Variable stars can tell us where and when to search for extraterrestrials

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Artist's impression of the Gaia spacecraft detecting artificial signals from a distant star system. In this synchronization scheme, the star system's inhabitants send the signal shortly after witnessing a supernova, which is also seen by telescopes on Earth. Credit: Danielle Futselaar / Breakthrough Listen

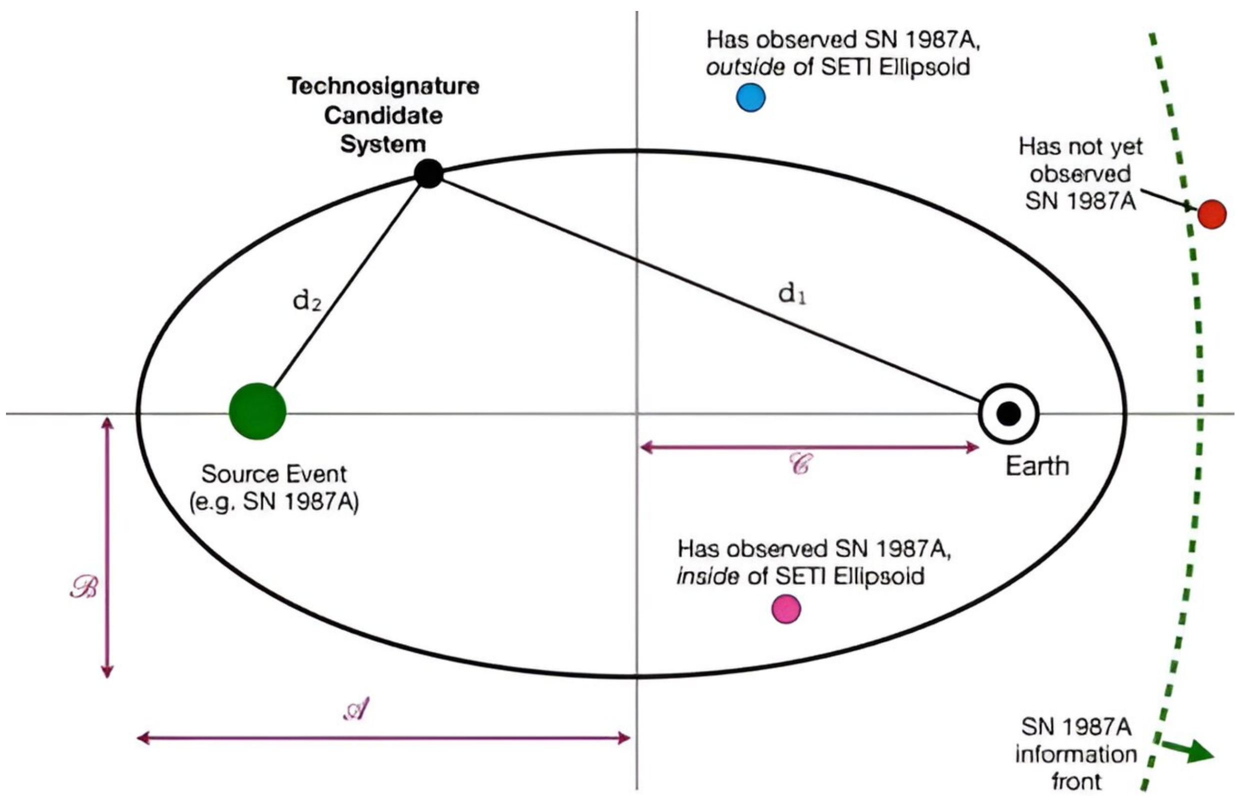
The European Space Agency's Gaia Observatory has been operating steadily at the Earth-sun L2 Lagrange Point for almost a decade. As an astrometry mission, Gaia aims to gather data on the positions, proper motion, and velocity of stars, exoplanets, and objects in the Milky Way and tens of thousands of neighboring galaxies. By the end of its primary mission (scheduled to end in 2025), Gaia will have observed an estimated 1 billion astronomical objects, leading to the creation of the most precise 3D space catalog ever made.

To date, the ESA has conducted three data releases from the Gaia mission, the latest (DR3) released in June 2022. In addition to the breakthroughs these releases have allowed, scientists are finding additional applications for this astrometric data. In a recent study, a team of astronomers suggested that the variable star catalog from the Gaia Data Release 3 could be used to assist in the Search for Extraterrestrial Intelligence (SETI). By synchronizing the search for transmissions with conspicuous events (like a supernova!), scientists could narrow the search for extraterrestrial transmissions.

The study was led by Andy Nilipour, an undergraduate student at the Yale University Department of Astronomy. He was joined by James R.A. Davenport, a Research Scientist at the University of Washington, Seattle; Adjunct Senior Astronomer Steve Croft from the Radio Astronomy Lab and the SETI Institute at UC Berkeley; and Andrew Siemion, the Bernard M. Oliver Chair for SETI Qualification at UC Berkeley, the Jodrell Bank Center for Astrophysics (JBCA) at the University of Manchester, and the Institute of Space Sciences and Astronomy at the University of Malta.

