Globular Clusters in LSB Dwarf Galaxies

New results from HST photometry and VLT spectroscopy

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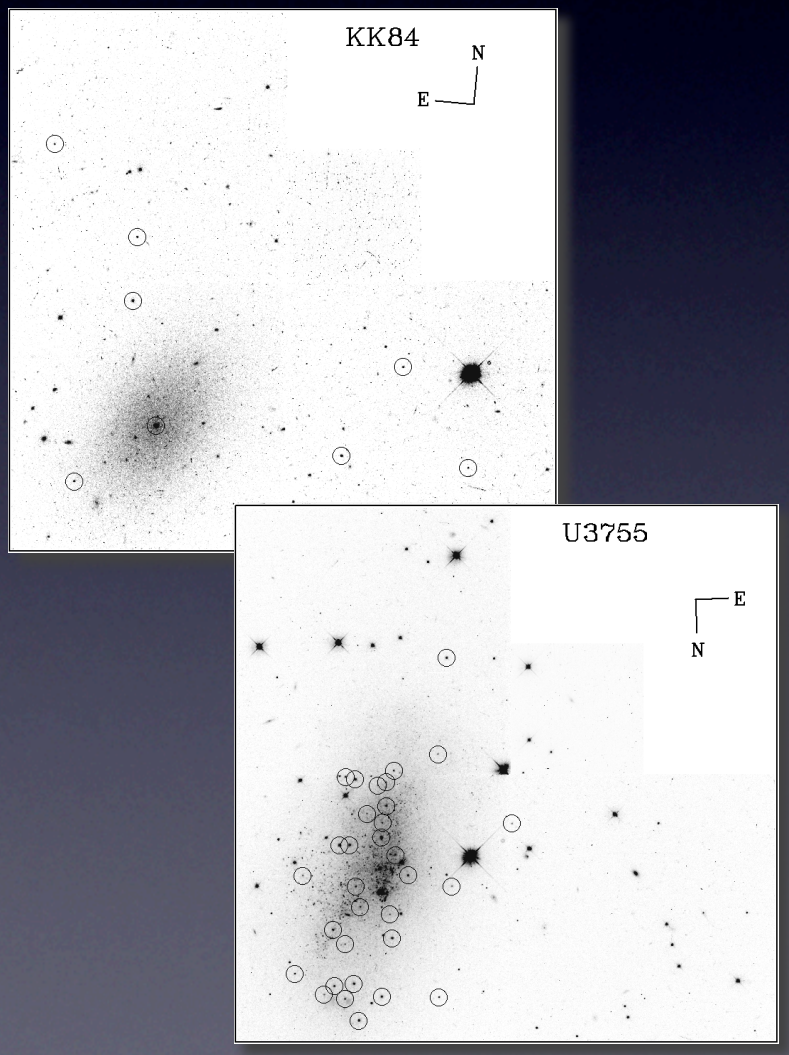
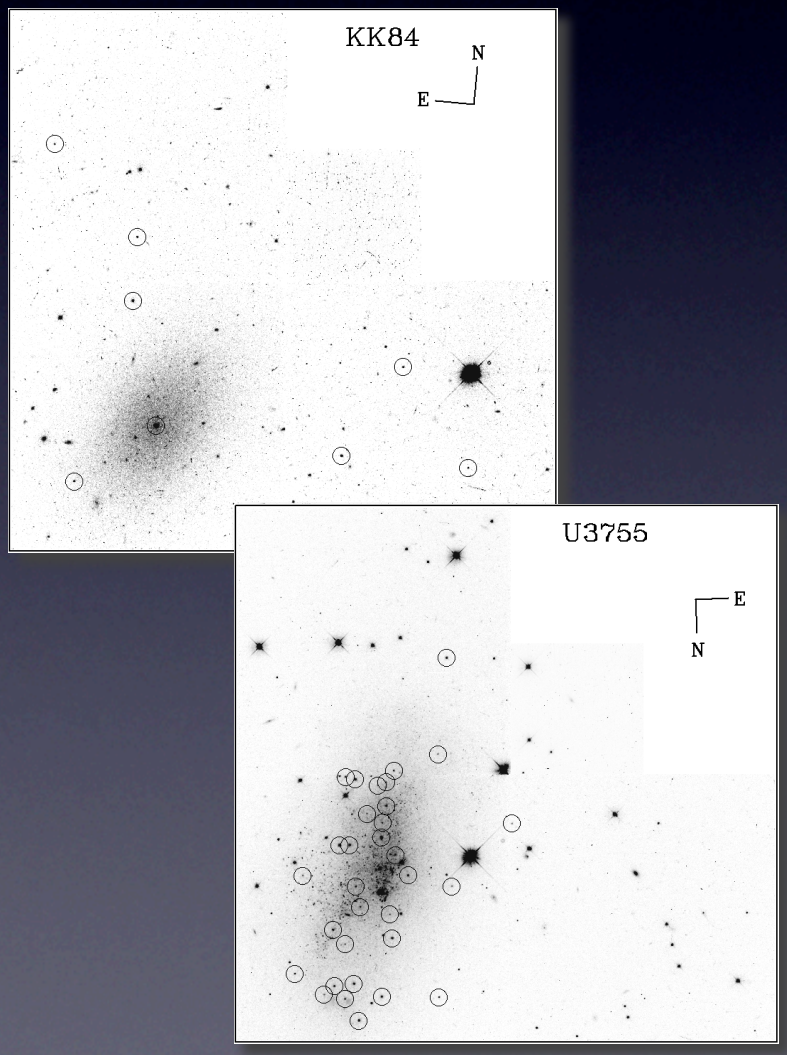
Low Surface Brightness Dwarf Galaxies

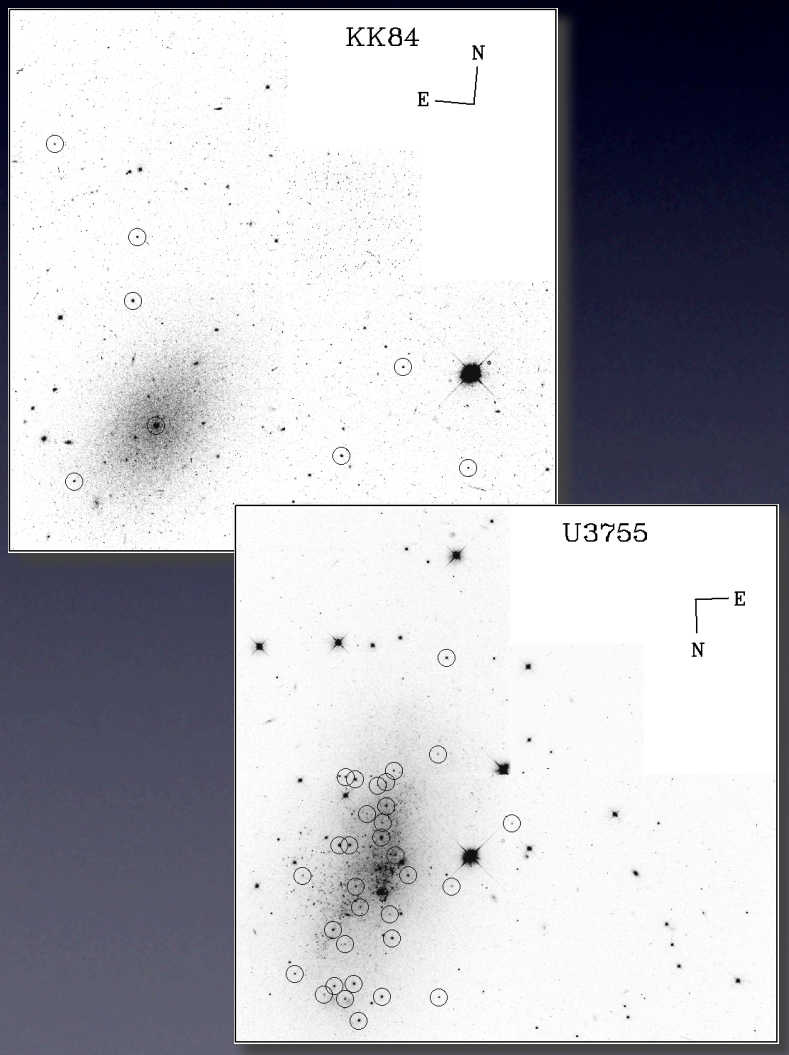


Low Surface Brightness Dwarf Galaxies



- most abundant galaxy type in the local Universe
- low-mass building blocks of Local Group galaxies (e.g. Sagittarius)
- evolutionary parameters of oldest stellar populations provide limits on the seed population of more massive halos.
- SF properties in uber-Halo

Low Surface Brightness Dwarf Galaxies



We searched 57 nearby (~2-6 Mpc) LSB dwarf galaxies (-10 > Mv > -16) for Globular Cluster candidates using HST WFPC2 imaging in V and I of snapshot programs GO-8192, 8601 (Seitzer dwarf census of LV).

