An Extraordinary Outburst Of The Magnetar SWIFT J1822.3-1606

[ApJ, 2015, 809, 152]

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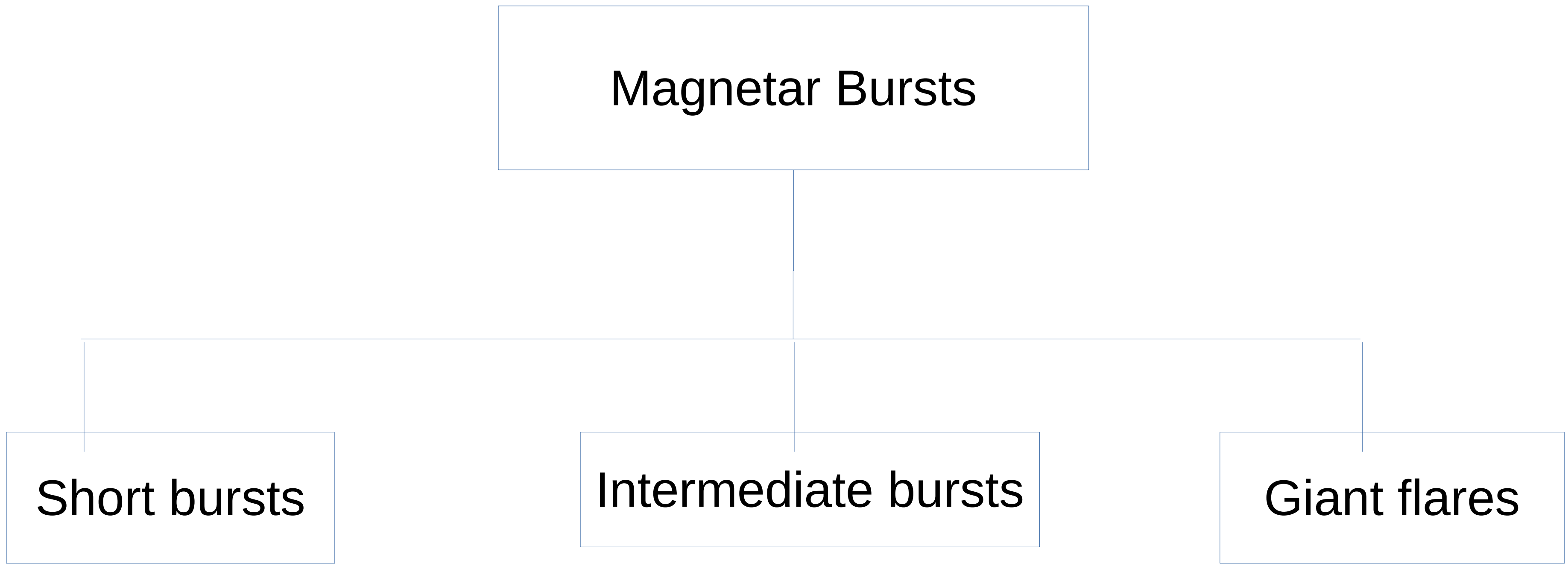
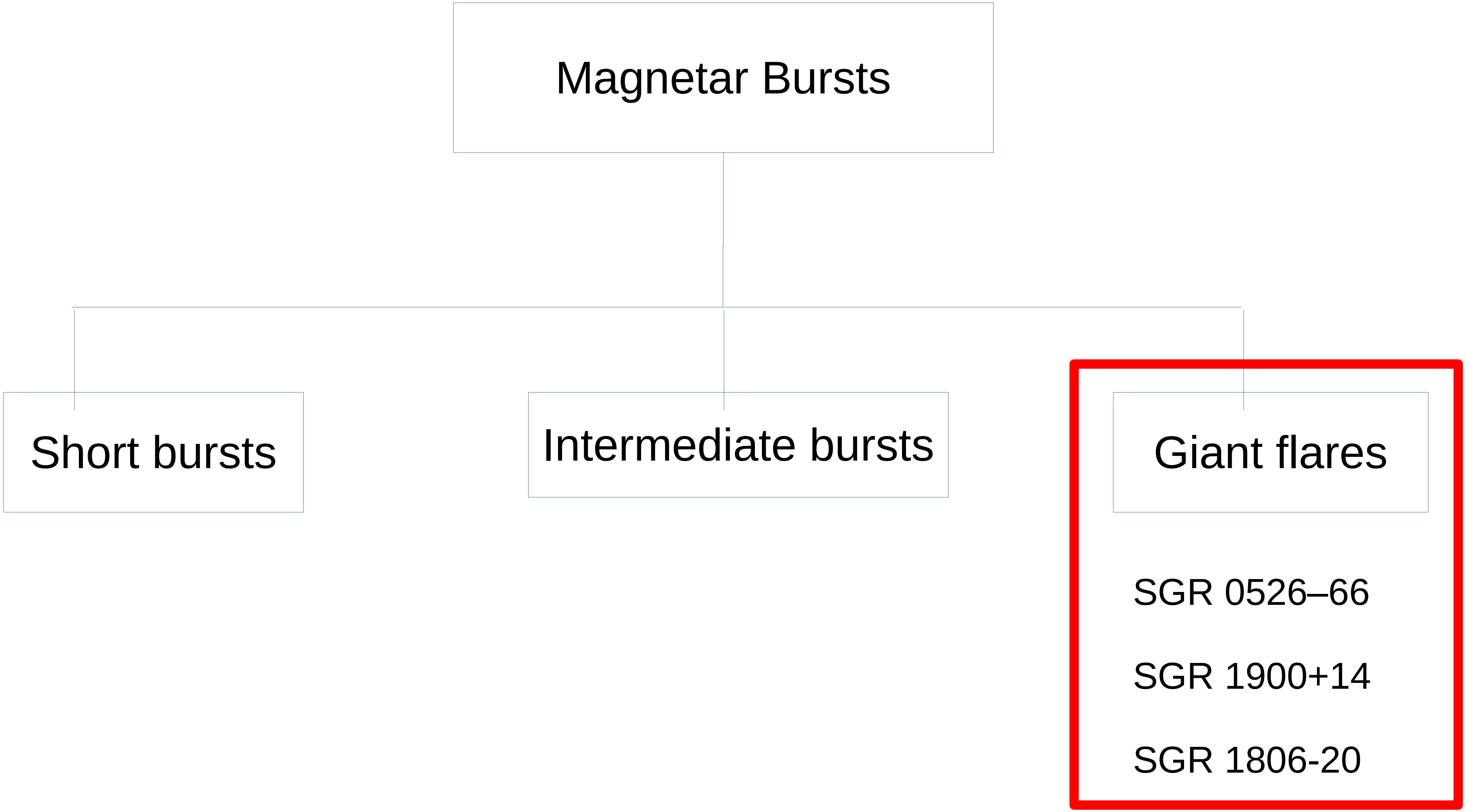
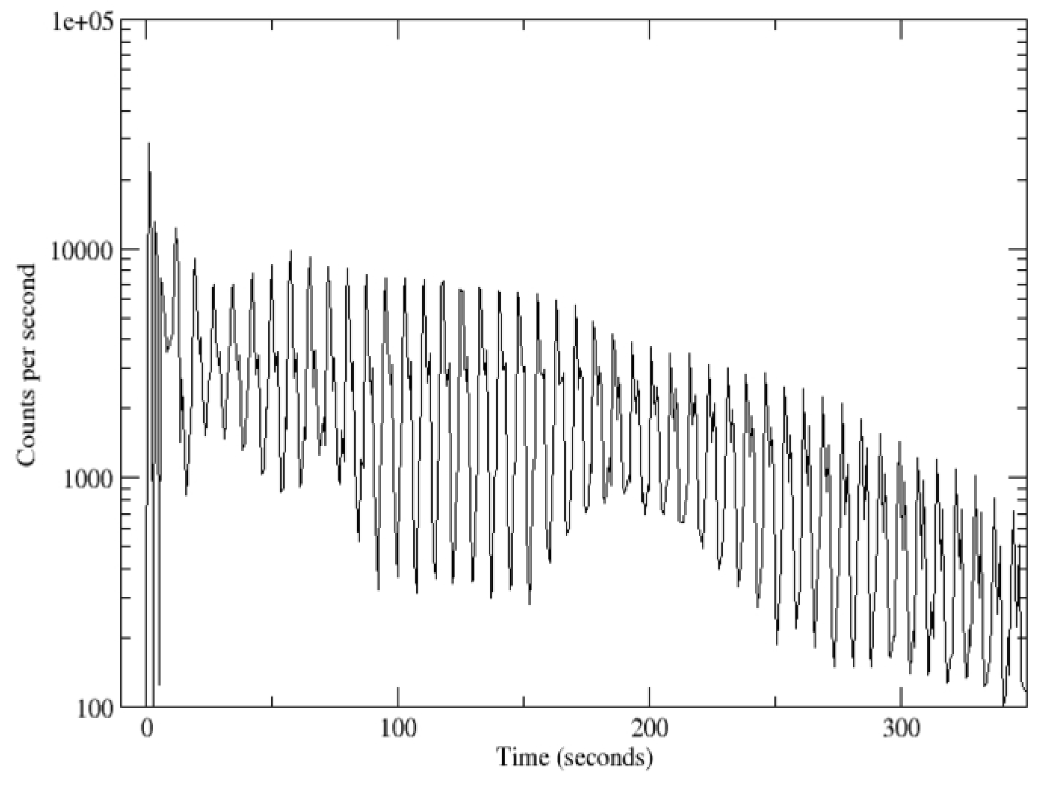

