X-RAY VARIABILITY PLANE:

IMPORTANCE OF OBSCURATION

OMAIRA GONZÁLEZ-MARTÍN / IRYA-UNAM (MÉXICO)

UPDATE ON THE X-RAY VARIABILITY PLANE FOR ACTIVE GALACTIC NUCLEI:
THE ROLE OF THE OBSCURATION

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ABSTRACT

Scaling relations are the most powerful astrophysical tools to set constraints to the physical mechanisms of astronomical sources and to infer properties that cannot be accessed directly. We re-investigate here one of these scaling relations in active galactic nuclei (AGN); the so-called X-ray variability plane (or mass-luminosity-timescale relation, McHardy et al. 2006). This relation links the power-spectral density (PSD) break frequency with the super-massive black hole (SMBH) mass and the bolometric luminosity. We used available *XMM*-Newton observations of a sample of 22 AGN to study the PSD and spectra in short segments within each observation. This allows us to report for the first time that the PSD break frequency varies for each object, showing variations in 19 out of the 22 AGN analyzed. Our analysis of the variability plane confirms the relation between the break frequency and the SMBH mass and finds that the obscuration along the line of sight N_H (or the variations on the obscuration using its standard deviation, ΔN_H) is also a required parameter, at least for the range of frequencies analyzed here ($\sim 3\times10^{-5} - 5\times10^{-2}$Hz). We constrain a new variability plane of the form: $\log(\nu_{Break}) = (-0.589\pm0.005)\log(M_{BH}) + (0.10\pm0.01)\log(N_H) - (1.5\pm0.3)$ (or $\log(\nu_{Break}) = (-0.549\pm0.009)\log(M_{BH}) + (0.56\pm0.06)\,\Delta N_H + (0.19\pm0.08)$). The X-ray variability plane found by McHardy et al. (2006) is roughly recovered when we use unobscured segments. We speculate that this behavior is well explained if most of the reported frequencies are related to inner clouds (within 1 pc), following Kepler orbits under the gravitational field of the SMBH.

Keywords: accretion – galaxies: active – galaxies: nuclei – X-rays: galaxies

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STORY OF THREE FAILURES!

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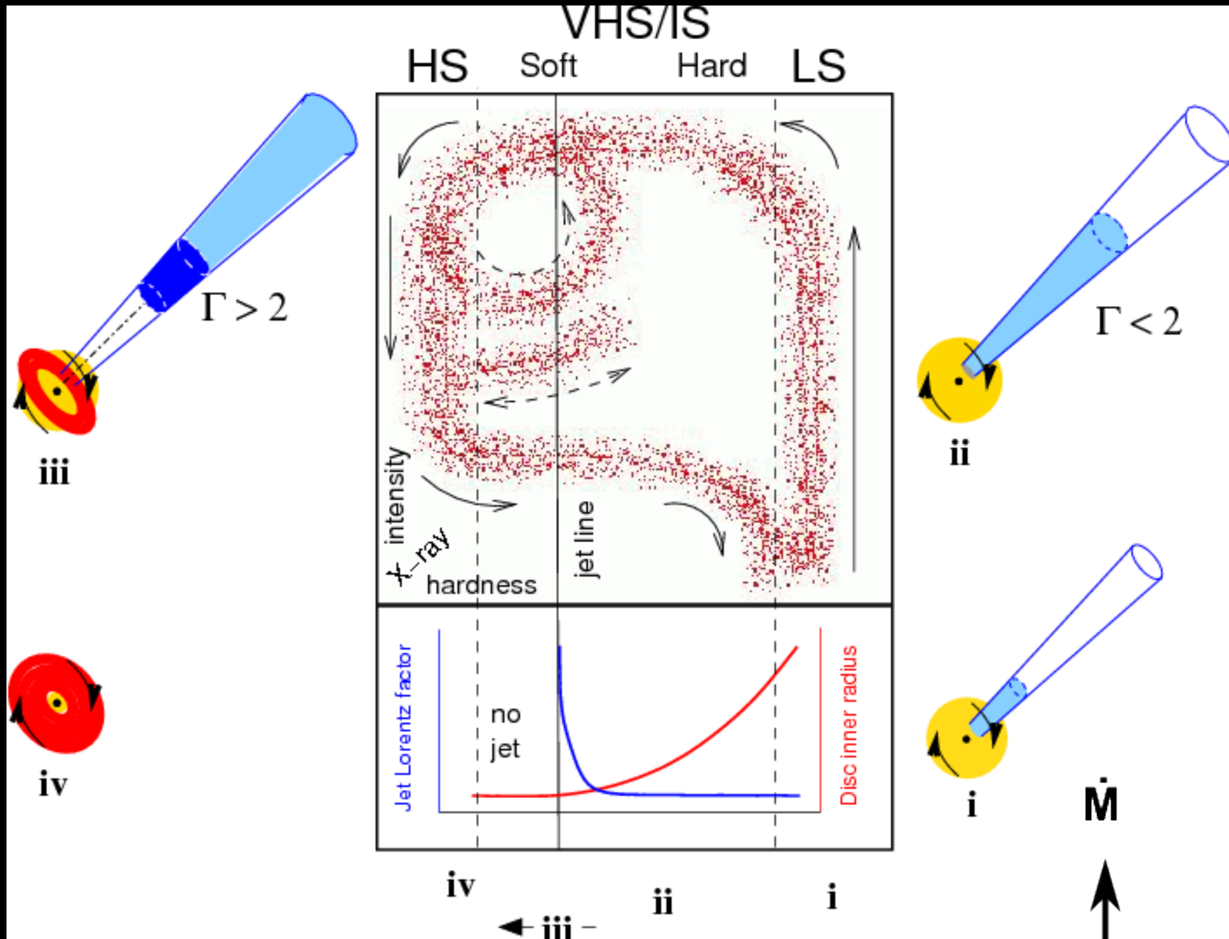
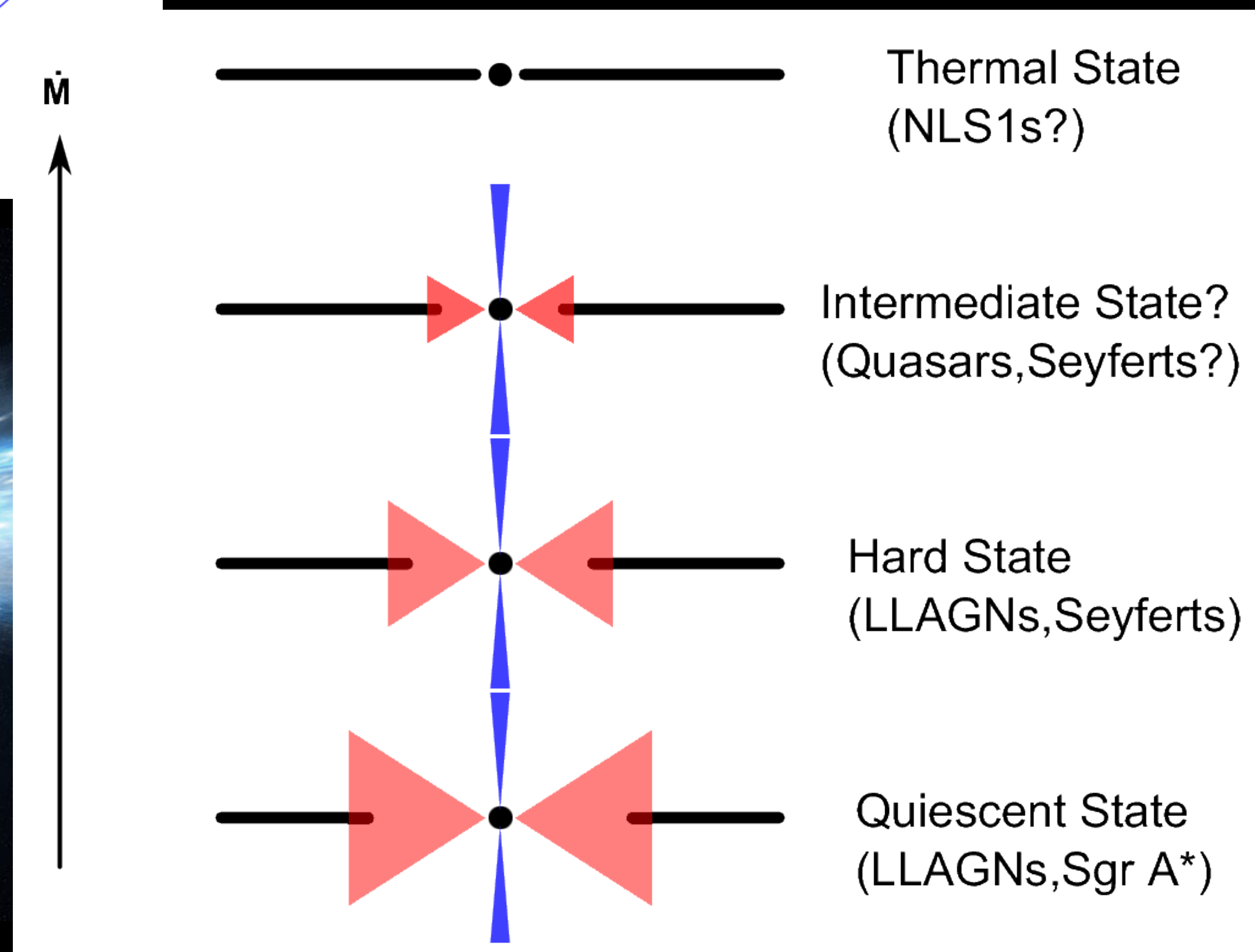
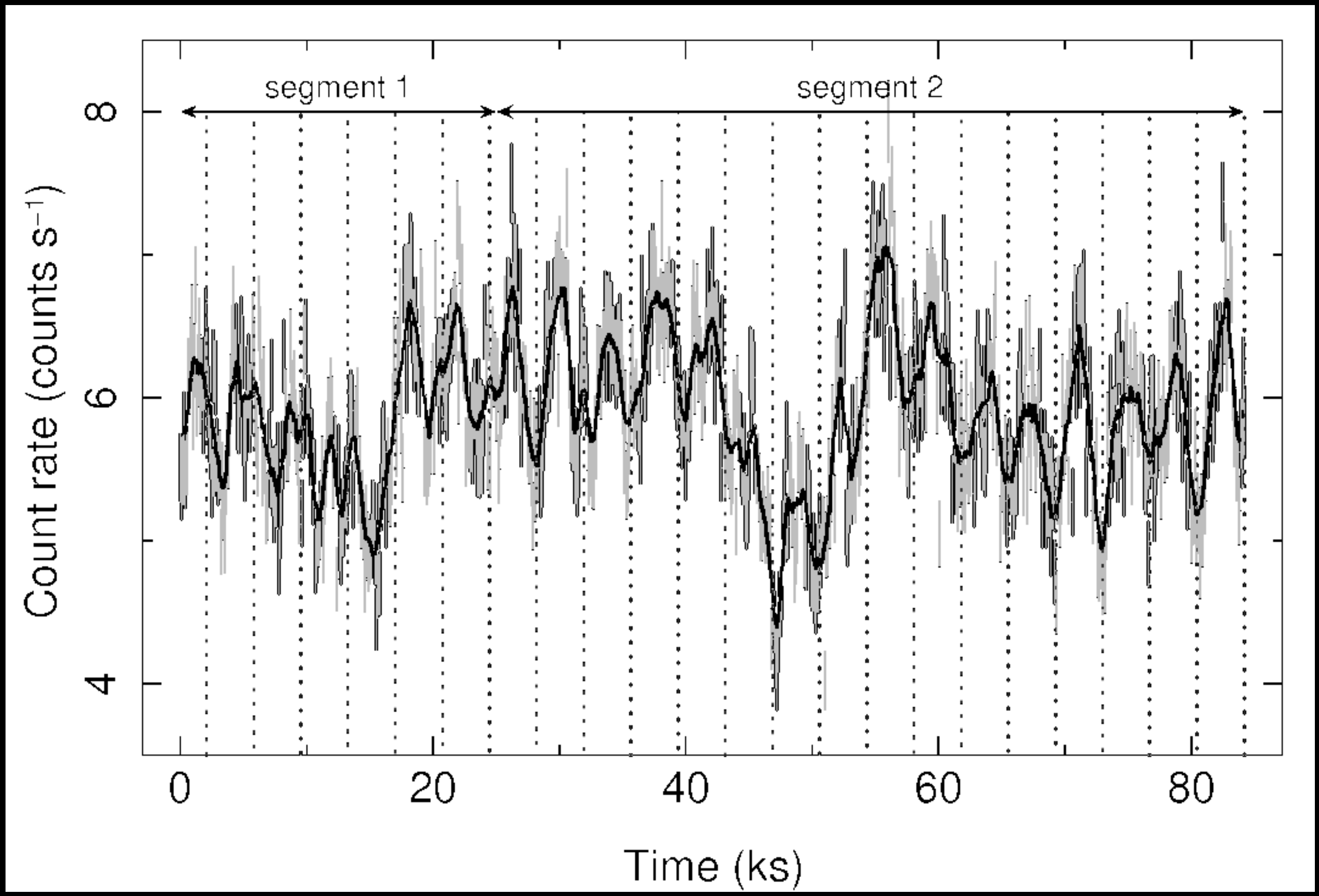
X-ray binaries versus AGN

