Variability in Quiescent Black Holes

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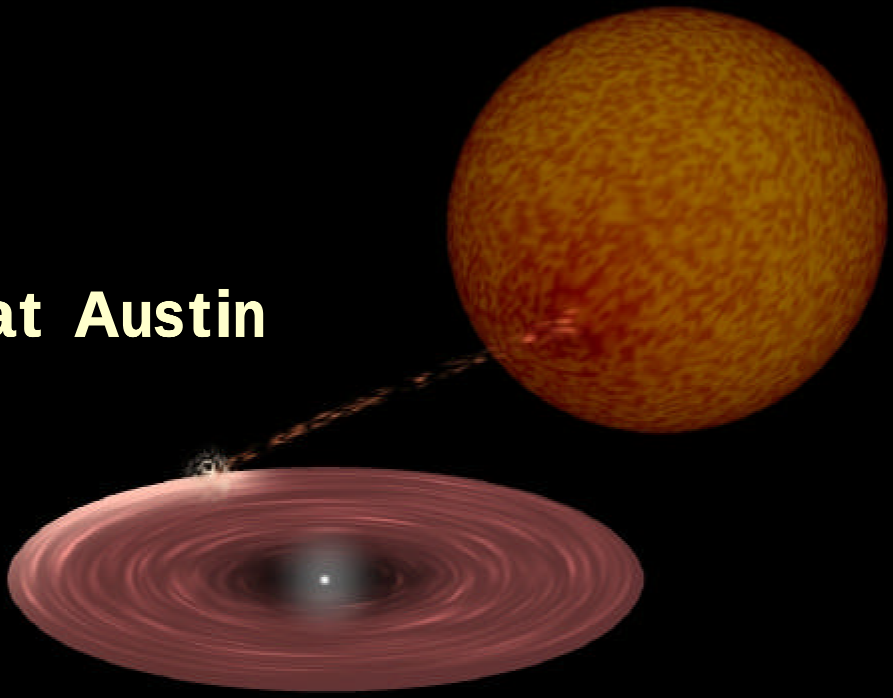
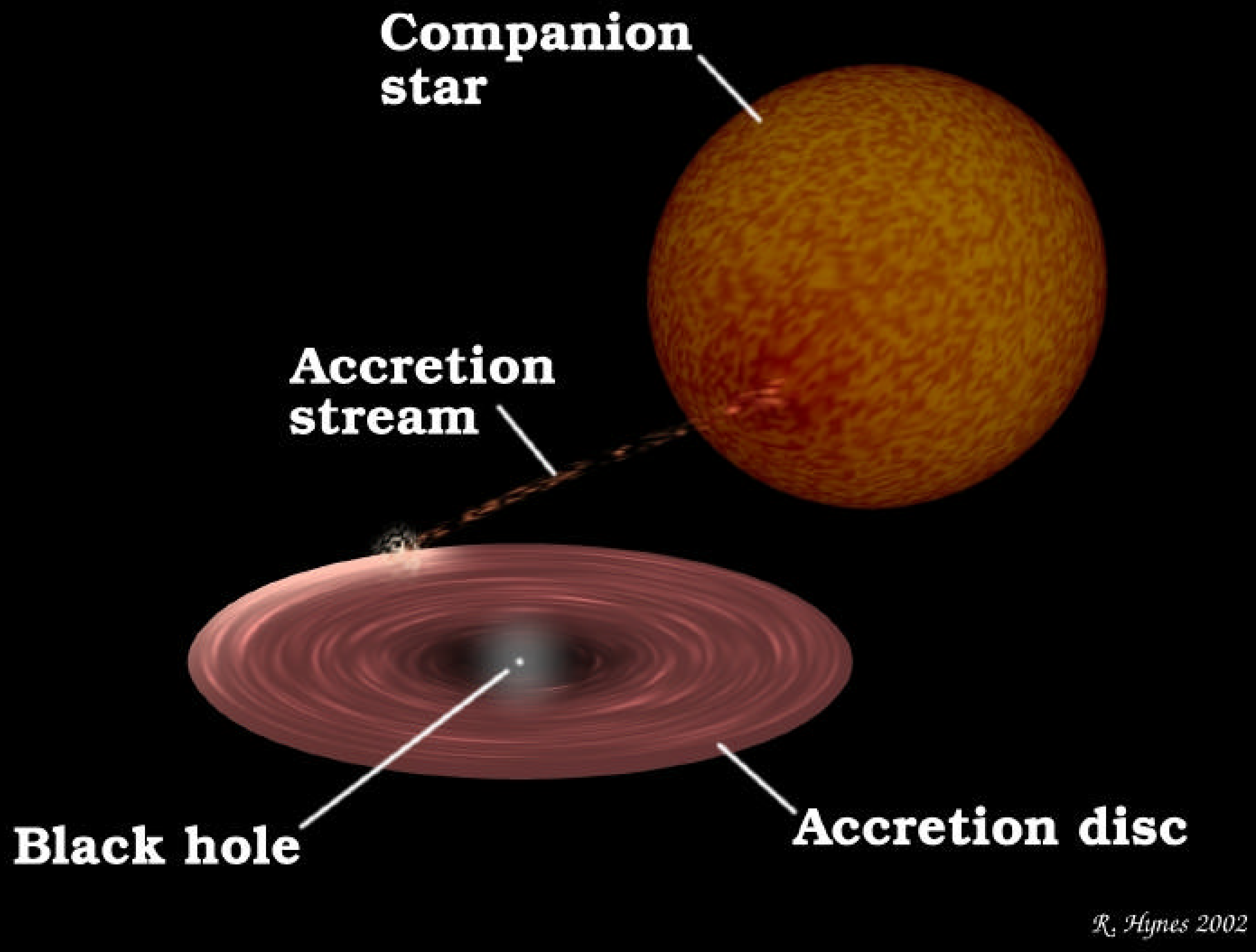


