Isolating the jet in broadband spectra of X-ray binaries

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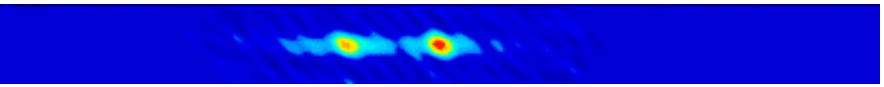
X-ray Binary Jets

Black hole XB: GRO J1655-40



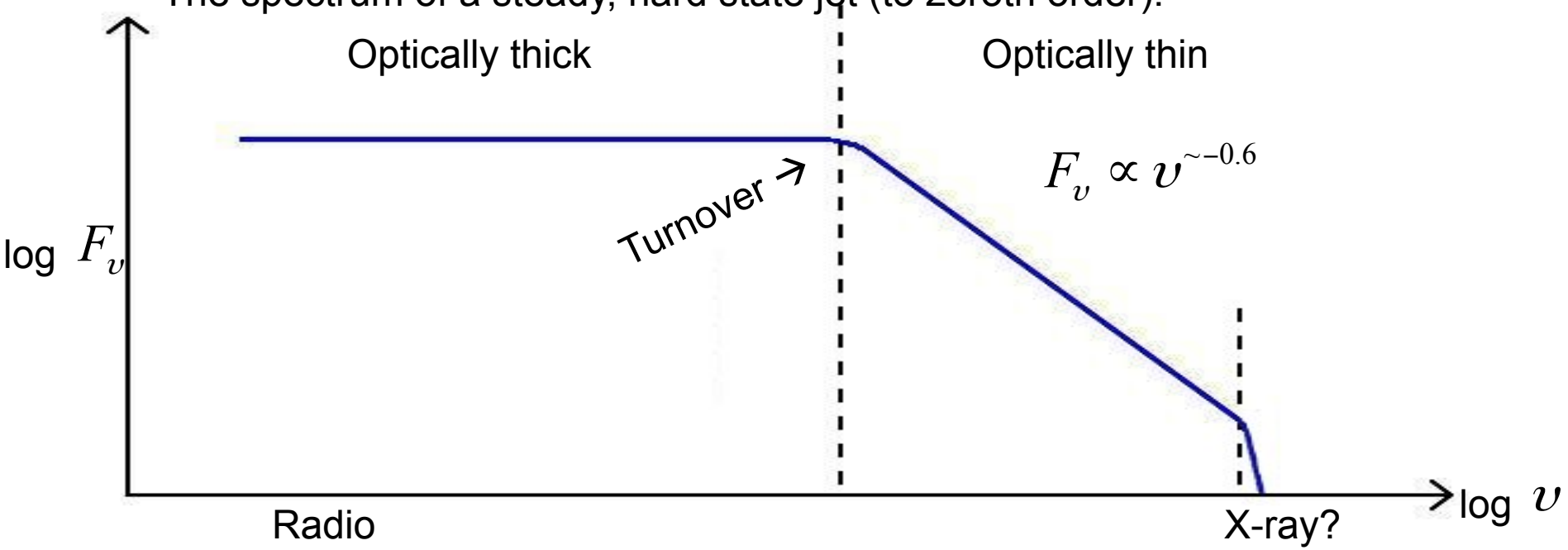
Tingay et al. 1995

Neutron star XB: Sco X-1

Fomalont et al. 2001

Radio emission: → is synchrotron in nature
→ unambiguously originates in collimated outflows (2 types of jet)

The spectrum of a steady, hard state jet (to zeroth order):

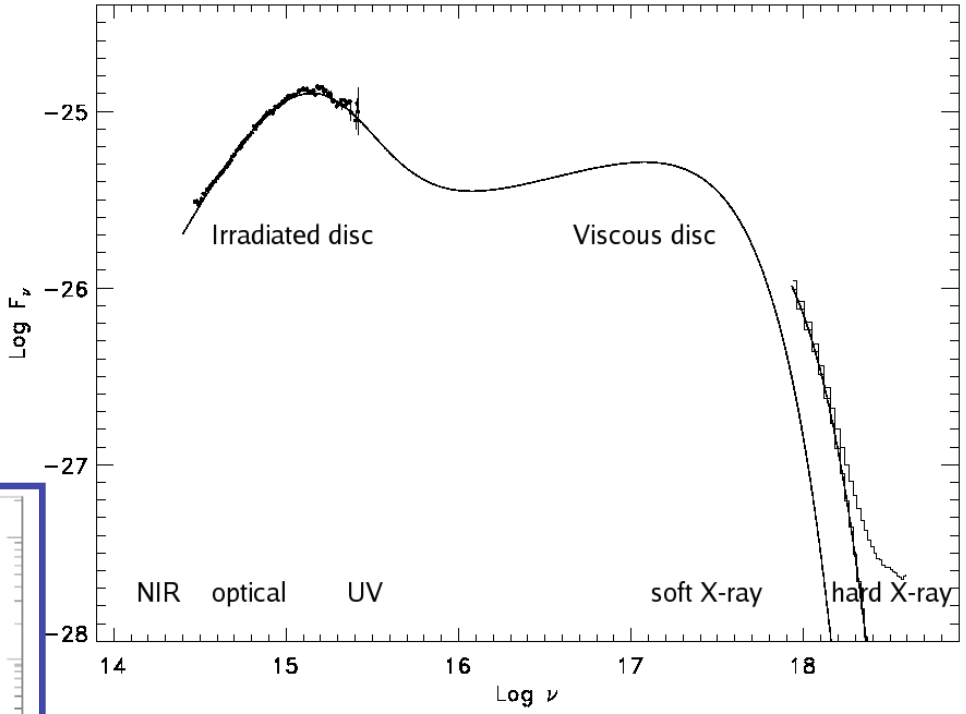


• The jets are radiatively inefficient, and the power carried in the jets is uncertain and highly dependent on the position of the turnover/break(s)

