The most mysterious star in the cosmos

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Credit: Georgia State University

Round 5 a.m. on a Tuesday this past May, Tabetha "Tabby" Boyajian sat staring at a laptop, cross-legged on her couch in the living room of her Baton Rouge, La., home. The coffee table was cluttered with the artifacts of an all-nighter: an empty wine glass to calm her nerves alongside an empty coffee mug to fuel her through the night.

Since midnight, Boyajian had been downloading and analyzing data from the Las Cumbres telescopes—two on Maui, Hawaii, and two more on the Spanish island of Tenerife off the coast of West Africa—that sat trained on an F-type star, bigger and hotter than the sun, near the constellation Cygnus.

She'd been working all night, but Boyajian had been waiting for this moment for four years. By 5 a.m., data from the telescopes in Maui confirmed what the ones in Tenerife had already said: The star formally known as KIC 8462852, now called "Tabby's Star," had started to dim again.

For the next five days—while Boyajian, her colleagues and a pack of crowdsourced amateur astronomers from around the world observed—the star grew dimmer and dimmer.

"I don't think I slept for a week," says Boyajian, an assistant professor of physics and astronomy at Louisiana State University (LSU).

An event never seen on any star in the universe, it was as if the hand of God had turned a giant dimmer in the sky. Science proffered no explanations for what was causing the star to wane, how long it would last or how much light the star would lose. After the star had faded by 2 percent over the course of five days, the lights mysteriously rebounded more slowly than they dimmed.

Since the star's discovery in 2009, the anomalous luminary has inspired theories behind its sensational odd-ball behavior. When astronomers and stargazers watch the star fade, are they witnessing the aftermath of a star devouring its planet? A catastrophic collision of planets? Or does the star's waning shed light on the ever elusive search for intelligent life?

This latest event in a string of inexplicable fluctuations could provide an

answer.

On March 7, 2009, the National Aeronautics and Space Administration (NASA) launched the Kepler Mission. Until May 2013, the Kepler spacecraft continuously monitored the same patch of sky in search of undiscovered exoplanets—that is, planets that orbit stars other than our sun.

While comprising less than one-tenth of a percent of the visible sky, the field under Kepler's gaze contained more than 150,000 stars. Throughout its mission, Kepler took a measurement known as a "light curve" of each star's brightness every 30 minutes. Dips in a star's brightness, also known as flux, can signal a planet is passing in front of it.

The light curves of more than 150,000 stars, captured every half-hour for four years, amount to more than 2.5 billion data points per year. Computer algorithms can search the data for light curves that would indicate the presence of an Earth-sized planet that orbits its star once a year but might not pick up planets whose orbits lasted longer than that.

Humans, however, have unique pattern-recognition abilities. So, Boyajian and her colleagues at Yale University, where she was then a postdoctoral fellow, decided to crowdsource the data analysis.

They started Planet Hunters, a citizen science project through which amateur astronomers can mine the data captured by Kepler for trends computers don't detect.

Posting their findings on an online forum, planet hunters sometimes detect patterns that lead to the discovery of a planet. Other times, they pick up on unusual behavior that puts certain stars on a watch list. That's what happened when amateur astronomer Adam Szewczyk saw that KIC 8462852 was dimming in a way planet transit couldn't cause.

When Boyajian saw the posts in the forum about KIC 8462852, the skeptical scientist figured the data had to be wrong. After all, "Extraordinary claims require extraordinary evidence," she says, quoting Carl Sagan.

When a planet passes in front of a star, it briefly blocks a miniscule shred of the star's light—less than one-tenth of a percent—for a few hours. Plotted on a graph, that slight dimming registers as a narrow, symmetrical dip in an otherwise straight line, like an icicle dangling from a rooftop. Once several of these dips are recorded, a pattern emerges, such as a star that loses .08 percent of its light for four hours every 75 days. That's how planets are discovered.

"But with this star, you don't have the regular, periodic dips," says Boyajian. "There is no period in which you know dips will occur. The dips last for extraordinarily long periods of time—different durations each time."

The shape of the dips on the light curve are irregular and asymmetrical—and different every time. Taken together, these behaviors hardly suggest a planet is passing in front of the star at regular intervals.

Boyajian was prepared to find an error in the data or a technical problem with the telescope itself.

"Stars just don't do that," she says.

