SYHM 1: Higgs Modes in Condensed Matter and Quantum Gases

Time: Wednesday 15:00–17:45 Location: H 0105

Invited Talk SYHM 1.1 Wed 15:00 H 0105

Amplitude or Higgs Modes in Condensed Matter — •Chandra Varma — University of California, Riverside, CA, USA

Spurred by some strange experimental observations in some superconductors, the theory of a new collective mode in superconductors and how it can be experimentally found under certain circumstances was provided in 1981. It was called the "Amplitude Mode" to distinguish it from the "Phase Modes" which provide Josephson effects and which in homogeneous superconductors are coupled to charge fluctuations and are at the energies of the plasmons. More generally, this mode is the amplitude mode of a particle-hole symmetric U(1) field, i.e., the model treated by Higgs and others in the 1960's whose generalizations have played an important role in the standard model of particle physics.

I will tell the story of the above and why such modes were missed in the theory of superconductivity for so long and the applications of the ideas about such modes for cold bosons and fermions in optical lattices and in quantum anti-ferromagnets. I will also comment, as a very interested outsider and an enthusiast, on the Higgs in particle physics being discovered at LHC from the point of view of the theory of superconductivity.

Invited Talk SYHM 1.2 Wed 15:30 H 0105

Higgs Particles for Systems with U(1) Symmetry in Two Dimensions — •Lode Pollet — Arnold Sommerfeld Center, Theoretical Physics, LMU Munich, Germany

We present solid evidence for the existence of a Higgs boson in two-dimensional relativistic field theories based on analytically continued results from quantum Monte Carlo simulations of the Bose-Hubbard model in the vicinity of the superfluid-Mott insulator quantum critical point, featuring emergent particle-hole symmetry and Lorentz-invariance. The Higgs boson, seen as a well-defined low-frequency resonance in the spectral density, is quickly pushed to high energies in the superfluid phase and disappears by merging with the broad secondary peak at the characteristic interaction scale. Simulations of a trapped system of ultra-cold Rb-87 atoms demonstrate that the low-frequency resonance feature is lost for typical experimental parameters, while the characteristic frequency for the onset of strong response is preserved. We compute the universal scaling function and comment on the agreements and disagreements with three dimensions and observations of Higgs particles in more traditional solid state experiments.

Invited Talk SYHM 1.3 Wed 16:00 H 0105

Massive Photons and the Anderson-Higgs Mechanism in Superconductors — •Dirk van der Marel — University of Geneva, Geneva, Switzerland

When we tune the temperature or the pressure of a solid transitions can occur between different states of matter. Usually such a phase transition is accompanied by a symmetry breaking and the emergence of one or several collective modes of the material. A superconducting gap has collective oscillations of its amplitude -equivalent to the Higgs particle- and of its phase. As shown by Anderson in 1958, coupling to the electromagnetic field creates an energy gap in the longitudinal oscillations of the charge density, and in the transverse oscillations of mixed photon-matter character. The energy-momentum dispersion of the latter can be measured experimentally, and reveals the mass acquired by the photons due the coupling to the superconducting order parameter. In certain superconductors two or more condensates coexist. Weak coupling between the condensates gives rise to the so-called Leggett-exciton, and the coupling to the electromagnetic field makes that two or more massive photon-branches coexist. Experimental examples of this will be discussed in this talk.

15 min. break.

Invited Talk SYHM 1.4 Wed 16:45 H 0105

Amplitude Higgs Mode in $2H$-$NbSe_2$ Superconductor — •Marie-Aude Méasson[1], Romain Grasset[1], Yann Gallais[1], Max Cazayous[1], Alain Sacuto[1], Pierre Rodière[2], and Laurent Cario[3] — [1]LMPQ, Universite Paris 7-CNRS, France — [2]Institut Neel, Grenoble, France — [3]IMN, Universite de Nantes, France

When a spontaneous breaking of a continuous symmetry takes place, as happens during a superconducting transition, collective excitations such as the amplitude Higgs mode of the order parameter emerge. The existence of such Higgs mode was proposed in the charge density wave (CDW) superconductor (SC) $2H$-$NbSe_2$, after the first experimental observation by Raman scattering. The Higgs mode could be unraveled via its coupling to the coexisting charge density wave mode. We will address here the questions of the nature of this mode as well as the mechanism of its observability.

We report experimental evidences for the Higgs mode scenario in $2H$-$NbSe_2$ using Raman scattering. By comparing $2H$-$NbSe_2$ and its iso-structural partner $2H$-NbS_2 which shows superconductivity but lacks the charge density wave order and by destroying the coexisting CDW order under high pressure in $2H$-$NbSe_2$, we demonstrate that the superconducting mode owes its spectral weight to the presence of the coexisting charge density wave order. In addition a full spectral weight transfer between both modes operates in $2H$-$NbSe_2$ upon entering the superconducting phase. All these observations are consistent with a superconducting Higgs mode. Intriguing symmetry dependent results under pressure will be discussed.

Invited Talk SYHM 1.5 Wed 17:15 H 0105

The Higgs Mode in Disordered Superconductors Close to a Quantum Phase Transition — •Aviad Frydman[1], Daniel Sherman[1,2], Uwe S. Pracht[2], Boris Gorshunov[2,3], and Martin Dressel[2] — [1]Department of Physics, Bar Ilan University, Ramat Gan, 52900, Israel — [2]Physikalisches Institut, Universität, Stuttgart, 70550 Stuttgart, Germany — [3]Moscow Institute of Physics and Technology, 141700, Dolgoprudny, Moscow Region, Russia

The Higgs theory, which generates mass for elementary particles, was inspired by screening of magnetic fields in superconductors. It is somewhat disappointing that in superconductors, the Higgs-amplitude mode has not yet been observed, partially because it can rapidly decay into unpaired electrons. Nevertheless, recent theories show that if the Higgs mass could be softened below the pairing gap it should be visible in two dimensions. Such conditions can be met by tuning a superconducting film towards a quantum critical point (QCP). We report on spectroscopic studies in the terahertz frequency regime of thin superconducting films for which the superconductor to insulator transition (SIT) is tuned by disorder. Tunneling spectroscopy determines the pairing gap 2Δ which remains finite on both sides of the SIT. In contrast, the threshold frequency for dynamical conductivity, which in BCS theory is associated with the gap, vanishes critically toward the SIT. The excess optical spectral weight below 2Δ is identified as an unambiguous observation of the Higgs mode in a superconductor.