Eos

SCIENCE NEWS BY AGU

VOL. 101 | NO. 9
SEPTEMBER 2020

A 1928 Dirigible Tragedy

Saving a Pagoda's Dome

How to Measure the World's Sand

SATELLITE RECON

Scientists are using remote sensing from orbit to hunt for underwater volcanoes, predict allergy seasons, and even plan better cities.

AGU
ADVANCING EARTH AND SPACE SCIENCE

Ghostly Particles from the Sun Confirm Nuclear Fusion

Deep within the Sun, high temperatures and pressures drive the fusion of hydrogen into helium. Absent these nuclear reactions, Earth would be a cold and dark world devoid of life. Now, using an exquisitely sensitive detector located deep underground, researchers have made the first direct observation of a rare breed of ghostly particles known as solar neutrinos. This discovery confirms a long-hypothesized mechanism for how the Sun—and other stars—fuses hydrogen into helium.

Two Pathways to Neutrinos

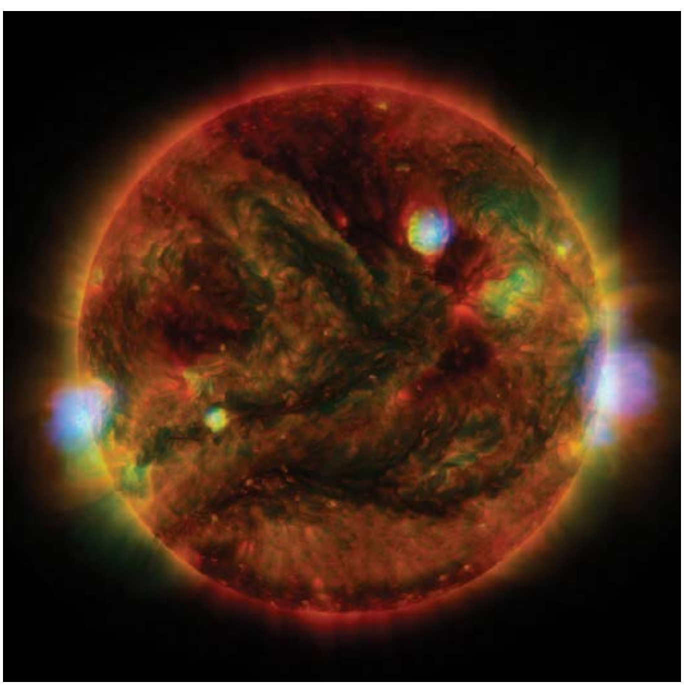
More than 8 decades ago, physicists Hans Bethe and Carl Friedrich von Weizsäcker independently proposed that hydrogen fusion in the Sun might be catalyzed by carbon, nitrogen, and oxygen nuclei. Researchers now understand that this so-called CNO cycle accounts for only a small fraction of the energy produced by the Sun—roughly 1%—but it's a dominant mechanism in more massive stars. Most of the Sun's energy derives from a fusion process known as the p-p chain.

Both the p-p chain and the CNO cycle produce neutrinos. These electrically neutral, nearly massless particles pervade space, yet they're maddeningly tough to pin down because they interact so weakly with matter. "Neutrinos are very difficult to detect," said Sarbani Basu, a solar and stellar astrophysicist at Yale University in New Haven, Conn., not involved in the research. "They pass right through you." (Hold up a hand. Tens of billions of neutrinos just zipped through.)

Neutrinos are a hallmark of the Sun's nuclear reactions, and they're a fundamental way of studying processes that occur deep within our nearest star. But it wasn't until 2014 that researchers reported detecting neutrinos from the primary reaction of the p-p chain. Now that same research group has pinpointed neutrinos from the CNO cycle.

A Detector Deep Underground

The team used the Borexino particle detector located roughly 1,400 meters underground near Rome, Italy. (The detector's subterranean environment shields it mightily—but not completely—from a barrage of cosmic particles.) The heart of Borexino is a spherical tank roughly 4 meters in diameter filled with about 280 metric tons of a liquid hydrocarbon. This "scintillator" liquid emits light whenever a charged particle moves through it. If a neutrino happens to collide with an electron in the tank, the resulting burst of light is captured by photomultiplier tubes within the detector. Neutrinos from the CNO cycle can be distinguished on the basis of the kick they impart to electrons.



Flaring, active regions of the Sun are highlighted in this image combining observations from several telescopes. High-energy X-rays from NASA's Nuclear Spectroscopic Telescope Array are shown in blue, low-energy X-rays from Japan's Hinode spacecraft are green, and extreme ultraviolet light from NASA's Solar Dynamics Observatory is yellow and red. Credit: NASA/JPL-Caltech/GSFC/JAXA

A long-standing challenge to detecting CNO cycle neutrinos has been background contamination. For example, the radioactive decay of bismuth-210, found in the nylon lining Borexino's innermost tank, releases charged particles that can trigger bursts of light, said Gioacchino Ranucci, an astroparticle physicist at the National Institute for Nuclear Physics in Milan, Italy, and a spokesman for the Borexino Collaboration. "Even if it's a small amount, it can mask the signal of the neutrinos."

Insulation to the Rescue

To combat this contamination, the scientists carefully controlled Borexino's thermal environment. They clad the detector in a thick layer of insulation and installed a heater

This discovery is "another milestone in solar neutrino physics."

nearby. Those efforts minimized convective currents within the detector's liquid, important for preventing the dispersal of bismuth-210 and its daughter products. The research team also limited its analyses to signals originating from deep within Borexino's innermost tank, far from the detector's nylon lining.

This summer, at the XXIX International Conference on Neutrino Physics and Astrophysics, the Borexino Collaboration reported a confident detection of CNO cycle neutrinos based on 3.5 years of data. Borexino spotted about seven of these elusive particles each day, the team estimated.

This discovery is "another milestone in solar neutrino physics," the team of nearly 100 reported in an accompanying paper (bit.ly/CNO-neutrinos).

These results are exciting, said Basu, but the error bars on the detection are still large. Those will get smaller as more data are collected, so it's important to keep the experiment going, she said. "Keep observing, keep observing."

By **Katherine Kornei** (@KatherineKornei), Science Writer