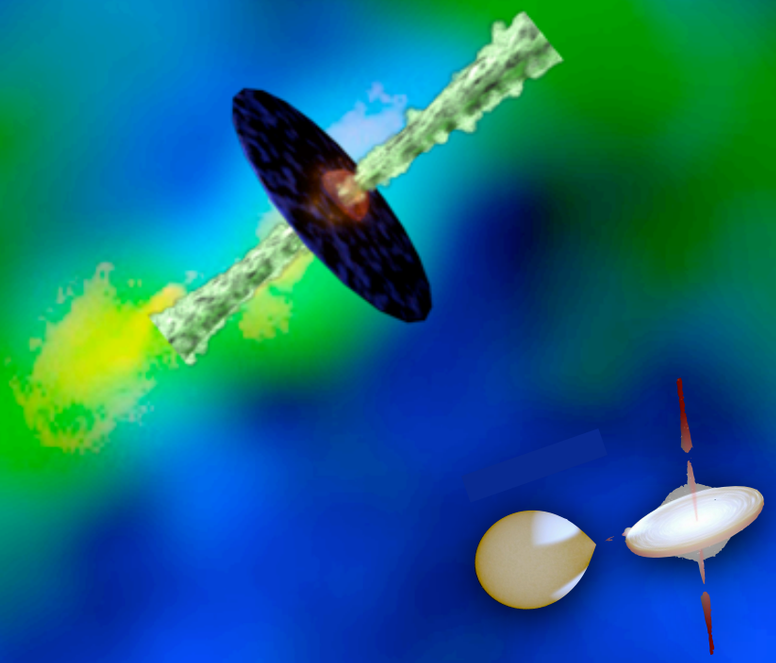
Constraining the role and power of jets (in black hole binaries)



Sera Markoff (API, University of Amsterdam)

[S.Corbel, J.Dexter, S.Dibi, S.Drappeau, H.Falcke, R.Fender, C.Fragile, C.Froning, E.Gallo, S.Heinz, R.Hynes, E.Körding, S.Migliari, J. Miller-Jones, M.Nowak, D.Russell, J.Wilms]

A brief history of XRB jets

A brief history of XRB jets

They predicted Xray jets?

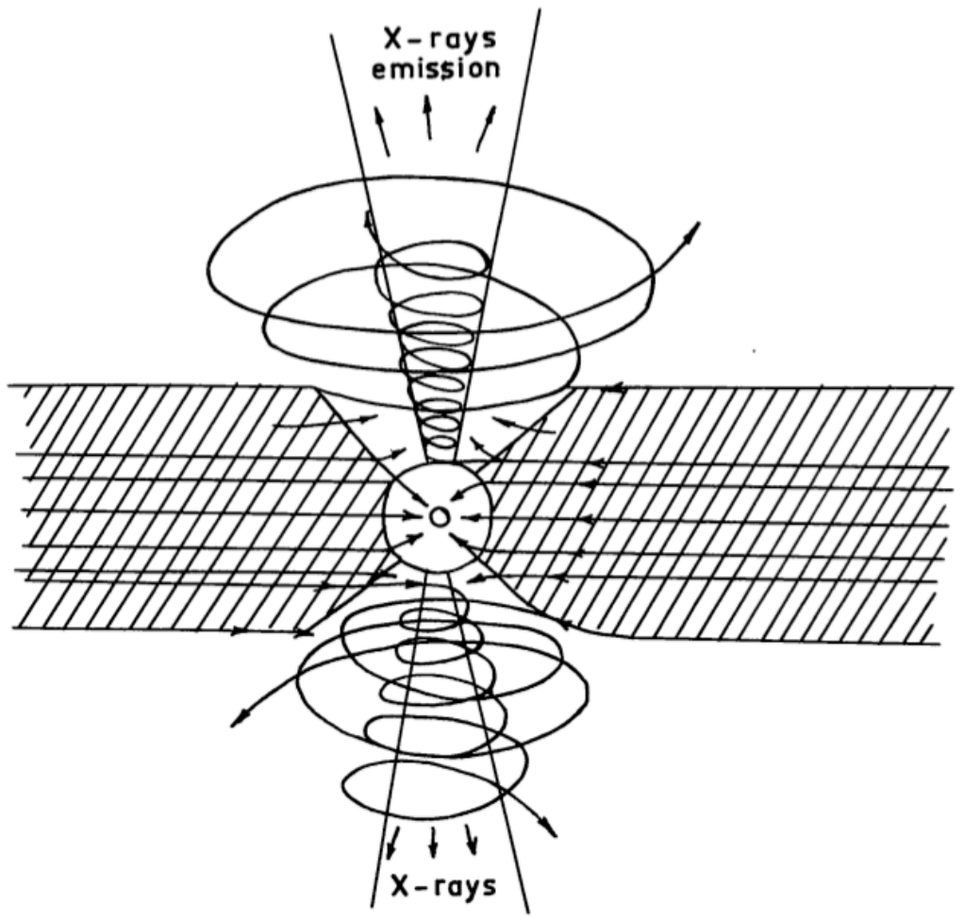


Fig. 9. The outflow of the matter from the collapsar at the supercritical regime of accretion

(Shakura & Sunyaev 1973)

A brief history of XRB jets

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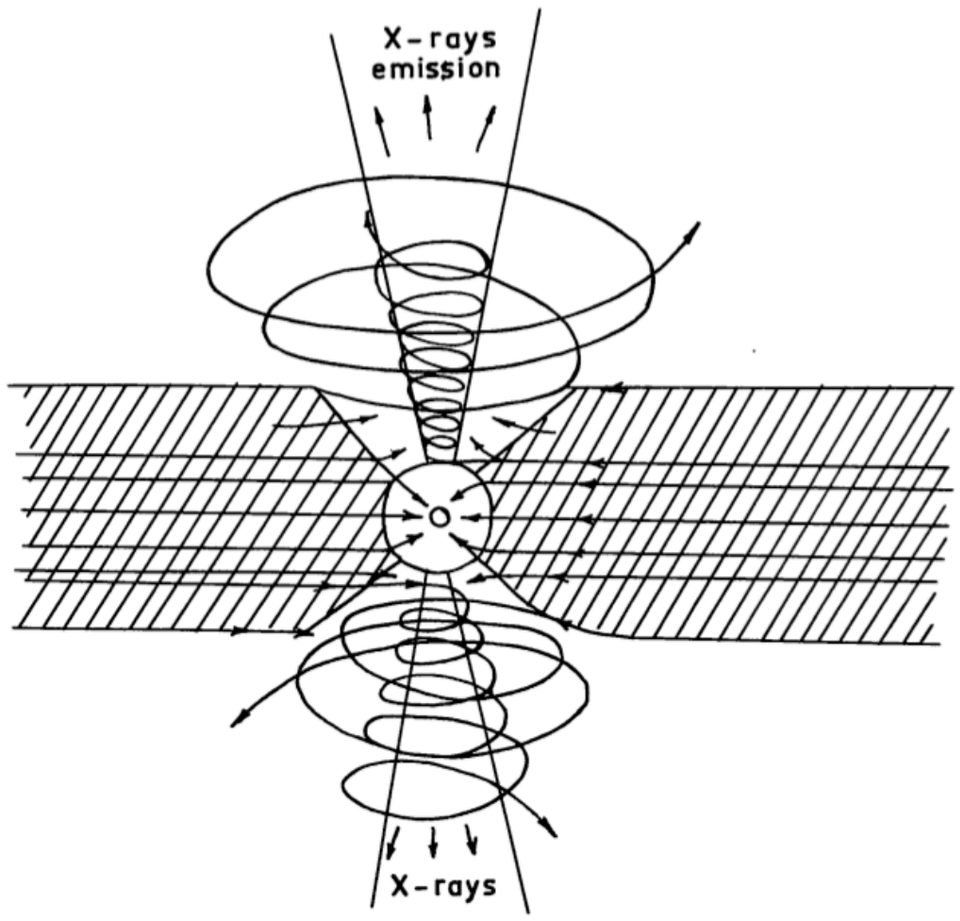

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SS433: first XRB jet

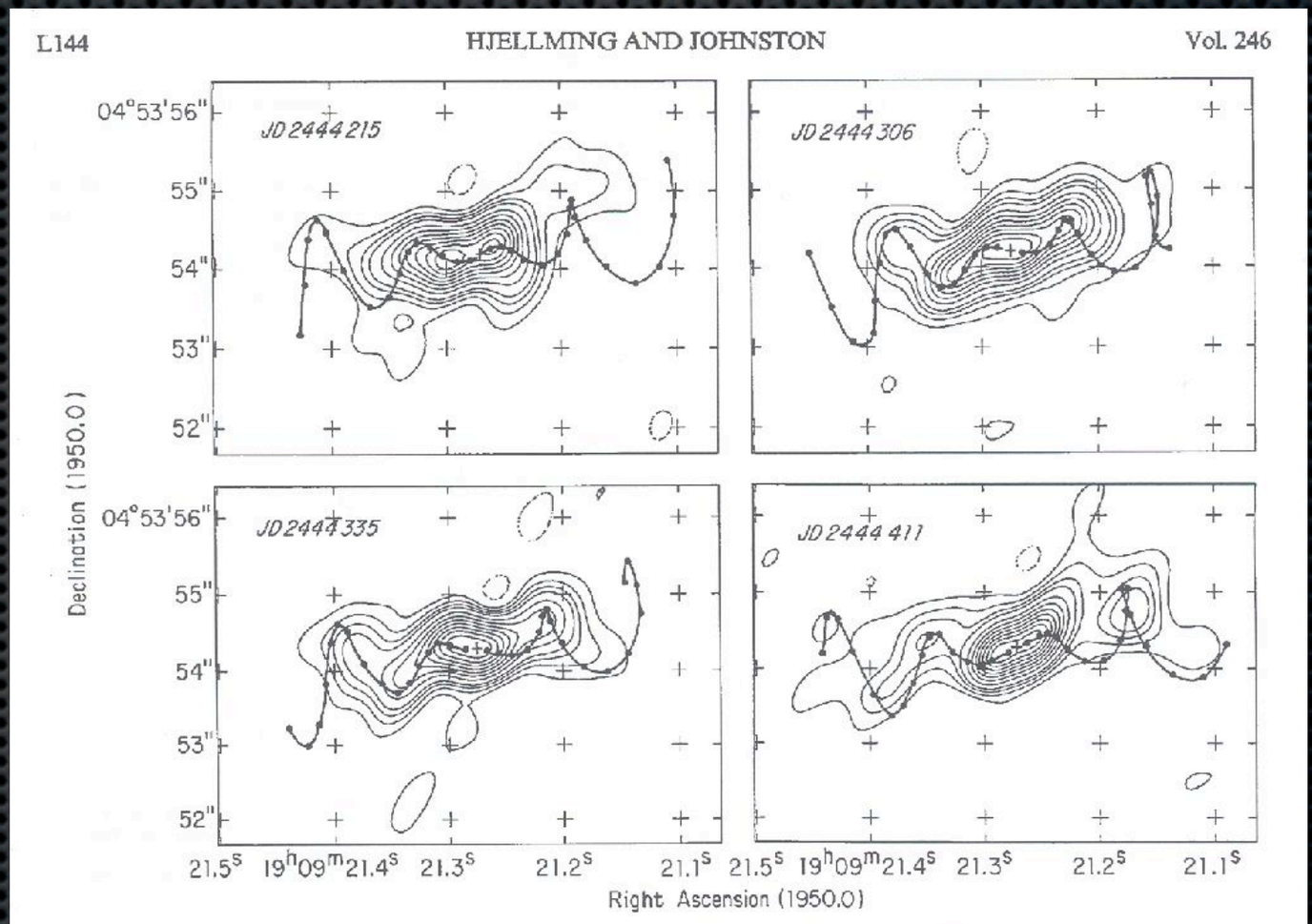


FIG. 2.—VLA radio contour maps of SS 433 at 4885 MHz for t=JD 2,444,215, 2,444,306, 2,444,335, and 2,444,111 are displayed in a form where the unresolved core radio source (small +) is removed, and the proper motion paths of material ejected at 20 day intervals with the parameters of Table 1 are drawn with filled circles. The contour levels correspond to 90, 80, 70, 60, 50, 40, 30, 20, 15, 10, 5, and −5% of the peak flux density values of 0.070, 0.030, 0.029, and 0.032 Jy per beam area for JD 2,444,215, 2,444,306, 2,444,306, and 2,444,411 maps, respectively.

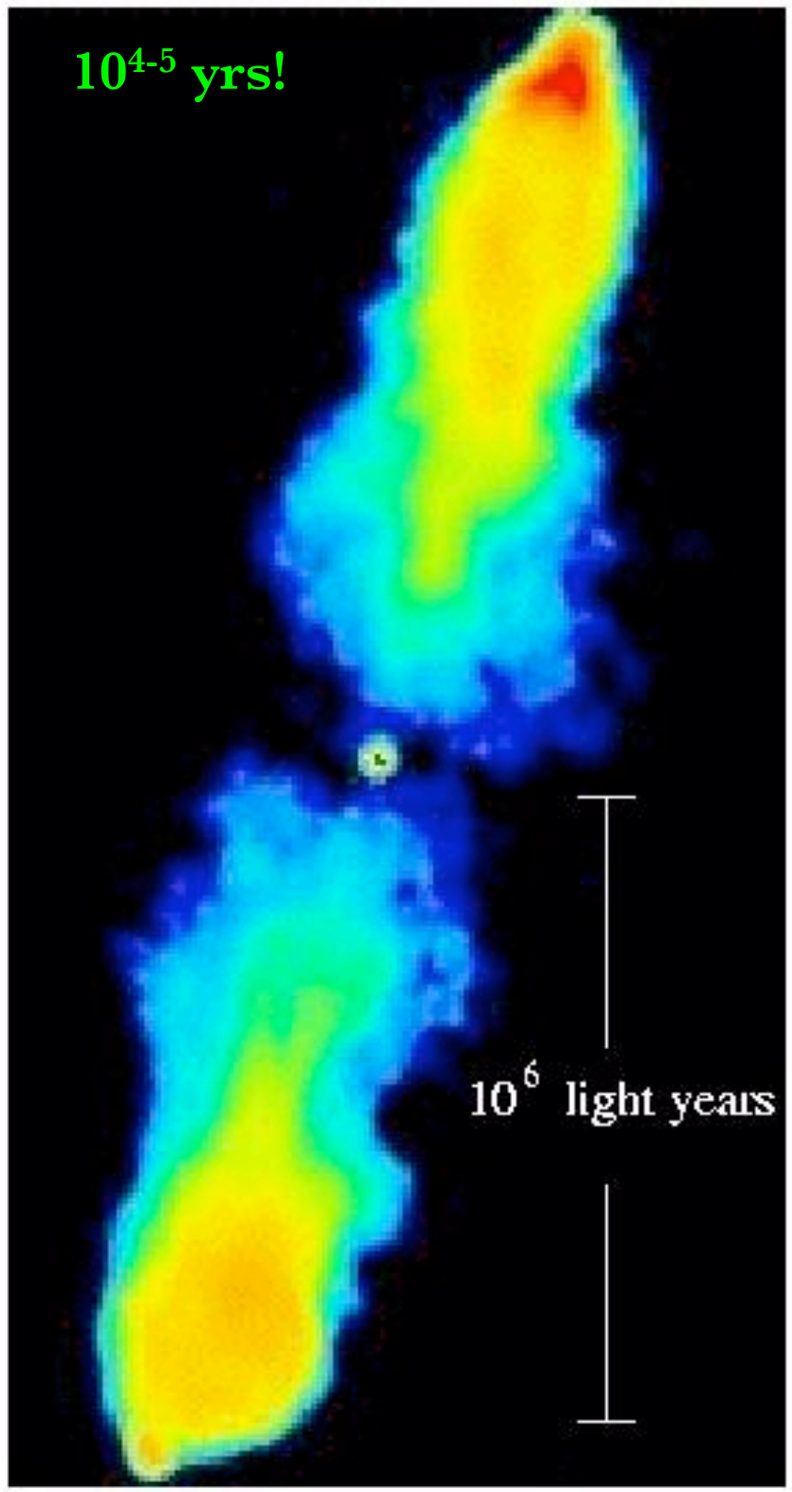
(Hjellming & Johnston 1981)

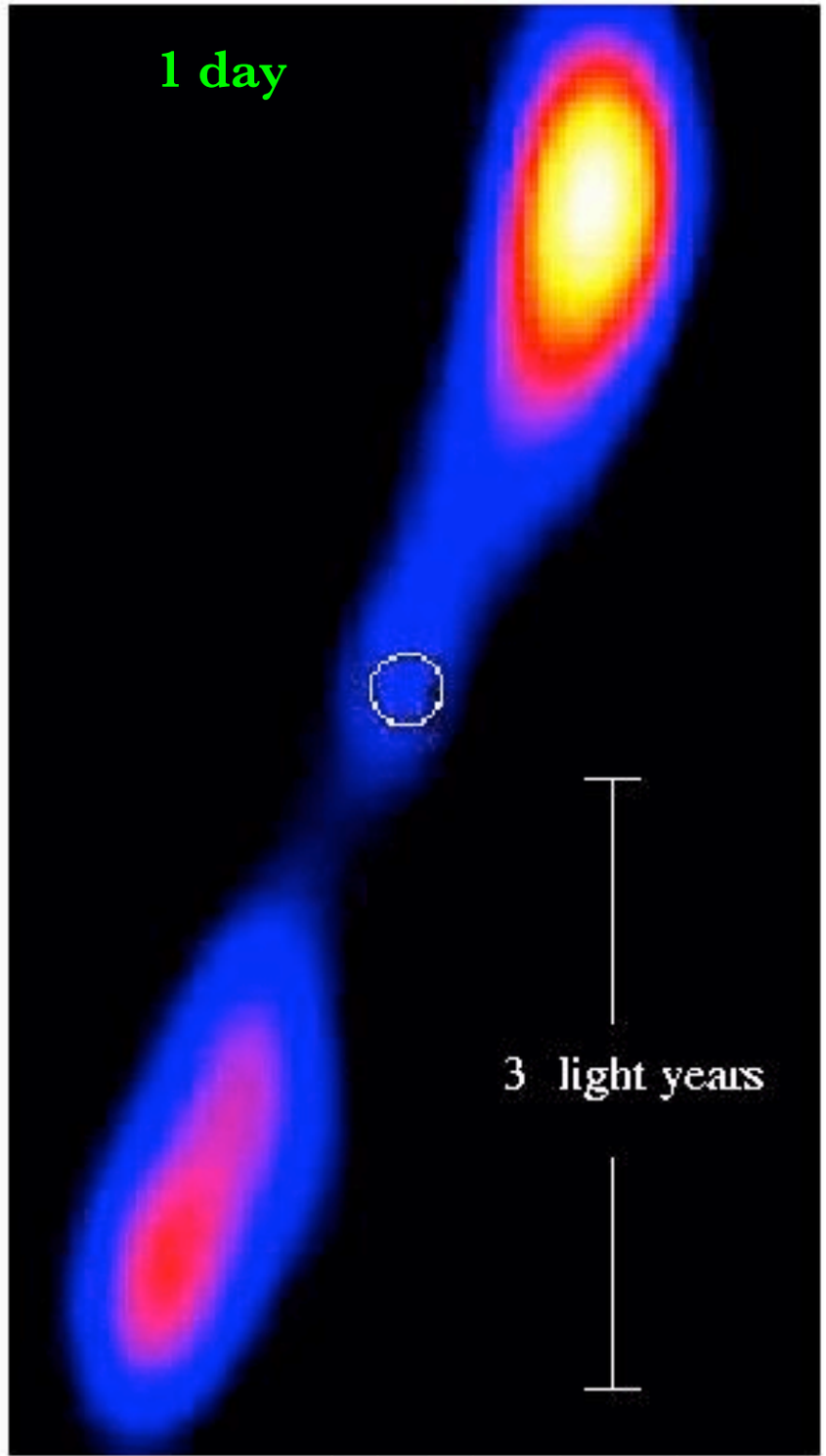
A brief history of XRB jets

QUASAR (AGN) **MICROQUASAR (XRB)**

They p

t





(Mirabel et al. 92,98)

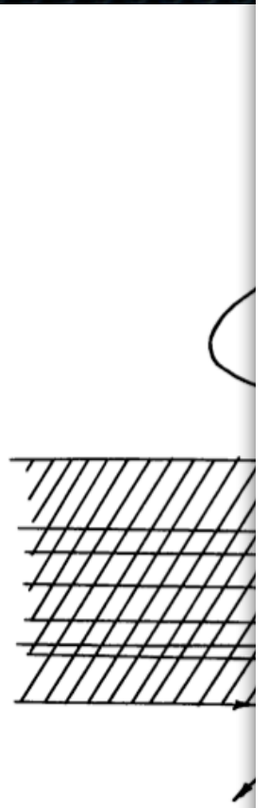
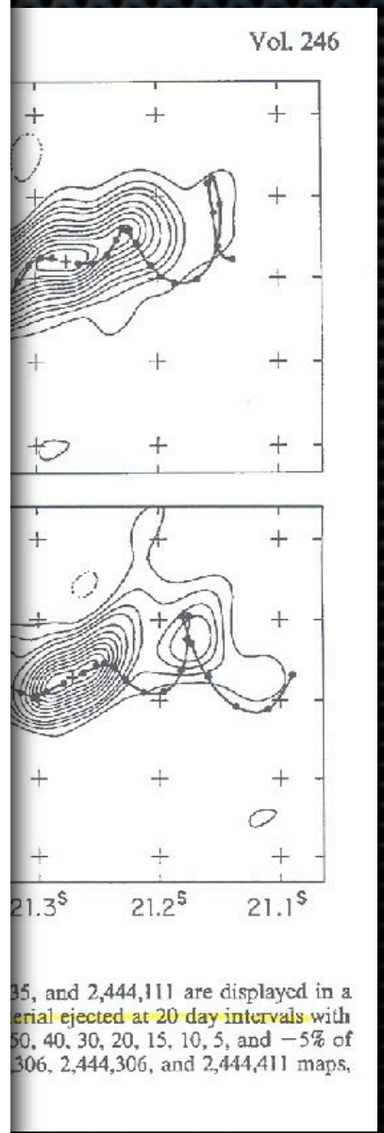


Fig. 9. The outflow
regime of accretio

(Sha



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50, 40, 30, 20, 15, 10, 5, and −5% of
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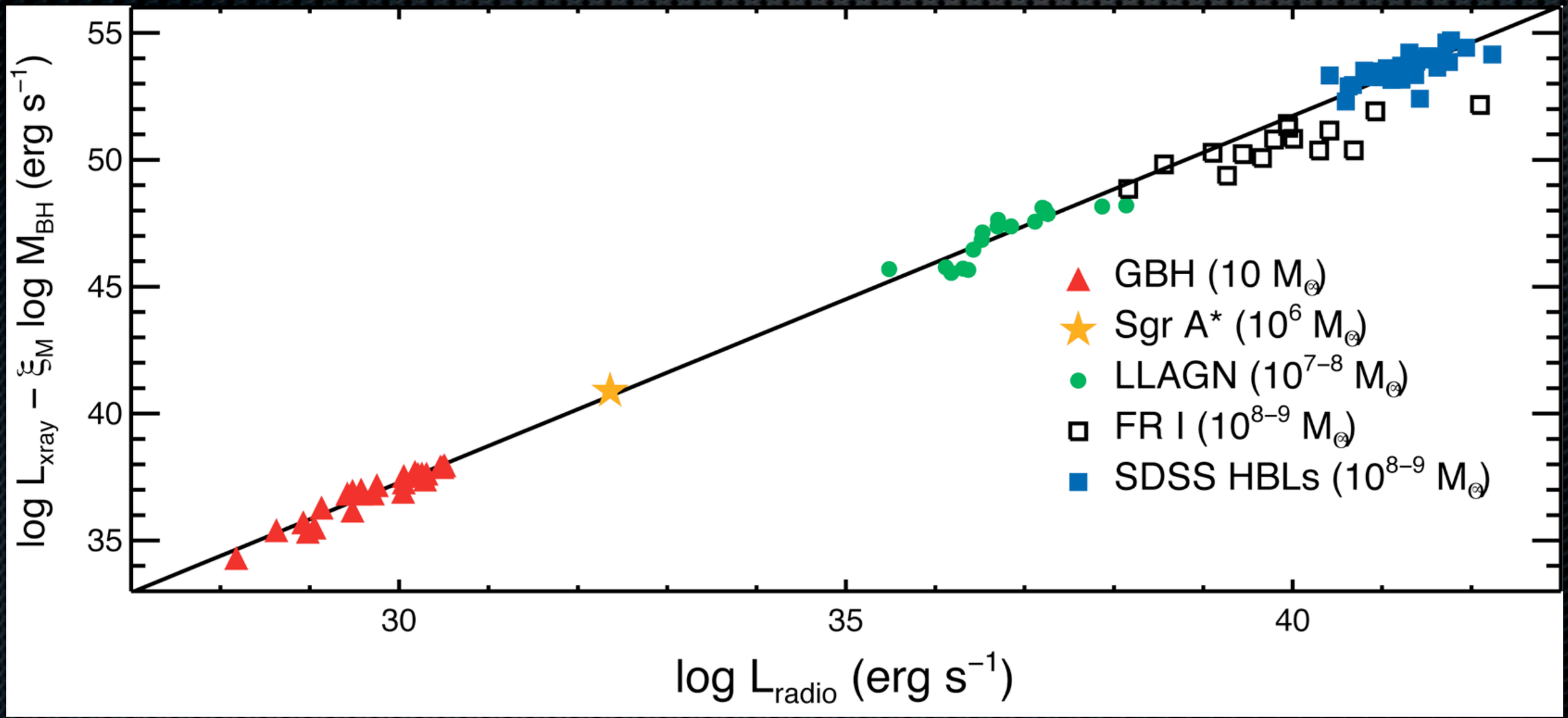
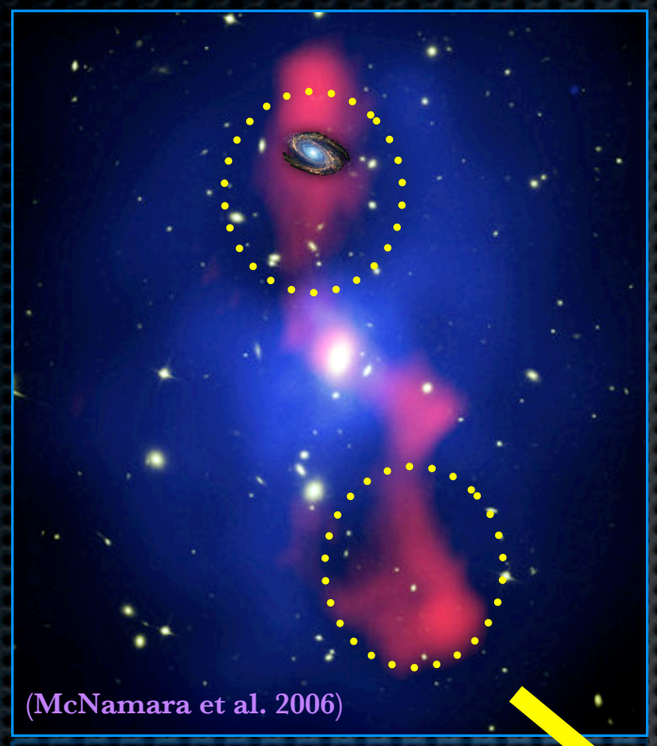
Fundamental Plane of Black Hole Accretion: XRBs ⇔ AGN



