# Relativistic Quantum Information

## Advanced Seminar Fall 2006
## Course No. P500-006
## Time: Tuesdays: 4:00 - 5:15 p.m.



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The promise and potential of the theoretical and experimental field of quantum information science has its foundations firmly rooted in non-relativistic quantum mechanics. The purpose of this advanced seminar is to explore recent theoretical investigations to extend the concepts of quantum information beyond their non-relativistic origins, to the domain of special and even general relativity.

In non-relativistic quantum mechanics it is possible to write the wave function of a particle as a product of the spatial and spin degrees of freedom. In relativistic quantum mechanics, this separation is not possible in general, and a particle is described by both its spin and momentum degrees of freedom. Under Lorentz transformations, which are momentum dependent, the spin and momentum degrees of freedom of even a single particle can become entangled, leading to a non-zero von-Neumann entropy for the reduced spin density matrix, after momentum degrees of freedom have been traced out. More interestingly, is the effect of the Lorentz transformations on maximally entangled bipartite Bell states, for both spin $\frac{1}{2}$ and spin 1 particles (electron and photons). The recent review article on this subject by D.R. Terno and A. Peres, Rev. Mod. Phys. **76**, 93 (2004), was essentially "out of date" the day it went to press due to all the recent activity in this area.

Going beyond special relativity, there has been much recent interest in the decoherence effects of accelerated motion on entanglement. In flat spacetime, a uniformly accelerated observer's detector will register a thermal flux of particles as it traverses the usual flat (Minkowski) vacuum. This is the flat spacetime version of the famous Hawking effect whereby a stationary observer at fixed coordinates sitting outside a black hole (and therefore undergoing constant acceleration - so as not to fall in) will detect a similar thermal flux of particles, although an observer freely falling into the black hole will not. We will explore both the Unruh and Hawking effect, and its effect on entanglement across horizons. This work also has implications for the black hole information loss paradox and to the generalized second law of black hole entropy. All these topics will be discussed in this seminar.

The format of this class will involve students reading the current, relevant literature on these topics and reporting on them in class. I will provide background lectures on various topics (some basic aspects of quantum field theory, transformations of quantum states under Lorentz transformations, basic aspects of general relativity, black hole thermodynamics, etc. . . ), while encouraging students and outside speakers to present such lectures as well. This will be an interdisciplinary seminar, involving quantum mechanics, quantum information, some quantum field theory and some general relativity (which we will learn as needed). Prerequisites involve only a good grasp of quantum mechanics.

I hope you will attend this seminar on this very active and exciting field. For more information, please feel free to contact the instructor by phone or email.