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November 16, 2010

A Costly Quest for the Dark Heart of the Cosmos

By DENNIS OVERBYE

After 16 years and \$1.5 billion of other people's money, it is almost showtime for NASA and Sam Ting.

Sitting and being fussed over by technicians in a clean room at the Kennedy Space Center in preparation for a February launching — and looking for all the world like a giant corrugated rain barrel — is an eight-ton assemblage of magnets, wires, iron, aluminum, silicon and electronics that is one of the most ambitious and complicated experiments ever to set out for space.

The experiment, if it succeeds, could help NASA take a giant step toward answering the question of what the universe is made of. It could also confer scientific glory on both the International Space Station and a celebrated physicist reaching one last time, literally, for the stars. If it fails, it will validate critics who think it a scandal the experiment was ever approved.

The device, named the Alpha Magnetic Spectrometer, is designed to sift the high-energy particles flying through space known as cosmic rays. On Feb. 27, the space shuttle Endeavour will ferry the spectrometer to a permanent berth on the space station. But the real destination is the shadow universe.

You might think you learned in high school that the universe is made of atoms and molecules, protons and electrons, stars and galaxies, but over the last few decades astronomers have concluded — not happily — that all this is just a scrim overlying a much vaster shadowy realm of invisible "dark matter" whose gravity determines the architecture of the cosmos.

If they are lucky, scientists say, the Alpha spectrometer could confirm that mysterious signals recorded by other satellites and balloons in recent years are emanations from that dark matter, revealing evidence of particles and forces that have only been theoretical dreams until now.

Even if dark matter won't ever become the ultimate diet — eat it and disappear — knowing what nature is made of could be useful someday in ways nobody can dream. Einstein's curved spacetime, equally elusive to the senses, proved crucial to the function of GPS devices that were invented decades after Einstein's death.

Or the device could find even something weirder.

"Real discovery is outside the ring of existing knowledge," said Samuel Chao Chung Ting, the 74-year-old Nobel laureate, Massachusetts Institute of Technology professor and leader of the cosmic ray project, in his laboratory at CERN outside Geneva in August. A few yards away, the hulking spectrometer was sitting in a test frame, being pinged by a beam of protons in final tests before being shipped to Cape Canaveral.

Dr. Ting, one of science's great control freaks and worrywarts, has spent his life commanding armies of physicists. In 1974 he discovered a particle that would revolutionize physics, but he took so long checking for errors and looking for more particles that another lab found it and he wound up splitting the Nobel.

Gazing at his spectrometer, almost ready for space at last, Dr. Ting shrugged off the question of what he had up his sleeve next.

"You must think I am really stupid," he said. "You see how much trouble this was."

The experiment was born in the early 1990s when, despite his prestige, Dr. Ting failed to land a role on the largest physics machines ever contemplated, the Superconducting Supercollider (canceled before completion in 1993 by Congress) or the Large Hadron Collider (now operating at CERN, as the European Organization for Nuclear Research is known).

So he turned his eyes to the heavens. According to the laws of physics, equal amounts of matter and its science-fictionsounding evil twin, antimatter, which annihilates ordinary matter in a flash of energy upon contact, should have been created during the Big Bang. It is one of the abiding mysteries of science why the universe is now all matter. Or is it?

The discovery of a single atomic nucleus heavier than anti-helium could mean there was an anti-star or maybe a whole antigalaxy somewhere.

"If you don't do the measurement, you will never know," Dr. Ting said.

In 1994 Dr. Ting told Dan Goldin, then NASA's administrator, that he could make that measurement with a space-based cosmic ray detector. Mr. Goldin was instantly smitten and agreed to put the spectrometer on the International Space Station, which was desperately lacking scientific credibility, bypassing the agency's normal peer-review procedures and setting off resentment among other cosmic-ray physicists that still lingers.

Part of the lure was that the space agency would not have to pay for it. The bulk would be paid for by Dr. Ting's army of collaborators abroad, which grew to 600 scientists from 16 countries, including Italy, Germany, Russia, China and Taiwan.

In 1998, a prototype of the spectrometer was built and flown successfully on the space shuttle for 10 days on a trip to the Mir space station, although not without some Tingian drama. Behind in the construction schedule, Dr. Ting announced one day that he was canceling the Christmas break. "Perhaps on Christmas Day we will take a few minutes to reflect," Peter Fisher, an M.I.T. physicist who was there, recalled Dr. Ting saying.

