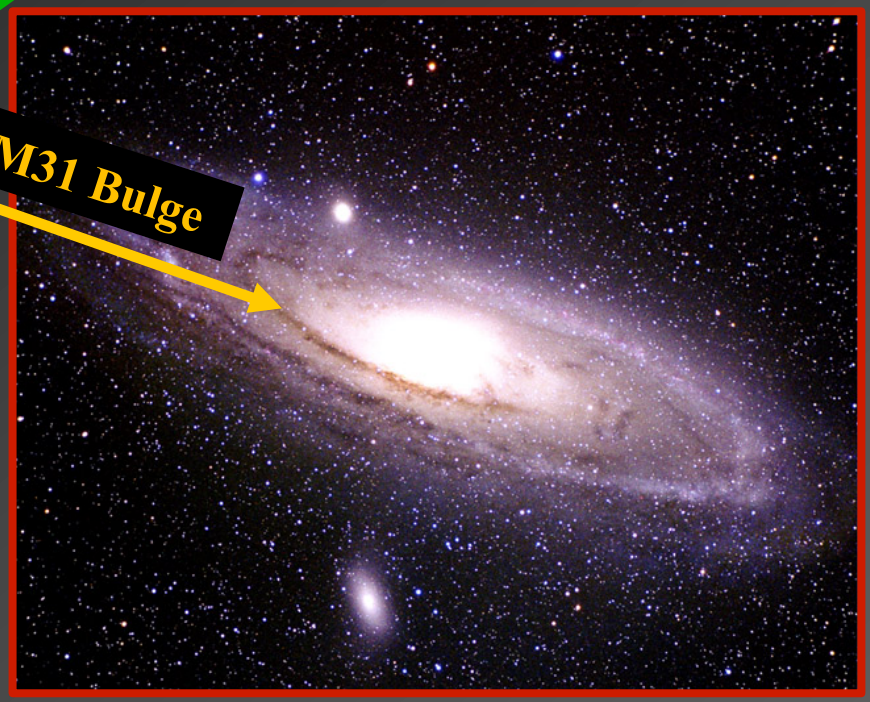
The Galactic Bulge: Overview

- Contains ~10^{10} $M_\odot$ of old, metal-rich stellar material
- 100x closer than the nearest bulge structure (M31)
- Only bulge system for which we can obtain detailed composition and kinematic information for individual stars
- Understanding chemical and dynamic formation/evolution critical for interpreting high Z observations

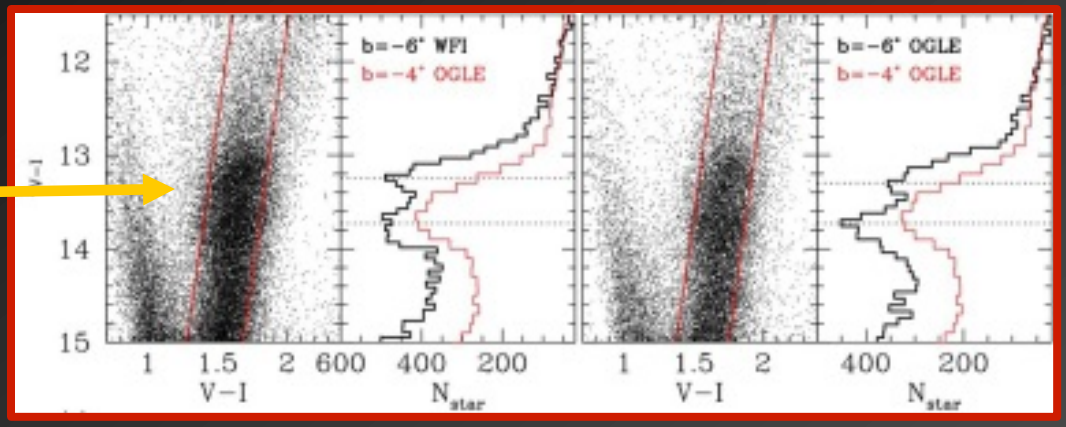




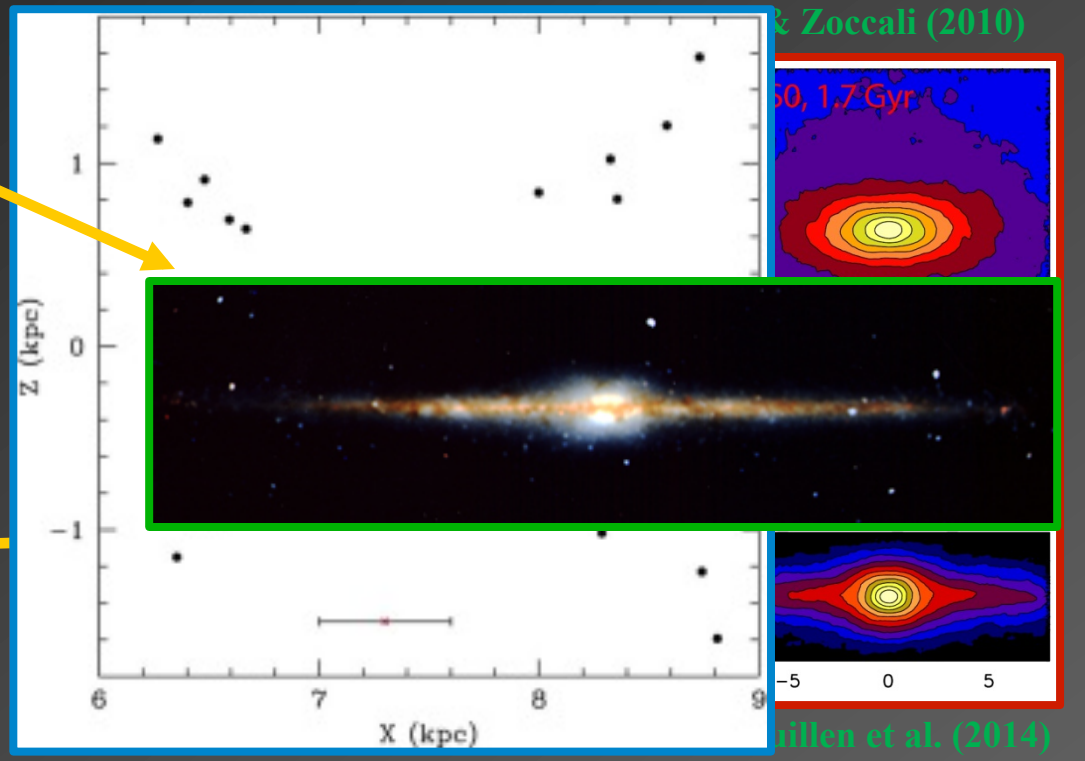
The Galactic Bulge: Recent Developments

The Galactic Bulge: Structure

- Optical and IR star counts reveal double red clump
- Tracing over multiple sight lines reveals X-shaped structure
- Orbital resonance from interaction with bar leads to X and boxy shape bulge
- X-shape or boxy shape depends on viewing angle



