# Co-evolution of black hole accretion and star formation in galaxies at 0.1<z<3.5


**Rosamaria Carraro**[a]

rosamaria.carraro@postgrado.uv.cl

P. Cassata[b], G. Rodighiero[b], M. Brusa[c]

[a]Universidad de Valparaíso, Chile; [b]Università degli Studi di Padova, Italy; [c]Università degli Studi di Bologna, Italy.


## Question

Galaxy growth and black hole growth both need cold gas in order to happen, but very different scales are involved. Local relations and their density evolution seem to point at a common evolution of star formation and black hole accretion. Just like the main sequence of star forming galaxies, is there a relation between the black hole accretion rate and stellar mass? How does it evolve? What about galaxies in the other life phases?

## X-ray stacking

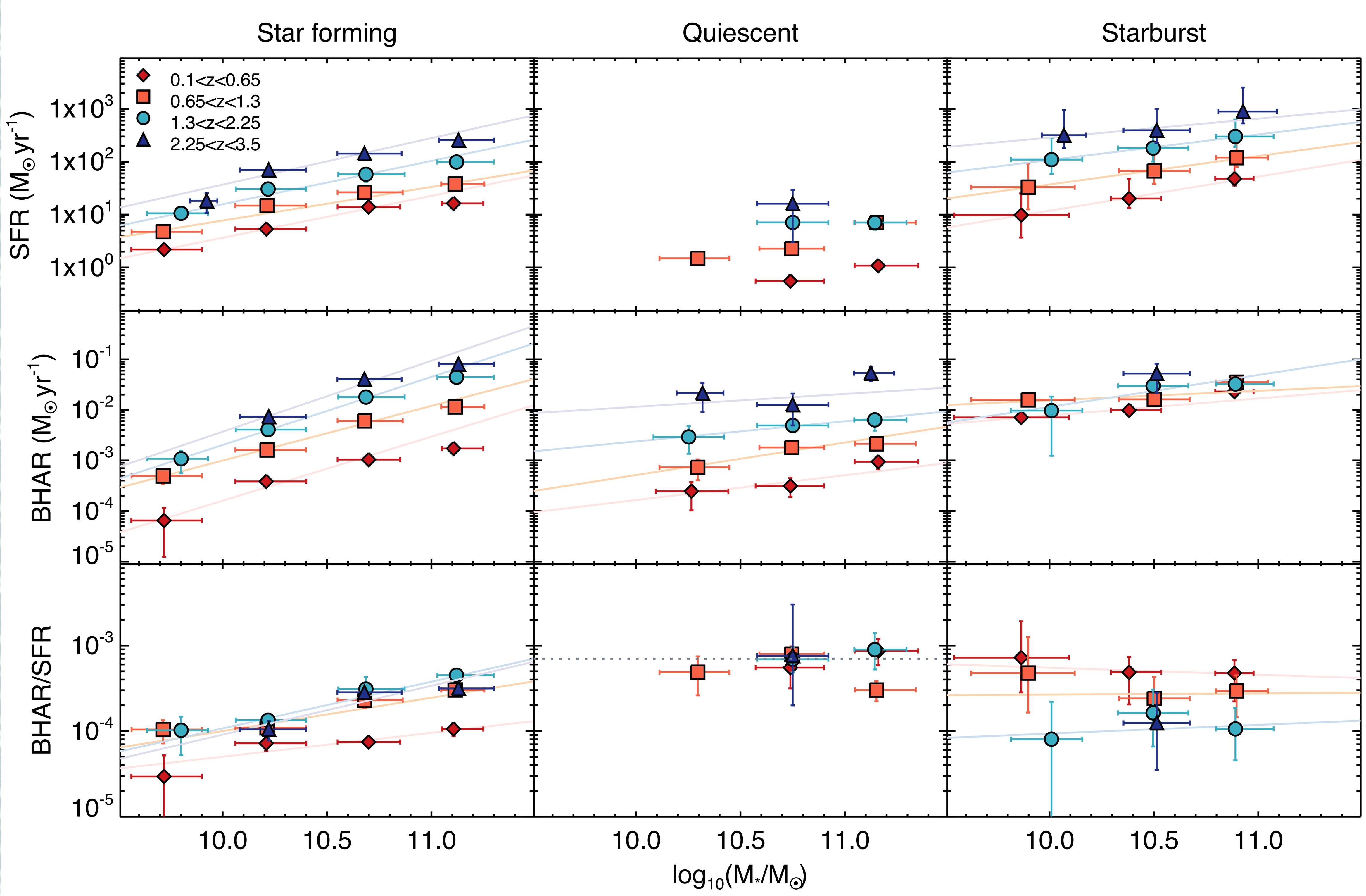
The introduction of X-ray stacking allowed to study *average* properties of mass complete samples of galaxies, including low accretion AGN. Preliminary studies using X-ray stacking [1] [2] showed that black hole accretion seems to mimic the star formation.

