Rapid variations of polarisation in X-ray binaries

Dave Russell

New York University Abu Dhabi

جامعة نيويورك أبوظبي
NYU | ABU DHABI

dave.russell@nyu.edu

In collaboration with Tariq Shahbaz (IAC, Tenerife)
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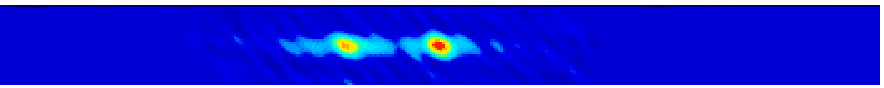
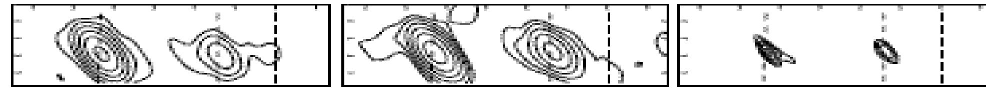
X-ray Binary Jets

Black hole XB: GRO J1655-40



Tingay et al. 1995

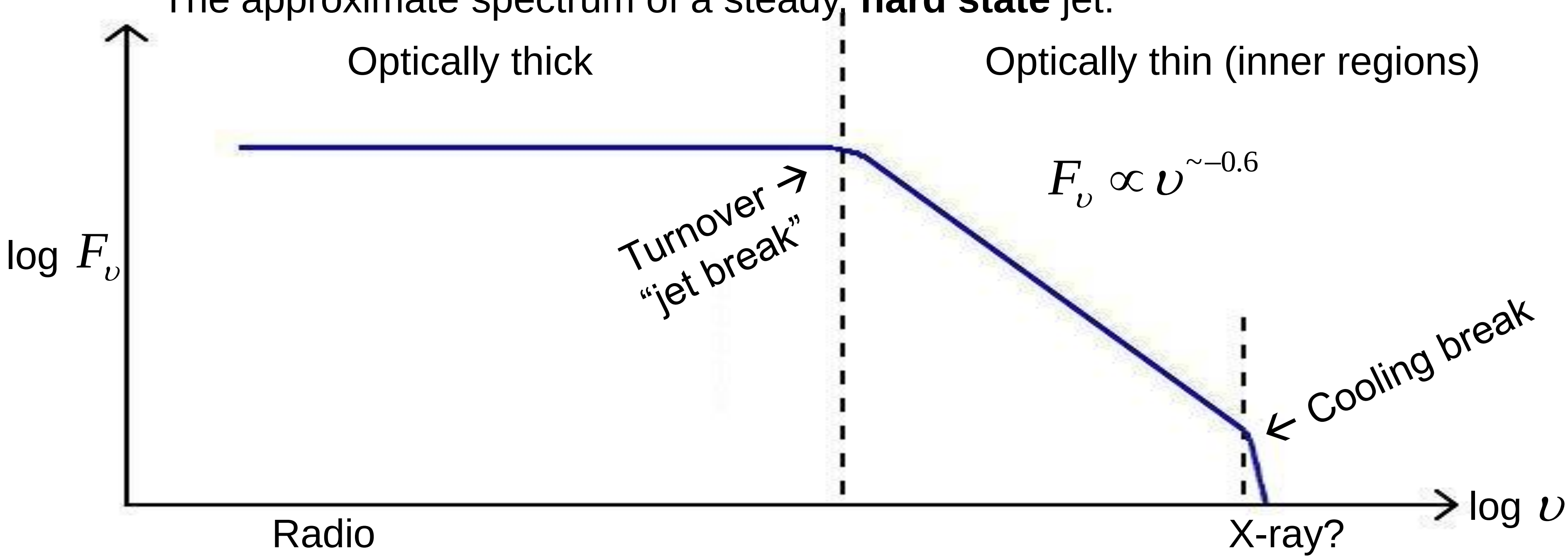
Neutron star XB: Sco X-1



Fomalont et al. 2001

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

The approximate spectrum of a steady, **hard state** jet:



• The total jet luminosity is highly dependent on the position of the spectral break(s)

• How does the jet spectrum evolve during outbursts? → **Time evolution (impossible for AGN)**

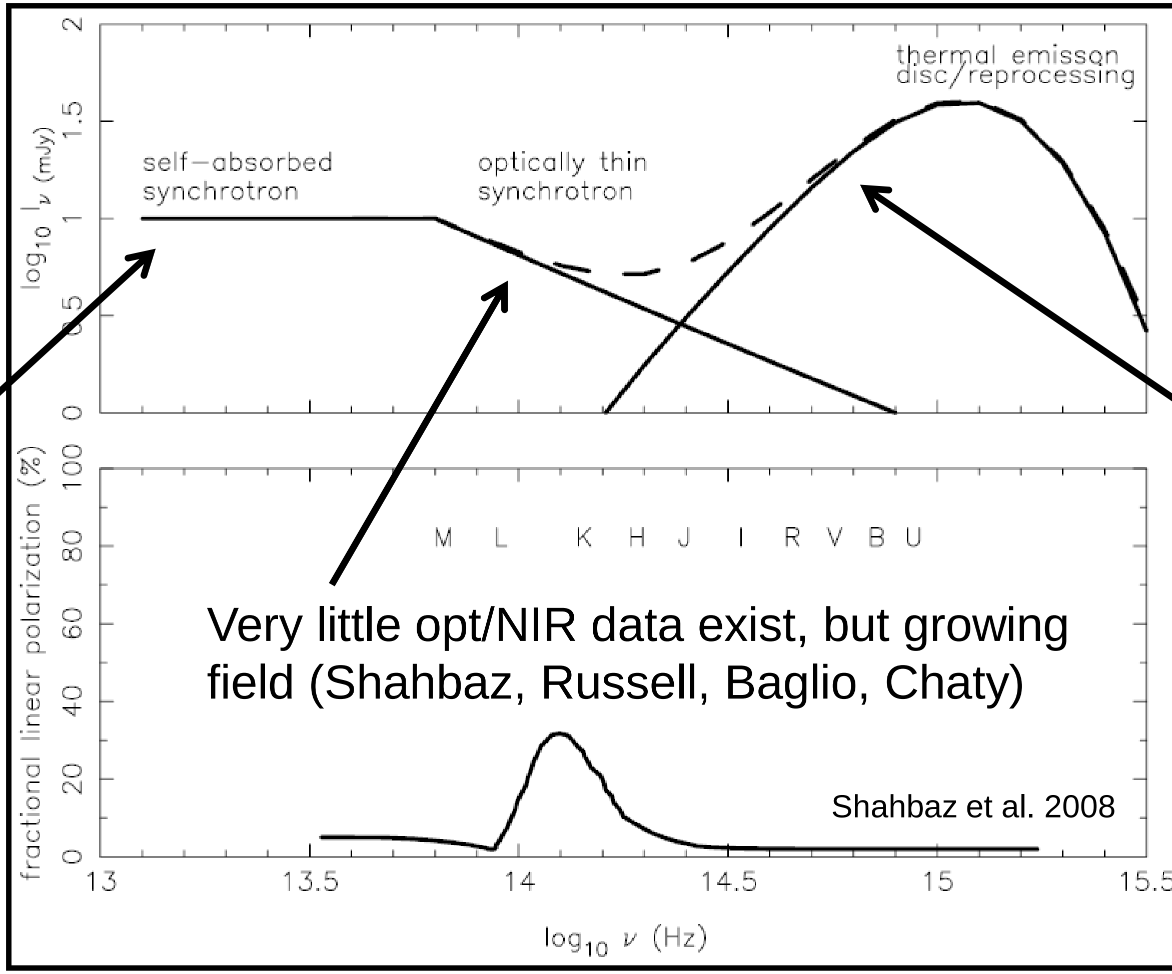
• **What are the conditions in the inner regions of the jets? → Polarisation**

