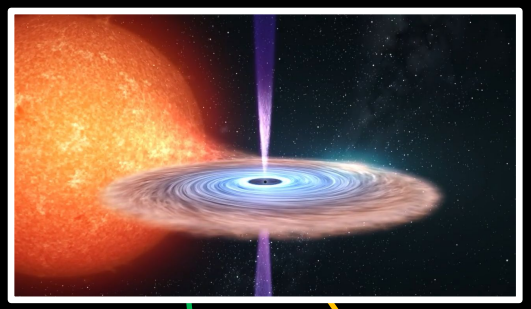
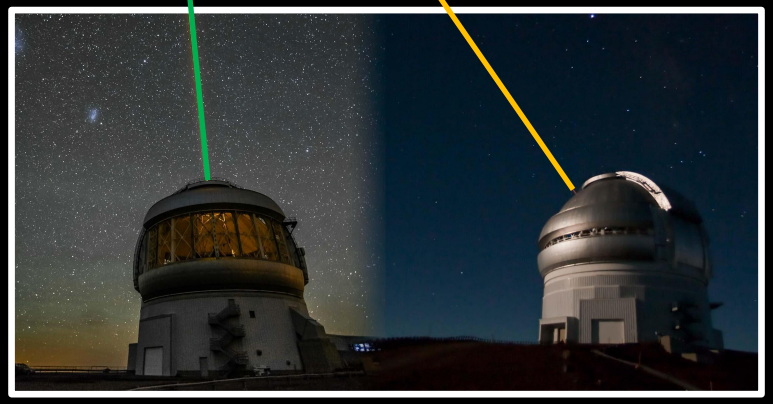
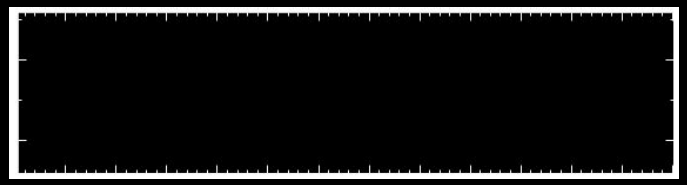
Optical Fast Timing of X-ray Binaries with Gemini's `Alopeke and Zorro







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Eli Pattie, Tom Maccarone (Texas Tech), Federico Vincentelli (IAC), and PG Casella (INAF)

With special thanks to Ricardo Salinas, Zach Hartman, and Steve Howell

ALOPEKE • ZORRO

NHFP

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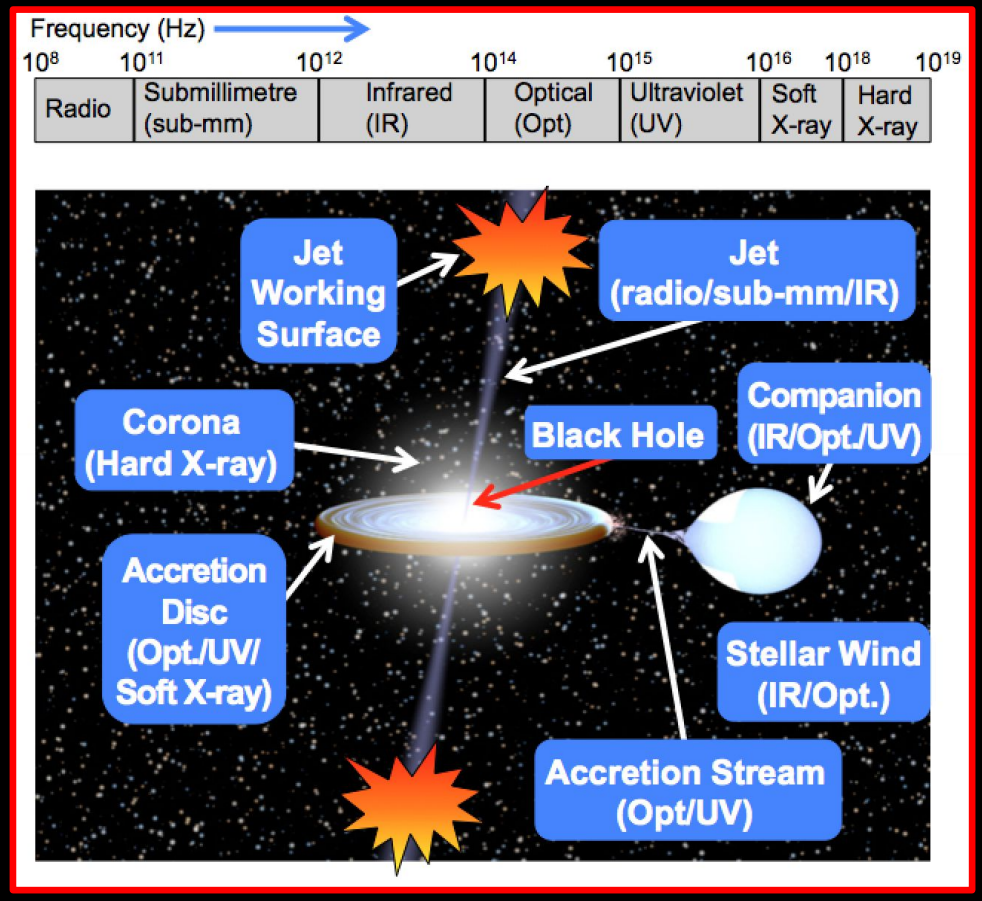
Black Hole X-ray Binaries



