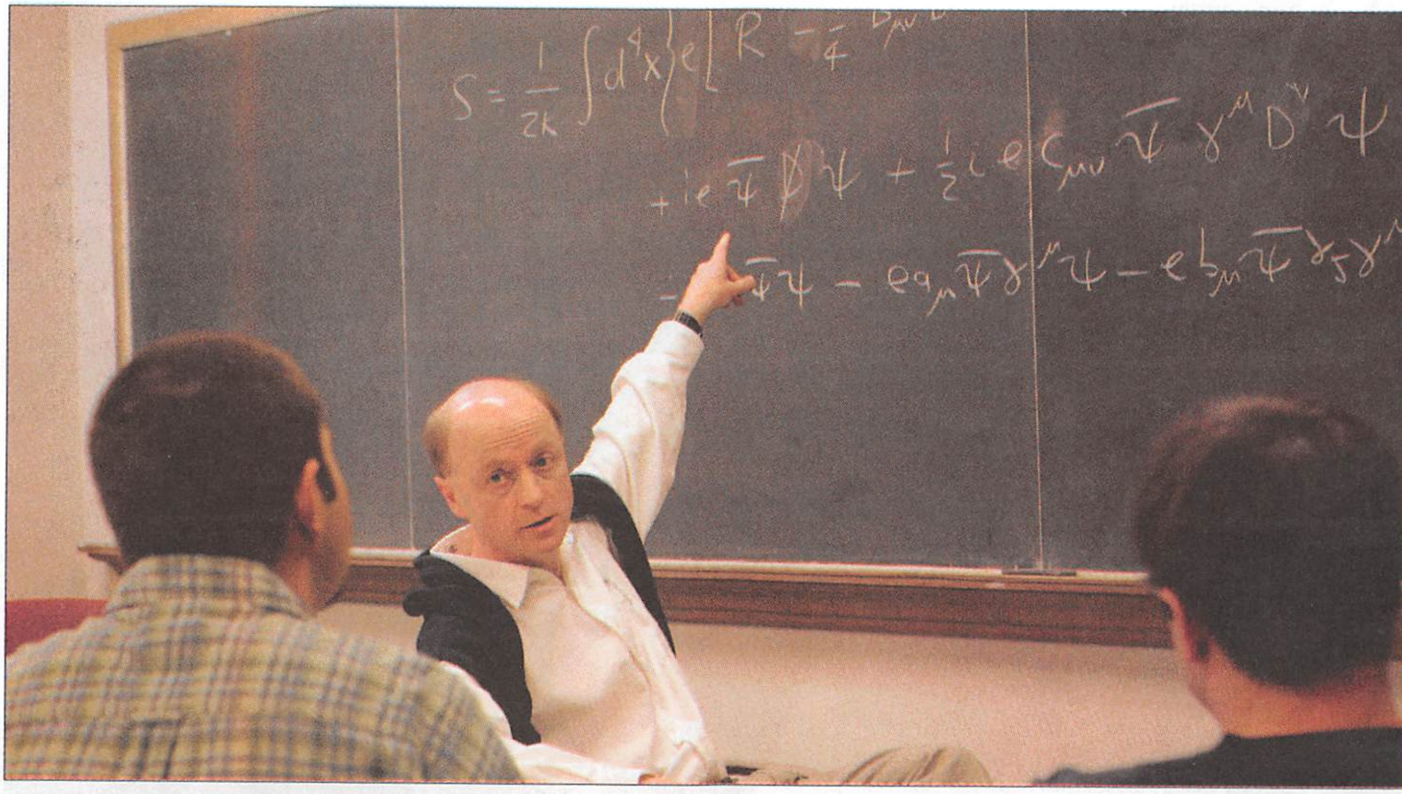

Photo by Chris Meyer

Alan Kostelecky

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'If an apple and an anti-apple were dropped simultaneously from the leaning Tower of Pisa, nobody knows whether they would hit the ground at the same or different times.'

If physics were basketball then physicist Alan Kostelecky is shooting for one of the biggest upsets in the history of modern science.

Kostelecky, with the help of graduate student Jay Tasson, is taking on his field's all-time leading thinker, Albert Einstein, with his proposition that there is a verifiable way for identifying an abnormality in a fundamental building block of Einstein's theory of relativity known as "Lorentz invariance."

If confirmed, the abnormality would disprove the basic tenet that the laws of physics remain the same for any two objects traveling at a constant speed or rotated relative to one another.

Kostelecky took on the long-held notion of the exact symmetry promulgated in Einstein's 1905 theory and showed in a recent publication of **Physical Review Letters** that there may be violations of Lorentz invariance. Even more important, those supposed violations can be detected.

"It is surprising and delightful that comparatively large relativity violations could still be awaiting discovery despite a century of precision testing," said Kostelecky. "Discovering them would be like finding a camel in a haystack instead of a needle."

If the findings help reveal the first evidence of Lorentz violations, it would prove relativity is not exact. Space-time would not look the same in all directions, and there would be measurable relativity violations, however minuscule.

The violations can be understood as preferred directions in empty space-time caused by a mesh-like vacuum of background fields. These would be separate from the entirety of known particles and forces, which are explained by a theory called the Standard Model that includes Einstein's theory of relativity. The background fields are predicted by a generalization of this theory called the Standard Model Extension, developed by Kostelecky to describe all hypothetical relativity violations.

Hard to detect, each background field offers its own universal standard for determining whether or not an object is moving or in which direction it is going. If a field interacts with certain particles, then the behavior of those particles changes and can reveal the relativity violations caused by the field. Gravity distorts the fields, and this produces particle behaviors that can reveal otherwise hidden violations.

The new violations change the gravitational properties of objects depending on their motion and composition. Objects on the Earth are always moving differently in different seasons because the Earth revolves around the sun, so apples could fall faster in some seasons than others. Also, different objects like apples and oranges, may fall differently.

No dedicated experiment has yet sought a seasonal variation of the rate of an object's fall in the Earth's gravity," said Kostelecky. "Since Newton's time over 300 years ago, apples have been assumed to fall at the same rate in the summer and the winter."

Spotting these minute variances is another matter, as the differences in rate of fall would be tiny, because gravity is a weak force. The new paper catalogs possible experiments that could detect the effects. Among them are ones studying gravitational properties of matter on the Earth and in space.

The Standard Model Extension predicts that a particle and an anti-particle would interact differently with the background fields, which means matter and anti-matter would feel gravity differently. So an apple and an anti-apple could fall at different rates, too.

"The gravitational properties of anti-matter remain largely unexplored," said Kostelecky. "If an apple and an anti-apple were dropped simultaneously from the leaning Tower of Pisa, nobody knows whether they would hit the ground at the same or different times."

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(Editor's note: for additional content– www.homepages.indiana.edu)