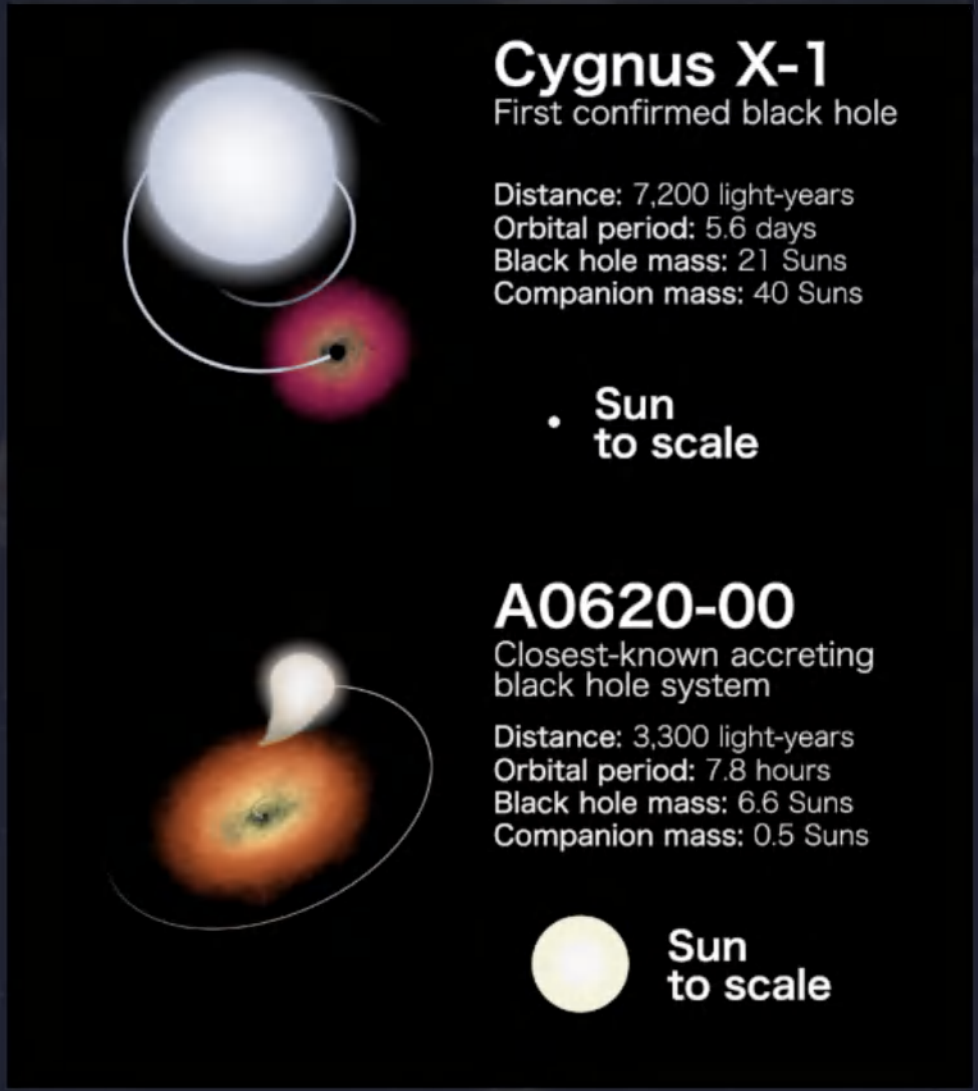
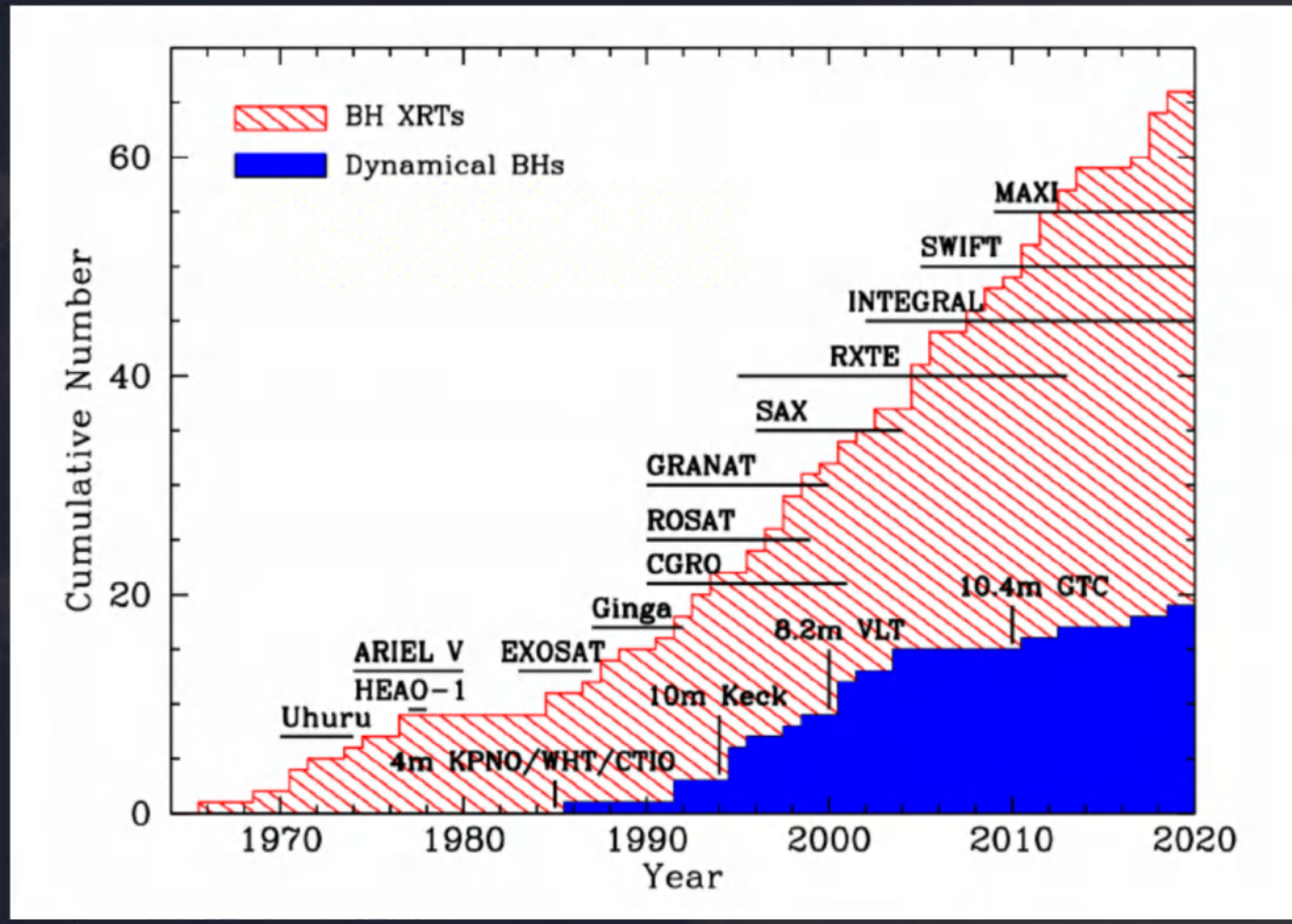
The puzzling low-luminosity accretion in black hole X-ray binaries

