Unification of accreting black holes across the mass scale

Variability in quiescent BH
➜ particle acceleration

Gabriele Ponti
Max Planck Institute for Extraterrestrial Physics (Garching)

Unification of accreting BH

➜ The same accretion theory can explain most observables

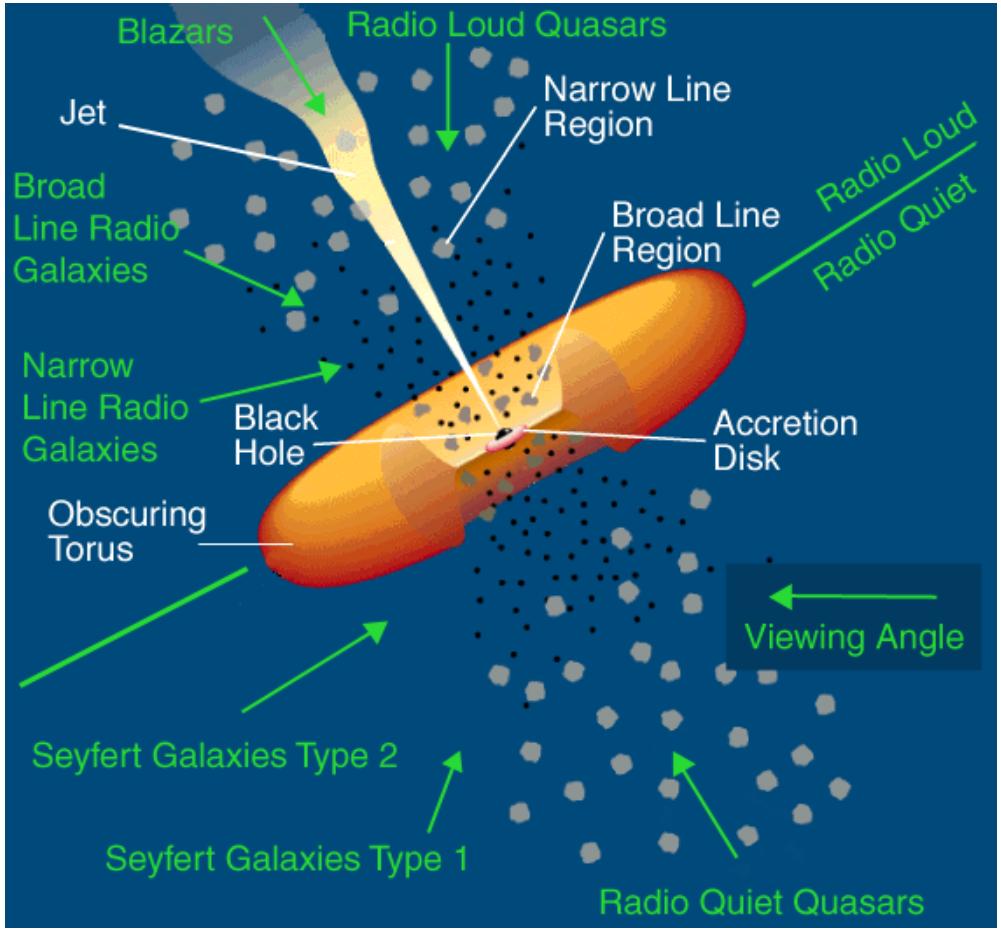
e.g., α-disc — Shakura Sunyaev +73

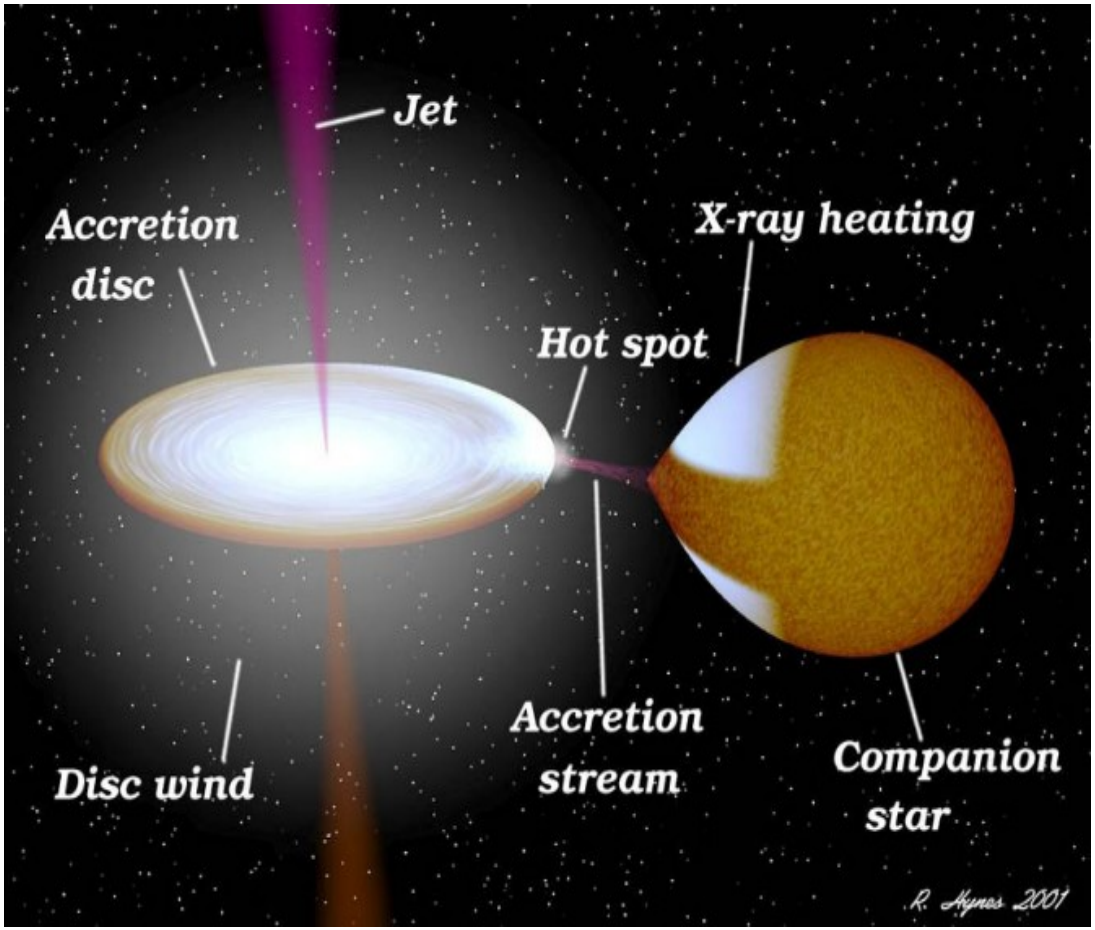
ADAF-RIAF — Narayan Yi +94; +95; Blandford Begelman +04

Jet-models — Blandford Znajek +77; Blandford Payne +82

➜ Same components:

e.g., disc, corona, jet, reprocessing, wind…

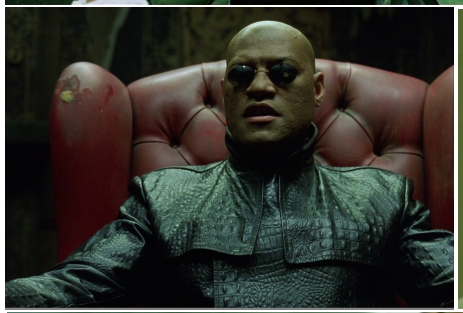


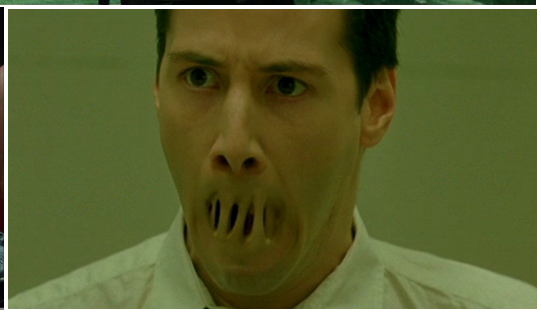


…despite differences…

e.g., environment; densities…

Unification of accreting BH





GBH

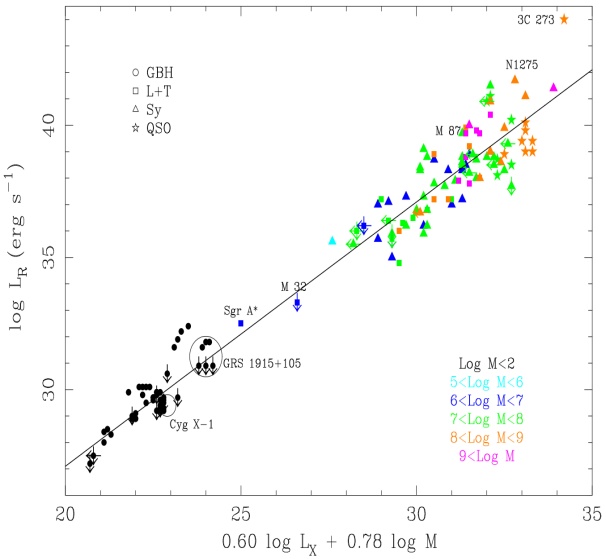
➜ **Full** (low resolution & gappy) **movie**