Ghisellini+10, Yuan & Narayan +14

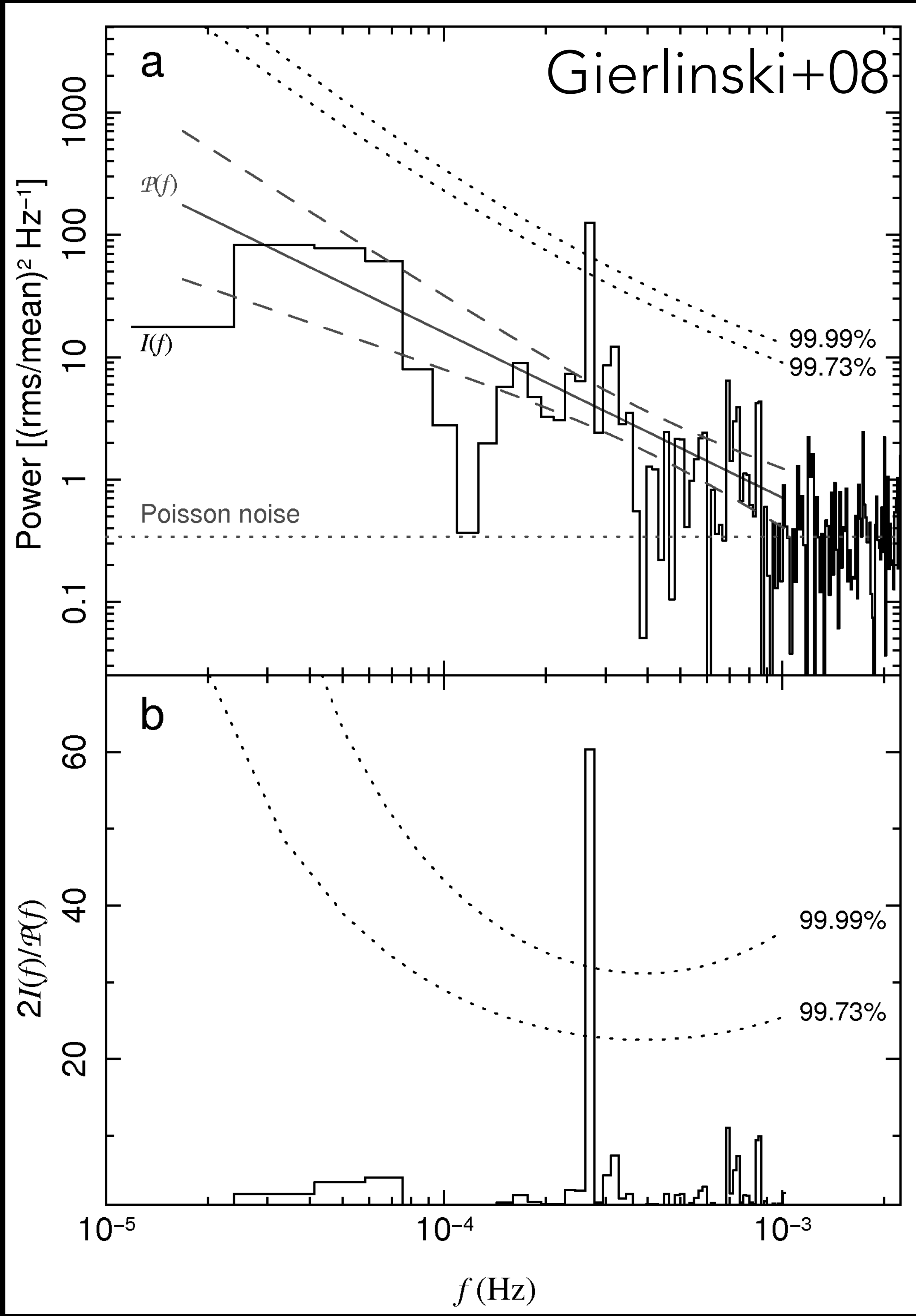




REJ1034+396



segment 1
segment 2
Count rate (counts s⁻¹)
4
6
8
0
20
40
60
80
Time (ks)



a
Gierlinski+08
Power [(rms/mean)² Hz⁻¹]
P(f)
I(f)
99.99%
99.73%
Poisson noise
0.1
1
10
100
1000
b
2I(f)/P(f)
20
40
60
99.99%
99.73%
10⁻⁵
10⁻⁴
10⁻³
f (Hz)

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Astronomy & Astrophysics

X-ray variability of 104 active galactic nuclei

XMM-Newton power-spectrum density profiles★

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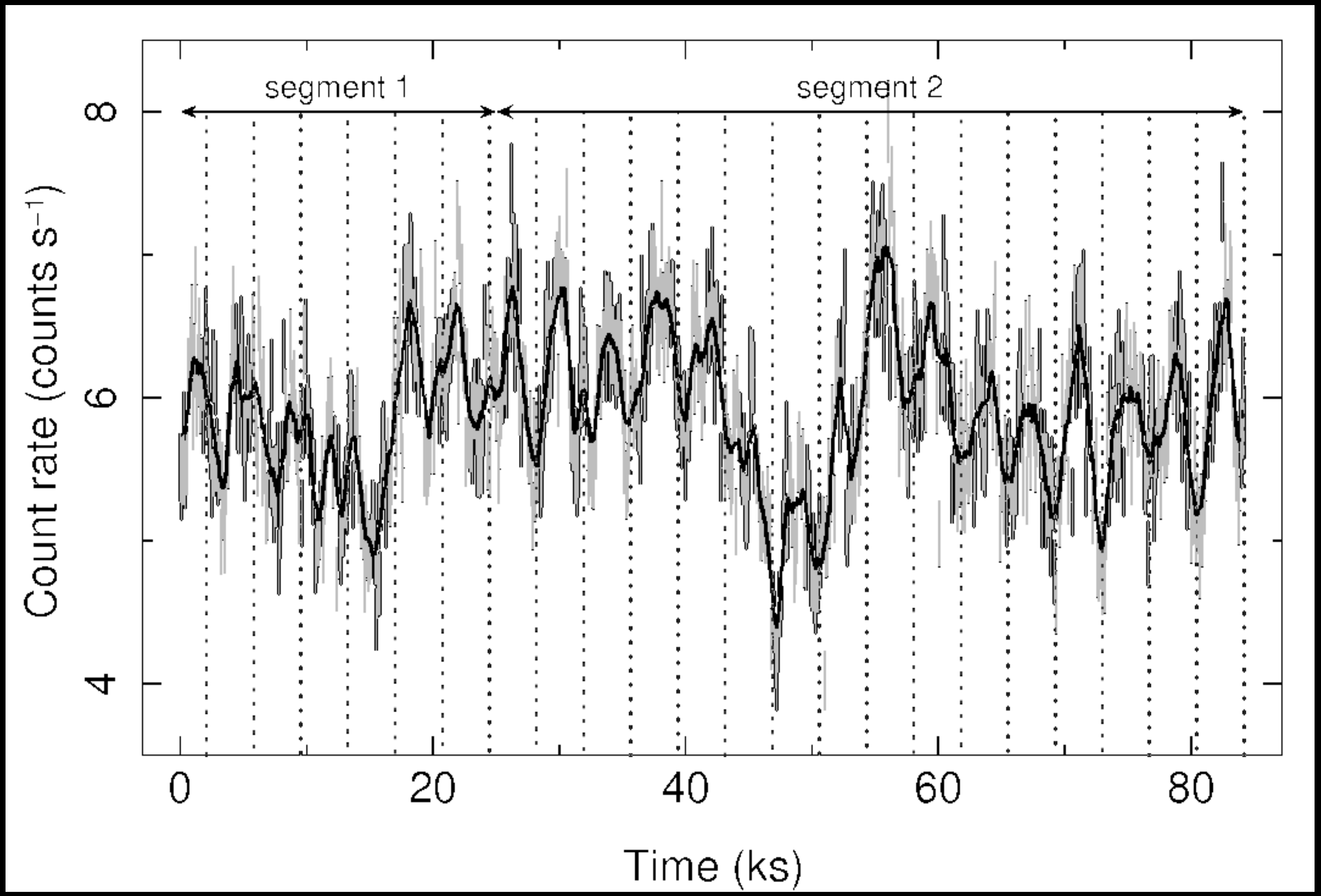
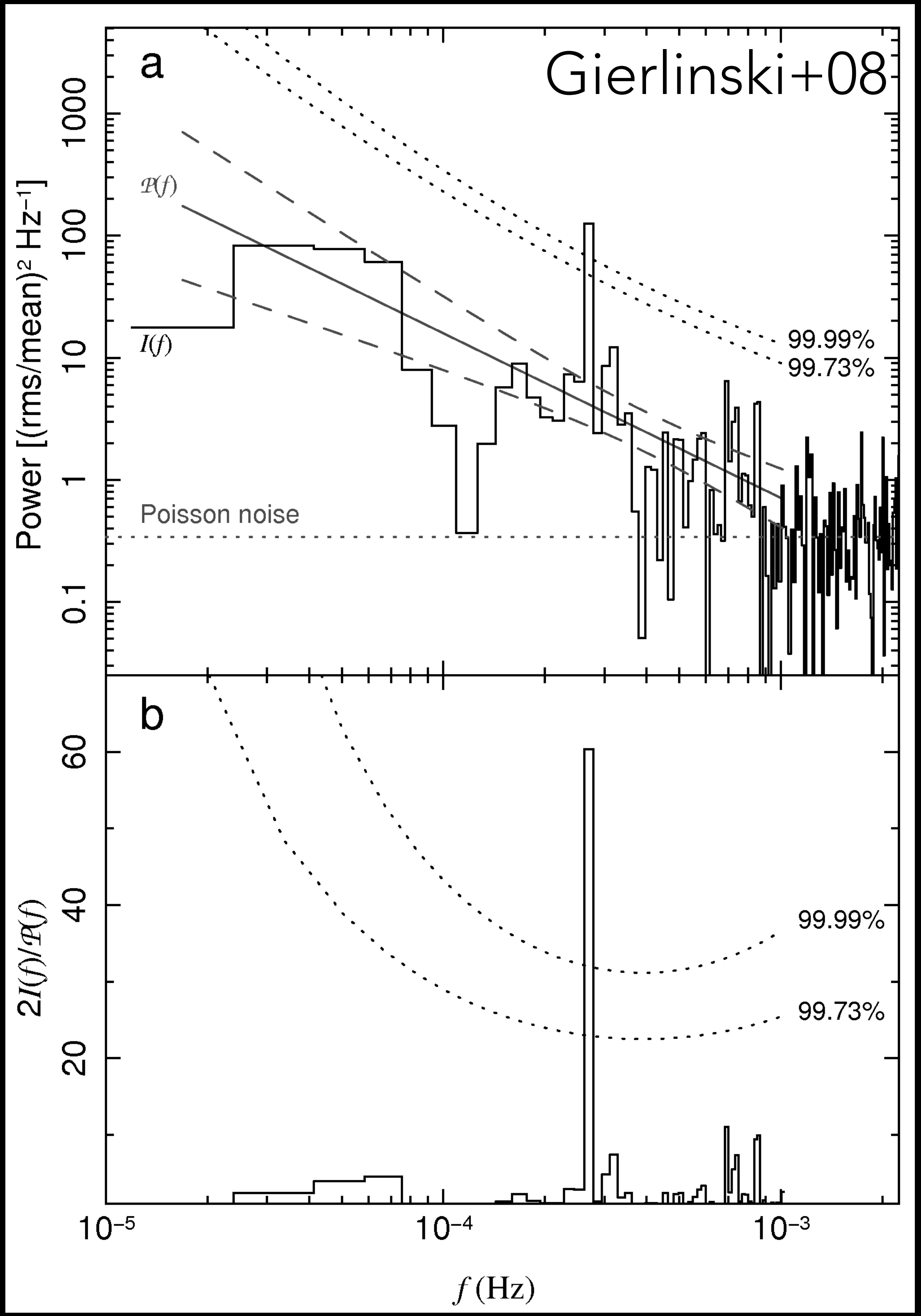
ABSTRACT