(SM ea. 2003; Heinz & Sunyaev 2003; Merloni, Heinz & diMatteo 2003; Falcke, Körding, SM 2004; SM 2005; Körding et al. 2006; Plotkin, SM, Kelly, Körding & Anderson 2012)

Black hole jets are major players in the universe

GALAXY EVOLUTION/ AGN FEEDBACK

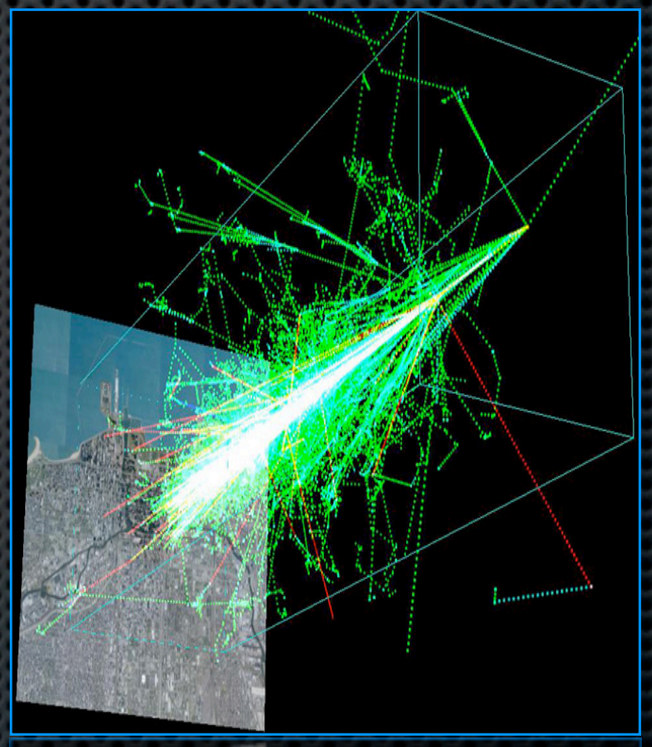


(McNamara et al. 2006)

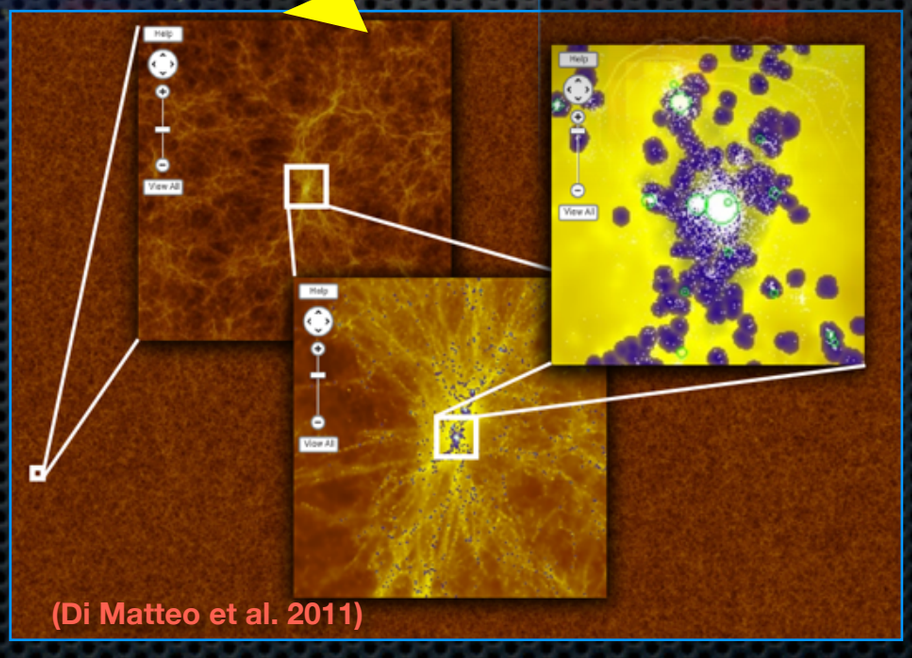
IONIZATION OF SURROUNDING GAS

(Pakull et al. 2010)

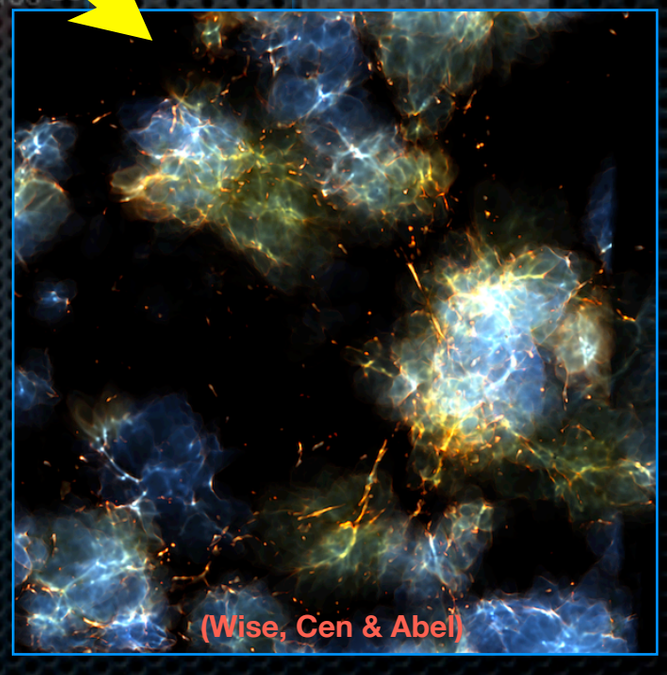
HIGH-ENERGY PARTICLE ACCELERATION



Cosmological Simulations:



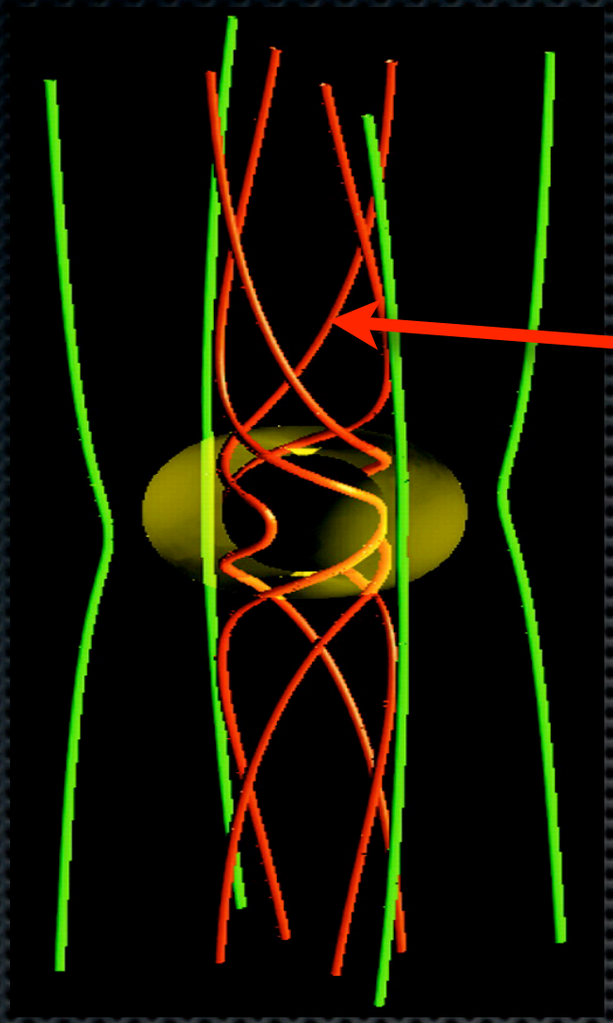
(Di Matteo et al. 2011)

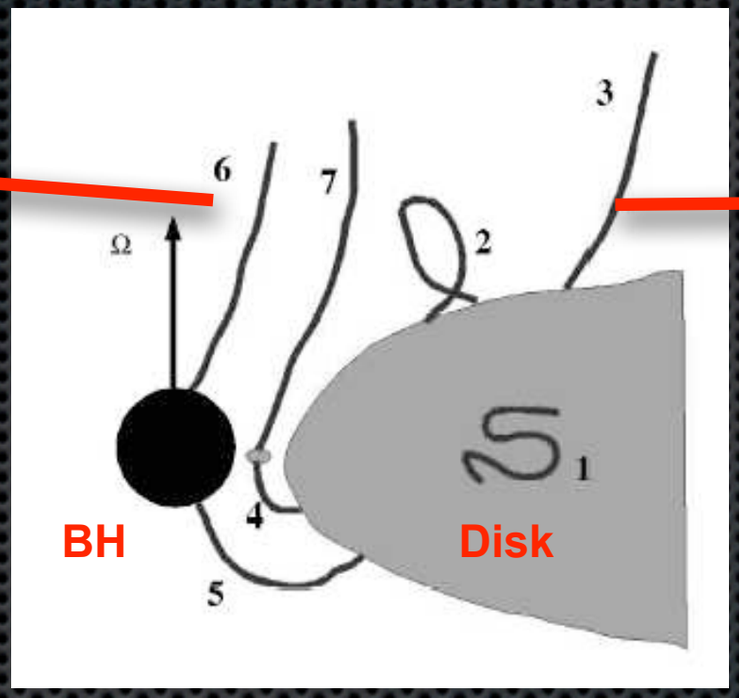


(Wise, Cen & Abel)

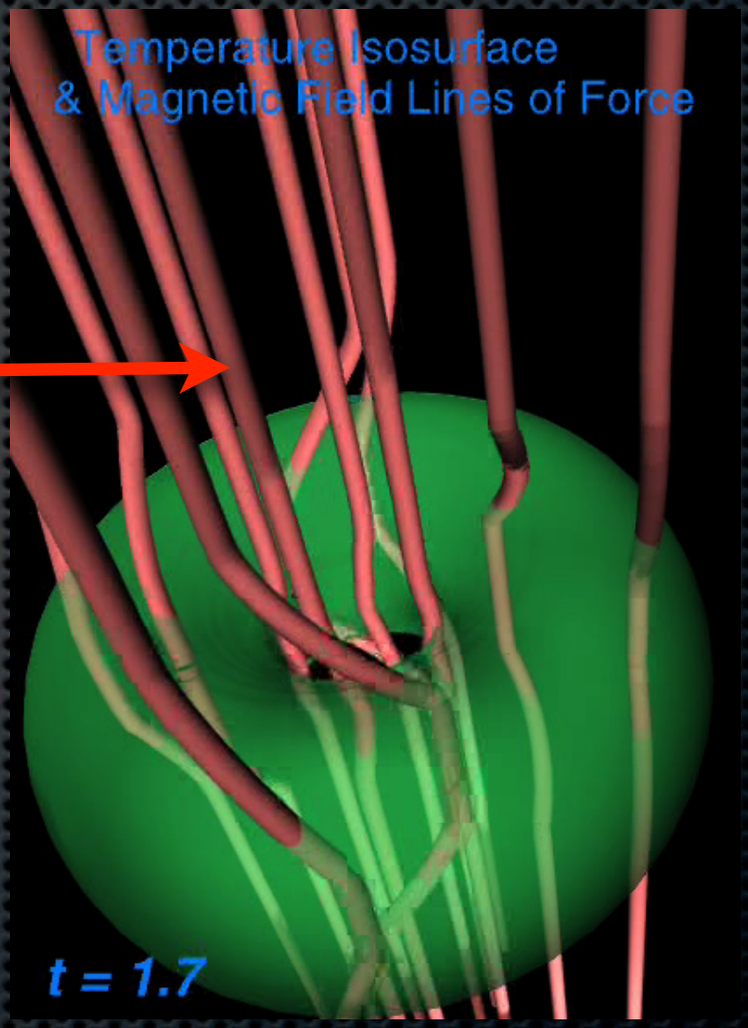
Jet power: two primary theoretical scenarios

Blandford-Znajek





Blandford-Payne



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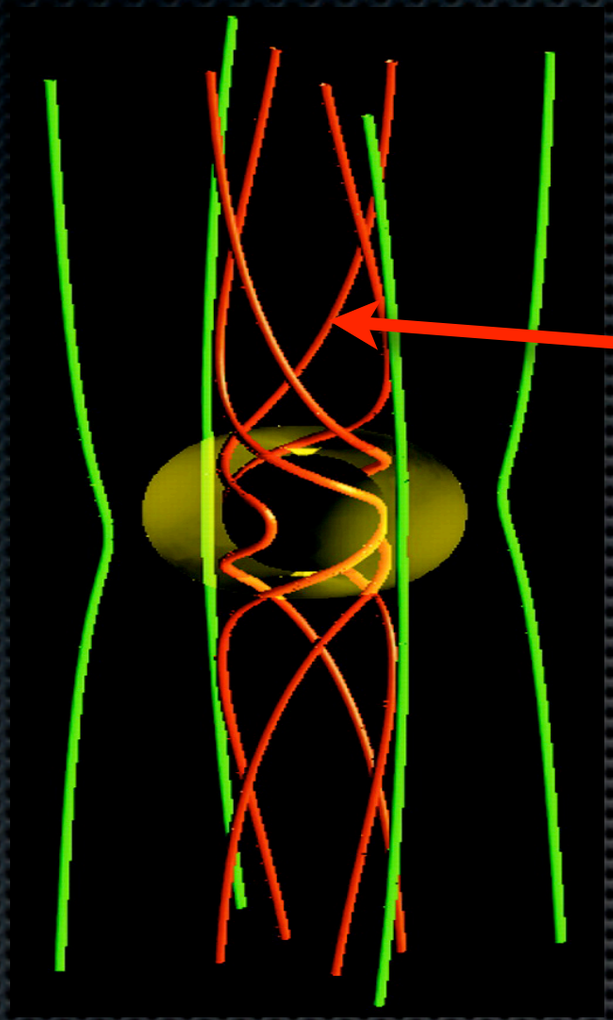

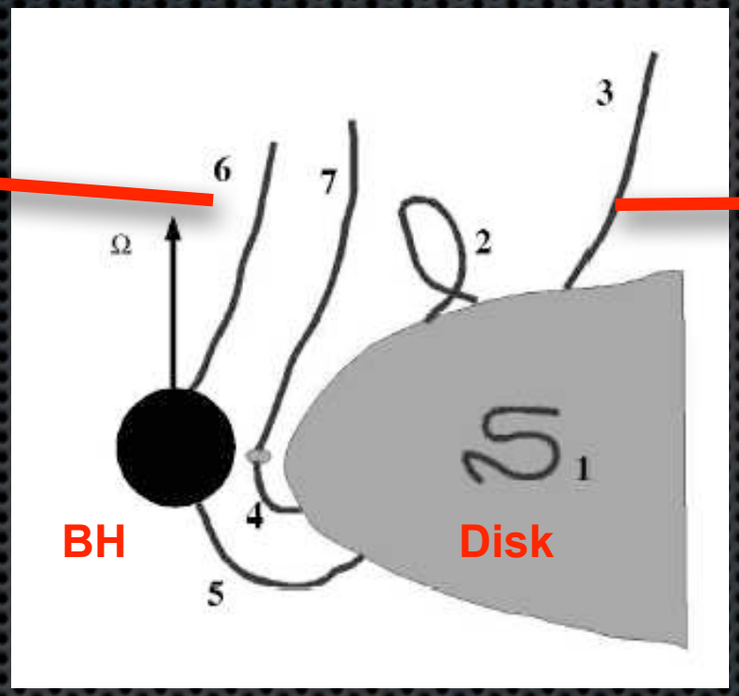

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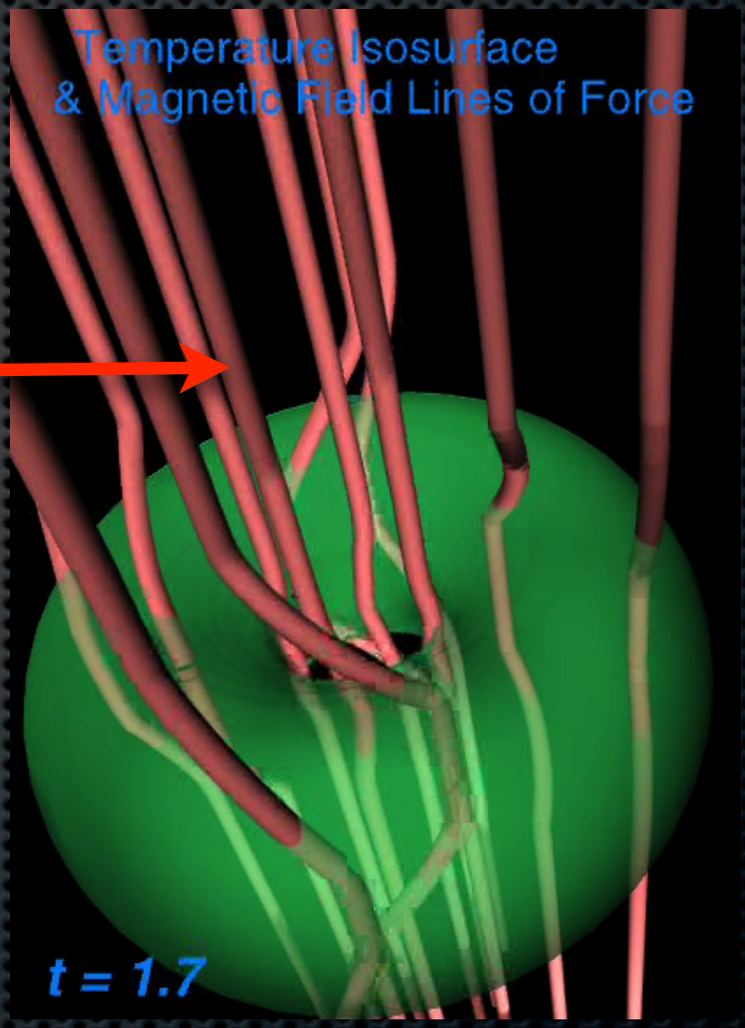

(Blandford & Znajek 1977, Blandford & Payne 1982)

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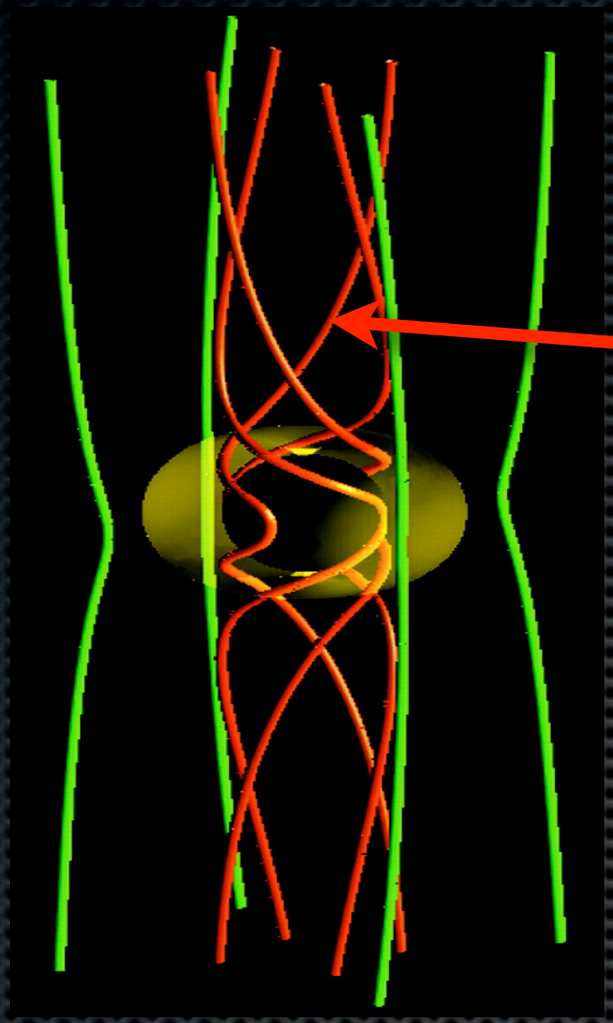
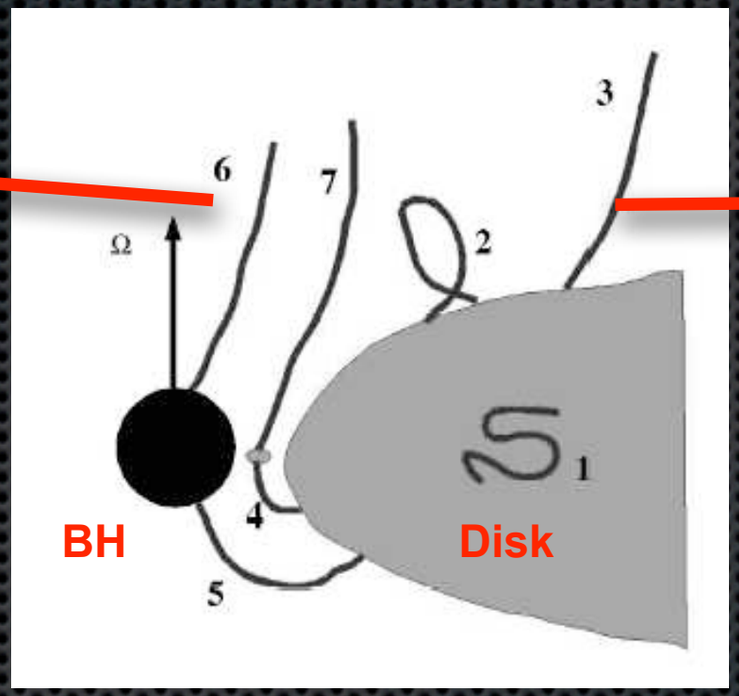
Blandford-Znajek





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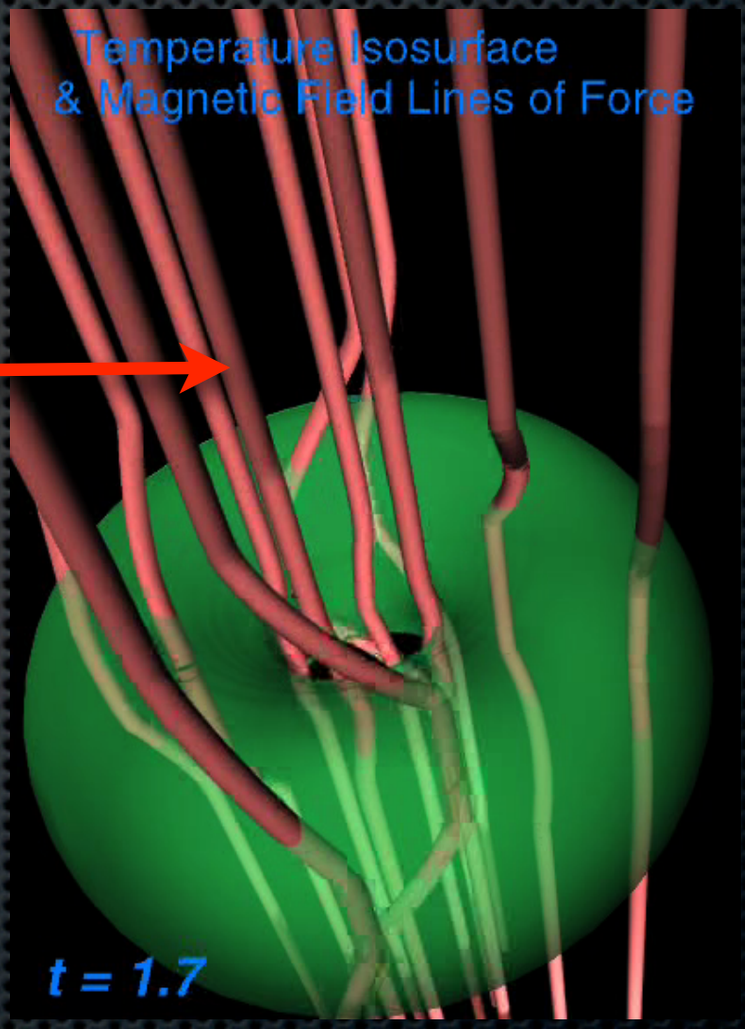

