Linking Star Formation and Black Hole Accretion in galaxies

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with

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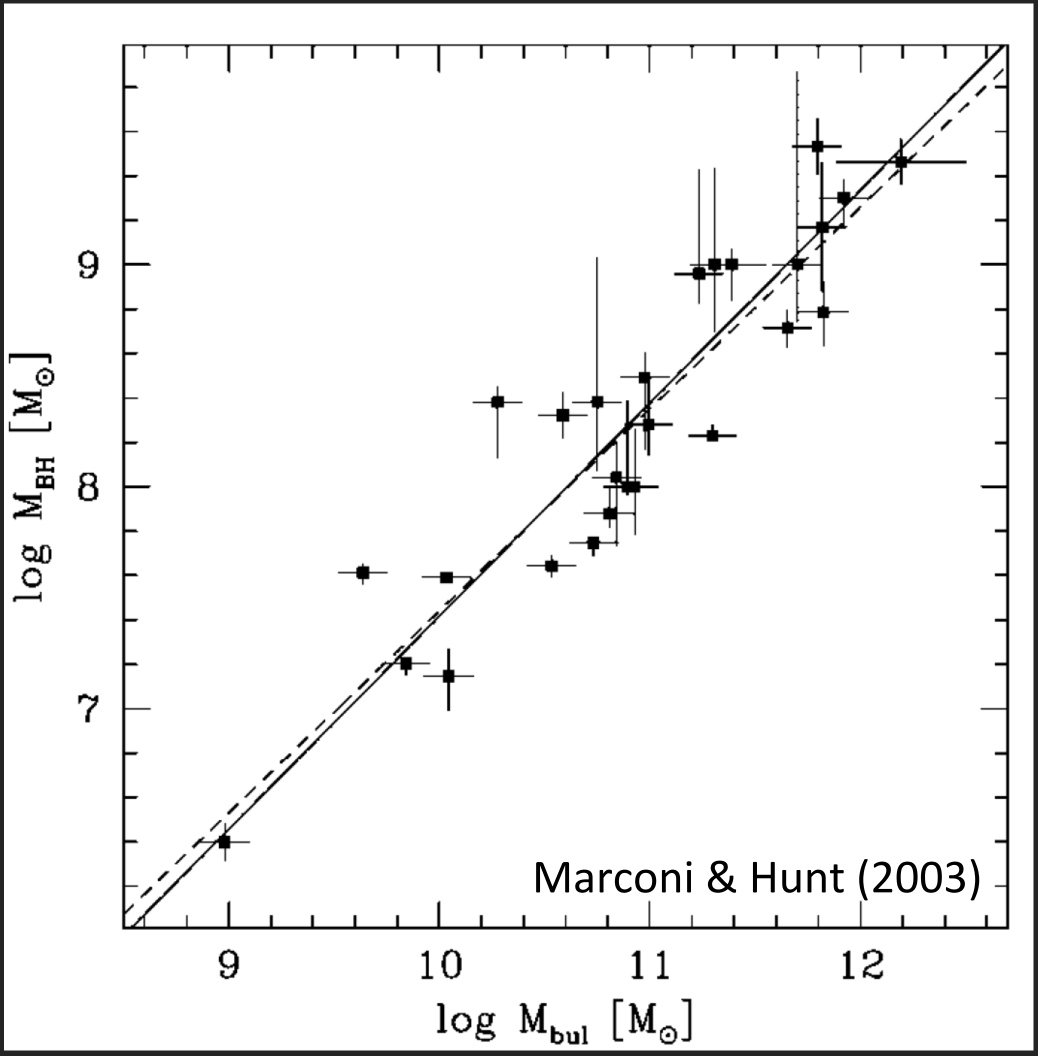
DIPARTIMENTO
DI FISICA
E ASTRONOMIA
"GALILEO GALILEI"

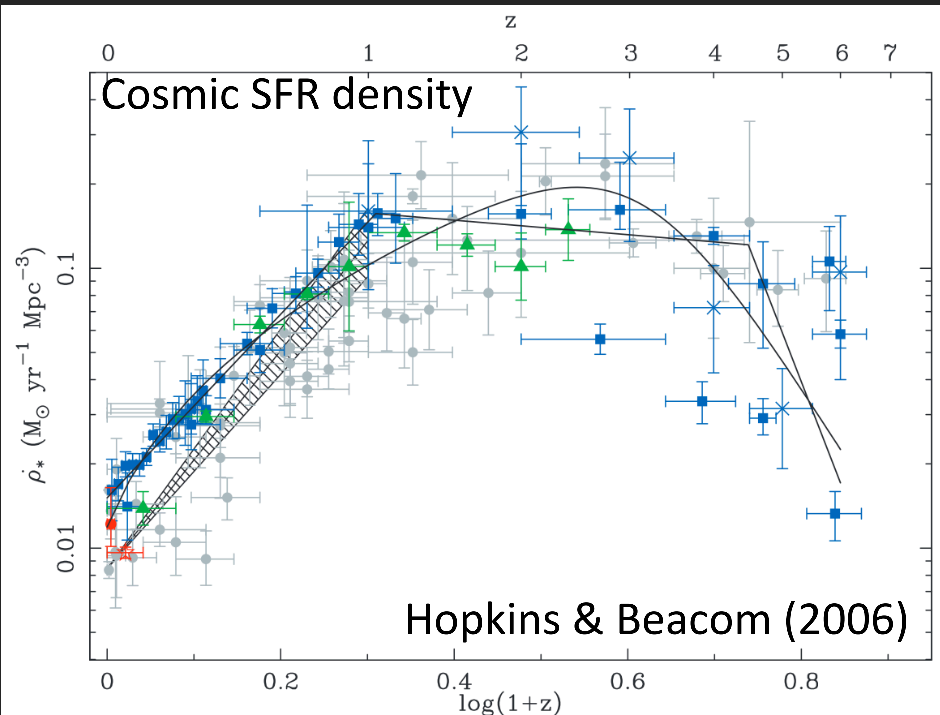
The self-regulation of host galaxies and their central BHs is a likely major ingredient for our understanding of galaxy evolution and key to explain the existence of local scaling relations between BH mass and galaxy properties.

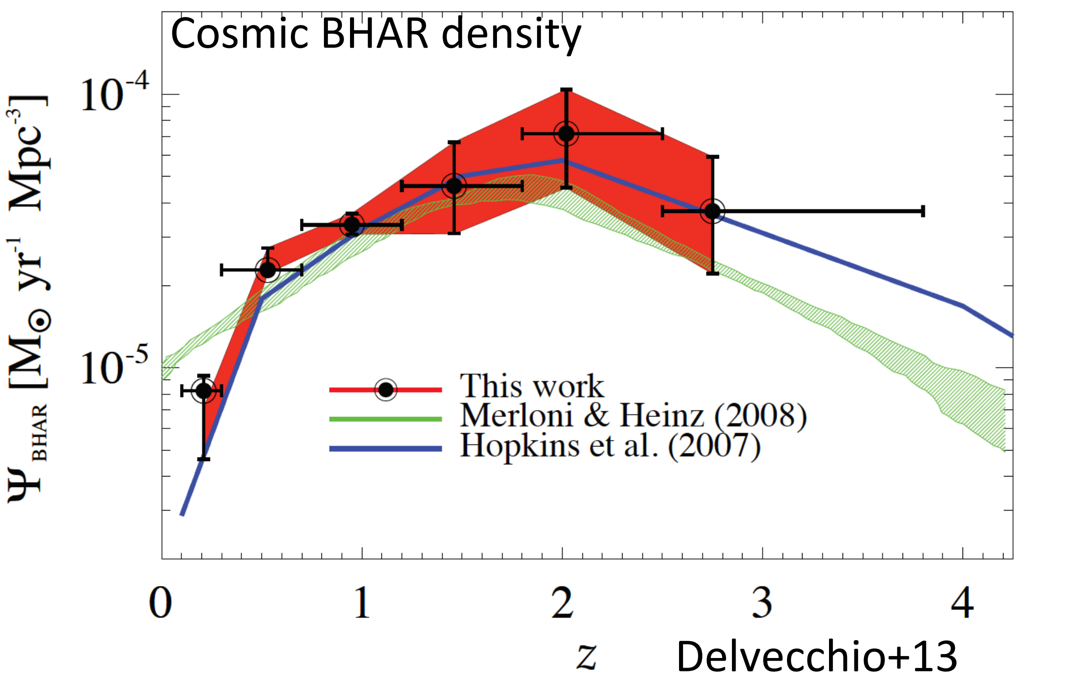


As a consequence, determining the relative roles of the various processes that drive the co-evolution of BHs and galaxies has emerged as a key goal of current astrophysics research.

