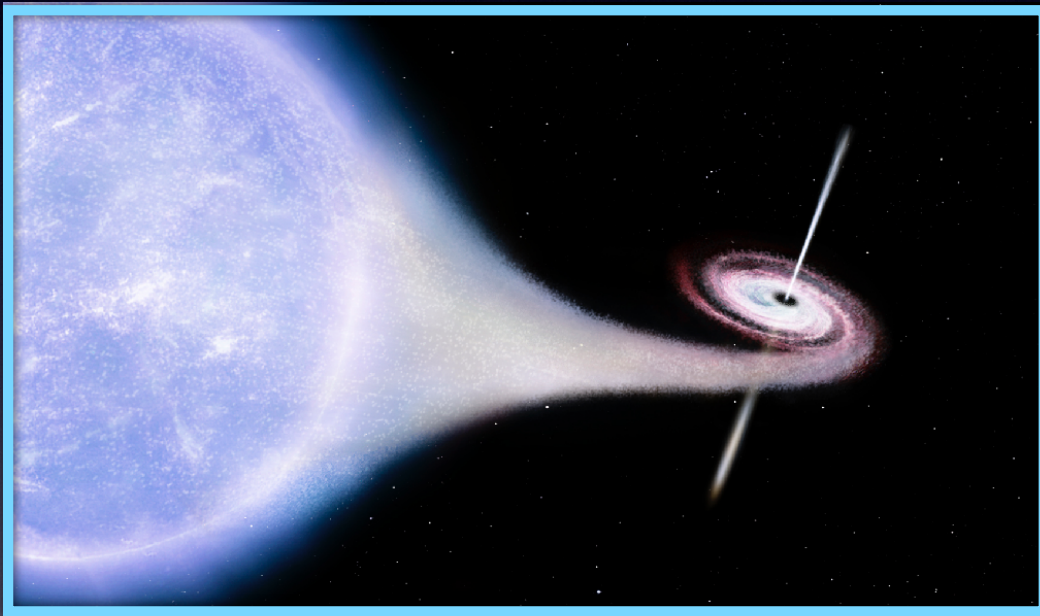


The HMXB z - z connection

Connecting the metallicity dependence
and redshift evolution of HMXBs



Francesca Fornasini

CENTER FOR **ASTROPHYSICS**

HARVARD & SMITHSONIAN

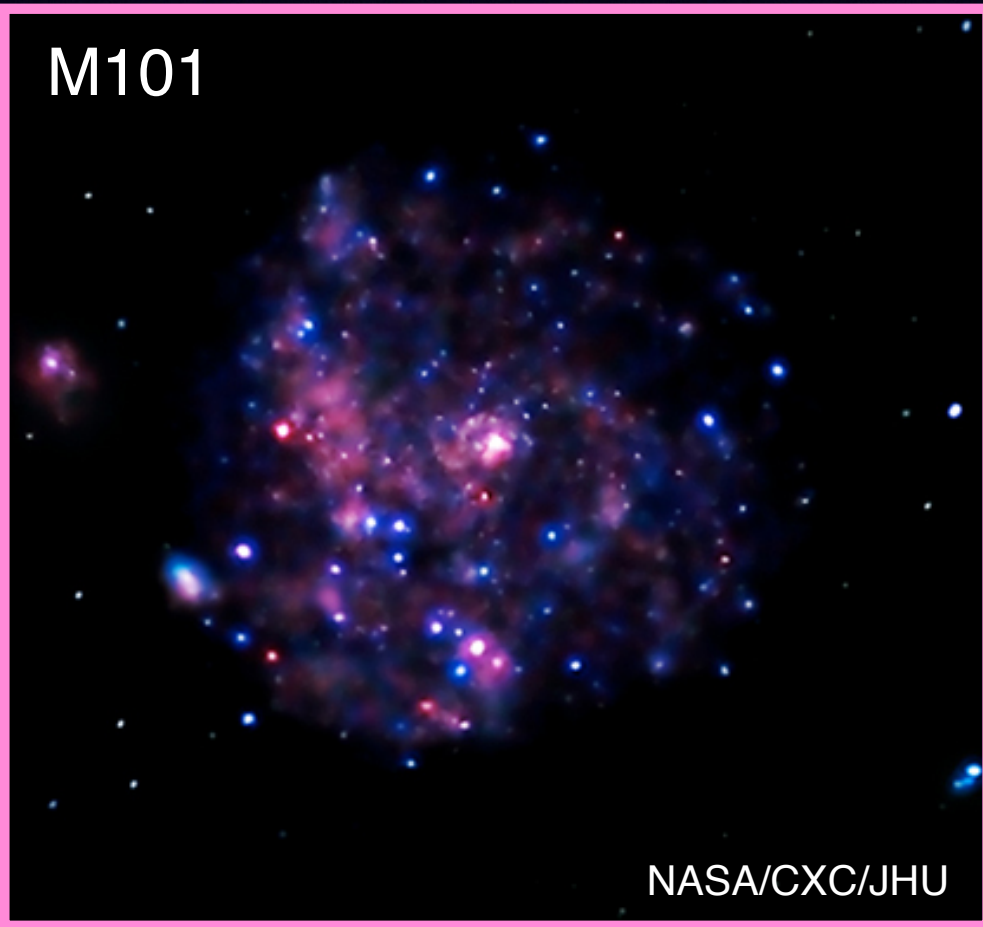
with F. Civano, M. Kriek, R. Sanders, I. Shivaeei,
H. Suh, and the MOSDEF survey team

