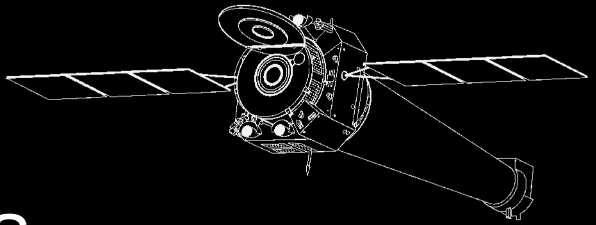
Accreting binary populations in nearby galaxies

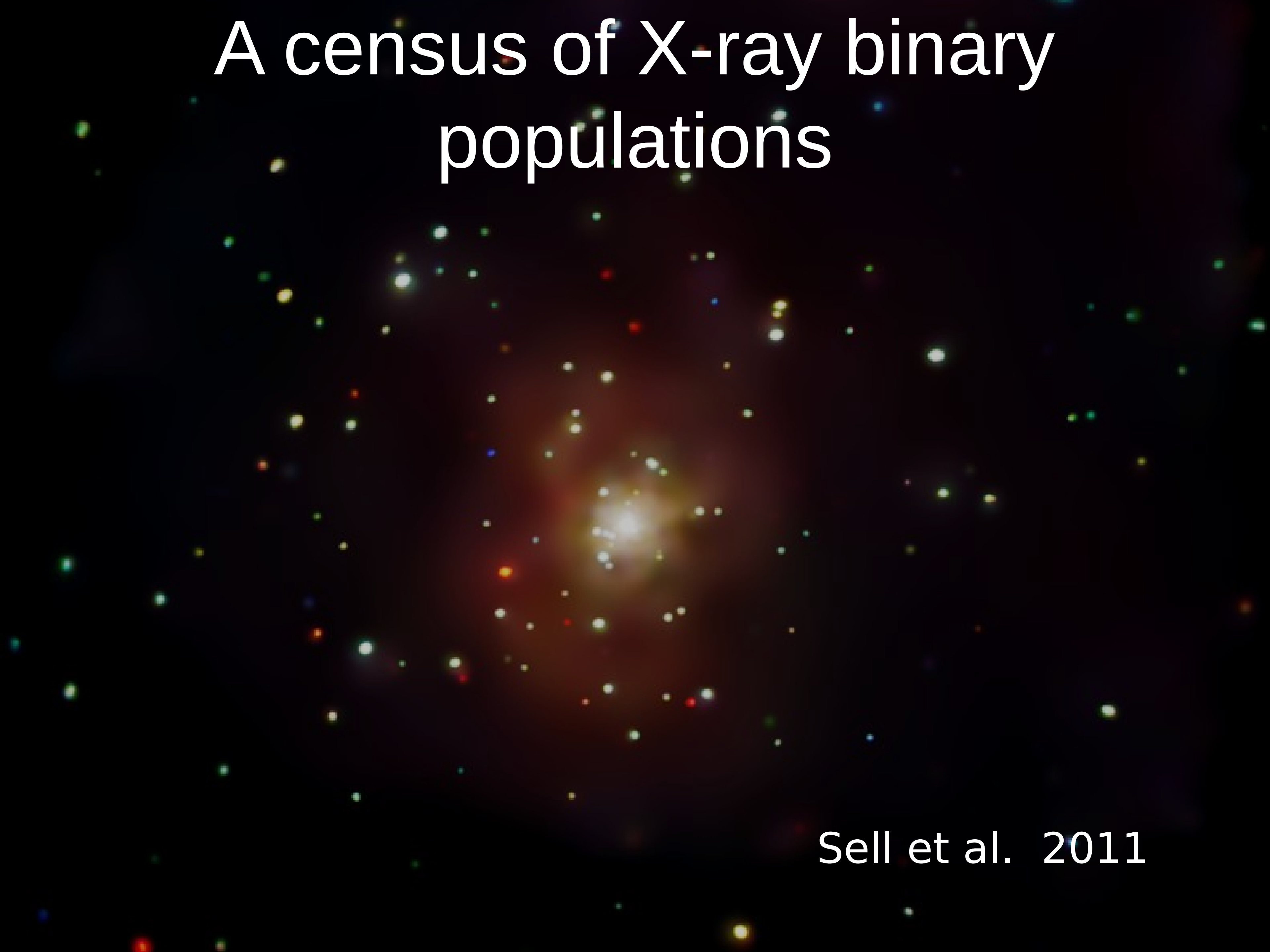


Andreas Zezas

University of Crete, CfA

V. Antoniou, P. Sell, J. Andrews, K. Anastasopoulou,
K. Kovlakas, K. Kouroubatzakis

A census of X-ray binary populations



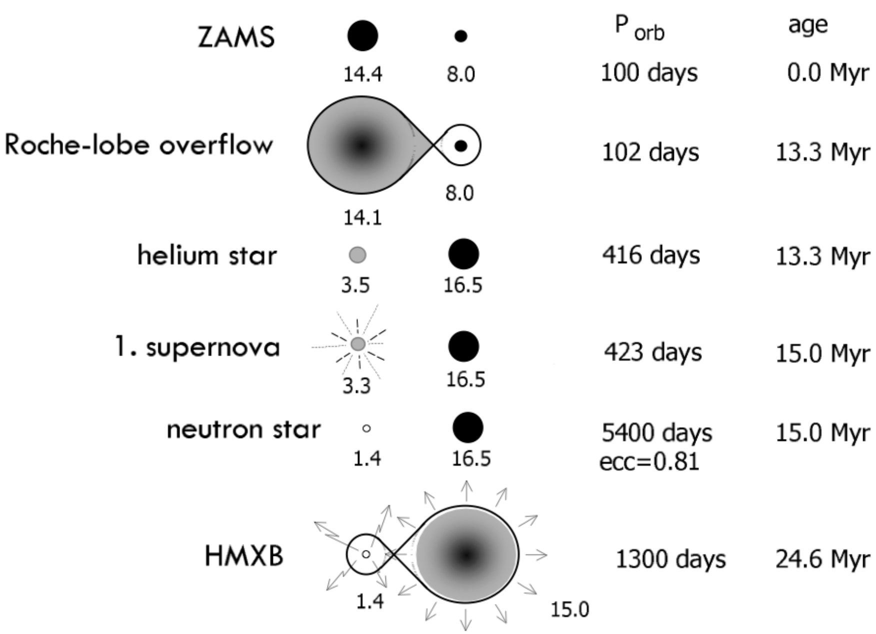
Sell et al. 2011

A census of X-ray binary populations

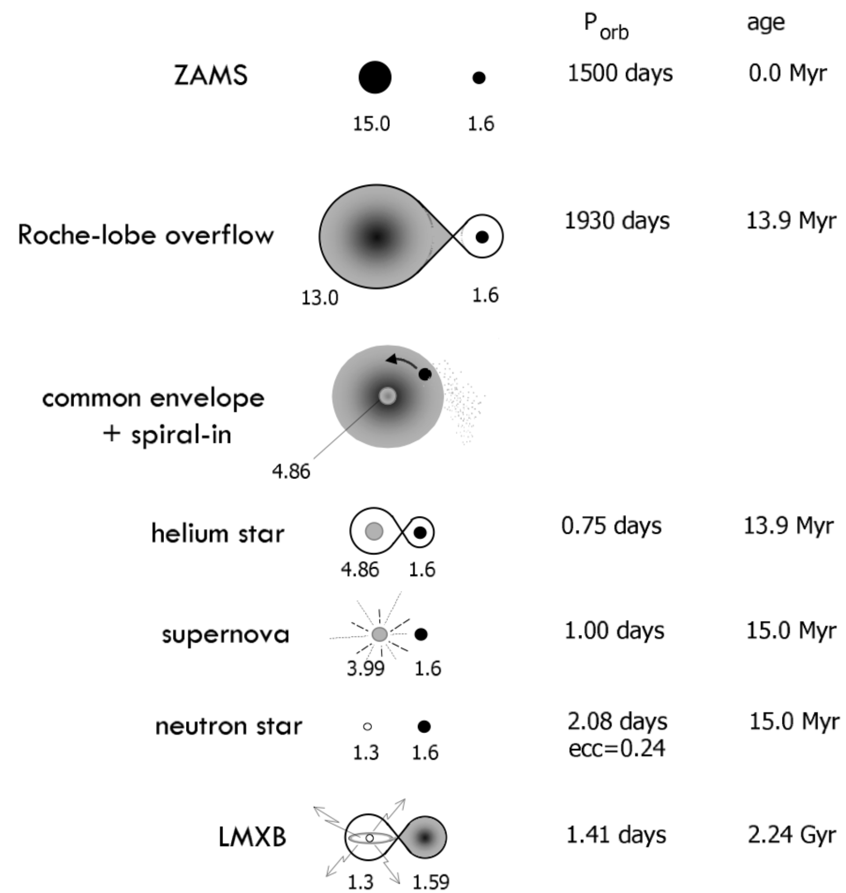
- Compact object demographics / mass spectrum
- Exotic / extreme objects
- Connection with parent stellar populations
- Constraints on binary evolution channels

