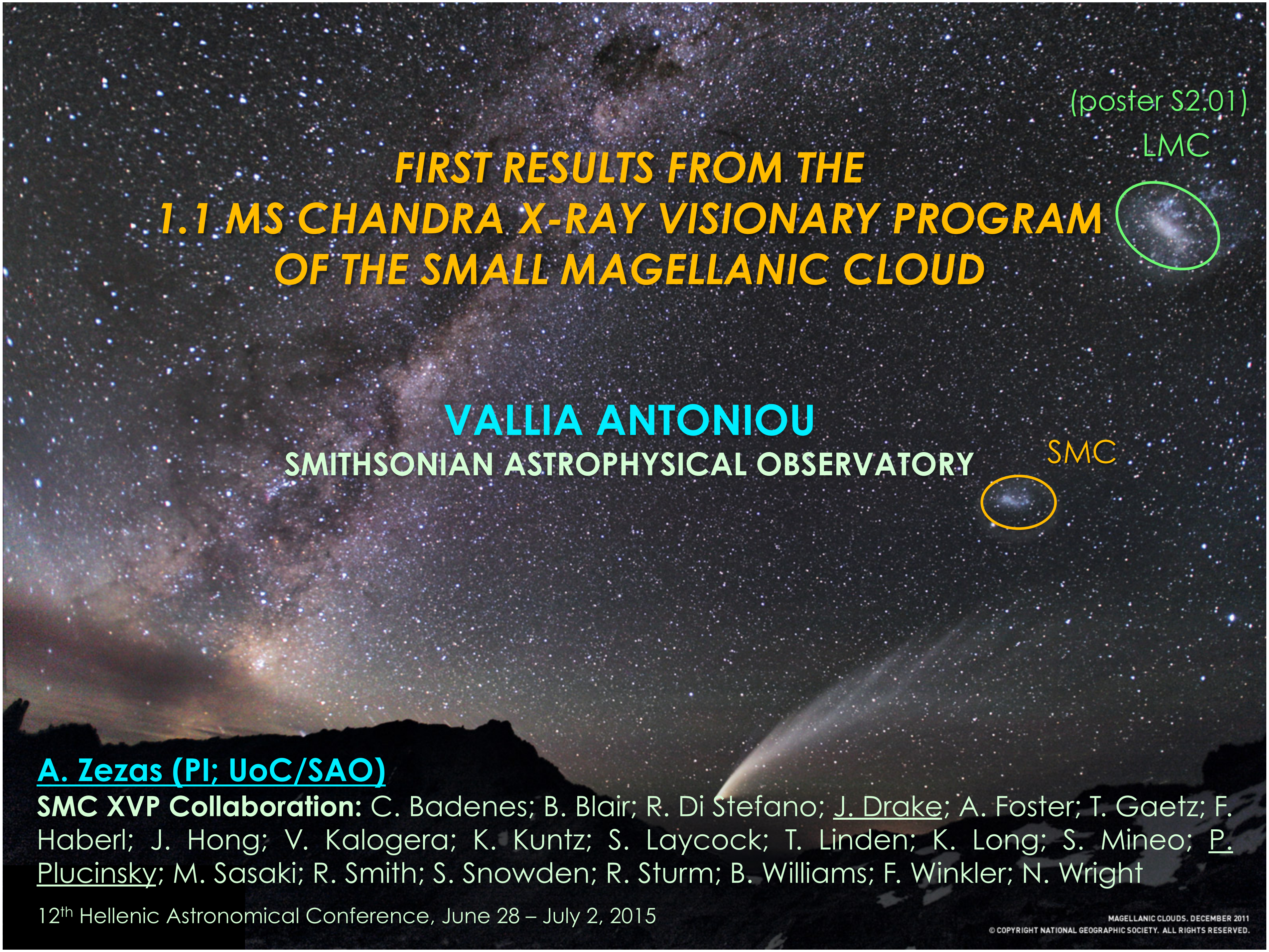
(poster S2.01)

FIRST RESULTS FROM THE 1.1 MS CHANDRA X-RAY VISIONARY PROGRAM OF THE SMALL MAGELLANIC CLOUD

VALLIA ANTONIOU

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

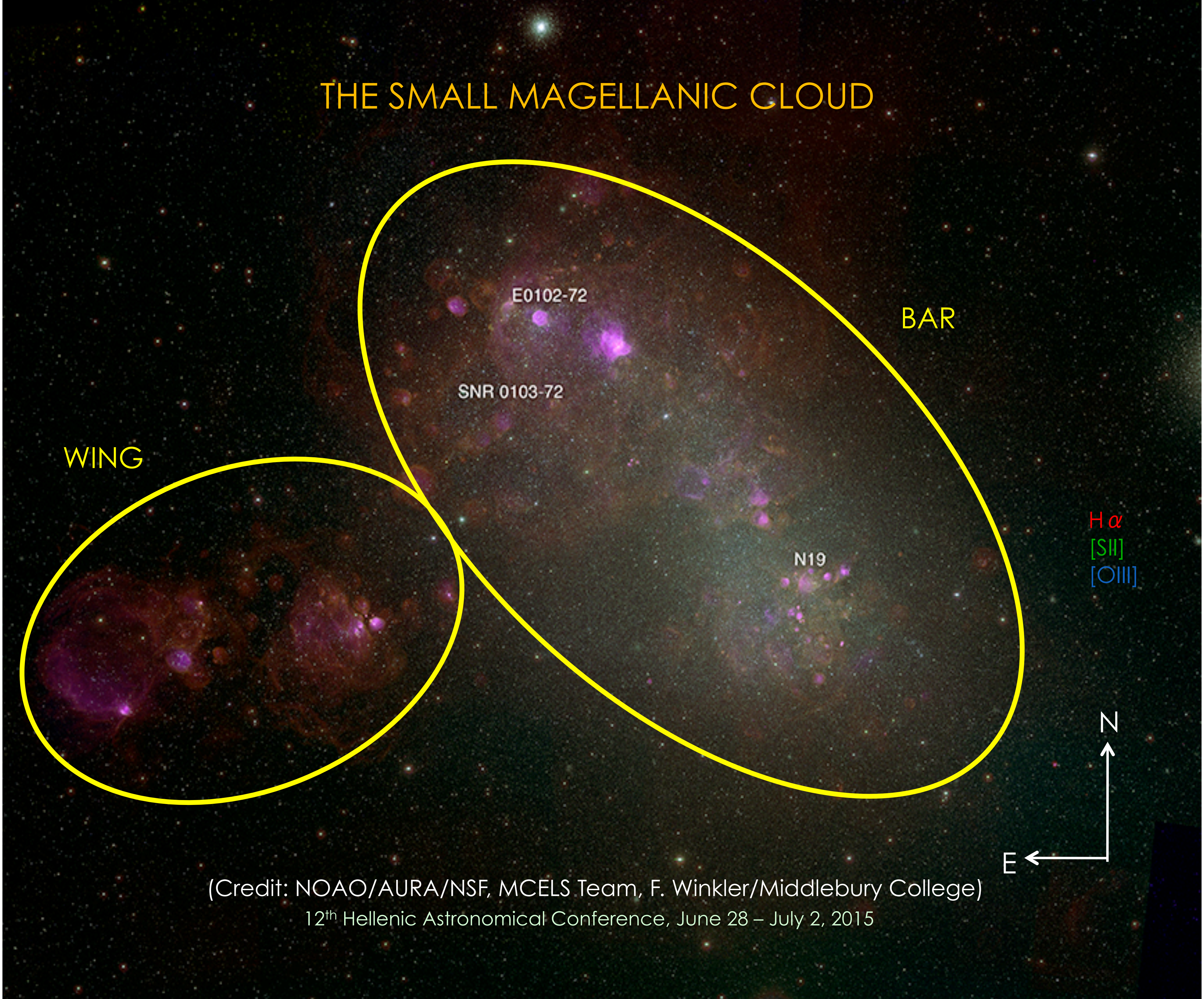


A. Zezas (PI; UoC/SAO)

SMC XVP Collaboration: C. Badenes; B. Blair; R. Di Stefano; J. Drake; A. Foster; T. Gaetz; F. Haberl; J. Hong; V. Kalogera; K. Kuntz; S. Laycock; T. Linden; K. Long; S. Mineo; P. Plucinsky; M. Sasaki; R. Smith; S. Snowden; R. Sturm; B. Williams; F. Winkler; N. Wright

12th Hellenic Astronomical Conference, June 28 – July 2, 2015

THE SMALL MAGELLANIC CLOUD



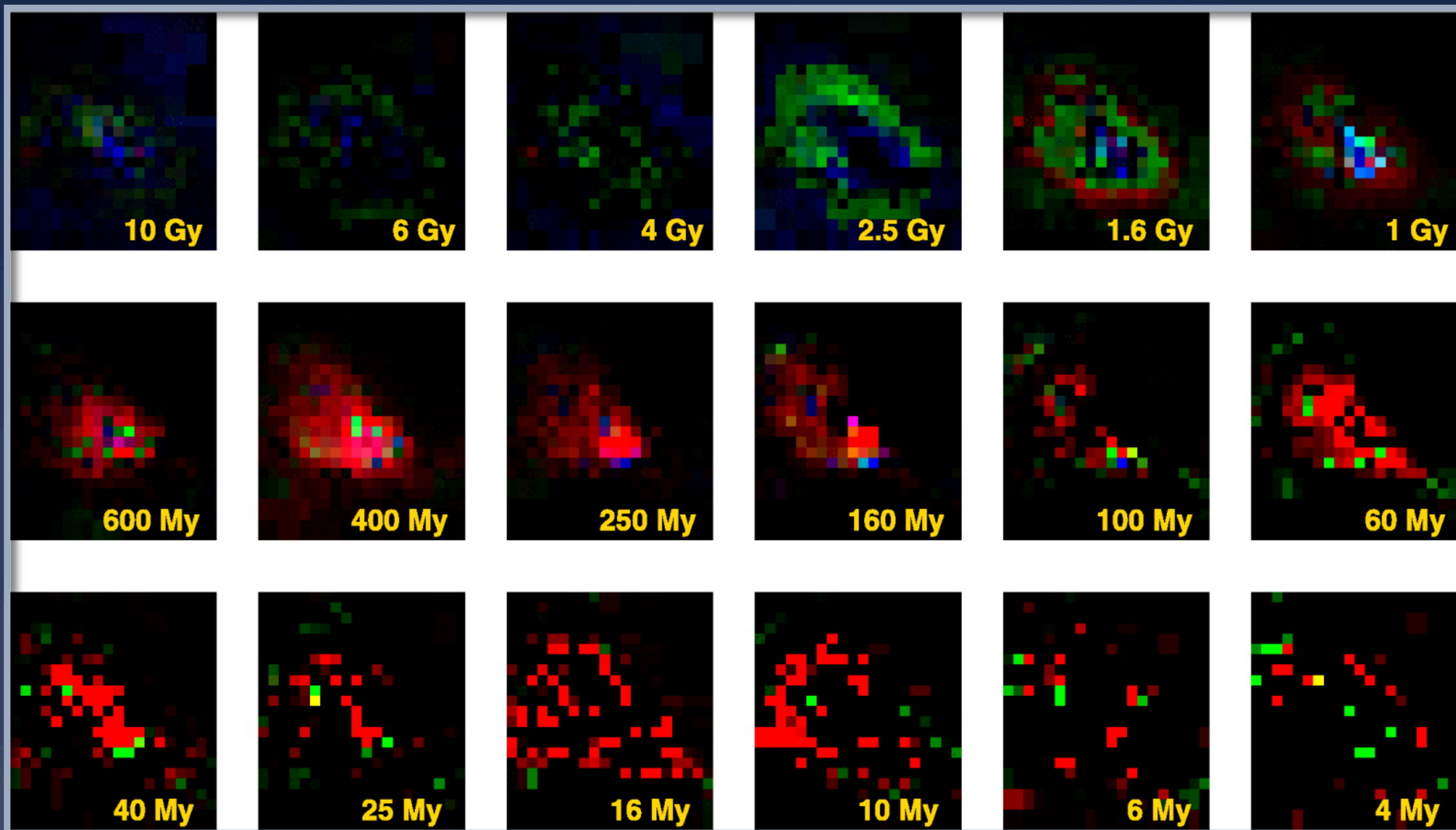
(Credit: NOAO/AURA/NSF, MCELS Team, F. Winkler/Middlebury College)

WHY OBSERVE THE SMALL MAGELLANIC CLOUD?

