



# Application of the JED-SAD model from X-ray Binaries to AGN

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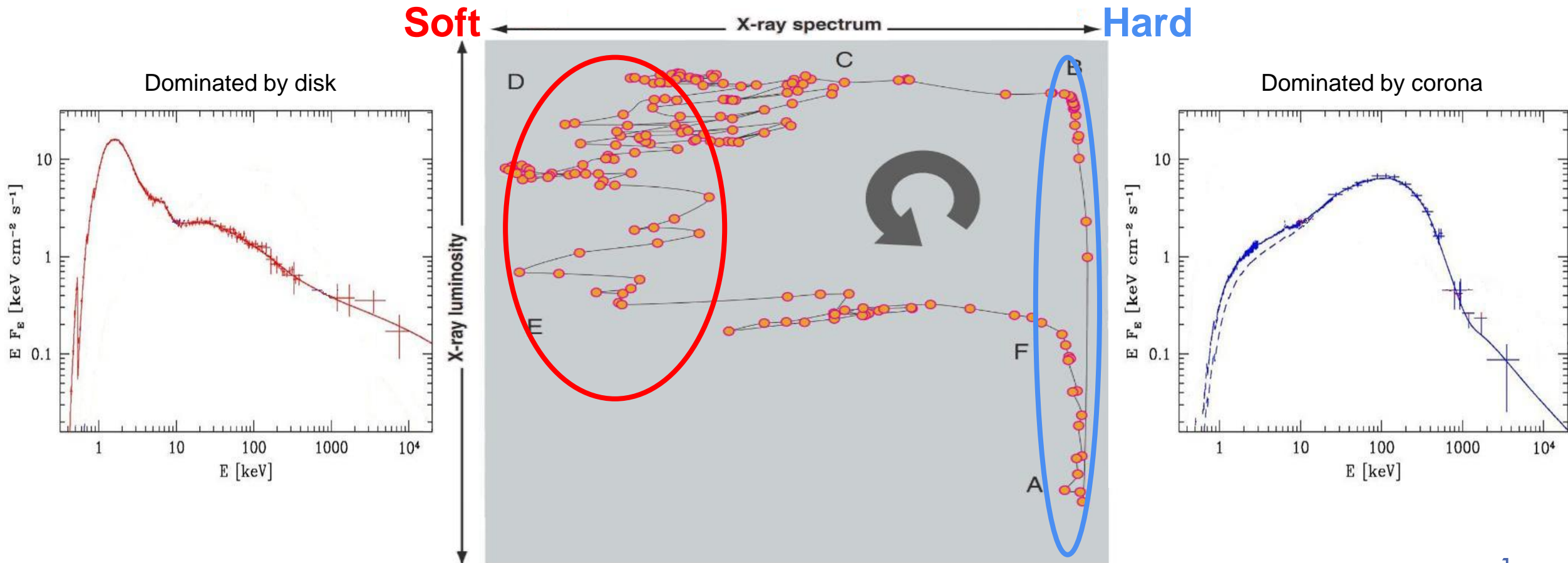
31/03/2022

Collaborators: **P.-O. Petrucci, J. Ferreira, G. Marcel,**  
R. Belmont, M. Clavel, S. Corbel, M. Coriat, G. Henri, J. Malzac

# Astrophysical context

X-ray Binaries :

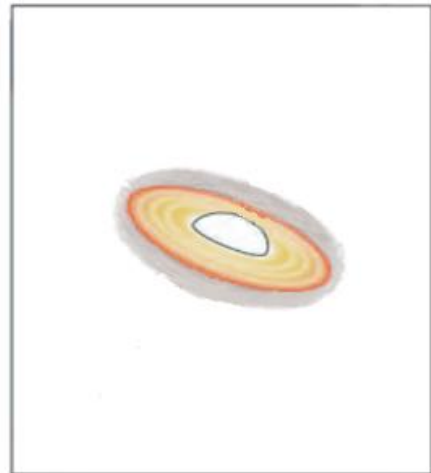
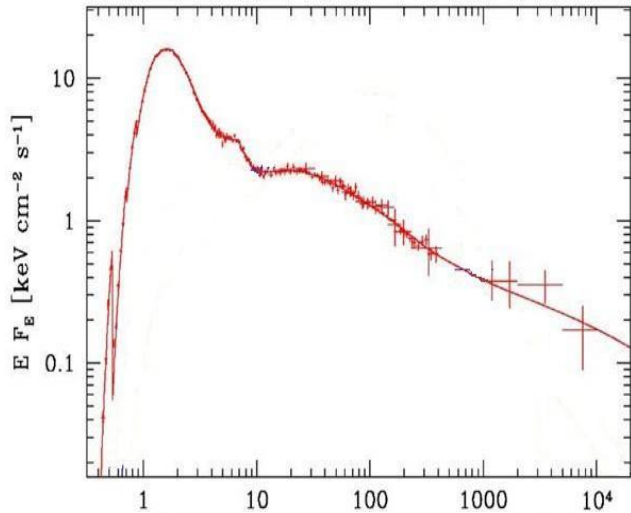
Spectral evolution



# Astrophysical context

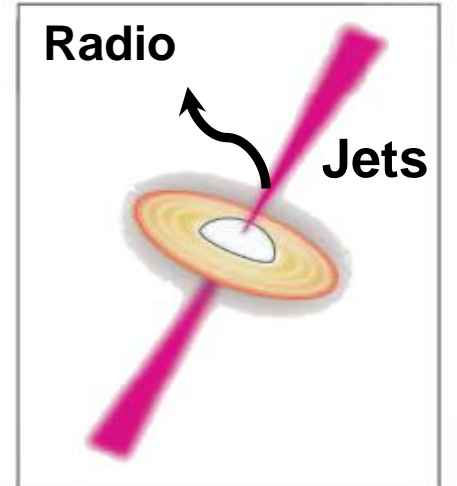
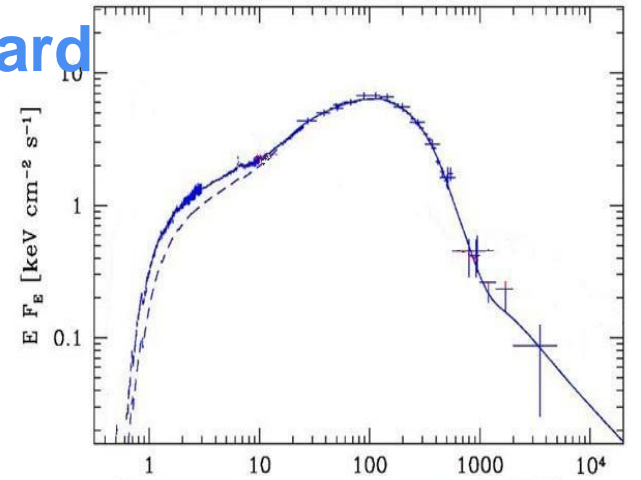
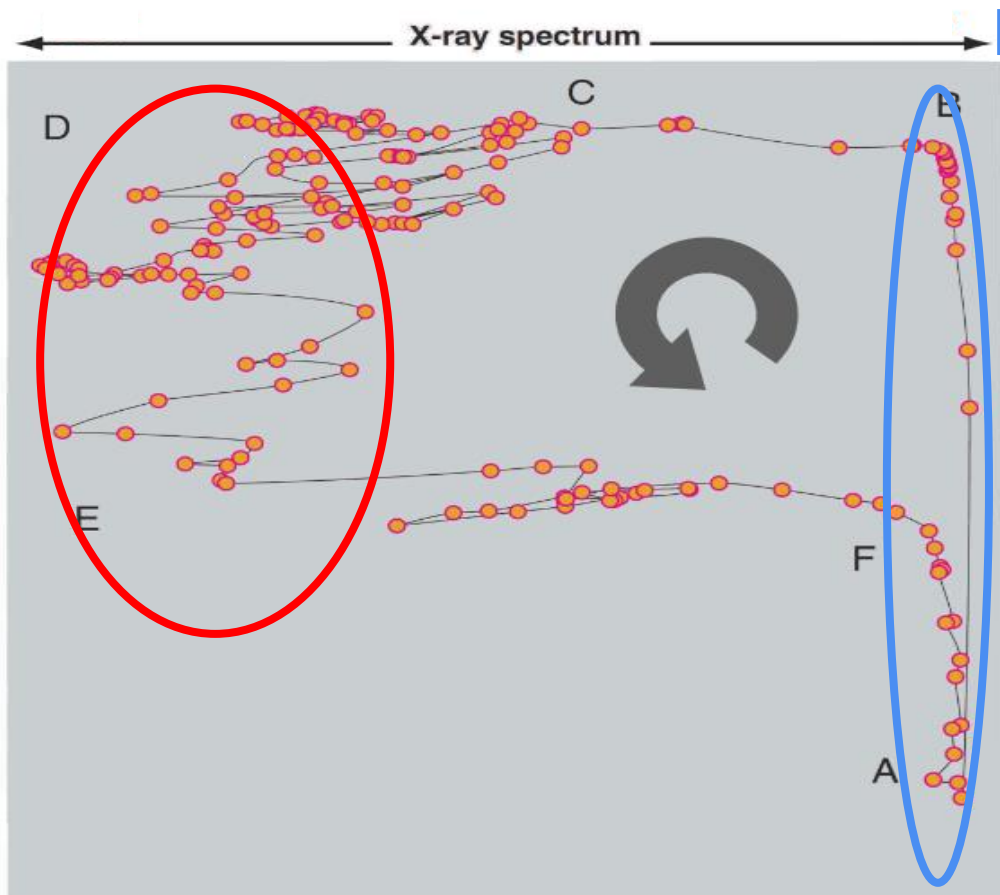
X-ray Binaries :

Spectral evolution



Soft

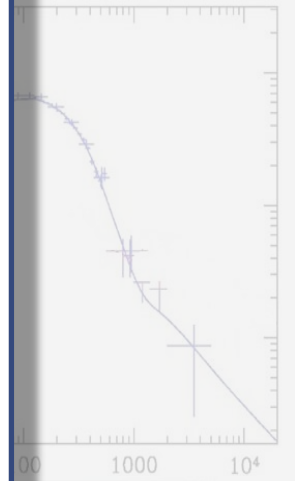
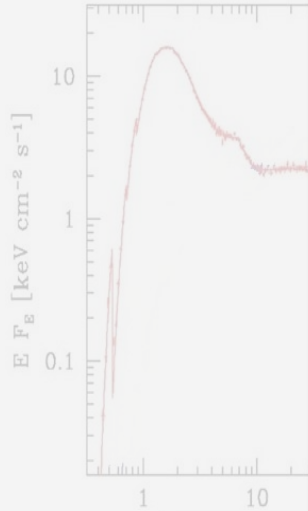
X-ray luminosity



# Astrophysical context

X-ray Binaries :

Spectral evolution



## Main questions:

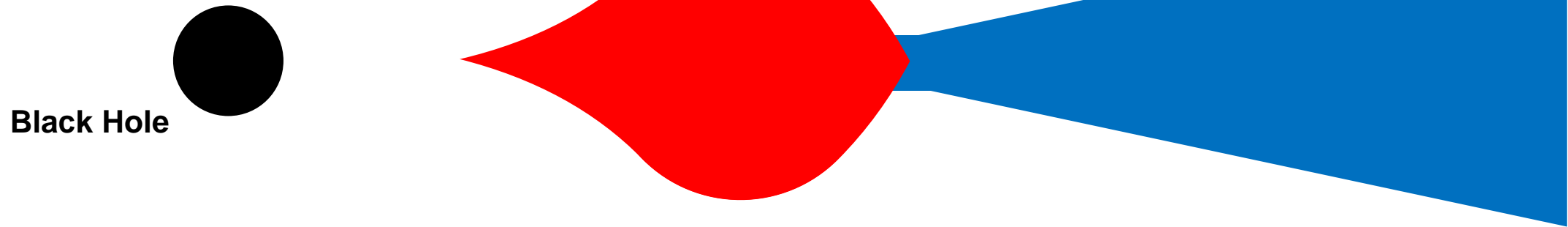
- What controls the spectral evolutions from hard to soft states?
- What is the link between the hot corona and the jets?
- What is the nature of the hot corona?