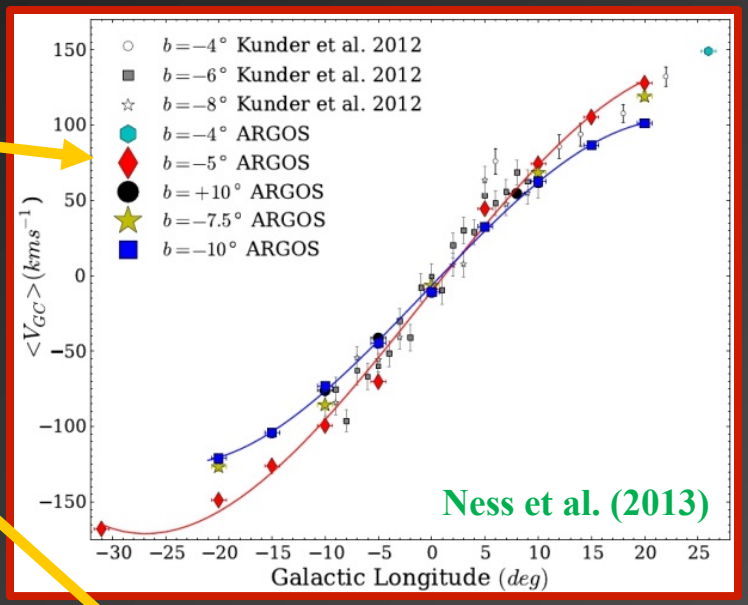
& Zoccali (2010)

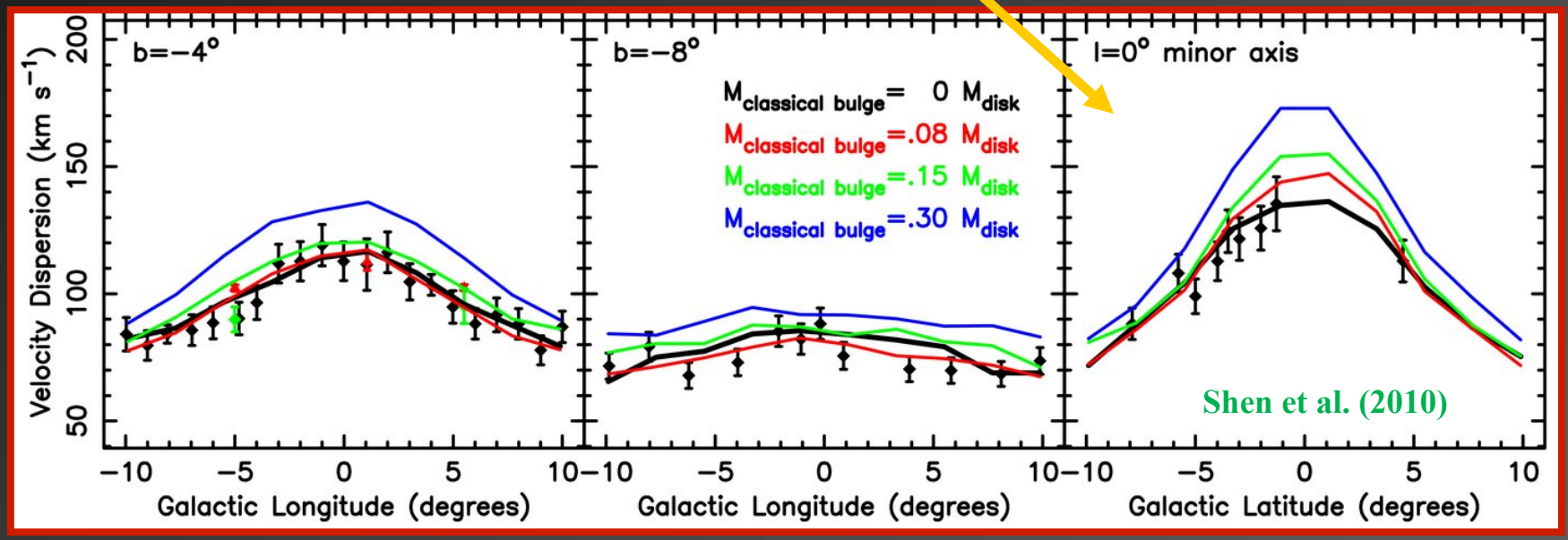


illen et al. (2014)