Polarisation of optically thin synchrotron emission

Some radio data exist:

A few % polarised

(papers by e.g. Brocksopp, Curran)



Very little opt/NIR data exist, but growing field (Shahbaz, Russell, Baglio, Chaty)

Some optical data exist:

A few % polarised due to scattering

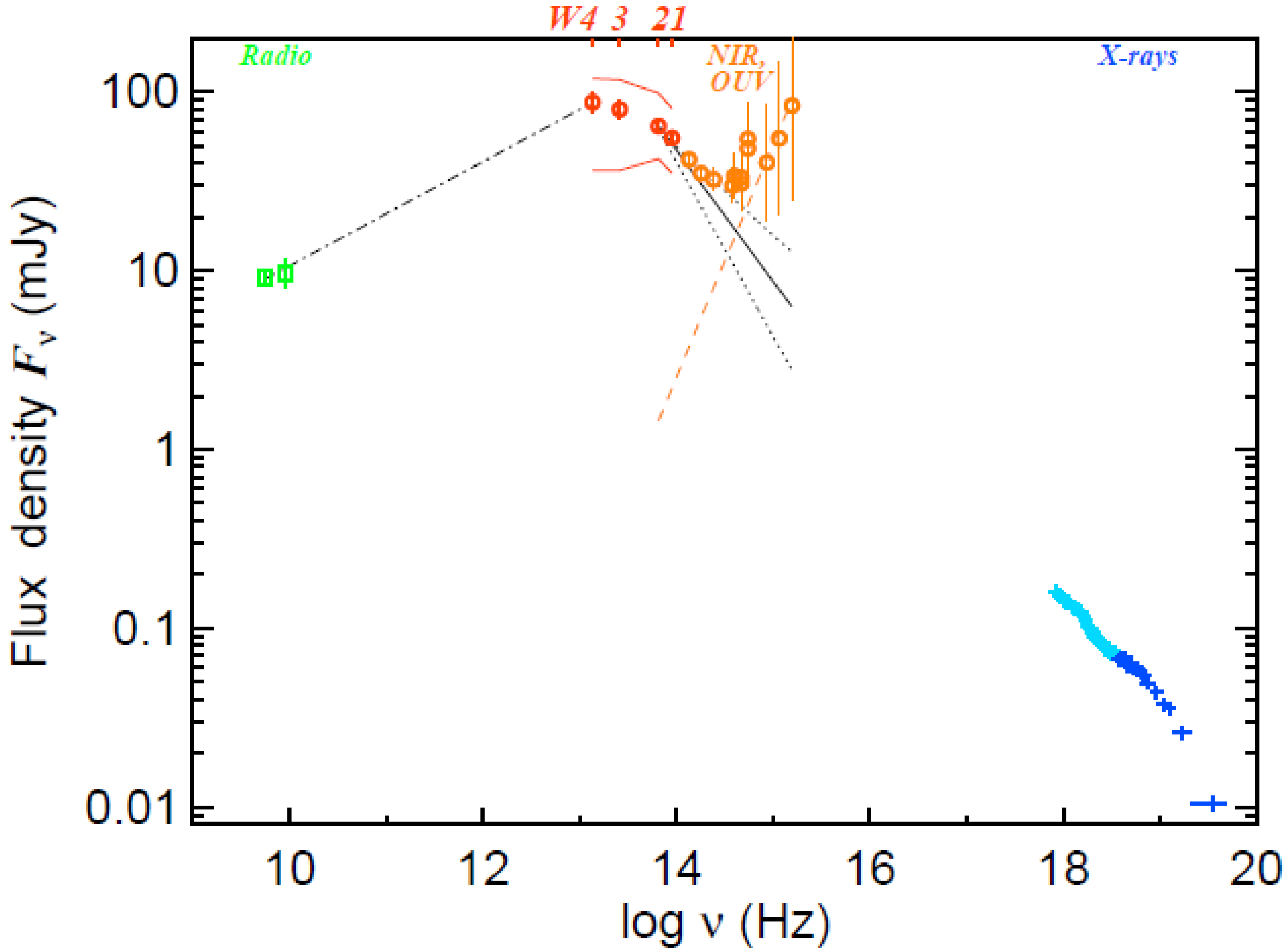
(e.g. Dolan, Gliozzi)

- In NIR, the observed emission of X-ray binaries can be highly polarised
- Depends on magnetic field configuration
- Ordered field → up to ~80% polarised

$$FLP_{\rm thin} = f\,\frac{p+1}{p+7/3} = f\,\frac{1-\alpha_{\rm thin}}{5/3-\alpha_{\rm thin}}$$

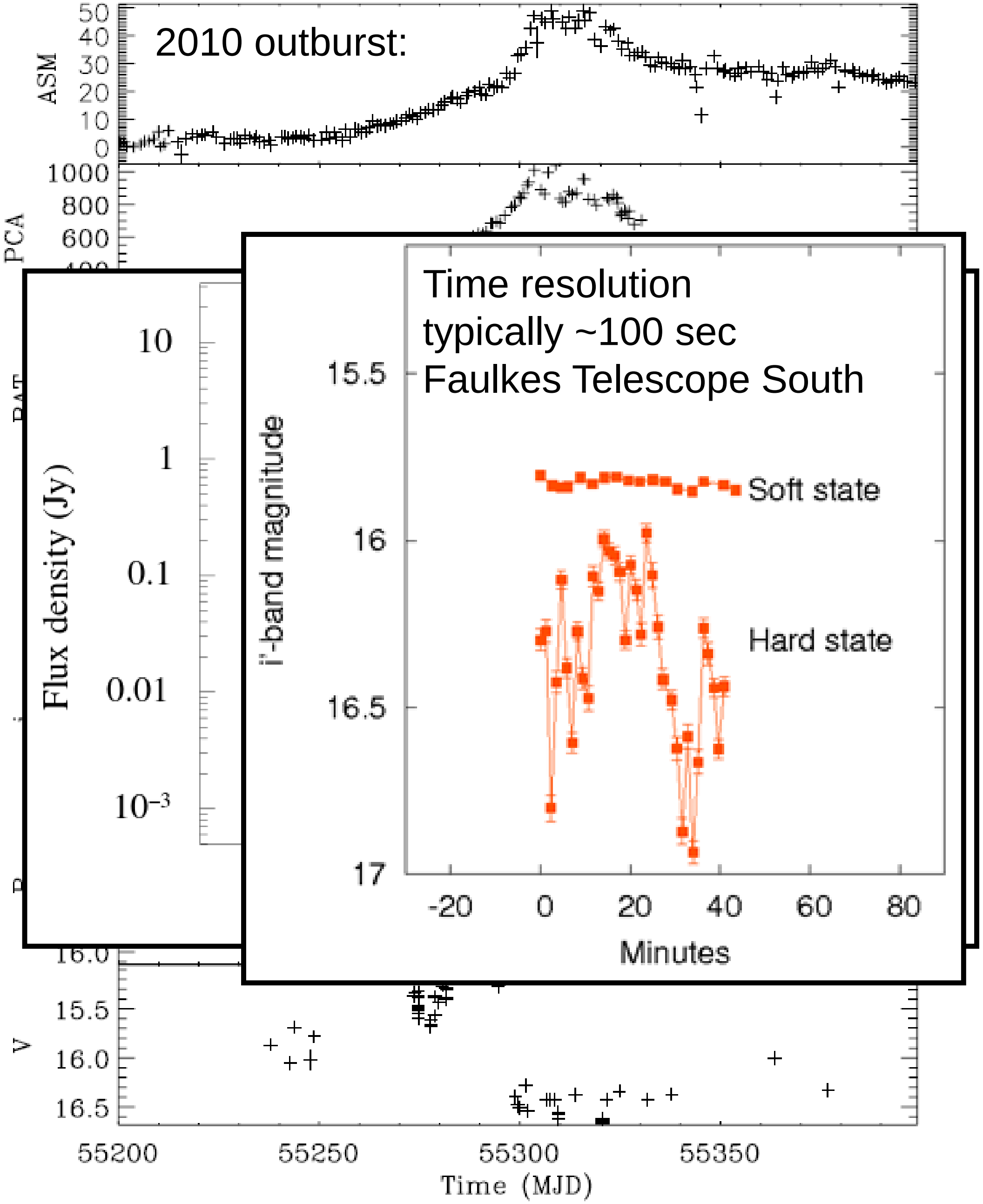
- Tangled field → ~ no net polarisation (low *f*)

