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Behind the Black-Hole Image: One Giant Leap for Teamwork

How a global team of scientists used relentless bias-testing to produce the black-hole image

By

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In the mid-1990s, Sheperd Doeleman, a doctoral student in astrophysics at MIT, became fixated on a radical idea. He thought it might be possible to take a picture of a black hole.

In a literal sense, the answer was no, it's not—don't be ridiculous. Black holes are fields of intense gravity from which no matter, or light, escapes. You can't snap a Polaroid of nothing. Besides, the only conventional way to see an object across 55 million light years of space is to build a telescope dish the size of Earth. (Good luck writing that grant application.)

The budding astronomer obviously knew this, but as a student of something called Very Long Baseline Interferometry, he suspected there might be a hack. It wouldn't be easy. The plan might take decades and cost millions of dollars. It would also require an unprecedented collaboration by scientists all over the world.

For years, Dr. Doeleman struggled to raise funds for his long-shot project. In 2008, a small technical breakthrough tipped the scales. The idea, he told me, "went from being impossible to improbable to having real potential."

The project, which calls itself Event Horizon Telescope, would ultimately raise more than $40 million and convince 60 institutes in 20 nations to offer resources, including eight of the world's most expensive telescopes. Before all of that, however, Dr. Doeleman needed a team.

Persuading scientists to join him was a tall order. "People have careers to think about," he says. His comrades had to be both obsessive and unfazed by the prospect of failure; self-starters who could operate independently in a startup environment with no assumptions or precedents. Above all, he says, they had to embrace a culture of trust, "one in which we can disagree but remain open to being convinced."

As determined as he was, Dr. Doeleman knew he was wading into the deep end. In business, any leader who bets audaciously on a new product or market position knows their work will be judged by the money it makes. In research, where the only currency is knowledge, experiments only succeed if the scientific community accepts the findings.

Astronomers didn't really know how black holes worked and had only indirect evidence they exist. In theory, they should look like dark rings. But whether Dr. Doeleman's team produced a picture of a ring, an elephant or just an indeterminate blob, it was likely to be picked apart mercilessly.

Put simply, Dr. Doleman, now an astronomer at the Harvard-Smithsonian Center for Astrophysics, was about to gamble his career on a plan he was not certain he could execute and whose findings could be discarded over a single misstep. "It was like jumping off a cliff and building a parachute on the way down," he says.

The only way to "see" a black hole is to capture an image of its shadow. Rather than building one massive telescope, the EHT team wanted to combine the perspectives of many existing ones. Instead of taking pictures, they would capture signals from electromagnetic waves tumbling around the black hole's invisible contours. By feeding that data through an imaging algorithm, they hoped to construct a virtual rendering.

Dr. Doeleman's small team slowly grew to an army of 200 ranging from veterans like Sera Markoff, a theoretical astrophysicist at the University of Amsterdam, to postdoctoral fellows like Kazunori Akiyama, who co-led the imaging group. As they

The project, which calls itself Event Horizon Telescope, raises more than $40 million and convinces 60 institutes in 20 nations to offer resources to produce the first image of a black hole. PHOTO: NATIONAL SCIENCE FOUNDATION/GETTY IMAGES

puzzled over how to retrofit telescopes with atomic clocks or ship frozen hard drives from the South Pole, Dr. Doeleman gave them wide latitude to improvise.

In April 2017, eight telescopes from Chile to Hawaii simultaneously focused on the same supermassive black hole, collecting five petabytes of wave-signal data. Once the data had been processed, the team held four exhaustive all-hands meetings to review it. The next step—reducing it all down to a single image—was the trickiest. This was where human bias might creep in.

Analysts working in fields like intelligence or meteorology often make predictions that impact millions of lives. The persistent danger is that whatever they want to believe, or assume to be true, will override their objectivity. In his 2011 book "Reducing Uncertainty," former intelligence analyst Thomas Fingar wrote: "The line between analysis produced to inform and analysis produced to influence can be very vague."

On business teams, the central enemy is groupthink, which occurs when a group's natural urge to seek agreement leads to catastrophically ill-adviseddecisions.

The chief threat to the EHT imaging team was the consensus that black holes look like rings. To build an algorithm that predicts what data might "look" like, they would have to make hundreds of assumptions. If they harbored any prejudice, even subconsciously, they might corrupt the formulas to produce nothing but rings.

To test their algorithms for bias, the imaging team generated "fake" data designed to evoke other shapes; a shadow, a crescent, even a snowman. If the algorithms still spit out rings, they were clearly biased.

After clearing that bar, the team split into four groups. They were given separate algorithms and sent to four distinct locations to run the real telescope data. In July 2018, the four groups reconvened in a seminar room in Cambridge, Mass. to reveal their images. Although they used different algorithms and didn't compare notes, a similar-size ring appeared in each of them, always brighter in the south. "That's when we knew we had something," Dr. Doeleman says.

In a final bias test, the team used real telescopes to collect data from oddly shaped celestial objects to make sure the algorithms translated those correctly. After scrutinizing their work again in two more teamwide reviews, they decided to accept three of the black-hole images and combine them into one.

The last hurdle was to write six academic papers, submit them to journals for peer review and wait for them to be accepted.

Finally, at a news conference on April 10, Dr. Doeleman unveiled the final image—a dark circular void surrounded by flares of orange and yellow. "We have seen what we thought was unseeable," he said. "We have seen and taken a picture of a black hole."

Some prominent skeptics weren't so sure. George Capline, a physicist at Lawrence Livermore National Laboratories, says it's "way premature" for the team to claim it "saw" a black hole. Nevertheless, he said the team's findings seem both solid and significant. "The technical accomplishment was quite amazing."

In science, "not everyone needs to be convinced," Dr. Doeleman says. "I fully expect there could be questions asked and points raised—and we welcome that." As far as he's concerned, he says, "I'm more certain about this than just about anything." He considers the image "the biggest return on an investment in the history of astronomy."

If there's a lesson to draw here, it's about setting the bar high, distributing authority, encouraging collaboration across disciplines and, most of all, being relentlessly self-critical. "At every point we encouraged dissent and debate, looked at different viewpoints and interrogated the algorithms," Dr. Doeleman says. "We had done so much work that when nature smiled on us, we were ready."

In the torrent of postannouncement coverage, Katie Bouman, a 29-year-old computer scientist, was anointed by the media as the team's chief algorithmic architect. Her response said a lot about the nature of the group. "I don't know why I'm getting so much press," she told PBS. "Lots of people processing those petabytes of data—that's what made it possible."

For Dr. Doeleman, the long pursuit of an image yielded something else he hadn't expected. The more time passes, he says, "the more I'm just proud of the team. I think of the team as the thing that was built here."

—Mr. Walker, a former reporter and editor at The Wall Street Journal, is the author of

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