Tracking the evolution of the accretion flow of **MAXI J1820+070** with the **JED-SAD** model

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(MARINO A. ET AL., 2021, A&A, 656, ID. A63)

ICE INSTITUT DE CIÈNCIES DE L'ESPAI CSIC IEEC

INAF ISTITUTO NAZIONALE DI ASTROFISICA · ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI PALERMO

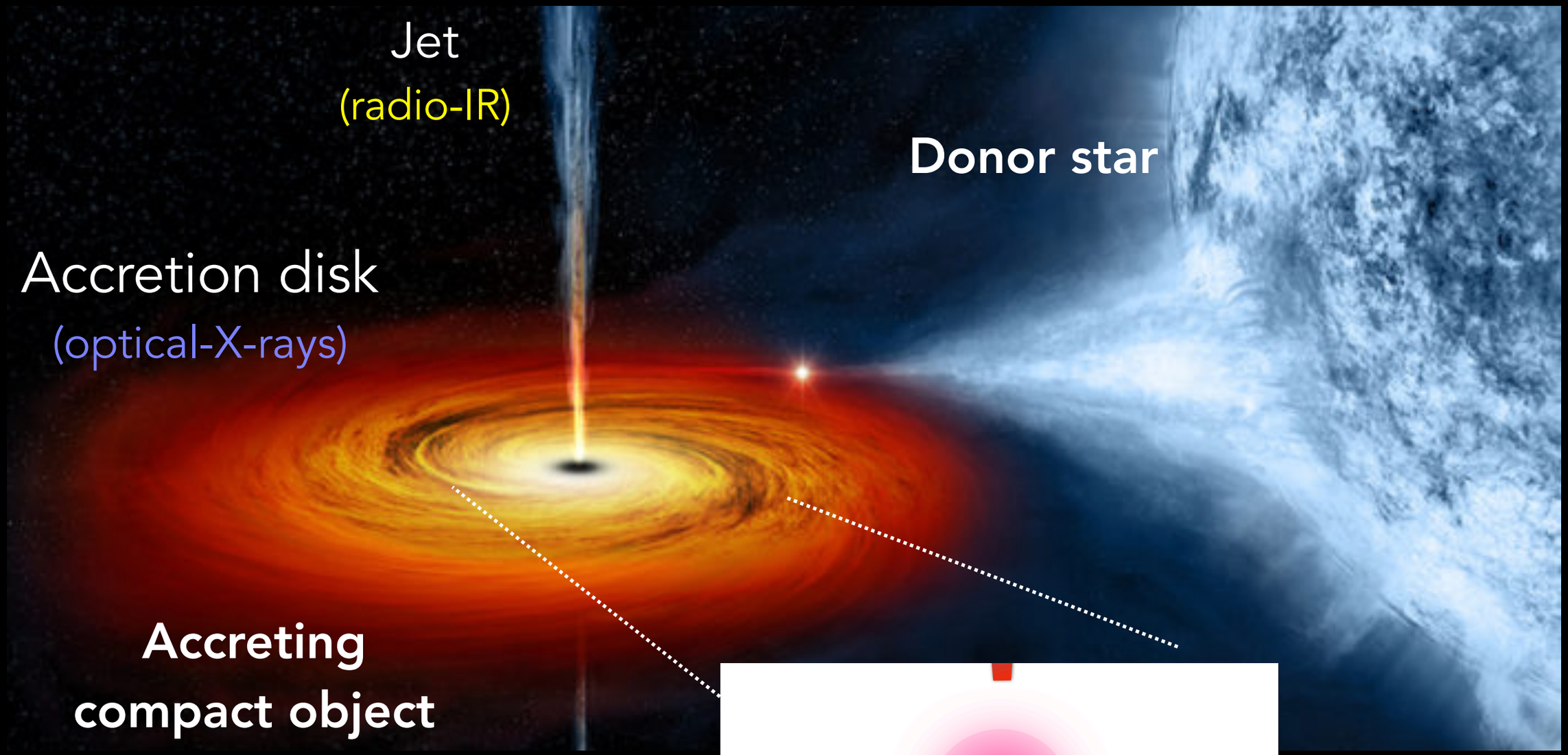
IPAG

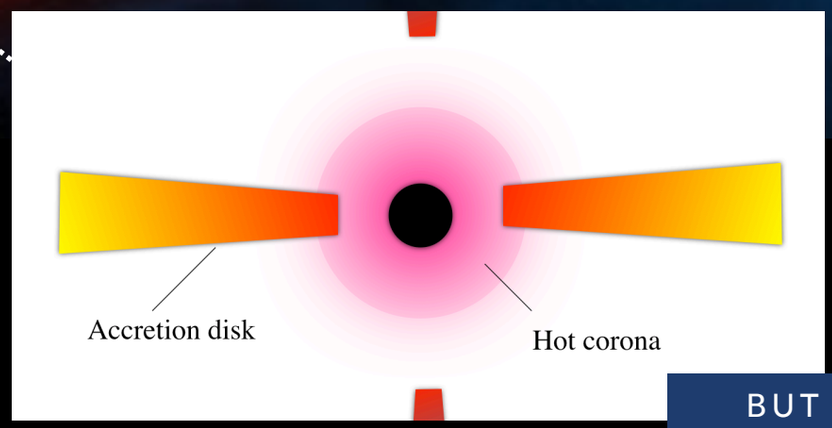
irap astrophysique & planétologie

UNIVERSITÀ DEGLI STUDI DI PALERMO

UNIVERSITÉ TOULOUSE III PAUL SABATIER Université de Toulouse

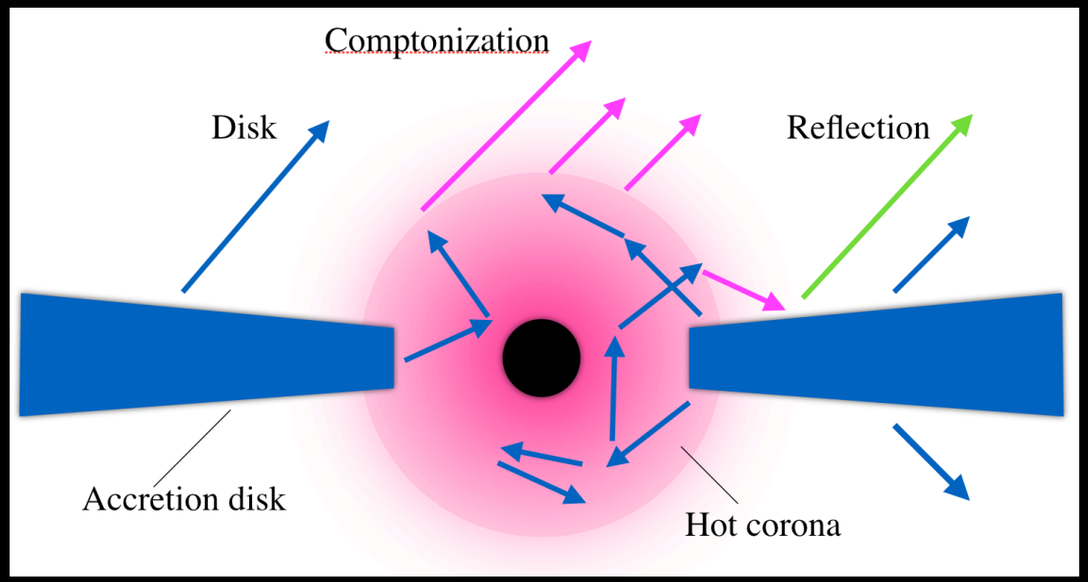
X-RAY BINARIES:
ACCRETION & EJECTION ENGINES



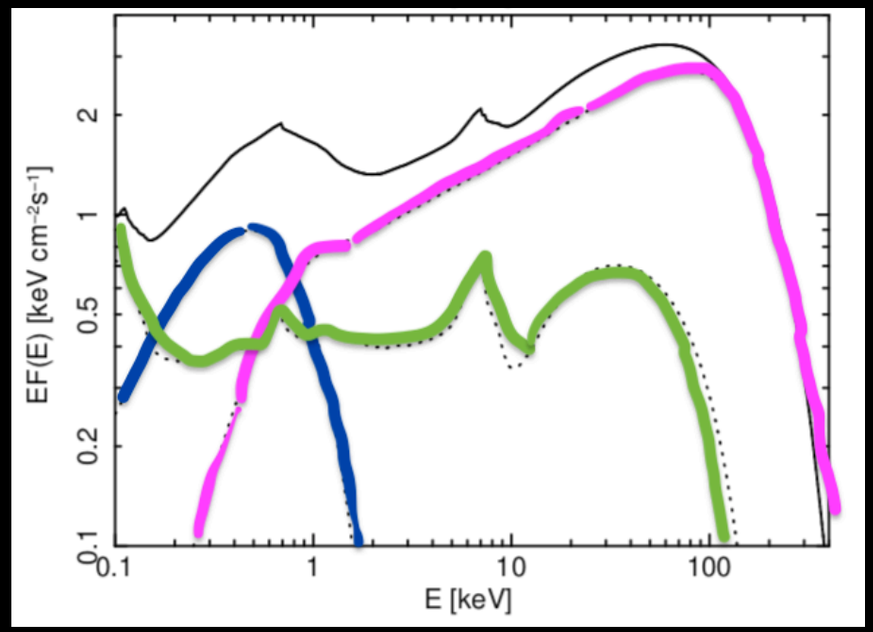


BUT THE GEOMETRY OF THE CORONA COULD BE DIFFERENT - SEE M. DOVCIAK'S TALK

SPECTRAL STATES IN XRBs

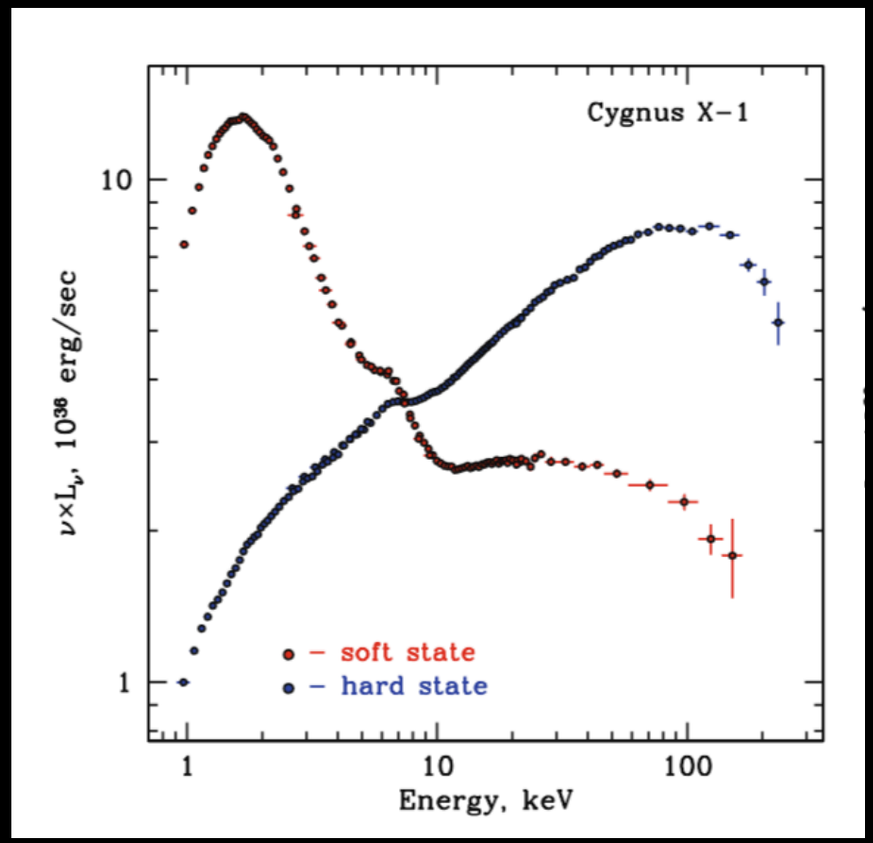


- Example of a typical XRB spectrum for the BH LMXB GX 339-4, **Zdziarski & De Marco 2020**



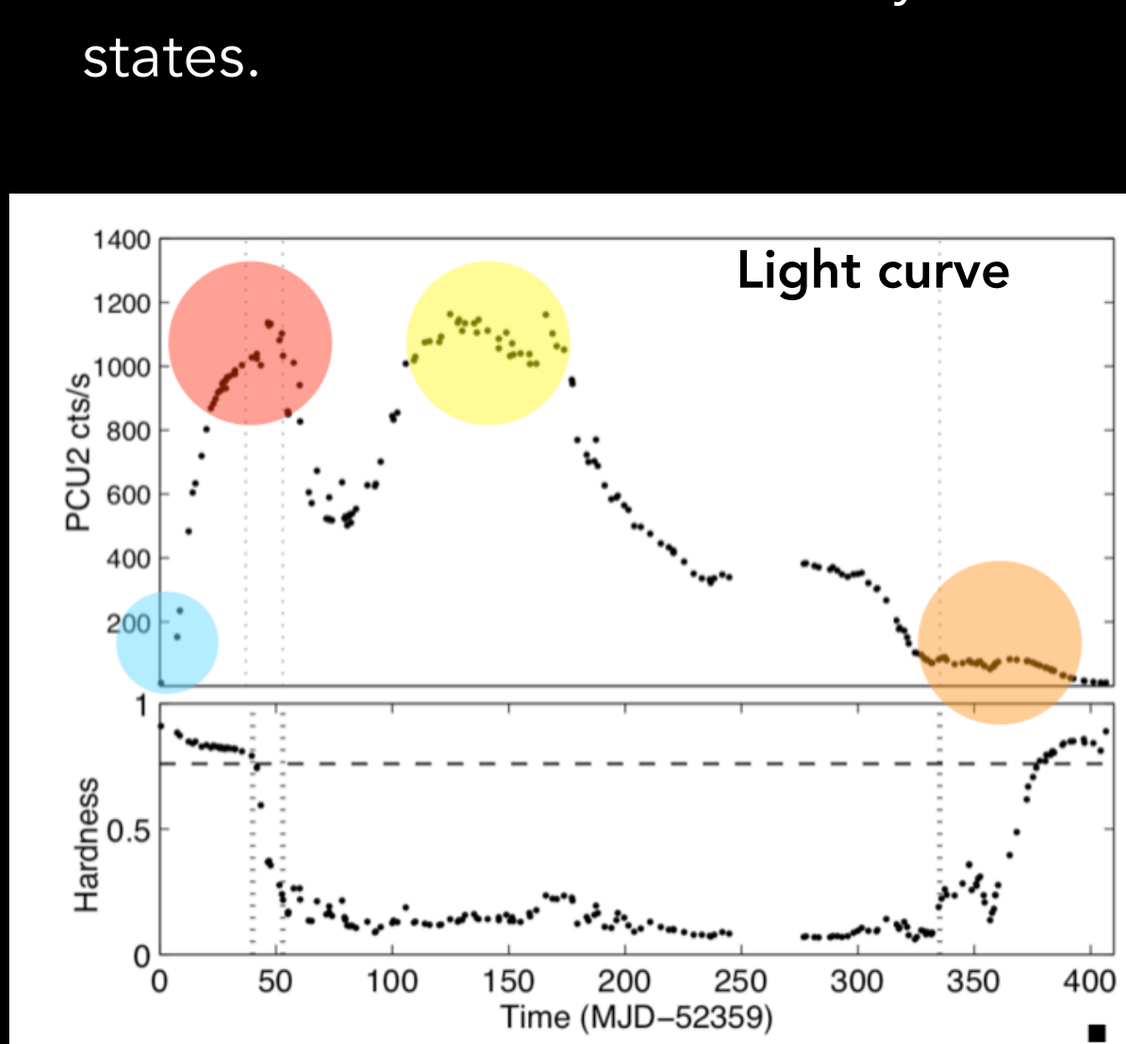
- XRBs are typically observed in **hard** (Comptonization-dominated), **intermediate** or **soft** (disk-dominated) spectral state.