Jet emission in the optical/NIR

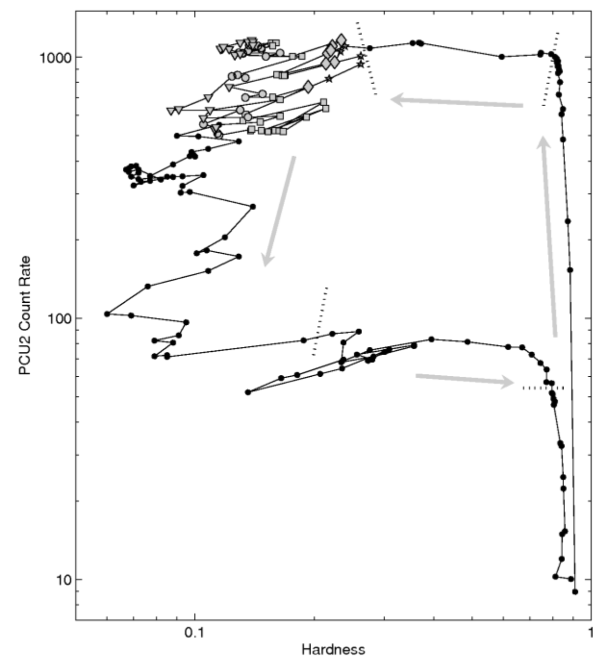


Jet break seen in **GX 339-4** in mid-IR in the **hard state** – the break is variable in time
Gandhi et al. 2011

We need polarisation data in the hard state



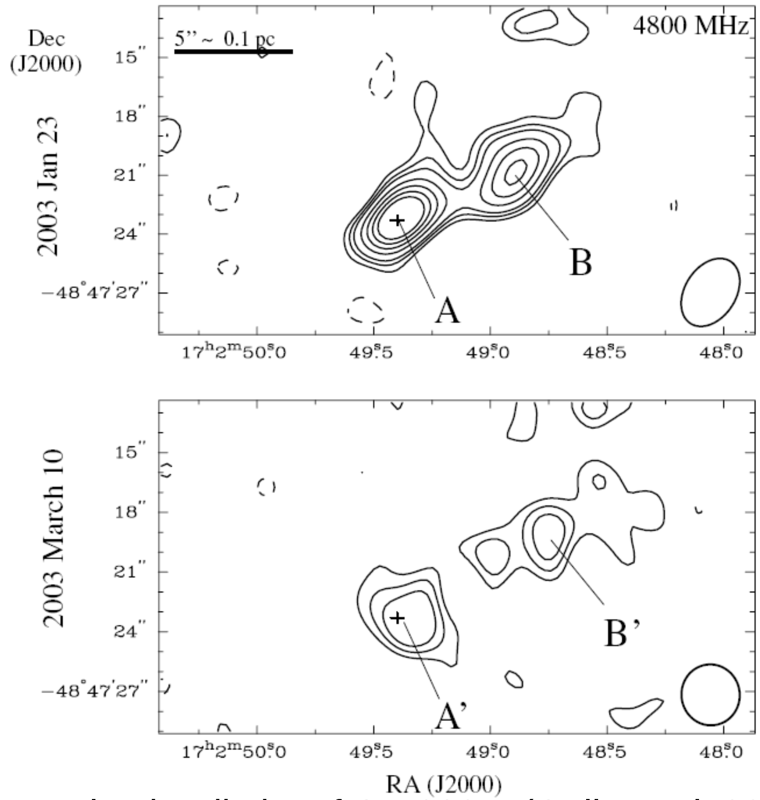
- → We have been monitoring GX 339-4 with the Faulkes Telescope South
- → Optical drop when the source left the hard state as jet is quenching (Cadolle Bel et al. 2011)
- → This happens in every outburst in which there are state transitions (Buxton et al. 2012)
- → The infrared component is highly variable (Casella et al. 2010, Kalamkar et al. 2015)



VLT observations of GX 339-4 in the hard state

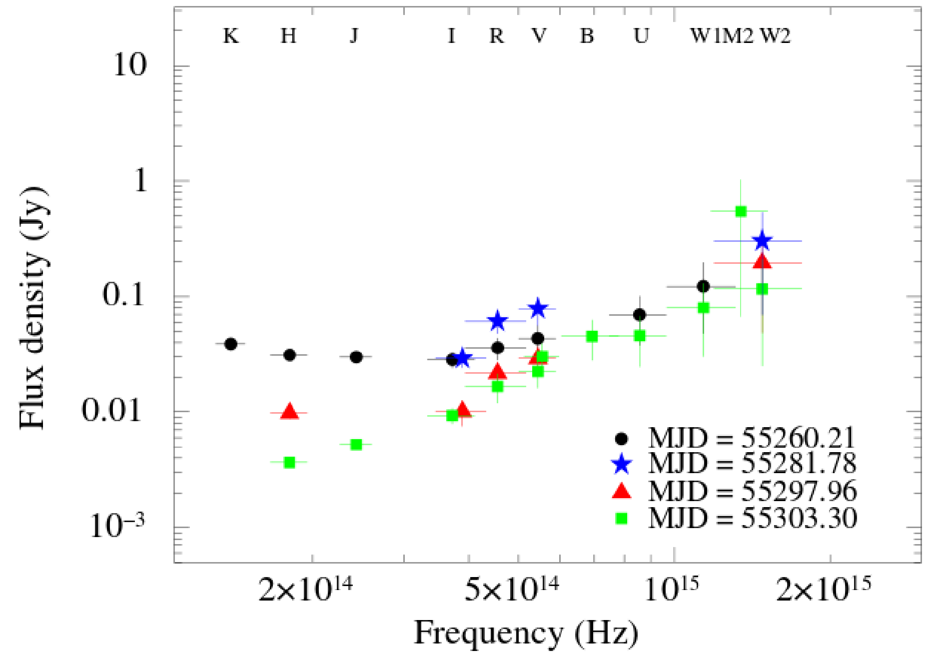
→ We observed GX 339-4 during a hard state with VLT+ISAAC