闫震

上海天文台

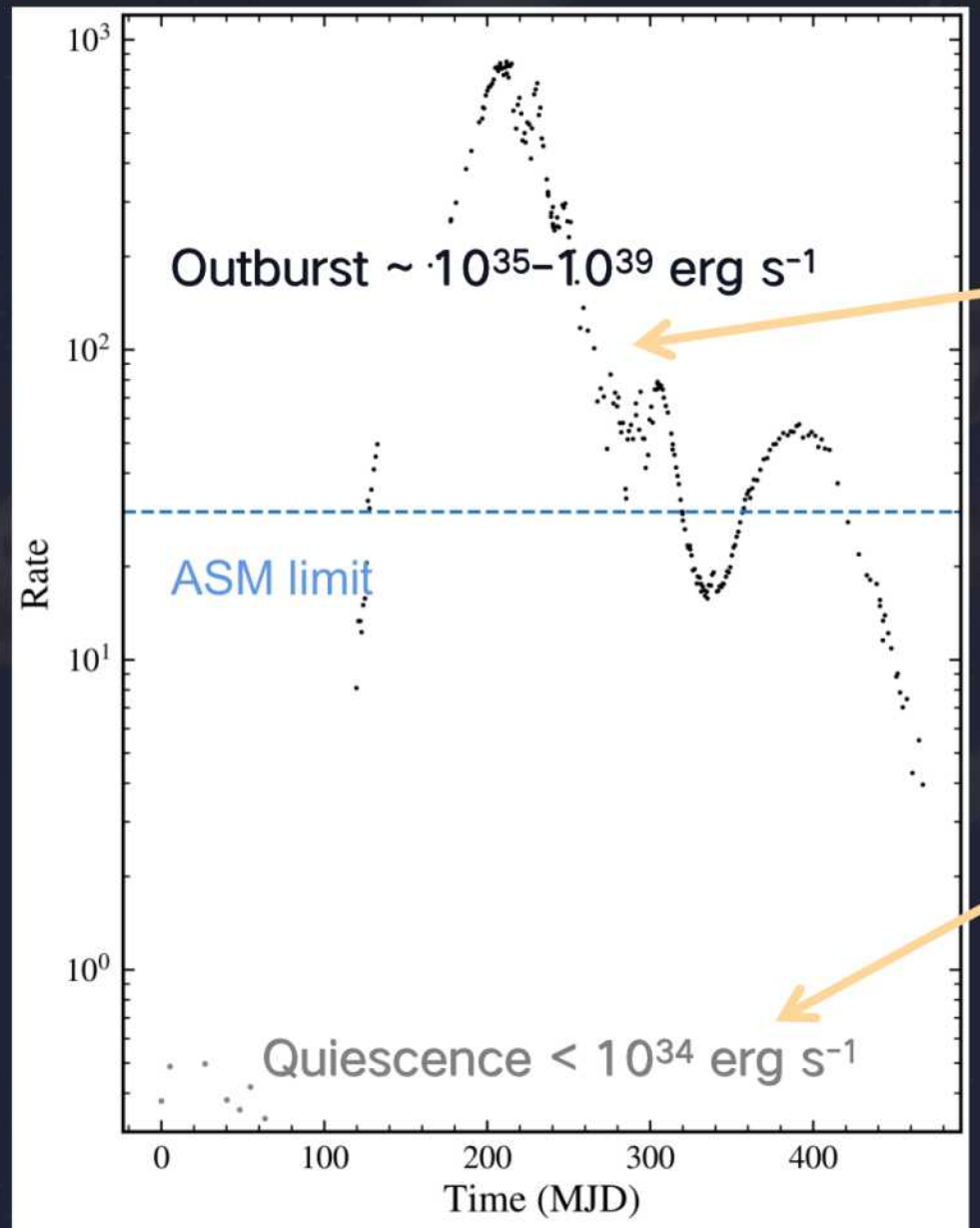
Black hole X-ray binary

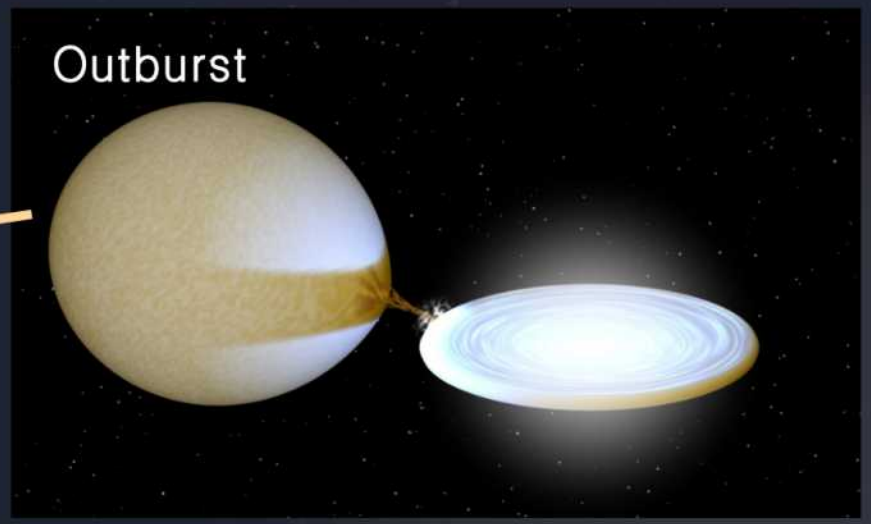


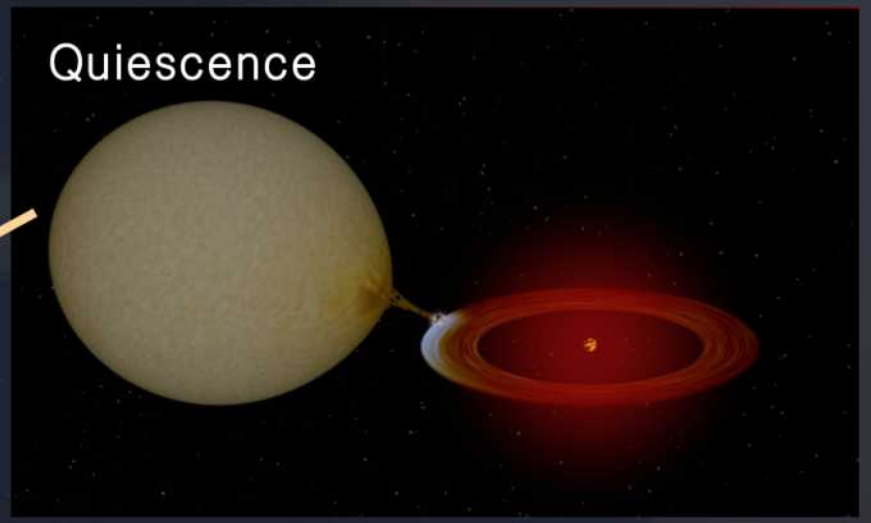


Charles et al. 2022, Corral-Santana et al. 2016

Transient BH X-ray binary







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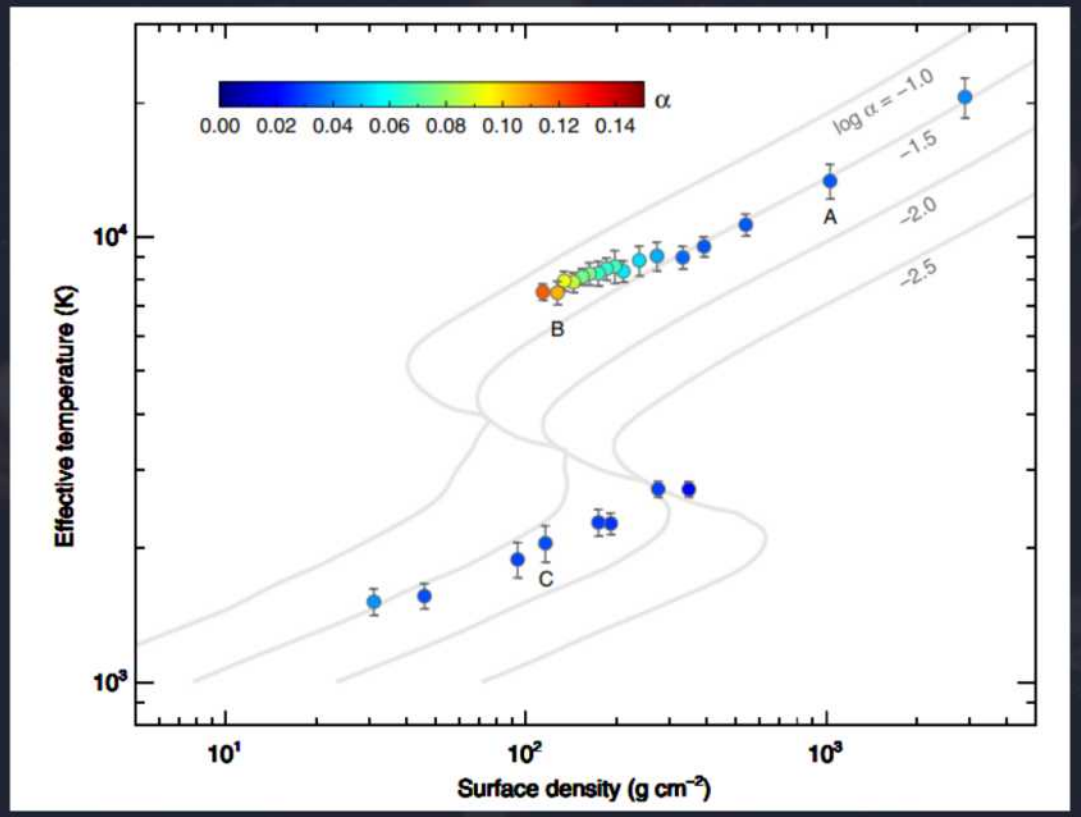
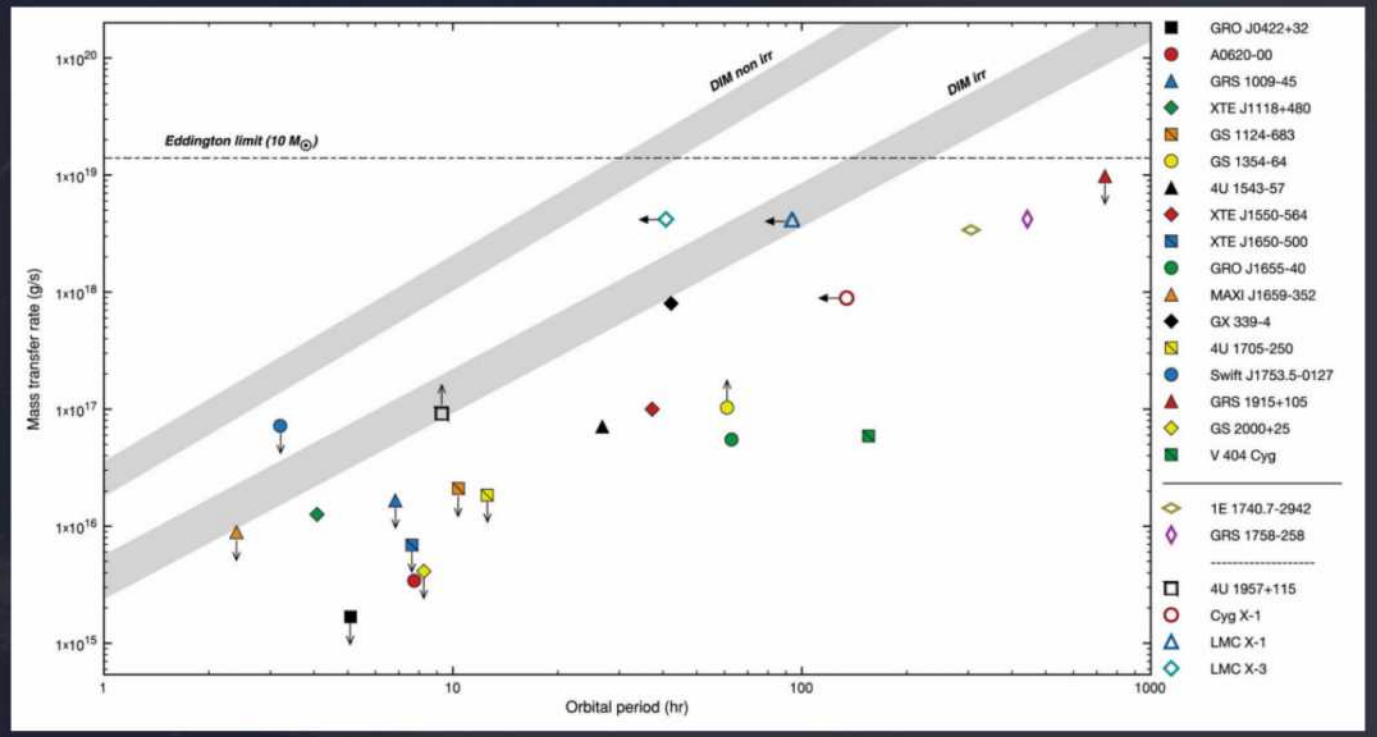
Why are they transient? -- disk instability model

