Accretion Process in Neutron Star Low-mass X-ray Binaries

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Outline

- Spectral modeling of neutron star (NS) low-mass X-ray binaries (LMXBs)
- Relation between subclasses
- Application: X-ray source populations in nearby galaxies
- Conclusions

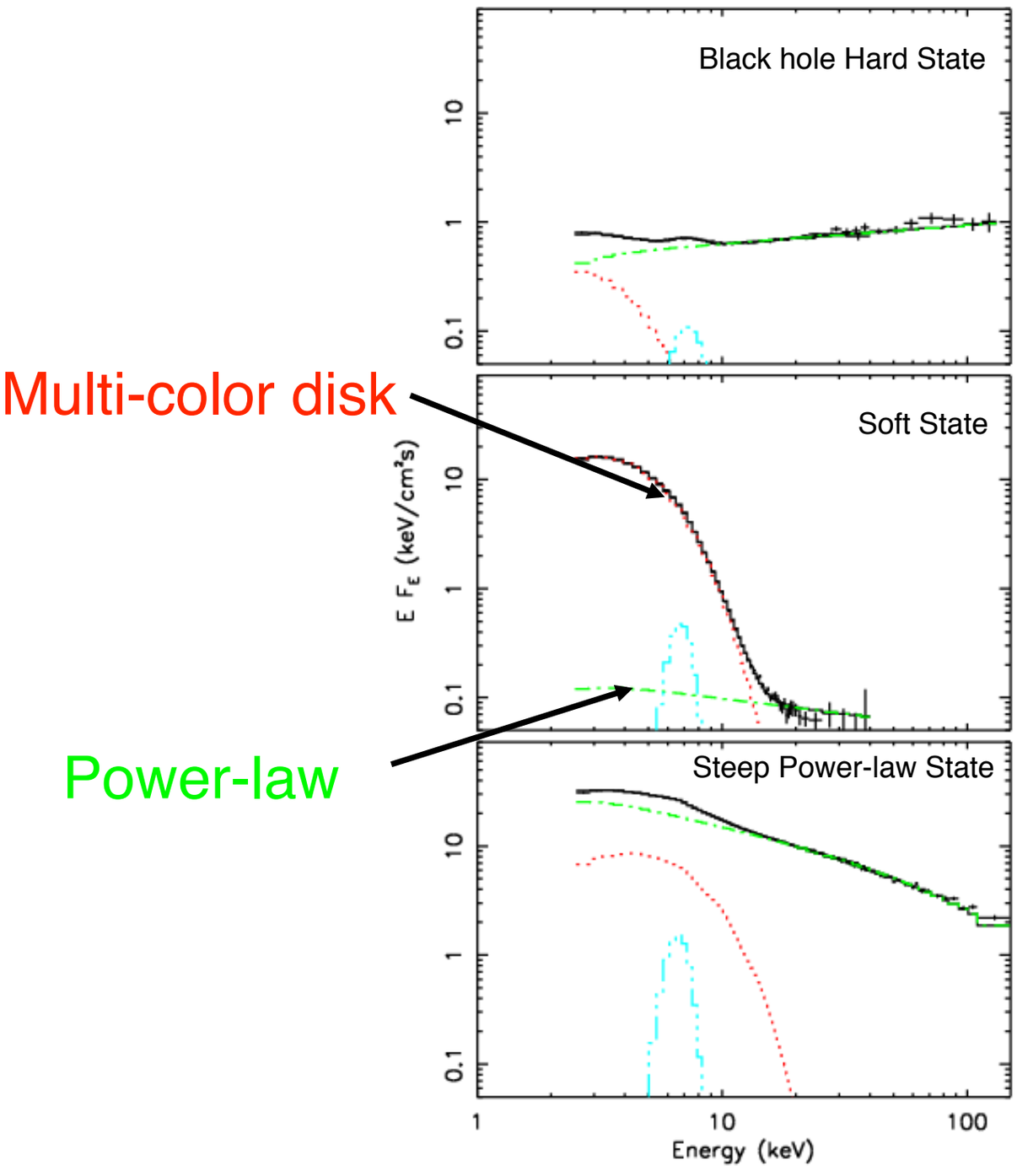
Accreting Stellar-mass Black Hole Spectral States

