

RXTE PCA Contributions to Monitoring Fast Transients

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RXTE takes data during slews.

Frank Marshall compares data to expectations based on cataloged sources; such a scan was the basis of triggering the 1998 outburst of SAX J1808.4-3658.

Target of Opportunity observations based on a low ASM flux can be confirmed by a short PCA point.

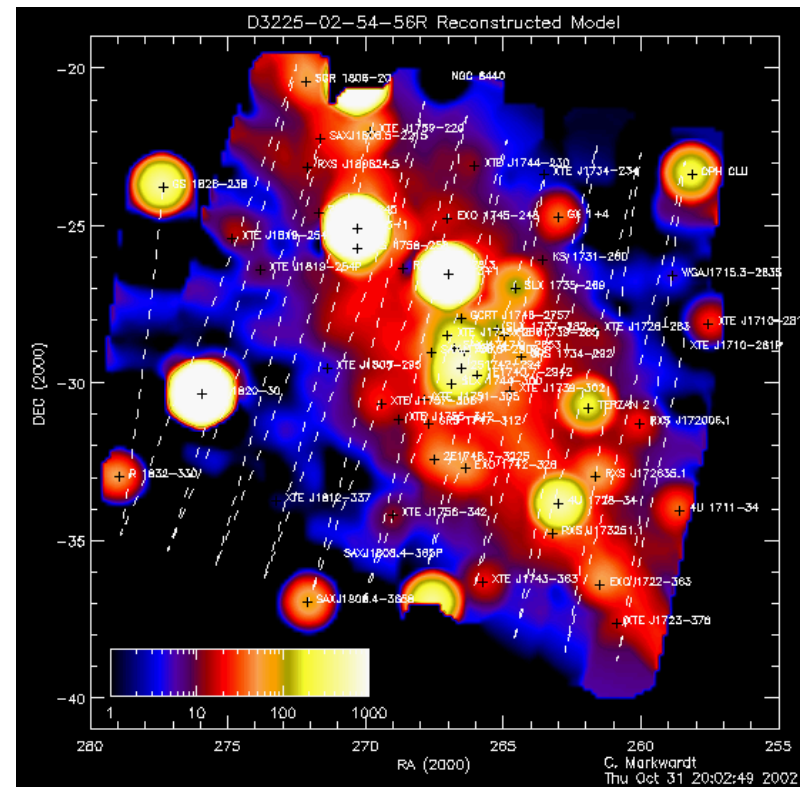
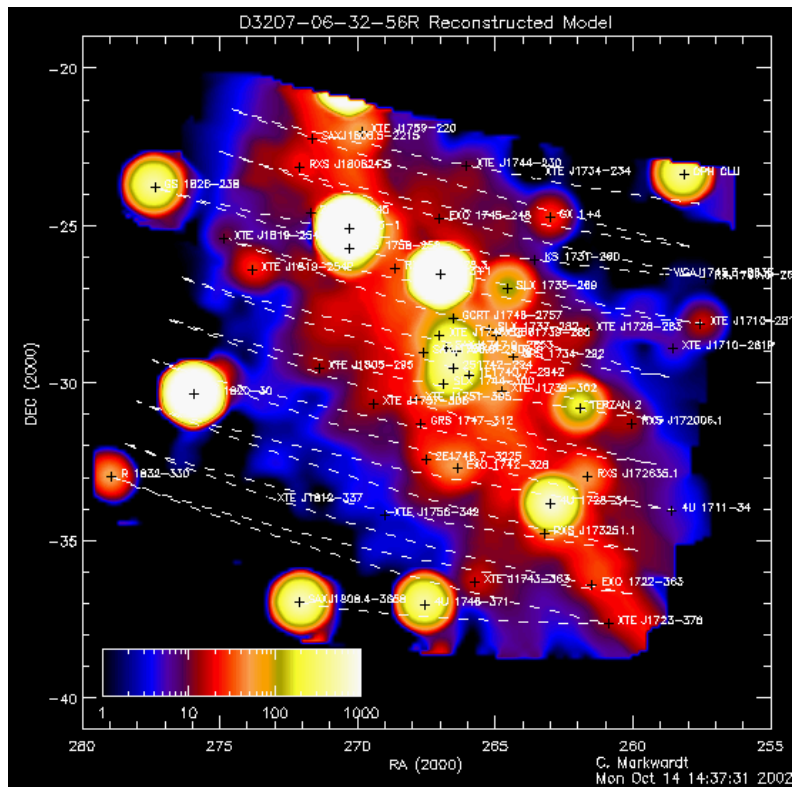
A cross scan can confirm assignment of observed flux to a point source; this is useful for sources in the galactic plane.

Monitoring for expected low intensity outburst can pin point the time; SAX J2239.3+611 was monitored for recurrence to enable a BeppoSAX observation which found 1247 s period (in't Zand et al. 2001).

We proposed Galactic Bulge scans after SAX J1808.4-3658 pulsations were discovered, to provide deeper monitoring for transients where source confusion makes the ASM less sensitive.

RXTE PCA scans of the Galactic Bulge

- Twice a week except for months when the sun is too close or too far, since 1999.
- $16^\circ \times 16^\circ$ to include bulge and take less than 2 RXTE orbits (6000s).
- 20 s to scan over a source or 3 minutes at scan endpoints.
- Reconstructed “images” are based on fits to scans.
- Fits are sensitive to sources above 0.5 - 1 mCrab, depending on position.
- Diffuse and unresolved emission are modelled.
- Bursts are generally identifiable.



