A multi-wavelength view of jets in accreting binaries

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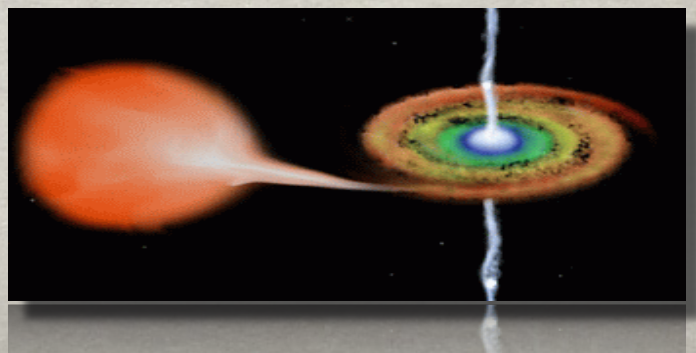
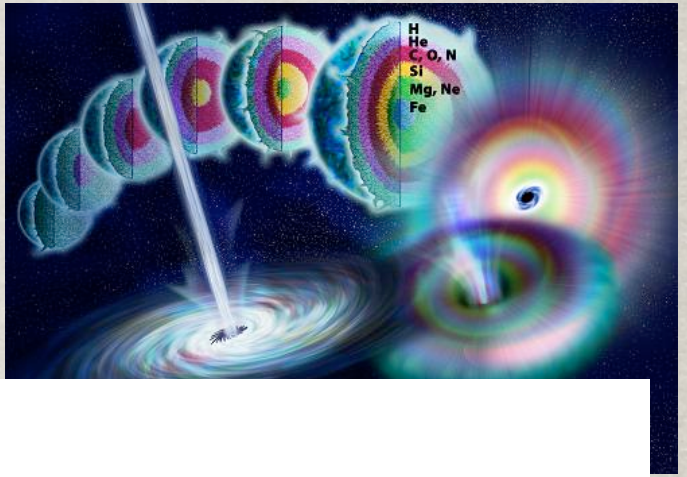
OUTLINE

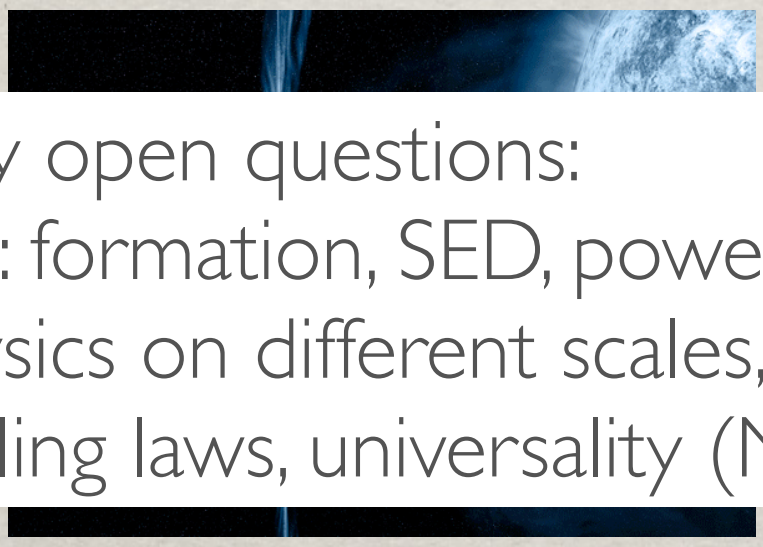
- General introduction : disc, jets and towards a general unification.
- Compact jets: another flavor of jets
- High energy emission from jets
- Transients jets in X-ray binaries
- Interactions jet/ISM



INTRODUCTION

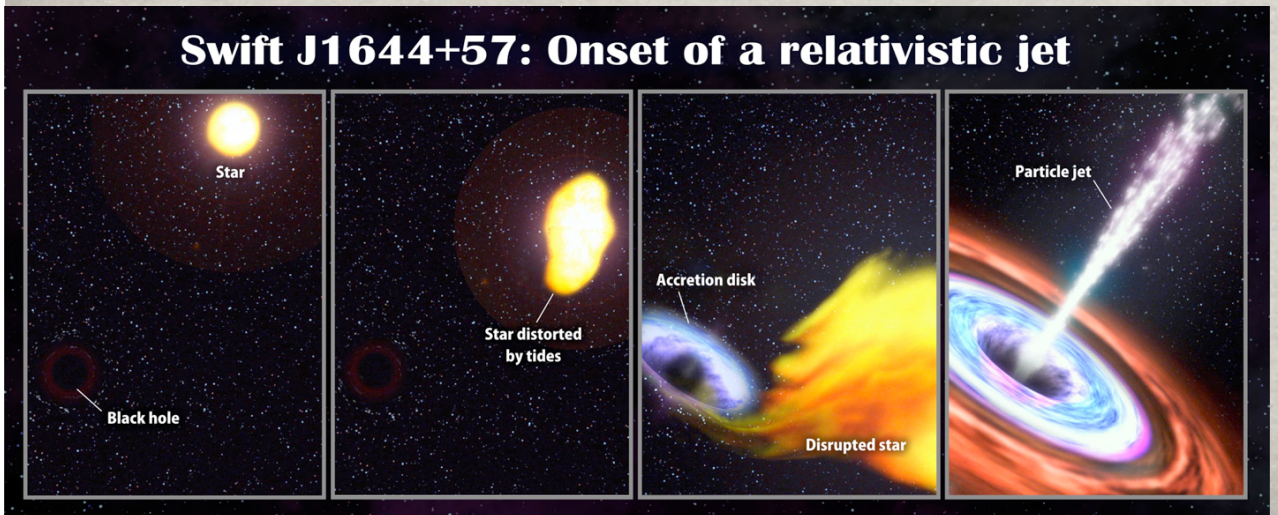
JETS ARE EVERYWHERE

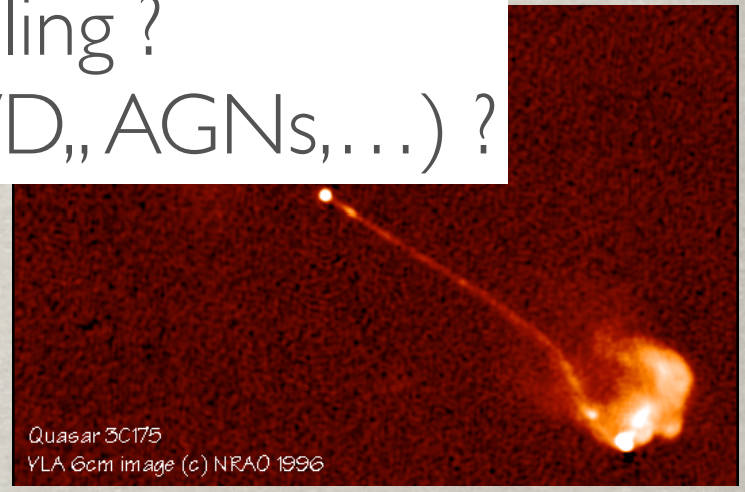




Many open questions:

- Jets: formation, SED, power, feedback ?
- Physics on different scales, coupling ?
- Scaling laws, universality (NS, WD,, AGNs,…) ?





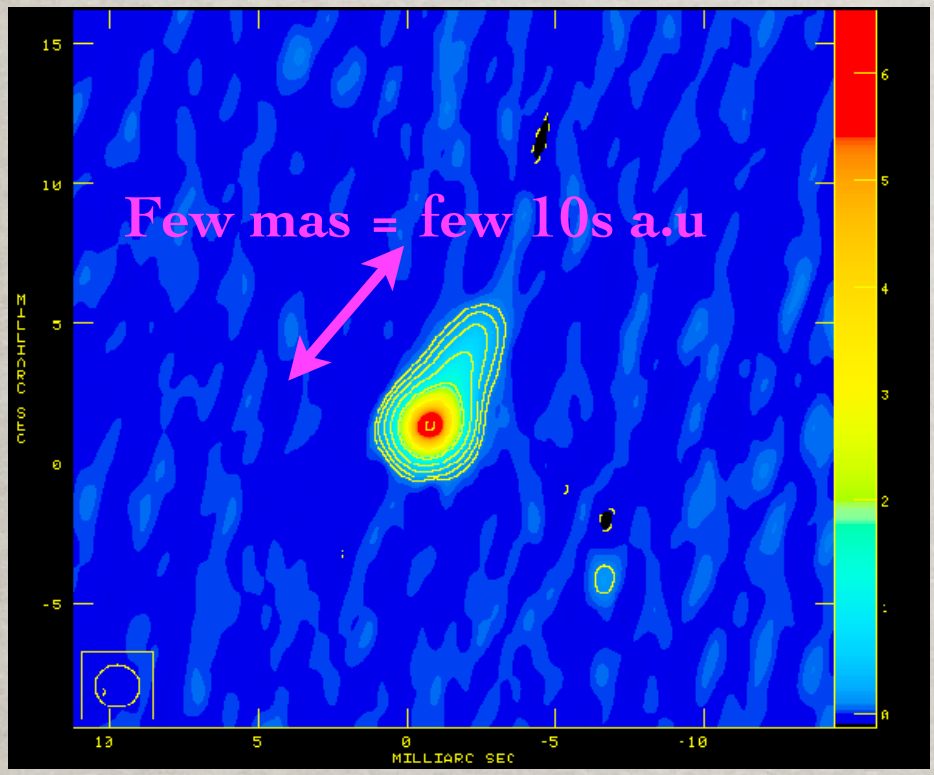
and strongly related to accretion

JETS IN BLACK HOLE TRANSIENTS

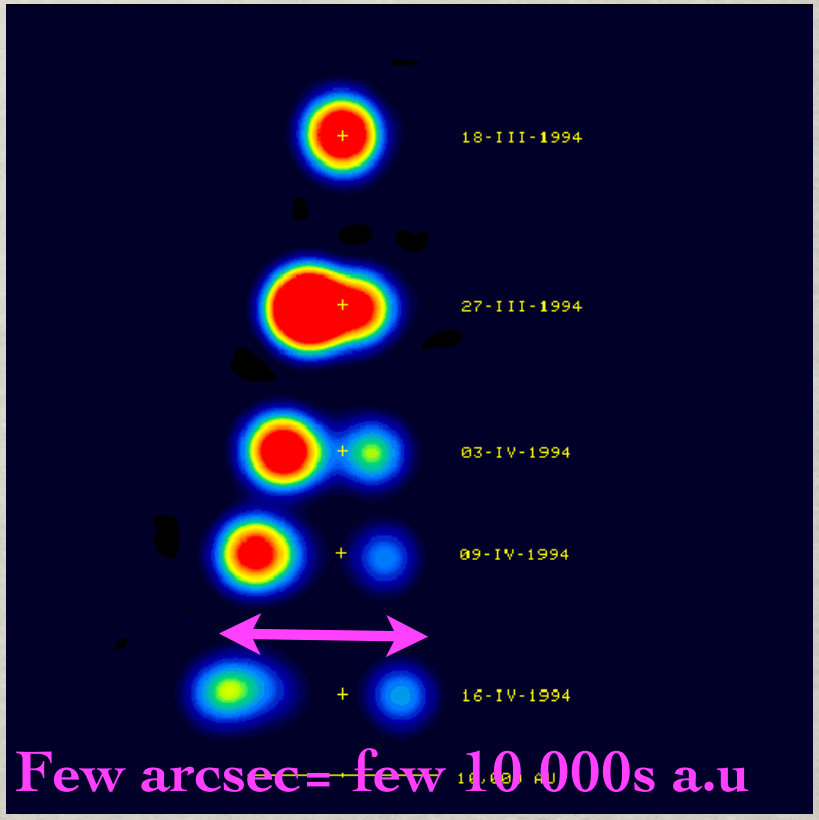
UNIFICATION

TWO FLAVORS OF RELATIVISTIC JETS ON TWO VERY DIFFERENT SCALES !!!!

- Compact, self-absorbed jets (on mas scale = 10s a.u.).
- Discrete ejections events (superluminal, ~ ballistic).