But over the remaining years of the Kepler Mission, the telescope continued to record arbitrary dips in flux that were confirmed by several other space- and land-based telescopes pointed at the star. Its luminosity plummeted up to 22 percent in dips that lasted anywhere from five to 80 days. The star also faded cumulatively over those four years. What's

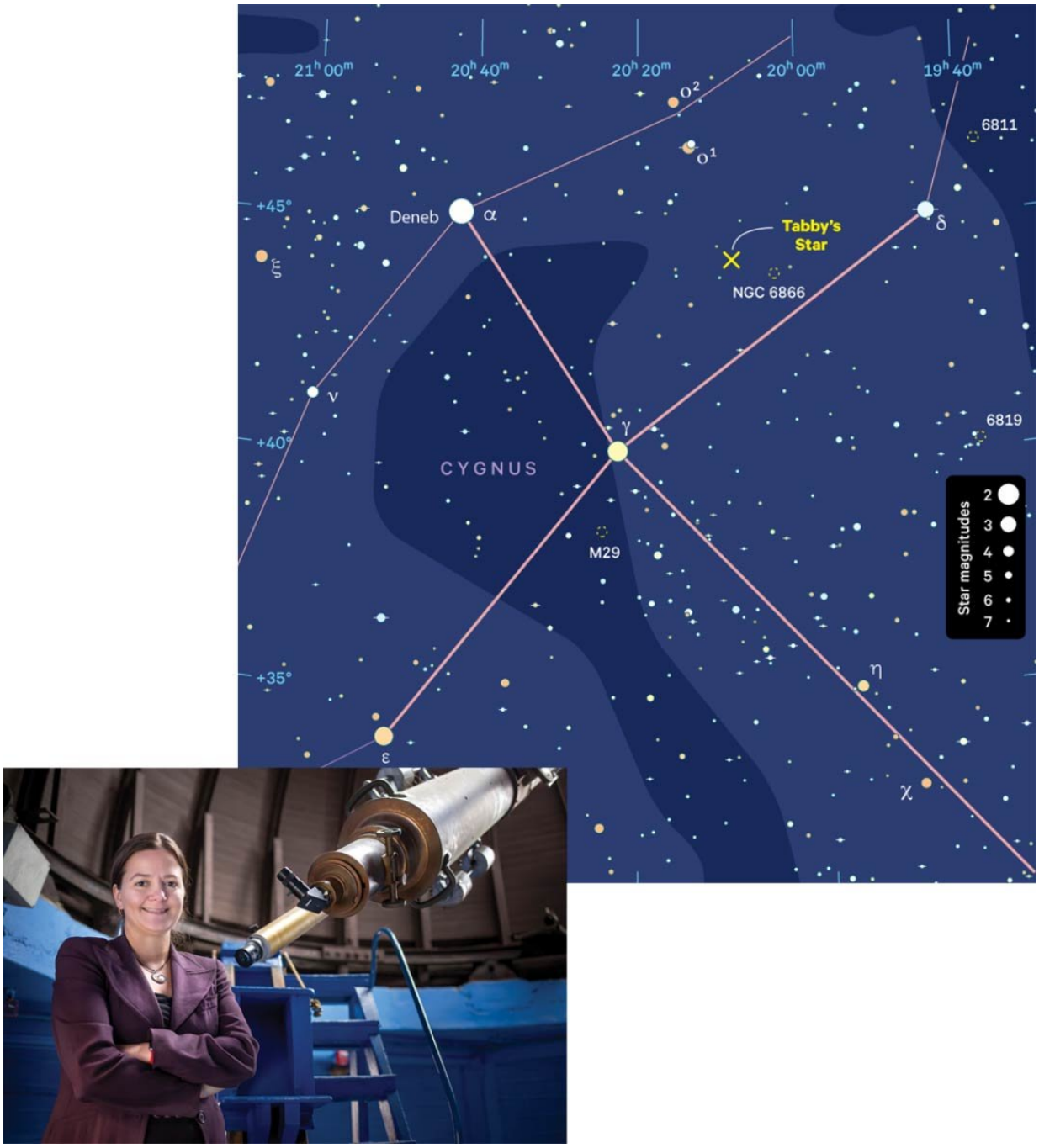
more, other—albeit hotly contested—data captured through a different method before the Kepler Mission say the star faded by a full 16 percent between 1890–1989.

Boyajian, several dozen other professional astronomers and 11 of the citizen scientists who helped uncover the star published a paper on its discovery in *Monthly Notices of the Royal Astronomical Society*, in which they cleverly asked, "Where's the flux?" and inspired followers of the luminary to call it the "WTF Star."

Boyajian suggests the flux could be hidden behind a swarm of comets that has fallen towards the star. Or perhaps rocky debris, stirred up after some sort of catastrophic collision, could be blocking the star's light at these unpredictable intervals.

But for each of the possible explanations Boyajian and her colleagues propose in their initial discovery paper, they offer solid reasons to question that theory.

"There's definitely nothing we know of now that's able to explain it," she says. "Nature is a lot more creative than we are."



Credit: Georgia State University

Maybe so, but Tabby's Star has captured the imaginations of astronomers

around the world. Their theories about what's blocking the star's light are nothing if not creative.