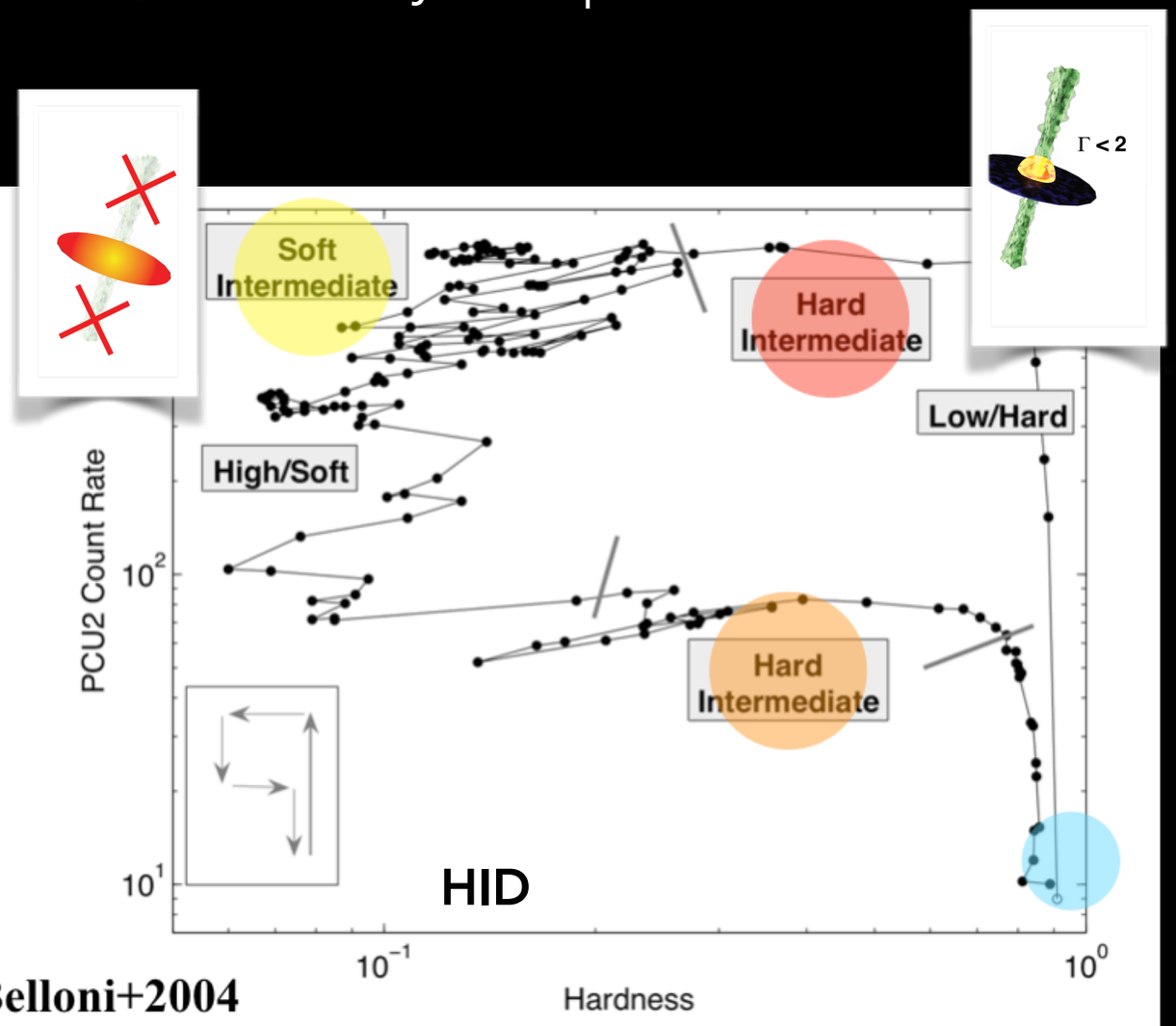
- The **truncation of the disk** in hard state is highly debated (e.g. Done+2007, Garcia+2015, Barak+2017, Zdziarski+2020)



ACCRETION AND EJECTION PROPERTIES DURING OUTBURSTS

- When in outburst, XRBs evolve in a **Hardness Intensity Diagram** following a specific pattern through the previously mentioned spectral states, a diagram called **q-diagram**.
- Jets emission is detected only in hard states, while they are quenched in soft states.





- **Belloni+2004**

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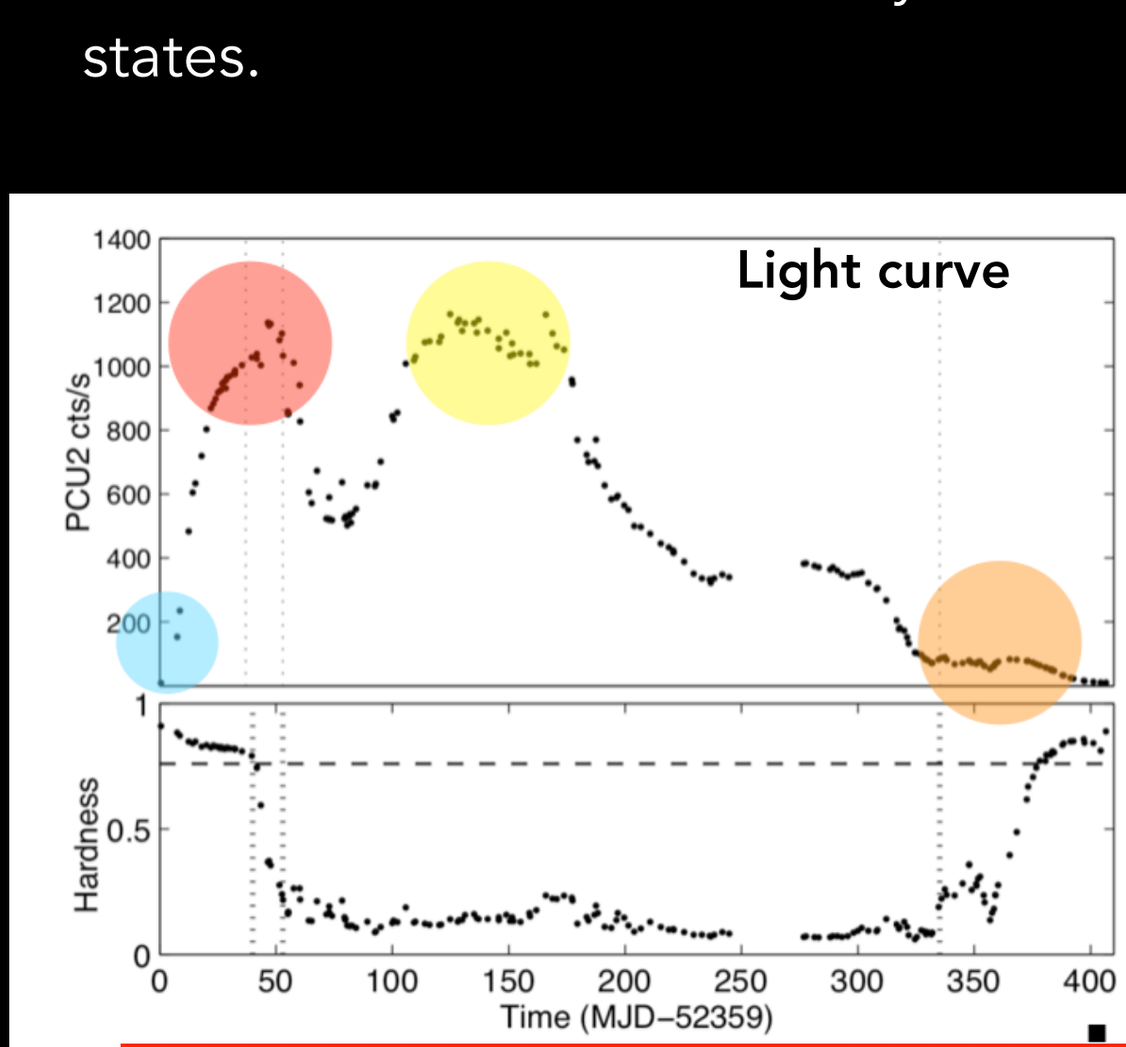
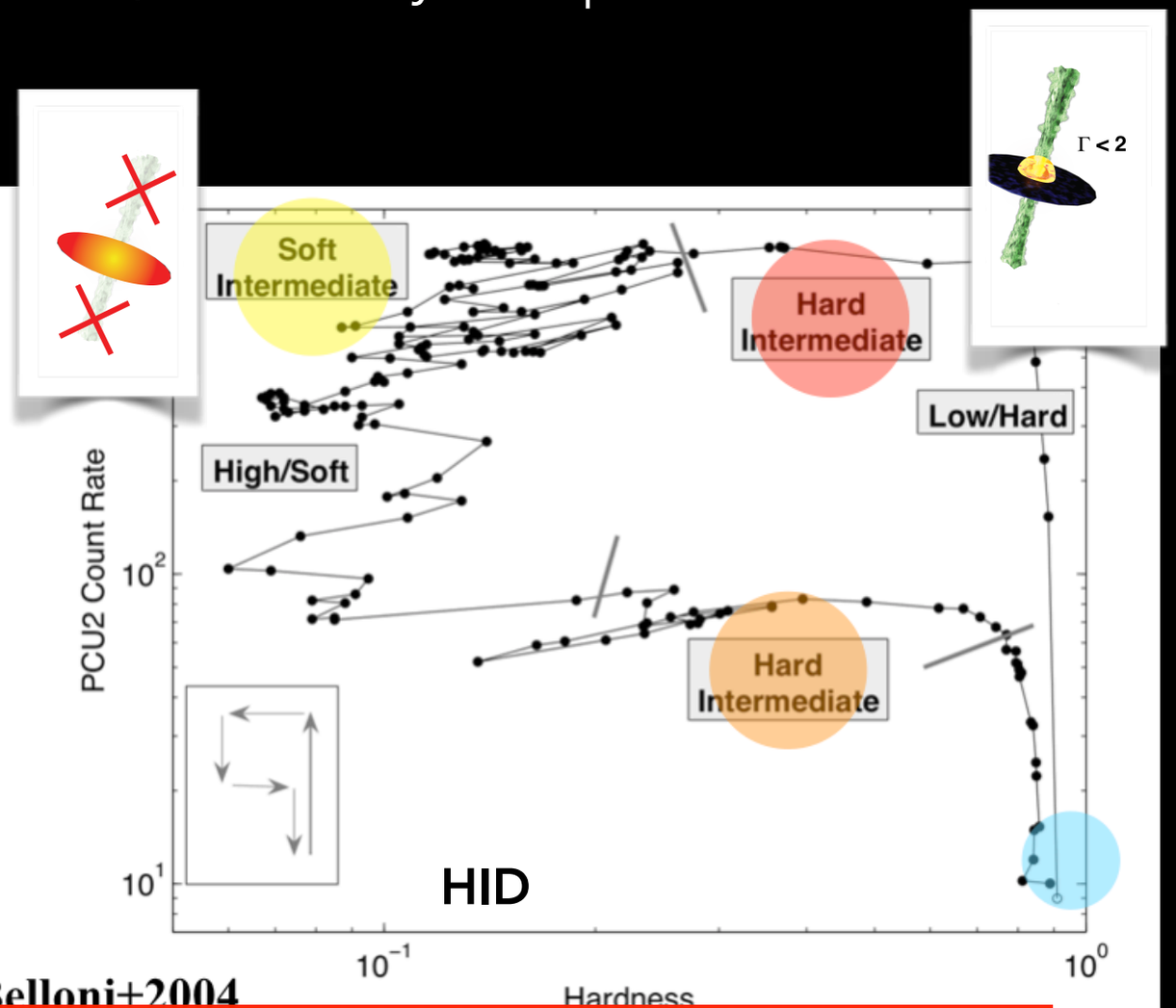




- **Belloni+2004**

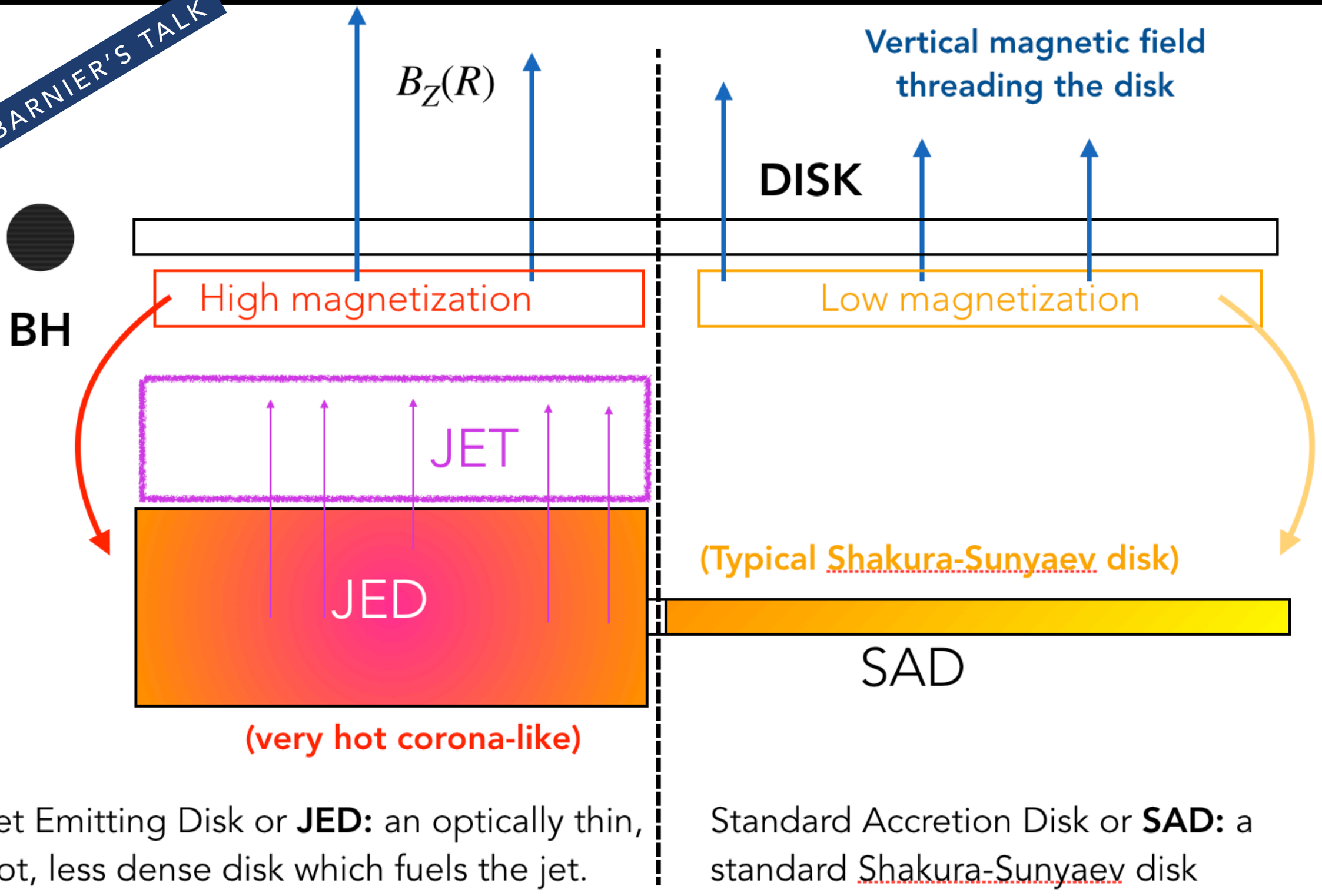
ARE ACCRETION AND EJECTION INTERCONNECTED?