Magnetar Bursts
Short bursts
Intermediate bursts
Giant flares

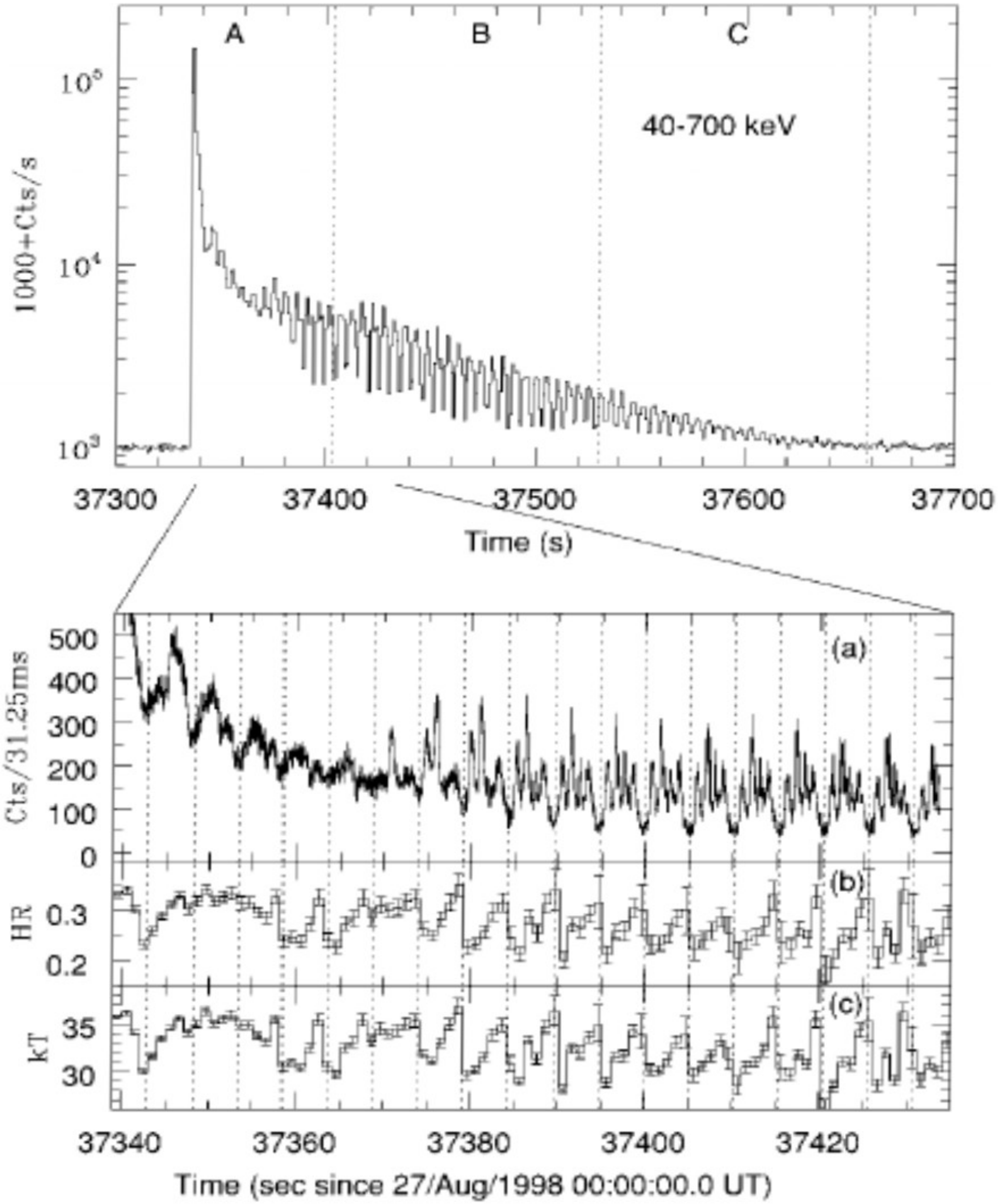

Magnetar Bursts
Short bursts
Intermediate bursts
Giant flares
SGR 0526–66
SGR 1900+14
SGR 1806-20

Giant Flares

- Lasted for minutes
- Peak flux reaching upto 10^{46} erg/s
- Luminosity ~ $10^{45} – 10^{47}$ erg/s
- Hard spike ~ 1 sec
- Few 100 s long tail
- Periodic modulation clearly observed during the tail
- Possibly due to the global fracturing of neutron star crust or global scale magnetic field reconnection



