PROBING THE LMXB-GC CONNECTION IN NGC1399

A wide field Chandra/Hubble-ACS study

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THE GC-LMXB CONNECTION

The Facts

- 5% of GC host LMXBs, but up to ~70% of LMXB are in GC in E galaxies.
- More abundant in GC than in field per unit stellar light
- More likely in brighter/more massive GC
- 3 times more abundant in red than in blue GC
- Reside preferentially in compact GC

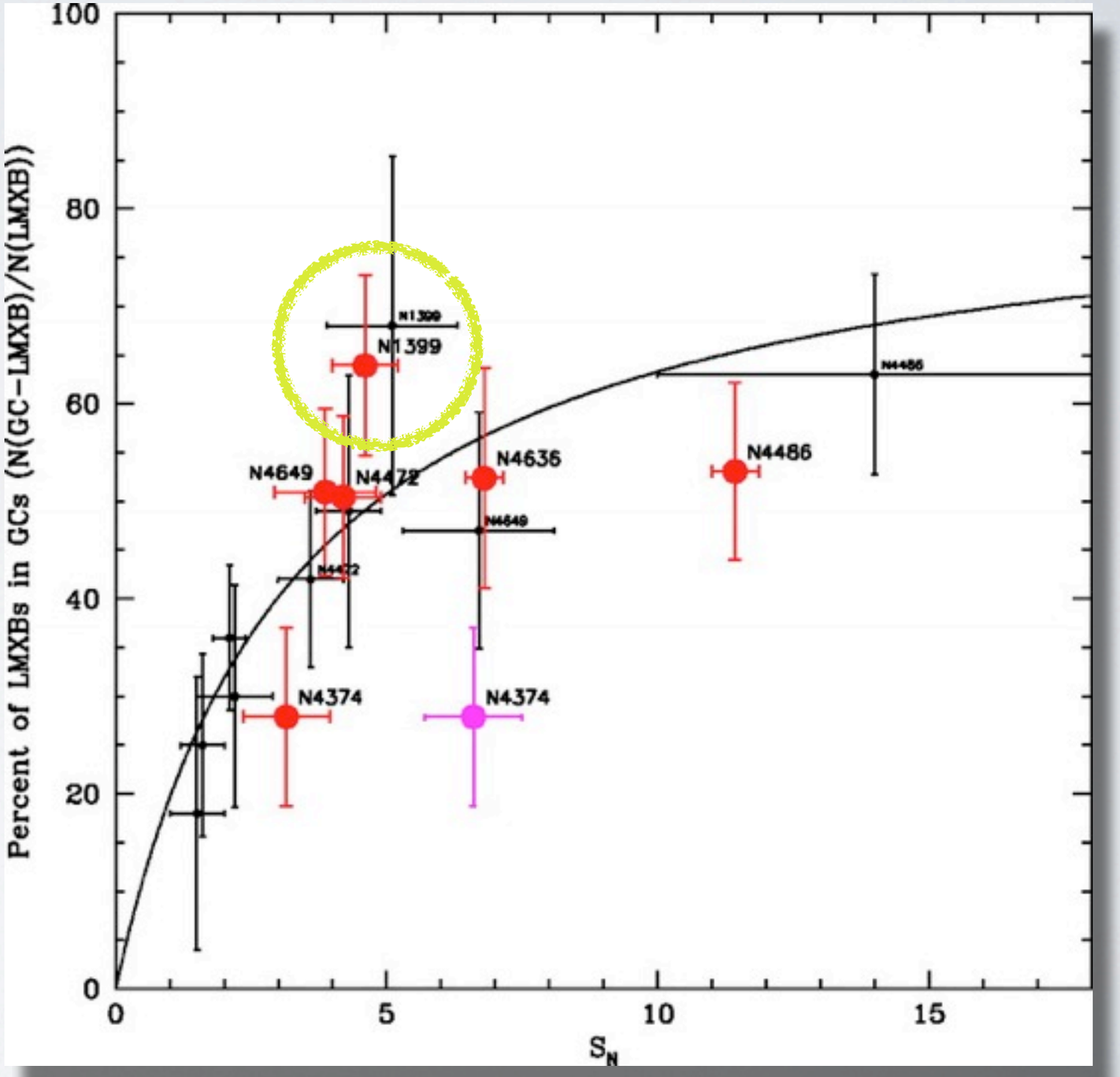
The Questions

- Do GC and field LMXB follow different evolutionary paths? Are they formed in GCs and later ejected/dispersed?
- Are different subpopulation intrinsically different?
- What are the primary factors influencing LMXB formation and survival?
- Are projection effects important?

Most high-resolution studies so far focused on the central region of early-type galaxies, which do not necessarily reflect the whole GC and LMXB population.

TARGET SELECTION

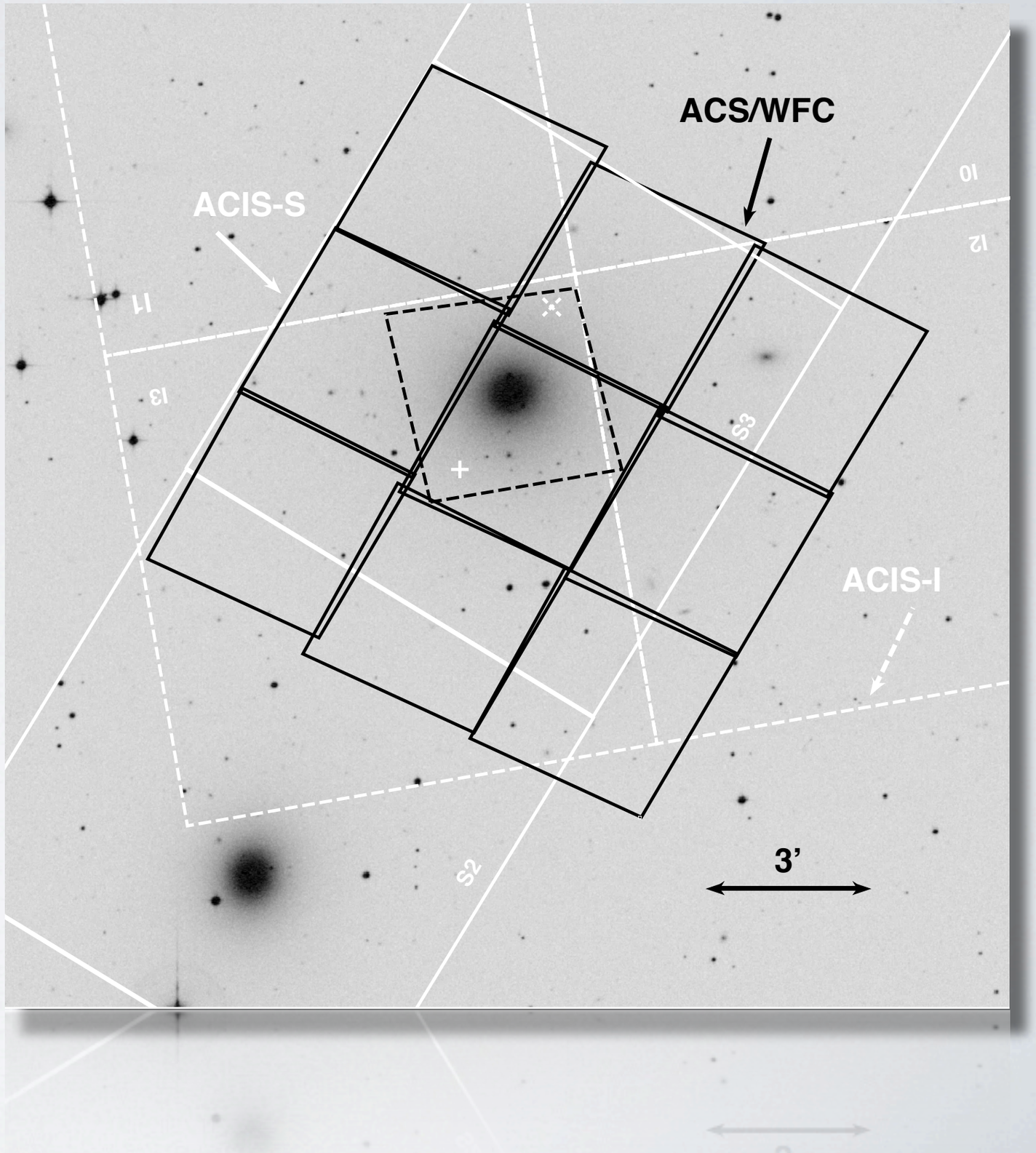
- Large Globular Cluster population
- Large number of X-ray binaries

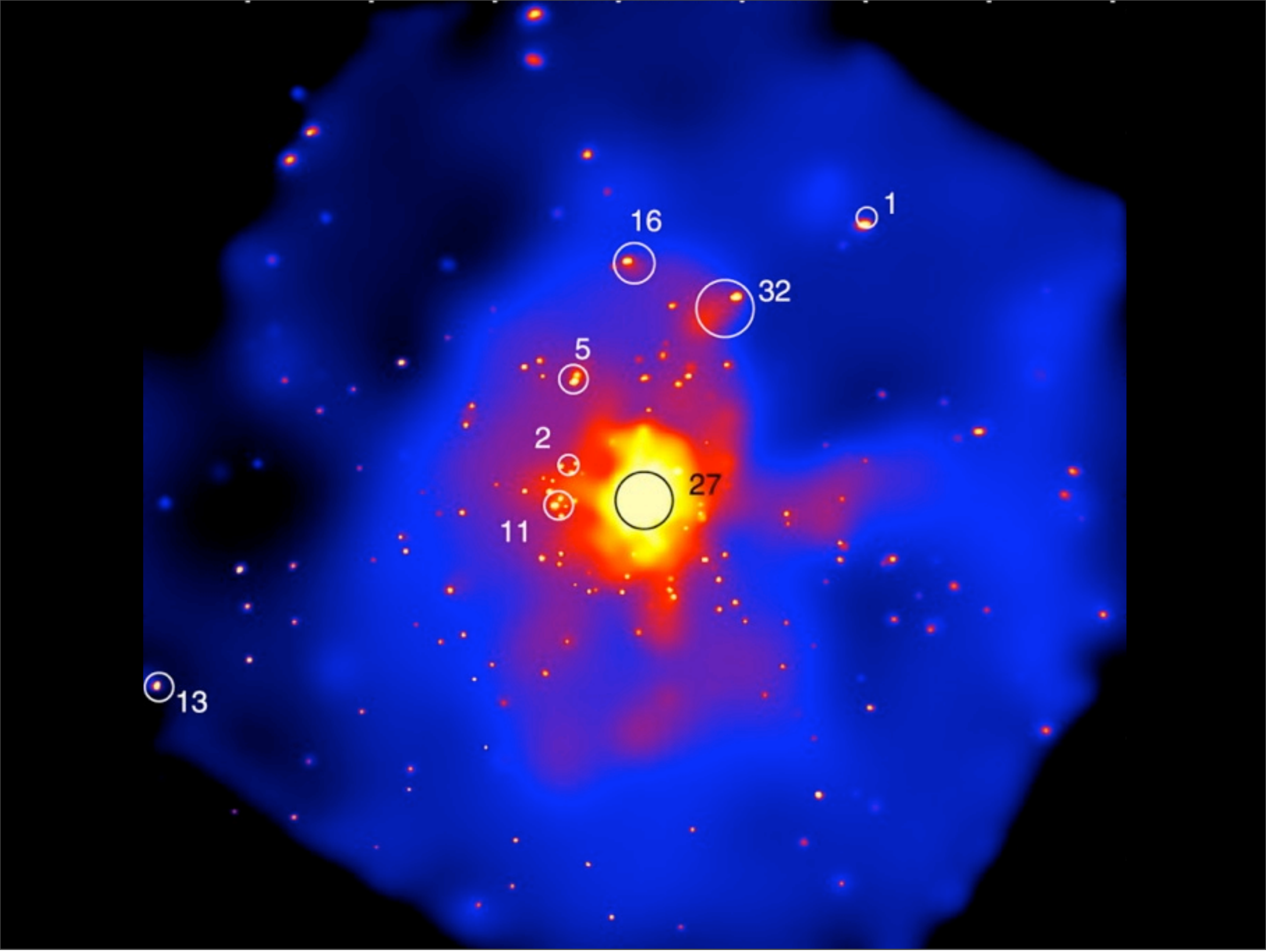


NGC1399 DATASET

NGC1399 (~20 Mpc) is an ideal target because allows to probe a large fraction of the galaxy and still resolve GC sizes.

