Searching for Quasi-periodic Oscillations in Active Galactic Nuclei of the Chandra Deep Field South

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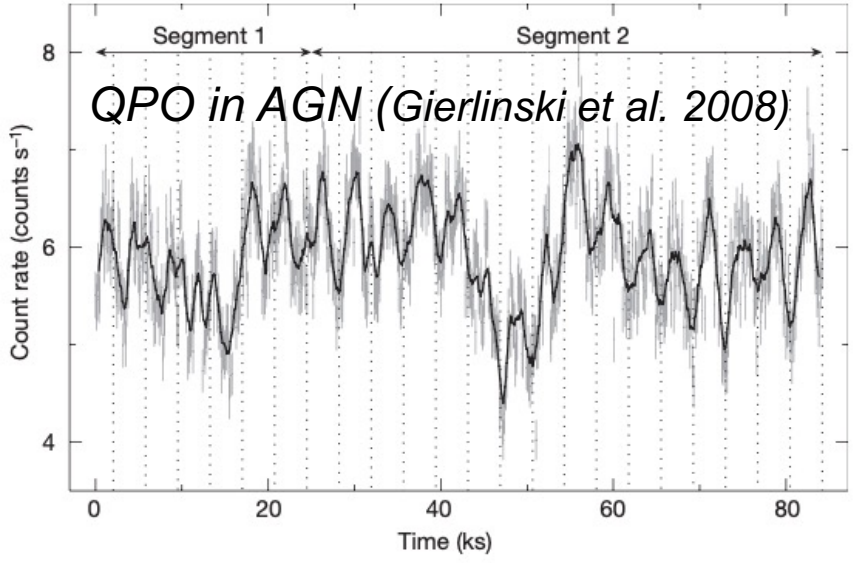
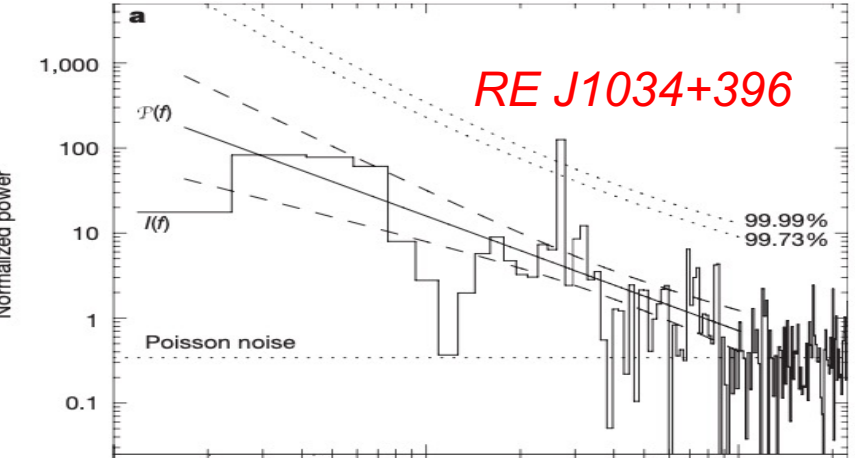
(Bao&Li, 2022, MNRAS, 509, 3596)

