



# Cours de physique théorique

agrée par l'École doctorale de physique en Île-de-France – ED PIF

## *Quantum entanglement in condensed matter systems*

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*Les vendredis 22 et 29 mai, 5 et 12 juin 2015 à 10h*

Quantum entanglement has become a central subject of research in the field of quantum many-body physics. In the last ten years, concepts of quantum information theory have found conceptual and practical applications to condensed-matter problems, from lattice spin models to the fractional quantum Hall effect.

In particular, an important discovery is that the low-energy states of short-ranged Hamiltonians are much less entangled than states picked at random in the Hilbert space, or than highly excited eigenstate of the same Hamiltonians. This is known as the area law (or boundary law): the entropy of a large subsystem scales like its surface, whereas an extensive thermal entropy would scale like the volume and therefore grow much faster as a function of the size. The entanglement entropy then encodes many important low-energy and long-distance physical properties of many-body systems, such as long-range order, spontaneous symmetry breaking, algebraic correlations, and the nature of elementary excitations.

These lectures will start by introducing some basic definitions and concepts:

- the reduced density matrix,
- the Schmidt decomposition,
- the Von-Neumann and Rényi entropies,
- the boundary law.

Then, we will describe and explain a selection of key ideas and results in the field:

- entanglement in free fermion systems and Fermi seas,
- logarithmic divergence of the entanglement entropy in critical 1d systems,
- matrix-product states,
- bulk-edge correspondence and the entanglement spectrum in 2d,
- the topological entanglement entropy.

**Lieu:** IPhT, CEA Saclay, Orme des Merisiers, Bât. 774, porte 1A Salle C. Itzykson

**Accès:** Navettes CEA du RER B Le Guichet vers CEA Ormes, toutes les 15 minutes de 8h à 9h45  
ou bus publics Mobicaps 9 et 10, Albatrans 91.06 et 91.10

**Renseignements:** <http://iph.t.cea.fr> ou [iph.t-lectures@cea.fr](mailto:iph.t-lectures@cea.fr)