Quantum quirk may reveal early universe

A TABLE-TOP experiment to mimic conditions in the early universe could steal some thunder from the Large Hadron Collider (LHC), the world's largest particle smasher.

As the hot infant universe rapidly expanded, cosmologists believe that particles were created from the vacuum of empty space. To find out how, physicists generally use giant accelerators like the LHC - currently being built at CERN in Switzerland - to generate the kind of energies that existed soon after the big bang.

Now Ralf Schützhold at Dresden University of Technology in Germany and his colleagues are proposing a considerably cheaper and easier experiment. "We could potentially model the conditions of the universe at times stretching back beyond the reach of the LHC," Schützhold claims.

The team's method relies on a quirk of quantum mechanics. Just as light waves can be thought of as a series of photon particles, sound waves moving through ions in a solid can be thought of as a beam of phonon particles. According to the team's calculations, the same quantum processes that gave rise to photons and other particles in the early universe should create pairs of phonons in a cloud of ions in the lab (www.arxiv.org/abs/0705.3755).

This isn't the first time physicists have suggested mimicking cosmological phenomena in the lab (see "Supersonic black holes"), but their ideas have been difficult to pull off in practice. By contrast, Schützhold's method uses a relatively simple ion trap, in which ions are captured between electrodes and manipulated with lasers.

To start with, magnesium ions are cooled until they don't vibrate at all, leaving them free of phonons. "The ion cloud mimics the empty vacuum [of space-time]," says Tobias Schätz at the Max Planck Institute for Quantum Optics in Garching, Germany, who is testing the set-up using a single ion before scaling up to a cloud of about a thousand ions.

The next step, which Schätz is working on, is to produce a precisely controlled drop in voltage across the electrodes to allow the ion cloud to suddenly spread, simulating the rapid expansion of the early universe. "This is really tricky because you don't want to accidentally lose the ions from the trap," says Schätz.

The calculations suggest that as the ion cloud expands, phonons will form spontaneously, setting the ions vibrating. The team intends to detect this motion using lasers. However, this will not be enough to confirm that quantum particles have been created. "People might argue: how do we know this is really the result of a quantum process?" says Schätz. "We have to rule out that the ions are vibrating simply because we have disturbed them."

Schätz has a solution. Since quantum particles are always created in pairs, the experiment should only produce even numbers of phonons and set the ions vibrating at specific frequencies, which the team should be able to pick out.

Astrophysicist Stefano Liberati at the International School for Advanced Studies in Trieste, Italy, is impressed. "They have a way to see the signature of quantum particle production from the vacuum," he says. "It will be a very important result if the experiment works." Quantum physicist Stefano Giovanazzi at the University of Heidelberg in Germany admires the experiment's simplicity. "This is much cheaper than using particle accelerators because you don't need huge energies," he says.

What's more, Giovanazzi says, the experiment could tell us more about the early universe than particle smashers. Cosmologists suspect that particle creation in the early universe could have had a feedback effect, perhaps slowing the expansion of the universe. "This is something that could be directly observed here by looking for effects on the expansion of the ion cloud," says Giovanazzi.

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Supersonic black holes

In 1981, William Unruh at the University of British Columbia in Vancouver, Canada, realised that black holes could be simulated using low-temperature superconducting fluids spinning faster than the speed of sound in the fluids. Sound waves travelling through such a liquid wouldn't keep up with parts of the fluid - effectively becoming trapped behind an "event horizon", just as light is trapped by a black hole.

Now South Korean researchers Xian-Hui Ge at the Asia-Pacific Center for Theoretical Physics in Pohang and Sung-Won Kim at Ewha Woman's University in Seoul say the method could detect the extra dimensions proposed by some string theories. "If our space-time is fundamentally a higher-dimensional one, extra dimensions should appear in supersonic black holes," says Ge.

The black holes would emit particles known as Hawking radiation, and the duo has shown that the radiation pattern would be different depending on whether or not extra-dimensions exist (www.arxiv.org/abs/0705.1404).

But nobody has yet made supersonic black holes, due to the difficulty of keeping such high-speed fluids cold.

(Source: New Scientist)