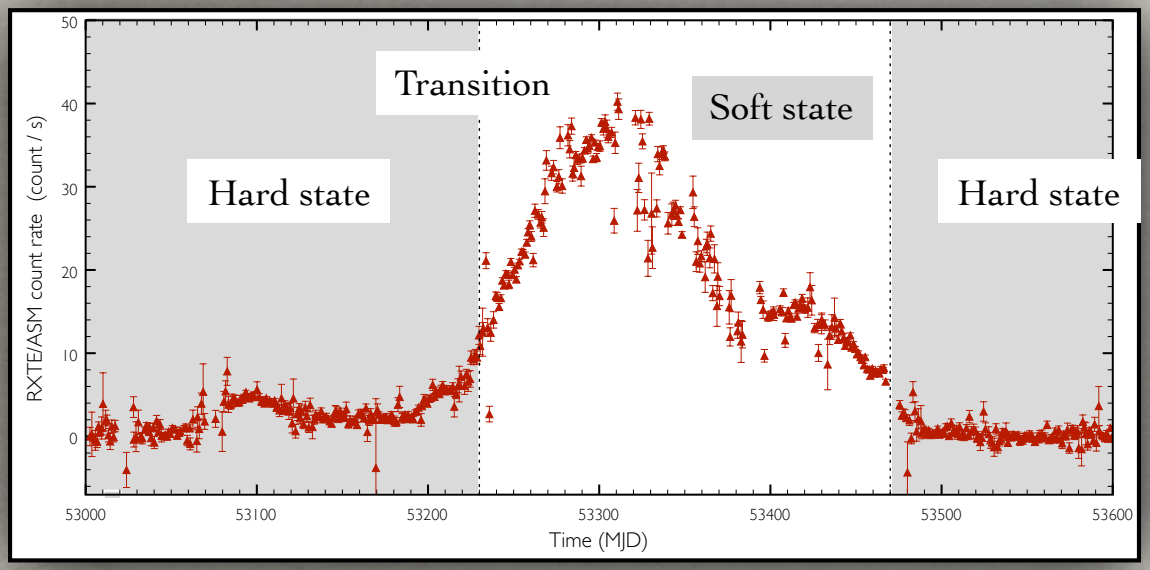
Stirling et al. 2001



Mirabel et al. 94

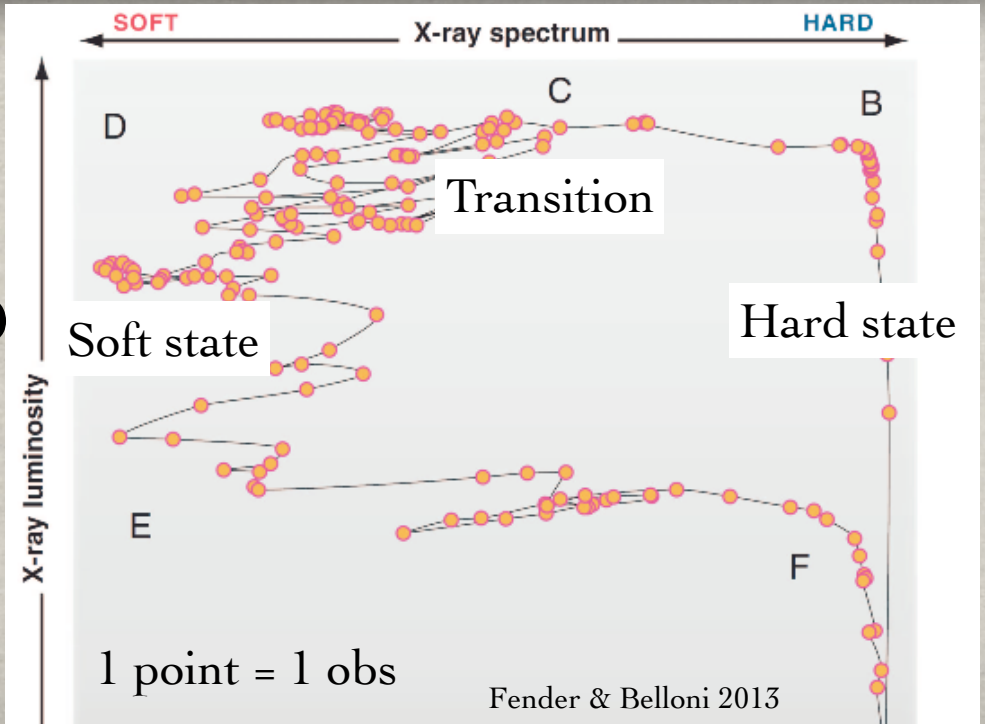
+ long term action of the jets on the ISM: lobes, hot spots...

X-RAY ACTIVITY



- X-ray **evolution** (energy spectrum + power spectrum): different states
- **Hardness Intensity Diagram**: hardness = ratio of counts in 2 different bands (model independent)
- **Disc Fraction Luminosity Diagram** (DFLD) : hardness = non thermal power-law/total flux. Allows comparison between different populations.

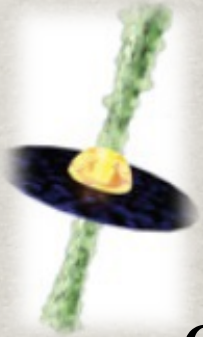
HID



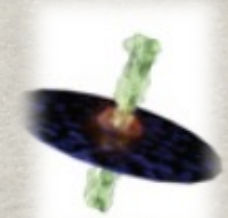
THE UNIFIED MODEL

Major radio flare(s)= Transient jets

Origin of the major flare ???? Internal shocks (Fender et al. 04) or ejection of the «corona» (Rodriguez et al. 03) ?



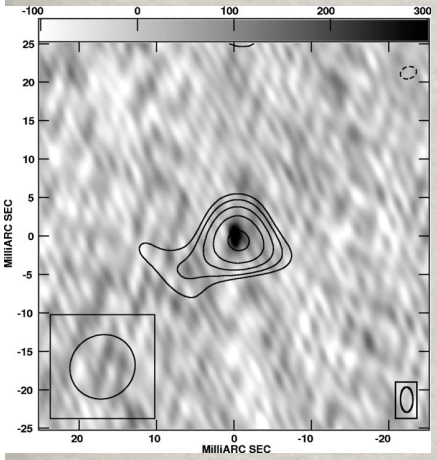
Compact jets in the hard state

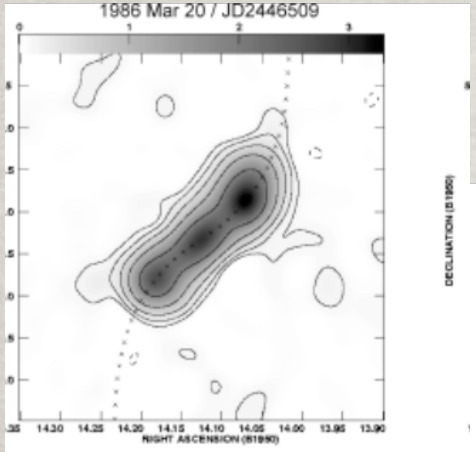


Jet emission quenched in soft state (up to / 700) .

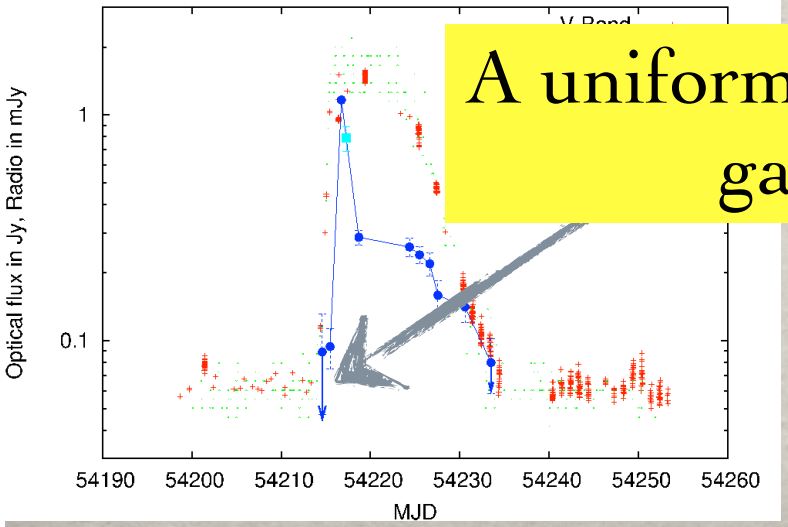
Unified model of:
Fender et al. 04
Corbel et al. 04

UNIFICATION IN GALACTIC COMPACT OBJECTS

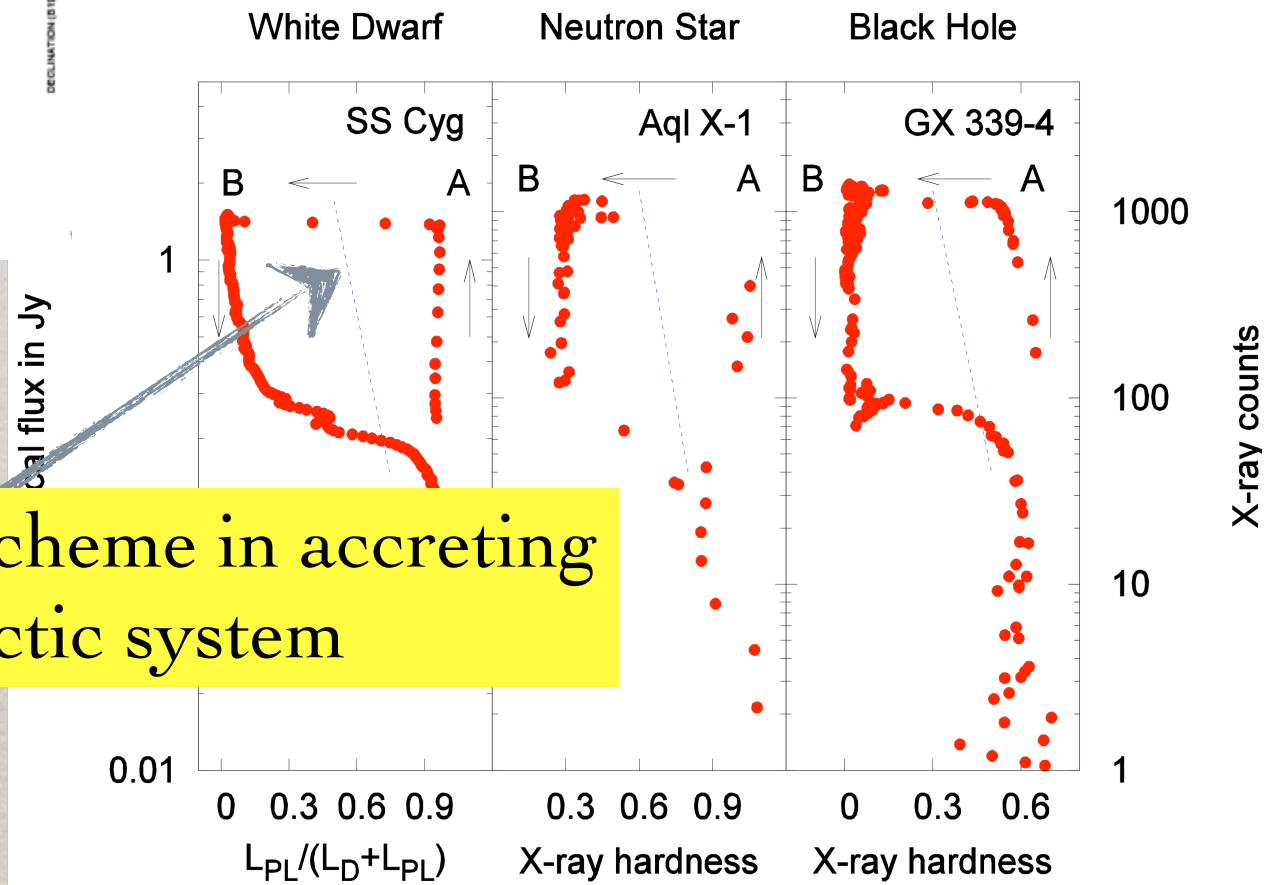




Jets in Aql X-1or CH Cyg (Miller-Jones et al. 2010, Crocker et al. 2007)