- 9 HST V-band (f606w) observations, drizzled to super-Nyquist sampling the ACS PSF (2.9 pc/pix).
- Chandra ACIS-I + ACIS-S
- ACS *g*-*z* colors for central region
- Ground-based *C*-*R* photometry for part of the sources over the whole field

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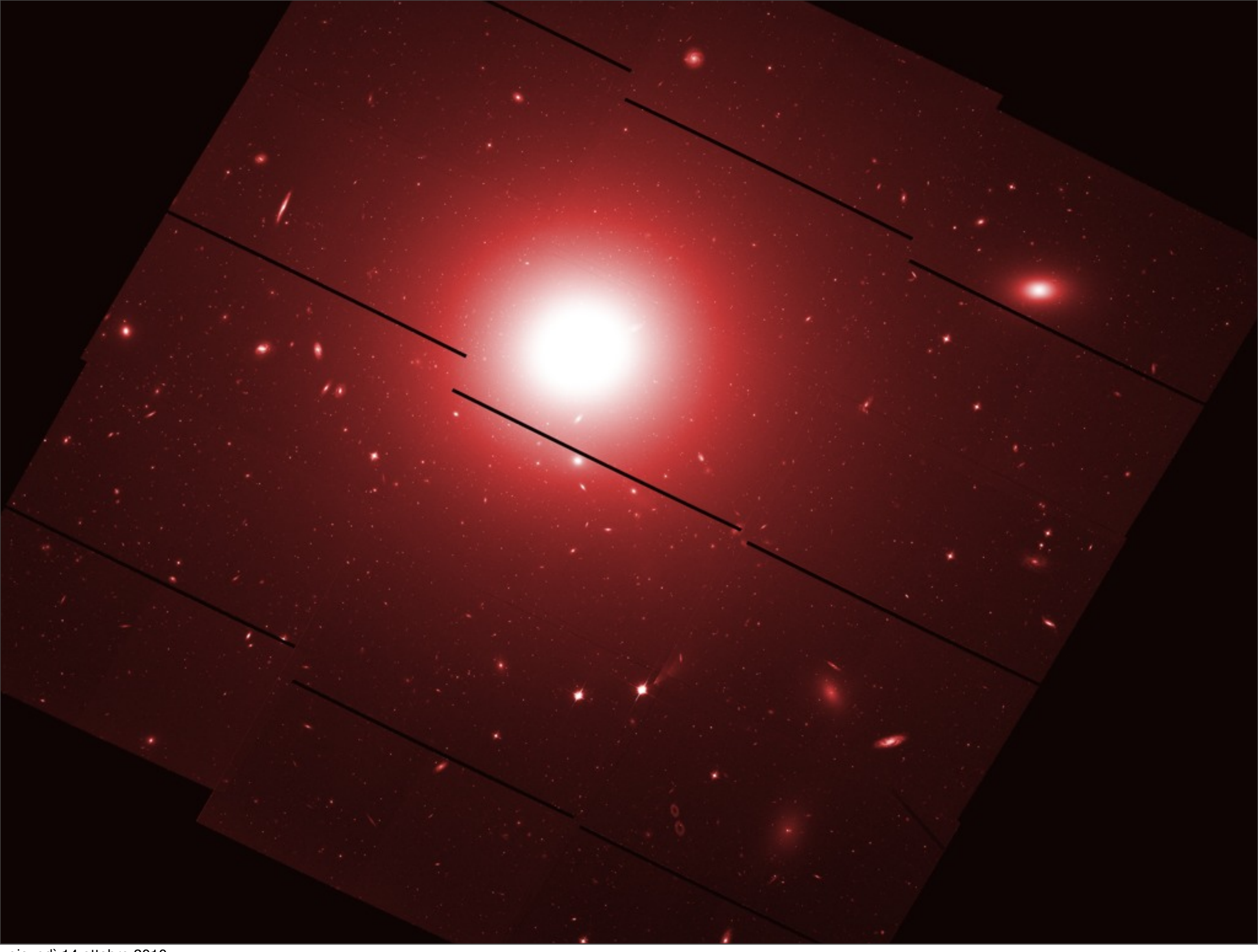
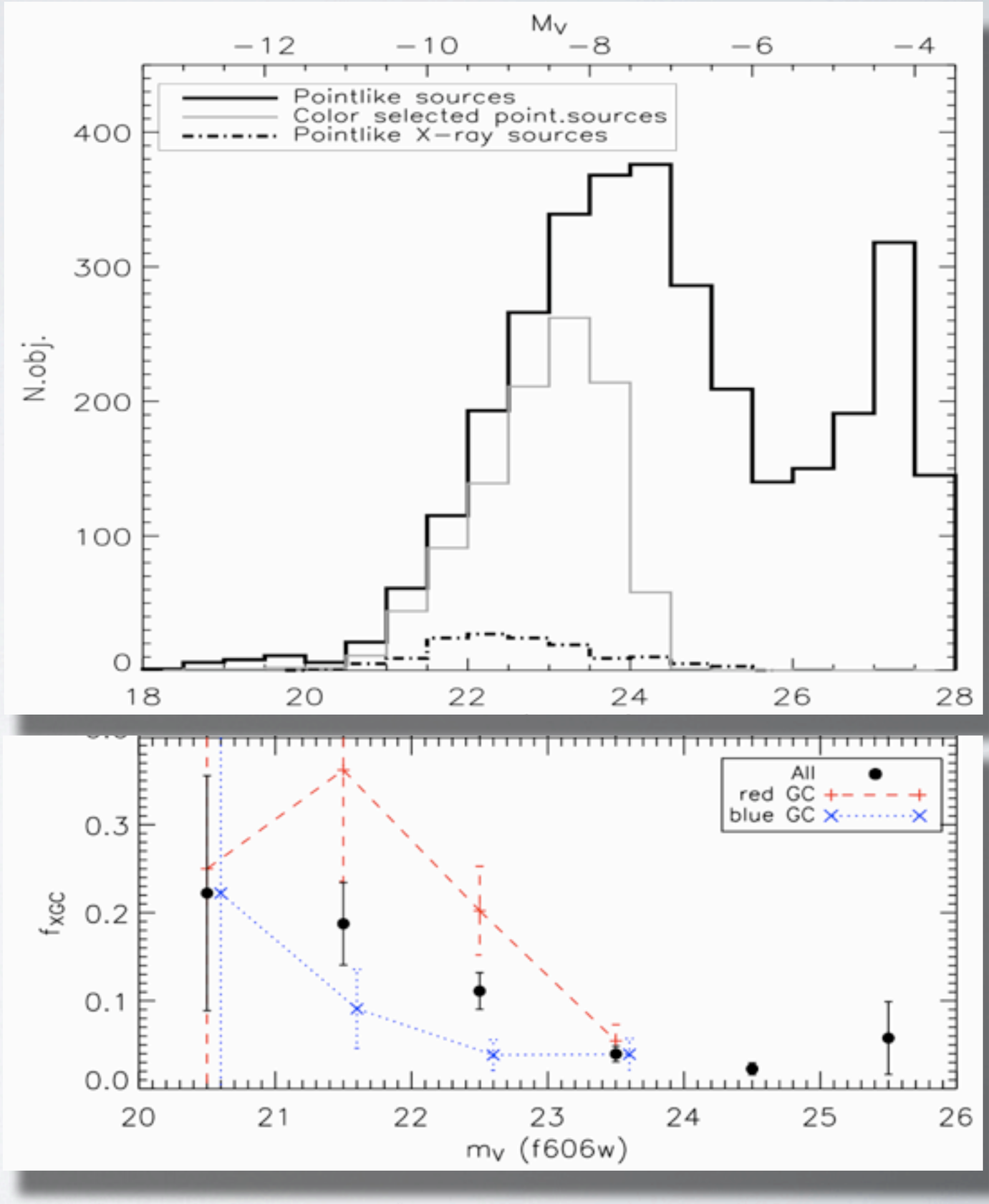


