Multiwavelength rapid timing of X-ray binaries

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Tom Marsh
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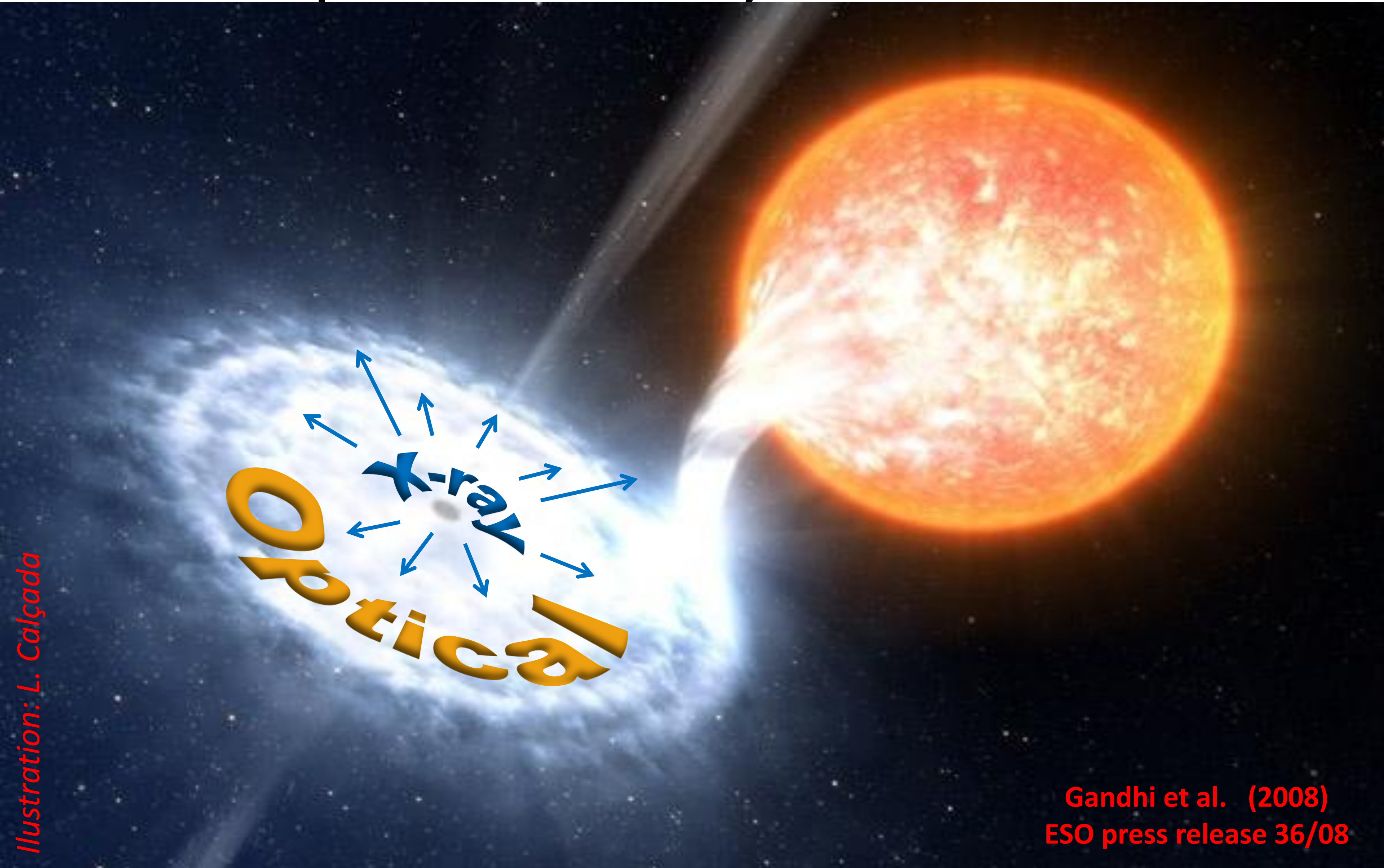
What is the source of the optical power of X-ray binaries?



Comparison to blackbody optical reprocessing model

Reprocessed emission
$\propto$
f(incident flux, area of reprocessor)

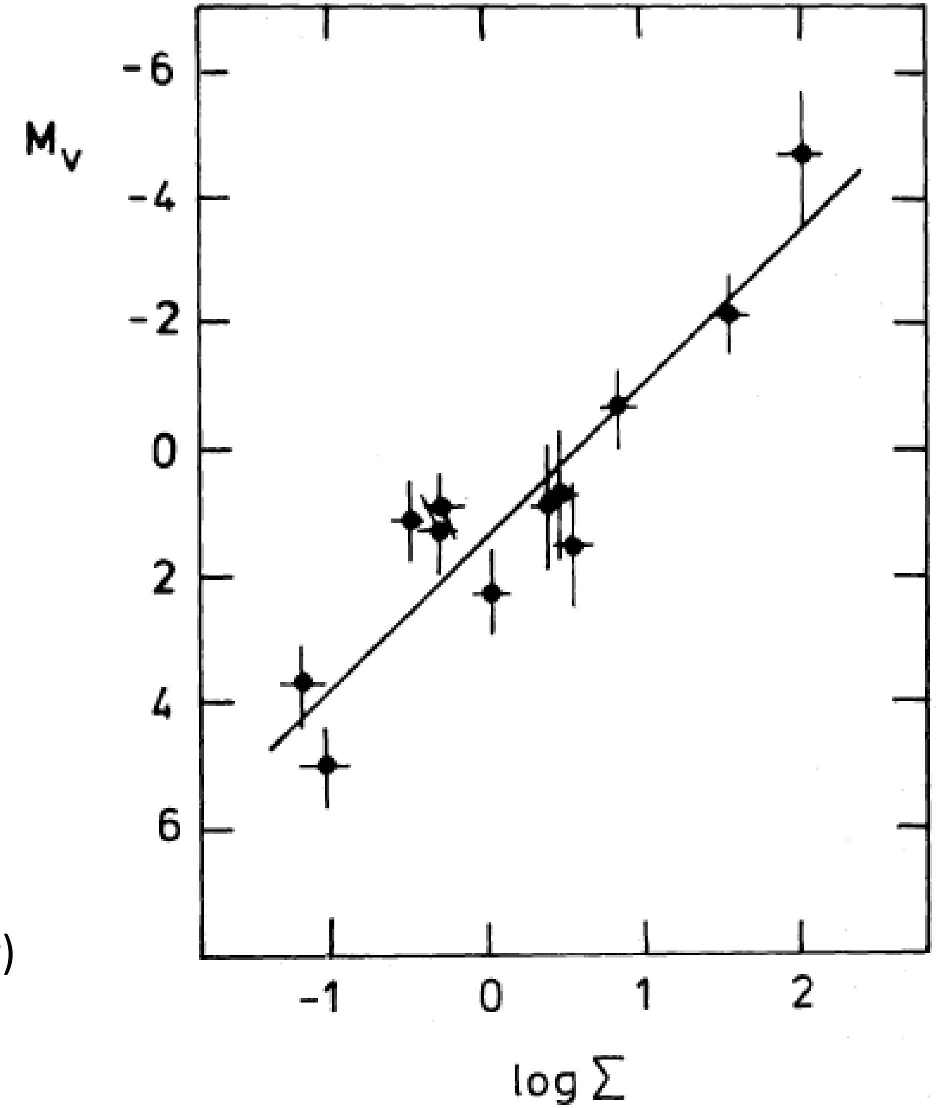
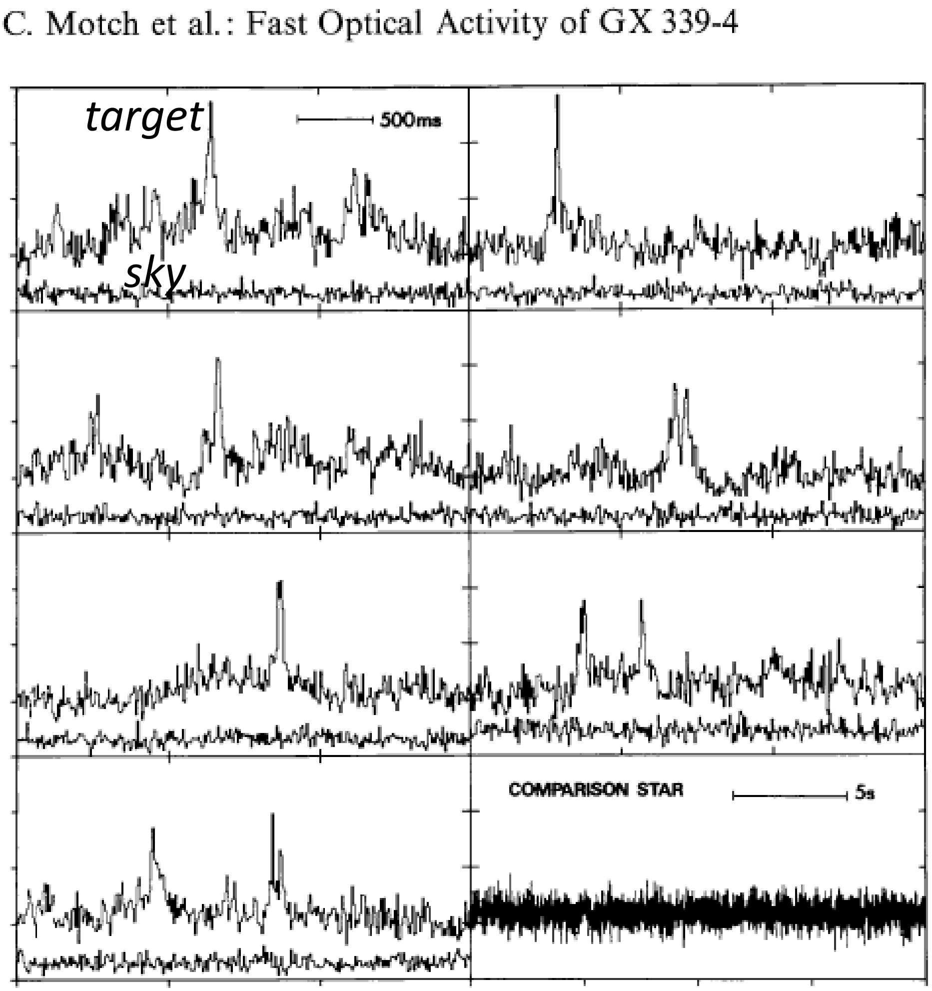


Fig. 2. Relation between the absolute visual magnitude M_V and $\Sigma = (L_X/L_{Edd})^{1/2}\,(P/\,1\mathrm{hr})^{2/3}$. The straight line represents the least-squares fit (see text)

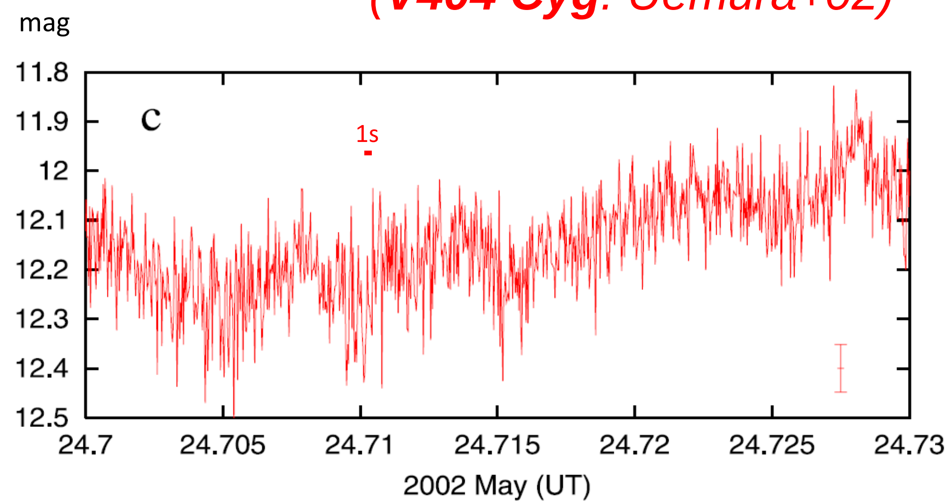
(van Paradijs & McClintock 1994)

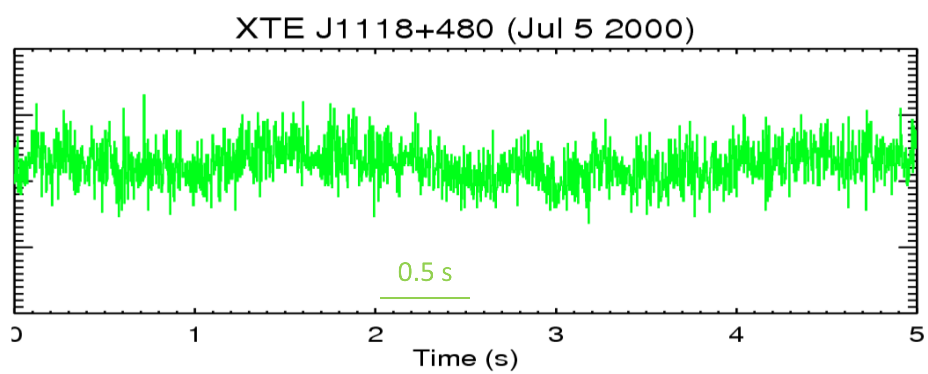
Speedy aperiodic optical variations in X-ray binaries



(***GX 339-4***: *Motch+82*)

(***V404 Cyg***: *Uemura+02*)





