SEAWIND meeting
Palermo, 22nd January 2026

Connecting X-ray Variability with AGN physical properties and a new path to Cosmological distances

Matilde Signorini
ESA Research Fellow
matilde.signorini@esa.int

+ F. Ricci, A. Tortosa, S. Bianchi,
F. La Franca and others

Introduction

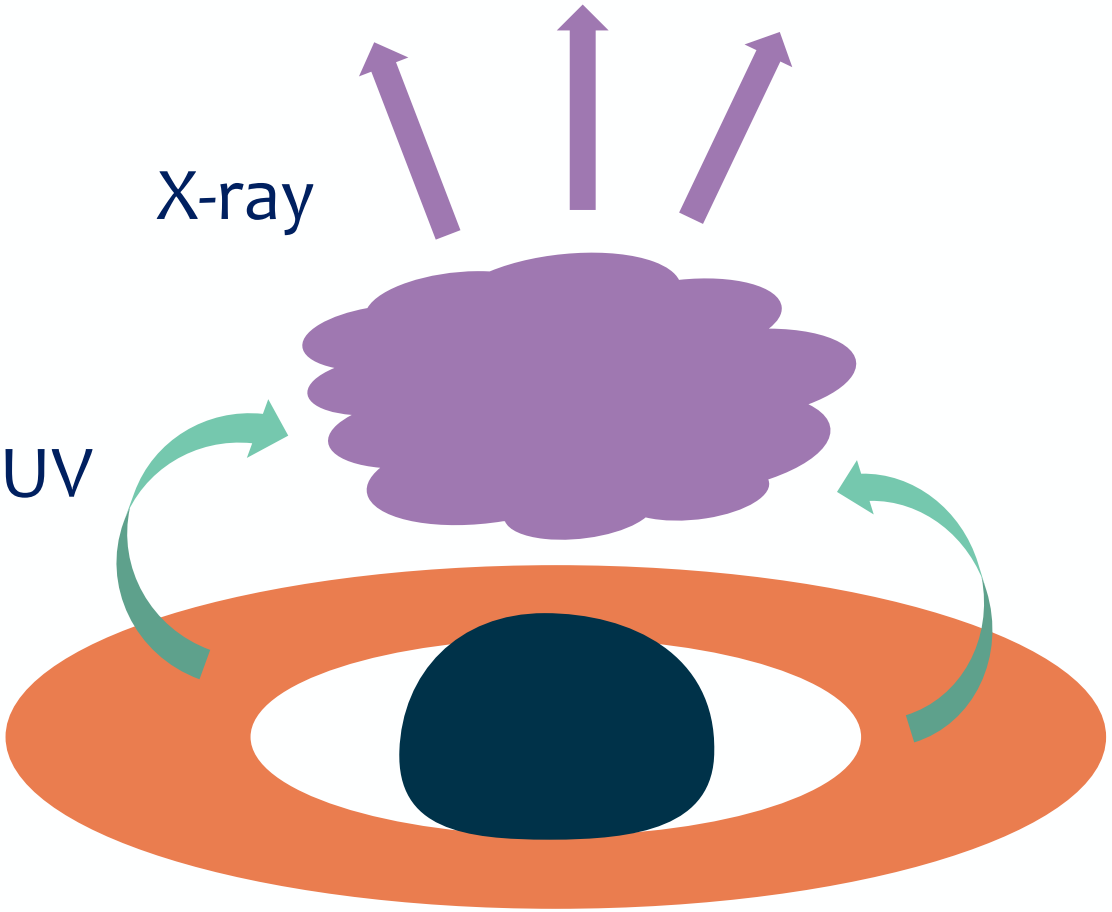
Some things we kind of know about the Corona:

- It is made from a hot electron plasma
- X-ray emission comes form Inverse Compton on UV photons coming from the disk
- It is small and close to the SMBH

Some things we do not know about the Corona:

- How is it fuelled?
- What does it know about the M_{BH}, the disc emission, and the accretion rate?

We can use the fact that the X-ray emission varies on short timescales: by looking at what correlates with the variations we can learn what the corona *cares about*



The sample

BASS

BAT AGN Spectroscopic Survey

The Swift Burst Alert Telescope Active Galactic Nuclei Spectroscopic Survey

(I learned this is called a 'nested acronym')

151 type-1 AGN at z<0.3 (most of them below 0.05)

- X-ray detected + XMM-Newton data
- Optical/UV data, 140 have Hα/Hβ lines, 40 have Paschen lines
  - All have M_{BH} estimates from Single Epoch, 34 from Reverberation Mapping

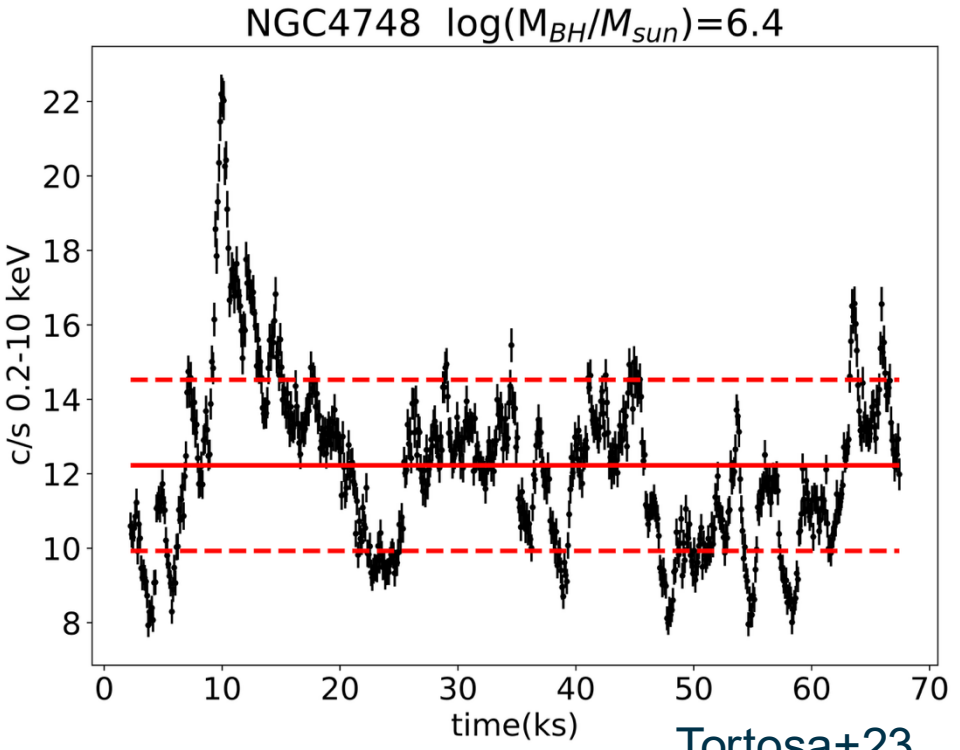


How do we measure variability?

Excess variance: we look at the lightcurve and compute *how much of the variability is too much to be consistent with uncertainties on flux estimates*

$$\sigma^2_{\mathrm{NXS}} = \frac{S^2 - \sigma^2}{\bar{x}^2}$$

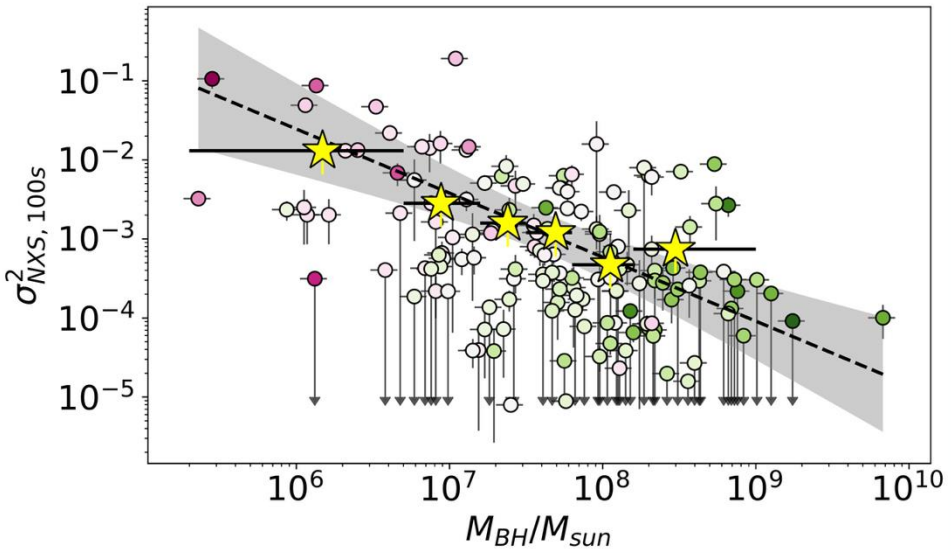
$$\langle S^2 \rangle = \int_{\nu_1}^{\nu_2} P(\nu) d\nu$$



Tortosa+23

Previous work

Tortosa+23

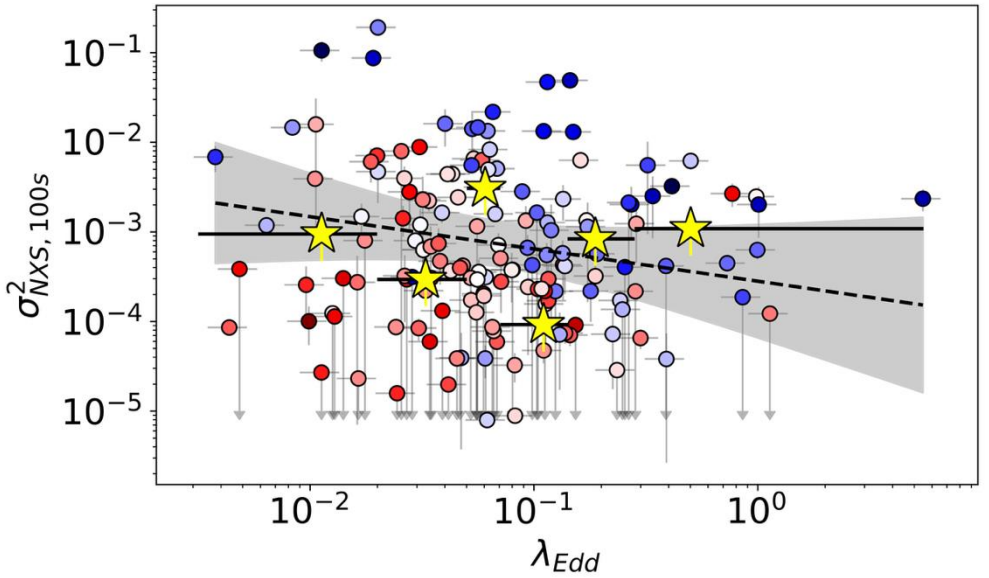


Tortosa+23 studied the correlation between the excess variance and physical properties