- 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

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Multi-wavelength Fast Timing of X-ray Binaries

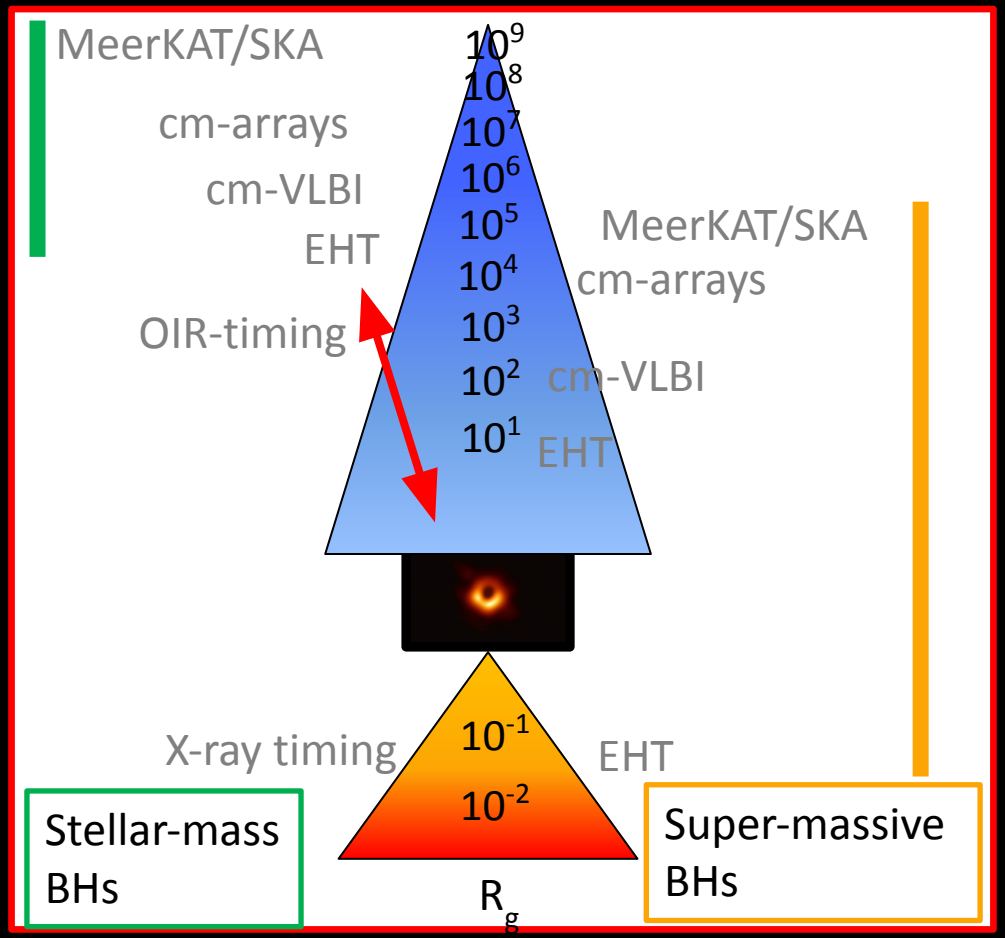

Image Credit:
Rob Fender

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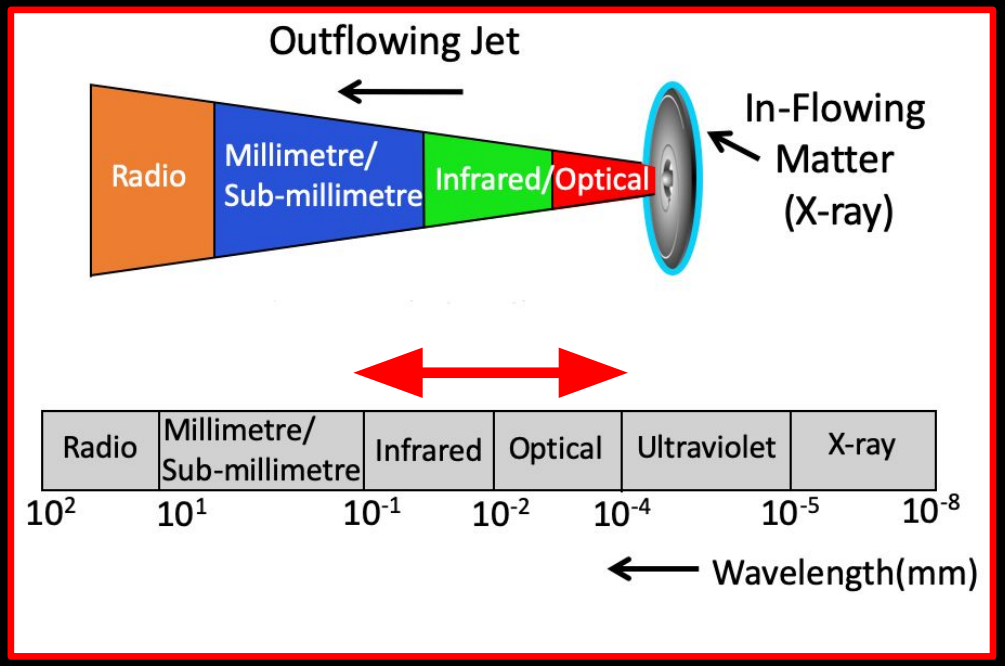