THE JED-SAD MODEL: A UNIFIED ACCRETION-EJECTION PARADIGM

THE JED-SAD SAGA

Ferreira+06,22, Petrucci+08,13, Marcel+18a,b,19,20,21, Barnier+21, Marino+21,+ (to be continued…)

SEE S. BARNIER'S TALK



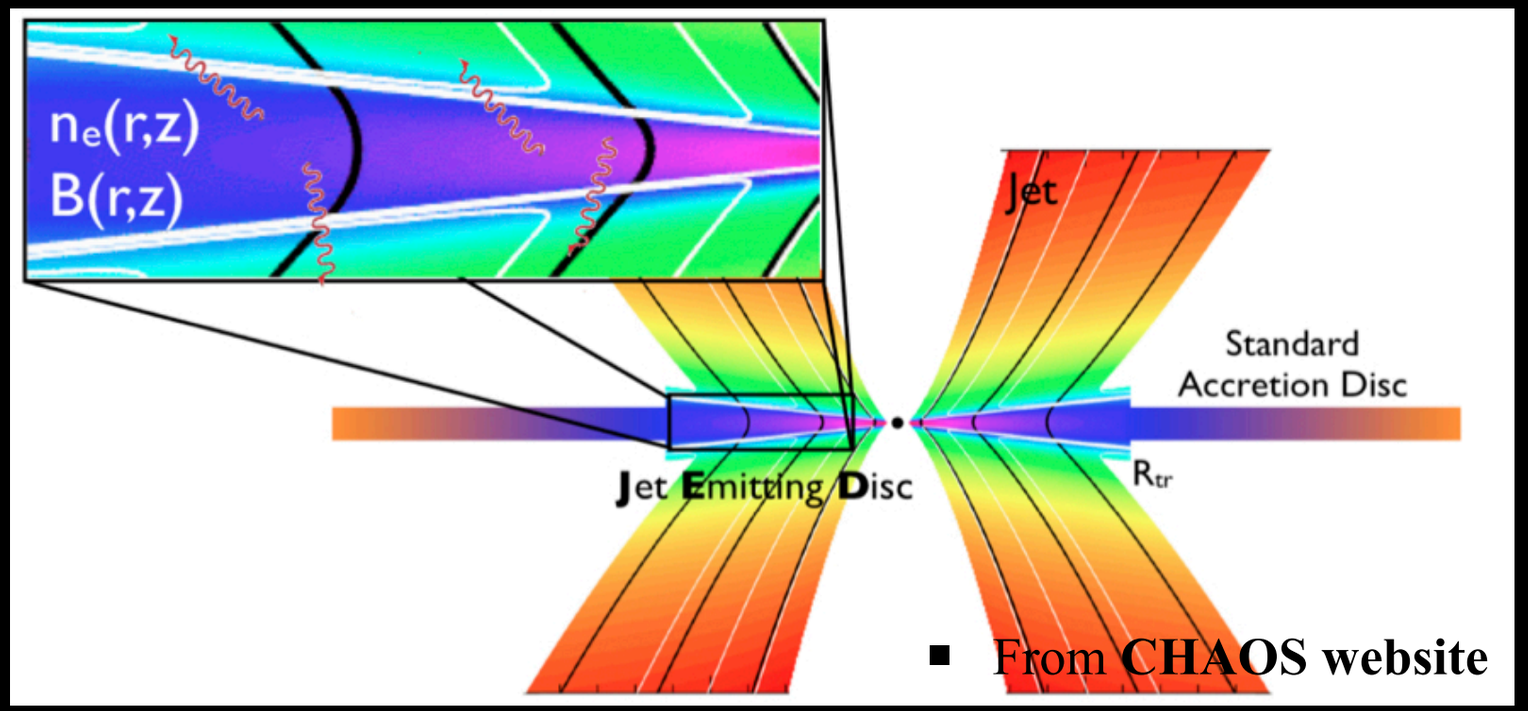
Jet Emitting Disk or **JED:** an optically thin, hot, less dense disk which fuels the jet.

Standard Accretion Disk or **SAD:** a standard Shakura-Sunyaev disk

THE JED-SAD MODEL: A UNIFIED ACCRETION-EJECTION PARADIGM

- The **JED-SAD model** is a spectral model able to tackle both observational evidence for accretion and ejection.

- It was used to reproduce both X-rays and radio behaviour of the archetypal BHT GX 339-4 in outburst (Marcel+2019,2020)



- From **CHAOS website**

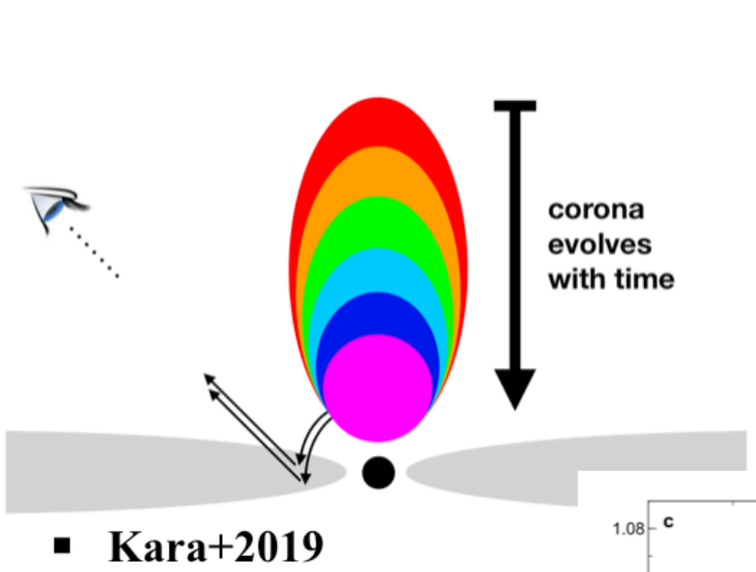
WE APPLIED THE JED-SAD MODEL TO A BROADBAND X-RAYS DATA SET OF THE BH LMXB MAXI J1820+070 DURING ITS HARD STATE TO CONSTRAIN THE (QUITE DEBATED) GEOMETRY OF THE ACCRETION FLOW IN HARD STATE.

MAXI J1820+070: ONE OF THE BRIGHTEST LMXBS EVER OBSERVED

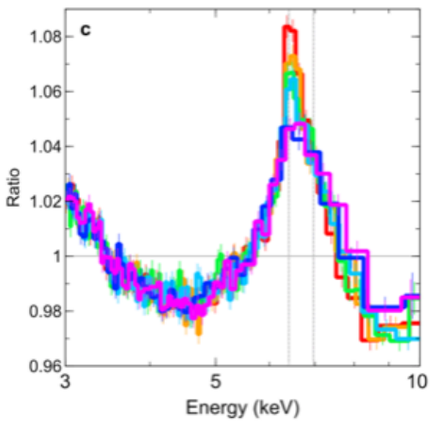
- A **high inclination** (75°, Kajava+2019) transient BH LMXB discovered in **outburst in 2018** and object of an unprecedented multi-wavelength observational campaign (e.g. Bharali+2019, Homan+2020, Bright+2020, DiazTrigo+2020, Atri+2020).

SEE B. DE MARCO & A. ZDZIARSKI'S TALKS

A debated accretion flow geometry (in hard state)

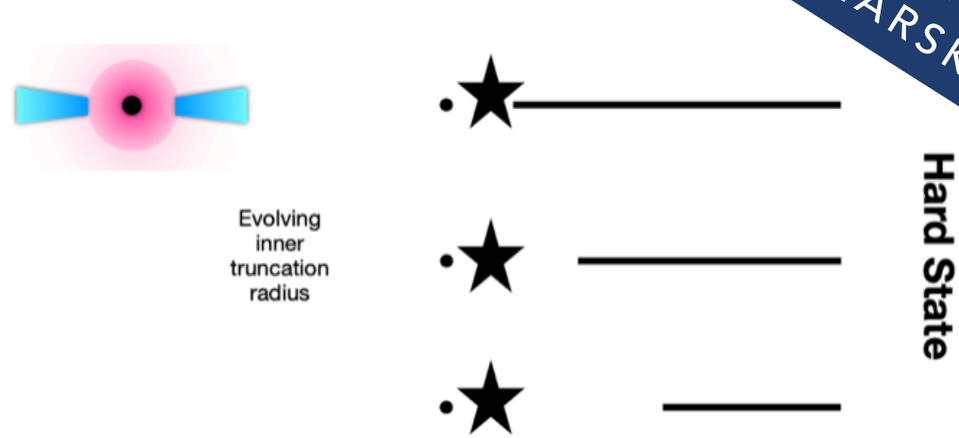


- Kara+2019

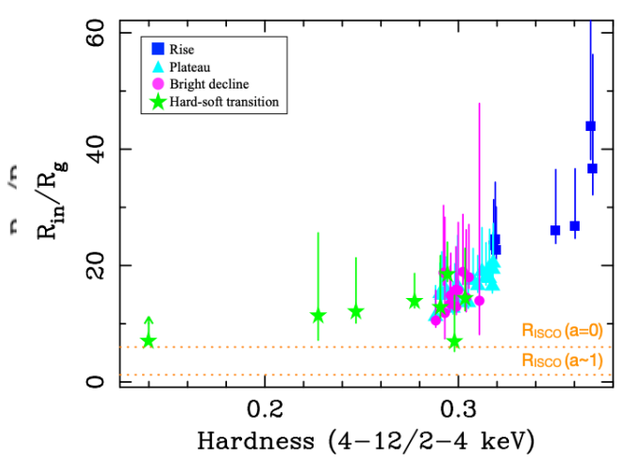


Untruncated disk + lamppost

Buisson+2019, You+2021, Wang+2021



- De Marco+2021

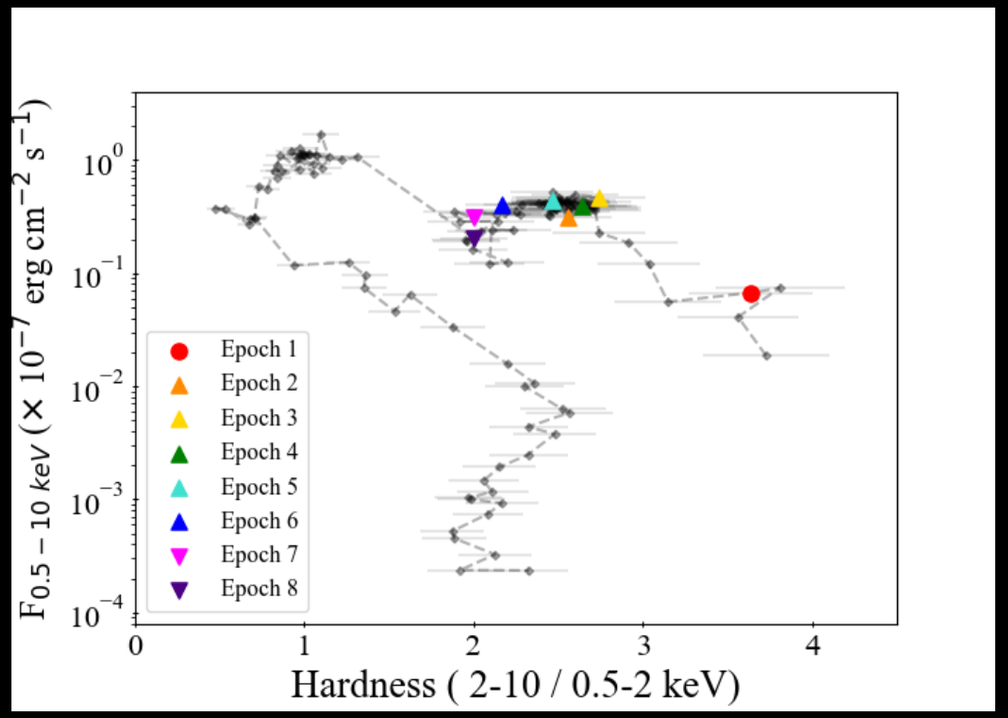


Truncated disk

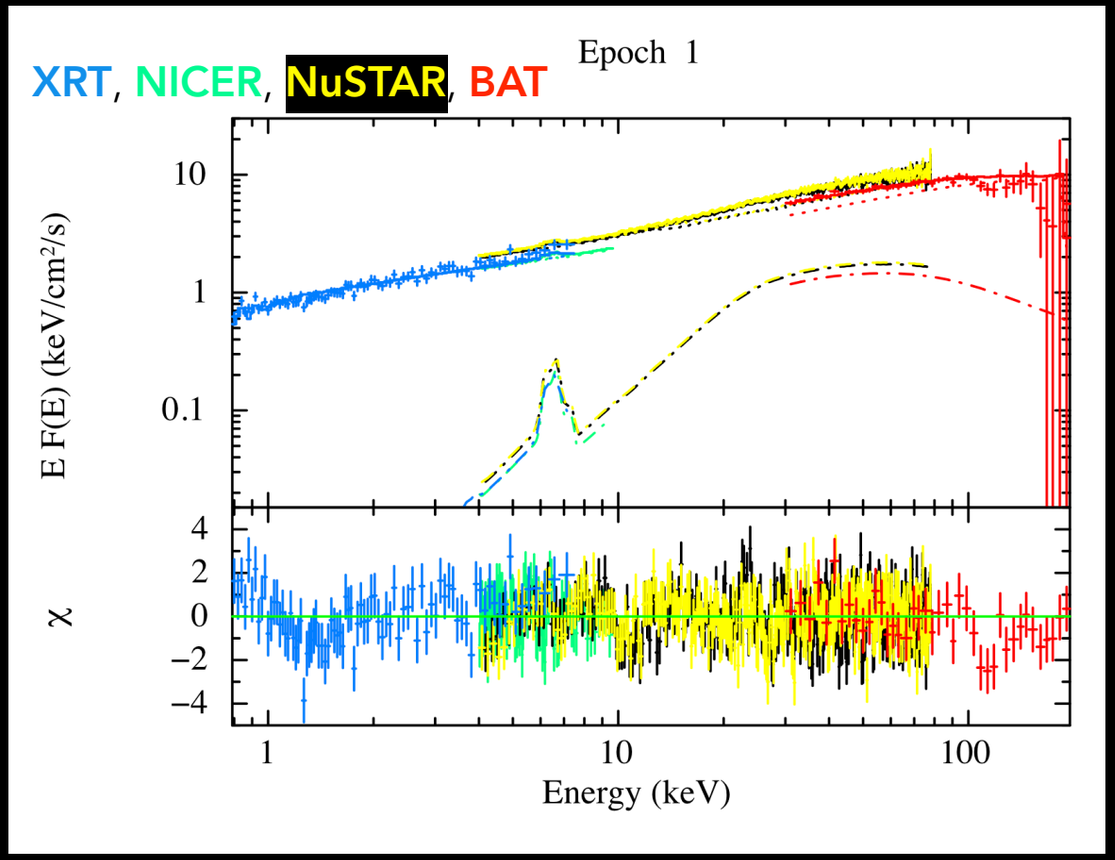
Zdziarski+2021, Dzialek+2021, Axelsson+2021

OBSERVATIONS

- We used **8 broadband data sets** (Epochs) of quasi-simultaneous **XRT** (0.8-10 keV) + **NuSTAR** (4.-78. keV) + **NICER** (4.-10. keV) + **BAT** (30.-200. keV) in hard state.



