Fast Variability as a Tracer of **Hysteresis and Accretion States** in Low Mass X-ray Binaries

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Rob Fender
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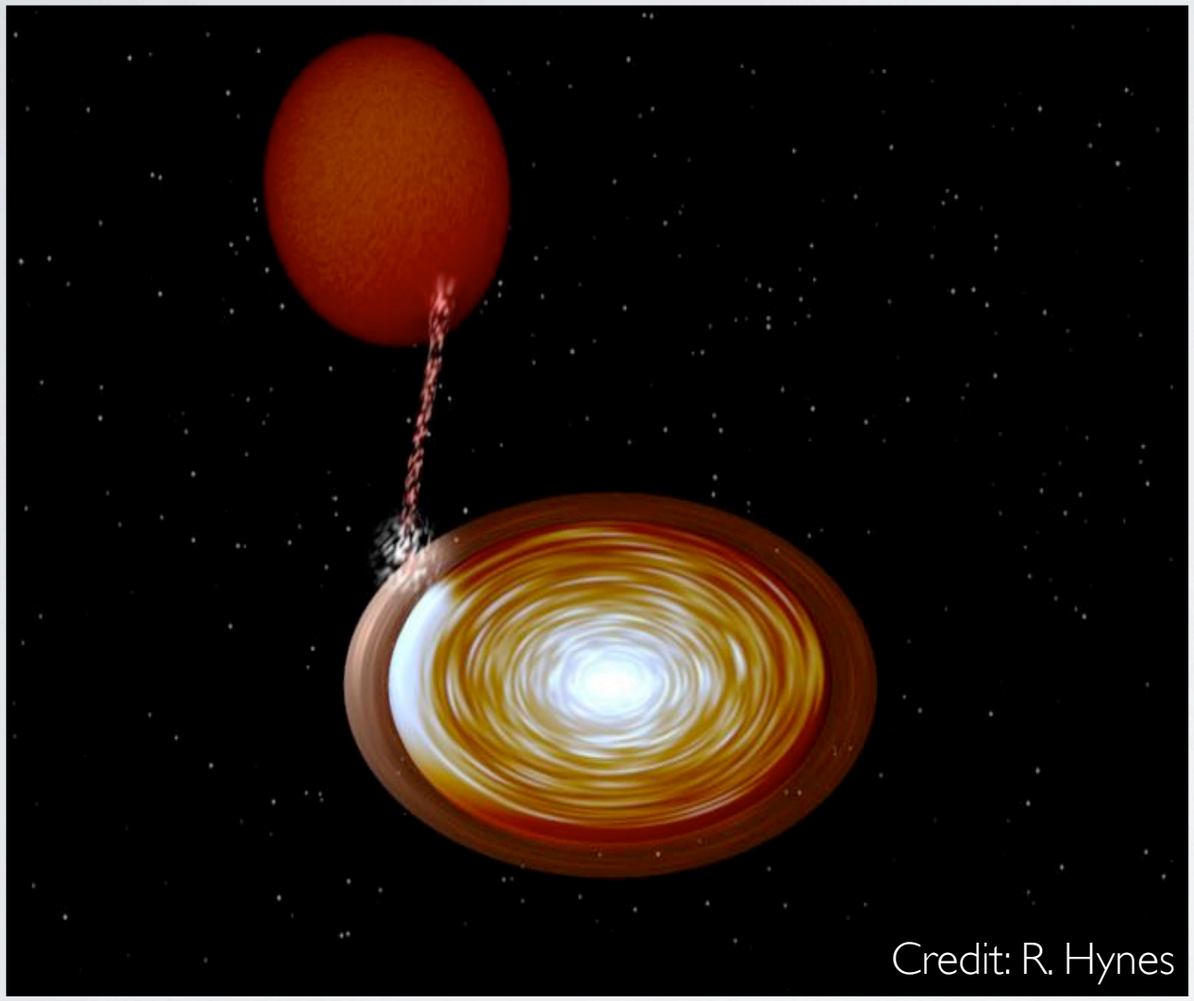
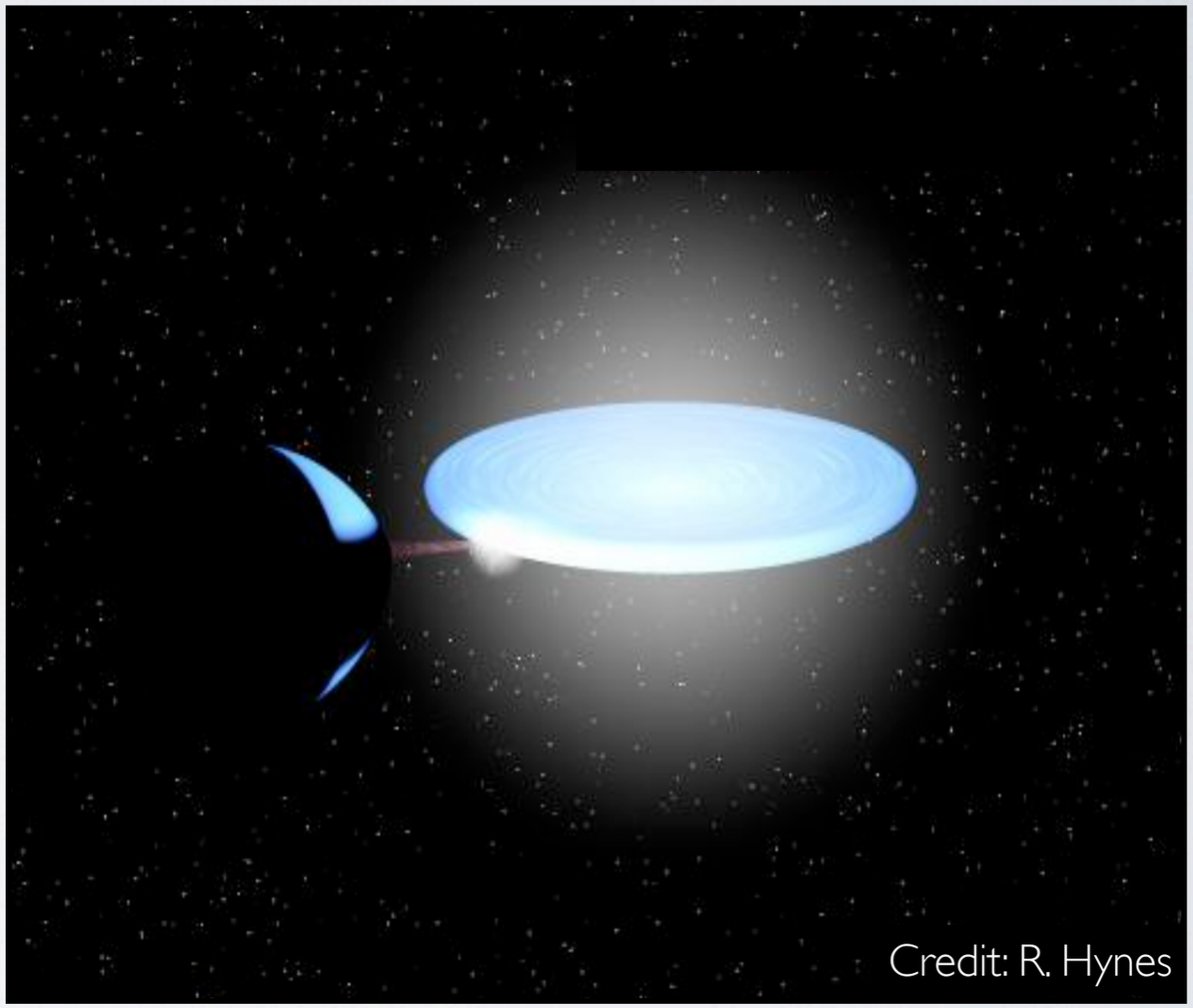
LOW MASS X-RAY BINARY

Quiescence



$L_X \sim 10^{-8 \text{ to } -6}\ L_{EDD}$

Outburst (and Persistents)



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LOW MASS X-RAY BINARY

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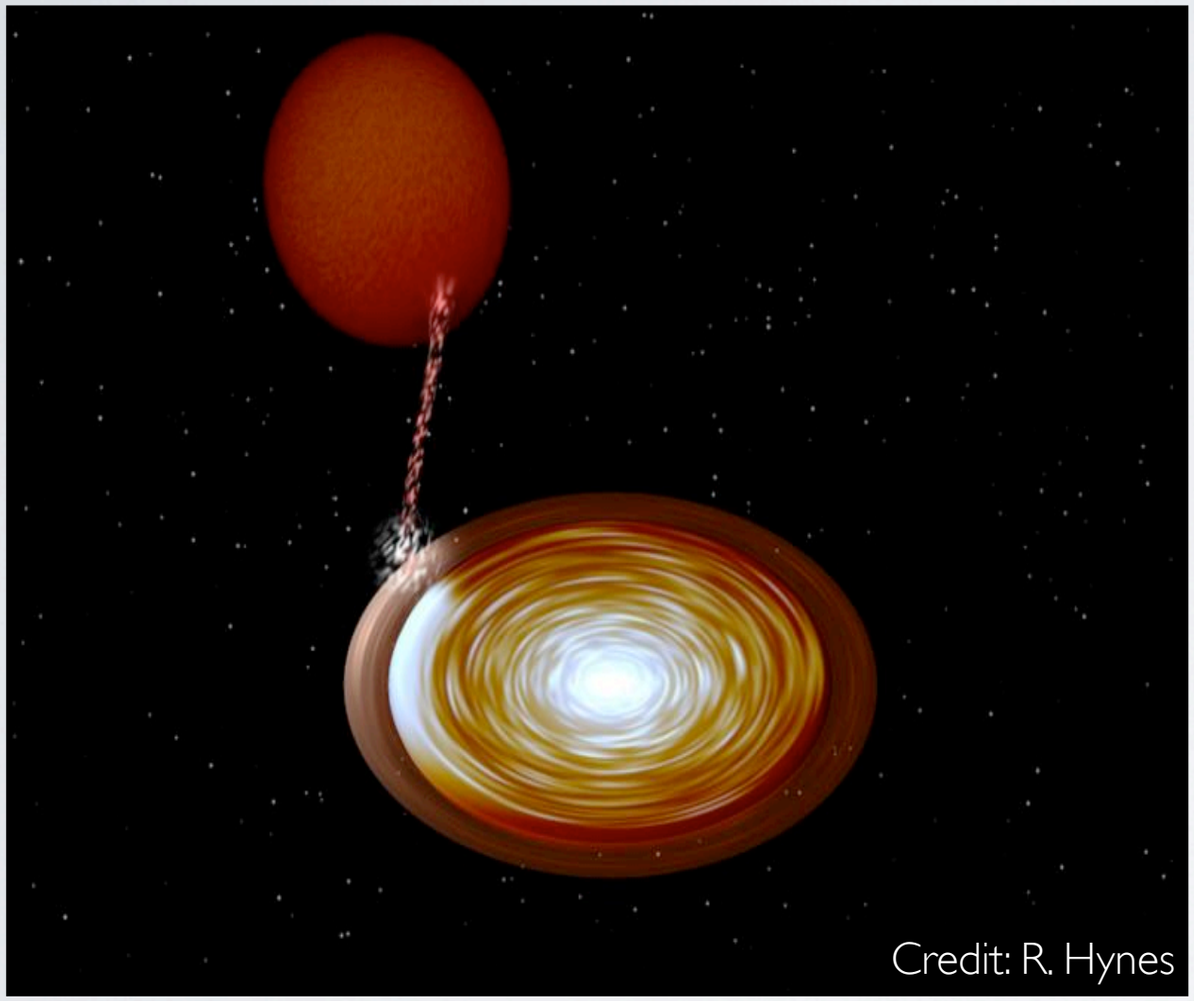

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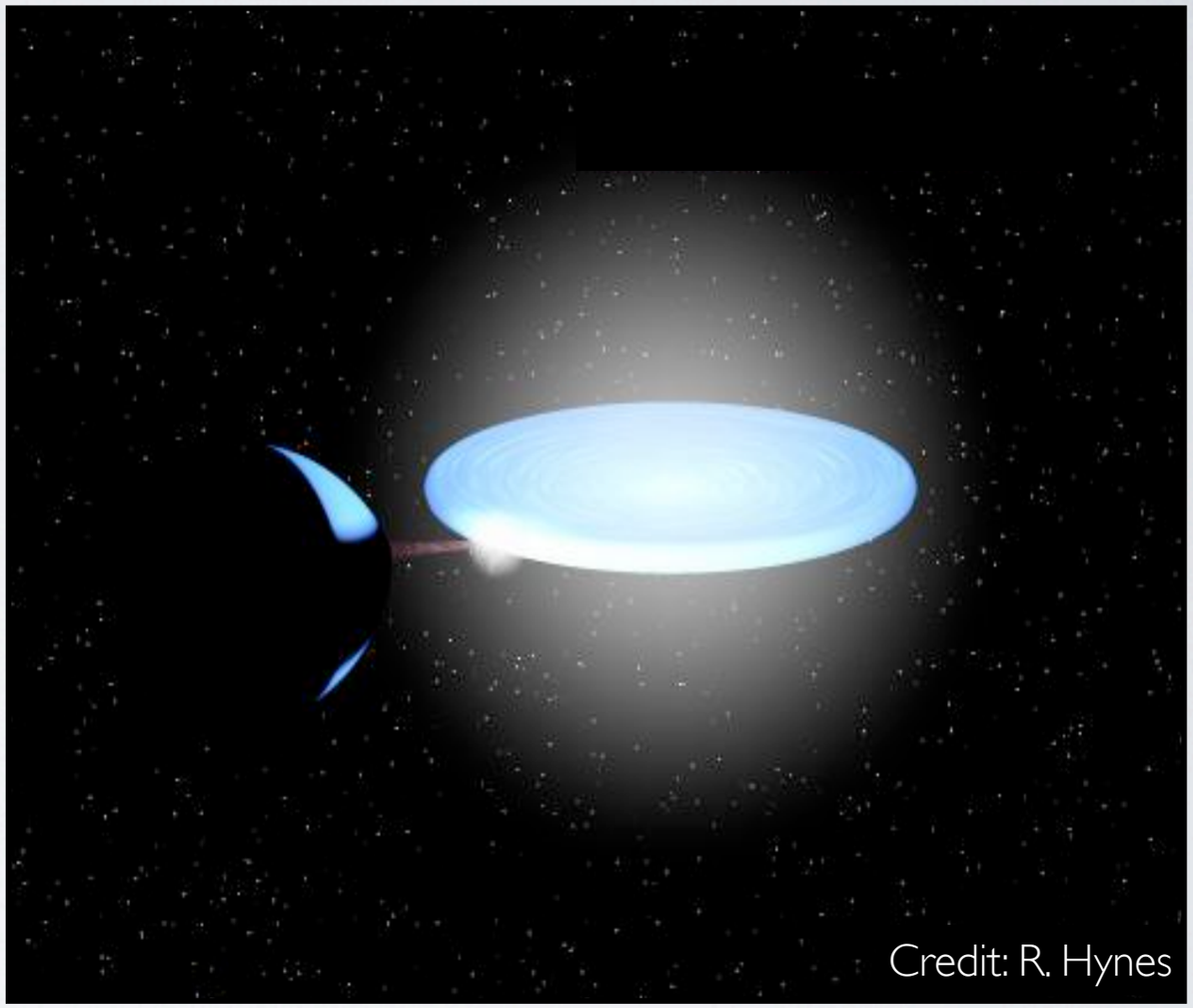

