An Accretion-Ejection Paradigm for Compact Objects

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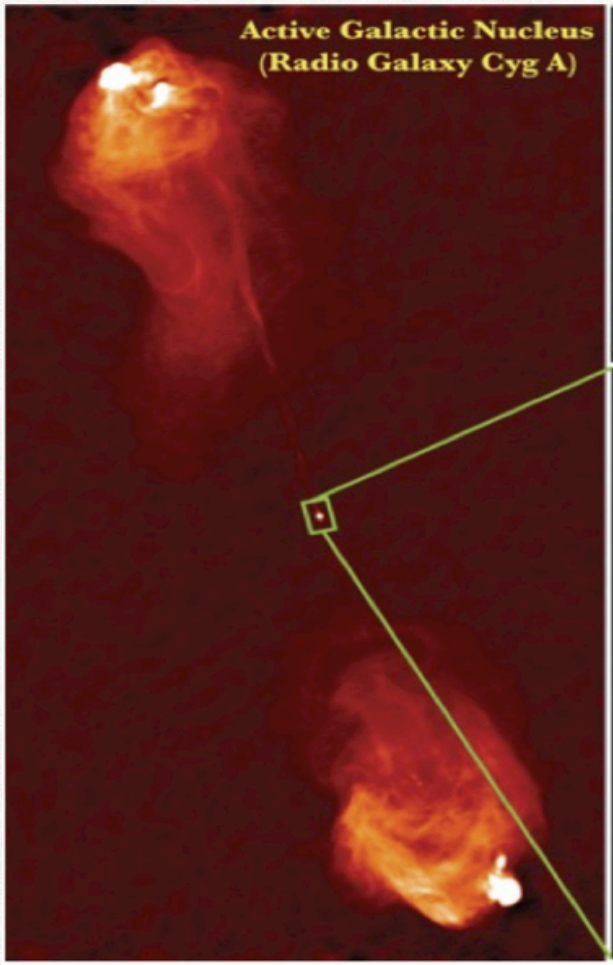
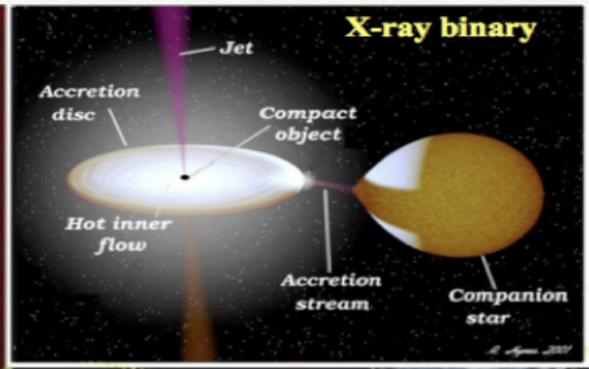
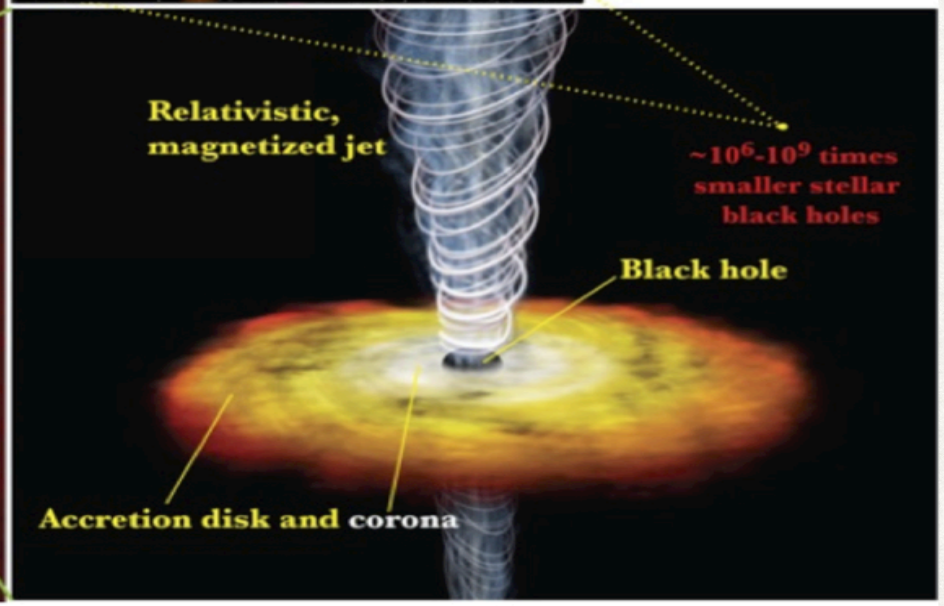


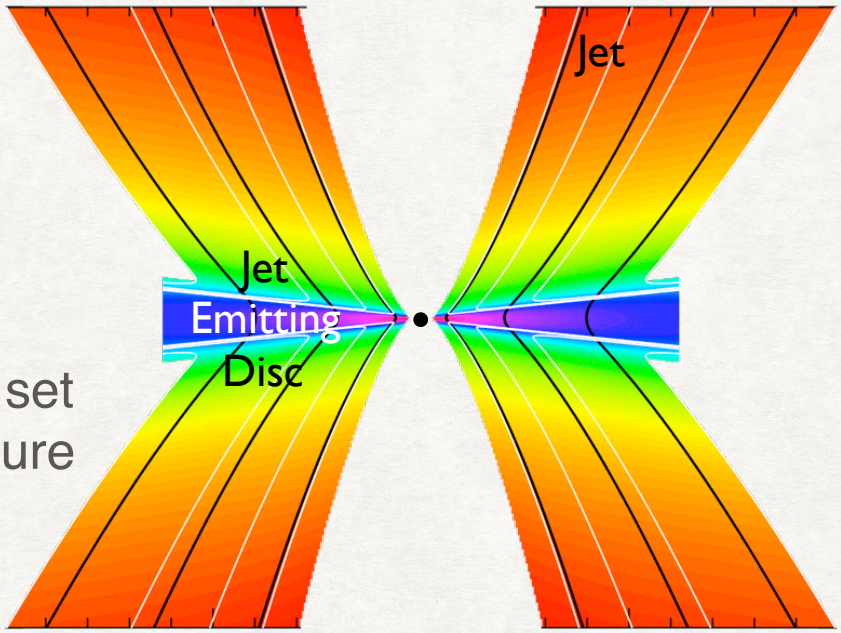




Collaborators: G. Marcel, T. Benitah, S. Barnier, F. Ursini, R. Middei, J. Ferreira, R. Belmont, J. Malzac, J. Rodriguez, F. Cangemi, M. Clavel, S. Corbel, M. Coriat, G. Henri, ...

Jet Emitting Disk

Ferreira (1997),
Ferreira et al. (2006),



✓ Assume a large-scale magnetic field

✓ Baryonic jet emitted by the accretion disk through MHD mechanism (Blandford & Payne, 1982)

✓ First self-similar solution of the complete set of equations of an accretion-ejection structure (Ferreira & Pelletier 1995; Ferreira 1997)

✓Some characteristics:

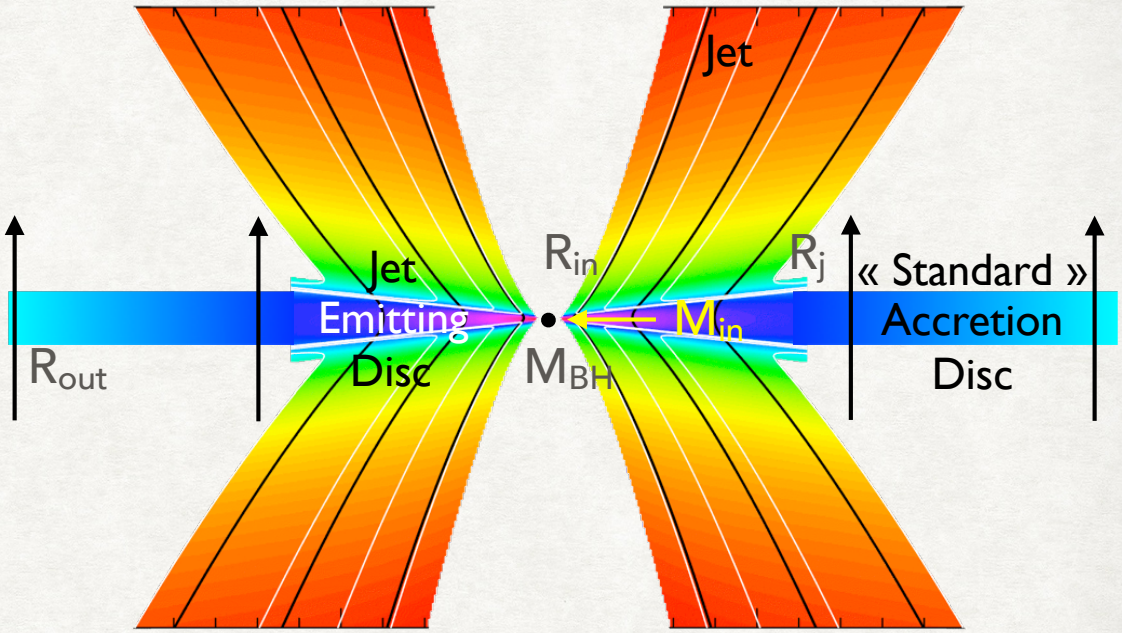
- $\dot{M}_{acc} \propto r^p$ **but p not a free parameter!**
- **Due to the jet torque, $V_{acc} \sim C_{sound}$!**