Their (complicated) evolution

High-mass XRBs

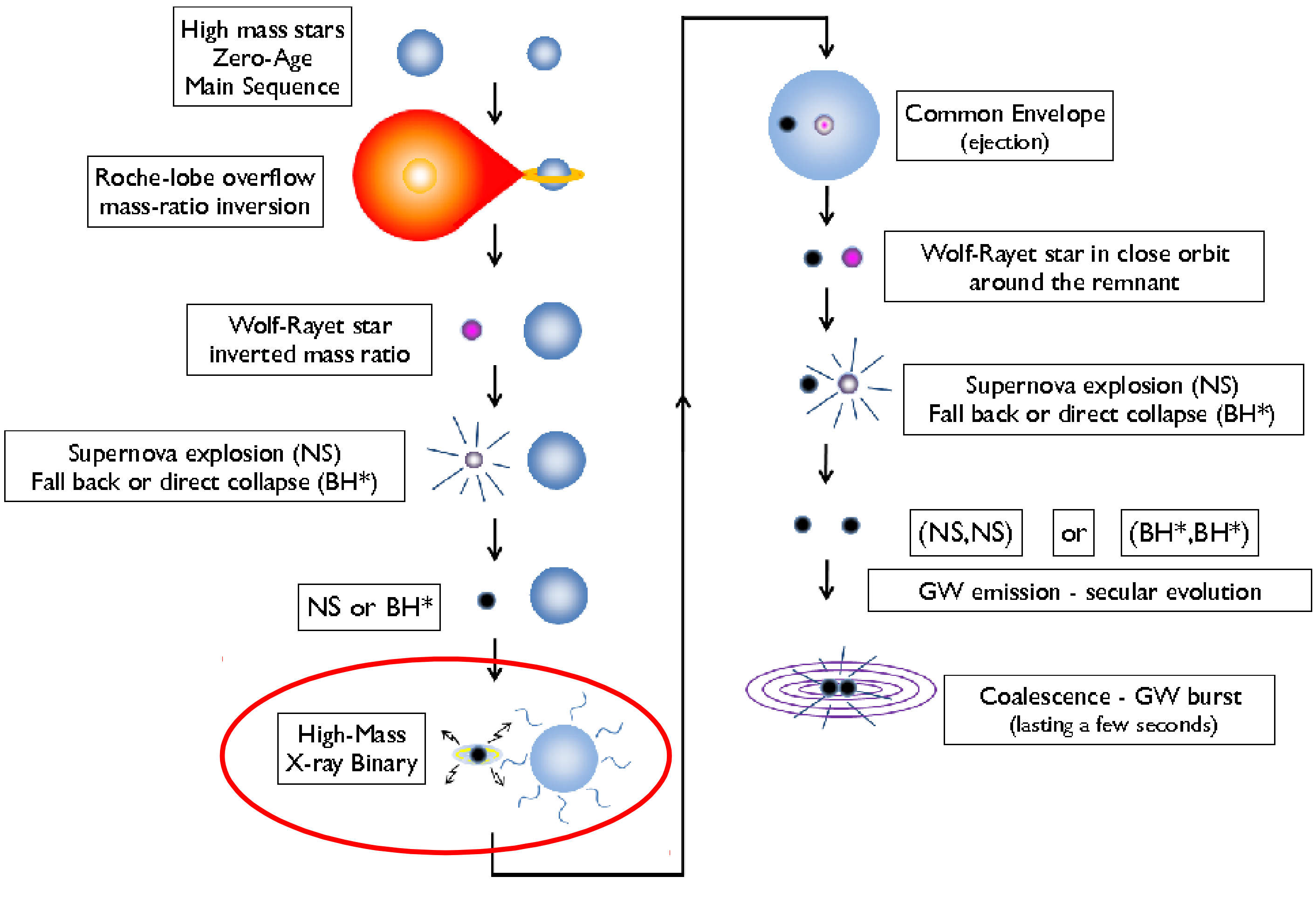


Low-mass XRBs



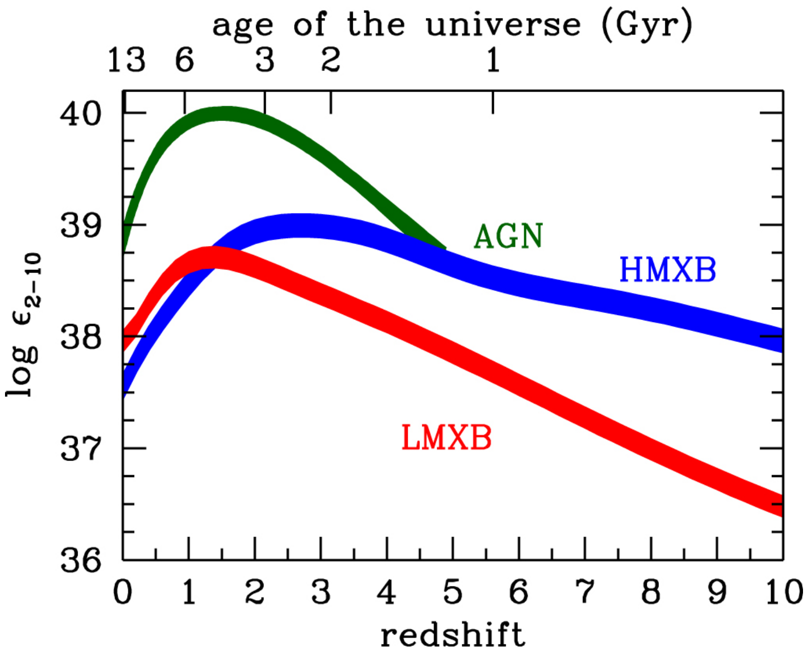
Tauris & van den Heuvel 2006

Gravitational wave sources

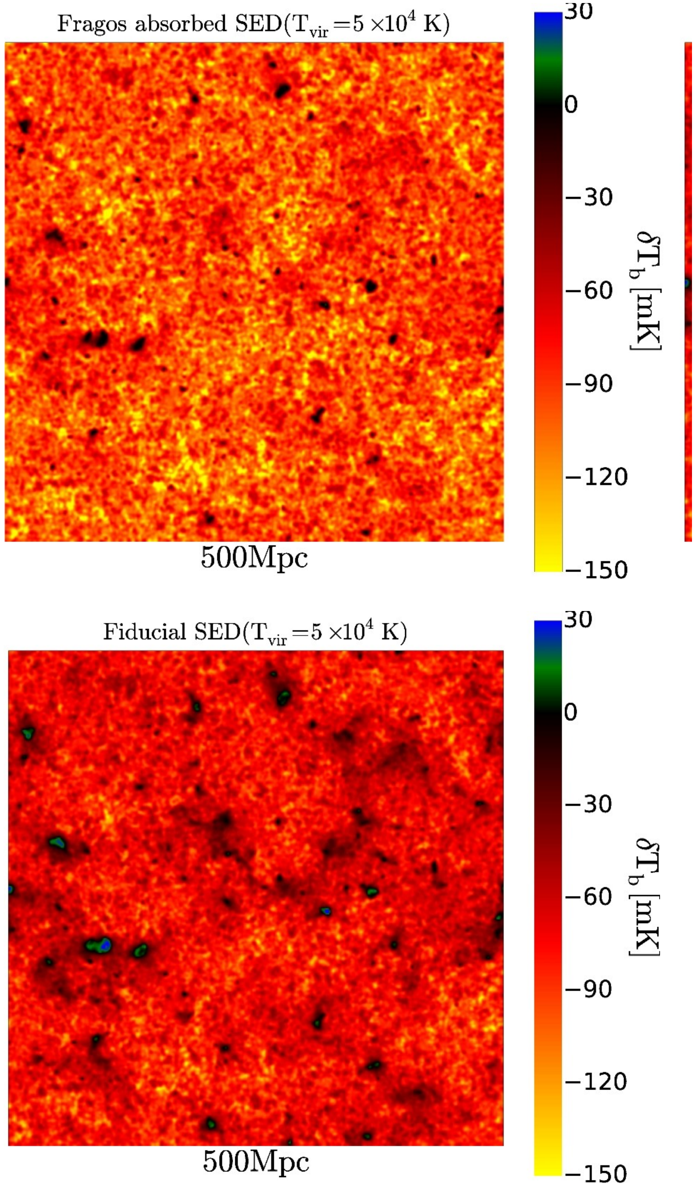


Marchant et al., 2016

IGM preheating

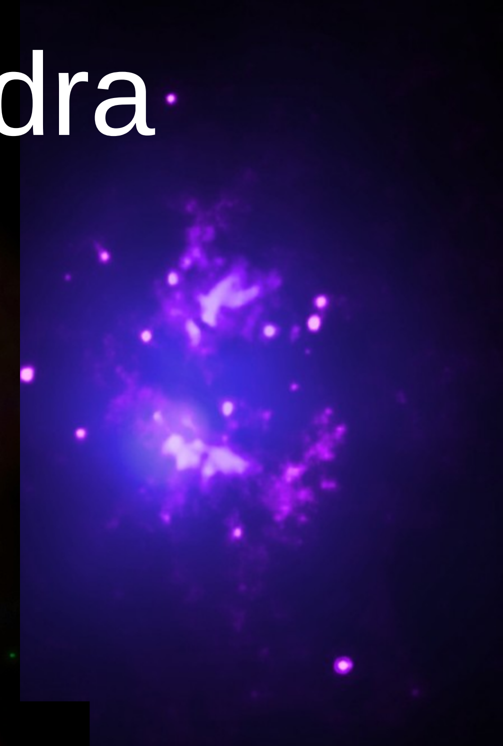


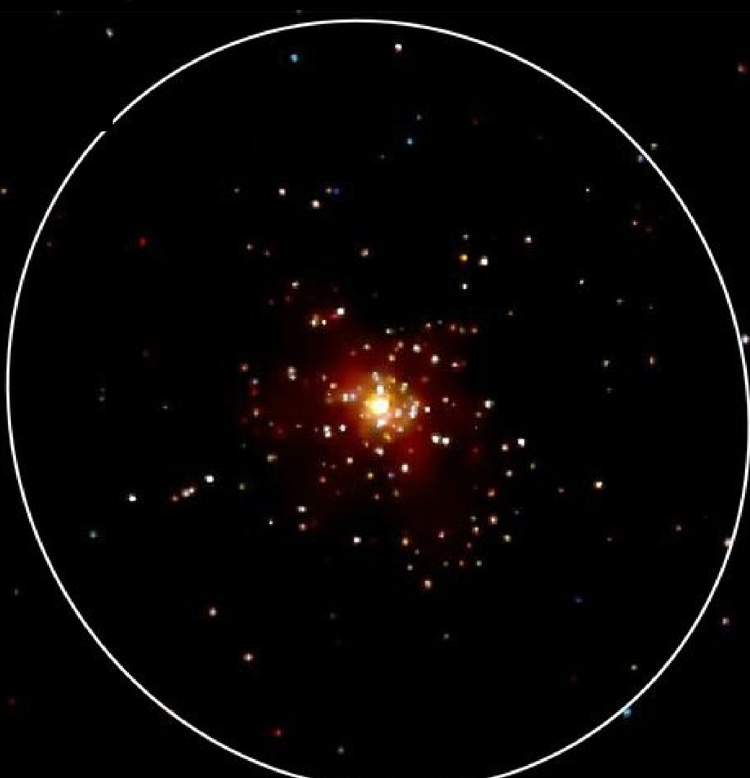
Madau & Fragos 2017

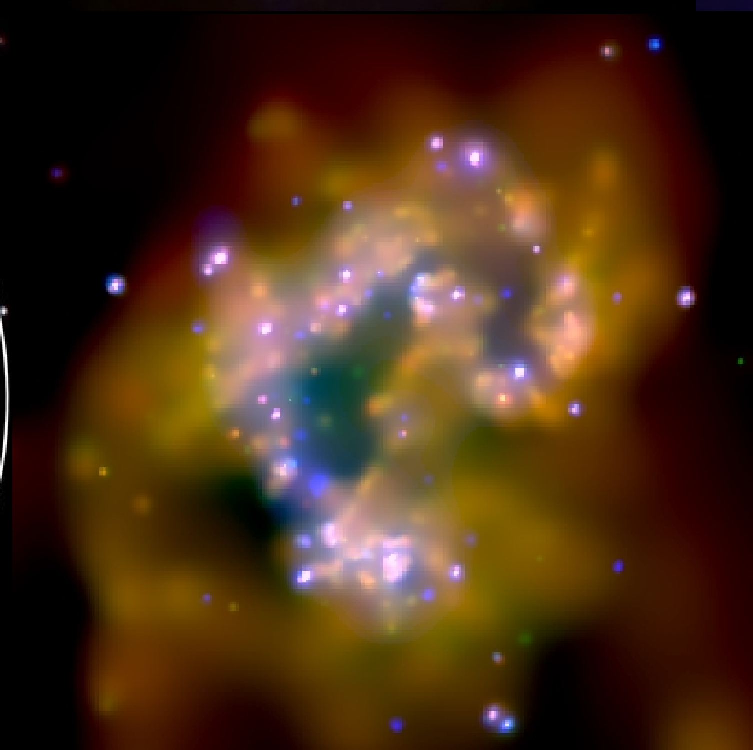


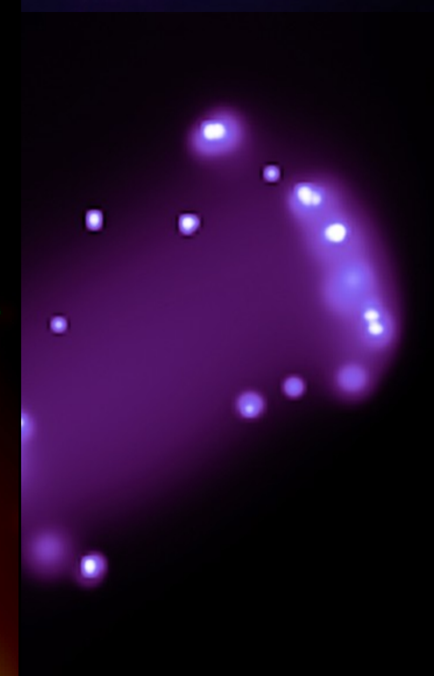
Das et al. 2017

The Legacy of Chandra



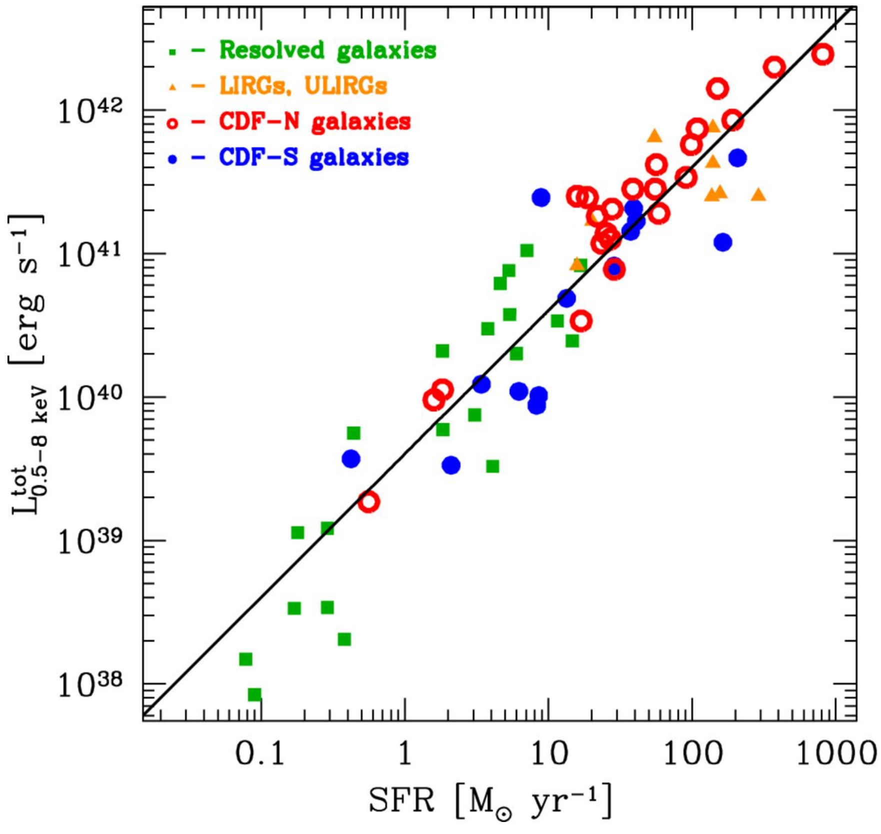






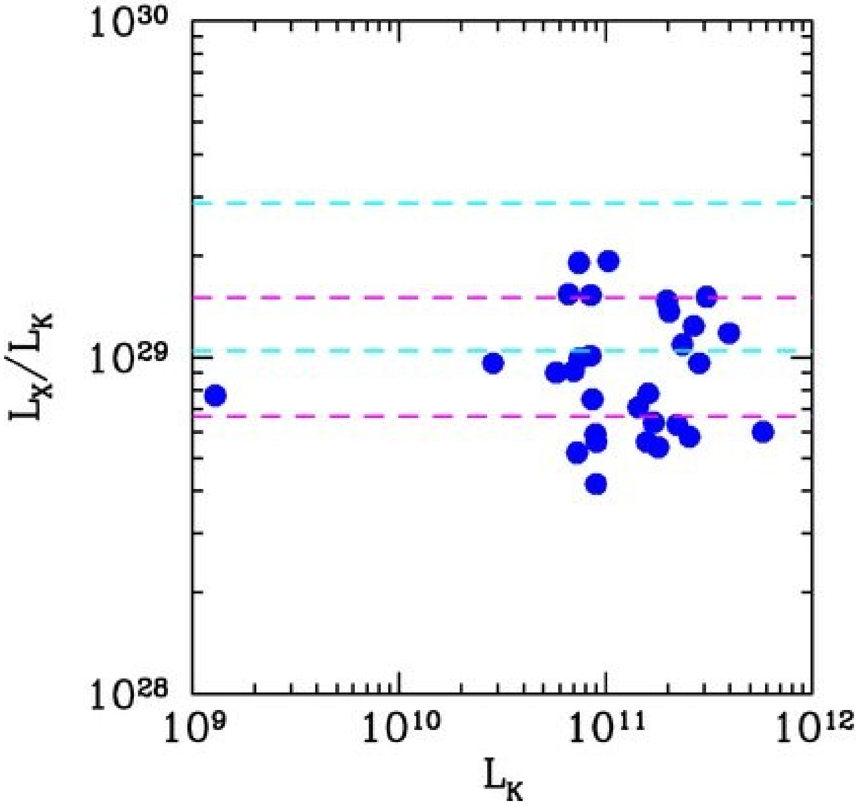
What we learned so far

HMXBs



Mineo et al. 2014

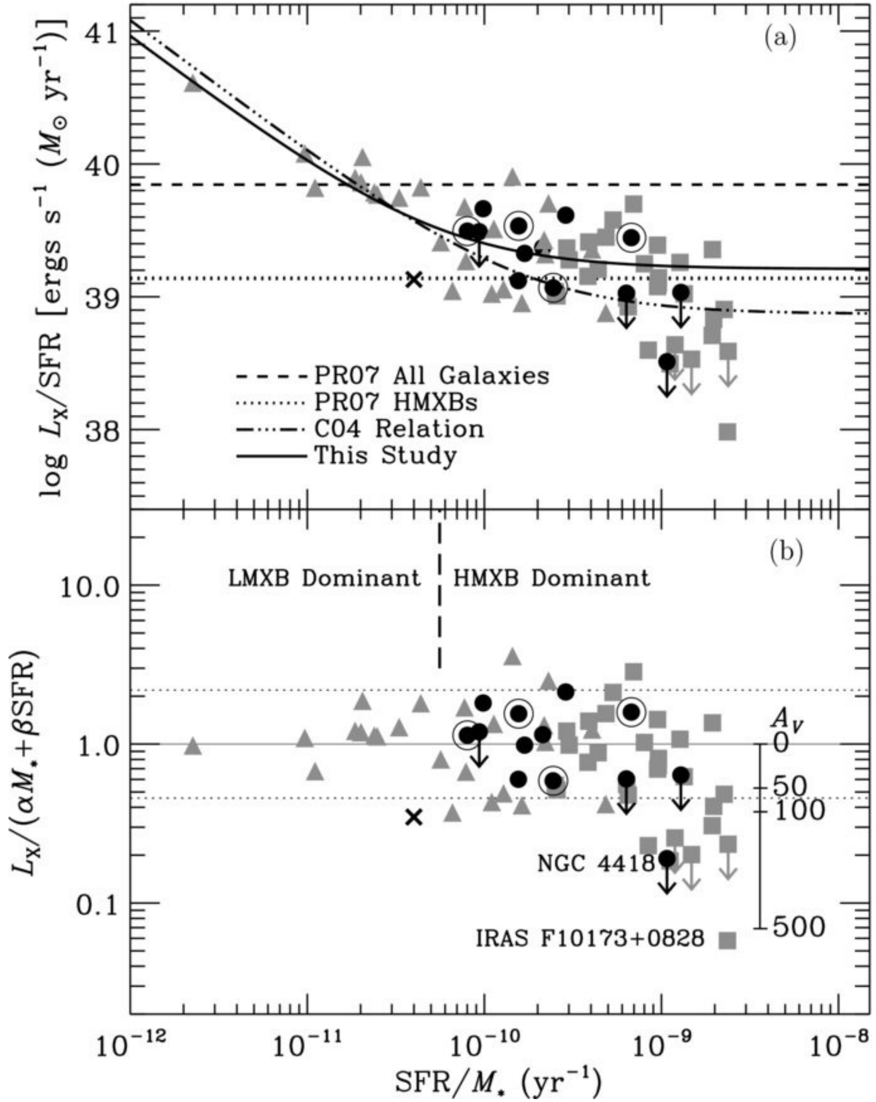
LMXBs



Boroson et al. 2011

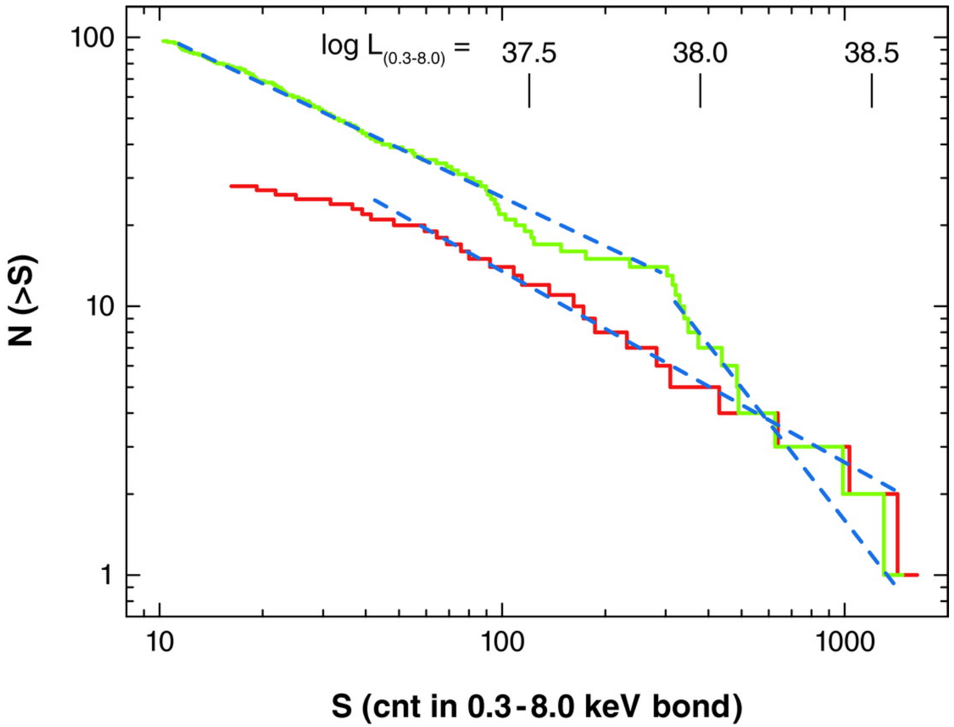
What we learned so far

HMXBs + LMXBs

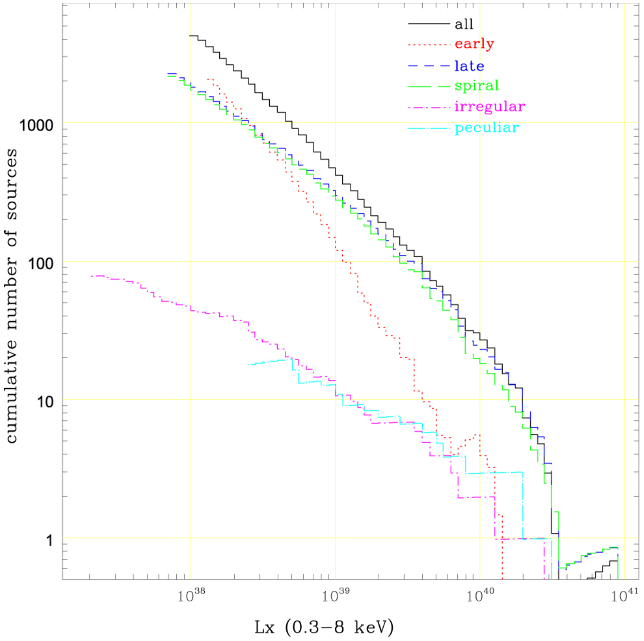


Lehmer et al. 2010

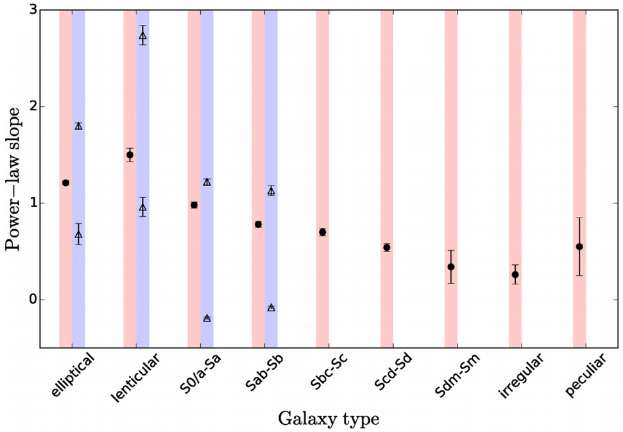
XLF evolution



Soria & Wu 2003



(a)



(a)

Wang et al. 2016

XLFs do not vary

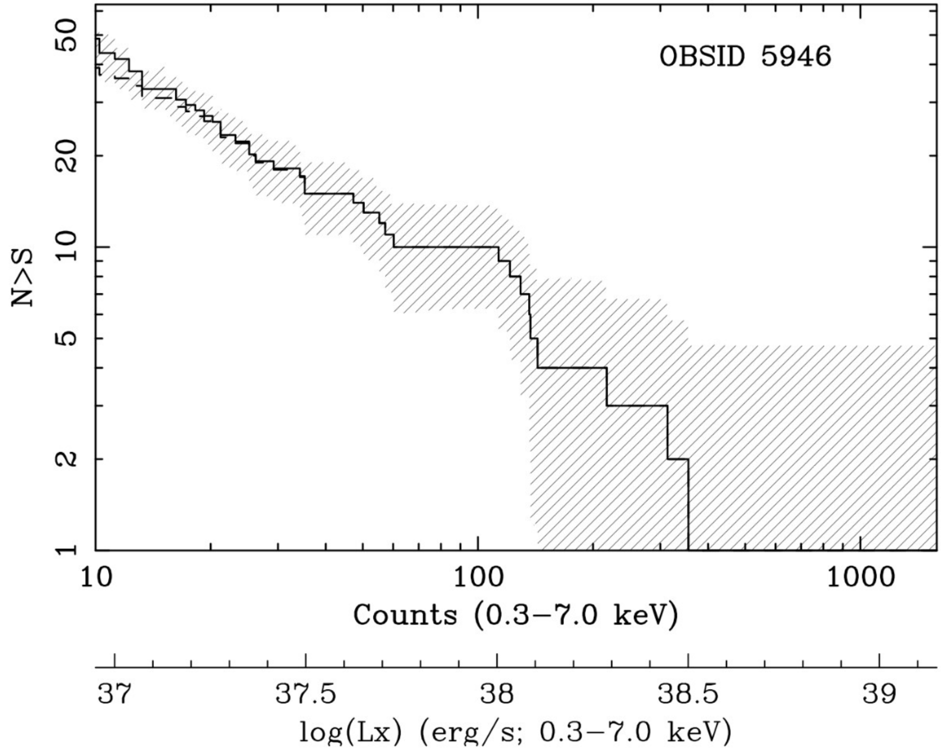
Antennae:

Zezas et al. 2007

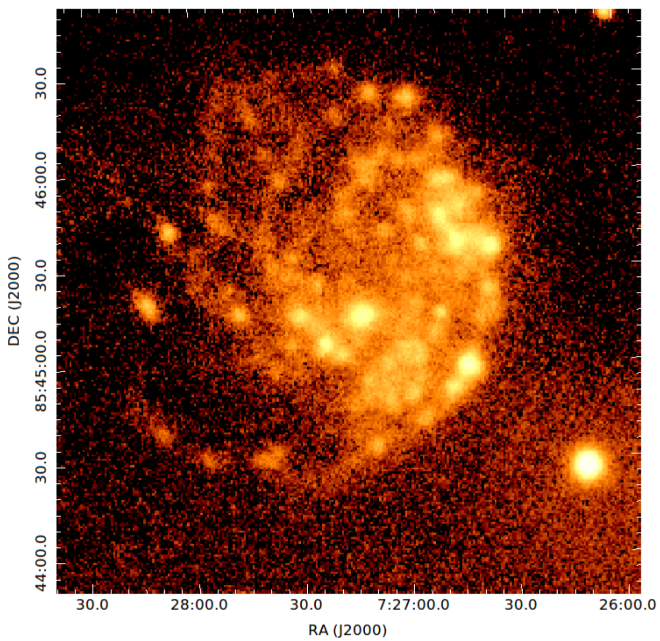
M81: Sell et al. 2011

NGC 300:

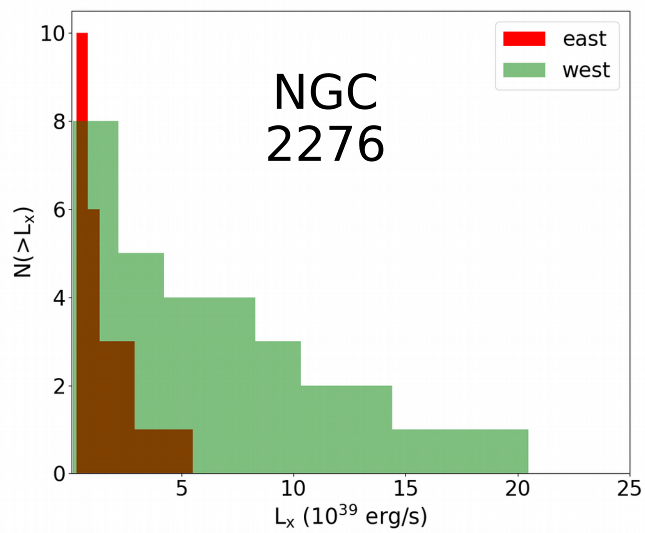
Binder et al. 2017

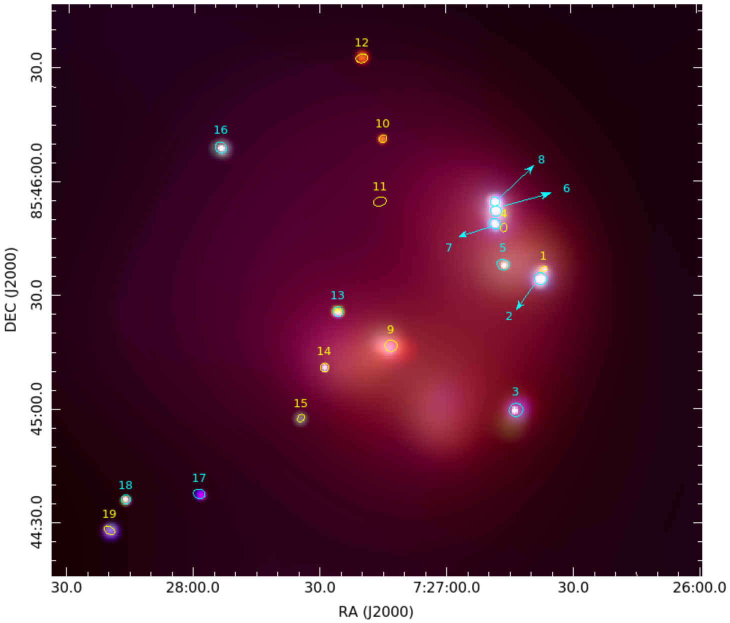


Evidence for age dependence

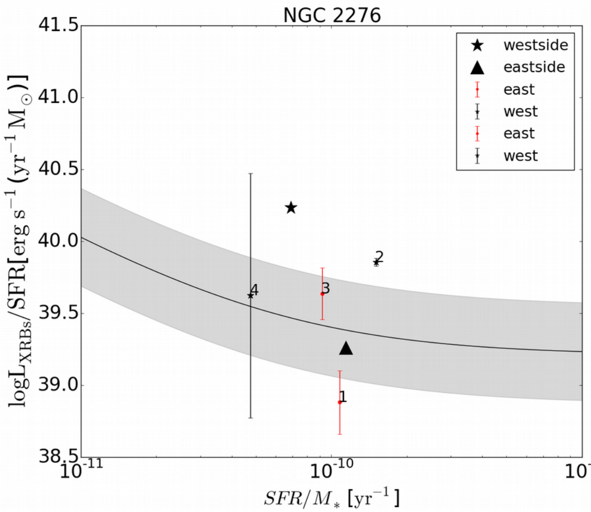


Ha



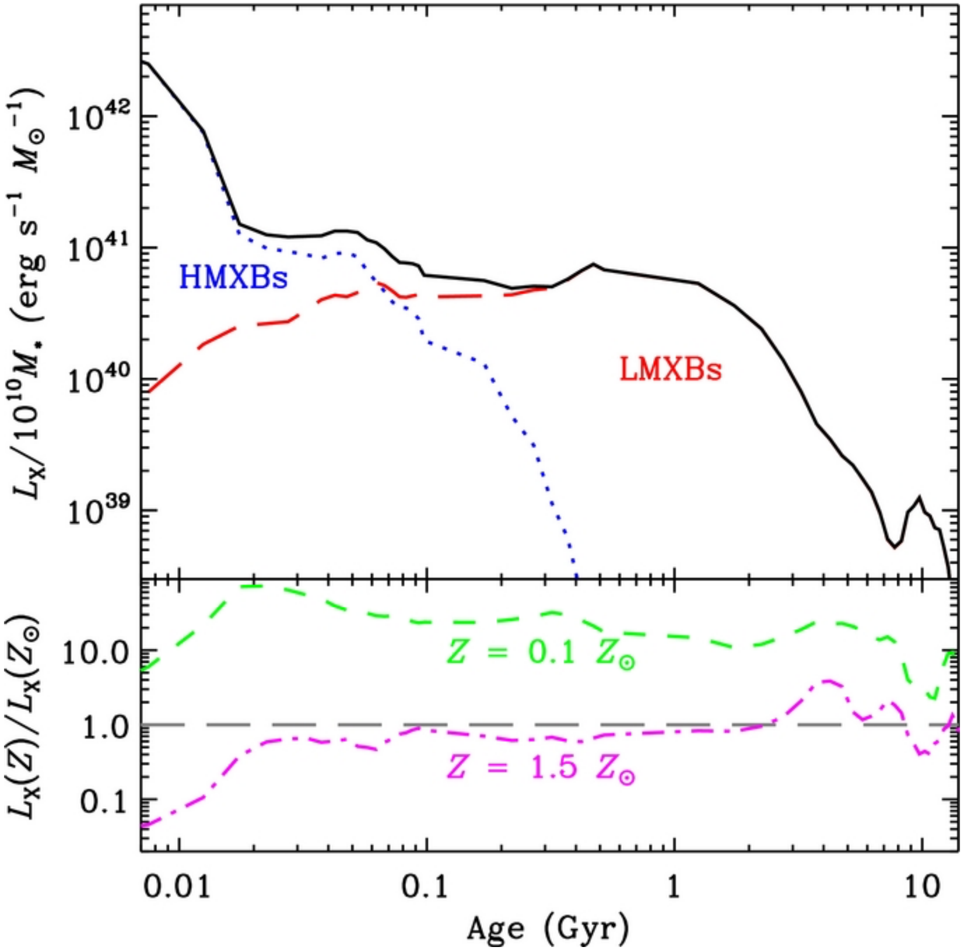


Chandra

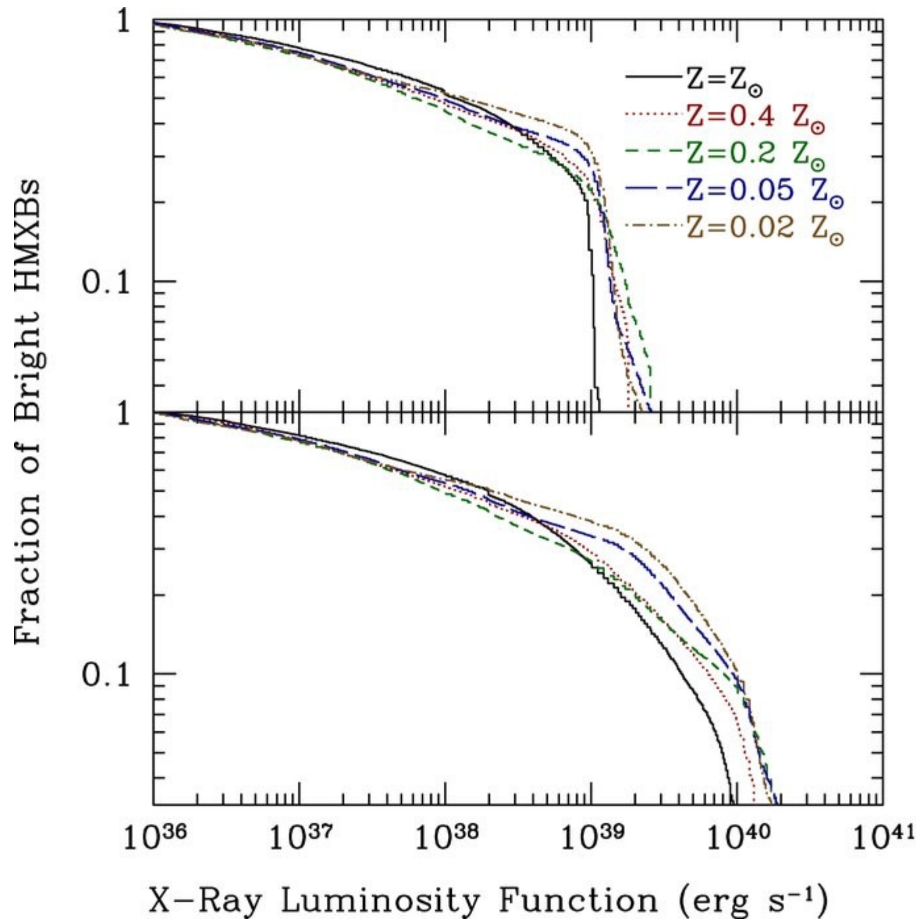


Anastasopoulou et al. 2018

X-ray binary populations



Fragos et al. 2013



Linden et al. 2010

X-ray binary populations

Dependence on age, Z

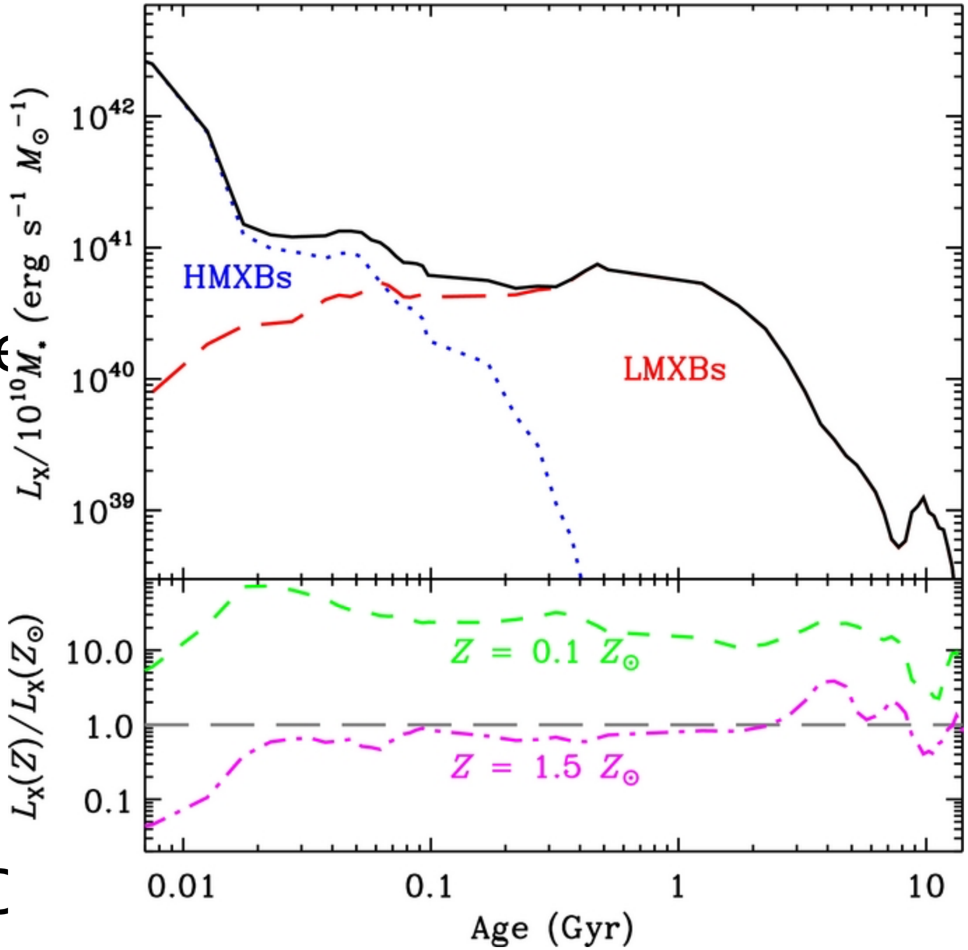
Only now start to explore

Important:

XRB formation/evolution

Modeling GW sources

XRB feedback in Cosmic D

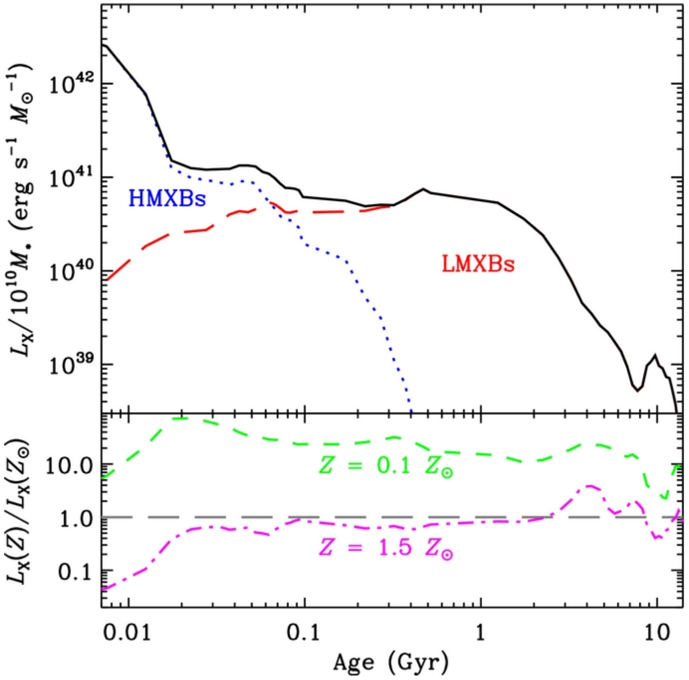


Fragos et al. 2013

Disentangling the age dependence

Results on individual galaxies

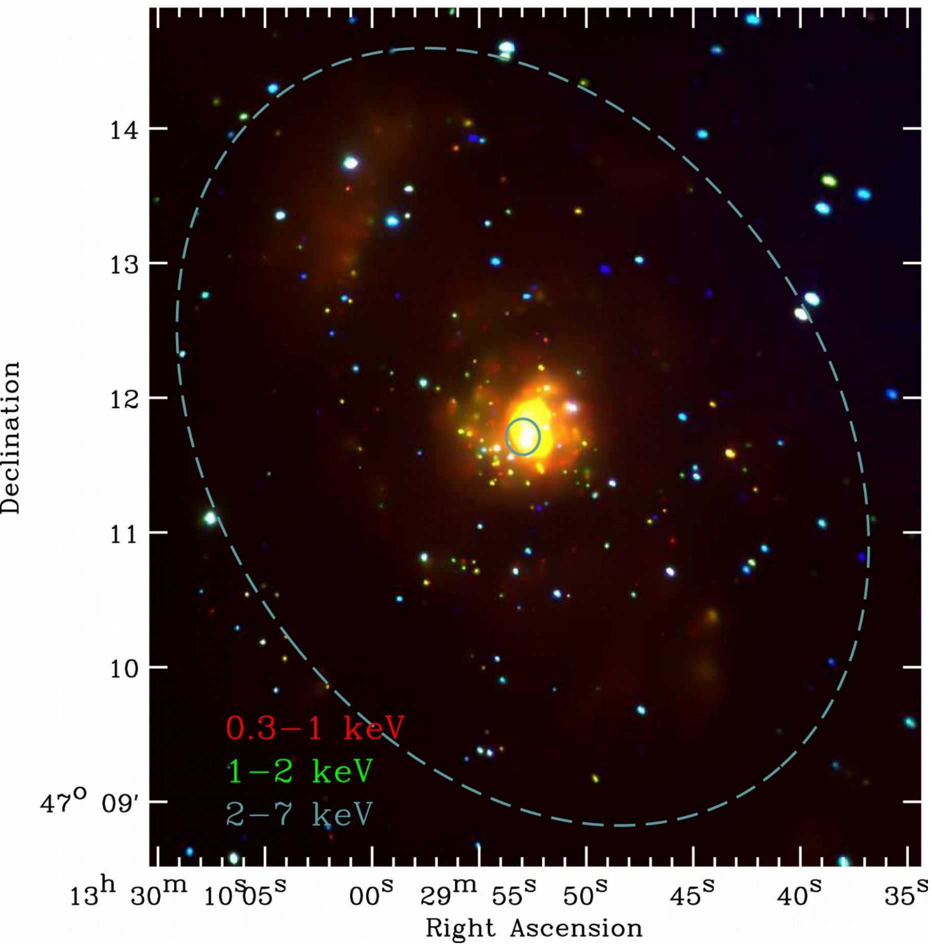
M51, SMC, M81

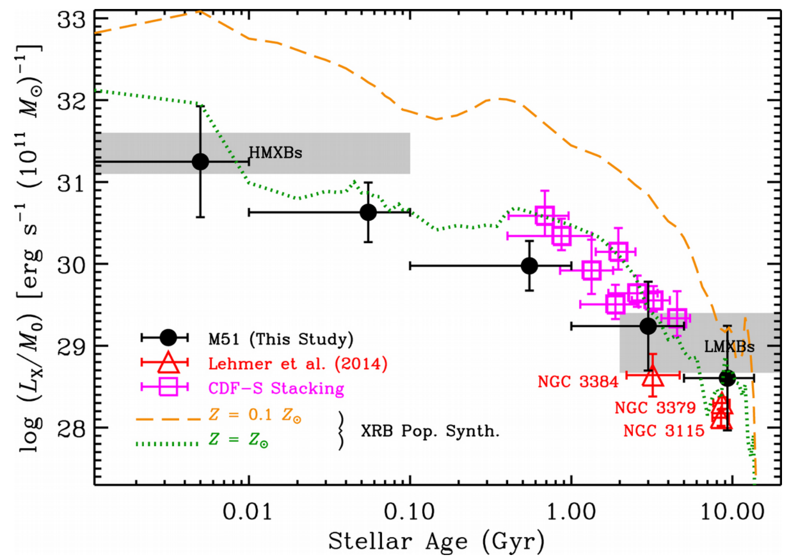


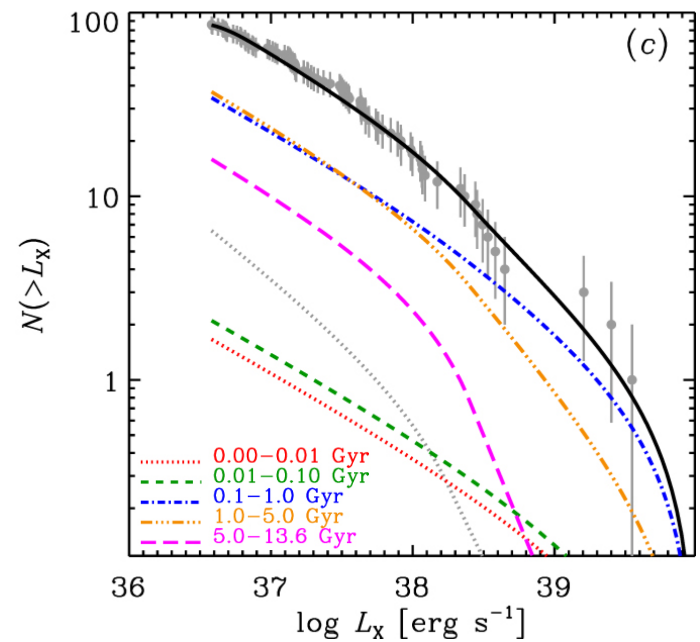
Fragos et al. 2013

Age dependence of XRBs

M51

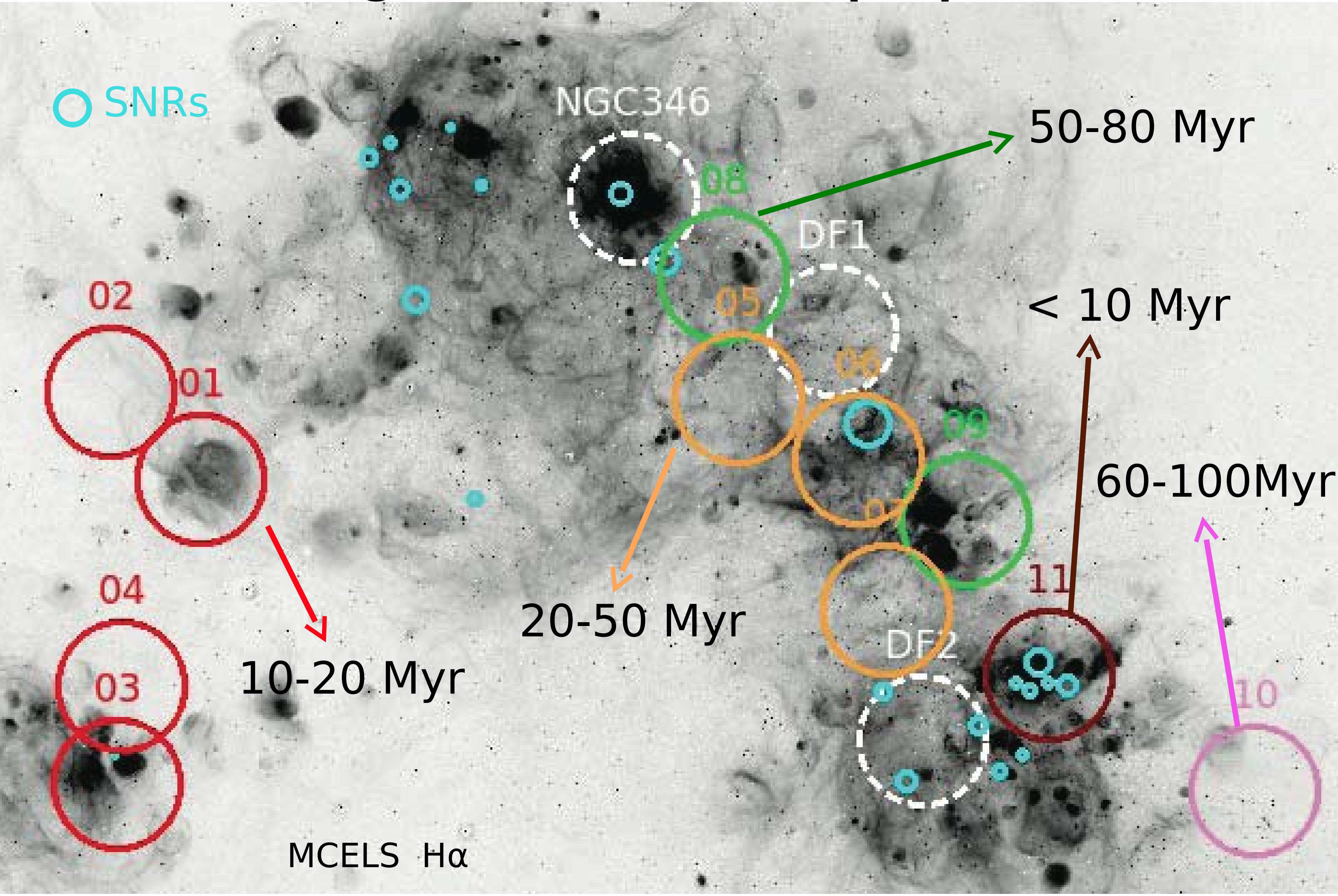


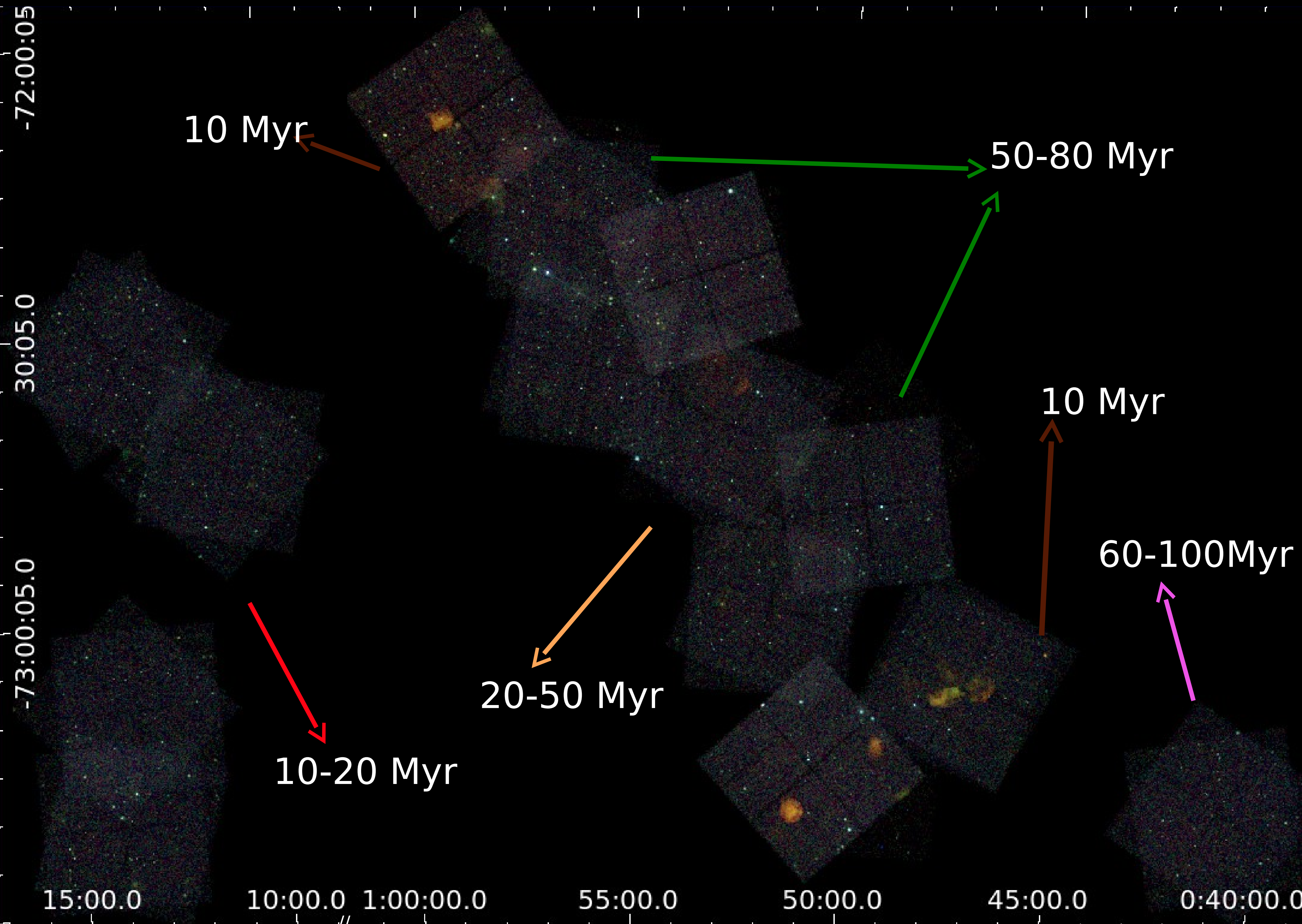




Lehmer et al. 2017

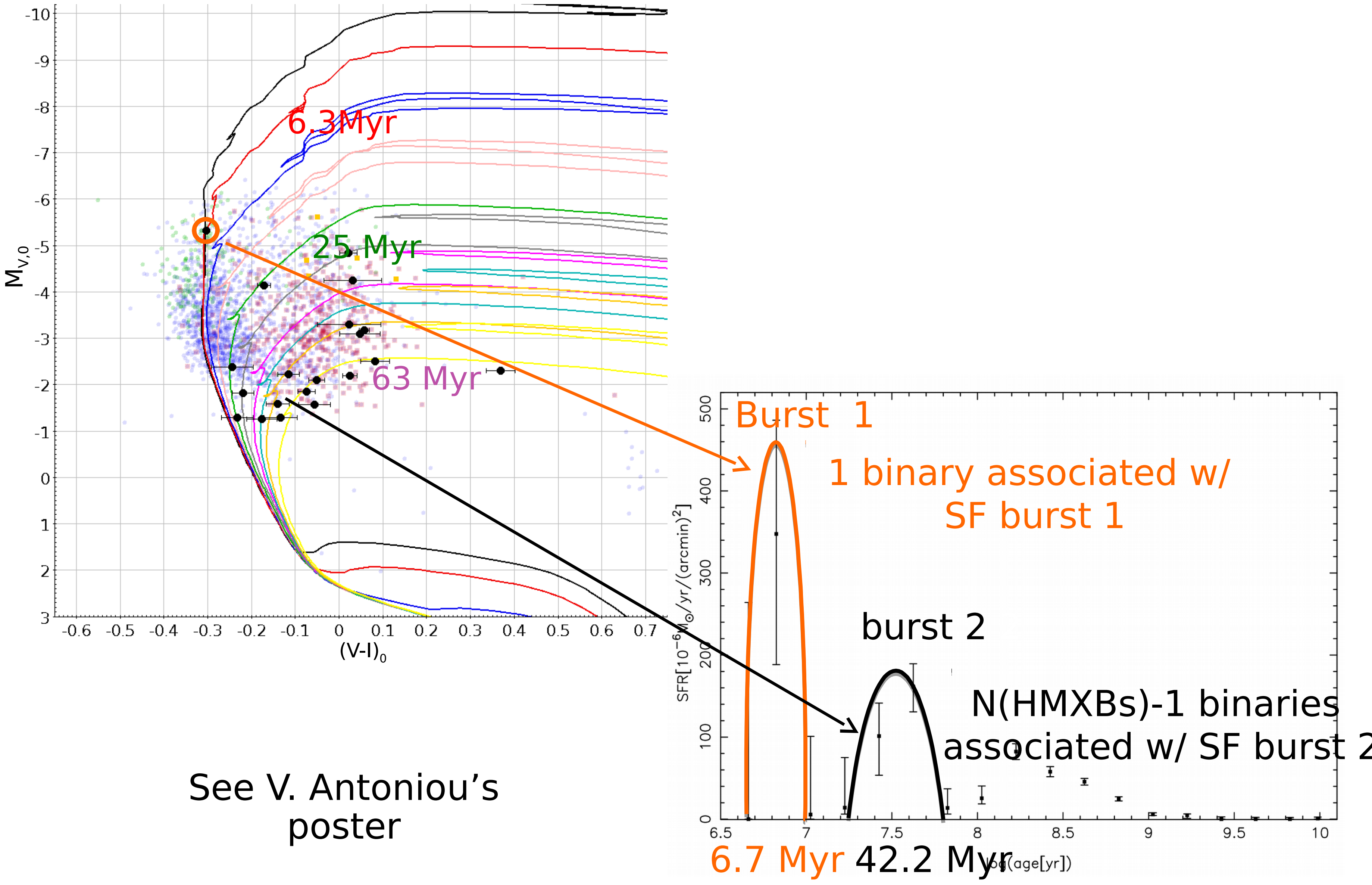
Probing the faintest populations





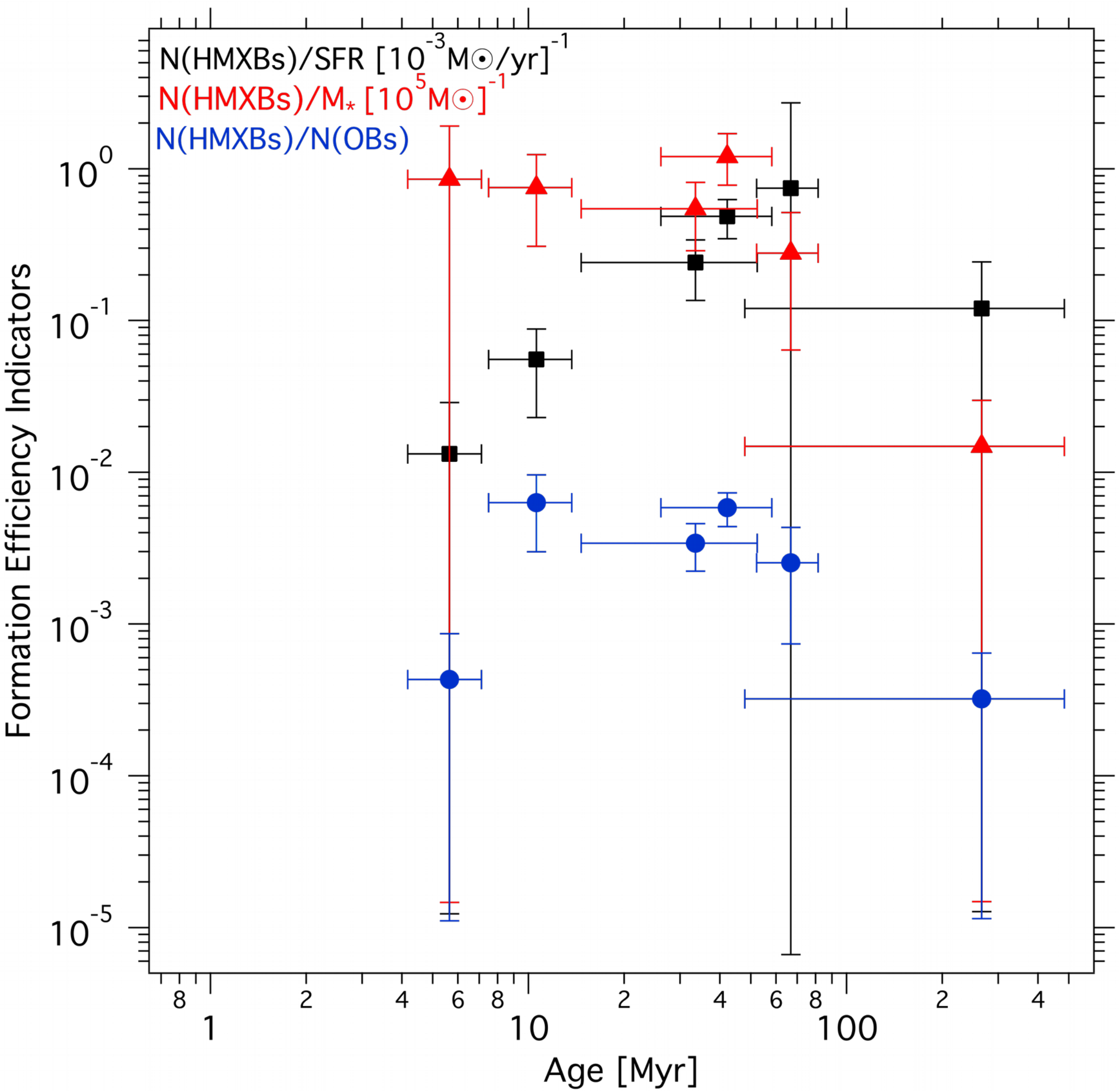
10 Myr
50-80 Myr
10 Myr
60-100Myr
20-50 Myr
10-20 Myr
-72:00:05
30:05.0
-73:00:05.0
15:00.0
10:00.0
1:00:00.0
55:00.0
50:00.0
45:00.0
0:40:00.0

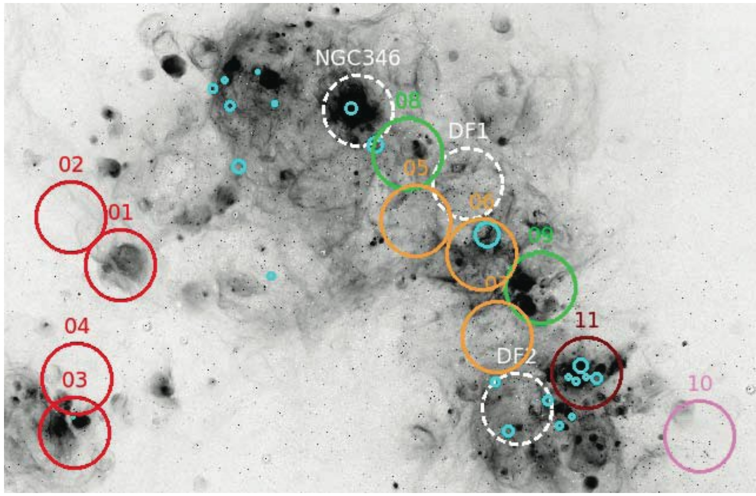
HMXB classification

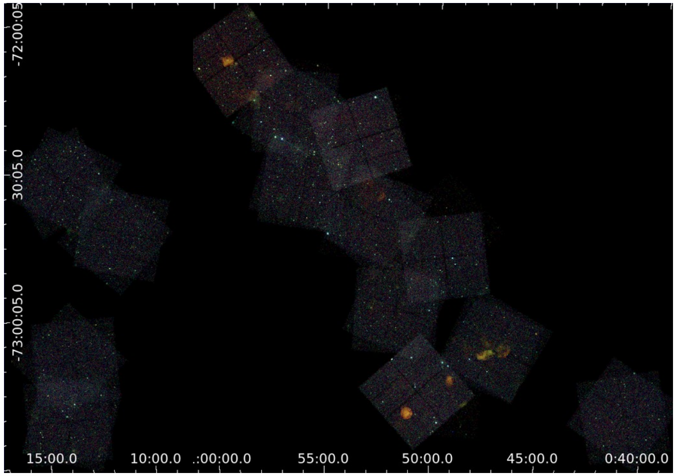


See V. Antoniou's poster

HMXB formation efficiency

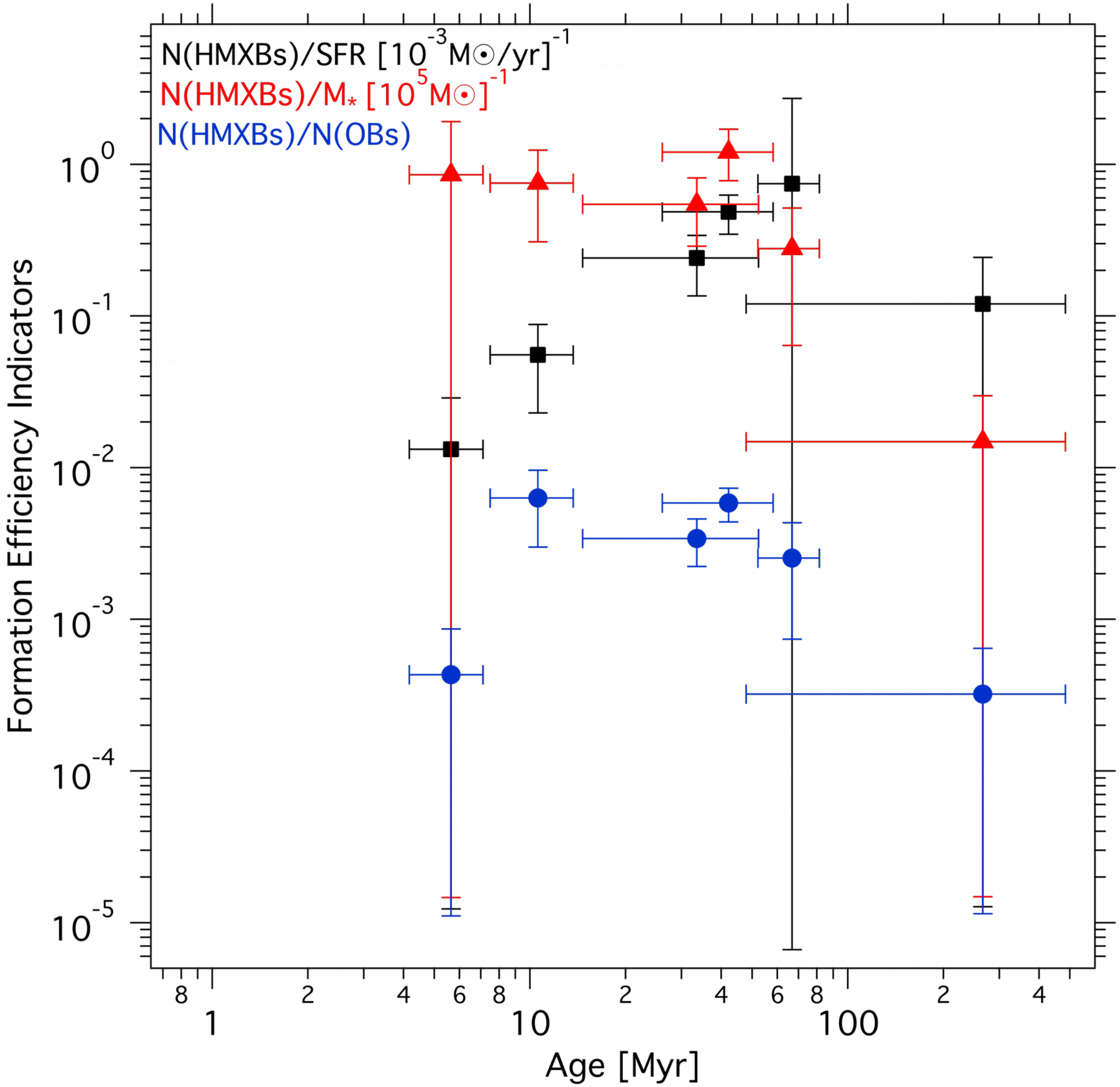




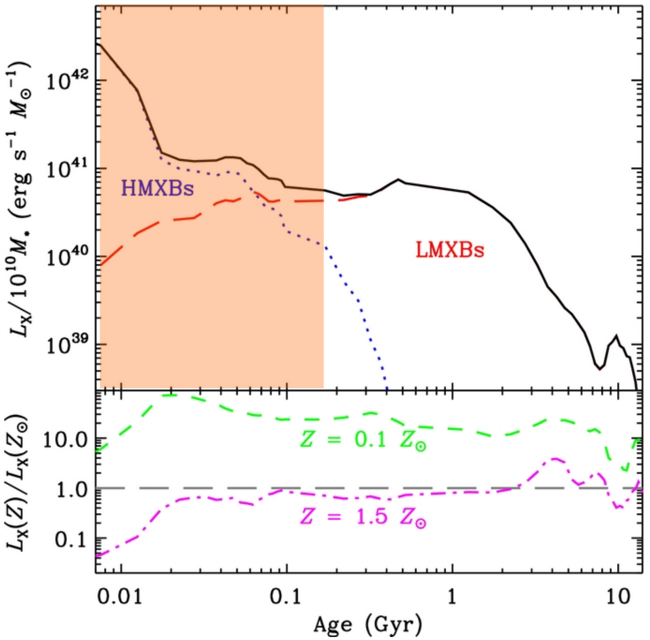


Antoniou et al, 2018

HMXB formation efficiency



Antoniou et al, 2018



Fragos et al. 2013

M81

Grand design spiral galaxy (3.6 Mpc)

- Deep Chandra coverage

  Sell et al. 2011; Swartz et al.

M81

Grand design spiral galaxy (3.6 Mpc)

- Deep Chandra coverage

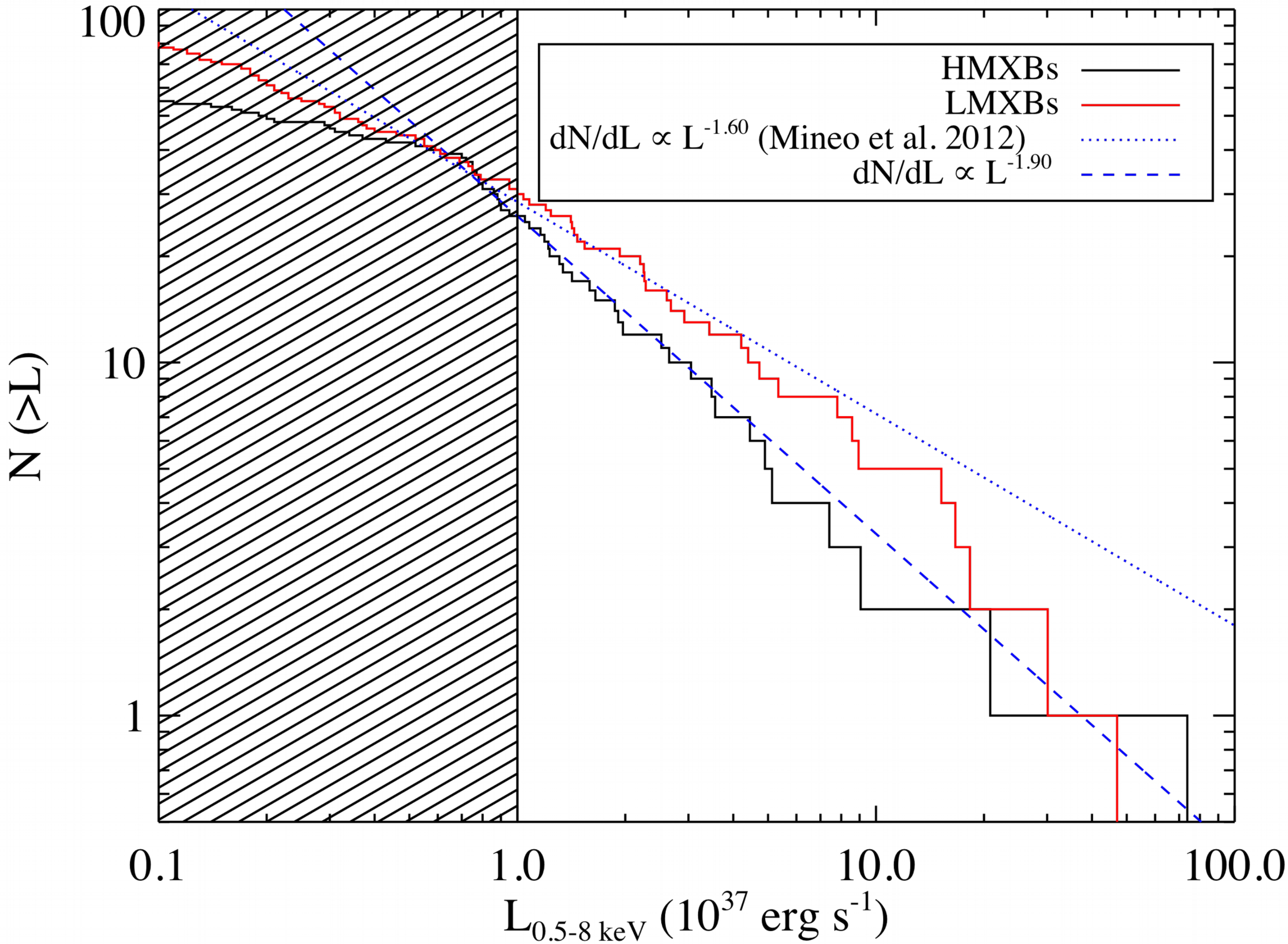
  Sell et al. 2011; Swartz et al.

