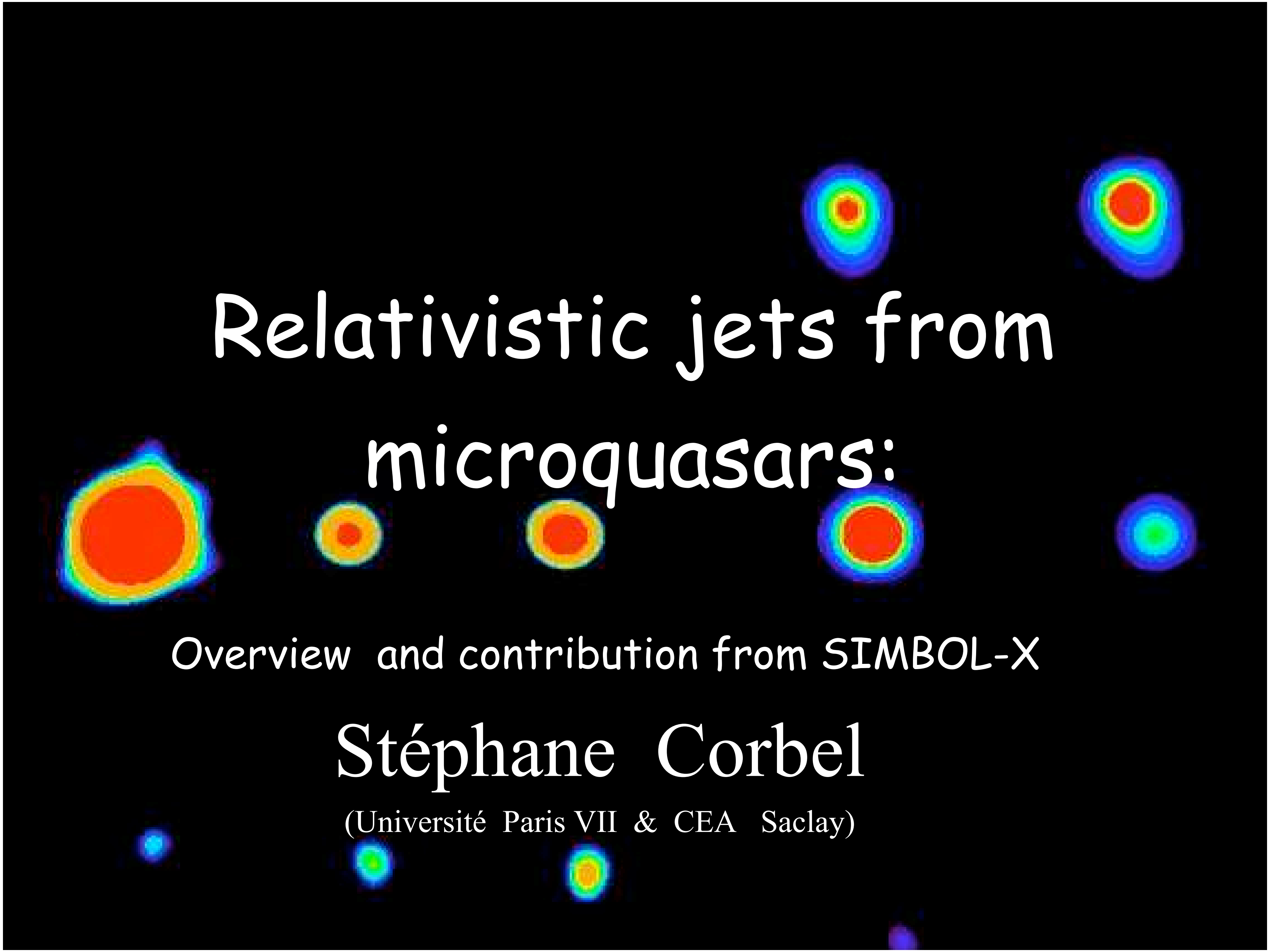
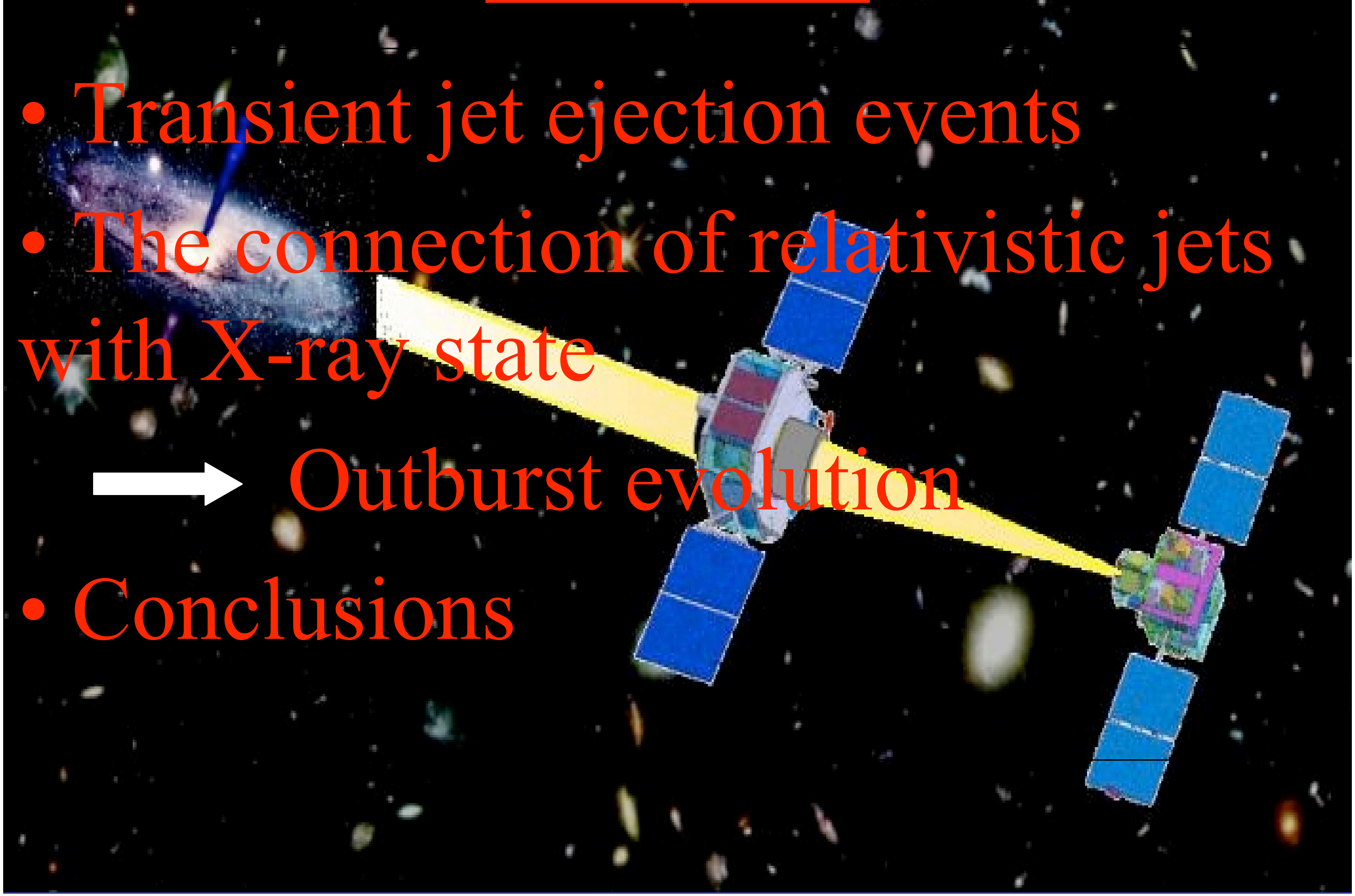

Relativistic jets from microquasars:
Overview and contribution from SIMBOL-X
Stéphane Corbel
(Université Paris VII & CEA Saclay)