Hybrid JED-SAD configuration

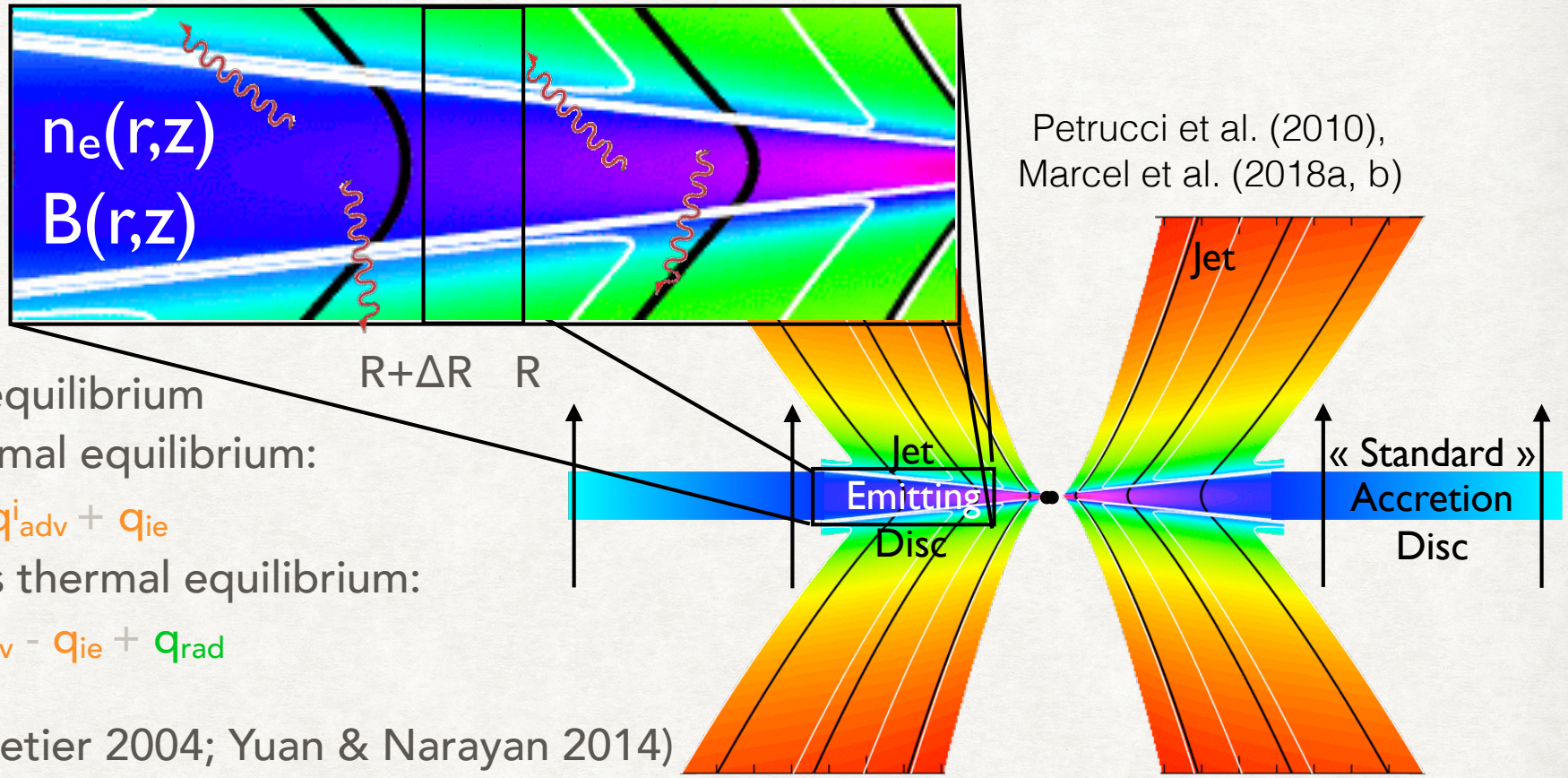
« à la » Esin et al. (1997)

- ✓ high magnetised inner region = JED
- ✓ low magnetised outer region = SAD
- ✓ A given configuration is defined by:
  - the transition radius R_j
  - the inner radius R_{in}
  - the inner accretion rate $\dot{M}_{in}$
  - the black hole mass M_{BH}
  - the SAD outer radius R_{out}

Ferreira et al. (2006),



JED Thermal Equilibrium



Petrucci et al. (2010),
Marcel et al. (2018a, b)

(1) Vertical equilibrium

(2) Ions thermal equilibrium:

$(1-\delta)\ q_{acc} = q^{i}_{adv} + q_{ie}$

(3) Electrons thermal equilibrium:

$\delta\ q_{acc} = q^{e}_{adv} - q_{ie} + q_{rad}$

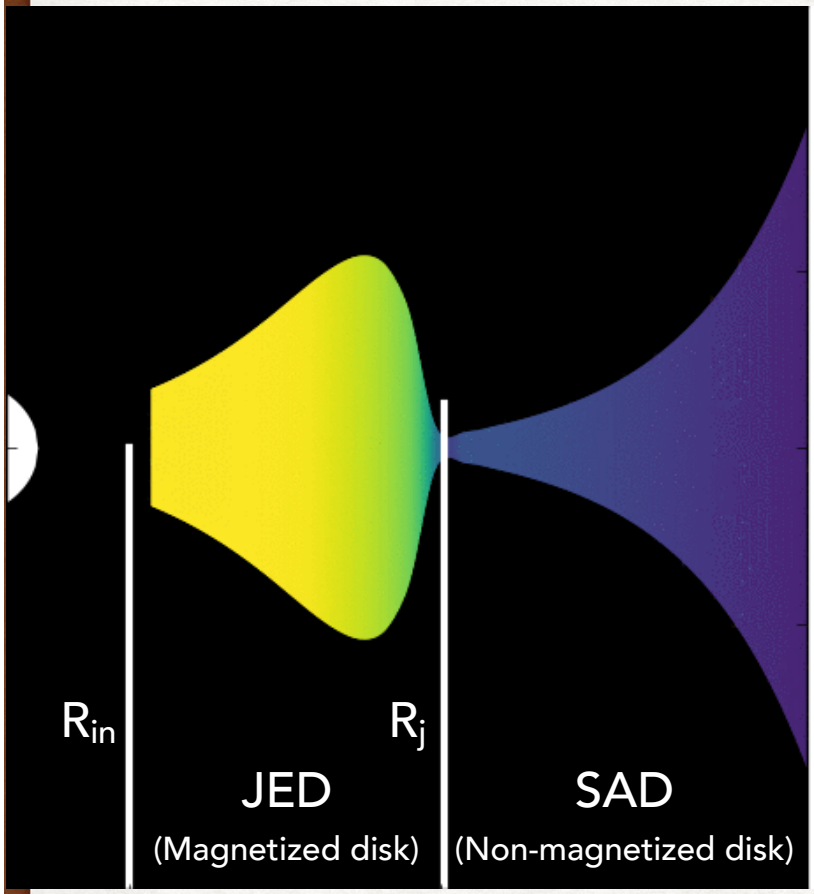
$\delta = 0.5$ (Pelletier 2004; Yuan & Narayan 2014)

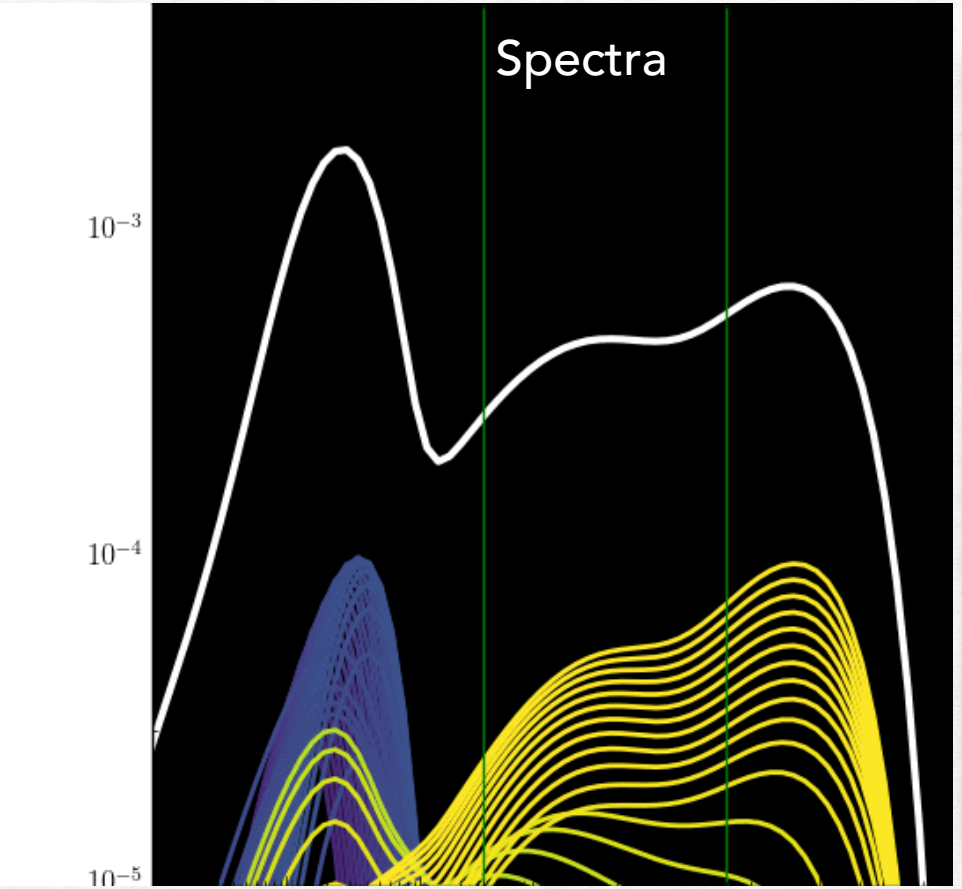
Radiative cooling as a **bridge formula** between:

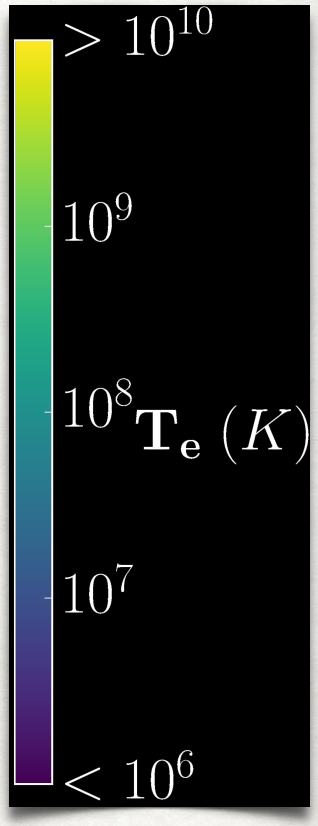
- Thick: Blackbody radiation,
- Thin: Synchrotron, Bremsstrahlung and Compton processes as well as inverse-Compton illumination from the SAD onto the JED using **BELM** (Belmont+08,09).