Millisecond Pulsars

SAX J1808.4-3658 was discovered by BeppoSAX in 1996.

RXTE discovered 2.5 msec pulses in 1998, 18 months later.

The source was too close to the sun at start of 2000 outburst.

The next one did not occur.

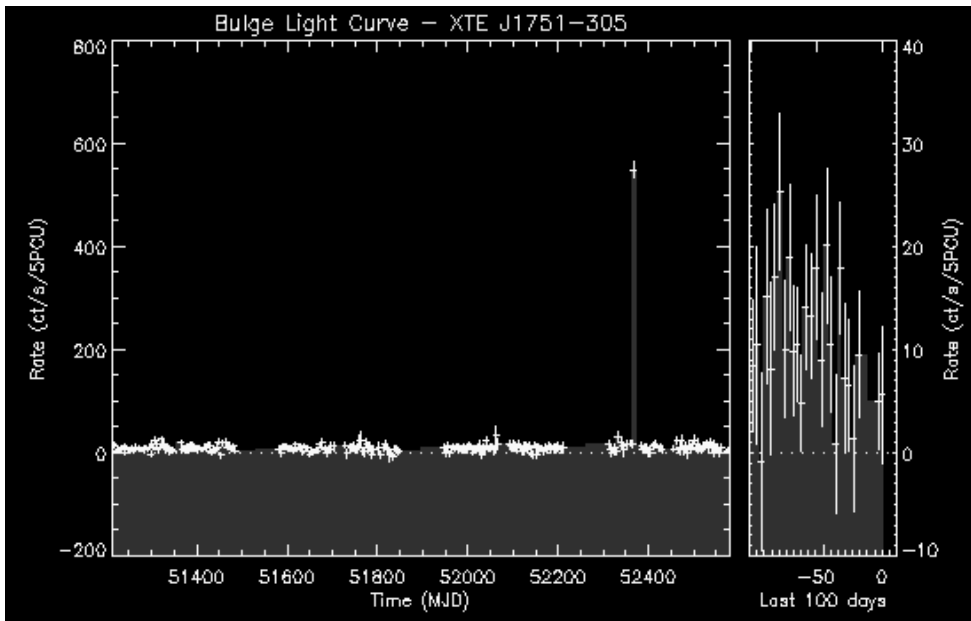
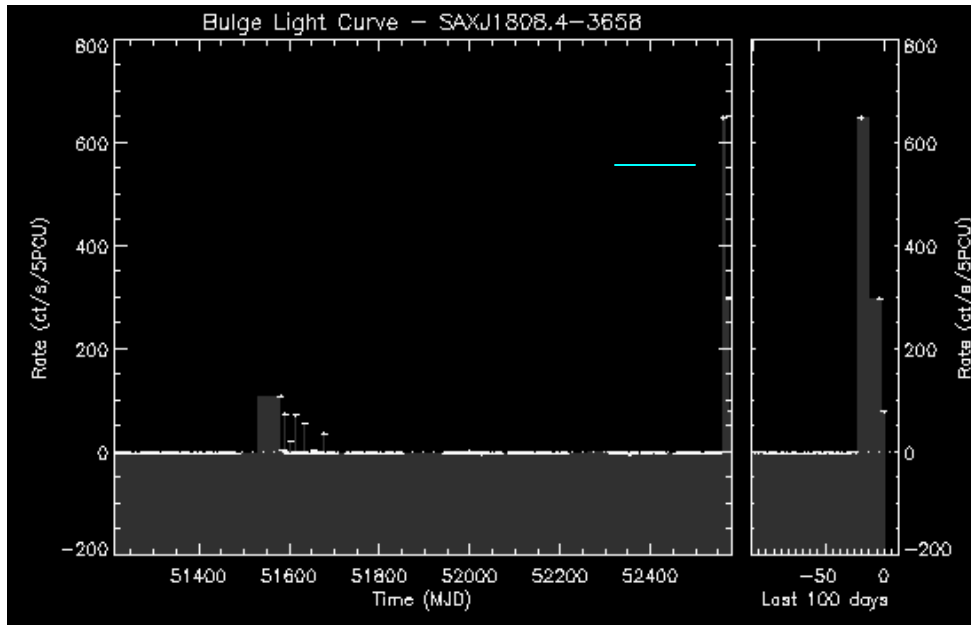
Finally, Oct 2002 in the ASM and the PCA, with pulsations making identification indisputable.

XTE J1751-305 was discovered in Apr 2002, with 2.2 msec pulsations.

Very similar, it shows that there is a class of such sources.

But a lot of other sources did not show pulsations.

XTE J0929-314, also similar, found with the ASM, not in the bulge!



3Accreting Millisecond Pulsars''

SAX J1808.4-3658

2.5ms

2.0 hr.

