Dark Side of Black Holes

Dark matter could explain the early universe's giant black holes BY CHARLES Q. CHOI

Black holes one billion times the sun's mass or more lie at the heart of many galaxies, driving their spin and development. Common today, some 14 billion years after the big bang, such supermassive black holes were rare in the early universe—or at least they were supposed to be. Evidence of supermassive black holes existing when the universe was less than one billion years old has stumped scientists, because current theories of stellar evolution suggest that such giants should take much longer to grow. Now it seems this enigma could be solved by a mystery substance—dark matter.

The puzzle of early supermassive holes took shape in 2003, when the Sloan Digital Sky Survey detected roughly half a dozen of them. According to conventional thinking, the first regular stars were born when the universe was about 200 million years old, but given the state of the universe at the time, they could have formed black holes at most only about 100 times the sun's mass. It would simply take too long to merge and make the billion-year-old, billion-solar-mass monsters seen by the Sloan survey.

Dark matter could solve the conundrum, say theoretical physicist Katherine Freese of the University of Michigan at Ann Arbor and her colleagues. Unseen but demonstrating its existence via gravity, the substance makes up at least 80 percent of the universe's matter (and about one quarter of the entire universe). But scientists are unsure exactly what dark matter is made of. Among the leading hypothetical candidates are weakly interacting massive particles called neutralinos. They can annihilate one another when they meet, generating heat, gamma rays, neutrinos, and antimatter particles such as positrons and antiprotons.

Freese and her co-workers calculate that when the universe was just 80 million to 100 million years old, as protostellar clouds of gas tried to cool and shrink, their gravity would have drawn in neutralinos that annihilated one another, unleashing energy that would have created the first stars. They dub these objects "dark stars," fueled by dark matter rather than nuclear energy as in normal stars.

Their initial findings hinted that dark stars would have dwarfed regular stars. Because dark stars do not need the high densities seen in regular stars, which depend on atomic nuclei getting forced together for fusion, they would be much fluffier, with the largest ones reaching up to approximately 200,000 times the sun's width. Scientists have also estimated that the cooler surface temperatures of dark stars would have allowed them to grow up to 1,000 times the mass of the sun, as compared with the roughly 150-solar-mass size limit of current stars.

Freese and her colleagues, who plan to submit their analysis to the *Astrophysical Journal,* figure that dark stars could have reached as much as 100,000 solar masses or more before they burned out their fuel and collapsed. They analyzed how frequently neutralinos would flow into dark stars and get captured by atoms, concluding that dark matter particles could have fueled the growth of dark stars for much longer than first thought.

After supermassive dark stars ran out of dark matter, they would have contracted, triggering nuclear fusion and continuing on as regular stars for roughly a million years. These stars would not have gone supernovae—"they are too big," Freese says—instead they collapsed into black holes of the same mass. Several of them could have then merged into giants within a billion years of the big bang.

Supermassive dark stars would have been up to one billion times as bright as the sun and yet able to shine at our sun's temperature with a yellow light. Freese hopes the James Webb Space Telescope, currently scheduled for launch in 2014, will see far enough to detect such fluffy giants. But no dark stars are likely to be forming today, because the density of dark matter now averages 1/8,000th of its dark star past, when the universe was far more compact.

Not everyone is convinced dark stars are real. Astrophysicist Brian O'Shea of Michigan State University contends the idea depends on too many assumptions regarding dark matter's properties—for instance, if dark matter were instead made of another theoretical particle dubbed the invisible ax-

Supersonic Bathtub Physics

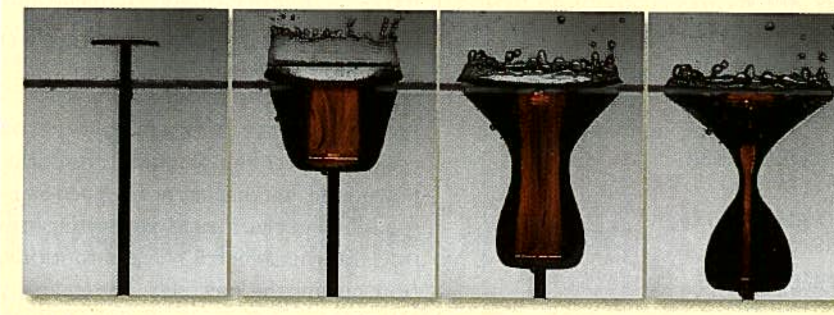
Sonic booms in your bathtub? Apparently, a hard object falling into a pool can push a jet of air out of the water so fast that it briefly breaches the sound barrier.

Physicists at the University of Twente in the Netherlands and at the University of Seville in Spain set up an experiment in which they pulled a disk-shaped object flat down into water so that it hit the water at the relatively leisurely speed of one meter per second (roughly equivalent to dropping the disk from a height of a few centimeters). The disk displaced the water and created an air bubble in its wake as it sank.