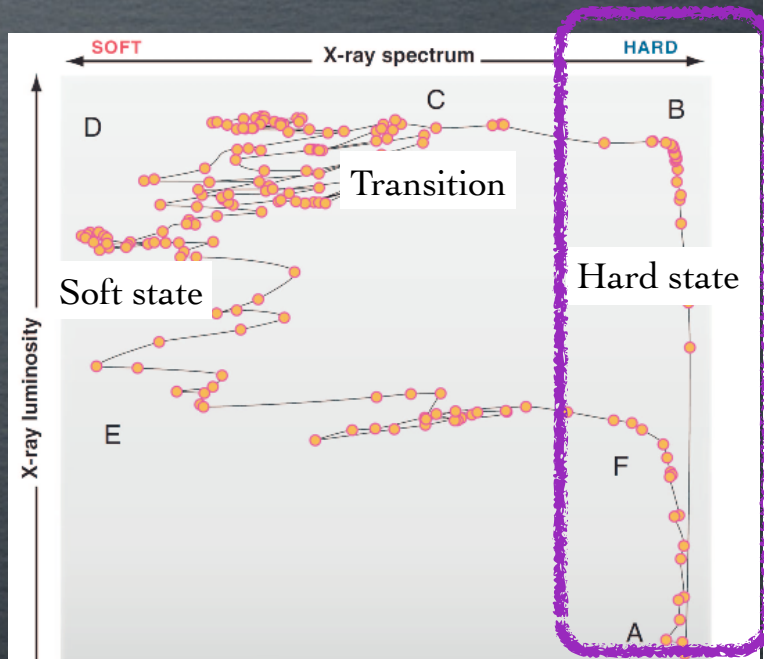


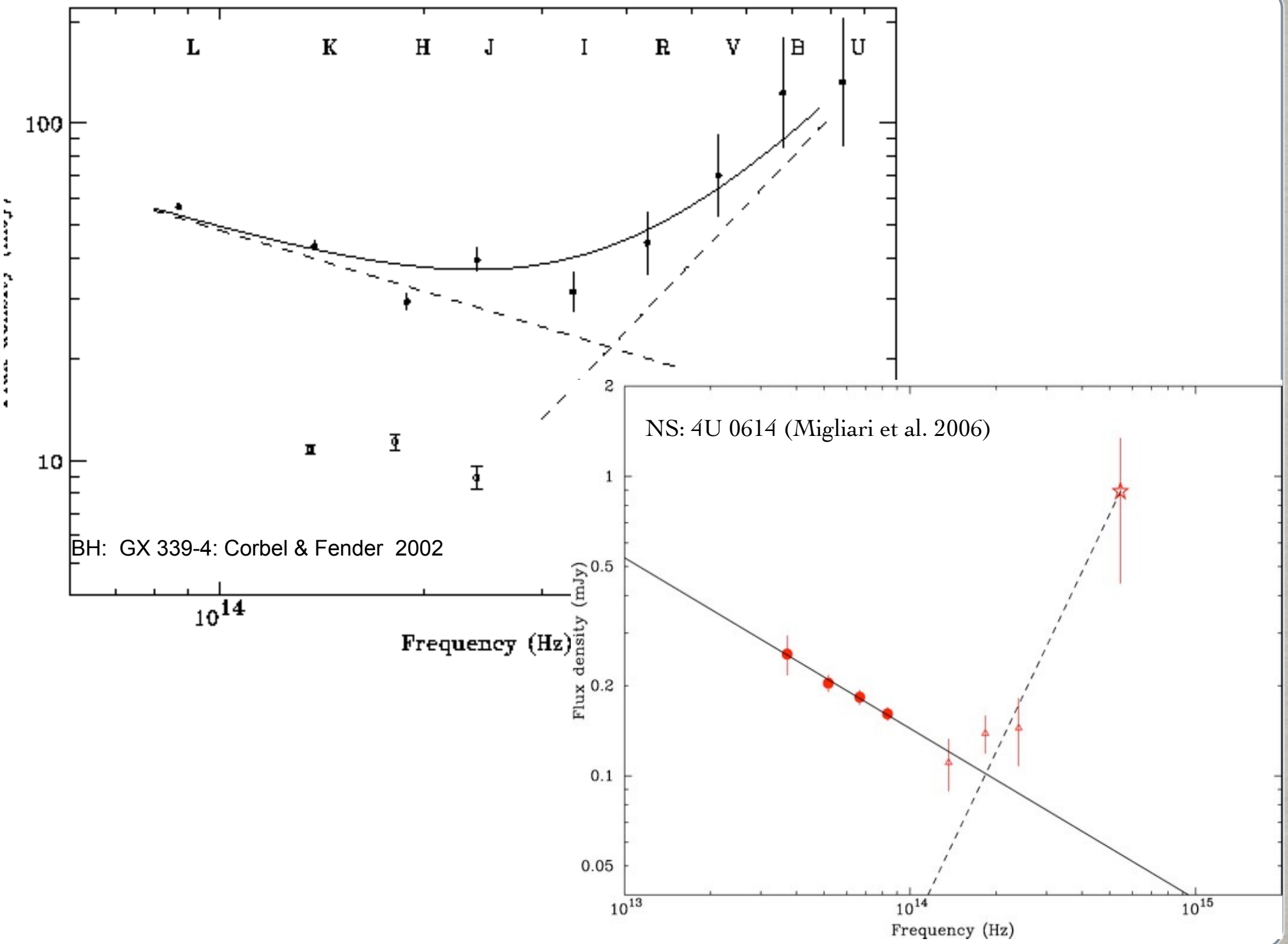
A uniform scheme in accreting galactic system



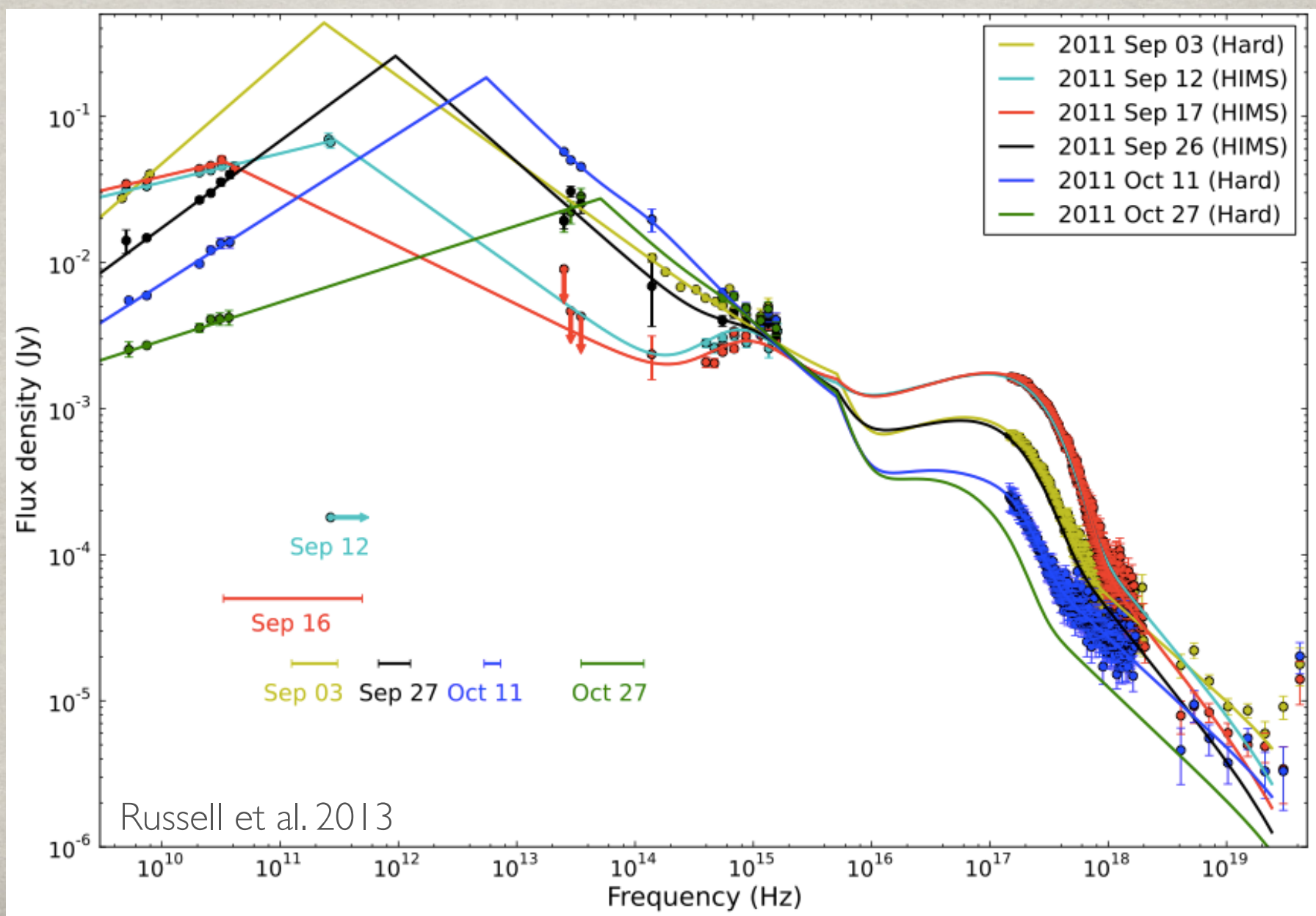
Koerding et al. 2008

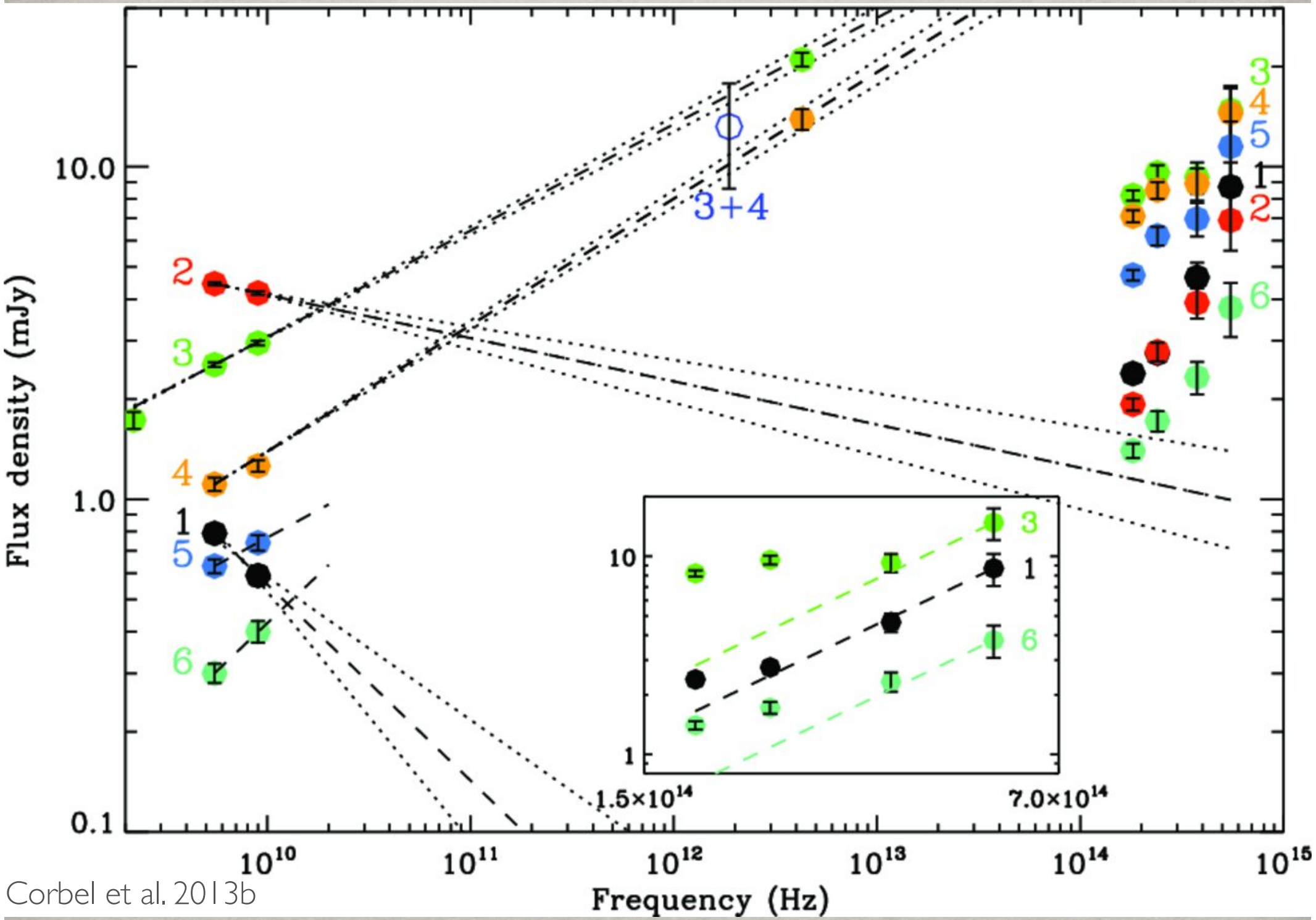
COMPACT JETS IN THE HARD STATE




L
K
H
J
I
R
V
B
U
100
10
10^{14}
Frequency (Hz)
BH: GX 339-4: Corbel & Fender 2002
NS: 4U 0614 (Migliari et al. 2006)
Flux density (mJy)
2
1
0.5
0.2
0.1
0.05
10^{13}
10^{14}
10^{15}
Frequency (Hz)