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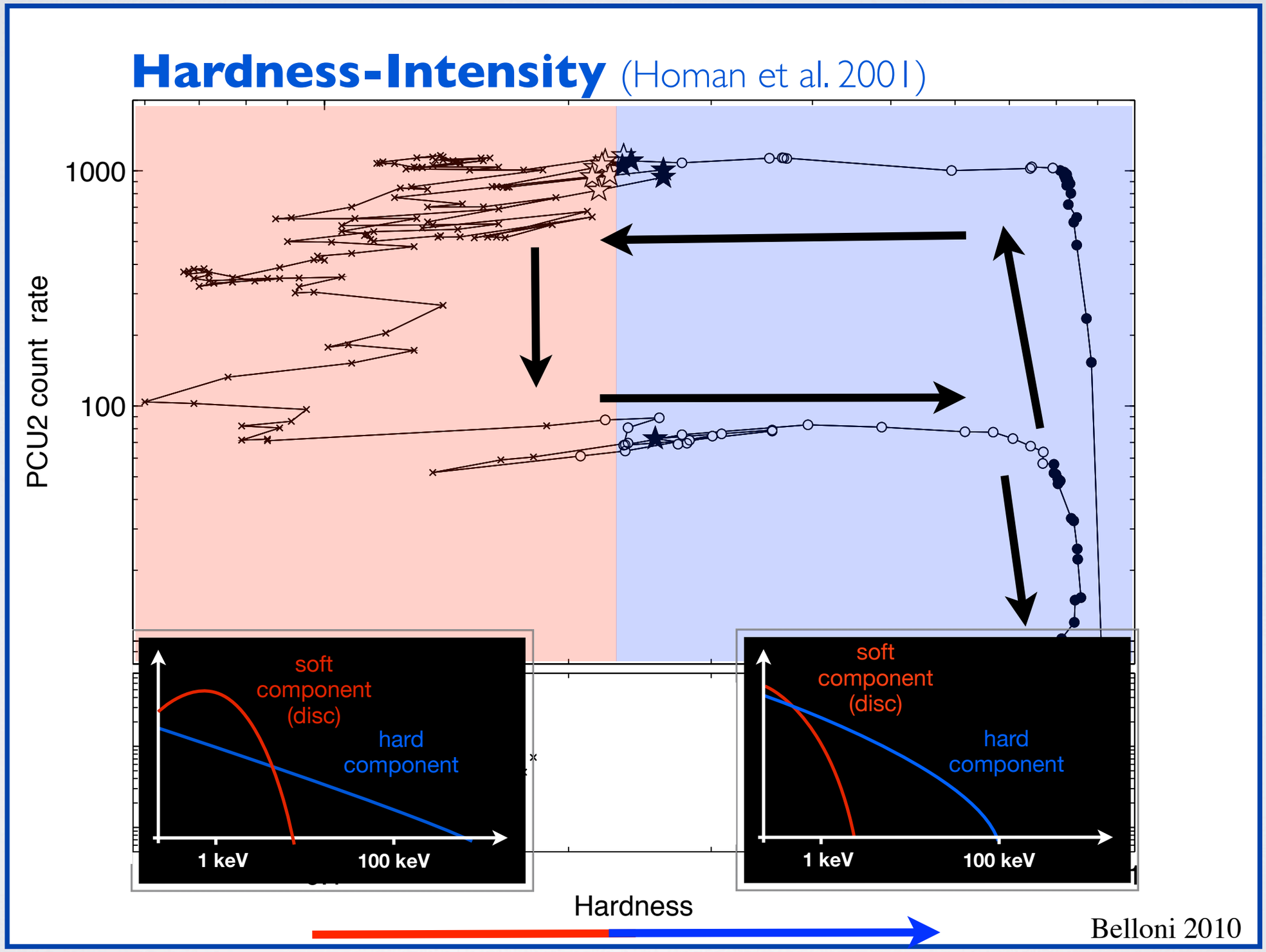
BLACK HOLE IN OUTBURST: HYSTERESIS

Daily basis monitoring (RXTE)



X-ray Luminosity

Variability

How hard the spectrum is

BLACK HOLE IN OUTBURST: HYSTERESIS

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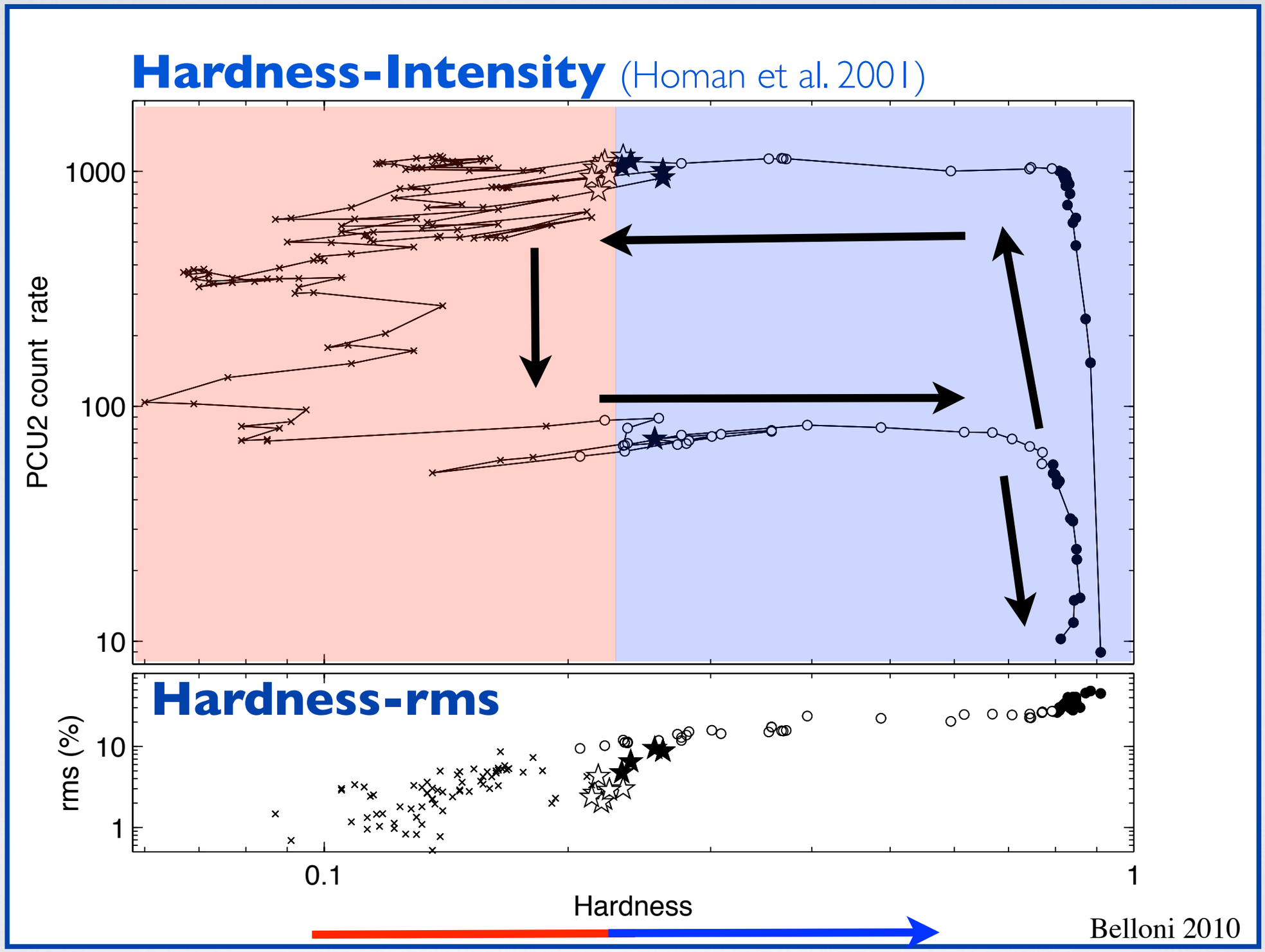