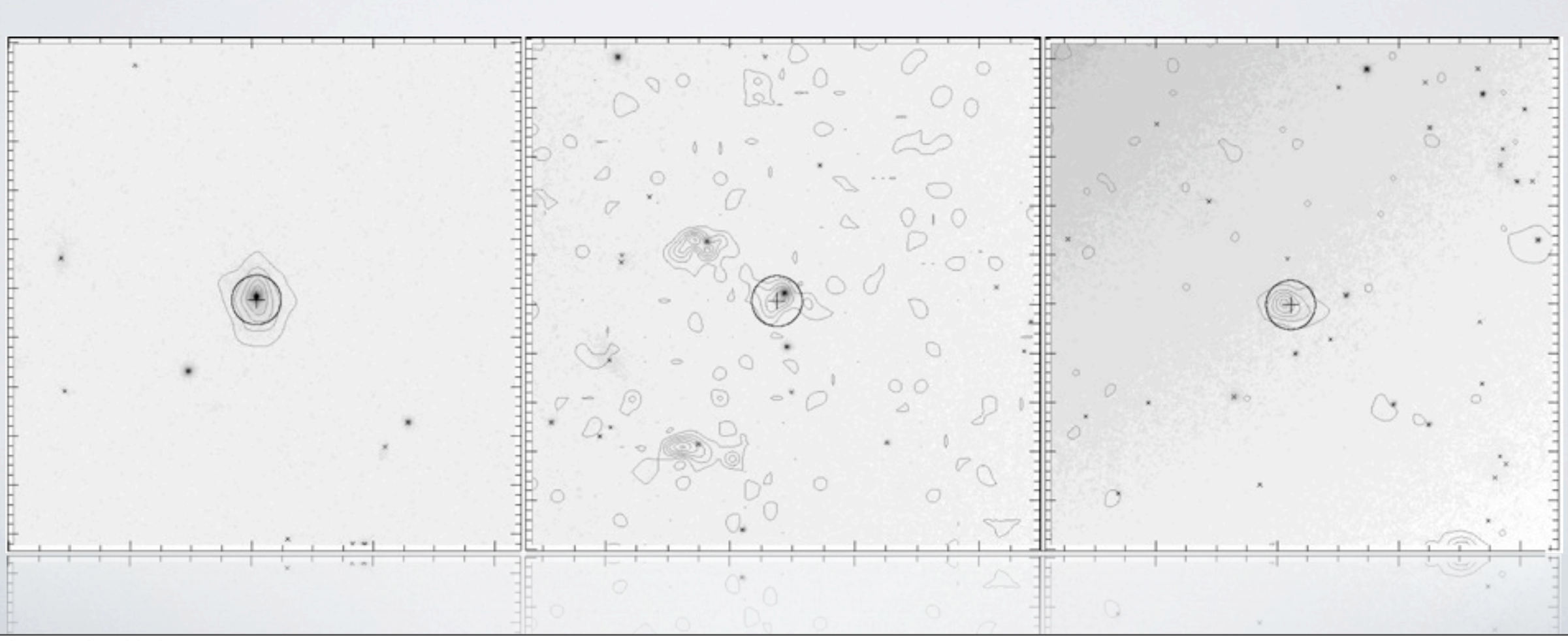
EXTRACTION AND IDENTIFICATION

- SExtractor generated catalog with 12915 sources
- GC selection: bright (m_V<26) compact (Stellarity index>0.9) sources resulting in ~2600 GCs
- Catalog is >80% complete and <10% contaminated by background galaxies
- LMXBs reside in bright/massive GC, scaling approx. linearly with magnitude



X-RAY/OPTICAL MATCHING

- optical catalog registered to USNO catalog with rms accuracy of 0.2”
- 230 X-ray sources detected in ~100 ks of Chandra time using *ACIS Extract* software (accounting for differential exposure, PSF etc.), resulting in positional accuracy of 0.33”
- X-ray sources matched to optical within 1” (*2.5* **σ** accuracy), 75% of which within 0.5”
- 164 sources with optical counterparts, 136 match GC candidates: $f_{GC-LMXB}$=65±5%



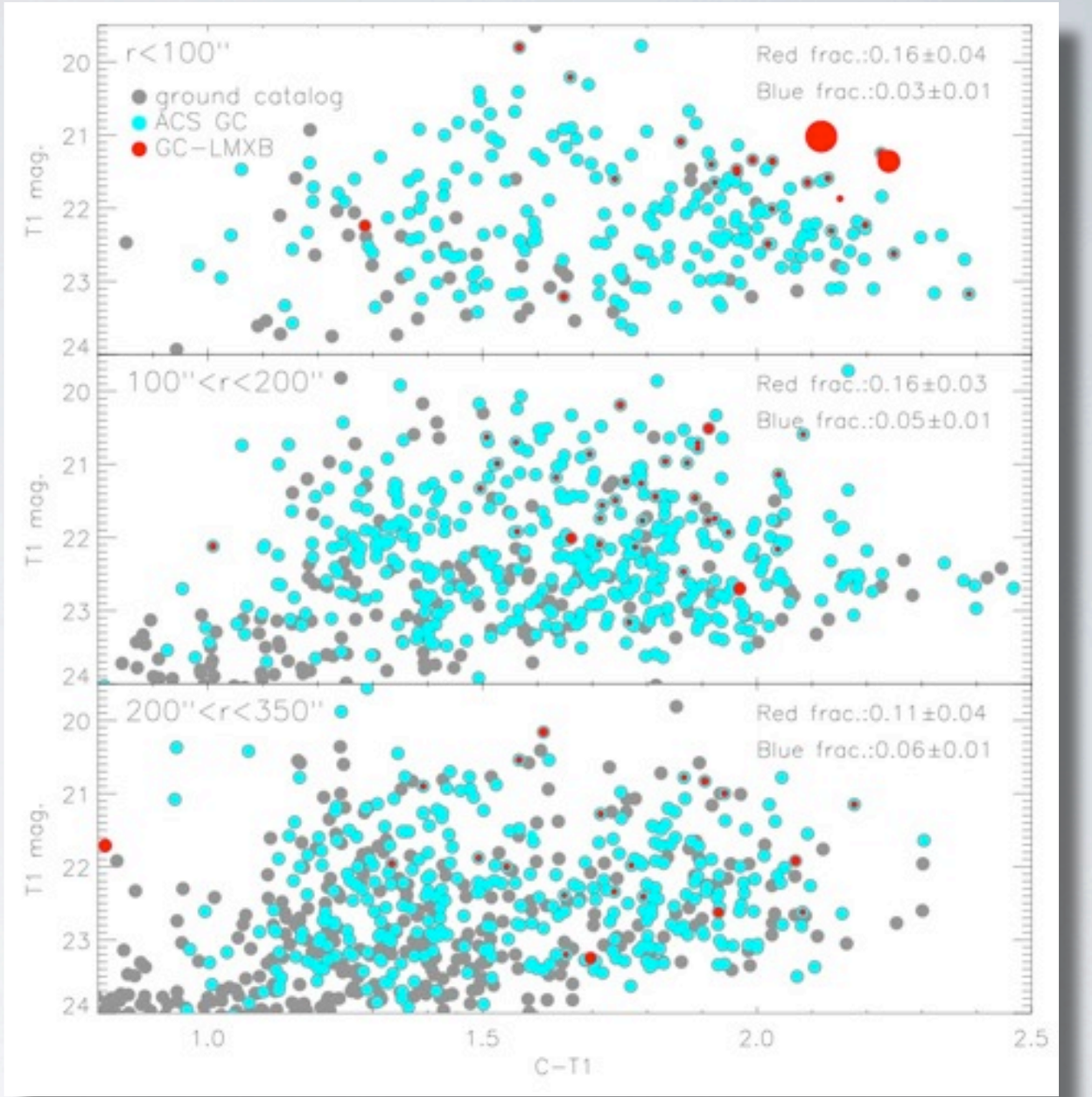
COLOR DISTRIBUTION

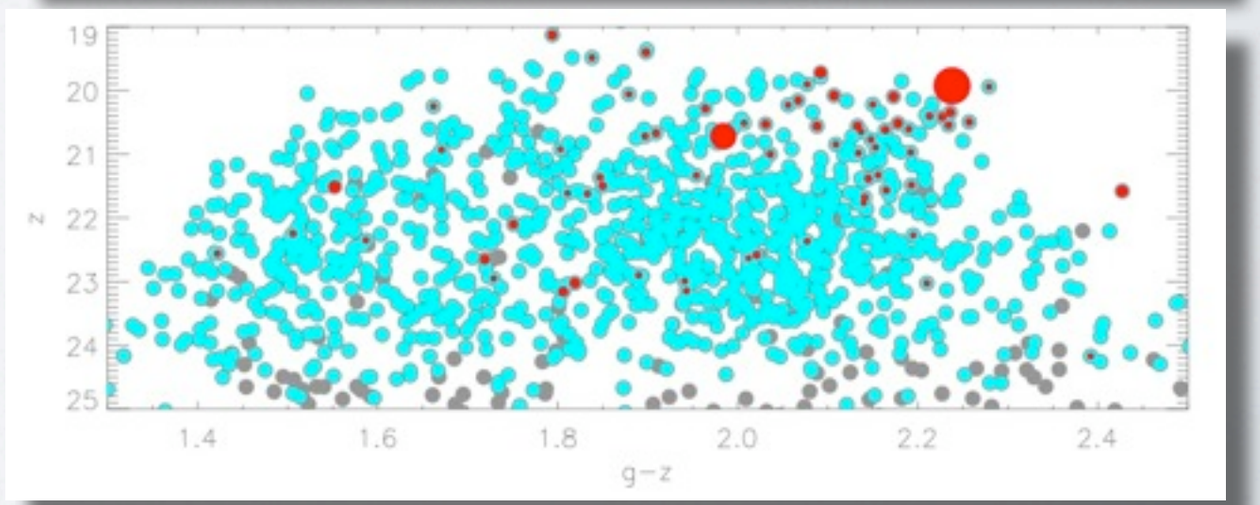
- GC are ~3 times more abundant in red GC, at all radii: ~15% in red GC vs ~5% in blue GCs (c.f. Kundu et al. 2007).

- The P_{LMXB} is constant (within errors) with respect to galactocentric distance

- We confirm the presence of a very red GC subpopulation in the galaxy core, hosting the majority of LMXBs.

	blue GCs	red GCs
Ground-based data	$T1 < 23$ $1.0 \leq C-R < 1.65$	$T1 < 23$ $1.65 \leq C-R < 2.2$
HST data	$z < 22.5$ $1.3 \leq g-z < 1.9$	$z < 22.5$ $1.9 \leq g-z < 2.5$