External galaxies provide us with uniform samples of XRBs in a variety of different environments

* *proximity* (2nd nearest star-forming galaxy @ ~60 kpc)
* *low interstellar absorption* ($N_H \sim 6 \times 10^{20}$ cm^{-2})
* *small angular size* (compared to the Galactic Plane)
* *"clean" X-ray source populations* (almost entirely HMXBs & SNRs)
* *resolved stellar populations* (young <100 Myr, intermediate ~500 Myr, old ~ few Gyr)
* *known SF parameters* (SFR, age & duration of bursts)

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 SFR

Harris & Zaritsky (2004)

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* has been extensively studied in *ALL wavelengths* over the years allowing us to obtain a very good picture of its properties

WHY OBSERVE THE SMALL MAGELLANIC CLOUD?

* Probe very faint populations

Earlier shallow X-ray surveys

Chandra: 10 ks → $L_{X,\ 0.7\text{-}10keV} \sim 4 \times 10^{33}$ erg/s

(e.g. Antoniou+2009)

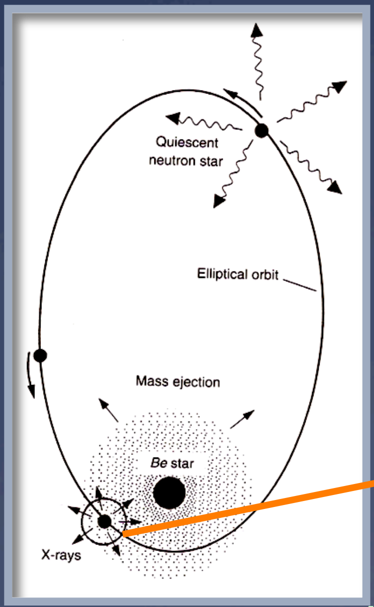
XMM-Newton: 20-30 ks → $L_{X,\ 0.5\text{-}12keV} \sim 10^{34}$ erg/s

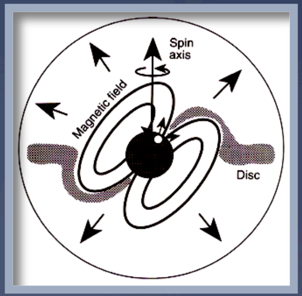
(e.g. Antoniou+2010; Haberl+2012)

* Large populations of HMXBs

Be-XRBs: most numerous sub-class (NS + Oe/Be)

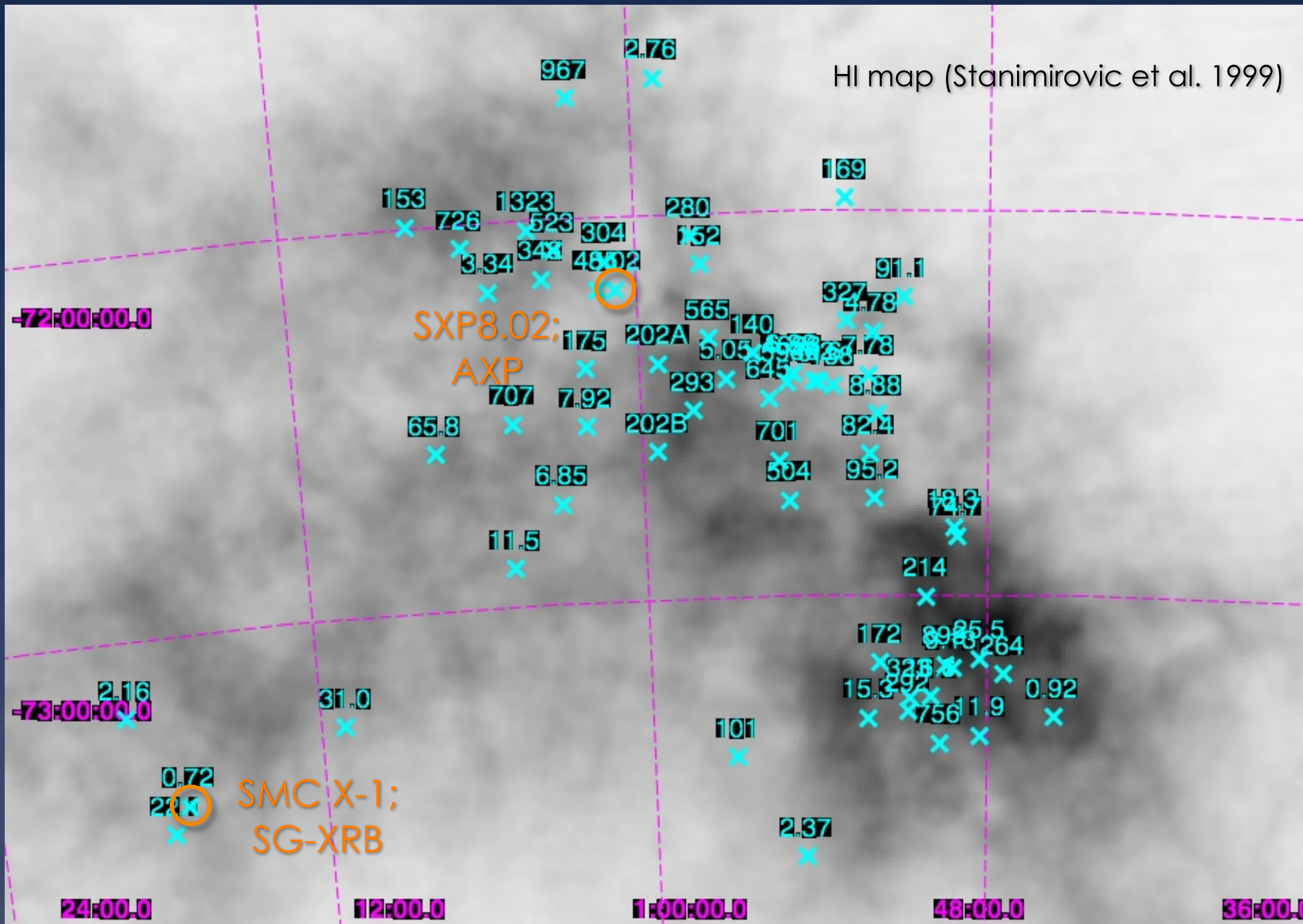
population associated with recent SF





Charles & Seward (1995)

THE X-RAY PULSAR POPULATION OF THE SMC



69 known to date …with the exception of 2 systems, all known pulsars are Be-XRBs

WHY OBSERVE THE SMALL MAGELLANIC CLOUD?

* Probe very faint populations

* Large populations of HMXBs

* Well known SF parameters (SFR, age & duration of burst)

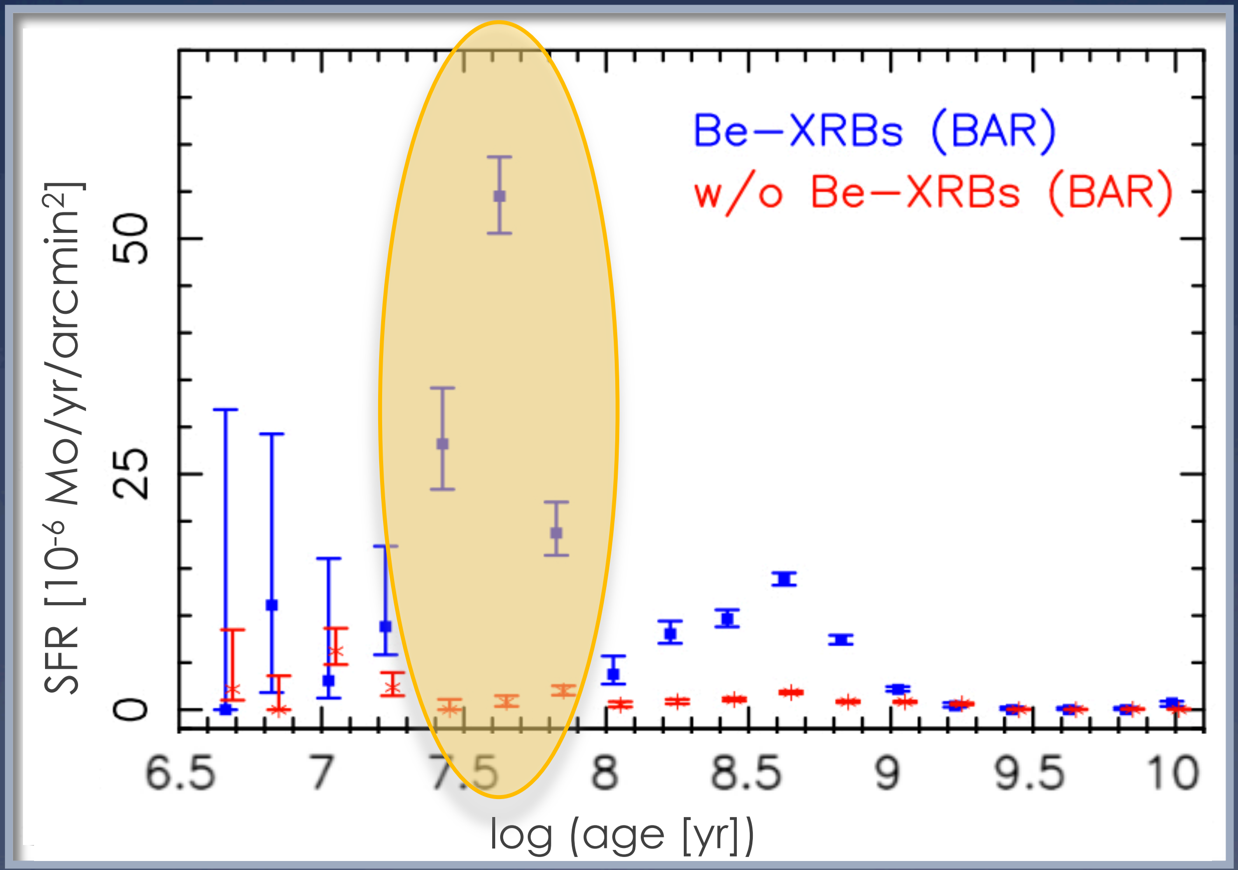
Unique environment to understand accreting binary evolution channels in low metallicities ($Z_{SMC} \sim 1/5\ Z_{\odot}$)

- XRBs formation efficiency
- Physics of accretion
- Physical parameters affecting the formation & evolution of young XRBs

