UC SANTA BARBARA

THE Current

December 18, 2025
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Astronomers discover huge dust clouds from violent collisions around nearby star

Young star systems are a place of violent collisions between rocks, comets, asteroids and larger objects as the dust and ice of a stellar nebula coalesce into planets and moons. But the largest collisions are expected to be rare over the hundreds of millions of years it takes to form a planetary system — perhaps once every 100,000 years.

Now, astronomers have seen the aftermath of two powerful collisions within a 20-year period around a nearby star called Fomalhaut. These are either lucky observations or a sign that collisions are more frequent than predicted during planet formation. The events — the first was detected in 2004 and a second imaged in 2023 — are the first collisions between large objects directly imaged in any solar system outside our own. The 2023 Fomalhaut observations are discussed in a paper published in the journal Science.

“We have witnessed what we believe to be a collisional event between two comet-like bodies in the Fomalhaut system,” said co-author Maxwell Millar-Blanchaer, an assistant professor in UC Santa Barbara’s physics department. “This is a fundamental evolutionary process in young planetary systems that’s difficult to see in real time.”

The dust cloud spewed from that violent event reflects light from the host star. “We don't see the two objects that crashed into each other, but we see the aftermath of this enormous impact,” said Paul Kalas, adjunct professor of astronomy at UC Berkeley. Over the course of tens of thousands of years, he said, the dust around Fomalhaut would be “sparkling with these collisions” — like fireworks.

Kalas first started searching for a dusty disk around Fomalhaut in 1993, hoping to see the debris left over after planet formation. Only 25 light years from Earth, the star is young — about 440 million years old — and a proxy for what our solar system looked like in its formative years. Thanks to NASA's Hubble Space Telescope (HST), he eventually found such a disk around the star and, in 2008, reported finding a bright spot near the disk that was likely a planet, the first to be imaged directly at optical wavelengths. He called it Fomalhaut b, per the naming convention for exoplanets.

That planet discovery has now turned to dust.

“This is a new phenomenon, a point source that appears in a planetary system and then over 10 years or more slowly disappears,” he said of the dust cloud. “It's masquerading as a planet because planets also look like tiny dots orbiting nearby stars.”

Based on the brightness of both the 2004 and 2023 events, the colliding objects are at least 30 kilometers (18 miles) across — at least twice the size of the object that collided with Earth 66 million years ago and killed off the non-avian dinosaurs. Objects of this size are referred to as planetesimals — objects similar in size to many of the asteroids and comets in our solar system but much smaller than a dwarf planet like Pluto.

The Formalhaut system

At 440 million years old, Fomalhaut is much younger than the solar system. But astronomers expect our solar system was also littered with planetesimals crashing into each other at that age. “That's the time period that we are seeing, when things are being cratered with these violent collisions or even being destroyed and reassembled into different objects,” Kalas said. “It's like looking back in time in a sense, to that violent period of our solar system when it was less than a billion years old."

"The Fomalhaut system is a natural laboratory to probe how planetesimals behave when undergoing collisions, which in turn tells us about what they are made of and how they formed," said co-author Mark Wyatt, a theorist and professor of astronomy at the University of Cambridge in the United Kingdom. "The exciting aspect of this observation is that it allows us to estimate both the size of the colliding bodies and how many of them there are in the disk, information which it is almost impossible to get by any other means."

He estimates that there are about 300 million objects around Fomalhaut the size of the ones that collided to generate these bright clouds of dust. Previous observations of the star detected the presence of carbon monoxide gas, which indicates that these planetesimals are volatile-rich and therefore very similar in composition to the icy comets in our solar system, he said.

Dust clouds masquerading as exoplanets

Fomalhaut, located within the southern constellation Piscis Austrinus, is 16 times more luminous than our sun and one of the brightest stars in the sky. After Kalas began observing it with HST in 2004, he discovered a large belt of dusty debris at a distance of 133 astronomical units (AU) from the star, more than three times the distance from the star as the Kuiper Belt is from the sun in our solar system. An AU is the average distance between the Earth and the sun, or 93 million miles.

The belt's sharp inner edge suggested that it had been sculpted by planets. After a second observation in 2006, Kalas concluded that a bright spot in the outer belt visible in both the 2004 and 2006 images was, in fact, a planet. He acknowledged at the time that it could be a very bright dust cloud caused by a collision in the disk, but the likelihood of that seemed very low.

Kalas was able to schedule four follow-up HST observations of Fomalhaut, in 2010, 2012, 2013 and 2014. In the last, however, Fomalhaut b was nowhere to be seen. Nine years later, after three failed attempts to image Fomalhaut with HST, he obtained a new image that revealed another bright spot not far from the first, now referred to as Fomalhaut cs1 for circumstellar source 1. Based on its location, however, the new spot, Fomalhaut cs2, could not be a reappearance of Fomalhaut cs1. Because of the nine-year hiatus between 2014 and 2023, it's unclear when Fomalhaut cs2 appeared.

In the new paper, an international team of astronomers analyzed the 2023 image of Fomalhaut and a subsequent, though poor image obtained in 2024, and concluded that it could only be light reflected from a dust cloud produced by the collision of two planetesimals.

At first, Fomalhaut cs1 moved like an exoplanet, but by 2013 its path had curved away from the star. This type of motion would be possible for very small particles being pushed outward by the radiation pressure of starlight. The appearance of cs2 supports the idea that cs1 was in fact a dust cloud.

Kalas compares these events to the dust cloud generated in 2022 when NASA's DART (Double Asteroid Redirection Test) mission slammed into the moonlet Dimorphos, which was orbiting the asteroid Didemos. The cloud around Fomalhaut is about a billion times larger, the researchers estimated.

They weren’t expecting to observe the second collision at all. “The whole team was extremely surprised,” UCSB’s Millar-Blanchaer said. “We were originally trying to detect the original collisional event from decades past.”

Kalas has been awarded time over the next three years to use the James Webb Space Telescope's Near-Infrared Camera (NIRCam) and the HST to observe Fomalhaut and track the evolution of the cloud to see if it expands in size and determine its orbit. It is already 30% brighter than Fomalhaut cs1. Additional observations in August 2025 confirmed that cs2 is still visible.

In anticipation of future space missions to directly image exoplanets, Kalas cautioned astronomers to be on the lookout for dust clouds masquerading as planets. “These collisions that produce dust clouds happen in every planetary system,” he said. “Once we start probing stars with sensitive future telescopes such as the Habitable Worlds Observatory, which aims to directly image an Earth-like exoplanet, we have to be cautious because these faint points of light orbiting a star may not be planets.”

Other co-authors of the paper are UC Berkeley research astronomer Thomas Esposito; Jason Wong at Northwestern University in Illinois; Michael Fitzgerald at UCLA; Robert De Rosa at the European Southern Observatory in Chile; Bin Ren of the Max Planck Institute for Astronomy in Germany; Maximilian Sommer of the University of Cambridge; and Grant Kennedy of the University of Warwick in the UK. *The work was supported by NASA (NAS5-26555, GO-HST-17139).*

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