Local L_{HMXB} -SFR correlation

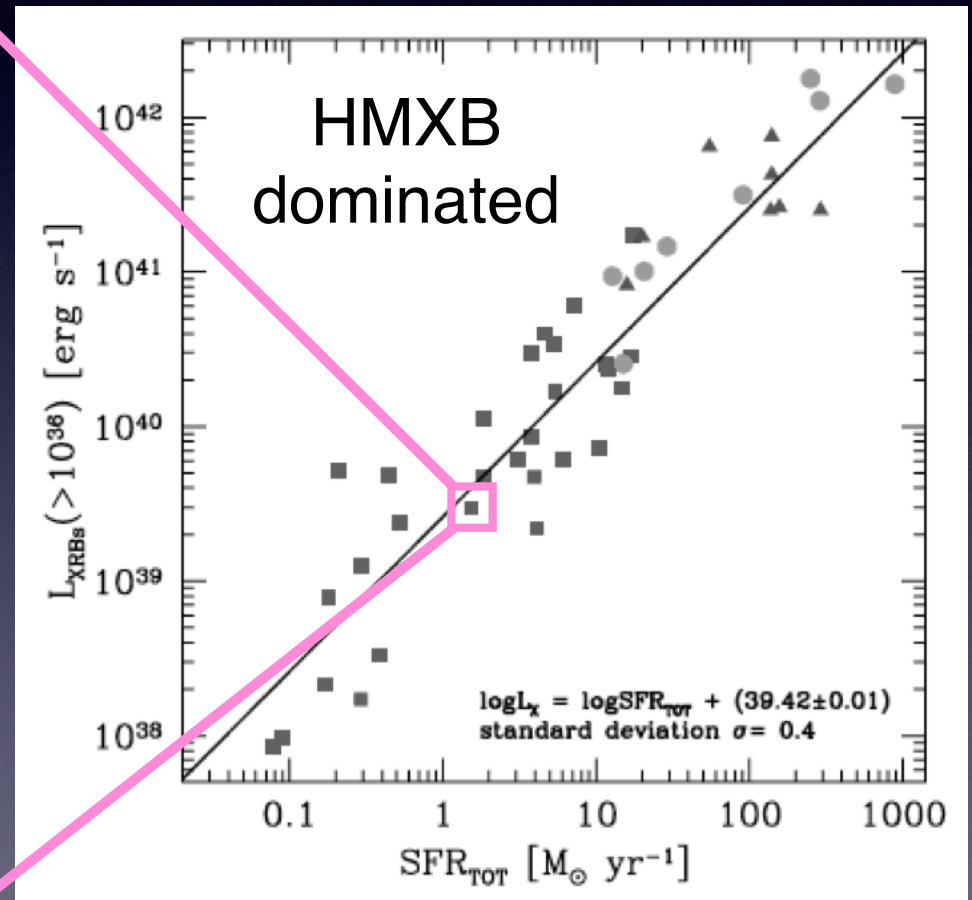
Star-forming (high sSFR) galaxies

$$\text{sSFR} = \text{SFR} / M_{\star}$$

M101



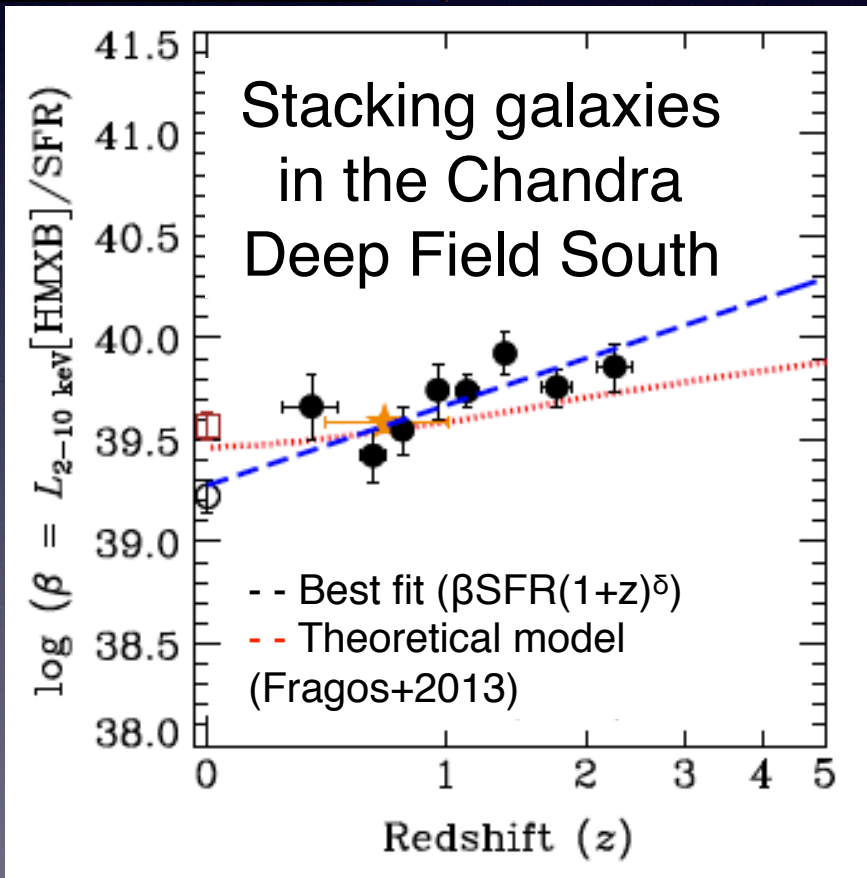
NASA/CXC/JHU



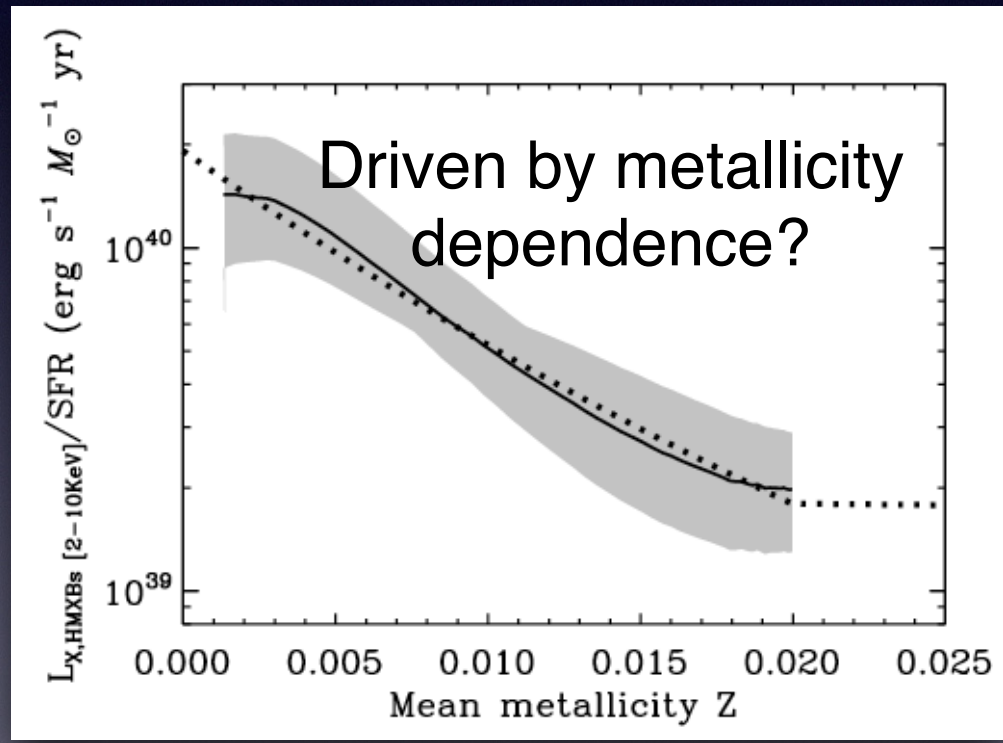
Mineo+2012



The little z: $L_{\text{HMXB}}/\text{SFR}$ evolves with redshift



Lehmer+2016



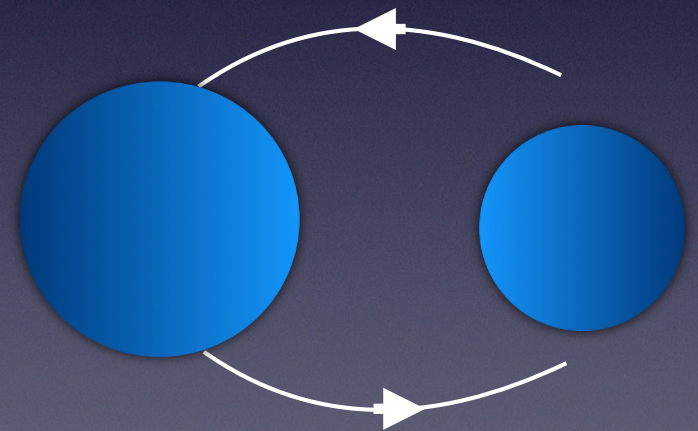
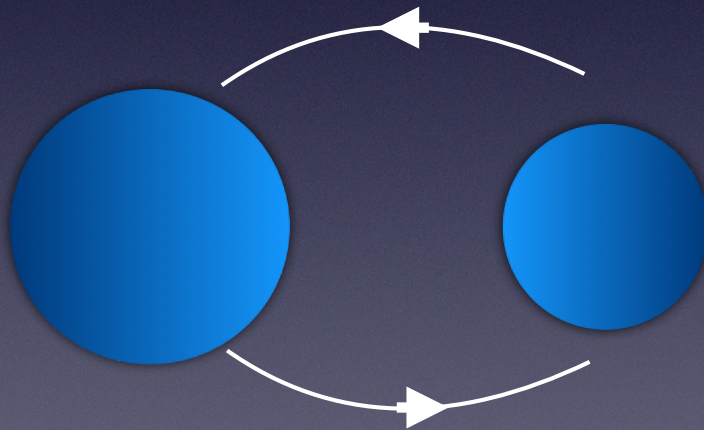
Fragos+2013



The big Z : The effect of metallicity on HMXB evolution

High- Z

Low- Z

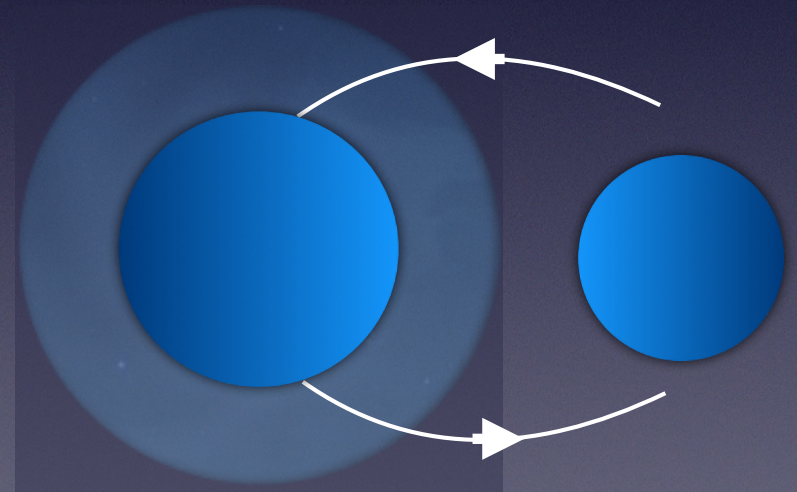
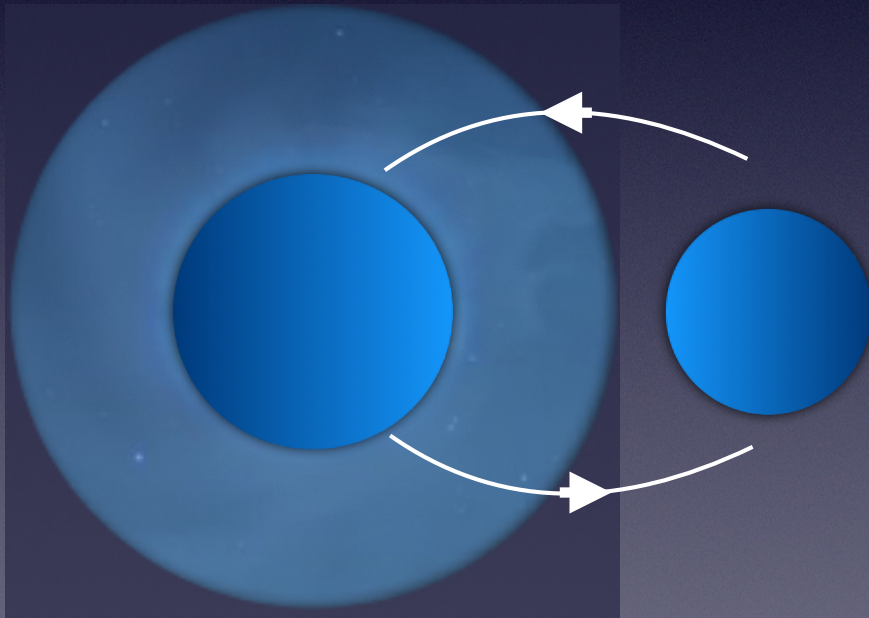




The big Z : The effect of metallicity on HMXB evolution

High- Z

Low- Z

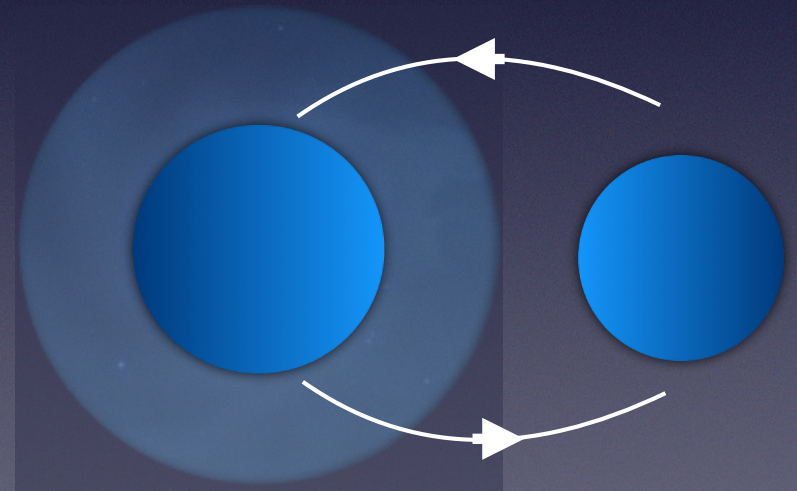
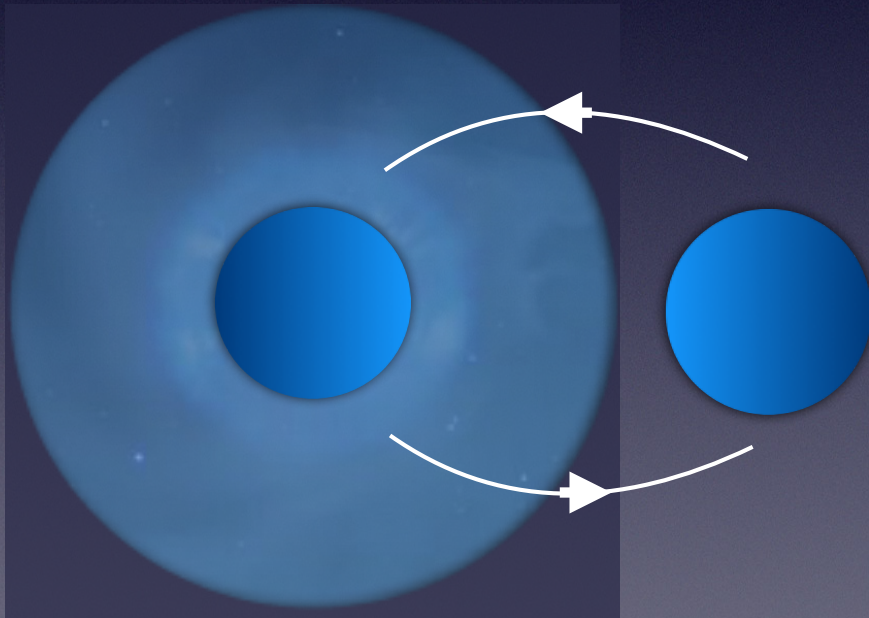




