APRIL/MAY 2020 | SCIENTIFICAMERICAN.COM

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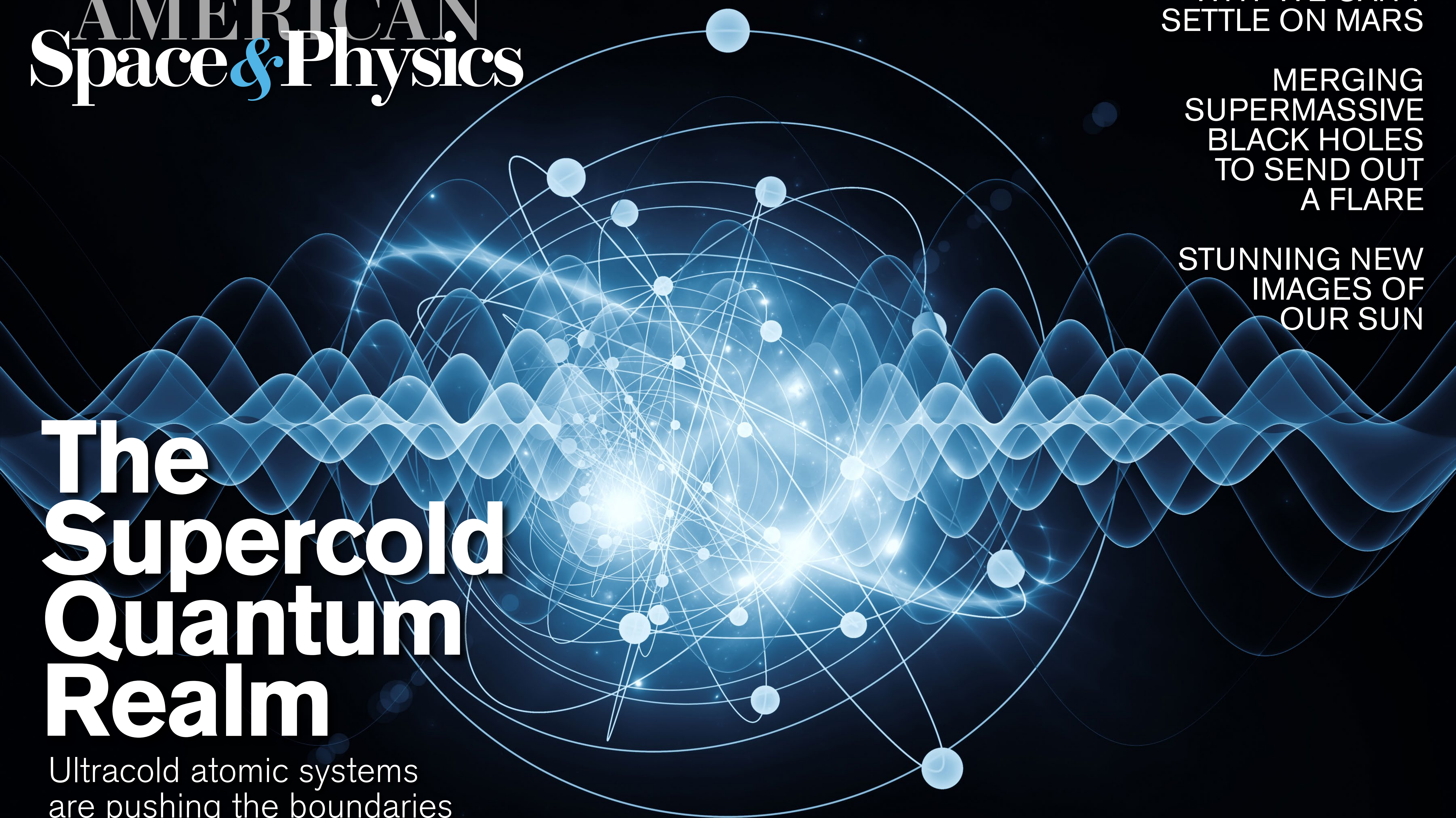

