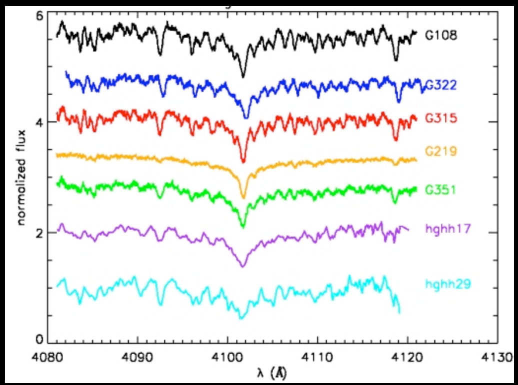
Chemical Abundances and Horizontal Branch Morphology of Extragalactic Globular Clusters : M31 First Results

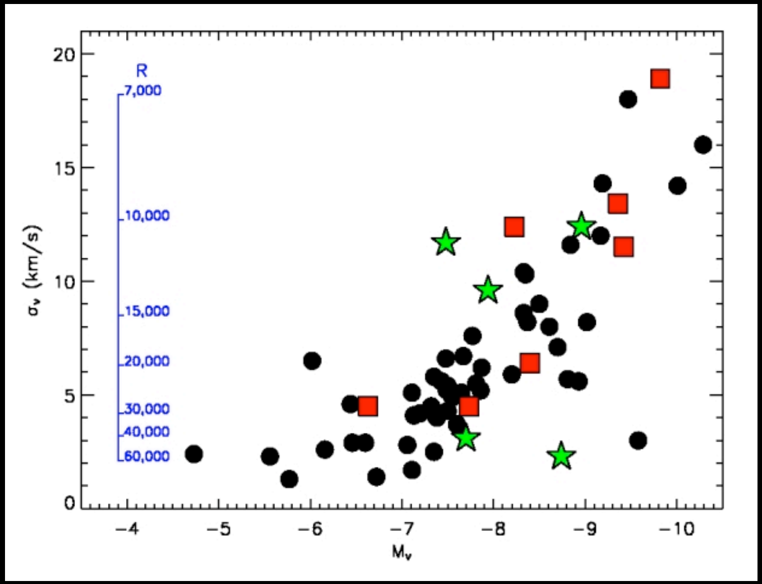


Janet E. Colucci (Michigan)
Rebecca A. Bernstein (Michigan)
Scott Cameron (Michigan)
Andrew McWilliam (Carnegie Observatories)
Judy Cohen (Caltech)

Motivation

- Abundances trace galaxy formation histories:
  - gas enrichment
  - star formation rates
  - supernovae rates/yields

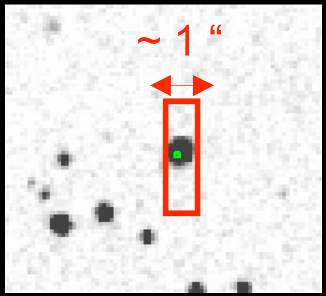
- Old stars provide *history*
  - Only reachable in
    - Milky Way
    - Closest Local Group galaxies



- Globular Clusters (GCs):
  - Accessible beyond closest galaxies
  - Trace properties of host galaxies
  - Bright -10 < M_V < -6
  - *Simple* stellar populations
    - Single age, single Z (easily modeled)
  - Small internal velocity dispersions (3 < σ_v < 20 km/s)

High resolution spectra integrated light (IL) spectra can be obtained out to D ~ 4 Mpc with current telescopes

New Integrated Light (IL) Abundance Analysis Method



Key Points of Technique:

- Based on stellar (RGB) abund. analysis
- Equivalent widths (EWs) measured for individual lines
- Build IL model of each line using using isochrones (with standard IMF, mass segregation, etc).
- spectrum synthesis with MOOG (Sneden 1974)

➔ Can get [X/H] for any input isochron age and Z
….only ~correct isochrones give *consistent solutions.*