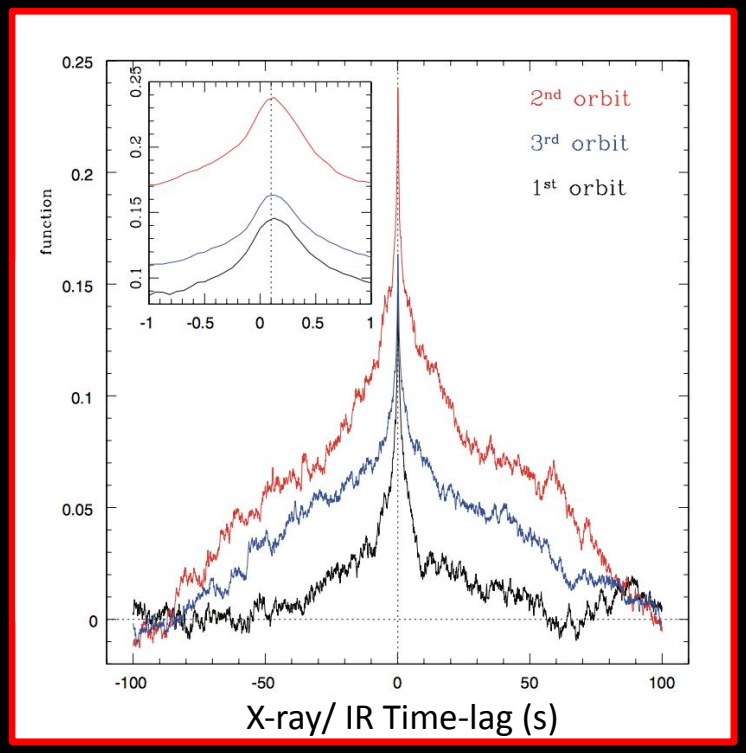
What can we learn from multi-wavelength variability studies?

- Map out the jet size scale.
- Probe jet geometry, beyond what we can accomplish with VLBI.
- Measure jet speed, energetics, B-Field.
- Probe the connection between the accretion flow and the jet.