- Complete HST coverage

Measure directly XLF and formation efficiency
of different XRB classes

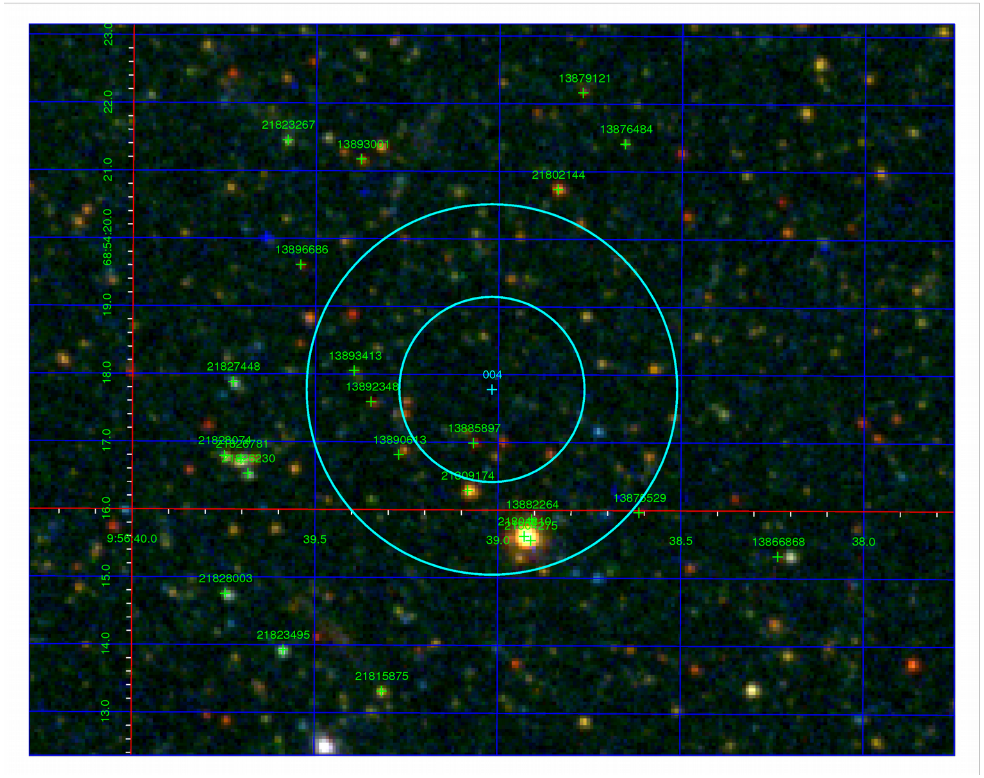
M81

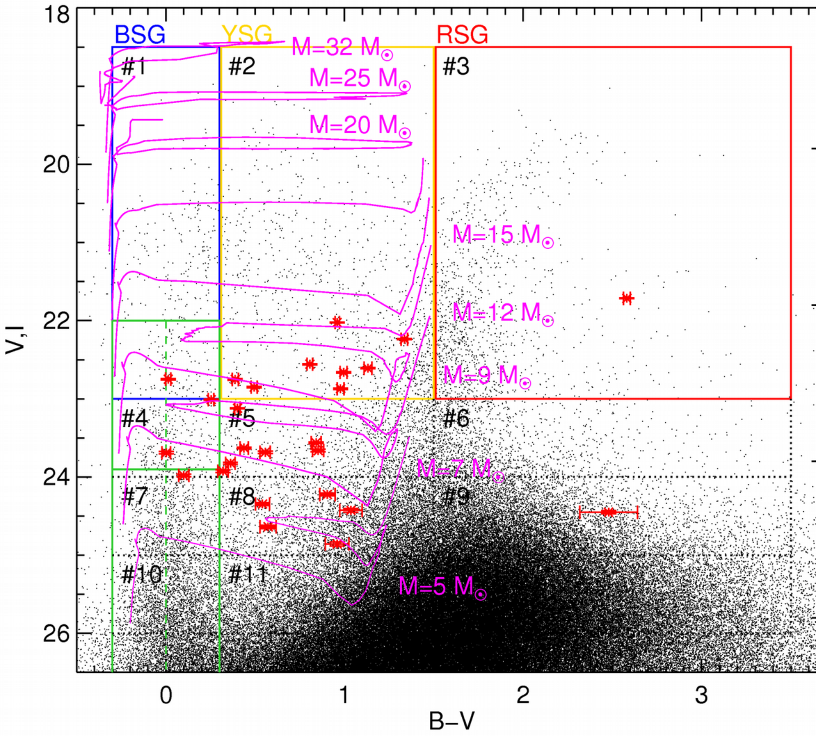
XLFs for different source classes (Sell et al. 2011)



M81

Optical counterparts: Donor star classification

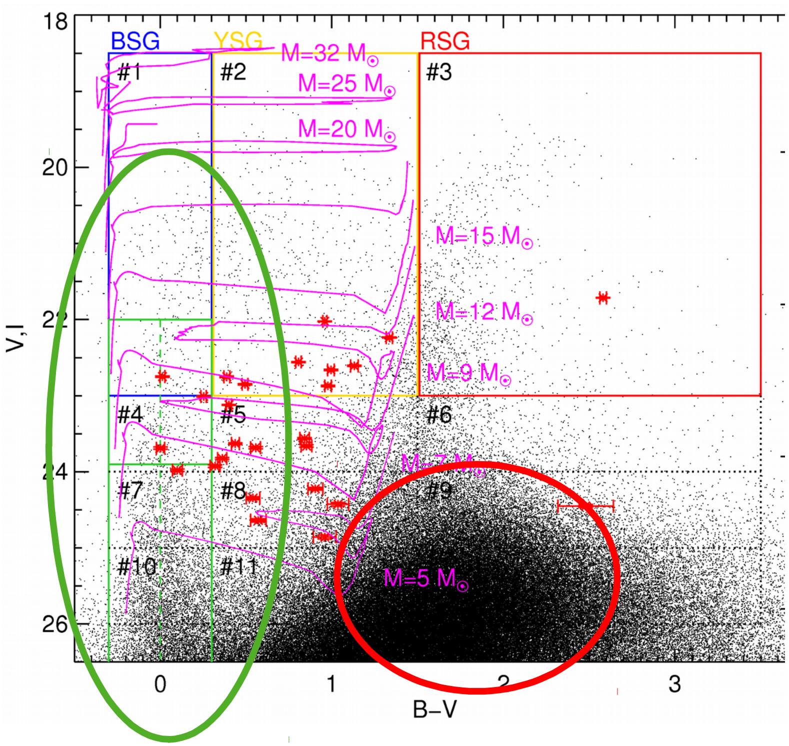


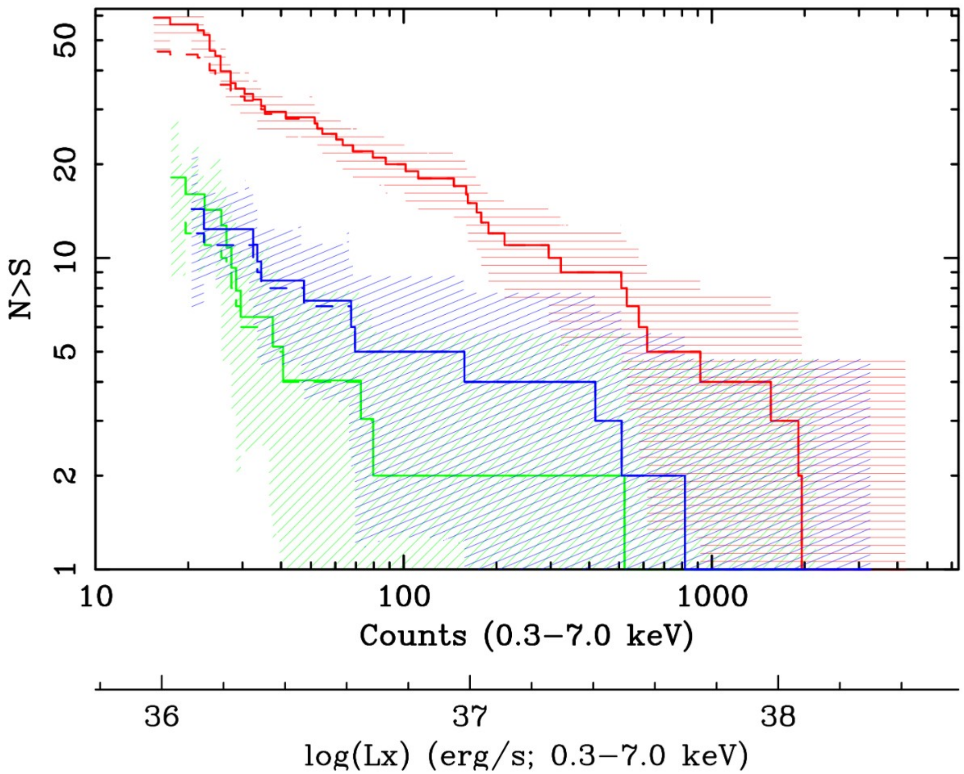


Sell et al. 2018

M81

XLFs for different source classes (Sell et al. 2018)





Summary

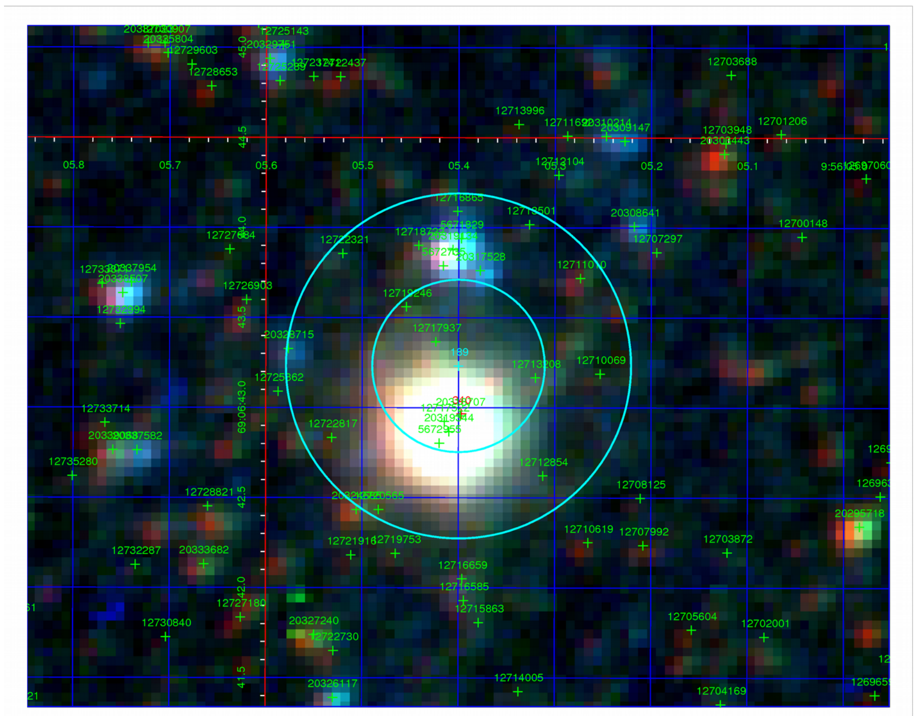
- We are starting to go beyond scaling relations
- Characterize the parameters affecting XRB populations

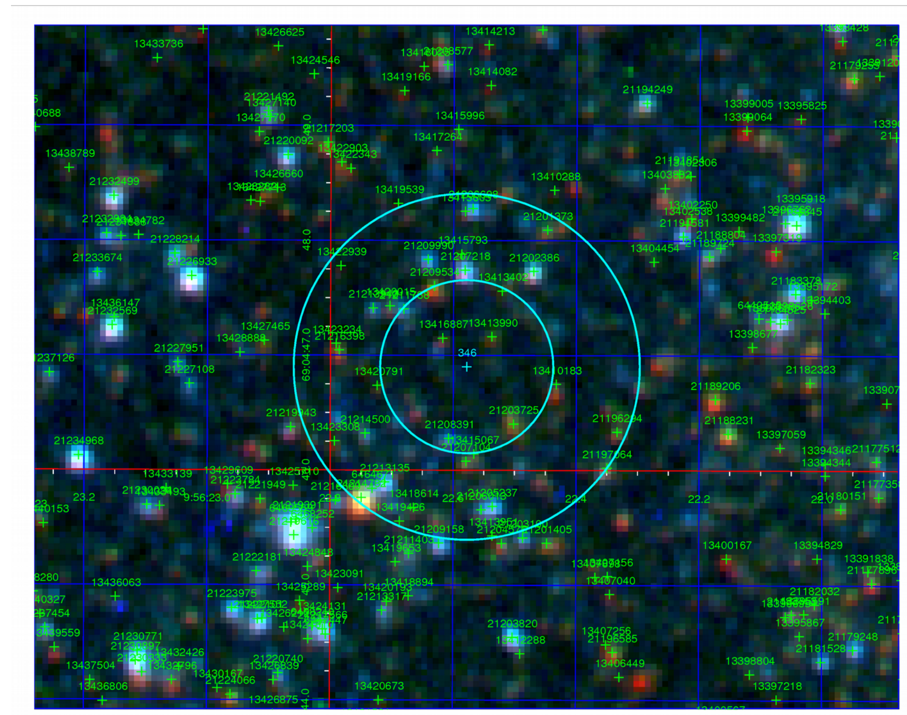
- Key for constraining XRB formation and evolution models
- Cosmological evolution of galaxies and compact objects
  - GW sources, XRBs in the early universe