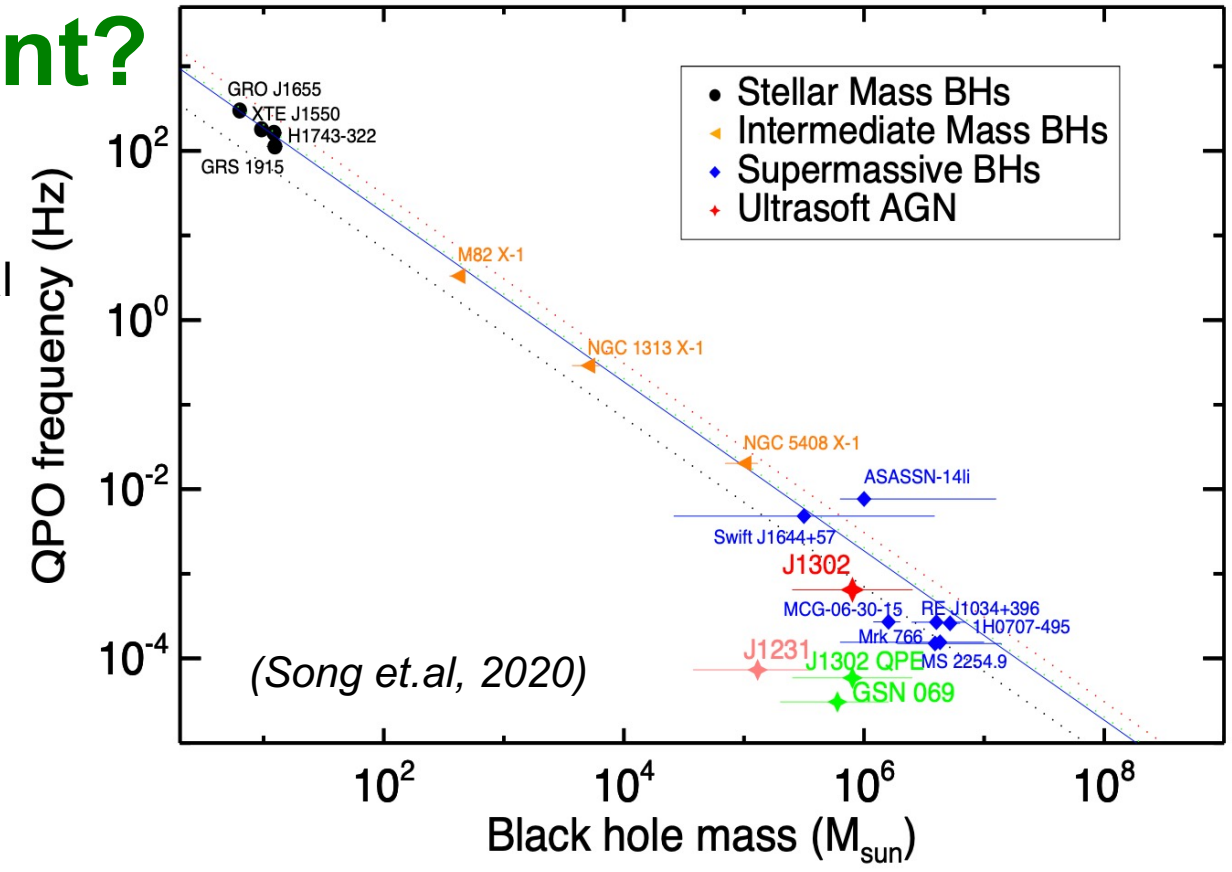
Why are AGN QPOs important?

QPOs are discovered in BHBs, ULXs, AGNs…

Origin: probably associated to disk instabilities? Geometrical effects (like precession), Keplerian motion near the ISCO.