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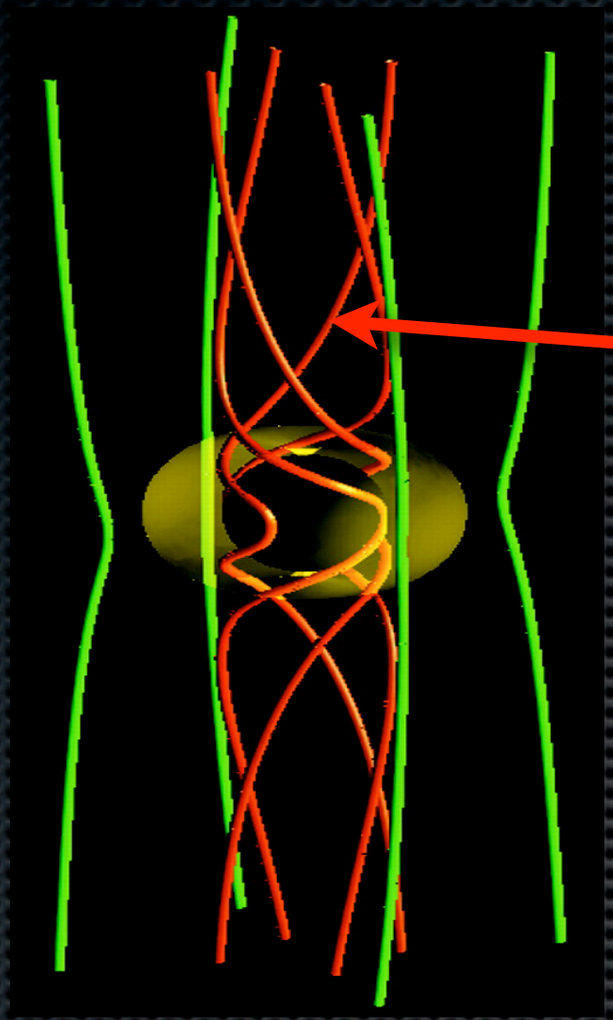

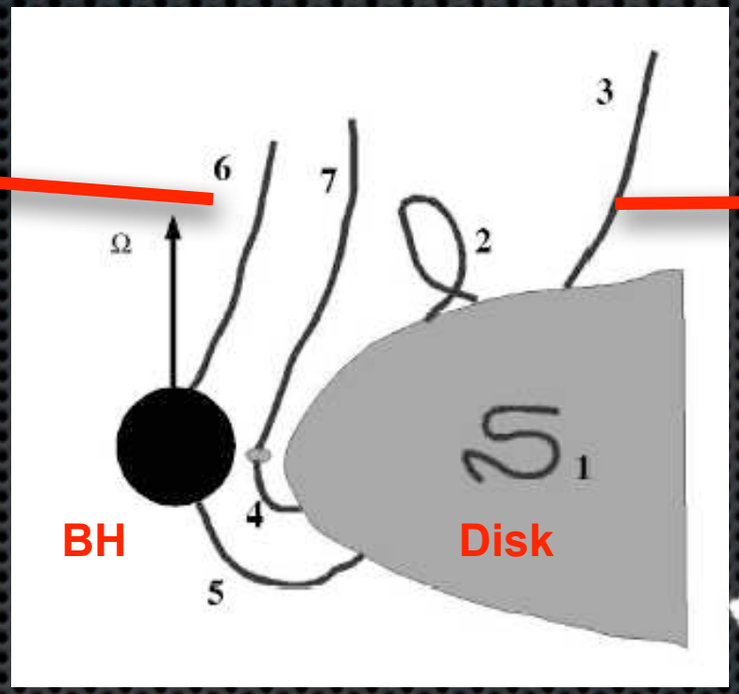

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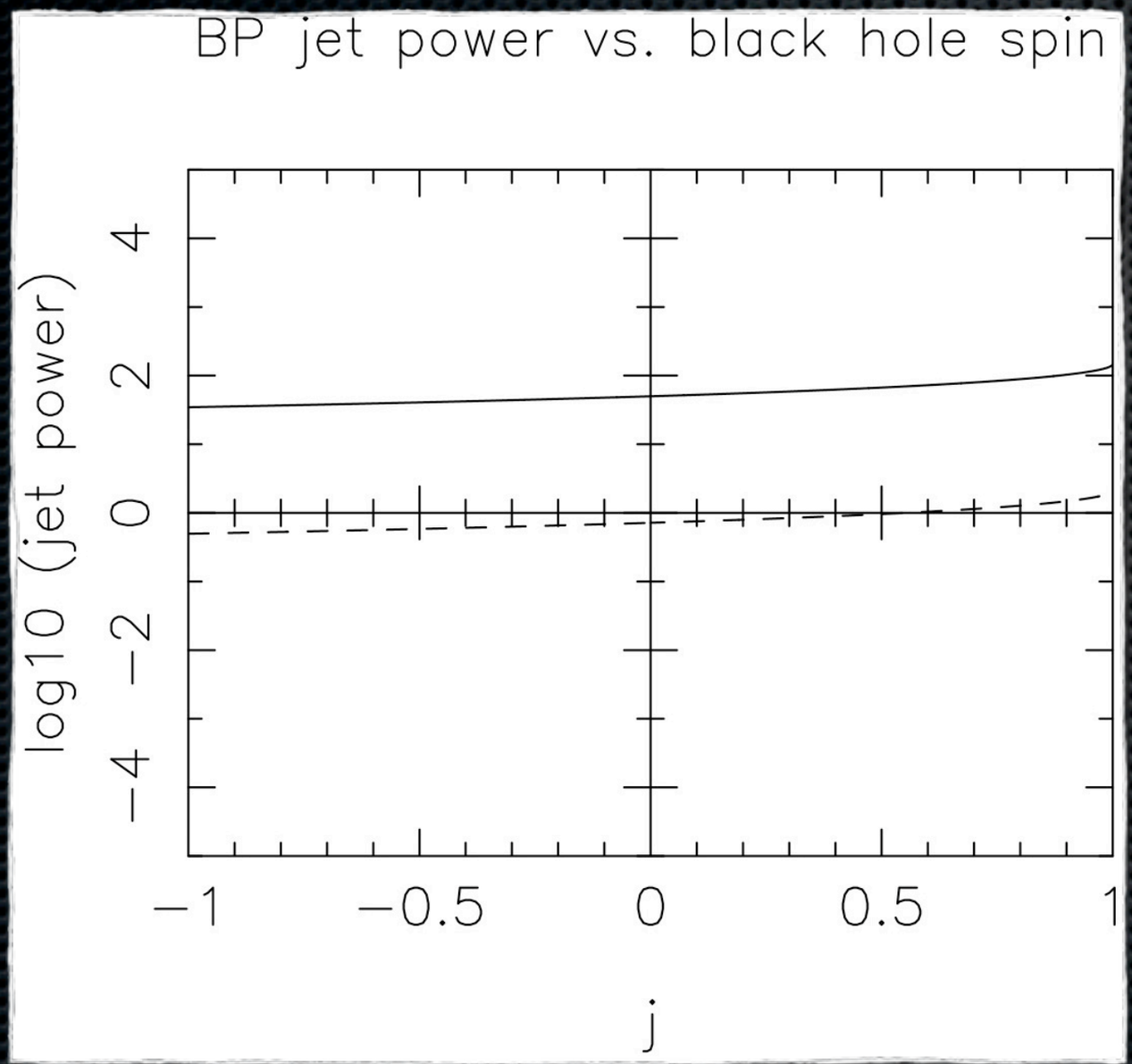
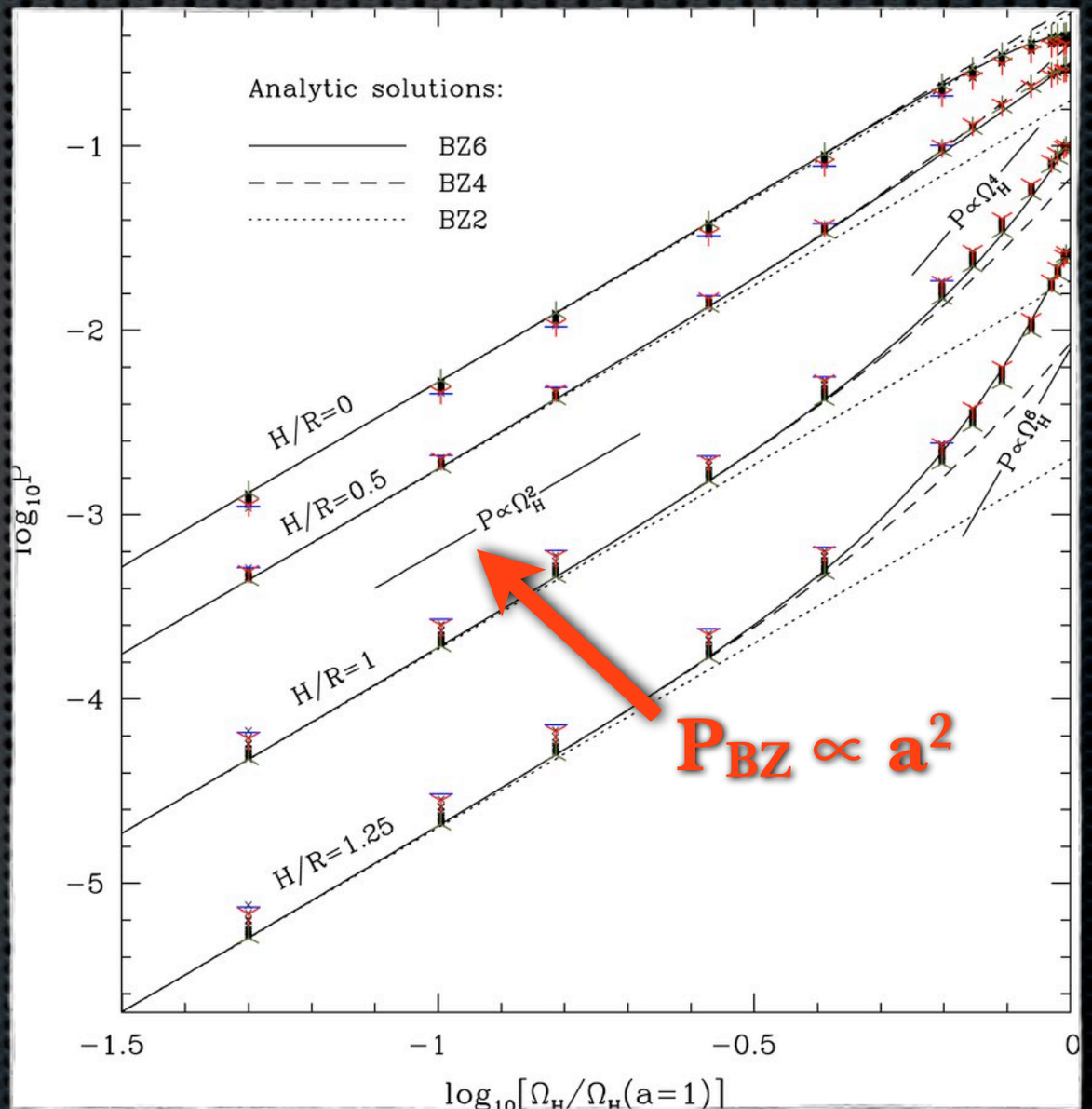
Jet power: dependence on spin

Blandford-Payne-like



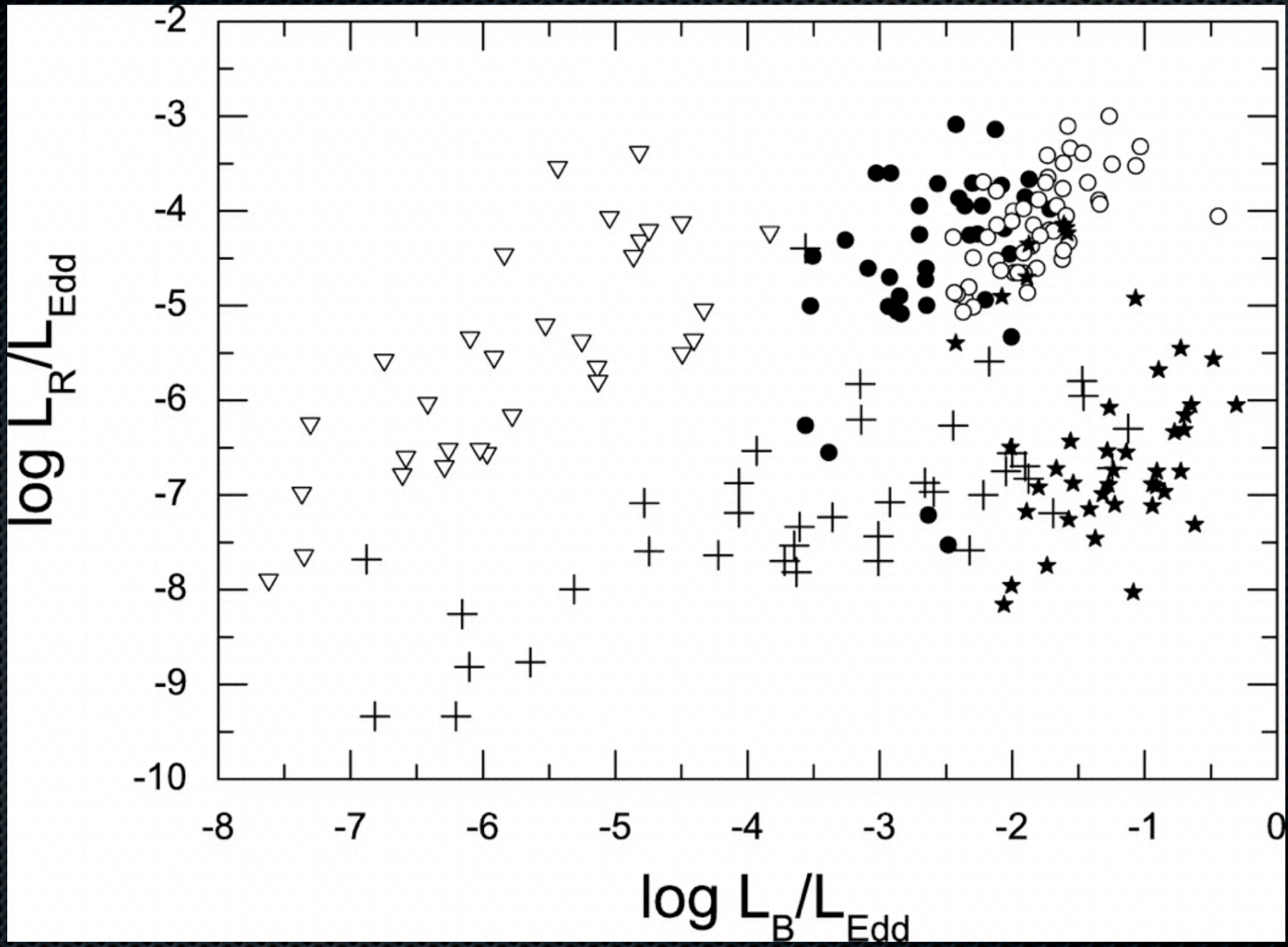
(Meier 2001, Meier 2012)

Blandford-Znajek-like



(Tchekhovskoy, Narayan & McKinney 2010)

Jet power: RL/RQdichotomy in AGN populations?



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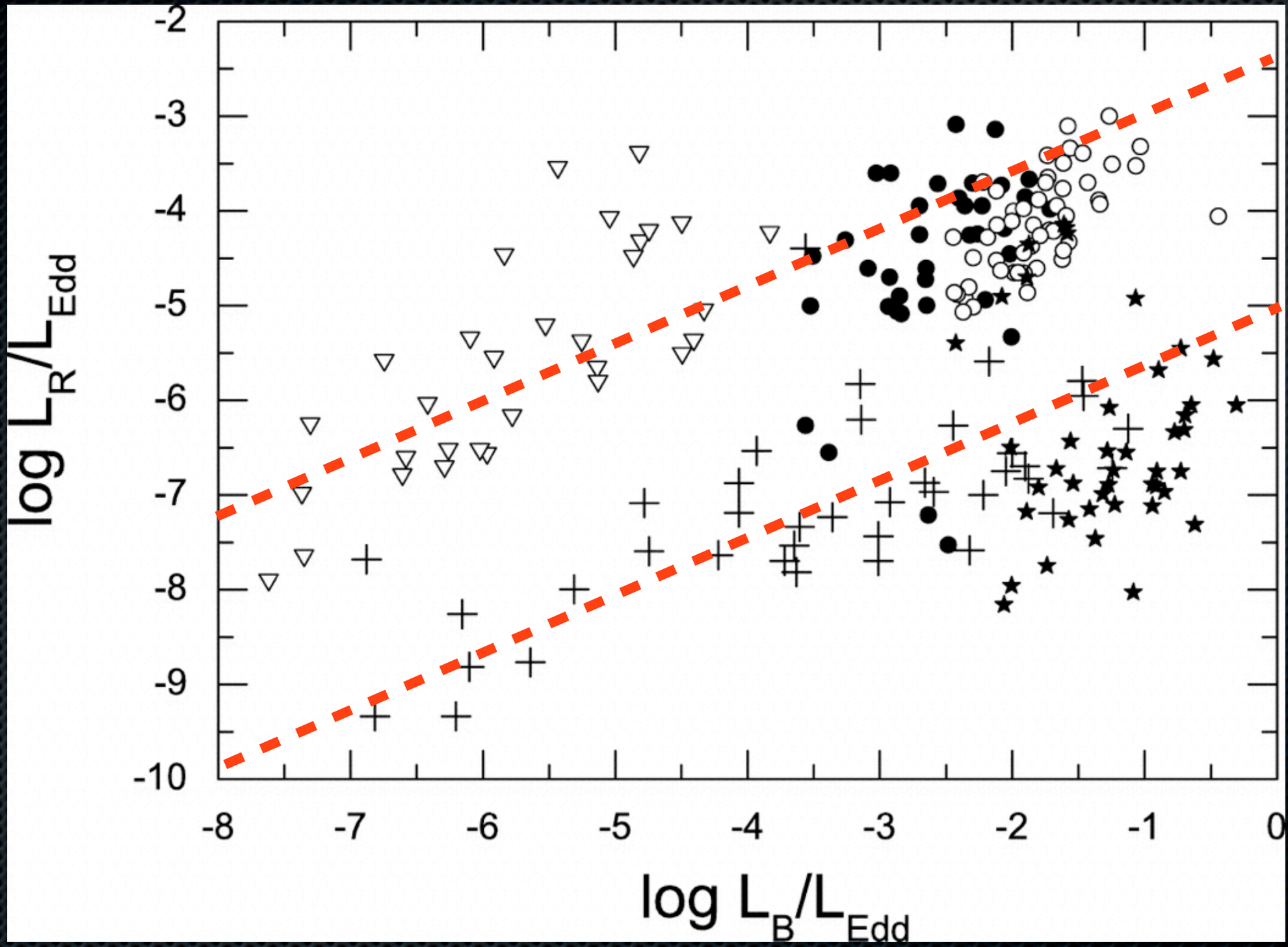

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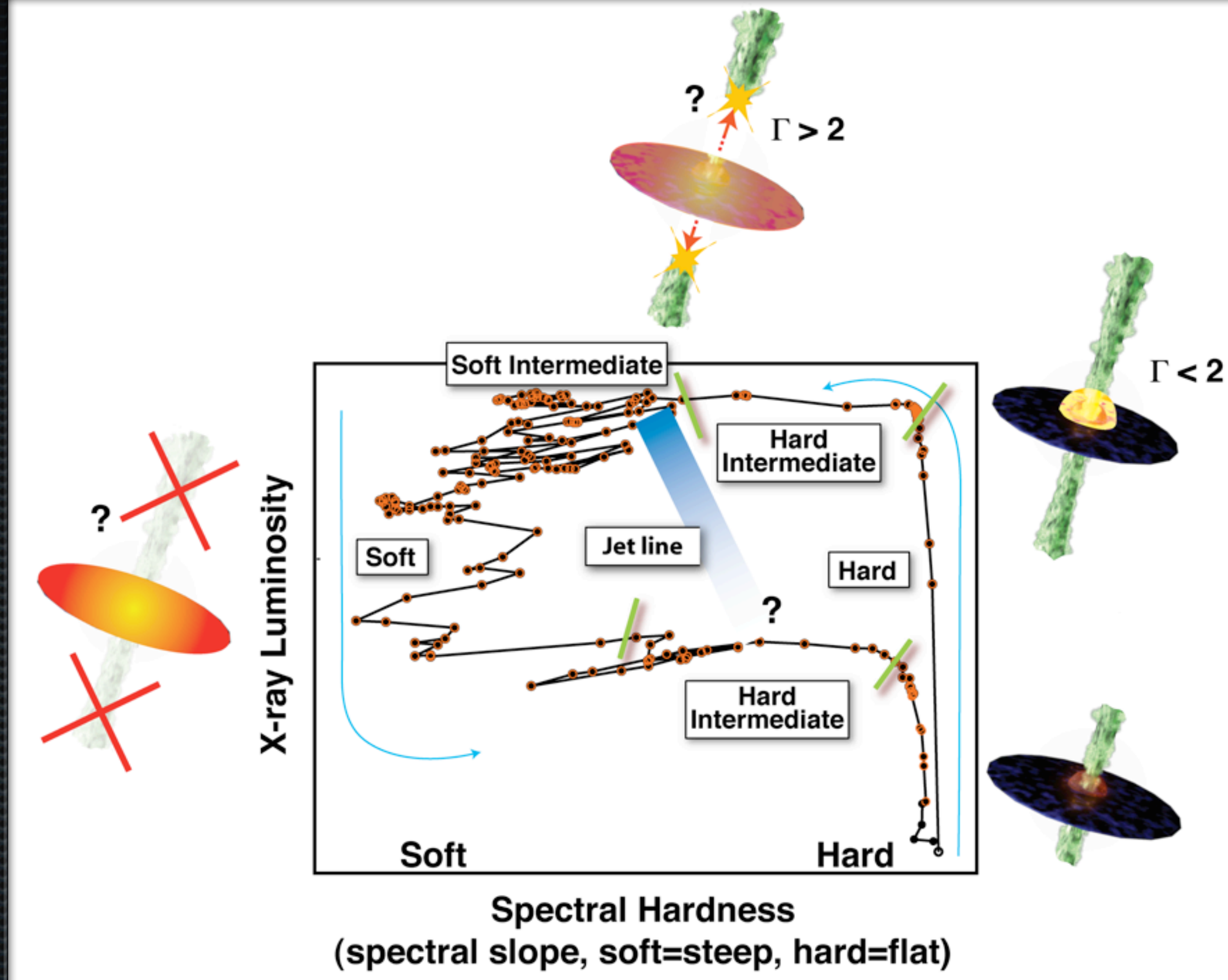
Problem: there are RL/RQ states seen in single XRBs!



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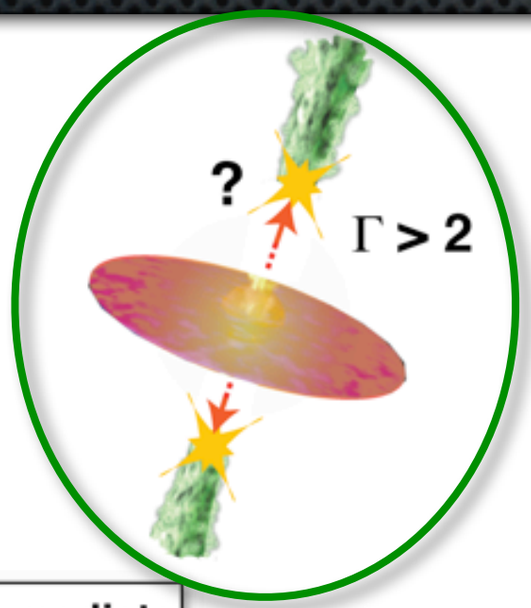
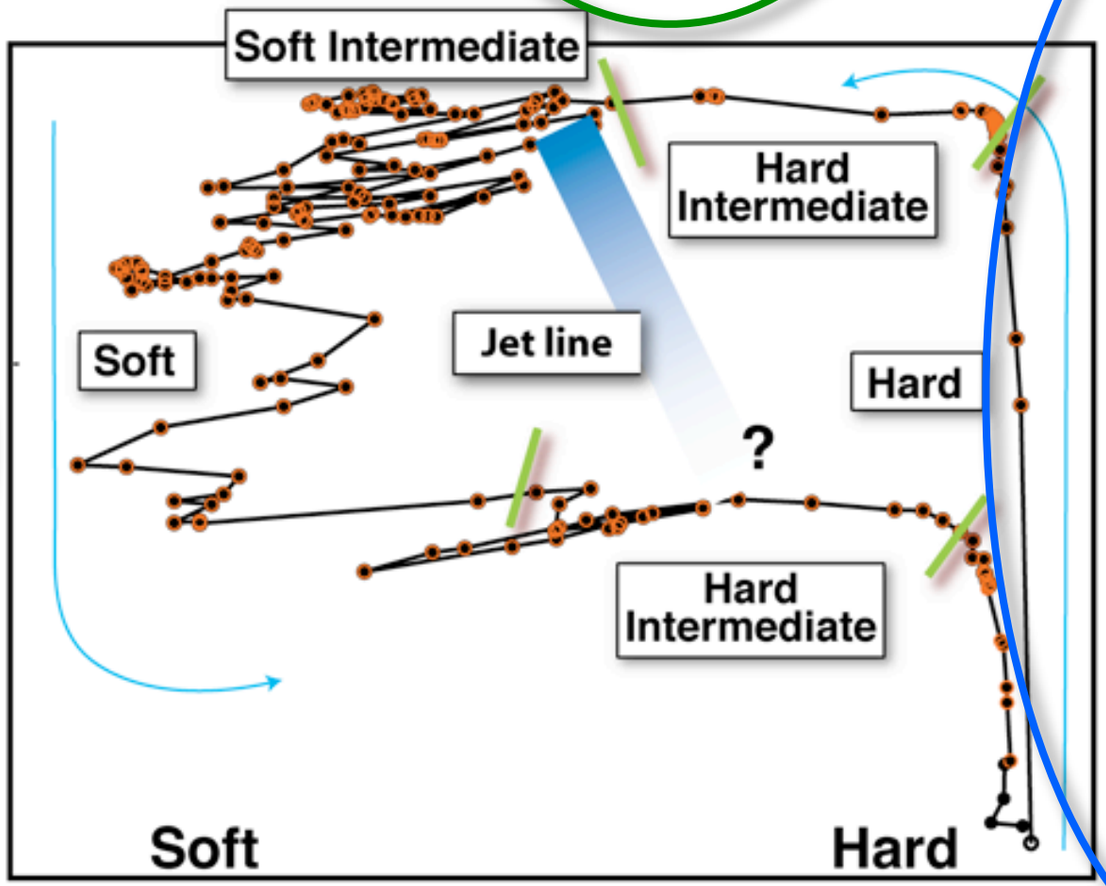
HIM/SIM transition
= ballistic jets