18 dSph (T < -1)
36 dIrr (T > 9)
3 dSph/dIrr (T = -1)

GCC Selection

- $0.3 < (V\text{-}I) < 1.5$,
  includes metallicities $-2.5 < [Z/H] < +0.5$
  for ages older than 100 Myr (B&C2003)

- $3 \lesssim r_h \lesssim 20$ pc,

  typical for majority of Local Group GCs

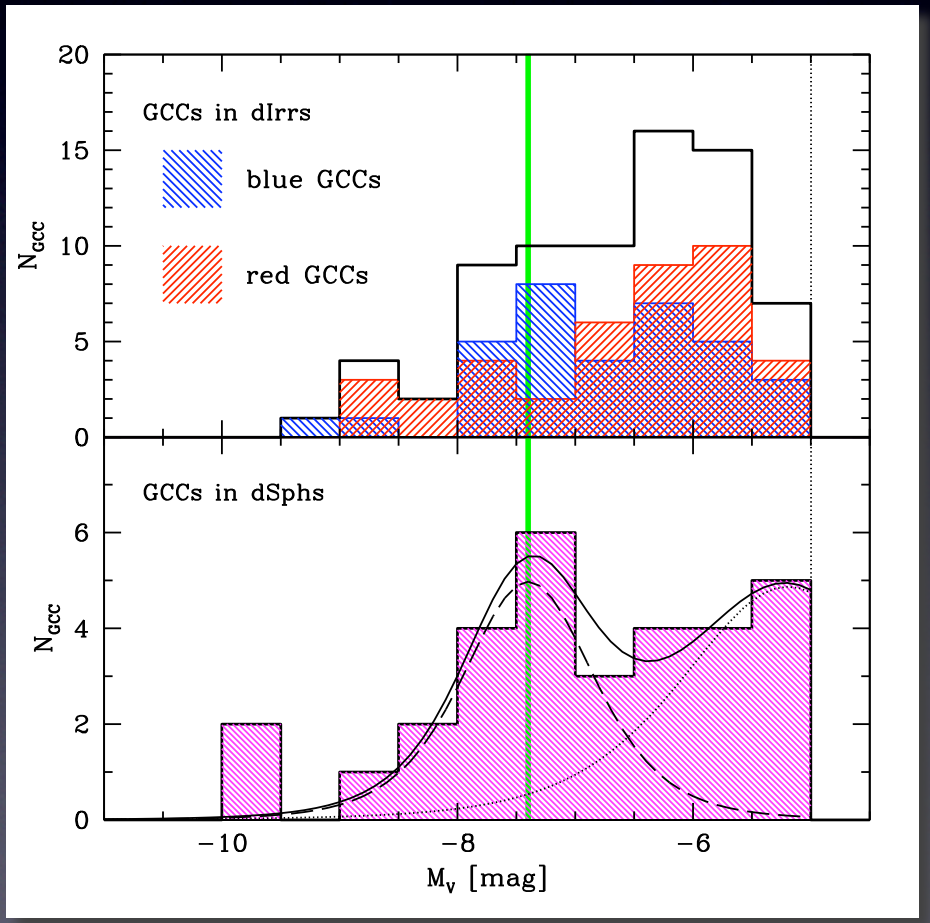
- M_V brighter than -5.0 mag,
  corresponds to completeness limit

- GCC inside $\mu_B = 26.5$ mag/arcsec^2,
  reduce the likelihood of contamination

50% of all LSBs contain Globular Cluster Candidates

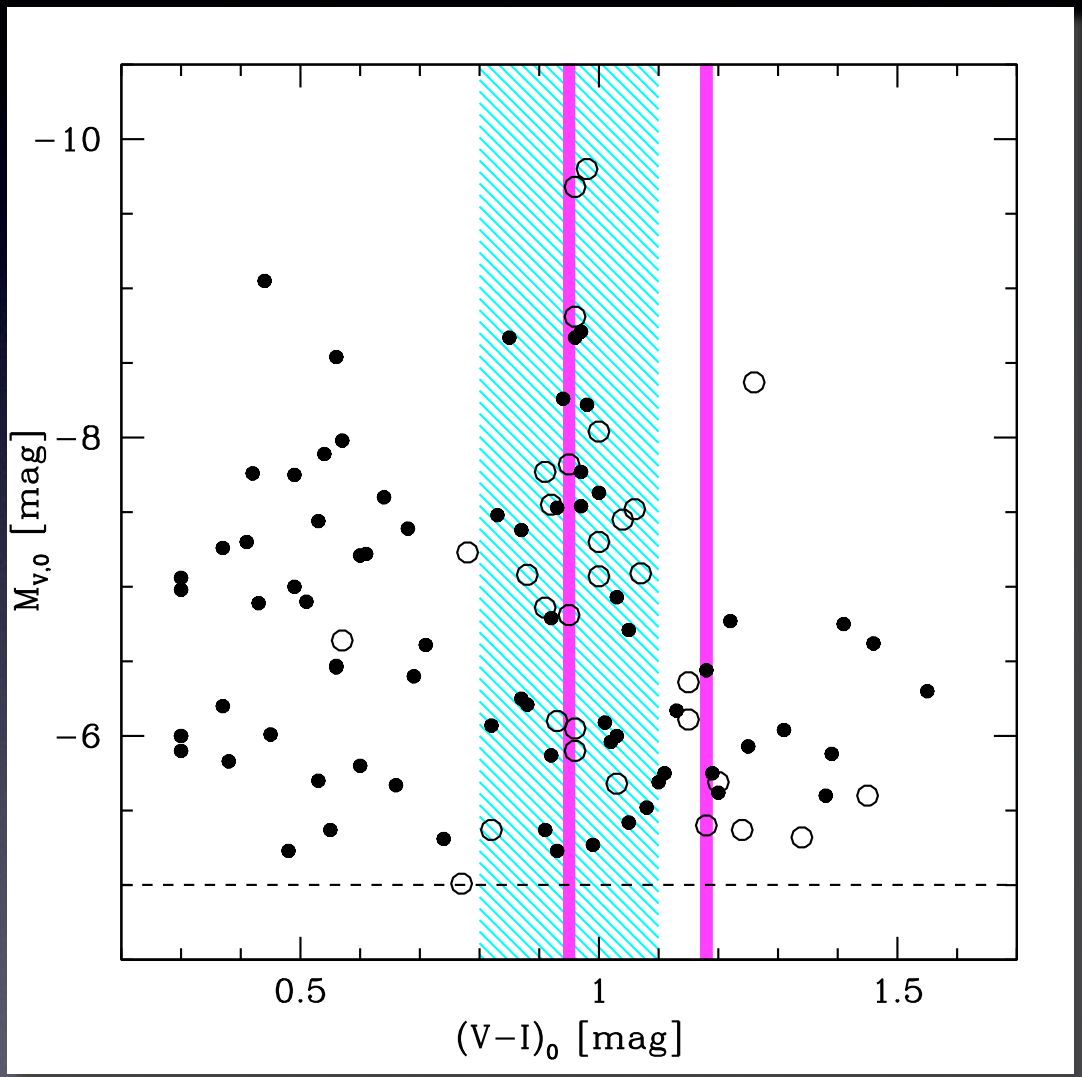
10 of 18 dSph have GCCs
18 of 36 dIrr have GCCs
2 of 3 dSph/dIrr have GCCs

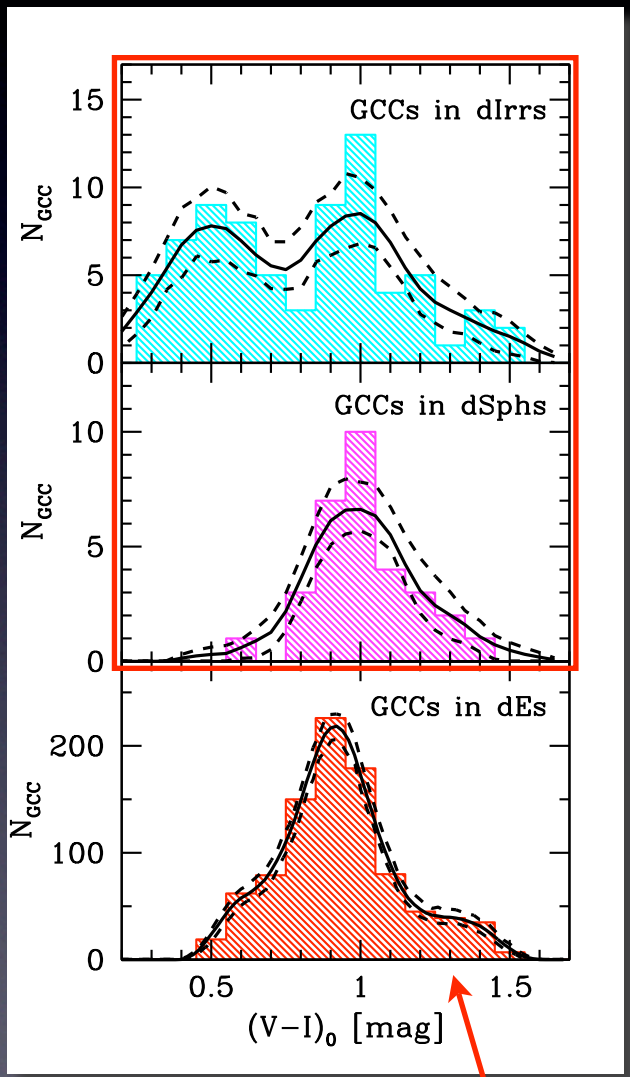
slightly higher fraction compared to Local Group where 12 of 36 galaxies host GCs (Hodge et al. 2002).



Sharina, Puzia, Makarov (2005, A&A 442, 85)