CONNECTING XRBs WITH THEIR PARENT STELLAR POPULATIONS

Average SFH of regions in the SMC w/ and w/o young XRBs

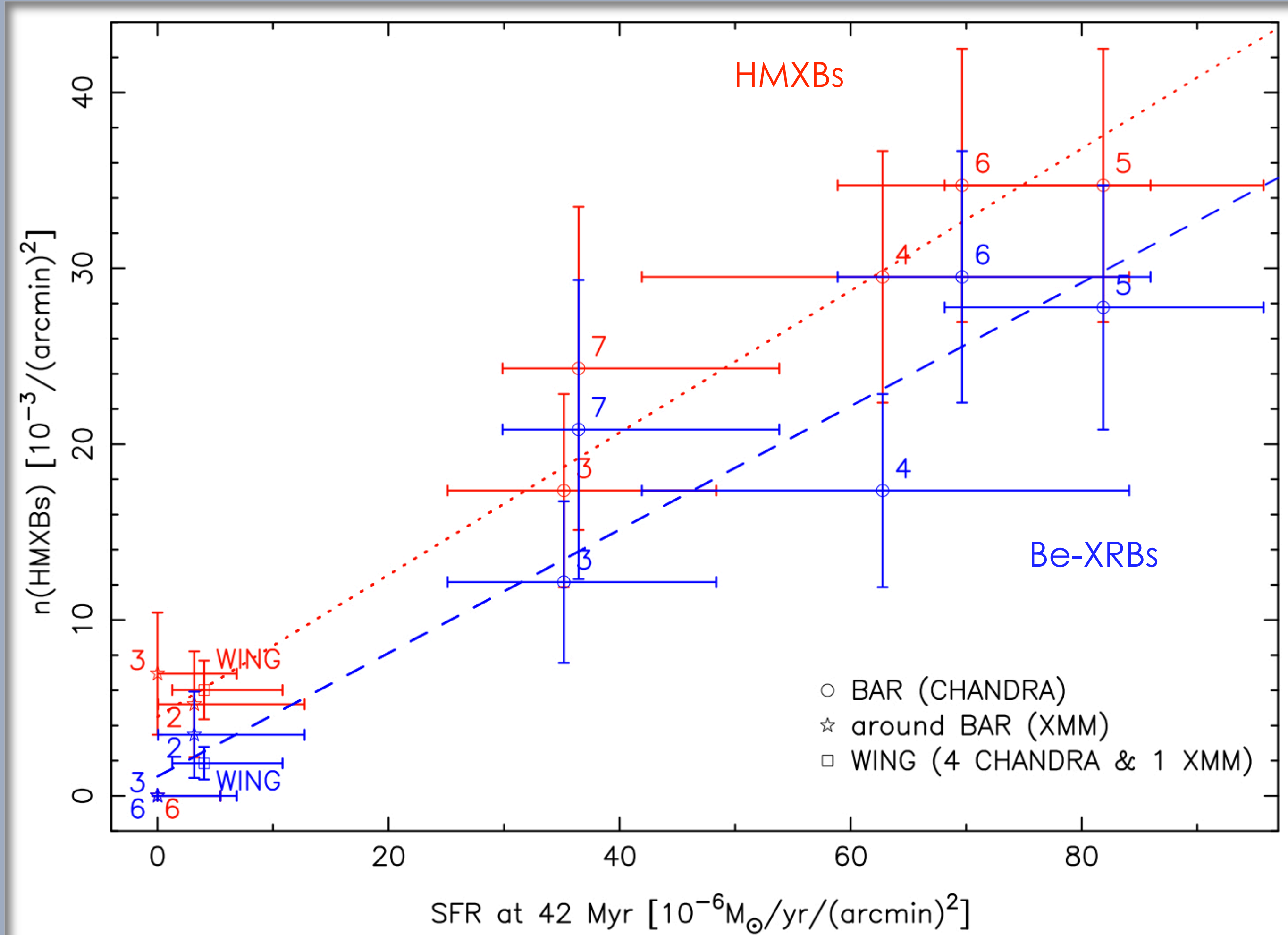
(using data from Harris & Zaritsky 2004)



~40 Myr

Antoniou et al. (2010)

HMXB FORMATION EFFICIENCY IN THE SMC



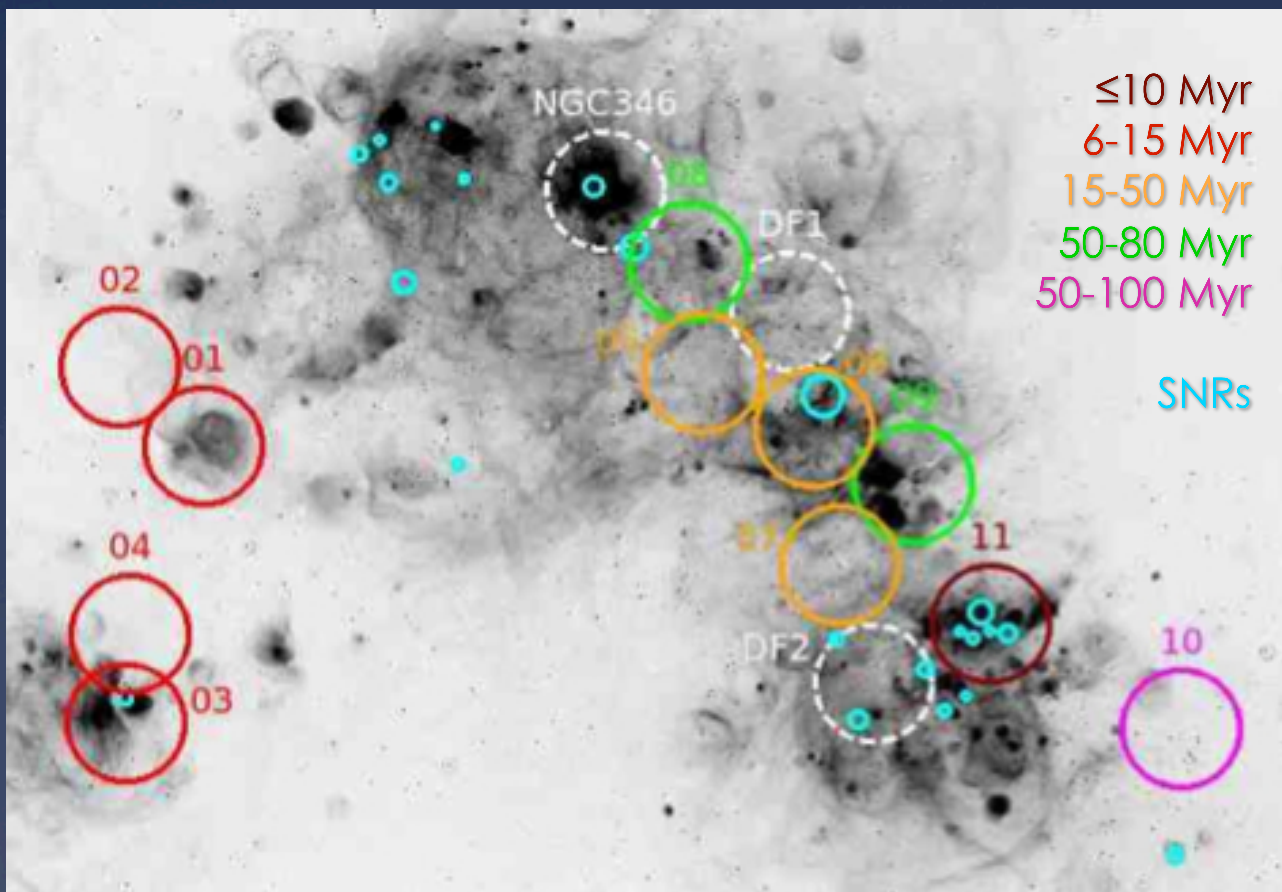
First *direct* calibration of the HMXB formation efficiency at 40 Myr: ~ 1 HMXB per 3 x 10^{-3} Mo/yr

Antoniou et al. (2010)

TOWARDS A MORE COMPLETE UNDERSTANDING OF HMXBs

Cycle 14 XVP Program (1.1 Ms)

A comprehensive survey of sources brighter than ~few x 10^{32} erg/s in 11 fields in the SMC representing young (<100 Myr) populations of different ages

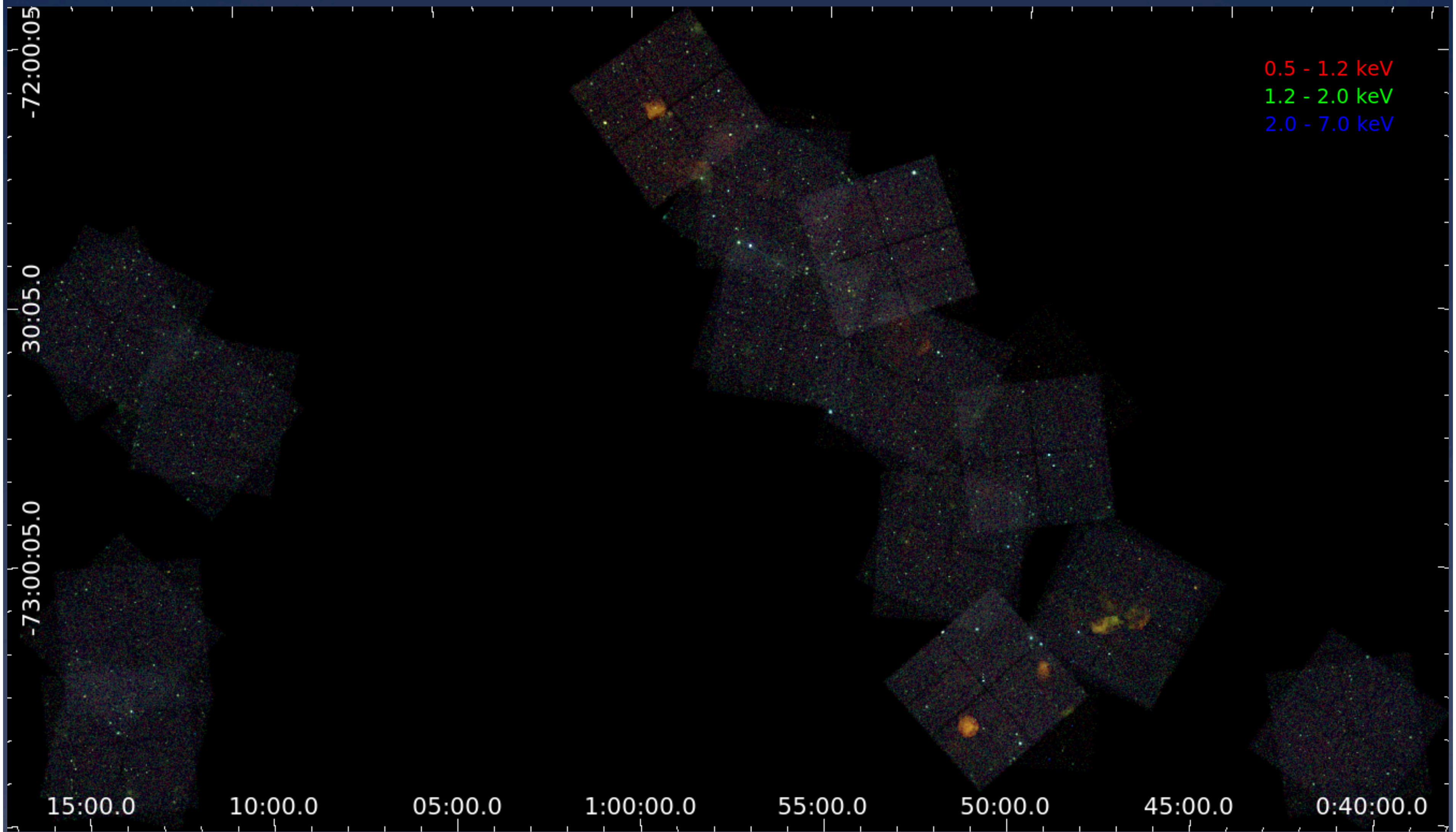


GOALS

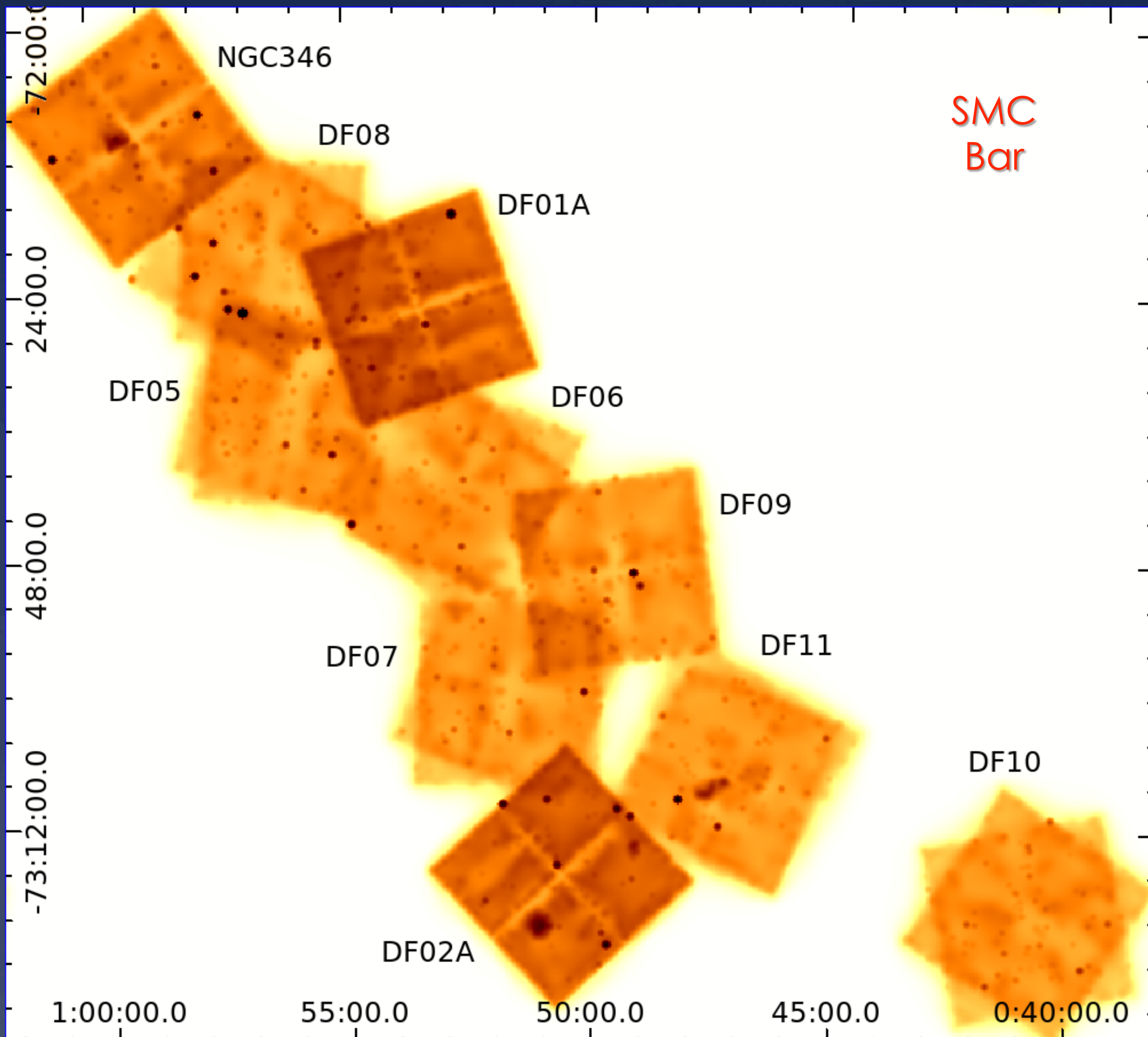
- A deep census of accreting pulsars
- HMXB formation efficiency at different ages
- Short/long term variability of accreting binaries
- Detailed studies of SNRs
- Stars at low metallicity