→ **T_e, τ, $\varepsilon = h/r$: thermal structure at any given radius!**

JEDSAD radial structure and global SED

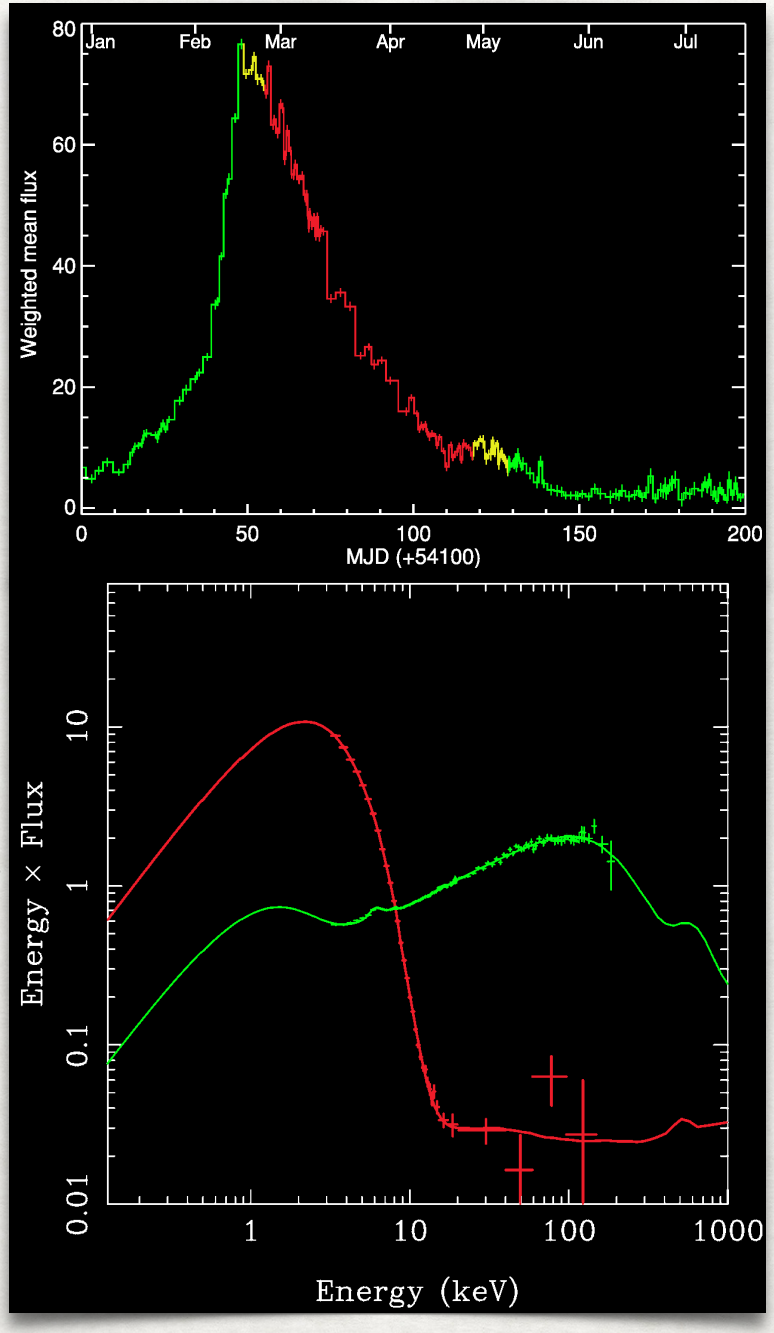






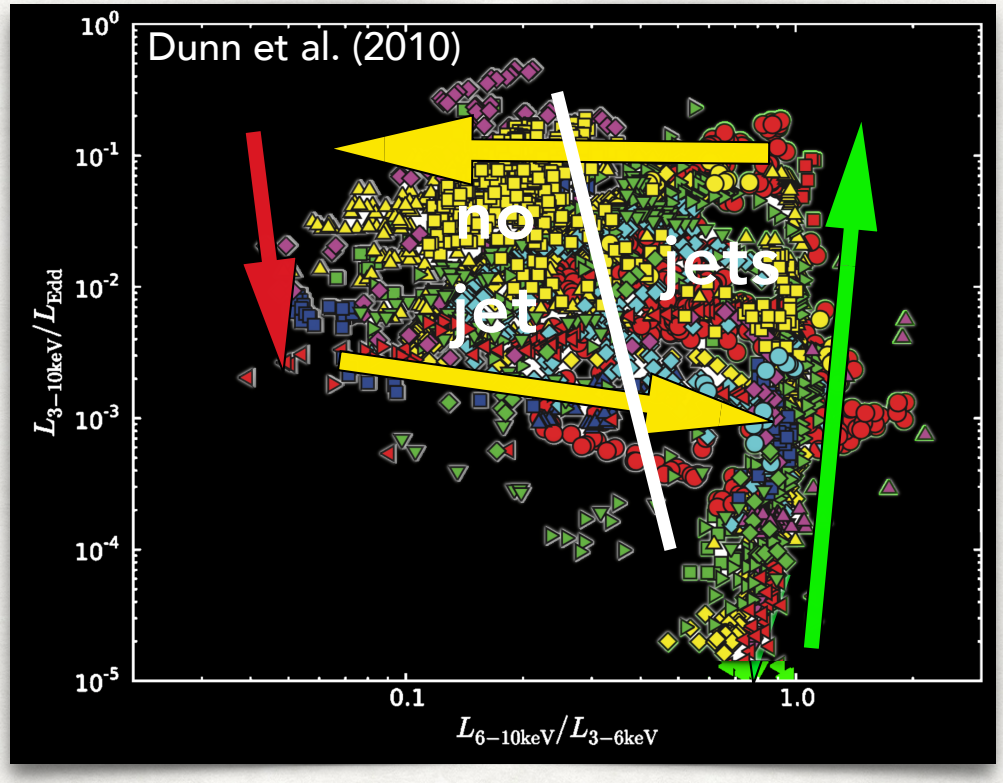
Marcel18 PhD Thesis

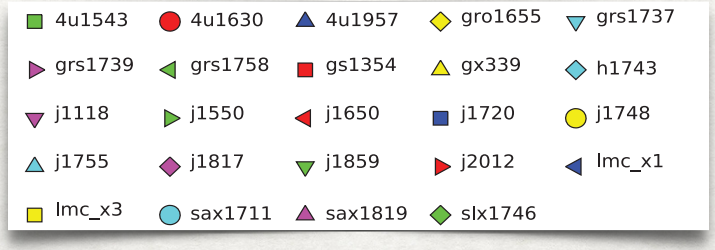
Application to X-ray Binaries



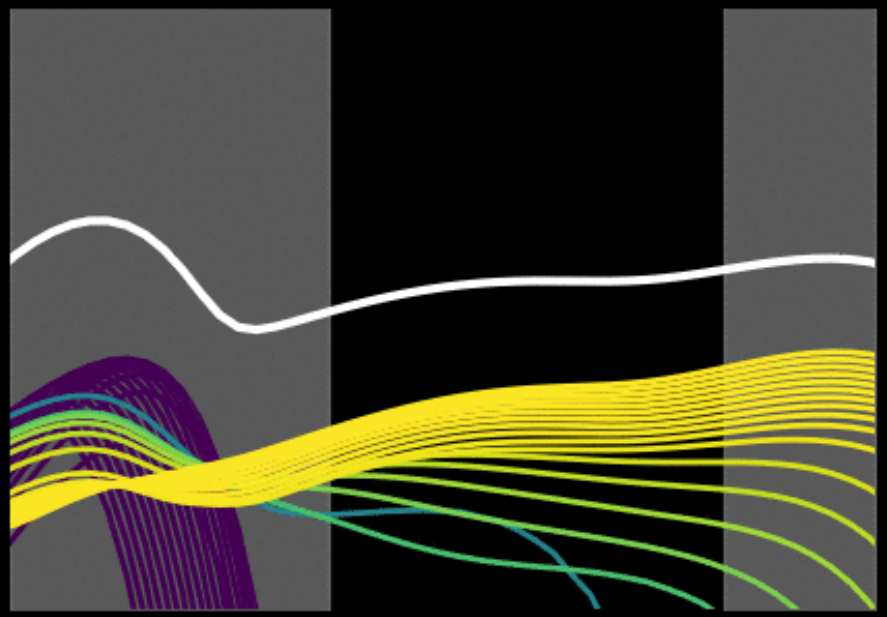
A spectral and dynamical hysteresis

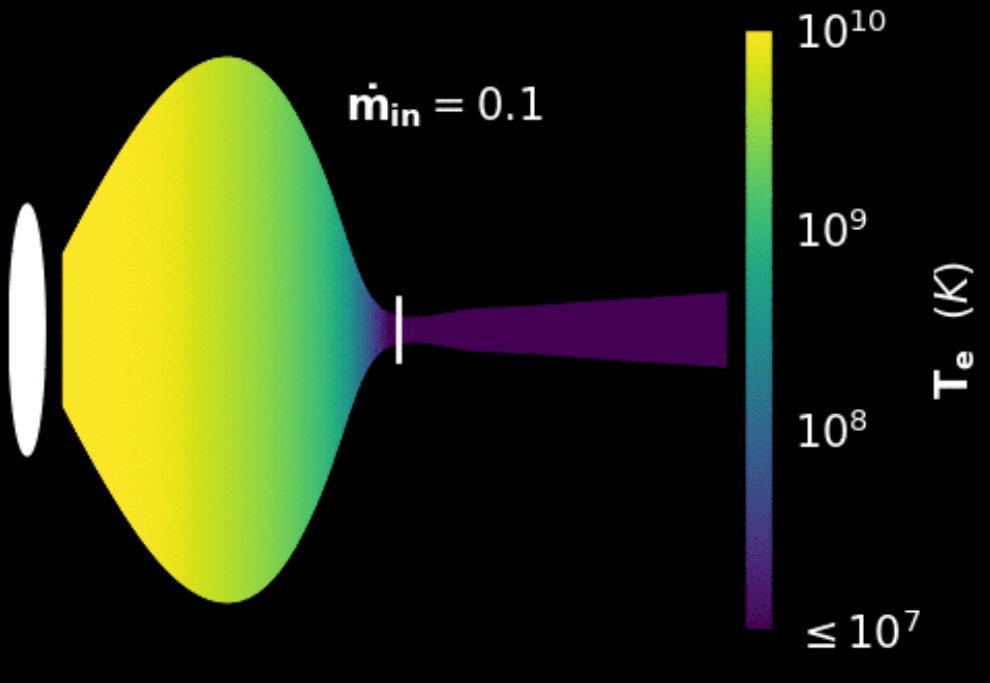
(e.g. Fender et al. 2004, 2009, Gandhi et al. 2010, Dunn et al. 2010, Zhang S.-N. 2013, Corbel et al. 2013)