SGR 1900+14: August 27 giant flare

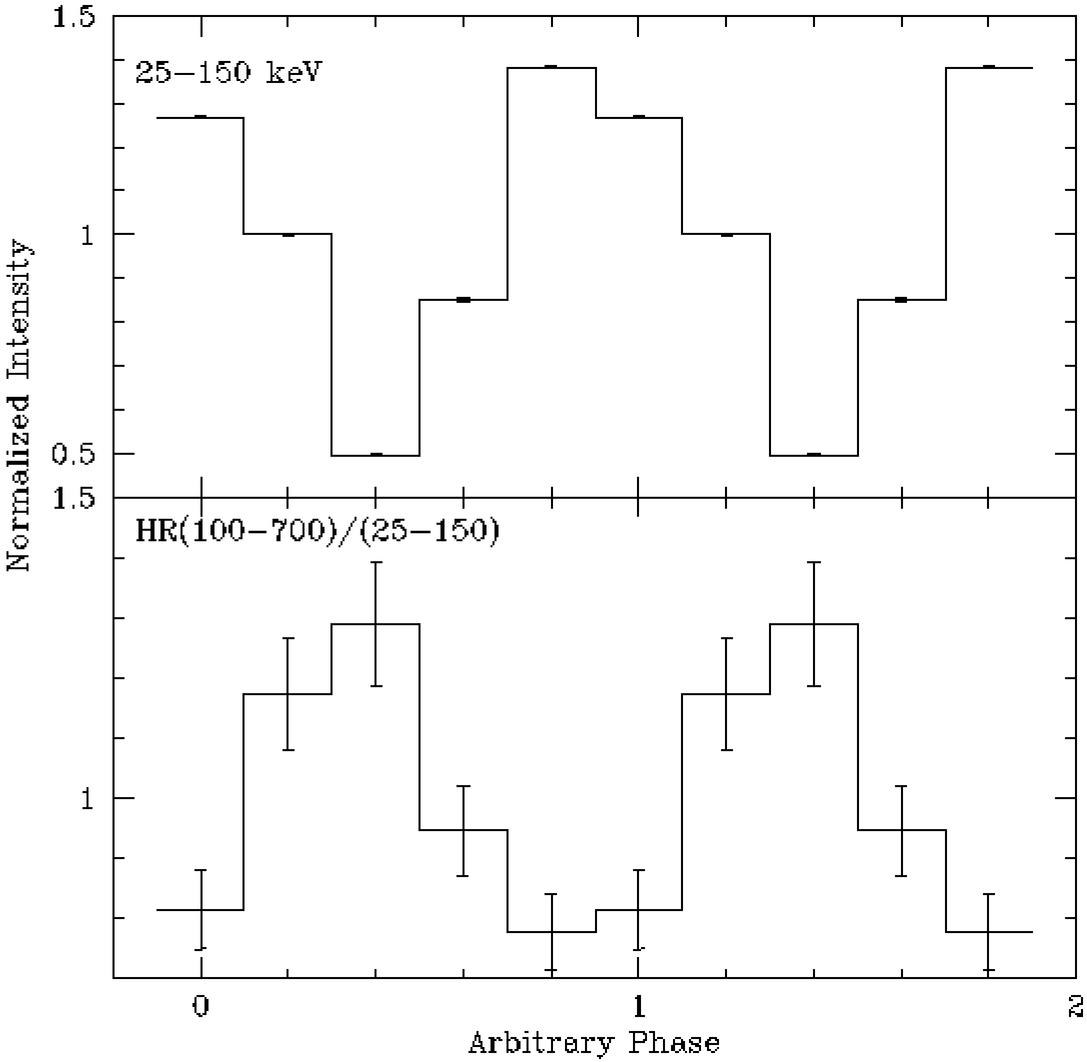


Ramp or 'see-saw' like patters observed in the hardness ratio

(Possibly due to acceleration of non-thermal particles or due to Comptonization by Alfven waves in the extended corona)