- Strong correlation with the M_{BH}
- Strong correlation with the L_X
- No correlation with the Eddington Ratio

Previous work

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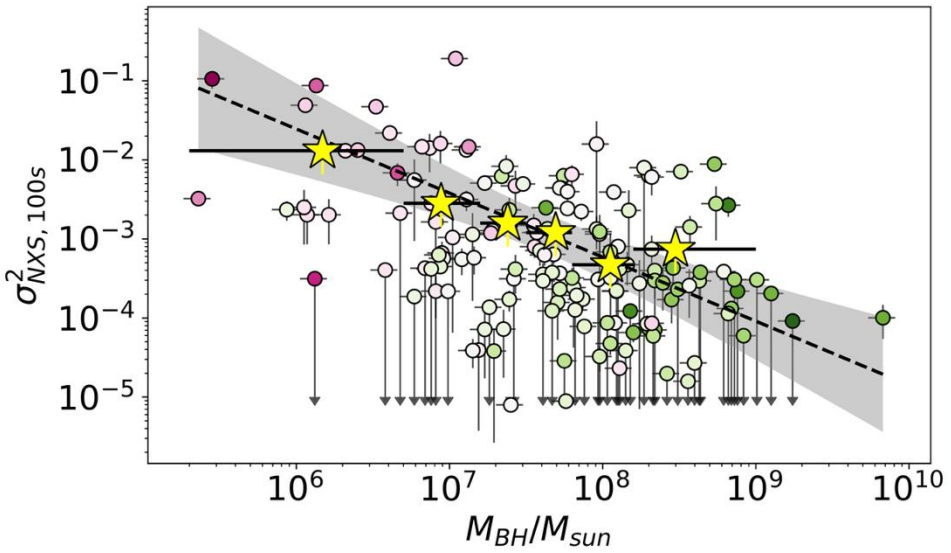


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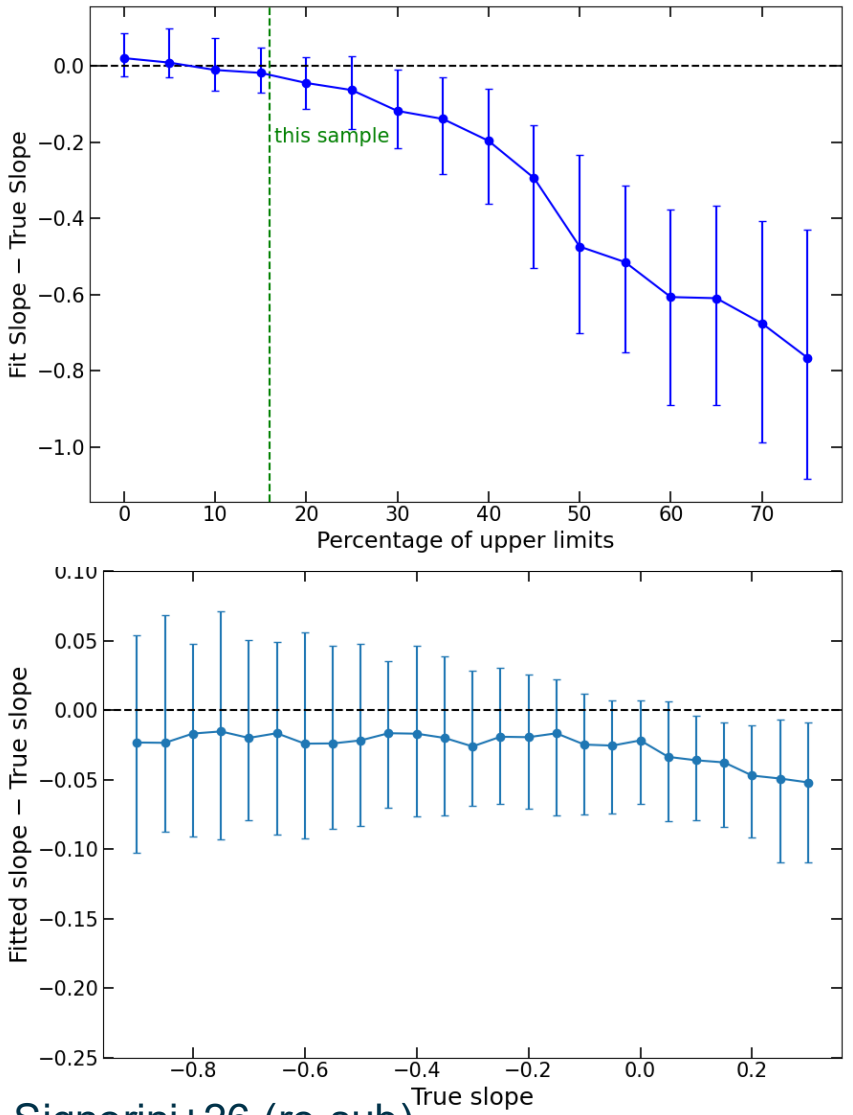
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In this work:

- Alessia Tortosa re-calculated the excess variance using 20ks instead of 10ks: the fraction of upper limits goes from 30% to 15%
- We have Eddington Ratio values where L_{bol} comes from SED fitting (Gupta+24)
- We want to test the possible cosmological implementation of the relation

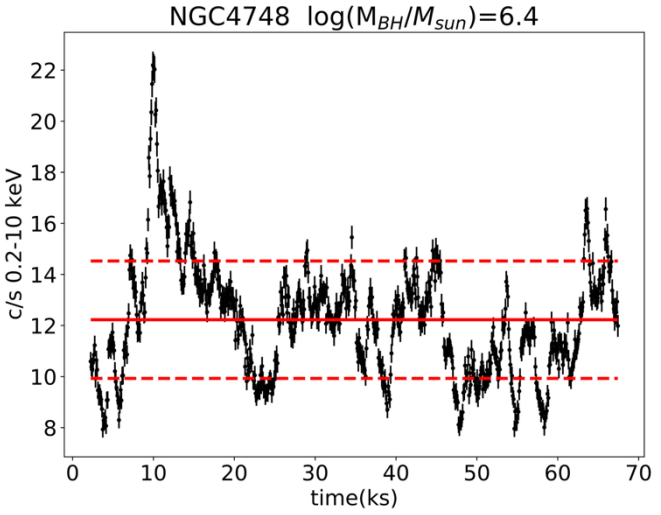
Fitting procedure

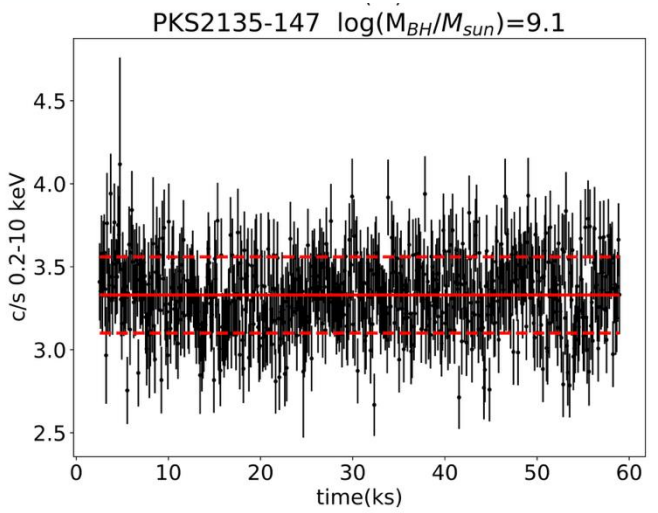


Signorini+26 (re-sub)

We have to deal with
- Asymmetric uncertainties
- Upper limits

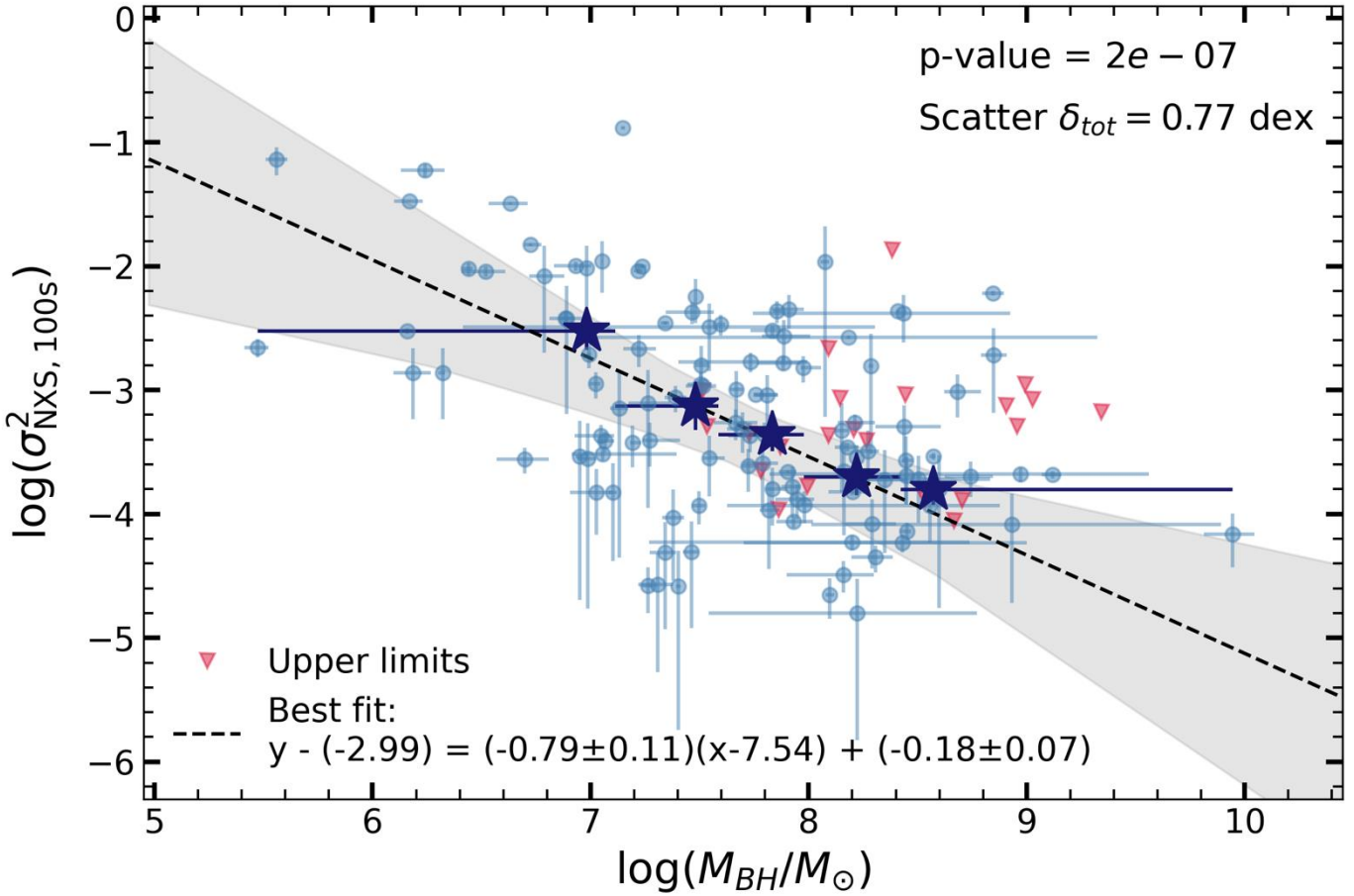
Mock samples show that we recover the true slopes between 1σ for percentage of upper limits up until 30% and for all the range of slope values that we are interested in