THE DEEP CHANDRA SURVEY

- survey completed (Dec 2012 – Feb 2014)
- 11 fields (each 2 x 50ks) + 3 archival fields with similar exposure times

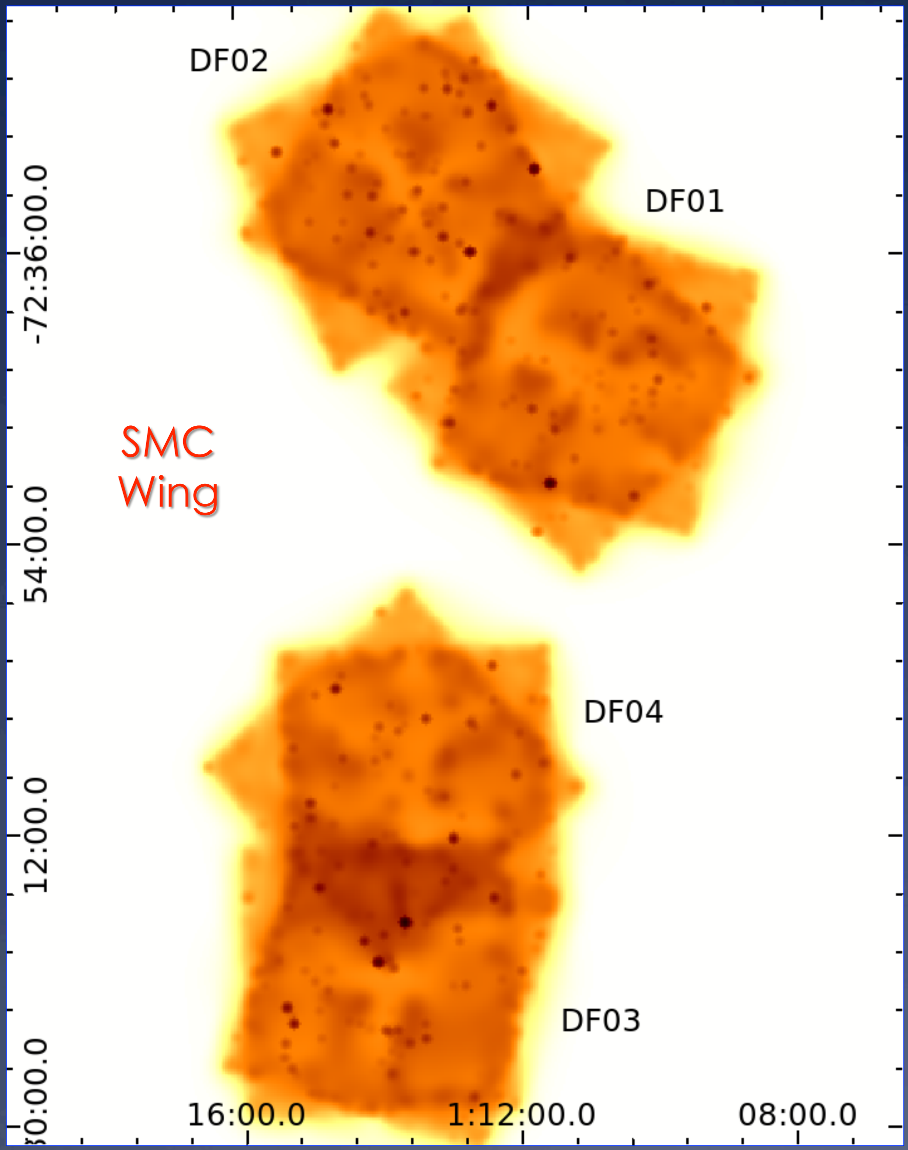


THE DEEP CHANDRA SURVEY



ACIS-I
full band
csmoothed
exposure
corrected
image
bin=2

THE DEEP CHANDRA SURVEY

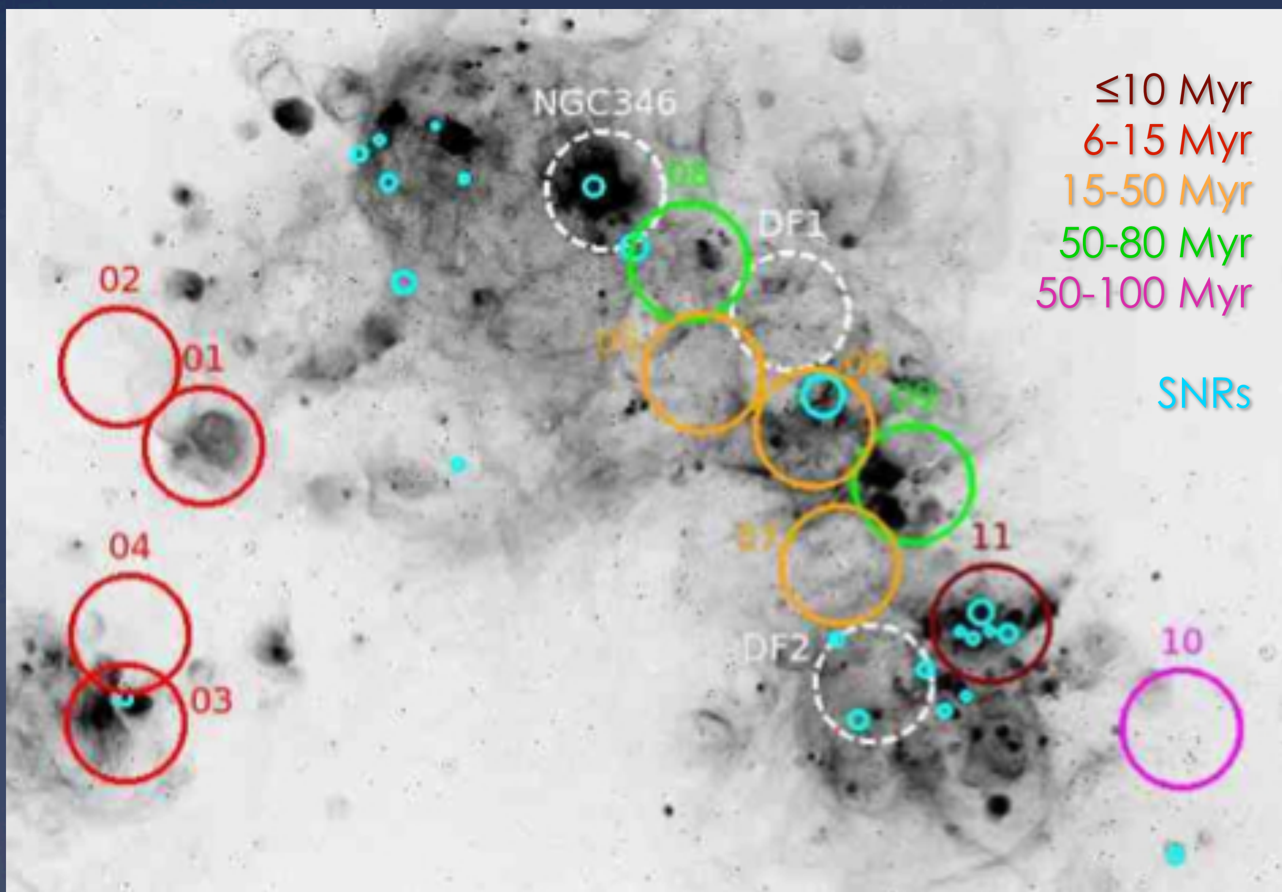


ACIS-I
full band
csmoothed
exposure
corrected
image
bin=1

THE DEEP CHANDRA SURVEY: FIRST RESULTS

Cycle 14 XVP Program (1.1 Ms)

- 11 fields (each 2 x 50ks) + 3 fields from the archive with similar exposure times
- survey just completed (Dec 2012 – Feb 2014)