The work got done on time.

After the shuttle Columbia disintegrated in 2003, killing its crew of seven astronauts, Dr. Ting's fortunes took a turn for the worse. NASA decreed an early end to the shuttle era, and the Alpha spectrometer was dropped from the flight manifest.

Dr. Ting fought back. In 2005, invited to address a Senate committee on the state of American science, he used his five minutes and nine transparencies to mount a rousing defense of basic science and of his experiment. "They were surprised to hear that the space station can do good science," Dr. Ting recalled.

In the following years powerful senators like Ted Stevens of Alaska, Bill Nelson of Florida and Kay Bailey Hutchison of Texas sat through Dr. Ting's PowerPoint shows or visited the project at CERN. In the end, Congress ordered NASA to provide an extra shuttle flight for the experiment.

"Three days after Barack Obama's inauguration, we were back on the manifest," Dr. Ting said.

By then nobody, with the possible exception of Dr. Ting, expected the experiment to find any primordial antimatter. Most theorists have concluded that it disappeared in the first moments after the Big Bang. "The original goal has evaporated," said Greg Tarle, a cosmic-ray physicist at the University of Michigan and longtime critic of the experiment.

Instead, the heavens were crackling with intimations of dark matter. Two years ago a European satellite named Pamela registered an excess of anti-electrons, or positrons, in space — perhaps from collisions of dark matter particles.

But that satellite had no way to tell positrons, which are exotic, from protons, which are humdrum, being the nuclei of hydrogen, and everywhere.

The Alpha spectrometer does. "It will tell us whether these things are there or not," said John Ellis, a CERN theorist.

The spectrometer is a miniature spacegoing version of the cathedral-size particle detectors that now line the Large Hadron Collider. At its heart was to be the most powerful magnet ever flown in space, a superconducting electromagnet like the ones in the collider, which would sort high energy particles according to their electrical charges and momenta.

According to some physicists, including Dr. Ellis and Dr. Ting, the positrons from dark matter should have a unique spectral signature that the cosmic ray spectrometer can measure. If the signal follows the model, Dr. Ting said, "Everyone will believe it is dark matter."

Others say it will be difficult, if not impossible, to distinguish the dark matter signal from the background violence of pulsars and black holes in the local universe. David Spergel, a Princeton astrophysicist, said, "Cosmic rays are the dirtiest

way of looking for dark matter."

And many physicists say they will not be satisfied that dark matter has been found until there is supporting data from particle accelerators and underground experiments that seek to detect the particles directly.

Nevertheless, Burton Richter, who shared the Nobel with Dr. Ting in 1976, said, "This was a good experiment when Sam proposed it; it's even hotter now."

But even Dr. Ting's supporters were nonplused by the latest twist in the Alpha experiment saga. Earlier this year, with a fall flight date finally secured, Dr. Ting announced he was ripping out the heart of his experiment and replacing his superconducting magnet with a weaker permanent magnet that had flown on the prototype flight. That meant he would miss the deadline for shipping the instrument to Cape Canaveral.

NASA promptly reshuffled the schedule and moved the flight to next year.

"If you're Sam, you're allowed to show up at the airport a few seconds before your flight," Michael Turner, a cosmologist at the University of Chicago, said.

Dr. Ting gave two main reasons for the last-minute change. Vacuum chamber tests in February revealed that the helium needed to keep the magnet cold and superconducting could run out in as little as two years. Refilling it in space was not an option.

In the meantime, he said, the station's lifetime had been extended from 2015 to 2020 or 2028, and it would not be right to occupy space on the station for all those years with a dead experiment.

The weaker field of the permanent magnet, Dr. Ting said, would be more than offset by the longer time the equipment would be aloft and a slight redesign of the particle tracking arrays. Indeed, Dr. Ting called it an "upgrade."

"If the space station was coming down in 2015, we would not change the magnet," he said.

The late change, however, led to renewed criticism from scientists who wondered if the experiment had been degraded or whether it was even safe to fly now. "This project has been given some kind of pass on everything," said Dr. Tarle.

Shuttle engineers, however, said they were relieved that they would not have to deal with liquid helium, which can vaporize explosively — as it did in the Large Hadron Collider two years ago.

Barry Barish of the California Institute of Technology, who had helped evaluate the project for the Department of Energy, said in an e-mail that despite the "apparently flawed process" by which the experiment had originally been approved, it should fly. "I wouldn't bet against Sam," he added.

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