GC and Field LMXBs in Nearby Elliptical Galaxies

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The LMXB - GC connection

- Could all LMXB originate in GCs?
  - First suggested for Galactic LMXB
  - Formation more efficient than in the field (Clark 1975)
  - GC disruption or formation kicks would disperse LMXBs in the field (Grindlay 1984)
- But evolution of native field binary can also form a LMXB (see Verbunt & van den Heuvel 1995)

- *Chandra* observations of early-type galaxies
  - Large samples of LMXBs
- *Hubble* observations
  - Large samples of GCs
- Combine
  - Identify GC and Field LMXBs
  - Study and compare properties
  - Observational constraints on models

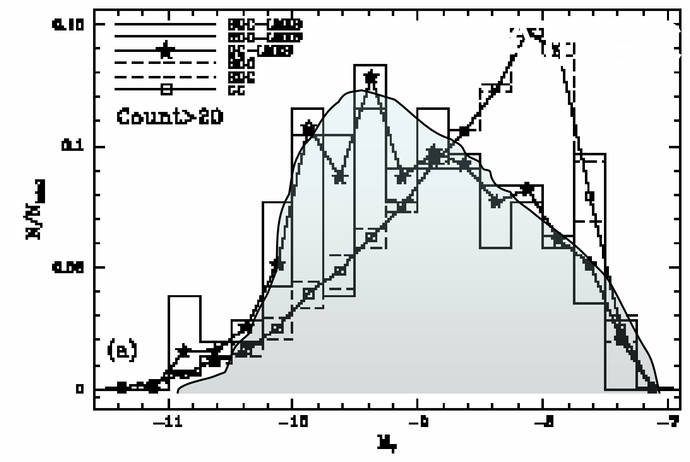
Cast of Characters

- The Chandra NGC 3379, NGC 4278 collaboration
  - G. Fabbiano (PI), D.-W. Kim, N. Brassington, L. Angelini, R. Davies, T. Fragos, J. Gallagher, V. Kalogera, A. King, A. Kundu, S. Pellegrini, G. Trinchieri, S. Zepf, A. Zezas
- The NGC 4697 GC-LMXB collaboration
  - + A. Jordan, G. Sivakoff, A. Juett, C. Sarazin
- Visiting post-graduates from Southampton University (UK)
  - Sarah Blake (now at Oxford)
  - Lindlay Lentati

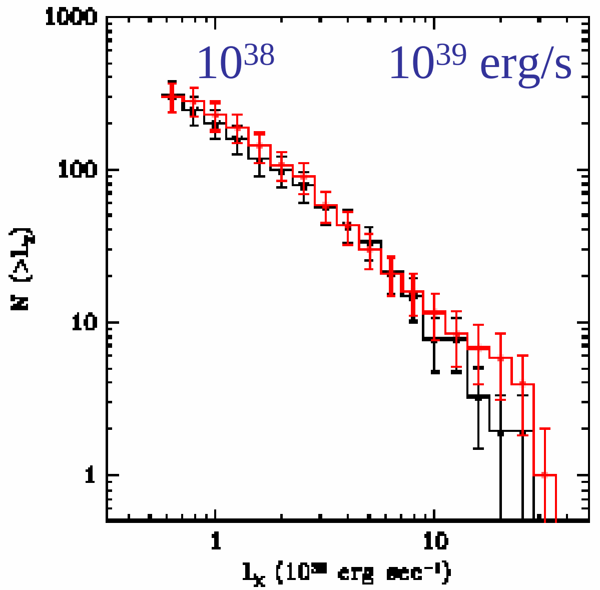
LMXBs and GCs - ‘consensus’

- L_X>~5×10[37] erg/s
  ~5% of GCs have an LMXB
  (e.g., Sarazin et al 2003)
- More luminous GCs more likely to host a LMXB
- Red/metal-rich GCs more likely to host an LMXB
  (e.g. Kundu et al 2002; Maccarone et al 2003; E. Kim et al 2006)

(Kim E. et al 2006)



- L_X>~5×10[37] erg/s
  consistent XLF for field and GC LMXBs (E. Kim et al 2006)



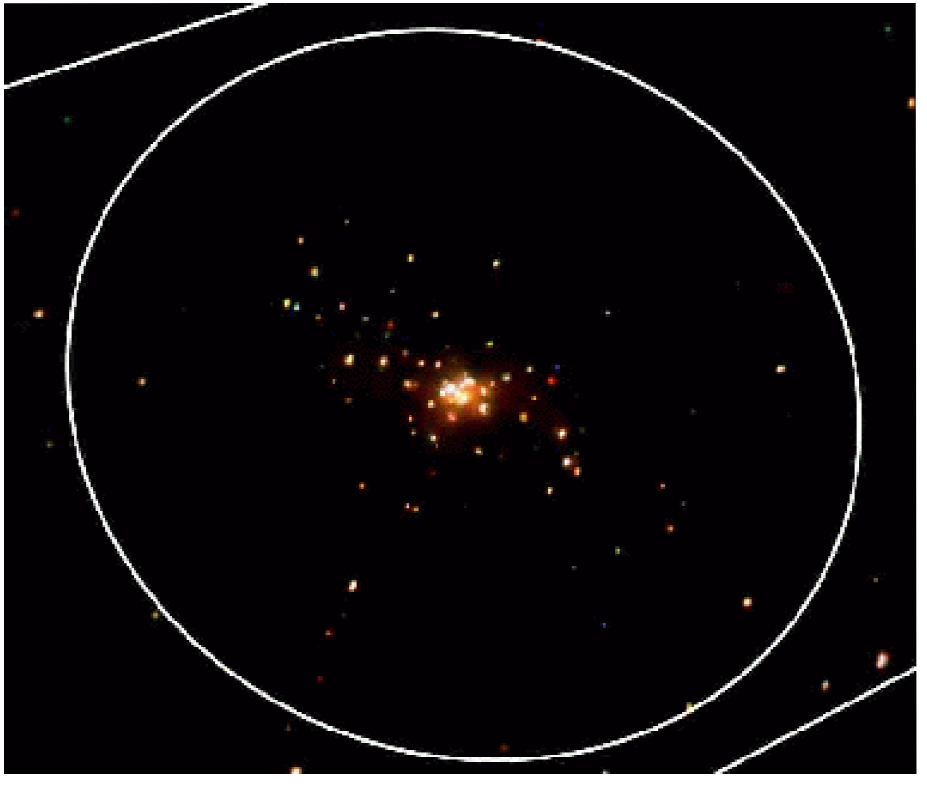
LMXBs and GCs - ‘discussion’

