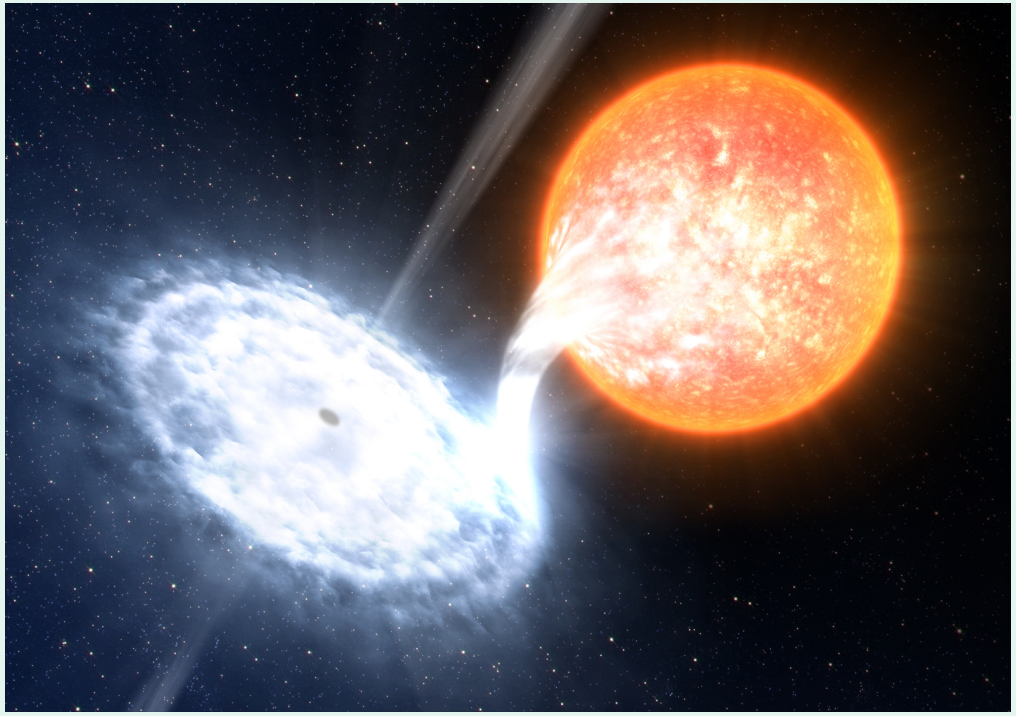
Hybrid hot flow as the source of optical-to-X-ray emission of black hole binaries



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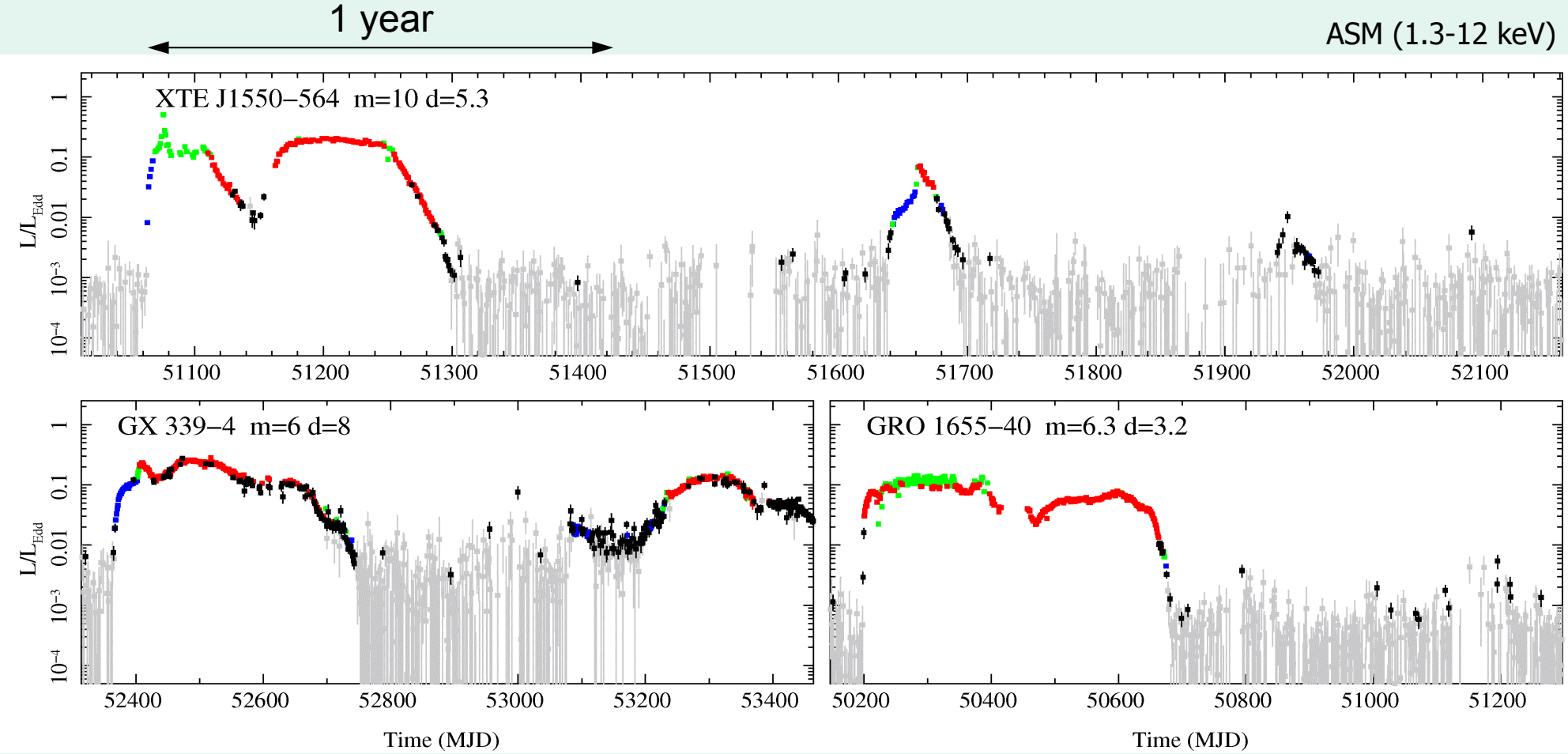
Veledina et al. 2011, ApJL, 737, L17; 2013, ApJ, 778, 165; MNRAS, 430, 3196
Poutanen & Veledina, 2014, SSRv, 183, 61
Poutanen, Veledina, Revnivtsev, 2014, MNRAS, 445, 398
Veledina et al. 2015, MNRAS, 454, 2855; 2017, MNRAS, in press

Rome, 08.06.2017

Plan:

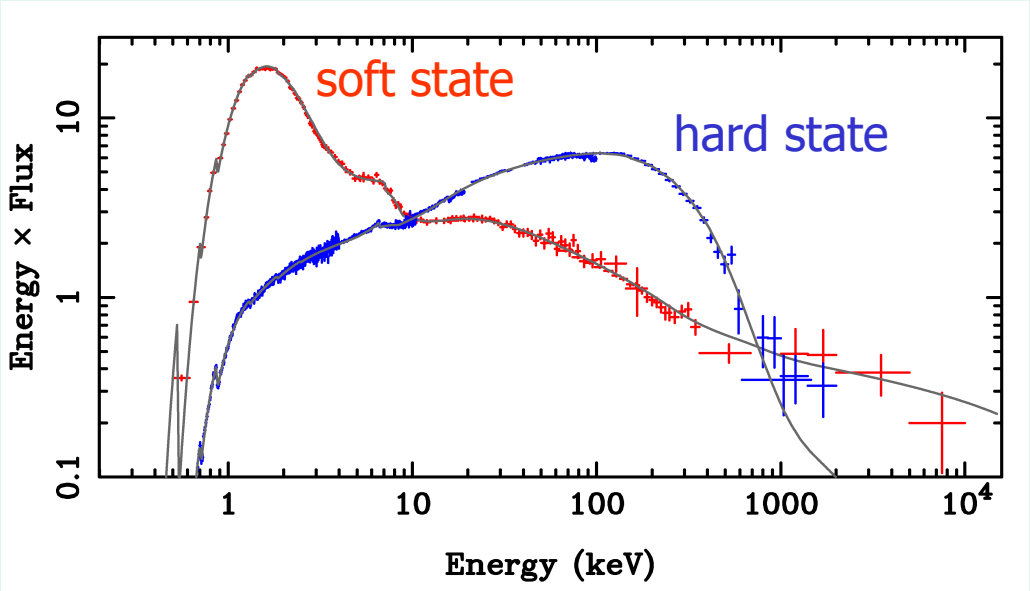
- Introduction: transient black hole X-ray binaries; spectral states and truncated disc model
- Spectral properties of optical/IR emission and flares
- A (hybrid) hot flow scenario
- Other properties explained