Black hole (BH) X-ray binary: three spectral states

GRO J1655-40

Multi-color disk

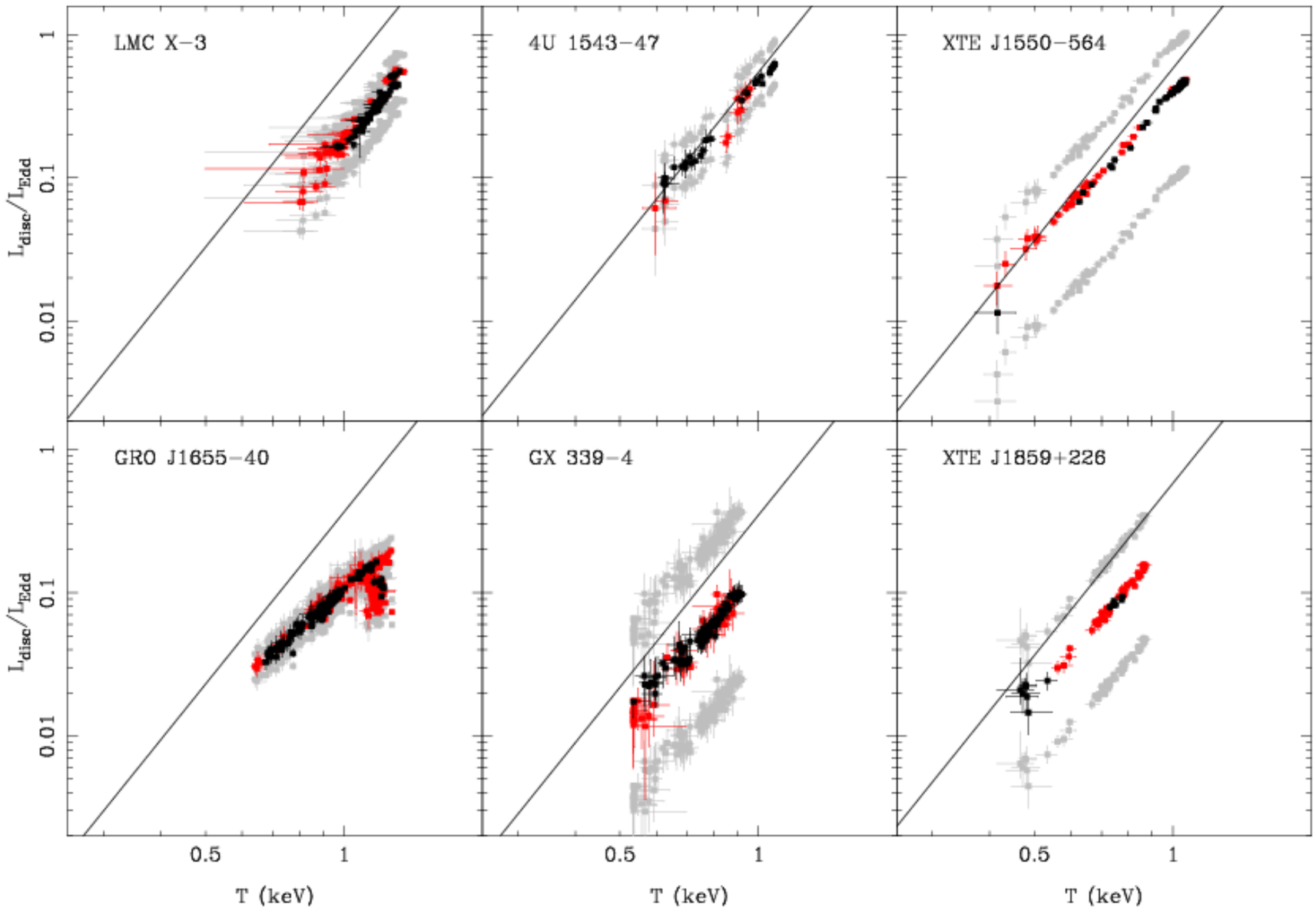
Power-law



Remillard & McClintock 2006

Accreting Stellar-mass BH Spectral States

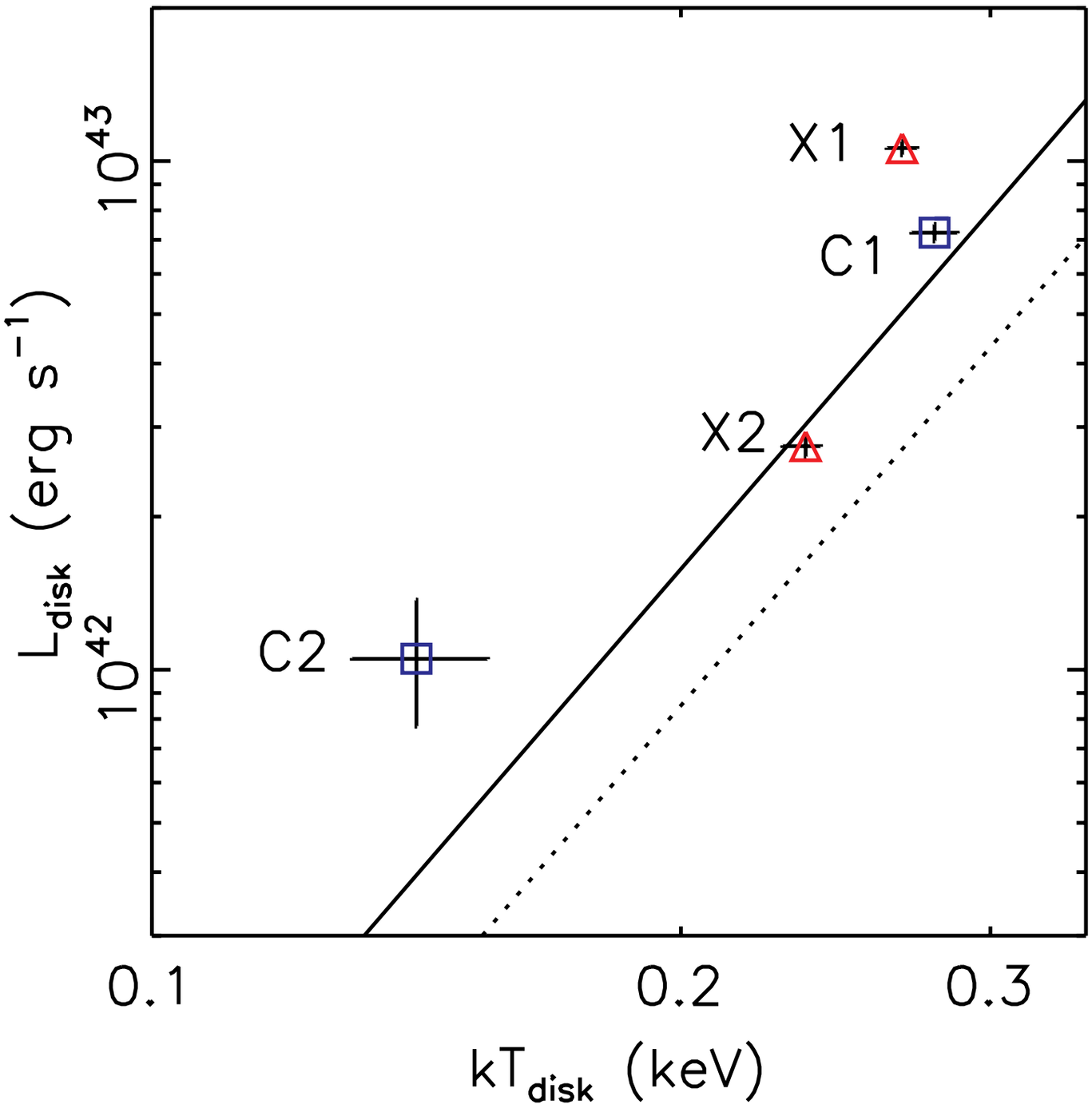
Thermal State: $L \propto T^4 \Longrightarrow$ inner disk truncated at ISCO



Done, Gierlinski & Kubota 2007

Accreting Intermediate-mass BH:

Thermal State: $L \propto T^4$



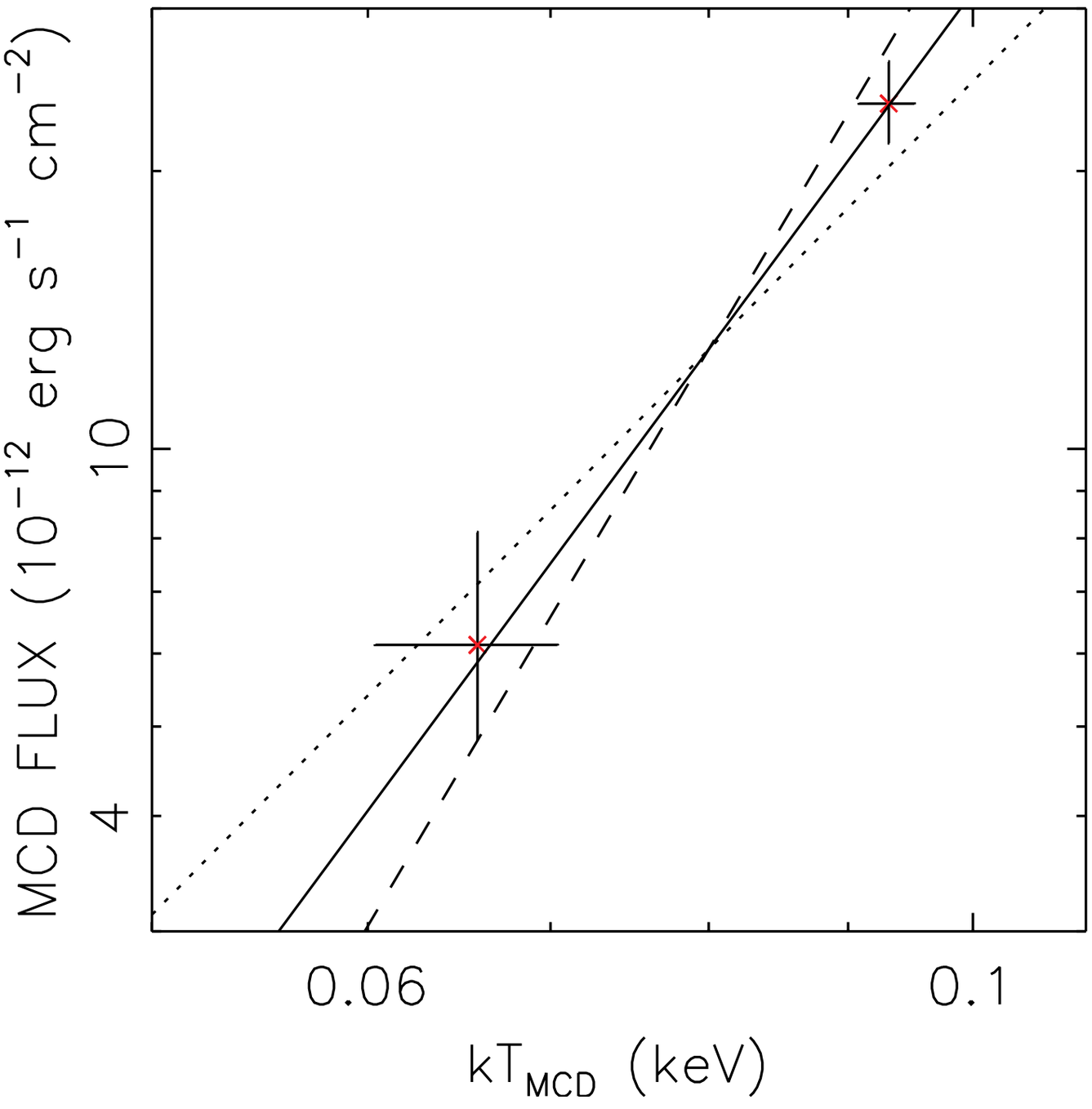
Solid line: 3XMM J215022.4-055108

Dotted line: ESO 243-49 HLX-1

Lin, Strader, Carrosco, et al. 2018

Accreting Supermassive BH:

Thermal State: $L \propto T^4$

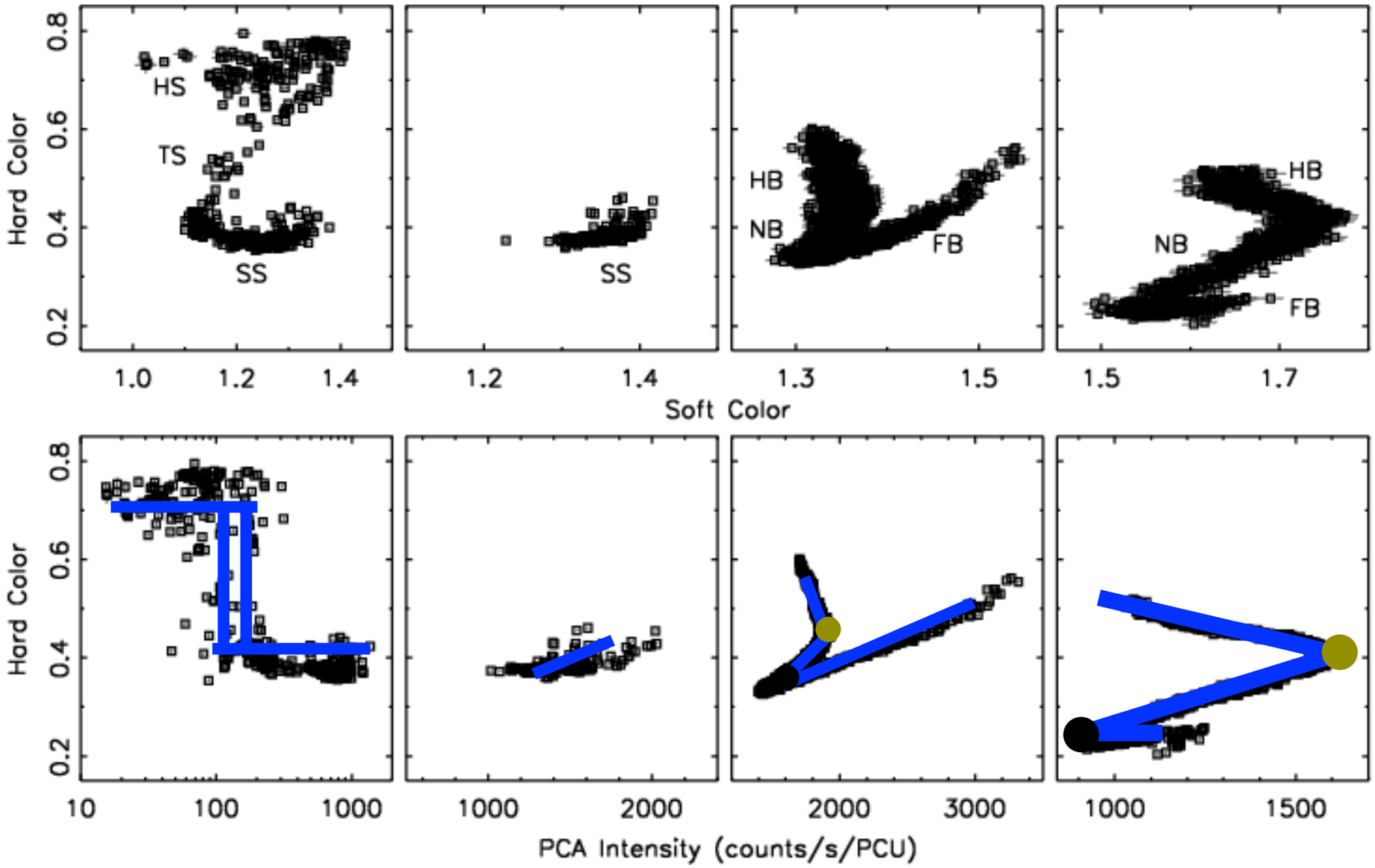


Tidal Disruption Event:
2XMMi J184725.1-631724

Lin, et al. 2011, ApJ, 738, 52

Different Types of NS LMXBs

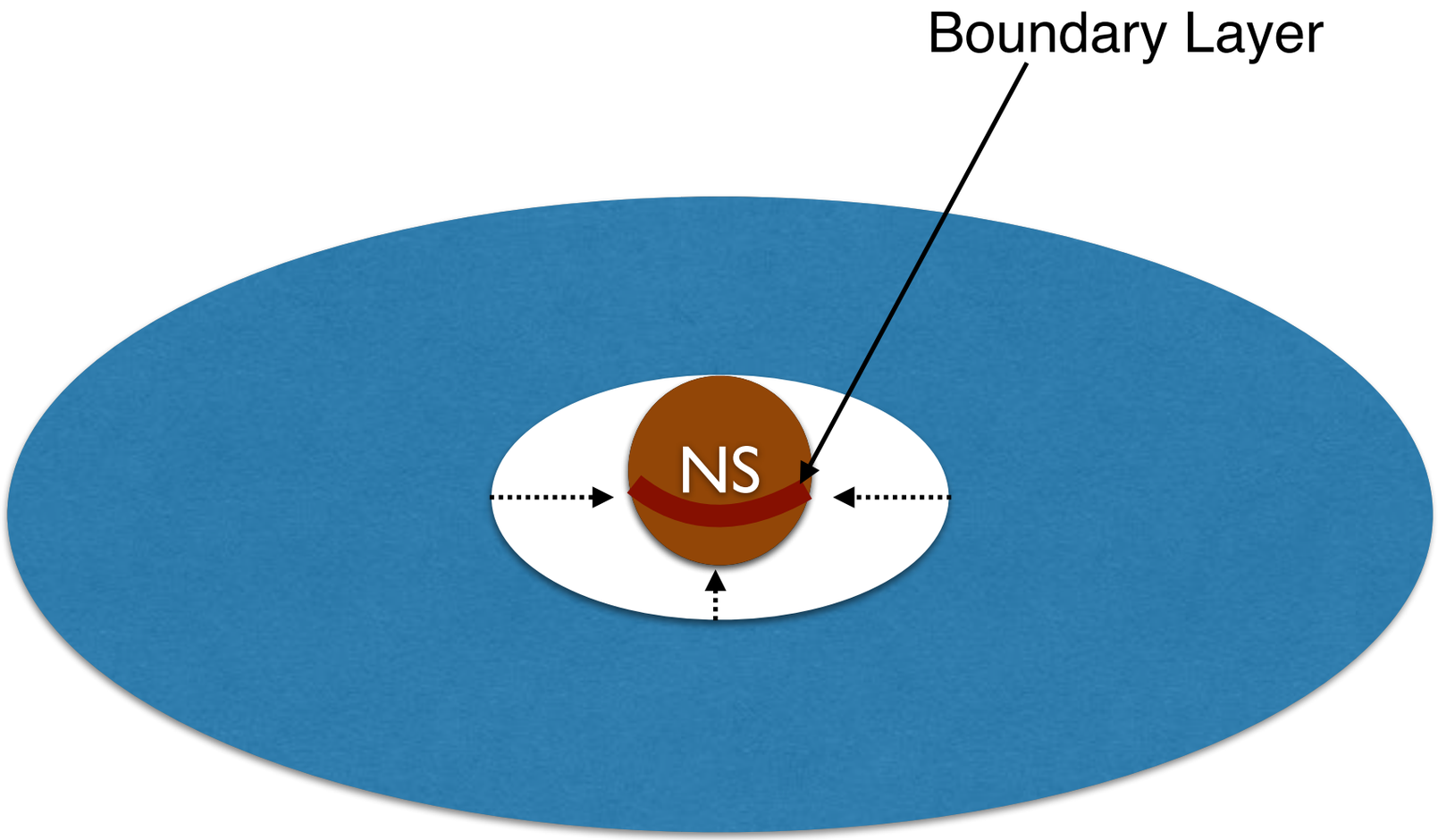
Sample color-color and hardness-intensity diagrams



Atoll source GX Atoll Sco-like & Cyg-like Z sources

Spectral modeling?

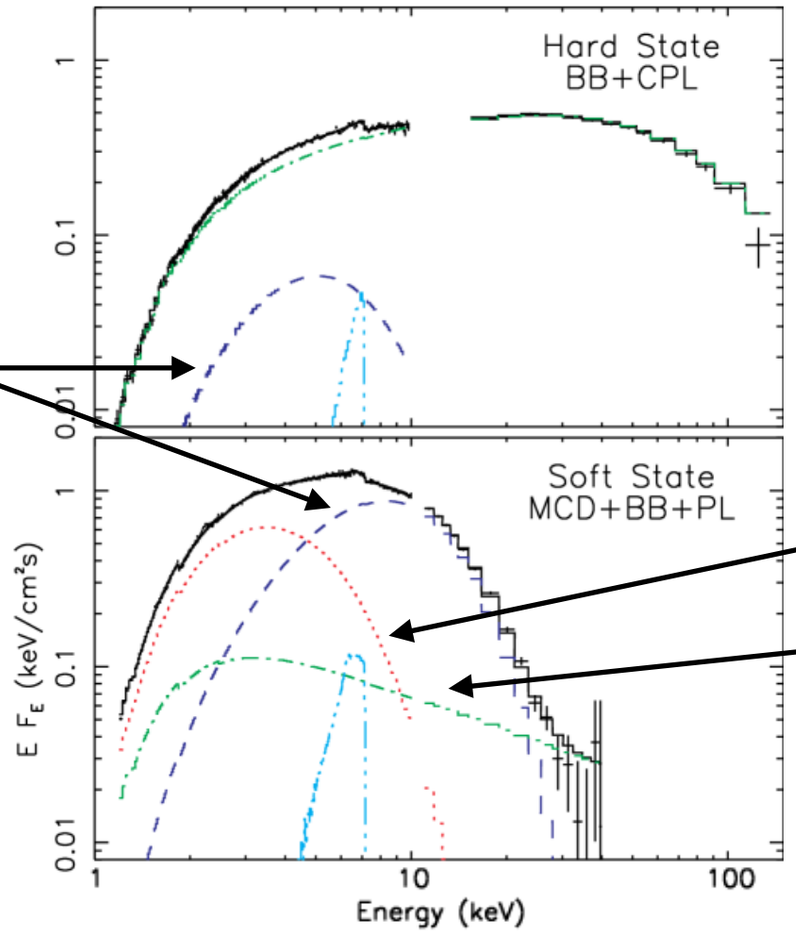
NS LMXB Spectral Modeling: Double Thermal