Connections and scaling relations

➜ Jet - accretion

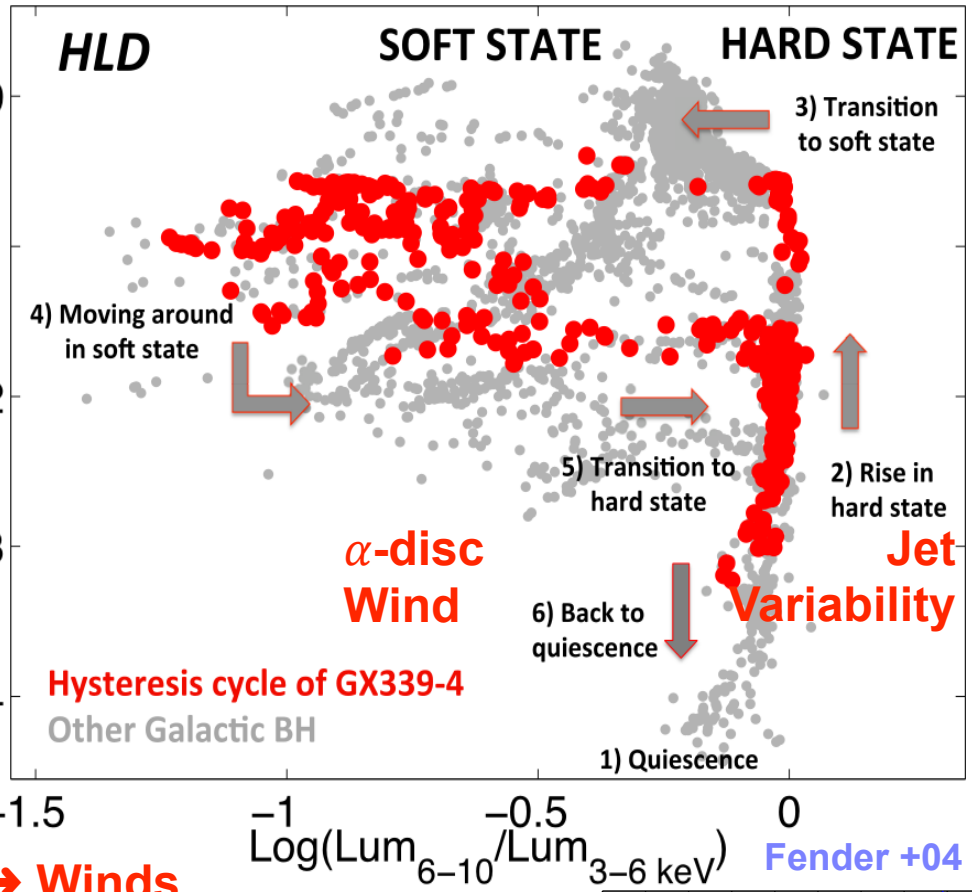
Radio-X-ray correlation

Fundamental plane



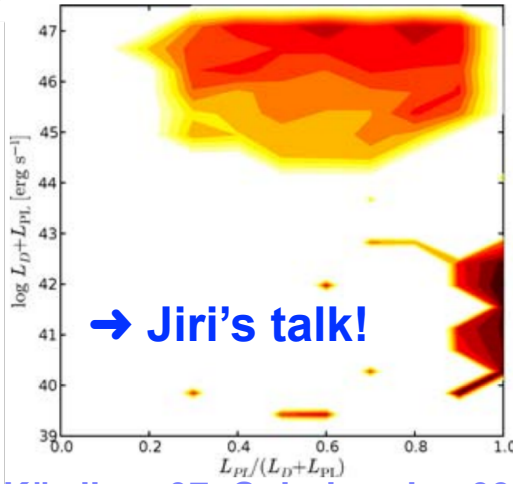
Merloni +03; Falcke + 04

The Hysteresis cycle of BH XRB



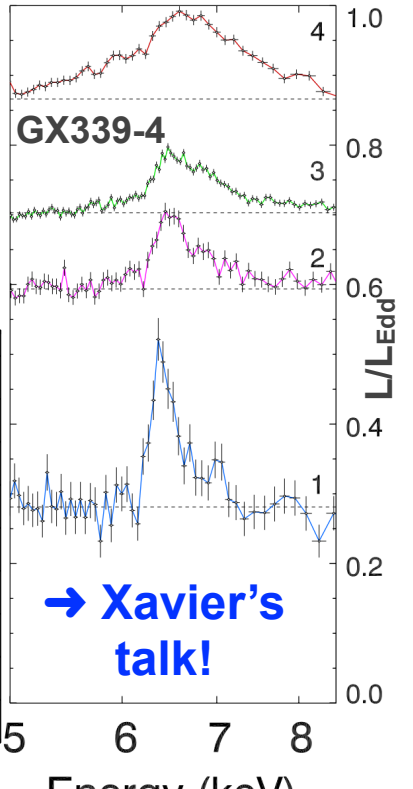
Fender +04

➜ Accretion states

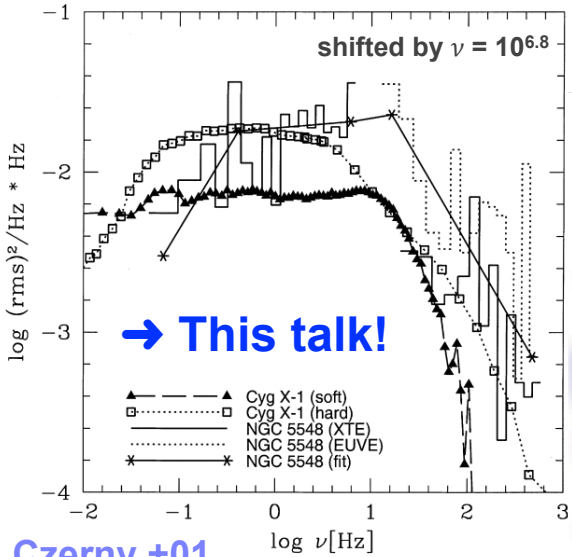


Körding+07; Sobolewska+09

➜ Geometry

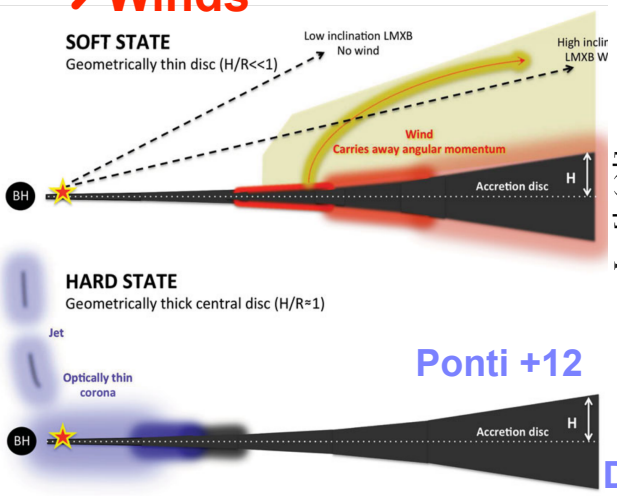


➜ Variability

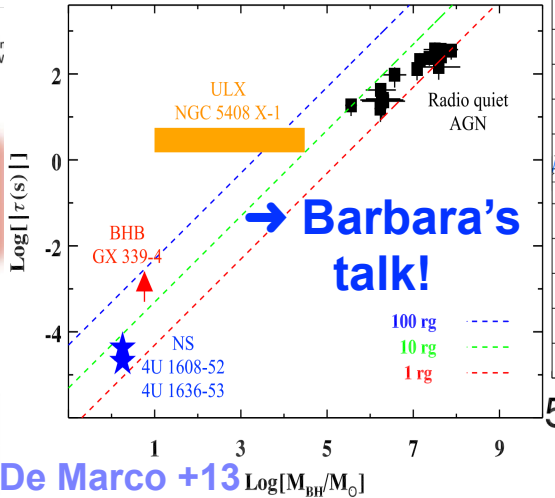


Czerny +01

➜ Winds

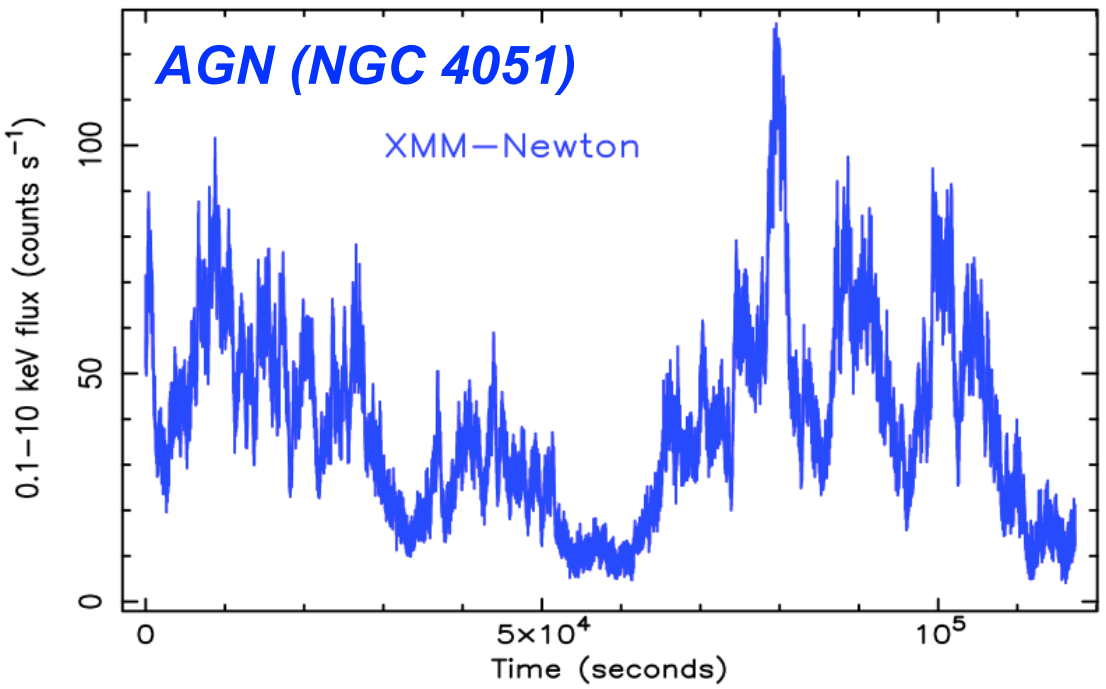


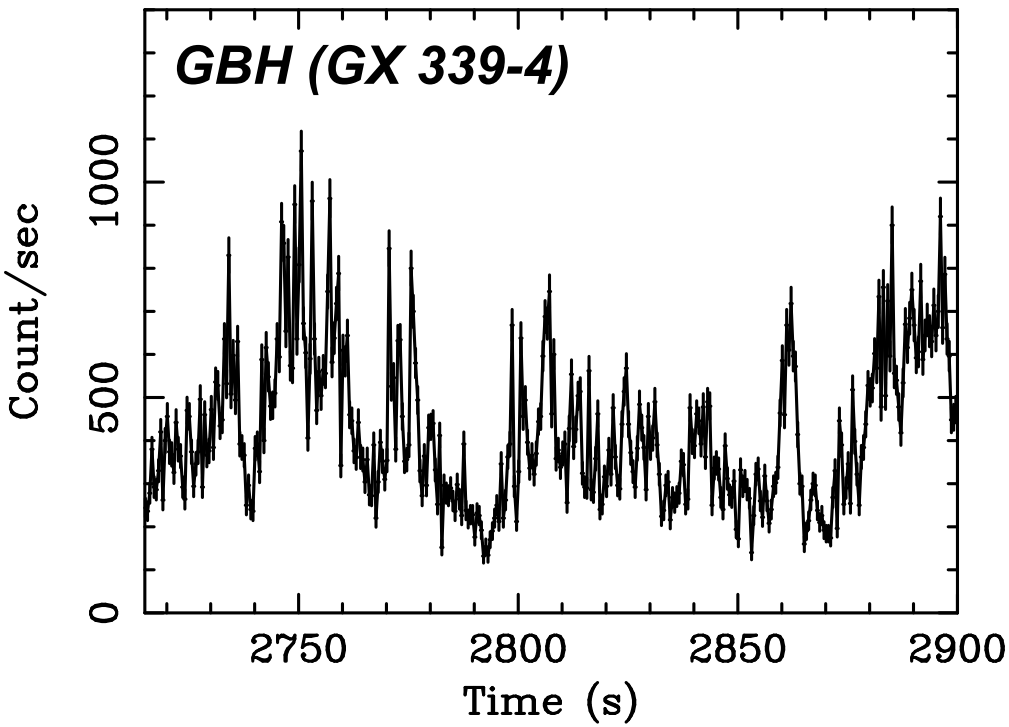
Ponti +12



De Marco +13