Color Distribution of Globular Cluster Candidates

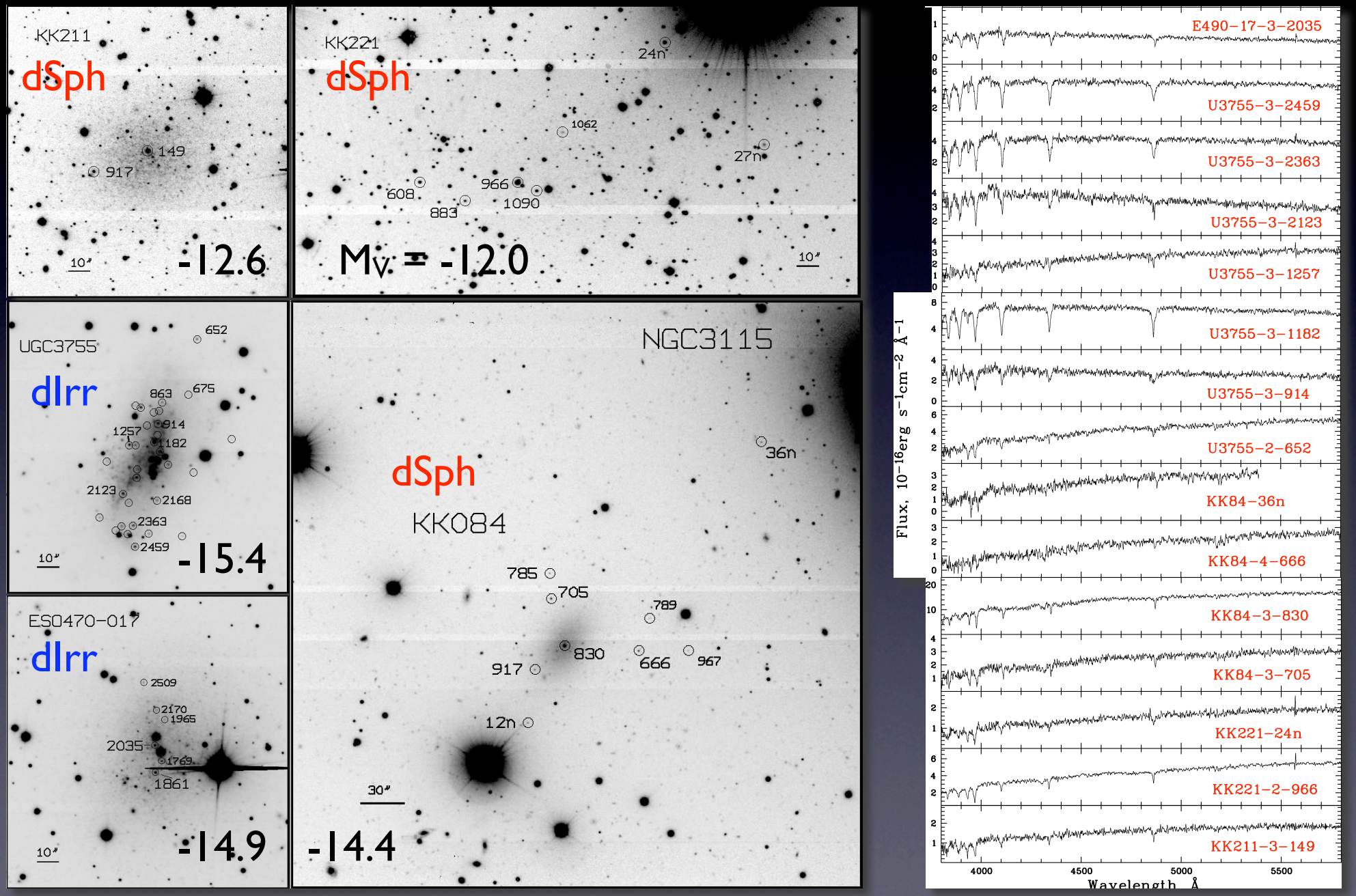




Sharina, Puzia, Makarov (2005, A&A 442, 85)

Virgo/Fornax
(Lotz et al. 2004)

VLT Spectroscopy



Confirmed GCs

TABLE 4
RESUMÉ OF GC DETECTIONS.

Name	GCCs	$Obj_{sel.}$	#Slits	$\#Slits_{SPM05}$	GCs	Gal.	Stars	Faint	faint GCCs
KK211	2	11	26	2	2	5	12	7	
KK221	5	19	36	5	6	6	5	19	KK221-3-1062
KK084	8	96	39	7	7	13	7	12	KK84-2-789
UGC3755	32	74	39	10	10	8	9	12	U3755-3-1963
E490-017	5	14	28	3	2	9	8	9	E490-017-3-1861

NOTE. — Columns contain numbers of: (2) GCCs in each galaxy listed by SPM05, (3) total number of GCCs selected on the VLT images, (4) slits on GCCs in total, (5) number of slits on SPM05 targets, (6) spectroscopically confirmed GCs, (7) number of background galaxies in slits, (8) Galactic stars, (9) faint object in total, the nature of which is unclear. In the last column we list the names of GCs that are too faint to measure their radial velocities with reliable accuracy from our observations.

26 of 27 HST-selected GCCs confirmed.

96% success rate!

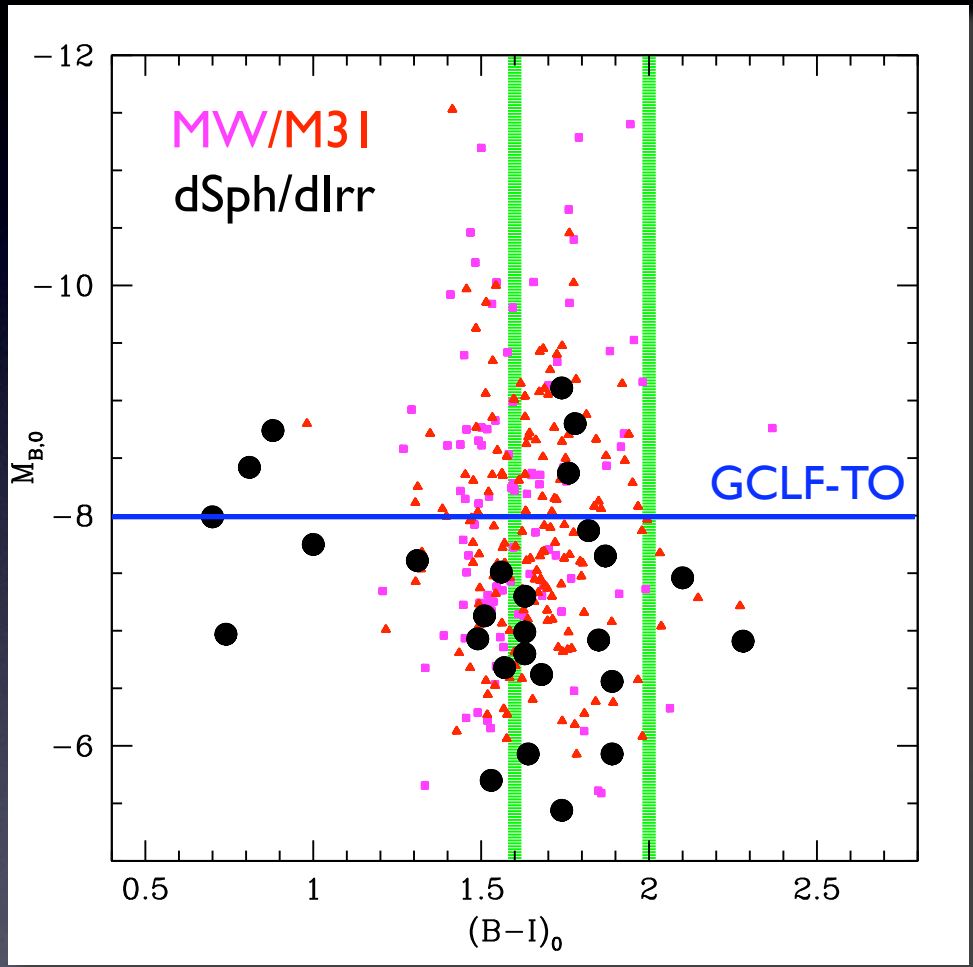
Most GCCs selected from ground-based pre-imaging are contaminants!

GC Sample

TABLE 5
PROPERTIES OF SPECTROSCOPICALLY CONFIRMED GCS IN OUR SAMPLE LSB DWARF GALAXIES

GC	RA (J2000) DEC	B	M_B	$B-V$	$B-I$	V_h
KK211-3-149	13 42 05.6 −45 12 18	20.64	−7.13	0.69	1.51	580±23
KK211-3-917	13 42 08.0 −45 12 28	21.84	−5.93	0.93	1.64	620±39
KK221-2-608	13 48 55.1 −47 00 07	21.08	−6.92	1.12	1.85	541±32
KK221-2-883	13 48 53.0 −47 00 16	22.07	−5.93	1.14	1.89	546±46
KK221-2-966	13 48 50.5 −47 00 07	19.20	−8.80	1.00	1.78	509±25
KK221-2-1090	13 48 49.6 −47 00 11	21.20	−6.80	0.97	1.63	478±29
KK221-24n	13 48 43.6 −46 58 59	20.70	−7.30	···	1.63	512±31
KK221-27n	13 48 39.0 −46 59 49	22.26	−5.44	···	1.74	466±35
KK084-2-785	10 05 35.8 −07 44 06	23.31	−6.62	0.68	1.68	856±24
KK084-3-705	10 05 35.7 −07 44 25	22.28	−7.65	0.73	1.87	670±31
KK084-3-830	10 05 35.0 −07 44 59	20.82	−9.11	0.57	1.74	594±32
KK084-3-917	10 05 36.5 −07 45 16	22.94	−6.99	0.53	1.63	619±28
KK084-4-666	10 05 31.5 −07 45 03	22.47	−7.46	0.91	2.10	678±21
KK084-12n	10 05 36.8 −07 45 54	23.00	−6.93	···	1.49	911±40
KK084-36n	10 05 25.6 −07 42 33	23.02	−6.91	···	2.28	1210±27
UGC3755-2-652	07 13 50.1 +10 32 15	21.48	−7.87	1.11	1.82	323±21
UGC3755-2-675	07 13 50.4 +10 31 49	23.65	−5.70	0.81	1.53	367±21
UGC3755-2-863	07 13 51.3 +10 31 45	22.79	−6.56	1.13	1.89	290±33
UGC3755-3-914	07 13 51.4 +10 31 35	21.74	−7.61	0.75	1.31	284±24
UGC3755-3-1182	07 13 51.5 +10 31 26	20.61	−8.74	0.56	0.88	335±32
UGC3755-3-1257	07 13 52.3 +10 31 24	20.98	−8.37	1.10	1.76	327±31
UGC3755-3-2123	07 13 52.5 +10 31 01	21.36	−7.99	0.53	0.70	329±22
UGC3755-3-2363	07 13 52.2 +10 30 45	21.60	−7.75	0.76	1.00	312±18
UGC3755-3-2168	07 13 51.4 +10 30 58	21.84	−7.51	0.88	1.56	324±28
UGC3755-3-2459	07 13 52.2 +10 30 35	20.93	−8.42	0.32	0.81	333±32
E490-017-3-2035	06 37 57.3 −25 59 59	21.16	−6.97	0.33	0.74	529±34
E490-017-3-1861	06 37 57.3 −26 00 13	21.45	−6.68	0.50	1.57	522±9