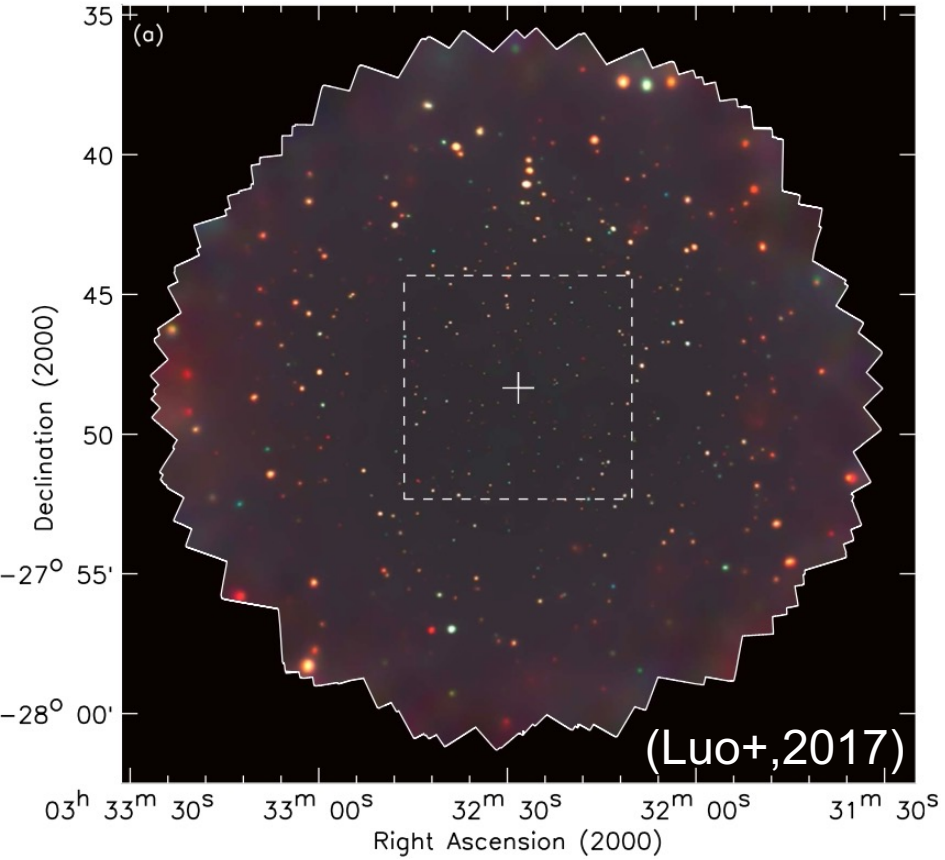


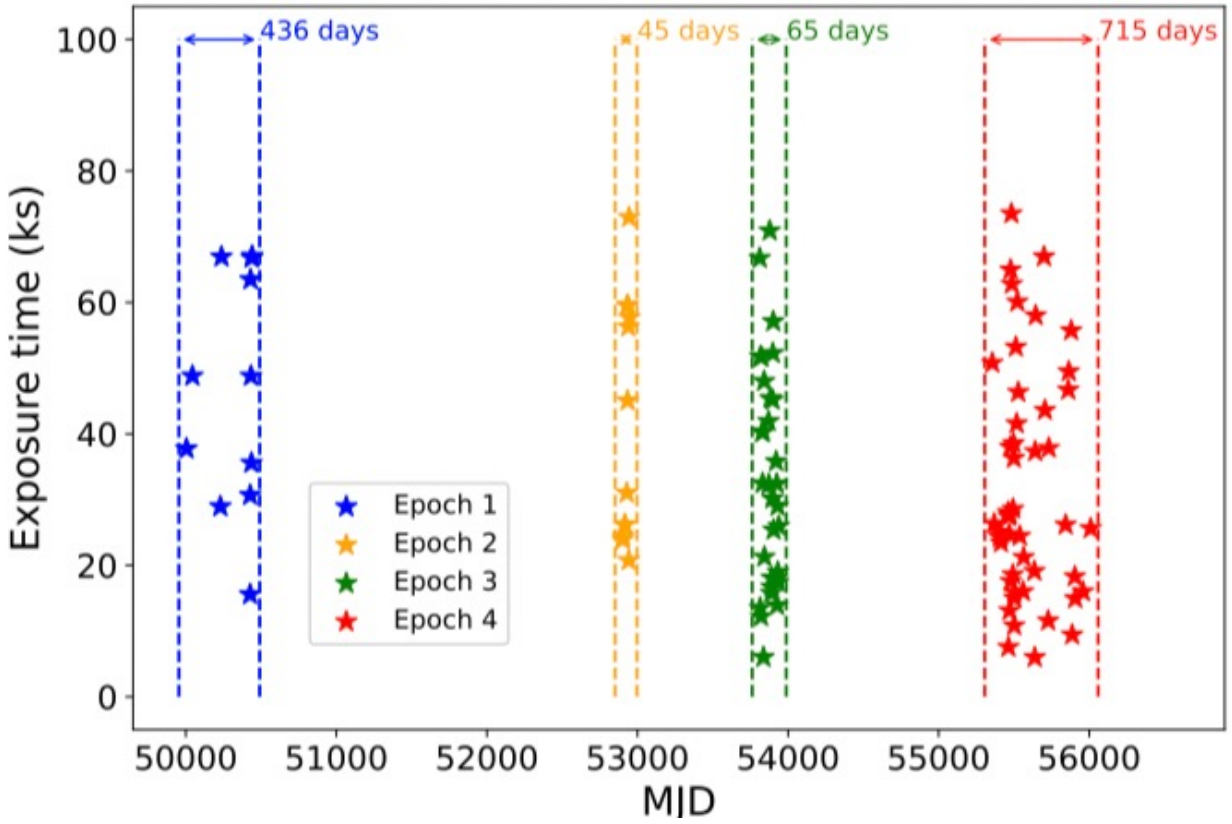


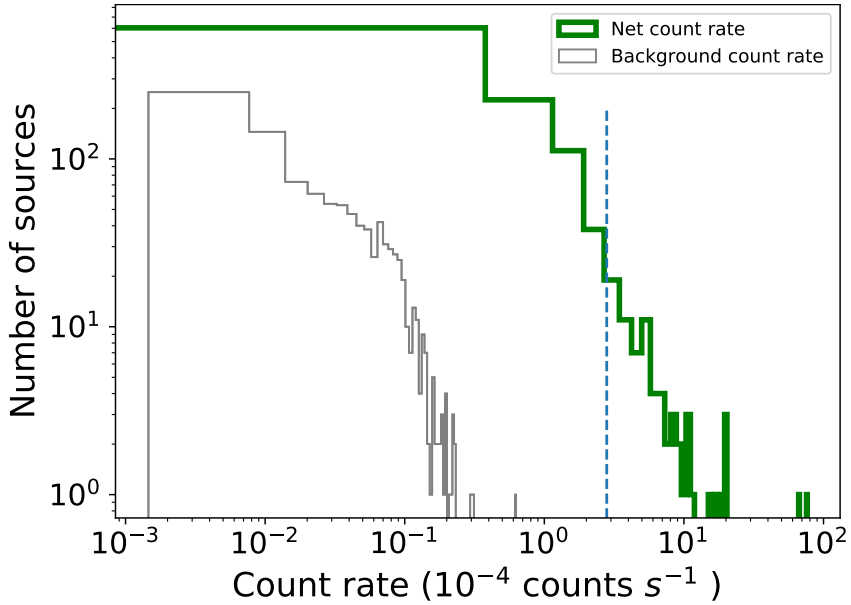


We here present the first dedicated search for AGN QPOs in deep field.