The big Z : The effect of metallicity on HMXB evolution

High- Z

Low- Z

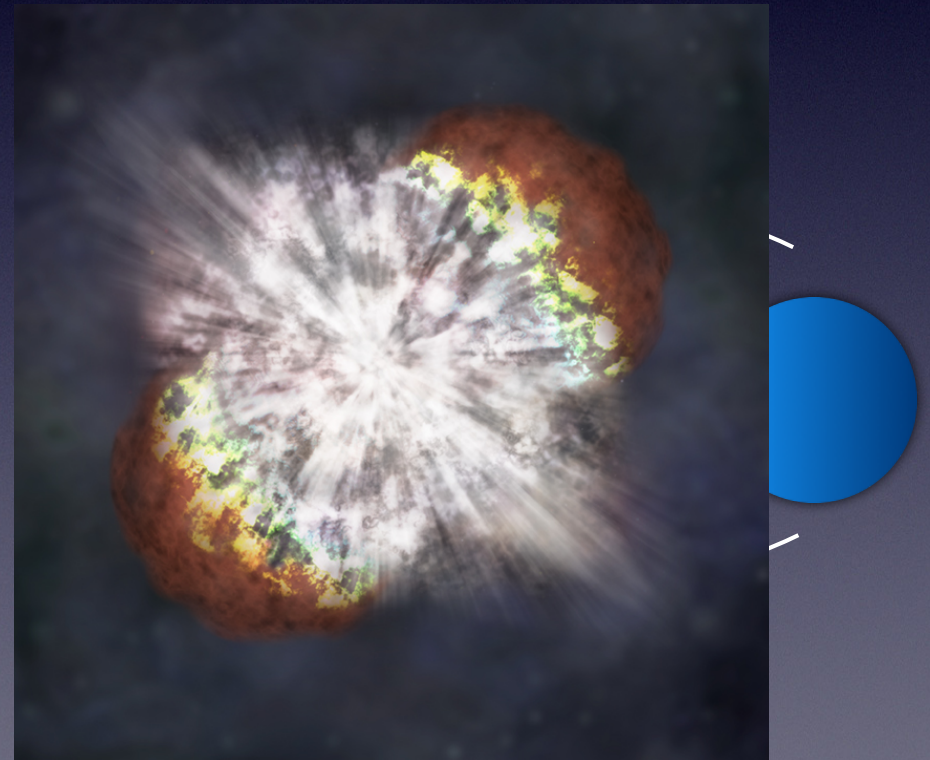
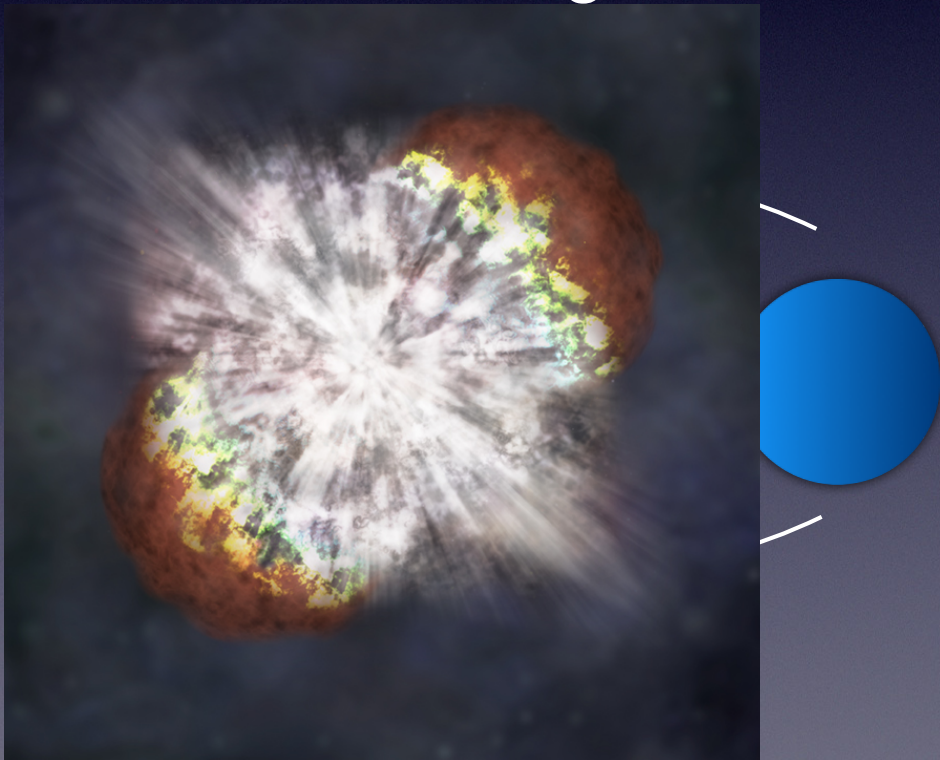




The big Z : The effect of metallicity on HMXB evolution

High- Z

Low- Z

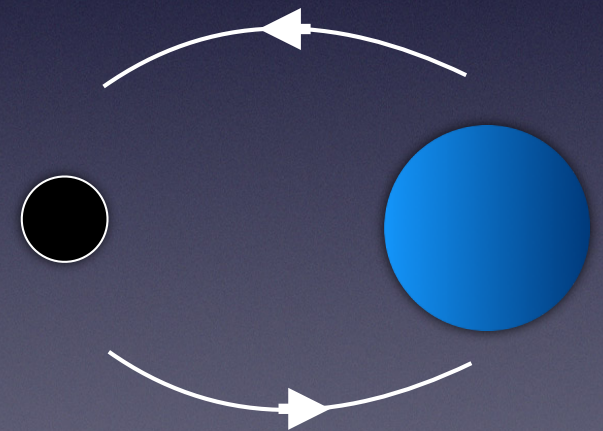
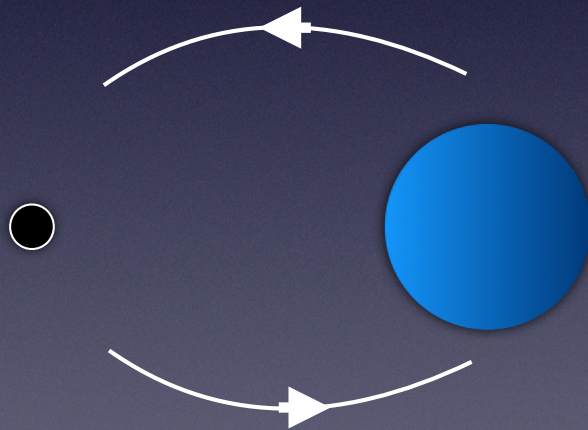




The big Z : The effect of metallicity on HMXB evolution

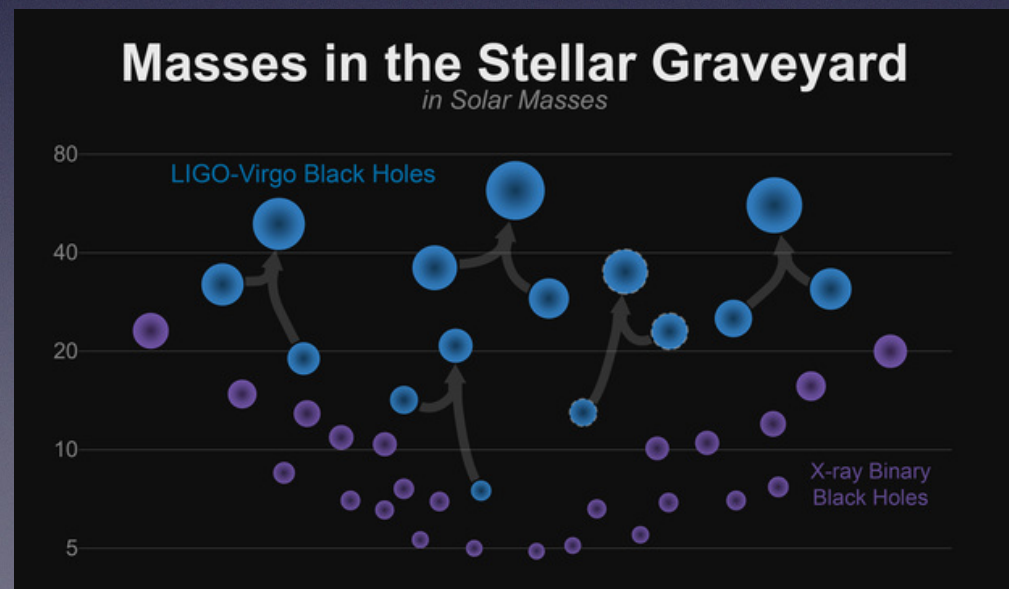
High- Z

Low- Z



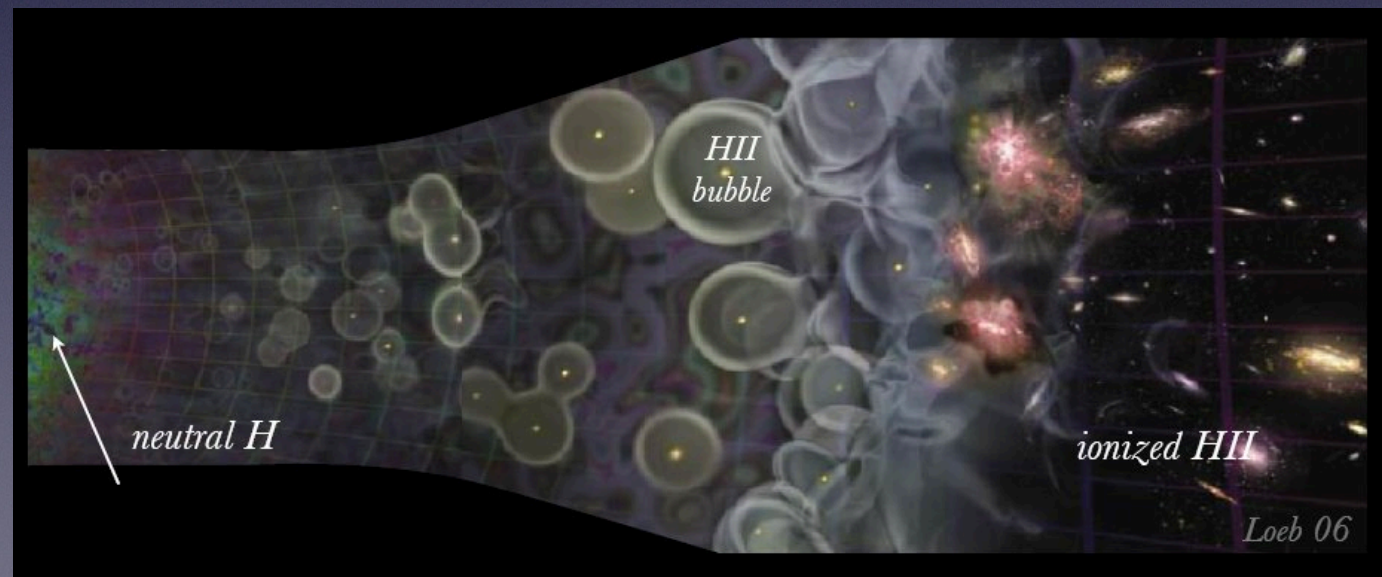
Implications of Z -dependence

- In addition to providing insight into models of stellar evolution, HMXB Z -dependence can also constrain:
 - progenitor pathways of GW sources
 - contribution of HMXBs to the heating/reionization of IGM
 - contamination of HMXBs to low- L_x AGN searches in dwarfs



