Jets from X-ray binaries

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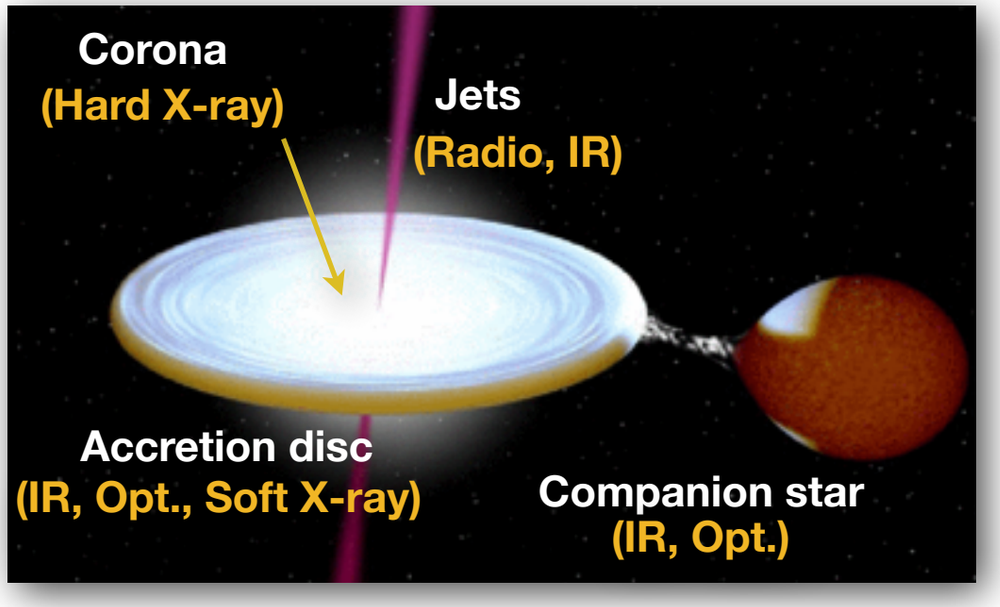
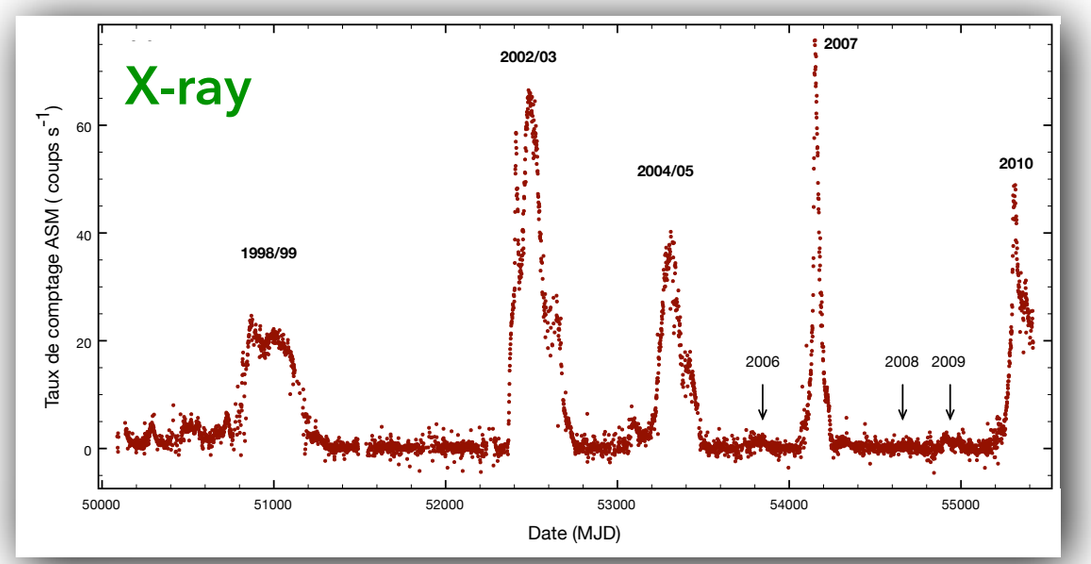
Outline

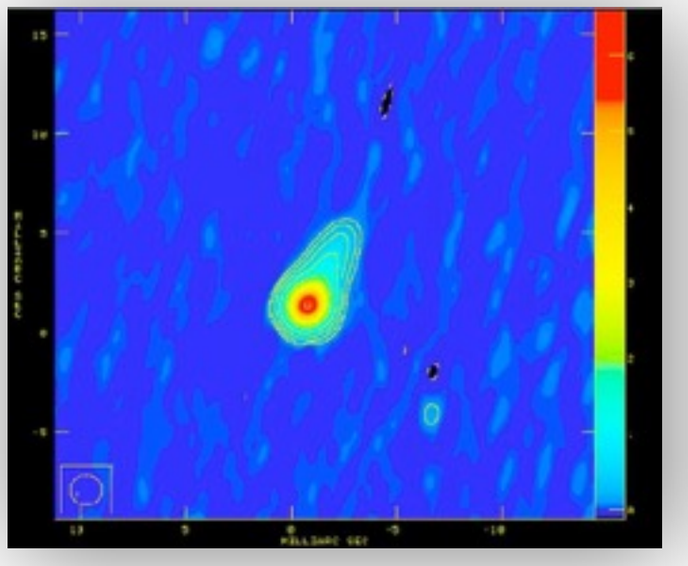
- X-ray binaries: overview
- The empirical picture
  - Luminosity correlations
  - Radio flares and major ejection events
  - Accretion disc winds
- Jet power
  - Jet power and spin
  - Jet power and particle content

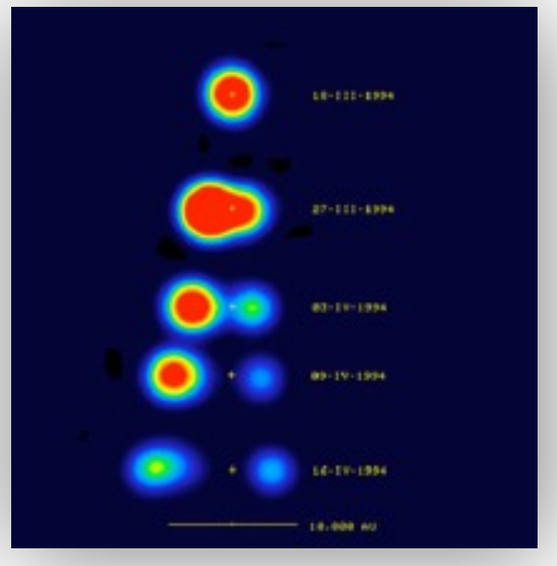
X-ray binaries: overview



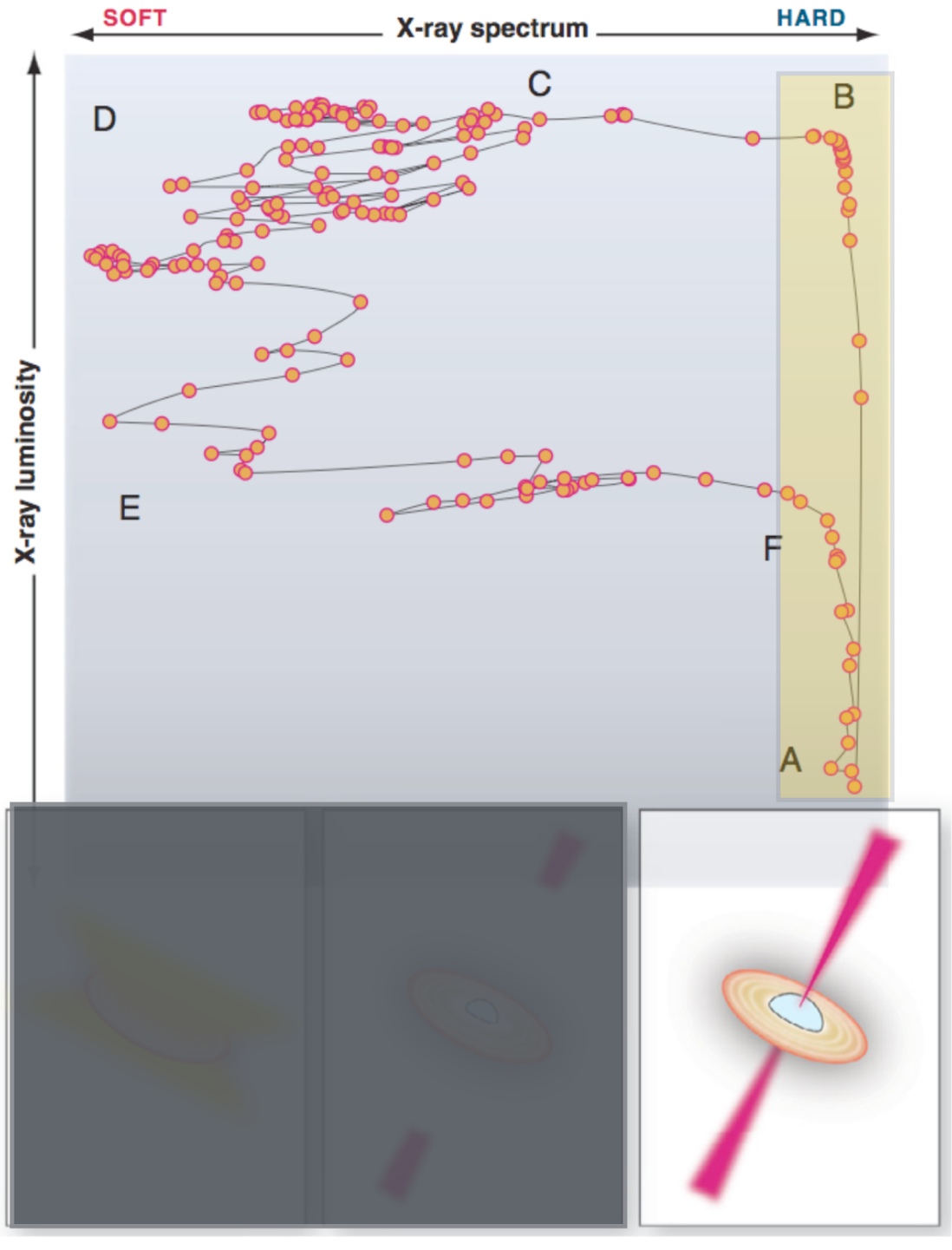
- Multi-wavelength emitters
- Highly variable (ms to years = "Human" timescales)
- Transient: outburst (~1 year) / quiescence (~10 years)
- Several accretion states
- Intermittent jets





