The Photon:

Spotlight

On Alumnus Max Repaci

The road to success physics style

by Sheldon Smith, Editor

On the ability to think critically, Max Repaci says, "I think that's probably the most valuable asset one can get out of the Physics program - especially if you don't end up doing physics."

Dr. Max Repaci was able to take the liberal arts classes he wanted as part of his physics curriculum

When James Maxwell (Max) Repaci came to the University of Maryland in the fall of 1984, he had visions of earning a degree in electrical engineering. He had considered physics, but decided in favor of electrical engineering, which he felt was "more practical."

"I was a kid, what do you want? I was planning to do engineering until I saw that they basically told you what classes to take, and that was too bad because I really wanted to take some liberal arts classes," he said.

Searching for other options, Repaci looked at the physics program. When he noticed there were only two required classes, he decided to give it a try. He went on to graduate with a double major in Physics and Math. "I ended up doing more than half my credits in liberal arts, so it turned out to be a good decision for me."

"I was here for undergraduate school, and came back for graduate school," Repaci said. "I was working at NASA - at Goddard - while I was doing my undergraduate work, when the guy I was working for asked me if I wanted to do graduate work with him."

Accepting the invitation, Repaci looked forward to being able to remain at Goddard. "Doing my research there would have been like going to another institution. I would have gotten my coursework from Maryland, and [done] my research with NASA."

The Photon: Spotlight

Questioning Relativity

Seeking the limits of Einstein's Theory

Dr. Theodore A. Jacobson
Physics Professor

"So, why is it that nothing can go faster than the speed of light?"

A journalist friend of mine used to ask me that every time he saw me. And every time I felt inadequate, since I couldn't truly answer his question. I cited the facts of special relativity theory, for example, that it would take an infinite energy to accelerate an object beyond the speed of light, but that was, of course, not the kind of answer he was looking for. I tried deeper statements like, "Wouldn't it be even stranger if things could go arbitrarily fast, influencing other things arbitrarily far away arbitrarily rapidly?" That didn't satisfy him either. So, I tried even deeper statements like, "Actually, there is only one speed -- the speed of light -- and everything that appears to be going slower is zigzagging back and forth rather than just going in a straight line." By this point my friend would just grin and shake his head.

Professor Theodore Jacobson is part of the Gravitational Theory group in the Maryland Physics Dept.

Einstein's special relativity theory is a beautiful, tightly knit framework. The speed of light barrier defines the causal structure of spacetime, which distinguishes between "timelike" and "spacelike" displacements. This causal ordering plays a fundamental role in modern physics, and after a century of use, relativity theory has shown no signs of breaking down...except maybe recently.

The relativity of uniform motion, first appreciated by Galileo, is a feature of Newtonian mechanics. It forms one of cornerstones of relativity theory. The symmetry of relativistic physics under transformations to a uniformly moving reference frame is called Lorentz invariance. This symmetry is built into the foundations of today's physics (although in Einstein's theory of gravity, which is general relativity, Lorentz symmetry is relegated to the status of a "local" symmetry on account of the curvature of the spacetime metric.)

So who in their right mind would question relativity? In fact, quite a few people. I attended a (reputable) meeting in August devoted entirely to this subject!

There are several reasons to question relativity, ranging from theoretical to philosophical to observational. Lorentz symmetry theoretically implies that particles of arbitrarily high energy exist. This unbounded energy spectrum produces infinities in quantum field theory. Although we have successful ways of living with those infinities, they nevertheless signify that the theory cannot be truly fundamental.

Another theoretical reason for doubting Lorentz symmetry comes from tentative results in various approaches to quantum gravity -- the unification of general relativity and quantum theory -- which hint that Lorentz symmetry will not survive. Philosophical reasons to doubt exact Lorentz symmetry is that to prove it observationally would require doing the impossible: carrying out observations on particles at arbitrarily high energies. As scientists, why should we assume something that cannot be proven?

In the past couple of years, two pieces of evidence have emerged in the form of puzzling observations involving very high energy cosmic rays hinting that Lorentz symmetry may be violated. I'll mention here just the strongest one.

The highest energy among currently observed cosmic rays is approximately 3 times 10^{20} electron volts -- a billion times higher than the highest collider energies. The problem lies in the presumption that these are protons. Yet, protons of this energy would not survive a trip to earth, since they would absorb cosmic microwave photons and lose energy by producing pions. Physicists have dreamed up several possible explanations of this phenomenon, but they are all quite exotic. One recent reviewer regarded a possible failure of Lorentz violation as the most straightforward explanation!