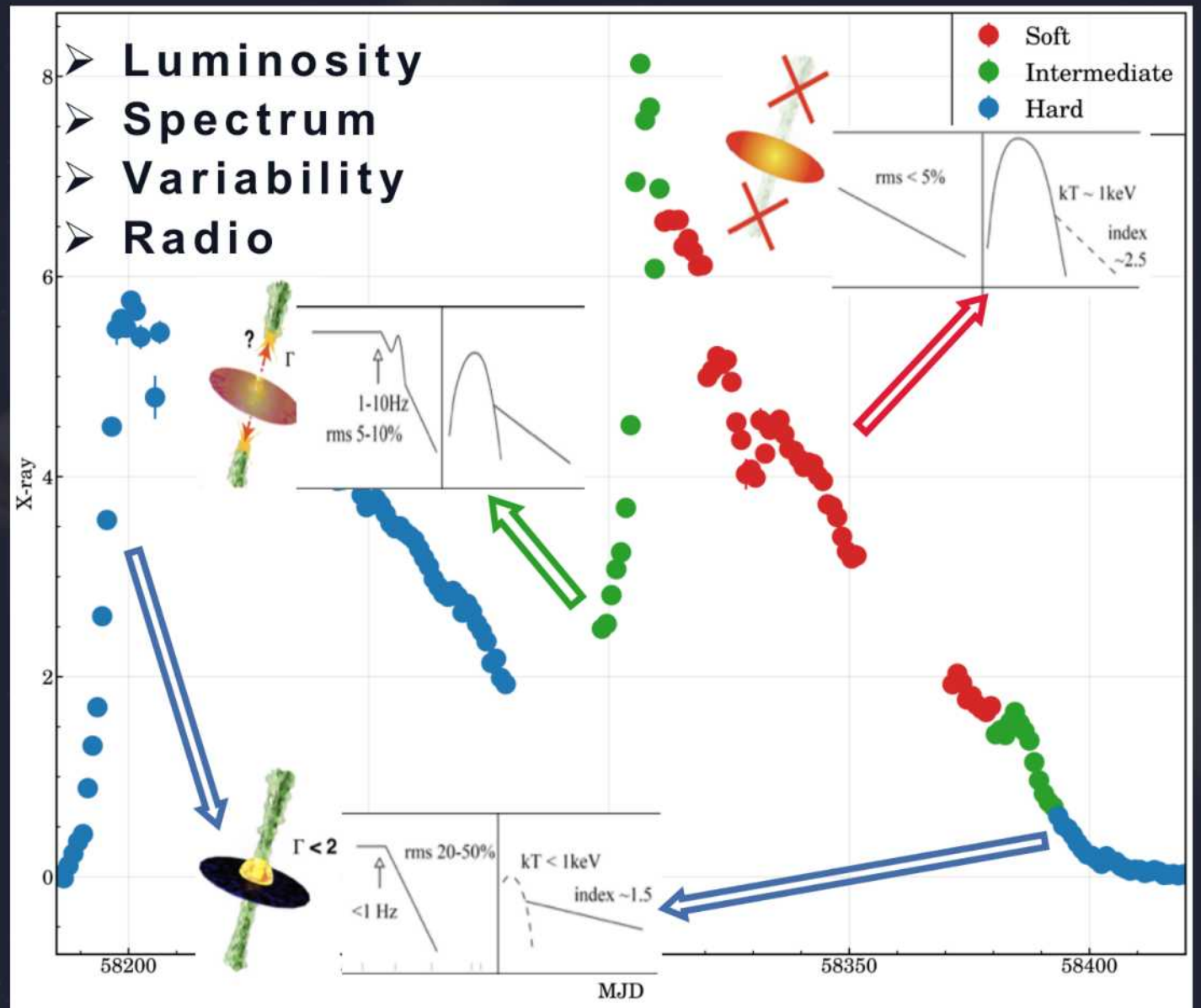


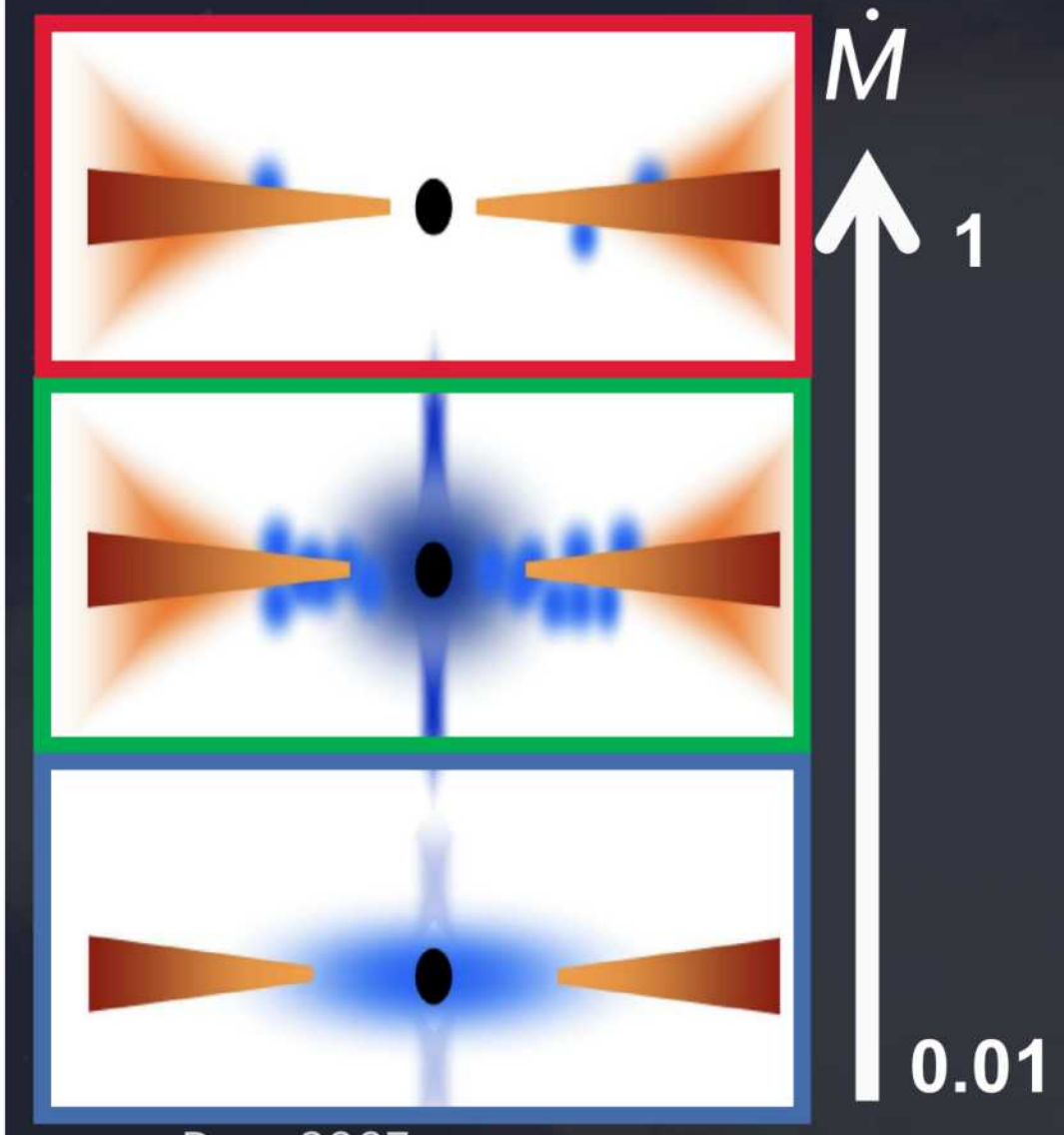
Hirose et al. 2014,Hameury 2020



Coriat et al. 2012

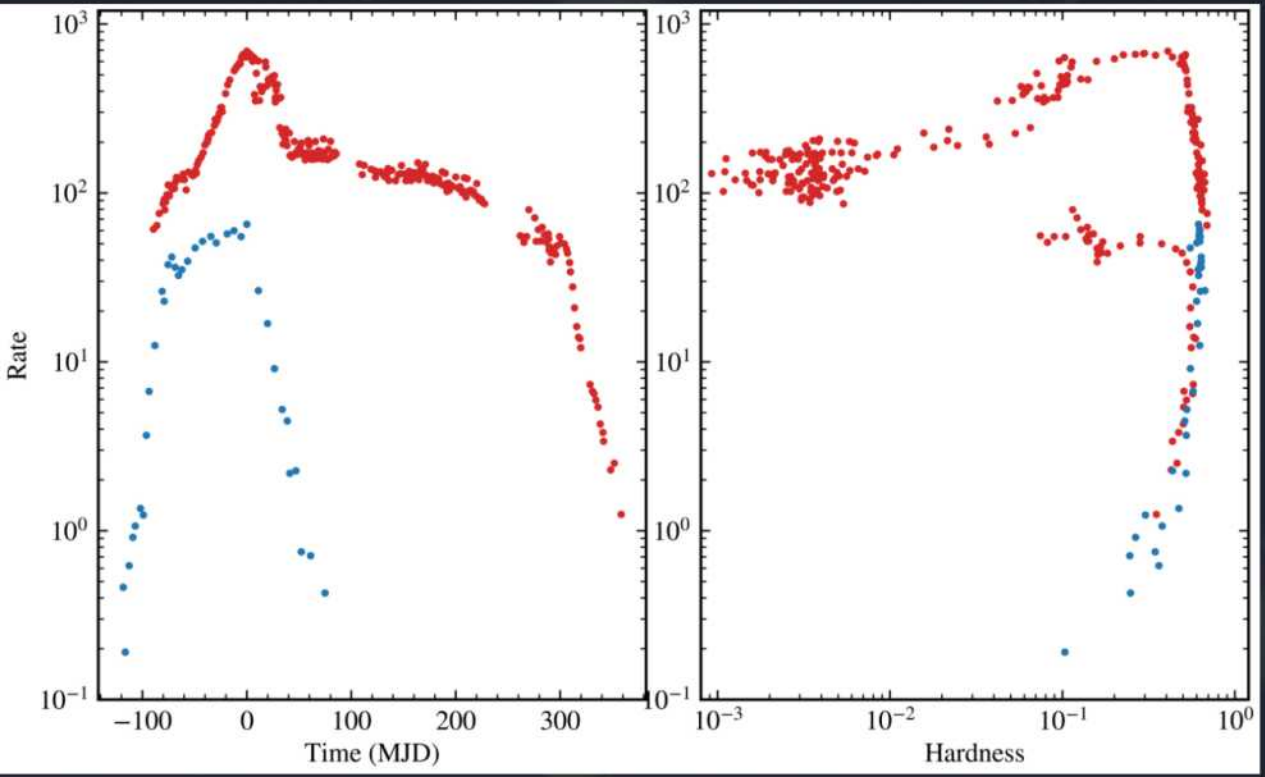
Ouburst Evolution -- Summary

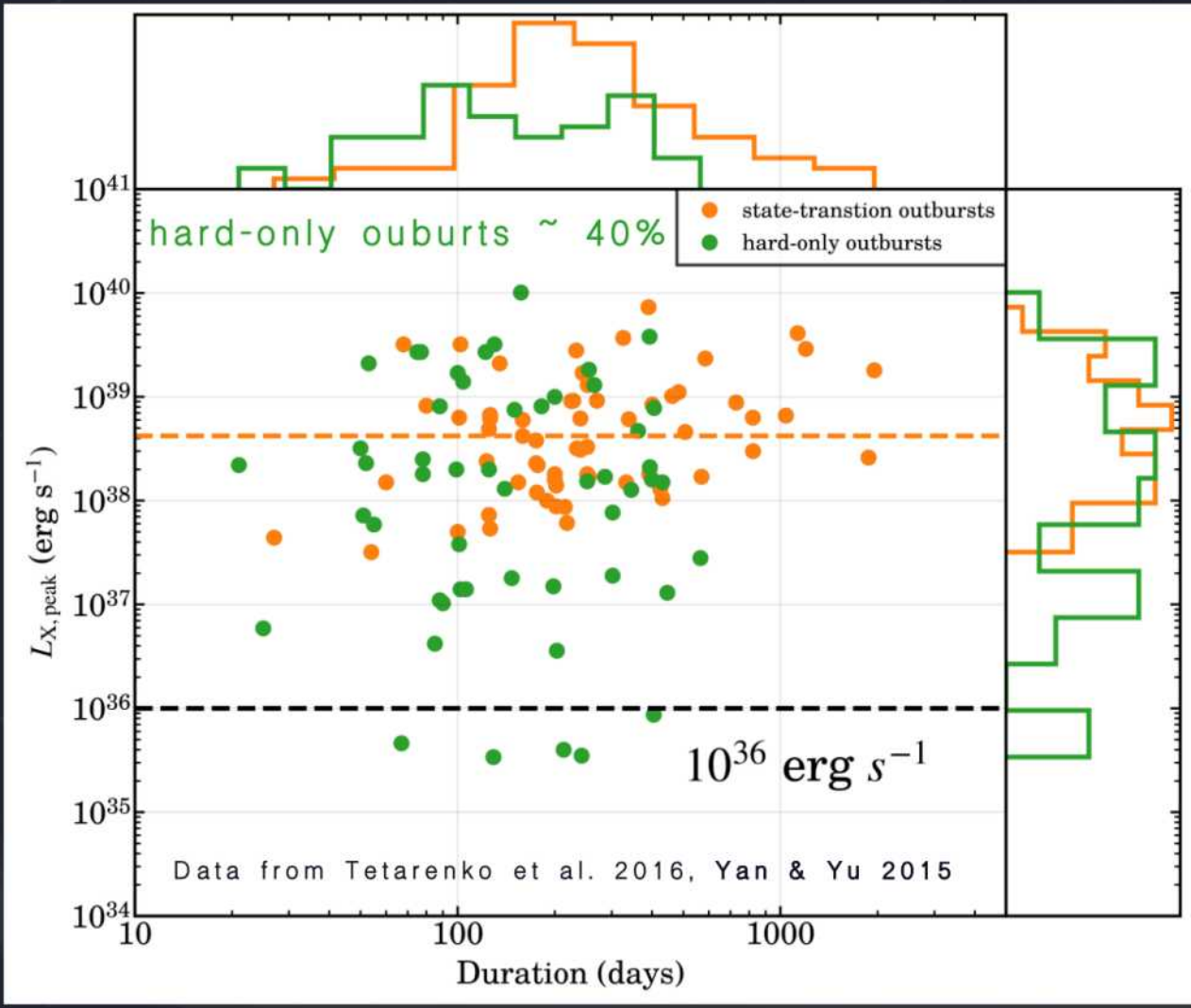




Done 2007

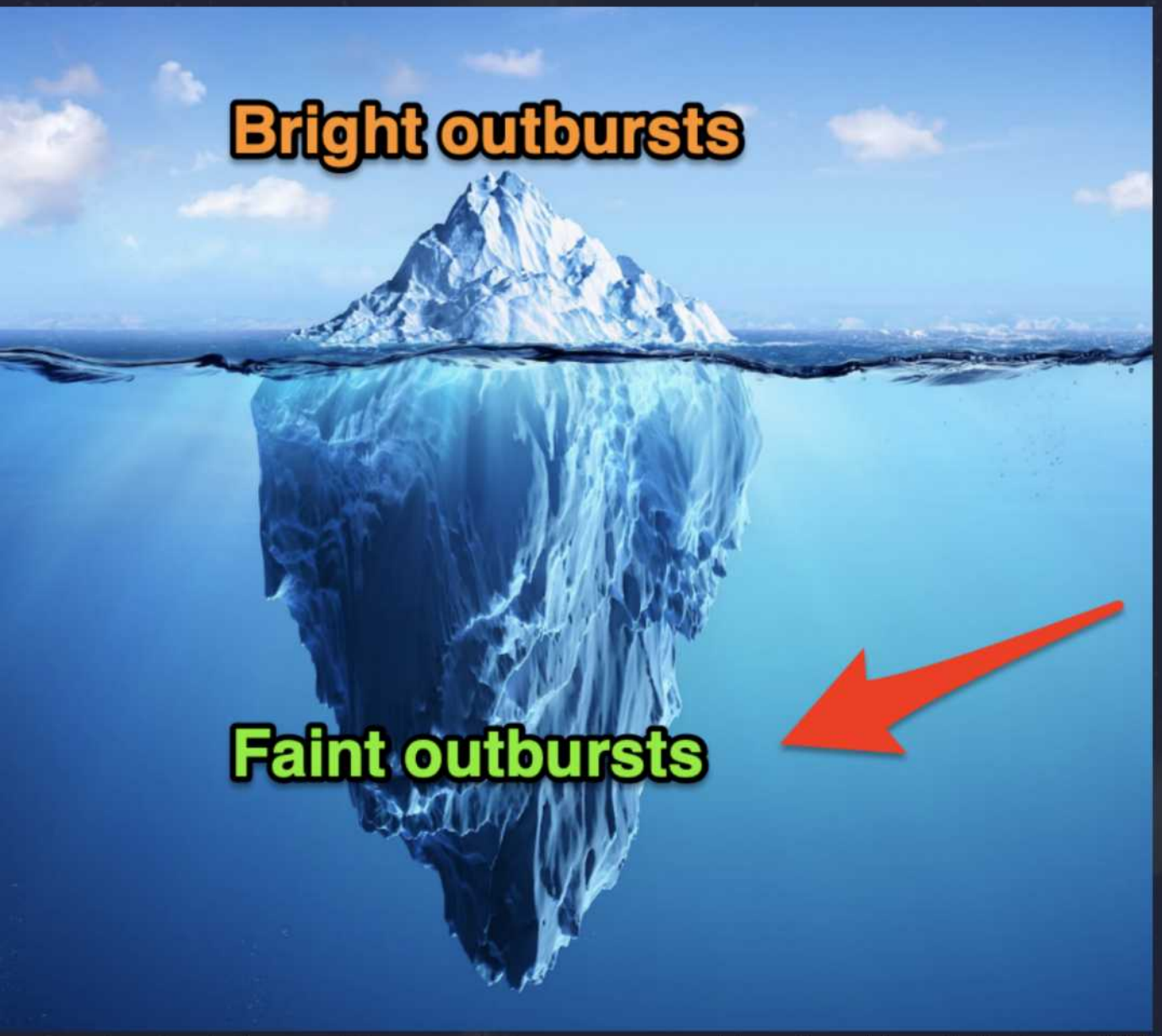
Hard-only outbursts



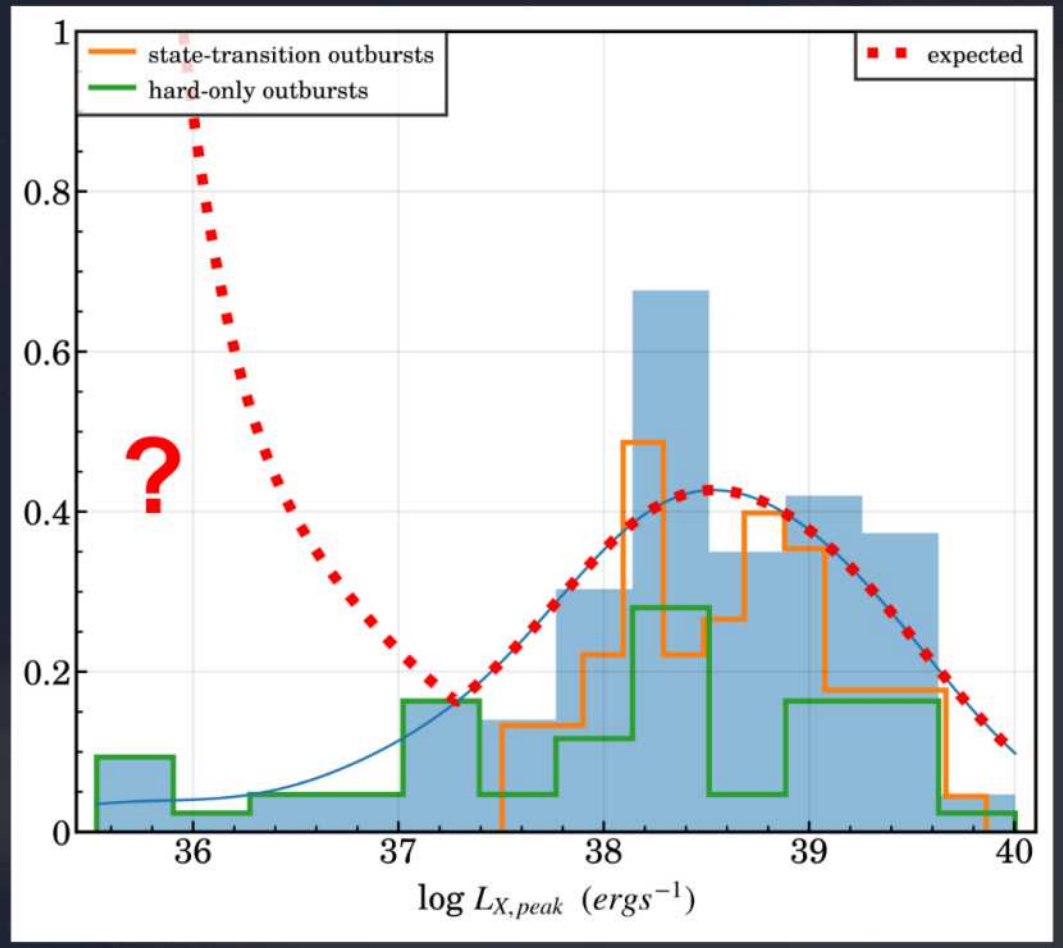


All the state-transition outbursts are bright

Not all the hard-only ouburts are faint



Outburst peak luminosity function

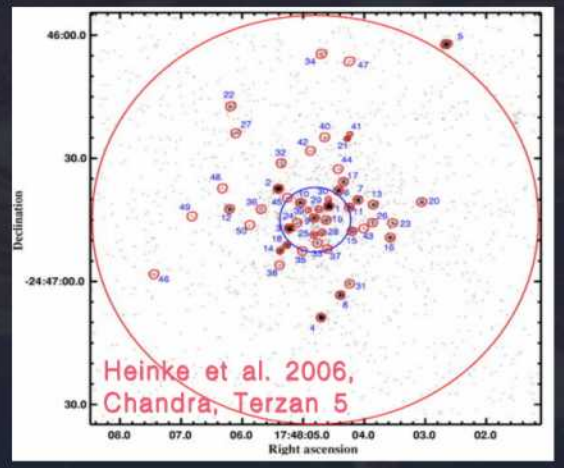


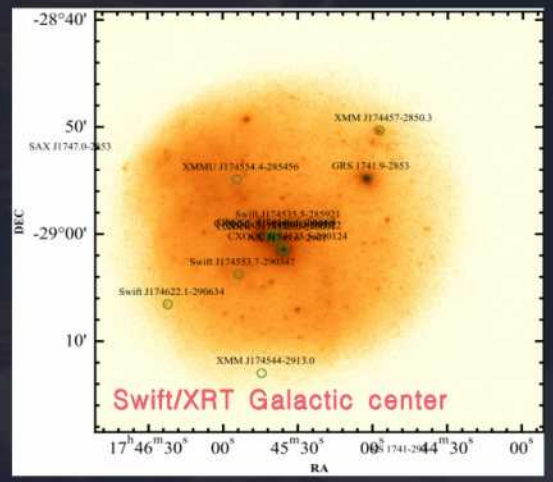