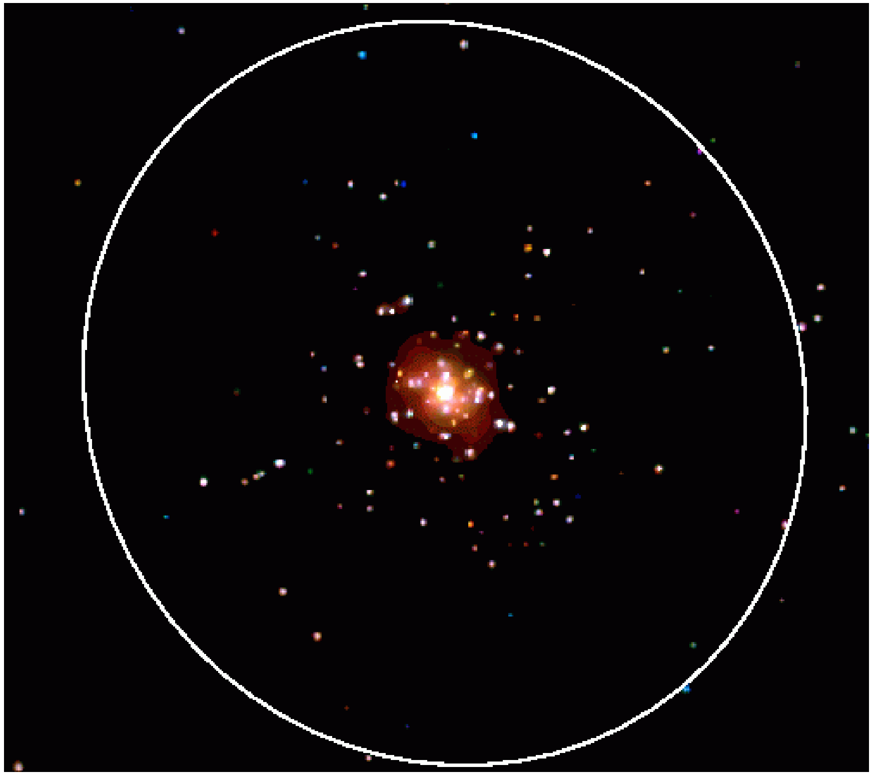
- Spectra
  - Harder spectra in blue GC LMXB? (NGC 4472; Maccarone et al 2003)
    - Absorption by radiatively induced winds in metal poor stars
    - Winds would speed up binary evolution resulting in a smaller number of LMXBs in metal poor blue clusters (Maccarone et al 2004)
  - ...But, no color dependence found in large sample (Kim et al 2006)
- Spatial Distribution (see Nicky Brassington’s talk)
  - Are GC and field LMXB both radially distributed like galaxy light (Kim et al 2006)
  - …Or not (Kundu, Maccarone & Zepf 2007)?
  - Spatial ‘irregularities’?
- Low luminosity XLF
  - Is there a dearth of GC sources (e.g., M31, Voss & Gilfanov 2007)?
- Time variability? Transients? (see Tassos Fragos’ talk)