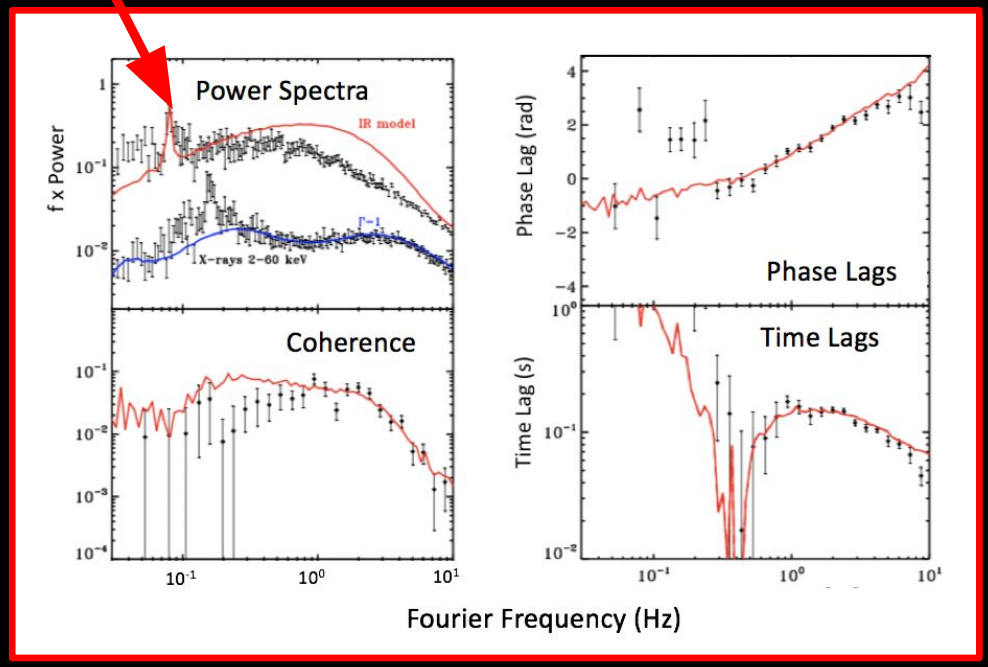


OIR Variability Studies in X-ray Binaries



Casella et al. 2010

Quasi-periodic Oscillation (QPO)



Malzac et al. 2018

<u>Timing Metrics Cheat Sheet</u>

Power Spectra – Amplitude of variability on different timescales.

Lags – Delays between intensity fluctuations.

Coherence – How correlated are our signals?

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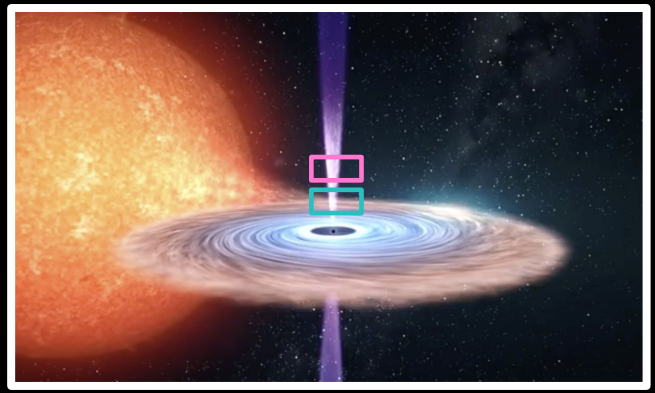
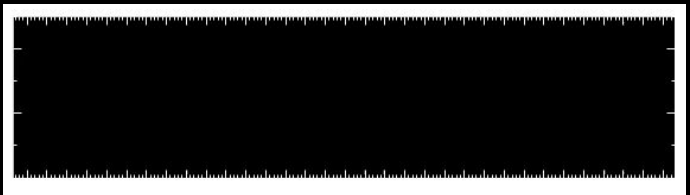
Gemini's `Alopeke and Zorro

- Tens of ms time resolution in two simultaneous filters.
- 60 arcsec FOV in wide-field mode.
- `Alopeke on North, Zorro on South for full sky coverage.
- Rapid ToO response and coordination with multi-wavelength facilities.