- XRT Hardness Intensity Diagram



EXAMPLE OF BROADBAND X-RAY SPECTRA

OBSERVATIONS

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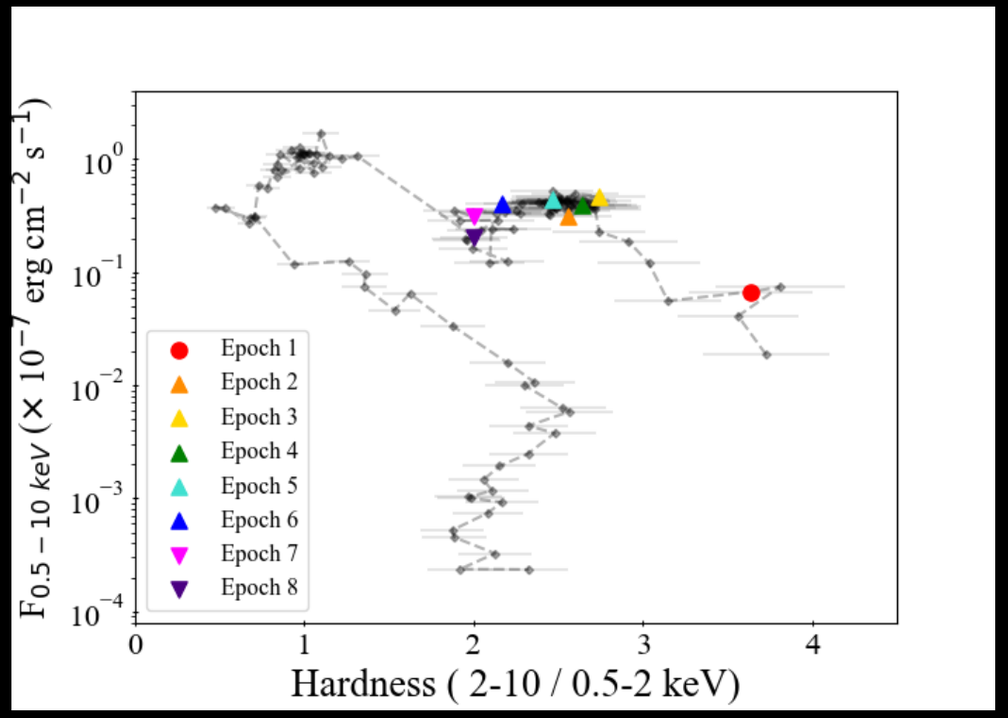


- XRT Hardness Intensity Diagram

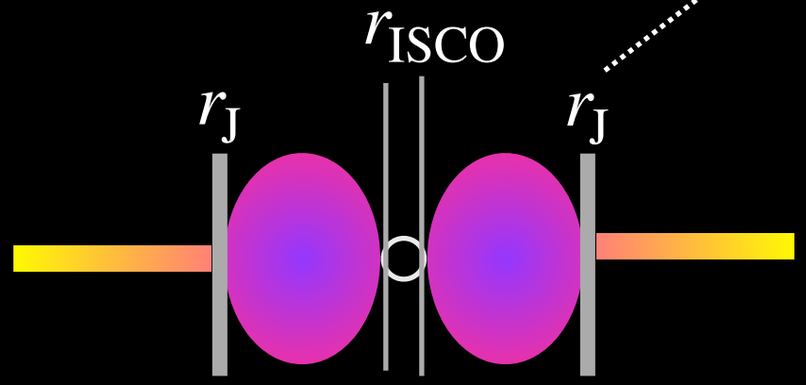
MODEL

- The main parameters of the JED-SAD model are:

Innermost stable circular orbit

$r_{\rm ISCO} = 4\ {\rm R_G}$

Fabian+2020, Zhao+2020, Guan+2020



Transition radius between the SAD and the JED

$\dot{m}_{\rm in}$ **Inner mass-accretion rate**

$m_{\rm S}$ **Sonic Mach number**

+ Reflection (based on `XILLVER`, Dauser+2013,Garcia+2015)

A DOUBLE REFLECTION COMPONENT?

- And considered two different models for reflection:

- **Model 1 (one reflection)** **model:** `const*tbabs*(JED+SAD+refl)`

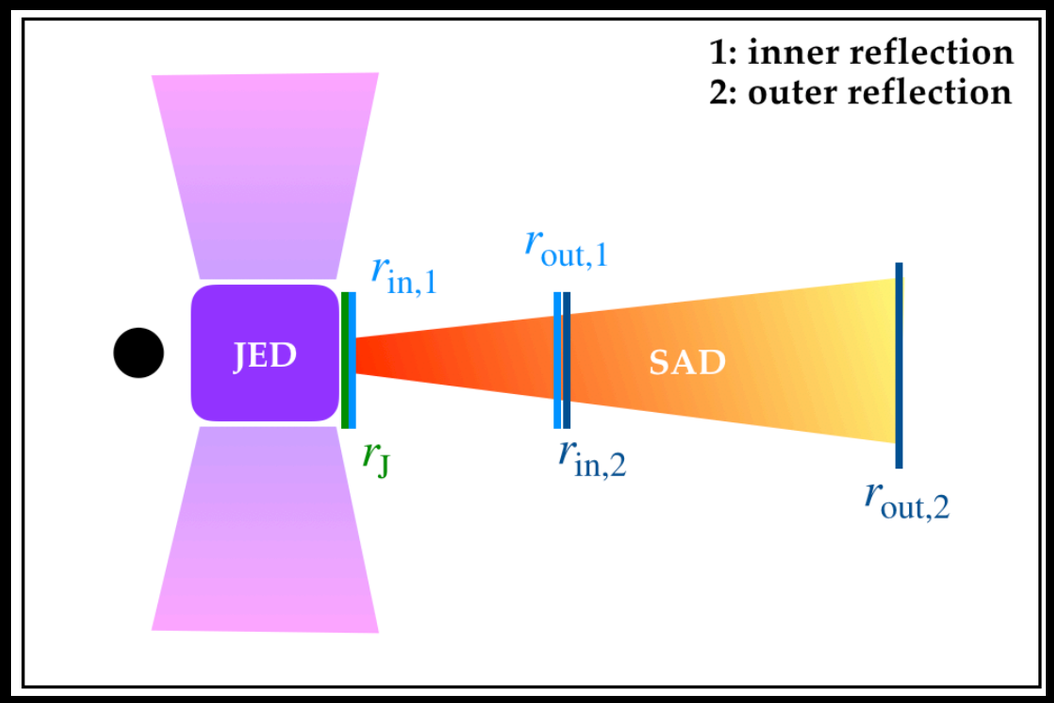
$r_{\rm in} = r_{\rm J}$ **Inner radius**

$\log \xi$ **Ionization**

- **Model 2 (double reflection)** **model:** `const*tbabs*(JED+SAD+refl+refl)`

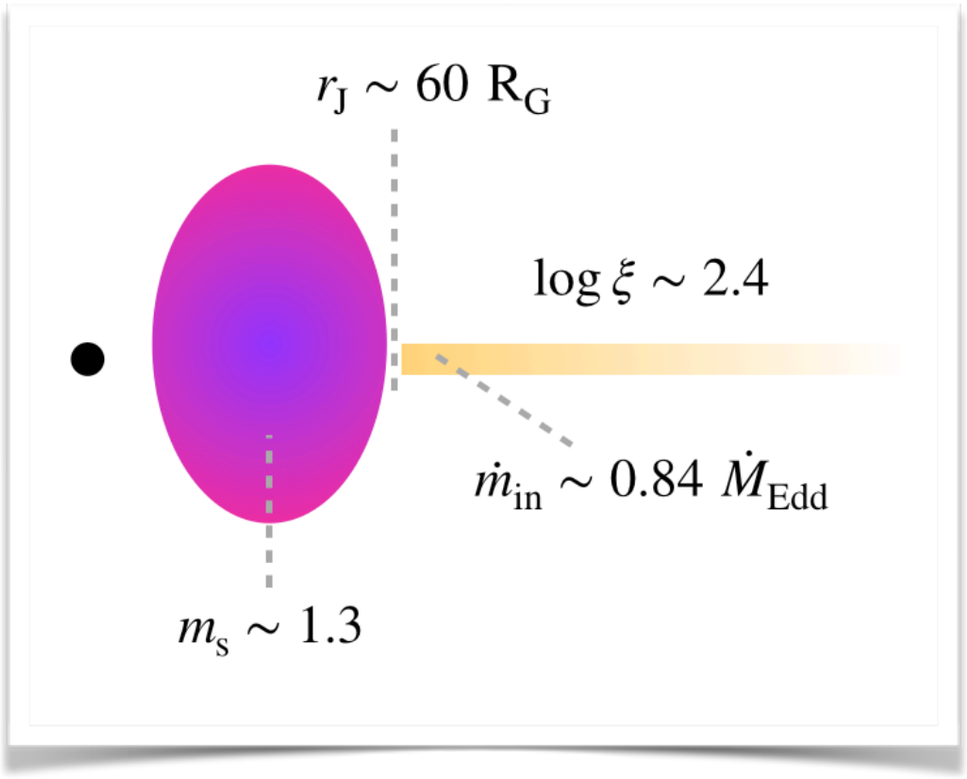
$r_{\rm in,1} = r_{\rm J}$ $r_{\rm in,2} = r_{\rm out,1}$ $r_{\rm out,2}$

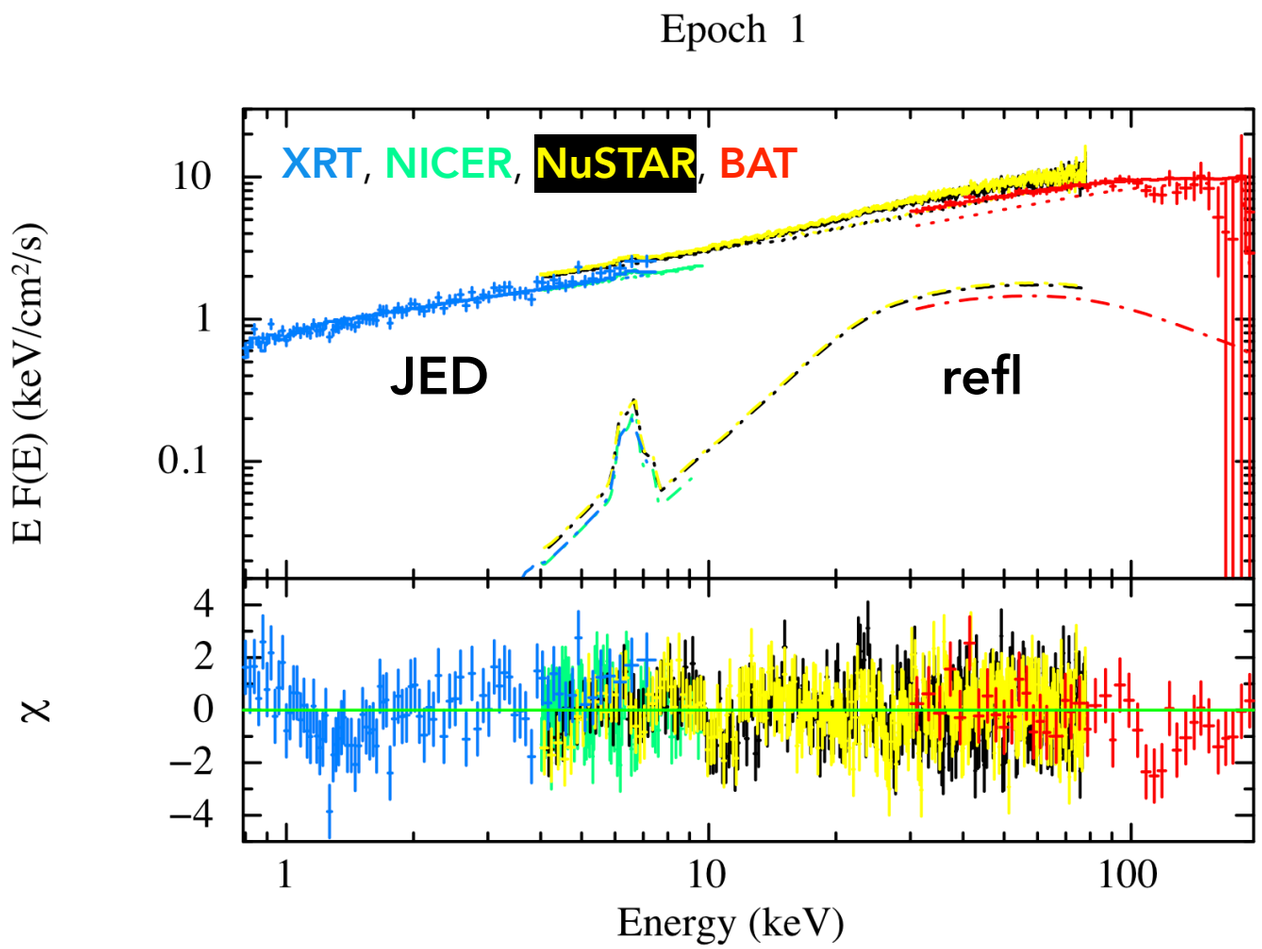
$\log \xi_1, \log \xi_2$ **Two Ionization values**



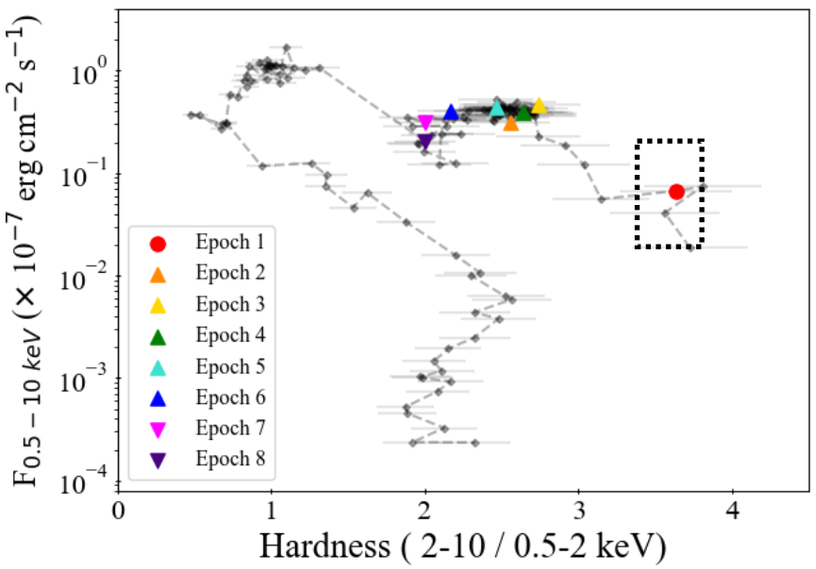
- Two reflection components already invoked by e.g. Kara+2019, Buisson+2019, You+2021, Zdziarski+2021.

