The Multi-Wavelength emission of accreting Black Holes and their Jets

2015

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(INAF - OAR)

Black-Hole X-ray binaries

SUMMARY

(of a highly biased, shallow, subjective and incomplete review)

adding further complexity (?)

- Complex objects, variable on many timescales
- Complex objects, variable at many wavelengths
- Complex objects, data sometimes insufficient
- Complex Physics, models sometimes oversold
- Complex Physics, sometimes revealed by **simple** exercises

→ the problem of the jet missing energy

→ "come ti individuo il getto" (how I tell you where the jet is)

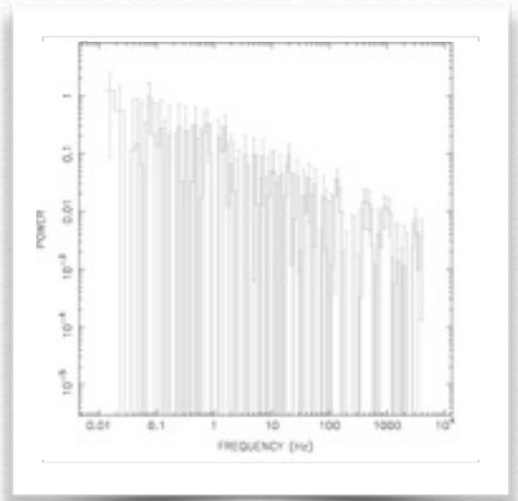
→ on the efficiency of the accretion flow

Media INAF would say

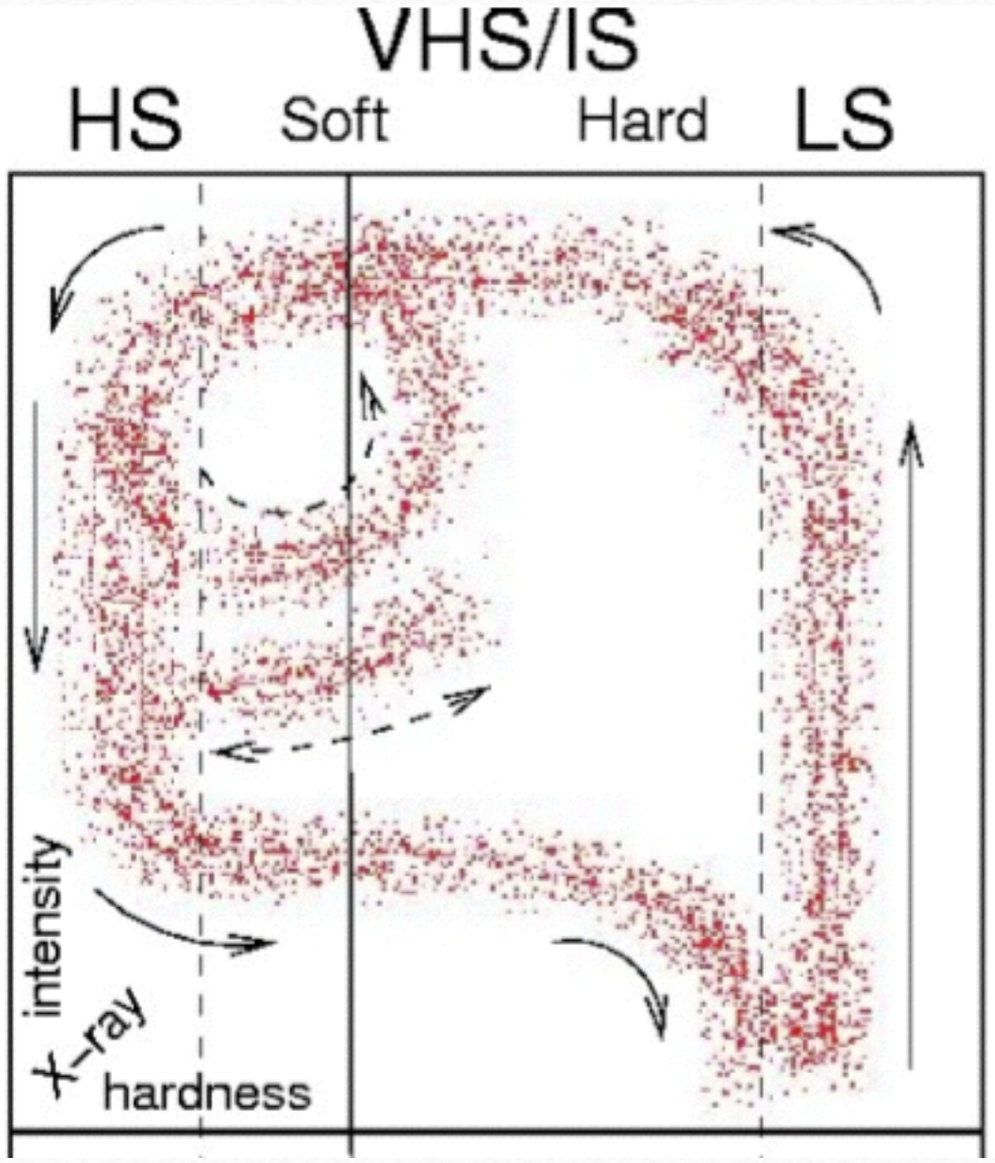
Black-Hole X-ray binaries

SOFT state

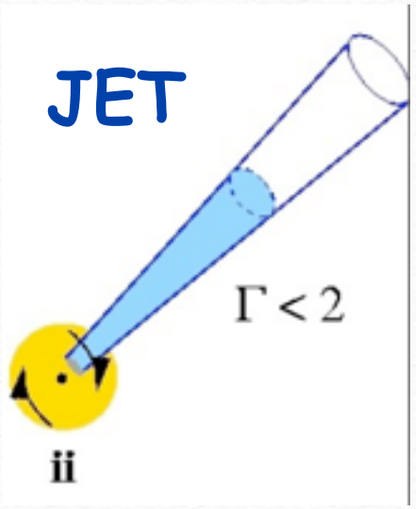
NO JET

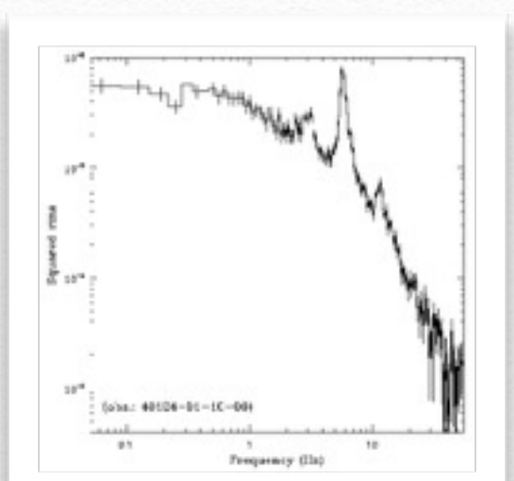


steady inflow
(thin cool disk)



HARD state

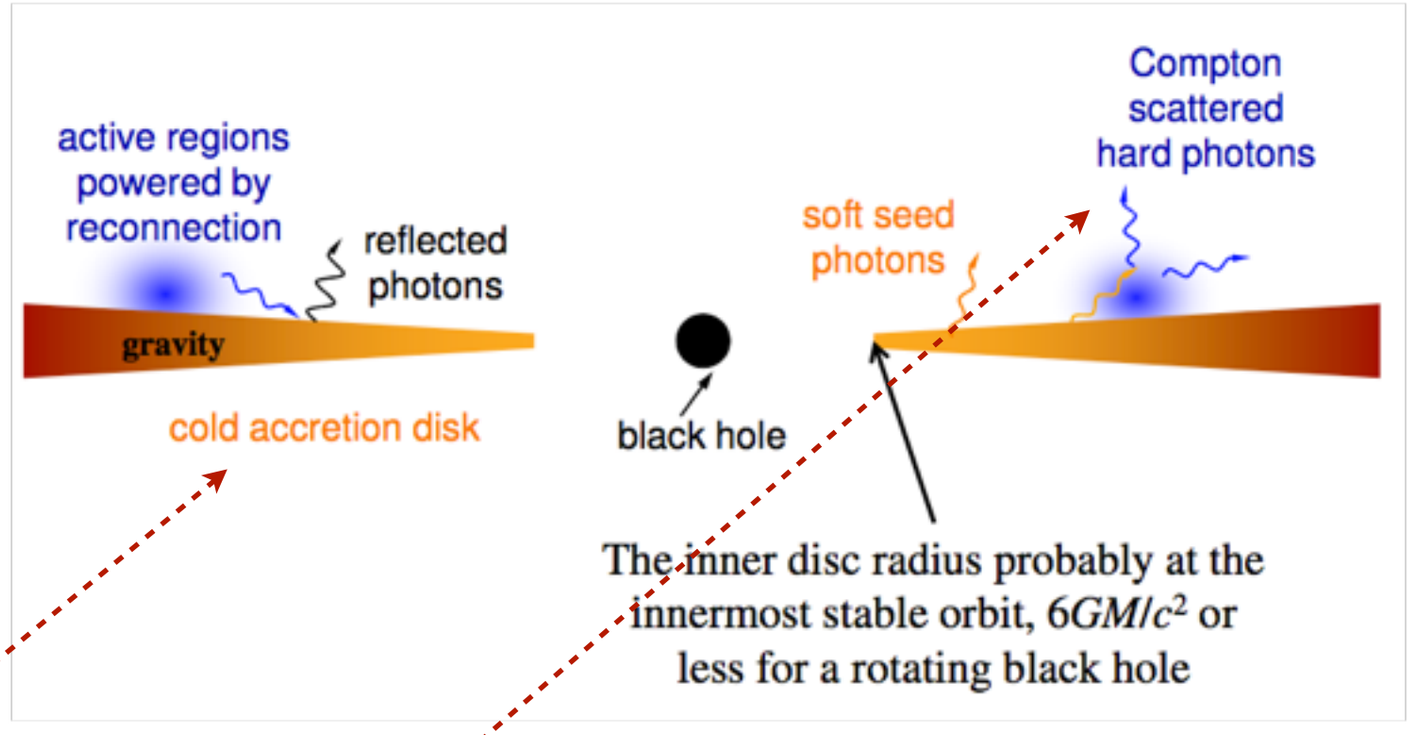


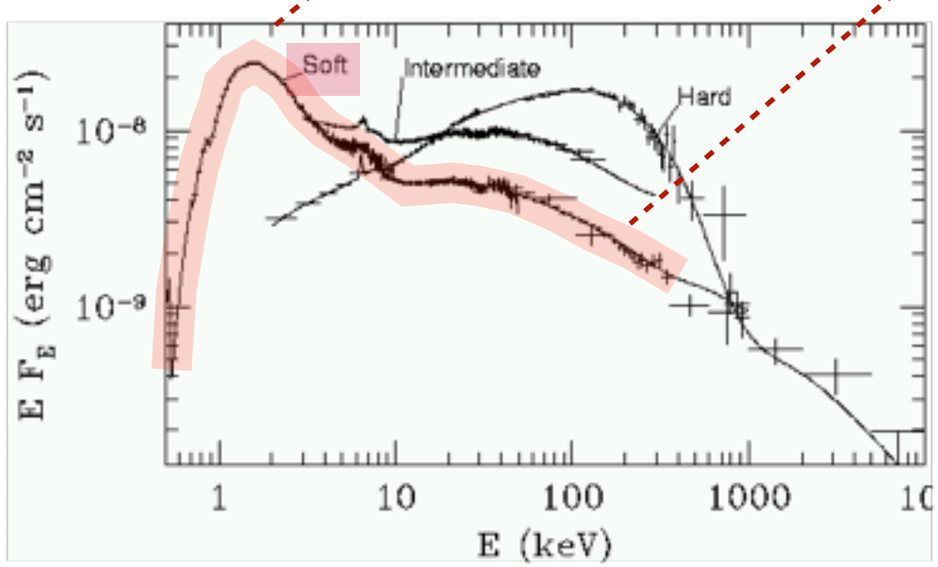


variable inflow
(thick hot flow)