Calibration and accuracy from Milky Way GCs:
Δ[Fe/H] ~ 0.05 – 0.1 dex

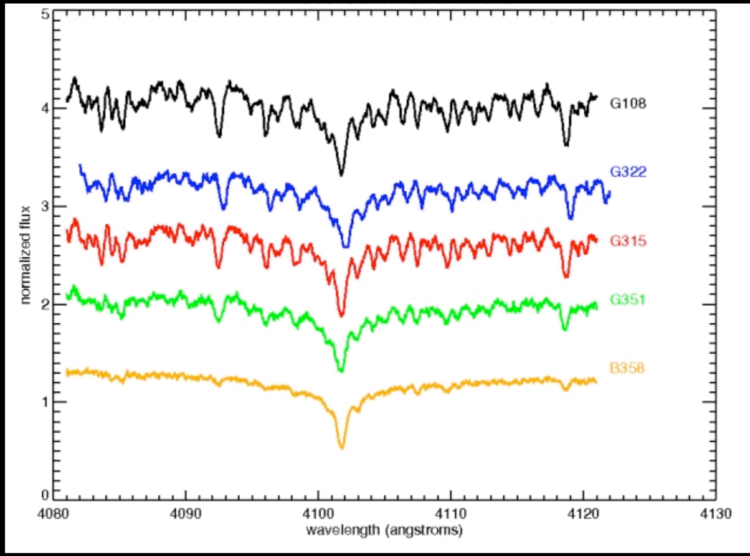
- See Bernstein & McWilliam 2005, McWilliam & Bernstein 2007

First Extragalactic Targets: M31**

Name	RA (J2000)	Dec (J2000)	V	Mv	Estimated [Fe/H]	Estimated [α/Fe]
G108-B045	00 41 43.26	41 34 21.76	15.78	-8.69	-0.94 (1) -1.05 (2)	0.22 ± 0.19 (3)
G219-B358	00 43 18.01	39 49 13.53	15.12	-9.35	-1.83 (1)	0.00 ± 0.27 (3)