NS LMXB Spectral Modeling: Double Thermal

NS LMXB model = BHB model + blackbody boundary layer

Atoll source 4U 1705-44

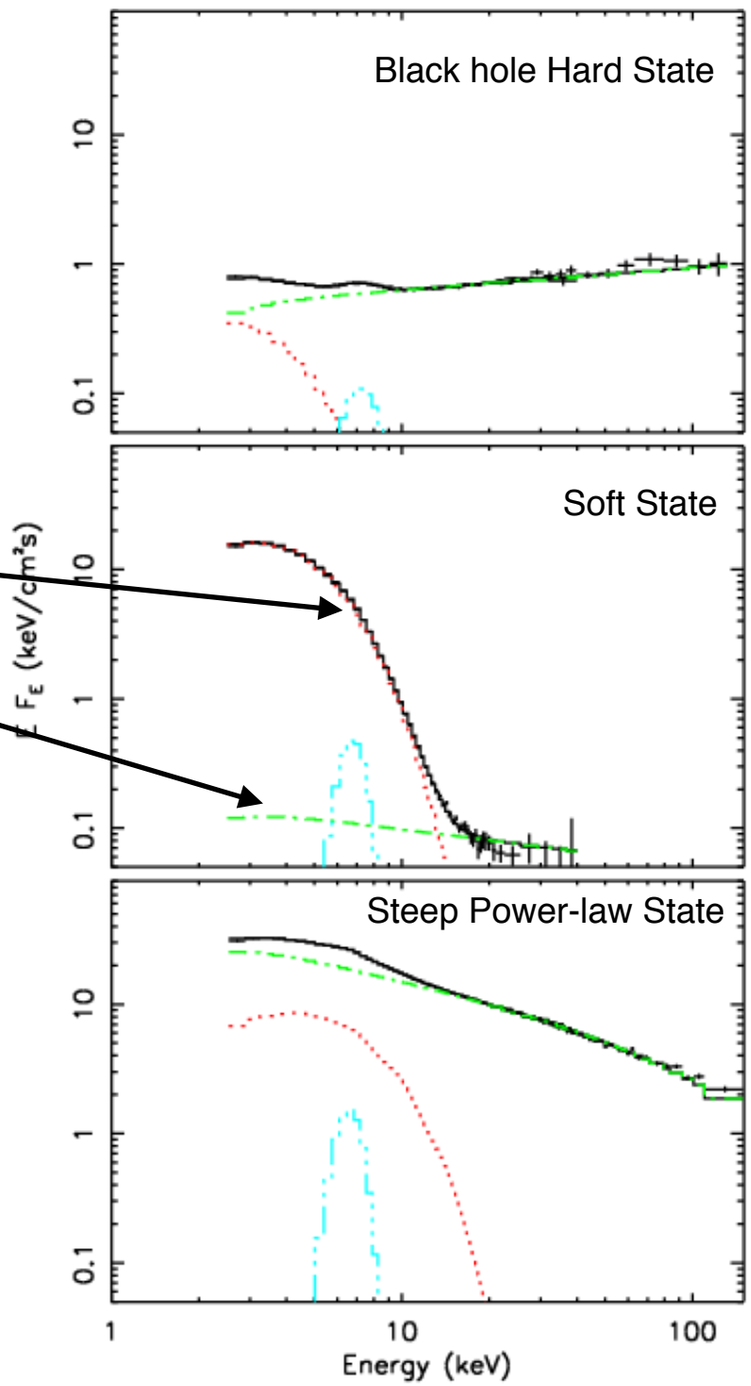


BB

MCD

PL

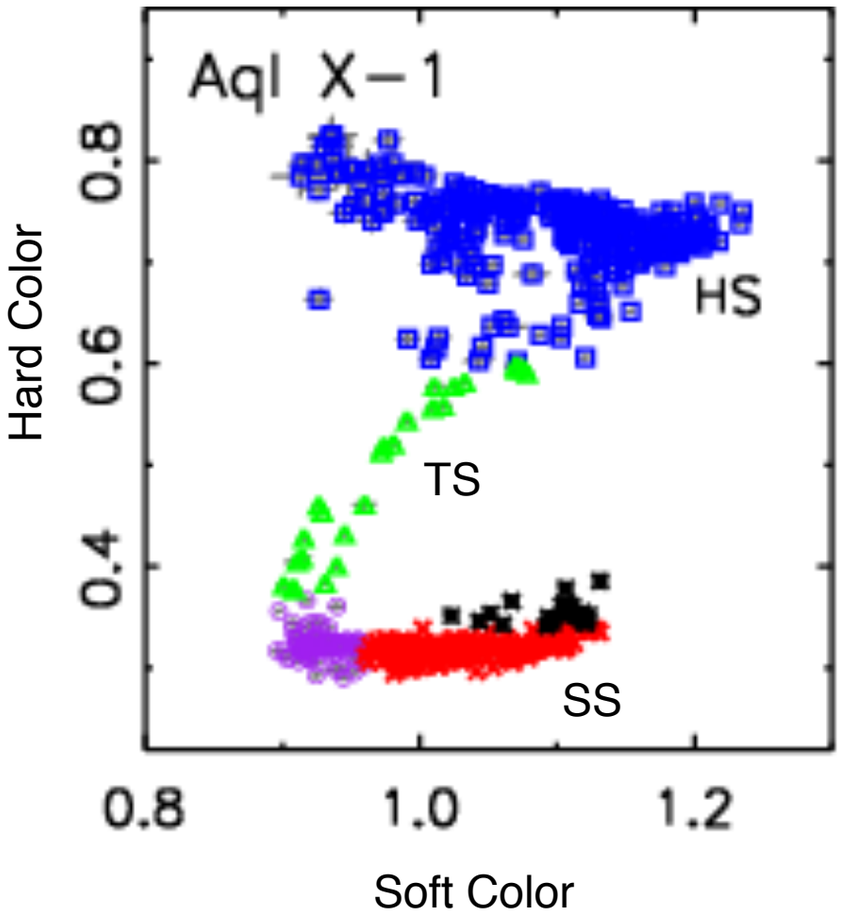
BHB GRO J1655-40



Lin, Remillard & Homan 2010

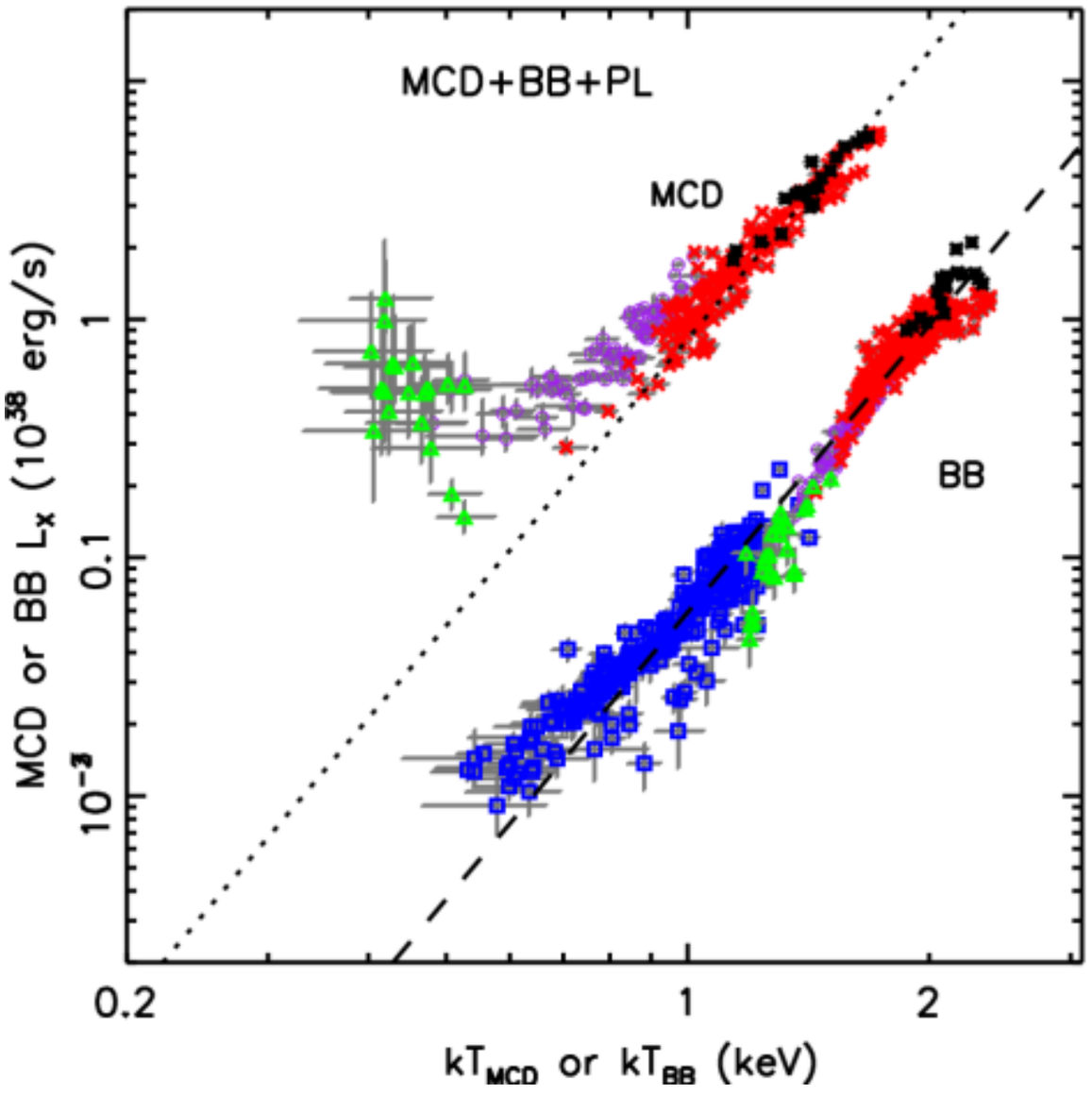
NS LMXB Spectral Modeling: Double Thermal