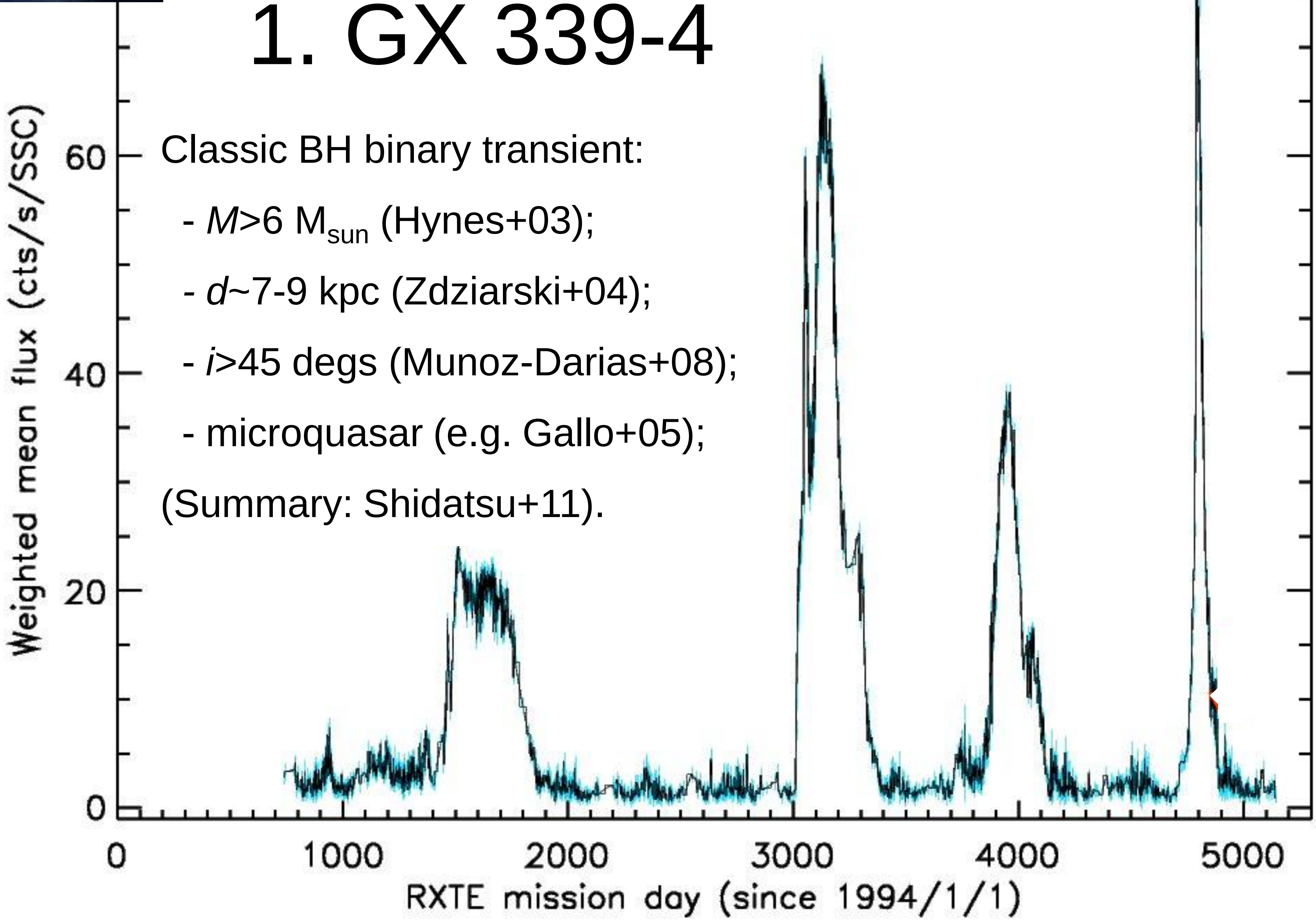
(***XTE J1118+480***: *Kanbach+01*)

1. GX 339-4

Classic BH binary transient:

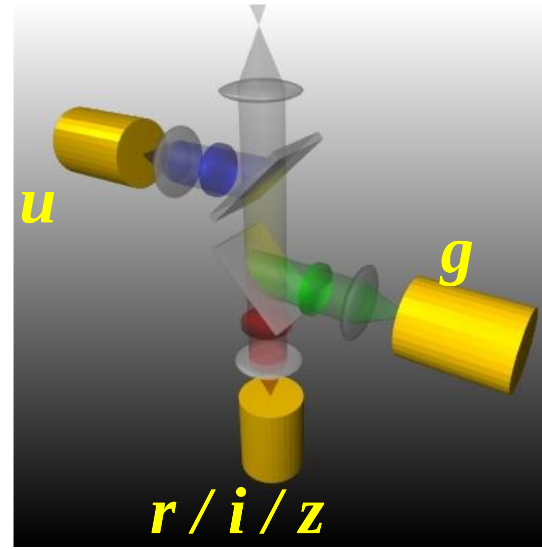
- M>6 M_{sun} (Hynes+03);
- d~7-9 kpc (Zdziarski+04);
- i>45 degs (Munoz-Darias+08);
- microquasar (e.g. Gallo+05);

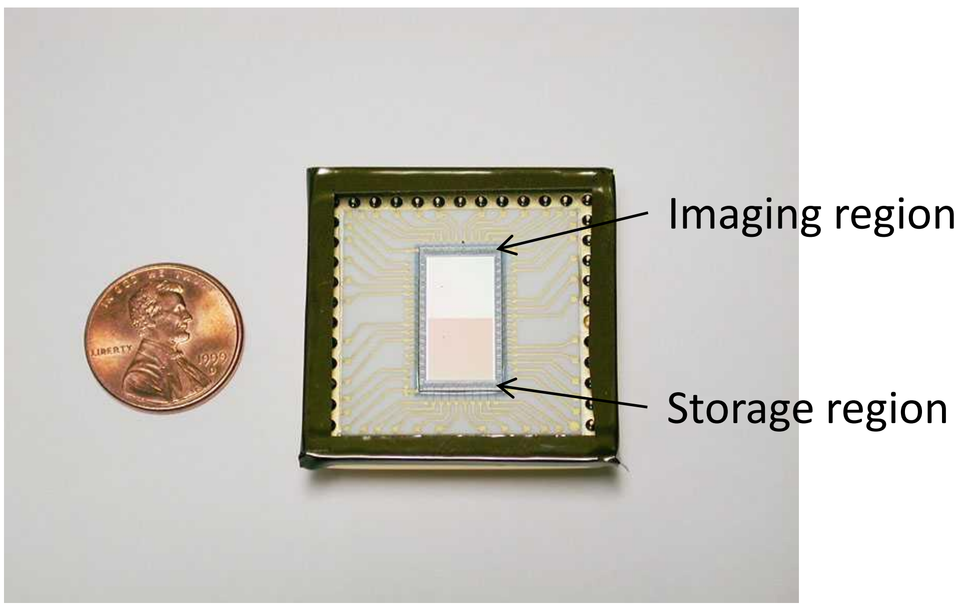
(Summary: Shidatsu+11).



ULTRACAM (on the VLT): ultra-fast, triple-beam CCD camera

- Frame-transfer CCDs with negligible dead-time
- Speeds ~ 500 frames / sec
- Beam splitters => 3 filter simultaneous imaging

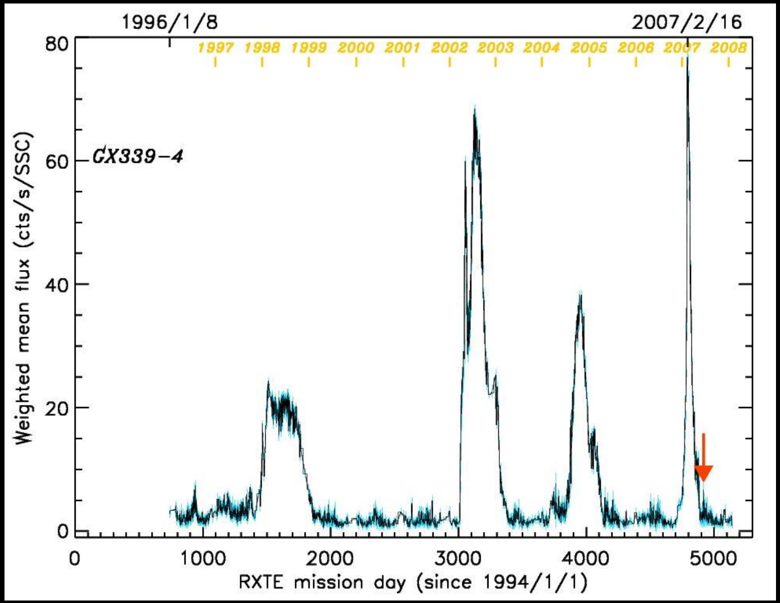




ULTRACAM @VLT

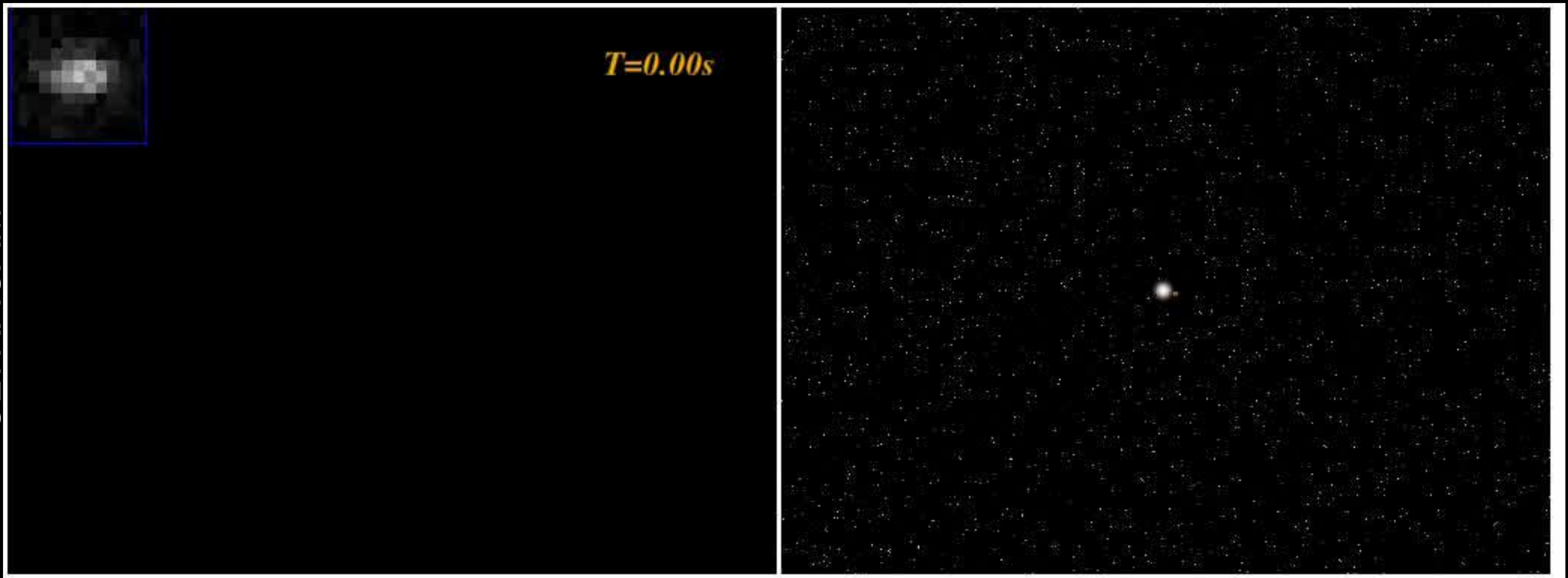
http://www.shef.ac.uk/physics/people/vdhillon/ultracam/