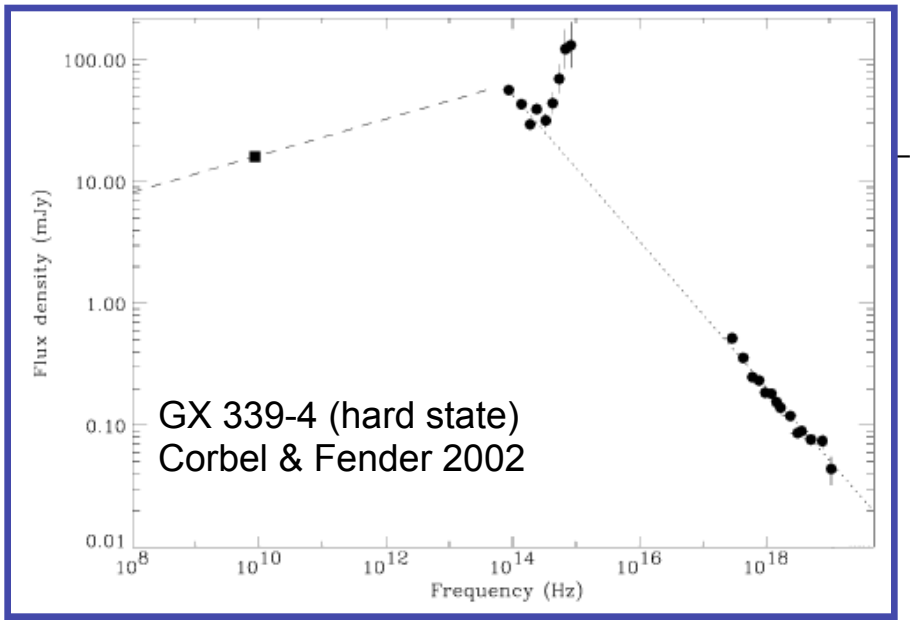
• Identifying the optically thin emission in optical/IR helps constrain the synchrotron contribution to X-ray

What do we see at optical and higher energies?

We see the X-ray heated disc (reprocessing) and the underlying viscous disc at optical to soft X-ray wavelengths



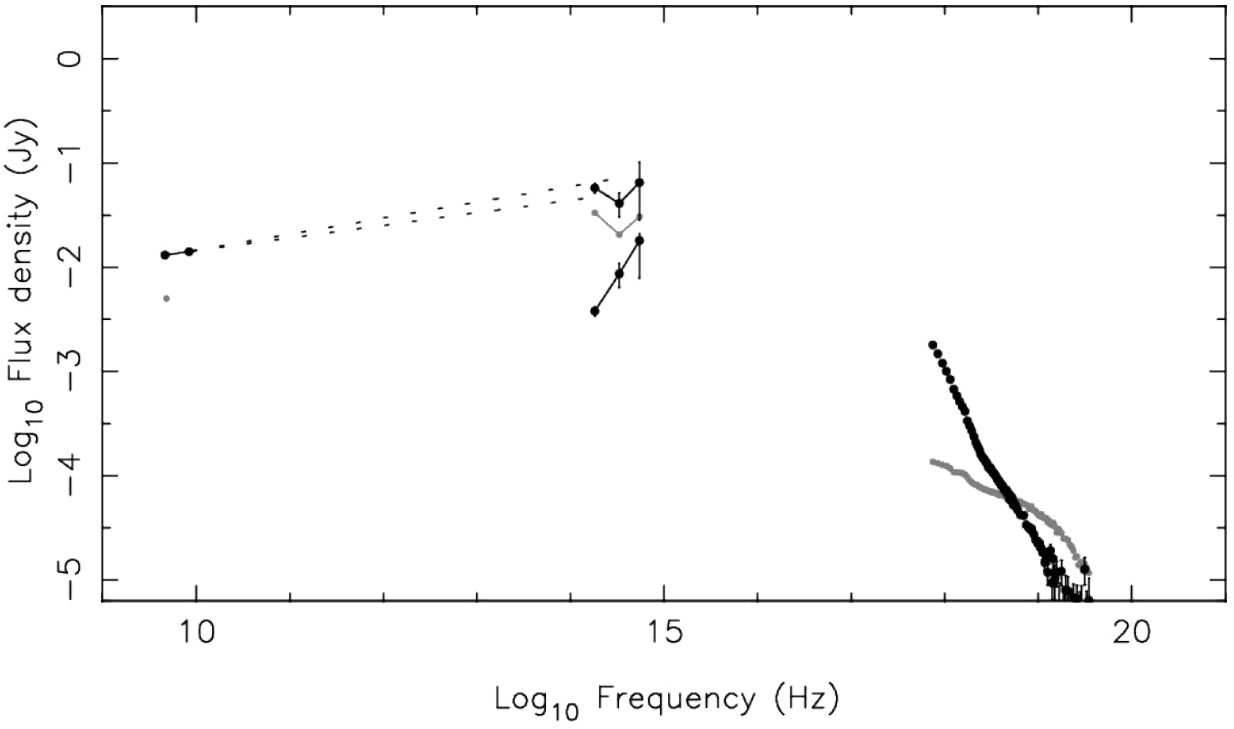
Hynes et al. 2002
(XTE J1859+226)



An extra red component is sometimes seen in the optical/NIR

What do we see at optical and higher energies?

Homan et al. (2005) showed NIR emission from GX 339-4 has negative spectral index in the hard state, and is quenched in the soft state