Black-Hole X-ray binaries

a **possible** geometry for the soft state
(X-ray defined)





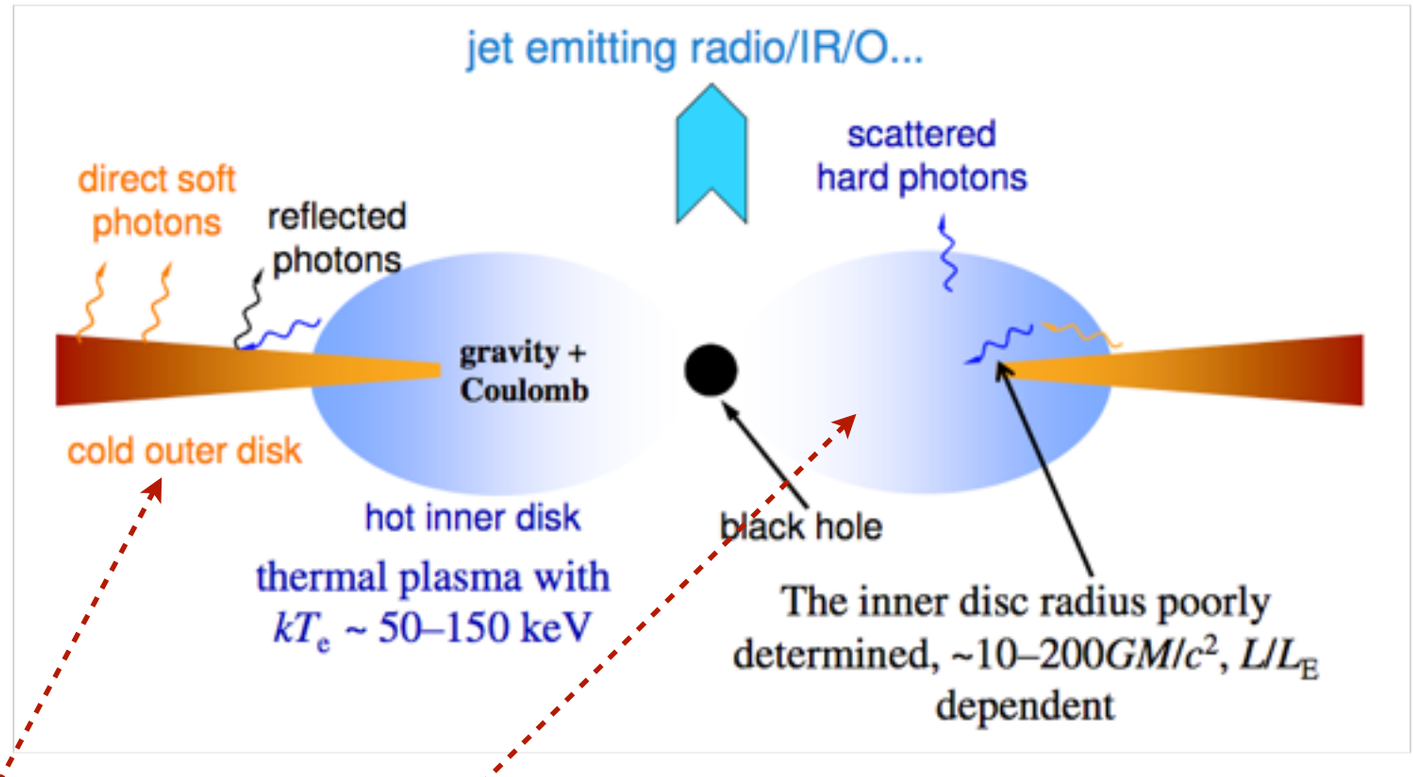
efficient flow?

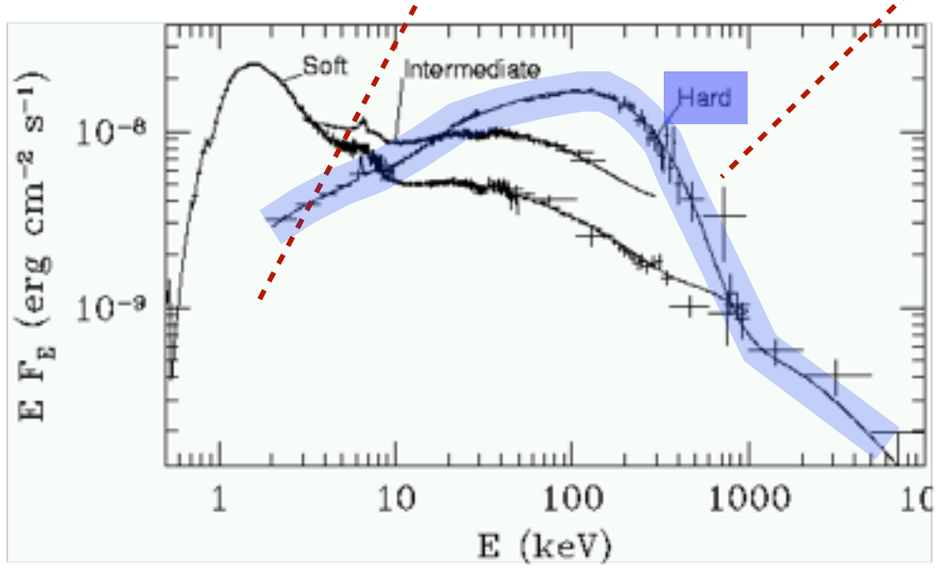
$L_X \propto \dot{M}$

courtesy of A. Zdziarski

Black-Hole X-ray binaries

a **possible** geometry for the HARD state
(X-ray defined)





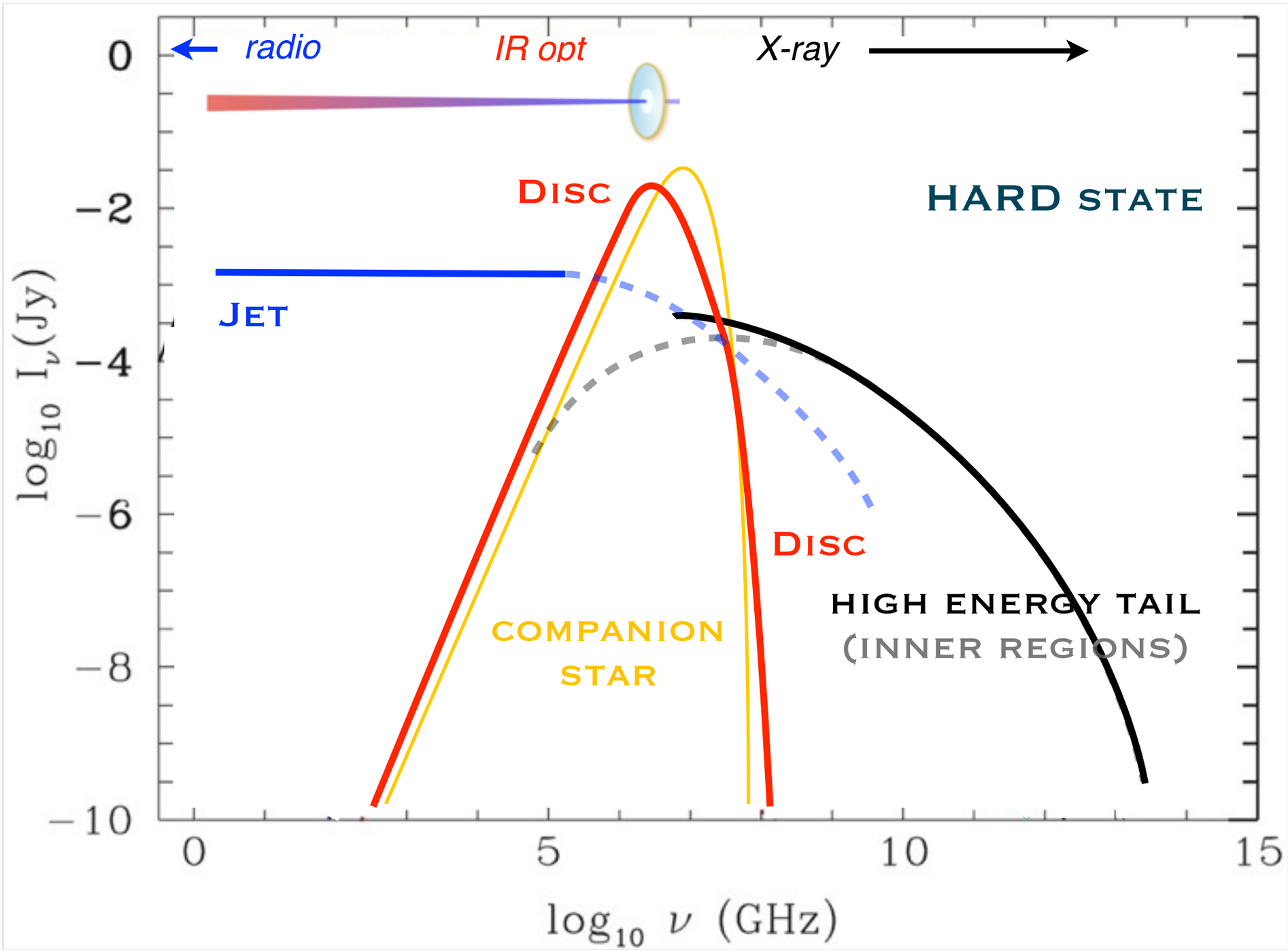
INEFFICIENT FLOW?