62.8 lt-ms

$3.8 \cdot 10^{-5} M_{\text{sun}}$ Mass function

$< 0.18 M_{\text{sun}}$ Companion mass

XTE J1751-305

2.3 ms

42.4 min

10.1 lt-ms

$1.3 \cdot 10^{-6} M_{\text{sun}}$

$0.0137-0.0174 M_{\text{sun}}$

XTE J0929-314

5.4ms

43.6 min

6.3 lt-ms

$2.7 \cdot 10^{-7} M_{\text{sun}}$

$0.01 M_{\text{sun}}$

2.5 kpc

1.5 yr

13-14 d peak-break

$4.6 \cdot 10^{36}$ ergs s^{-1}

$1.7 \cdot 10^{35}$ ergs s^{-1} av

7 kpc

3.8 yr

10 d peak-break

$2 \cdot 10^{37}$ ergs s^{-1}

$1.4 \cdot 10^{35}$ ergs s^{-1} av

6 kpc

>6.5 yr

>30 d peak-break

$8 \cdot 10^{36}$ ergs s^{-1}

$6.3 \cdot 10^{34}$ ergs s^{-1} av

Wijnands & van der Klis

Chakarabarty & Morgan

Brown dwarf?

Markwardt et al.

He white dwarf?

Galloway et al.

He white dwarf?

Census of Bulge Scan Sources

62 sources are in the current fit list, including:

18 XTE

6 SAX

4 GRS

3 SLX

3 EXO

6 RXS

+ 4U, 2S, GS, 1E, NGC, SGR².

(Many were seen by more than 1 mission and which name we use may be “accidental”.)

~ 31 of these are transient (not there at the 3 sigma level at some time).

~ 31 have been on always - the light curves complement the ASM's;

would make triggering on anticipated behavior easier,

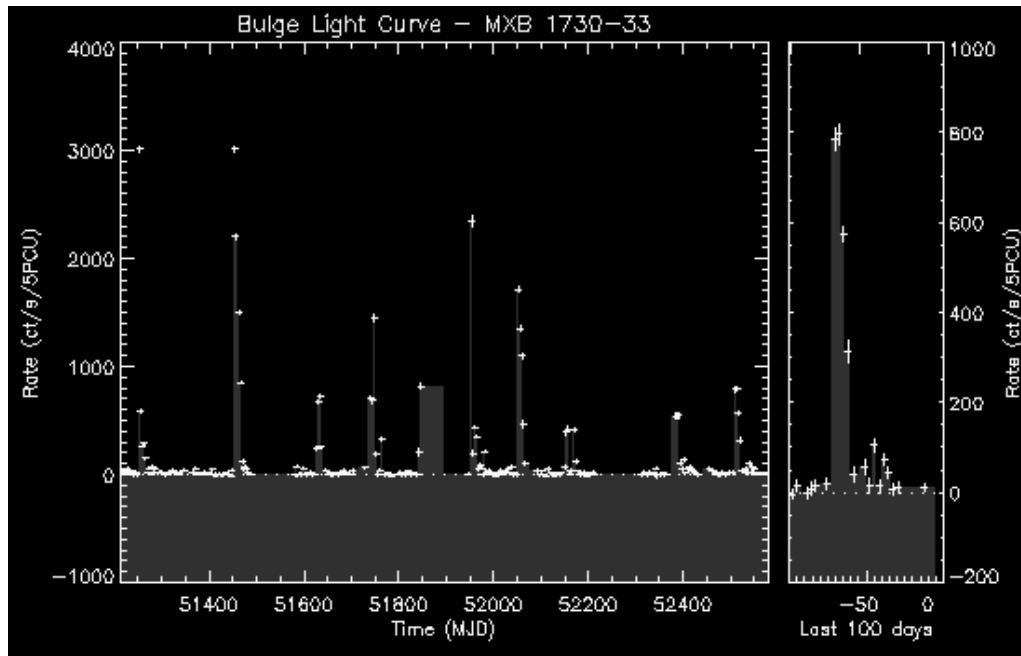
but except for eclipses their behaviors are erratic.

“Not there” only means $< 10^{35} - 10^{36}$ ergs s⁻¹ at 4-12 kpc.

How many of previously seen transients in the region have been seen?

“XTE” sources presumably were bright before, but escaped notice.

27 known to be neutron stars; 5 black hole candidates.

