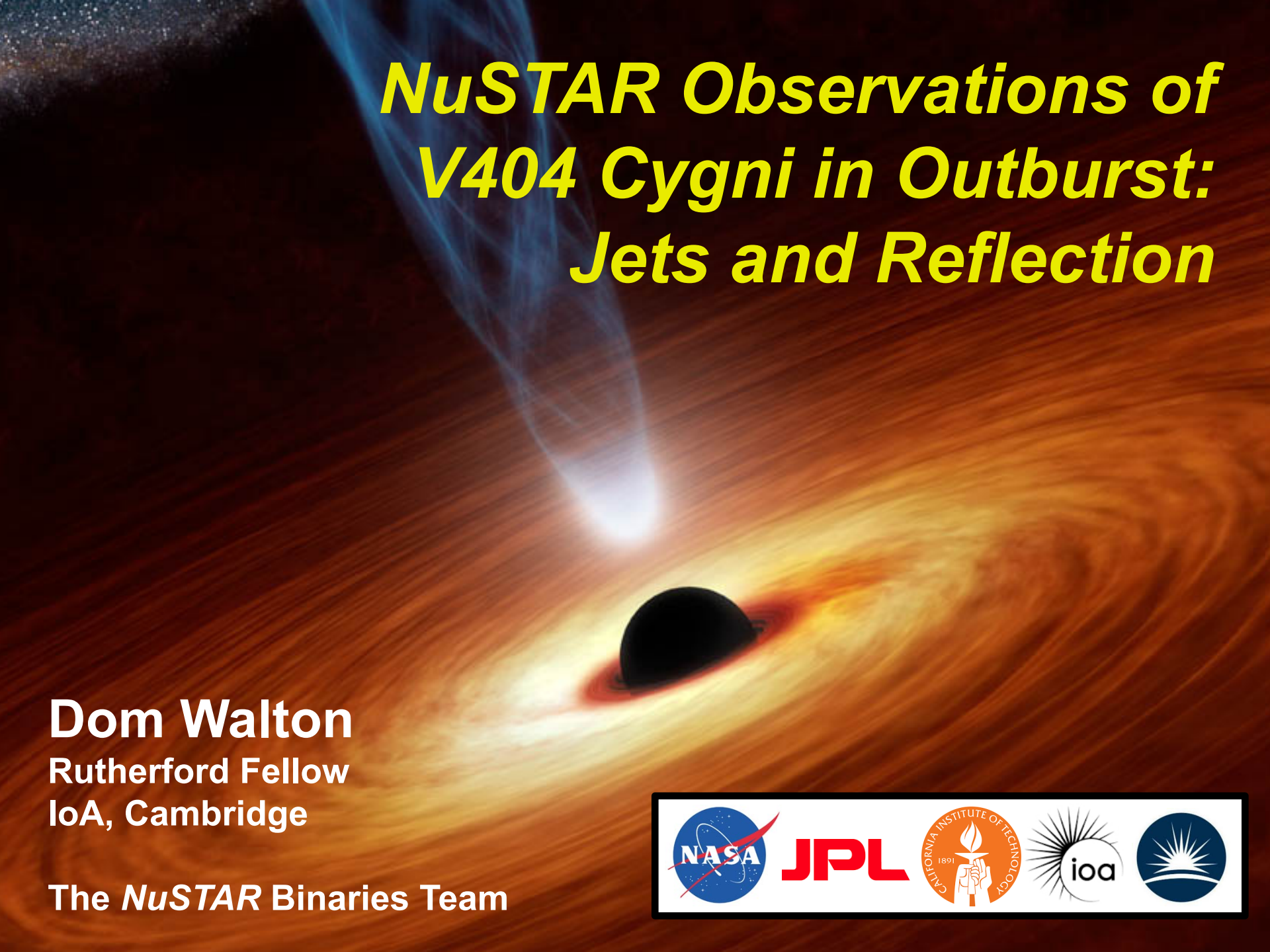
NuSTAR Observations of V404 Cygni in Outburst: Jets and Reflection



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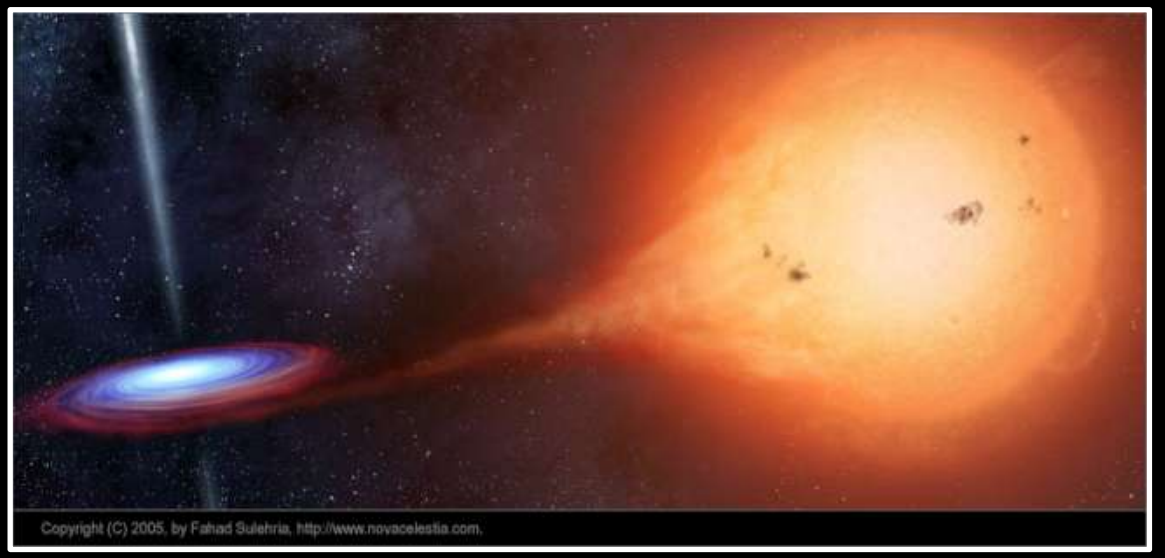
V404 Cygni