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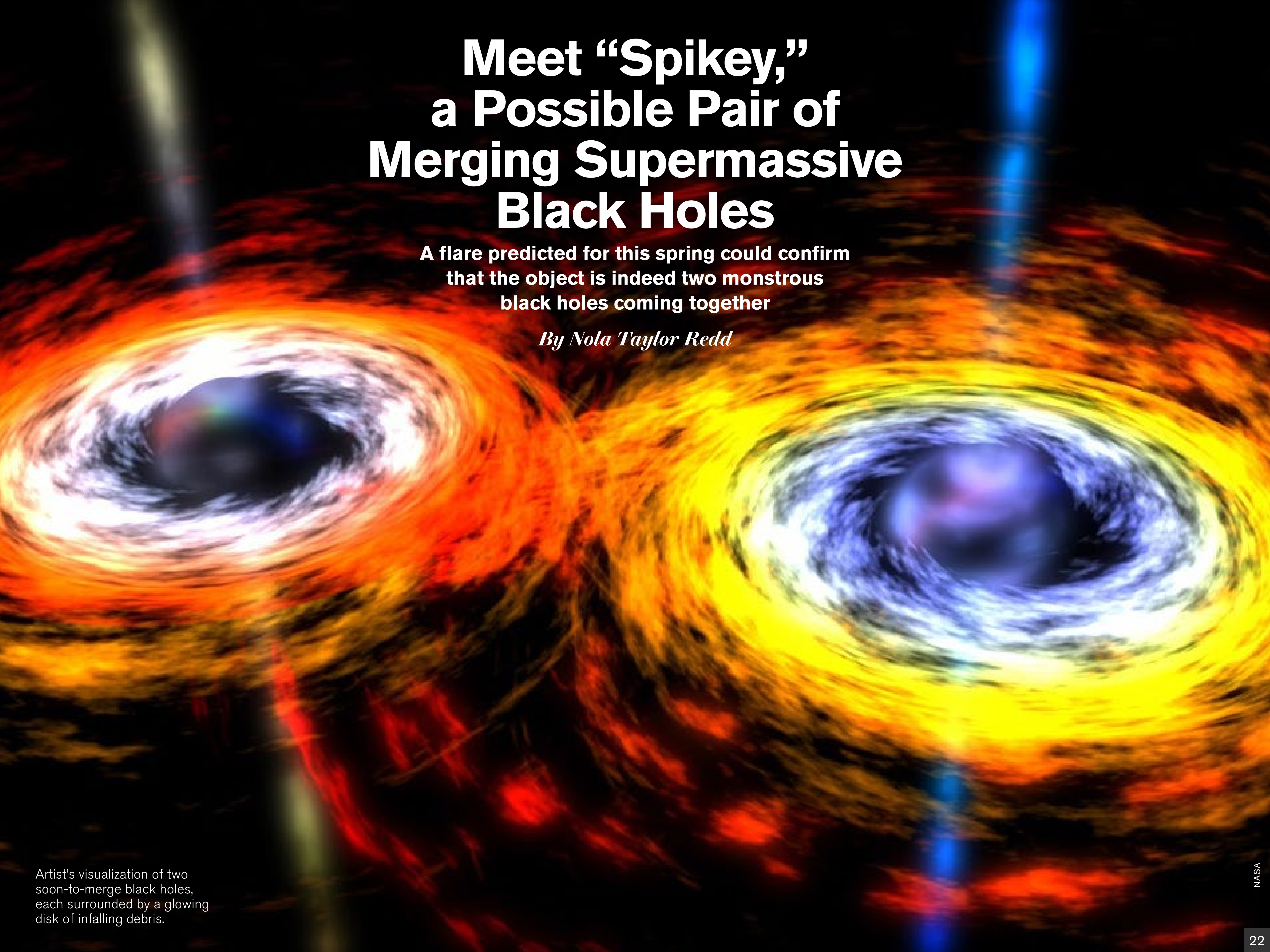
Meet "Spikey," a Possible Pair of Merging Supermassive Black Holes

A flare predicted for this spring could confirm that the object is indeed two monstrous black holes coming together

By Nola Taylor Redd



Artist's visualization of two soon-to-merge black holes, each surrounded by a glowing disk of infalling debris.