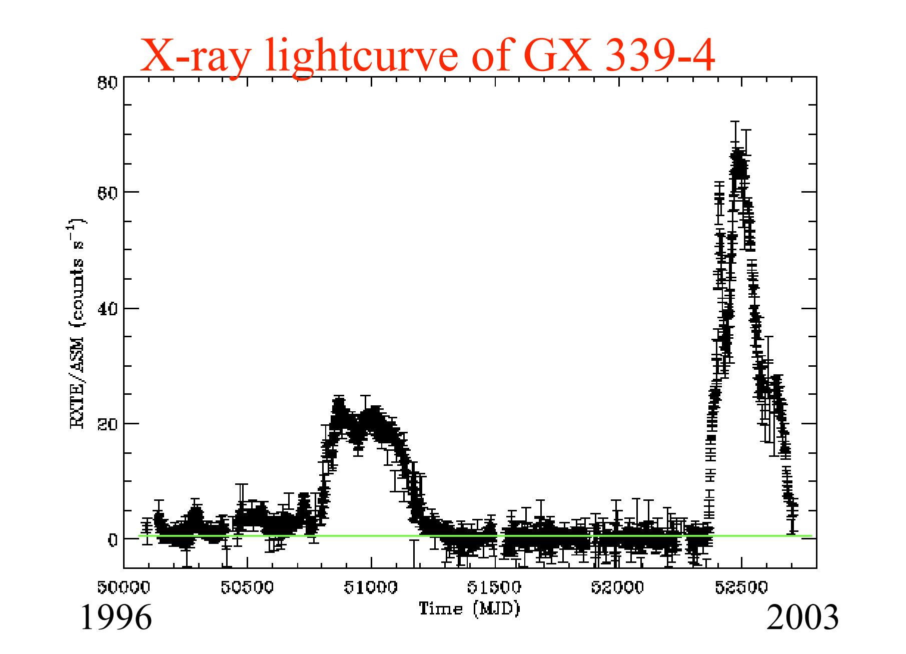
# Outline

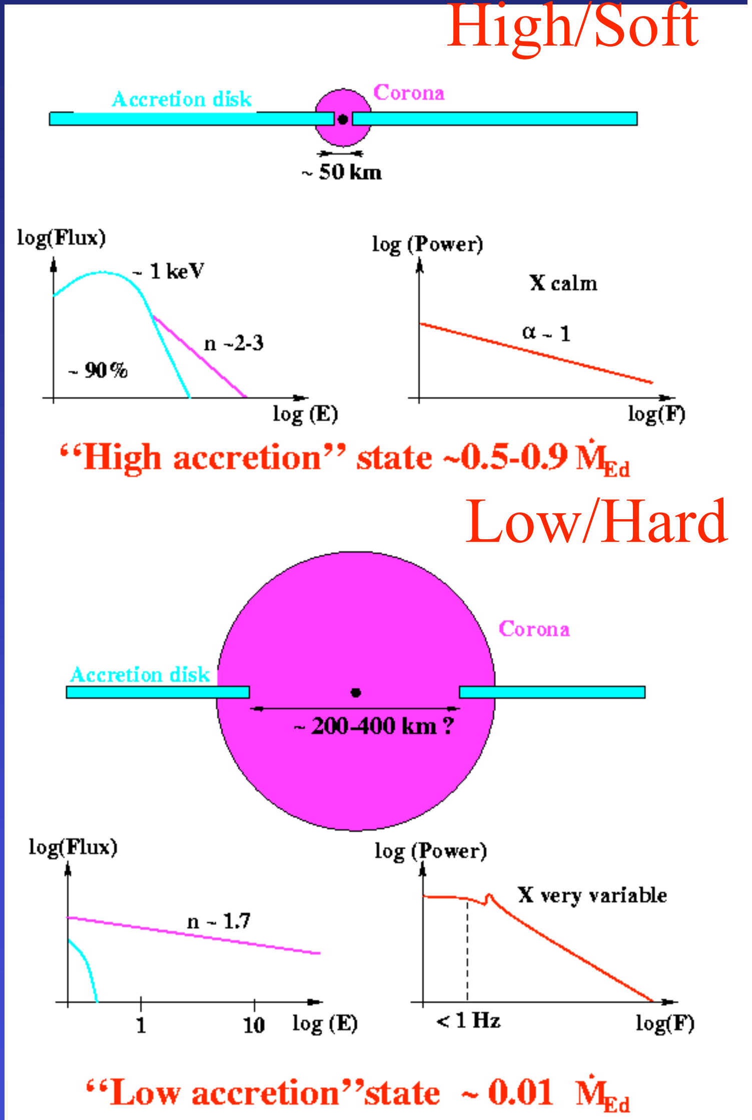


- Transient jet ejection events
- The connection of relativistic jets with X-ray state

  → Outburst evolution
- Conclusions

# Time variability & X-ray state

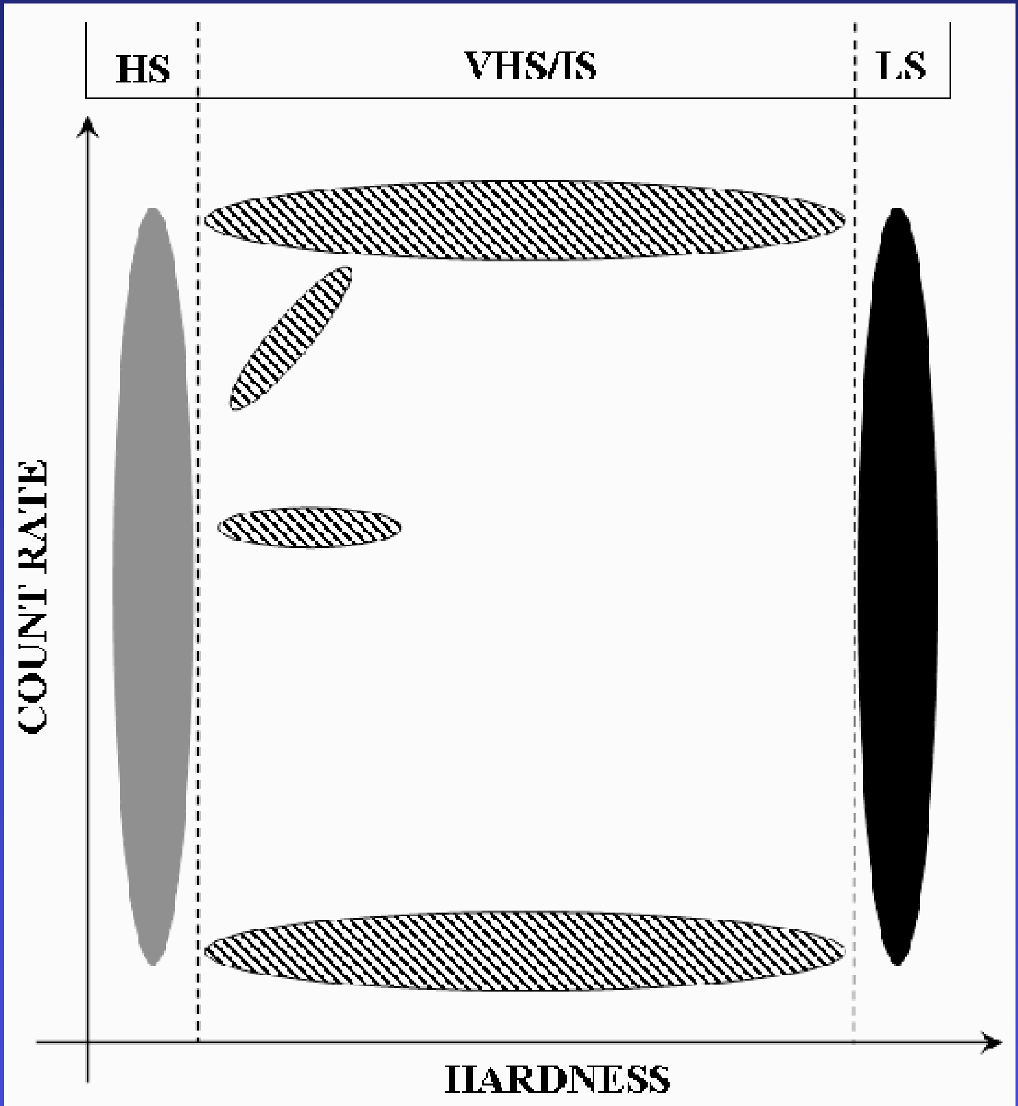


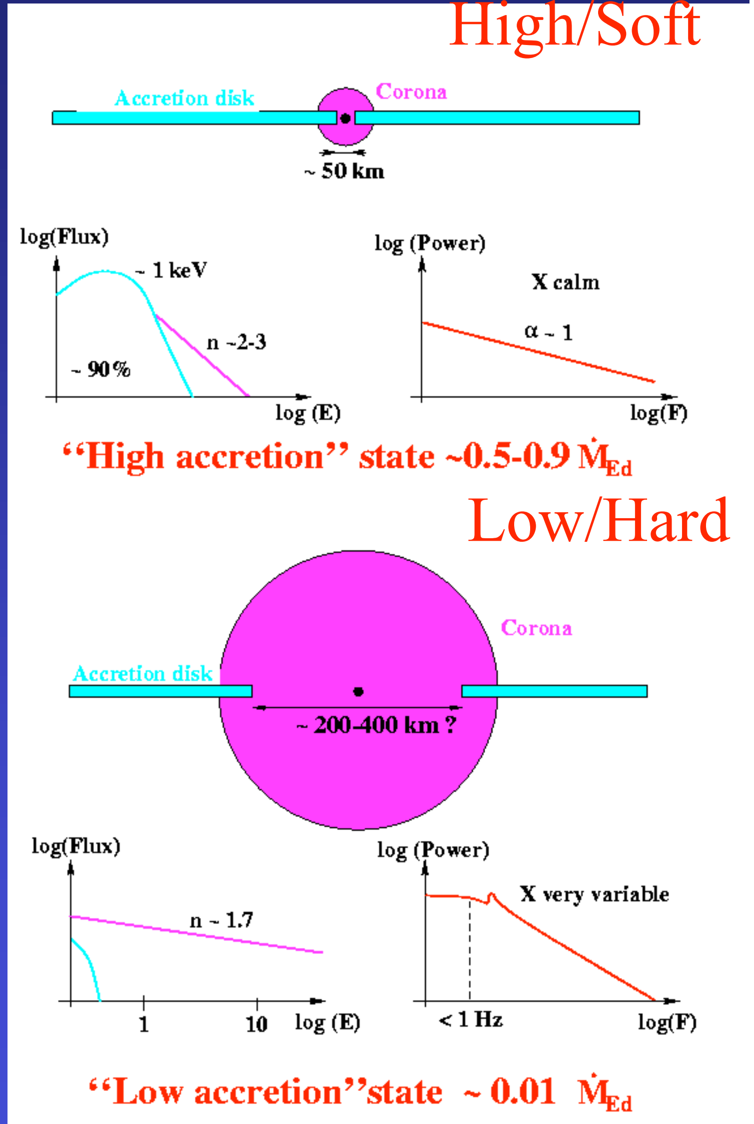

Transition between various X-ray states: mainly High-Soft or Low-Hard states

« Standard picture: disk+corona»: JETS ????

