Out of the string theory swampland: New models may resolve problem that conflicts with dark energy

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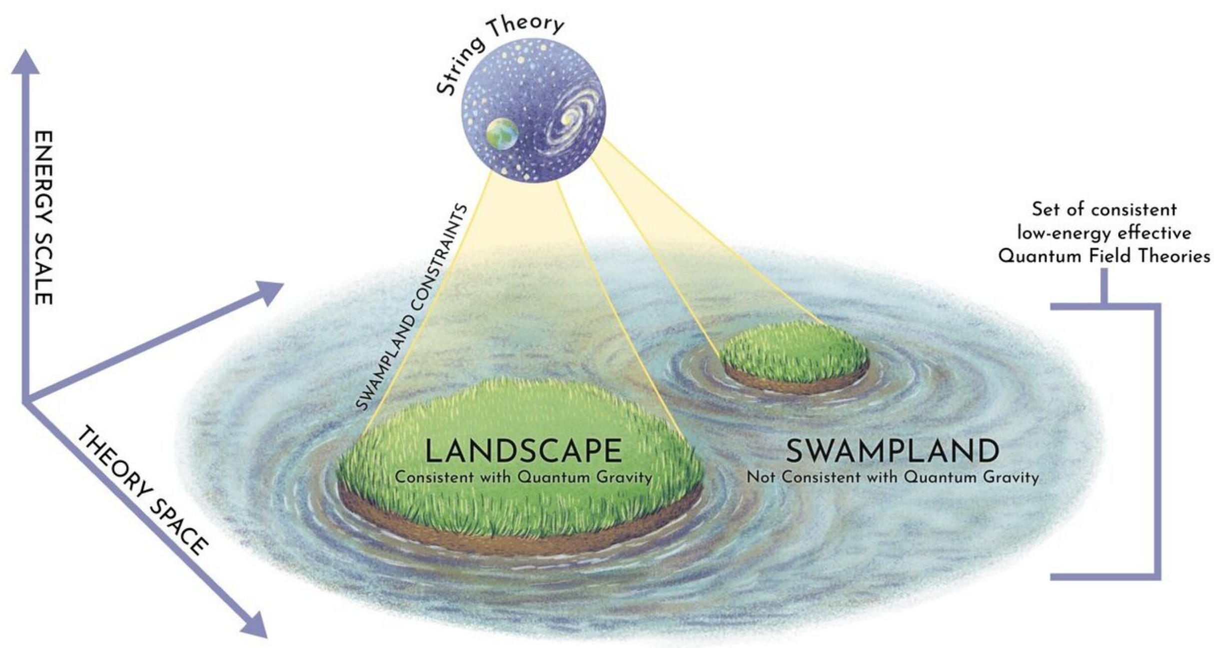

String theory's equations give rise to a near infinite variety of potential universes in a 'landscape.' This landscape is surrounded by a 'swampland' of solutions that are incompatible with any workable theory of quantum gravity. Credit: Created by Haley Grunloh for the Foundational Questions Institute, FQxI FQxI (2025)

String theory has long been touted as physicists' best candidate for describing the fundamental nature of the universe, with elementary particles and forces described as vibrations of tiny threads of energy. But in the early 21st century, it was realized that most of the versions of reality described by string theory's equations cannot match up with observations of our own universe.

In particular, conventional string theory's predictions are incompatible with the observation of dark energy, which appears to be causing our universe's expansion to speed up, and with viable theories of quantum gravity, instead predicting a vast 'swampland' of impossible universes.

Now, a new analysis by FQxI physicist Eduardo Guendelman, of Ben-Gurion University of the Negev, in Israel, shows that an exotic subset of string models—in which the tension of strings is generated dynamically—could provide an escape route out of the string theory swampland.

In the early 2000s, string theorists realized that string theory's equations don't give rise to just one description for the universe, but to a mind-boggling 10^{500} possible solutions, corresponding to a near infinite variety of potential universes. Each of these universes has its own particles and forces, creating what has become known as the 'string theory landscape' of multiple possible cosmoses.

Shortly after, making things even worse, in 2005, it was realized that this landscape is itself surrounded by a so-called "swampland" of solutions–superficially viable-looking quantum field theories that, in fact, turn out to be incompatible with any workable theory of quantum gravity, on closer inspection.

Swampland constraints

To delineate the landscape from the swampland, it was proposed that plausible theories in the landscape must obey certain "swampland constraints." The problem is that when conventional string theories satisfy these constraints, physicists find that they cannot easily reproduce inflation–the short burst of rapid expansion that our early universe is believed to have undergone–or dark energy, which is thought to be accelerating the growth of our universe today.

"The more conventional string theories are very unfriendly to inflation, in particular to 'slow-roll scenarios,' and even to the existence of de Sitter space as a vacuum of the theory–the vacuum of our actual universe–which is the basis not only of inflation, but also of dark energy," says Guendelman, a member of FQxI, the Foundational Questions Institute.

"The swampland constraints are making cosmology impossible or almost impossible for the practical cosmologist because the real universe appears to be firmly in the swampland of the conventional string theory."

Now Guendelman has a new paper published in *The European Physical Journal C*, which shows a certain exotic subset of string theories may be more conducive to describing our real universe compared with its more conventional cousins.

Generating tension

In all string theory models, the strings have some tension; but in most conventional models the value of this tension is a constant that is added in by hand, arbitrarily. Guendelman has been examining models in which this tension arises dynamically, generated by the behavior of the strings in the model.

Guendelman's new paper describes the formulation of such a theory and shows that due to the dynamical nature of the tension, the swampland constraints are greatly weakened. This is because calculations deriving the constraints are related to the size of the so-called "Planck scale"–thought to correspond to the smallest possible size of anything in the universe, including a string.

But because the Planck scale is itself related to the string tension, in these models, the Planck scale itself becomes dynamical, says Guendelman.

"In the regime where the dynamical tension, and therefore also the Planck scale, becomes very big, the constraints become irrelevant or very weak," says Guendelman. "So dynamical tension string theory is friendly to inflation and dark energy."

More information: E. I. Guendelman, Dynamical string tension theories with target space scale invariance SSB and restoration, *The European Physical Journal C* (2025). DOI: 10.1140/epjc/s10052-025-13966-9

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