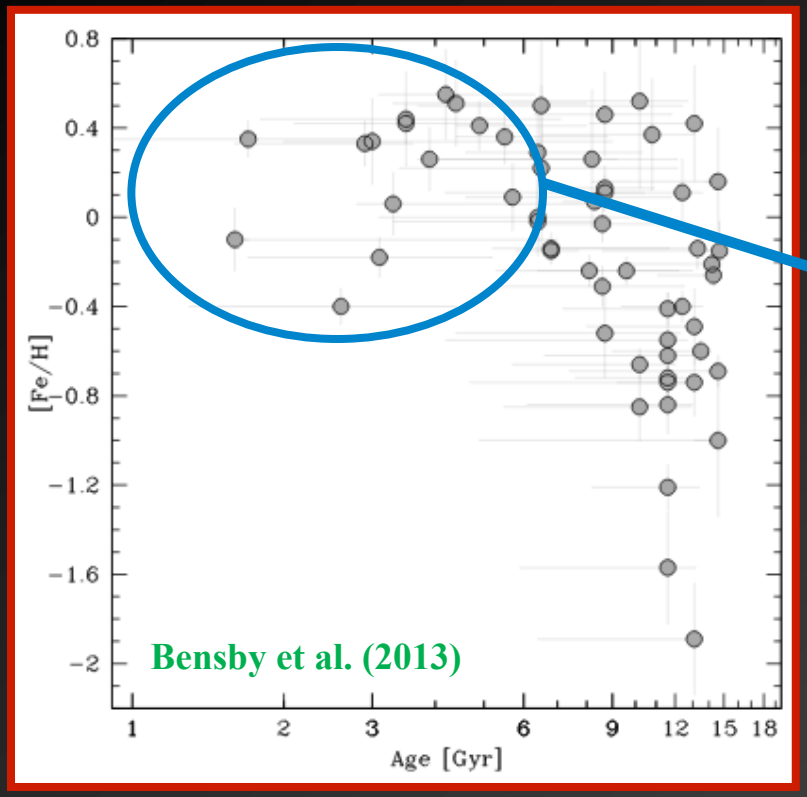
The Galactic Bulge: Kinematics

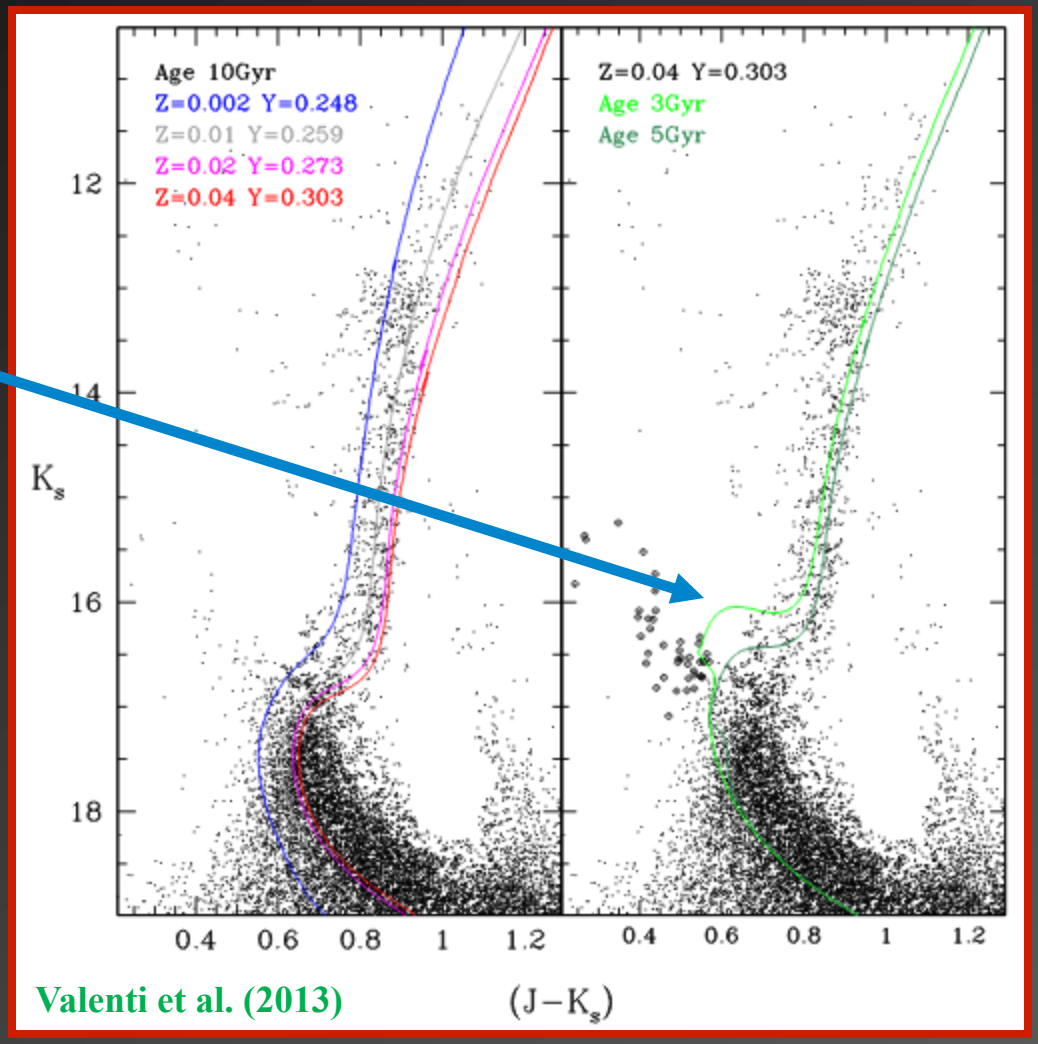
- BRAVA and ARGOS surveys find bulge rotates cylindrically
- N-body model fits to BRAVA data rule out a significant (>10% disk mass) classical bulge component
- Bulge likely formed from secular dynamical processes rather than mergers