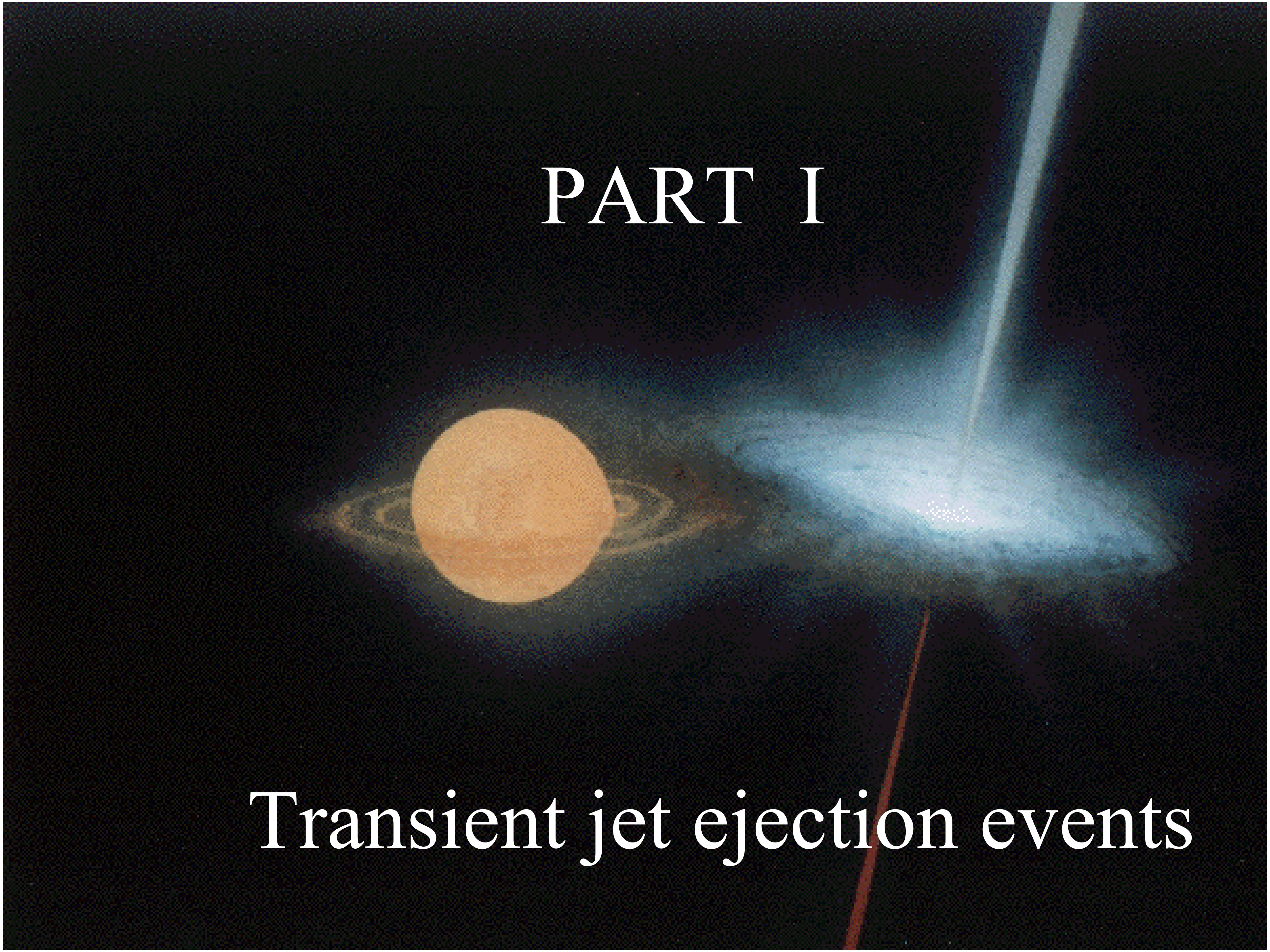
# Time variability & X-ray state




Homan et al. 01; Belloni 03



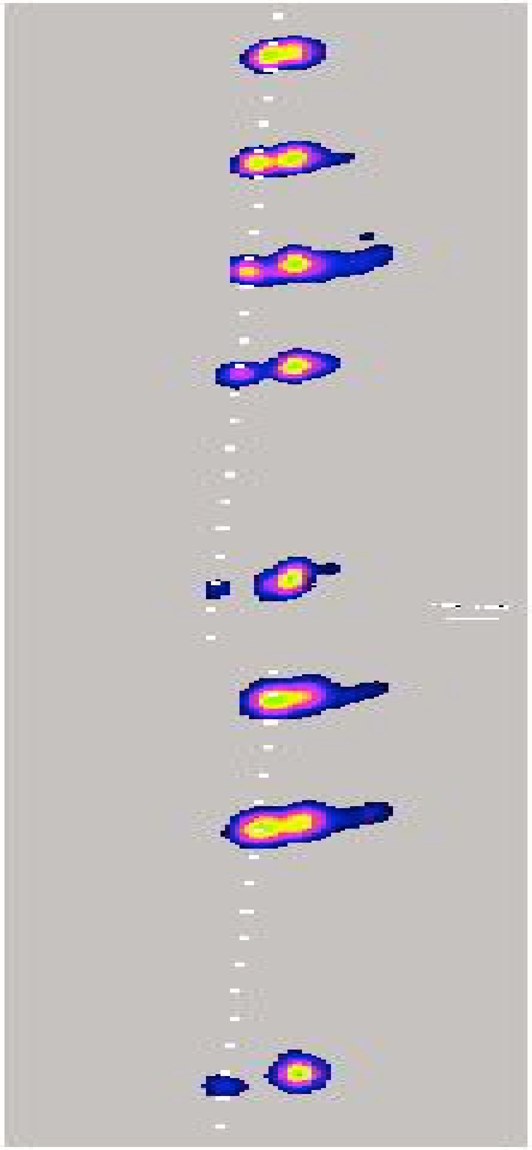

« Standard picture: disk+corona»: JETS ????


PART I
Transient jet ejection events

GRS 1915+105 (MERLIN)

# Transients and persistents

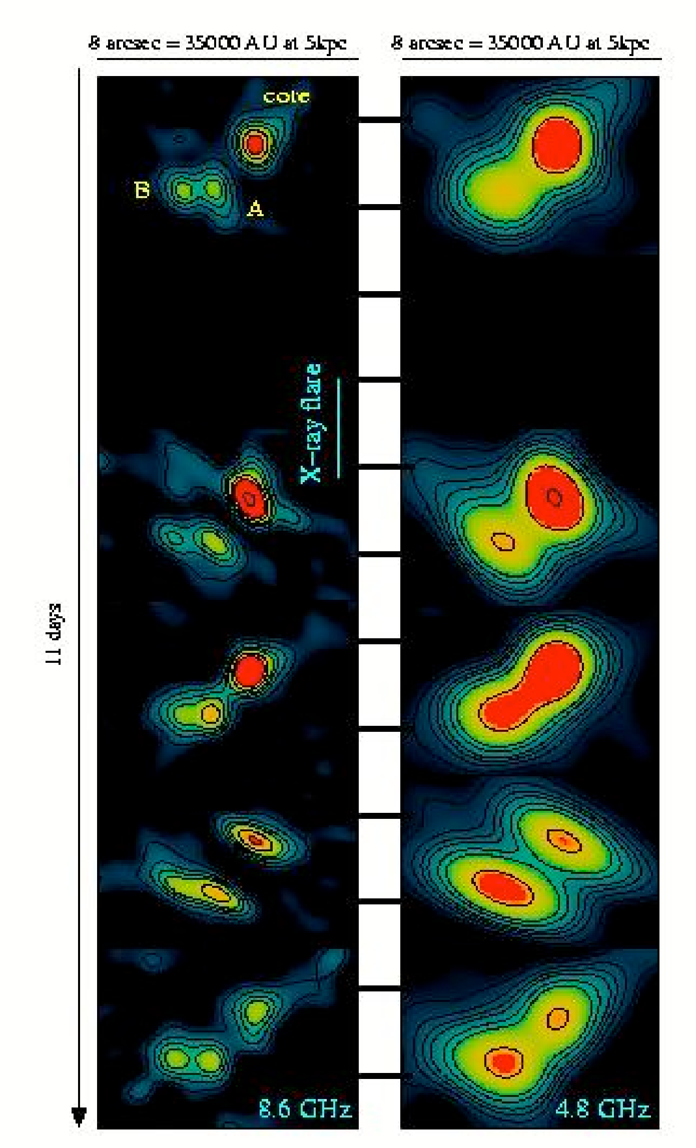
Cir X-1 (ATCA)



In both BH and NS systems, transient X-ray outbursts are accompanied by radio outbursts.

When resolved, these reveal highly relativistic ejection events

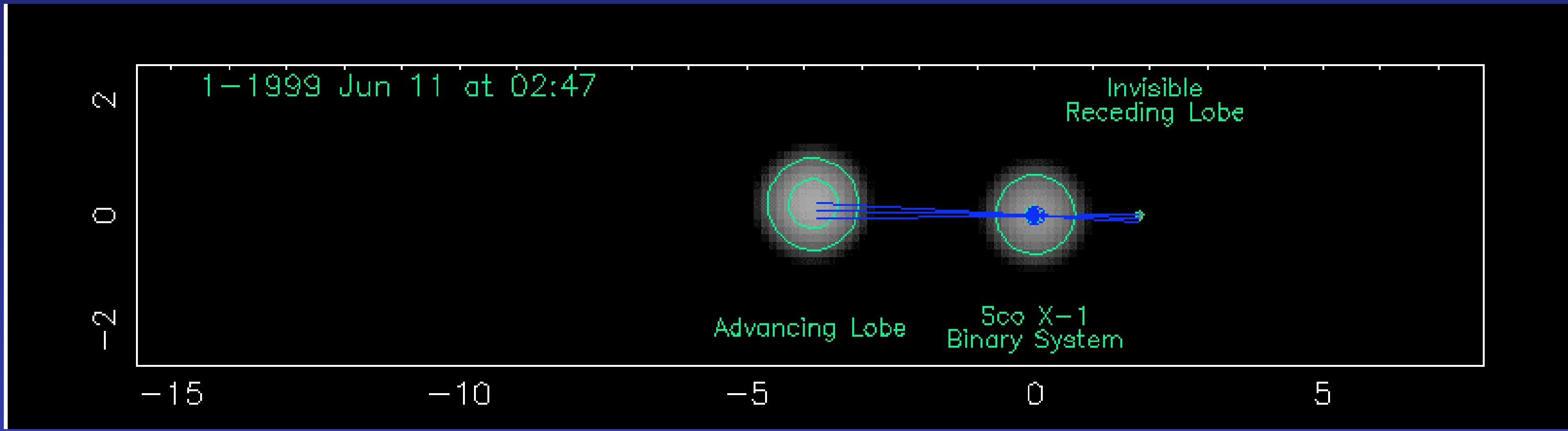
← BH NS →




McCormick et al.(2003)

Fender et al. (2003)

# ENERGY TRANSFER FROM THE CORE TO RADIO LOBES



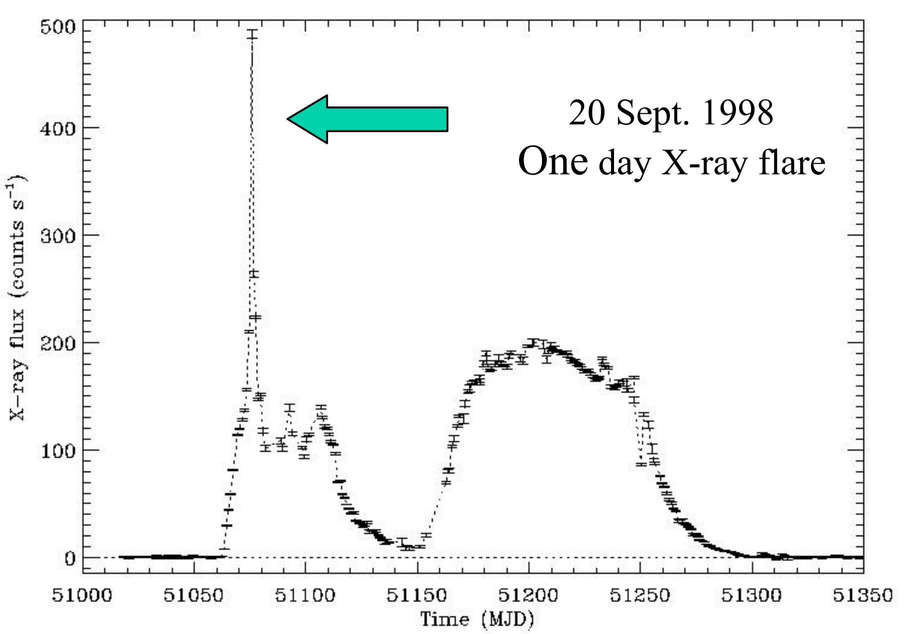

Fomalont et al. (2001a,b)

**Highly relativistic jets in Sco X-1 acting on sub-relativistic sites of particle re-acceleration… (bulk Lorentz factor > 3; for Cir X-1 > 15)**