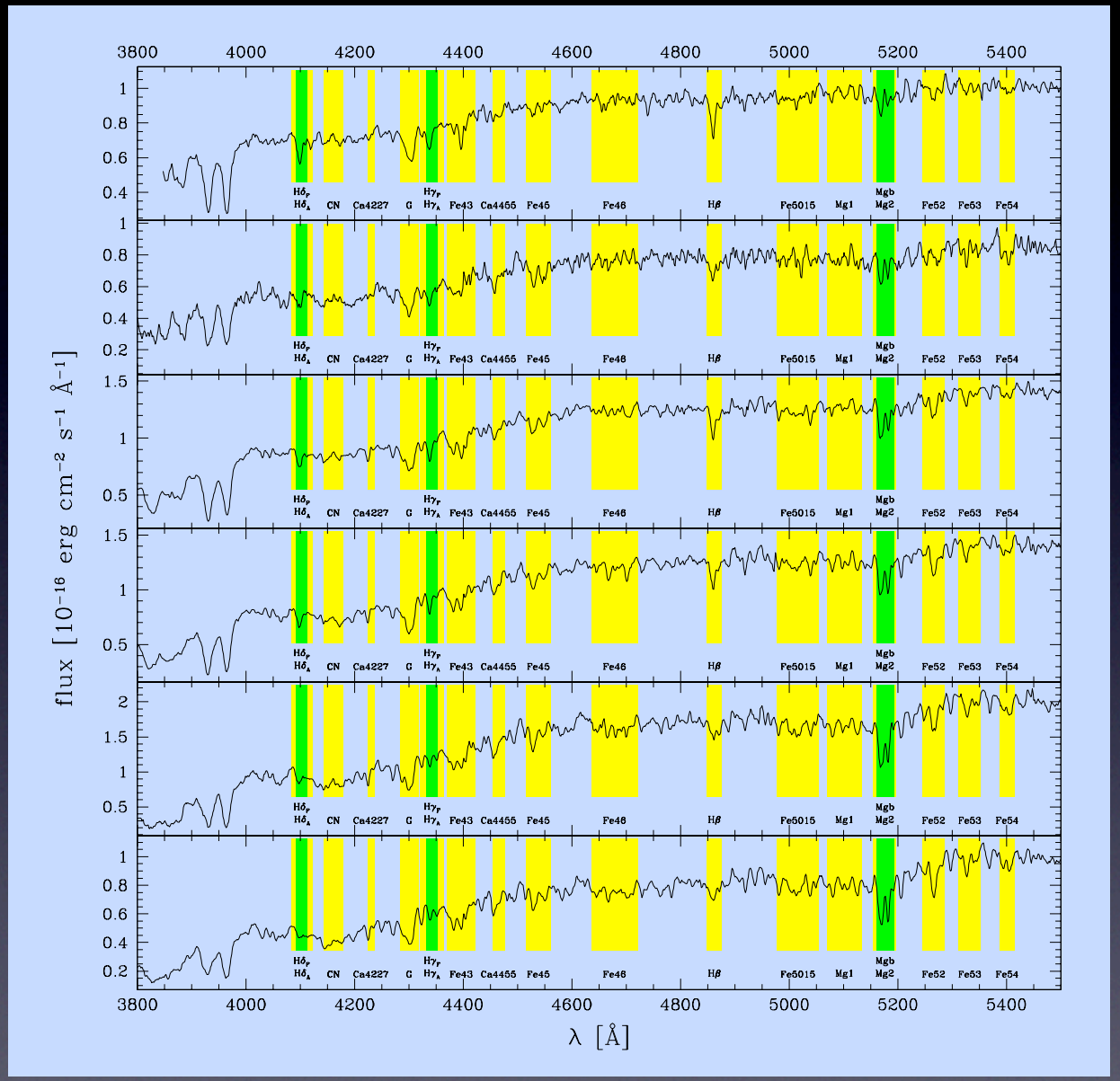
NOTE. — Columns contain the following data: (2), (3) equatorial coordinates, (4) integrated B magnitude from our FORS2 photometry corrected for Galactic extinction (Schlegel et al. 1998), (5) absolute magnitude computed with the distances from Table 1, (6),(7) integrated $B-V$ and $B-I$ colours corrected for Galactic extinction (Schlegel et al. 1998), (8) heliocentric radial velocities measured in this study.



Contamination is very unlikely...

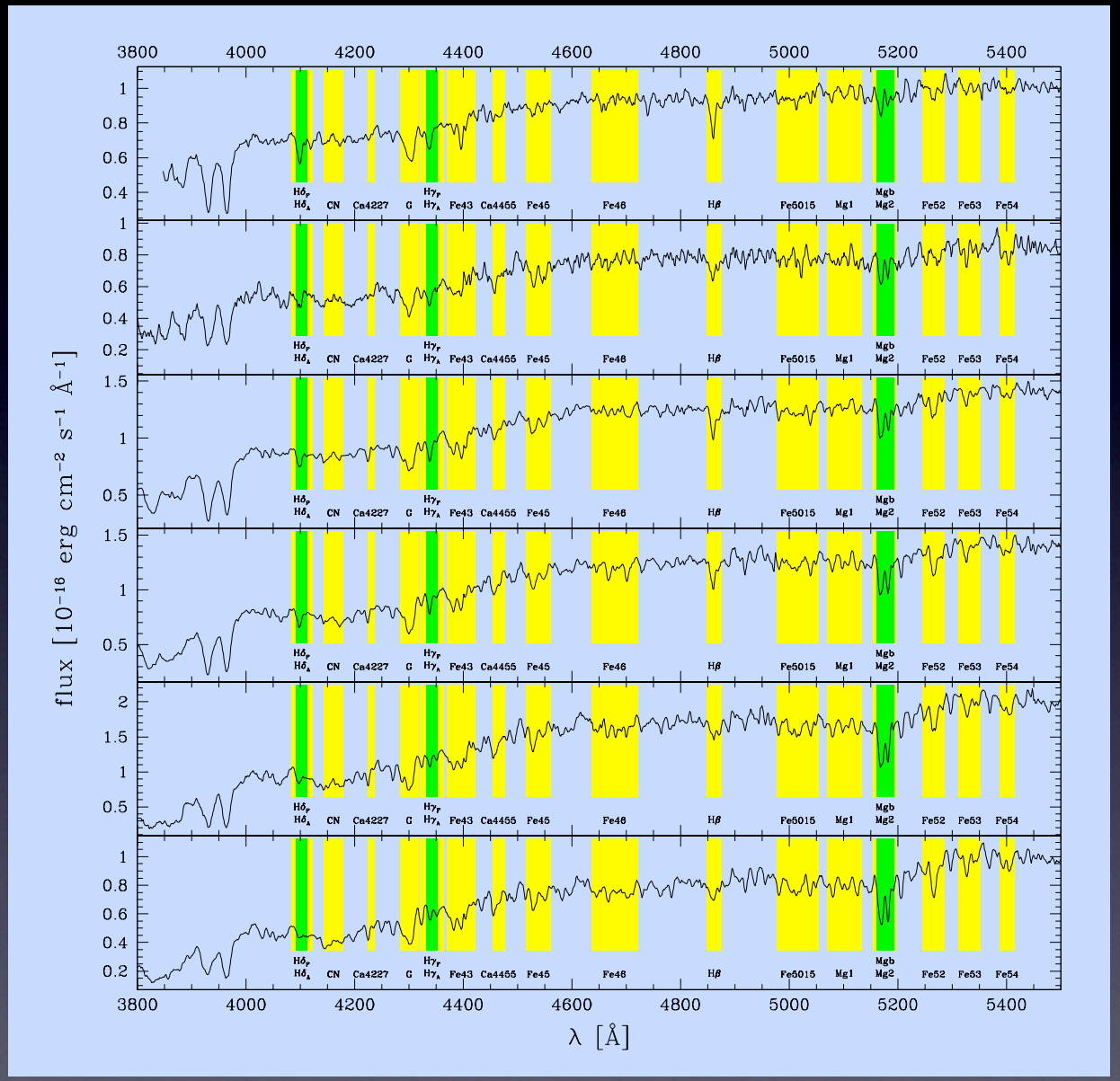
Puzia & Sharina (2007, ApJ submitted)

GC spectroscopy: Lick index system



GC spectroscopy: Lick index system

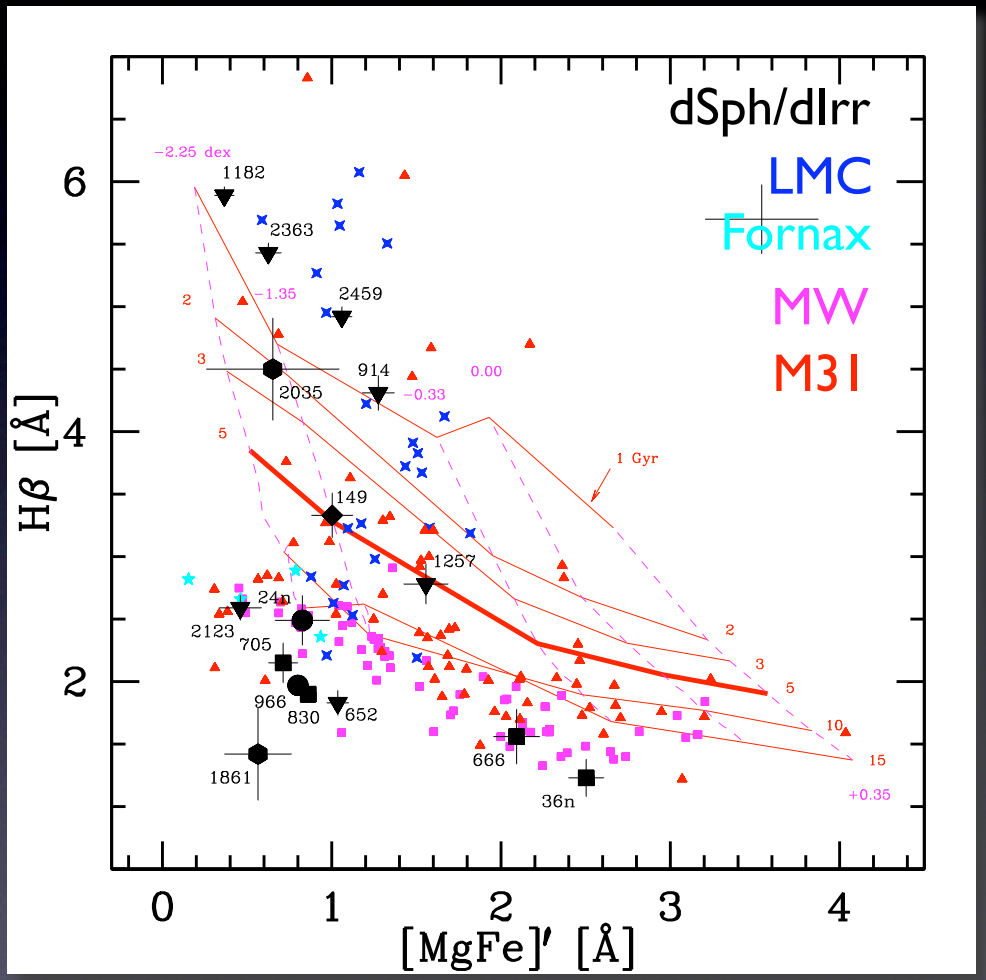
- defined in the 80s by the Lick group (Burstein, Faber et al.)
- 25 indices that cover 4100-6400 Å
- Lick system provides "simple" means to calculate theoretical index predictions
- designed to investigate stellar populations of giant elliptical galaxies ⇒ 8-12 Å resolution