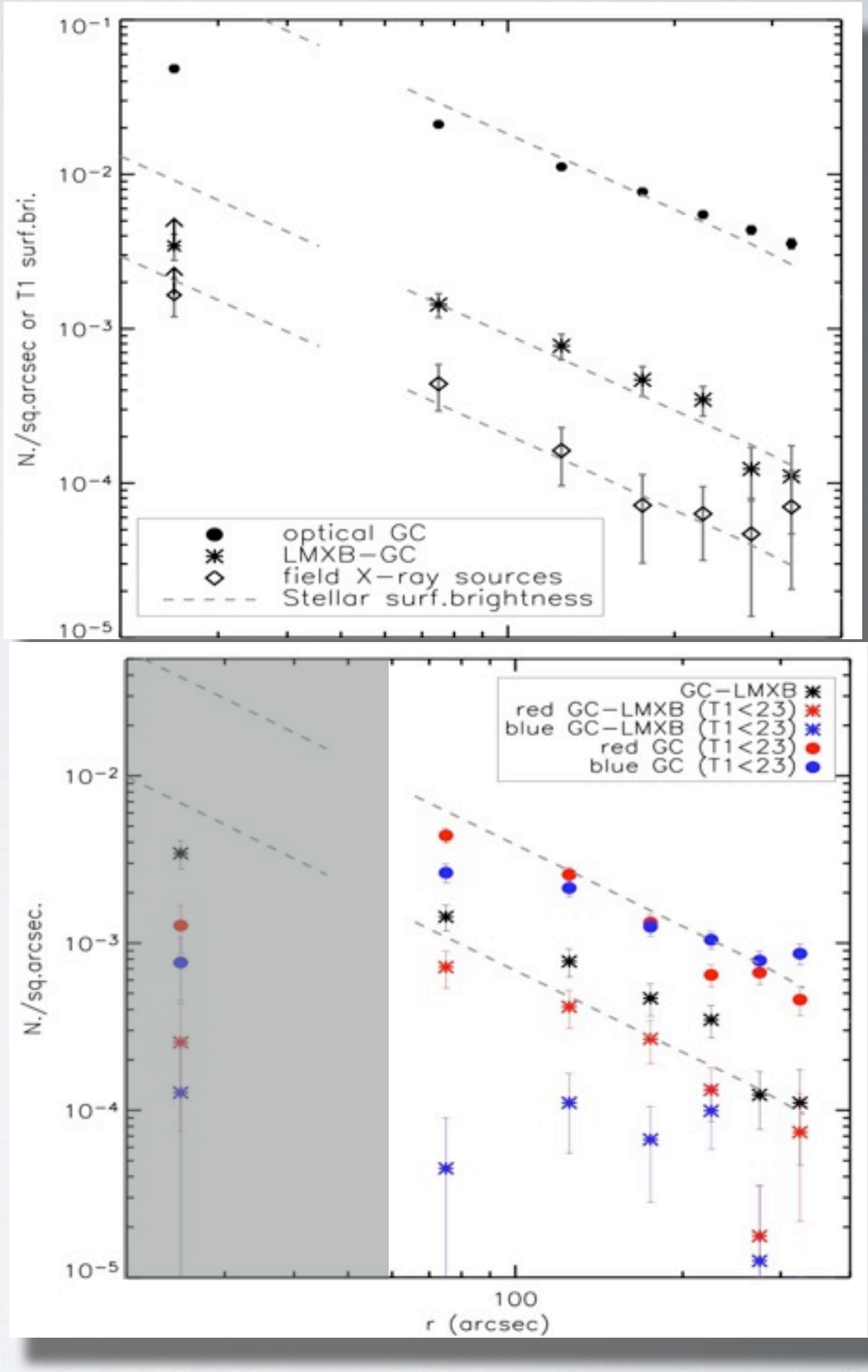


RADIAL PROFILES

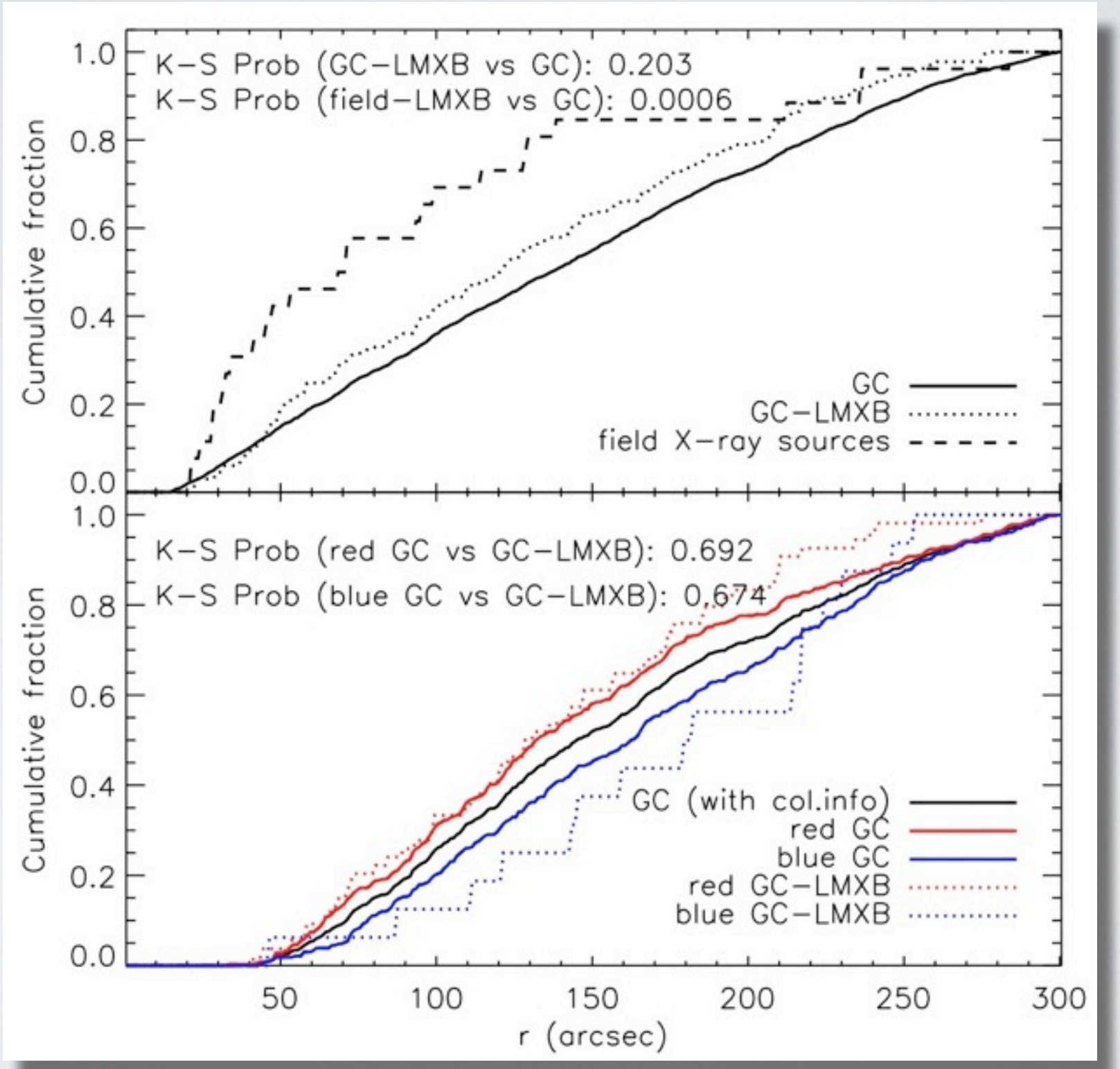
- GC have a shallower profile with respect to the galaxy light. This is mainly due to the blue sub-population, while red GC are distributed more like the field stellar population.

- GC-LMXB follow the distribution of their parent GC population, mainly the red GC (c.f. with Kundu et al. 2002, 2007, see Kim et al. 2006 for different result).

- Field LMXB instead follow the galaxy light: not produced in GC and later released by SN kicks or GC disruption (e.g. White et al .2002).

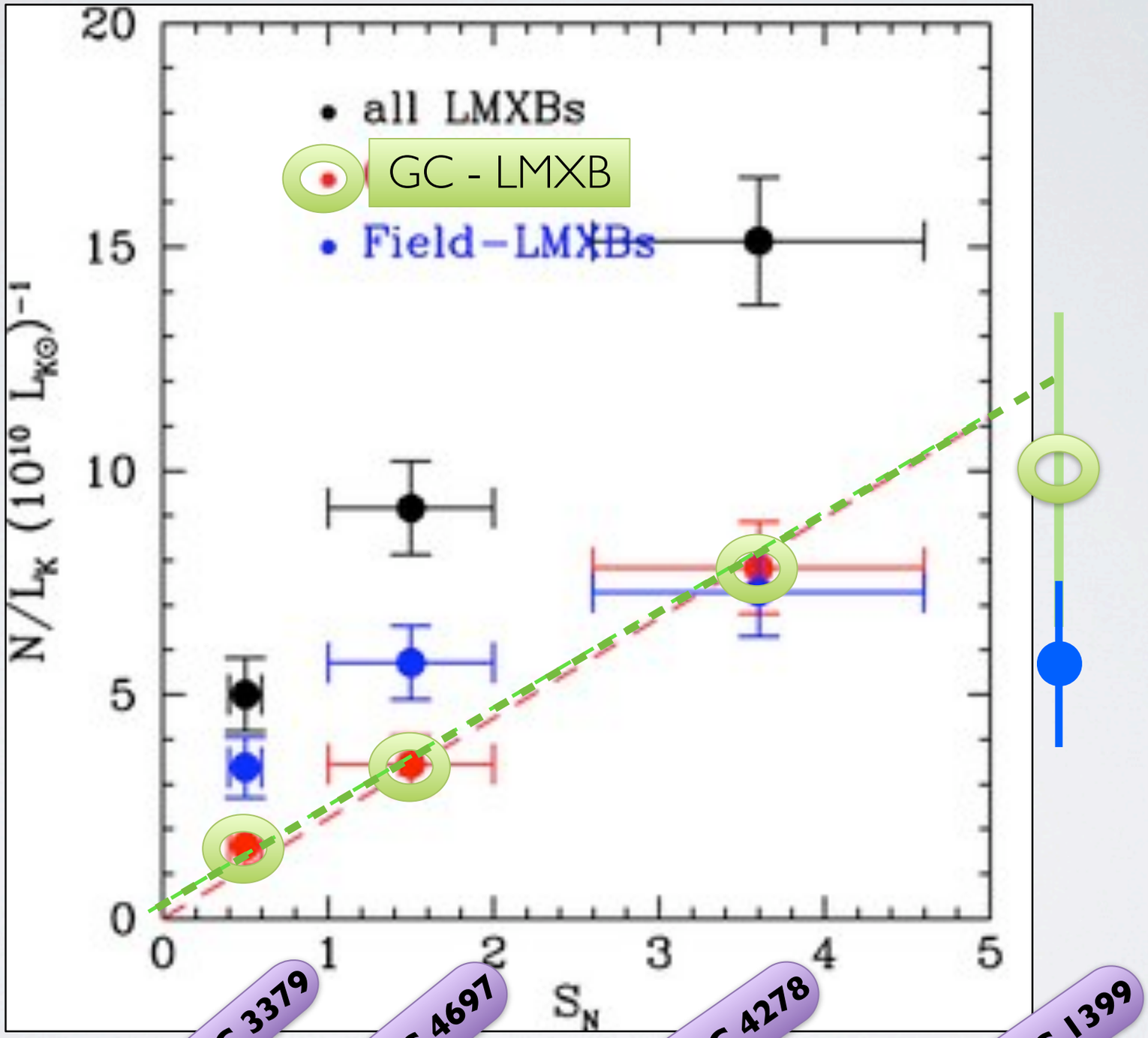


RADIAL DISTRIBUTION (CONT.ED)