X-ray Luminosity

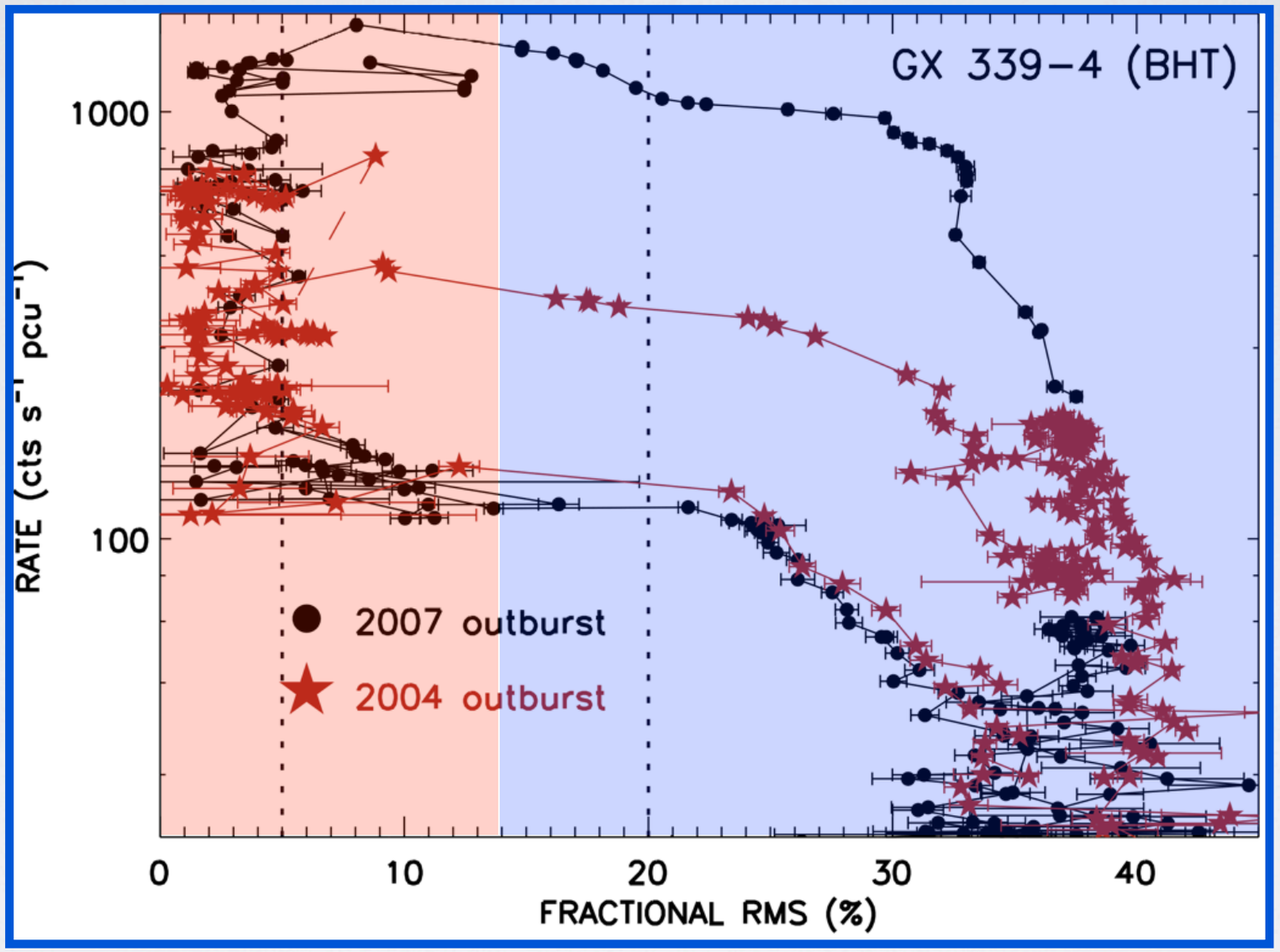
Variability

How hard the spectrum is

RMS-INTENSITY DIAGRAM

VARIABILITY-LUMINOSITY

Muñoz-Darias, Motta & Belloni, 2011



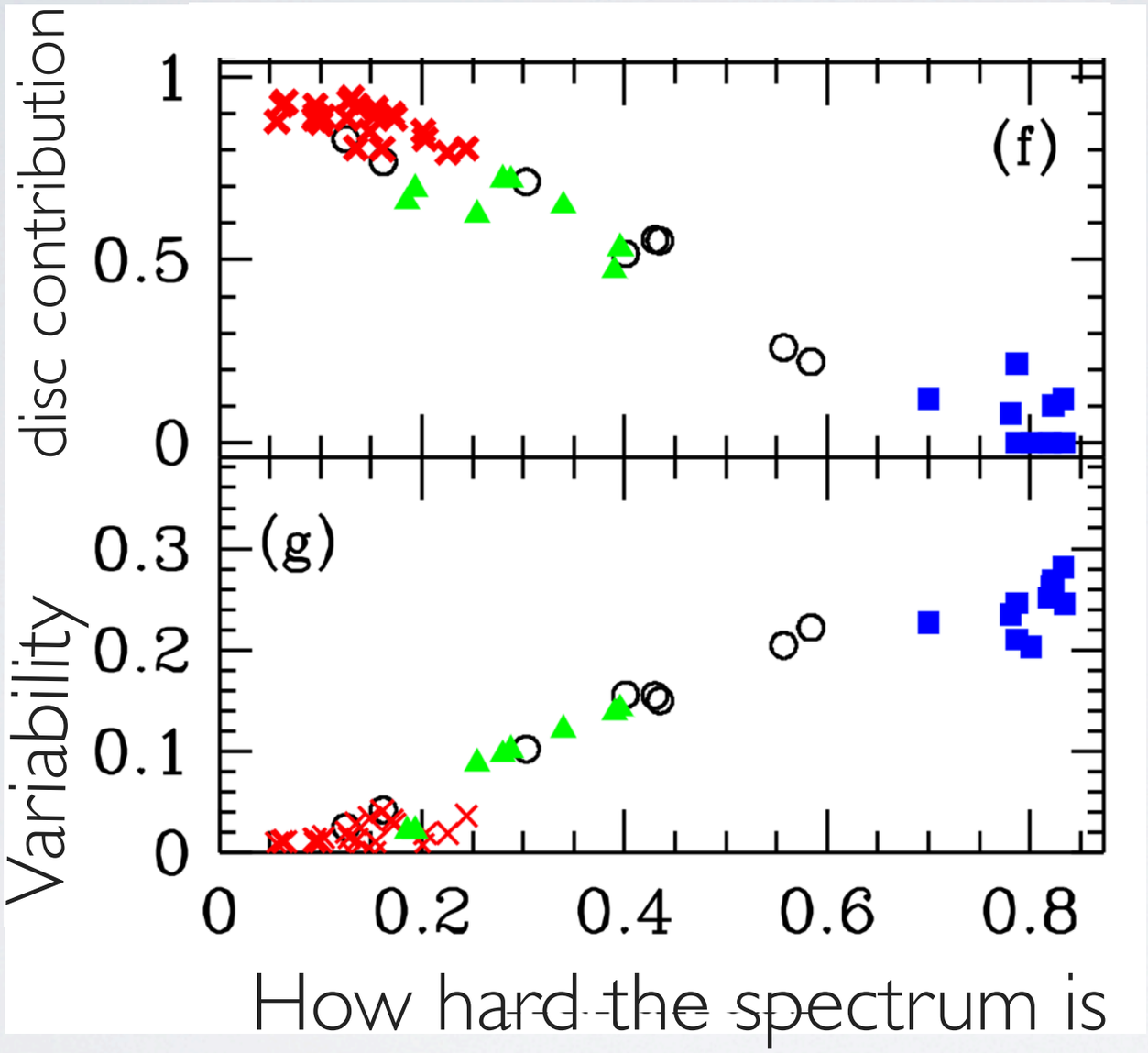
X-ray Luminosity

Variability

Fast variability traces accretion states and hysteresis

COMPTONIZATION FRACTION AND VARIABILITY

Remillard & McClintock 2006



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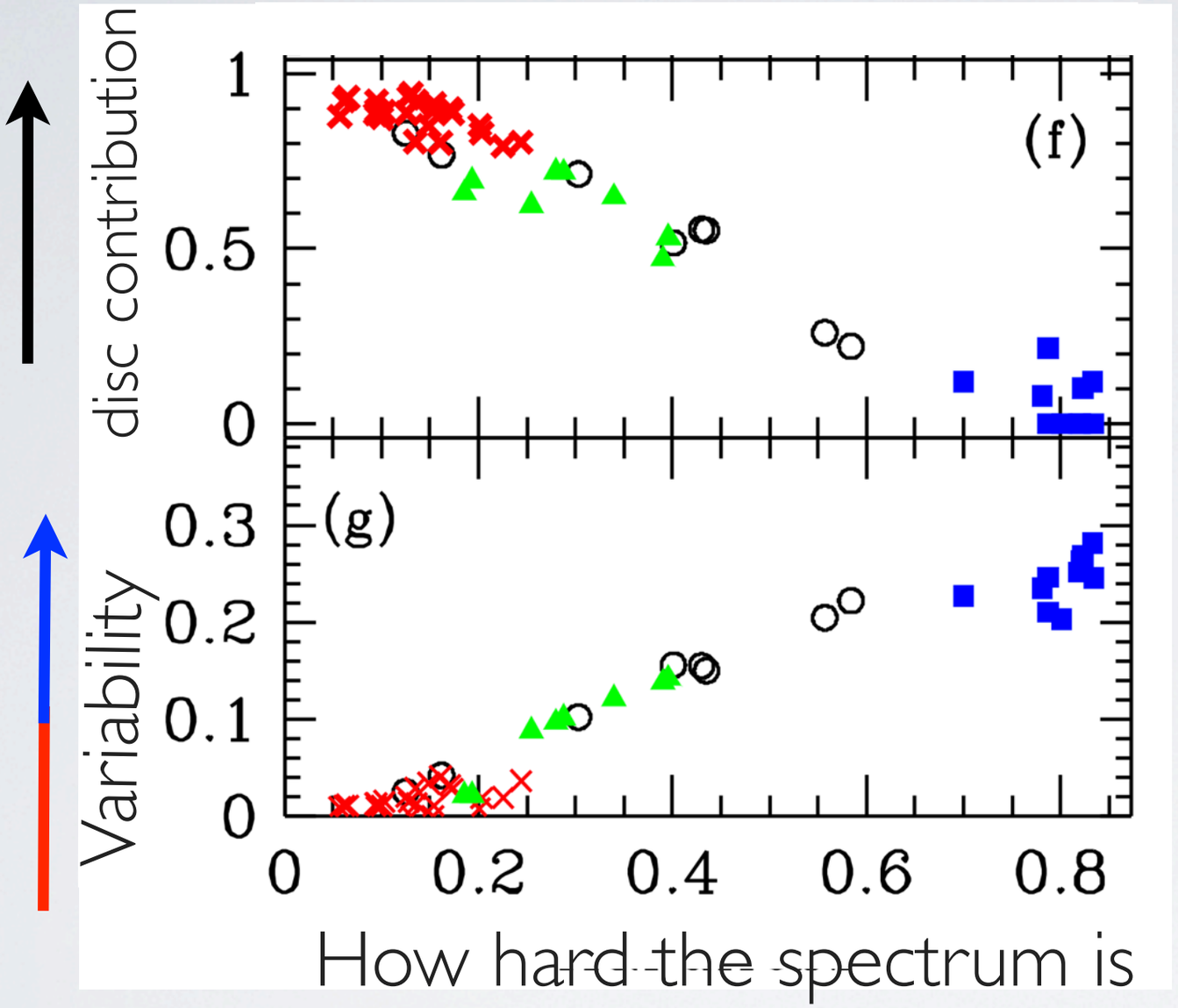
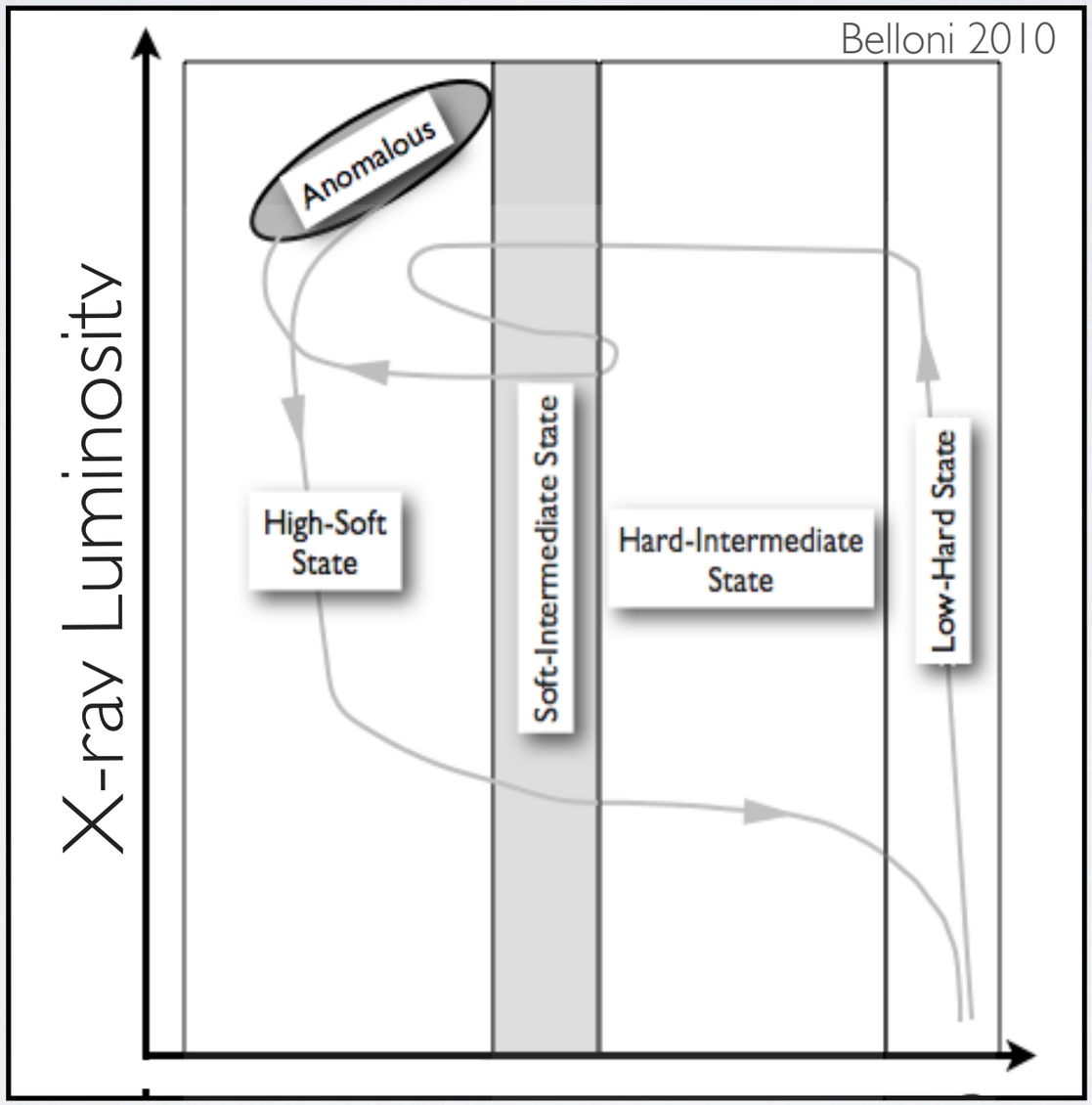


Fast variability traces Power-law contribution (Comptonization Fraction)

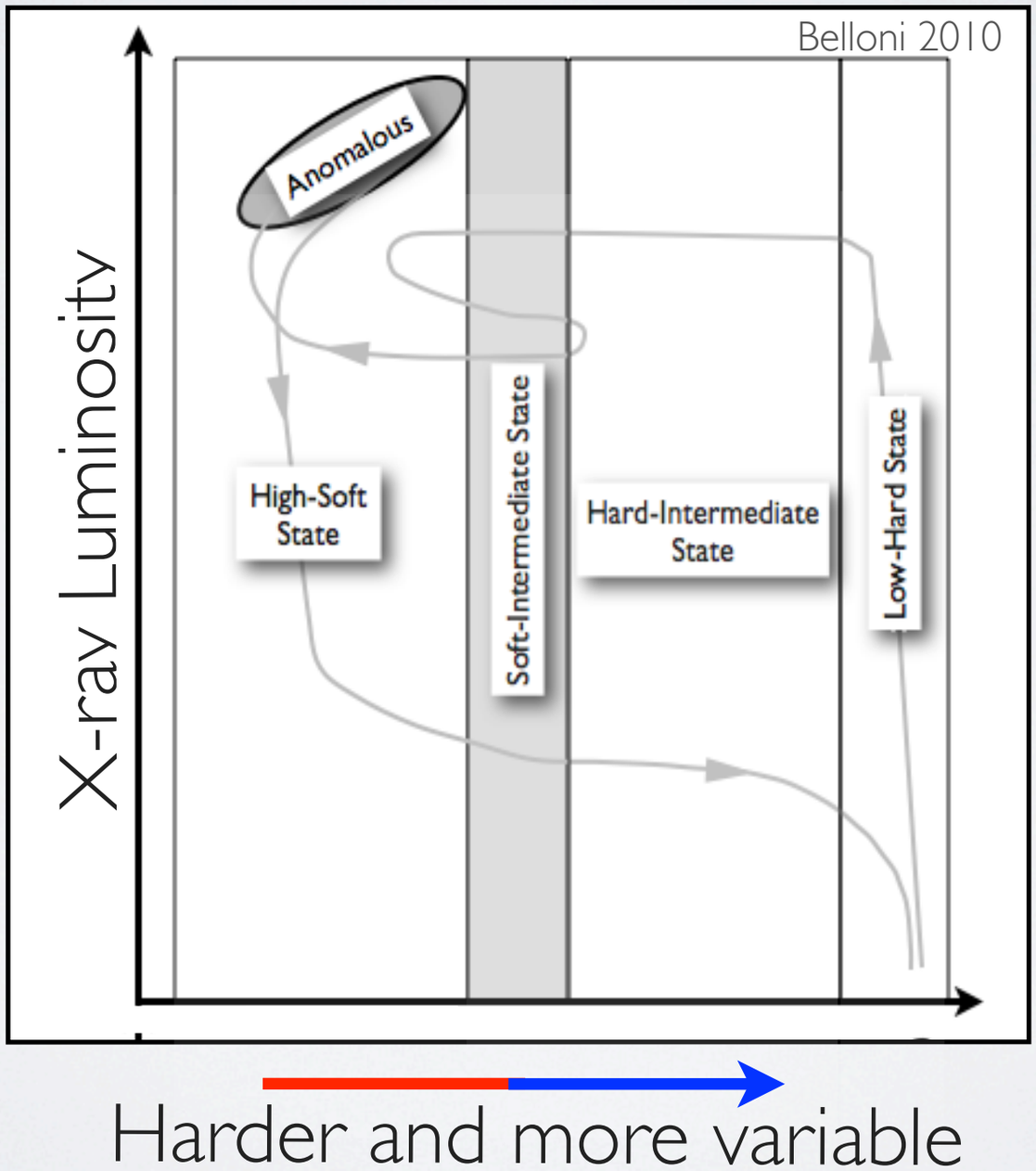
DISTINCTIVE **ACCRETION FLOW** PROPERTIES



