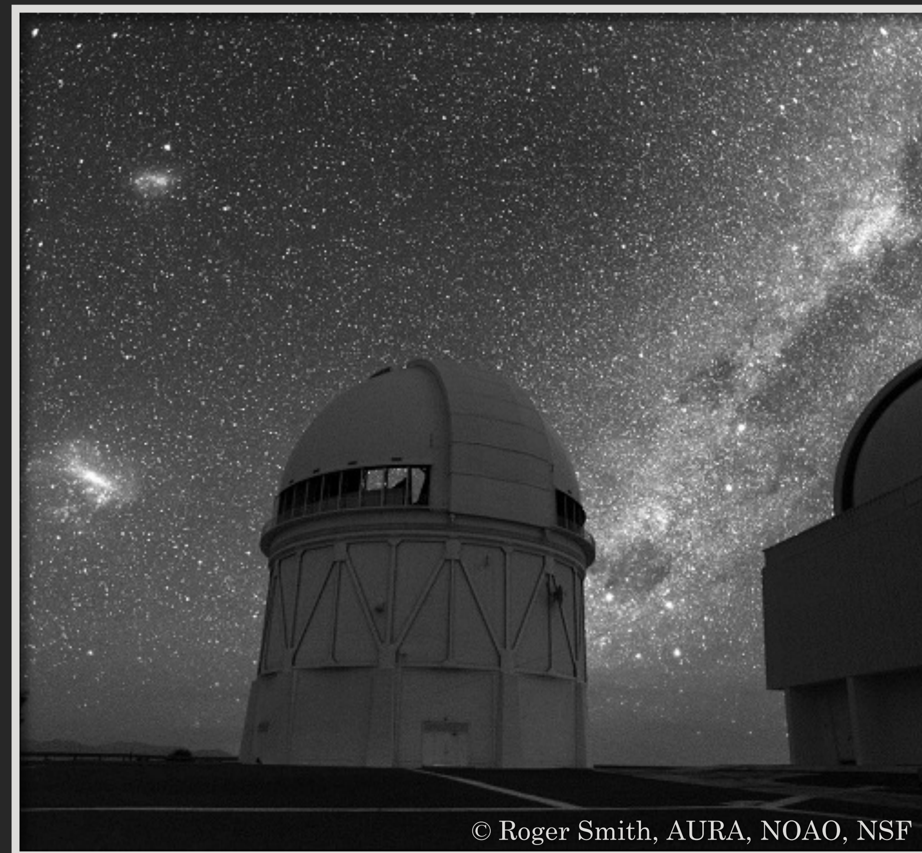


CONNECTING THE YOUNG ACCRETING BINARY POPULATION OF THE MAGELLANIC CLOUDS WITH THEIR STAR-FORMATION HISTORY

VALLIA ANTONIOU
Iowa State University

10th Hellenic Astronomical Conference, Ioannina, 5-8 Sept 2011

MAGELLANIC CLOUDS: OUR NEAREST STAR-FORMING GALAXIES

- Thought to be gravitationally bound to the Milky Way

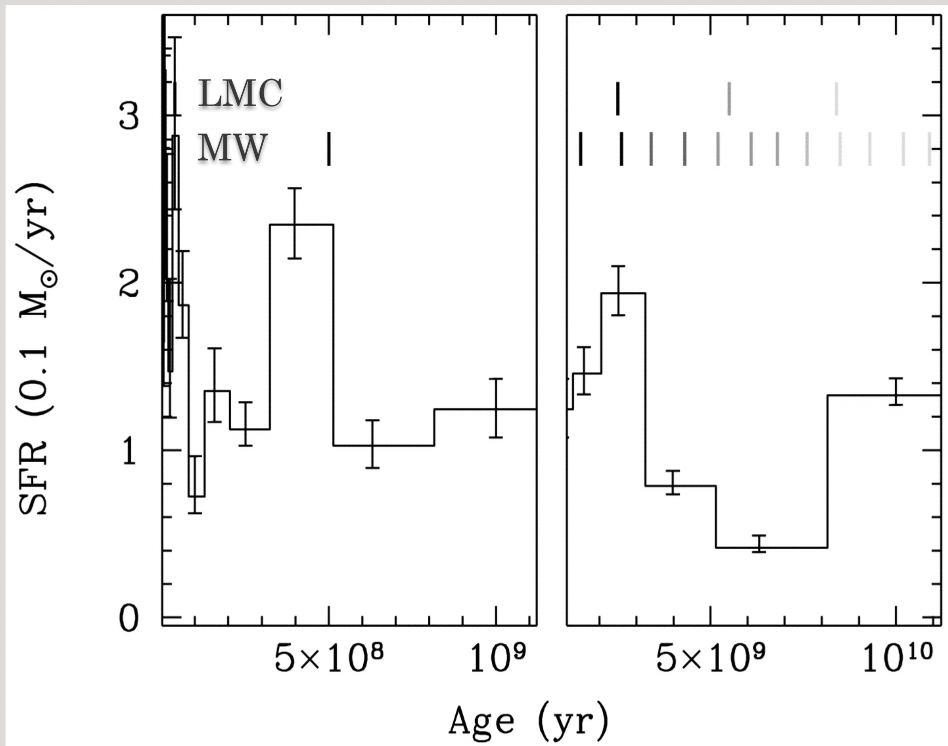
- High 3D velocities indicate that instead they are "just passing through"

- Rather than forming stars continuously (like the MW), the MCs have undergone several burst of SF followed by long quiet periods

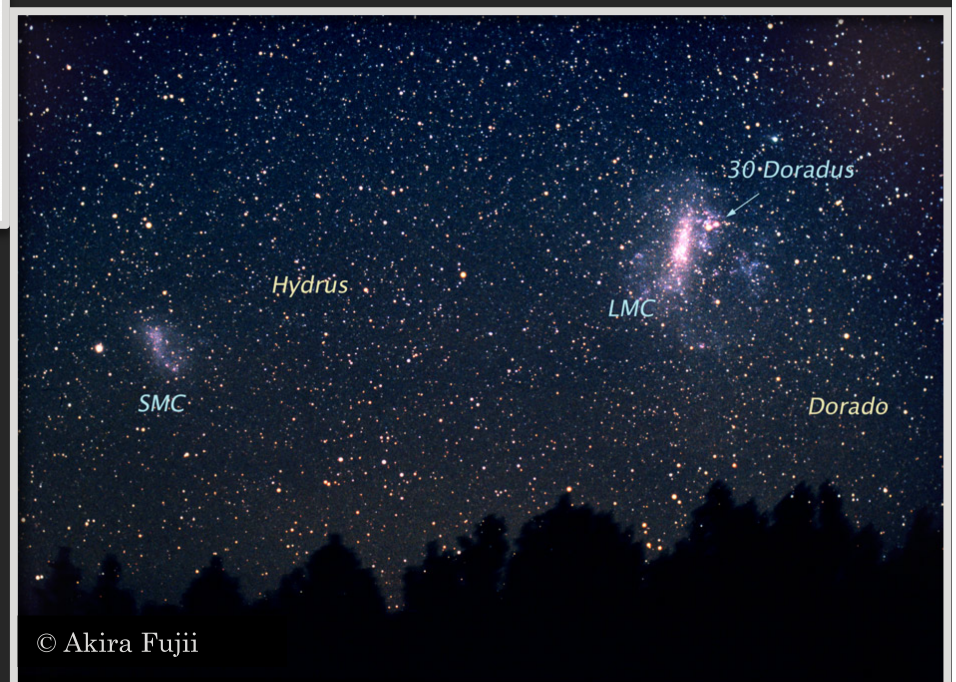
- *Interactions between the SMC and LMC may be the primary force driving star formation in both galaxies*

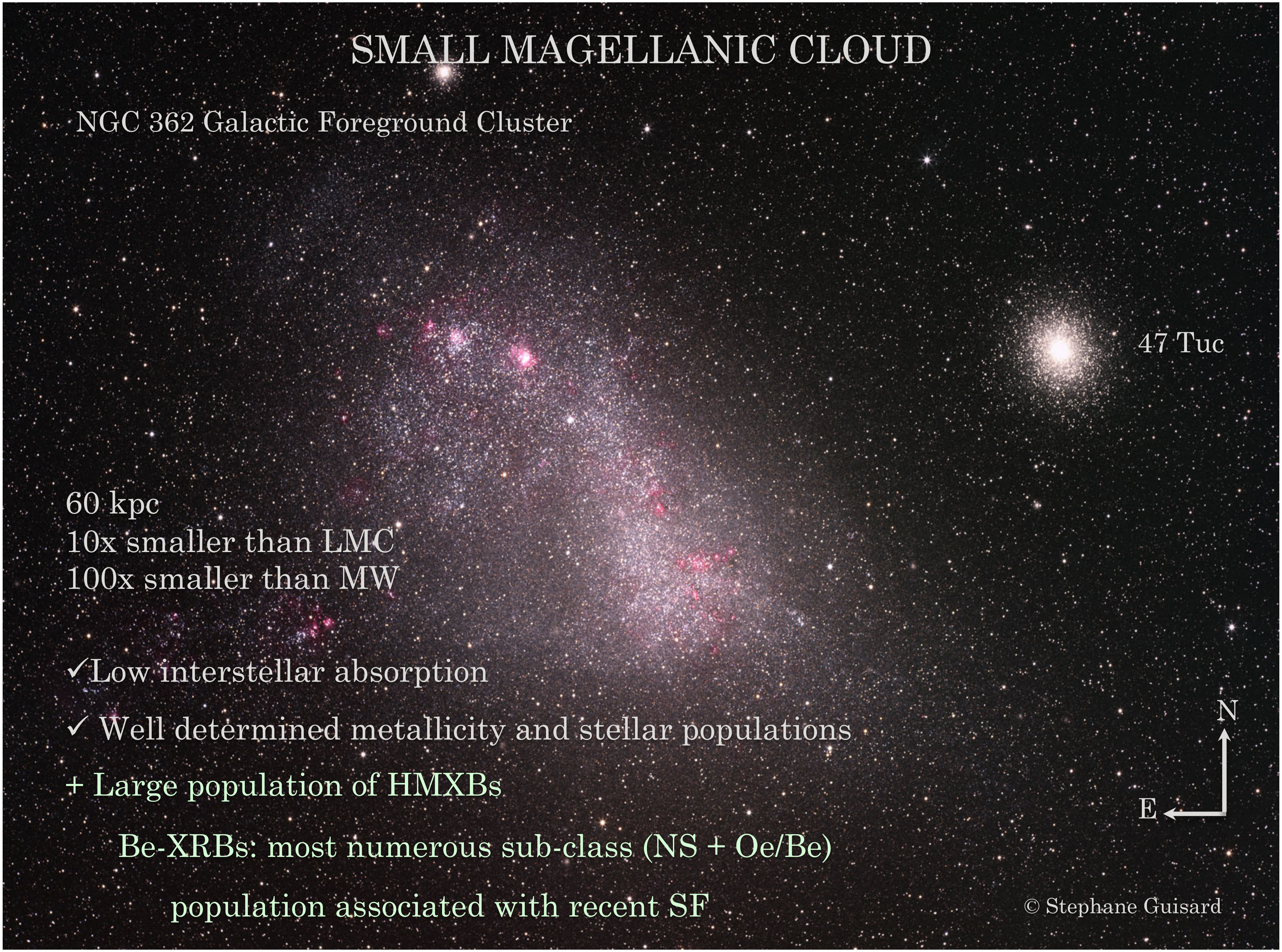
Besla et al. (2007, ApJ, 668, 949)