G322-B386	00 46 26.94	42 01 52.94	15.64	-8.92	-1.21 (1) -1.62 (2)	0.25 ± 0.22 (3)
G351-B405	00 49 39.81	41 35 29.40	15.2	-9.27	-1.80 (1)	
G315-B381	00 46 07.28	41 35 29.22	15.76	-8.71	-1.22 (1)	

(1) Huchra, Brodie, & Kent (1991)
(2) Perrett et al. (2002)
(3) Puzia, Perrett & Bridges (2006)

Low Res spectra



G108-B045 and G315-B381

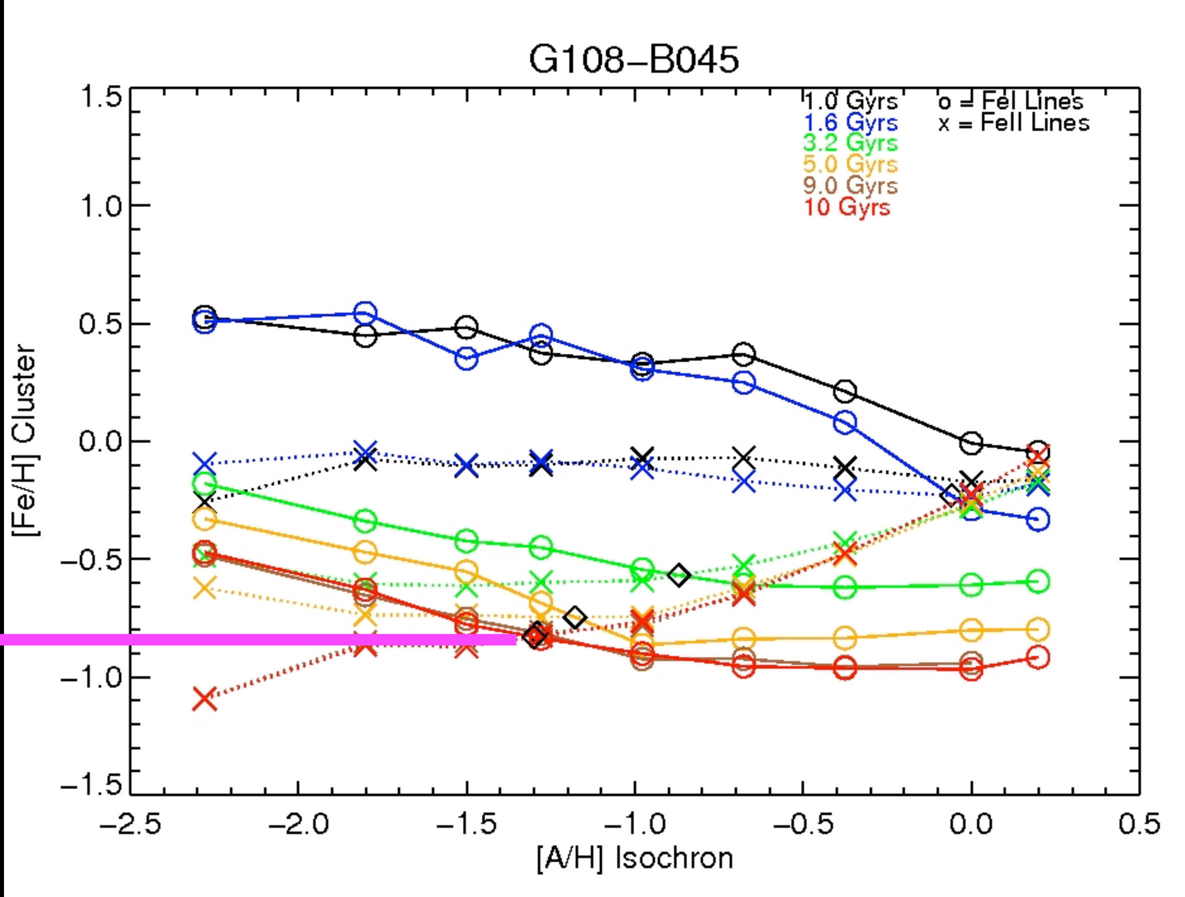
- Well studied
- Old, Halo GCs
- Red Horizontal Branches*