Data from Tetarenko et al. 2016, Yan & Yu 2015

- bright outbursts are well studied by with many X-ray missions

Detection of faint outbursts

- Monitoring observations targeted Galactic center/globular clusters -- NS



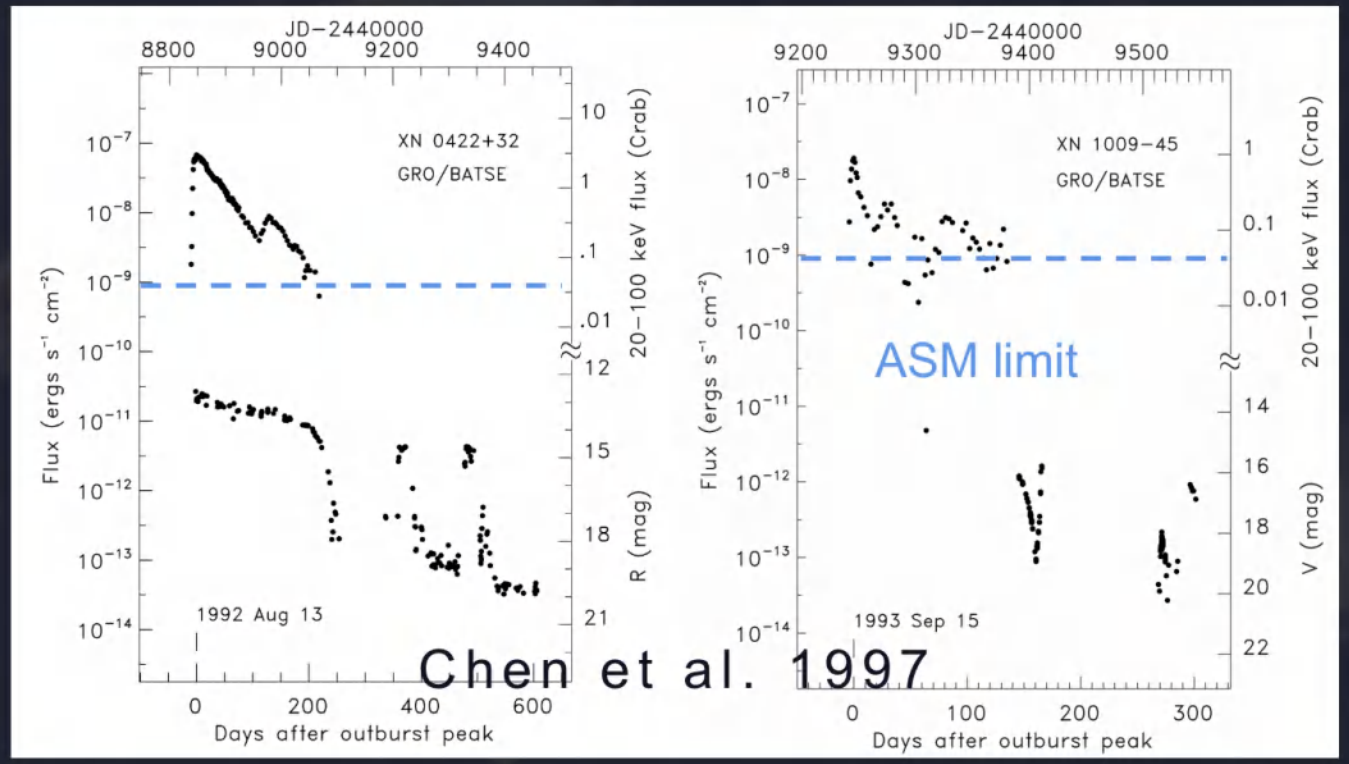


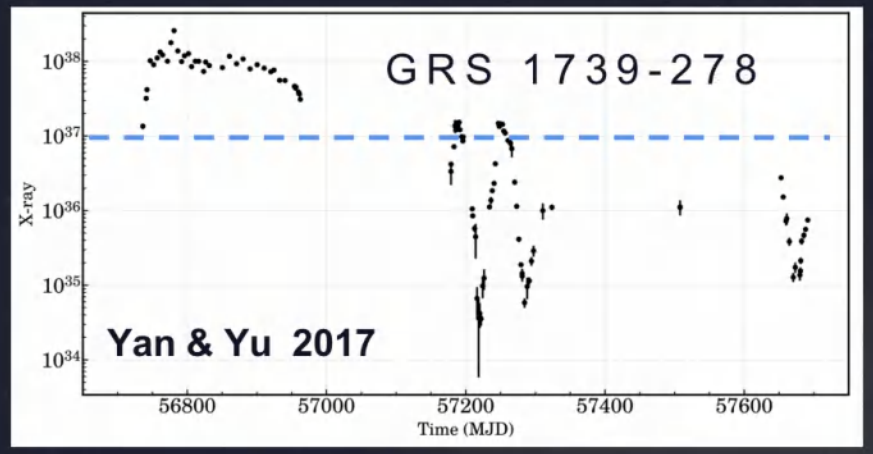
very faint X-ray transients
$< 10^{36}$ erg s^{-1}

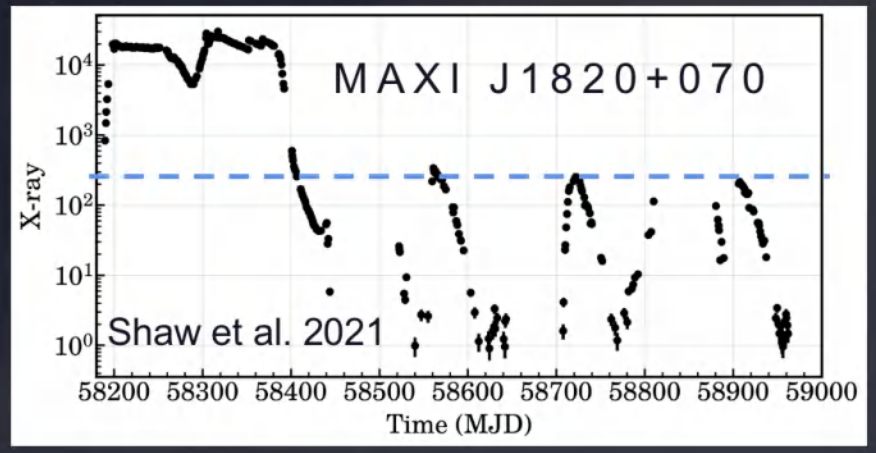
Wijnands et al. 2006

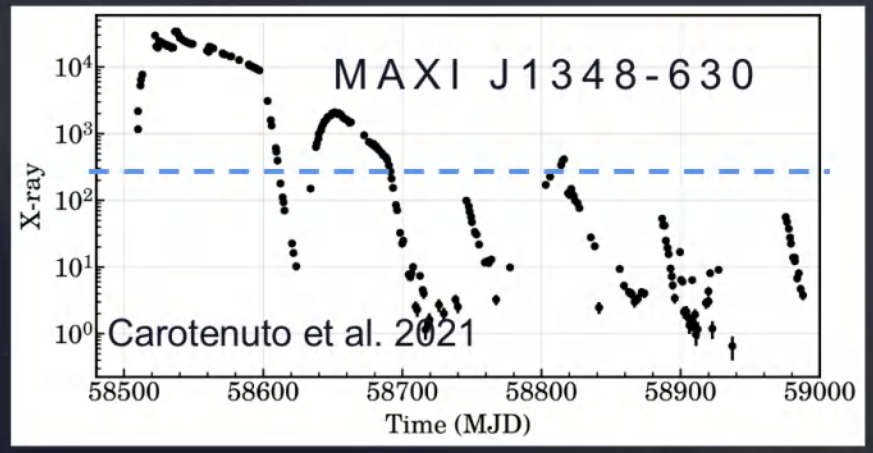
- Radio/optical/X-ray monitoring observations during quiescence
- Following up observations after returning to the quiescence

