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A Global View of X-ray time lags in Seyfert Galaxies

Erin Kara
ekara@ast.cam.ac.uk

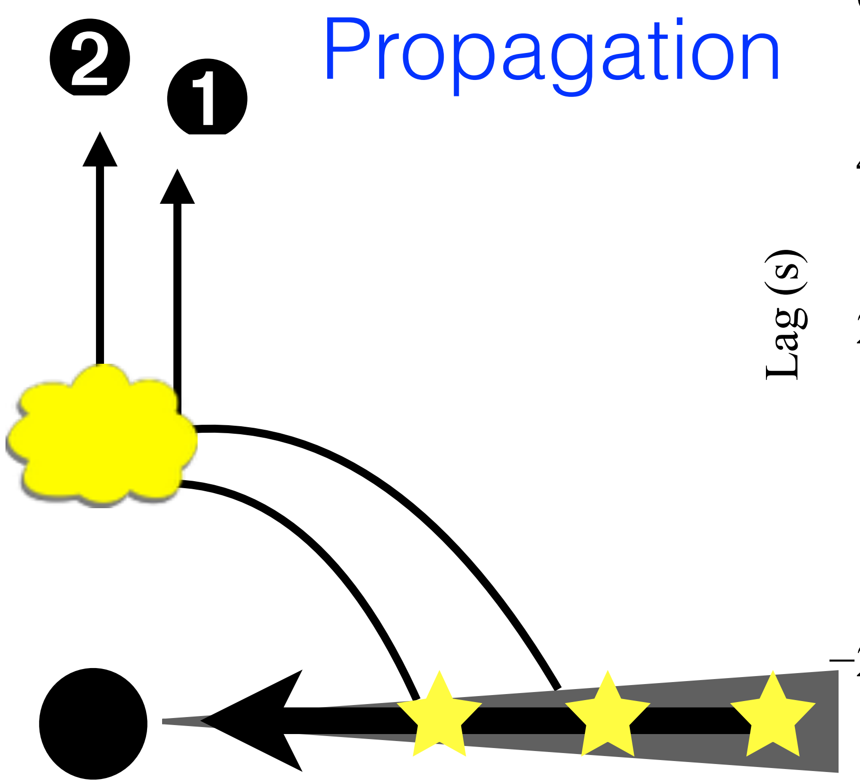
Collaborators:
Will Alston, Andy Fabian, Ed Cackett, Phil Uttley, Abdu Zoghbi, Giorgio Matt, Andrea Marinucci, Dom Walton, Fiona Harrison, Michael Parker