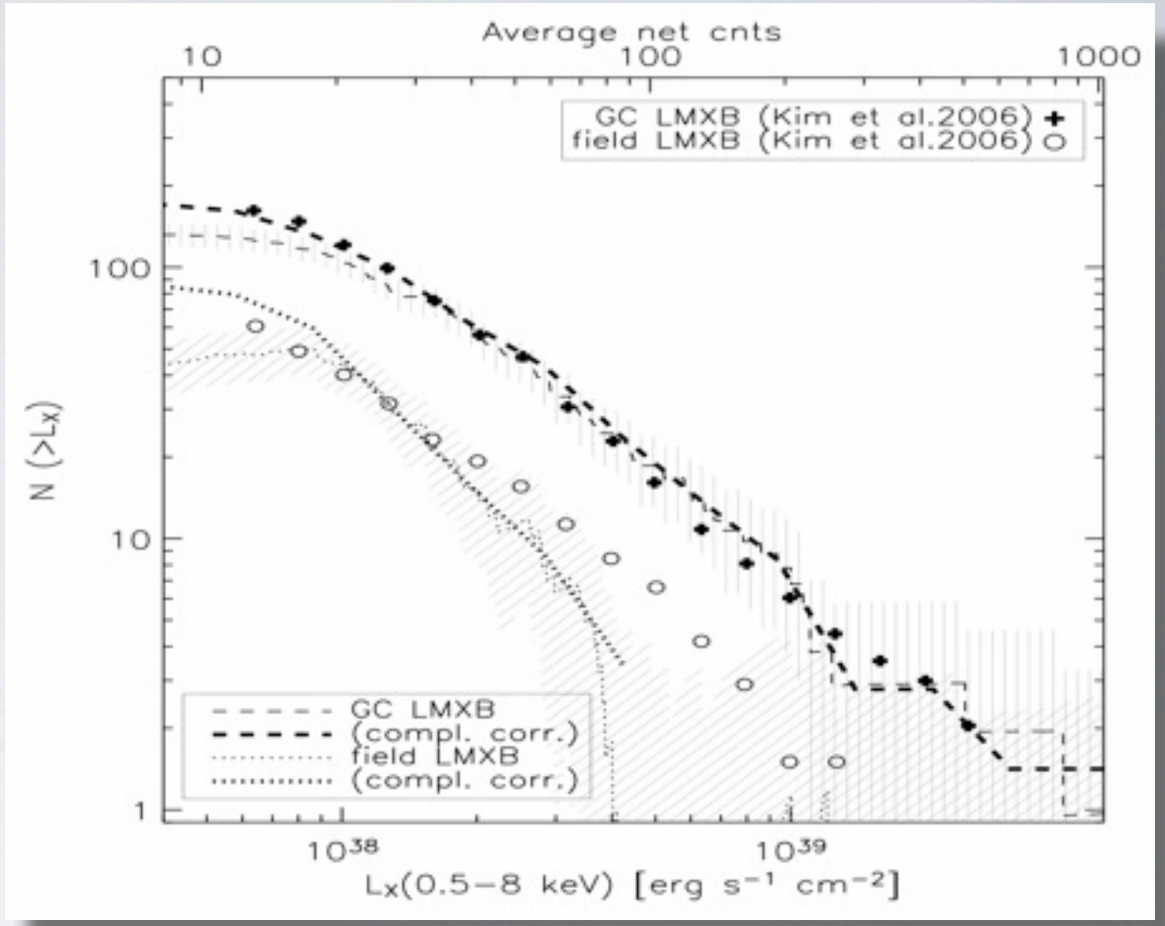
GLOBULAR CLUSTERS AND LMXB FORMATION
- CORRELATION WITH S_N -

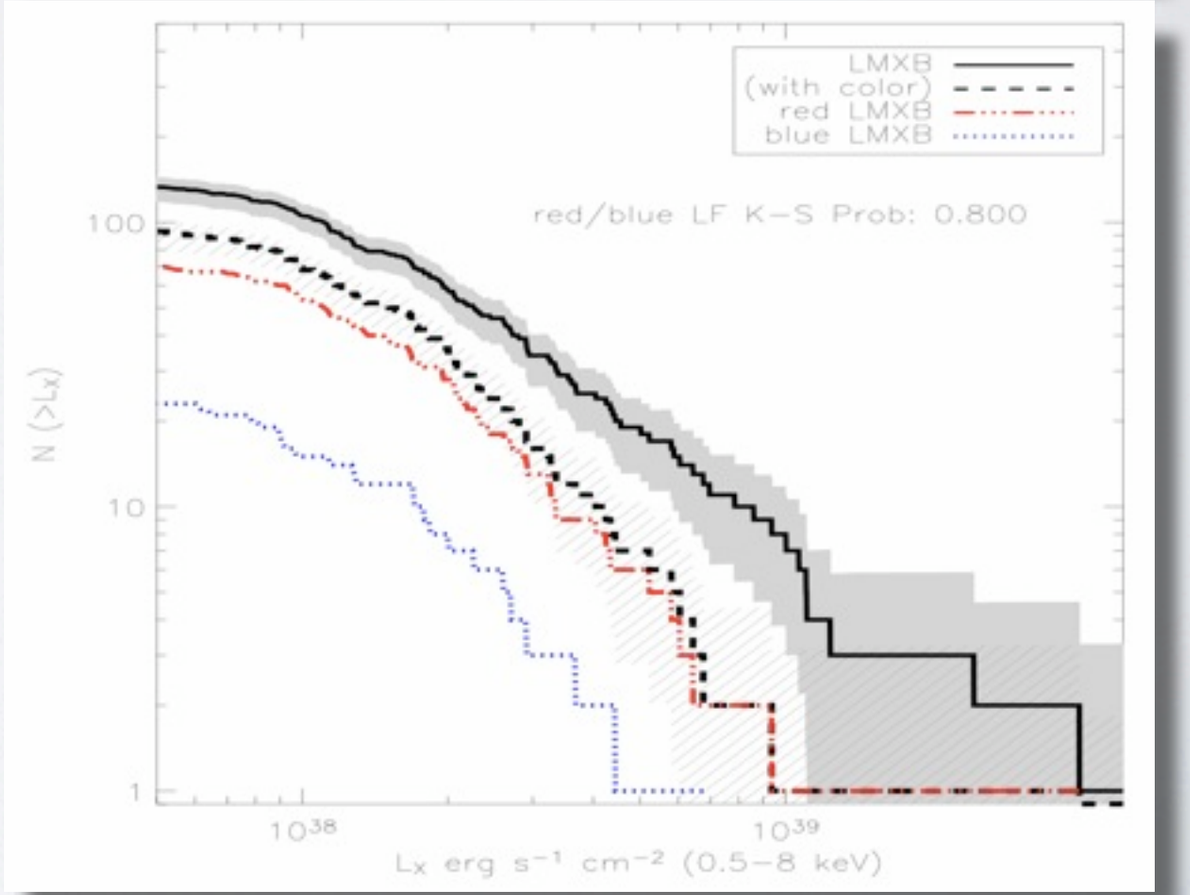
(KIM ET AL 2009)



X-RAY LFs

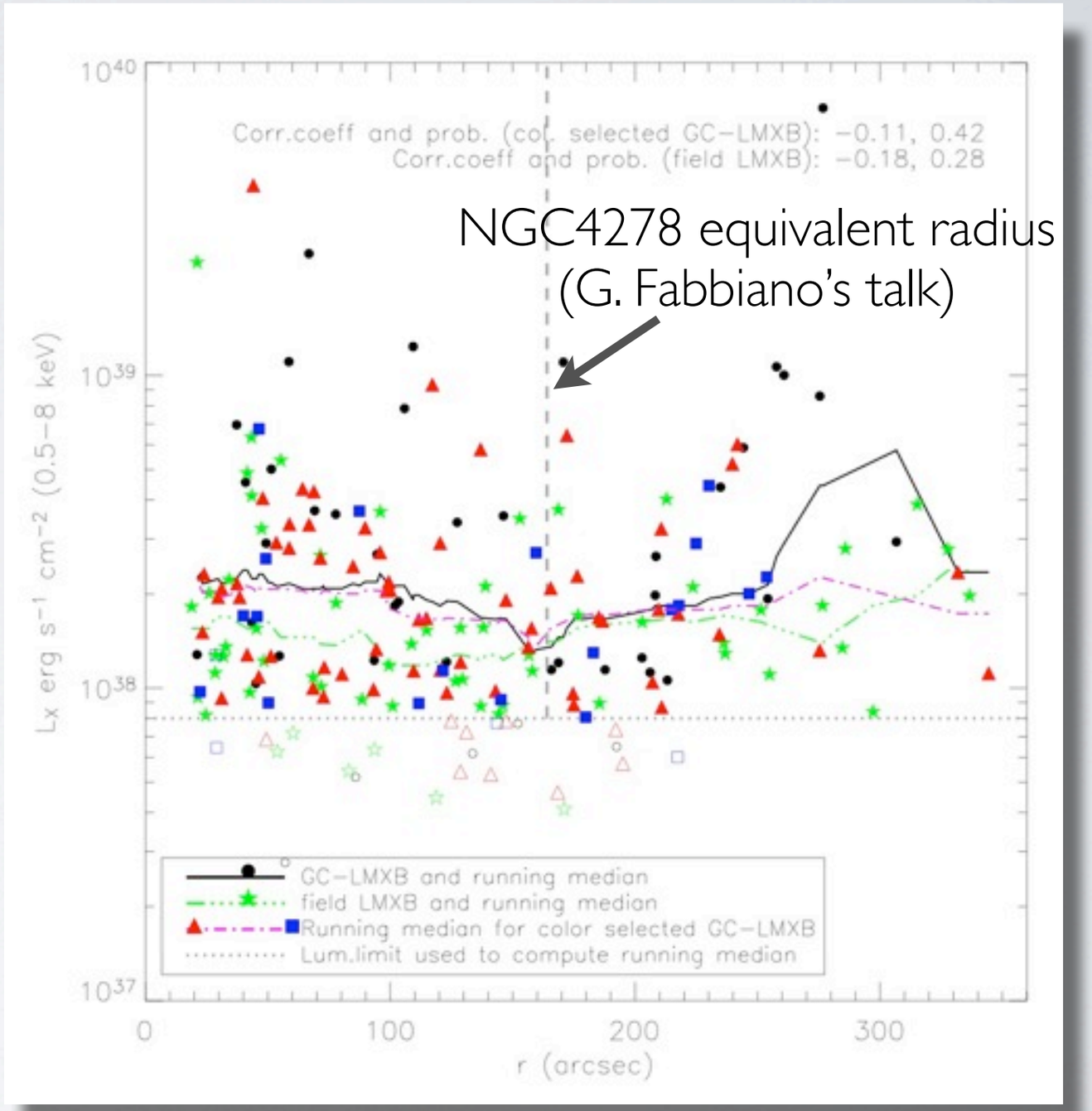
- GC-XLF agrees with literature (e.g. Kim et al. 2006)
- Field XLF appears steeper: lack of bright LMXBs (also confirmed by median value) as also found by Kundu et al. (2007)
- XLF of red and blue GC-LMXBs are consistent, but brightest sources tend to reside in red GC.





LMXB LUMINOSITY vs DISTANCE

- Median of field and GC LMXBs differs in the central region
- GC-LMXBs reach higher luminosities: evidence for multiple sources in the brightest GCs?
- Variability analysis suggest one LMXB per GC on average, but multiple LMXB at least in the brighter color-confirmed GC.