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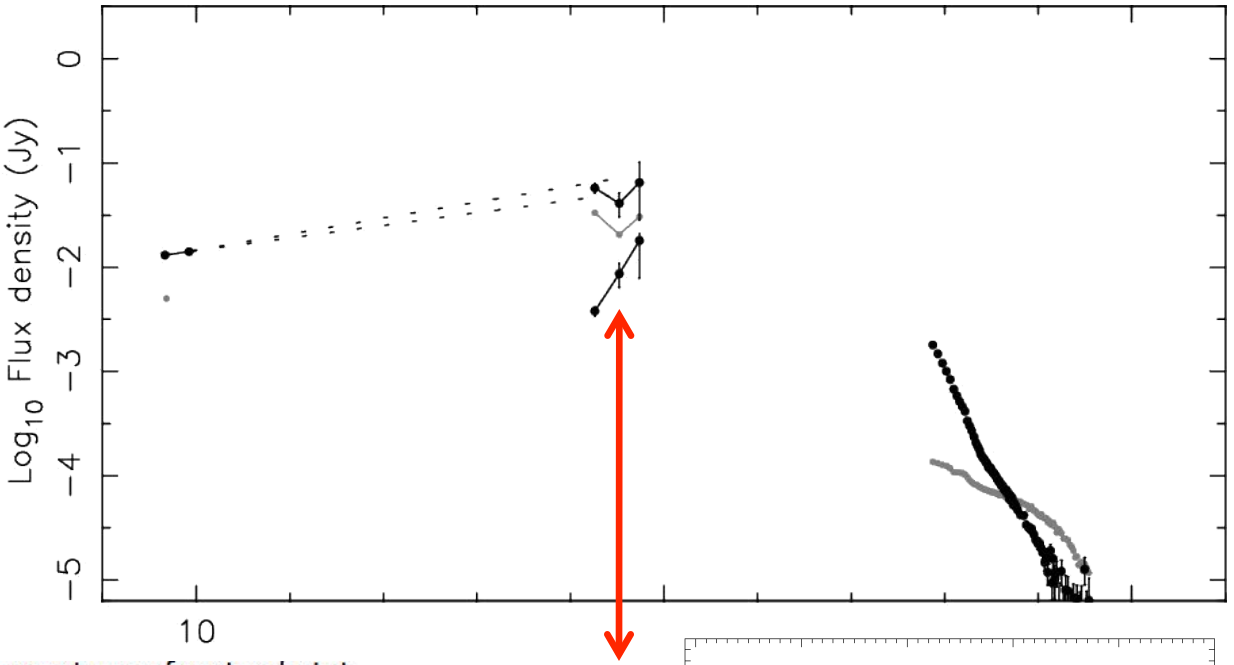
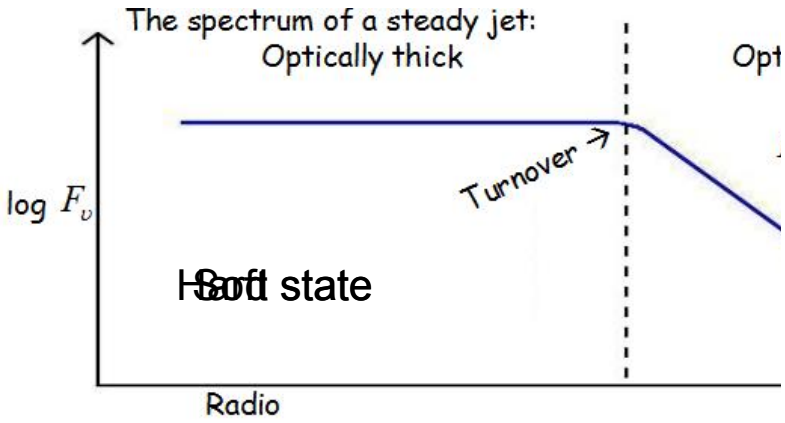
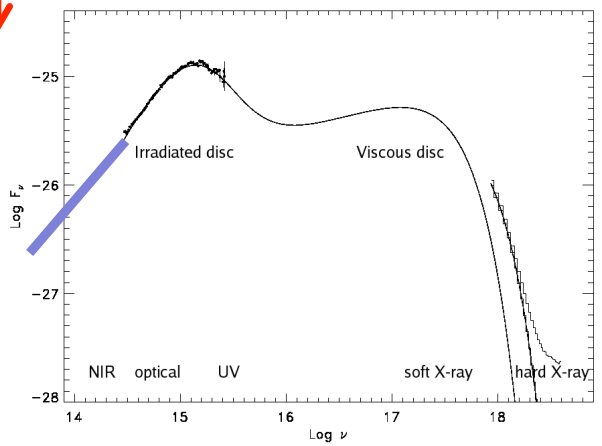
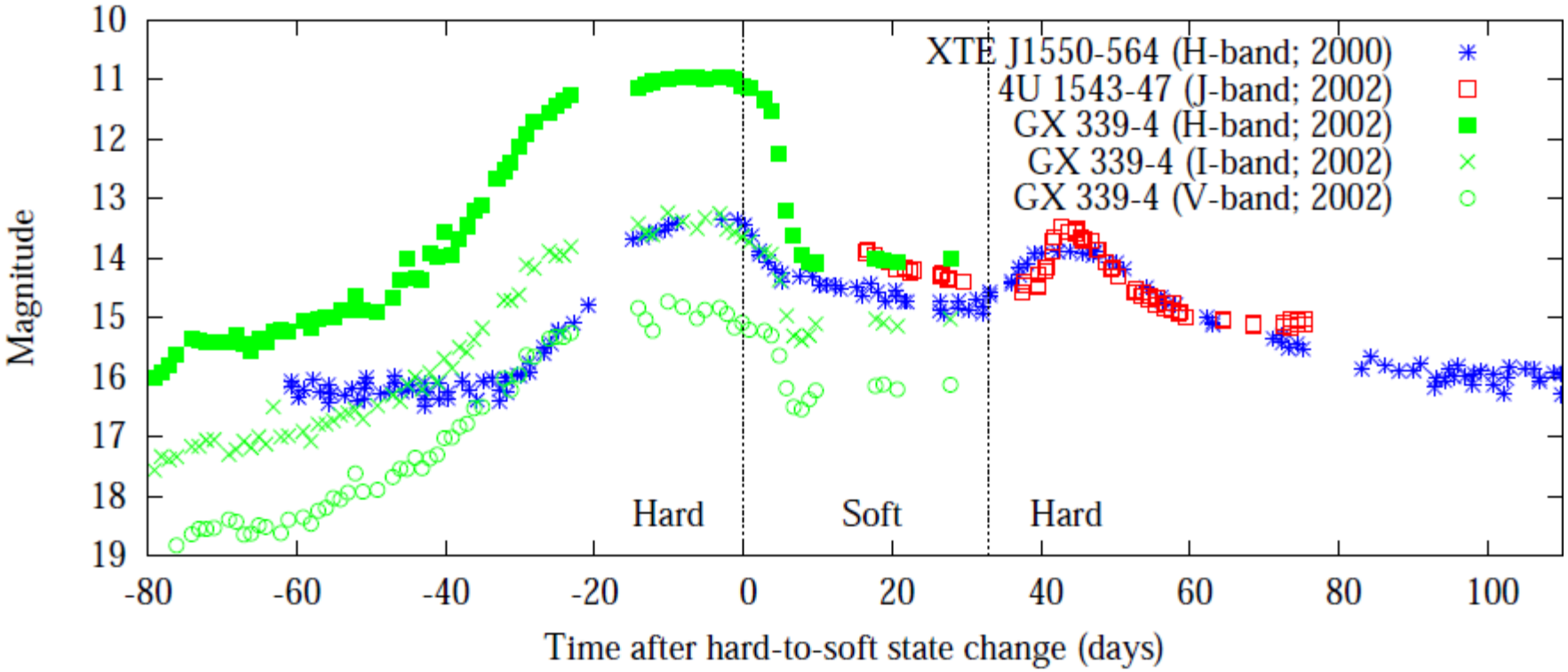






Jet emission in the optical/NIR

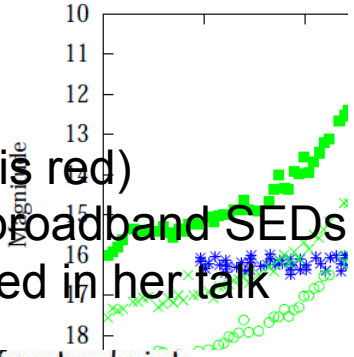
The NIR emission is seen to fade and then reappear over state transitions, similar to the radio



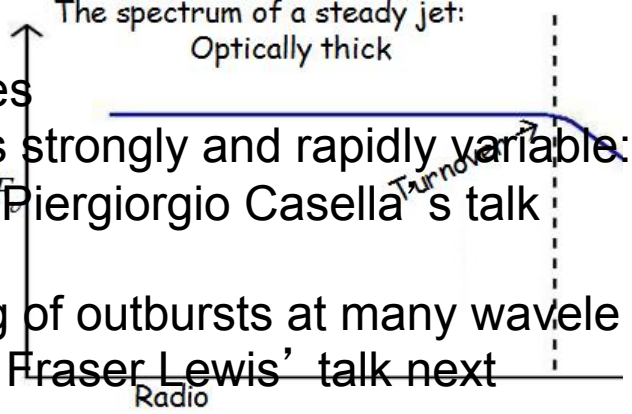
Data from Homan et al. 2005, Jain et al. 2001, Buxton & Bailyn 2004

How can we identify and isolate the jet emission?