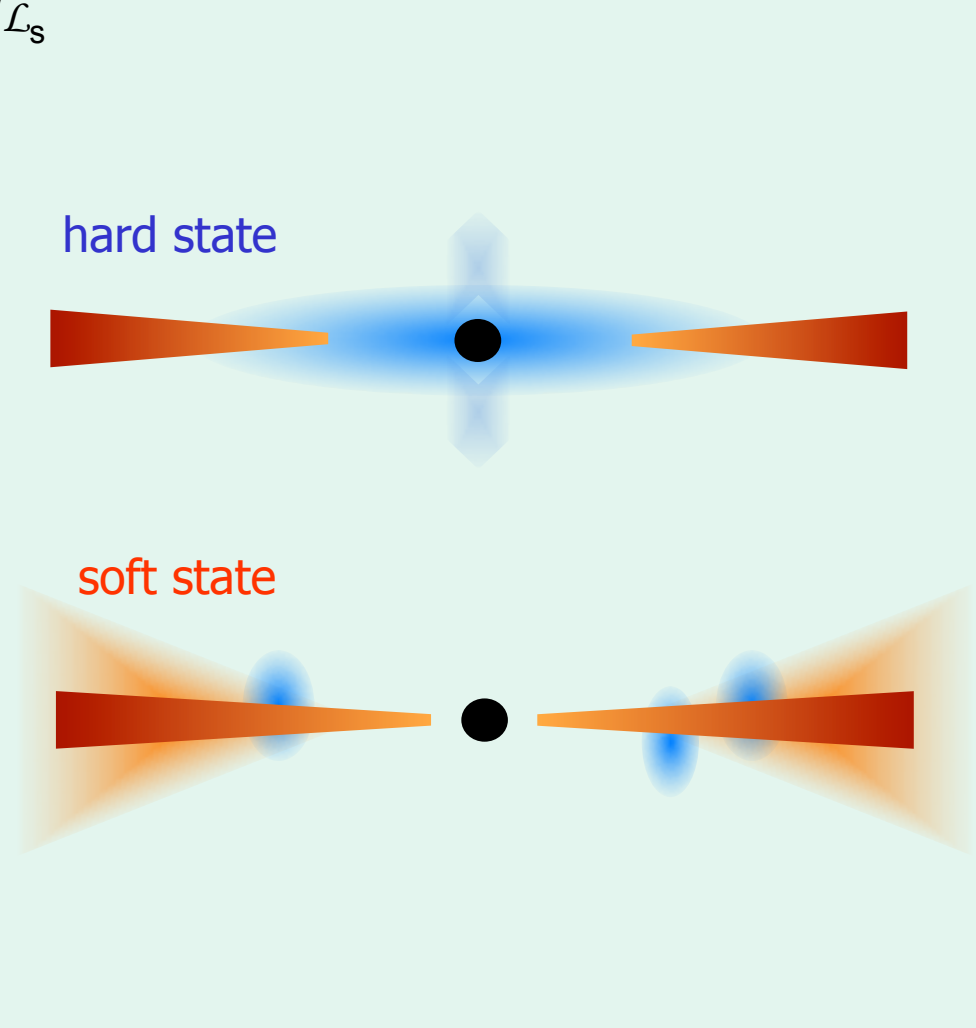
Black hole binaries: transients



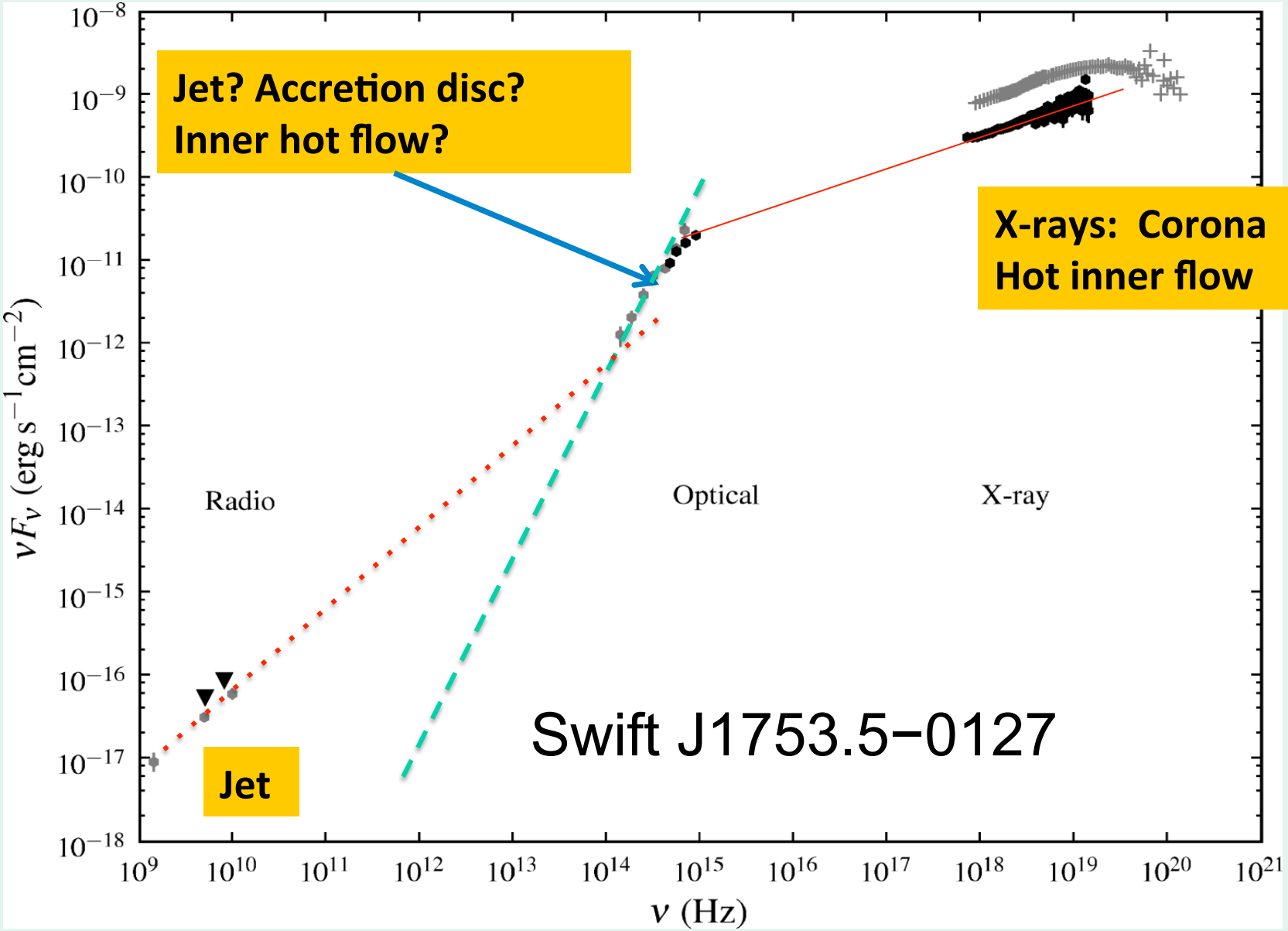
Done, Gierliński & Kubota 2007

Spectral states – moving truncation radius



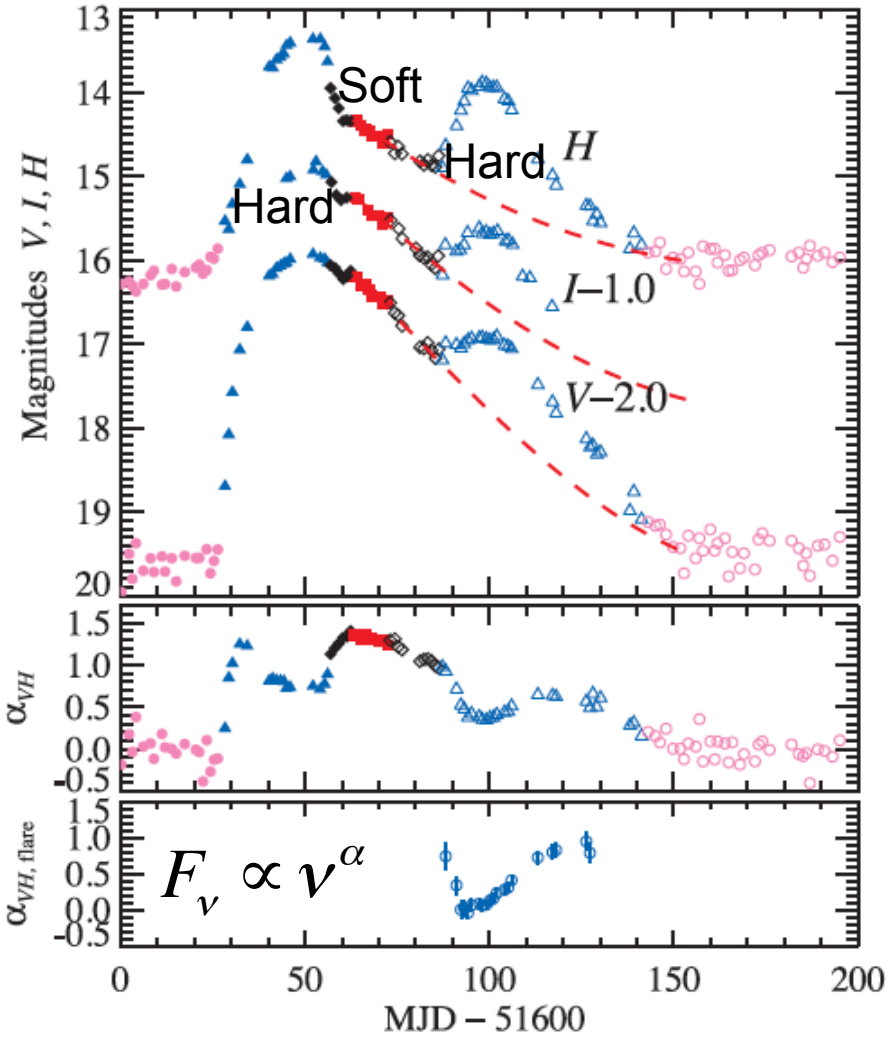


Broad-band spectrum of LMXB

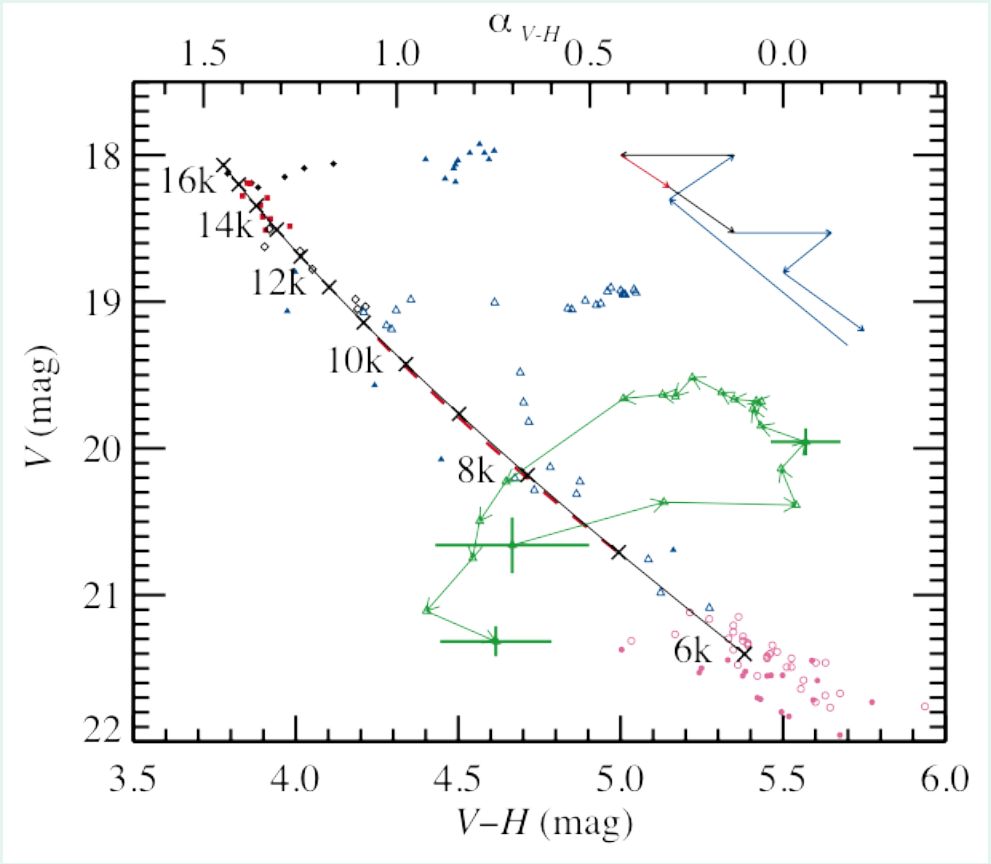


Cadolle Bel et al. 2007,
Durant et al. 2009

XTE J1550−564 in 2000 in OIR

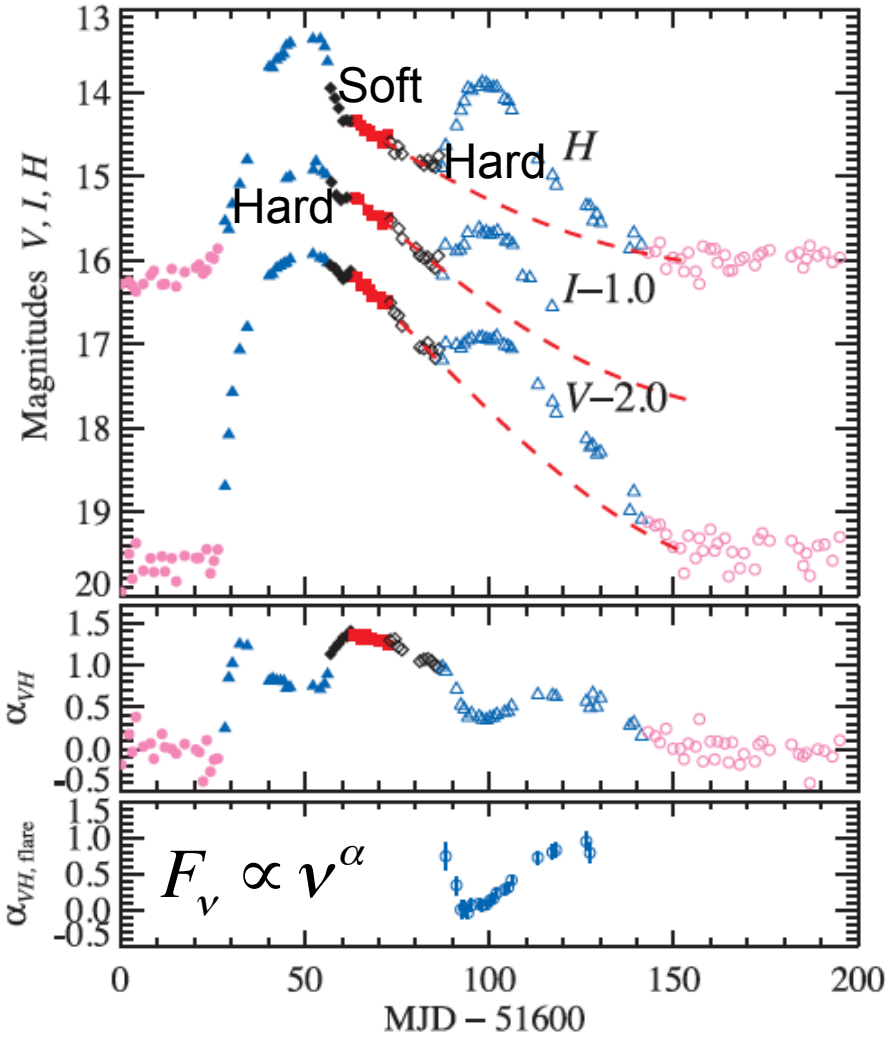