** Spectra from Keck/HiRES in collaboration with J. Cohen

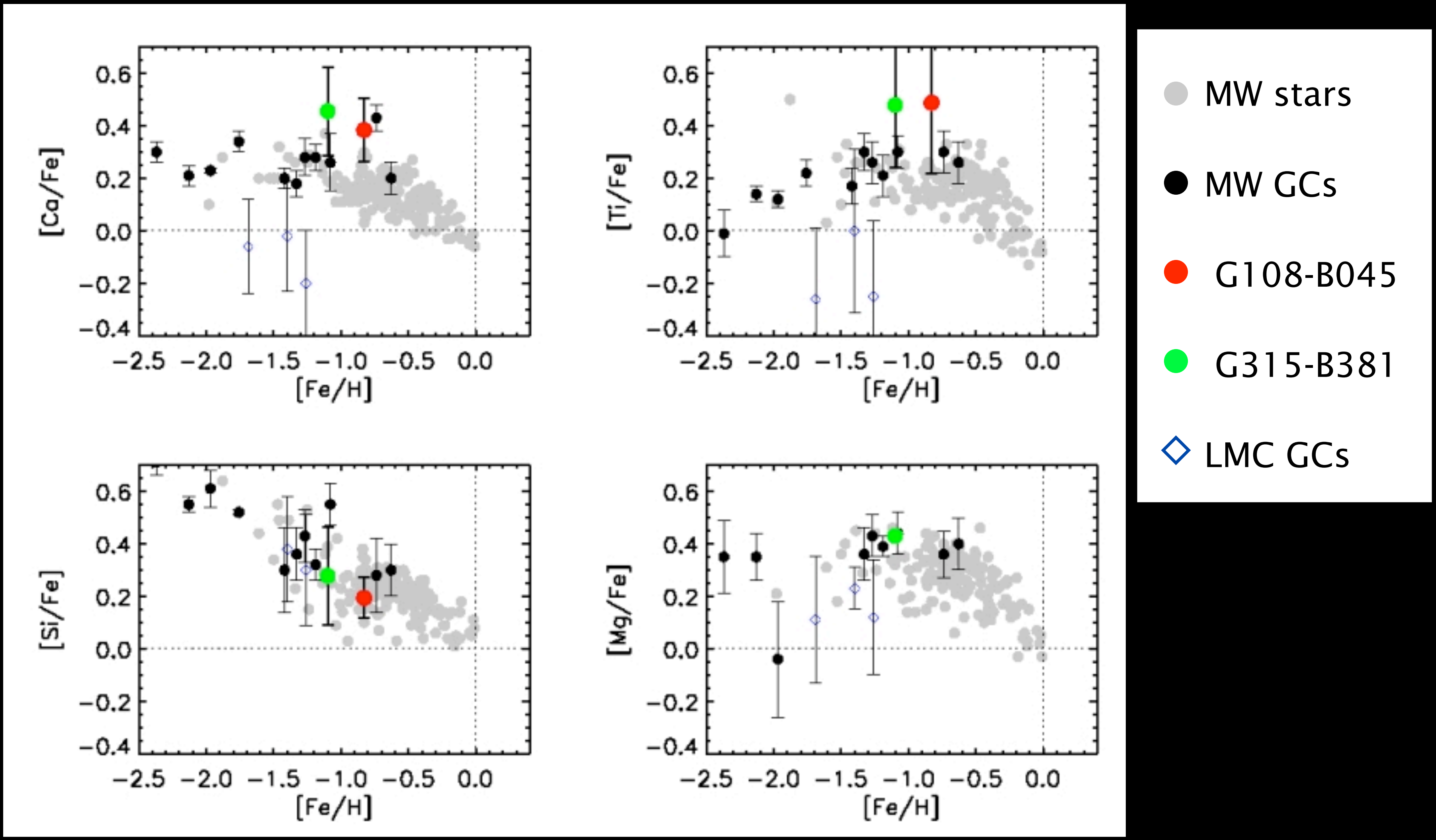
Fe Abundance Results : G108-B045

- Mean $[Fe/H]_I$ and $[Fe/H]_{II}$ solutions for any CMD (54 solutions)
- consistent solutions for: $[Fe/H]_I$ and $[Fe/H]_{II}$ (5 solutions)
- consistent solutions for: excitation potentials, EWs, and Wavelengths – 2 solutions!

[Fe/H]= -0.82
Age = 9, 10 Gyrs



Results for Other Elements



MW stars -- Reddy, Lambert, & Allende Prieto (2006), 47Tuc -- Carretta et al. (2004), NGC 288, 362 -- Shetrone & Keane (2000), M3, M13 -- Sneden et al. (2004), M68 -- Lee et al. (2005), M71 -- Ramirez & Cohen (2002), NGC 6287, 6293, 6541 -- Lee & Carney (2002), M4 -- Ivans et al. (1999), M5 -- Ivans et al. (2001), NGC 1898, 2005, 2019 (LMC) -- Johnson, Ivans, & Stetson (2006)