- Flux and colour changes over the state transitions

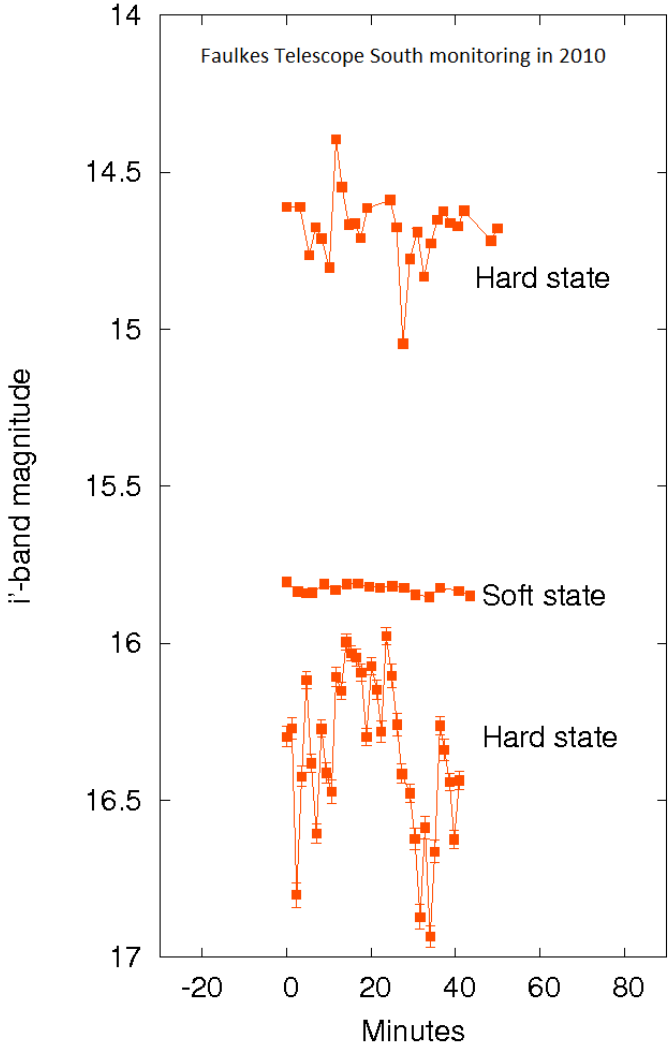


- SEDs (the disc is blue, the jet is red)
  → especially modelling broadband SEDs as Sera Markoff showed in her talk



- Fast timing studies
  → The jet is strongly and rapidly variable: also see Piergiorgio Casella's talk

- Dense monitoring of outbursts at many wavele
  → also see Fraser Lewis' talk next