With Jorge Casares, Phil Charles, Rob Fender, Mike Garcia, Carole Haswell, Albert Kong, Jeff McClintock, Elena Pavlenko, Rob Robinson, Tariq Shahbaz, Cristina Zurita and others…

Outline

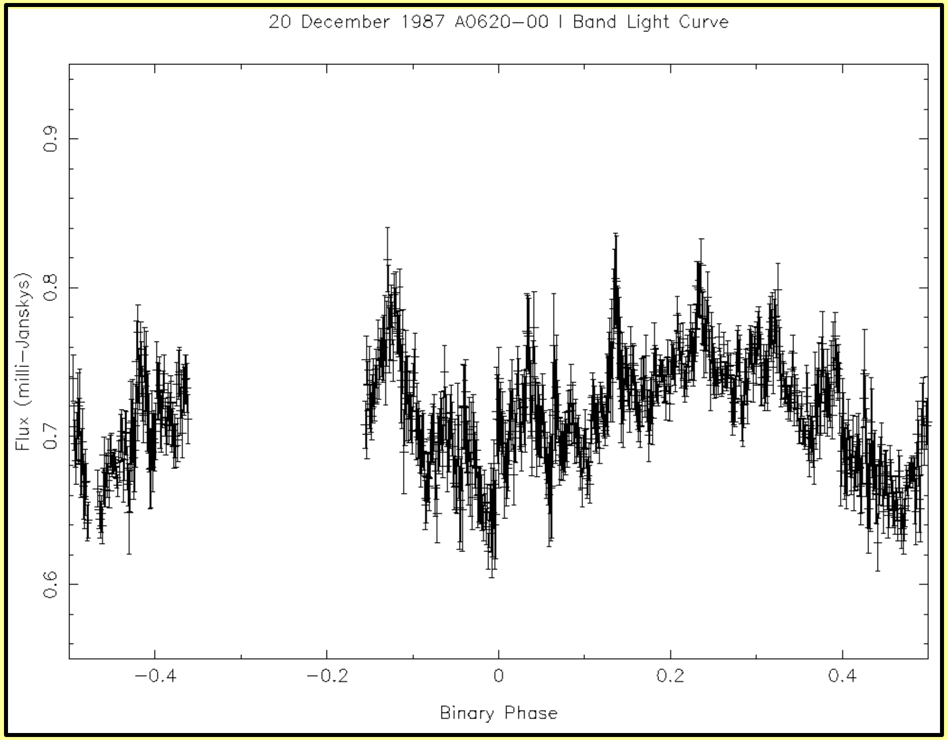
1. Optical photometry
2. Optical spectroscopy
3. X-ray observations
4. Putting it all together

Black Hole X-ray Transients (BHXRTs)



Optical Flaring

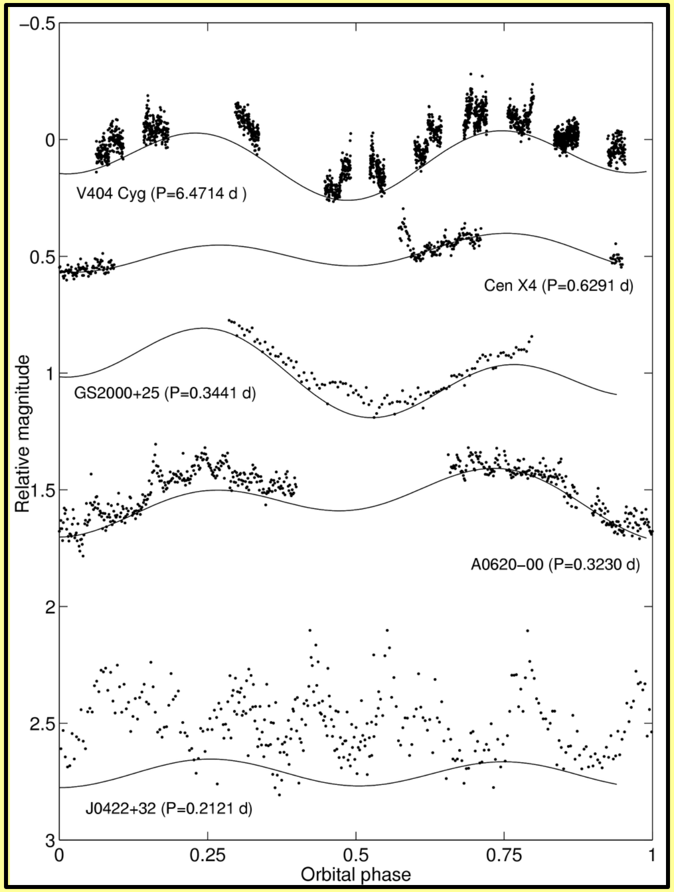
- **Some (all?) quiescent BHXRTs flare in optical**
- **Origin unknown:**
  - **Companion star?**
  - **Stream (impact)?**
  - **Outer disc?**
  - **Advective flow?**
- **Can probe structure of accretion flow?**