Low-mass, black hole X-ray binary

D = 2.4 kpc

$M_{BH} \sim 10\ M_{sun}$



Previous outbursts: 1989, 1956, 1938 – long periods of quiescence

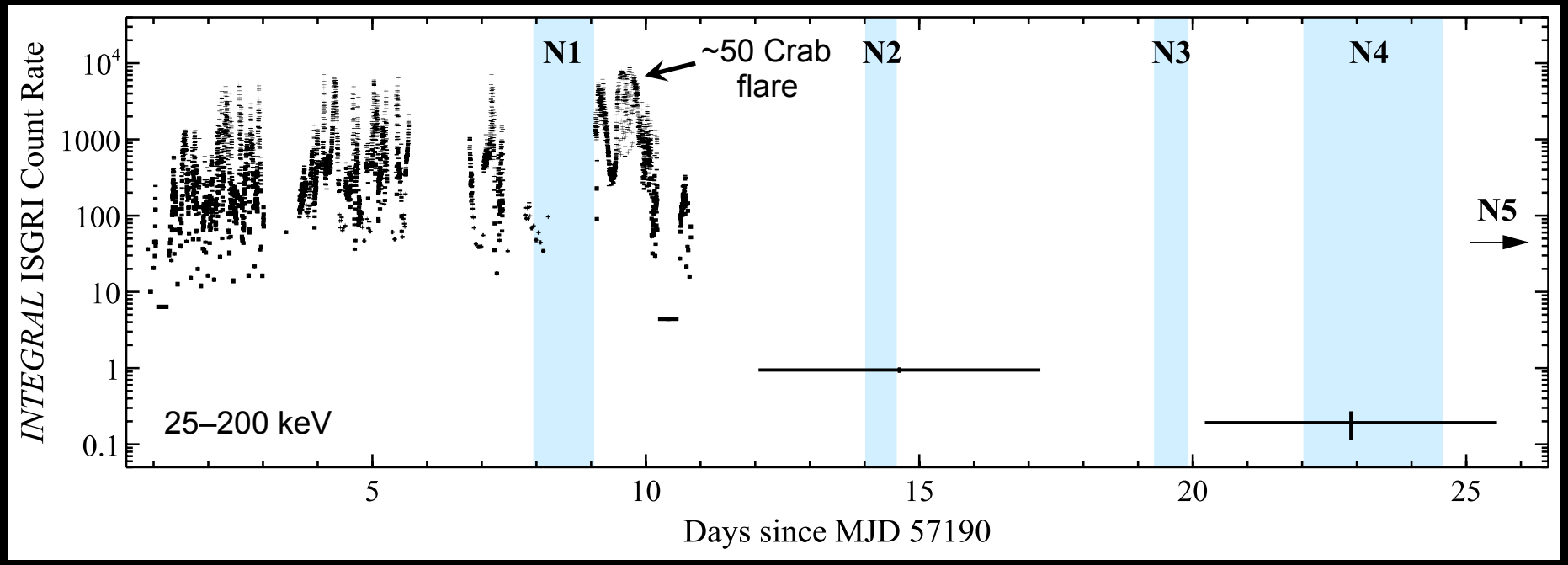
During outburst, V404 Cygni becomes one of the brightest X-ray sources in the sky, reaching ~50 Crab!

2015 Outburst

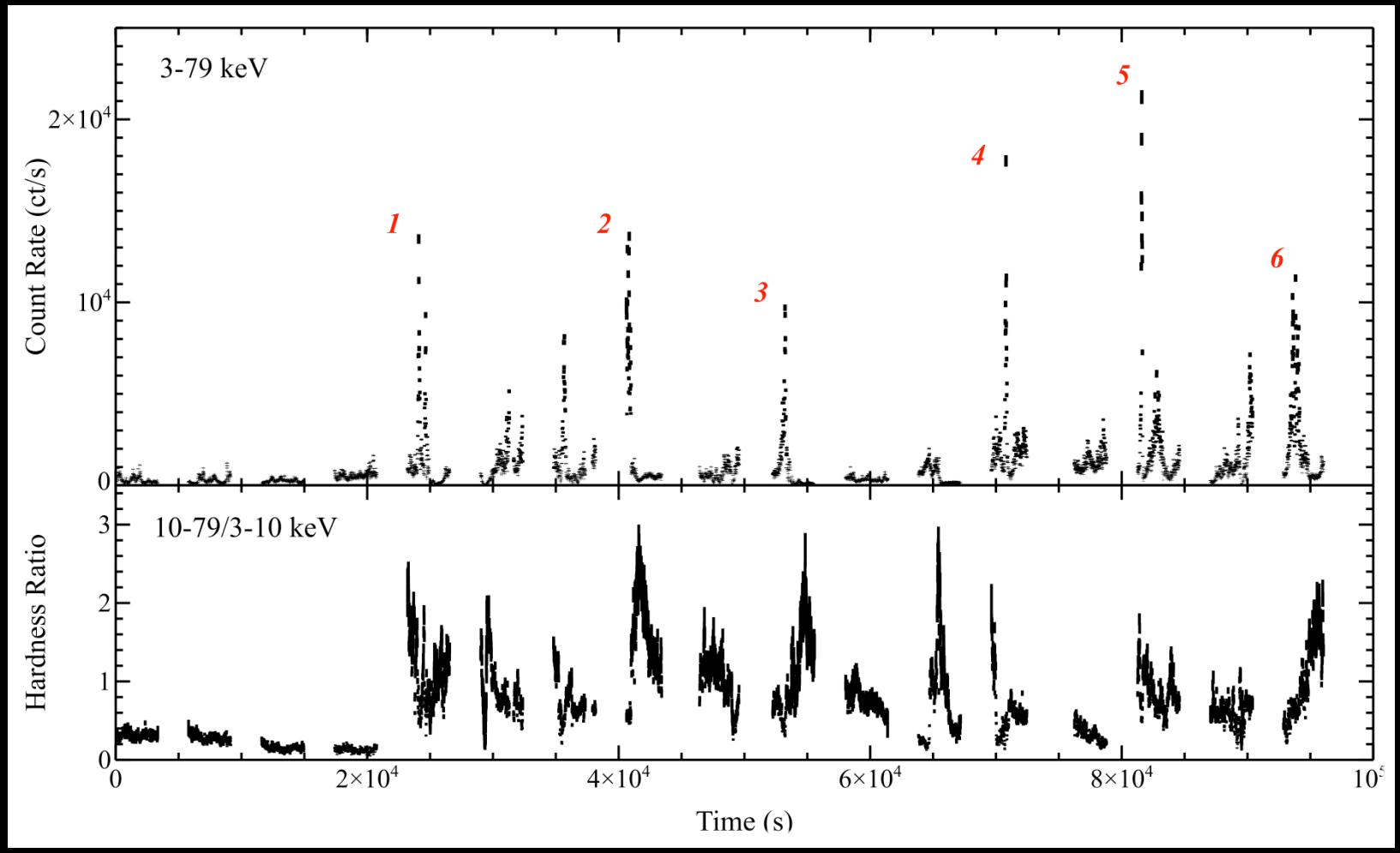
Renewed activity detected from V404 Cygni on 16 July 2015

Huge multi-wavelength campaign to follow the outburst (radio, OIR, X-ray)