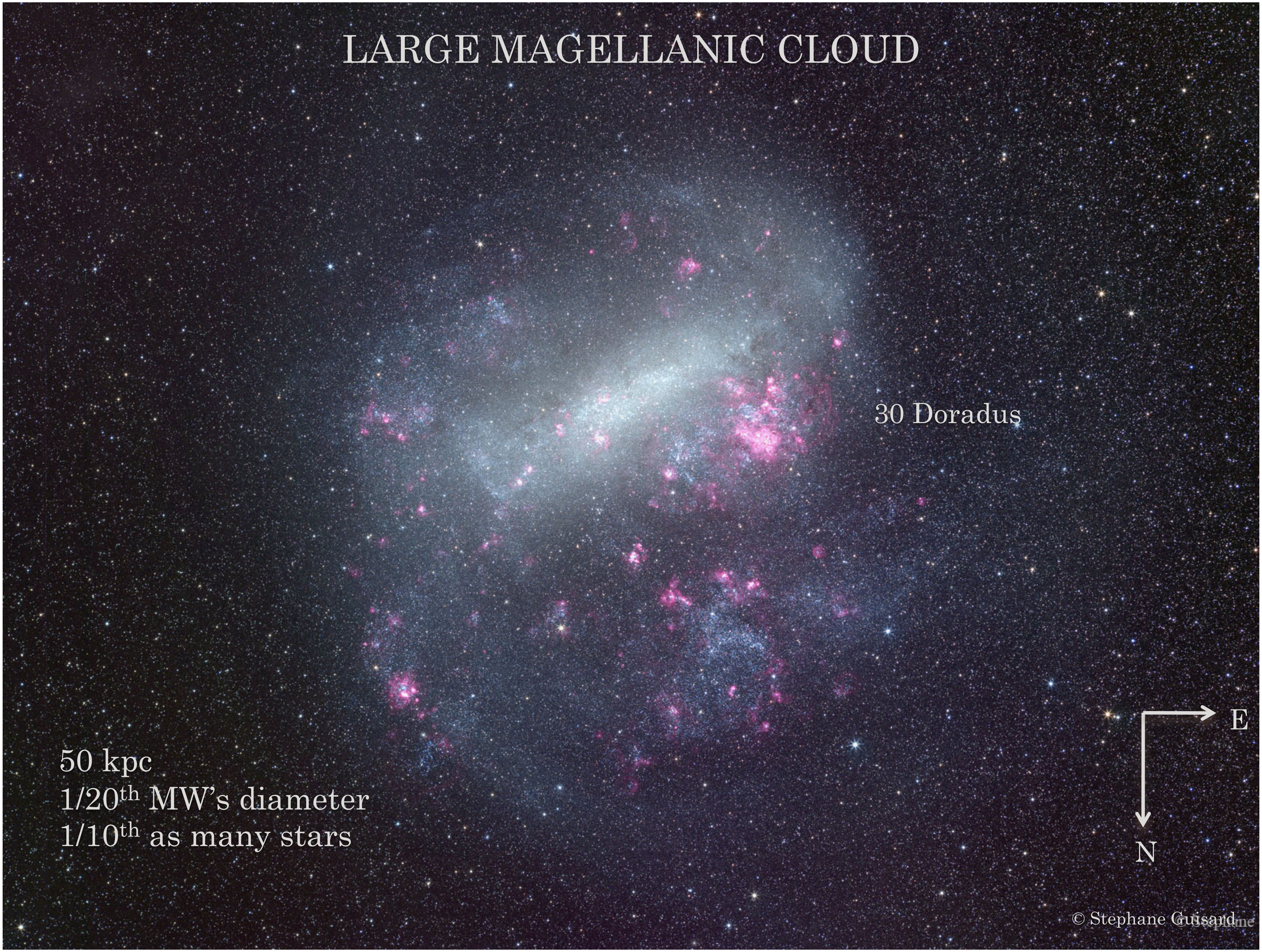
MAGELLANIC CLOUDS: FIRST-TIME VISITORS



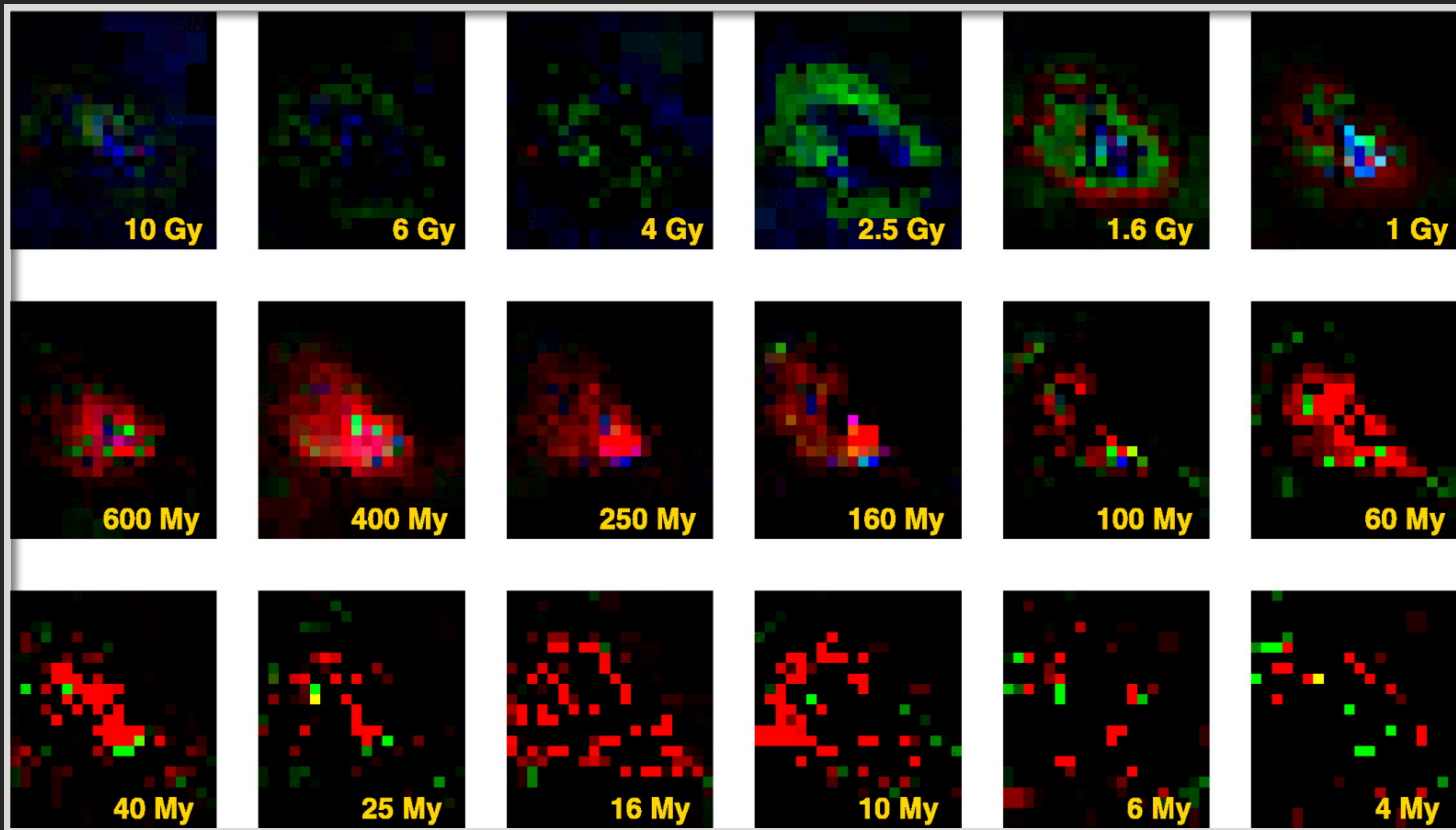
Global star-formation history of the SMC
Harris & Zaritsky (2004)




SMALL MAGELLANIC CLOUD
NGC 362 Galactic Foreground Cluster
47 Tuc
60 kpc
10x smaller than LMC
100x smaller than MW
✓Low interstellar absorption
✓ Well determined metallicity and stellar populations
+ Large population of HMXBs
Be-XRBs: most numerous sub-class (NS + Oe/Be)
population associated with recent SF
N
E
© Stephane Guisard


LARGE MAGELLANIC CLOUD
30 Doradus
50 kpc
1/20th MW's diameter
1/10th as many stars
E
N
© Stephane Guisard