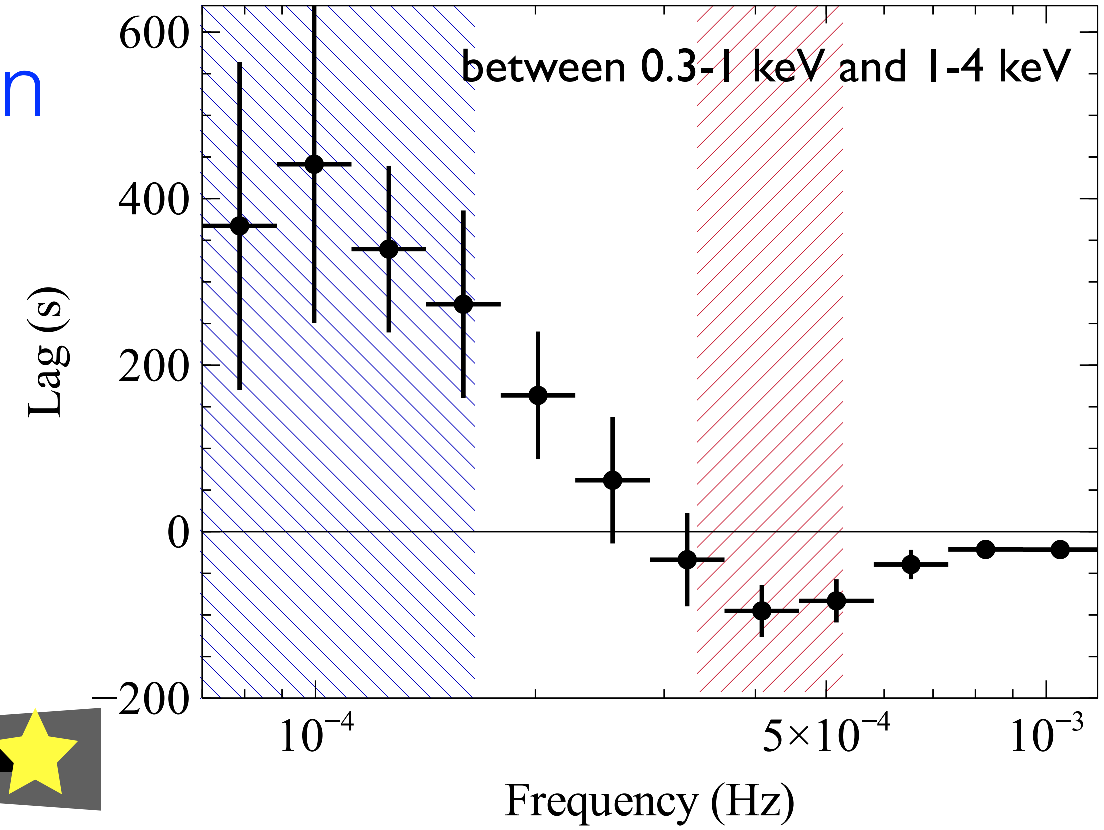
UNIVERSITY OF CAMBRIDGE

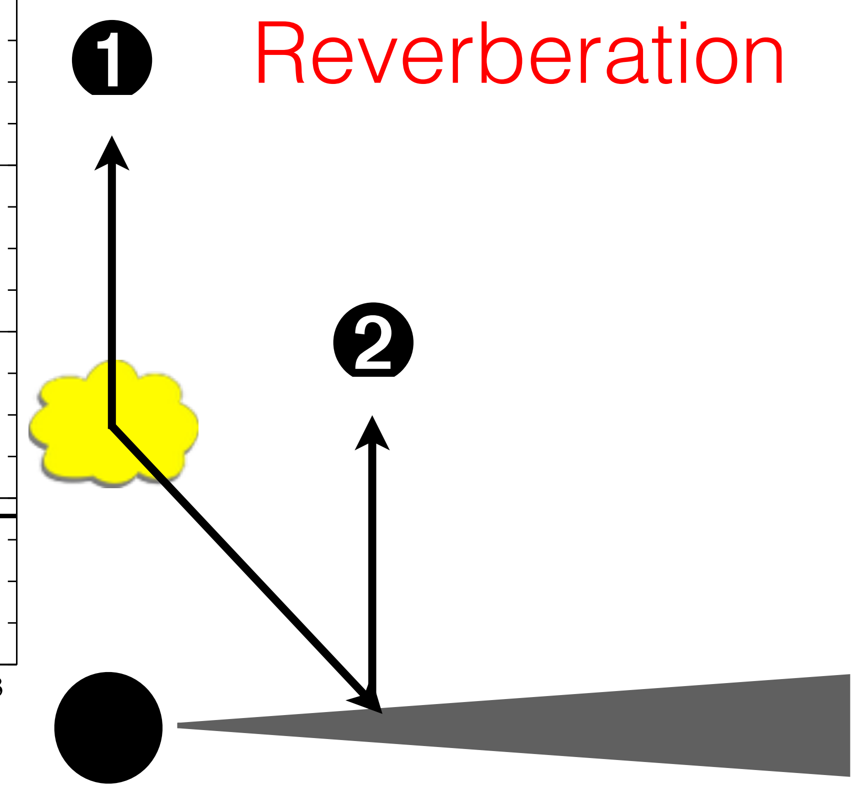
ioa

STRONGGRAVITY
EU FP7-SPACE research project 312789 2013 - 2017

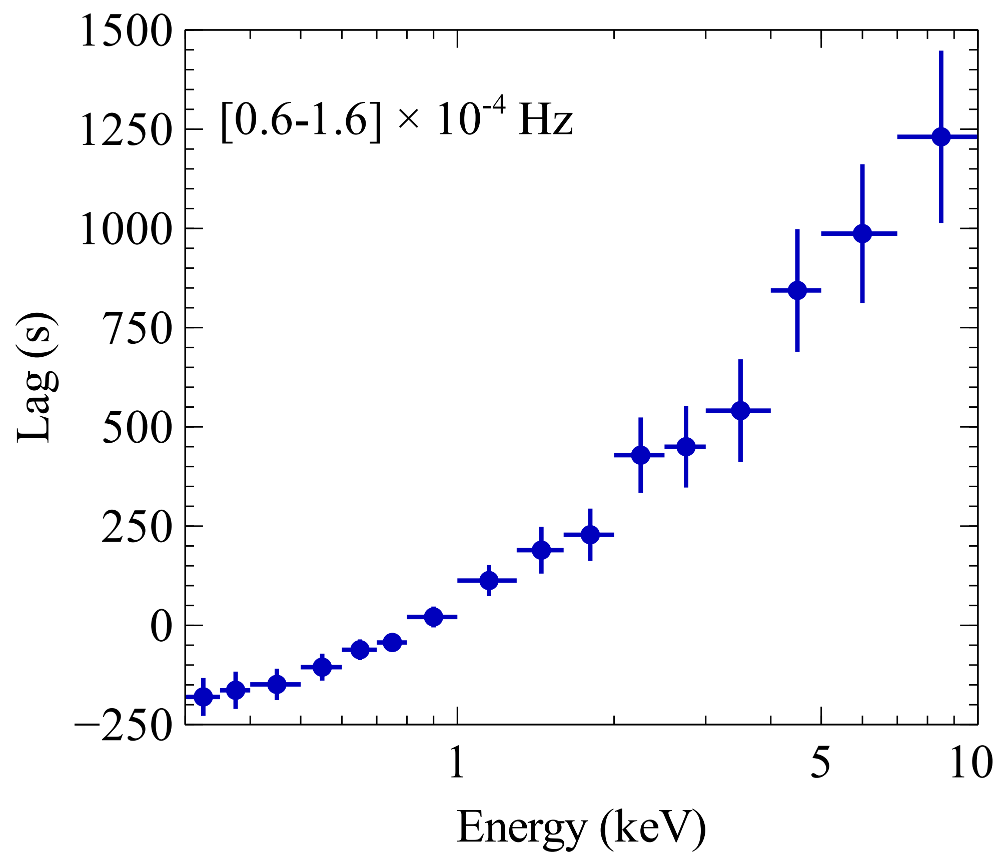
Reverberation with XMM-Newton

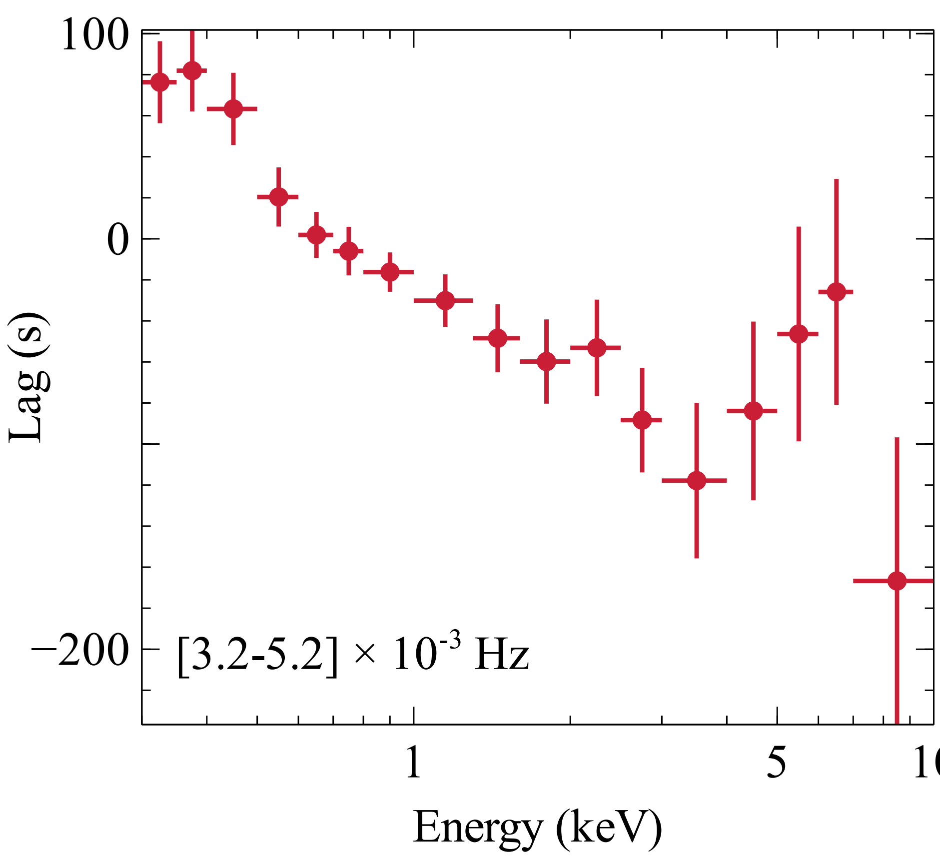






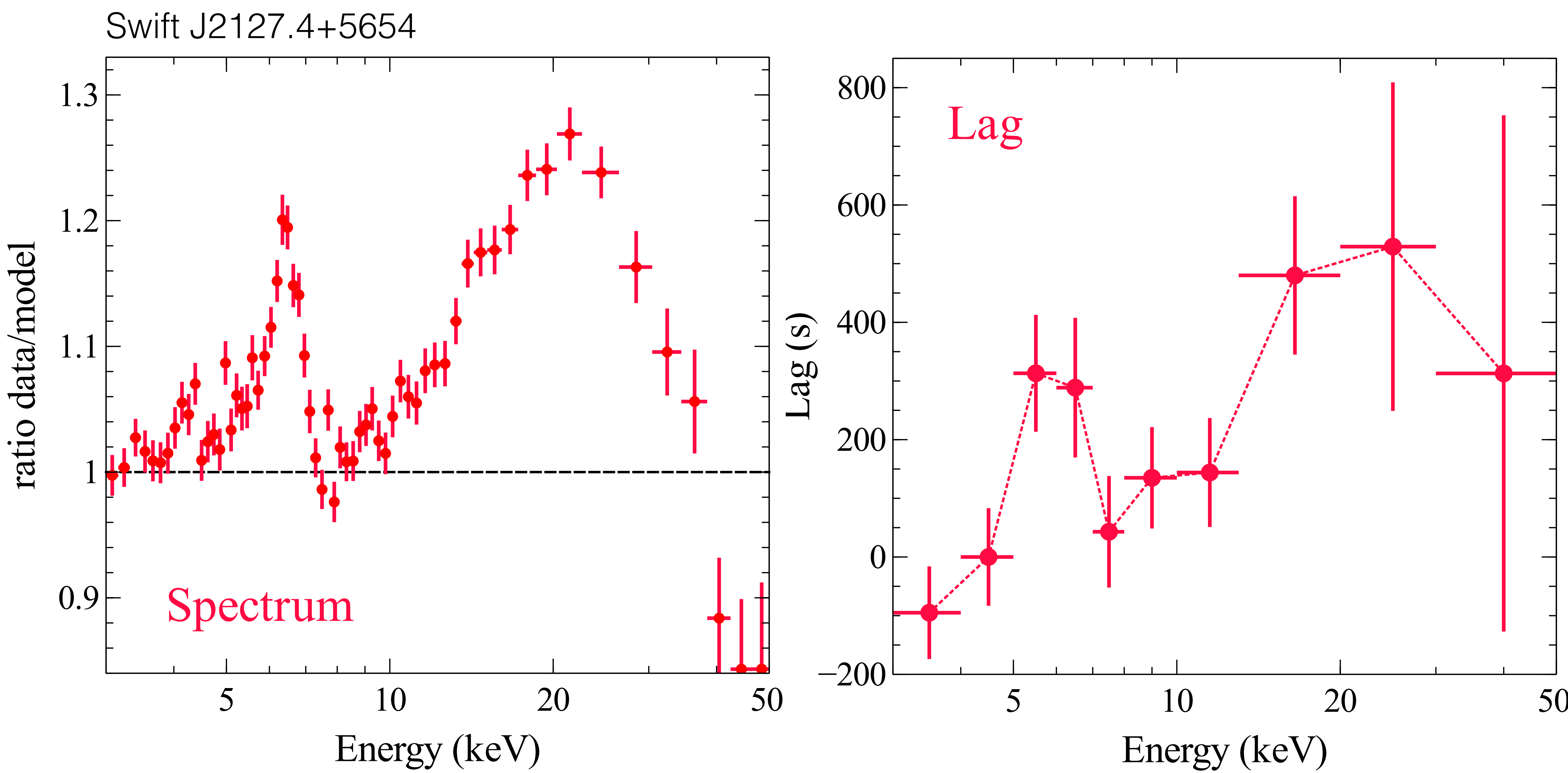
Kotov+04
Arevalo+06





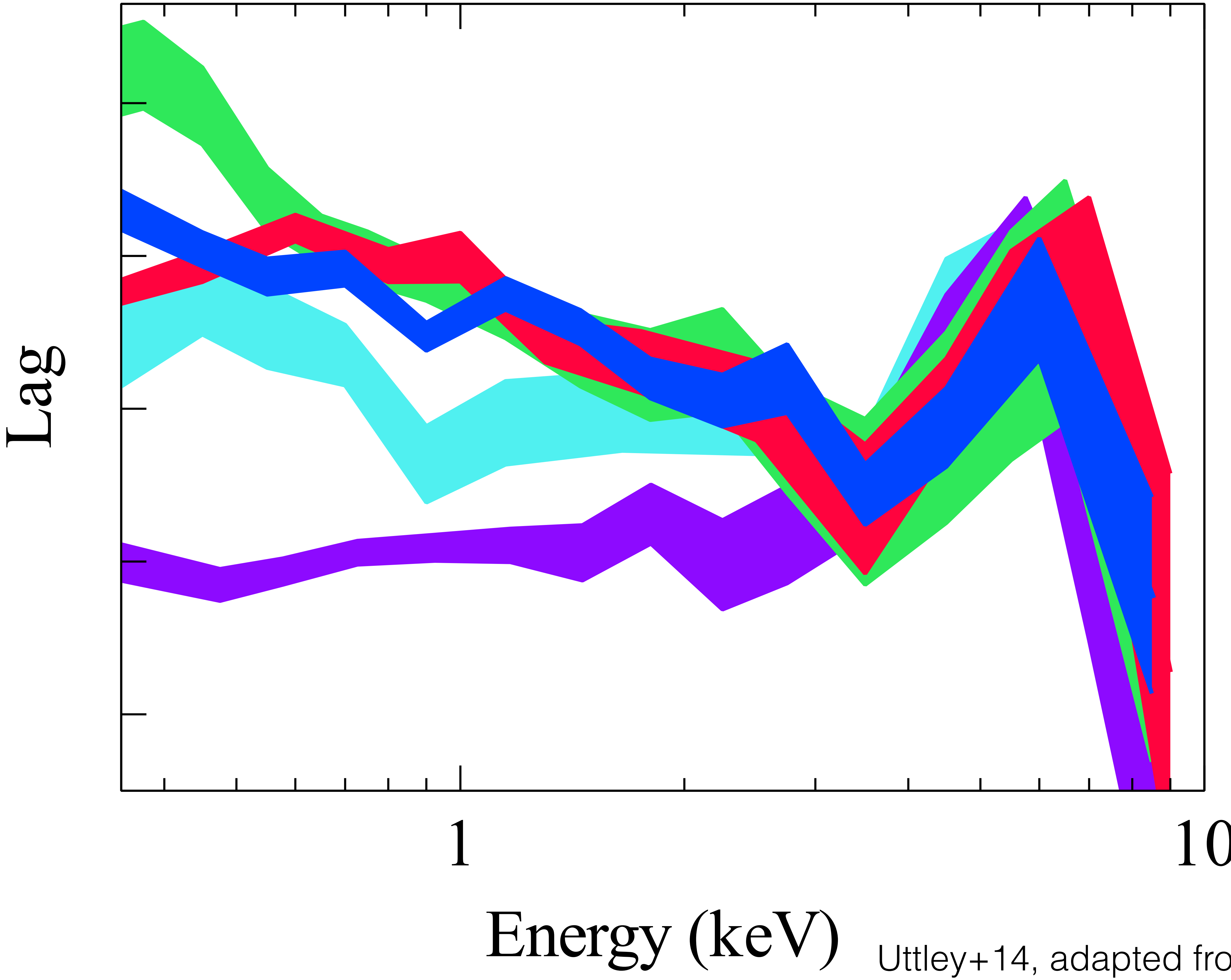
EK+13, also Zoghbi+12,13 Cackett+13, De Marco+13, Emmanoloupolous+14, Uttley+14 for a review

