

Exercises Stellar Transients

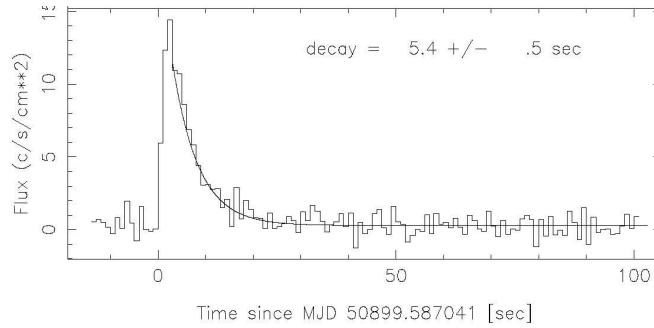
Useful numbers

These numbers may be useful when solving the exercises.

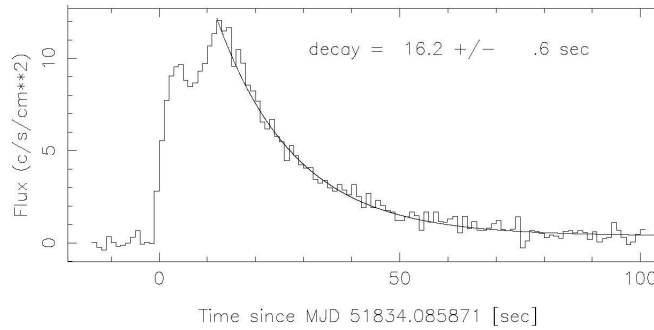
Solar mass	M_{\odot}	$1.99 \cdot 10^{33}$ g
Solar luminosity	L_{\odot}	$3.85 \cdot 10^{33}$ erg s ⁻¹
Parsec	pc	$3.086 \cdot 10^{18}$ cm
Speed of light	c	$2.998 \cdot 10^{10}$ cm s ⁻¹
Gravitational constant	G	$6.673 \cdot 10^{-8}$ erg cm g ⁻²
Mass of proton	m_p	$1.66 \cdot 10^{-24}$ g
Energy	1 eV	$1.602 \cdot 10^{-12}$ erg
	1 erg	10^{-7} Joule

Exercise 7: X-ray burst time profiles

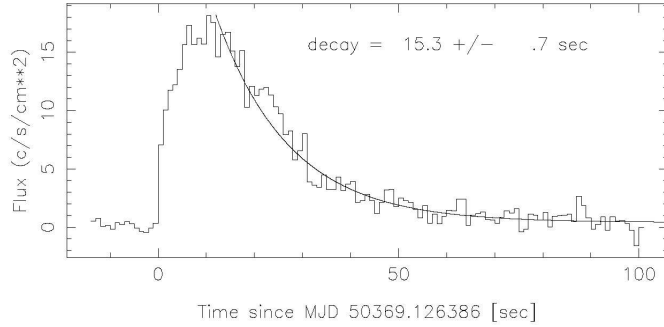
Evaluate each of these light curves (**a**, **b**, **c**, **d**, **e**), assessing qualitatively the content of the hydrogen participating in the flash and the possibility that photospheric radius expansion (PRE) is occurring.



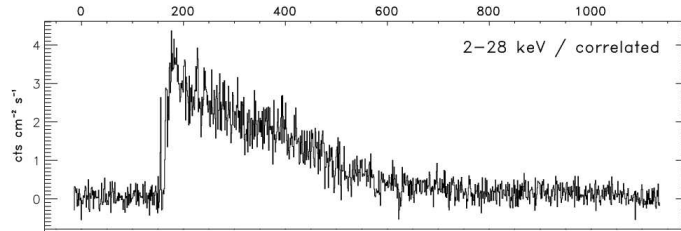
a.



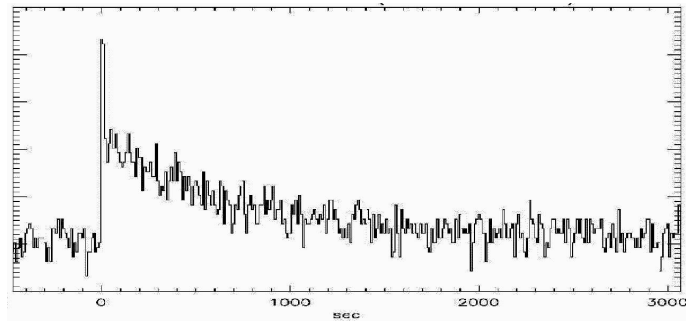
b.



c.



d.