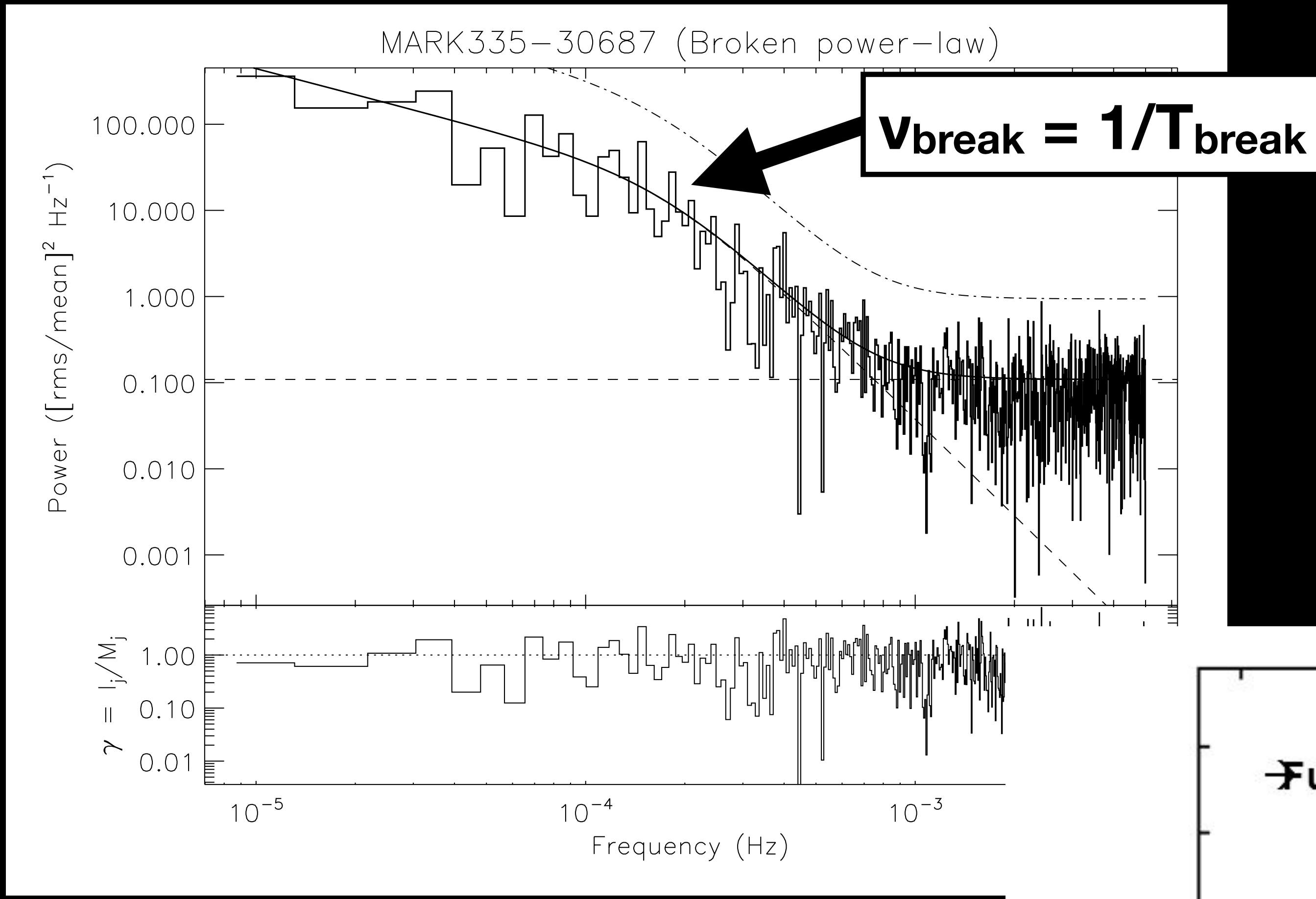
Context. Active galactic nuclei (AGN), powered by accretion onto supermassive black holes (SMBHs), are thought to be scaled up versions of Galactic black hole X-ray binaries (BH-XRBs). In the past few years evidence of such correspondence include similarities in the broadband shape of the X-ray variability power spectra, with characteristic bend times-scales scaling with mass.
Aims. The aim of this project is to characterize the X-ray temporal properties of a sample of AGN to study the connection among different classes of AGN and their connection with BH-XRBs.

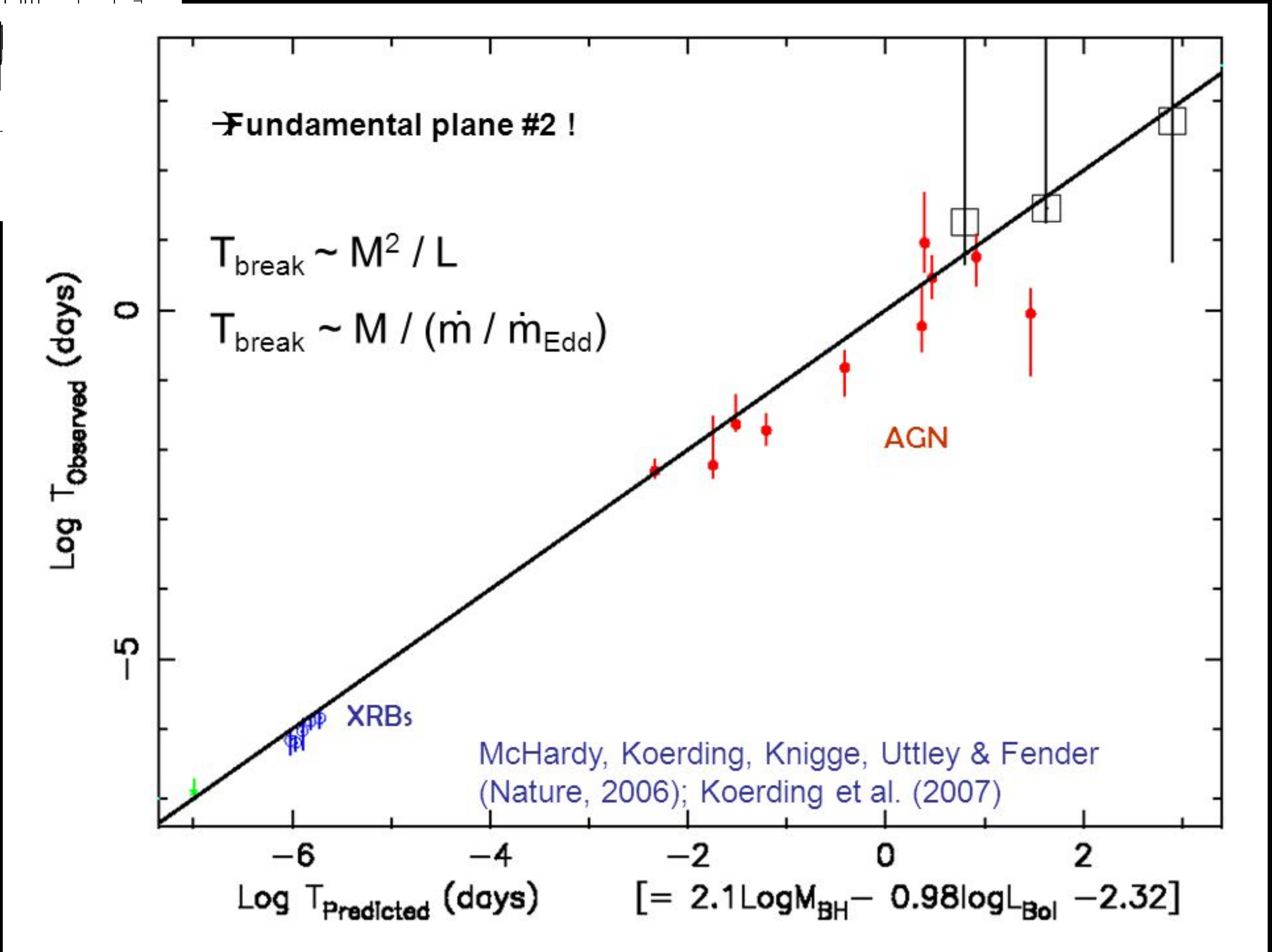
FAILURE 1:

REJ1034+396






MARK335−30687 (Broken power−law)
νbreak = 1/Tbreak
Power ([rms/mean]² Hz⁻¹)
100.000
10.000
1.000
0.100
0.010
0.001
γ = Ij/Mj
1.00
0.10
0.01
10⁻⁵
10⁻⁴
10⁻³
Frequency (Hz)

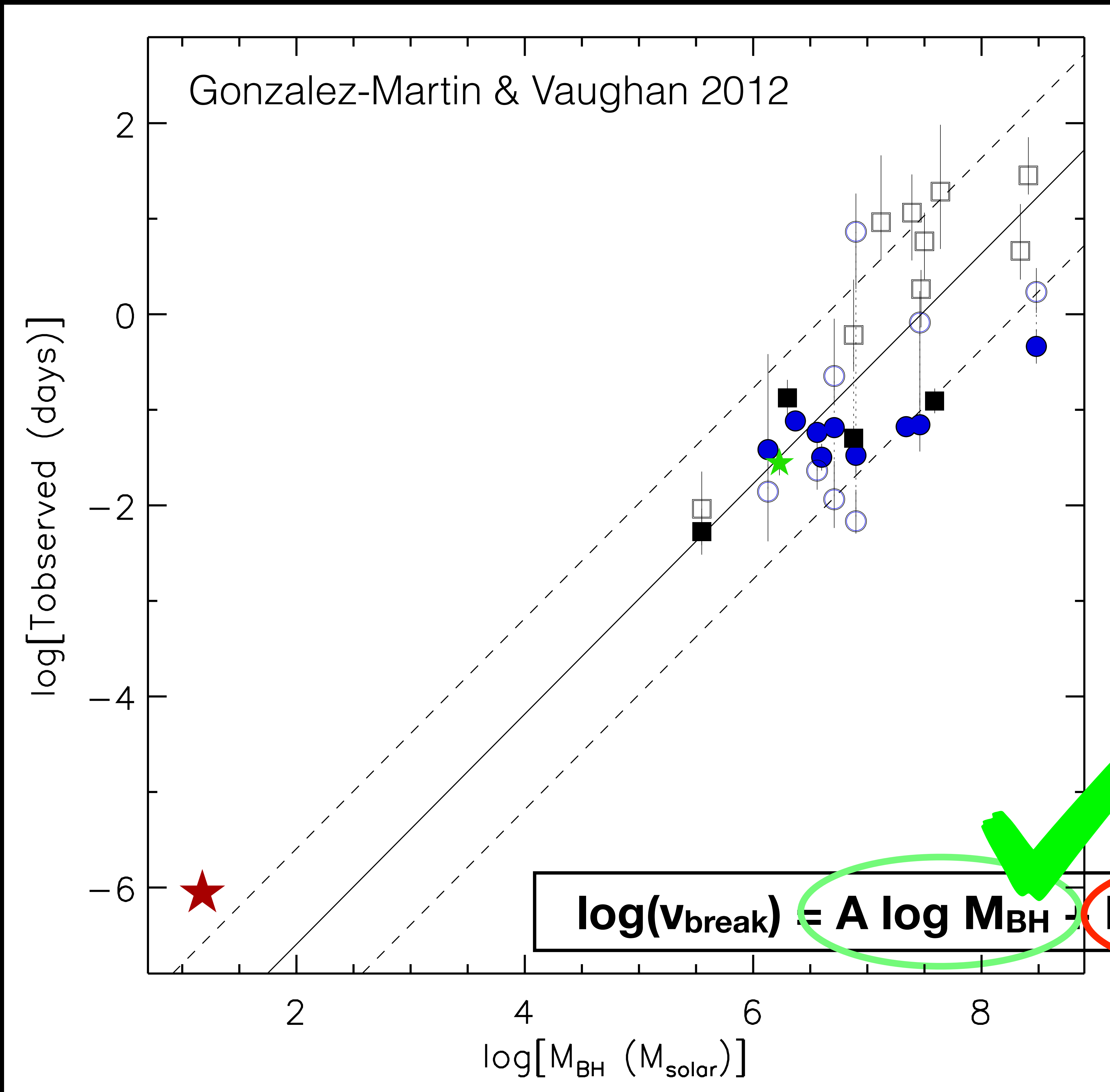

Fundamental plane #2 !
Tbreak ~ M² / L
Tbreak ~ M / (ṁ / ṁEdd)
AGN
XRBs
McHardy, Koerding, Knigge, Uttley & Fender
(Nature, 2006); Koerding et al. (2007)
Log TObserved (days)
0
−5
−6
−4
−2
0
2
Log TPredicted (days)
[= 2.1LogMBH− 0.98logLBol −2.32]

22 AGN: BLS1 and NLS1

Table 1. Main properties of the AGN sample

Objname	*Type*	$log(M_{BH})$	N_{obs}	*Expos.* (*ksec*)	*count-rate* (*counts/s*)	*bin* (*s*)	$log(L_{bol})$	$log(N_H)$	$log(\nu_{Break})$	N_{Break}/N_{N_H}
MRK 335	*NLSy*1	$7.23 \pm 0.04^1(R)$	4	389	0.96	50	[43.7, 44.8]	[20.8, 21.9]	[−3.9, −2.6]	116/8
ESO 113-*G*010	*Sy*1		1	93	0.34	100	[43.4, 43.6]	21.5	[−3.7, −2.9]	42/1
Fairall 9	*Sy*1	$8.3 \pm 0.1^1(R)$	5	332	1.45	50	[44.7, 45.1]	21.1	−3.6	1/0
PKS 0558-504	*NLSy*1	$8.48 \pm 0.05^2(RP)$	5	564	1.11	50	[45.7, 46.4]	[20.9, 21.4]	[−4.0, −2.8]	69/0
1*H* 0707-495	*NLSy*1	$6.3 \pm 0.5^3(L)$	14	1095	0.12	200	[42.7, 43.8]	[21.1, 22.2]	[−3.5, −2.7]	58/4
ESO 434-*G*40	*Sy*1	$7.57 \pm 0.25^4(S)$	5	382	7.62	50	[44.0, 44.3]	[21.8, 22.2]	[−4.1, −2.9]	232/232
NGC 3227	*Sy*1	$6.8 \pm 0.1^1(R)$	2	124	2.02	50	[42.4, 43.0]	[20.7, 22.6]	[−3.6, −2.5]	46/43
REJ 1034+396	*NLSy*1	$6.6 \pm 0.3^5(L)$	7	277	0.12	200	[43.3, 43.8]	[21.4, 21.9]	[−3.5, −2.9]	4/0
NGC 3516	*Sy*1	$7.40 \pm 0.05^1(R)$	6	440	2.77	50	[43.6, 44.3]	[20.6, 21.9]	[−4.5, −2.8]	47/37
NGC 3783	*Sy*1	$7.37 \pm 0.08^1(R)$	3	223	3.81	50	[43.9, 44.2]	[20.6, 21.5]	[−4.4, −3.4]	28/5
NGC 4051	*NLSy*1	$6.1 \pm 0.1^1(R)$	13	435	1.12	50	[41.8, 42.7]	[20.9, 22.1]	[−3.6, −2.2]	63/12
NGC 4151	*Sy*1	$7.55 \pm 0.05^1(R)$	13	440	3.73	50	[42.7, 43.5]	[22.2, 23.1]	[−4.0, −2.9	9/9
MRK 766	*NLSy*1	$6.2 \pm 0.3^6(R)$	9	596	1.21	50	[43.1, 43.9]	[20.9, 21.9]	[−3.7, −2.4]	257/44
NGC 4395	*Sy*1	$5.4 \pm 0.1^7(R)$	3	175	0.38	100	[40.9, 41.1]	[21.0, 22.8]	[−3.2, −2.4]	70/53
MCG-06-30-15	*NLSy*1	$6.3 \pm 0.4^5(L)$	7	563	3.06	50	[43.2, 43.9]	[20.5, 21.7]	[−3.7, −2.6]	336/81
IC 4329*A*	*Sy*1	$8.3 \pm 0.5^8(S)$	1	125	7.41	50	[44.6, 44.7]	[20.5, 21.4]	[−4.4, −3.0]	51/48
Circinus	*Sy*2	$6.04 \pm 0.08^9(M)$	4	190	0.57	50	[41.3, 41.4]	[21.4, 22.0]	[−4.2, −4.2]	11/0
NGC 5506	*NLSy*1	$8.1 \pm 0.2^{10}(R)$	3	276	5.87	50	[43.4, 43.9]	[22.4, 22.6]	[−3.9, −2.8]	110/110
NGC 5548	*Sy*1	$7.72 \pm 0.02^1(R)$	8	349	2.10	50	[44.3, 44.8]	[20.8, 22.3]	[−4.2, −2.9]	17/4
NGC 6860	*Sy*1	$7.6 \pm 0.5^{11}(L)$	1	88	2.12	50	[43.8, 44.0]	[20.8, 22.0]	[−4.0, −3.7]	48/48
ARK 564	*NLSy*1	$6.3 \pm 0.5^{12}(S)$	9	494	1.78	50	[44.0, 44.7]	21.1	[−3.1, −2.2]	398/1
NGC 7469	*Sy*1	$6.96 \pm 0.05^1(R)$	9	719	2.31	50	[43.8, 44.1]	[20.7, 21.3]	[−4.1, −2.7]	50/0

FAILURE 2:



$$\log(\nu_{break}) = A \log M_{BH} + B \log L_{bol} + C$$

Fact

BH MASS IS QUITE STABLE

(few Msolar/year)

BOLOMETRIC LUMINOSITY IS VARIABLE

(up to 200% variations within days)