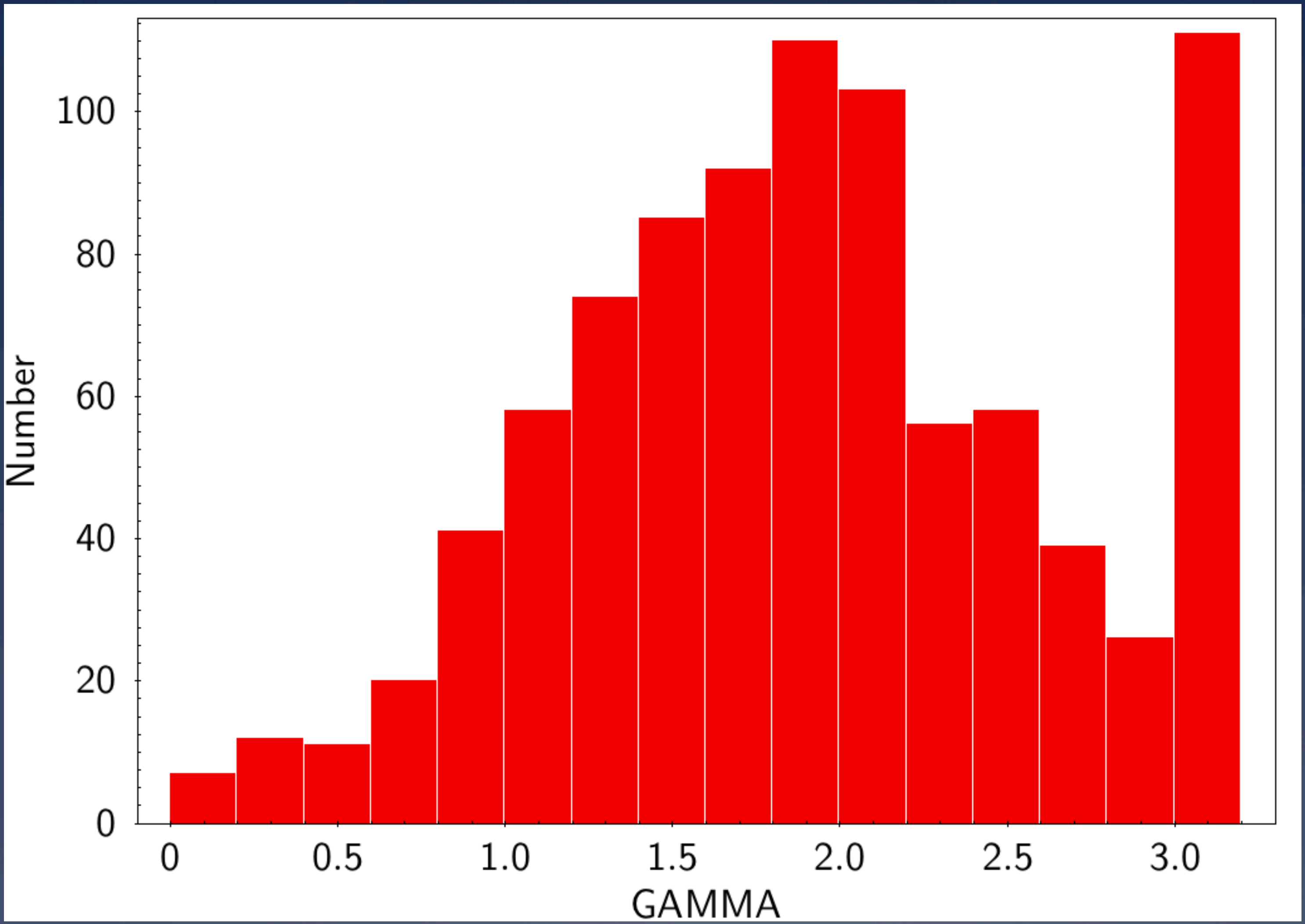


FIRST RESULTS

- ~120 srcs per field

$L_{X,limit}$ ~ 5 x 10^{32} erg/s

SPECTROSCOPIC PROPERTIES



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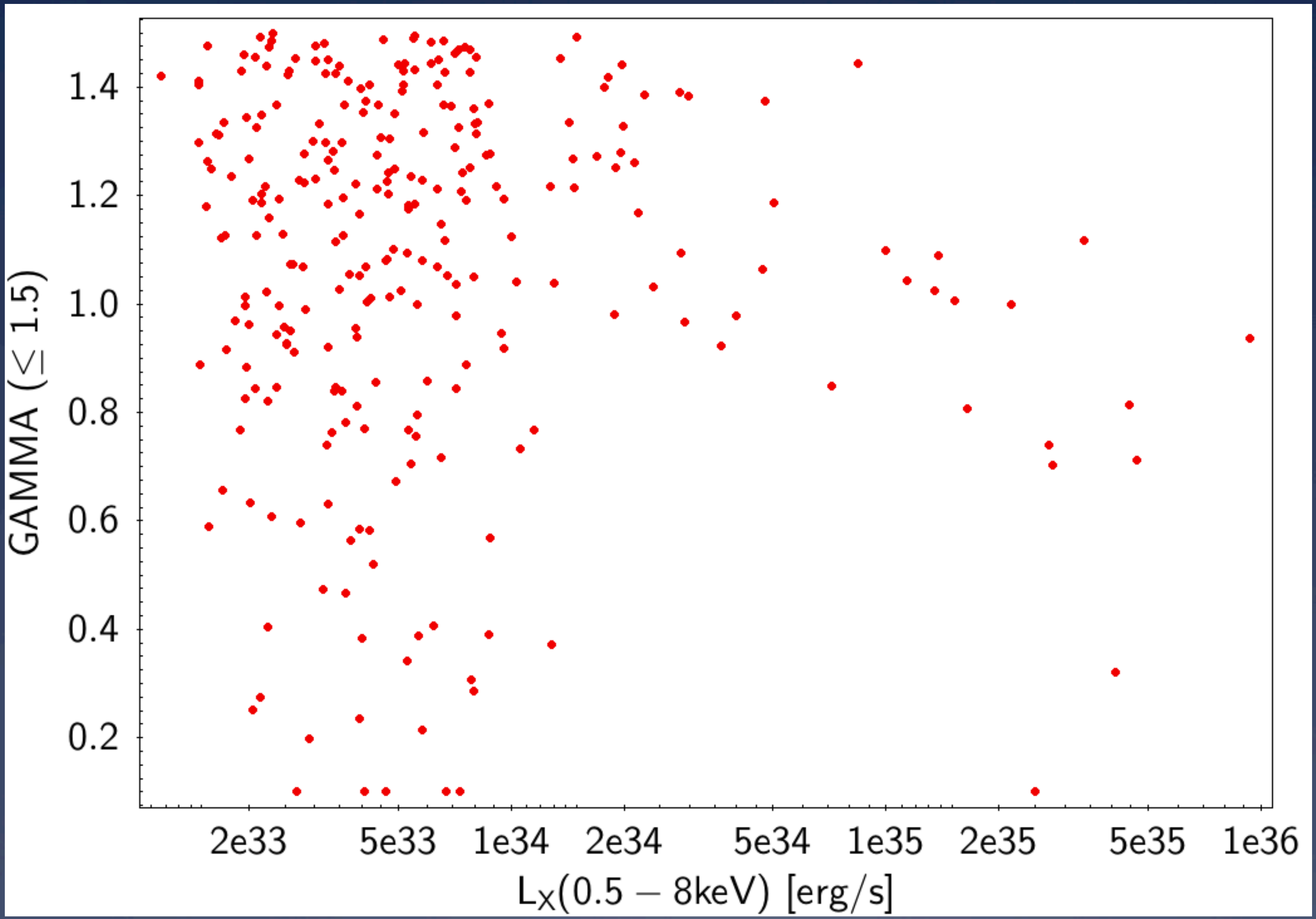
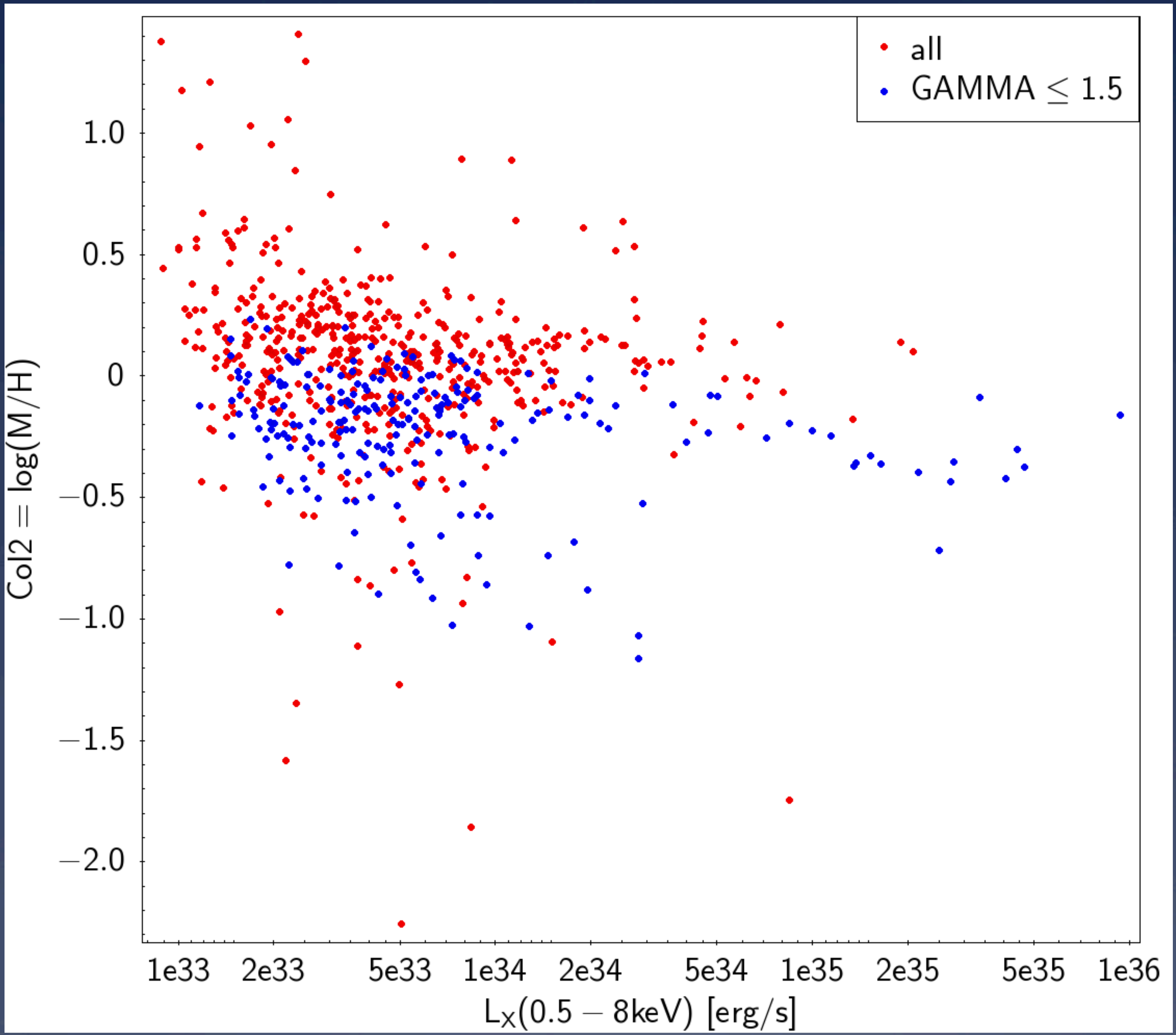
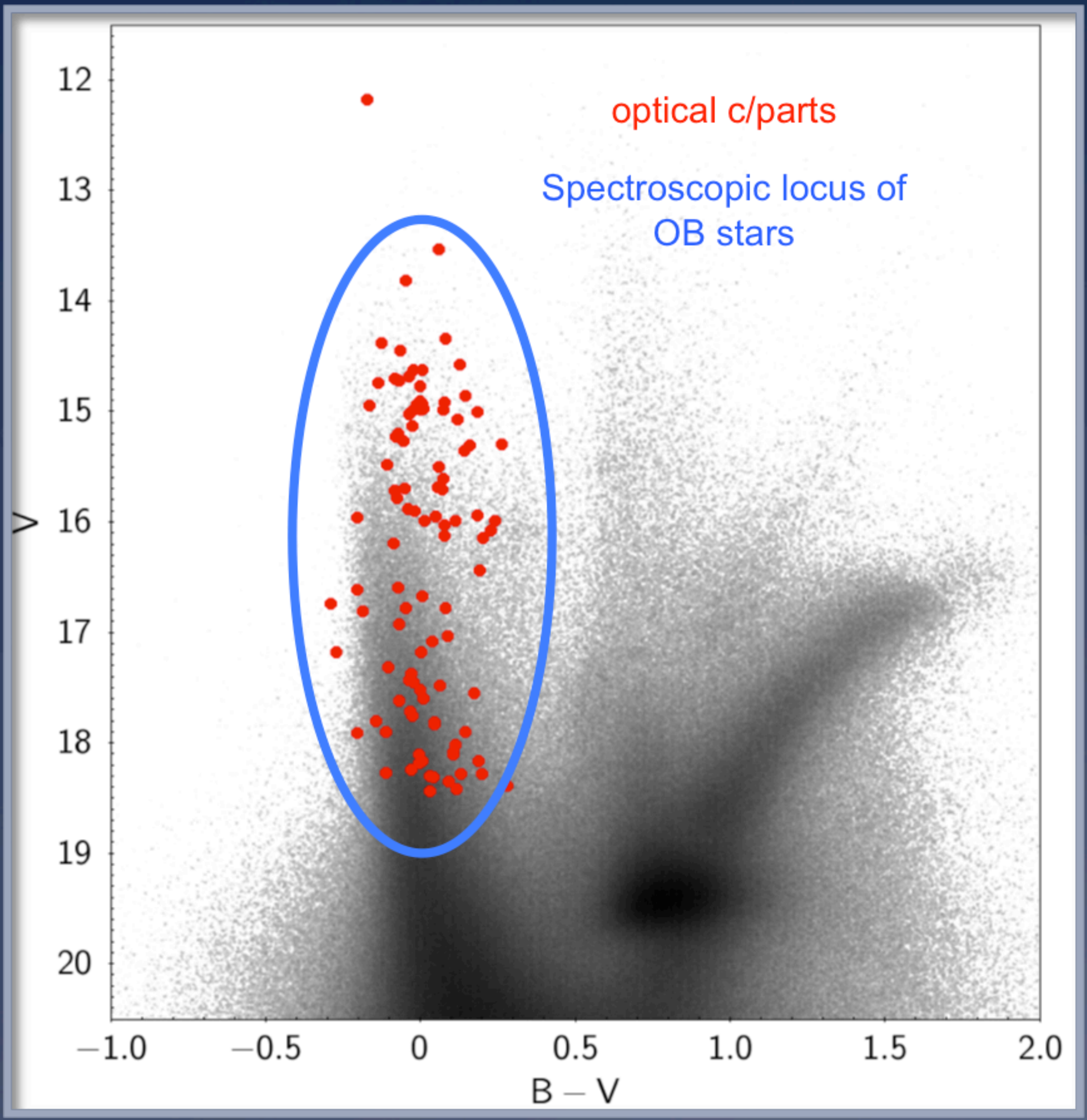