1. GX 339-4

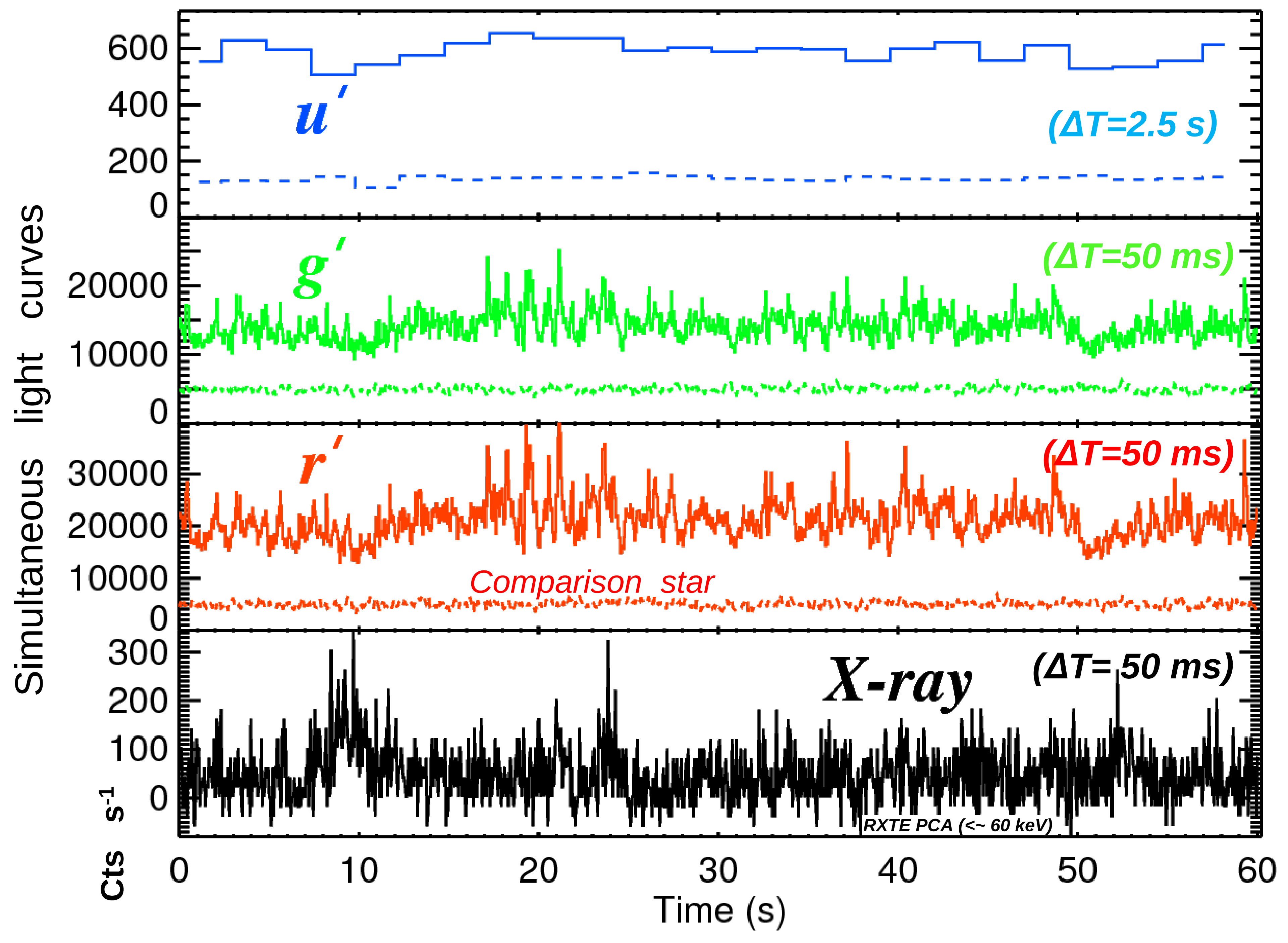


ΔT=50 ms

ULTRACAM

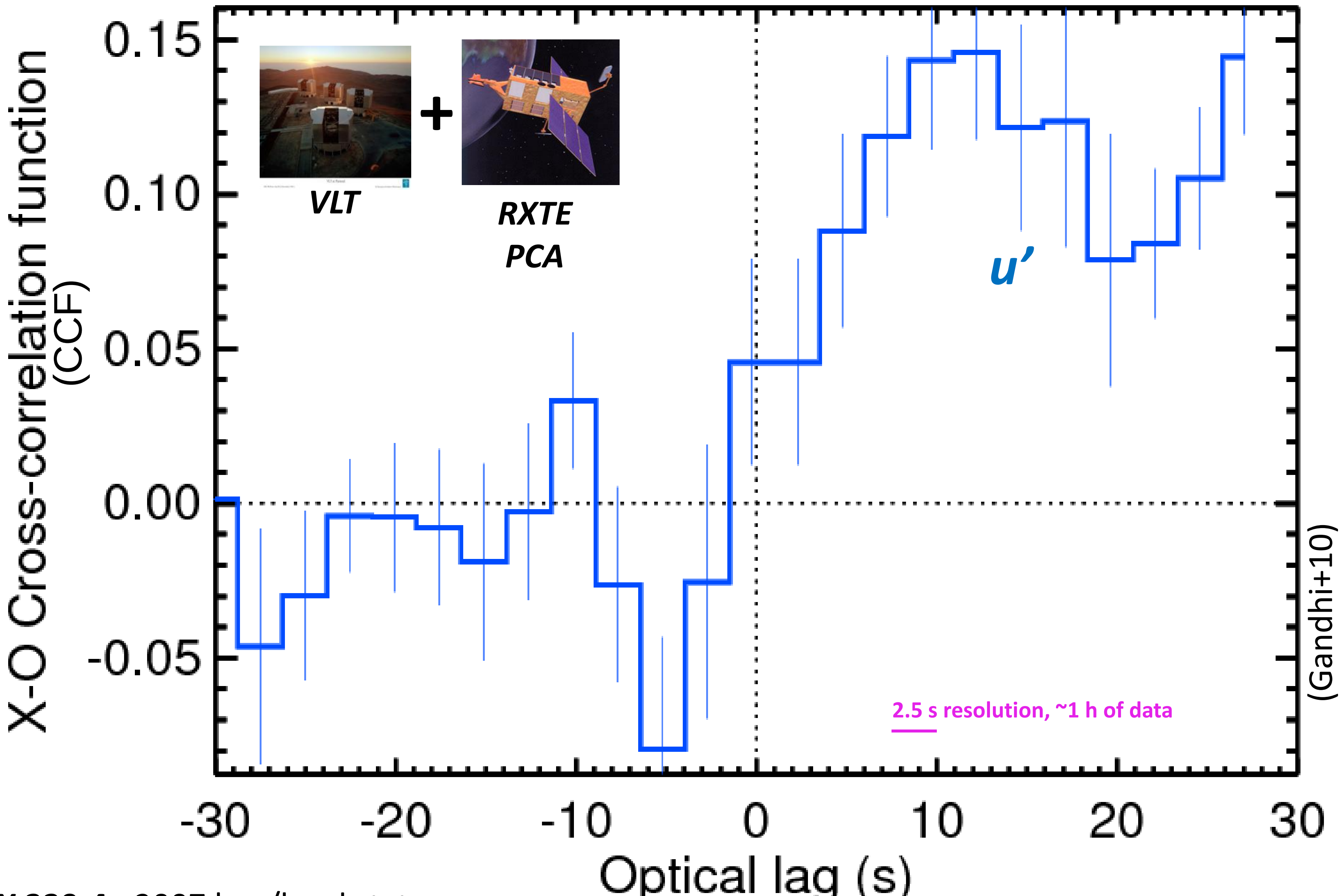


Animation: binsim



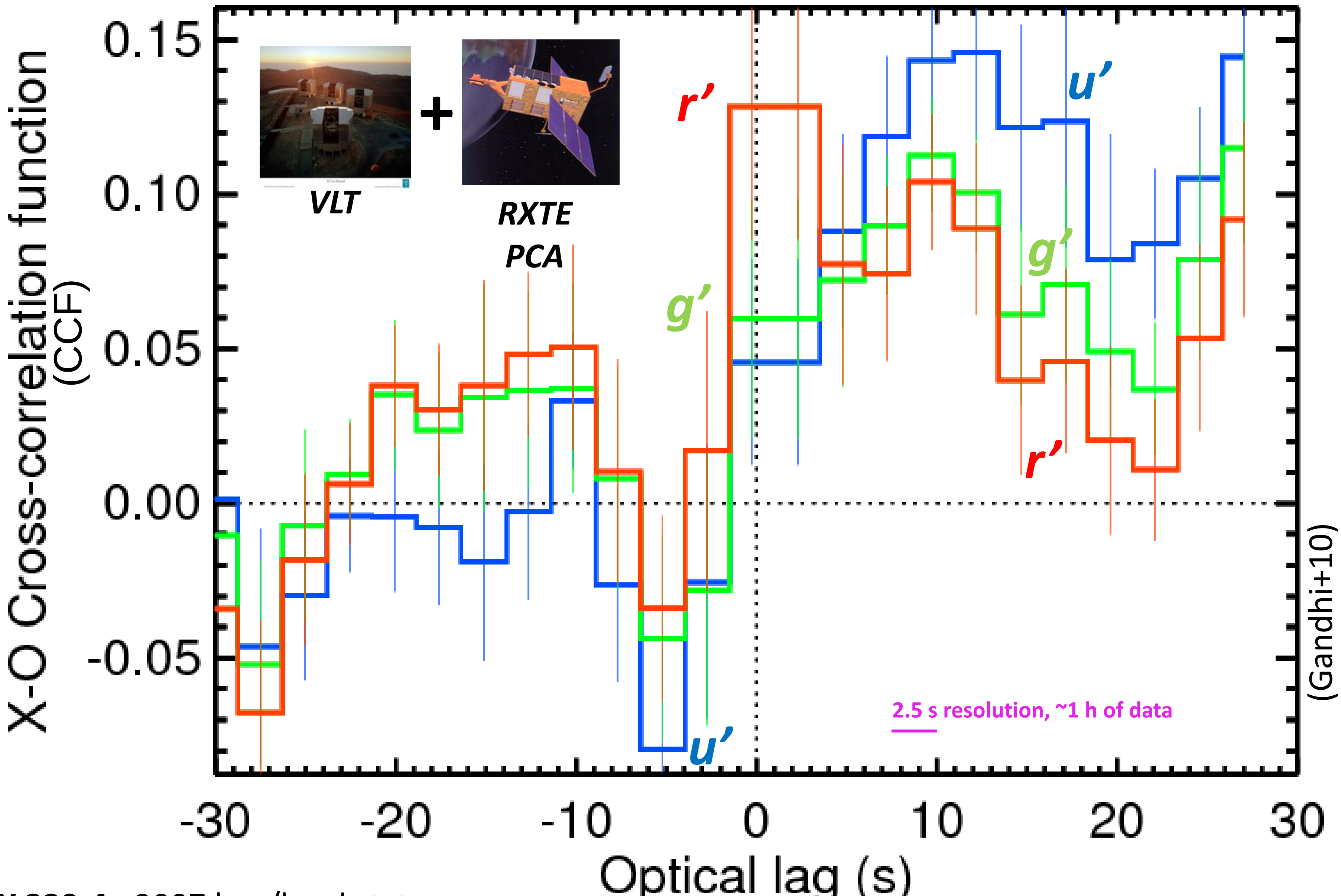
u´
(ΔT=2.5 s)
g´
(ΔT=50 ms)
r´
(ΔT=50 ms)
Comparison star
X-ray
(ΔT= 50 ms)
RXTE PCA (<~ 60 keV)
Simultaneous light curves
Cts s-1
Time (s)

Optical and X-ray simultaneous timing



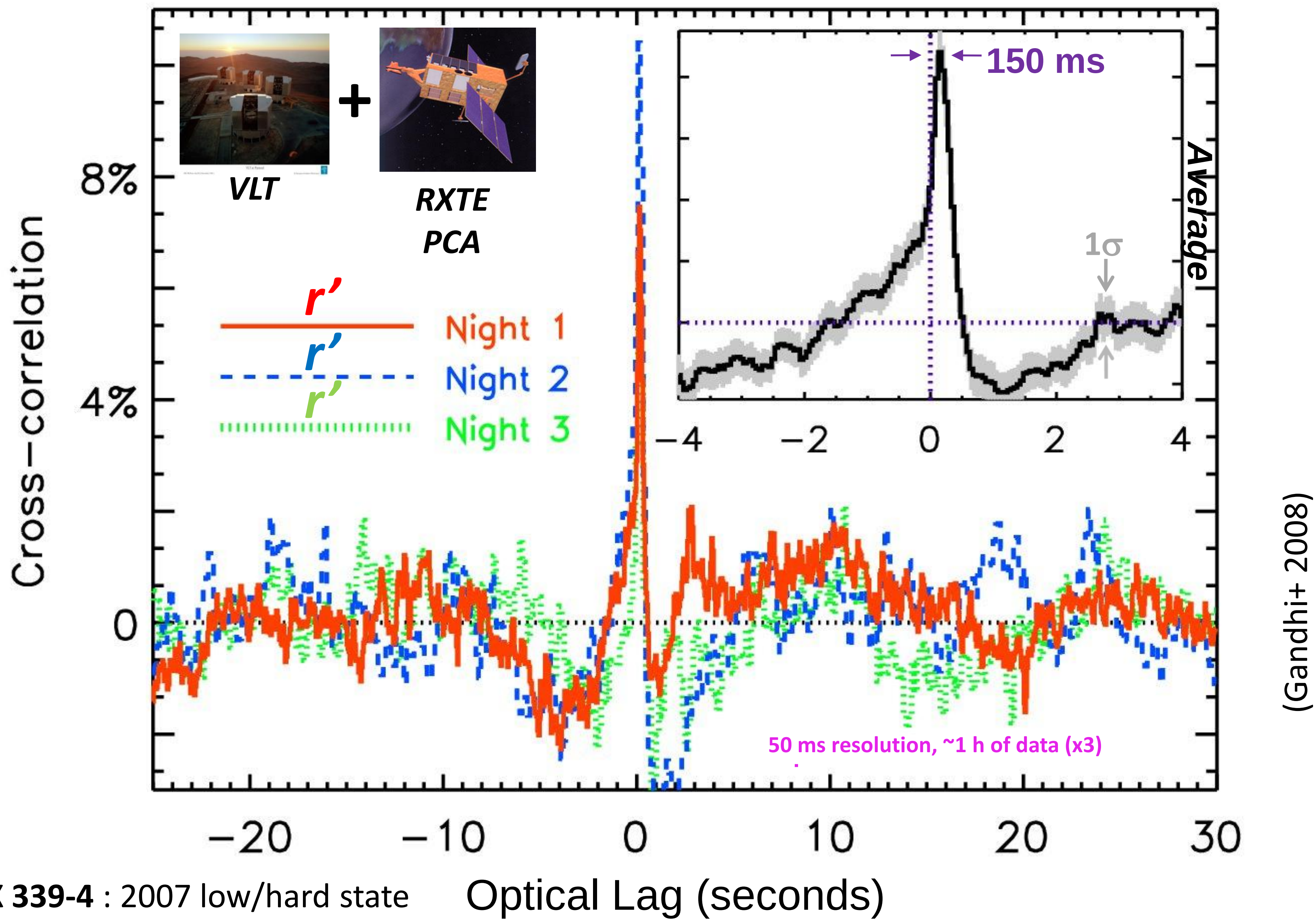
GX 339-4 : 2007 low/hard state

New fast red component in CCF?



GX 339-4 : 2007 low/hard state

Sub-second X-O Cross Correlation Function (CCF)

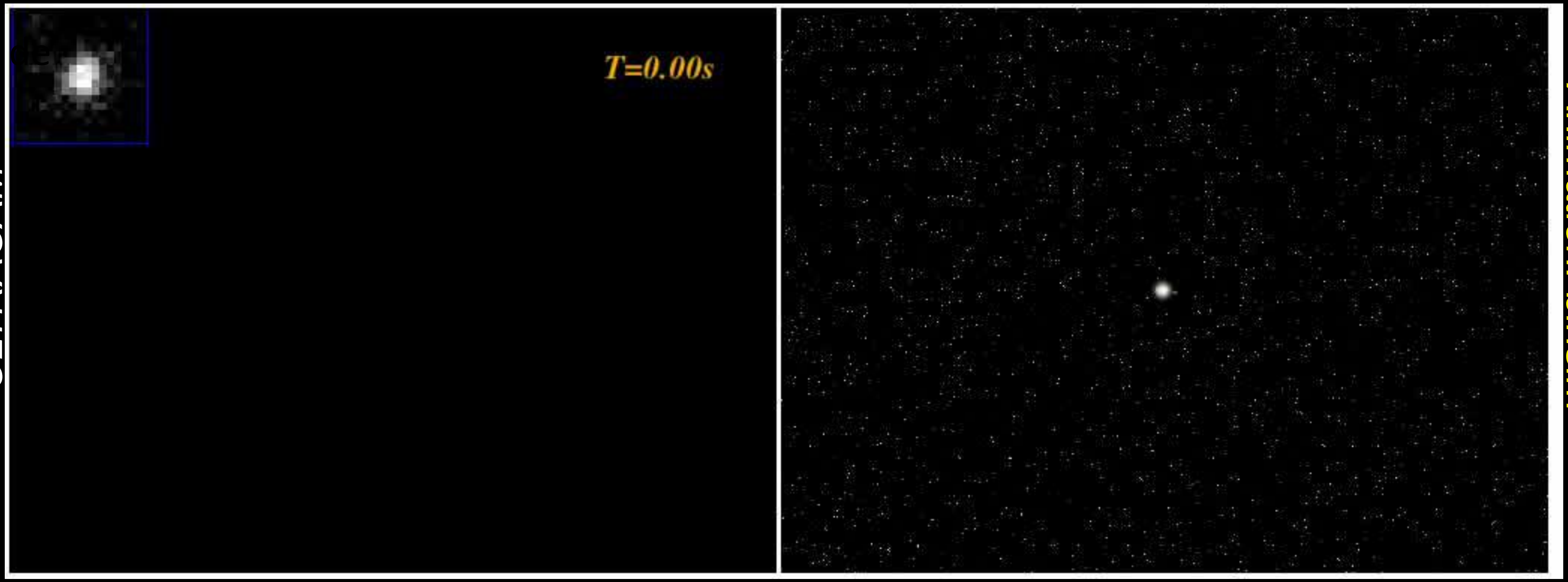


GX 339-4 : 2007 low/hard state

2. Swift J1753.5-0127

- Galactic halo BH transient
- Very short period ~ 3h (Zurita+08)
- Lives in the low/hard state
- Radio weak source