STAR-FORMATION HISTORY OF THE SMC



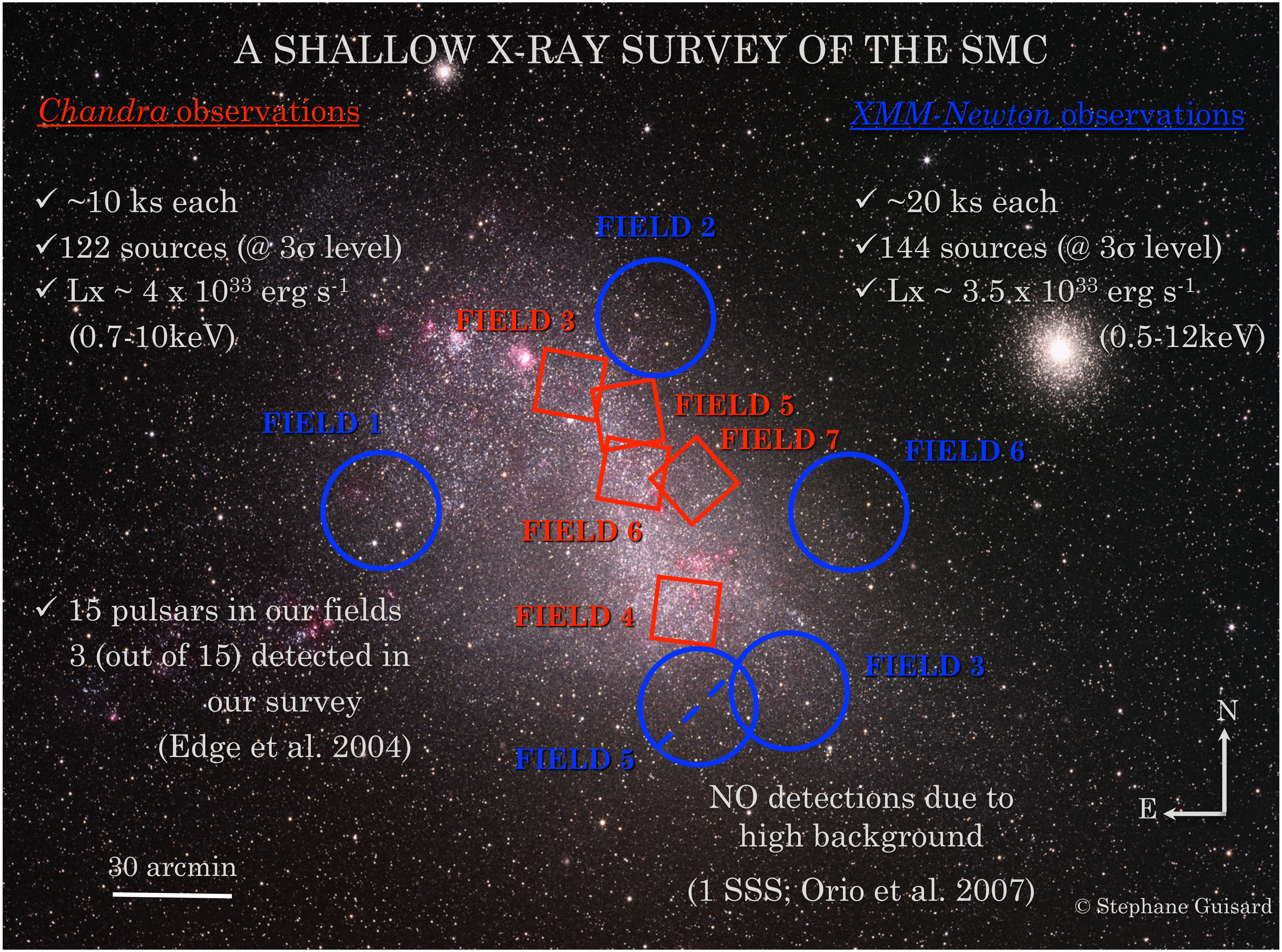
Z = 0.008 ⇔ [Fe/H] = -0.4

Z = 0.004 ⇔ [Fe/H] = -0.7

Z = 0.001 ⇔ [Fe/H] = -1.3

pixel intensity proportional to the subregion's SFR

Harris & Zaritsky (2004)


A SHALLOW X-RAY SURVEY OF THE SMC
Chandra observations
✓ ~10 ks each
✓122 sources (@ 3σ level)
✓ Lx ~ 4 x 10^33 erg s^-1
(0.7-10keV)
✓ 15 pulsars in our fields
3 (out of 15) detected in
our survey
(Edge et al. 2004)
XMM-Newton observations
✓ ~20 ks each
✓144 sources (@ 3σ level)
✓ Lx ~ 3.5 x 10^33 erg s^-1
(0.5-12keV)
FIELD 2
FIELD 3
FIELD 5
FIELD 7
FIELD 1
FIELD 6
FIELD 6
FIELD 4
FIELD 3
FIELD 5
NO detections due to
high background
(1 SSS; Orio et al. 2007)
N
E
30 arcmin
© Stephane Guisard

THE HMXB POPULATION OF THE SMC

* Spectral fits or X-ray color-color diagrams ➔ Hard X-ray sources

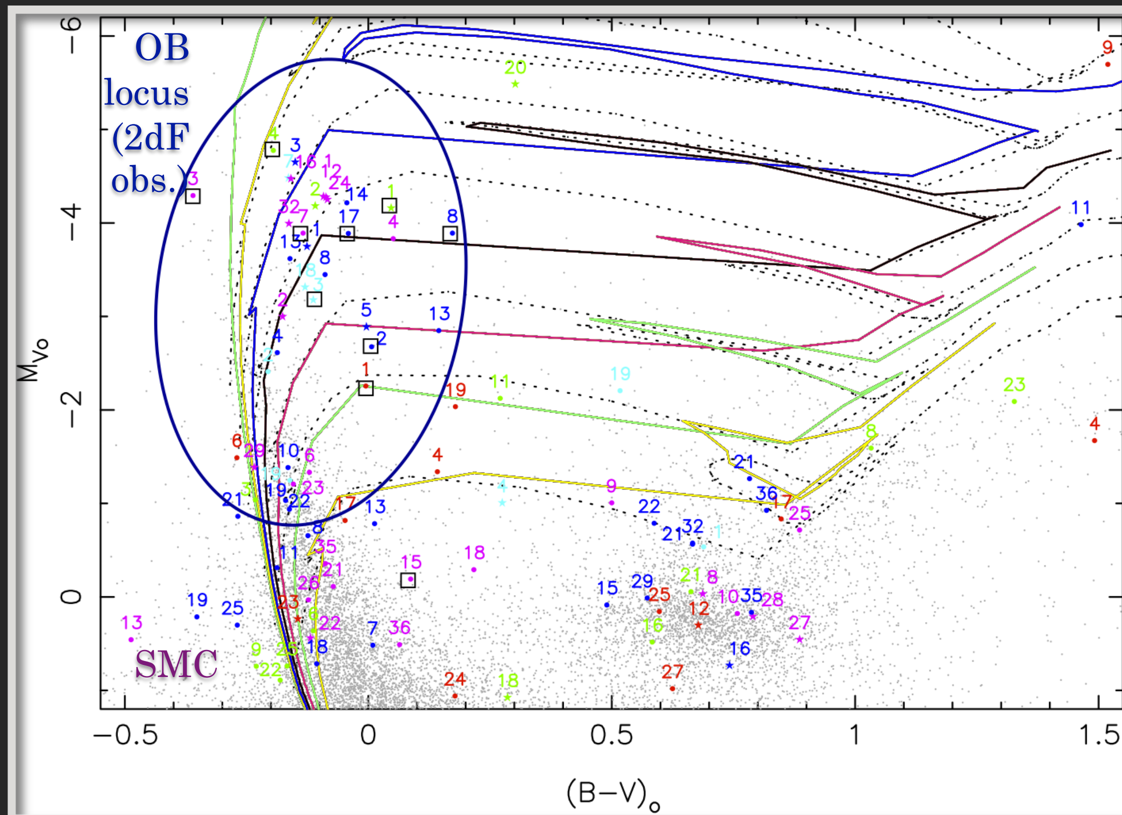
* Cross-correlate their position with optical photometric catalogs ➔ identify their counterparts

OGLE-II (Udalski et al. 1998) coverage of our surveys: *Chandra* ~70%, XMM-Newton <40%

MCPS (Zaritsky et al. 2002) coverage of both surveys ~100%

* Position of counterparts on their V, B-V CMD with respect to a spectroscopically identified locus of OB stars or optical spectroscopy of counterparts ➔ early-type companions

PARENT STELLAR POPULATIONS OF SMC HMXBs



Geneva isochrones (top to bottom; Z = 0.004 = 0.2$Z_\odot$):
8.7 Myr, 15.5 Myr, 27.5 Myr, 49.0 Myr,
87.1 Myr, 154.9 Myr, 275.4Myr, …

black squares: OGLE-II (type-4) candidate Be stars from Mennickent et al. (2002)

Antoniou et al. (2009, ApJ, 697, 1695)

THE HMXB POPULATION OF THE SMC

Chandra results

✓ 9 new candidate Be-XRBs

✓ 2 new candidate HMXBs

✓ consistent results with previous classifications in all cases of overlap (18 in total; all Be-XRBs)

✓ chance coincidence probability for bright ($V_o < 18.5$, $(B\text{-}V)_o < -0.11$) sources ~ 20%

Antoniou et al. (2009, ApJ, 697, 1695)

XMM-Newton results

✓ 6 new candidate Be-XRB

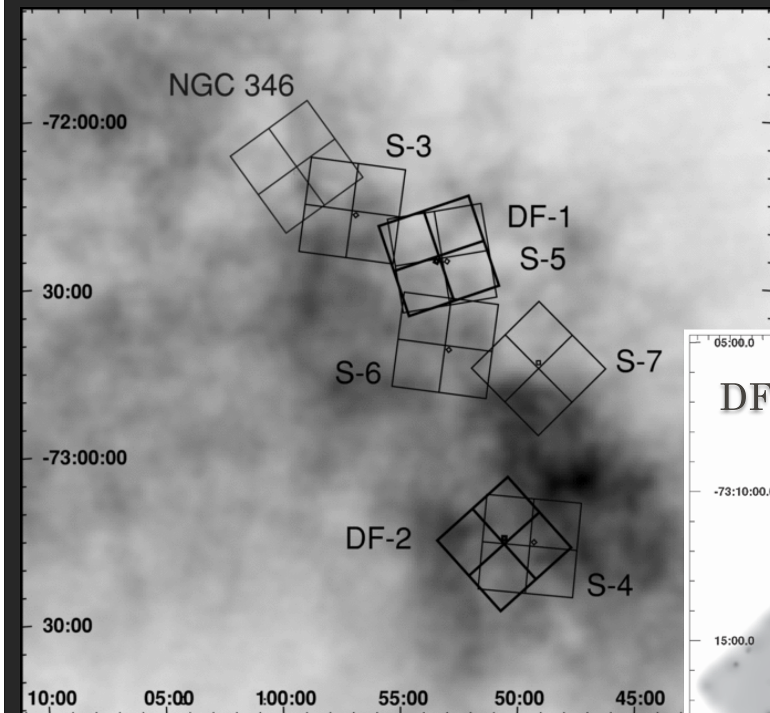
✓ chance coincidence probability for bright sources >20%

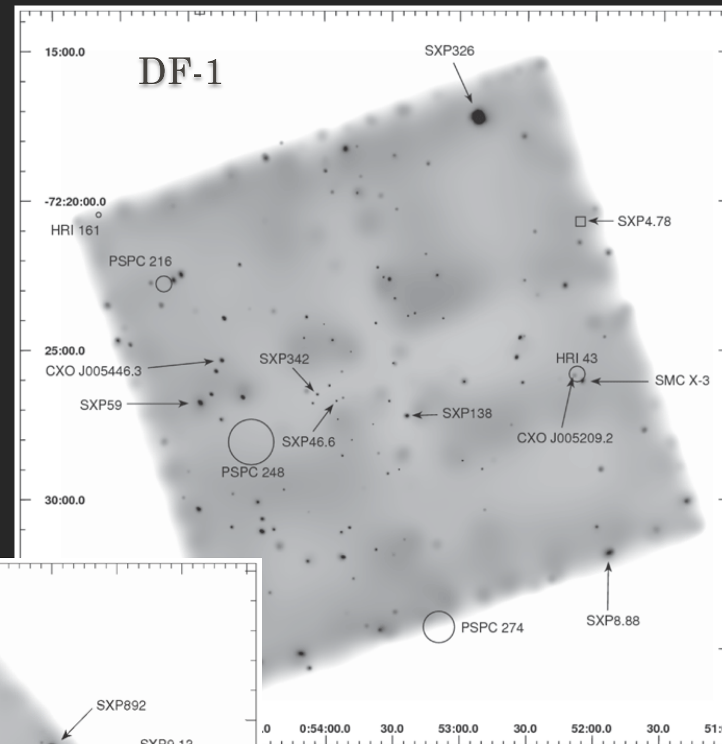
Antoniou et al. (2010, ApJL, 716, 140)