Performed 5 observations with *NuSTAR* (N1-5) – **<u>focusing on N1 here</u>**

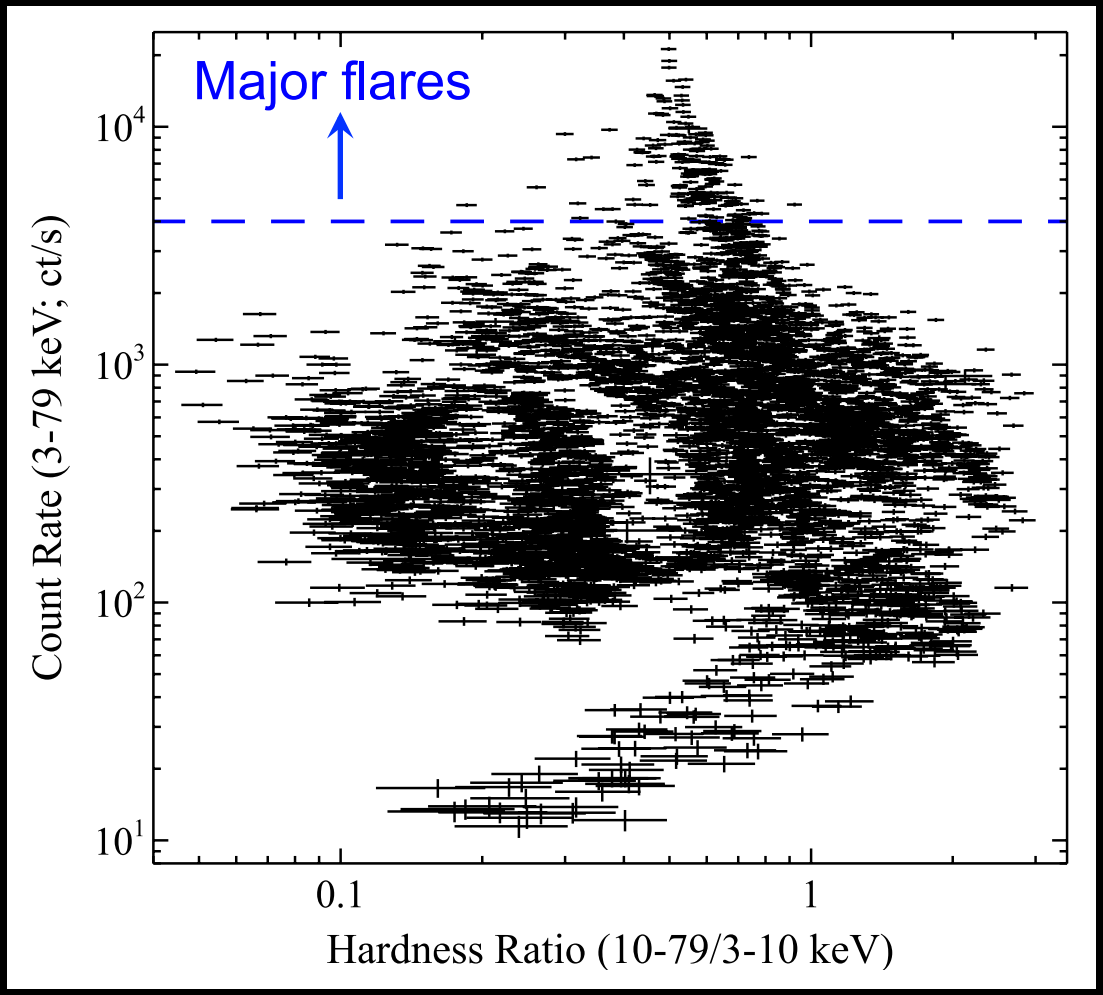


NuSTAR Lightcurve



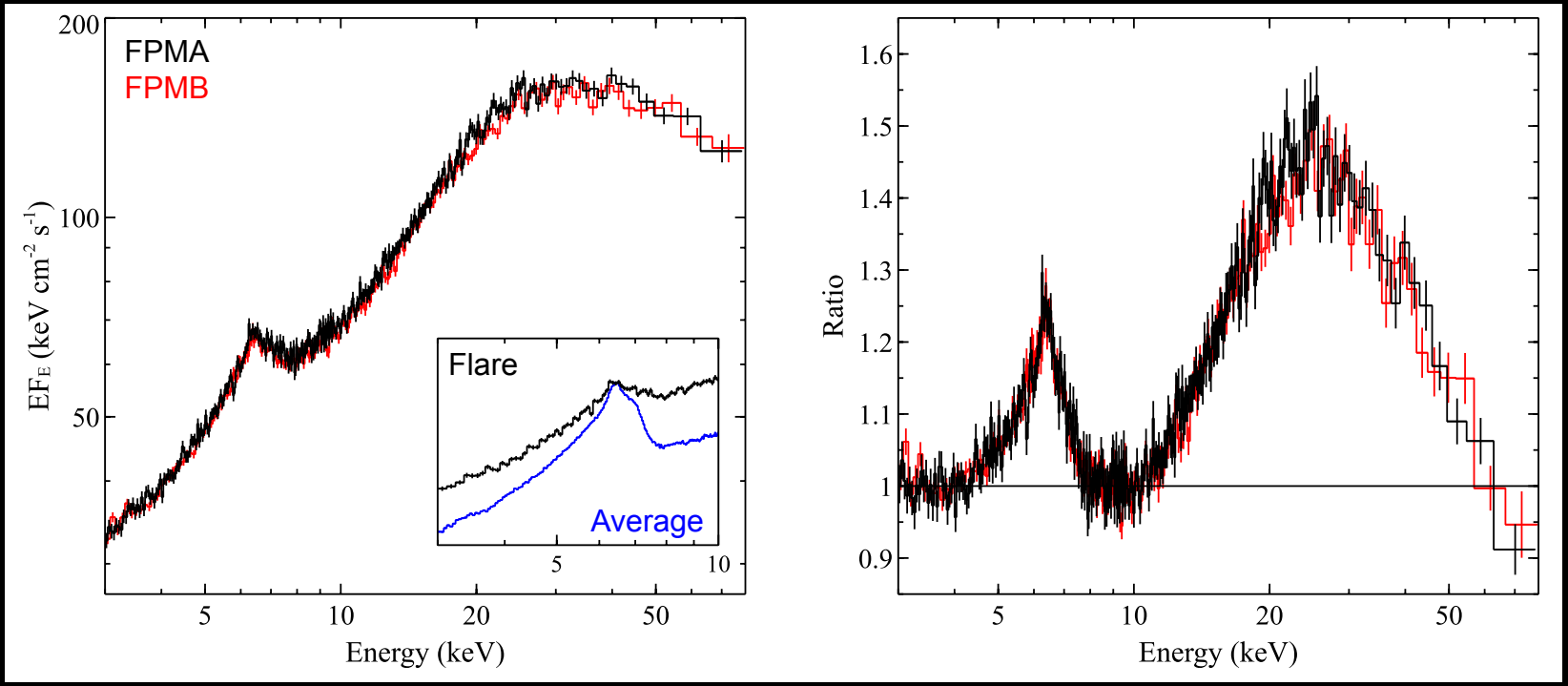
Astonishing flux and spectral variability, incl. flares reaching ~ the Eddington luminosity (labeled 1-6)

Hardness vs Intensity



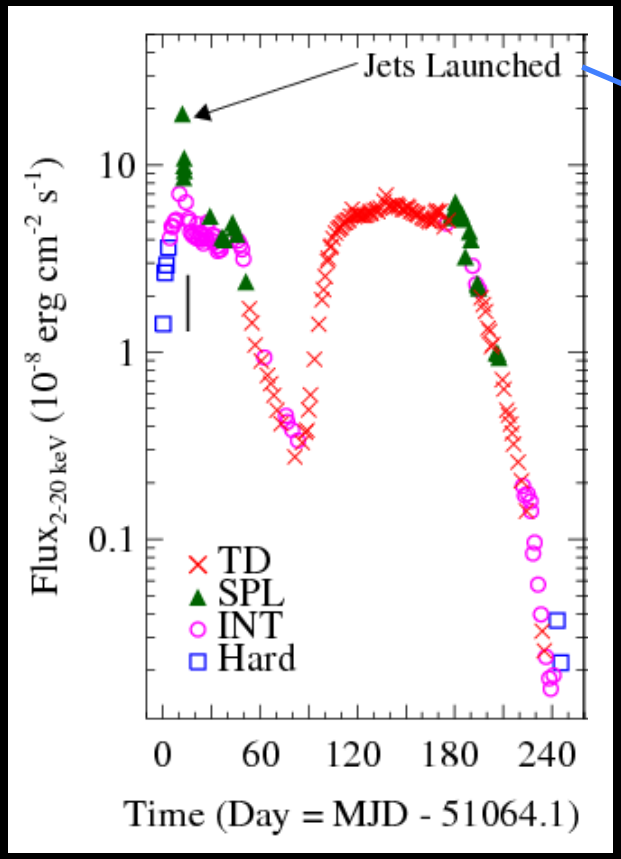
This is a mess!