Jets

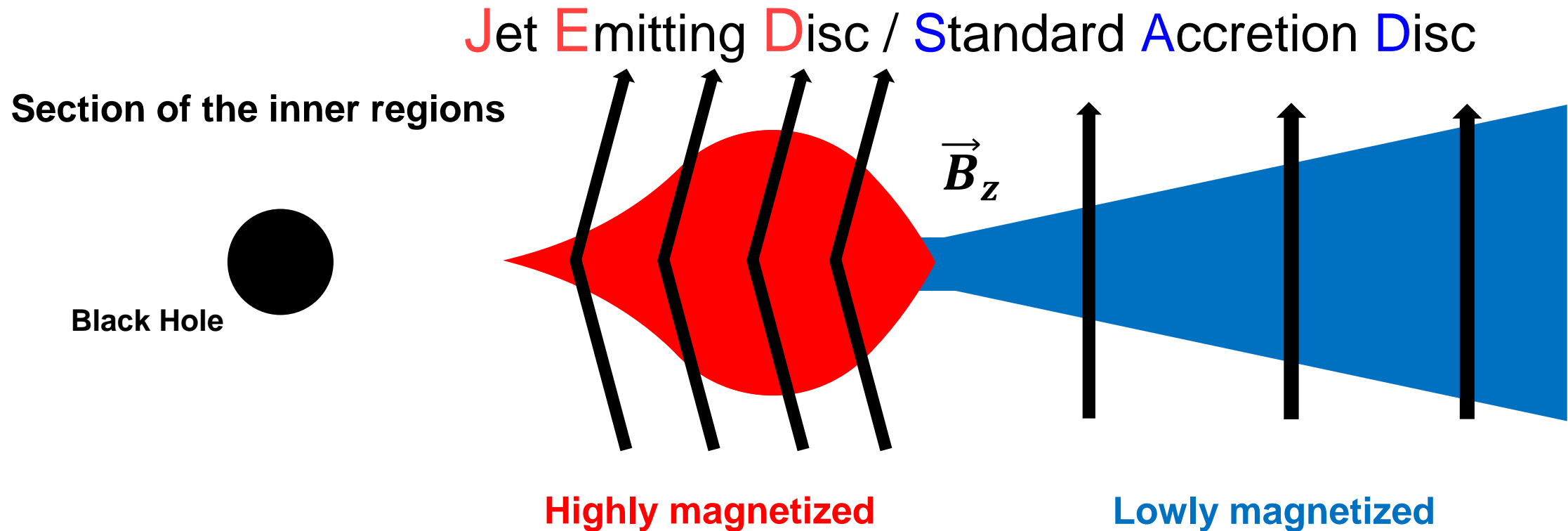
# Model

Jet Emitting Disc / Standard Accretion Disc

Section of the inner regions

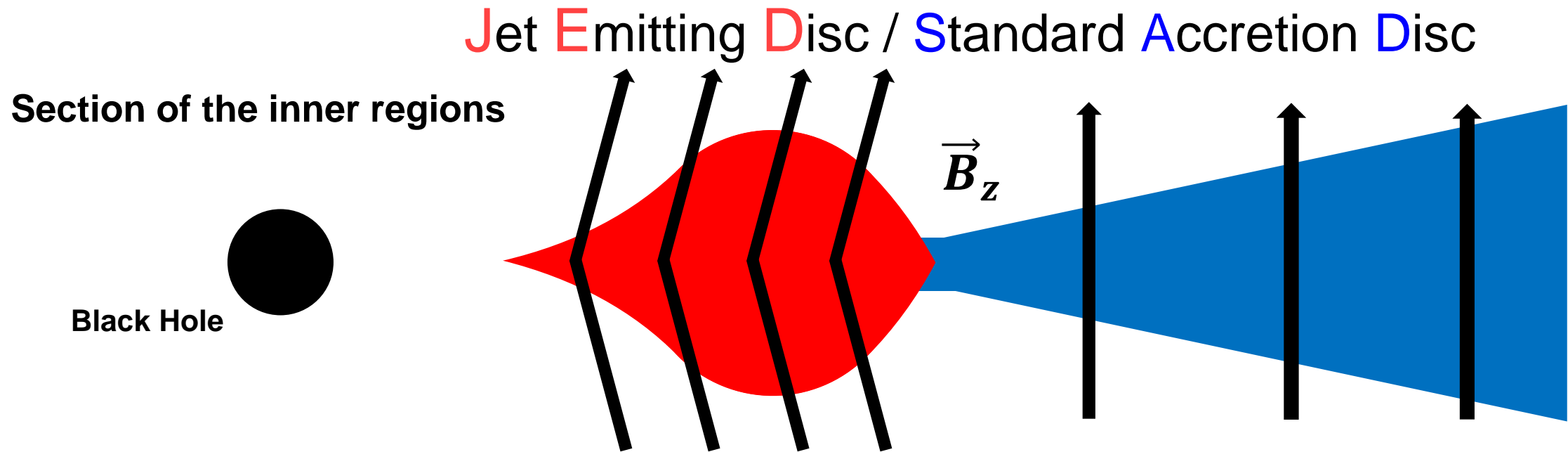


# Model



- Radial stratification of magnetization validated by MHD simulations:
  - Scepi et al. 2020
  - Liska et al. 2020
  - Jacquemin-Ide et al. 2021

# Model



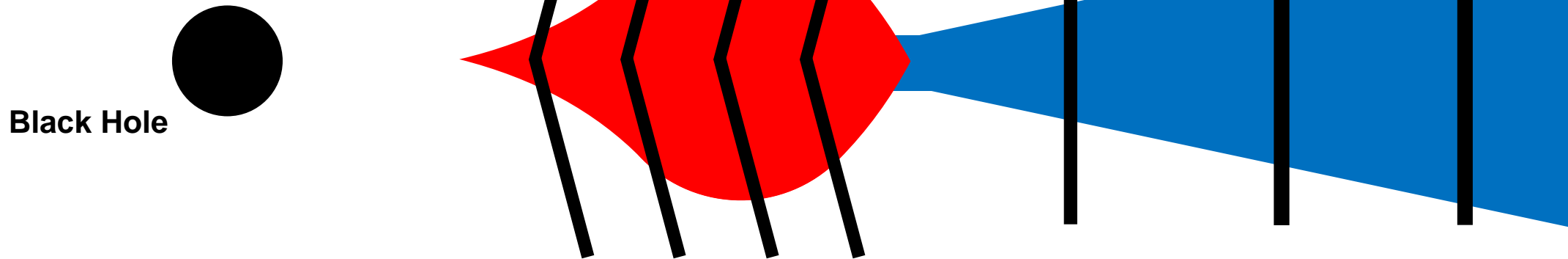
## Standard Accretion Disc

- From (Shakura & Sunyaev, 1973)
- Optically thick
- Geometrically thin
- Cold ~1 keV

# Model

## Jet Emitting Disc / Standard Accretion Disc

Section of the inner regions



### Jet Emitting Disc

- Self similar MHD solutions (**Ferreira 1997**)
- **Supersonic accretion speed**

### Standard Accretion Disc

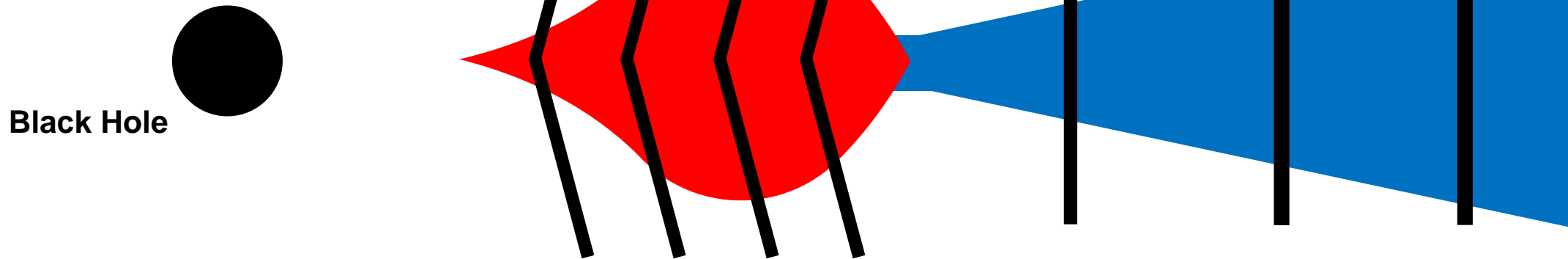
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## Jet Emitting Disc / Standard Accretion Disc

Section of the inner regions



### Jet Emitting Disc

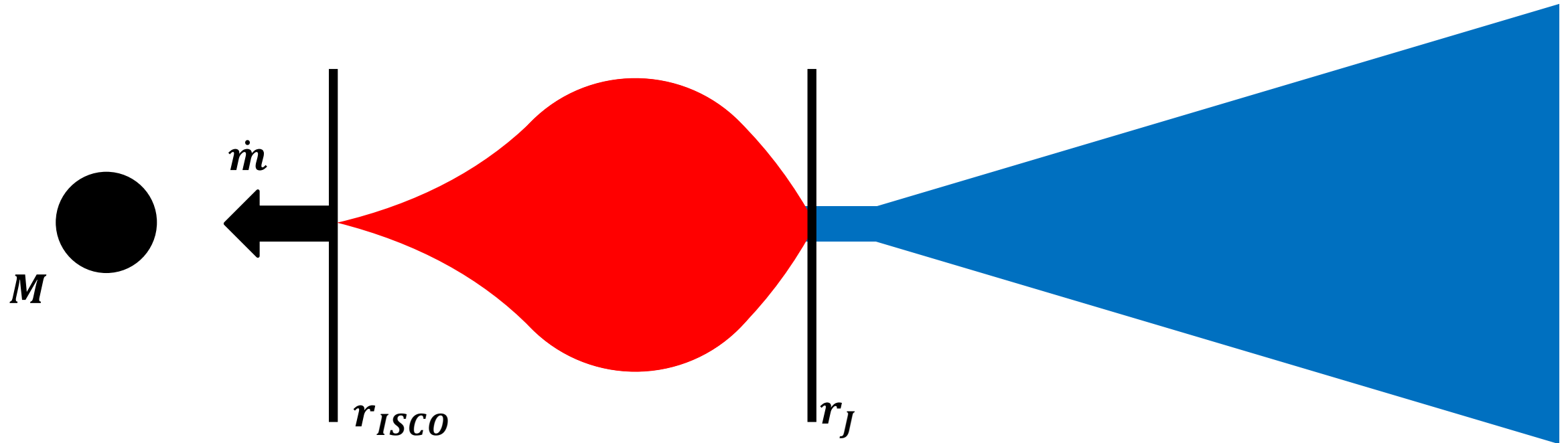
- Self similar MHD solutions (**Ferreira 1997**)
  - **Supersonic accretion speed**
  - Optically thin
  - Hot
- } **Even at high  $\dot{m}$**

### Standard Accretion Disc

- From (**Shakura & Sunyaev, 1973**)
- Optically thick
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- Cold ~1 keV

# Model

## Jet Emitting Disc / Standard Accretion Disc



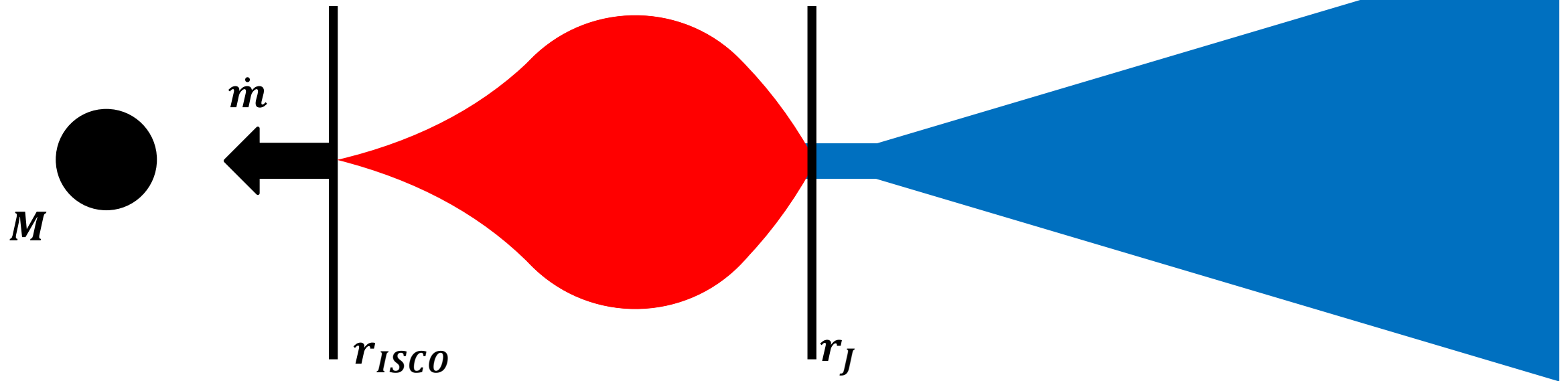
- $M$ : Mass of the Black Hole
- $r_{ISCO}$