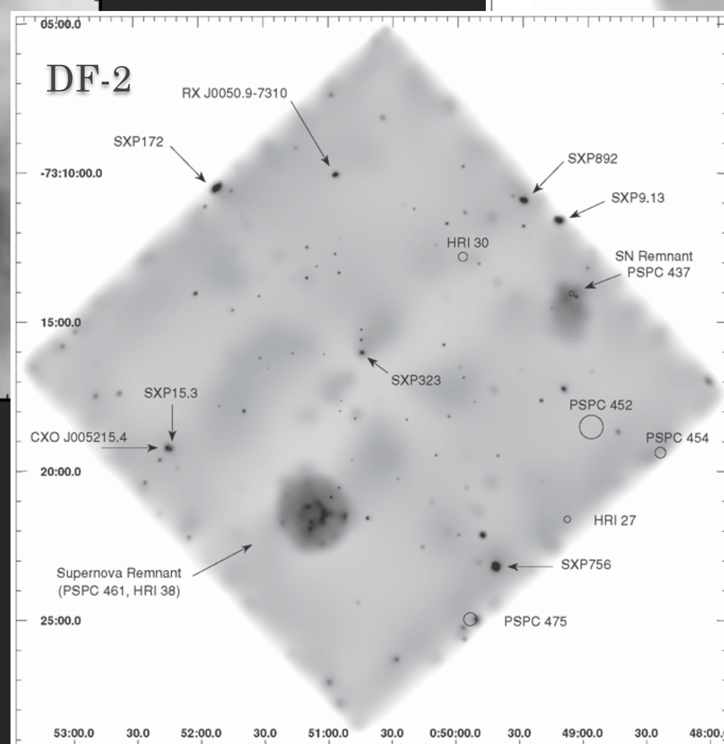
A DEEP X-RAY SURVEY OF THE SMC

✓ ~100 ks each

✓ Lx ~ 4.3 x 10^{32} erg s^{-1}





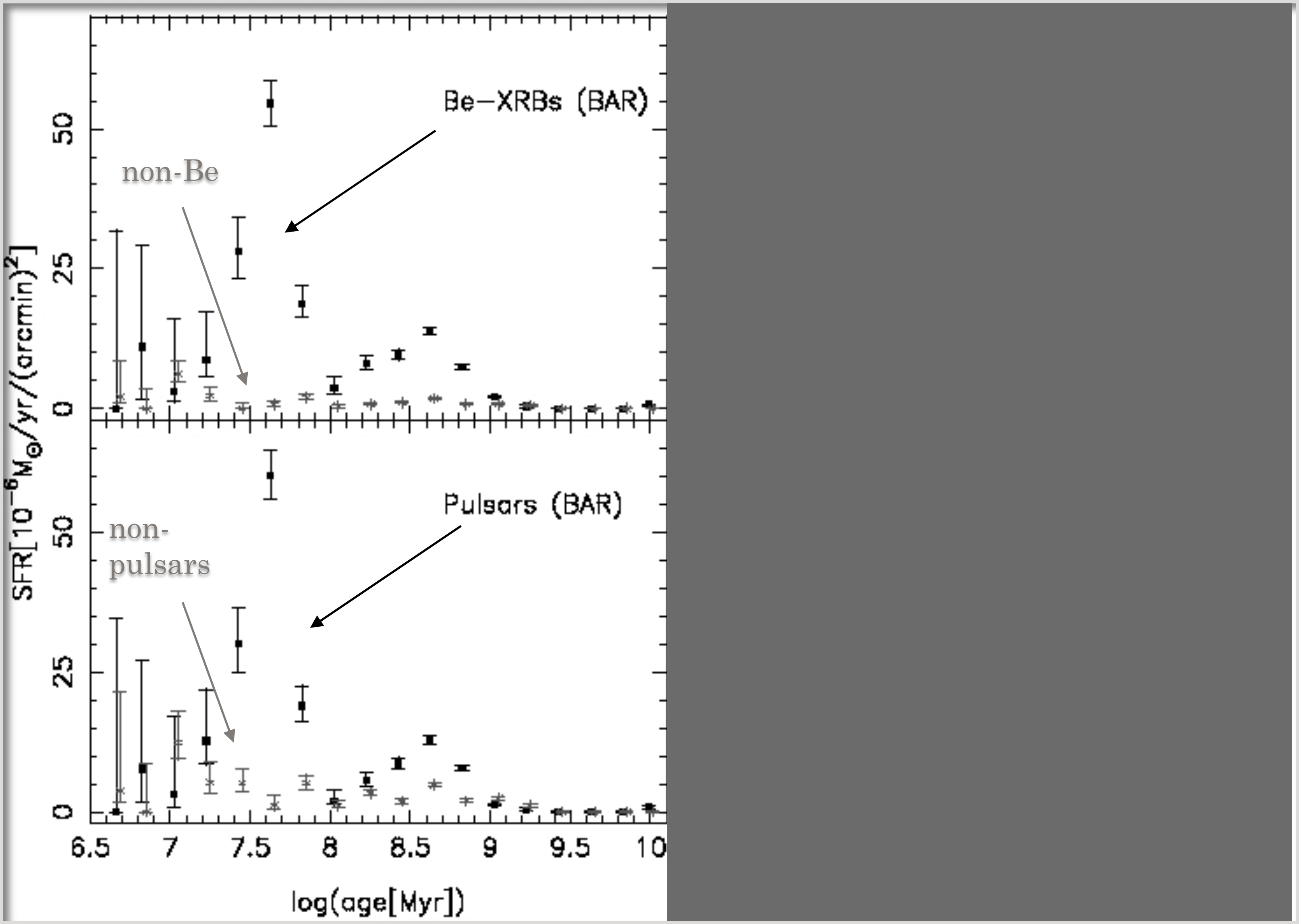


✓ 19 HMXBs, including 11 previously known pulsars, 2 new pulsars, and 4 other HMXB candidates

17 sources in DF1 & 23 in DF2 have bright (V < 17) optical c/parts

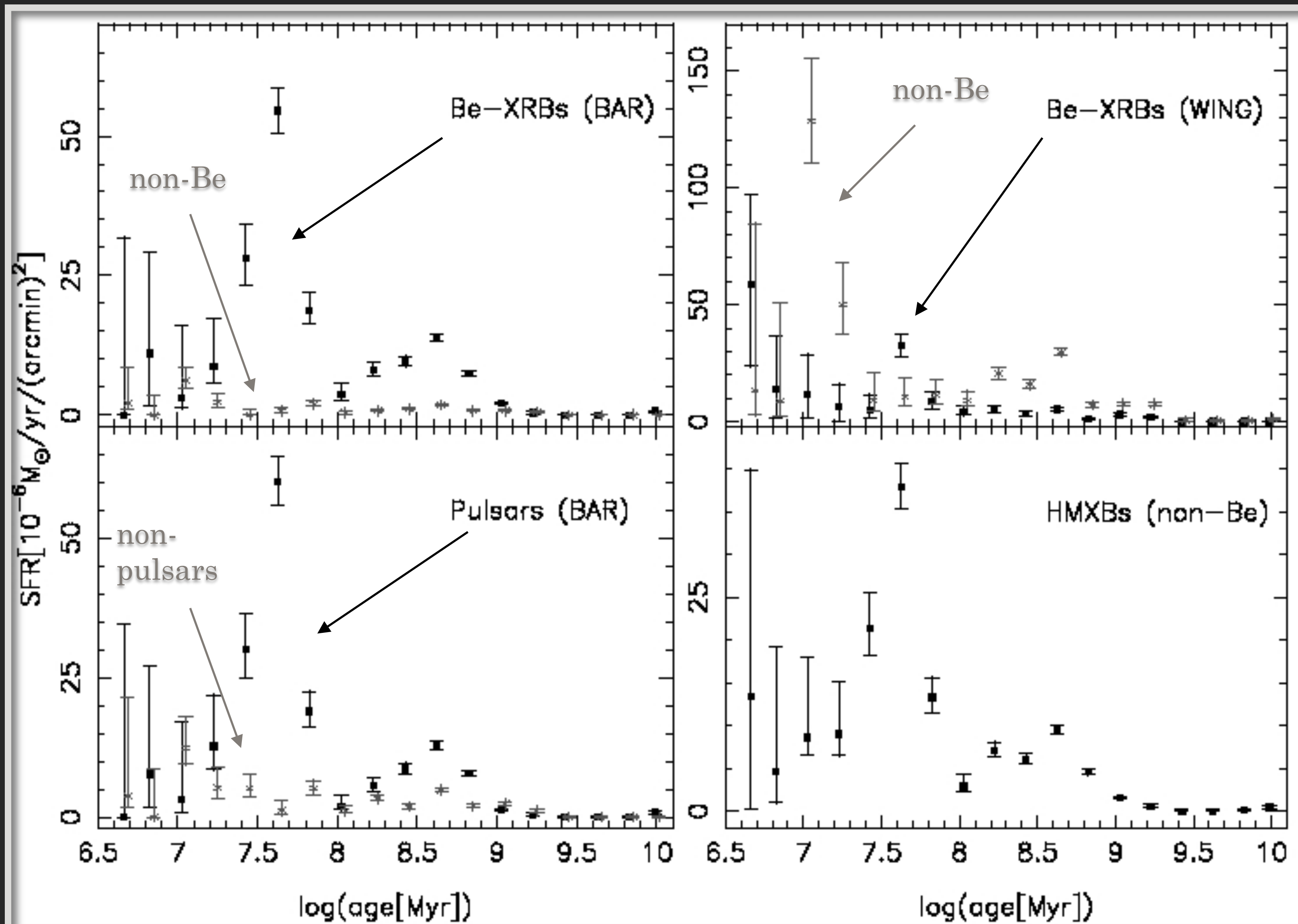
Laycock et al. (2010, ApJ, 716, 1217)