NASA

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A strangely flaring object at the center of a distant galaxy may be the key to unlocking the mystery of how the universe's most monstrous black holes merge.

Weighing in at millions to billions of times the mass of our sun, supermassive black holes are the ultimate heavyweights—and they lurk at the centers of almost every large galaxy. Although they emit no light, these objects can nonetheless create spectacular celestial fireworks as they feed on gas and dust, creating jets of high-energy particles and whirling disks of debris that can be seen clear across the cosmos as active galactic nuclei (AGNs). Now scientists have identified a flare in a faraway AGN that they suspect is created by a supermassive black hole amplifying the emissions of another one nearby, suggesting that the pair may merge in the next 100,000 years. If the two are in fact primed to merge, they would offer astronomers an unprecedented view into the poorly understood process of how giant black holes manage to get together at all.

In 2017 astrophysicists Daniel D'Orazio and Rosanne Di Stefano detailed how a pair of soon-to-merge supermassive black holes should gravitationally lens one another and how the resulting signal could be seen if the imminent merger's orbital plane aligned with Earth. Material surrounding the black holes should glow in the x-ray wavelength as it accelerates toward either member of the pair. If one black hole passes in front of the other, the immense, spacetime-warping gravitational field of the "foreground" black hole will act much like a lens, magnifying the background light source. "It's a very distinctive signature," says Di Stefano, a researcher at the Center for Astrophysics at Harvard University and the Smithsonian Institution.

In October she and D'Orazio, working with several collaborators, reported the discovery of an object emitting a signal that matched their theoretical prediction. Data gathered in 2011 by NASA's planet-hunting Kepler space telescope revealed an unusual AGN with a strange spike. If the object, nicknamed Spikey, repeats its flare again this spring, as predicted by D'Orazio and his colleagues, it will be what he calls the "smoking gun" confirming that Spikey is a pair of supermassive black holes on the cusp of merging. D'Orazio, an astronomer at Harvard, presented the new analysis last month at a meeting of the American Astronomical Society in Honolulu.

THE "FINAL PARSEC PROBLEM"

When galaxies collide, the supermassive black holes at their centers eventually find their way to the heart of the newly created galaxy and are ultimately drawn together. Observations of the cores of merging galaxies have revealed either a single supermassive black hole (presumably where two or more have already merged) or black holes that are orbiting within a few parsecs of one another (a parsec is roughly 3.26 light-years).

"We are very confident that when two galaxies merge, the black holes they host will get within a parsec of each other," says Scott Hughes, an astrophysicist at the Massachusetts Institute of Technology, who did not take part in the study.

The problem comes in the final parsec, where gravity is not strong enough to overcome the centrifugal force of each black hole's orbit to pull the pair closer together. Without a steady influx of material to shake things up, the two may stop just shy of merging and remain in a holding pattern over the lifetime of the universe. This "final parsec problem" does not affect pairs of smaller, stellar-mass black holes, which can more easily merge by bleeding off excess orbital energy via their copious emission of gravitational waves. But larger black holes need something to push them over that final hump before their own gravitational-wave emission can kick in, at which point an eventual merger becomes inevitable.

"We don't have a good understanding of what goes on in that final parsec," says Matthew Graham, a cosmologist at the California Institute of Technology, who was not involved in the new study. "We have a theoretical understanding, but we don't have good observational evidence to match against theory." At least, researchers do not have such evidence quite yet.