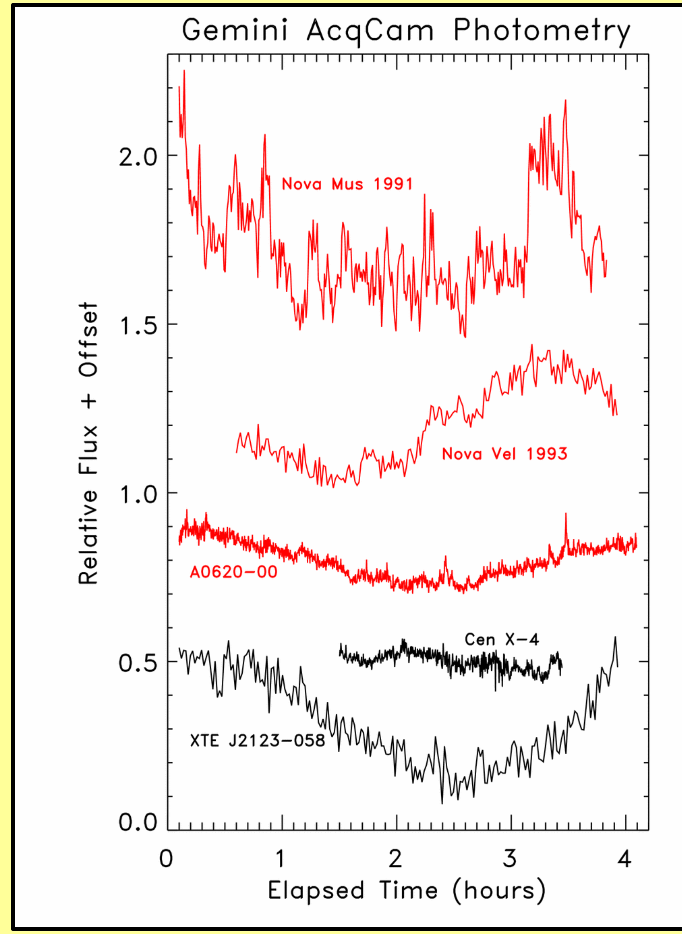
Data from Haswell, 1992, PhD Thesis

A0620-00, December 1987

A Variability Census



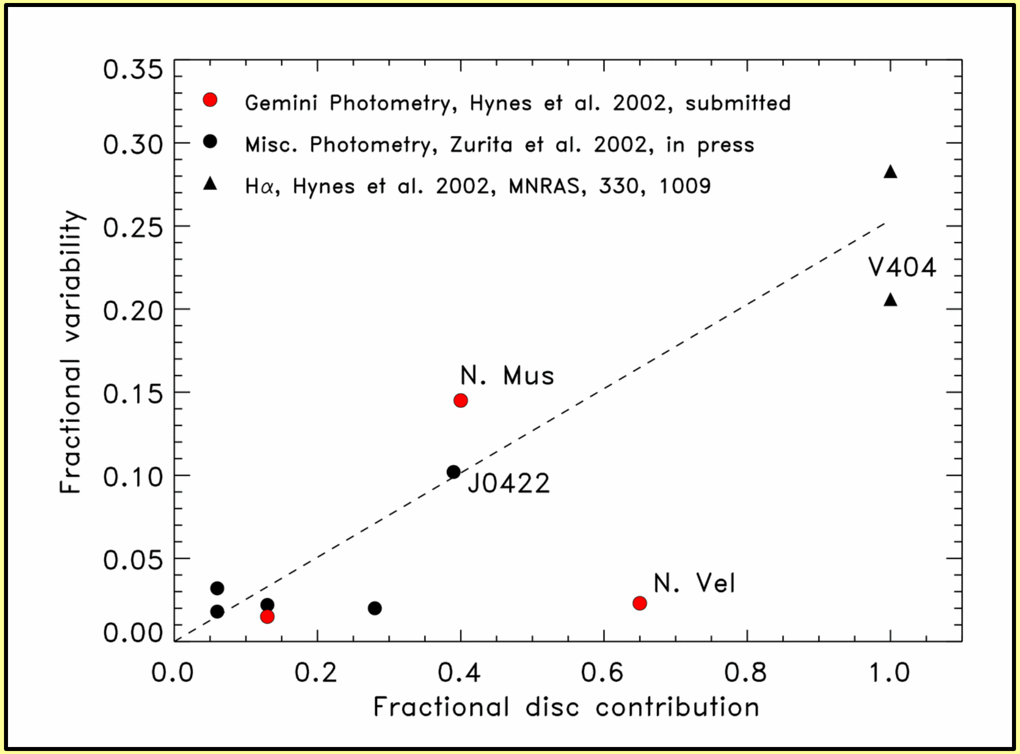
From Zurita, Casares & Shahbaz, 2003, ApJ, 582, 369



