Distributed computing project Einstein@Home discovers 13 new gamma-ray pulsars

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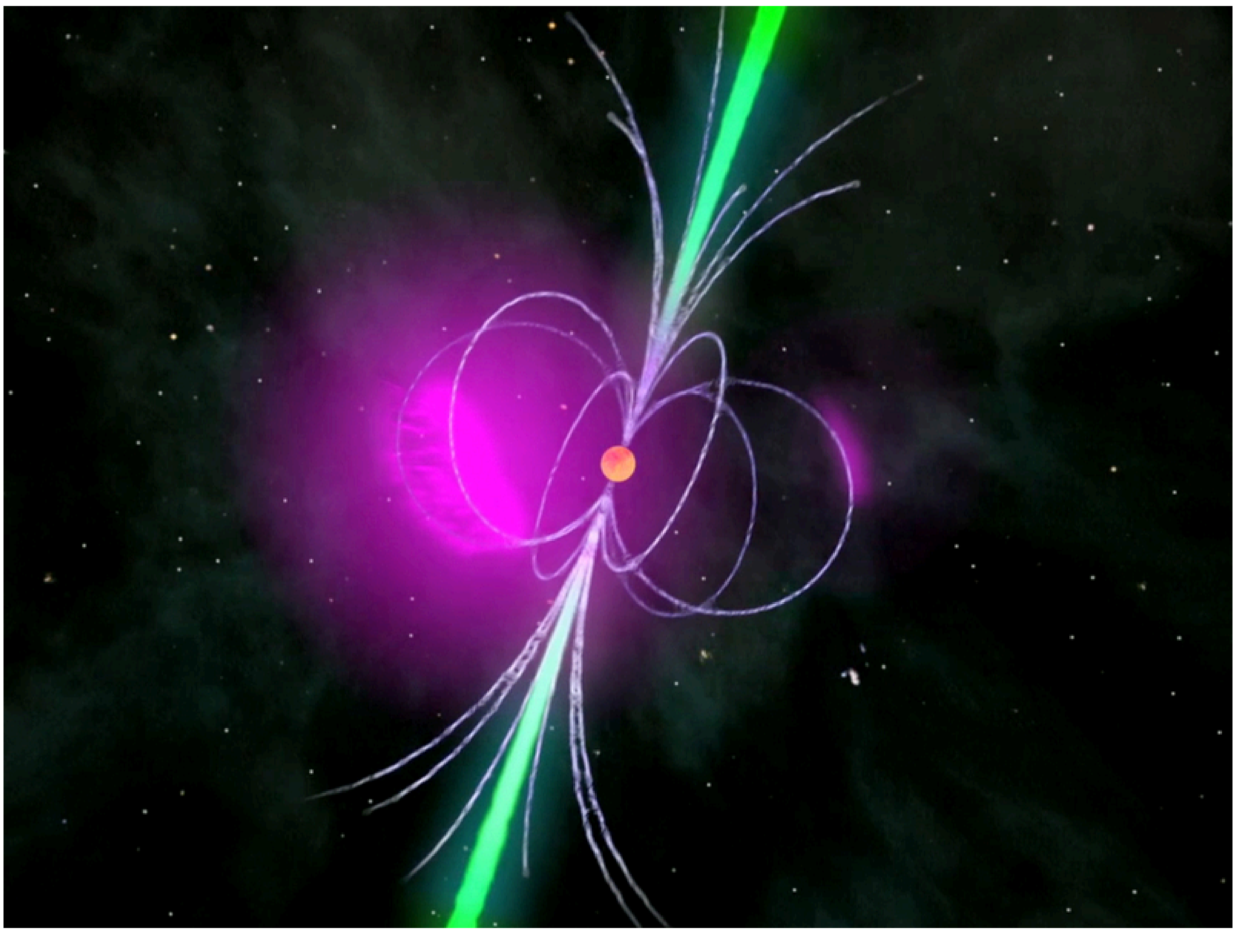


A gamma-ray pulsar is a compact neutron star that accelerates charged particles to relativistic speeds in its extremely strong magnetic field. This process produces gamma radiation (violet) far above the surface of the compact remains of the star, for example, while radio waves (green) are emitted over the magnetic poles in the form of a cone. The rotation moves the emission regions across the terrestrial line of sight, making the pulsar light up periodically in the sky. Credit: © NASA/Fermi/Cruz de Wilde