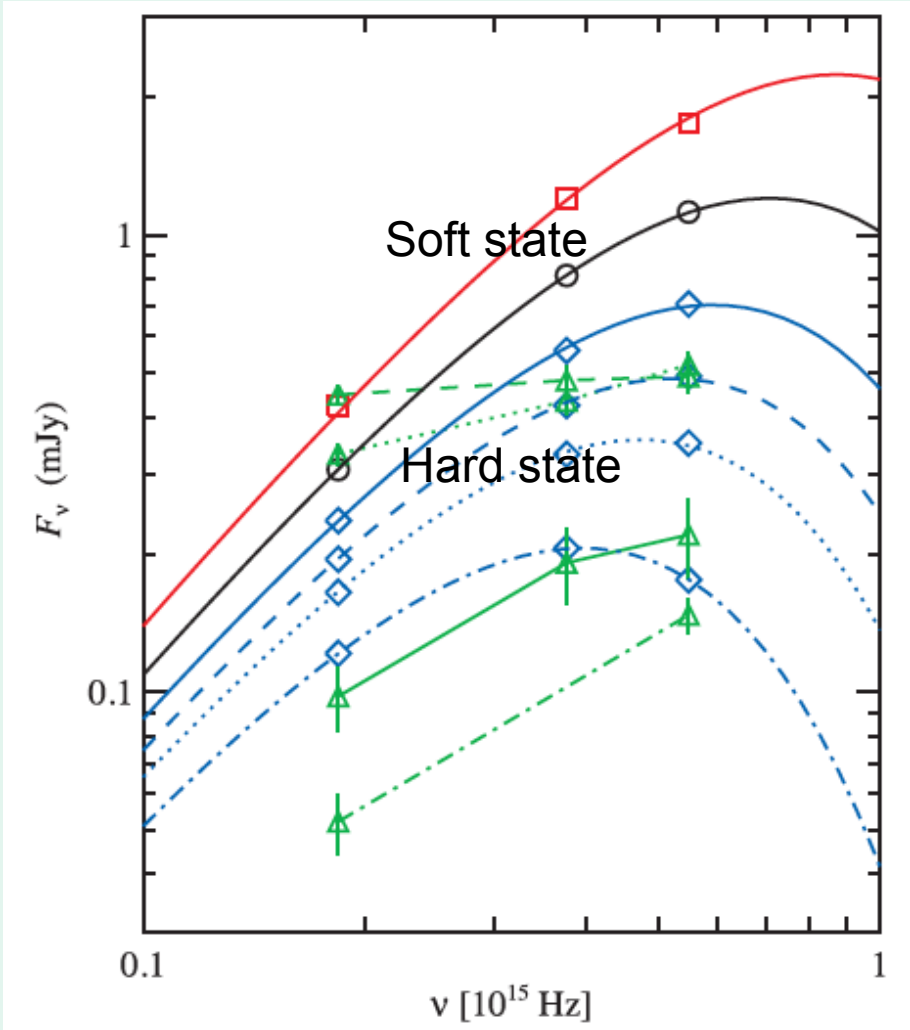
$F_\nu \propto \nu^\alpha$



Flare in the OIR starts with alpha=+0.7. This contradicts the jet models (Russell et al. 2010, 2011).

XTE J1550−564 in 2000 in OIR





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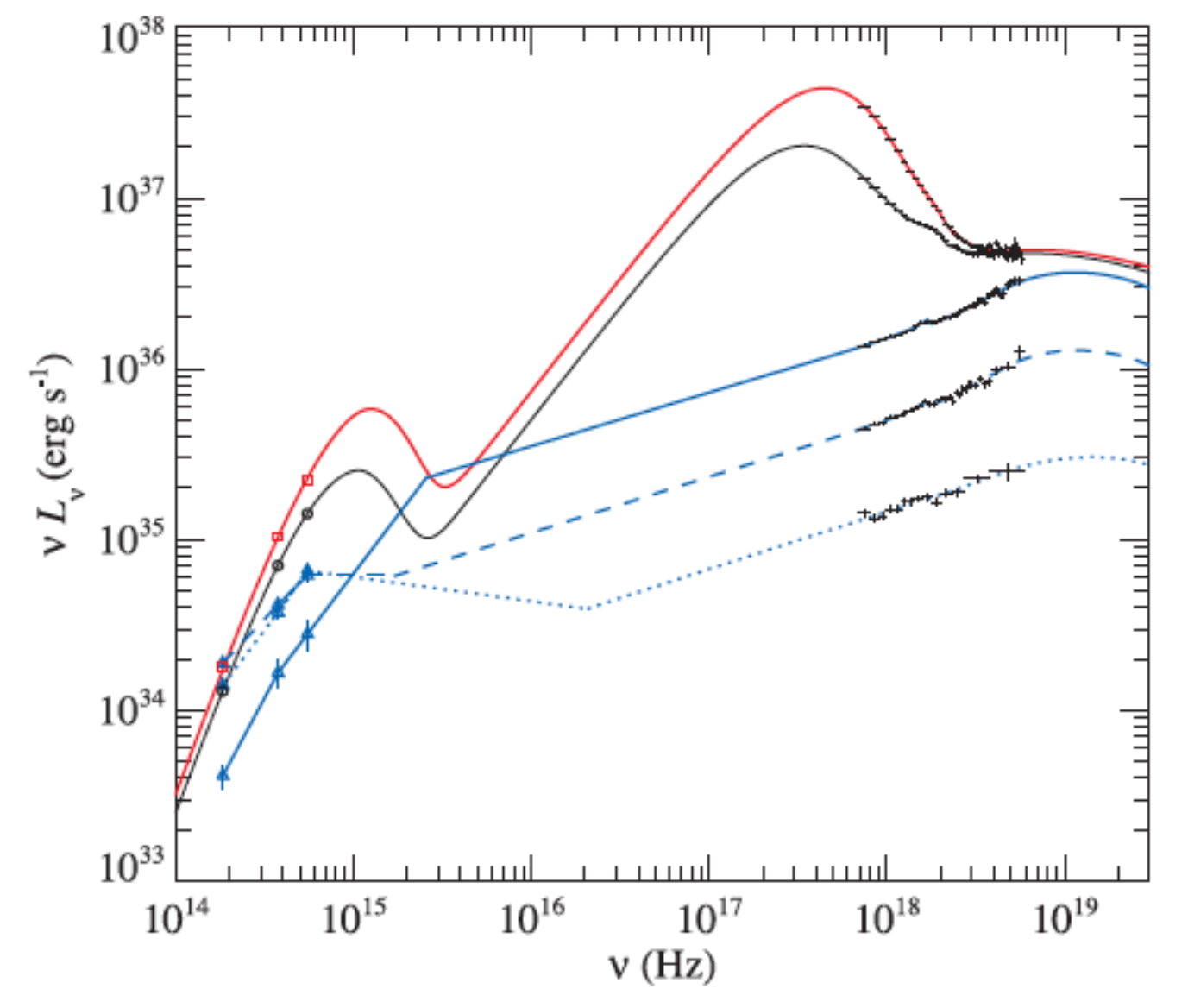
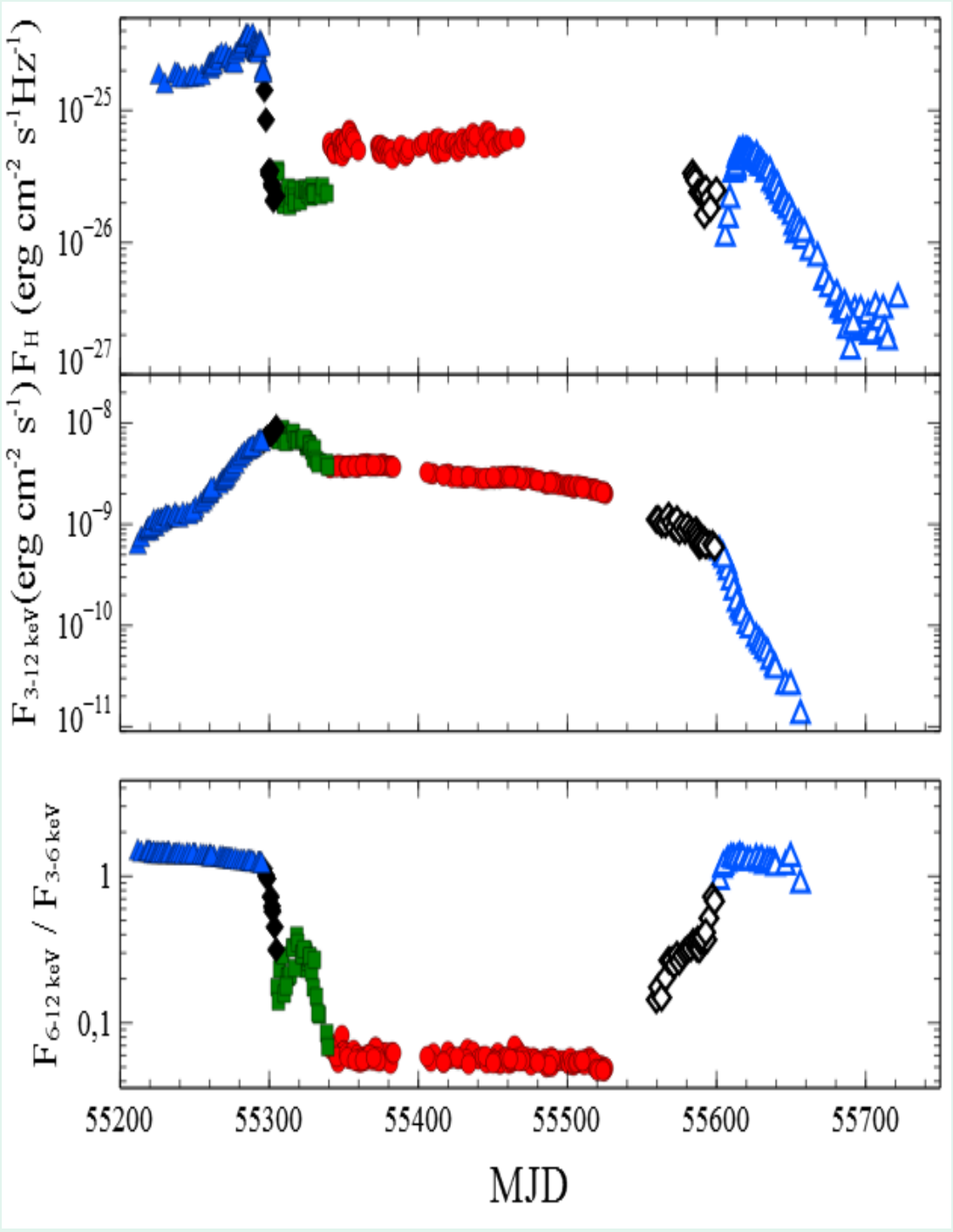
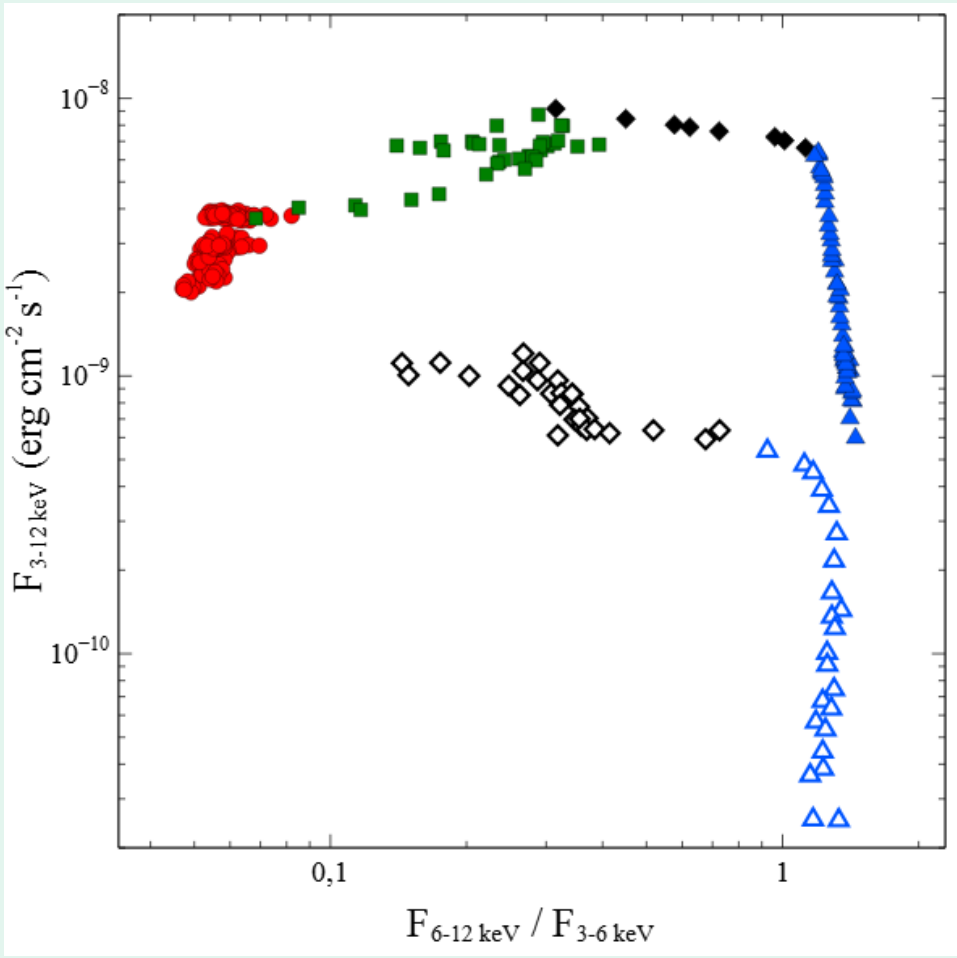
Broad-band spectrum of XTE J1550−564 in 2000