TRACING THE YOUNG HMXBs IN THE SMC



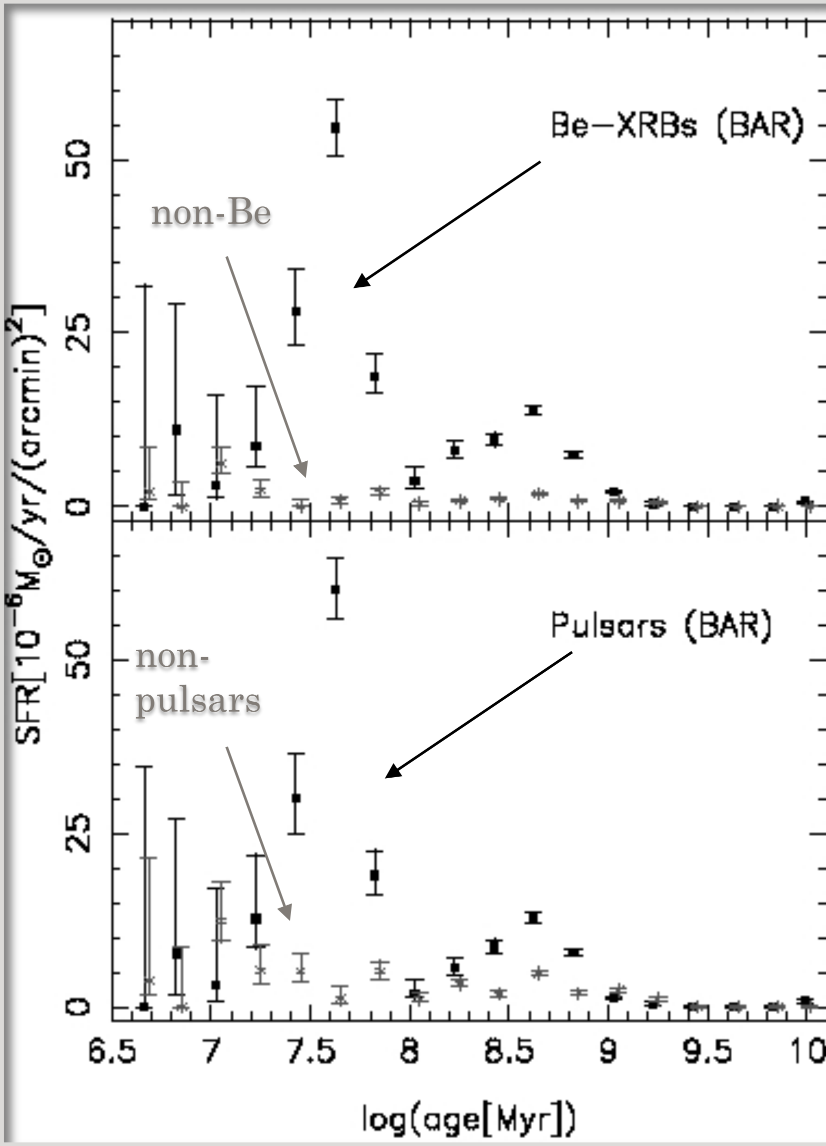
Antoniou et al. (2010, ApJL, 716, 140)

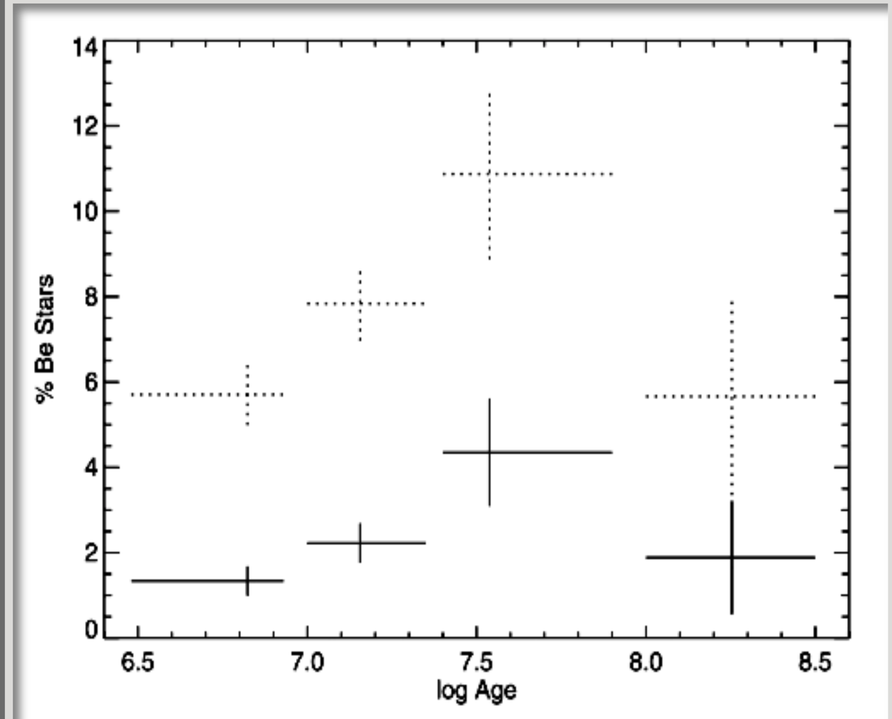
TRACING THE YOUNG HMXBs IN THE SMC



Antoniou et al. (2010, ApJL, 716, 140)

TRACING THE YOUNG HMXBs IN THE SMC

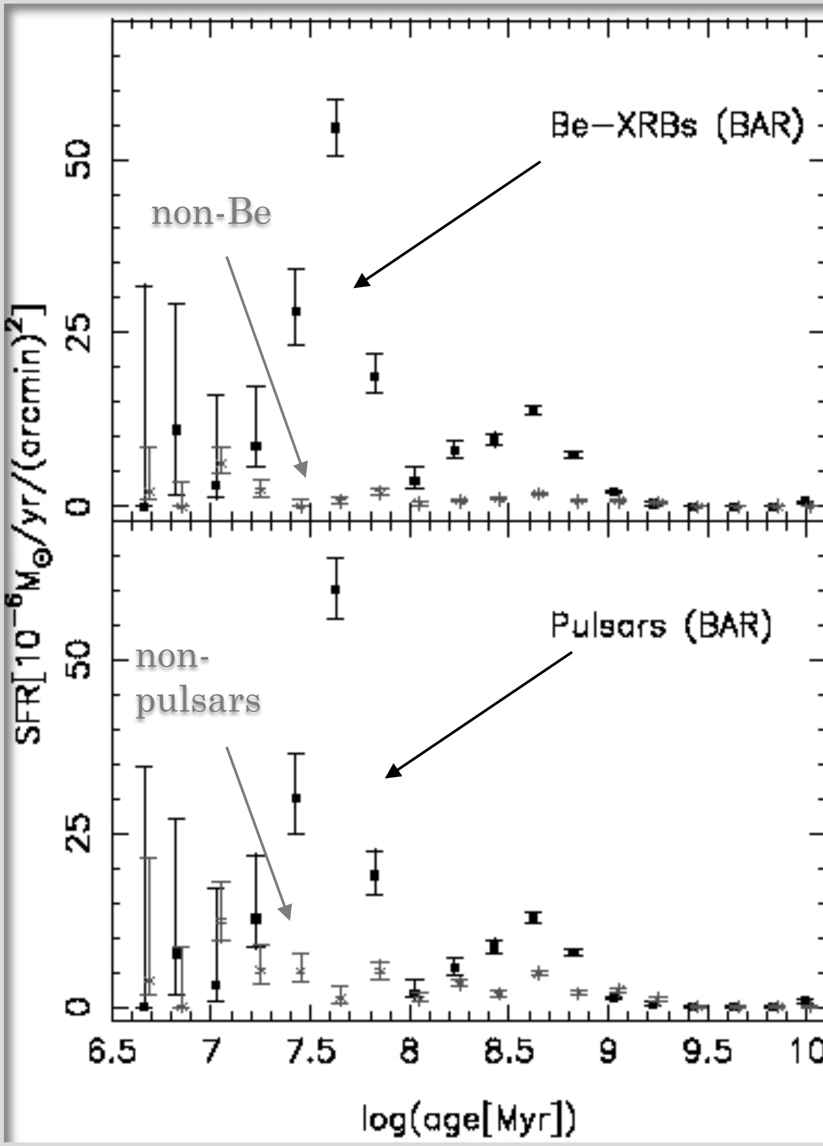




McSwain & Gies (2005)

Antoniou et al. (2010, ApJL, 716, 140)

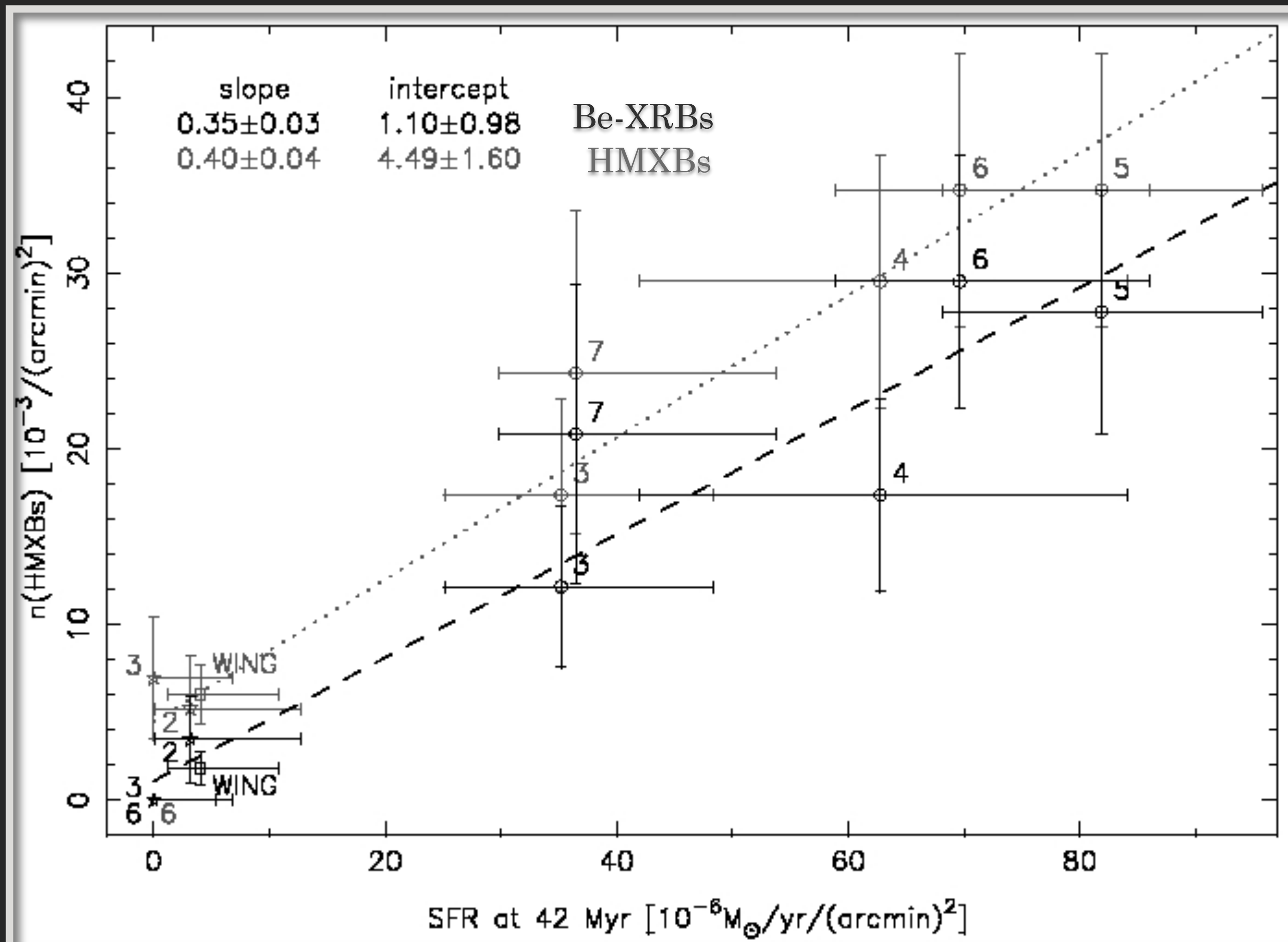
TRACING THE YOUNG HMXBs IN THE SMC



Strong correlation (XRB number & the age of the stellar pops. at their location) allows us to measure for the *first time* the XRB formation rate per unit SFR of their parent populations