Deep *Chandra* ACIS Monitoring

NGC 3379 T_{exp}=337ks
D= 10.6 Mpc L_B = 1.3 ×10^{10} $L_\odot$
GC poor

NGC 4278 T_{exp}=470ks
D=16.1 Mpc L_B = 1.6×10^{10} $L_\odot$
GC rich



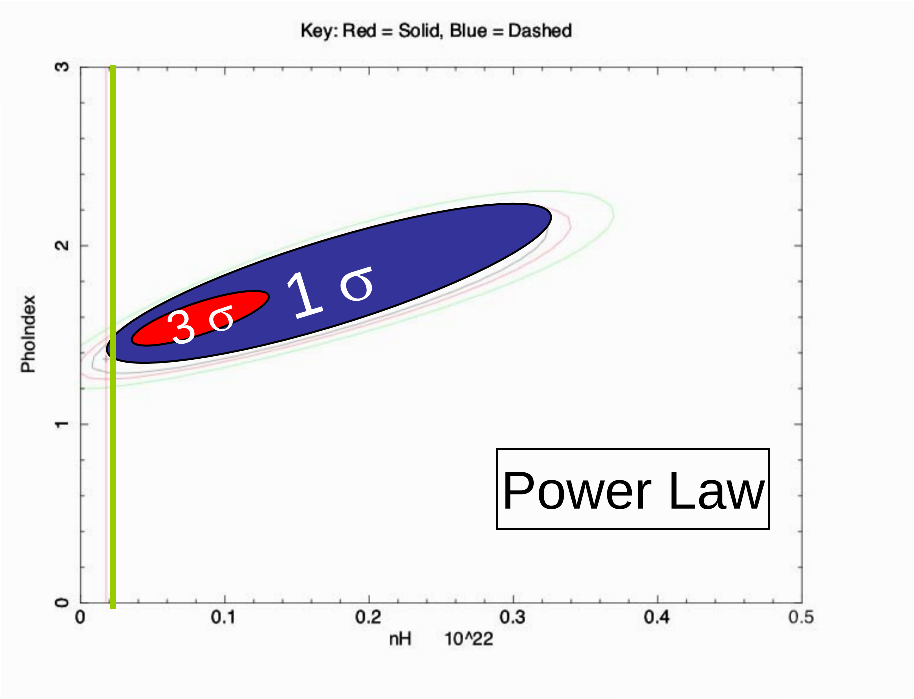


- Both galaxies have very little hot gaseous emission, to optimize faint LMXB detection
  - NGC3379: 98 sources
  - NGC 4278:180 sources

LMXBs co-added spectra in NGC 4278

Lentati et al. 2009, AAS

- Overall, field and GC sources have similar spectra

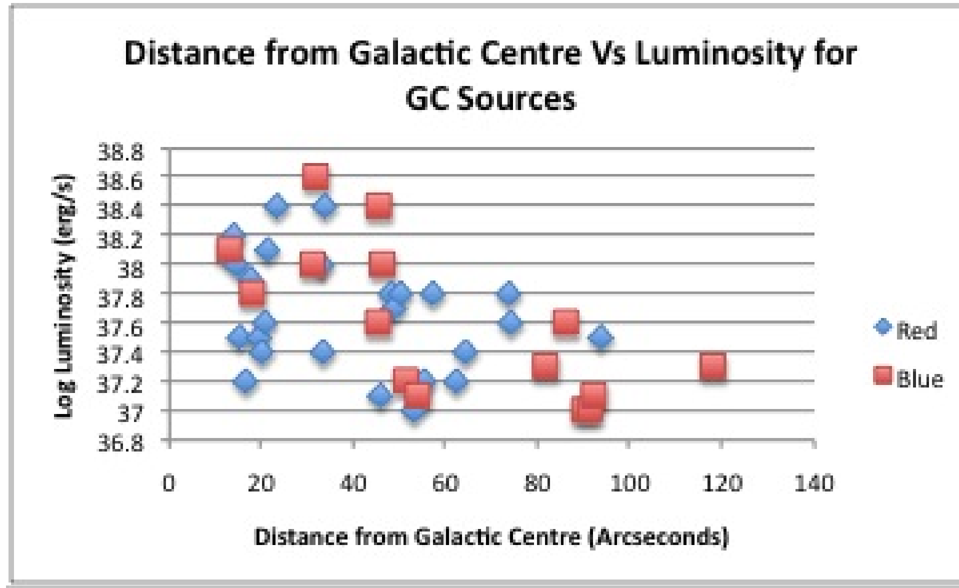


- No statistical difference between Red (V-I > 1.5) and Blue GC spectra
(Red Counts = 4095 - 26 sources; Blue Counts = 1363 - 17 sources)
- Consistent with absence of outer convective zone/magnetic braking/accretion in low metallicity star (Ivanova 2005)

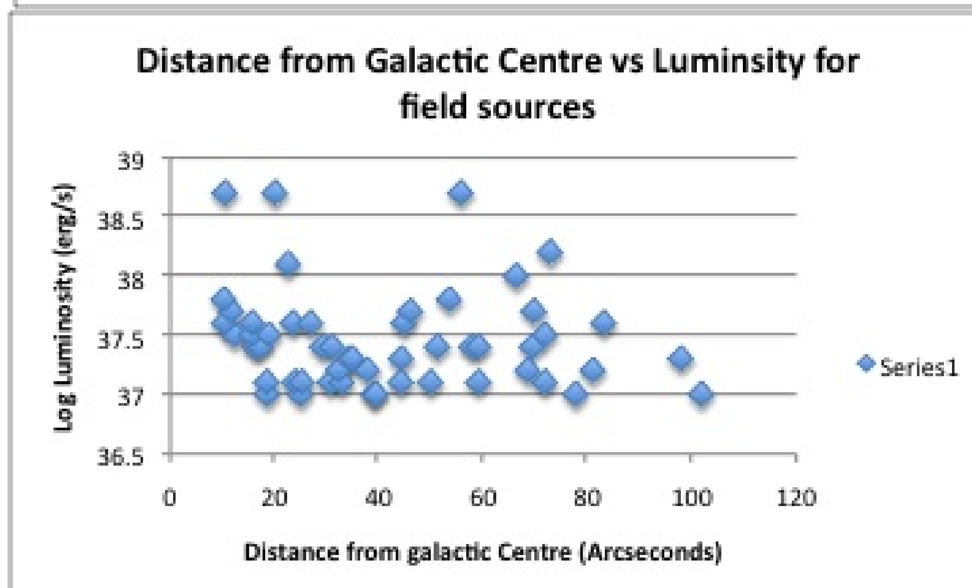
GC LMXBs in NGC 4278 - Radial L_X effect

(Lentati et al 2009, AAS)

- GC-LMXB in NGC 4278 tend to have a larger spread of luminosity at smaller galactocentric radii
  - SR P = 0.00009 (of no correlation)
  - Related to more massive/dense GC?