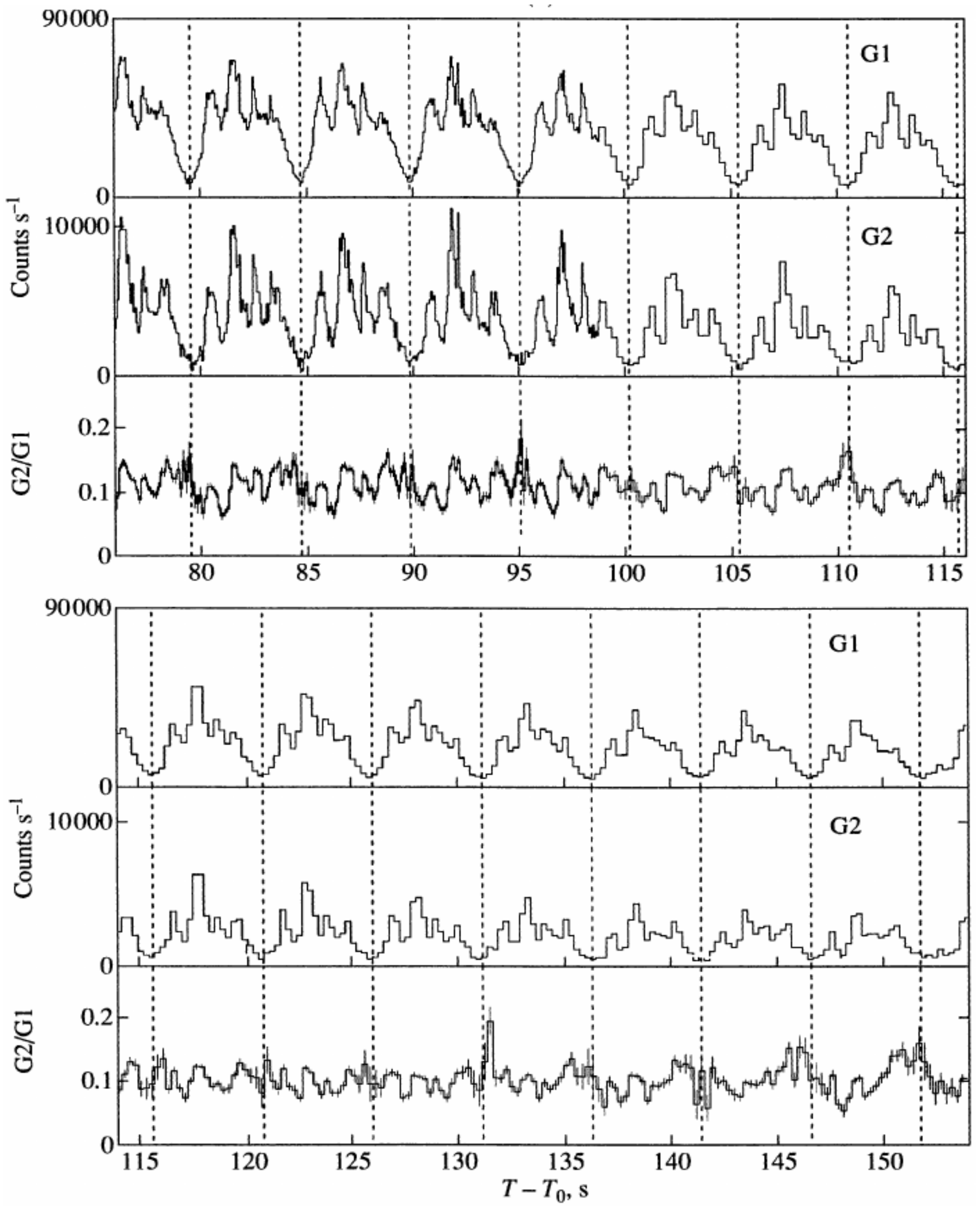
Feroci 1999

Giant flare: profile intensity and hardness-ratio anti-correlation



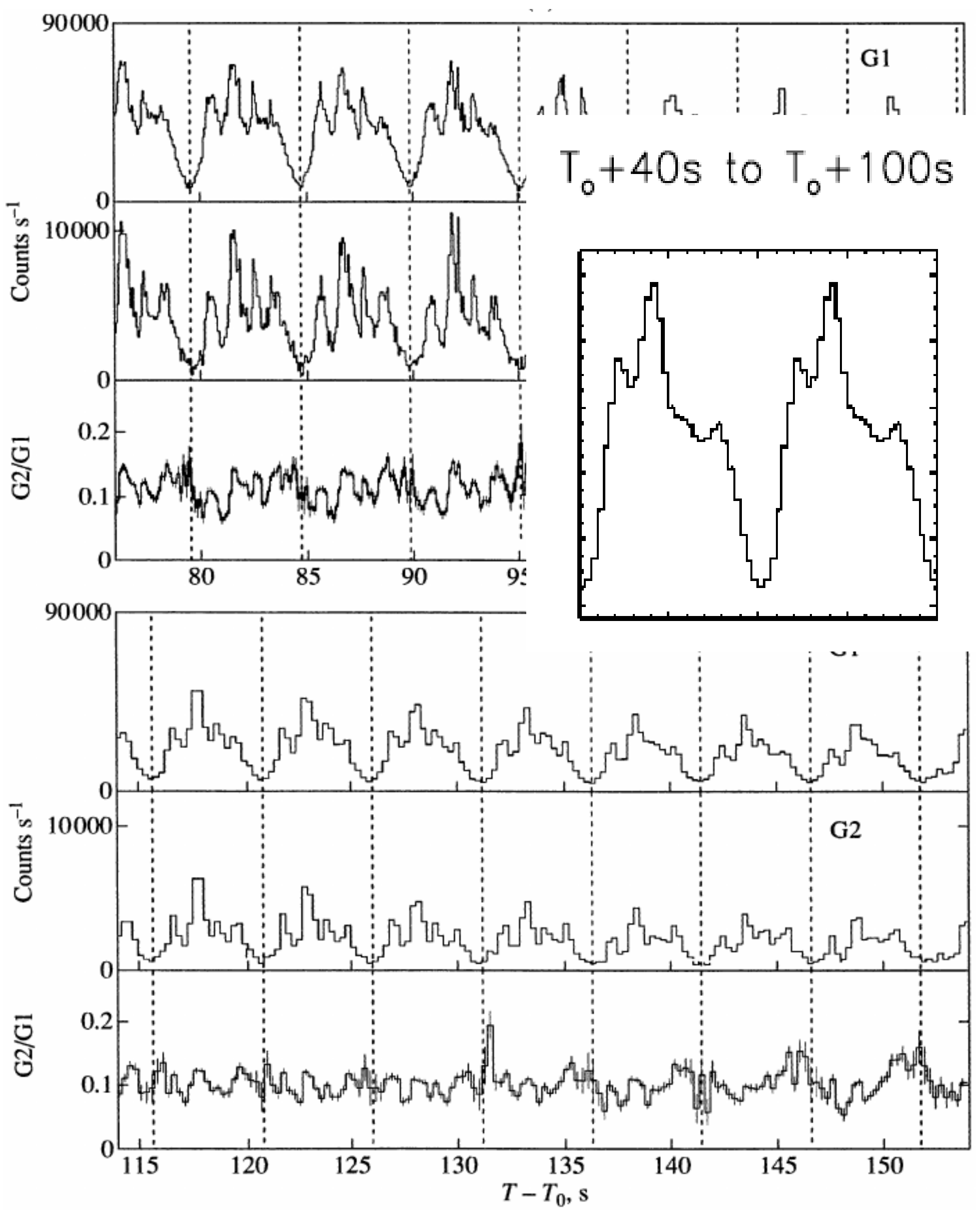
Feroci 2001

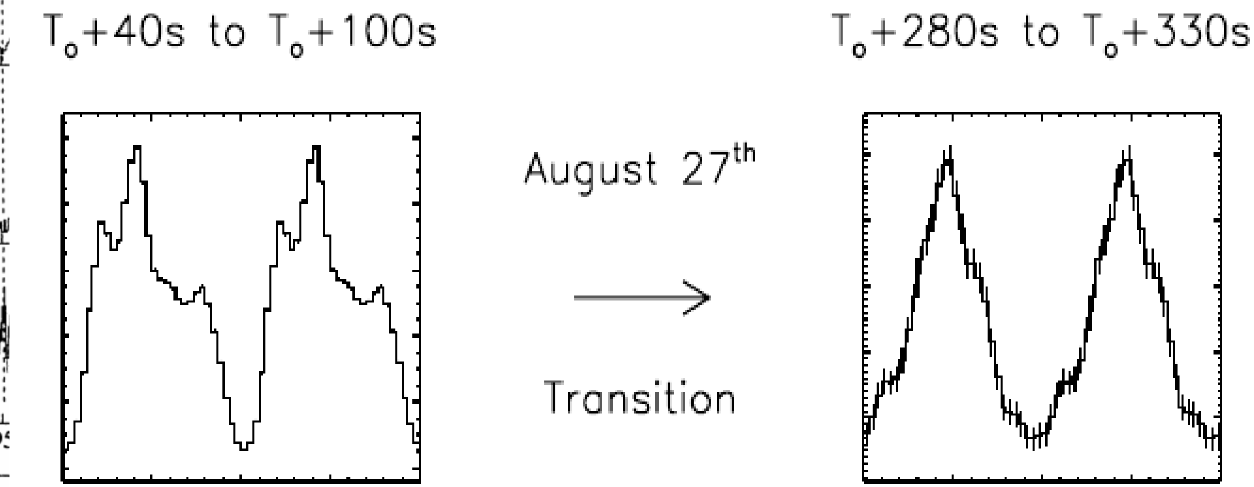
Complex pulse profile evolution and hardness ratio during giant flare



