*PRL 111, 100404:* **Nonequilibrium Model of Photon Condensation**
Peter Kirton and Jonathan Keeling
We develop a nonequilibrium model of condensation and lasing of photons in a dye filled microcavity. We examine in detail the nature of the thermalization process induced by absorption and emission of photons by the dye molecules, and investigate when the photons are able to reach a thermal equilibrium Bose-Einstein distribution. At low temperatures, or large cavity losses, the absorption and emission rates are too small to allow the photons to reach thermal equilibrium and the behavior becomes more like that of a conventional laser.

---

*Science 341, 1213*: **From Cosmology to Cold Atoms: Observation of Sakharov Oscillations in a Quenched Atomic Superfluid**
Chen-Lung Hung, Victor Gurarie, and Cheng Chin
Predicting the dynamics of many-body systems far from equilibrium is a challenging theoretical problem. A long-predicted phenomenon in hydrodynamic nonequilibrium systems is the occurrence of Sakharov oscillations, which manifest in the anisotropy of the cosmic microwave background and the large-scale correlations of galaxies. Here, we report the observation of Sakharov oscillations in the density fluctuations of a quenched atomic superfluid through a systematic study in both space and time domains and with tunable interaction strengths. Our work suggests a different approach to the study of nonequilibrium dynamics of quantum many-body systems and the exploration of their analogs in cosmology and astrophysics.

*arXiv:1309.2229*: **Probing macroscopic realism via Ramsey correlations measurements**
A. Asadian, C. Brukner, and P. Rabl
The predictions of quantum mechanics differ in a very fundamental way from those of classical physics or more general realistic (hidden variable) theories, which, for example, is manifested in the violation of Bell- or Leggett-Garg type inequalities or quantum contextuality. These predictions are accurately confirmed on a microscopic level with photons and atoms, but similar tests with more massive systems are still outstanding. Here we describe an experimentally feasible approach for performing such tests, by using a single two level system to probe the motion of a nanomechanical resonator via multiple Ramsey interference measurements. This scheme enables the measurement of modular variables of macroscopic continuous variable systems, and we show that correlations thereof violate a Leggett-Garg inequality or can be applied for tests of quantum contextuality. Our method can be implemented with a variety of different qubit-resonator systems and provides clear experimental signatures to distinguish the predictions of quantum mechanics from those of other alternative theories at a macroscopic scale.

*arXiv:1309.2180*: **Self-protected polariton states in photonic quantum metamaterials**
Matteo Biondi, Sebastian Schmidt, Gianni Blatter, and Hakan E. Türeci
We investigate the single-photon transport properties of a one-dimensional coupled cavity array (CCA) containing a single qubit in its central site by coupling the CCA to two transmission lines supporting propagating bosonic modes with linear dispersion. We find that even in the nominally weak light-matter coupling regime, the transmission through a long array exhibits two ultra-narrow resonances corresponding to long-lived self-protected polaritonic states localized around the site containing the qubit. The lifetime of these states is found to increase exponentially with the number of array sites in sharp distinction to the polaritonic Bloch modes of the cavity array.

*arXiv:1309.2464:* **Fermionic Superradiance in a Transversely Pumped Optical Cavity**
J. Keeling, M. J. Bhaseen, and B. D. Simons
Following the experimental realization of Dicke superradiance in Bose gases coupled to cavity light fields, we investigate the behavior of ultra cold fermions in a transversely pumped cavity. We focus on the equilibrium phase diagram of spinless fermions coupled to a single cavity mode and establish a zero temperature transition to a superradiant state. In contrast to the bosonic case, Pauli blocking leads to lattice commensuration effects that influence self-organization in the cavity light field. This includes a sequence of discontinuous transitions with increasing atomic density and tricritical superradiance. We discuss the implications for experiment.

arXiv:1309.3255: **Dissipative transverse-field Ising model: steady-state correlations and spin squeezing**
Tony E. Lee and Ching-Kit Chan
We study the steady-state properties of the transverse-field Ising model with infinite-range coupling and spontaneous emission on every site. We find that there is spin squeezing in steady state due to the presence of the transverse field. This means that there is still many-body entanglement, despite the decoherence from spontaneous emission. We use a phase-space approach, which involves converting the master equation into a Fokker-Planck equation for the Wigner function. Our calculations are relevant to current experiments with trapped ions.