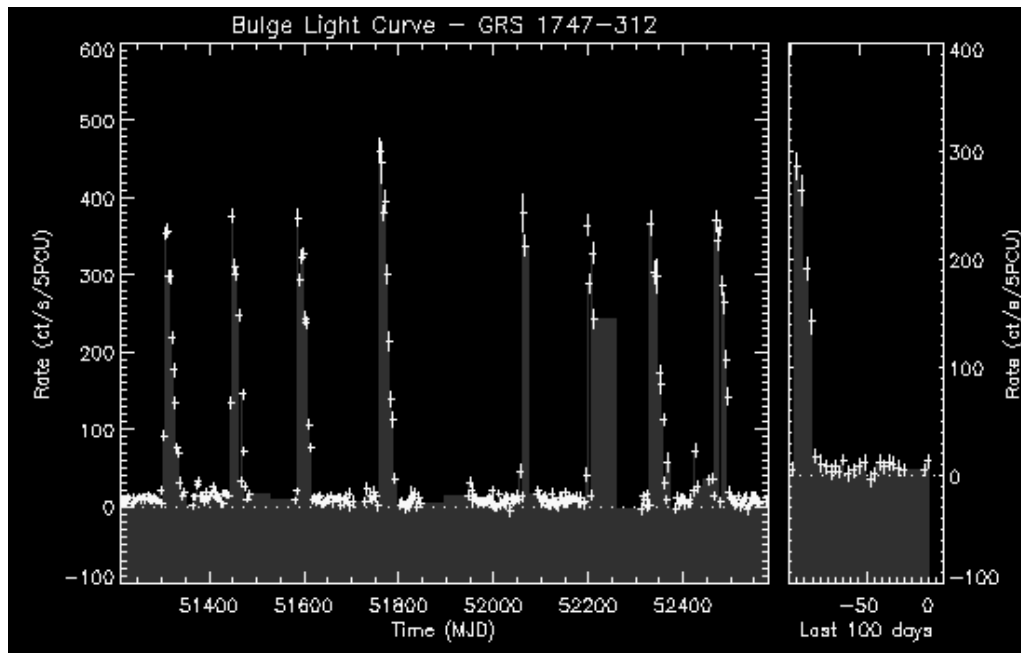


**Shortest Recurrence Times
of Transients: 150-200 days
lasting only ~ 20 days**

**Rapid Burster persistent flux
(does not include burst flux).**

**Chandra saw 2 nearby members.
of Liller 1; could brighten too
(Homer et al. 2001).**

2×10^{38} ergs s^{-1} .



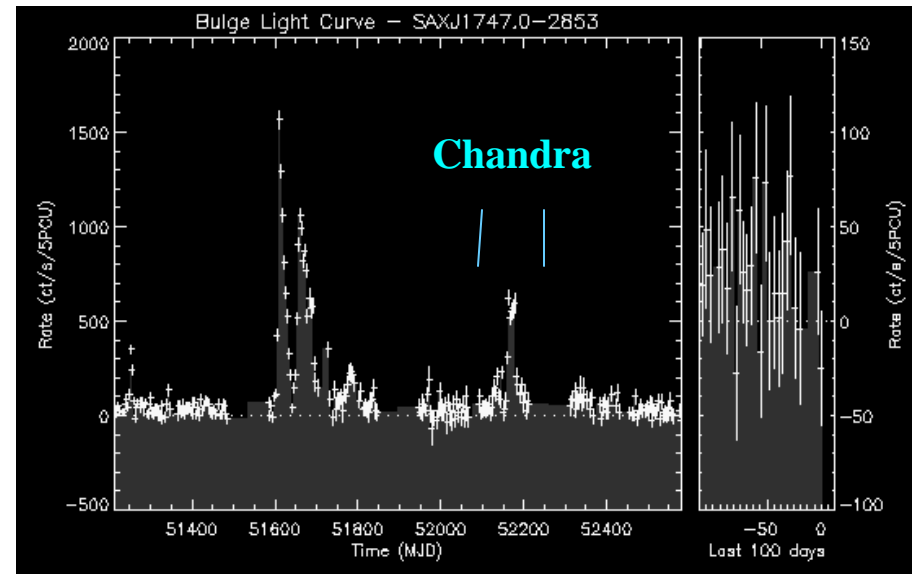
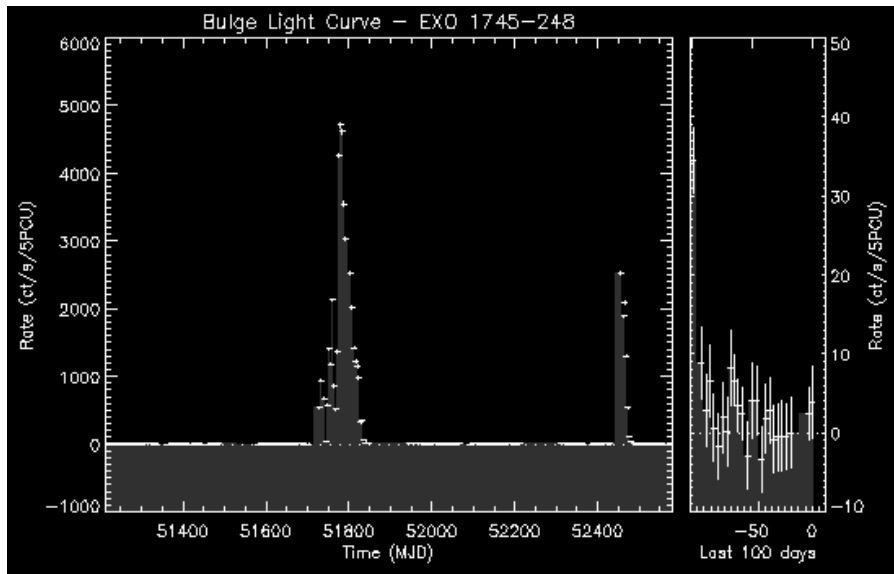
GRS 1747-312 in Terzan 6

**12 hr eclipsing binary (in't Zand
et al 2000).**

7×10^{36} ergs s^{-1} at peak.

Bursts? Is the neutron star seen?

