

# NÉEL INSTITUTE Grenoble

## Topic for Master 2 internship and PhD

### Quantum electronic states and collective modes

#### General Scope :

When a spontaneous breaking of a continuous symmetry takes place, for instance when crossing the normal to superconducting transition, collective excitations of the order parameter emerge: in the simplest case of the Mexican hat potential, they are the phase mode and the massive amplitude mode, as illustrated Fig.1. These collective modes are fingerprint of the nature of the quantum orders (such as symmetry of the order parameter), and of their interaction with other electronic orders (magnetism, charge-density-wave). There is growing interest in the search and the study of these fundamental collective modes, some of them being theoretically predicted but remaining elusive to experimental observations. Our purpose is to identify these modes in compounds with different type of quantum states (superconductivity, charge-density-wave, hidden orders...) by electronic Raman spectroscopy and to extract fundamental information on the electronic quantum orders.

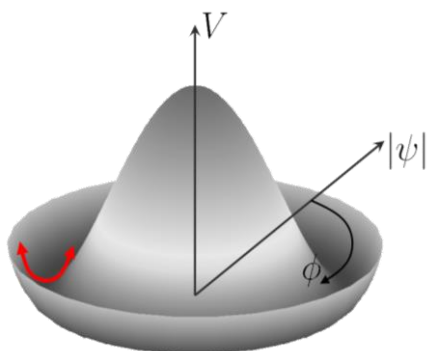


Fig. 1: Mexican-hat-shaped potential of the free energy as a function of the complex order parameter  $|\psi| e^{i\phi}$ . There are two types of fundamental collective mode around the new equilibrium state taken spontaneously in the line of minima. One, the amplitude mode in red, remains elusive to experimental observation. In superconductor, it corresponds to coherent oscillatory pairings and depairings of the Cooper pairs of electrons.

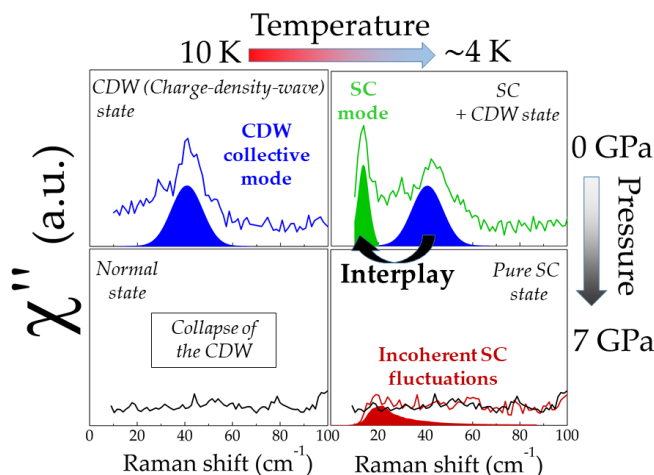


Fig. 2: Raman spectra of 2H-NbSe<sub>2</sub> under high pressure and at low temperature. Pressure-induced concomitant collapse of the superconducting (SC) mode and Charge Density Wave (CDW) state, showing the requisite of the CDW for the observation of this superconducting mode.

#### Research topic and facilities available:

The master student will look for observation of amplitude superconducting mode in family of compounds. He/she will study the mechanism that help to unveil it (Cf. figure 2 for the mechanism in NbSe<sub>2</sub>). The student will perform symmetry dependent electronic Raman scattering experiment under extreme conditions, at low temperature and under high pressure, on a chosen family of superconductors. The PhD project is much broader, contact us for more information.

**Possible collaboration and networking:** close theoretical collaborations (CNR, Roma).

Collaborations with samples' growers (France, Germany, Japan...), high magnetic field facilities (Nijmegen, LNCMI), High pressure labs (Paris), Optics (Germany in the context of an international lab). Networking: ERC project.

**Possible extension as a PhD:** YES. This study will be done in the context of a financed European ERC project.

**Required skills:** knowledge of condensed matter physics, curiosity, taste for delicate experiments.

**Starting date:** 2023

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