Thermal component dominates

Comptonization component dominates

DISTINCTIVE **ACCRETION FLOW** PROPERTIES
DISTINCTIVE **RADIO** PROPERTIES



Thermal component dominates

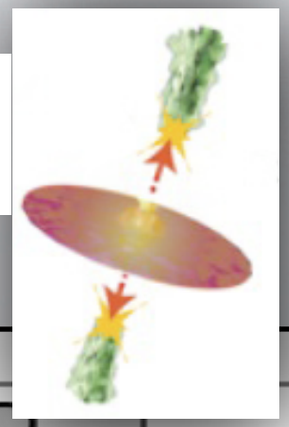
Compact jet

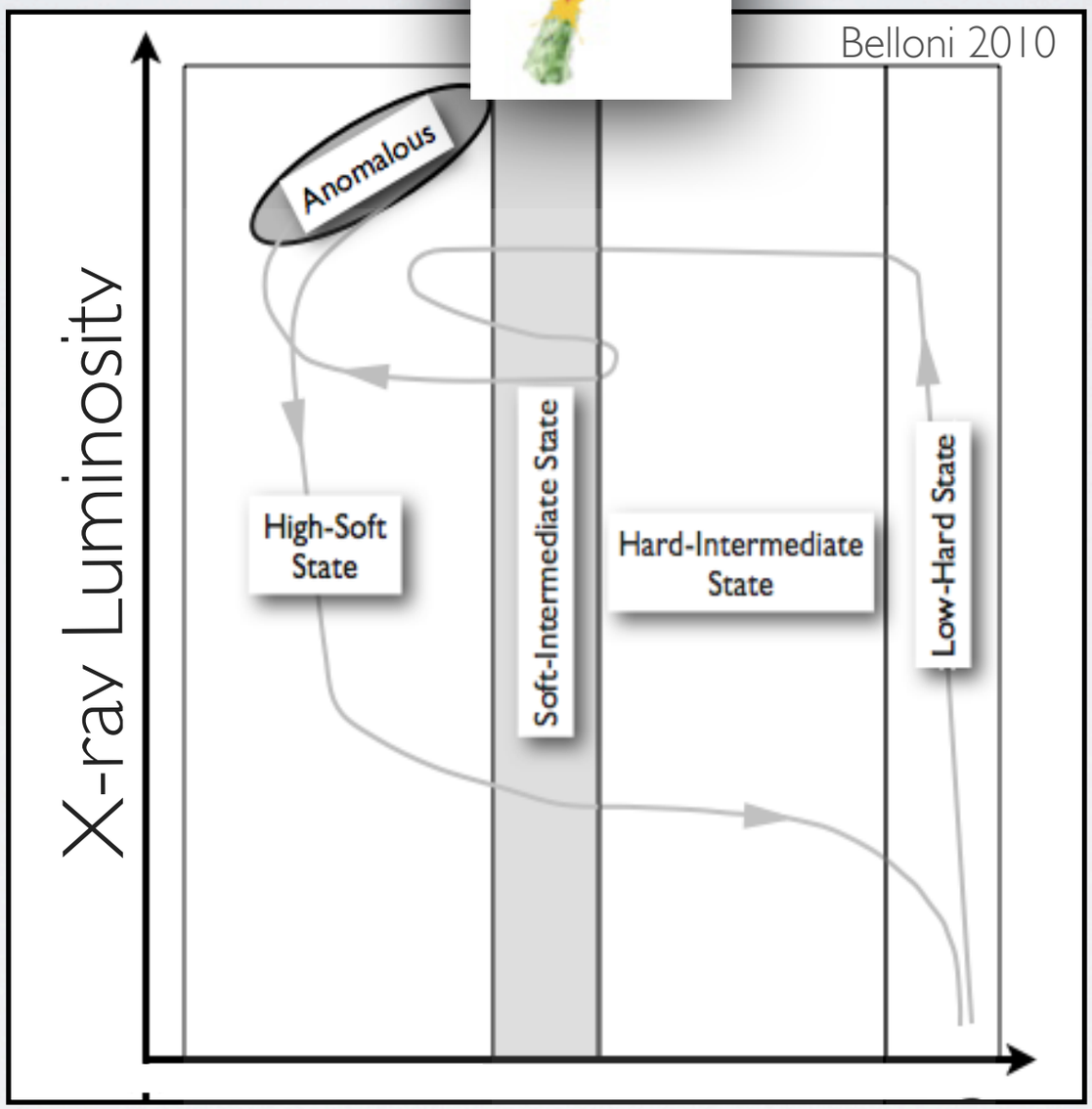
- **X-ray-Radio correlation** (Corbel et al., Gallo et al. 2003)

Comptonization component dominates

DISTINCTIVE **ACCRETION FLOW** PROPERTIES
DISTINCTIVE **RADIO** PROPERTIES

Relativistic ejections
(e.g. Mirabel & Rodriguez 1994)





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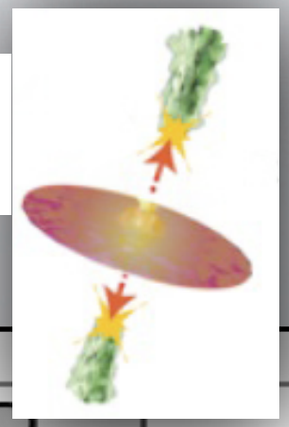
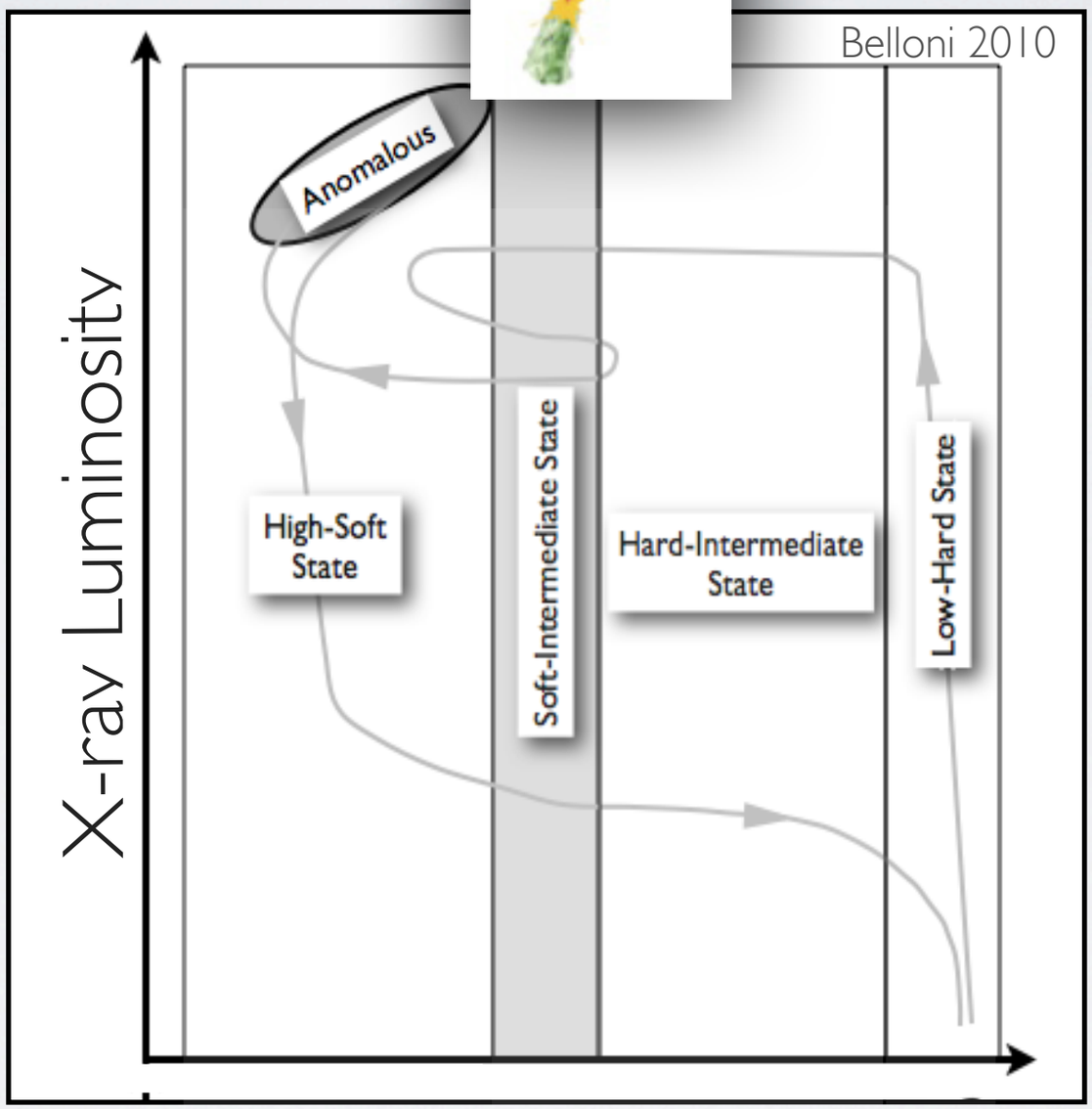


Compact jet

- **X-ray-Radio correlation**
(Corbel et al., Gallo et al. 2003)

Soft State: NO JET
(e.g. Russell et al 2011)