States in color-color diagram



➪ Disk: $L \propto T^4$, large inner radius in thermal state

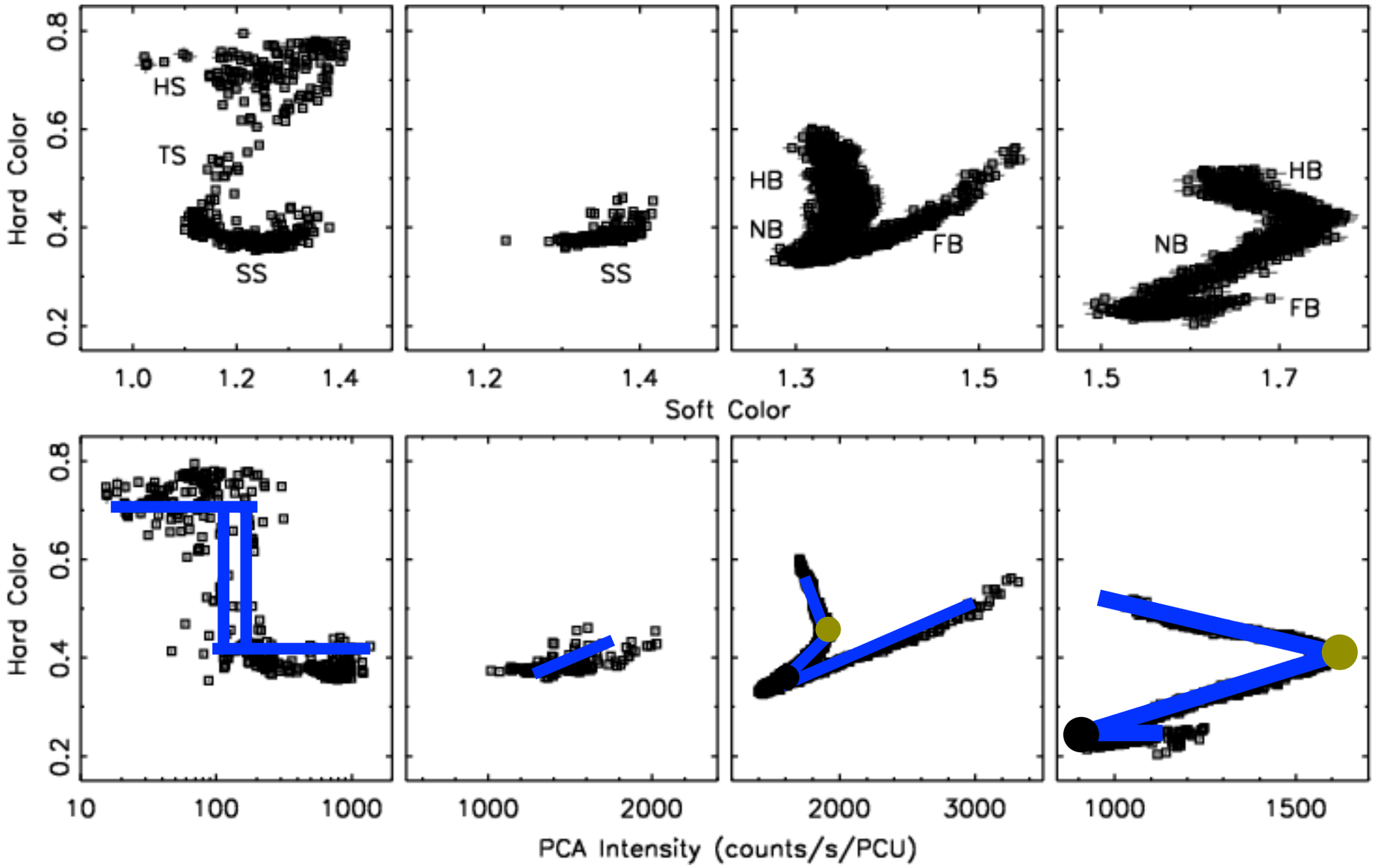
➪ Boundary Layer: constant but small emission area from the hard to the soft state.



Lin, Remillard & Homan 2007

Different Types of NS LMXBs

Sample color-color and hardness-intensity diagrams

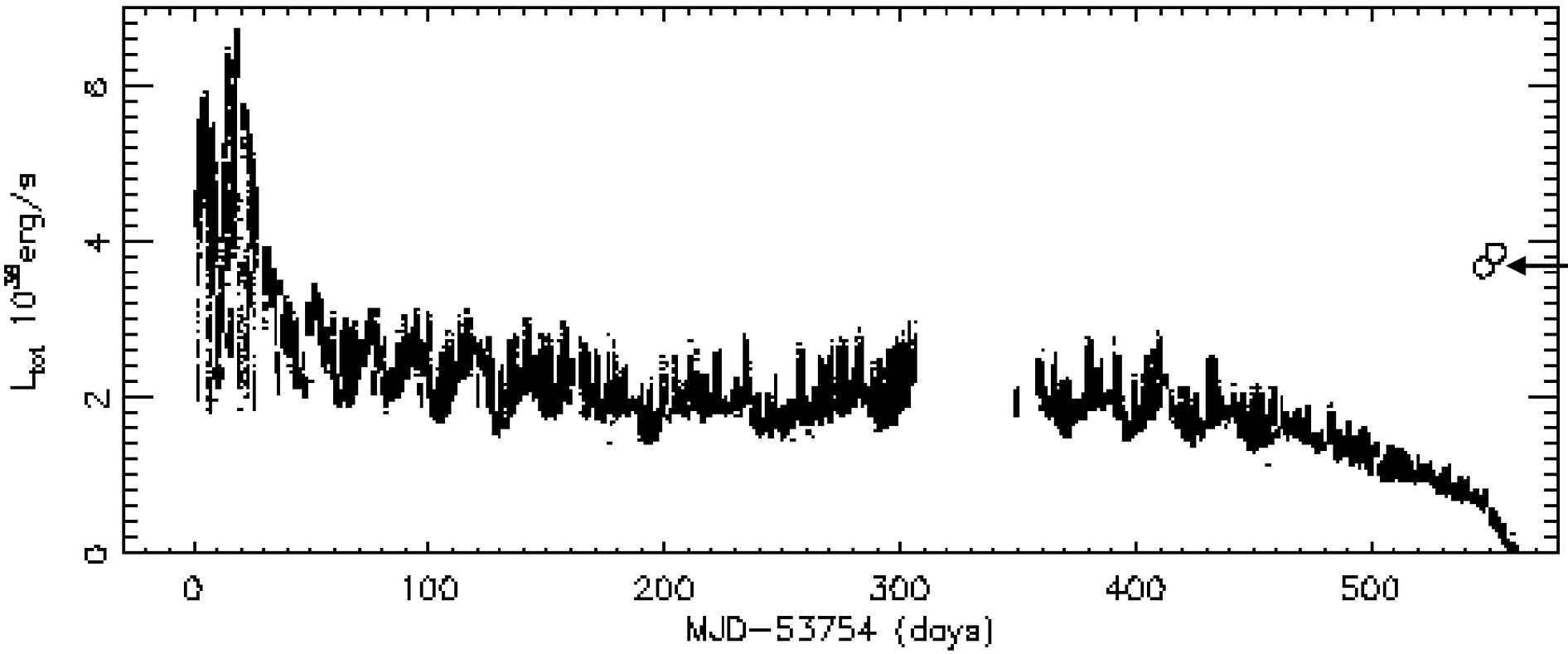


Atoll source GX Atoll Sco-like & Cyg-like Z sources

Relation between subclasses?

XTE J1701-462

- First Z transient showing different types of NS LMXBs
- Peak super-Eddington luminosity

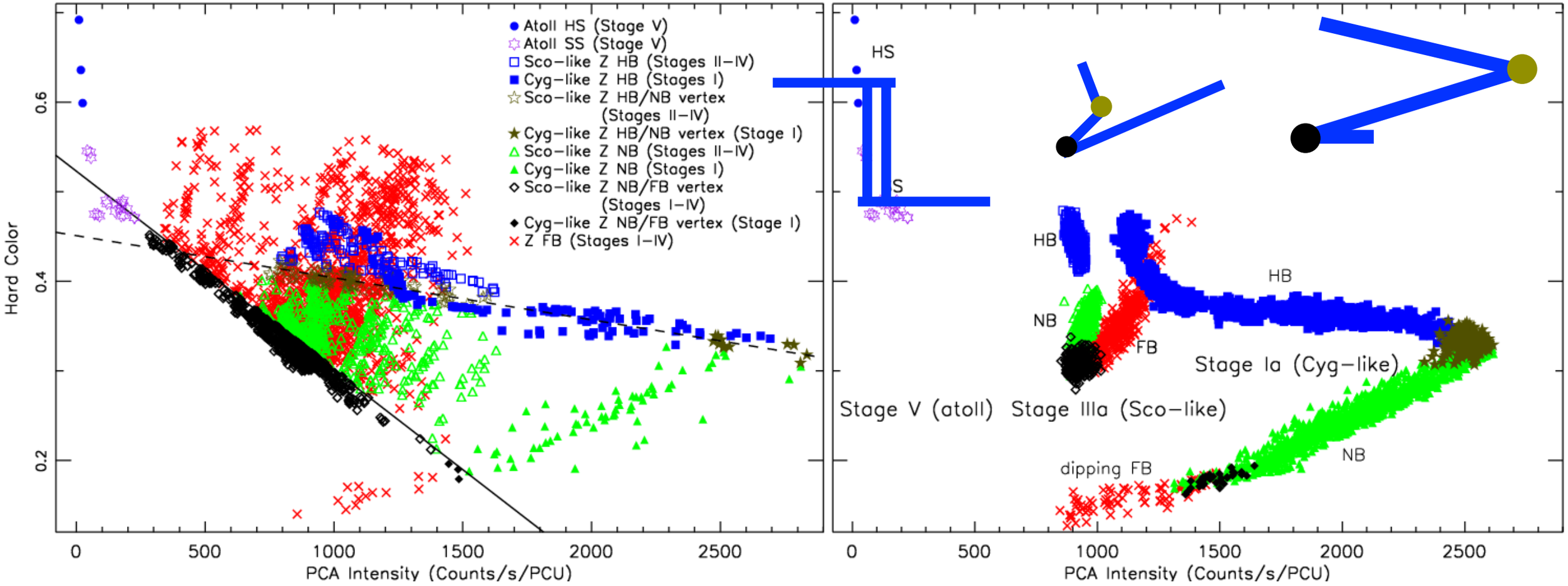


Lin, et al. 2009a,b

XTE J1701-462

- The source changes from one type to another as count rate decreases
- Two vertices of Z tracks evolve along two distinct lines.
- lower vertex $\Longrightarrow$ Atoll soft state, as flaring branch disappears.