Reverberation with NuSTAR



EK+15, see also Zoghbi+14

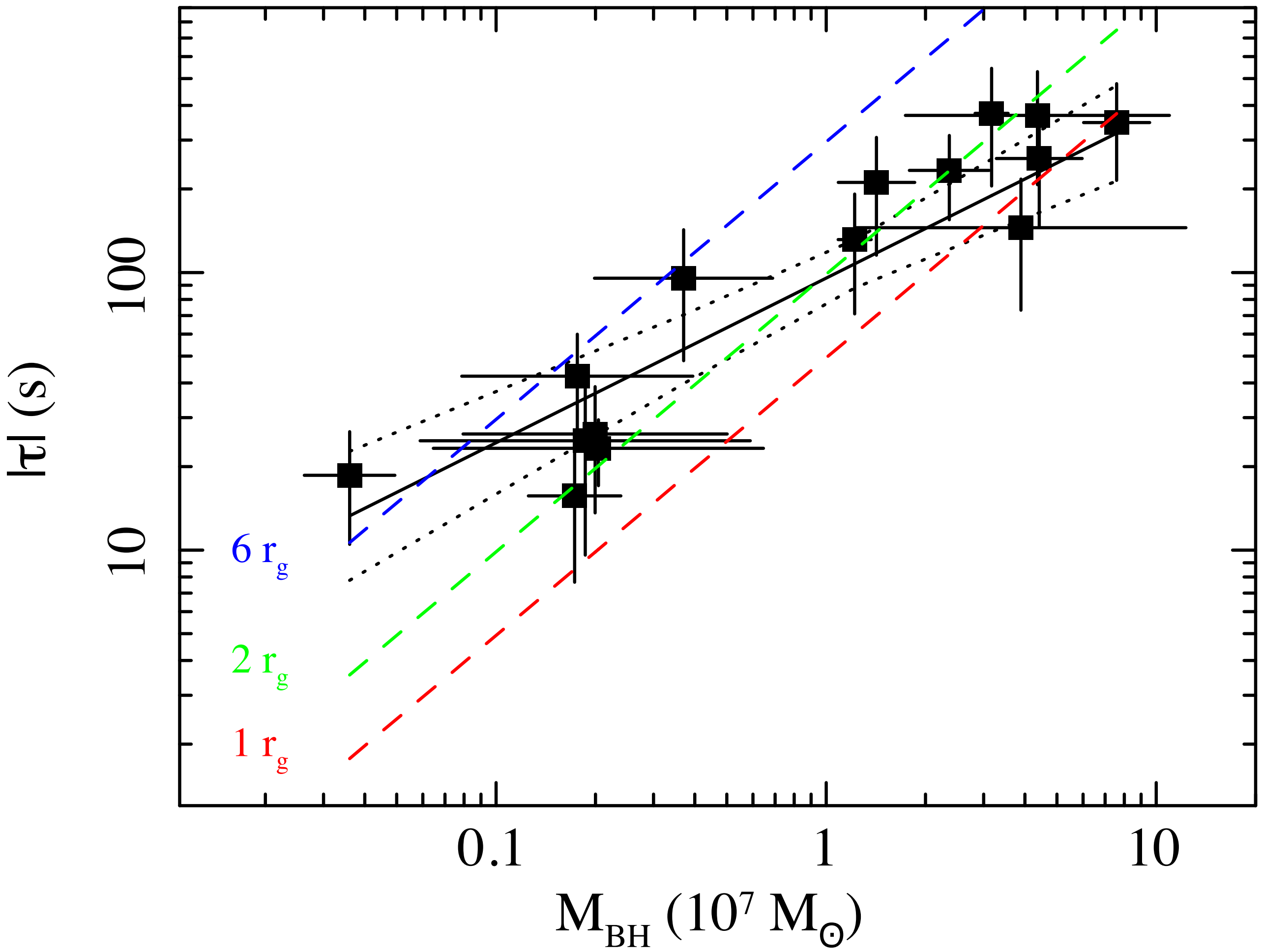
A Growing Sample of Reverberation



Uttley+14, adapted from EK+14

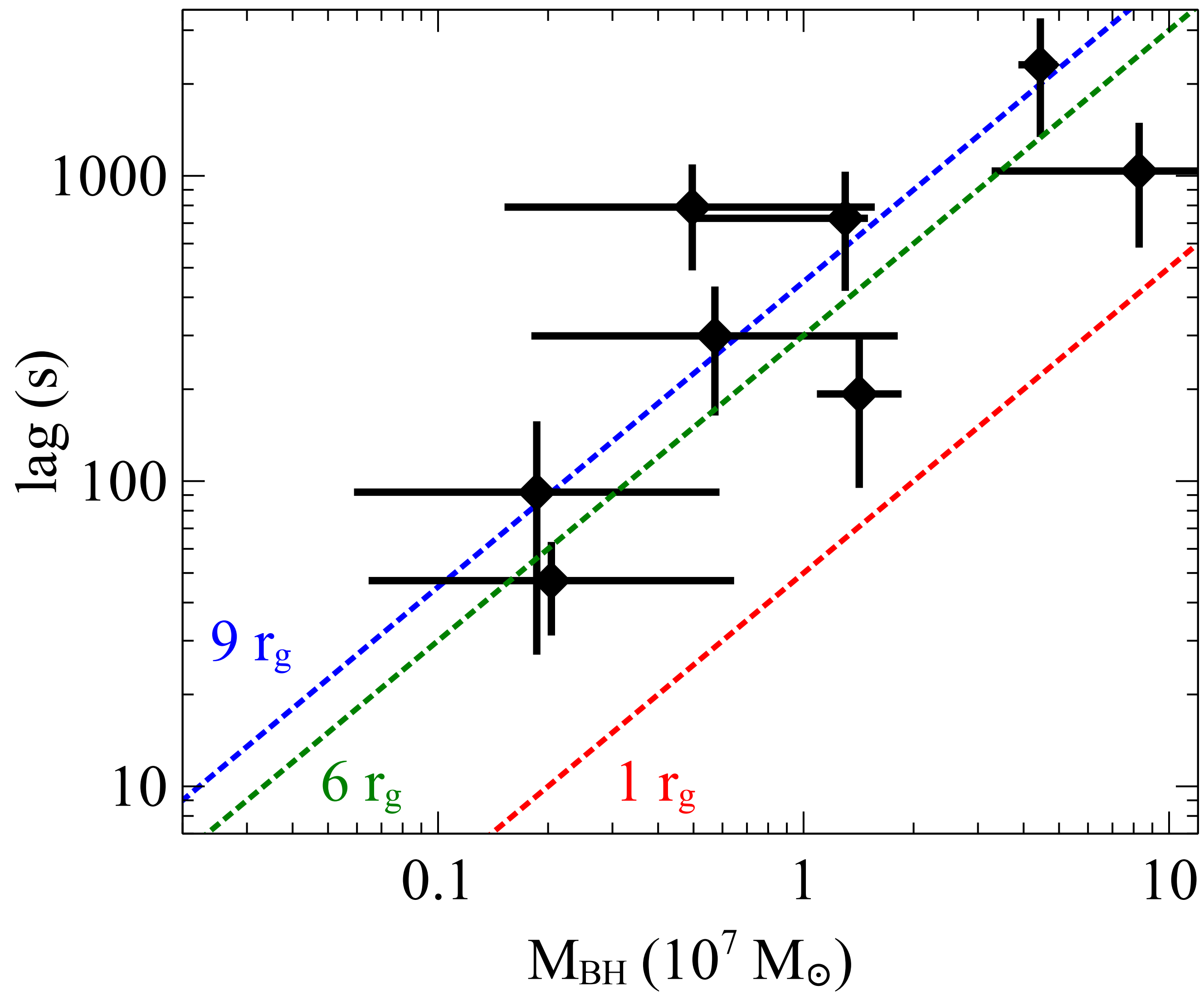
A Growing Sample of Reverberation

Soft excess lag



De Marco+13

iron K lag

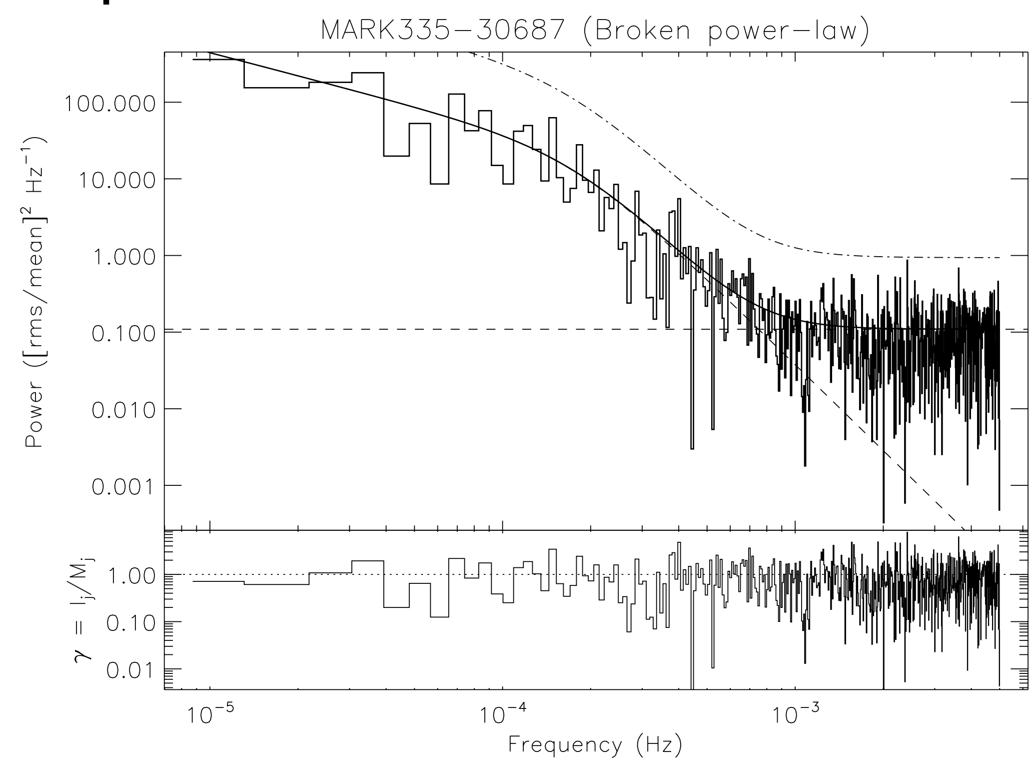


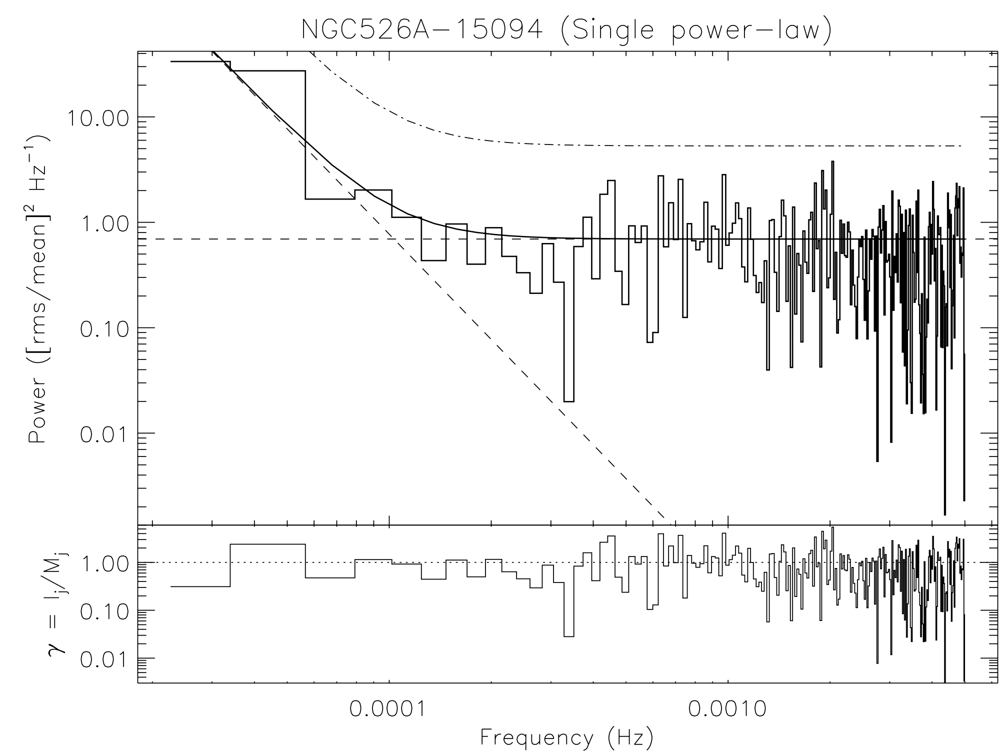
EK+13

A Global View

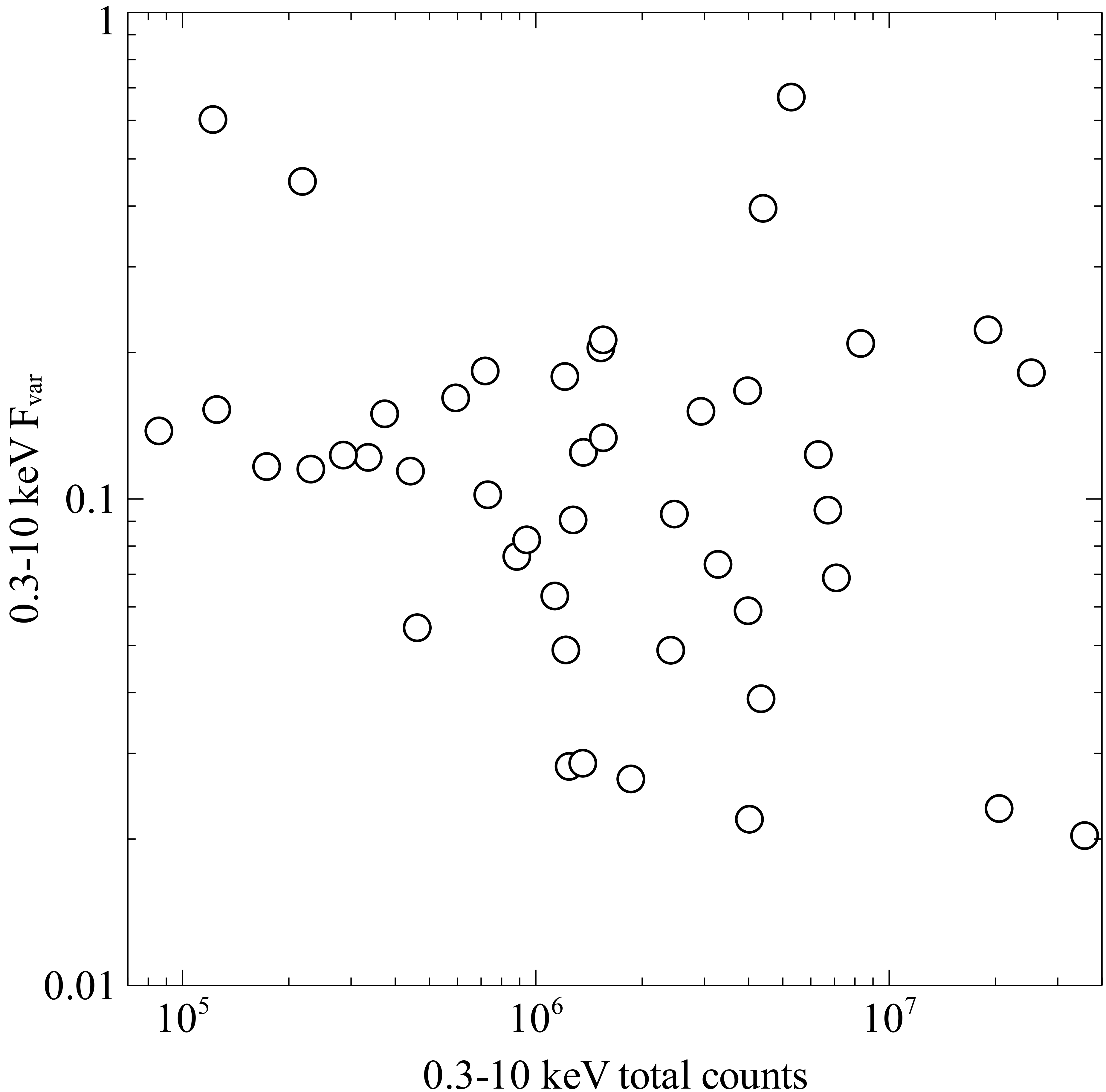
The Sample

- All public XMM-Newton observations of Seyfert Galaxies
- Must be >40 ks exposure
- Must have some variability…