**Is the persistent source faint
because of being seen edge on?**



**“Typical” Transients: 3 Bursters with 100-200 day outbursts
2-20 yr apart; fast rise, slow fall. Oscillations are common.**

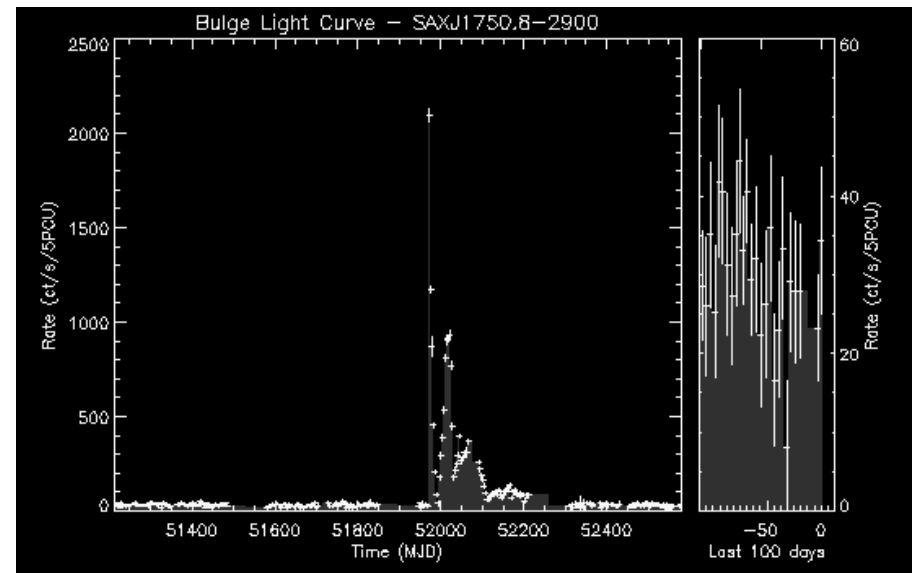
EXO 1745-248 7.6 kpc (Terzan 5)

SAX J1747-2853 9 kpc (bursts, Natalucci 2000; Wijnands 2002); maybe quiescence is still 2×10^{35} ergs s.

SAX J1750-2900 < 6.3 kpc (Natalucci et al. 1999; Kaaret 2002) 601 Hz burst oscillation, 543-1017 Hz oscillations.

Factor of 3 range in peak luminosity and duration. Peaks are $0.3-1.0 \times L_{\text{Edd}}$.

Bounces in persistent flux of outburst.



KS 1731-260 turned off, after 12.5 yrs of accreting and bursting.

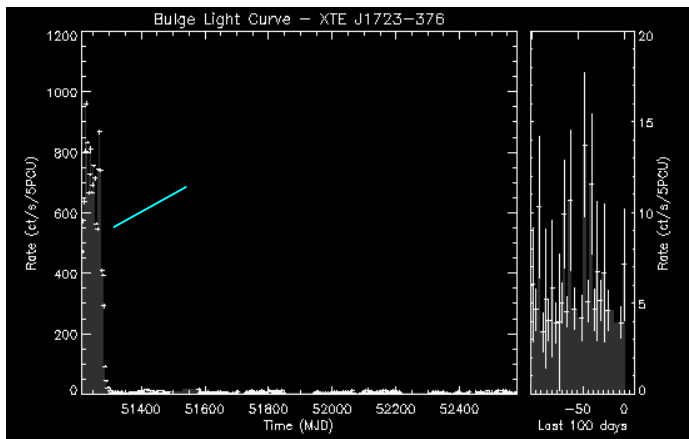
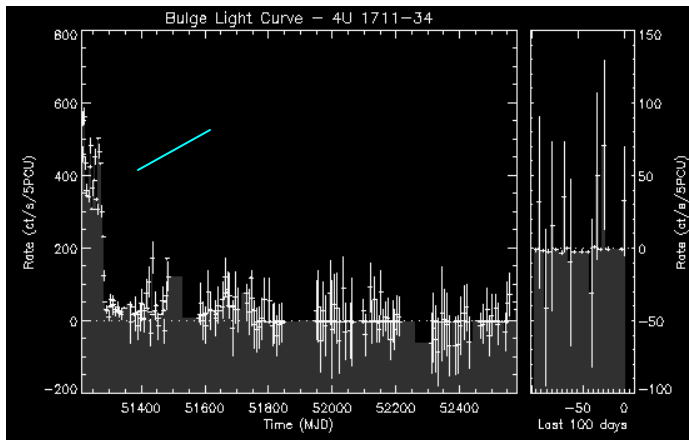
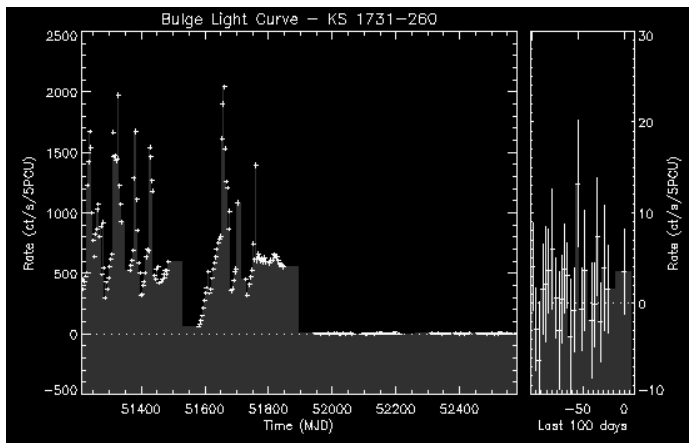
Theory implied that with standard cooling, the flux and temperature would decline slowly (Rutledge 2002) .