Antoniou et al. (2010, ApJL, 716, 140)

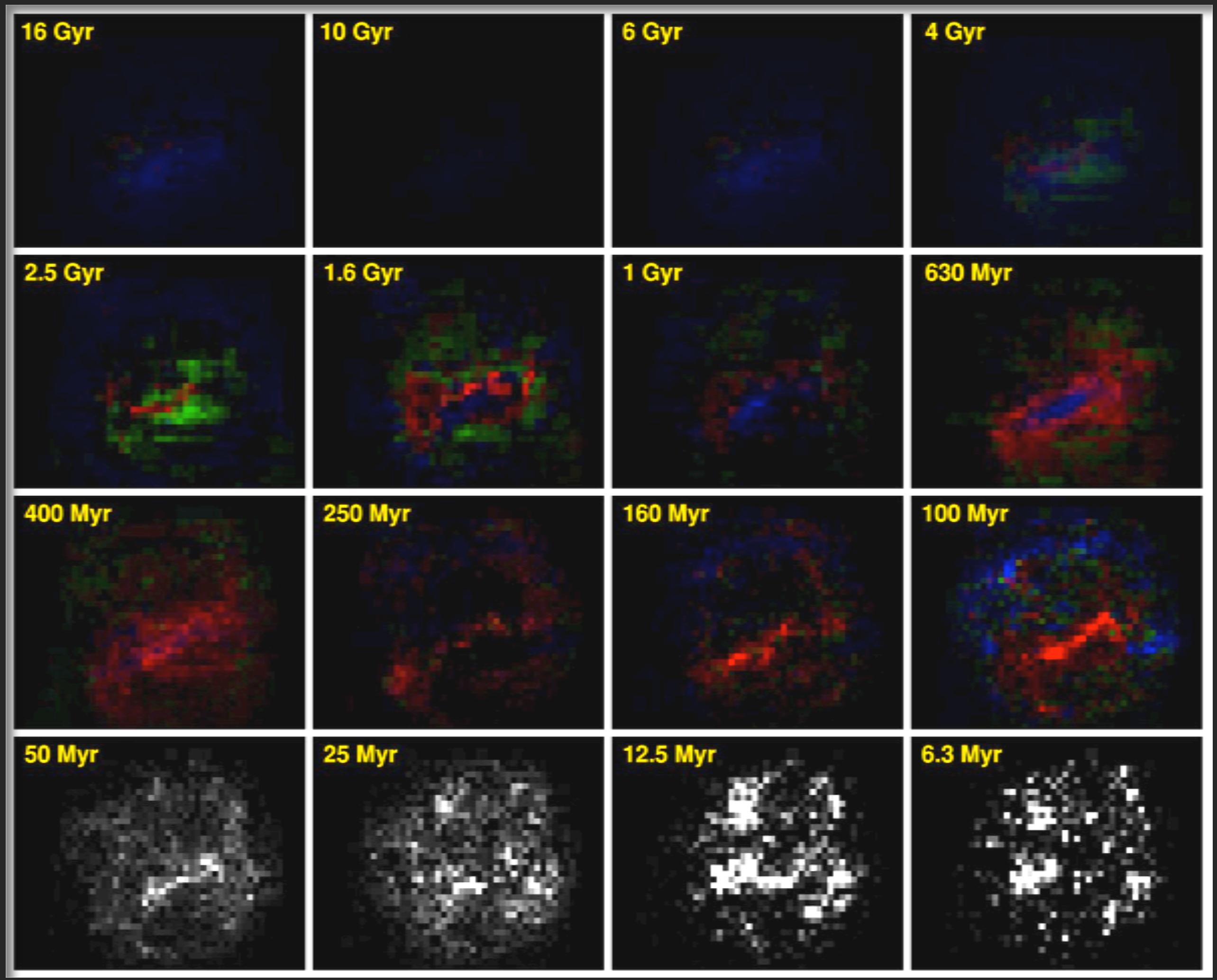
HMXB FORMATION RATE IN THE SMC



- Our Chandra Shallow Survey (circles) / our XMM-Newton (asterisks) fields
- "WING" point: XMM-Newton field 1 and 4 fields from the Chandra Wing survey (P.I. M. Coe)

Antoniou et al. (2010, ApJL, 716, 140)

STAR-FORMATION HISTORY OF THE LMC



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Z = 0.004 ⇔ [Fe/H] = -0.7

Z = 0.001 ⇔ [Fe/H] = -1.3

pixel intensity proportional to the subregion's SFR

Harris & Zaritsky (2009)

THE HMXB POPULATION OF THE LMC

- ❑ Latest census: 36 sources in Liu et al. (2005)

- ❑ Since then: a couple more new systems have been identified by Swift & INTEGRAL

- ❑ Nowadays: we know 41 LMC HMXBs (9 are X-ray pulsars)

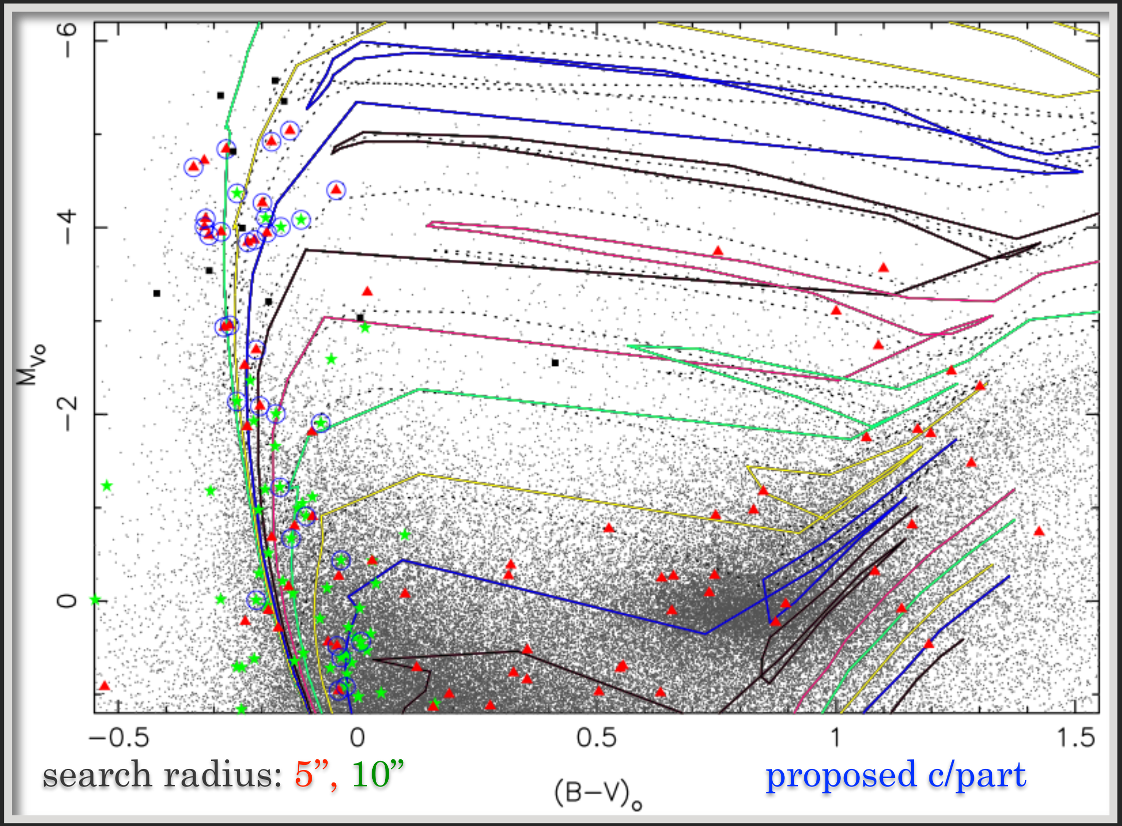
- ❑ Spectral types: available for 18 systems (~O8 to B2), 5 of which are pulsars…2 additional sources have rough spectral types derived from photometry

- ❑ Optical identification: 26 are still missing one

- ❑ Using the MCPS catalog (Zaritsky et al. 2009) we identified counterparts for all 41 sources in good agreement with previous studies… in a couple of cases we propose a different counterpart

Antoniou et al. (2011, to be subm.)

