What can bright neutron star binaries tell us about ultra-luminous X-ray pulsars?

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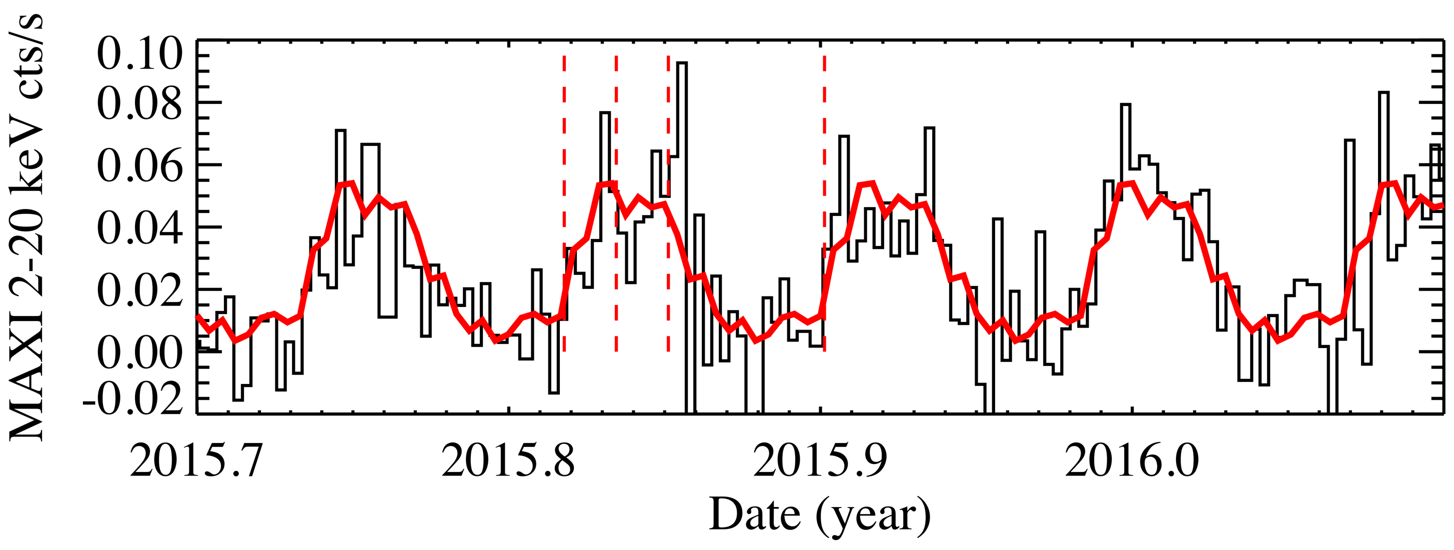
1. A bright X-ray binary