Universal variability pattern in accreting BH



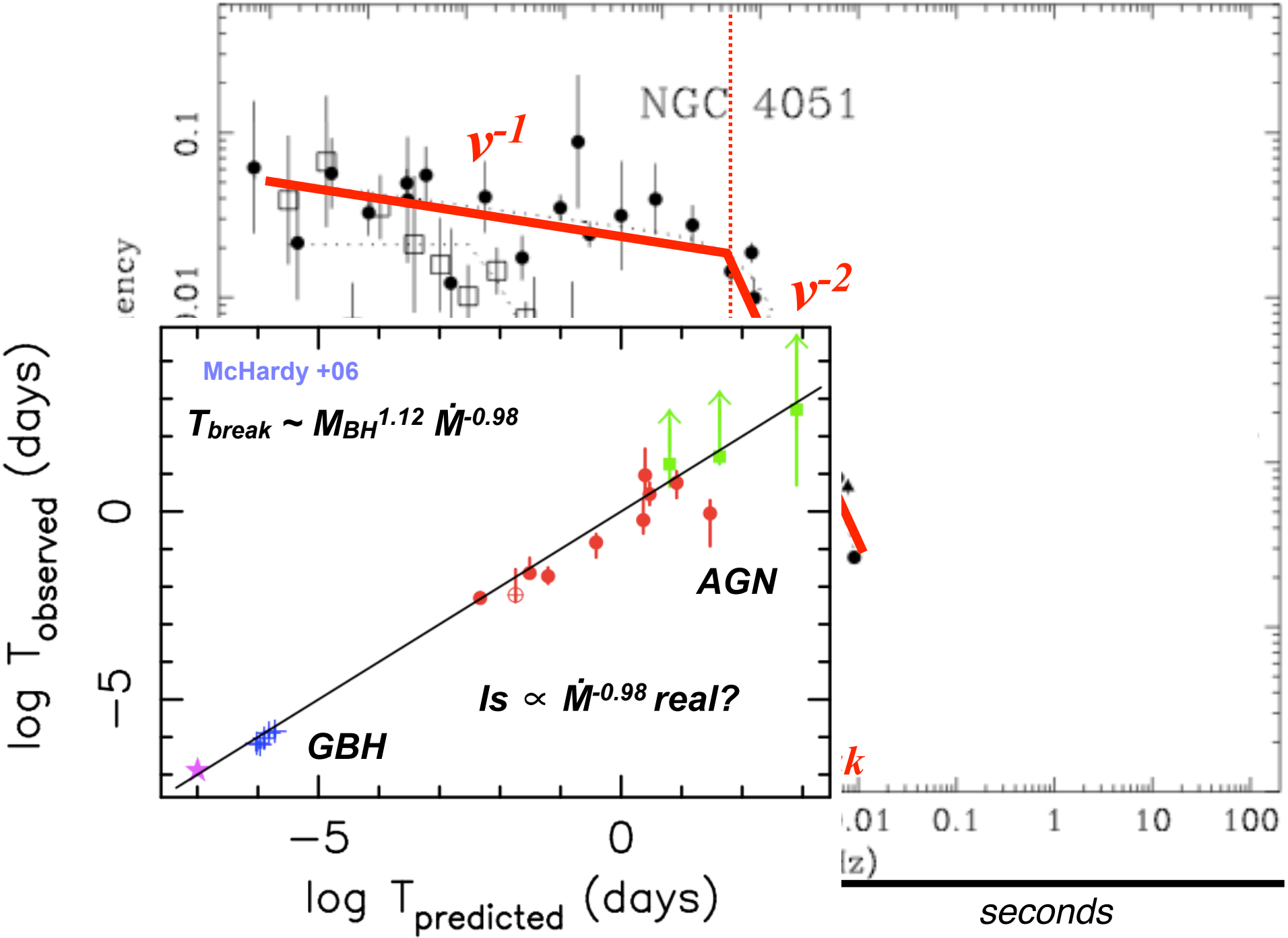


Days

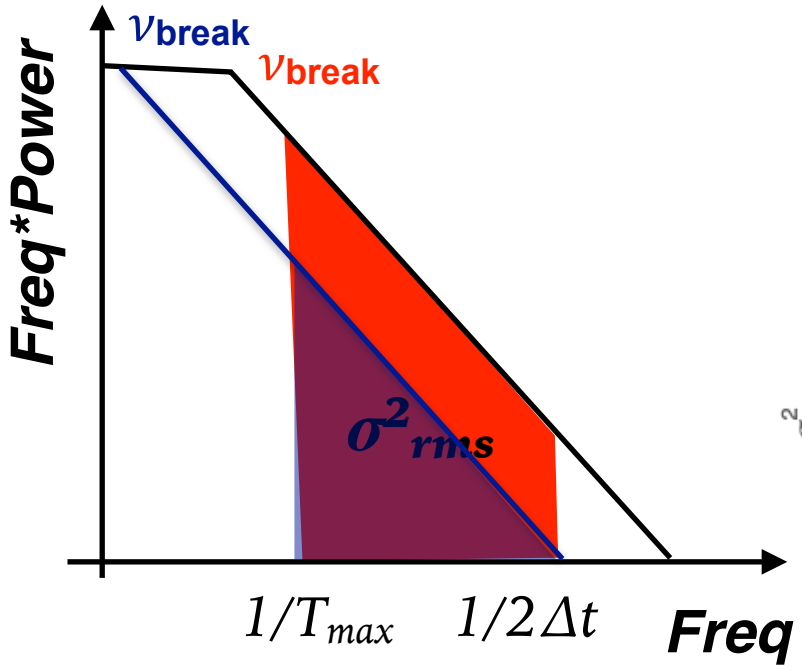
Seconds

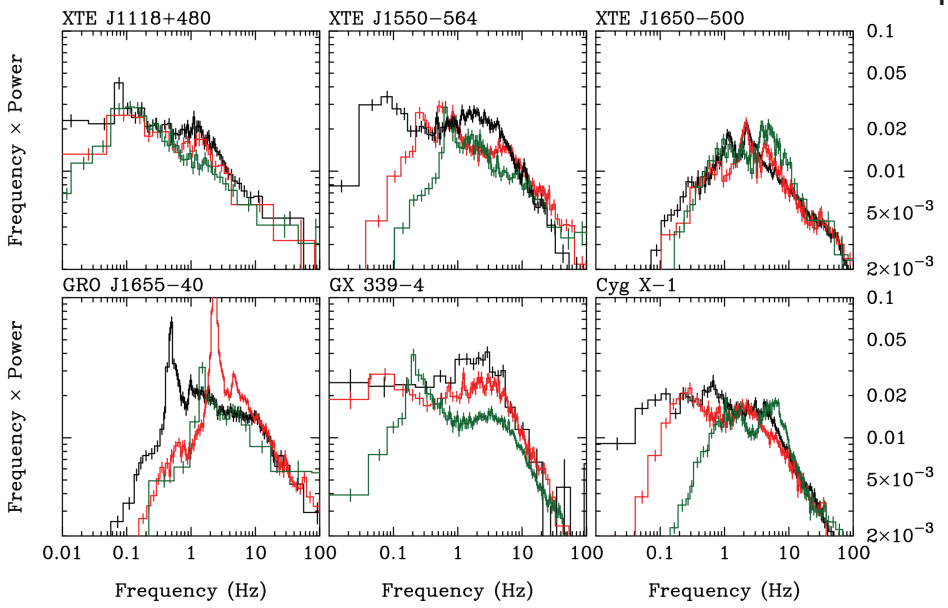
Universal variability in accreting BH

Czerny +01; Uttley +02; McHardy +04; 06; Koerding +07; Gonzalez-Martin +18

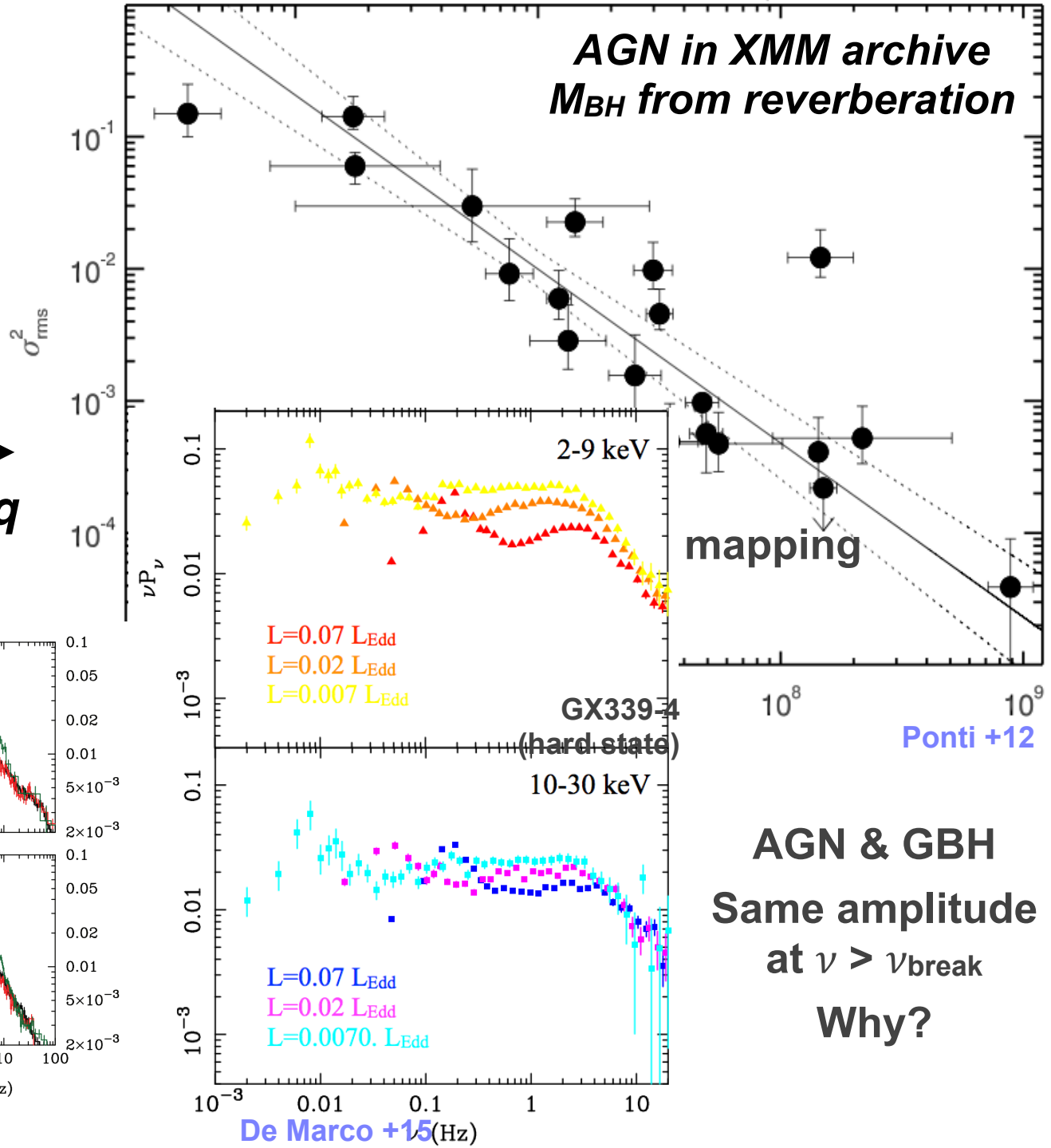


Universal variability ➜ measure M_{BH}





Gierlinski +08



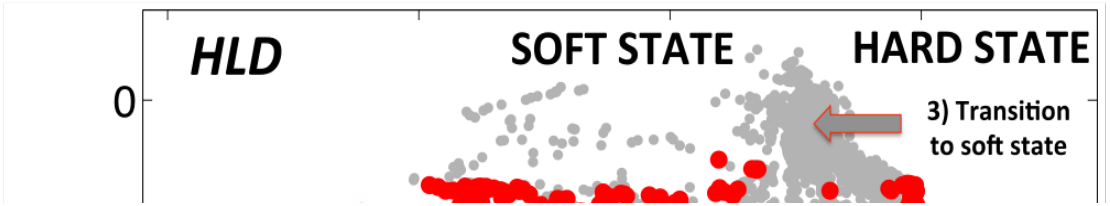
De Marco +15

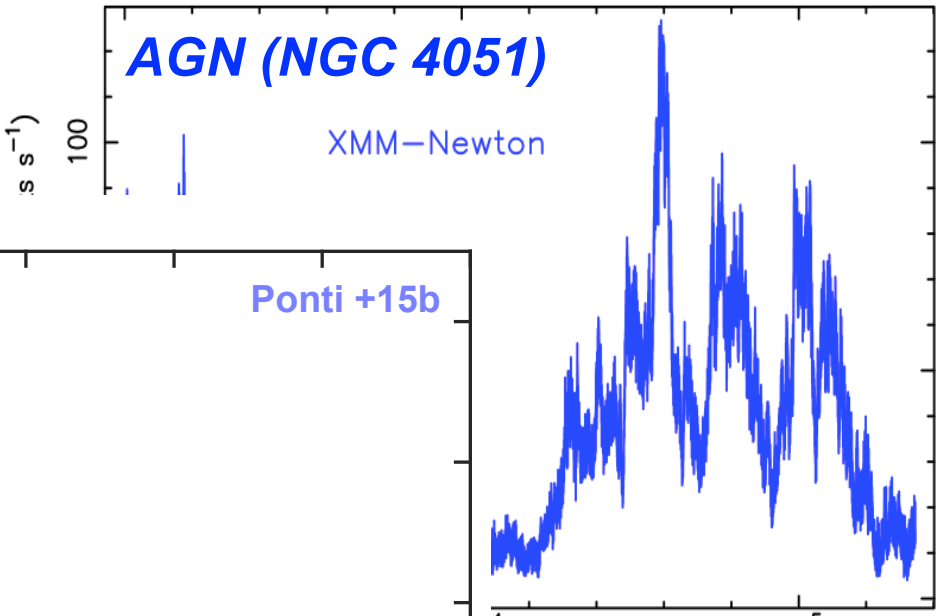
AGN & GBH

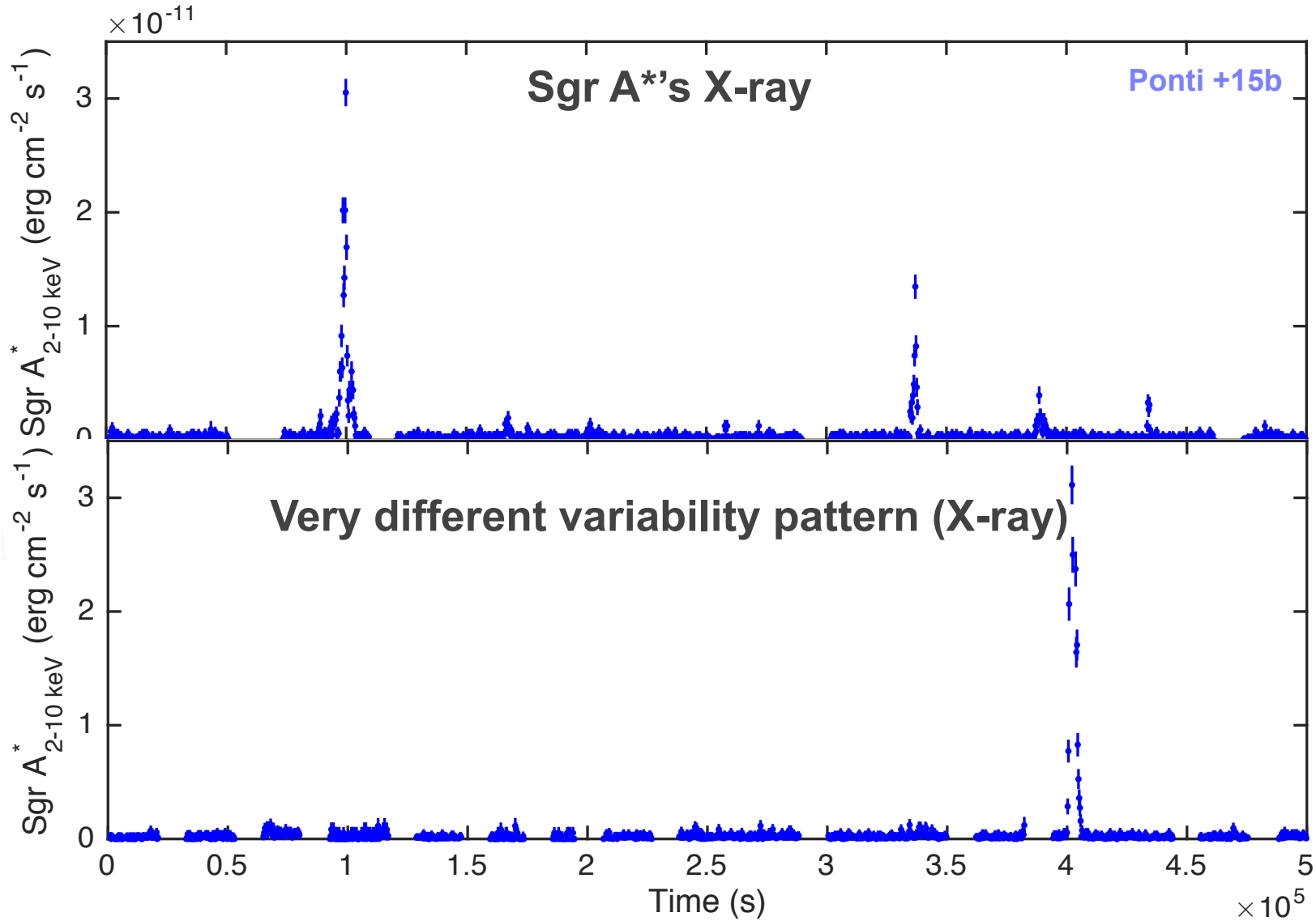
Same amplitude at $\nu > \nu_{break}$

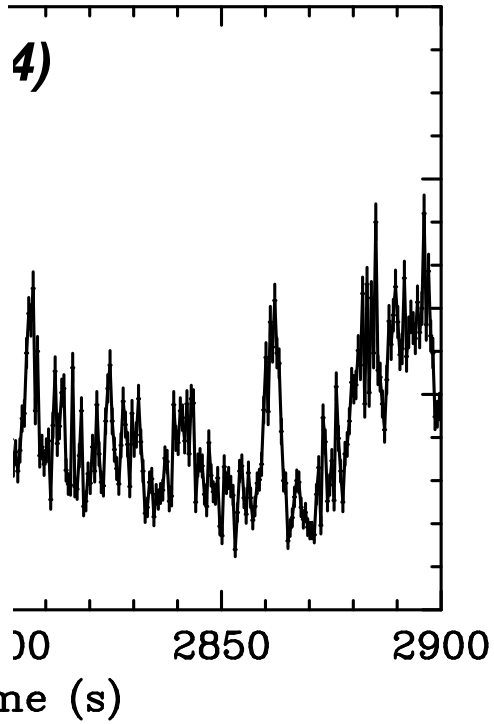
Why?