Tortosa+23

Excess Variance - Black Hole Mass

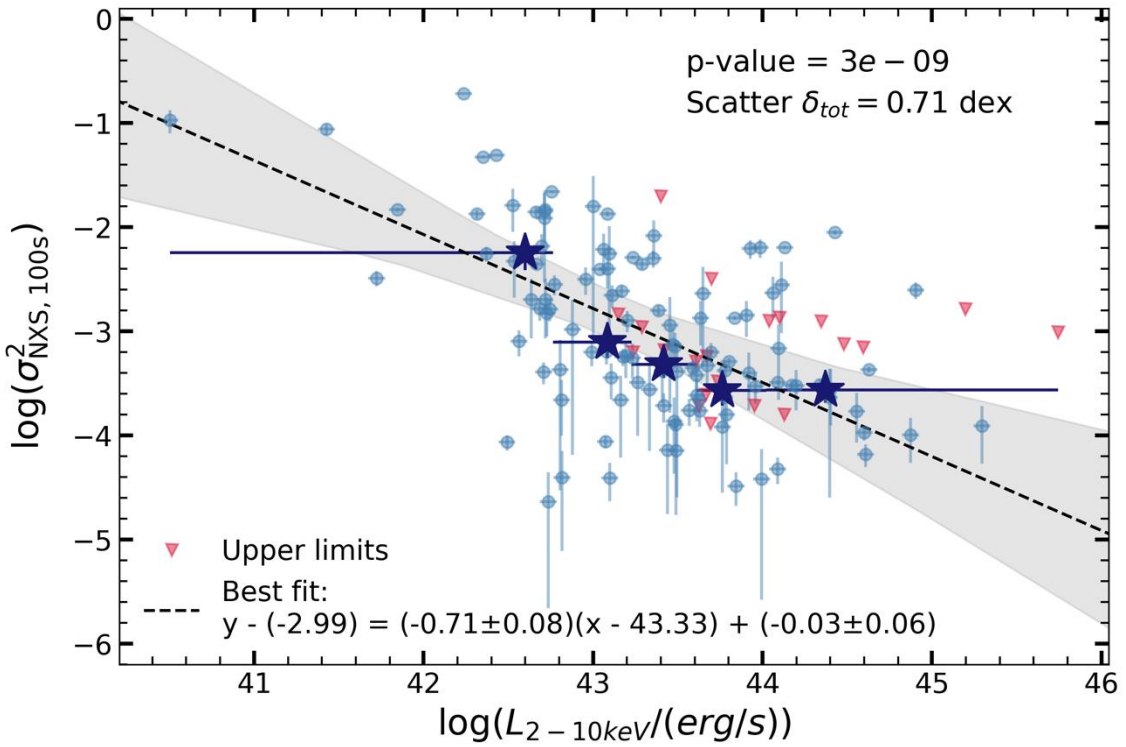


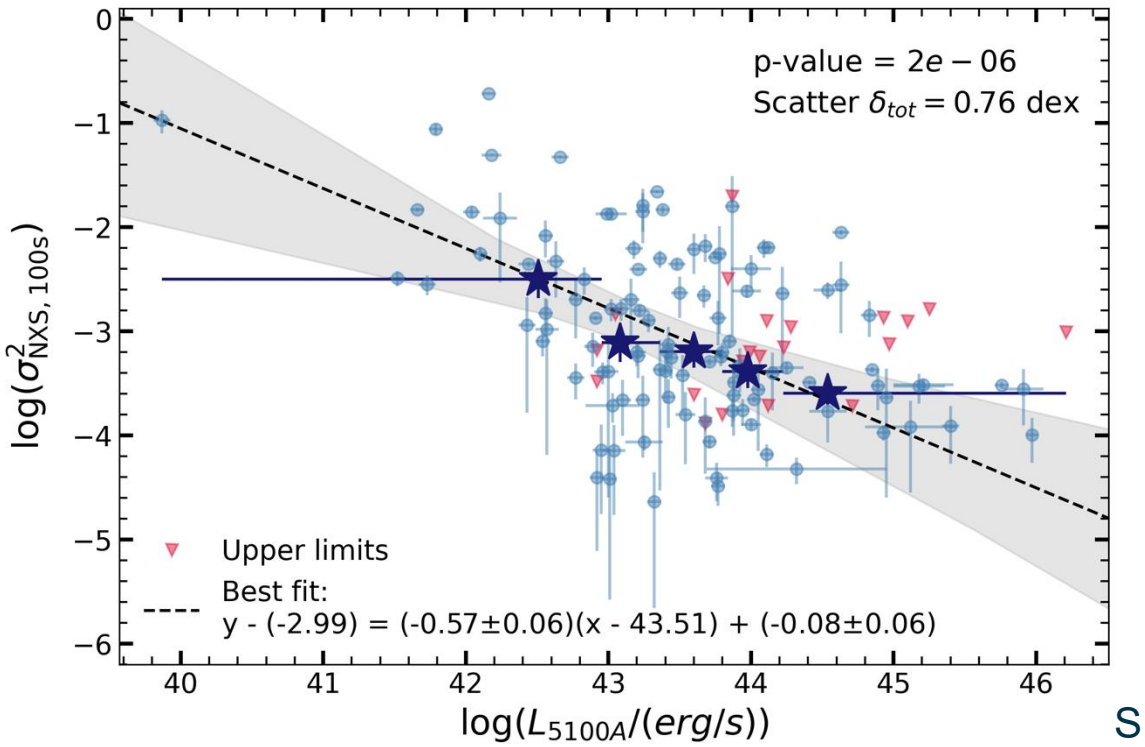
Slope: -0.79±0.11
Dispersion: 0.77 dex

Consistent with Tortosa+23 and literature results

Signorini+26

Excess Variance - Luminosity





Signorini+26

X-ray luminosity :

(i) Steeper relation (consistent with L_X-L_{UV} relation)

(ii) Has the lower scatter

What is the main driver?

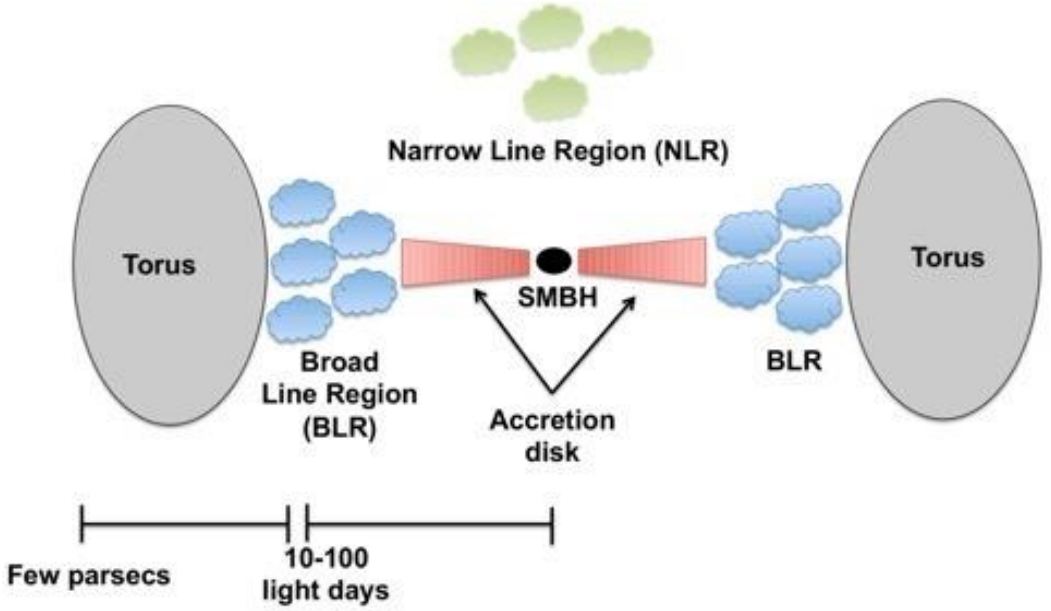
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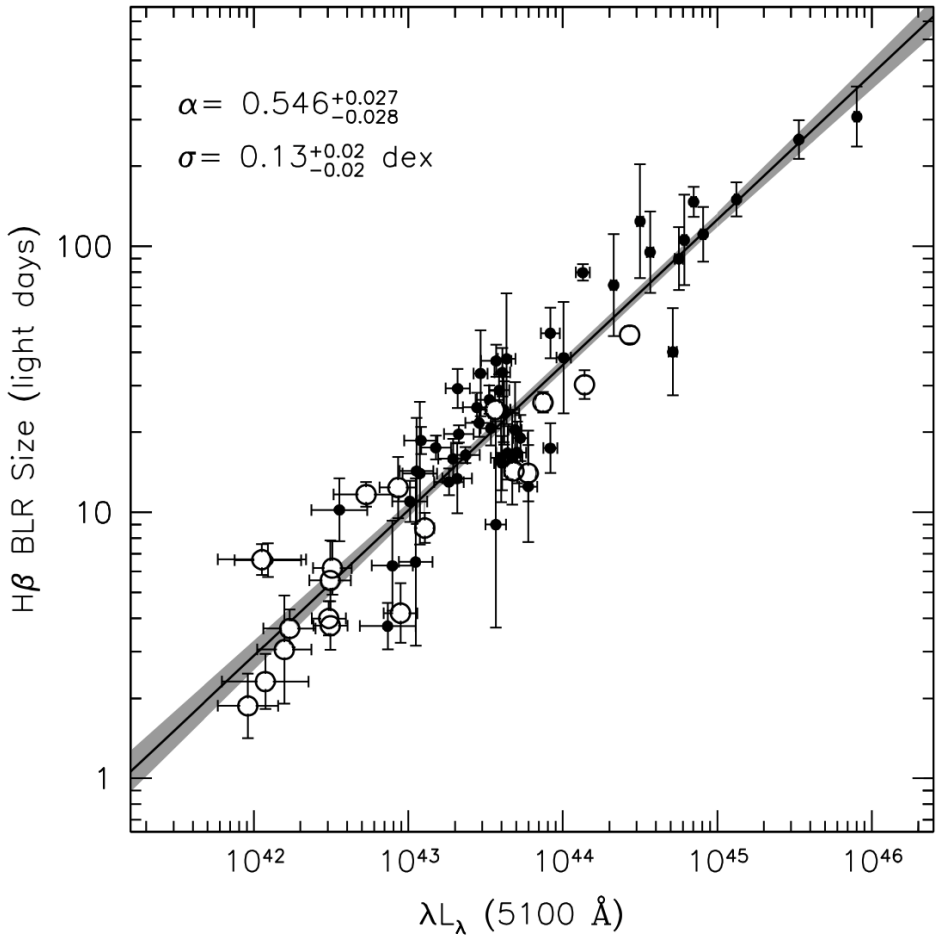
C. Ricci