Average Flare Spectrum



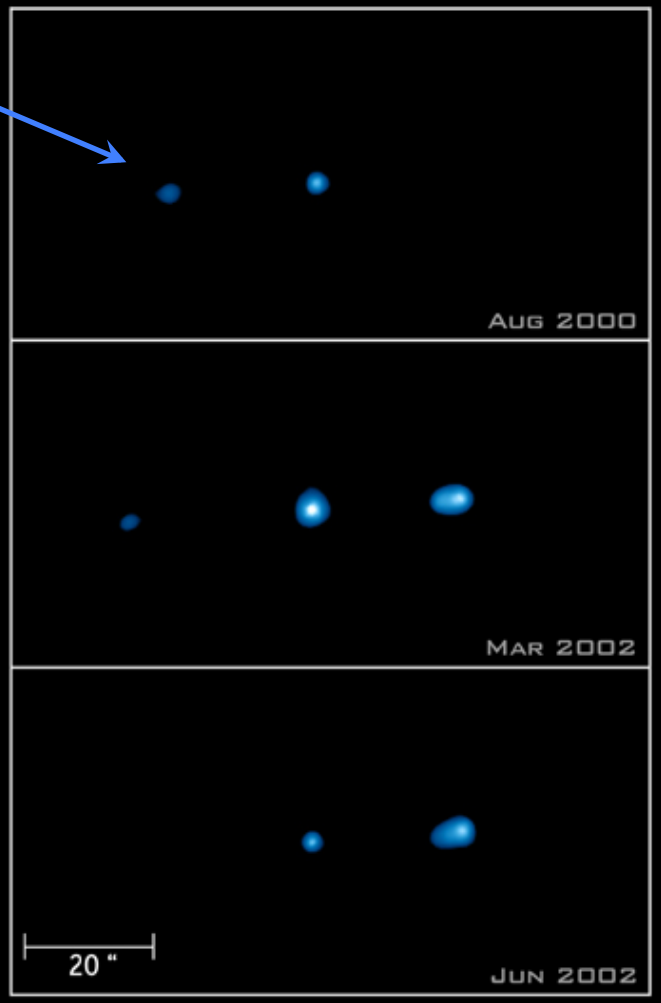
- Average flare spectra shows no absorption, but is much harder than the expectation for an ~Eddington luminosity accretion flow (Γ ~ 1.4)
- These X-ray flares are likely associated with **jet ejection events**
- Clear evidence of reflection from the inner disc

X-ray Flares and Jet Ejections



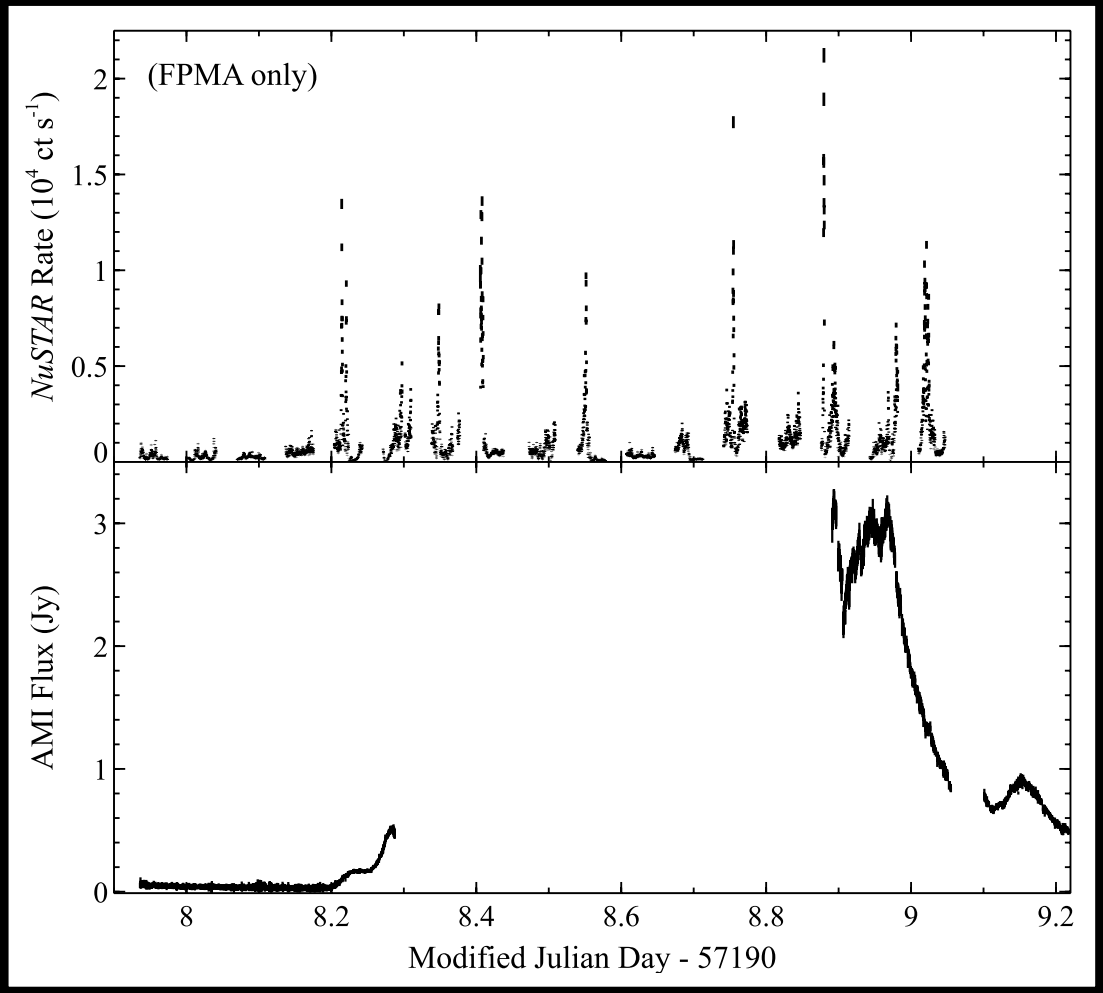
(later)

XTE J1550-564



(Corbel et al. 2002, Kaaret et al. 2003, Steiner et al. 2012)