Hardness-intensity diagram



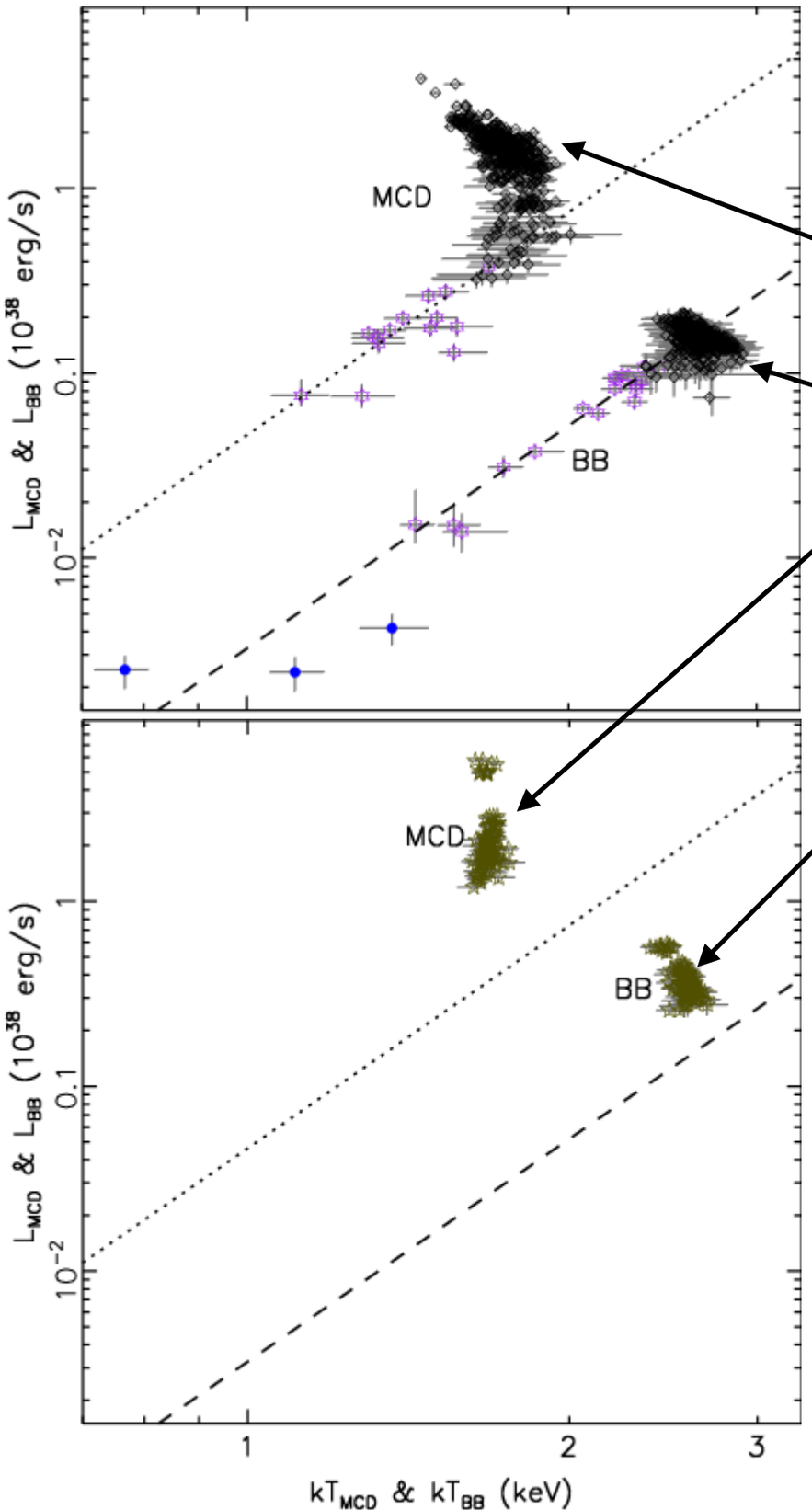
Lin, Remillard, Homan 2009

XTE J1701-462

☛Different types of NS LMXBs are due to different mass accretion rates (not due to inclination, magnetic field)

☛What is going on in Z-source stage? What causes different branches of Z sources?

XTE J1701-462: Double thermal model fit



➪ Atoll stage: both disk and boundary layer $L \propto T^4$

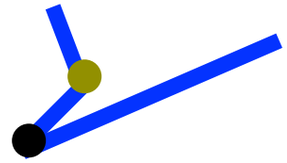
Z source stage:

➪ Disk deviate from $L \propto T^4$: inner disk reaches local Eddington limit

➪ Boundary Layer at Eddington temperature seen in type-I X-ray burst

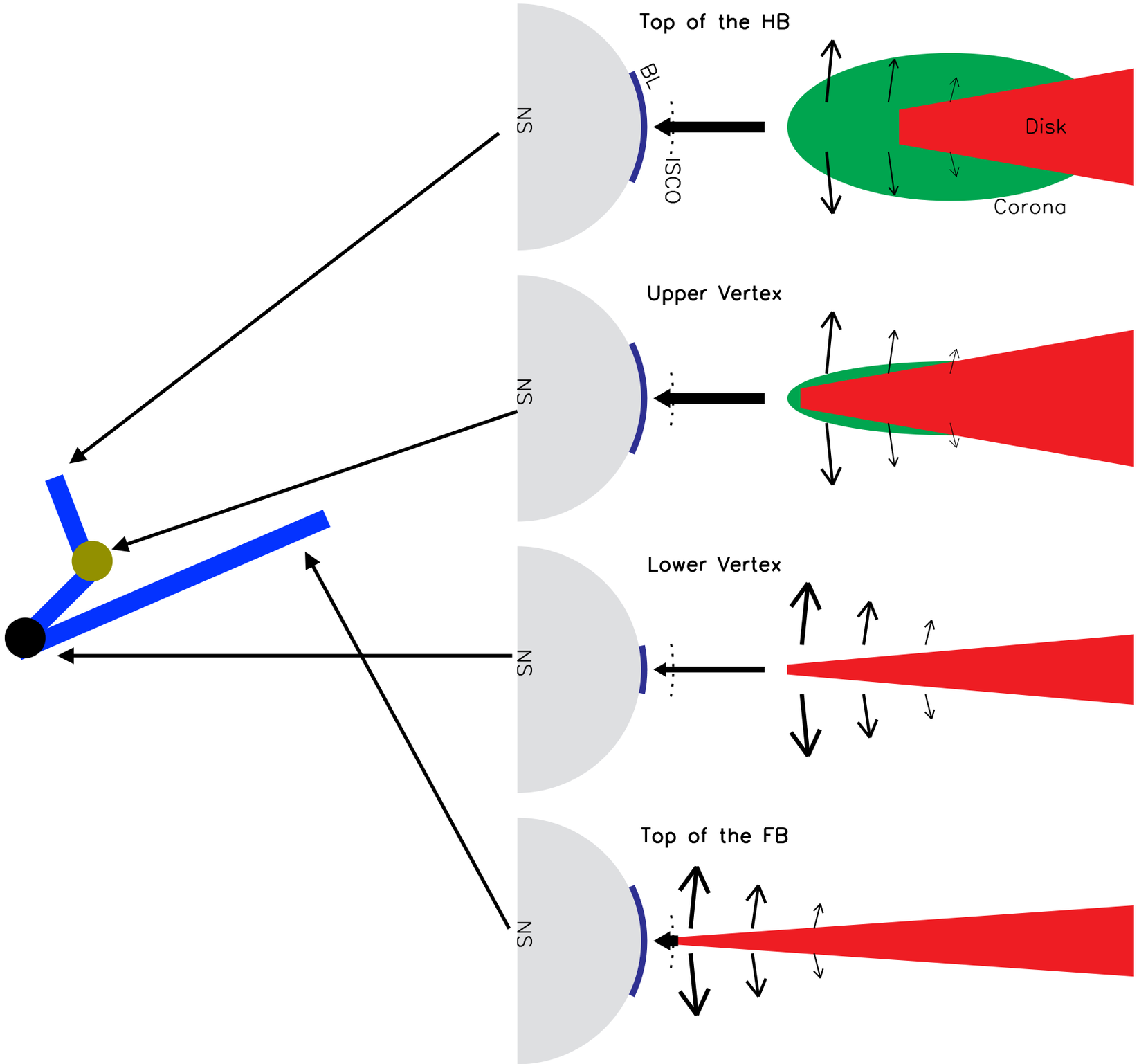
Lin, Remillard, Homan 2009

☛ What causes different branches of Z sources? Could it be $\dot{M}_{\rm disk}$?