$L_X \propto \dot{M}^{2\sim3}$

courtesy of A. Zdziarski

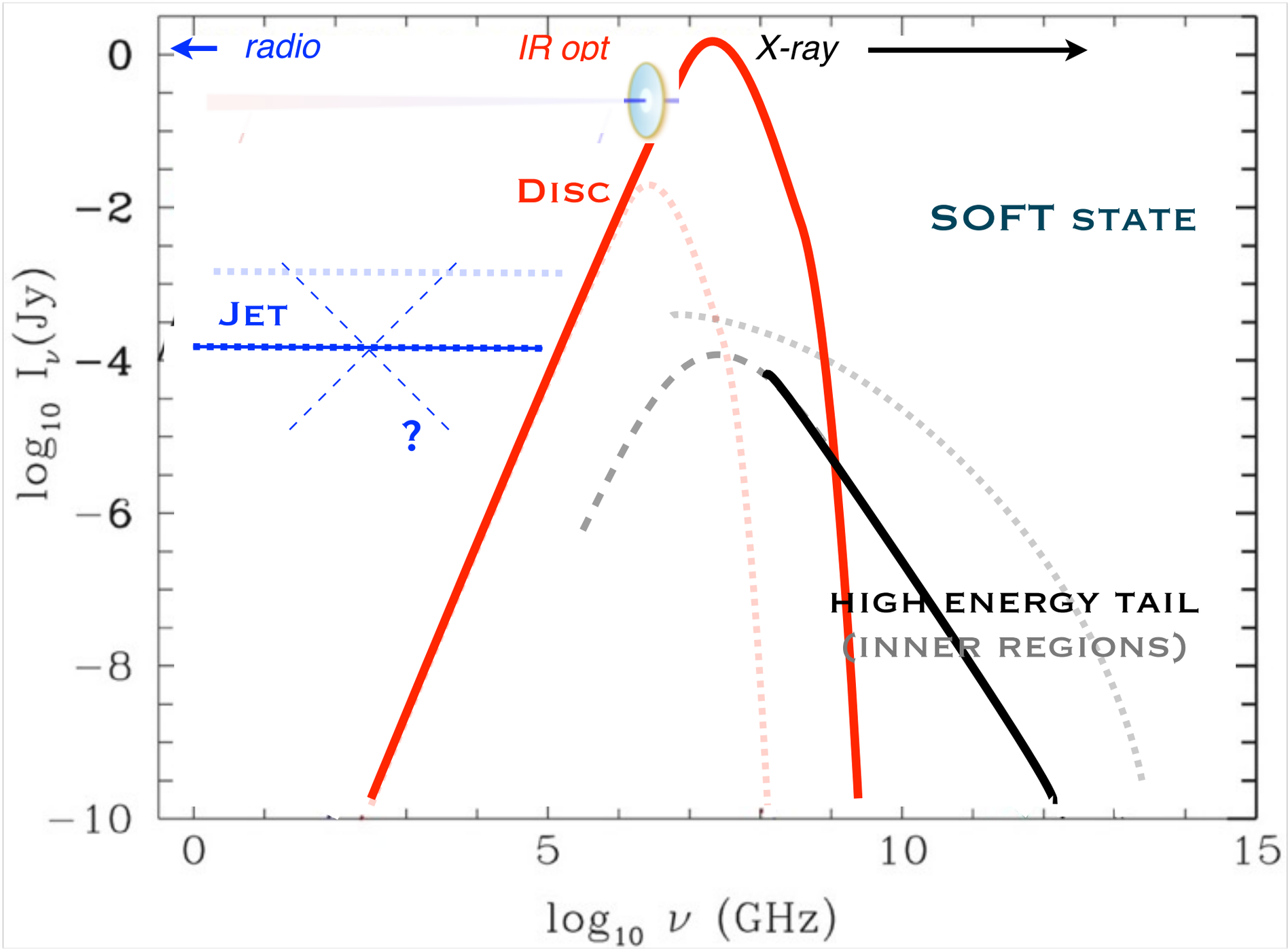
Black-Hole X-ray binaries

multi-wavelength emission



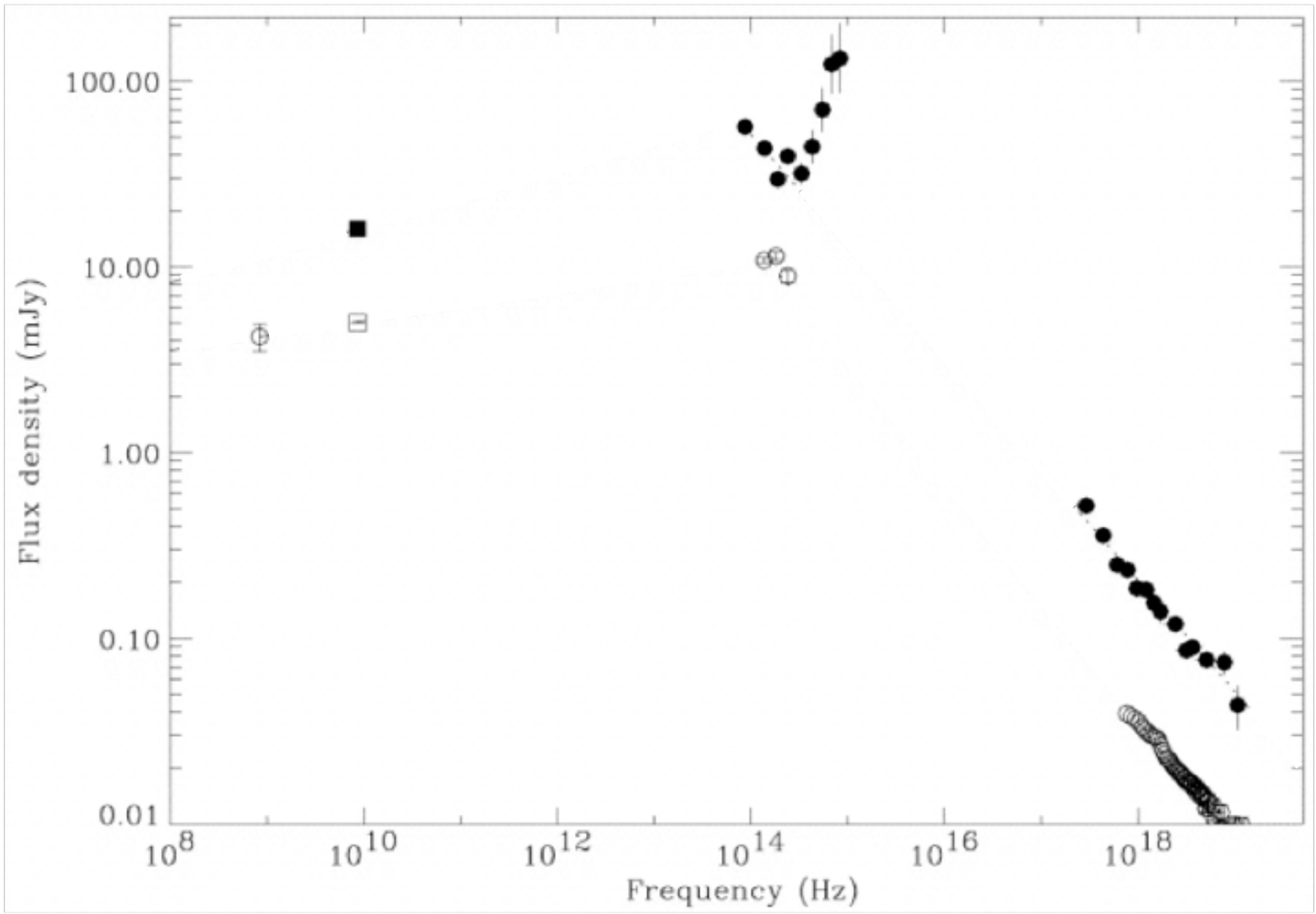
Black-Hole X-ray binaries

multi-wavelength emission



Black-Hole X-ray binaries

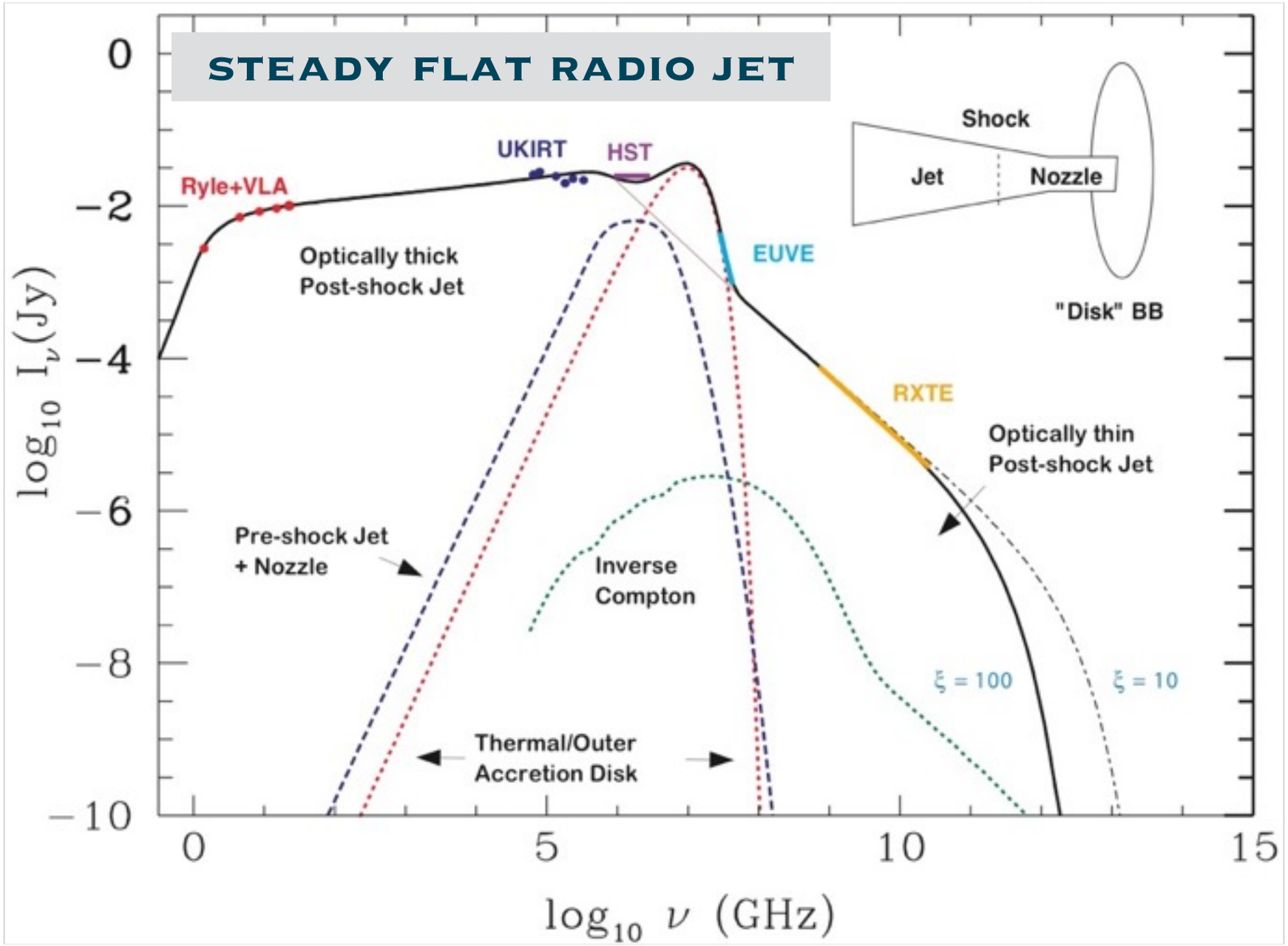
real data



Corbel & Fender 2002