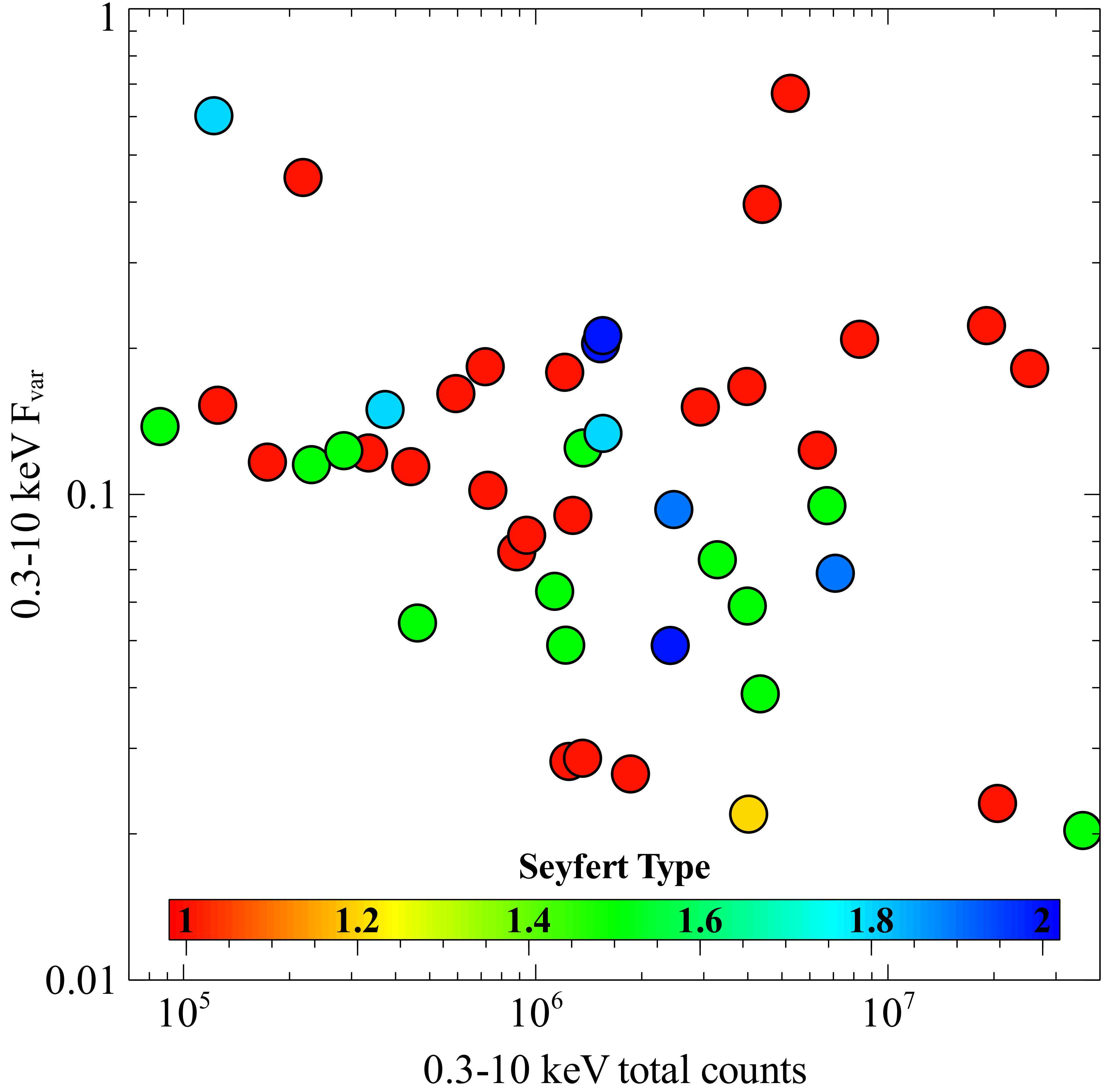




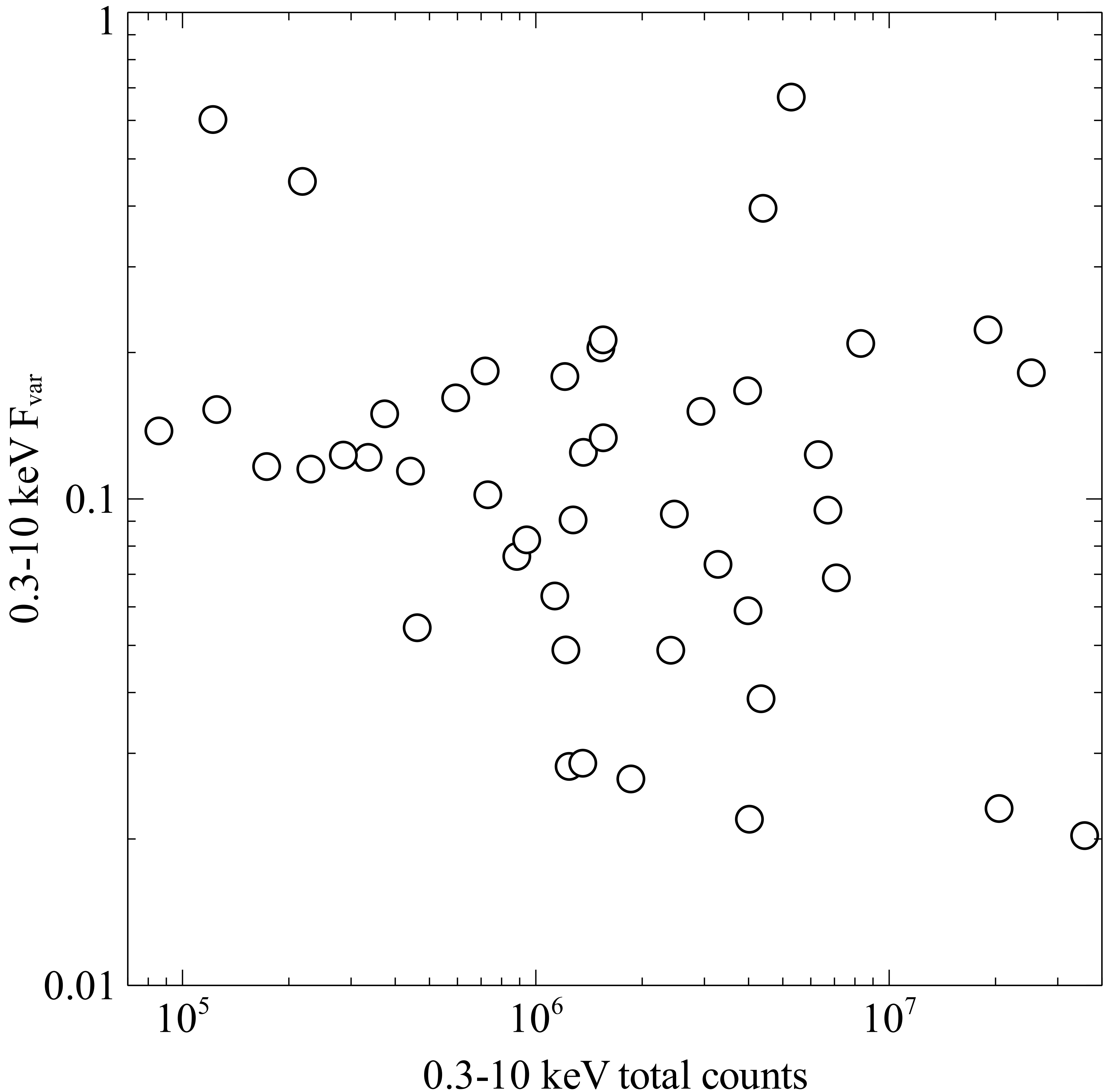
González-Martín & Vaughan 12



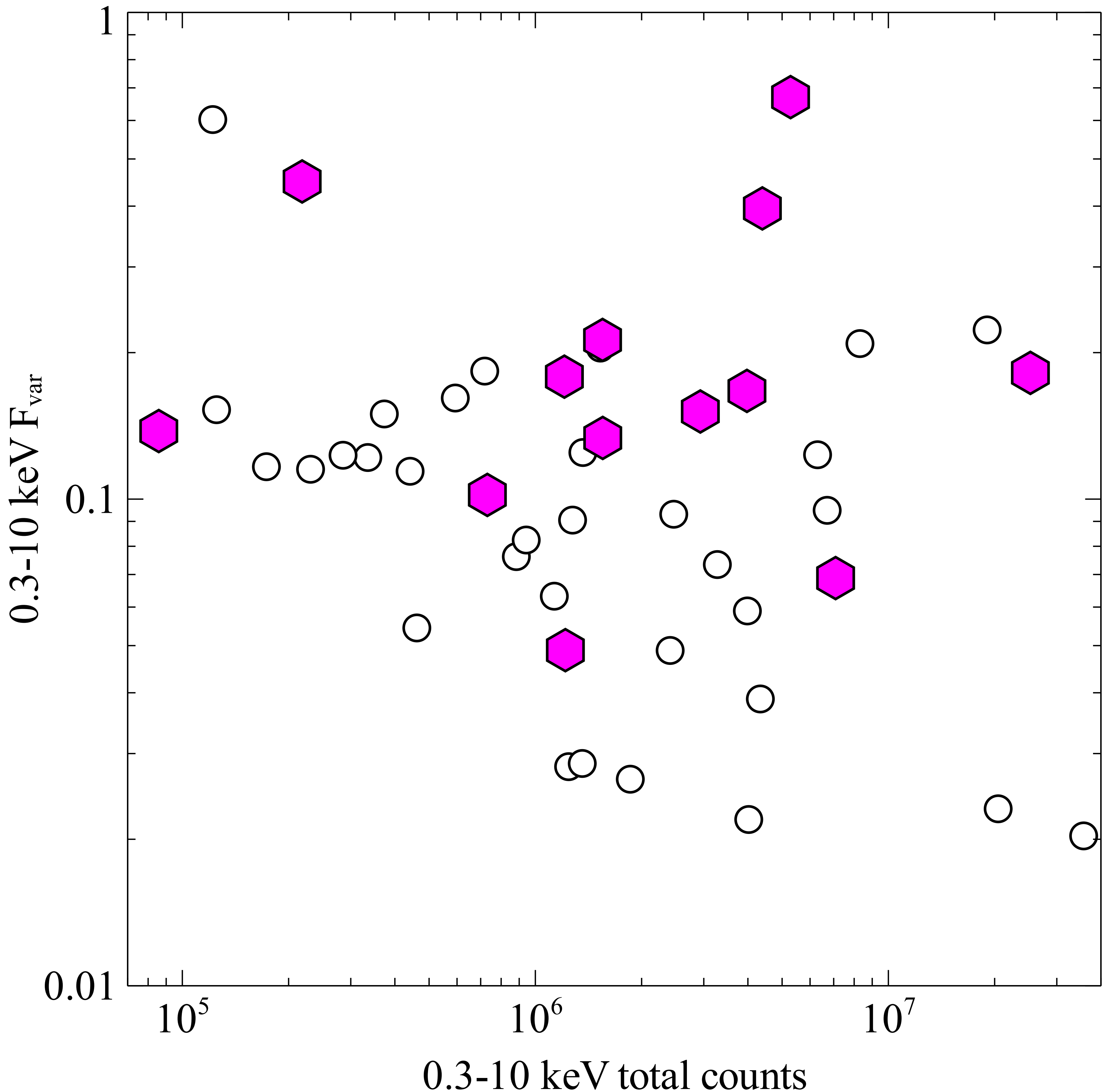
45 sources



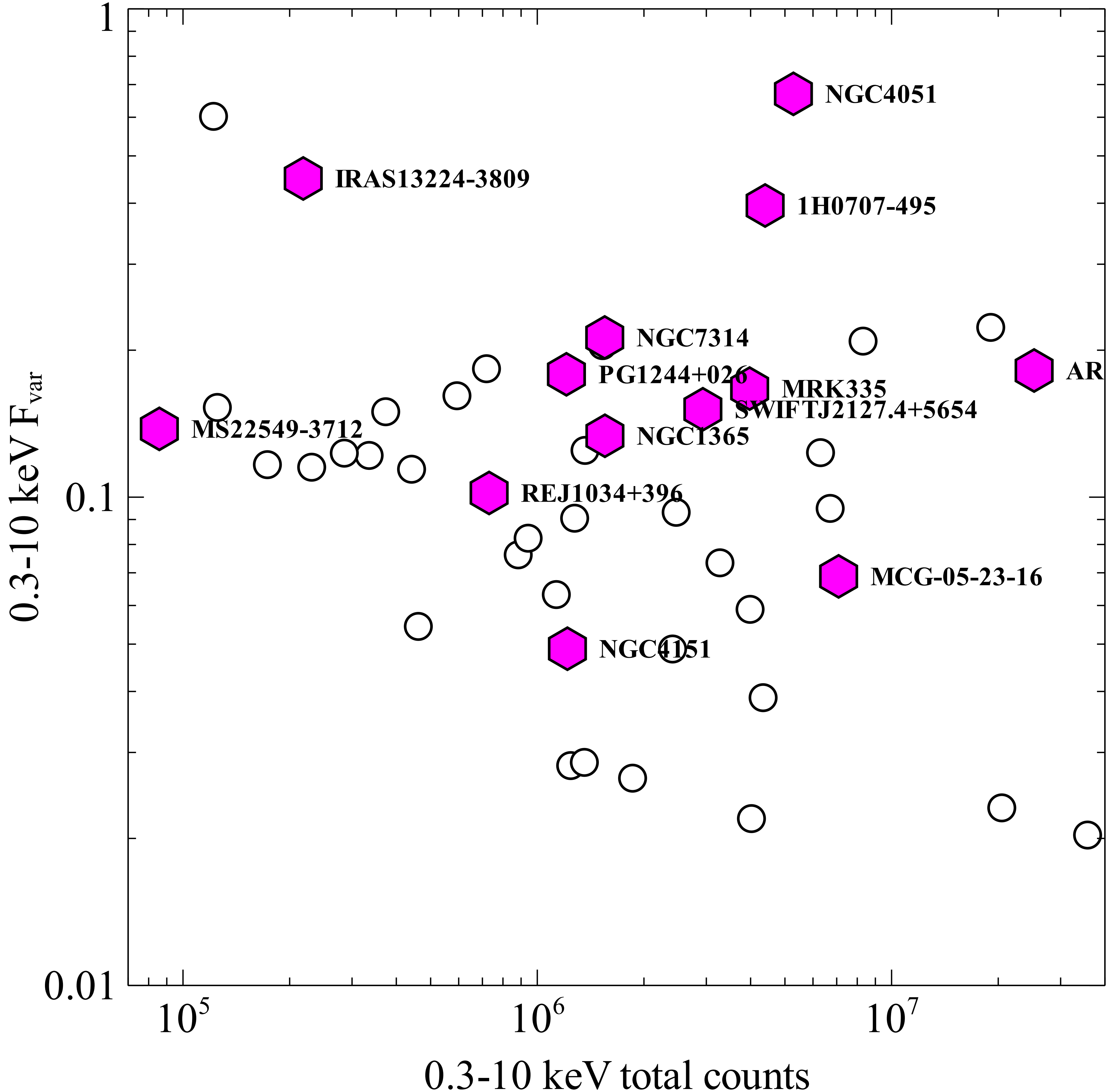
25 S1-S1.2
12 S1.5
8 S1.8-2



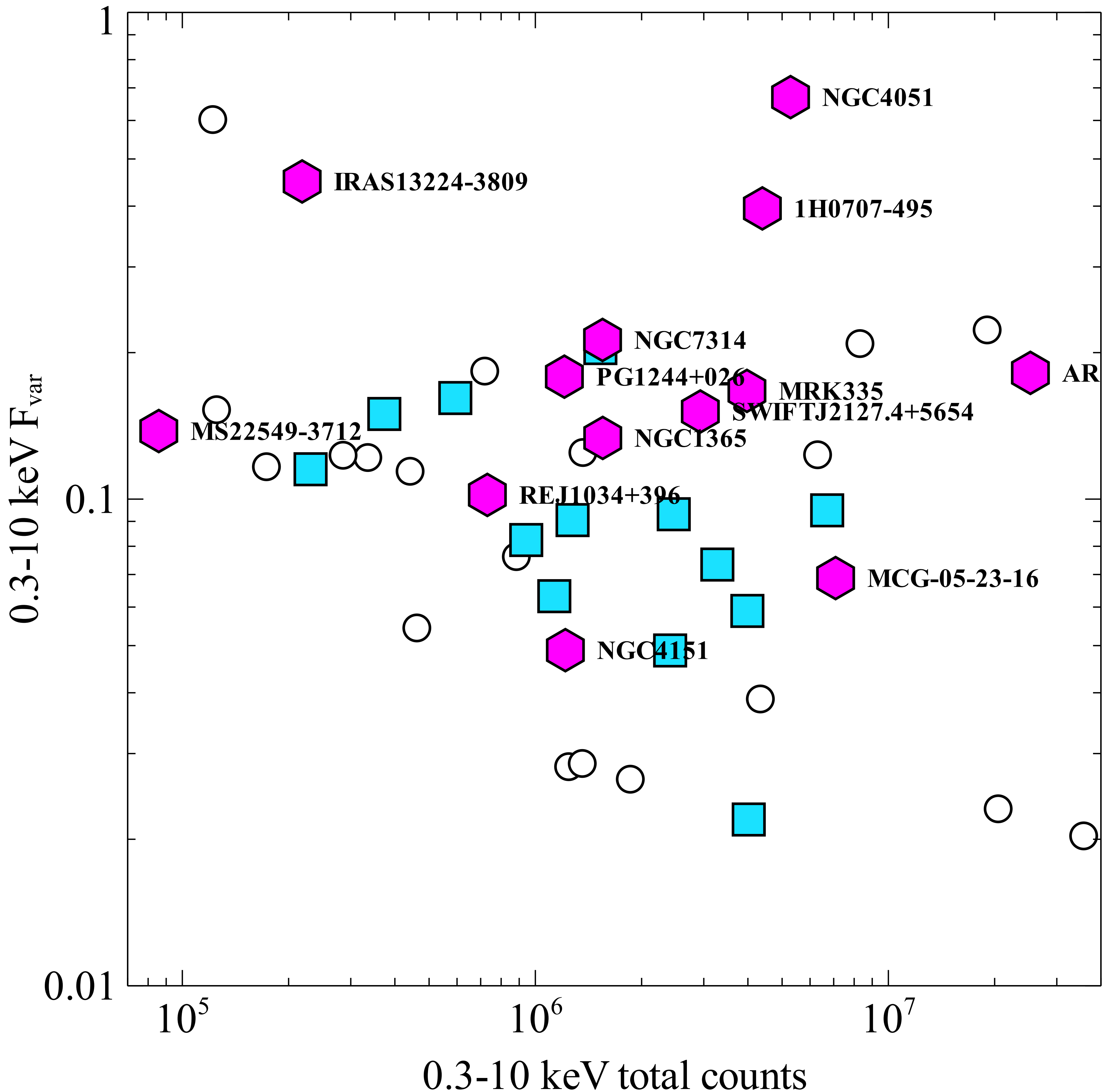
1
0.1
0.01
10^5
10^6
10^7
0.3-10 keV total counts
0.3-10 keV F_{var}