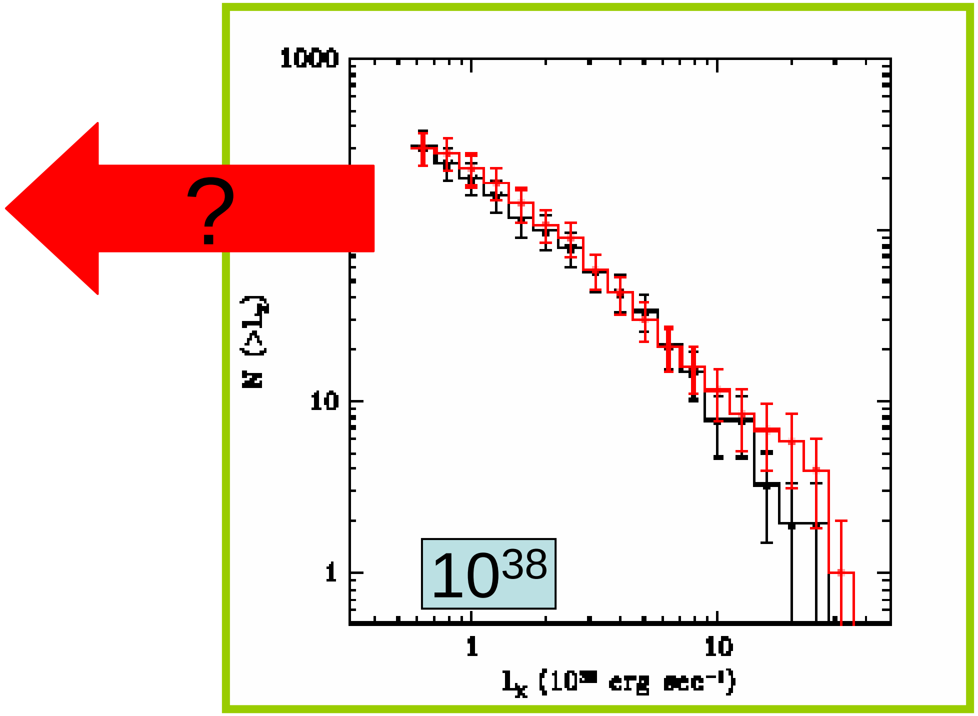


- No significant radial L_X effect for field sources
  - SR P = 4.5%



Old X-ray binary populations - LMXBs

Field and GC XLF - $L_X > 5\times10^{37}$ erg s^{-1}



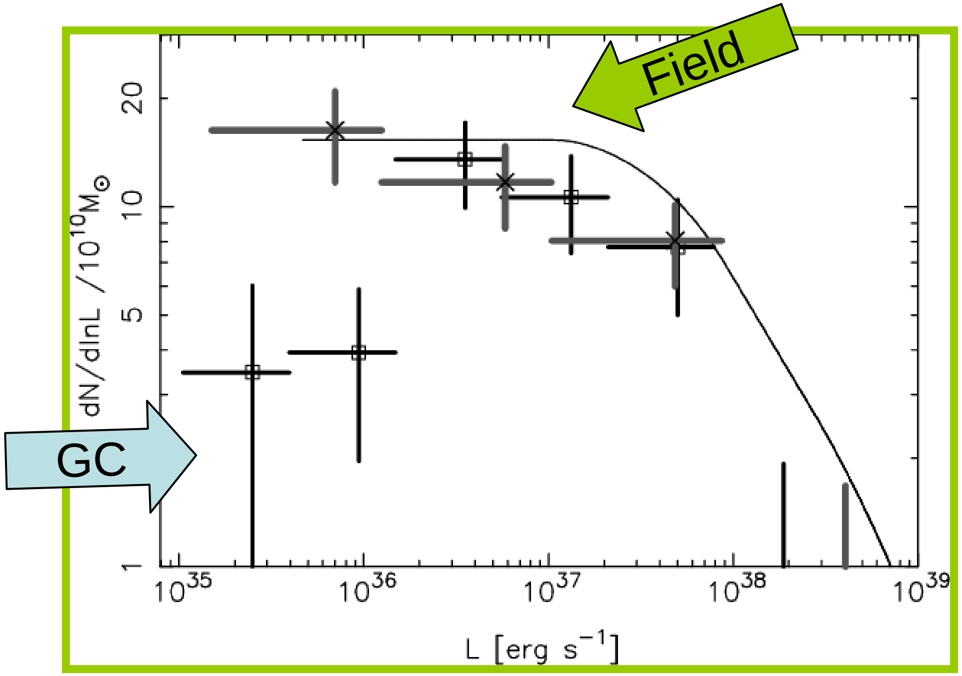
The high luminosity XLFs of GC and Field LMXBs are the same
(Kim E. et al 2006)

- Consistent with (but not proving) a similar origin

Does this similarity extends to lower luminosities?

Old X-ray binary populations - LMXBs

Field and GC XLF - Going deep



In M31 the XLF of GC LMXBs drops relative to that of Field LMXBs at low LX
(Voss & Gilfanov 2007)

Is this a general feature, that may point to differences in the two populations?