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



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

→ Polarisation variability timescale: < 60 sec

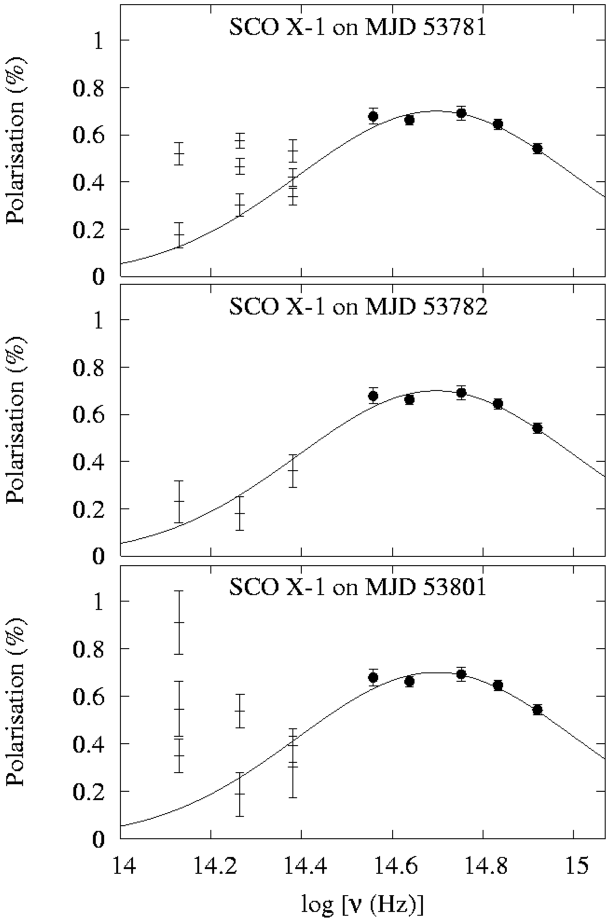


We infer a predominantly tangled, variable magnetic field near the jet base (1 – 3 % polarised)

→ The PA of polarisation is ~ perpendicular to the PA of the resolved radio jet

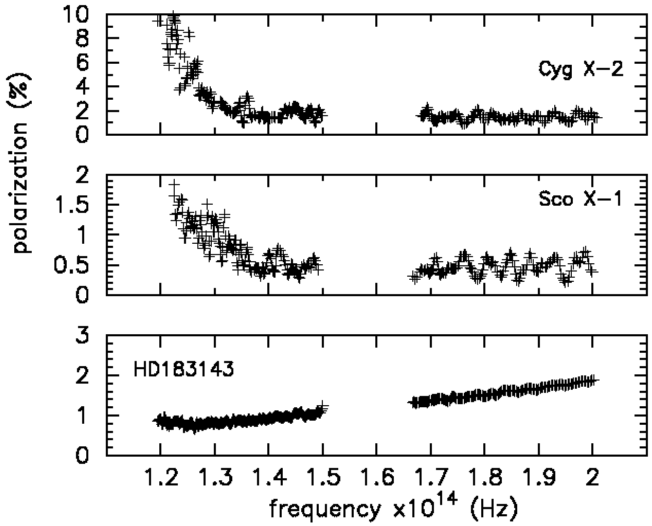
→ The magnetic field is approximately parallel to the jet axis

Polarisation of neutron star XRBs



Sco X-1

NIR (Russell & Fender 2008) and optical (Schultz et al. 2004) polarisation



Cyg X-2 and Sco X-1

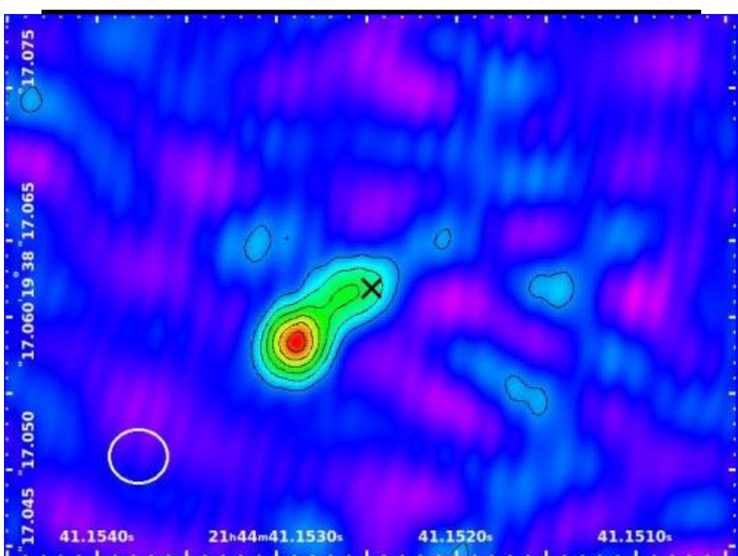
NIR spectropolarimetry (Shahbaz et al. 2008)

All detections are stronger at low frequencies

The results imply a predominantly tangled, likely variable magnetic field near the jet base

Cyg X-2 has an infrared excess (Wang & Wang 2014)

The radio jet of Cyg X-2 has now been resolved (Spencer et al. 2013)