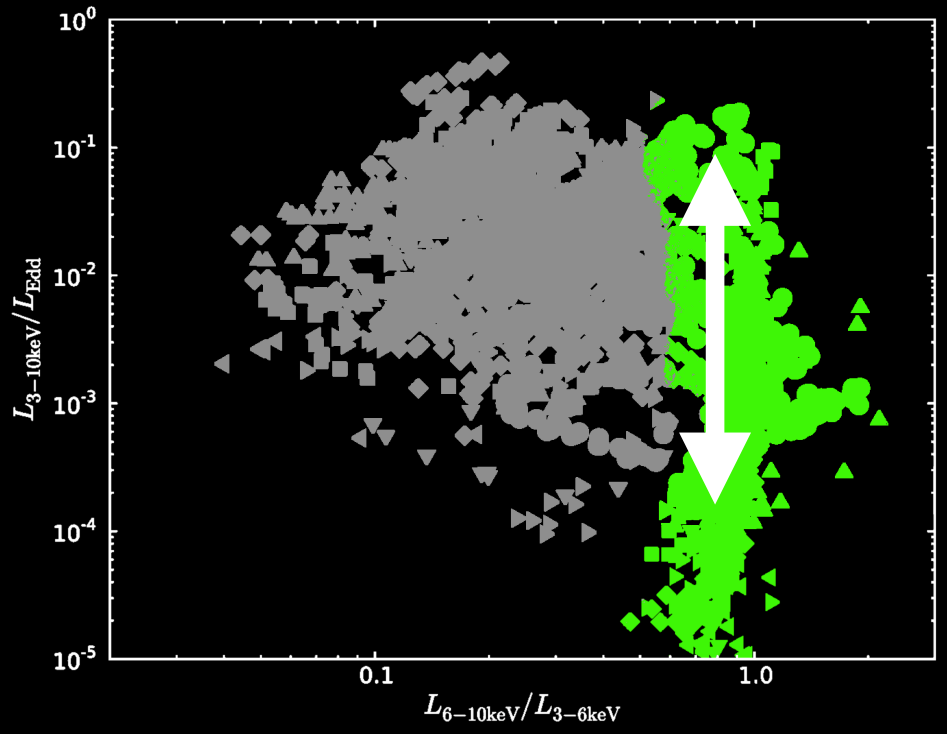


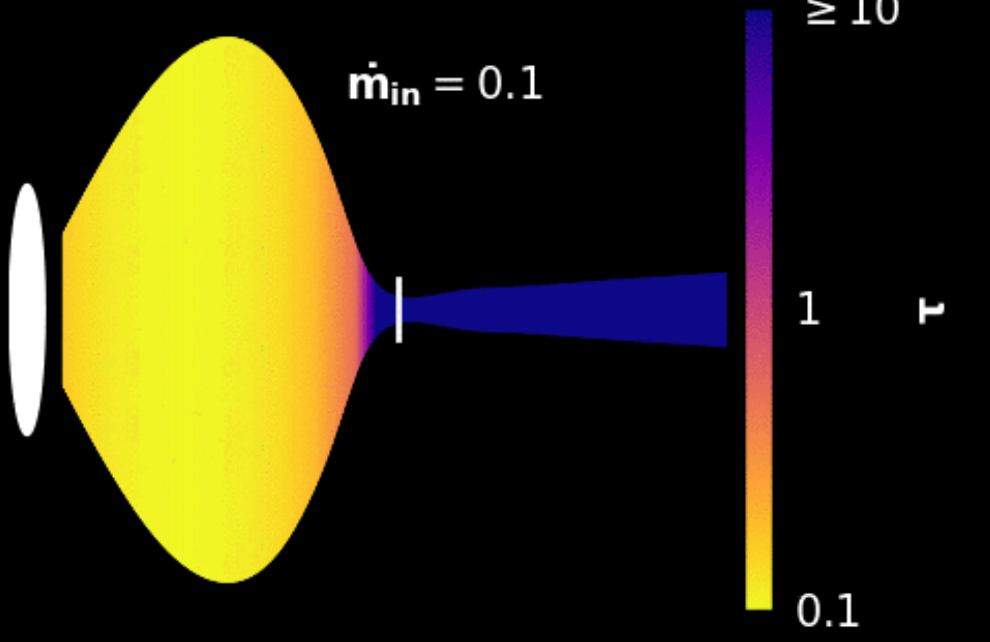


Reaching high luminosity hard states









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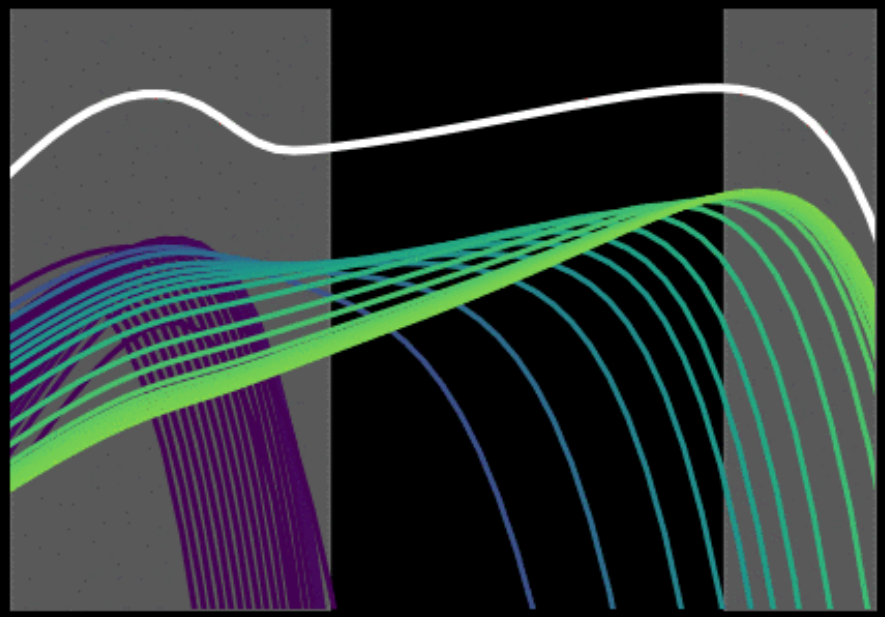
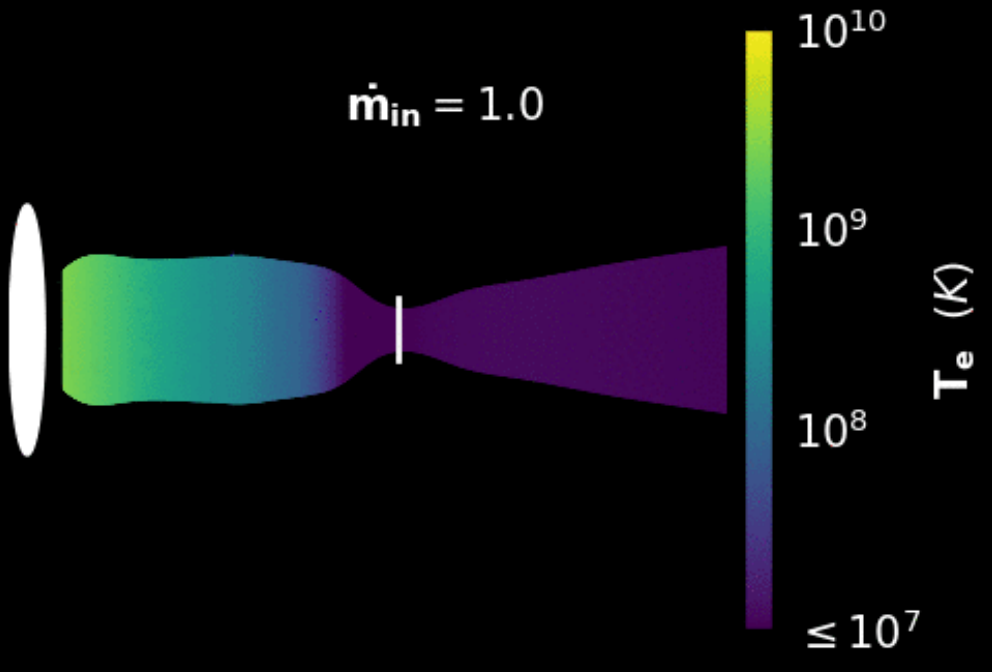
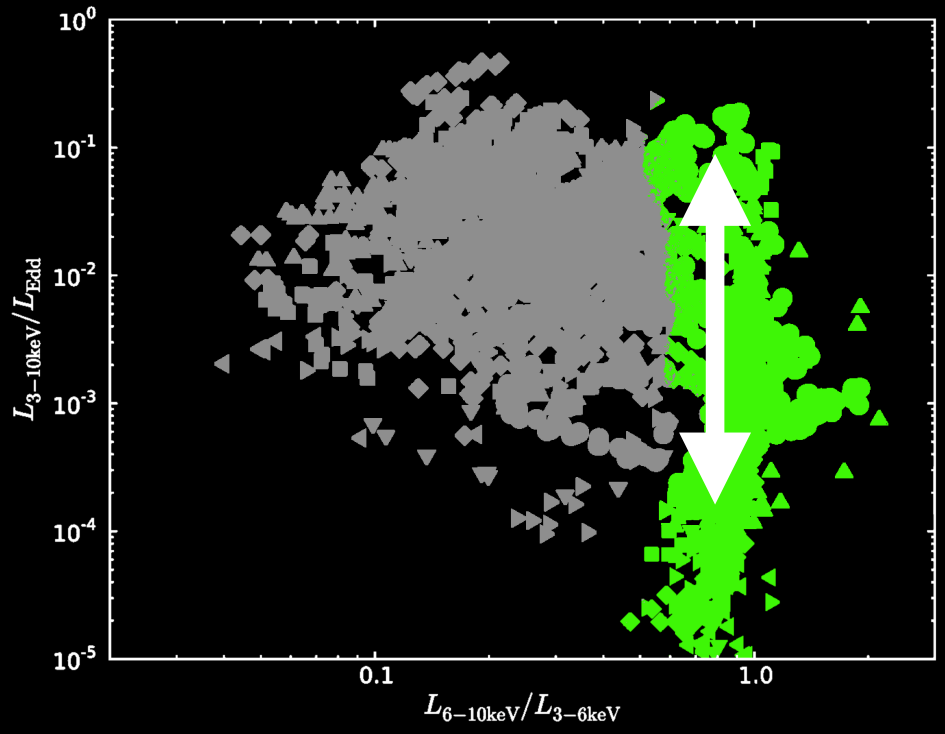
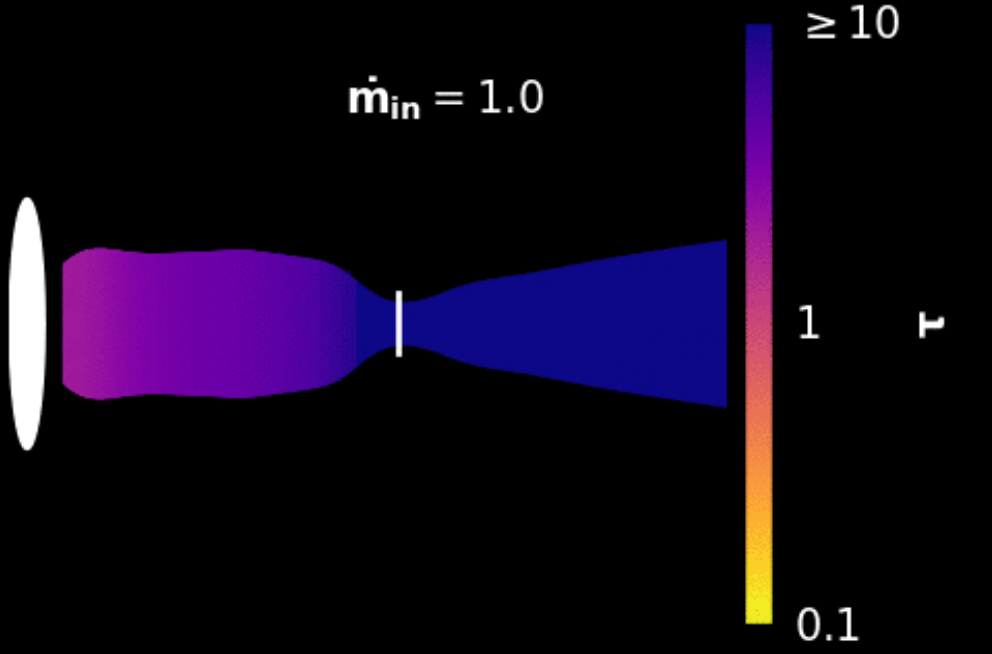
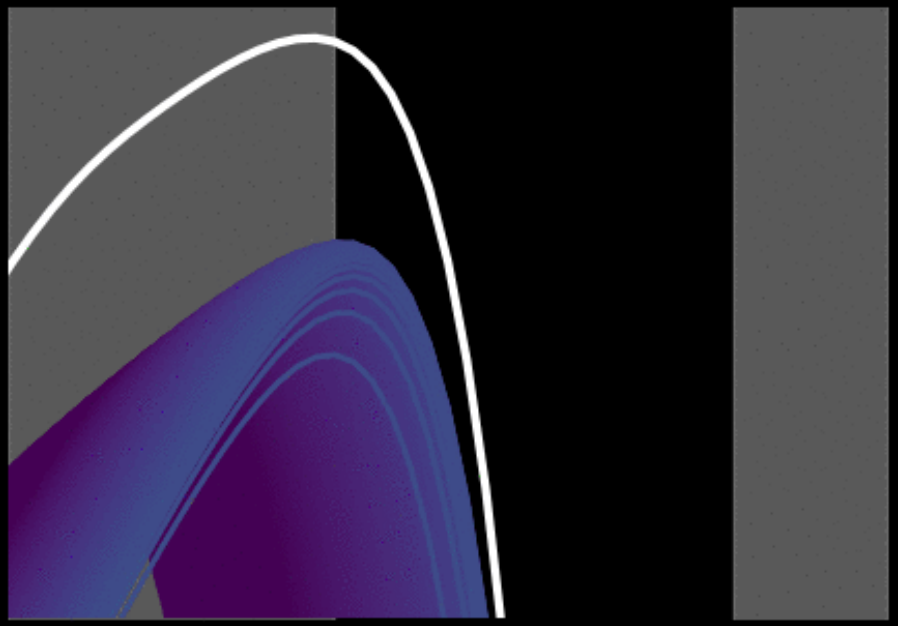


