PHYSICS

Scientists Just Built the Most Precise Clock Ever to Help Understand Our Crazy Universe

Ryan F. Mandelbaum
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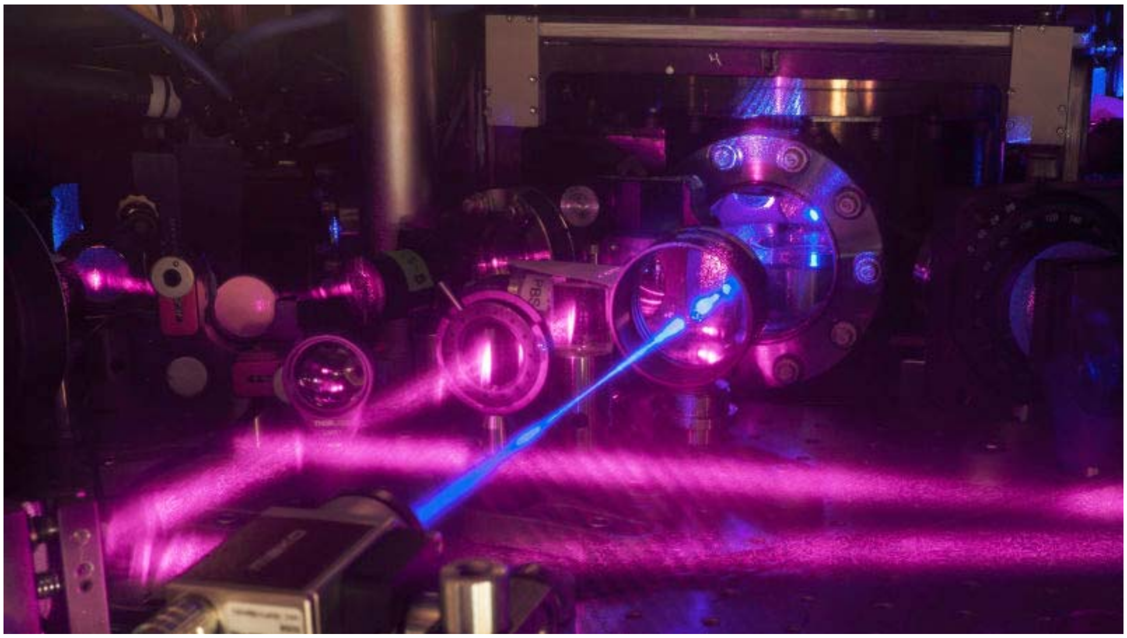

Image: G.E. Marti/JILA

How accurate a clock do you really need, honestly? You'll still probably show up late to parties and dial exactly three minutes late into every scheduled phone call. But scientists creating ultra-precise new atomic clocks don't really have you in mind. Instead, they're using wild physics to understand mysteries of the Universe that could alter time itself.

A team of physicists lead by Sara Campbell at the National Institute of Standards and Technology used the weirdness of quantum mechanics to create the most precise atomic clock yet. This clock employs atoms vibrating in three dimensions, using laser light to trap them in a sort-of miniature modular Ikea bookcase where they count down the tiniest measurable time units. The clock could one day help scientists devise some mind-boggling experiments.

"Developing a clock like this represents the most sensitive and inquisitive instruments mankind has built," said Jun Ye, study author from the NIST told Gizmodo. "We want to use it to describe the connection between quantum mechanics," the mathematics describing the smallest pieces of the universe, "and general relativity," the theory describing gravity.

Atomic clocks are just atoms that vibrate in a very special way in response to light. Electrons orbiting atoms arrange themselves in particular locations like single LEGO bricks on a big LEGO mat, with the preferred locations ordered by the energy required to move the electron there. Incoming energy from a laser can snap the electron into a higher-energy position, and after a set amount of time it falls back and releases its own light. Clocks take advantage of the regular oscillations of this process and define units of time based on the total number of back-and-forth snaps.