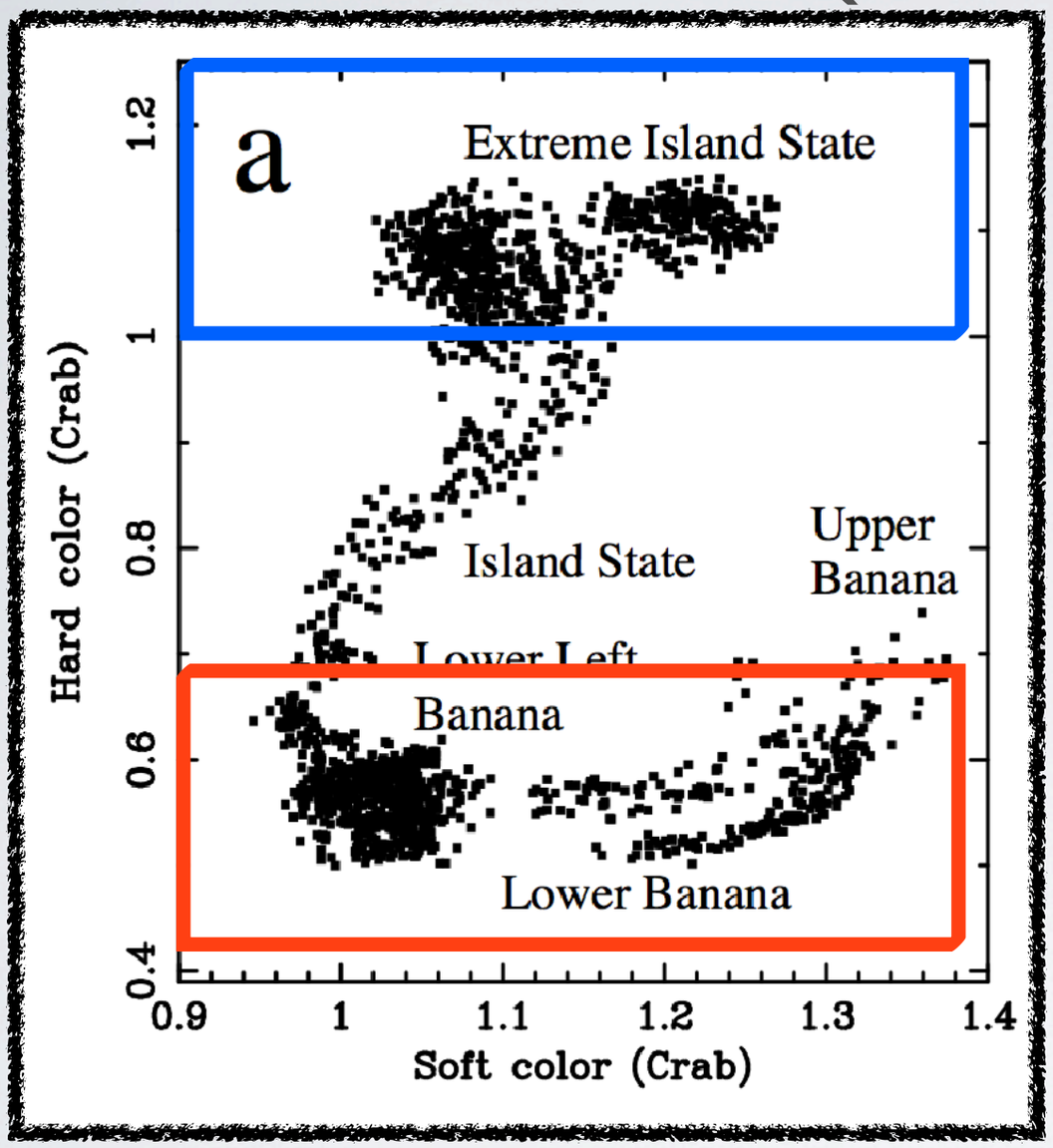
Thermal component dominates



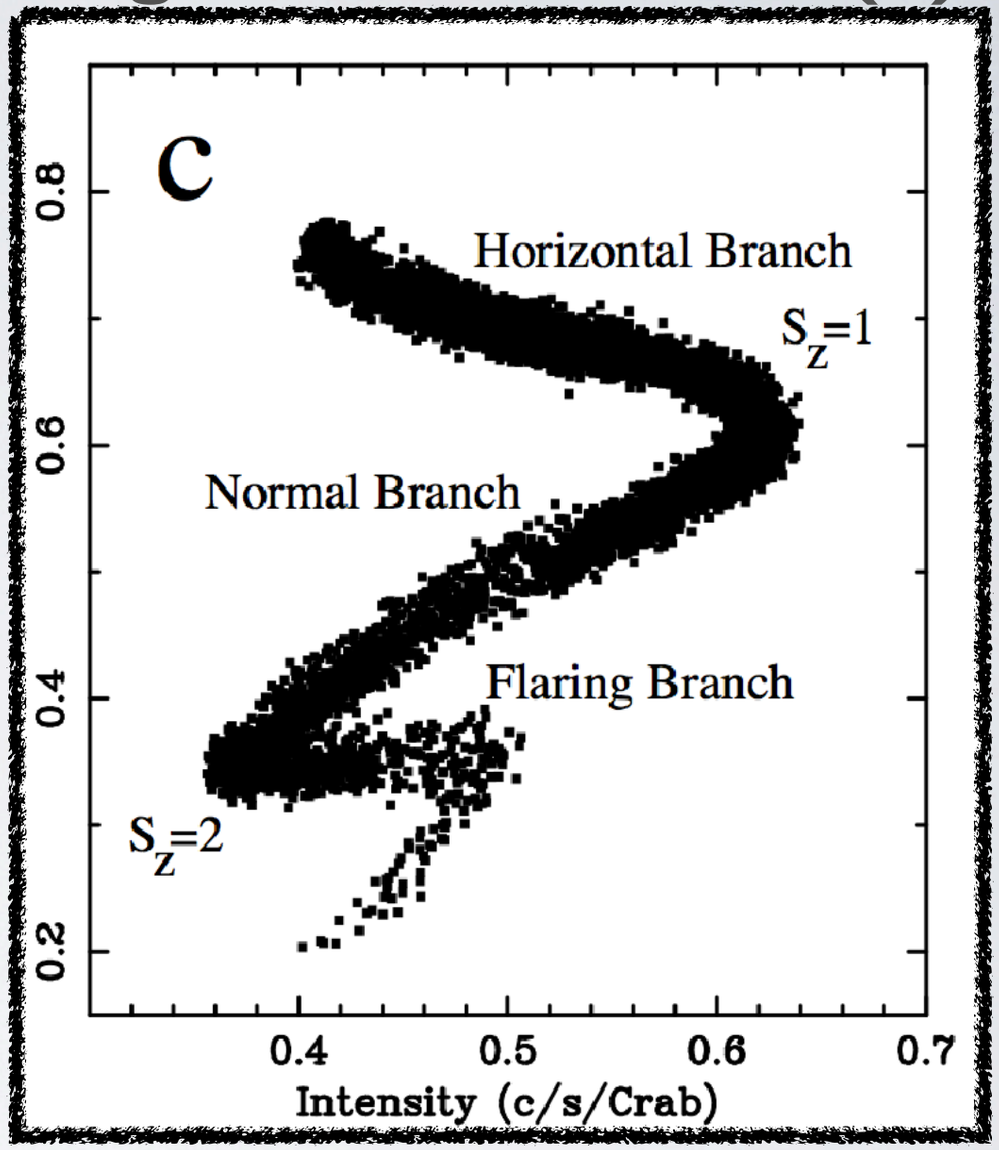
Comptonization component dominates

NEUTRON STARS LOOK DIFFERENT

Low accretion rate (atolls)



High accretion rate (Z)



van der Klis 2006 (Hasinger & van der Klis 1989)

- Spectral fitting (more) degenerate. Extra component from the NS surface
- Very similar Timing properties than BHs

(Wijnands & van der Klis 1999; Belloni, Psaltis & van der Klis 2002).

NEUTRON STARS: A GLOBAL STUDY

Muñoz-Darias, Fender, Motta & Belloni 2014

- Large data base (~15 years of RXTE): **50 systems, 10000+ observations**

- PERSISTENT and TRANSIENT sources accreting in the range **0.01-1 L_{EDD}**

- Colour and fast variability as a function of the Luminosity

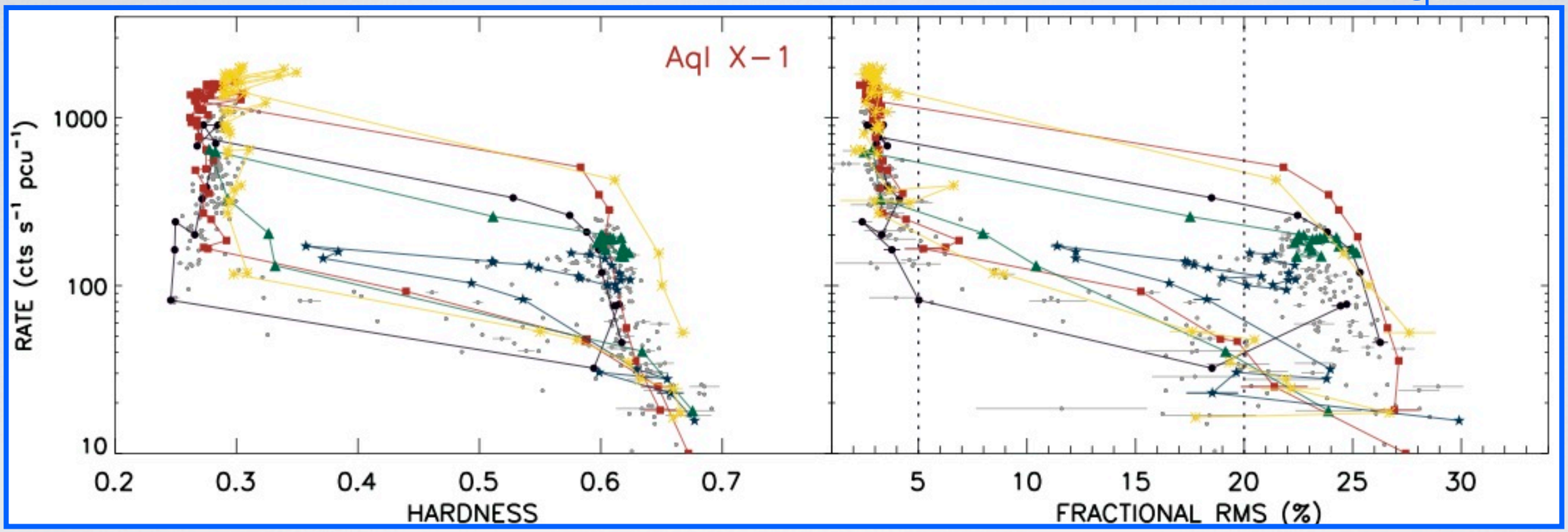
For the **interpretation** we use results from Lin, Remillard & Homan 2007, 2009

Multi-colour disc component
Power-Law (Comptonization)
+
BB component (NS)

NEUTRON STARS: A GLOBAL STUDY

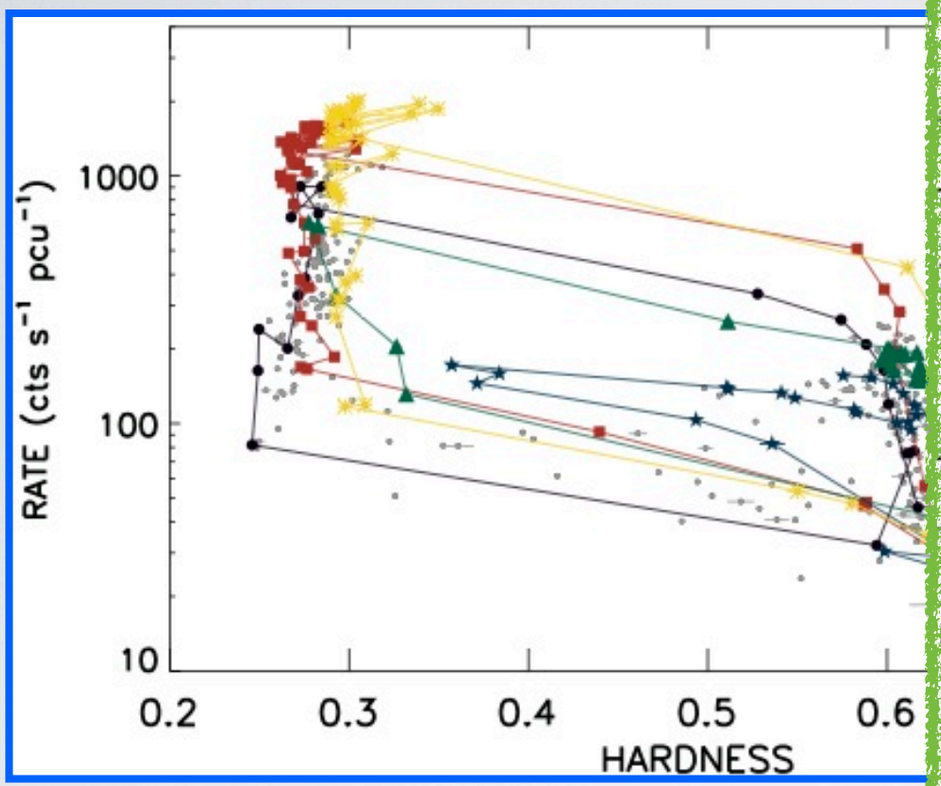
Muñoz-Darias, Fender, Motta & Belloni 2014

