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X-ray Burst Activity of Magnetar SGR J1935+2154 and implication for Fast Radio Burst Phenomenon

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The magnetar SGR J1935+2154 is not only one of the most active magnetars detected so far, but also the unique confirmed source of fast radio bursts. We report the GECAM observations of the burst activity of SGR J1935+2154 from 2021 January to 2022 December, which results in a unique and valuable data set for this important magnetar. We find that both the burst duration and the waiting time between two successive bursts follow lognormal distributions. The period of burst activity is 134 ± 20 days. We further investigate the temporal clustering of the bursts and the complementary cumulative distributions (CCDs) of the waiting time and fluence/flux. It is found that the burst activity could be generally divided into four active episodes over these two years. The observations further indicates that the hardness ratio of X-ray bursts tends to be softer during these two years, especially during the active episode with radio bursts detected.

Specifically, the CCDs of the waiting time and fluence of the XRBs can be empirically described by modified power laws. This general statistical property indicates that the XRBs could belong to a self-organized critical system (e.g., starquakes), making them very similar to the earthquake phenomena. According to the statistical property of earthquakes as well as their aftershocks, a unified scaling law can be written between the waiting time (Δt) and fluence (S) of a self-organized critical system as

$$y=f(x)\sim\begin{cases}\text{const.} & \text{for } x<1\\ x^{-\gamma}, & \text{for } x\geq 1\end{cases}$$

where $x\equiv c\Delta t\, S^{\beta}$ and $y\equiv \Delta t^{-\alpha}P(\Delta t)$ with α and β being the power-law index of the CCDs of the corresponding quantities. According to this unified scaling law, we find that the fast radio burst (FRB) episode owns more dependent burst events than the other episodes. It is indeed showed that the bursts occurring in the episode hosting FRB 20200428 have obviously shorter waiting times than those in the other episodes. This indicates that the FRB emission could be produced by the interaction between different burst events, which could correspond to a collision between different seismic/Alfvén waves or different explosion outflows. Such a situation could appear when the magnetar enters into a global intensive activity period.

Finally, we discover a peculiar type of burst that owns a nearly plateau light curve, which enables us to identify four candidates with eclipsing characteristics. Then, the viewing angle of the magnetar relative to its spin axis is measured by the fitting of eclipsed light curves. Furthermore, the emitting fireballs are found to be more than 50 km away from the magnetar rather than adhere to the stellar surface, which is consistent with the implication of the cyclotron resonance scattering feature in their spectra. This indicates that the fireballs are probably formed directly by magnetic reconnections within the magnetosphere rather than starquakes.

References
[1] Xie, S. L. et al. ApJS, **277**, 5(2025)
[2] Xie, S. L. et al. ApJ, **967**, 108(2024)
[3] Xie, S. L. et al. Under review

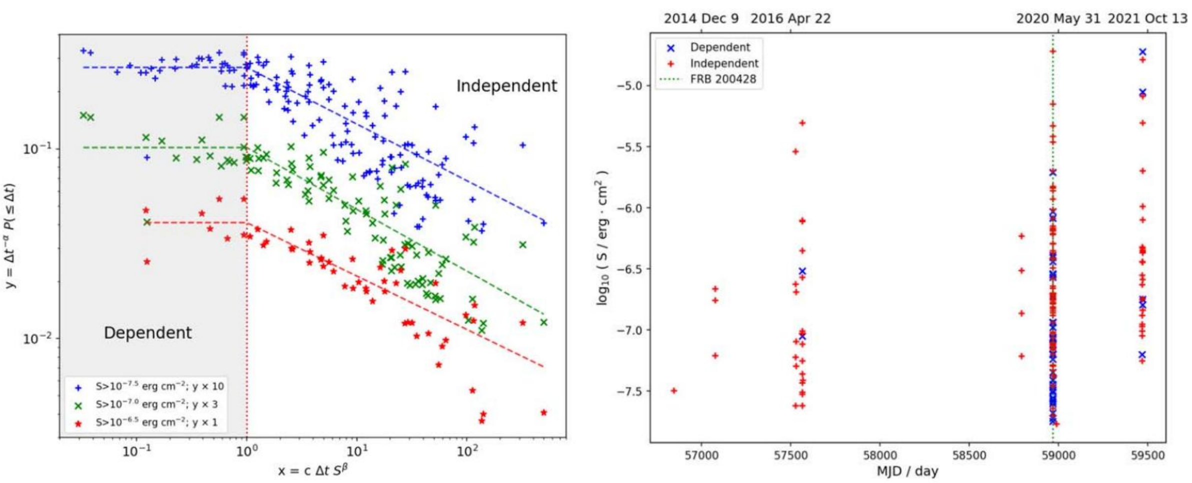

Figure 1: The unified scaling law of XRBs for four different episodes (*Left*) and the fluence vs. the occurring time of XRBs where the dependent and independent types of the bursts are defined according to the x-y relationship (*Right*).