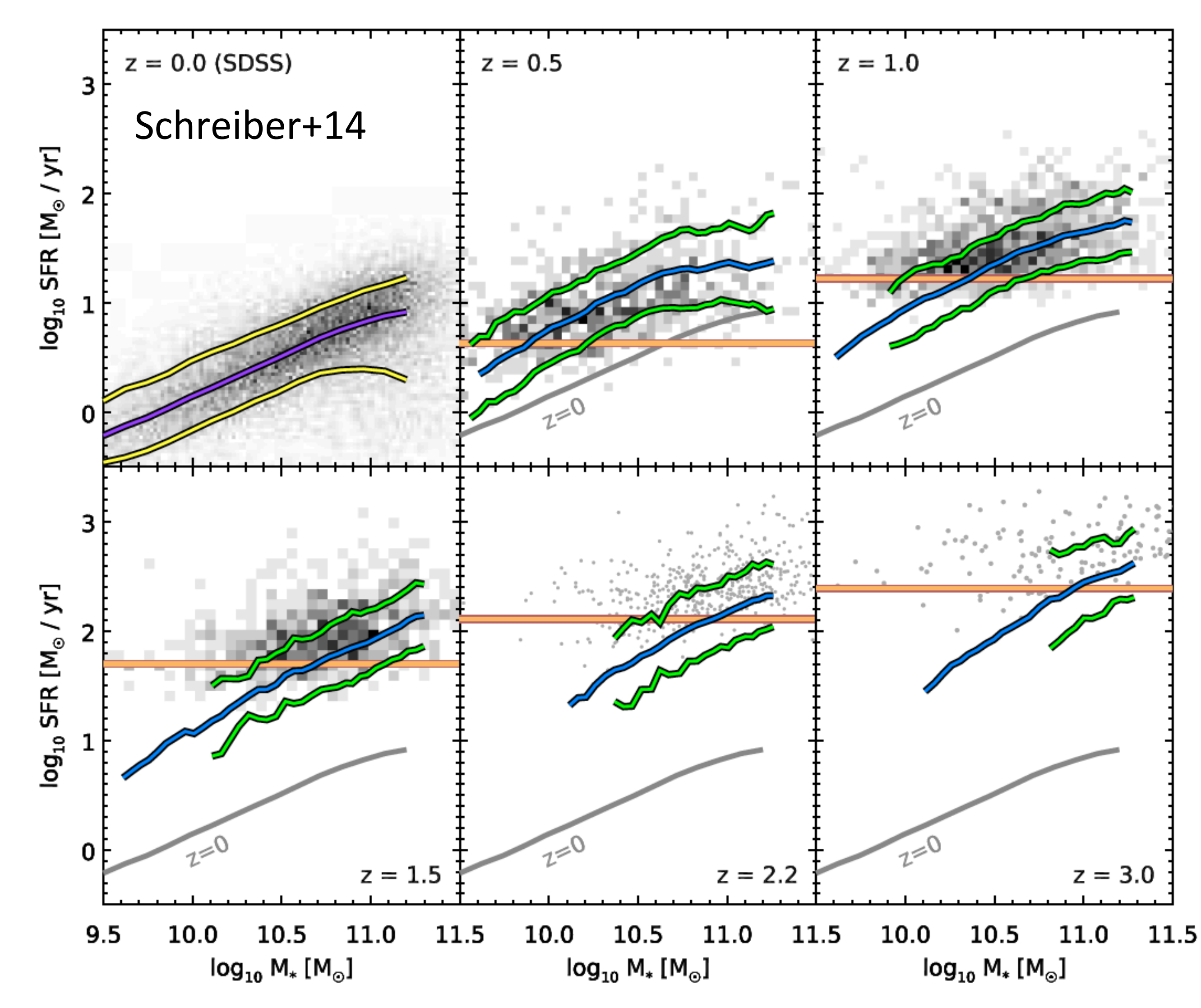
- M_{BH}-M_{Bulge} indicates a tight link between BH and galaxy growth.
- Global SF and BH growth follows same trends.
- Not clear why this is the case.
- How is BH and galaxy growth linked?

The emerging observational framework supports the idea that secular processes are responsible for both SFR and SMBH growth in a large majority of galaxies displaying moderate nuclear activity (Cisternas 2011, Kocevski 2012).





Connection to star formation and stellar mass assembly?



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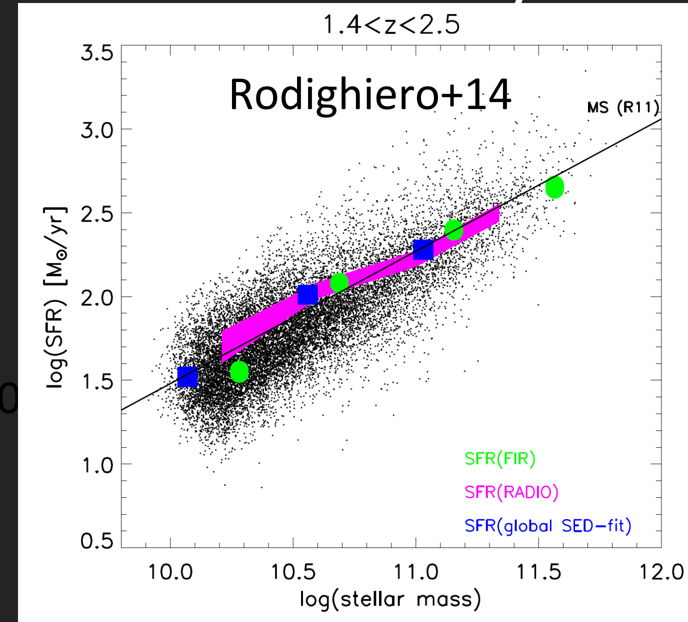
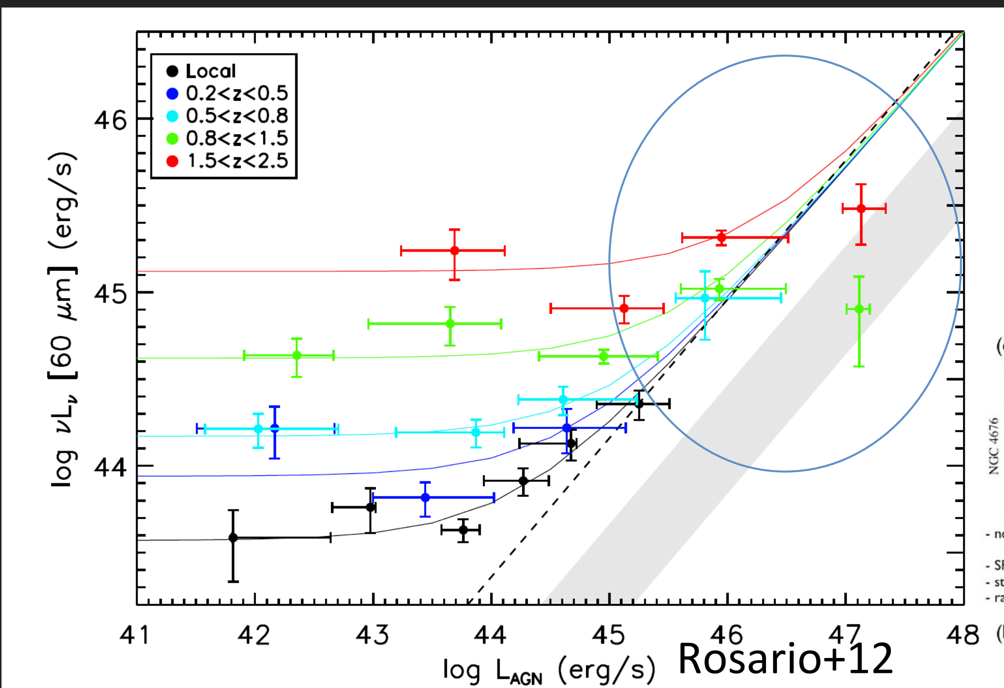
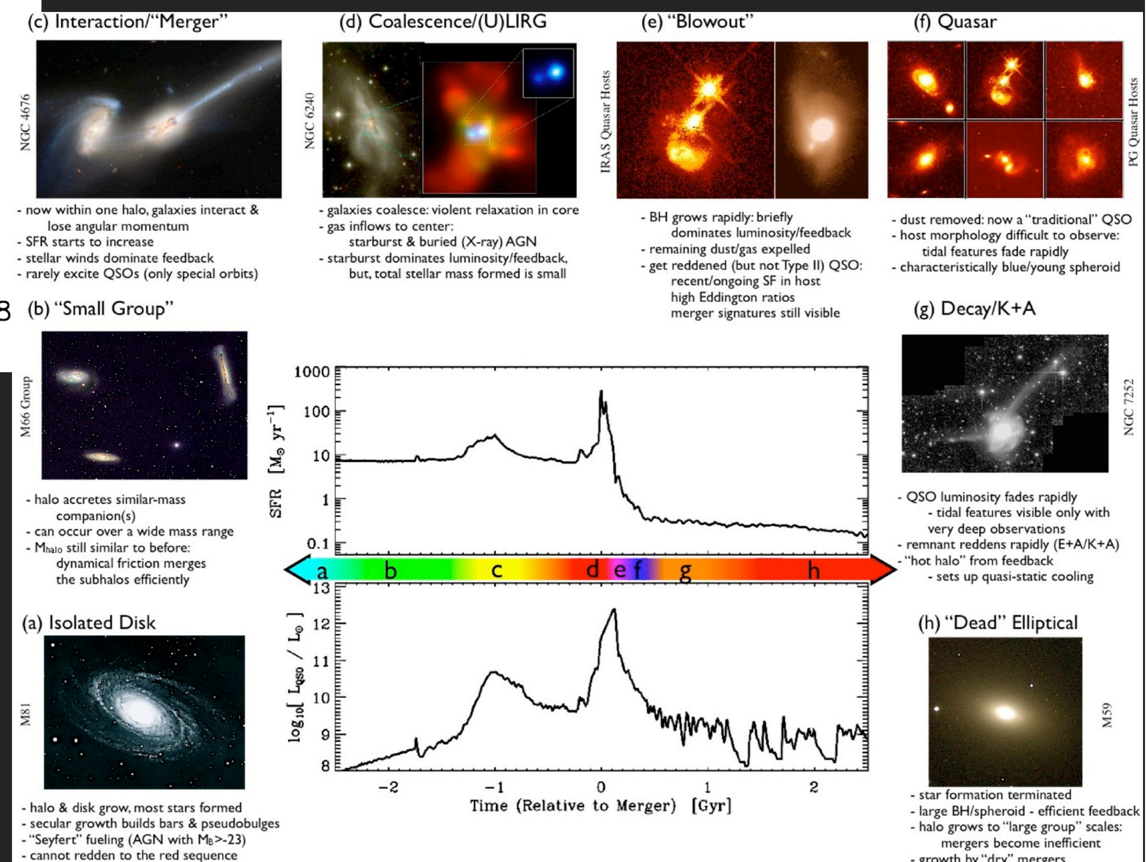