PHOTOMETRIC PROPERTIES



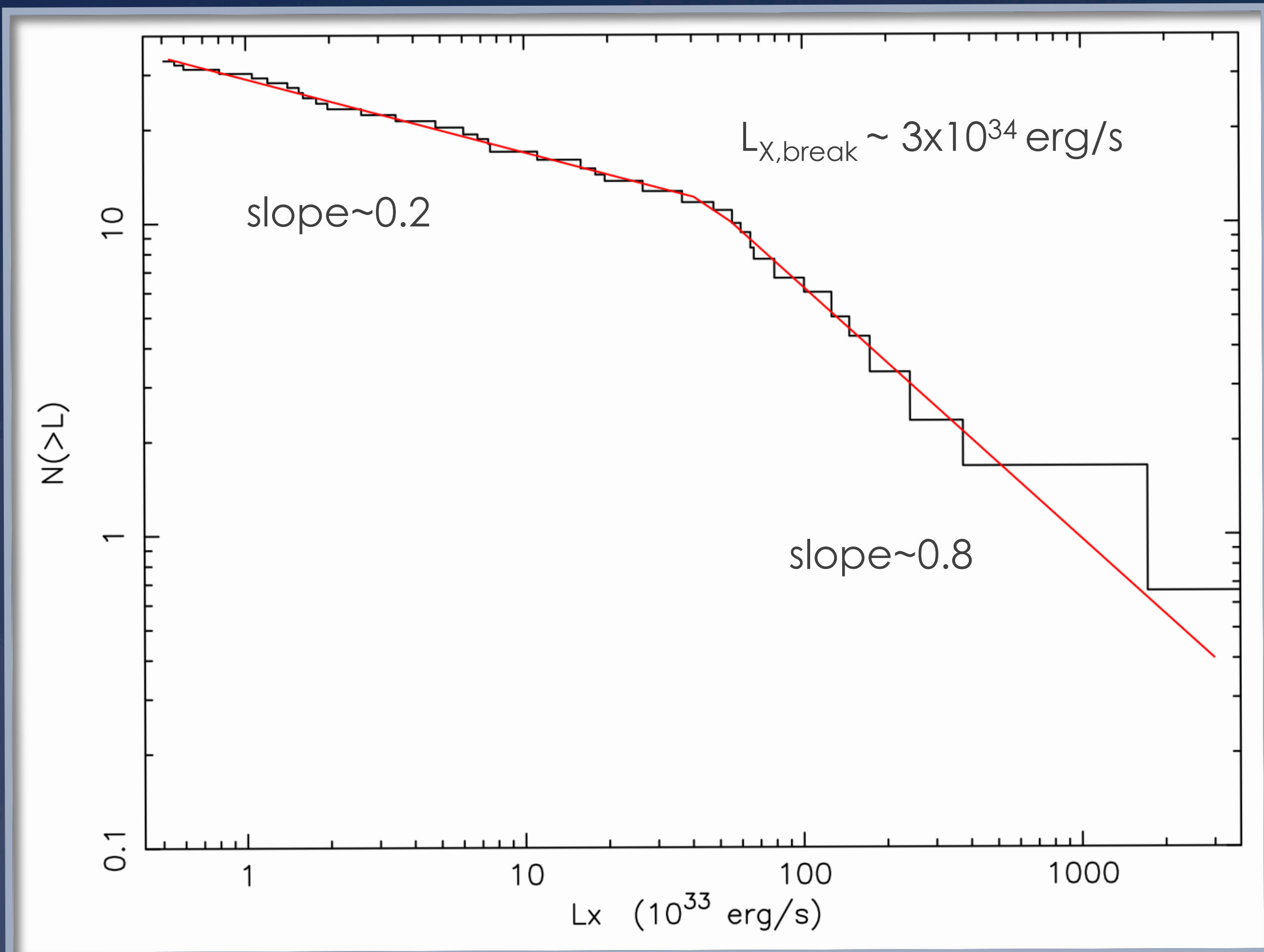
OPTICAL COUNTERPARTS



Using the MCPS optical photometric survey (Zaritsky et al. 2002):

~100 candidate HMXBs down to $L_X \sim 5 \times 10^{32}$ erg/s

HMXBs X-RAY LUMINOSITY FUNCTION



- Flat slope
- Evidence for break

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

- *Deepest XLF ever recorded for a galaxy!*

THE DEEP CHANDRA SURVEY: FIRST RESULTS

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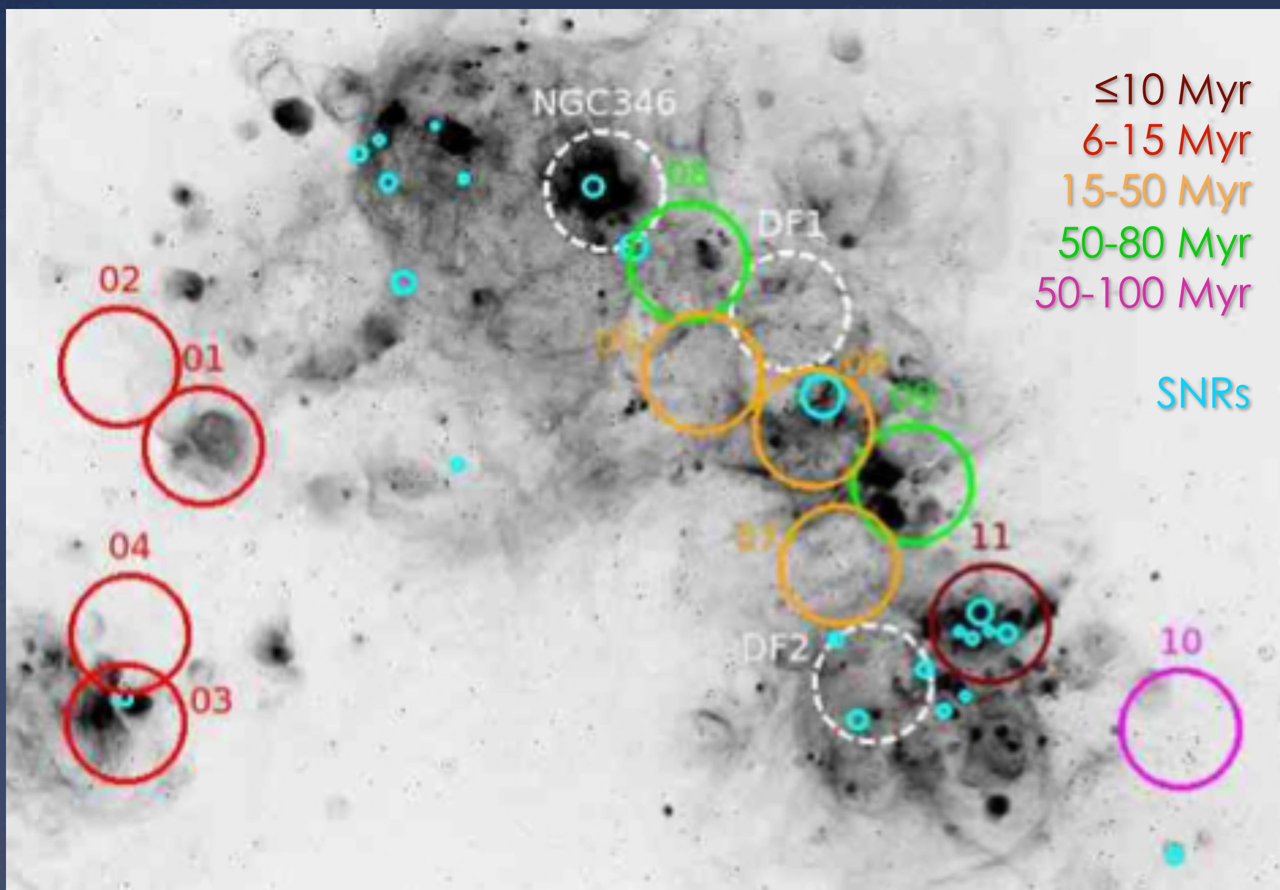

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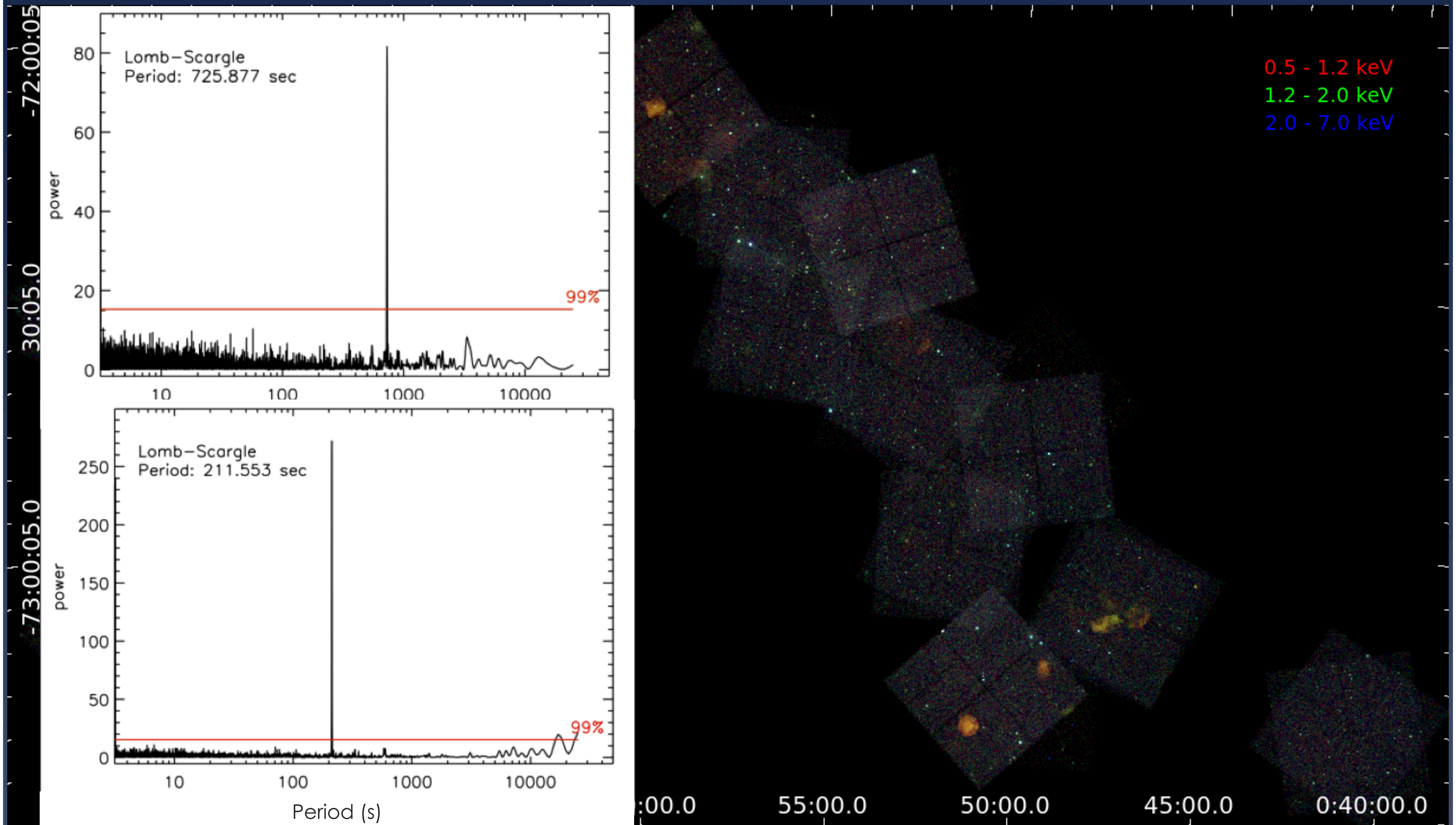
- ~120 srcs per field