CDF-S data







Sample: 1055 sources (including 12 FG stars)

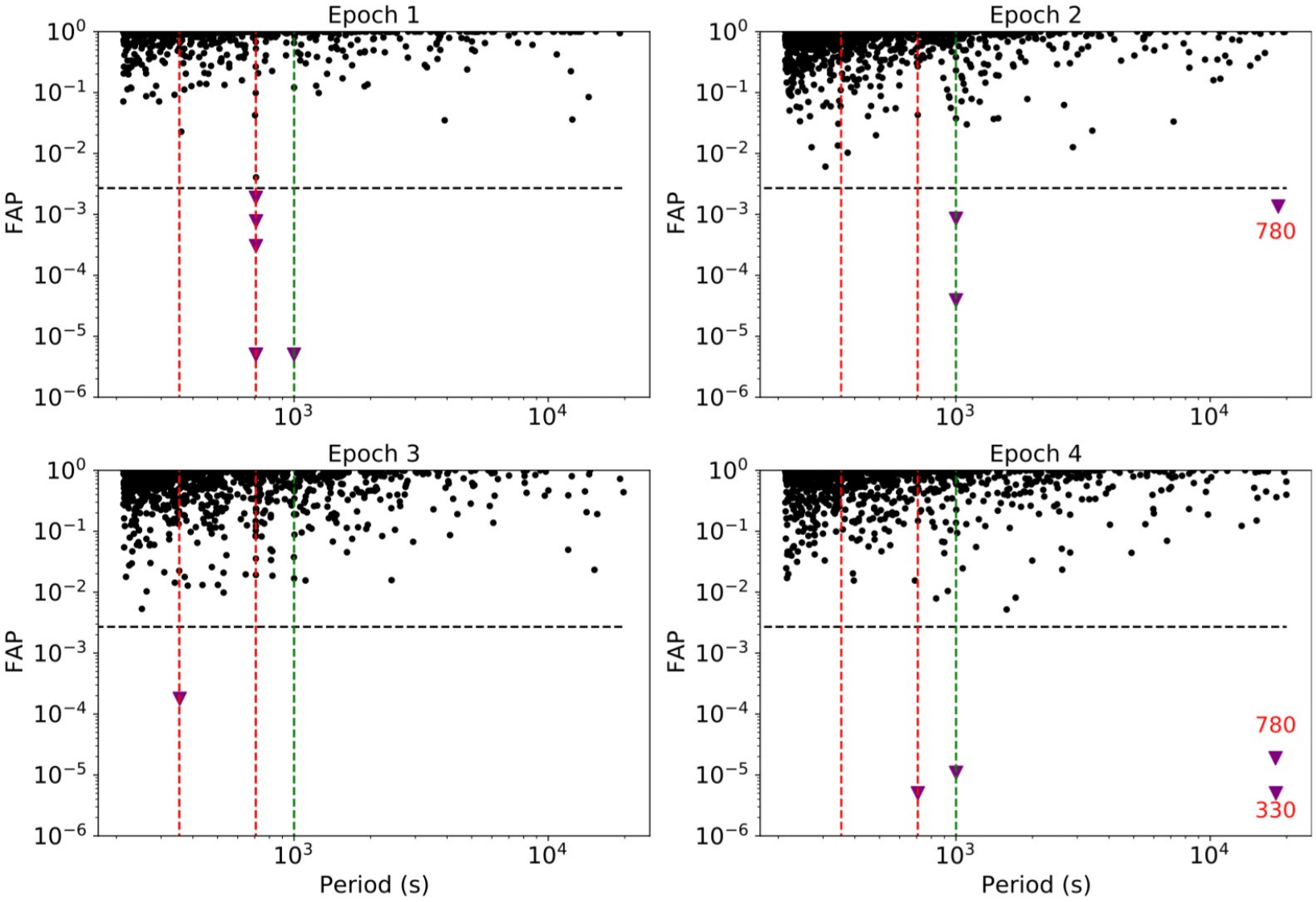
Method: Lomb-Scargle periodogram,

proved to be successful in the detection of a few AGN QPO.