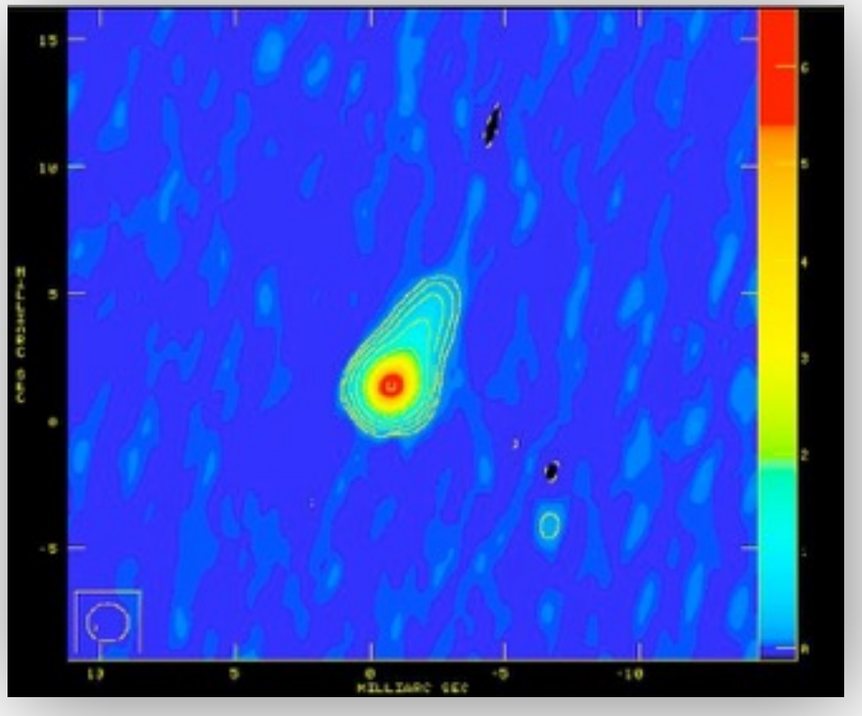


The empirical picture



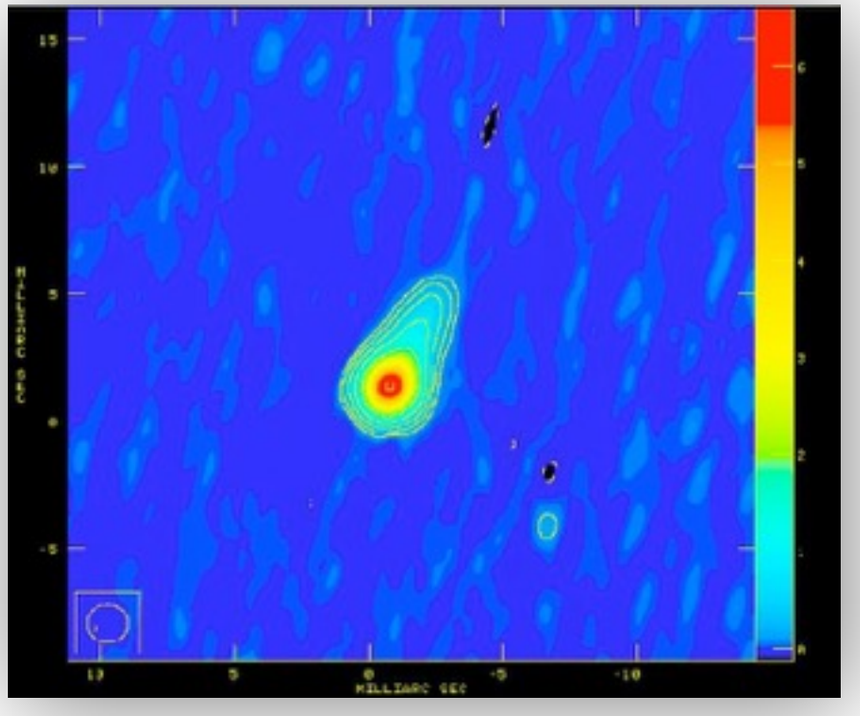
The hard state

- From ~10^{32} ergs/s (quiescence) up to ~ 10^{37} ergs/s
- Corona dominates X-ray emission
- Strong X-ray variability (frequency range 0.01-100 Hz)
- Compact jets

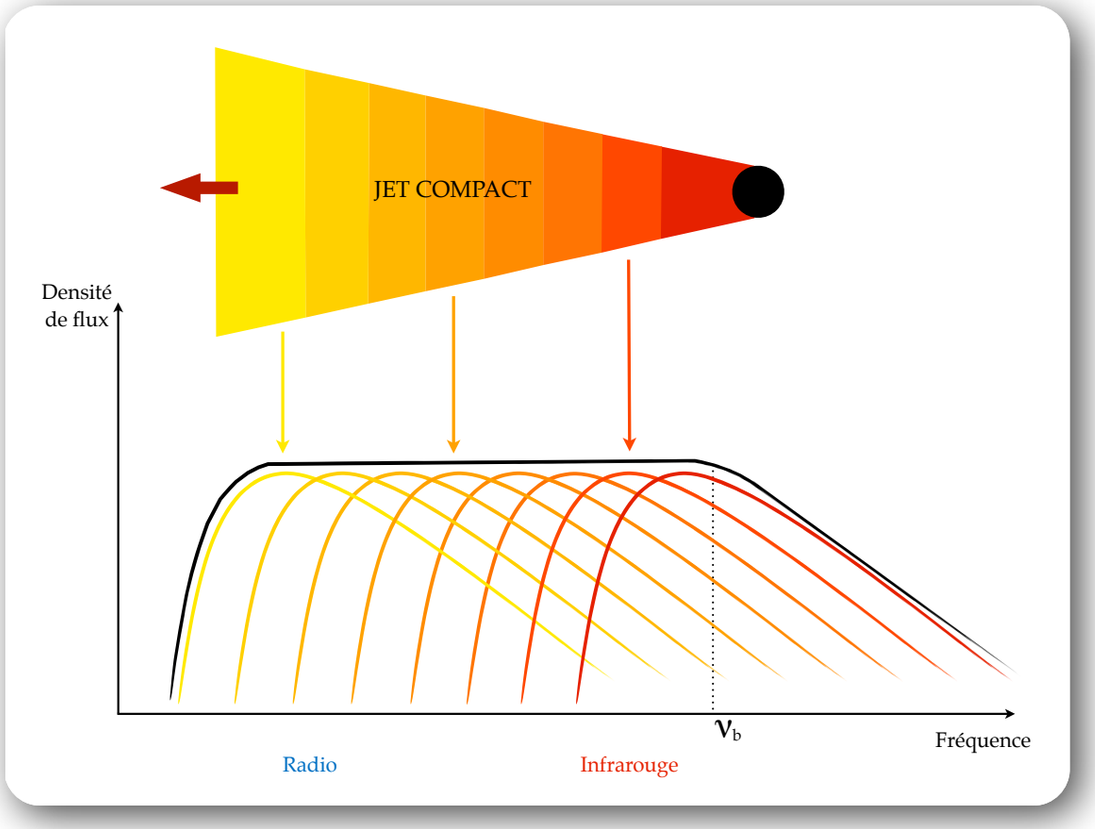


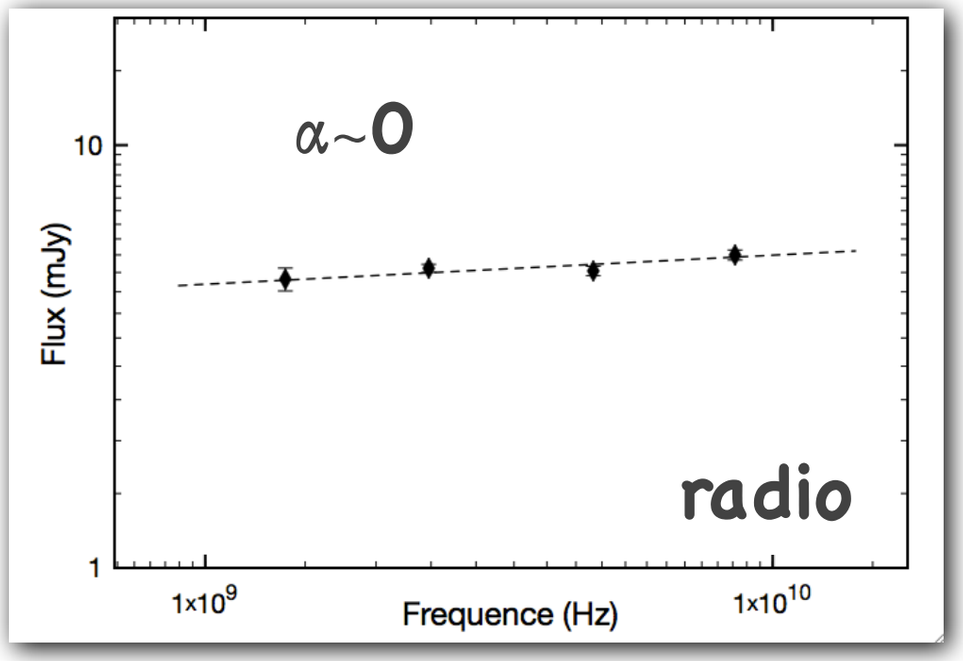
Compact jets

- Few m.a.s. = few 10 A.U.
- Steady emission
- Flat spectrum from radio to IR
- Self-absorbed synchrotron emission
- Internal shocks (see Julien's talk)