But Chandra reaches only the tip of the iceberg…

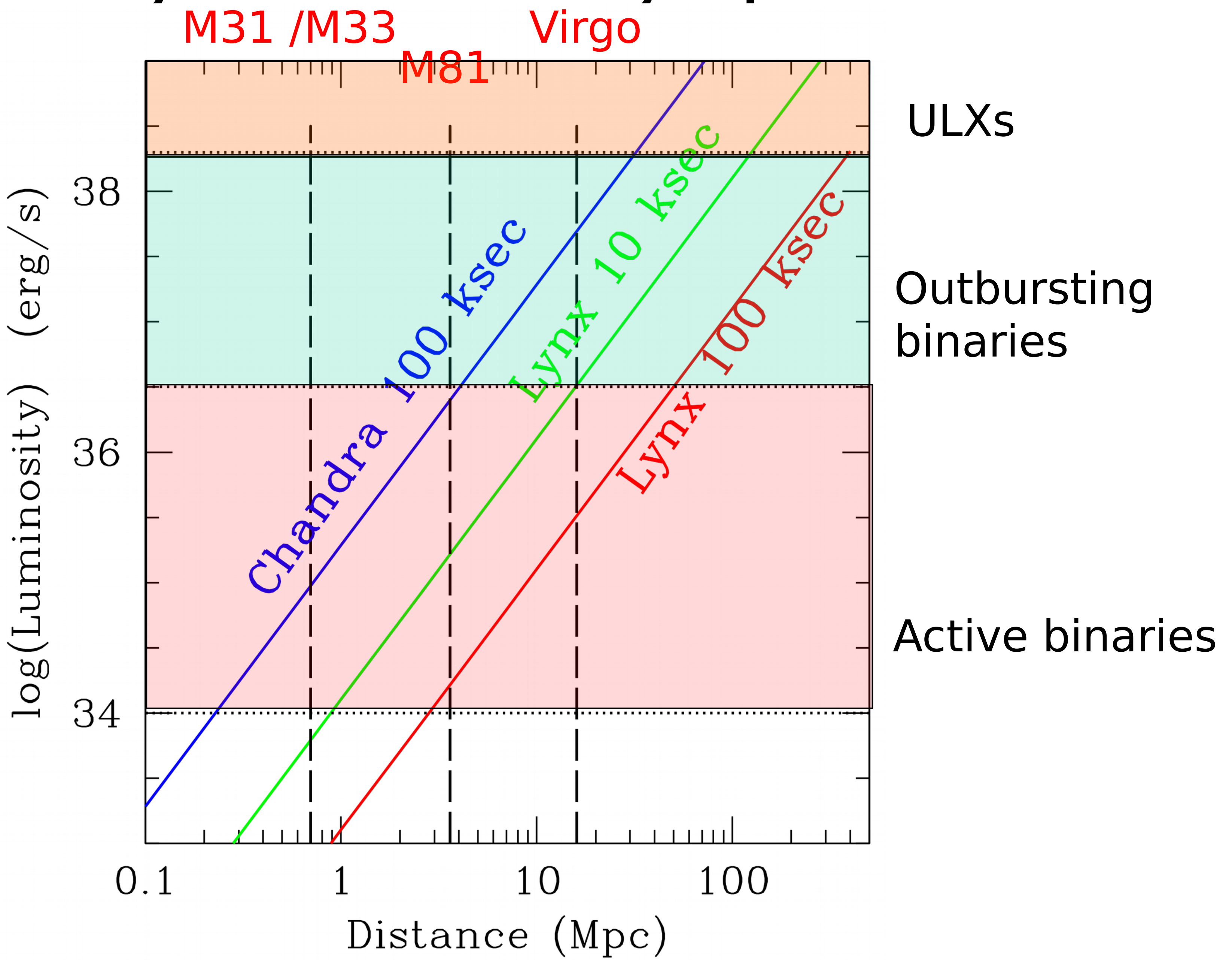
Beyond Chandra

Limitations of Chandra : variable under-sampled PSF



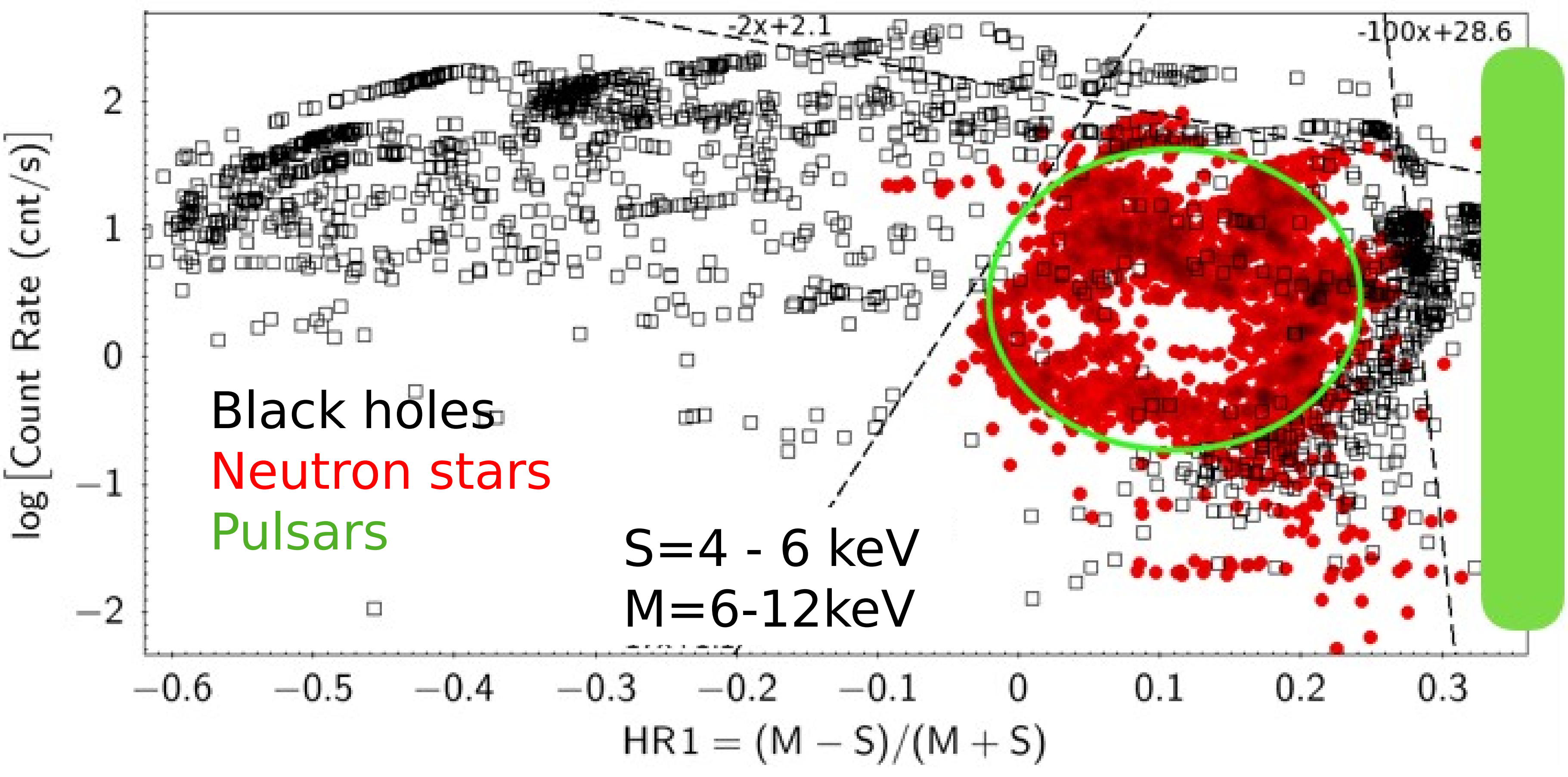


Lynx discovery space



Full characterization of XRBs

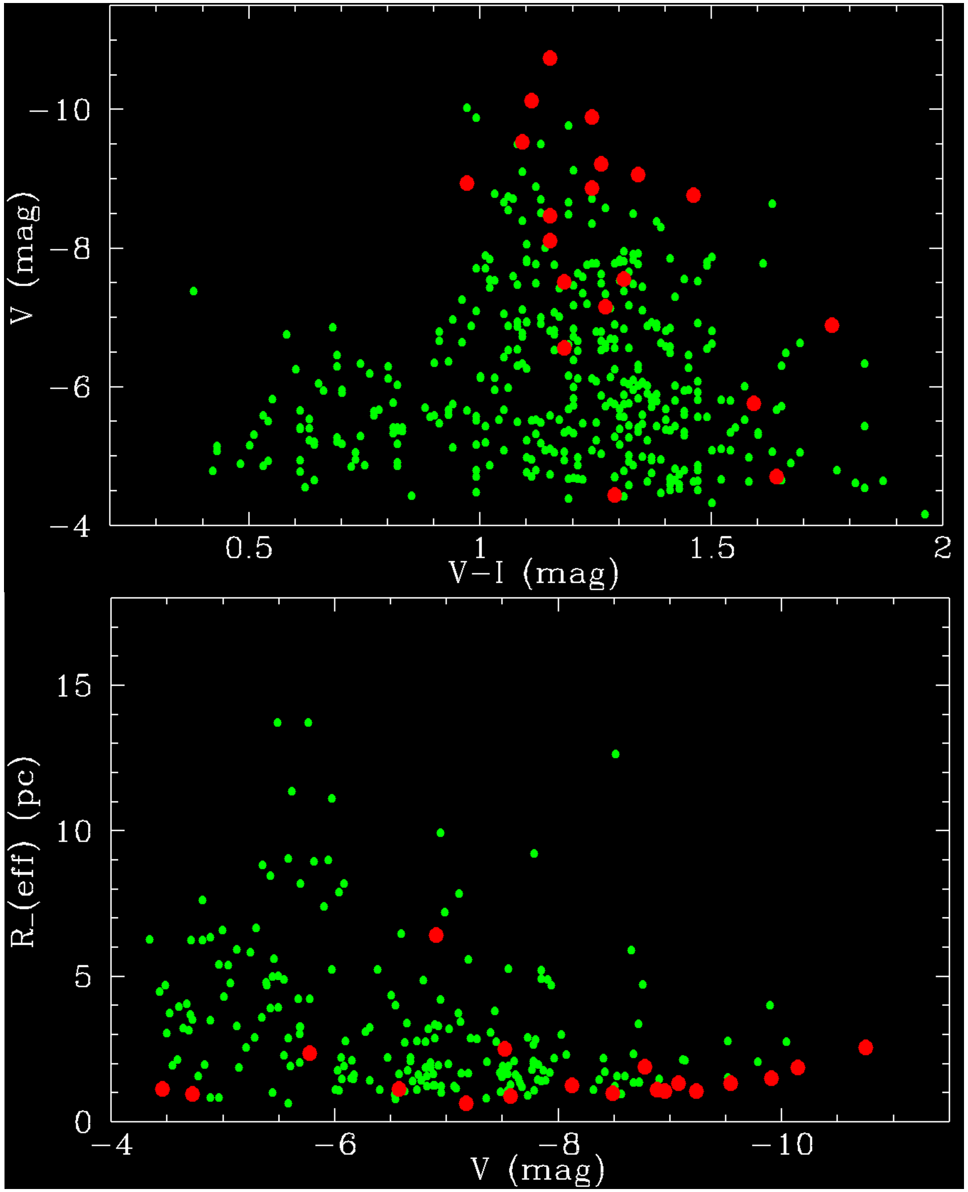
Classify compact objects and donors

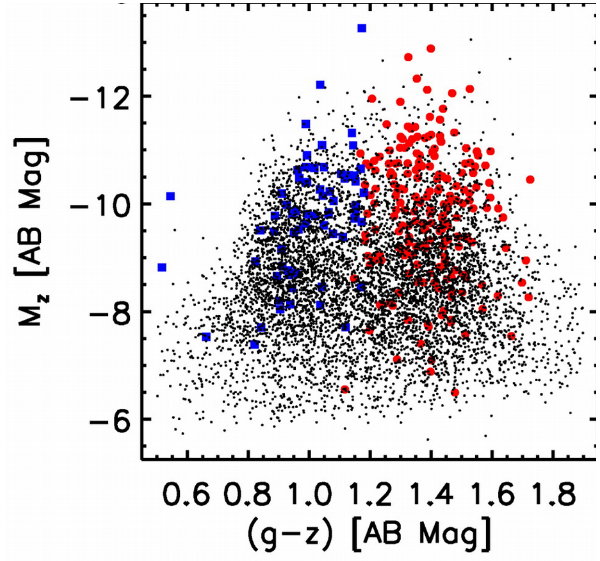


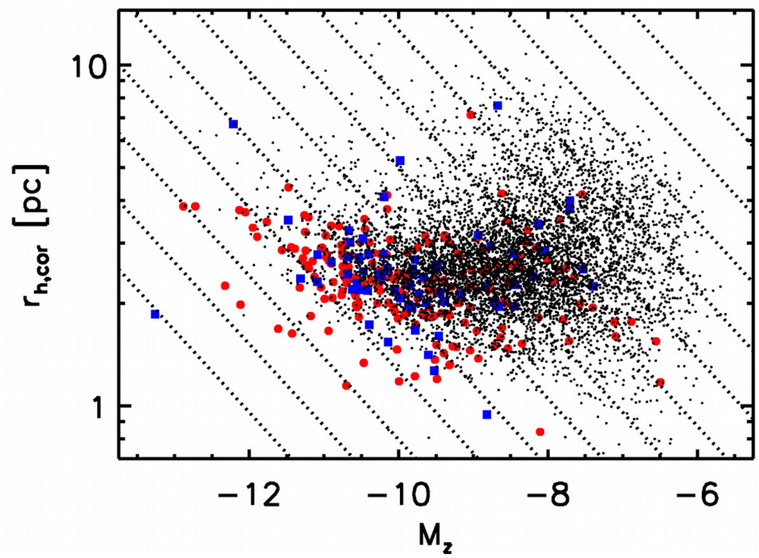
Discrete X-ray sources in galaxies : The basic ingredients

Accreting pulsar

M81 Globular clusters

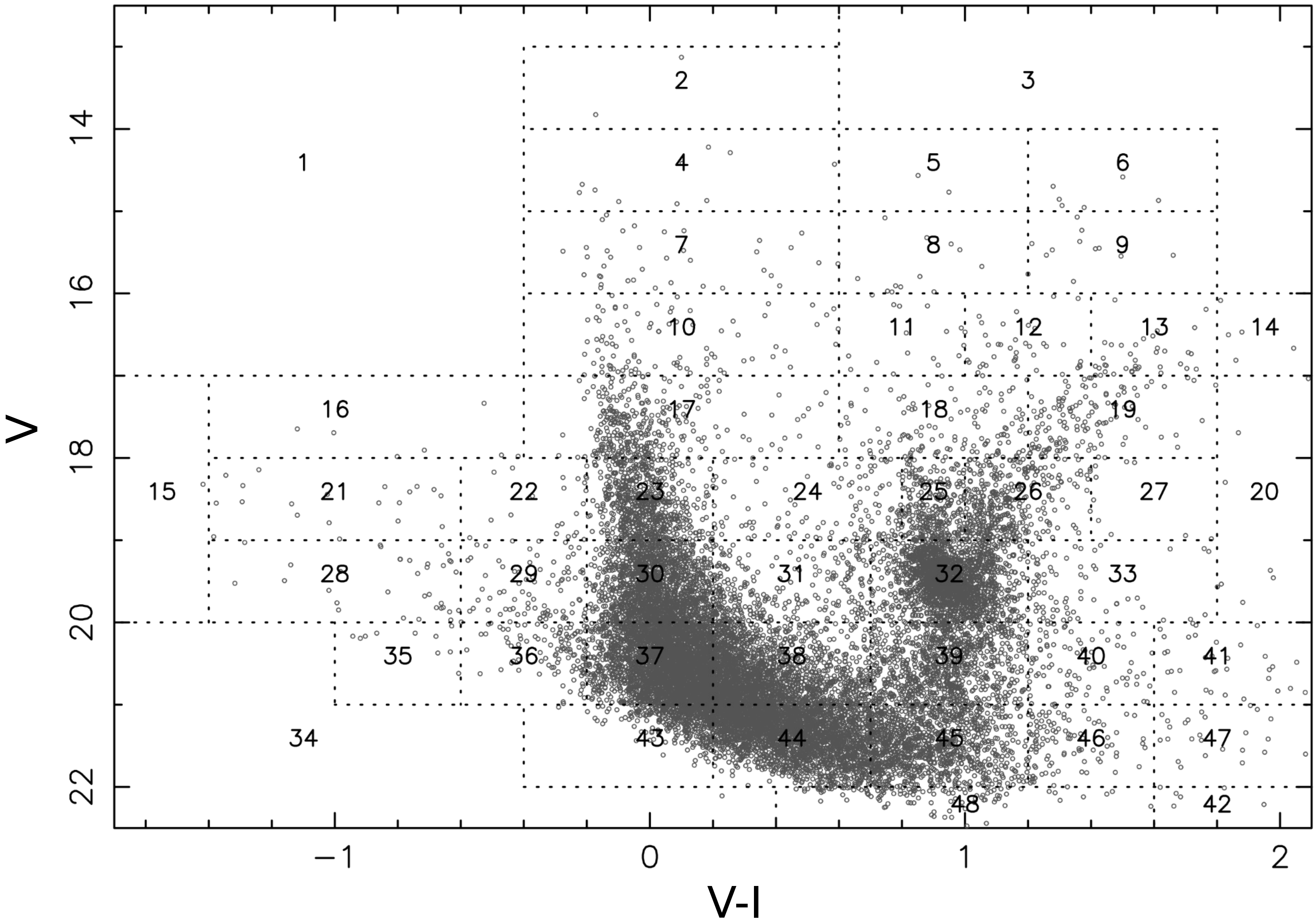




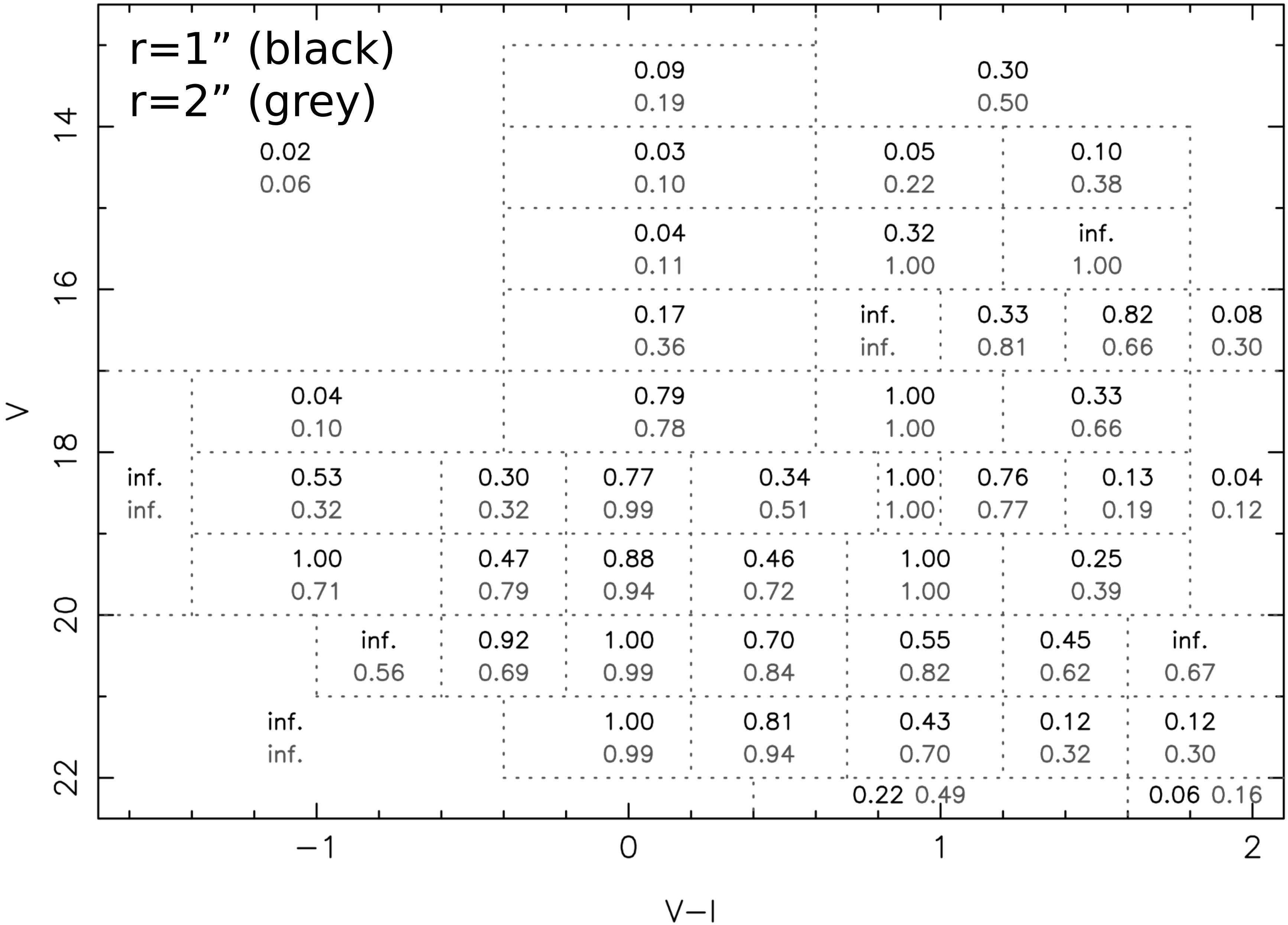


Sivakoff etal 1997

Chance coincidence

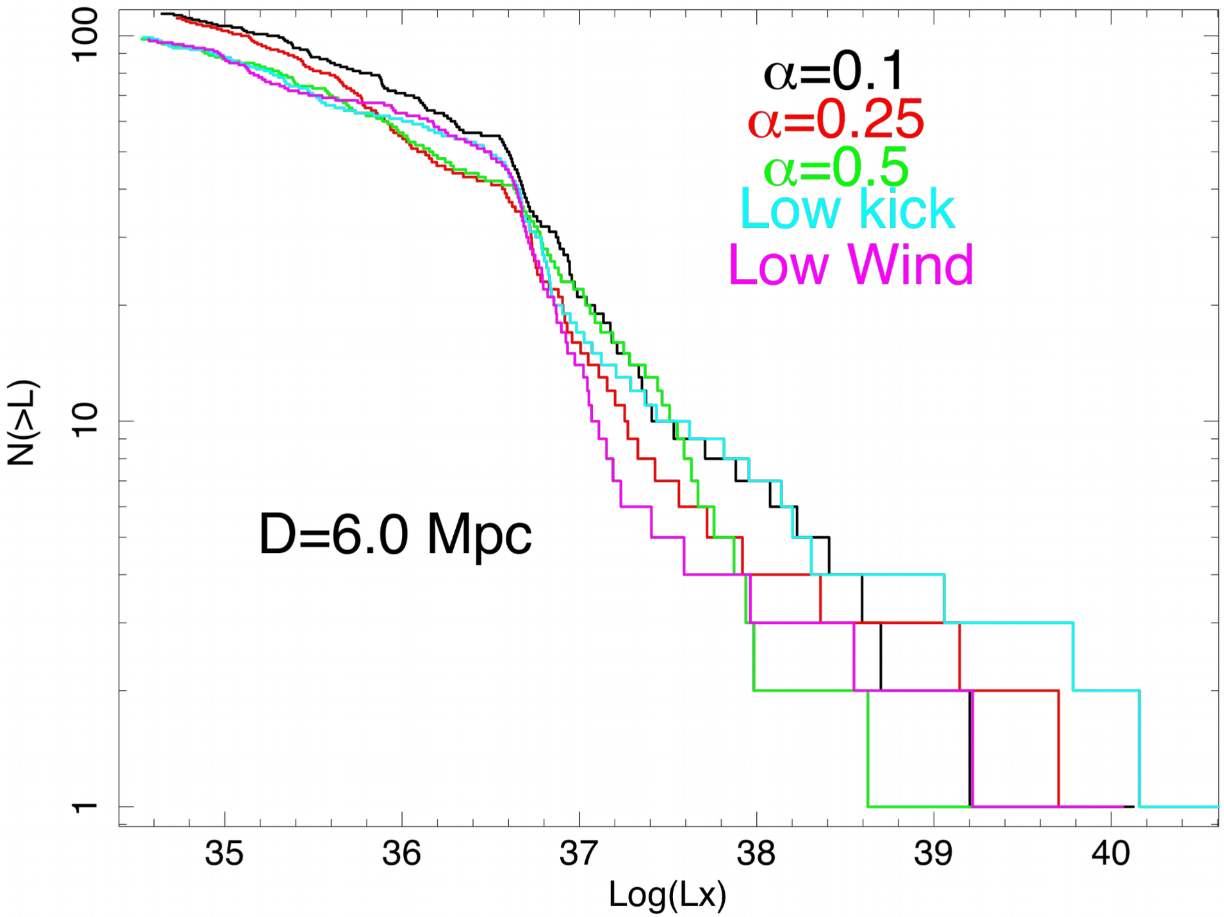


Chance coincidence



Beyond Chandra

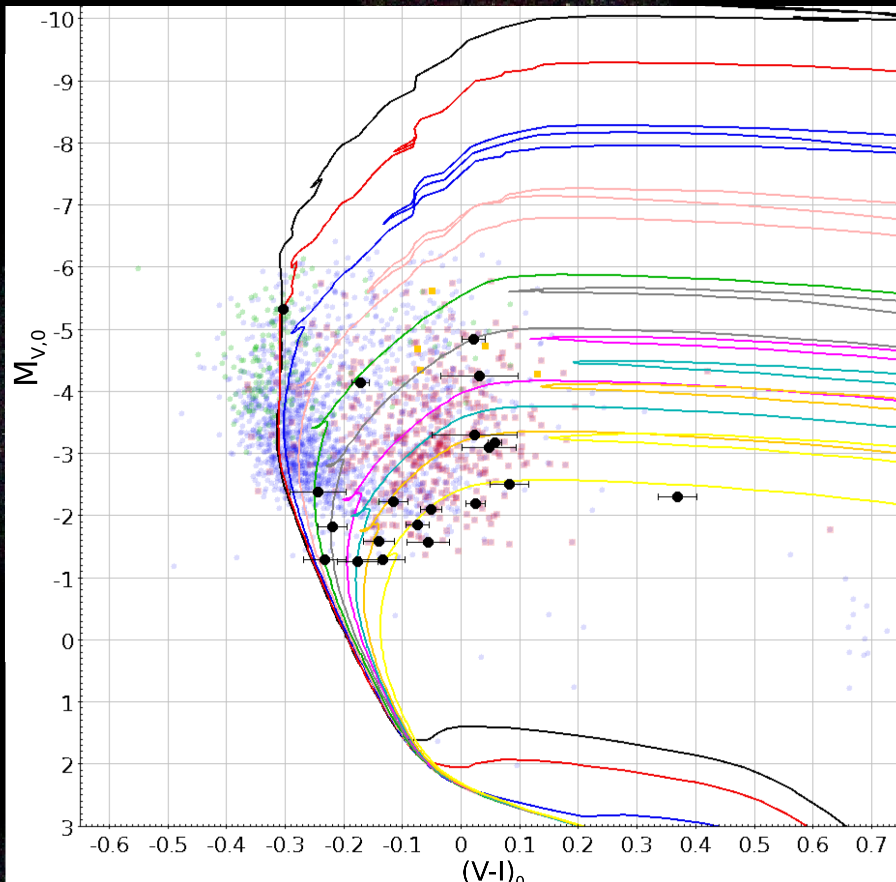
With 0.5” resolution and $2m^2$ we can reach fainter populations (end-to-end simulations)



Pop. Synthesis

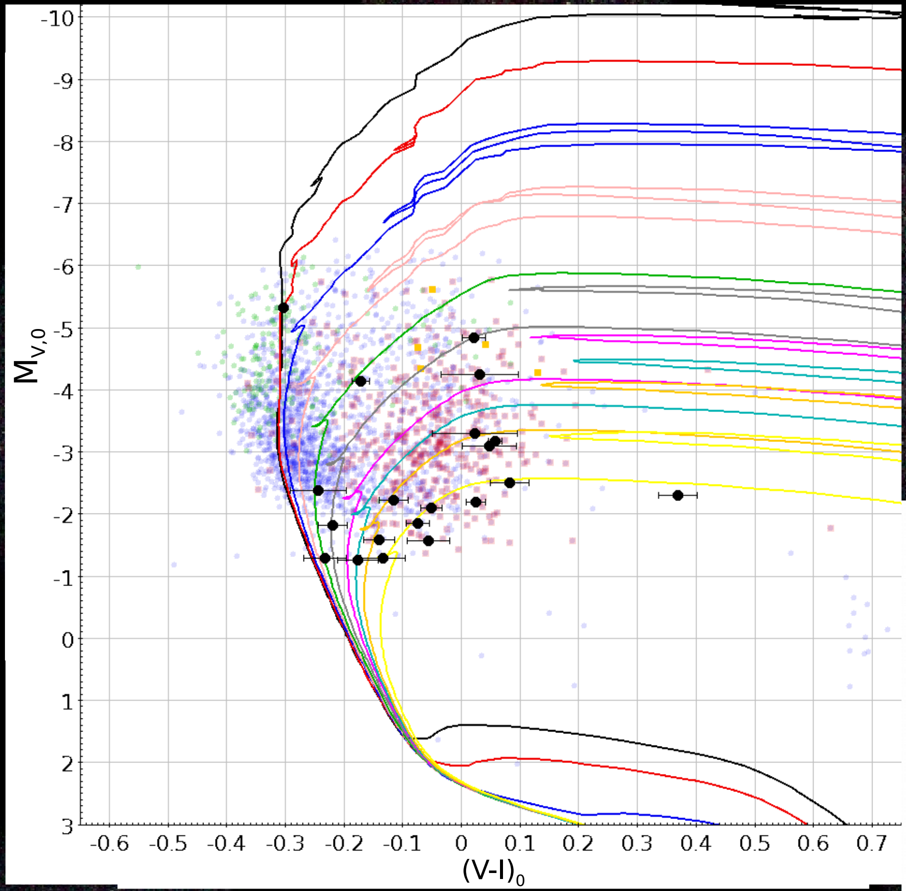
Andrews et al.

