Distant black hole wave twists like giant whip

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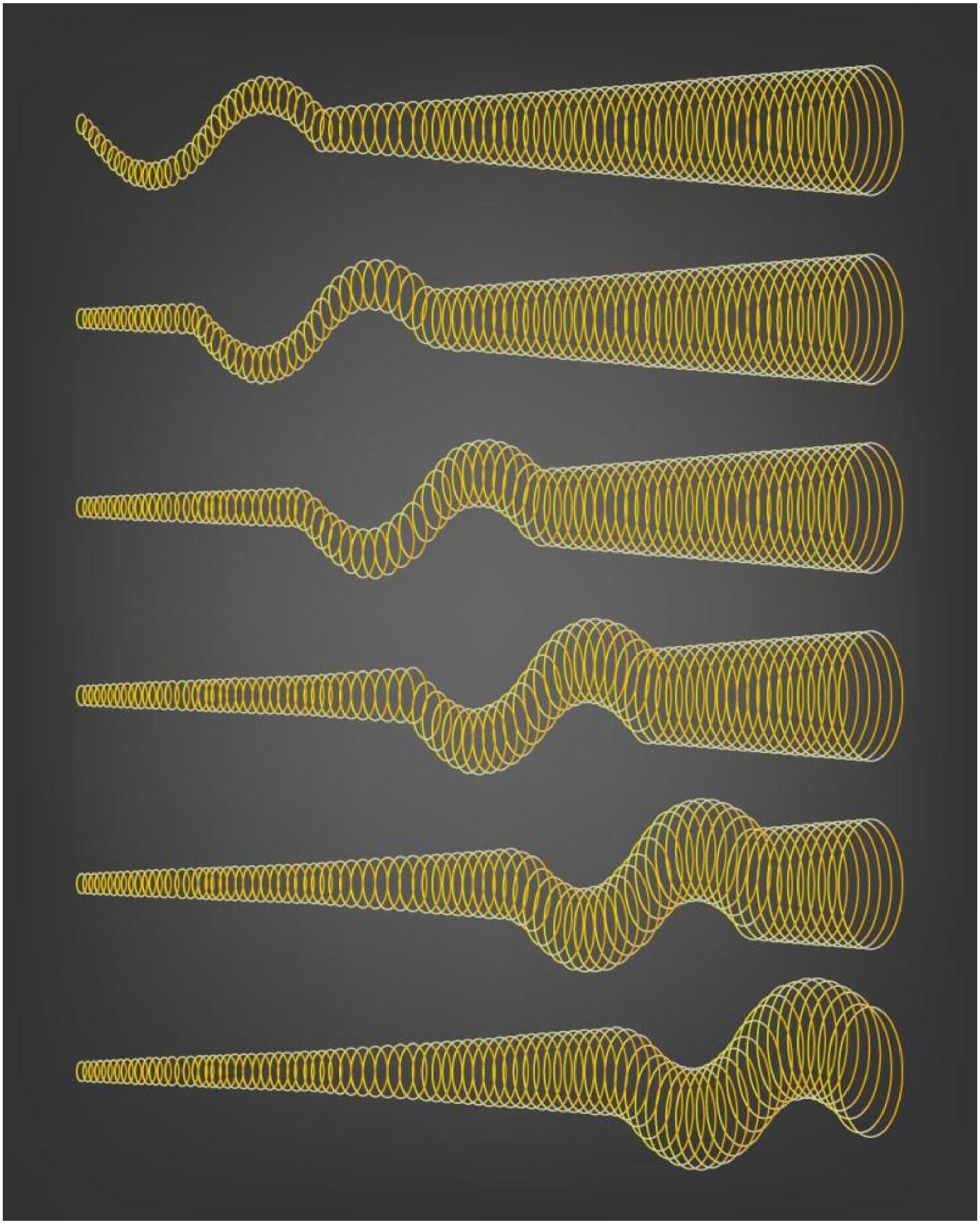