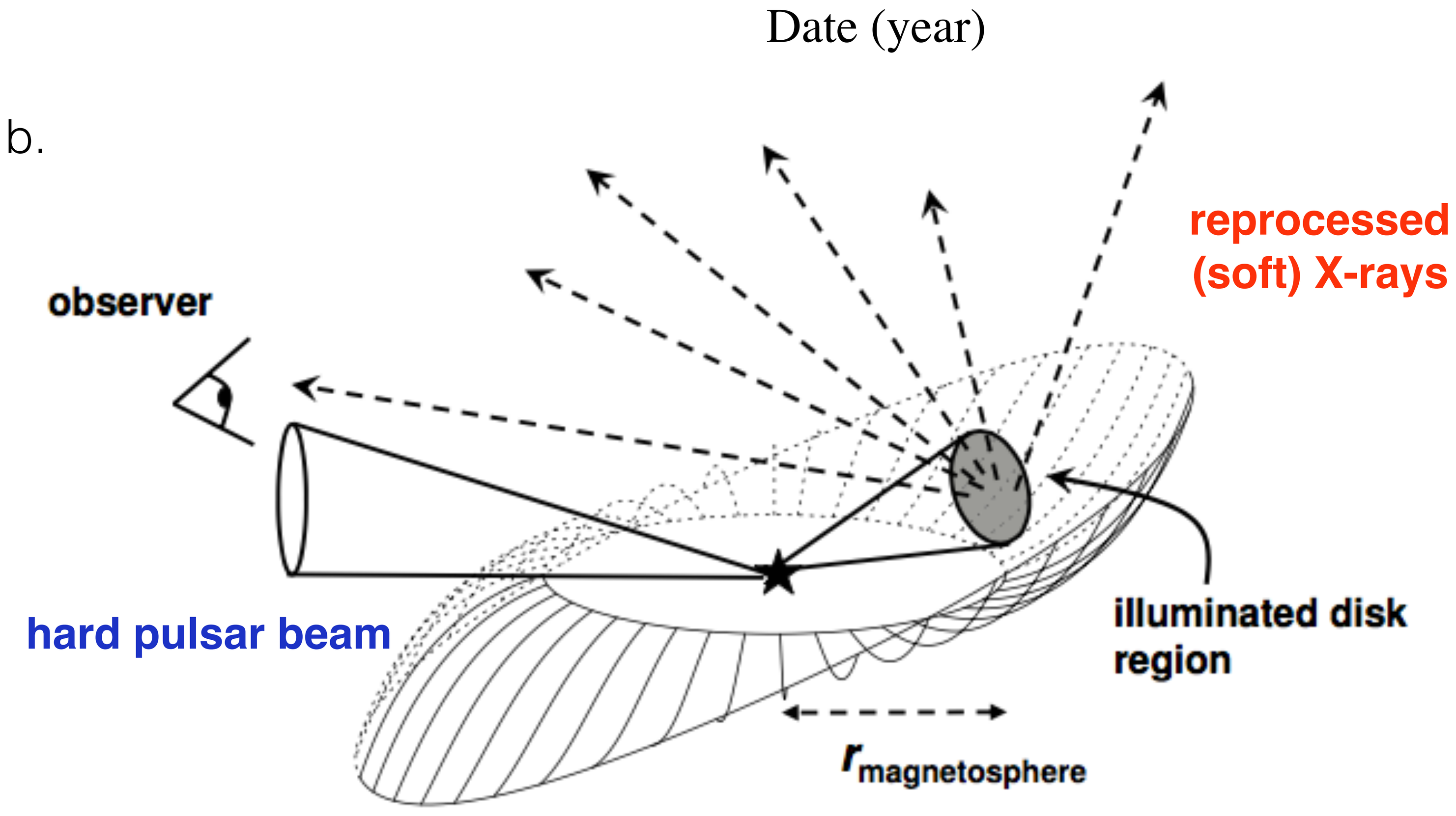
Ultra-luminous X-ray (ULX) pulsars, which accrete at hundreds of times the neutron star Eddington limit, display many unusual properties compared to typical X-ray binaries, including pulsation transience. **Examining bright, well-studied binaries may shed light on the unique properties of ULX pulsars.**

LMC X-4, a high mass neutron star X-ray binary, shows periodic changes in luminosity with a period of 30 days (Fig. 1a). These variations are likely caused by a warped precessing inner accretion disk (Fig. 1b). The typical source X-ray flux of 2x10^{38} erg s^{-1} is just below the Eddington limit for neutron stars. However, **flares during two observations reach super-Eddington luminosities of ~10^{39} erg s^{-1}.**

1a.