PHASE 1: RISE

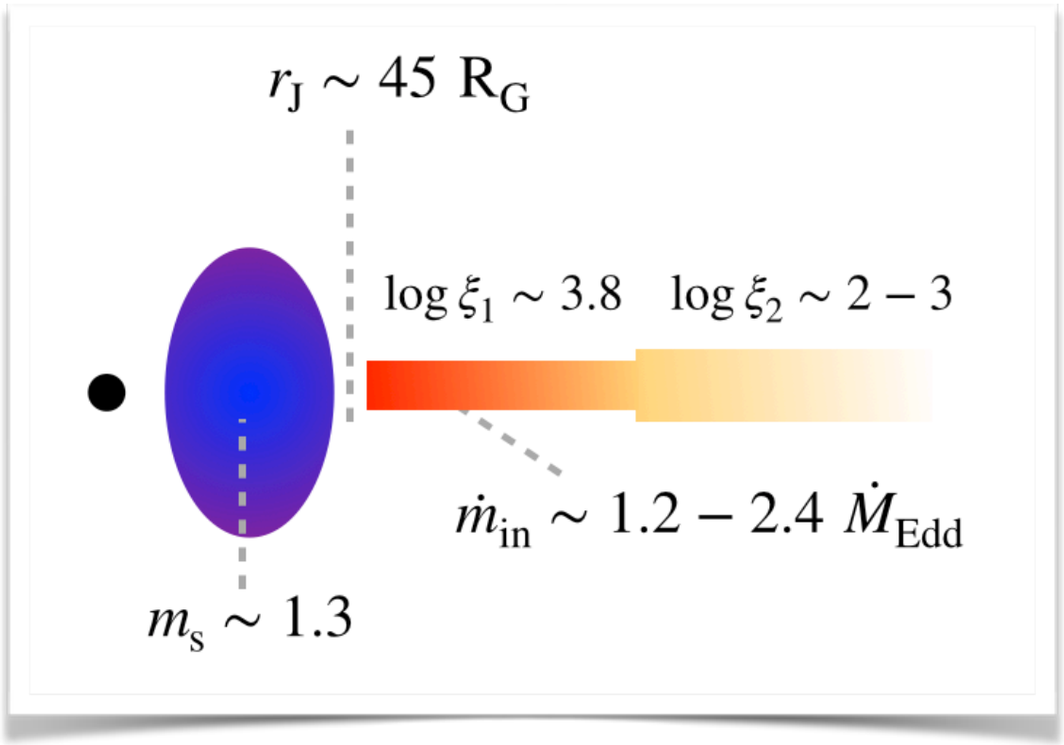


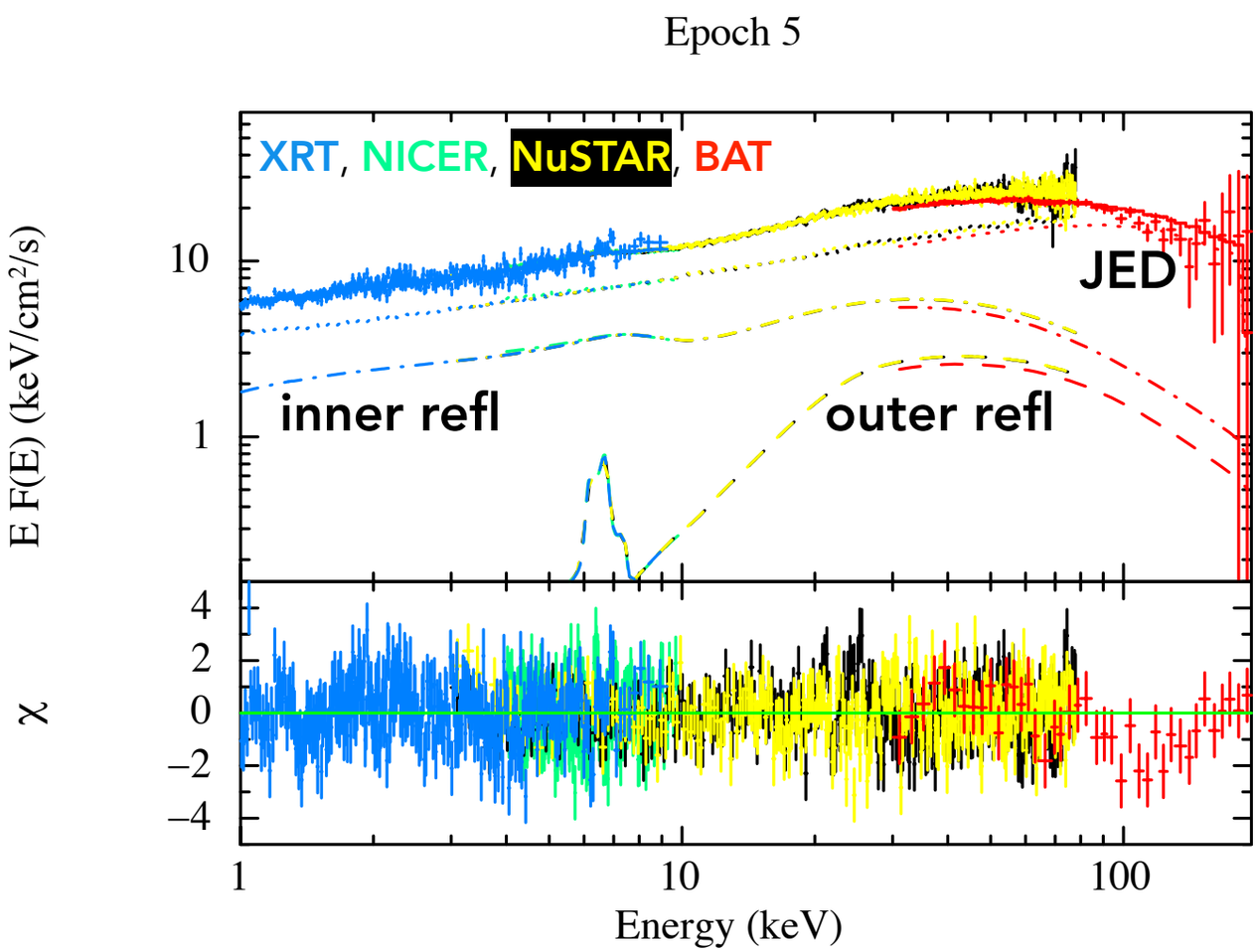


model: `const*tbabs*(JED+SAD+refl)`

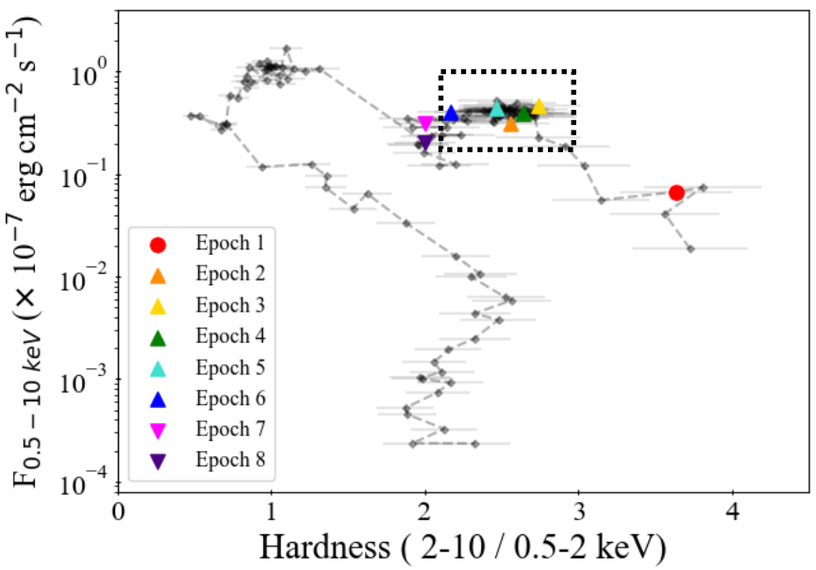


PHASE 2: PLATEAU + DOUBLE REFLECTION

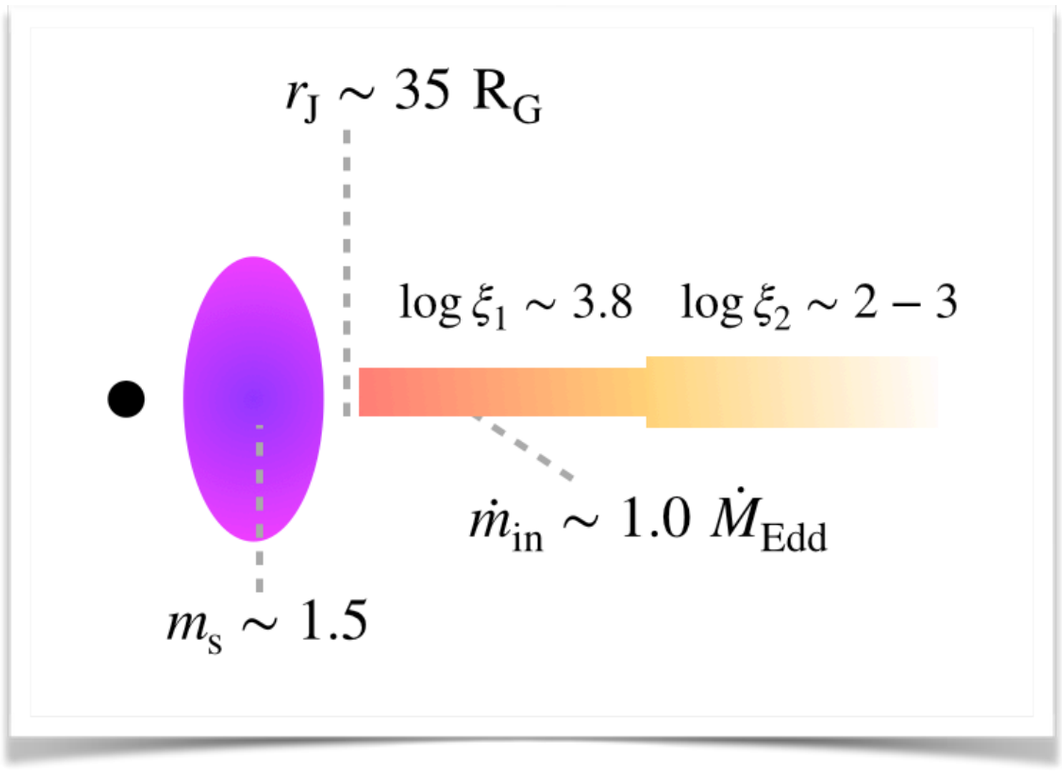


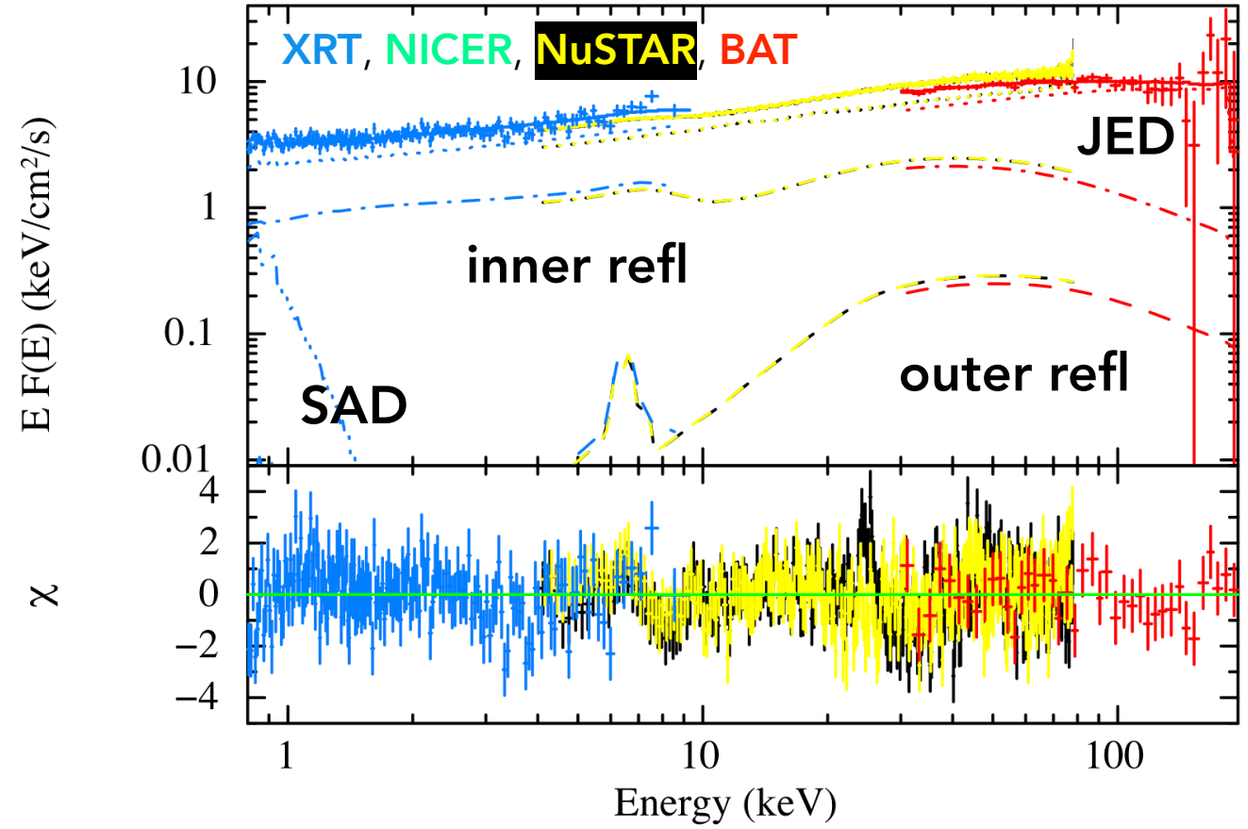


model: `const*tbabs*(JED+SAD+refl+refl)`

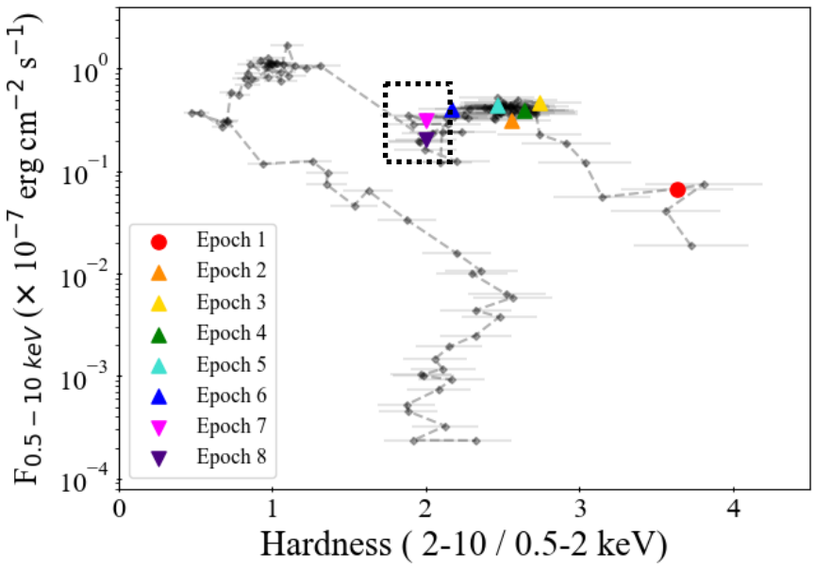


PHASE 3: BRIGHT DECLINE TOWARDS THE INTERMEDIATE STATE



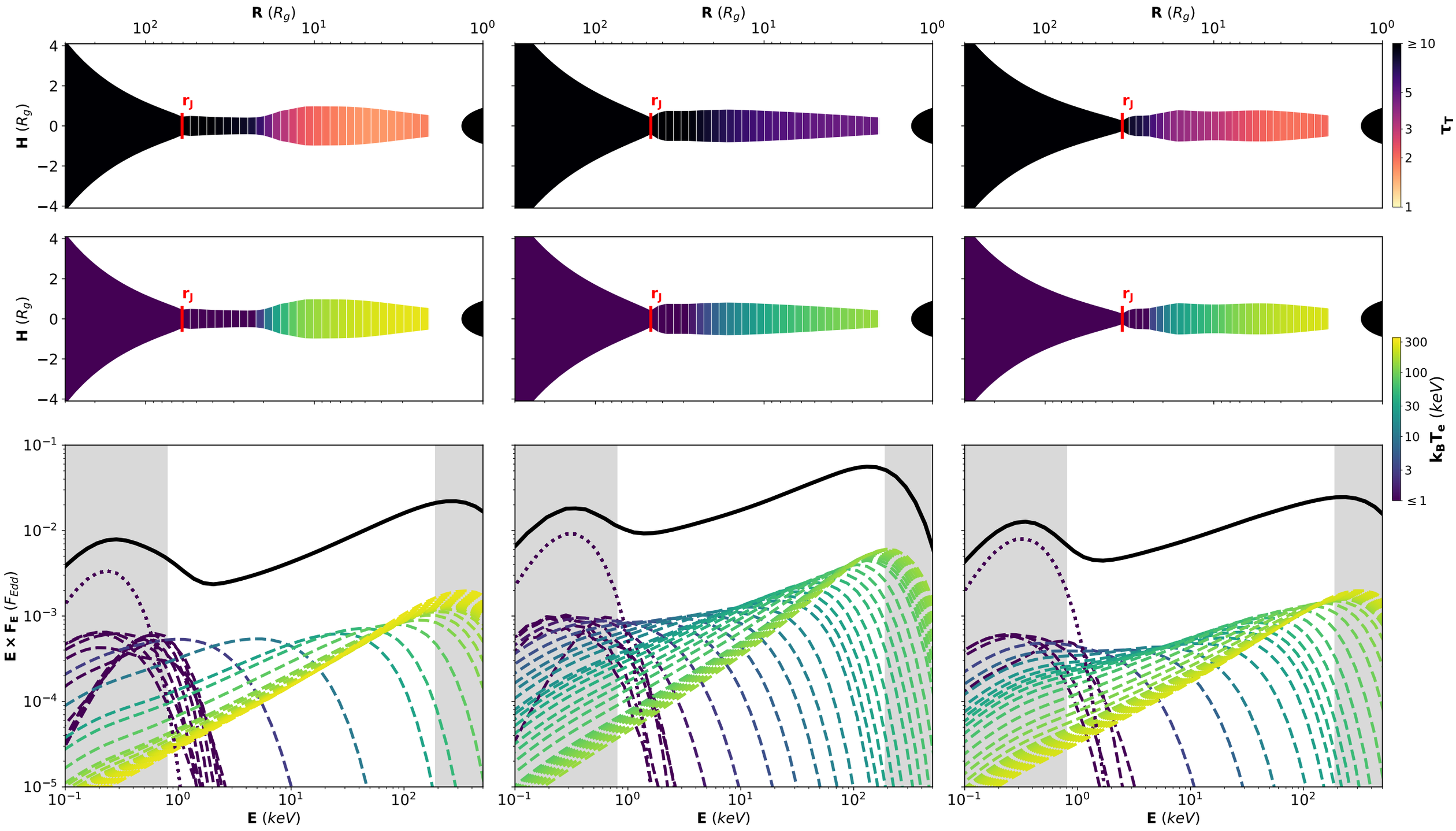


model: `const*tbabs*(JED+SAD+refl+refl)`



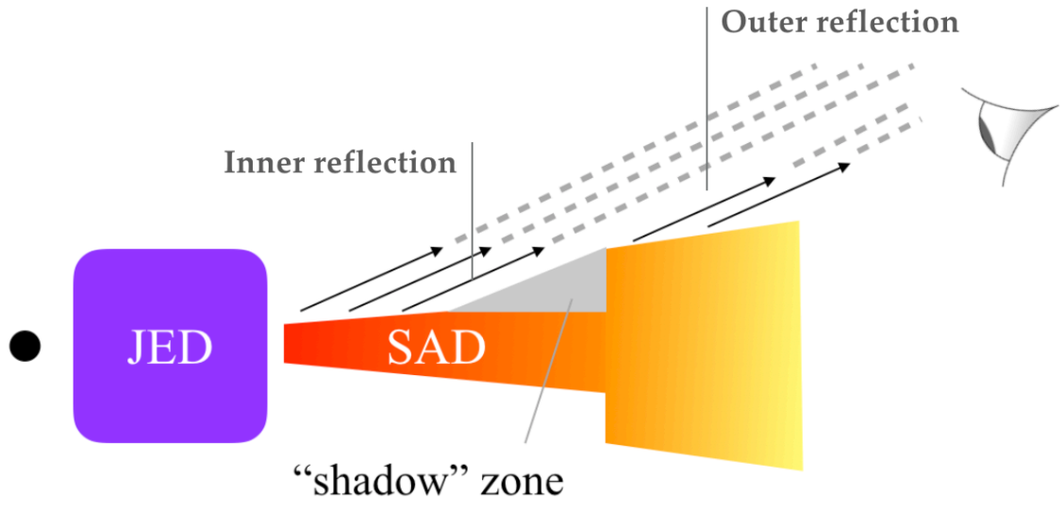
Results

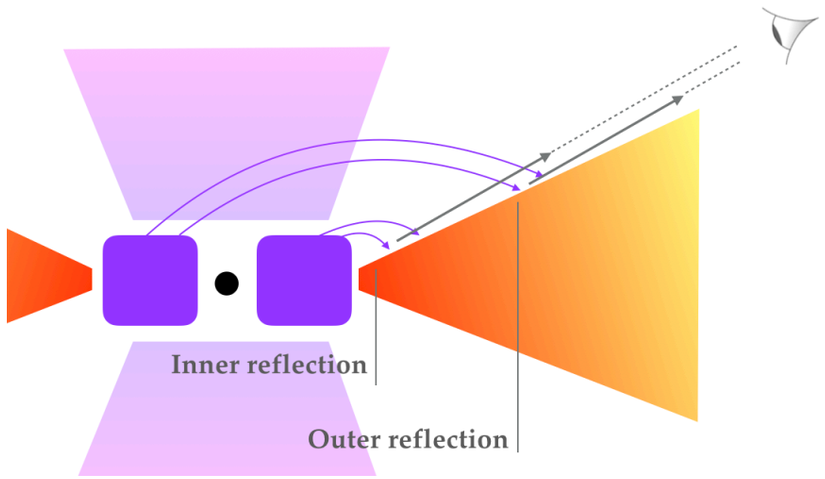
TRACKING THE EVOLUTION OF THE ACCRETION FLOW



THE ORIGIN OF THE DOUBLE REFLECTION