X-ray vs Radio Emission



Clear radio activity coincident with period of intense X-ray flaring

Variable Source Geometry

- Relative contribution of the disc reflection (R_{disc}) varies with flux

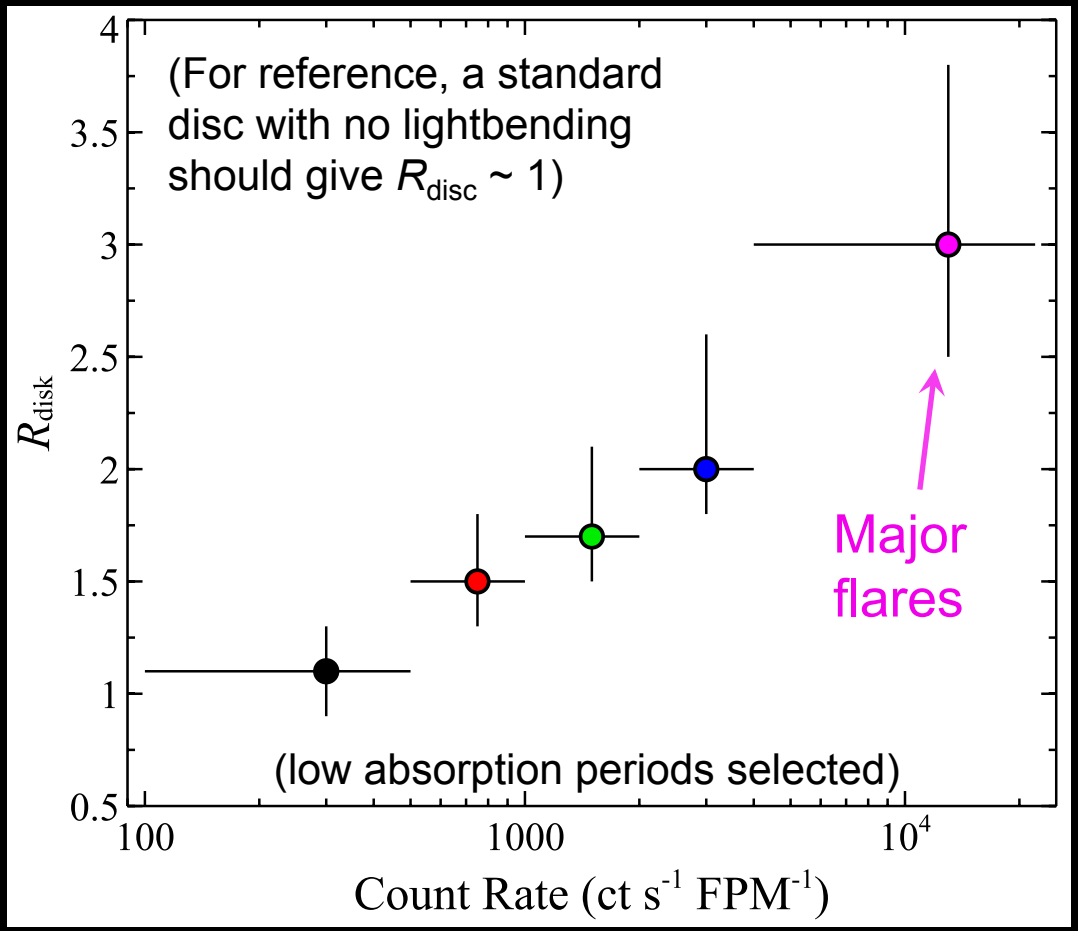
  ↓

  Average source geometry must be variable

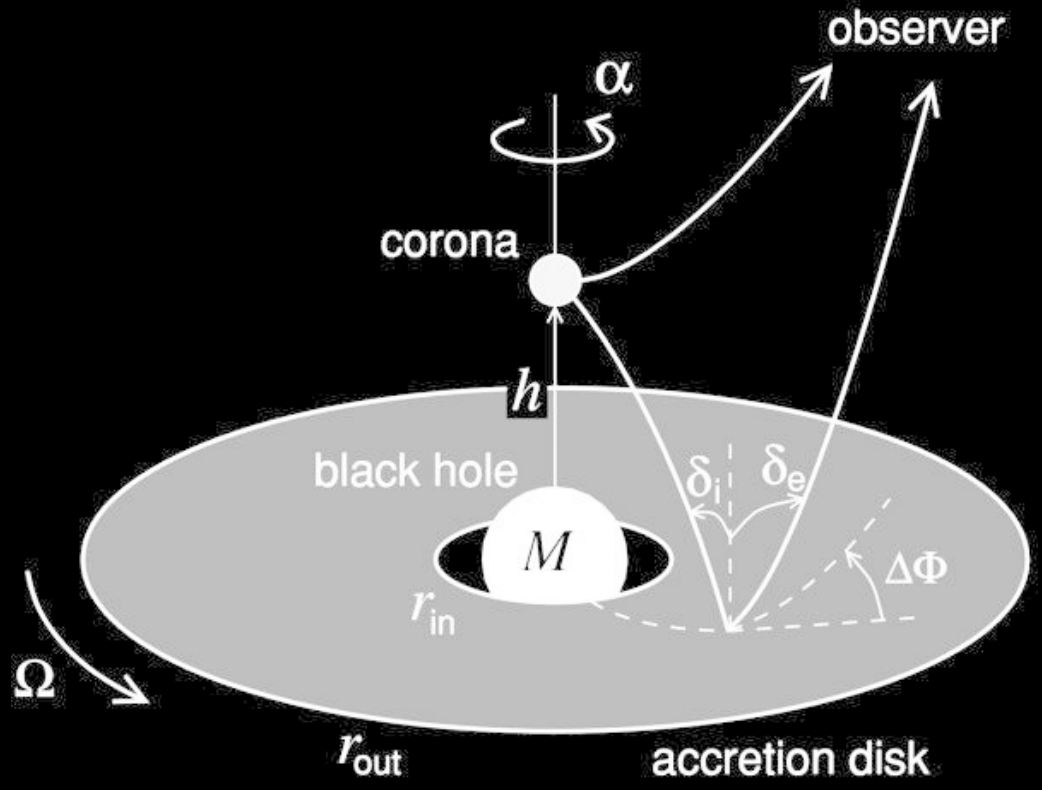
- During the flares, we find that the disc reflection is very strong, R_{disc} ~ 3!

  ↓

  Strong lightbending



‘Lamppost’ Geometry



The trend in R_{disc} could potentially be explained by changes in r_{in} or h (both may even be expected for high-Eddington jet ejections)