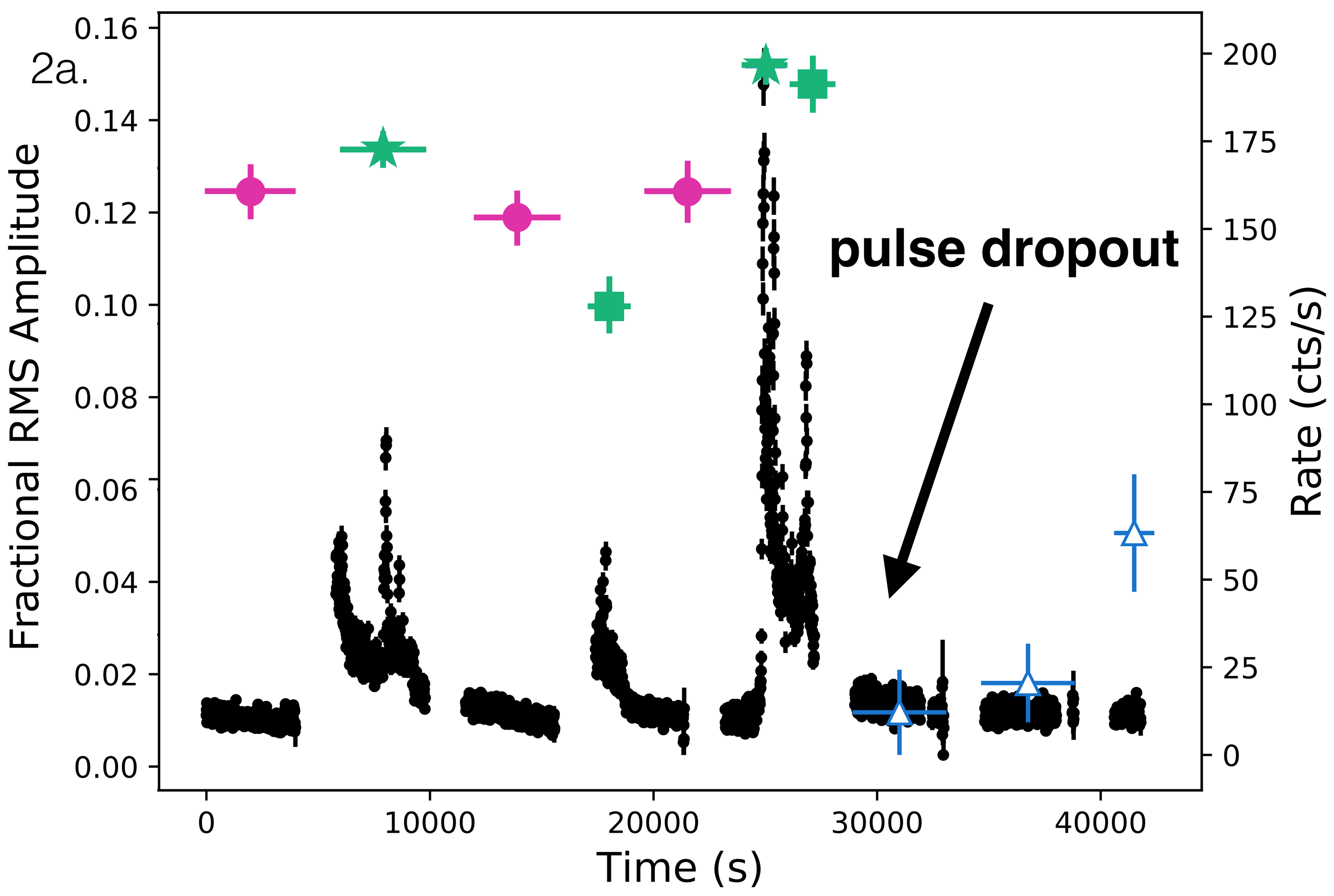
1b.