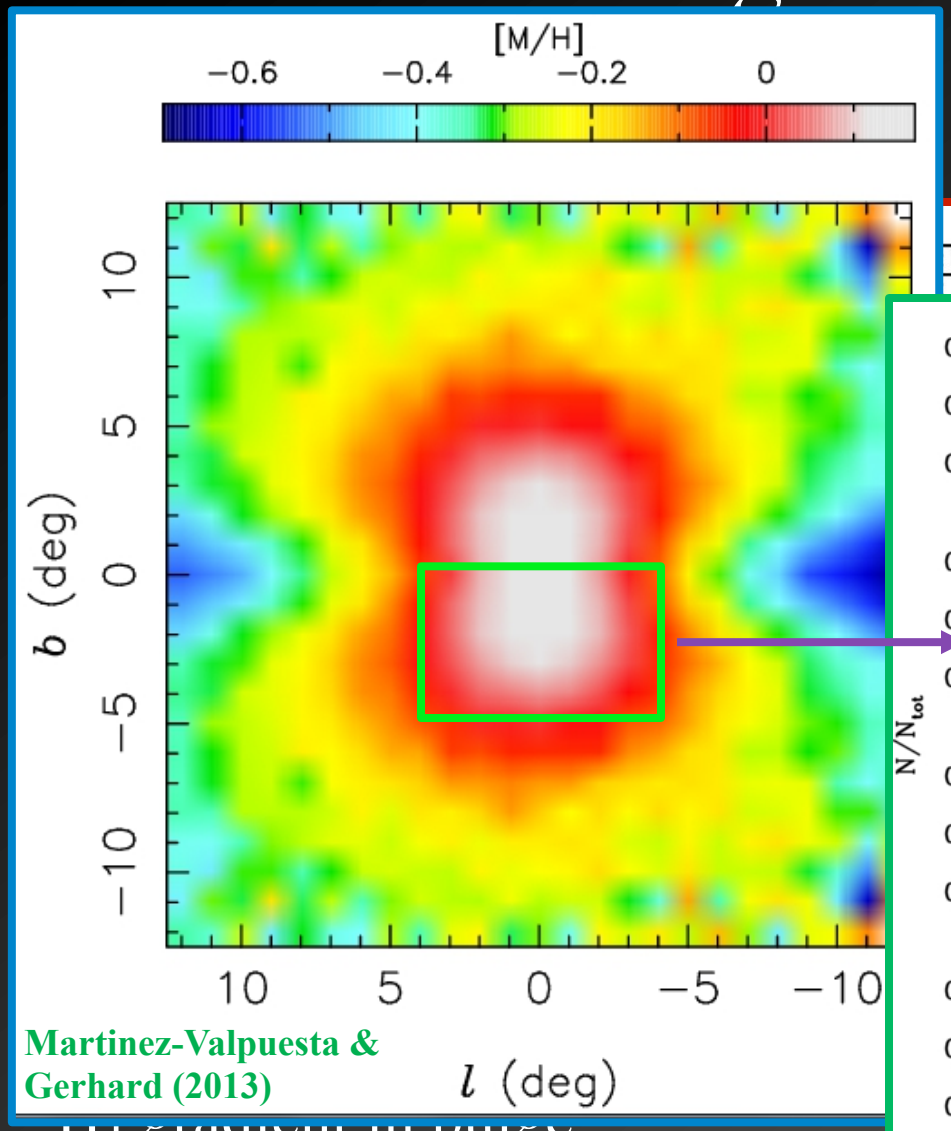
The Galactic Bulge: Age Distribution



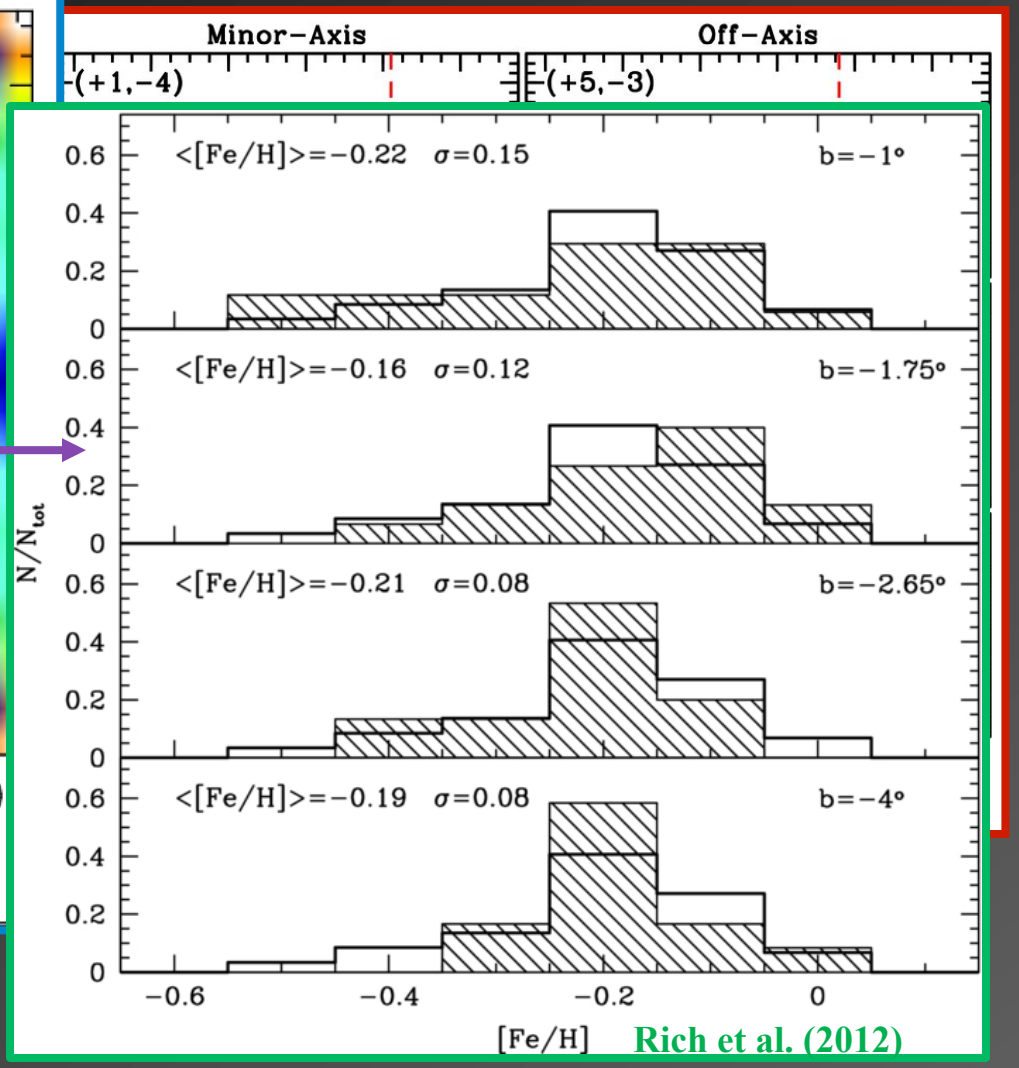


Microlensing studies find ~25% of metal-rich bulge dwarfs are young (< 5 Gyr); CMD analyses do *not* verify this population

