*The course of lectures in physics*

S. Brazovski & N. Kirova

CNRS, Orsay, France

**Solitons in correlated electronic systems,
at low dimensions and beyond.**

We review a progress in experiments and theory, elucidating the role of microscopic solitons in quasi one-dimensional electronic systems with a spontaneous symmetry breaking.

Physics of microscopic solitons in electronic processes was boosted in early 80's by experiments on conducting polymers and by theories for charge density waves. Re-entrance of solitons in 2000's is motivated by appearance of new polymers, by discovery of the ferroelectric charge ordering in organic conductor, by new nano-scale tunnelling experiments in charge density wave materials, by direct observations via local probes – the STM and micro-diffraction, by studies in very high magnetic fields. Solitons show up in conductivity, tunnelling spectroscopy, optical absorption, they are seen directly via the STM at atomic scales. They are seen as anomalous carries of the charge without the spin (holons) or of the spin without the charge (spinons). Instantons - the processes of dynamic conversion of normal electrons into solitons - are responsible for subgap transitions leading to a pseudogap formation, to optical and tunnelling features. The solitons' aggregates – domain walls or vortices show up in a ground state reconstruction of junctions, in an evolution under intense optical or electric impacts; their formation may serve as a model for the confinement transition.

The confirmations for solitons call for a search in a broad class of strongly correlated systems at higher dimensions. We preview topologically bound spin- or charge- half-integer roton configurations with charge- or spin- kinks localized in the core. These complex excitations are derived from holons and spinons seen as amplitude solitons in D=1 cases. They can be also viewed as nucleus of the melted stripe phase in doped Mott insulators or of in spin polarized superconductors and charge density waves.

***Schedule*** :

**1. Introduction.**

Realisations of low dimensional correlated electronic systems:

organic crystals, inorganic chain compounds, conducting polymers.

History and geography, major experimental methods, main theoretical concepts.

**2**. **Collective ground states and spontaneous symmetry breaking.**

Interactions: electron- phonon, electron-electron and their combination.

Multiple ground state instabilities. Peierls effect, Charge density wave, Spin density wave, Spin-Peierls state, Charge ordering, Superconductivity.

Band insulator, Mott insulator, and Peierls insulator.

**3. Solitons**.

History introduction: from tsunami to domain walls and microscopic defects.

Exact solutions for solitons and their lattices.

Spin-charge decoupling.

Solitonic lattices; Peierls and spin-Peierls effect in magnetic field.

**4. Discrete symmetry breaking - spontaneous dimerization.**

Polyacethylene old and new: dimerized ground state, spin and charge solitons, polarons, excitons. Optics: direct and photoinduced; solitons manifestation.

Solitons’ confinement, bipolarons, excitons,

Ferroelectric (AB)x polymers. Non-integer charges.

**5. Conducting organic crystals.**

Main (quai-1D and quasi-2D families of organic metals).

Firework of spontaneous phases: Charge and Spin Density Waves, Spin-Peierls state, Superconductivity, Charge ordering (Wigner crystallization) , Ferroelectricity, High Magnetic Field phases.

Charge Ordering and electronic Ferroelectricity in organic metals.

A workshop on solitons.

**6. Continuous symmetry breaking: Charge Density Waves and superconductors.**

The common instability towards incommensurate charge waves.

Sliding and gigantic dielectric response.

Conversion of electrons and plastic flows.

Topological defects: solitons and dislocations.

Macroscopic and microscopic identification of intrinsic defects via space- resolved X-ray diffraction, coherent microdiffraction, STM.

**7. Instantons**

Dynamic processes for transformation of electrons into solitons.

Various symmetries: airs of kinks, complex amplitude-phase instanton, phase slips.

**8. Dynamical patterns of electronic phase transitions induced by ultrafast optical pumping.**