L_X is directly measured, while M_{BH} is a derived quantity:

We assume the virial relation holds:

$$M_{BH} = f \frac{R_{BLR} V^2}{G}$$

What is the main driver?



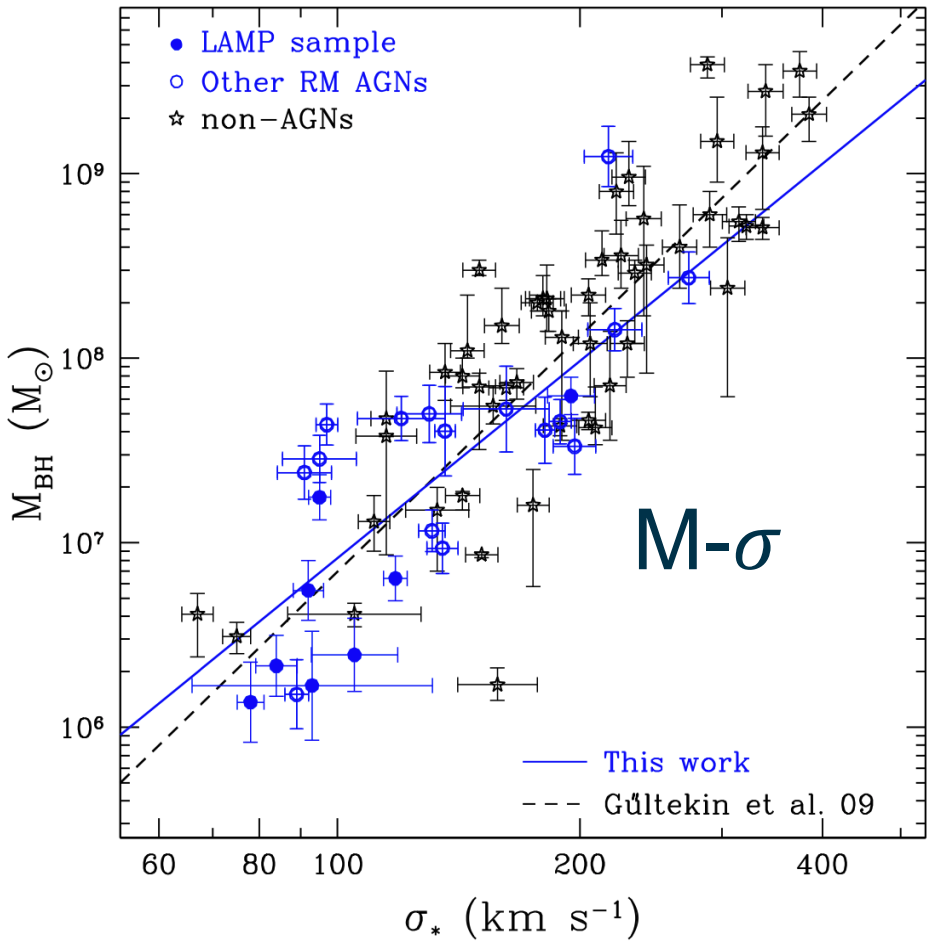
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R_{BLR} is obtained directly only for object with Reverberation Mapping (in BASS, 34/151)

For the others, we rely on Single Epoch measurements and on the R_{BLR}-L relation

Bentz+13

What is the main driver?



Woo+18

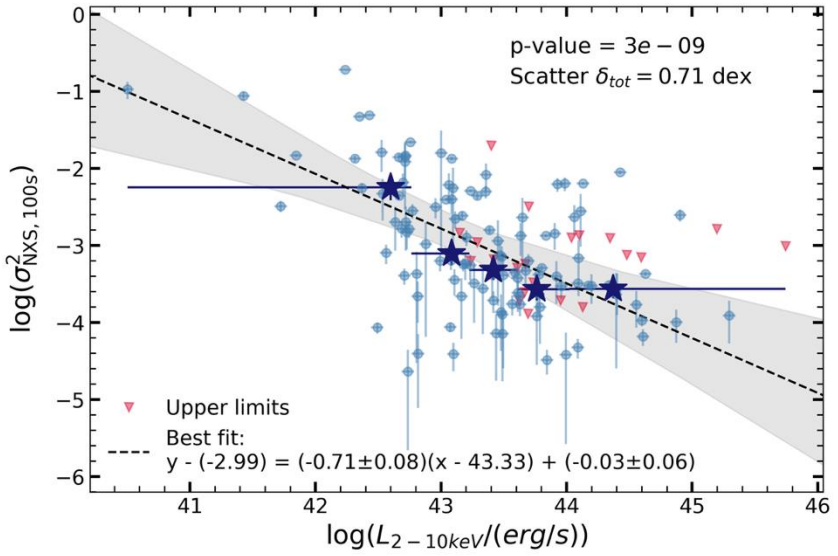
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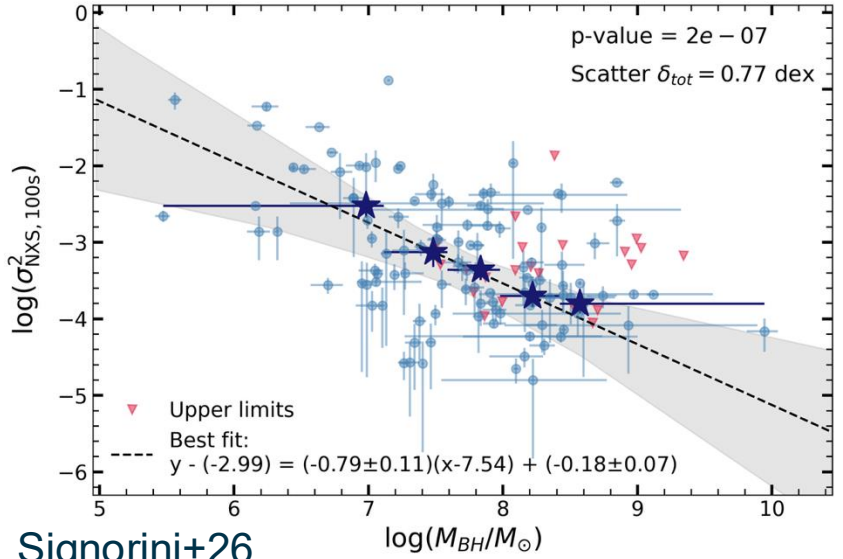
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We also calibrate an average value for the virial factor f, but we know it has a different value for each object

What is the main driver?