13 confirmed
iron K lags



13 confirmed iron K lags

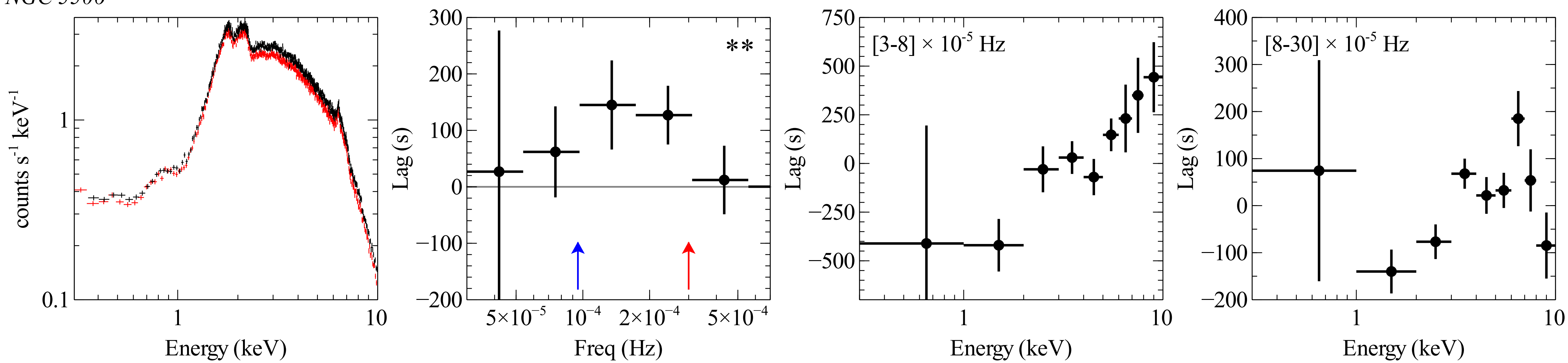


13 tentative iron K lags

Tentative iron K lags

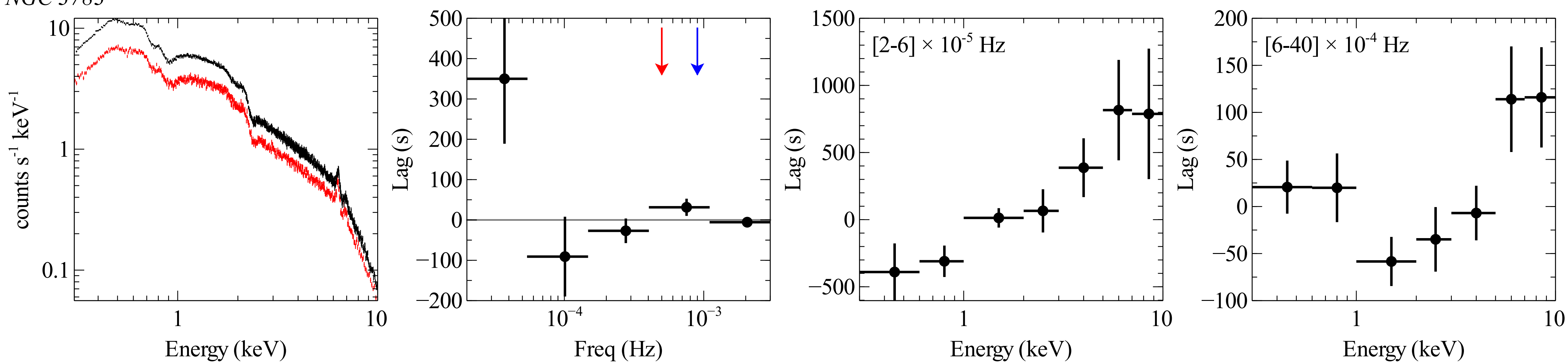
Best case

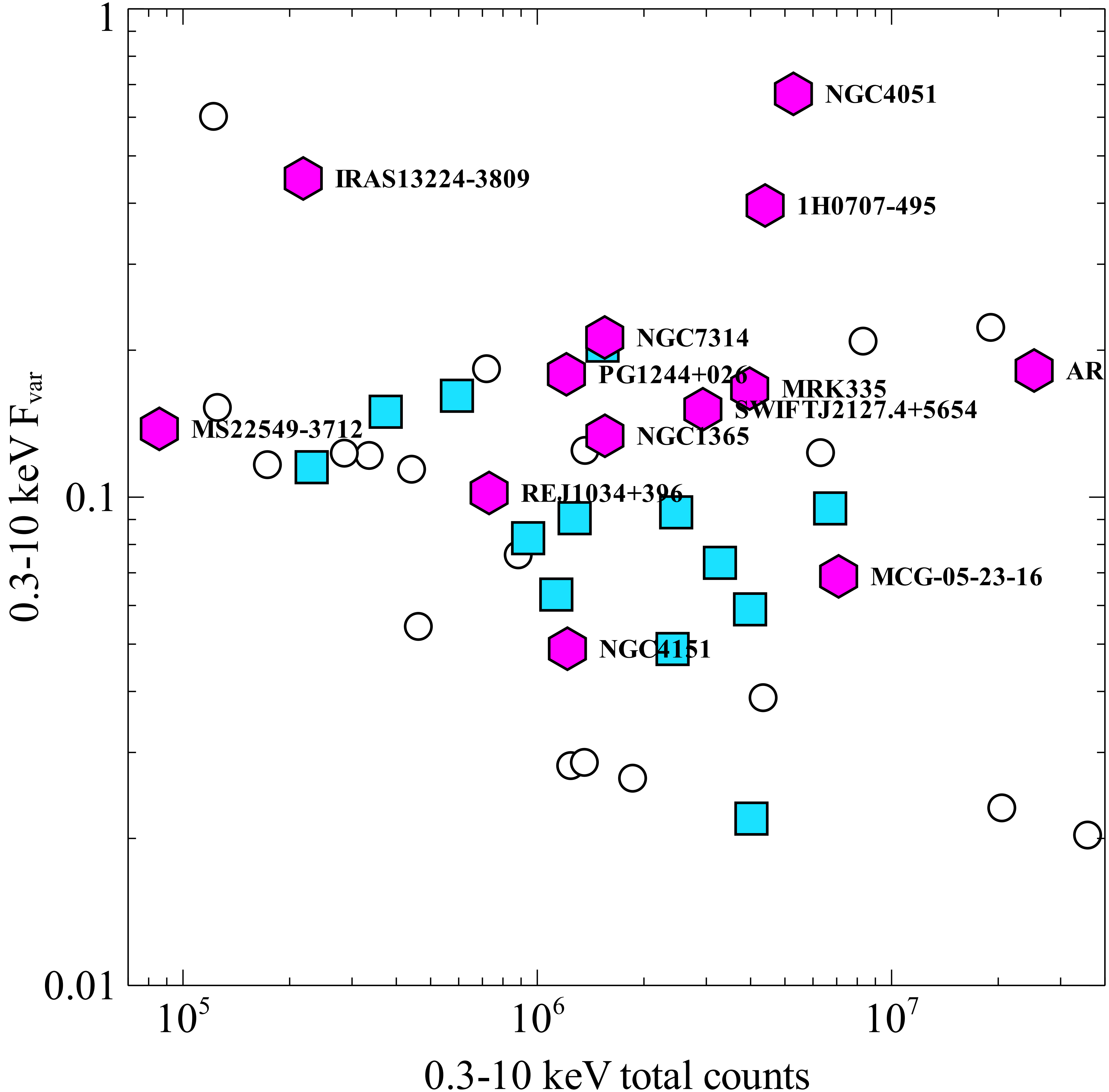
NGC 5506



Worst case

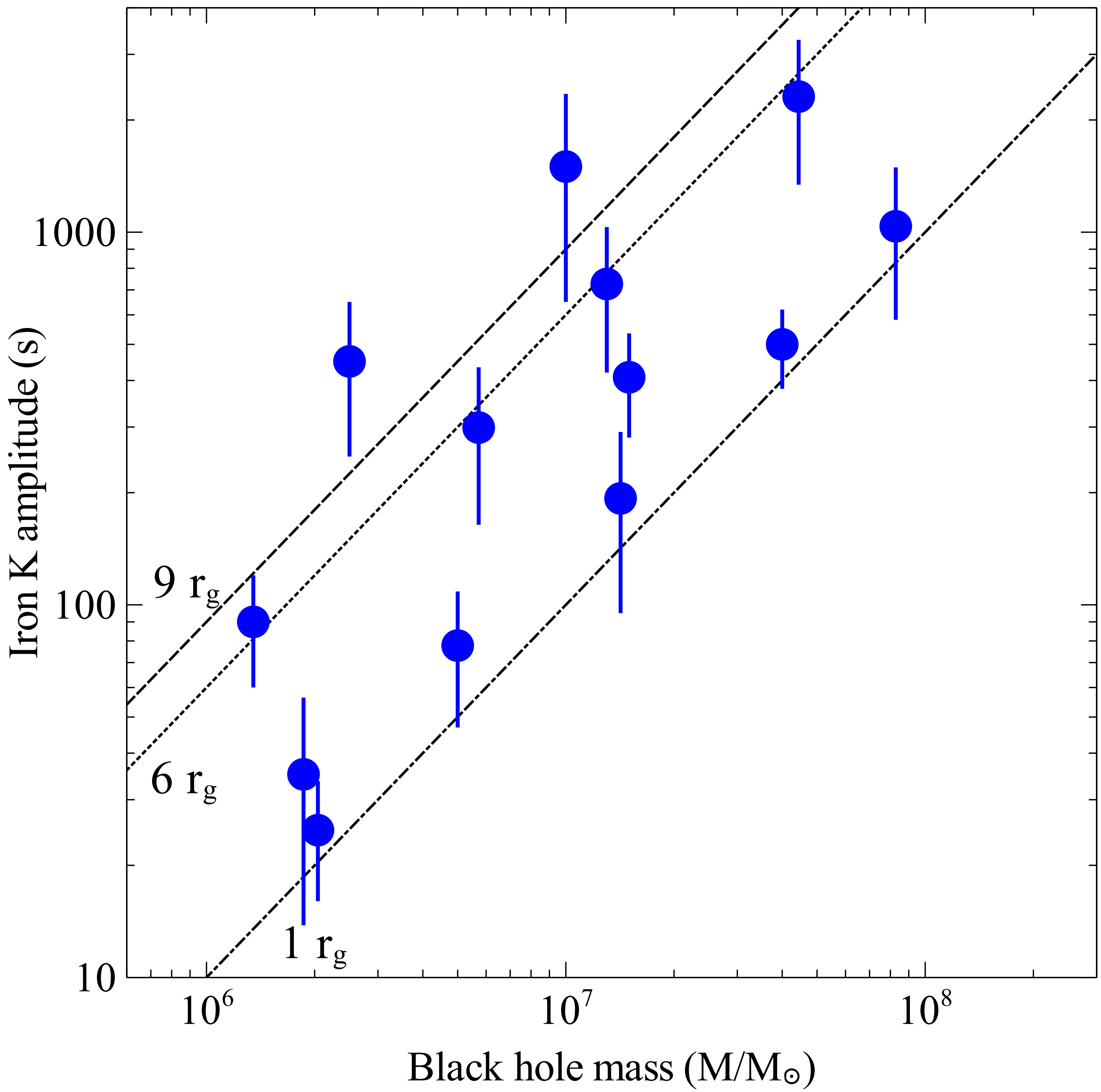
