Winter 2004 Colloquium Series
Physics Department, University of Oregon

3:30 Thursdays, 100 Willamette
(Reception at 3:15 in the Atrium)

January 8	No Colloquium Scheduled
January 15 Eduardo Ponton Theoretical Physics Department, Fermilab	Physics in more than four dimensions The Standard Model of Particle Physics is a remarkably succesful description of physics at subatomic scales. However, we now have information for physics beyond the standard model coming from the observation of neutrino oscillations. In addition, we have strong reasons to expect further new physics associated with the last missing ingredient in the standard model: the Higgs particle. Although mostly theoretical, these arguments imply that we will be able to discover and study this new physics in detail in upcoming collider experiments. One exciting possibility is the existence of extra spatial dimensions at the TeV scale, which leads to striking signatures through the production of Kaluza-Klein particles. I will describe the general properties associated with extra dimensional physics and how they may shed new light on questions ranging from the smallness of neutrino masses to the stabiliy of matter. (Host: Desh)
Tuesday January 20 4PM	The Shear Excitement of Confined Colloidal Suspensions

331 Klamath **Note special day, time, and place!** Itai Cohen Harvard University	Packing constraints play a crucial role in determining the structures formed by a colloidal suspension in thermodynamic equilibrium. However, many technological applications of colloidal suspensions entail application of large strains which drive the suspension out of equilibrium and significantly modify its structure. In such flows, the complex interplay between shear induced stresses and particle packing which leads to structure formation is very poorly understood. To investigate this interplay, we have built a shear cell which can be loaded onto a confocal microscope thus allowing us to image the 3-D microstructure of a dense colloidal suspension when it is subjected to an imposed oscillatory strain. In this talk, I will describe the dramatic restructuring of extremely dense colloidal suspensions subjected to shear and confined to a narrow gap. I will show that confinement forces the suspension to adopt structures that include striking gaps in the particle packing which nevertheless allow the particles to pack more efficiently than those observed in bulk. I will then present a model that accounts for our observations by elucidating the interplay between shear stress, particle packing and geometric confinement that leads to these ordered but highly non-equilibrium structures. (Host: Cohen)
January 22 Graham Kribs Institute for Advanced Study, Princeton	Natural Compositeness Short distance physics is composite. This simple statement has had continual application as the physics of shorter and shorter distances was measured. Many times in history we have been tempted to think we have found the fundamental ingredients, only to later be humbled by the discovery that they too are made up of smaller bits. Particle physics today presumes that a collection of bits -- quarks, leptons, gauge and Higgs bosons -- comprise the fundamental ingredients of our

	observable world. I will discuss how we know this and what clues we have for (and against) further substructure. Finally, I will begin speculating about a Nature that is partly composite (and supersymmetric), why this could solve many puzzles in the Standard Model, and what this means for upcoming collider experiments. (Host: Desh)
January 29 David Rainwater Deutsches Elektronen Synchrotron (DESY)	The Puzzle of Electroweak Symmetry Breaking We observe a short-range force in nature, the weak interaction, which very successfully describes nuclear processes. S-matrix unitarity, however, reveals the theory is incomplete without the existence of an undiscovered spinless particle, the Higgs boson. Using unitarity, I describe the minimal Higgs sector and its basic phenomenology, and a well-known argument why this is actually insufficient. The cure may be supersymmetry, strong dynamics, Little Higgs, or extra dimensions. Each of these solves the minimal Higgs and other Standard Model problems in a different way, and varies with its ease of discovery. (Host: Desh)
February 5 Daniel Steck Los Alamos National Laboratory	Quantum Control in Atom Optics: Present and Future With the recent advances in the field of atom optics, the study of quantum mechanics is entering a truly exciting era. Laser light can now be used to manipulate atoms with an unprecedented degree of control. The present state of the art in quantum control is passive, or "open-loop," quantum control, where light forces atoms into a desired quantum state using a preset sequence of actions. This type of quantum control, while bringing us closer to the realization of quantum

	technologies such as the quantum information processor, has also opened up many possibilities for fundamental studies in quantum mechanics. In particular, I will discuss the application of such quantum control methods to the area of quantum chaos, where precisely prepared atomic wave packets can probe novel phenomena in quantum systems that are chaotic in the classical limit. Yet, in spite of the impressive successes so far, the area of quantum control still has enormous untapped potential. The next step beyond the current paradigm of quantum control lies in active, or "closed-loop," quantum control, where the system is perturbed in response to a continuous measurement process. Specifically, I will discuss cavity quantum electrodynamics, where light additionally provides a real-time measurement of an atom, as one of the most promising avenues for the realization of such quantum feedback control. (Host: Raymer)
February 12 Josh Erlich University of Washington	Einstein's Greatest Blunder: The Problem with Nothing Believing the universe was static, Einstein was forced to introduce a new ingredient into his theory of gravity, the cosmological constant, the energy of the vacuum. We now know that the universe is not static, yet the cosmological constant still haunts us as an apparently necessary ingredient in order to explain various observations. I will explain what we know about gravity and the history of the universe, and why the cosmological constant poses a deep theoretical challenge for particle physics. I will then describe some of the modern approaches towards a resolution of this mystery. (Host: Desh)

