

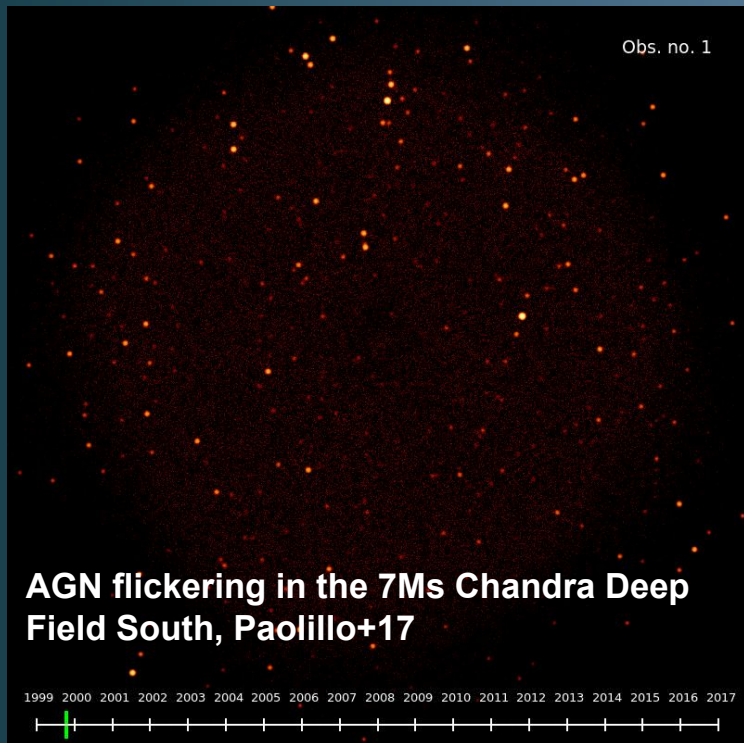
# Modelling the ensemble variability of AGN: Constraints on the Black Hole Mass vs Stellar Mass Relation

Antonios Georgakakis (National Observatory of Athens)

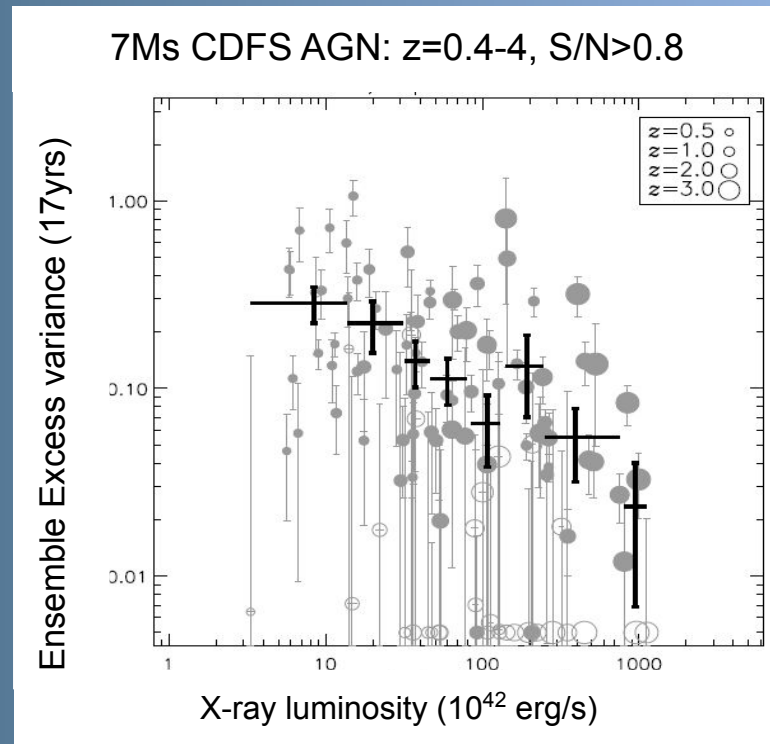
I. Papadakis (University Crete)