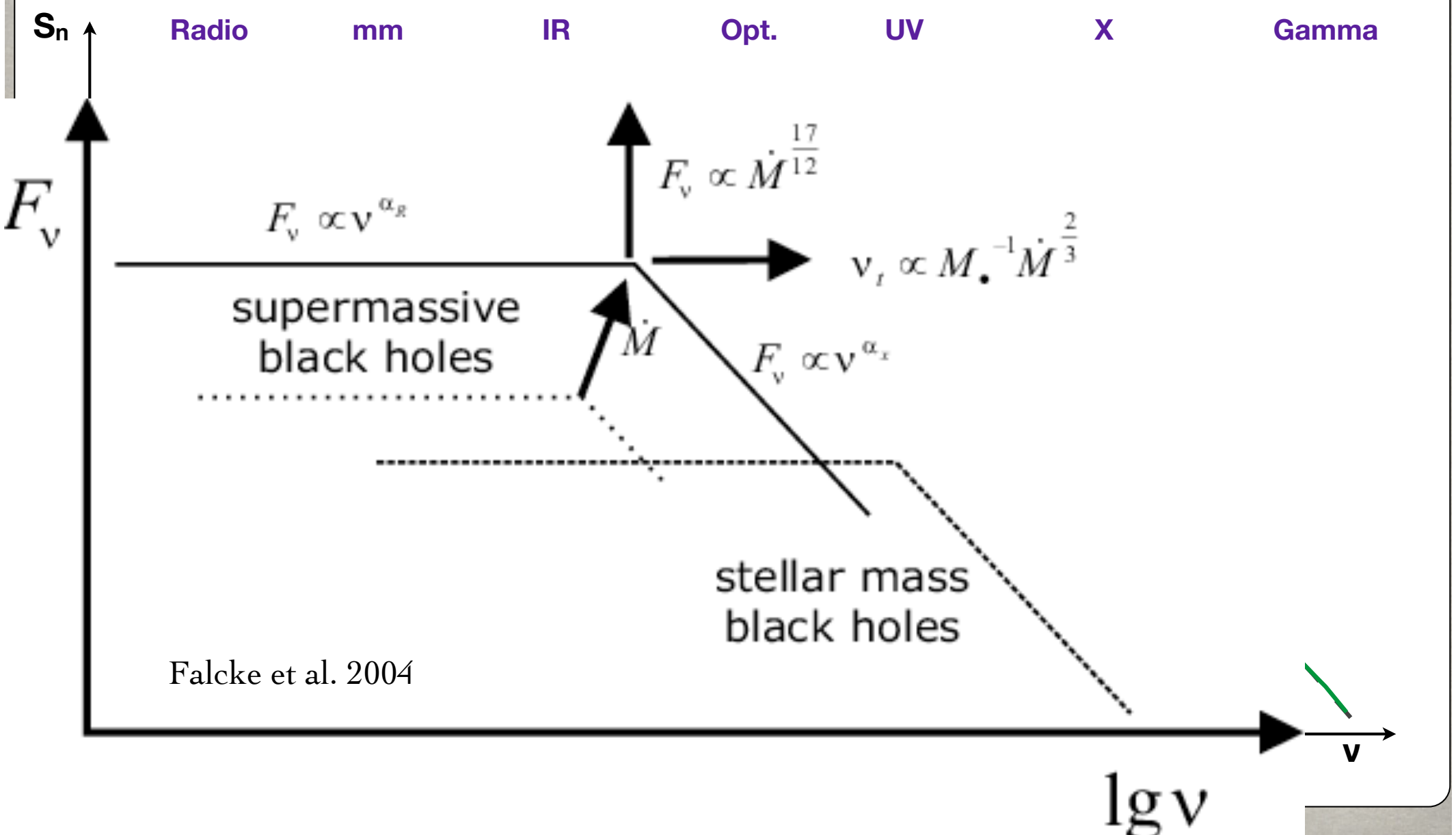
More spectral break evolution



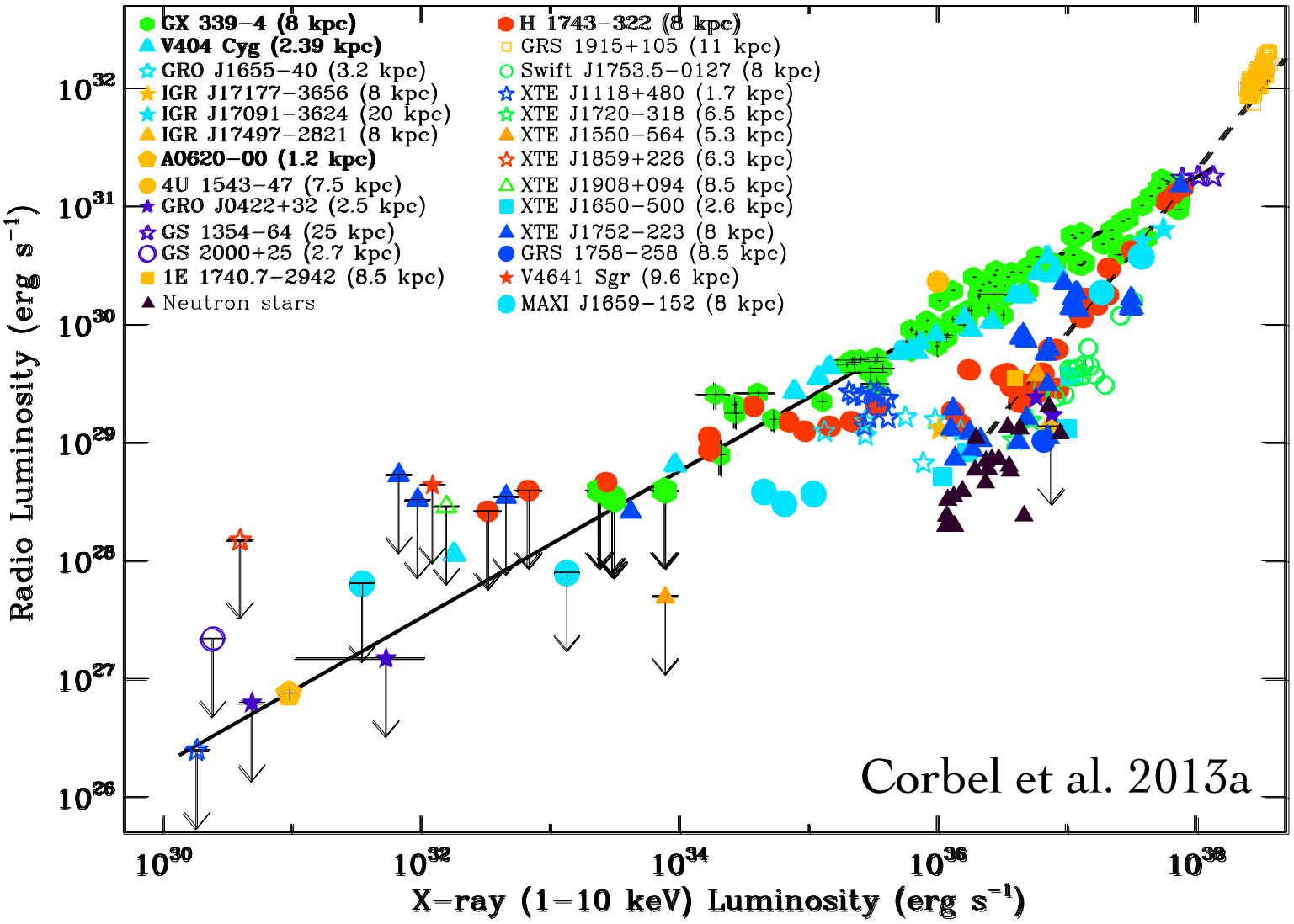


Corbel et al. 2013b

TYPICAL SED OF BH IN THE HARD STATE

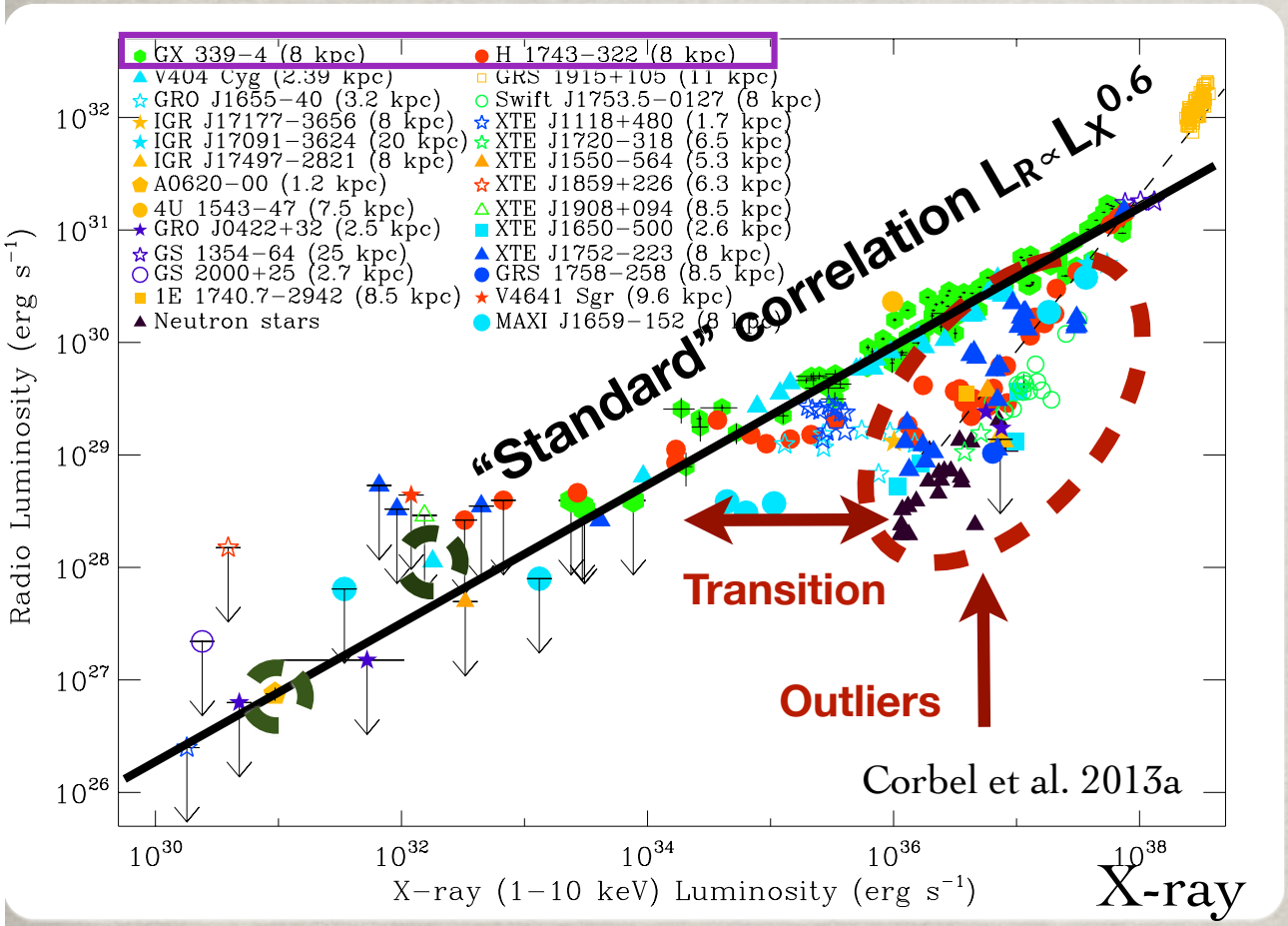


R/X CORREL. STATE OF THE ART



THE MOST UP TO DATE VERSION OF THE R/X CORRELATION

Radio



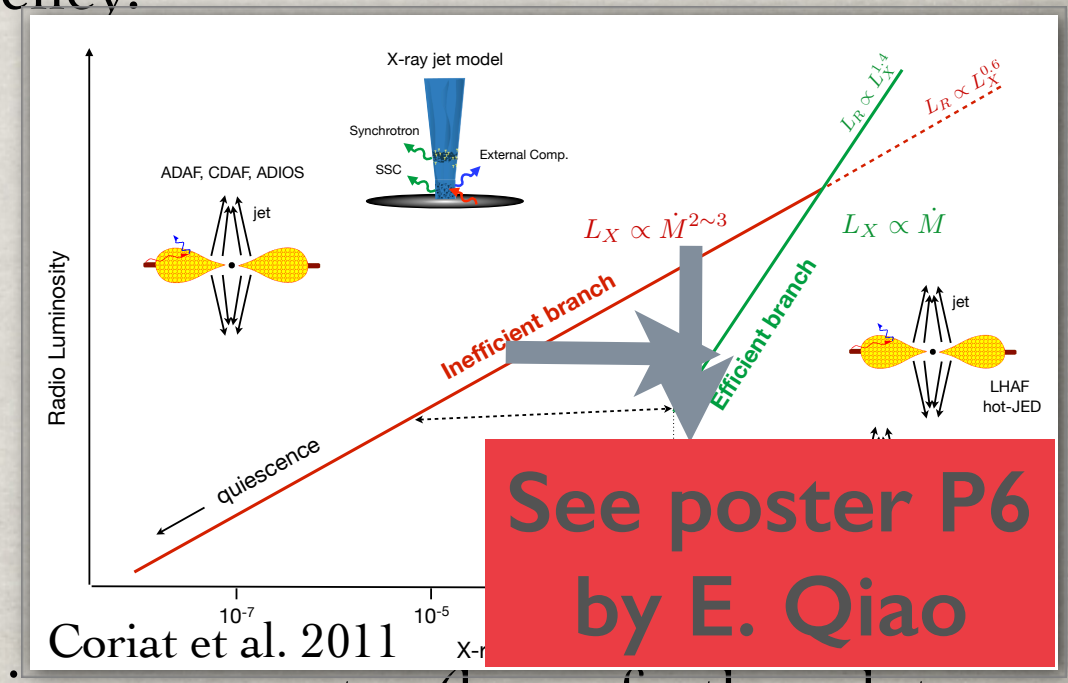
- Incl. new data of GX 339-4 ove 15 years and multiple outbursts: very stable correl. (Corbel et al. 2013a). Hard S.
- Quiescent BHs consistent with «standard» correl.
- More and more sources below the std correl: **the «outliers».** (Corbel et al. 04, Coriat et al. 11, Gallo et al 12.)
- Transition between 2 groups: Outliers move back to the std correlation @ low flux

- **Properties of the outliers ?** The odyssey of H 1743-322 over the course of seven outbursts ⇒ Steeper slope: 1.4 instead of 0.6 (Coriat et al. 11).
- **Transition**: now also MAXI J1659-152 (Ratti et al. 12) & XTE J1752-223 (Jonker et al. 12).

