Exploring the relationship between (RL) Quasars and Microquasars

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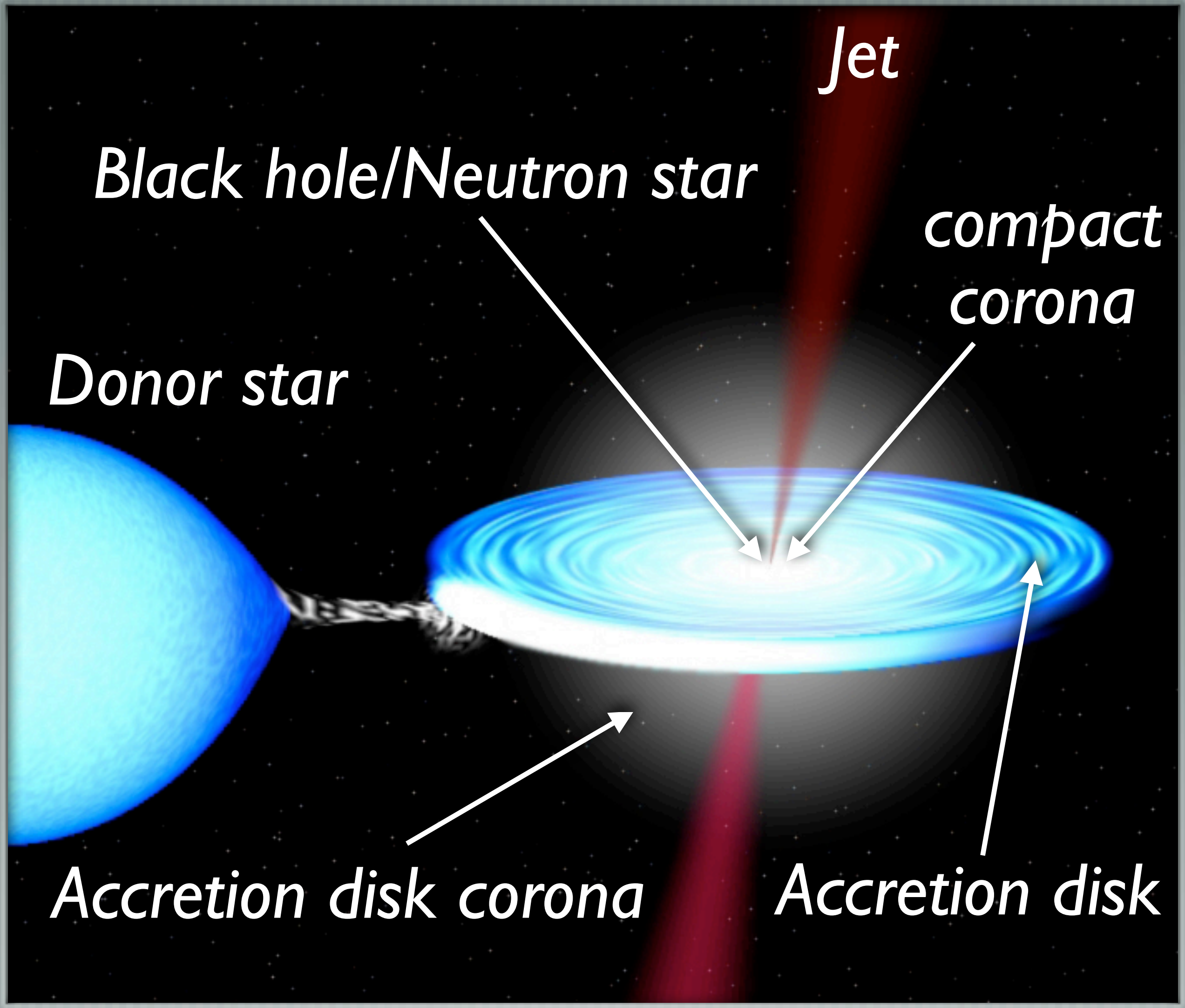
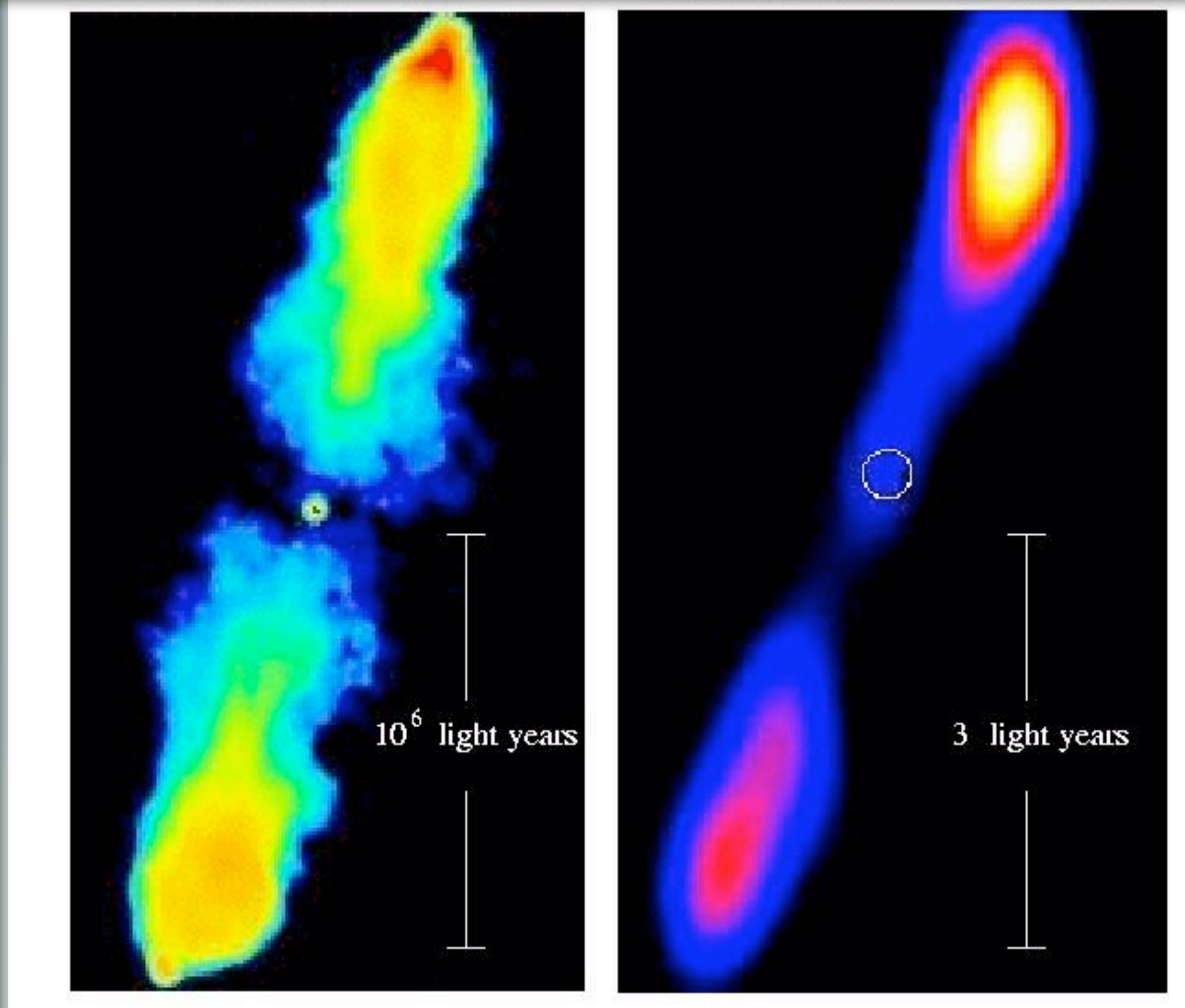
Outline

- Introduction
- Some X-ray binary phenomenology
- XRB state ⇔ AGN class mapping?
- Conclusions and outlook