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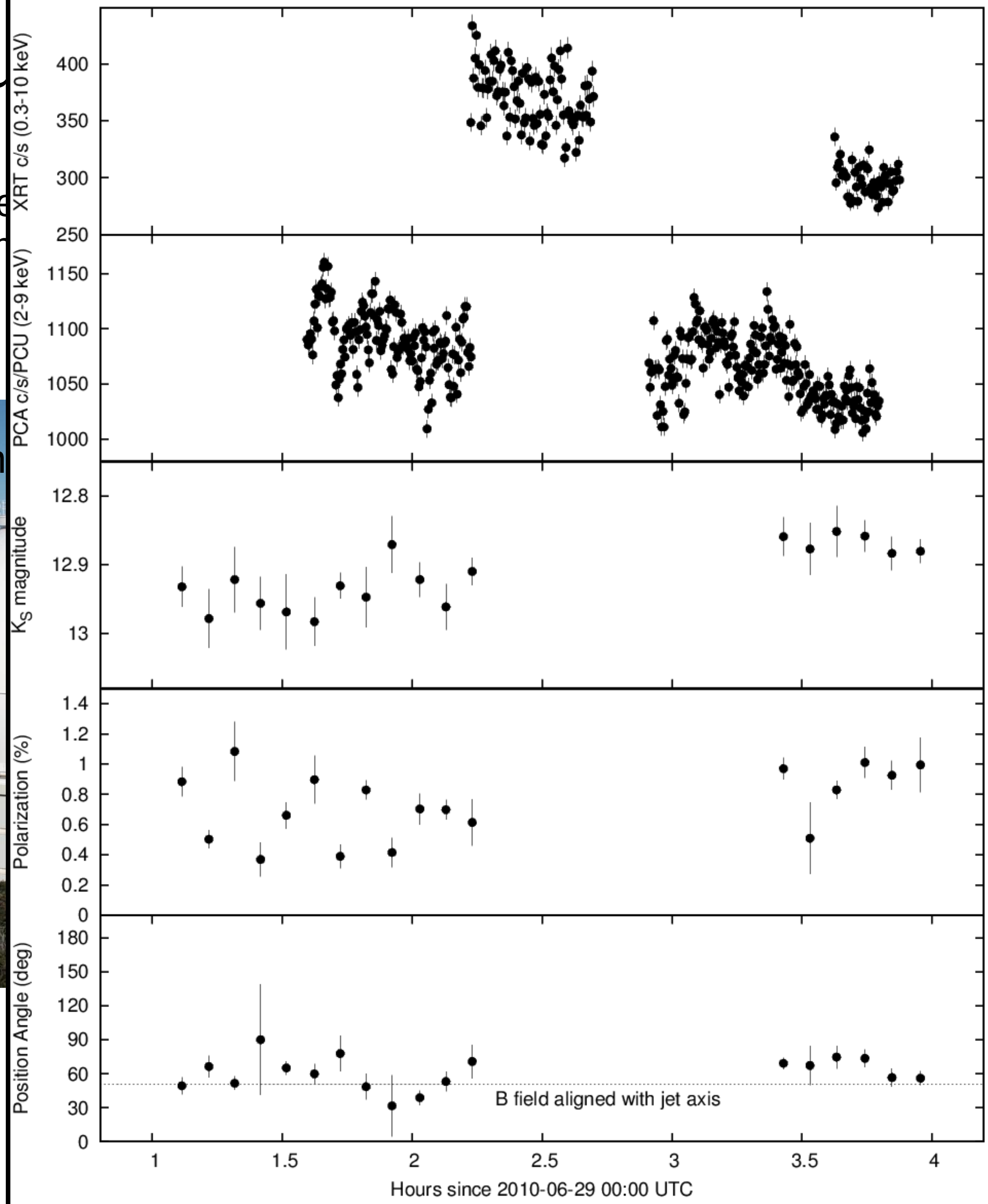
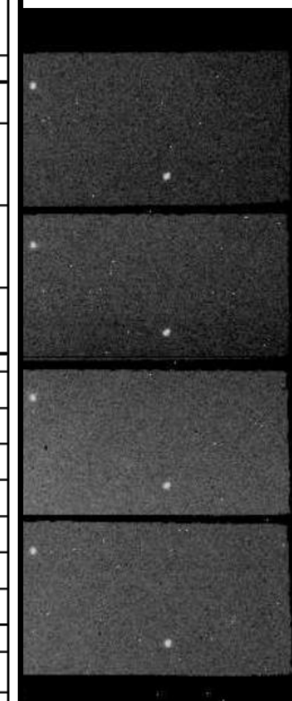
We took time   RIS of
Cyg X-2, sim

4.2 m William

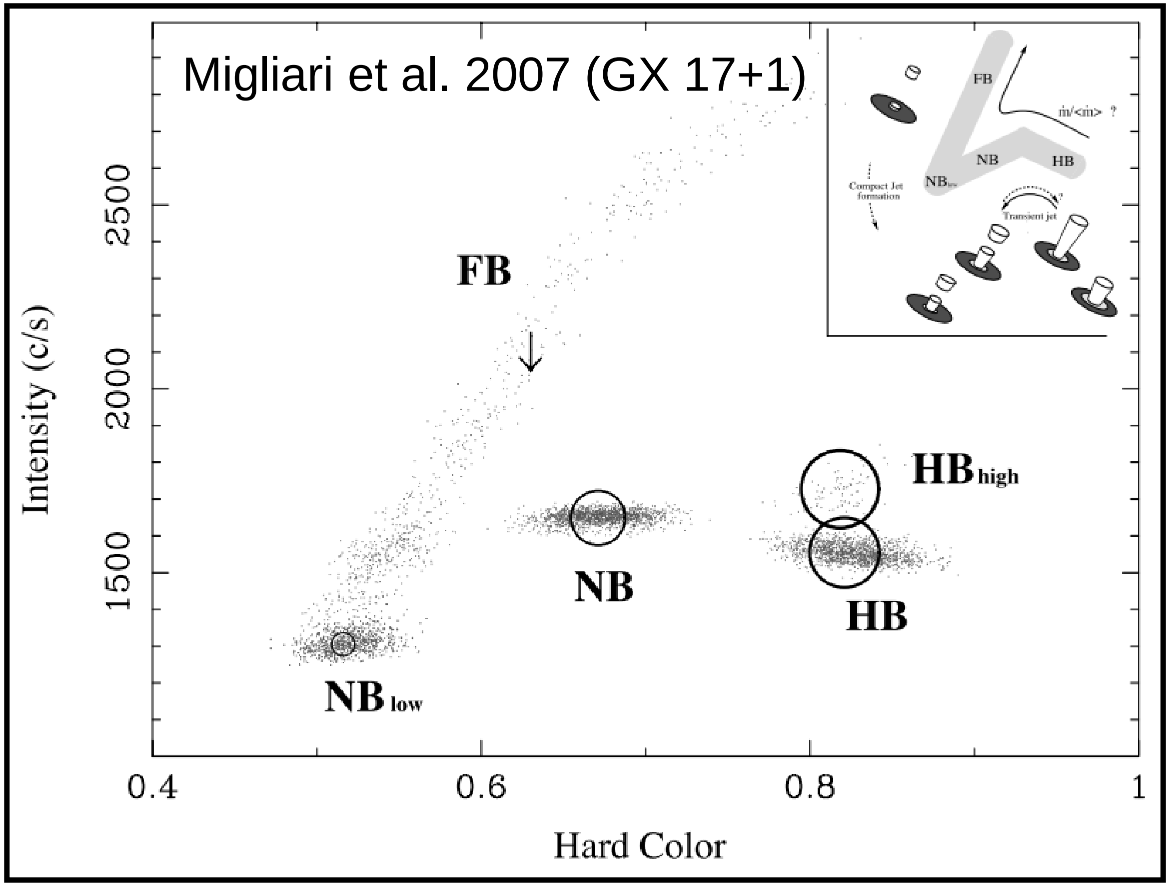




A multiwavelength campaign on Cyg X-2

We took time-resolved NIR polarisation observations with WHT + LIRIS of Cyg X-2, simultaneously with X-ray (Swift and RXTE) in 2010

The X-ray data suggest the source was in the *normal branch* at the time of our observations → transient jets are launched during this state