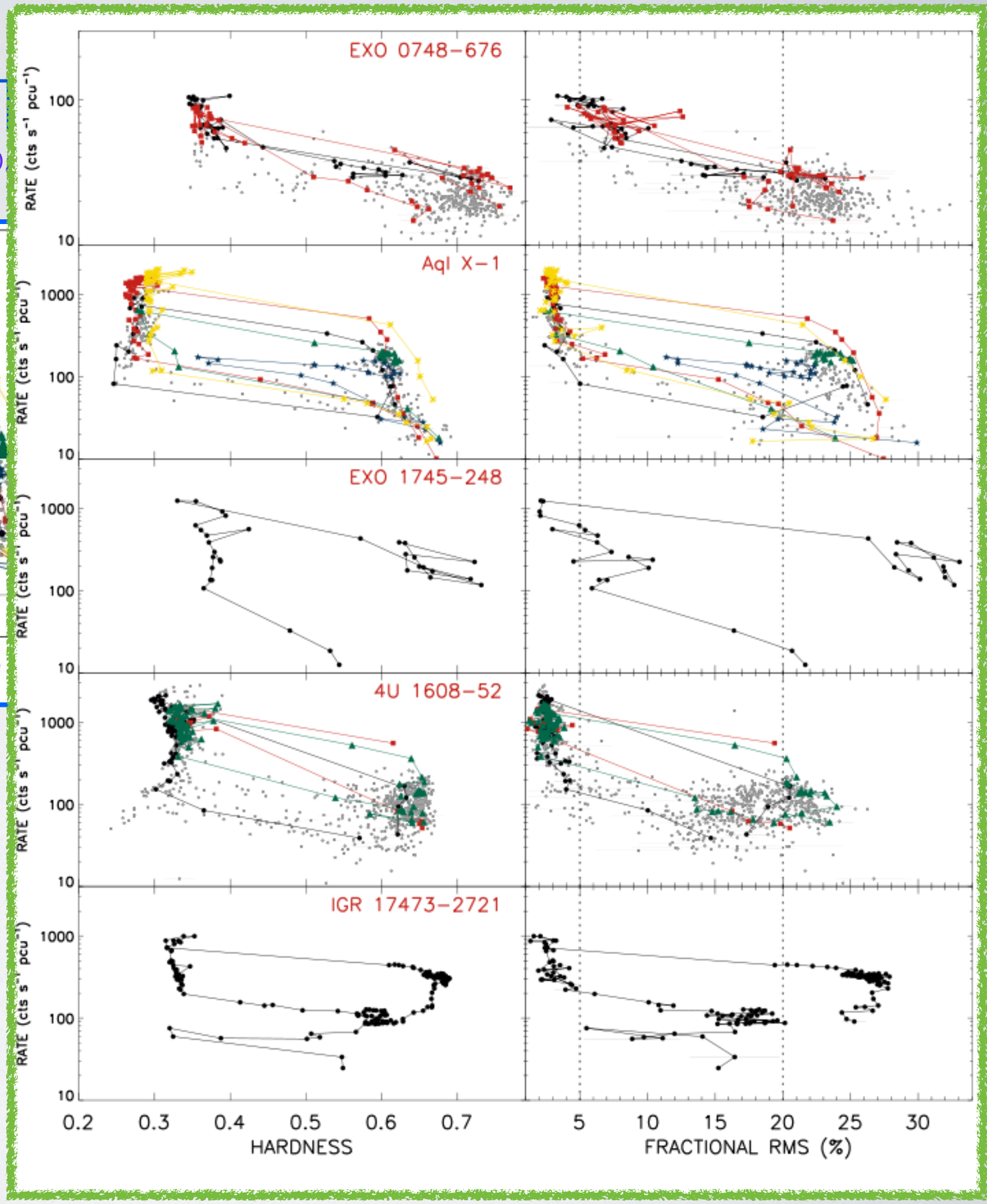
Aql X-1



NEUTRON ST

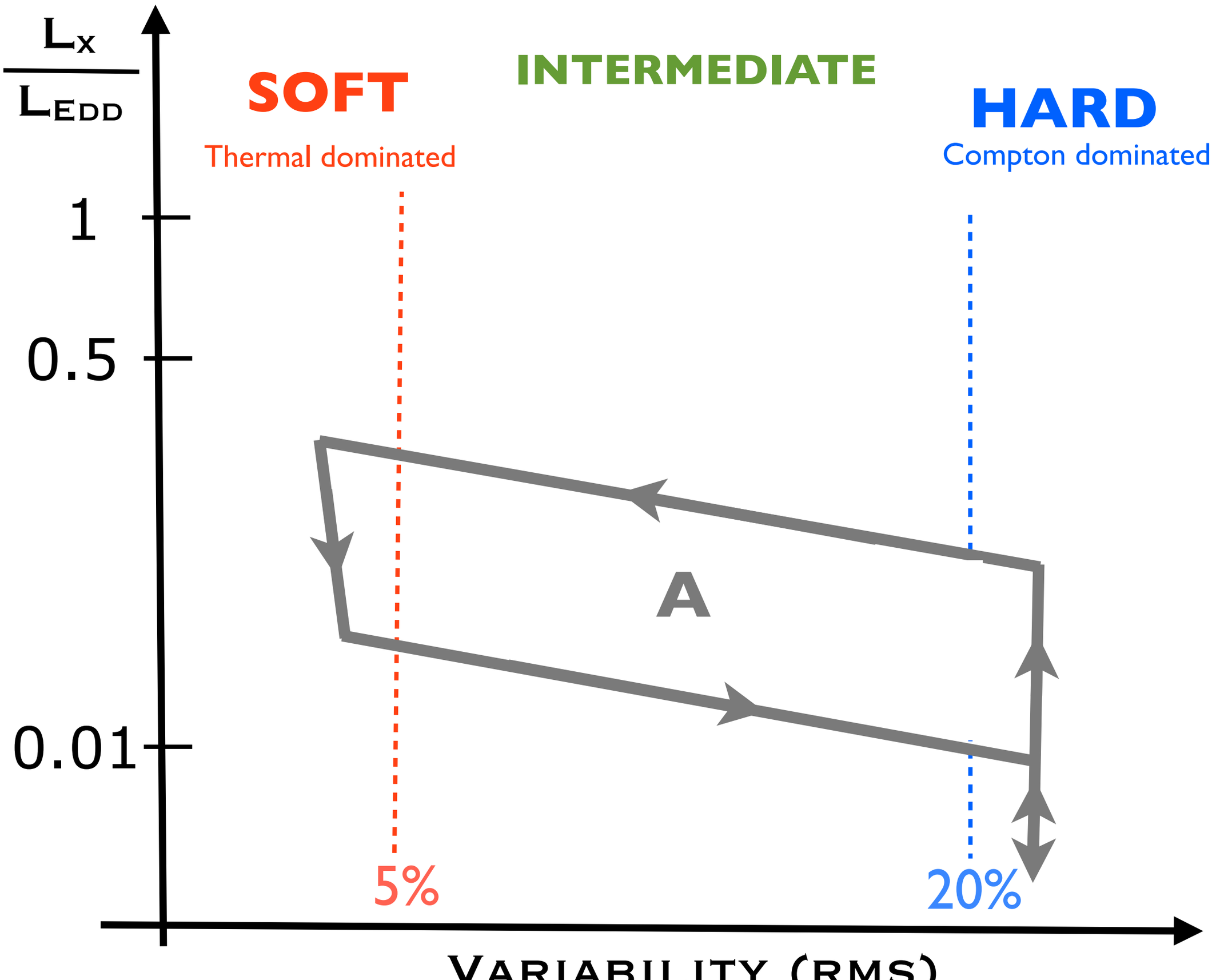
Muñoz-D





4U 1820−303
4U 0614+09
4U 1636−53
4U 1705−44
4U 1728−34
EXO 0748−676
Aql X−1
EXO 1745−248
4U 1608−52
GR 17473−2721
RATE (cts s^{-1} pcu^{-1})
1000
100
1000
100
1000
0.2
0.3
0.4
0.5
0.6
0.7
HARDNESS
5
10
15
20
25
30
FRACTIONAL RMS (%)
0.6
0.7
5
10
15
20
25
30
FRACTIONAL RMS (%)

1-30% L_{EDD}: Hysteresis



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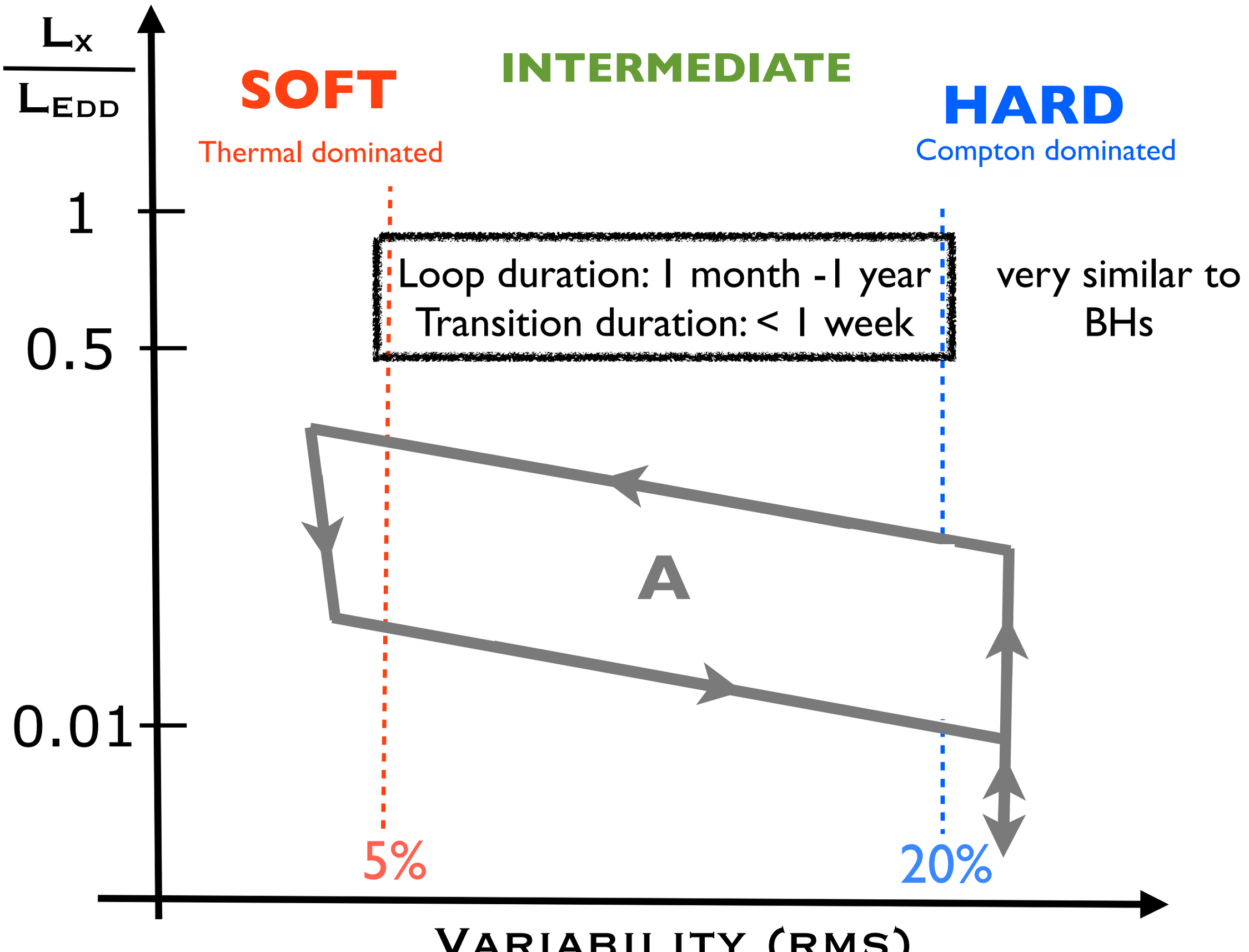
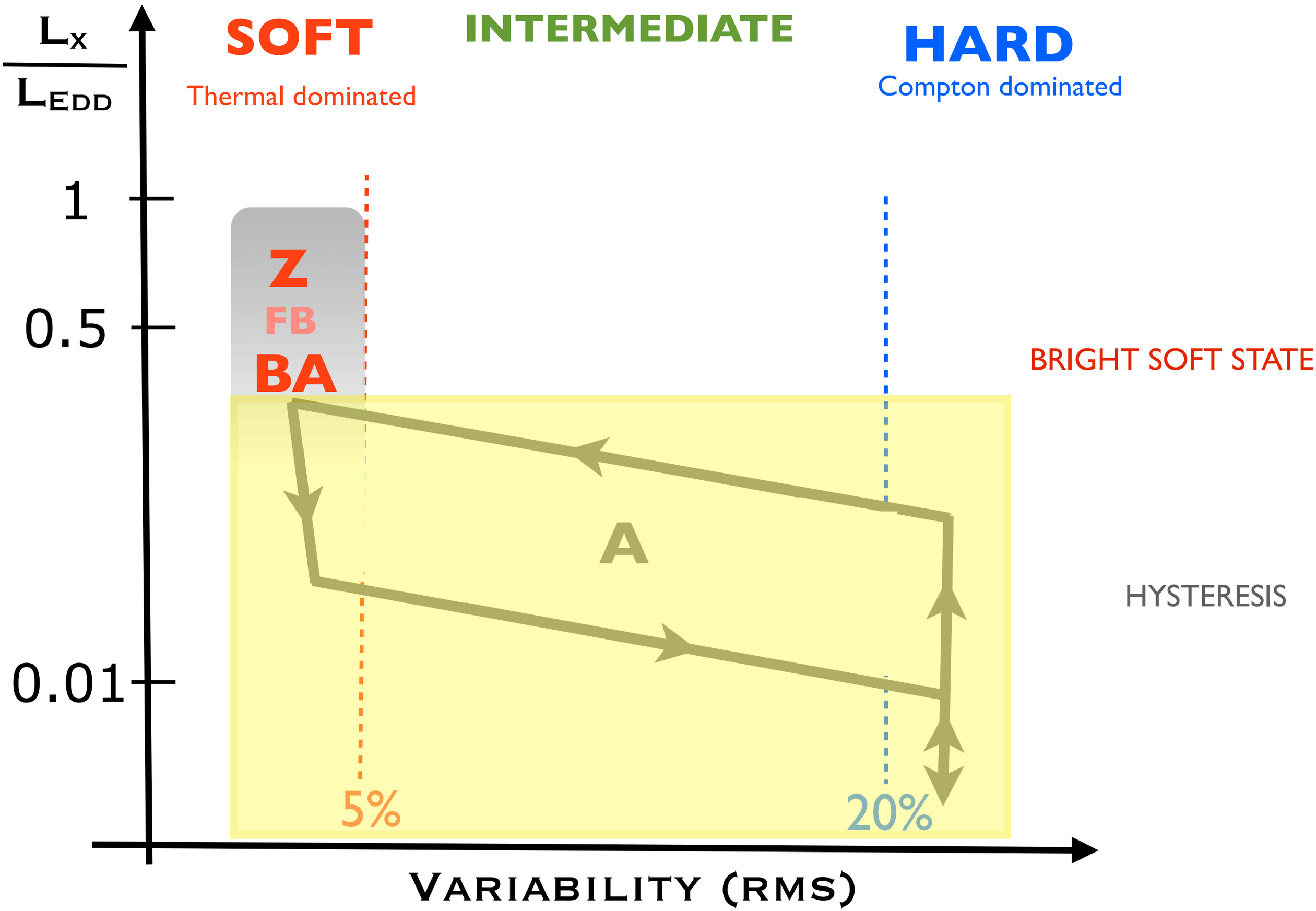
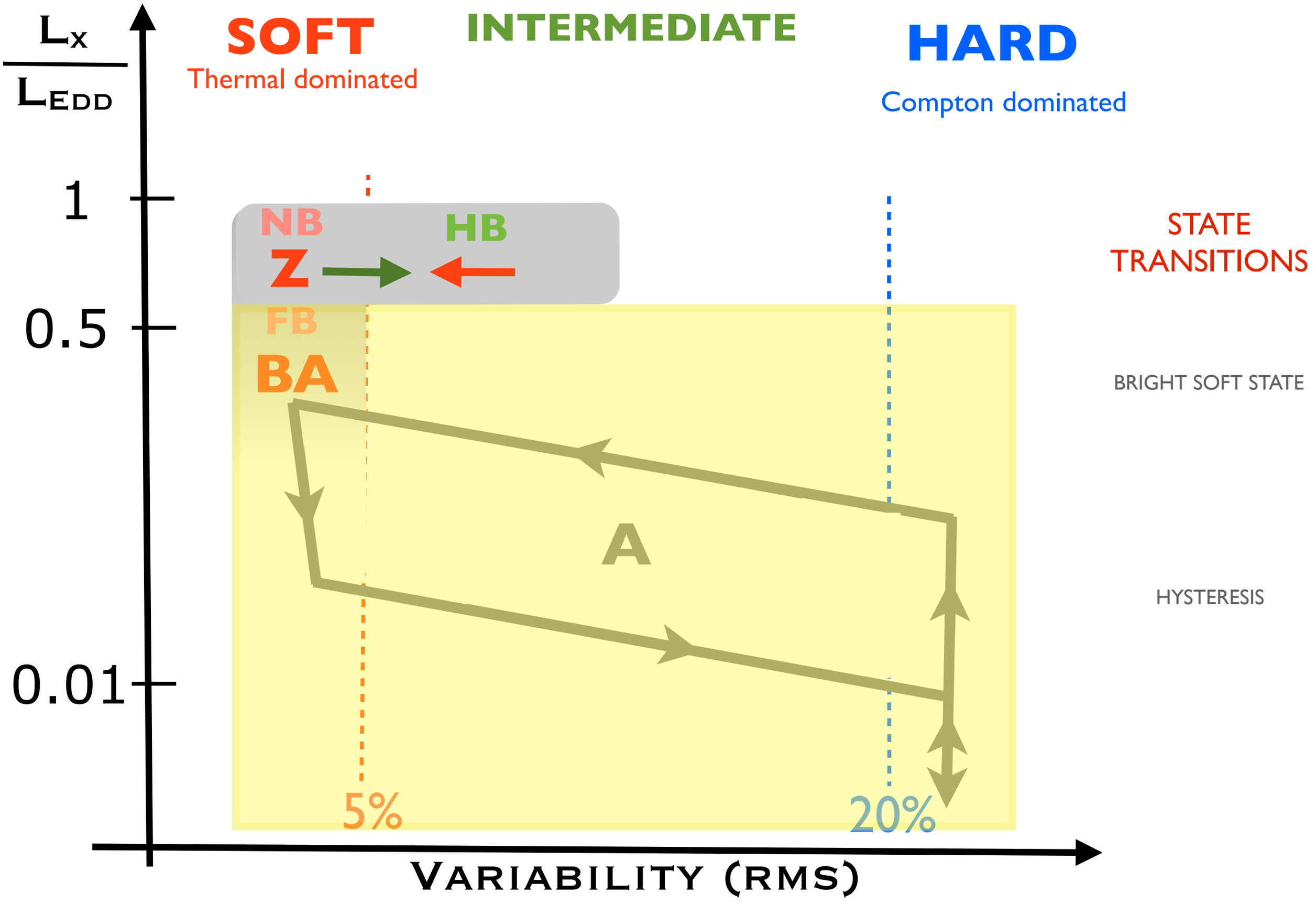