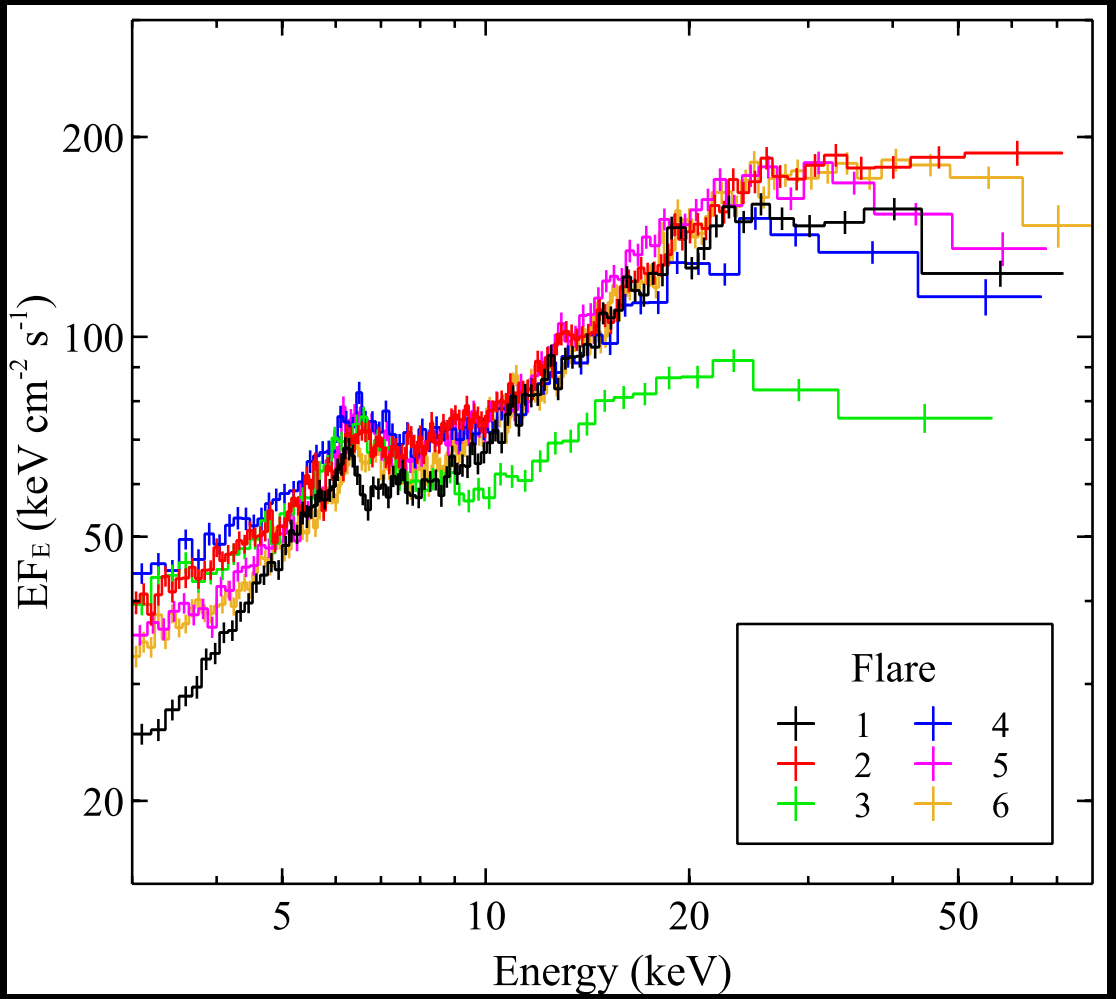
Tested each independently; both scenarios find h <~ 5 R_G for the highest fluxes (major flares)

Individual Flares

Also investigated each of the 6 strongest flares individually:

- X-ray source heights remain compact, all <~ 10 R_G
- BH spin found to be high: $a^* > 0.92$ (99%, statistical)

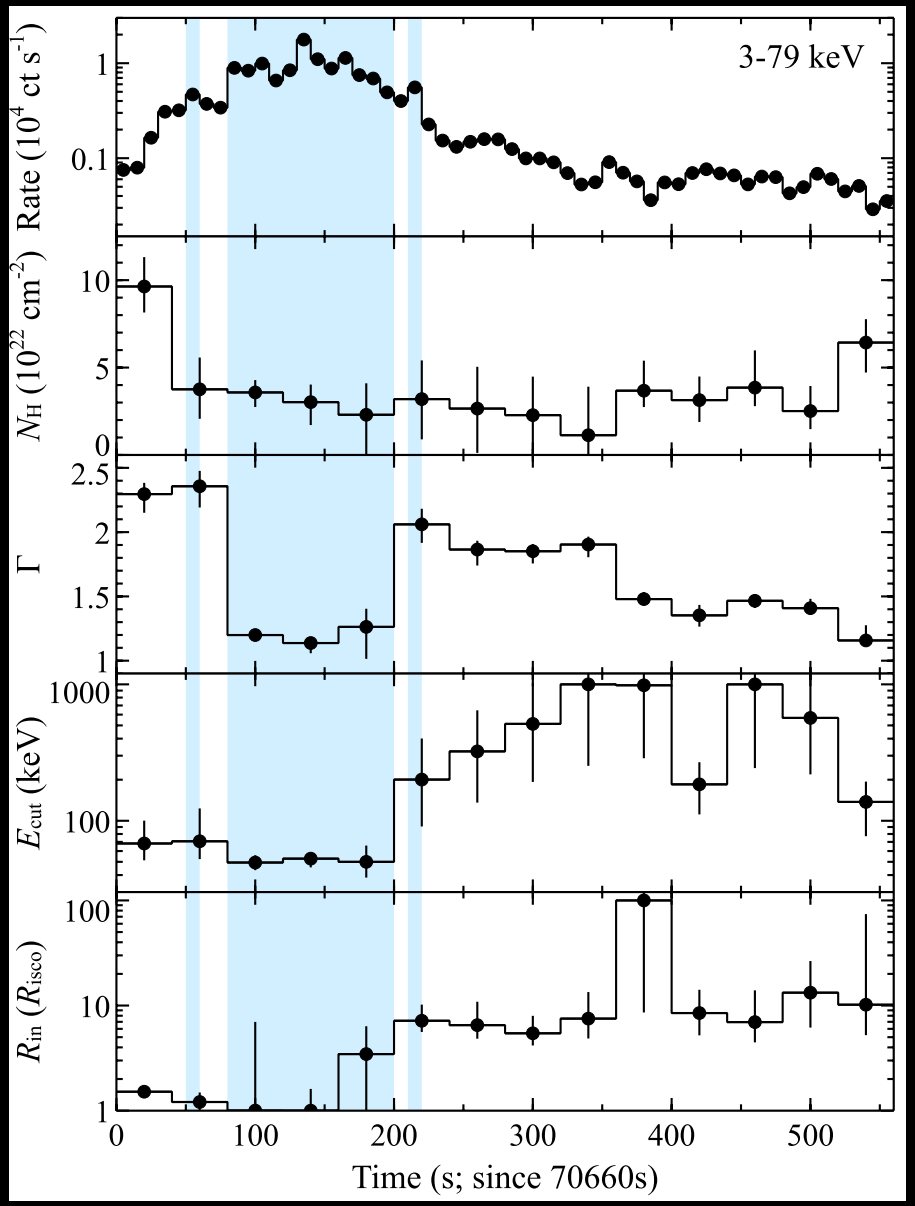
(BH spin: $-1 < a^* < 1$)