PARENT STELLAR POPULATIONS OF LMC HMXBs

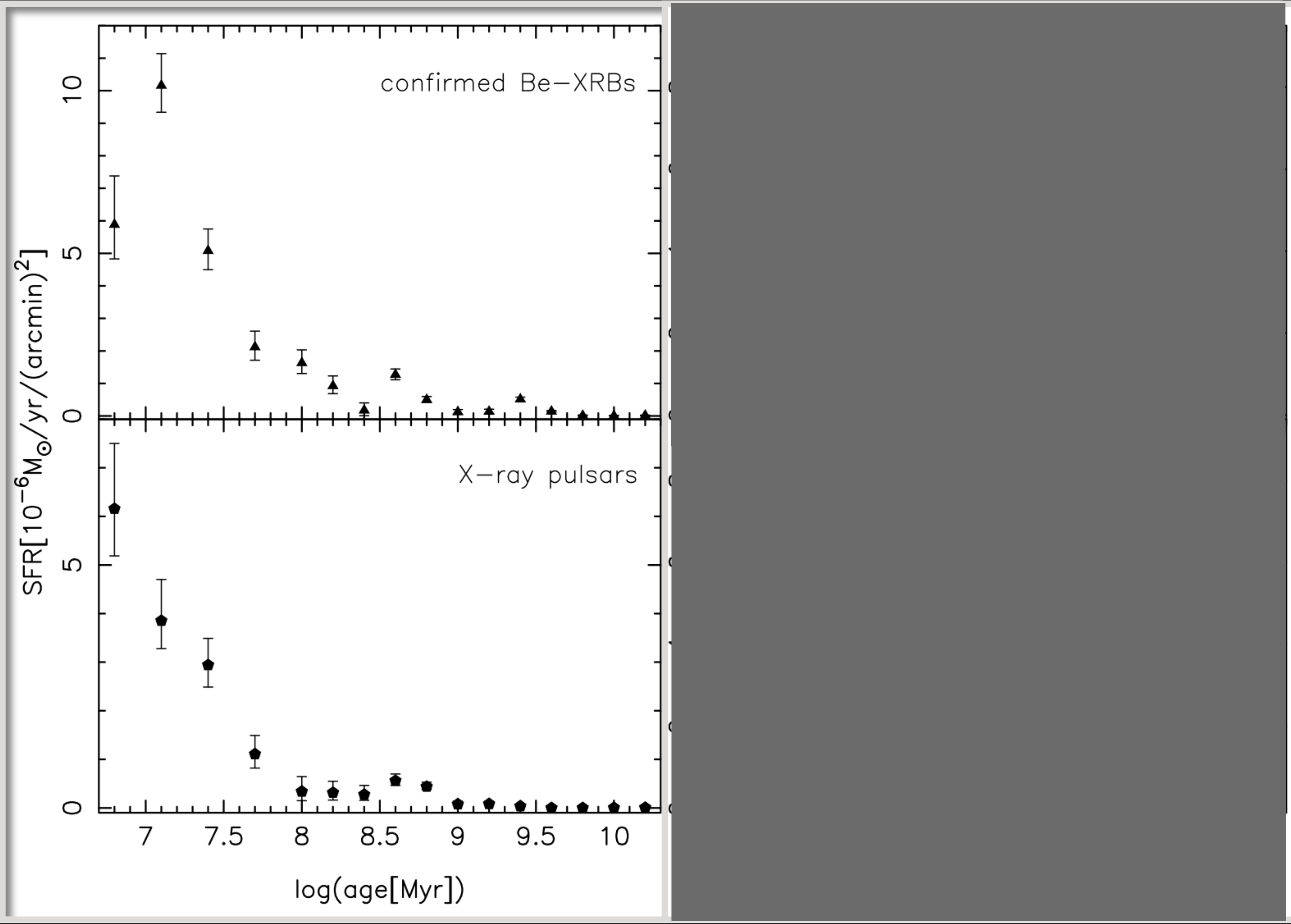


Geneva isochrones (top to bottom; $Z = 0.008 = 0.4Z_{\odot}$):
8.7 Myr, 15.5 Myr, 27.5 Myr, 49.0 Myr,
87.1 Myr, 154.9 Myr, 275.4Myr, …

black squares: OGLE-II (type-4) candidate Be stars from Sabogal et al. (2005)

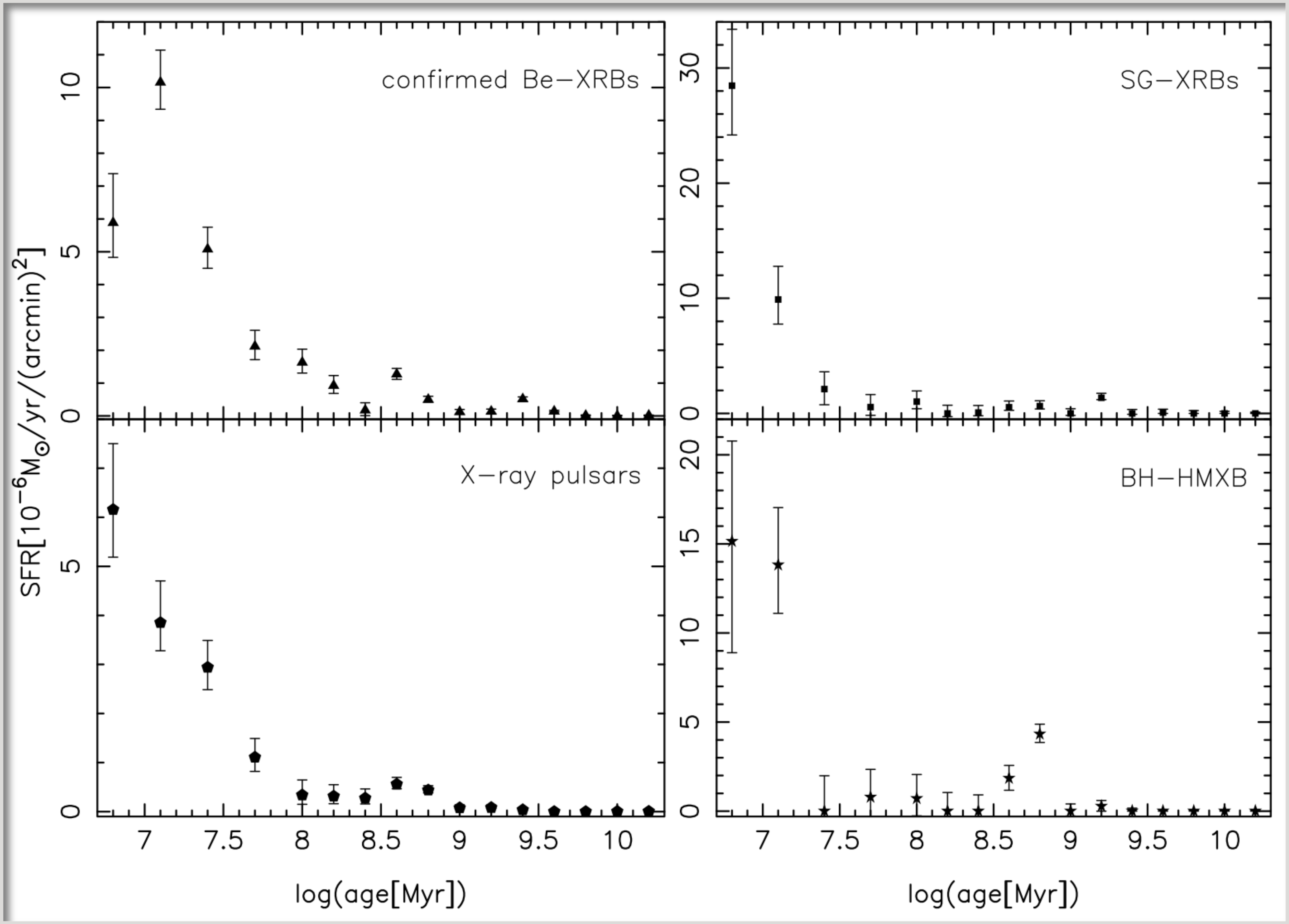
Antoniou et al. (2011, to be subm.)

TRACING THE YOUNG HMXBs IN THE LMC



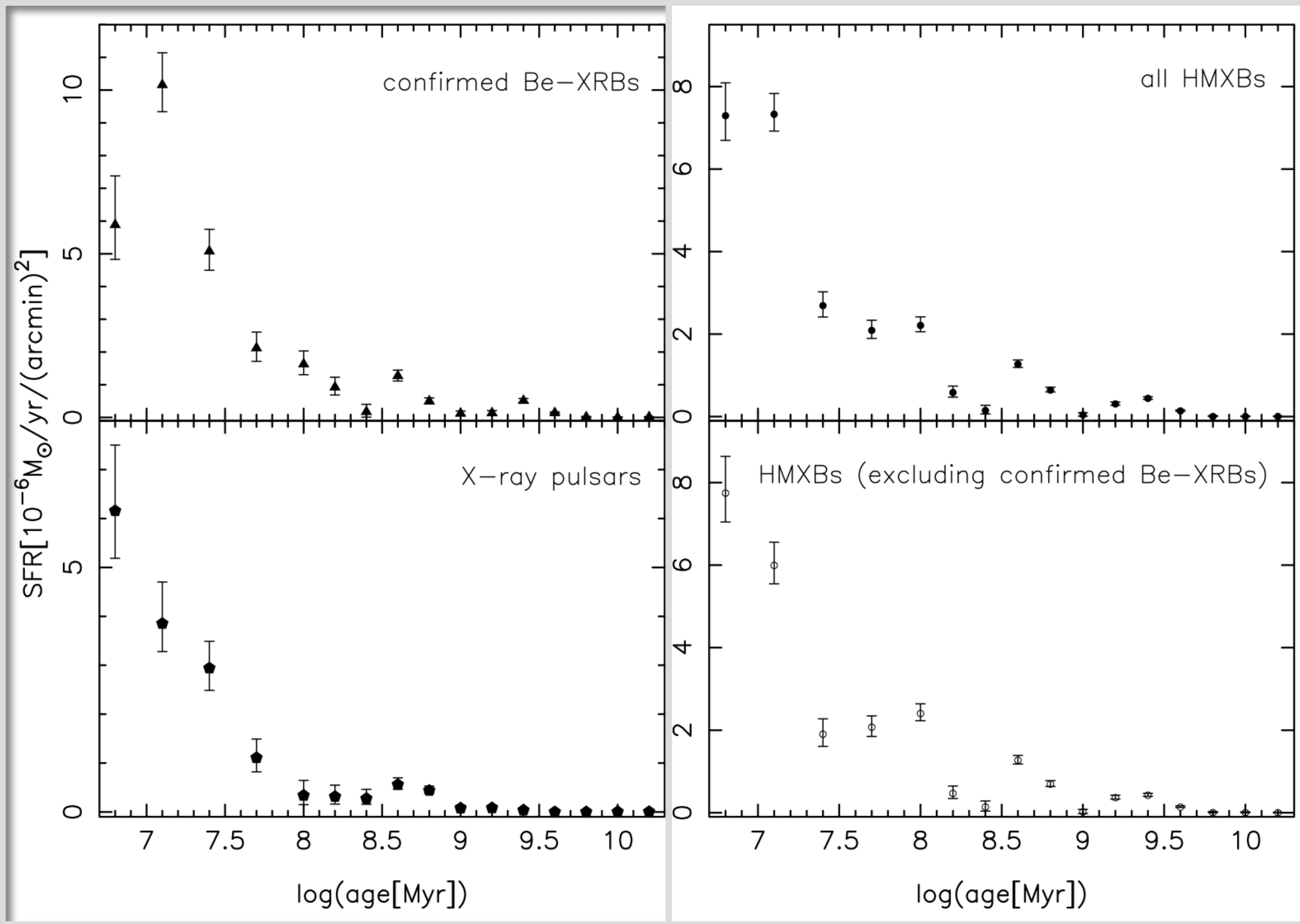
Antoniou et al. (2011, to be subm.)

