Rings of debris are the most likely explanation for the mysterious dimming of Tabby's Star, as seen in this artist's concept. The rings could be the remnants of ploonets — moons that escaped their host planets. NASA/JPL-CALTECH

there is one — from a background star as their motions through the galaxy separate them on the sky.

WAYWARD MOONS

If planets can go rogue, what about their moons? The search has already begun for orphaned exomoons within stellar systems — which one team of researchers has dubbed ploonets. Since astronomers think exomoons are more numerous than exoplanets, the existence of ploonets seems likely. But detecting them will stretch the capabilities even of next-generation current technology.

So far, nearly everything we have learned about ploonets comes from models. According to recent simulations, ploonets are born from chaotic tangos between their parent planet and the host star. The team in Chile that coined the term was focused on hot Jupiters, giant exoplanets that have spiraled inward to Mercury-like distances from their stars. As such a planet gets closer to its host star, it experiences tidal forces that distort it. Due to a complex interplay of gravity and friction, the tidal bulge slows the planet's rotation while giving a boost to the moon's momentum, sending the latter into a higher orbit. As distance grows, the gravitational bond between planet and moon can become so weak that the host star tears the moon away as a distinct planet.

A 2019 study identified another way moons might go rogue — when a giant planet and its moons orbit a star that is part of binary system. The gravity of the second star nudges the planet into a disrupted, eccentric orbit that sends it whipping so close by its host star that the planet loses "custody," and the star adopts the moon into an independent circumstellar orbit — assuming it doesn't swallow and vaporize it first.

The study found that only 10 percent of ploonets outlive their parent planets. The rest plummet into their star, smash into their parents, or are vaporized by stellar radiation, leaving an orbiting ring of dust, gas, and debris. Such debris rings can also repeatedly dim their host star, which could explain the erratic — and mysterious — dimming of Tabby's Star in the constellation Cygnus. Moons that fail to achieve runaway status and are destroyed by their parent planet also may explain the peculiar case of an exoplanet roughly 430 light-years away, which appears to have no fewer than 37 rings around it.

"All these scenarios almost definitely happen," says Miguel Martinez of Northwestern University, lead author of the 2019 study. "The question is whether the rates are large enough that we can detect these events with current data and instruments. The fact that we've seen one Tabby's Star so far, instead of a lot of them, shouldn't be surprising."

For now, such leftover debris fields may be the best chance for astronomers to infer the existence of ploonets. After all, even if astronomers detect a runaway ploonet orbiting its host star, it would be hard to distinguish it from normal planets. "I don't think anyone has seriously looked at that problem yet," says Martinez. Perhaps astronomers will find ploonets and not even realize they have found them.

STARS UNLEASHED

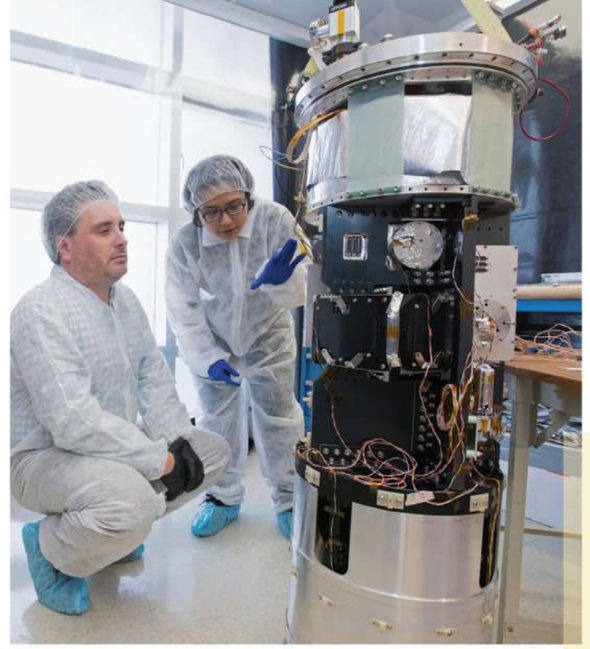
If moons can be dislodged from planets and planets can be torn from stars, can stars be flung from galaxies? A century ago, even the question would have been nonsensical, for our galaxy was thought to encompass the entire universe. The very concept of multiple galaxies was mocked by the world's top astronomers.