Jargon: Microquasars are just "outgoing" X-ray binaries

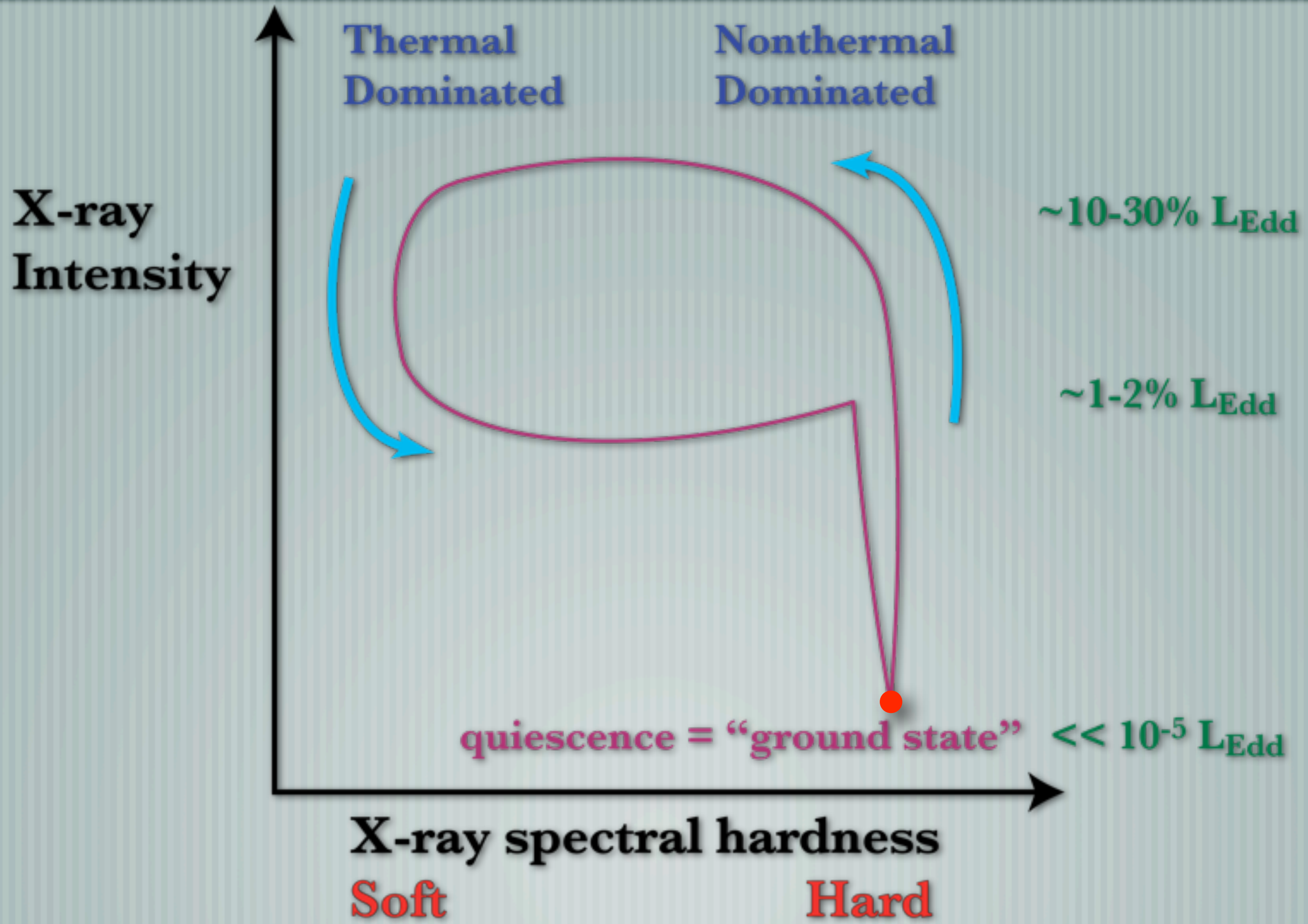


Black hole jets: similar across the mass scale?

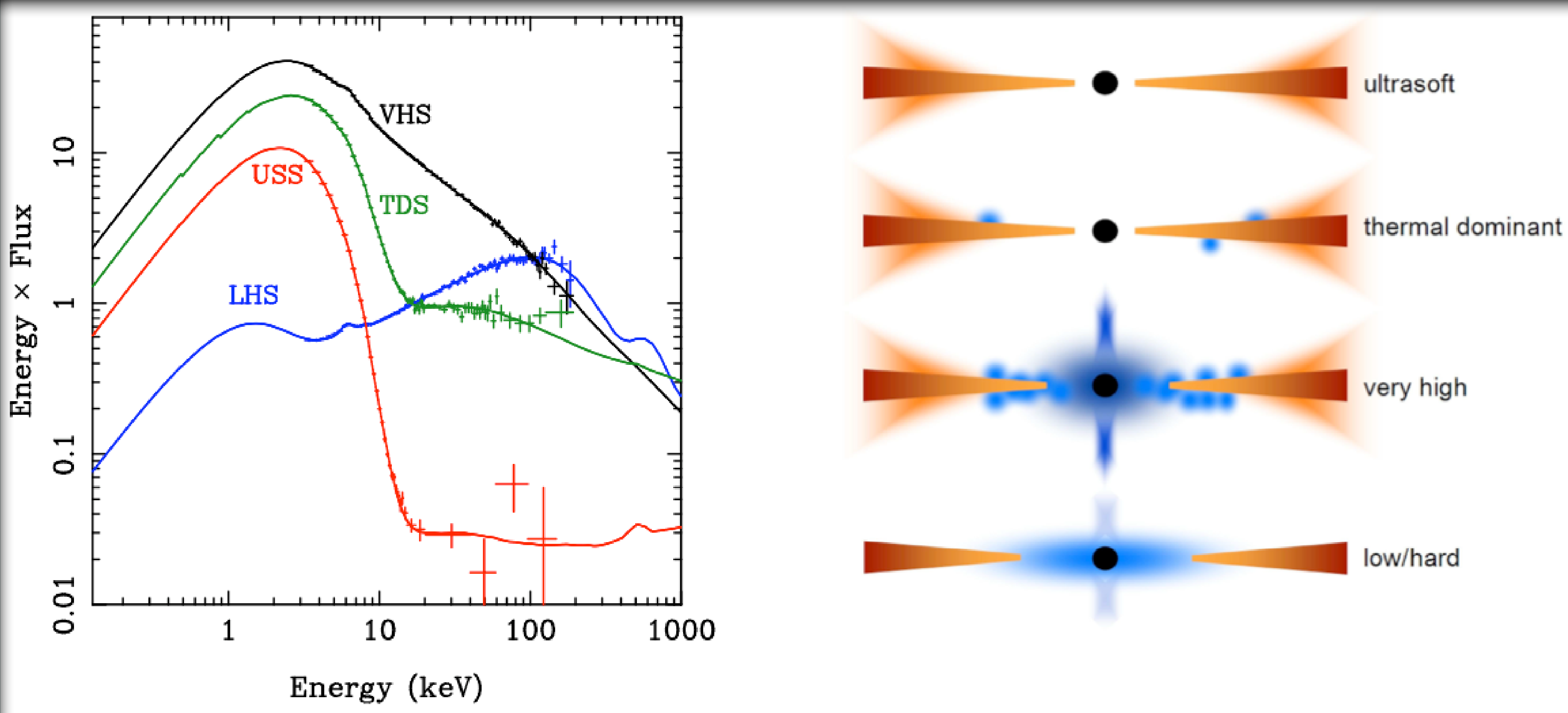


(Mirabel et al. 92,98)