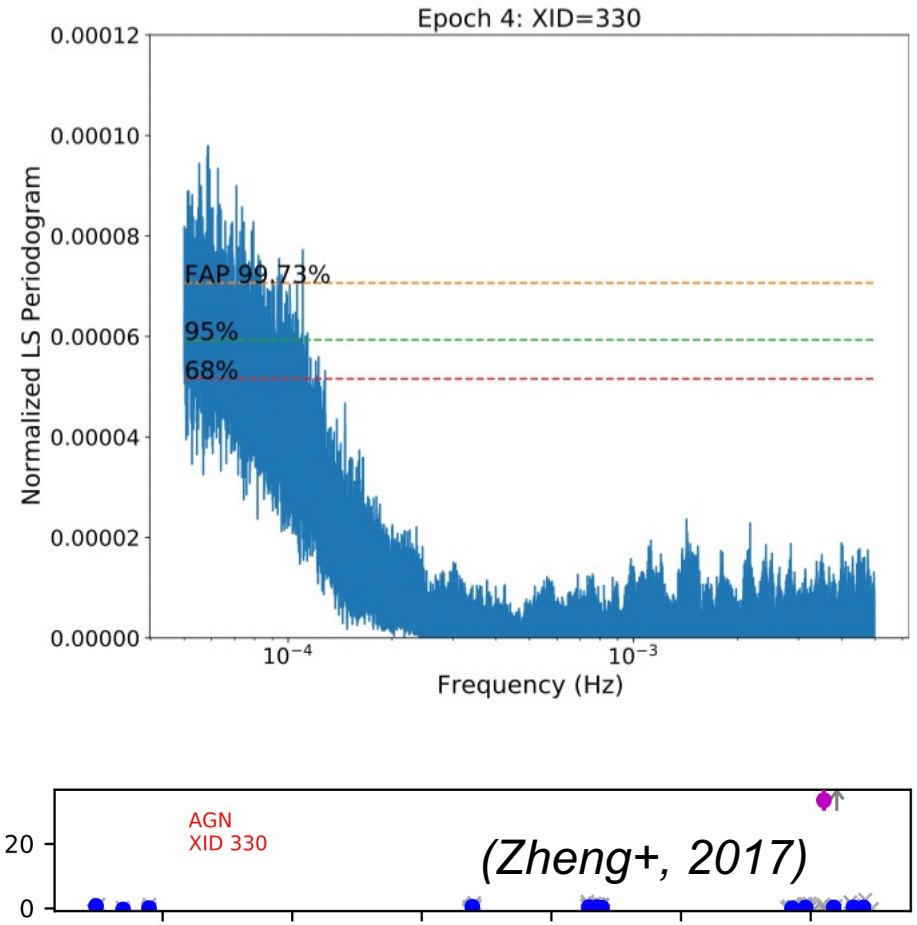
（e.g., Zhang et al. 2017; Gupta et al. 2018; Song et al. 2020）

QPO searching

By applying normalized Lomb-Scargle method……



Example of fake periodic signal from extremely variable source



No significant genuine periodic signals among the CDF-S sources.

The Occurrence rate of persistent QPOs

$$N_{\mathrm{QPO,det}} = DE \times f_{\mathrm{QPO}} \times N_{\mathrm{sou}}$$

Detected QPOs: 0

Detection efficiency

Intrinsic fraction of AGNs with a (persistent) QPO

CDF-S sample

The power spectrum model

The PSD of a typical AGN: $$P_{\rm b}(\nu) = N\nu^{-1}(1+(\frac{\nu}{\nu_{\rm b}})^{\alpha-1})^{-1}$$

The PSD of a QPO: $$P_{\rm L}(\nu) = \frac{R^2 Q \nu_0/\pi}{{\nu_0}^2 + Q^2(\nu-\nu_0)^2}$$

(1) N : the amplitude of the intrinsic noise, with greatest impact on QPO searching.
The observational results provides: $N = 2 \cdot \nu_{\rm b} \cdot P_{\rm b}(\nu=\nu_{\rm b}) \approx 3\times10^{-3}\lambda_{\rm Edd,X}^{-0.8}$ *(Ponti+, 2012)*

(2) ν_0 is expected to be inversely scaled with BH mass. We take ν_0=1/7200, 1/5400, 1/3600 Hz

(3) R approximately represents the strength of QPO signal.