- Star-formation rate correlated with galaxy stellar mass.
- SFR per unit stellar mass increases dramatically with redshift.
- Rodighiero+11: ~98% of SF galaxies and 90% of SF takes place in these "***main-sequence***" (MS) galaxies.

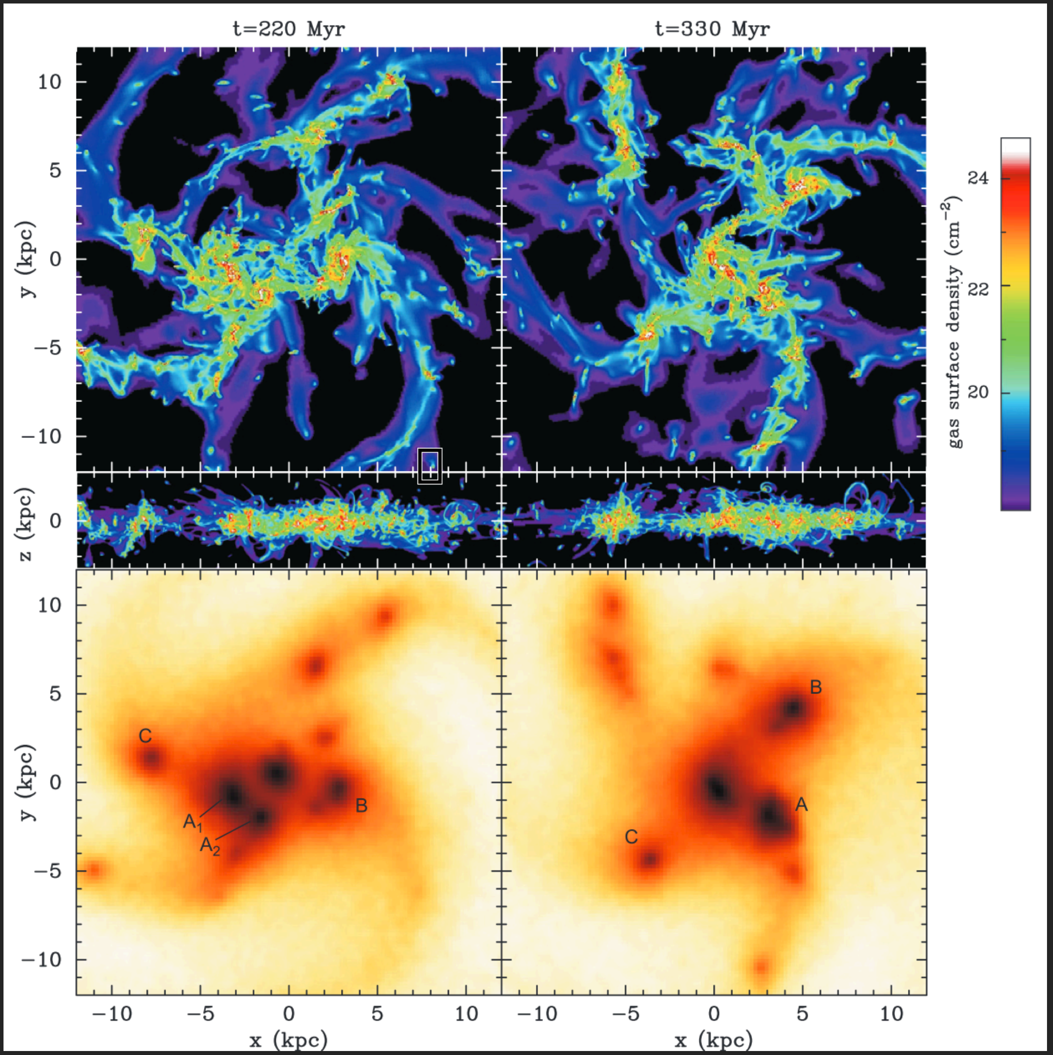
The role of violent mergers is, however, still considered an important triggering mechanism for BH growth (i.e. AGN activity), in particular in very luminous QSO (Hopkins 2008, Treister 2012).



The classical merger/QSO paradigm (Hopkins+08)

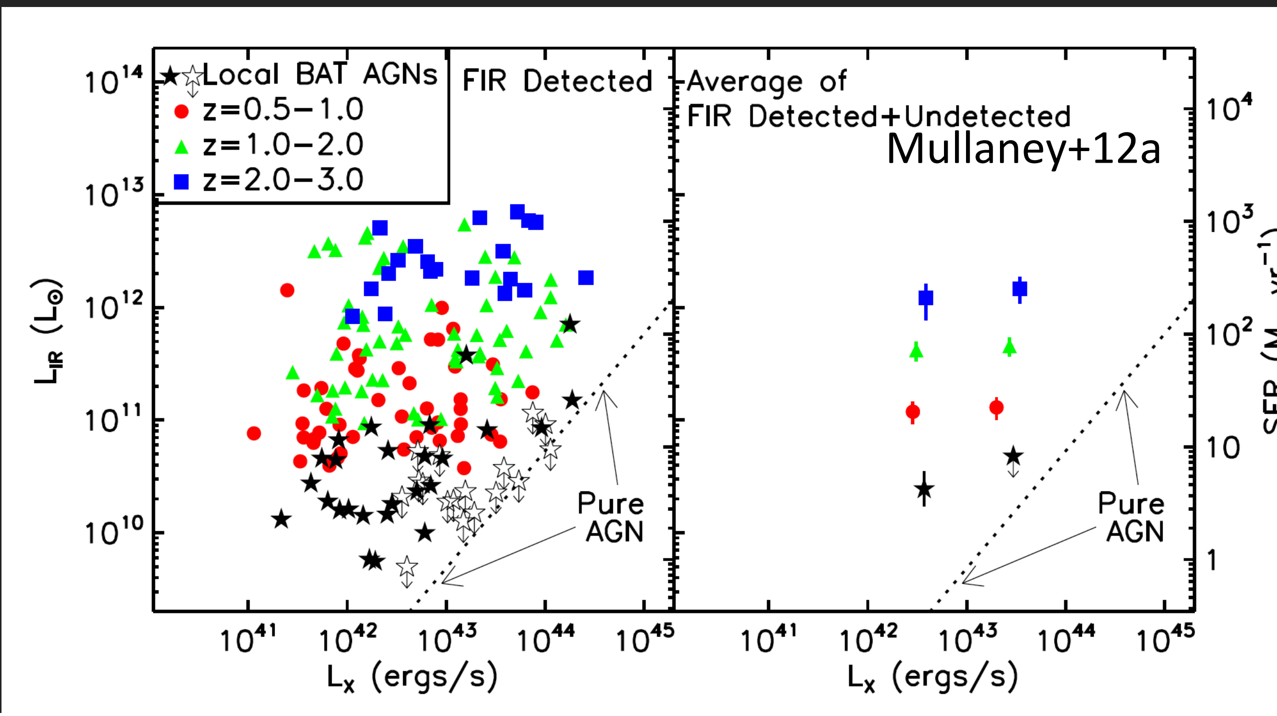


However, it is now clear that processes other than galaxy mergers, such as gas turbulence or disk instabilities, play an important role in triggering BHAR (Bournaud et al. 2012).



