Exploring superfluid ^{3}He universe with coherent bosons

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Bose-Einstein condensation of quasiparticles brings new macroscopic quantum systems to laboratory. In such systems quasiparticles are externally pumped, but are sufficiently long-lived to form a coherent state. This talk presents an overview of recent findings made using BEC of quantized spin waves (magnons) in superfluid ^{3}He. Experimentally such condensates are manifested via coherently precessing magnetization. Free precession breaks continuous time-translation symmetry and the magnon BEC is identified as a time crystal.[1] The discrete time-translation symmetry under pumping is also broken in incommensurate way, providing the first realization of time quasicrystals. Since magnon condensates possess spin superfluidity, they can be called time supersolids. Moreover, the magnon BEC in ^{3}He-B is the first experimental demonstration of a Q-ball[2] – self-bound bosonic object from high-energy physics. Q-balls were speculatively used to explain e.g. baryogenesis and dark matter. Now they have been observed moving and interacting in a ^{3}He-B sample at temperatures below 200 μK.
Magnon BEC and its Nambu-Goldstone (NG) mode, which is a phonon originating from breaking of time-translation symmetry in a time crystal, are also found[3] in the polar phase of ^{3}He. By tilt of magnetic field, one can tune velocity of the NG bosons down to a complete stop.[4] This gives a possibility to simulate experimentally a black-hole horizon. These new features build on long coherence times, which have turned magnon condensates into ultra-sensitive probes of relaxation sources in studies of topological objects and various bosonic and fermionic excitations in topological superfluid ^{3}He.

[1]Autti et al, PRL **120**, 215301 (2018).
[2]Autti et al, PRB **97**, 014518 (2018).
[3]Autti et al, PRL in print (2018), arXiv:1711.02915.
[4]Nissinen & Volovik, JETP Lett. **106**, 234 (2017).

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