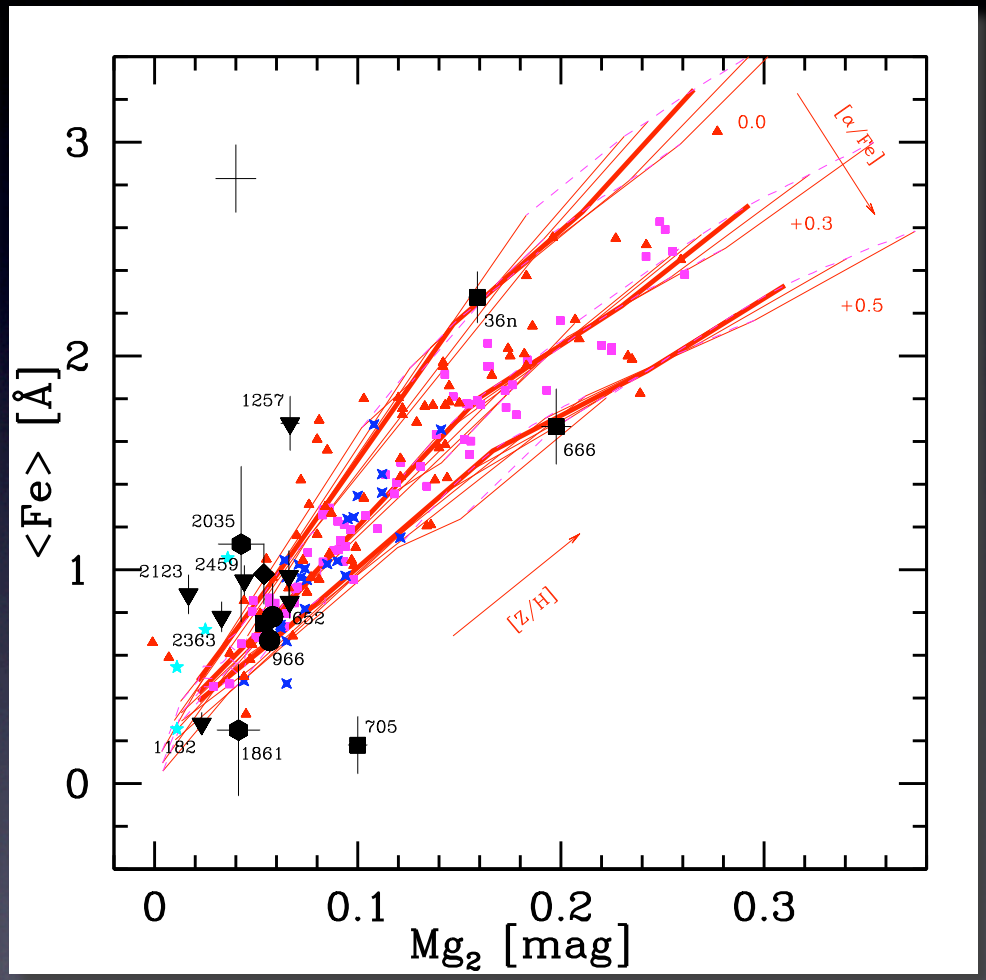


metallicities, chemical compositions, ages

Diagnostic Diagrams

models from Thomas et al. (2003)

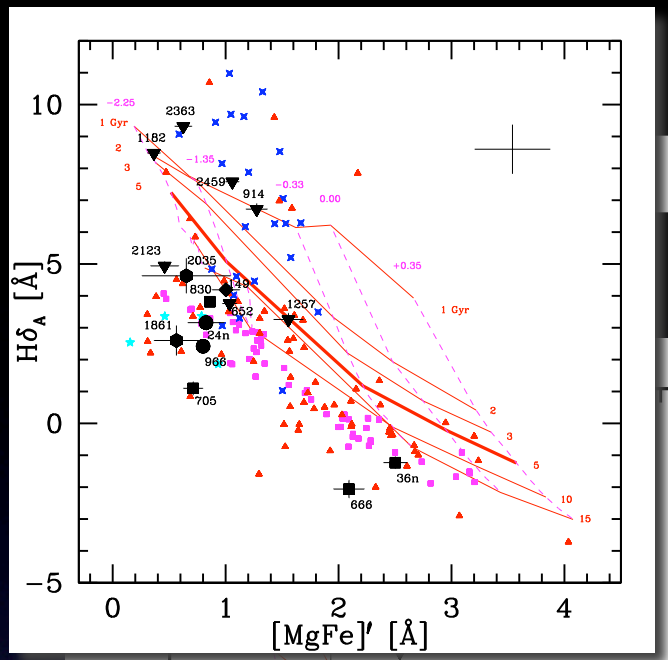


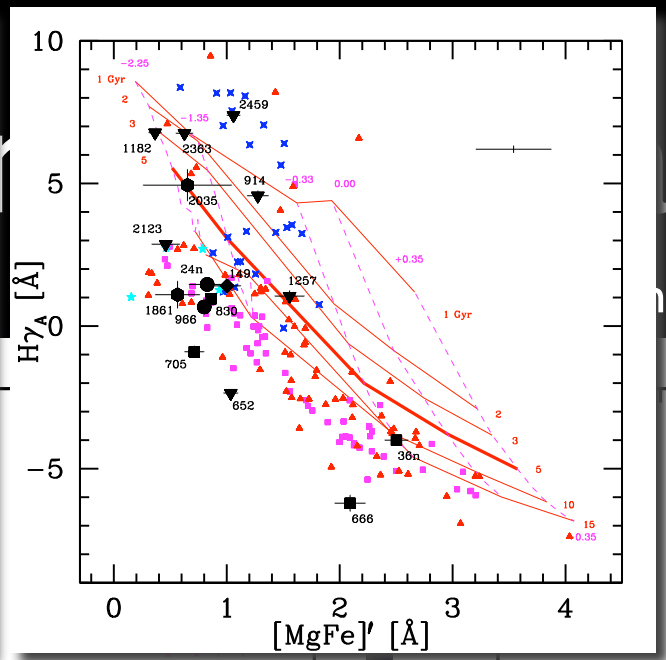


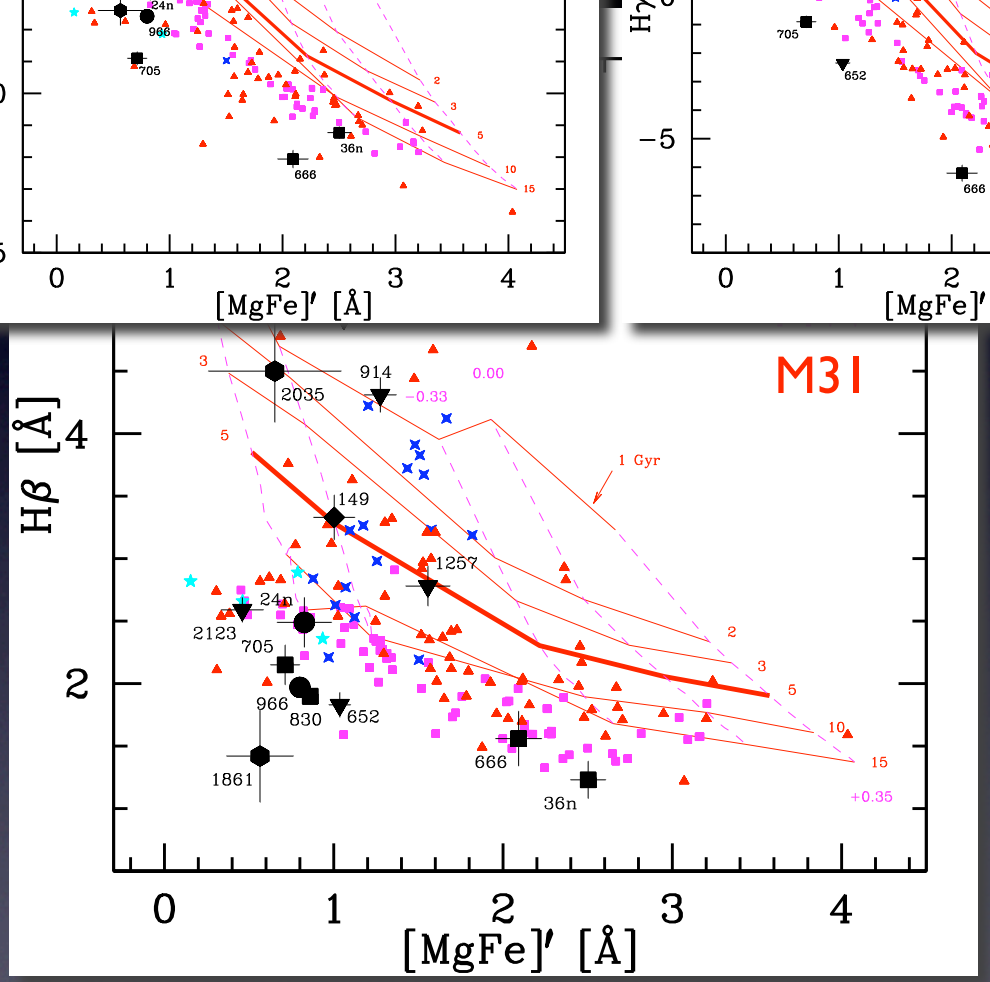
GCs are metal-poor, show a bimodal age distribution, and have a spread in [α/Fe] ratios.