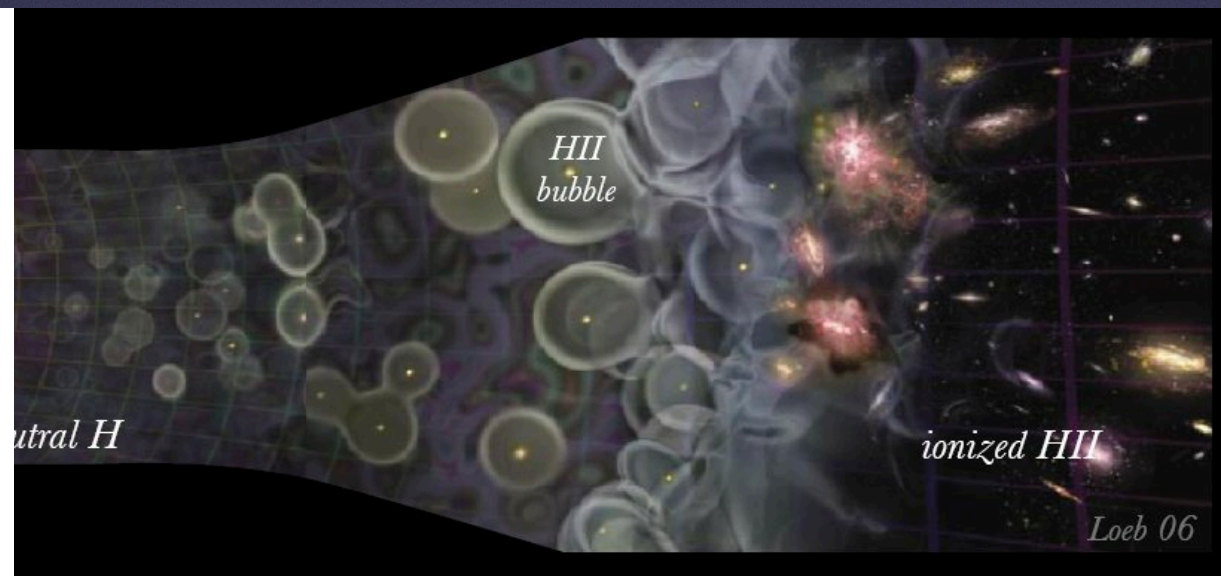
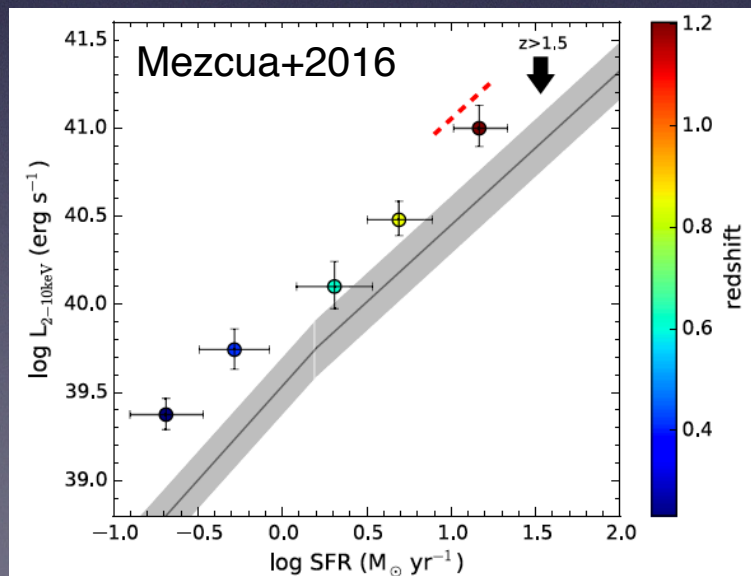
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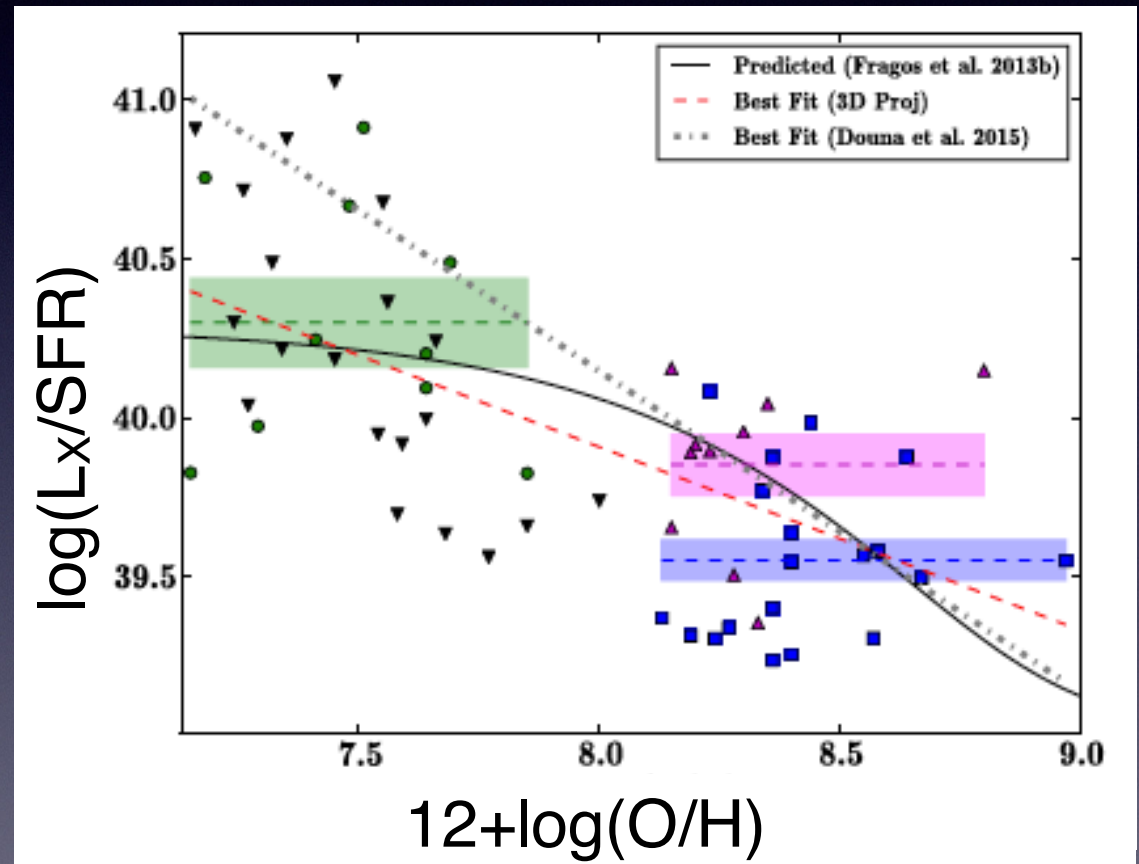
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Evidence of Z -dependence

- Local galaxies exhibit L_X -SFR- Z correlation, but samples may be biased
- Redshift evolution of HMXB relation could be effect of Z -dependence or driven by other factors

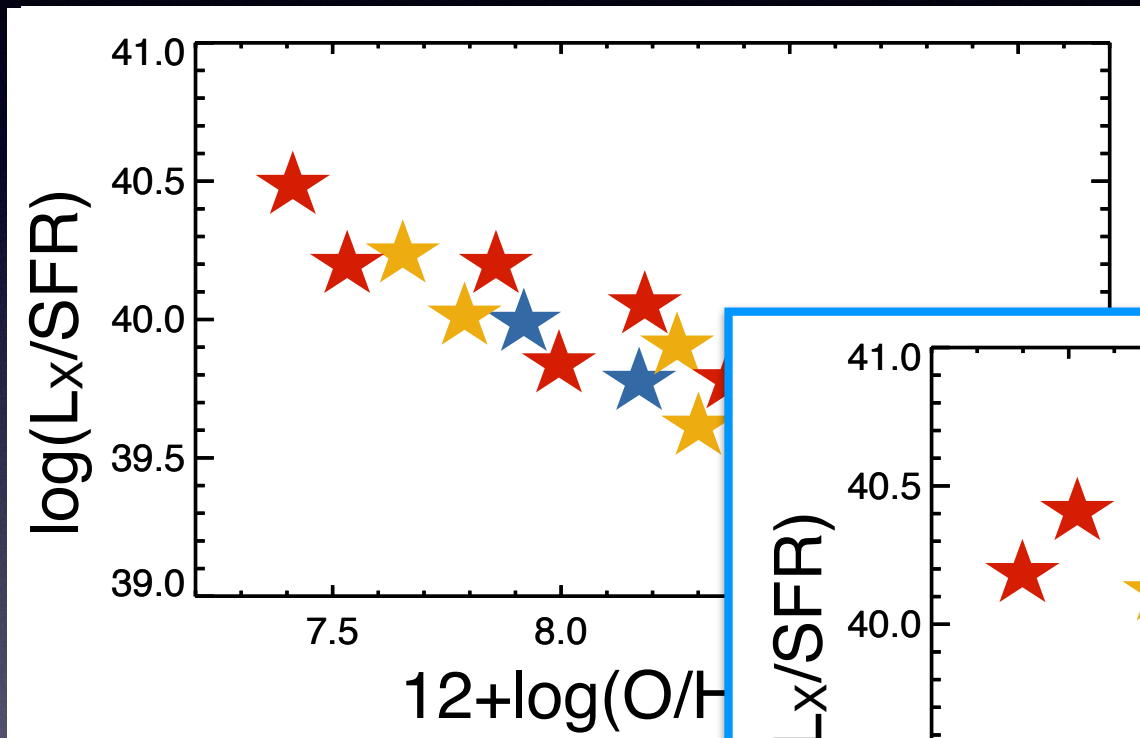


Brorby+2016

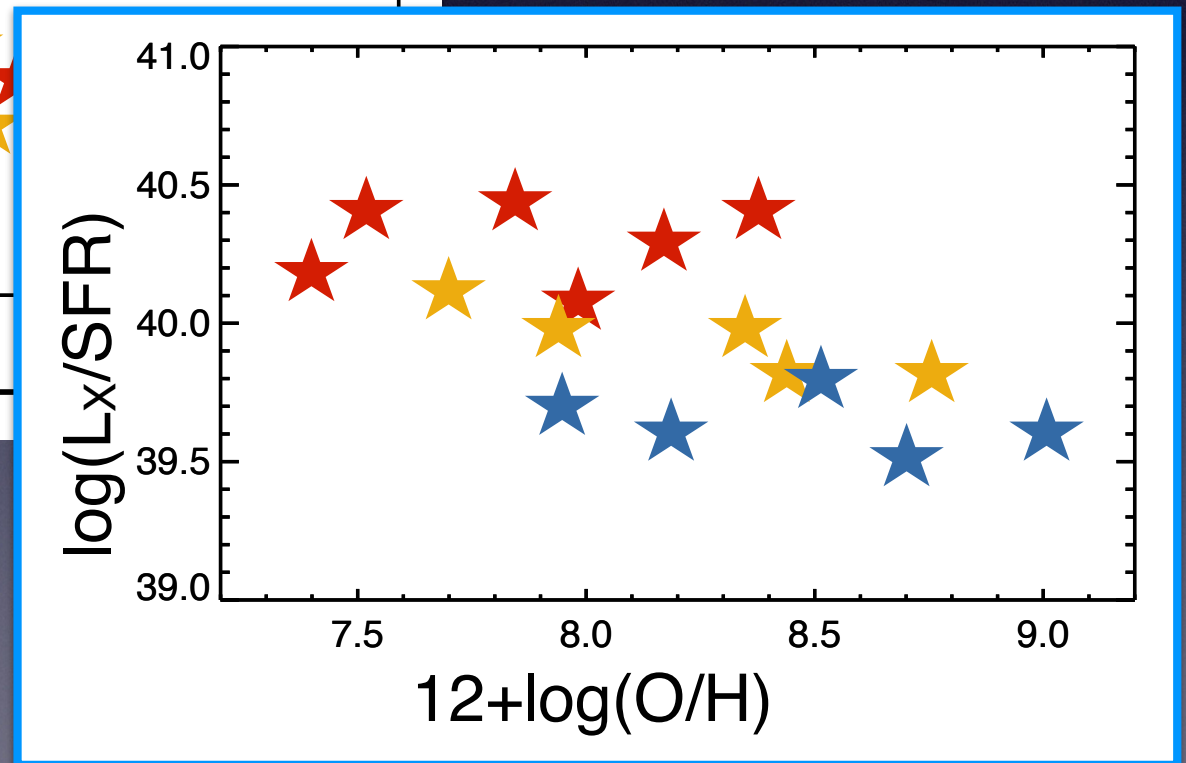
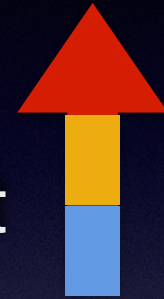
Z proxy for HMXBs