NGC 3783





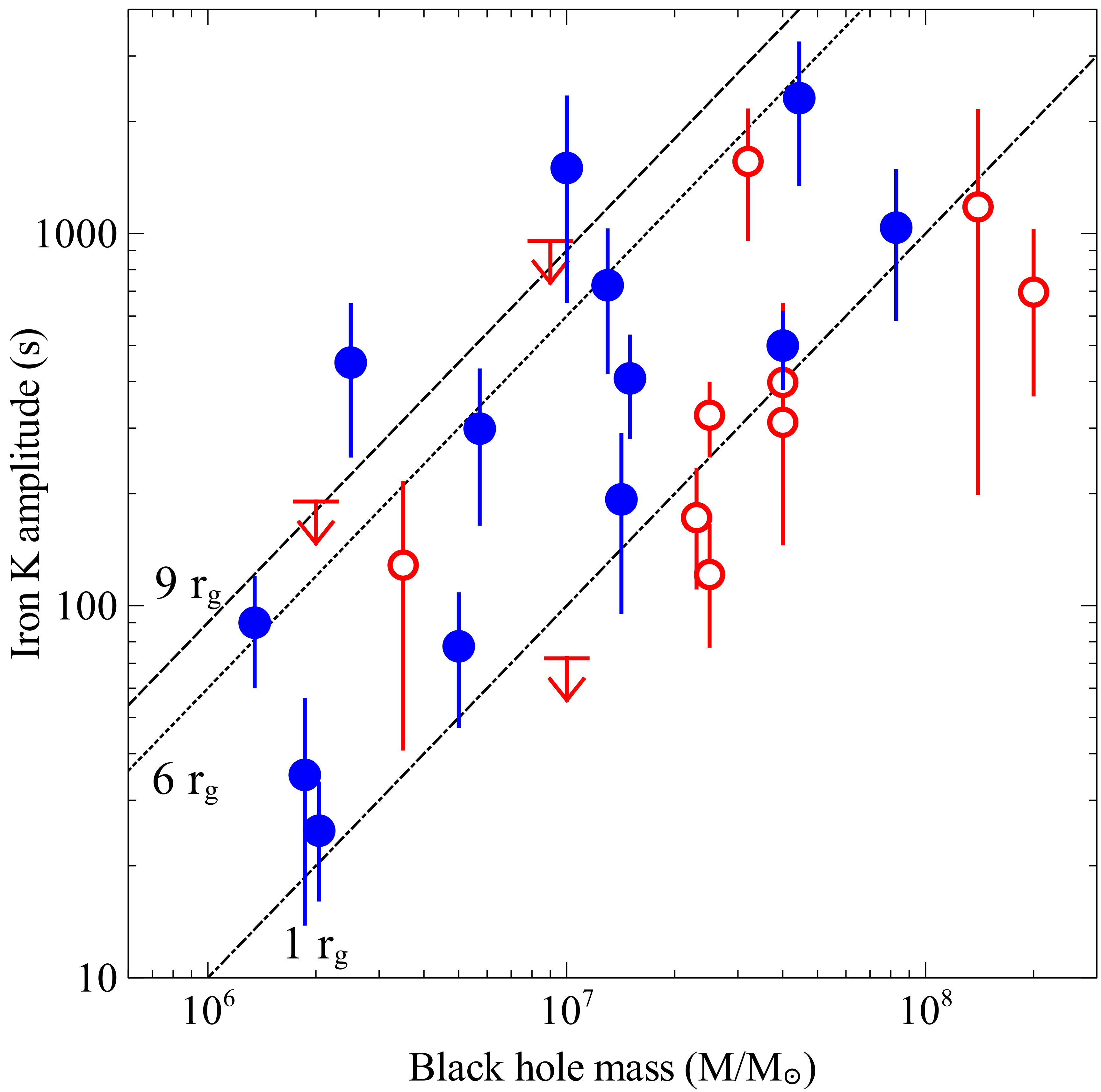
26 total
iron K lags

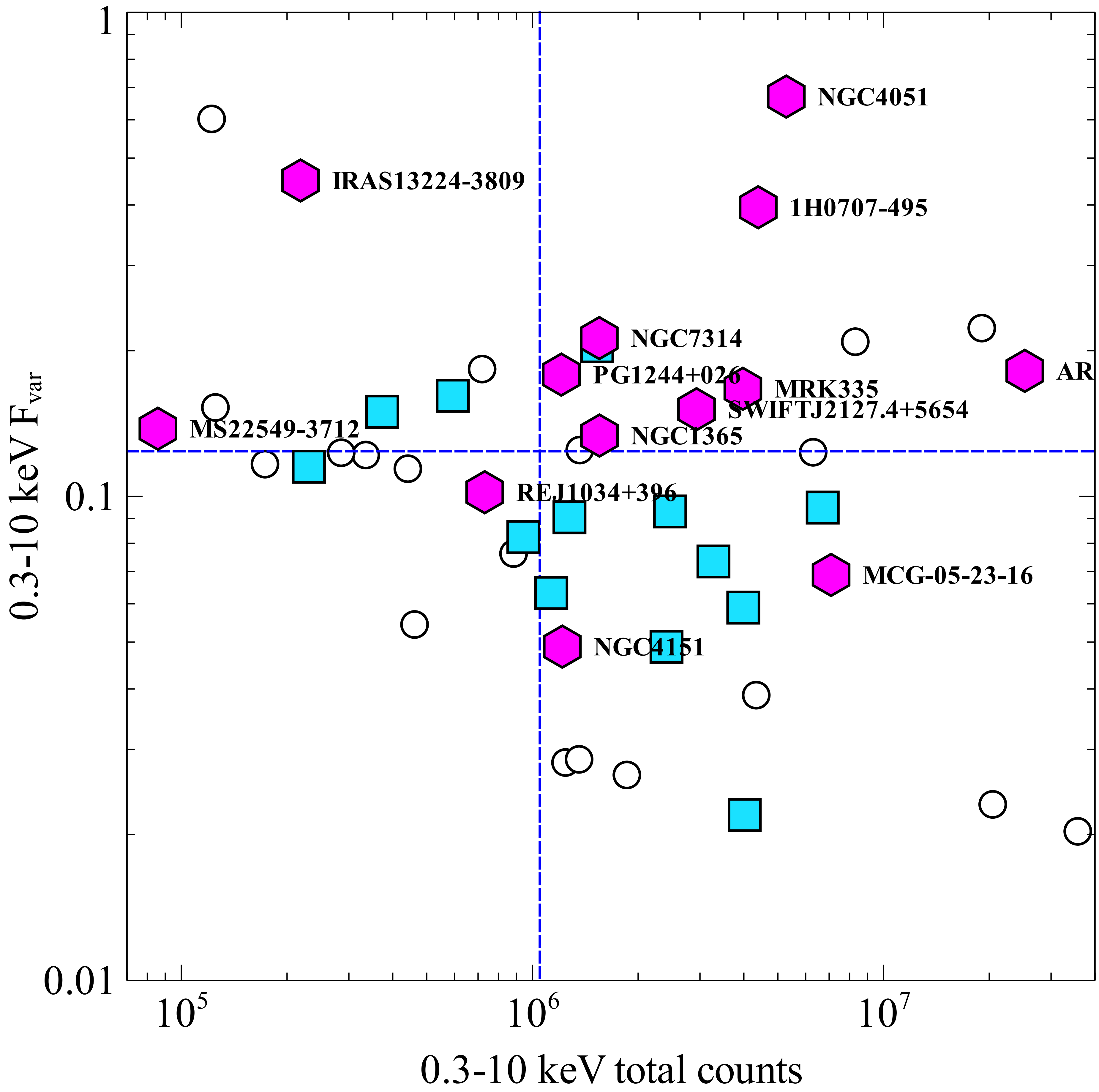
Lag-mass relation



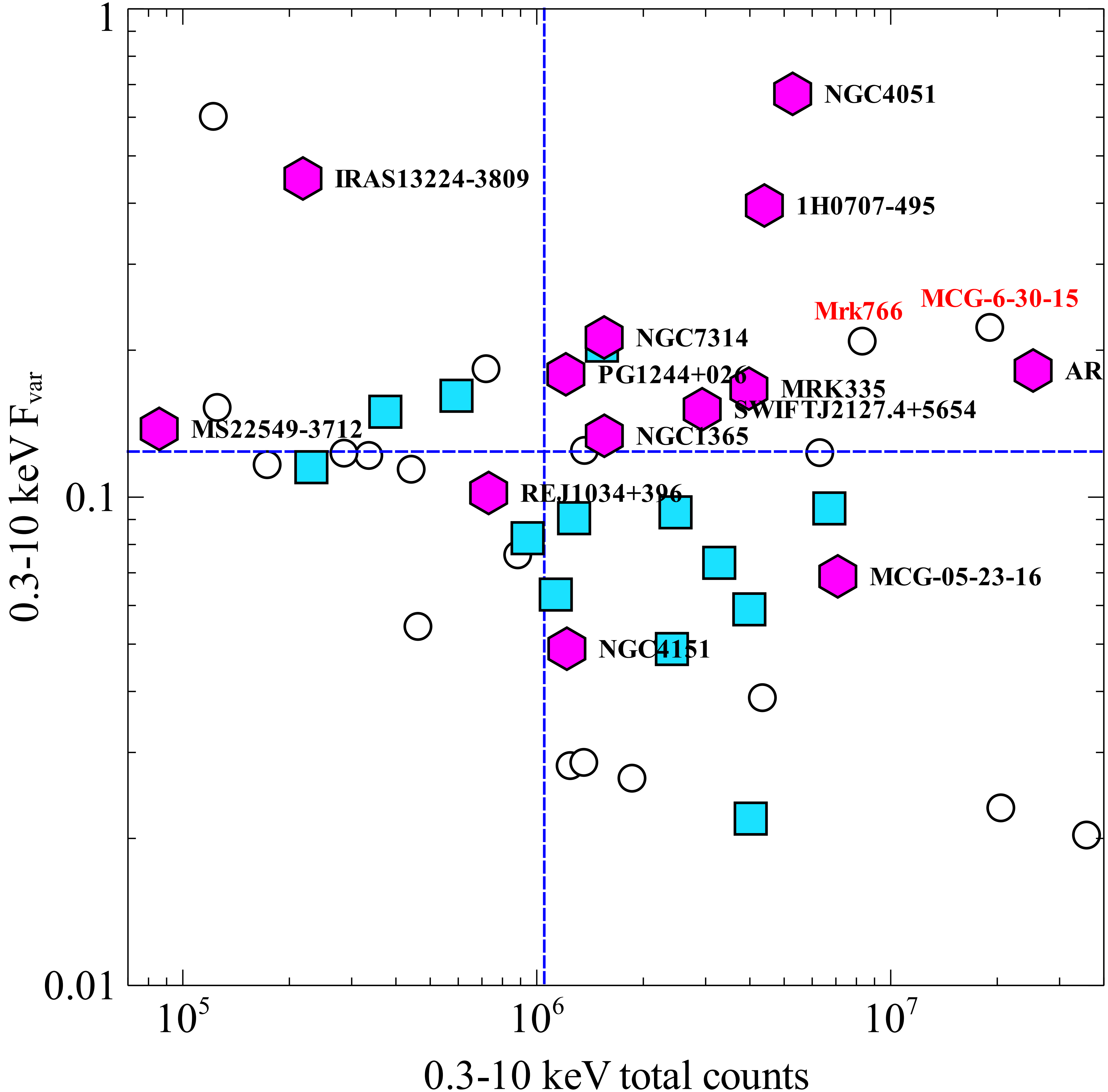
assuming
disc inclination
of 45 deg

Reverberation lag—mass relation



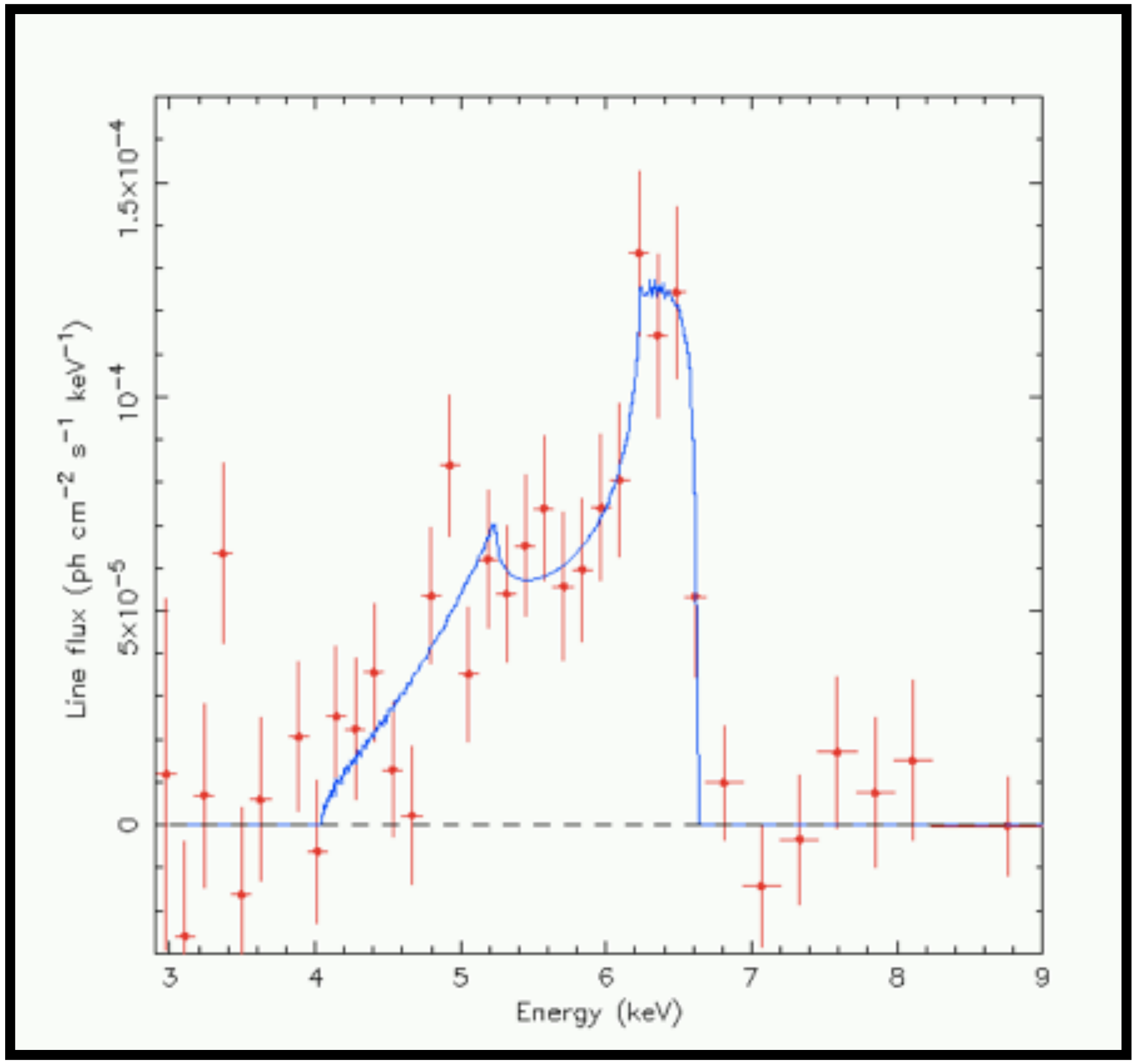


