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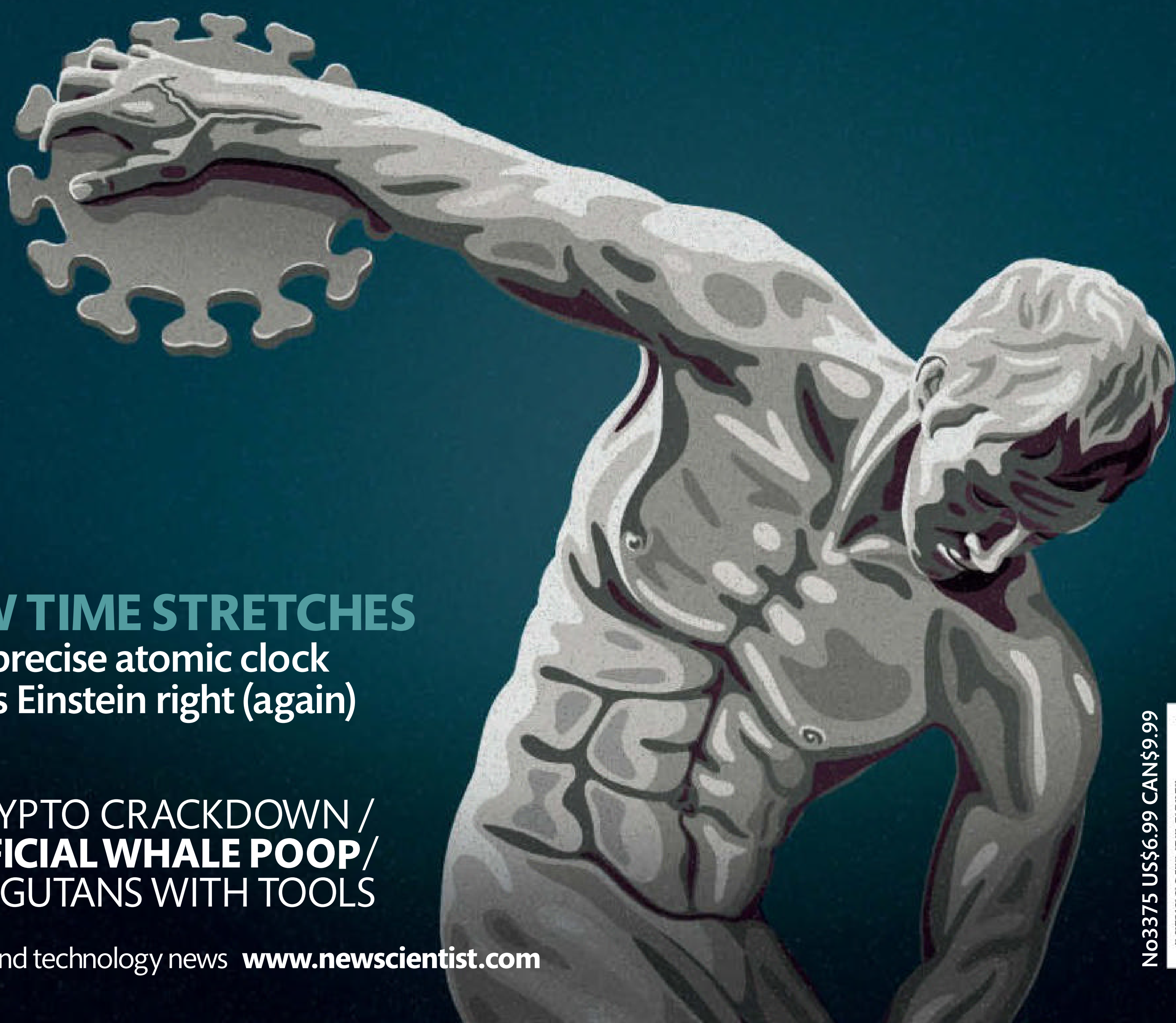

HOW TIME STRETCHES
Most precise atomic clock proves Einstein right (again)

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Climate change

Oil giants accused of greenwashing over clean-energy switch

Adam Vaughan

FOUR of the world's biggest oil companies have failed to match their words on climate change with action, according to a study which concluded that the firms aren't seriously transitioning to low-carbon energy.

Gregory Trencher at Kyoto University, Japan, and his colleagues analysed the corporate reports, statements and spending of BP, Shell, Chevron and ExxonMobil. From 2009 to 2020, the companies' annual reports showed a clear increasing trend in the use of 39 keywords and phrases such as "climate change" and "transition".

But the researchers found a lack of concrete actions to meet targets for clean energy set over the period. Shell and Chevron have increased oil and gas production since 2015, and BP had too until 2020. All the firms spent only a tiny fraction of the billions they invest in energy projects each year on low-carbon projects (*PLoS One*, doi.org/gphdqw).