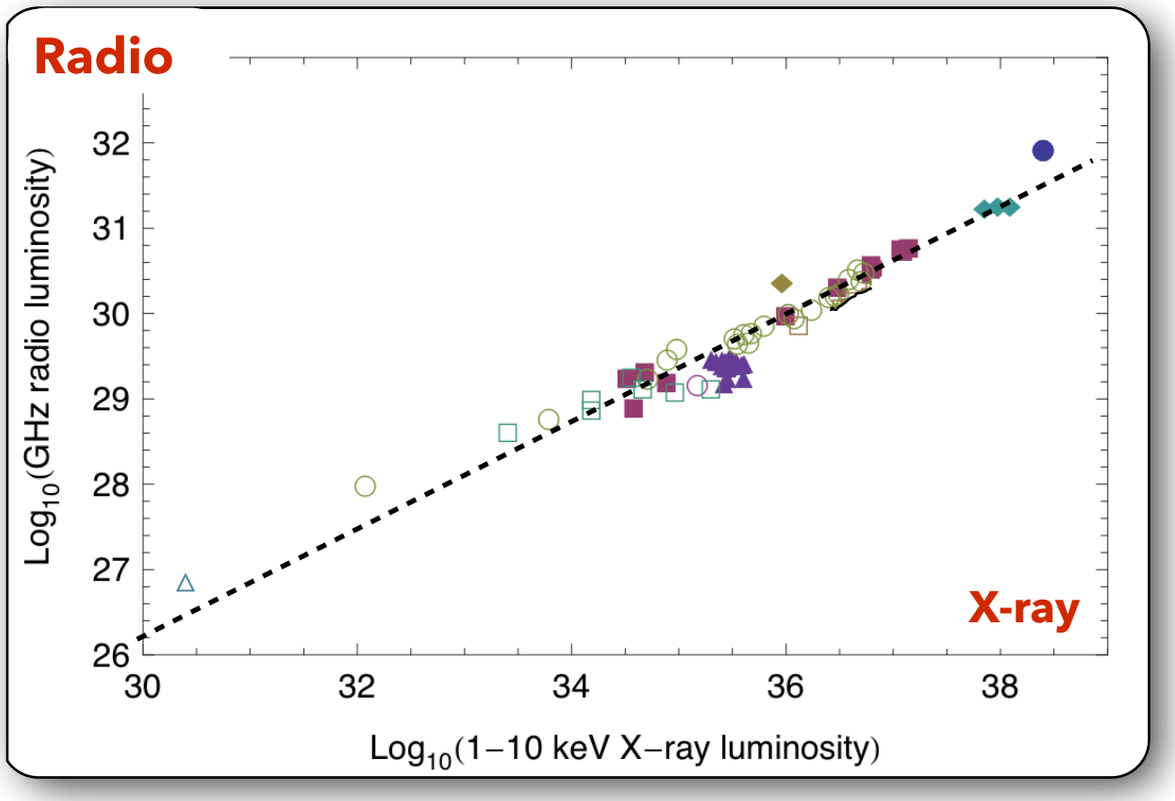
Stirling et al 2001





Luminosity correlations

Stellar mass BH

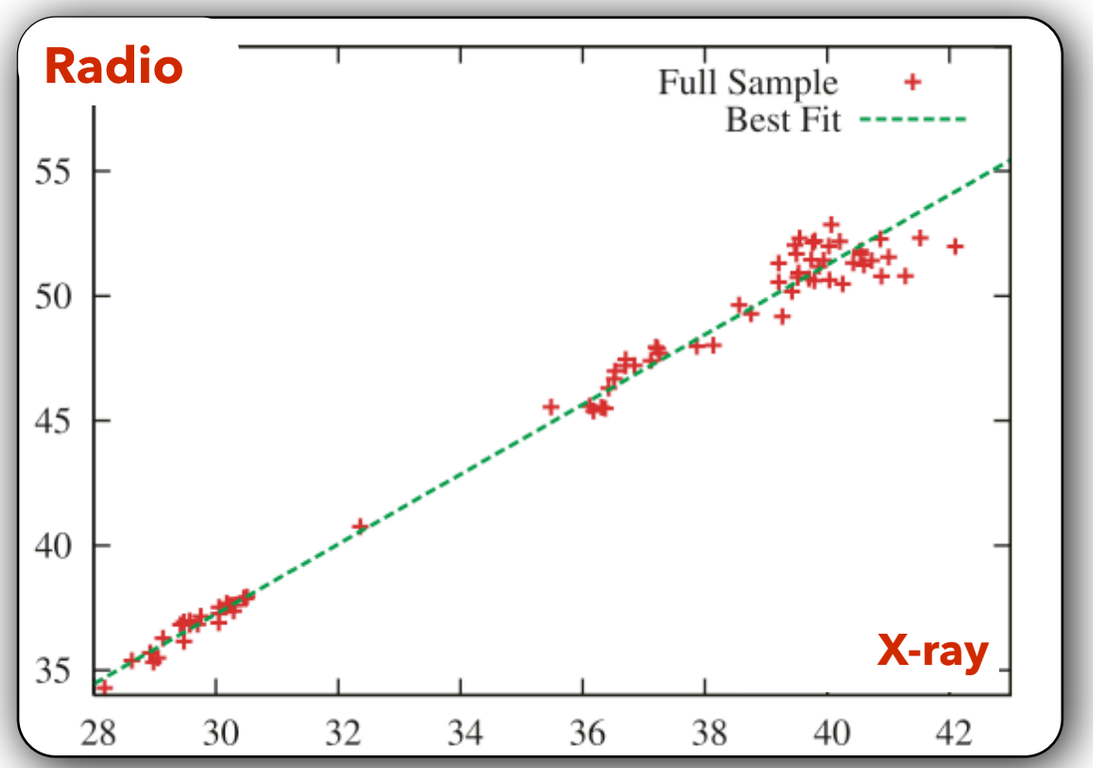


JET

Fender et al. (2010)

Accretion

Stellar mass and supermassive BH



JET

Koerding et al (2006)

Accretion

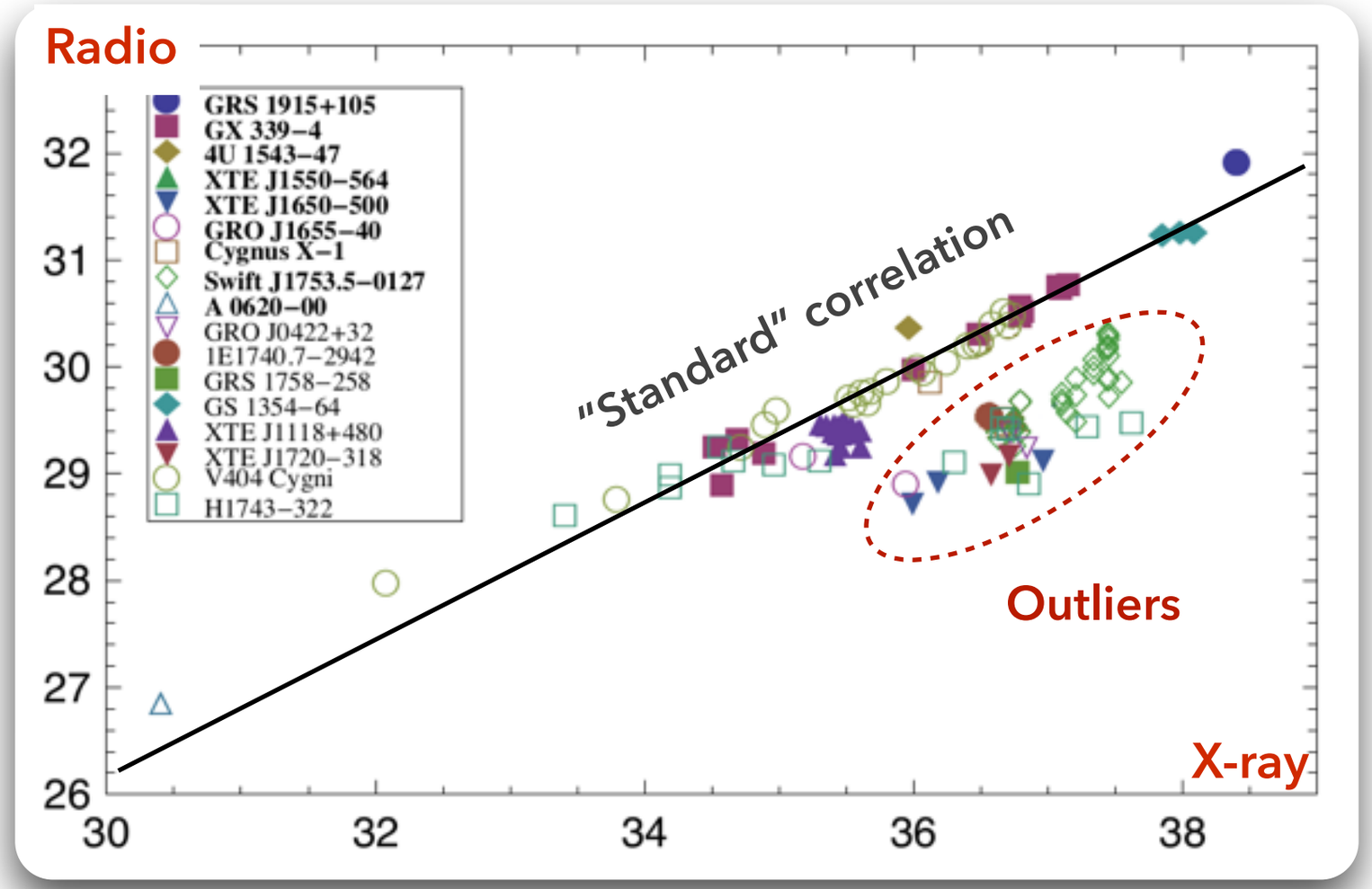
$$L_R \propto L_X^{0.6}\, M^{0.8}$$

Universality of accretion-jet coupling

Self-absorbed synchrotron emitting jets + Radiatively inefficient accretion flow

Dichotomy

Stellar-mass BH



Adapted from Fender et al. 2010

"Standard" black holes

$$L_R \propto L_X^{\sim 0.6}$$

(Corbel et al. 2003 Gallo et al. 2003)

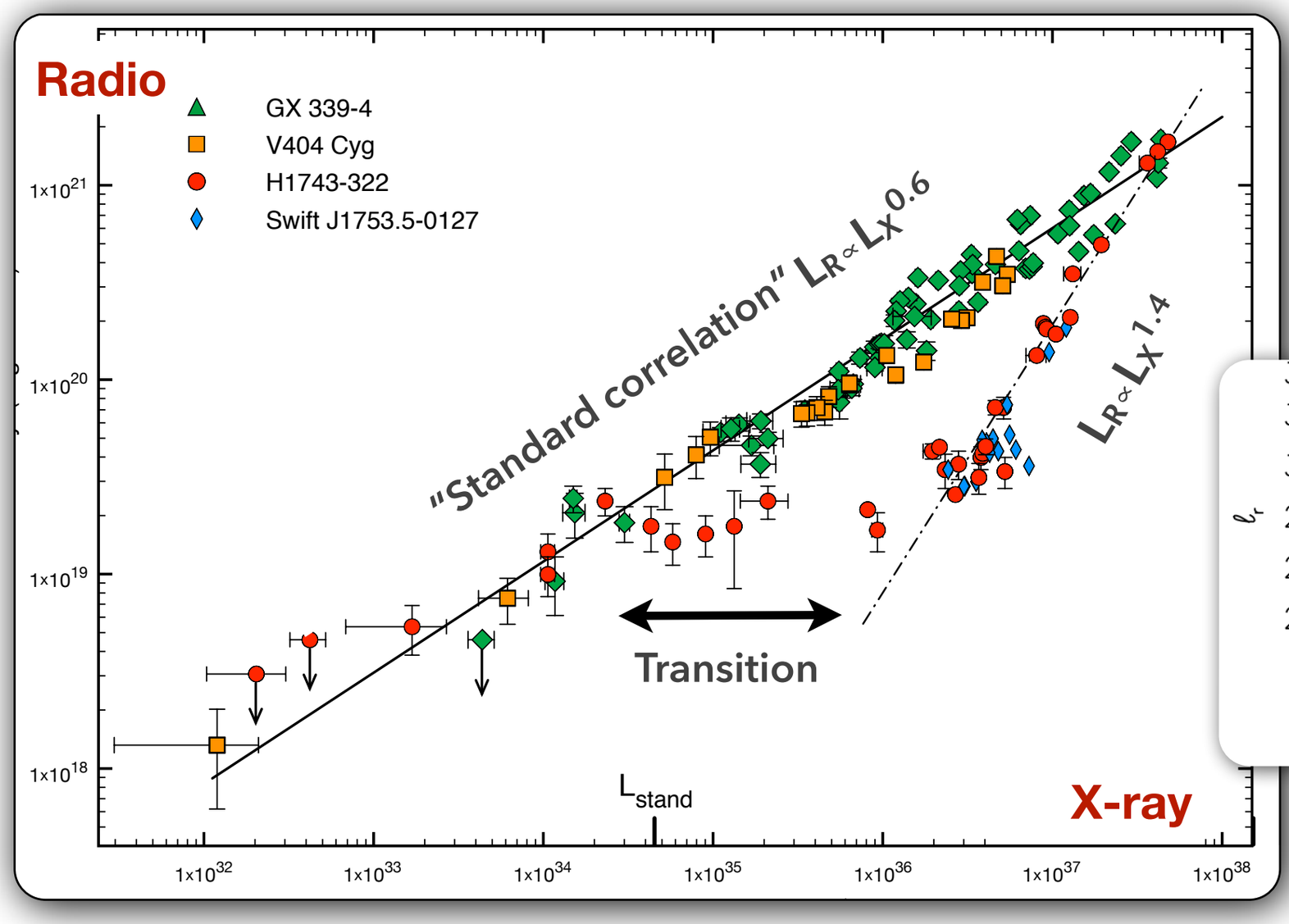
Outliers

Same correlation index but lower normalisation?

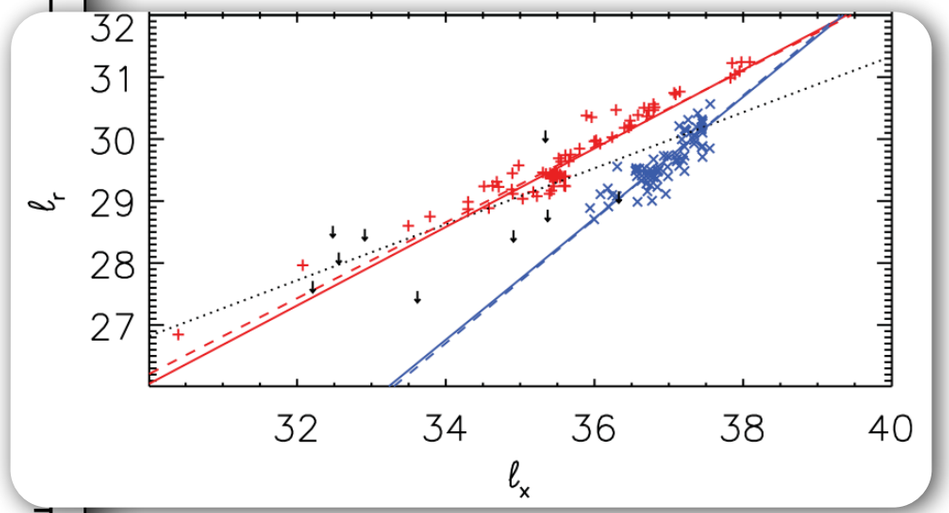
Behaviour at low luminosity?

Radio-quiet stellar-mass black holes?