What happens in quiescence?



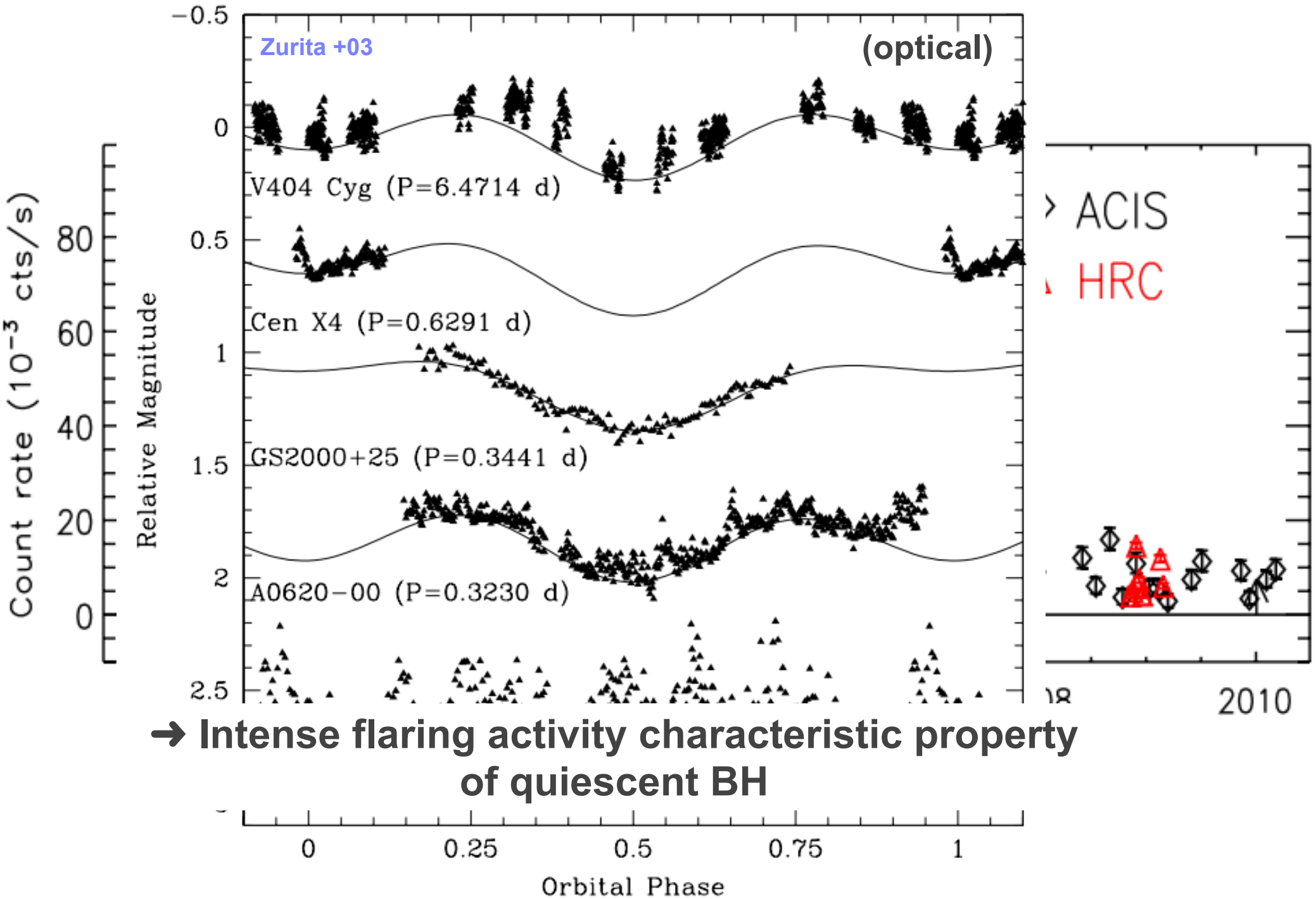






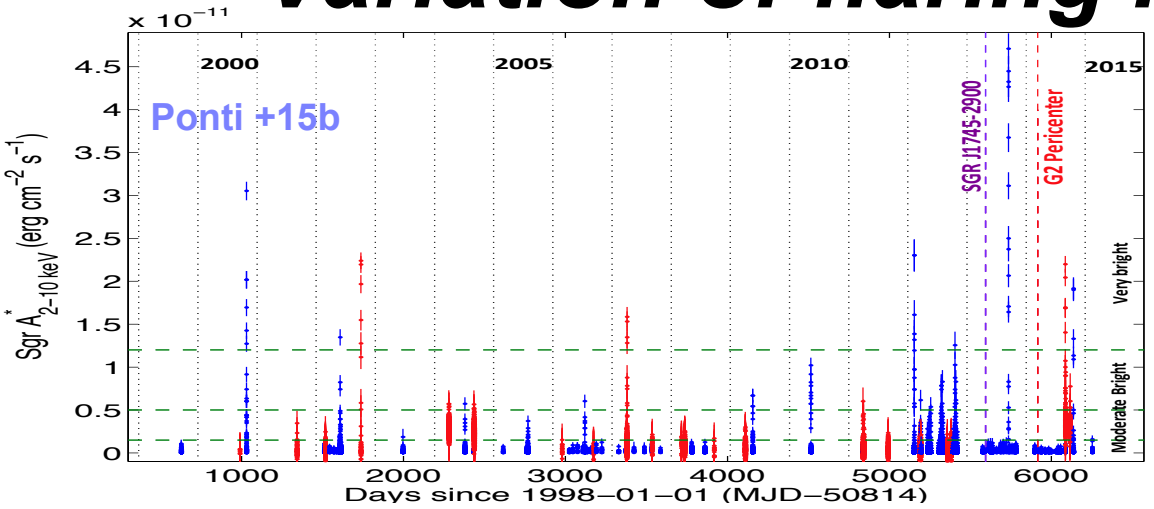
Baganoff +01; Goldwurm +03; Porquet +03; 08; Belanger +05; Nowak +12; Neilsen +13; Barriere +14; Ponti +15b; Mossoux +16; +17; Capellupo +17; Li+17; Yuan +18

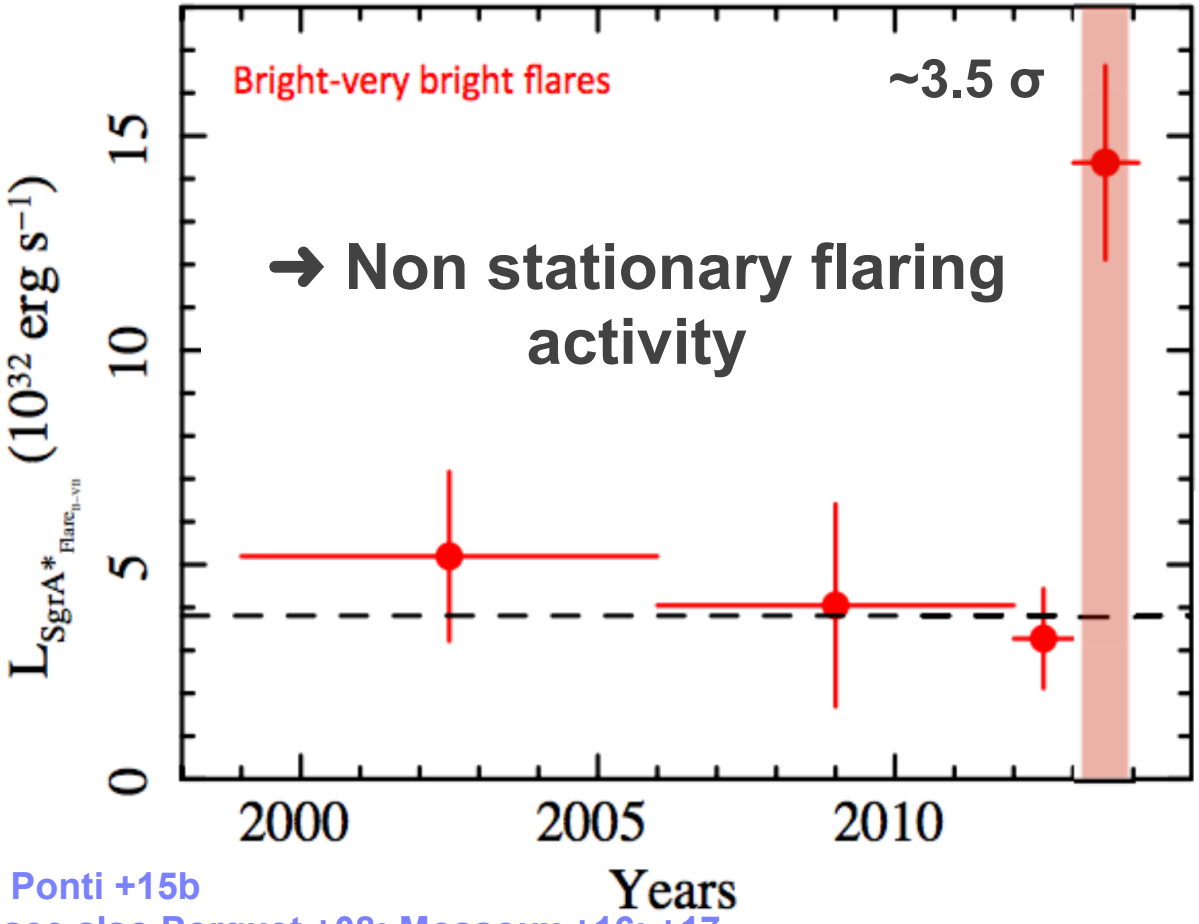
Is Sgr A unique?*

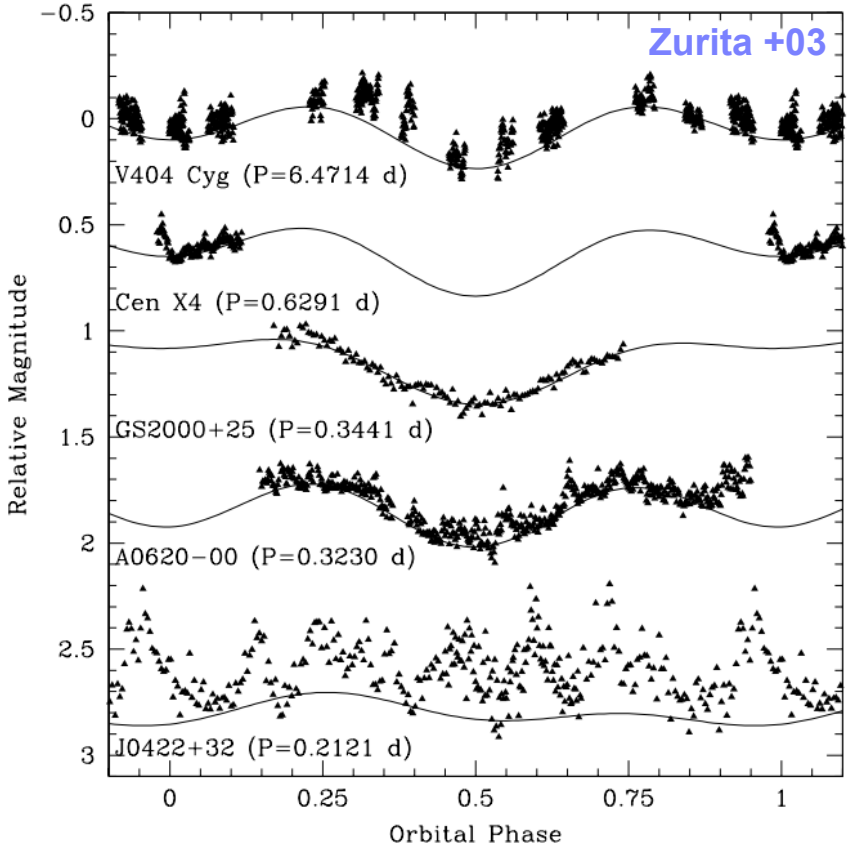


➜ **Intense flaring activity characteristic property of quiescent BH**

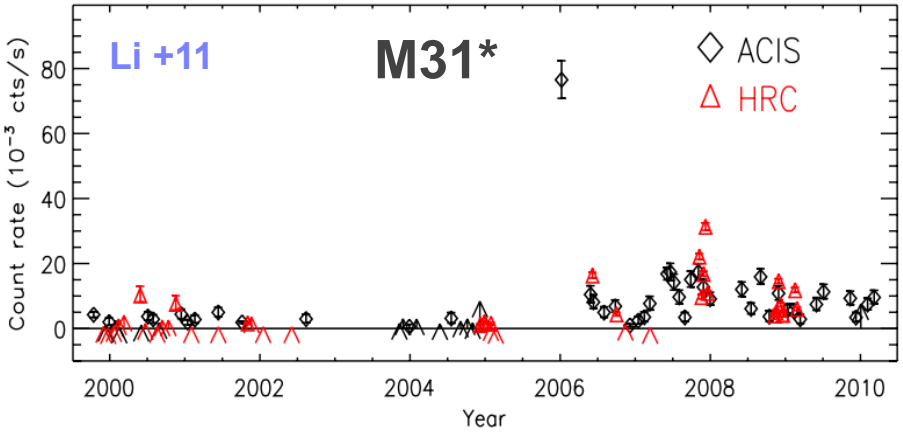
Variation of flaring rate of Sgr A*







Zurita +03; Hynes +04; Shahbaz +05; Cantrell +08



Why is the X-ray variability of quiescent BH (Sgr A*) so peculiar?

