Variability in Quiescent Black Holes

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Black Hole X-ray Transients (BHXRTs)

- Companion star
- Accretion stream
- Black hole
- Accretion disc

R. Hynes 2002
Optical Flaring

Some (all?) quiescent BHXRTs flare in optical

Origin unknown:
- Companion star?
- Stream (impact)?
- Outer disc?
- Advective flow?

Can probe structure of accretion flow?

Data from Haswell, 1992, PhD Thesis
A0620-00, December 1987
A Variability Census


Several arguments against variability from companion star (see Zurita et al. 2003)

Simplest is that variability correlates with disc contribution to spectrum

High flaring activity only in sources with large disc veiling

So variability is from some part of disc

Individual Flares in A0620-00

Profiles resolved. On average symmetric
Rise times as short as 15s

Clues From Power Density Spectra I

- In outburst can use power spectrum to classify states
  - High/soft: Low amplitude red noise
  - Low/hard: High amplitude band limited noise
- What is power spectrum of quiescent state?

- Quiescent optical power spectrum is band limited noise!
- Looks like frequency shifted low/hard state, e.g. XTE J1118+480
Models for low/hard state similar to quiescence

Evaporated inner region, but smaller

In XTE J1118+480 we measure $r_{in} \sim 350 \ R_{sch}$ (Chaty et al. submitted)

Does break frequency scale with size of region?

If so, $r_{in} \sim 10^4 \ R_{sch}$ in A0620-00 in quiescence

Similar to assumptions of advective models!

But scaling may not be so simple...
Clues From Optical Emission Lines

- Are line flares correlated with continuum?
- Can use emission line kinematics to locate variability
  - Companion star, stream impact point - narrow line moving over orbit
- Magnetic reconnection in disc - narrow line at random velocity
- Advective region - no direct line emission
- Could be indirect emission from whole disc - broad, double peaked line
Optical Variability in V404 Cyg

- **V404 Cyg** is ideal:
  - Bright
  - Strong variability on long timescales
- Observed WHT, July 1999
- Large flares, line + continuum correlated
- Line amplitude much larger, up to x2
- Weak flickering as well

Line Profiles

- Flares are spread across whole profile
- Difference profile is double peaked
  ⇒ whole disc participates
- Photoionised by X-ray source?
If we are right there is clear prediction: X-ray variability should be correlated with lines.

Is this true?

X-rays are extremely variable

E.g. ROSAT showed up to x10 changes in <0.5 days (Wagner et al. 1994)

SAX data also shows large variability

Source too faint for detailed study with these facilities...

X-rays do vary with similar amplitude and timescale as Hα

Simultaneous observations are obvious next step

Based on Hynes et al. (2002) and Kong et al. (2002)
Flare Energetics

- Quiescent black holes are faint X-ray sources
- Is photoionisation scenario energetically possible?
  - Hα luminosity \( \sim 1.4 \times 10^{32} \text{ erg s}^{-1} \)
  - Ionising luminosity \( \sim 10^{34} \text{ erg s}^{-1} \)
  - Assume <30% of incident flux reprocessed to Hα
    ⇒ Require >5% of ionising flux to fall on disc
- Possible, but constrains models
Comparison with Models

- Intercepting 5% is hard with point source (e.g. original ADAF)
- Much easier with extended emission (e.g. CDAF)
- Many uncertainties...
- But testable prediction - given any advective model, can predict ionising flux incident on disc + observable X-ray flux
What do we Know?

- Most or all BHXRTs are variable in quiescence
- Variability in X-rays, optical continuum, lines, (radio)
- Associated with disc (but is origin in outer or inner region?)
- Rapid events present
- Band-limited noise (i.e. broken power-law power spectrum)?
Future Work

Future Work

- Simultaneous observations are obvious next step
- Measure $H\alpha$ to X-ray ratio in flares $\Rightarrow$ test models
- We have 60ks Chandra + 5 orbits HST ACS
- Also get WHT+HET+MMT+Gemini $\Rightarrow$ 60ks continuous spectroscopy!
- Radio also known to vary...
- Also need more photometry to better define power spectra and search for break
- Brighter sources allow detailed study of individual flares, e.g. rise times, asymmetry...
- Look at optical continuum spectrum of flares