Observation of the roton mode in a dipolar quantum gas

L. Chomaz[1], D. Petter[1], S. Baier[1], J. H. Becher[1], G. Faraoni[1], G. Natale[1], A. Patscheider[1], M. J. Mark[1,2] and F. Ferlaino[1,2]
[1] *Institut for Experimental physics, University of Innsbruck, 6020 Innsbruck.*
[2] *IQOQI, Austrian Academy of Sciences, Innsbruck.*
E-mail: `lauriane.chomaz@uibk.ac.at`

In my poster, I will present our experimental observation of the roton mode in a dipolar BEC of strongly magnetic erbium atoms. The roton mode denotes an elementary excitation of minimal energy at finite momentum. It links to the celebrated case of superfluid helium, He II, for which the roton mode was an essential key, brought by Lev Landau in the early 1940's, to understand the mysterious behavior of the quantum fluid [1]. It was then related by Richard Feynman to the strong correlations, resulting from the strong interactions occurring in the liquid. The roton mode in a dipolar BEC also arises from the interparticle interactions but, in contrast to He II, it does not require strong interactions. It arises from the long-range and anisotropic nature of the dipolar interactions, already at a mean-field level. First predicted in 2003 [2], it has remained elusive to observation. To investigate the roton mode in our experiment, we first performed an interaction quench on an elongated BEC of ^{166}Er atoms and observed the apparition of symmetric side peaks in the momentum distribution of the atomic cloud, when quenched below a threshold scattering length. We probed the scaling of the momentum and the imaginary energy of the roton mode via a detailed study of the measured density distribution and a comparison with theory predictions from both an analytical model and extensive numerical simulations [3]. I will also present new results on our investigation of the roton mode in the stationary dispersion relation of our dipolar BEC, that is for real and finite energy of the roton mode. We probe this regime in our experiment thanks to precise Bragg spectroscopy measurements.

[1] L. D. Landau, The theory of superfluidity of helium II *J. Phys. (Moscow)* **5**, 71 (1941).

[2] L. Santos, G. V. Shlyapnikov, & M. Lewenstein, Roton-maxon spectrum and stability of trapped dipolar Bose-Einstein condensates. *Phys. Rev. Lett.* **90**, 250403 (2003).

[3] L. Chomaz, R. M. W. van Bijnen, D. Petter, G. Faraoni, S. Baier, J. H. Becher, M. J. Mark, F. Wächtler, L. Santos & F. Ferlaino, Observation of roton mode population in a dipolar quantum gas. *Nature physics*, **14**, 442 (2018).