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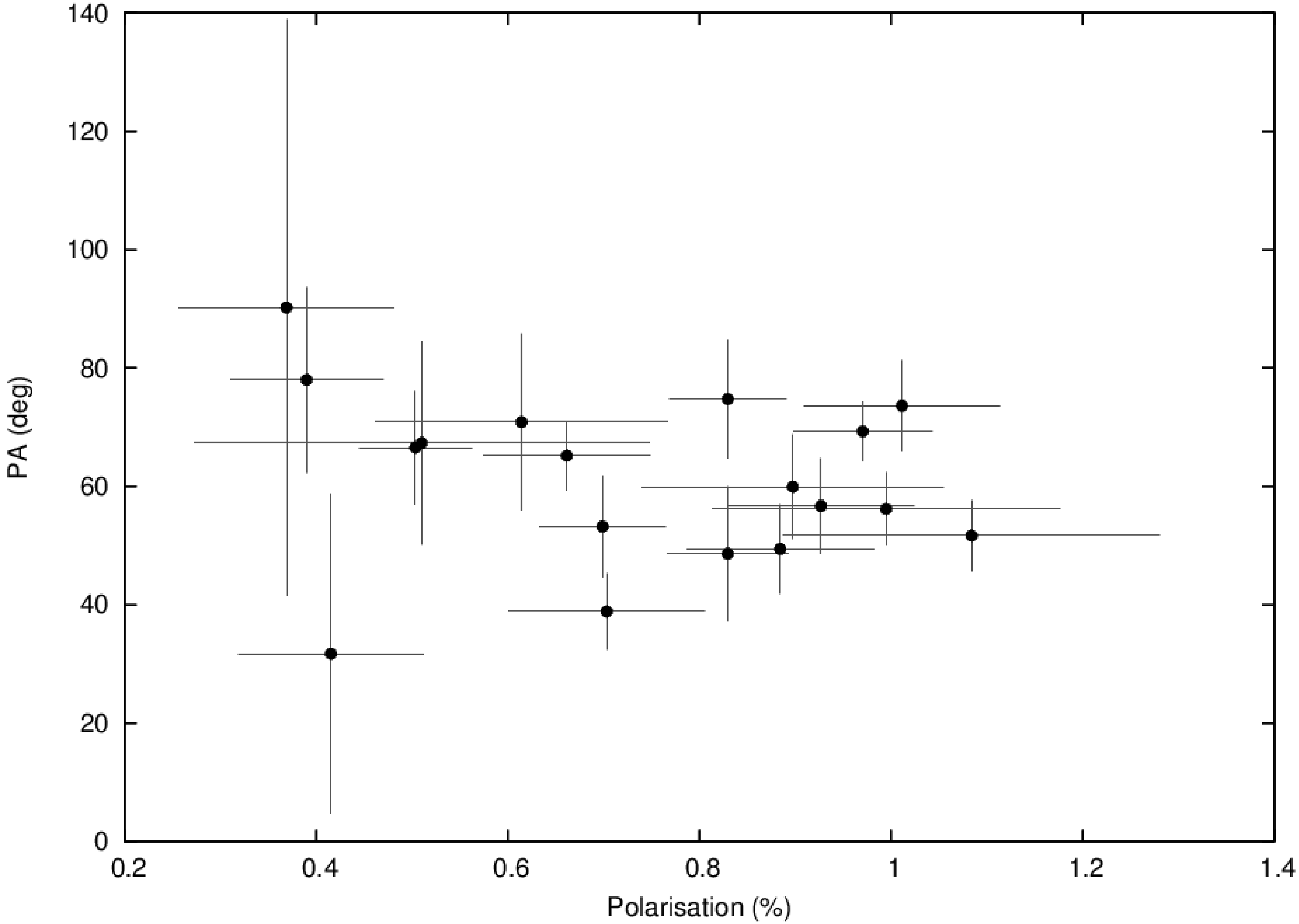

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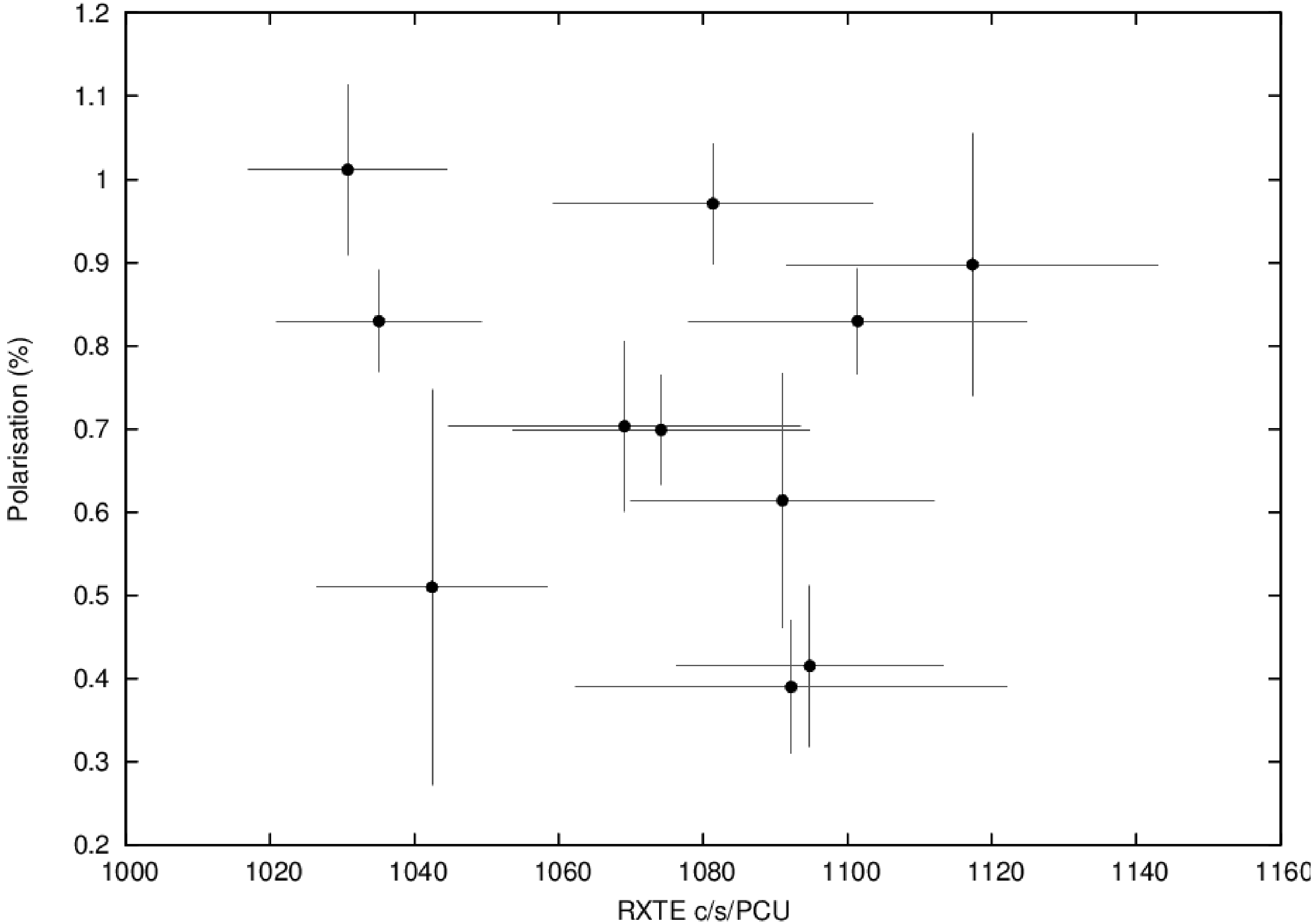
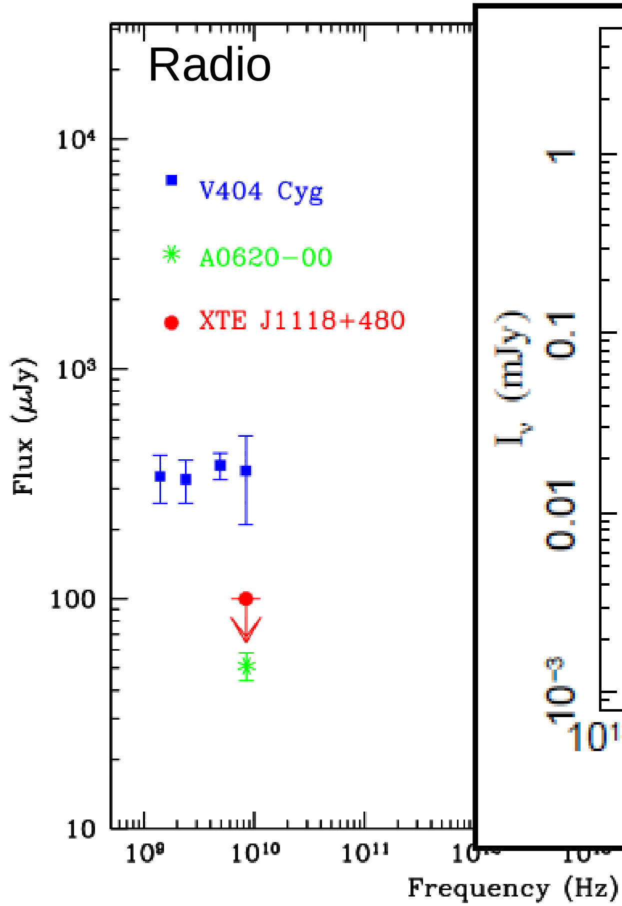
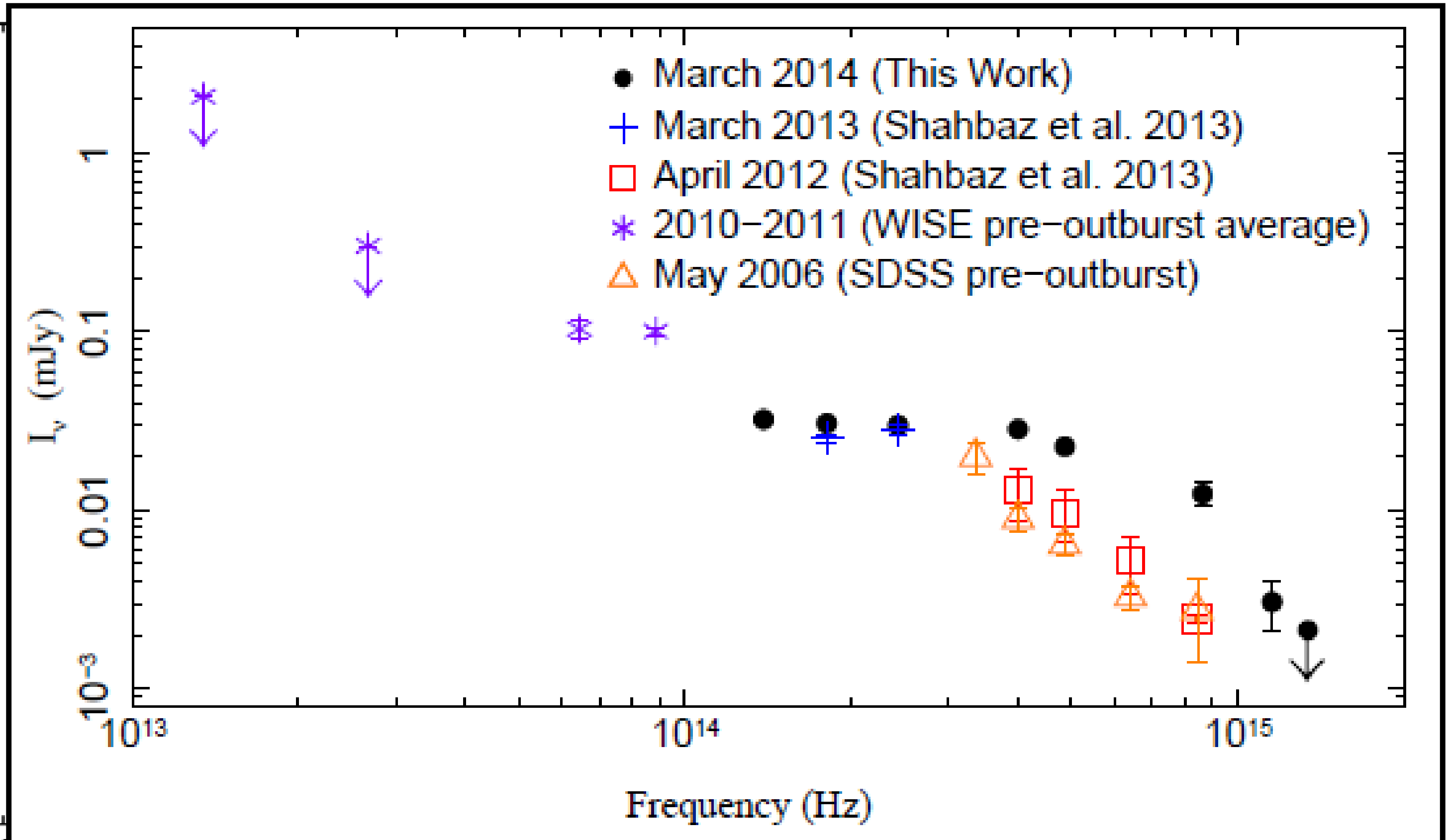


