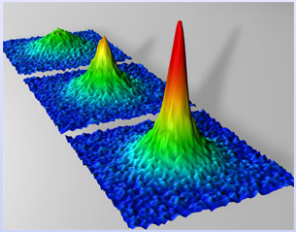
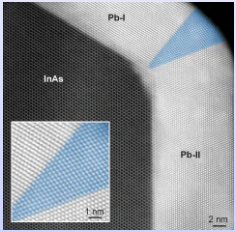
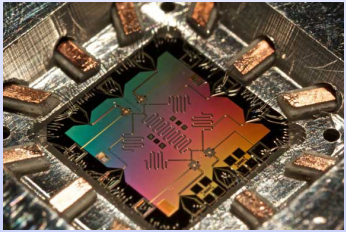
Condensed matter physics

Center for Quantum Devices





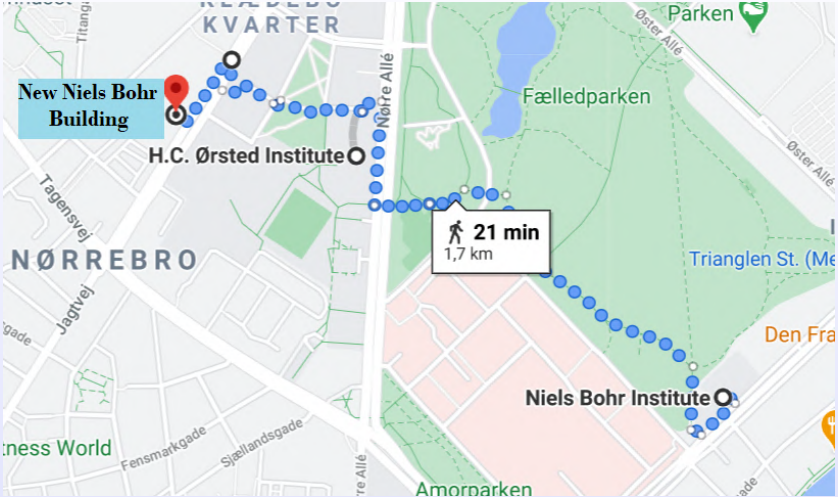


Michele Burrello
michele.burrello@nbi.ku.dk

Berislav Buca
berislav.buca@physics.ox.ac.uk

Condensed Matter Theory and QDEV

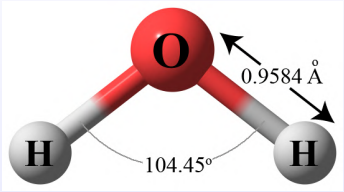
Where are we?



More is different!

P. Anderson

The challenge of many-body physics is to master the complexity of thermodynamic systems and describe their emergent properties.



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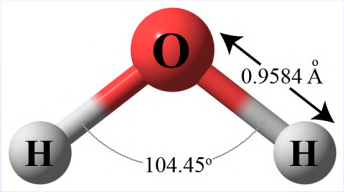

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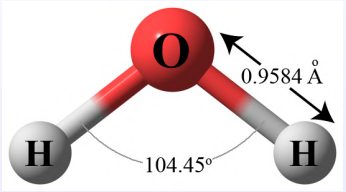

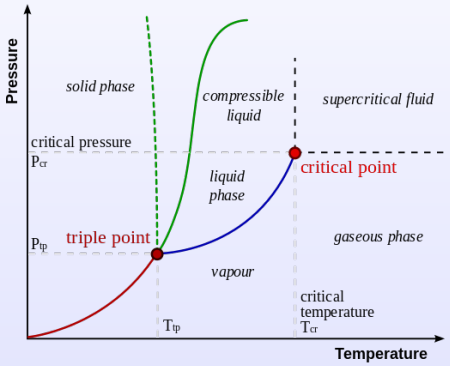

Let’s discuss about energies

From High Energy....

... to Low Temperatures

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- Free kick (vs ENG) by Damsgaard:
  $\sim 10^{21}$ eV $\sim 1.2 \times 10^{25}$K

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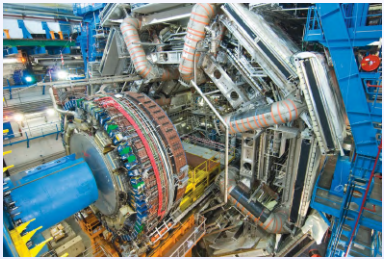

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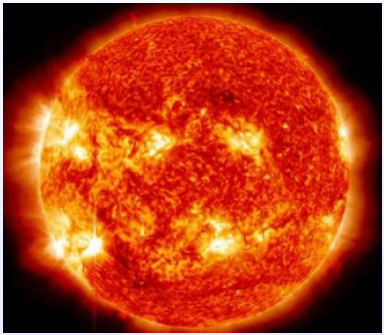

