How did the universe begin?

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One of the most interesting questions considered by astrophysicists deals with the start of our universe. Indeed, there is a great deal of speculation on the subject, with different theories about how the universe began, and what may have existed before the universe came into being.

Several prominent astrophysicists around the world are interested in answering these questions. In one paper, “No-Boundary Measure of the Universe,” published in *Physical Review Letters*, James Hartle, Stephen Hawking and Thomas Hertog calculate the probabilities that the no-boundary wave function predicts in terms of classical space-time possibilities.

“Theories regarding the beginning of the universe are expressed as wave functions,” Hartle tells PhysOrg.com. “The no-boundary wave function is one theory about the origins of the universe.” The goal of this particular work with Hawking and Hertog, he continues, was to model the universe and see what kind of probabilities exist that the current universe could have originated in a certain way.

The no-boundary proposal predicts that expansion in the early universe would have proceeded smoothly from a moment in time. The idea is that inflation was a feature of our early universe. “It collapsed from a previous large phase, bounced at a small but not zero radius, and expanded again to the large phase we are living in,” says Hartle.

The no-boundary wave function also states that space-time was not what we see today at the outset of universal expansion. “When the universe started out," Hartle explains, "there wasn't ordinary space-time. Instead of three space directions, as we have now, there were four space directions. At some point, a transition was made to ordinary space-time."

Hartle and his colleagues examined models of the universe that were homogenous, isotropic and closed. A cosmological constant was assumed, as was a scalar field with quadratic potential. They looked at entire classical histories, examining the ideas of a singularity, such as a Big Bang, or considering a bounce with a finite radius. The point was to get a picture of which scenarios are most likely to produce a universe that is similar to what we see currently.

"Both things, a Big Bang or a bounce, are possible," Hartle says. "However, we found a significant probability that the early universe might have bounced."

Hartle does admit that the simple model used by him and his colleagues does have its limitations. For one thing, the universe is not completely homogenous as the model assumes. "You see a certain lumpiness in the real universe," he concedes. However, most of the irregularities are small, and many of them can, in fact, be ultimately accounted for in a no-boundary proposal.

"Our model does make a number of strong assumptions," Hartle continues. But, he insists, "this is a standard trade-off in physics. Our model is simplified so that we can analyze it completely."

"In present cosmology, we test models to see if different proposals fit the universe that we see. In this instance, we see that the no-boundary wave function does," Hartle says. "We see that there is a good chance the universe originated in a bounce."

"We hope that can extend this to other, more sophisticated models, with different potentials and different degrees of freedom.”