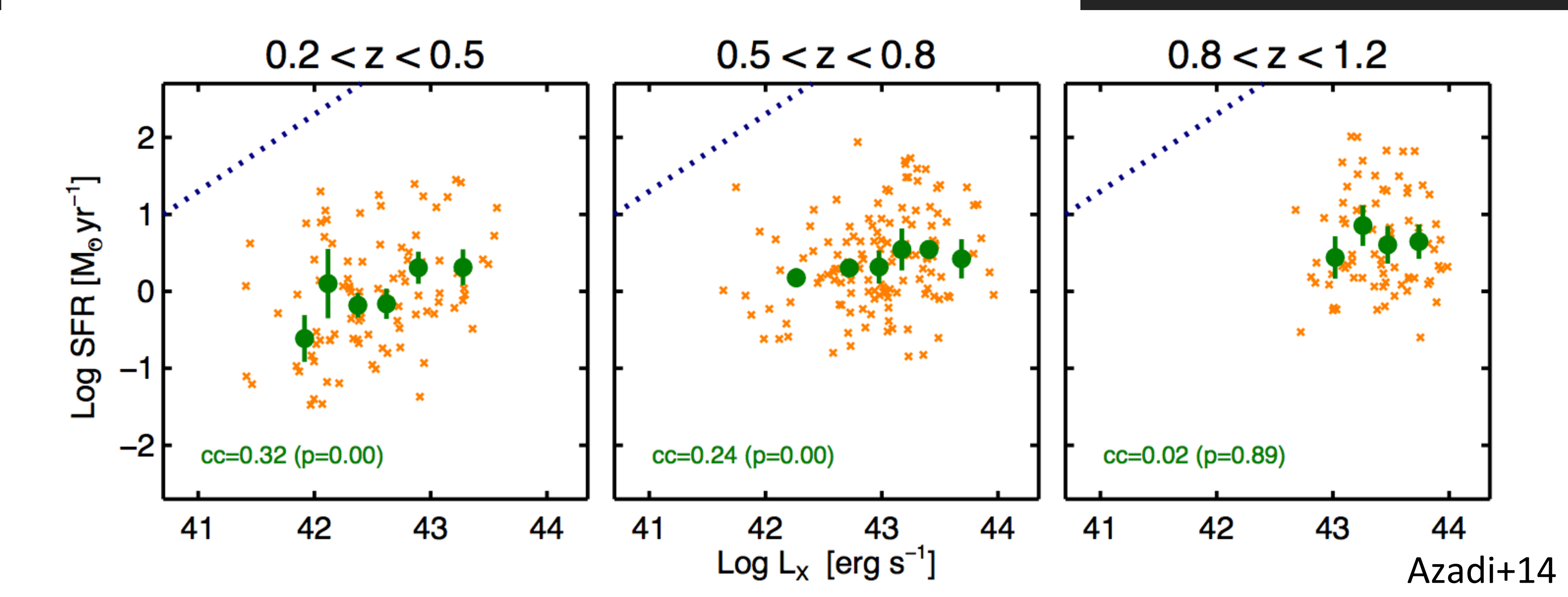
Bournaud et al. (2011)

Dai+15



Many studies find no clear correlation between instantaneous BH growth and SF for individual galaxies of moderate X-ray luminosities (Silverman+09, Shao +10, Mullaney et al. 2012a, Azadi et al. 2014).

Correlated SF-BH growth in low-z QSOs (Netzer+07, Lutz+10, Rosario+12)



Key step forward: adoption of X-ray stacking analyses to derive the average BH growth rate of large samples of galaxies (including undetected, low accretion rate BHs).

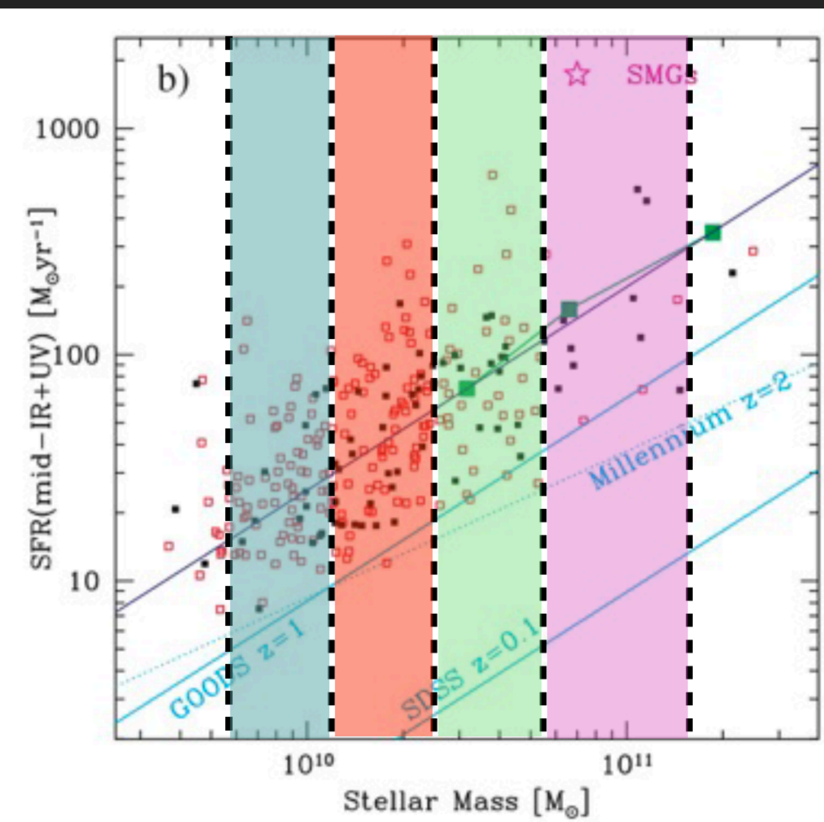
➔ Demonstration that the average BHAR is tightly correlated with both M* and SFR (Mullaney+12b, Chen+13), and mimics the SFR relation of normal SF galaxies (e.g. Elbaz+07, Rodighiero+14).

Average BH growth in SF galaxies: the AGN MS

Mullaney+12b

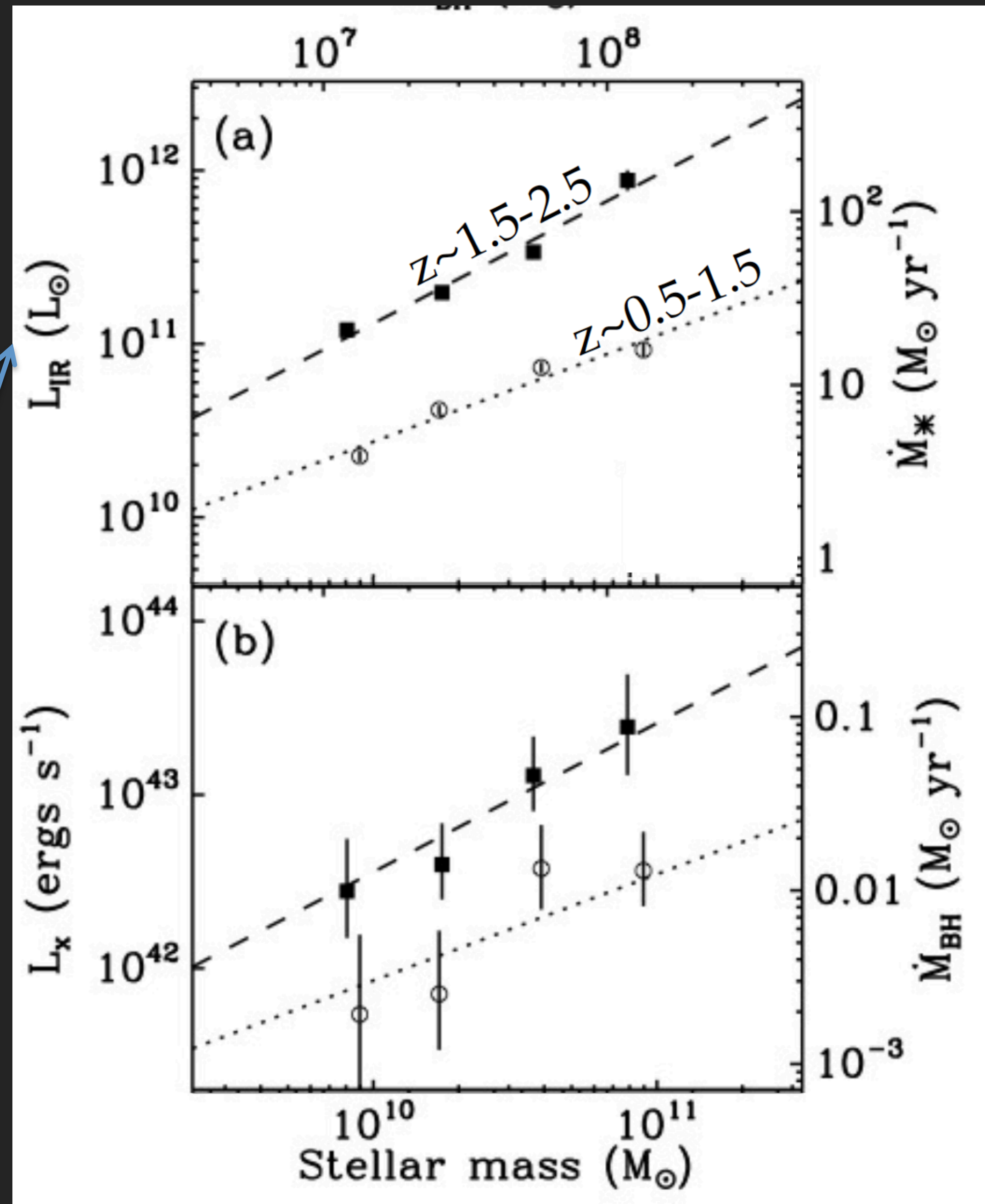
Identify a complete sample of SF galaxies. Average over AGN duty cycles using X-ray stacking.