26 total
iron K lags

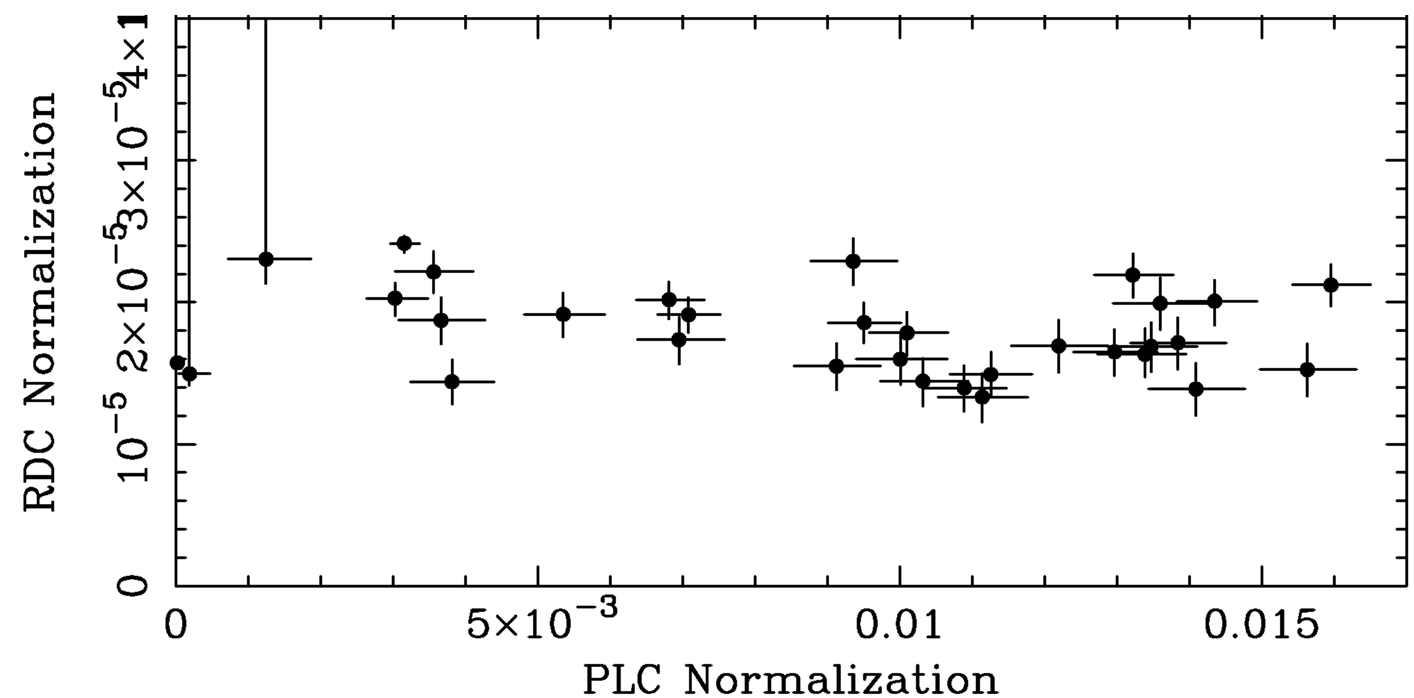


26 total
iron K lags

MCG-6-30-15



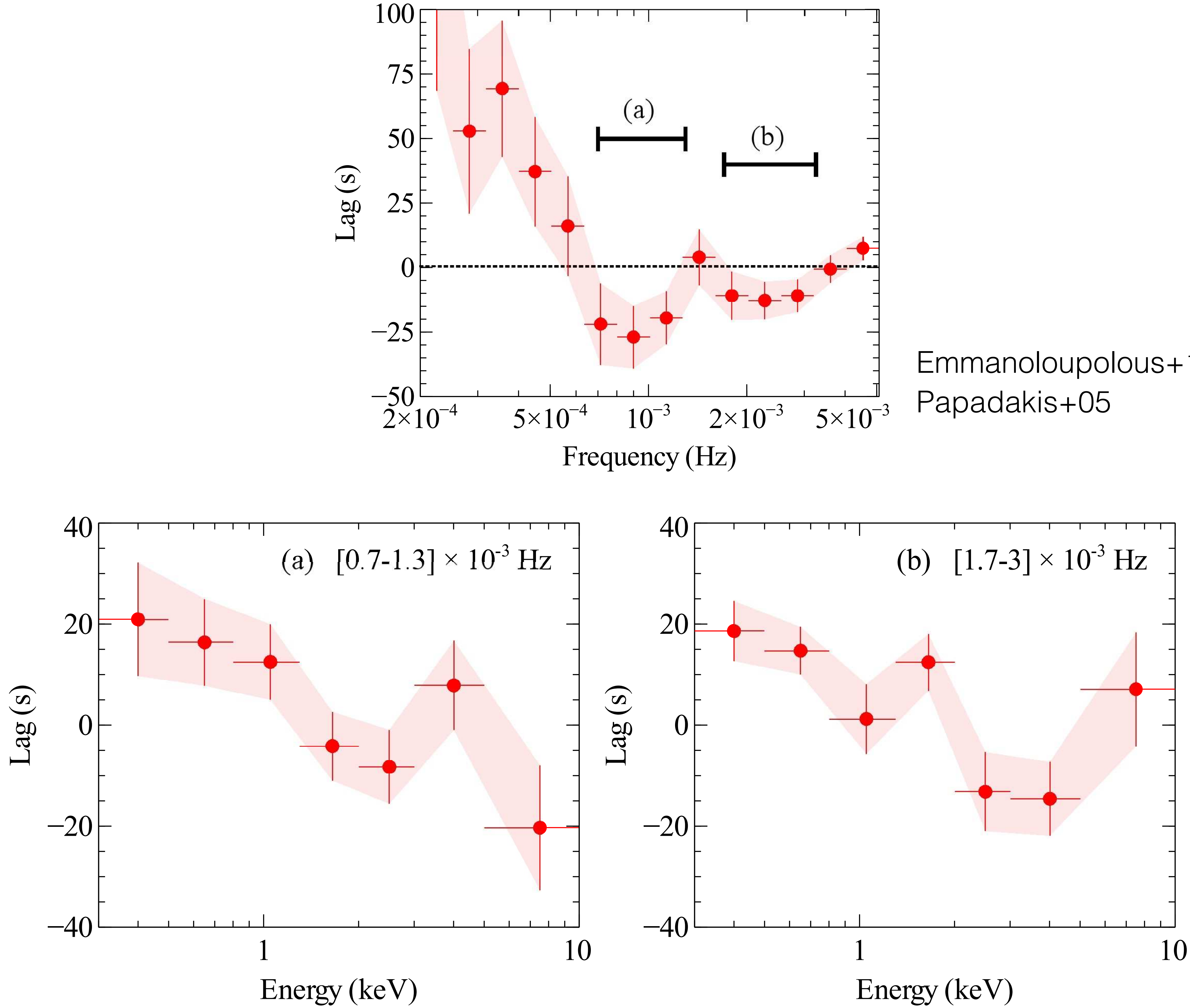
First broad iron line



evidence for light bending?

Tanaka+95, Fabian+03, Vaughan+03, Miniutti+04, Brenneman+06, Chiang+11, Miyakawa+12, Marinucci+14, …