Chandra XX

Is redshift evolution of HMXBs driven by metallicity?

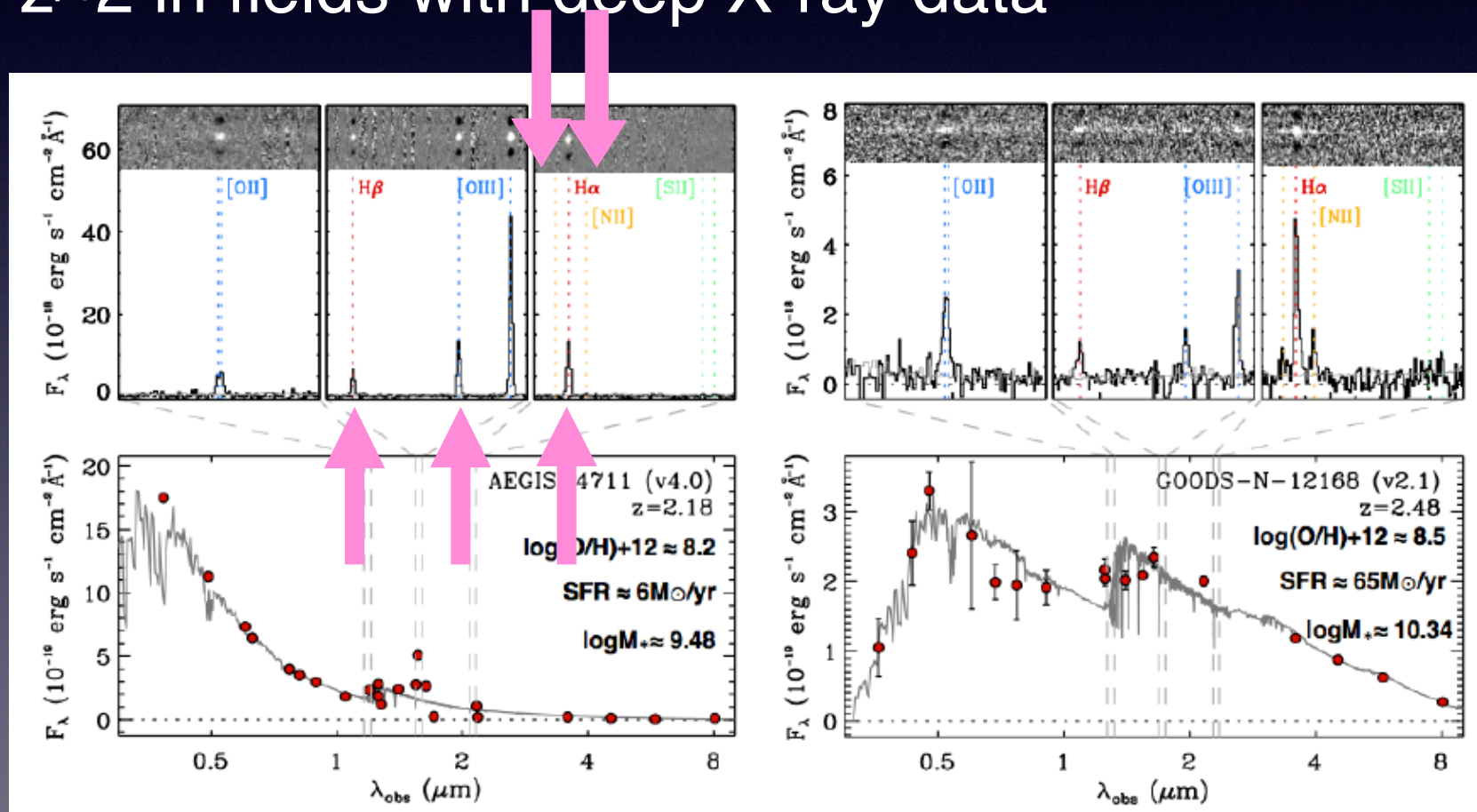


redshift



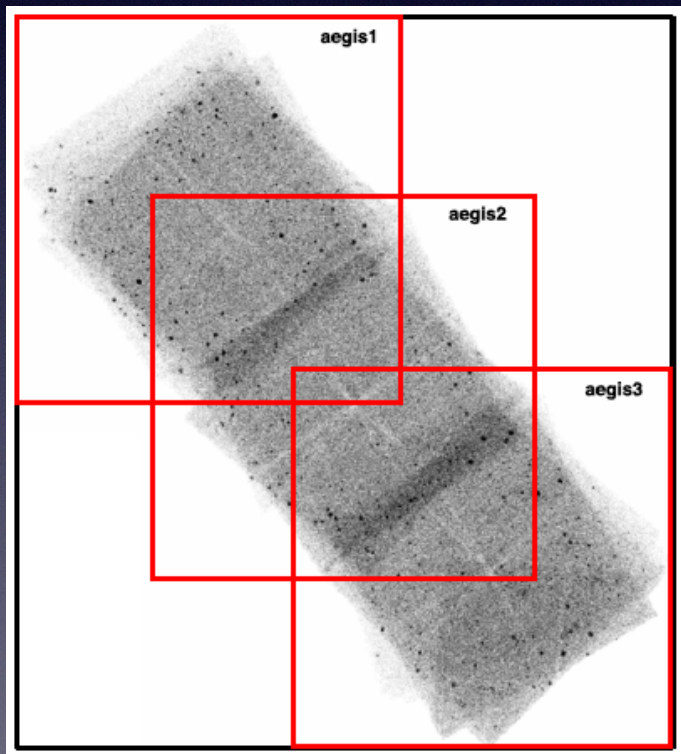
The MOSDEF Survey

- Rest-frame optical spectra for ~ 1500 galaxies at $z \sim 2$ in fields with deep X-ray data



Chandra extragalactic surveys

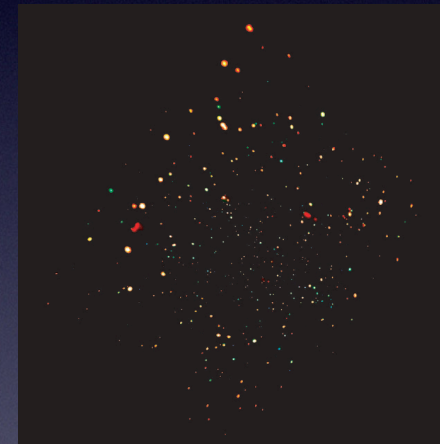
AEGIS-X
800 ks exposure



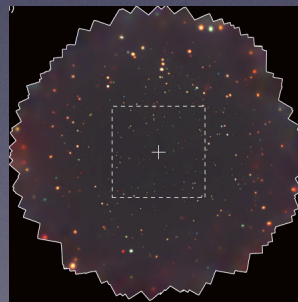
Nandra+2015



Deep Field North
2 Ms exposure



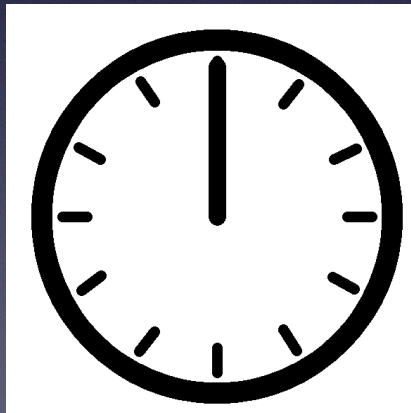
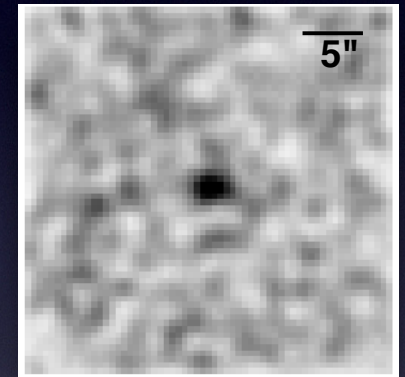
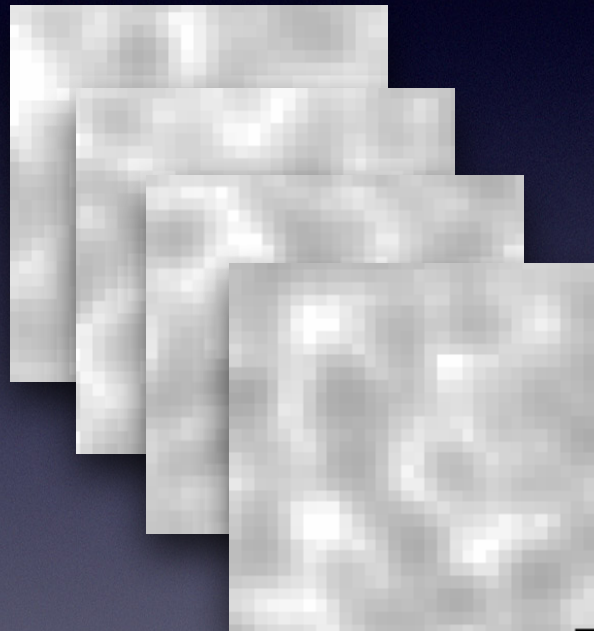
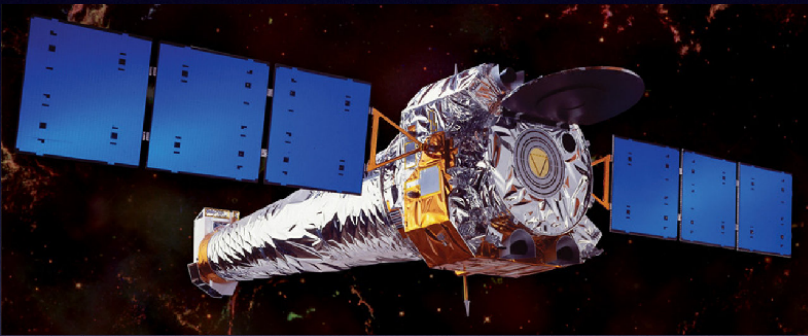
Alexander+2003