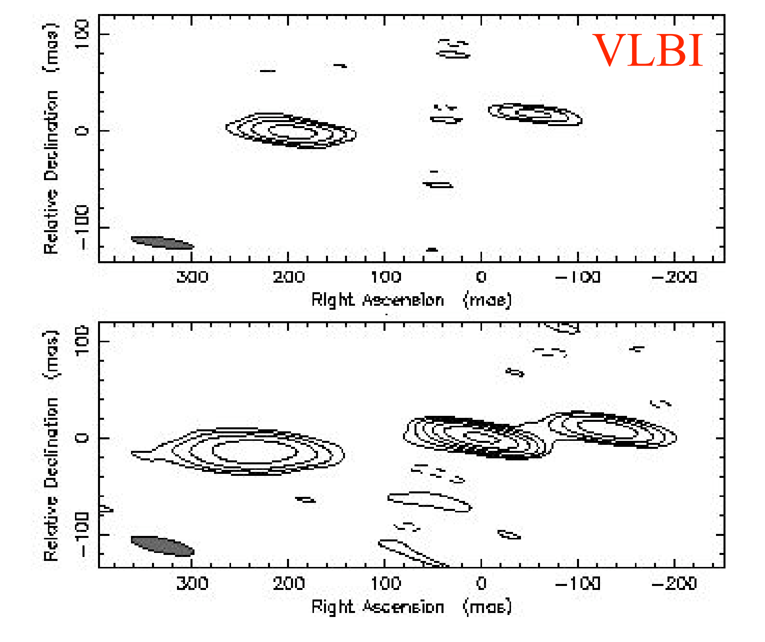
**… and Sco X-1 is the prototype of a class of six objects (the "Z" sources) which all have the same radio properties…**

**The observed radio knots are only tracers of an underlying (unseen) ultrarelativistic flow**

# Large-Scale, Decelerating Relativistic X-ray Jets from the Microquasar XTE J1550-564




RXTE/ASM lightcurve (1998-99)



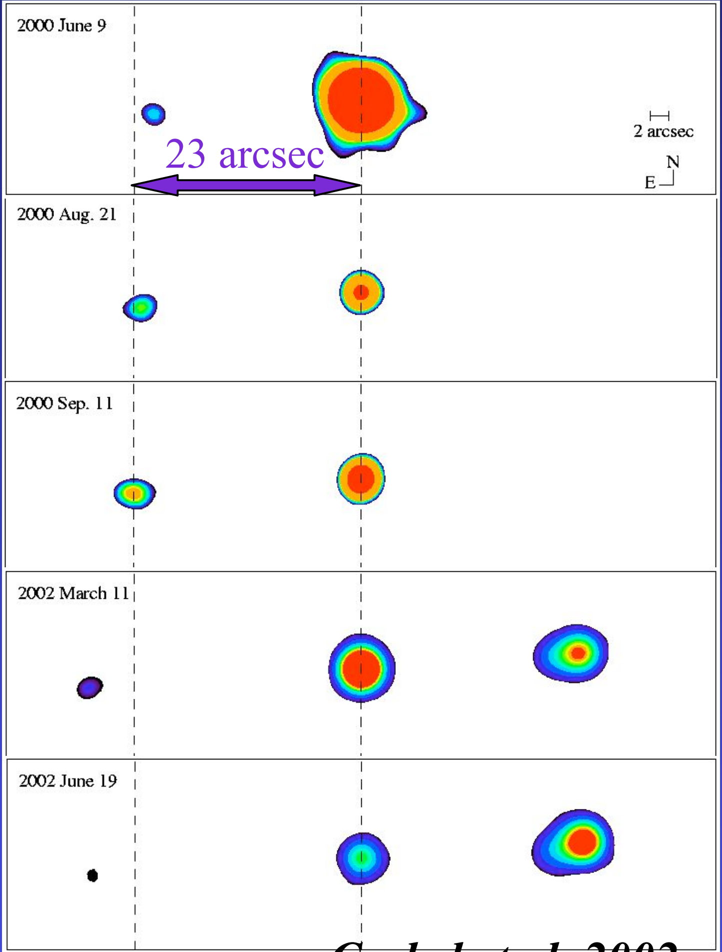

Hannikainen et al (2001)

- $M_{bh}$= 10.5 +/- 1.0 $M_{\odot}$ ; d ~ 5 kpc (Orosz et al. 2002)
- 20 Sept. 1998: Strong and brief X-ray flare

Relativistic ejection imaged with VLBI (Hannikainen et al. 2001)

# Large scale X-ray jets

Chandra 0. 3 - 8 keV images




*Corbel et al. 2002*

- Discovery of X-ray sources associated with radio lobes
- Moving and decelerating lobes
- Alignment + proper motion

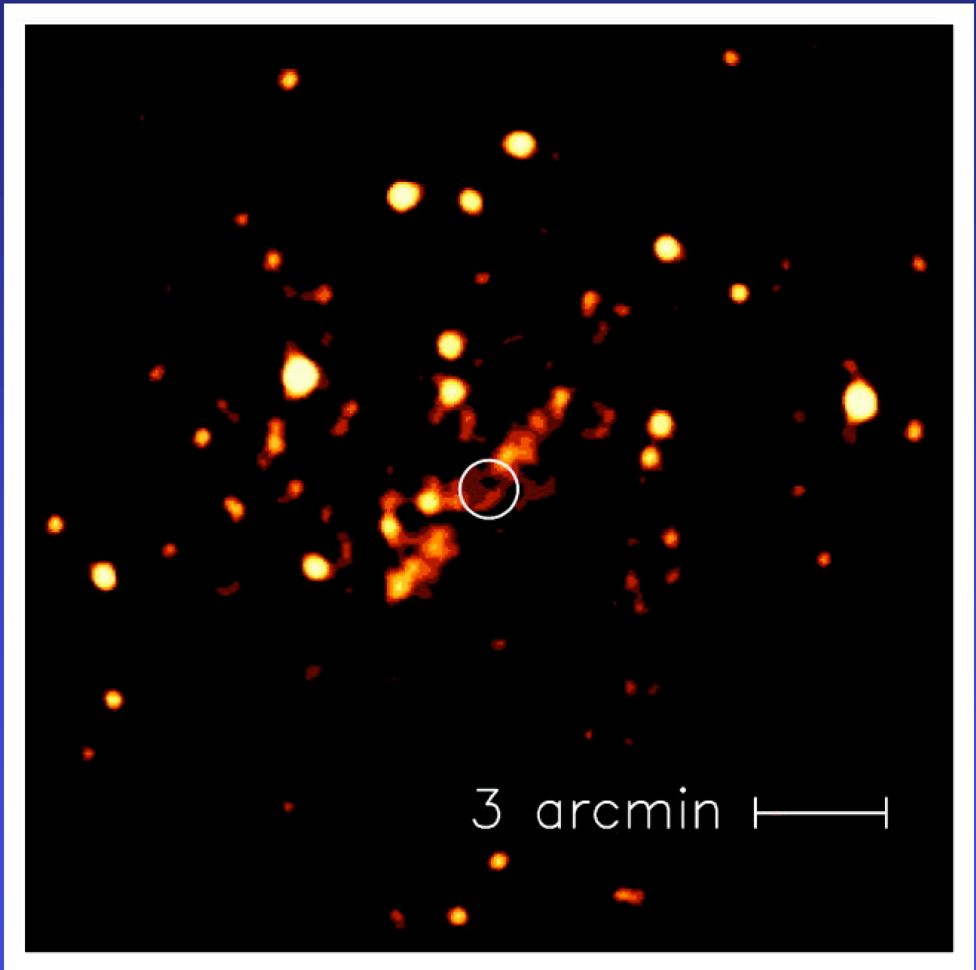
Related to the brief flare of Sept. 1998

First detection of moving relativistic X-ray jets

Evidence than radio through X-rays is synchrotron emission: interactions with denser ISM

**Particle *in-situ* acc. (>10TeV) powered by bulk deceleration**

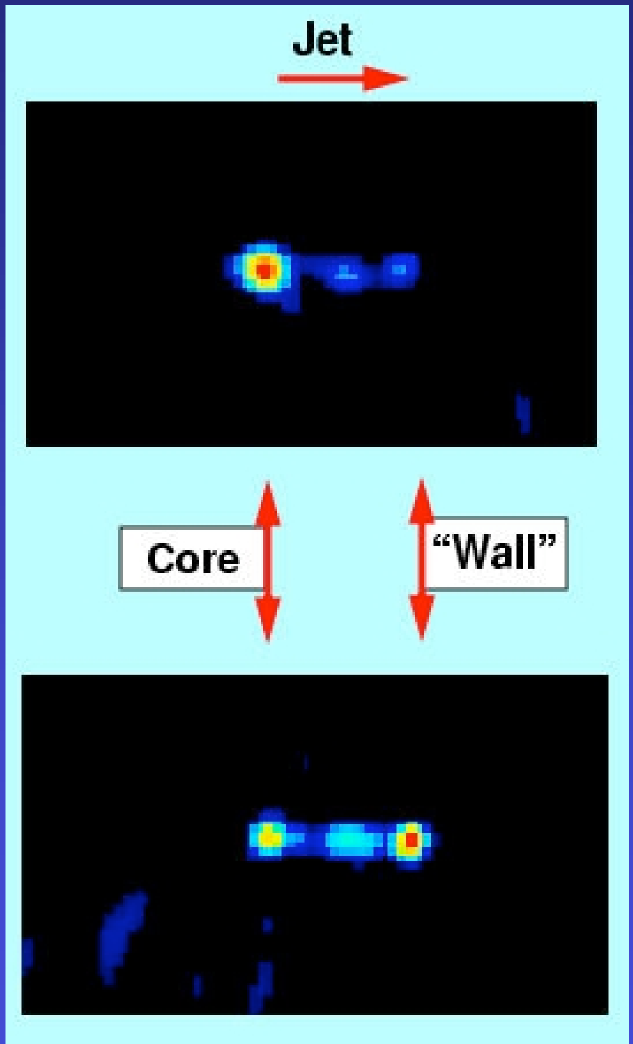
# A fossil X-ray jets in 4U 1755-33




Angellini & White(2003)

- •XMM newton observations of 4U1755 in 2000 (in quiescence since 1995)
- •Large (7') scale two-sided X-ray jets
- •BHC active for > 25 years
- •If v~c, it would have take 13 yr to extend to its current length

# XTE J1748-248



Radio (VLA)

XTE J1748-248: a cosmic jet hits the wall ? (Hjellming, unpublished)