INTERPRETATION OF THE CORRELATIONS

- **Outliers = X-ray loud ⇒** Origin of the dichotomy: ≠ X-ray mechanisms have ≠ radiative efficiency.

Possible to explain the 1.4 correlation index with models such as LHAF, ADC, hot-JED.



Coriat et al. 2011

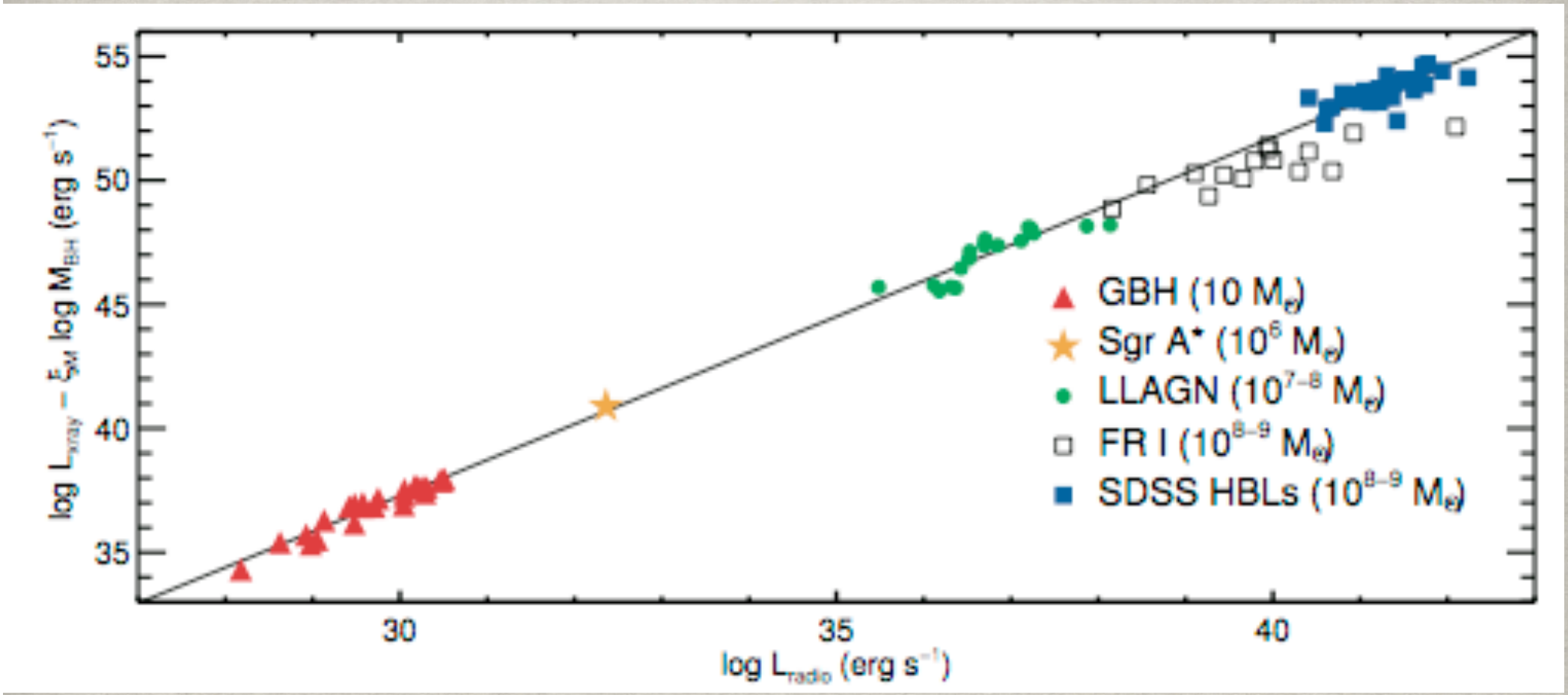
See poster P6 by E. Qiao

Transition = possible switch

LHAF to ADAF like, due change in α parameter (henceforth m dot critical in LHAF) for different sources (Xie & Yuan 2012)

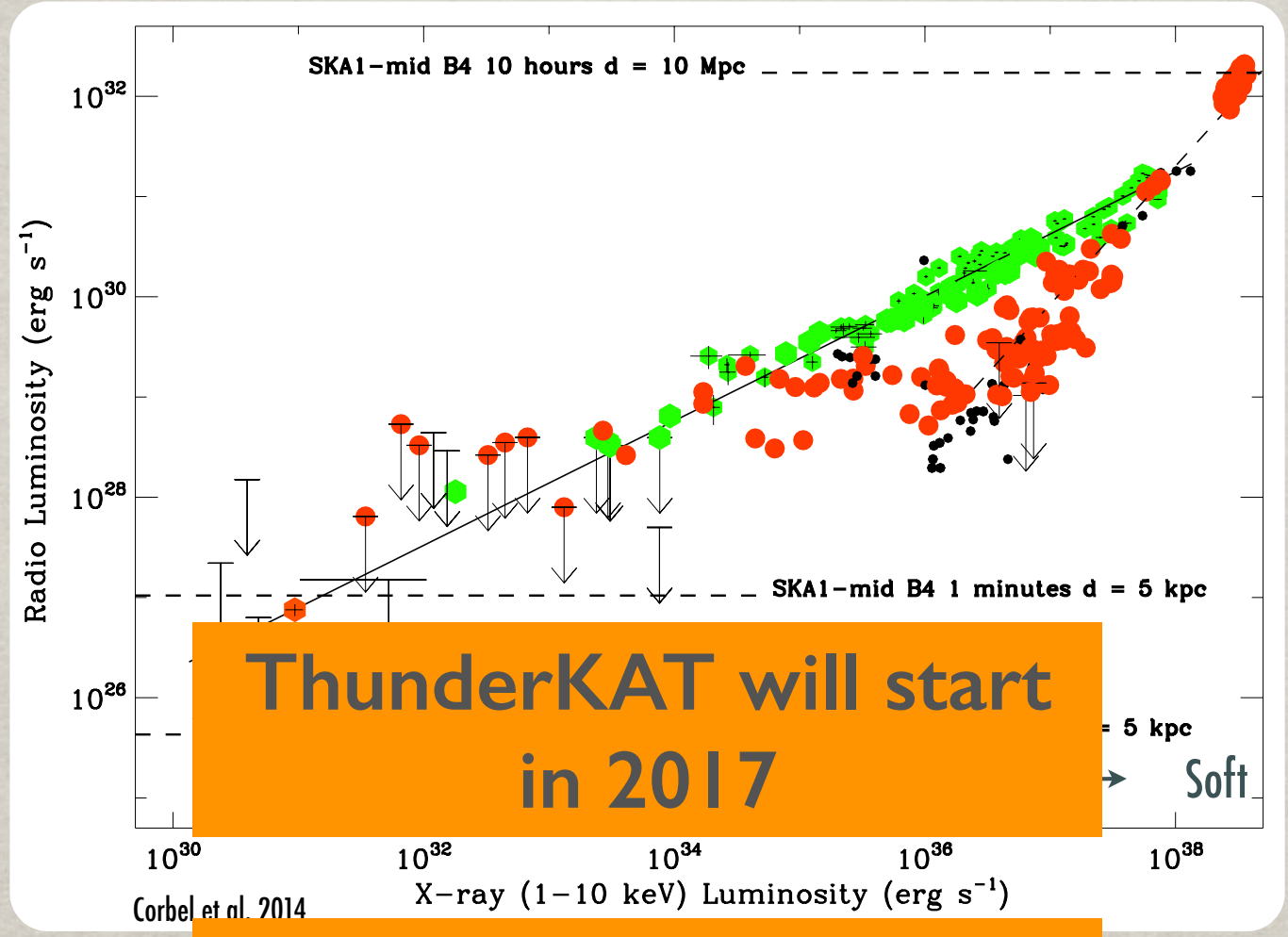
- **Outliers = radio faint.** Origin of the dichotomy related to jet properties. ⇒ $Q_{\rm jet} = f_j \dot{M} c^2$ (e.g. Falcke & Biermann 95). If f_j variable for outliers(e.g. $f_j \propto \dot{M}$) then X-ray emission for both population could still be related to radiatively inefficient accretion flow in the hard state.

FUNDAMENTAL PLANE OF BH ACTIVITY



Plotkin et al. 2011

PROSPECT WITH THE SKA



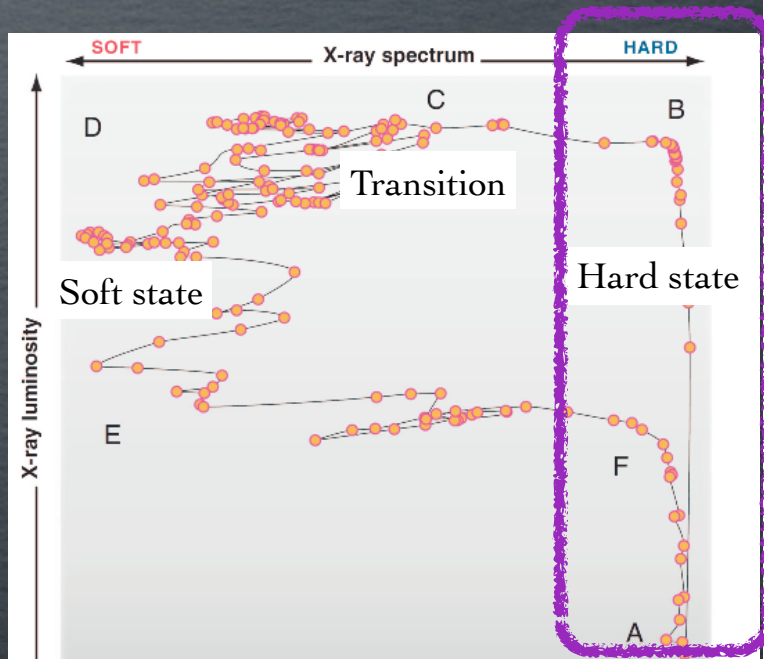
ThunderKAT will start in 2017

We still need an active sensitive X-ray monitor

SKA: probing **a sig** **urst** duration for

All **flaring transient** BHs accessible in the **local Universe** (possibly also up to Virgo @ 15 Mpc)