Image shows how magnetic waves, called Alfvén S-waves, propagate outward from the base of black hole jets. The jet is a flow of charged particles, called a plasma, which is launched by a black hole. The jet has a helical magnetic field (yellow coil) permeating the plasma. The waves then travel along the jet, in the direction of the plasma flow, but at a velocity determined by both the jet's magnetic properties and the plasma flow speed. The BL Lac jet examined in a new study is several light-years long, and the wave speed is about 98 percent the speed of light. Fast-moving magnetic waves emanating from a distant supermassive black hole undulate like a whip whose handle is being shaken by a giant hand, according to a study using data from the National Radio Astronomy Observatory's Very Long Baseline Array. Scientists used this instrument to explore the galaxy/black hole system known as BL Lacertae (BL Lac) in high resolution. Credit: NASA/JPL-Caltech

Fast-moving magnetic waves emanating from a distant supermassive black hole undulate like a whip whose handle is being shaken by a giant hand, according to a new study using data from the National Radio Astronomy Observatory's Very Long Baseline Array. Scientists used this instrument to explore the galaxy/black hole system known as BL Lacertae (BL Lac) in high resolution.

"The waves are excited by a shaking motion of the jet at its base," said David Meier, a now-retired astrophysicist from NASA's Jet Propulsion Laboratory and the California Institute of Technology, both in Pasadena.

The team's findings, detailed in the April 10 issue of The *Astrophysical Journal*, mark the first time so-called Alfven (pronounced Alf-vain) waves have been identified in a black hole system.

Alfven waves are generated when magnetic field lines, such as those coming from the sun or a disk around a black hole, interact with charged particles, or ions, and become twisted or coiled into a helical shape. In the case of BL Lac, the ions are in the form of particle jets that are flung from opposite sides of the black hole at near light speed.

"Imagine running a water hose through a slinky that has been stretched taut," said first author Marshall Cohen, an astronomer at Caltech. "A sideways disturbance at one end of the slinky will create a wave that travels to the other end, and if the slinky sways to and fro, the hose running through its center has no choice but to move with it."

A similar thing is happening in BL Lac, Cohen said. The Alfven waves are analogous to the propagating sideways motions of the slinky, and as the waves propagate along the magnetic field lines, they can cause the field lines—and the particle jets encompassed by the field lines—to move as well.

This artist's concept illustrates a supermassive black hole with millions to billions times the mass of our sun. Supermassive black holes are enormously dense objects buried at the hearts of galaxies. (Smaller black holes also exist throughout galaxies.) In this illustration, the supermassive black hole at the center is surrounded by matter flowing onto the black hole in what is termed an accretion disk. This disk forms as the dust and gas in the galaxy falls onto the hole, attracted by its gravity. Also shown is an outflowing jet of energetic particles, believed to be powered by the black hole's spin. The regions near black holes contain compact sources of high energy X-ray radiation thought, in some scenarios, to originate from the base of these jets. This high energy X-radiation lights up the disk, which reflects it, making the disk a source of X-rays. The reflected light enables astronomers to see how fast matter is swirling in the inner region of the disk, and ultimately to measure the black hole's spin rate. Credit: NASA/JPL-Caltech

It's common for black hole particle jets to bend—and some even swing back and forth. But those movements typically take place on timescales of thousands or millions of years. "What we see is happening on a timescale of weeks," Cohen said. "We're taking pictures once a month, and the position of the waves is different each month."

"By analyzing these waves, we are able to determine the internal properties of the jet, and this will help us ultimately understand how jets are produced by black holes," said Meier.

Interestingly, from the vantage of astronomers on Earth, the Alfven waves emanating from BL Lac appear to be traveling about five times faster than the speed of light, but it's only an optical illusion. The illusion is difficult to visualize but has to do with the fact that the waves are traveling slightly off our line of sight at nearly the speed of light. At these high speeds, time slows down, which can throw off the perception of how fast the waves are actually moving.

Provided by NASA