Mini-outbursts
--unexpected by the DIM

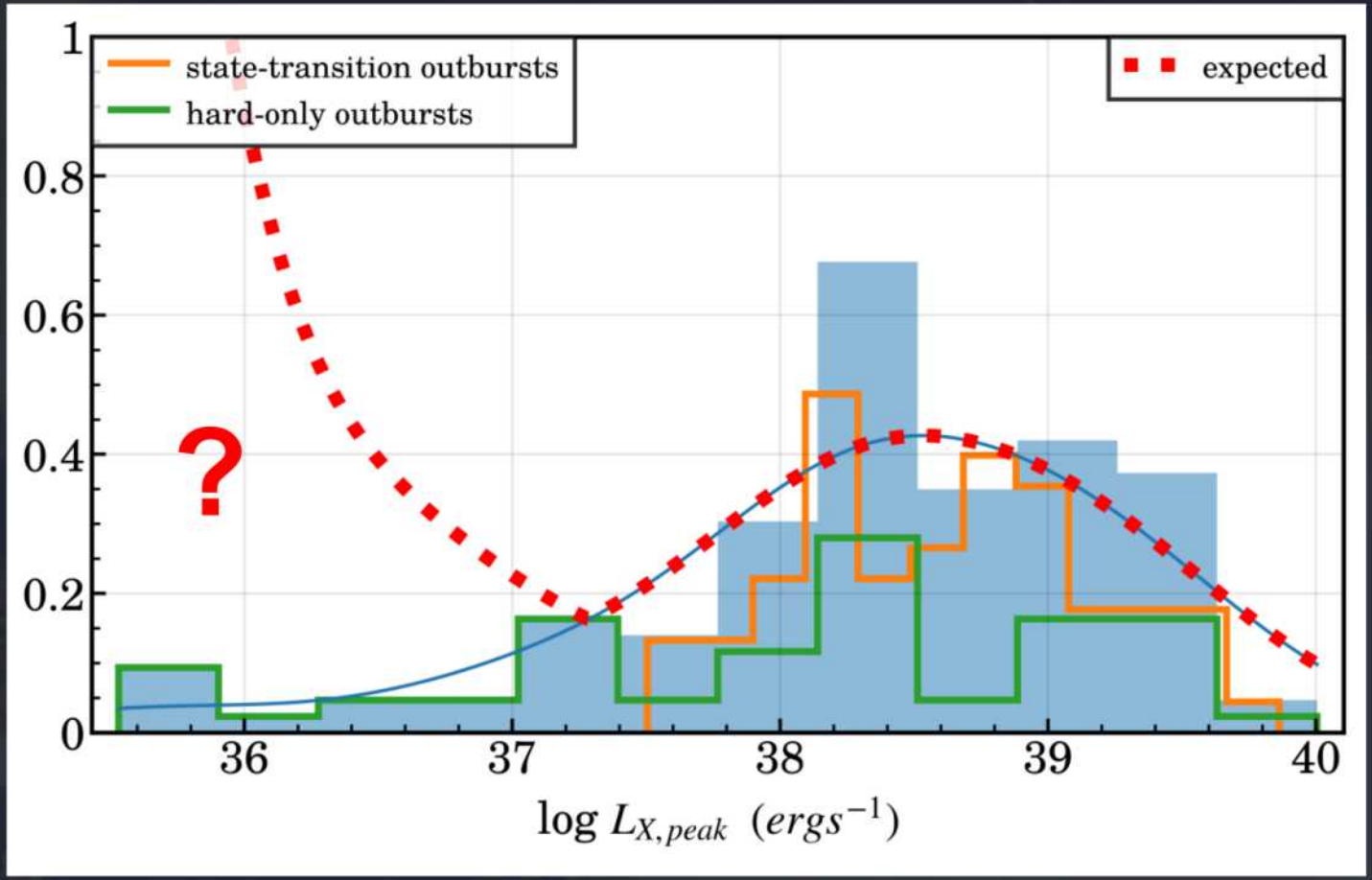








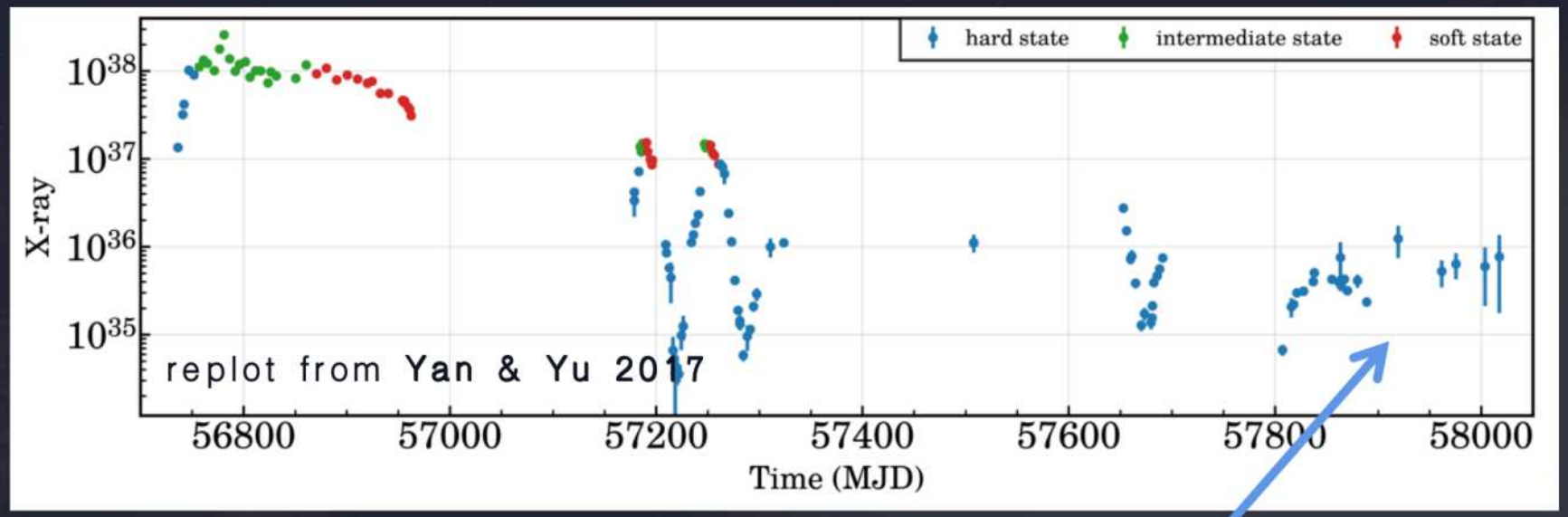
Similar mini-outbursts also appear in other accreting systems



Are the mini-outbursts are hard-only outbursts ?

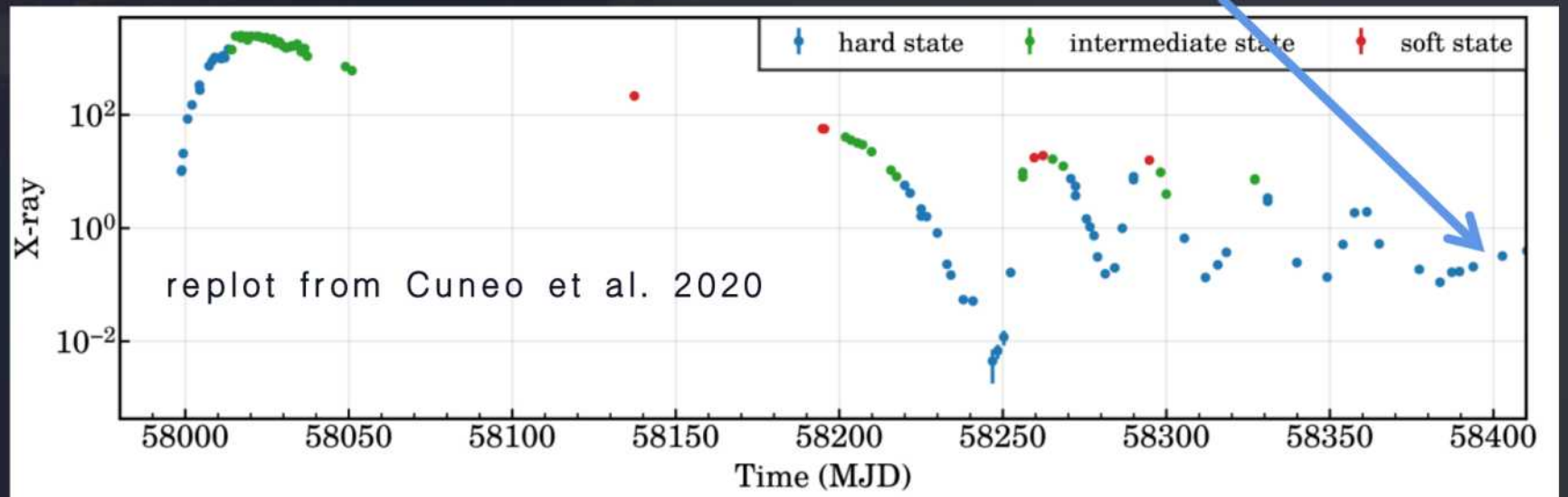
Mini-outbursts of two BH XRB with state transitions

GRS 1739-278
3×10^{34}––1.5×10^{37} *erg /s*

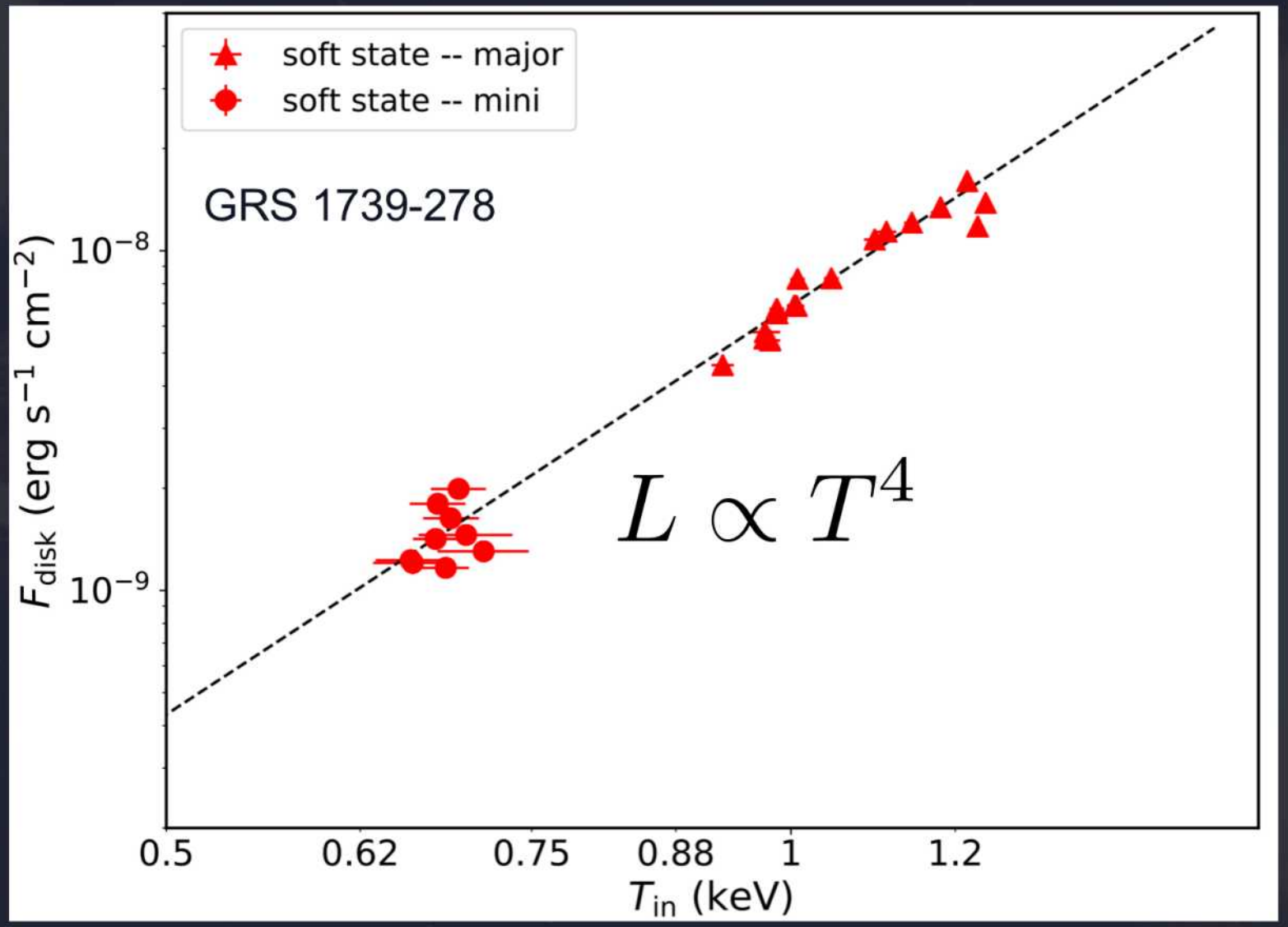


Metastable low-level accretion?