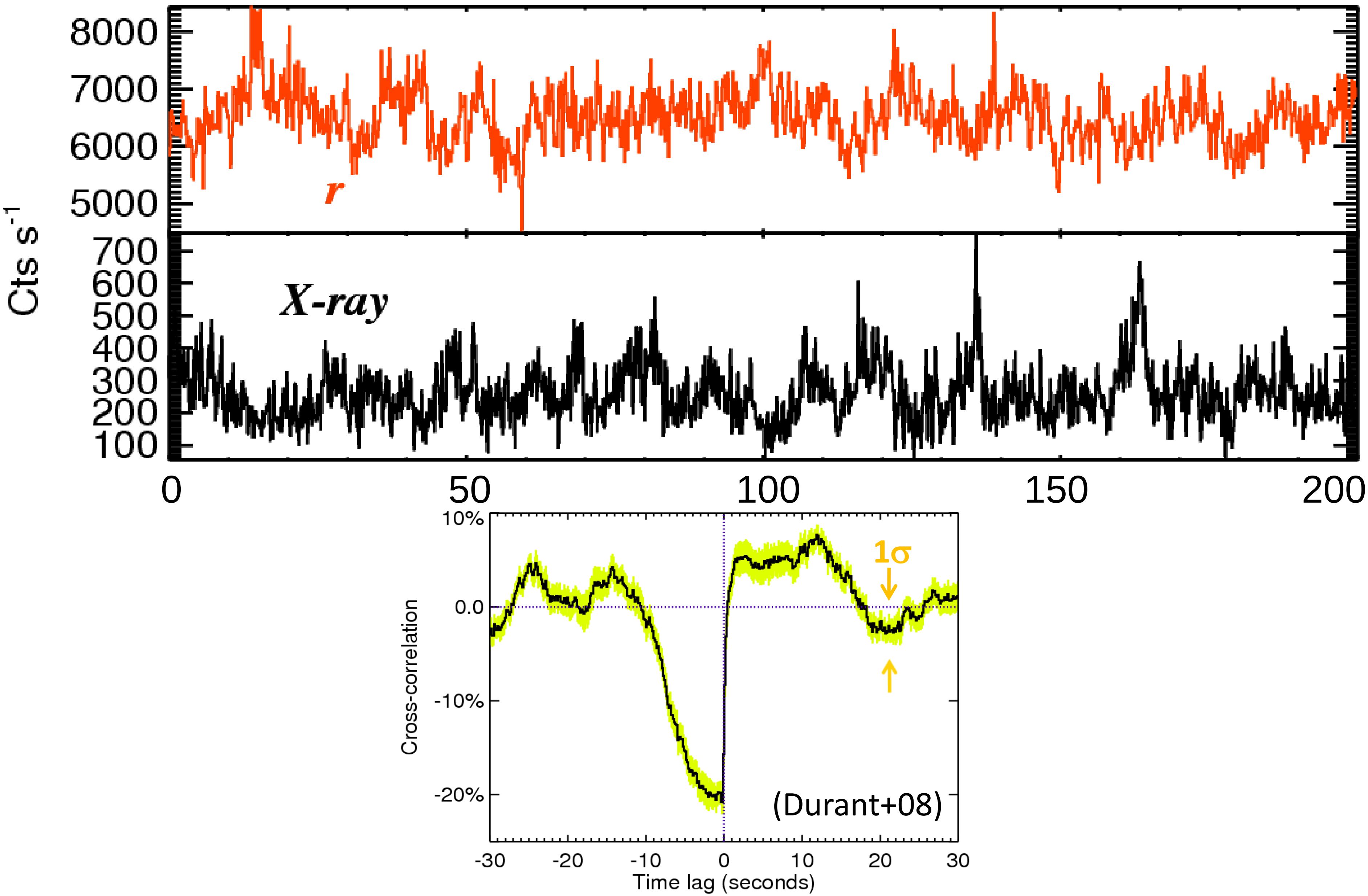
ULTRACAM



Animation: binsim

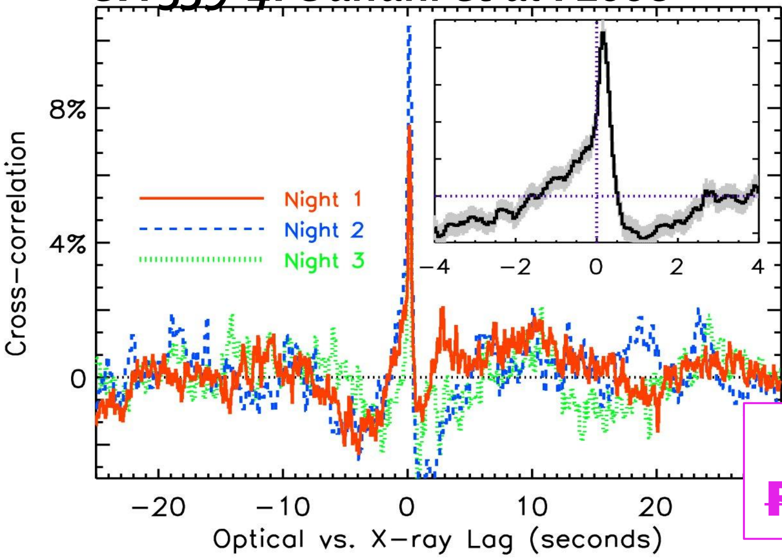
ΔT=39 ms

Swift J1753.5-0127

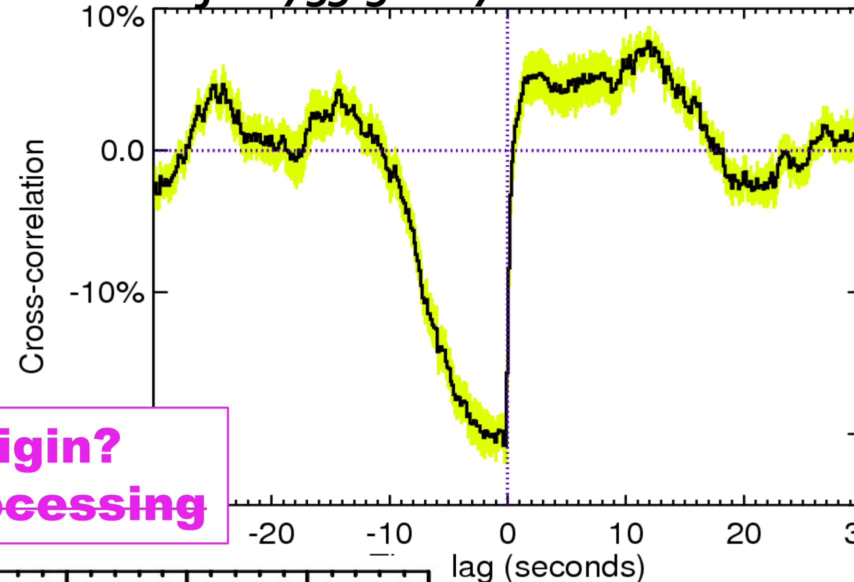


Asymmetric and complex optical/X-ray cross-correlation functions in X-ray binaries

GX 339-4: Gandhi et al . 2008

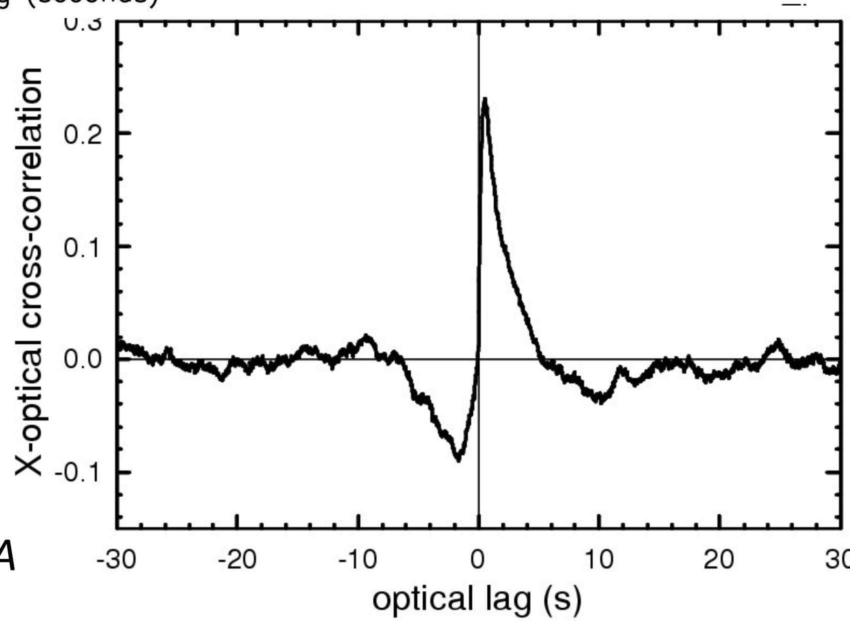


Swift J1753.5-0127: Durant et al. 2008



Origin?

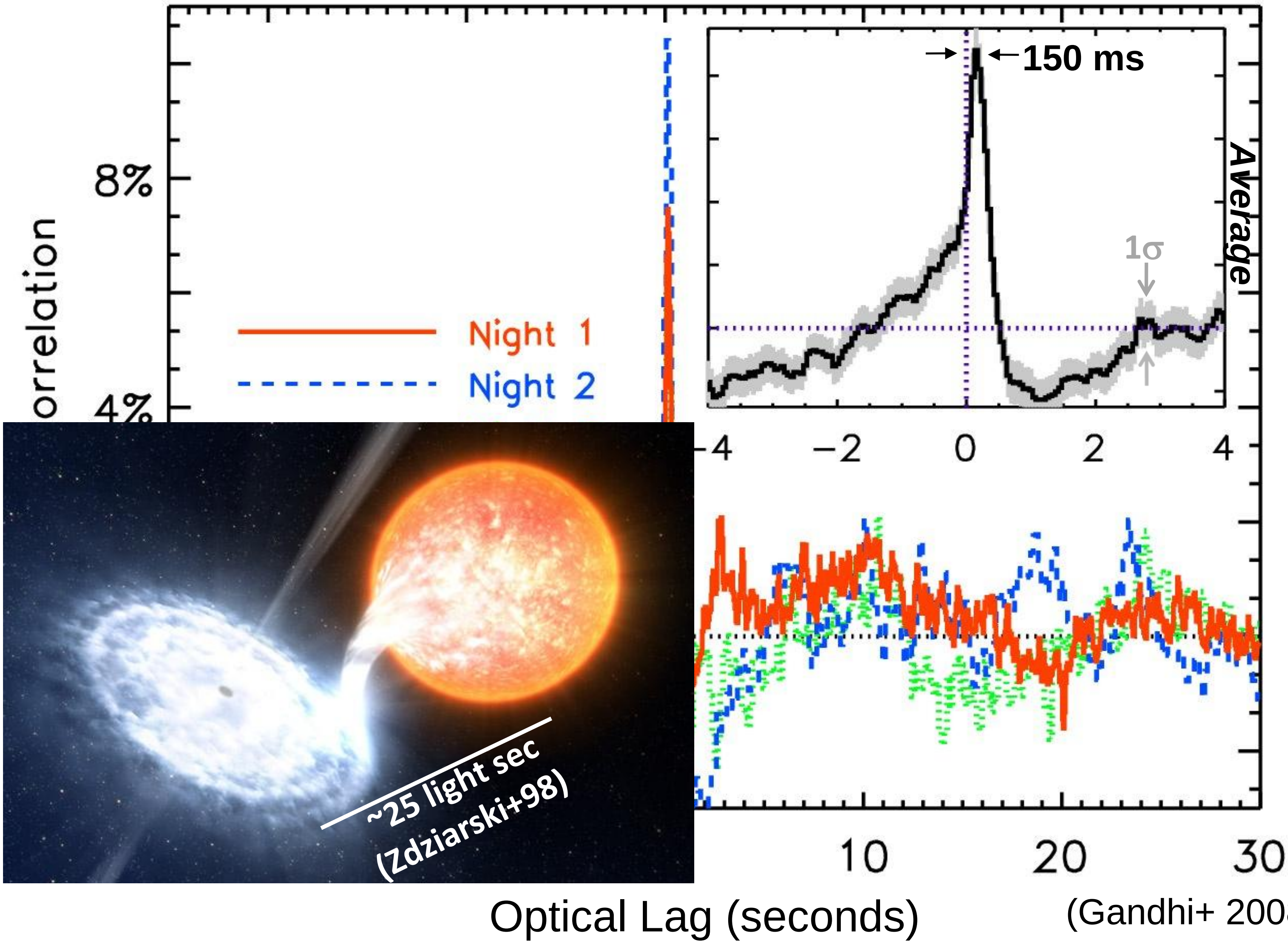
~~Reprocessing~~



XTE J1118+480: Kanbach et al. 2001

All X-ray data: RXTE PCA

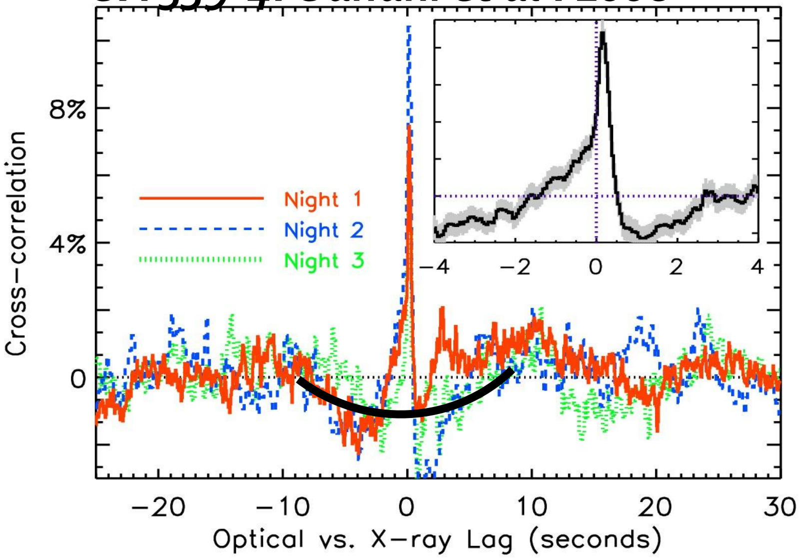
1. Small time delay, sharp positive response