In addition to revealing thousands of exoplanets, Kepler also discovered a few dozen AGNs. A 2018 study of these objects revealed unusual flaring activity in one called KIC 11606854. A closer look revealed that the flare's waxing and waning light mirrored predictions of how a pair of merging black holes might gravitationally lens each other. Hello, Spikey.

"It ended up being very fortuitous," says Betty Hu, a graduate student at Harvard University and first author of the preprint paper reporting Spikey's discovery. The researchers studying the Kepler AGNs passed the information on to D'Orazio and his colleagues, who found that the signal matched up "very well" to the lensing model, Di Stefano says.

According to Di Stefano, the merging black holes might each be ringed by a "mini disk" embedded in a larger shared disk that orbits both objects. The mini disks could dissipate as the black holes gobble them down, only to be occasionally replenished with material from the larger outlying disk. Each black hole munching on a mini disk has a beneficial side effect, shedding additional orbital energy and allowing the two to spiral closer together, potentially overcoming the final parsec problem. According to the researchers' models, Spikey should merge in the next 100,000 years or so—an eyeblink on astronomical timescales.

UNTIL NEXT TIME

A single flare alone, however, is not enough to confirm that Spikey is a pair of merging black holes. D'Orazio and his colleagues are already planning to study Spikey this spring in search of more evidence. Based on their best estimates of the pair's orbits, they have tentatively identified the next gravitational-lensing event as most likely to occur in April 2020. But, Hu says, lingering uncertainties mean the flare could take place anywhere between February and July.

"I think [D'Orazio] has done a fantastic job of trying to figure out all the ways possible to follow up on this system because it is the best candidate [of merging black holes]."

—Rosanne Di Stefano

The team has already secured time on NASA's Chandra X-ray Observatory to watch for April's predicted flare, which should span about 10 days. In the meantime, the researchers are continuing to monitor the system using ground-based instruments. If Spikey starts acting up before April, they hope to catch a glimpse in order to shift their observations with Chandra and other facilities to compensate. "I think [D'Orazio] has done a fantastic job of trying to figure out all the ways possible to follow up on this system because it is the best candidate [of merging black holes]," Di Stefano says.

If Spikey shows the predicted flare this spring, it will be a big deal. "If it holds up and is, in fact, a binary, I think it will give us a case of what to look for if we're trying to find cases of close binaries not yet merged," Hughes says. Such an example should make hunting merging supermassive black holes easier in the future.

And that result would be good news for the European Space Agency's Laser Interferometer Space Antenna (LISA) mission, set to launch sometime in the 2030s to hunt for gravitational waves emitted by supermassive black holes. Although Spikey probably will not merge on LISA's watch, it can give mission planners a better idea of how many merging giants are out there for the spacecraft to see.

A FLARELESS WONDER

Then again, Spikey could fail to flare again; perhaps it is not a pair of supermassive black holes at all. According to Graham, the past few years have seen a rising number of claims of potentially merging supermassive black holes that wound up being something else.

If July passes with no sign of the unique signature, then it could be that the original event was just a never-before-seen flare type from a relatively normal AGN. Although there are still a handful of other candidates for near-merging supermassive black holes waiting to be confirmed, a nondetection would set those hunting merging black holes almost back to square one.

But a nondetection would not necessarily mean Di Stefano and D'Orazio's model is wrong. "This is a process that has to happen" somewhere in the universe, Di Stefano says. As long as two black holes are orbiting each other, gravitational lensing should occur; it is just a matter of the pair being in a suitable orientation for the effect to be seen from Earth. In their original paper, she and D'Orazio predicted that roughly 10 percent of binaries would be properly angled to give astronomers a glimpse of their gravitational-lens flares.

"Should Spikey not work out, we know that this process happens," Di Stefano says. "Ultimately we should be able to detect it, but we may have to look at other systems to see it." Graham agrees. "It's a conceptually neat idea," he says. "These things *should* be lensing."