MAXI J1535-571
4×10^{34}––6×10^{36} *erg /s*

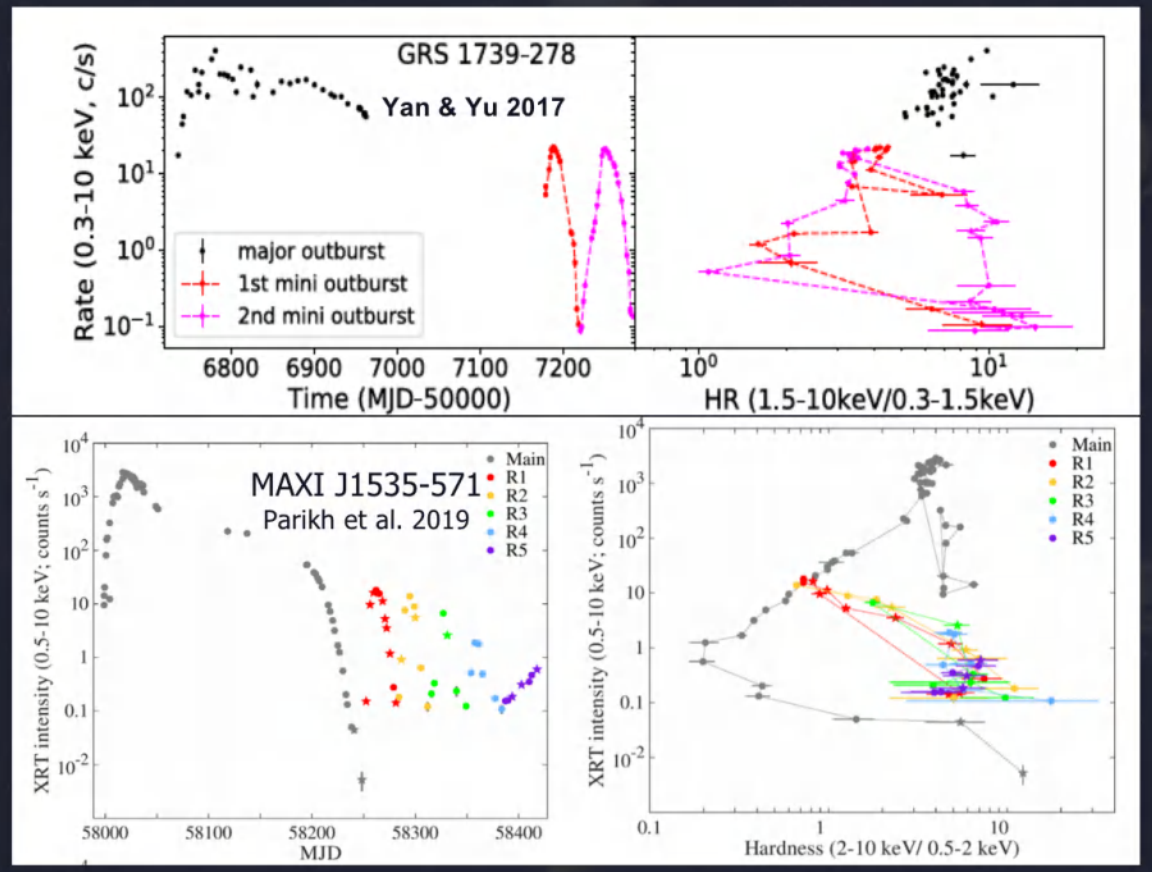


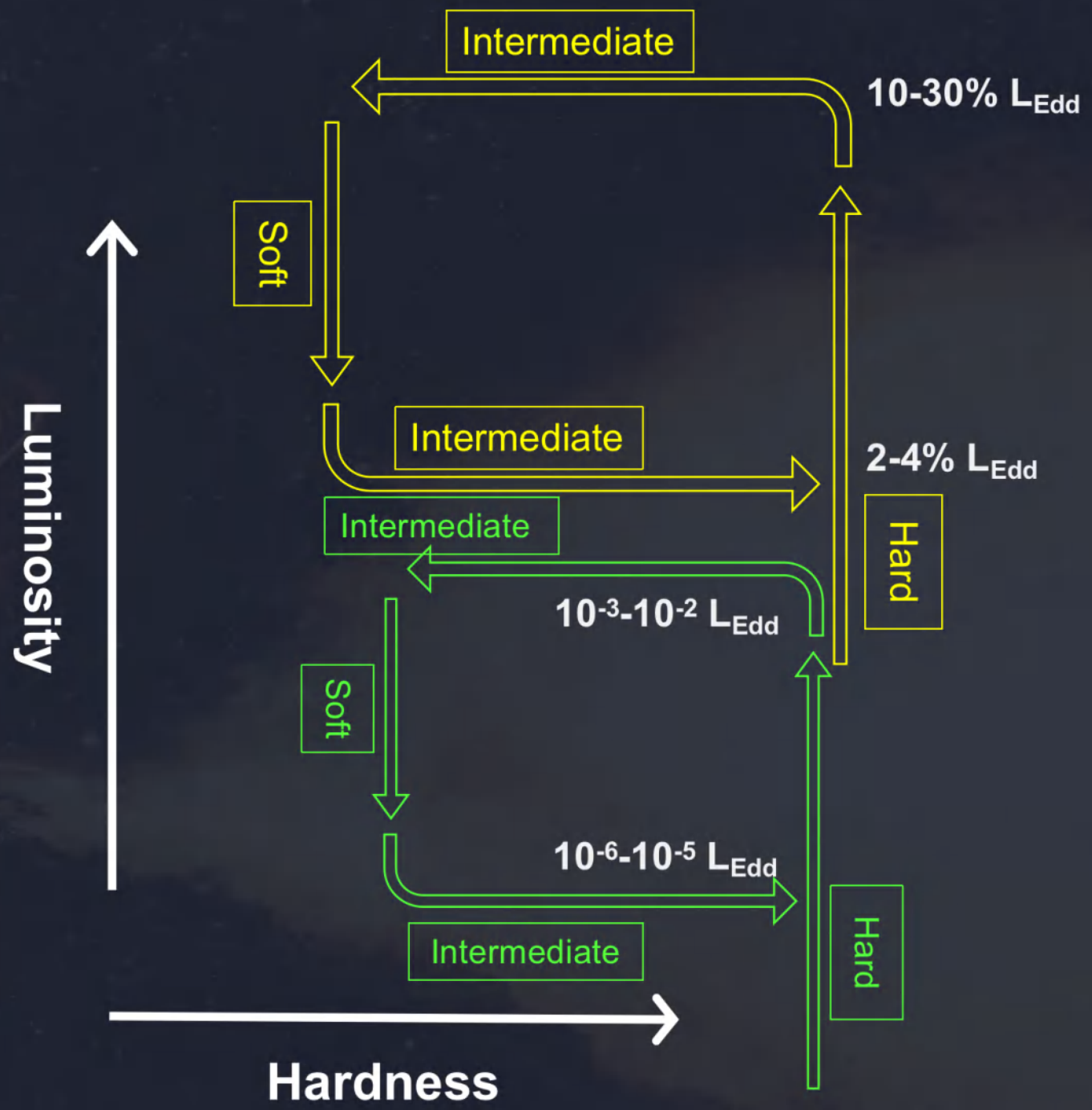
R_{in} during soft state of mini-outbursts -- ISCO



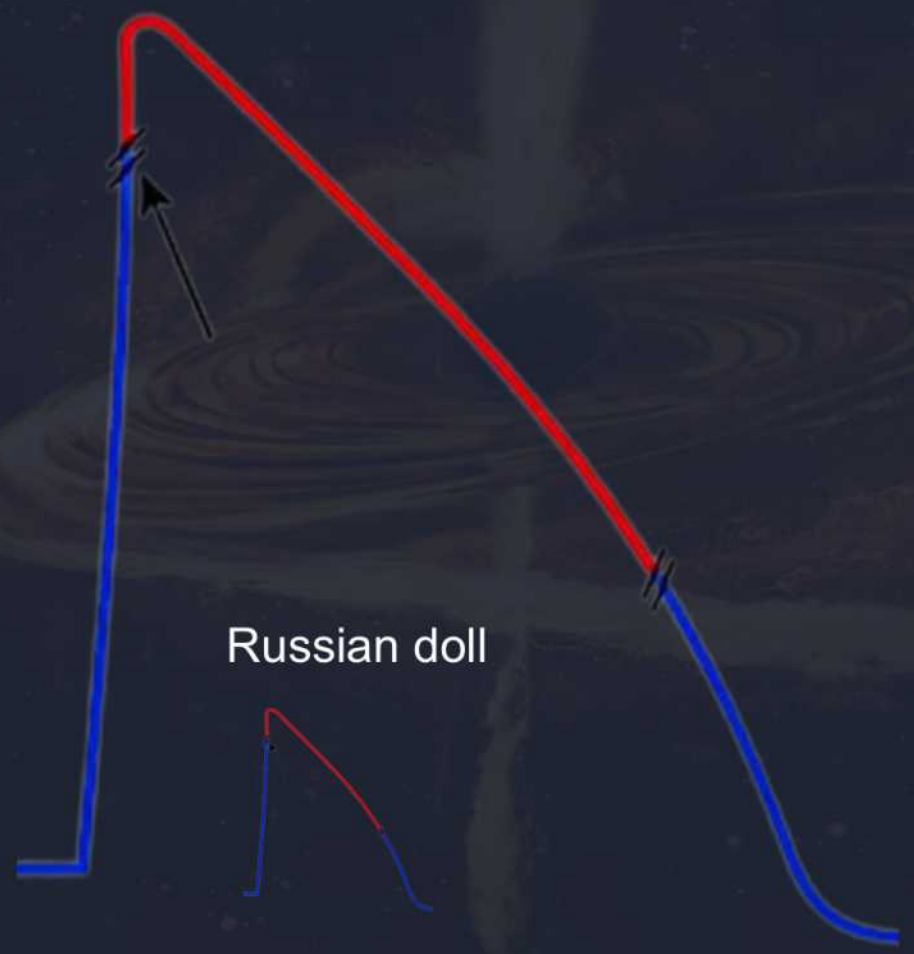
Yan & Yu 2017

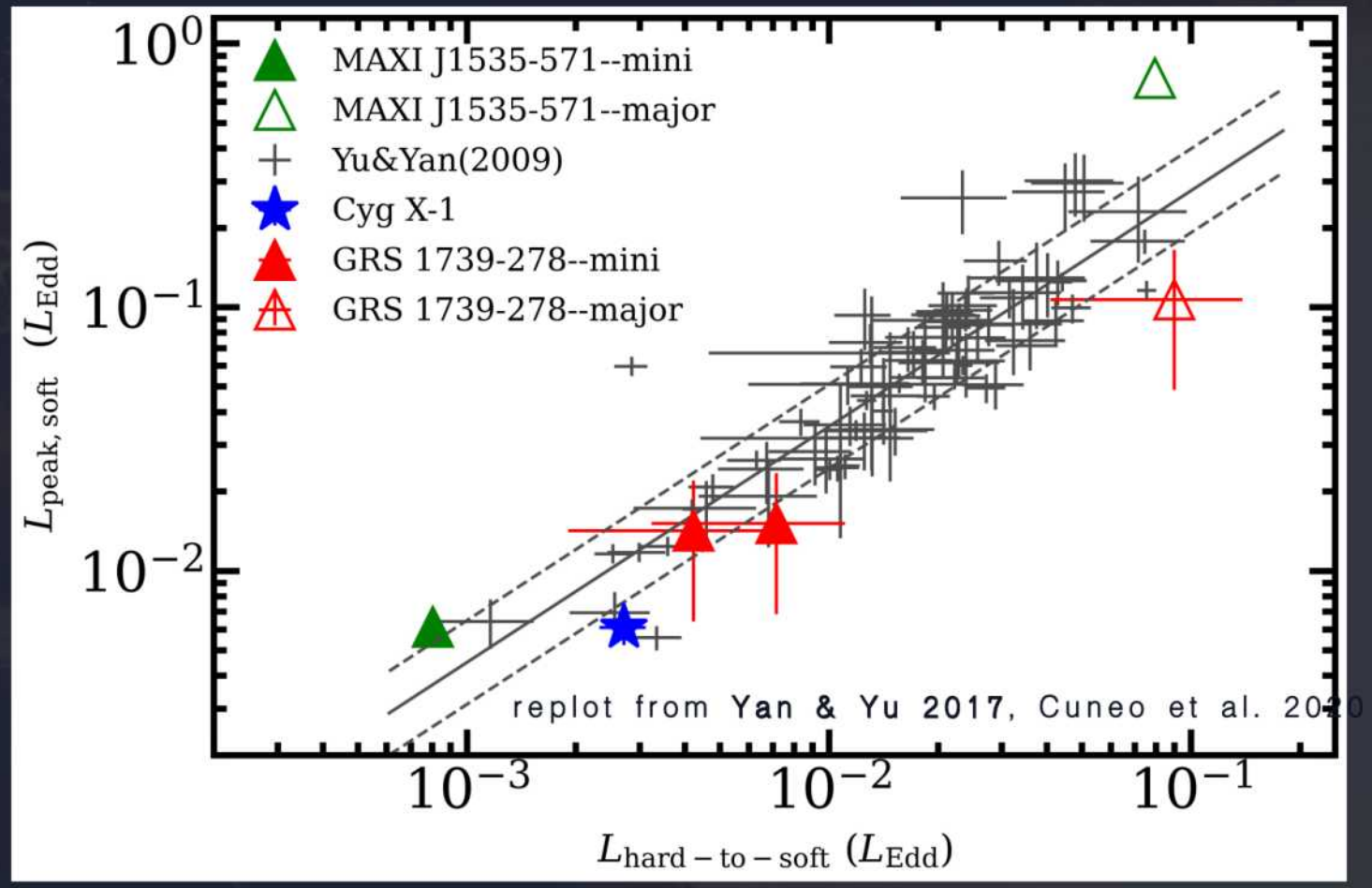
HID of mini-outburts





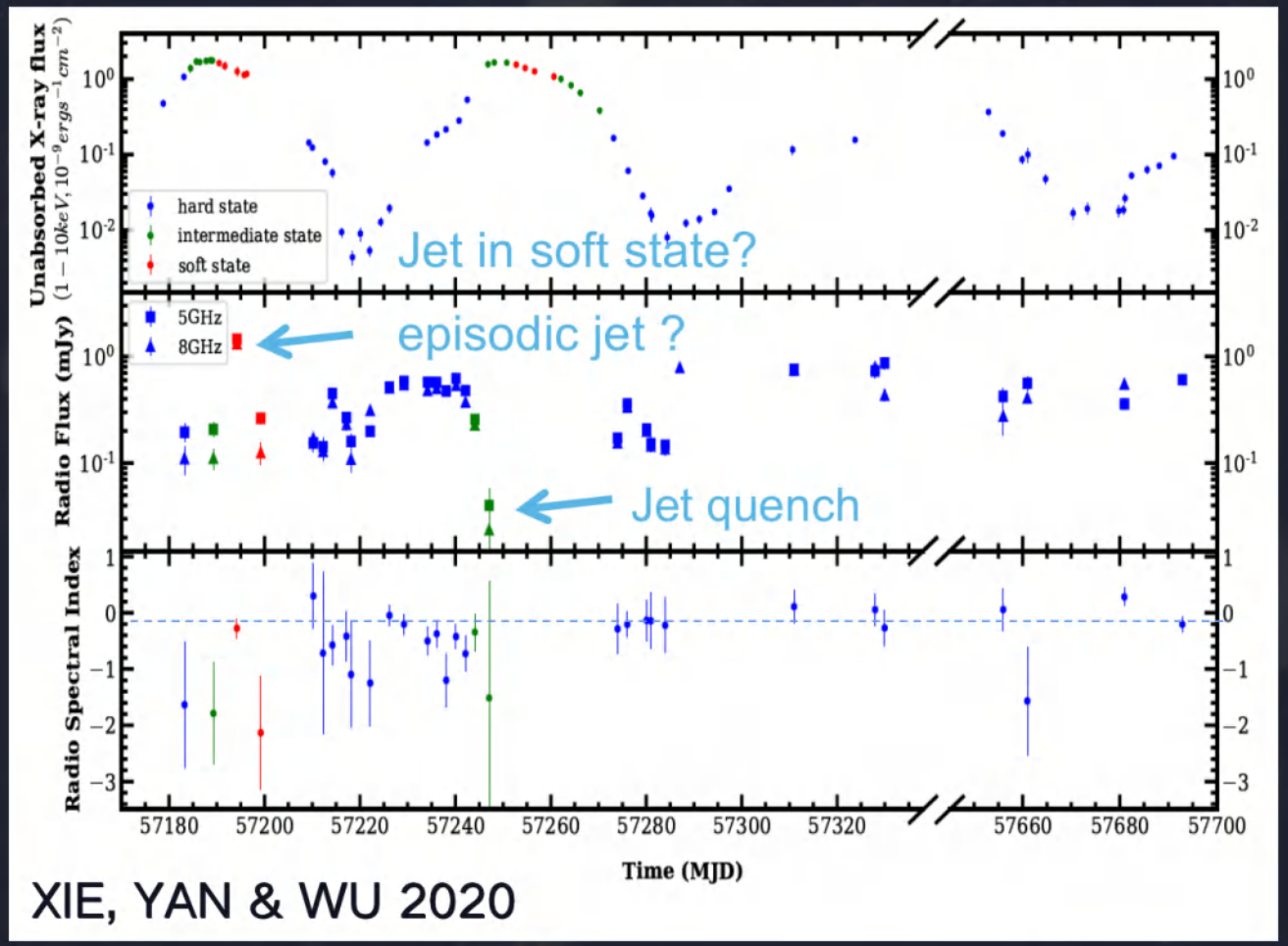
A universal correlation between L_{peak} and $L_{hard\text{-}to\text{-}soft}$