- A **self-shielding effect** due to a **"jump"** in the disk profile at large distance? (Irradiation likely plays a role)

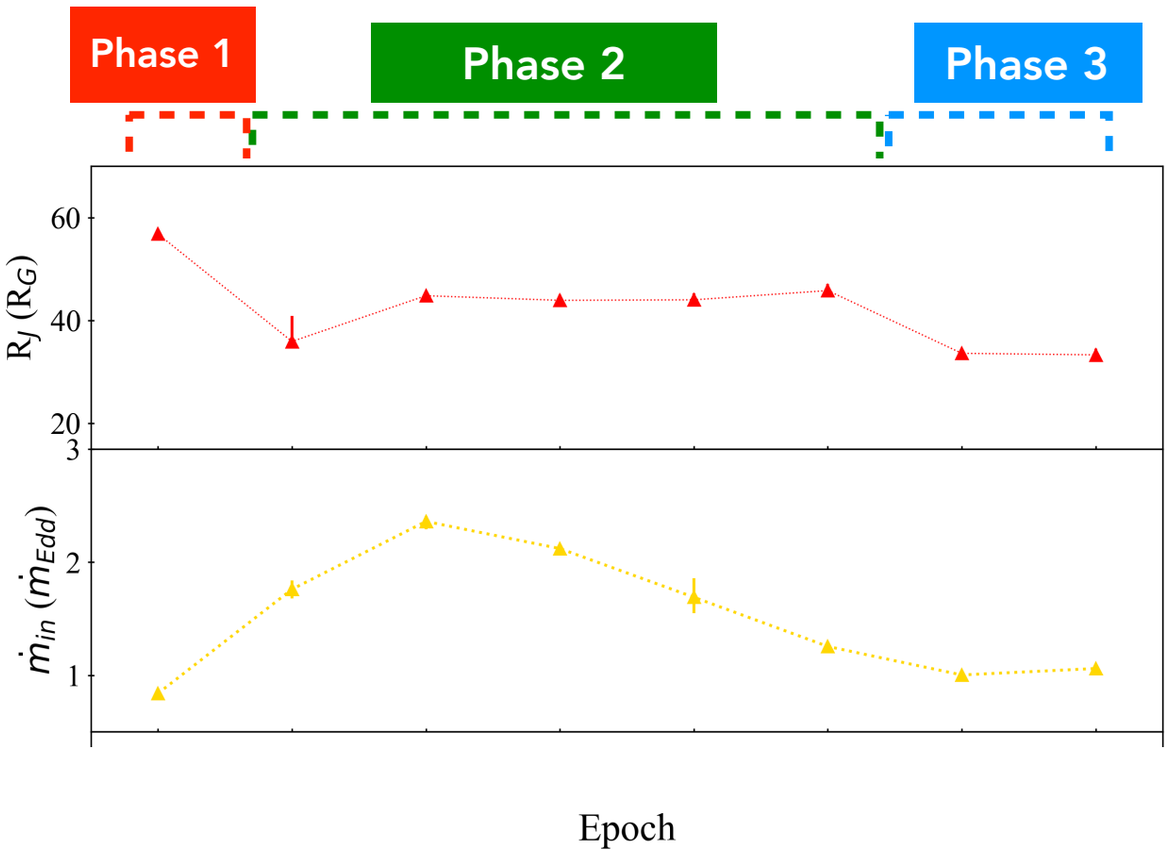




- Does the emission from the JEDs at the two sides of the BHs illuminate different areas of the SAD?

CONCLUSIONS (SO FAR..)

- We fitted eight broadband X-rays spectra of the BHT **MAXI J1820+070 with the JED-SAD model**. This is the first time that the model is directly applied to the data through spectral fits and that reflection is taken into account.



- The best-fitting results show that **the disk is truncated** and it approaches the BH during the transition to the intermediate state.

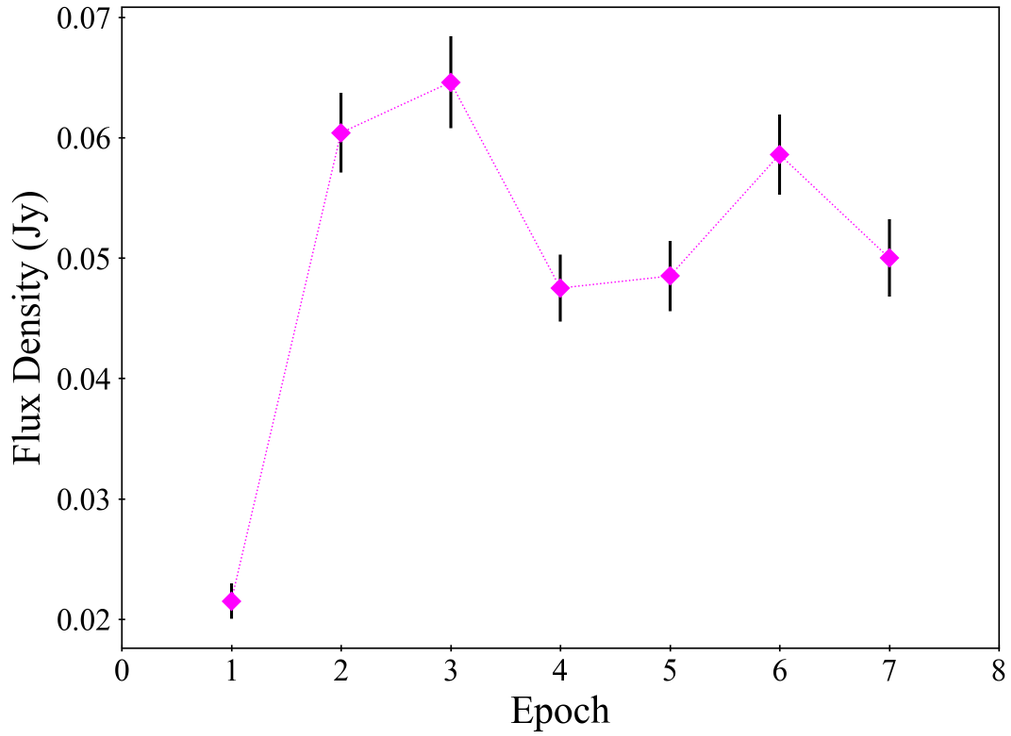
- **Two reflection components** almost always required: what is the origin? Self-shielding effect?