Hard state:
= steady jets



Soft state:
= no jets? winds

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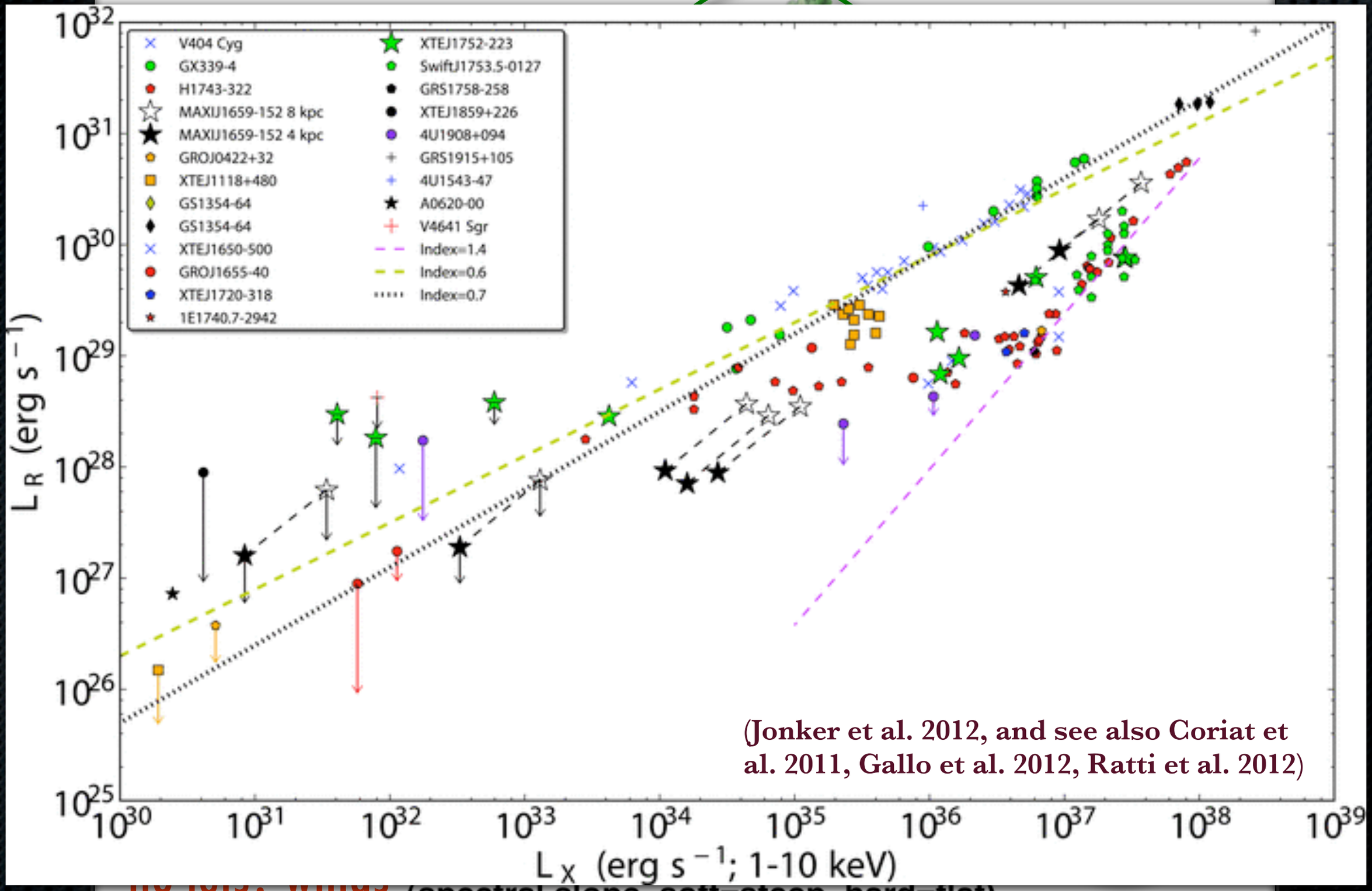

(Jonker et al. 2012, and see also Coriat et al. 2011, Gallo et al. 2012, Ratti et al. 2012)

(spectral slope, soft=steep, hard=flat)

So which power should we use to compare to spin??

HIM/SIM transition
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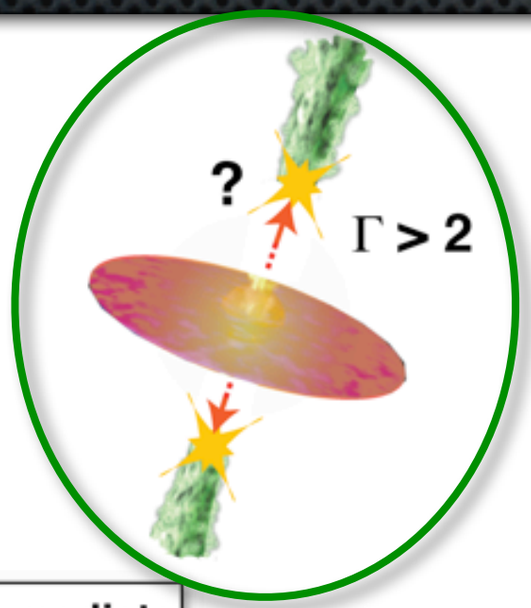

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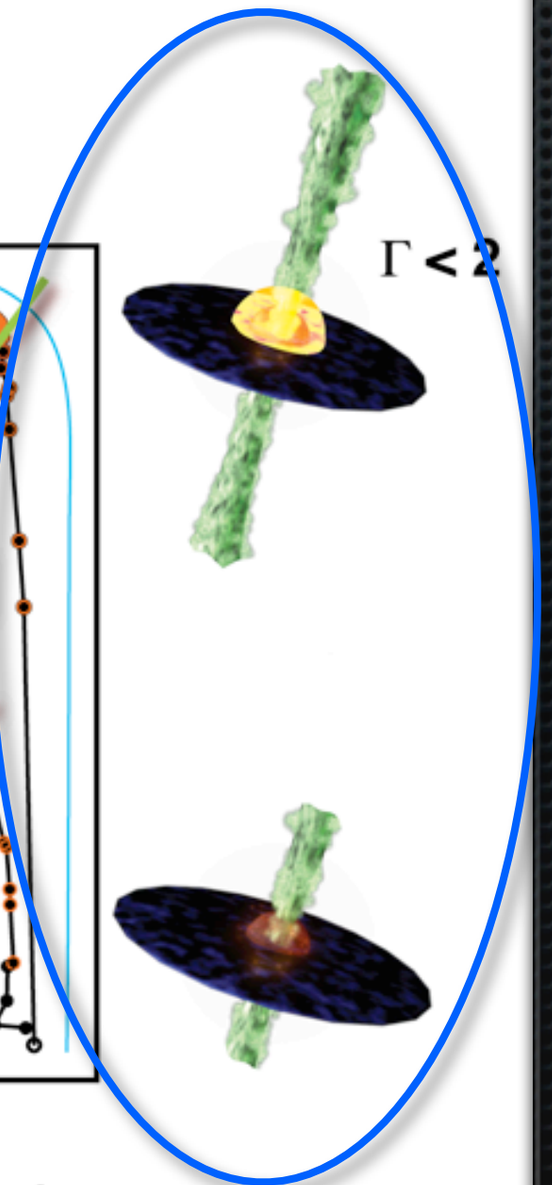

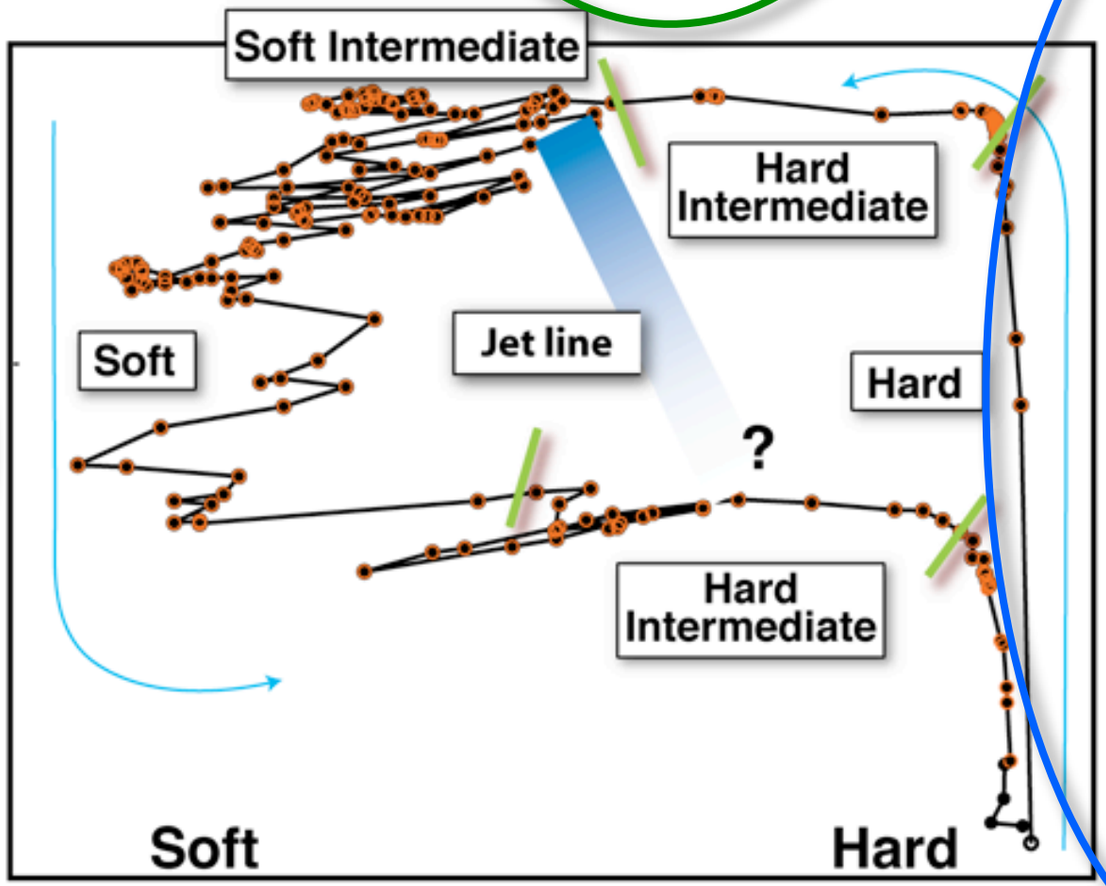

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Compact jets: flat spectra up to a break (τ: >1→0)

F_ν

$$\nu_{break} \propto (\dot{m}/M)^{2/3}\, M^{-1} \propto \dot{m}^{2/3}\, M^{-1/3}$$

ν

(Blandford & Königl 1979, Falcke & Biermann 1995, SM et al. 2003, Heinz & Sunyaev 2003)

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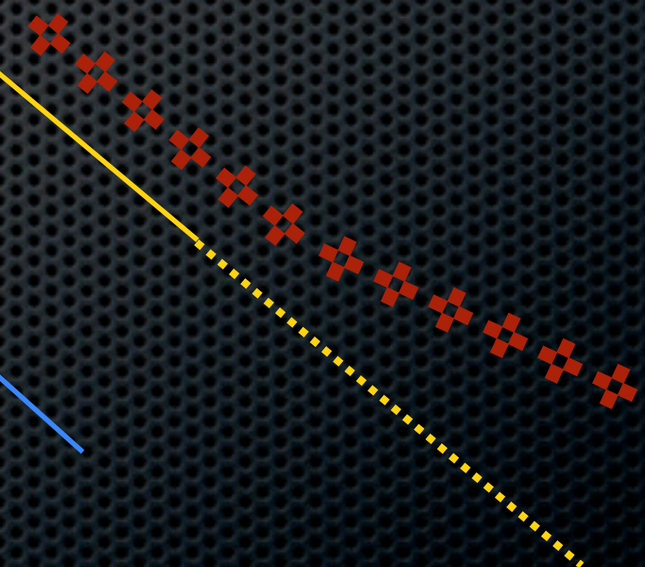

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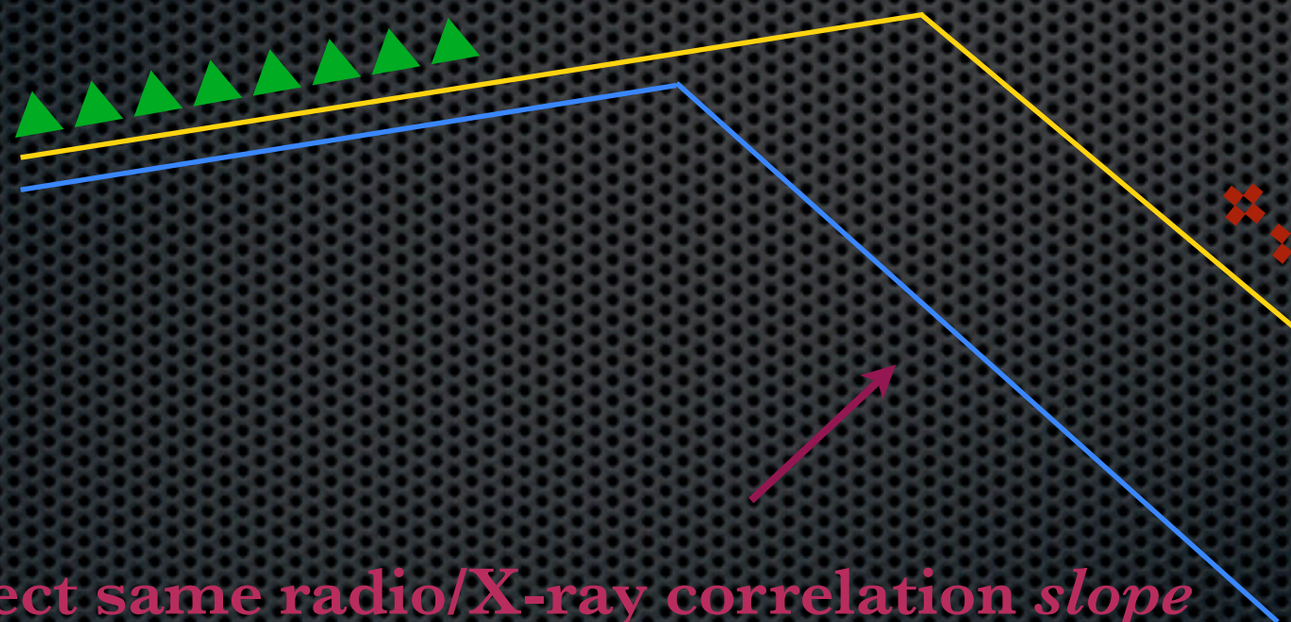

Expect same radio/X-ray correlation *slope* but AGN will have lower "normalization" in X-ray luminosity, comparatively!

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νFν peaks here!

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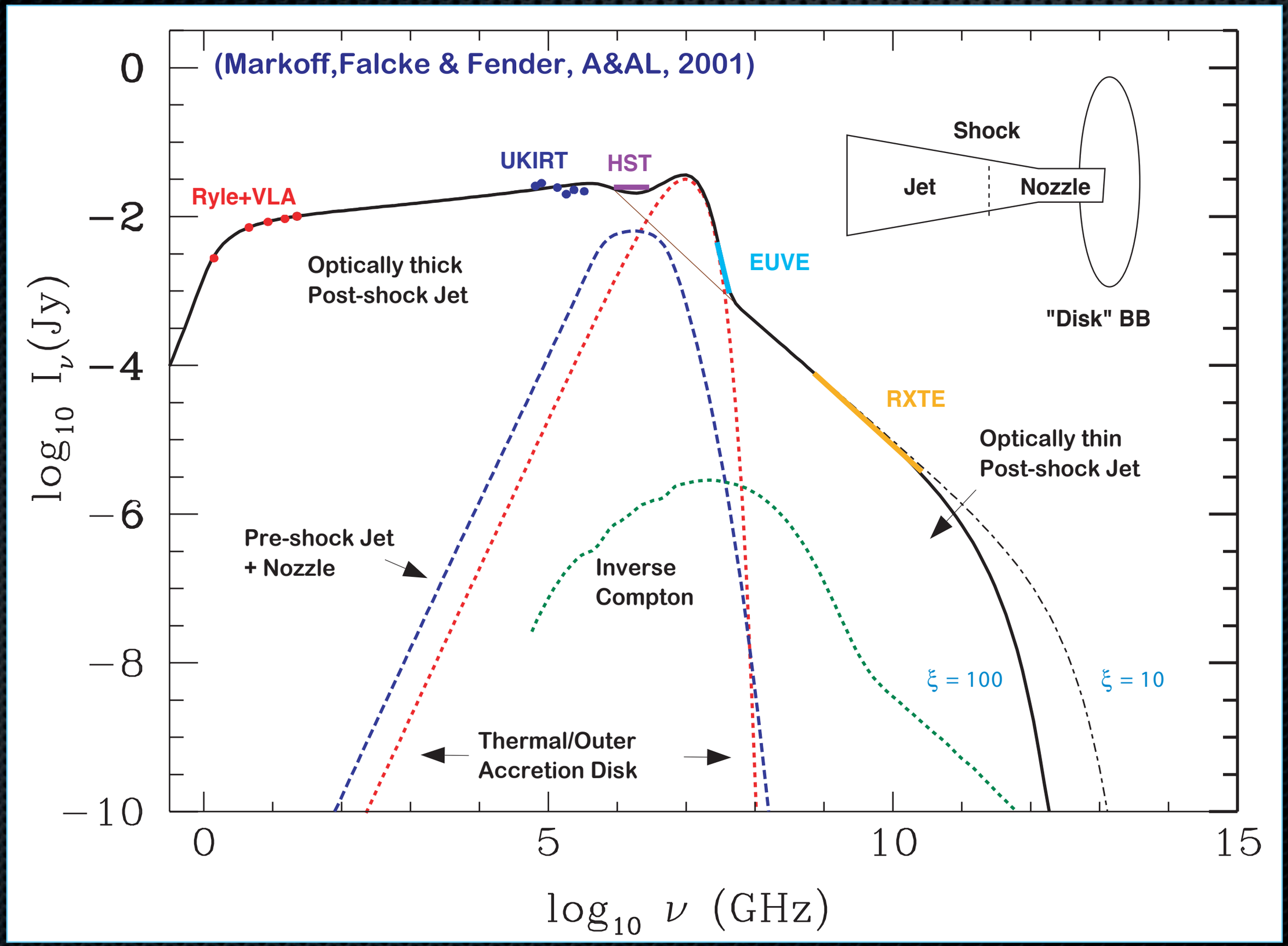
- **Even 10% "contamination" of hard state X-rays changes the entire paradigm of thermal Comptonization!!**

First application to XRB: XTE J1118+480



(SM ea. 01, SM ea. 03, SM, Nowak & Wilms 05, Migliari ea. 07, Gallo ea. 07, Maitra ea. 09)

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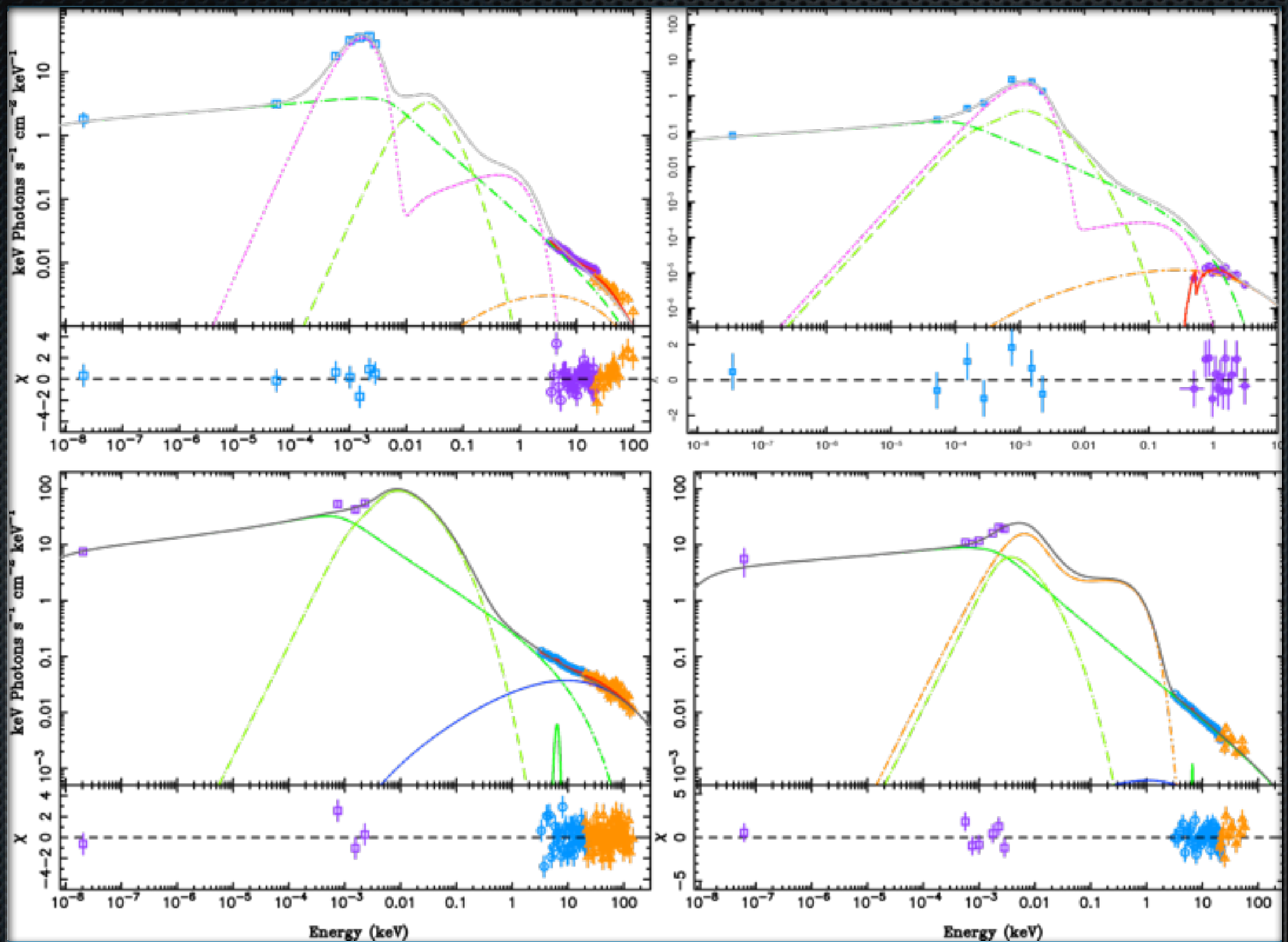

