Scientists develop a 3-D view of an interstellar cloud, where stars are born

May 16 2018, by Amina Khan, Los Angeles Times

Two astronomers from Greece have managed to model the three-dimensional structure of an interstellar gas cloud, and found that it's on the order of 10 times more spacious than it originally appeared.

The shape and structure of Musca, described in the journal *Science*, could help scientists probe the mysterious origins and evolution of stars—and by extension, the planets that surround them.

Finding the 3-D structure of such clouds "has been a 'holy grail' in studies of the interstellar medium for many years now," said senior author Konstantinos Tassis, an astrophysicist at the University of Crete.

Interstellar clouds serve as the celestial cradles for nascent stars, which condense out of these enormous conglomerations of gas and dust. These cold, dusty, magnetized clouds can reach a million times the mass of the sun. But because they're filled with molecular hydrogen that blocks the light of background stars, they typically appear as holes in an otherwise bright night sky. They're more easily studied using infrared light.

But even in infrared light, these clouds are difficult to study because we can see them only as flat structures, even though they're actually three-dimensional. We know very little about how dense they are, what shape they are and how they're organized inside.

"All sorts of different physical and chemical processes take place in their interior, and as a result, the process of star formation is poorly understood," Tassis said in an email. "How does a giant cloud of a million solar masses break up into smaller pieces, and how do these fragments condense into stars similar to our sun? What makes a cloud form a lot of small stars or a few larger ones?"

"These problems, although they are directly related to the question of the origin of our sun, our planet, and, ultimately, ourselves, are still very much a mystery," he added.

About a decade ago, astrophysicist Paul Goldsmith of the Jet Propulsion Laboratory in La Canada Flintridge and his colleagues discovered strange hair-like wisps surrounding such gas clouds, rather like the cilia of a bacterium. Amid the chaos of a gas cloud, these ordered structures drew astronomers' attention. How did they form, and why?

"Understanding how you make new stars is really a critical challenge for modern astrophysics," Goldsmith, who was not involved in the new paper, said in an interview. "These molecular clouds are where new stars are formed, and so understanding the structure of these clouds, and how deep they are, what their three-dimensional structure is, is obviously critical for understanding the whole picture."

While completing his doctoral work at the University of Crete, lead author Aris Tritsis (now a postdoctoral fellow at Australian National University) concluded that these striations were actually caused by magnetic waves leaving their imprint on the cloud's gas.

"It was then that we realized that these striations might encode a global vibration if the cloud is isolated, a 'song,' a pattern of frequencies that could reveal the true, 3-D shape of the cloud," Tassis said.

To try and use those magnetosonic waves to understand the shape of an interstellar cloud, they pulled data from the European Space Agency's infrared Herschel Space Observatory, which can see into the infrared. They focused on Musca, which lies in the Southern Hemisphere roughly 500 light-years from Earth.

Musca, a filamentary cloud that's long and thin, made an ideal target because it was relatively isolated. This meant that its striations were unlikely to have been warped by "noise" coming from nearby structures, Tassis said.

Because the waves are basically trapped within the interstellar cloud, the wavelength will actually hold information about its dimensions. After using the striations to determine the wavelength of this "global vibration," the scientists were able to determine the true shape of this gas cloud.

From our vantage point, Musca looks like a needle. But the magnetosonic waves revealed that the gas cloud actually was shaped like a pancake—one we were viewing edge-on. All in all, the cloud seems to measure roughly 24 light-years wide by 18 light-years across and one light-year thick.

"In much the same way that a piccolo flute makes a much different sound than a tuba (the air vibrates with different frequencies in the two cases because the shape and size of the instruments are very different), a pancake-shaped cloud vibrates in a tune that is very different than that of a needle-shaped cloud," Tassis said. "Musca very clearly vibrates like a pancake, not a needle. It is not a subtle effect, it is eye-popping!"

This meant that the gas cloud was far more voluminous than previously thought—roughly on the order of 10 times larger, Tassis said. And because the same amount of gas filled that bigger-than-expected space, it meant the cloud was much less dense than scientists had expected.

"It was a huge surprise to us," Tassis said.

Goldsmith, whose team originally identified the existence of striations, praised the work.

"This is great. This is exciting," the astrophysicist said. "Now we have to figure out if we can confirm that by some other kind of measurement."

The discovery that Musca is a pancake and not a prototypical needle-like filament totally changes scientists' understanding of the balance of forces that shaped this gas cloud and influenced its star-forming process, Tassis added.

For one thing, a less dense gas cloud would have a much lower rate of star formation. On top of that, the molecular demographics of sparser clouds are different from denser ones. Dense clouds, for example, are more likely to have nitrogen-based molecules such as ammonia.

The shape of such a cloud can be very telling too: Magnetic forces make pancake-like clouds, turbulence forms needle-like clouds and thermal forces result in roundish, blobby clouds, Tassis said. If scientists can now start to render more of these clouds in three dimensions, they won't mistake a pancake-shaped cloud for a needle-shaped one. That means they'll start to have a much better sense of the forces at play.

"Now that we know Musca is a pancake, we know that at least for this particular cloud, magnetic forces must play a key role in the star-formation process taking place in its interior," Tassis said.

Armed with knowledge of Musca's three-dimensional structure, other scientists can now draw out more information about the chemical and physical properties of this interstellar gas cloud.

"With its 3-D structure revealed, Musca will now act as a prototype laboratory to study star formation in greater detail than ever before," Tassis said. "The Musca star-formation saga is only now beginning, and this is a very exciting development that goes beyond this particular discovery."

More information: Aris Tritsis et al. Magnetic seismology of interstellar gas clouds: Unveiling a hidden dimension, *Science* (2018). DOI: 10.1126/science.aao1185