- $\dot{m}(t)$ : mass accretion rate
- $r_J(t)$ : transition radius

# Model

## Jet Emitting Disc / Standard Accretion Disc

$$\dot{m} = \frac{\dot{M}}{\dot{M}_{Edd}} = \frac{\dot{M} c^2}{L_{Edd}}$$

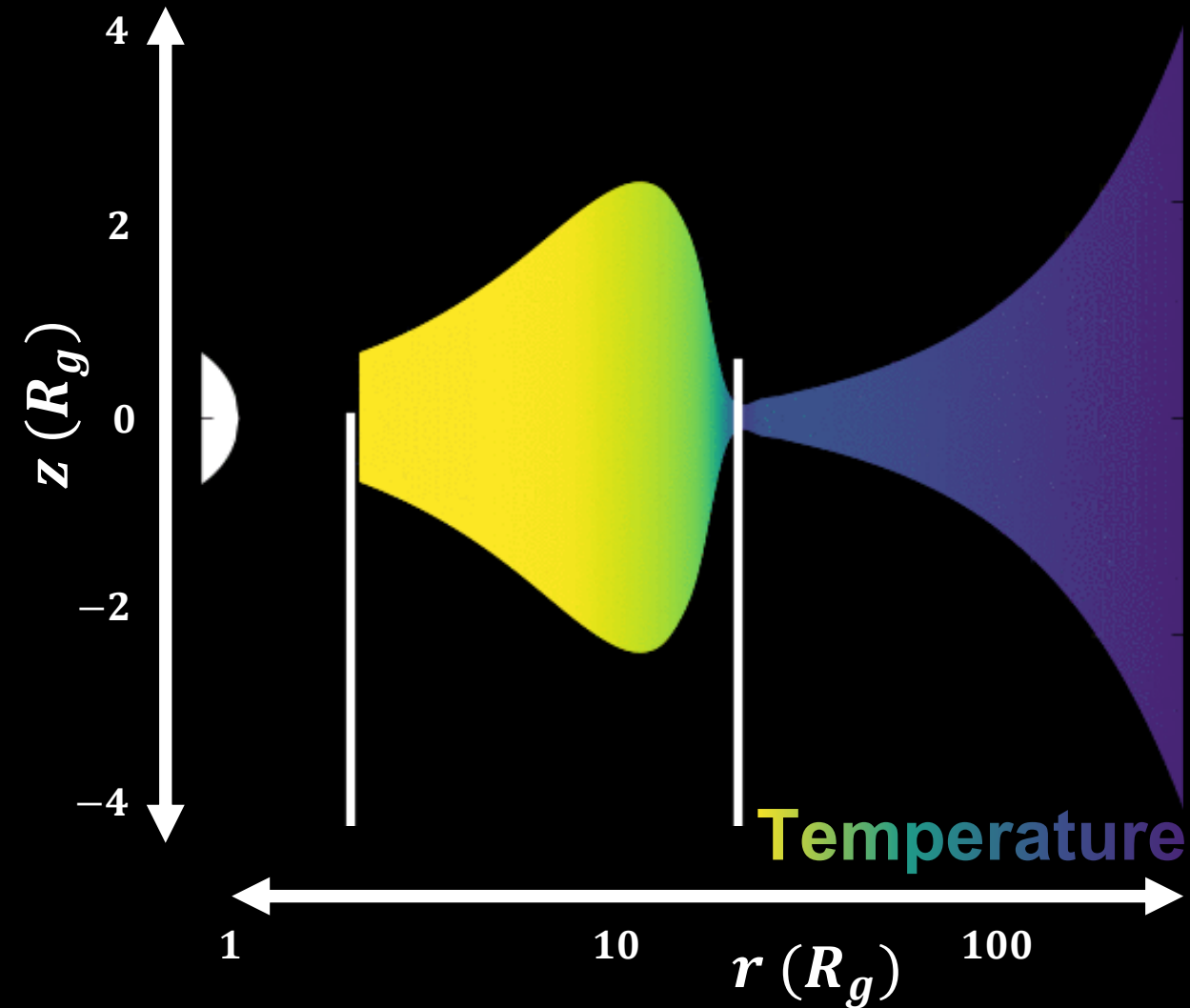


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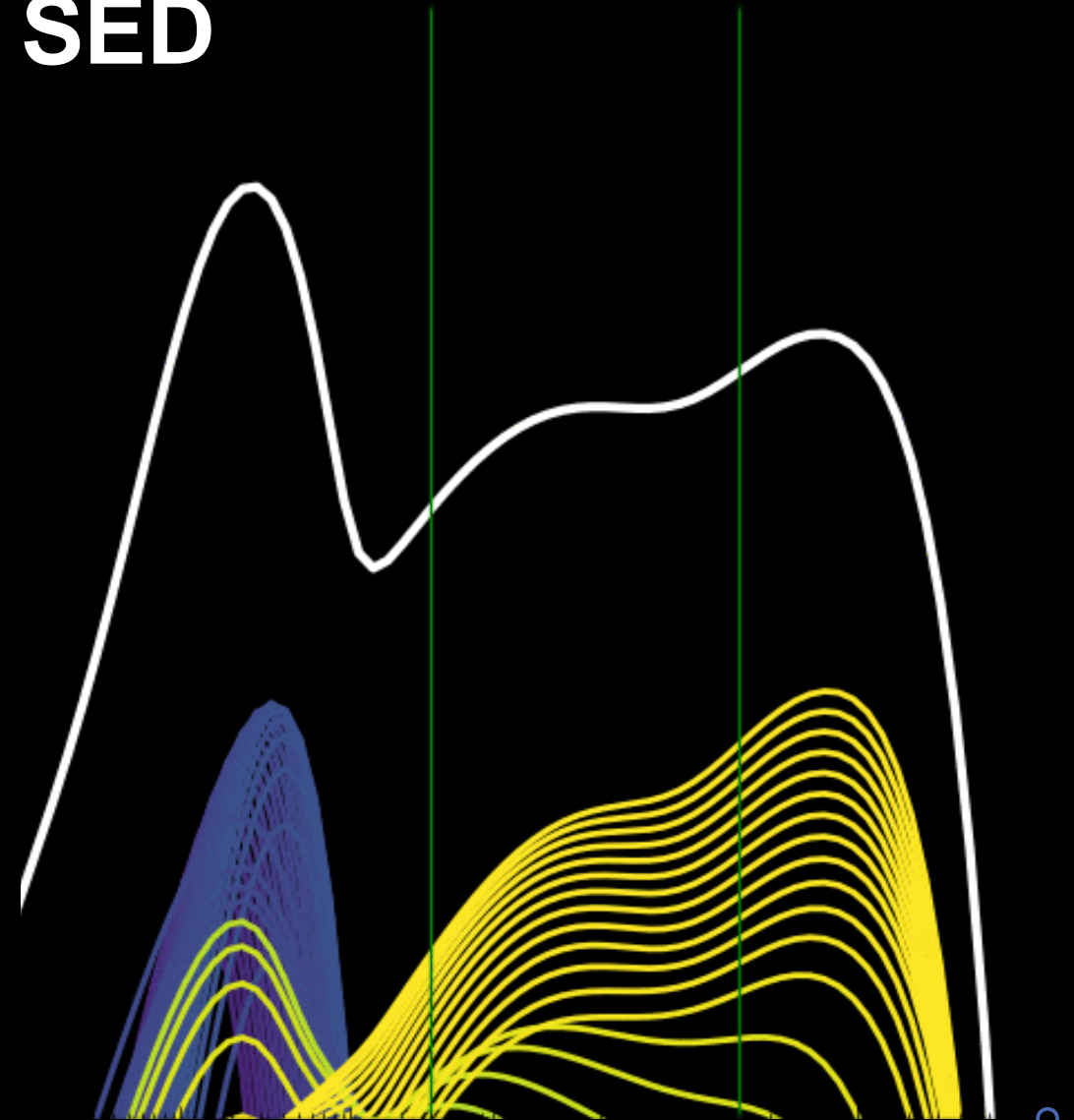
- $\dot{m}(t)$ : mass accretion rate
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# Model SED

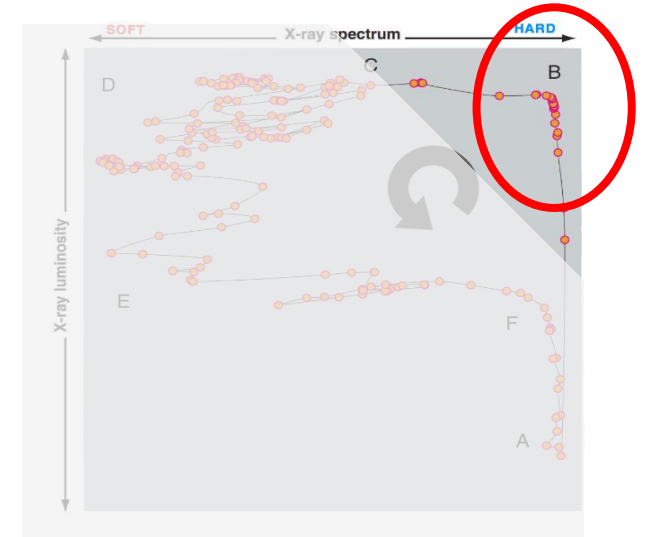
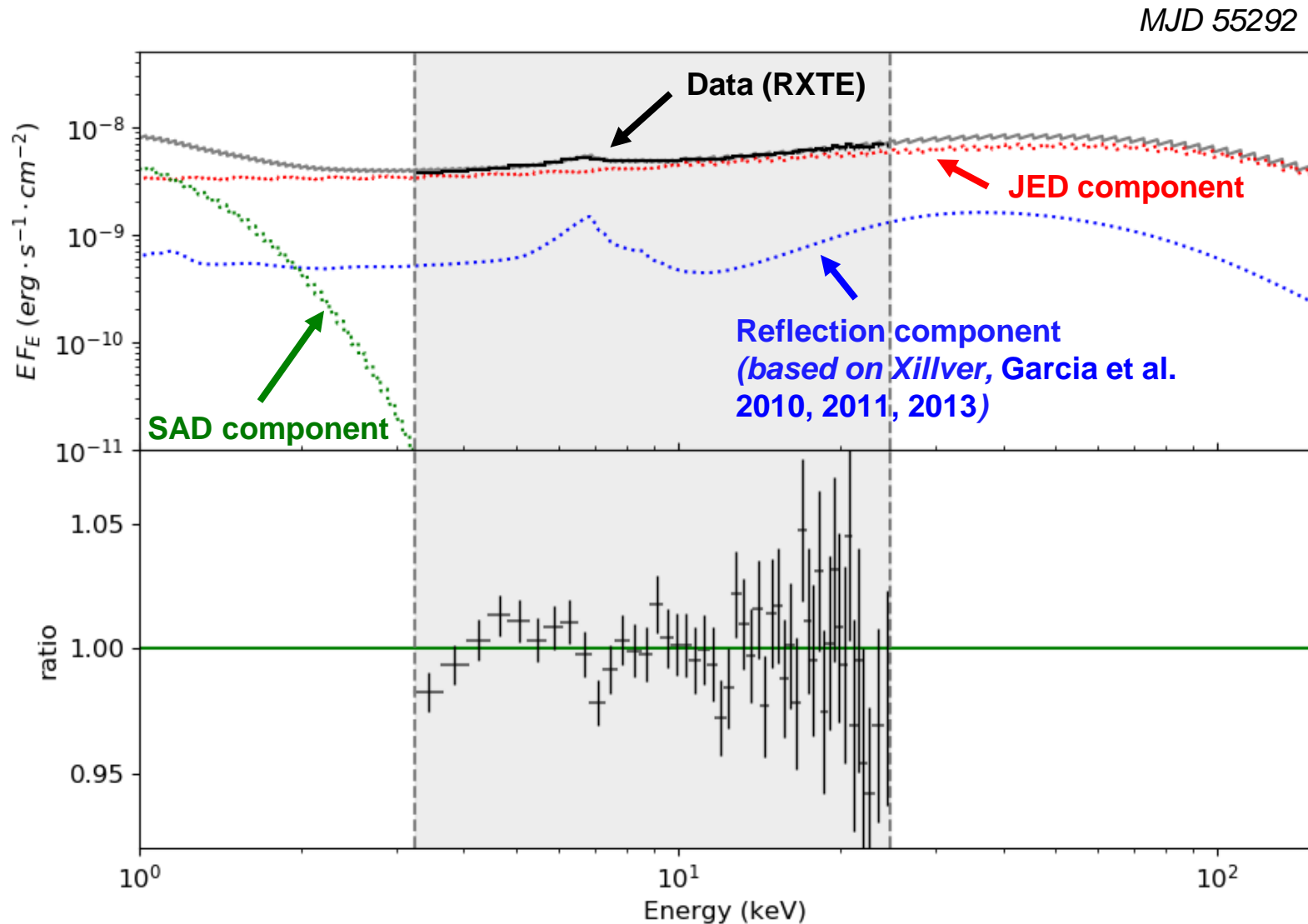
## Geometry



