Stability and dynamics of spinor Bose-Einstein condensates

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The spin degree of freedom of spinor Bose-Einstein condensates (SBECs) leads to a wealth of new phenomena not possessed by single-component “spin-frozen” condensates. The quest to understand the properties of these multi-component matter waves has attracted theorists and experimentalists alike, however there are still fundamental questions to be answered. We have sought to answer three of these key questions: what are the properties of an SBEC in a weak homogeneous magnetic field? What is the relationship between excitations and the speed of sound in a SBEC? How does the spin degree of freedom affect matter wave dynamics in a double well? The results in each of these areas are described in turn.

1. **Excited spin states and phase separation in spinor Bose-Einstein condensates** [1]. We have shown recently that a homogeneous antiferromagnetic SBEC in the presence of a weak homogeneous magnetic field may be unstable and develop spin domains in evolution [2] however this prompted the question, what is the ground state in this case? We have found that in the presence of a weak magnetic field the ground state of an antiferromagentic condensate displays spin domains, with the relative extent and spin populations fixed by the magnetization of the condensate and the strength of the magnetic field. In the presence of a spatially varying magnetic field (such as a harmonic trap) these spin domains persist, with the $m_f = 0$ spin component occupying the centre of the trap (see Fig. 1). These results open up the possibility of the experimental observation of spin domain formation in trapped antiferromagnetic condensates.

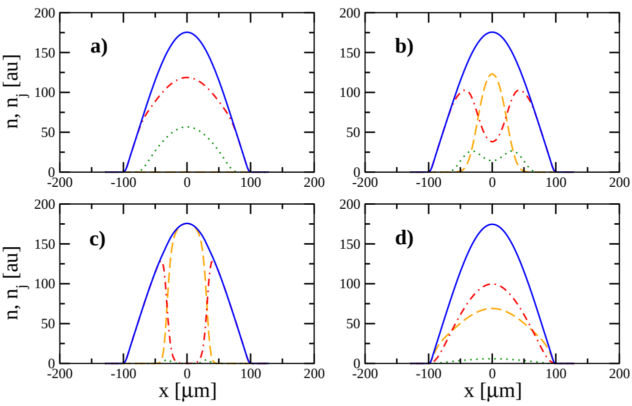

Fig. 1: Ground state profiles in a harmonic trap potential. Phase separation occurs in the polar ^{23}Na condensate when the magnetic field strength is increased from (a) $B = 0.1$ G to (b) $B = 0.12$ G and (c) $B = 0.25$ G. For comparison, the ground state of a ^{87}Rb condensate is shown in (d) for $B = 0.2$ G. The $m_f = +1, 0, -1$ components are depicted by dash-dotted, dashed, and dotted lines, respectively. The solid lines show the total density.

2. **Spinor Bose-Einstein condensate flow past an obstacle** [3]. We examined the problem of a defect moving through a SBEC above and below the speed of sound. We found that there are two speeds of sound in a three-component SBEC, however only one of these appears to be important. We found that exceeding this speed of sound dark or vortex solitons are generated. The effect of the second speed of sound is still an open question.

3. **Spinor Bose-Einstein condensates in double-well potentials** [4]. We characterised completely the possible stationary solutions and their stability for an SBEC in a double well potential. We discovered new asymmetric double-well states and demonstrated the existence of periodic spin oscillations, all made possible by the parametric spin interaction.

References

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