☛ Our solution: three mechanisms/instabilities with constant $\dot{M}_{\rm disk}$ (two stable disk solutions at any super-Eddington accretion rate)

Schematic sketch of accretion flow along Z track

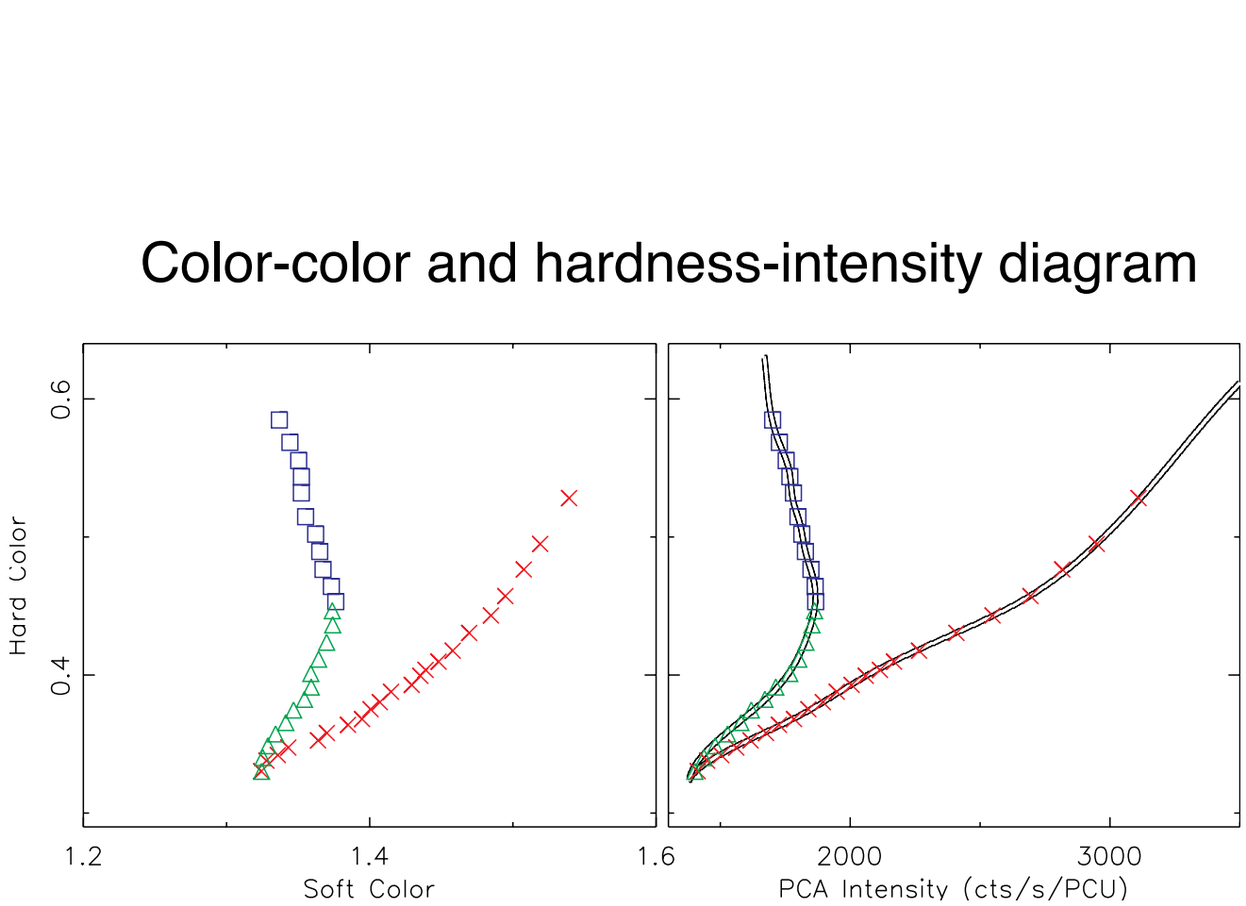


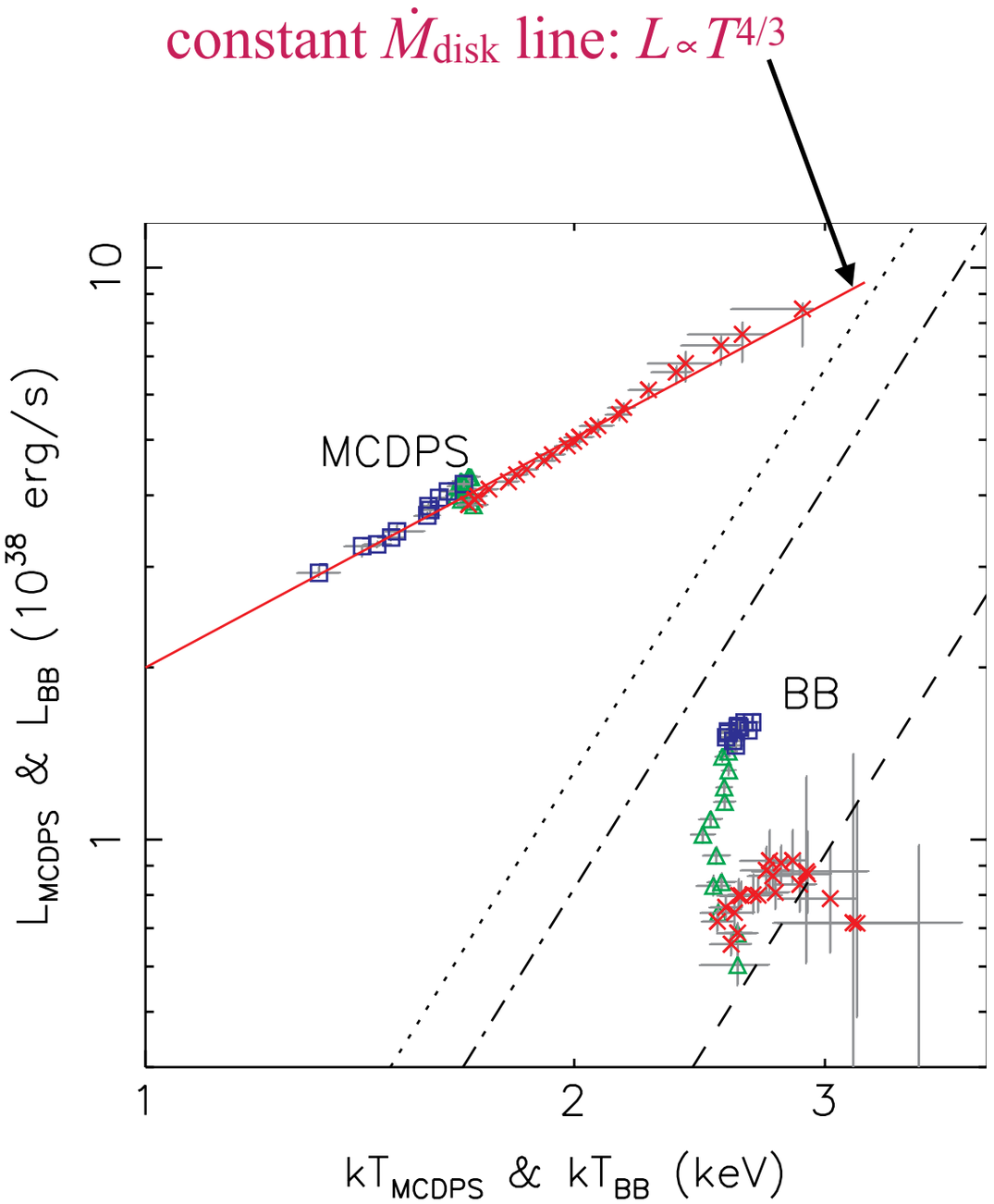
Inner disk strong advection

Inner disk strong outflow

Lin, Remillard, Homan, Barret 2012

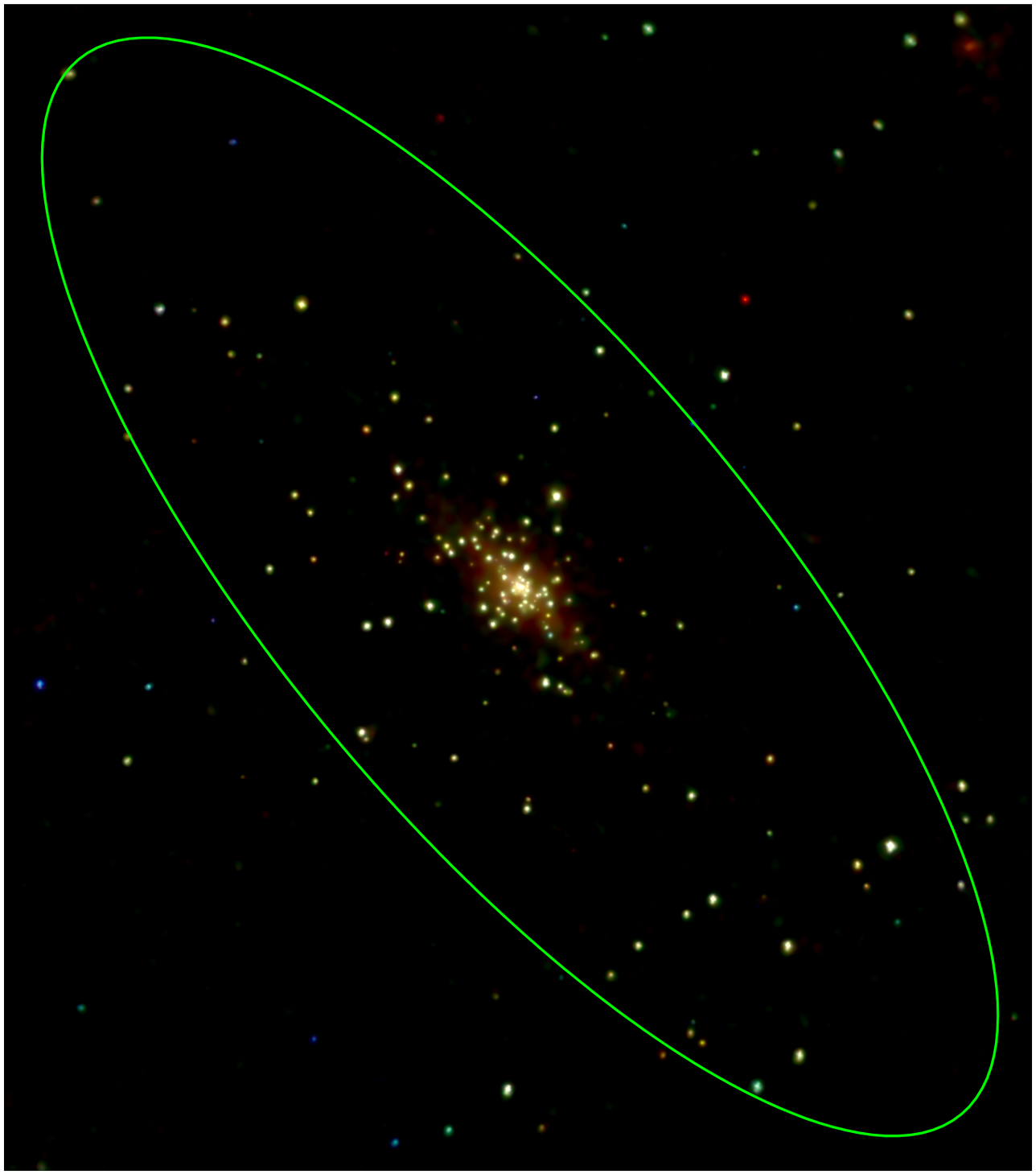
GX 17+2: constant $\dot{M}_{\rm disk}$ along Z track