Mazets 1999

Complex pulse profile evolution and hardness ratio during giant flare





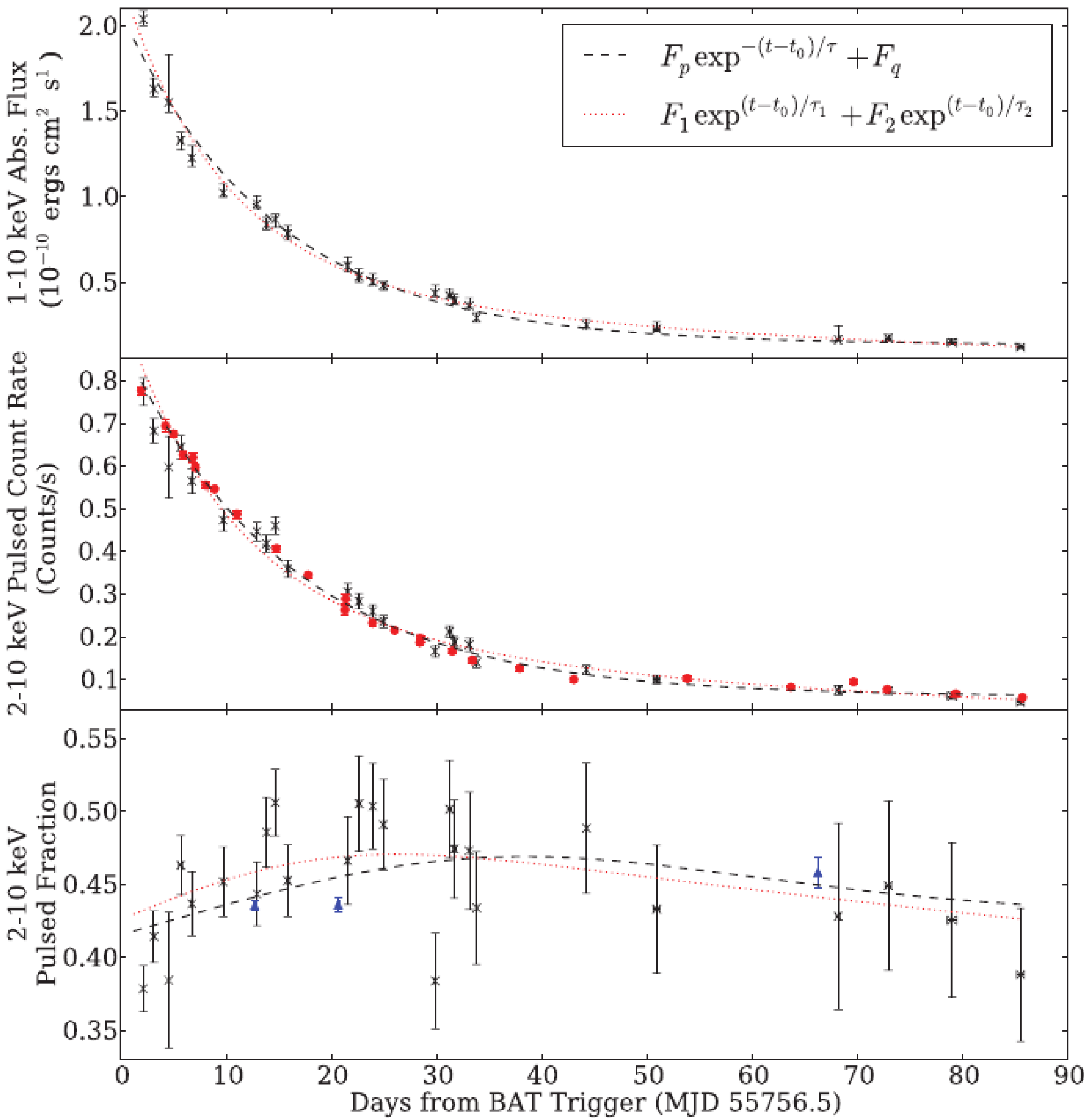
Woods 2001

Mazets 1999

2011 outburst of Swift J1822.3--1606

- BAT detected hard X-ray bursts from this source on July 14, 2011
- P : 8.43772016 (2) s
- $\dot{P}$: 8.3 (2) X 10^{-14} s s^{-1}
- B : 2.7 X 10^{13} G ⇦ One of the low magnetic field SGRs
- Following the hard X-ray bursts, a long lasting outburst followed which lasted for few hundred days

Flux evolution during the 2011 outburst



Decay constant for the flux evolution during the outburst:

T_1 = 15 .5 days

T_2 = 177 days

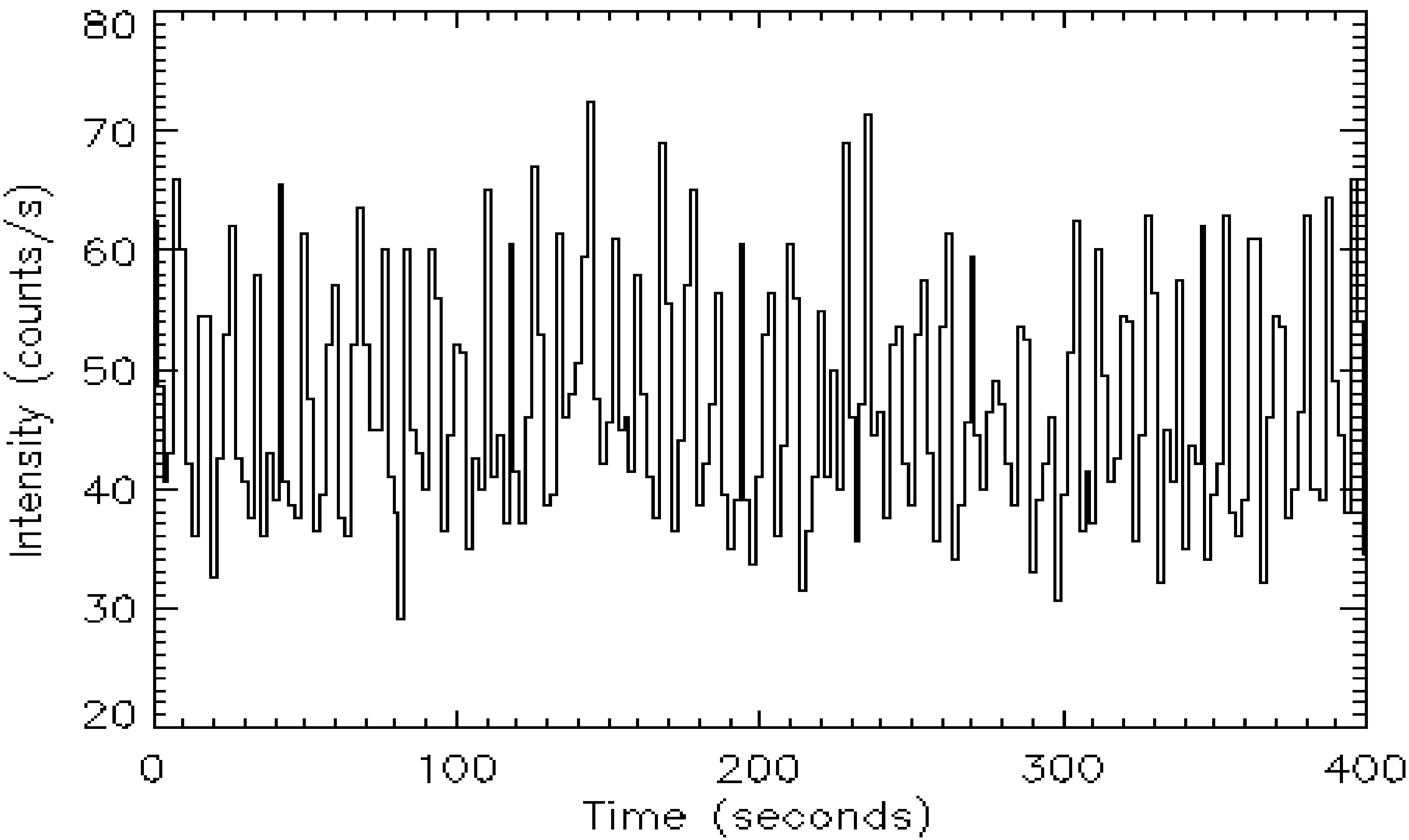
(Decay constant for the flux evolution during the giant flare:

T_1 = 5 s

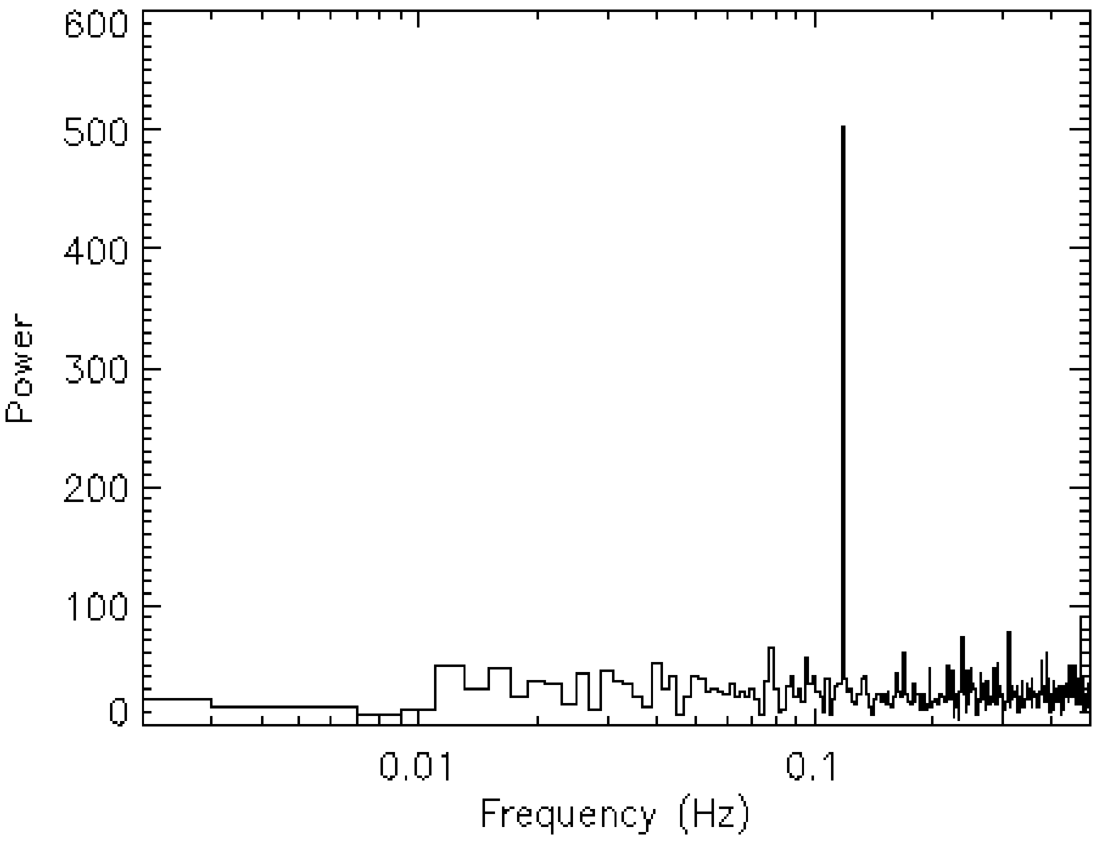
T_2 = 80 s)

Livingstone 2011

Clear Periodic oscillations observed in the light curve during the 2011 outburst of Swift J1822.3-1606



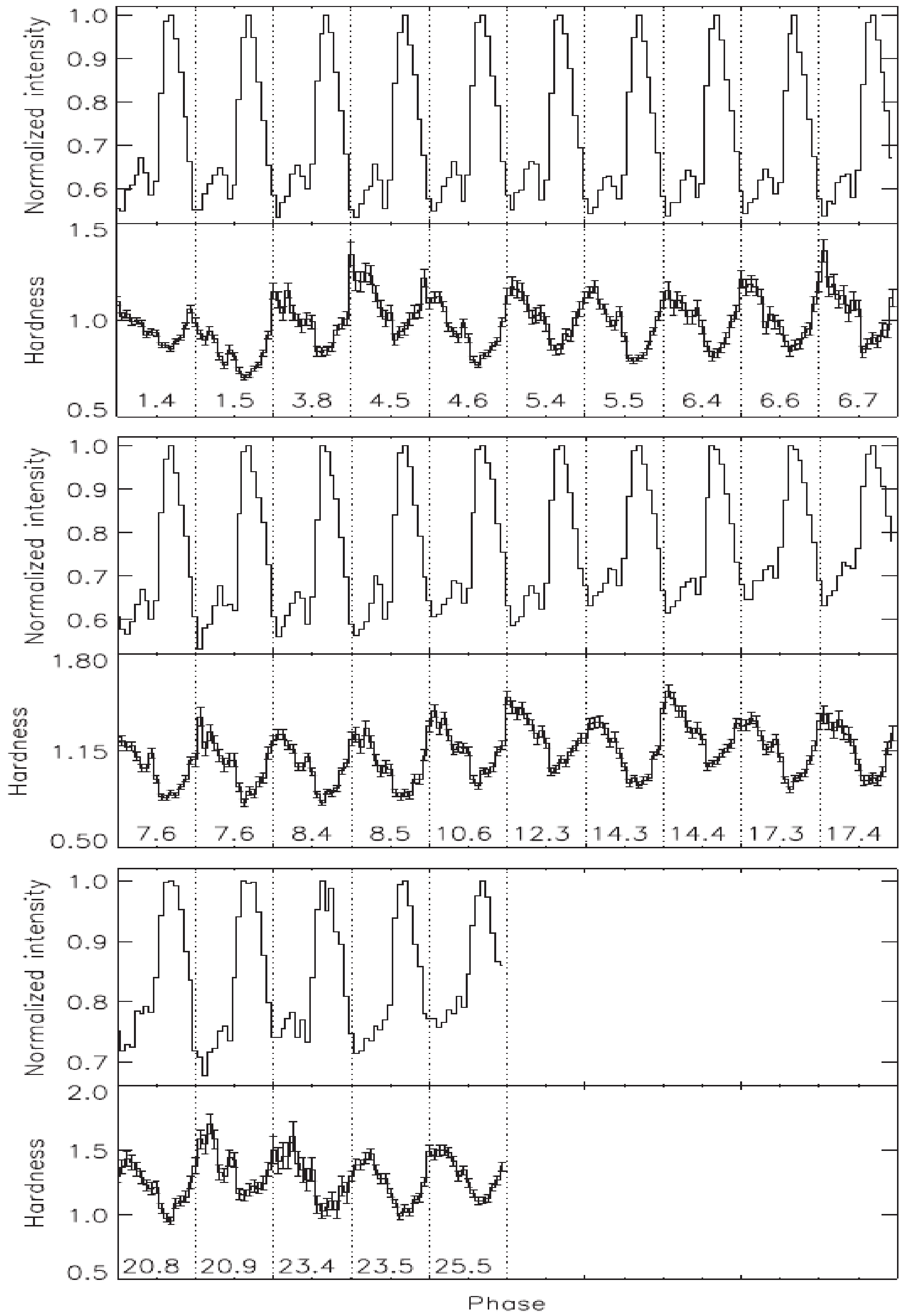
Power spectrum of harness ratio and lags



- HR: ratio of intensities in the range 5.0-14.0 and 2.0-5.0 keV
- Significant peak at pulsar frequency
- Phase lag > 2.5 rad