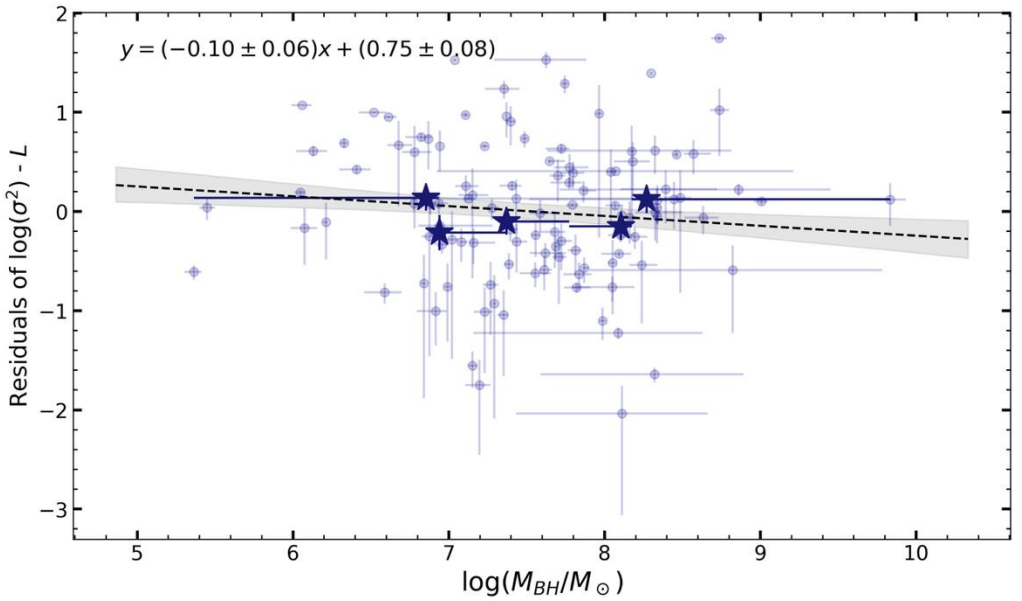
Signorini+26

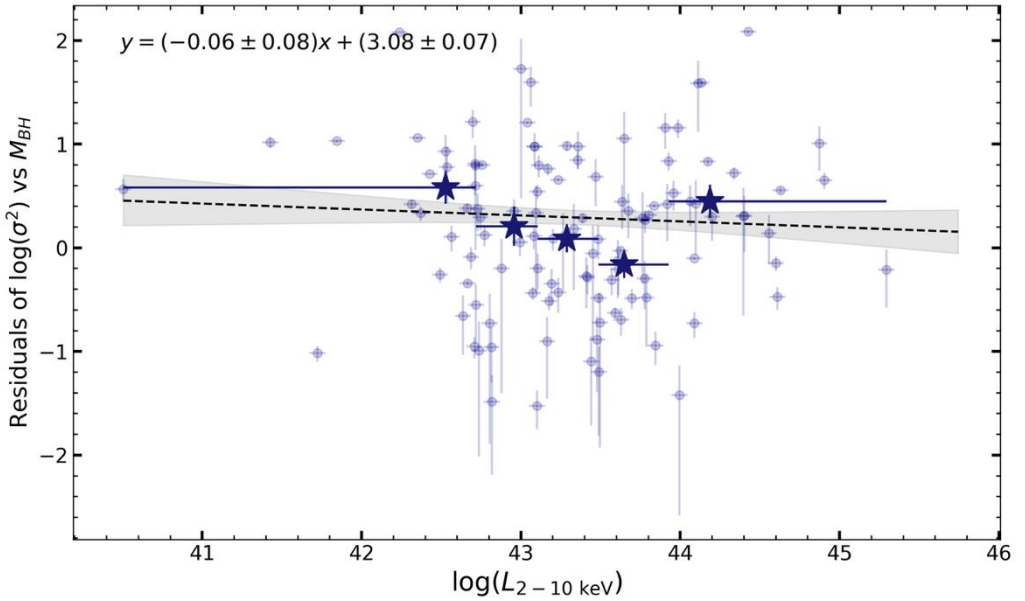
$$\log(MBH) = a + b * \log(L) + c * \log(FWHM)$$

All of this give us a 0.30-0.50 dex scatter in M_{BH} estimates that we need to consider!

If we do so, $\sigma^2 - LX$ has a bigger scatter (0.71 dex) than $\sigma^2 - M_{BH}$ (0.65-0.68 dex) but they are still very close…

What is the main driver?





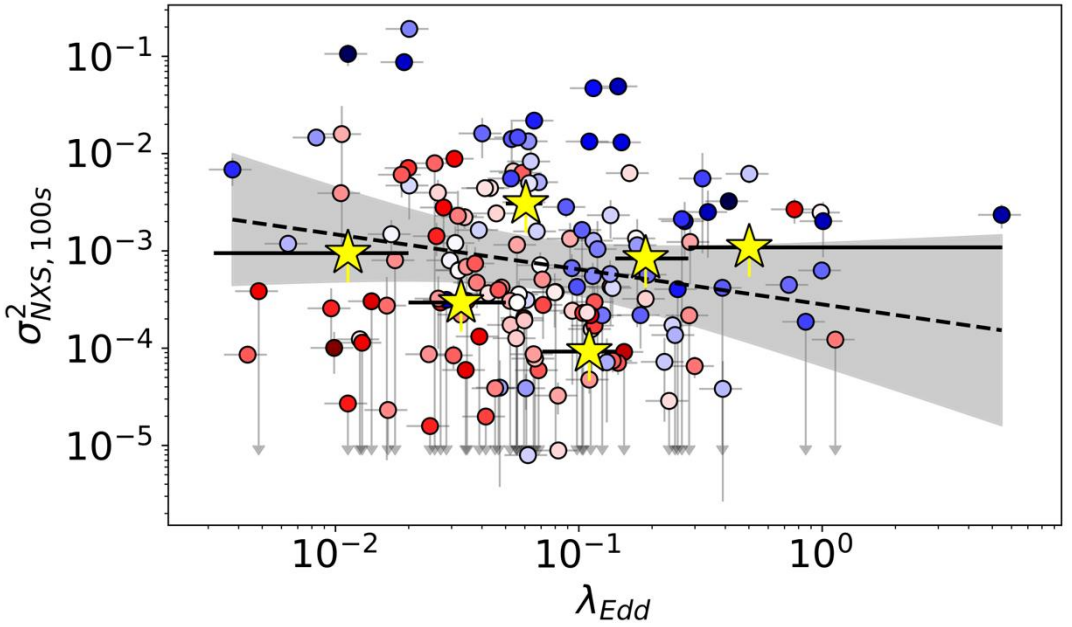
Signorini+26

Additional test to find wether L of MBH is the ‘main driver’: we fit the residuals of one fit against the other variable, and found no trend

(i) M_{BH} and L play an equal role, or
(ii) they both depend on something else, or
(iii) the trend is not so strong and/or it is washed out by uncertainties

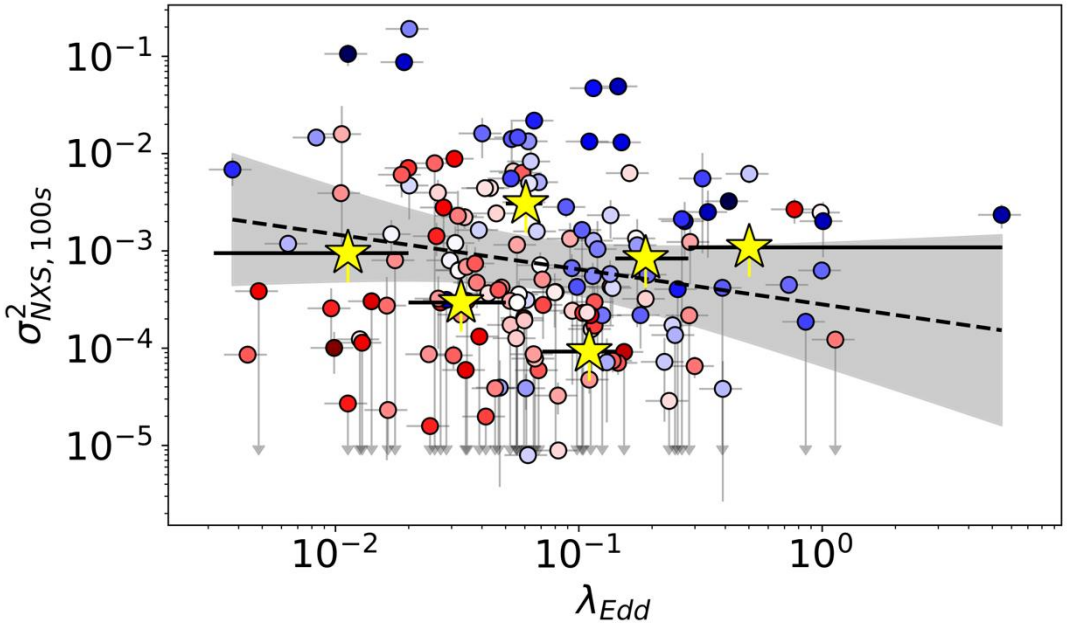
Excess variance – Eddington Ratio

Tortosa+23



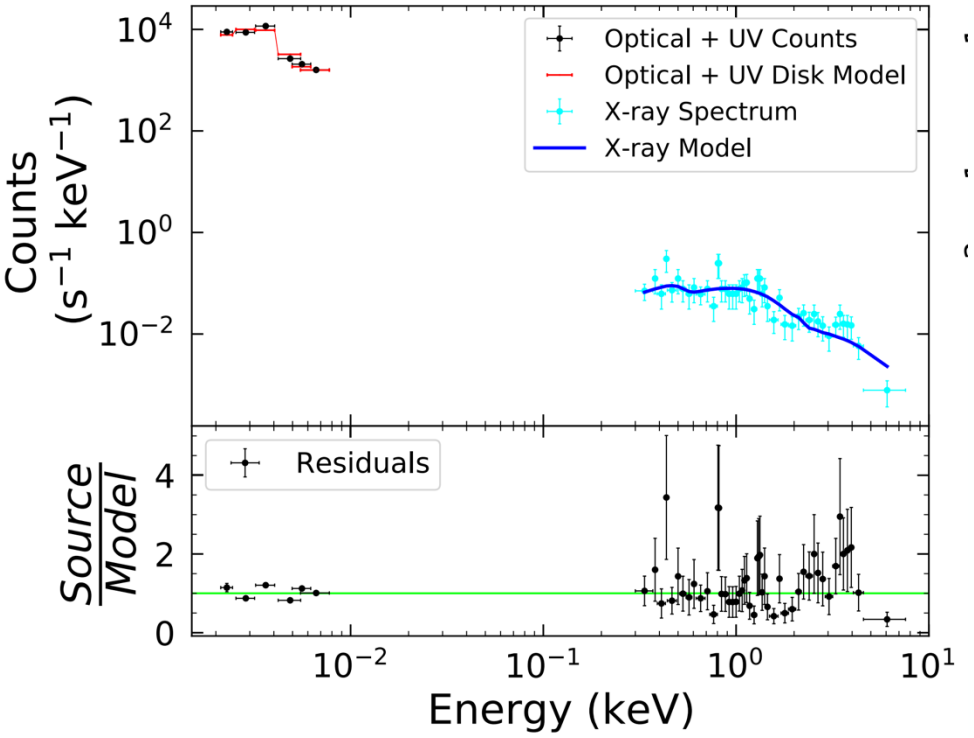
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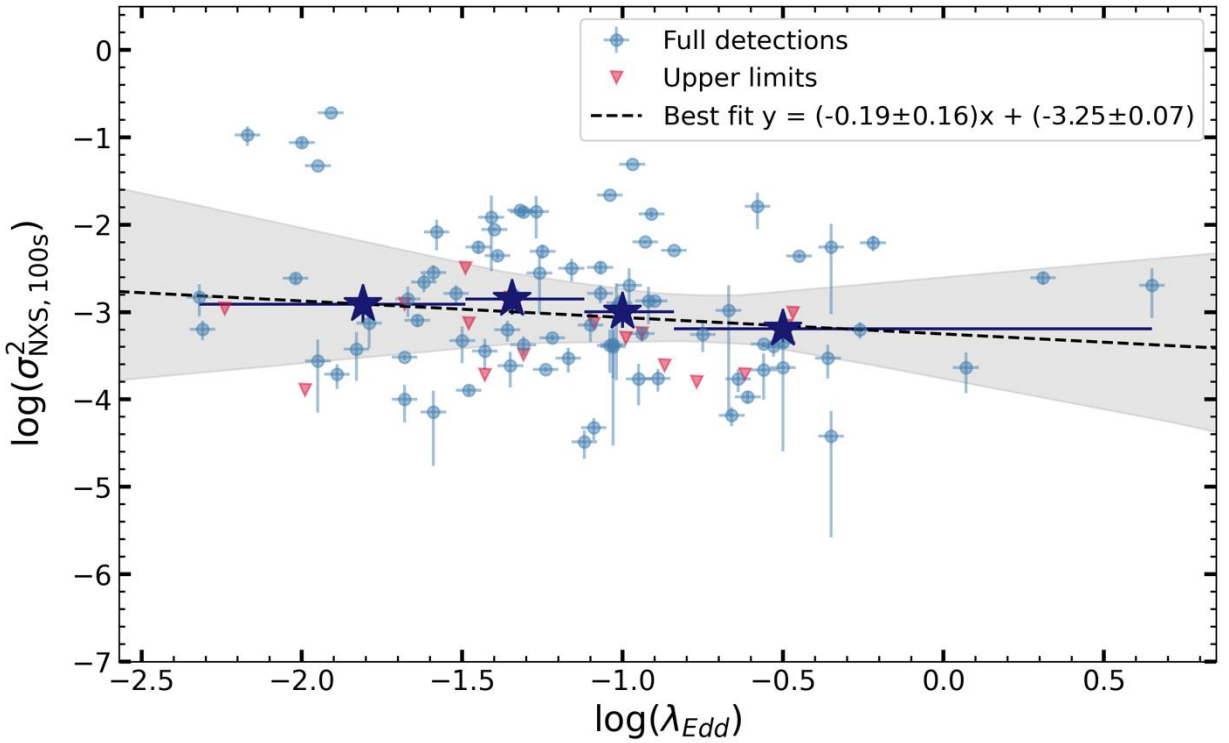