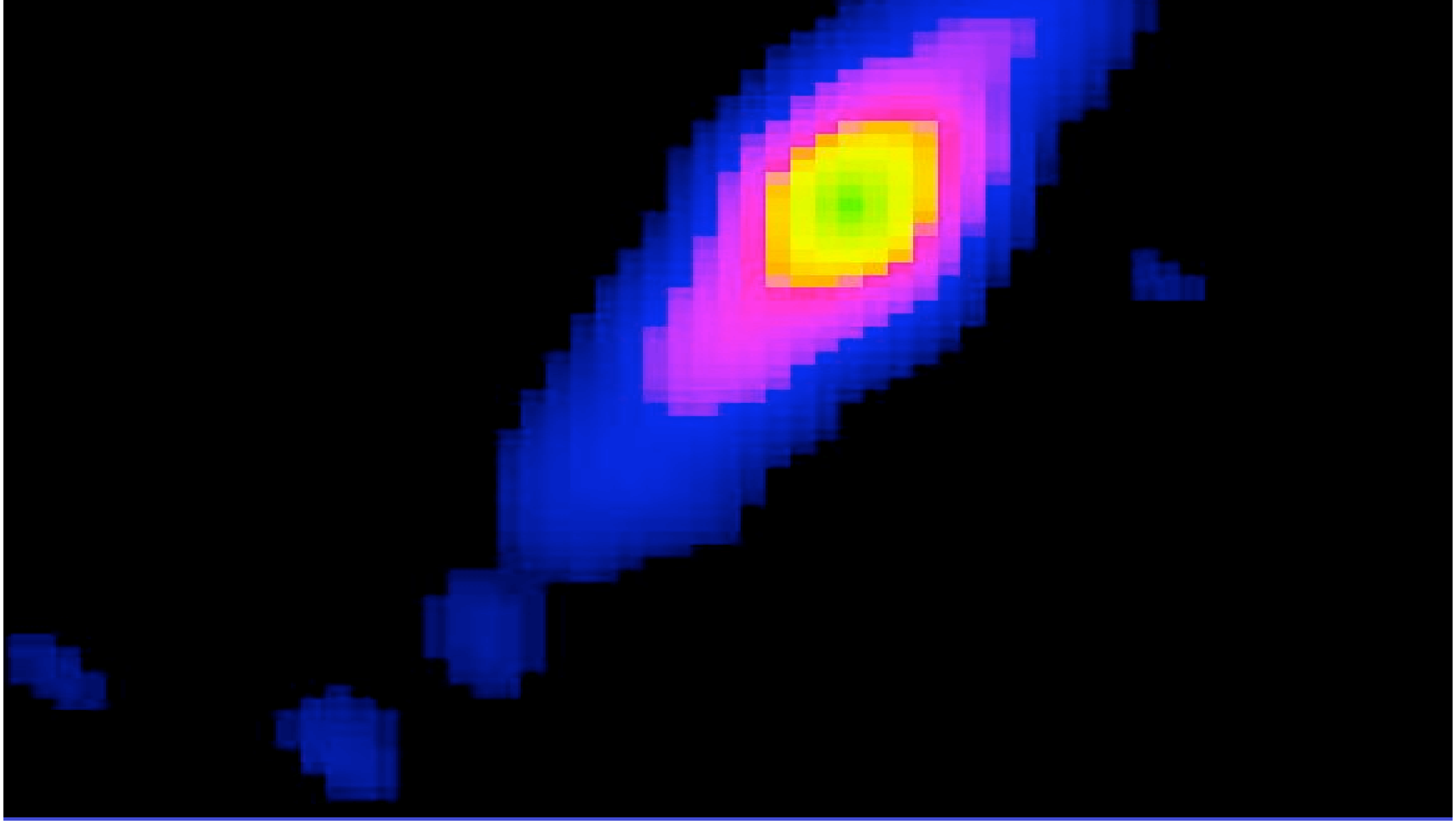
+ GX 339-4 (Gallo et al. 03)
+ XTE J1650-500 (Corbel et al. 04)
+ ???? (Corbel et al. 2004)

TeV particle acceleration in jet : more common than previously thought

***Strong analogy with AGN jets***

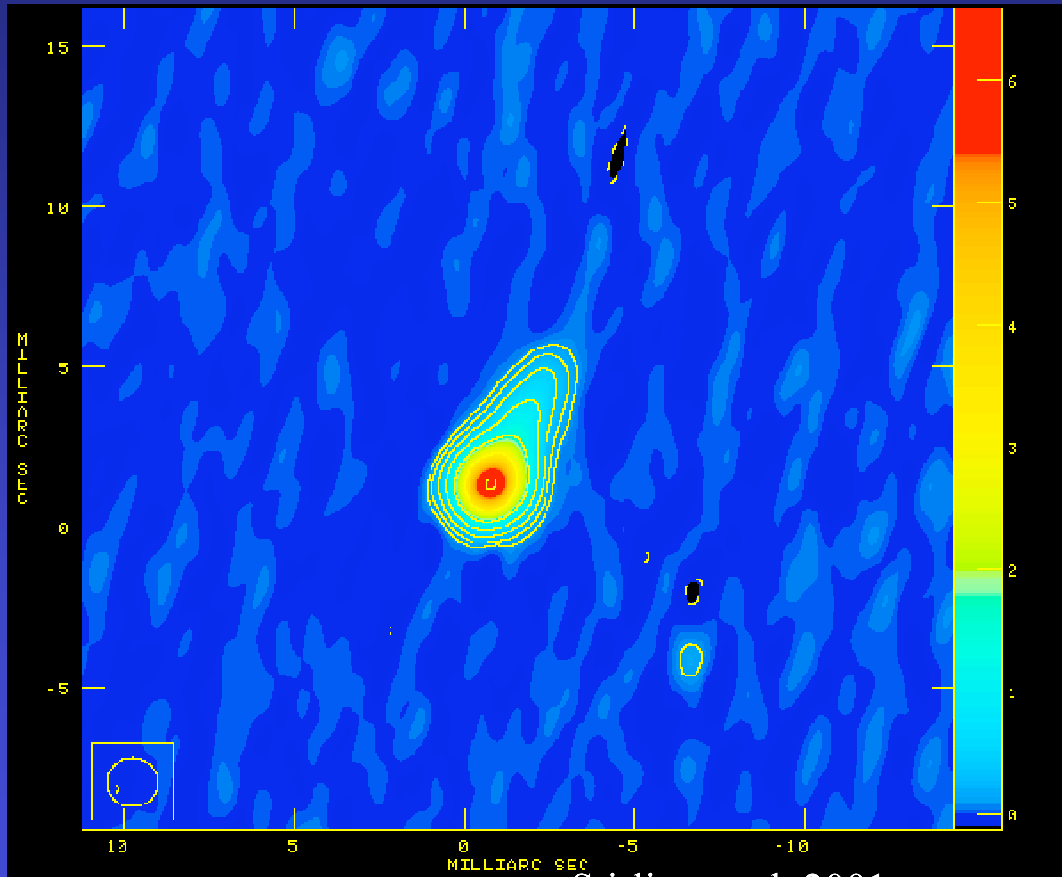
***X-ray jets easily detected with Simbol-X: what is the maximum energy of e- ?***

# PART II: the connection of relativistic jets with X-ray state



# An ubiquitous, powerful (?), compact jet associated with the Low-Hard state

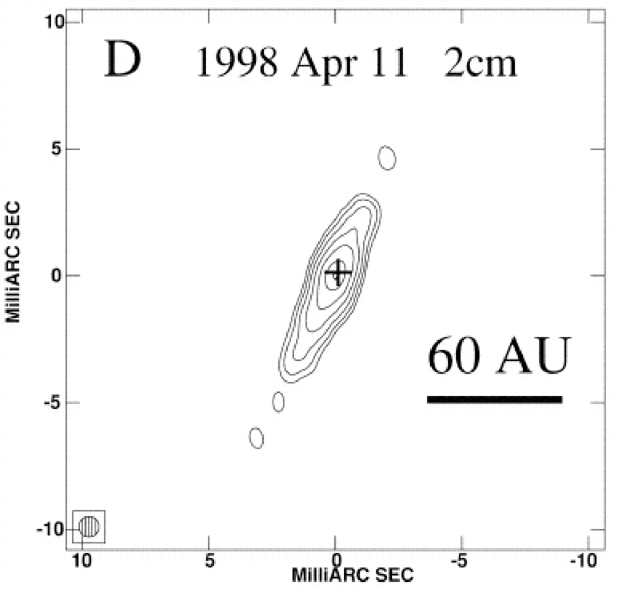
A compact jet on mas scale in Cyg X-1




Stirling et al. 2001

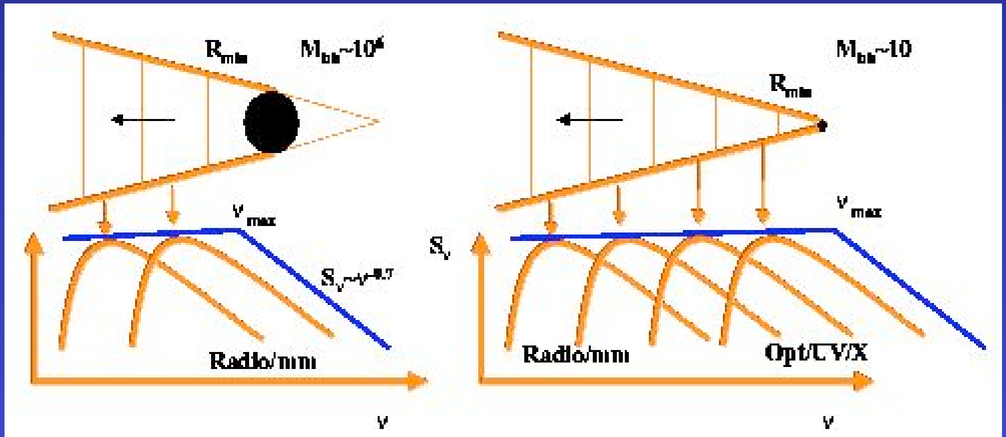
8.4 GHz image

GRS 1915+105 (plateau state)



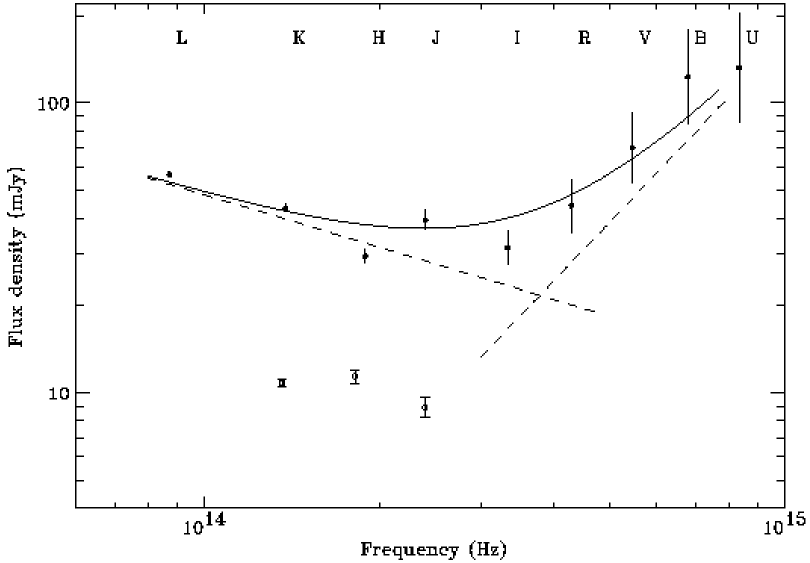

*Dhawan et al. (2000)*

Compact jet usually not resolved, but inverted or flat radio spectra (Corbel et al. 2000, Corbel et al. 2001, Fender 2001)




**Optically thick synchrotron emission from a conical self-absorbed outflow:** Blandford & Konigl (1979) , Hjellming & Johnson (1988), Falcke (1996)

→ Cut-off frequency at high frequency ??? And above ???