Luo+2017

Deep Field South
7 Ms (80 day) exposure

Going deeper with existing data

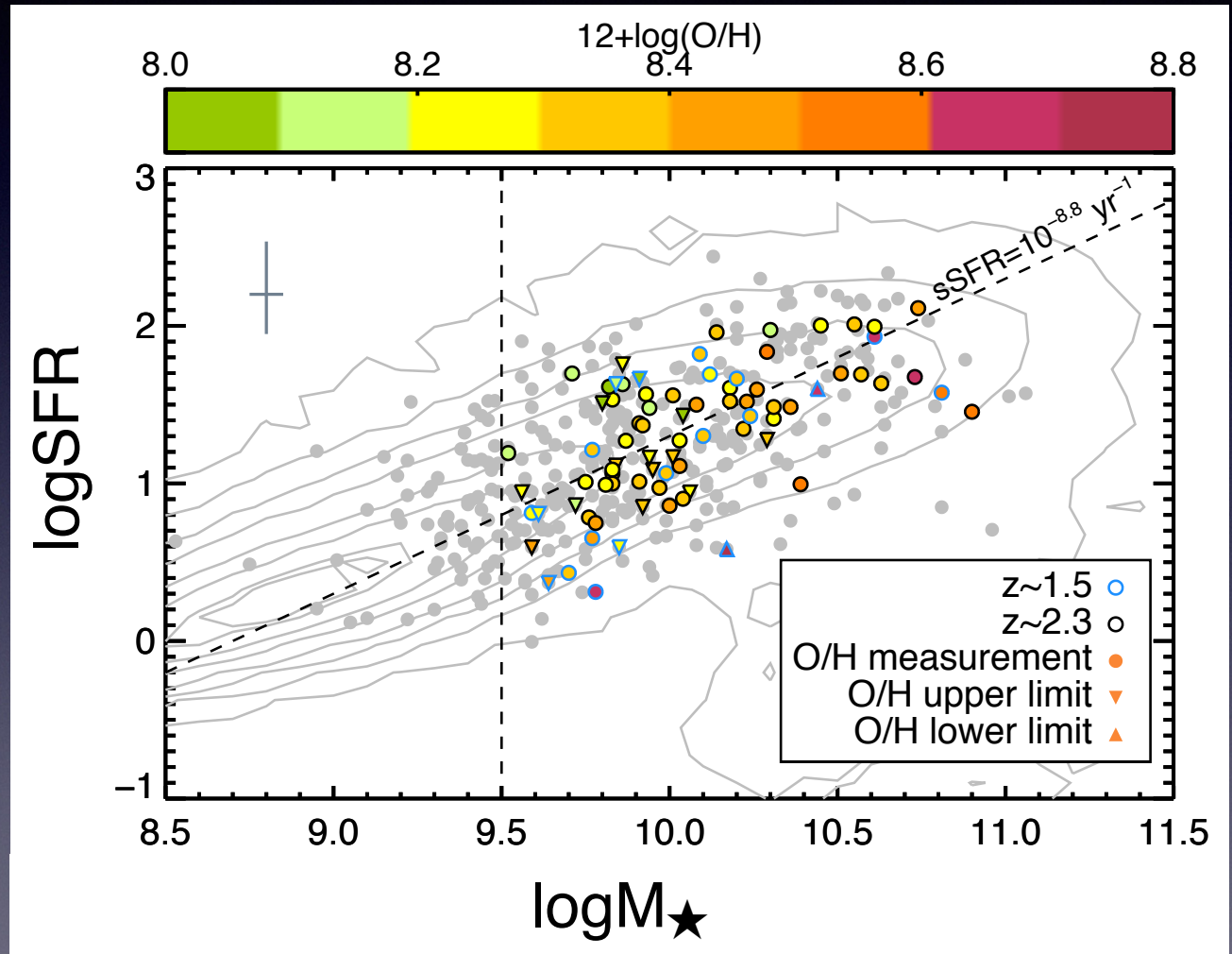


Individual
detections of
small number
of objects

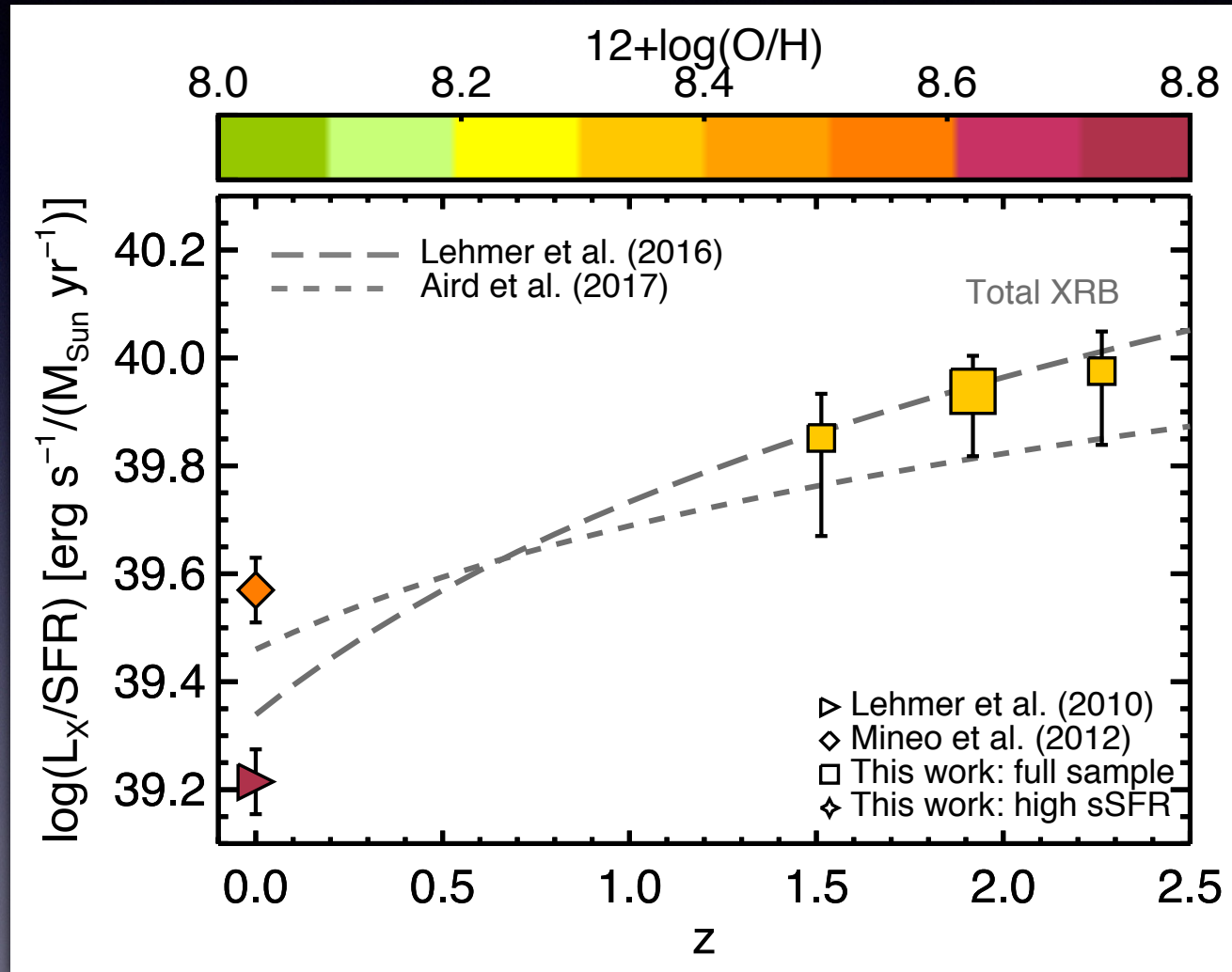
Average X-ray
properties for
large sample
of objects

The MOSDEF sample

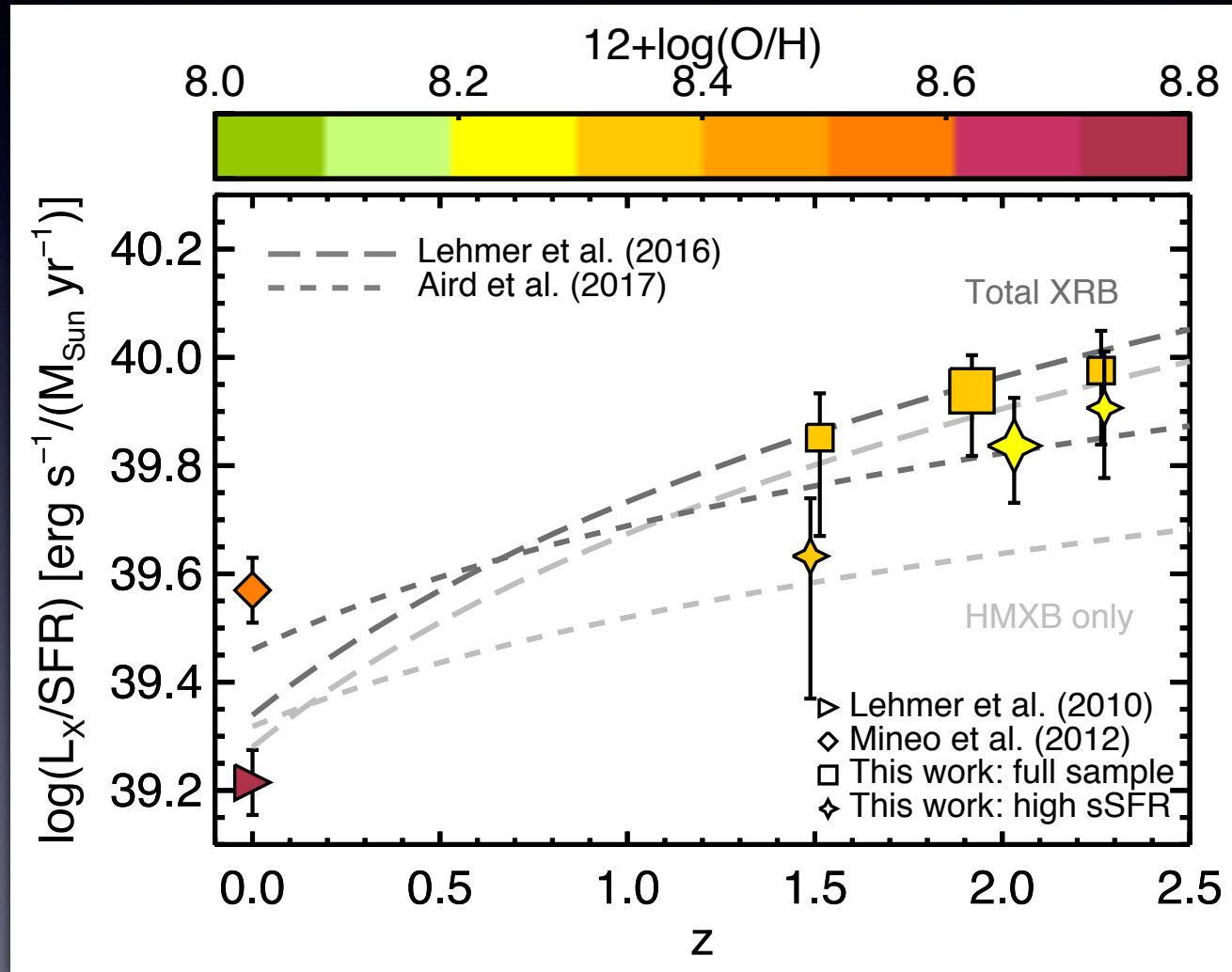
- O3N2 z indicator
- H α SFR
- Exclude X-ray, IR, and optical AGN
- *Chandra* PSF $< 3.5''$
- 79 galaxies
- Stacked exposures: 20-50 Ms (200-600 days!)