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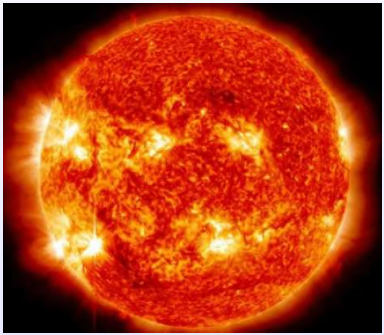

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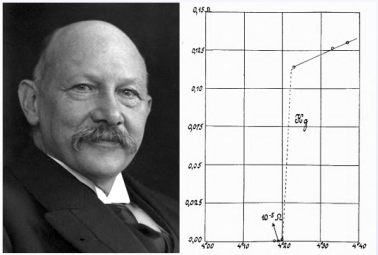

Kamerlingh Onnes 1911

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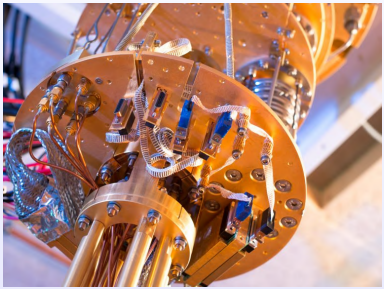

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- Ultracold atoms: 10^{-8}K

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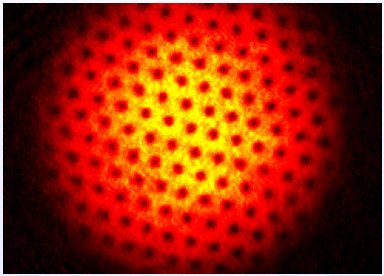
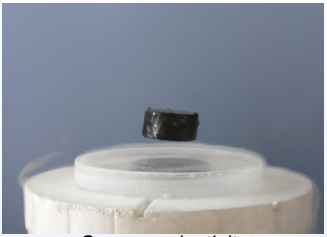


Quantum world at low temperature



Superconductivity

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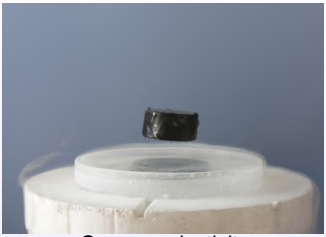

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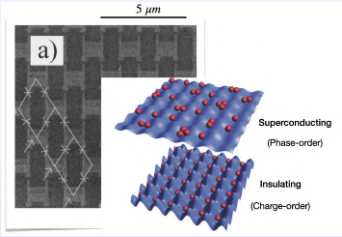
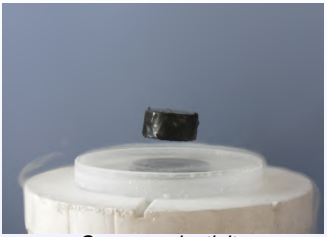


Superconductor-Insulator phase transition in Josephson Junctions array

Quantum world at low temperature



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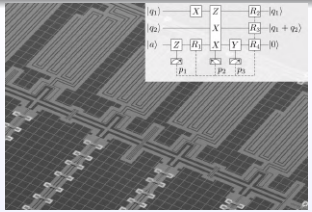
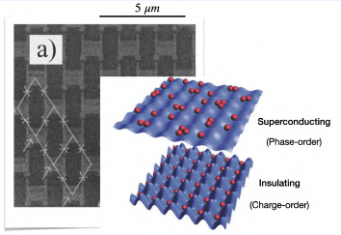


Quantum simulations



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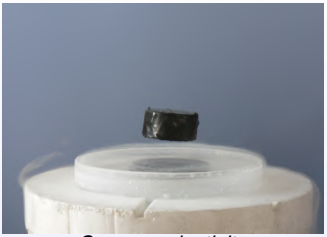

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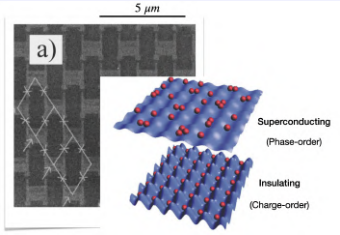

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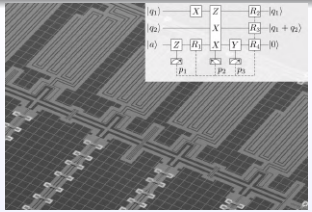

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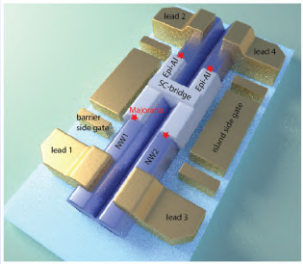
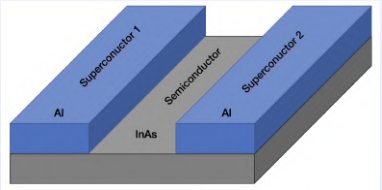


