Our Universe: A Quantum Loop

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“There are two classical branches of the universe connected by a quantum bridge. This connects the former collapse with the current expansion.” While Abhay Ashtekar and his colleagues, Tomasz Pawlowski and Parampreet Singh, may not have come with a completely new theory, what they have done is create a systematic way, through quantum equations, to look back in time to the birth of our current universe.

Ashtekar’s team from Pennsylvania State University’s Institute for Gravitational Physics and Geometry published a Letter in *Physical Review Letters* on April 12th, detailing what was found, and shedding a little more light on what actually happened at the time the universe began expanding.

“The idea of a bounce has been around for a while,” Ashtekar explains to *PhysOrg.com*, “and it has been looked at in many contexts. One of them is String Theory.” He continues: “The pre-Big Bang cosmology considered the idea that a branch of the universe existed before the Big Bang, and in the Ekpyrotic scenario, a `brane’ collides with another `brane,’ causing a bounce.”

What makes the PSU explanation different, says Ashtekar, is the fact that while it was assumed that there might possibly be something before the Big Bang, a systematic determination of what that might have been was missing. Additionally, “one never had systematic equations that are determinate, leading from the pre- to post-Big Bang branches of the universe.”

Ashtekar and his colleagues use Einstein’s quantum equations from Loop Quantum Gravity (LQG), an approach to the unification of general relativity and quantum physics. LQG does not presuppose the existence of a space-time continuum. Ashtekar and his fellow team members find that quite likely there is a classical universe, one that looks and behaves pretty much like our currently universe, on the other side of the Big Bang, which he describes as more of a Big Bounce. In these classical universes, spacetime is a continuum and Einstein’s theory of general relativity is mostly accurate. But between these two classical universes, Ashtekar says, is a point at which general relativity doesn’t apply. “We know that on the quantum level the theory of general relativity breaks down,” he explains, “and this quantum bridge, which lasts for such a small period of `time,’ connects the two branches of the universe.”

Using the collapse of stars as an example, Ashtekar explains how the pre-Big Bang universe retracted and became smaller until it bounced out and began expanding again in what we recognize as our universe: “Stars like our sun are in equilibrium. There is a radiation that push outward against gravity, which tries to collapse. When the star runs out of fuel, the radiation reduces, and there is nothing to stop the collapse. For stars with three times the mass of our sun or less, when it gets to a certain point, the neutrons repulse each other and they become neutron stars or pulsars.” He pauses and then continues to explain that in larger stars, stars with more than three times the mass of our sun, the crushing gravity causes the star to continue its collapse, becoming a black hole. “The forces of nature, which we understand well, just aren’t enough to stop that collapse.”

The universe, says Ashtekar, acts in much the same way. The pre-universe collapses-in on itself. However, a new kind of repulsive force comes into play because of the quantum properties of the geometry itself. “No matter how heavy, how much mass,” says Ashtekar, “this repulsive force still wins out. When the universe reached a point of high Planck density, [named after Max Planck, the founder of quantum mechanics] the repulsive force bounced it out.” Ashtekar’s team created the first detailed calculations that show classical behavior in the universe before the epoch of the Big Bang. “This is the time when quantum physics and relativity must be combined, and at this point the new physics causes a Big Bounce. And we find the equations that tell us that before this Big Bounce, there was a classical universe."

While different scenarios abound as to what is on the other side of the Big Bang, no one had definitively predicted a classical universe. "The fact that there is a classical universe on the other side of the bounce, rather than a sort of quantum foam in which the space-time geometry fizzles out, was so surprising to us that we had to run more tests for several months to make sure it wasn't a fluke. And the result was robust."

Ashtekar does admit one limitation to the equations on which this idea is based: "We start by assuming that the universe is homogeneous and isotropic. It is an approximation done in cosmology, even though we know that the universe is not exactly like that. So the question is how to make the model more and more realistic. And this is an ongoing work."

"All of this offers a solution to long-standing problems," says Ashtekar. "We can show that spacetime was classical before the Big Bounce, and became classical again surprisingly close to after the bounce. We showed that there is no quantum foam on the other side, but that there is a classical branch connected by quantum geometry. And the coherence of these results shows that quantum geometry effects play a crucial role in understanding the true nature of the Big Bang."

Ashtekar also adds that this work, as he and his colleagues continue to probe the Big Bounce and work toward overcoming the limitations of their equations and models, will contribute to better understanding quantum gravity, and developing a more complete theory. "Our work has some essential features of a theory of quantum gravity," he says. "It gives us confidence in our underlying ideas."

By Miranda Marquit, Copyright 2006 PhysOrg.com

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