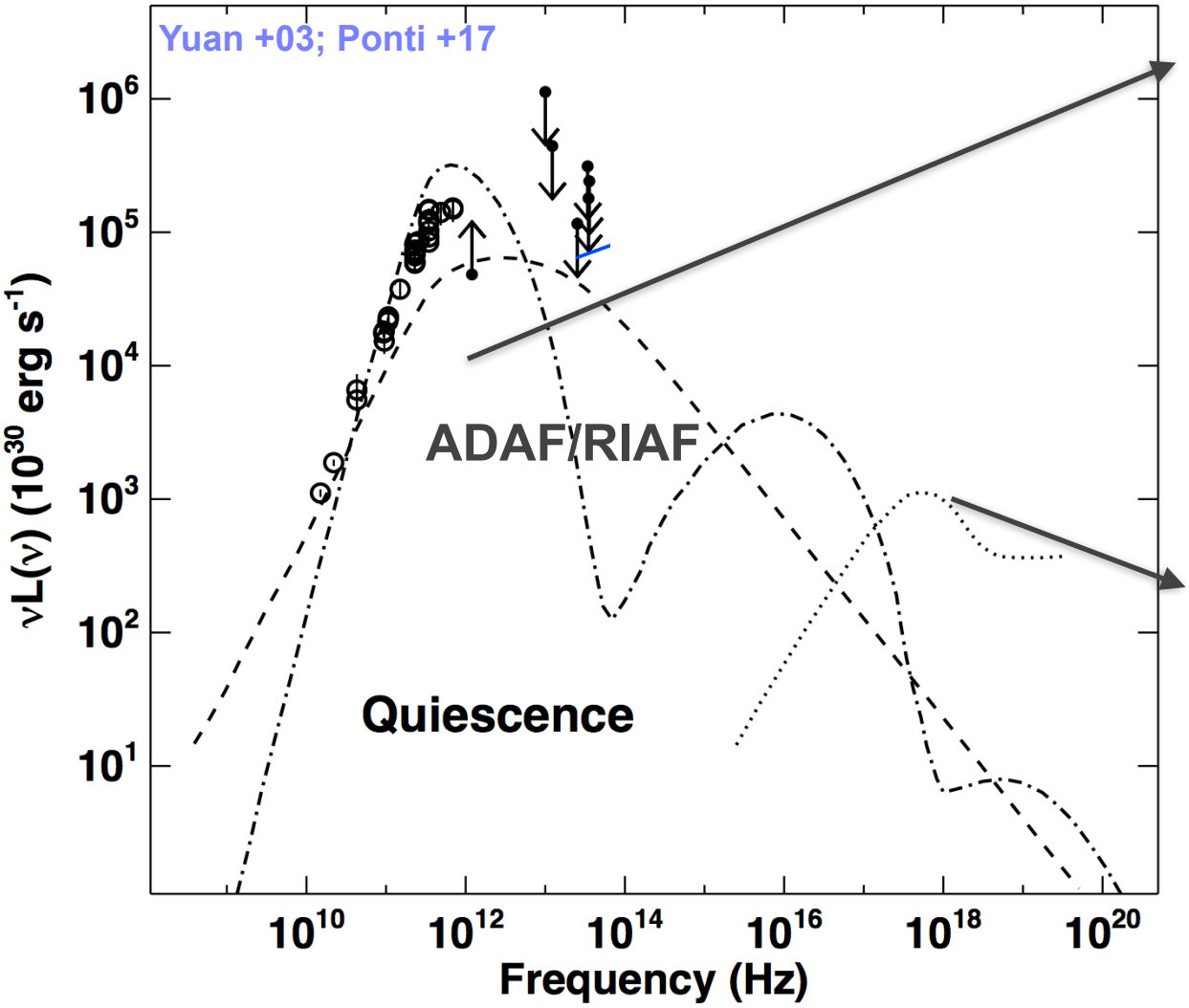
➜ ***A consequence of particle acceleration?***

Ponti +17

Sgr A's quiescent emission*

$L_{Sgr\ A^*} \sim 10^{-9}\ L_{Edd}$

Best target to study low luminosity accretion



Optically thin synchrotron

r ~ 10 R_S

Thermal e^- (γ_e~10)

B ~ 20-50 G

$kT_e \sim 10^{10}$ K

$n_e \sim 10^6$ cm^{-3}

$\dot{M} \sim 10^{-7}$-10^{-9} M_{Sun} yr^{-1}

Bremsstrahlung

r ~ 10^5 R_S

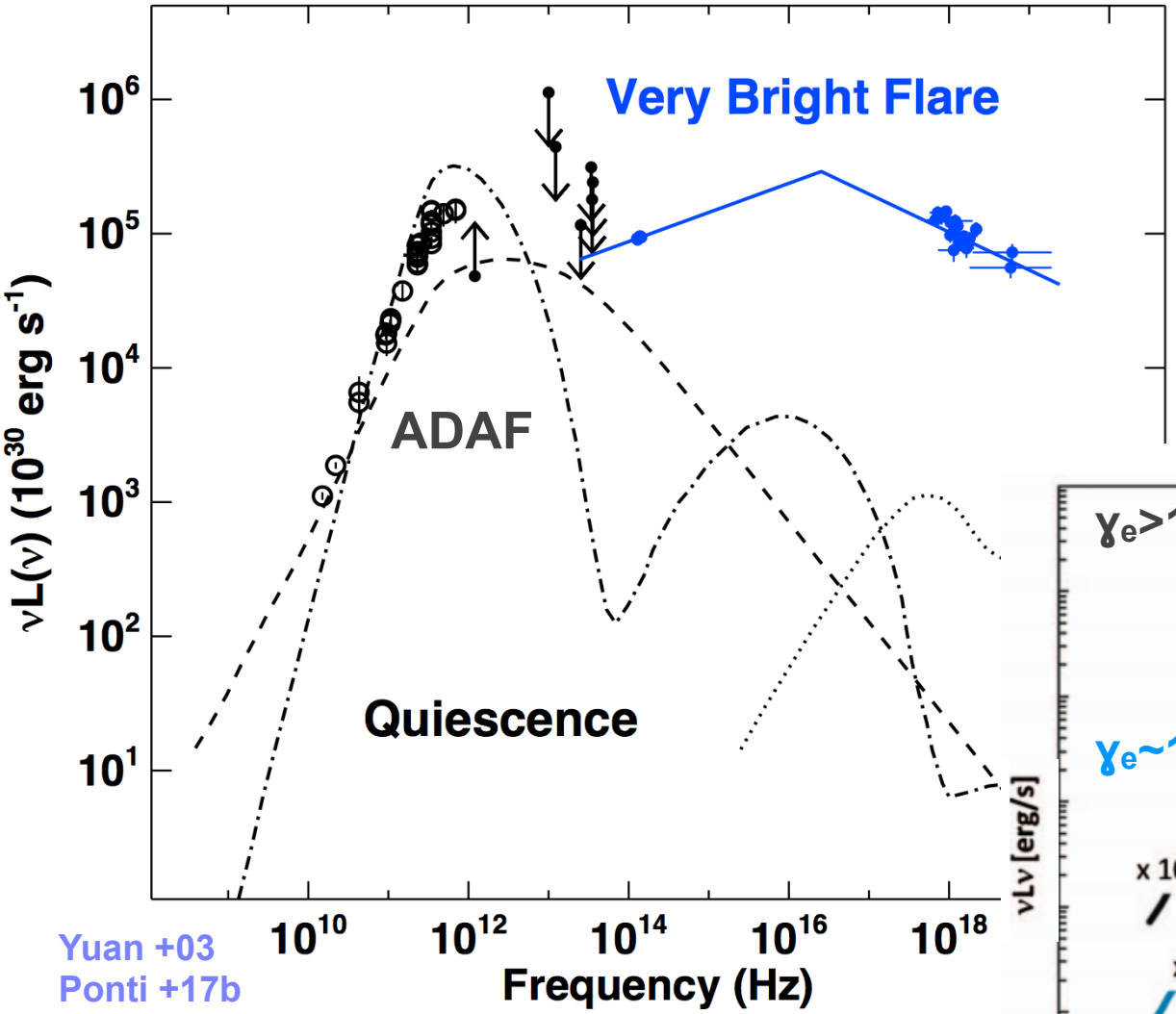
$kT_e \sim 7\times10^7$ K

$n_e \sim 100$ cm^{-3}

$\dot{M} \sim 10^{-6}$ M_{Sun} yr^{-1}

Falcke +98;
Markoff +01;
Yuan +03;
Zhao +03; +04;
Baganoff +03;
Herrnstein +04;
An +05; Xu +06;
Marrone +06; +07;
Schoedel +07; +11;
Dodds-Eden +09;
Trap +11; Wang +13;
Bower +15;
Brinkerink +15;
Liu +16; Stone +16

Sgr A*'s emission during flares?



