Galactic gamma ray bursts predicted last year show up on schedule

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An artist's depiction of a hiccup in the magnetic field of a magnetar — a highly magnetized neutron star — that produces a powerful gamma ray burst visible from across the galaxy. UC Berkeley physicists have found an unusual pattern to these bursts that could help pin down the precise mechanism triggering the hiccups and generating the soft gamma bursts. Credit: NASA's Goddard Space Flight Center/Chris Smith, USRA/GESTAR

Magnetars are bizarre objects—massive, spinning neutron stars with magnetic fields among the most powerful known, capable of shooting off brief bursts of radio waves so bright they're visible across the universe.

A team of astrophysicists has now found another peculiarity of magnetars: They can emit bursts of low energy gamma rays in a pattern never before seen in any other astronomical object.

It's unclear why this should be, but magnetars themselves are poorly understood, with dozens of theories about how they produce radio and gamma ray bursts. The recognition of this unusual pattern of gamma ray activity could help theorists figure out the mechanisms involved.

"Magnetars, which are connected with fast radio bursts and soft gamma repeaters, have something periodic going on, on top of randomness," said astrophysicist Bruce Grossan, an astrophysicist at the University of California, Berkeley's Space Sciences Laboratory (SSL). "This is another mystery on top of the mystery of how the bursts are produced."

The researchers—Grossan and theoretical physicist and cosmologist Eric Linder from SSL and the Berkeley Center for Cosmological Physics and postdoctoral fellow Mikhail Denissenya from Nazarbayev University in Kazakhstan—discovered the pattern last year in bursts from a soft gamma repeater, SGR1935+2154, that is a magnetar, a prolific source of soft or lower energy gamma ray bursts and the only known source of fast radio bursts within our Milky Way galaxy. They found that the object emits bursts randomly, but only within regular four-month windows of time, each active window separated by three months of inactivity.

On March 19, the team uploaded a preprint claiming "periodic windowed behavior" in soft gamma bursts from SGR1935+2154 and predicted that these bursts would start up again after June 1—following a three month hiatus—and could occur throughout a four-month window ending Oct. 7.

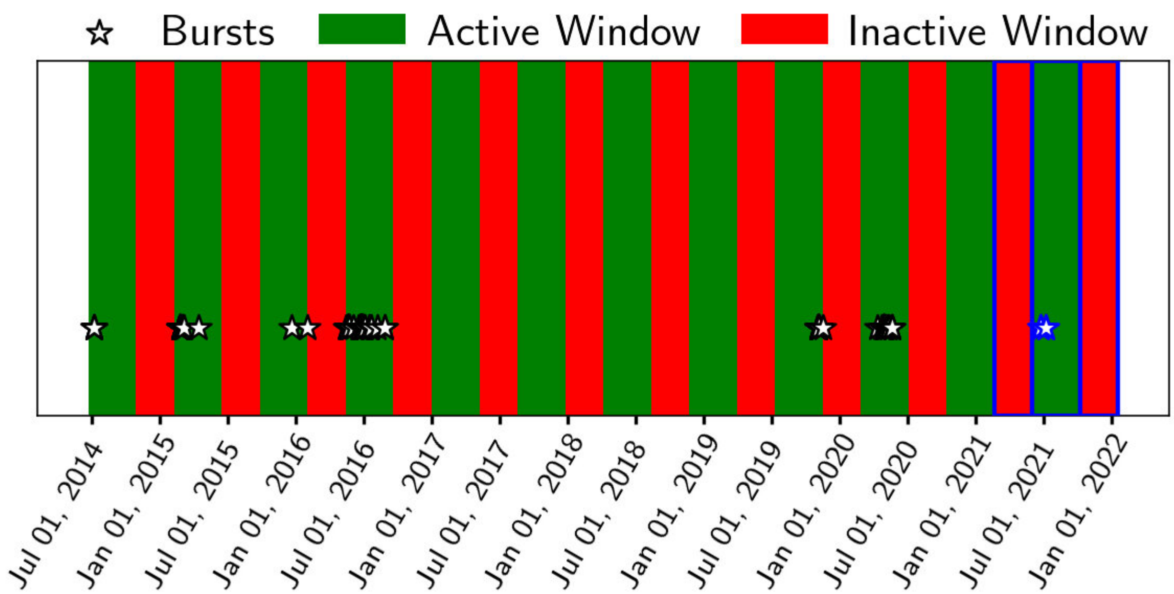
On June 24, three weeks into the window of activity, the first new burst from SGR1935+2154 was observed after the predicted three month gap, and nearly a dozen more bursts have been observed since, including one on July 6, the day the paper was published online in the journal *Physical Review D.*

"These new bursts within this window means that our prediction is dead on," said Grossan, who studies high energy astronomical transients. "Probably more important is that no bursts were detected between the windows since we first published our preprint."