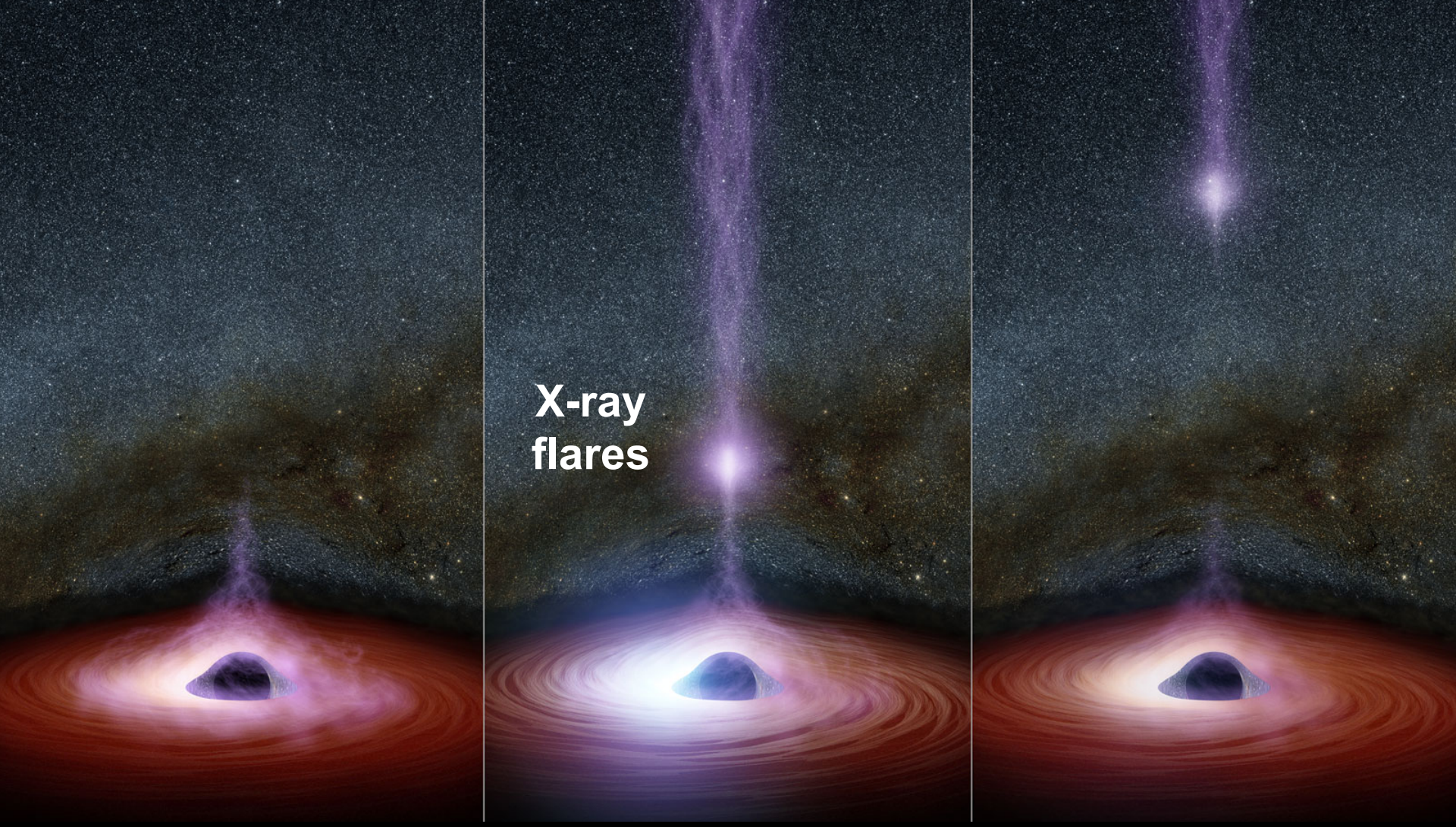


Evolution Across Flare 4

Time-resolved spectroscopy across Flare 4 reveals:

- Sudden change in spectral form at peak flux
- An increase in the max. electron energy across the flare
- A change in system geometry across the flare



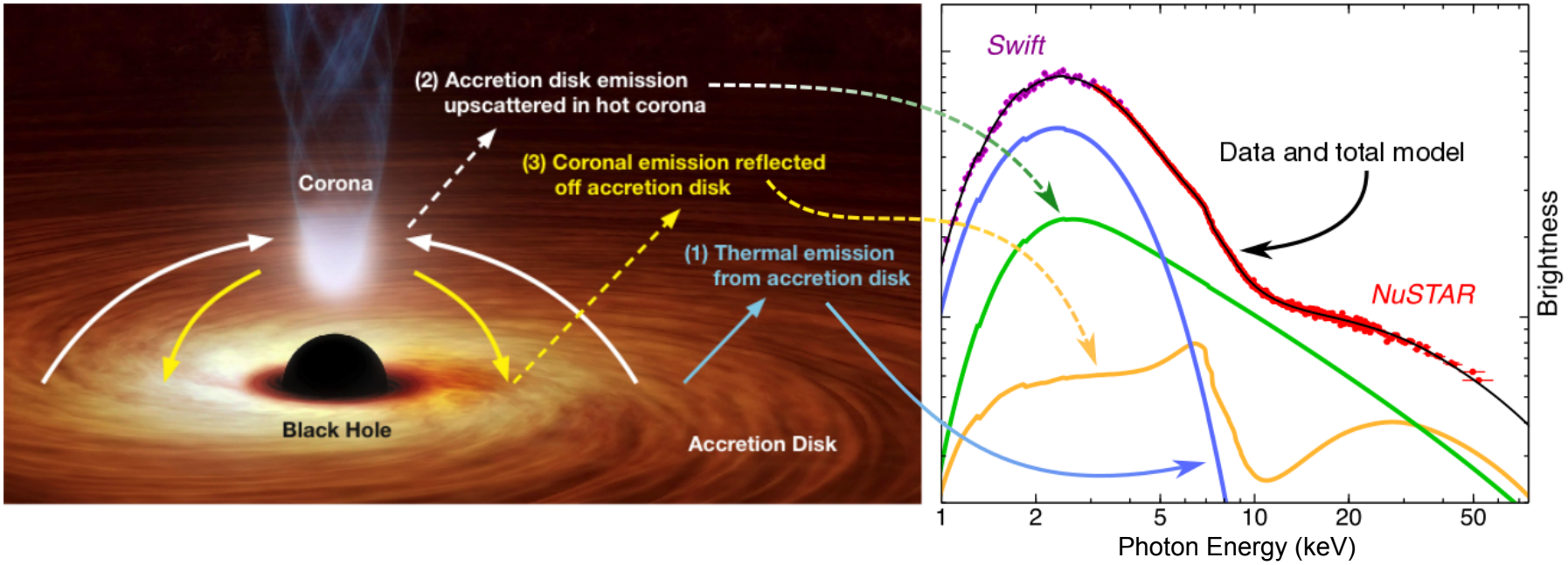


- Major X-ray flares associated with transient jet ejections
- These flares originate from within ~5-10 R_G of the BH
- V404 Cygni hosts a rapidly rotating BH