NASA's Nancy Grace Roman Space Telescope — seen here in an artist's concept — is scheduled to launch later this decade. NASA'S GODDARD SPACE FLIGHT CENTER

But Henrietta Leavitt's discovery in 1908 that the pulse of variable Cepheid stars could be used to mark distances — plus Edwin Hubble's measurements of Cepheids in the Andromeda Galaxy in 1924 — proved that the universe comprises countless galaxies, each containing billions of stars held together by extraordinary gravitational glue.

That made it hard to imagine that stars could breach and escape such rigid boundaries. Then, in 1997, Hubble imaged hundreds of red giant stars hovering amid the Virgo galaxy cluster, far removed from any particular galaxy. Subsequent measurements in 2005 by scientists at the Harvard-Smithsonian Center for Astrophysics clocked stars flung from our galaxy at nearly 1.5 million mph (2.4 million km/h). Several years ago, a team led by Vanderbilt astronomers discovered hundreds more such hypervelocity stars — which they called rogue stars — on the outskirts of the Milky Way, heading for the Andromeda Galaxy.

Around that same time, Michael Zemcov, an assistant professor at Rochester Institute of Technology, started using sounding rockets carrying near-infrared telescopes to peer into the darkest patches of the sky, hoping to detect light from primordial galaxies. His team succeeded in detecting a faint, diffuse glow — but it was far too blue and bright to come from such distant sources, whose light has been heavily redshifted, or stretched out to redder wavelengths. They concluded the glow came from rogue stars — more rogue stars than anyone had ever imagined existing in the universe.



ABOVE: The CIBER-2 mission will be launched on a Black Brant sounding rocket similar to this one, seen launching from NASA's Wallops Flight Facility in Virginia. NASA

LEFT: Michael Zemcov and Chi Nguyen of the Rochester Institute of Technology examine the CIBER-2 payload in February 2019. A. SUE WEISLER/RIT

Zemcov thinks these stars are ejected when galaxies crash into each other. These collisions are "sloppy," he explains. "[The galaxies] merge and get bigger, but you lose some of the batter out of the bowl."

He believes extremely distant rogue stars may help solve a problem of missing matter: According to cosmologists, a significant amount of mass and light that should be visible is missing from the universe, even after adding up all known galaxies. (This "missing baryon problem" is separate from dark matter, the mysterious stuff that permeates the universe and holds galaxies together.) "Our work says that if you sum up all of the light from the galaxies that you see, it would be roughly the same as the amount of light outside of galaxies [from rogue stars]," Zemcov says.

There are more exotic, alternative explanations for this feeble ubiquitous light, such as decaying dark matter, but Zemcov believes his explanation fits best. This spring, his team plans to launch a follow-up rocket, called the Cosmic Infrared Background ExpeRiment-2, or CIBER-2. With additional capability extending into the visible-light spectrum, they think it will be able to prove the mysterious signal is starlight.

INTO THE FOLD

Our gallery of intergalactic rogues doesn't end there. Some scientists suspect that the globular clusters wandering the gaps between galaxies in the Virgo cluster might actually be orbiting homeless black holes flung from galaxies in fatal mismatches with bigger opponents.

And last August, astronomers in Japan took the notion of homelessness to its most extreme. They calculated that, amid the vast maelstrom of gas and debris spinning around supermassive black holes at the centers of galaxies, starless planets 3,000 times the mass of Earth could form. These blanets, as the team called them, would be trapped in 1-million-year orbits 10 light-years from their surrogate "star," the event horizon.

The realm of rogues can be dizzying. Moons become ploonets. Failed stars become planets. Interstellar asteroids behave like comets. Black holes give rise to blanets. And astronomers believe there may be as many planets floating between stars as stars in our galaxy — or stars drifting between galaxies as galaxies in the universe. As telescopes peer ever more keenly into space, the cast of characters promises to grow richer, upending the story of our solar system, our galaxy, and the farthest reaches of the cosmos.

Randall Hyman *writes about science and natural history for various magazines including* Discover, Science, Smithsonian *and* National Wildlife.