See Hynes et al., 2003, MNRAS, in press

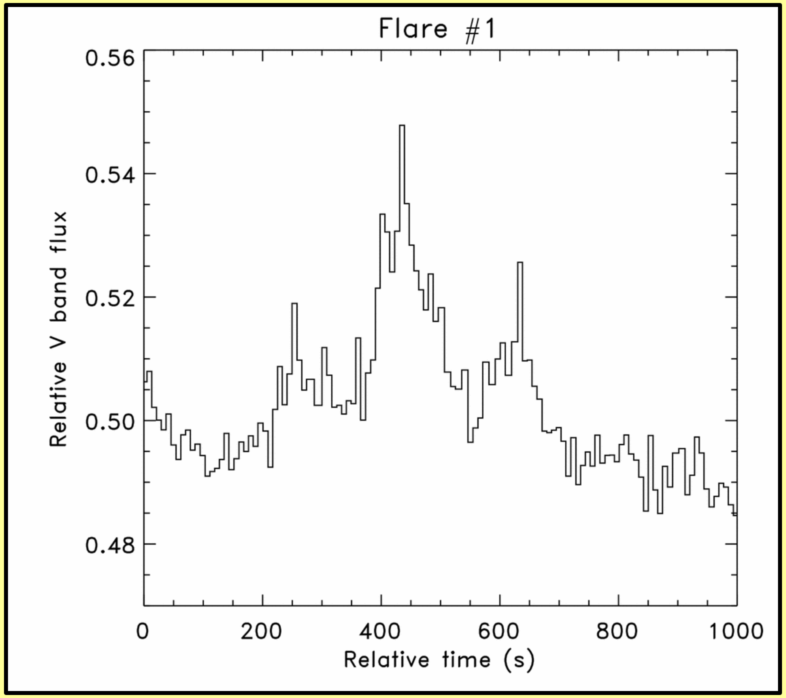
Disc Variability?

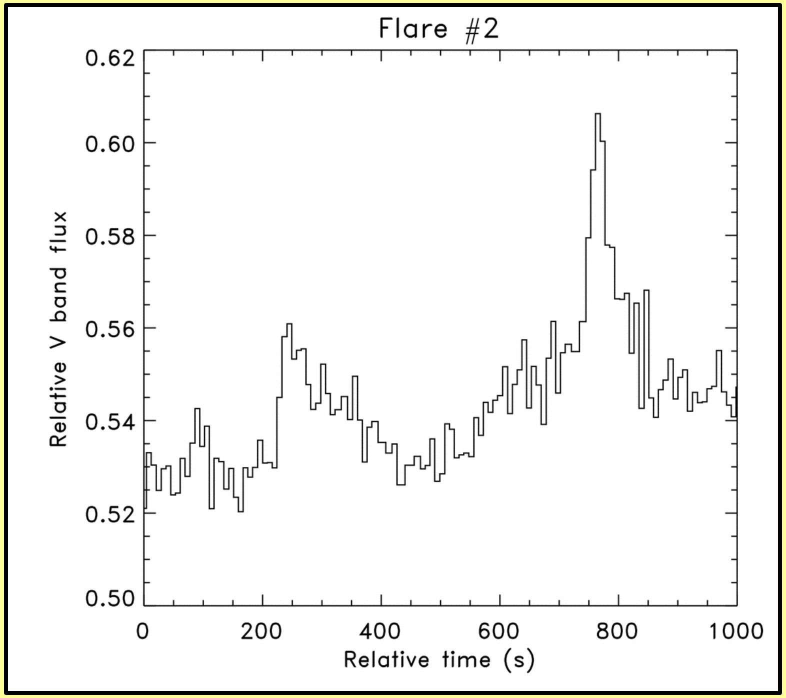
- **Several arguments against variability from companion star (see Zurita et al. 2003)**
- **Simplest is that variability correlates with *disc* contribution to spectrum**
- **High flaring activity only in sources with large disc veiling**
- **So variability is from some part of disc**