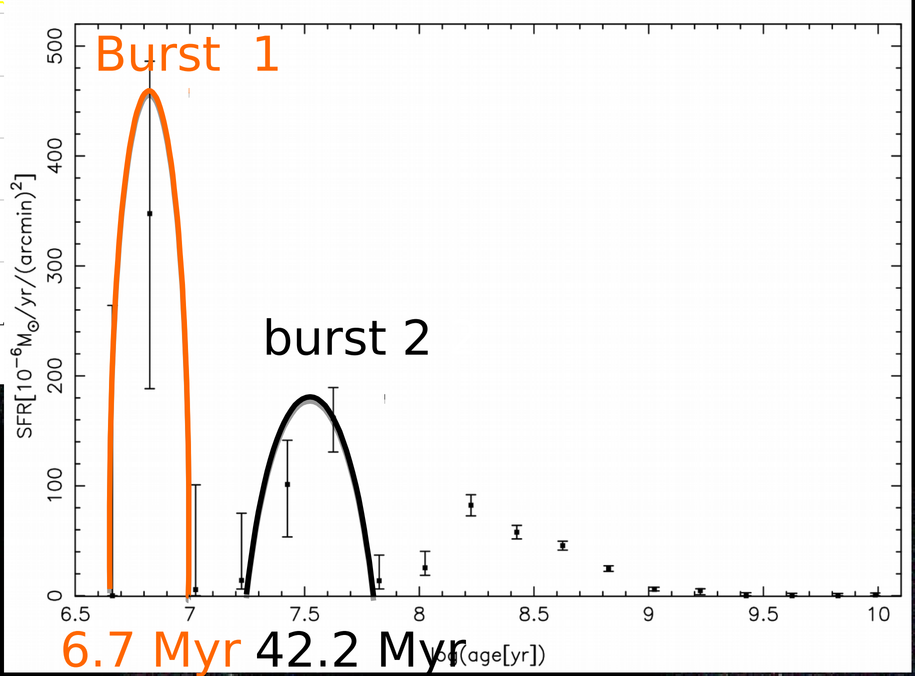
HMXB classification



Antoniou et al, 2017

HMXB classification

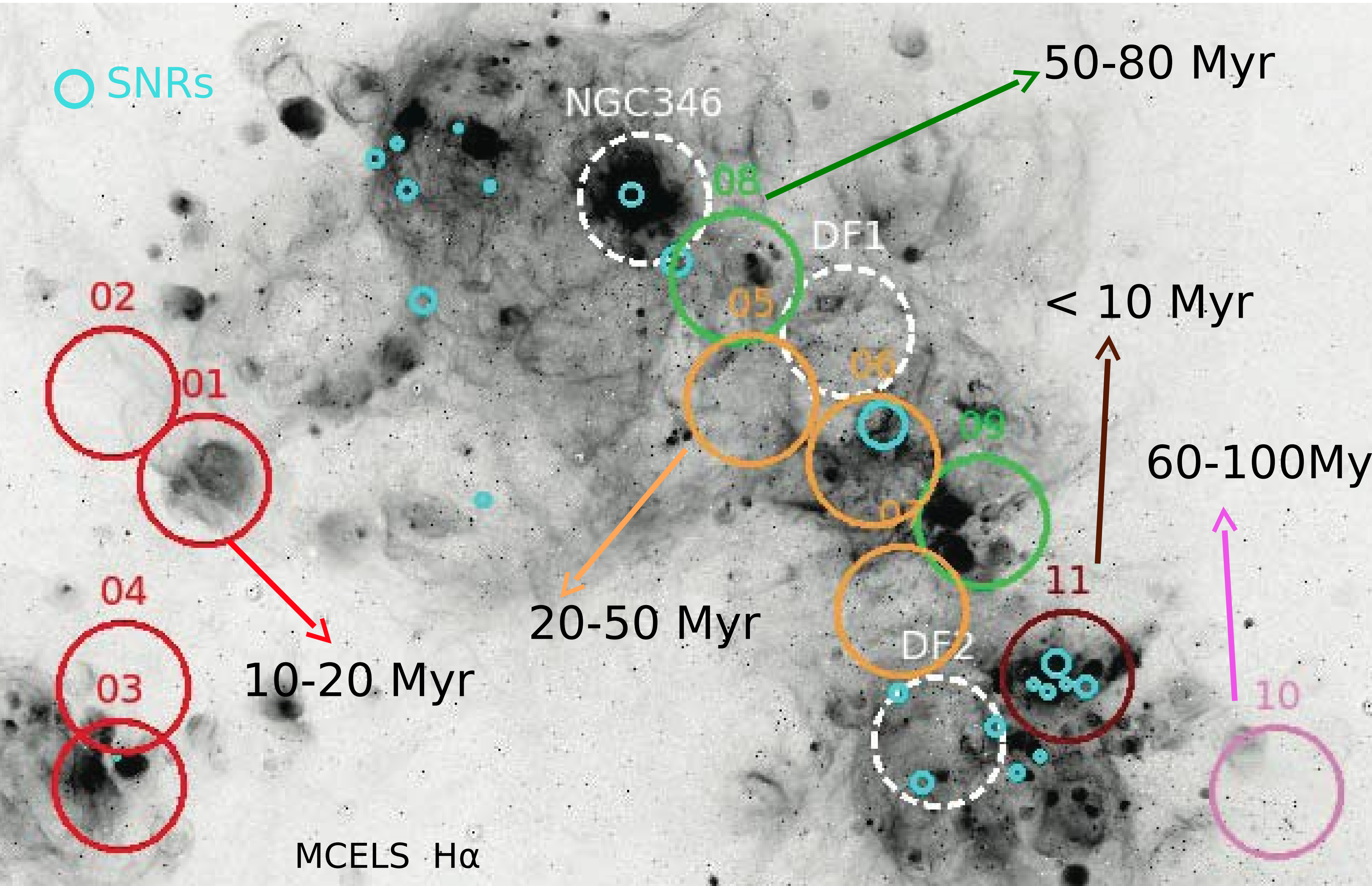




Antoniou et al, 2017

Results

- 2393 sources detected (1095 > 5σ significance) (limiting $L_X \sim 3.5 \times 10^{32}$ erg/s; 0.5 – 7 keV @ 50% compl.)
- ~ 65 (Wing) – 75 (Bar) sources per field
- 21 pulsars detected (Hong et al. 2017) (out of the 34 known in these regions)
- A Be-XRB pulsar emerging from the companion circumstellar disk (Hong et al. 2016)
- 12 SNRs detected
- 128 sources associated with an OB star



SNRs
NGC346
08
DF1
05
06
09
07
02
01
04
03
50-80 Myr
< 10 Myr
60-100My
20-50 Myr
10-20 Myr
11
DF2
10
MCELS Hα

Magellanic Clouds

Nearest star-forming galaxies (50-60 kpc)

Advantages :

- Probe very faint populations ($L_x \sim 10^{33}$ erg/s)
- Large populations of HMXBs (e.g. Haberl & Sturm 2016)
- Well determined star-formation history

  metallicity ($1/5\ Z_{\odot}$ - $1/3\ Z_{\odot}$)

Magellanic Clouds

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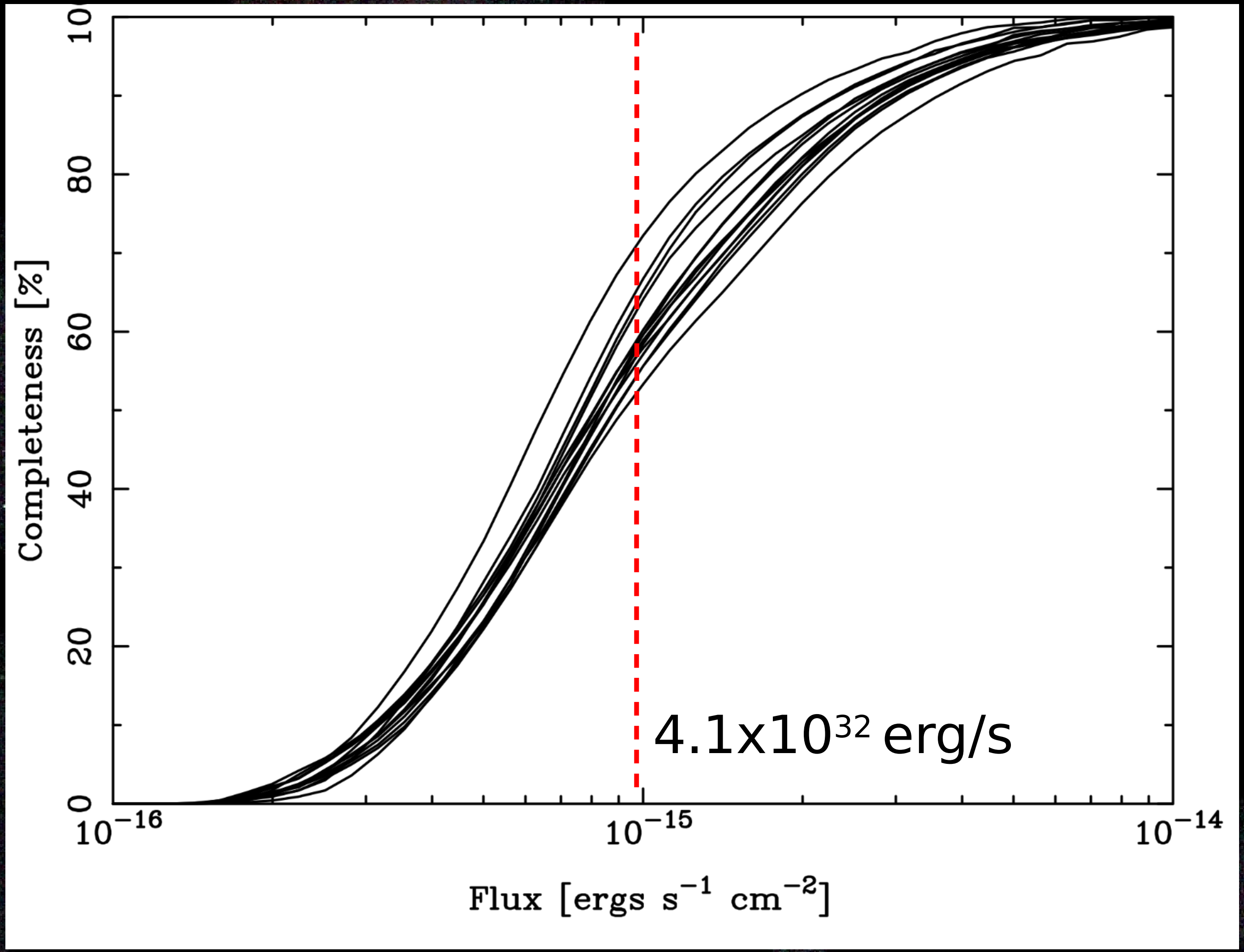
- Well determined star-formation history
  metallicity (1/5 $Z_{\odot}$ - 1/3 $Z_{\odot}$)

Unique laboratories for the study of HMXBs

Address: formation efficiency of XRBs
accretion physics, interaction of
accretion flow and magnetic fields.

Survey sensitivity



First results

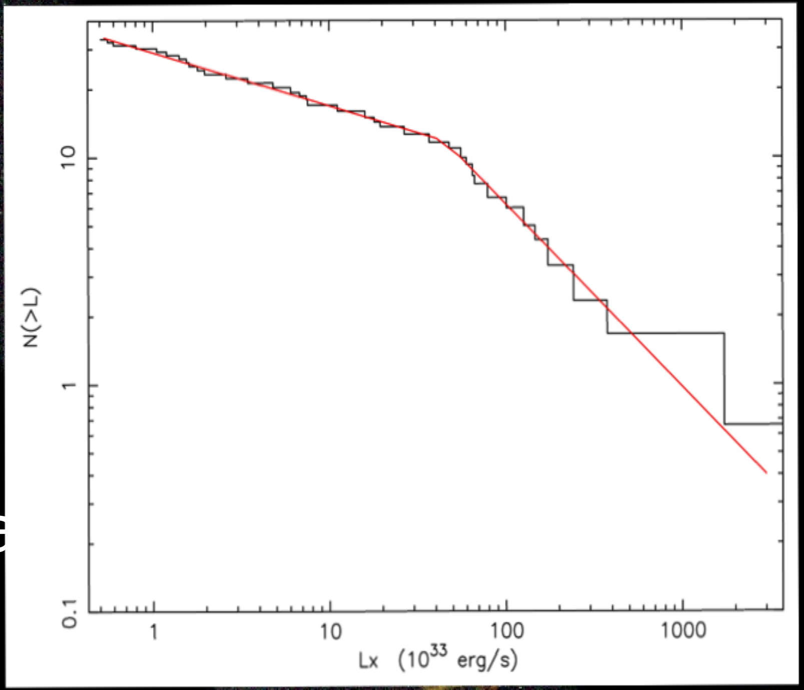
The luminosity function:

Flat slope : α ~0.2 / 0.8

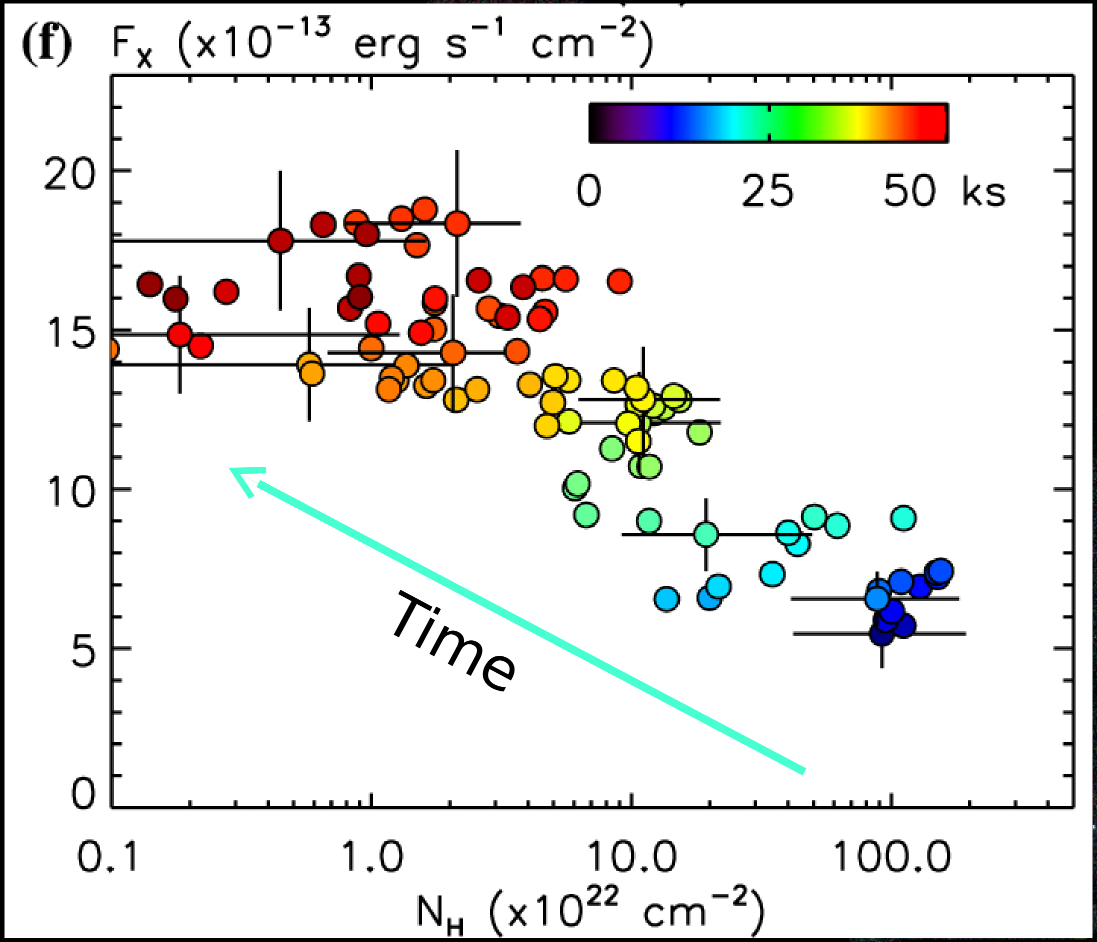
Indication for break at

3×10^{34} erg/s

consistent with accretion in a inhomogeneous environment and the onset of the propeller effect (c.f. Shtykovskiy & Gilfanov 2004).