## SED



# GX339-4 – First fits



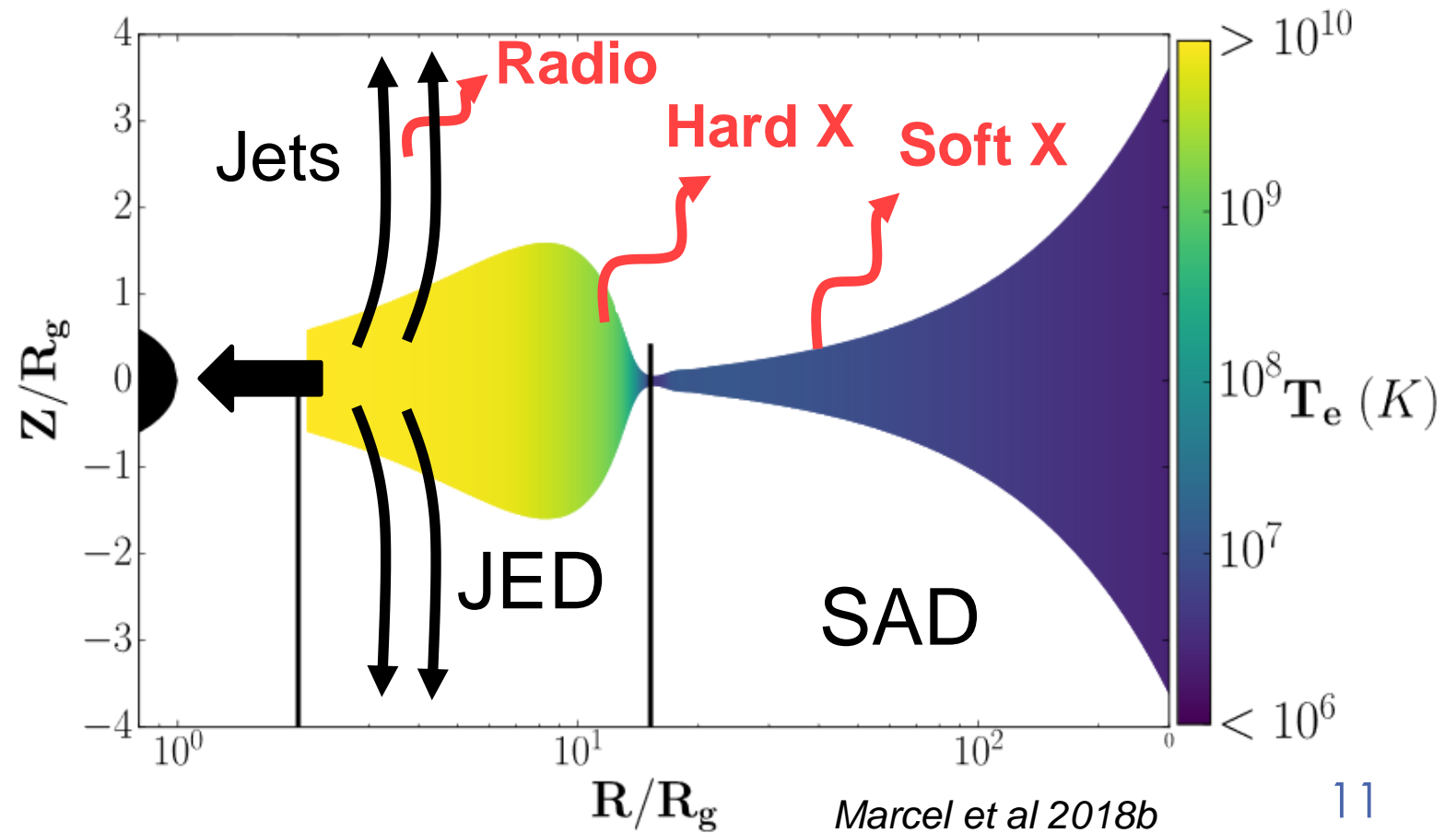
$$r_J(R_G) \sim 14.3 \pm 0.6$$

$$\dot{m}(\dot{M}_{Edd}) \sim 2.31 \pm 0.02$$

Adapted from Barnier et al. 2021

# GX339-4 – Constrains on the radio emission

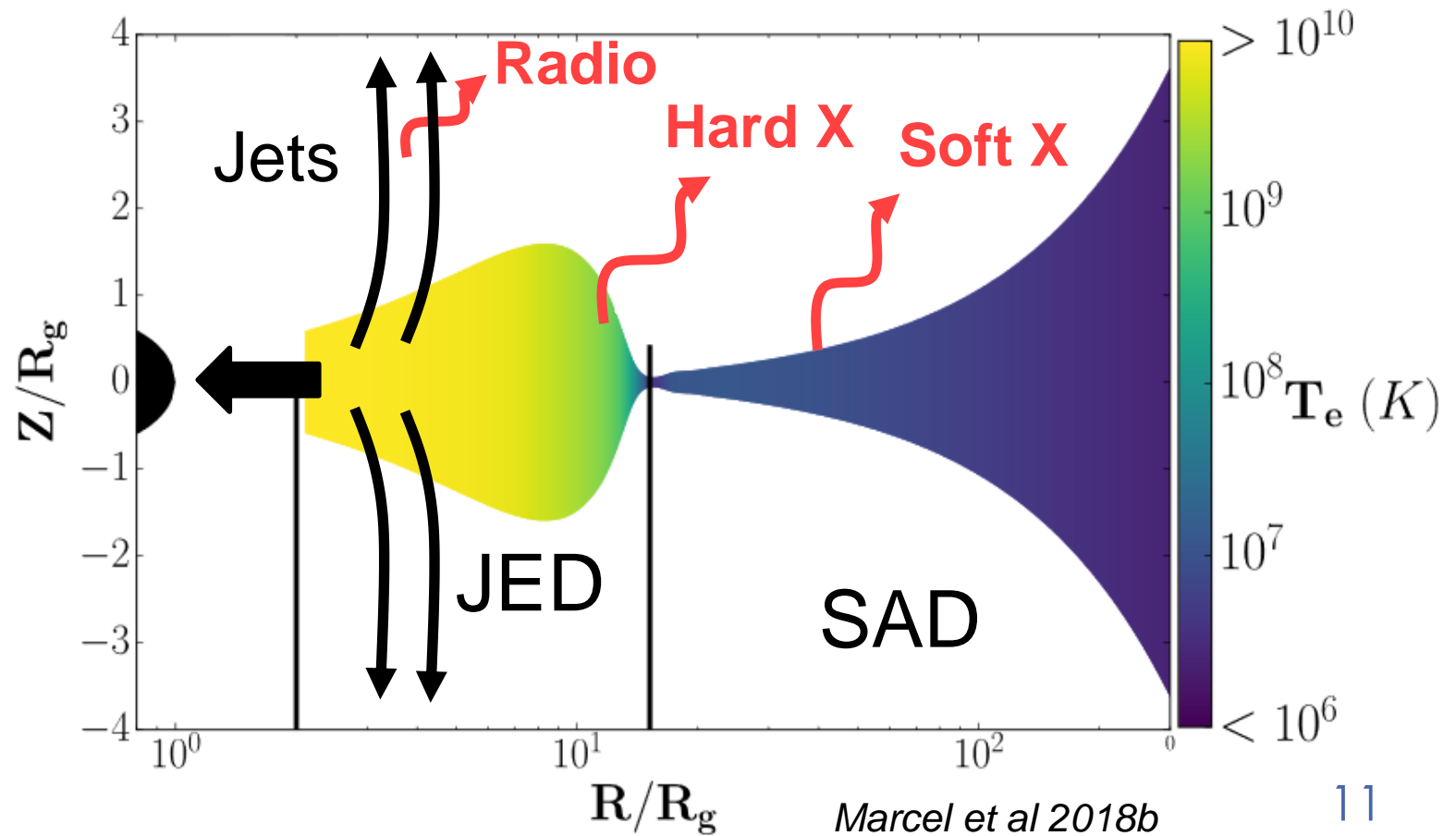
## Methodology



# GX339-4 – Constrains on the radio emission

- **X-ray spectrum :**
  - Constrains physical parameter  $(r_J; \dot{m})$

## Methodology



# GX339-4 – Constrains on the radio emission

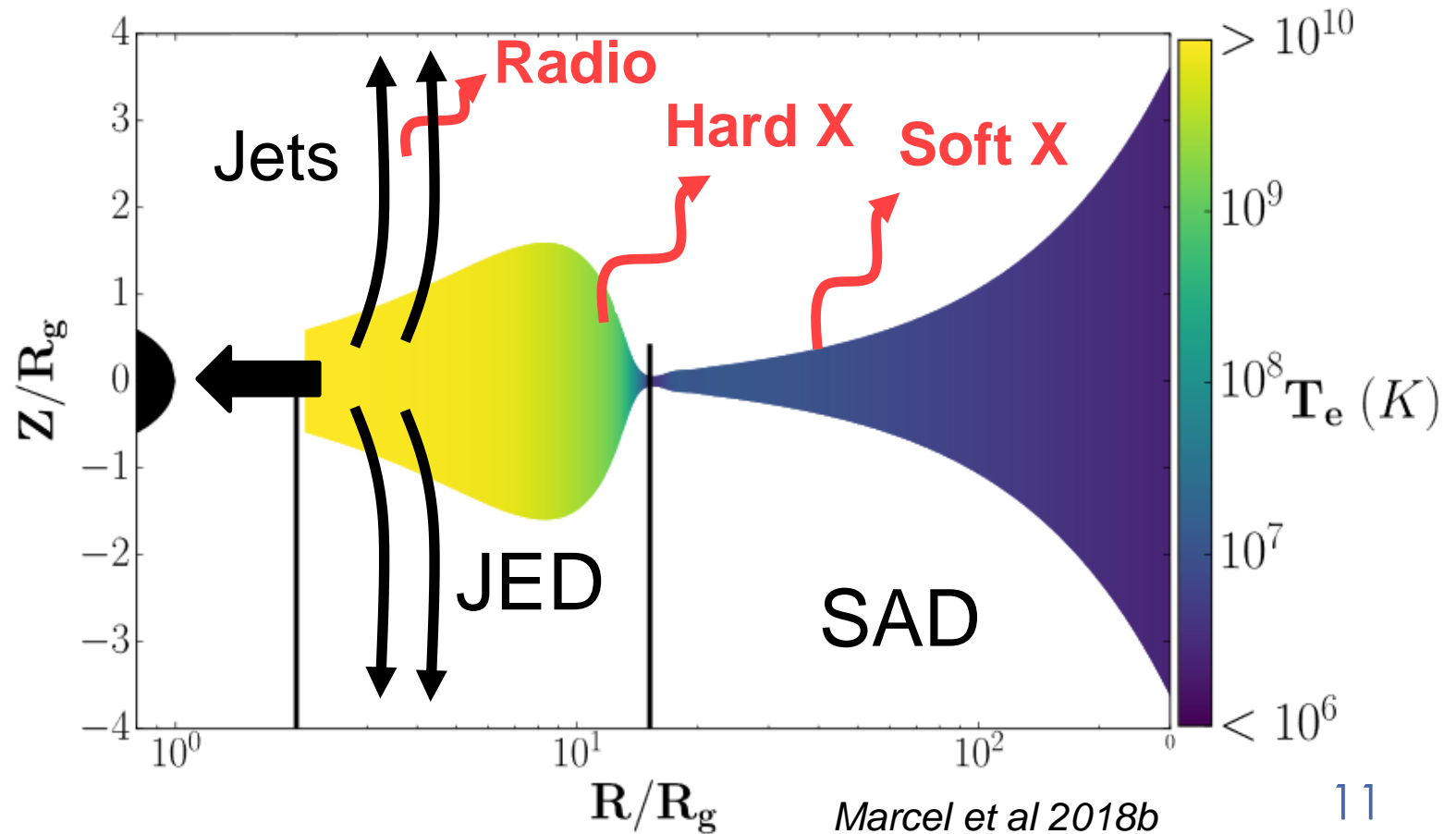
- **X-ray spectrum :**
  - Constrains physical parameter

$$(r_J; \dot{m})$$

- Reproduce **Radio** with :

$$F_R \propto \dot{m}^\beta r_J^\alpha$$

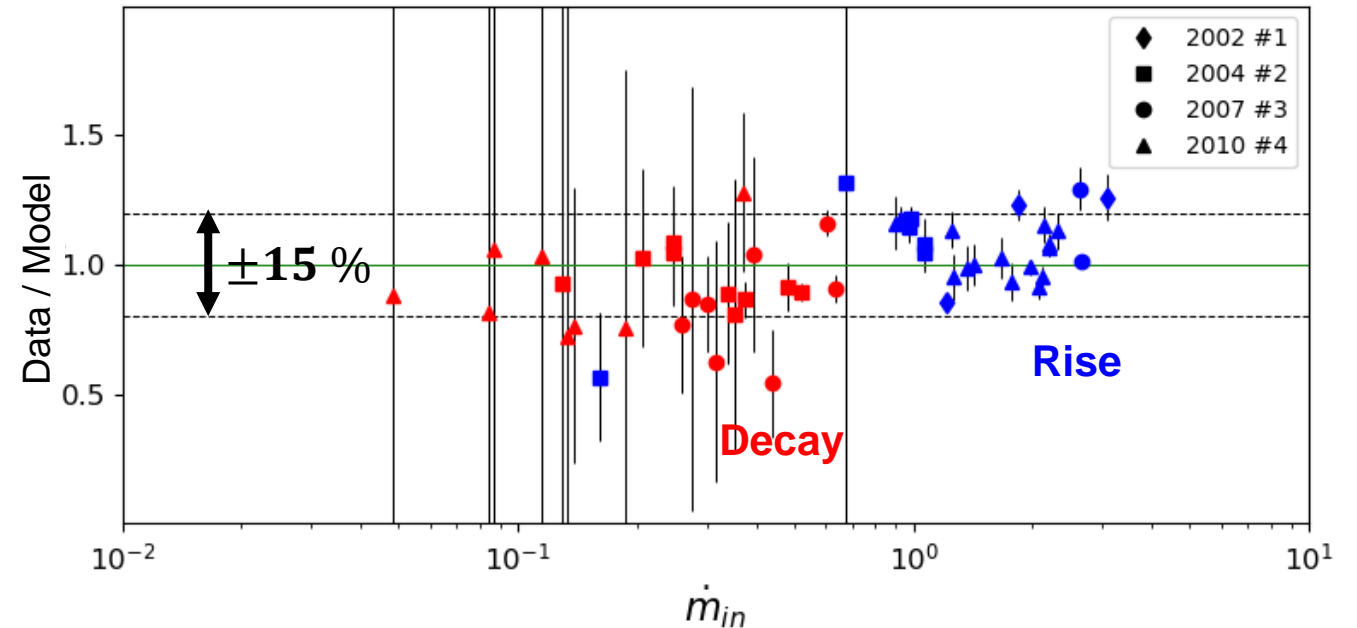
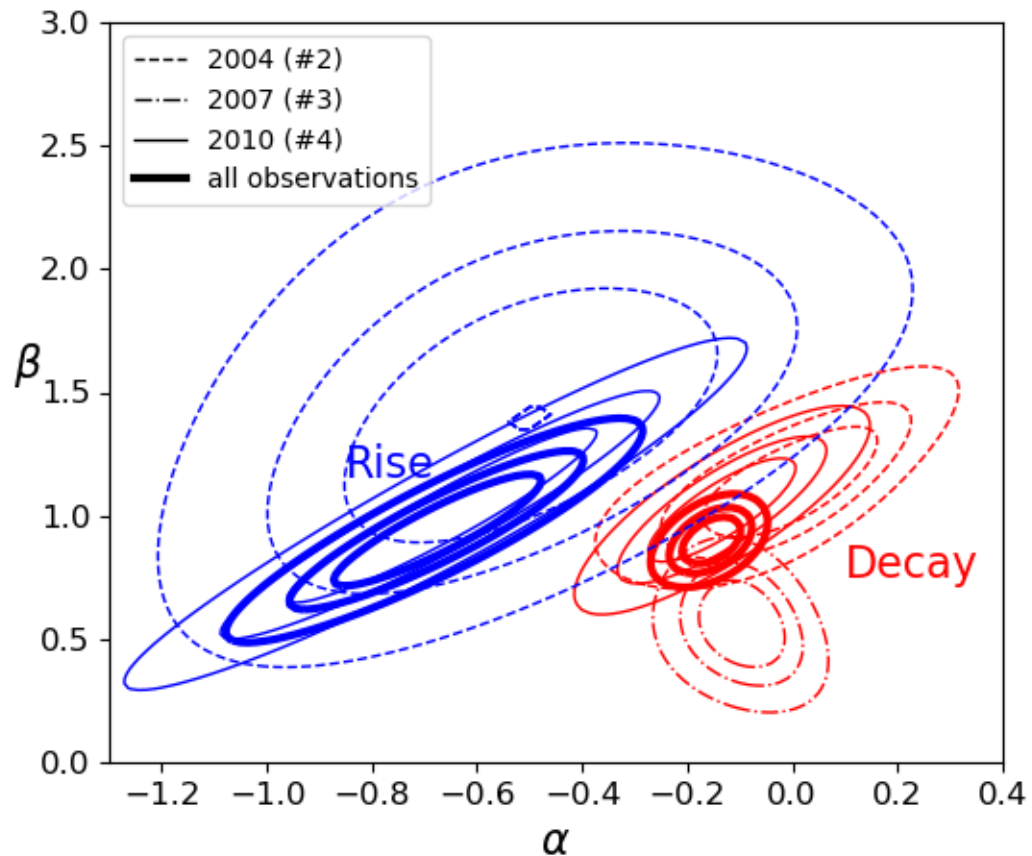
## Methodology