If all of modern physics is based on relativity, how can we even begin to formulate a clear alternative? Surprisingly, it is not all that difficult. The theory can be "deformed" in a continuous manner, and the deformation can be compared to observations. A convenient way to parameterize the Lorentz symmetry violation is via the relation between energy and momentum for particles. In ordinary relativity, the energy E of a particle of mass m and momentum p is given by

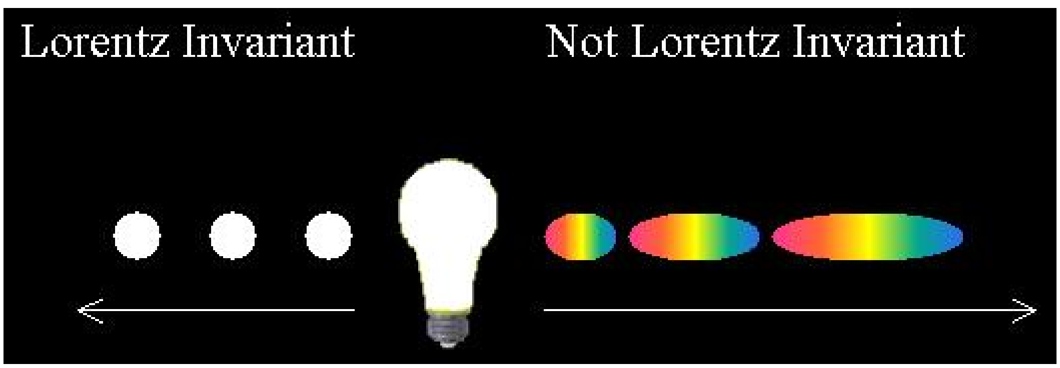
$$E^2 = m^2c^4 + p^2c^2$$

where c is the speed of light. For a particle at rest this reduces to the famous formula $E = mc^2$. A deformation of this might take the form.

$$E^2 = m^2c^4 + p^2c^2 + \eta p^n$$

The constant η parameterizes the amount of Lorentz symmetry violation, and the natural supposition is that it would be of the order of one in Planck units h=c=G=1. The likely exponent n in the extra term is unknown.

Photons -- particles of light -- always travel at speed c in standard physics, independent of their wavelength, or equivalently momentum, which is inversely proportional to their wavelength. If the energy relation is deformed, photons of different wavelengths would travel at different speeds, so a short burst of radiation would separate into component wavelengths as it propagates through empty space, as if the vacuum were a dispersive medium. (See the illustration.) Even if the difference in speeds is tiny, the dispersion would accumulate as the radiation travels cosmological distances across the universe. In this way, observations of the time resolution of gamma ray burst spectra have been used to place limits on the amount of Lorentz symmetry violation.



Physics grad student David Mattingly, postdoc Stefano Liberati, and I have recently been studying observational limits on Lorentz symmetry violation. One of our studies involved deformations of the energy-momentum relations for electrons and photons. In general such modifications allow photons above a certain threshold to decay to electron positron pairs, and they allow electrons above a threshold to emit photons in "vacuum Cerenkov radiation". The threshold at which a pair of photons annihilates and creates an electron positron pair is also modified.

For the case of a cubic deformation n=3, we have shown that current observations limit the allowed two-parameter space to a narrow wedge near. The allowed region seems to include deformations that could potentially explain the cosmic ray puzzle not mentioned explicitly above: an excess of high energy gamma rays from Markarian 501, an active galactic nucleus. Much related work, involving other particles and other deformations, continues around the world today.

So, what about my friend's question? Well first of all if Lorentz symmetry is violated it may be that some particles can go faster than light. This would happen for high momenta if the parameter η in the energy relation is a positive number. However, the region of allowed parameter space in our study includes only negative values. More broadly, if Lorentz symmetry is violated that will mean that there is a preferred rest frame, contrary to what we have all been taught. Presumably this would coincide with the frame defined by the cosmic microwave background radiation, a feature of the global structure of the universe. This would represent such a drastic change of the foundations of physics that it is hard to predict what the ultimate speed limit might or might not be. Perhaps someday we'll know, and my journalist friend will stop teasing me.

Click here for more information on Professor Jacobson.

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But, as fate would have it, funding was cut, and Repaci needed another opportunity, which came to him in the form of the new Center for Superconductivity Research. More inclined toward hands-on, experimental research, he decided to work there under Professor Christopher Lobb.

"I decided to try things out there, and that's where I ended up getting my PhD," he said.

Fondly reflecting on his time at Maryland, Repaci recalled a comment Professor Richard Farrell would make at the beginning of class when calling roll. "He would look at my name and say, 'James Maxwell. Now that's a good name for a physicist.'"

Although physics played a role in landing his first job at NASA, what Repaci does now is not directly related. Since June 1997, Global Science and Technology has employed him in such projects as the Interplanetary Internet, preparing the Air Force Satellite Control Network to use the Internet, and Skipware - a product that enables internet via satellite.

"[Skipware] is actually the first commercial product I've worked on," Repaci said. "We're implementing a [communications protocol] standard a lot of people have worked on for many years - to figure out how to do it right. And, as far as I know, we're the first commercial product that uses that standard."

The rest of his work has been research, for which physics has prepared him well. "The one thing physics gives you that other engineering-type courses don't is a critical approach to problems," he said.

"Instead of saying, 'here is a problem and this is the standard solution that people use to solve this problem,' it's more like, 'Here's a problem, and this is a set of solutions, and you can come up with your own if you can' - I think that's probably the most valuable asset one can get out of the Physics program - especially if you don't end up doing physics. I'm not actually doing physics research."

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