Liquid spacetime: A very slippery superfluid, that's what spacetime could be like

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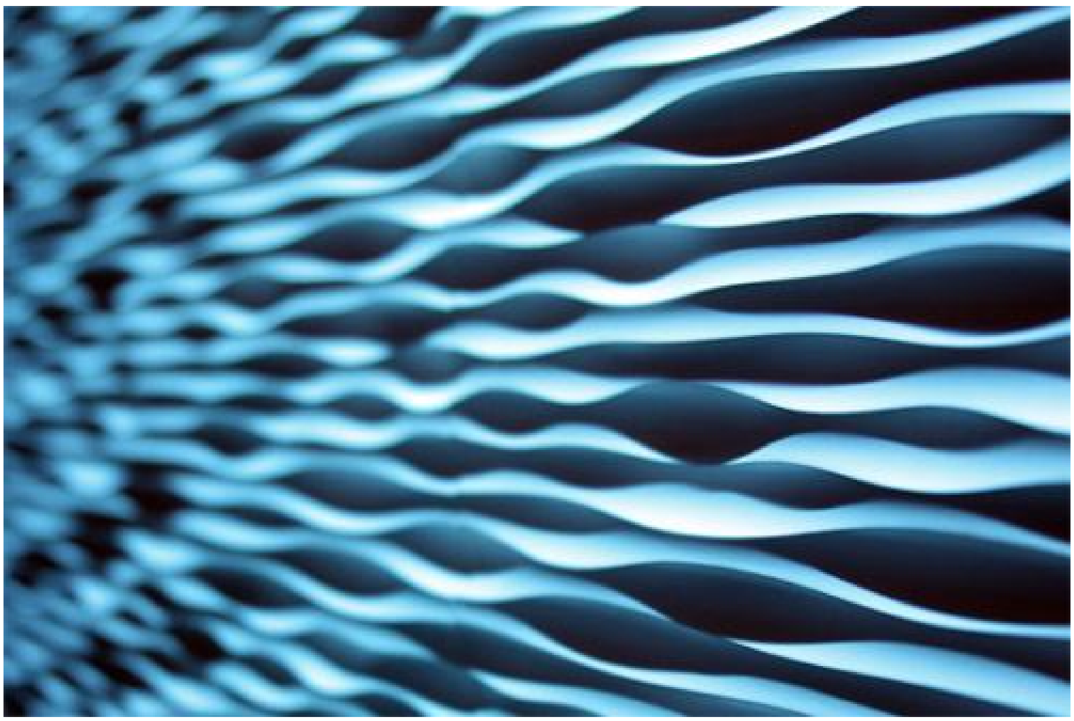

Credit: Jason Ralston/Flickr

What if spacetime were a kind of fluid? This is the question tackled by theoretical physicists working on quantum gravity by creating models attempting to reconcile gravity and quantum mechanics. Some of these models predict that spacetime at the Planck scale (10^{-33}cm) is no longer continuous – as held by classical physics – but discrete in nature. Just like the solids or fluids we come into contact with every day, which can be seen as made up of atoms and molecules when observed at sufficient resolution. A structure of this kind generally implies, at very high energies, violations of Einstein's special relativity (a integral part of general relativity).

In this theoretical framework, it has been suggested that spacetime should be treated as a fluid. In this sense, general relativity would be the analogue to fluid hydrodynamics, which describes the behaviour of fluids at a macroscopic level but tells us nothing about the atoms/molecules that compose them. Likewise, according to some models, general relativity says nothing about the "atoms" that make up spacetime but describes the dynamics of spacetime as if it were a "classical" object. Spacetime would therefore be a phenomenon "emerging" from more fundamental constituents, just as water is what we perceive of the mass of H2O molecules that form it.

Stefano Liberati, professor at the International School for Advanced Studies (SISSA) in Trieste, and Luca Maccione, a research scientist at the Ludwig-Maximilian University in Munich, have devised innovative ways of using the tolls of elementary particle physics and high energy astrophysics to describe the effects that should be observed if spacetime were a fluid. Liberati and Maccione also proposed the first observational tests of these phenomena. Their paper has just been published in the journal *Physical Review Letters*.

More in detail...

Quantum mechanics is able to effectively explain three of the four fundamental forces of the Universe (electromagnetism, weak interaction and strong interaction). But it does not explain gravity, which is currently only accounted for by general relativity, a theory developed in the realm of classical physics. Identifying a plausible model of quantum gravity (that is, a description of gravity within a quantum physics framework) is therefore one of the major challenges physics is facing today. However, despite the many models proposed to date, none has proved satisfactory or, more importantly, amenable to empirical investigation. Studies like the one carried out by Liberati and Maccione provide new instruments for assessing the value of possible scenarios for quantum gravity.

In the past, models considering spacetime as emerging, like a fluid, from more fundamental entities assumed and studied effects that imply changes in the propagation of photons, which would travel at different speeds depending on their energy. But there's more to it: "If we follow up the analogy with fluids it doesn't make sense to expect these types of changes only" explains Liberati. "If spacetime is a kind of fluid, then we must also take into account its viscosity and other dissipative effects, which had never been considered in detail".

Liberati and Maccione catalogued these effects and showed that viscosity tends to rapidly dissipate photons and other particles along their path, "And yet we can see photons travelling from astrophysical objects located millions of light years away!" he continues. "If spacetime is a fluid, then according to our calculations it must necessarily be a superfluid. This means that its viscosity value is extremely low, close to zero".

"We also predicted other weaker dissipative effects, which we might be able to see with future astrophysical observations. Should this happen, we would have a strong clue to support the emergent models of spacetime", concludes Liberati. "With modern astrophysics technology the time has come to bring quantum gravity from a merely speculative view point to a more phenomenological one. One cannot imagine a more exciting time to be working on gravity".

More information: Astrophysical Constraints on Planck Scale Dissipative Phenomena, *Phys. Rev. Lett*. 112, 151301 – Published 14

April 2014. Stefano Liberati and Luca Maccione, DOI: 10.1103/PhysRevLett.112.151301 . journals.aps.org/prl/abstract/ … ysRevLett.112.151301

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