Low luminosity Field and GC LMXB XLFs

in the *Hubble* WFPC2 field (A. Kundu)

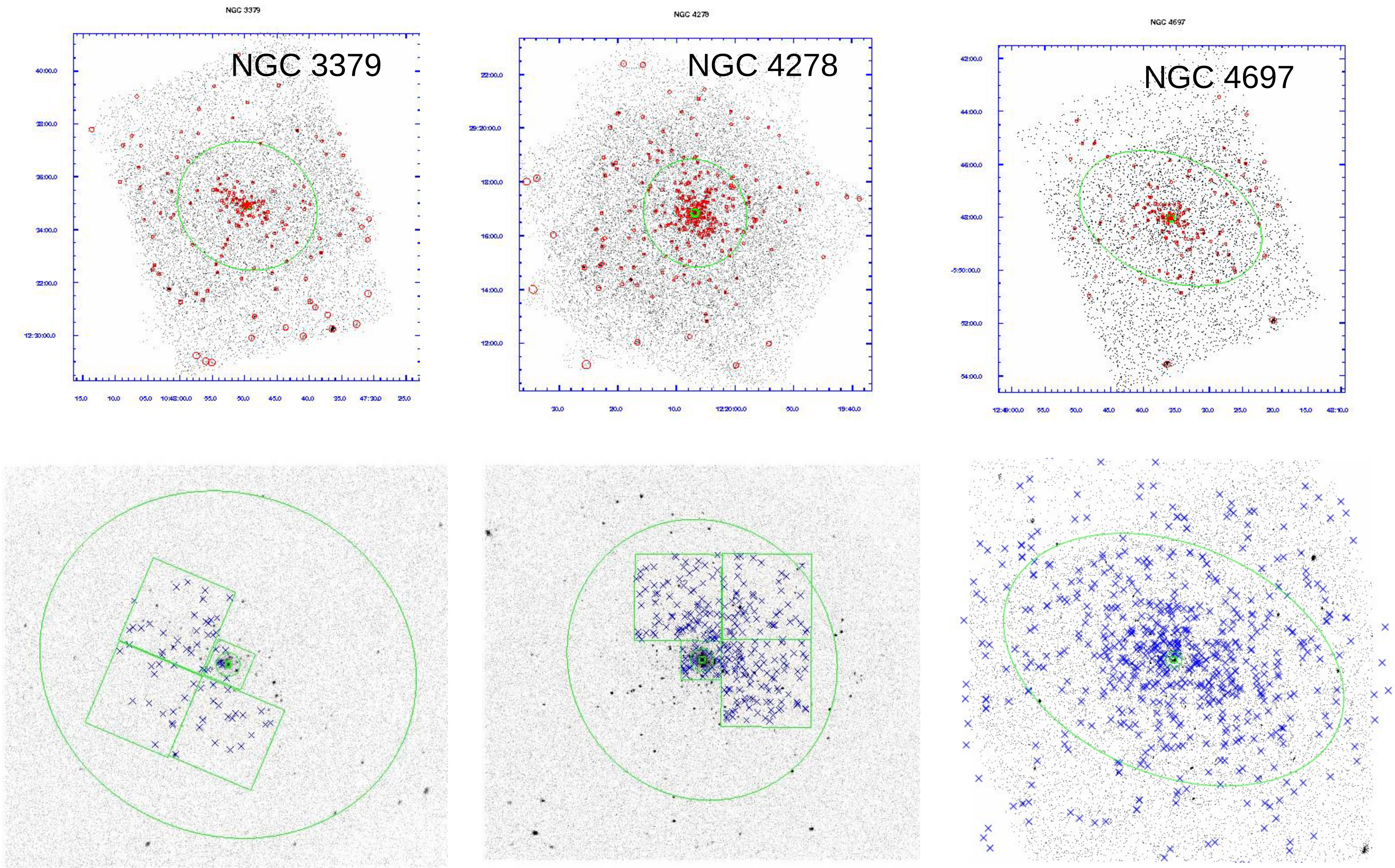
NGC 3379

T_{exp} (ks)	GC[a]	LMXB[c]	LMXB-GC	$f_{(GC\ with\ LMXB}$	$f_{LMXB\ in\ GC}$	Ref.
30	61	26	7	12%	27%	KMZ
337	70	62	9	13%	15%	B07

