Physics 496
Introduction to Research

Lecture 7.0: How to Read a Paper

Papers are dense descriptions of complicated results

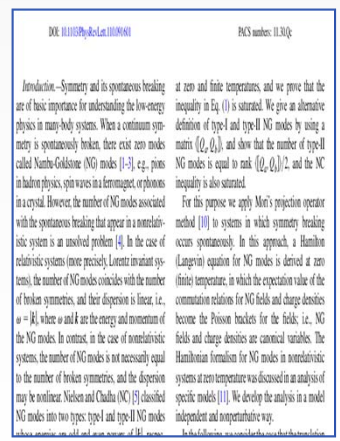
Physical Review Letters has a length limit of 3500 words.

- This corresponds to about 4.5 pages, including title, abstract, and references.

Try describing the work you have spent the last few years doing in so little space!

Other journals have looser rules, but only a few have no length limit at all.

So how do you understand such dense prose?



DOI: 10.1103/PhysRevLett.110.091601 PACS numbers: 11.30.Qc

Introduction.—Symmetry and its spontaneous breaking are of basic importance for understanding the low-energy physics in many-body systems. When a continuum symmetry is spontaneously broken, there exist zero modes called Nambu-Goldstone (NG) modes [1–3], e.g., pions in hadron physics, spin waves in a ferromagnet, or phonons in a crystal. However, the number of NG modes associated with the spontaneous breaking that appear in a nonrelativistic system is an unsolved problem [4]. In the case of relativistic systems (more precisely, Lorentz invariant systems), the number of NG modes coincides with the number of broken symmetries, and their dispersion is linear, i.e., $\omega = |k|$, where ω and k are the energy and momentum of the NG modes. In contrast, in the case of nonrelativistic systems, the number of NG modes is not necessarily equal to the number of broken symmetries, and the dispersion may be nonlinear. Nielsen and Chadha (NC) [5] classified NG modes into two types: type-I and type-II NG modes

at zero and finite temperatures, and we prove that the inequality in Eq. (1) is saturated. We give an alternative definition of type-I and type-II NG modes by using a matrix $\langle[Q_a, Q_b]\rangle$, and show that the number of type-II NG modes is equal to rank $\langle[Q_a, Q_b]\rangle/2$, and the NC inequality is also saturated.

For this purpose we apply Mori's projection operator method [10] to systems in which symmetry breaking occurs spontaneously. In this approach, a Hamilton (Langevin) equation for NG modes is derived at zero (finite) temperature, in which the expectation value of the commutation relations for NG fields and charge densities become the Poisson brackets for the fields; i.e., NG fields and charge densities are canonical variables. The Hamiltonian formalism for NG modes in nonrelativistic systems at zero temperature was discussed in an analysis of specific models [11]. We develop the analysis in a model independent and nonperturbative way.

Start with the abstract

Storage and Control of Optical Photons Using Rydberg Polaritons

We use a microwave field to control the quantum state of optical photons stored in a cold atomic cloud. The photons are stored in highly excited collective states (Rydberg polaritons) enabling both fast qubit rotations and control of photon-photon interactions. Through the collective read-out of these pseudospin rotations it is shown that the microwave field modifies the long-range interactions between polaritons. This technique provides a powerful interface between the microwave and optical domains, with applications in quantum simulations of spin liquids, quantum metrology and quantum networks.

http://dx.doi.org/10.1103/PhysRevLett.110.103001

This is a compact summary of the paper. Now you know what you're in for.

Next, read the introduction

The future success of quantum technologies will depend on the ability to integrate components of different systems. Strongly interacting systems, such as ions [1,2] or superconductors [3] are ideal for processing, large ensembles for memory [4], and optical photons for communication [5]. However, interfacing these components remains a challenge. For example, although cavity QED in the microwave domain, using Rydberg atoms [6] or superconducting circuits [7], provides efficient coupling between photons and static qubits, microwave photons are not ideal for quantum communication due to the blackbody background. For this reason, quantum interfaces that combine different functions of a network are desirable.

Here we demonstrate a system that allows processing of optical photons using microwave fields [8]. We store optical photons in highly excited collective states (Rydberg polaritons) of a cold atomic ensemble using electromagnetically induced transparency (EIT) [9,10]. Because of the strong dipole-dipole interaction between Rydberg excitations only one excitation is allowed within a volume known as the blockade sphere. Consequently, an ensemble smaller than the blockade sphere produces an efficient single photon source [11]. Similarly, Rydberg EIT [12] gives rise to giant optical nonlinearities [13,14] that can be exploited to modify light at the single photon level [15]. Here we exploit Rydberg EIT to write a bounded number of photons into a cold atomic ensemble. Subsequently, we perform quantum state control of the stored photons using a microwave field resonant with a close-lying Rydberg state. We show that the microwave field modifies the long-range interactions between the stored photons providing a key step toward the realization of an all-optical analog of neutral atom quantum gates based on dipole blockade [16,17].

This should provide a motivation for the work (what the authors are trying to do and why) as well as citations to relevant previous work.

If you are new to the subject, these citations are the key to coming up to speed.

Temporarily, skip the bulk of the paper

In conclusion, we have demonstrated control over the quantum state of Rydberg polaritons using a microwave field. By tuning the strength of the microwave field we have shown that the interaction between neighboring polaritons can be varied. This effect was observed in Rabi oscillations of the polariton state, which exhibit a many-body character consistent with $\mathcal{N} = 3$ Rydberg excitations. The ability to control the quantum state of Rydberg polaritons opens some interesting prospects for advances in quantum information and quantum simulation of strongly correlated systems. For example, the competition between resonant energy exchange (hopping) and localisation is reminiscent of the Jaynes-Cummings-Hubbard model [18,30]. In addition, Rydberg polaritons provide a powerful platform for studying strongly coupled atom–light interactions without a cavity, quantum simulation of spin liquids [31], and quantum metrology using Dicke states [29]. The ability to control the interactions between polaritons using microwave fields allows a second blockade scale to be established. This provides a viable route towards fully deterministic photonic phase gates using single photons [15], or to generate nonclassical states of light from classical input fields [32]. It is also an ideal system to study resonant energy transfer [25]. Finally, Rydberg polaritons provide a convenient interface between quantum systems that operate in the microwave and optical domains, such as circuit QED [7] and atomic ensembles, respectively. Rydberg polaritons act as a source of quantum light, that can be coupled to on-chip [33] microwave resonators which in turn interface to solid state qubits [7,8], forming a complete architecture for transmitting, storing and processing quantum information.

The conclusion will summarize all the stuff you skipped.

Sometimes references to previous work appear in the conclusions too (citations to follow).

Now you know what they did and why.

Ready? Clueless? Confused?

Go back and try reading the details and examining the figures.

If you’re confused, follow the references and learn the background material.

Keep following references, and references within references (maybe you can find a review article) and coming back to the paper.

Eventually you’ll get it.

The Moral of the Story is

You can find out what a paper is about from the abstract, intro and conclusions.

Don't expect the paper to be self contained. Use the references to learn the background material.

If you can find a review article, start with that and the references within.