Will miss AGNs in low-SFR galaxies and in starbursting systems



SFR

BHAR



Average SFR vs. M* shows MS trend.

On average, M_{bh} growth rate follows the same trend with M* (the so-called AGN main sequence).

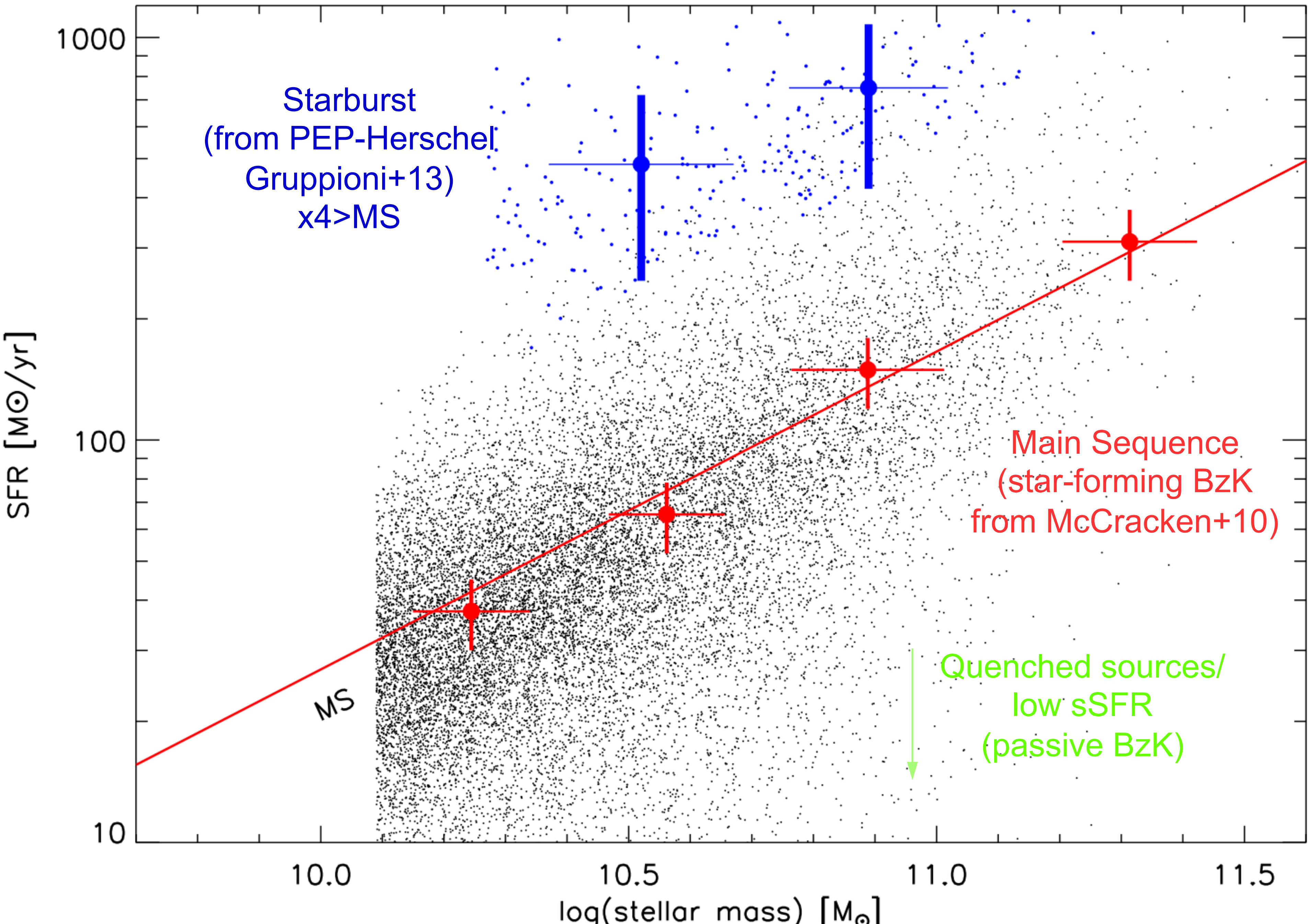
Suggests the same underlying physics (gas fractions?) drive SF and BH growth to produce M_{bh}-M_{bulge} correlation

These studies did not discriminate between different types of galaxies, whereas it is known that different levels of SFR may be triggered by different events (mergers vs secular processes for starbursts and normal MS galaxies), which may also trigger different levels of BH growth.

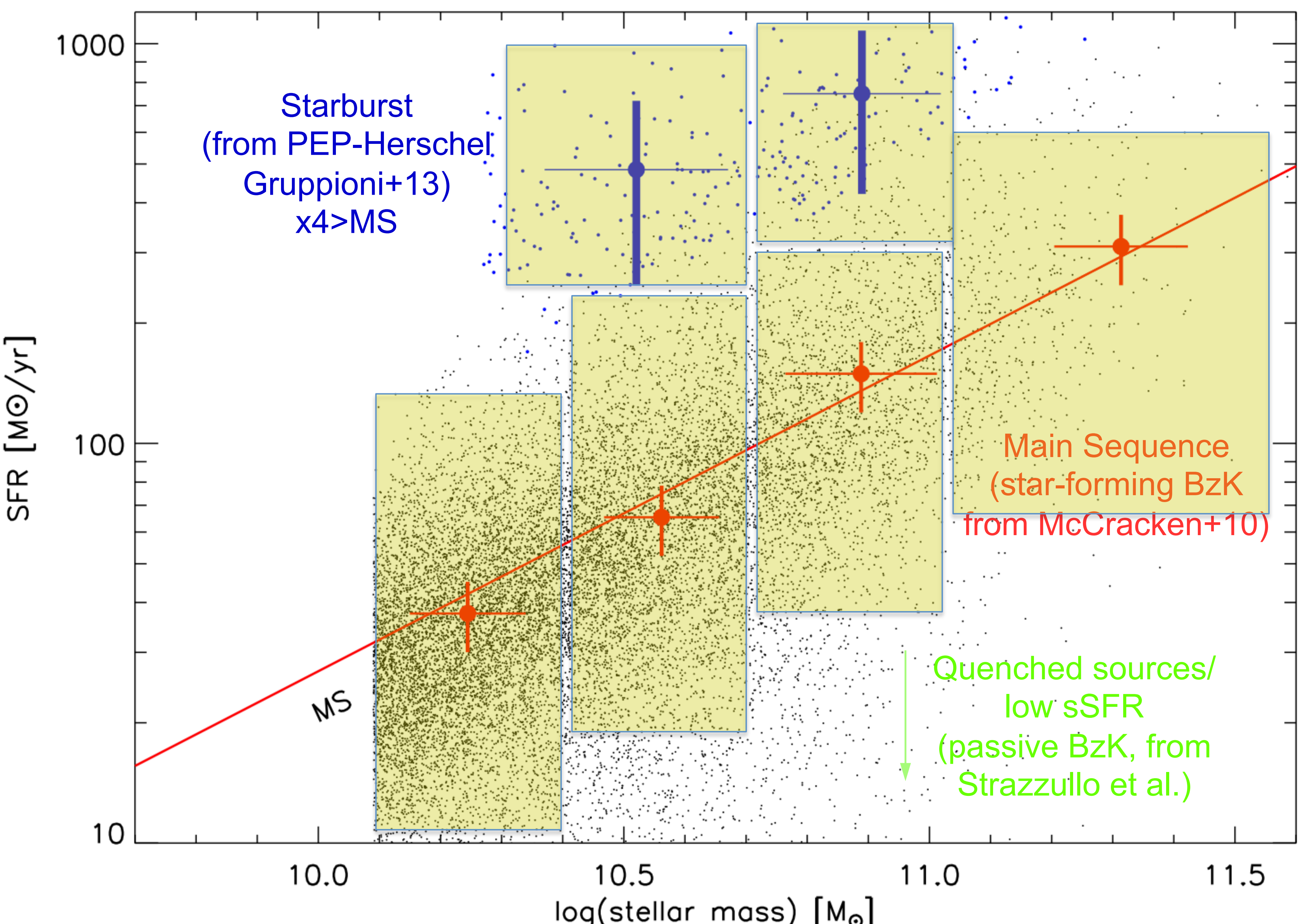
To investigate the relative BHAR in galaxies displaying different levels of SF properties (i.e. evolutionary stages), we employ X-ray stacking to investigate how the average Lx varies across bin of stellar mass and specific SFR using large statistical M* selected samples.