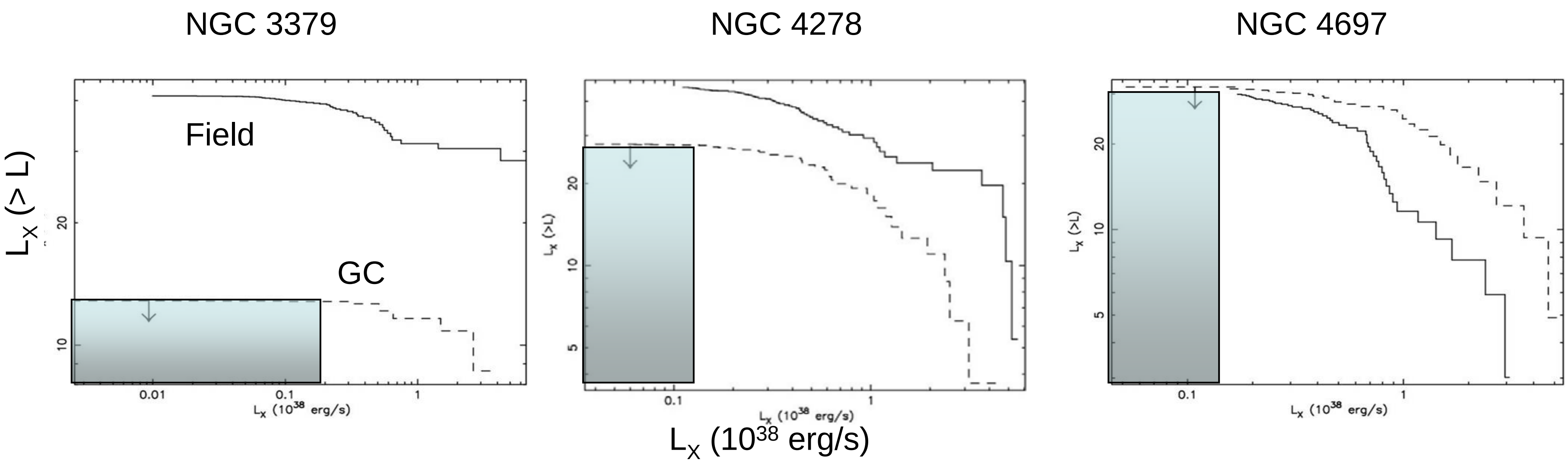
a) in the *Hubble* WFPC2 field

- 5% of GCs host an LMXB is ~5% @ $L_X > 4 \times 10^{37}$ erg s^{-1}
  (see review Fabbiano 2006; Kundu, Maccarone & Zepf 2007)
- The fraction of GCs with LMXB is constant (~12%) for LMXB detection threshold from ~2×10^{37} erg s^{-1} down to a few 10^{36} erg s^{-1}
- The number of detected LMXBs increases by a factor of 2.4 in the deeper data set, that of LMXB-GC is basically constant

We expect 17 LMXB-GC - We detect 9
(P=1.2%)

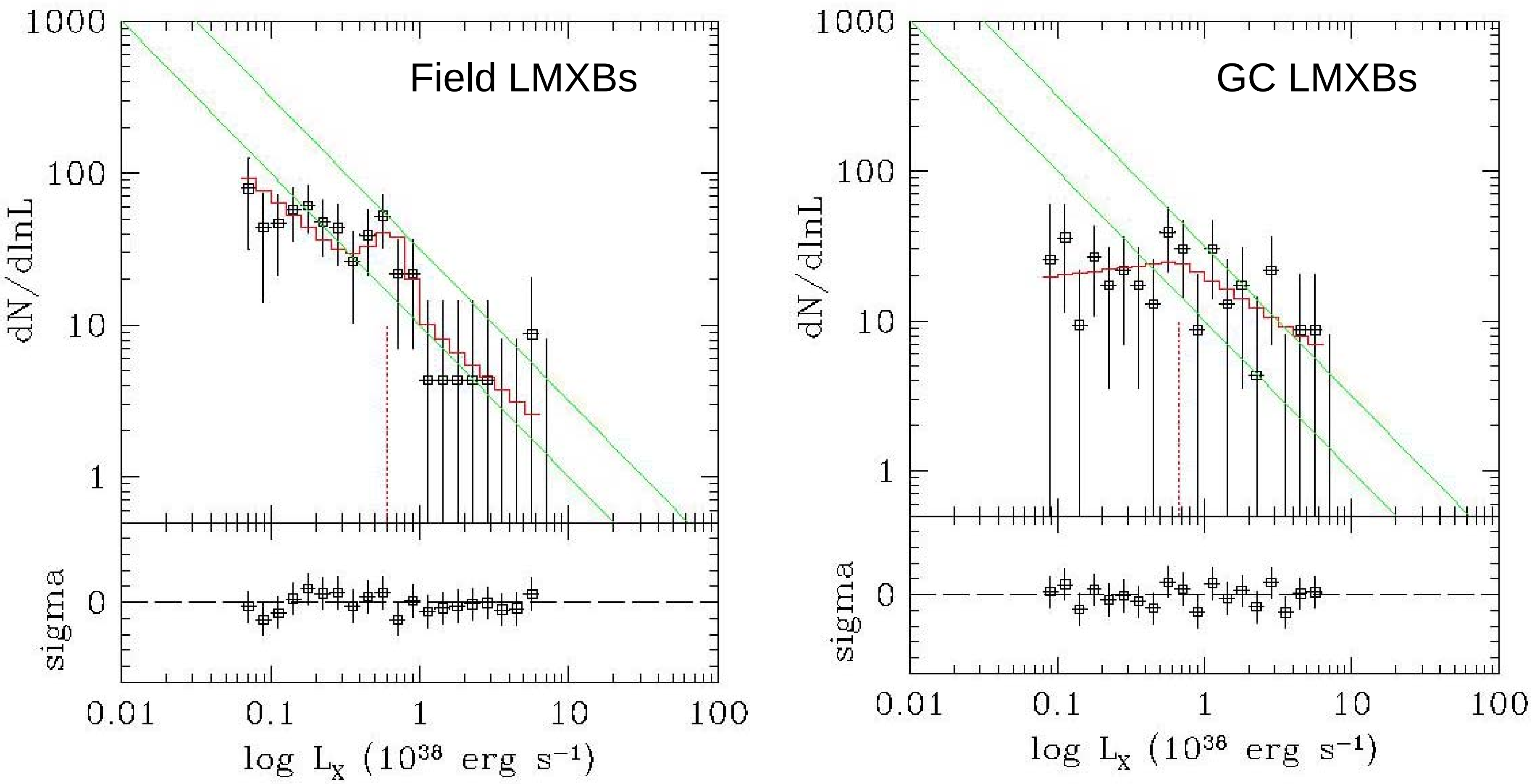

NGC 3379
NGC 4278
NGC 4697

Field and GC LMXBs - Cumulative Luminosity Distributions



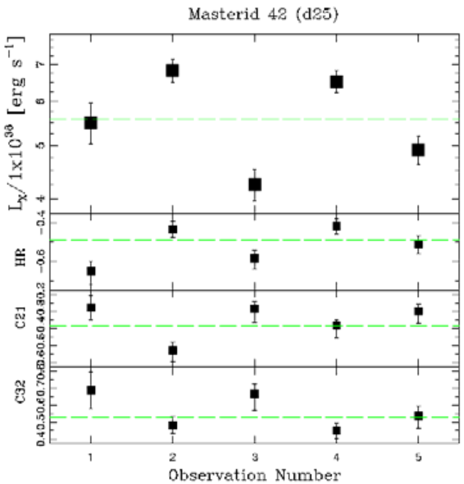
- Field and GC distributions are not statistically consistent
  - including upper limit for non detected GC (stacking)
- GC distributions appear to flatten up at low L_X