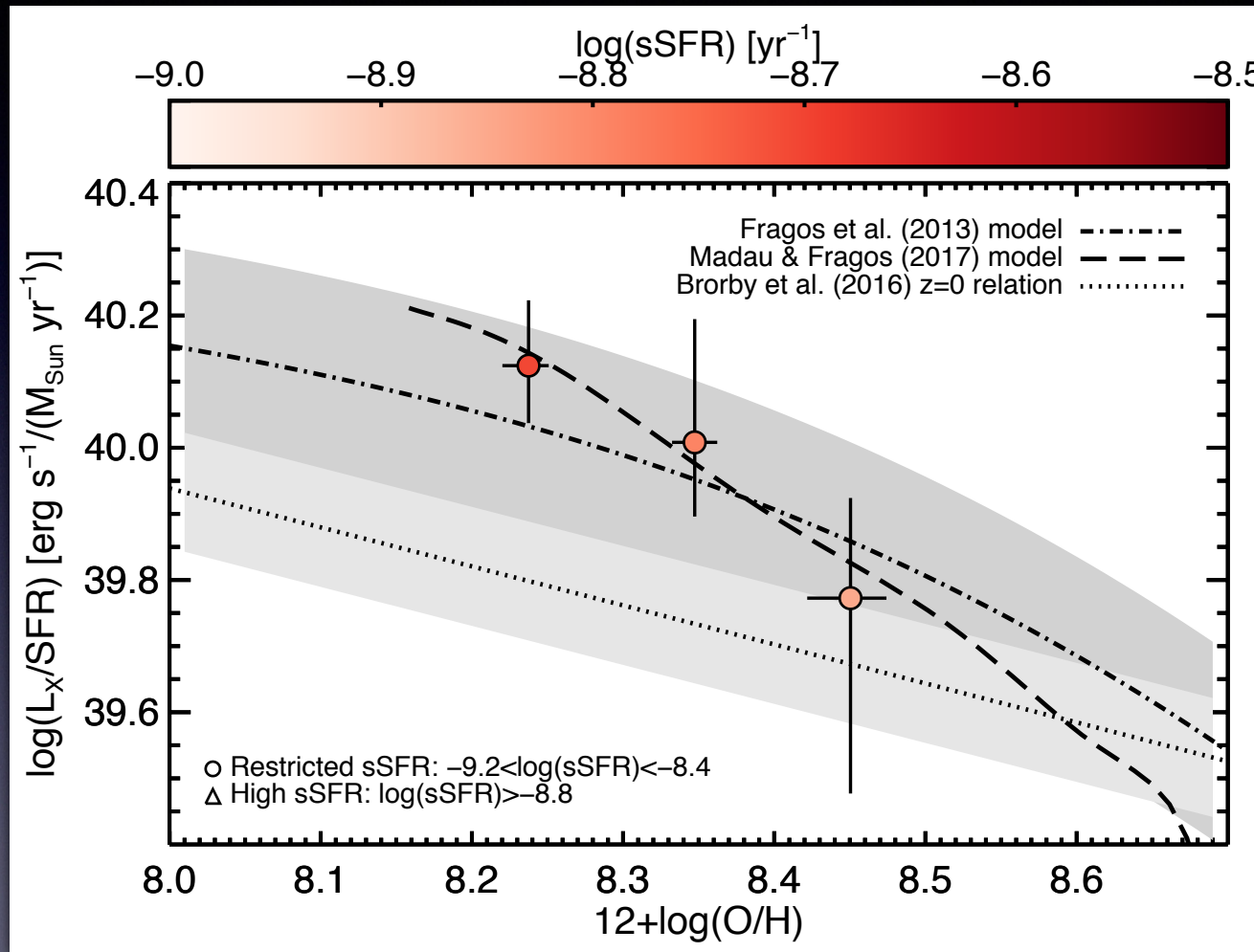
Redshift evolution consistent with previous studies



Redshift evolution consistent with previous studies

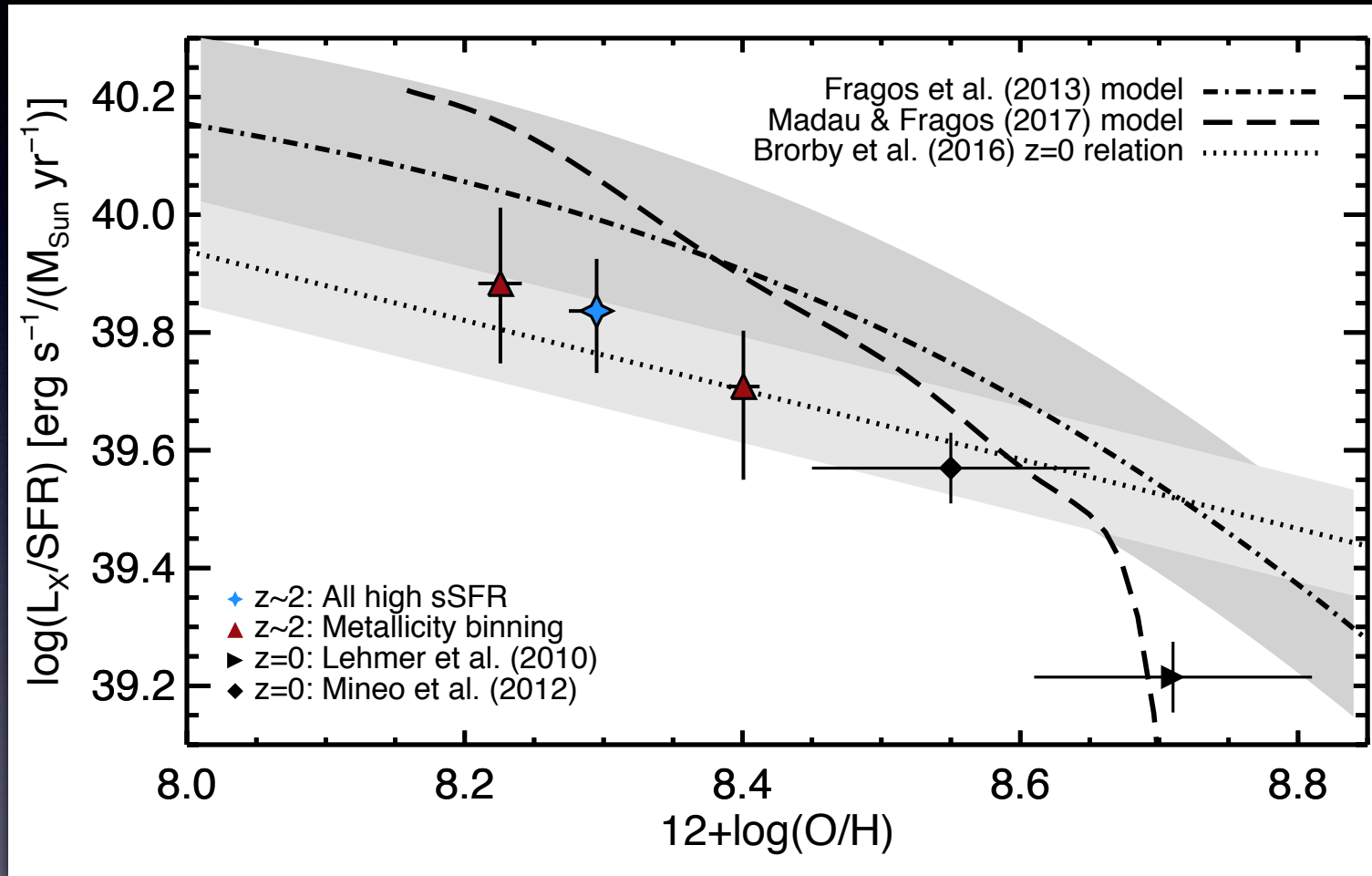


HMXBs exhibit Z -dependence at $z \sim 2$



- First evidence for Z -dependence at $z > 0$ (97% confidence)
- Likely driven by HMXBs rather than LMXBs