"Given the mismatch between discourse, pledges, actions and investments, aligning with recent studies, we conclude that no major [oil company] is currently on the way to a clean energy transition," the team wrote.

Responding to the study, a BP spokesperson highlighted the firm's post-2020 action on renewables and electric car chargers. A Shell spokesperson says: "We have always been clear that the business plans we have today will not get us to net zero. So, our plans must change over time." The other firms didn't respond to a request for comment.

SHUTTERSTOCK/JAMES JONES JR

An oil rig at Cromarty Firth in Invergordon, UK

Physics

Time dilation seen on smallest scale ever in an atomic clock

Alex Wilkins

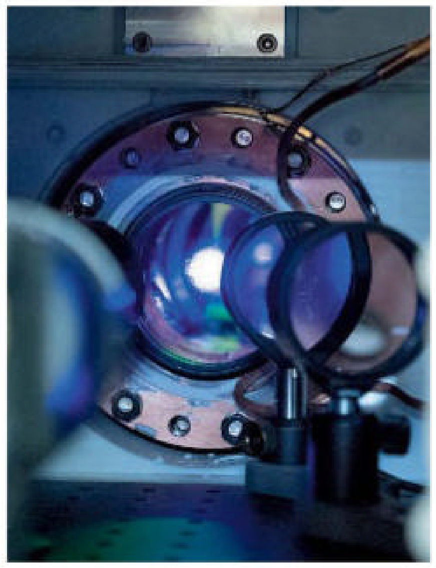
THE world's most precise atomic clock has confirmed that the time dilation predicted by Albert Einstein's theory of general relativity works on the scale of millimetres.

Physicists have been unable to unite quantum mechanics – a theory that describes matter at the smallest scales – with general relativity, which predicts the behaviour of objects at the largest cosmic scales, including how gravity bends space-time. Because gravity is weak over small distances, it is hard to measure relativity on small scales.

But atomic clocks, which count seconds by measuring the frequency of radiation emitted when electrons around an atom change energy states, can detect these minute gravitational effects.

Tobias Bothwell at JILA in Boulder, Colorado, and his colleagues separated hundreds of thousands of strontium atoms into "pancake-shaped" blobs of 30 atoms. They used optical light to trap these into a vertical stack 1 millimetre high. Then they shone a laser on the stack and measured the scattered light with a high-speed camera.

Because the atoms were arranged vertically, Earth's gravity caused the frequency of oscillations in each group to shift by a different amount, an effect called gravitational redshift. At the top of the clock, a second was measured as 10^{-19} of a second longer than it was at the bottom (*Nature*, doi.org/gphczn). This means if you were to run the clock for the age of the universe – about 14 billion years – it would only be off by 0.1 second, says team member Jun Ye at JILA.



JACOBSON/NIST

A stack of strontium atoms held in place with a laser

This redshift measurement, calculated to a certainty of 21 decimal places, was predicted by Einstein's theory. Previous measurements had observed the redshift over larger scales by comparing separate clocks, but the JILA team measured it in a single clock.

"This is the first time where, instead of comparing separate clocks over something like 30 centimetres, we're now looking within a single clock," says Bothwell.

10^{-19}

The increase in the length of a second over 1 millimetre

One reason for the clock's precision is because the groups of strontium atoms are close together and share environmental properties, such as their thermal environment, so can be more easily compared and imaged with JILA's high-resolution camera.

"It's a very impressive result that they've demonstrated. It's very interesting that, considering different parts of the apparatus, it might give you a different answer [as to the length of a second]," says Patrick Gill at the National Physical Laboratory, UK.

Bothwell says this atomic clock design could eventually be used to measure gravitational waves in space or the possible ways that dark matter couples to matter, as well as having uses in more practical areas, such as improving the accuracy of the Global Positioning System (GPS), which uses the precise timing of atomic clocks to calculate distance.

A group at the University of Wisconsin-Madison has also produced a new atomic clock set-up. Shimon Kolkowitz and his team used comparisons between six strontium atomic clocks to measure a second (*Nature*, doi.org/hg53). This comparative model, known as a multiplex clock, means the team can use a less stable laser but still achieve a very high level of precision.

"It's a nice demonstration that you can use lasers with much lower performance, which are more portable and more robust, and still do these kinds of clock comparisons, with pretty amazing levels of precision," says Kolkowitz.

He and his team's clock measures the relative differences between atomic clocks, so it is well suited to pinning down hard-to-measure effects that propagate through space, such as gravitational waves or dark matter. The group is now looking at measuring gravitational redshift using the multiplex clock on similar scales to the JILA team's clock.