=>anti-correlation

Anti-correlation of hardness intensity with pulse profile intensity

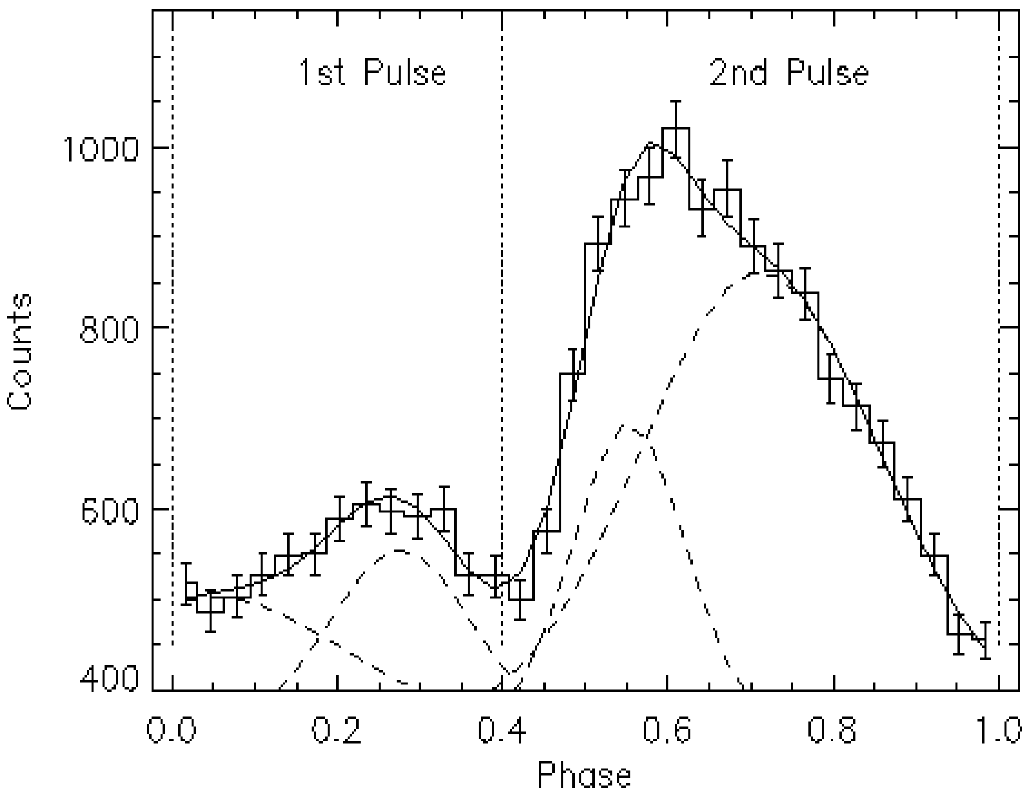


Correlation coefficient

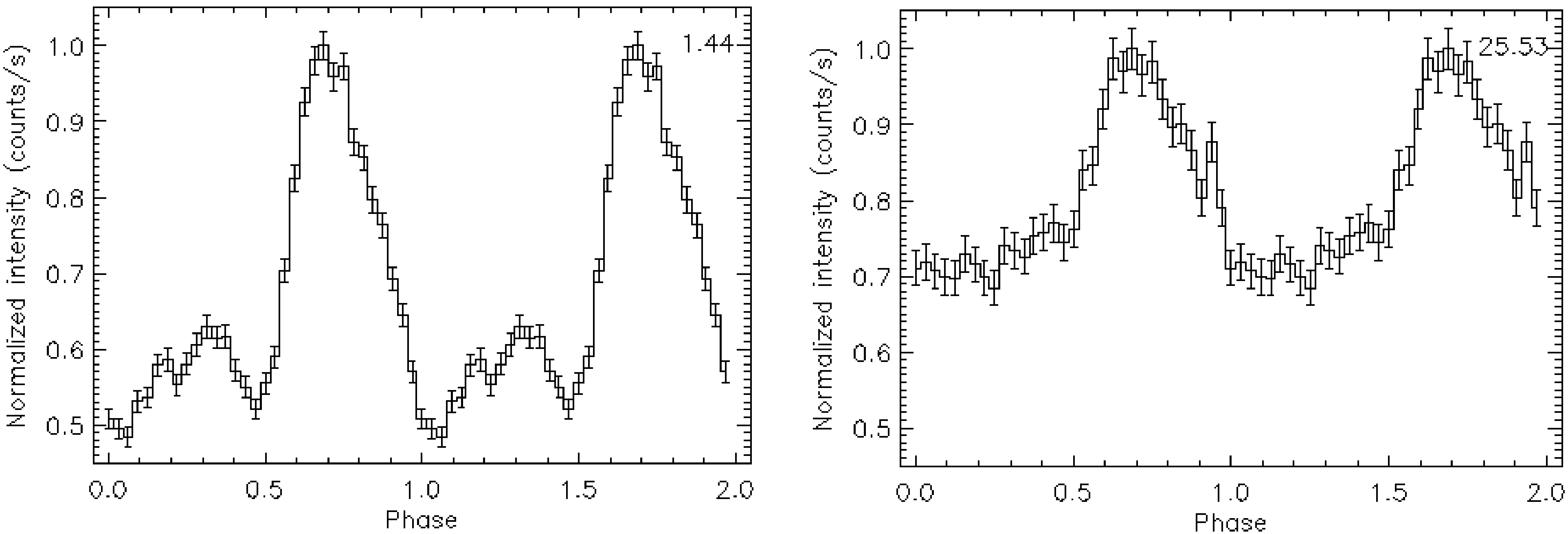
-0.691 to -0.956

Pulse profile morphology

- Complex profile
- Constitutes of 4 sub-pulses
- We modeled using 4 Gaussians



Time evolution of the pulse profile



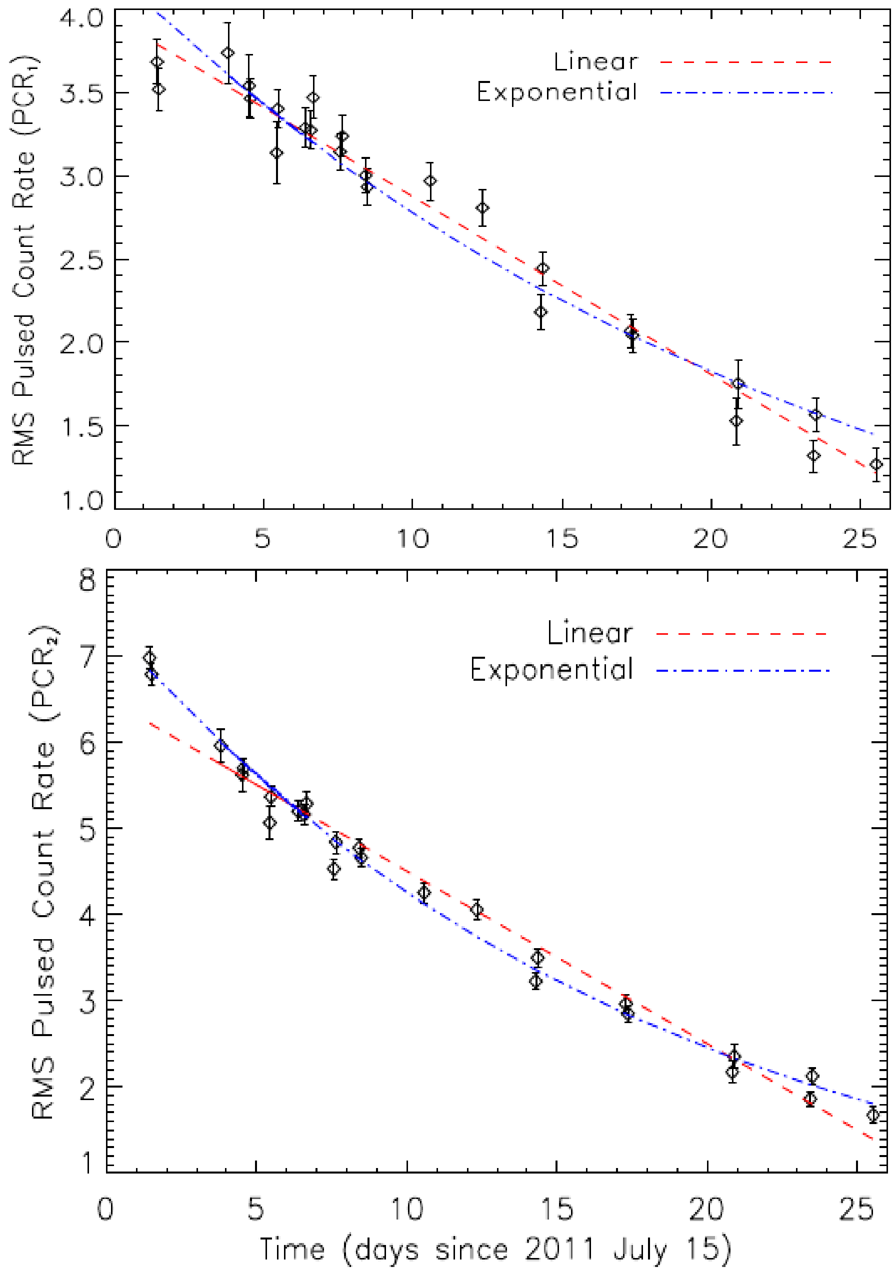
The complex profile gets simplified as time evolves