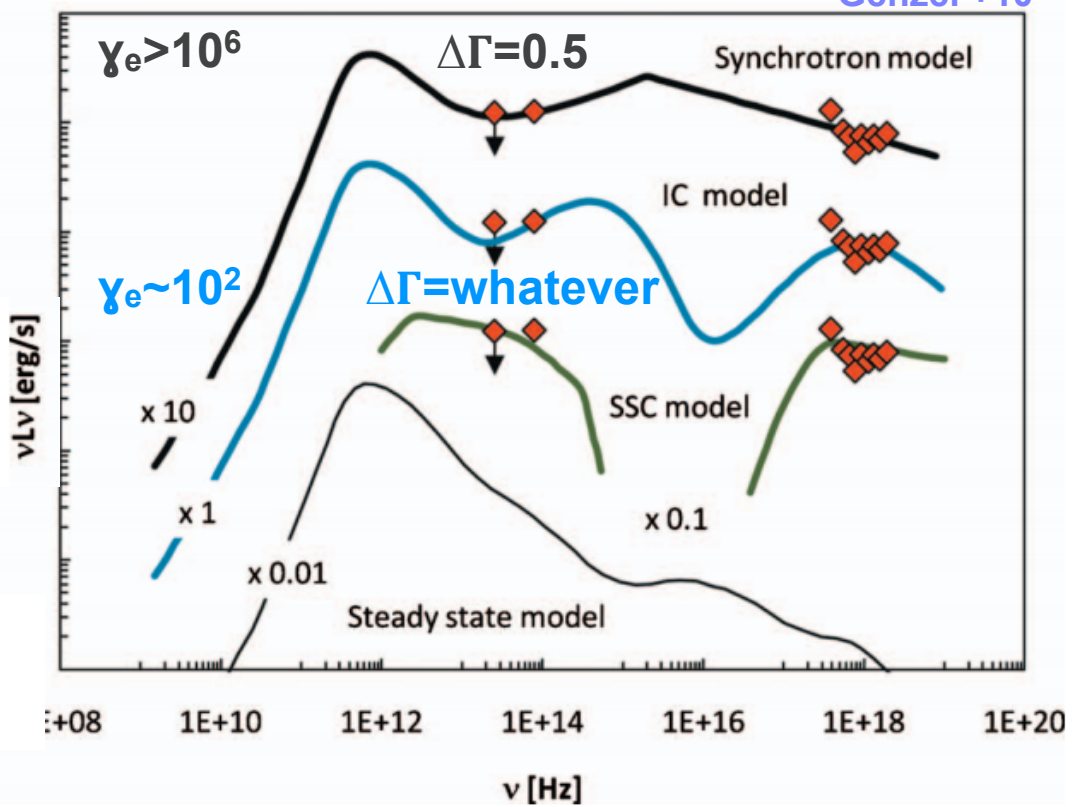
Yuan +03
Ponti +17b

During flares
$\Gamma_{IR} \sim 1.6$
IR polarised
➜ Synchrotron

(Quiescent GBH too!) Shahbaz +13

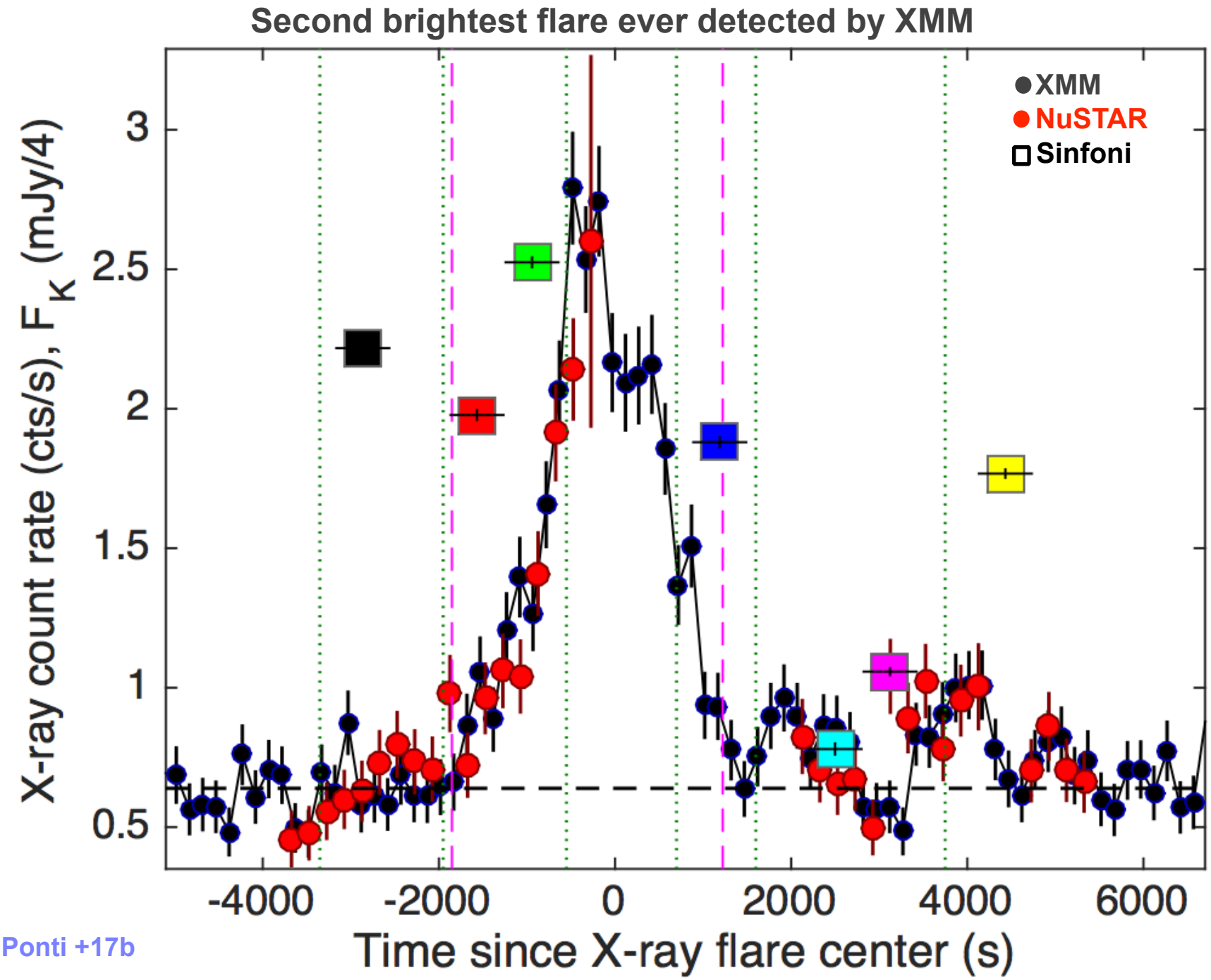
What is the radiative process in X-ray?

Genzel +10



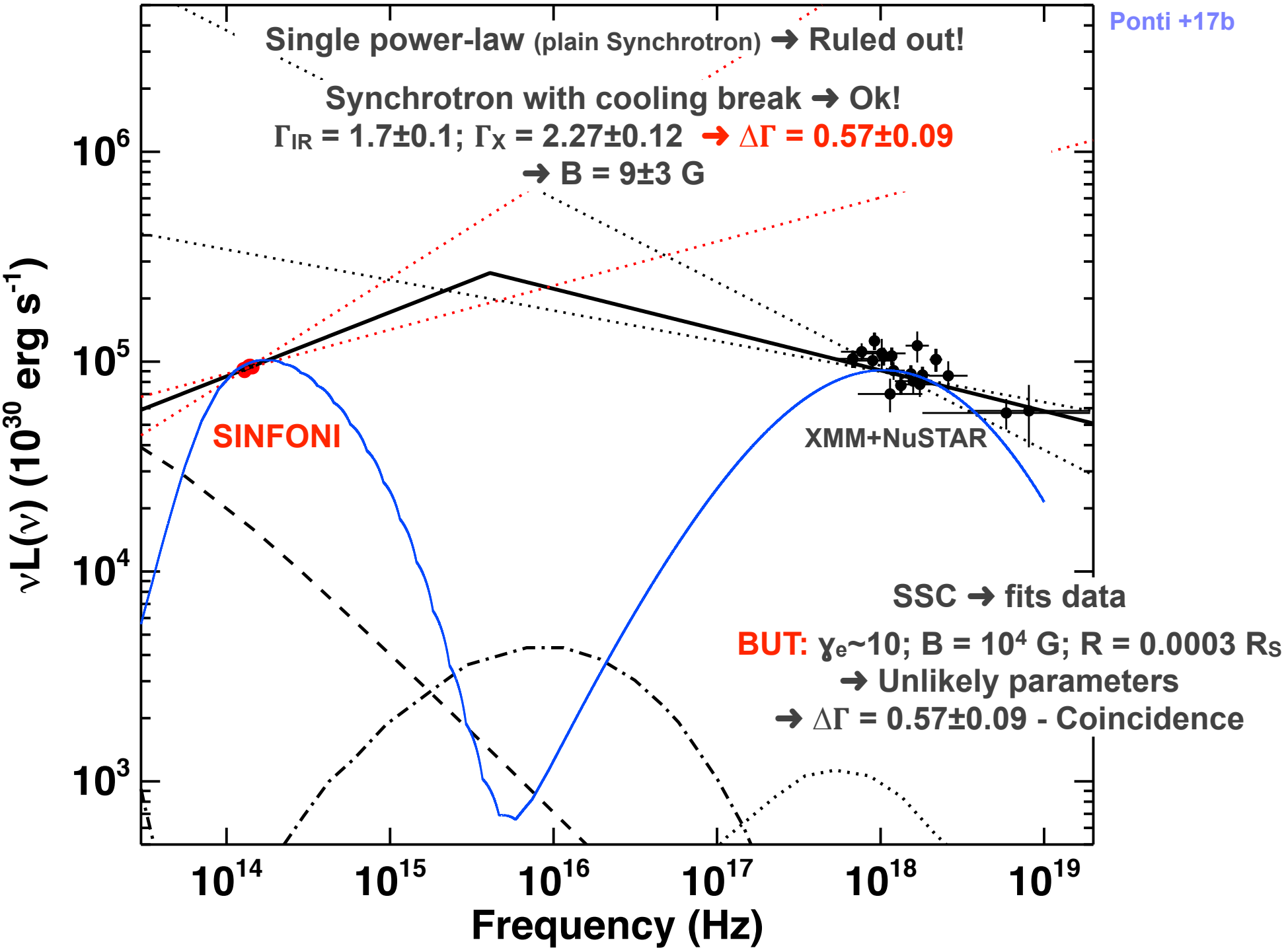
Major question since 15 yr…
We've solved it!

First NIR and X-ray spectrum of a flare!

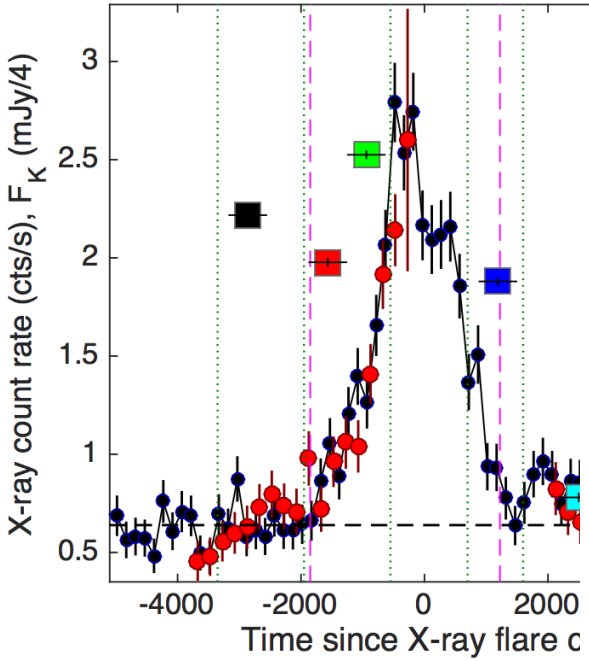


Ponti +17b

First NIR and X-ray spectrum of a flare!

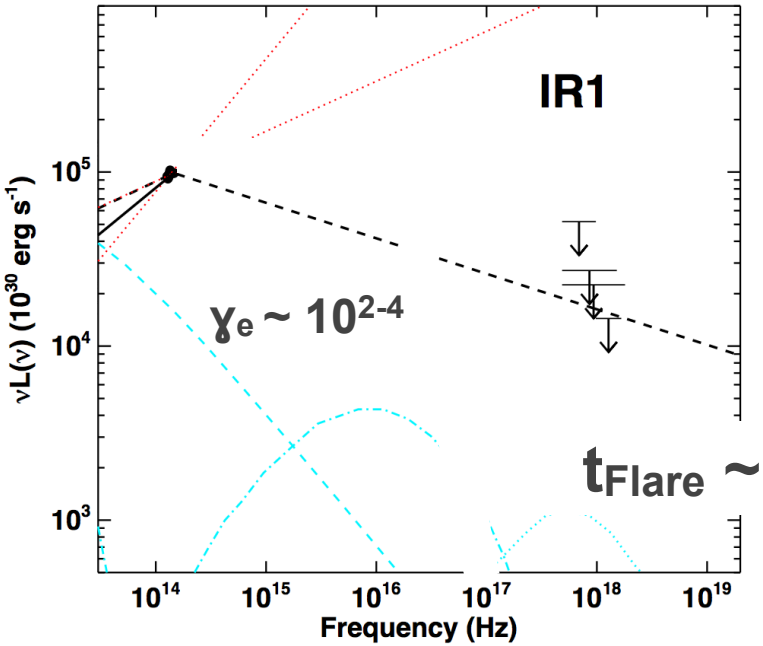


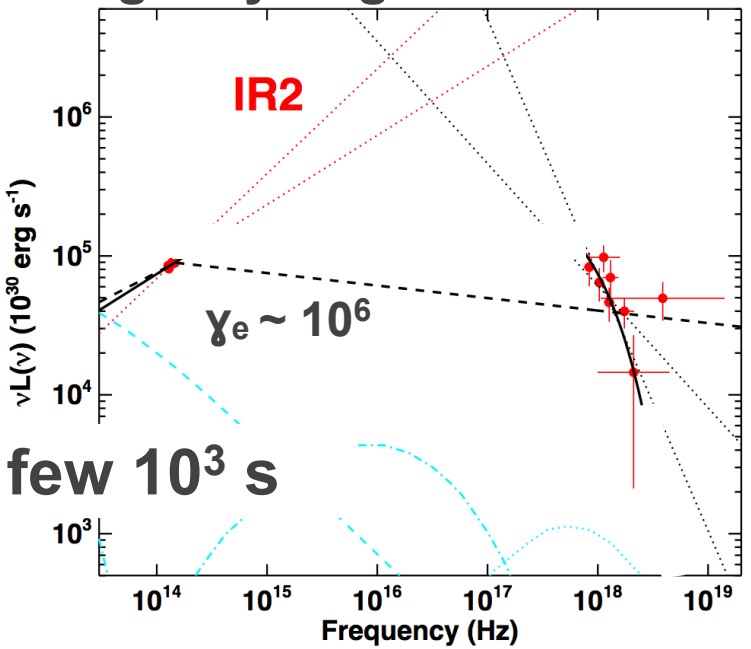
Evolution of γ_e during flares?