Transition between



Coriat et al (2011)



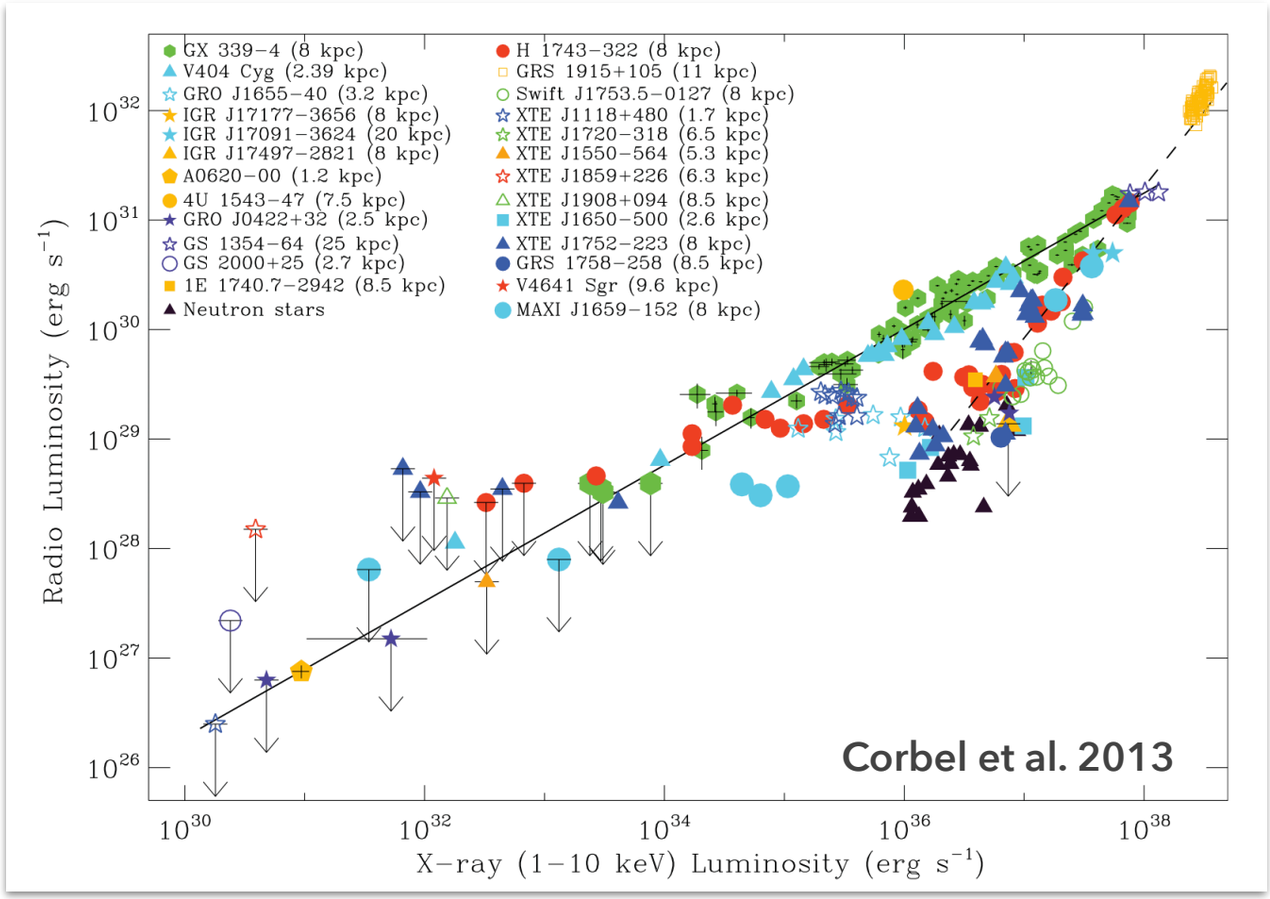
Gallo et al (2012)

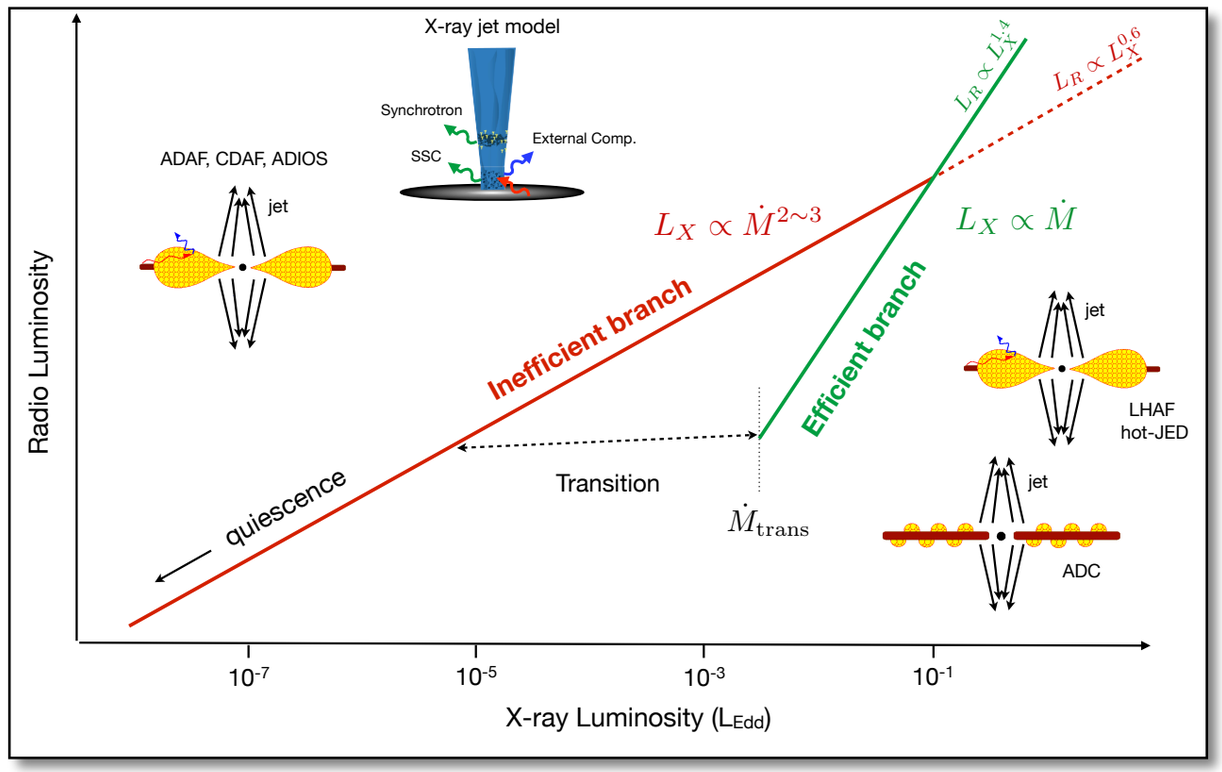
Accretion

- Different correlation index
- Transition between the 2 tracks
- Two populations statistically distinct
- Standard model seriously questioned…

Two modes of disc-jet coupling?

Luminosity correlations

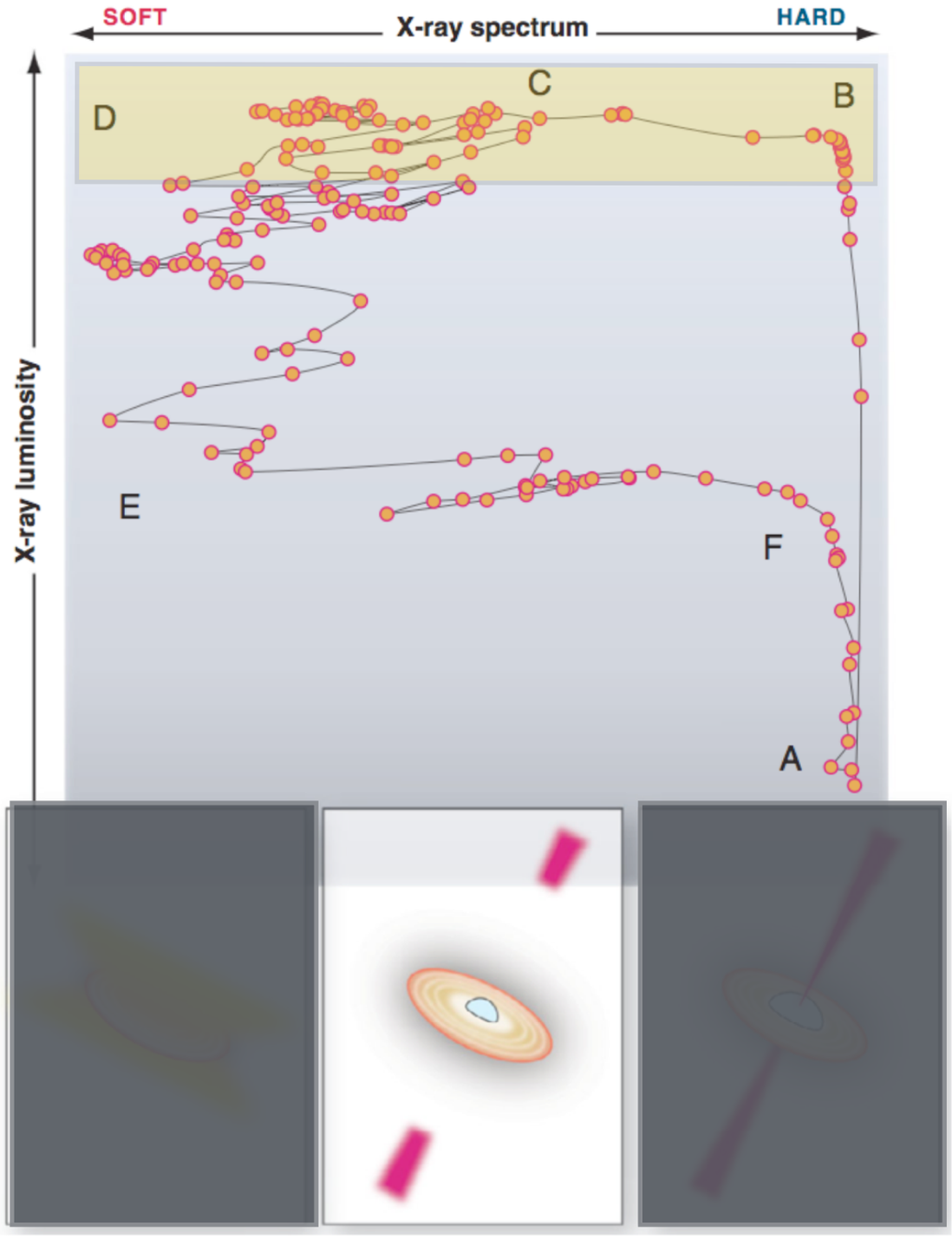




Coriat et al. 2011

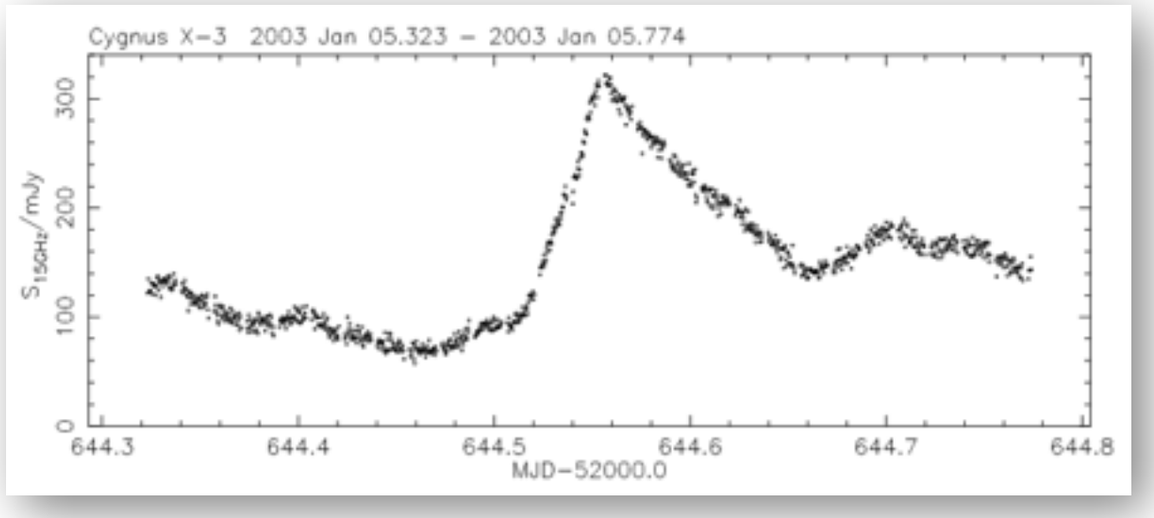
- Possible interpretation: Radiatively efficient jet-emitting accretion flow
- Transition efficient –> inefficient accretion flow below a critical accretion rate.
- Re-condensation of optically thin gas within the inner regions enhances seed photons for Comptonization (Meyer-Hofmeister & Meyer, 2014)