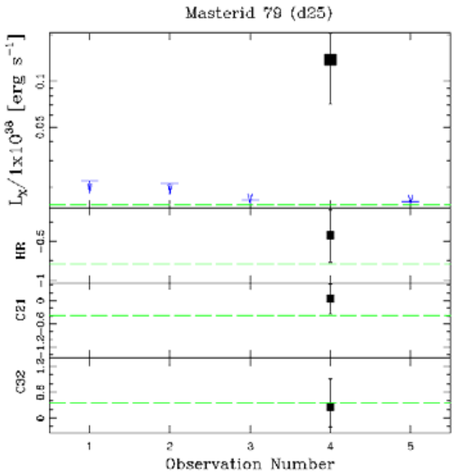
Field and GC LMXBs - Co-added XLF



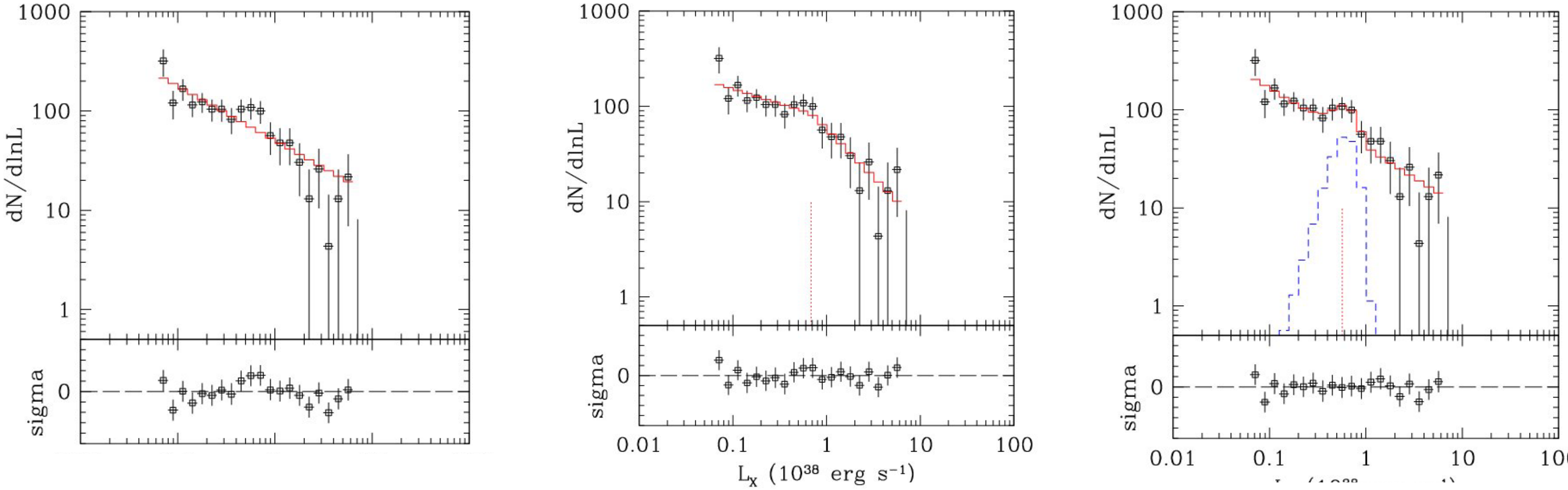
Why do Field and GC XLF differ?

- Multiple LMXBs in a given GC at the high L_X end?
  - ‘Deplete’ the low luminosity XLF
  - Maybe NOT - variability points to single sources
- Transients dominating high L_X field sources?
  - Decrease the number of high L_X field sources, steepening the high L_X XLF
  - Possible - High L_X transients rarer in GCs?
    - But they exist
- Onset of transient behavior at low L_X in GC LMXBs?
  - B08 detects a possible transient just above 10^{37} erg s^{-1}
  - XLF break at $5{\times}10^{37}$ erg s^{-1} may be too high for ultracompact binaries
  - Consistent with MS donor systems
    - Mass transfer driven by magnetic braking at high L_X
    - Mass transfer driven by gravitational radiation below the break