M. Paolillo (University of Napoli)

# Ensemble Variability of AGN populations: The 7Ms Chandra Deep Field South Field



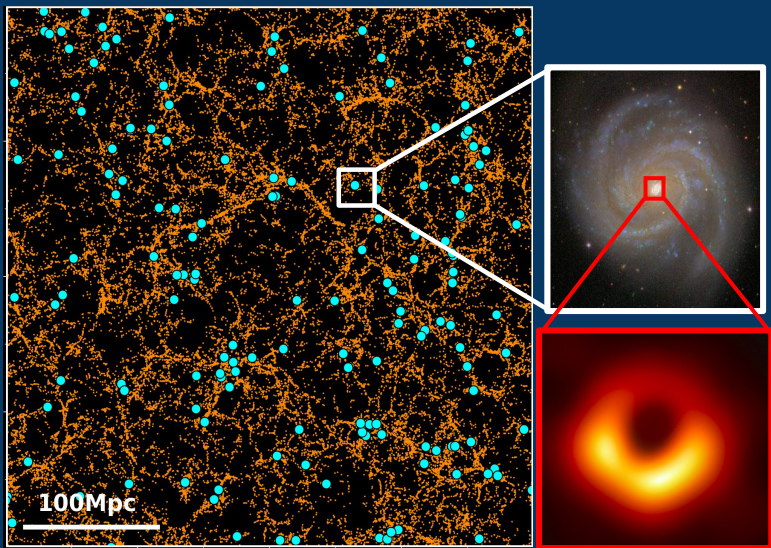
<https://people.na.infn.it/~paolillo/CDFS.html>



7Ms CDFS: Paolillo+17

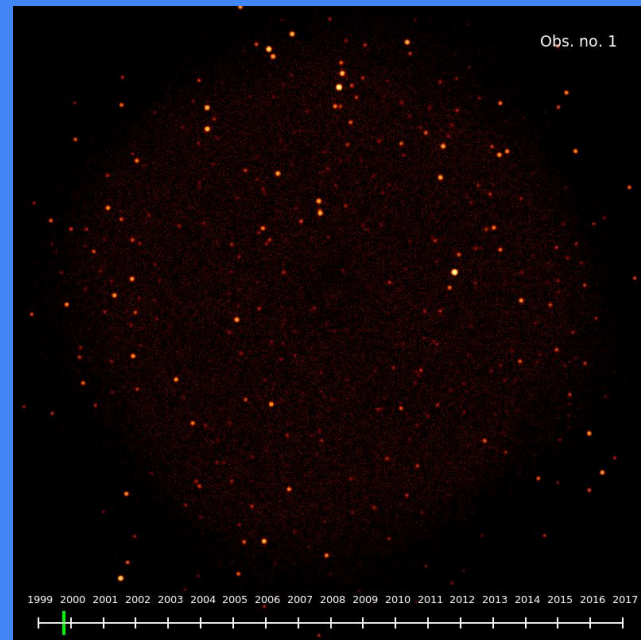
# AGN Demographics

Incidence of active black holes in galaxies



# AGN Variability

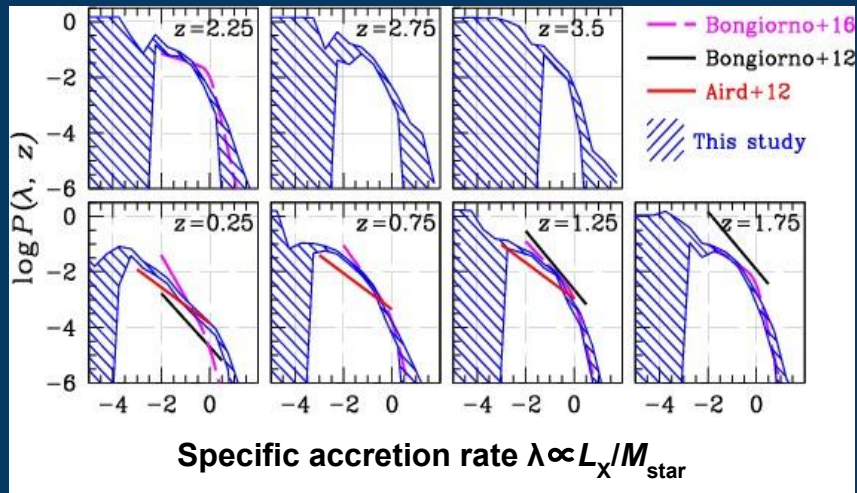
Stochastic flux variations, ensemble variability of AGN populations