See Hynes et al., 2003, MNRAS, in press

Individual Flares in A0620-00



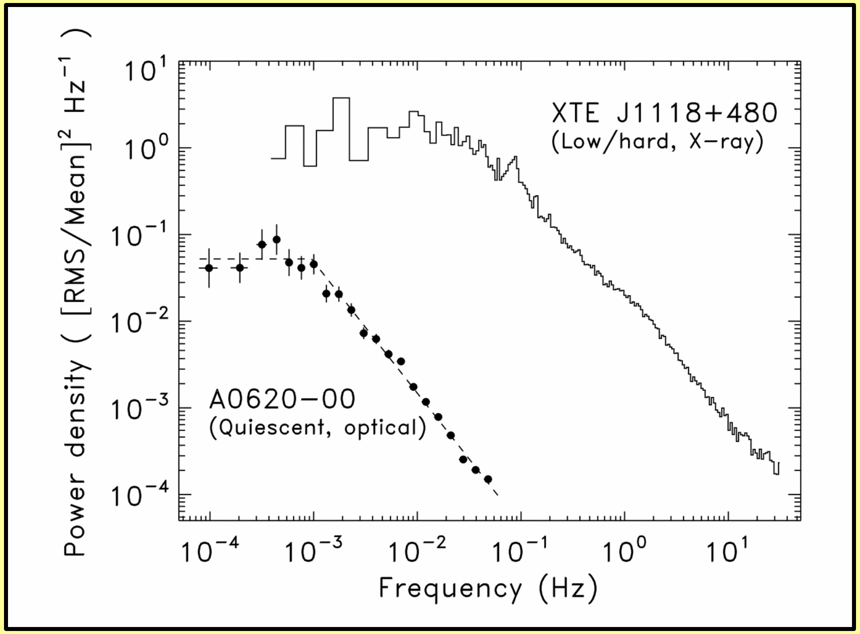


See Hynes et al., 2003, MNRAS, in press

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

Clues From Power Density Spectra I

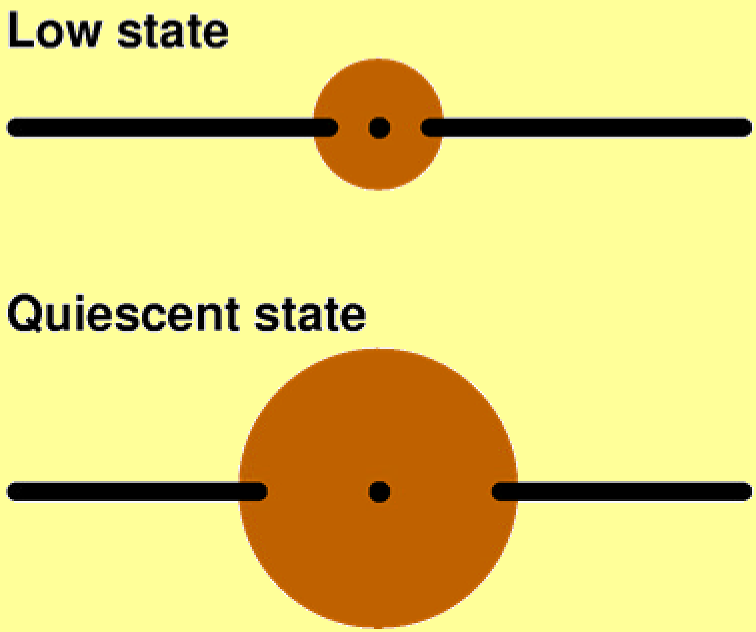
- In outburst can use power spectrum to classify states
- High/soft: Low amplitude red noise
- Low/hard: High amplitude band limited noise
- What is power spectrum of quiescent state?