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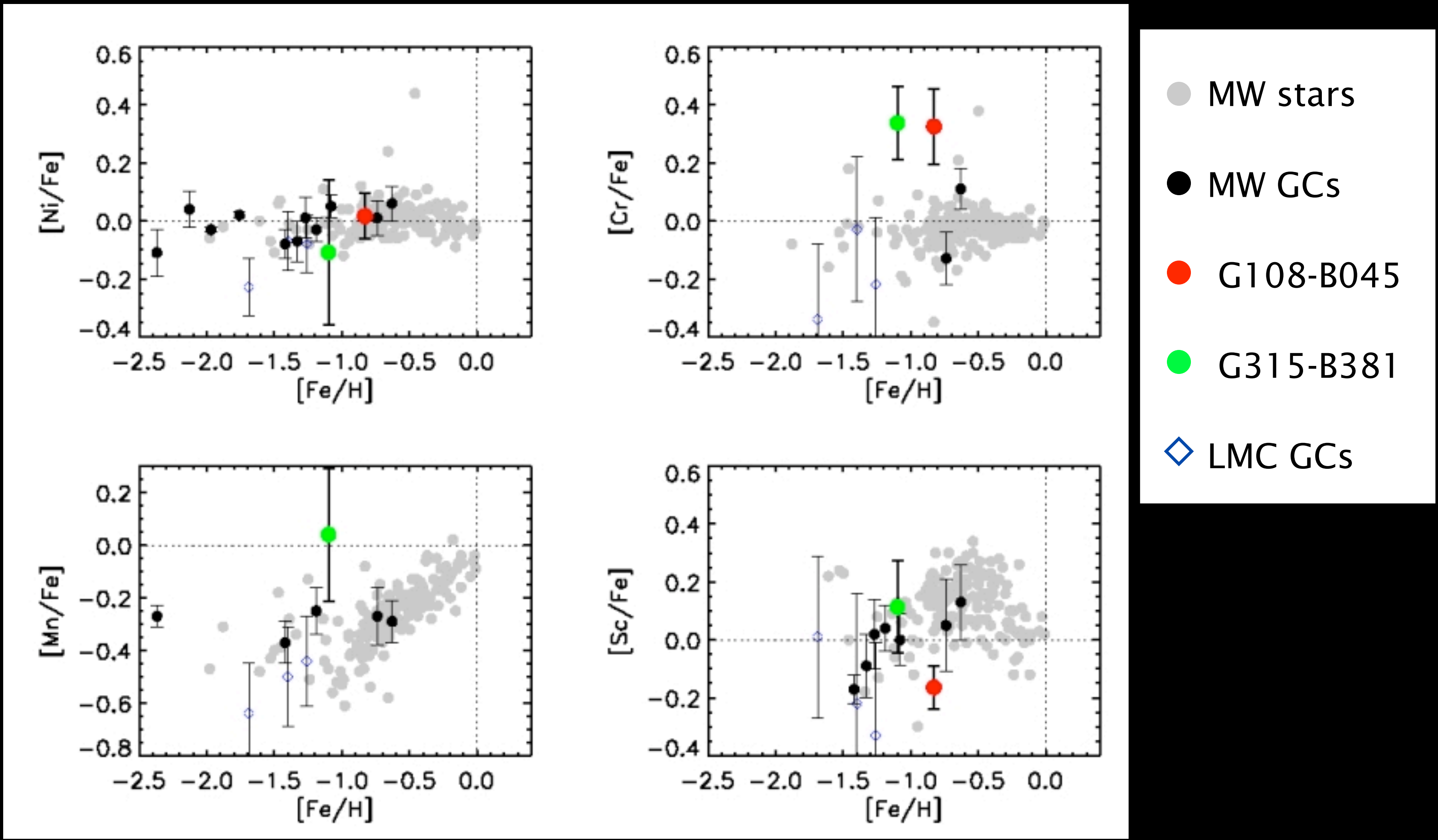

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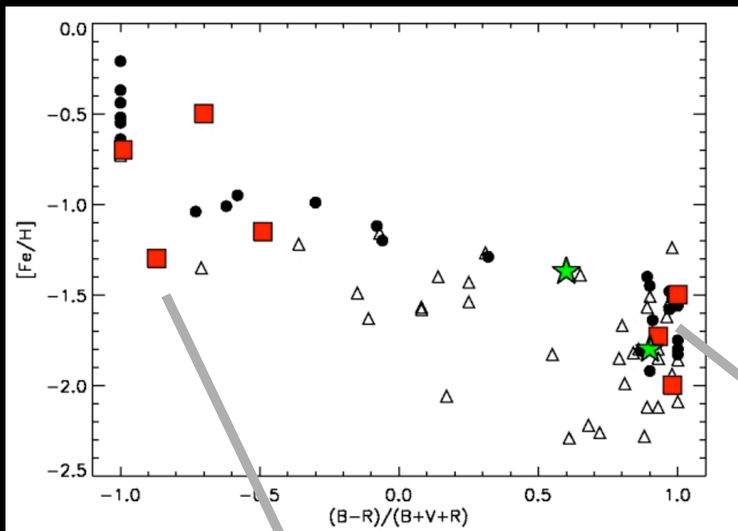
Estimating Horizontal Branch Morphology