BH XRBs in quiescence have jets





V404 Cyg has flat radio spectrum (Gallo et al. 2005, 2007) with instabilities (Rana et al. 2015)

Jets exist in quiescence

Swift J1357.2–0933 has a steep IR–optical spectrum, high rms variability (20 – 30%)

Optical, NIR, WISE mid-IR (3.4 to 22 mu)

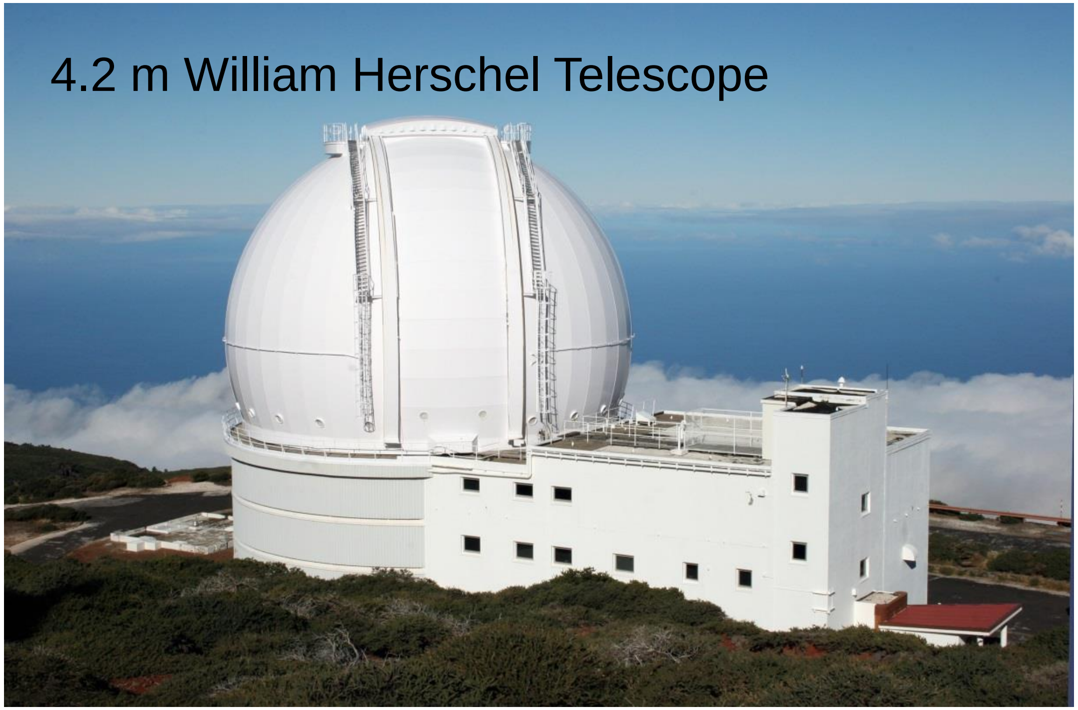
power-law with index -1.4 (Shahbaz et al. 2013)