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

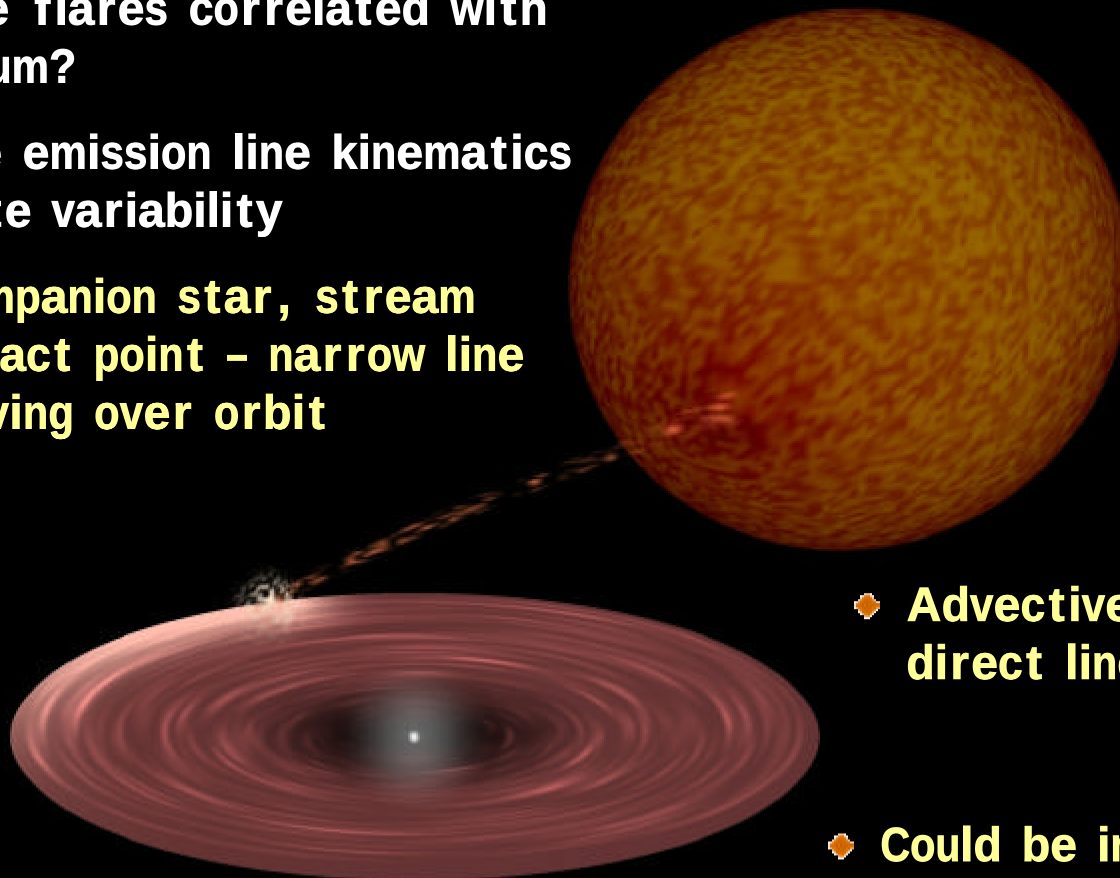
Clues From Power Density Spectra II

- 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...



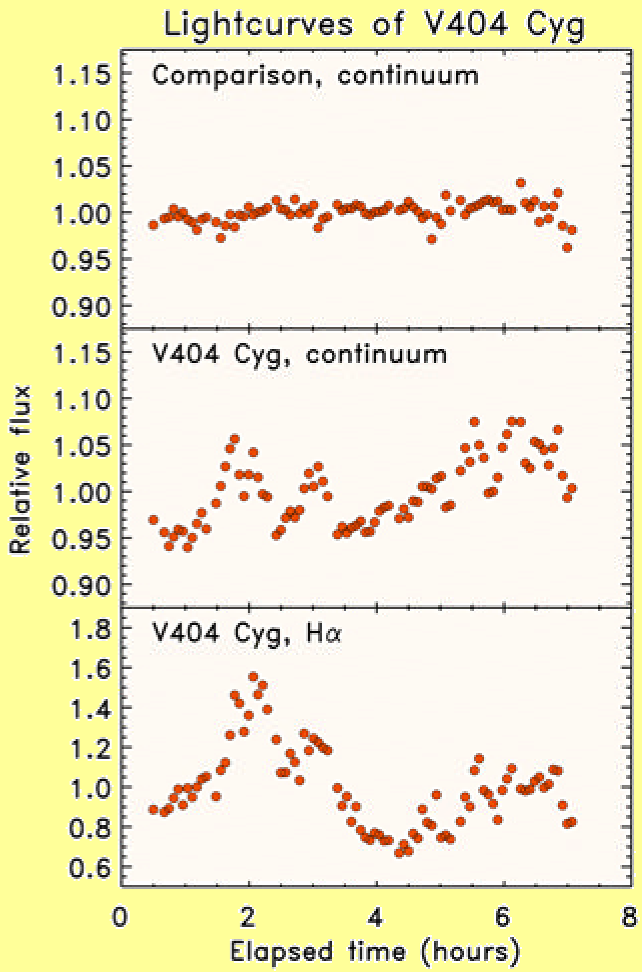
Clues From Optical Emission Lines

- Are line flares correlated with continuum?
- Can use emission line kinematics to locate variability
  - Companion star, stream impact point – narrow line moving over orbit



- Advective region – no direct line emission
- Could be indirect emission from whole disc – broad, double peaked line
- Magnetic reconnection in disc – narrow line at random velocity