$L_{X,limit} \sim 5 \times 10^{32}$ erg/s

- detection of 19 pulsars (+ 5 marginal detections)

THE DEEP CHANDRA SURVEY: FIRST RESULTS



Timing analysis by J. Hong (SAO)

THE DEEP CHANDRA SURVEY: FIRST RESULTS

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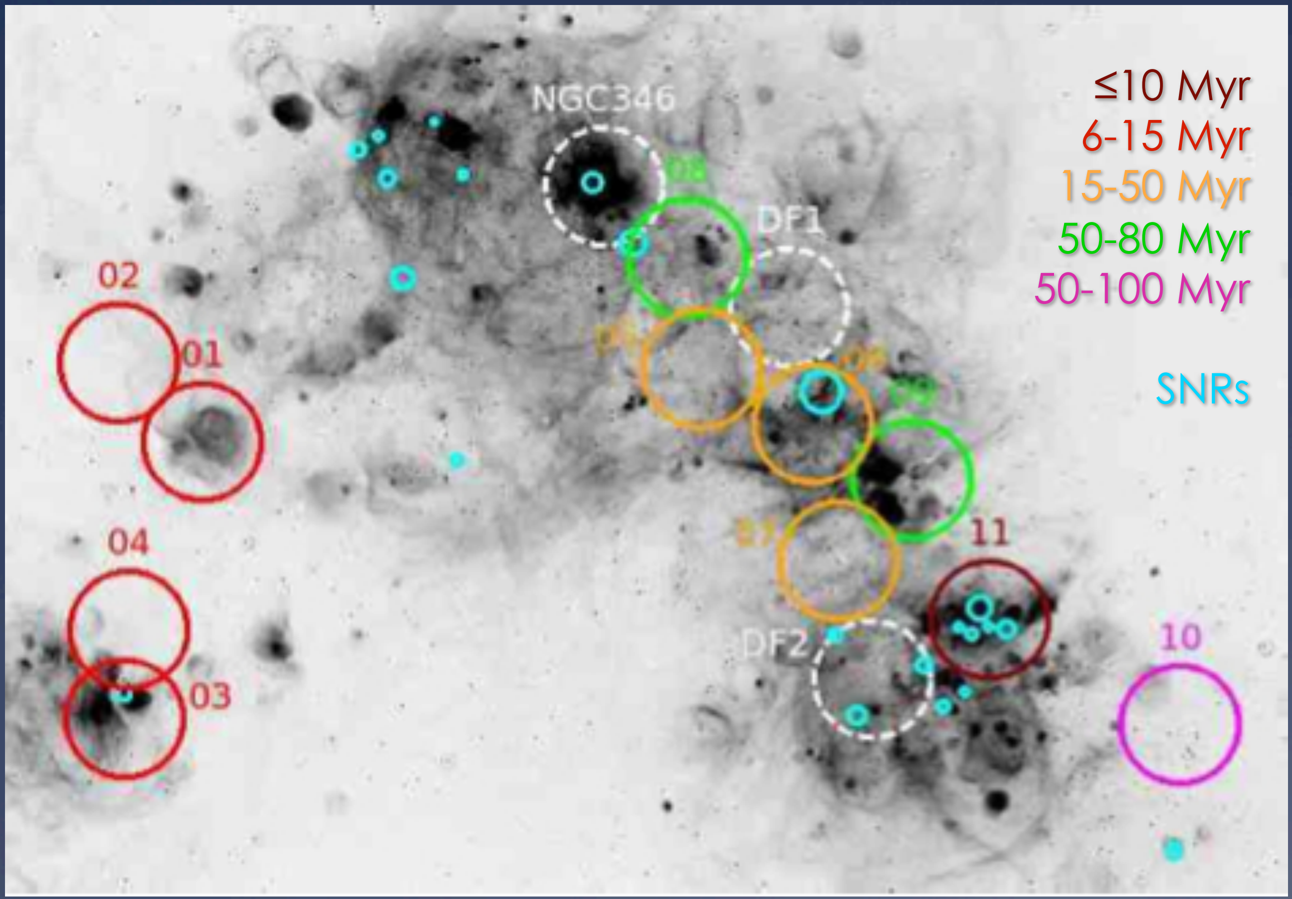


FIRST RESULTS

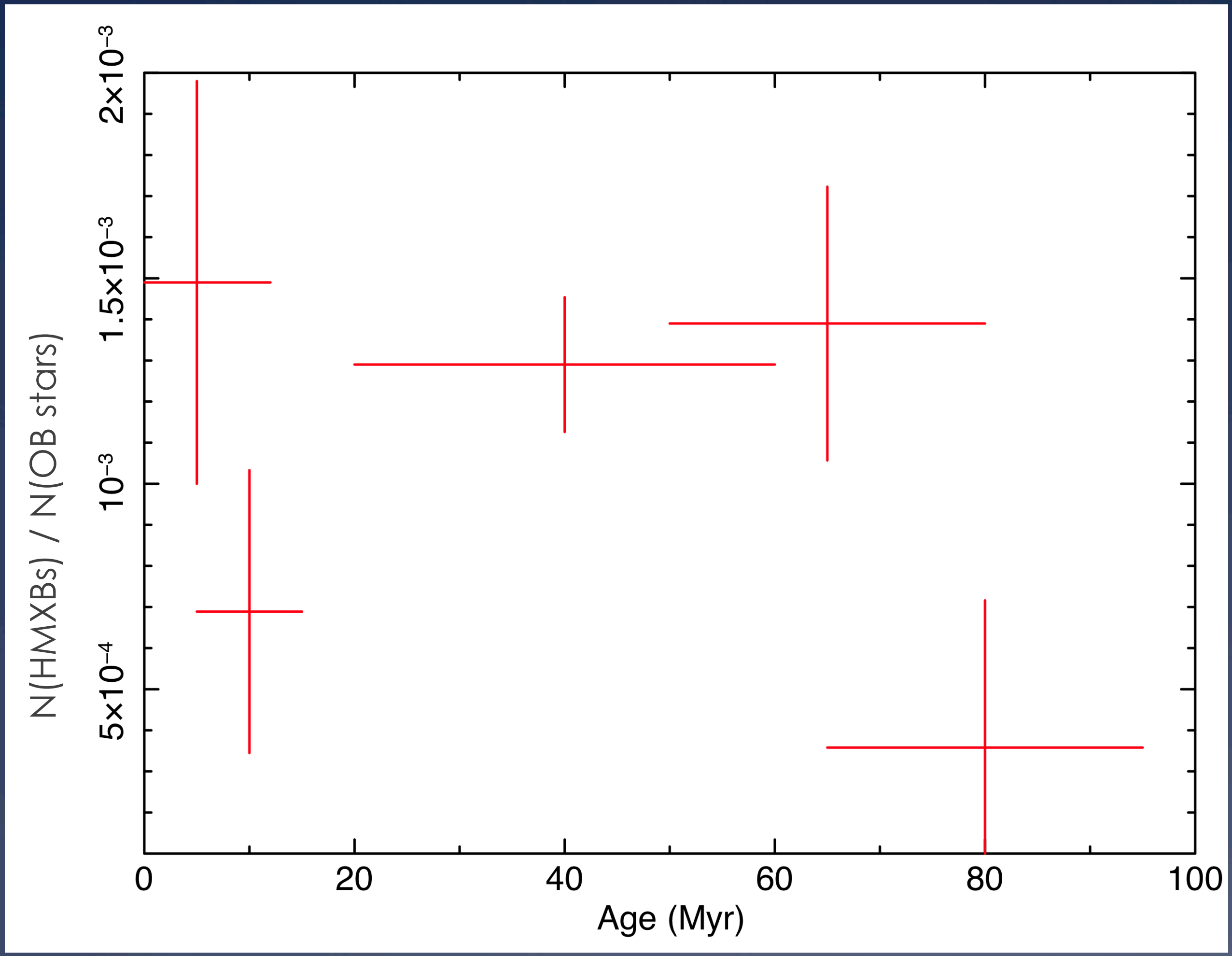
- ~120 srcs per field

$L_{X,limit}$ ~ 5 x 10^{32} erg/s

- detection of 19 pulsars (+ 5 marginal detections)

- HMXB formation efficiency

HMXB FORMATION EFFICIENCY



For the *first* time

as a function of age

Peak at ~ 40 – 60 Myr

THE DEEP CHANDRA SURVEY: FIRST RESULTS

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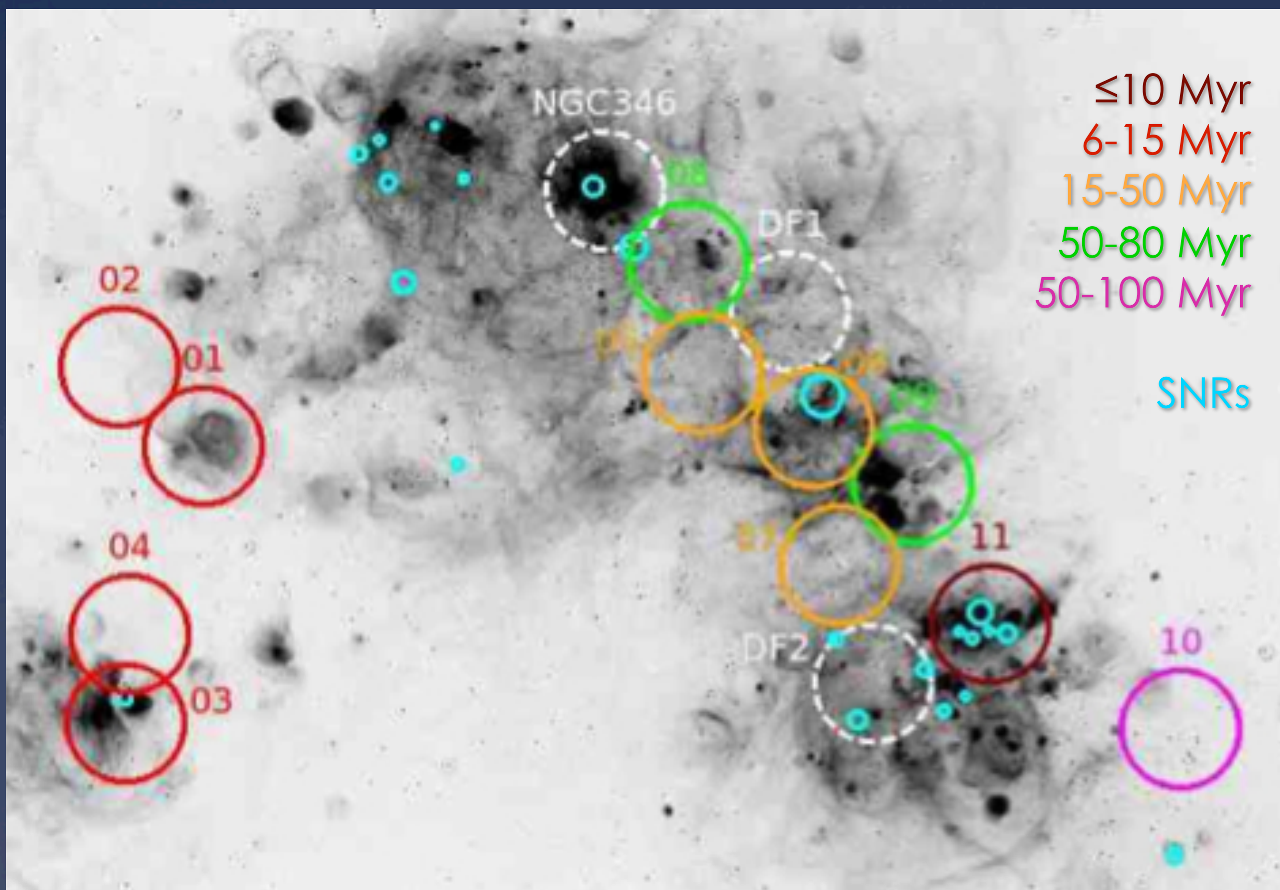