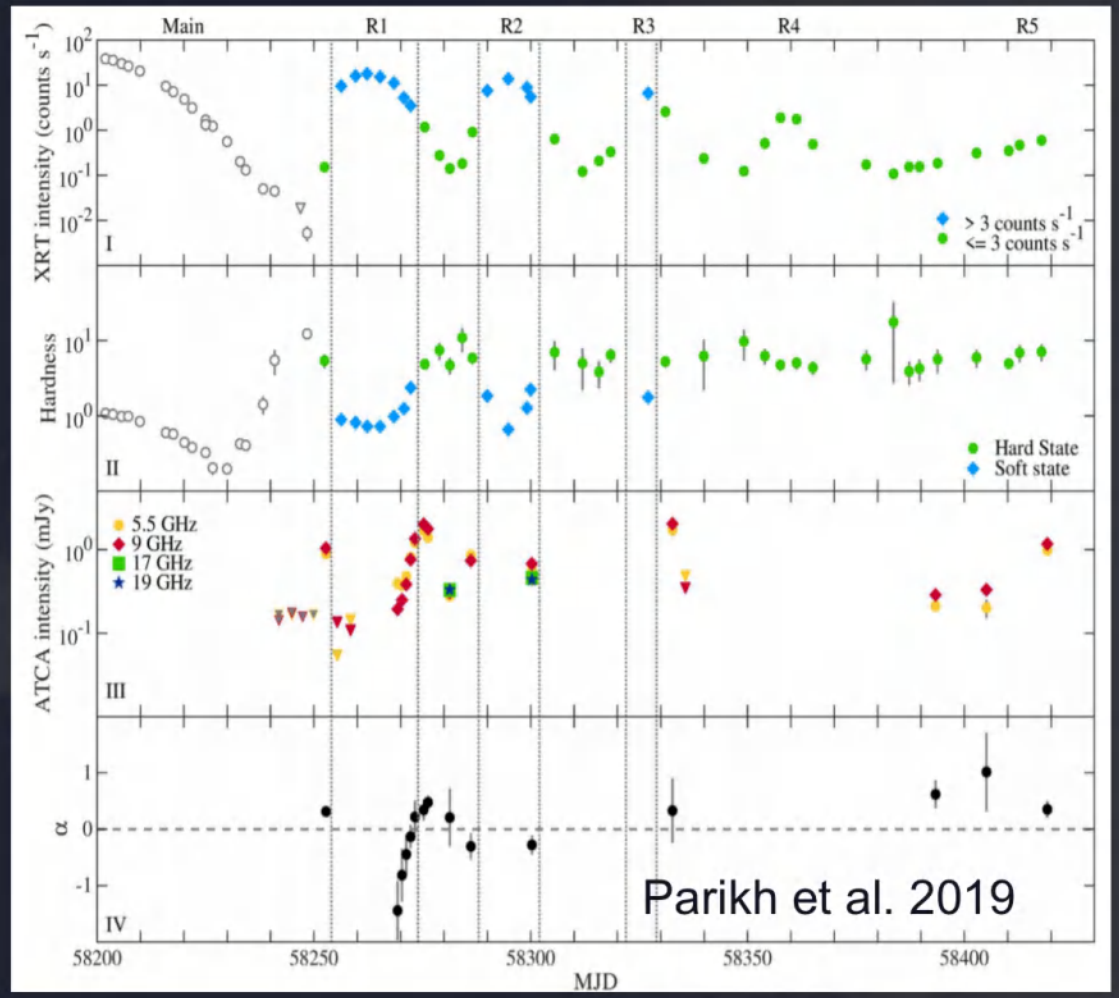




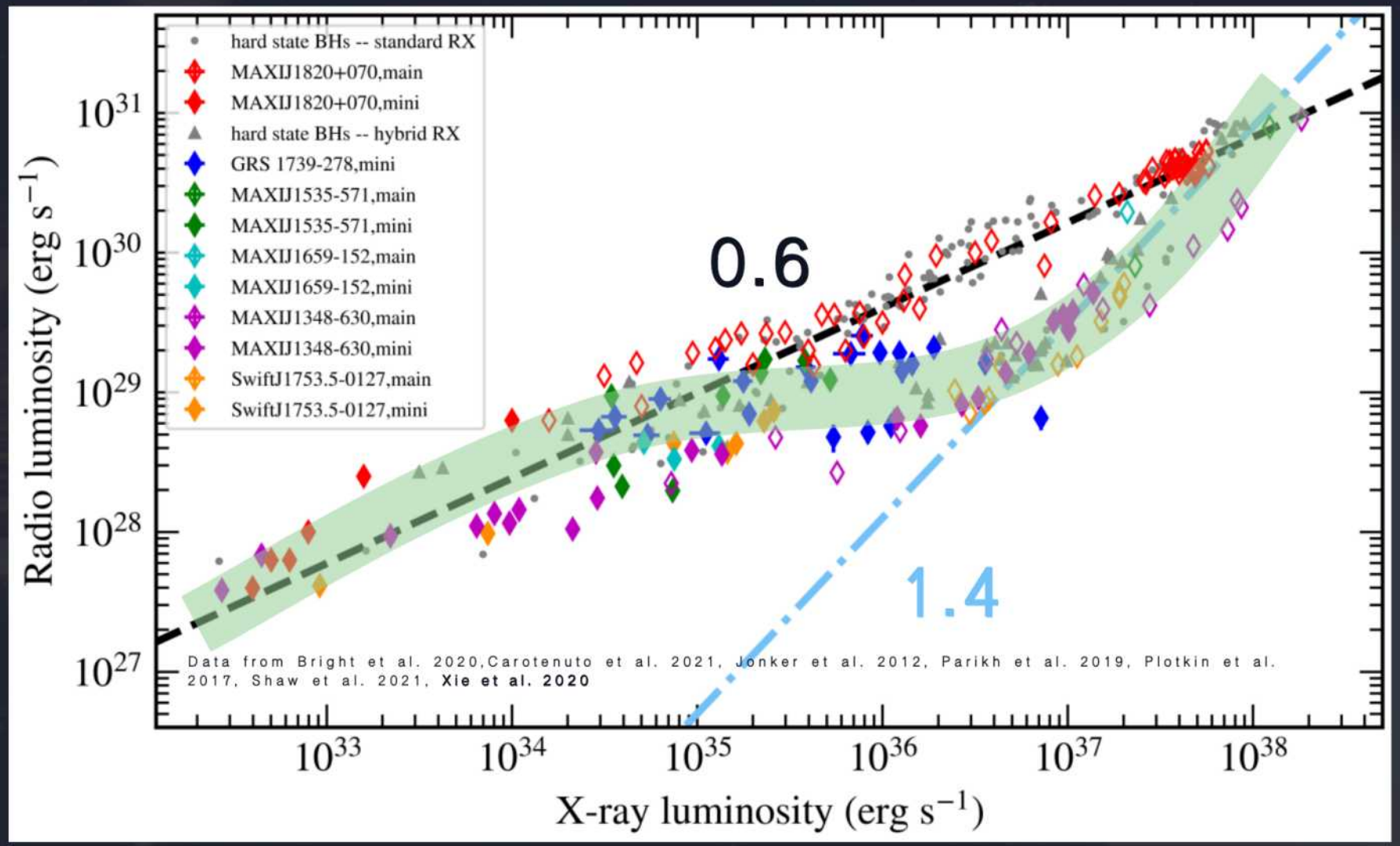
H-to-S transition luminosity is determined by the same mechanism

Radio jet evolution during the mini-outbursts with state transtion



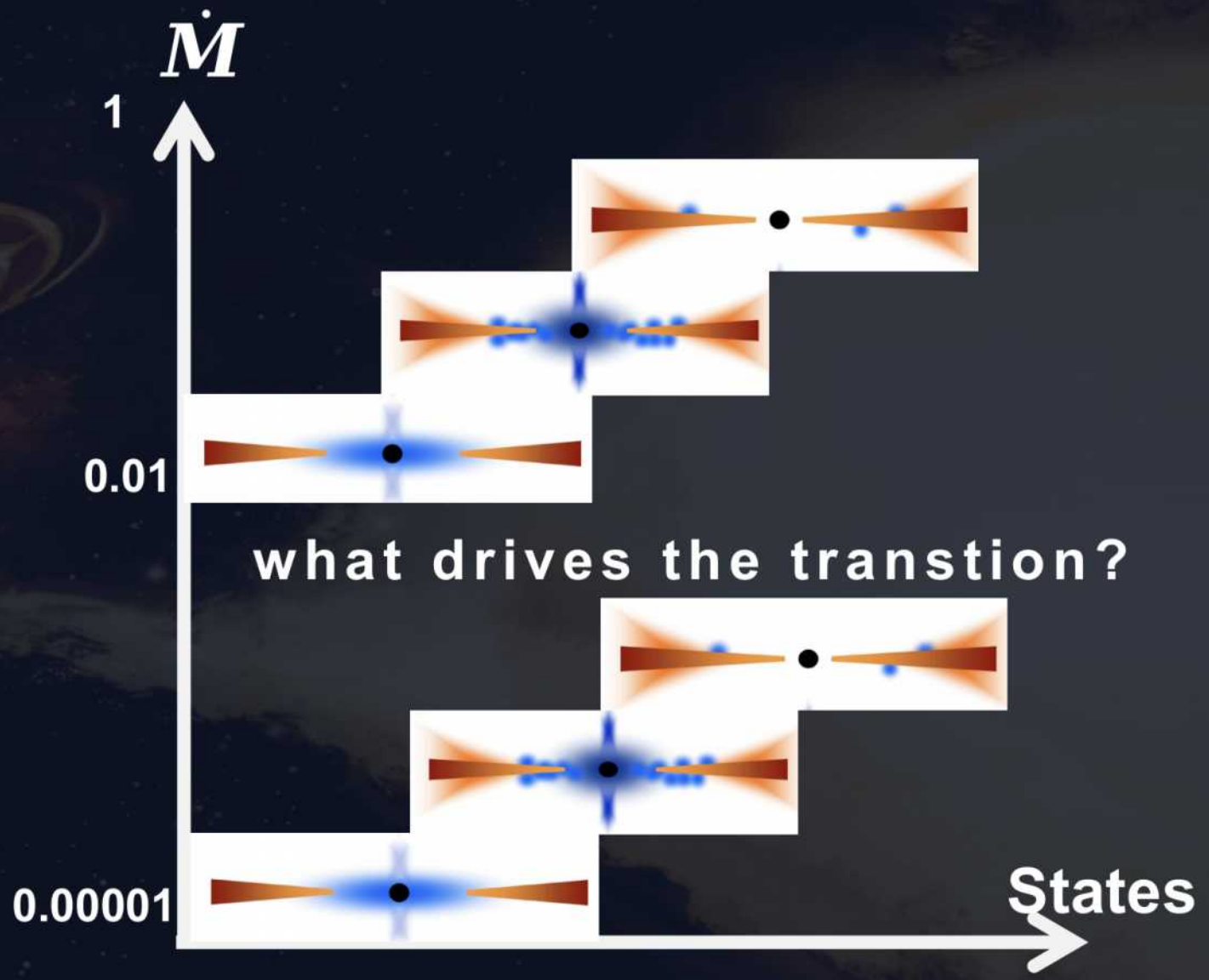


Hybrid R-X Correlation



Most sources with mini-outbursts show a hybrid R-X correlation (except MAXI J1820+070)

A new luminosity regime for accretion state evolution



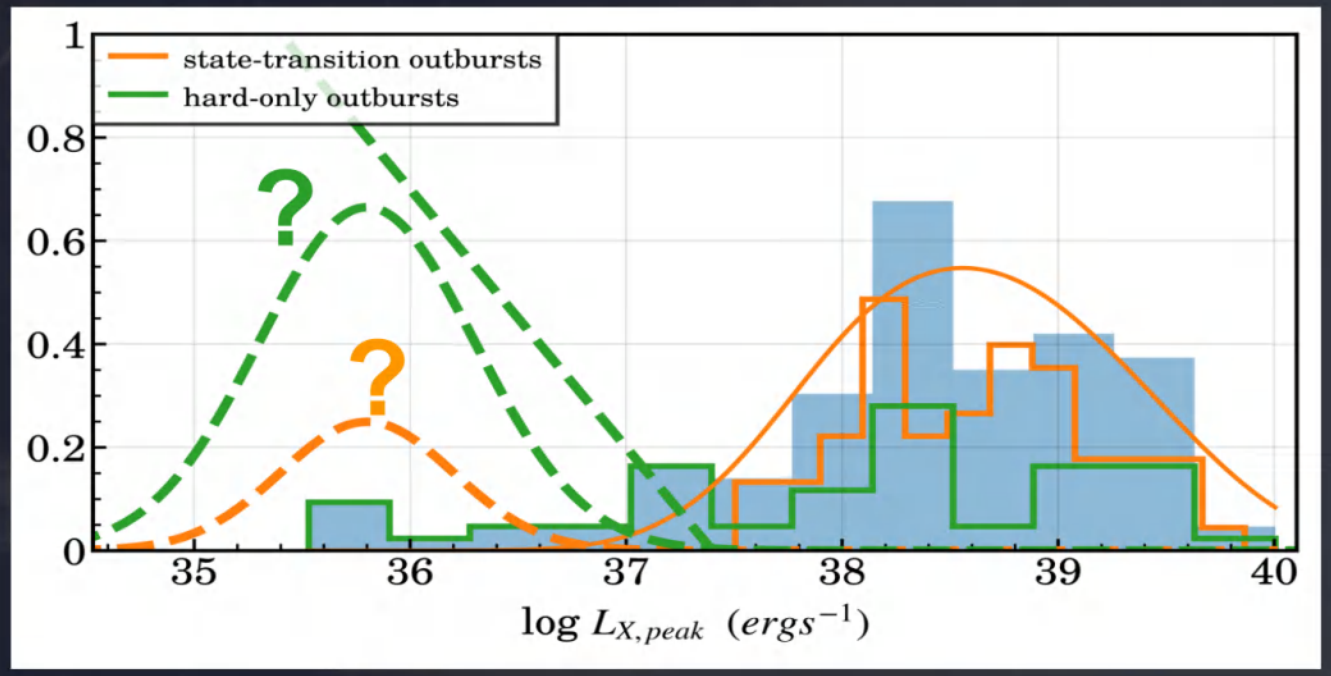
what drives the transtion?

mini-outburst evolution

- Truncated radius ?
- Radiative efficiency ?
- Jet -- episodic?