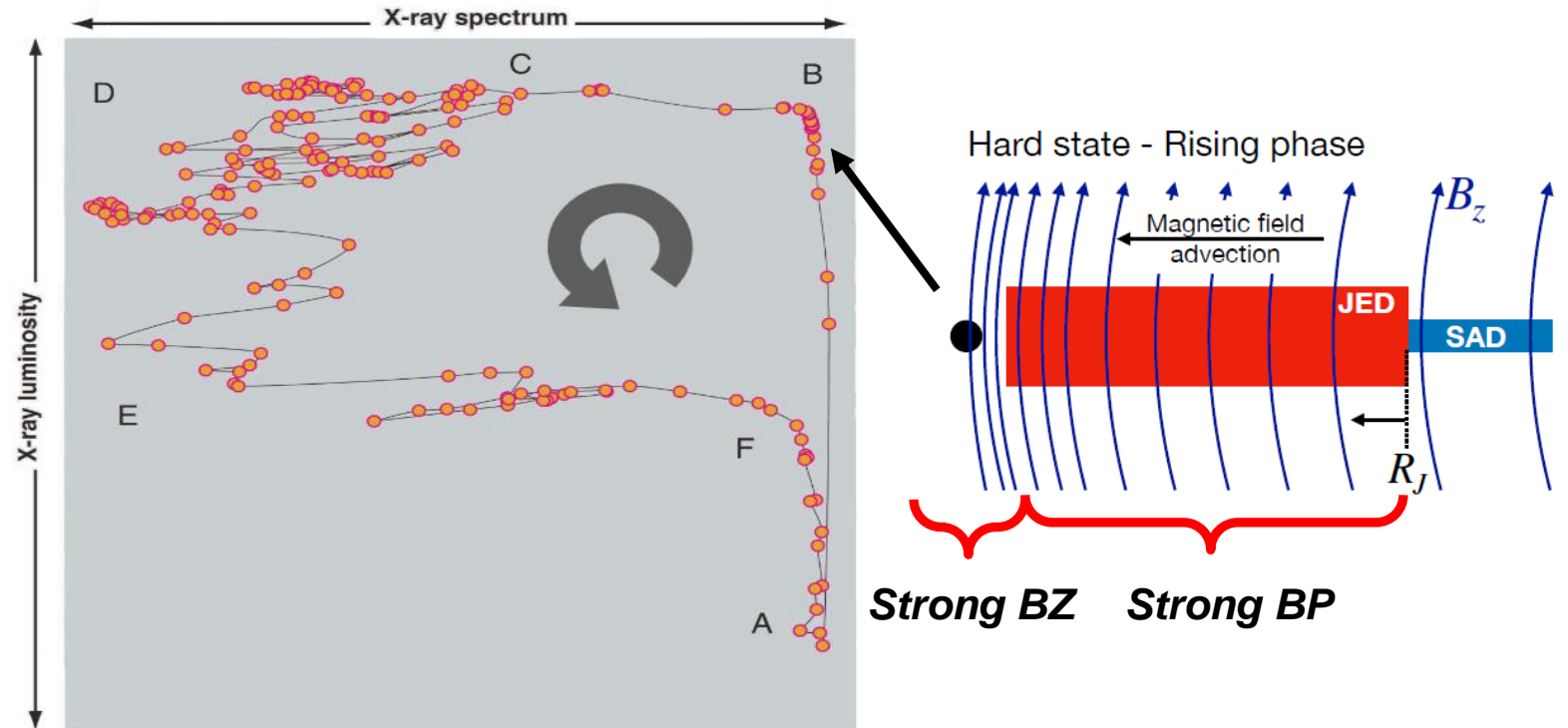
# GX339-4 – Constrains on the radio emission

$$F_R \propto \dot{m}^\beta r_J^\alpha$$



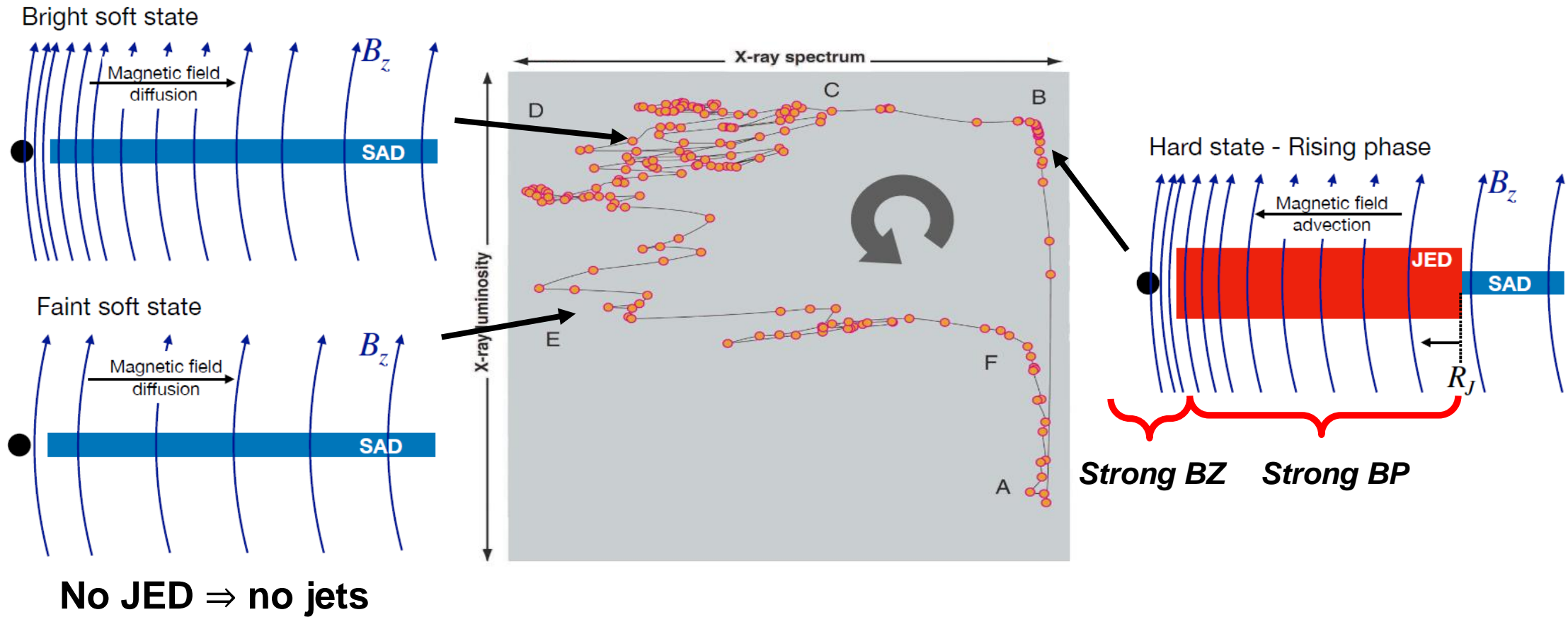
See *Barnier et al. 2021*

# GX339-4 – BP vs BZ ?



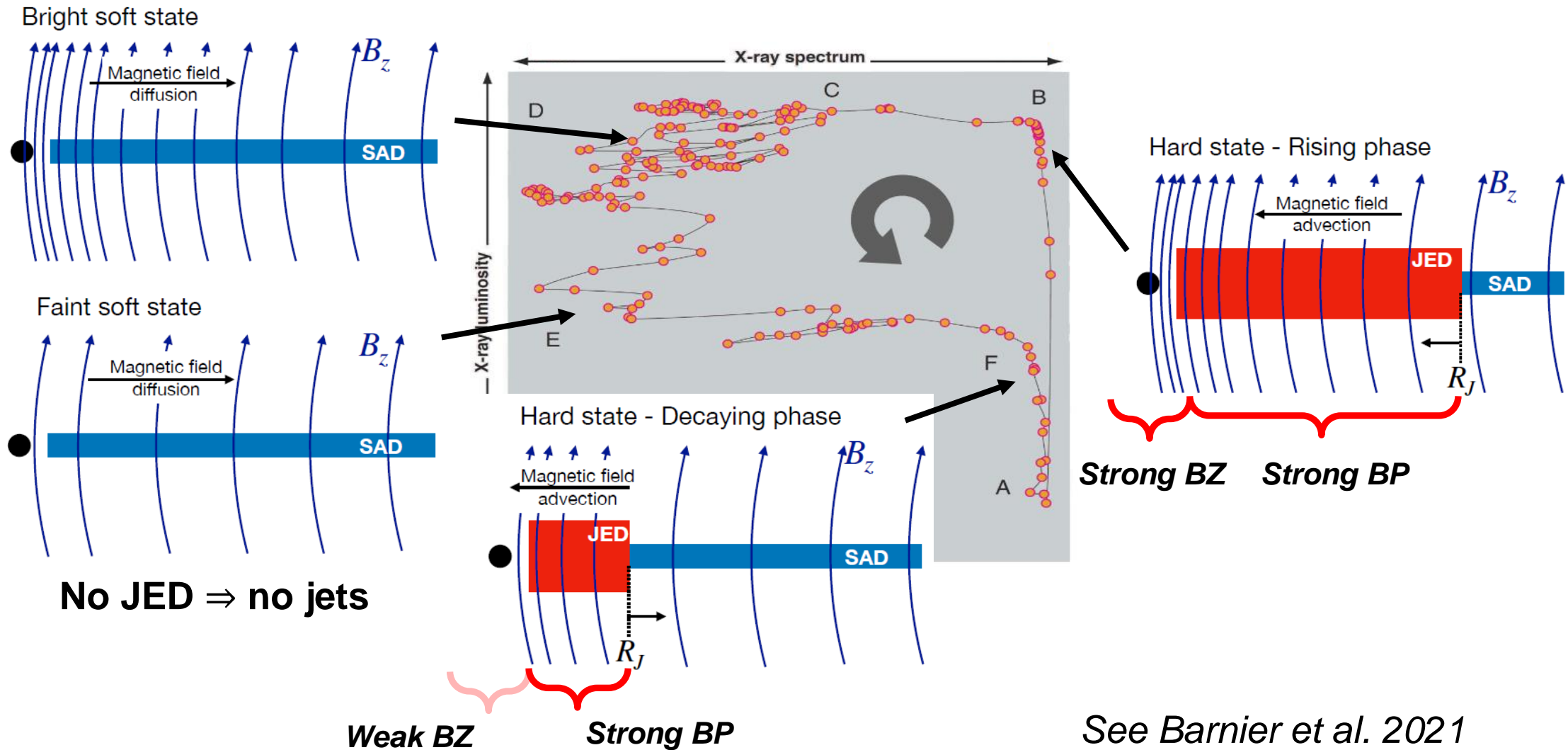
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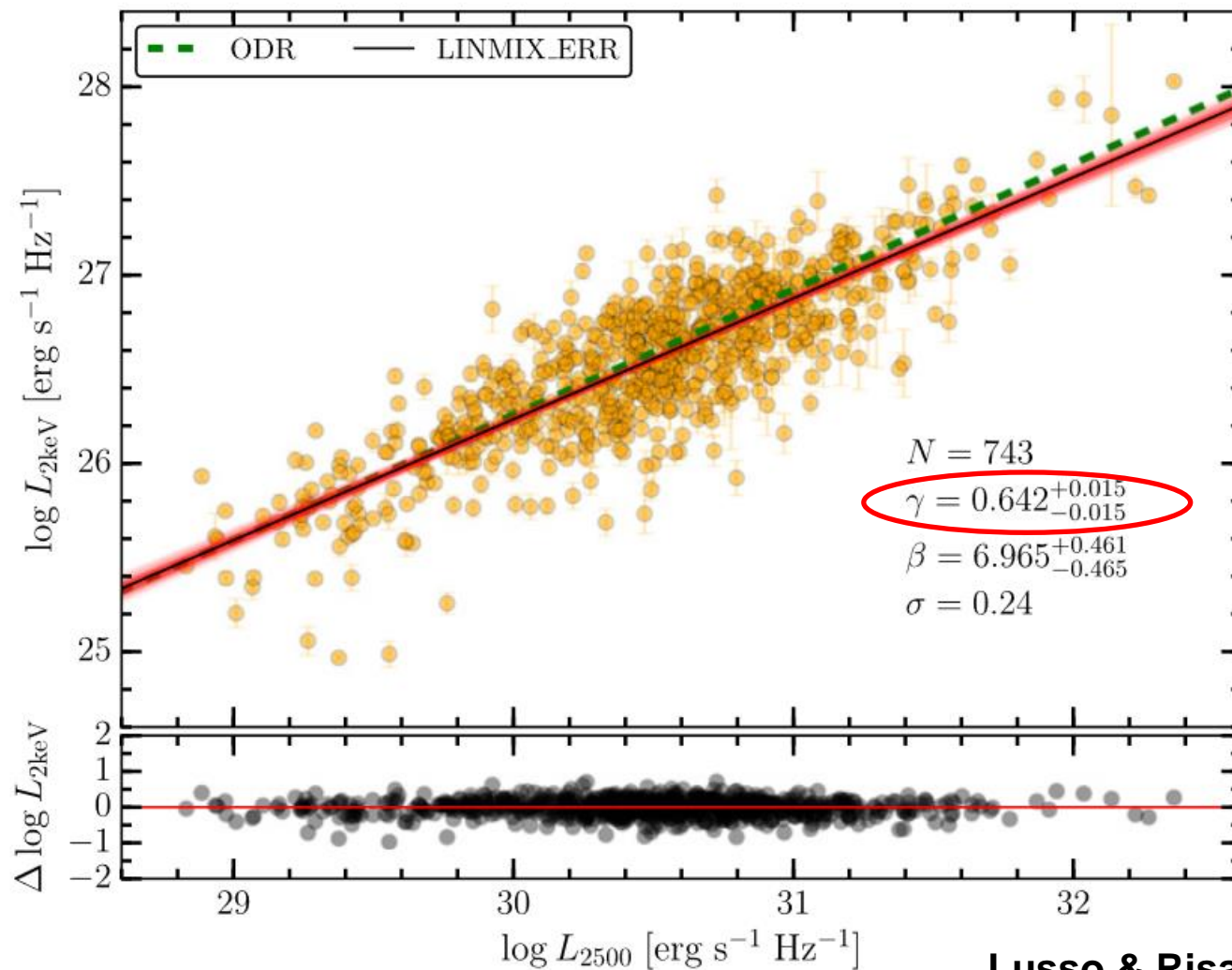
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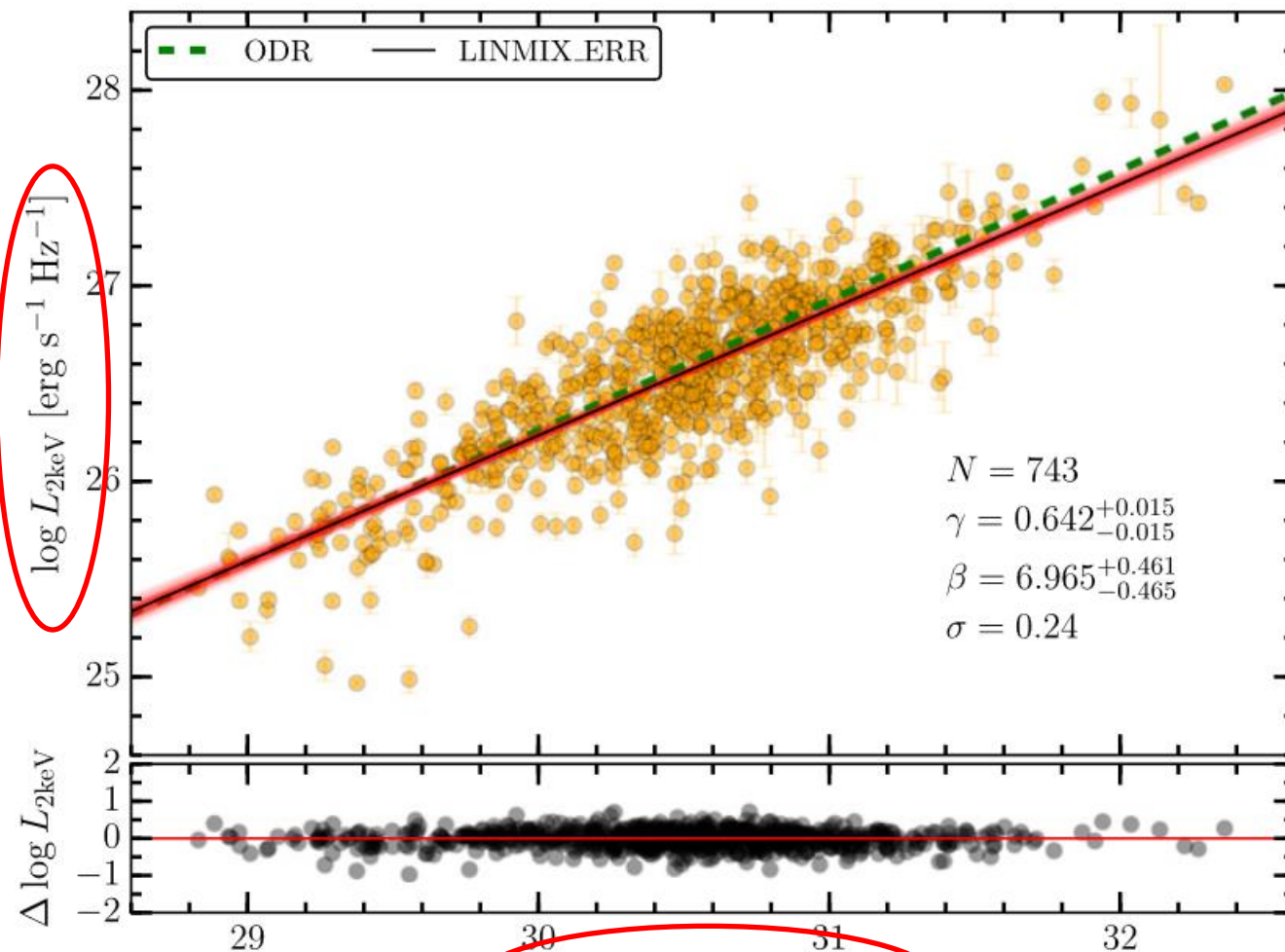
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# AGN : The UV-Xray correlation