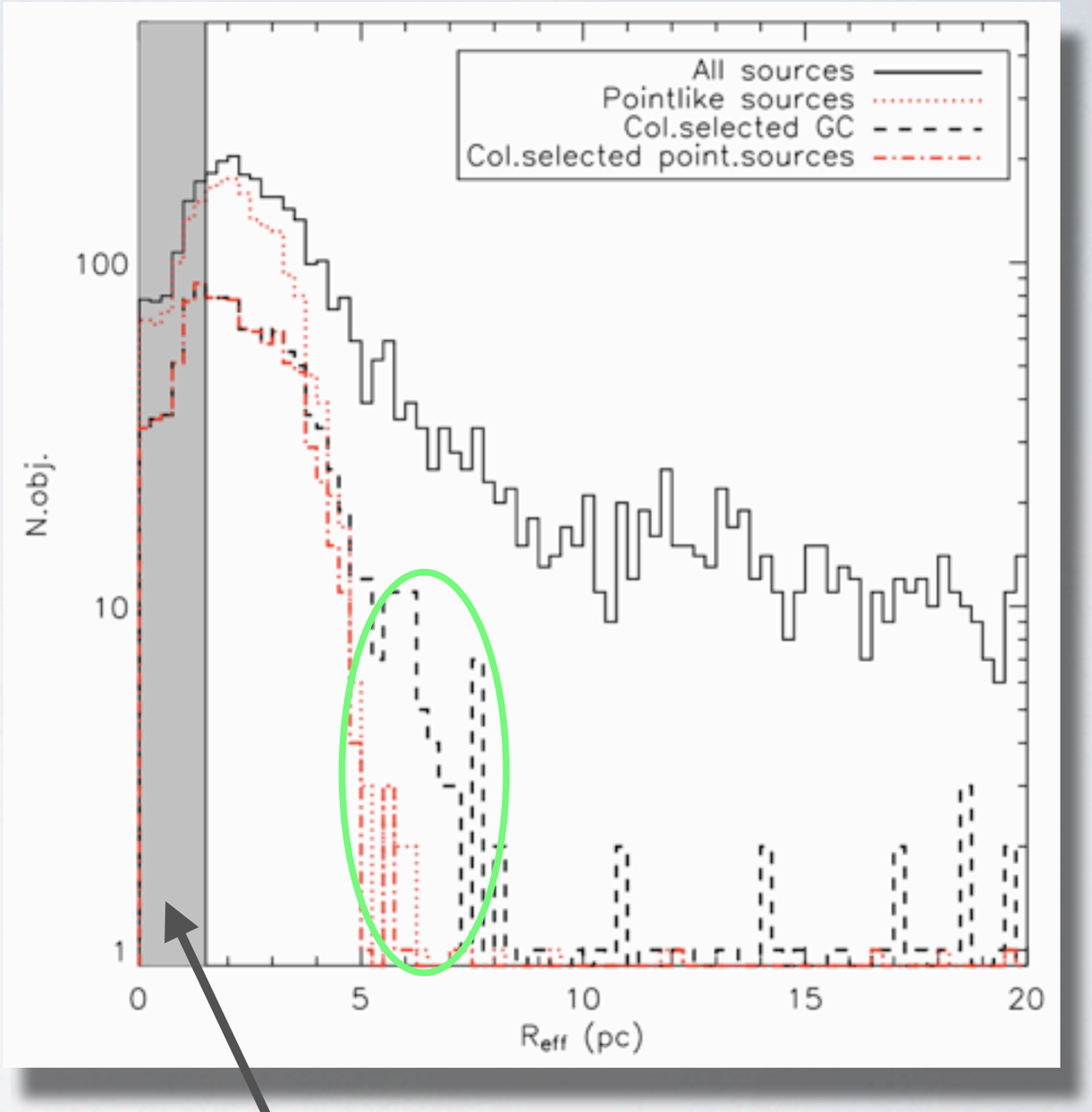
GC STRUCTURAL PARAMETERS

-SAMPLE COMPLETENESS-

- Measured using Galfit (Peng et al. XX); validated through simulations produced with the MULTIKING code (*http://www.na.infn.it/~paolillo/Software.html*) accounting for dithering, PSF variations, sampling pattern etc.

- Our selection is incomplete only for the largest GC with Reff>5 pc

- Complete analysis of optical structural parameters in Puzia et al. (in prep.)



Unresolved sources

GC STRUCTURAL PARAMETERS

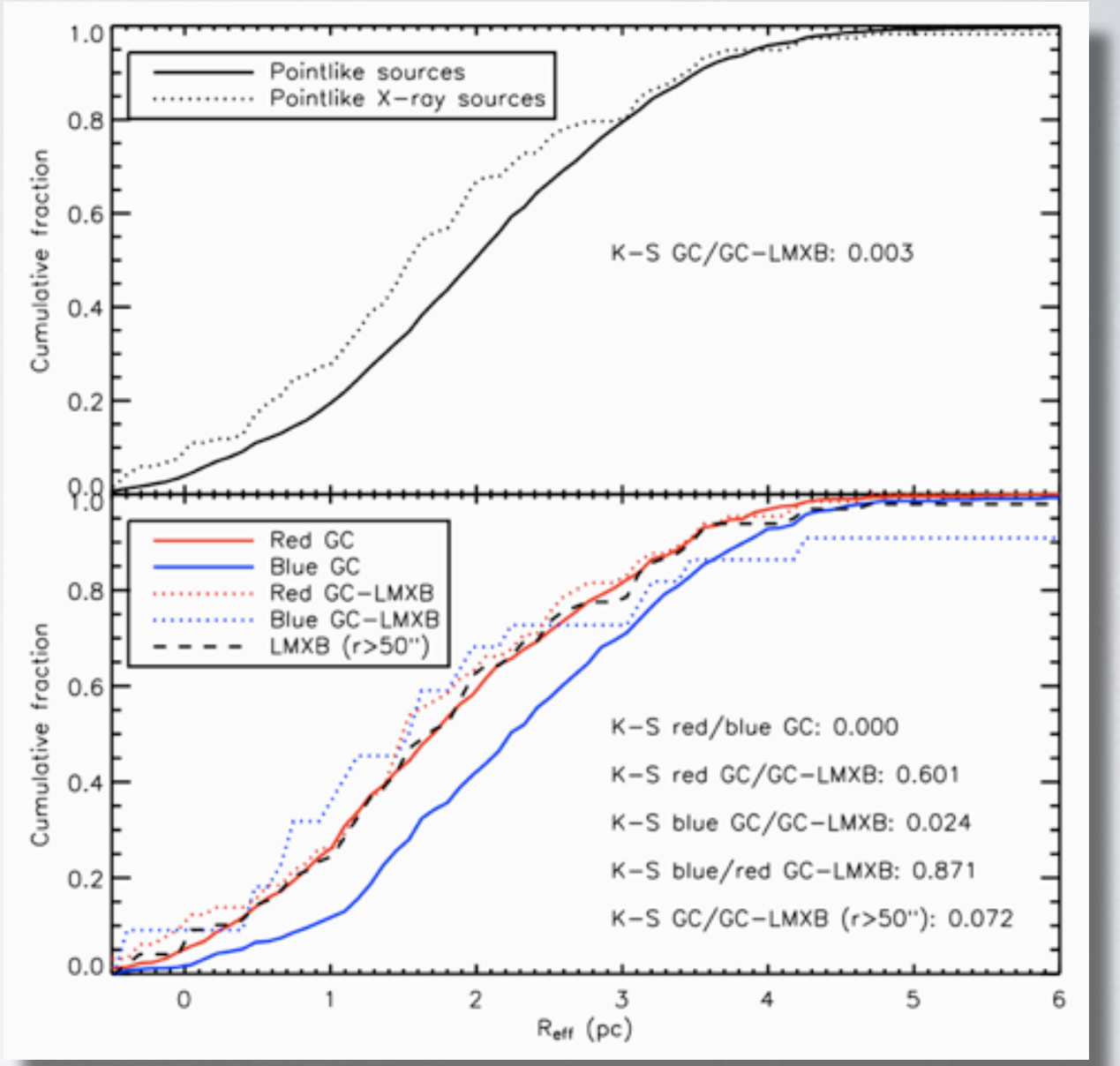
- GC SIZES -

- GCs hosting LMXBs are more compact than the overall GC population (also see Jordan et al. 2004, 2007; Sivakoff et al .2007).

- Red and blue GCs have different sizes at a significance level > 99%,

- We do not detect any significant difference between red XGCs and the overall red GC sub-population.

- LMXBs residing in blue GCs seem to prefer the most compact systems



GC STRUCTURAL PARAMETERS

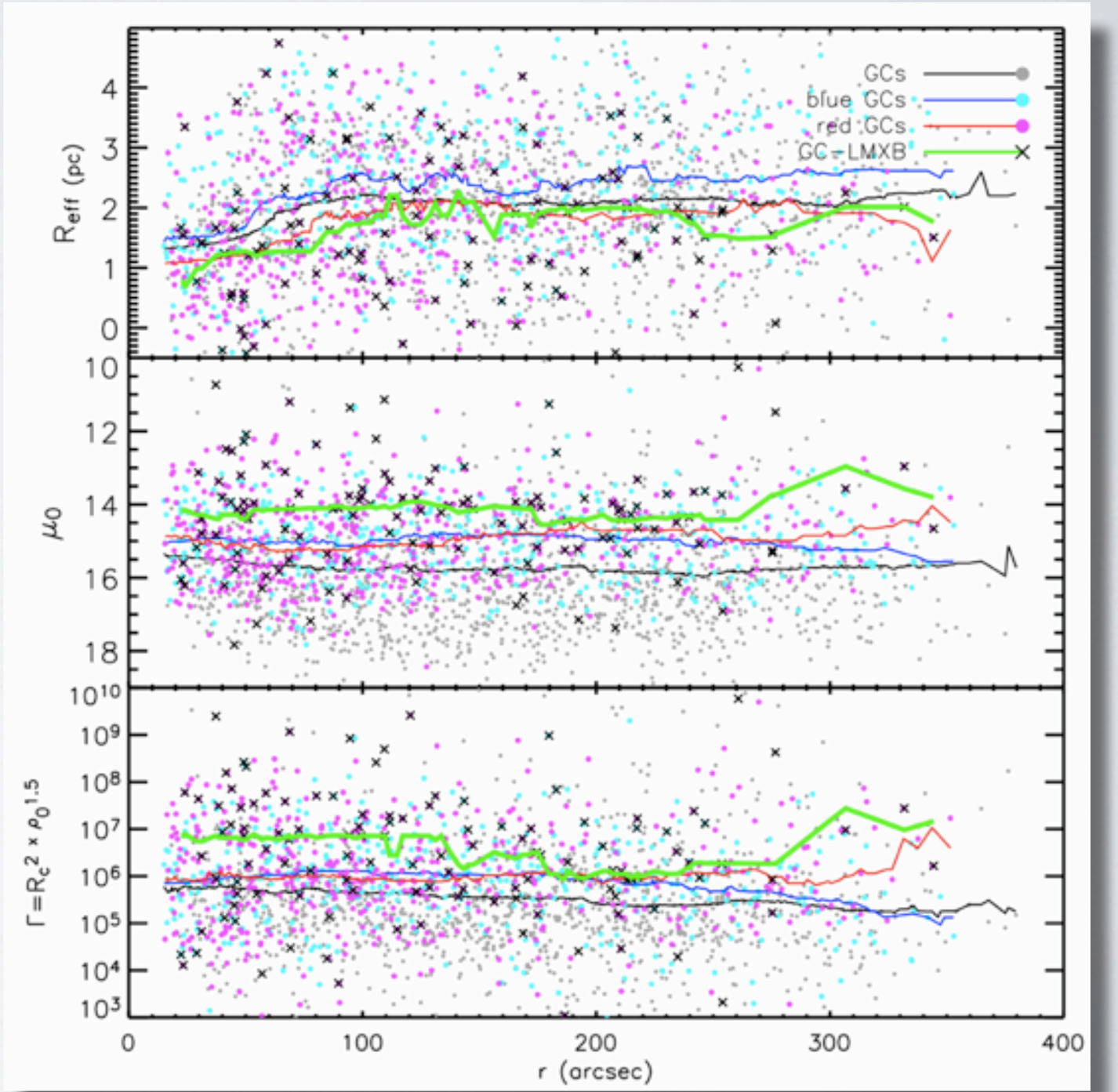
- DEPENDENCE ON GALACTOCENTRIC DISTANCE -

- GC size depends on galactocentric distance: more compact GC reside in the galaxy center (R<1 R_{eff}).

