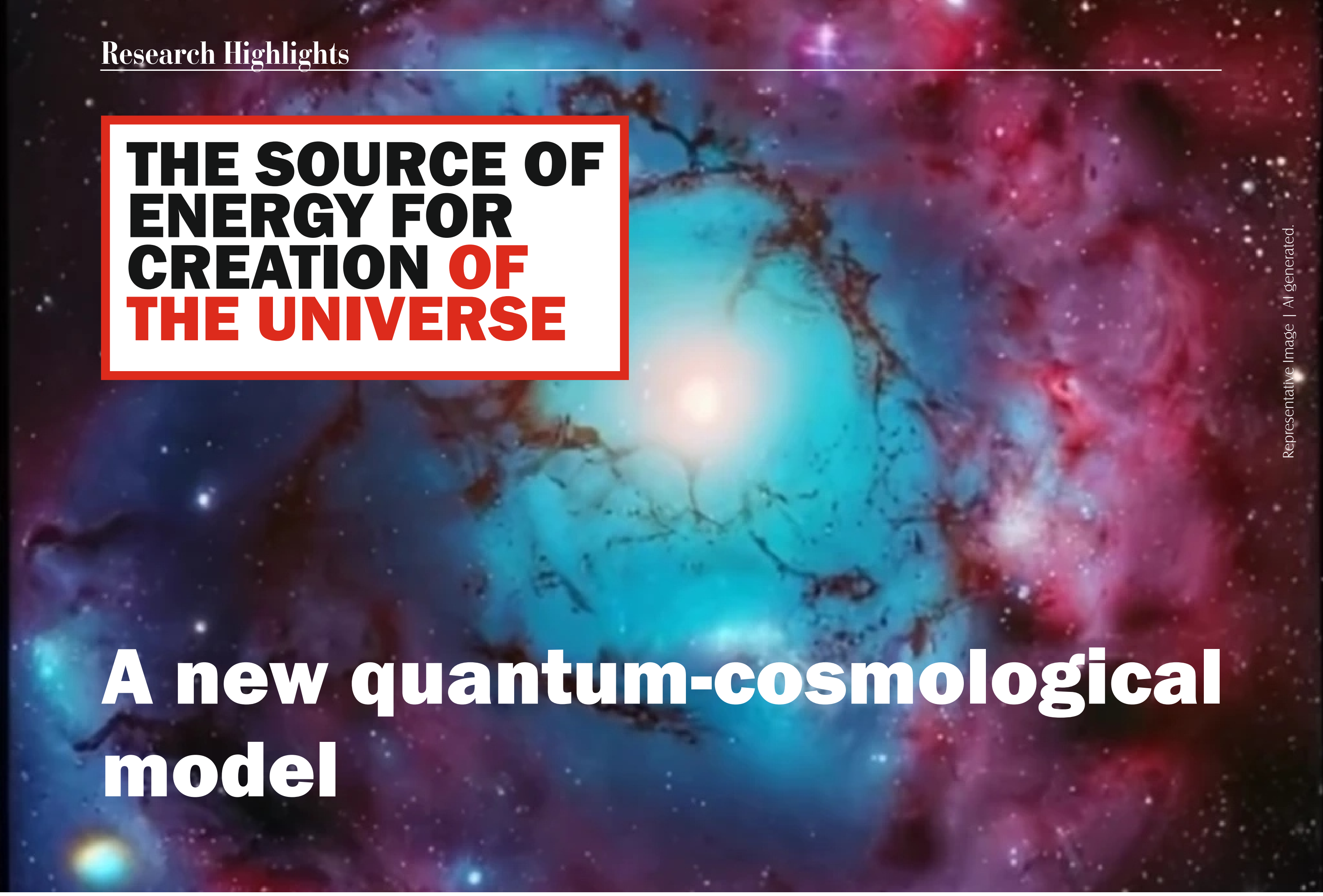

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THE SOURCE OF ENERGY FOR CREATION OF THE UNIVERSE

A new quantum-cosmological model

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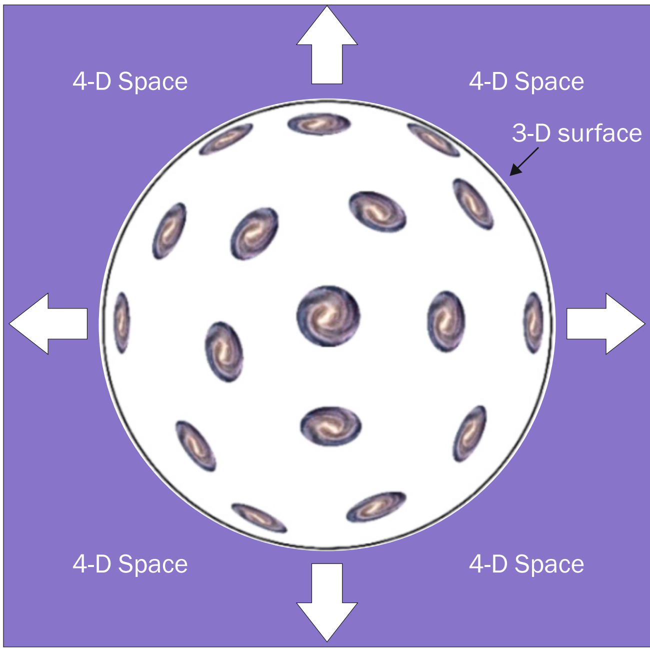
The law of conservation of energy is the most sacred law in the history of science as not a single experiment till date has reported violation of the law. Then, a natural question arises, what was the source of energy for creation of all the matter in the universe? (matter including the dark part is about ~10^{54} kg). As per uncertainty principle, a quantum vacuum fluctuation can at most create energy of ~0.02 mg in a Planck time of ~5.4×10^{-44} s. To solve this problem, it has been proposed that the sum total of energy due to matter/vacuum and gravitational potential energy might be zero. This is possible as the sign of gravitational potential energy is negative, whereas that of other forms is positive. However, a mathematical proof for the zero-energy universe didn't exist yet.