CDFS: Paolillo+17

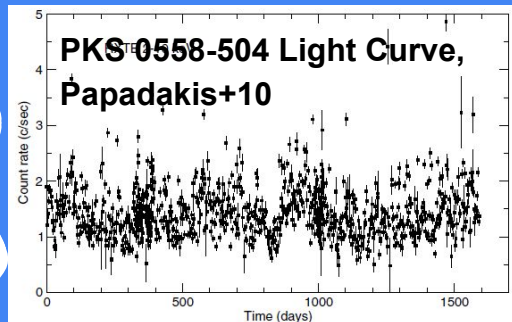
# AGN Demographics

Incidence of active black holes in galaxies



# AGN Variability

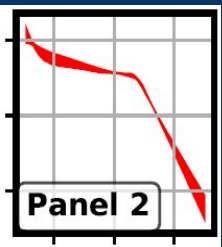
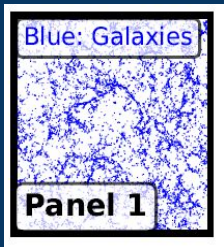
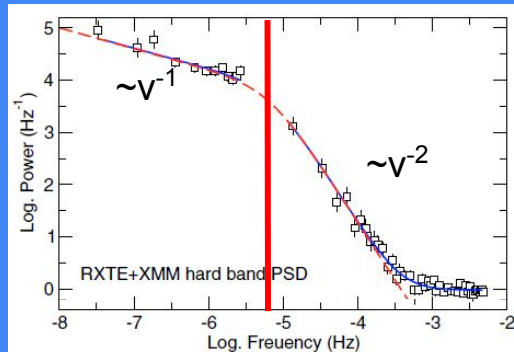
Stochastic flux variations, ensemble variability of AGN populations



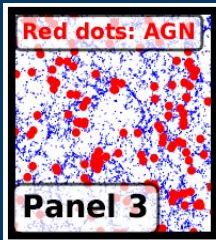
Fourier Space

Power Spectral Density, PSD:

$$\text{PSD} = f(M_{\text{BH}}, \lambda_{\text{EDD}})$$

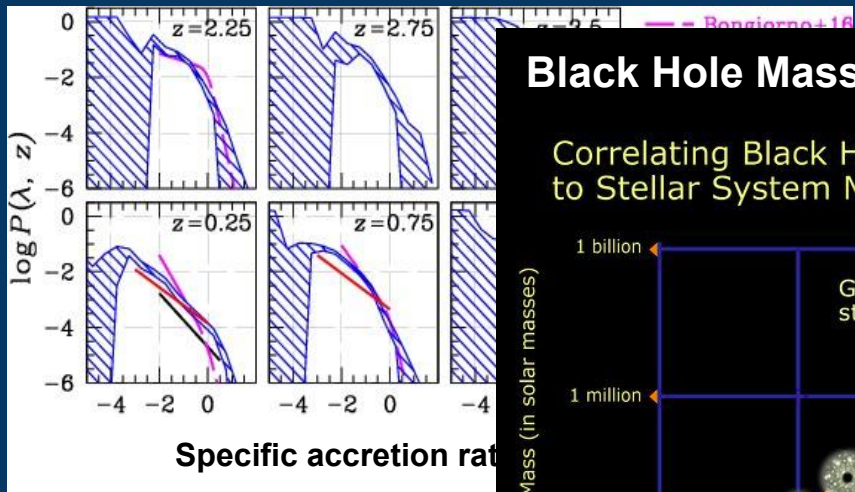


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# AGN Demographics

Incidence of active black holes in galaxies

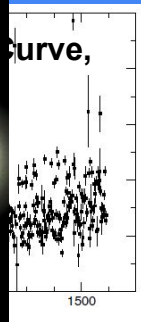
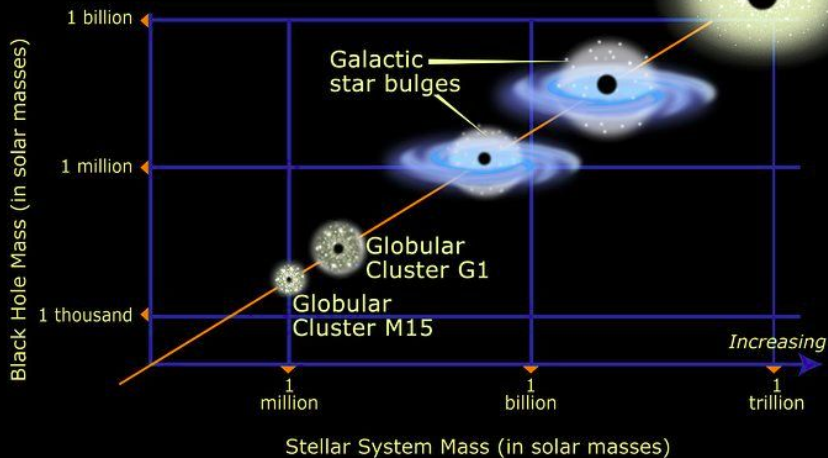


# AGN Variability

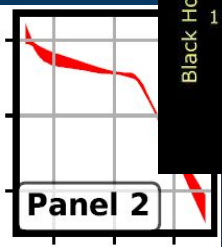
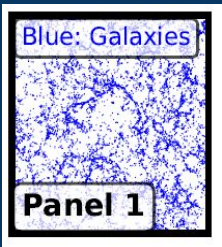
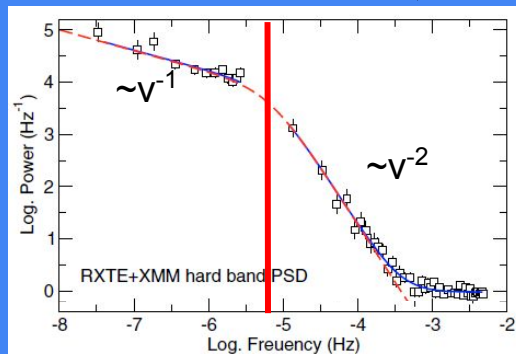
Stochastic flux variations, ensemble variability of AGN populations

## Black Hole Mass - Stellar Mass Relation

Correlating Black Hole Mass to Stellar System Mass



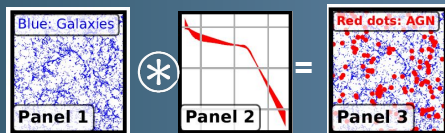
Fourier Space



# Modeling the ensemble variability of AGN vs X-ray luminosity in the CDFS

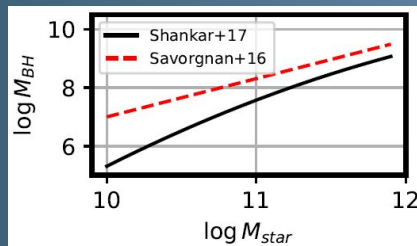
Demographics

Simulate AGN and their host galaxies in a cosmological volume ( $L_{\text{AGN}}$ , redshift,  $M_{\text{star}}$ )



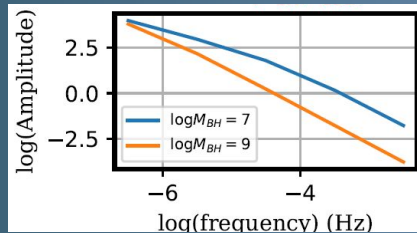
$M_{\text{BH}}-M_{\text{star}}$  relation

$M_{\text{BH}}-M_{\text{star}}$  relation: seed AGN with Black Holes ( $L_{\text{AGN}}$ , redshift,  $M_{\text{star}}$ ,  $M_{\text{BH}}$ ,  $\lambda_{\text{EDD}}$ )