- Red and blue GCs have different sizes at all radii, thus arguing against projection effects (see e.g. Spitler et al. 2006)

- LMXB reside in most compact GCs at all radii.

- GCs hosting LMXBs have larger central surface brightness μ_0 and dynamical interaction rate $\Gamma = R_c^2 \rho_0^{1.5}$ (Verbunt & Lewin 2006)



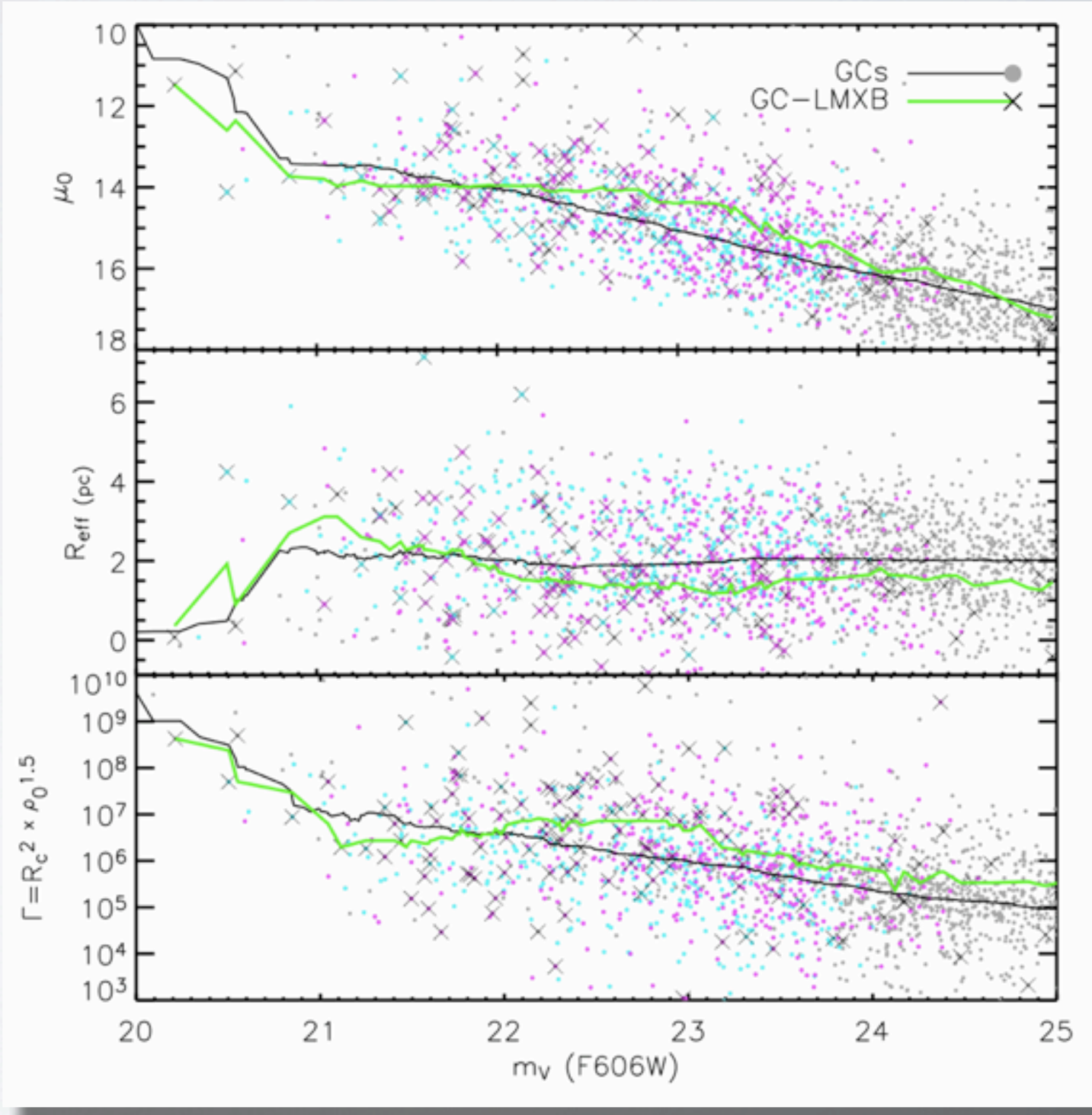
GC STRUCTURAL PARAMETERS

- DEPENDENCE ON MAGNITUDE (MASS) -

- On average LMXBs reside in centrally bright, more compact, higher interaction rate GCs.

- However, at odd with previous works (e.g. Peacock et al. 2009) the difference is limited to less luminous (m_V>22.5) GCs.

- At bright luminosities LMXB likelyhood seems to saturate: massive GC more likely to form/retain GC (Verbunt 2005; but see Smiths 2006)?

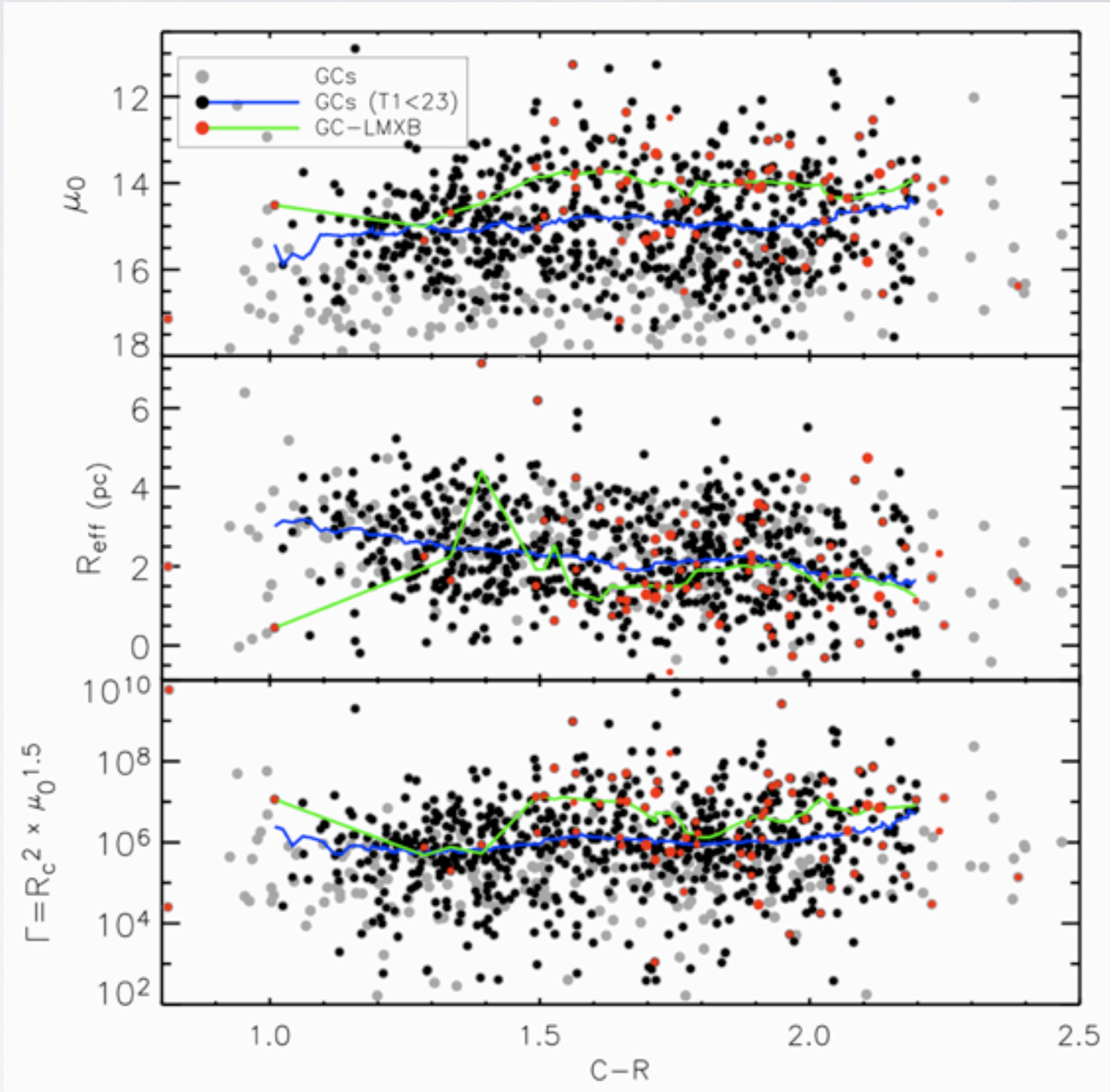


GC STRUCTURAL PARAMETERS

- DEPENDENCE ON COLOR -

- Color has an intrinsic effect on LMXB formation likelyhood, since structural parameters for GC hosting LMXB do not depend strongly on color, except possibly at the very blue end.