COSMOS field to avoid small number statistics that prevented previous X-ray stacking studies to separate their samples in terms of sSFR.

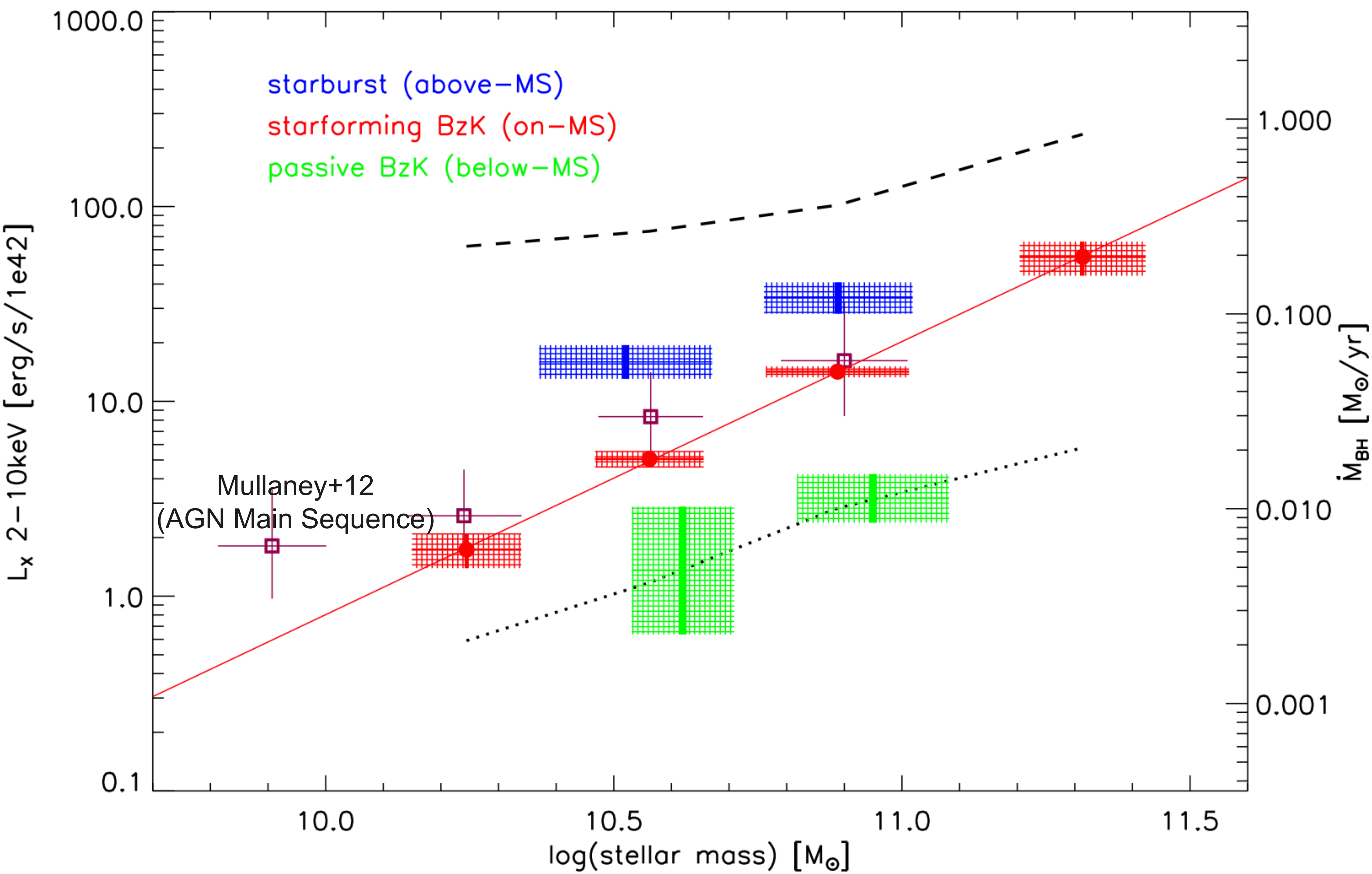
Sample selection: above/on/below the MS at 1.4<z<2.5 in the COSMOS field (Rodighiero+15)



