Physicists continue to investigate why the universe did not collapse

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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)—According to the best current physics models, the universe should have collapsed shortly after inflation—the period that lasted for a fraction of a second immediately after the Big Bang.

The problem lies in part with Higgs bosons, which were produced during inflation and which explain why other particles have the masses that they do. Previous research has shown that, in the early universe, the Higgs field may have acquired large enough fluctuations to overcome an energy barrier that caused the universe to transition from its standard vacuum state to a negative energy vacuum state, which would have caused the universe to quickly collapse in on itself.

In a new paper published in *Physical Review Letters*, Matti Herranen at the University of Copenhagen and coauthors may have come a step closer to solving the problem by constraining the strength of the coupling between the Higgs field and gravity, which is the last unknown parameter of the standard model.

As the physicists explain, the stronger the Higgs field is coupled to gravity, the larger are the fluctuations that may eventually trigger a fatal transition to the negative energy vacuum state.

In the new paper, the scientists calculated that a collapse after inflation would have happened only if the coupling strength had been above a value of 1.

Combining this result with the lower bound of 0.1, which the same physicists derived last year by analyzing the requirements for stability during (rather than after) inflation, and the range of 0.1-1 constrains the coupling to near its historically estimated value of 1/6. This value of 1/6 is traditionally used as an estimate because it corresponds to zero Higgs-gravity coupling, though it is likely incorrect.

Narrowing down the Higgs-gravity coupling strength will guide physicists when analyzing experimental data to help pinpoint the coupling value with greater precision. Data on the cosmic microwave background radiation and gravitational waves, for example, are expected to help further constrain the value. When combined with other parameters, the Higgs-gravity coupling strength should produce a picture of a universe that did not transition to a state of collapse.

"It's a combination of parameters that actually determines the occurrence of such a transition, including the Higgs coupling to gravity, but also the energy scale of the inflation, which are not tightly constrained by current measurements," Herranen told *Phys.org*. "So, presently it is not possible to draw a conclusion on whether the standard model is in trouble due to instability-related issues, but it would be very interesting if the Higgs-gravity coupling and the scale of inflation could be constrained more tightly in the future by independent measurements, for example by observing primordial gravity waves resulting from inflation."

Taken together, the results should help scientists modify inflation models in order to describe a universe more like the one we live in.

More information: M. Herranen, et al. "Spacetime Curvature and Higgs Stability after Inflation." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.115.241301