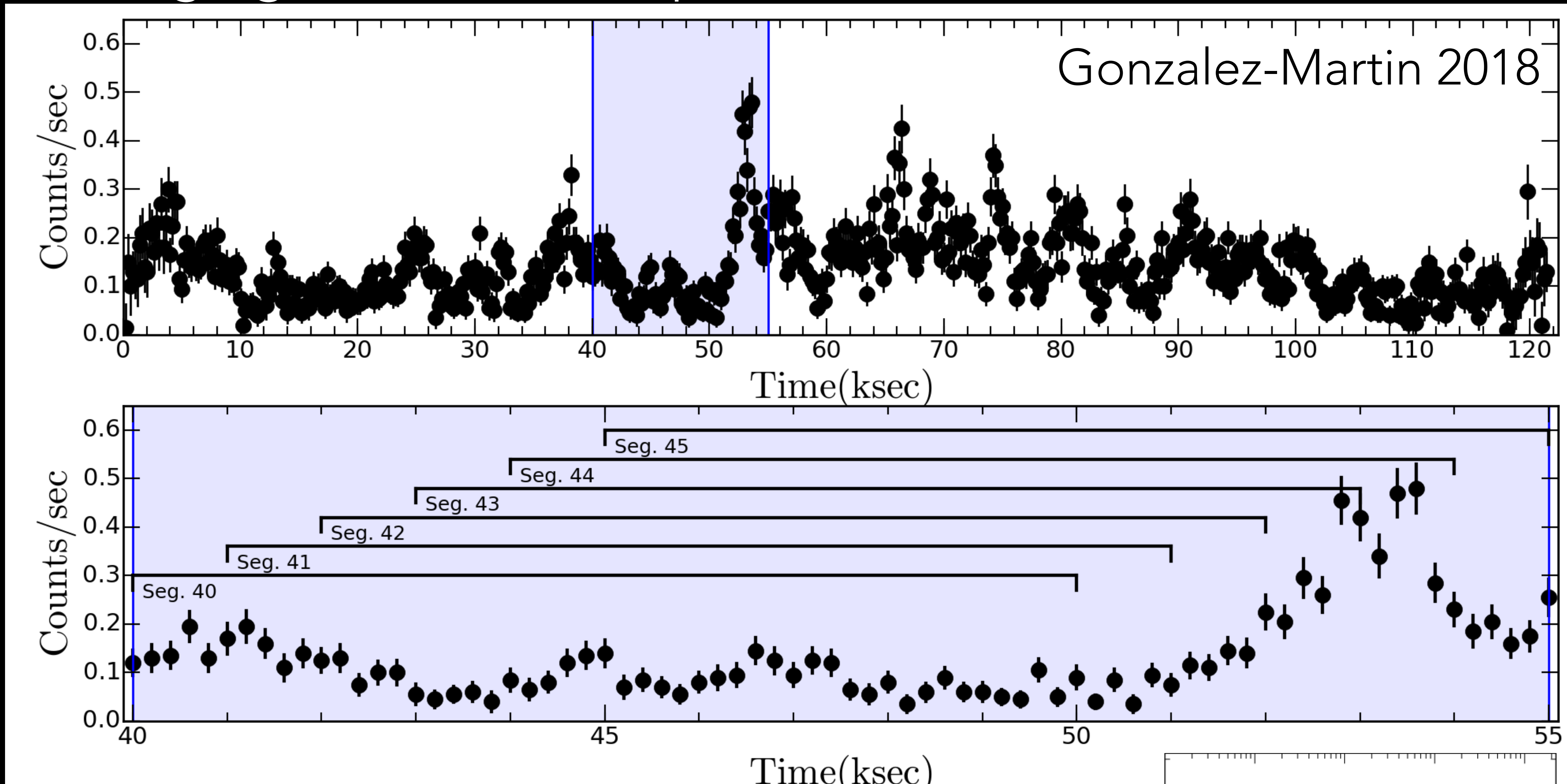
Hypothesis

WE MISSED THE BOLOMETRIC LUMINOSITY VERSUS BREAK RELATION BECAUSE LUMINOSITY VARIATIONS

Consequence

PSD BREAK SHOULD BE VARIABLE WITHIN DAYS!

