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Astronomers Detect First 'Heartbeat' of a Newborn Neutron Star in Distant Cosmic Explosion

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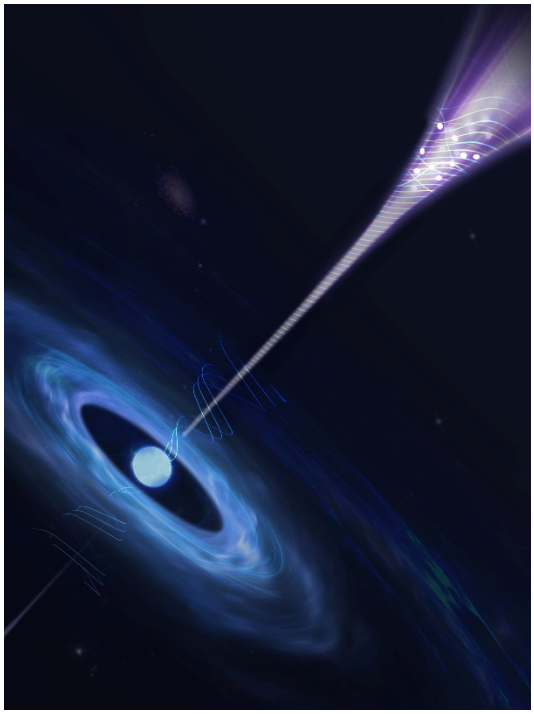

Figure 1: An artistic illustration of the magnetar and the gamma-ray burst jet in this work (Illustration: Yuja Tian and Yuting Wu, Nanjing Zhijiao Cloud Intelligent Technology Co., Ltd.; Scientific concept guidance: Runchao Chen and Binbin Zhang, Nanjing University).

A discovery involving researchers at The University of Hong Kong (HKU) has, for the first time, unveiled millisecond pulsations hidden within a powerful cosmic explosion known as a gamma-ray burst (GRB).

A collaboration among HKU, Nanjing University, and the Institute of High Energy Physics of the Chinese Academy of Sciences (CAS) detected a brief but highly coherent oscillation in the GRB designated GRB 230307A on 7 March 2023. The signal, spinning nearly a thousand times per second, points to the birth of a "millisecond magnetar"—a rapidly rotating neutron star with an ultra-strong magnetic field. The findings have recently been published in *Nature Astronomy*, marking a milestone in astrophysics and providing the clearest evidence yet that magnetars can power some of the most luminous explosions in the universe.

Deciphering the 'Heartbeat'

Gamma-ray bursts are the brightest explosions known, briefly outshining the entire gamma-ray sky. They are triggered when compact stars—such as neutron stars—collide and merge, or when massive stars collapse, leaving behind exotic remnants. For decades, scientists have debated whether these remnants collapse immediately into black holes or survive as highly magnetised neutron stars.

GRB 230307A detected by China's GECAM satellites (B and C) and NASA's Fermi satellite (GBM), was the second brightest GRB ever recorded. Optical follow-up observations confirmed that it originated from a compact star merger. Yet its unusually long, one-minute duration defied standard expectations, which predict less than two seconds of emission from such events.

'This event gave us a rare opportunity,' said Professor Bing ZHANG, Chair Professor of the Department of Physics at HKU and co-corresponding author of the study. 'By uncovering its hidden "heartbeat", we can finally say with confidence that some GRBs are powered not by black holes, but by newborn magnetars.'

The research team sifted through more than 600,000 datasets collected by the GECAM satellites—dedicated gamma-ray detectors designed and launched by the Institute of High Energy Physics (CAS) in Beijing. The analysis, led by Nanjing University, revealed a striking 909-Hz quasi-periodic oscillation (QPO) lasting just 160 milliseconds.

"This is the first time humanity has directly observed a periodic signal from a millisecond magnetar inside a gamma-ray burst," said PhD student Run-Chao CHEN of Nanjing University, the paper's first author. 'It is like hearing the first heartbeat of a newborn star.'

The detection was independently confirmed using data from GECAM-B, GECAM-C, and NASA's Fermi Gamma-ray Burst Monitor, cementing its astrophysical origin.

Why So Brief?

The fleeting pulse raised new questions. HKU Professor Zhang offered a theoretical explanation, "The magnetar's rapid spin imprints a periodic signal onto the gamma-ray jet through its magnetic field. However, because the jet evolves quickly, this signal appears only when the emission briefly becomes asymmetric. For just 160 milliseconds, the heartbeat was visible before the jet's symmetry hid it again."

This interpretation suggests that GRB 230307A was powered by a *Poynting-flux dominated jet*—a stream of energy driven primarily by magnetic fields rather than matter. Both the millisecond magnetar and magnetised jet concepts were proposed by Professor Zhang more than a decade ago. This "heartbeat" detection provides the strongest evidence yet linking theory to observation.

Research Impact

Until now, GRB central engines could only be inferred indirectly from afterglow modelling or theoretical assumptions. This study provides the first direct observational imprint of a magnetar's spin in a gamma-ray burst.

'This discovery transforms our understanding of the most extreme explosions in the cosmos,' Professor Zhang emphasised. 'It shows that newly born magnetars can survive compact star mergers and act as powerful cosmic engines. This opens a new frontier in multimessenger astronomy, linking gamma rays, gravitational waves, and the physics of compact stars.'

The team plans to search for similar pulsations in other bright GRBs. Each detection will bring astronomers closer to understanding the life and death of compact stars, the role of magnetars in cosmic evolution, and the origins of extreme astrophysical phenomena.

'As more advanced space observatories come online, we expect to uncover more of these fleeting signals," Professor Zhang said. "Each one will be a heartbeat from the depths of space, telling us the story of the mysterious universe under the most extreme conditions imaginable.'

The research was carried out jointly by HKU, Nanjing University, and the Institute of High Energy Physics, CAS. Professors Bin-Bin Zhang (Nanjing University) and Shao-Lin Xiong (CAS) are co-corresponding authors alongside HKU's Professor Bing Zhang. The project received support from the China Ministry of Science and Technology's Key R&D Program, the National Natural Science Foundation of China, the China Space Station Program, and Jiangsu Province Innovation Programs. The GECAM satellite mission was developed under the Strategic Pioneer Program on Space Science (Phase II) of CAS.

The journal paper can be accessed from here: http://doi.org/10.1038/s41550-025-02649-w

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