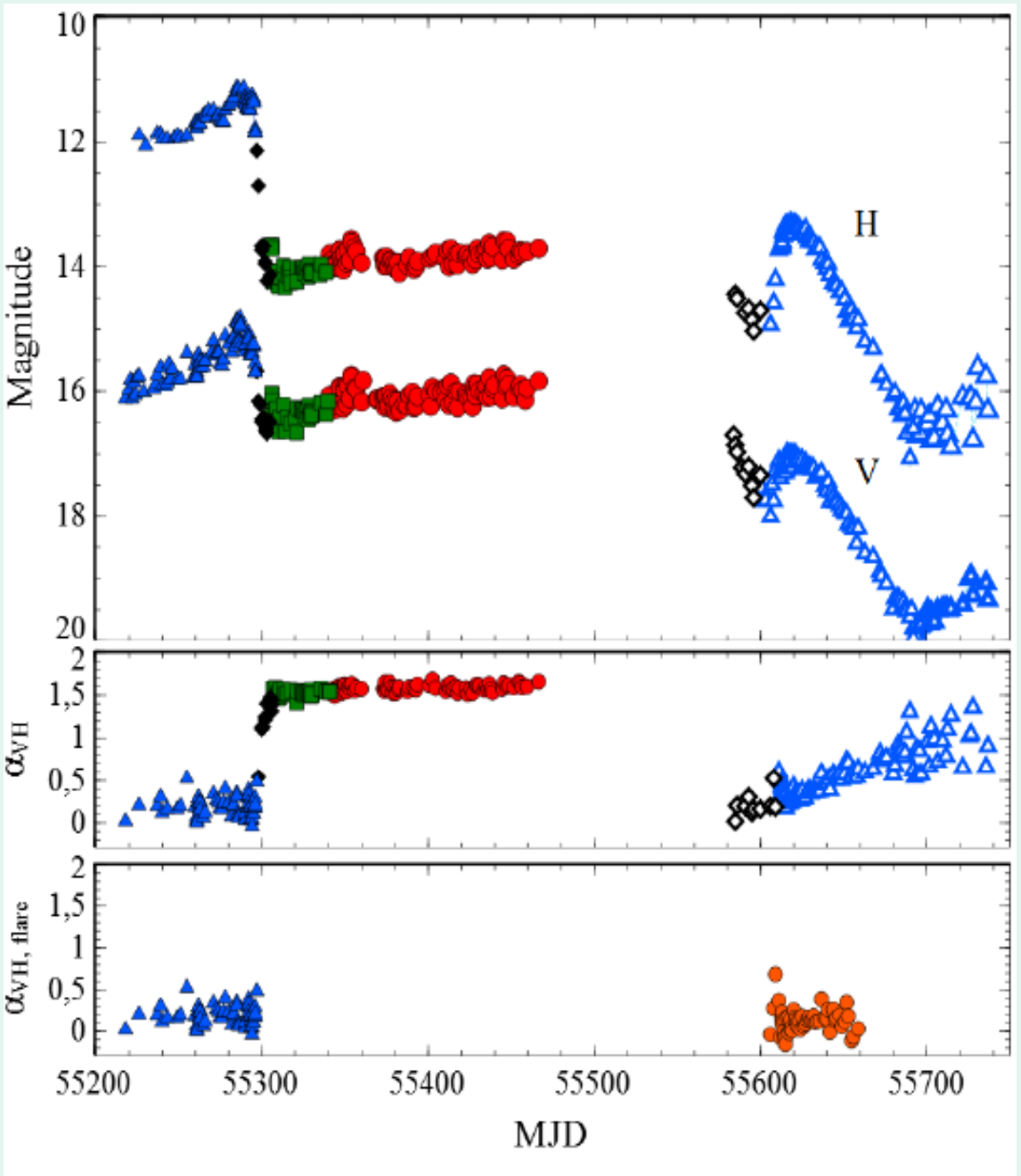


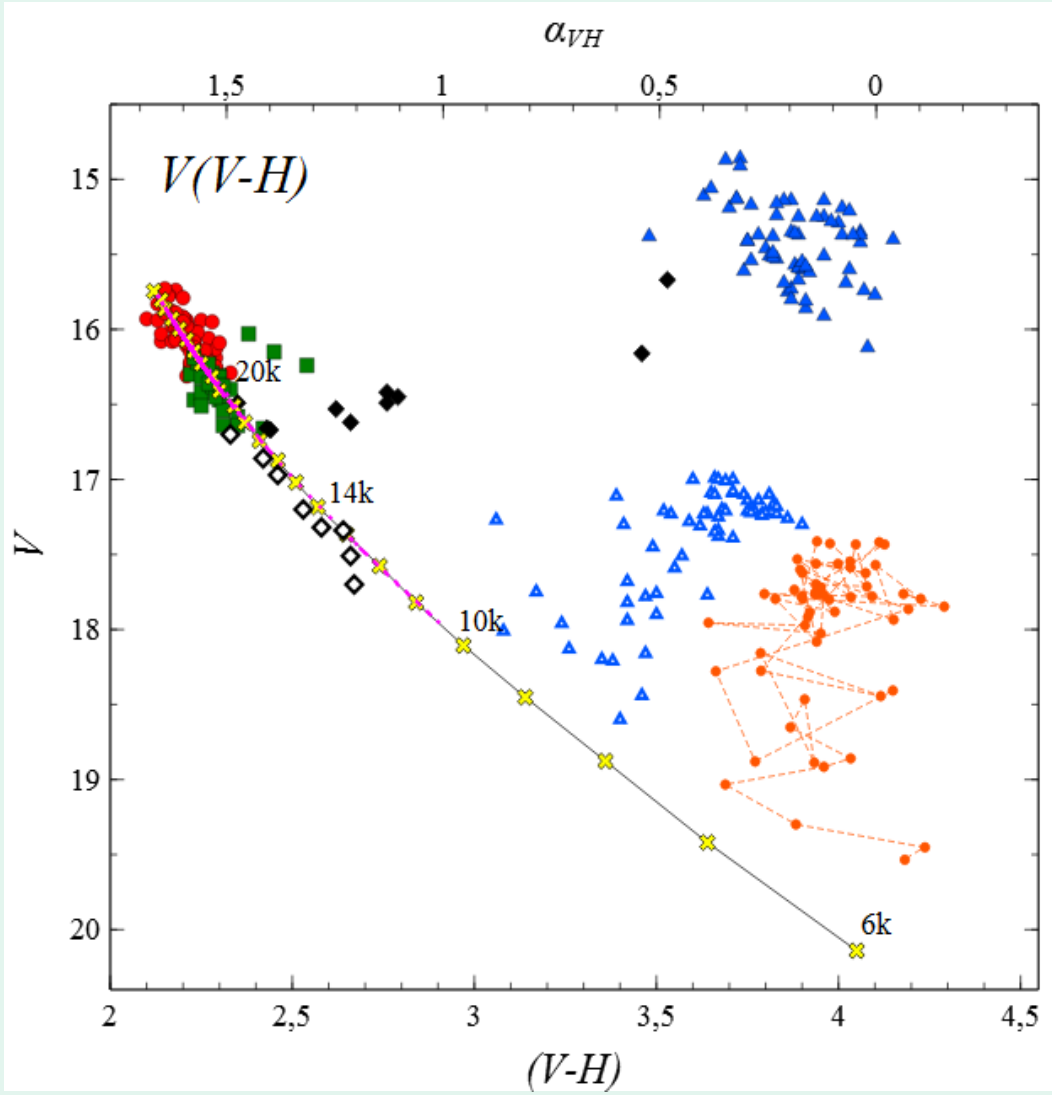
GX 339−4 in 2009-2010



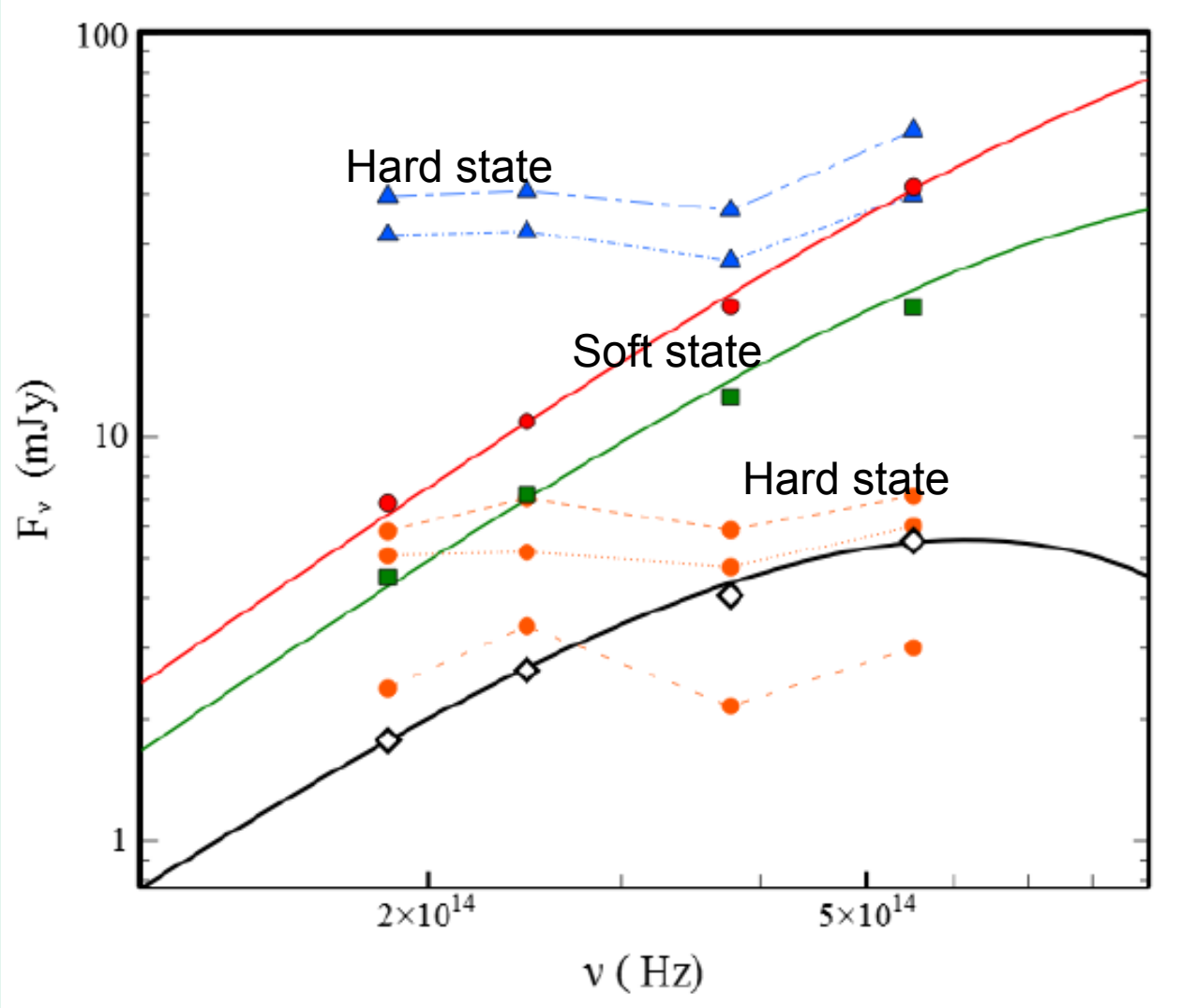


GX 339−4 in 2009-2010

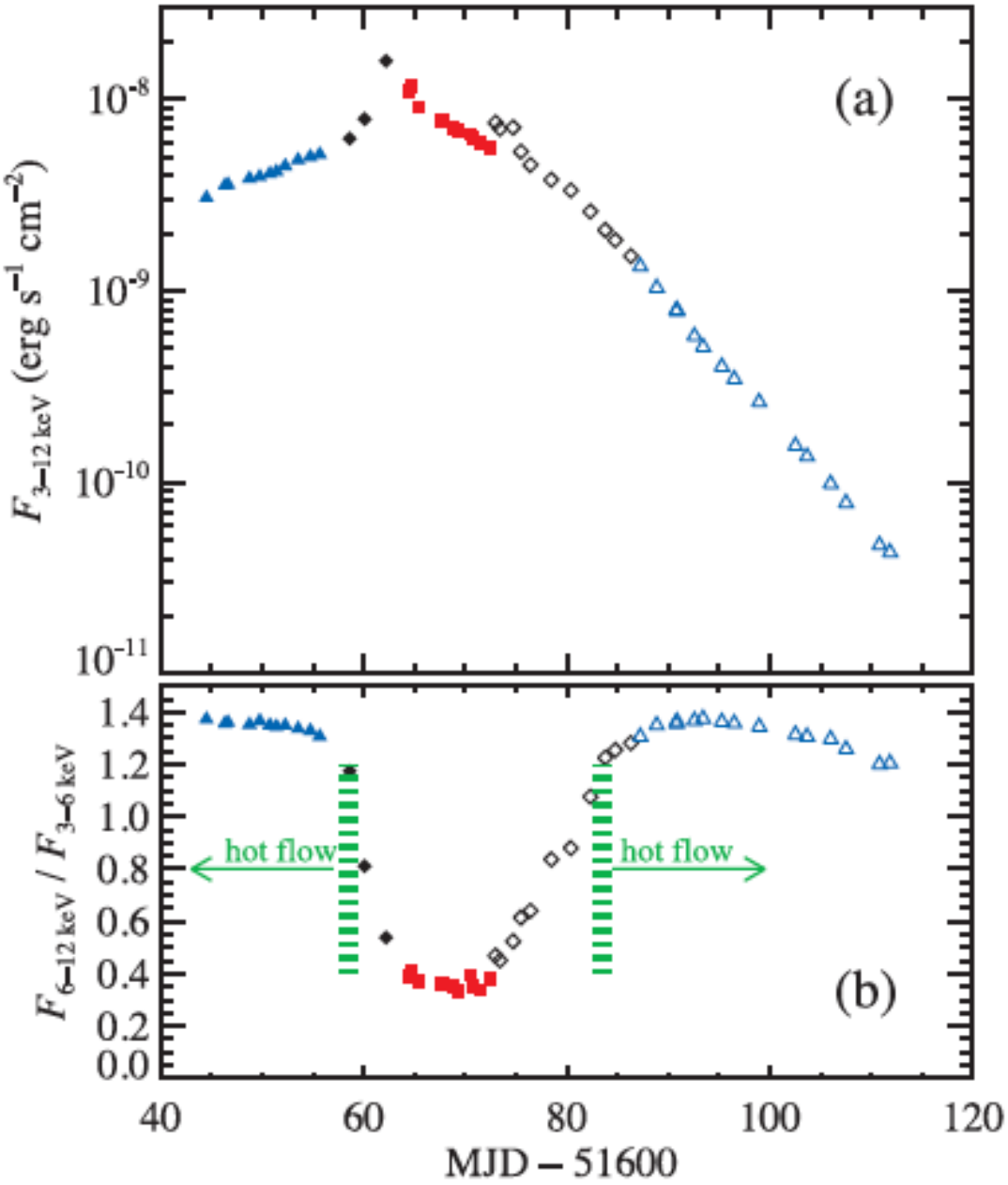


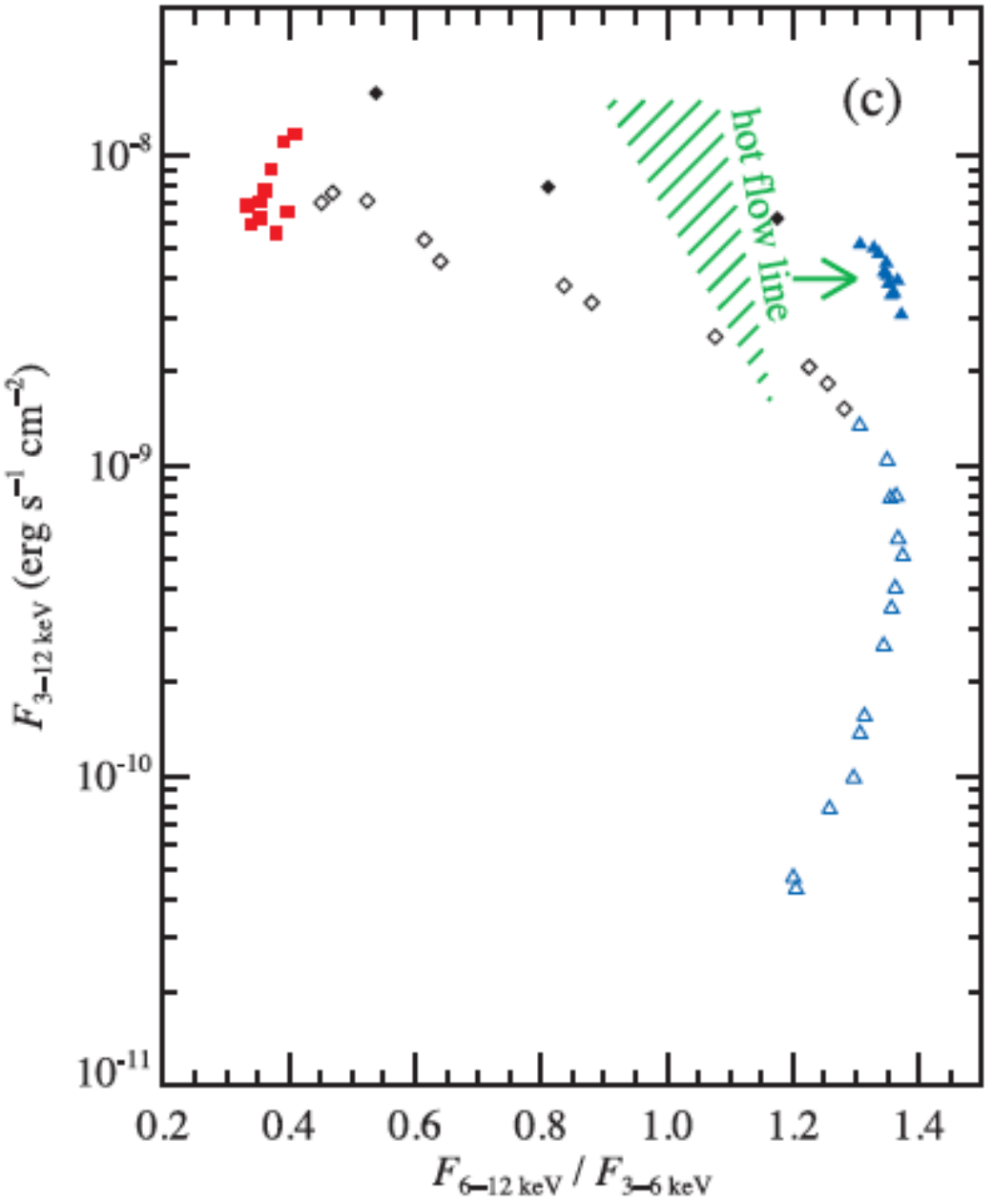


GX 339−4 in 2009-2010



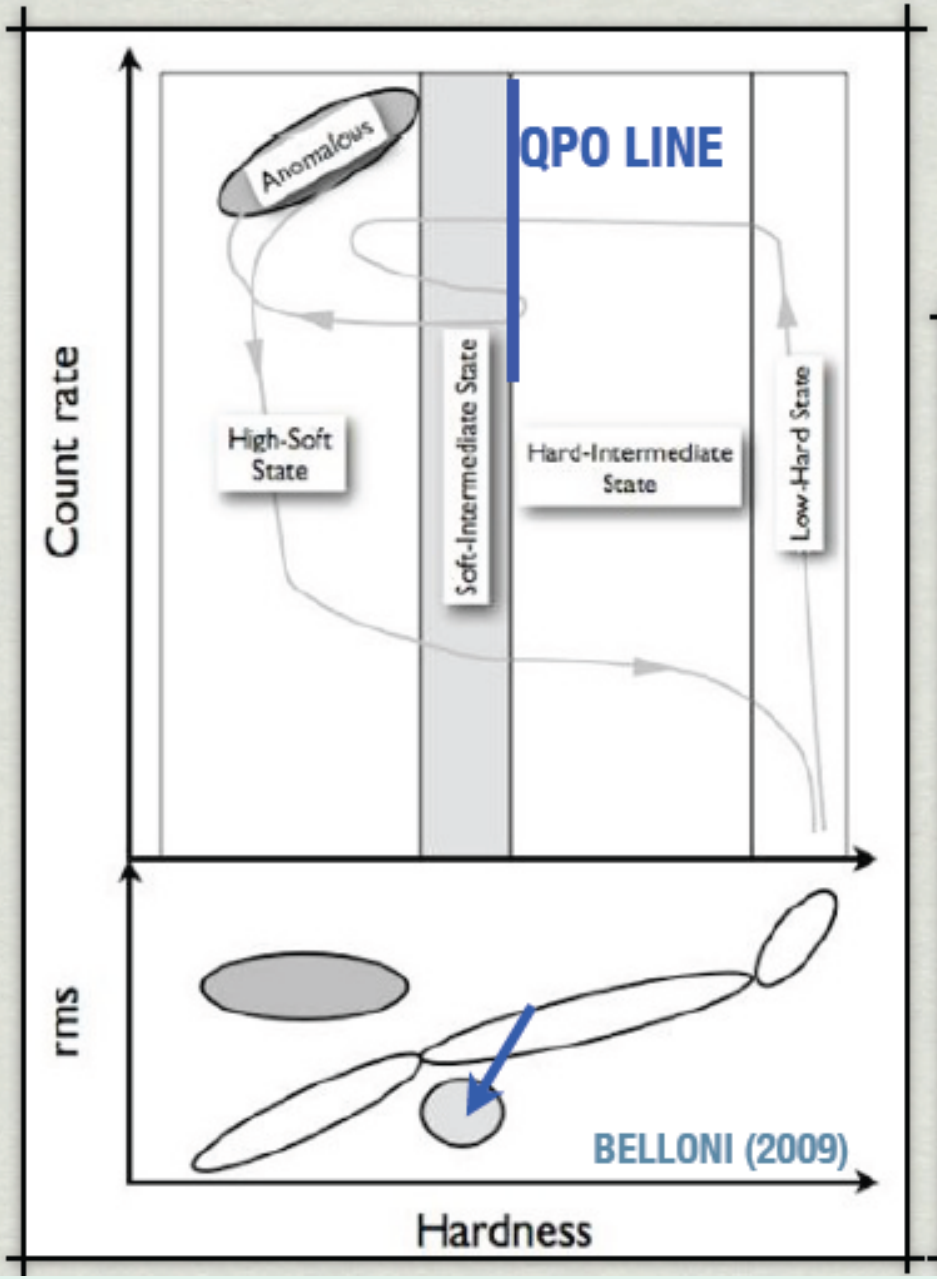
XTE J1550−564 in 2000 in X-rays