An analysis that would have taken more than a thousand years on a single computer has found within one year more than a dozen new rapidly rotating neutron stars in data from the Fermi gamma-ray space telescope. With computing power donated by volunteers from all over the world an international team led by researchers at the Max Planck Institute for Gravitational Physics in Hannover, Germany, searched for tell-tale periodicities in 118 Fermi sources of unknown nature. In 13 they discovered a rotating neutron star at the heart of the source. While these all are – astronomically speaking – young with ages between tens and hundreds of thousands of years, two are spinning surprisingly slow – slower than any other known gamma-ray pulsar. Another discovery experienced a "glitch", a sudden change of unknown origin in its otherwise regular rotation.

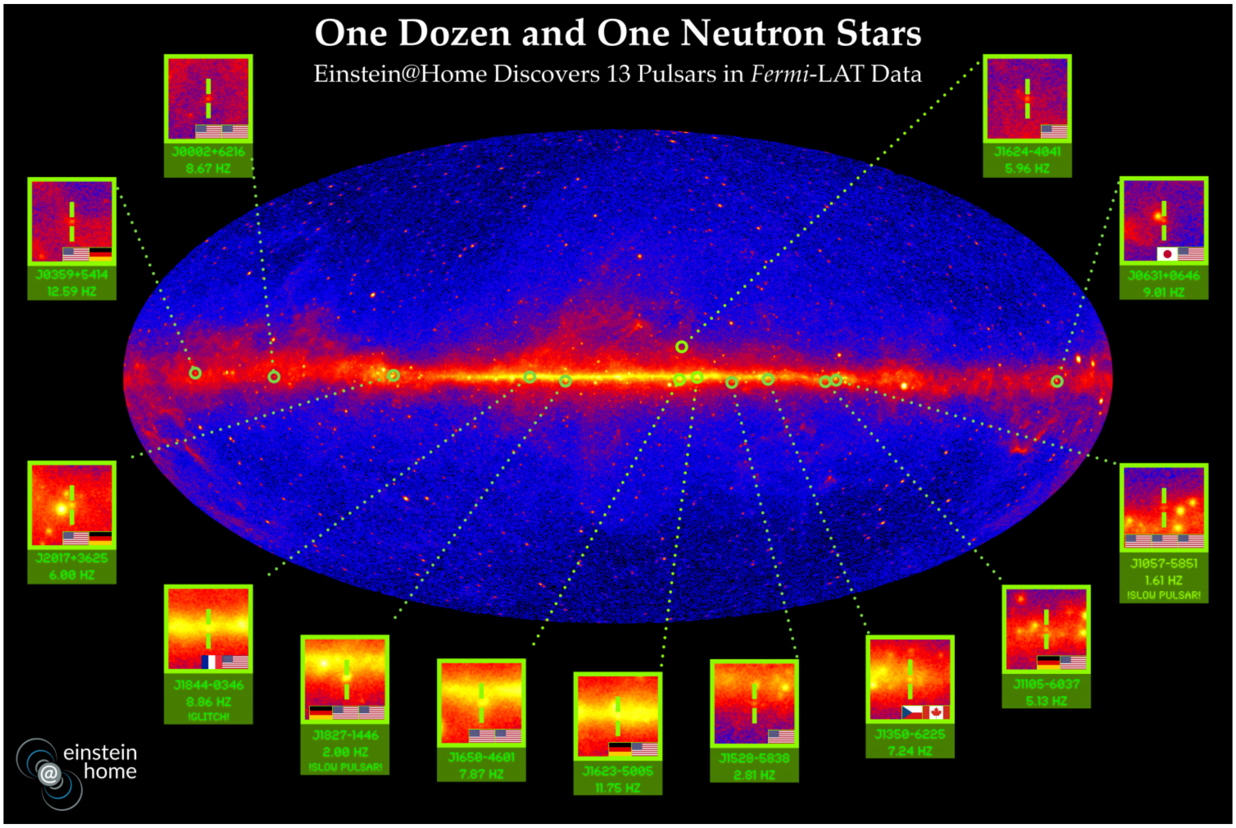
"We discovered so many new pulsars for three main reasons: the huge computing power provided by Einstein@Home; our invention of novel and more efficient search methods; and the use of newly-improved Fermi-LAT data. These together provided unprecedented sensitivity for our large survey of more than 100 Fermi catalog sources," says Dr. Colin Clark, lead author of the paper now published in The *Astrophysical Journal*.