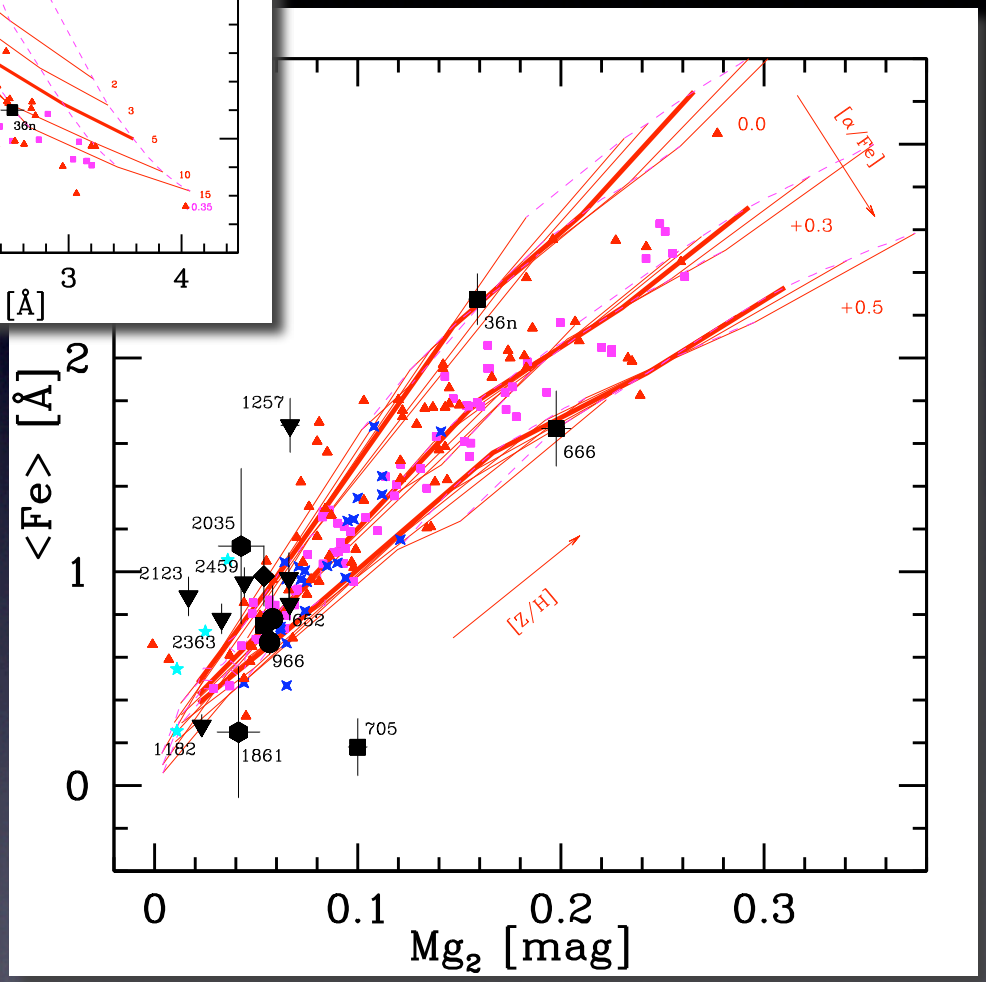
grams

odels from Thomas et al. (2003)









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Ages, Metallicities, [α/Fe]

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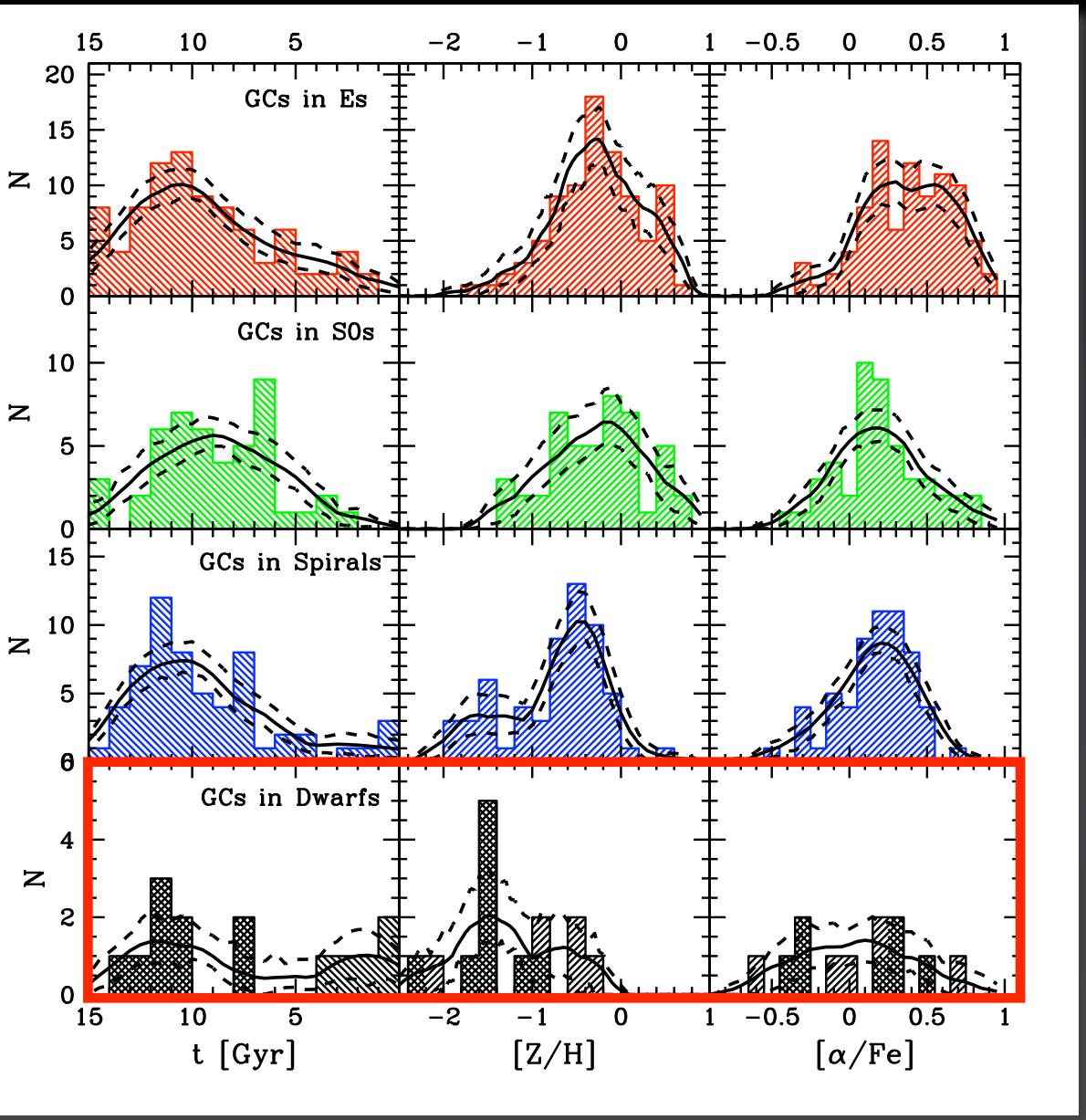
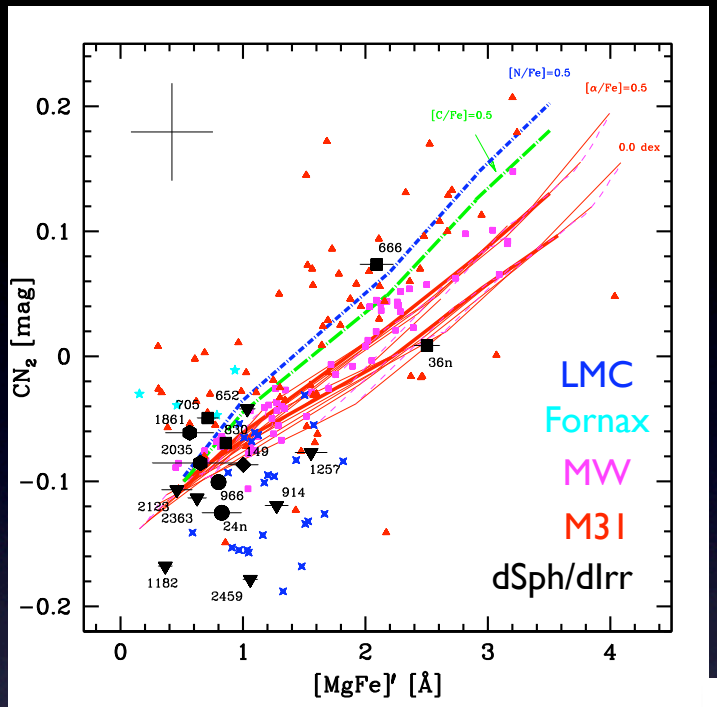
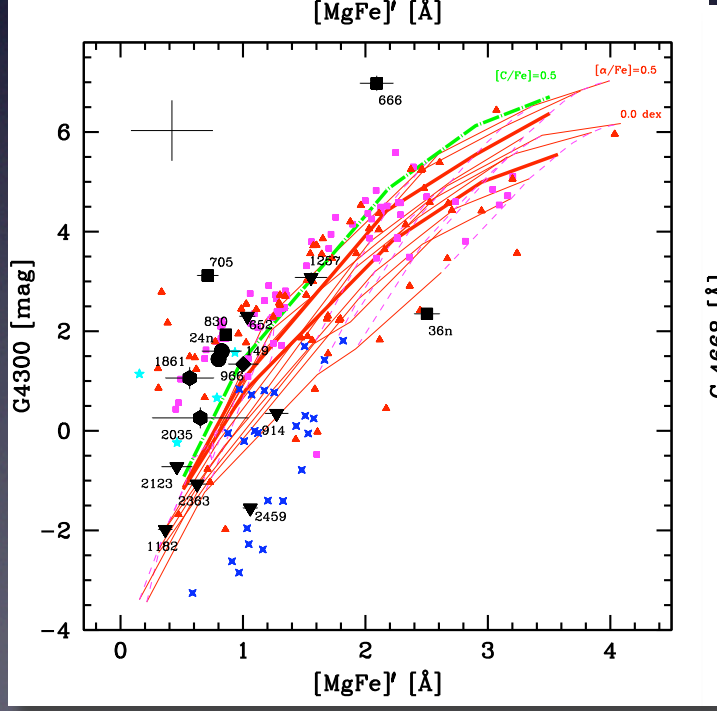
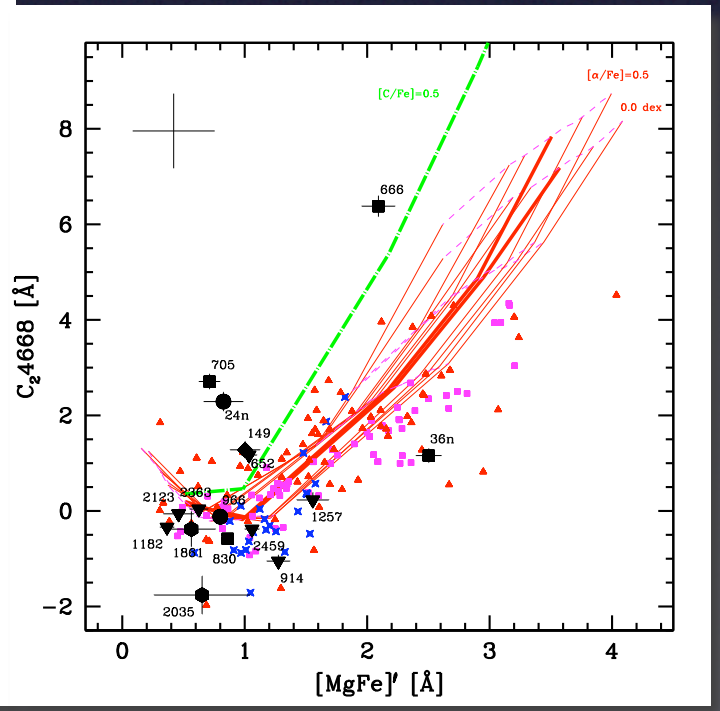