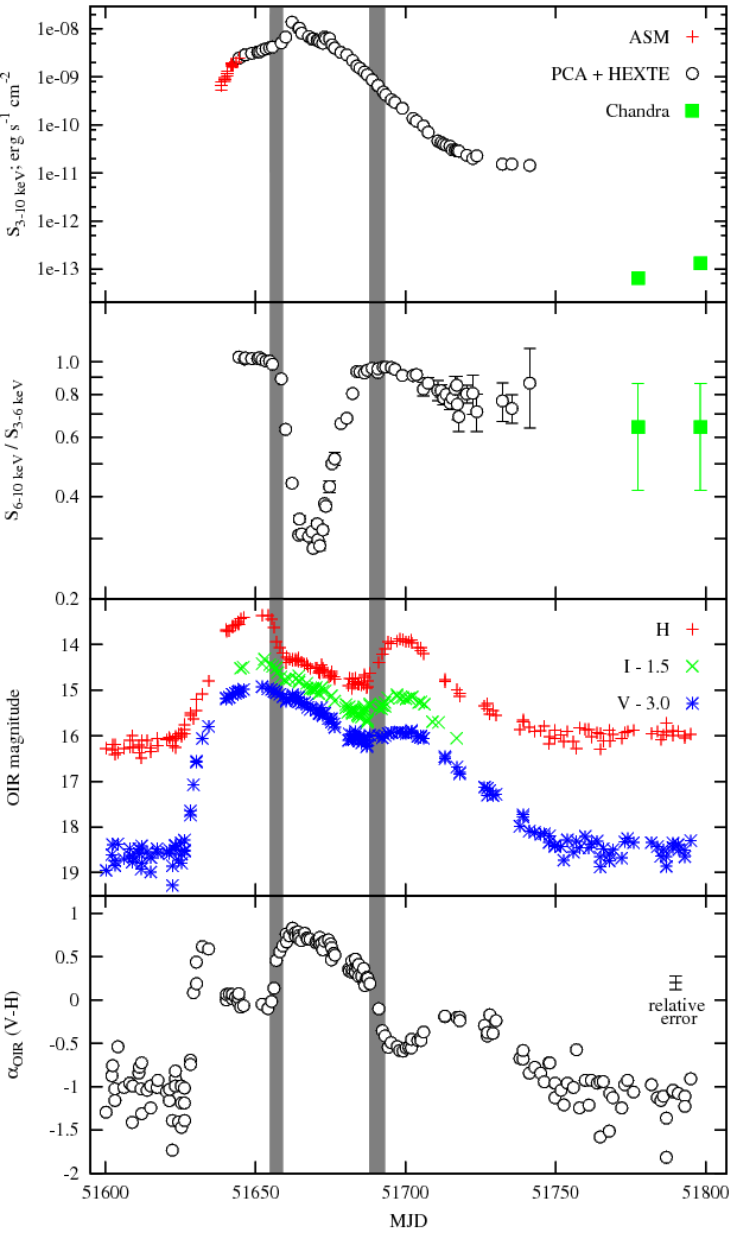


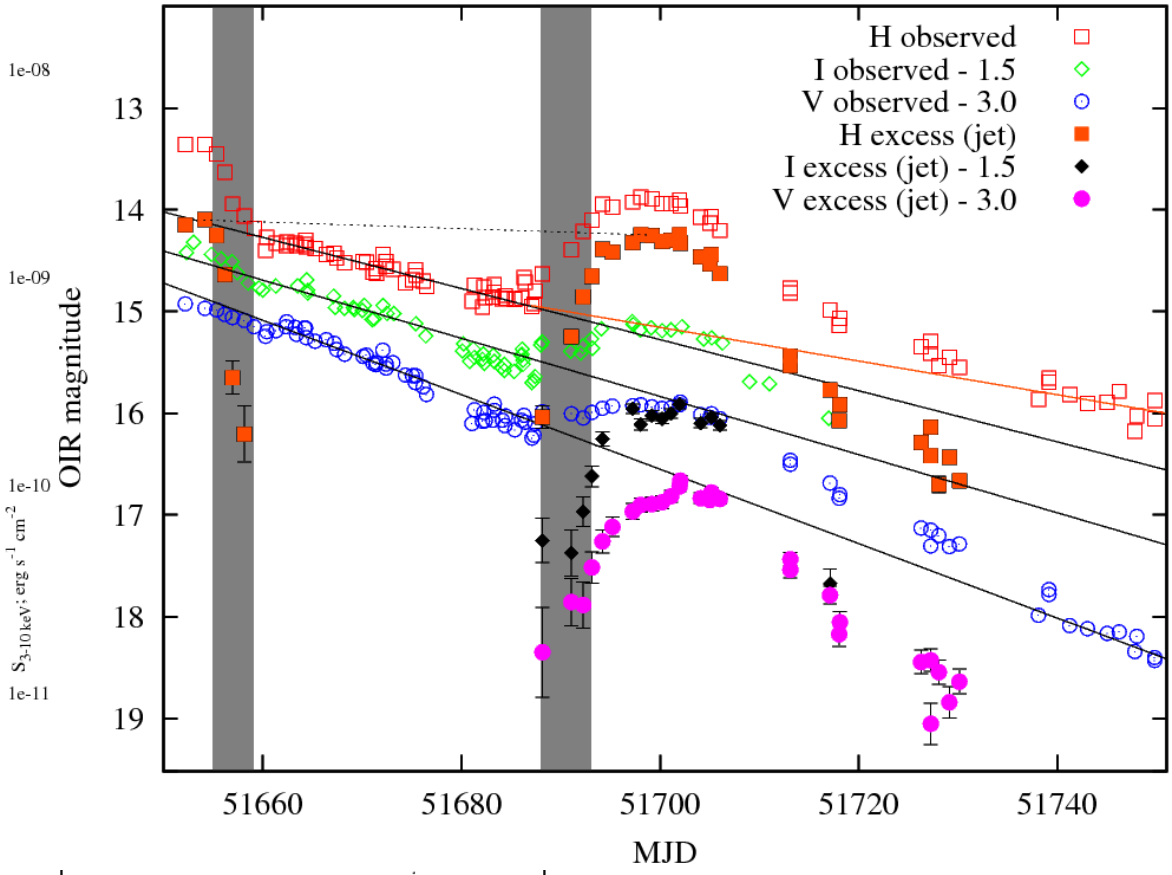
- Colour-magnitude diagrams

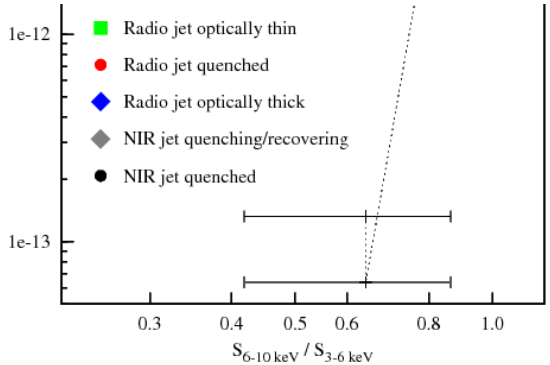
- Polarization

Introducing the 2000 outburst of XTE J1550-564

Well monitored in X-ray, optical and near-infrared (NIR)





