Looking for the quantum properties of the Big Bang

June 13 2008, By Miranda Marquit

"General relativity doesn't recognize quantum physics," Martin Bojowald tells *PhysOrg.com*. And that, he insists, causes problems when it comes to understanding the evolution of the universe from the Big Bang: "You get to a point where you derive all these infinite values and classical physics stop making sense."

The key Bojowald, a scientist at Pennsylvania State University, believes, is integrating quantum equations with general relativity to get a picture of what might have happened at the earliest moments in the cosmic development of our universe. He discusses this subject, and presents his equations, in *Physical Review Letters*: "How Quantum is the Big Bang?"

In order to build a picture of what happened at the Big Bang (or even before), Bojowald has been slowly adding different terms to his equations that address different quantum properties. "Sometimes these are written as 'additional forces,'" he explains, "and one that we looked at was a consequence of the ability of quantities to fluctuate in time."

"Fluctuating behaviors cause quantities to change rapidly in time. We would measure something twice in a row, and get different quantities," Bojowald says. The complex equations used to get this information, though, "remain sensible and can tell us what happens. But we don't know the complete theory, and the equations are still difficult to analyze."

But one thing these fluctuating behaviors do offer is confirmation: "We confirmed some of the indications that we received early regarding the upper bound energy densities can have," Bojowald explains. "In classical physics, you have this infinite number. With quantum effects, we see that there must be an upper limit to energy densities and temperatures."

What happens when these upper bounds are reached? Bojowald continues: "One possibility is that the universe bounces. Initially, a collapsing universe became denser and denser. When the upper energy bounds were reached, it turned into the expanding universe we see now."

The next question, though, is how long these quantum fluctuations affected the universe. "We often think of it as a very short amount of time," Bojowald says, "and maybe it was. But with quantum fluctuations, it could be a longer time. Either there was a really short bounce, or the universe spent a long time in a quantum state, and once the right value was reached, it started to expand." It all depends on what quantum state the universe was in at the time. Whether the universe contracts, expands or oscillates depends upon the quantum state.

Understanding how our universe came to be could answer other questions. "While models of the early universe seem complex," Bojowald insists, "they are really some of the mathematically simplest models that have something to do with reality. In a sense, this can help us understand fundamental physics."

But in terms of cosmic evolution, this work has potential that could be even more exciting. "This can affect what sorts of observations we can make," Bojowald says. "That is motivation to look at these equations and see what they imply. We might be able to observe what happened right after the Big Bang – and even before."