Most low luminosity accretion -- hard state

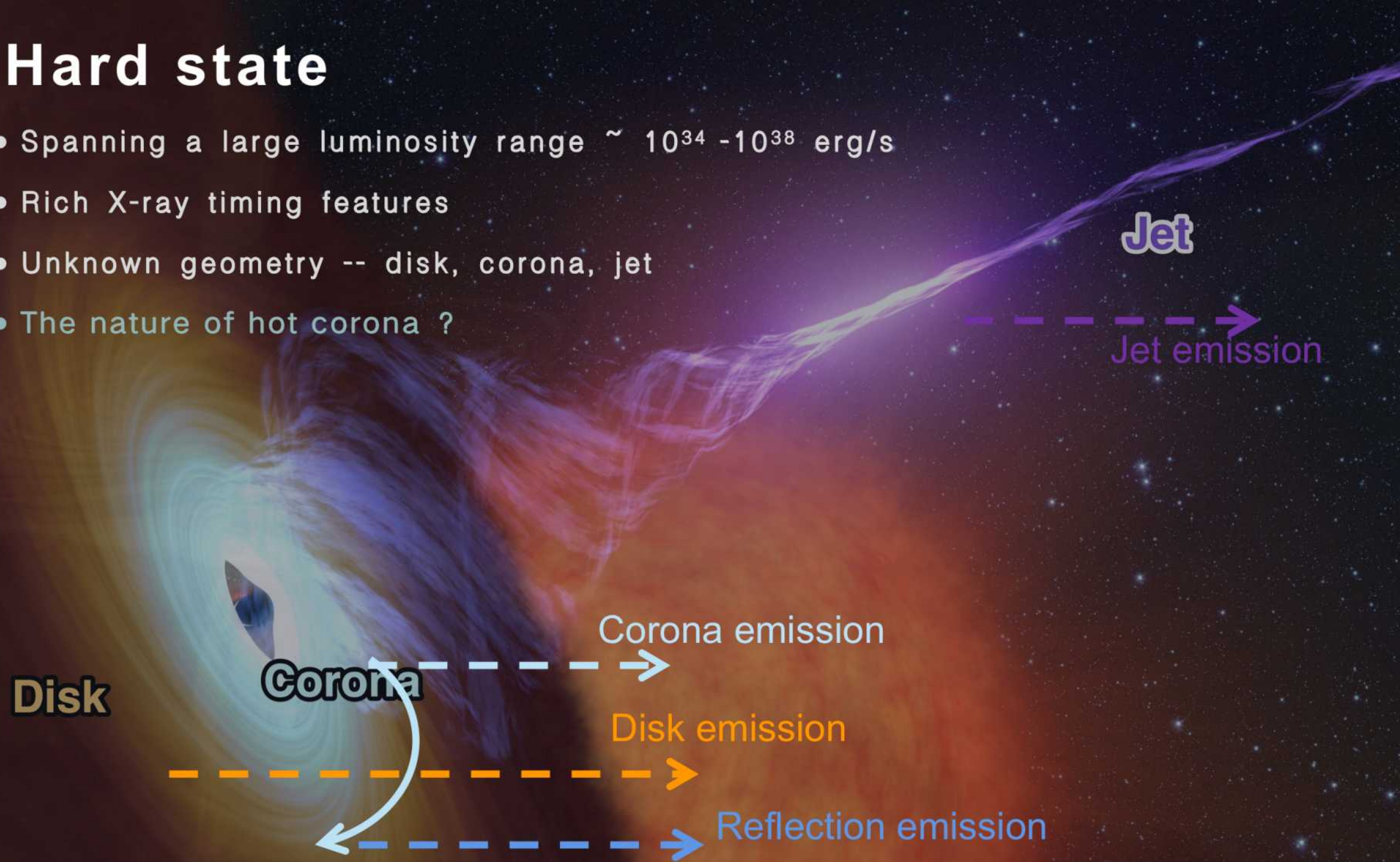
Name	Year	State transition
XTE J1859+226	1999	No X-ray data
GRS 1009−45	1994	No X-ray data
GRO J0422+32	1993	YES ?
XTE J1650-500	2002	NO
MAXI J1659-152	2011	NO
Swift J1753.5-0127	2017	NO
MAXI J1820+070	2019	NO
MAXI J1348-630	2019	NO
V404 Cyg	2015	NO
MAXI J1535-571	2018	YES
GRS 1739-278	2017	YES



- Bi-model profile of outburst peak luminosity function?

Hard state

- Spanning a large luminosity range ~ 10^{34} -10^{38} erg/s
- Rich X-ray timing features
- Unknown geometry -- disk, corona, jet
- The nature of hot corona ?

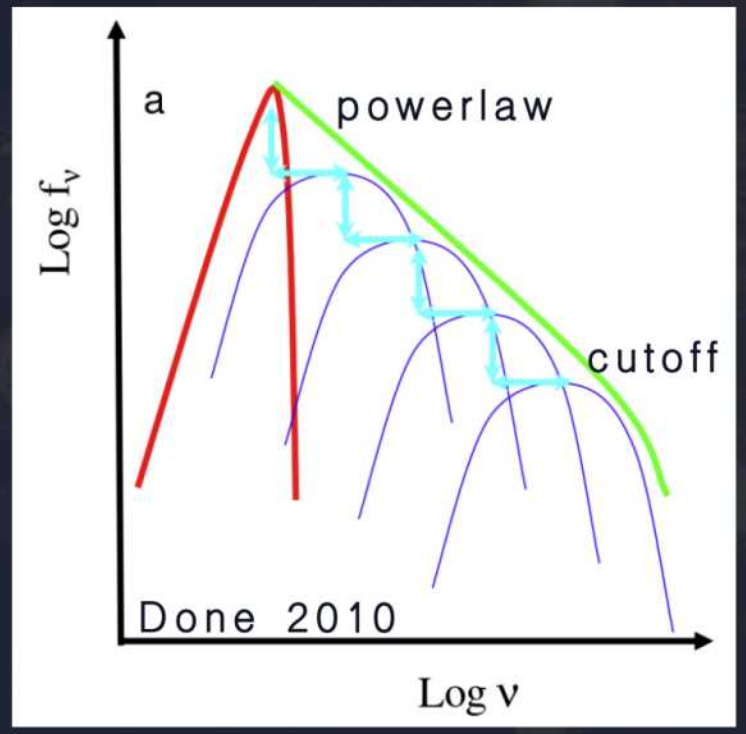


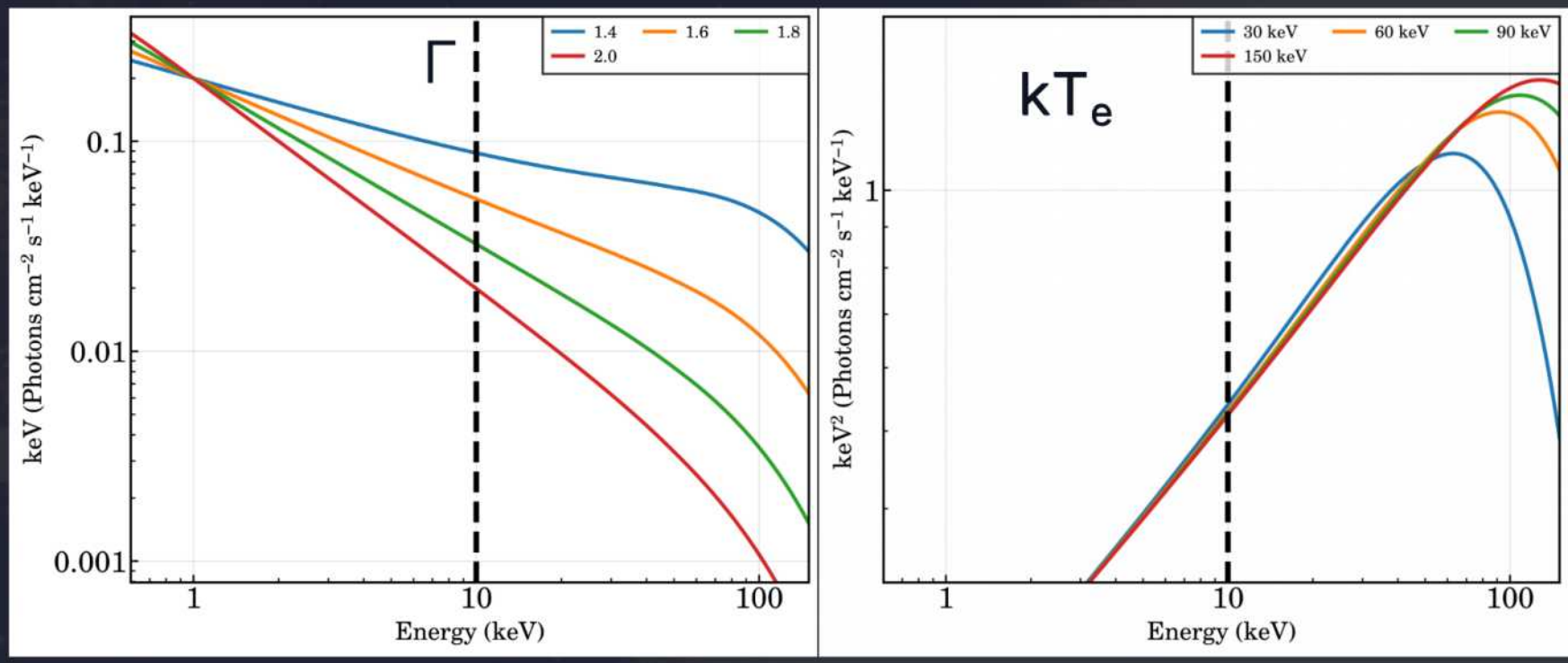
How to constrain the nature of corona ?

- Physical parameters, and the relations between them
- Corona geometry (size, position, shape).
- Corona/disk geometry (lamppost, sandwich, toroidal, spherical, slab)

Compton emission

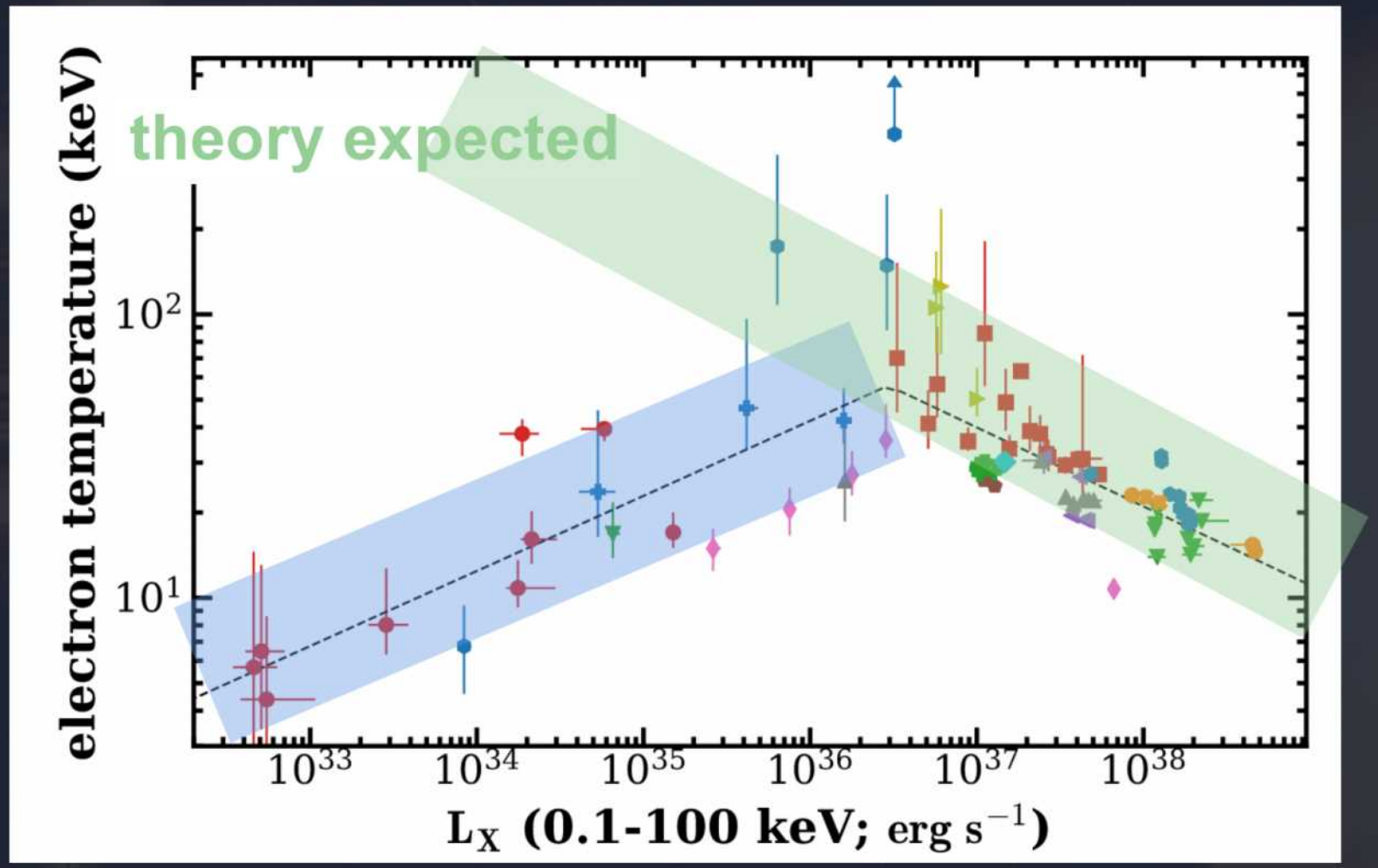
- A broad spectral coverage up to ~100 keV with high sensitivity is fundamental to measure the parameters of the corona emission at low luminosity





High sensitivity and broad energy range of NuSTAR

Unexpected kT_e-L_X correlation at low L of BHXRB



Yan et al. 2020

New insights into low *L* accretion

- Parallel accretion states evolution track at low luminosity regime.

  What dirves the accretion state evolution at low luminosity regime ?
  --accretion physics
  --accretion and ejection connection

- Corona temperature -- cooler when fainter.

  What determines the corona temperature at low luminosity ?
  -- the nature of corona
  -- heating/cooling mechanism