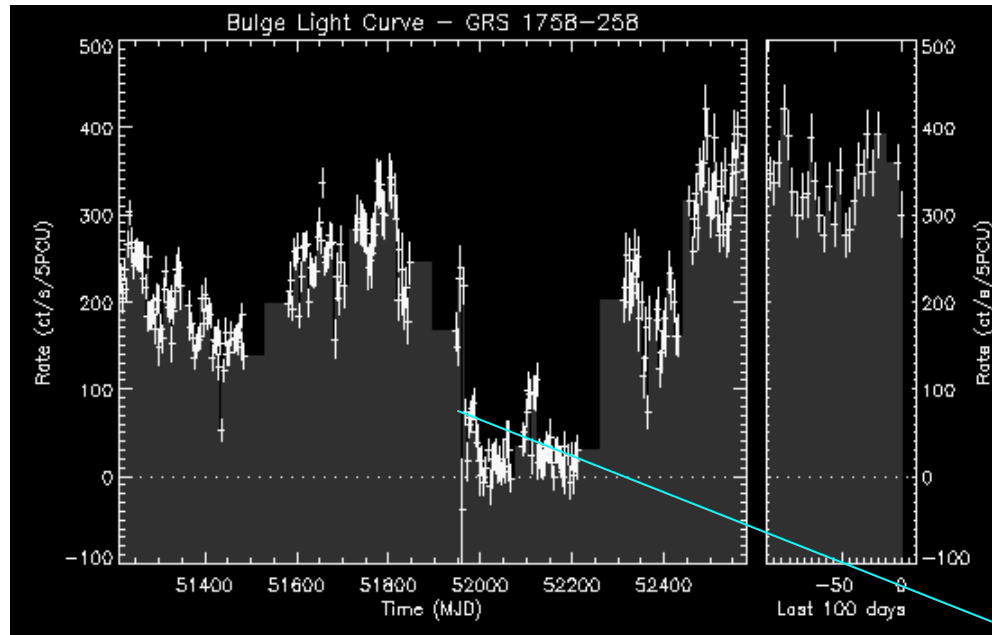
Chandra and XMM-Newton observations (Wijnands 2001,2002) found the fluxes to be about 13×10^{-14} and 5×10^{-14} ergs $\text{cm}^{-2} \text{s}^{-1}$; low levels imply enhanced core cooling (with enhanced neutrino production?).

10^{33} ergs s^{-1} upper limit to thermal emission is 2 orders of magnitude less than implied by SAX 1747.0-2853 or 2S1742-294, which have outbursts, but probably do not completely cease accreting in between.

4U 1711-34 and XTE J1723-376 were detected by the ASM (50 mCrab) as well; they turned on about 200 days before the PCA observations began.

What causes sudden declines?