The empirical picture



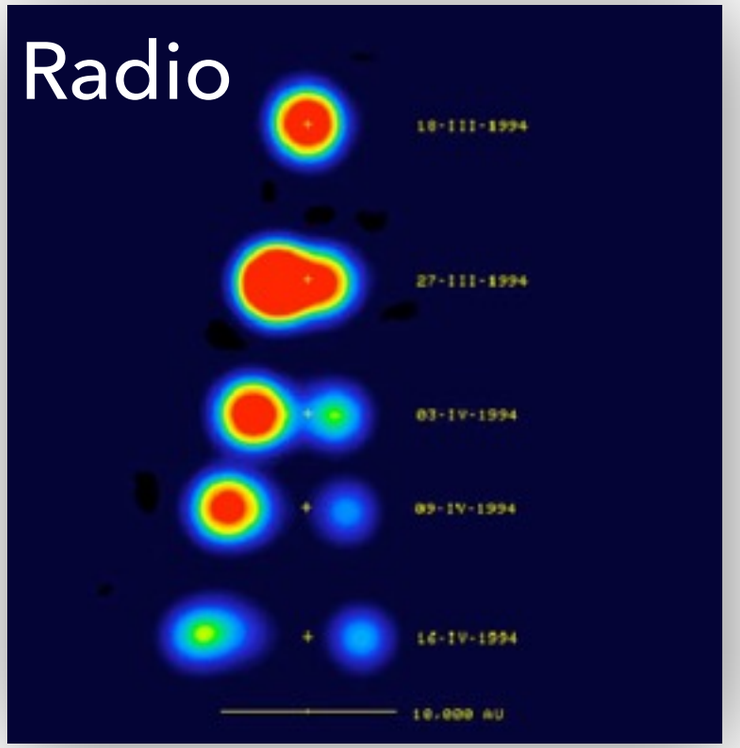
From hard to soft

- "Usually" above 10^{37} erg/s
- Corona emission drops
- Dramatic change in spectral shape
- Marginal change in broadband luminosity
- Broadband noise drops. Strong QPOs appear.
- Radio flares (single or sequence)