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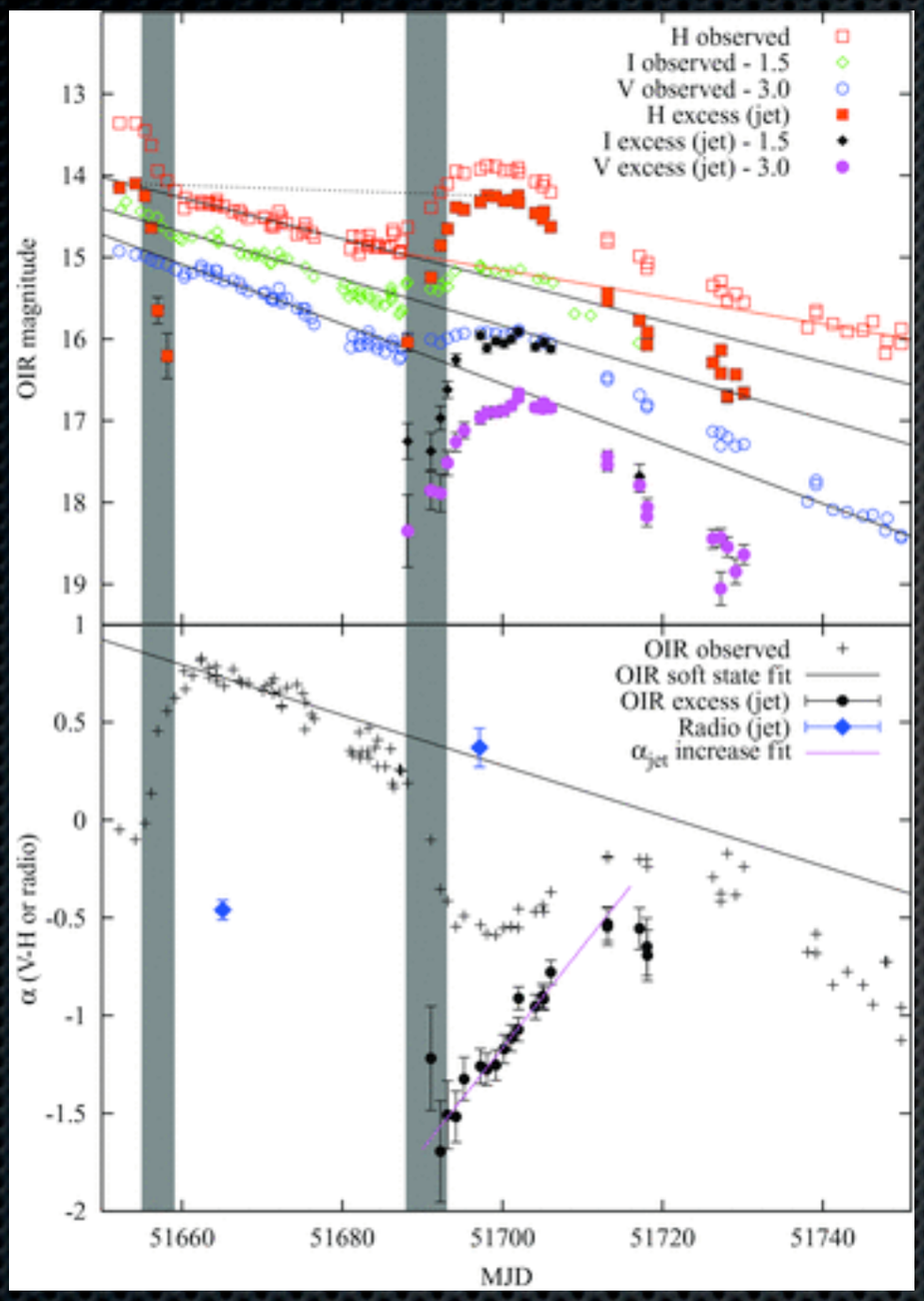
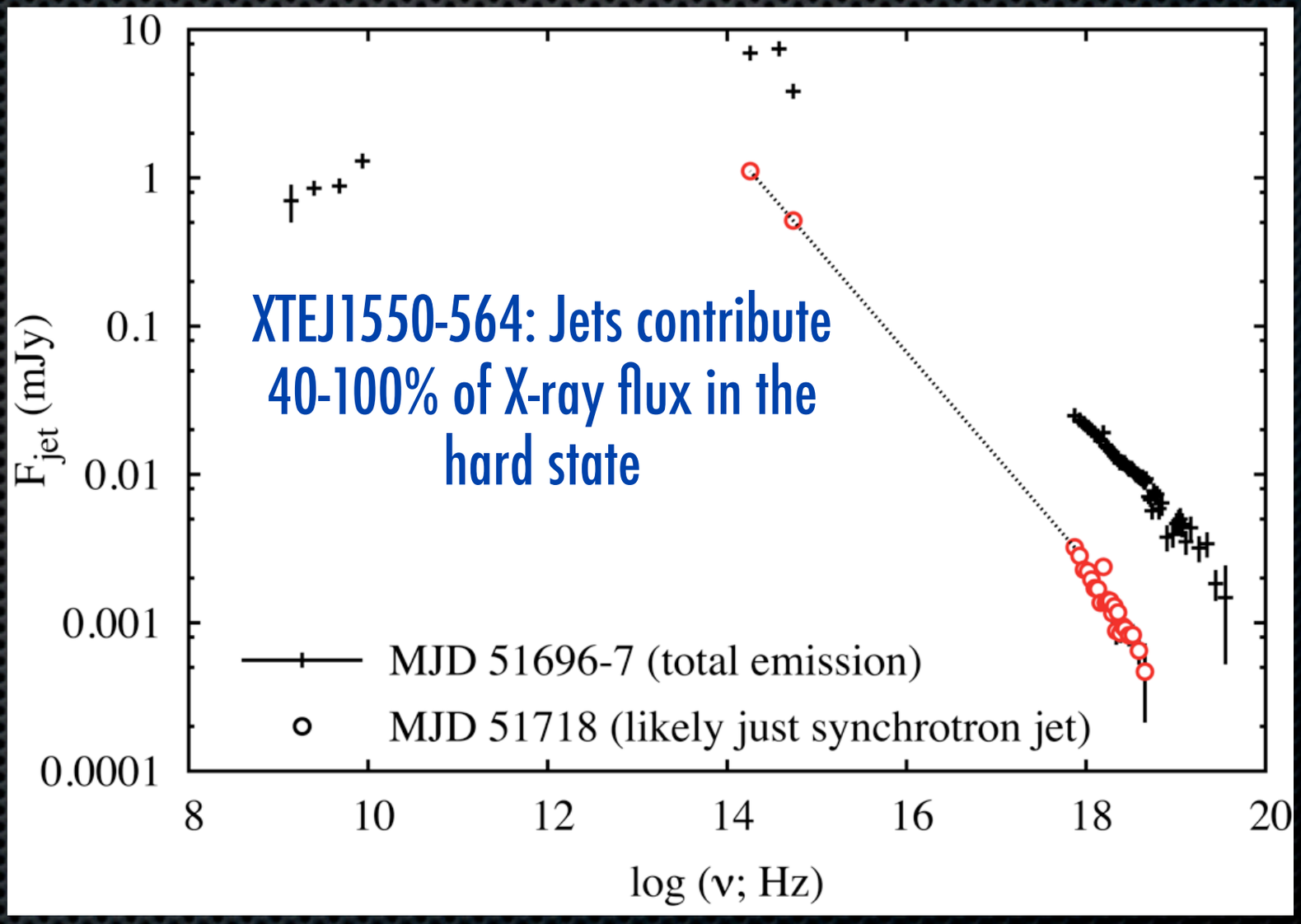
XTE J1550-564: jet synchrotron fractions during outburst

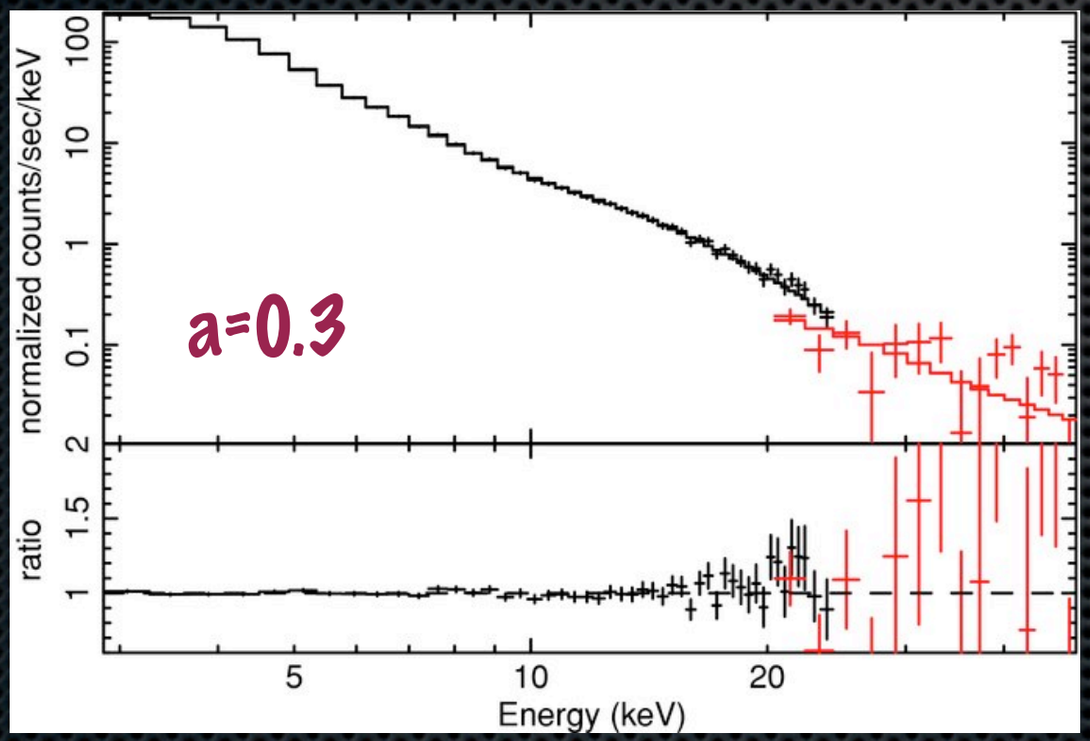


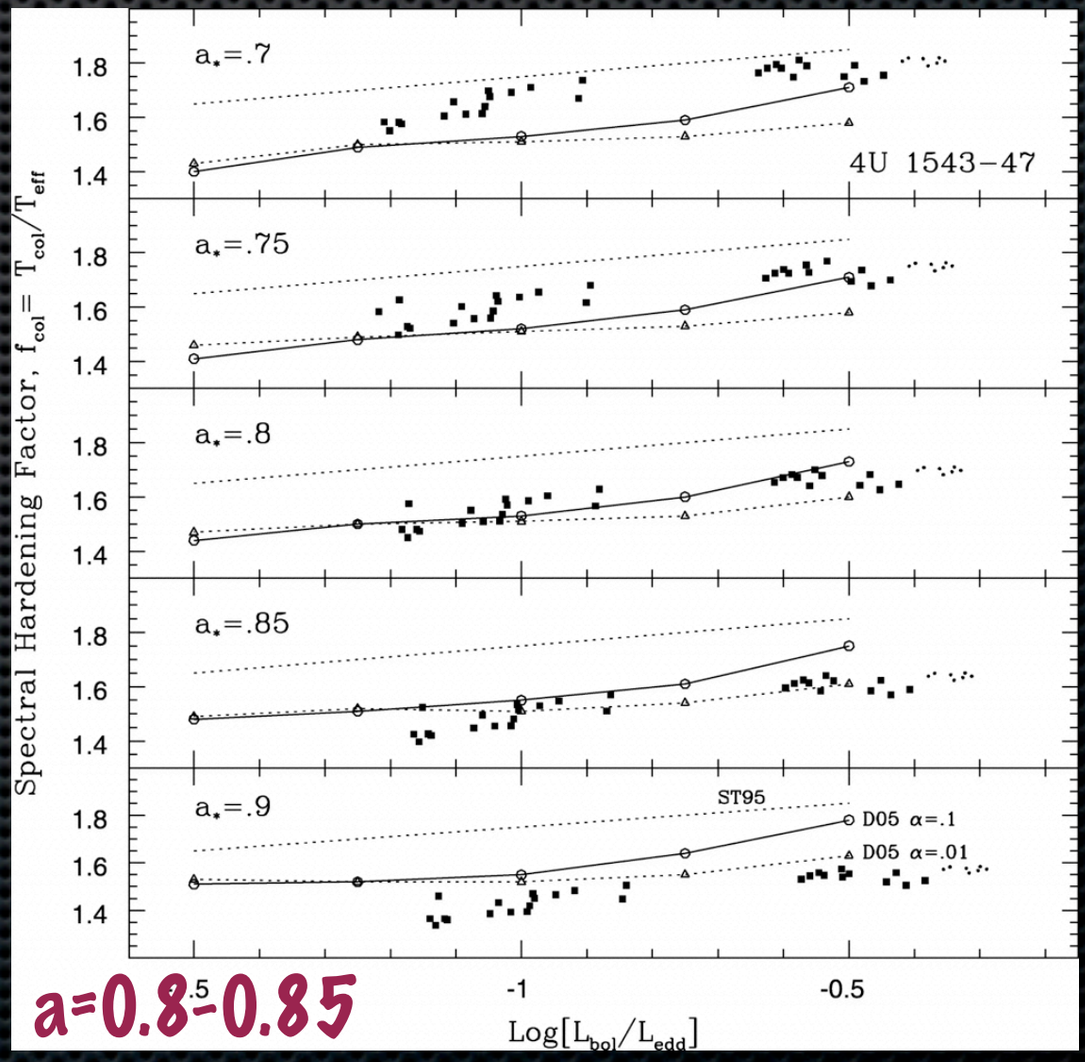


(Russell ea. 2010)

How can we connect this jet output to spin in XRBs?

- ★ **XRBs offer two methods: disk continuum (only possible for XRBs!) and relativistic Fe K_α line/reflection fitting (AGN too)**
- ★ **For many sources only one is possible, and there is not always agreement for sources with both (e.g. 4U1543-47):**





(Miller ea. 2009, Shafee ea. 2007 ➠ Dovciak ea 2004; Li ea. 2005; Davis ea. 2006; Brennemen & Reynolds 2006, +++)

Putting it all together: forays into spin vs jet power

- Two groups are looking at this, without really converging

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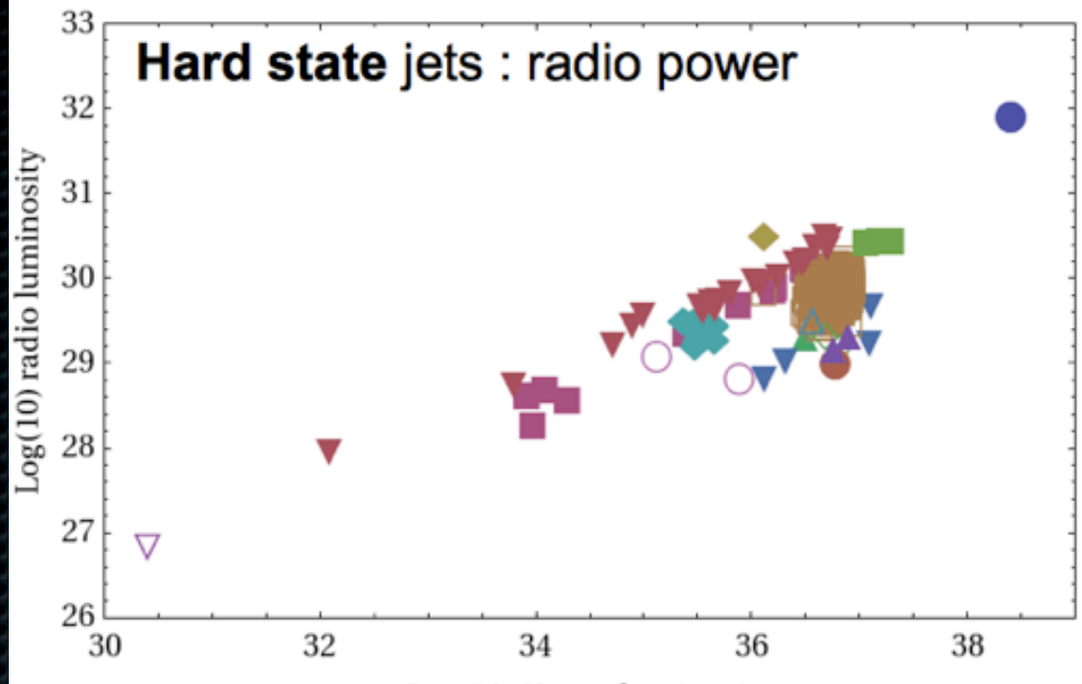

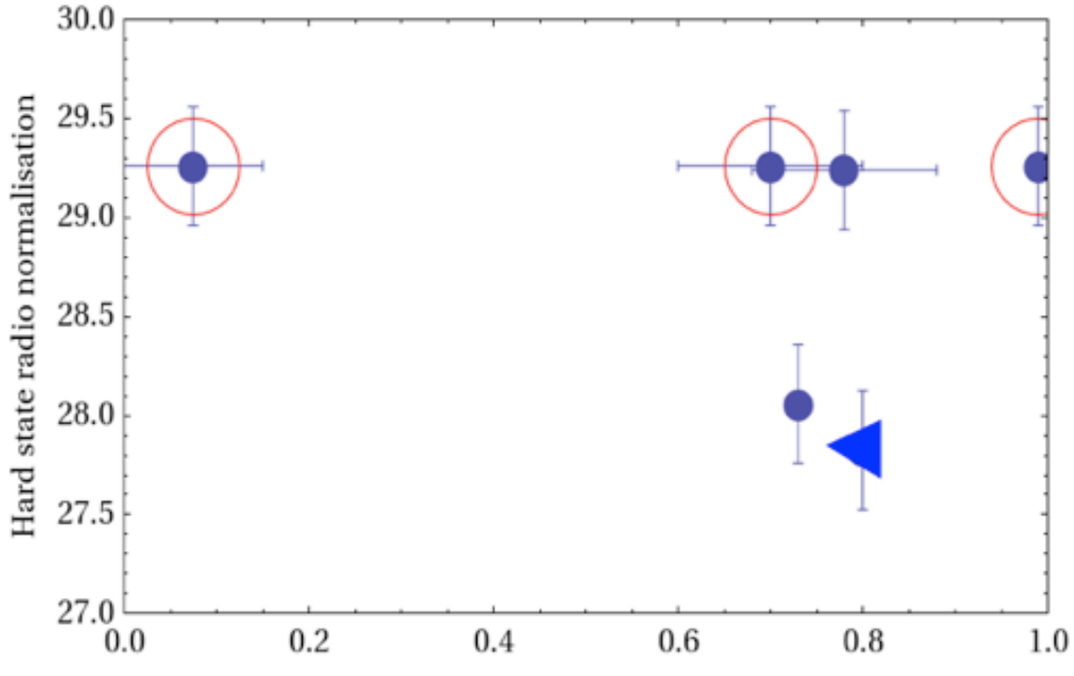

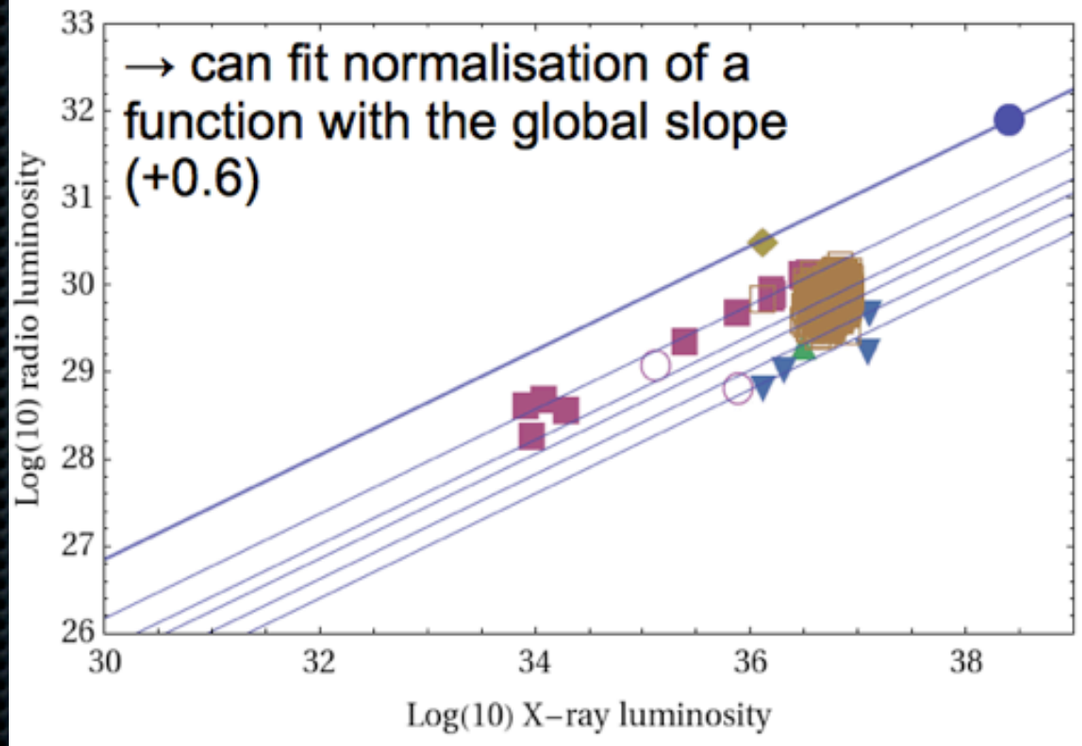

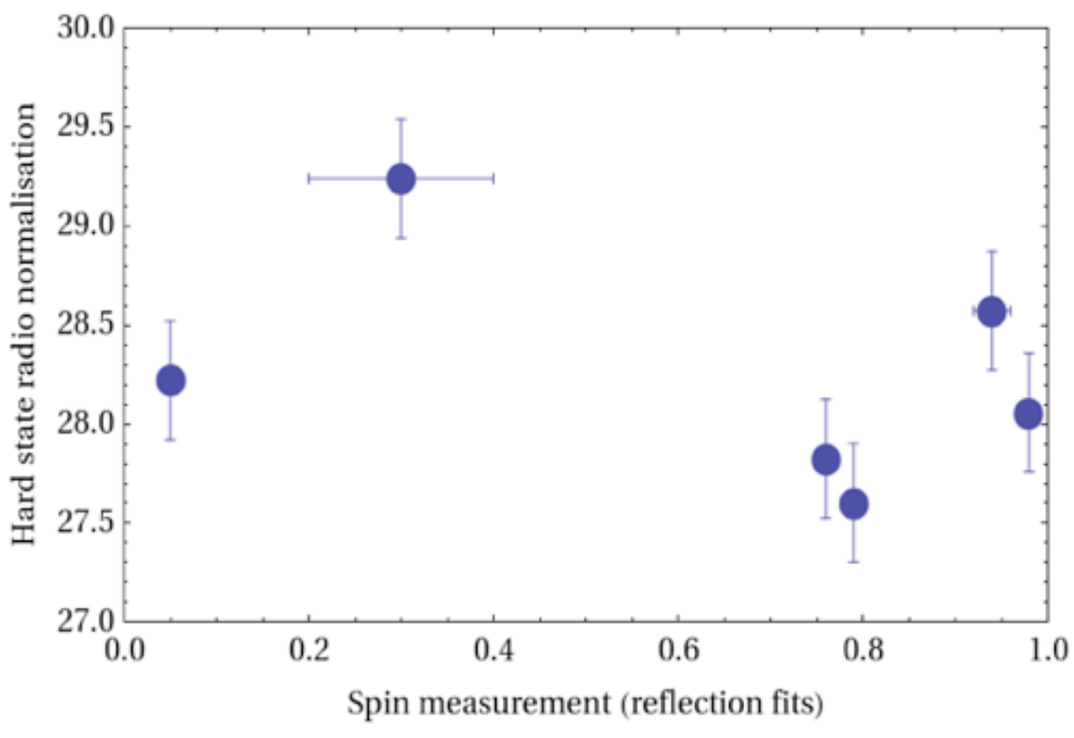

Fender, Gallo & Russell (2010)

Putting it all together: forays into spin vs jet power

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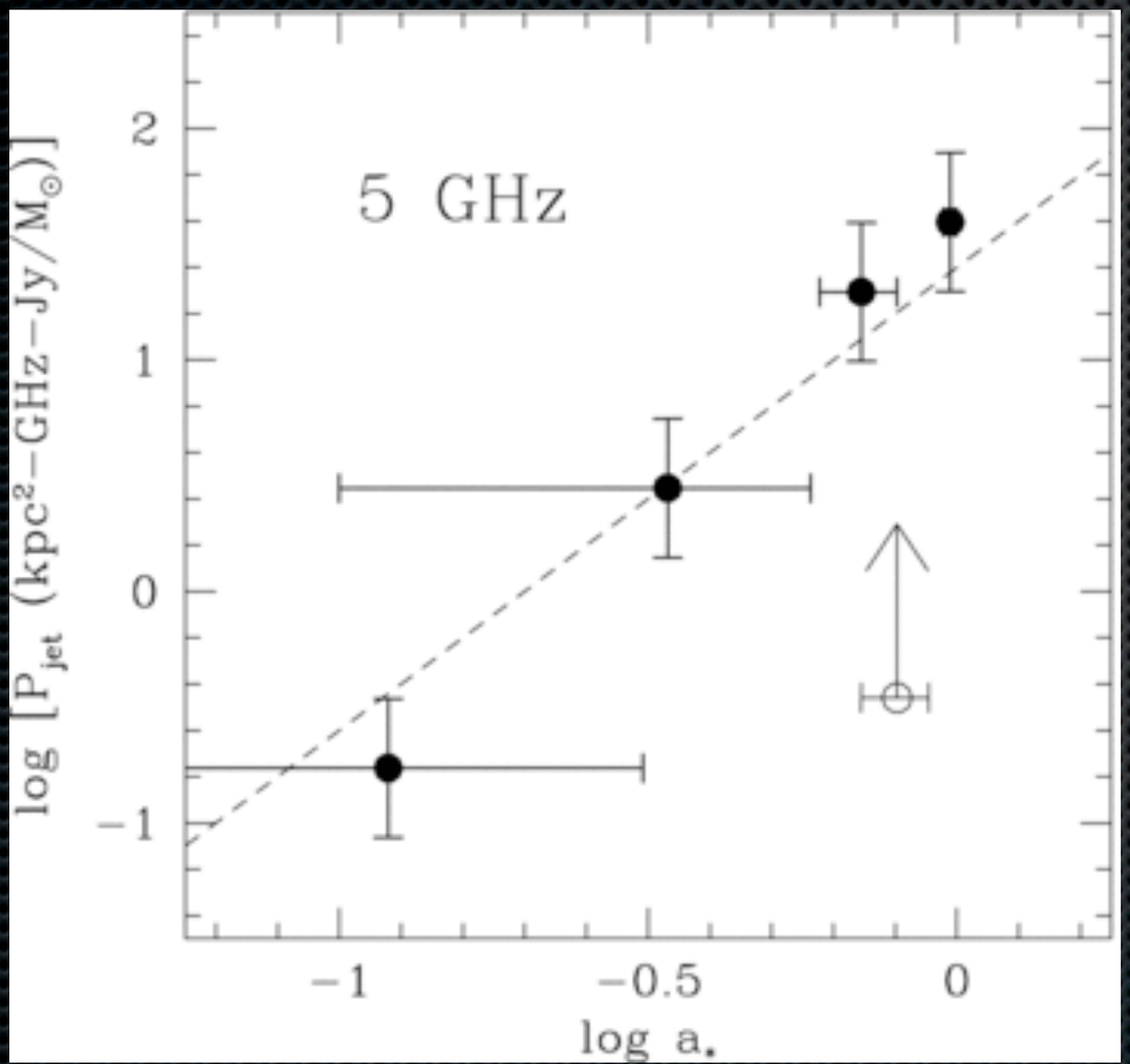
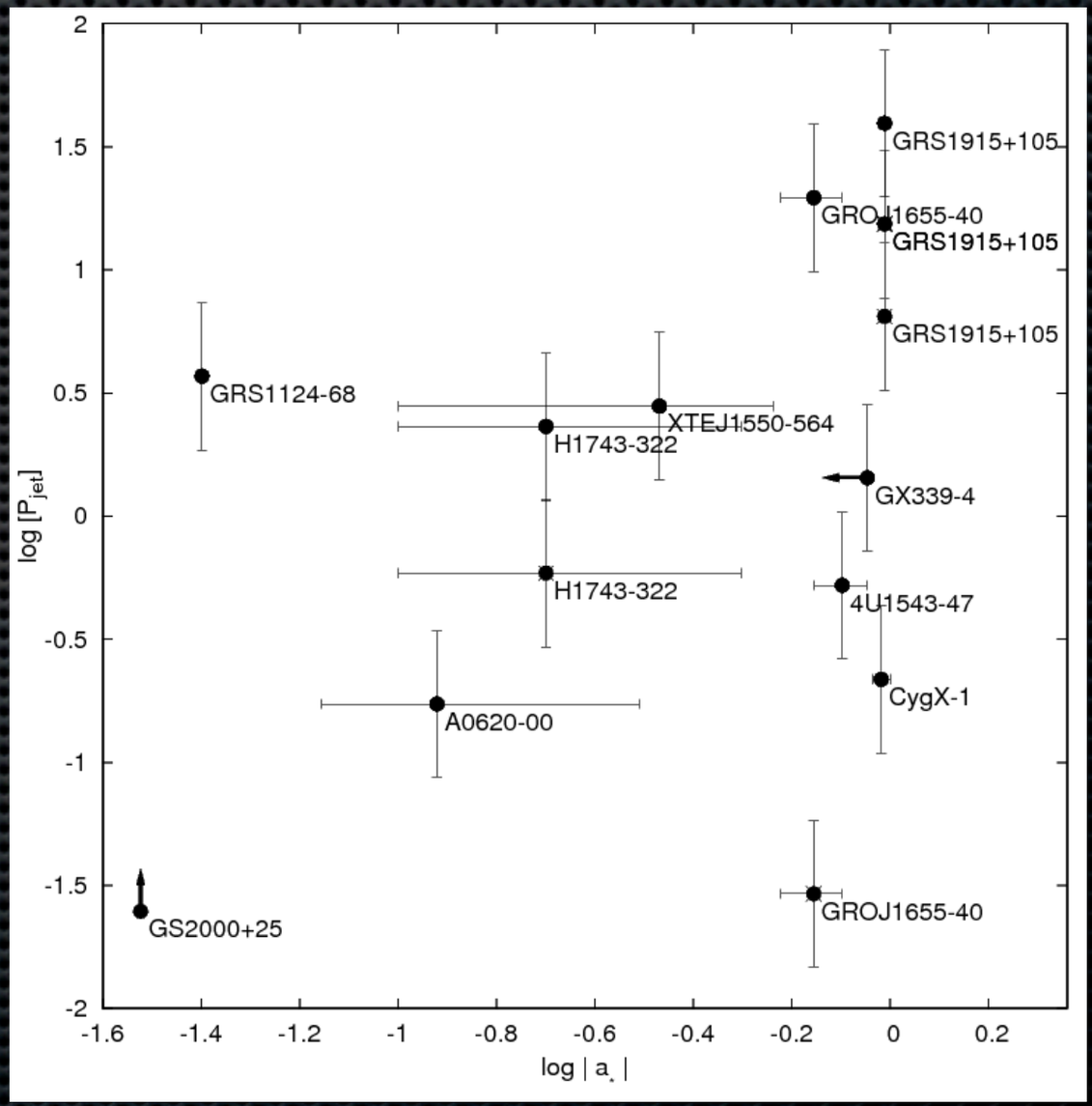


(Narayan & McClintock 2012)



(Russell, Gallo & Fender, in prep.)