- large age spread (driven by UGC 3755!)
- most GCs in dwarfs have low metallicities ([Z/H] ≲ -1.0)
- spread in [α/Fe] with average ~0.0 dex for young and old GCs!
- Limits on accretion of GCs onto massive galaxies, ... but beware of selection!

Chemical Composition

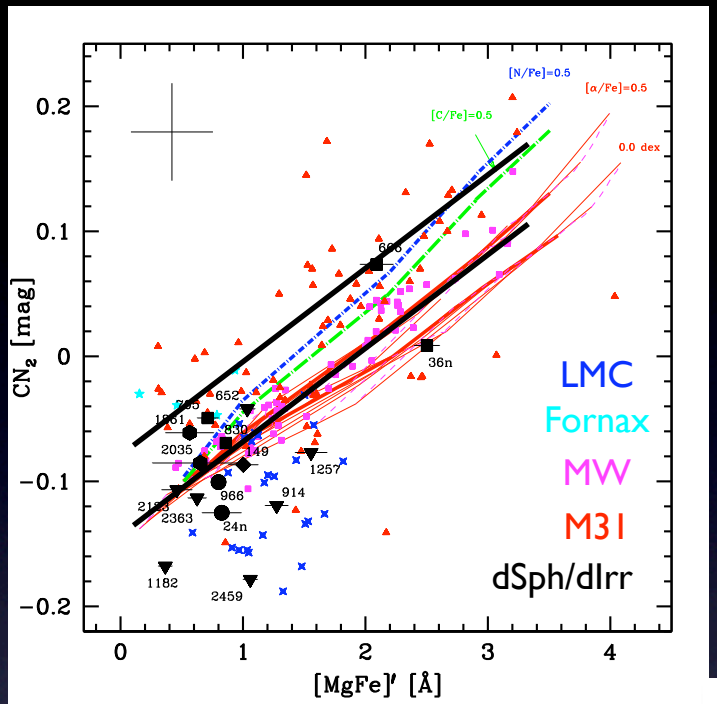


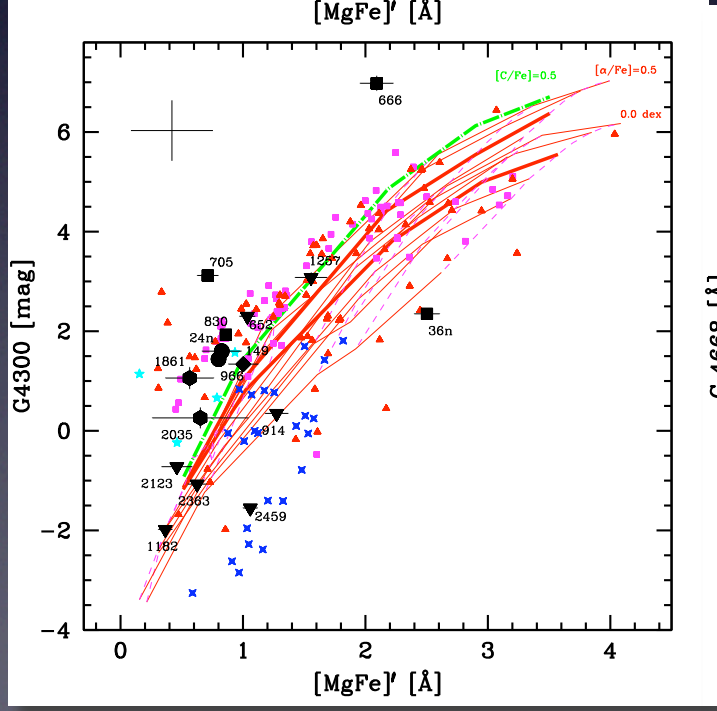


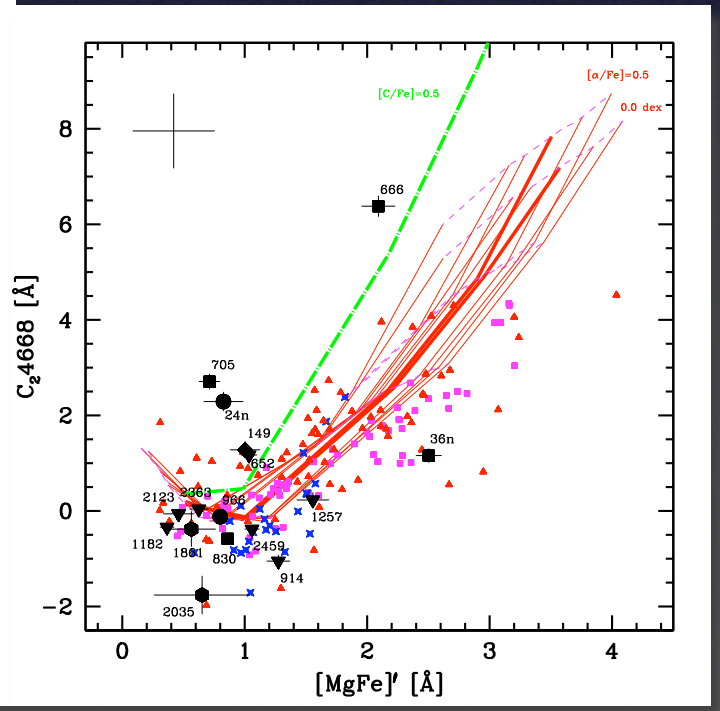


Chemical Composition

CN offset between MW and M31 GCs!







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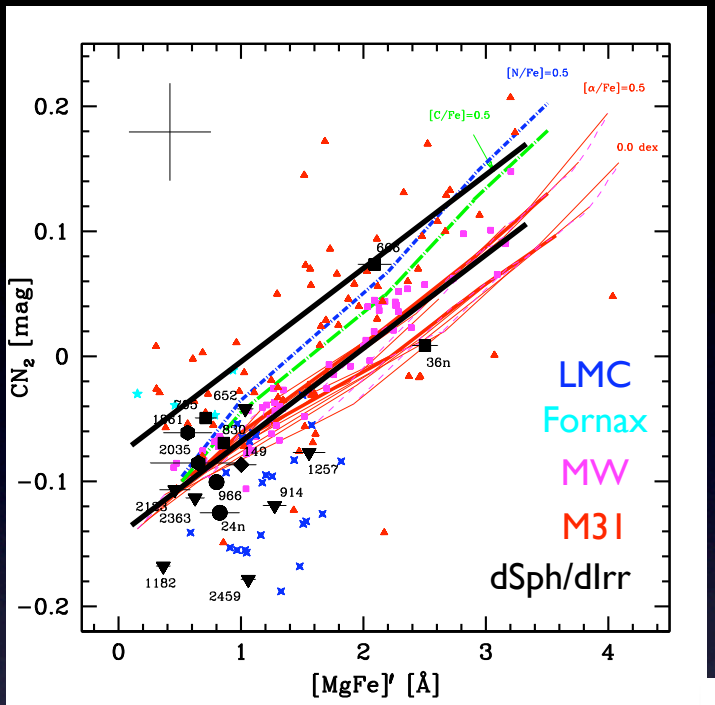
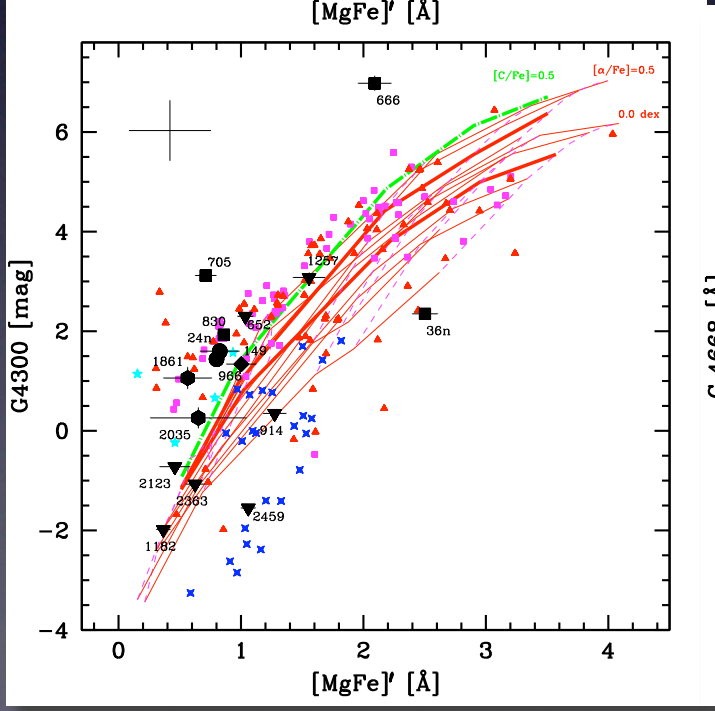
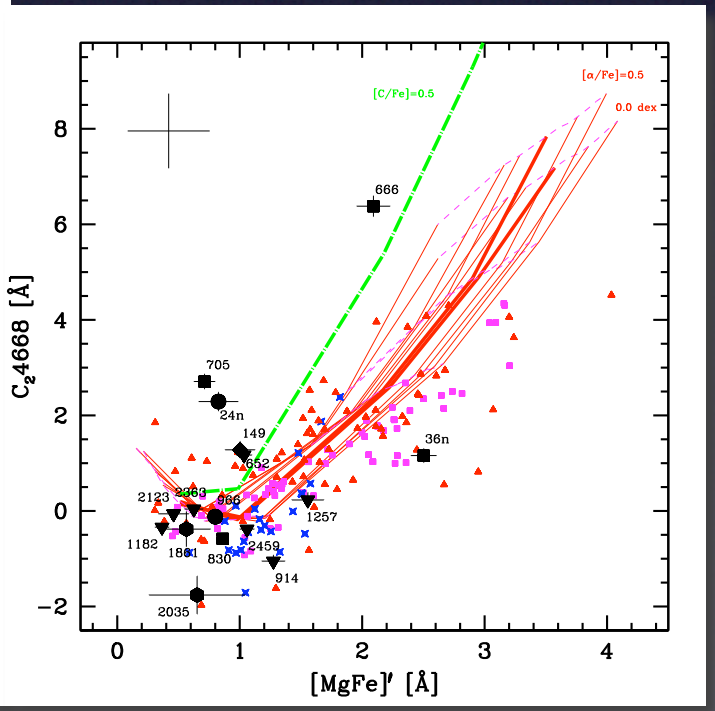