## This work

We perform a statistical study on the COSMOS field in order to constrain the history and the co-evolution of star formation (SF) and black hole (BH) accretion in star forming, quiescent and starburst galaxies.
We select a mass complete sample from the COSMOS 2015 catalog [3], classifying normal star forming and quiescent galaxies through the NUV-r/r-J color-color diagram. We select a starburst sample from the Gruppioni et al. (2013) catalog [4] with SFR=4 x $SFR_{MS}$.
We perform X-ray stacking analysis to estimate average X-ray luminosity and therefore average BHAR.
We estimate SFR from FIR stacking and UV SED fitting.

Black Hole Accretion Rate (BHAR)
traced by
X-ray luminosity

Star Formation Rate (SFR)
traced by
FIR + UV luminosity




## Comparison between SFR and BHAR and their evolution in time

Left column, star forming galaxies:

- We find a robust correlation between BHAR and stellar mass ($M_*$) which simulates that of the SFR at all considered redshifts, with a similar evolution. We also see a bending of the BHAR at high stellar masses.
- More efficient BH accretion at higher stellar masses.
- By integrating the relation between BHAR/SFR and $M_*$, we see that the black hole mass ($M_{BH}$) has a superlinear dependence on $M_*$: $M_{BH} \propto M_*^{1.45}$.

Central column, quiescent galaxies:

- BHAR has a strong evolution with redshift but weak dependence on stellar mass.
- BHAR has high values, close to those of star forming galaxies.
- BHAR/SFR flat with stellar mass and is compatible with a constant ratio at all redshifts. An integration of the BHAR/SFR and $M_*$ relation shows that the value is close to that of the local relation $M_{BH}=10^{-3}M_{spheroid}$

Right column, starburst galaxies:

- BHAR has weak evolution with redshift.
- BHAR comparable to star forming galaxies at the highest redshift.
- BHAR/SFR ratio flat with mass but evolution in normalization with redshift.