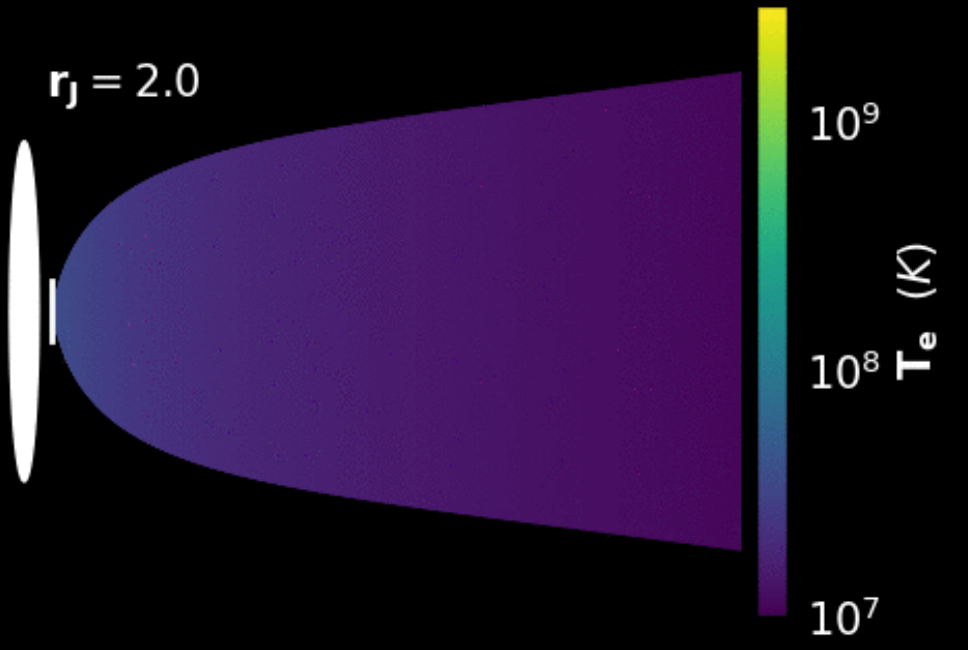


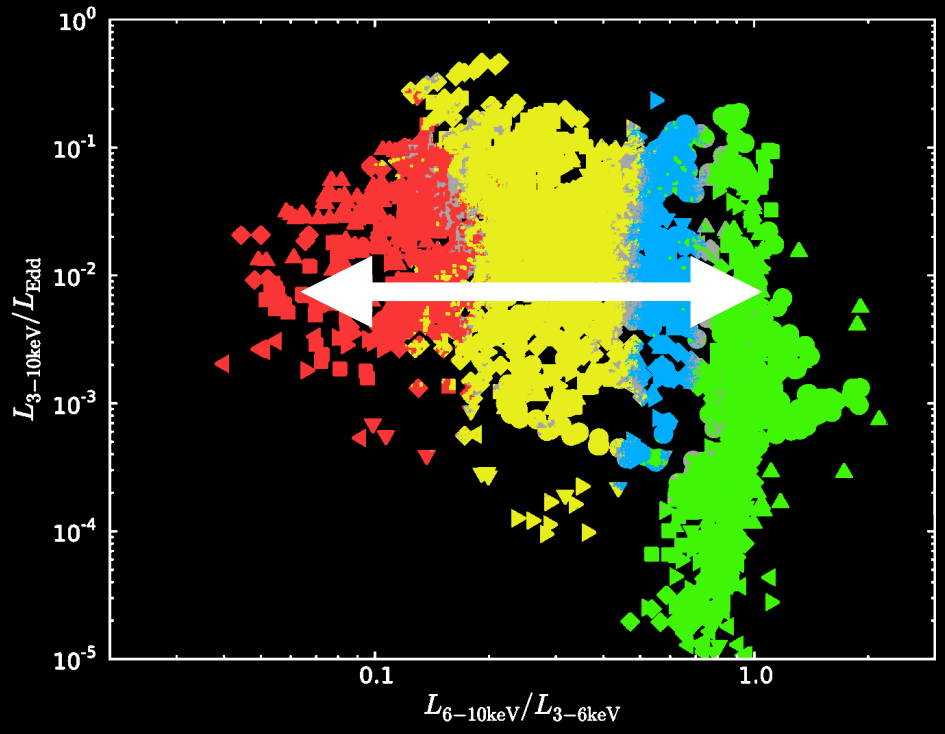


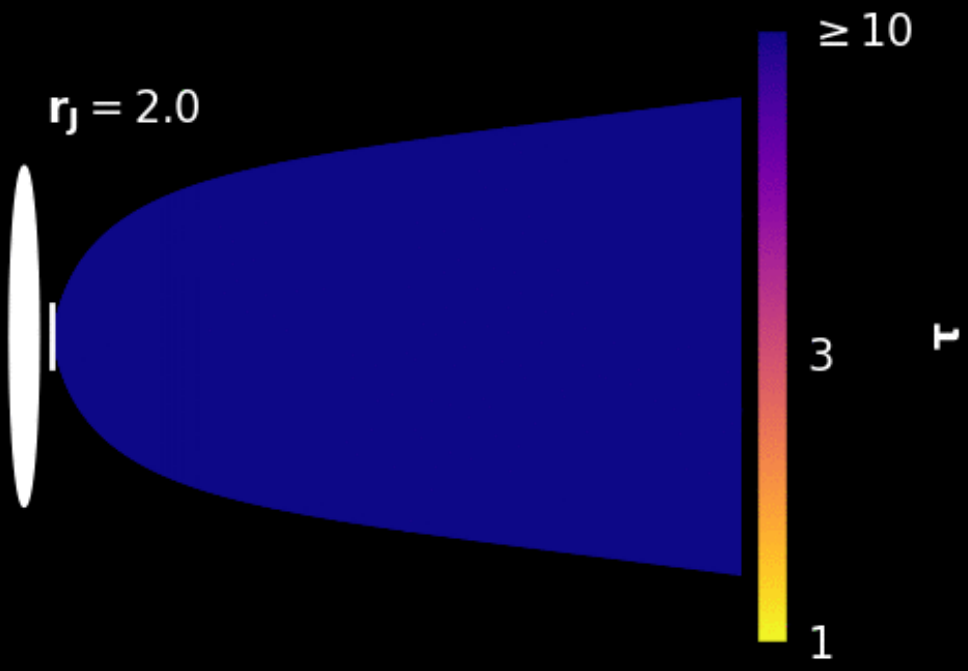


From soft to hard states!