MCG-6-30-15

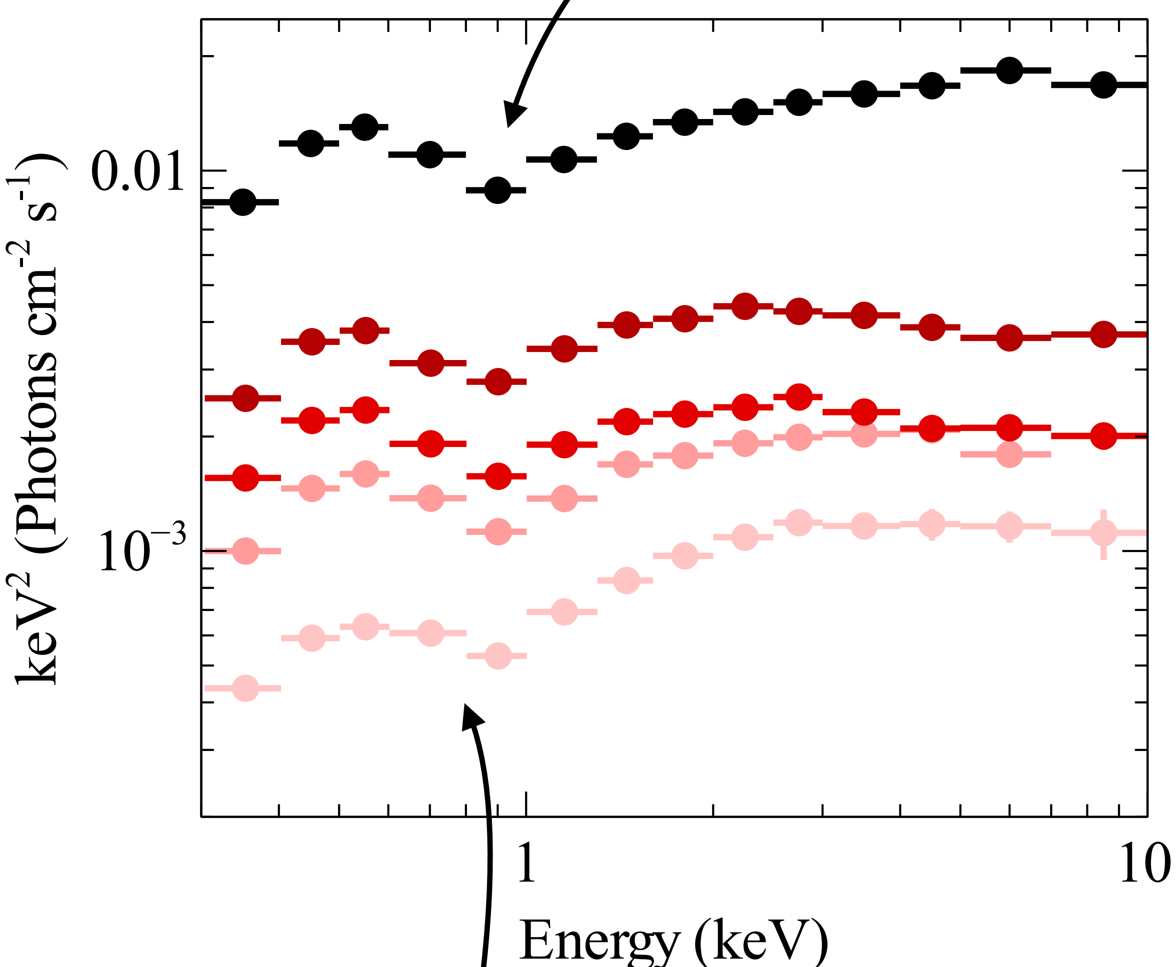


Emmanoloupolous+11
Papadakis+05

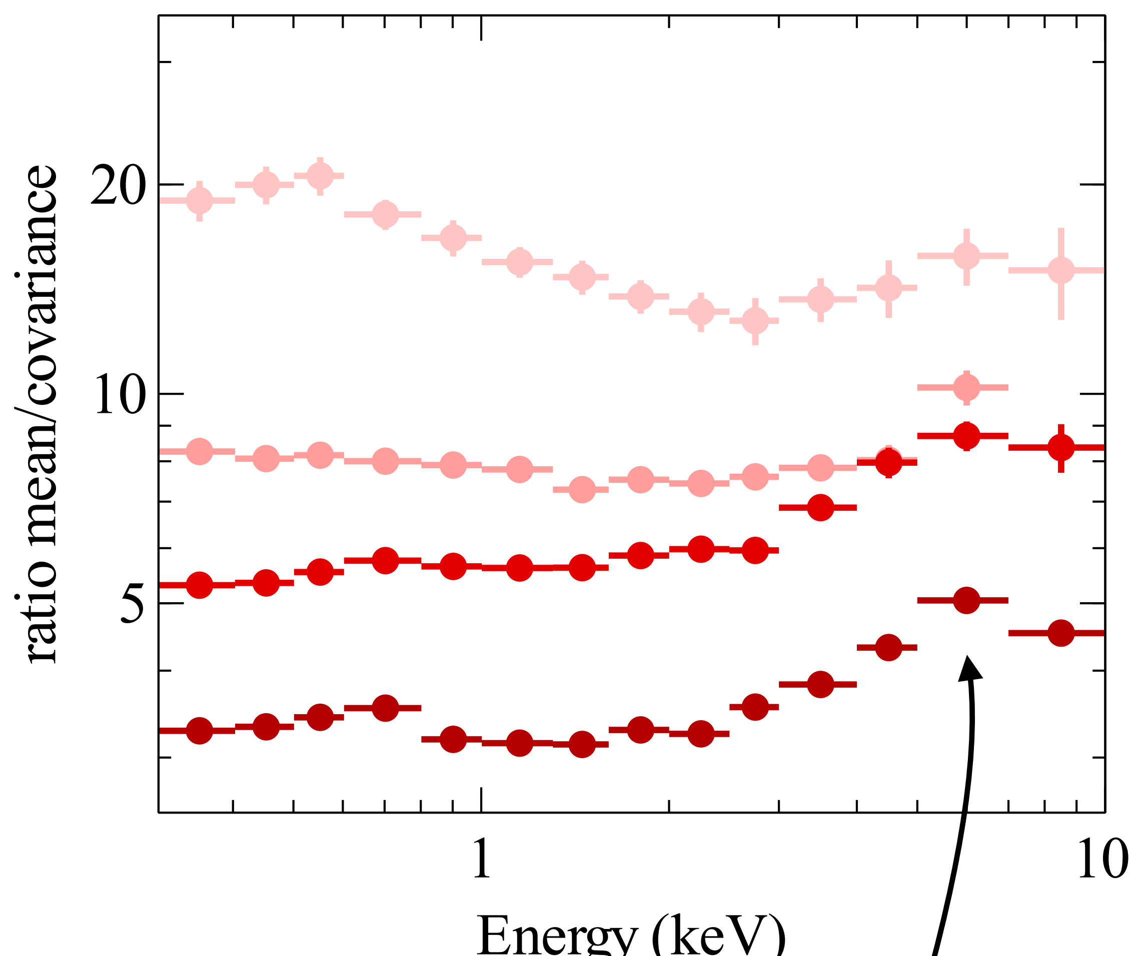
EK+14

MCG-6-30-15

mean spectrum

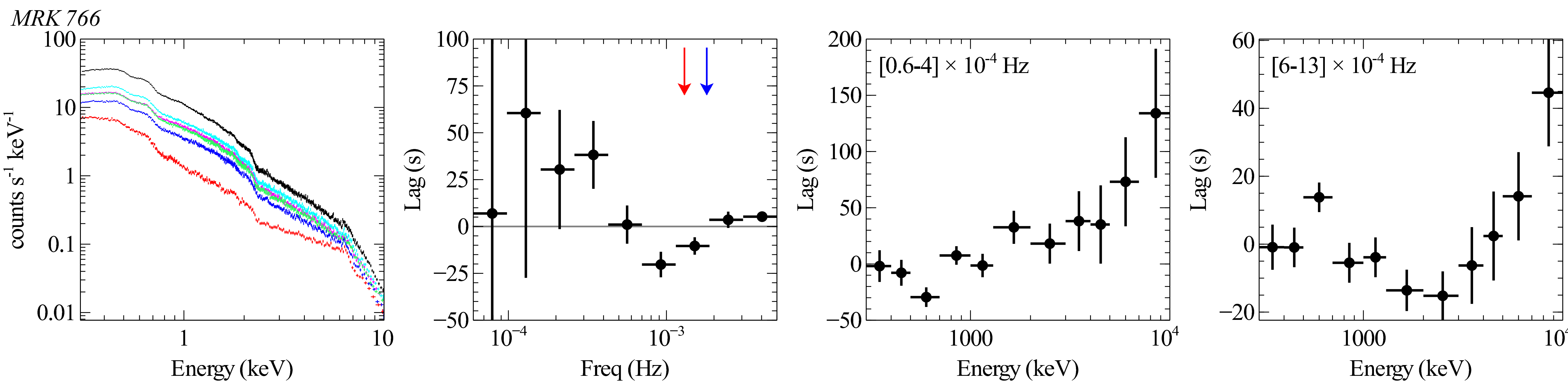


covariance spectra:
spectrum contributing to lags



uncorrelated and/or
non-varying component

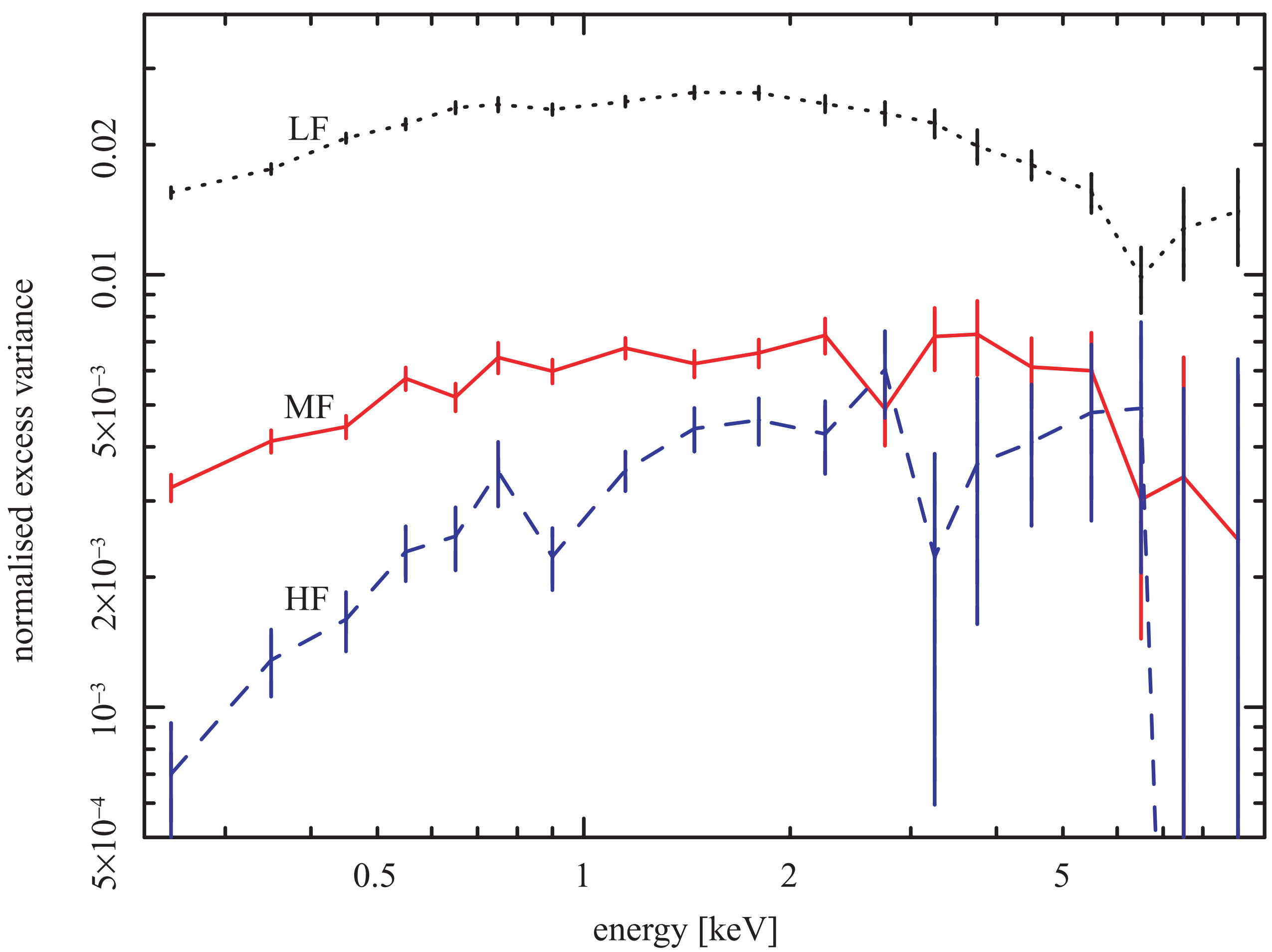
Mrk 766

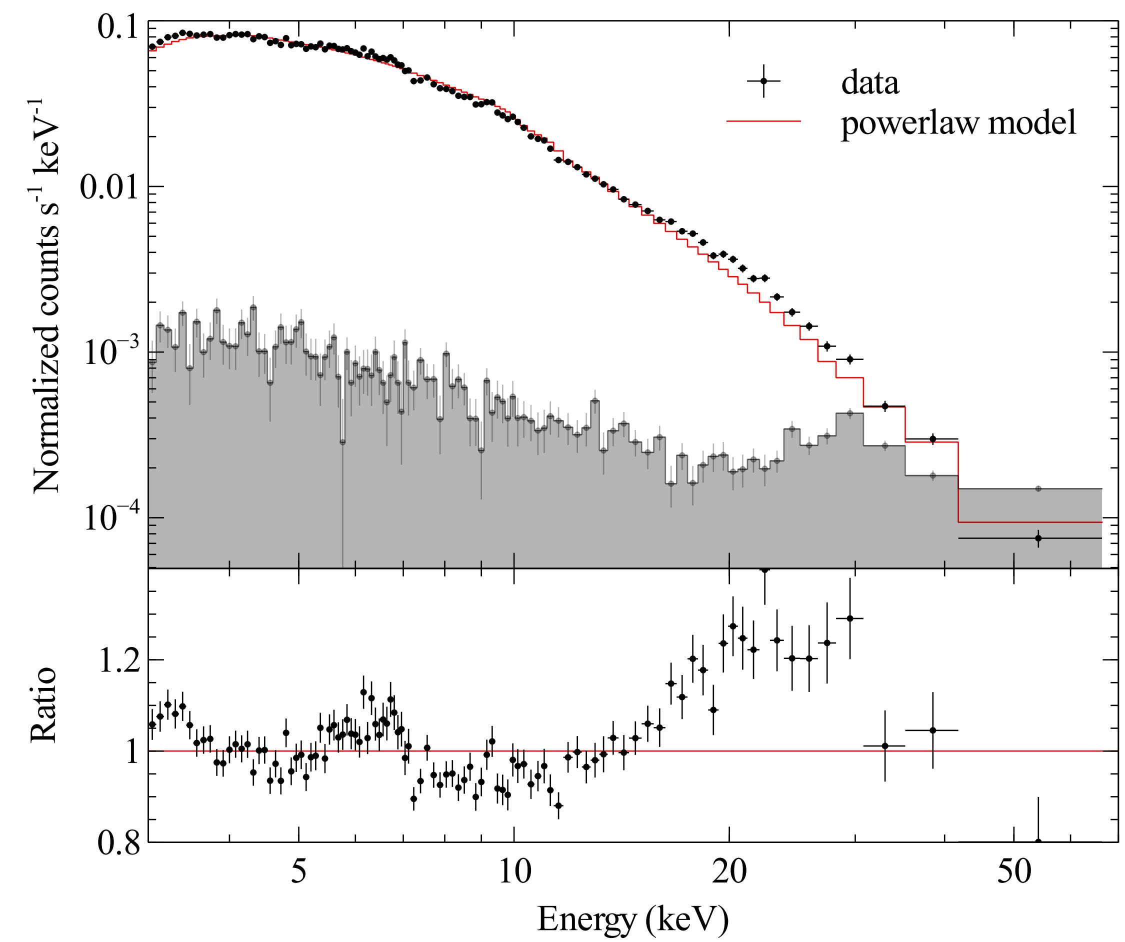


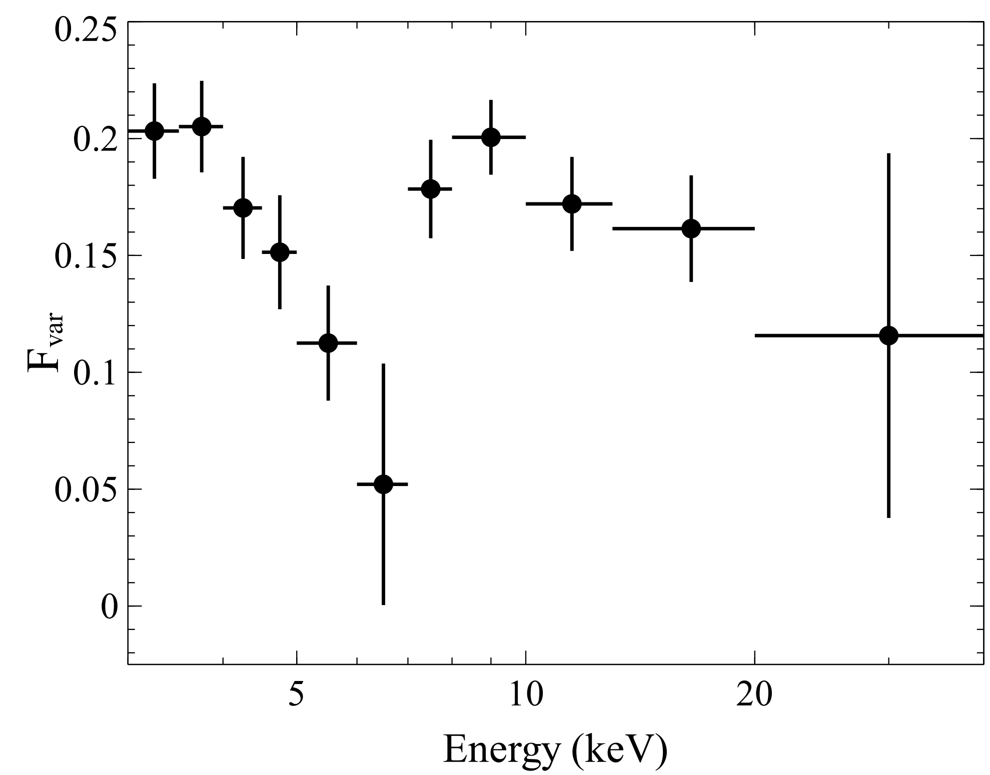
MRK 766
counts s^{-1} keV^{-1}
Energy (keV)
Lag (s)
Freq (Hz)
Lag (s)
[0.6-4] × 10^{-4} Hz
Energy (keV)
Lag (s)
[6-13] × 10^{-4} Hz
Energy (keV)

Mrk 766

Recent 100 ks NuSTAR observation
Parker, EK+ in prep







Frequency-resolved rms spectra
Arevalo+08

Conclusions

- Global study of time lags in Seyferts is ongoing
- Reverberation (confirmed+tentative) found in 26/45 sources
- Most non-detections clearly due to lack of statistics, but two sources—MCG-6-30-15 and Mrk 766—have "should" show reverberation
- Further evidence for light bending?