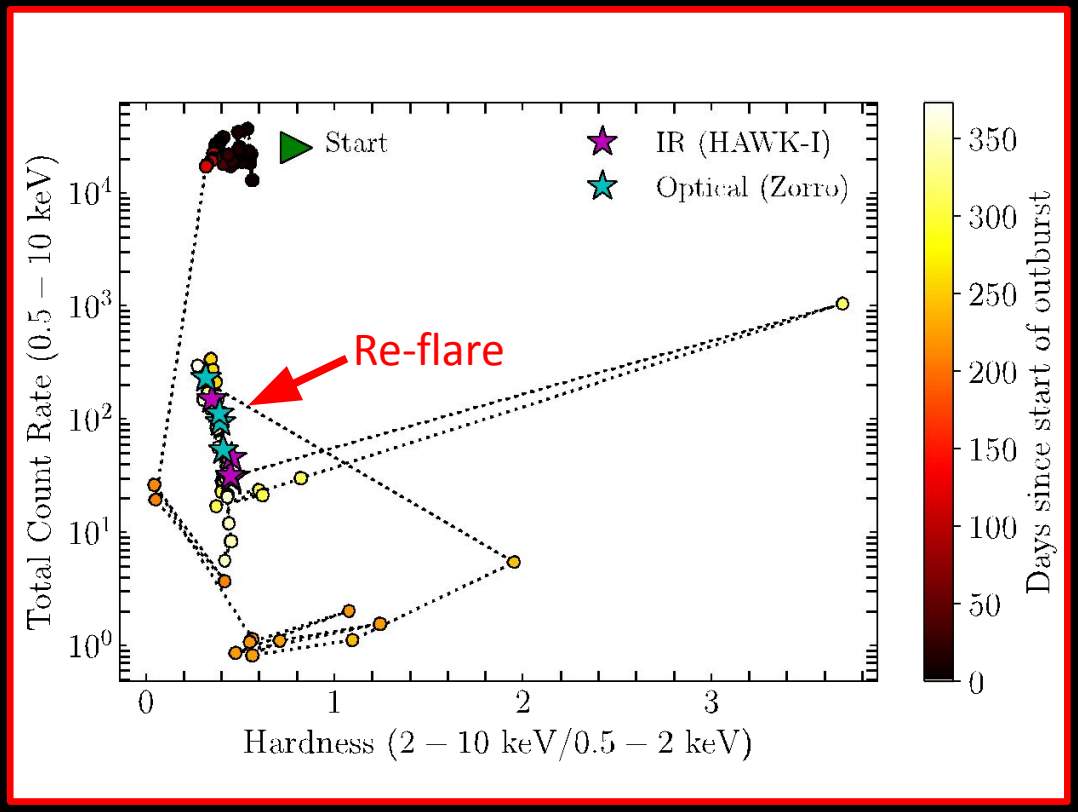


4U 1543-47

Eli Pattie

Timeline

- First outburst in 17 years detected in Jun 2021.
- Outburst fading in Jan 2022.
- Re-flare in Feb 2022.
- Our observations in March 2022.



Tetarenko et al., in prep

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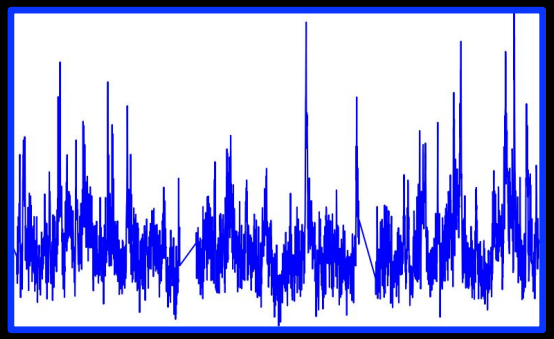
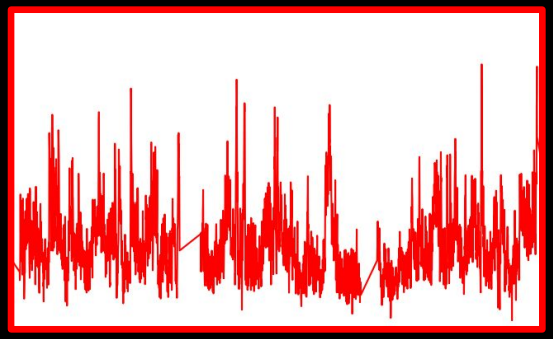
4U 1543-47 - Zorro