XRB Behavior: The Hardness-Intensity Diagram (HID) – schematic view

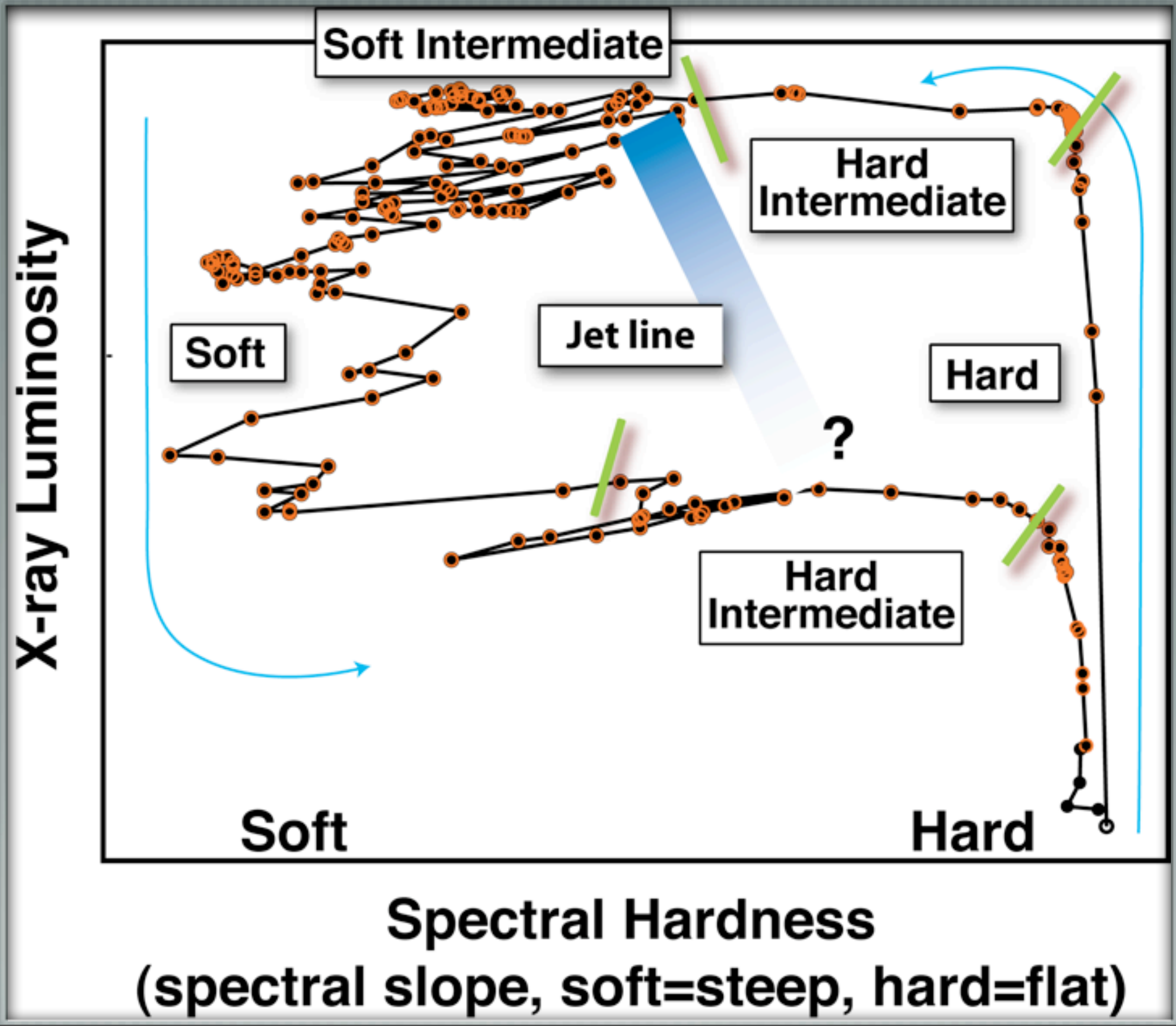


XRB Behavior: The Hardness-Intensity Diagram – X-ray spectrum

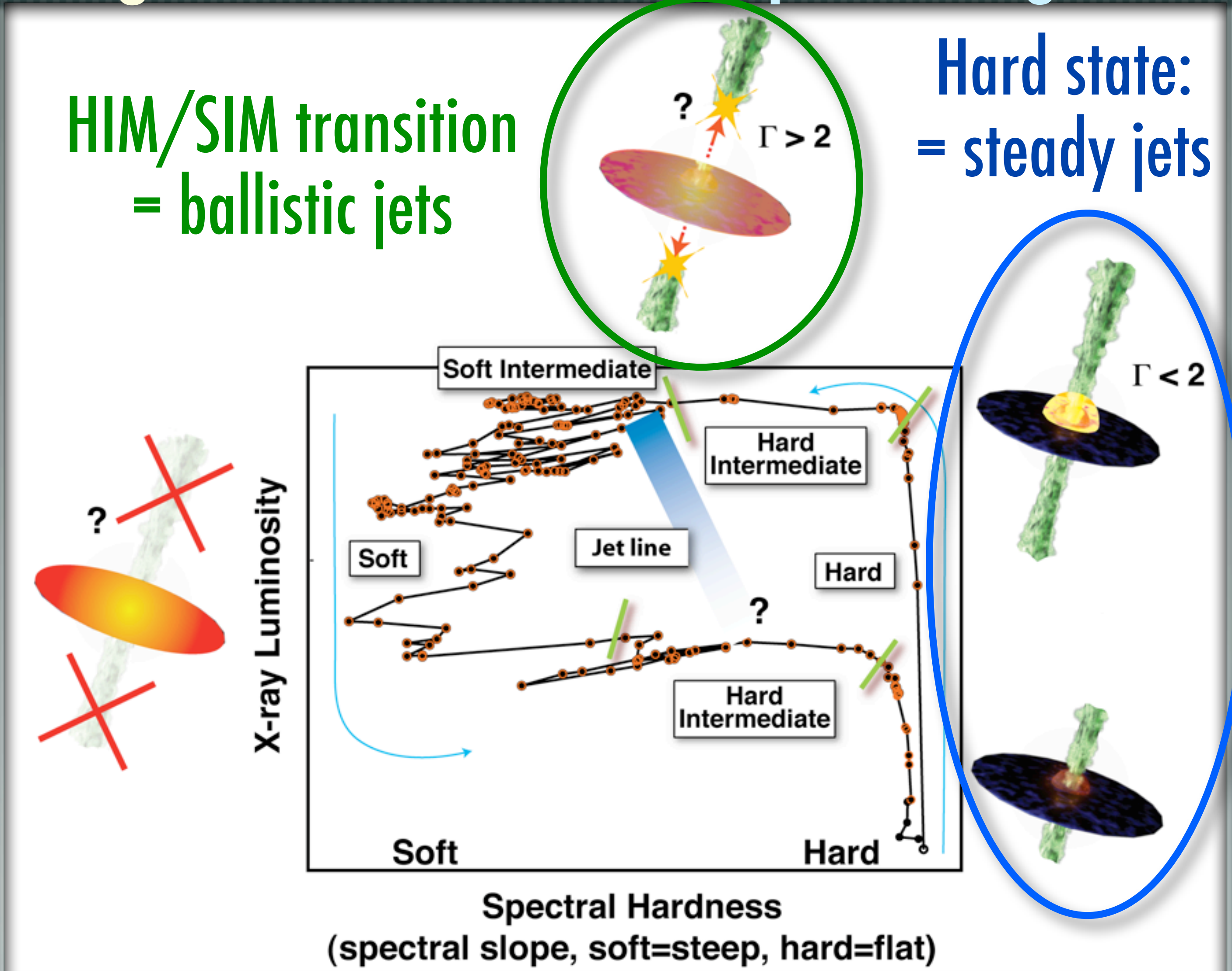


(Done, Gierlinski & Kubota 2007)

XRB Behavior: The Hardness-Intensity Diagram (HID)– real data with states



XRB Behavior: The Hardness-Intensity Diagram – what are the jets doing?



So how does all this relate to AGN?

Backing up, *should* this all relate to AGN??

- For black holes with roughly the same spin, does accretion behavior scale predictably with mass/power?
  - Accretion off single star vs. off central cluster/gas
  - Spin depends on formation/accretion history, and we don't yet have a surefire way to measure it
  - We don't have a fully self-consistent theory of everything going on in accretion

So how does all this relate to AGN?

Mass scaling makes testable predictions

- The main effect of black hole mass difference will be in the timescales, $\tau_{dyn} \propto$ size $\propto$ M:

  $\tau_{XRB} \sim$ week @ 10 $M_\odot$

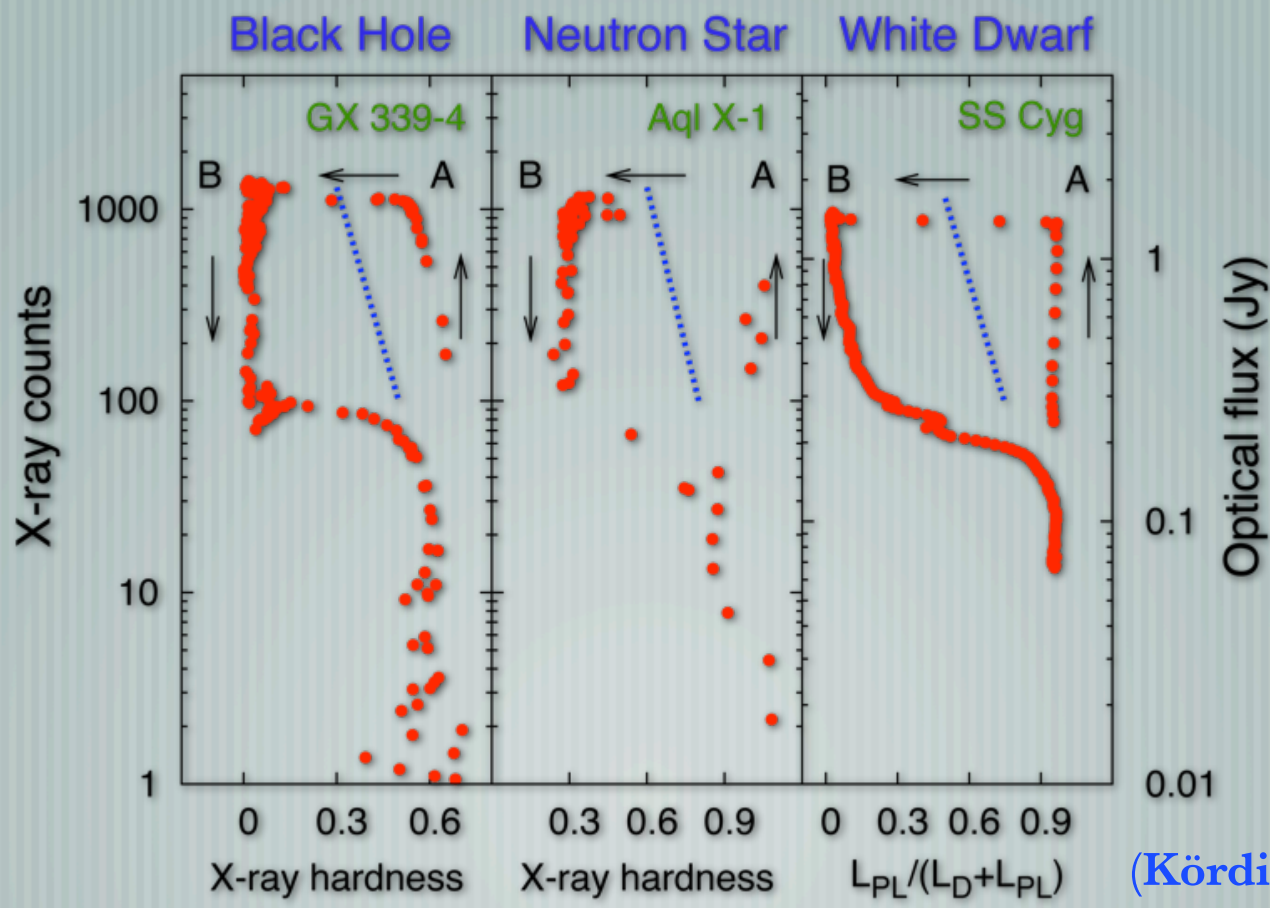
  $\tau_{AGN} \sim 10^6$ years @ 10^8 $M_\odot$!!

- If such scaling exists, consequences are grand: some AGN classes could be "unified" in a HID of their own

➡ We can test this idea, by searching for trends discovered from XRB monitoring in AGN populations

Evidence that HIDs (or equiv. evolution) are universal to accreting sources

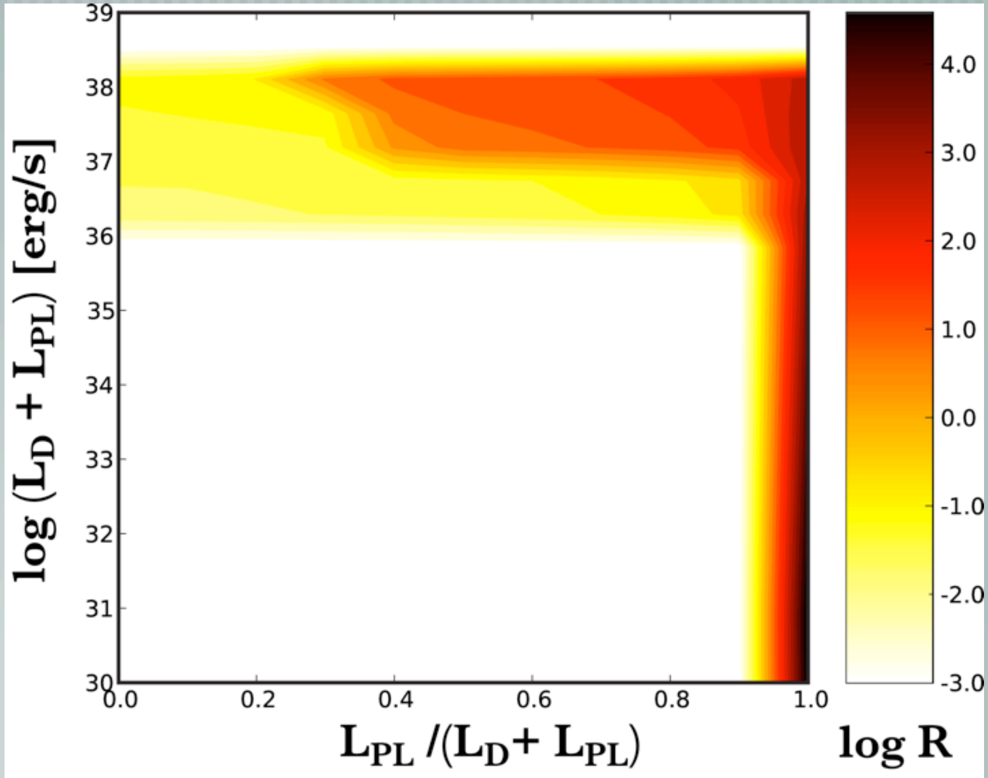
- There's certainly reason to think AGN would also have an equivalent evolution/states. NS's and WD's do!