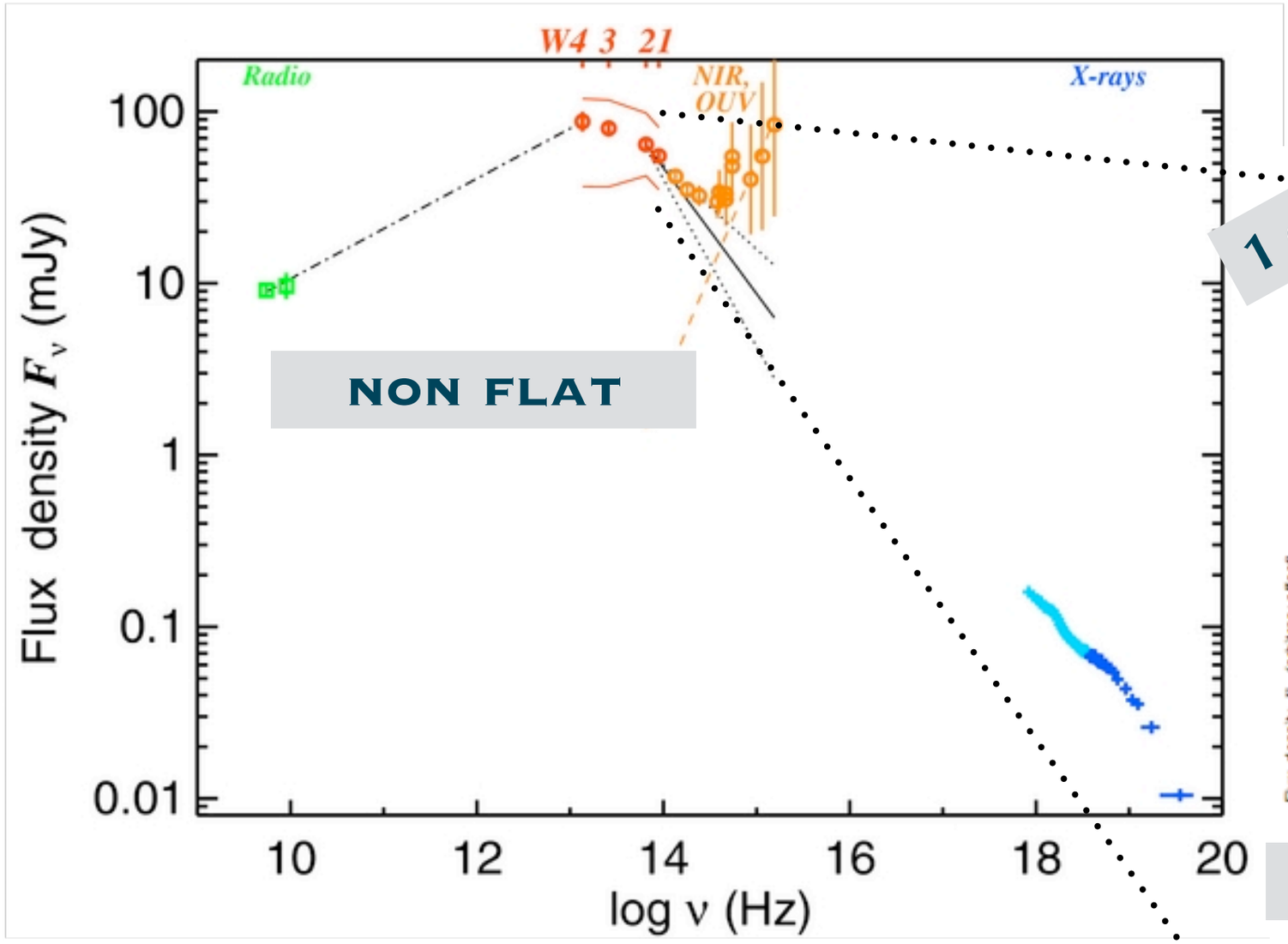
Black-Hole X-ray binaries

real data + complex model



Markoff, Falcke & Fender 2001

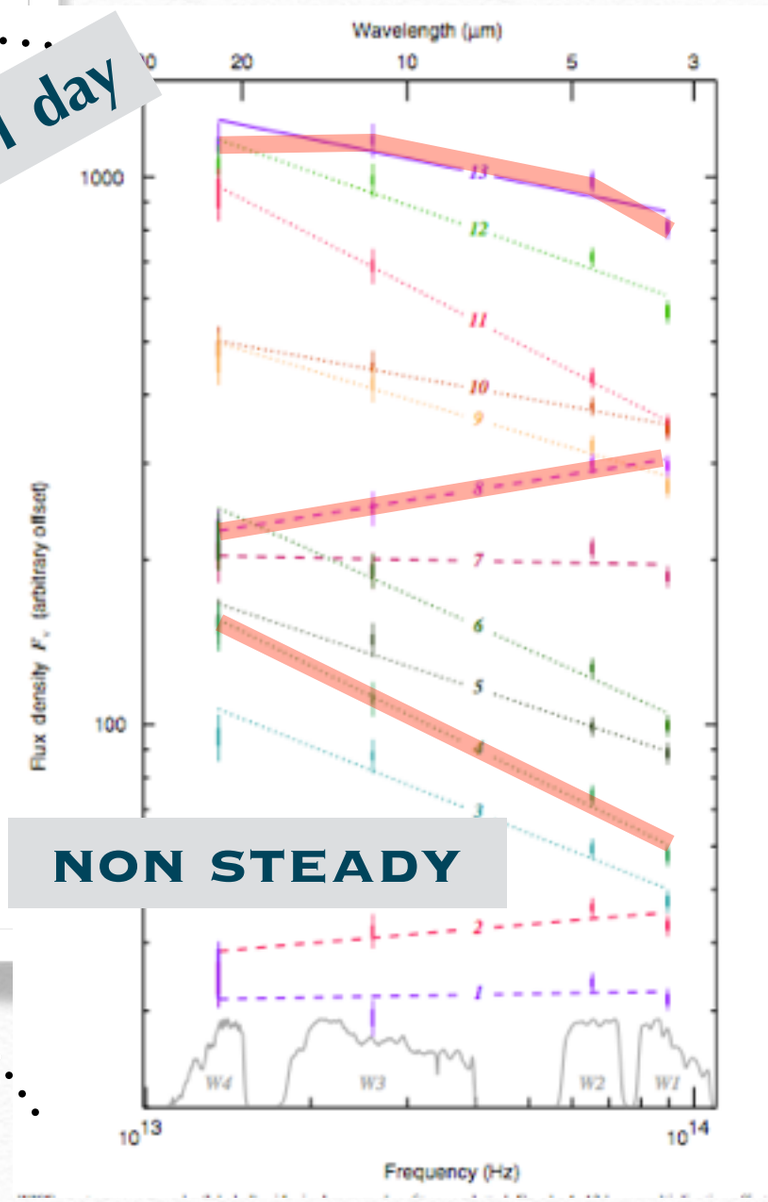
Black-Hole X-ray binaries



NON FLAT

1 day

MORE REAL DATA

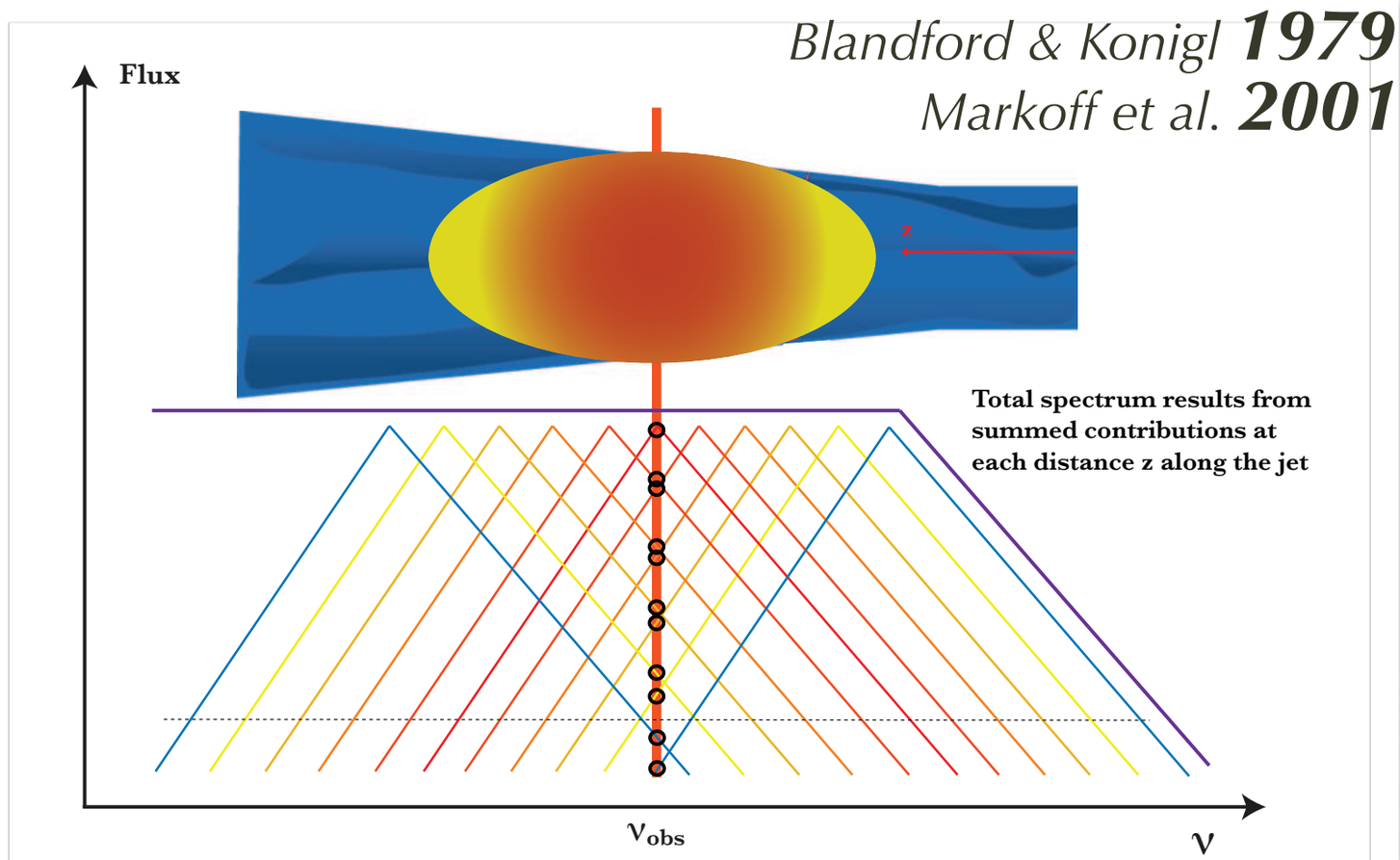


NON STEADY

Gandhi et al. 2010

Black-Hole X-ray binaries

Standard jet model



Basic assumptions

$n=c\Upsilon^{-p}\sim r^{-2}$

