

Short gamma-ray bursts traced farther into distant universe

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Short gamma-ray burst host galaxies across cosmic time. Credit: W.M. Keck Observatory/Adam Makarenko

A Northwestern University-led team of astronomers has developed the most extensive inventory to date of the galaxies where short gamma-ray

bursts (SGRBs) originate.

Using several highly sensitive instruments and sophisticated galaxy modeling, the researchers pinpointed the galactic homes of 84 SGRBs and probed the characteristics of 69 of the identified [host galaxies](#). Among their findings, they discovered that about 85% of the studied SGRBs come from young, actively star-forming [galaxies](#).

The astronomers also found that more SGRBs occurred at earlier times, when the universe was much younger—and with greater distances from their [host galaxies](#)' centers—than previously known. Surprisingly, several SGRBs were spotted far outside their host galaxies—as if they were "kicked out," a finding that raises questions as to how they were able to travel so far away.

"This is the largest [catalog](#) of SGRB host galaxies to ever exist, so we expect it to be the gold standard for many years to come," said Anya Nugent, a Northwestern graduate student who led the study focused on modeling host galaxies. "Building this catalog and finally having enough host galaxies to see patterns and draw significant conclusions is exactly what the field needed to push our understanding of these fantastic events and what happens to stars after they die."

The team will publish two papers, detailing the new catalog. Both papers will publish on Monday, Nov. 21 in *The Astrophysical Journal*. Because SGRBs are among the brightest explosions in the universe, the team calls its catalog BRIGHT (Broadband Repository for Investigating Gamma-ray burst Host Traits). All of BRIGHT's data and modeling products are publicly available online for community use.

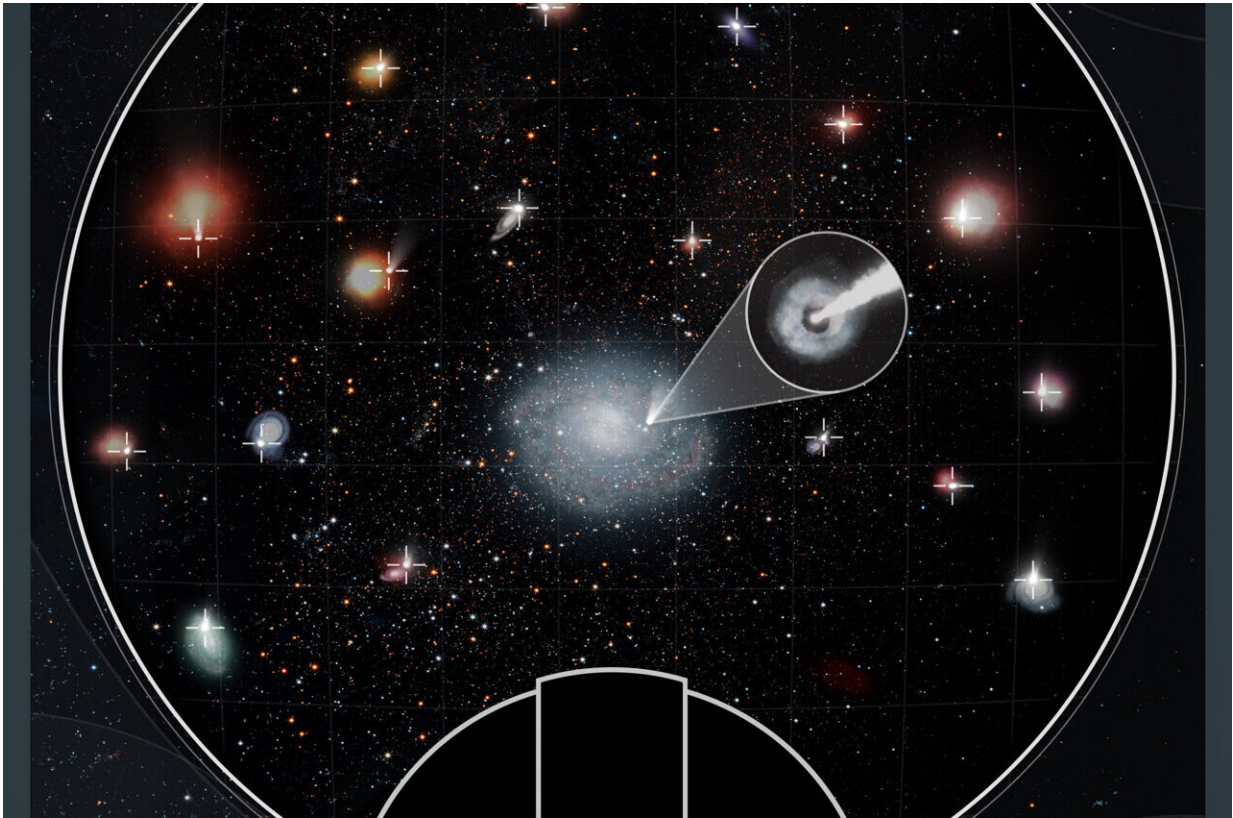
Nugent is a graduate student in physics and astronomy at Northwestern's Weinberg College of Arts and Sciences and a member of the Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA).