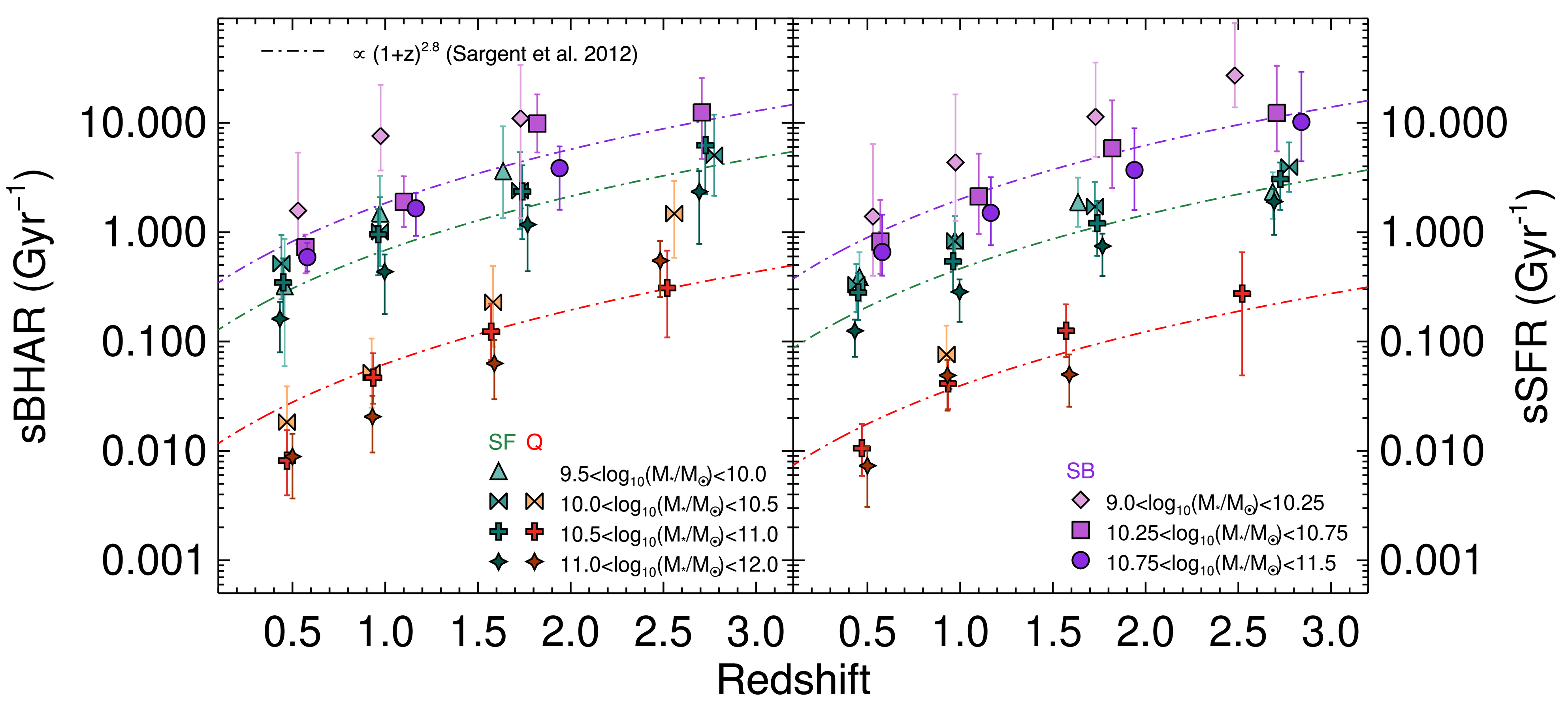
## Evolution with redshift of sBHAR and sSFR

We define $sBHAR = \frac{BHAR}{M_{BH}}$ and $sSFR = \frac{SFR}{M_*}$

We estimate $M_{BH}$ from the integration of the relation between the ratio BHAR/SFR and the $M_*$ in the above figure.

We see a very similar trend of both sBHAR and sSFR with redshift of the three galaxy types:

- Increasing trend with redshift, compatible with $\propto(1+z)^{2.8}$ as in Sargent et al. (2012) [5].
- The splitting in stellar mass is a hint of downsizing - more massive galaxies accreted most of their stellar/BH mass at earlier times.
- Different normalization of relations tells us the mass-doubling time-scale of galaxy/BH is shorter for starbursts than for star forming galaxies, and longer for the quiescent ones.
- Higher normalization of sBHAR than sSFR for star forming and quiescent galaxies, while starbursts have same normalization.




## Conclusions

- We find host galaxy and black hole co-evolution at all redshifts and in all galaxy life phases.
- The bulk of the black hole mass seems to be accreted in galaxies in the main sequence phase through secular processes, where more massive galaxies are more efficient at accreting the black hole.
- Quiescent galaxies have BHARs comparable to those of star forming galaxies. The BHAR for starburst galaxies shows almost no evolution with redshift.
- The BH accretion is faster (shorter mass-doubling time-scales) than galaxy accretion in star forming and quiescent galaxies, while they grow at the same pace in starburst galaxies.

## References


[1] Rodighiero, G. et al. 2015, ApJL, 800L, 10
[2] Mullaney et al. 2012a, ApJL, 753, L30
[3] Laigle, C. et al. 2016, ApJS, 224, 24
[4] Gruppioni, C. et al. 2013, MNRAS, 432, 23G
[5] Sargent, M.T. et al. 2012, ApJL, 747, L31


## Acknowledgements


CONICYT/FONDECYT Regular/1150216
CONICYT-PCHA/Doctorado Nacional/2016-21161487
CONICYT/Anillo/ACT172033