Non linear correlation

# AGN : The UV-Xray correlation

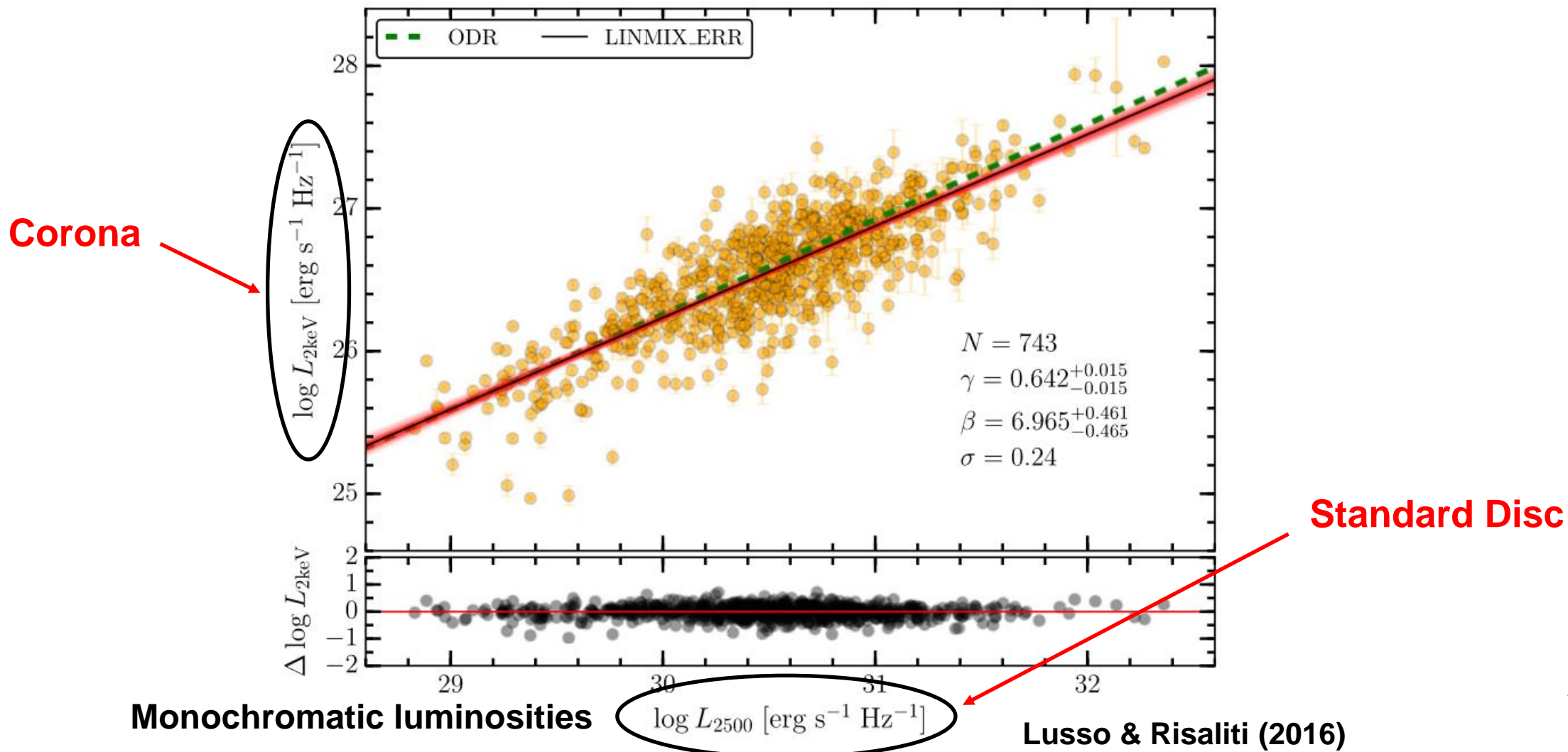


Monochromatic luminosities

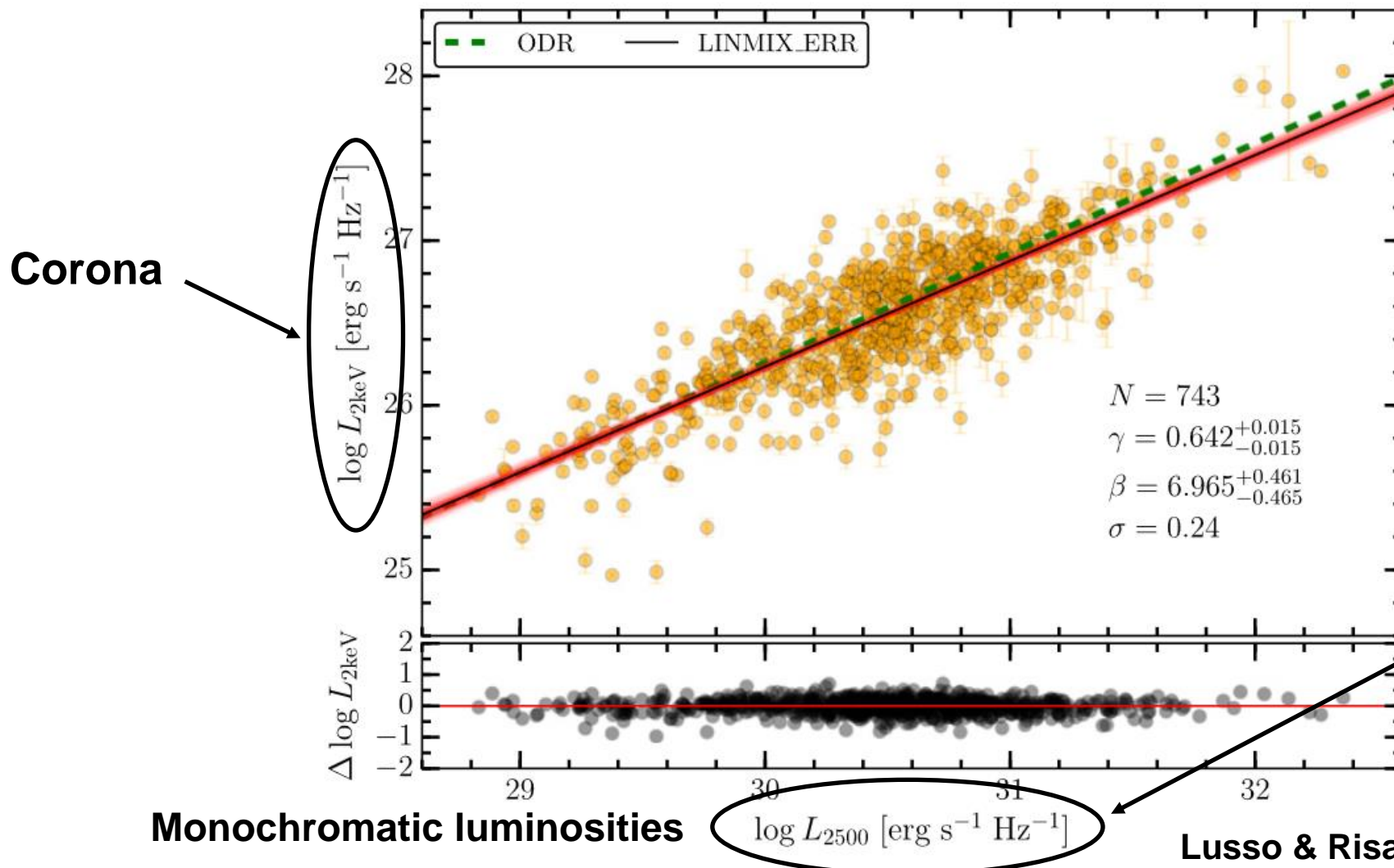
$\log L_{2500} [\text{erg s}^{-1} \text{Hz}^{-1}]$

Lusso & Risaliti (2016)

# AGN : The UV-Xray correlation



# AGN : The UV-Xray correlation



See also  
Kubota & Done 2018  
Arcodia et al. 2019

Lusso & Risaliti (2016)