February 19	No Colloquium Scheduled
Monday February 23, 4PM **Note special day and time!** Jay A. Gupta IBM Almaden Research Center	Studies of molecular motion using the scanning tunneling microscope The scanning tunneling microscope (STM) can be used to study the motion of atoms or molecules in controlled environments that can be engineered on the atomic scale. As an example, the quantum tunneling of single carbon monoxide molecules can be harnessed for the transmission of one bit across a surface. The mechanism for this information transmission is based on metastable arrangements of molecules called chevrons. In analogy to a row of toppling dominoes, these chevrons can be linked in series to transport information and perform computation on the nanometer scale. Due to the light mass and correspondingly large zero point motion, atomic and molecular hydrogen are often delocalized to some degree on metal surfaces at low temperature. In atomic hydrogen, this delocalization is apparent as hopping between lattice sites via quantum tunneling. Both single H atoms and collections of atoms in troughson (110) surfaces exhibit this kind of motion. Delocalization of adsorbed molecular hydrogen is sufficiently pronounced that individual molecules are not resolved in STM images. Within a range of surface coverage, tunneling spectra reveal prominent nonlinearities that deceptively resemble the quasiparticle excitation spectrum of a Tc>200K BCS superconductor. An additional negative differential resistance feature appears as the STM tip is moved closer to the surface. These nonlinearities are attributed to states of adsorbed H2 that are coupled by discrete excitations which do not readily correspond to any known rotational, vibrational or electronic transition of H2. A model for understanding these nonlinearities is developed by extending the framework for inelastic tunneling spectroscopy to include saturation effects. This model can give information on excited state

	lifetimes and explains a characteristic lineshape. These studies were motivated by the possibility of achieving novel phases of hydrogen when the strength of intermolecular interactions is mediated by surface electronic structure. (Host: Cohen)
February 26 Alexander Lvovsky Universität Konstanz	**License to operate a photon** Although the concept of the light particle has been introduced more than a hundred years ago, it is only now that the technology has reached the level enabling us to generate single photons and experiment with them. I will present a series of experiments which explore various aspects of the electromagnetic field quanta and reveal their potential for quantum information processing. (Host: Raymer)
March 4 JM Geremia Caltech	**Real-Time Quantum Feedback with Cold Atoms** Free from observation, a quantum mechanical system evolves deterministically- its entire evolution can be predicted (at least in principle) from its state at one point in time. However, when a measurement is performed, quantum mechanics postulates that the observer will obtain a random post-measurement outcome. Conveniently, measurement can produce states that are difficult to otherwise obtain. Of course, quantum mechanics does not predict the outcomes of individual experiments, only their likelihood. Therefore using measurement to prepare sought-after quantum states is hindered by non-determinism, and the most desired measurement outcomes are often the least likely. Fortunately, the probabilistic nature of quantum observation does not preclude external intervention. I will describe our recent experiment to

	steer a quantum nondemolition (QND) measurement of spin angular momentum in a cloud of cold atoms toward a fiducial outcome. We have employed real-time feedback to prepare unconditional spin-squeezing and have used the resulting quantum entanglement to perform atomic magnetometry below the standard quantum limit (i.e., the shotnoise limit). (Host: Raymer)
March 11 Raffi Budakian IBM Almaden Research Center	**Towards Single-Spin Detection Using Magnetic Resonance Force Microscopy** We have recently demonstrated spin detection using Magnetic Resonance Force Microscopy (MRFM) with a sensitivity approaching the single-spin level. Achieving this high sensitivity has been possible by overcoming numerous technical challenges as well as developing a detailed understanding of the spin dynamics. In the first part of my talk, I will review the fundamentals of MRFM and discuss the key advances that have enabled us to realize our current detection sensitivity. One of these key advances has been the development of a novel spin manipulation protocol that allows us to detect the sqrt(N) statistical fluctuations in small spin ensembles. Using this technique, we have shown that we can follow the fluctuations in real-time and apply feedback on the spin system to control the time evolution of the spin orientation. Through the use of active feedback, we have demonstrated that spins can be hyperpolarized or cooledin the rotating frame, transferred and stored in the lab frame and then read out at some later time. One potential application of this technique could be for state initialization and readout in quantum computing. In the last part of my talk, I will present our most recent results on our progress towards single-spin imaging and discuss future experiments beyond single-spin detection. (Host: Cohen)

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Eric Torrence