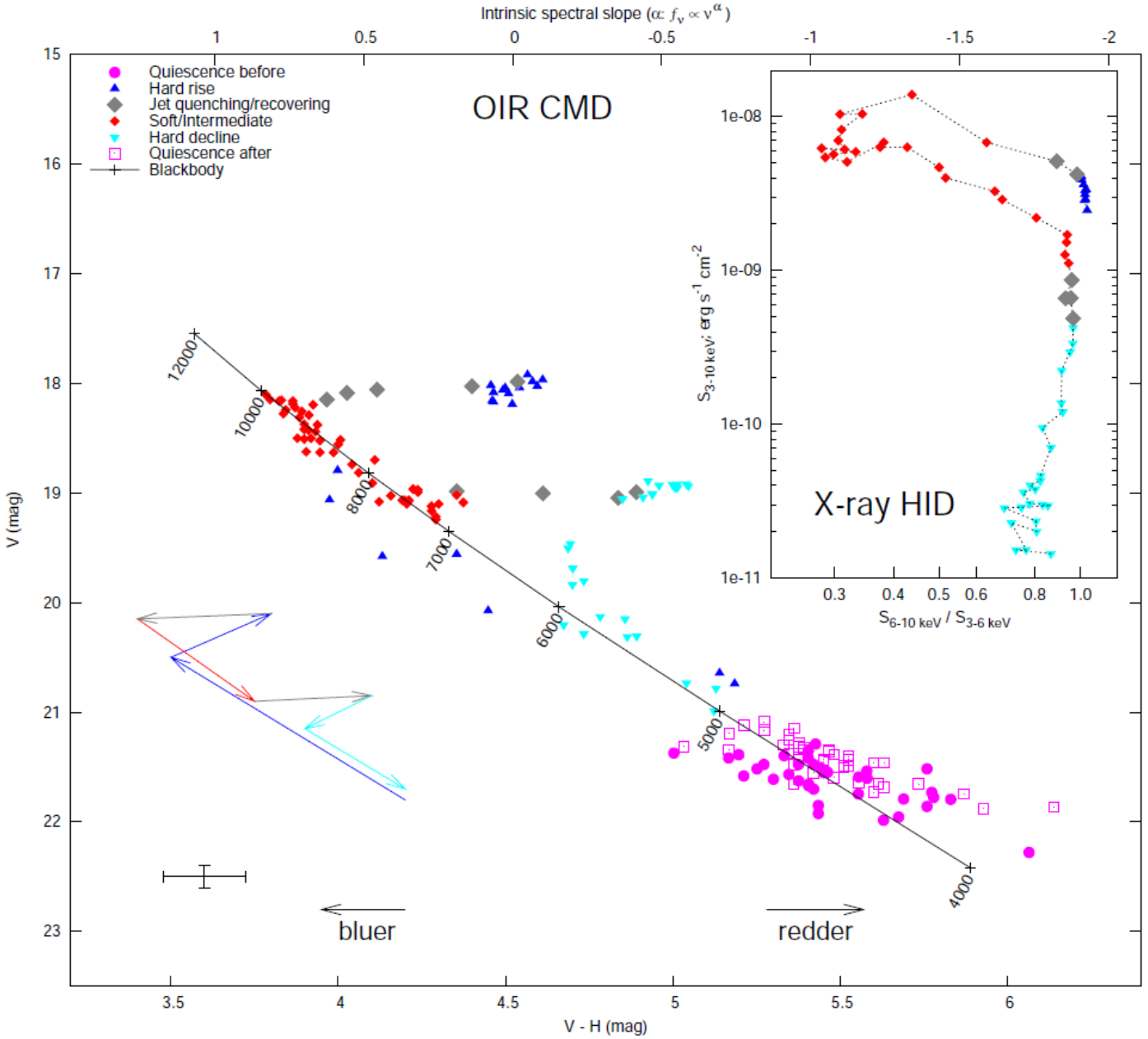


We can separate disc and jet emission

Assumes continuation of the exponential decay of disc flux

Jet has optically thin spectrum

Hardness-intensity vs colour-magnitude diagrams

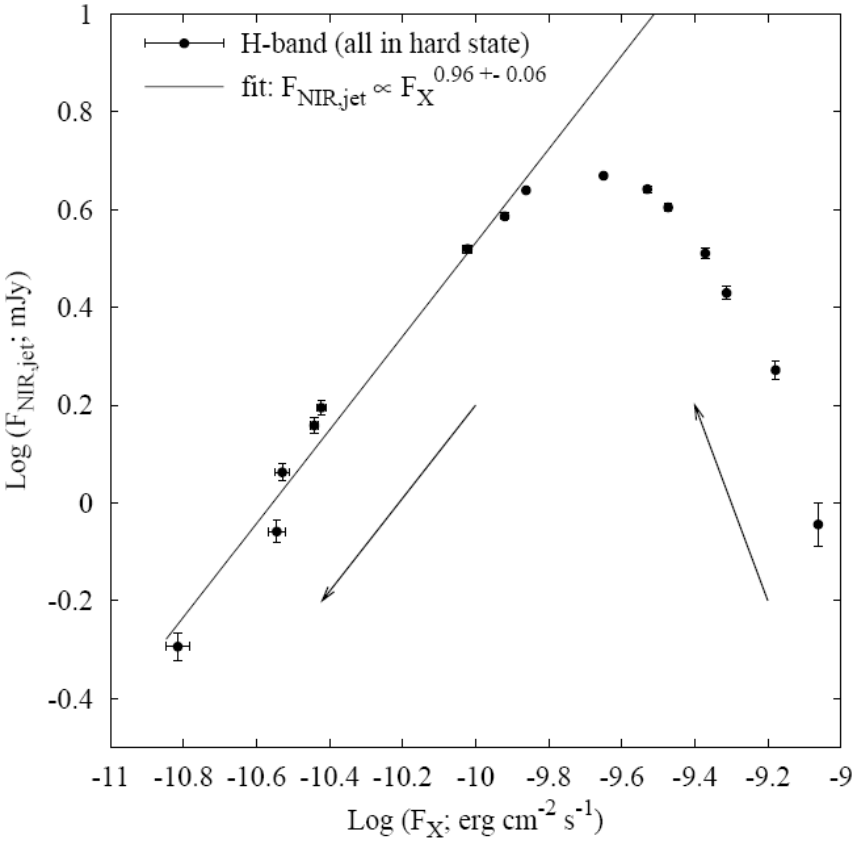


Russell, Maitra, Dunn & Fender 2011, MNRAS, in press

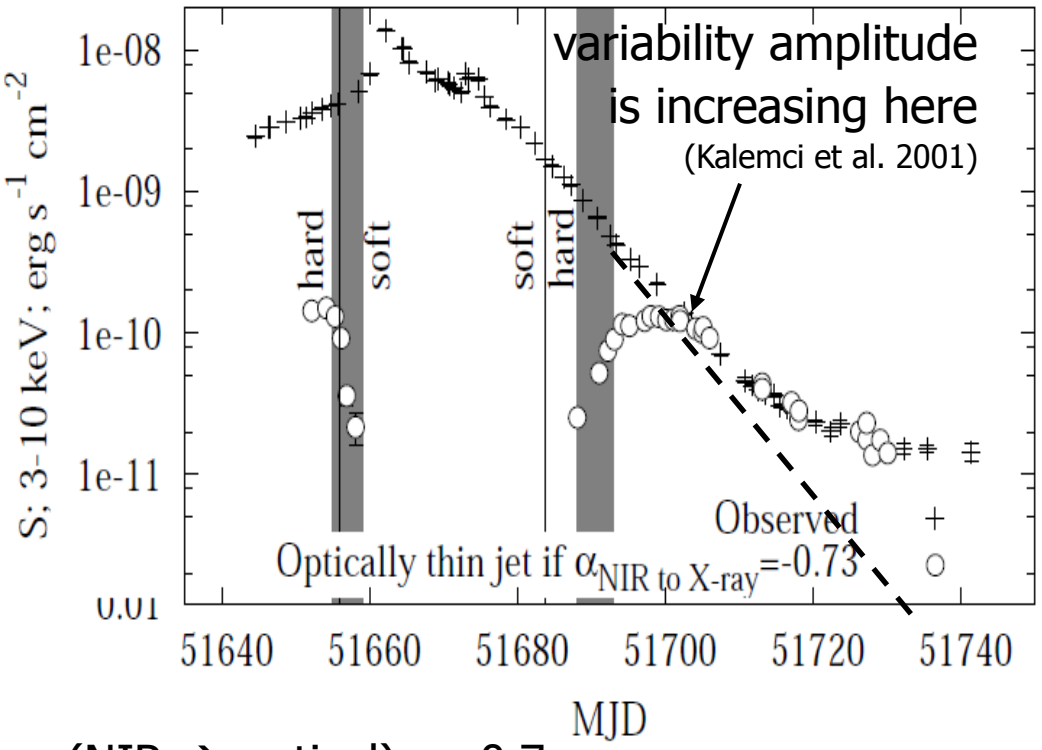
Could it be a synchrotron jet dominating X-ray?

