CONTACT: **Jean-Luc Vay**
Phone: 510-486-4934

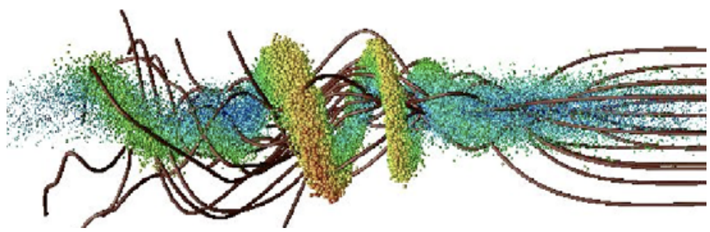
FOR IMMEDIATE RELEASE

Effects of Relativity Lead to "Warp Speed" Computations

An overlooked consequence of Einstein's theory of relativity leads to a spectacular speedup of some computer simulations.

ORLANDO, Florida—A scientist at Lawrence Berkeley National Laboratory has discovered that a previously unnoticed consequence of Einstein's special theory of relativity can speedup computer calculations by orders of magnitude when applied to the computer modeling of a certain class of physical systems. This new finding offers the possibility of tackling some problems in a much shorter time and with far more precision than was possible before, as well as studying some configurations in every detail for the first time.

The basis of Einstein's theory is the principle of relativity, which states that the laws of physics are the same for all observers, whether the "observer" is a turtle "racing" with a rabbit, or a beam of particles moving at near light speed. From the invariance of the laws of physics, one may be tempted to infer that the complexity of a system is independent of the motion of the observer, and consequently, a computer simulation will require the same number of mathematical operations, independently of the reference frame that is used for the calculation.



The image shows a snapshot from a computer simulation of a beam of protons (colored spheres) interacting with a flow of counter-streaming electrons (brown wires). The calculation in a fast moving frame was one thousand times faster than the same calculation in the laboratory frame.

Length contraction and time dilation are well known consequences of the special theory of relativity, which lead to very counterintuitive effects. An alien observing human activity through a telescope in a spaceship traveling in the vicinity of the earth near the speed of light would see everything flattened in the direction of propagation of its spaceship (for him, the earth would have the shape of a pancake), while all motions on earth would appear extremely slow, slowed almost to a standstill. Conversely, a space scientist observing the alien through a telescope based on earth would see a flattened alien at a near standstill in a flattened spaceship. Meanwhile, an astronaut sitting in a spaceship moving at some lower velocity than the alien spaceship with regard to earth might see both the alien spaceship and the earth flattened in the same proportion and the motion unfolding in each of them at the same speed.

Let us now assume that each protagonist (the alien, the space scientist and the astronaut) is to run a computer simulation describing the motion of all of them in a single calculation. In order to model a physical system on a computer, scientists often divide space and time into small chunks. Since the computer must calculate some things for each chunk, having a large system containing numerous small chunks translates to long calculations requiring many computational steps on supercomputers. Let us assume that each protagonist of our intergalactic story uses the space and time slicing as described and chooses to perform the calculation in its own frame of reference. For the alien and the space scientist, the slicing of space and time results in an exceedingly large number of chunks, due to the wide disparity of spatial and time scales needed to describe both their own environment and motion together with the other extremely flattened environment and slowed motion. Since the disparity of scales is reduced for the astronaut, who is traveling at an intermediate velocity, the number of computer operations needed to complete the calculation in his frame of reference will be significantly lower, possibly by many orders of magnitude.

Analogously, the new discovery at Lawrence Berkeley National Laboratory shows that there exists a frame of reference minimizing the number of computational operations needed for studying the interaction of beams of particles or light (lasers) interacting at, or near, light speed with other particles or with surrounding structures. Speedups ranging from ten to a million times or more were predicted, and recently demonstrated, for the modeling of beams interacting with electron clouds, such as those in the upcoming Large Hadron Collider "atom smasher" accelerator at CERN (Switzerland), and for free electron lasers.

The discovery has surprised many physicists and was received initially with much skepticism. It sounded too much like a "free lunch"! Yet, the demonstration of a speedup of a stunning one thousand times in a test simulation of a particle beam interacting with a background of electrons (see image), has proven that the effect is real and can be applied successfully, at least to some problems. Work is being actively pursued at Berkeley Lab and elsewhere to validate the feasibility of the method for a wider range of applications, as well as to apply the already successful method to more problems. One field of special interest to the plasma physics community is the development of tabletop wakefield accelerators, which rely on the complex interaction of a particle or laser beam with a plasma. For this application, the new discovery predicts a speedup of the calculations of more than two orders of magnitude in a moving frame. This would provide significant help toward understanding the complicated processes at play, and give a boost to a field which, if successful, carries the promise of a revolution in accelerator physics.

Contact:

Jean-Luc Vay, Lawrence Berkeley National Laboratory, 510-486-4934, jlvay@lbl.gov

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Noninvariance of Space- and Time-Scale Ranges under a Lorentz Transformation and the Implications for the Study of Relativistic Interactions.

Invited Session YI2: HEDP and Plasma Simulations

11:30 AM–12:00 AM, Friday, November 16, 2007
Orlando Rosen Centre Hotel - Salon 3/4