Black Hole Candidate Dips

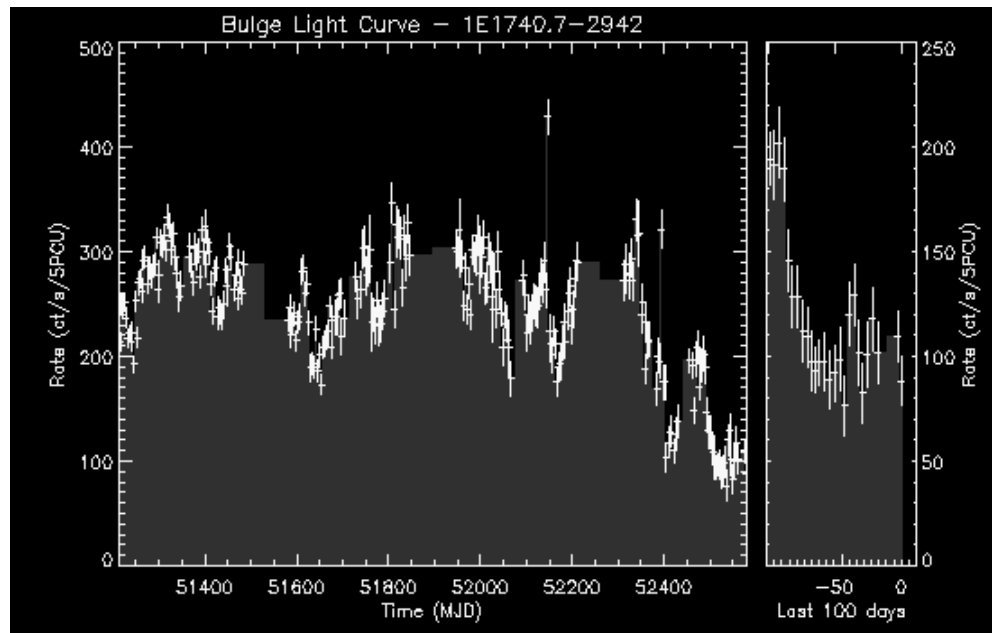
GRS 1758-258 300 days

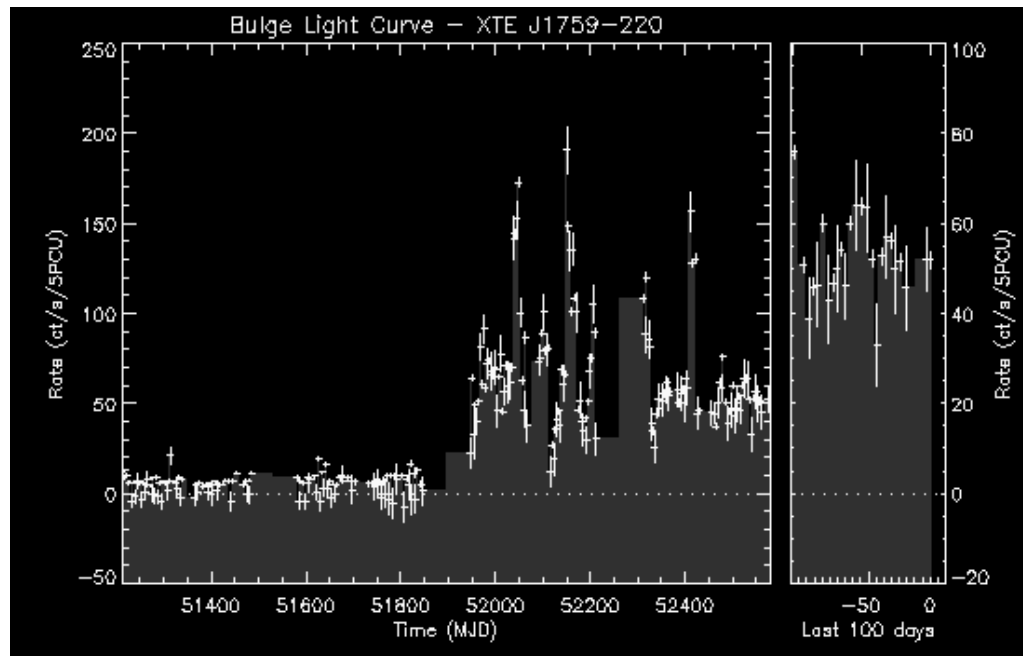
Smith et al. (2000).

1E1740.7-2942 > 50% dip.

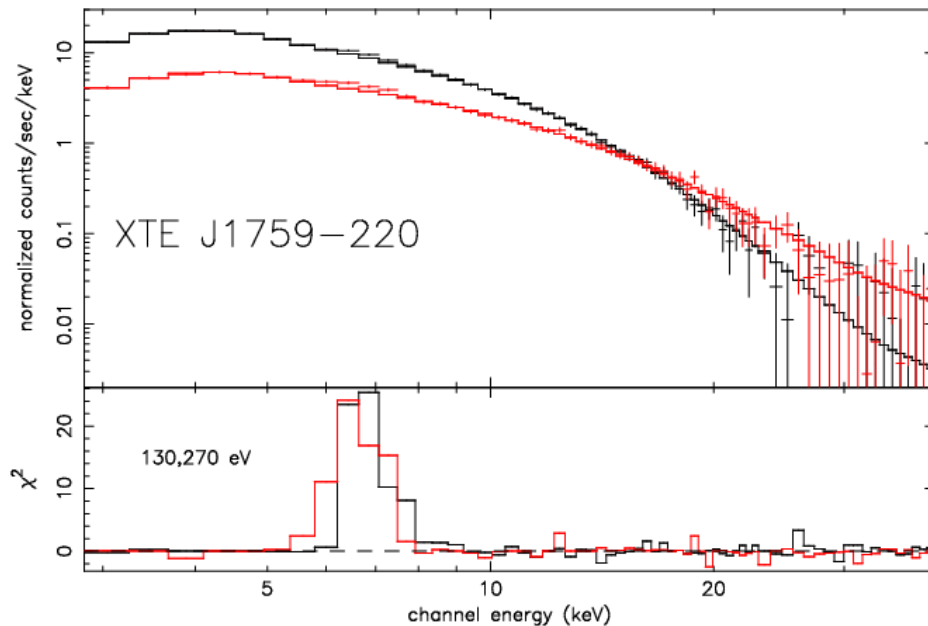
Long term monitoring program obtains spectral and temporal information.

Loss first of hard power-law component, followed by drop-off of soft disk component.





Data and Folded Models



XTE J1759-220 turned on 2 years ago, Feb 2001.

Variability similar to KS 1731-260 (but 5 times weaker).

Short observations saw no neutron star bursts, pulsations, or QPO.

Strong spectral variations.

Model fits are not unique, but consistent with disk and powerlaw components.

Photon index 2.9-1.9 when low.

Fe K emission at 4 sigma.

Suggests black hole candidate.

No evidence for any QPO.