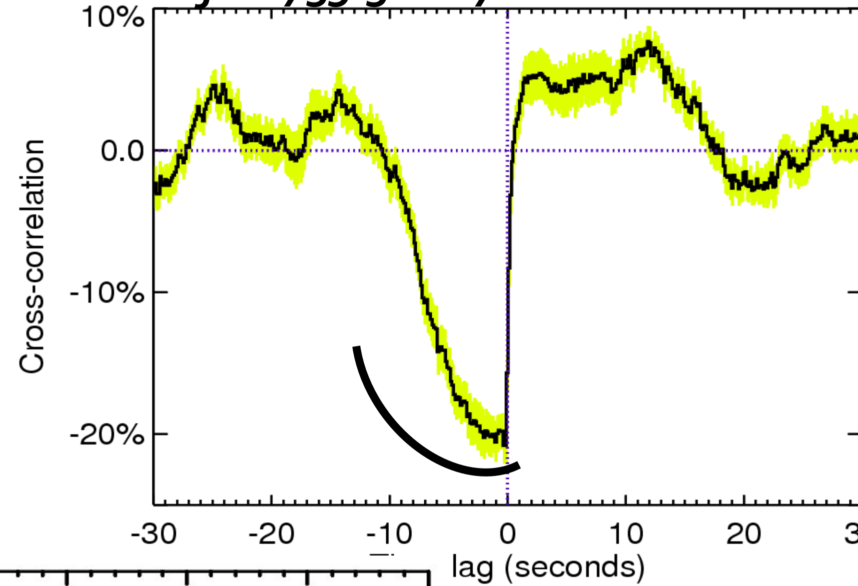
(Gandhi+ 2008)

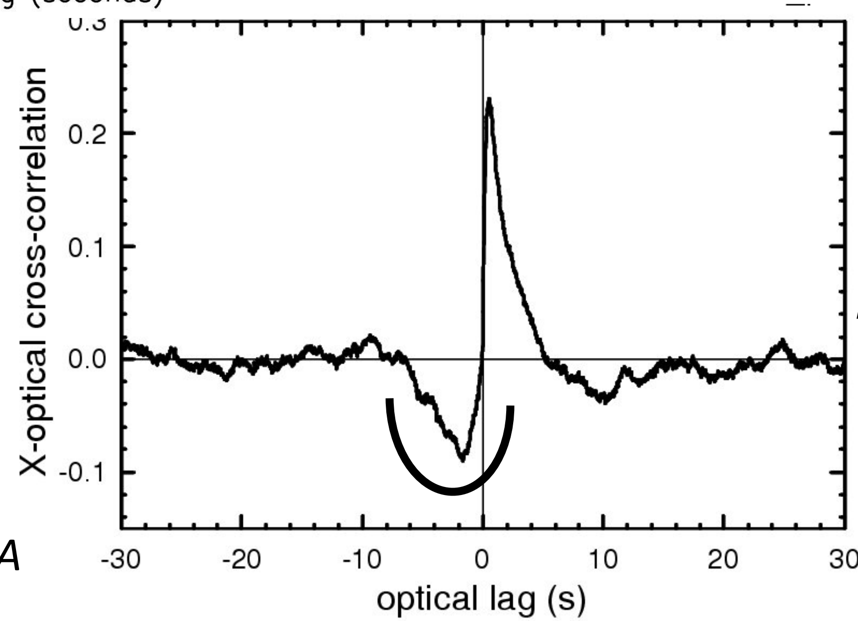
2. Anti-correlation

GX 339-4: Gandhi et al . 2008



Swift J1753.5-0127: Durant et al. 2008



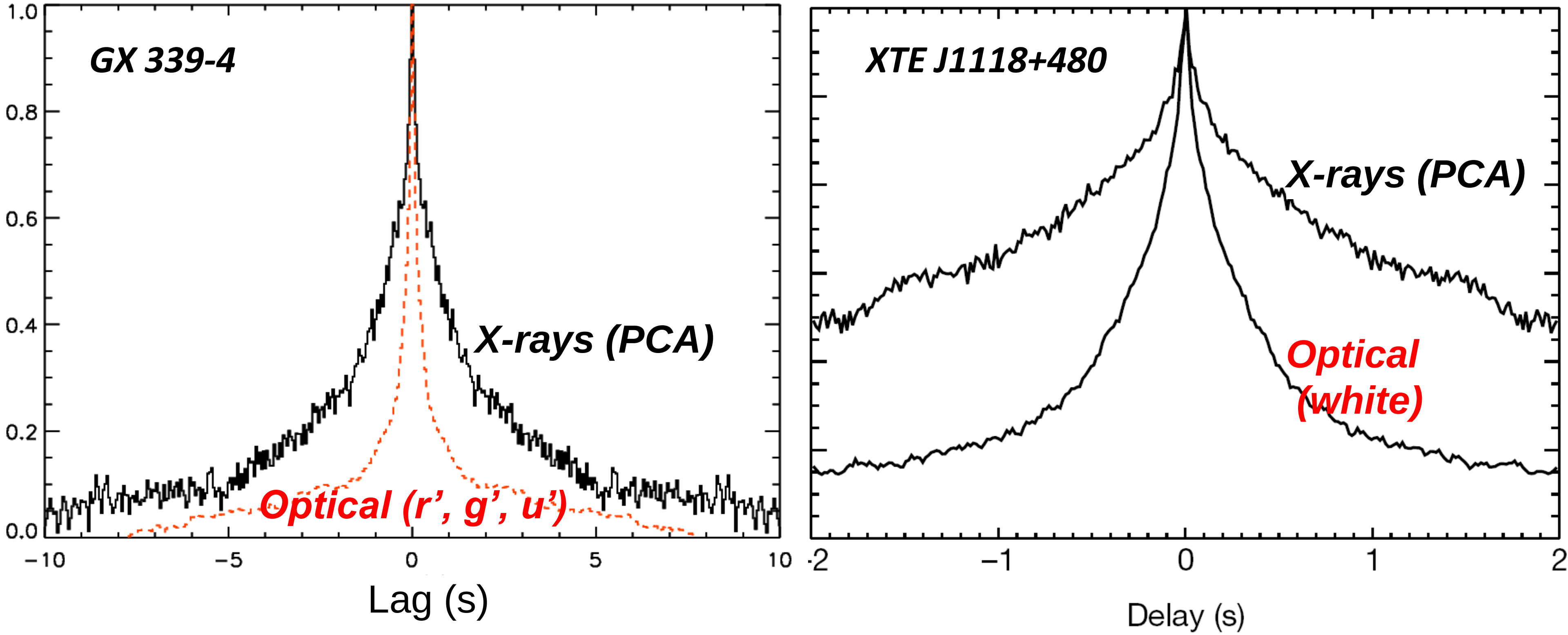


XTE J1118+480: Kanbach et al. 2001

All X-ray data: RXTE PCA

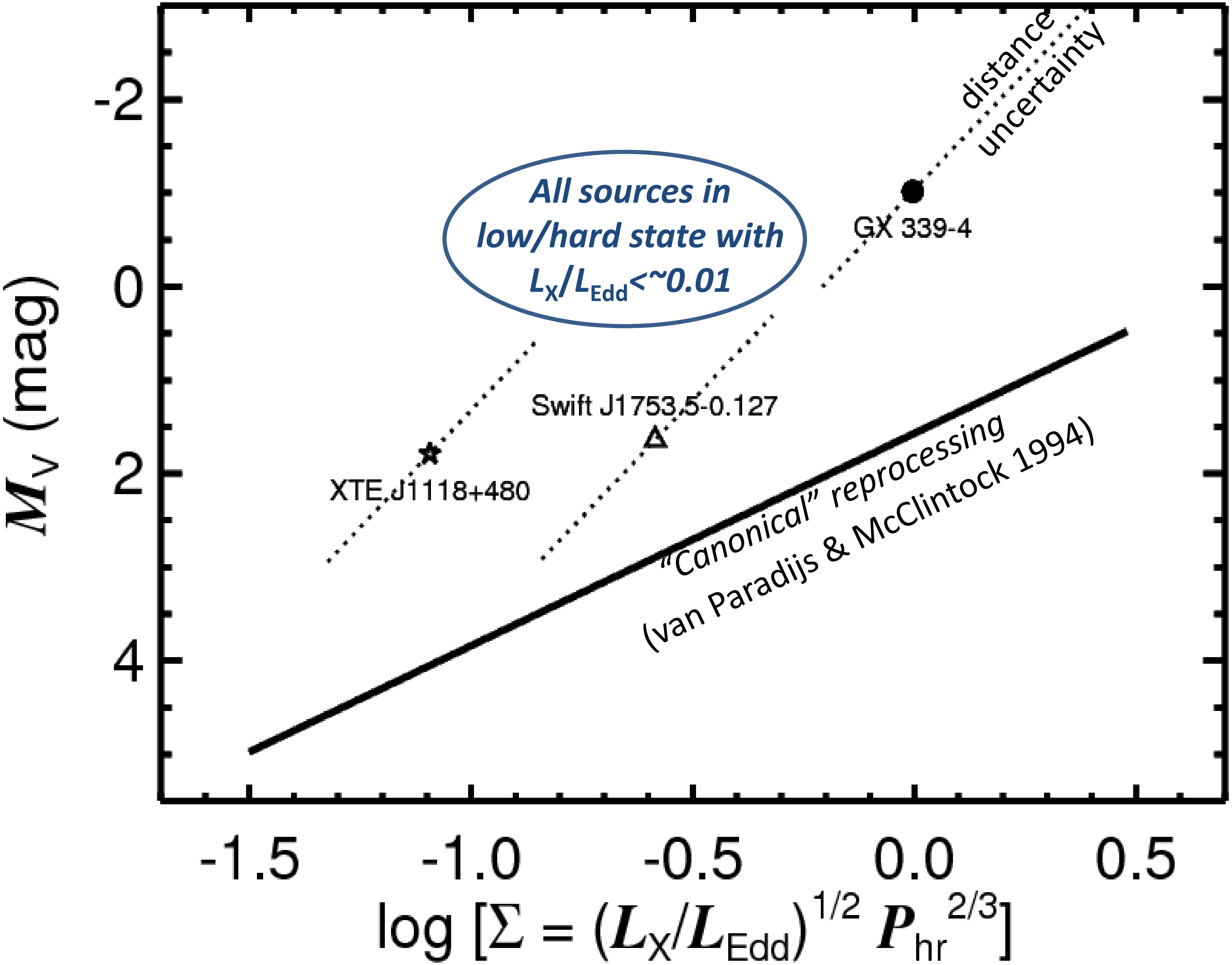
3. Small optical coherence times

Auto Correlation Function
(Poisson corrected)



Optical ACFs narrower than X-ray ACF for two sources

4. How much reprocessing is expected?



Speedy optical variability: scales and power

- Fastest flares have timescales <~ 20-100 ms.

  => R <~ 10^4 km <~ 10^3 R_G

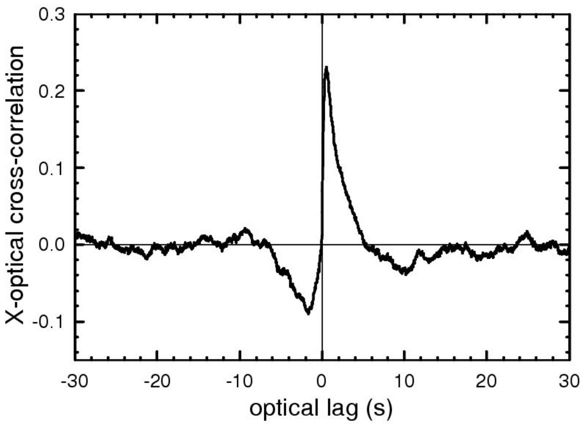
- Brightness temperature

  => T_B >~ 10^7 K

- Equipartition

  => $B > 10^4$ G

Models for XTE J1118+480



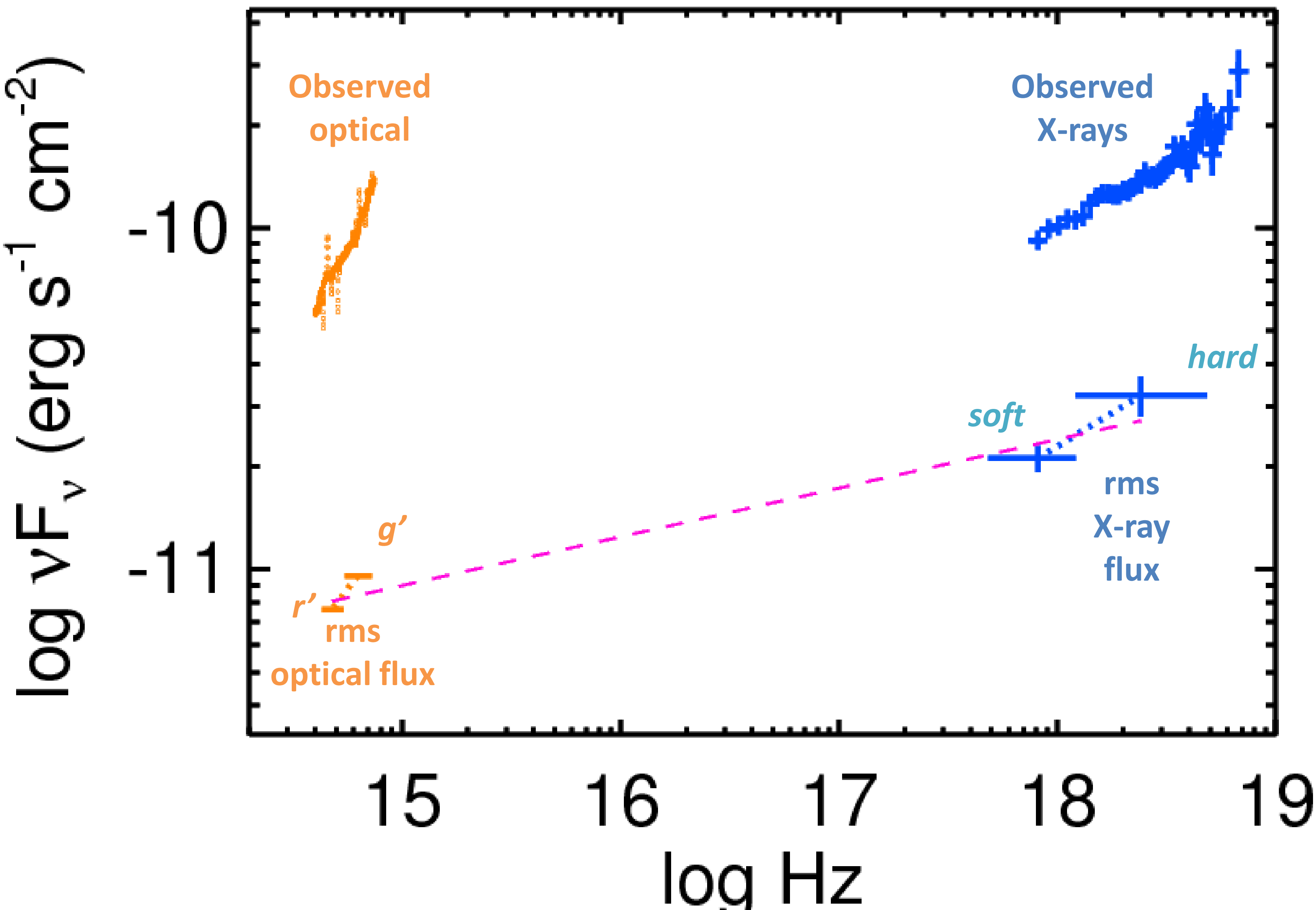
⇨ Optical (cyclo)synchrotron.

