Recent developments in science: Particle physics, climate science, galactic astronomy

Evidence hints at existence of fourth neutrino

Our reporters
24 June 2016

Researchers from China and the United States, working at the Daya Bay Reactor Neutrino Experiment, have produced initial data indicating the existence of a fourth type of neutrino. If confirmed, this would be the discovery of a new type of fundamental particle, one not currently described by the standard theories of particle physics.

Neutrinos are electrically neutral particles that barely interact with matter: 100 trillion pass unimpeded through the human body every second. They are produced by various types of radioactive and particle decay, including the processes that generate energy in the core of the Sun, and come in three known types: electron neutrino, muon neutrino and tau neutrino. The Daya Bay results suggest the possibility that a fourth, even more ghostly type of neutrino exists—one more than physicists' standard theory allows.

This potential fourth neutrino, dubbed the sterile neutrino, would carry no charge and only interact with matter through gravity. It would only react to current detectors when it transforms into an electron, muon or tau neutrino. If confirmed, this result would open up previously unforeseen paths in humanity's understanding of fundamental physics.

Evidence for the fourth neutrino arises from a conflict between theory and experiment. It has been known for more than five decades that if a nuclear reactor produces just one type of neutrino, some should change into other types as they travel. By studying more than 300,000 electron antineutrinos (the antimatter version of the electron neutrino), researchers at Daya Bay found 6 percent fewer particles than predicted. The main hypothesis to explain this is that some of the antineutrinos produced transformed into an undetectable fourth type of neutrino, one with about one-millionth the mass of an electron.

As of yet, however, the results are not significant enough to be considered a discovery. There is still enough uncertainty in the data, and in the underlying physics, that other explanations could account for the lack of electron antineutrinos. It is hoped that further experiments will reduce this uncertainty to the point where the result can be confirmed.

Melting ice in Greenland linked to Arctic warming

Research in Nature Communications has shown that the warm waters of the Arctic over the past year, a result of lower levels of sea ice caused by increasing global temperatures, are likely linked to an increased amount of melting ice in Greenland in 2015.

One of the doomsday scenarios for global warming is for the Greenland ice sheet, second in size only to Antarctica, to melt completely. In doing so, it would raise global sea levels by about seven meters, permanently flooding cities and coastal areas where about one-third of the world's population lives. In fact, most of the rise in sea level since 2000 has been a result of increased melting from Greenland. Accordingly, understanding and forecasting the level of ice melting off of Greenland is a high priority among climate scientists.

Arctic temperatures have peculiarly large effects on Greenland's ice because of what is known as Arctic amplification. This refers to the fact that temperatures in the Arctic are increasing faster than other parts of the Northern hemisphere as the sea ice in that region melts. As more sea ice melts, less sunlight is reflected back to space and more heat is absorbed by the exposed water. This has created a positive feedback loop that is strong enough to influence temperatures, particularly in Northern Greenland, causing more melting than normal. This was exacerbated by higher surface temperatures and lower snowfall amounts over that region last year.

Another effect, though not as well understood, is the impact of warmer Arctic temperatures on the jet stream. Climate models have shown that as the temperature difference between the Arctic and temperate zone decreases, warmer air from southern latitudes will begin penetrating further north. This is a change from the standard jet stream, which normally acts to separate the cold polar air from warm air in the south. Though more data needs to be collected on this process, what has been obtained over the past decade suggests that the jet stream might start acting as a warming agent instead of a cooling agent over Greenland.

The melt of 2015 will likely continue into this year. Already, the melting measured in April is comparable to what occurred in April 2012, which was the precursor to record-setting melting that occurred later that summer.

Faintest early-universe galaxy confirmed

An international team of astronomers from Australia, Germany, Italy, Japan, Norway, and the United States has confirmed the detection of the faintest early-universe galaxy ever seen. The galaxy was observed using the W.M. Keck Observatory on the summit of Mauna Kea in Hawaii and the Hubble Space Telescope, and is seen as it was more than 13.3 billion years ago.

The galaxy was discovered using a technique known as gravitational lensing. One of the consequences of Albert Einstein’s General Theory of Relativity is that large concentrations of mass bend light, a hypothesis first shown to be true in 1919 when Arthur Eddington detected rays of light from distant stars bent around the Sun. This effect scales to the galactic level, where clusters of galaxies focus and magnify light emitted from other, more distant galaxies. The newly confirmed galaxy, which as yet lacks an official designation, is behind galactic cluster MACS2129.

The age and distance of the galaxy provide clues to what the universe was like during a period known as the “cosmic dark ages.” According to the Big Bang theory, the early universe cooled as it expanded. About 380,000 years after the Big Bang, the universe was cool enough that protons and electrons could bind together to form hydrogen. And yet, it seems to have taken another few hundred million years before the first stars formed.

What happened in these intervening years is largely a mystery. It is known from observations that galaxies began to form in this period, but the method of formation is not clear. One theory suggests that supermassive black holes, millions or billions the mass of our Sun, acted as seeds for such large collections of gas and dust, but this raises the question of how such large black holes themselves formed.

There is also the observation that hydrogen atoms a few hundred million years after the Big Bang were stripped of their electrons. The two leading theories are that either the ultraviolet light produced from early stars or radiation from gas falling into primordial black holes was responsible.