HE EMISSION FROM THE JETS OF V404 CYG

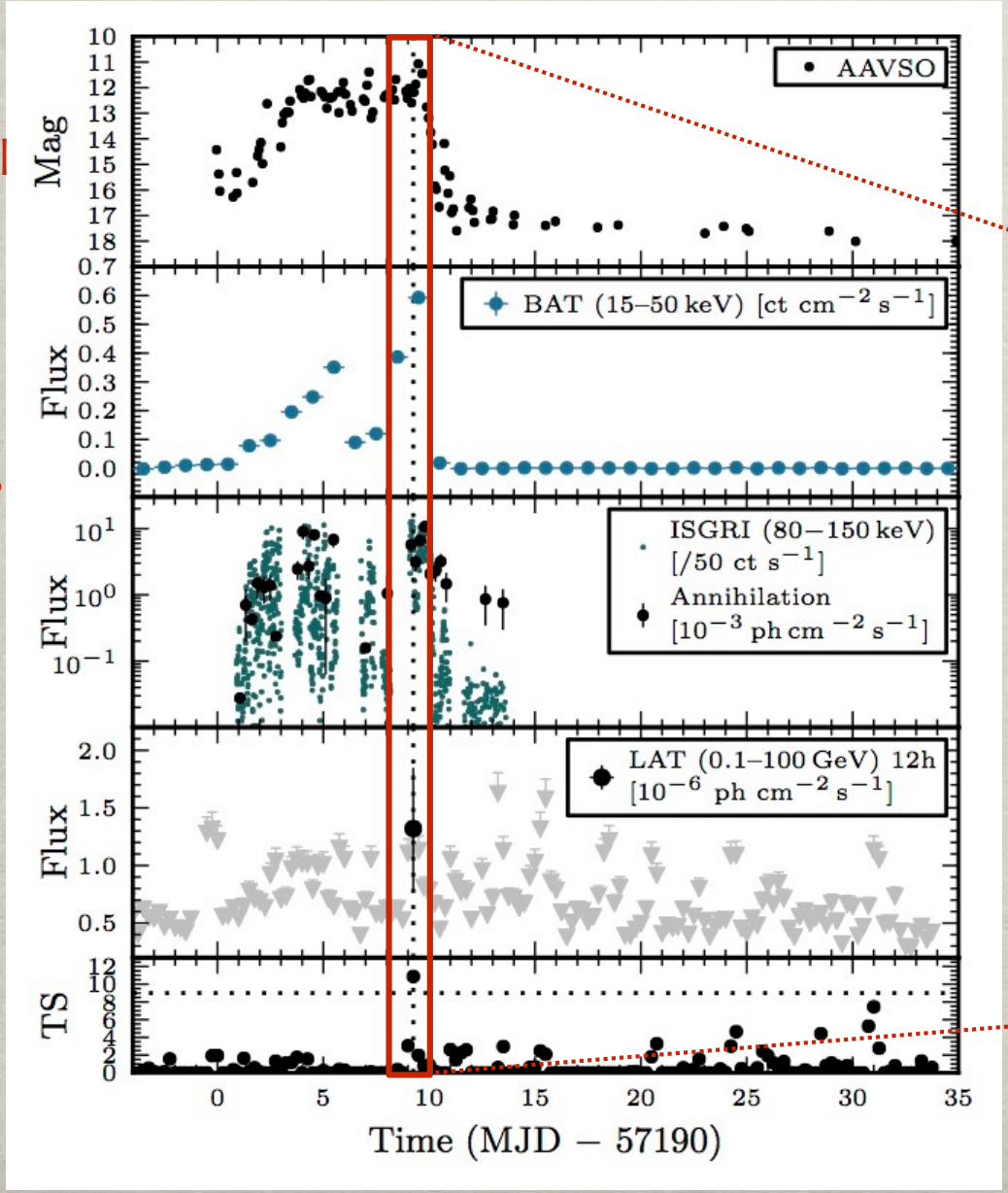


Search for HE gamma rays from V404 Cyg

optical

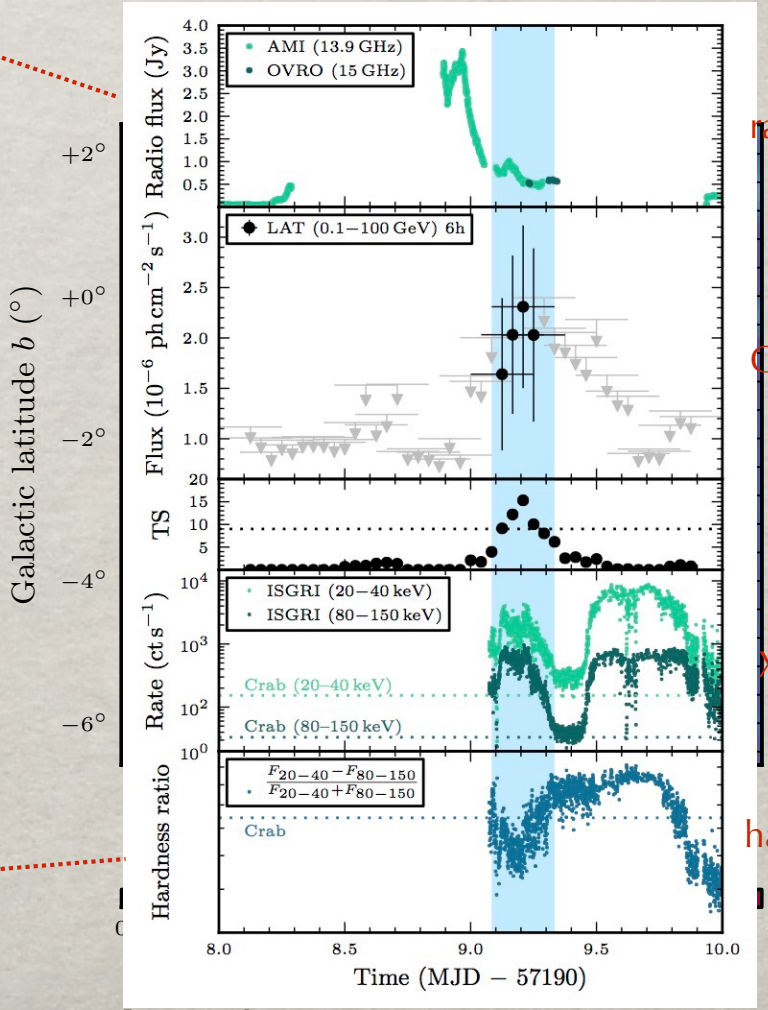
X-rays

GeV



Variability analysis MJD 57140 - 57225

Single excess @ MJD 57199.2±0.1



radio

GeV

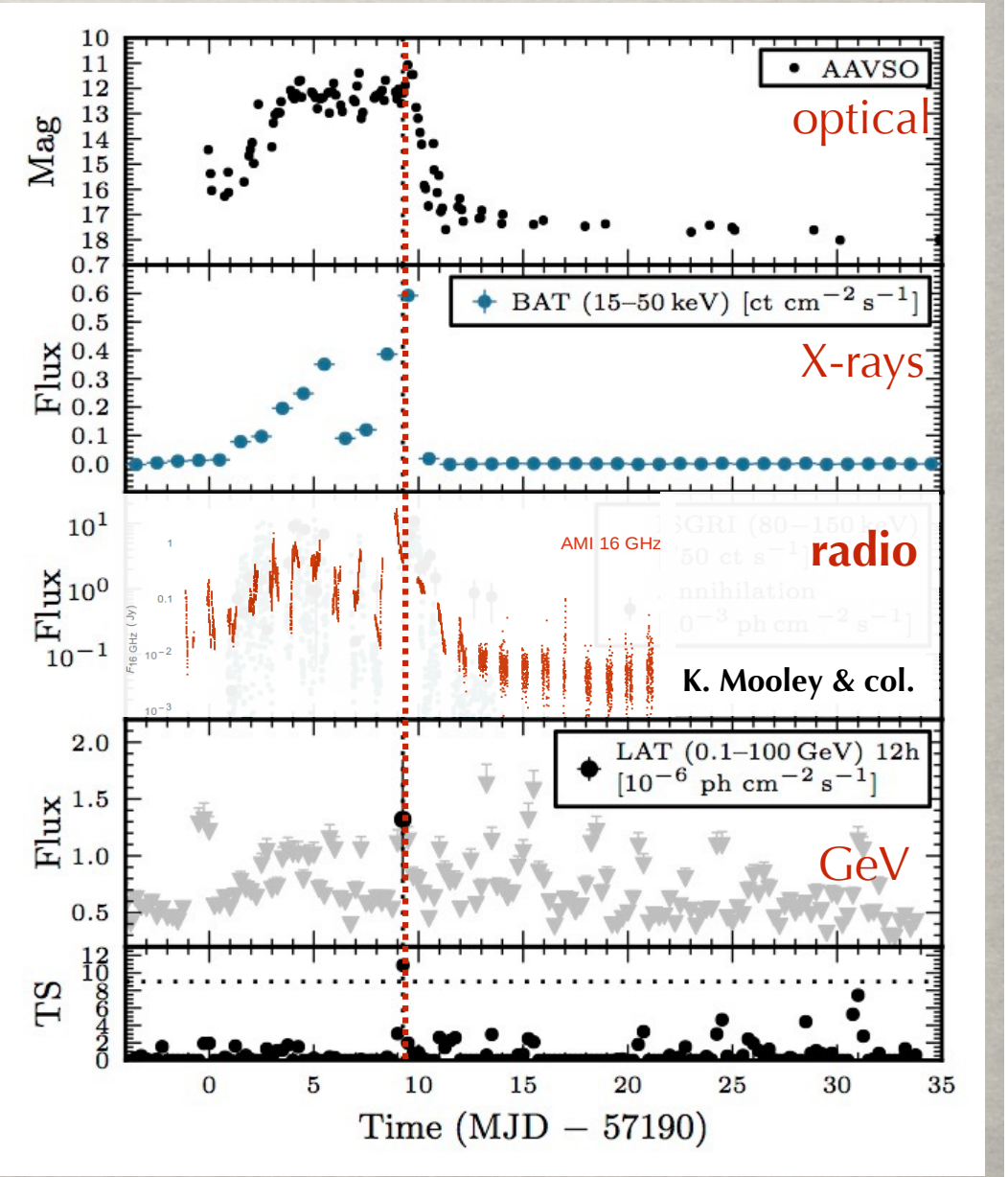
X-ray

hardness

Loh et al. 2016, MNRAS, 462, L11

Gamma rays detected from V404 Cyg ?

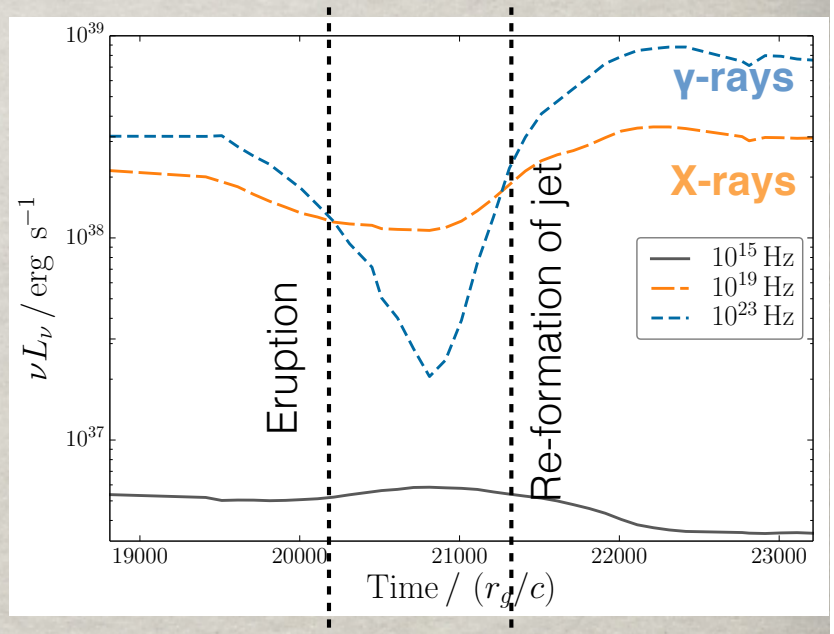
- Peak flux = $(2.3\pm0.8) \times 10^{-6}$ ph cm^{-2} s^{-1} or L(>100 MeV) ~ 2×10^{35} erg s^{-1}
- Photon spectrum very soft dN/dE~E$^{-3.5\pm0.8}$
- TS~15.3 not significant on its own to claim a detection but association with period of brightest radio/ X-ray activity followed by marked change in MWL properties makes it compelling



Loh et al. 2016, MNRAS, 462, L11

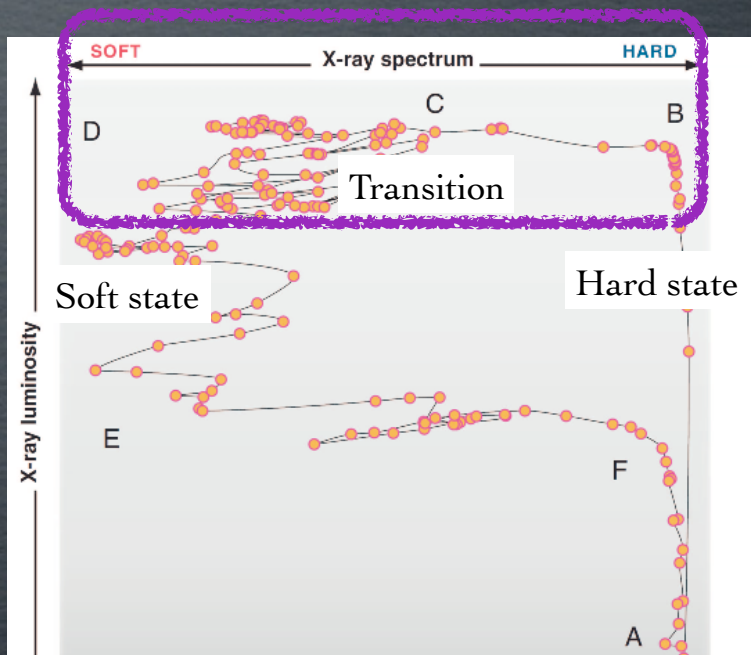
TAPING ROTATION ENERGY FROM BH ?