# AGN : The UV-Xray correlation

## Main questions:

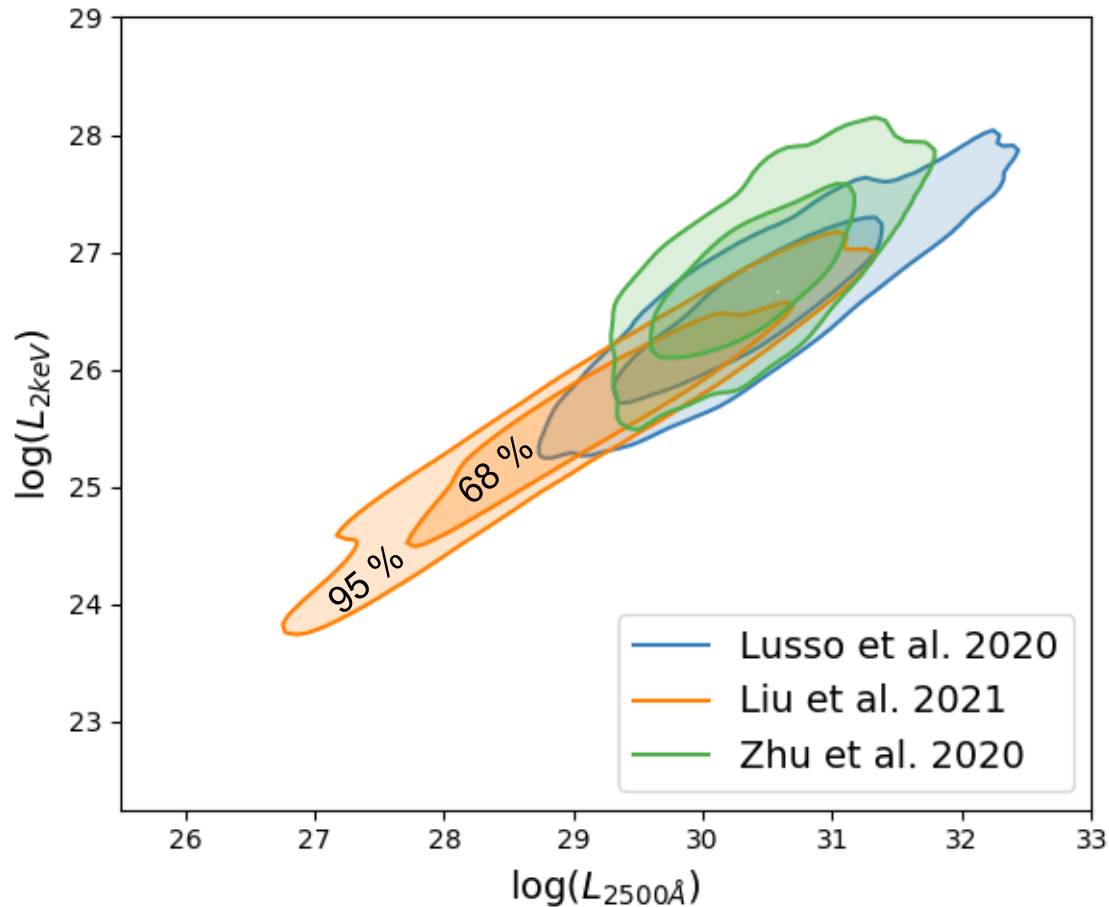
- Can we reproduce such a correlation with the JED-SAD ?
- What constrains on the parameters do we obtain ?
- How do we physically explain this non linear correlation ?

Monochromatic luminosities

$\log L_{2500} [\text{erg s}^{-1} \text{Hz}^{-1}]$

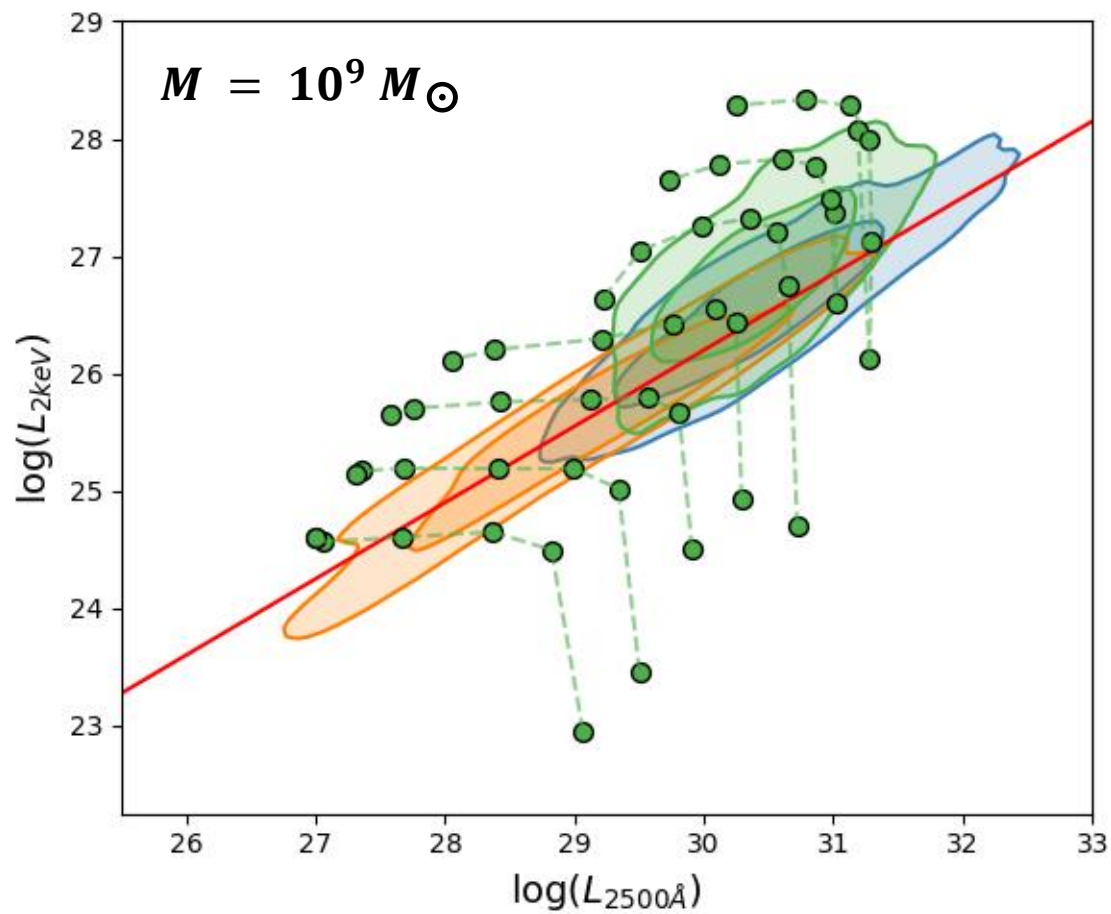
Lusso & Risaliti (2016)

# AGN : Sample

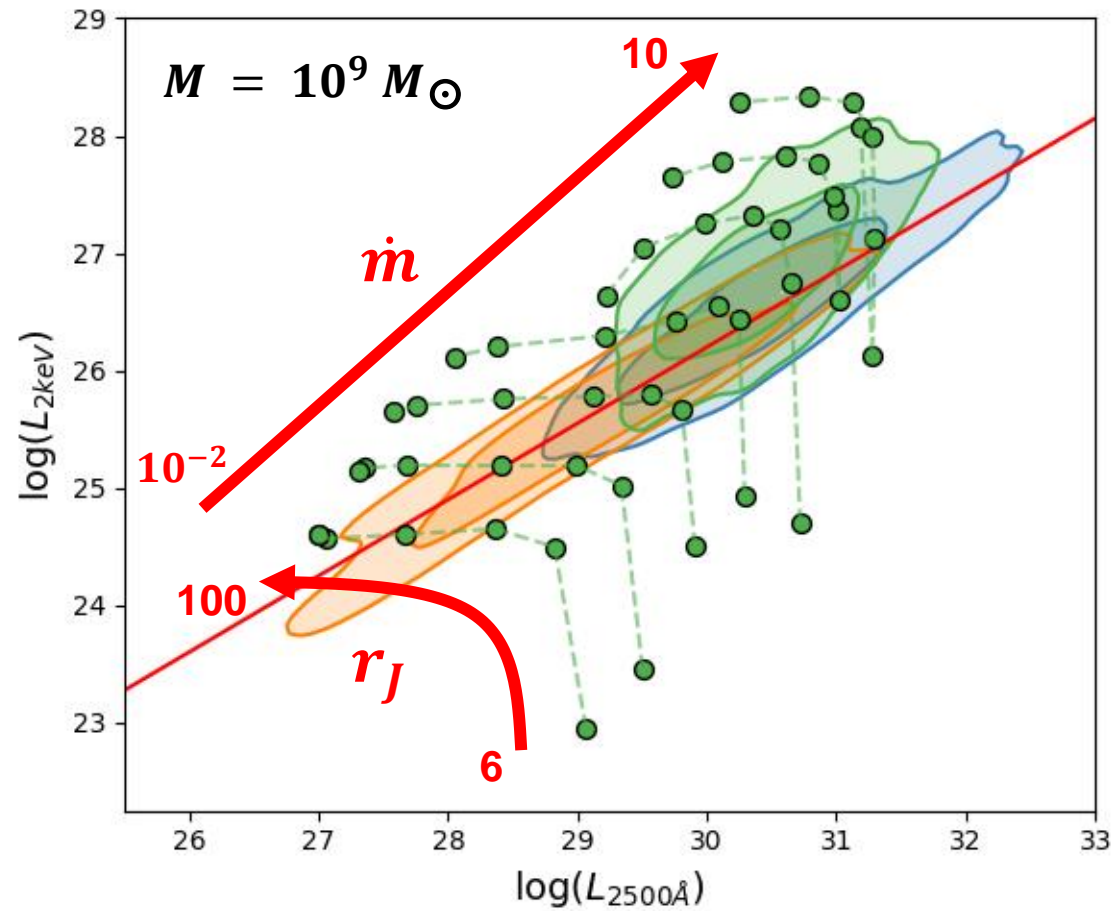


- **Lusso et al. 2020**
  - Bright luminous quasar ; radio quiet
- **Liu et al. 2021**
  - 47 AGN ; lower luminosities
- **Zhu et al. 2020**
  - Radio loud sources