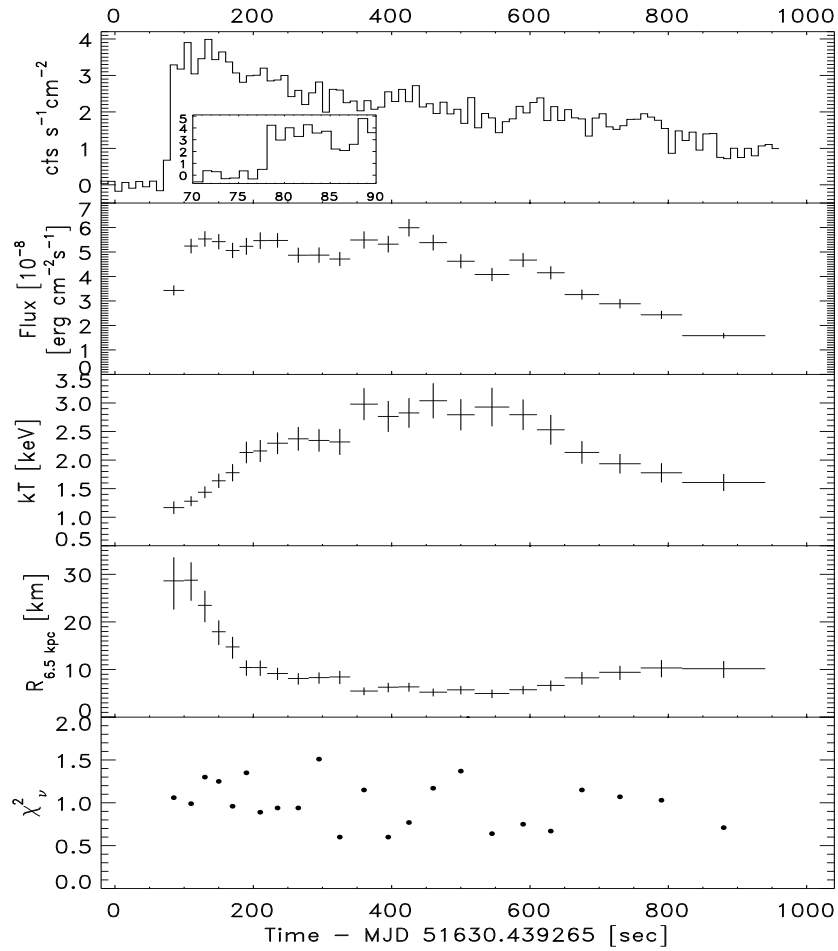
e.

f. Why is it not possible from these plots to provide a definitive answer about PRE?

g. PRE may last from a few seconds to minutes. What does the duration of a PRE phase suggest about the nature of the flash?

Exercise 8: Analysis of a long X-ray burst

Let us study a particular burst whose time-resolved spectroscopy is plotted in the Figure. The top panel shows the observed photon rate in a 2-30 keV bandpass, with the inset showing the rise in detail. The noise in this plot is statistical in nature. The second panel shows the bolometric flux extrapolated from the black body fits to the spectrum of every time bin. Obviously this burst exhibits a long phase of PRE.



- a. Estimate the total energy output based in the bolometric flux depicted in the second panel and a distance of 6.5 kpc. Assume that the flux continues its exponential decay ($\tau=600$ s from 450 s after the burst onset on) .
- b. This is a LMXB which has been detected since the 1980s with a constant approximately bolometric flux of $1.2 \cdot 10^{-10}$ erg/s/cm². Infer the expected recurrence time as a function of the α -parameter.
- c. If the source was observed for a total of 15 million seconds distributed over 100 observations in 10 years, how many bursts like these would be detected? Is it a surprise that only one was detected?
- d. This burst is rather long. Some might argue long enough for a superburst. Why are they wrong?

- e. The PRE phase lasts fairly long. The longevity may either be due to high hydrogen content or an energetic helium flash. Based on the long PRE phase and the consecutive decay phase, assess which possibility is more likely.

Exercise 9: Dependence of X-ray bursts on neutron star (NS) parameters

- a. Predict trends in burst recurrence time and energy as a function of NS mass, assuming that the heating by the crust core and accretion remains the same.
- b. Do the same for NS radius.

Exercise 15: Novae vs. X-ray bursts

Argue that in both novae and X-ray bursts the released energy through nuclear burning per gramme of burnt matter is of the same order. Estimate this quantity, and use it to explain why nova explosions eject most of the accreted matter and X-ray bursts do not.