Gupta+24: SED fitting for Lbol, more reliable Eddington Ratio estimates

Gupta+24



Excess variance – Eddington Ratio

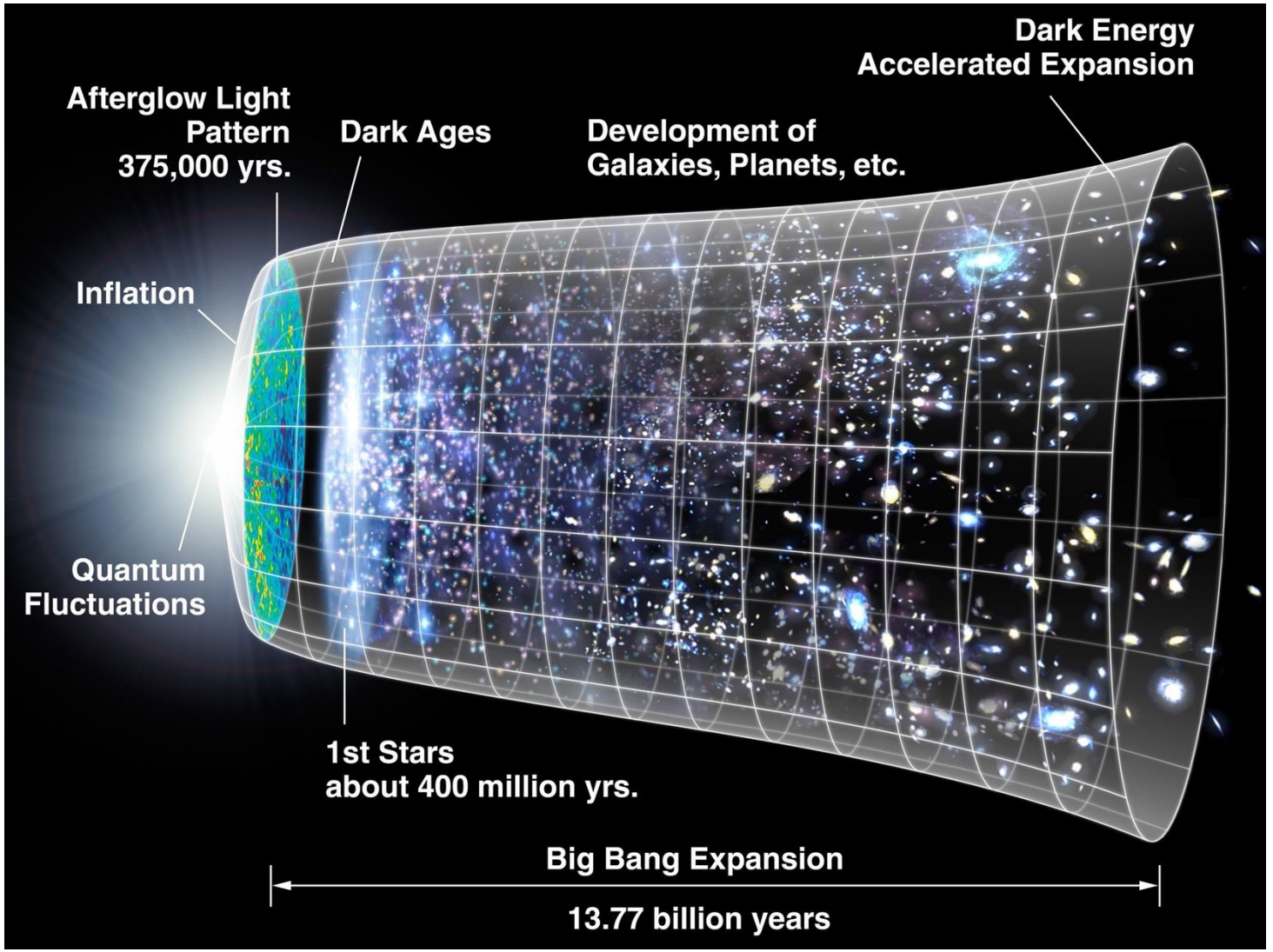


We still find no relation with the Eddington ratio

One way to further test this would be to monitor single objects and see if/how variability amplitudes change when we get a change in Eddington Ratio