The Galactic Bulge: Metallicity Distribution

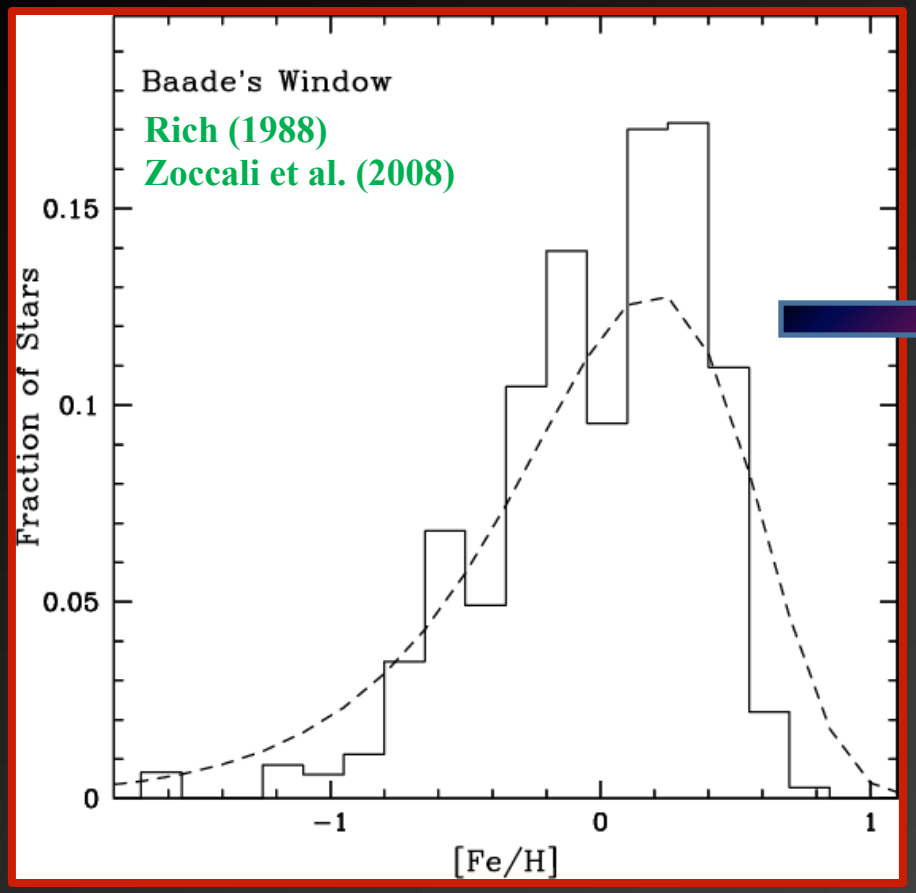


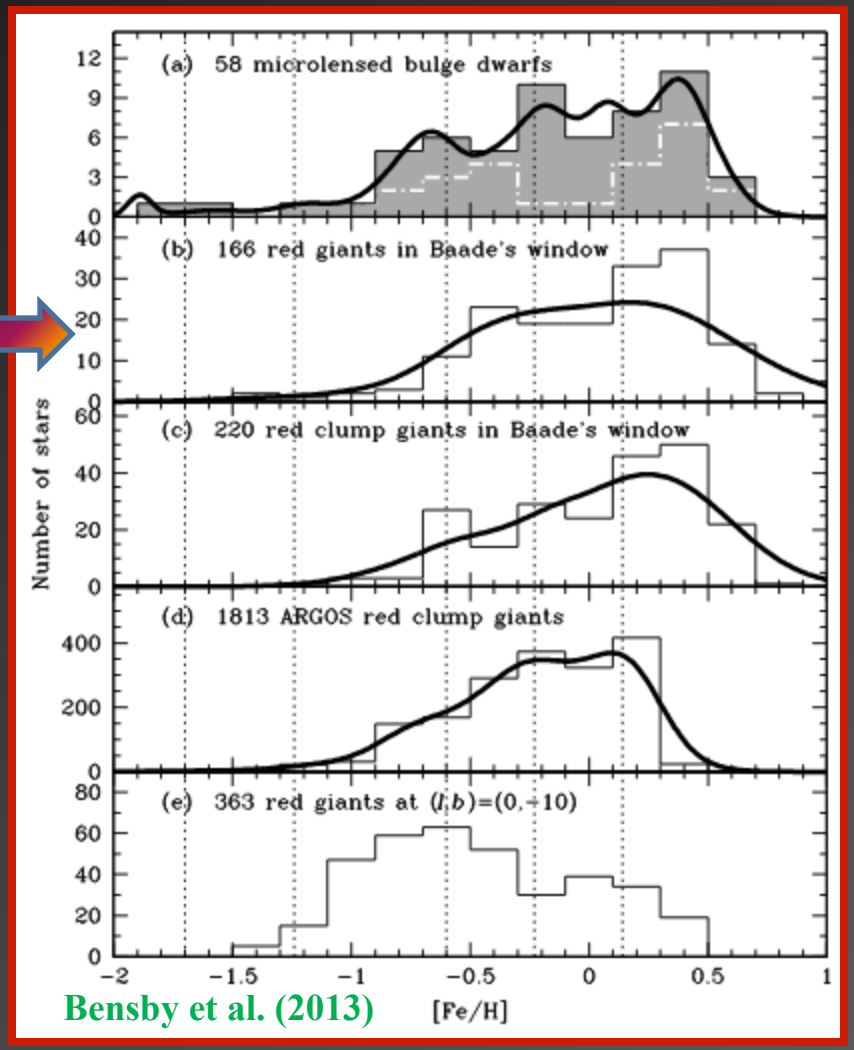
Martinez-Valpuesta & Gerhard (2013)



Rich et al. (2012)