30-60% L_{EDD}: Bright Soft State



~L_{EDD}: State transitions



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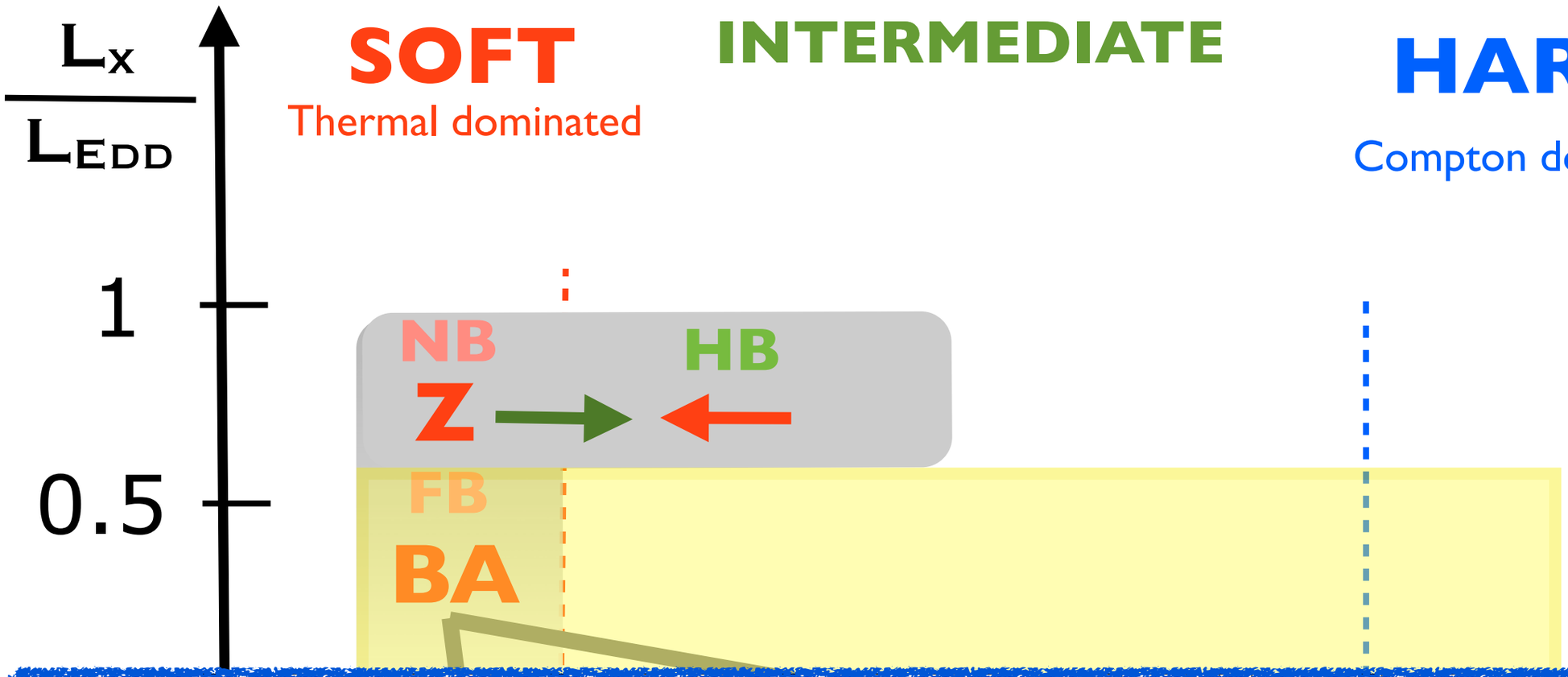

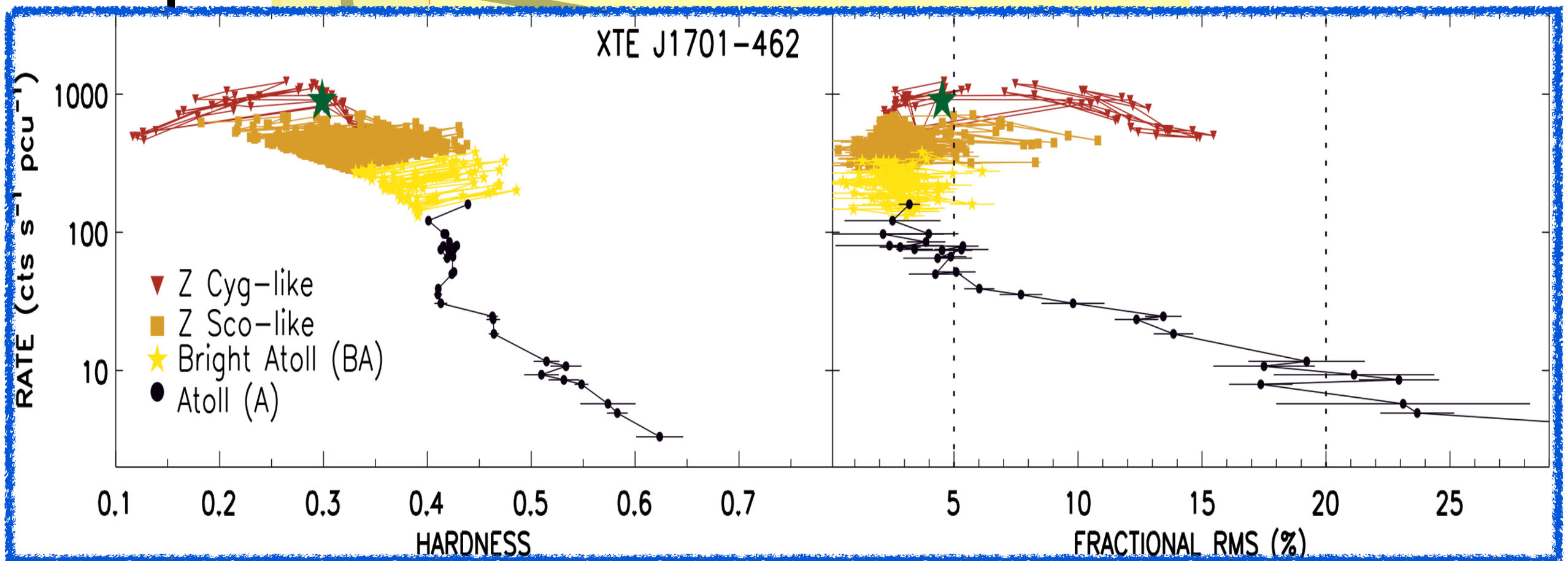

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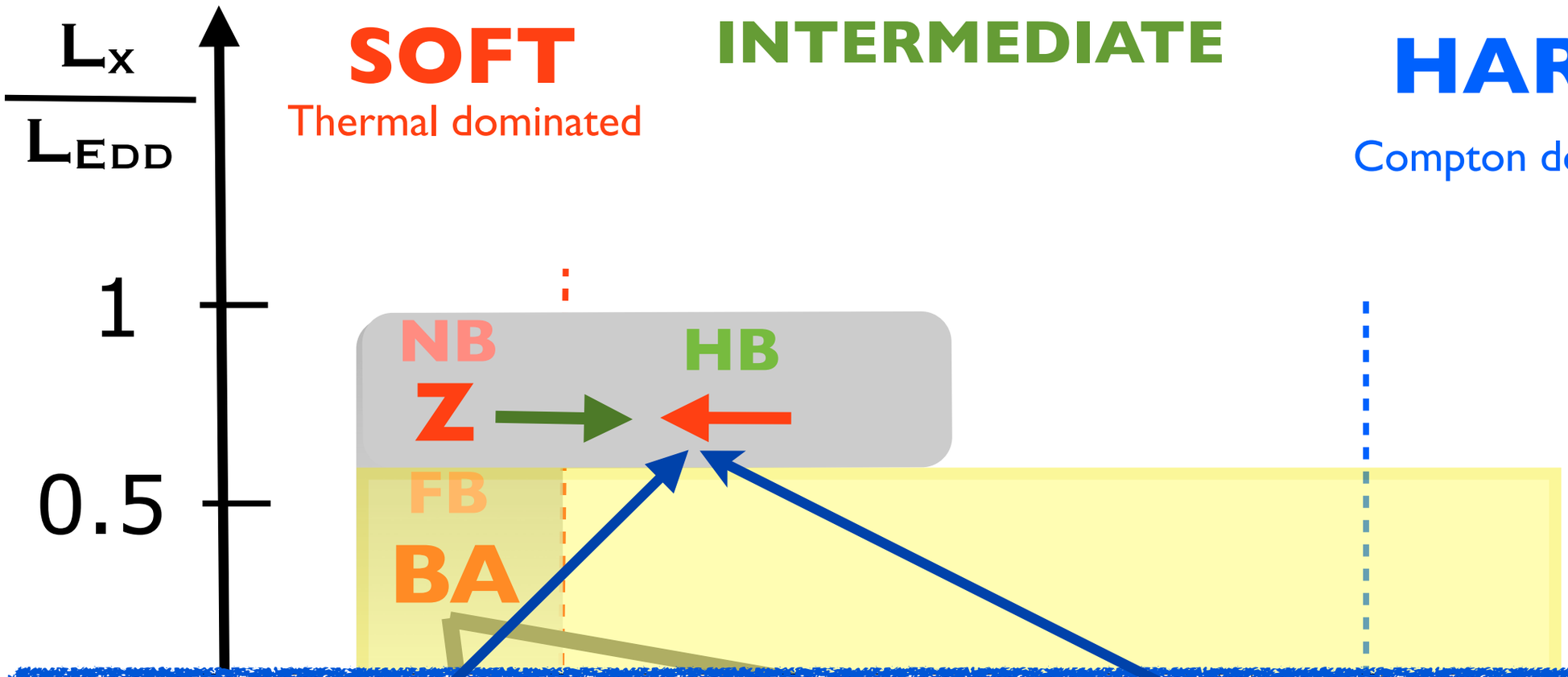
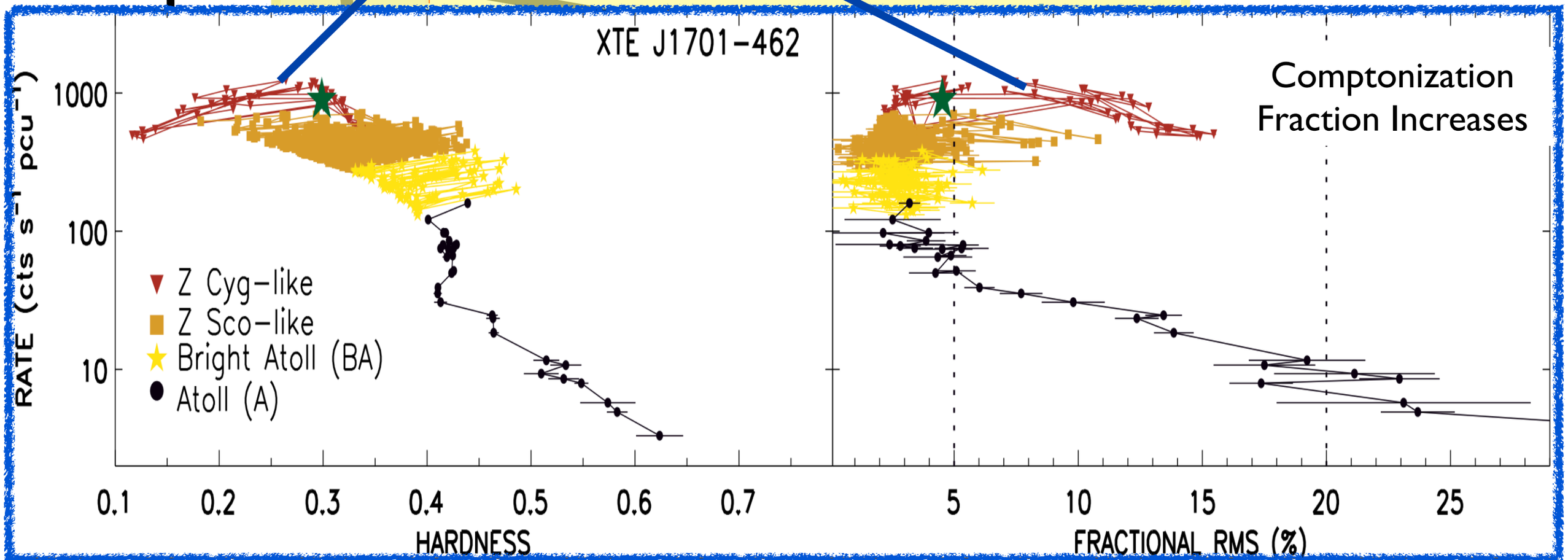