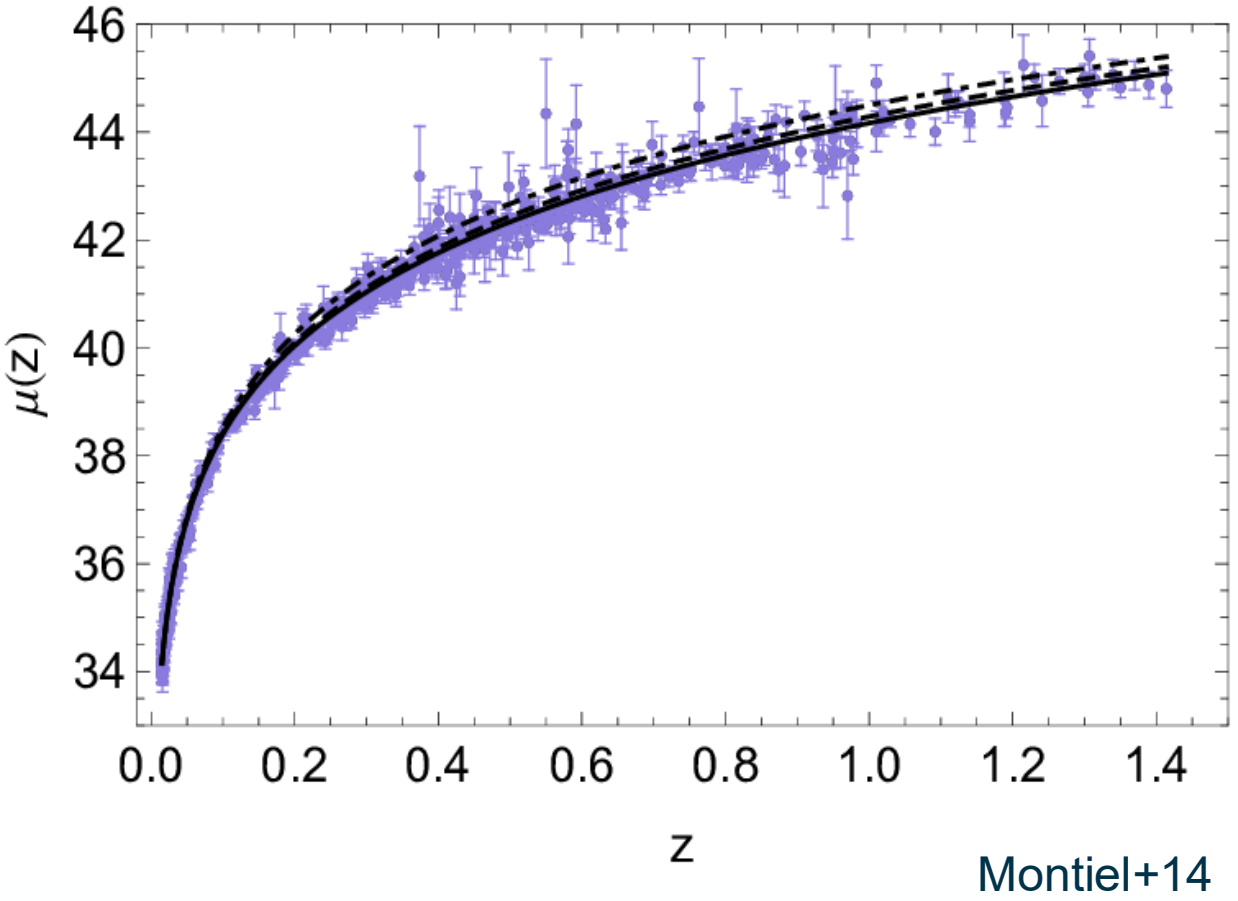
Signorini+26

Cosmological implementation



How do we trace the expansion history of the Universe? We need standard candles

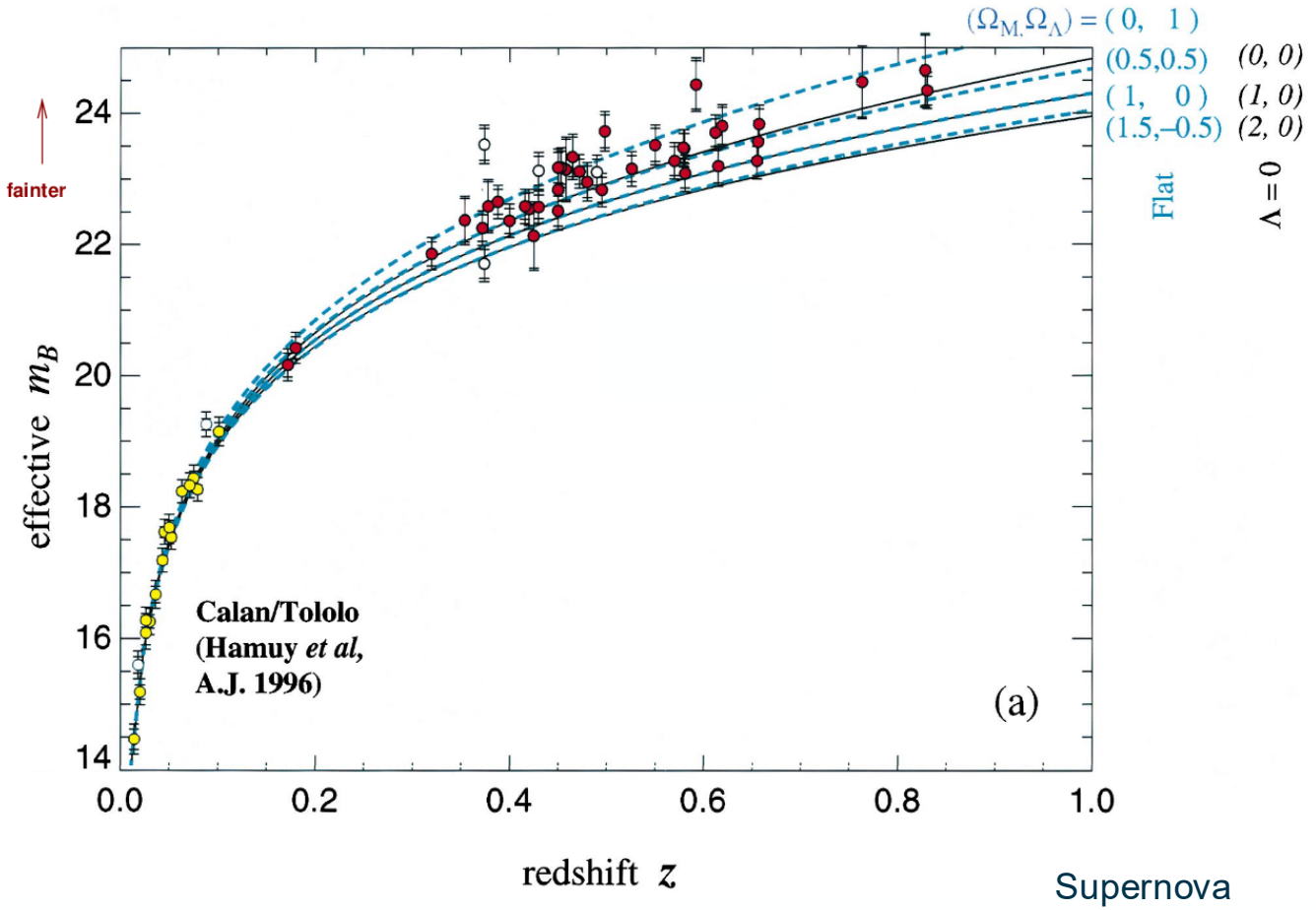
Cosmological implementation



Montiel+14

Supernovae Ia are great but are not observed at high redshift, where it is easier to distinguish between different cosmological models

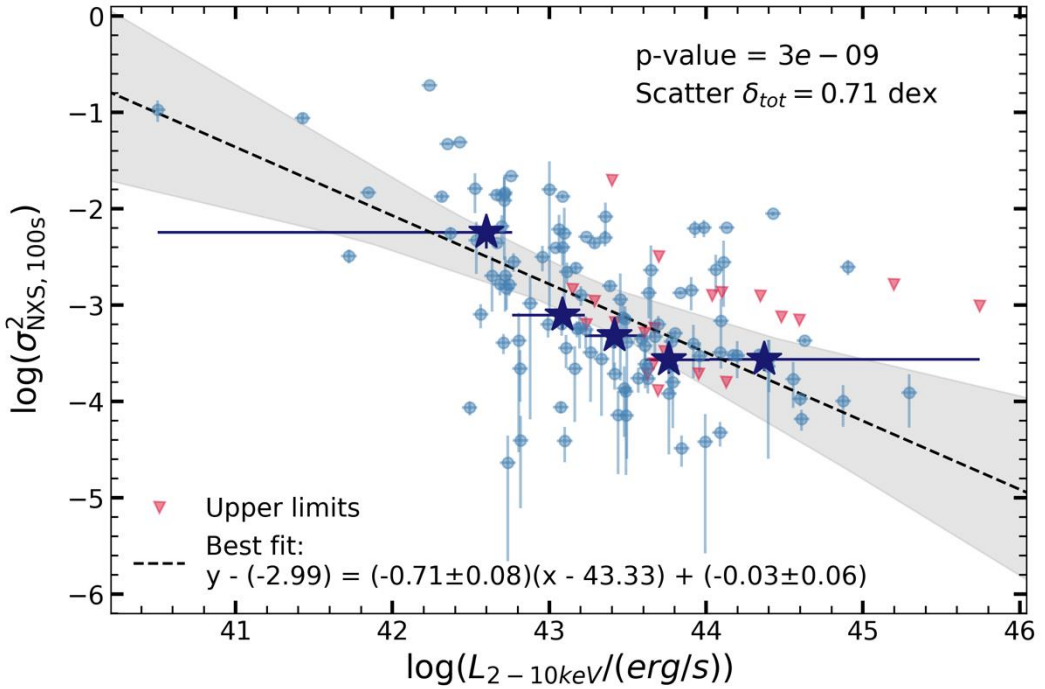
Cosmological implementation



Supernova Cosmology Project
Perlmutter+1998

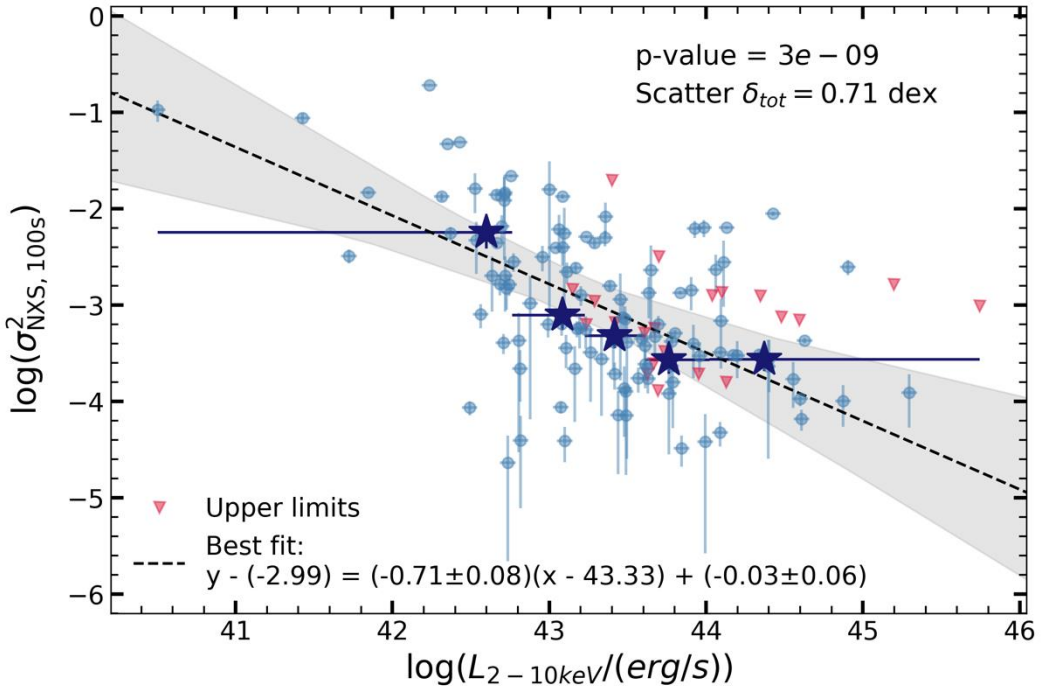
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Cosmological implementation



We can use this relation to derive Luminosity and therefore Distance by measuring the X-ray excess variance

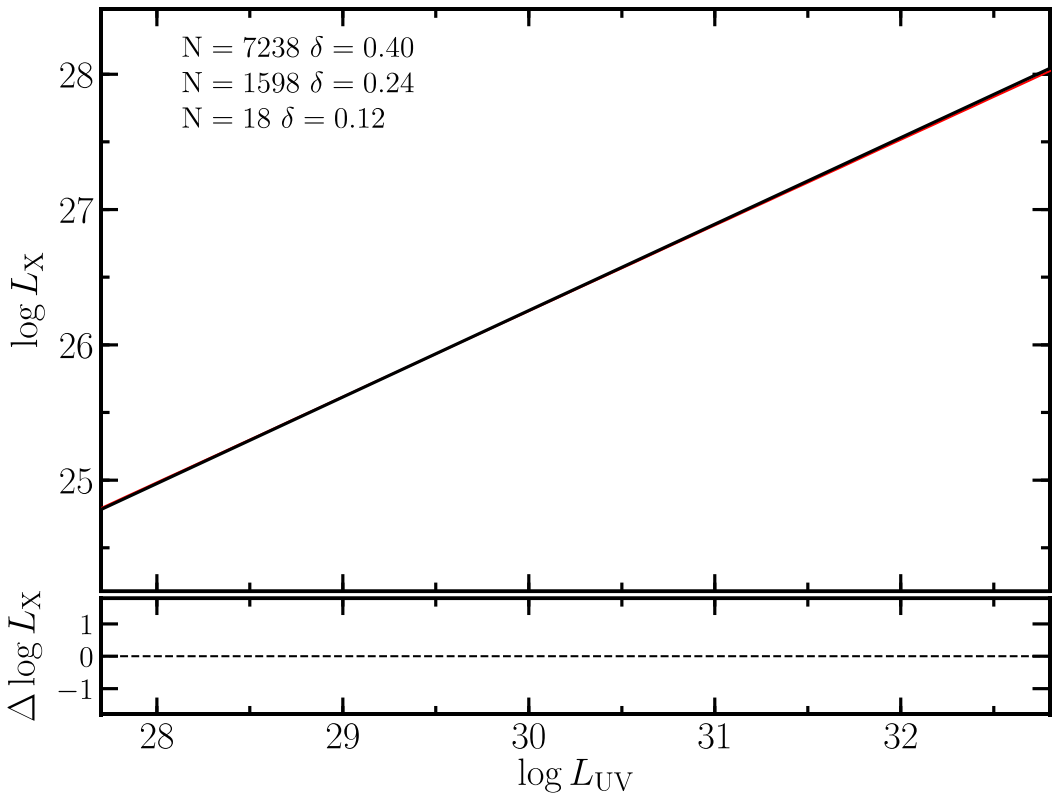
Cosmological implementation



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The main issue is that dispersion is big, uncertainties on Distances are of ~73%
Half of what was found in La Franca+14!