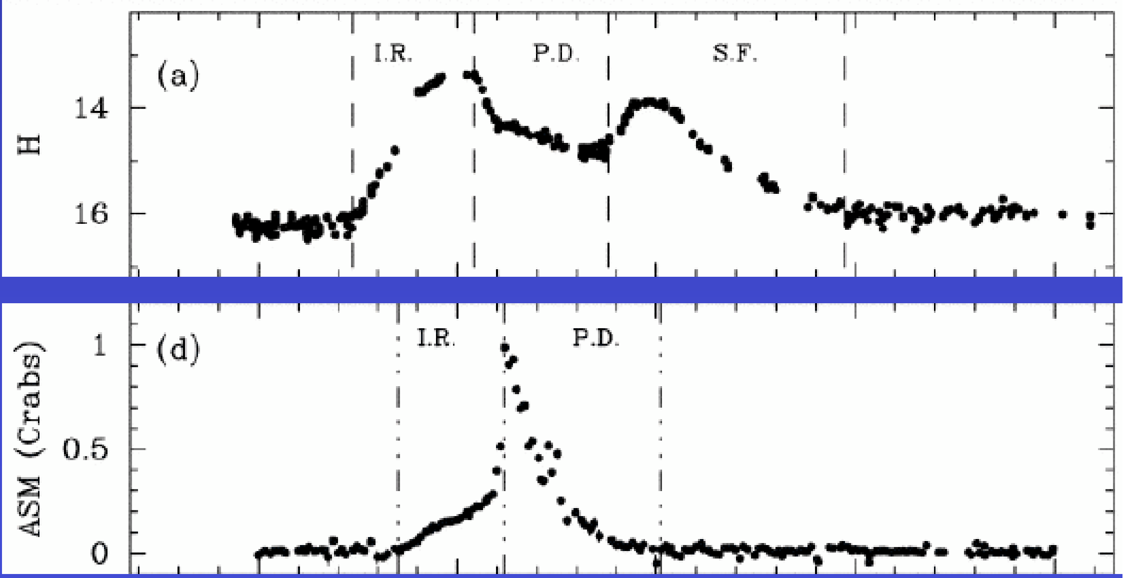



Corbel & Fender (2002)

# Cut-off frequency in near-infrared

IR synchrotron emission in GX 339-4, but also XTE J1550-564,… (Corbel et al. 01, 02)

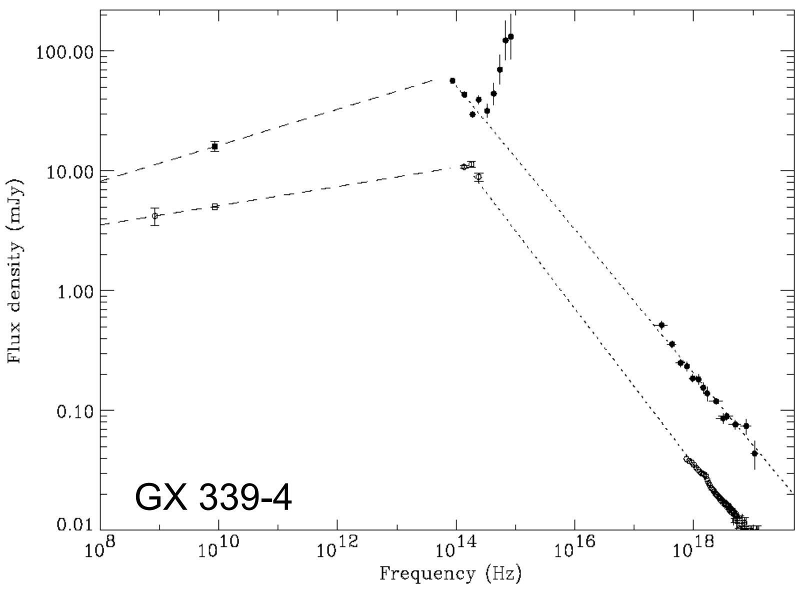
Secondary peak (corresponding to a LHS transition) due to nonthermal infrared emission associated with the formation of the compact jet (Jain et al. 01)



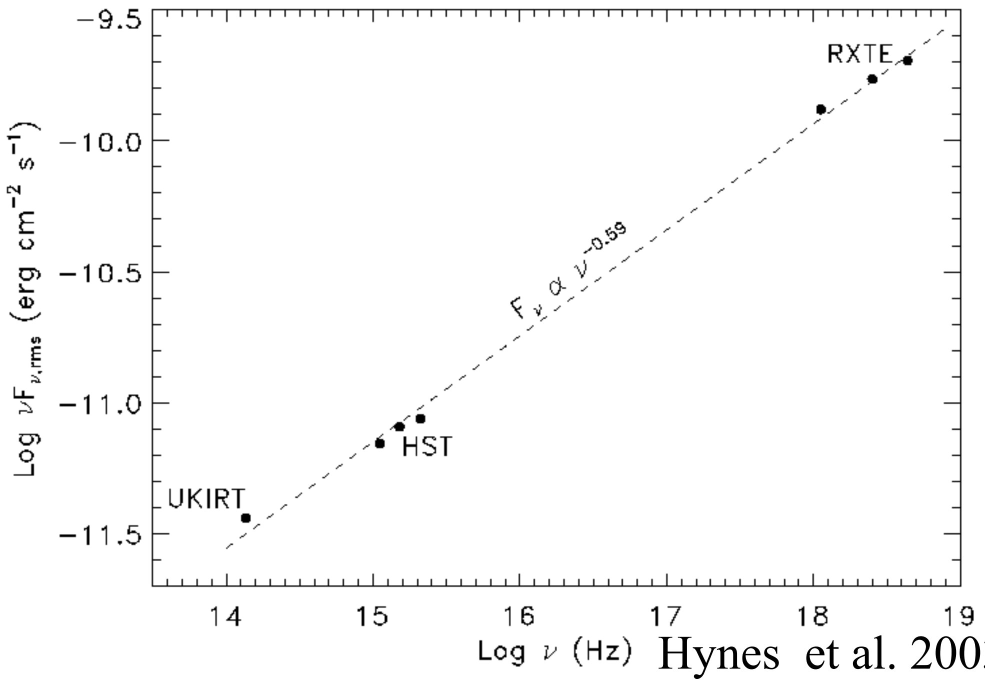

2000 outburst of XTE J1550-564 (Jain et al. 01)

**See also 4U 1543-47 (Buxton)**

Above this frequency: the X-ray spectra are consistent with an extension of a powerlaw from the IR: optically thin synchrotron emission in X-rays?



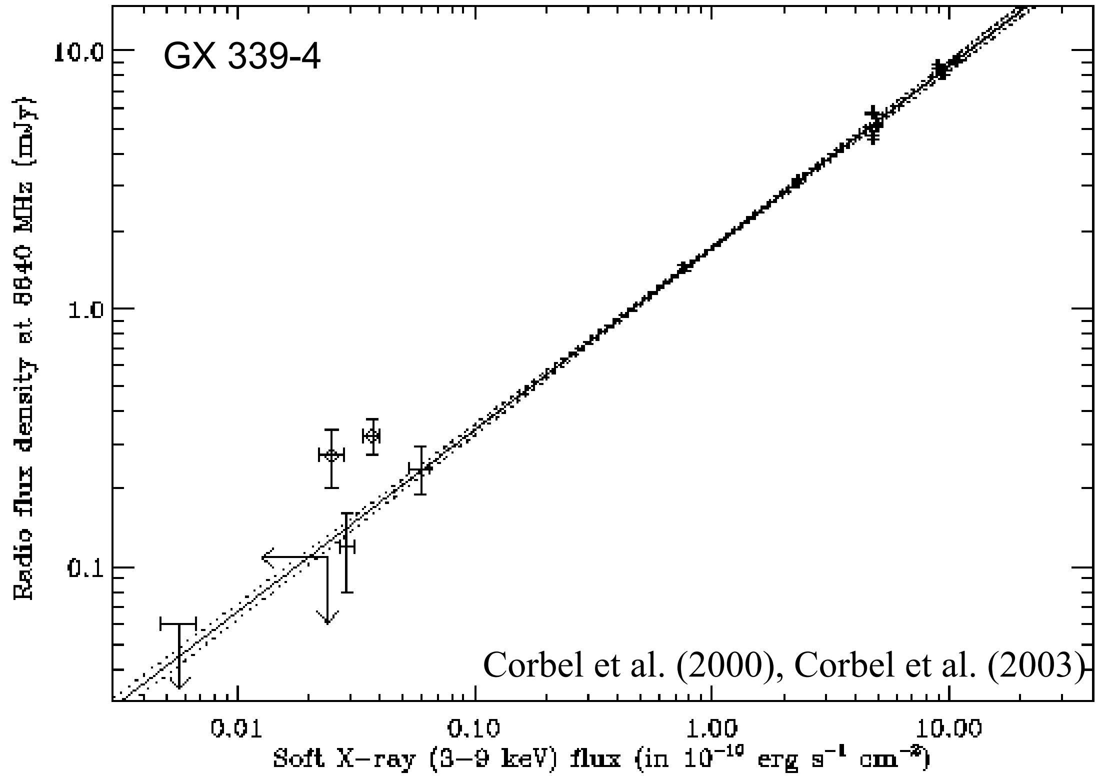

Corbel & Fender (2002)




Hynes et al. 2003

Broadband SED of the rms variability of XTE J1118+480: consistent with expectation of optically thin synchrotron emission (Hynes et al. 03)