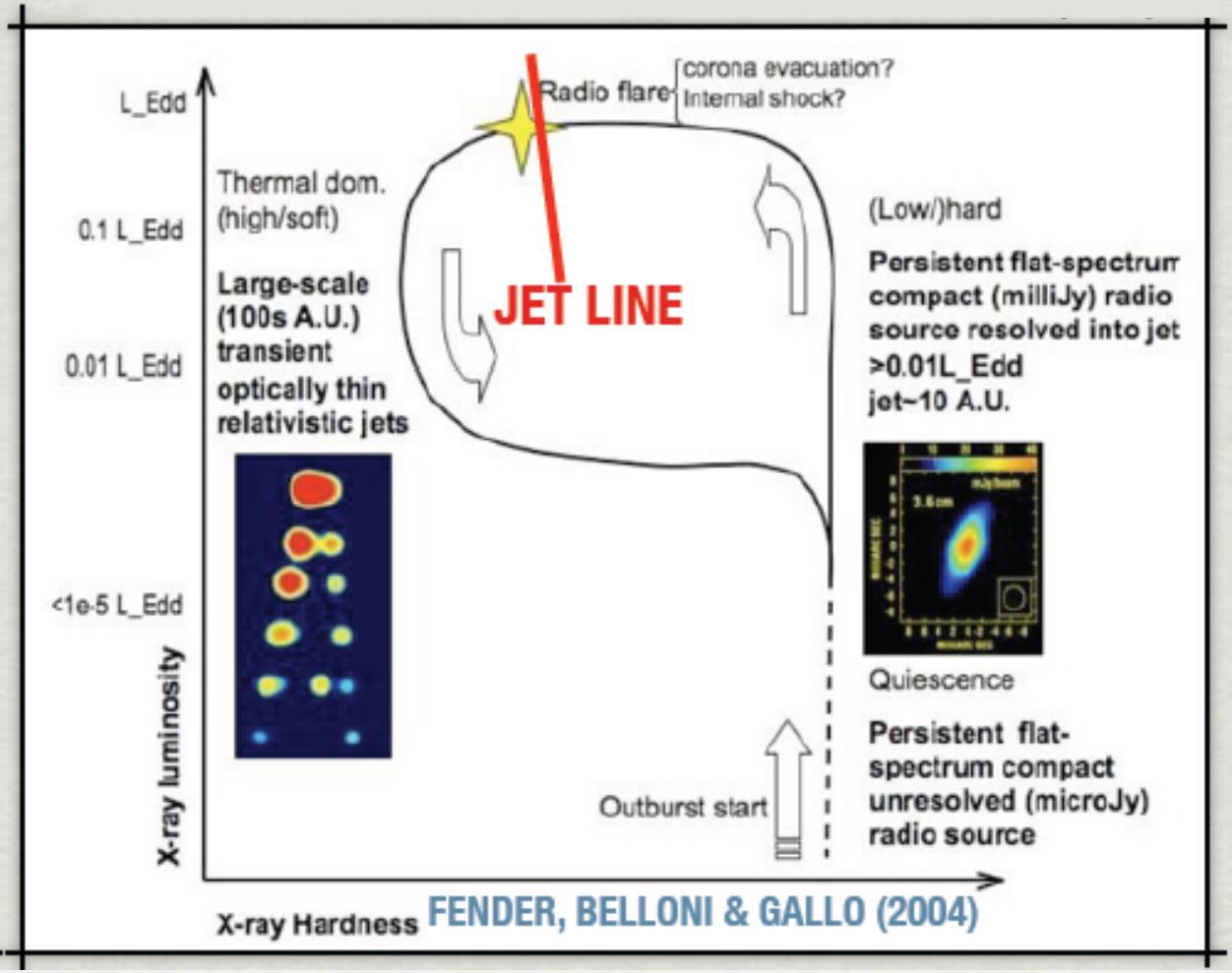




Poutanen+ 2014

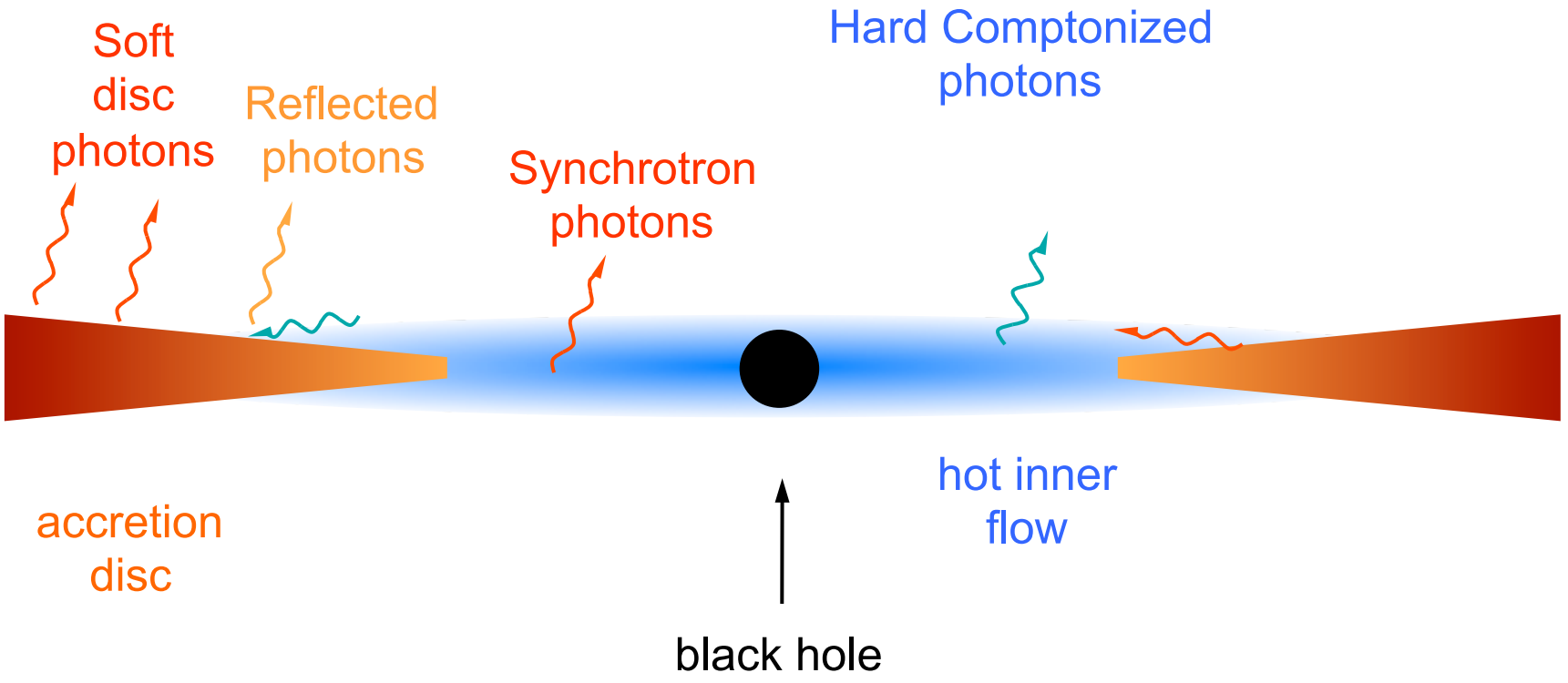
Radio vs X-rays: the jet and QPO line



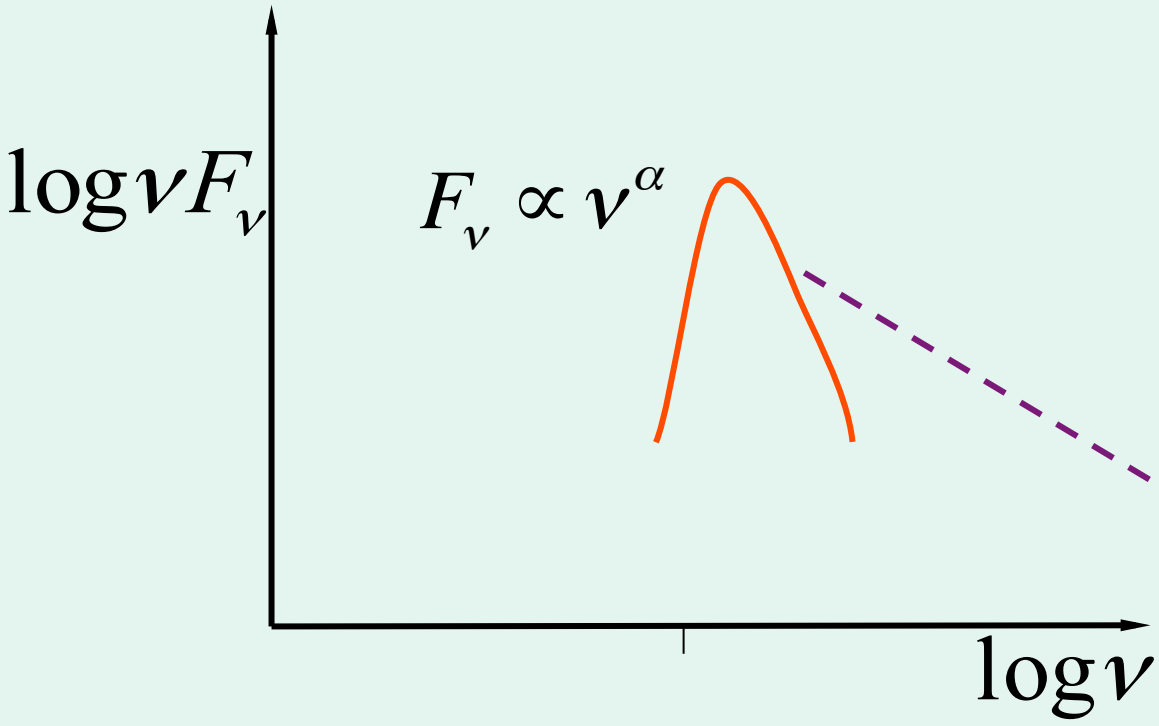


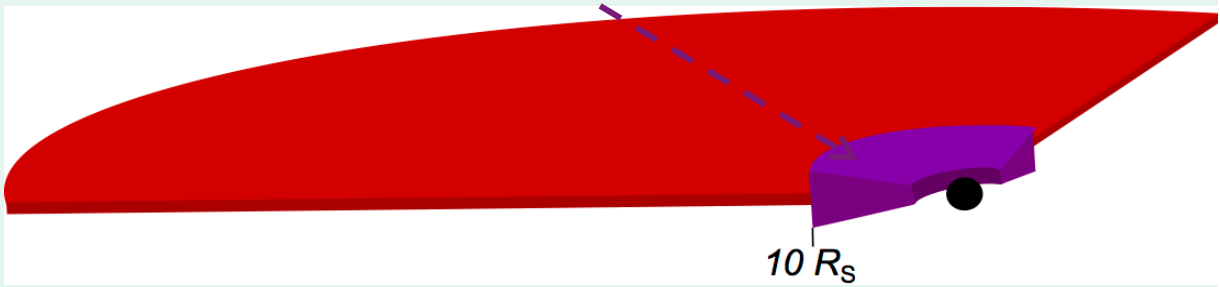
Belloni 2009

Hot inner flow in the hard state

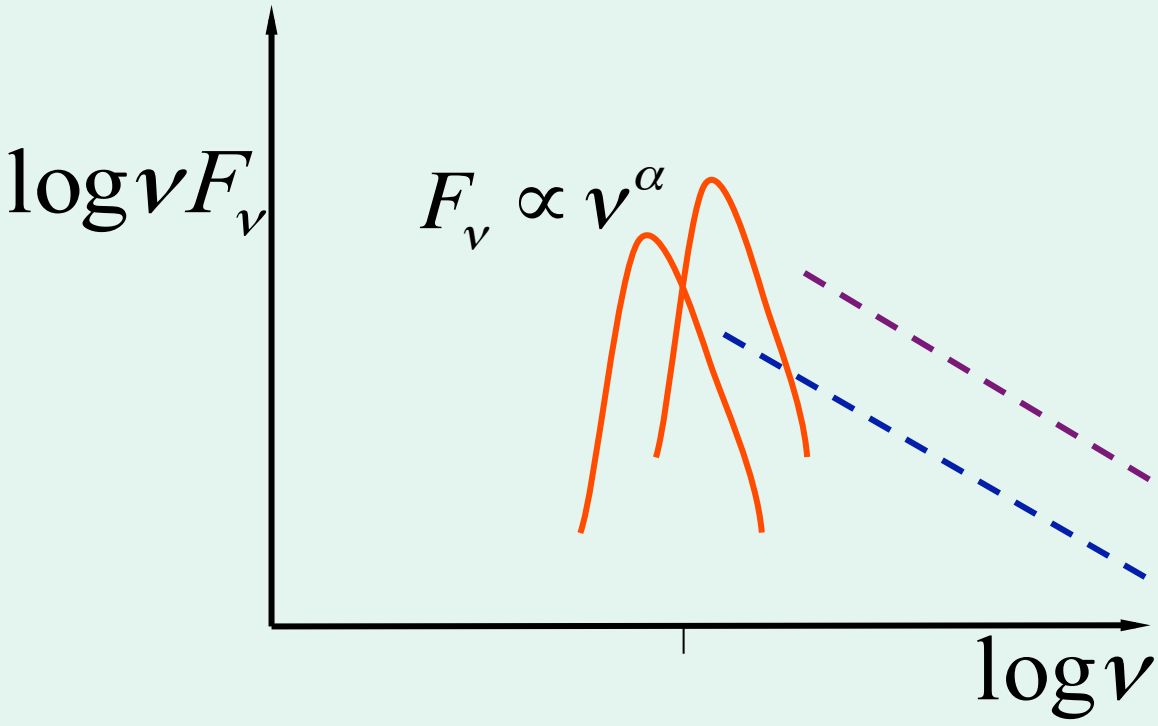