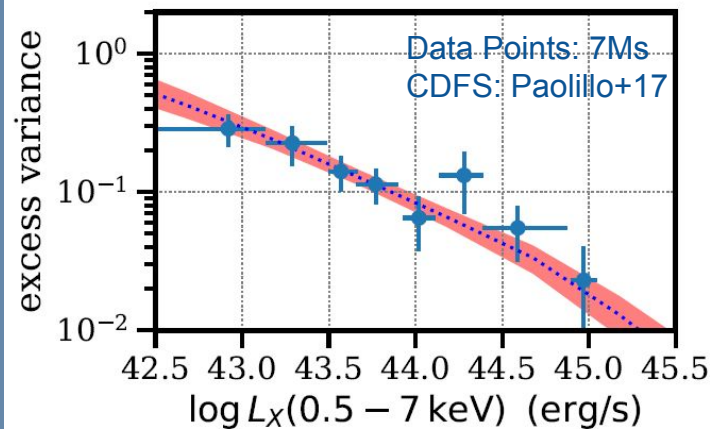


Variability

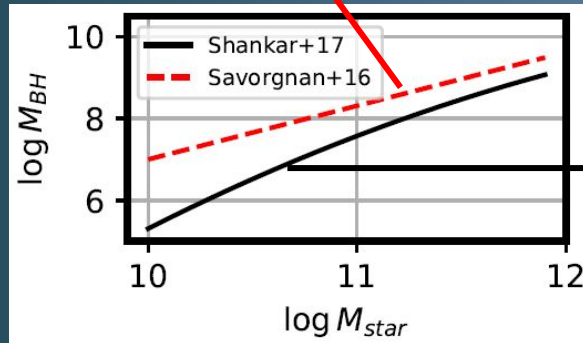
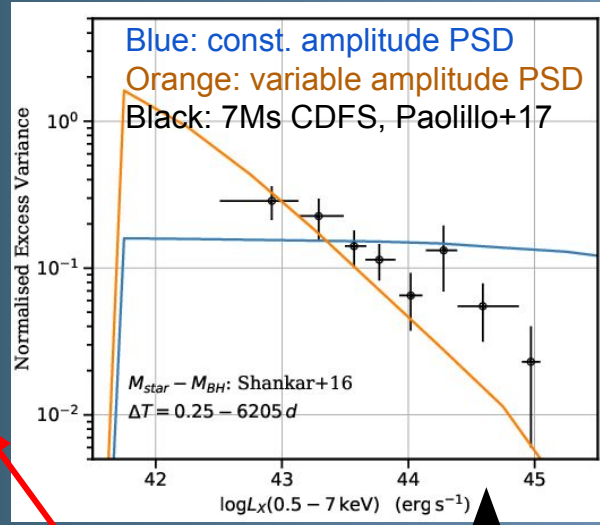
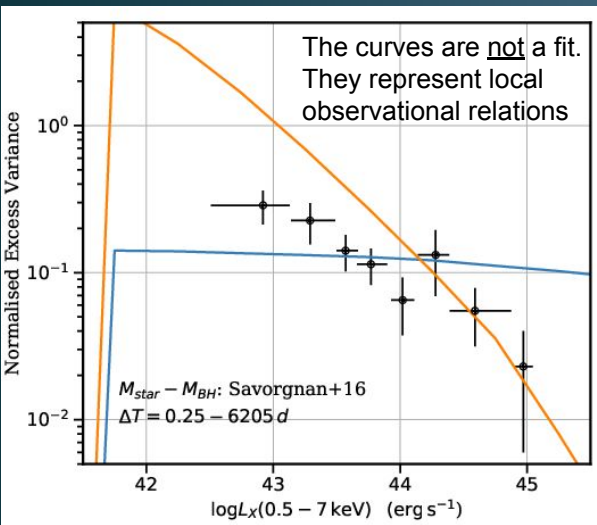
PSD model:  $\text{PSD} = f(M_{\text{BH}}, \lambda_{\text{EDD}})$ , variability dependence on physical params.



Ensemble Excess Variance vs AGN luminosity CDFS



# Ensemble variance: observations vs model predictions



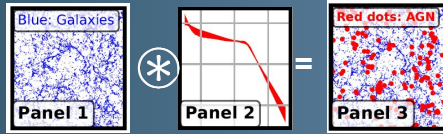
1. Observations favour PSD models with variable amplitude that depends on the physical properties of the AGN, e.g.  $\lambda_{\text{Edd}}$ .
2. Model predictions sensitive to  $M_{\text{BH}} - M_{\text{star}}$  relation.