Open issues I: any indication of BZ vs BP for XRBs?

(Migliari ea 2006, Heinz ea 2007, Tudose ea. 2008, Soleri ea. 2009a, Soleri ea. 2009b, Sell ea. 2010, Miller-Jones et al. 2012)

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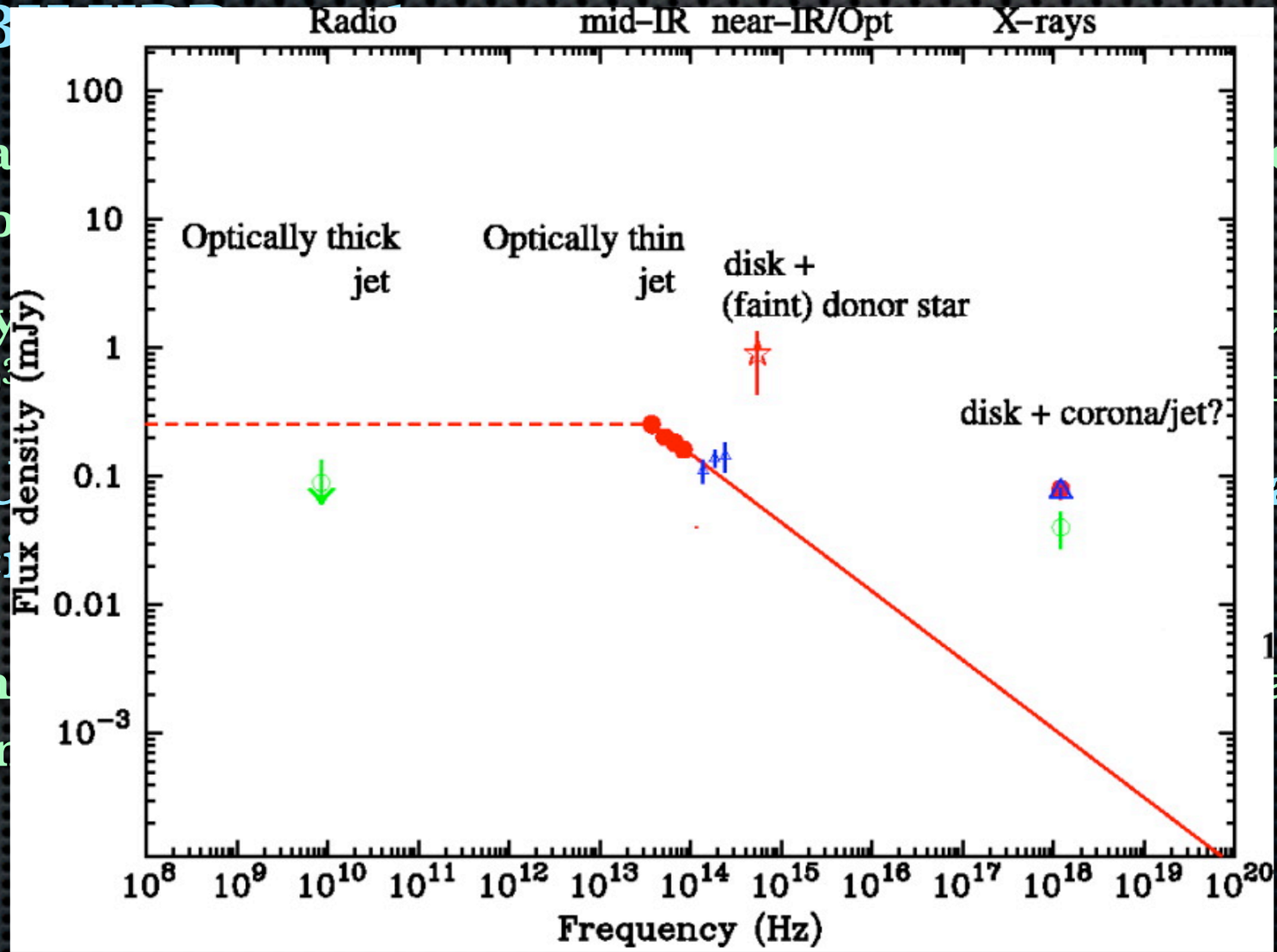

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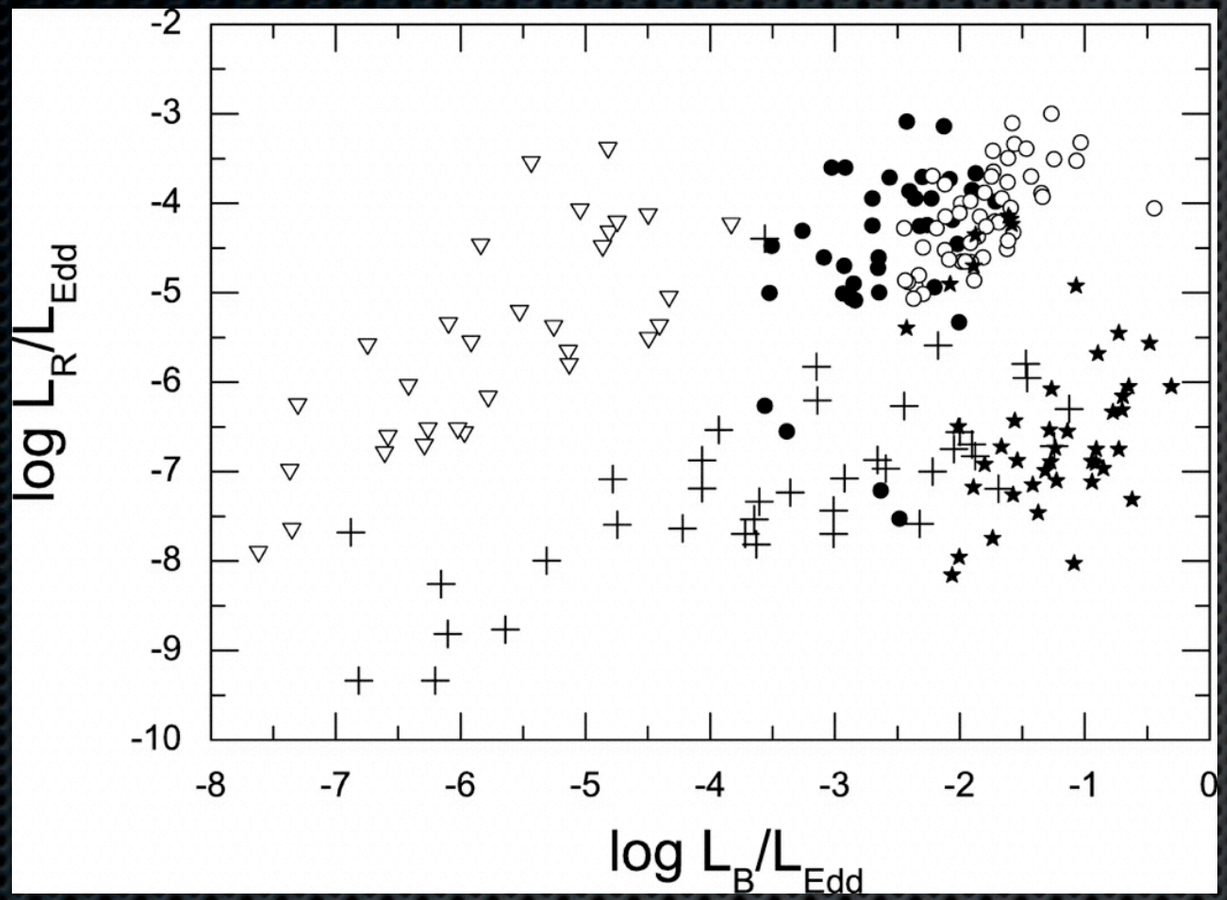
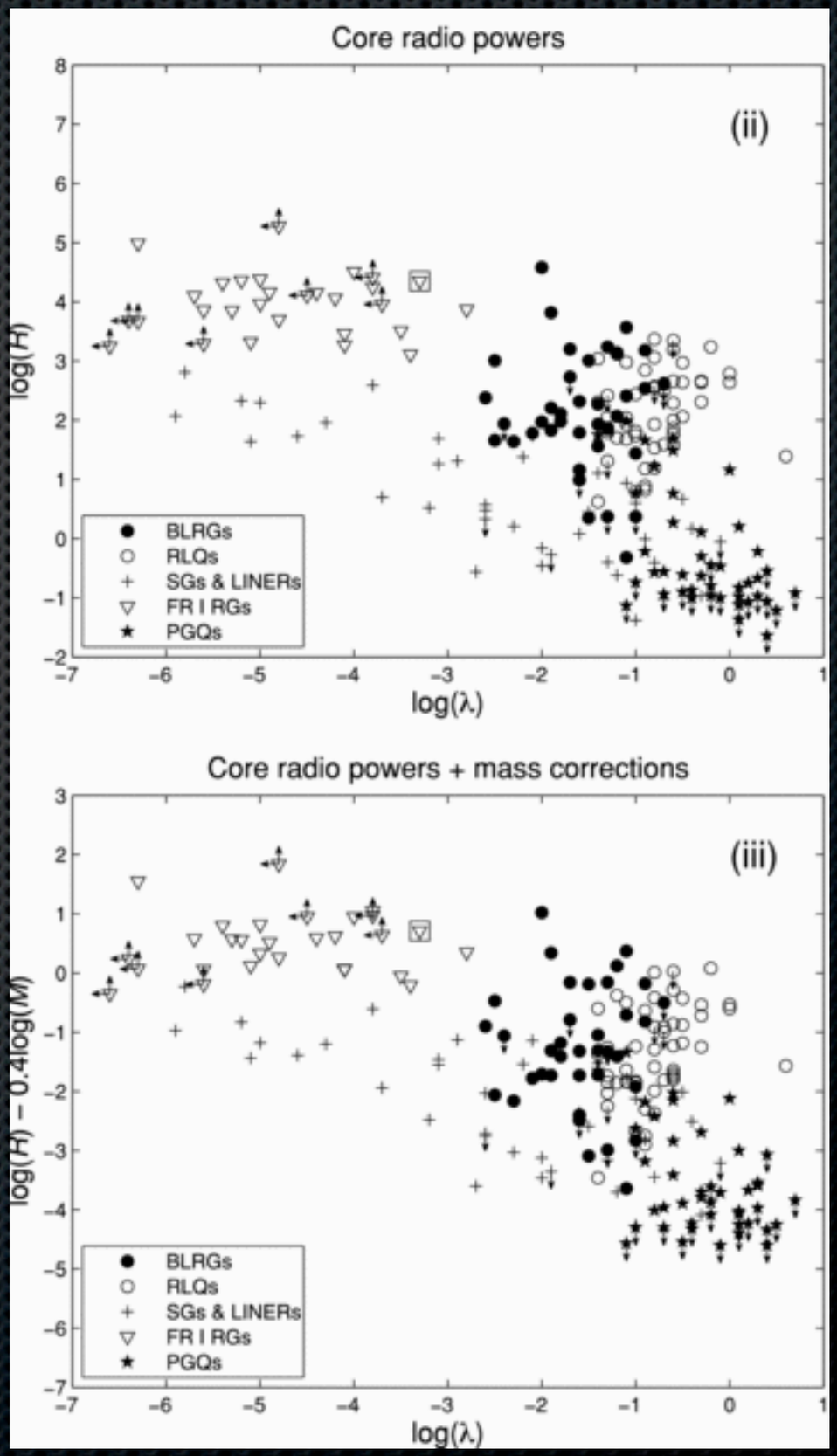
(Migliari ea 2006, Heinz ea 2007, Tudose ea. 2008, Soleri ea. 2009a, Soleri ea. 2009b, Sell ea. 2010, Miller-Jones et al. 2012)

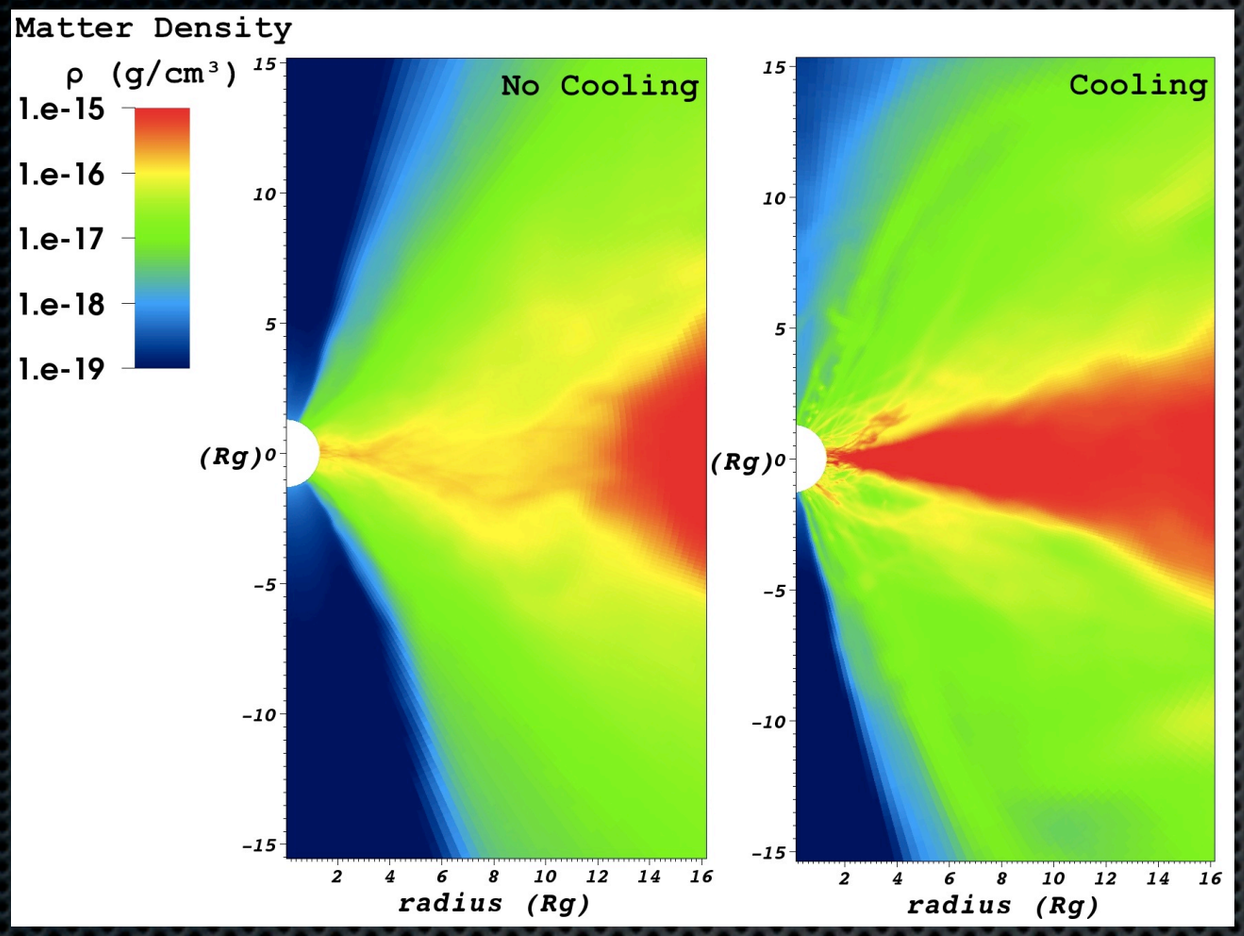
Open Issues II ➠ Do we really need spin power?

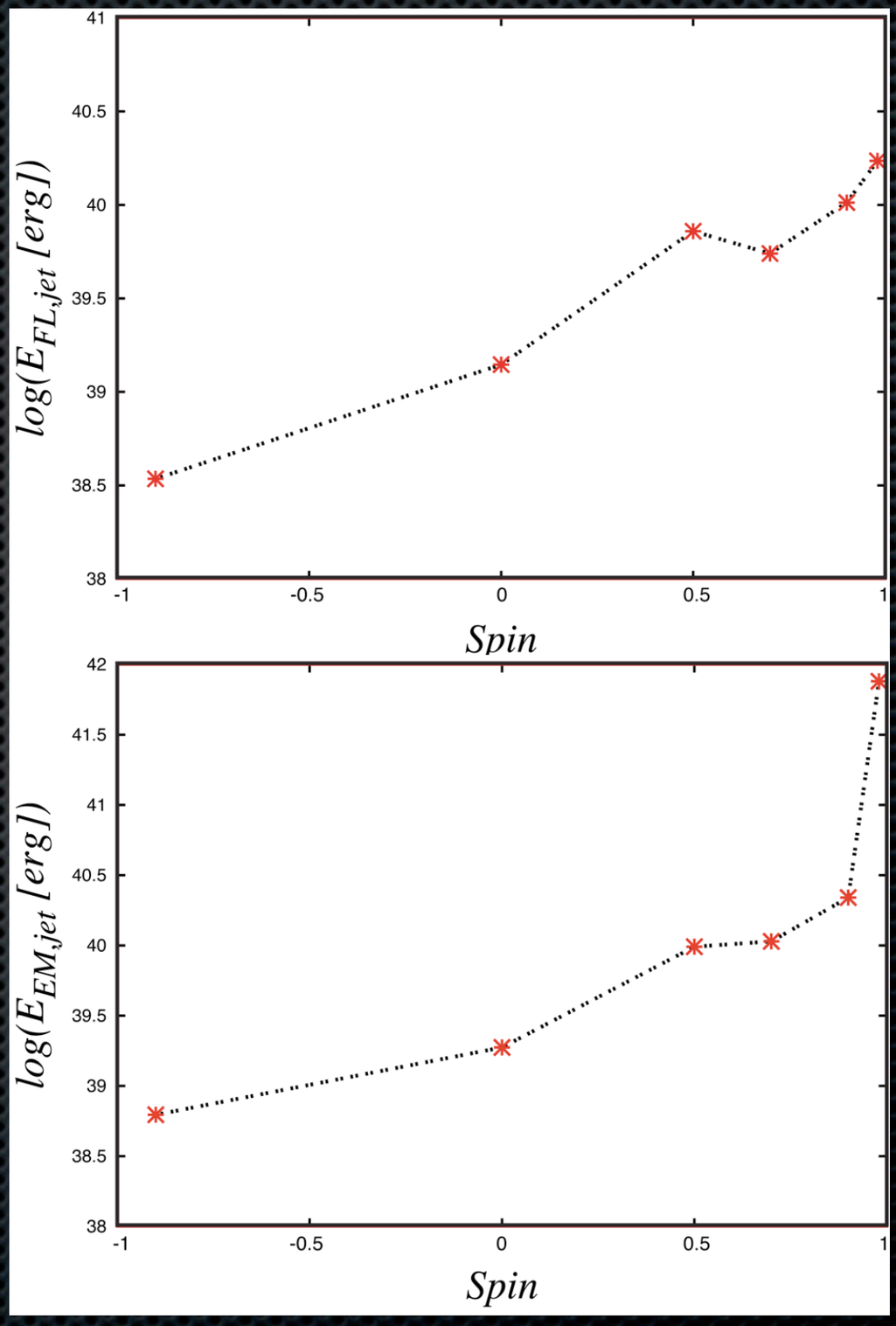




(Sikora, Stawarz & Lasota 2007; Broderick & Fender 2011)

Open Issues III ➠ we still don't understand jets!

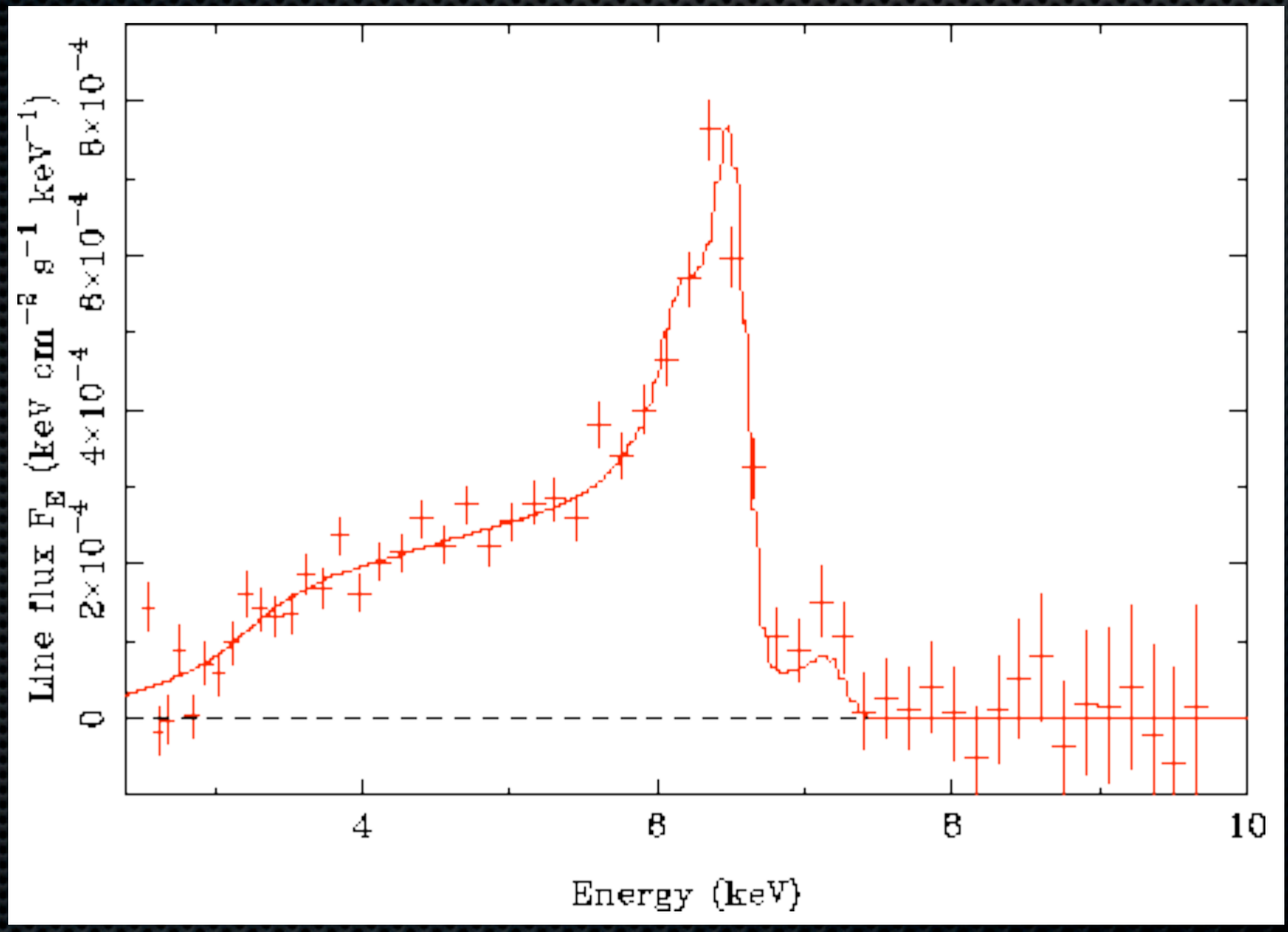




(Dibi, Drappeau et al. 2012, and many others: Krolik++, Koide++, Gammie++, McKinney++, Tchekhovskoy++, Nakamura++, etc.)