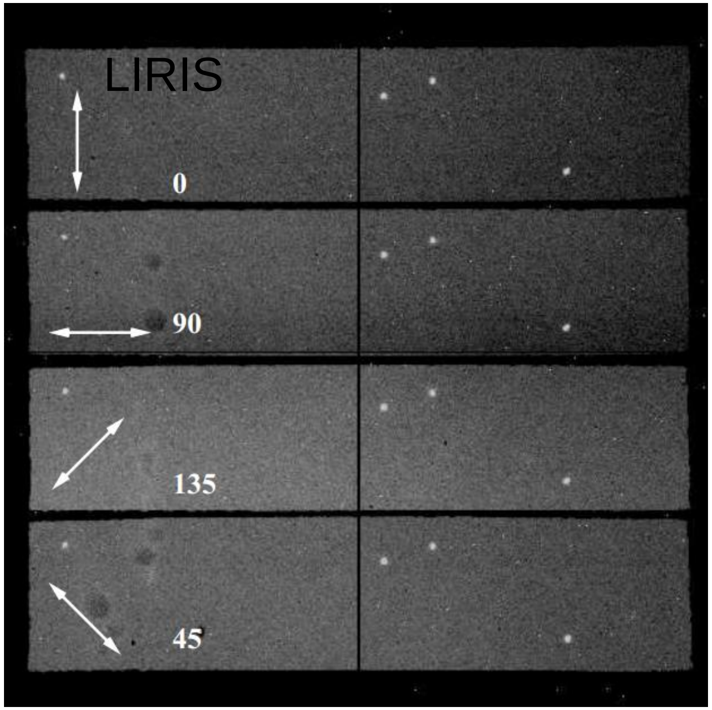
Could be a thermal, possibly Maxwellian distribution of electrons in a weaker jet

Jet break is seen by Plotkin et al. 2015

New results from quiescent jets

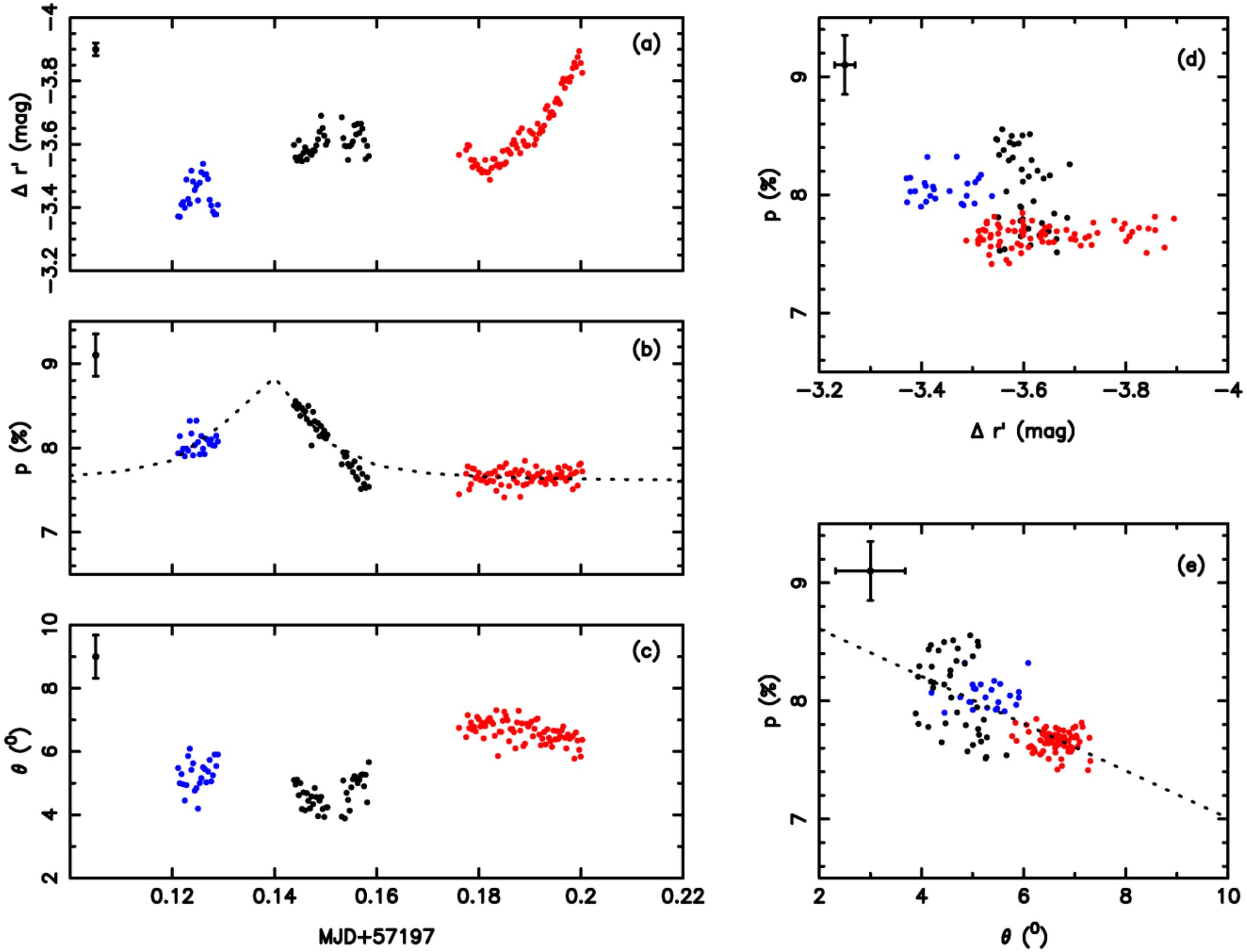
We took NIR polarisation observations with WHT + LIRIS of Swift J1357.2–0933 in quiescence





- The synchrotron emission is polarised at a level of 8.0 ± 2.5 % (J to K) (a detection of intrinsic polarisation at the 3.2σ level)
- The mean magnitude and rms variability of the flux agree with previous observations (fractional rms of 15–21 per cent)
- These properties imply a continuously launched (stable on long timescales), highly variable (on short timescales) jet, which has a moderately tangled magnetic field close to the jet base

And finally…. V404 Cyg



see also
ATel #7674, #7678, #7696

- Shahbaz et al. in prep: time-resolved optical polarimetry of V404 during brightest flaring episodes of the 2015 outburst, with Telescopio Nazionale Galileo (TNG)
- A polarisation flare is seen just before a bright optical & X-ray flare
- Position angle implies the **B** field is perpendicular to the jet axis (known from radio; Miller-Jones et al. in prep) → internal shocks?

Conclusions

- **NIR-optical synchrotron emission from jets in X-ray binaries is polarised**
- **The results so far suggest:**
- **Near the jet base the magnetic field is probably:**
  - **→ generally turbulent (only partially ordered) and rapidly changing**
  - **→ parallel to the jet axis (but perpendicular in V404 Cyg: shocks?)**
- **Open questions:**
  - **→ What are the timing properties of the variable polarisation?**
  - **→ Does polarisation correlate with anything in the inflow?**
  - **→ What drives the magnetic field changes?**
- **More data and more models are needed to explain the observations**

Thanks for listening