⇨ Interaction between components.

- Merloni+00 *Magnetic corona*
- Esin+01 *Advection flow (ADAF)*
- Markoff+01 *Pure jet*
- Malzac+04 *Magnetic ‘reservoir’ jet + corona*
- Yuan+05 *ADAF+jet*
- Veledina+11 *Synchrotron-self-Compton+reprocessing*

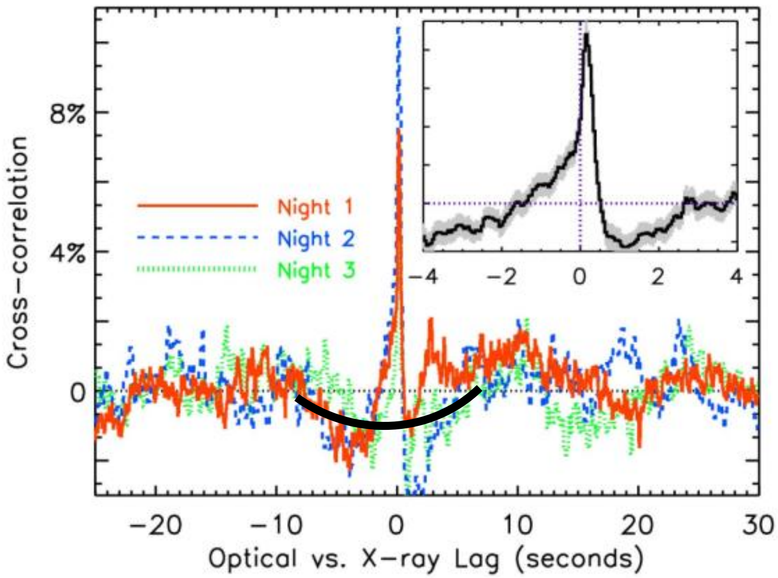
…

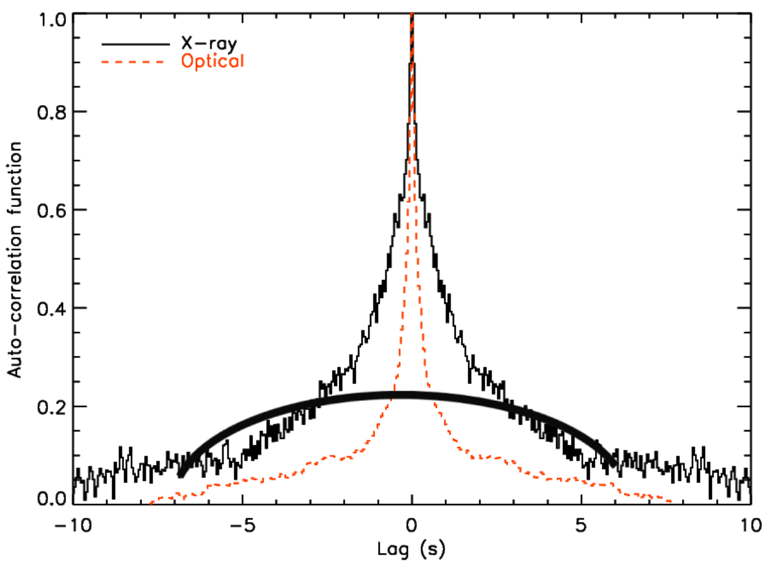
GX 339-4: Two separate components? Or one?



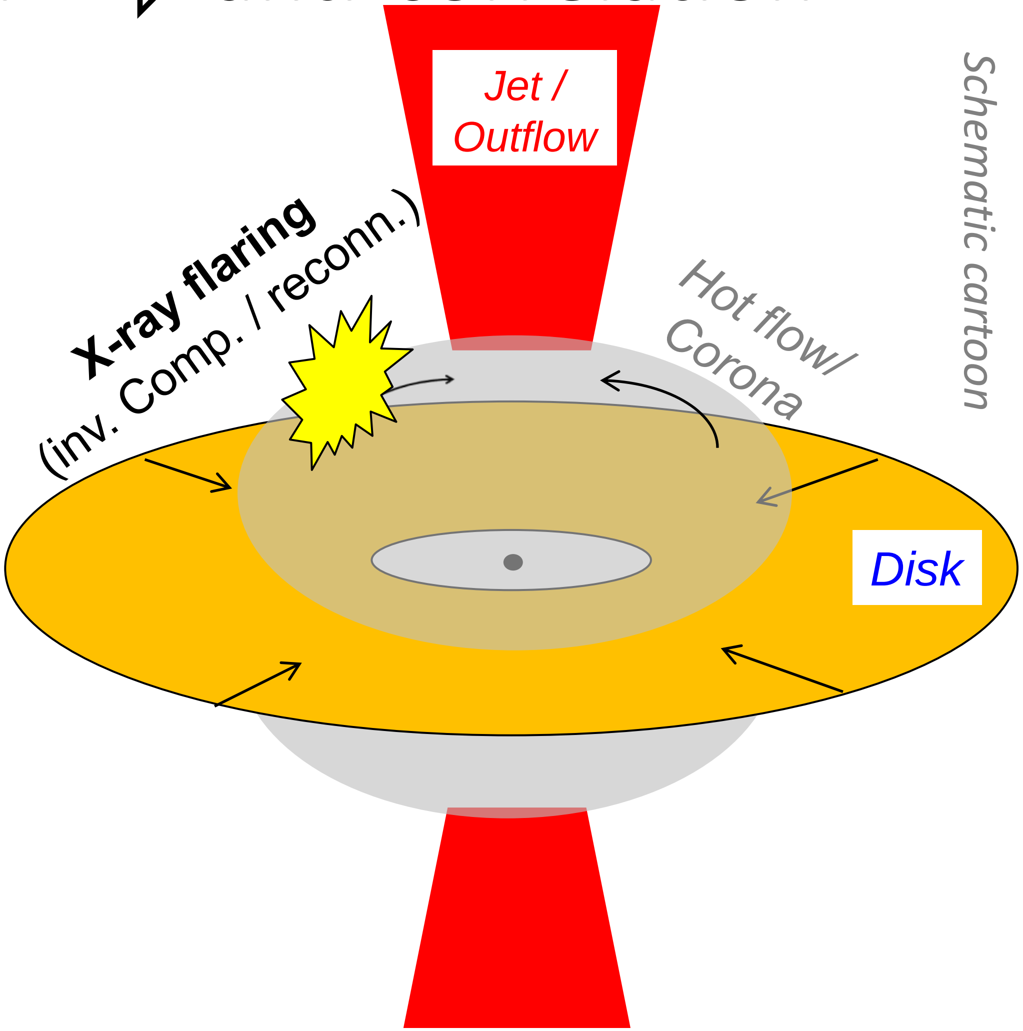
RMS spectrum optical and X-ray slopes differ, suggesting two different components (Gandhi+10).

B field dissipation ⇨ anti-correlation





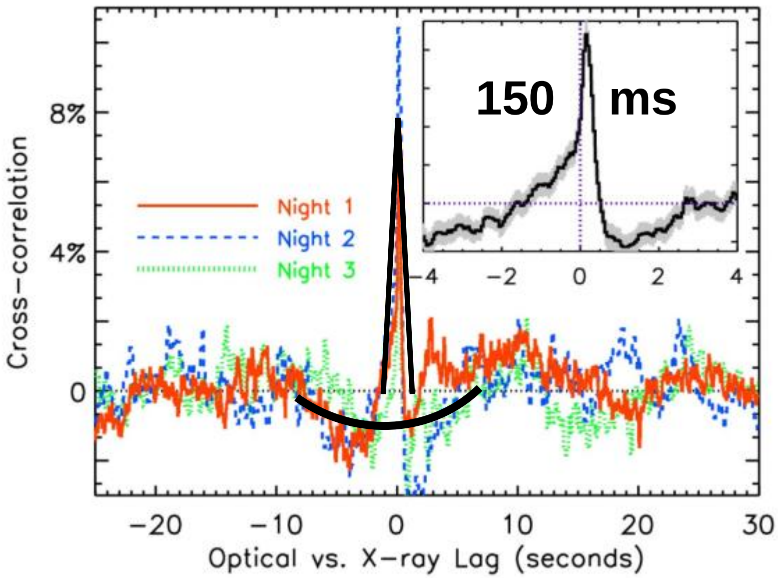
(Gandhi+10)



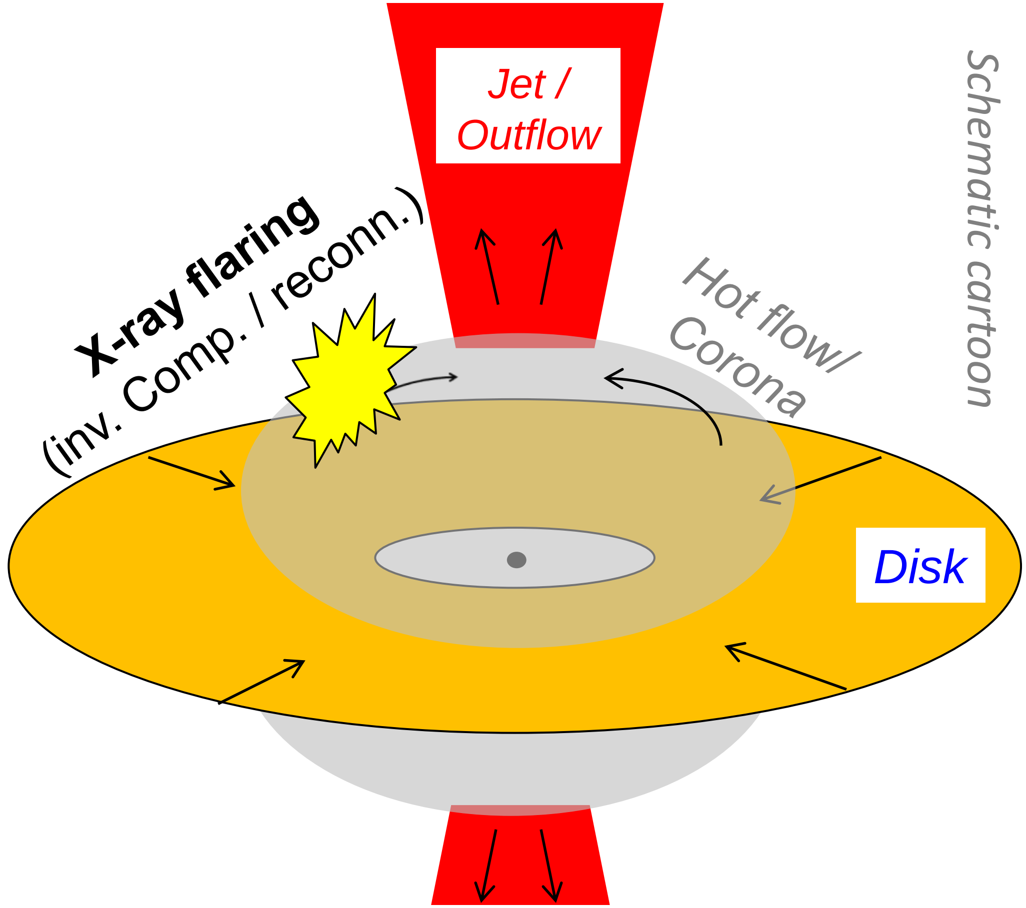
Release of <u>coronal</u> *B* energy density

⇒ ↓ optical cyclosynchrotron

Jet ⇨ positive correlation



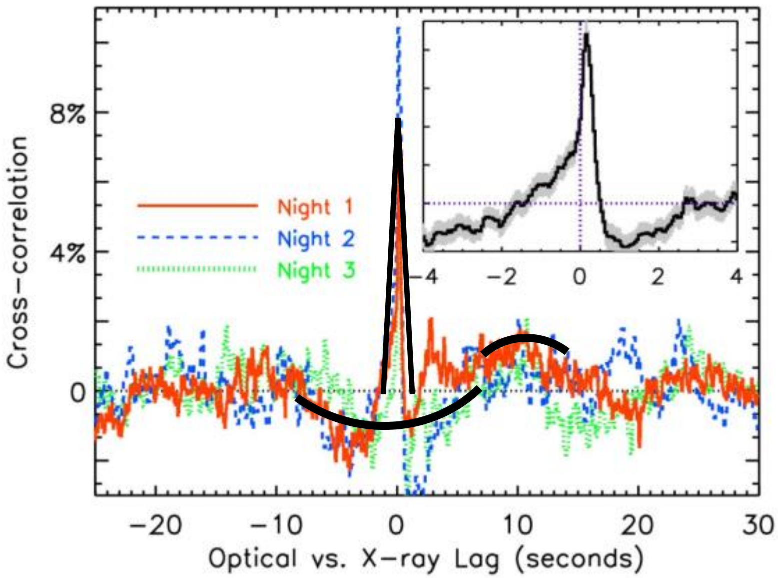
(Gandhi+10)



