Oldest stars may shed light on dark matter

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The universe's earliest stars may hold clues to the nature of dark matter, the mysterious stuff that makes up most of the universe's matter but doesn't interact with light, cosmologists report.

The first stars in an early universe filled with moderately energetic, or "warm," dark matter would probably have developed in long strings, according to a study in the 14 September issue of the journal *Science*. In contrast, simulations with slow-moving, cold dark matter generally show the first stars forming in clumps.

Efforts are underway to find some of these ancient stars, so it's hypothetically possible that new star discoveries could help clarify whether the universe is made up of warm or cold dark matter.

Scientists have developed a variety of experiments, many deep below ground, for detecting dark matter particles on Earth, but the new findings suggest that additional clues may come from the night sky.

"If the dark matter is warm, some of these primordial stars should be lurking around our galaxy. This raises the exciting prospect of learning about the nature of dark matter from studying the oldest stars," said coauthor Tom Theuns of Durham University in Durham, United Kingdom and the University of Antwerp in Antwerp, Belgium.

"Dark matter's gravity anchored the nascent stars but its energy affected how and where they were born. If the first constellations can be mapped by future telescopes, the energy of the underlying dark matter may be

deduced simply by reading the stars, telling us what dark matter is potentially made of," said Joanne Baker, associate editor at *Science*.

The findings, which are based on cutting-edge numerical simulations, may also give researchers a better understanding of when the first stars began to illuminate the universe. And, they provide a possible new explanation for how some black holes form.

After the Big Bang, the universe expanded rapidly but stayed mostly smooth and dark for about 100 million years. The dark matter began to form structures, its gravity pulling in hydrogen, helium and lithium gasses that condensed and formed stars.

Cold dark matter, which has been relatively well-studied in simulations, is thought to have been spread across the universe in ripples. It would have collapsed in small, nearly spherical structures, creating "wells" that drew in these gasses, leading to the formation of stars.

Because the particles of warm dark matter are moving fast, however, they would likely have smeared out the smallest ripples, preventing the formation of the small structures that emerge in the cold dark matter scenario. According to the authors' simulations, the gas would have condensed into long filaments instead, shrinking fastest along their shortest axis due to gravity.

"The filaments would have been about 9,000 light years long, which is about a quarter the size of the Milky Way galaxy. They would have fragmented in a huge burst of star formation, a spectacular event to contemplate," said first author Liang Gao of Durham University in Durham, United Kingdom.

In addition to producing the first light in the dark universe, these stars would have formed the first heavy elements, such as carbon, oxygen and

silicon. These elements are crucial for forming solid objects such as Earth and other rocky planets.

Some of the stars that formed would have had particularly low masses. The lower a star's mass, the longer its lifetime, so some of these tiny first stars may still be detectable in galaxies like the Milky Way.

Another option for detecting this big star burst would be to look for light coming in from the very farthest reaches of the universe, which would show the earliest stars as they were forming.

The warm dark matter scenario may also provide an important piece to the puzzle of how to form the supermassive black holes that lie in the center of many galaxies. These monster black holes may weigh as much as a billion times the mass of the sun, and they require a massive seed to enable them to grow so much.

The seed's possible origins have been unclear, but Gao and Theuns propose that the string of stars could collapse, causing the stars to collide with each other and creating a seed black hole.

Source: American Association for the Advancement of Science