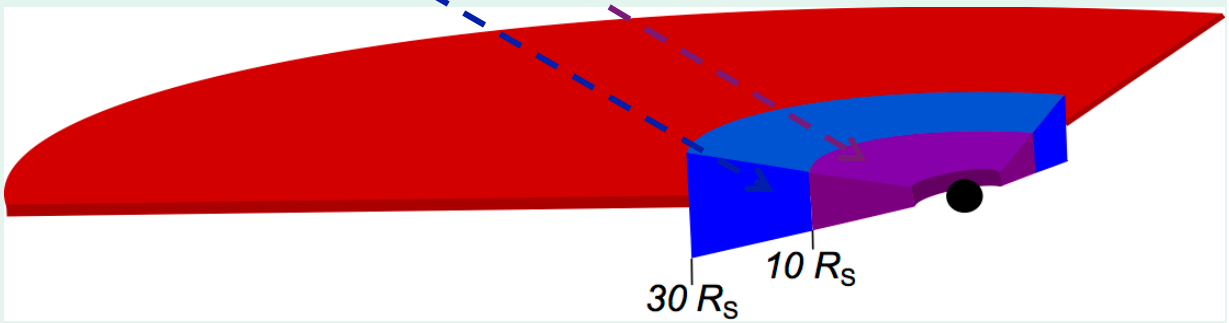
Inhomogeneous accretion flow





Inhomogeneous accretion flow





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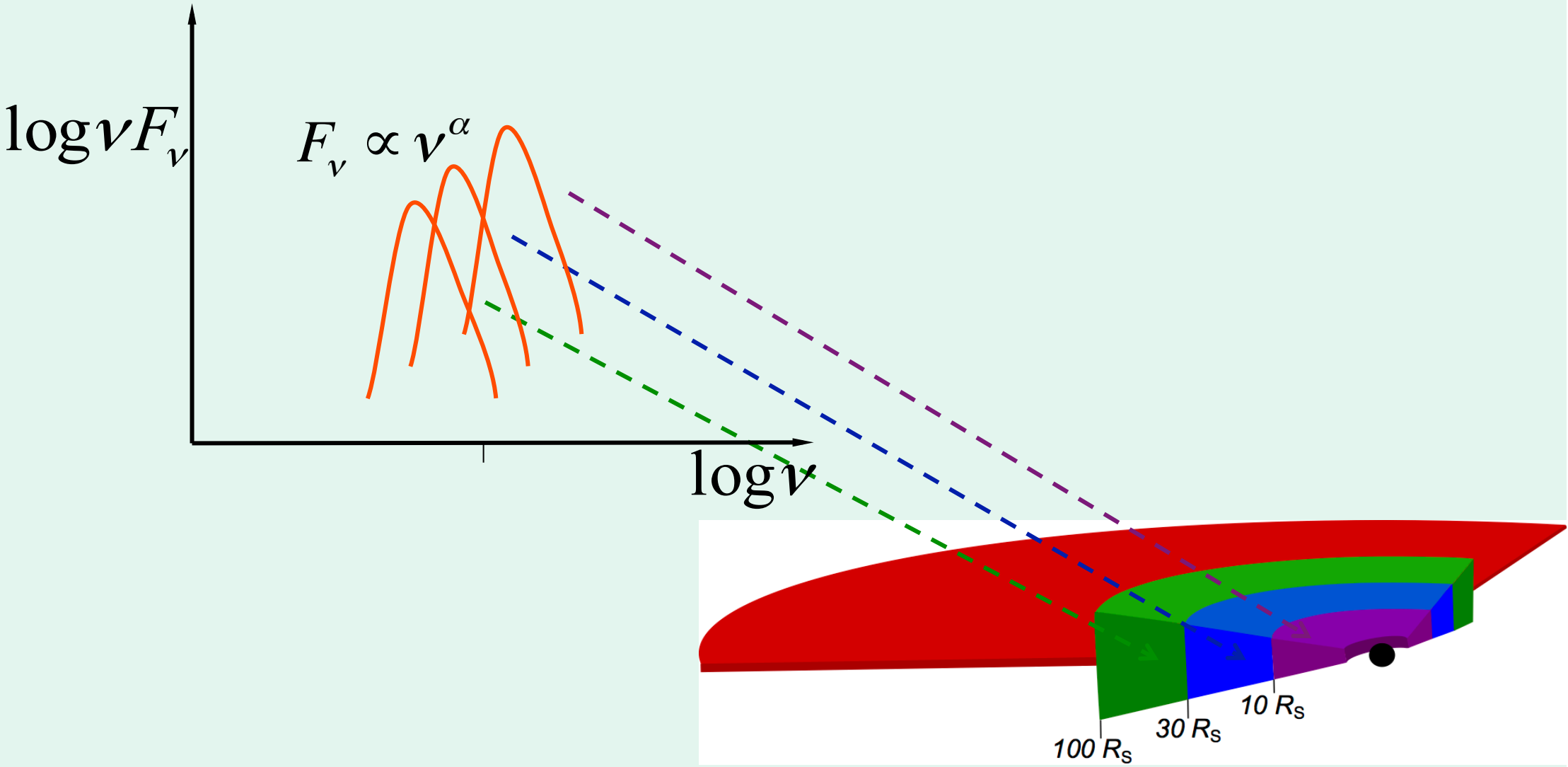
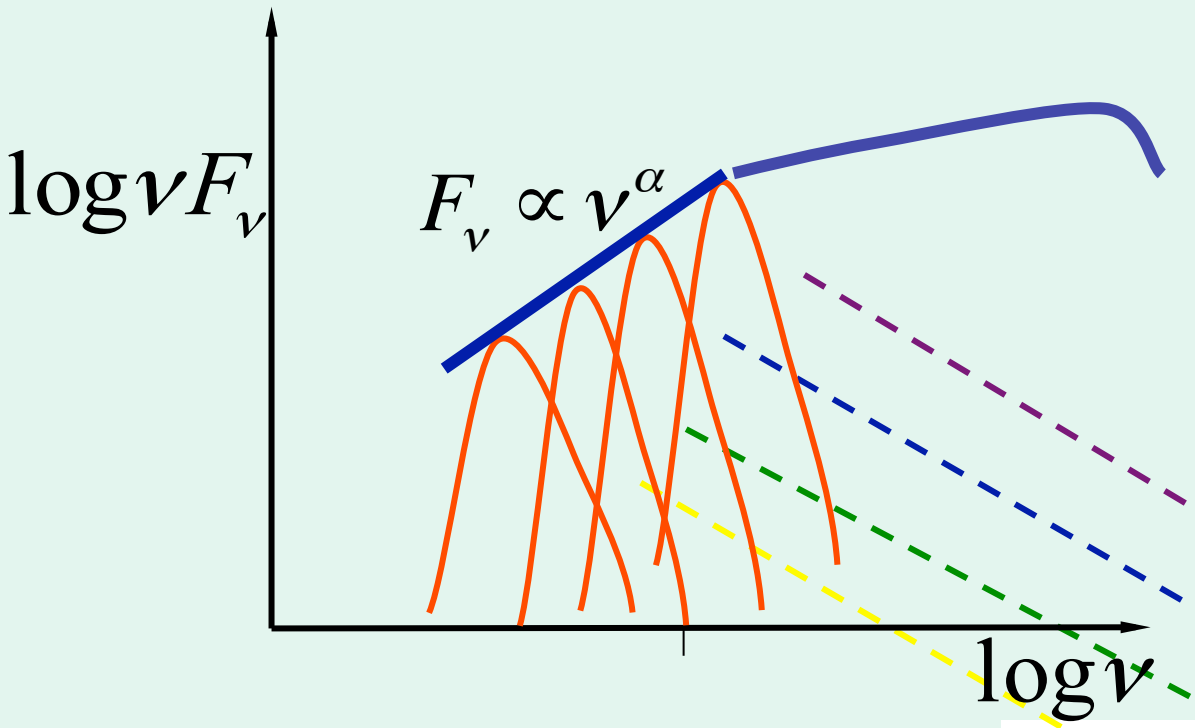


Inhomogeneous accretion flow

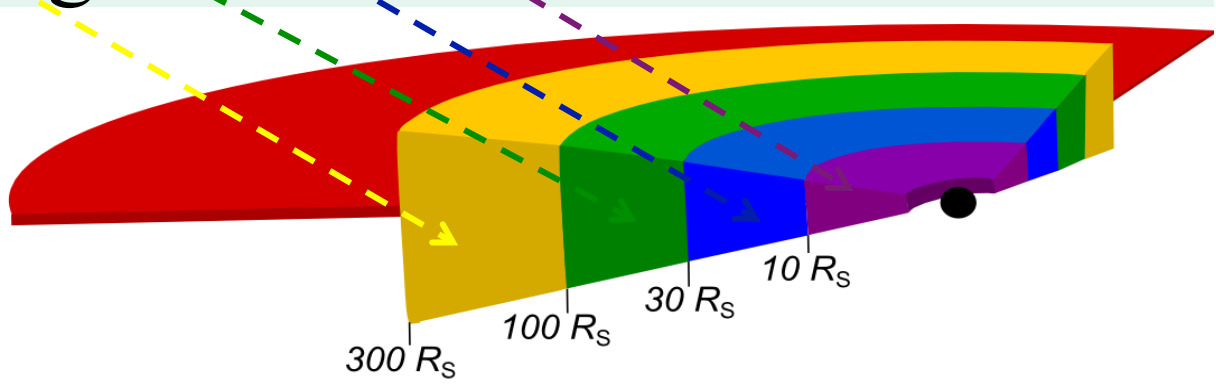


$$B \propto R^{-\beta}$$

$$\tau \propto R^{-\theta}$$