(Körding et al. 2008)

Evidence that HIDs (or equiv.) are universal to accreting sources – AGN

For (cyclic)AGN, hardness is not the best diagnostic. Körding et al. 2006 suggest "Disk fraction/luminosity diagrams" (DFLG)



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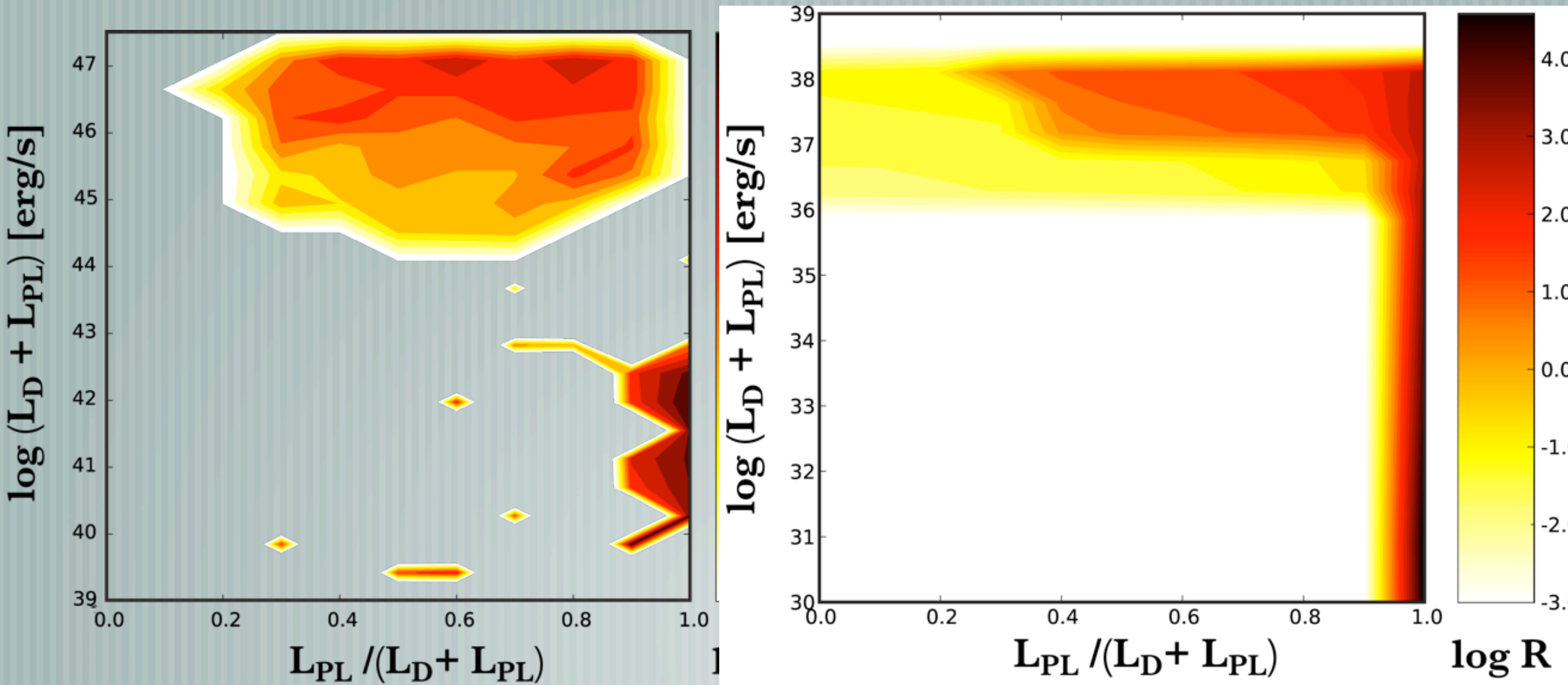

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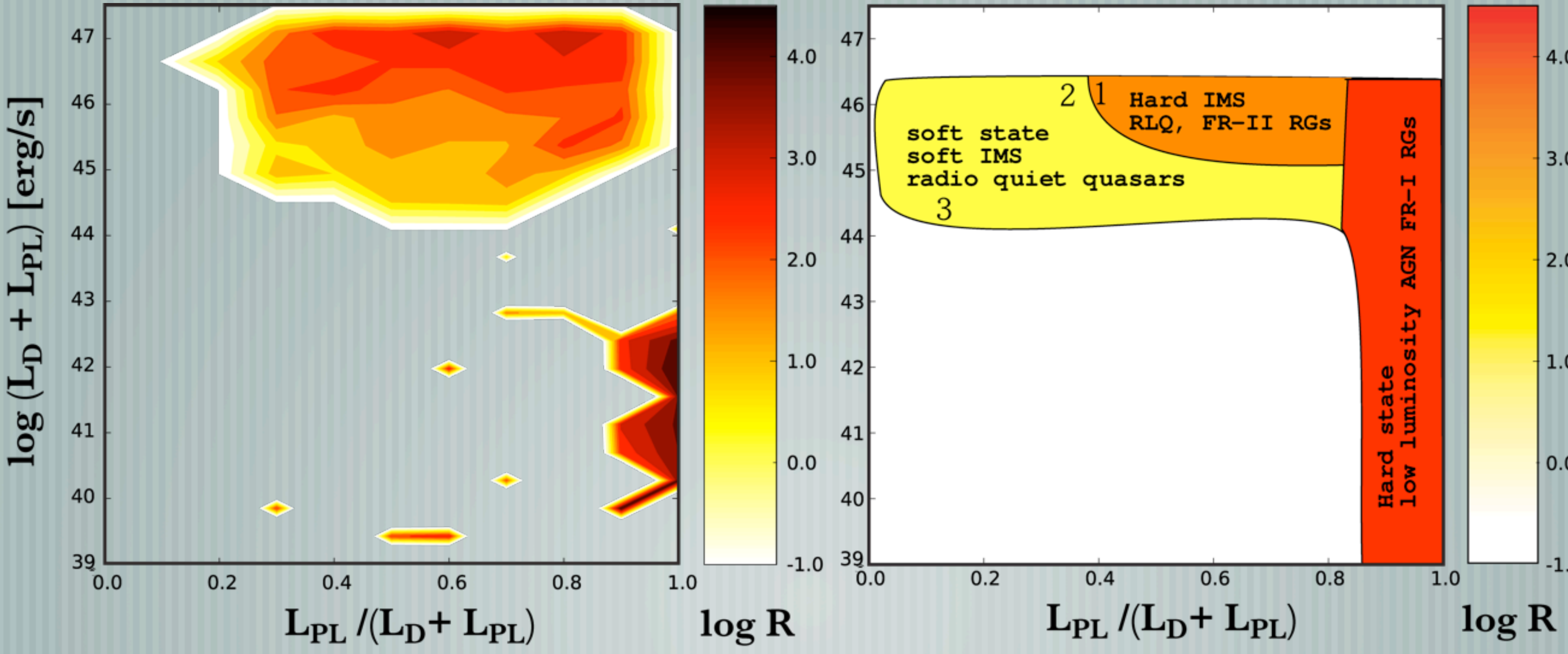
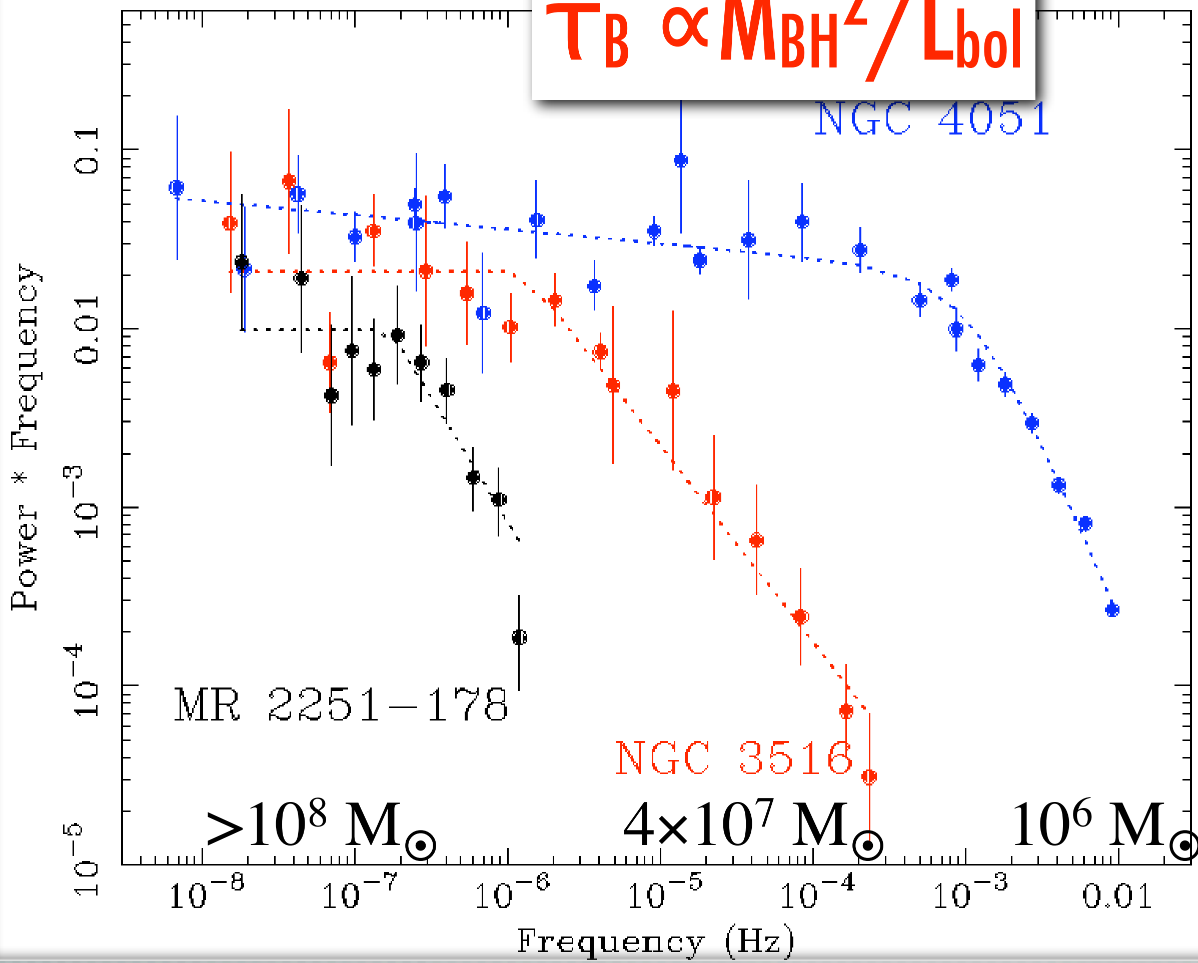
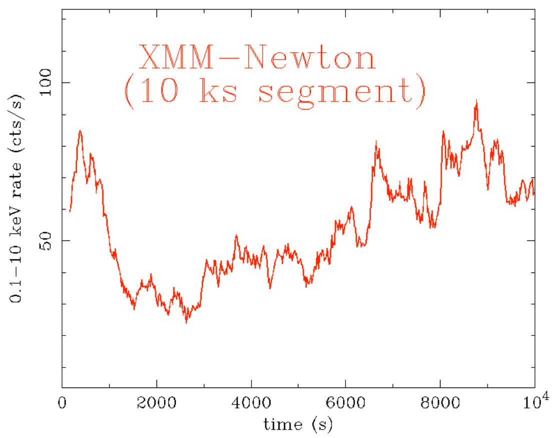