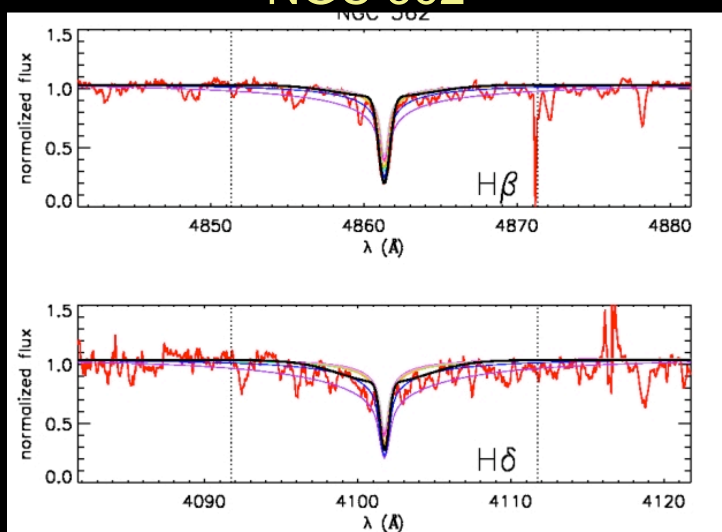


As shown in Zinn 1993

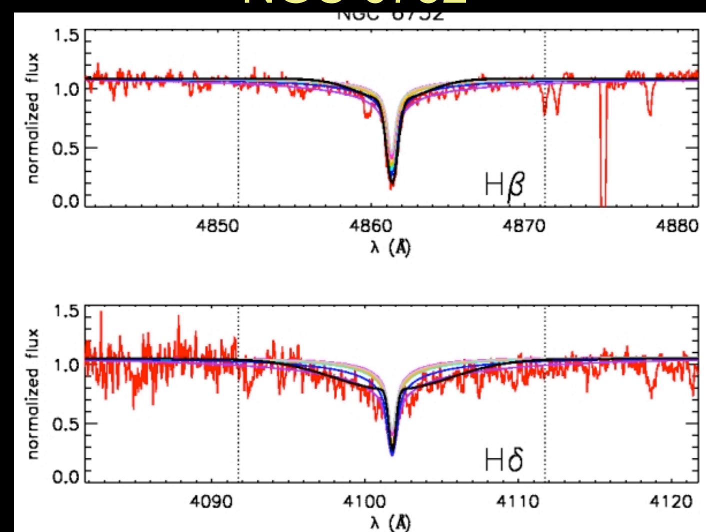
- Compare:
  <u>model</u> IL Balmer lines (w/o BHB)
  to
  <u>observed</u> IL Balmer lines

- Based on Hβ and Hδ in model vs data we can identify the contribution of BHB stars.

NGC 362



NGC 6752



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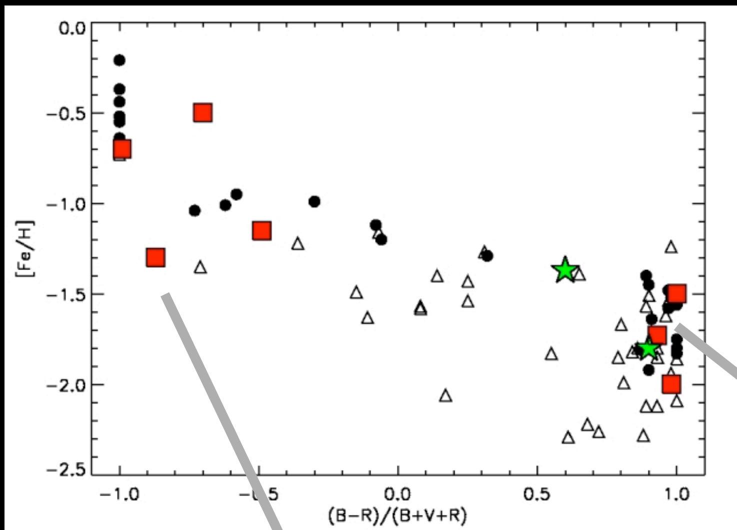

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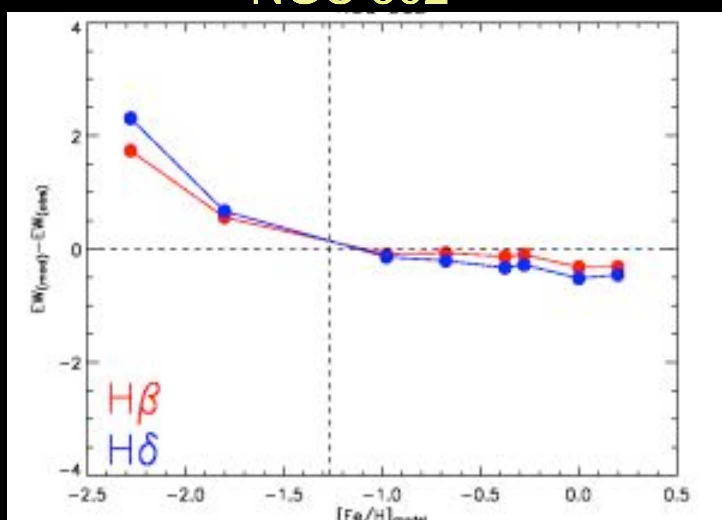