A team of astronomers from Columbia University and the University of California (UC), Berkeley, says Tabby's Star might have devoured a planet or a moon more than 100 years ago. The energy intake froma meal like that would cause the star toshine brighter, which would explain the century of fading: The star was returning to its original luminosity after digesting the meal.

As for the random dips in flux since then, "Anything that didn't quite get ealike leftover crumbs from a snack, could still be orbiting the star and occasionally blocking its light," says astronomer Jason Wright, assistant professor of astronomy and astrophysics at Penn State University.

Wright keeps track of the latest theories on his blog. (Incidentally, he is the one who called KIC 8462852 "Tabby's Star" in an interview with a reporter, and the moniker stuck. "Yes, it's all my fault," he admits.)

While the planet-devouring theory explains the century-long dimming and the episodic dips, the architects of the theory acknowledge the statistical improbability of such an occurrence in their 2017 paper in Monthly Notices of the Royal Astronomical Society.

"The problem with Tabby's Star," says Daryll LaCourse, amateur astronomer and a co-author of the discovery paper, "is that every explanation that doesn't involve aliens has some sort of problem, some unresolved big issue with that particular theory."

Astronomers don't waste their time pinning alien theories on any old cosmic anomaly they encounter. They save these eyebrow-raising claims for oddities that simply can't be explained by natural causes. That makes Tabby's Star "the most promising stellar SETI [search for extraterrestrial

intelligence] target discovered to date," says Wright in his 2015 paper in the *Astrophysical Journal*.

Wright says a swarm of structures—alien megastructures, he calls them—built by other inhabitants of our universe could be orbiting the star to harness its energy, as humans do through solar panels.

"Imagine a flock of starlings flying in front of the sun," he says. In some places the flock would block out the sun's light; in others, fingers of light would poke through. Like a flock of birds, the formation of these alien structures could change, accounting for the irregular light curves.

To test any any of these hypotheses, astronomers needed more data than the Kepler Mission provided. They needed to observe the star for many more years and record many more dips in flux. But telescope time costs money. So Boyajian turned to Kickstarter, the online funding platform for creative projects.

"The most mysterious star in the galaxy," reads the title of Boyajian's campaign page. More than 1,700 backers contributed $107,421 to cover surveillance of Tabby's Star over a private, robotic network of telescopes. Las Cumbres Observatory gifted 200 hours on its Maui and Tenerife telescopes, which covered observation from March 2016 through February 2017. The Kickstarter funds covered observation thereafter, which will continue through May 2018. Data from the telescopes downloads to Boyajian's computer, where she plots it on a chart so she can identify when the star's light begins to drop.

That's what kept her up all night that Tuesday in May.

At 5 a.m., when it was clear the star was losing flux, Boyajian called Wright.

"It's time," she told him.

The beauty of scientific research that has been crowdsourced and crowdfunded almost from the start is that Boyajian can quickly send out an "all hands on deck" across the globe to people who want to help. She needed the support right away of anyone who could observe the dip via telescope or analyze the data the scopes produce.

"We had an awesome response from the entire astronomers' community, pitching in observations on telescopes we didn't know we had, folks taking their own time to take observations for us and figuring out how to share enormous amounts of data," she says.

It's a good thing Boyajian got to see her scientific support network in action. That way, she was ready for the next dip. By early June, Tabby's Star was bright again. Then, June 11, the flux began to trend back down. Like last time, the star faded by two percent, but this time the fading and rebounding took two weeks.

Data gathered from these events can help astronomers determine whether the material blocking the light is solid or diffuse. If the material is solid, alien megastructures can't be ruled out.

"As long as we don't have a convincing explanation for what's going on, and there's a possibility that what we're seeing is due to an advanced technology, we'll certainly continue to observe the star," says Andrew Siemion, director of UC Berkeley's SETI Research Center, who follows the star.

Astronomers at Berkeley's SETI Research Center have spent a couple dozen hours observing Tabby's Star through the Green Bank telescope, the largest fully steerable radio telescope on Earth. In the spirit of crowdsourcing, the raw data will be made public so anyone with the

skills can analyze it for signs that communication technology is present near the star.

Aliens capable of building massive structures that harvest the star's light would certainly have such technology. So far, no signs have been uncovered, but Siemion is undaunted.

"There is no more profound or fundamental question we can ask as scientists or human beings than whether there is other life elsewhere in the universe," he says. "So, as long as I have a good idea and the means to pursue it, I will personally keep looking."

Siemion is not alone. There's not a SETI researcher out there, he says, who hasn't looked at Tabby's Star.

For now, cosmic collisions, planet-devouring fireballs and, yes, even aliens are still on the table—the coffee table in Boyajian's living room in Baton Rouge.

Boyajian hasn't figured out exactly what's happening on her star yet, but she knows she's getting closer.

Provided by Georgia State University