Linder likens the non-detection of bursts in three-month windows to a key clue—the "curious incident" that a guard dog did not bark in the nighttime—that allowed Sherlock Holmes to solve a murder in the short story "The Adventure of Silver Blaze".

"Missing or occasional data is a nightmare for any scientist," noted Denissenya, the first author of the paper and a member of the Energetic Cosmos Laboratory at Nazarbayev University that was founded several years ago by Grossan, Linder and UC Berkeley cosmologist and Nobel laureate George Smoot. "In our case, it was crucial to realize that missing bursts or no bursts at all carry information."

The confirmation of their prediction startled and thrilled the researchers, who think this may be a novel example of a phenomenon—periodic windowed behavior—that could characterize emissions from other astronomical objects.



Since 2014, a magnetar in our galaxy (SGR1935+2154) has been emitting bursts of soft gamma rays (black stars). UC Berkeley scientists concluded that they occurred only within certain windows of time (green stripes) but were somehow blocked during intervening windows (red). They used this pattern to predict renewed bursts starting after June 1, 2021 (stripes outlined in blue at right), and since June 24, more than a dozen have been detected (blue stars): right on schedule. Credit: Mikhail Denissenya

Mining data from 27-year-old satellite

Within the last year, researchers suggested that the emission of fast radio bursts—which typically last a few thousandths of a second—from distant galaxies might be clustered in a periodic windowed pattern. But the data were intermittent, and the statistical and computational tools to firmly establish such a claim with sparse data were not well developed.

Grossan convinced Linder to explore whether advanced techniques and tools could be used to demonstrate that periodically windowed—but random, as well, within an activity window—behavior was present in the soft gamma ray burst data of the SGR1935+2154 magnetar. The Konus instrument aboard the WIND spacecraft, launched in 1994, has recorded soft gamma ray bursts from that object—which also exhibits fast radio bursts—since 2014 and likely never missed a bright one.

Linder, a member of the Supernova Cosmology Project based at Lawrence Berkeley National Laboratory, had used advanced statistical techniques to study the clustering in space of galaxies in the universe, and he and Denissenya adapted these techniques to analyze the clustering of bursts in time. Their analysis, the first to use such techniques for repeated events, showed an unusual windowed periodicity distinct from the very precise repetition produced by bodies rotating or in orbit, which most astronomers think of when they think of periodic behavior.

"So far, we have observed bursts over 10 windowed periods since 2014, and the probability is 3 in 10,000 that while we think it is periodic windowed, it is actually random," he said, meaning there's a 99.97% chance they're right. He noted that a Monte Carlo simulation indicated that the chance they're seeing a pattern that isn't really there is likely well under 1 in a billion.

The recent observation of five bursts within their predicted window, seen by WIND and other spacecraft monitoring gamma ray bursts, adds to their confidence. However, a single future burst observed outside the window would disprove the whole theory, or cause them to redo their analysis completely.

"The most intriguing and fun part for me was to make predictions that could be tested in the sky. We then ran simulations against real and random patterns and found it really did tell us about the bursts," Denissenya said.

As for what causes this pattern, Grossan and Linder can only guess. Soft gamma ray bursts from magnetars are thought to involve starquakes, perhaps triggered by interactions between the neutron star's crust and its intense magnetic field. Magnetars rotate once every few seconds, and if the rotation is accompanied by a precession—a wobble in the rotation—that might make the source of burst emission point to Earth only within a certain window. Another possibility, Grossan said, is that a dense, rotating cloud of obscuring material surrounds the magnetar but has a hole that only periodically allows bursts to come out and reach Earth.

"At this stage of our knowledge of these sources, we can't really say which it is," Grossan said. "This is a rich phenomenon that will likely be studied for some time."

Linder agrees and points out that the advances were made by the cross-pollination of techniques from high energy astrophysics observations and theoretical cosmology.

"UC Berkeley is a great place where diverse scientists can come together," he said. "They will continue to watch and learn and even 'listen' with their instruments for more dogs in the night."

More information: Mikhail Denissenya et al, Distinguishing time clustering of astrophysical bursts, *Physical Review D* (2021). DOI: 10.1103/PhysRevD.104.023007

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