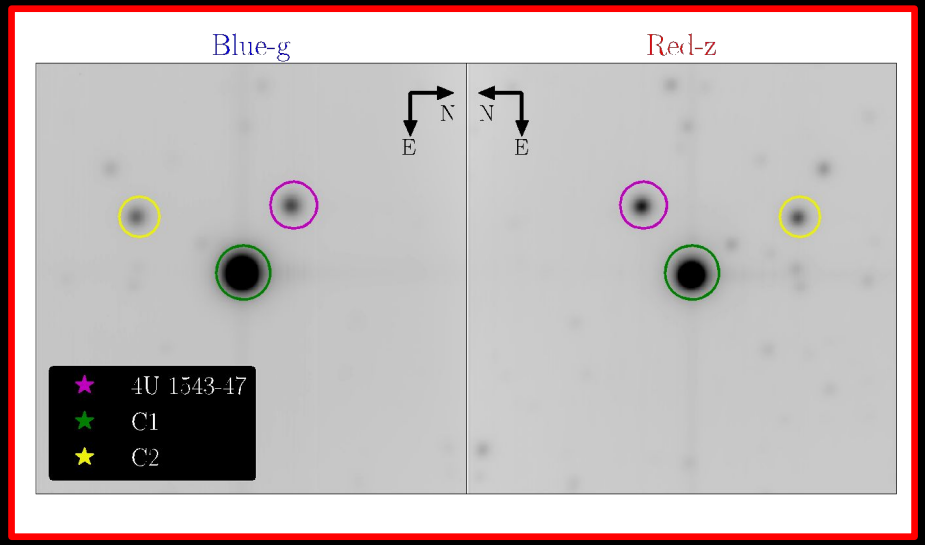
g-band (479 nm)





z-band (947 nm)

Rapid flaring clearly observed!



Tetarenko et al., in prep

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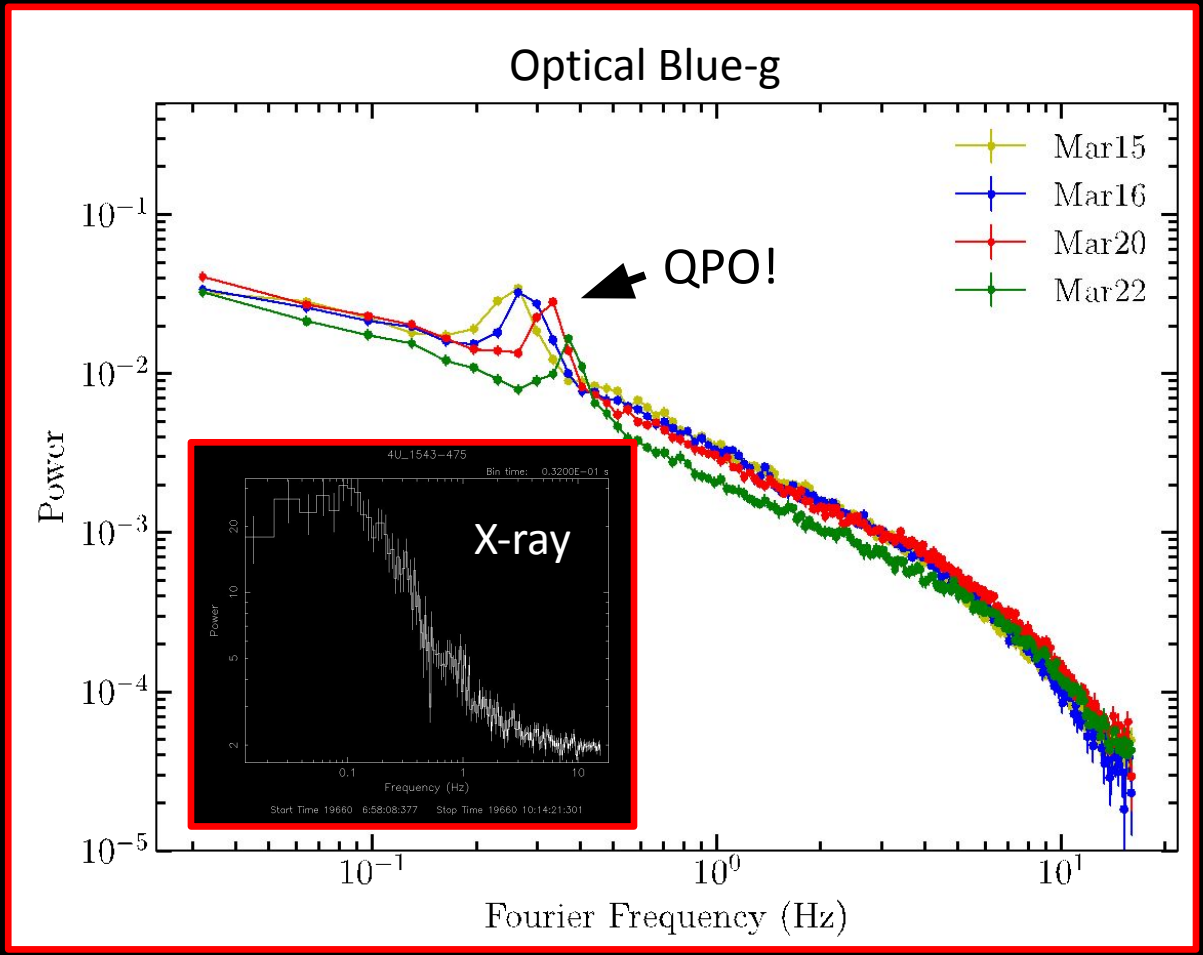
Fourier Power Spectra



- Evolving optical quasi-periodic oscillation (QPO)!
- Also see an IR QPO at frequencies ~factor of 2 lower.
- No significant QPO feature in X-ray.