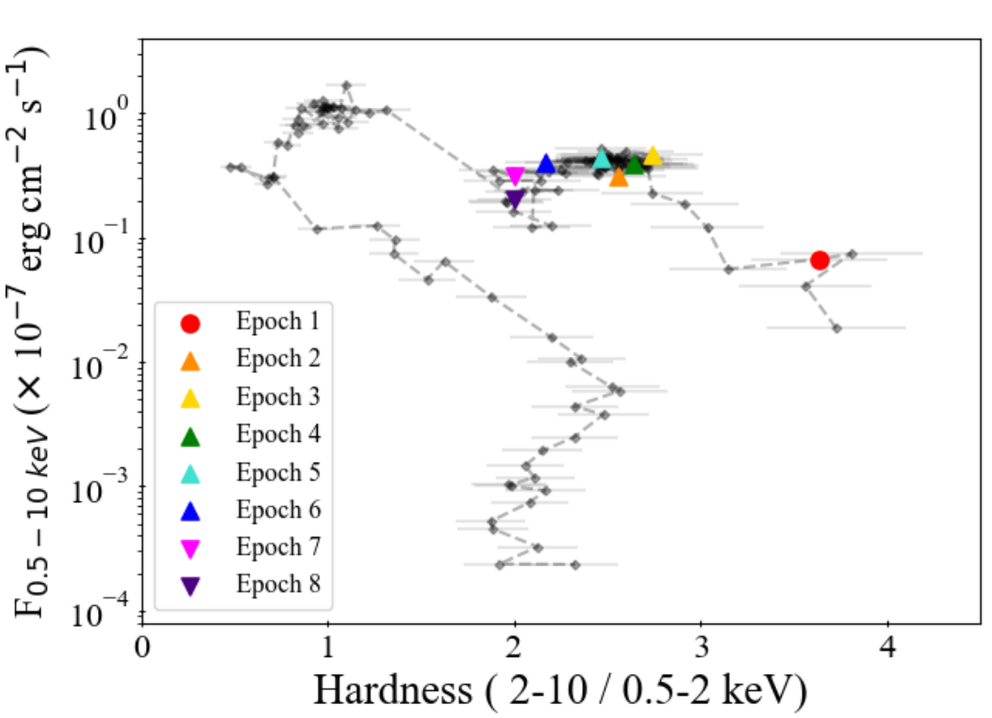
- Next step: try to reproduce the radio evolution of the system during this stage as well.

WHAT'S NEXT?

RADIO OBSERVATIONS OF MAXI J1820+070 WITH JED-SAD

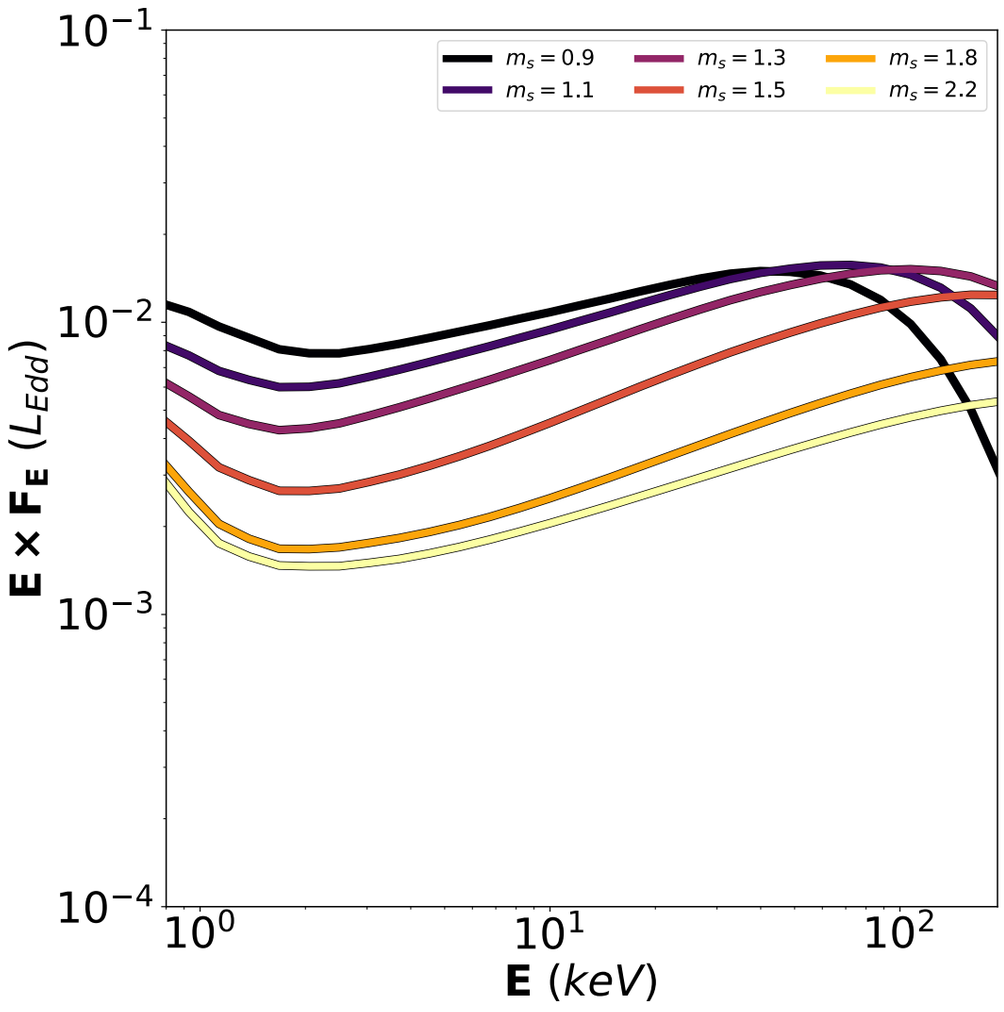
- We have **AMI-LA data** (courtesy of Joe Bright, Northwestern Uni, *Bright+,in prep*) quasi-simultaneous to 7 out of 8 of the considered Epochs. Next step would be to try to reproduce the radio evolution of the system during this stage.
- + one LOFAR and VLA (58220) + RATAN monitoring (Trushkin+2018, Atel);

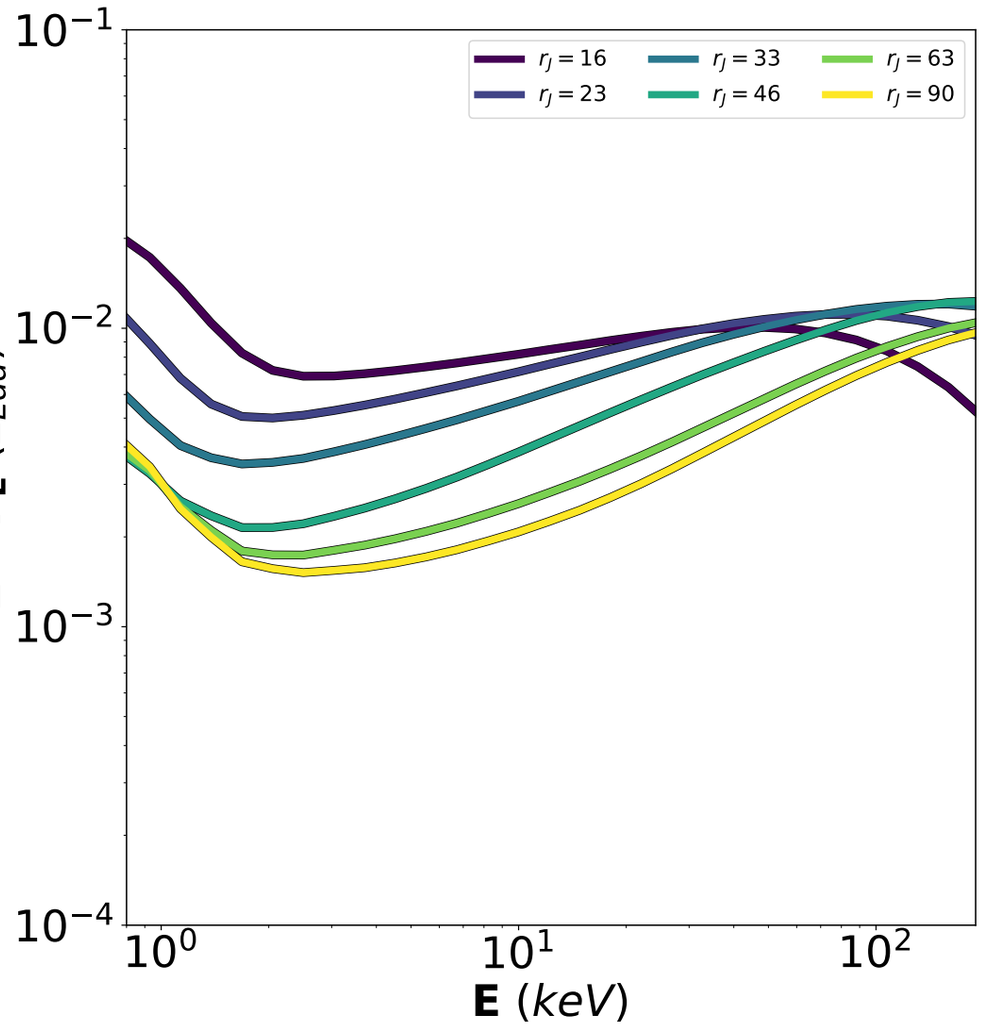




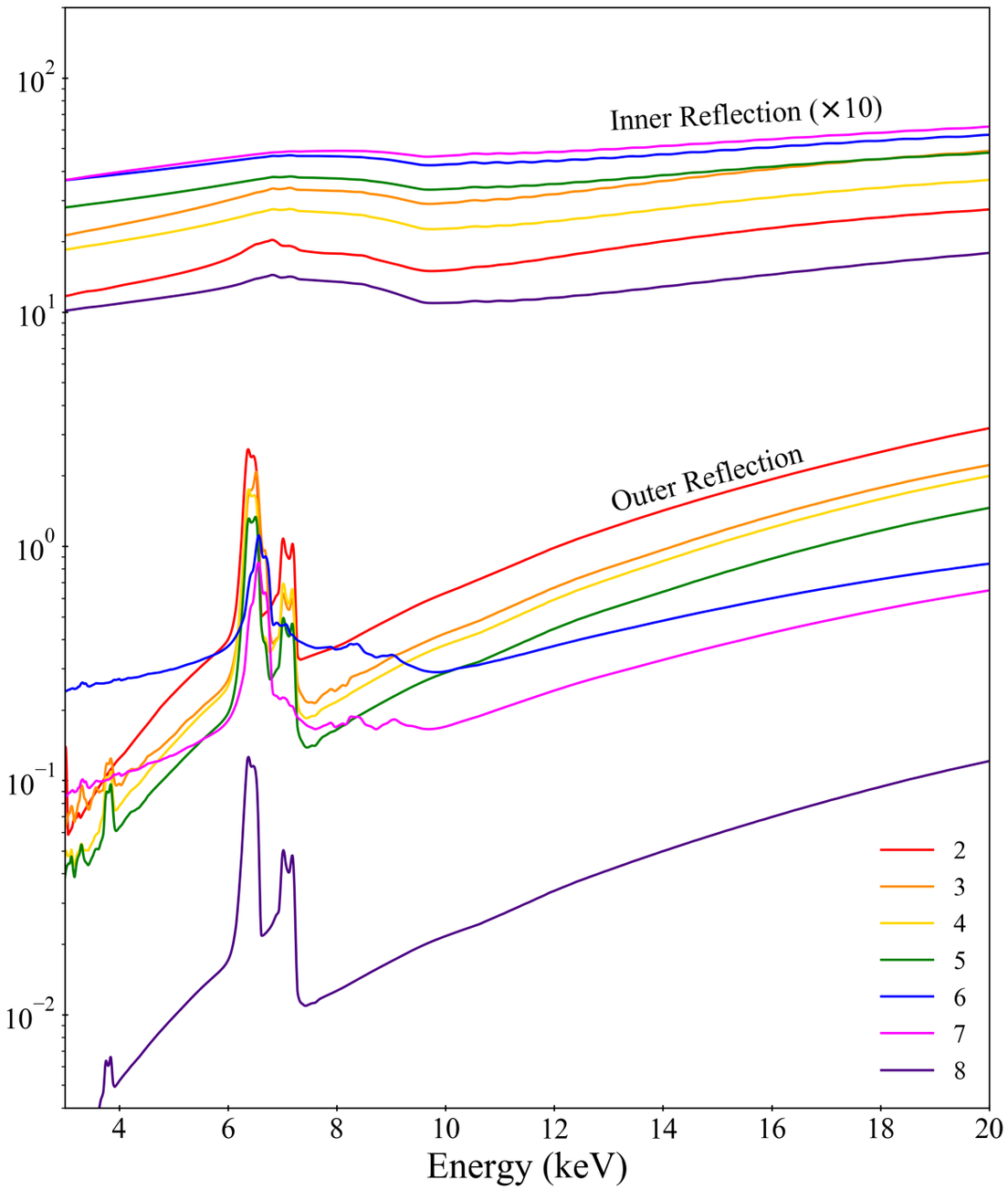
Backup slides

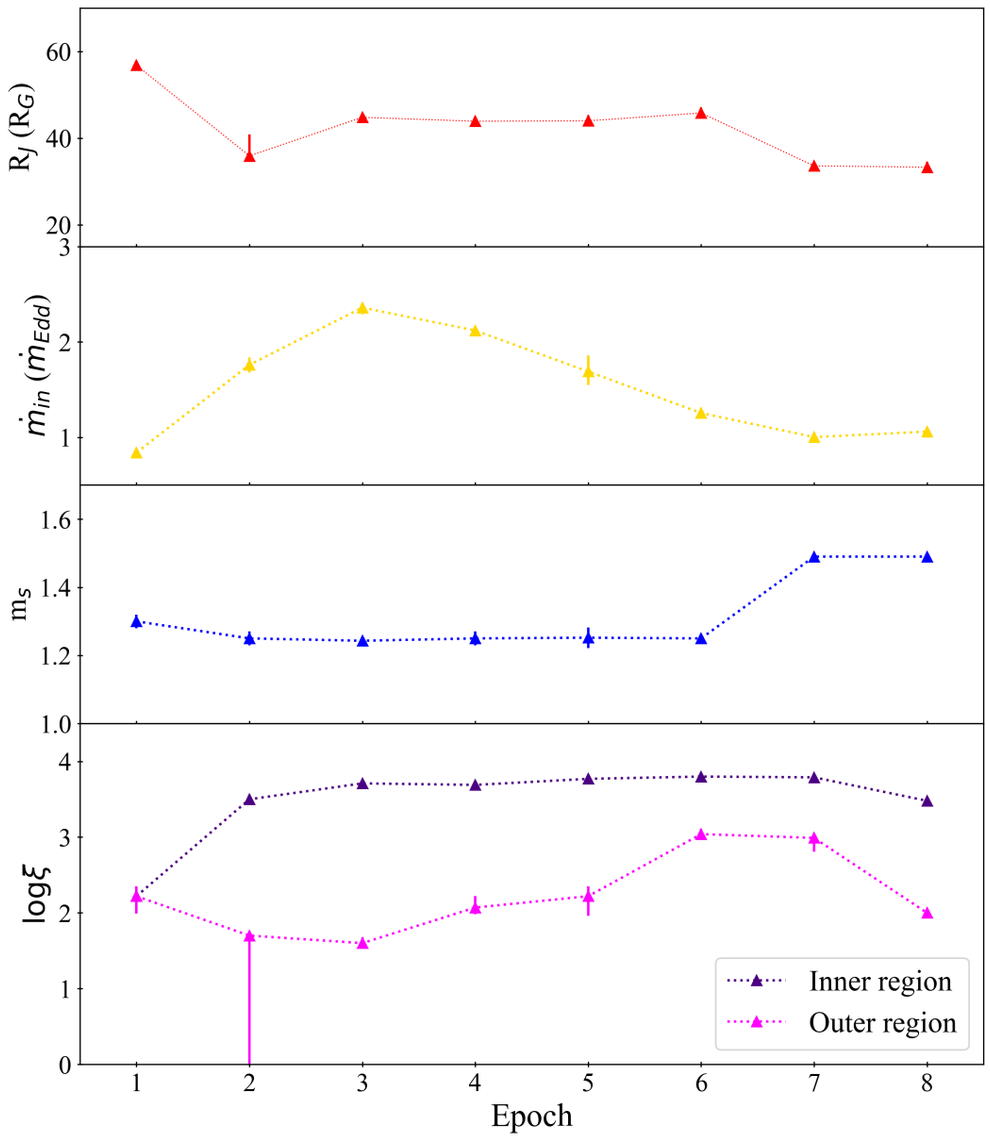
m_s vs r_j effect on softening the high energy cut-off