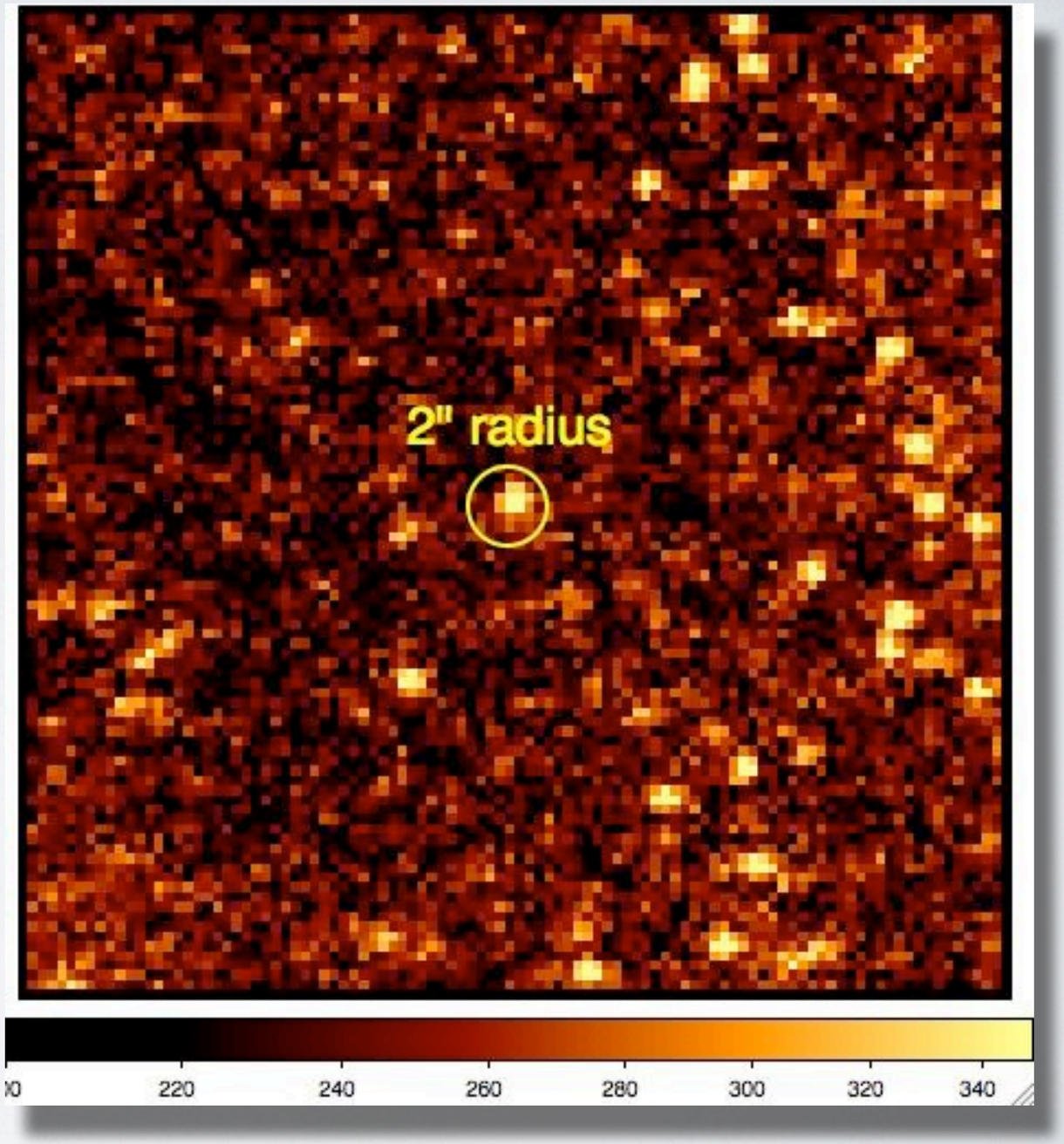
- Testing through resampling techniques we find that all mass, structure and color are relevant parameters.



PUSHING THE LIMIT

-STACKING ANALYSIS FROM G.D'AGO-

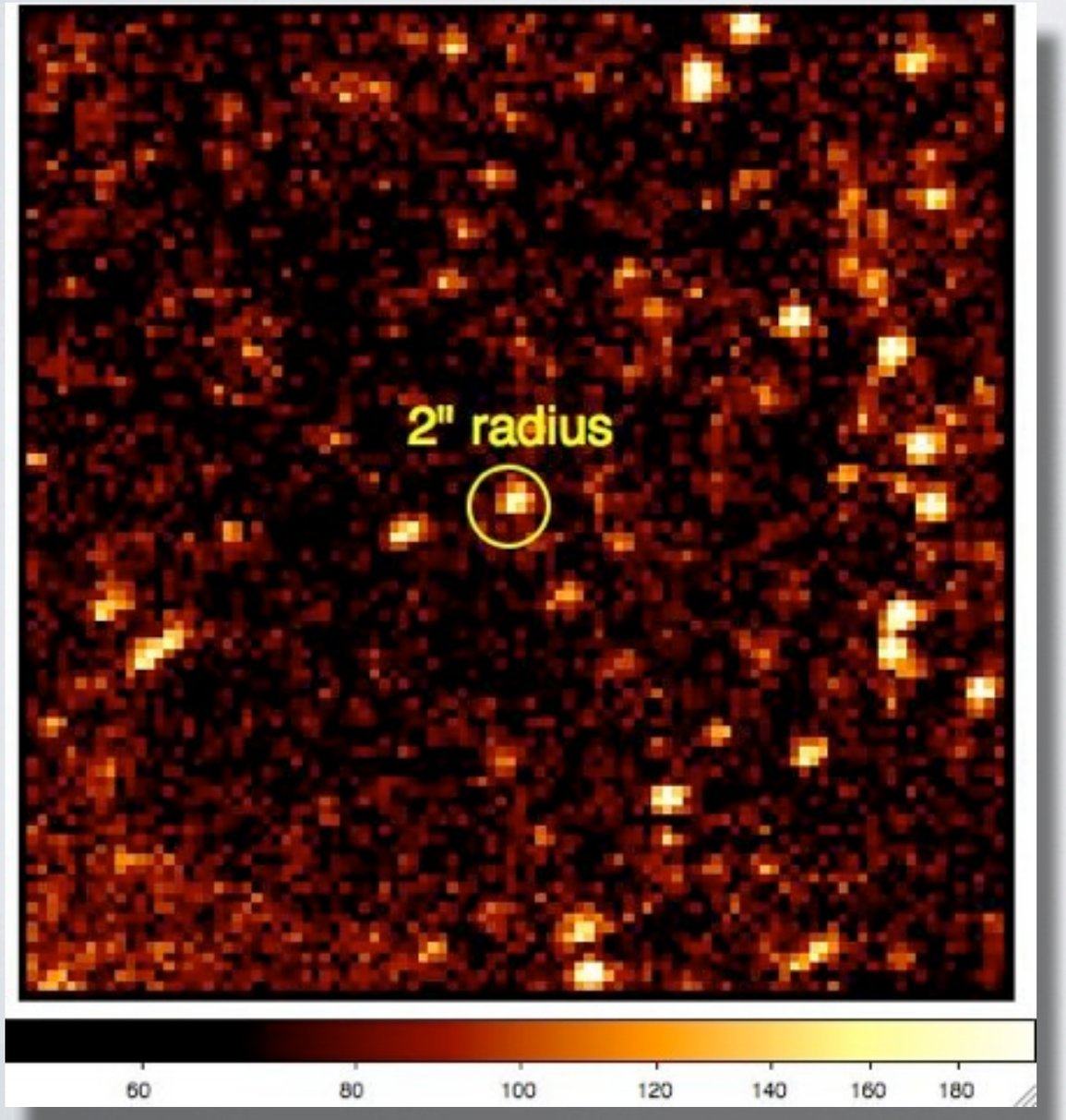
- Stacking 291 sources between 50" and 250" we get a significant detection



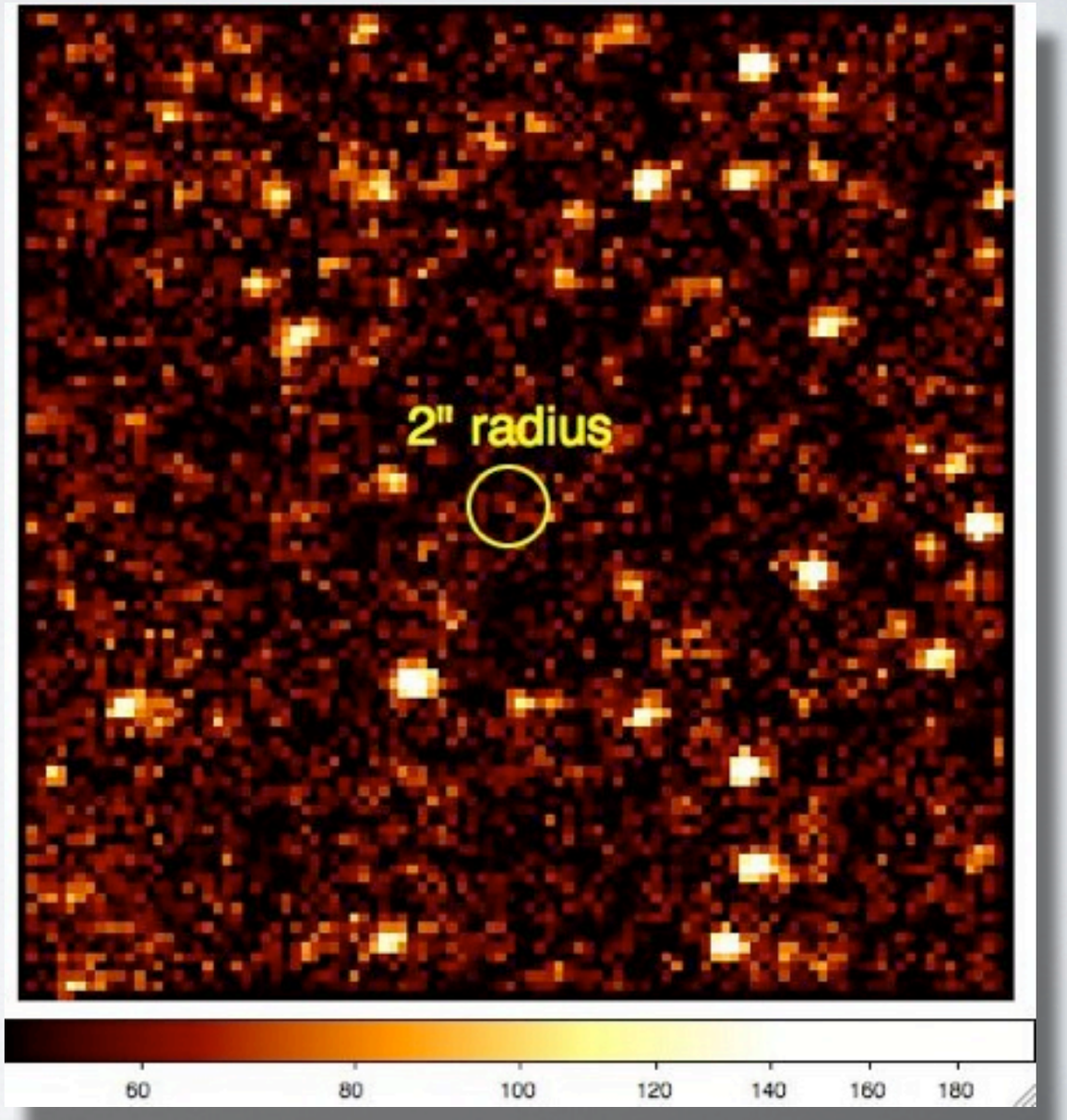
PUSHING THE LIMIT

-STACKING ANALYSIS FROM G.D'AGO-

164 stacked red GC



127 stacked blue GC



CONCLUSIONS

- NGC 1399 has a very high fraction of LMXB residing in GCs among early-type galaxies studied so far, $f_{GC-LMXB}$ = 65% ± 5%, even after accounting for its rich GC system.
- LMXB fraction depends on galactocentric distance since the distributions of field- and GC-LMXBs follow different surface density profiles. This argues against a common origin of all LMXBs.
- The majority of LMXBs are hosted by the red GC population, which closely follows the optical galaxy light, while the blue GC-LMXB population has a more extended profile. We also confirm the presence of a very red GC sub-population residing in the galaxy core that hosts a large fraction of LMXBs.
- We find that LMXBs tend to follow the spatial distribution of the red GC sub-population, thus suggesting that dynamical interactions with the host galaxy do not affect the LMXB formation.
- GC mass, color (metallicity), and central density all seem to affect the LMXB formation likelihood at any given galactocentric distance.
- We find no evidence of a dependence of LMXB properties (LF, spectra) on those of the host GCs, as expected if LMXB evolution is primarily driven by the properties of stellar binary systems.
- While most GCs are likely to host a single LMXB, the steeper LF of multiple accreting binaries in some of the X-ray brightest GC.