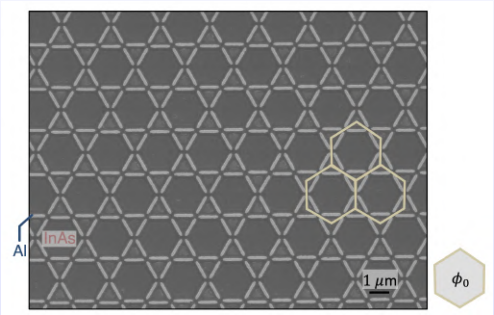
Topological Phases of Matter
Majorana devices @ QDEV

Josephson Junctions array in planar geometries

- Superconducting islands connected by Josephson Junctions
- Quantum engineering of effective Hamiltonians
- Possibility of studying a variety of physical phenomena such as phase transitions, frustration and vortex dynamics



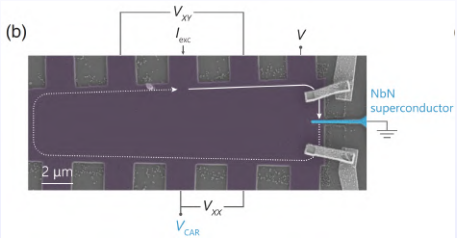
Josephson Junction



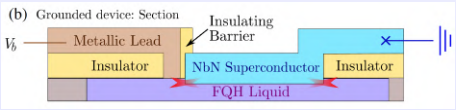
Kagome lattice of Josephson Junctions

Topological phases of matter

Fractional quantum Hall:



Robustness against local perturbations



Topologically protected quasiparticles

Topological phases of matter

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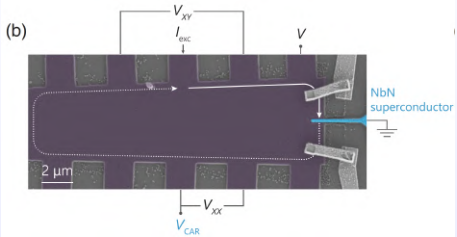

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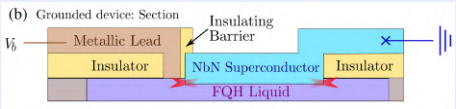

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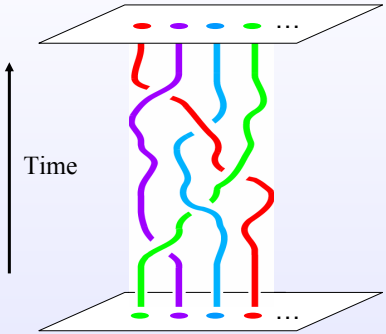


Quasiparticles with fractional charges and anyonic statistics

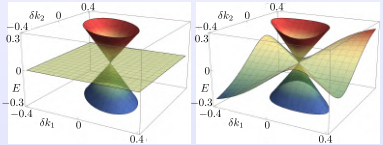
Methods and techniques

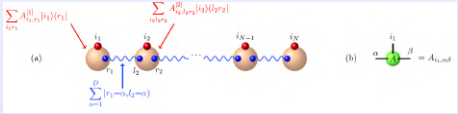
Analytical methods:

- Advanced quantum mechanics
- Quantum field theories
- Feynman path integral
- Gauge theories
- ...

Numerical methods:

- Exact diagonalization
- DMRG and tensor networks
- Machine learning
- ...





Condensed matter courses

IV year

- **Block 2:**
  - Condensed matter physics 2 (Course, 7.5 ECTS)
    Karsten Flensberg
  - Condensed matter theory 1 (Course, 7.5 ECTS)
    Brian Andersen

- **Block 3:**
  Condensed matter theory 2 (Course, 7.5 ECTS)
  Jens Paaske

- **Block 4:**
  Advanced condensed matter theory (**PUK: Study Project**, 7.5 ECTS)
  Michele Burrello
  Visit: https://absalon.instructure.com/courses/63923
  Enroll: https://absalon.instructure.com/enroll/AHD8JC (Enroll beginning of block 3)

CMT @ NBIA

see also nbi.ku.dk/english/research/condensed-matter-physics/condensed-matter-theory/

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Berislav Buca

berislav.buca@physics.ox.ac.uk

Other CMT professors:

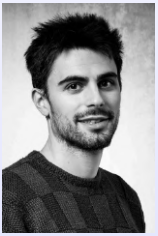
Jens Paaske
Karsten Flensberg
Brian Andersen
Per Hedegård
Constantin Schrade
Andreas Kreisel
Evert van Nieuwenburg

NBIA CMT juniors

Matteo Wauters

Morten Christensen

Ida Nielsen



Lorenzo Maffi