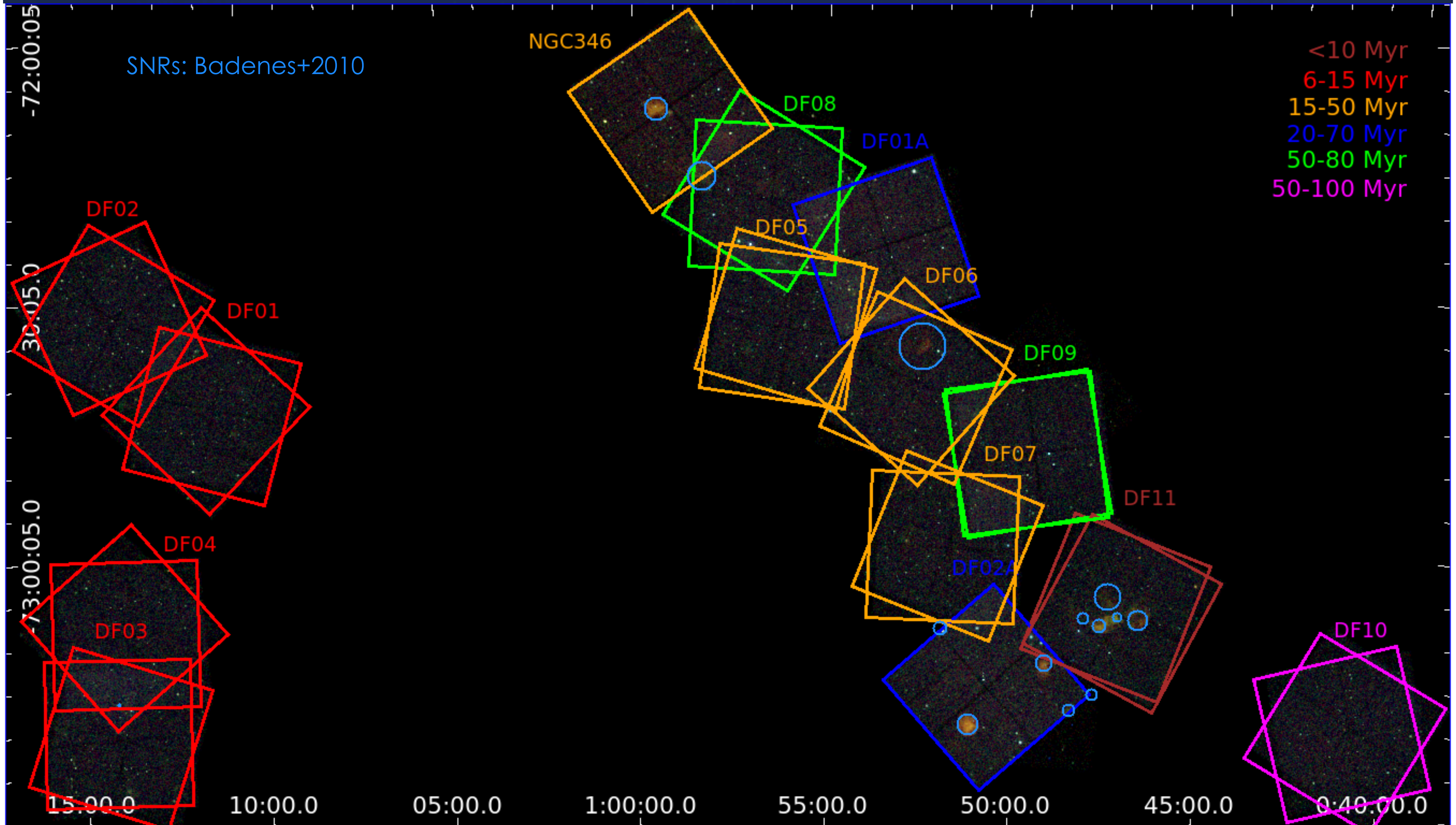
FIRST RESULTS

- ~120 srcs per field

$L_{X,limit}$ ~ 5 x 10^{32} erg/s

- detection of 19 pulsars (+ 5 marginal detections)
- HMXB formation efficiency
- 8 SNRs

THE DEEP CHANDRA SURVEY: AN SNR GALLERY



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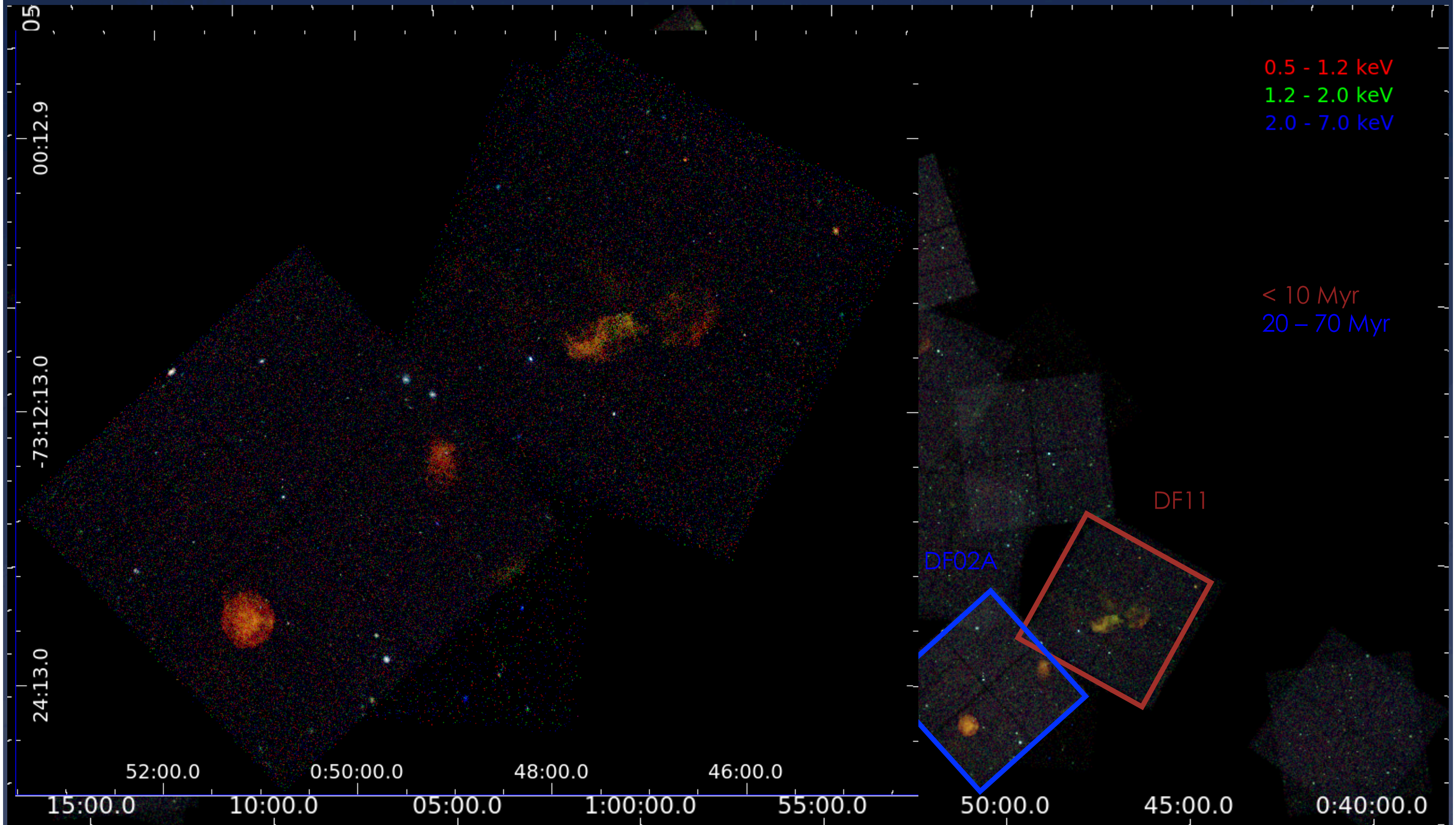


THE DEEP CHANDRA SURVEY: SUMMARY & FUTURE PLANS

Very promising first results

✓ Measure XLF down to Lx ~ 5 x 10^{32} erg/s

✓ Evidence for changes in formation efficiency of HMXBs with age

What's next?

✧ Follow-up spectroscopically the identified optical counterparts (ESO time / VIMOS multi-slit spectrograph @ UT3 telescope) → Characterize the sources

✧ Investigate differences in XLFs as a function of age

✧ Extend this work to other galaxies

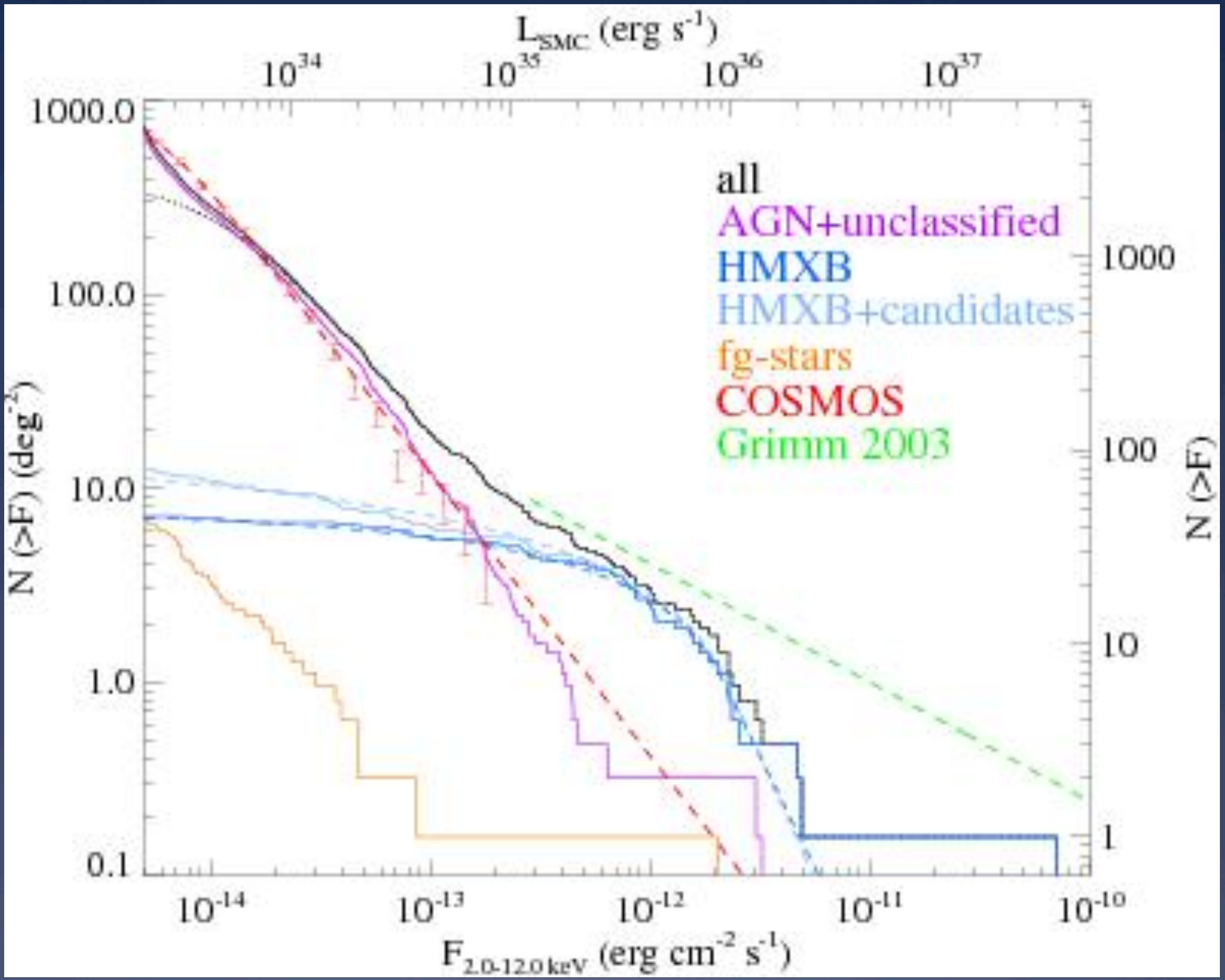
AGN CONTAMINATION

14 Chandra fields ~ 1 deg^2

~ 1000 AGN/deg^2 down to L_X ~ 10^{33} erg/s

🡇

~ 300 – 500 sources related with the SMC



Sturm et al. (2013, A&A, 558, 3)