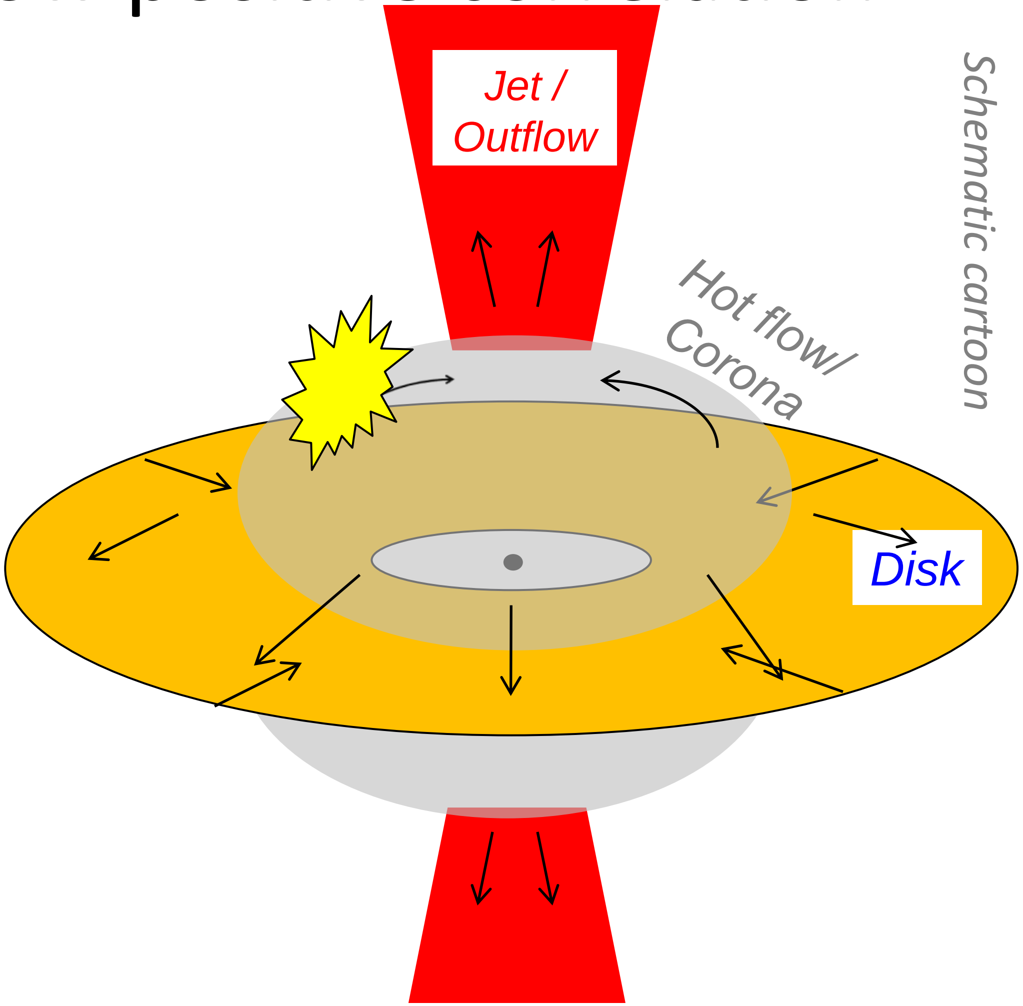
Time delay of 150 ms => ↑ <u>jet</u> optical (cyc)syn, at

1. 5000 R_G @ lightspeed, or
2. 50 R_G @ $v_{Alvenic}$, for jet poloidal field perturbations on times ~ tens x $t_{dynamical}$ ~ 100 ms; (Livio+03; Malzac+04)

Outer disc ⇨ slow positive correlation



(Gandhi+10)

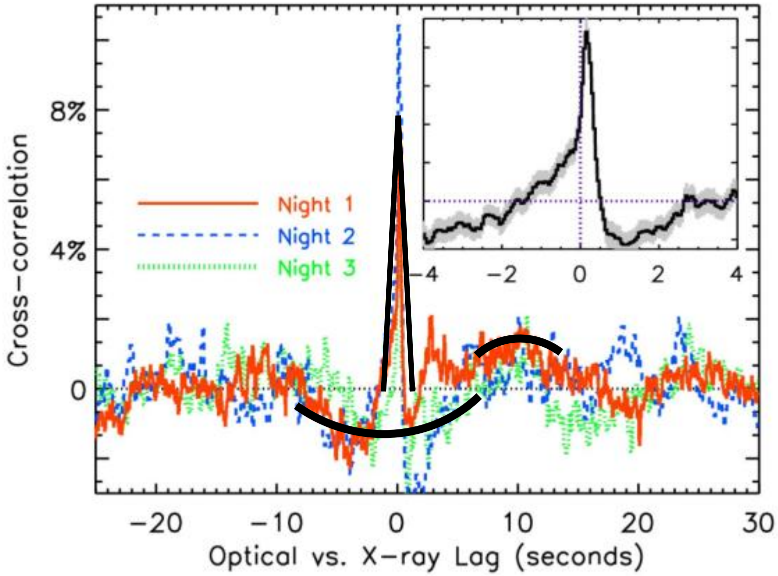


Slow delay on ~seconds time lag
=> Positive Opt/X CCF due to
reprocessing on outer disc

Inferences from CCF characteristic times

Positive correlation delay => perturbation delay from disc/corona to jet

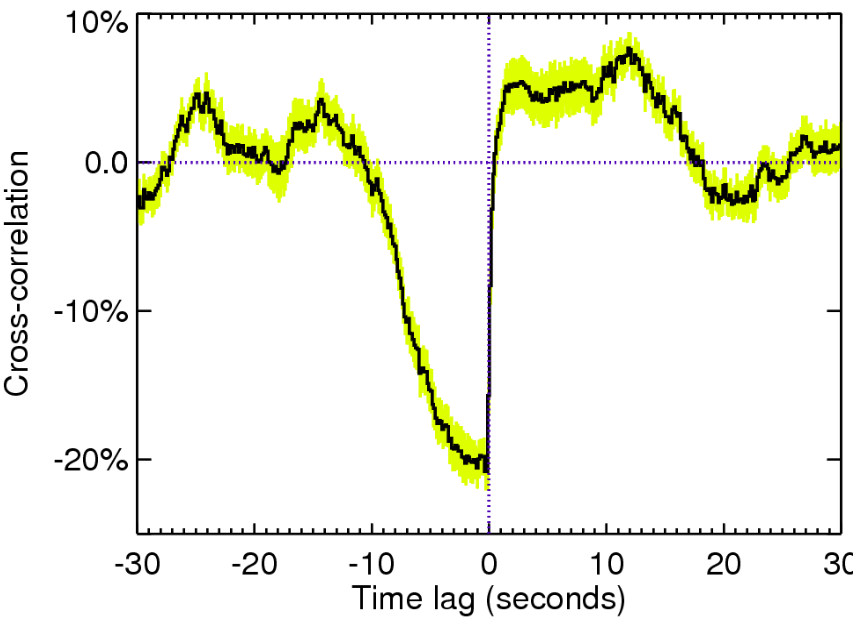
Slow positive correlation delay => constrain reprocessing in outer disc

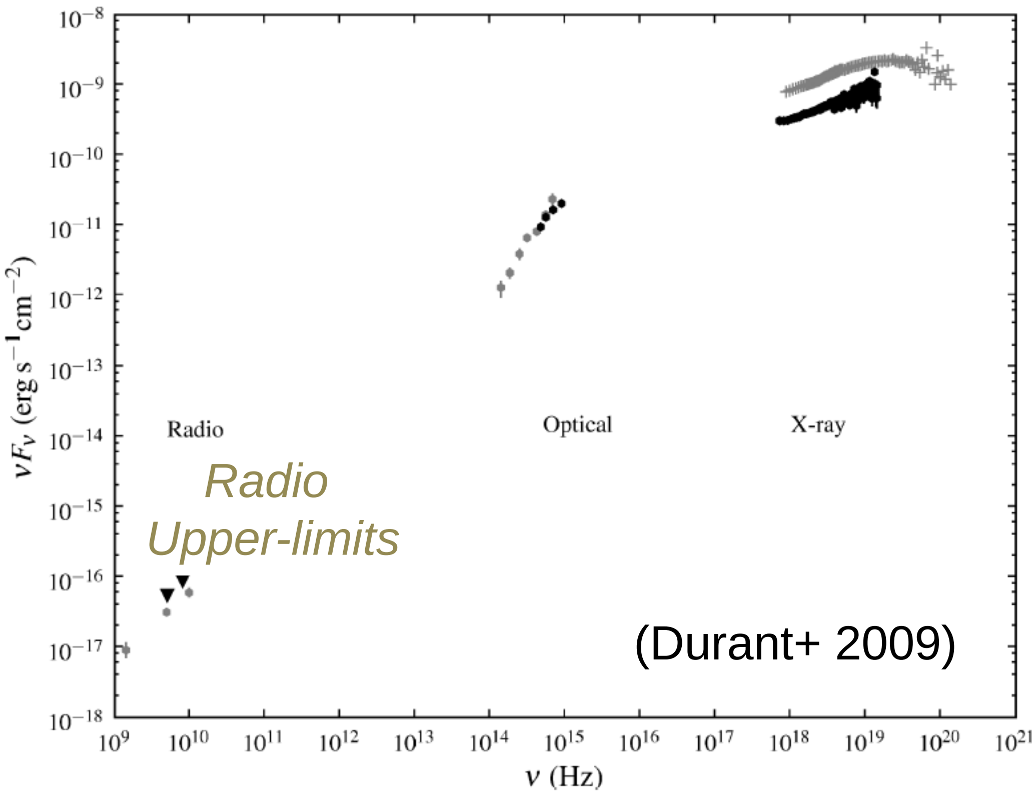


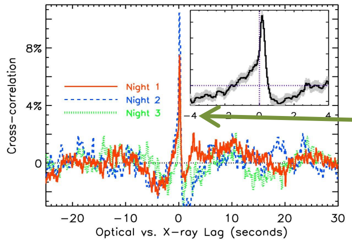
Anti-correlation time => size of corona/hot flow and/or strength of X-ray flaring episodes.

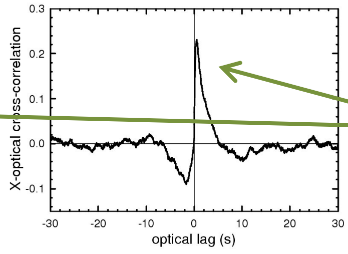
(Gandhi+10)