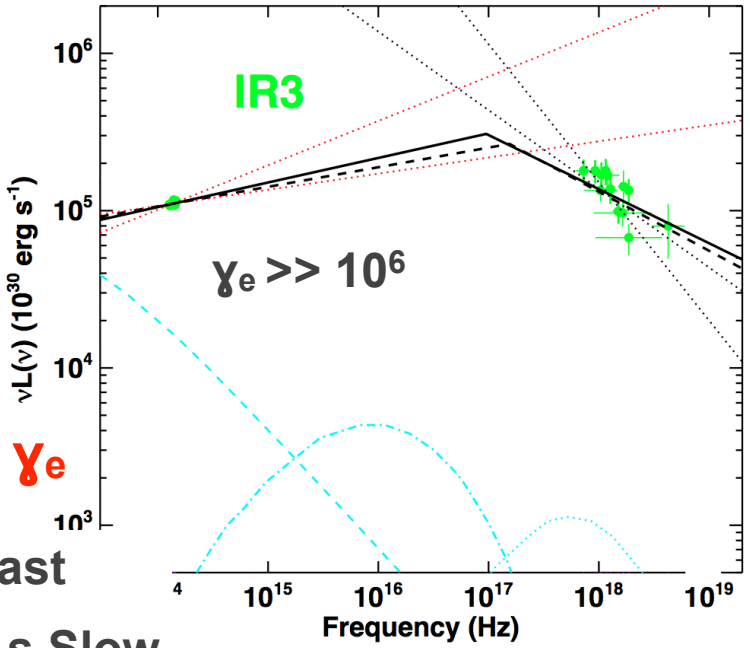
Ponti +17b

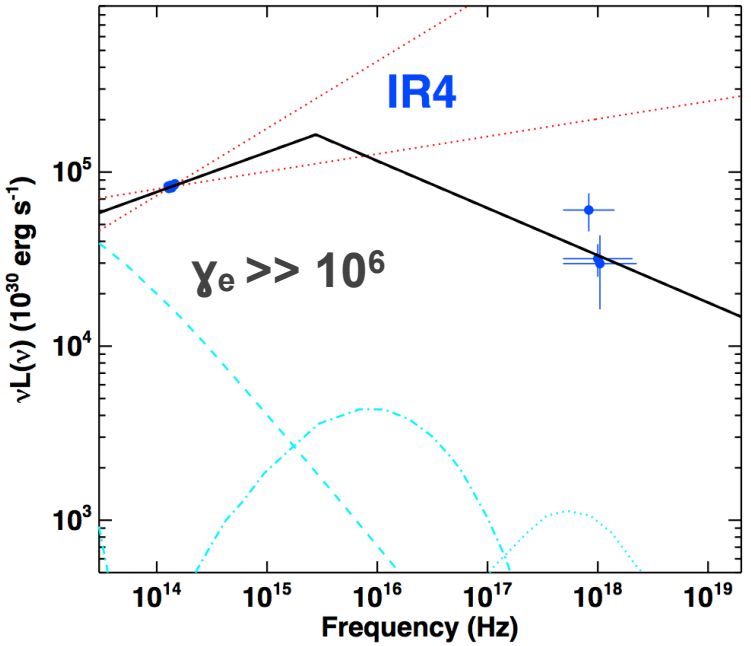
SED evolution during very bright flare





$t_{Flare} \sim$ few 10^3 s





Ponti +17b

Synchrotron with cooling and $\gamma_e > 10^6$

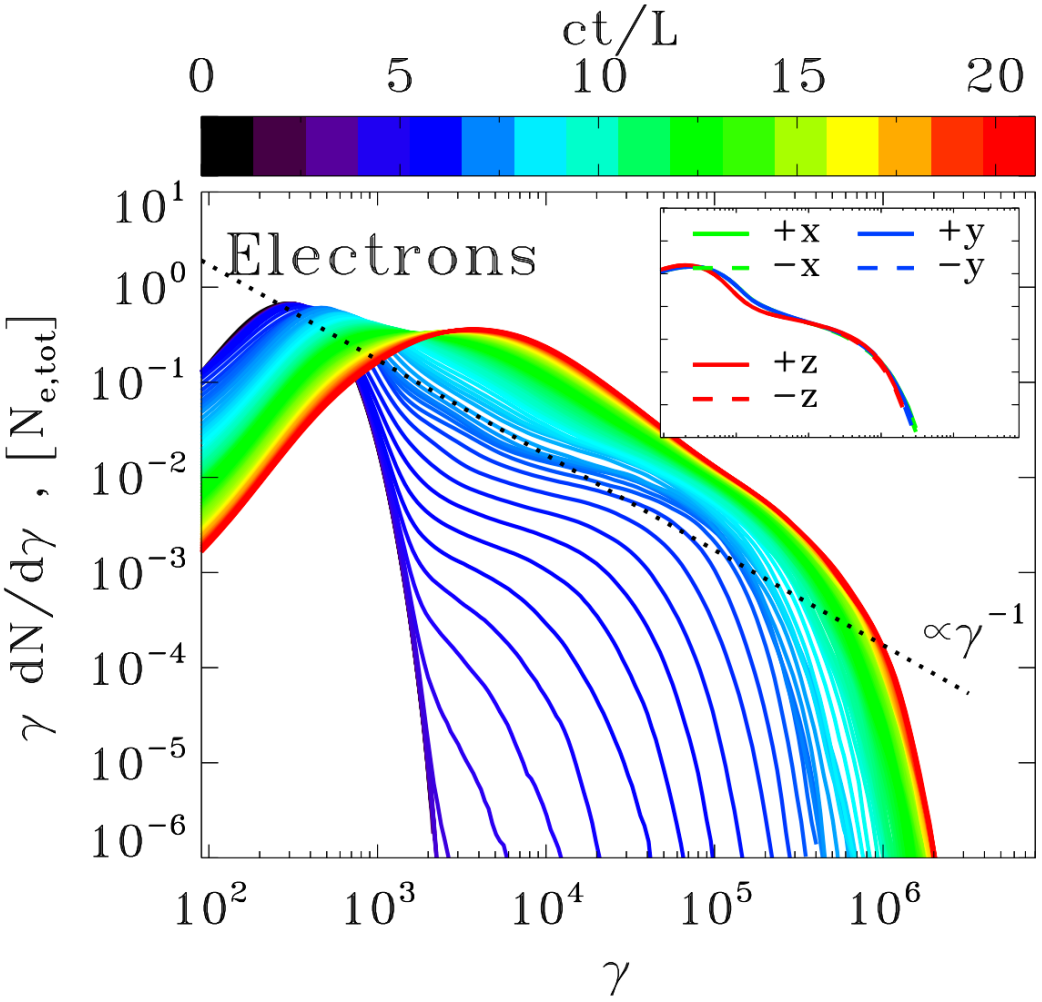
Break in NIR ➜ No
IR2 slope ➜ No

➜ **Slow evolution of γ_e**

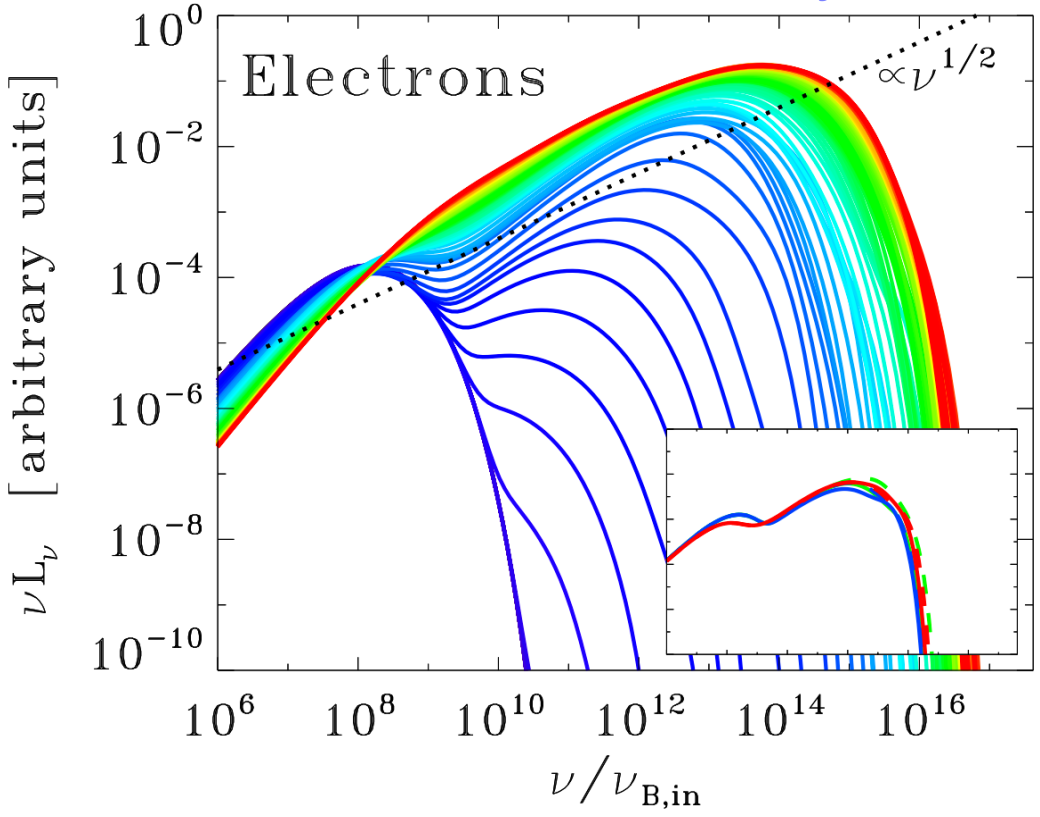
$t_{acc} \sim r_{gyro}/c$ ➜ 10^{-4} s Fast