$B(r) \sim r^{-1}$

+

Basic synchrotron theory

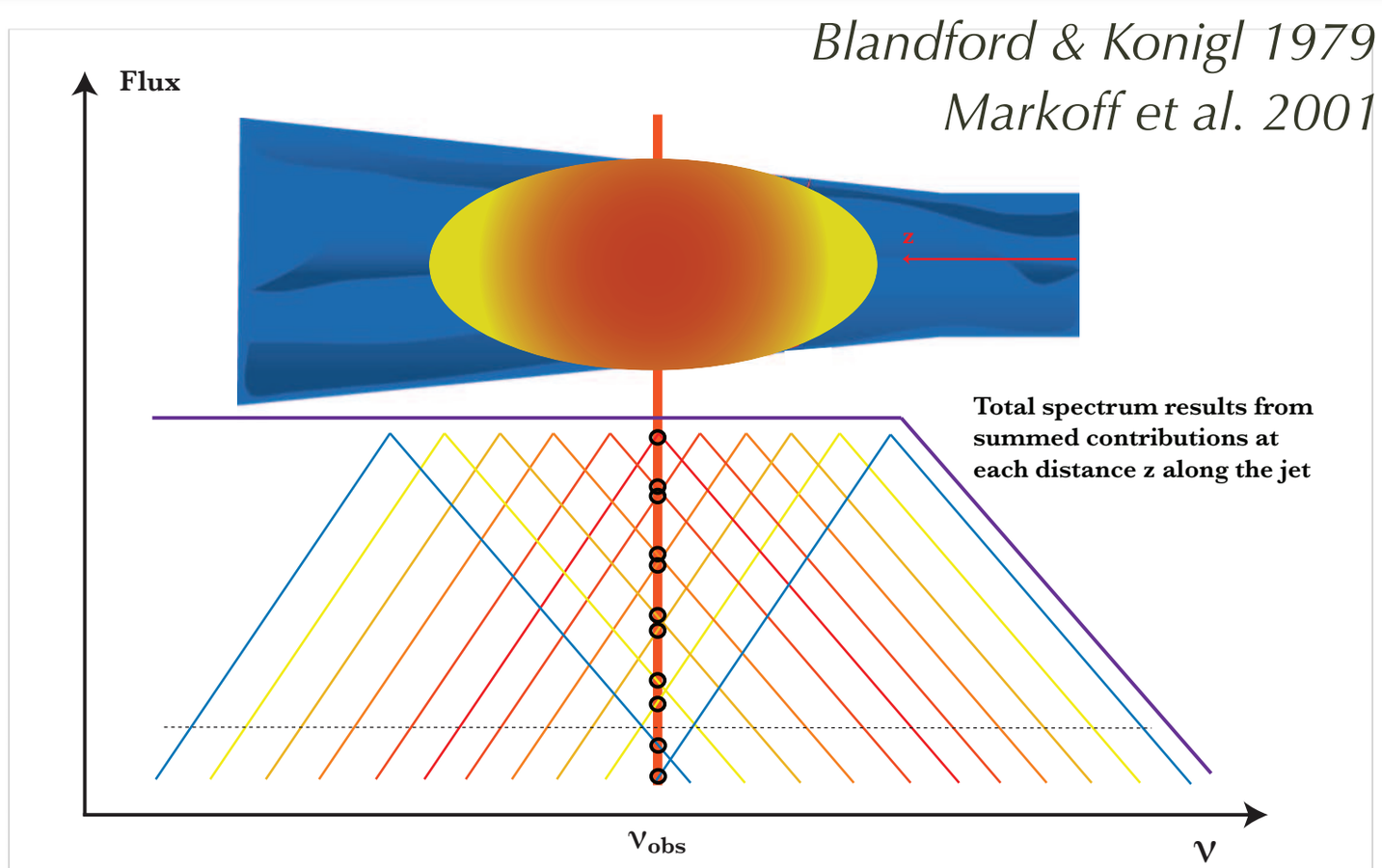
$\nu_{break}=\nu|_{\tau_\nu=1} \sim r^{-1}$

=>

Flat radio spectrum

Black-Hole X-ray binaries

Standard jet model



problem

cooling is missing

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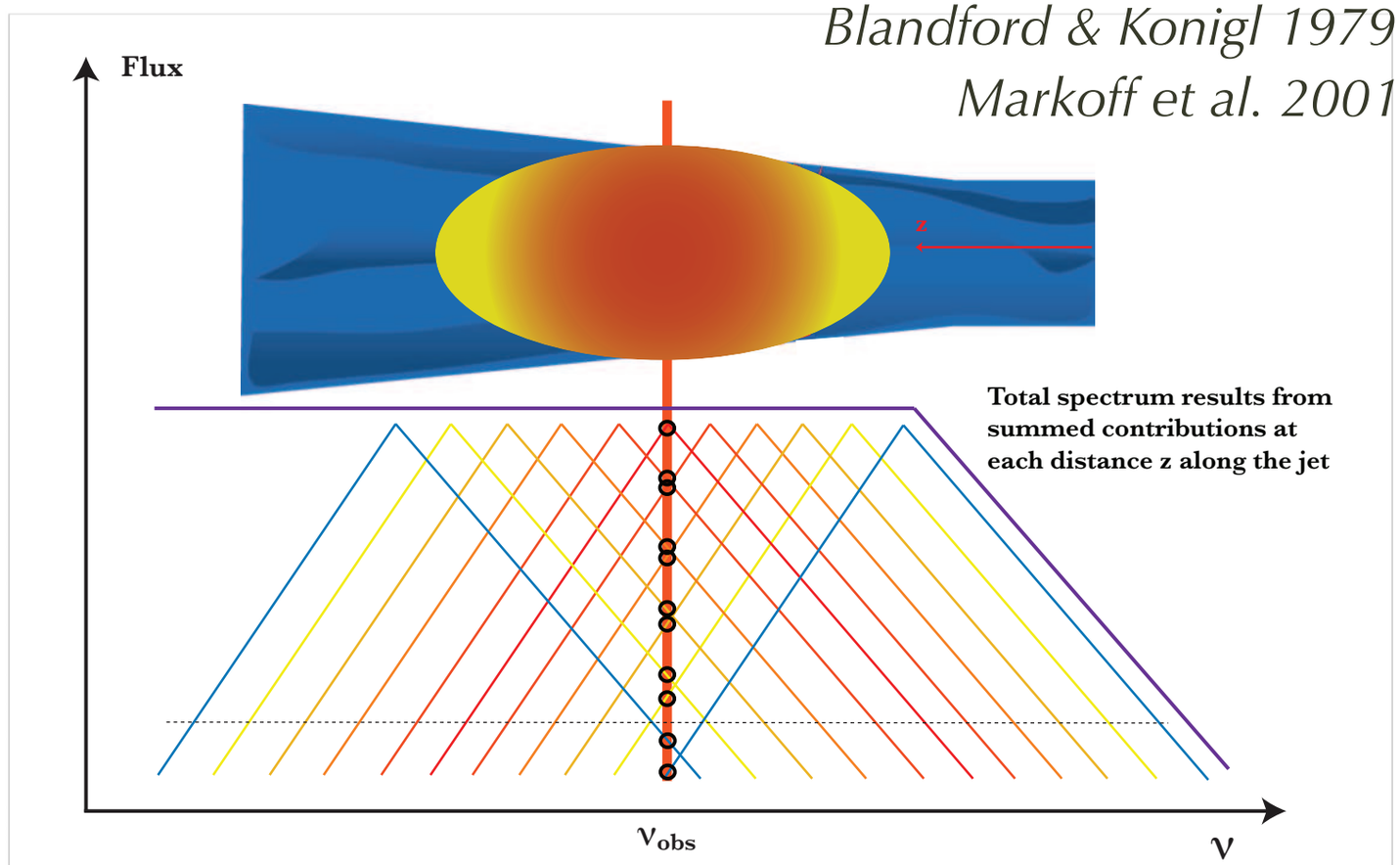
Black-Hole X-ray binaries