- Pair production (opacity) implies **GeV away in jets.**
- **Spin of black hole a>0.98** from reflection spectrum (Walton et al. 2016).
- Gamma rays only for **magnetically-arrested disks** (MAD, McKinney et al. 2012) tapping BH rotational energy (Blandford & Znajek 1977)
- Accumulation of poloidal magnetic flux in inner region close to BH.
- **Destruction of MAD** by accretion of B opposite polarity: X-ray state changes ? (Dexter et al. 2014)
- **Gamma-ray flux variability & mildly relativistic ejection as MAD destroyed & rebuilt** (O'Riordan+ 2016a)
- **Bright gamma-ray emission** from jets after ejection

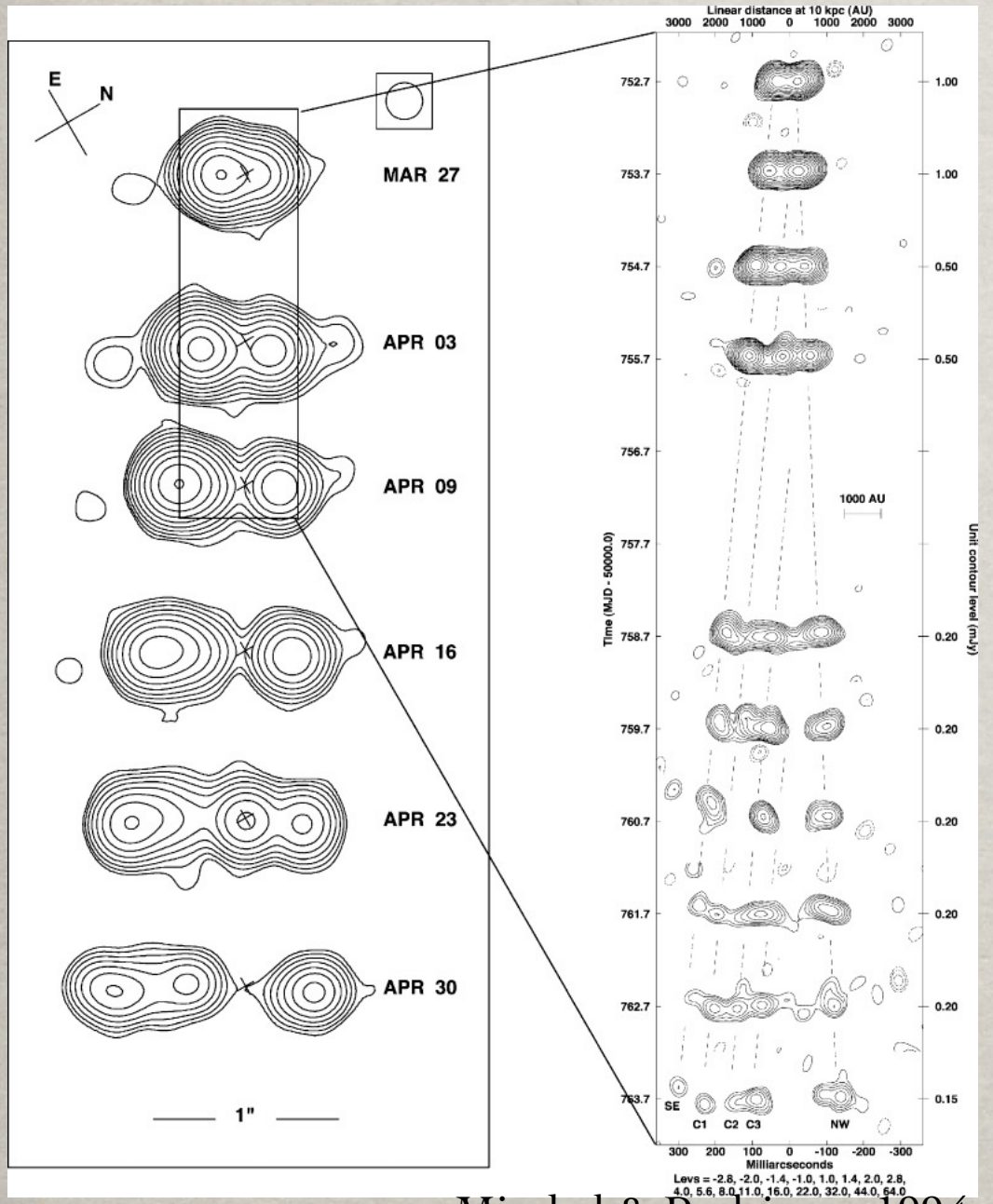


O'Riordan et al. 2016a+b

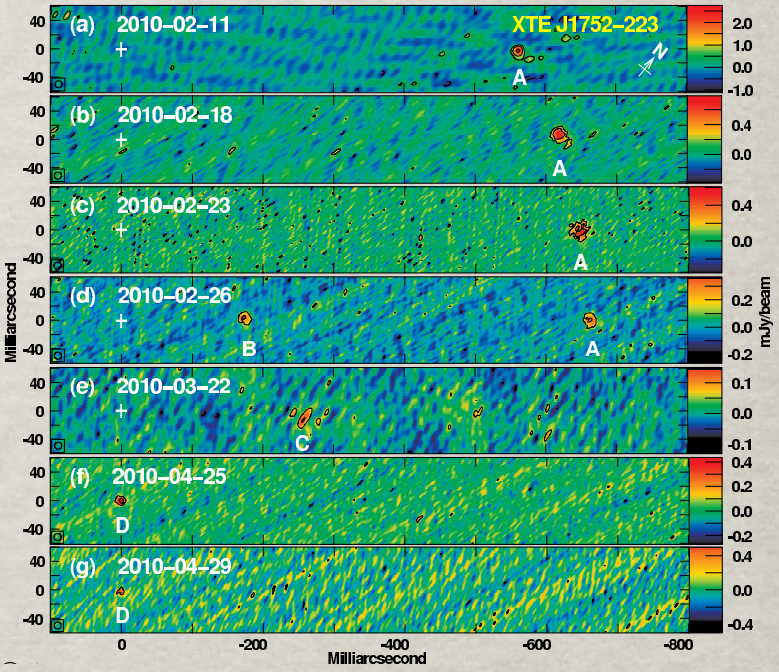
STATE TRANSITION AND THE UNIFIED MODEL



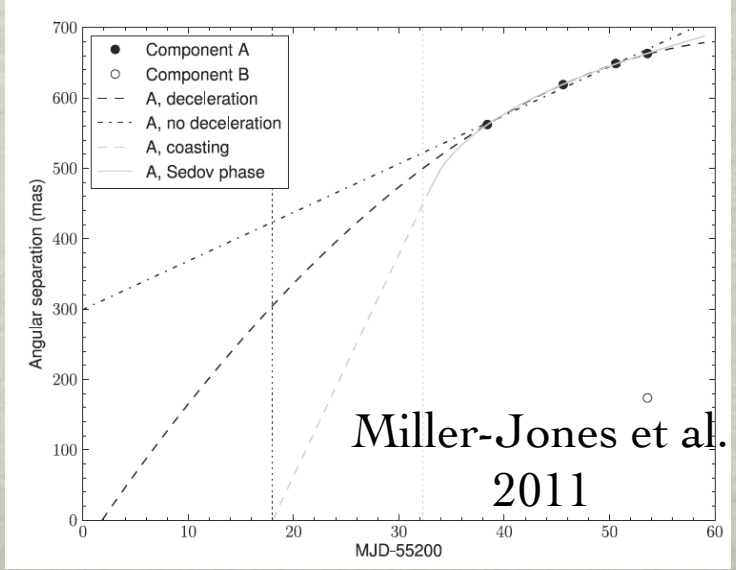
TRANSIENT JETS



Mirabel & Rodriguez 1994
Fender et al. 1999



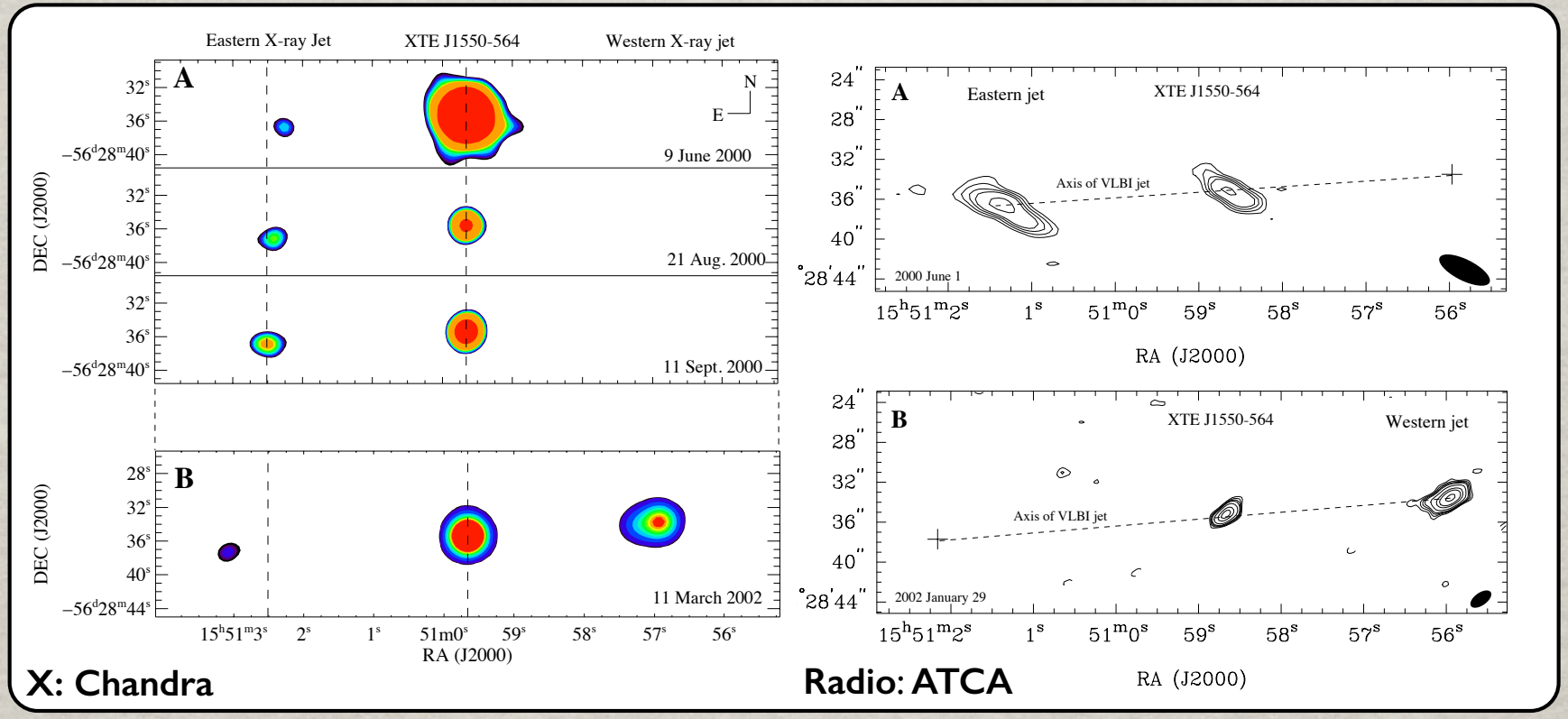
Yang et al. 2010, 2011



Miller-Jones et al. 2011

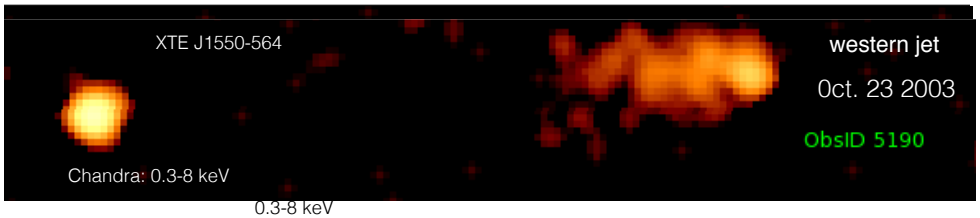
JETS INTERACTION WITH THE ISM

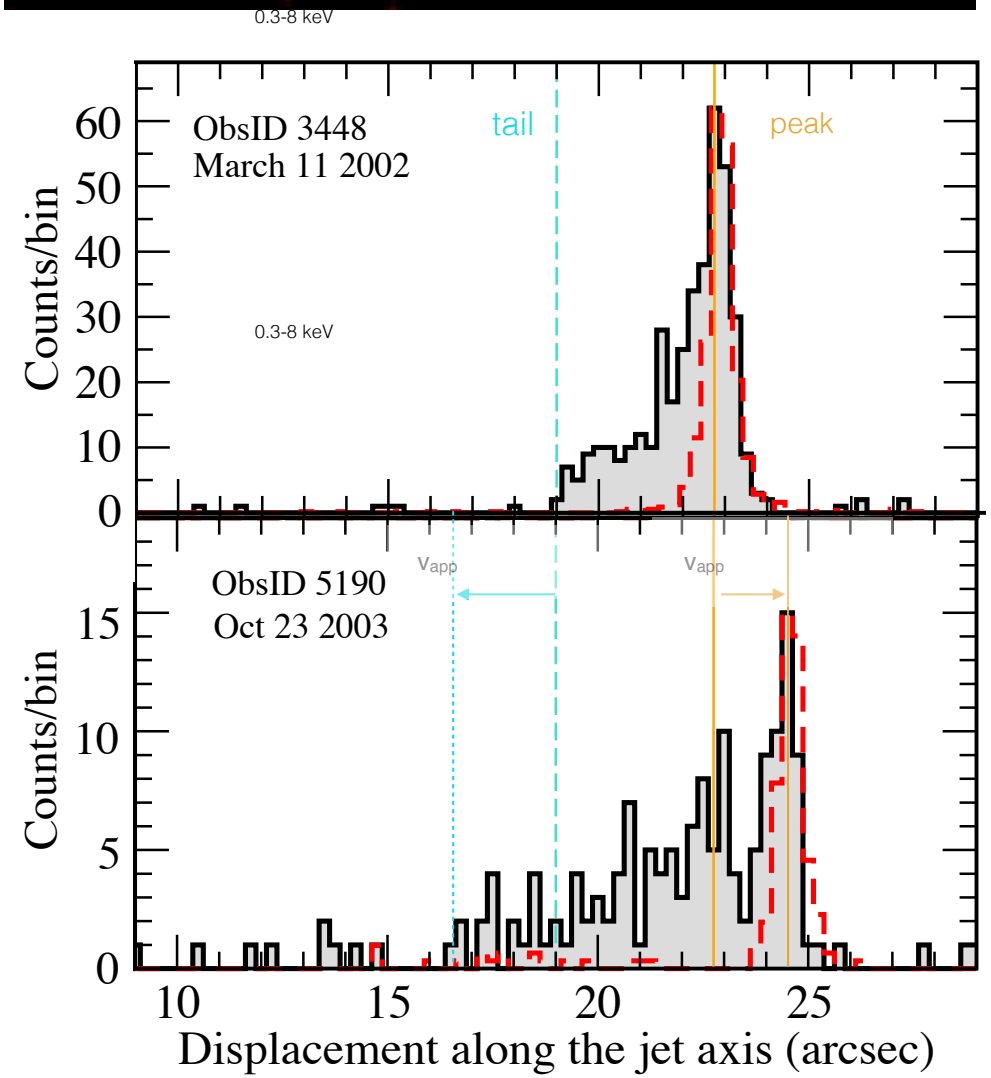
Corbel et al. 2002



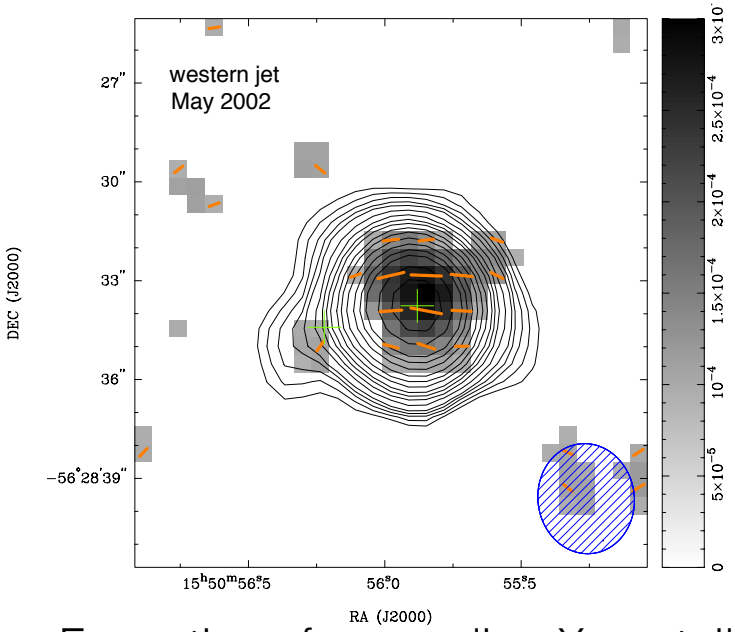
- Origin of the event = big flare during the 1998 outburst
- Jets deceleration + Particles re-acceleration up to TeV energy. Synchrotron X-rays. Few more cases now.

EVOLUTION OF THE JET



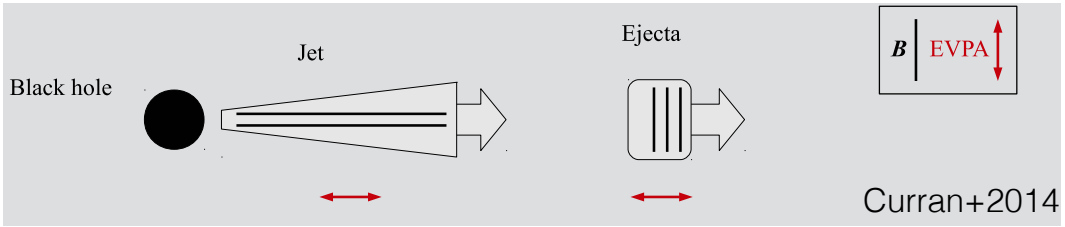


Migliori, Corbel et al., to be submitted



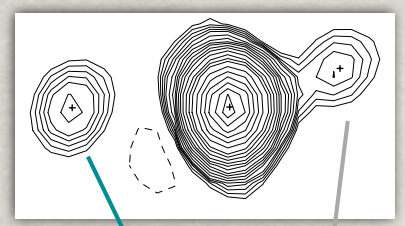