The Galactic Bulge: Metallicity Distribution

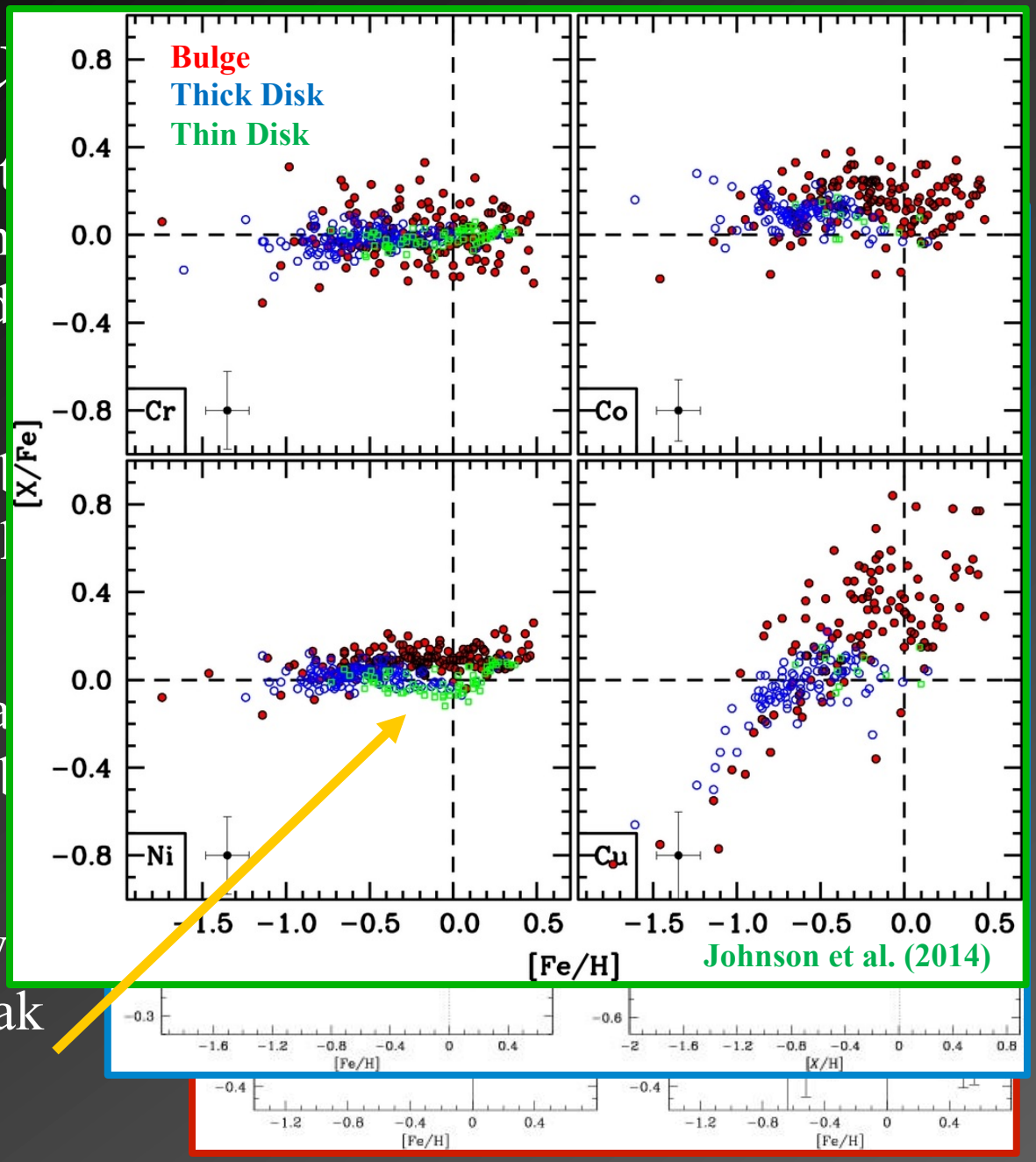




Bulge MDF has transformed from a simple population to a multi-component complex population; 5 populations?

The Galactic Bu

- [α/Fe] and possibly light elements have similar abun patterns between bulge and especially the thick disk
- Some evidence that the l decline in [α/Fe] begins at l metallicity than thick disk
- Little field-to-field varia abundance patterns across l lines-of-sight
- Possible variations betw bulge and disk from Fe-peak elements

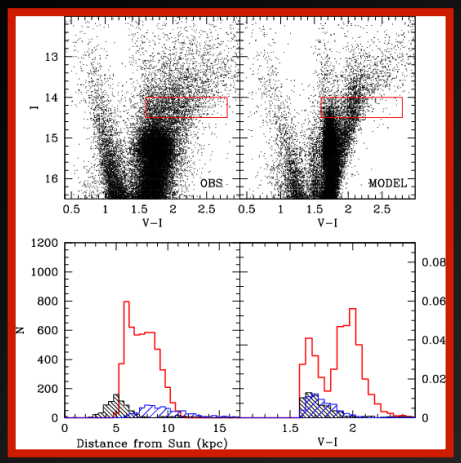


Classical Bulge vs. Pseudobulge

Classical Bulge	Pseudobulge
Uniformly old age (~10 Gyr)	Age dispersion > 5 Gyr
Enhanced [α/Fe] at high values of [Fe/H]	Similar Composition to Thick Disk
Vertical [Fe/H] gradient	Boxy X-shape with bar
Existence of possible "building block" objects like the GC Terzan 5	Cylindrical rotation profile that seems to rule out a major classical bulge component

All of these characteristics are supported by observations in the Milky Way bulge!

Population Separation with WFIRST



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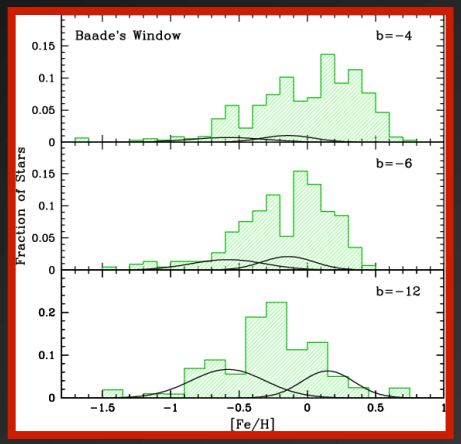
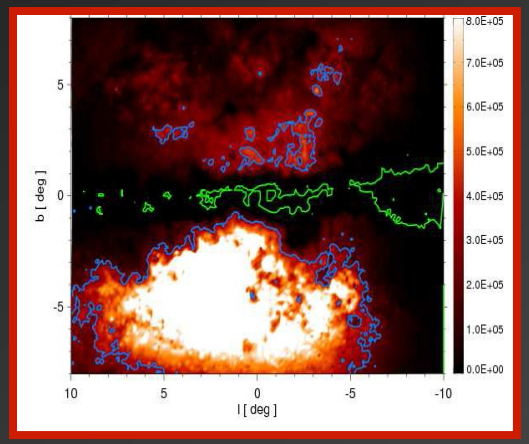
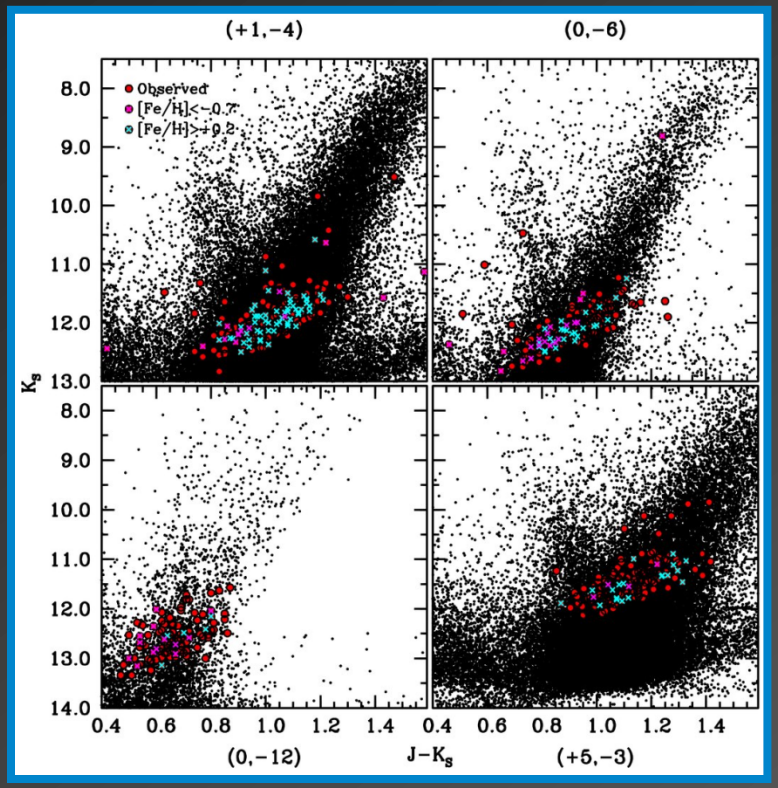