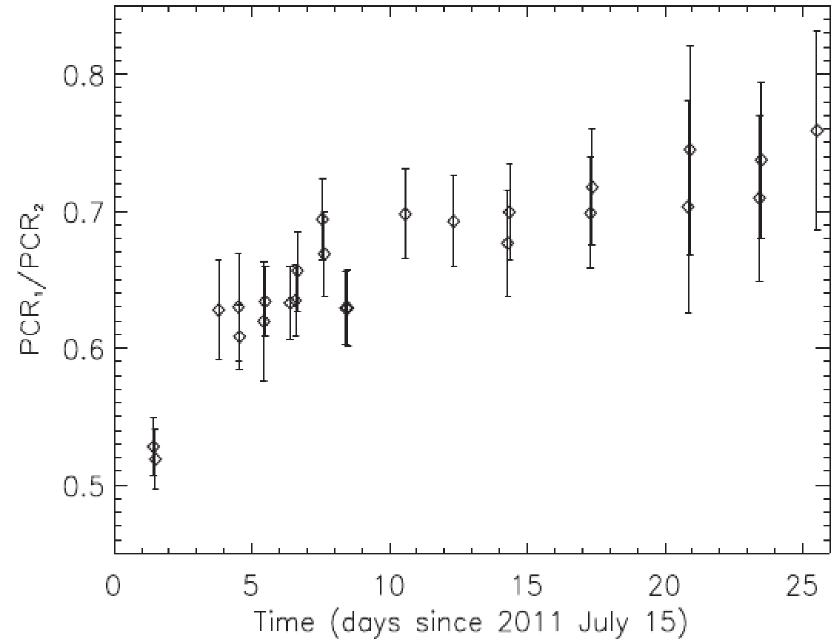
Quantifying the sub-structures

$$\mathrm{PCR} = \left(\frac{1}{N} \sum_{i}^{N} \left(\left(R_i - R_{\mathrm{avg}} \right)^2 - \Delta R_i^2 \right) \right)^{\frac{1}{2}}$$

- We could not resolve the 4 sub-pulses for the entire outburst
- 2 broad sub-pulses identified in the ranges 0.0-0.4 and 0.4-1.0
- PCR values were calculated for each sub-pulse for the first 25 days during which the pulsation was prominent

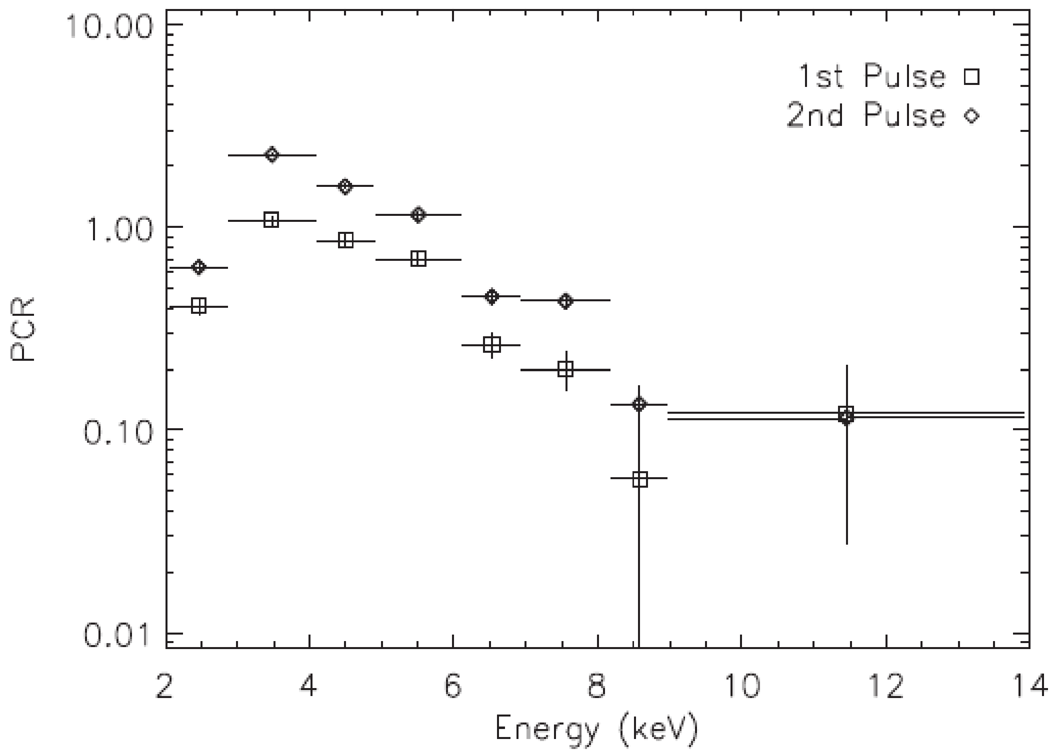
Evolution of the sub-pulses





- The two sub-pulses evolve differently as the outburst decays
- Relative contribution of the two sub-pulses increases as the outburst decays

Evolution of pulses with energy



- Similar though distinct evolution of the two sub-pulses with time and energy
- This implies similar origin mechanism but slightly different radiative behavior suggesting two separate components
- Complex surface emission topology, possibly two major trapped fireballs emitting throughout the outburst

Energetics of the outburst

- Energy emitted in 0.5-10 keV ~ 8.4×10^{40} erg
- Contribution of high energy emission from Swift BAT data
- 15-150 keV flux on July 15, 2011 : 2×10^{-10} erg s^{-1} cm^{-2} which corresponds to a luminosity of 6.2×10^{34} erg
- No significant high energy detection with BAT following the July 15 detection => fading of high energy emission

Giant flares and this outburst, similar?

- Clearly observable periodic modulation in the tail
- Anti-correlation between hardness and pulse profile intensity
- Complex pulse profiles that evolves and simplifies with time
- The sub-pulse phases are stable with time and energy in both cases
- Flux decay show a similar evolution though on different time scales
- Hard X-ray

Mechanism

- Giant flare origins:
  - Large-scale crustal deformation (Tompson & Duncan 1995, 2001)
  - Global magnetospheric reconnection (Lyutikov 2003, 2015)

- Crustal deformation: Similar injected energy for both radiated away over different time scales in each case

- Reconnection: influenced by the magnetohydrodynamic currents. For giant flares the magnetic field should be sufficiently strong. For a low magnetic field magnetar like this one, effect gets suppressed resulting in enhanced persistent emission

Energetics

- The typical energy released in a giant flare (10^{42} erg), needs ~ 200 days to get radiated away at the typical flux level corresponding to the outburst (obtained using *Swift* XRT data)

- The outburst flux decay was modeled using a double exponential model, the larger decay constant being ~177 days which is consistent with the above quoted timescale

Thank You