~L_{EDD}: State transitions

$\frac{L_X}{L_{EDD}}$

1

0.5

SOFT
Thermal dominated

INTERMEDIATE

HARD

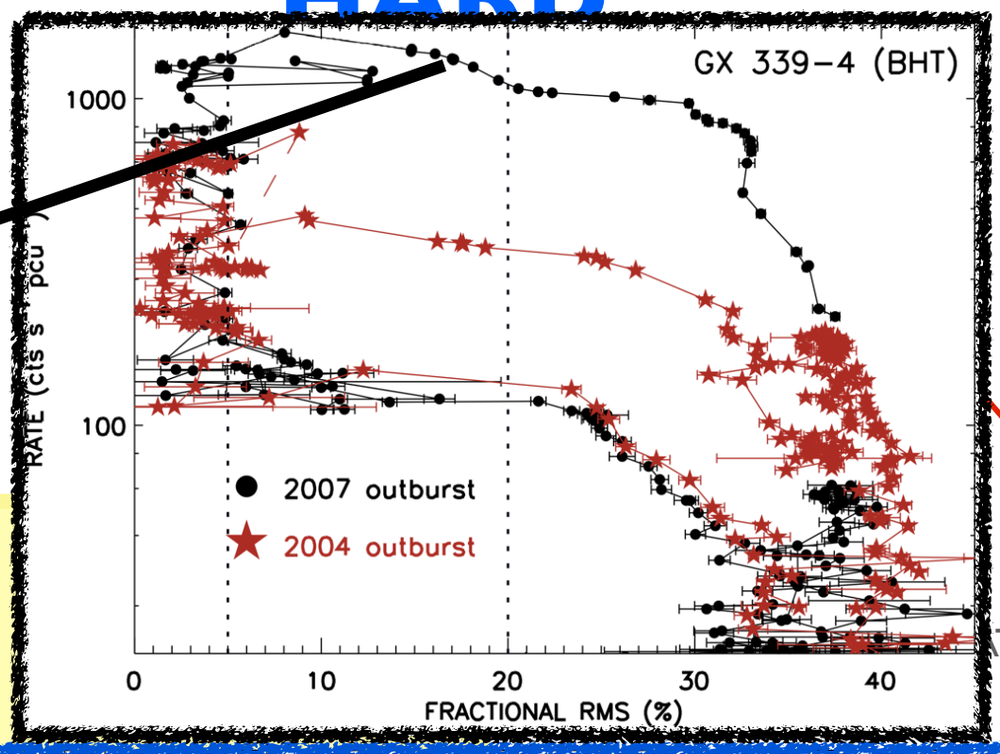
NB

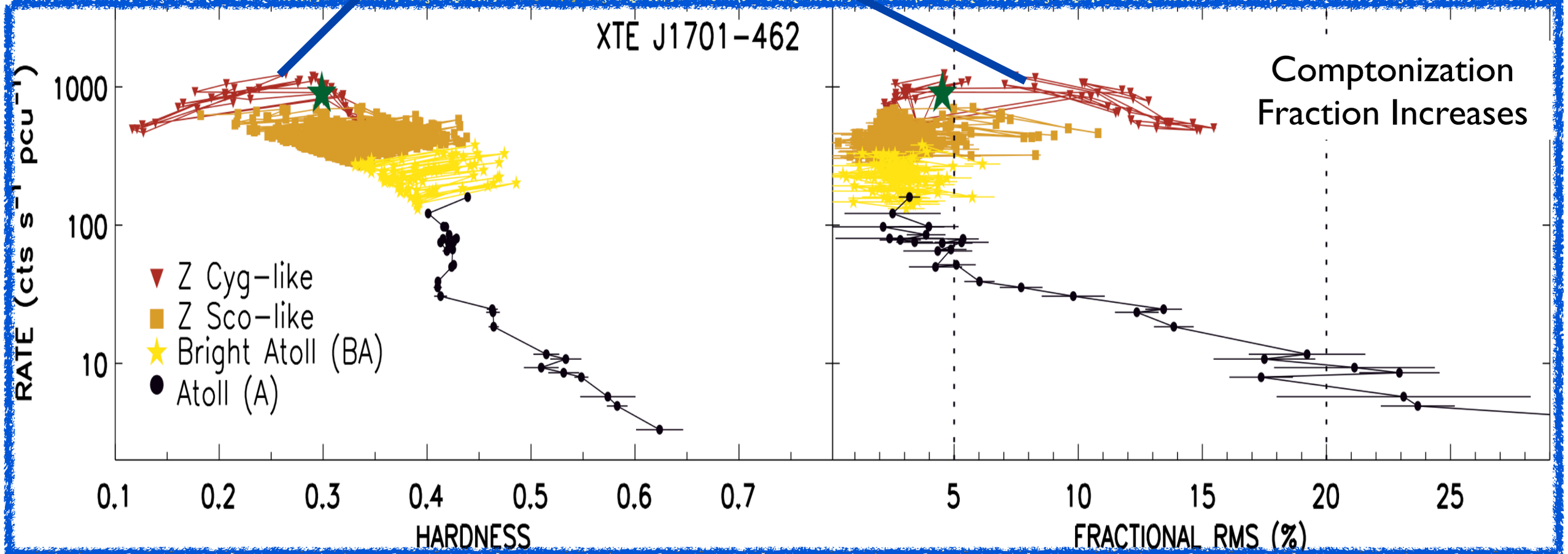
HB

Z

FB

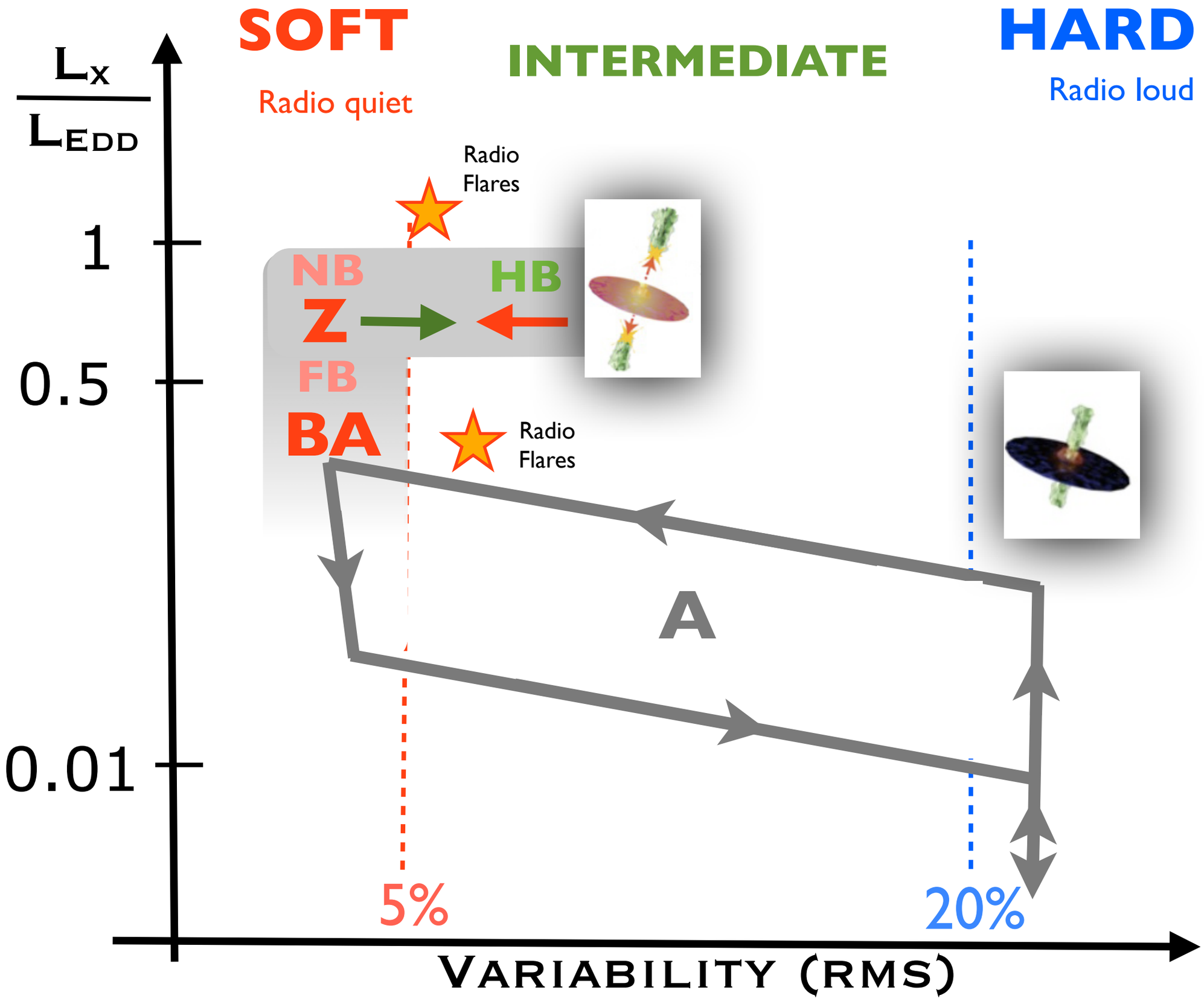
BA



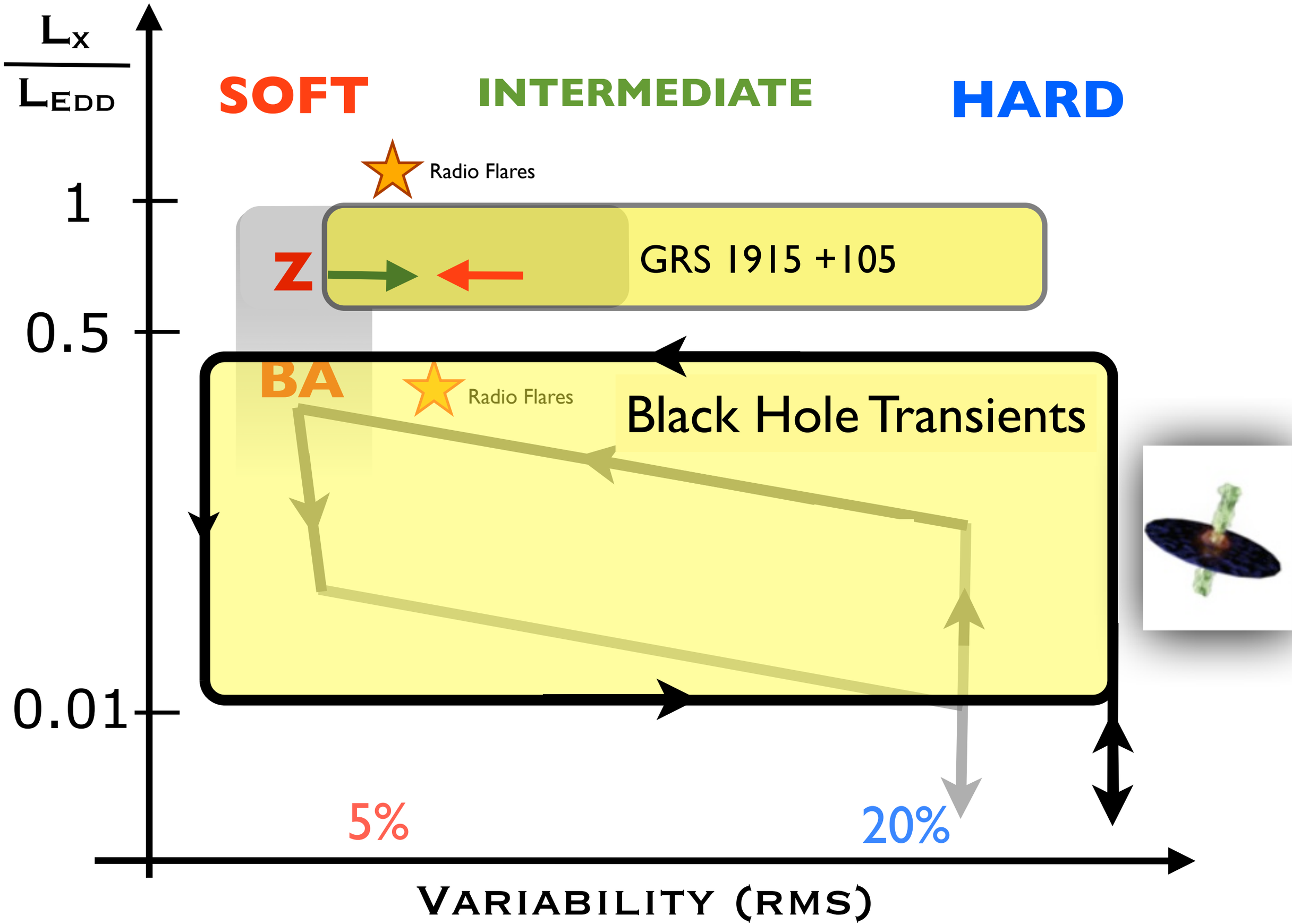


The Radio Picture

(based in Migliari & Fender 2006)



Neutron Stars vs. Black Holes



SUMMARY

★**Large Neutron Star data base** accreting at 0.01-1 L_{EDD}

★(Fast) Variability - Luminosity Diagram:
common framework for accretion states in NS and BHs

- ✦Fast Variability traces the ratio between thermal and Comptonized emission
- ✦**(Heavily) supported** by multi-wavelength observations
- ✦**Hysteresis** is commonly observed below ~30 % L_{EDD}
    - (very) comparable to that seen in Black holes