standard jet model

Blandford & Konigl 1979
Markoff et al. 2001



problem

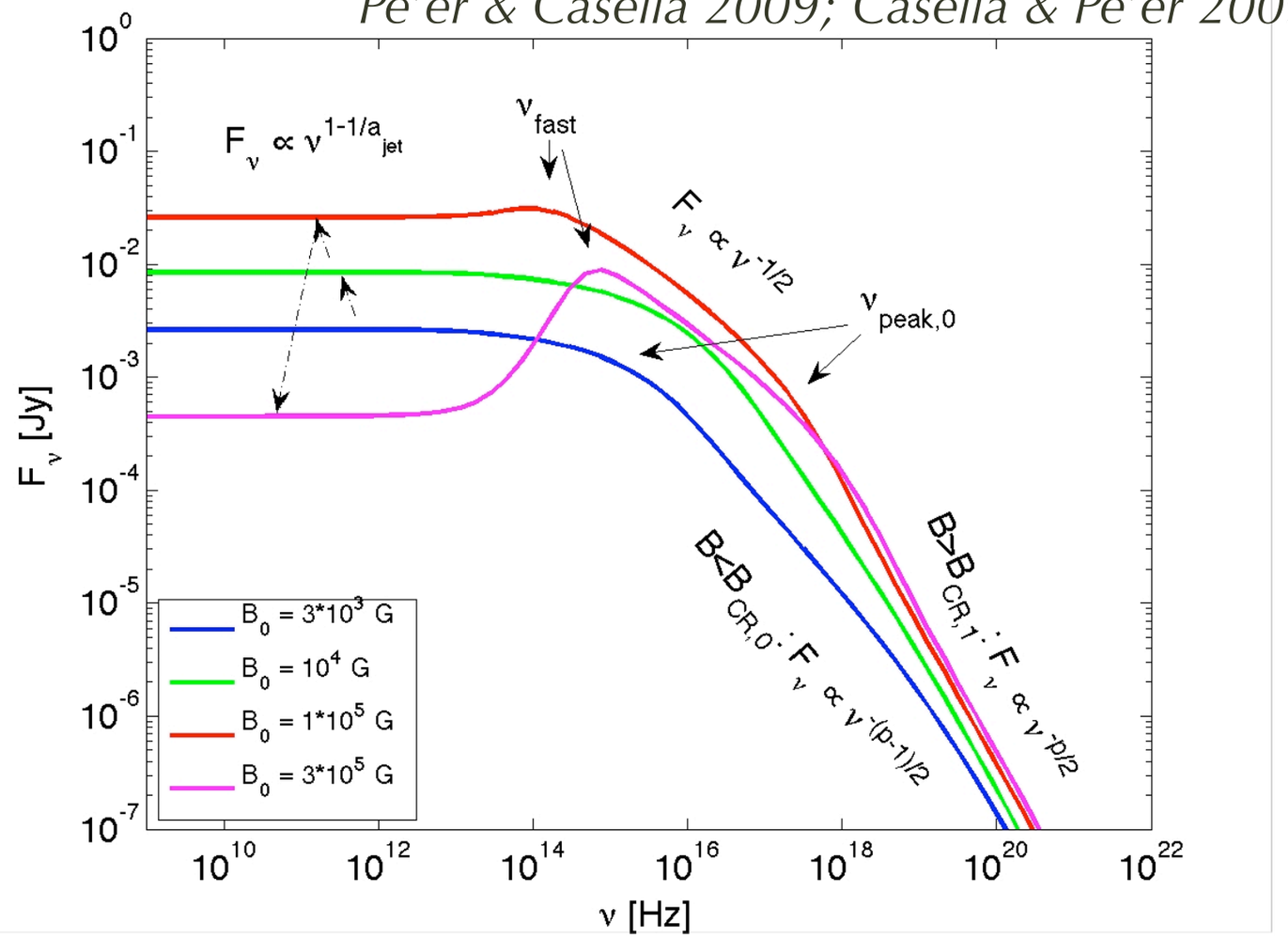
cooling is missing

(measured in the frame of the fluid) which will vary as r^{-2}, where r is the distance from the apex (cf. the model of NGC 6251 in Readhead, Cohen, and Blandford 1978). We assume that relativistic electrons can be accelerated continuously within the jet, and that their distribution function is $N(\gamma_e) = K\gamma_e^{-2}$, with $\gamma_{e\,\min} < \gamma_e < \gamma_{e\,\max}$ and $\gamma_{e\,\max} \gg \gamma_{e\,\min}$. These electrons will radiate synchrotron radiation with a spectral index $\alpha = \frac{1}{2}$. The electron energy

Blandford & Konigl 1979

Black-Hole X-ray binaries

Pe'er & Casella 2009; Casella & Pe'er 2009



if cooling included...no radio emission

(obviously: the electrons can't have infinite energy)

We need EXTRA energy (i.e. electrons re-heating)

Black-Hole X-ray binaries

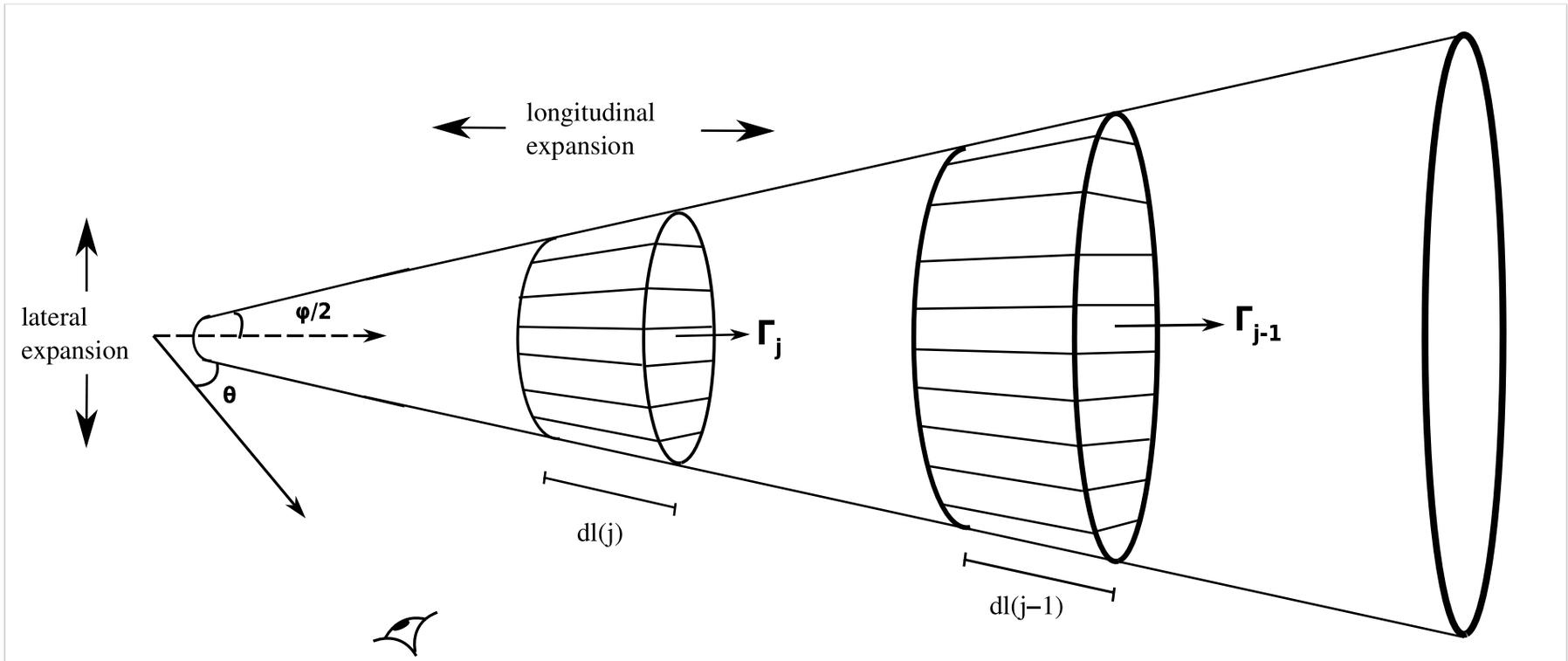
a possible key ingredient:

VARIABILITY

Black-Hole X-ray binaries

re-heating from internal shocks between discrete shells with different velocity

Jamil, Fender & Kaiser 2010; Malzac 2013; Drappeau et al. 2014



is the jet powered by variability in the accretion flow?

Black-Hole X-ray binaries

re-heating from internal shocks between discrete shells with different velocity

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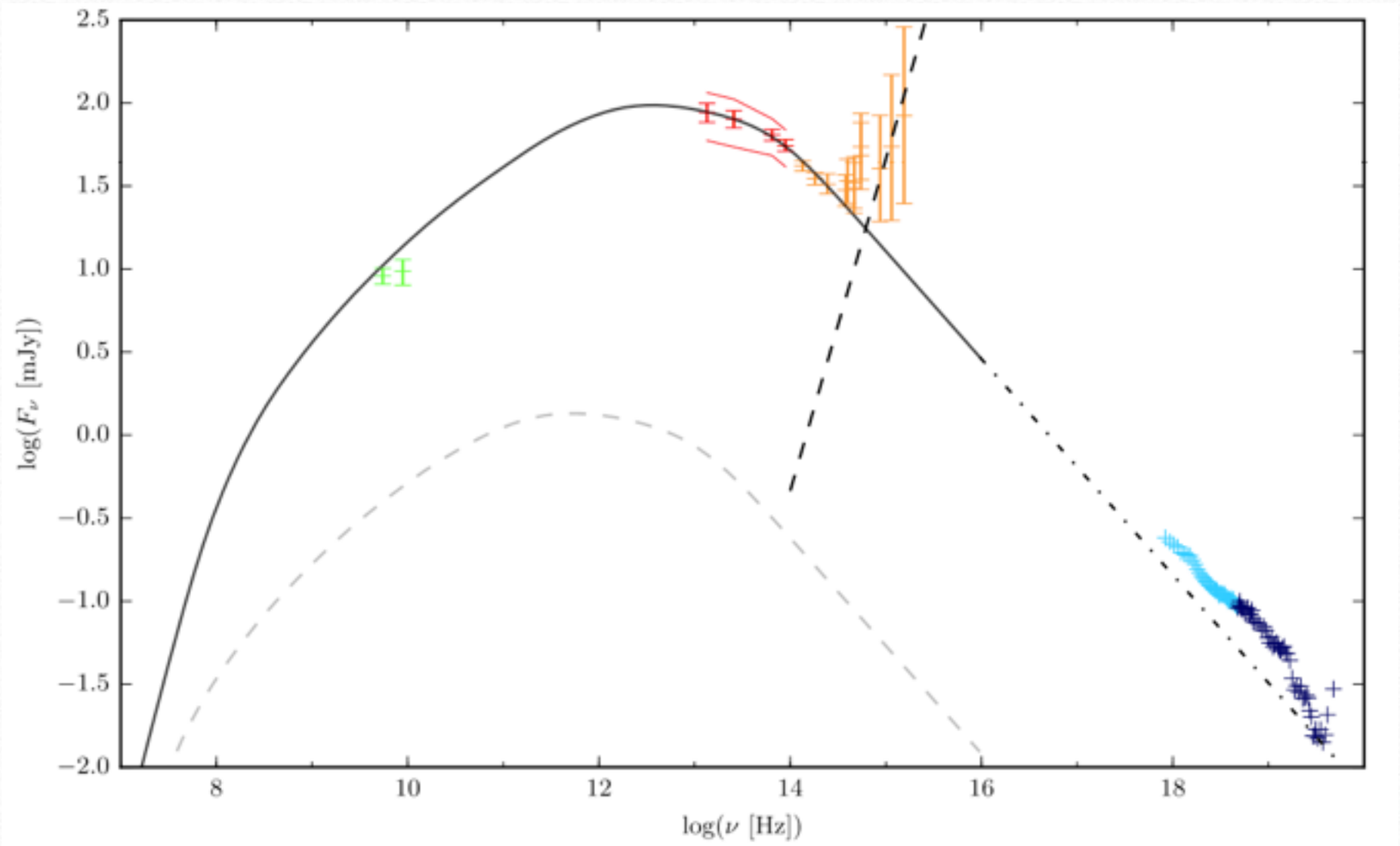
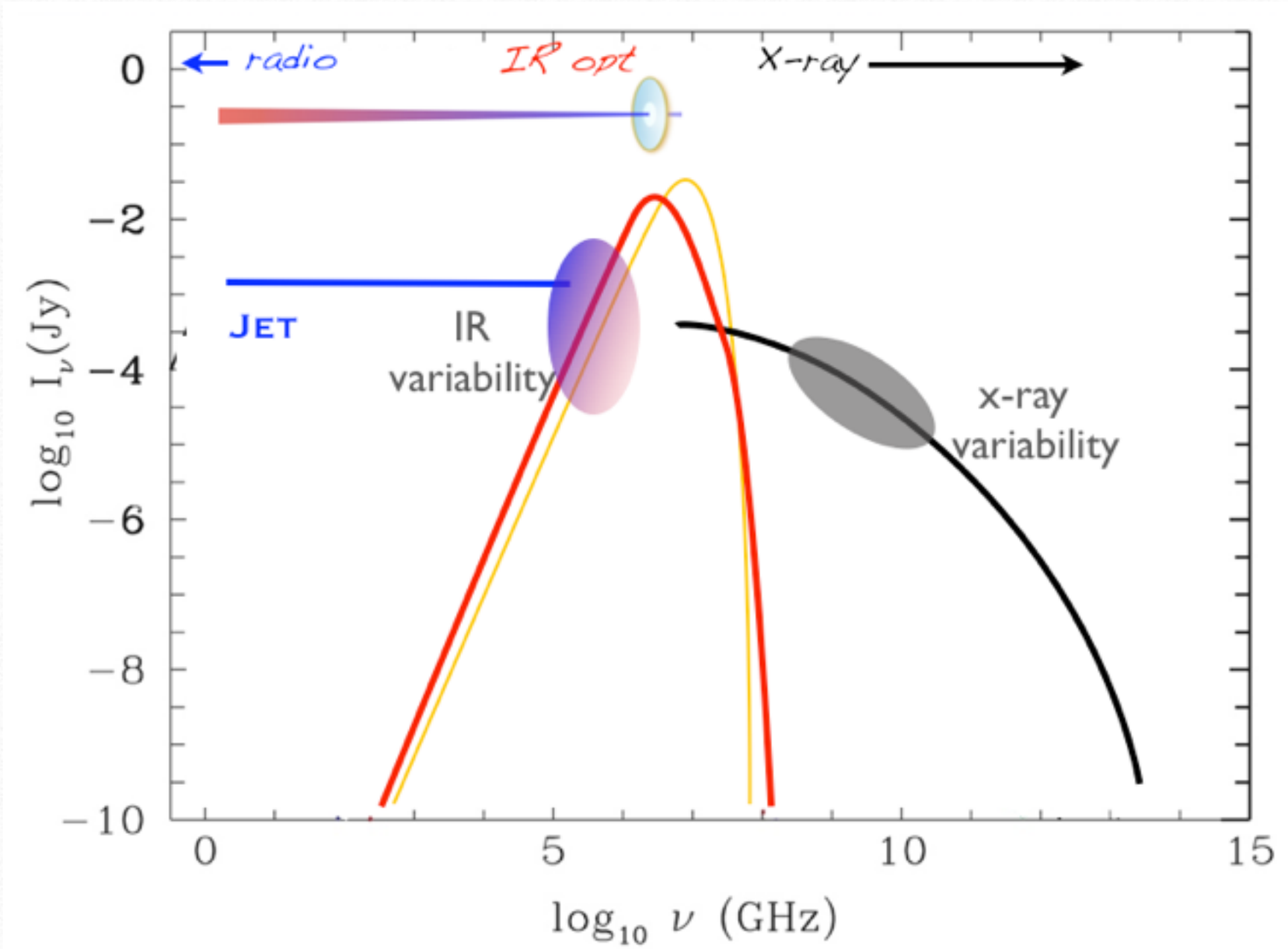