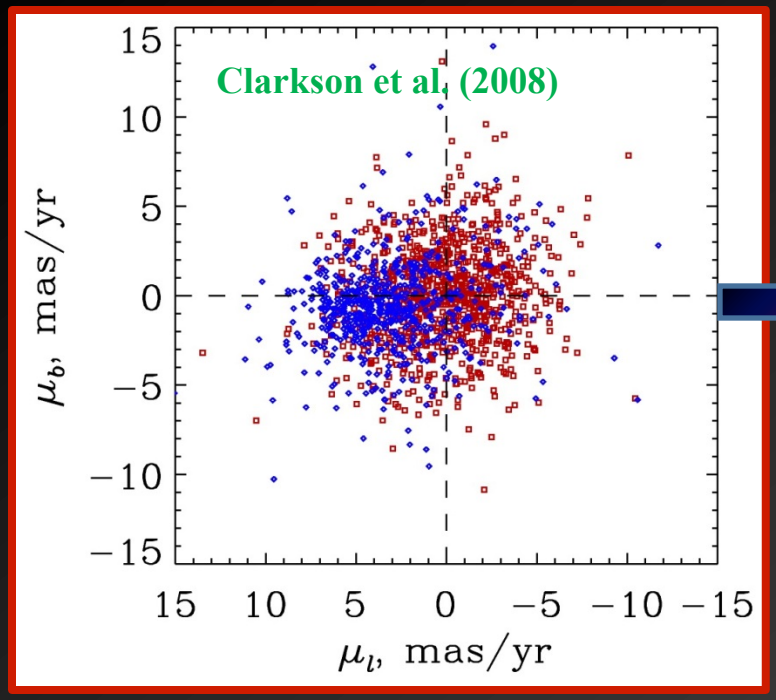


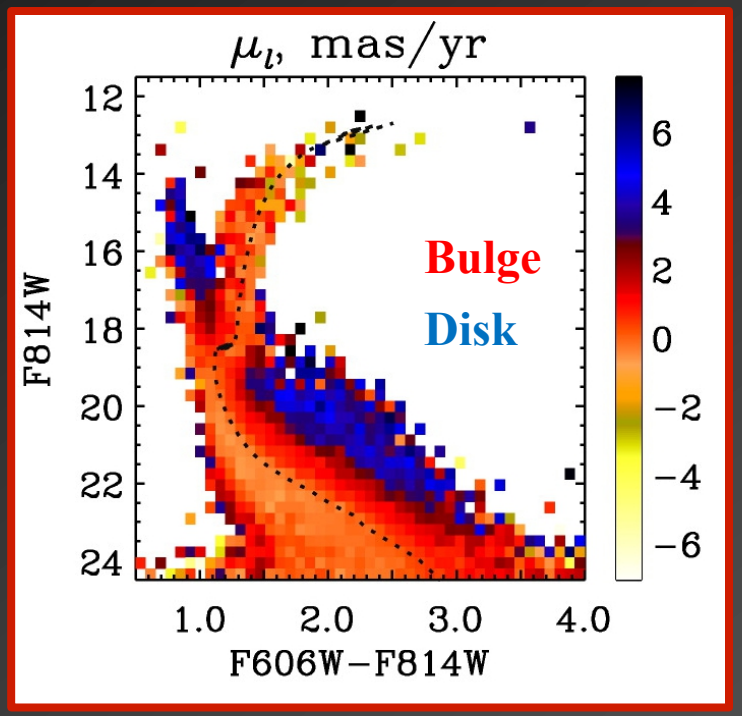
Johnson et al. (2013)

(1) Distance uncertainty
(2) Foreground disk/halo contamination
(3) Extinction
(4) Crowding

→ Challenging to interpret CMD and composition analyses

Population Separation with WFIRST

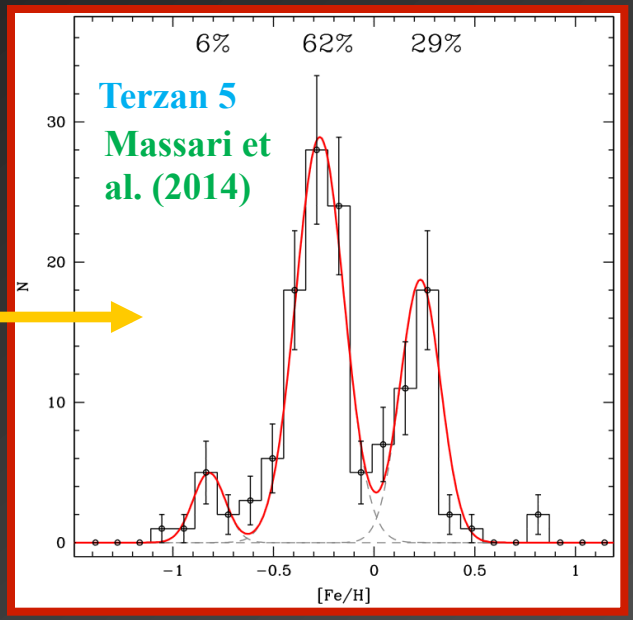


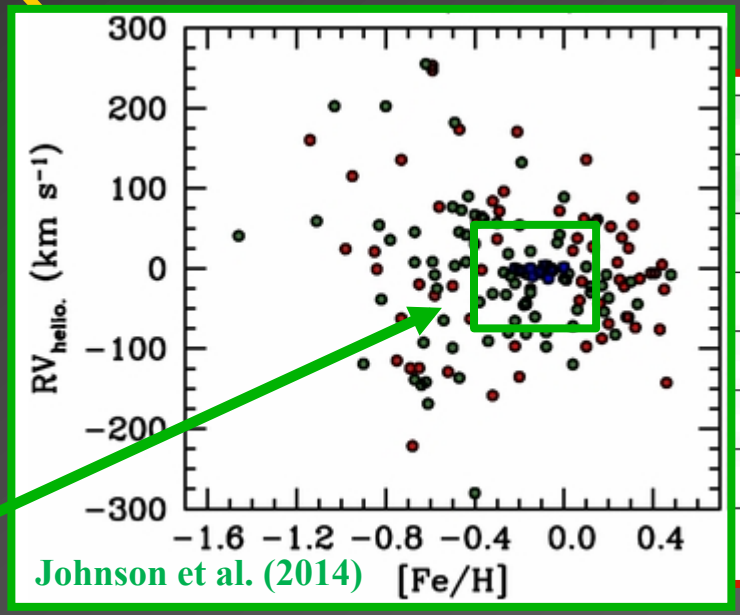


- HST quality astrometry
- Large field-of-view
- Long base line
- IR minimizes extinction