Tetarenko et al., in prep

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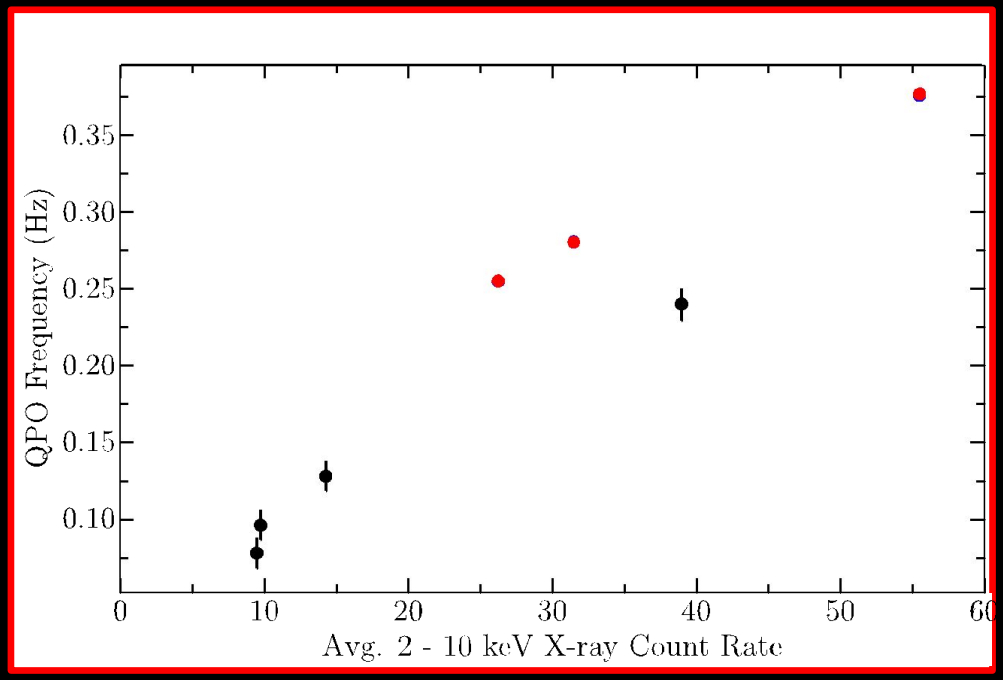
A closer look at the QPO



