Quantum thermodynamics

The project aims at studying quantum thermal machines with systems of indistinguishable particles which show the strongest quantum features, due to quantum statistics and observable in degenerate quantum gases, namely at low temperatures. The grandcanonical ensemble better captures the role of quantum statistics, and genuine quantum phases as Bose-Einstein condensation or in strongly interacting systems not considered in quantum cycles using the canonical ensemble. Moreover, the grandcanonical ensemble enriches the spectrum of thermodynamic processes as resources for thermal machines, including isochemical potential transformations which are basic ingredients for thermodynamic open systems.

New states of matter, experimentally realised but not yet considered in the framework of thermodynamic transformations, are Bose-Einstein condensation in many modes. Examples are low dimensional BEC occurring in highly anisotropic confinements when excited states lying in the less confined directions are macroscopically occupied [1, 2, 3]. Further systems not yet fully studied as quantum thermal machines are mean-field and weakly interacting Bose gases that describe Bose-Einstein condensates [4, 5]. This project also has applications in metastable systems out of equilibrium, e.g. magnons in magnetic systems [6] and exciton-polaritons in semiconductors [7, 8]. Despite being out of equilibrium, these systems are effectively described by equilibrium quantum degenerate gases of quasi-particles, featuring Bose-Einstein consendation even at room temperature.

Supervisior: Ugo Marzolino (ugo.marzolino@ts.infn.it)

References

[1] Ketterle, W. & van Druten, N. J. Bose-einstein condensation of a finite number of particles trapped in one or three dimensions. *Phys. Rev. A* **54**, 656 (1996).

[2] Beau, M. & Zagrebnov, V. A. Generalized boseâĂŞeinstein condensation. *Condens. Matter Phys.* **13**, 23003 (2010).

[3] Mullin, W. J. & Sakhel, A. R. Generalized boseâĂŞeinstein condensation. *J. Low Temp. Phys.* **166**, 125 (2012).

[4] Zagrebnov, V. A. & Bru, J.-B. The bogoliubov model of weakly imperfect bose gas. *Phys. Rep.* **350**, 291 (2001).

[5] Andersen, J. O. Theory of the weakly interacting bose gas. *Rev. Mod. Phys.* **76**, 599 (2004).

[6] Safonov, V. L. *Nonequilibrium Magnons* (Wiley-VCH Verlag GmbH, 2013).

[7] Deng, H., Haug, H. & Yamamoto, Y. Exciton-polariton bose-einstein condensation. *Rev. Mod. Phys.* **82**, 1489 (2010).

[8] Carusotto, I. & Ciuti, C. Quantum fluids of light. *Rev. Mod. Phys.* **85**, 299 (2013).