Sample selection: above/on/below the MS at 1.4<z<2.5 in the COSMOS field

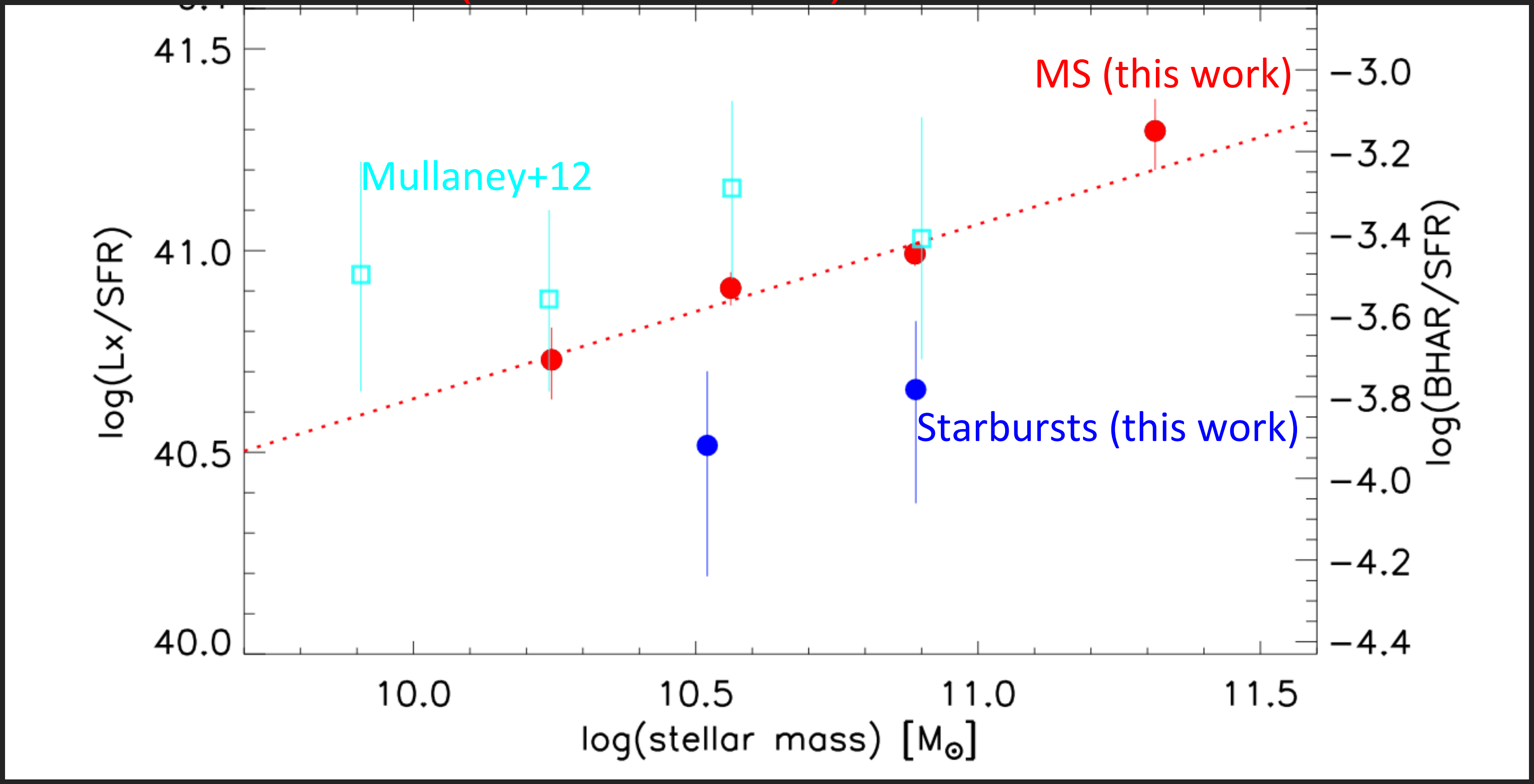


Chandra X-ray stacking analysis to characterize Lx over the whole mass-SFR plane



- Our analysis shows a robust L_x-M_* correlation (the hidden AGN MS of M12) for normal star-forming galaxies, confirming its existence also at higher M_*. This is a linear relation (in log) with a slope of 1.40(+/-0.09) (steeper than Mullaney+12).
- Starburst galaxies show higher levels of BHAR (x3), with respect to MS galaxies at fixed M_*. By contrast, quiescent galaxies have a deficit of an average factor 5.5 in terms of Lx with respect to the MS, suggesting that they belong to an evolutionary phase where the gas fuelling the central engine (and the SFR) is almost exhausted (or the accretion is simply temporarily suppressed).
- Given the number densities and average Lx of starburst, normal star-forming and quiescent galaxies, we argue that *the accretion activity during the starburst phase is just 7(+/-1)% of the cosmic integral BHAR at this redshift, while that of quiescent sources is 11(+/-1)%.*
- *The bulk of the accretion density of the Universe at z=2 is associated with normal star-forming*

Lx/SFR (for normal SF) not mass invariant



- L_x/SFR α $M_*^{0.4}$ ➔ M_{bh} α $M_*^{1.5}$ (not constant!) but still consistent within the observed scatter of the local M_{bh}/M_* relation.
- BHs accrete more mass with respect to their host galaxies at the high mass.
- During the starburst phase, where the SFR is enhanced by a factor of 6 on average, the average X-ray luminosity is also enhanced, but by a smaller amount (by a factor of 3). Possible delay in the BHAR enhancement relative to that of the SFR (e.g. Hopkins+12).

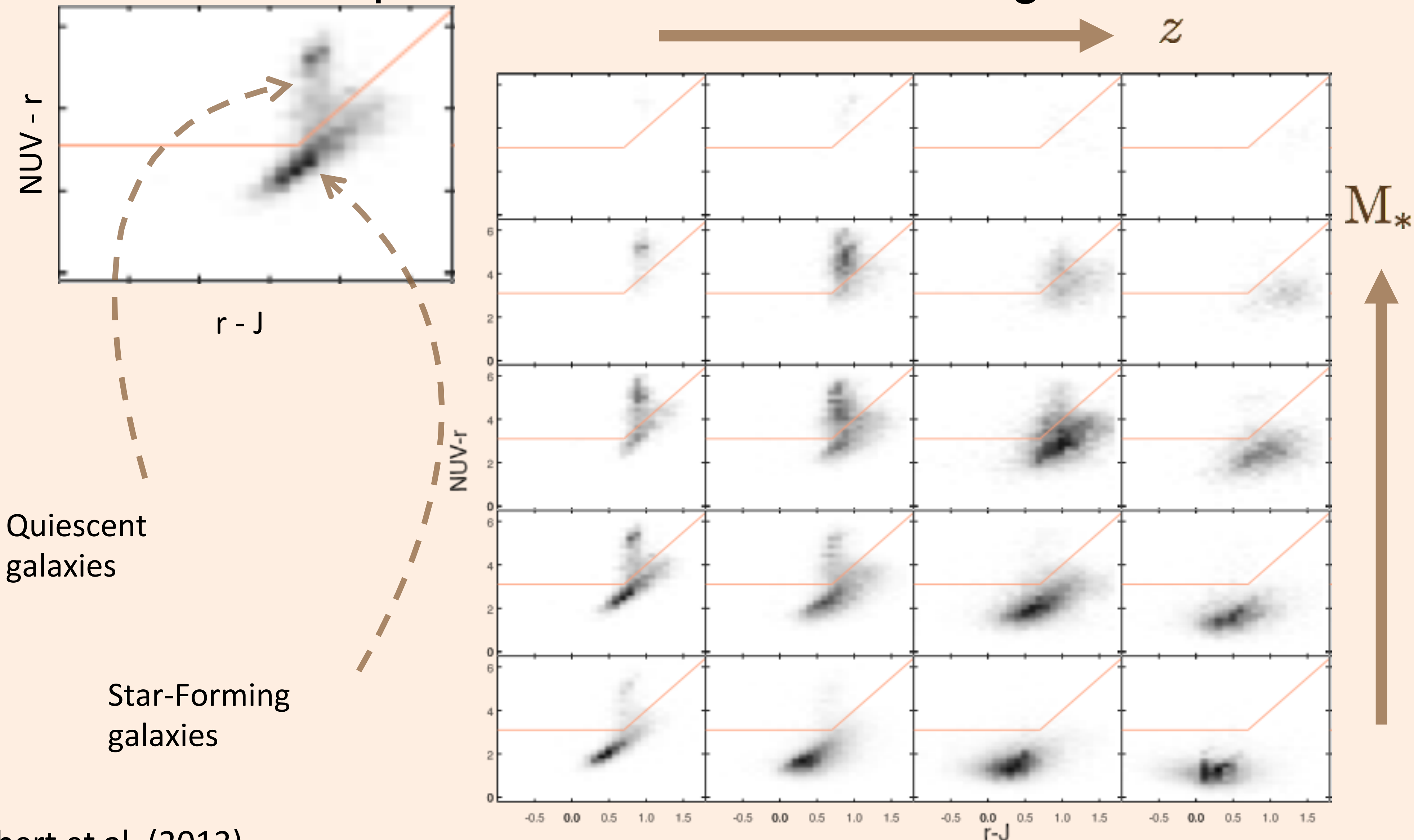
SUMMARY

- We found a robust BHAR-M_* correlation for normal star-forming galaxies.
- M_{bh}/M_* not constant with mass (scales as $M_*^{1.5}$)
- On average, BH accretion more efficient than SF
- On average, BH growth mimics galaxy growth in MS.
- The bulk of the accretion density of the Universe is associated with normal star-forming.

Extension of the analysis to the new COSMOS2015 catalog, with UltraVISTA Ultra-deep data (Laigle et al., in prep)

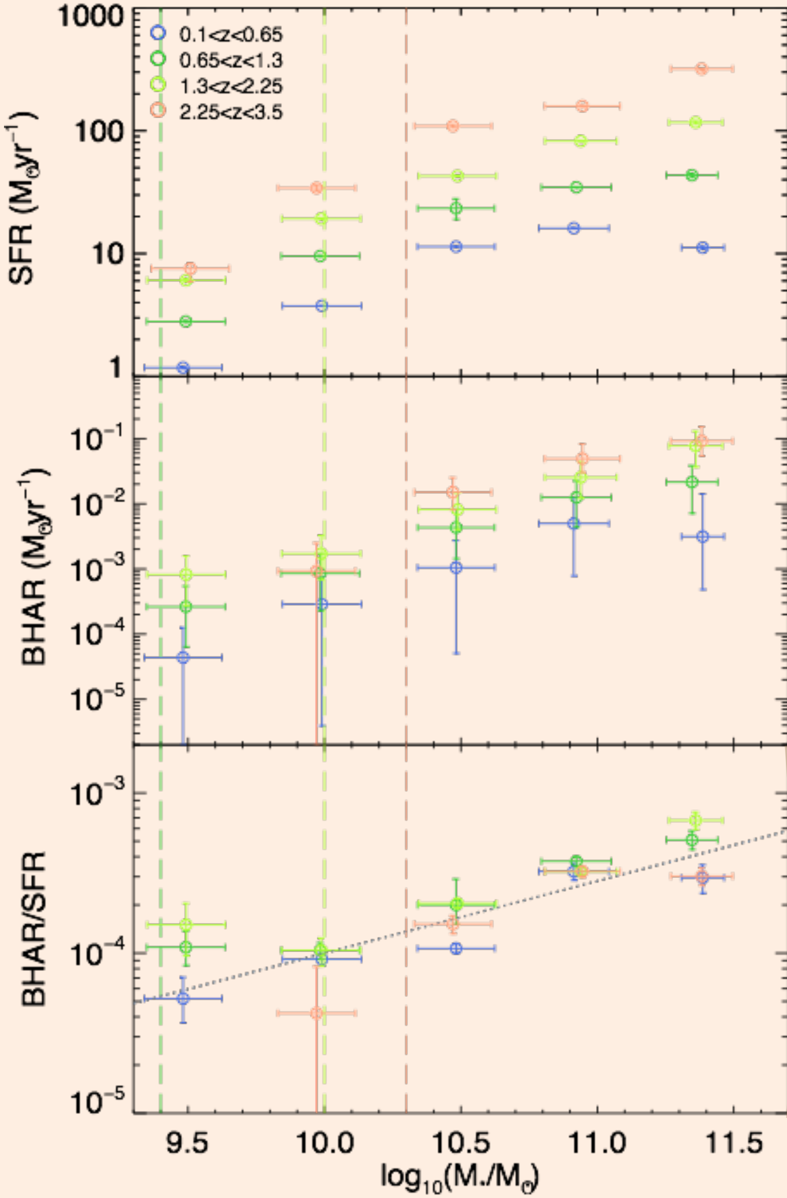
evolution with *z* over 2 sq deg with Chandra-Legacy (Civano+15)