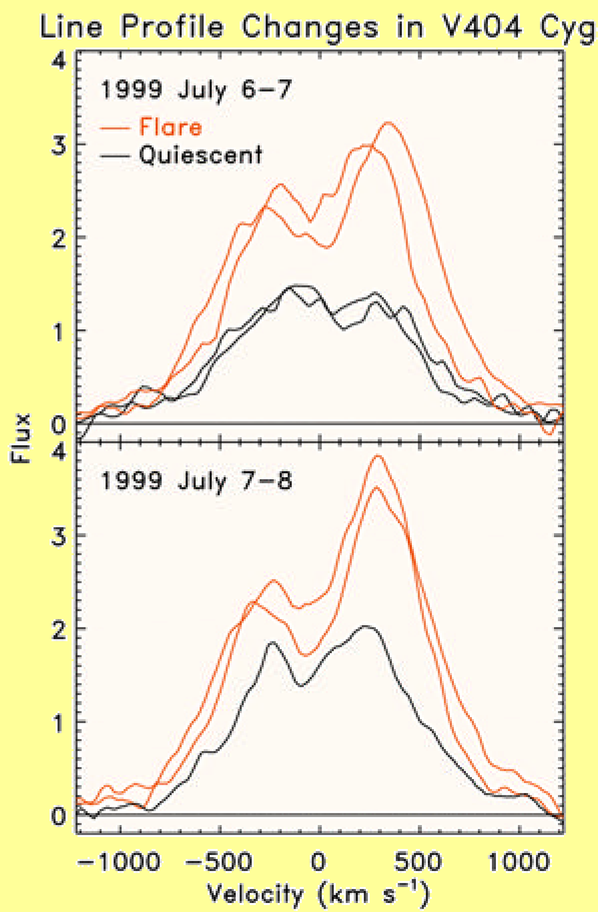
Optical Variability in V404 Cyg



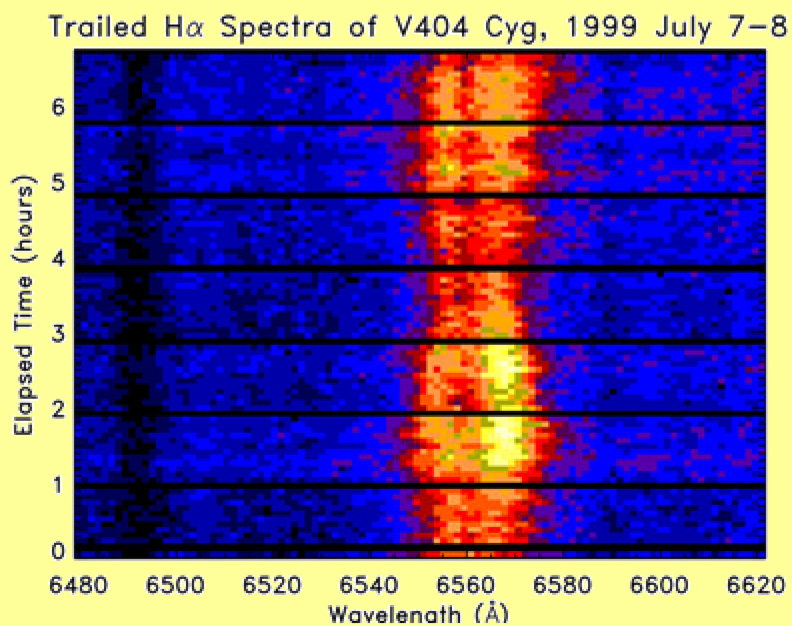
- **V404 Cyg is ideal:**
  - **Bright**
  - **Strong variability on long timescales**
- **Observed WHT, July 1999**
- **Large flares, line + continuum correlated**
- **Line amplitude much larger, up to x2**
- **Weak flickering as well**

See Hynes et al., 2002, MNRAS, 330, 1009

Line Profiles

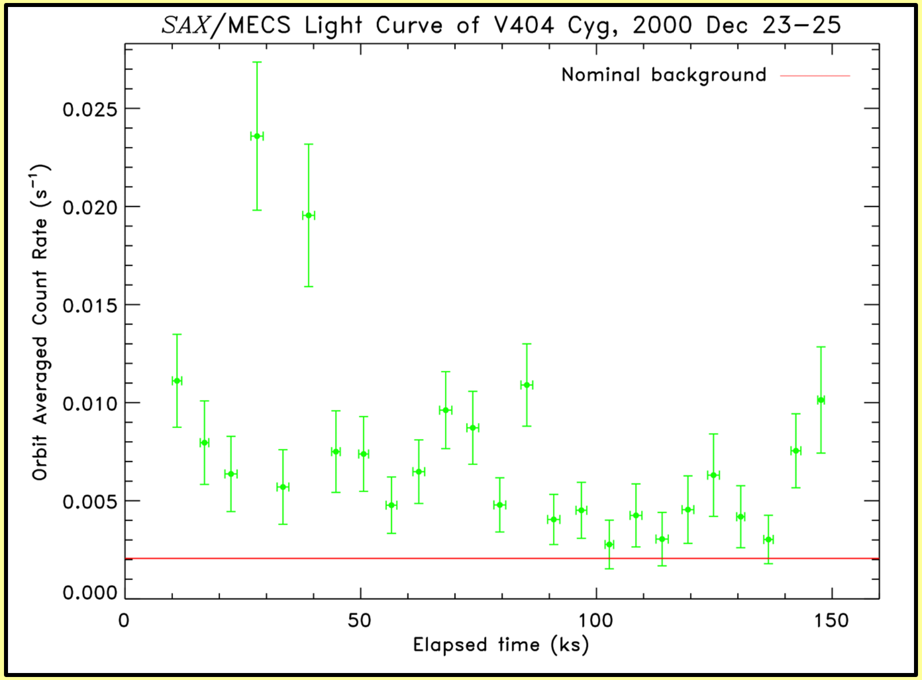


- Flares are spread across whole profile
- Difference profile is double peaked
  Þ whole disc participates
- Photoionised by X-ray source?