seems possible

(still too much fine tuning)

Black-Hole X-ray binaries

hunting for jet fast variability



we can go and study the variability.

Does the jet vary?

Is it correlated with the X-ray variability?

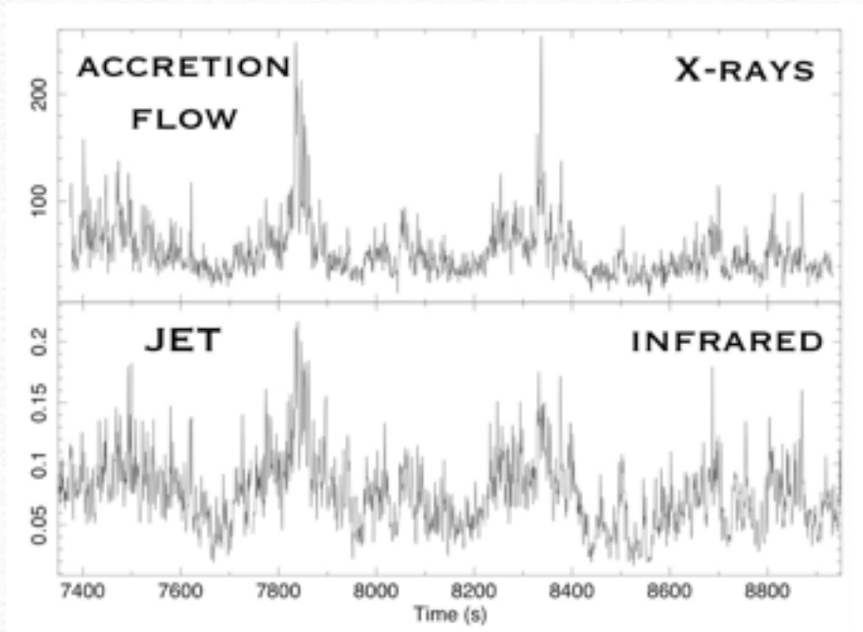
Black-Hole X-ray binaries

hunting for jet fast variability

FOUND!

The beautiful Brightness Temperature argument

Casella et al. 2010



- **We see variability > 5 Hz**
  - *Maximum size of the region*
    (< 6 10^9 cm)
- **Amplitude of such variability**
  - *Minimum IR flux from the region*
- **Assumption: thermal emission**
  - *Black Body formula gives you X-ray flux*

Check in X-rays. Do you see it? NO!

more on JET variability in TALKS by:

Federico Vincentelli (these data)

Maithili Kalamkar (more data!)

IT'S NOT THERMAL MUST BE A JET

Complex Physics vs. simple exercises

A word on radiative efficiency

Radio = Compact Jets

- Conical jet, power-law distribution of electrons, energy losses replenished, etc. (Blandford & Königl 79, Falcke & Bierman 95):

$$L_{\rm radio} \propto Q_{\rm jet}^{1.4}$$

- Power injected is a fraction of the accretion power:

$$Q_{\rm jet} = f_j \, \dot{M} \, c^2$$

- f_j independent of $\dot{M}$ $\Rightarrow$ $L_{\rm radio} \propto \dot{M}^{1.4}$

X-ray component

- Radiatively efficient (e.g. thin disc, ADC...) :

$$L_X \propto \dot{M}$$

- Radiatively inefficient (e.g. ADAF, X-ray jet model) :

$$L_X \propto \dot{M}^{2-3}$$

$$\longrightarrow \quad L_X \propto \dot{M}^{\beta}$$

$$L_{\rm radio} \propto L_X^{1.4/\beta}$$

Standard correlation

$$L_{\rm radio} \propto L_X^{0.6} \longrightarrow \beta = 2-3$$

Radiatively inefficient component

Outliers

$$L_{\rm radio} \propto L_X^{1.4} \longrightarrow \beta = 1$$

Radiatively efficient component

Coriat et al. 2011

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Standard correlation | *Outliers*

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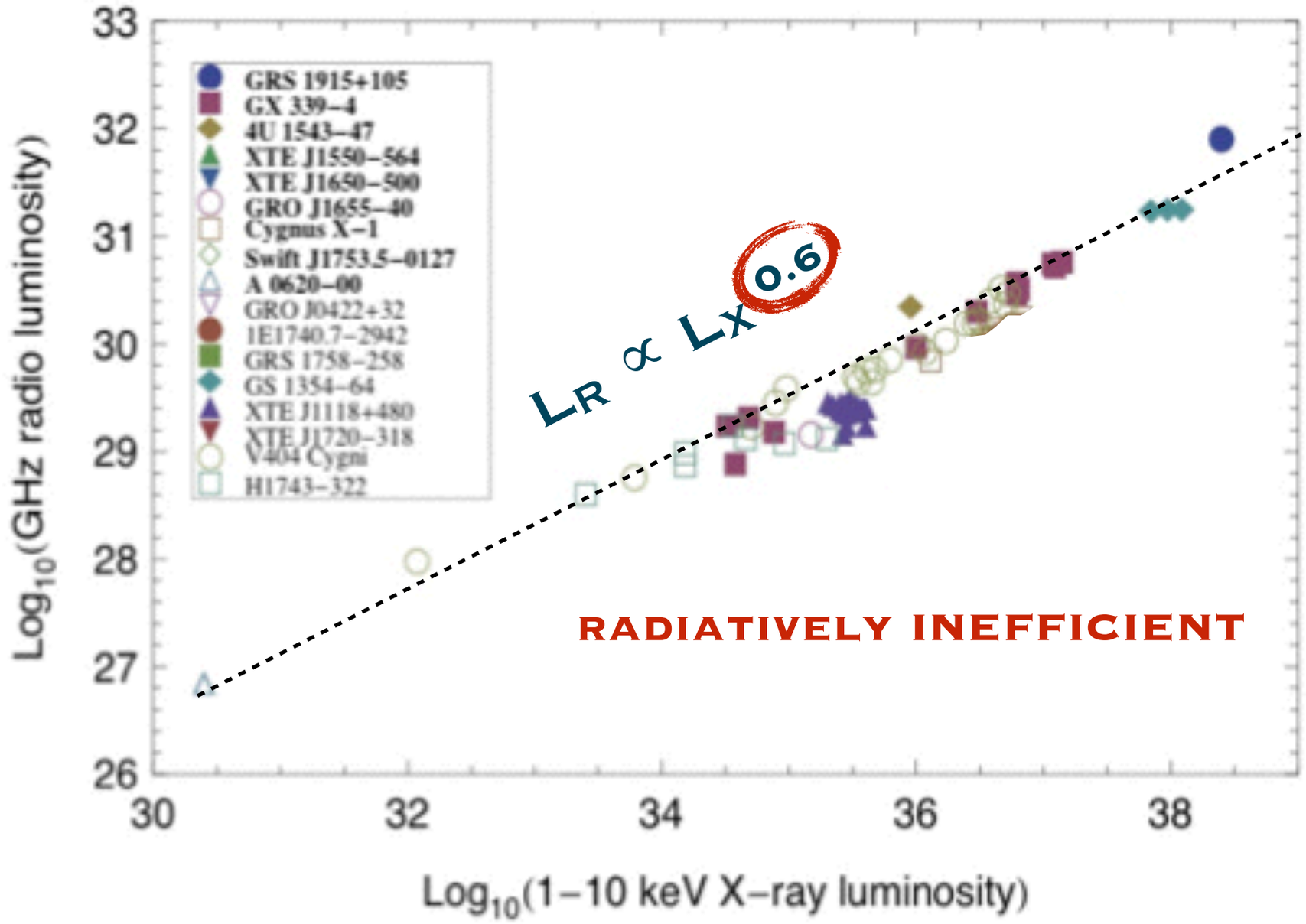
Coriat et al. 2011