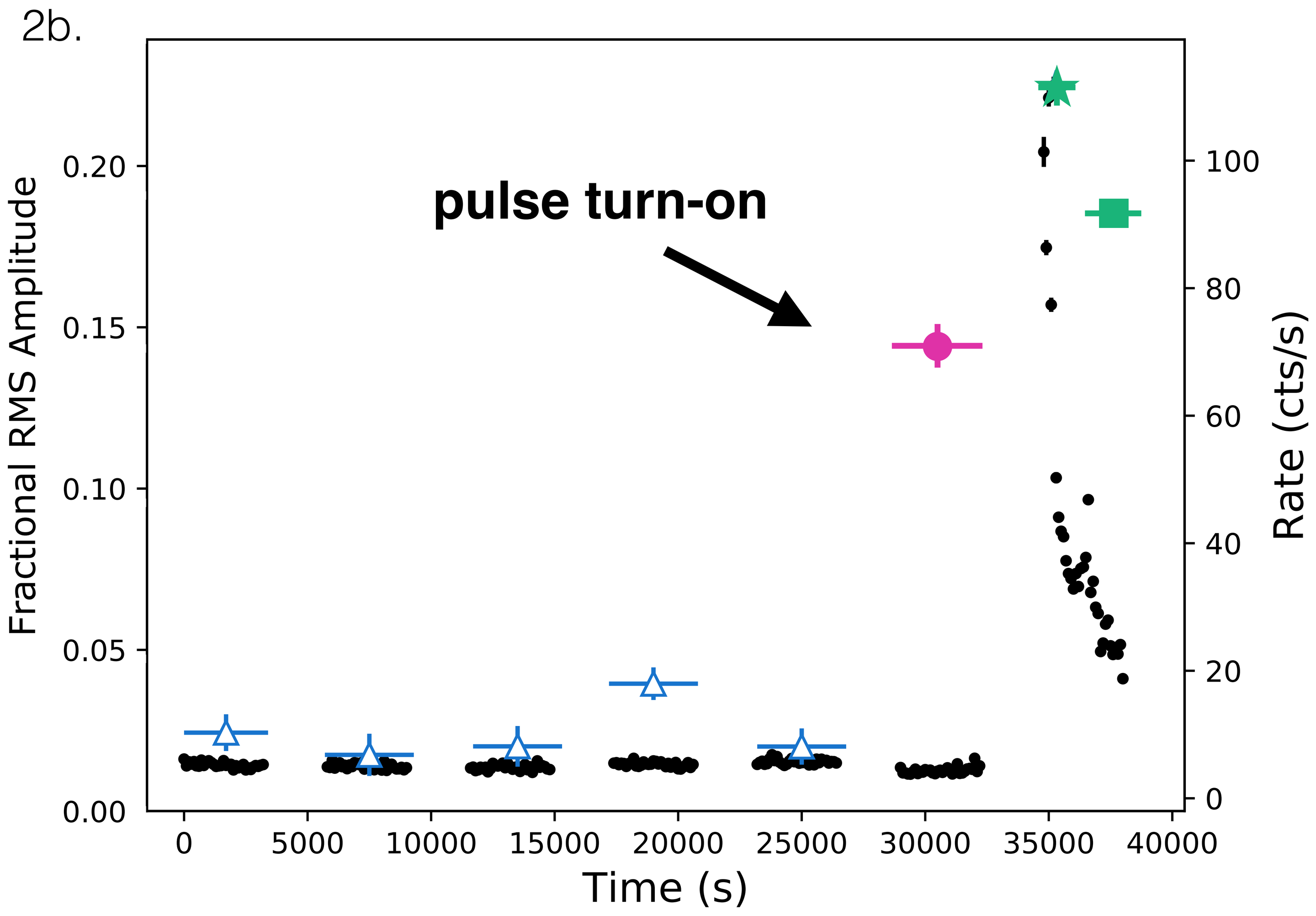
2. Pulsation transience

Fractional RMS amplitude for the *NuSTAR* 3-79 keV pulse profiles (colored points) for each time interval within Observation I (Fig. 2a) and Observation IV (Fig. 2b). The color of the RMS amplitude data points indicates the light curve and pulse behavior: typical flux with weak pulsations are blue, typical flux with strong pulsations are pink, and flaring activity with strong pulsations are green. The *NuSTAR* light curve is shown in black. Pulsations are strongly detected during time intervals of flaring activity, and in time intervals immediately preceding flares. At longer time scales before the flares and after, the pulsation strength dramatically decreases. **This is the first detection of pulsation dropout and turn-on associated with super-Eddington activity in LMC X-4.** This pulsation transience coupled with super-Eddington accretion makes LMC X-4 a unique analogue to the ULX pulsar population.

2a.

