RESEARCH HIGHLIGHT

The prompt phase mechanism of gamma-ray bursts

Self-organized criticality during the prompt phase of gamma-ray bursts shows that they may arise from magnetic reconnection events.

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Gamma-ray bursts (GRBs) are flashes of gamma-rays occurring at cosmological distances (for a recent review see [1]). They are divided into two classes based on their prompt emission durations: short-duration ($<$ 2 seconds) hard-spectrum bursts and long-duration soft-spectrum bursts ($>$ 2 seconds). The observations (including discoveries of both the gravitational wave event GW170817 from an inspiral of two neutron stars and its electromagnetic counterparts) indicate that long-duration GRBs result from core collapses of massive stars and short-duration GRBs are produced from mergers of neutron star–neutron star binaries or black hole–neutron star binaries. After the prompt phase, multi-wavelength (X-ray, optical and radio) afterglows of GRBs have been detected, and in particular, during an early afterglow phase, X-ray flares from a great number of GRB sources have been observed. Two important questions appear: What's the prompt phase physical mechanism of GRBs? Do X-ray flares have a similar origin?

Wang and I [2], for the first time, analyzed statistical results (e.g., power-law frequency distributions of energies, durations, and waiting times) of X-ray flares of GRBs with known redshifts and showed that X-ray flares and solar flares share three statistical properties. This implies that both types of flares may be driven by a similar self-organized criticality (SOC) process (e.g., magnetic reconnection events around strongly magnetized millisecond pulsars as a central engine of GRB X-ray flares proposed in Ref. [3]), because it has been widely argued that the energy and duration frequency distributions of solar fares are attributed to a magnetic reconnection process based on the fractal-diffusive avalanche SOC model [4–6]. In a recent paper published in *Frontiers of Physics*, Lyu and her collaborators [7] presented new power-law frequency distributions of the isotropic energy, waiting time, and peak count rate of each pulse for GRBs with more than 3 pulses in each burst to reveal the mechanism of the prompt emission phase. Their sample consists of 454 pulses in 93 GRBs observed by the CGRO/BATSE satellite. They show that these distributions are basically consistent with the physical framework of an SOC system with three dimensions. This interesting result suggests that the physical mechanism during the prompt phase of GRBs could be similar to that of X-ray flares, i.e., a magnetic reconnection process (see Fig. 1). It is expected that a larger sample of GRBs with known redshifts would confirm such a mechanism in future.

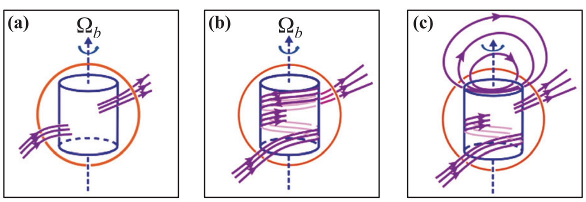

Fig. 1 Schematic picture of a magnetic reconnection event [8]. Differential rotation in the interior of a highly-spinning neutron star leads to windup of poloidal magnetic fields **(a)** and the resulting toroidal fields are strong enough to float up and break through the stellar surface **(b)**. Magnetic reconnection–driven explosive events then occur **(c)**, producing a gamma-ray burst.

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