Supplementary Material

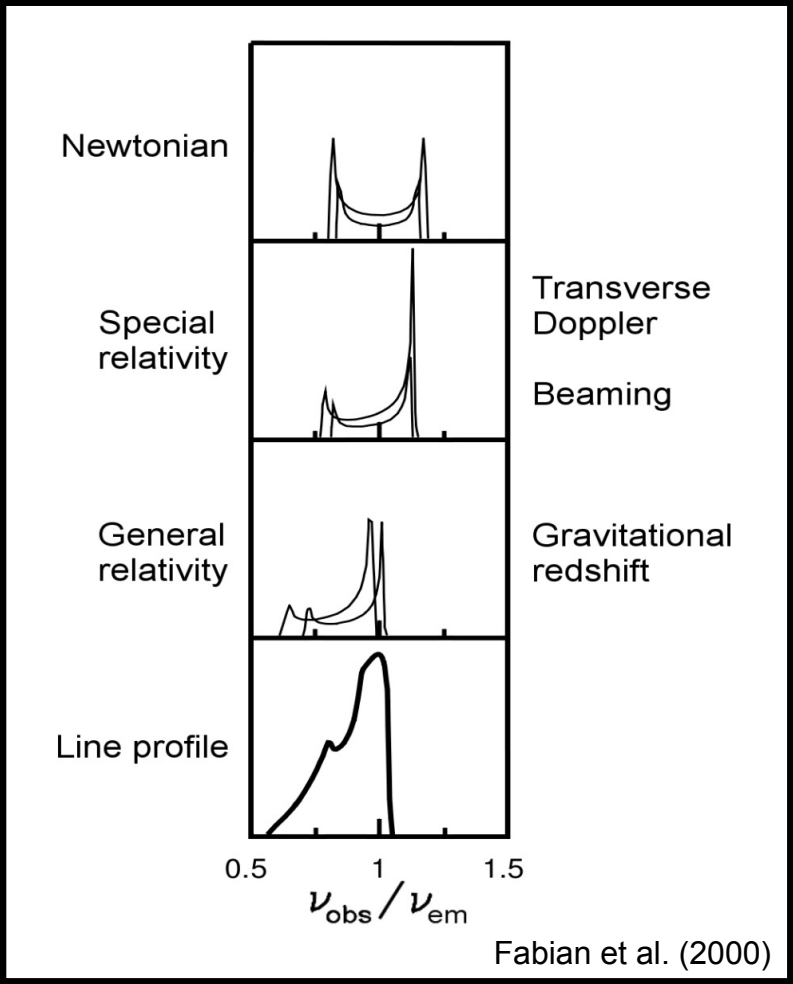
Black Hole Accretion

Basic picture of accretion: ⟶ X-ray spectrum:



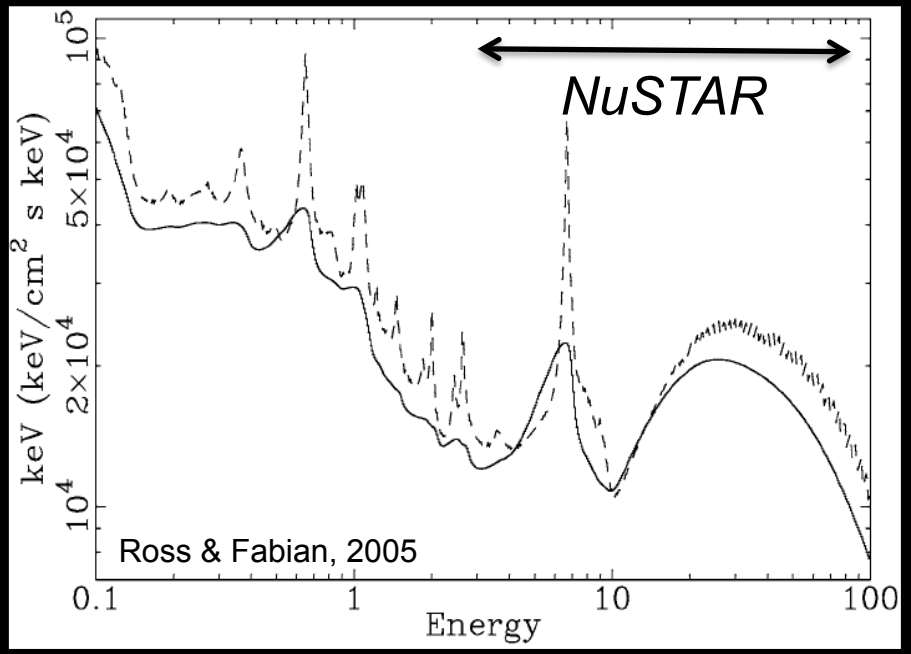
Relativistic reflection carries information regarding the geometry of both the accretion disc (BH spin) and the corona

Relativistic Disc Reflection

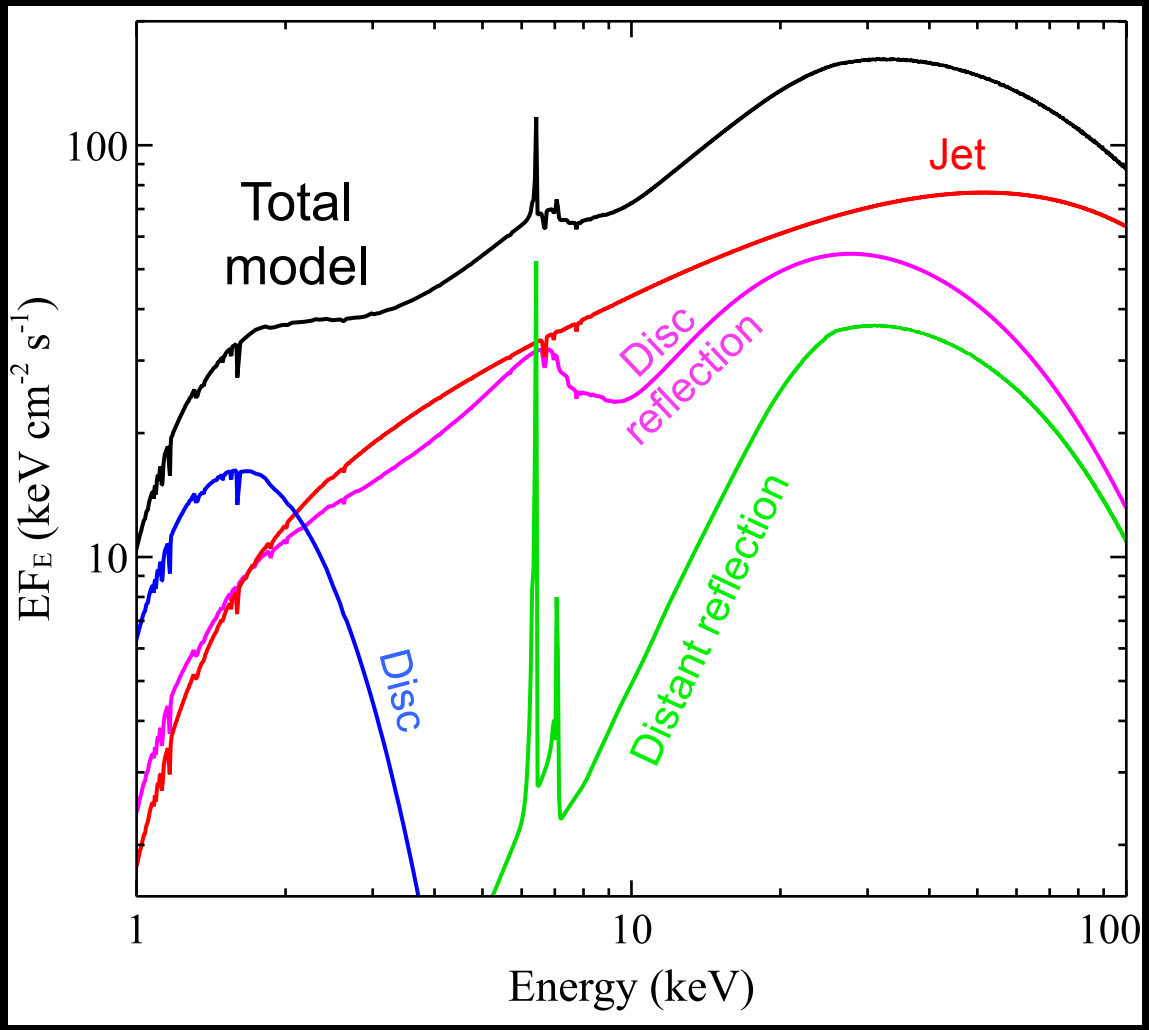


Fabian et al. (2000)

Characterising the disc reflection component is one way in which we can measure black hole spin ***for both binaries and active galaxies***



Spectral Decomposition



Spin Constraints