**Ensemble variance can provide constraints on both PSD models and  $M_{\text{BH}} - M_{\text{star}}$  parametrisations.**

# Bayesian inference modeling of the ensemble variability of AGN vs X-ray luminosity in the CDFS

Demographics

Simulate AGN and their host galaxies in a cosmological volume ( $L_{\text{AGN}}$ , redshift,  $M_{\text{star}}$ )



$M_{\text{BH}}-M_{\text{star}}$  relation

$M_{\text{BH}}-M_{\text{star}}$  relation: seed AGN with Black Holes ( $L_{\text{AGN}}$ , redshift,  $M_{\text{star}}$ ,  $M_{\text{BH}}$ ,  $\lambda_{\text{EDD}}$ )

$$\log M_{\text{BH}} = \alpha + \beta \cdot (\log M_{\star} - 10)$$

Variability

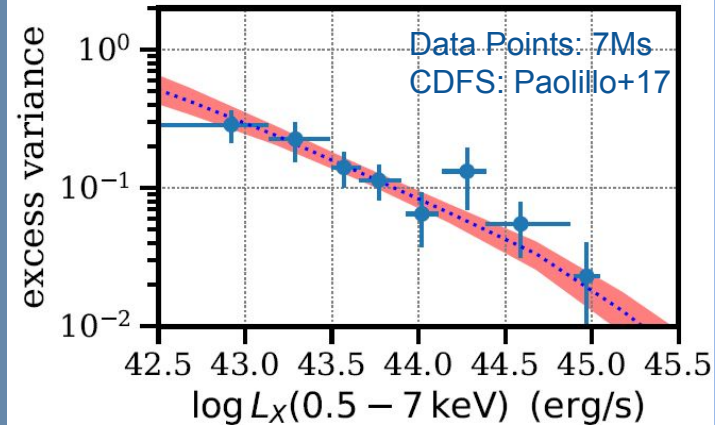
PSD model:  $\text{PSD} = f(M_{\text{BH}}, \lambda_{\text{EDD}})$ , variability dependence on physical params.

$$\text{PSD}(\nu) = A \nu^{-1} \left(1 + \frac{\nu}{\nu_b}\right)^{-1}$$

$$A = 2 \cdot \nu_b \cdot \text{PSD}(\nu_b) = \delta \cdot \lambda_{\text{Edd}}^{\gamma}$$