X-ray Variability I

- 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

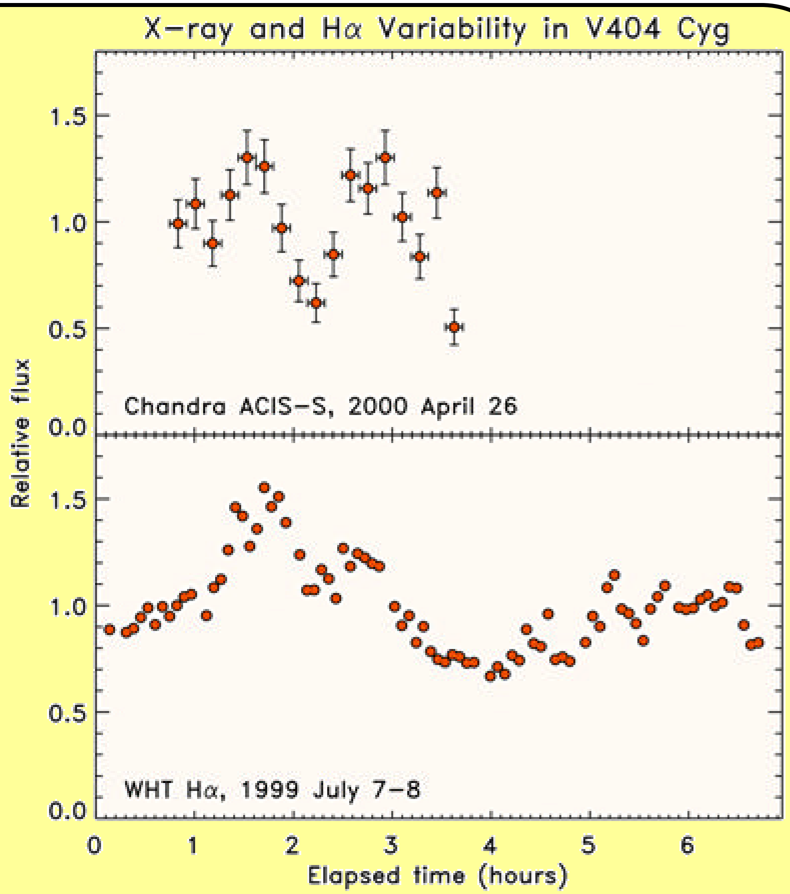


SAX data, PI Phil Charles

- Source too faint for detailed study with these facilities…

X-ray Variability II

- ***Chandra*** **(and *XMM*) allow more detail (Kong et al. 2002, ApJ, 570, 277)**
- **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

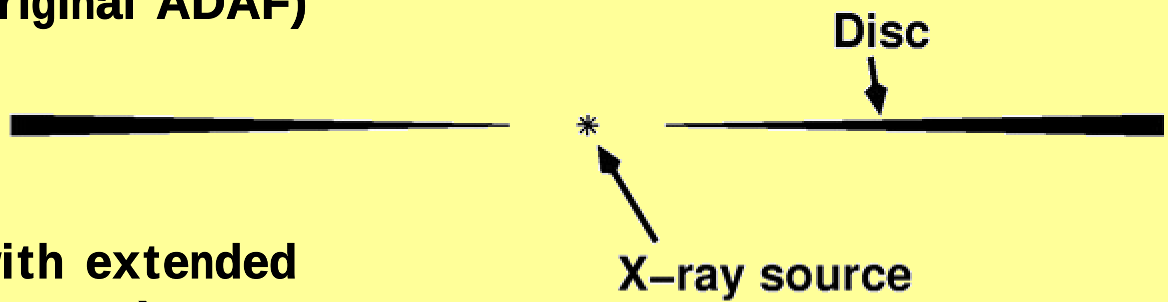
- Quiescent black holes are faint X-ray sources
- Is photoionisation scenario energetically possible?
  - Ha luminosity ~1.4×10^{32} erg s^{-1}
  - Ionising luminosity ~10^{34} erg s^{-1}
  - Assume <30% of incident flux reprocessed to Ha

    Þ Require **>5% of ionising flux** to fall on disc

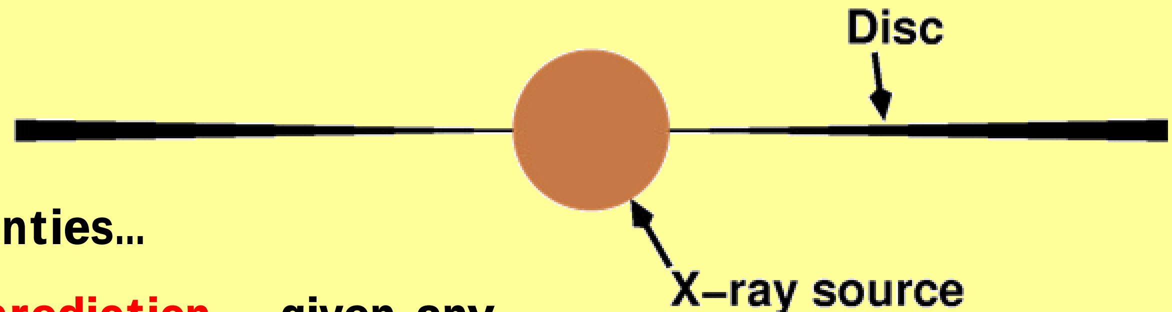
- Possible, but constrains models

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

- 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