Neutron stars are compact remnants from supernova explosions and consists of exotic, extremely dense matter. They measure about 20 kilometers across and weigh as much as half a million Earths. Because of their strong magnetic fields and fast rotation they emit beamed radio waves and energetic gamma rays similar to a cosmic lighthouse. If these beams point towards Earth once or twice per rotation, the neutron star becomes visible as a pulsating radio or gamma-ray source – a so-called pulsar.

"Blindly" detecting gamma-ray pulsars

Finding these periodic pulsations from gamma-ray pulsars is very difficult. On average only 10 photons per day are detected from a typical pulsar by the Large Area Telescope (LAT) onboard the Fermi spacecraft. To detect periodicities, years of data must be analyzed, during which the pulsar might rotate billions of times. For each photon one must determine exactly when during a single split-second rotation it was emitted. This requires searching over years long data sets with very fine resolution in order not to miss a signal. The computing power required for these "blind searches" – when little to no information about the pulsar is known beforehand – is enormous.

Previous similar blind searches have detected 37 gamma-ray pulsars in Fermi-LAT data. All blind search discoveries in the past 4 years have been made by Einstein@Home which has found a total of 21 gamma-ray pulsars in blind searches, more than a third of all such objects discovered through blind searches.



The entire sky as seen by the Fermi Gamma-ray Space Telescope and the 13 pulsars discovered by Einstein@Home that were now published. The field below each inset shows the pulsar name and its rotation frequency. The flags in the insets show the nationalities of the volunteers whose computers found the pulsars. Credit: Knispel/Clark/Max Planck Institute for Gravitational Physics/NASA/DOE/Fermi LAT Collaboration

Computing resource Einstein@Home

Enlisting the help of tens of thousands of volunteers from all around world donating idle compute cycles on their tens of thousands of computers at home, the team was able to conduct a large-scale survey with the distributed computing project Einstein@Home. In total this search required about 10,000 years of CPU core time. It would have taken more than one thousand years on a single household computer. On Einstein@Home it finished within one year – even though it only used part of the project's resources.

The scientists selected their targets from 1000 unidentified sources in the Fermi-LAT Third Source Catalog by their gamma-ray energy distribution as the most "pulsar-like" objects. For each of the 118 selected sources, they used novel, highly efficient methods to analyze the detected gamma-ray photons for hidden periodicities.

One dozen and one new neutron star

"So far we've identified 17 new pulsars among the 118 gamma-ray sources we searched with Einstein@Home. The latest publication in The *Astrophysical Journal* presents 13 of these discoveries," says Clark. "We knew that there had to be several unidentified pulsars in the Fermi data, but it's always very exciting to actually detect one of them and at the same time it's very satisfying to understand what its properties are." About half of the discoveries would have been missed in previous Einstein@Home surveys, but the novel improved methods made the difference.

Most of the discoveries were what the scientists expected: gamma-ray pulsars that are relatively young and were born in supernovae some tens to hundreds of thousands of years ago. Two of them however spin slower than any other gamma-ray pulsar known. Slow-spinning young pulsars on average emit less gamma-rays than faster-spinning ones. Finding these fainter objects is therefore useful to explore the entire gamma-ray pulsar population. Another newly discovered pulsar experienced a strong "glitch", a sudden speedup of unknown origin in its otherwise regular rotation. Glitches are observed in other young pulsars and might be related to re-arrangements of the neutron star interior but are not well understood.

Searching for gamma-ray pulsars in binary systems

"Einstein@Home searched through 118 unidentified pulsar-like sources from the Fermi-LAT Catalog," says Prof. Dr. Bruce Allen, director of Einstein@Home and director at the Max Planck Institute for Gravitational Physics in Hanover. "Colin has shown that 17 of these are indeed pulsars, and I would bet that many of the remaining 101 are also pulsars, but in binary systems, where we lack sensitivity. In the future, using improved methods, Einstein@Home is going to chase after those as well, and I am optimistic that we will find at least some of them."

More information: C. J. Clark et al. THE EINSTEIN@HOME GAMMA-RAY PULSAR SURVEY. I. SEARCH METHODS, SENSITIVITY, AND DISCOVERY OF NEW YOUNG GAMMA-RAY PULSARS, *The Astrophysical Journal* (2017). DOI: 10.3847/1538-4357/834/2/106