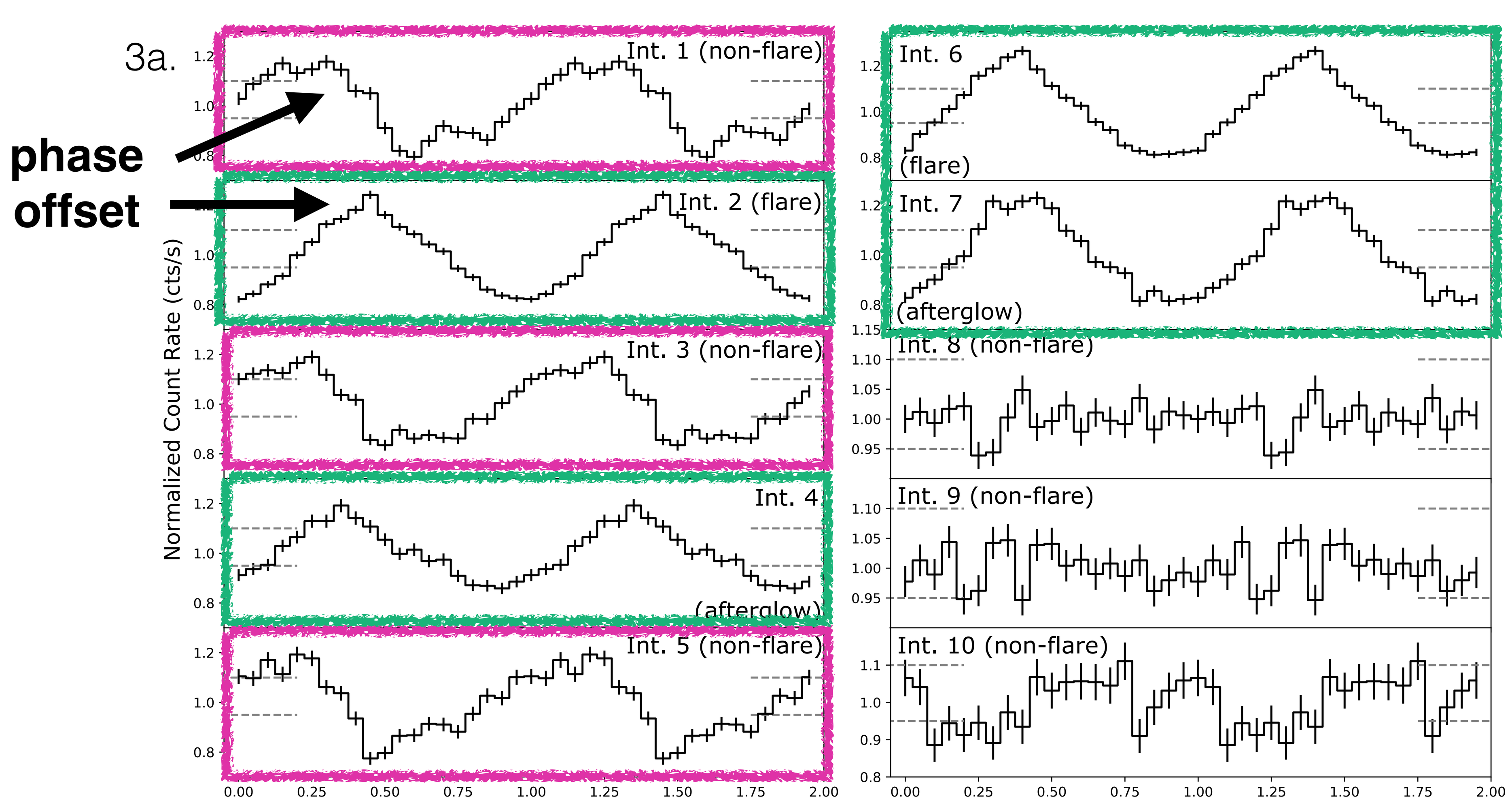


2b.