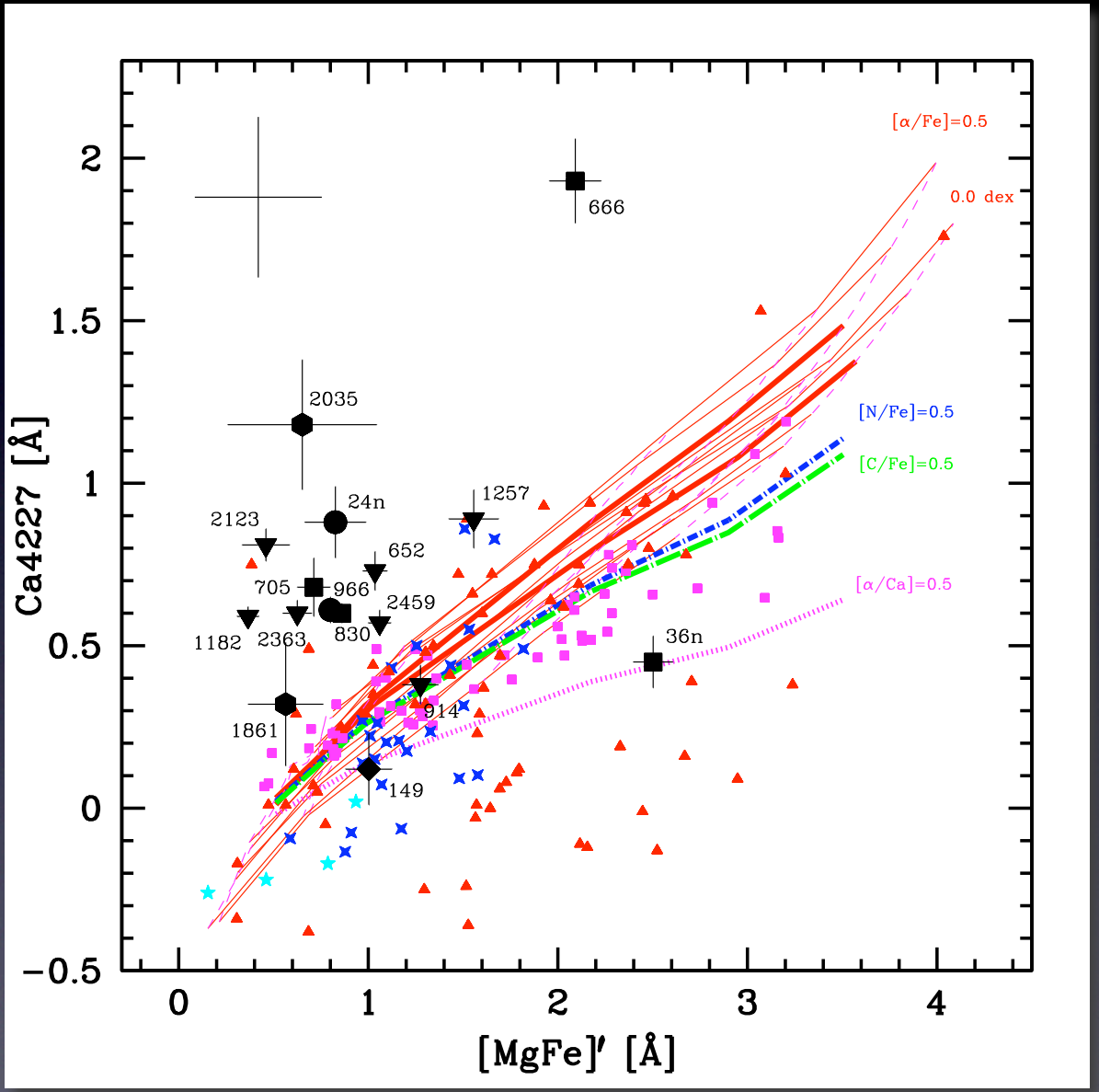
no offset in C-sensitive indices!





- CN offset + no offset in G4300 and $C_2$4668, implies a factor >3 Nitrogen enhancement of old M31 GCs relative to dSph/dIrr GCs at similar [Z/H]
- Consistent UV spectroscopy of NH band @3300A (Li & Burstein (2003).
- GCs in dSph/dIrr galaxies cannot have contributed to the assembly of M31's old GC system but perhaps to intermediate-age GCs, and only partly to the Galactic cluster system.

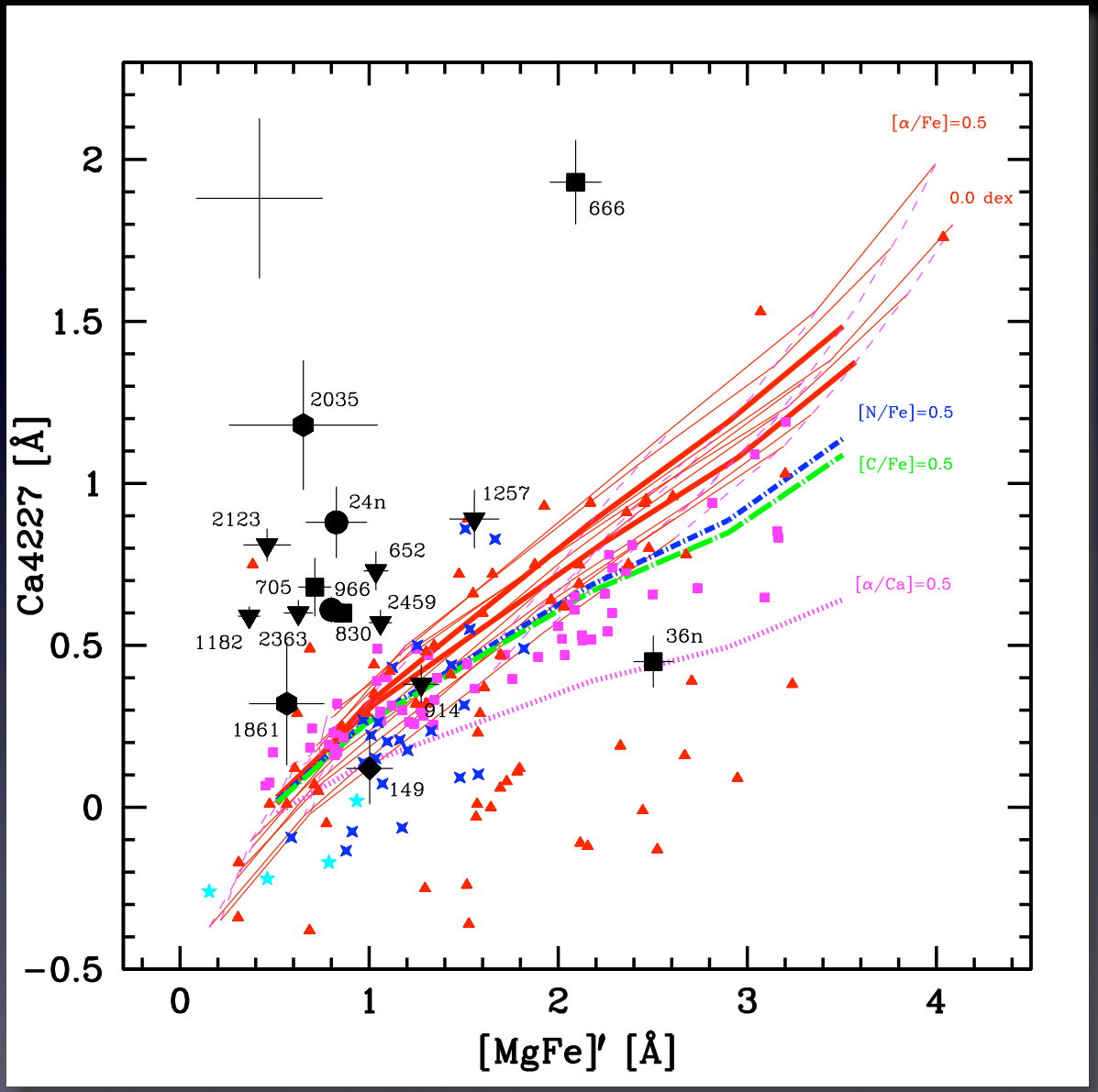
Chemical Composition II



Chemical Composition II

Ca enhancement in dSph/dIrr GCs?

Not due to C and/ or N abundance variations!



Summary

Summary

- GCs exist in dSph/dIrr galaxies down to M_V = -12.0!
- 26/27 HST selected GC candidates were confirmed as genuine GCs via radial velocities; in particular faint GCs with M_V > -7 mag were all confirmed!
- most GCs in dSph/dIrr are metal-poor and have spectroscopic [Z/H] < -1.0
- age spread: mainly old GCs + few ~1Gyr clusters
- spread in [α/Fe] with mean ≃ 0.0 dex; young+old GCs
- unique chemical composition of GCs in dSph/dIrr; attractive option for chemical tagging of GCs in massive galaxies