This study, which was recently published in *The Astronomical Journal* ("Signal Synchronization Strategies and Time Domain SETI with Gaia DR3"), was Nilipour's first academic study. As he explained in an interview with Yale News, "My two mentors, Steve Croft, and James Davenport, chose this for me, the idea of developing a geometric technique for constraining [technosignature] searches. It's probably the biggest challenge in SETI right now because there are so many possibilities for the location of a transmission and the nature of the signal."

Put simply, technosignatures are evidence of activity that unambiguously demonstrates the presence of an advanced technological civilization. To date, the vast majority of SETI experiments have searched for radio signals since the technology is known to be viable and radiowaves propagate well through space—the most advanced and comprehensive being Breakthrough Listen. These experiments also consisted of listening to various stars for a set period in the hopes of discerning radio signals coming from orbiting planets. But in recent years, scientists have expanded the range of potential technosignatures and]considered other methods as well.



The “SETI ellipsoid” is an egg-shaped zone of space where alien civilizations would have had enough time to observe an astronomical event and then send out a signal that could be observed from Earth. Credit: Davenport et al. (2022)

Said Nilipour, "There are lots of thoughts about what technosignatures might look like. The most common form that we look for is narrowband radio emission, because, based on our sample size of human technology, this seems to be something that a technological civilization should be producing. Other forms might be laser emission, close encounters of stars at high velocities, and emission from a star suddenly and dramatically decreasing."

For their study, Nilipour and his team theorized that an intelligent civilization would understand how difficult it is to monitor all the space surrounding their planet in every possible mode—radio, optical, infrared, ultraviolet, X-ray, gamma-ray, etc. As such, they might opt to time their signals of greeting (fingers crossed!) with a conspicuous astrophysical event that would draw the attention of observers—i.e., supernovae. Nilipour began working on this theory as part of a summer undergraduate program offered by the National Science Foundation (NSF) and the Breakthrough Listen Initiative at the Berkeley SETI Research Center.

As a first step, Nilipour and his colleagues chose four historical supernovae from the past 1,000 years and examined how long it took light from their explosions to reach Earth. As Nilipour explained, "We merged two searching frameworks—the ellipsoid method, which synchronizes signals to a conspicuous astronomical event, and the Seto method, which is tied to geometric angles and not distance—and applied them to four events.

"We chose four historically documented supernovae from the years

1054, 1572, 1604, and 1987, respectively. In this case, a supernova would act like a lighthouse, a common focal point for the sender of the signal and the receiver of the signal—us."

They determined that the light caused by these four events took 6,300 years, 8,970 years, 16,600 years, and 168,000 years to reach Earth (respectively). They then compared these results to light signals from over 10 million stars recorded by the Gaia observatory that were included in the DR3 catalog. This revealed 465 stars whose light took the same amount of time to reach Earth and 403 stars whose light signals traveled to Earth from an advantageous angle in relation to these supernovae. While none of the 868 systems yielded evidence of technosignatures, their results have provided important constraints for future searches.

Artist’s impression of Green Bank Telescope connected to a machine learning network. Credit: Breakthrough Listen/Danielle Futselaar

As Nilipour indicated, their method can also be used to search through other archival data to tease out possible signs of technosignatures.

"Finding a technosignature would have been incredible, but this really was more about showing a methodology that we can use in the future. What we've done here can be applied to additional Gaia data, to data from TESS [the Transiting Exoplanet Survey Satellite], and to other data as it becomes available. We're currently running the same type of analysis using a new supernova in the galaxy M101 that became visible in May of this year, which is the closest supernova in over a decade."

Given the number of stars in our galaxy alone, the amount of background noise, the time-sensitive nature of transmissions, and (as if that wasn't enough) the likelihood of obtaining false positives, searching for potential technosignatures is an extremely daunting task. Were it possible to monitor every sector of the sky—indefinitely and in multiple wavelengths simultaneously—it would just be a matter of time before transmissions could be heard (assuming anyone out there was transmitting). Unfortunately, we don't have the time or the resources for such thorough all-sky coverage.

Herein lies the value of research like this, which effectively narrows the search by exploring different types of technosignatures, frequency ranges, and locations in the night sky. Little by little, SETI researchers are improving the odds of an unambiguous detection that can be confirmed by follow-up studies. If there is a needle to be found in the cosmic haystack, we will find it sooner or later. Despite the limits imposed on us by such a large universe and so many possibilities, it is still just a matter of time.

More information: Andy Nilipour et al, Signal Synchronization Strategies and Time Domain SETI with Gaia DR3, *The Astronomical Journal* (2023). DOI: 10.3847/1538-3881/acde79

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