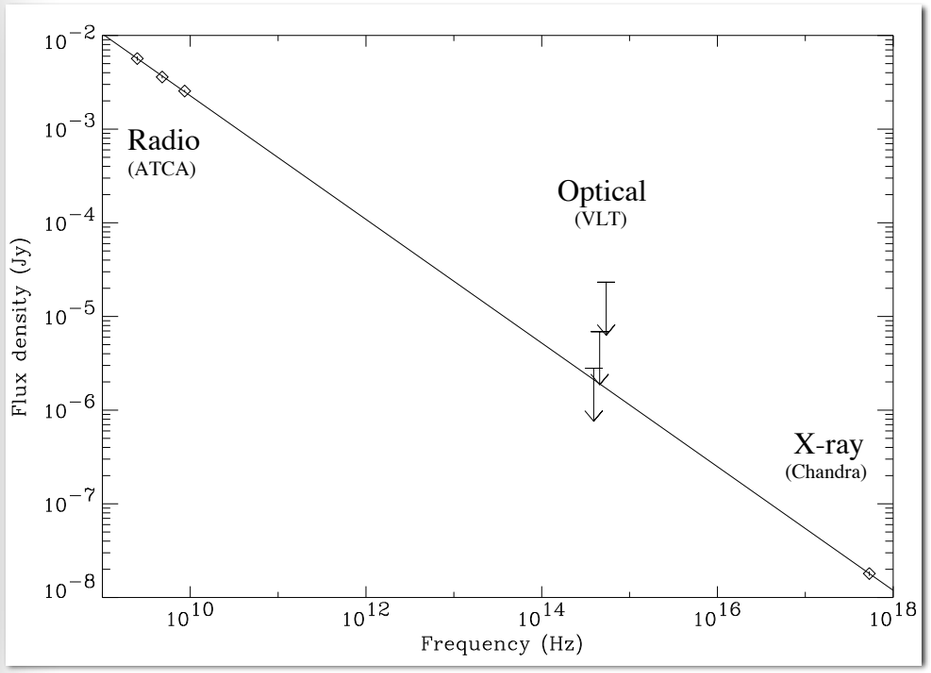


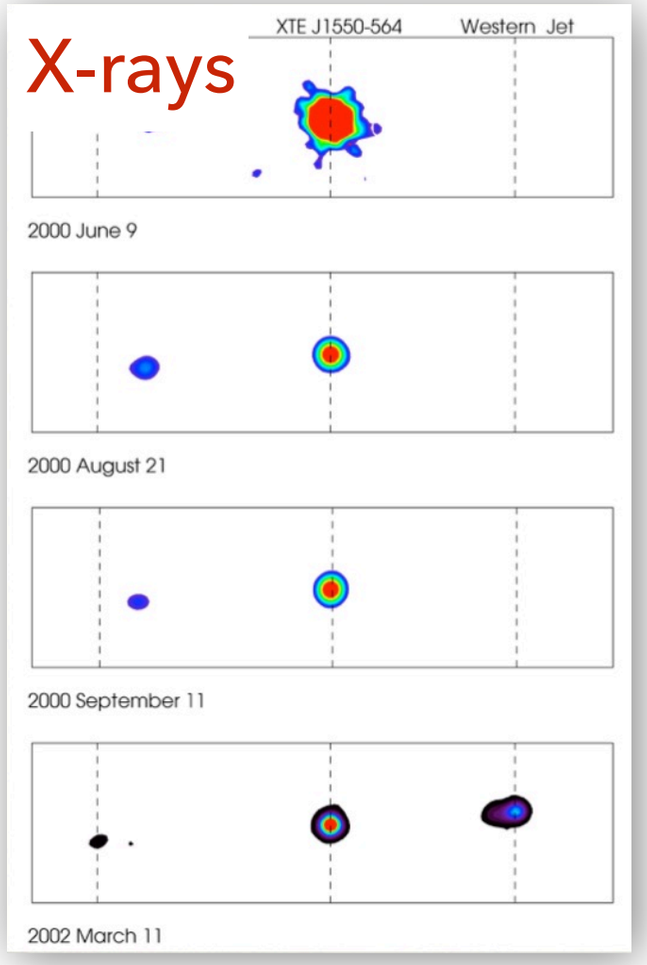
Courtesy G. Pooley

Radio flares and major ejection events



Mirabel & Rodriguez 94

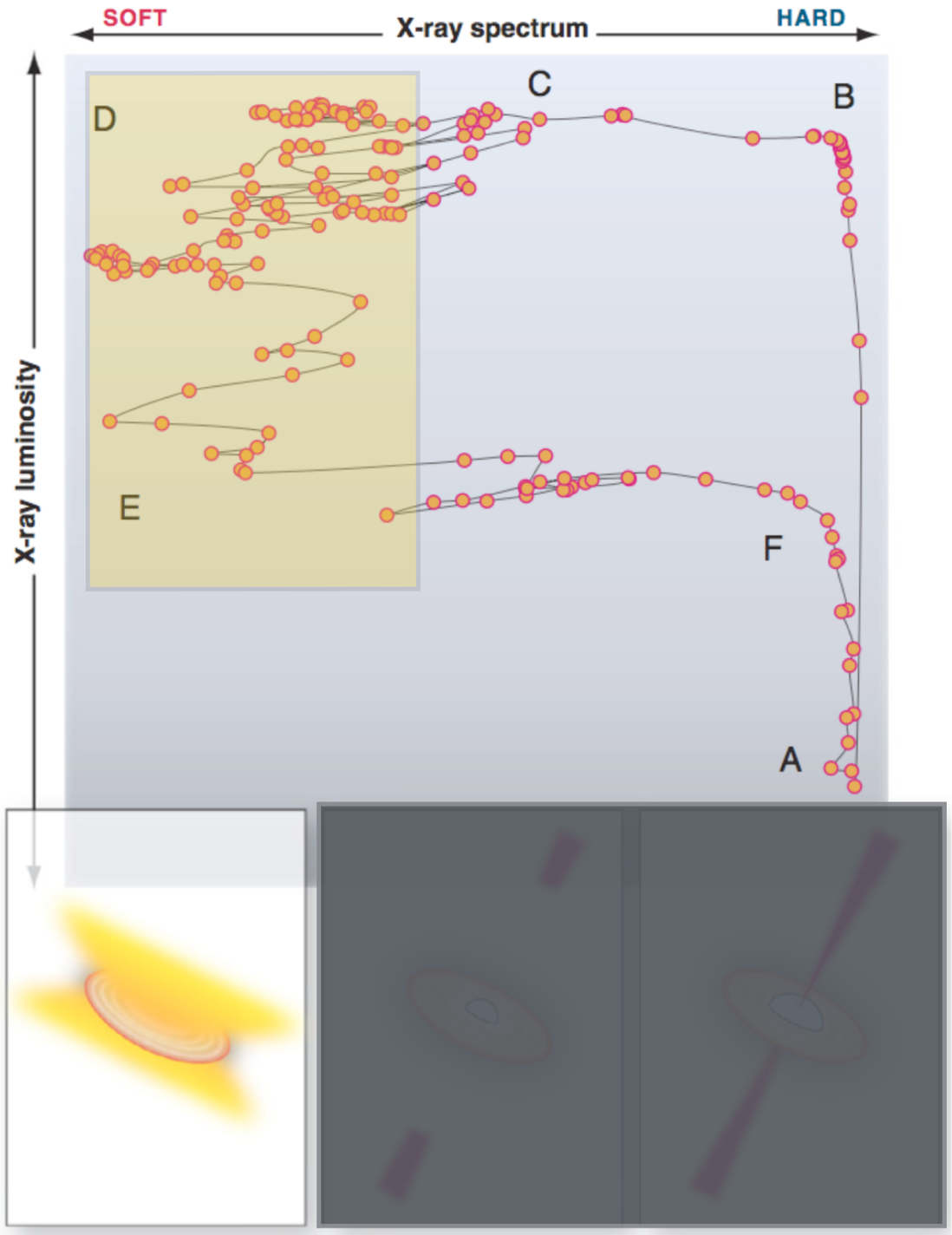




Corbel et al. 2002

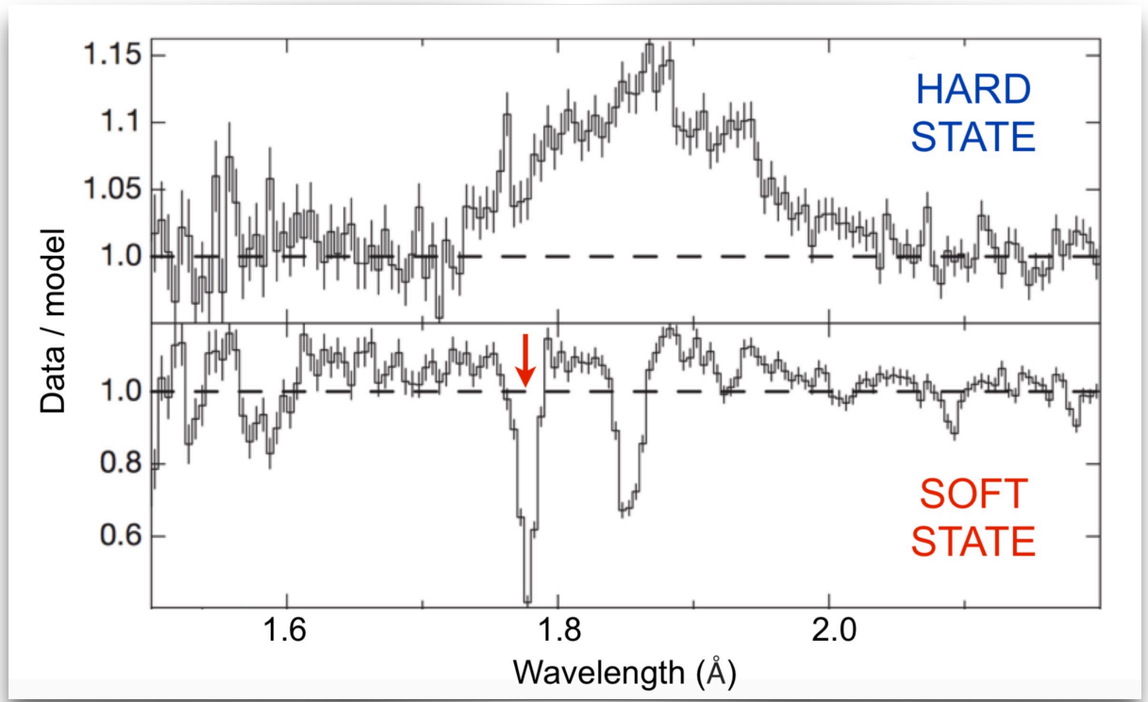
- Spatially resolved as radio knots moving at relativistic speed
- Substantial mass ejection and/or internal shock propagation ?
- Coronal plasma ejected ?
- Spectrum evolution follows the ‘standard’ expanding synchrotron bubble model (e.g. van der Laan 1966)
- Jets/ISM interaction sometimes observed in X-rays

The empirical picture



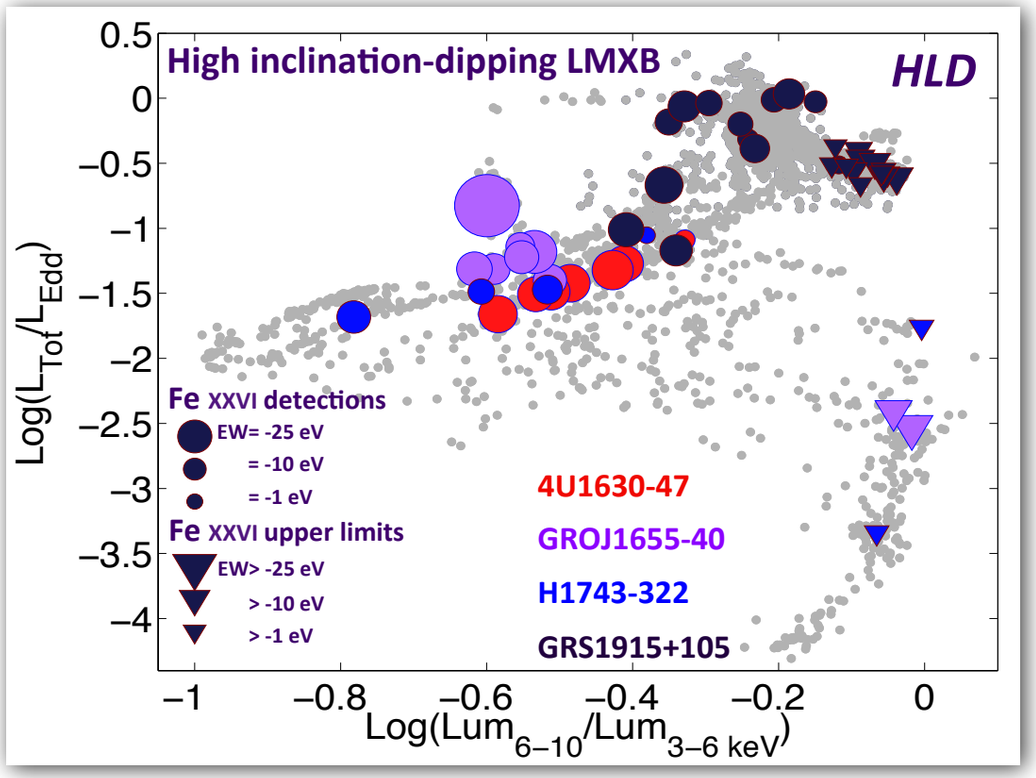
The soft state

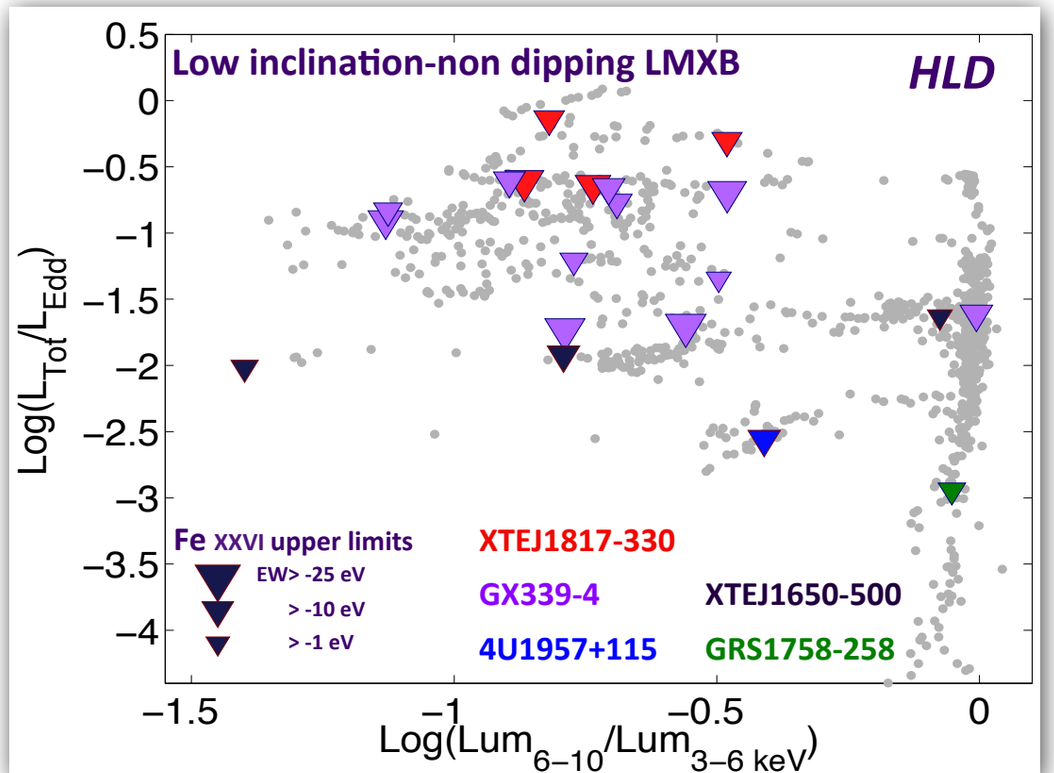
- Disk blackbody dominates X-ray (peak at ~1 keV)
- Very low X-ray variability (< 5% r.m.s.)
- No jets emission detected
- Strong accretion disc winds detected as blueshifted absorption lines in X-ray