Swift J1753.5-0127: Weak positive CCF and faint jet



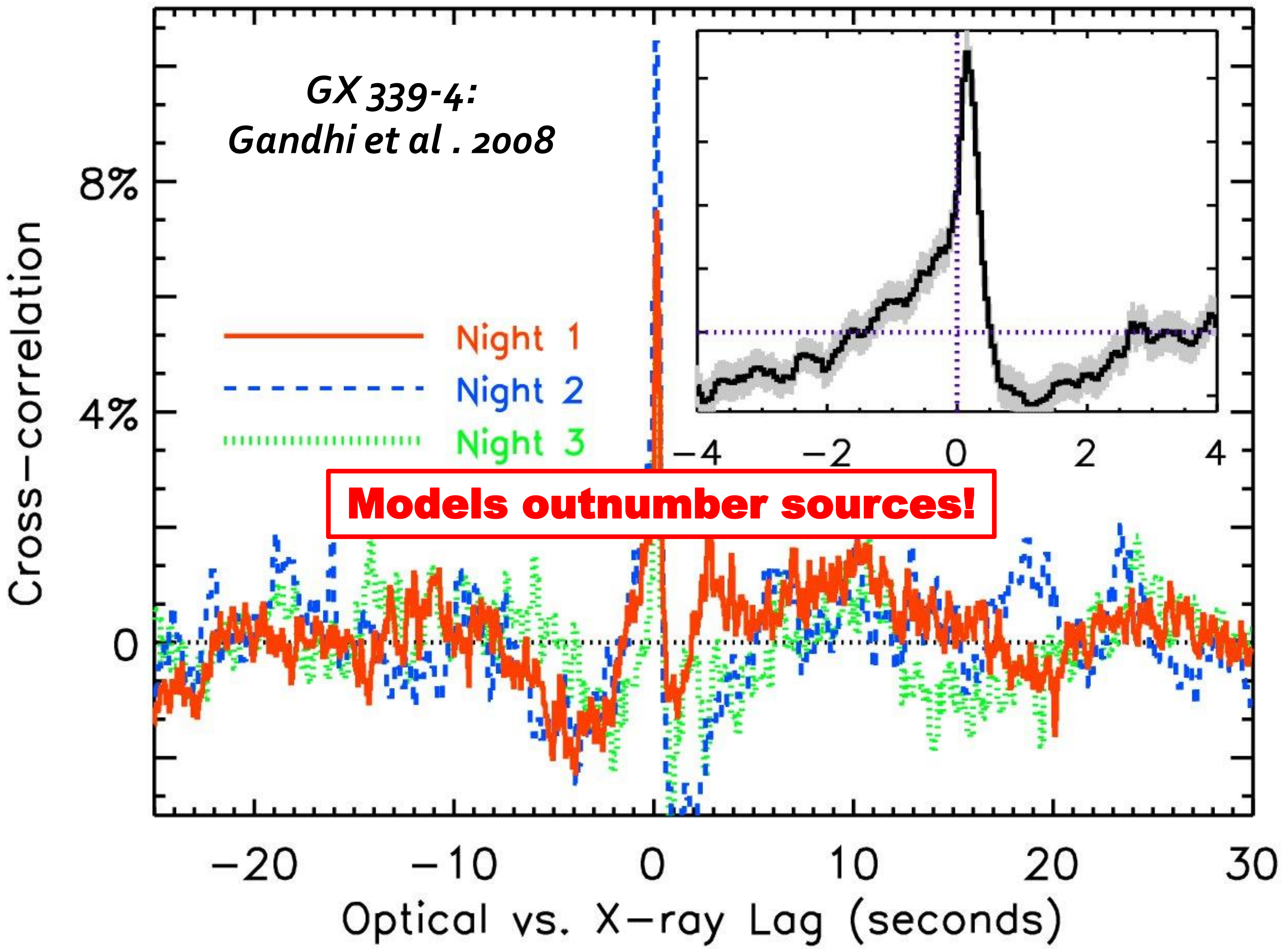




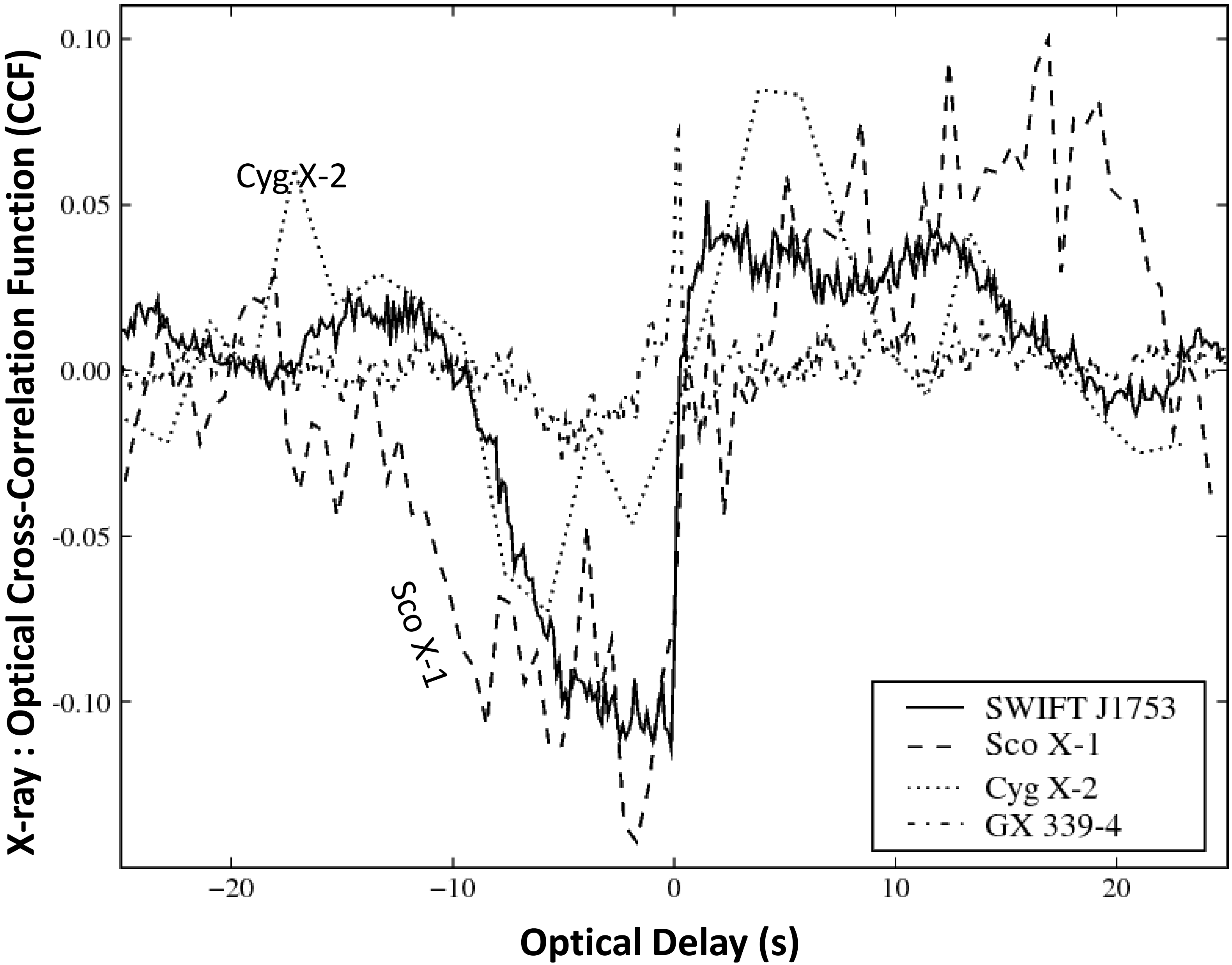


Strong jetted sources have sharp positive correlation (Gandhi+10)

Complex optical/X-ray correlations

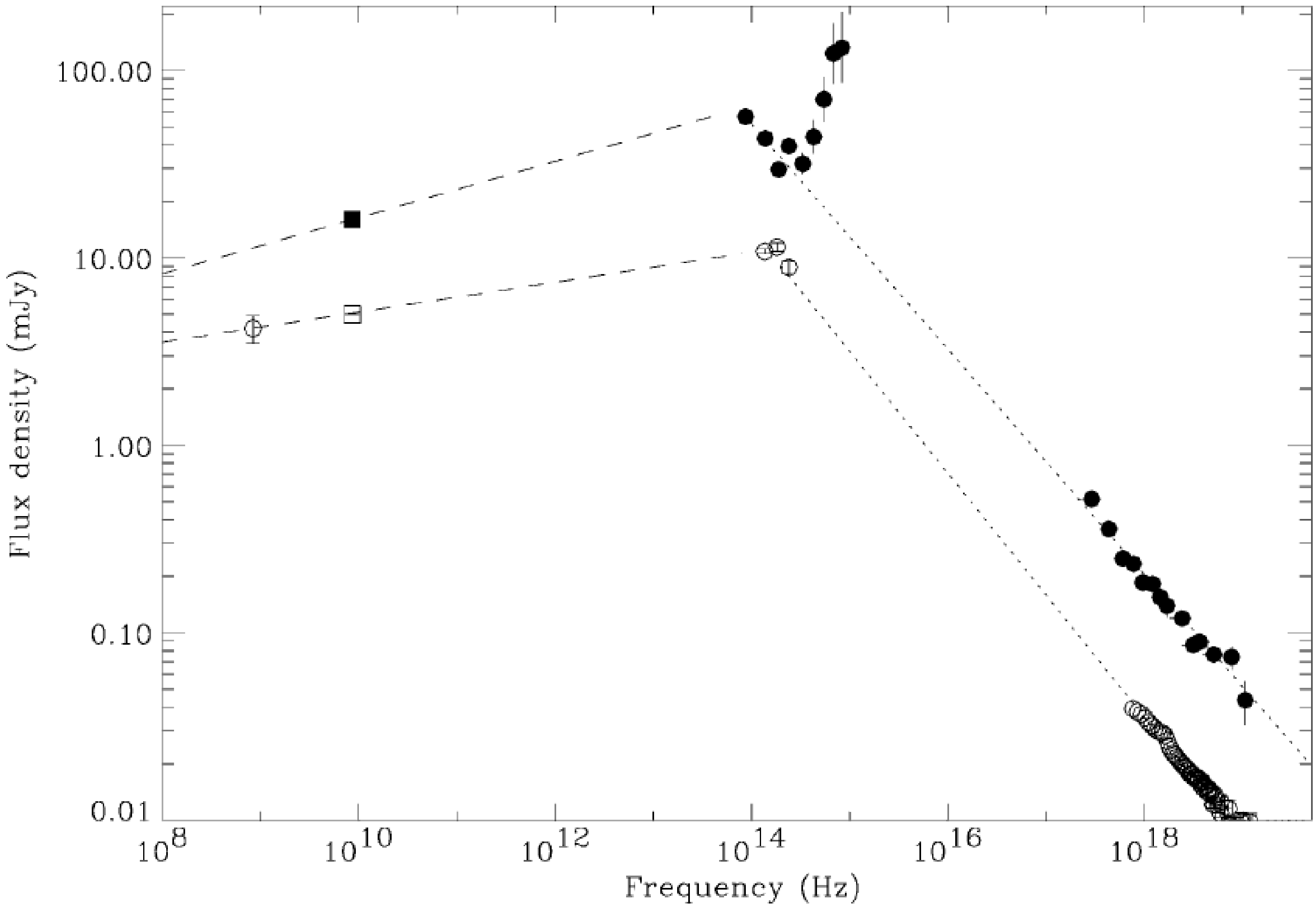


Neutron star binaries



(Durant+11)

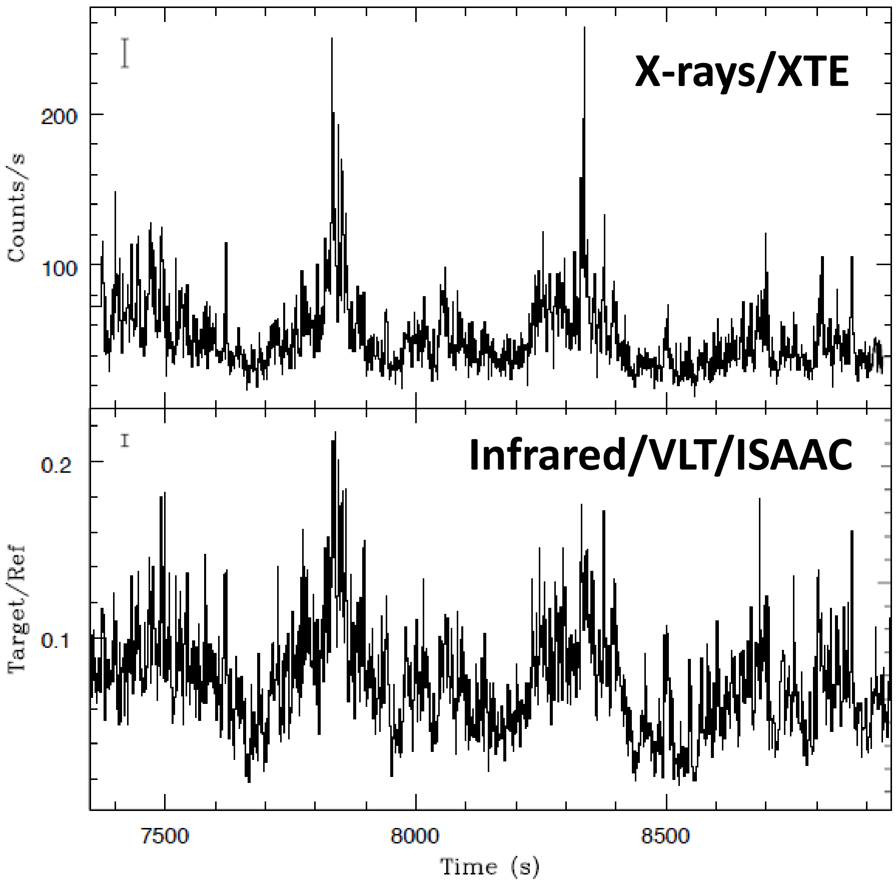
IR : clean probe of jet?



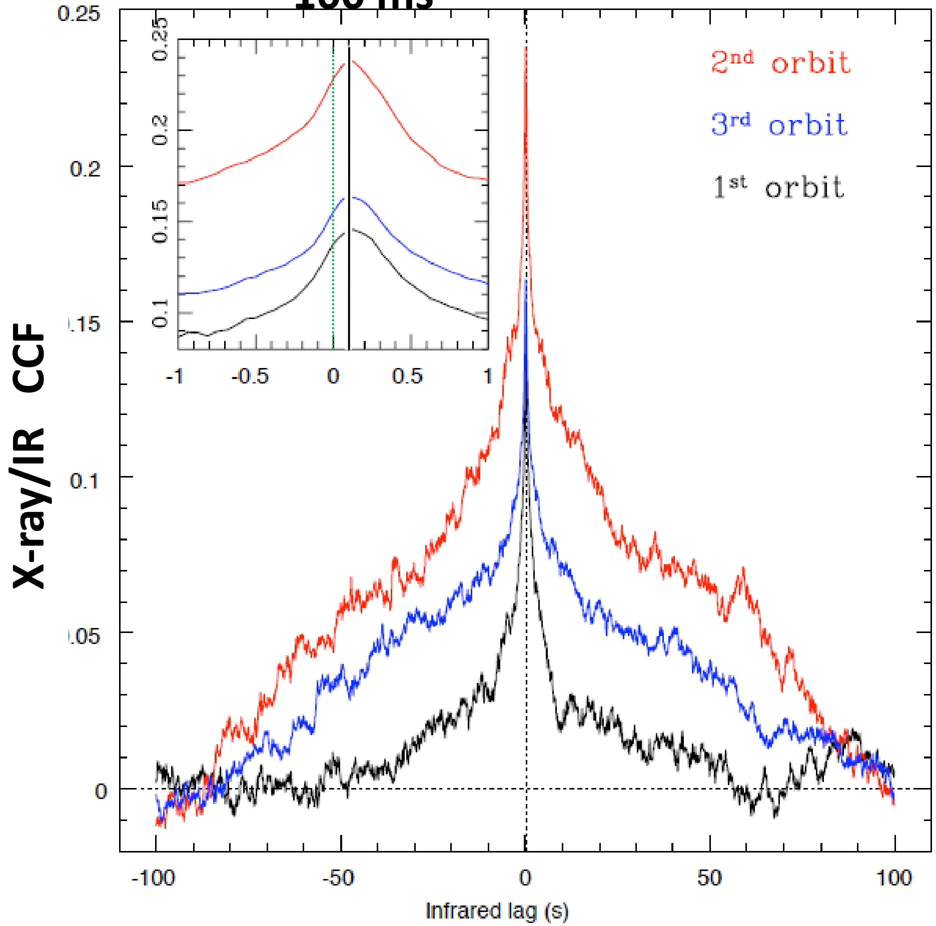
Corbel & Fender 2002

Infrared variability

GX 339-4 2008 low/hard state

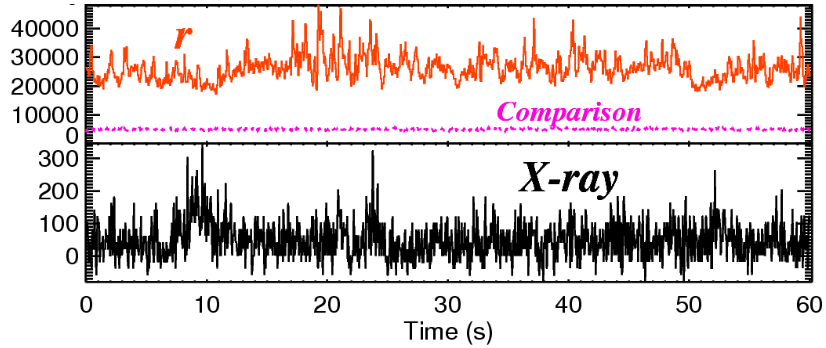


IR lag
100 ms

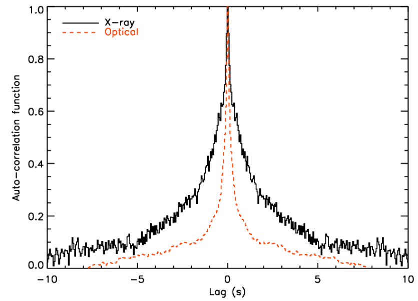


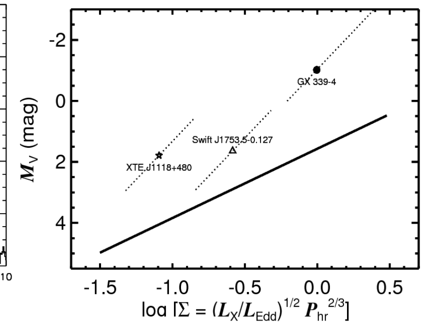
(Casella+10,
Gandhi+11 submitted)

Summary

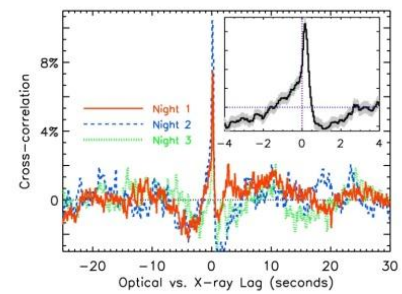


- Rapid optical flaring in low/hard state observations of several binaries.





- Optical not reprocessed simply.



- Complex CCF
  => jet/corona/disk interaction.

Multi-wavelength timing gives independent, quantitative constraints on accretion on a wide range of timescales.