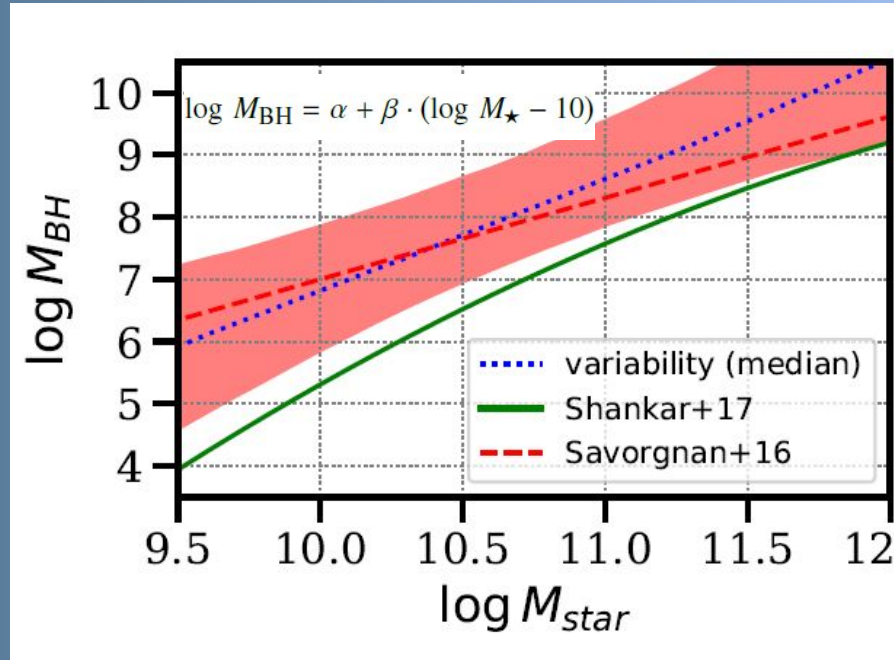
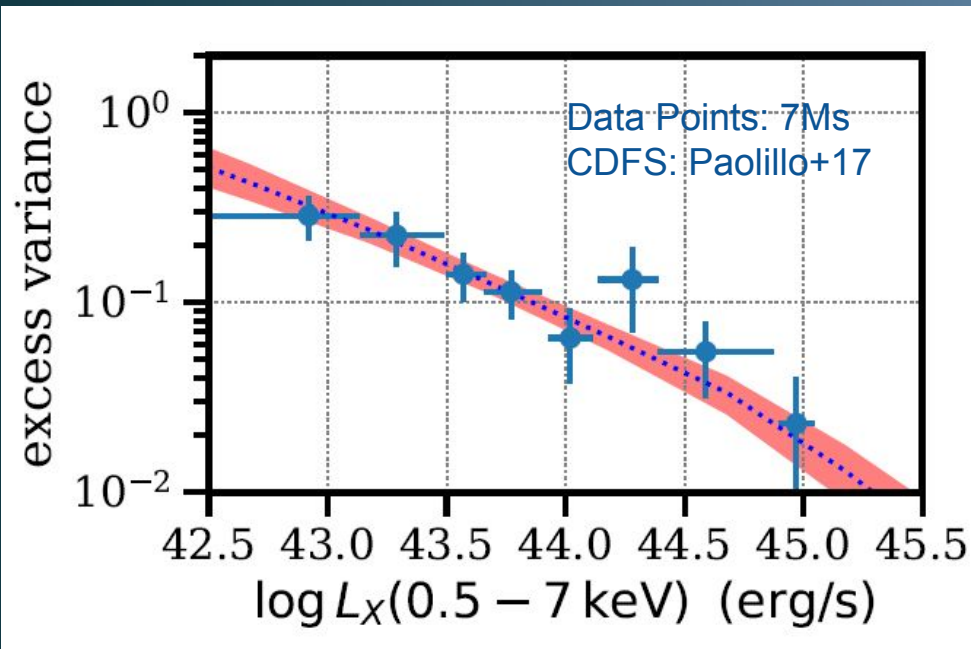
$$\nu_b = \frac{580}{M_{\text{BH}}/M_{\odot}} \text{ (s}^{-1}\text{)}$$

Ensemble Excess Variance vs AGN luminosity CDFS





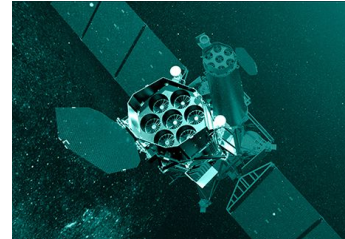
# Bayesian inference: joint constraints on the PSD and the $M_{\text{BH}} - M_{\text{star}}$ relation.



Results consistent with  $M_{\text{BH}} - M_{\text{star}}$  relations derived using dynamical masses

# Conclusions and future prospects

- The ensemble variance of AGN provides a handle on both the  $M_{\text{BH}} - M_{\text{star}}$  relation and models of the variability of AGN.
- Main limitations:
  - small size of current samples
  - systematics
- eROSITA provides light curves for millions of AGN with 0.5yr cadence over 2.5 years.
  - Study ensemble variance as a function of  $L_x$ ,  $M_{\text{star}}$ ,  $z$ .
  - Explore  $M_{\text{BH}} - M_{\text{star}}$  relations as a function of redshift.
  - Constrain PSD models.
  - Requires control over systematics (via simulations).



# Model Posteriors

Model:

$$\log M_{\text{BH}} = \alpha + \beta \cdot (\log M_{\star} - 10)$$

$$PSD(\nu) = A \nu^{-1} \left( 1 + \frac{\nu}{\nu_b} \right)^{-1}$$

$$A = 2 \cdot \nu_b \cdot PSD(\nu_b) = \delta \cdot \lambda_{\text{Edd}}^{\gamma}$$

$$\nu_b = \frac{580}{M_{\text{BH}}/M_{\odot}} \text{ (s}^{-1}\text{)}$$