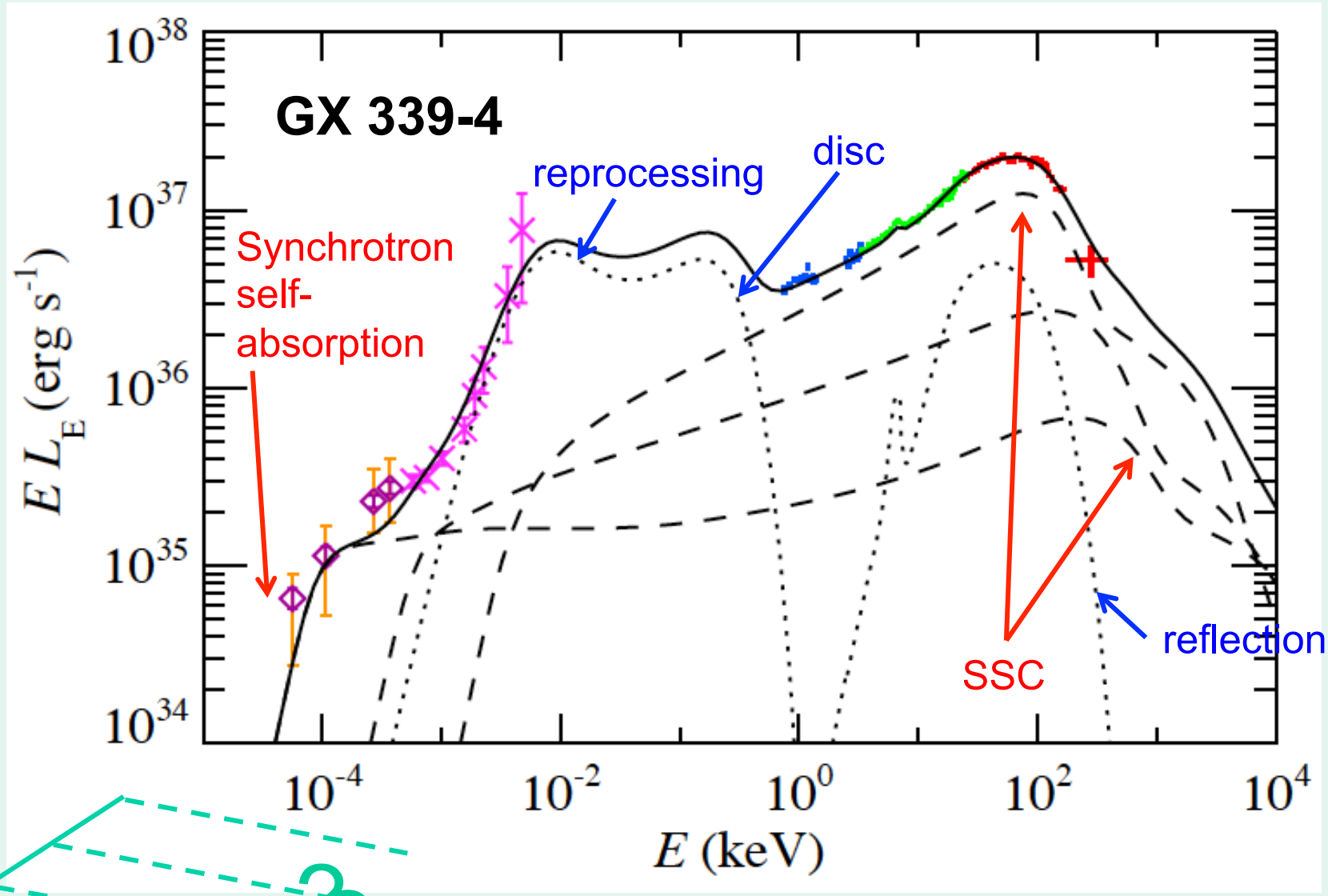
$$\tau(\gamma) \propto \gamma^{-p}$$

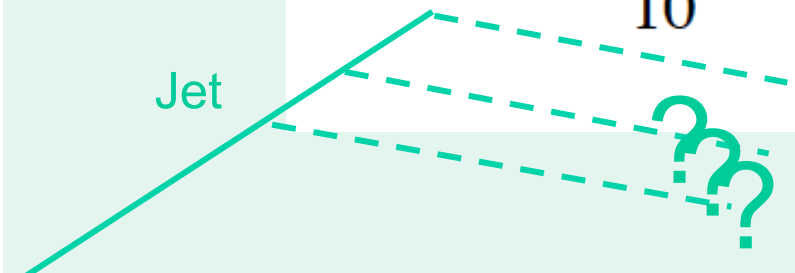
$$\nu_t \propto R^{-[\beta(p+2)+2\theta]/(p+4)}$$



$$\alpha = \frac{5\theta + \beta(2p+3) - 2p - 8}{\beta(p+2) + 2\theta}$$

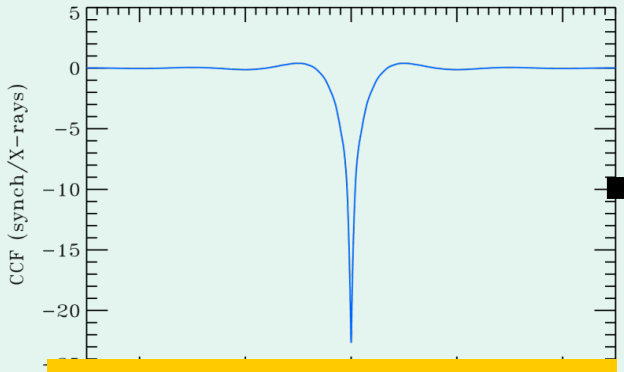
Broad-band spectrum from a hybrid hot accretion flow