In our recent paper [1] published in Canadian Journal of Physics, by quantizing the zero-point fields existing in the space, we have mathematically proved that the total energy of the universe could be zero right from the beginning of the universe and law of conservation of energy can be satisfied even during creation of the universe. A short description of the model and some additional merits as compared to standard inflationary cosmological model are given below.

To maintain isotropy of space, following the Einstein's model, we consider the universe to lie on the surface of a 3-sphere existing in a four-dimensional (4-D) space. Just like in a 3-D space, surface of a football (2-sphere) is two dimensional and isotropic, in a 4-D space, surface of a 3-sphere is three dimensional and isotropic. Even if our universe is closed, its spatial curvature cannot be detected by us as our space freely expands under gravitation (just as an observer freely falling in a gravitational field cannot detect the curvature of space-time). Since the space of our universe is closed and spherical, circumference must be integer multiple of wavelength of zero-point wave leading to quantization of the zero-point fields. So, counting all possible modes of zero-point field, we calculated the vacuum energy (or dark energy) to be, $u_{vac} = \frac{c^2H^2}{4\pi G} = 5.2 \text{ X } 10^{-10} J/m^3$ which agreed well with the observational data. Thus, we solved the cosmological constant problem in which prediction for vacuum energy in standard cosmological model was ~10^{123} times more than the observed value.

In addition, our new cosmological model theoretically predicts the matter energy density (including dark matter) of the universe to be, $u_{nonvac} = \frac{c^2H^2}{8\pi G} = 2.6 \text{ X } 10^{-10} J/m^3$, which agrees well with the observation. But, modern inflationary cosmological model fails to theoretically predict the matter energy density. In the new model, ratio of dark energy to matter energy comes out to be equal to '2' irrespective of age of the universe. Thus, the new model explains the cosmic coincidence problem which questions why dark energy and matter energy are of the same order at present time. Standard Big-Bang model fails to explain the cosmic coincidence.

In our model, total energy density due to vacuum and matter comes out to be, $u = \frac{3c^2H^2}{8\pi G}$ which is equal to the critical density required to explain the observed flatness of space. Thus, in contrast to conventional cosmological theory, our model doesn't need fine tuning or inflation field having a specific potential energy distribution to prove flatness.



The new quantum-cosmological model

Key highlights

- **Overcomes the cosmological constant problem and cosmic coincidence problem.**
- **Satisfies the law of conservation of energy during creation of universe.**
- **Theoretically predicted dark (or vacuum) energy density,** $u_{vac} = \frac{c^2H^2}{4\pi G} = 5.2 \text{ X } 10^{-10} J/m^3$
- **Theoretically predictedmatter energy density (including dark matter),** $u_{nonvac} = \frac{c^2H^2}{8\pi G} = 2.6 \text{ X } 10^{-10} J/m^3$
- **Explains flatness of space and predicts smallest possible wave length to be,** $\lambda_{min} = l_p\sqrt{\pi/2} \approx 1.25 \text{ X } l_p \approx 2.0 \text{ X } 10^{-35} m$ *where l_p is Planck length*

The mathematical treatment in the new model shows that magnitude of vacuum/matter energy (which is positive) and magnitude of gravitational potential energy (which is negative) can be exactly equal to each other resulting in zero net energy of the universe only if smallest wave length of zero-point field in space is taken to be $\lambda_{min} = l_p\sqrt{\pi/2} \approx 1.25 \text{ X } l_p \approx 2.0 \text{ X } 10^{-35} m$ where l_p is Planck length. This minimum value λ_{min} bears significance in QED, quantum gravity and string theory as it gives an upper limit of momentum of any particle in nature. Thus, the zero-energy universe is mathematically possible and can lead to creation of the universe from empty space without violating law of conservation of energy.

To summarize, our new quantum-cosmological model not only satisfies the law of conservation of energy during creation of the universe but also correctly predicts the dark energy density, matter density and flatness of space.

Acknowledgements

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Reference

[1] Biswaranjan Dikshit, "A new cosmological model based on quantization of the zero-point field", *Canadian Journal of Physics,* 100, 218–225 (2022).

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