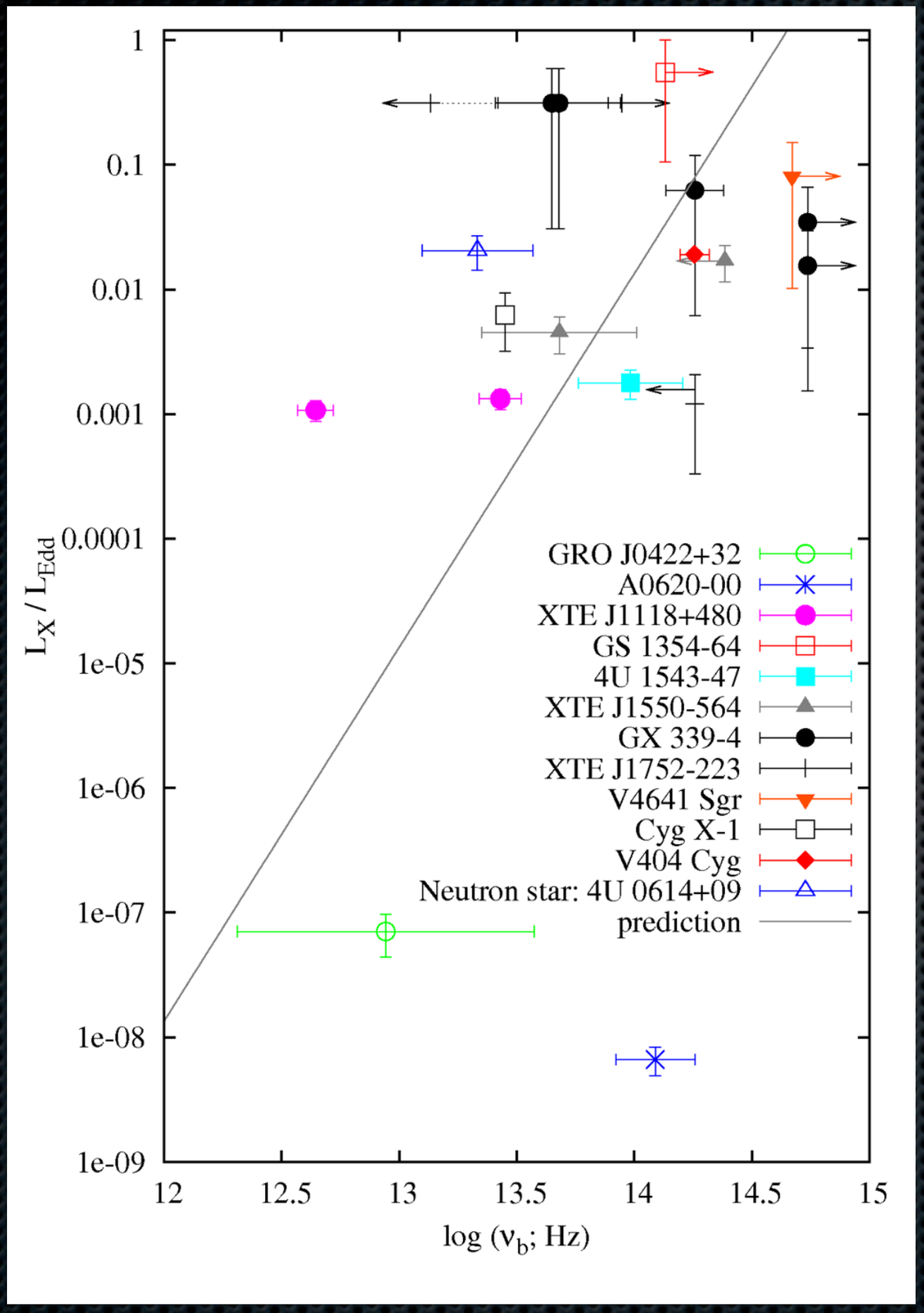
Open Issues IV ➠ MCG 6-30-15

- ★ **The most secure spin measured (in an AGN) is almost maximal, yet associated with a Radio Quiet object??**



(Wilms et al. 2001)

Outlook: Our simplest scaling models may be too simplistic



(Russell ea. in prep., SM ea. in prep)

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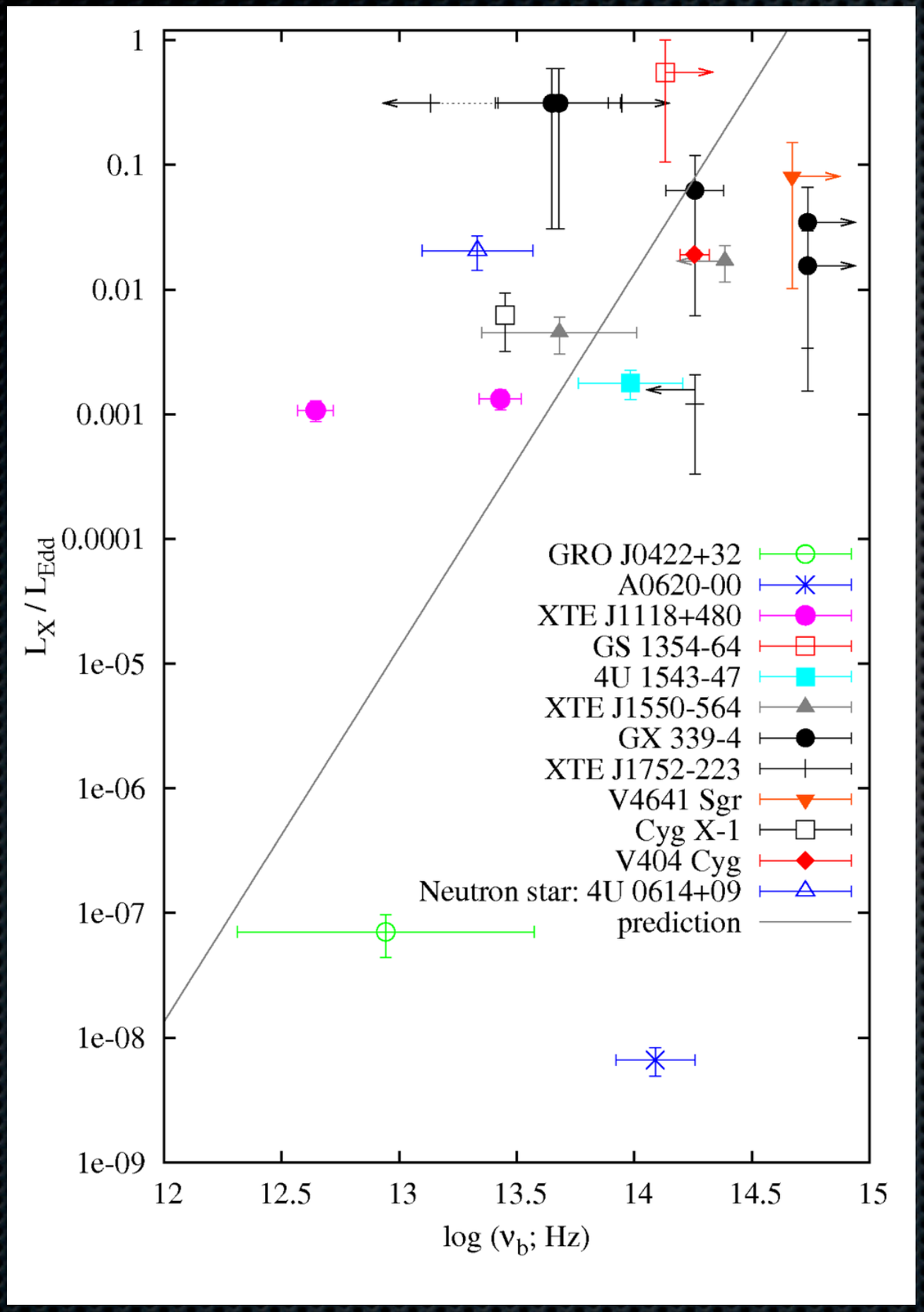
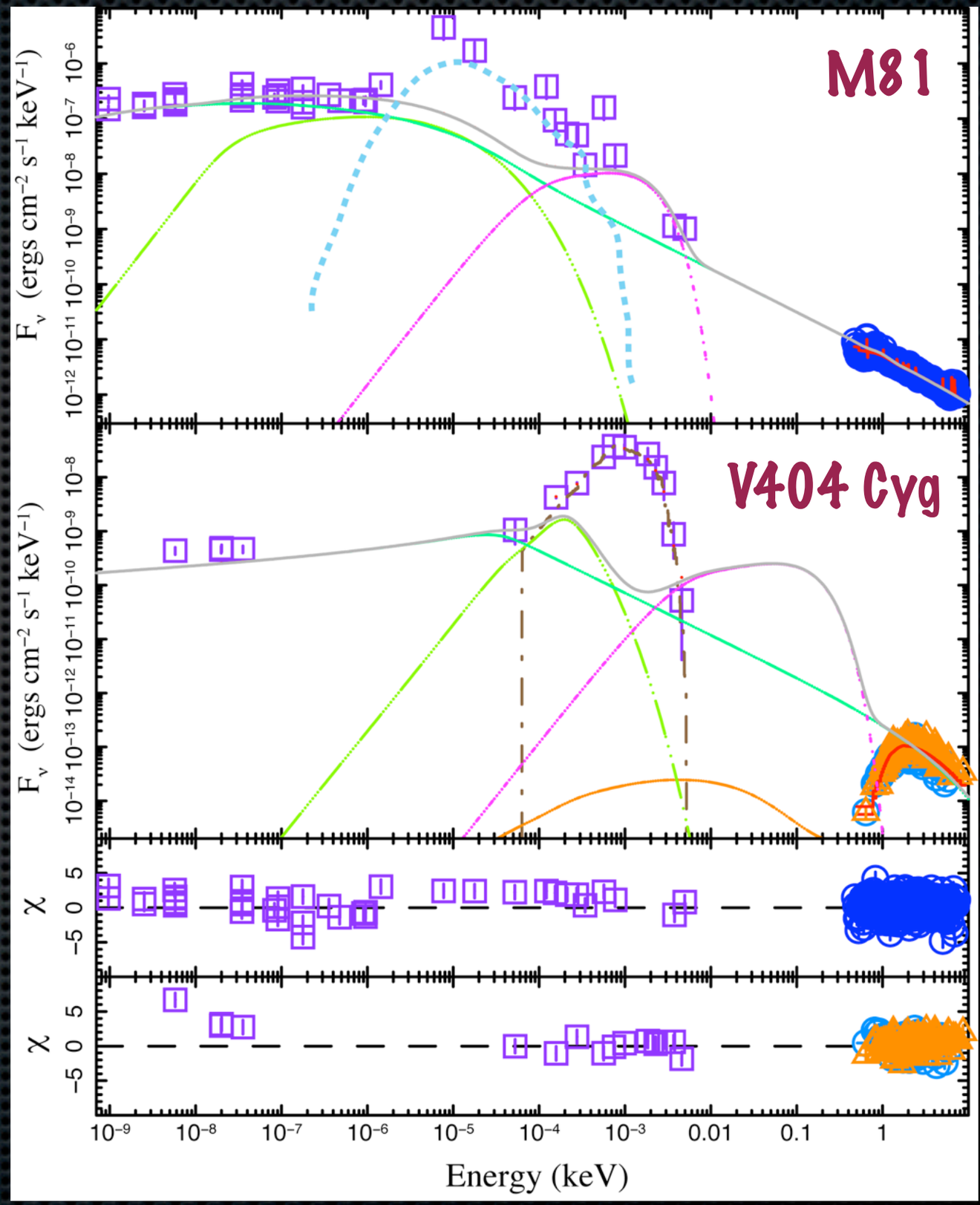
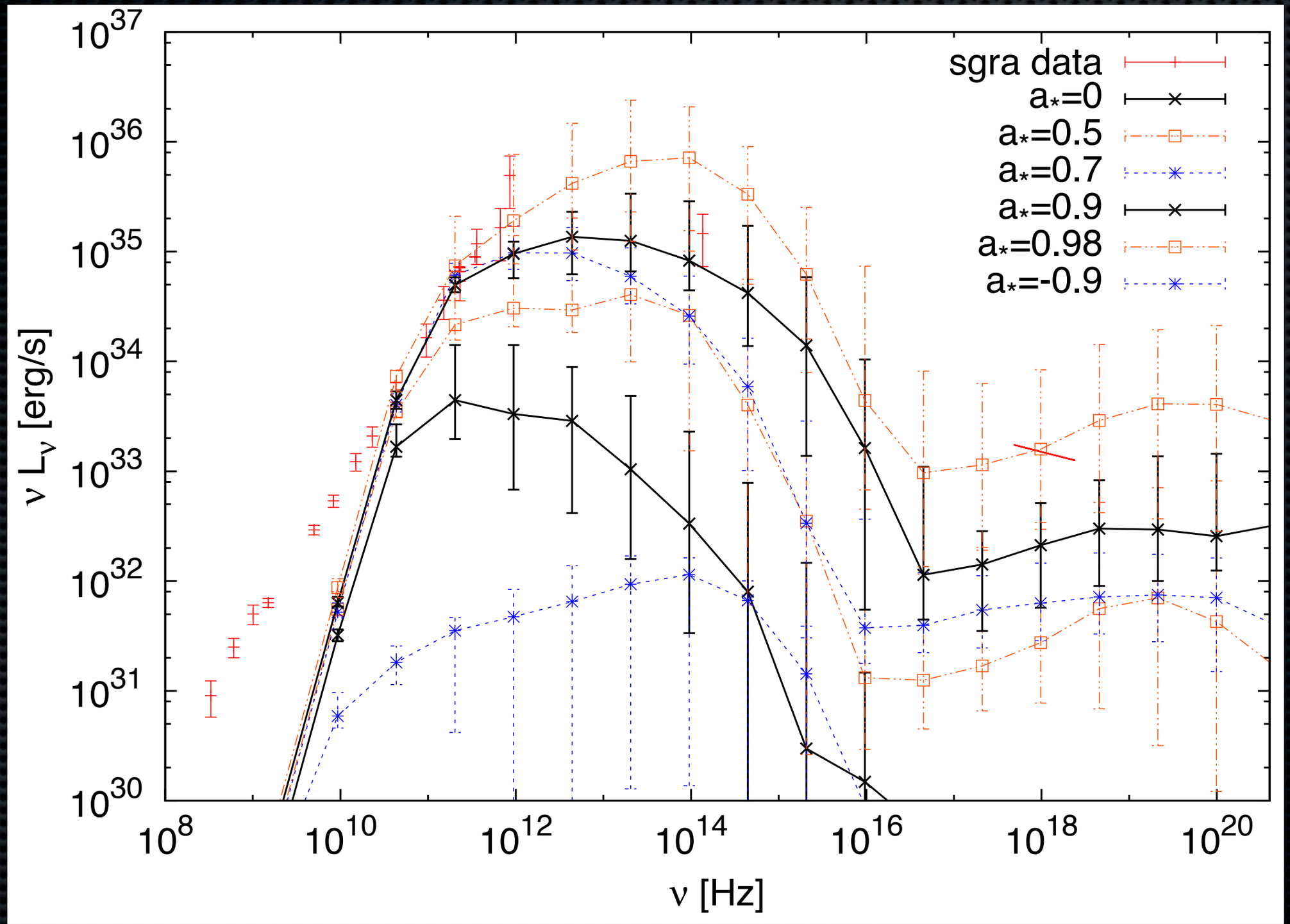




(Russell ea. in prep., SM ea. in prep)

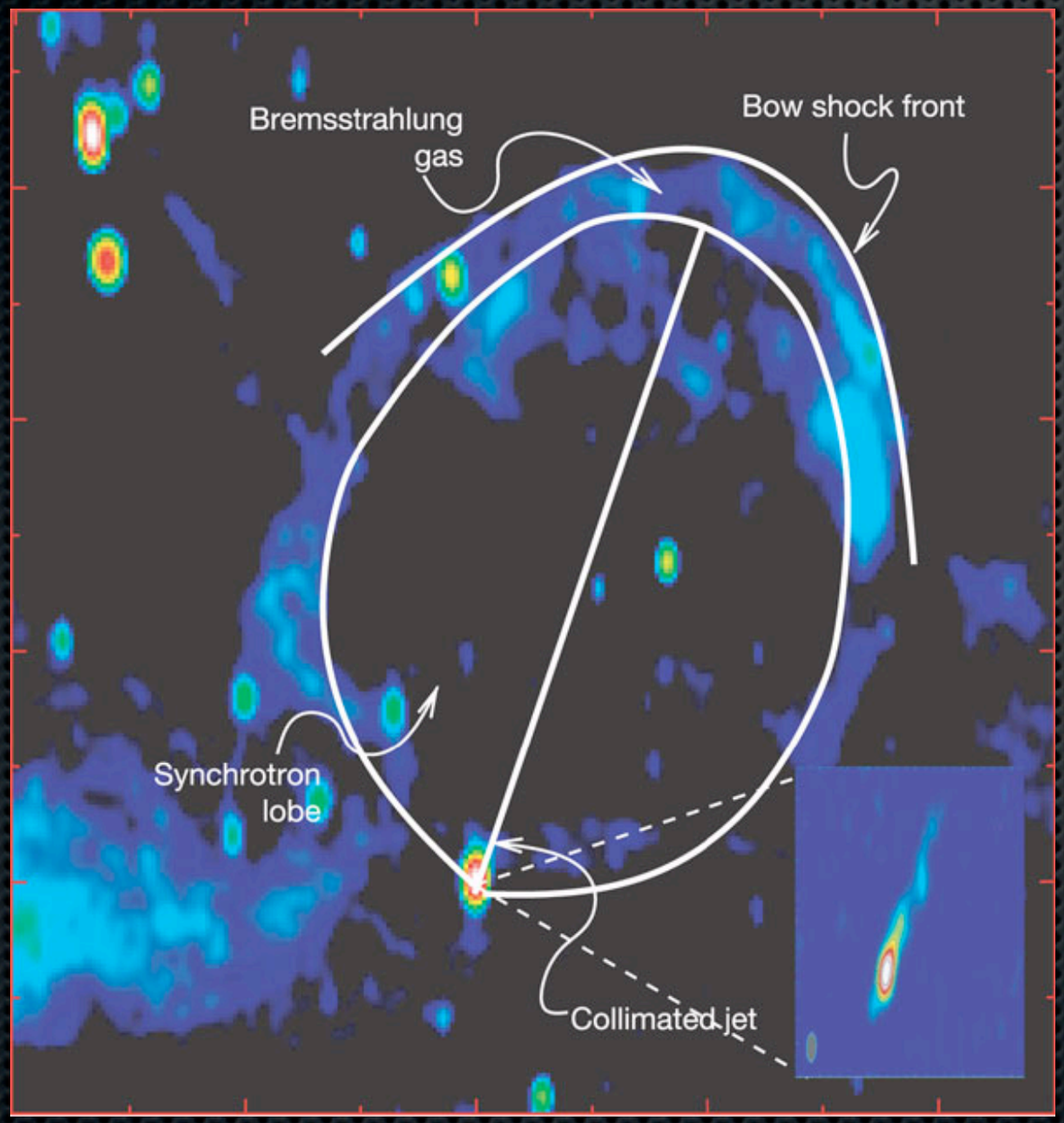
New spin probes using event horizon physics (AGN)

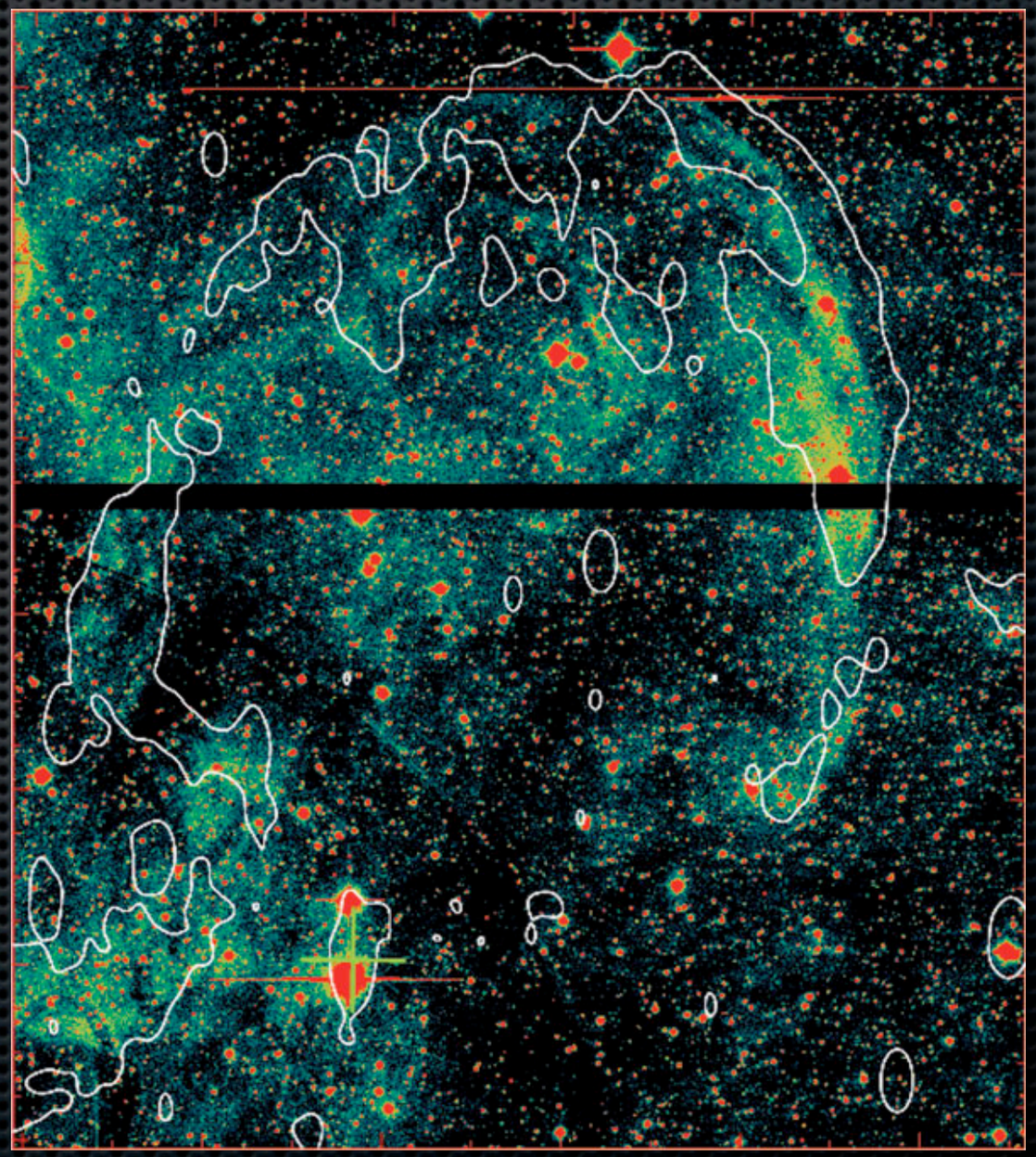


(Drappeau, Dibi, Dexter, SM & Fragile, in prep.)

Using the environment as a "calorimeter"

- Cyg X-1 bubbles imply power in jets ~100x greater than L_{radio} [and see Paul Sell's talk!], other nebulae are starting to be detected





(Gallo et al. 2005, Russell et al. 2006)

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- Jets are the vehicles for transporting black hole-released accretion power, important for understanding relation to event horizon physics
- Jets play a significant role in the power output of XRBs, increasingly dominating as luminosity decreases
- XRBs are key for jet studies: offer both real-time evolution and two ways to measure spin, results likely to apply also to AGN
- Jet power vs. spin: it's complicated! Clear relation predicted by theory but not so obvious from data so far, very important to settle!
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- Outlook:

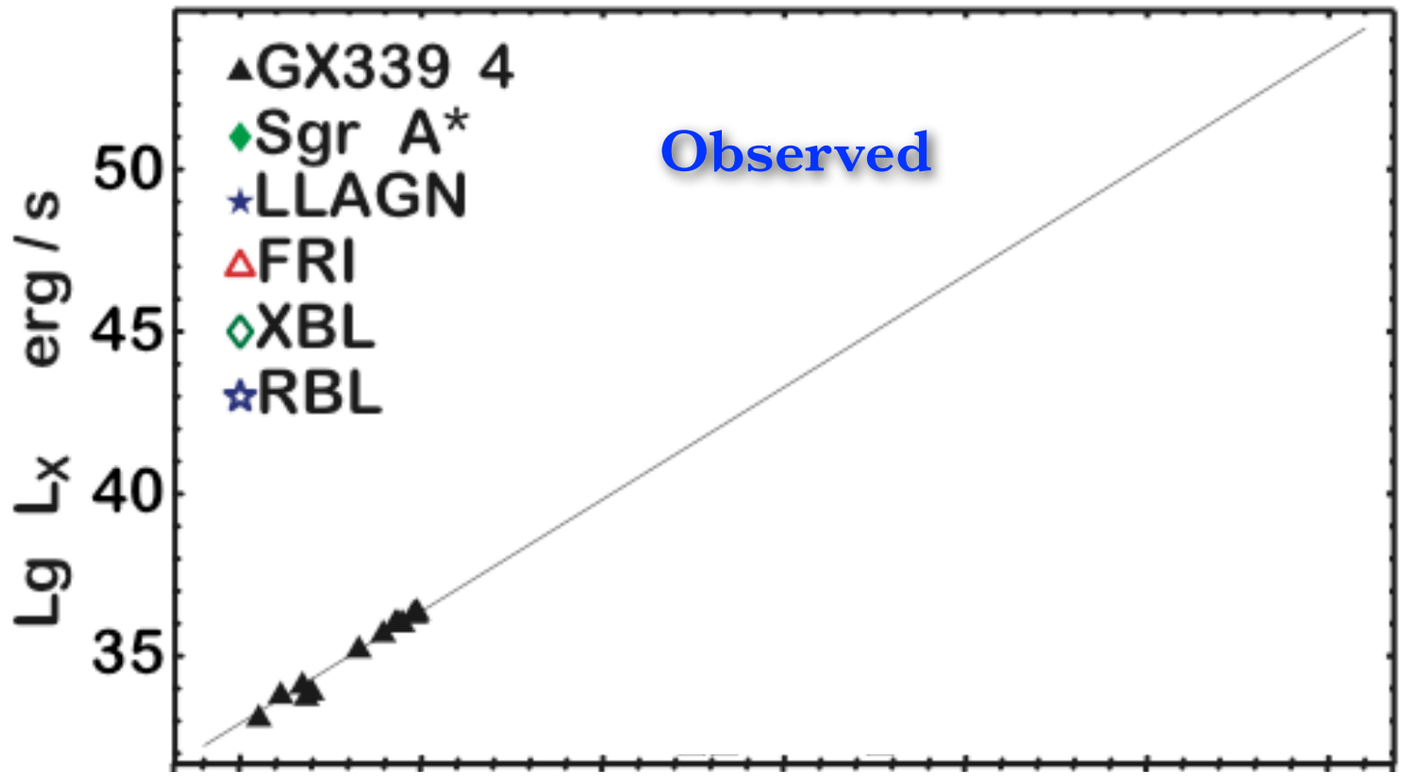
➠ Improved models/simulations: need to "capture" jet physics better

➠ New facilities: ALMA, "transient factories":LOFAR/MeerKAT/ ASKAP/LSST (but sadly, no RXTE), NuSTAR, an X-ray polarimeter??