Complex Physics vs. simple exercises

A word on radiative efficiency



Complex Physics vs. simple exercises

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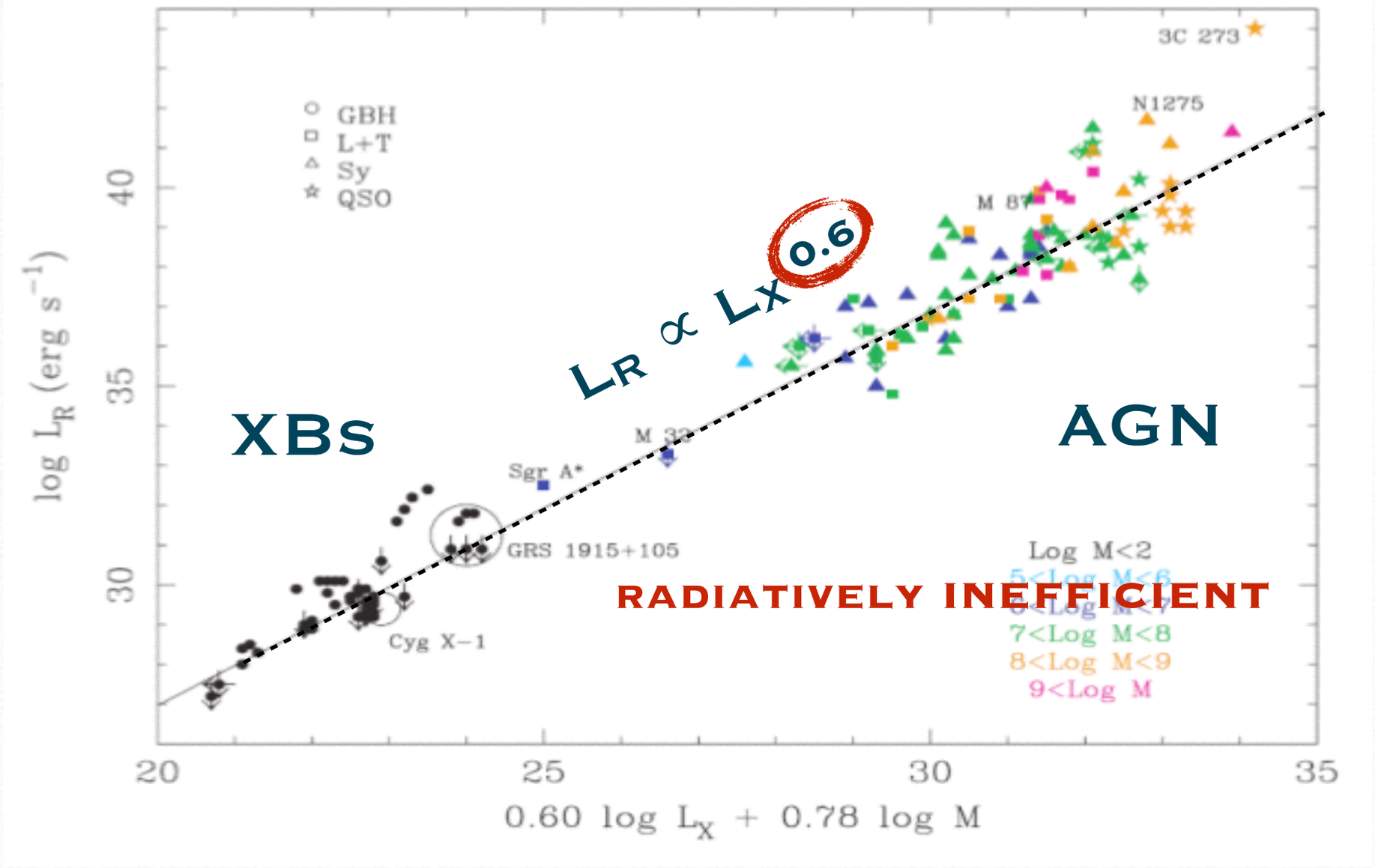
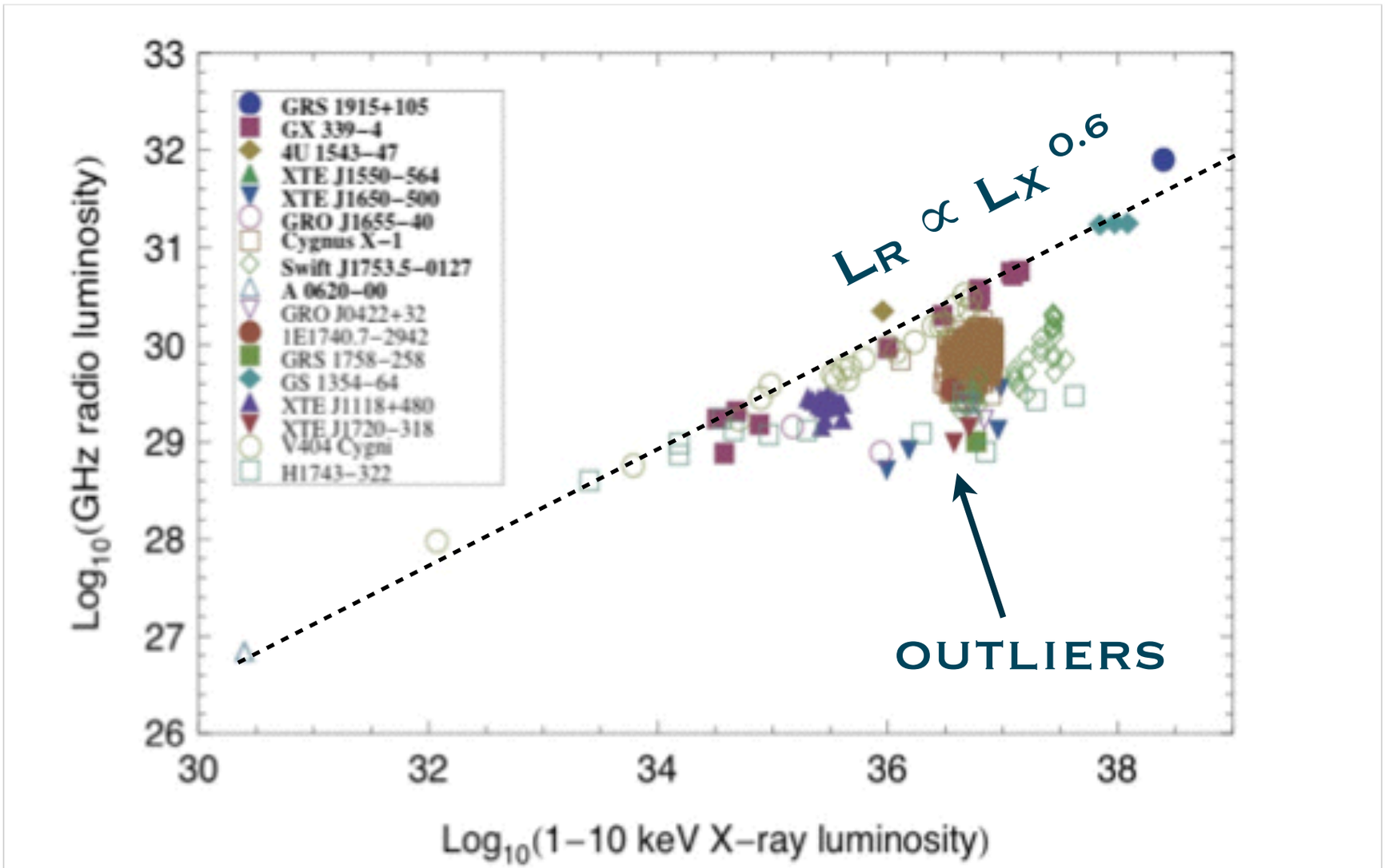


Complex Physics vs. simple exercises

Perhaps not that simple...



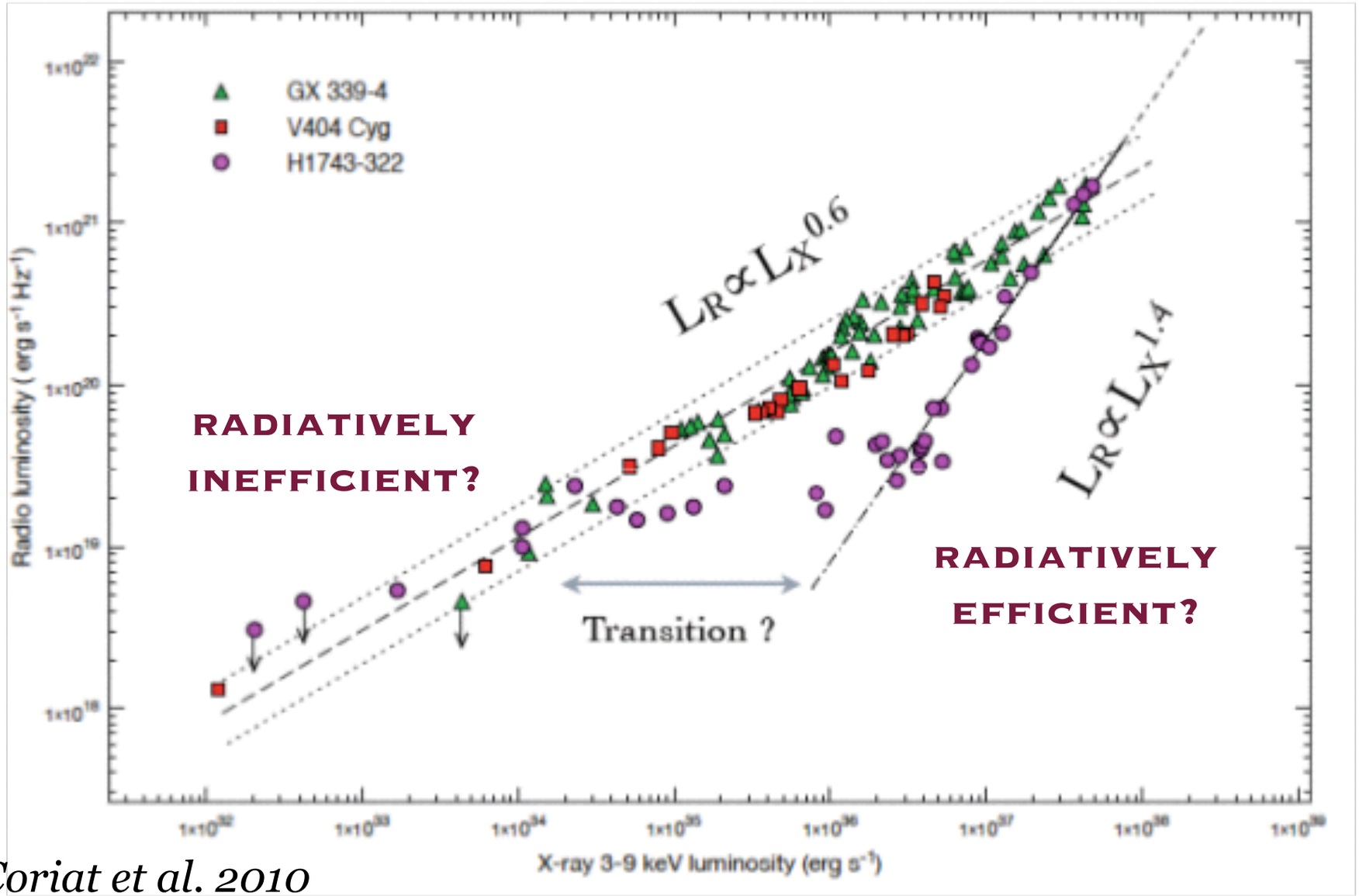
Fender et al. 2011; Soleri & Fender 2011

no clear connection with other properties

(e.g. BH spin, orbital period, BH mass, ...)

Complex Physics vs. simple exercises

Perhaps not that simple...



Coriat et al. 2010

more on flux-flux correlations in TALKS by:

Federico Vincentelli (in IR, fast)

Federico Bernardini (in Opt, BH vs. NS)