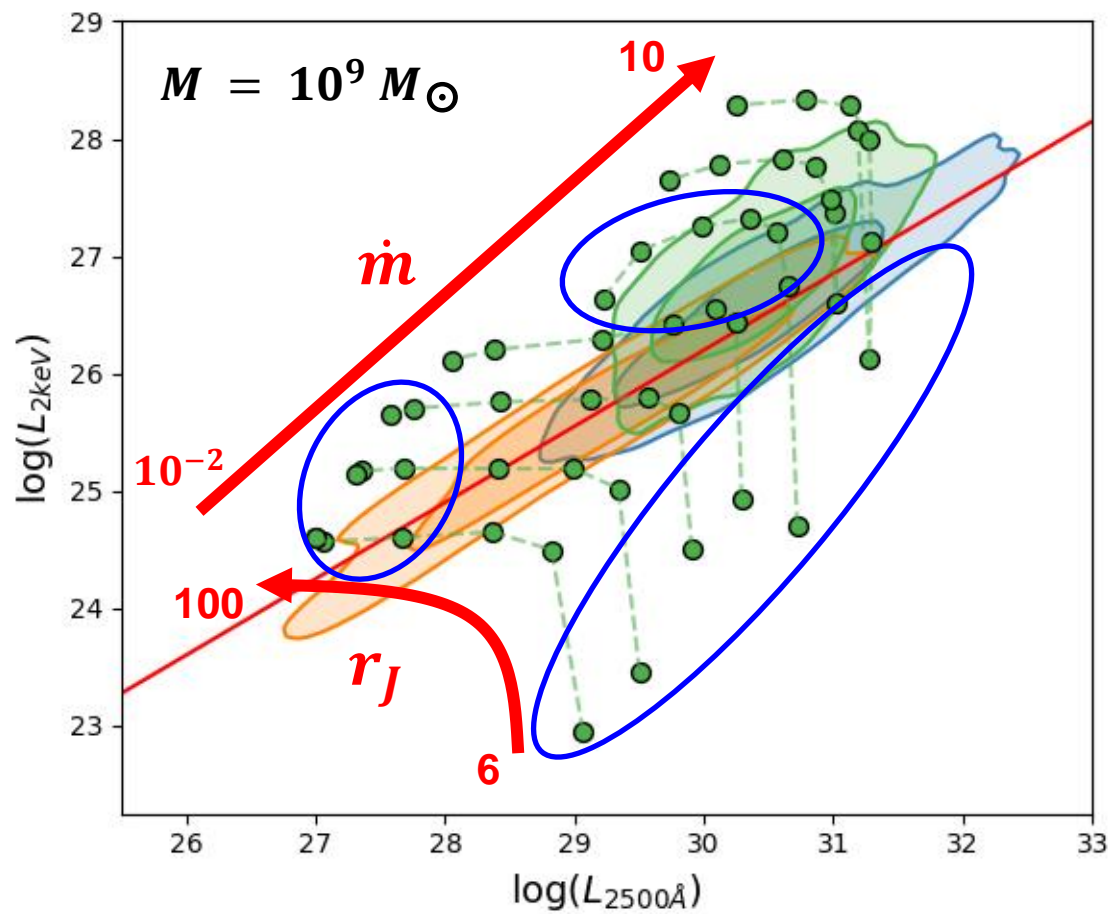
# AGN : $r_J; \dot{m}$ grid



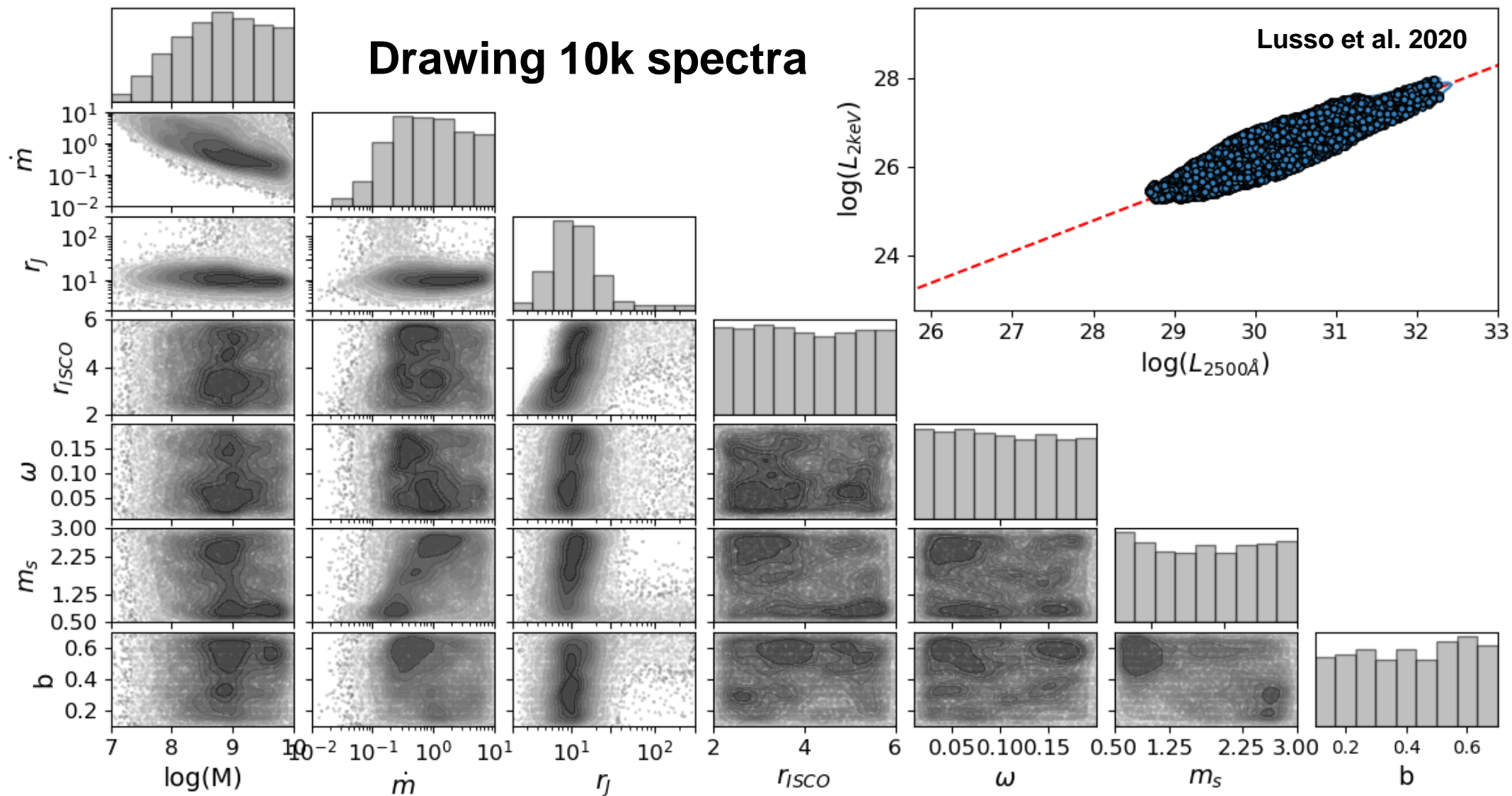
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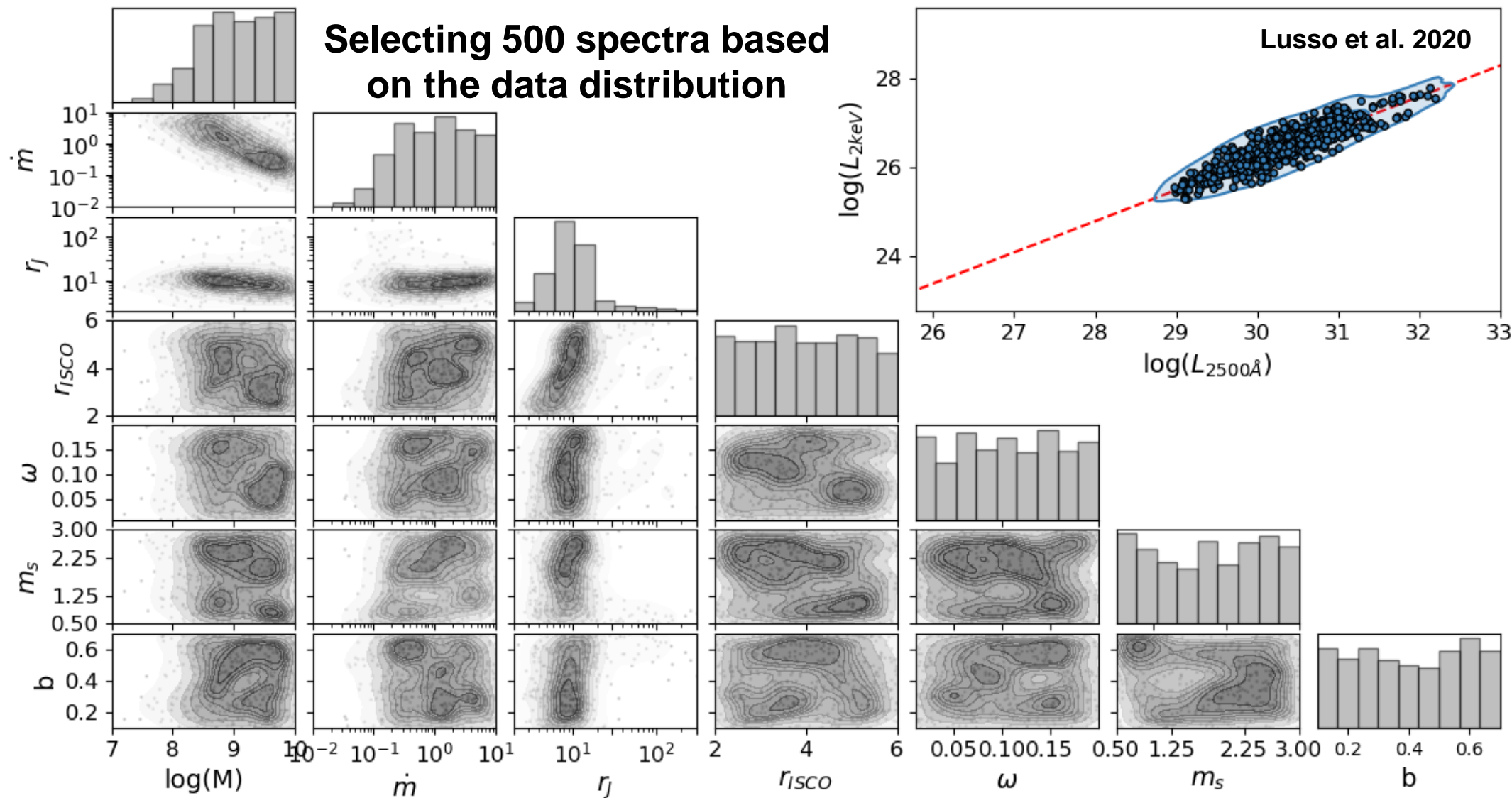
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# AGN : statistical approach

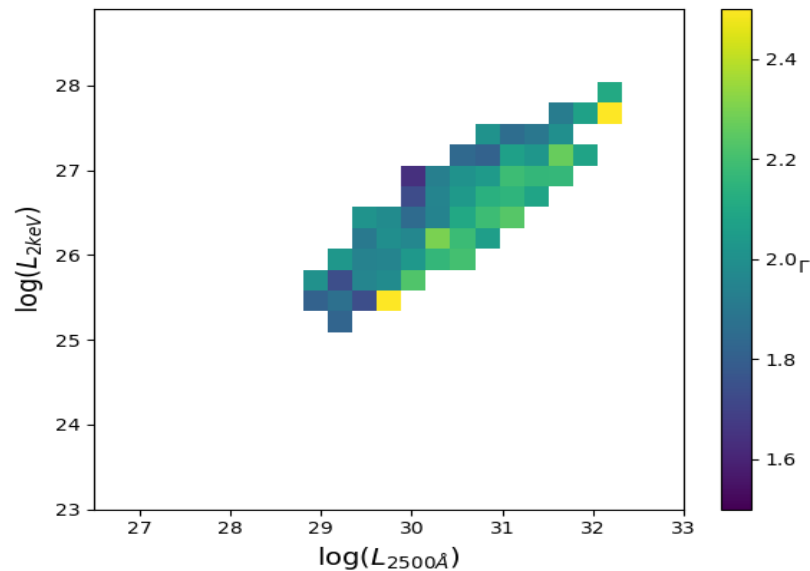
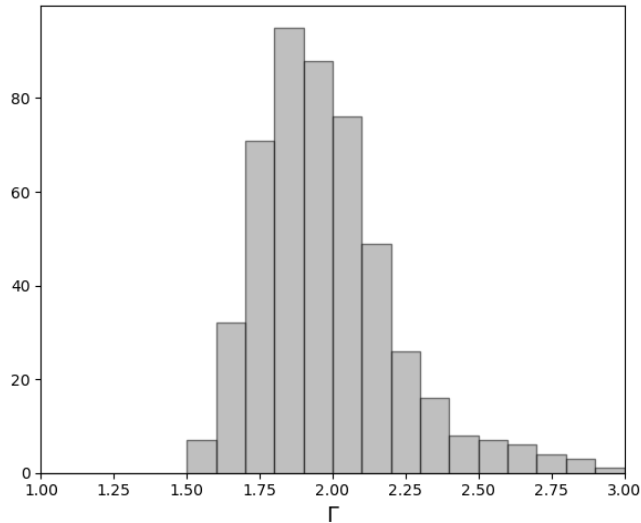


# AGN : statistical approach

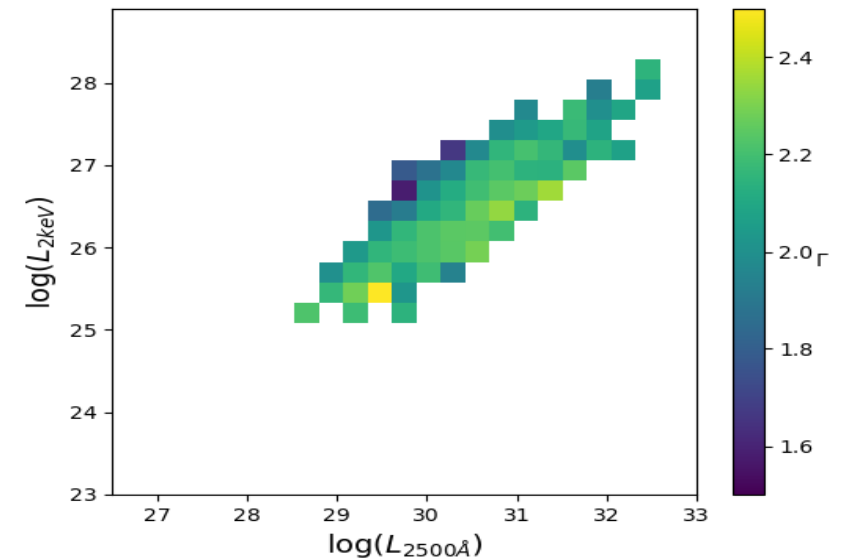
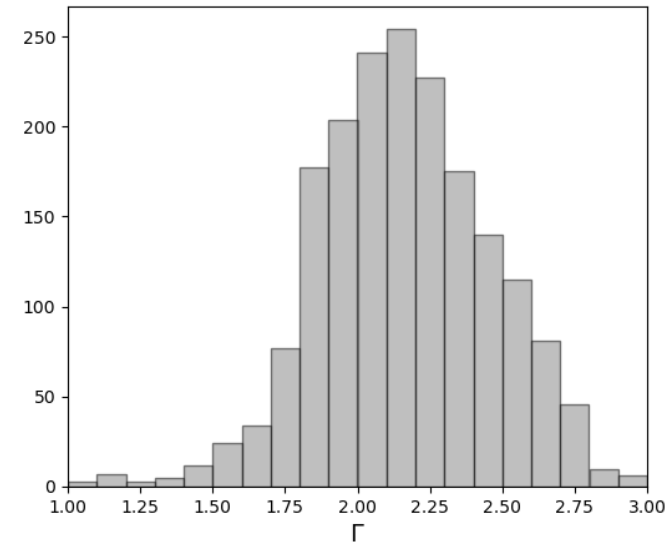


# AGN : Do we reproduce the correct Xray spectra ?

Selection of 500 simulated spectra



Lusso et al. 2020 Data





# AGN : Do we reproduce the correct Xray spectra ?

Selection of 500 simulated spectra

Lusso et al. 2020 Data

## What is next ?

- Drawing simulated sample respecting the Mass and  $\Gamma$  distributions in the UV – Xray plane.
- Physical explanation for the non linear correlation ?
- How does an XrB outburst transposes for AGNs ?
- What about the fundamental plane of black hole activity ?
- Spectral applications
- Can we understand the AGN population with the JED-SAD model ?

80  
60  
40  
20  
0  
28  
27  
26  
25  
24  
23

$\log(L_{2500\text{\AA}})$

$\log(L_{2500\text{\AA}})$

2.4  
2.2  
2.0  $\Gamma$   
1.8  
1.6

# Conclusions

- JED-SAD model simultaneously explains **the X-ray spectral and jet dynamical evolution**
  - JED is characterized by **supersonic accretion speed**

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- **Successful spectral applications** to GX339-4 and MAXI J 1820
- **Simultaneous radio / X-ray fit of GX339-4 :**
  - **Two different radio behavior** are observed between the rising and decaying phases
  - **Different ejections processes ?**

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- **Simultaneous radio / X-ray fit of GX339-4 :**
  - **Two different radio behavior** are observed between the rising and decaying phases
  - **Different ejections processes ?**
- **JED-SAD covers the entire UV-Xray correlation**
  - **Reproduction of AGN sample (WIP)**