$t_{acc} \sim r_S/c \sim r_S/v_{Alfven}$ ➜ 10^2 s Slow

Magnetic reconnection: slow evolution of γ_e



Lyutikov +18



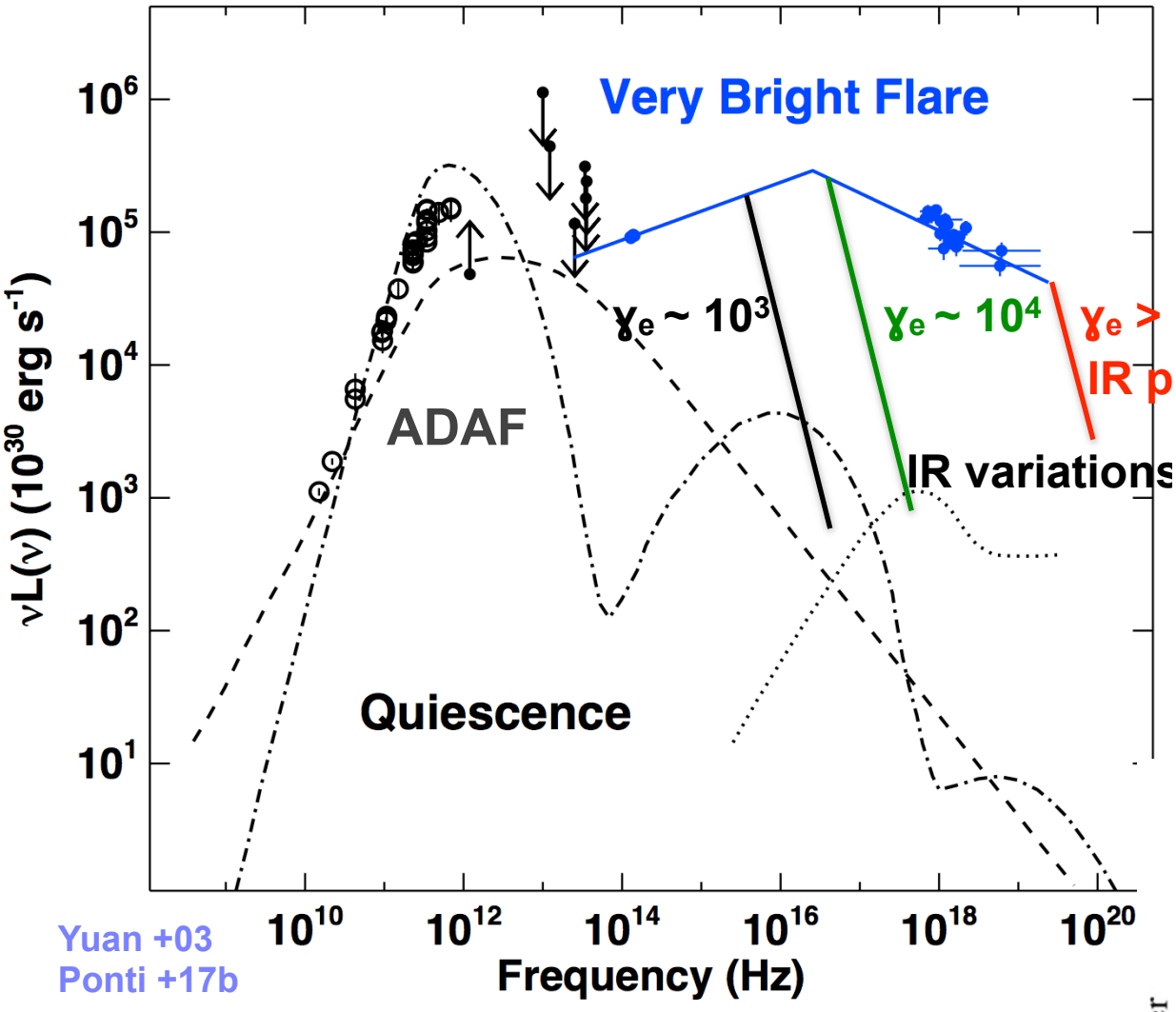
➜ **Slow evolution of γ_e**

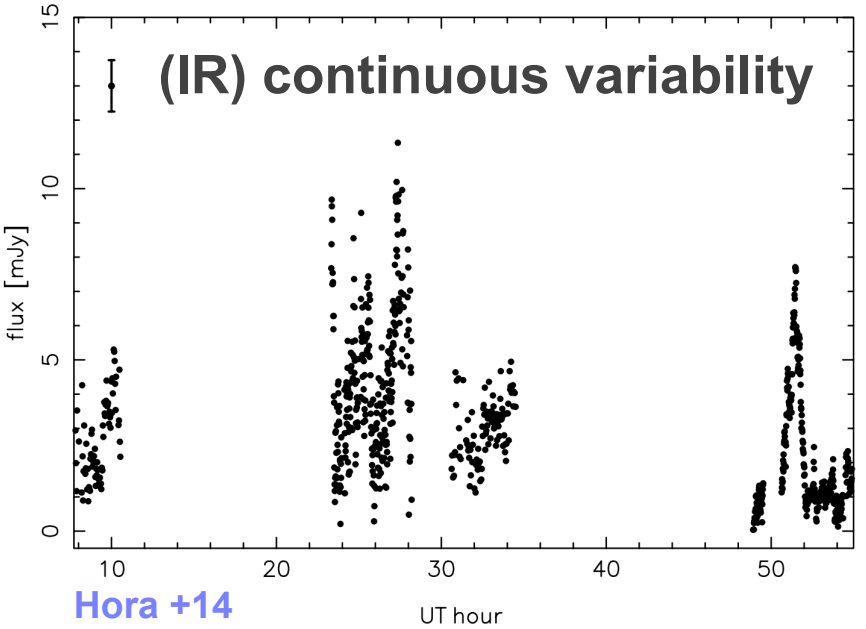
Lyutikov +18

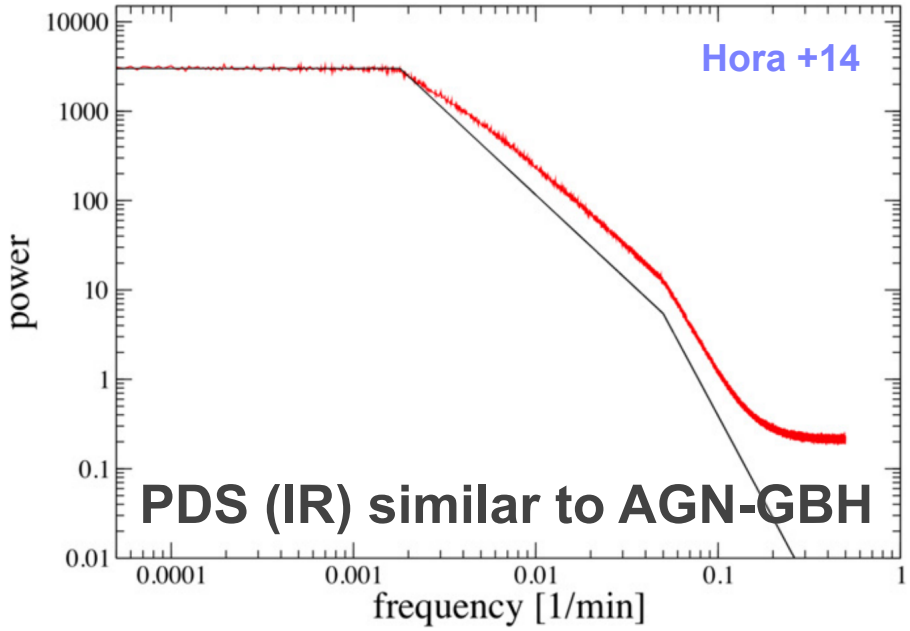
$t_{acc} \sim 10\ r_S/c$

For Sgr A*: $t_{acc} \sim t_{Flare} \sim$ few 10^3 s

Implications of slow evolution of γ_e



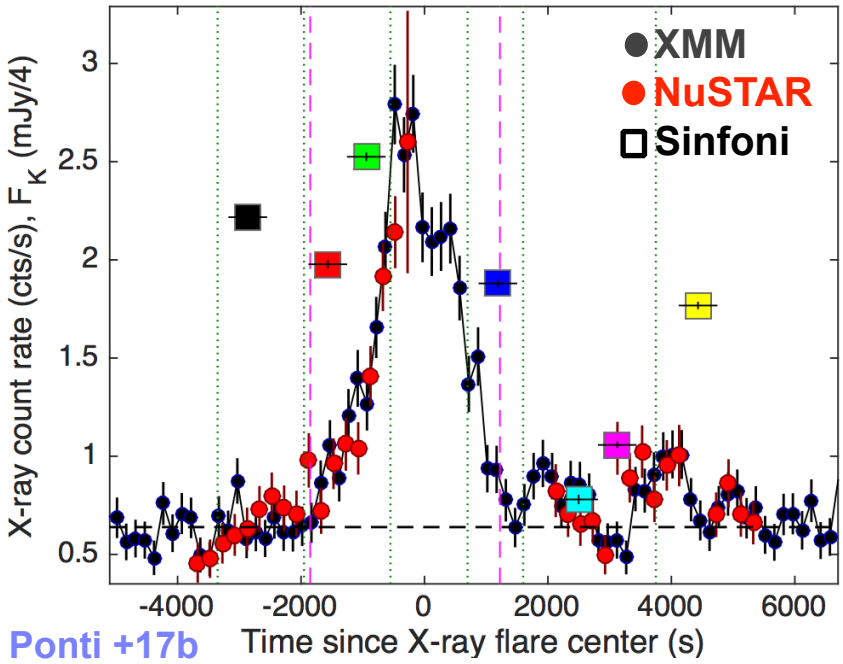




➜ Slow evolution of γ_e naturally explains:

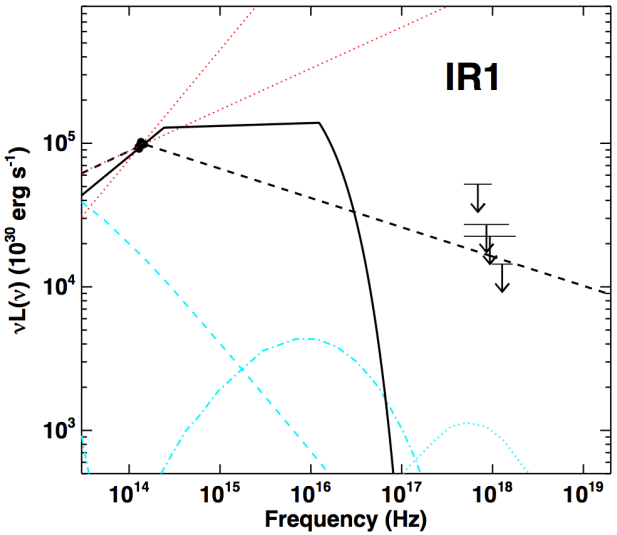
1) Peculiar X-ray flaring
2) Different IR/X-ray behaviour

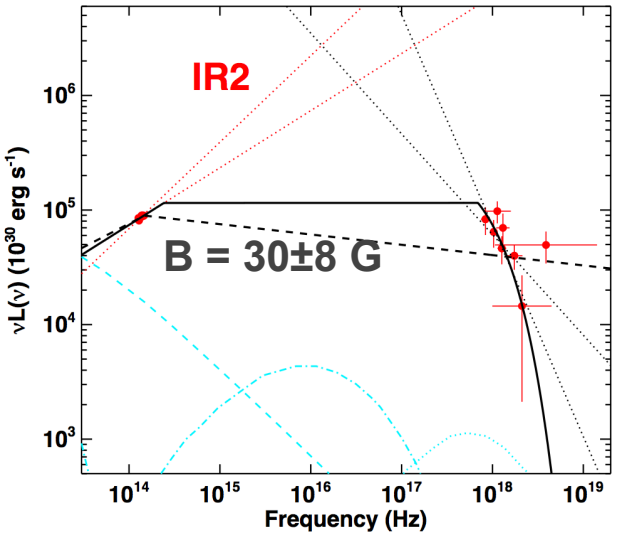
Evolution of B during flares!

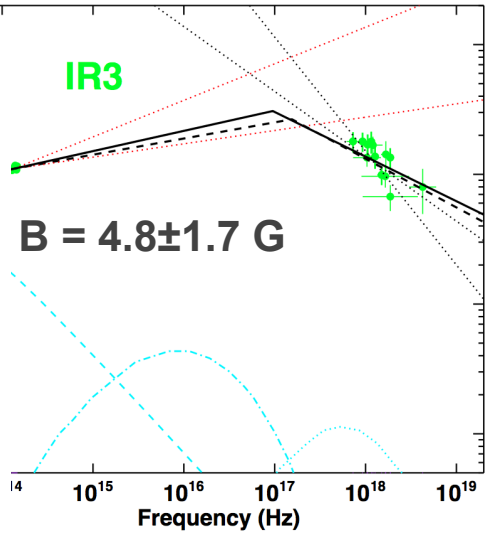


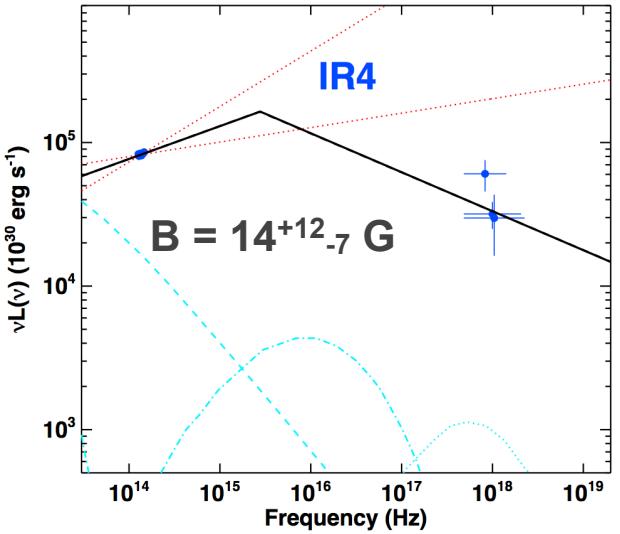
Ponti +17b

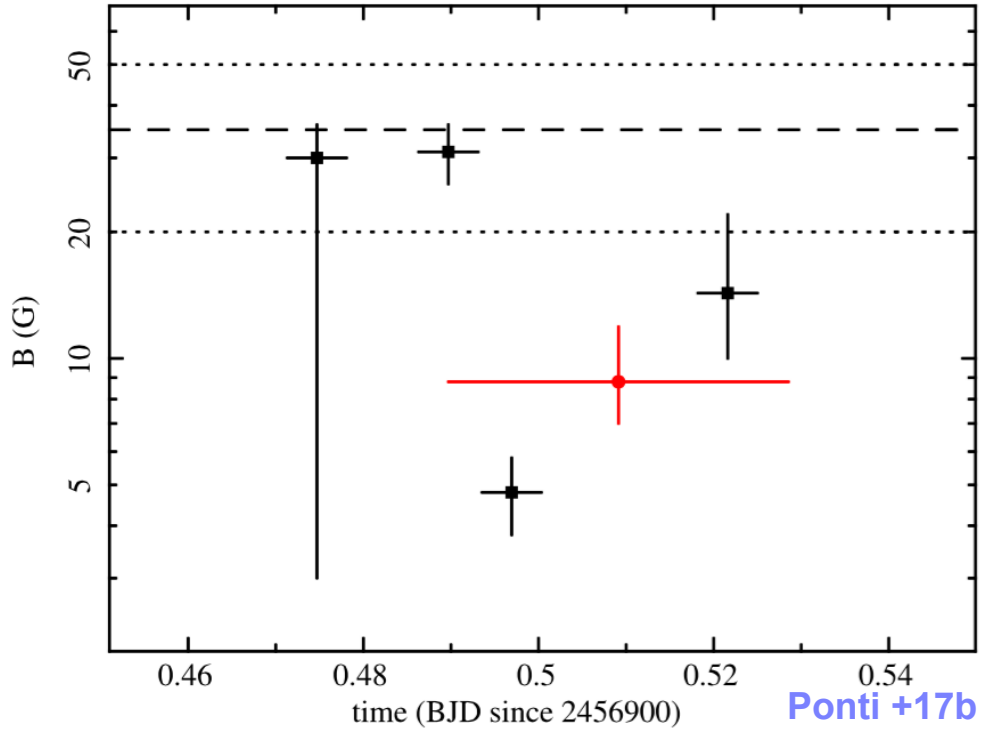
SED evolution during very bright flare











Ponti +17b

Evolution of ➜ magnetic field

➜ Flares powered by magnetic energy

$\Delta E_{magnetic} \approx \Delta E_{particles}$

➜ magnetic reconnection

Ponti +17b

Conclusions:

GBH template to decipher AGN

➜ Universal variability pattern above the PDS break (when active)

➜ Accurate M_{BH} Ponti +12

$\nu_{break} \propto \dot{M}$? ➜ eROSITA will answer Merloni +12

➜ Peculiar X-ray flaring in quiescence

➜ non-stationary flaring Ponti +15b; see also Porquet +08; Mossoux +16; +17

IR flares ➜ synchrotron Shahbaz +13

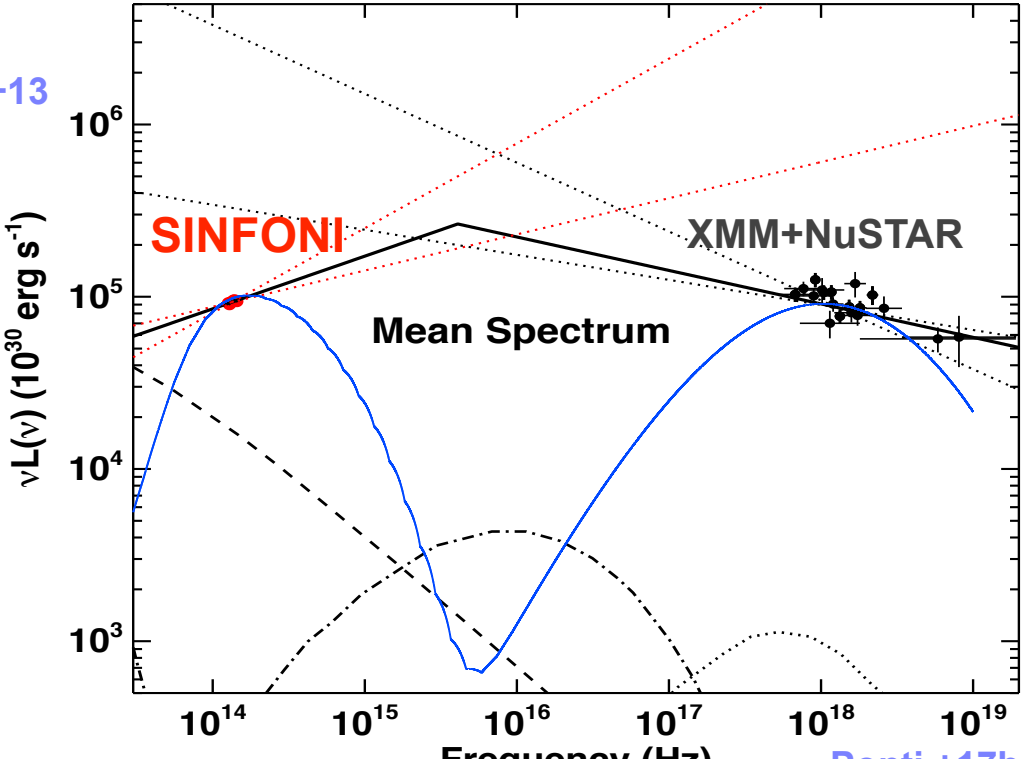
➜ Powerful flare from Sgr A* confirms synchrotron origin of the X-ray Ponti +17b

Flare SED evolution and X-ray light curves

➜ Slow evolution of γ_e Ponti +17b

Lower B at flare peak

➜ Magnetic reconnection?



Ponti +17b