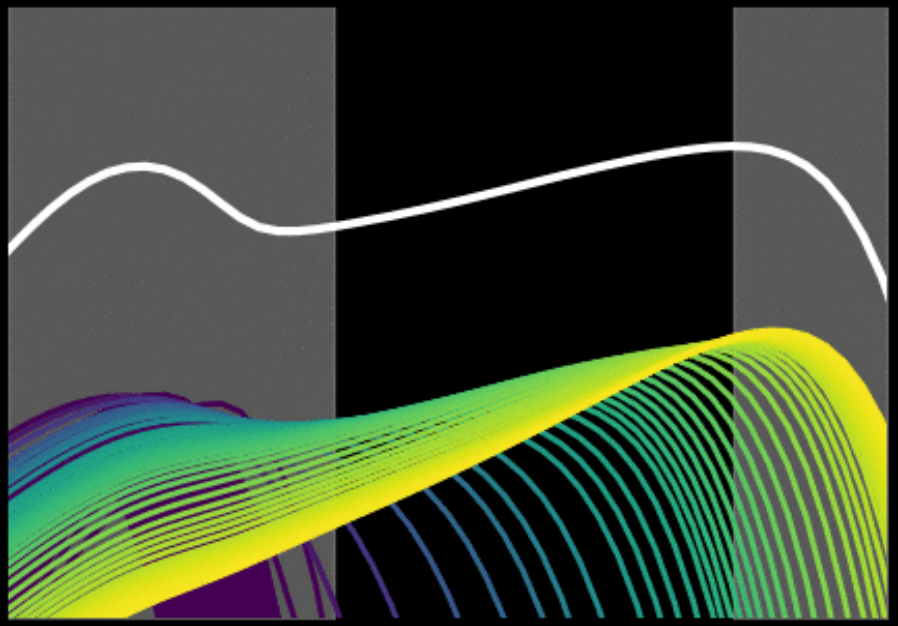


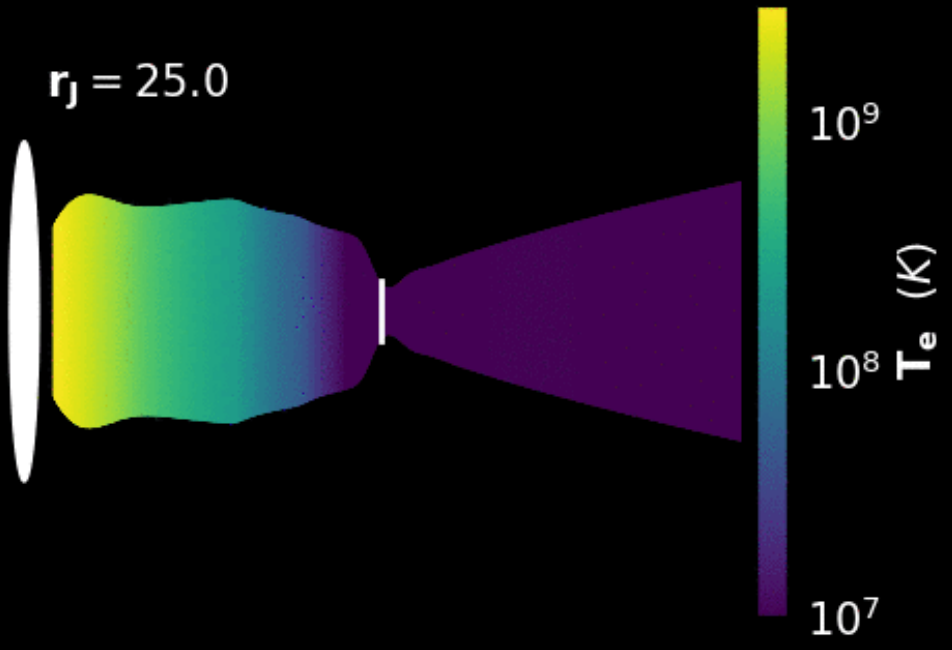


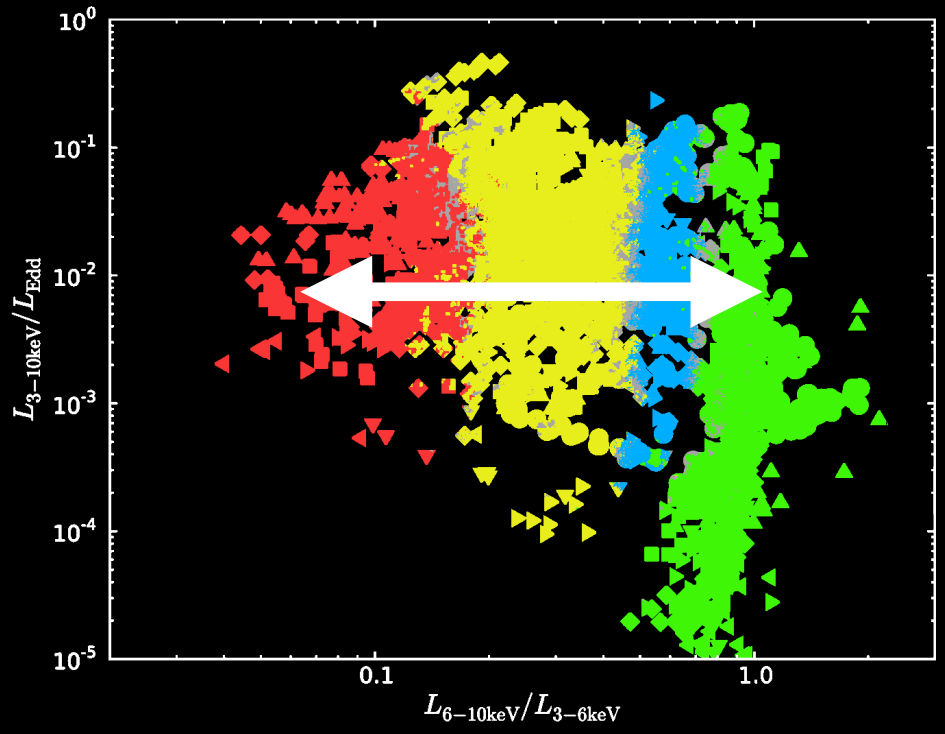


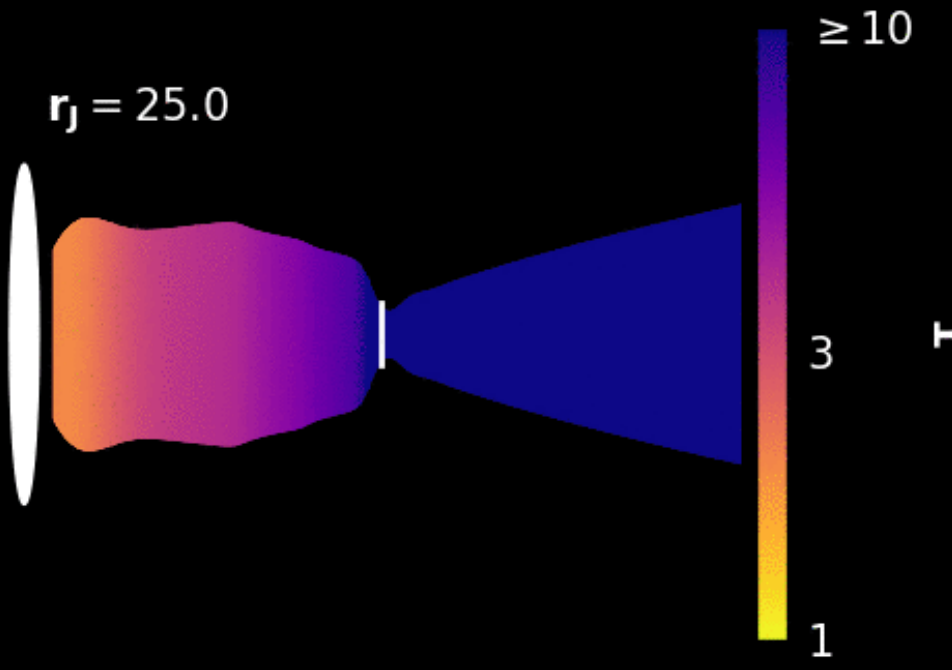


From soft to hard states!