TRACING THE YOUNG HMXBs IN THE LMC



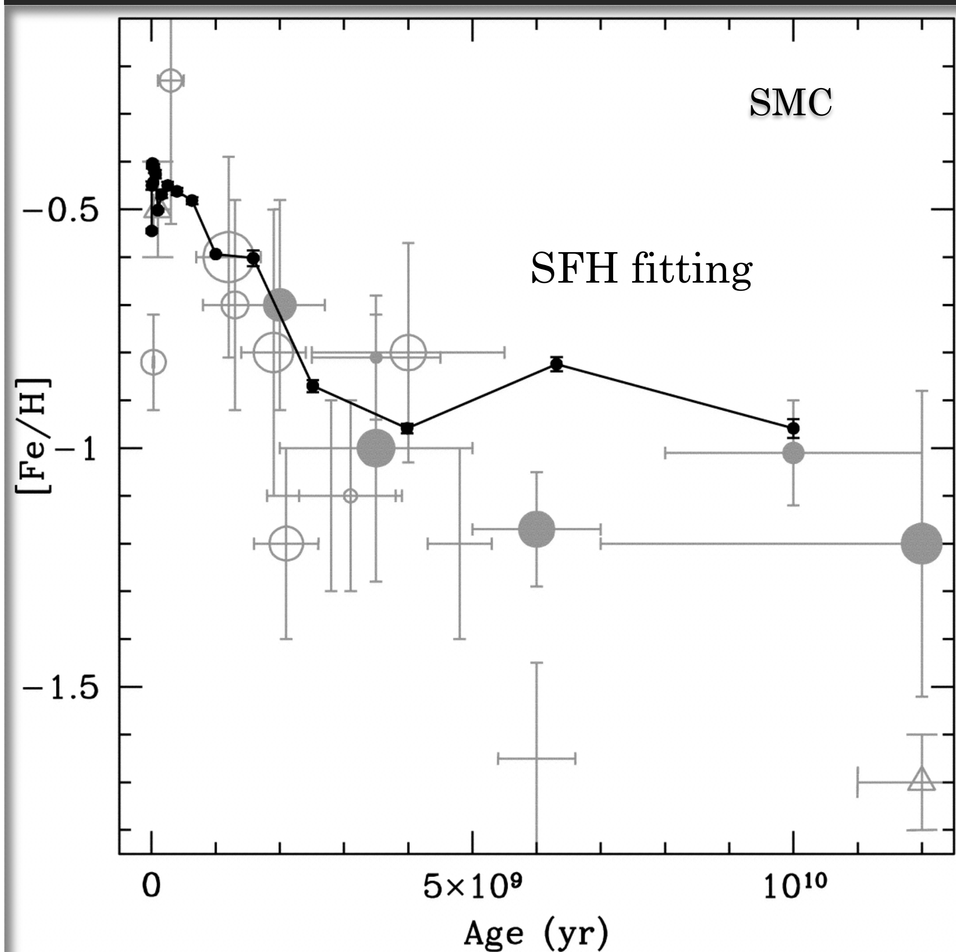
Antoniou et al. (2011, to be subm.)

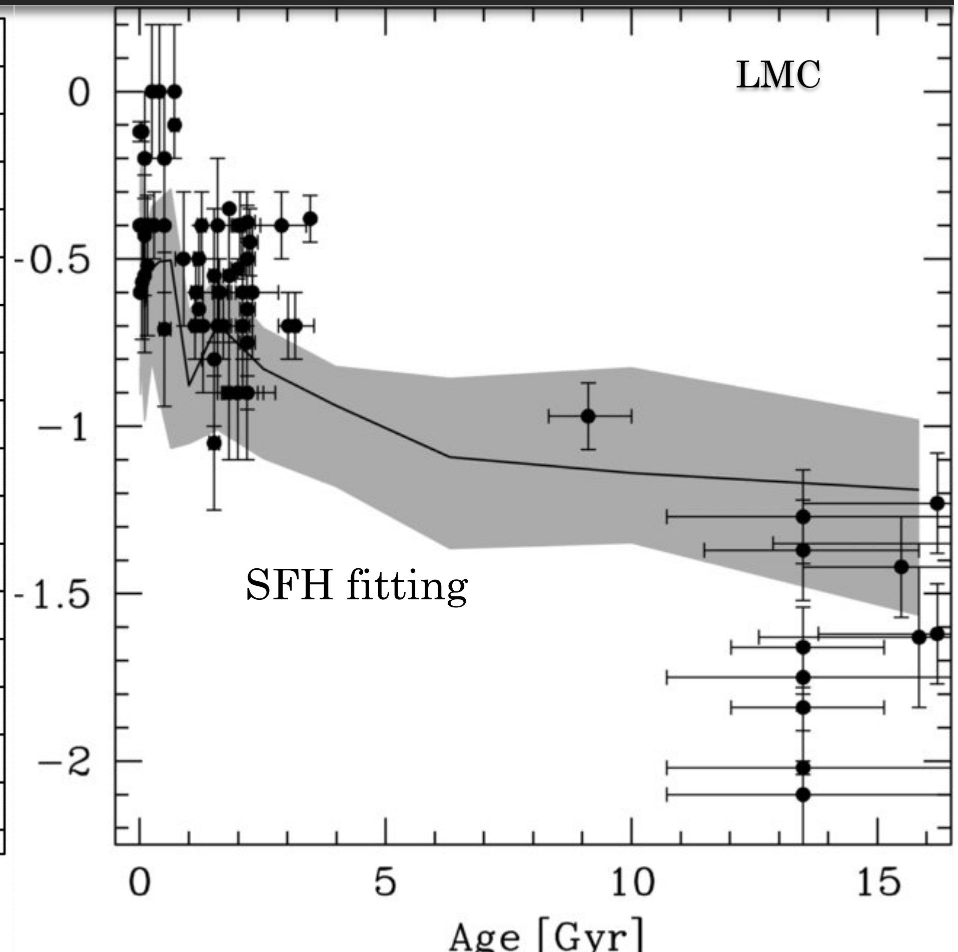
TRACING THE YOUNG HMXBs IN THE LMC



Antoniou et al. (2011, to be subm.)

AGE-METALLICITY RELATION FOR THE MAGELLANIC CLOUDS





Derived from the SFH analysis…

85 LMC clusters

Harris & Zaritsky (2004)

Harris & Zaritsky (2009)

AGE & METALLICITY OF YOUNG MAGELLANIC CLOUDS CLUSTERS

Younger than 100 Myr:

LMC

16 from Harris & Zaritsky (2009) + 2 additional in the literature

$<[Fe/H]_{LMC}> \sim -0.37 \pm 0.13$

SMC

9 in the literature

$<[Fe/H]_{SMC}> \sim -0.71 \pm 0.04$

$[Fe/H] = \log(Z/Z_{\odot})$ and

$Z_{\odot}=0.02$ for the solar metallicity of [Fe/H]=0 (Russel & Dopita 1992)

$<Z_{LMC}> \sim 0.43 Z_{\odot} \sim 0.009$

$<Z_{SMC}> \sim 0.19 Z_{\odot} \sim 0.004$

CONCLUSIONS

✧ For the same (!!!) metallicity $Z \sim 0.4 Z_{\odot}$, the number of HMXBs (and Be-XRBs) peaks at earlier ages in the LMC (~12 Myr) than in the SMC (~42 Myr)

…Why? Simply because at these ages the SFR is higher in each of the 2 galaxies! In any case, "same metallicity" is a simplifying assumption!

…NEED for detailed metallicity studies of regions with HMXBs

✧ The X-ray pulsar population of the LMC is connected with a burst of star-formation ~6-25 Myr ago

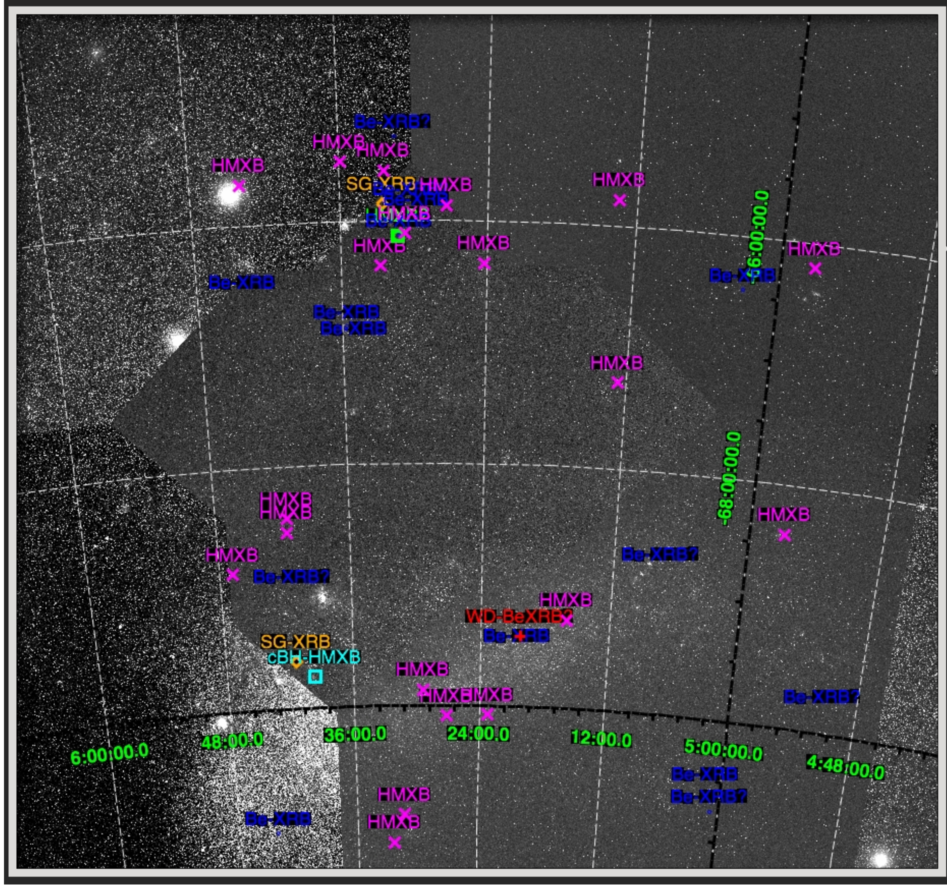
…Do current population synthesis models predict X-ray pulsars at that young ages? No, they predict BHs instead of NSs as compact objects!

…NEED for detailed stellar evolution models

CONCLUSIONS

✧ Based on the lower star-formation rate of the parent stellar populations in the LMC, a smaller number of Be-XRBs and X-ray pulsars is expected

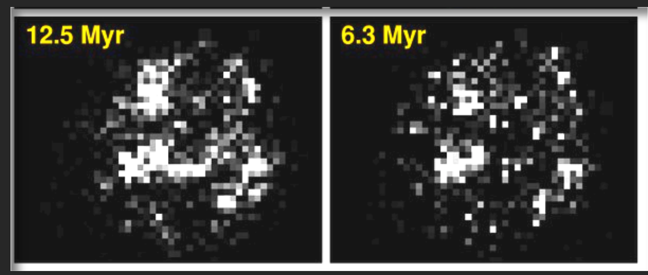
and along these lines…



✧ What is the formation rate of HMXBs in the LMC?

Limited by small number statistics

…NEED for a systematic study of the LMC X-ray source population in *young* stellar regions



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  CfA
- Jose Galache
  CfA
- Silas Laycock
  University of Massachusetts, Lowell