As the water closed in to form the bubble, it pushed air up through a narrower and narrower neck, accelerating the air. "It's like a little nozzle which closes," explains Twente's Detlef Lohse, similar to what happens in a rocket engine. To track the air's motion, the team filled it with glycerin droplets produced by a smoke machine of the type used in dance clubs.

Using a high-speed camera and computer simulations, the researchers estimated that the jet reached a speed of 350 meters per second at its peak, or just above the speed of sound. Their report appears in the January 15 *Physical Review Letters.* Although the details change for objects of different shapes and sizes, "the physics is the same," Lohse says. "By dropping a stone into the water, you create a supersonic jet."

—Davide Castelvecchi



SUPERSONIC SPLASH: A disk pulled into water by a piston at a leisurely one meter per second creates a bubble that, as it collapses, briefly forces air to move faster than sound.

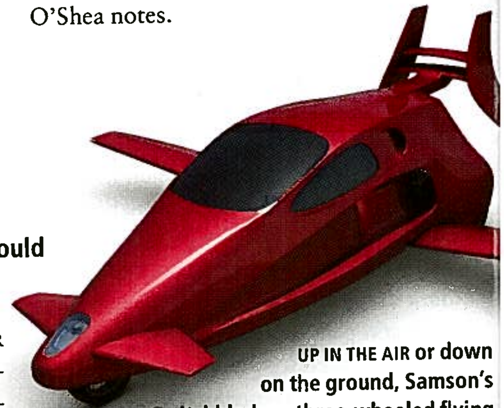
FROM "SUPERSONIC AIR FLOW DUE TO SOLID-LIQUID IMPACT," BY STEPHAN GEKLE, IVO R. PETERS, JOSÉ MANUEL GORDILLO, DEVARAJ VAN DER MEER AND DETLEF LOHSE, IN *PHYSICAL REVIEW LETTERS,* VOL. 104; JANUARY 15, 2010 (*splash sequence*) ion, which does not self-annihilate, dark stars could not form.

Still, astrophysicist Paul R. Shapiro of the University of Texas at Austin thinks dark stars "are reasonable consequences of a reasonable model for dark matter." And if scientists do find dark stars, they could help elucidate more than just black holes—they would hint at what dark matter actually might be. "If dark stars do exist, they would be incredibly cool," O'Shea notes.

Technology

Easy Flier

A build-it-yourself flying motorcycle could be ready soon BY JIM NASH



UP IN THE AIR or down on the ground, Samson's Switchblade, a three-wheeled flying motorcycle, is meant to do both.

It is safe to bet that a flying motorcycle will never be a practical transportation option. Yet that has not stopped Samson Motorworks, a small engineering firm in California's Sierra Nevada foothills, from playing the long odds. The company is building a prototype called the Switchblade Multi Mode Vehicle, and it hopes to sell a do-it-yourself kit as early as 2011.

Sexy design and the promise of air-ground transport have kept alive dreams of a flying vehicle in every garage. Samson chose a three-wheel design because it meets the definition of a motorcycle, which is not as highly regulated as cars are. For example, motorcycles need not have bumpers, which would add weight and expense to a flying vehicle.

As the company envisions it, occupants would sit in the aerodynamic Switchblade side by side in leather seats and in climate-controlled luxury, behind an aggressively angled nose and canard. Samson is working with a third-party avionics maker to create an instrument display that switches from air to ground readings on landing. The Switchblade's stubby wings would open on pivots and behind the cockpit as a box kite–like stabilizer extends from the rear. On solid ground, the wings would swing into clamshell compartments, protected by a steel keel. Two large rearview mirrors would then swing out.

To contain costs while building revenue, design skills and manufacturing experience, Samson is following the path of other would-be aviation entrepreneurs by offering the Switchblade as a kit aircraft, in which no more than 49 percent of a craft can be preassembled by the manufacturer. It plans to sell the body for $60,000, but do-it-yourselfers will need to lay out another $25,000 for the engine and avionics. The craft would require a 120- to 150-horsepower engine (candidates on the market include Lycoming's O-320 aircraft engine, Suzuki's Hayabusa motorcycle engine and Kawasaki's Jet Ski personal watercraft engine). Samson president Sam Bousfield says he is also watching the development by entrepreneurs of small rotary engines that run cleaner than conventional piston motors.

The Switchblade will succeed, Bousfield believes, because it will morph easily between transportation mediums. If pilots encountered bad weather, they could put down at a small airstrip—at least 610 meters in length, according to Bousfield—fold in the wings, and finish the trip on the ground with no manual disassembly.

The reality is a bit more complicated, given that aircraft are prohibited from operating on roads and tightly regulated as to how close they can fly to homes, military installa-