DANIEL ZENDER

astronomers turn back the cosmic clock.

Earlier this year, Japanese astronomers reconstructed what the universe may have looked like as early as the Big Bang. Using ATERUI II, a supercomputer that specializes in astronomy simulations, their team created 4,000 simulations of the early universe.

One of ATERUI II's main goals is to investigate cosmological inflation—the theory that the early universe expanded exponentially from one moment to the next. Astronomers agree that this expansion would have left extreme variations in the density of matter that would have affected both the distribution of galaxies and the way they developed.

By comparing 4,000 simulations—all with different density fluctuations—against the real thing, scientists could rewind time and ask why some places in the universe are rife with cosmic activity while others are barren.

Masato Shirasaki, an assistant professor at the National Astronomical Observatory of Japan, says that question would be almost impossible to answer without these simulations. The project requires a huge amount of data storage (about 10 terabytes, equivalent to 22,000 episodes of Game of Thrones).

Shirasaki's team developed a model of how the universe is thought to have evolved and applied it to each of the simulations to see which result may be closest to how the universe looks today. This method made it easier to explore the physics of cosmic inflation.

In the next few years, Shirasaki's discovery could help shorten the observation time needed for future efforts like SPHEREx, a two-year mission slated for 2024 involving a spacecraft that will orbit Earth and gaze at nearly 300 million galaxies across the sky. With these leaps in computing, our understanding of the universe is expanding, bit by bit. universe is expanding, bit by bit. n

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IMPOSSIBLE INSTRUMENTS

Researchers wanted to build hyper realistic digital instruments. Musicians had other plans.

When Gadi Sassoon met Michele Ducceschi backstage at a rock concert in Milan in 2016, the idea of making music with mile-long trumpets blown by dragon fire, or guitars strummed by needle-thin alien fingers, wasn't yet on his mind. At the time, Sassoon was simply blown away by the everyday sounds of the classical instruments that Ducceschi and his colleagues were recreating.

"When I first heard it, I couldn't believe the realism, I could not believe that these sounds were made by a computer," says Sassoon, a musician and composer based in Italy. "This was completely groundbreaking, next-level stuff."

What Sassoon had heard were the early results of a curious project at the University of Edinburgh in Scotland, where Ducceschi was a researcher at the time. The Next Generation Sound Synthesis, or NESS, team had pulled together mathematicians, physicists, and computer scientists to produce the most lifelike digital music ever created, by running hyper-realistic simulations of trumpets, guitars, violins, and more on a supercomputer.

Sassoon, who works with both orchestral and digital music, "trying to smash the two together," was hooked. He became a resident composer with NESS, traveling back and forth between Milan and Edinburgh for the next few years.

It was a steep learning curve. "I would say the first year was spent just learning, they were very patient

with me," says Sassoon. But it paid off. At the end of 2020, Sassoon released "Multiverse," an album created using sounds he came up with during many long nights hacking away in the university lab.

Computers have been making music for as long as there have been computers. "It predates graphics," says Stefan Bilbao, lead researcher on the NESS project. "So it was really the first type of artistic activity to happen with a computer."

But to well-tuned ears like Sassoon's, there has always been a gulf between sounds generated by a computer and those made by acoustic instruments in physical space. One way to bridge that gap is to recreate the physics, simulating the vibrations produced by real materials.

The NESS team didn't sample any actual instruments. Instead they developed software that simulated the precise physical properties of virtual instruments, tracking things like the changing air pressure in a trumpet as it moves through tubes of different diameters and lengths, the precise movement of plucked guitar strings or the friction of a bow on a violin. They even simulated the air pressure inside the virtual room in which the virtual instruments were played, down to the square centimeter.

Tackling the problem this way let them capture nuances that other approaches miss. For example, they could recreate the sound of a brass instruments played with their valves held down only part of the way, which is a technique used by jazz musicians to get a particular sound. "You get a huge variety of weird stuff coming out that would be pretty much impossible to nail otherwise," says Bilbao.

Sassoon was one of 10 musicians who were invited to try out what the NESS team was building. It didn't take long for them to start tinkering with the code to stretch the boundaries of what was possible: trumpets that required multiple hands to play, drum kits with 300 interconnected parts.

Will Douglas Heaven is a senior editor for AI at MIT Technology Review.

One downside is that fewer people will learn to play physical instruments. On the other hand, computers could start to sound more like real musicians—or something different altogether.

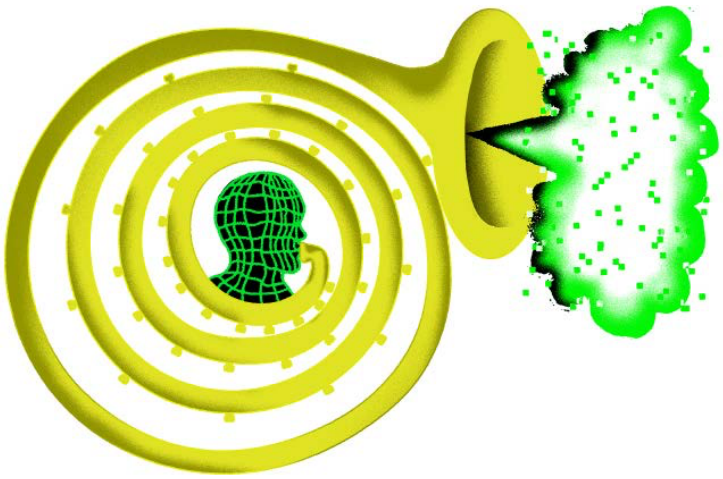
At first the NESS team was taken aback, says Sassoon. They had spent years making the most realistic virtual instruments ever, and these musicians weren't even using them properly. The results often sounded terrible, says Bilbao.

Sassoon had as much fun as anyone, coding up a mile-long trumpet into which he forced massive volumes of air heated to 1,000 Kelvin, aka "dragon fire." He used this instrument on "Multiverse," but Sassoon soon became more interested in more subtle impossibilities.

By tweaking variables in the simulation he was able to change the physical rules governing energy loss, creating conditions that don't exist in our universe. Playing a guitar in this alien world, barely touching the fretboard with needle-tip fingers, he could make the strings vibrate without losing energy. "You get these harmonics that just fizzle forever," he says.

The software developed by NESS continues to improve. Their algorithms have sped up with the help of the university's parallel computing center, which operates the UK's supercomputer Archer. And Ducceschi, Bilbao, and others have spun off a startup called Physical Audio, which sells plugins that can run on laptops.

Sassoon thinks this new generation of digital sound will change the future of music. One downside is that fewer people will learn to play physical instruments, he says. On the other hand, computers could start to sound more like real musicians—or something different altogether. "And that's empowering," he says. "It opens up new kinds of creativity." n



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