Formation of a receding X-ray tail & polarized radio emission: signature of particle acceleration process in action.

Direct obs. of reverse shock ?



Shock-compressed B-field

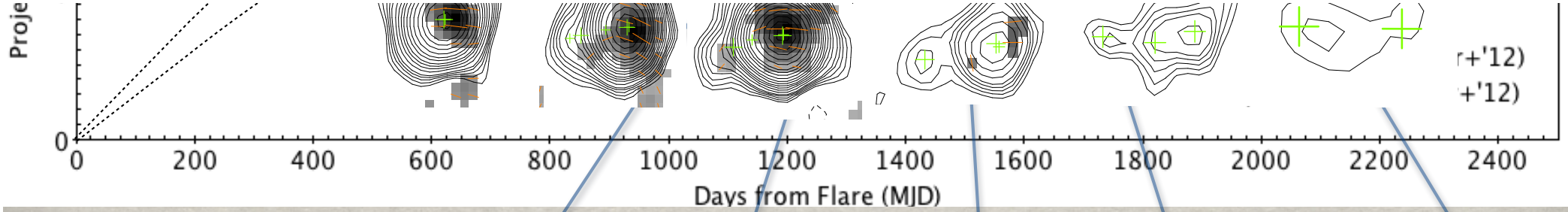
JETS' DYNAMICS

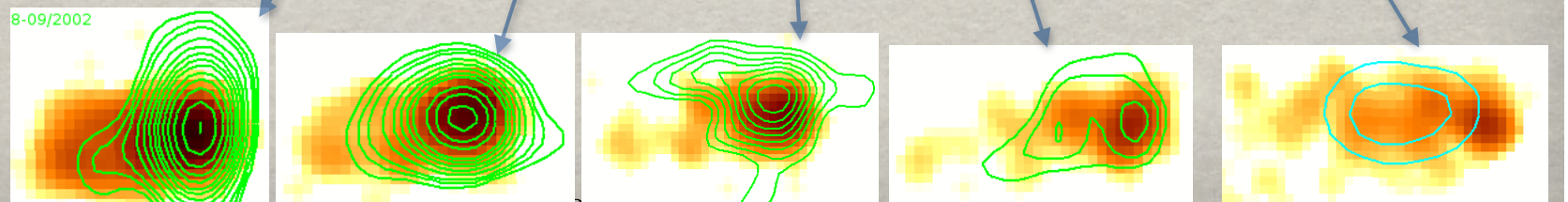


western jet first detection in 2001

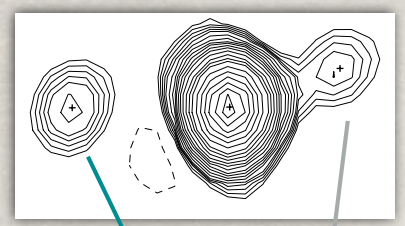
➡ beginning of the deceleration phase

- Broadband emission most-likely of synchrotron origin;
- Evidences of spectral changes over 1.5 yrs: multiple sites of particle acceleration?
- Chromatic flux decay: faster in radio than in X-rays;
- Jet motion **consistent with the jet-in-a cavity model**





JETS' DYNAMICS



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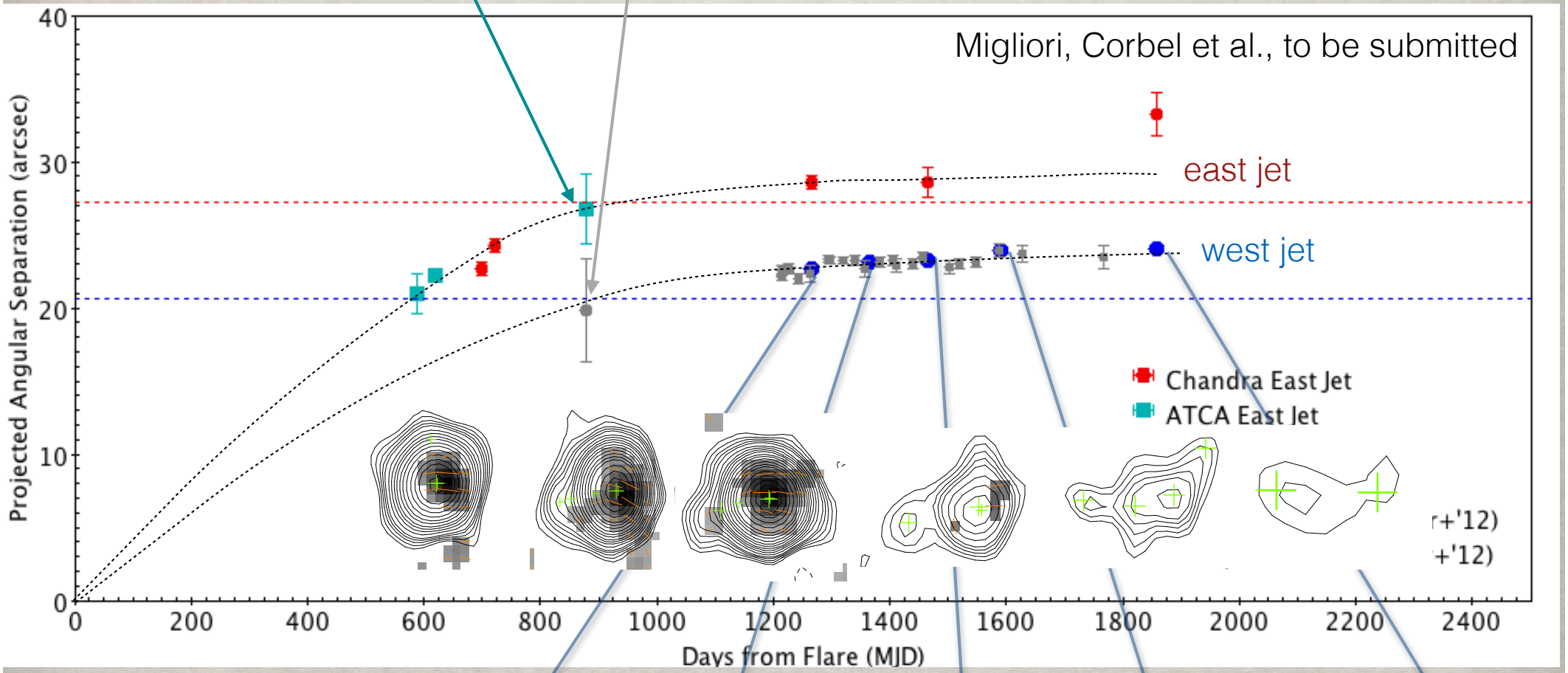

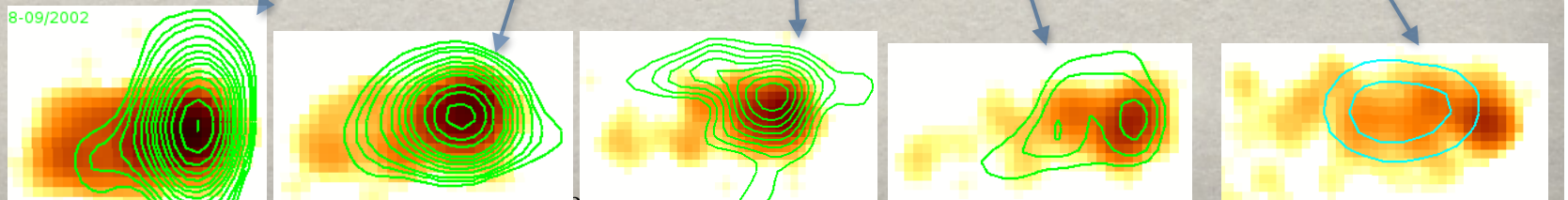

CONCLUSIONS

- **Compact jets** in the hard state: a universal radio/X-ray correlation ⇒ diagnostic of emission processes. Similar coupling in AGNs (low m dot).
- Nature of the «**outliers**» = a radiative efficient flow in the hard state ? Extension to AGNs ?
- **Transients jets** in all XRBs (low B, you need a disc): uniform jet line. Questioning the role of central object in jet formation (BH spin, potential well, GR) ?
- **Jets feedback** on the ISM: particles re-acceleration. Direct observations of a reverse shock in XTE J1550-564 ?
- **High energy emission** now observed in jets with Fermi/LAT !
- New prospects for transients with the SKA !! **But needs all sky X-ray monitor.**