The Z-z connection

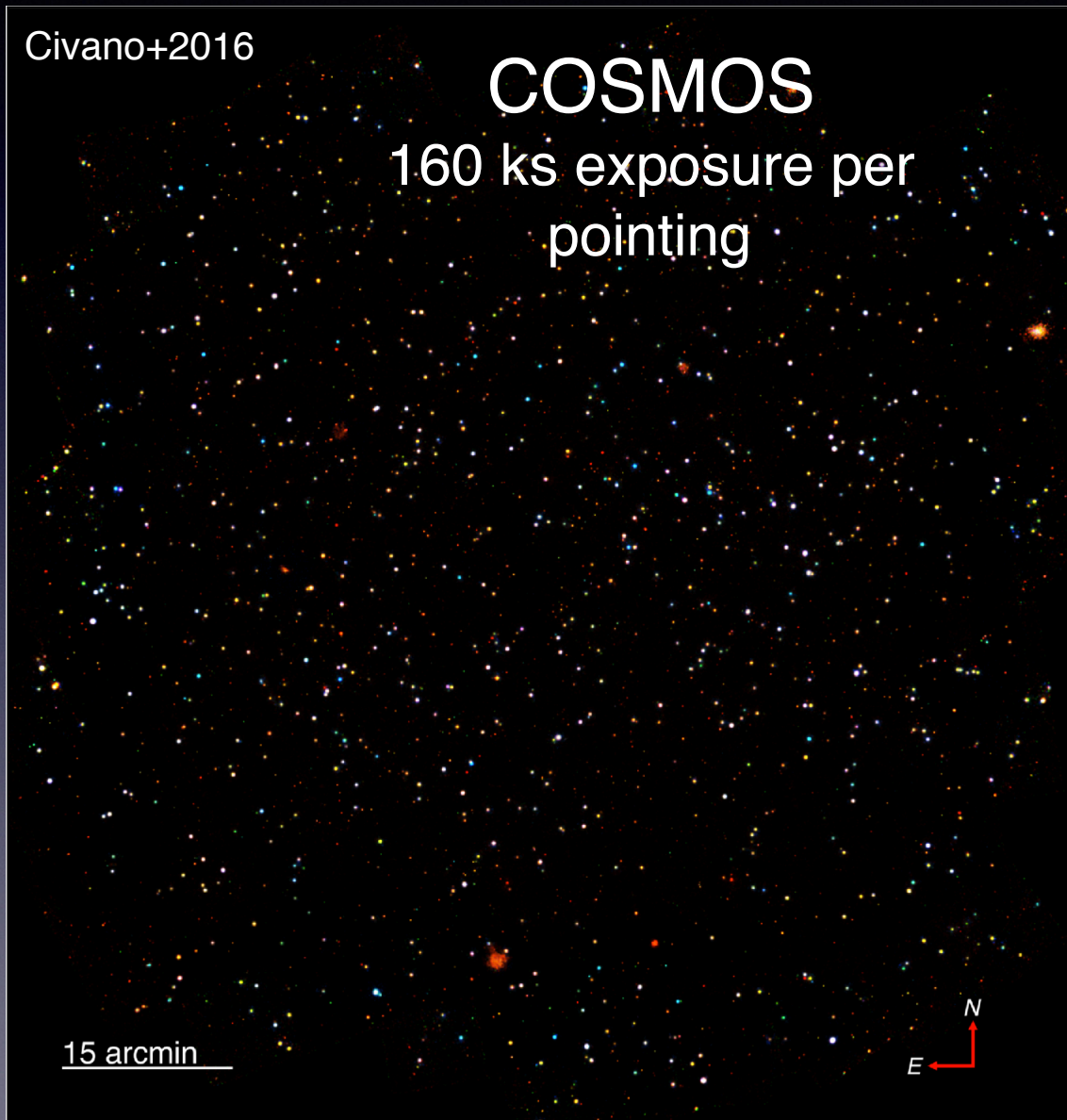


- HMXB-only normalization consistent with $z=0$ relation

Evidence favors Z - z connection

- But is the local L_X -SFR- Z relation biased?
- Can we improve measurements of this relation to provide better constraints for theoretical models?

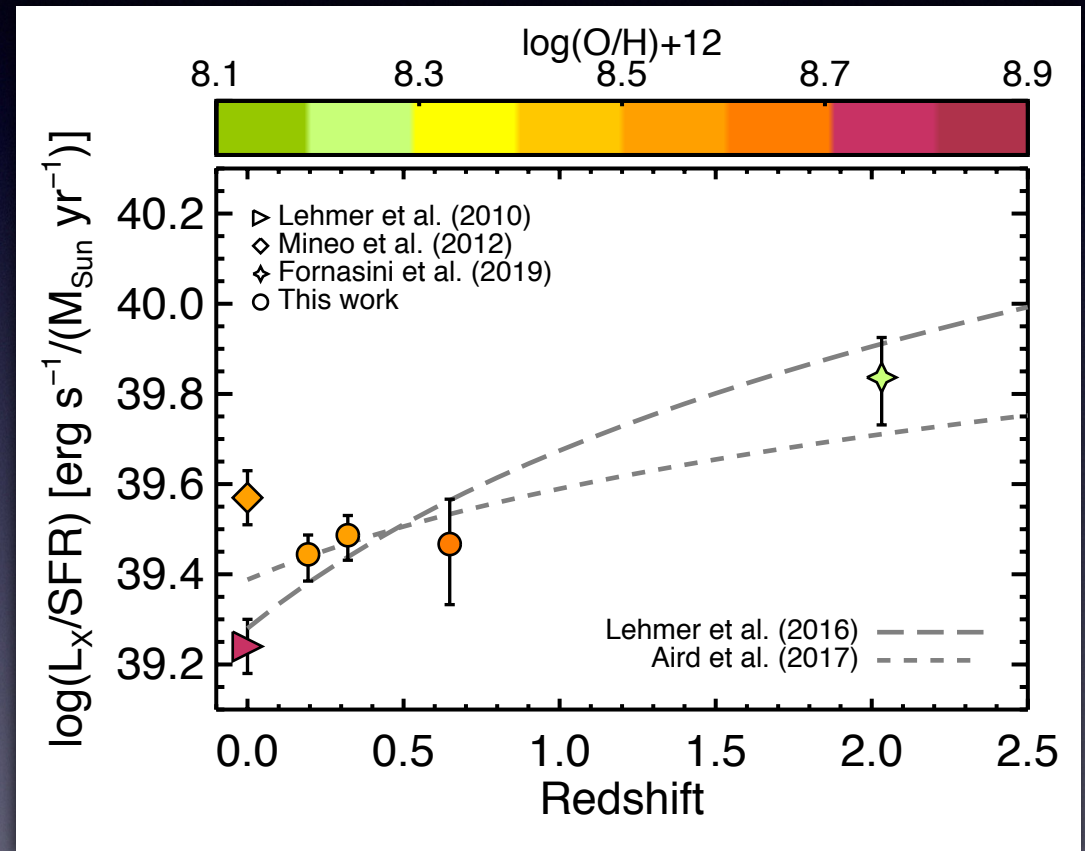
Studying z dependence at low z



Galaxy information from two spectroscopic surveys:
hCOSMOS ($z=0.1-0.4$)
zCOSMOS ($z=0.5-0.9$)

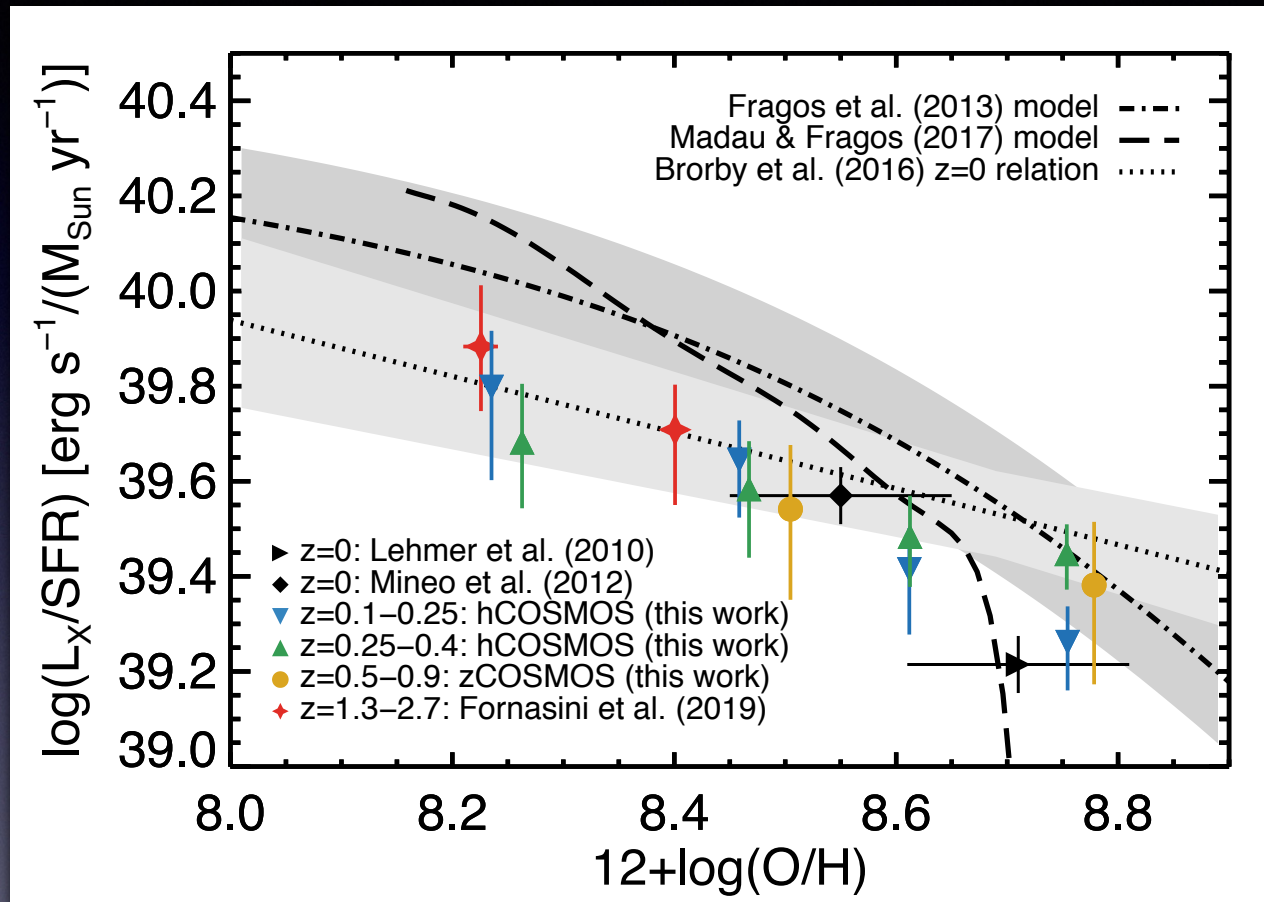
Studying Z dependence at low z

- hCOSMOS sample:
858 galaxies at
 $z=0.1-0.4$
- zCOSMOS sample:
787 galaxies at
 $z=0.5-0.9$
- R23 Z indicator
- SED (UV+IR) SFR
- Exclude X-ray, IR,
and optical AGN



Different redshifts, same story

Fornasini+in prep



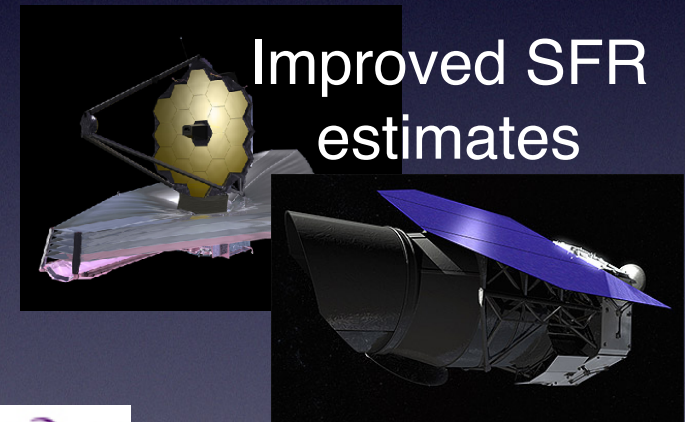
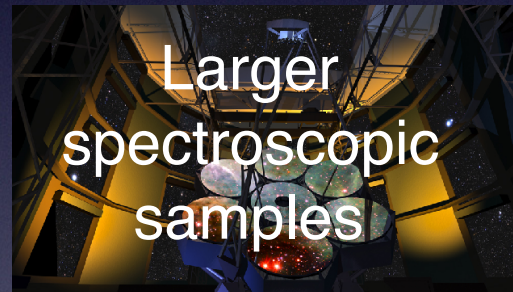
- Further support that z-evolution driven by metallicity
- Theoretical models with high L_x/SFR are in disagreement but SFR systematics are important

The z - z connection: summary & outlook



We have measured the HMXB z -dependence at $z > 0$.
 z -dependence at different redshifts is consistent and accounts for the observed z -evolution of $L_{\text{HMXB}}/\text{SFR}$

hCOSMOS+ survey



Improved SFR estimates



+



Larger, deeper X-ray surveys