Russell, Maitra, Dunn & Markoff 2010, MNRAS, 405, 1759

NIR jet flux is proportional to X-ray flux



A single power law decreasing in flux by a factor of ten



α (NIR → optical) ~ -0.7

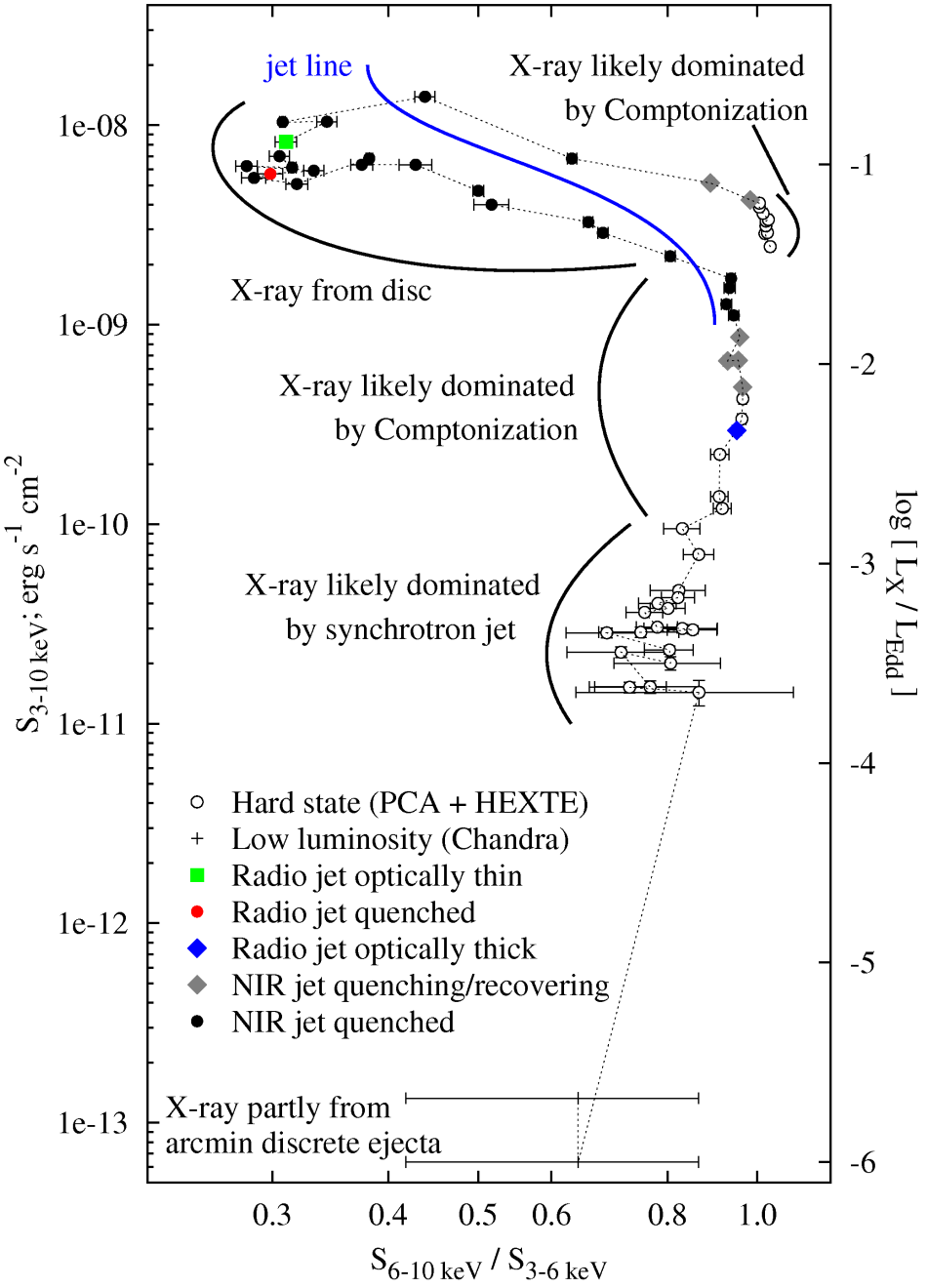
α (optical → X-ray) = -0.7

α (X-ray power law) = -0.7
(photon index = 1.7)

α (X-ray power law before) = -0.6

Jet origin of X-ray emission predicted by Markoff, Falcke & Fender 2001
(modelling of multiwavelength SED of XTE J1118+480)

A possible revised picture for BH outbursts

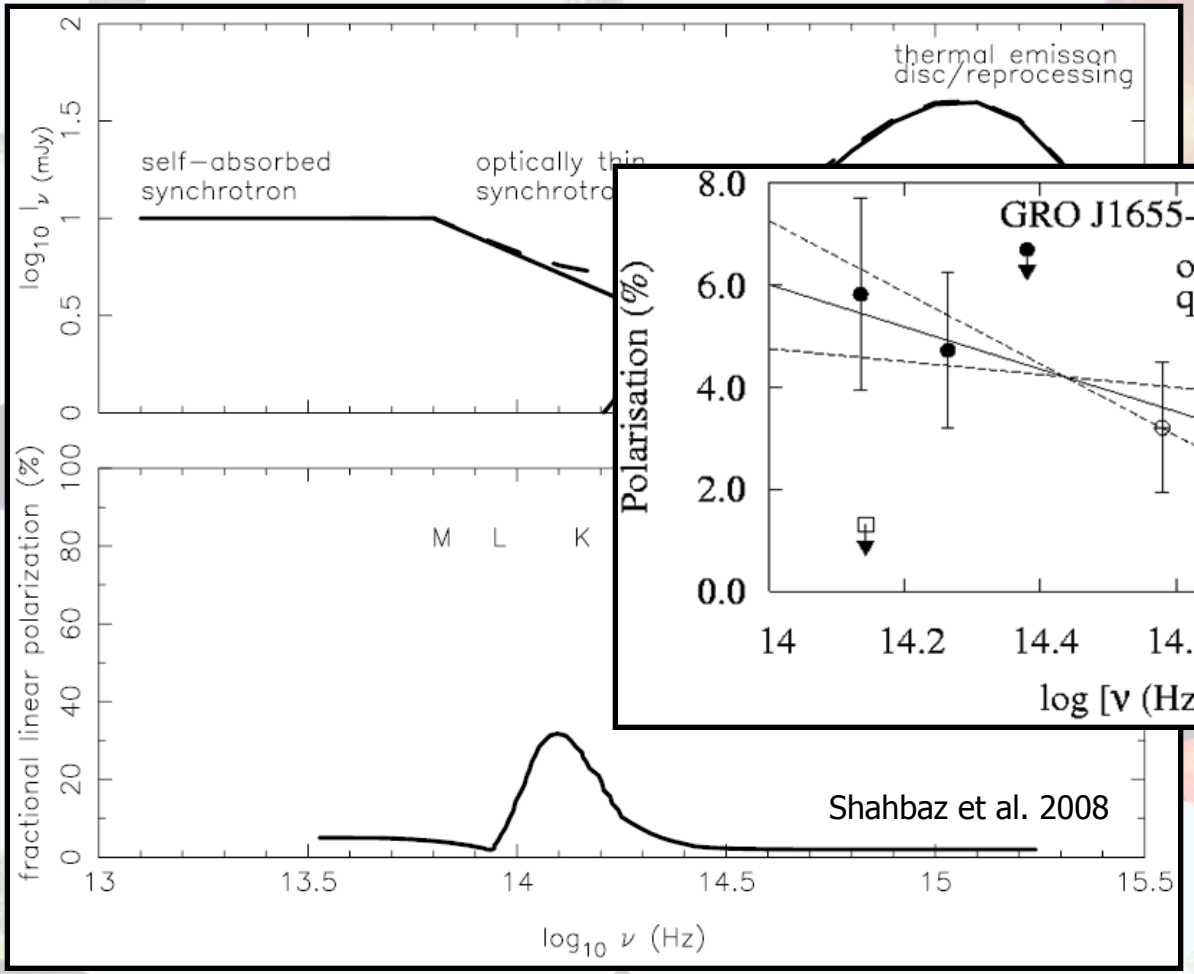


Fender, Gallo & Jonker 2003:

Energetics are jet dominated at low luminosities in the hard state

Jet could dominate X-ray flux in the hard state between $\sim (2 \times 10^{-4} - 2 \times 10^{-3})\ L_{\rm Edd}$

Polarization of optically thin synchrotron emission



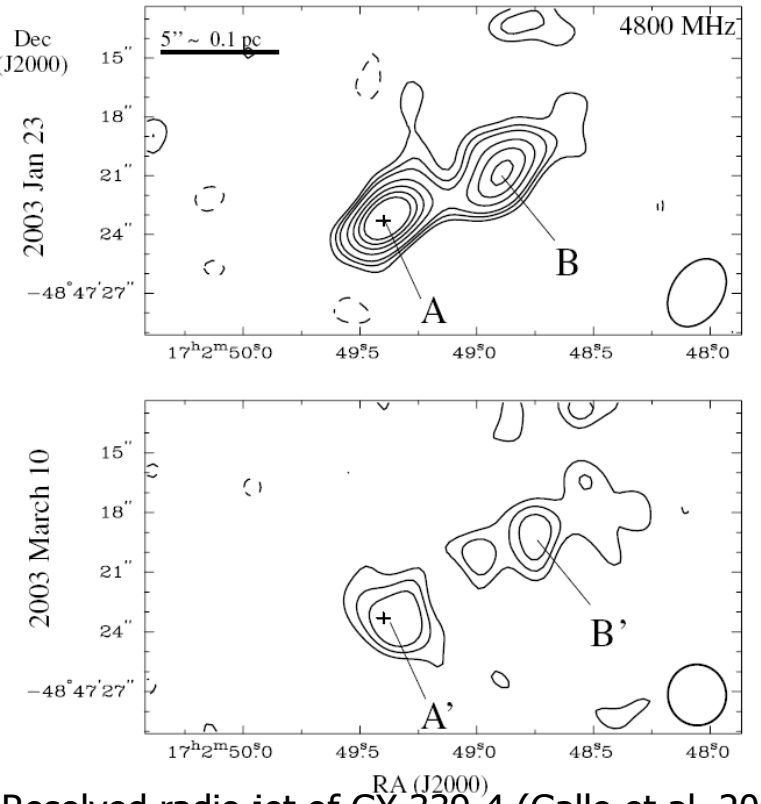
Russell & Fender 2008

- In NIR, the observed emission can be highly polarized
- Depends on magnetic field configuration
- Ordered field → up to 70% polarized
- Tangled field → ~ no net polarization

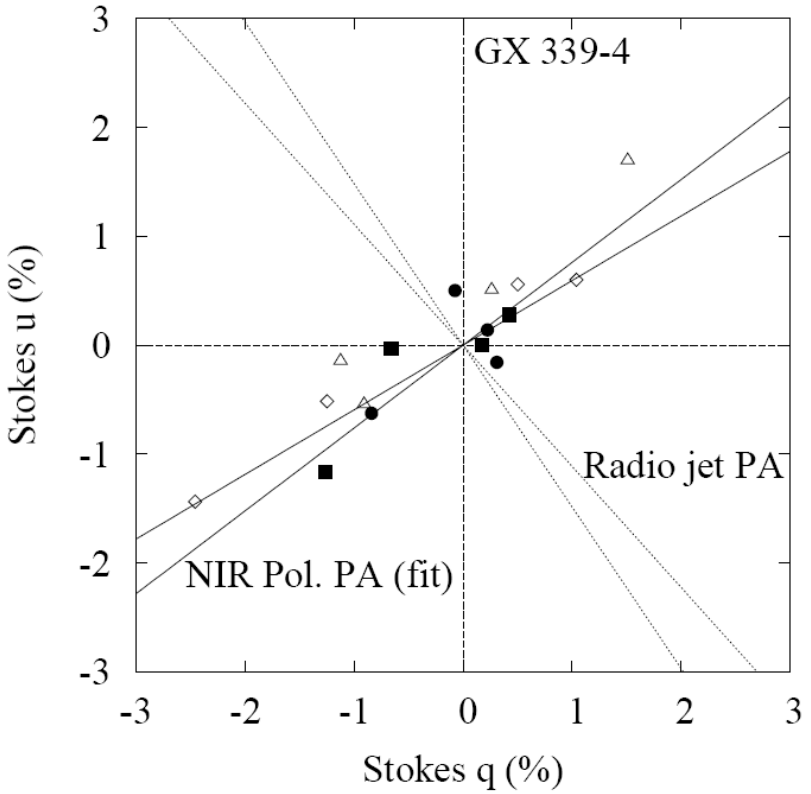
VLT observations of GX 339-4 in the hard state

→ We observed GX 339-4 in September 2008 during a hard state with VLT+ISAAC

→ We detect significant, variable linear polarization in the near-infrared (when the jet dominated)



Resolved radio jet of GX 339-4 (Gallo et al. 2004)



We infer a predominantly tangled, variable magnetic field near the jet base of GX 339-4

→ The PA of polarization is ~ perpendicular to the PA of the resolved radio jet in GX 339-4

→ The magnetic field is approximately parallel to the jet axis

It is much more tangled than Cyg X-1 inferred from γ-ray polarization (J. Rodriguez's talk)

Conclusions

- **Many techniques can be employed to isolate the disc & jet emission in XRBs**
- **Results so far:**
  - **→ Jets can be detected from radio to X-ray**
  - **→ The optically thick jet spectrum extends to IR, but dependency on luminosity (and similarities between sources) are yet to be tested**
  - **→ The optically thin jet spectrum appears to be rapidly variable in flux and in polarization, in at least one black hole XRB**
  - **→ This synchrotron emission can occasionally dominate the X-ray flux (this is probably true for XTE J1550-564 at low luminosities)**
  - **→ Future spaceborne X-ray polarimeters like GEMS and NHXM may detect variable X-ray polarization from synchrotron jets**
- **Regular X-ray, radio & optical/NIR (such as SMARTS & Faulkes) monitoring is beneficial → Fraser Lewis' talk next**