*arXiv:1309.2808*: **Majorana bound states in two-channel time-reversal-symmetric nanowire systems**
Erikas Gaidamauskas, Jens Paaske, and Karsten Flensberg
We consider time-reversal-symmetric two-channel semiconducting quantum wires proximity coupled to a conventional s-wave superconductor. We analyze the requirements for a non-trivial topological phase, and find that necessary conditions are 1) the absolute value of the interchannel pairing must be larger than the smallest intrachannel pairing amplitude and 2) the channels must have different spin-orbit coupling. For the case of parallel spin-orbit directions in the two channels, we find a general expression for the topological invariant by block diagonalization into two blocks with chiral symmetry only. A projection to the low-energy sector allows us to solve for the zero modes explicitly and to study the details of the gap closing, which in the general case happens at finite momenta.

*arXiv:1309.2651:* **Single-photon nonlinear optics with graphene plasmons**
M. Gullans, D. E. Chang, F. H. L. Koppens, F. J. García de Abajo, and M. D. Lukin
We show theoretically that it is possible to realize significant nonlinear optical interactions at the few photon level in graphene nanostructures. Our approach takes advantage of the electric field enhancement associated with the strong confinement of graphene plasmons and the large intrinsic nonlinearity of graphene. Such a system could provide a powerful platform for quantum nonlinear optical control of light. As an example, we consider an integrated optical device that exploits this large nonlinearity to realize a single photon switch.

*arXiv:1309.2633*: **Enhanced anti-ferromagnetic exchange between magnetic impurities in a superconducting host**
Norman Y. Yao, Leonid I. Glazman, Eugene A. Demler, Mikhail D. Lukin, and Jay D. Sau
It is generally believed that superconductivity only weakly affects the indirect exchange between magnetic impurities. If the distance r between impurities is smaller than than the superconducting coherence length (r < \xi), this exchange is thought to be dominated by RKKY interactions, identical to the those in a normal metallic host. This perception is based upon a perturbative treatment of the exchange interaction. Here, we provide a non-perturbative analysis and demonstrate that the presence of Yu-Shiba-Rusinov bound states induces a strong 1/r^2 anti-ferromagnetic interaction that can dominate over conventional RKKY even at distances significantly smaller than the coherence length. Experimental signatures, implications and applications are discussed.

*arXiv:1309.2308*: **Breakdown of quasi-locality in long-range quantum lattice models**
J. Eisert, M. van den Worm, S. R. Manmana, and M. Kastner
We study the non-equilibrium dynamics of correlations in quantum lattice models in the presence of long-range interactions decaying asymptotically as a power law. For exponents larger than the lattice dimensionality, a Lieb-Robinson-type bound effectively restricts the spreading of correlations to the interior of a causal region, but allows supersonic (faster than linear) propagation. We show here that this decay is not only sufficient but also necessary. Using tools of quantum metrology, for any exponents smaller than the lattice dimension, we construct Hamiltonians giving rise to quantum channels with capacities not restricted to any causal region. An analytical analysis of long-range Ising models illustrates the disappearance of the causal region and the creation of correlations becoming distance-independent. Numerical results obtained using matrix product state methods for the XXZ spin chain reveal the presence of a sound cone for large exponents, and supersonic propagation for small ones. In all models we analyzed the fast spreading of correlations follows a power law, but not the exponential increase of the long-range Lieb-Robinson bound.

*PRL 111, 110504*: **Superconducting Circuits for Quantum Simulation of Dynamical Gauge Fields**
D. Marcos, P. Rabl, E. Rico, and P. Zoller
We describe a superconducting-circuit lattice design for the implementation and simulation of dynamical lattice gauge theories. We illustrate our proposal by analyzing a one-dimensional U(1) quantum-link model, where superconducting qubits play the role of matter fields on the lattice sites and the gauge fields are represented by two coupled microwave resonators on each link between neighboring sites. A detailed analysis of a minimal experimental protocol for probing the physics related to string breaking effects shows that, despite the presence of decoherence in these systems, distinctive phenomena from condensed-matter and high-energy physics can be visualized with state-of-the-art technology in small superconducting-circuit arrays.

*PRL 111, 110501*: **Quantum Information Processing with Hybrid Spin-Photon Qubit Encoding**
S. Carretta, A. Chiesa, F. Troiani, D. Gerace, G. Amoretti, and P. Santini
We introduce a scheme to perform quantum information processing that is based on a hybrid spin- photon qubit encoding. The proposed qubits consist of spin ensembles coherently coupled to microwave photons in coplanar waveguide resonators. The quantum gates are performed solely by shifting the resonance frequencies of the resonators on a nanosecond time scale. An additional cavity containing a Cooper-pair box is exploited as an auxiliary degree of freedom to implement two-qubit gates. The generality of the scheme allows its potential implementation with a wide class of spin systems.