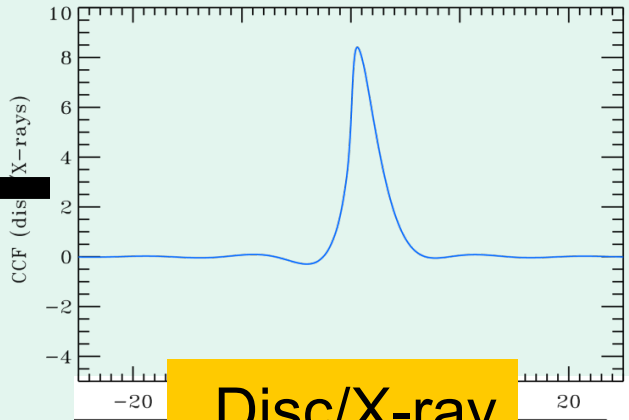


Veledina+ 2017+

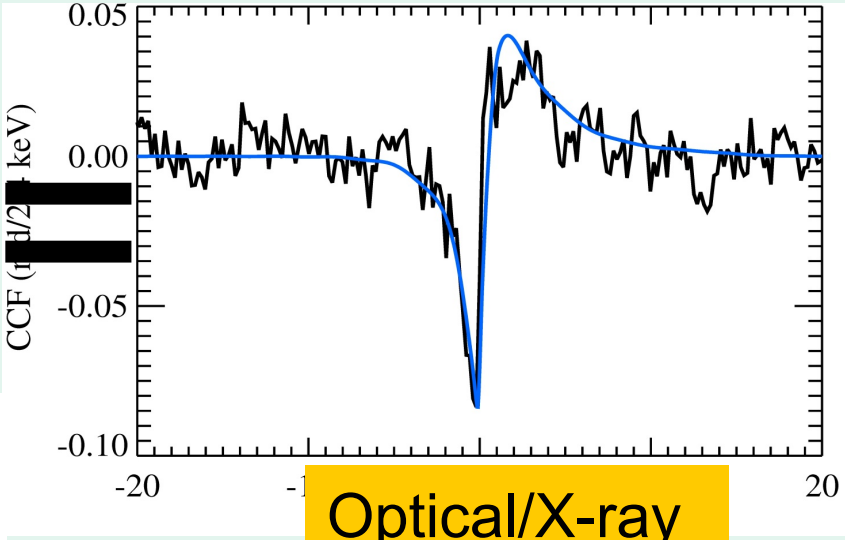
Optical/X-ray cross-correlation



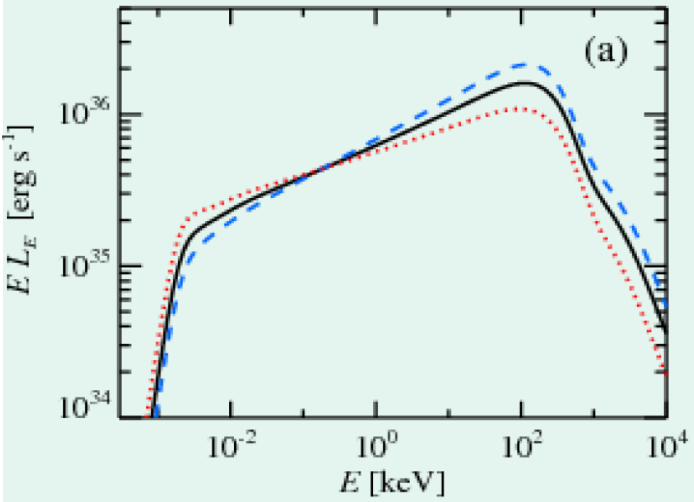
Synchrotron/X-ray

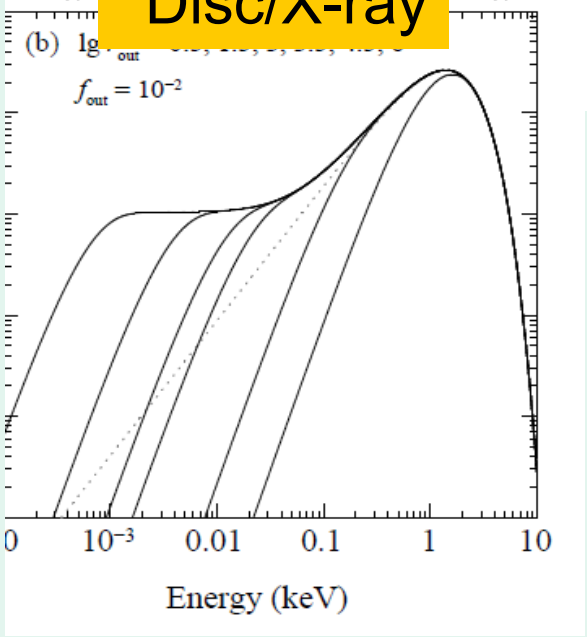


Disc/X-ray



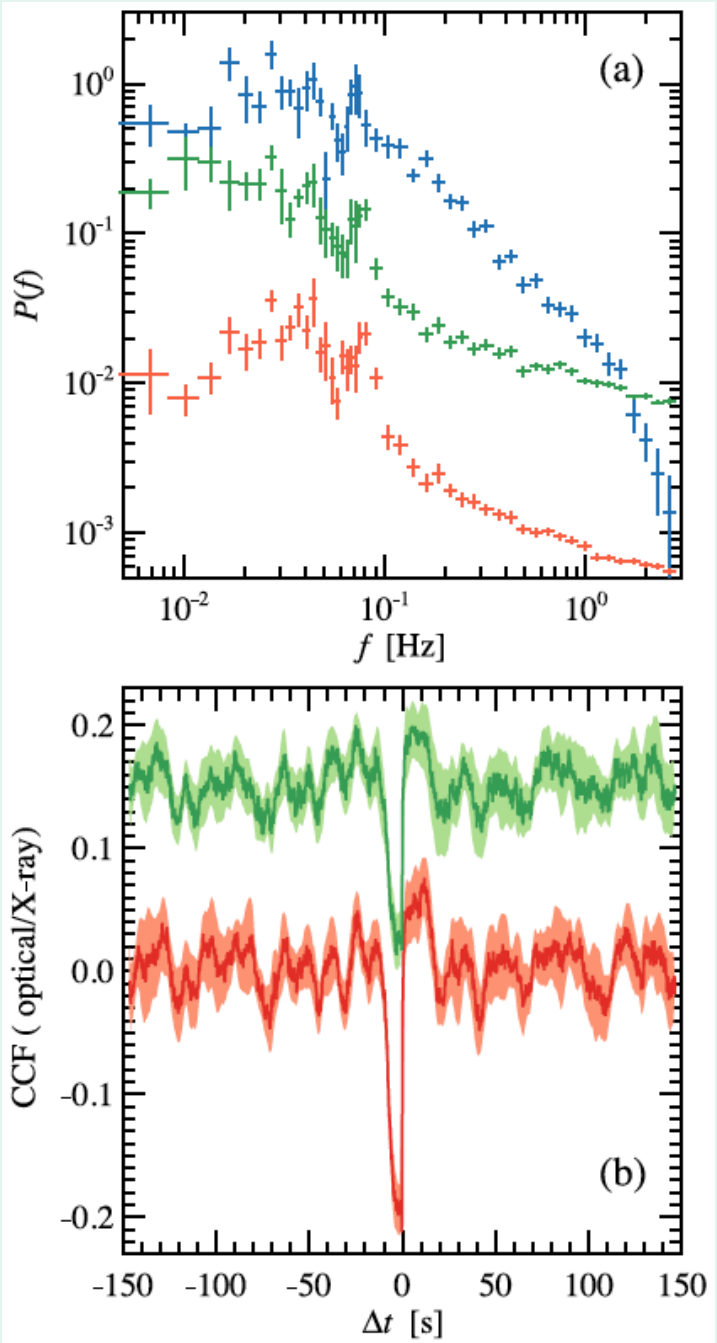
Optical/X-ray



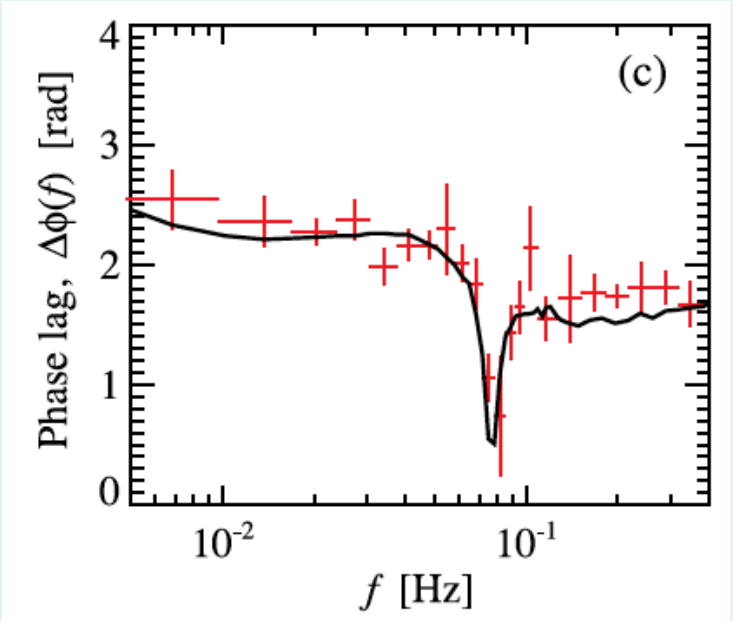


Veledina et al. 2011

QPO: X-ray vs. optical

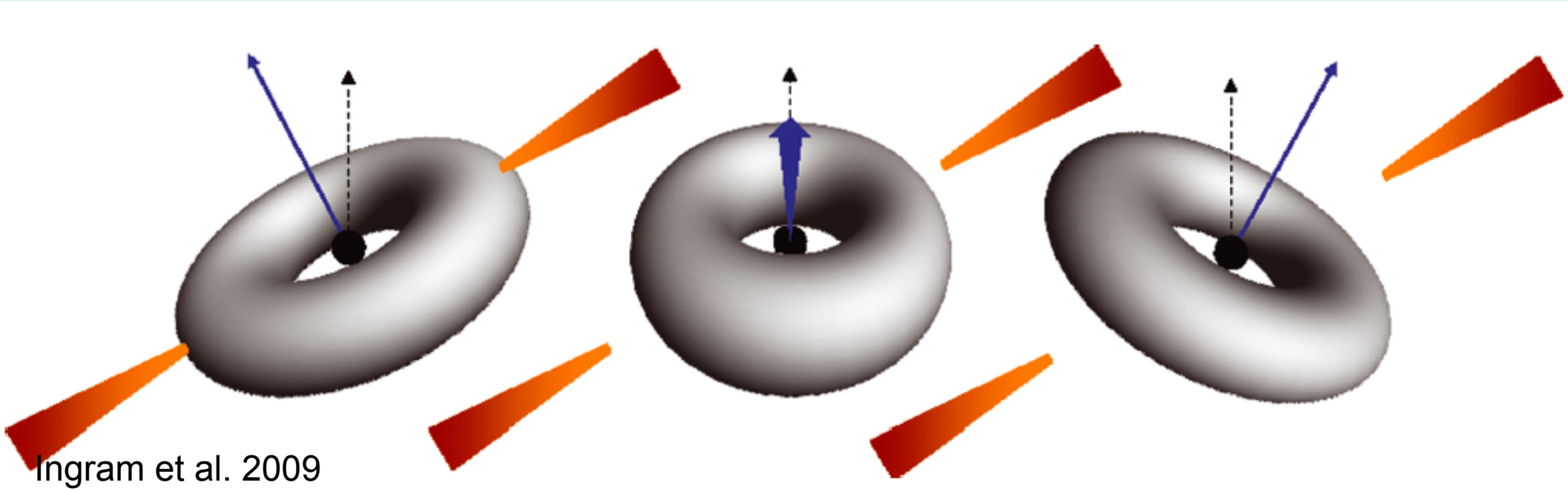


X-ray and optical QPOs coming in phase are observed



Swift J1753.5−0127
Veledina et al. 2015

QPOs from precessing hot flow



Ingram et al. 2009

The X-rays are produced in the inner part of the precessing hot flow. The flow precesses as a solid body if $H/R > \alpha$ (Fragile et al. 2007).

Optical, IR emission is produced in the outer part of the hot flow and the QPOs can be produced by the same precessing flow (Veledina et al. 2013).

Conclusions

- Power-law-like OIR spectrum of LMXBs in the hard state can be produced by an extended hot flow.
- In the soft state, OIR emission is thermal and the irradiated disc is the likely source.
- OIR flares are consistent with the synchrotron emission from the hybrid hot flow. The “hot flow line” seems to coincide with the “radio jet line” and the “QPO line”.

- The hot flow paradigm can also explain: optical-X-ray CCF, QPOs, hard X-ray time lags.