She is advised by Wen-fai Fong, an assistant professor of physics and astronomy at Weinberg and a key member of CIERA, who led a second study focused on SGRB host observations.

Benchmark for future comparisons

When two [neutron stars](#) collide, they generate momentary flashes of intense gamma-ray light, known as SGRBs. While the gamma rays last mere seconds, the optical light can continue for hours before fading below detection levels (an event called an afterglow). SGRBs are some of the most luminous explosions in the universe with, at most, a dozen detected and pinpointed each year. They currently represent the only way to study and understand a large population of merging neutron star systems.

Since NASA's Neil Gehrels Swift Observatory first discovered an SGRB afterglow in 2005, astronomers have spent the last 17 years trying to understand which galaxies produce these powerful bursts. Stars within a galaxy can give insight into the environmental conditions needed to produce SGRBs and can connect the mysterious bursts to their neutron-star merger origins. So far, only one SGRB (GRB 170817A) has a confirmed neutron-star merger origin—as it was detected just seconds after [gravitational wave detectors](#) observed the binary neutron-star merger (GW170817).



Short gamma-ray burst host galaxies across cosmic time. Credit: W.M. Keck Observatory/Adam Makarenko

"In a decade, the next generation of gravitational wave observatories will be able to detect neutron star mergers out to the same distances as we do SGRBs today," Fong said. "Thus, our catalog will serve as a benchmark for comparison to future detections of neutron star mergers."

"The catalog can really make impacts beyond just a single class of transients like SGRBs," said Yuxin "Vic" Dong, study co-author and astrophysics Ph.D. student at Northwestern. "With the wealth of data and results presented in the catalog, I believe a variety of research projects will make use of it, maybe even in ways we have yet not thought of."

Insight into neutron-star systems

To create the catalog, the researchers used several highly sensitive instruments at W.M. Keck Observatory, the Gemini Observatories, the MMT Observatory, the Large Binocular Telescope Observatory and the Magellan Telescopes at Las Campanas Observatory to capture deep imaging and spectroscopy of some of the faintest galaxies identified in the survey of SGRB hosts. The team also used data from two of NASA's Great Observatories, the Hubble Space Telescope and Spitzer Space Telescope.

Prior to these new studies, astronomers characterized host galaxies from only a couple dozen SGRBs. The new catalog is quadruple the number of existing samples. With the advantage of a much larger dataset, the catalog shows that SGRB host galaxies can be either young and star-forming *or* old and approaching death. This means neutron-star systems form in a broad range of environments and many of them have quick formation-to-merger timescales. Because neutron-star mergers create heavy elements like gold and platinum, the catalog's data also will deepen scientists' understanding of when precious metals were first created in the universe.

"We suspect that the younger SGRBs we found in younger host galaxies come from binary stellar systems that formed in a star formation 'burst' and are so tightly bound that they can merge very fast," Nugent said. "Long-standing theories have suggested there must be ways to merge neutron stars quickly, but, until now, we have not been able to witness them. We find evidence for older SGRBs in the galaxies that are much older and believe the stars in those galaxies either took a longer time to form a binary or were a binary system that was further separated. Hence, those took longer to merge."

Potential of JWST

With the ability to detect the faintest host galaxies from very early times in the universe, NASA's new infrared flagship observatory, the James Webb Space Telescope (JWST), is poised to further advance the understanding of neutron star mergers and how far back in time they began.

"I'm most excited about the possibility of using JWST to probe deeper into the homes of these rare, explosive events," Nugent said. "JWST's ability to observe faint galaxies in the universe could uncover more SGRB host galaxies that are currently evading detection, perhaps even revealing a missing population and a link to the early universe."

"I started observations for this project 10 years ago, and it was so gratifying to be able to pass the torch onto the next generation of researchers," Fong said. "It is one of my career's greatest joys to see years of work come to life in this catalog, thanks to the young researchers who really took this study to the next level."

More information: Short GRB Host Galaxies I: Photometric and Spectroscopic Catalogs, Host Associations, and Galactocentric Offsets, *Astrophysical Journal* (2022). iopscience.iop.org/article/10.1086/4357/ac91d0

Short GRB Host Galaxies II: A Legacy Sample of Redshifts, Stellar Population Properties, and Implications for their Neutron Star Merger Origins, *Astrophysical Journal* (2022). iopscience.iop.org/article/10.1086/4357/ac91d1

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