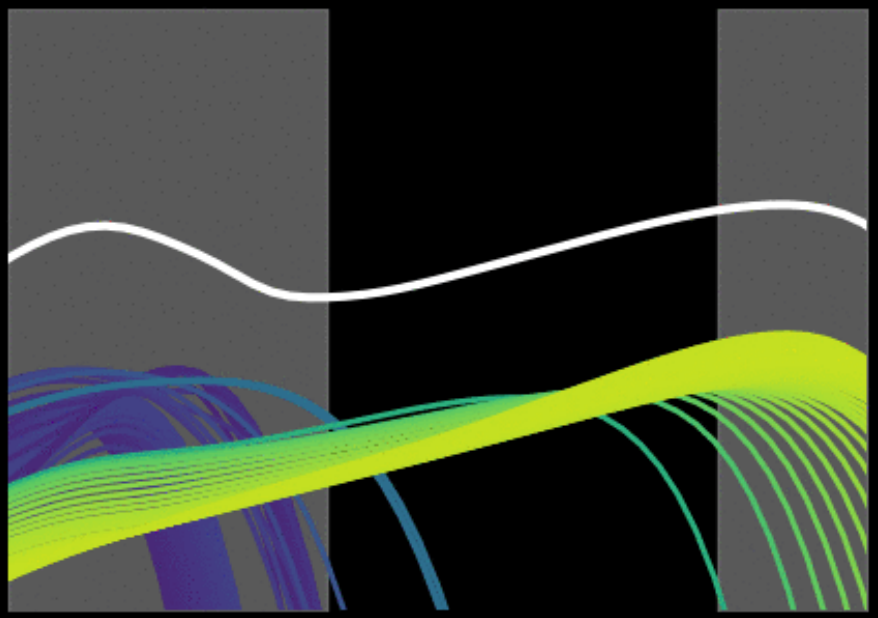


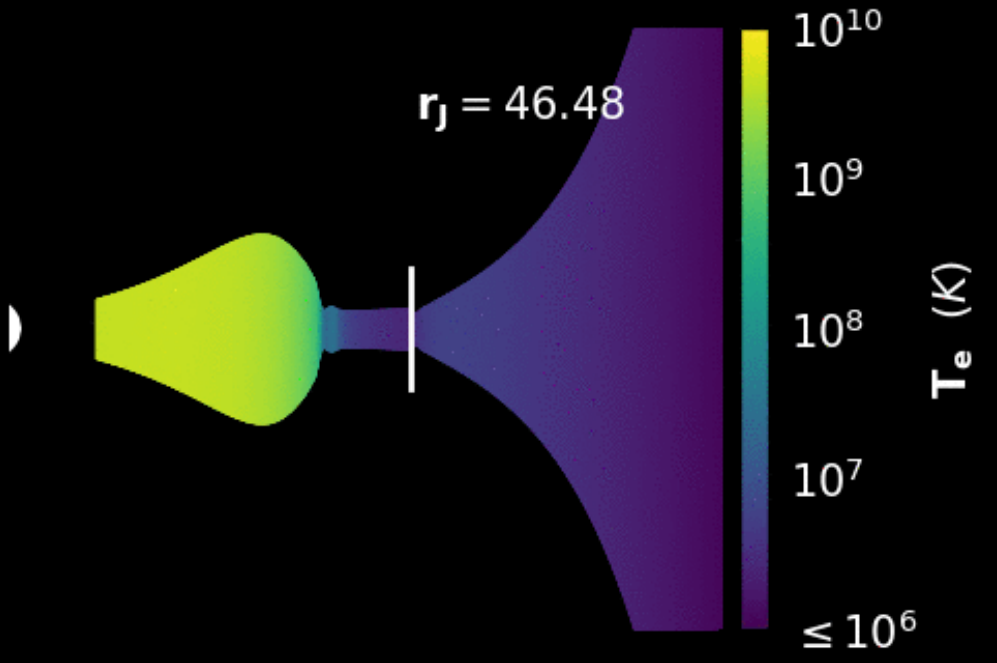


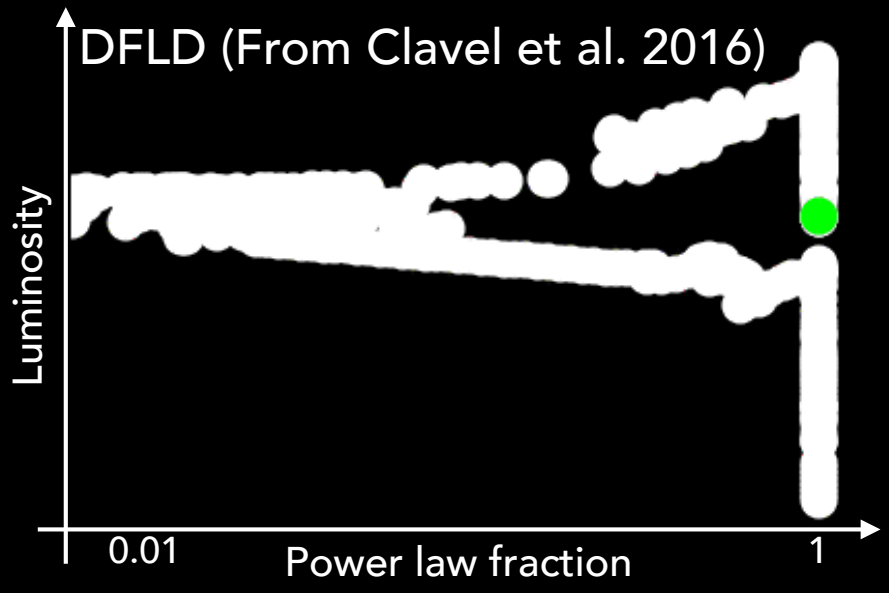


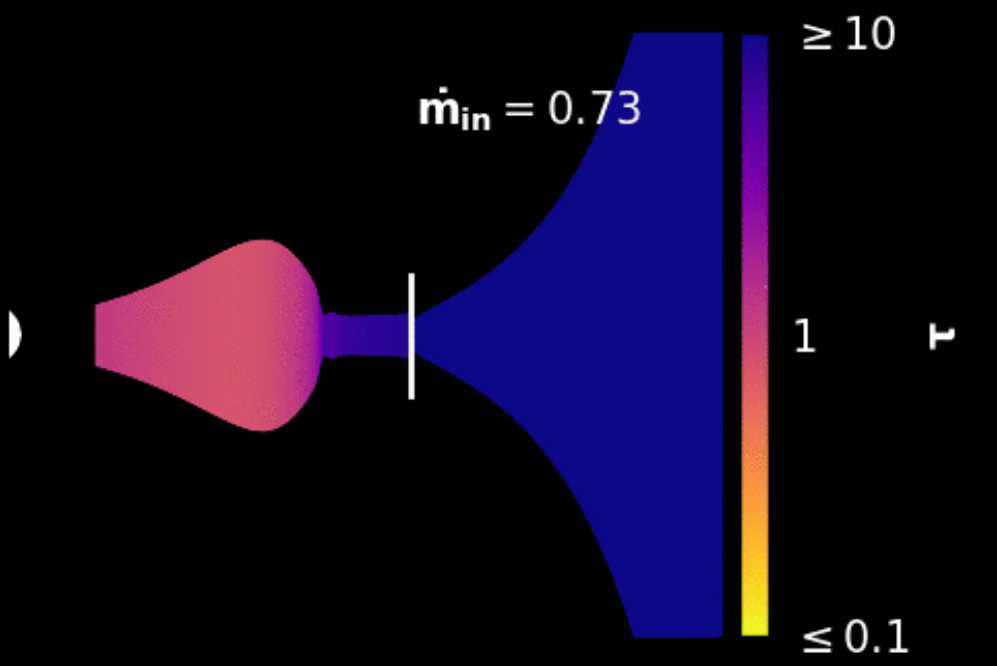


Replication of GX339-4 behavior in 2010-2011





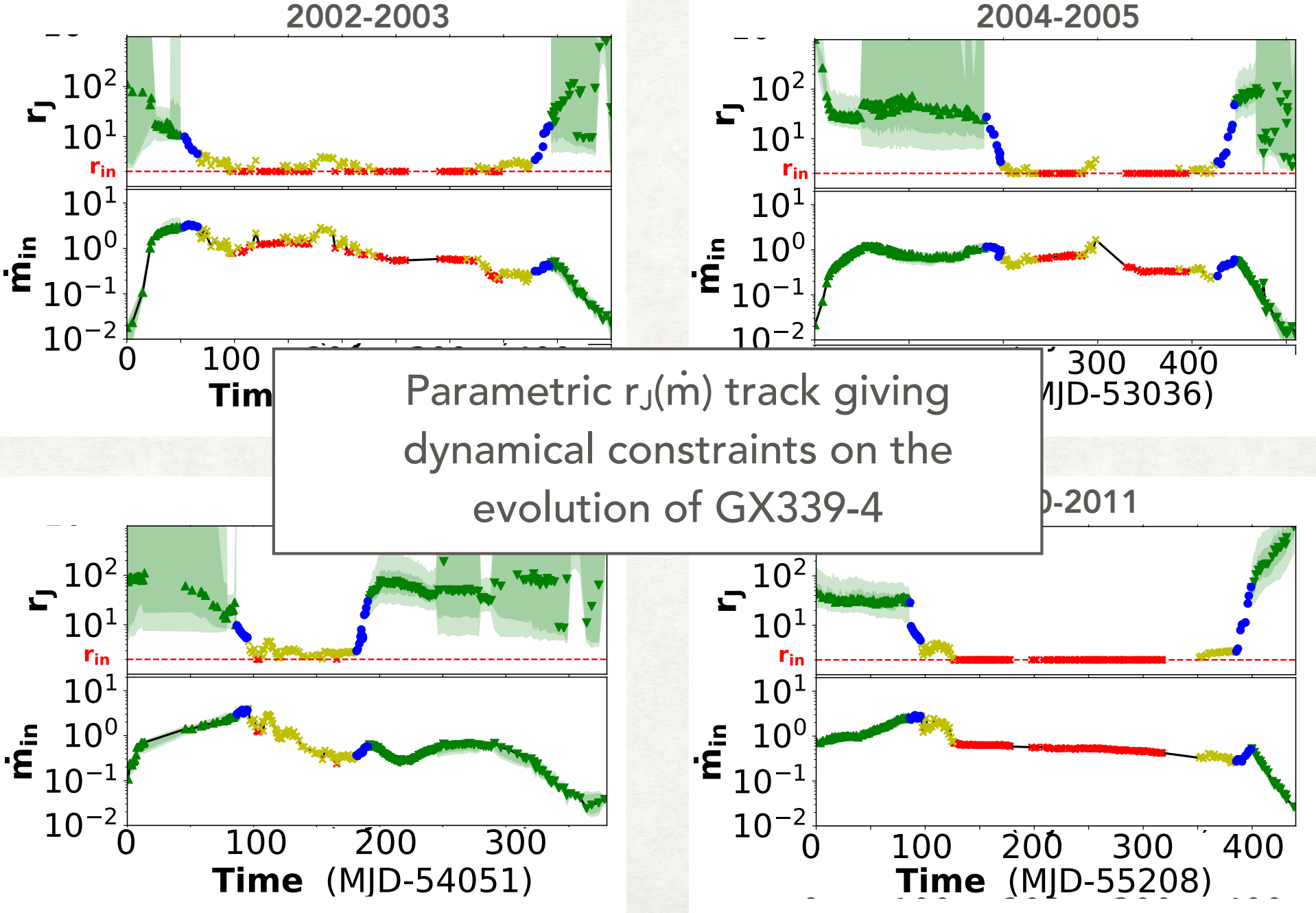




Marcel et al. 2019a, A&A in press

GX339-4: 15 years of RXTE

Marcel et al. 2019b

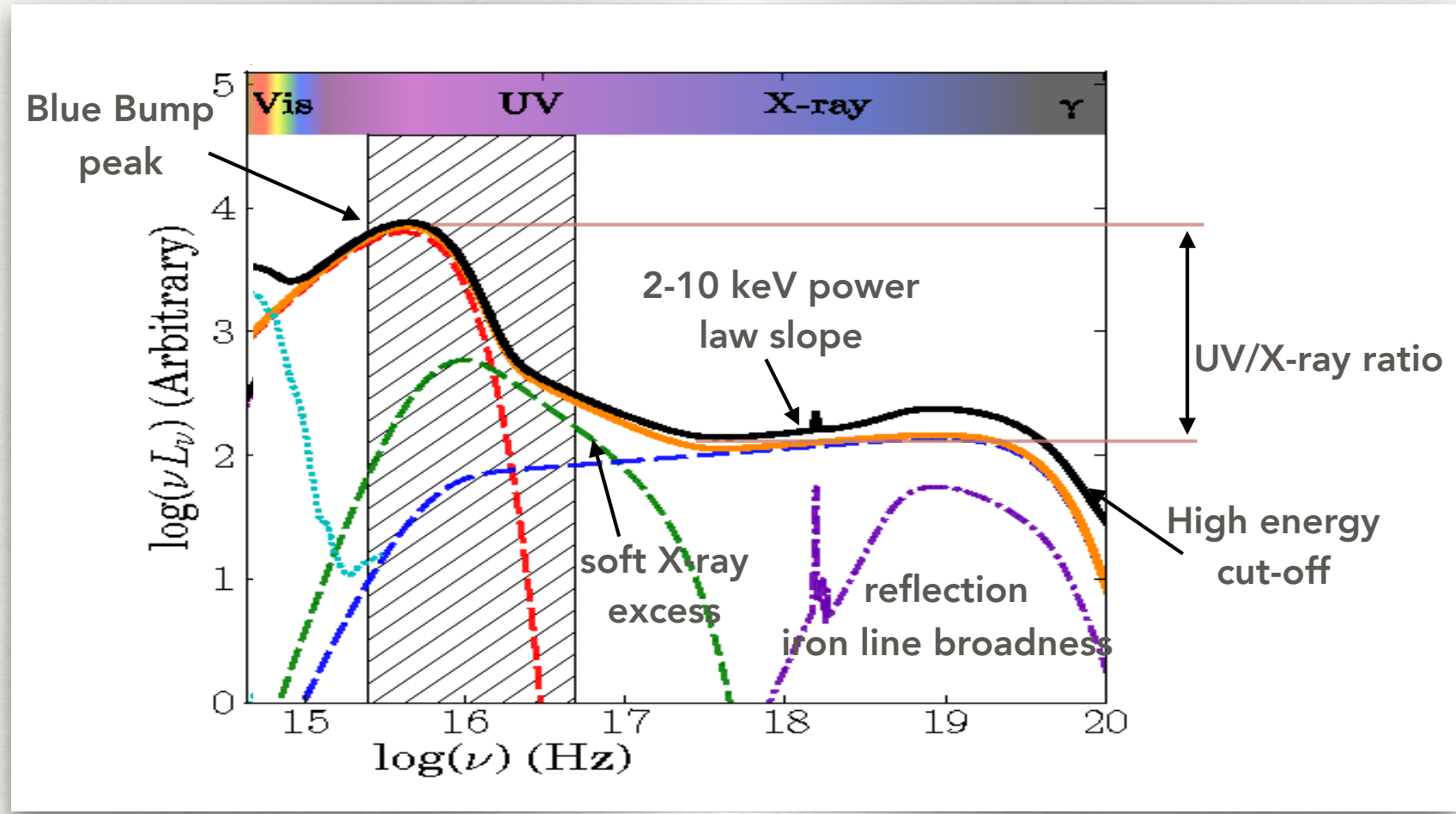


Parametric $r_J(\dot{m})$ track giving dynamical constraints on the evolution of GX339-4

Next Steps: Direct Fits

- JED and SAD tables for XSPEC and ISIS
- coherent Reflection tables (using reflionx or xillver)
- Application to other X-ray binaries
- Application to AGNs