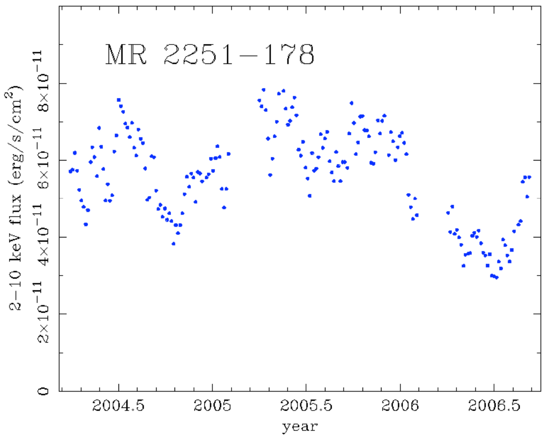
Characteristic timescales scale with black hole mass and inversely with $\dot{M}$ – PSDs

$\tau_B \propto M_{BH}^2/L_{bol}$

(Uttley, McHardy, et al.)





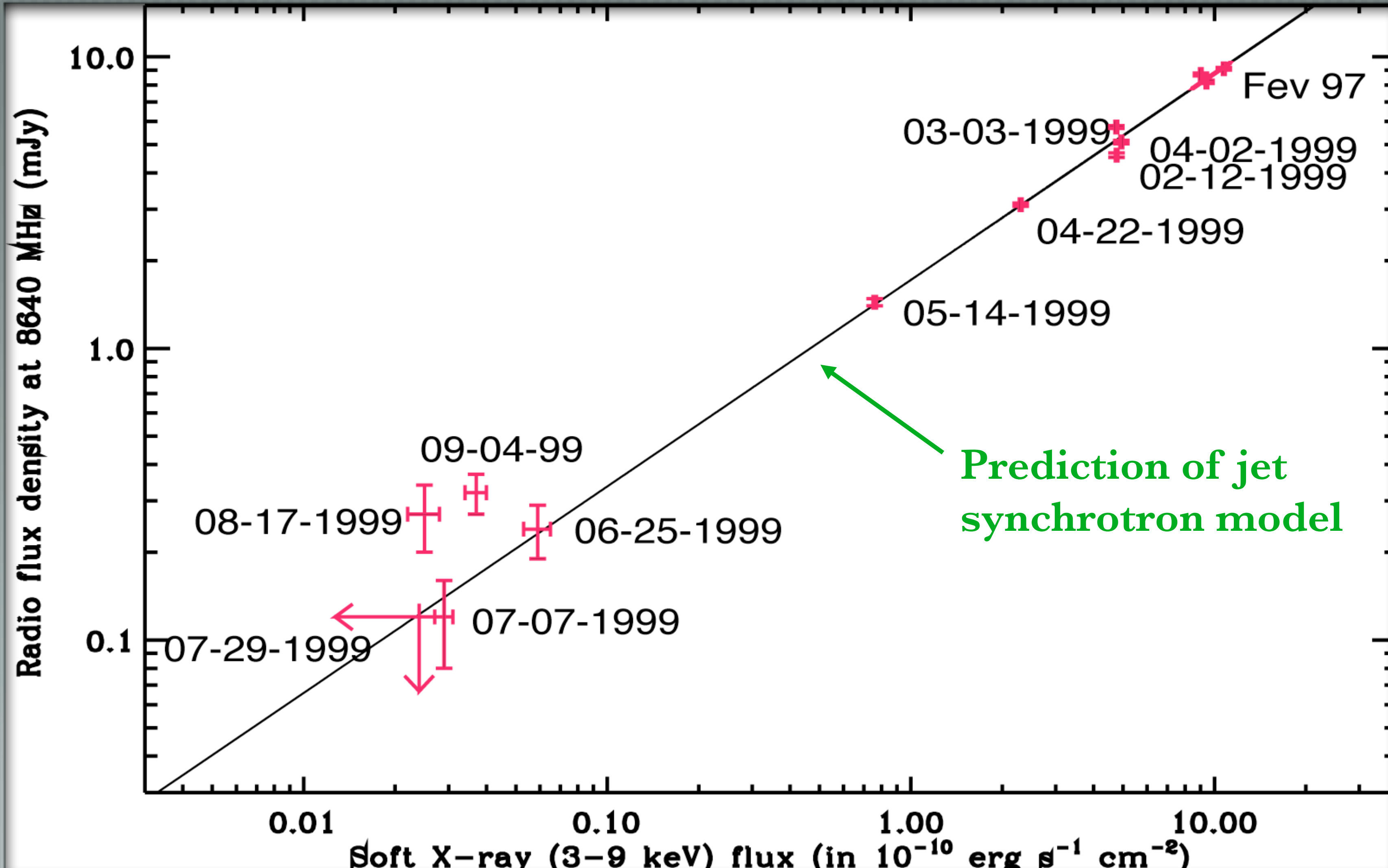


Hard XRB state ⇔ LLAGN, FR Is

Strong case on both empirical and theoretical grounds

- “Fundamental plane of black hole accretion” linking radio and X-ray luminosities with black hole mass
- Same physical models fit broadband data across the mass scale with the same physical parameters

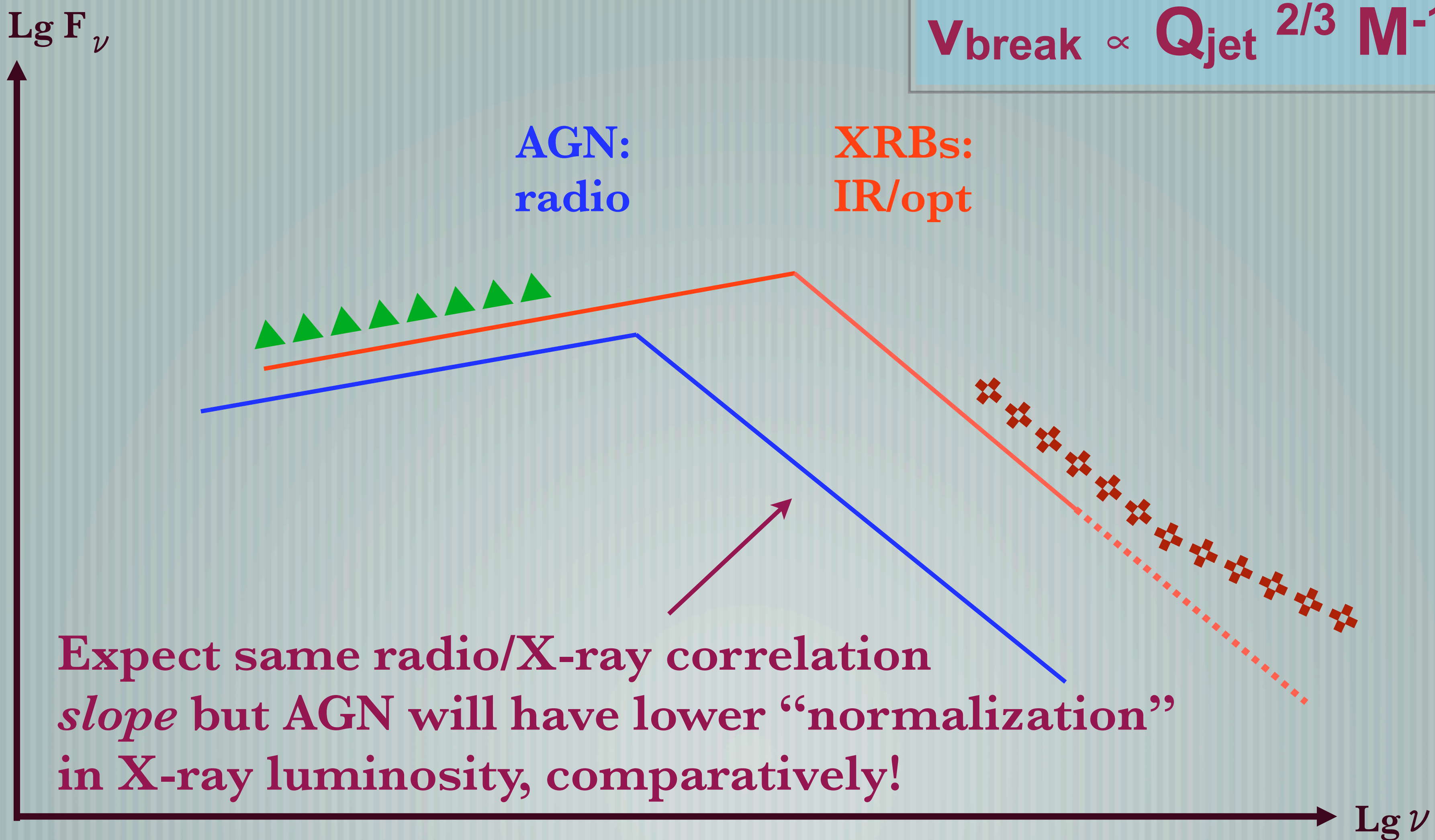
XRB hard state – Radio/Xray correlation



(Corbel ea. 2000, 2003; Markoff et. 2003, Gallo ea. 2003)

