Universe may be on the brink of collapse (on the cosmological timescale)

March 23 2015, by Lisa Zyga

This is the "South Pillar" region of the star-forming region called the Carina Nebula. Like cracking open a watermelon and finding its seeds, the infrared telescope "busted open" this murky cloud to reveal star embryos tucked inside finger-like pillars of thick dust. Credit: NASA

(Phys.org)—Physicists have proposed a mechanism for "cosmological collapse" that predicts that the universe will soon stop expanding and collapse in on itself, obliterating all matter as we know it. Their calculations suggest that the collapse is "imminent"—on the order of a few tens of billions of years or so—which may not keep most people up at night, but for the physicists it's still much too soon.

In a paper published in *Physical Review Letters*, physicists Nemanja Kaloper at the University of California, Davis; and Antonio Padilla at the University of Nottingham have proposed the cosmological collapse mechanism and analyzed its implications, which include an explanation of dark energy.

"The fact that we are seeing dark energy now could be taken as an indication of impending doom, and we are trying to look at the data to put some figures on the end date," Padilla told *Phys.org*. "Early indications suggest the collapse will kick in in a few tens of billions of years, but we have yet to properly verify this."

The main point of the paper is not so much when exactly the universe will end, but that the mechanism may help resolve some of the unanswered questions in physics. In particular, why is the universe expanding at an accelerating rate, and what is the dark energy causing this acceleration? These questions are related to the cosmological constant problem, which is that the predicted vacuum energy density of the universe causing the expansion is much larger than what is observed.

"I think we have opened up a brand new approach to what some have described as 'the mother of all physics problems,' namely the cosmological constant problem," Padilla said. "It's way too early to say if it will stand the test of time, but so far it has stood up to scrutiny, and it does seem to address the issue of vacuum energy contributions from the standard model, and how they gravitate."

The collapse mechanism builds on the physicists' previous research on vacuum energy sequestering, which they proposed to address the cosmological constant problem. The dynamics of vacuum energy sequestering predict that the universe will collapse, but don't provide a specific mechanism for how collapse will occur.

According to the new mechanism, the universe originated under a set of specific initial conditions so that it naturally evolved to its present state of acceleration and will continue on a path toward collapse. In this scenario, once the collapse trigger begins to dominate, it does so in a period of "slow roll" that brings about the accelerated expansion we see today. Eventually the universe will stop expanding and reach a turnaround point at which it begins to shrink, culminating in a "big crunch."

Currently, we are in the period of accelerated expansion, and we know that the universe is approximately 13.8 billion years old. So in order for the new mechanism to work, the period of accelerated expansion must last until at least this time (needless to say, a mechanism that predicts that the universe has already collapsed is obviously flawed). The collapse time can be delayed by choosing an appropriate slope, which in this case, is a slope that has a very tiny positive value—about 10^{-39} in the scientists' equation. The very gradual slope means that the universe evolves very slowly.

Importantly, the scientists did not choose a slope just to fit the observed expansion and support their mechanism. Instead, they explain that the slope is "technically natural," and takes on this value due to a symmetry in the theory.

As the physicists explain, the naturalness of the mechanism makes it one of the first ever models that predicts acceleration without any direct fine-tuning. In the mechanism, the slope alone controls the universe's evolution, including the scale of the accelerated expansion.

"The 'technically natural' size of the slope controls when the collapse trigger begins to dominate, but was it guaranteed to give us slow roll and therefore the accelerated expansion?" Padilla said. "Naively one might have expected to have to fine-tune some initial conditions to guarantee this, but remarkably that is not the case. The dynamics of vacuum energy sequestering guarantee the slow roll."

The idea is still in its early stages, and the physicists hope to build on it much more in the future.

"There is much to do," Padilla said. "Right now we are working on a way to describe our theory in a way that is manifestly local, which will make it more conventional, and more obviously in keeping with some of the key principles behind quantum theory (namely, linear superposition). We would also like to devise more tests of the idea, both cosmological and astrophysical.

"Over the longer term, we would like to understand how our theory could emerge from a more fundamental theory, such as string theory. It is also important to ask what happens when we consider vacuum energy corrections from quantum gravity."

If there was ever a justification that more work is needed, it may be in the paper's conclusion:

"The present epoch of acceleration may be evidence of impending doom. . . A detailed analysis to better quantify these predictions is certainly warranted."

More information: Nemanja Kaloper and Antonio Padilla. "Sequestration of Vacuum Energy and the End of the Universe." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.114.101302