SCUBA-2 Photometry of X-ray Binary Jets

Dr. Alex Tetarenko
East Asian Observatory
Relativistic Jets Launched From Black Holes

Credit: J. Miller-Jones
Credit: Gallo et al. 2005
Credit: NRAO

Radio galaxy Cen A
Cygnus X-1

6 kpc
6 pc
18 AU

Alex Tetarenko – UH Labs
Black Hole X-ray Binaries

- Black hole accreting matter from a companion star
- Rapidly evolve through bright outburst periods on timescales of days to months
- Emit across the electromagnetic spectrum
Outburst and Jet Behaviour

- High State ($>0.5 \ L_{\text{edd}}$)
- Intermediate States ($\sim 0.3 \ L_{\text{edd}}$)
- Soft State
- Compact Jet
- Jet Ejecta
- Hard State ($<0.1 \ L_{\text{edd}}$)

Alex Tetarenko – UH Labs
Hard State Compact Jets

Flux Density

- Optically Thick
- Spectral Break
- Optically Thin

Sub-mm

Frequency
Broad-band Spectrum

• Originates from superposition of many synchrotron components along jet axis
• Jet properties encoded within exact spectral shape
• Key observables: spectral indices, location of spectral break
Jet Spectral Breaks

- Location evolves as accretion properties change during outburst
- Evolution contrary to simple jet models
- Correlates with X-ray photon index
Jet Spectral Breaks

• Location evolves as accretion properties change during outburst
• Evolution contrary to simple jet models
• Correlates with X-ray photon index
Relativistic Jet Simulations

- Broad-band observations needed to test and guide simulations
- Tie jet dynamics, plasma conditions to the jet spectral break

New solutions in agreement with observed spectral break evolution!

Alex Tetarenko – UH Labs
(Sub)-Millimetre Frequencies

- Fill 2 order of magnitude gap in broad-band spectrum
- Uniquely probe jet emission close to compact object
- Need rapid response ToOs to obtain data of X-ray binaries.

Alex Tetarenko – UH Labs
Target Source: V404 Cygni

- Prolonged quiescent period of 26 yrs.
- Well determined system parameters
- Low optical extinction
- Parallax distance

P$_{\text{orb}}$ = 6.5 days

\( d = 2.39 \pm 0.14 \) kpc

M$_{\text{BH}}$ = 7.15 $\pm$ 0.35 M$_\odot$

i = 60-80 degrees

E(B-V) = 0.1

Credit: R. Hynes

Alex Tetarenko – UH Labs
Lab Procedure

- Reduce a JCMT SCUBA-2 observation of V404 Cygni during the decay of its 2015 outburst.
- Combine your SCUBA-2 sub-mm measurement with other simultaneous multi-wavelength data to build a broad-band spectrum.
- Fit different emission models to your spectrum to deduce jet properties.
Additional Notes

• Follow the detailed procedure in the lab writeup for reducing your data.
• You will NEED to FIRST download the data!
• You will NEED to have the Starlink software installed on your machine.
• This lab involves some coding, don’t freak out if you haven’t done any coding before!
• All coding and analysis should be done in the jupyter notebook provided.
What do you need to hand in?

• Please email me your lab writeup and jupyter notebook
• Please use the subject line: UH Labs XRB Spectrum – [NAME]
• My email is: a.tetarenko@eaobservatory.org
• Questions? – Email me!

Thanks!

Alex Tetarenko – UH Labs