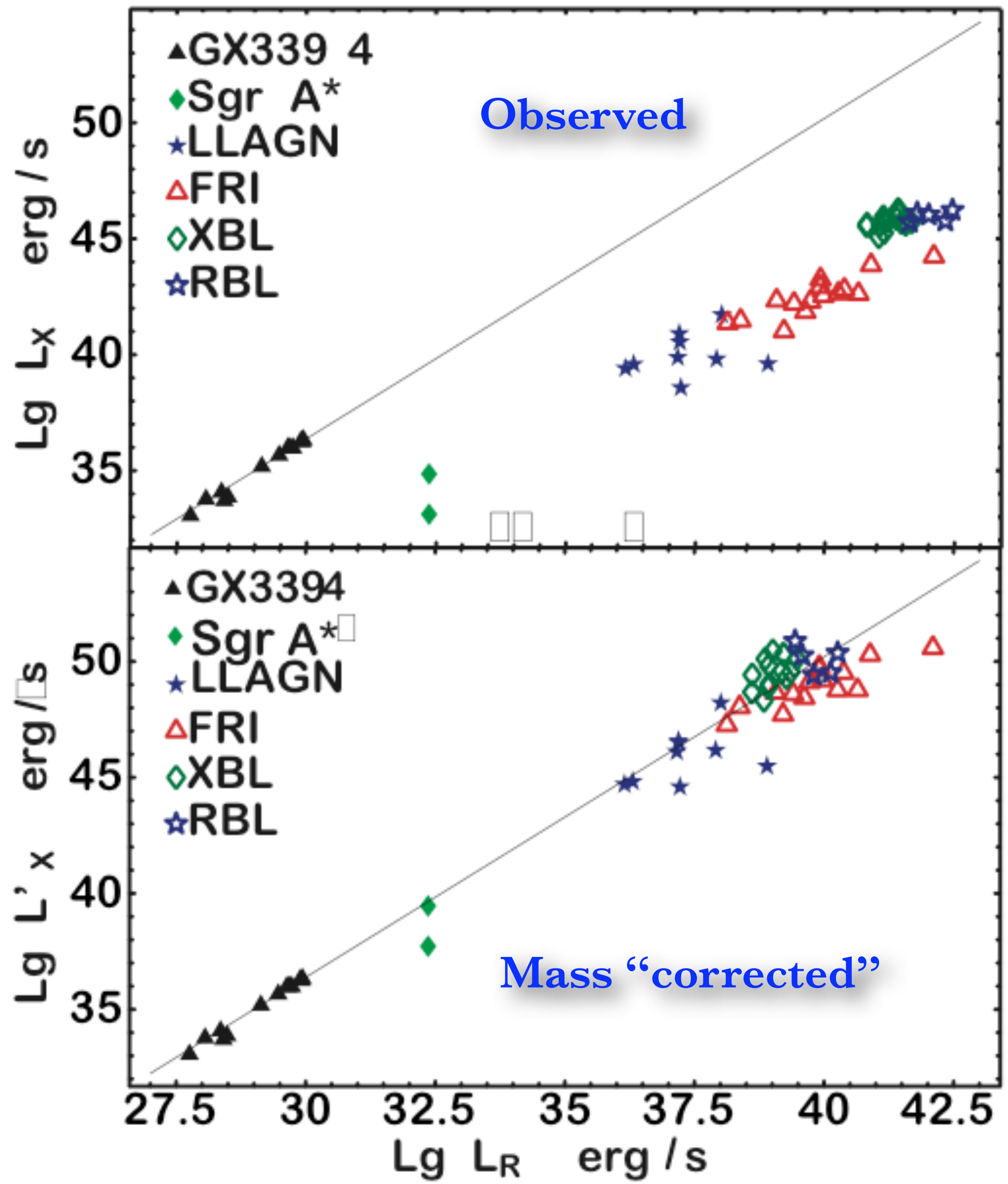
Mass scaling of jet break frequency

$$\nu_{break} \propto Q_{jet}^{2/3} M^{-1}$$



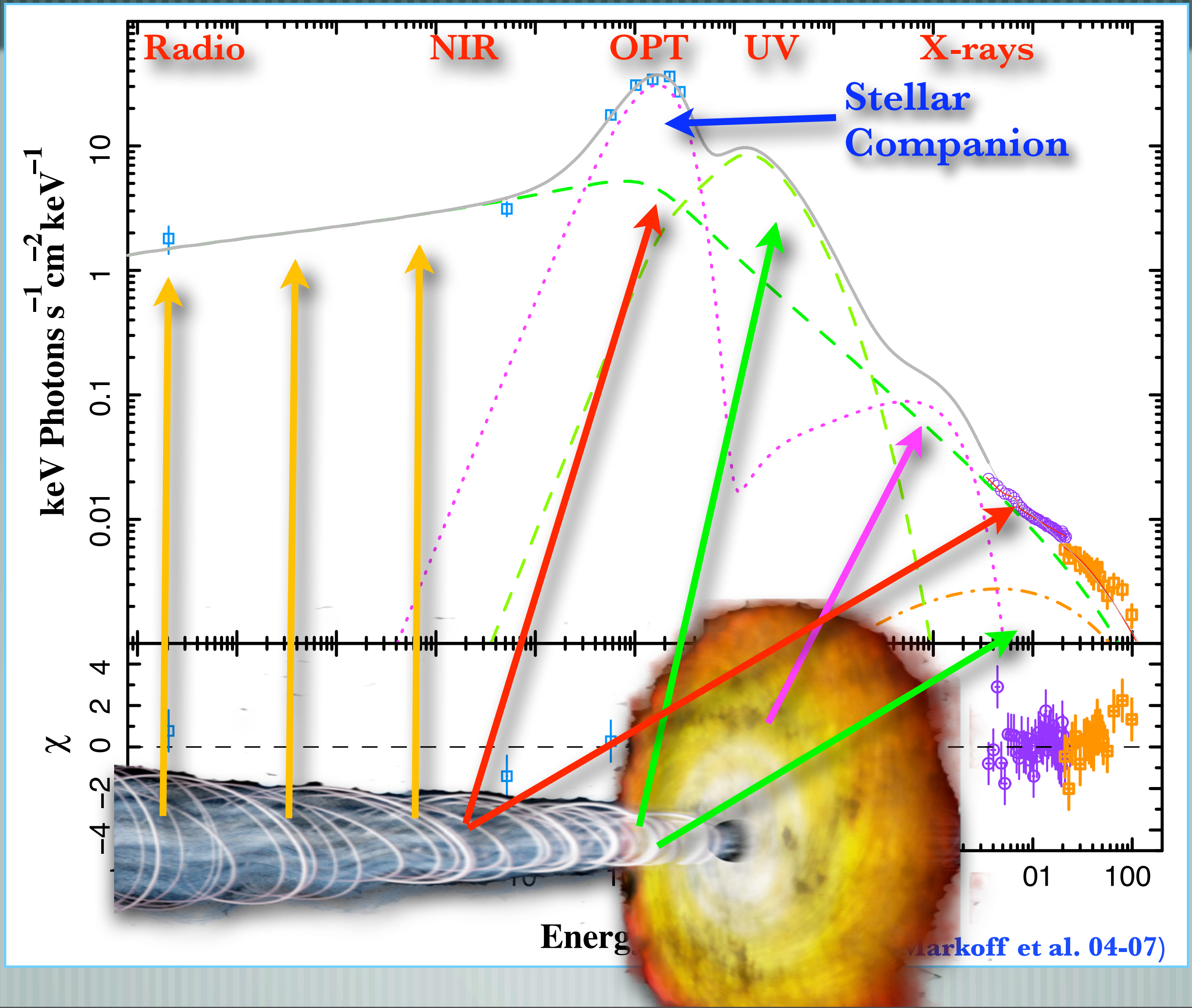
Expect same radio/X-ray correlation *slope* but AGN will have lower "normalization" in X-ray luminosity, comparatively!