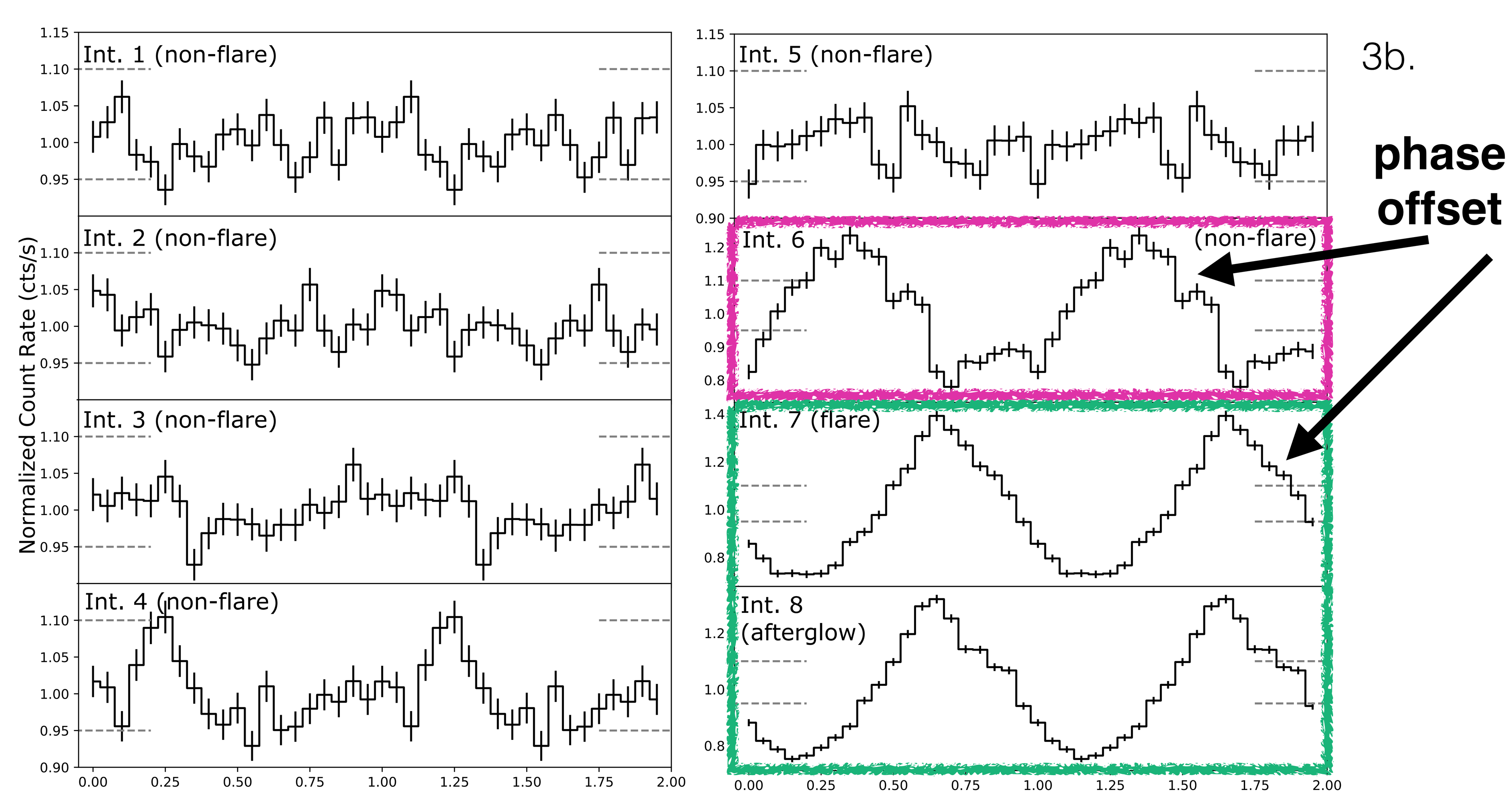


3. A possible emission geometry change

3a.



3b.



Pulse profiles for each time interval in Observation I (Fig. 3a) and Observation IV (Fig. 3b). The horizontal dashed lines indicate the scale. The pulsation dropout and turn-on can be seen. Also apparent is a difference in pulse shape and phase between strongly pulsed pre-flare intervals (pink) and the flares and their afterglows (green). The changes in pulse shape and phase are consistent across all flares and both observations. **Changes in emission geometry at the onset of super-Eddington accretion could be responsible for these observed changes in phase and shape.** Understanding these changes could increase our understanding of super-Eddington accretion in ULX pulsars.

References and Acknowledgements

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