# Radio/X-ray flux correlation



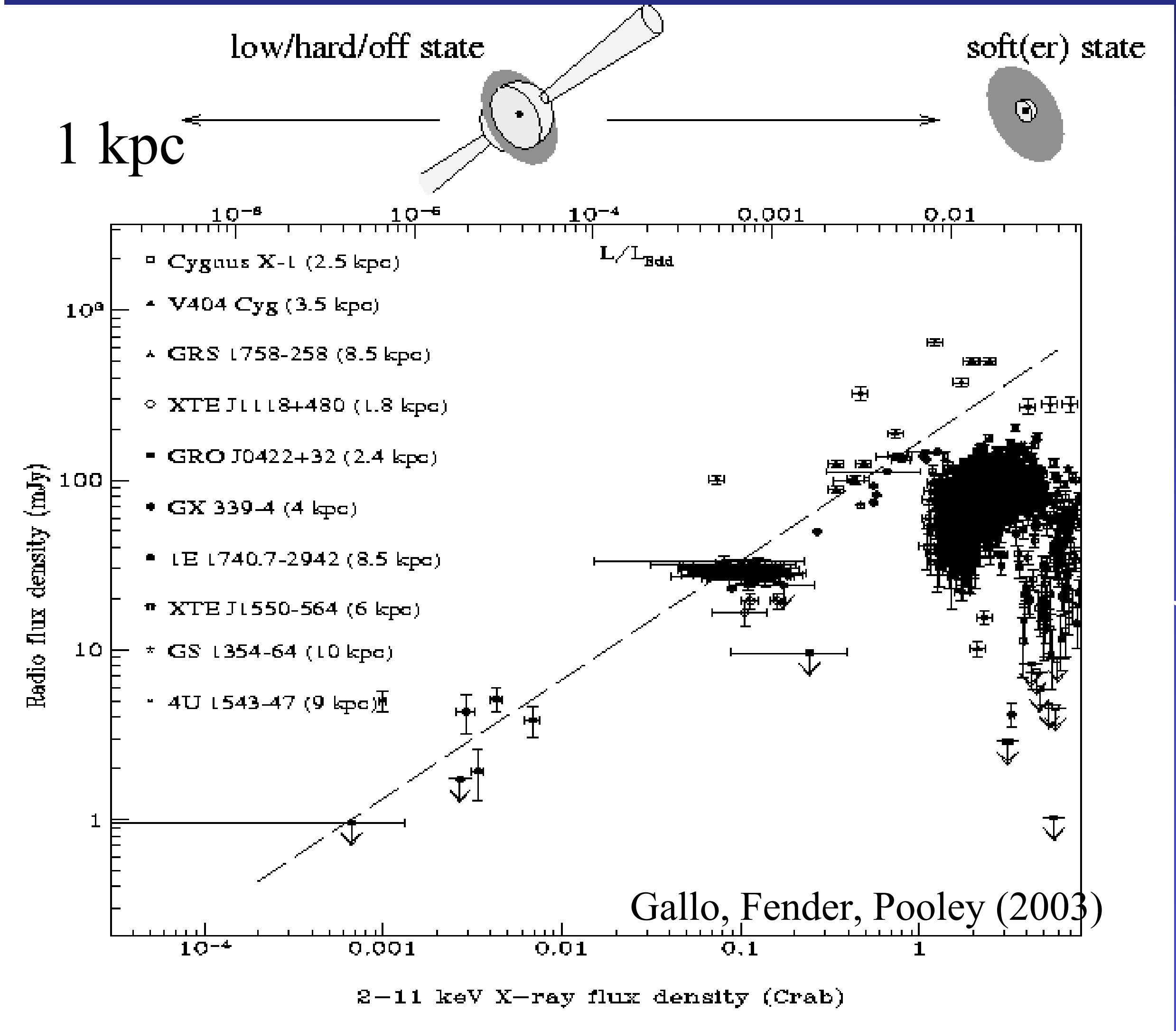

Very strong correlation between radio and X-ray emission over more than 3 decades in flux (down to quiescence !!!)

$$F_{rad} \qquad F_X^{+0.7}$$

→ Origin of emission of black hole candidate in quiescence ???

JDAF: Jet Dominated Accretion Flow (Fender, Gallo, Jonker 03)

# A universal radio/X-ray correlation



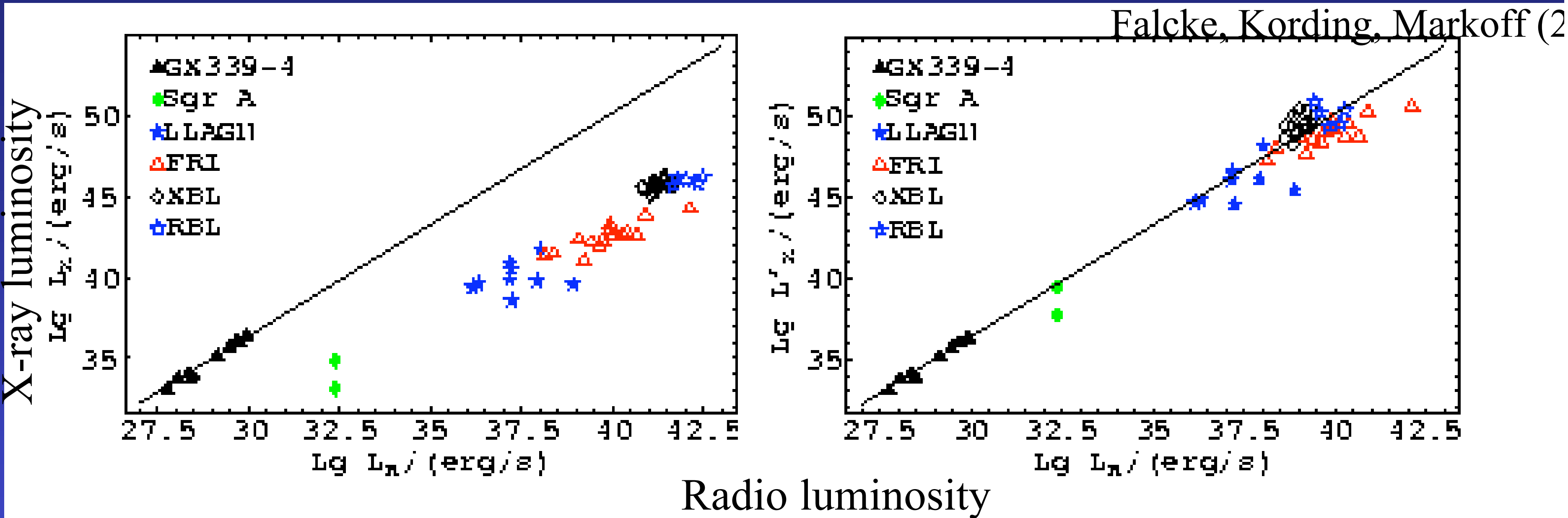

$F_{rad}$ $F_X^{+0.7}$

Same coupling !!!

Important for understanding of accretion/outflow coupling: jet model, TCAF (Choudhury 03

No strong Doppler boosting: low velocity jet (□ < 0.8 c)

# Unifying Low-power accreting black holes




No mass correction

With mass correction

(X-ray luminosity scaled for a 6 $M_\odot$ BH)

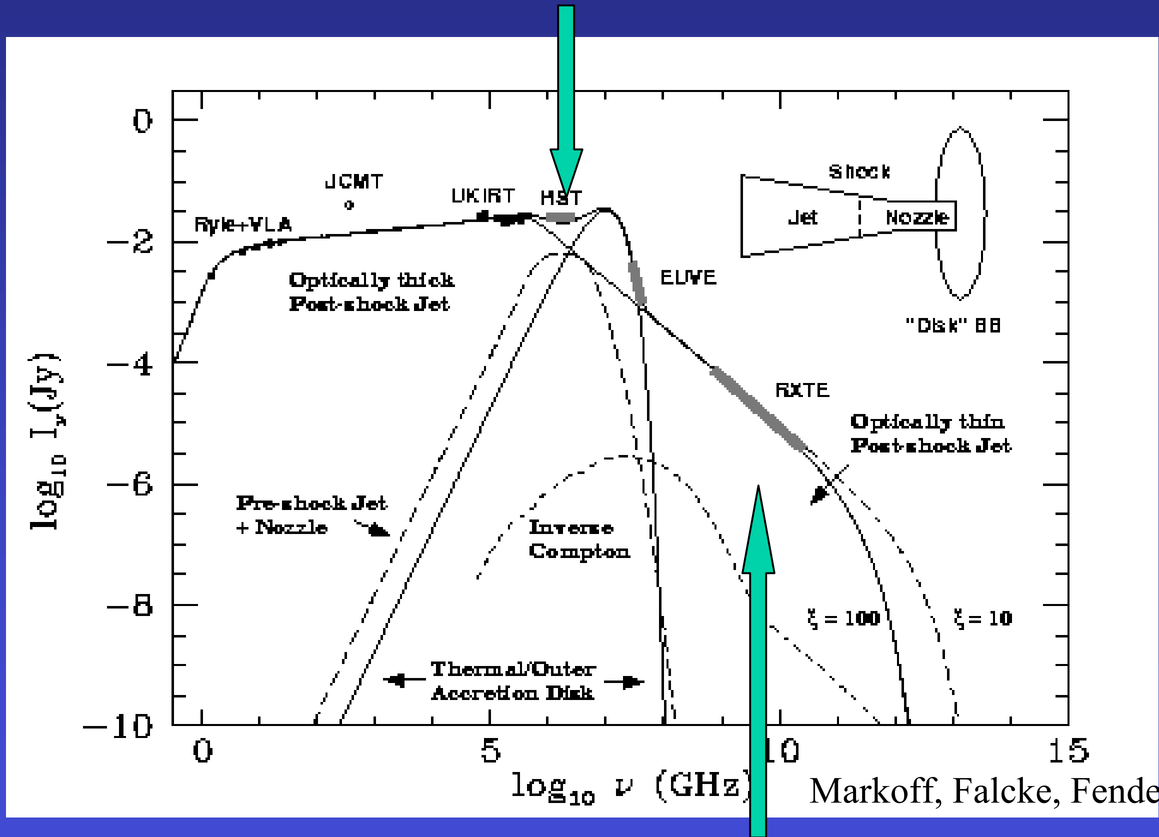
GX339-4

$$F_X \quad F_{Rad}^{m} \cdot M^{(\square_x \square m \square_{rad})} \qquad \text{with} \qquad m = \frac{\frac{17}{12} \square \frac{2}{3} \square_x}{\frac{17}{12} \square \frac{2}{3} \square_r}$$

SED of BH operating at sub-Eddington accretion rate are dominated by non-thermal emission from a relativistic jet (see also Merloni, Heinz, Di Matteo 2003)