➠ XRB jet feedback: ionization, Galactic/low-energy cosmic rays ➠ rather unexplored territory and transient monitoring studies pave the way towards understanding the effect of the entire population

Extra slides

Fundamental plane of BH accretion



(SM et al. 2003, Merloni,Heinz & diMatteo 2003, Falcke, Körding & SM 2004, SM 2005, Merloni et al. 2006, Kording et al. 2006)

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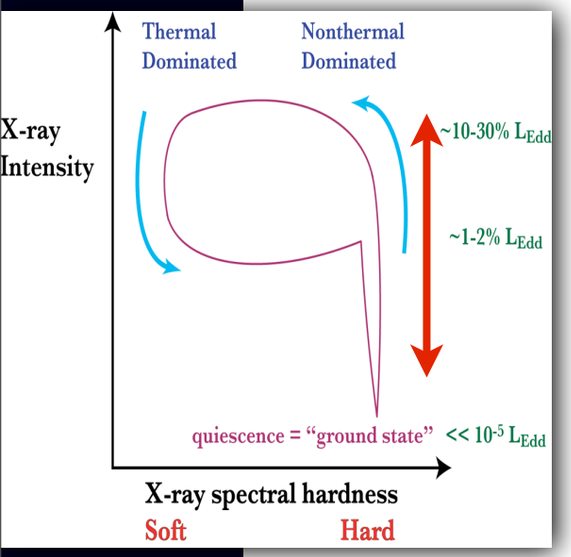

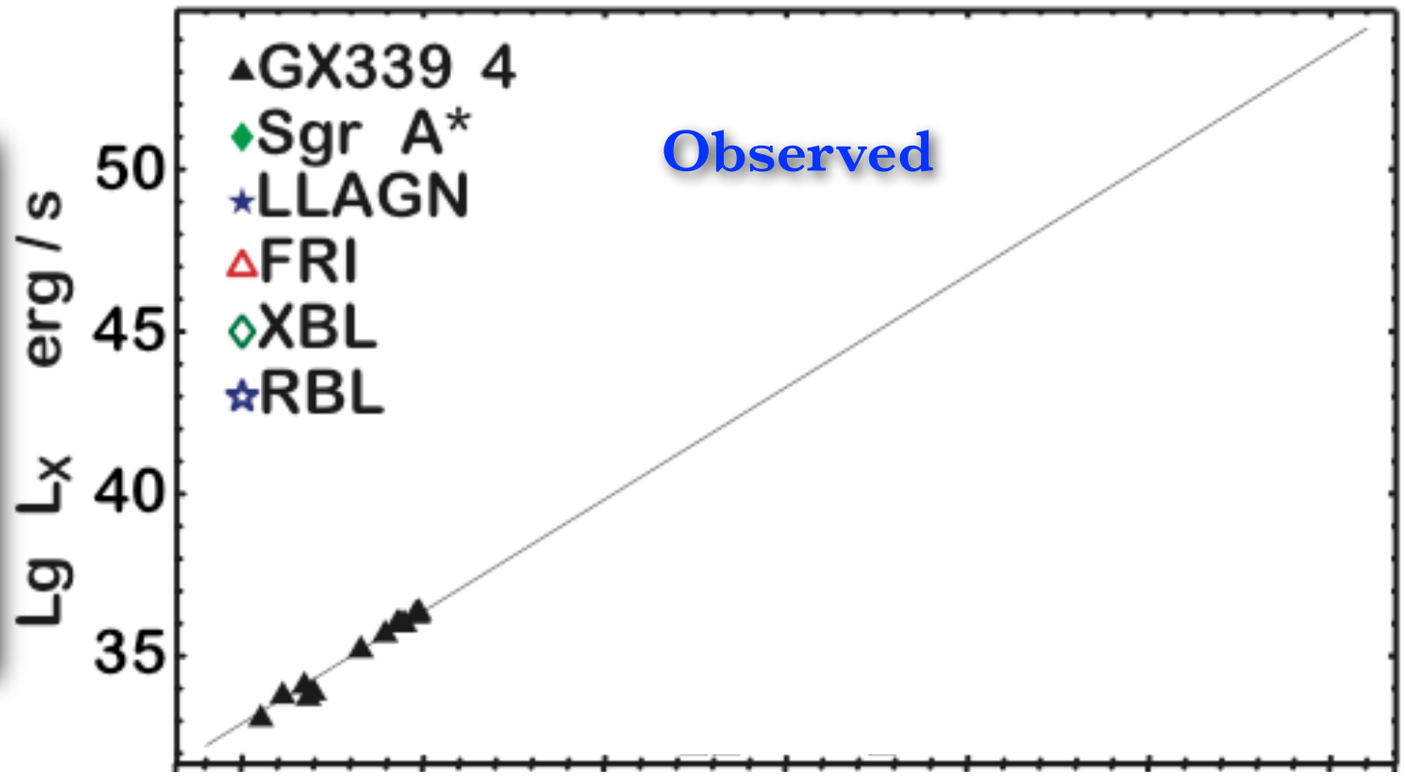

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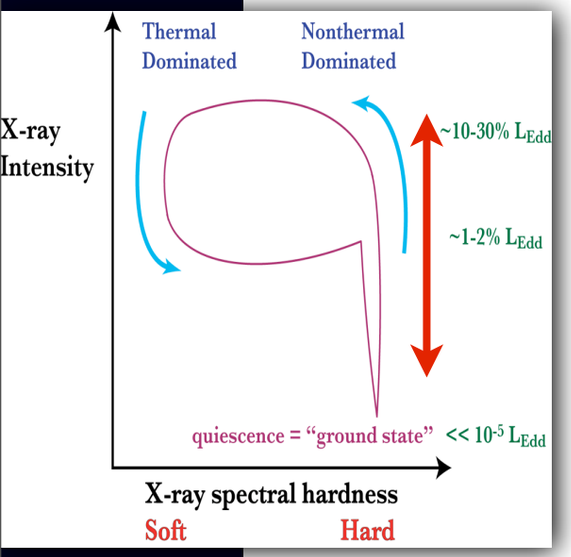

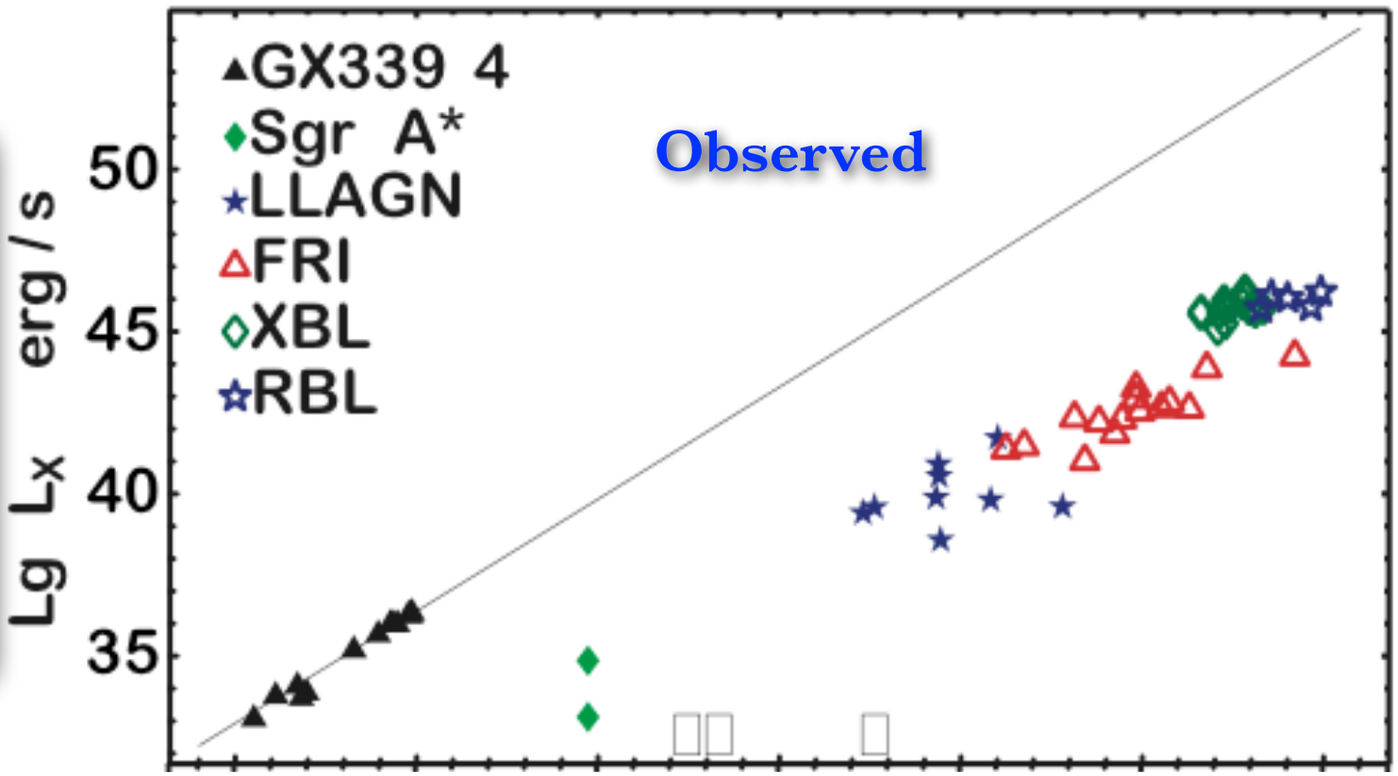

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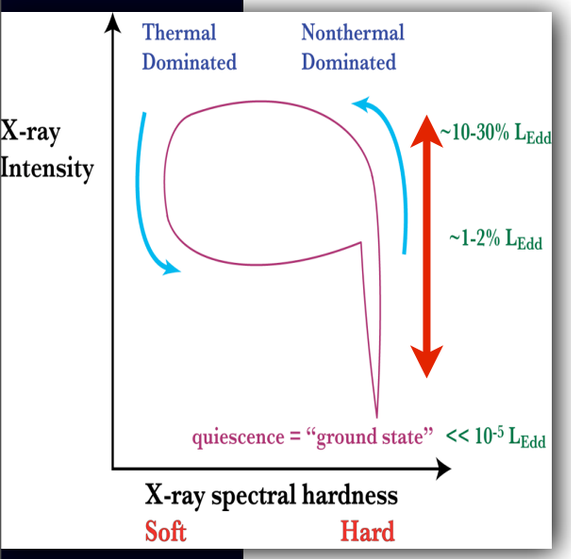

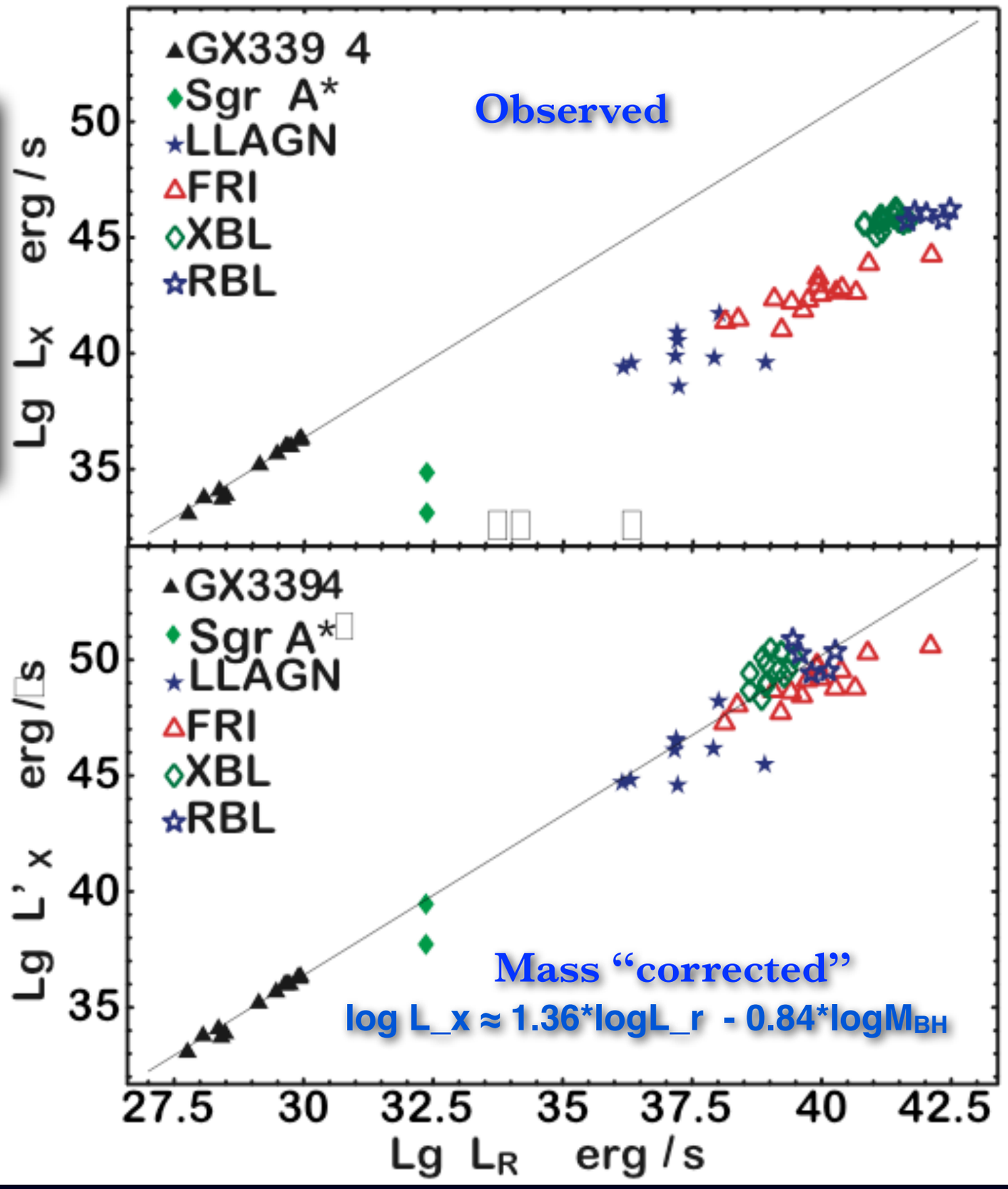

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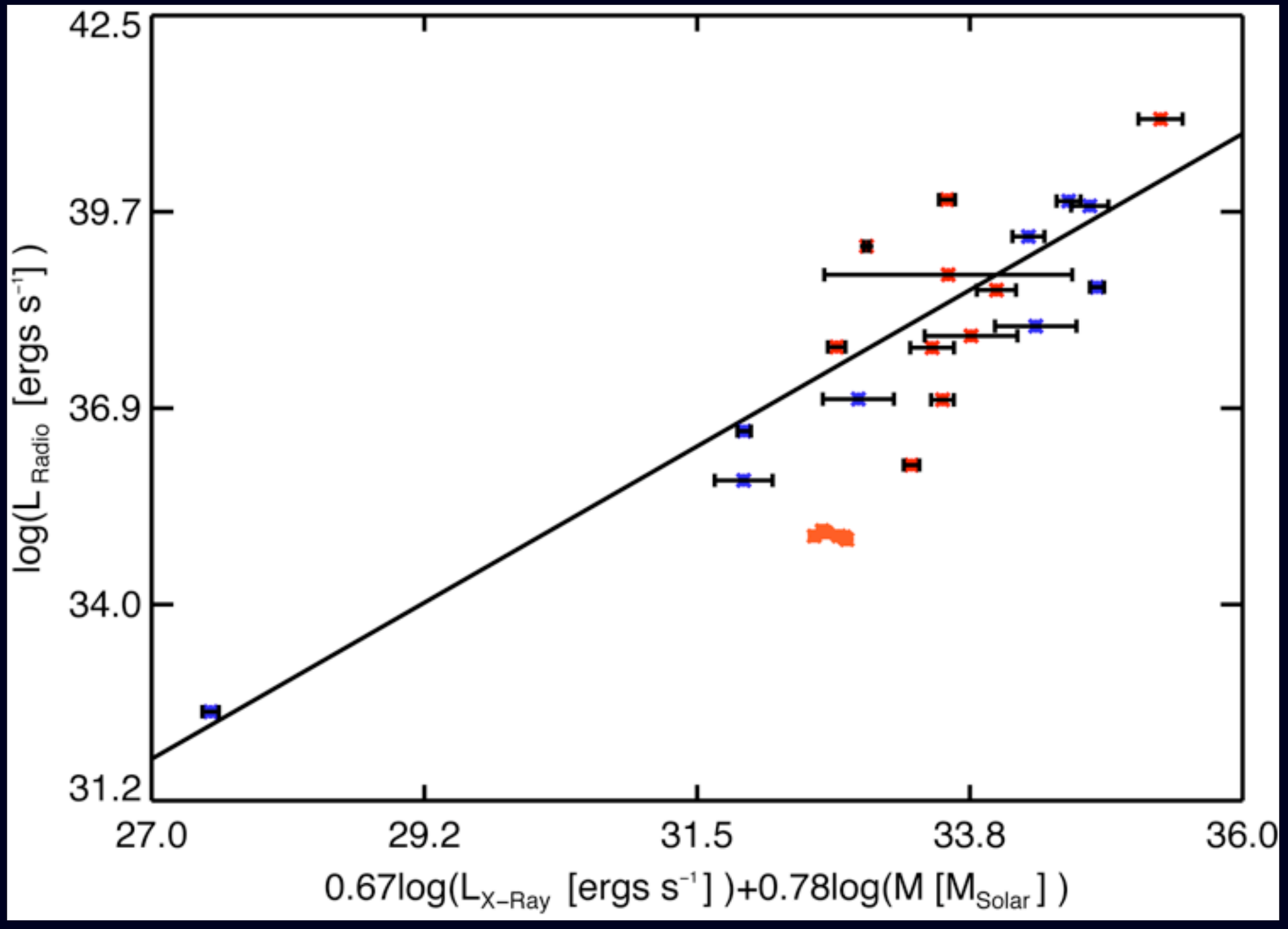
Scatter from error in masses, or by including Seyferts? M-σ sources only:



(Gültekin et al. 2009, King et al. 2011)

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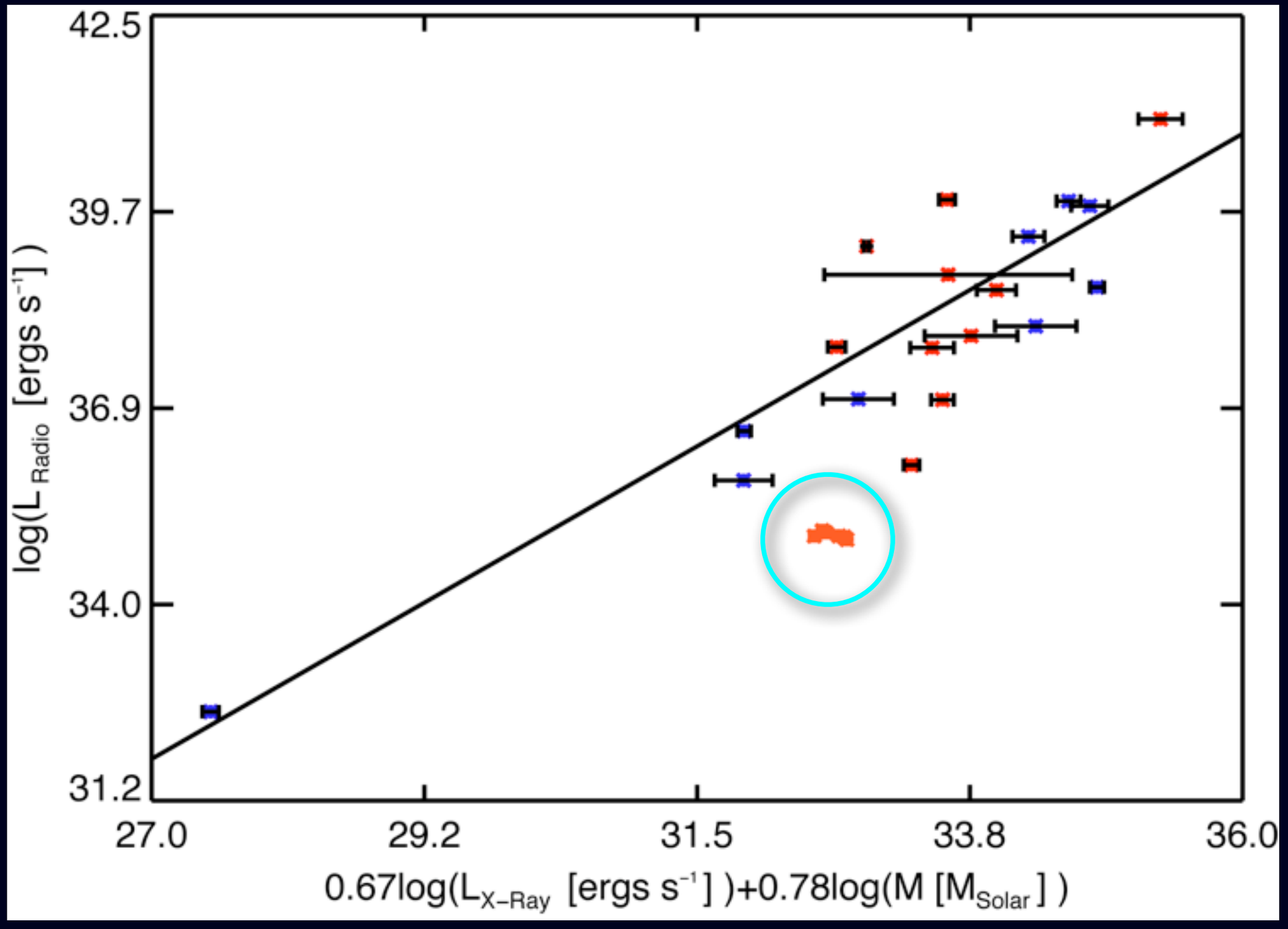

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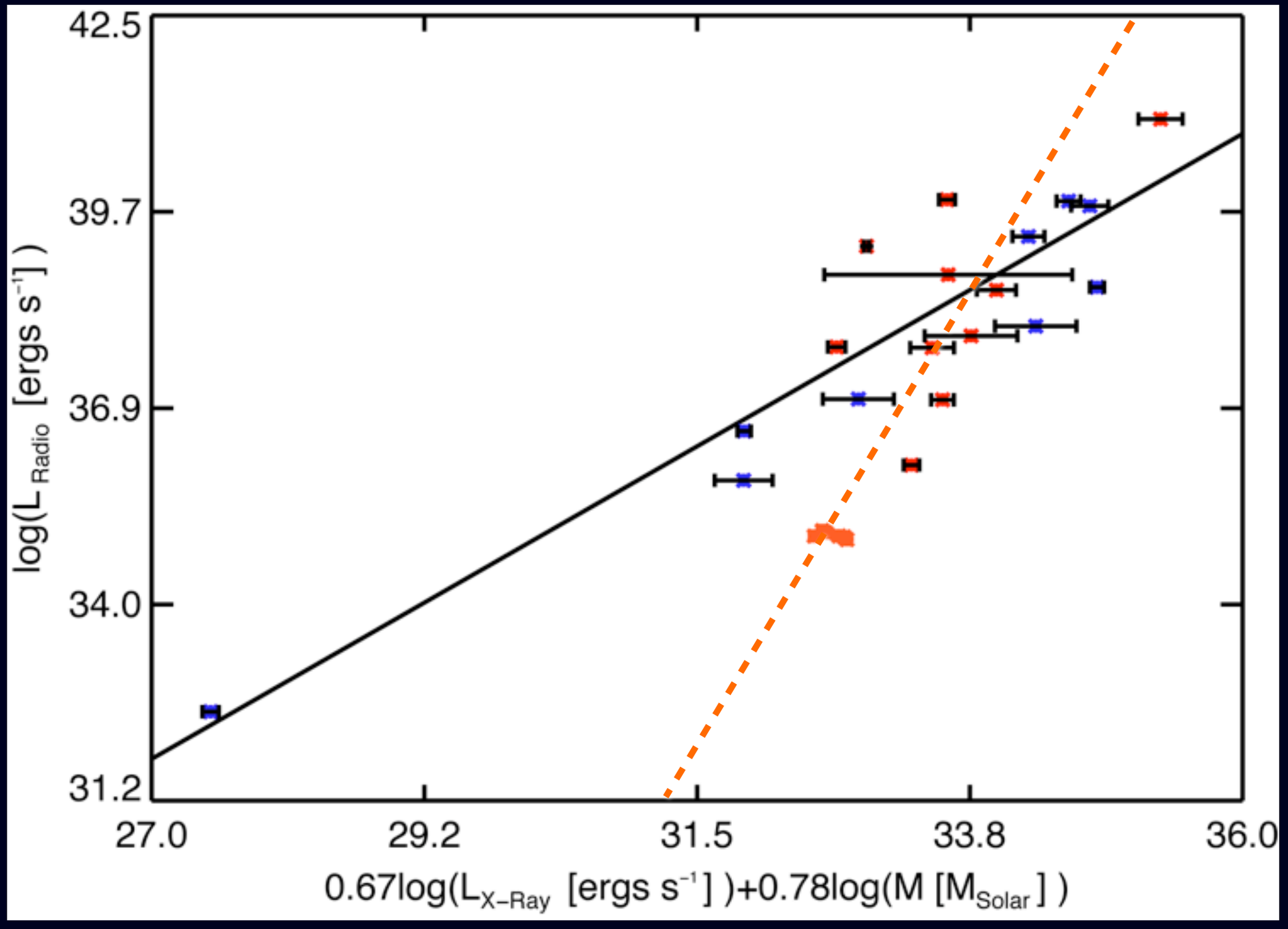

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