Population Separation: Globular Clusters

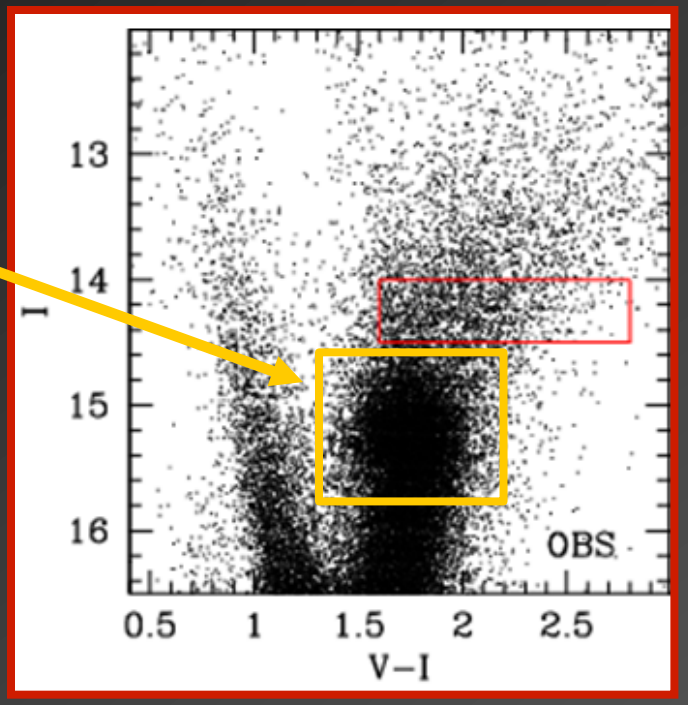
- Bulge GCs range from [Fe/H] = -2 to roughly solar (higher than halo clusters)
- Terzan 5 discovered to have complex star formation history, similar to ω Cen?
- Terzan 5, NGC 6569, and NGC 6440 among bulge clusters with double HB
- Some bulge GCs also have very blue HBs despite high metallicity
- WFIRST kinematics (astrometry) helpful for separating cluster and field stars
- Proper motions also useful for finding tidal streams associated with GCs

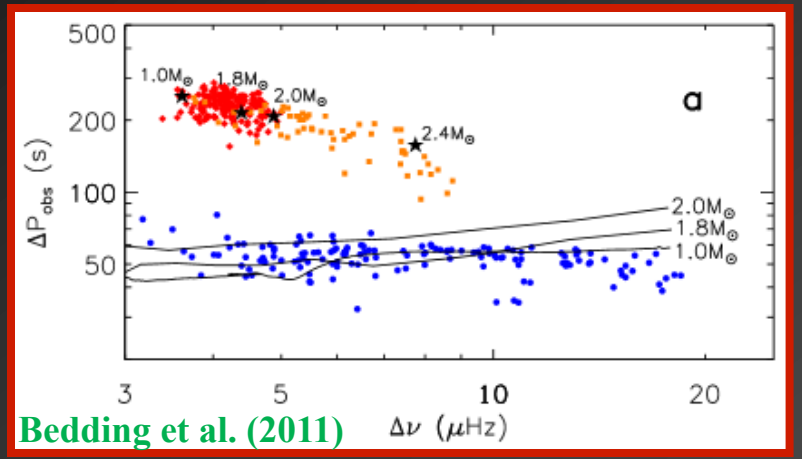




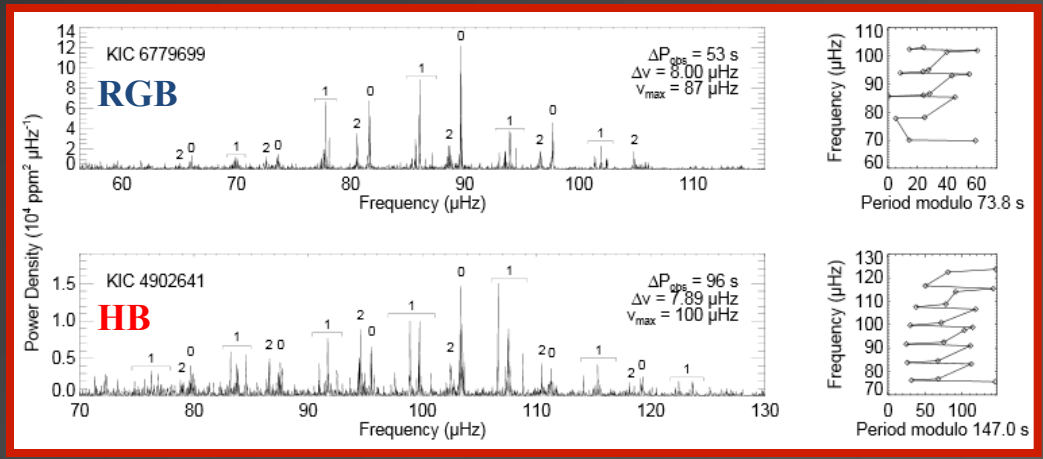
Population Separation: Asteroseismology

- CMD includes mixture of bulge RGB, bulge HB, bulge AGB, and foreground MS, RGB, HB, and AGB stars
- Asteroseismology offers possibility for population separation
- Requires high precision, repeated photometry → may complement WFIRST bulge microlensing survey





Bedding et al. (2011)



Summary

- Many high quality photometric, astrometric, and spectroscopic measurements of Galactic bulge stars exist, but interpretation is hampered by complex geometry and population mixing
- WFIRST offers several opportunities to identify true bulge stars and provide a better understanding of inner Galactic structure
- Both deep and shallow WFIRST exposures are useful for interpreting ground-based Galactic bulge observations
- WFIRST's wide-field, HST quality astrometry combined with pre-existing (e.g., BRAVA; ARGOS) and future (APOGEE2-South) kinematic/composition surveys will provide a better 3D picture of the bulge and inner Galaxy populations
- Additional insight may be gained by observing lines-of-sight predicted by upcoming models to provide the most discriminating power