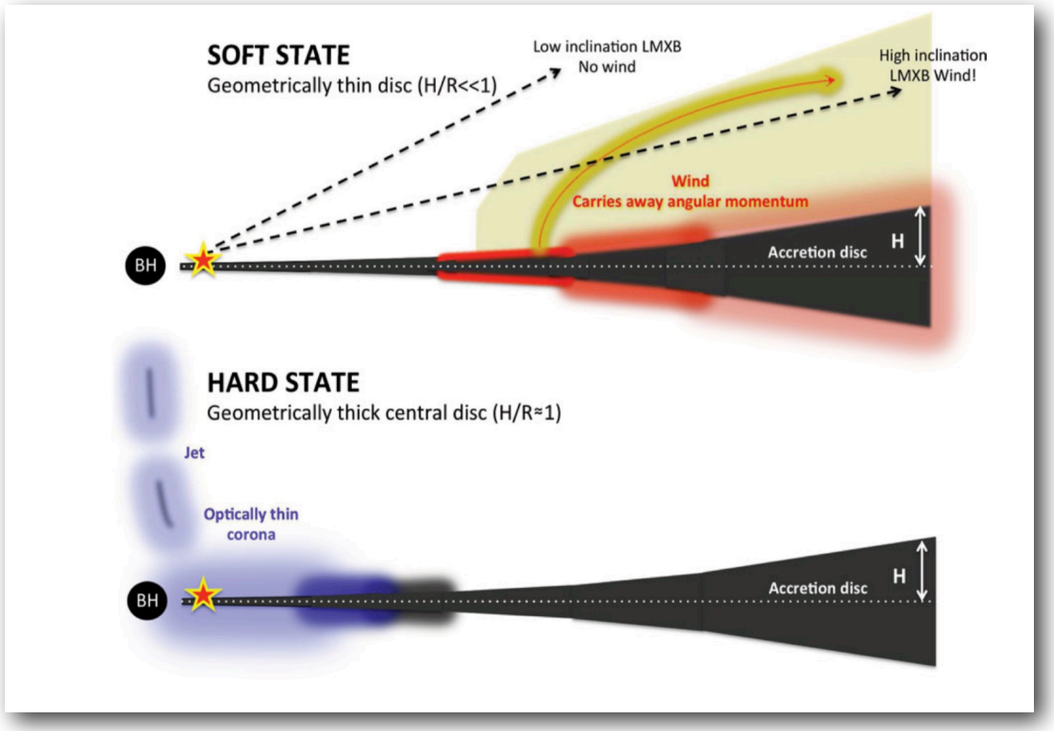
Neilsen & Lee 2012

Accretion disc winds





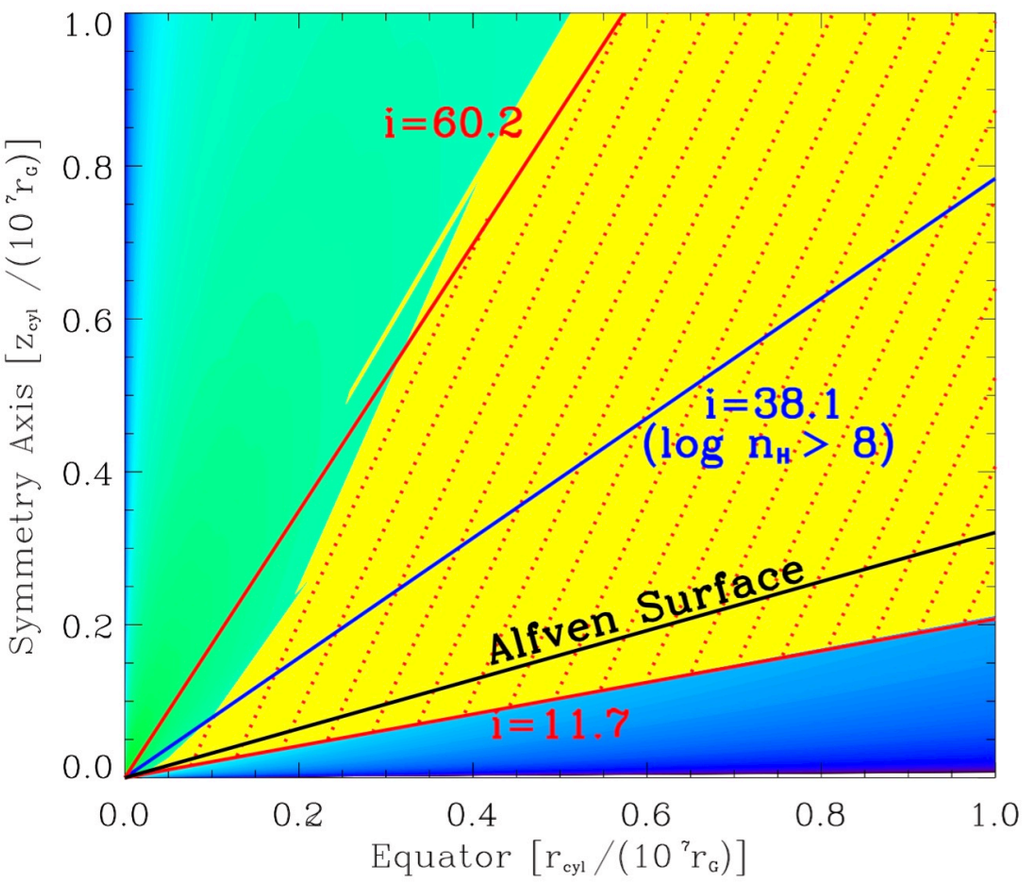
Ponti et al. 2012



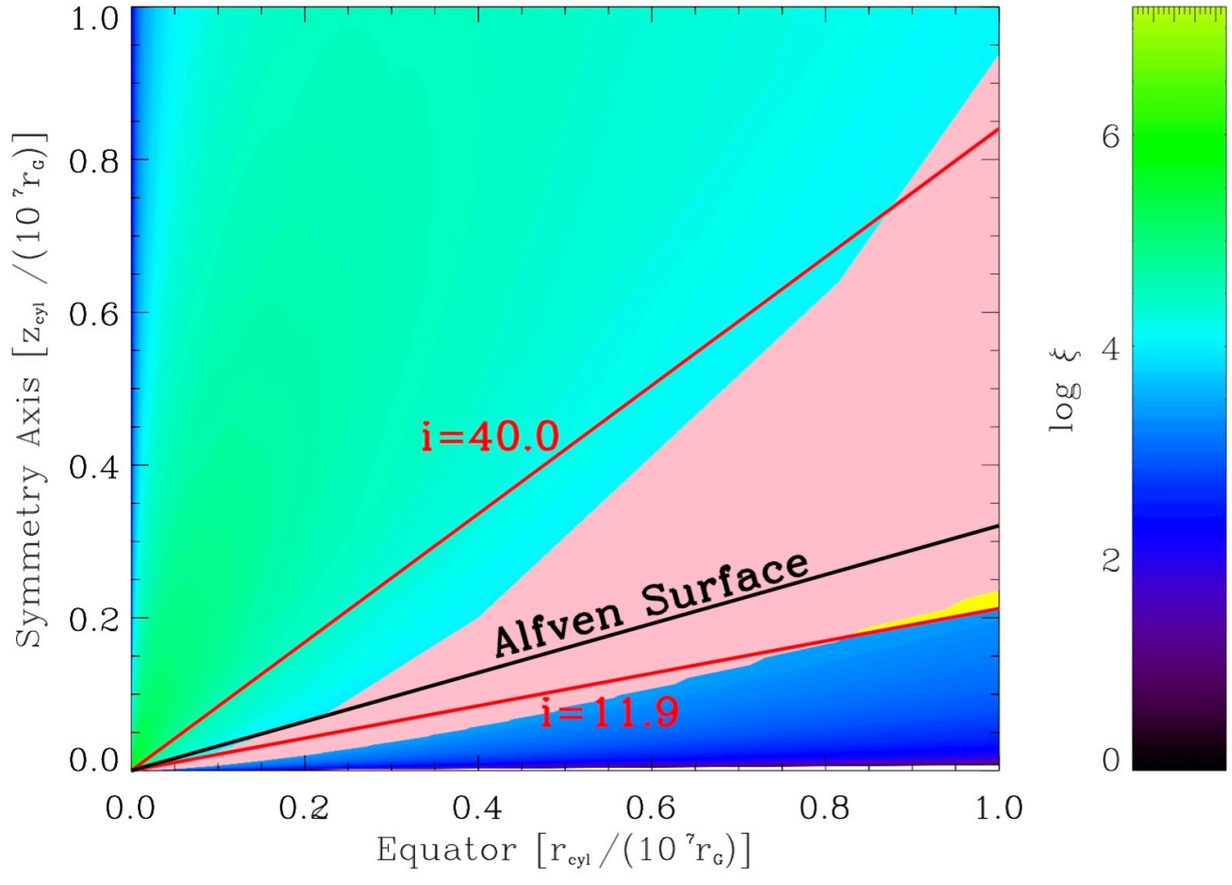
- Winds only visible in soft state of high inclination sources –> Equatorial winds
- Mass ejected ≳ Mass accreted
- V_{wind} ~ 1000 km/s
- Jets/winds dichotomy ?

Magnetically driven winds

Chakravorty et al. 2016



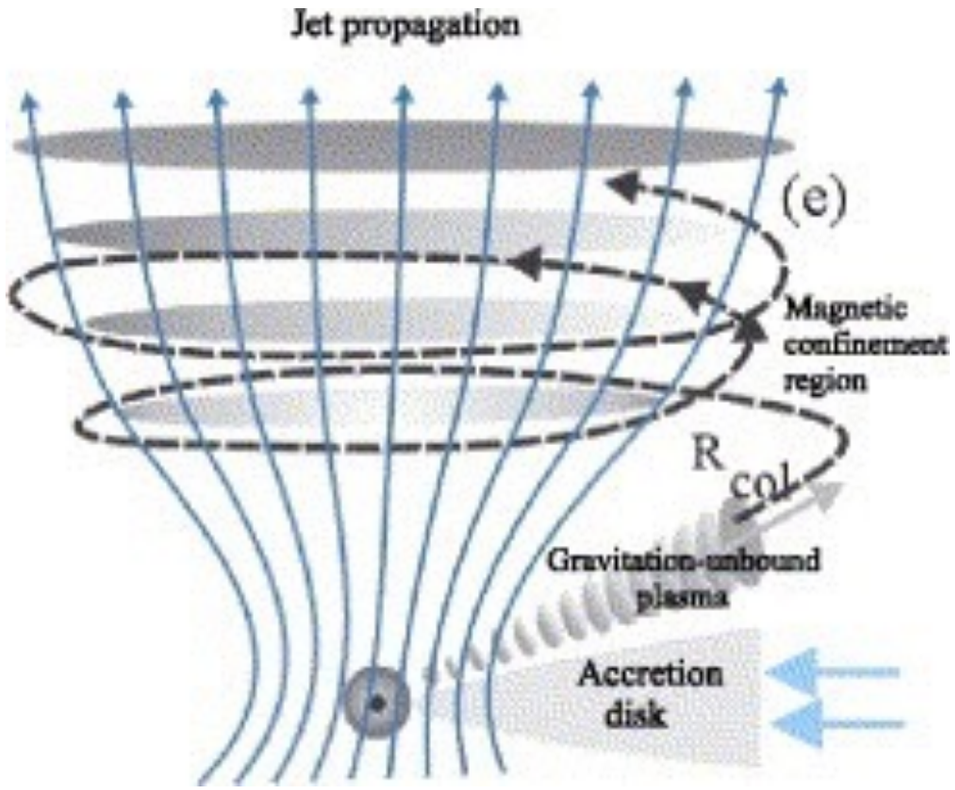
Soft state

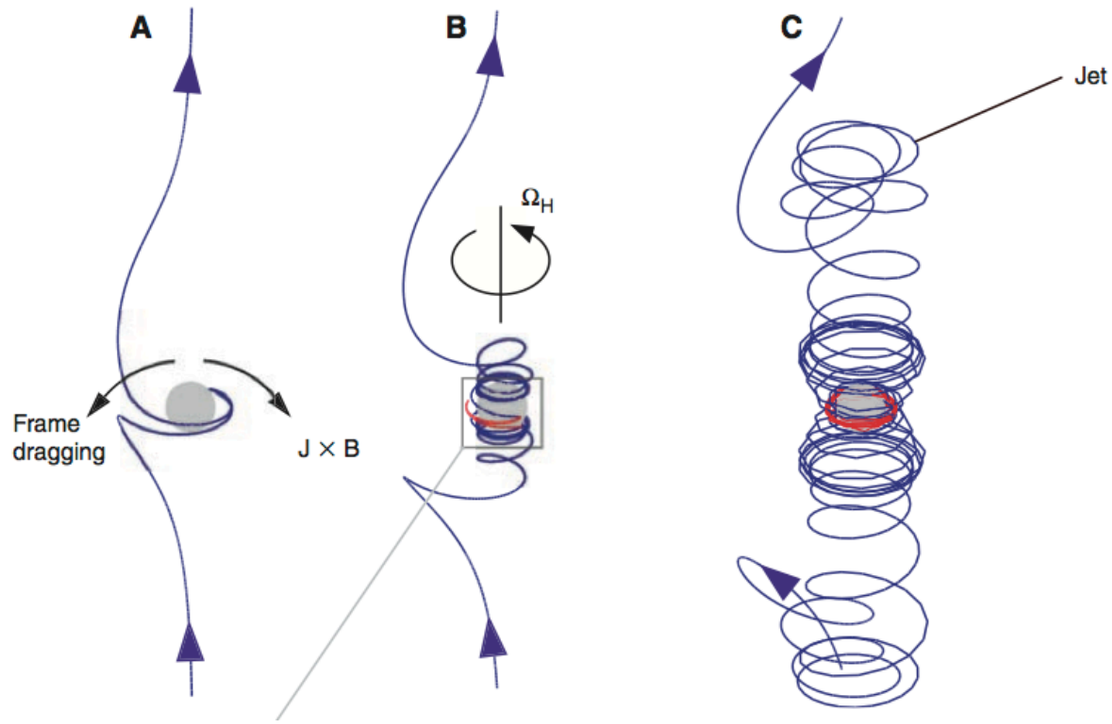


Hard state

- MHD wind model can reproduce most of the observations
- Wind could be present in hard state as well but non detected (thermal instabilities)

Jet power and BH spin





Accretion-powered jets

Blandford & Payne (1982)

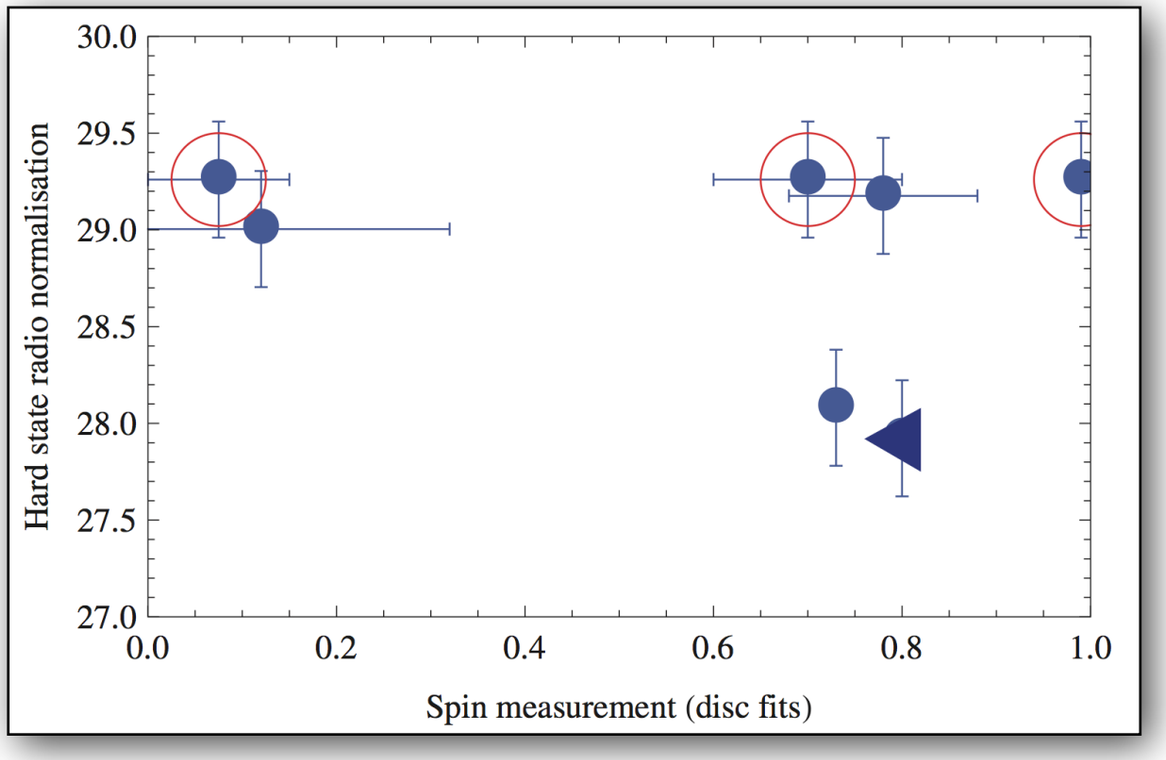
Spin-powered jets

Blandford & Znajek (1977)