Fundamental plane of black hole accretion

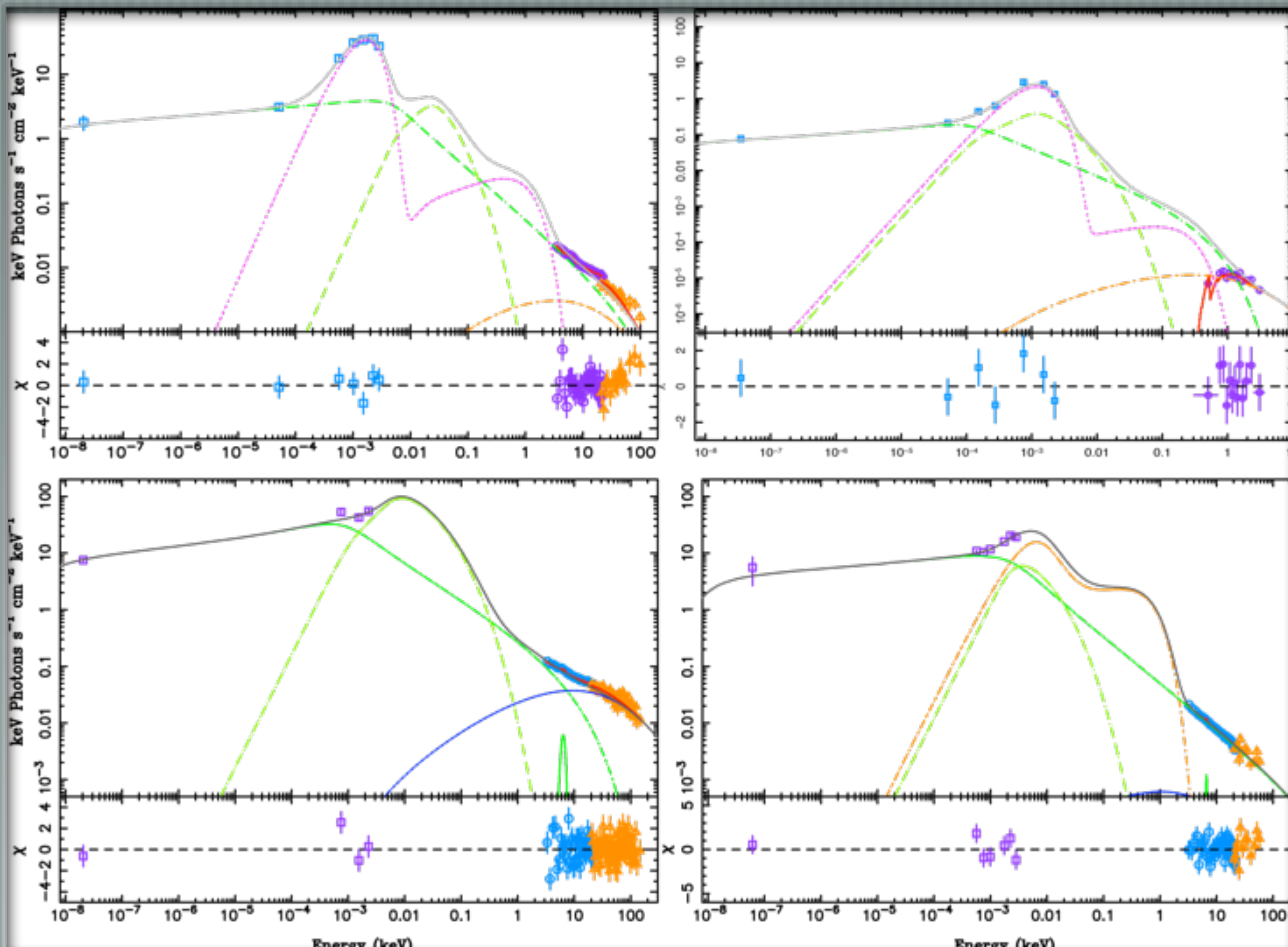


(Markoff et al. 2003, Merloni,Heinz & diMatteo 2003, Falcke, Körding & Markoff 2004, Markoff 2005, Merloni et al. 2006, Kording et al. 2006)

Modeling hard state XRBs

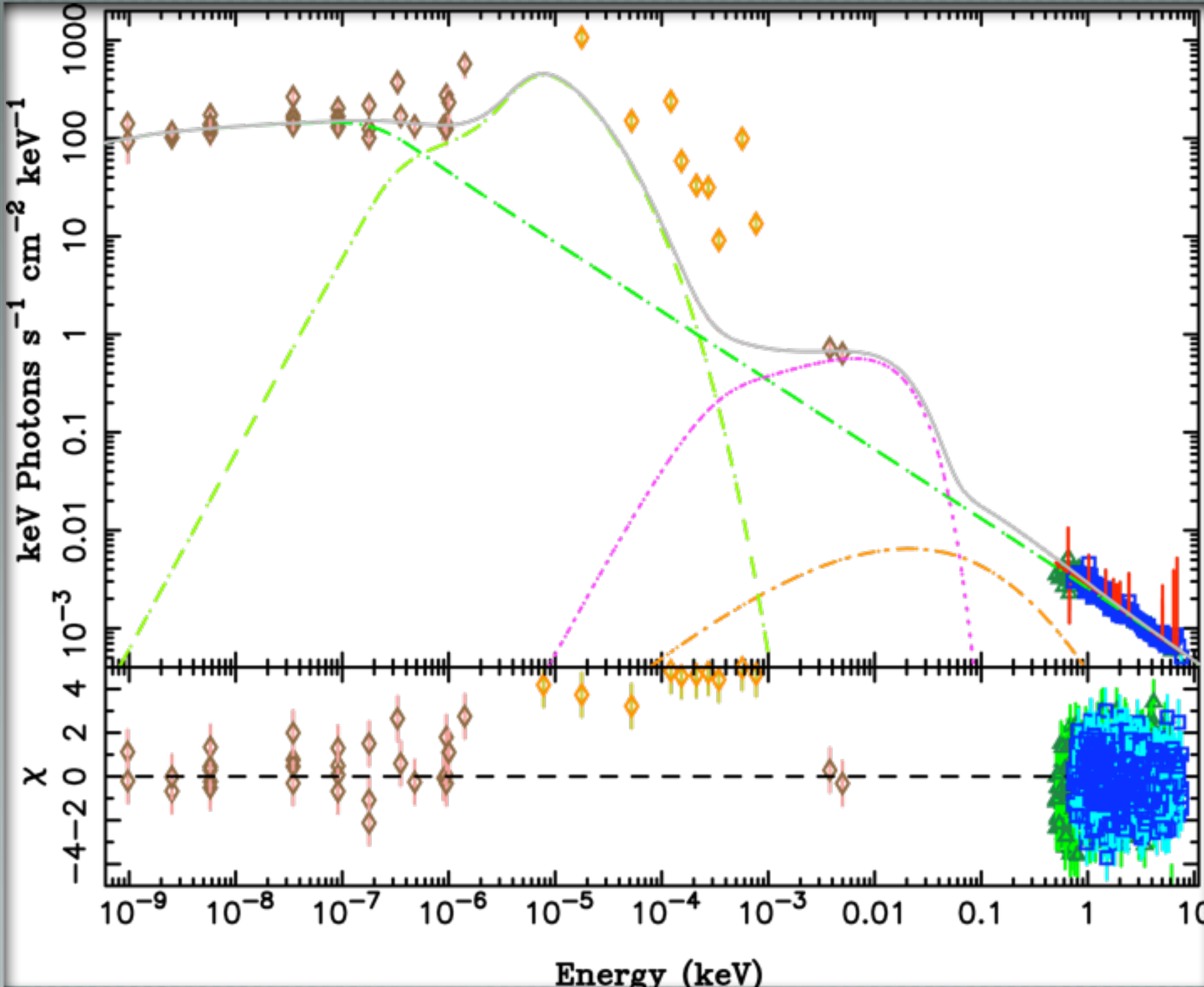


Modeling simultaneous data: hard state



(Markoff et al. 03, Markoff, Nowak & Wilms 05, Migliari et al. 07, Gallo et al. 07, Maitra et al. 08)

M81: Hard state equivalent (LLAGN)?



(Markoff et al. 2008)

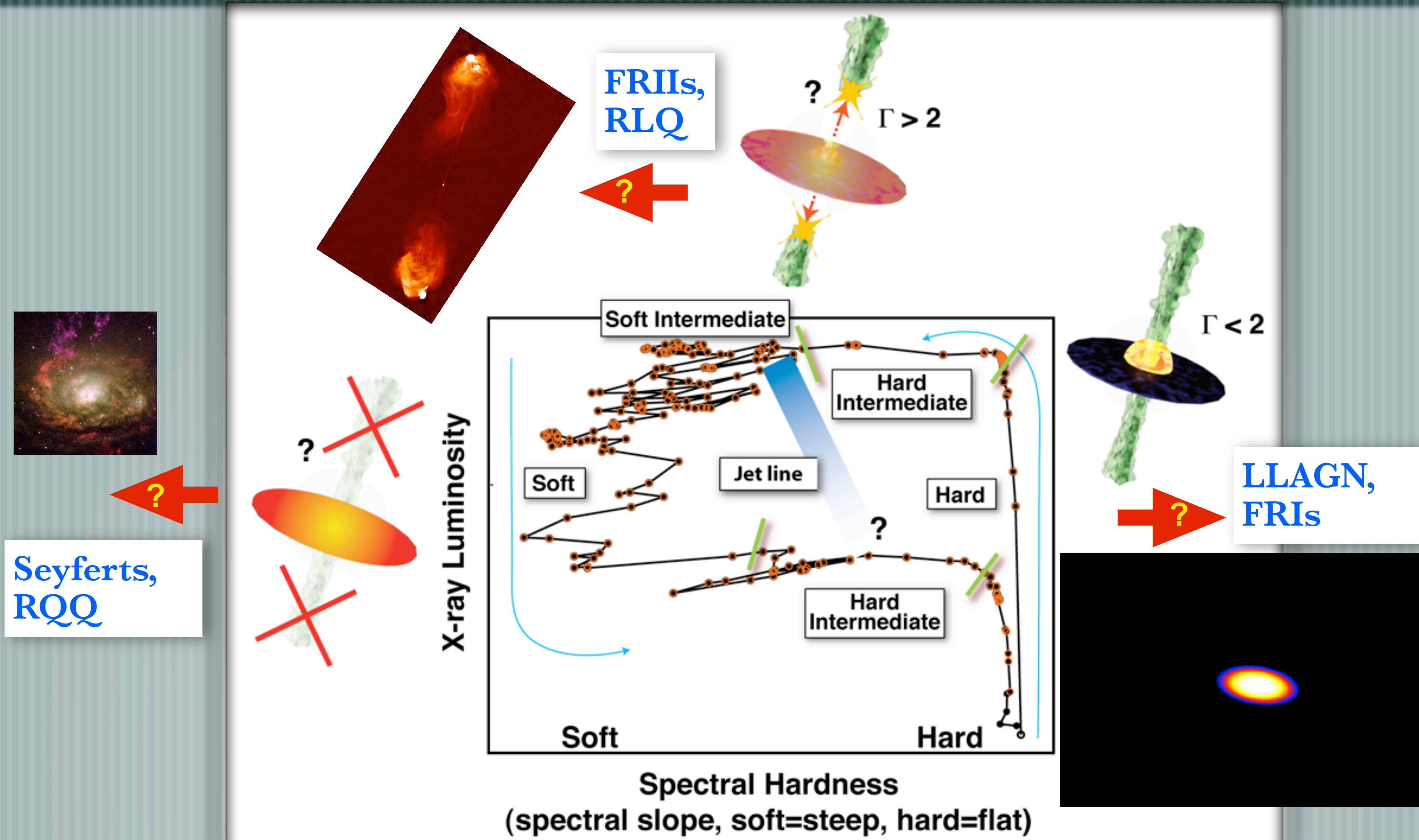
XRB/LLAGN model comparisons

L < 10^{-7} L_{Edd}

Parameter	HS-XRBs	M81	A0620	Sgr A*
M ($M_{\odot}$)	~10	$7x10^7$	~10	$4x10^6$
R_0 (R_g)	2–20	2.4	2–7	2.5
H_0 (R_0)	1.5*	1.5*	1.5*–2.8	1.5*
z_{acc} (R_g)	10–400	144	3–1250	$>10^4$
p_{elec}	2.4–2.9	2.4	2.2–3.4	>3.8
PL frac	0.75*	0.75*	<0.75*	<0.01
T_e (K)	$2–5x10^{10}$	$1x10^{11}$	$2x10^{10}$	$1x10^{11}$
equip (1/β)	1–5	1.4	1.5	>10

(SM, Nowak & Wilms 2005, Migliari et al. 2007, Gallo et al. 2007, SM, Bower & Falcke 2007, SM et al. 2008, Maitra et al. subm., SM & van Oers, in prep., SM, Tramper, et al. in prep.)