Sample selection: NUV-r/r-J diagram



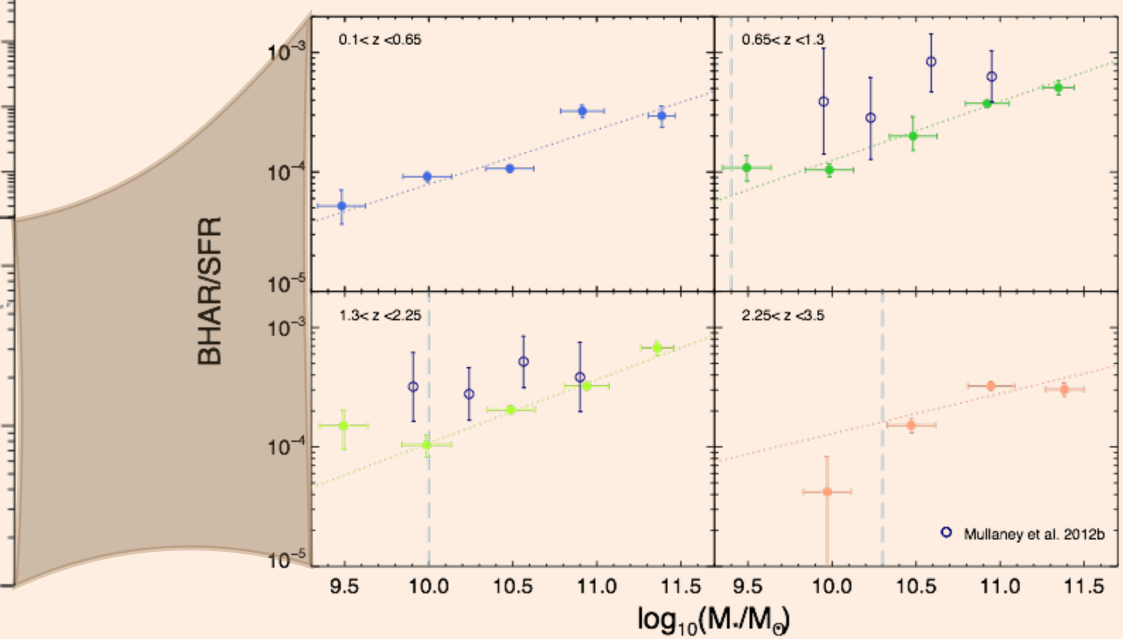
Ilbert et al. (2013)

Evolution of SFR & BHAR



$$\mathrm{BHAR}(\mathrm{M}_*, z) = \frac{(1-\epsilon)\cdot \mathrm{L_{bol}}(\mathrm{M}_*, z)}{\epsilon\, c^2}$$

$$\log \frac{\mathrm{BHAR}}{\mathrm{SFR}} \propto 0.45 \cdot \log \mathrm{M}_*$$

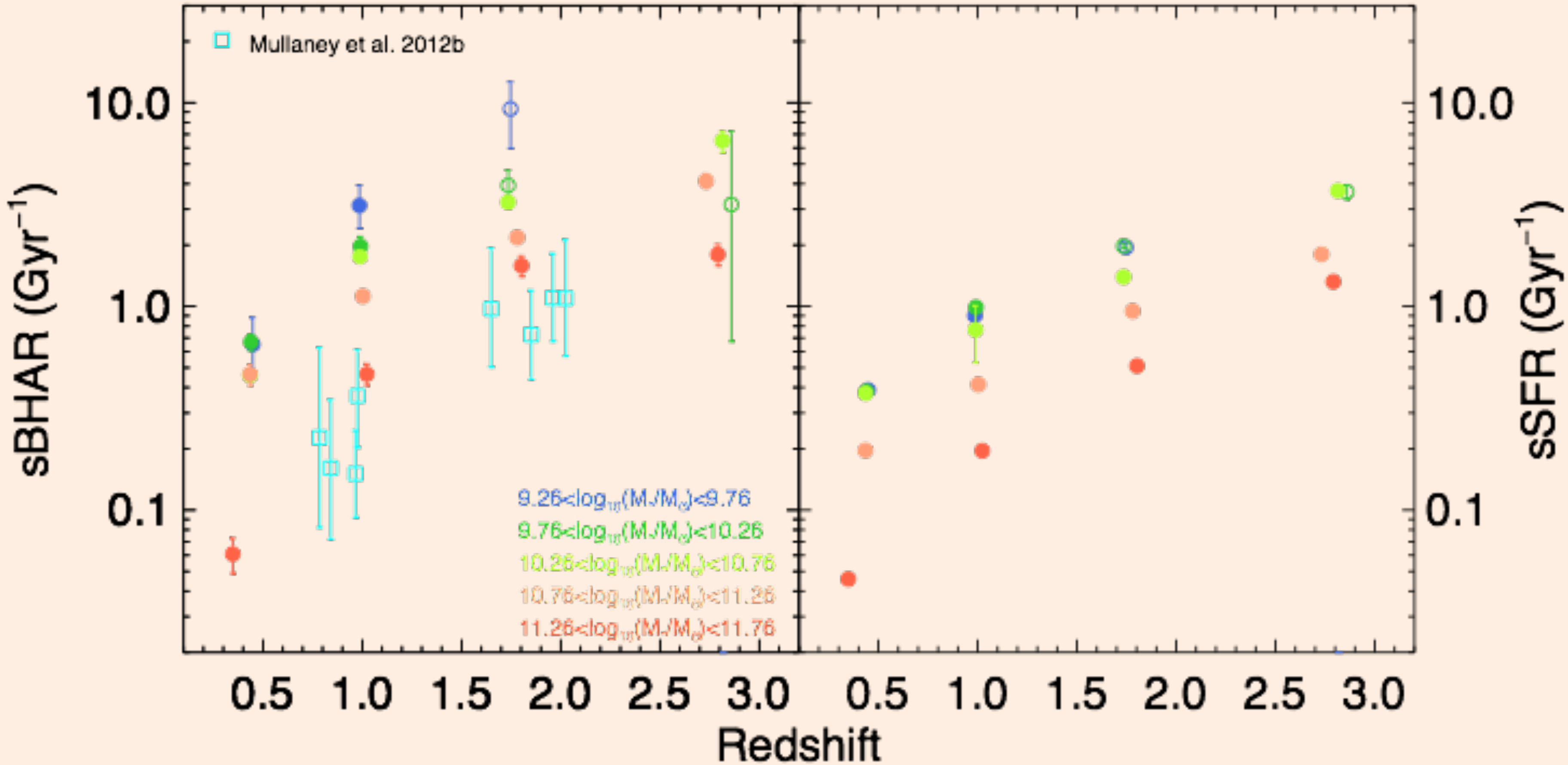


Rodighiero, Carraro et al. (in prep.)

specific BHAR and specific SFR evolution

if $M_{BH} \propto M_*^{1.45}$

$$sBHAR = \frac{BHAR}{M_{BH}} \qquad sSFR = \frac{SFR}{M_*}$$



- Decrease with cosmic time
- Downsizing
- Mass-doubling timescale of M_{BH} shorter than that of M_*

SUMMARY

- We found a robust BHAR-M_* correlation for normal star-forming galaxies up to z=3.5
- Downsizing evidences for both SF and BH accretion
- Suggestion that it is the same underlying physics (gas fractions?) that drive SF and BH growth, to produce the M_{BH}-M_{bulge} correlation.

The case for SPICA: ….

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See Carlotta's talk
See Peter's talk
See Andrea's talk
See Juan's talk
See Enrico's talk
See Cristian's talk
See Francesca's talk…..