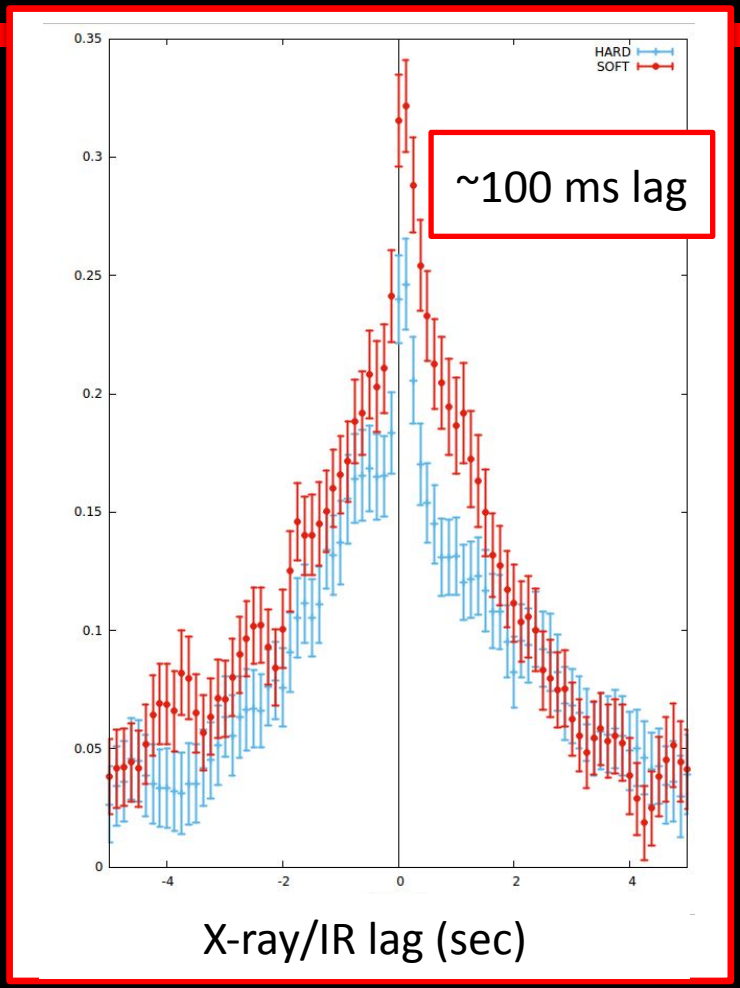
Tetarenko et al., in prep

- Two scenarios for multi-band QPO:
  - Observing different harmonics in different bands.
  - QPO is evolving with time.

How is the variability connected?

- Is the emission correlated?
  - Red and blue optical ✅
  - X-ray and IR ✅
  - X-ray and optical ❌

Vincentelli et al., in prep



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Conditions in the Jet/Accretion Flow

- Precessing jet (OIR) driven by precessing inner accretion flow (X-ray).
- Why no X-ray QPO?
  - Obscured accretion flow.
  - Low inclination source.
  - Low S/N.

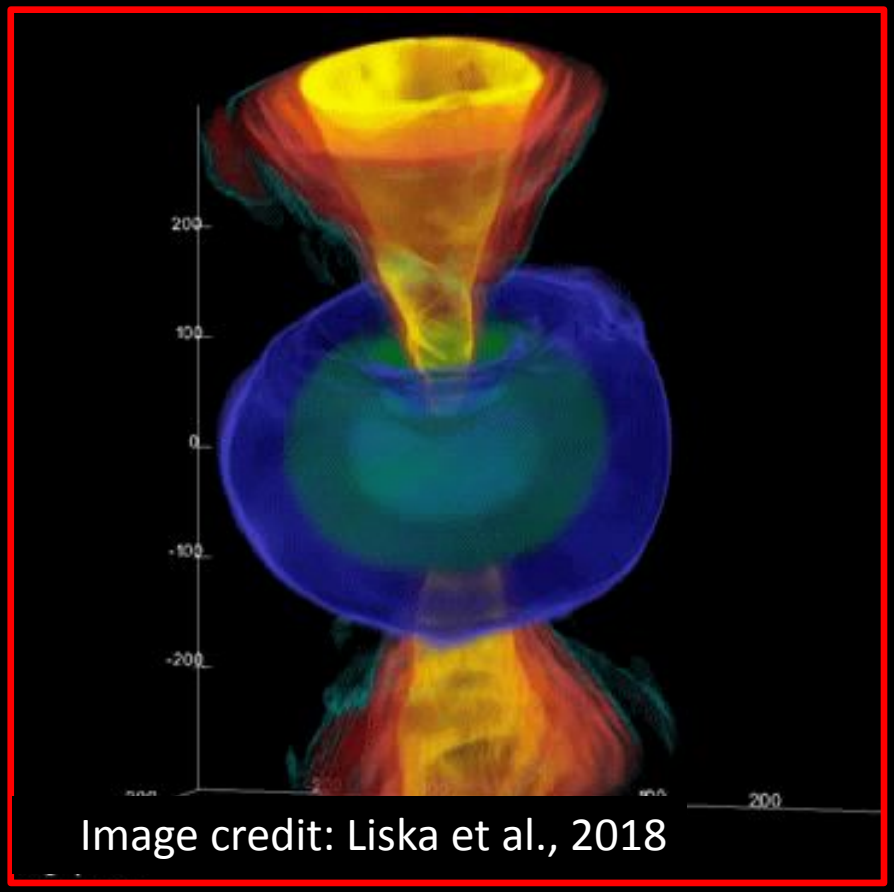

Image credit: Liska et al., 2018

Summary

- Multi-wavelength spectral-timing is an incredibly powerful tool for unlocking complicated jet and accretion physics.
- We need a suite of fast timing capable facilities to take full advantage of the time-domain.
- Gemini's `Alopeke/Zorro offer an exciting new option in the optical.

Thank you!

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