# Broadband spectra: role of jets in the low/hard state?

If jet emission extends up to optical band, jet has > 10% of all power

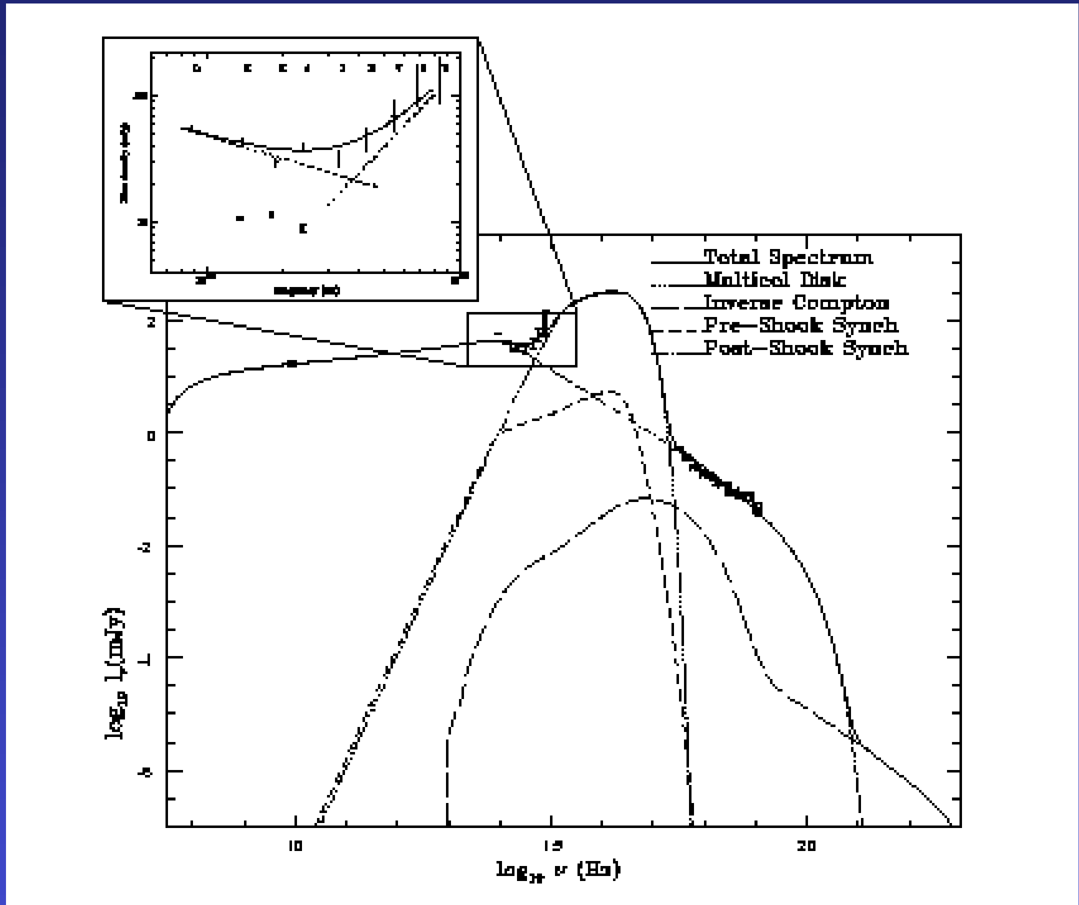



Markoff, Falcke, Fender (2001)

XTE J1118+480

If jet emission dominates X-ray band, jet has > 90% of all power !!!!

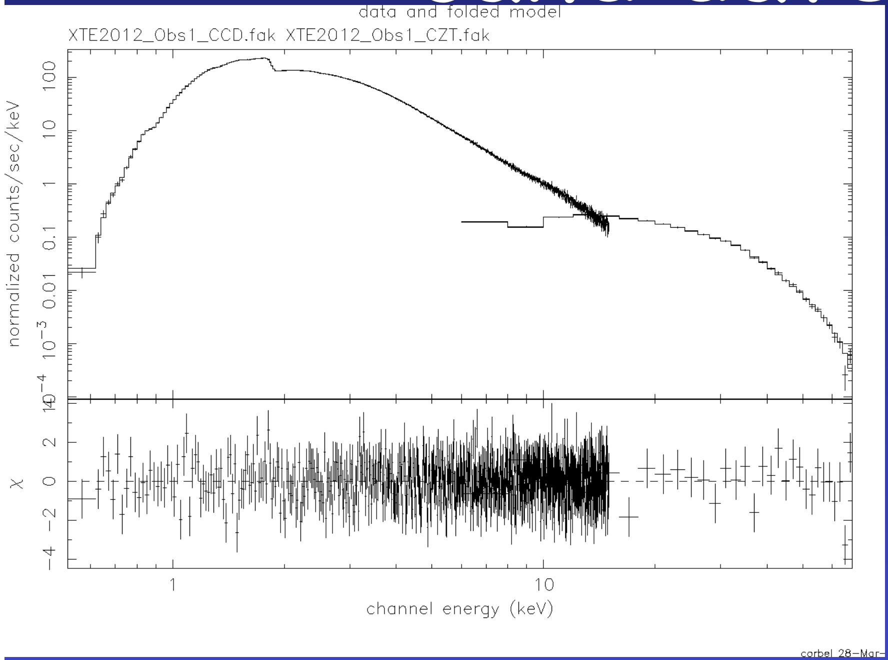
# Another example of SED: 1981 bright low-hard state of GX 339-4




Corbel & Fender (2002), Markoff et al. (2003)

Jet model can account for all broadband spectra of GX 339-4, by changing only two parameters: the input power and the location of the first acceleration zone, Markoff et al. (2003)

# SIMBOL-X and black hole candidates in outburst




XTE J2012+338
Outburst (100 mCrab) - 10 ks

**Various emission components:**

- Accretion disk
- Iron line
- Corona: powerlaw + reflection
- Compact jets (+ reflection < 10 %)

***Overlap in the 4 – 15 keV en. range***

***SX: Soft and hard X-rays***

***~ XMM/Chandra*** ***100 better than ISGRI***

SX: precise spectral evltn (geometry,…) during outburst (and no pile up !)

***ToO reaction time very good : 4 times better than XMM !!! (even FF)***

*Relativistic Iron line: more constraint if simultaneous fit ( as in AGN, cf J. Wilms) of the reflection component :*

→

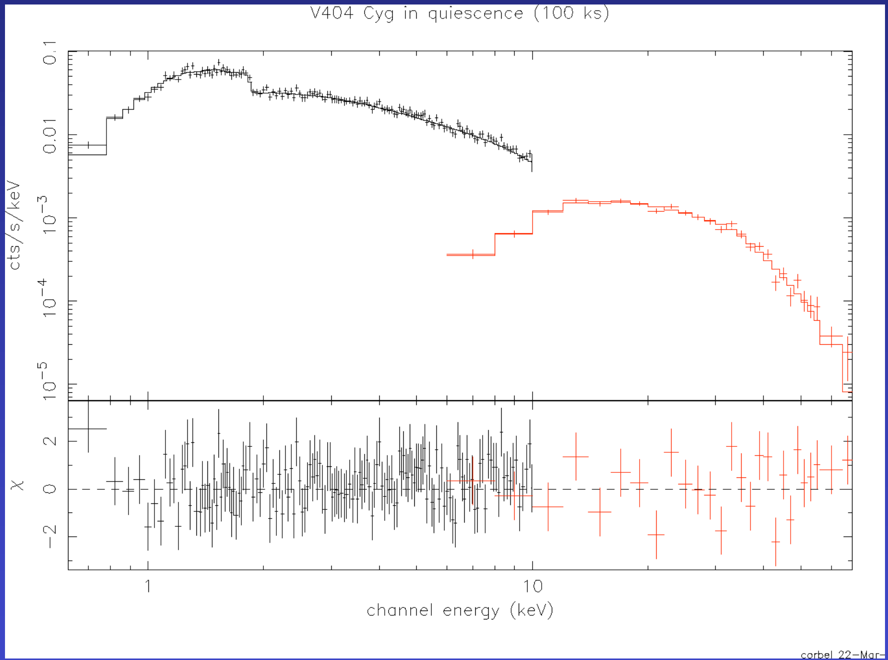
- *Spin of the black hole*
- *X-ray emissivity profile*

*BZ mechanism : magnetic extraction of black hole spin energy*

*Starting point for launching powerful relativistic jets ???*

+ QPOs studies: see talk by J. Rodriguez

# Black hole in quiescence




V404 Cyg
quiescence 100 ks

***Origin of X-ray emission at low accretion rate: contribution of jets ?***

***What fraction of accretion energy is given back to ISM ?***

***Turlulence in ISM : trigger star formation ?***

***See talk by S. Campana***

# Conclusions

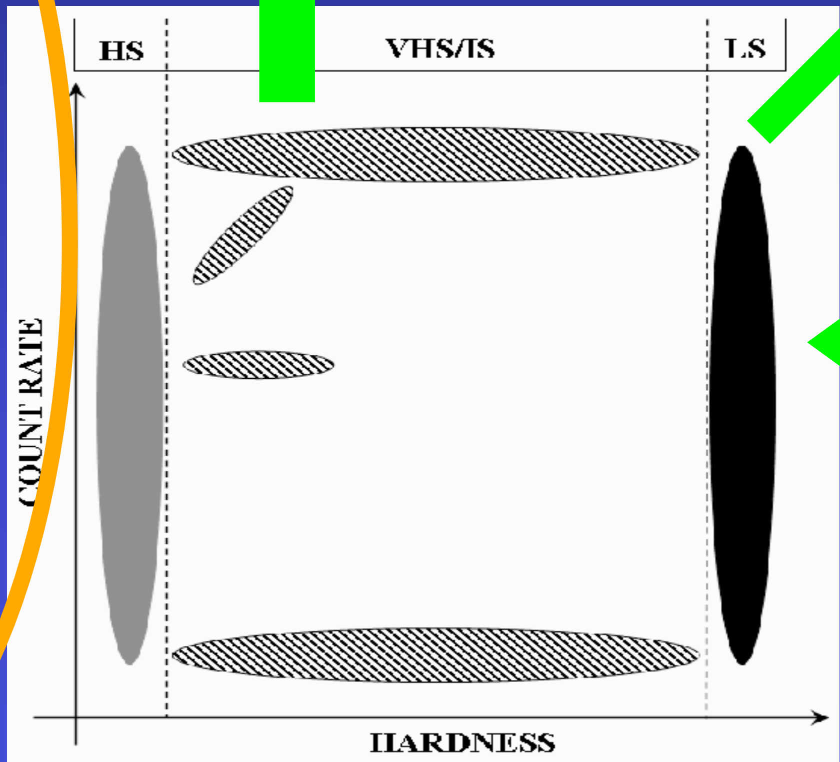
Interaction with ISM: shock acceleration of particles up to TeV → Formation of large scale lobes

I/VHS: unstable acc disk with period of radio flaring and quenched radio activity

State transition: major ejection event

## SIMBOL-X and jets

**SX and BHC spectra**




LHS and quiescence: powerful compact jet, whose emission may dominate the entire SED

HSS: quenched radio emission