Scientists originally used microwaves to run these clocks, but are now moving to visible light which can potentially offer better accuracy and precision—there are more oscillations for a fixed amount of time, explained Ye. But researchers have dealt with some issues with these visible-light clocks. The more atoms they use, the more accurate a clock they can build in theory, but more atoms also introduces the chance for inter-atomic interactions that can undo those accuracy gains. Additionally, the signal from the vibrating atoms can get fuzzy.

The NIST scientists report a new solution today in the journal *Science*. Older clocks constrained the atoms to one dimension but moving to three dimensions better separated the signal from the fuzziness. Using a special gas at hyper-cold temperatures allowed quantum mechanics' rules to kick in on a larger scale. This amplified one specific property shared by the atoms in the gas, which reduced the interactions between them and helped make the clock more precise. The advance may soon allow researchers to build bigger clocks with as many atoms as they want.

In short, the team took advantage of physics' weirdness to make the most precise (but not the most accurate) atomic clock yet—and a scalable one.

Ye thought it would be a long time until the National Institute of Standards and Technology adopts such a clock as the standard, given how much we rely on our existing clocks. But he, and everyone I spoke with, was more excited about the clocks' potential for basic research. In a wristwatch, "you lose 1 second over a year," explained Asimina Arvanitaki from The Perimeter Institute in Canada. But the new clock "loses one second not every year, but every age of the universe." It's important to note that the quantum mechanical effects fall apart after ten seconds—but this is something the team is currently working on, and is eons if you think about just how many times the atoms are vibrating per second.

Super precise clocks like these can be used to probe never-before-seen physics. You may have heard of dark matter, the mysterious source of a majority of the Universe's mass that scientists can only observe indirectly. Perhaps these hyper-precise clocks can be used as detectors, looking for the tiniest change in their vibration when dark matter passes by. Additionally, gravity changes the way clocks tick. Perhaps a clock based on this system could detect passing gravitational waves, allowing for tabletop detectors instead of several-kilometer-long ones.

Naturally, there's still work to do. Francesco Scazza from the European Laboratory for Non-Linear Spectroscopy explained (and Ye confirmed) that these clocks are precise, meaning there isn't a lot of discrepancy between the ticks, but Ye's team hasn't tested the clocks for accuracy, how the ticking compares to the way the Universe itself ticks time. "Usually what they need to do is benchmark it with another clock," said Scazza. Ye also told Gizmodo that there is still the potential for other accuracy-harming interactions between atoms, and ways to make the clock tick longer than ten seconds before collapsing out of the quantum mechanical system it was held in.

Ye was most excited about using new aspects of quantum physics and applying them to the real world in a way that will both impact our lives and help uncover the mysteries of the Universe. He said “this opens a new wave of building an atomic clock where inside the core of a clock is a quantum matter.”

[Science]

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Humans Have Even More Neanderthal DNA Than We Realized

George Dvorsky
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A international team of researchers has completed one of the most detailed analyses of a Neanderthal genome to date. Among the many new findings, the researchers learned that Neanderthals first mated with modern humans a surprisingly long time ago, and that humans living today have more Neanderthal DNA than we assumed.

Before this new study, only four Neanderthal specimens have had their genomes sequenced. Of these, only one—an Altai Neanderthal found in Siberia—was of sufficient quality, where scientists were able to accurately flag variations in the genome. The new analysis, enabled by a remarkably well-preserved genome taken from a 52,000 year old bone fragment, is now the second Neanderthal genome to be fully sequenced in high fidelity. The resulting study, now published in *Science*, confirms a bunch of things we already knew about Neanderthals, while also revealing some things we didn't know.

The international research team that conducted this study—a group led by Kay Prüfer and Svante Pääbo from the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany—sequenced the genome of a female Neanderthal, dubbed Vindija 33.19, whose remains were uncovered at Vindija Cave in northern Croatia. By studying Neanderthal genomes in detail, and by comparing their DNA to those of modern humans, scientists can learn more about our evolutionary history and biology. And indeed, the researchers made some interesting discoveries.