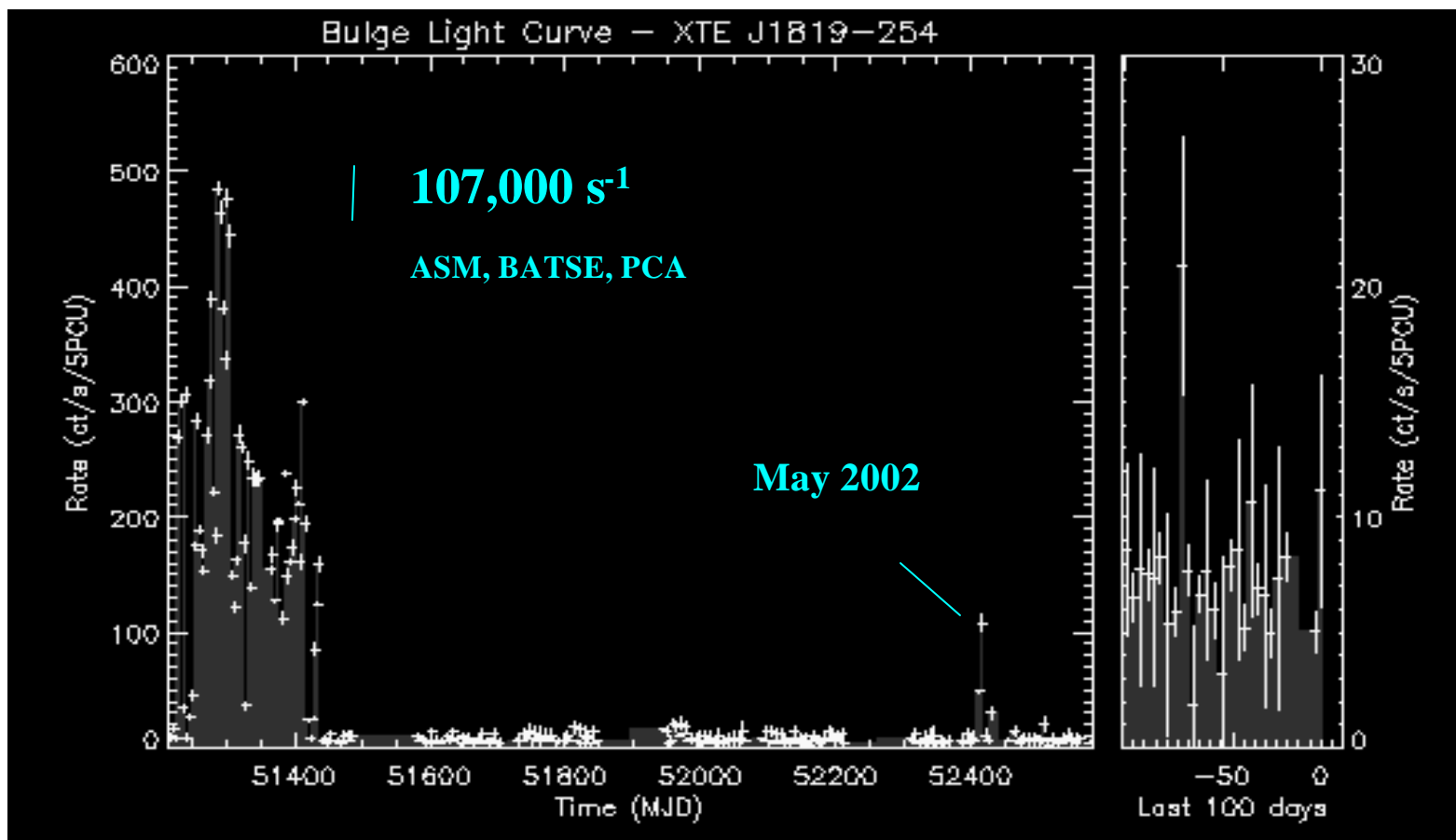
V4741 SGR

XTE J1819-254 found 1/2 yr before intense flare in optical, xray, radio.
(See Revnivtsev et al. 2002)

Erratic variations made target of opportunity observations difficult.

Flare level > 2 times Eddington for black hole mass about $10 M_{\text{sun}}$.

1-10 mCrab indications of further flow onto the black hole in May 2002 .



Characteristics of the Transients

Recurrence times of the transient outbursts range upward from 1/2 year.

Duration of outburst is (roughly) correlated with peak luminosity in the same object and probably from object to object. Caveats:

**Rapid Burster and GRS 1747-312: similar durations, different luminosities;
XTE J1751-305 vs SAX J1808.4-3658: shorter, but higher luminosity.**

Many faint transients with distance estimates (from bursts or globular cluster membership) are just distant, not low luminosity at peak or low average dM/dt .

For some orbital periods both persistent and transient binaries exist, with dM/dt probably too high ($> 10^{-11} M_{\text{sun}} \text{ yr}^{-1}$) for post-minimum period binaries.

During transient decays the disk goes through instabilities (flux bounces). Perhaps interaction with the pulsar and the magnetosphere are involved.

Other instabilities besides the thermal-viscous disk instability may cause the flips between quiescence and steady accretion.

Several sources have had variable accretion in the range 10^{34} - 10^{35} ergs s^{-1} for years, while others have 10^{32} - 10^{33} ergs s^{-1} and must cool quickly.

Some of the transients may be black hole candidates, in which case black holes can have at least some of the same characteristics as neutron stars. This still needs proving; none is identified and has a dynamical mass (V4641 exceptional).

Composite Evolutionary Scenario

The history of binary formation and evolution leads to a distribution of binary periods and Roche lobe filling companion masses (e.g. Podsiadlowski et al. 2002).

Higher mass companions and larger orbits with larger accretion disks produce higher accretion rates and longer recurrence times.

Various endpoints are predicted and should be represented among the observations. Are faint transients a special class (Heise & in't Zand 2001) or is there a continuous distribution?

The dM/dt can be driven (partly) by other forces than gravitational radiation. Roughly the border between transient and steady accreter is in accord with van Paradijs' predictions (1996), but there must be complications.

The millisecond pulsar binaries are close to the predictions. (Irradiation and magnetic interactions still need to be included.)

Post minimum systems (proposed by King (2000) as the faint transients) may have such low dM/dt that they may be Millisecond Radio Pulsars instead (Bildsten & Chakrabarty 2001), or they may be among the among the low persistent emission burst sources that BeppoSAX discovered (Cornelisse et al. 2002).

It is becoming realistic now to investigate these possibilities.