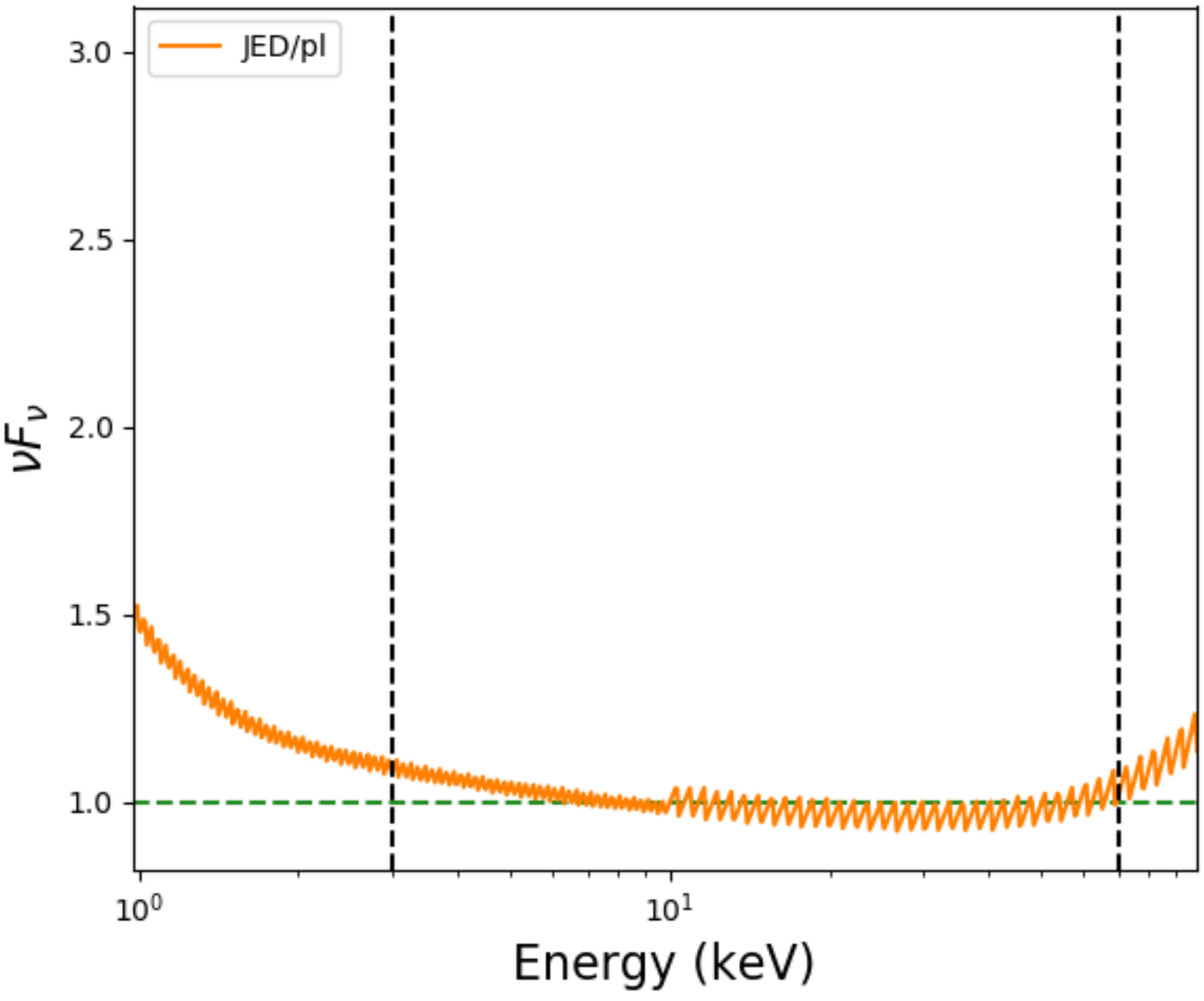
Backup slides

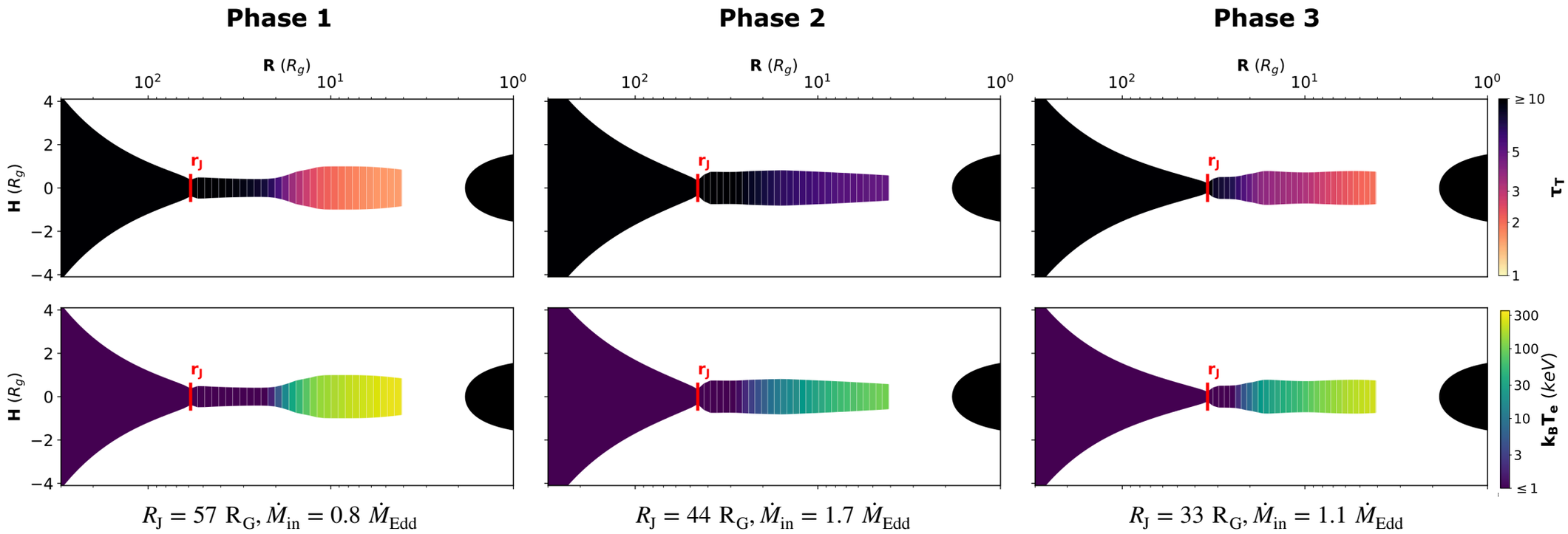




Backup slides

Comparison between JED and an illuminating power-law to generate reflection: does it originate the broadened line?

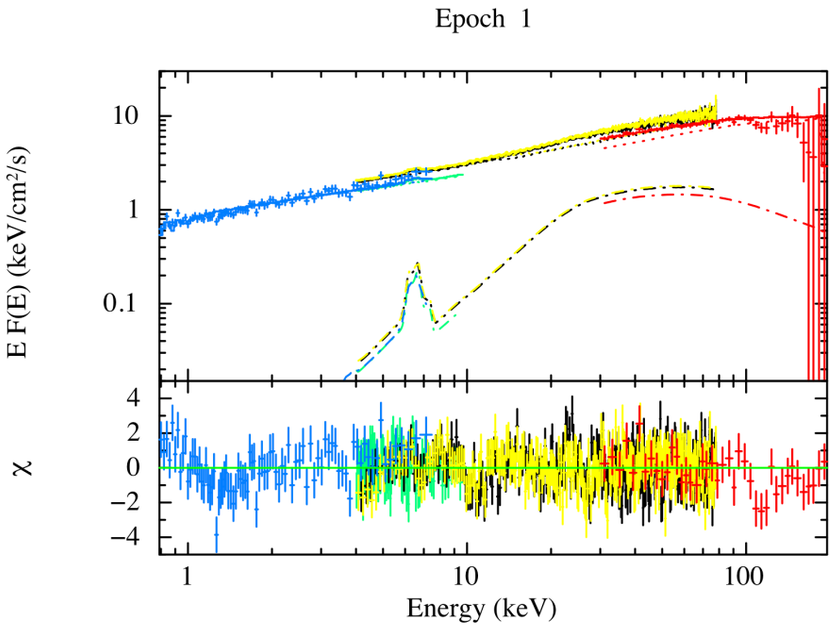


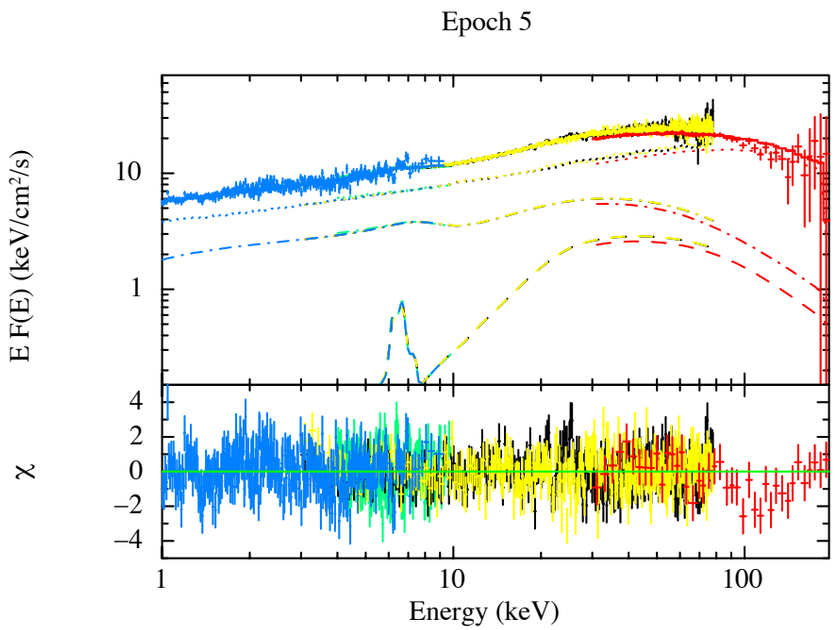


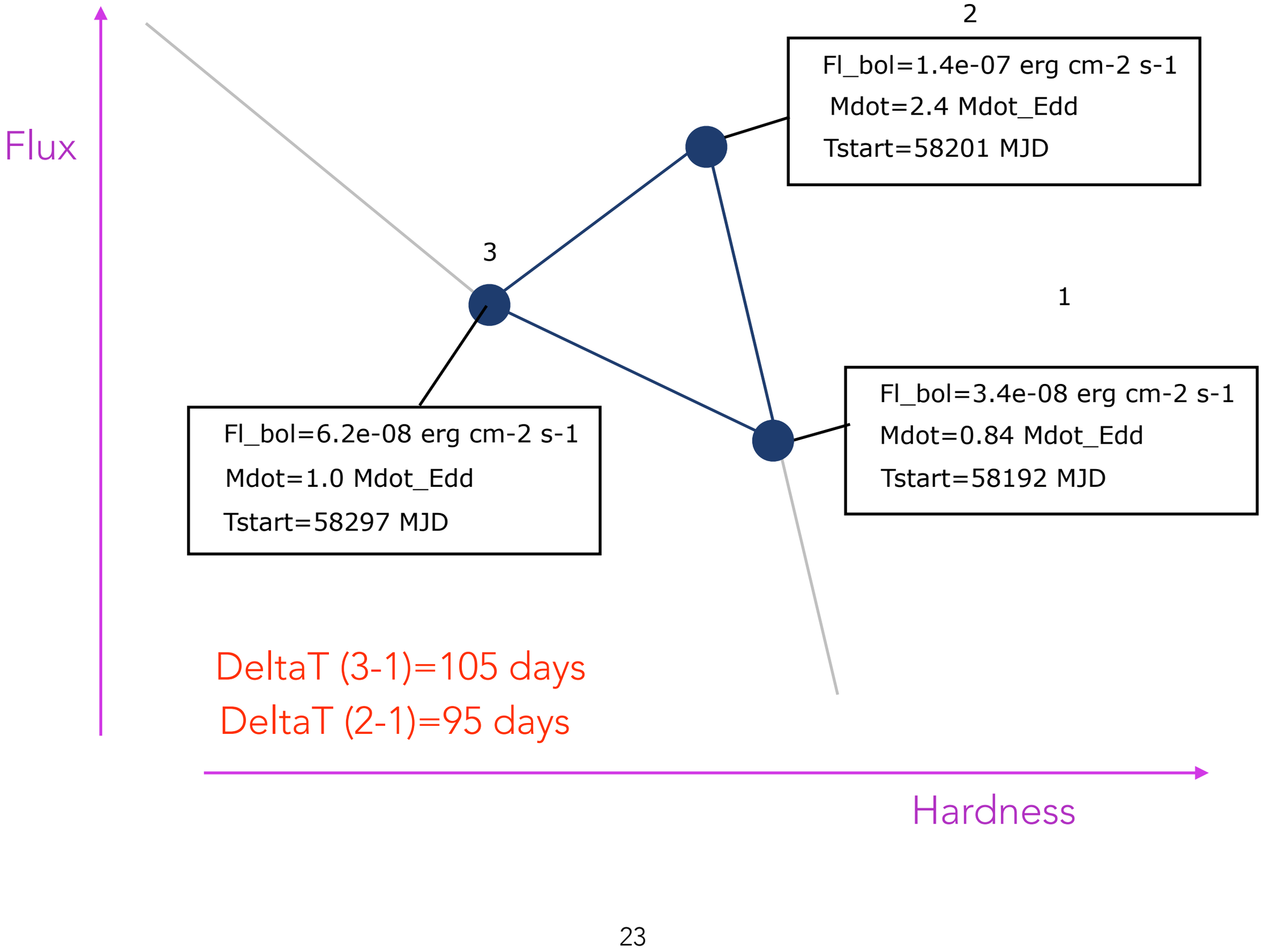
$R_{\rm J} = 57\ {\rm R_G}, \dot{M}_{\rm in} = 0.8\ \dot{M}_{\rm Edd}$

$R_{\rm J} = 44\ {\rm R_G}, \dot{M}_{\rm in} = 1.7\ \dot{M}_{\rm Edd}$

$R_{\rm J} = 33\ {\rm R_G}, \dot{M}_{\rm in} = 1.1\ \dot{M}_{\rm Edd}$






Flux
2
Fl_bol=1.4e-07 erg cm-2 s-1
Mdot=2.4 Mdot_Edd
Tstart=58201 MJD
3
1
Fl_bol=6.2e-08 erg cm-2 s-1
Mdot=1.0 Mdot_Edd
Tstart=58297 MJD
Fl_bol=3.4e-08 erg cm-2 s-1
Mdot=0.84 Mdot_Edd
Tstart=58192 MJD
DeltaT (3-1)=105 days
DeltaT (2-1)=95 days
Hardness