Application to AGNs



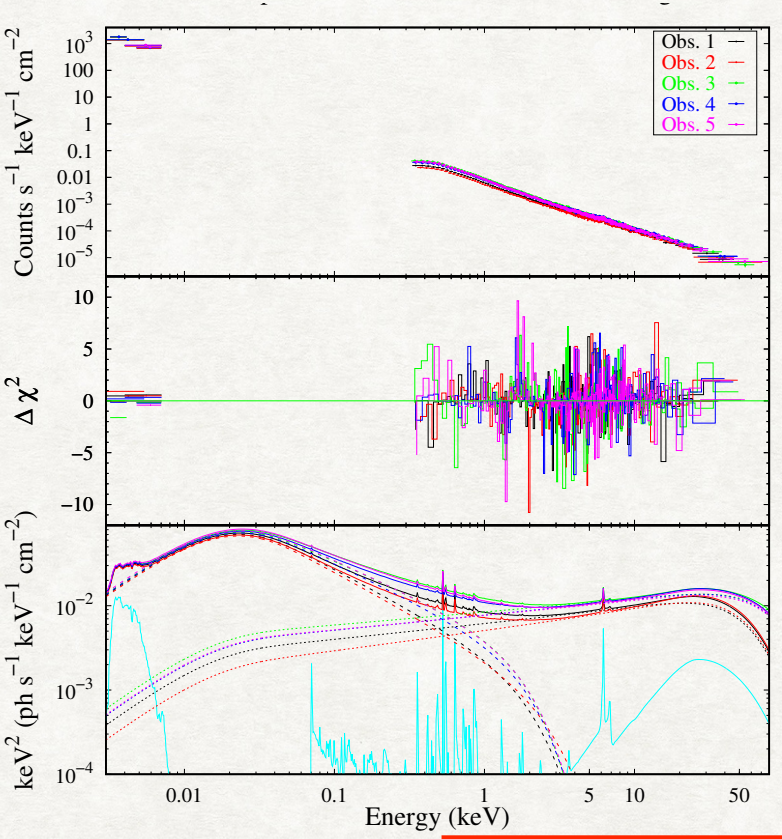
- Data from UV to hard X-rays
- Soft X-ray excess: warm comptonisation of the SAD (*simpl* model of *XSPEC*)

Model parameters: R_{in}, R_j, M_{BH}, M_{in}, R_{out}

The Case of the Seyfert HE 1143-1810

Ursini et al. (2019) submitted

- Hosting a supermassive black hole with $M_{BH} \sim 5 \times 10^7 M_{sun}$
- Luminosity estimated > L_{Edd}
- Blue bump, soft X-ray excess, high energy cut-off, no broad iron line
- Radio-quiet but shows an unresolved radio emission consistent with L_x-L_{radio} fundamental plane of black hole activity



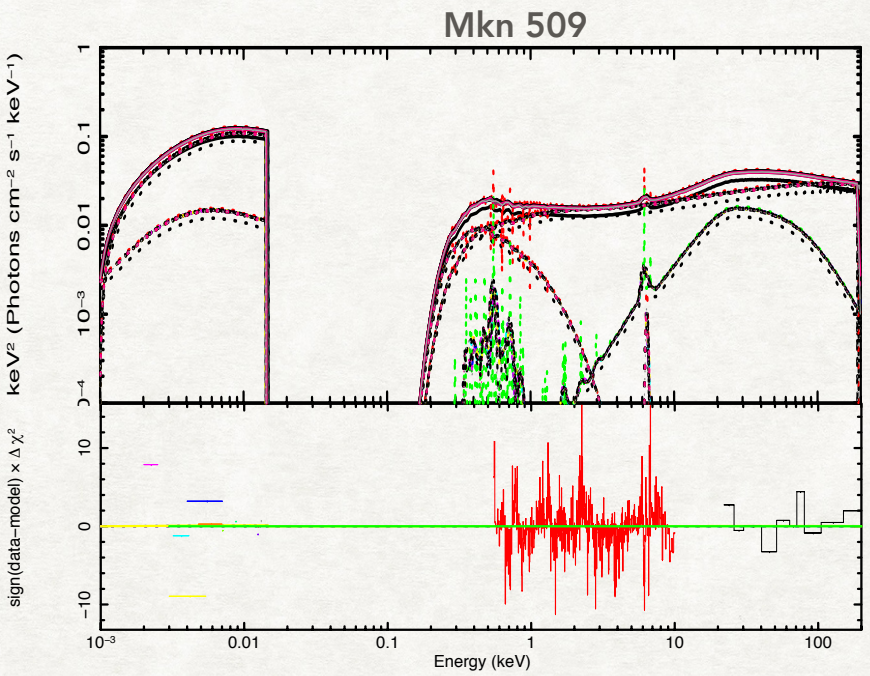
	all obs.	obs. 1	obs. 2	obs.3	obs. 4	obs. 5
M_{BH} (10^7 $M_\odot$)	3.71 ± 0.07					
Γ_s		2.55 ± 0.02	2.58 ± 0.02	2.40 ± 0.0	2.44 ± 0.02	2.40 ± 0.02
E_s (keV)		1.33 ± 0.13	$1.44^{+0.18}_{-0.15}$	1.18 ± 0.07	1.19 ± 0.09	1.11 ± 0.06
r_J (R_G)		17.9 ± 0.5	18.8 ± 0.6	19.3 ± 0.4	19.7 ± 0.4	18.9 ± 0.4
$\dot{m}$ (L_{Edd}/c^2)		0.79 ± 0.02	0.734 ± 0.014	0.92 ± 0.02	0.89 ± 0.02	0.89 ± 0.02
χ^2/dof	2050/2001					

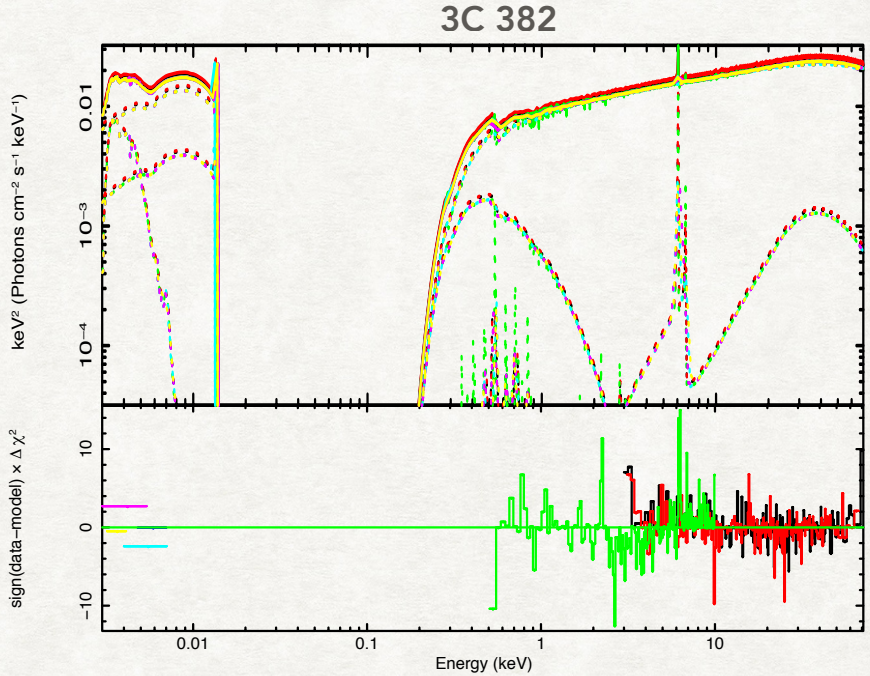
$$\frac{M_{BH}}{M_\odot} \simeq 4 \times 10^7$$

$$\langle R_j \rangle \simeq 20 R_g$$

$$\langle \dot{M} \rangle \simeq 0.8 \dot{M}_{Edd}$$

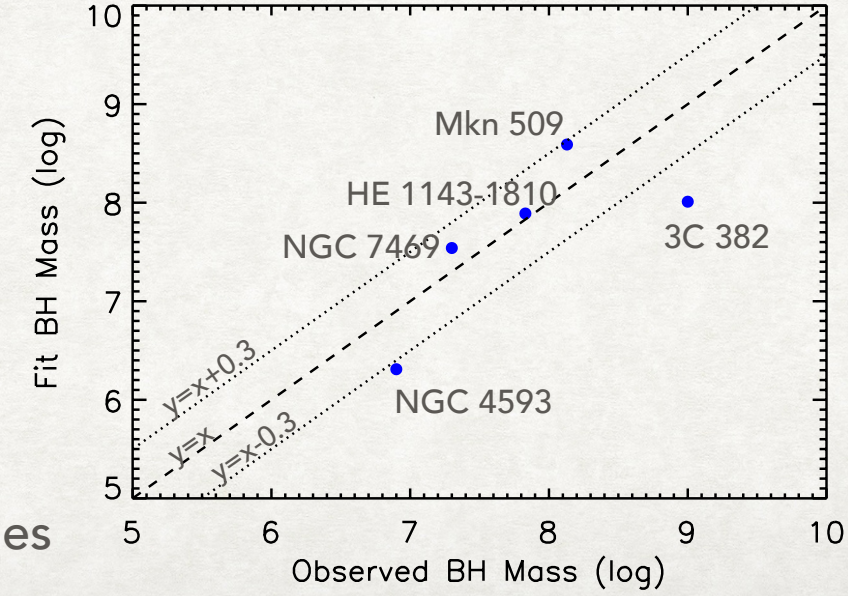
Other AGNs





Source	R_j/R_g	$\dot{M}/\dot{M}_{Edd}$	$\log M_{BH}$	R_{in}/R_g
HE 1143	$23.77^{+0.32}_{-0.38}$	0.70±0.02	7.89±0.03	6.00±0.09
Mrk 509	$13.68^{+0.11}_{-0.08}$	0.32±0.01	$8.59^{+0.01}_{-0.02}$	2.20±0.04
3C382	$14.91^{+0.21}_{-0.41}$	$1.12^{+0.04}_{-0.06}$	8.01±0.01	$1.79^{+0.06}_{-0.10}$
NGC 4593	$26.51^{+0.42}_{-0.96}$	1.09±0.06	$6.31^{+0.04}_{-0.03}$	$5.98^{+0.36}_{-4.44}$
NGC 7469	$14.33^{+0.10}_{-0.01}$	0.41±0.01	7.54±0.01	$3.30^{+0.05}_{-0.06}$

BH masses in agreement with published ones



Conclusion

- JEDoSAD model for compact objects (Ferreira et al. 2006, Marcel et al., 2018a, b)

- Reproduced the different outbursts of GX 339-4 observed by RXTE (Marcel et al., 2019a, b)

- Built XSPEC/ISIS table model with reflection (xillver & reflionx). Already applied to:
  - ➡ MAXI J1535-571 (Marcel, Neilsen et al., in prep)
  - ➡ H1743-322 & GX339-4 (Barnier, Petrucci et al., in prep.)
  - ➡ GRS1739-278 (Petrucci et al.),
  - ➡ AGN HE1143-1810 (Ursini et al. 2019, subm.)
  - ➡ Sample of AGNs (Barnier et al., in prep)
  - ➡ …

THANKS!