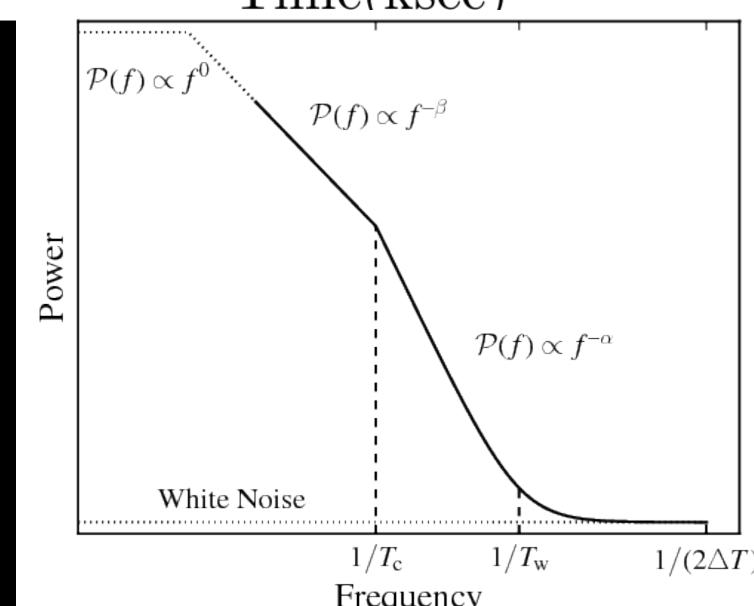
Cutting light-curves into pieces…

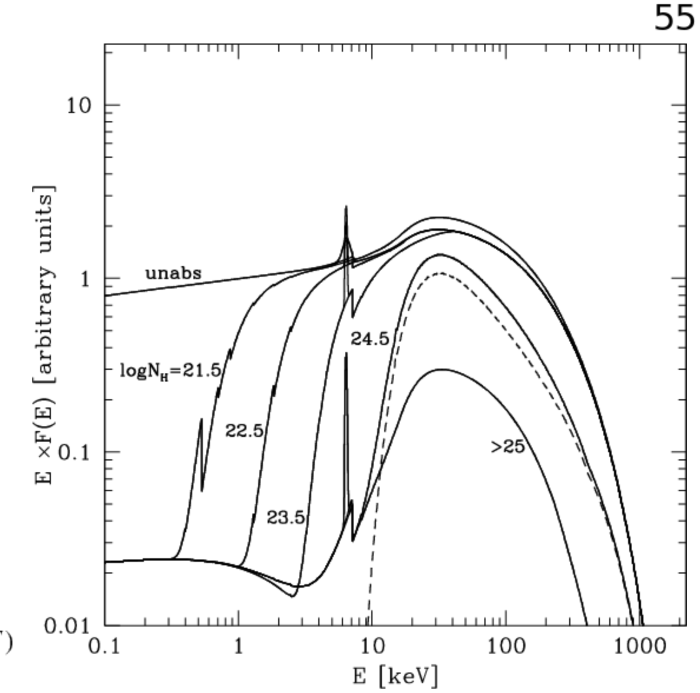


22 objects

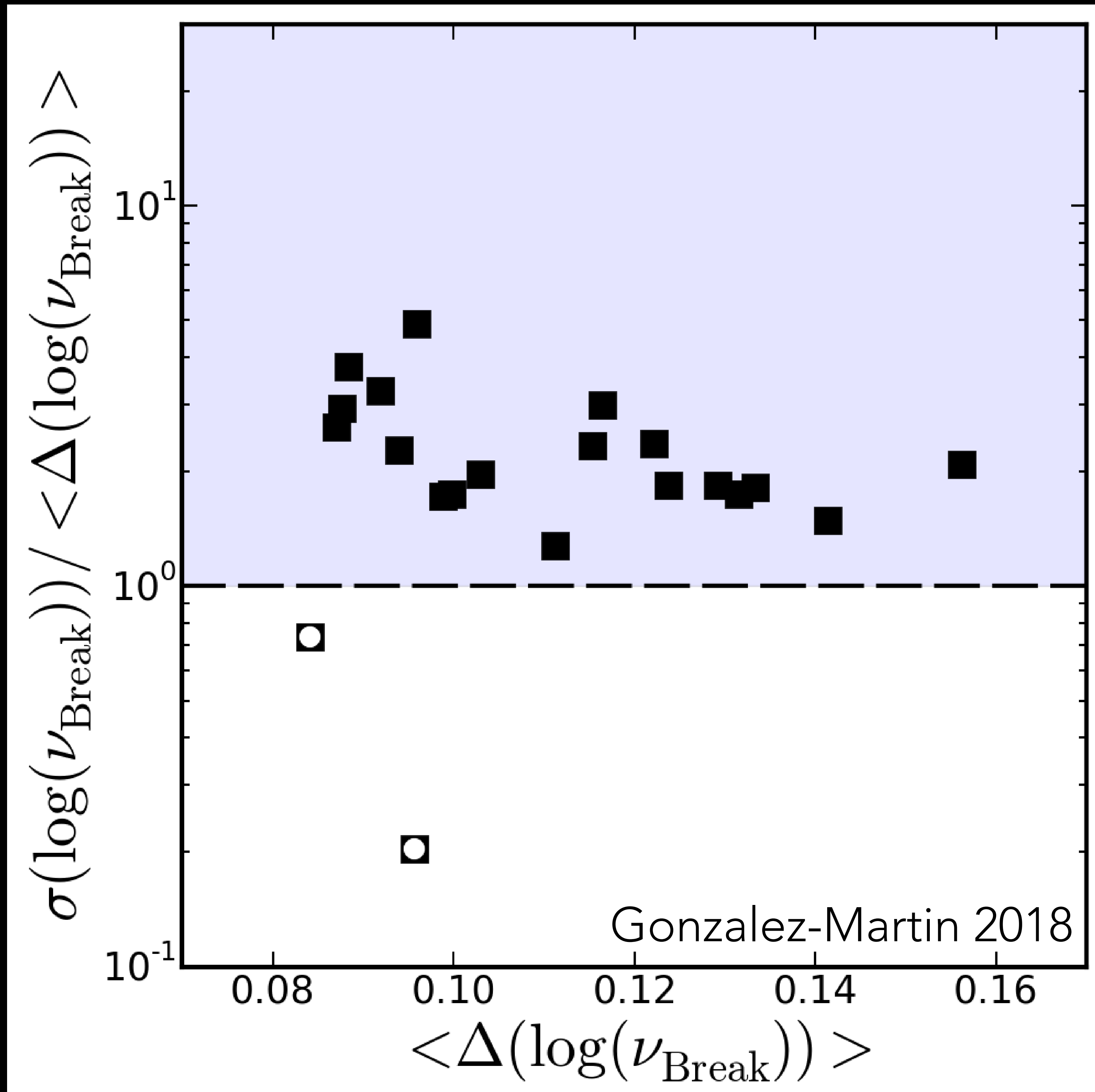
>100 days of observations

>2000 breaks



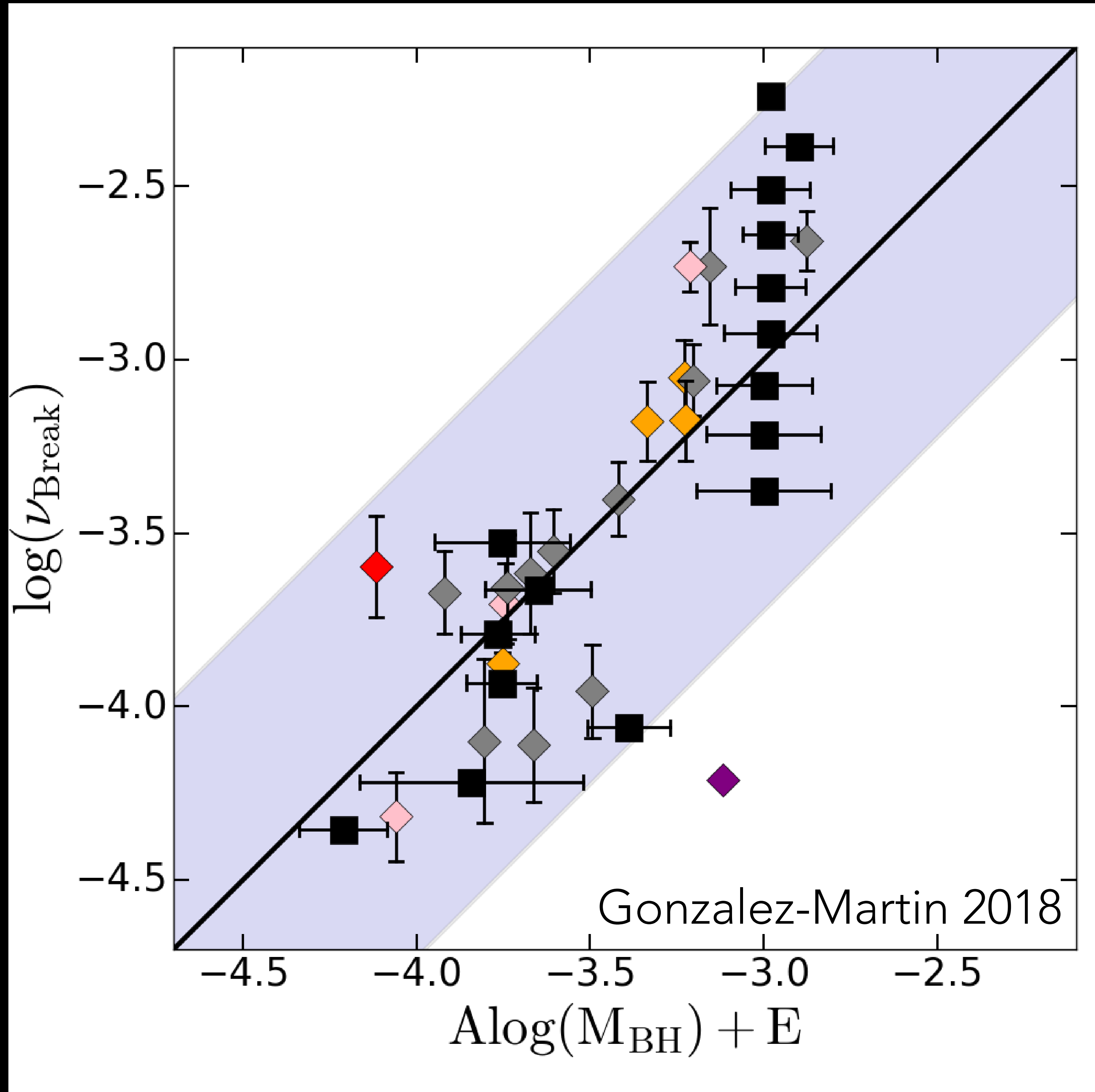


Indeed PSD frequency break varies!



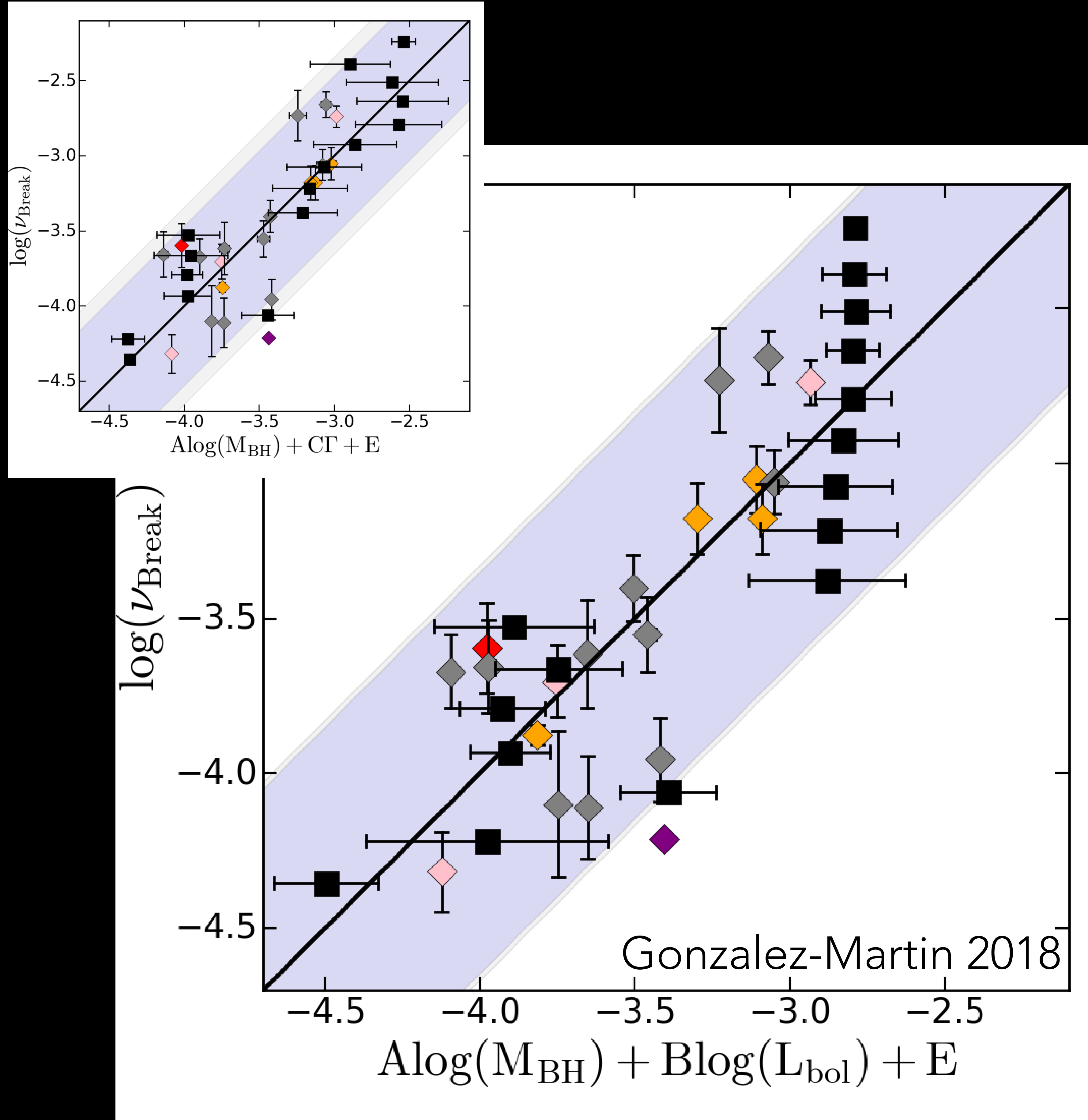
Tested models

Model
$Alog(M_{BH}) + E$
$Alog(M_{BH}) + Blog(L_{bol}) + E$
$Alog(M_{BH}) + C\Gamma + E$
$Alog(M_{BH}) + Dlog(N_H) + E$
$Alog(M_{BH}) + D^{\star}\Delta(N_H) + E$



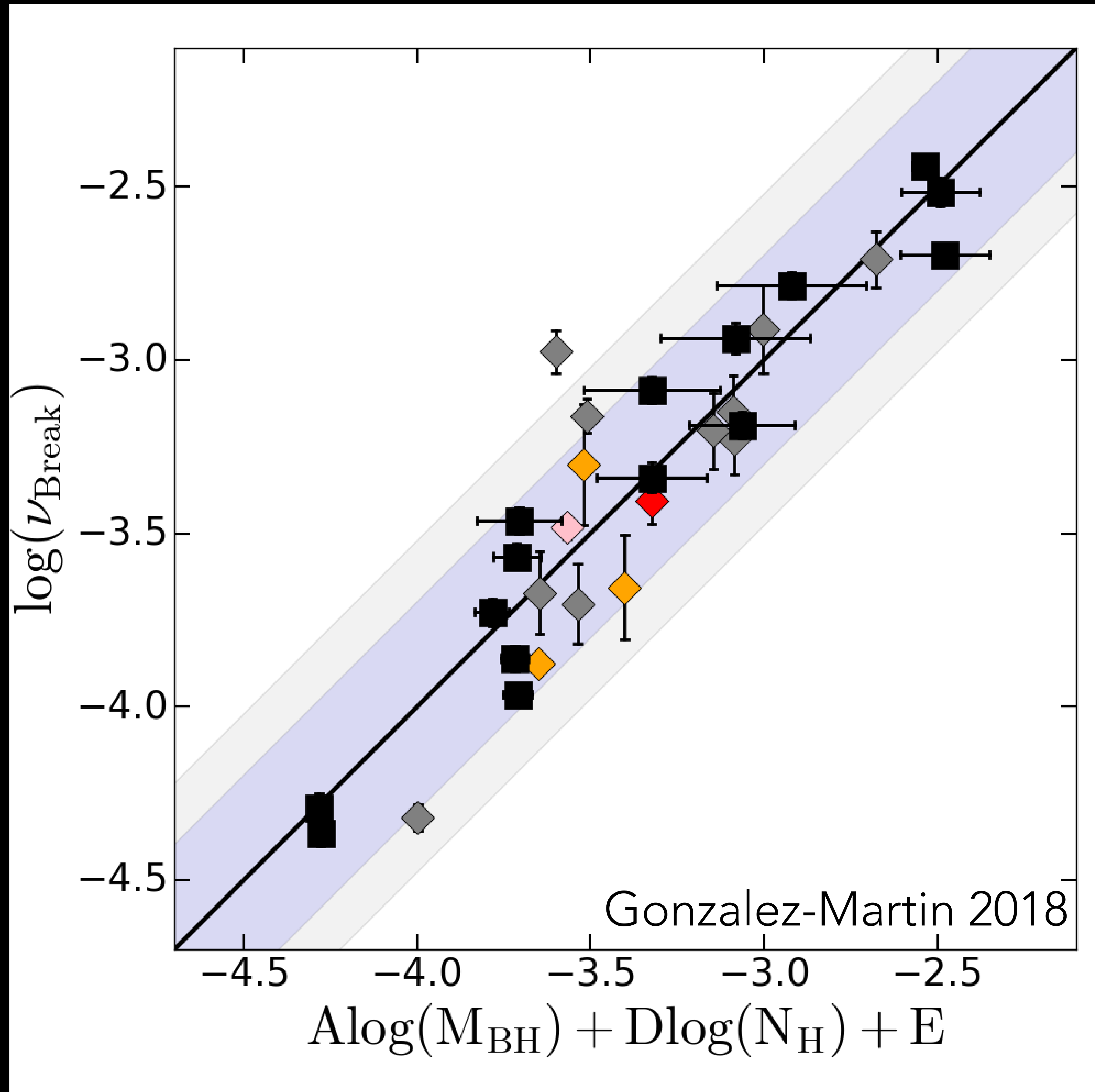
FAILURE 3:

Model
$A log(M_{BH}) + E$
$A log(M_{BH}) + B log(L_{bol}) + E$
$A log(M_{BH}) + C\Gamma + E$
$A log(M_{BH}) + D log(N_H) + E$
$A log(M_{BH}) + D^{\star}\Delta(N_H) + E$