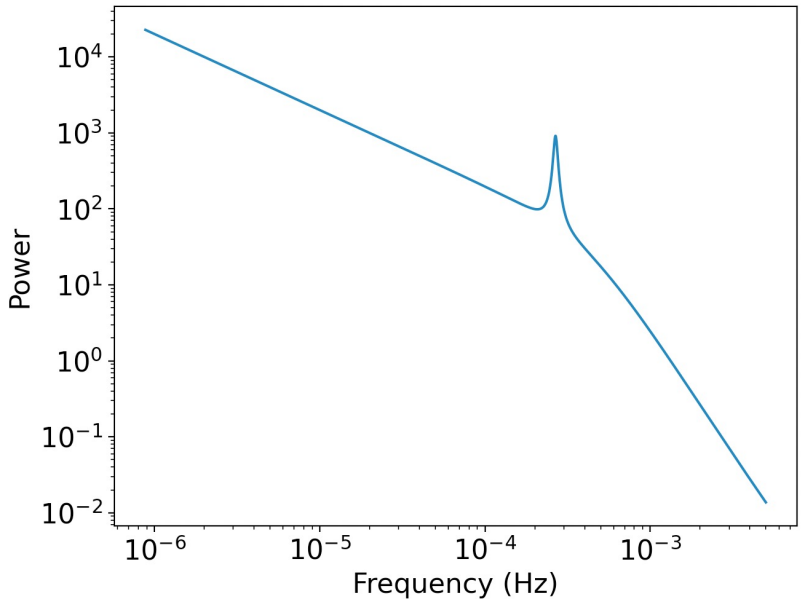
Model A: N= 0.0023; R=0.05

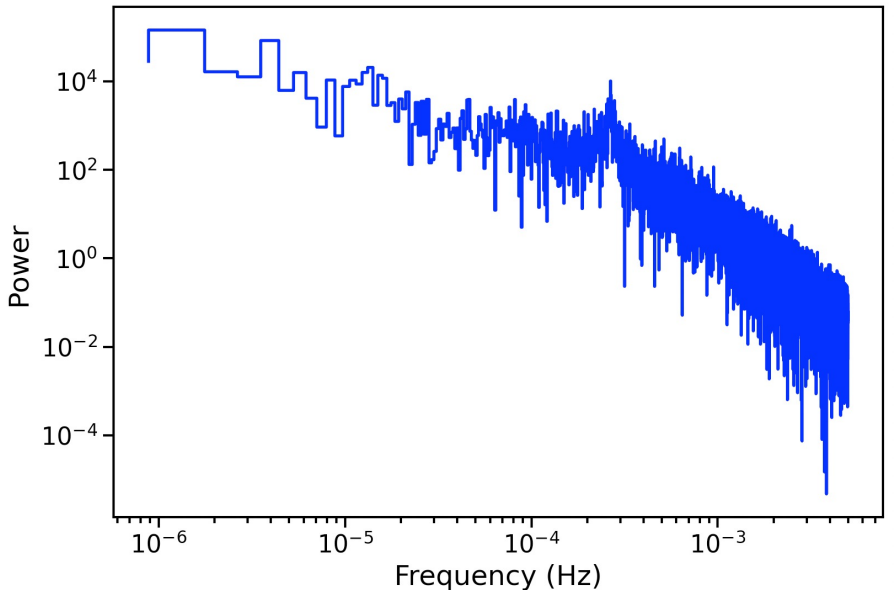
low noise but weak QPO signal (RE J1034 -like)

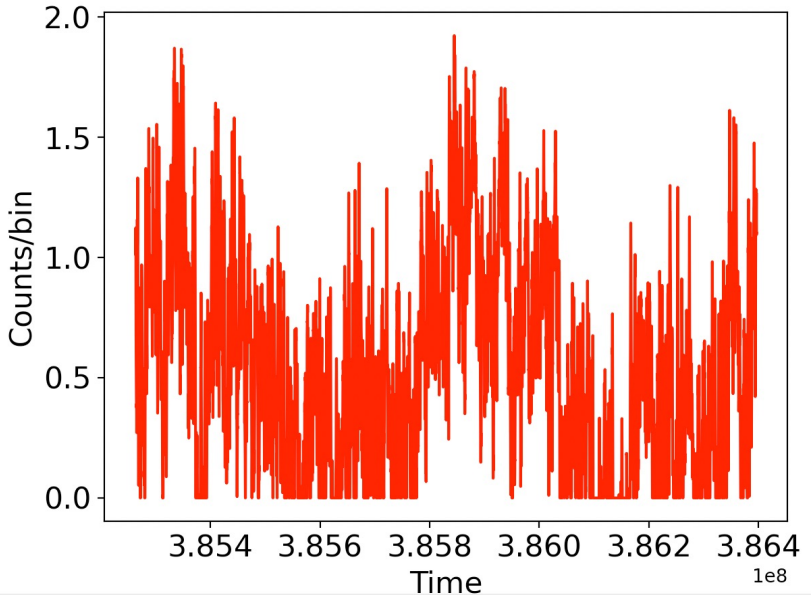
Model B: N= 0.02 ($\lambda_{Edd}\sim0.1$); R=0.15

