

A purely dipolar quantum gas

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In usual experiments with BECs, the only relevant interaction is the isotropic and short-range contact interaction, which is described by a single parameter, the scattering length a . In contrast, the dipole–dipole interaction between particles possessing an electric or magnetic dipole moment is of long range character and anisotropic, which gives rise to new phenomena ¹.

Most prominently, the stability of a dipolar BEC depends not only on the value of the scattering length a , but also strongly on the geometry of the external trapping potential. Here, we report on the experimental investigation of the stability of a dipolar BEC of ⁵²Cr as a function of the scattering length and the trap aspect ratio. We find good agreement with a universal stability threshold arising from a simple theoretical model. Using a pancake-shaped trap with the dipoles oriented along the short axis of the trap, we are able to tune the scattering length to zero, stabilizing a purely dipolar quantum gas ².

We also experimentally investigated the collapse dynamics of a dipolar condensate of ⁵²Cr atoms when the s-wave scattering length characterizing the contact interaction is reduced below a critical value. A complex dynamics, involving an anisotropic, d-wave symmetric explosion of the condensate, was observed on time scales significantly shorter than the trap period. At the same time, the condensate atom number decreases abruptly during the collapse. We compare our experimental results with numerical simulations of the three-dimensional Gross-Pitaevskii equation, including the contact and dipolar interactions as well as three-body losses (see Fig.1). The simulations indicate that the collapse is accompanied by the formation of two vortex rings with opposite circulations.³

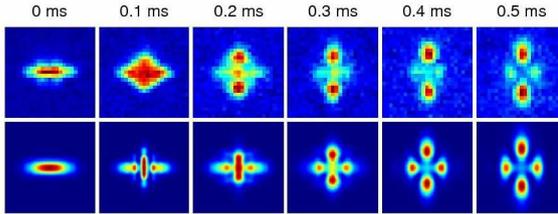


Figure 1: *Dipolar collapse dynamics for different hold times in the trap. Upper line: experiment, lower line: theory.*

¹Th. Lahaye, T. Koch, B. Fröhlich, M. Fattori, J. Metz, A. Griesmaier, S. Giovanazzi, T. Pfau "Strong dipolar effects in a quantum ferrofluid" *Nature* **448**, 672 (2007) and references therein.

²T. Koch, Th. Lahaye, J. Metz, B. Fröhlich, A. Griesmaier, T. Pfau "Stabilizing a purely dipolar quantum gas against collapse", *Nature Physics* **4**, 218 (2008)

³Th. Lahaye, J. Metz, B. Fröhlich, T. Koch, M. Meister, A. Griesmaier, T. Pfau, H. Saito, Y. Kawaguchi, M. Ueda "d-wave collapse and explosion of a dipolar Bose-Einstein condensate" *cond-mat arXiv:0803.2442* (2008)