Lin, Remillard, Homan, Barret 2012

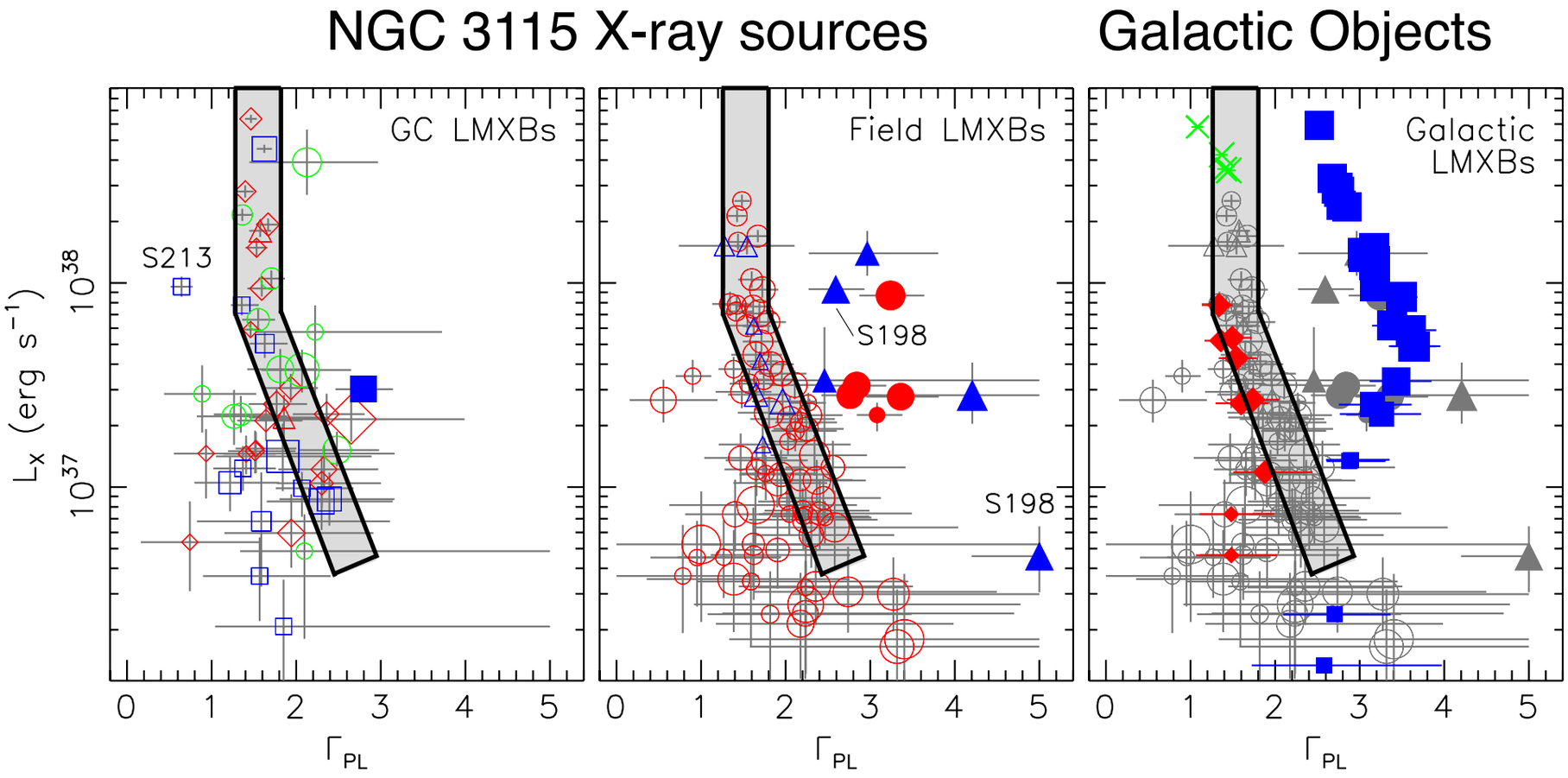
X-ray Population in early-type galaxy NGC 3115



Lin, et al. 2015a,b

X-ray Population in early-type galaxy NGC 3115

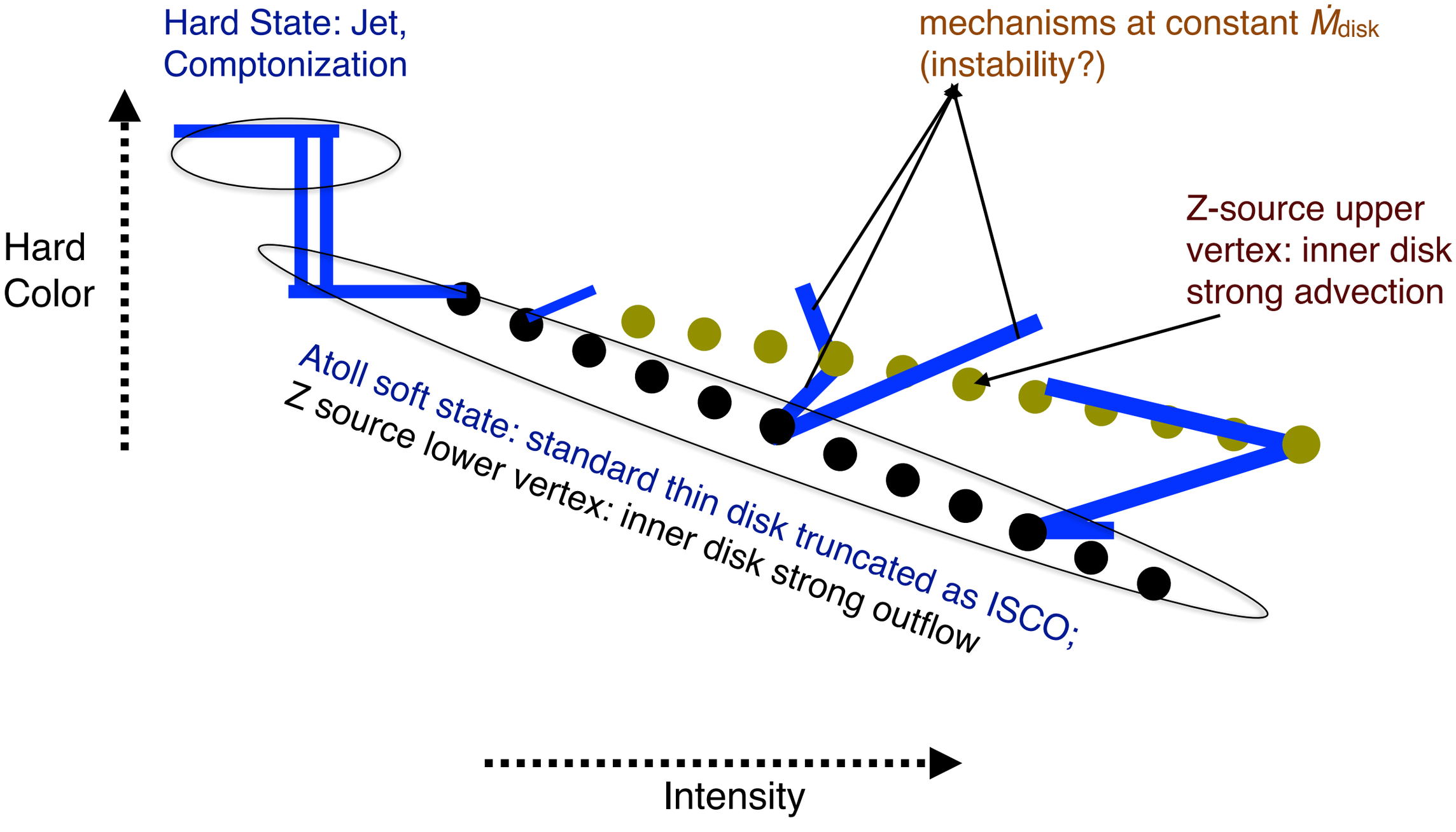
Most NGC 3115 bright X-ray sources fall in the NS LMXB soft-state track



Fit Chandra spectra with an absorbed powerlaw

Lin, et al. 2015a

Conclusions



Thanks