$$P_J \propto a^2 \quad ?$$

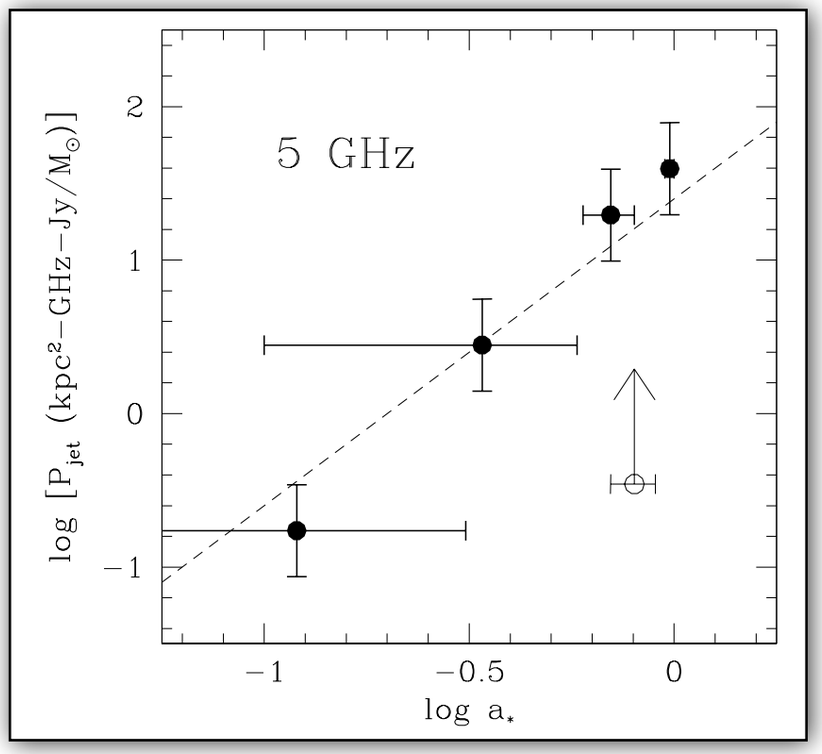
Jet power and BH spin

Compact jets



Fender et al. (2010)

Transient jets

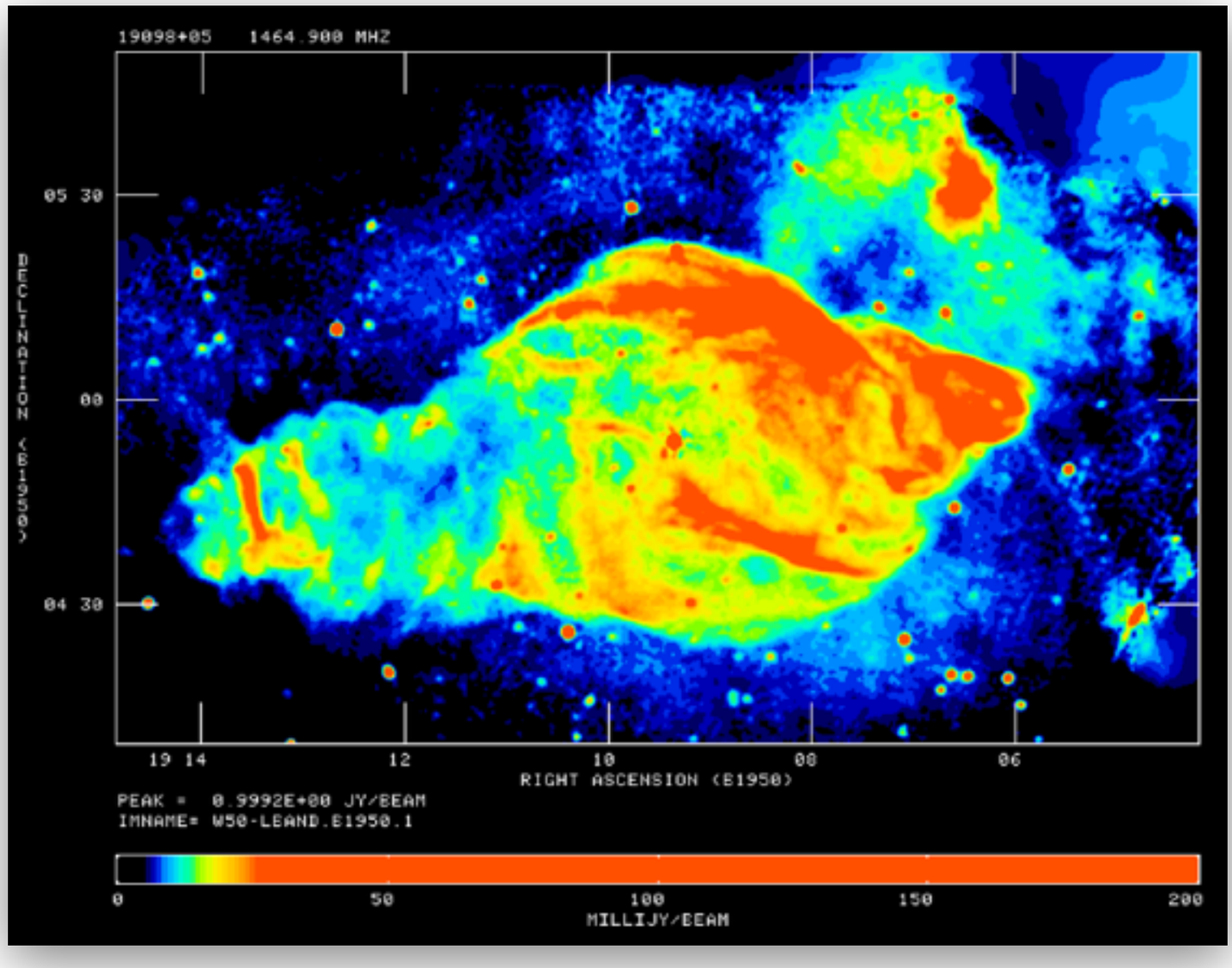


Narayan & McClintock (2012)

- No evidence for spin powering of compact jets
- Potential contribution to transient jets power (but controversial, e.g. Russell et al. 2013)
- But methods for estimating spin and jets power are uncertain…

Jet particle content

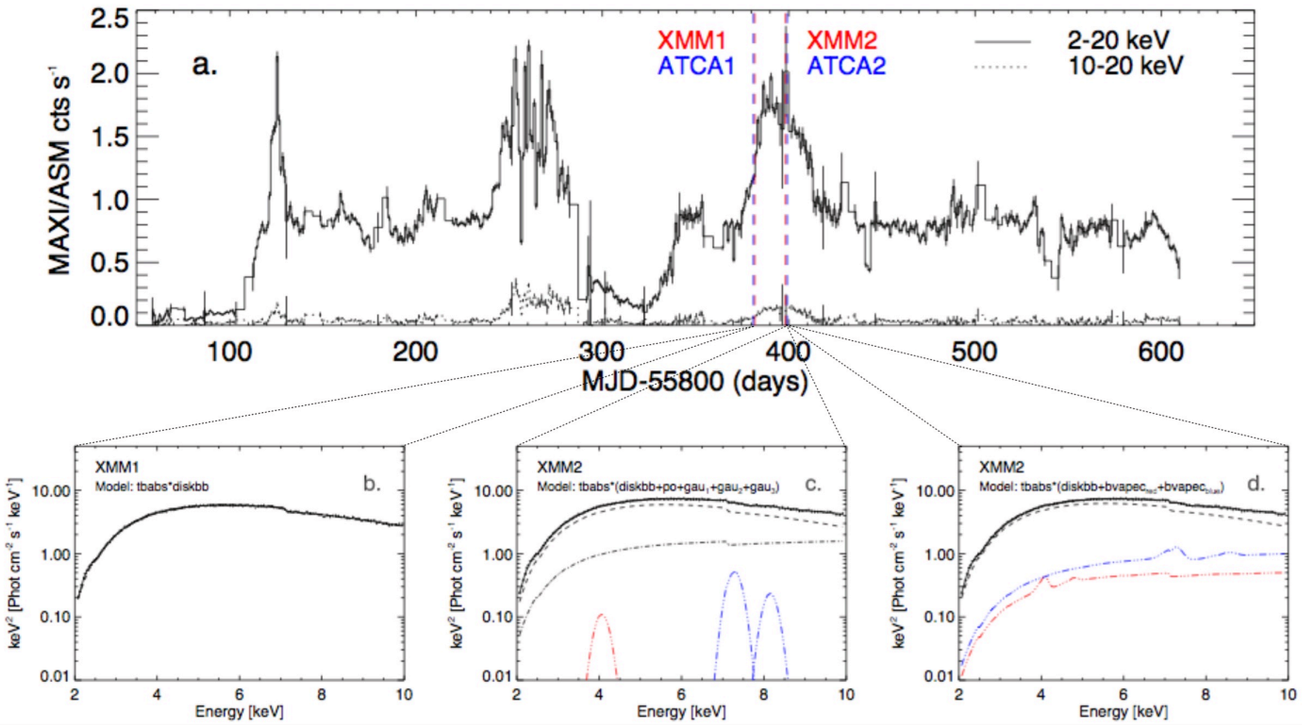
- Electron:positron, electron:proton ?
- Important consequences for jet power and formation mechanism
- No clear evidence yet for the presence of baryons in jets except in SS433

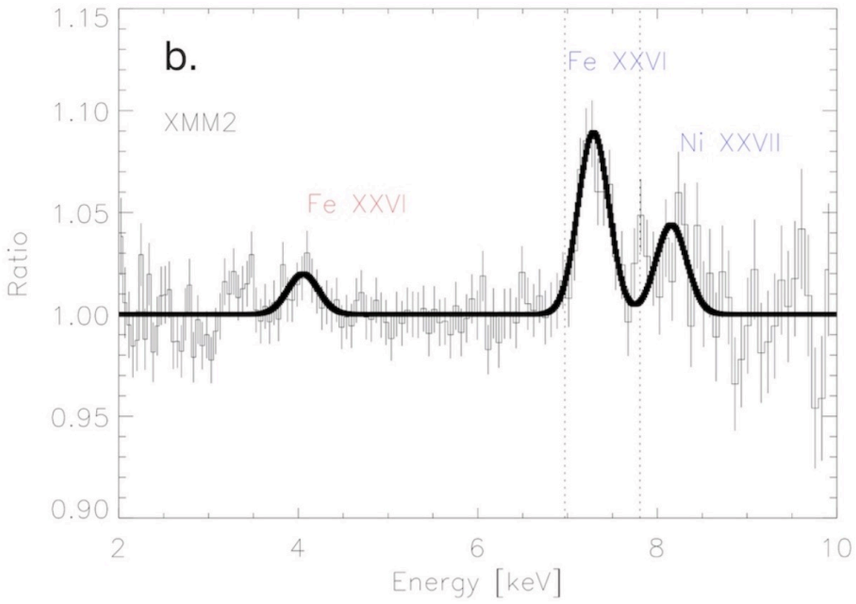


Dubner et al. 1998

Baryons in jets from 4U 1630-47 ?

- Detection of blueshifted iron lines in X-ray coincident with re-appearance of jets in radio





Diaz-Trigo et al. 2013

- But no detections during the rest of the outburst…
- Baryons could be launched during specific phases only

Nielsen et al. 2014