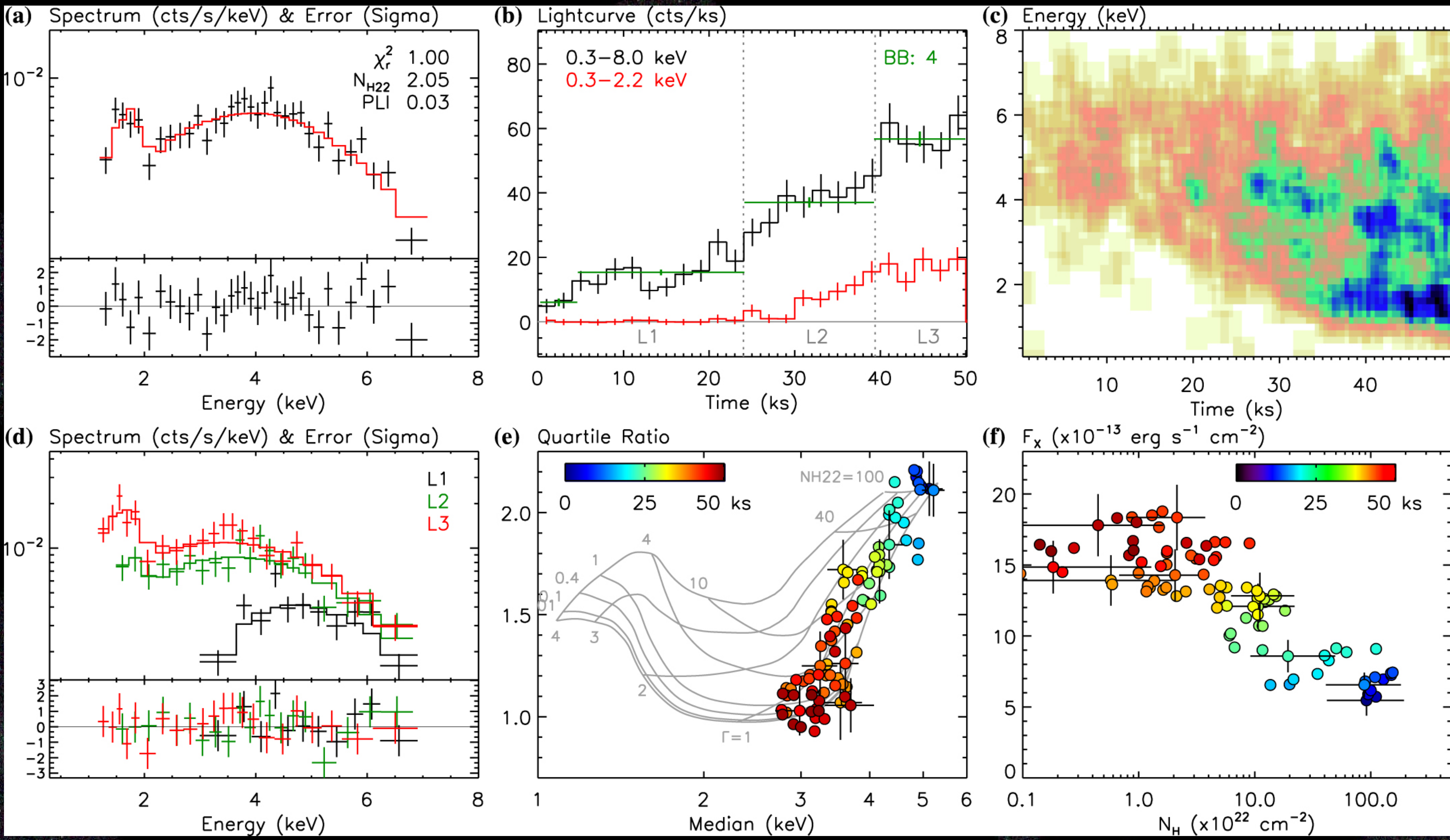


First results

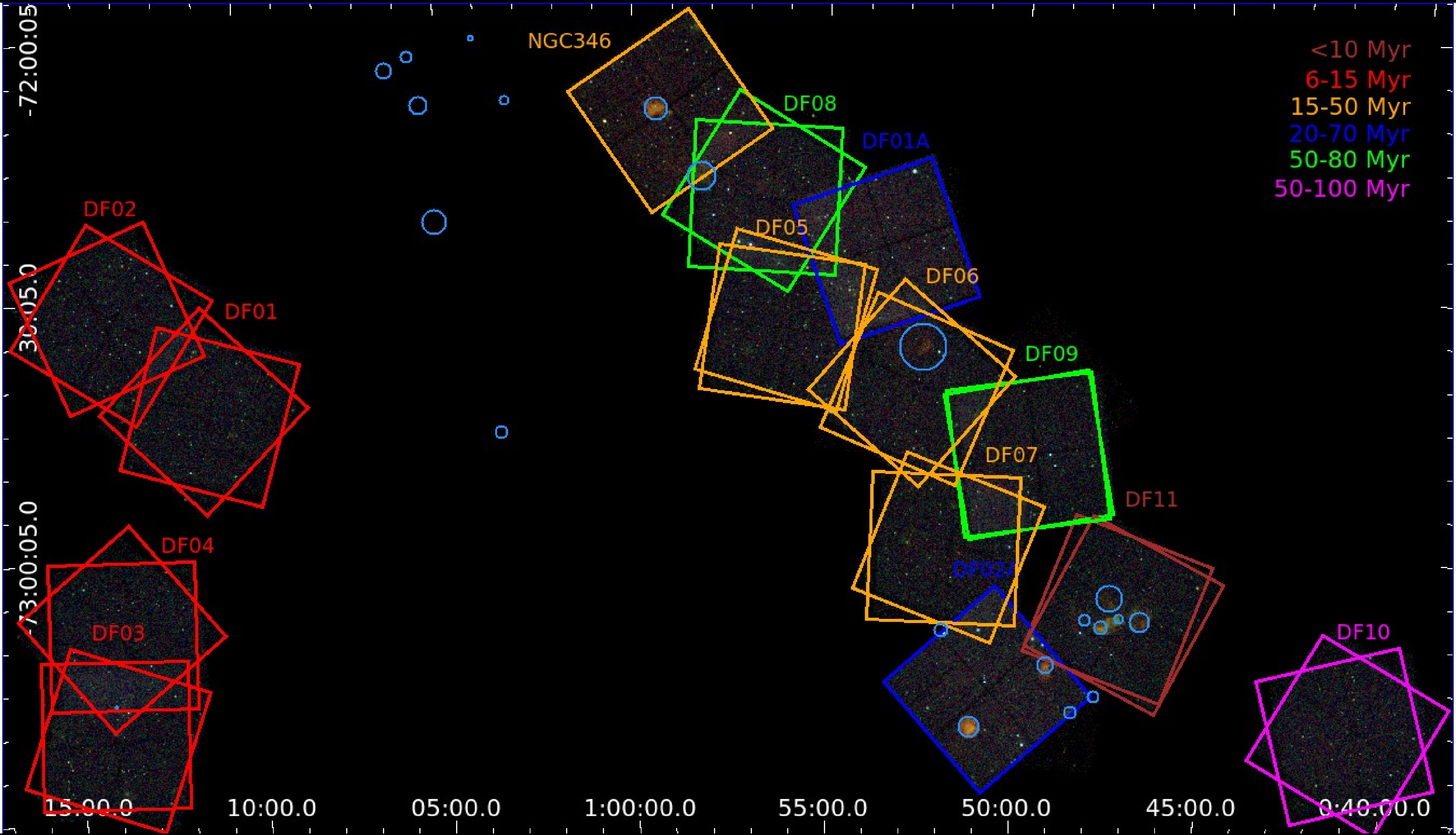


Hong et al. 2016

First results



First results



The deep Chandra SMC Survey

A Chandra “X-ray Visionary Program”:

11 +3 Fields in the SMC   (50-60 kpc)

2 x 50ksec exposures (1.1 + 0.3 Msec total)

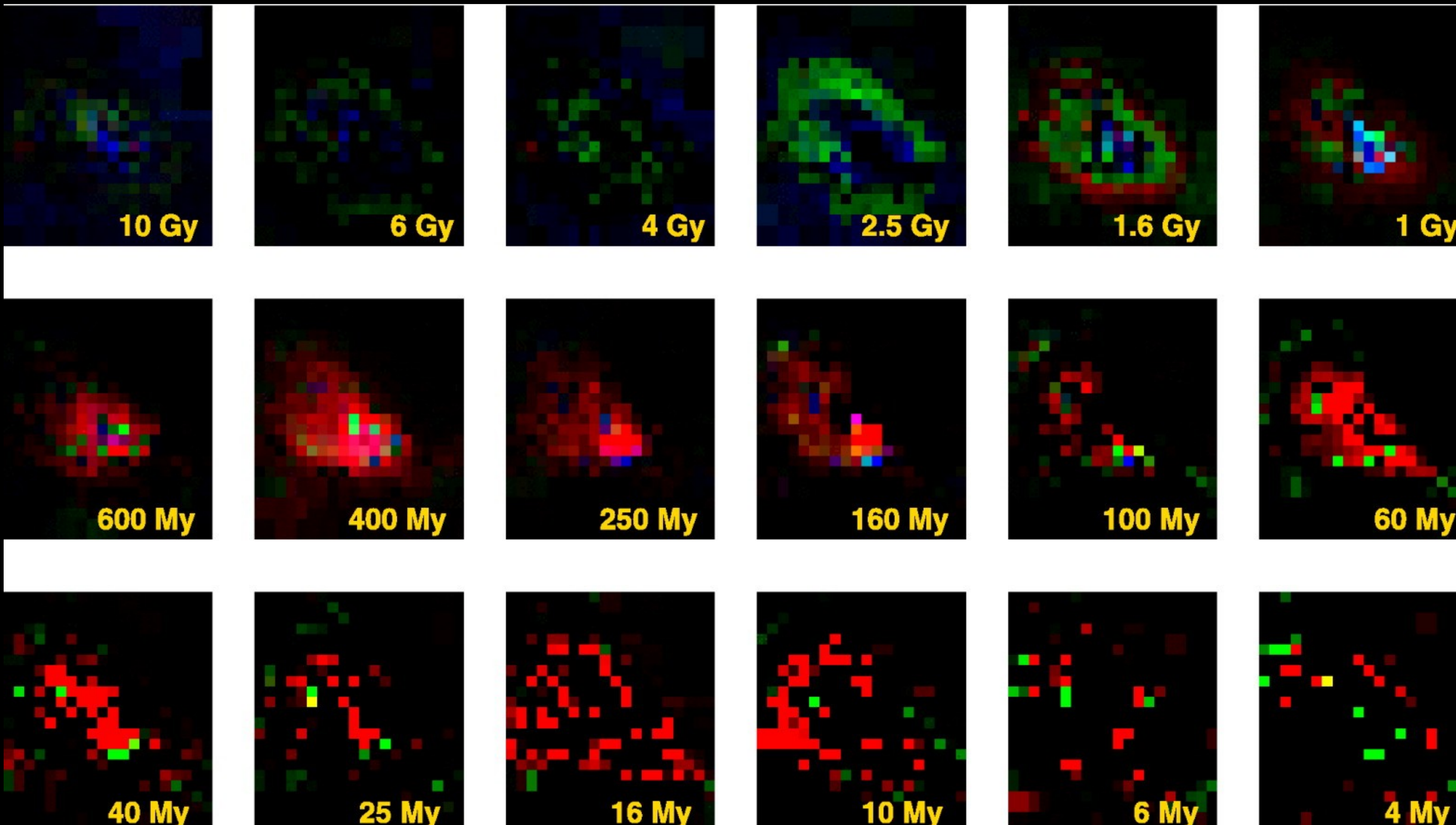
Key Goal

- A deep census of accreting pulsars ($L_x \sim 10^{33}$ erg/s)
- HMXB formation efficiency at different ages

  Well determined star-formation history

  metallicity (1/5 $Z_{\odot}$ - 1/3 $Z_{\odot}$)

SMC star-formation history



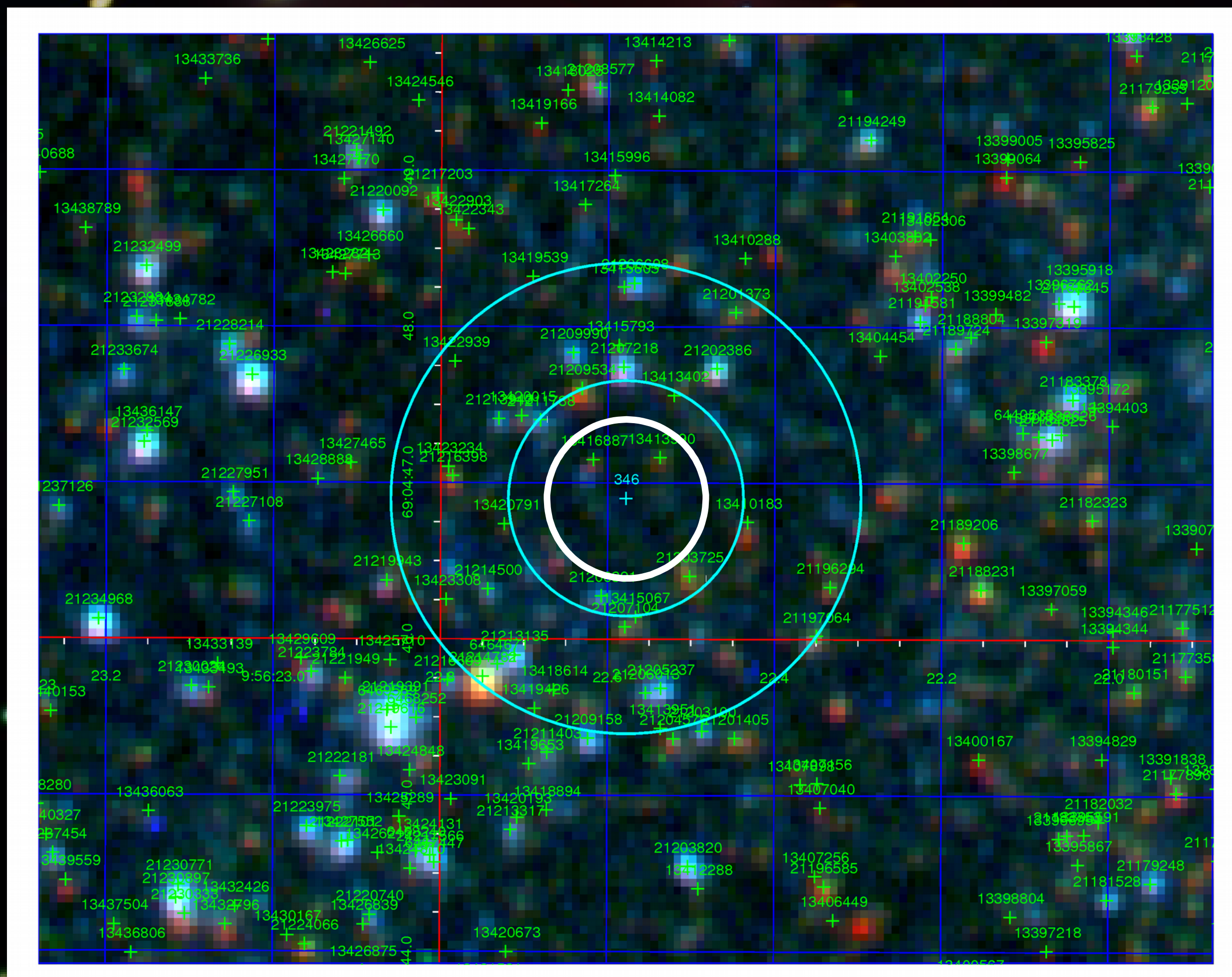
$0.05Z_\odot$ $0.2Z_\odot$ $0.4Z_\odot$

Harris & Zaritsky, 2004

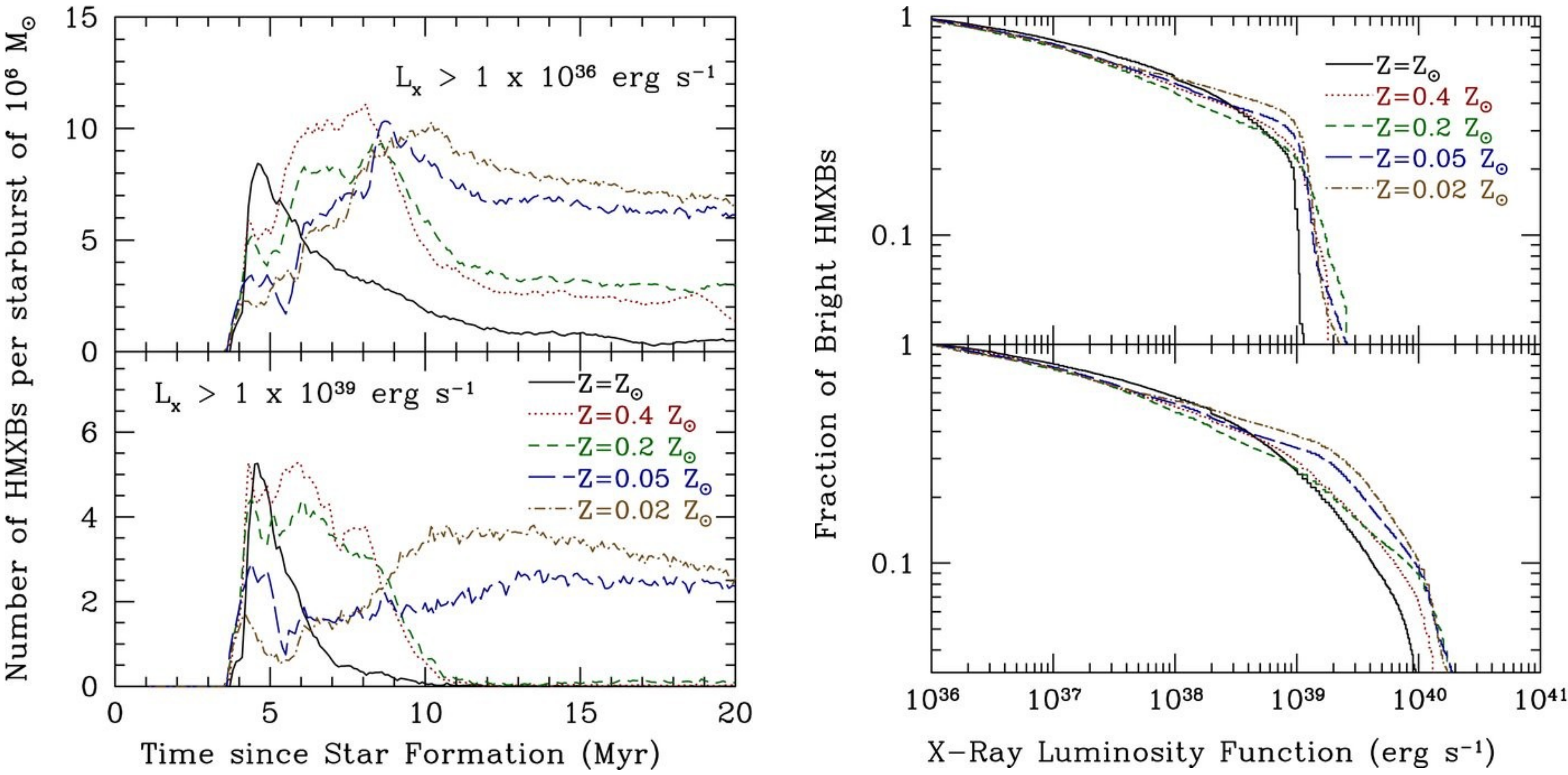
From Chandra to Lynx

With well-sampled 0.5” PSF across the field we can:

- Characterize X-ray sources



X-ray binary populations



Linden et al. 2010

Looking ahead: Oth

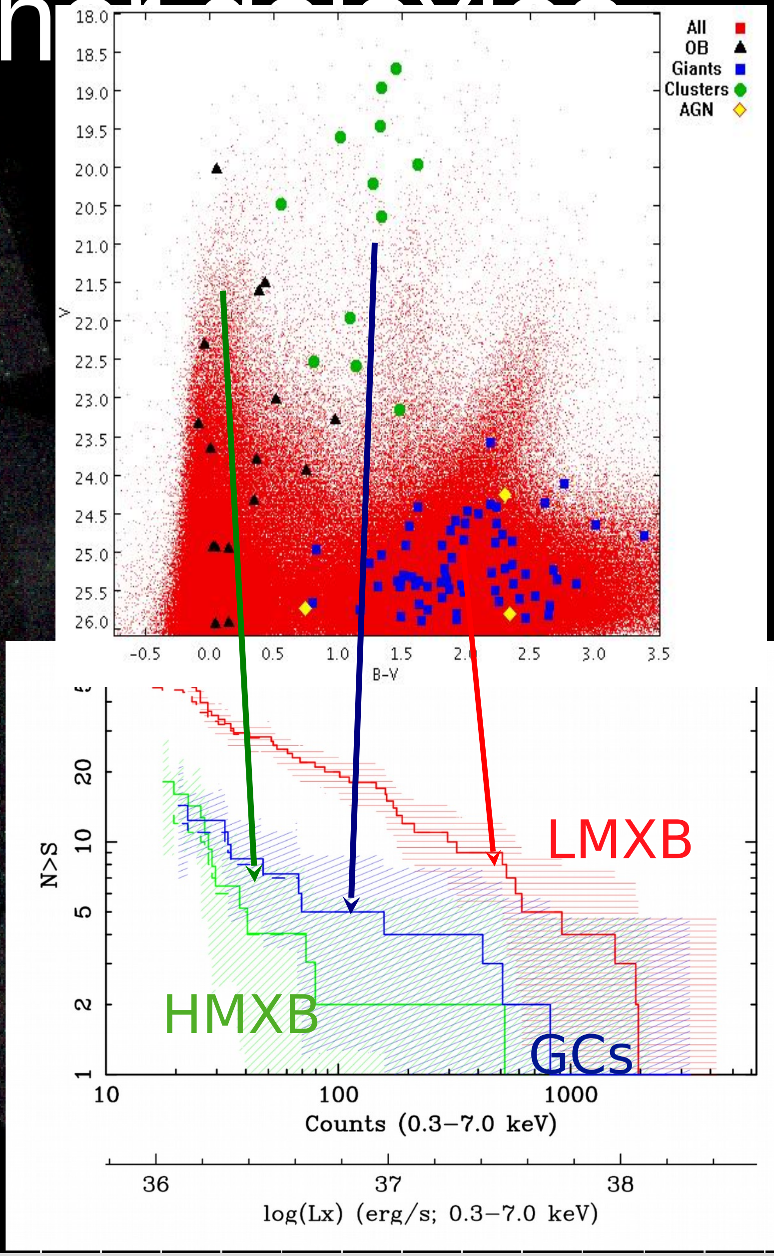
Goal: A more complete picture of XRB formation/evolution

Need:

- Cover age / metallicity space

Deep observations

- Uniform sensitivity
- Chandra – HST synergy



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-73:00:05.0
15:00.0
10:00.0 1:00:00.0
55:00.0