Based on previous archaeological and genetic evidence, archaeologists and anthropologists suspected that Neanderthals were thinly dispersed across Europe and Asia. The lack of genetic diversity (low heterozygosity) in the Vindija 33.19 specimen affirms these earlier findings, showing that Neanderthals "lived in small and isolated populations" and "with an effective population size of around 3,000 individuals," the researchers write in their study.

The earlier genomic analysis of the female Altai Neanderthal showed that her parents were half-siblings, which got scientists thinking that Neanderthals made it a habit of breeding with immediate family members. But the Vindija 33.19 genome is different; her parents were not as closely related, so we can no longer say that extreme inbreeding is a common fixture of the Neanderthals. That said, the Croatian Neanderthal shared a maternal ancestor with three other individuals found in the Vindija Cave (whose genomes aren't nearly as complete).

The previous Altai Neanderthal study also suggested that Neanderthals starting breeding with archaic modern humans around 100,000 years ago, but the new analysis pushes that back even further to between 130,000 to 145,000 years ago. The location of these sub-species encounters probably happened in the Middle East or the Arabian Peninsula, but before modern humans spread en masse into Europe and Asia.

A comparative analysis of the Vindija 33.19 DNA to living humans resulted in an uptick in the amount of genes retained by *Homo sapiens*. When our ancestors mated with Neanderthals, we absorbed and retained some of their genes—some good, and some bad (more on this in just a second). Some of these genes have been lost forever (due to natural selection weeding out unfavorable inherited traits), but some have stuck around. Prüfer and Pääbo say that, based on the new high-quality genome, modern populations carry between 1.8 to 2.6 percent Neanderthal DNA—that's higher than the previous estimates of about 1.5 to 2.1 percent. More specifically, East Asians have about 2.3 to 2.6 percent Neanderthal DNA, while people from western Europe and Asia have retained about 1.8 to 2.4 percent DNA. African populations have virtually none because their ancestors did not mate with Neanderthals.

Finally, the researchers were able to identify the functions of the gene variants that are still exerting a force on humans today. These include genes associated with plasma levels of LDL cholesterol and vitamin D, eating disorders, visceral fat accumulation, rheumatoid arthritis, schizophrenia, and response to antipsychotic drugs. "This adds to mounting evidence that Neanderthal ancestry influences disease risk in present-day humans, particularly with respect to neurological, psychiatric, immunological, and dermatological phenotypes [disease of skin, nails, hair]," write the researchers. Some of these inherited characteristics allowed modern humans to survive outside of Africa, but now make us susceptible to diseases today.

Anne Stone, an anthropological geneticist at Arizona State University who wasn't involved in the study, says the most surprising thing about the new research is that the scientists were able to acquire such a beautifully preserved genetic sequence.

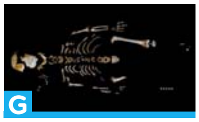
"From that information, however, I think what was most interesting to me was the evidence that ancient modern humans interbred with Neanderthals really early (we see this in the Neandertal genomes) during a time that was prior to when we think the big movement out of Africa occurred (that resulted in the colonization of the rest of the world by modern humans)," Stone told Gizmodo. "The other surprising aspect was that the level of genetic diversity was similar to that seen in some isolated modern human populations. This is different from what was seen in the Altai Neandertal who was quite inbred."

An aspect of the study that did not surprise Stone—but one she found cool nonetheless—was that the Vindija 33.19 individual was more closely related to the population of Neanderthals that interbred with ancient modern humans who had moved out of Africa. "This is not surprising given the location of the cave [which is] much closer to the area where we think this happened," she said.

Pretty amazing what scientists can learn from a 52,000-year-old strand of DNA.

[Science]

NEANDERTHALS IN THE NEWS!



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