XRB state ⇔ AGN Mapping?

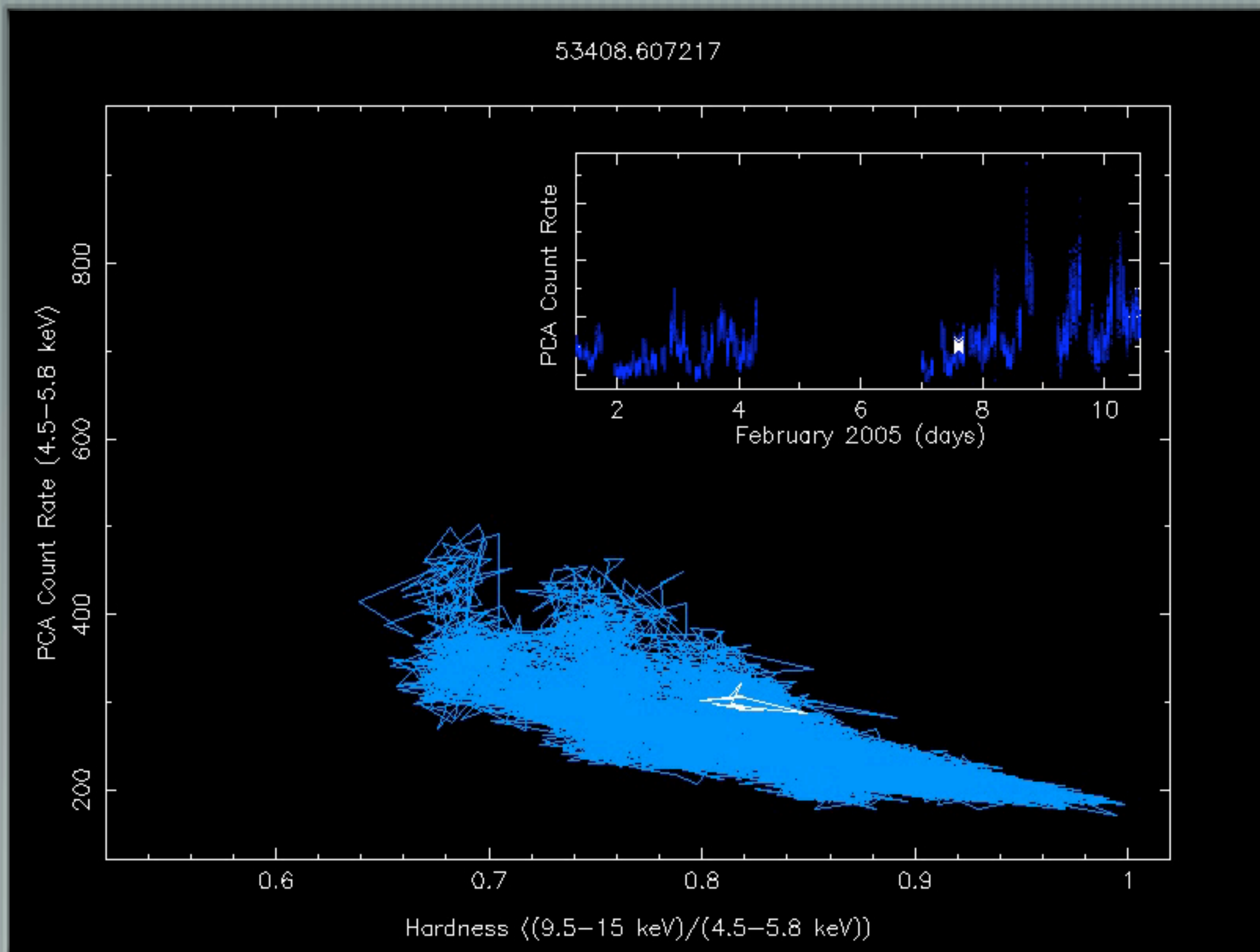


Summary/Outlook

X-ray binaries seem remarkably like scaled down AGN analogs (despite many reasons they shouldn't be...)

- Faster timescales valuable for studying evolution that may relate/unify AGN classes, cast light on jet formation and physics
- Need more complete multiwavelength AGN samples to compare with trends found in XRBs
- Need better theoretical understanding of state evolution (disk recessing? What's the difference between the two kinds of jet ejecta? role of spin?!?)
- Chandra is key (sensitivity/resolution) for both the above points!!
- Big questions: what drives the timescale of the state transitions for XRBs/AGN, and how can we use XRB evolution to understand AGN cycles? How can we know where on its potential cycle a given AGN is and what triggers activity?

What we're up against: Cyg X-1

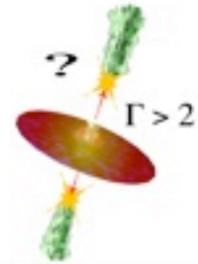


(Movie courtesy M. Böck, from monitoring campaign by Markoff, Nowak, WIlms, et al.)

EXTRA SLIDES

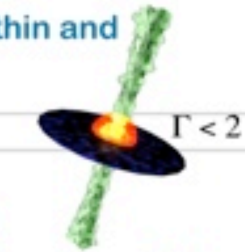
JET LINE AREA:

- 2 - 50% L_{Edd}.
- High-frequency QPOs (after) .
- Type A & B QPOs (after).
- See radio ejecta (fast) each "crossing" of jet line.
- RMS drop ("The Zone") associated with ~0.2 Hz lowest freqency Lorentzian, close to ejecta time.



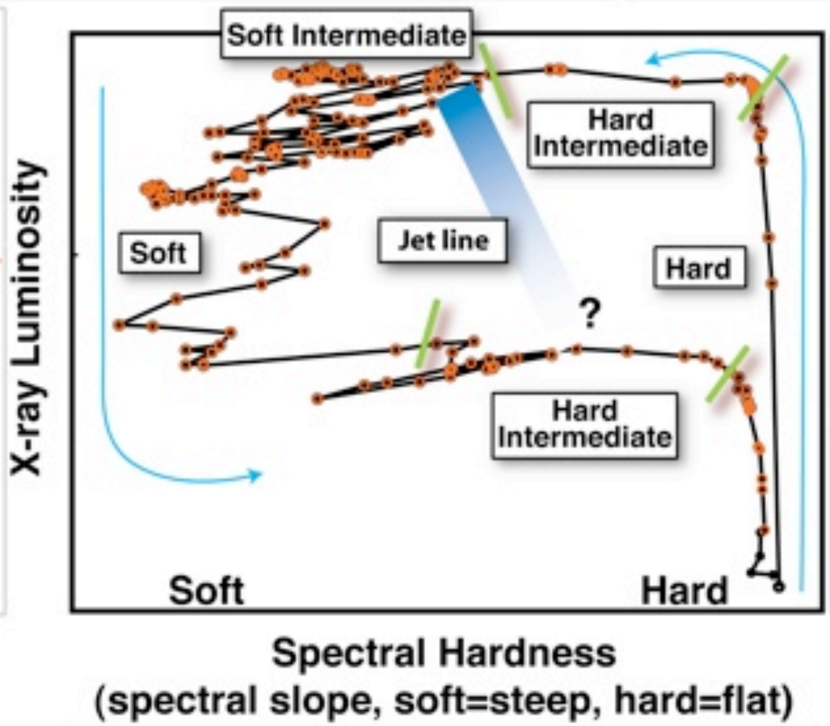
HIMS:

- Disk starts near ISCO.
- Transition starts around 2 - 50% L_{Edd}.
- Type C QPOs.
- IR drops.
- Radio starts going optically thin and variable (new ejecta?).



SOFT STATE:

- Optically nuclear thin jet radio emission observed initially, but quenched by at least 20-50x by full transition.
  Detected radio flux not nuclear?
- Type C QPOs.
- Non-thermal power law extending to ~MeV .
- Thin disk ~0.1-1.0 L_{Edd} at ISCO.



HARD STATE:

- Disk moves in to ~ few R_g by 10% L_{Edd}.
- Lorentzian/broad noise components.
- High RMS variability.
  - Flat spectrum jet up to IR/opt.
  - Compact jet sometimes resolved.
  - Radio/IR/X-ray correlations.
  - Reflection "bump".

T. Belloni, A. Celotti, S. Corbel, R. Fender, E. Gallo, M. Hanke, E. Kalemci, D. Maitra, S. Markoff, I. McHardy, M. Nowak, P.-O. Petrucci, K. Pottschmidt, J. Wilms

HIMS:

Same as upper branch but:

- No optically thin radio flare.
- Radio recovers close to hard state.
- Lower flux level (hysteresis).

QUIESCENCE:

- Thin disk recessed to > 10^2 R_g
- BB component seen in UV/Optical.
- Disk 10-100x more luminous than LX. By ~10^{-4} L_{Edd}.
- No iron lines?