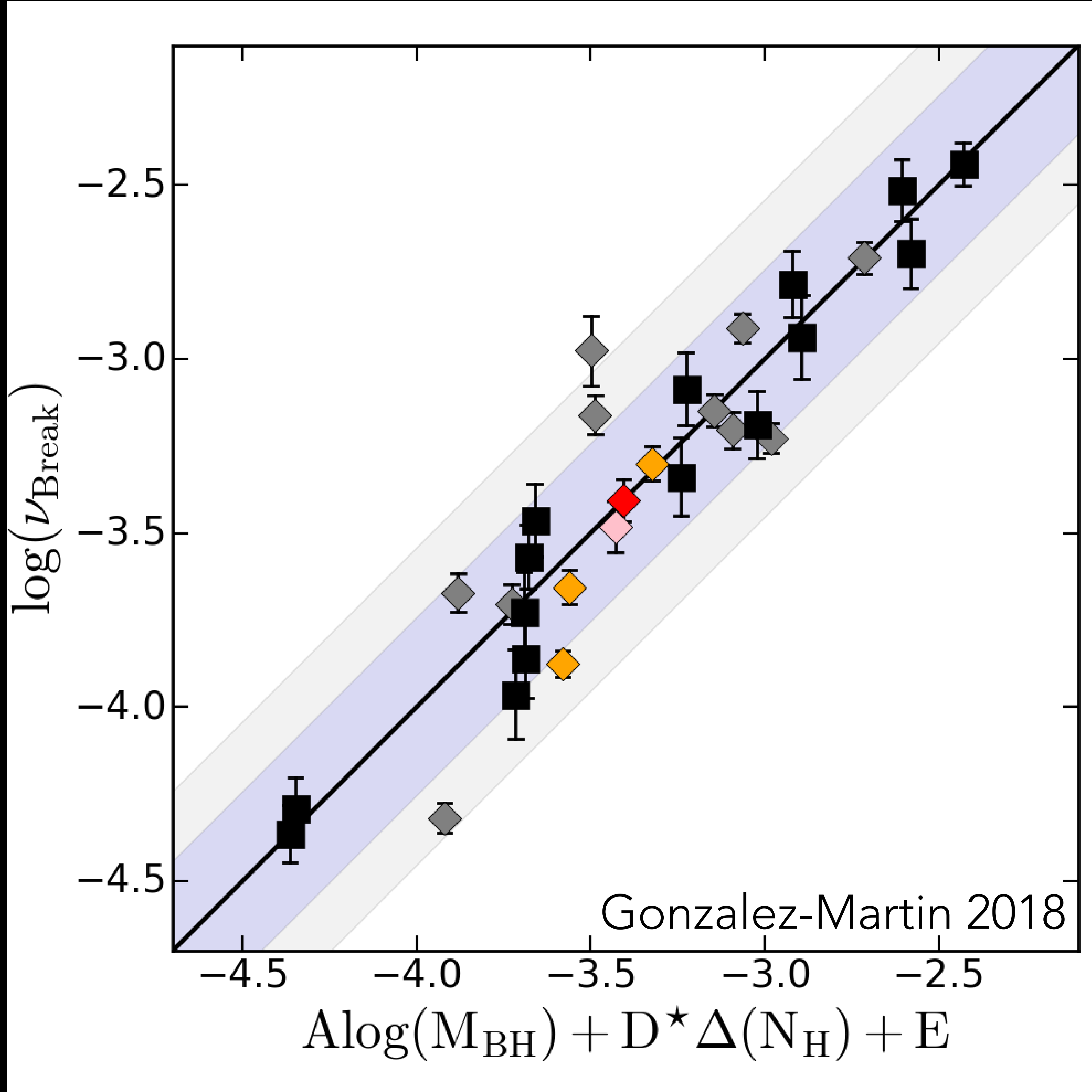
Obscuration!

Model
$A\log(M_{BH}) + E$
$A\log(M_{BH}) + B\log(L_{bol}) + E$
$A\log(M_{BH}) + C\Gamma + E$
$A\log(M_{BH}) + D\log(N_H) + E$
$A\log(M_{BH}) + D^{\star}\Delta(N_H) + E$

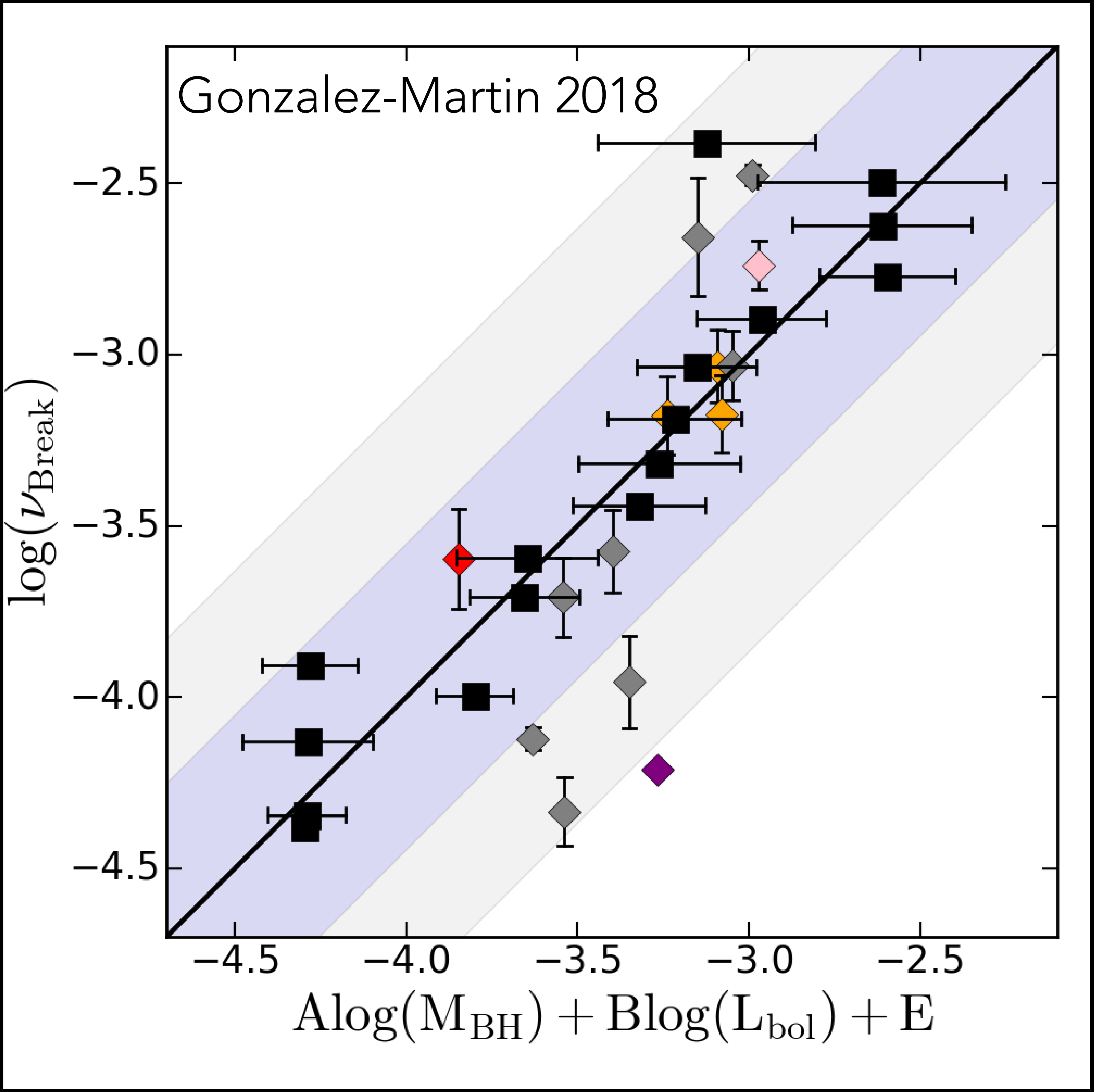


Obscuration!

Model
$Alog(M_{BH}) + E$
$Alog(M_{BH}) + Blog(L_{bol}) + E$
$Alog(M_{BH}) + C\Gamma + E$
$Alog(M_{BH}) + Dlog(N_H) + E$
$Alog(M_{BH}) + D^{\star}\Delta(N_H) + E$