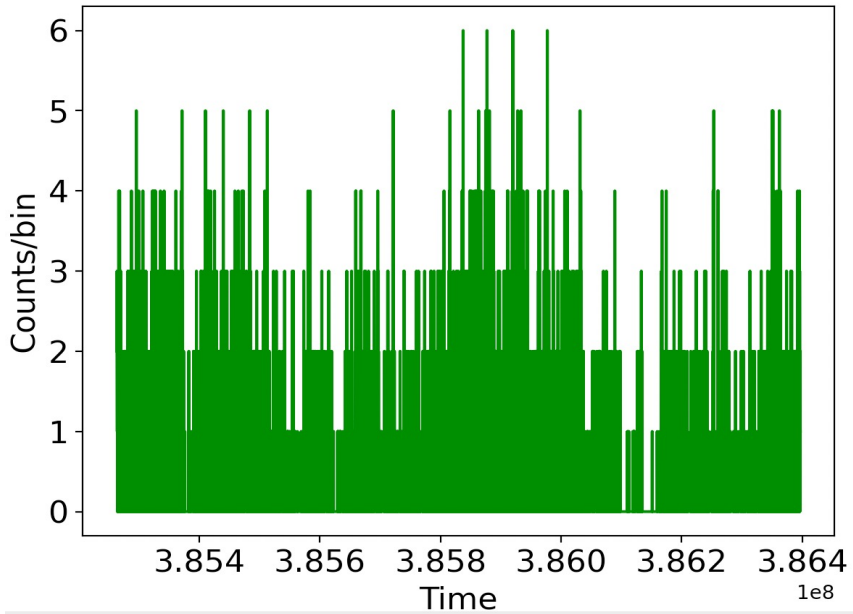
high noise but strong QPO signal

Simulated light curve

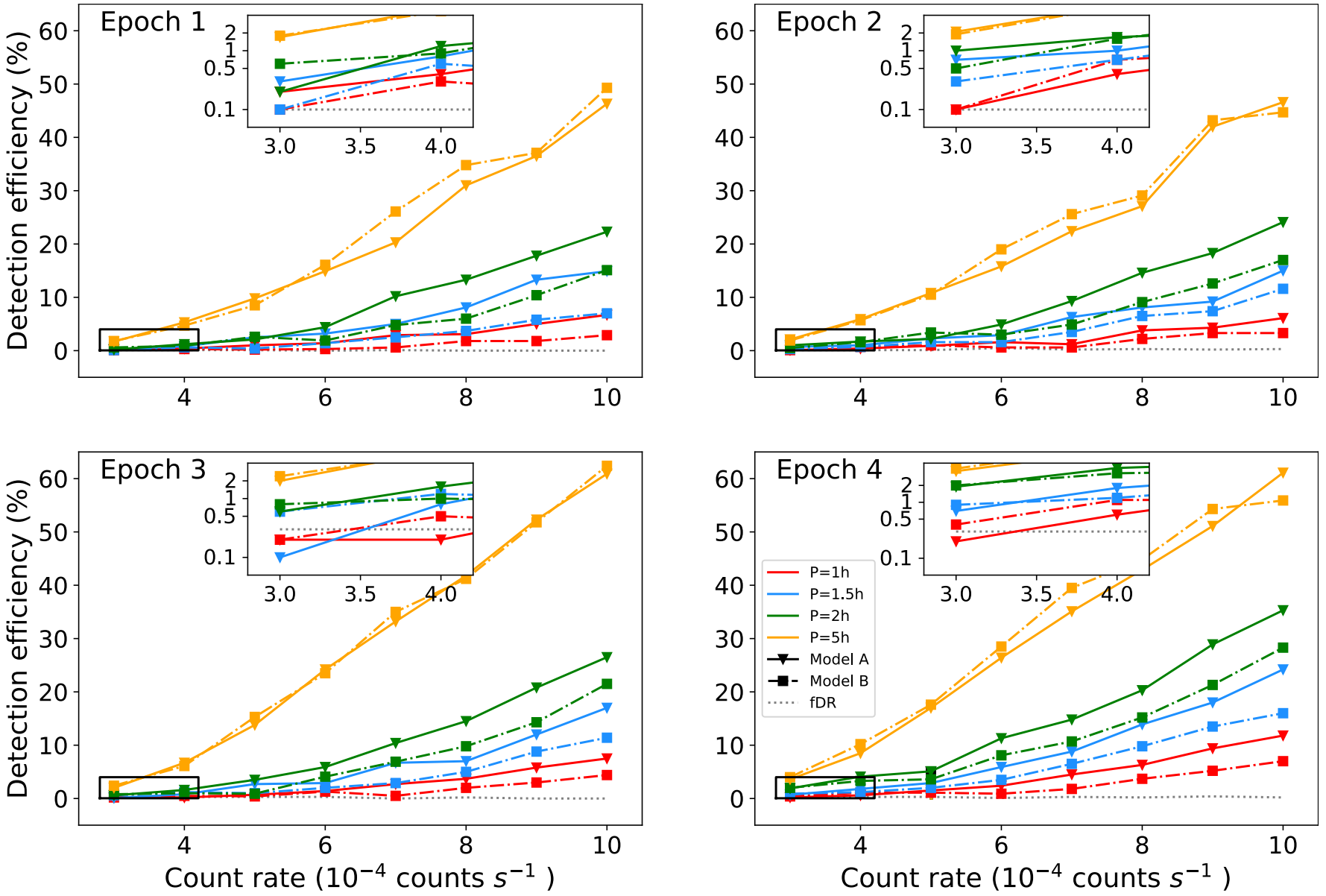








The Occurrence rate of persistent QPOs



$$f_{\mathrm{QPO}} \approx N_{\mathrm{QPO,det}} / \left(\sum_i DE(\bar{x}_i, P) \times N_i \right)$$