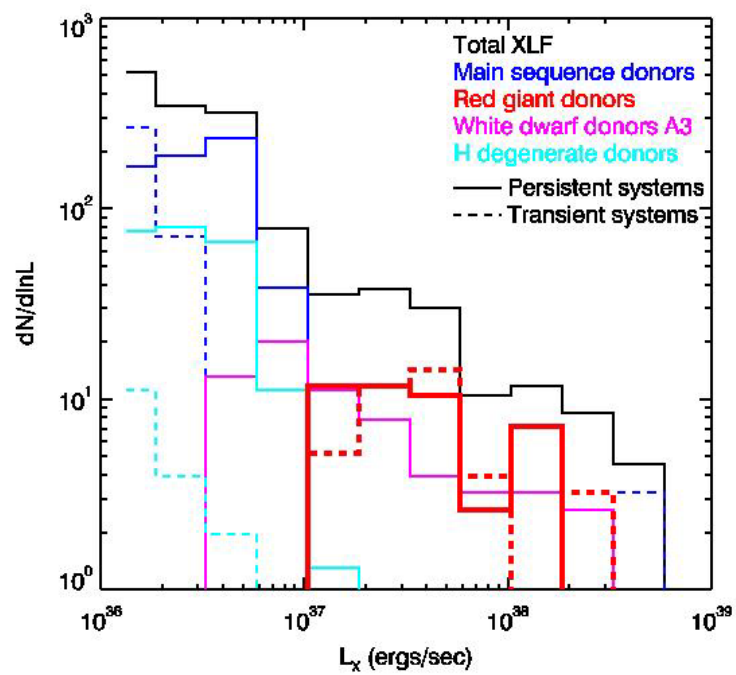


The 5×10^{37} erg/s Feature

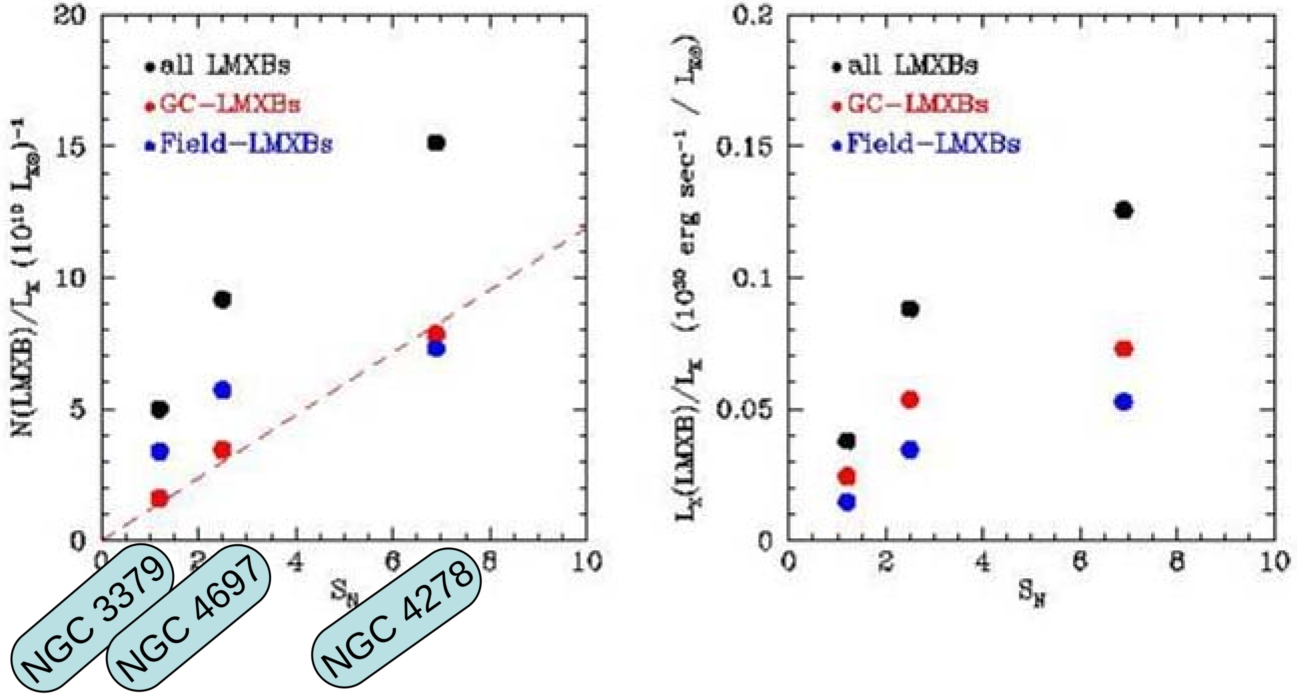


- In co-added field + GC XLF
  - Either break
  - Or localized excess

- Population synthesis models of Fragos et al (2006)
  - Strong magnetic braking law
  - Or, if localized excess, due to RG donor contribution



Globular Clusters and LMXB formation
Correlation with S_N (Kim et al 2009)



- For our 3 galaxies with deep *Chandra* and *Hubble* observations
  - The number of GC LMXBs scales with the GC specific frequency S_N
  - The number of field LMXB also increases with S_N, but with a shallower dependency
- Field LMXBs are of mixed origin
- BUT… we need more galaxies to firm this up

Summary of Results

- 'Well known' - $L_X > 5\times10^{37}$ erg/s
  - 5% of GC have LMXBs
  - LMXBs more likely in more luminous GCs
  - More likely in red, metal rich GCs
  - XLF of field and GC LMXBs consistent

- New / In debate (…this talk)
  - Field and GC LMXBs have similar X-ray spectra
  - No 'statistical' difference in spectra of Red and Blue GC
  - In NGC 4278, more luminous GC LMXBs found at smaller radii (no effect for field)
  - 'Correlation' with S_N suggests that fraction of field LMXBs originates in GC
  - Fraction of GC with LMXB increases at lower luminosity, but not as fast as expected from the field LMXB increase
    - XLF of field and GC LMXBs differ at $L_X < 5\times10^{37}$ erg/s
    - Relative lack of GC LMXBs
    - Break at $L_X < 5\times10^{37}$ erg/s (or localized excess) also seen in field XLF

What do we need to do?

- Observationally
  - Larger samples of galaxies with Hubble and Chandra coverage
  - Deep monitoring Chandra observations
  - Maybe we can discuss proposals and collaborations here at Santa Barbara

- From the Theory side
  - Fine tuned (tunable) evolutionary population synthesis models
  - Including scenarios for
    - Field formation and evolution
    - GC formation and evolution
    - GC formation and field evolution
    - Formation and evolution under distress (mergers, see Nicky's talk)