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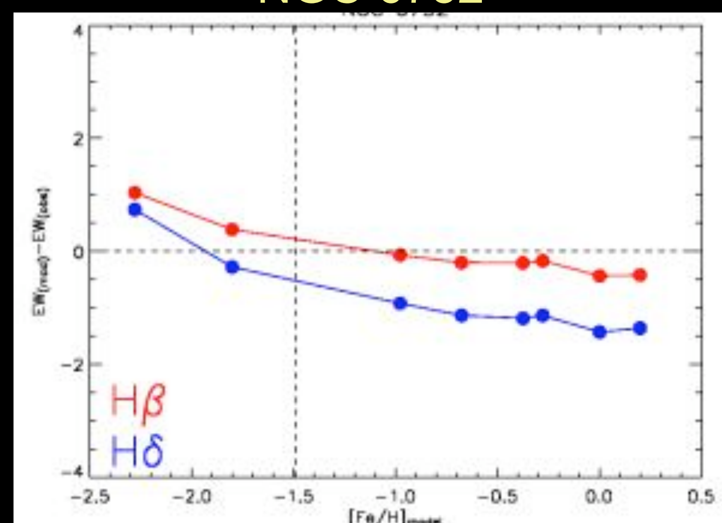
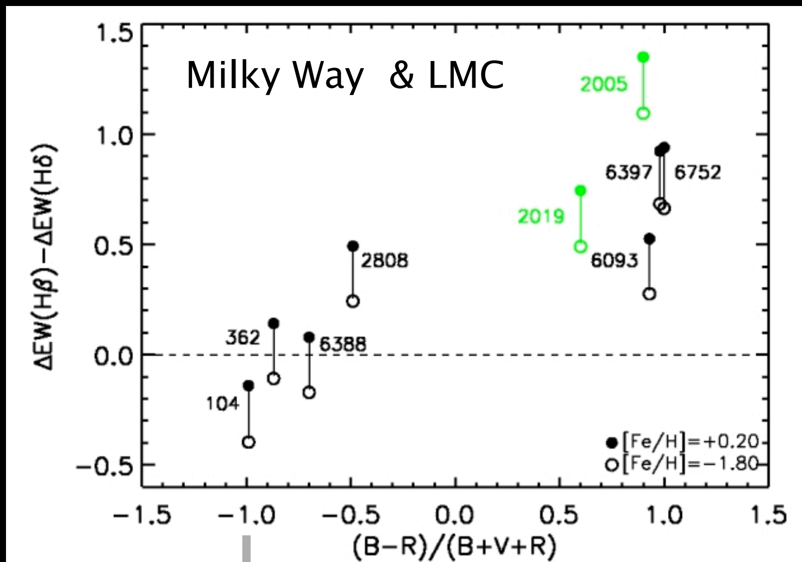
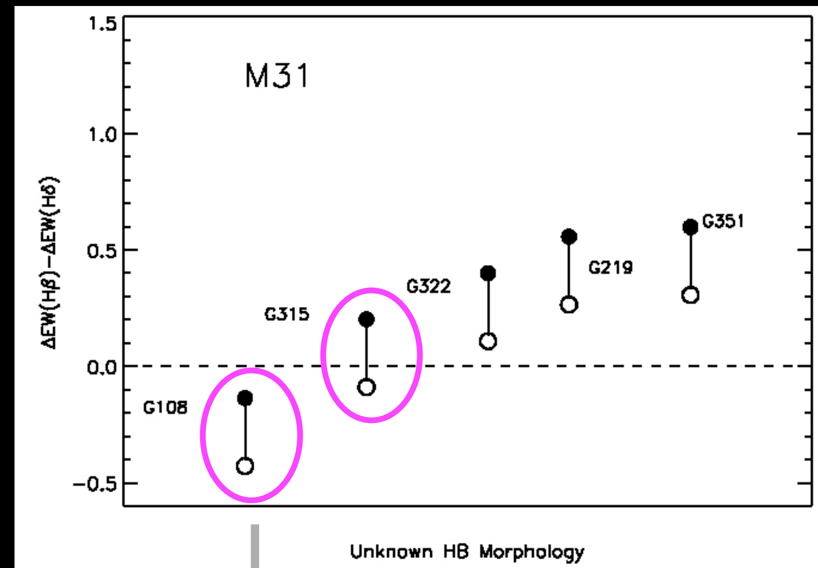
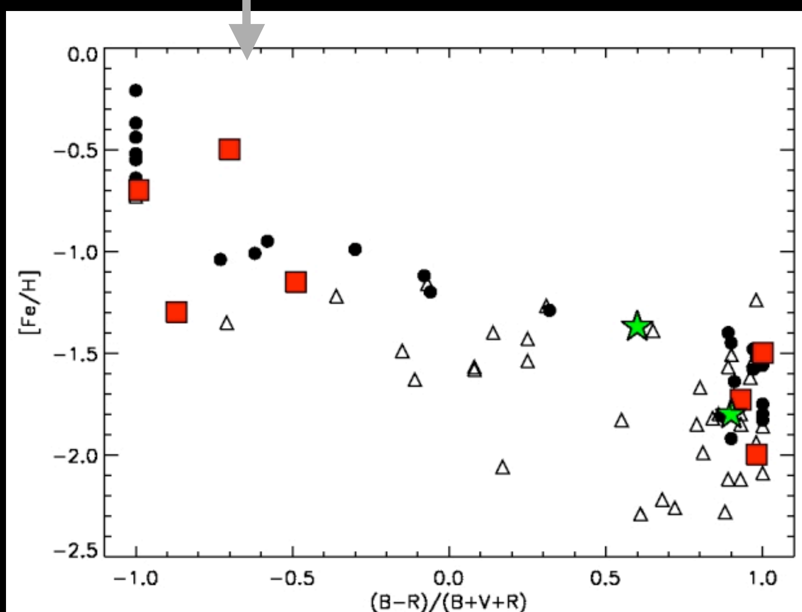
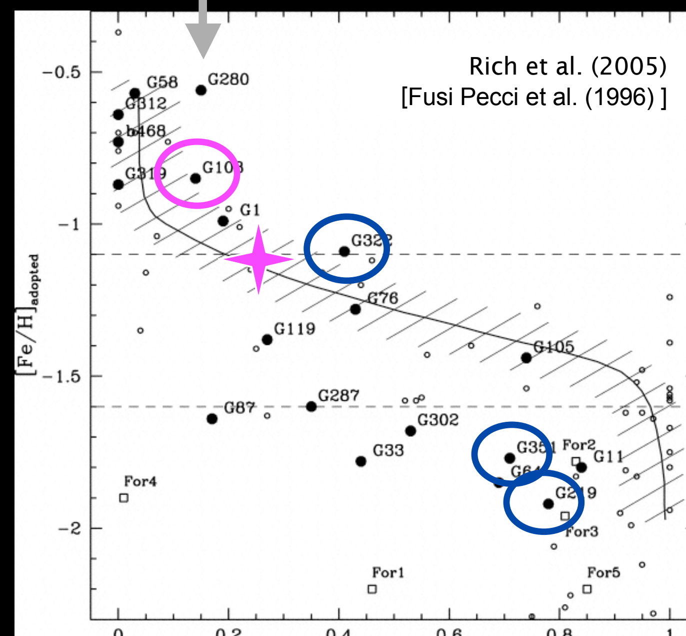


Estimates of Horizontal Branch Morphology









B / (B+R)

Summary

- Detailed chemical abundances of OLD STARS in M31 (G108-B045, G315-B381)
  - [Fe/H] results:
    - G108-B045 [Fe/H] = –0.82
    - G315-B381 [Fe/H] = –1.10
  - Abundances of 11 different elements
    - slightly higher α–enrichment than Milky Way GCs (Ca,Ti) (unlike Dwarf GCs)
    - Not sensitive to assumed abundances!
  - Confirmed ages:
    - older than 9 Gyrs
- New technique to get HB morphology of unresolved GCs
  - 5 done so far. (4 known from HST CMDs. 1 new result)