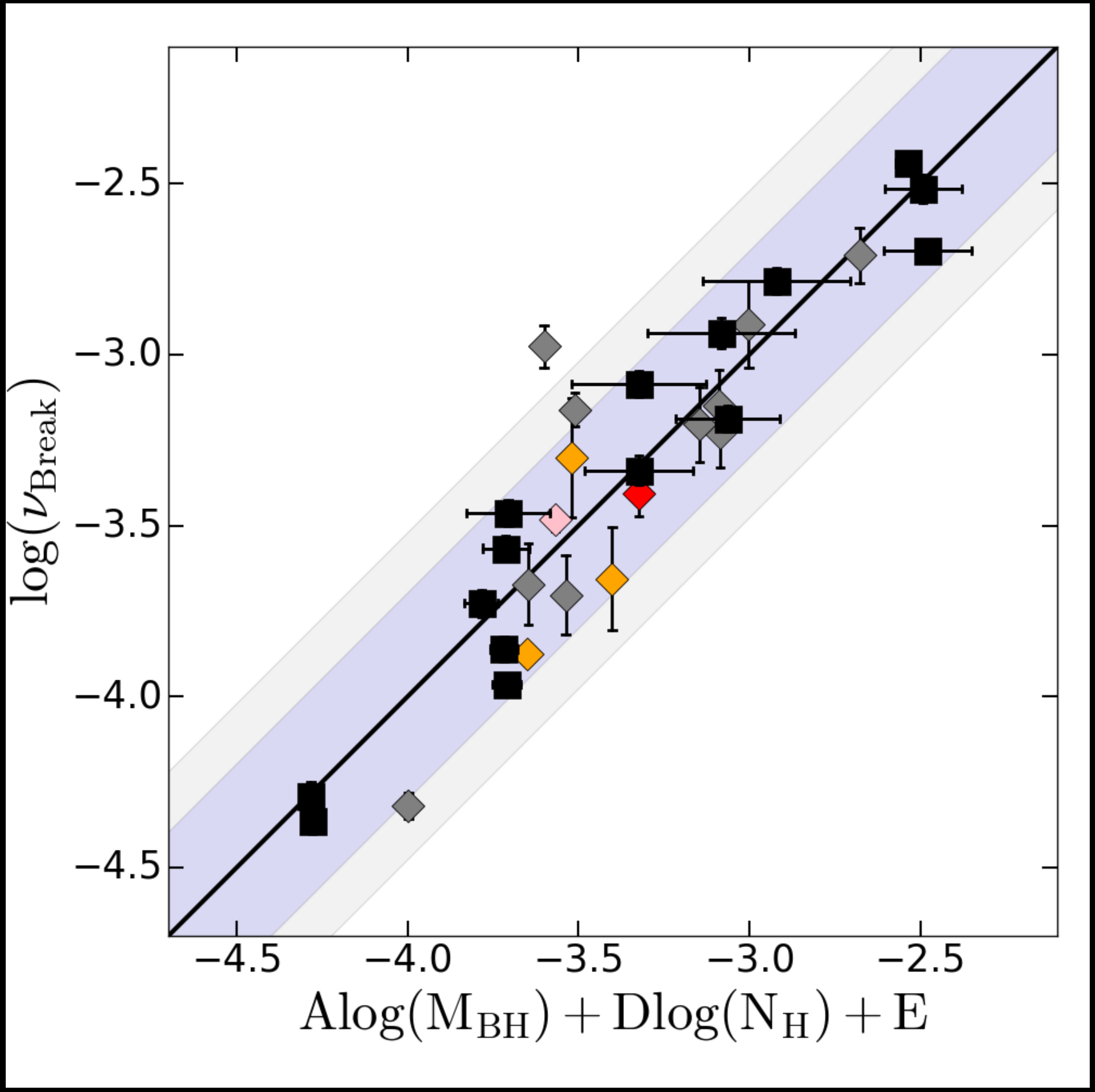
Obscured segments are removed



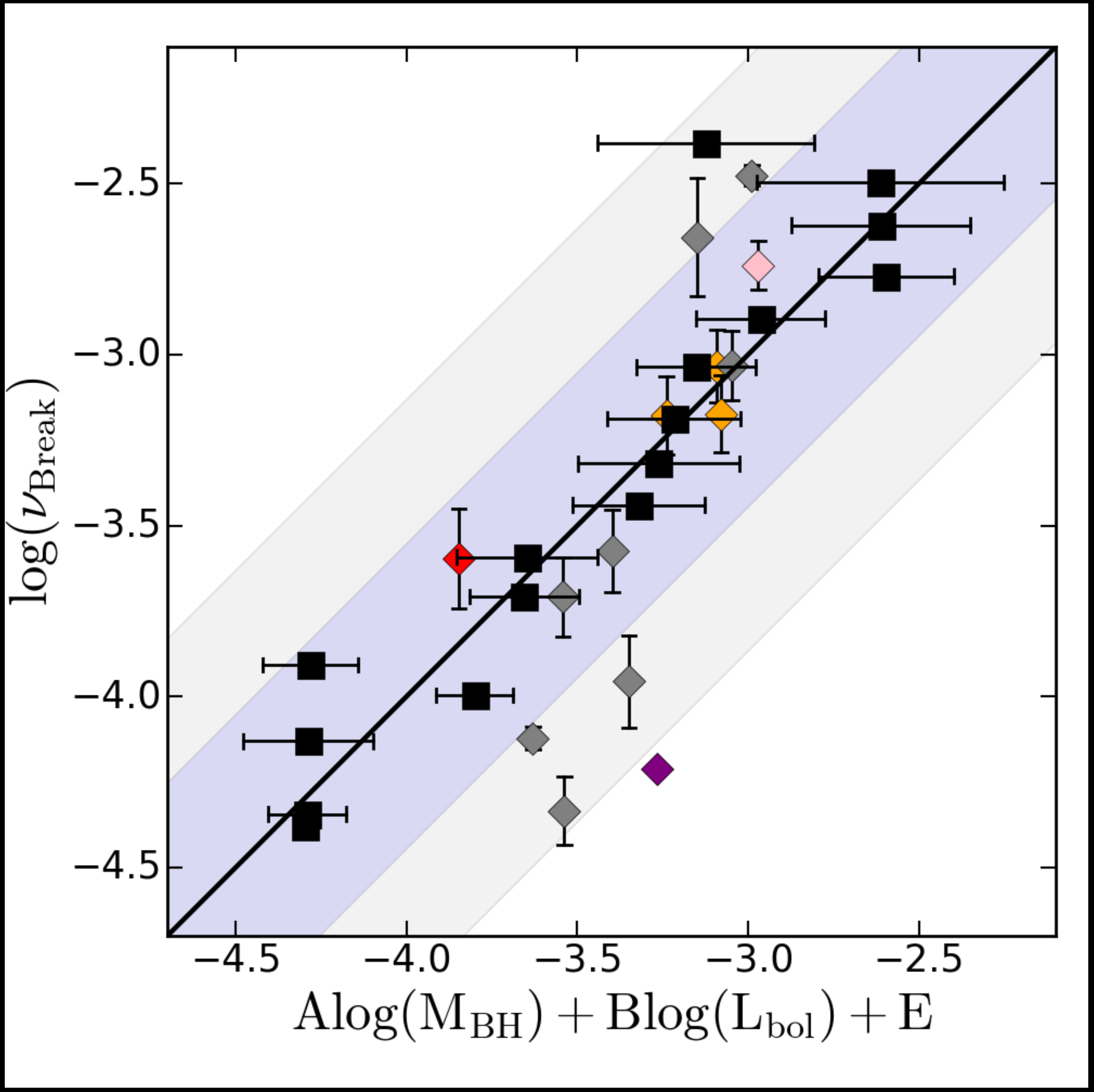
FREQUENCY BREAKS < 10^{-5} HZ (LONG TERM MONITORING)

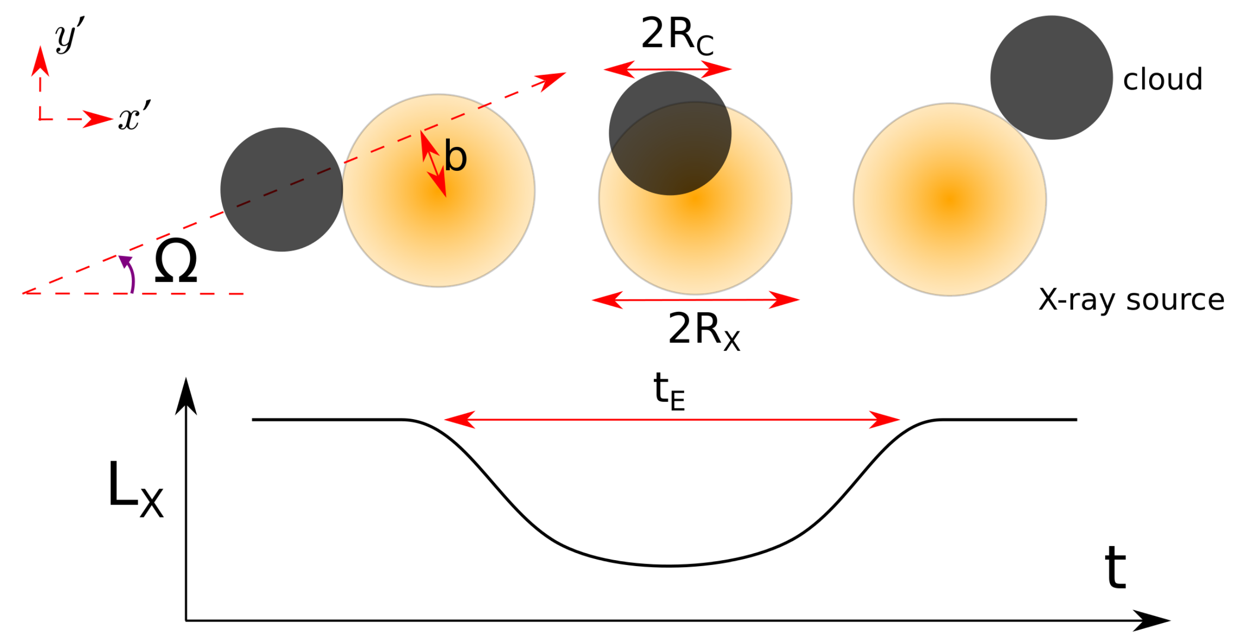
FREQUENCY BREAKS > 10^{-5} HZ (SINGLE OBSERVATION)

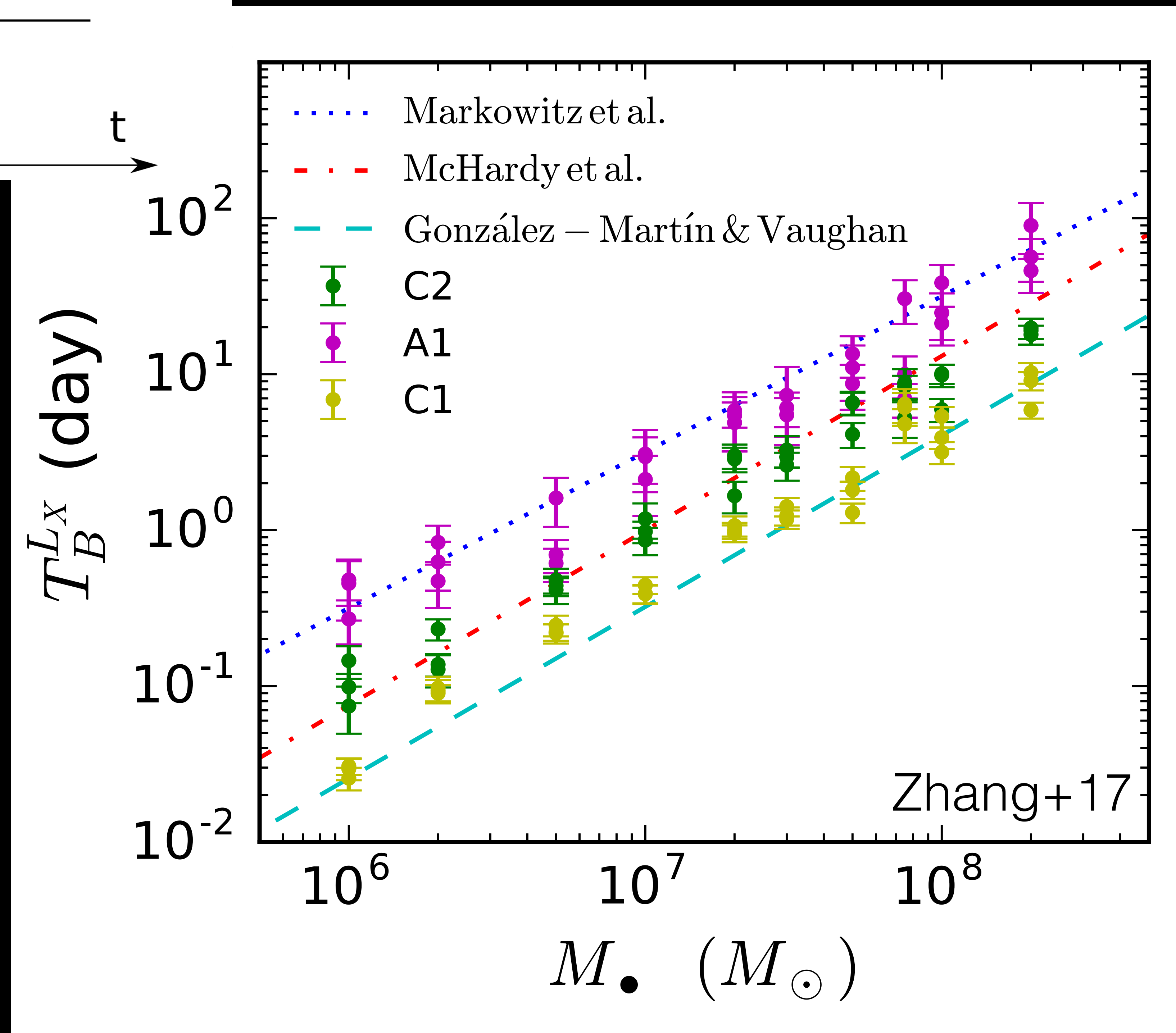
WHEN THE OBJECT IS OBSCURED



WHEN THE OBJECT IS NOT OBSCURED




y′
x′
2R_C
cloud
b
Ω
2R_X
X-ray source
t_E
L_X
t


Markowitz et al.
McHardy et al.
González – Martín & Vaughan
C2
A1
C1
Zhang+17
T_B^{L_X} (day)
M• (M⊙)
10^-2
10^-1
10^0
10^1
10^2
10^6
10^7
10^8

Summary

The variability plane is reinforced but the parameters involved are not. The new variability plane (~10^{-5} - 10^{-3} Hz range) is:

$$\frac{A log(M_{BH}) + D log(N_H) + E}{A log(M_{BH}) + D^{\star}\Delta(N_H) + E}$$

Is then related to eclipsing clouds at the BLR rather than to the accretion process. The accretion process underlaying relation is obtained only when obscured segments are removed from the analysis. Use these relations carefully to obtain BH masses. It is a new way to study the clumpy medium by comparing PSD and spectra with models.

THANKS!