Cosmological implementation



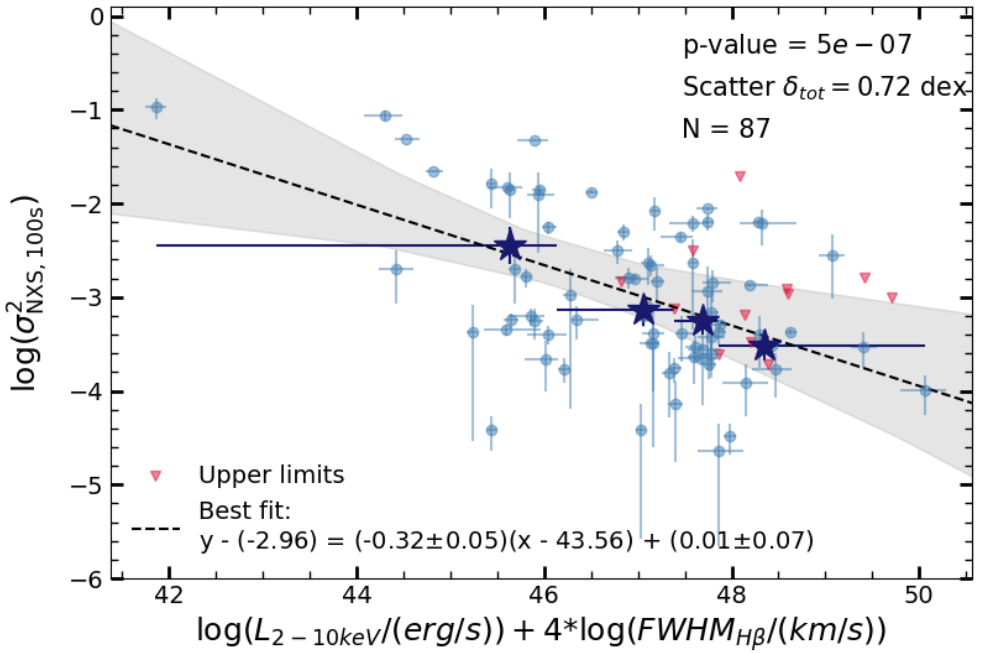
Risaliti&Lusso+19

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quasars L_X-L_{UV} relation:12-20%

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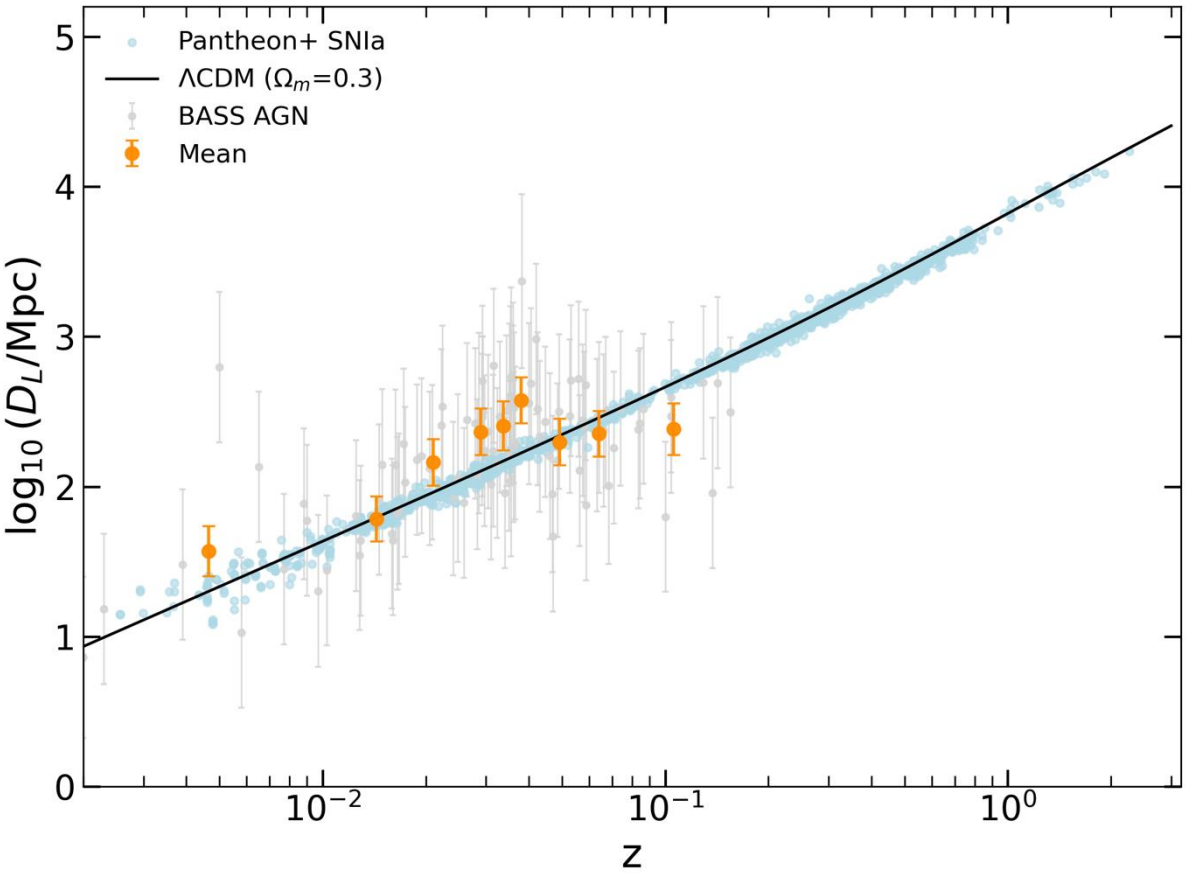
Can including broad lines information reduce the scatter? Not really (I have backup slides)

Cosmological implementation

The current sample is in the same redshift range as SNIa

Uncertainties on single objects are much bigger than in SNIa, but if we combine objects in small redshift bins we reduce uncertainties by a $\sqrt{N}$ factor

Signorini+26



Cosmological implementation

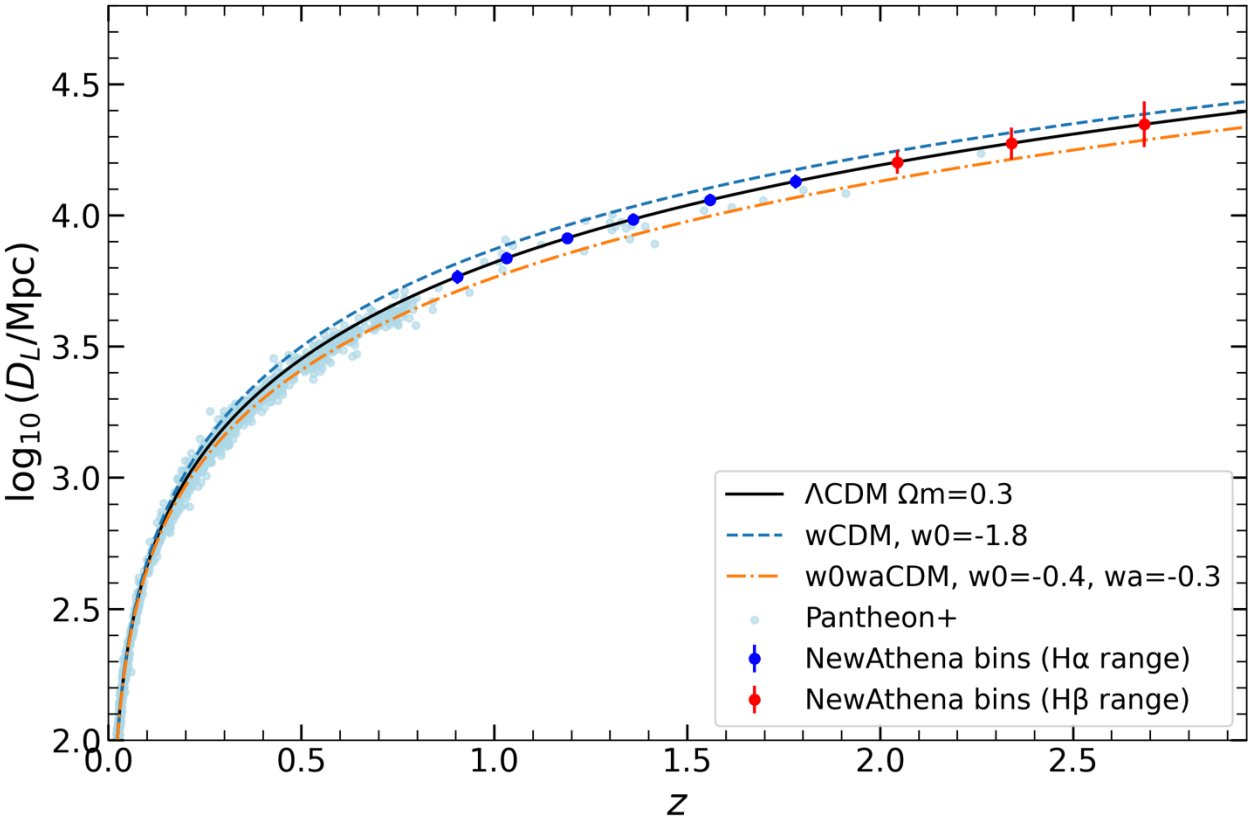
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Assuming NewAthena observing strategy (priv. comm.) and a 100% Euclid sky overlap for redshift measurement, we obtain this average Hubble Diagram

We could measure distances up to redshift ~3!

Signorini+26



Conclusions

- Longer lightcurve baselines give us fewer upper limits in excess variance measurements
- We confirm a strong correlation between X-ray variability and both the M_{BH} and monochromatic luminosities
- The M_{BH} might be the main driver, but the indication is tentative
- We still do not find a correlation between the excess variance and the Eddington Ratio
- We could use X-ray variability to obtain intrinsic luminosities and thefore distances for cosmological implementation up to redshift ~3

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