Stars Fueled by Dark Matter Could Hold Secrets to the Universe

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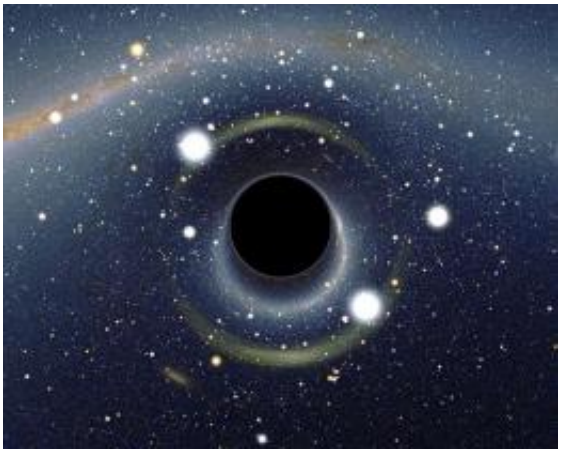

Simulated view of a black hole in front of the Large Magellanic Cloud. Dark stars could grow to become much larger than normal stars, and might collapse to form the giant black holes in the centers of galaxies. Credit: Wikimedia Commons.

(PhysOrg.com) -- The first stars in the universe may have been very different from the stars we see today, yet they may hold clues to understanding some of the mysterious features of the universe. These "dark stars," first theorized in 2007, could grow to be much larger than modern stars, and would be powered by dark matter particles that annihilate inside them, rather than by nuclear fusion. In the early universe, dark stars would have emitted visible light like the Sun, but today their light would be redshifted into the infrared range by the time it reaches us, and so dark stars would be invisible to the naked eye.

Over the past two years, researchers have further investigated the properties of dark stars, as well as how these unusual stars may help scientists better understand dark matter, black holes, and other astronomical features. In a new study, the group of scientists that originally theorized dark stars has presented a review of the research on dark stars and predicted future areas of research. Katherine Freese of the University of Michigan; Paolo Gondolo of the University of Utah; Peter Bodenheimer of the University of California, Santa Cruz; and Douglas Spolyar, currently with Fermilab, have published their results in a recent issue of the New Journal of Physics.

As the scientists explain, dark stars would represent a new phase of stellar evolution - the first phase, occurring just 200 million years after the big bang. At that time, dark matter densities in the early universe were higher than they are today, and the first stars are predicted to have formed in the middle of dark matter haloes (which are precursors to galaxies) as opposed to today's stars that are scattered about the edges of a galaxy. According to the theory, these early stars grew larger by accreting mass from their surroundings, pulling in dark matter along with the surrounding gas.

Inside these stars, weakly interacting massive particles (WIMPs), a candidate for dark matter, could accumulate. Since WIMPs can be their own antiparticles, they could annihilate to produce a heat source. If the dark matter density was high enough, this heating would dominate over other heating (or cooling) mechanisms, such as nuclear fusion. Compared with fusion, WIMP annihilation is a very efficient power source, so that only a small amount of dark matter is required to power the star.

"Dark stars are a natural consequence of WIMPs as dark matter particles ... although it took us a while to put the necessary ingredients together to realize this!" Freese told *PhysOrg.com*. "At the time we proposed these

objects in 2007, we didn't realize that they are really stars in the sense of being hydrostatically stable objects that shine and produce visible light. Now that we have succeeded in finding the stellar structure of these objects, we understand their properties: they are giant puffy objects (like suns that extend out to the radius of the earth) and the light they produce looks a lot like that from the Sun. But they grow to become a thousand or even a million times as massive! These are our new results since we first began our research in this area."

As the scientists explained, modern stars eventually burn up their hydrogen and transition into other star types on the main sequence diagram. On the other hand, dark stars can keep growing indefinitely, as long as they keep accreting dark matter from their surroundings. If not disturbed, these stars could potentially grow to be tens of thousands of times larger than the Sun. However, most dark stars would probably eventually stray from their locations at the centers of dark matter haloes. Their dark matter fuel would run out, so that the stars would start to collapse and eventually be powered by fusion from the stars' normal hydrogen atoms, and finally collapse into black holes. The scientists calculated that dark stars have a lifetime of at least one million years, and perhaps billions of years; they might even still be around today.

The scientists predict that it should be possible to detect dark stars, either by detecting their light with upcoming telescopes, or by using neutrino telescopes to measure neutrinos from dark stars. Compared with conventional main sequence stars, dark stars that have run out of dark matter fuel and started using fusion would be much larger, cooler, and "puffier." And while dark stars ultimately become black holes, the first stars in the traditional view (without dark matter) turn into supernova, giving the researchers a point of comparison.

"These supernova populate the universe with element abundances in very precise ratios (the ratio of even to odd elements is very precise)," Freese

explained. “However, we predict that this doesn't happen in dark stars. So this distinction provides a measurable test of the two different scenarios. These element abundances should be measured in the next five years and then we'll know.”

By measuring the properties of dark stars with future instruments, scientists could discover detailed properties of dark matter. Since different dark matter particles produce different annihilation products, measurements could reveal information about the properties of dark matter, such as their mass, their annihilation mechanisms, etc. Freese also plans to investigate whether dark stars could become large enough to produce the giant black holes that are currently unexplainable.

“So far we have built up dark stars to 1,000 times the mass of the Sun,” she said. “But if they keep accumulating dark matter by capturing it from the surroundings, they can end up much larger: possibly even a million times as massive as the Sun. This is my immediate goal as far as research endeavors. Such supermassive objects were first proposed in the ‘60s by Fowler and Hoyle, but nobody knew how to make them. If this is right, it certainly helps explain the enormous black holes seen in the universe that nobody knows how to explain: when the supermassive stars die, they become black holes. There are billion-solar-mass black holes seen at basically the time the first galaxies formed, as well as the ones in centers of galaxies.”

More information: Katherine Freese, Peter Bodenheimer, Paolo Gondolo, and Douglas Spolyar. “Dark stars: a new study of the first stars in the Universe.” *New Journal of Physics* 11 (2009) 105014.