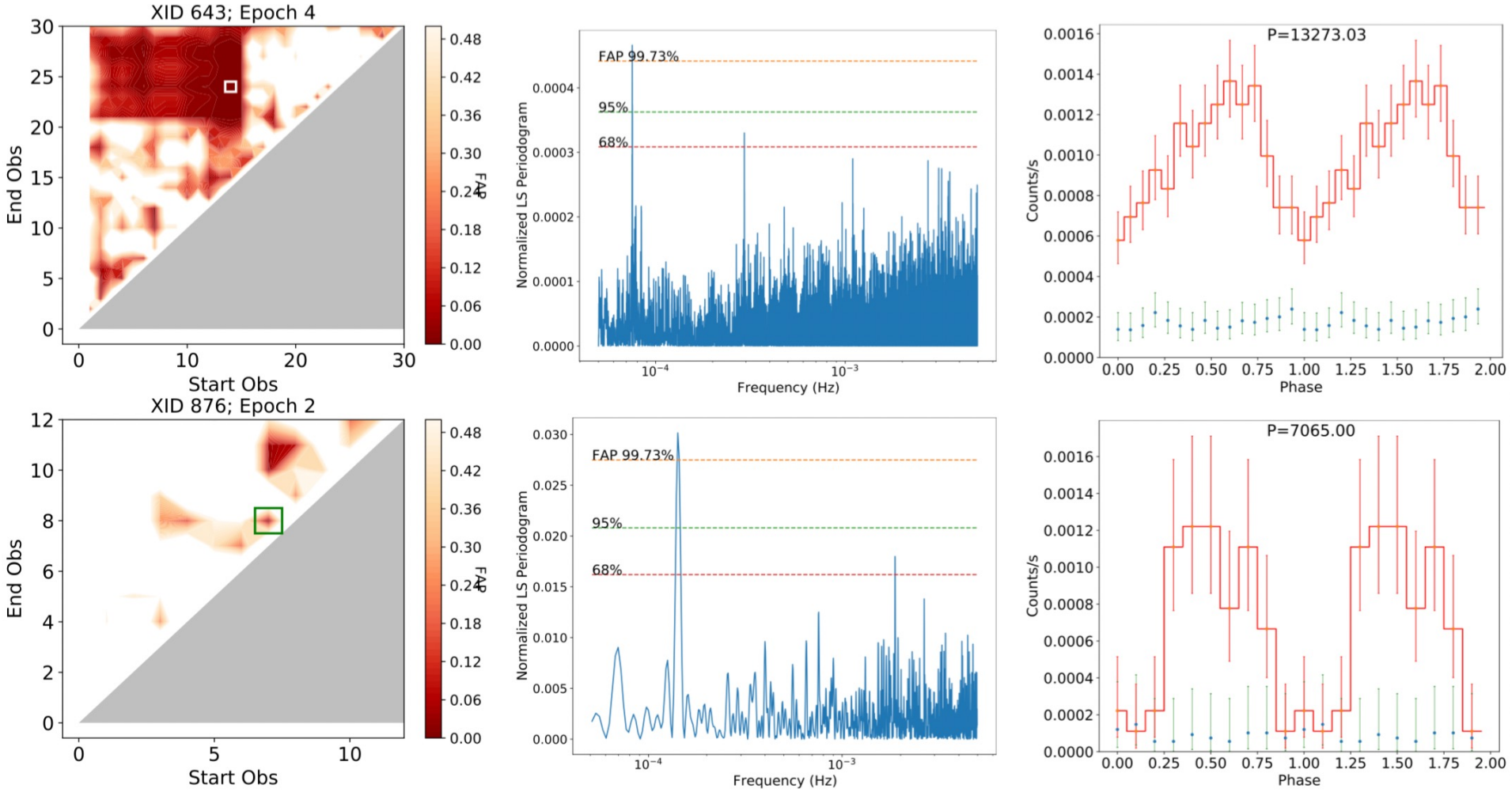
$$\approx N_{\mathrm{QPO,det}} / \left(\sum_i \overline{DE}(\bar{x}_i) \times N_i \right)$$

$N_{\mathrm{QPO,det}} = 0$

$f_{\mathrm{QPO}} < 15\text{-}20\%$

Two short-lived QPO candidate

Short-term light curve: one that contains any number of successive observations within a certain epoch.



Summary

1. No statistically significant QPO is found from CDFS sample (~ 1000 sources).

1. The intrinsic occurrence rate of persistent QPOs, is constrained to be < 15-20%, from a nearly complete AGN sample.

3. Two short-lived QPO candidate (only detected over a small subset of all observations) are found.