Shell-shaped Bose-Einstein condensates realized with dual-species mixtures

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BEC2021, September 15th, 2021

Team

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Shell-shaped BECs based on rf dressing

Idea

Generate bubble potentials by combining magnetic traps with rf fields to realize quasi 2D topologies in 3D.

Zobay & Garraway, PRL 86, 1195 (2001)

Lundblad et al., npj Microgravity 5, 1 (2019)

+ lots of theory studies (especially since 2018)

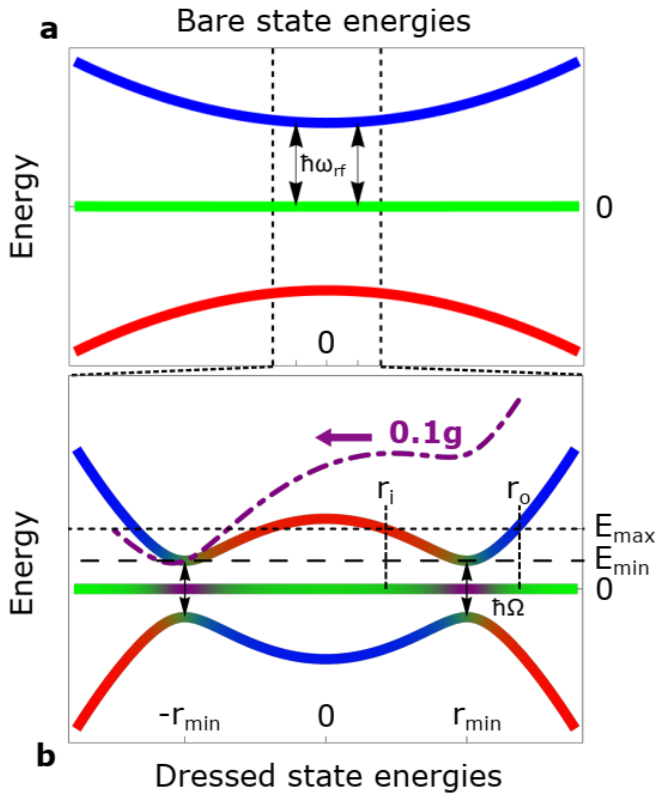
Challenge

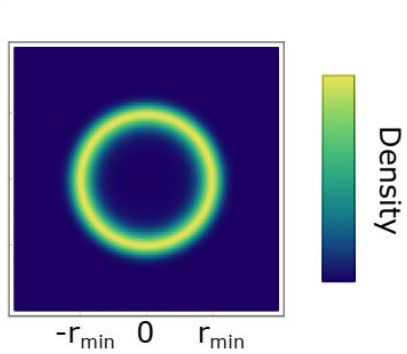
Gravity & magnetic inhomogeneities prevent completely filled BEC bubbles (on Earth).

Experimental progress

First experiments in microgravity (ISS) show improved filling.

Carollo et al., arXiv:2108.05880 (2021)





Ring in 2D
Shell in 3D

Sketch from Carollo et al., arXiv:2108.05880 (2021)

Alternative realization with BEC mixtures

Idea

Exploit repulsive interactions in a BEC mixture to achieve shell structures for one species.

Paper in preparation by the authors.

Requirements

Optically trapped dual-species mixture in microgravity with Feshbach resonance to tune interactions.

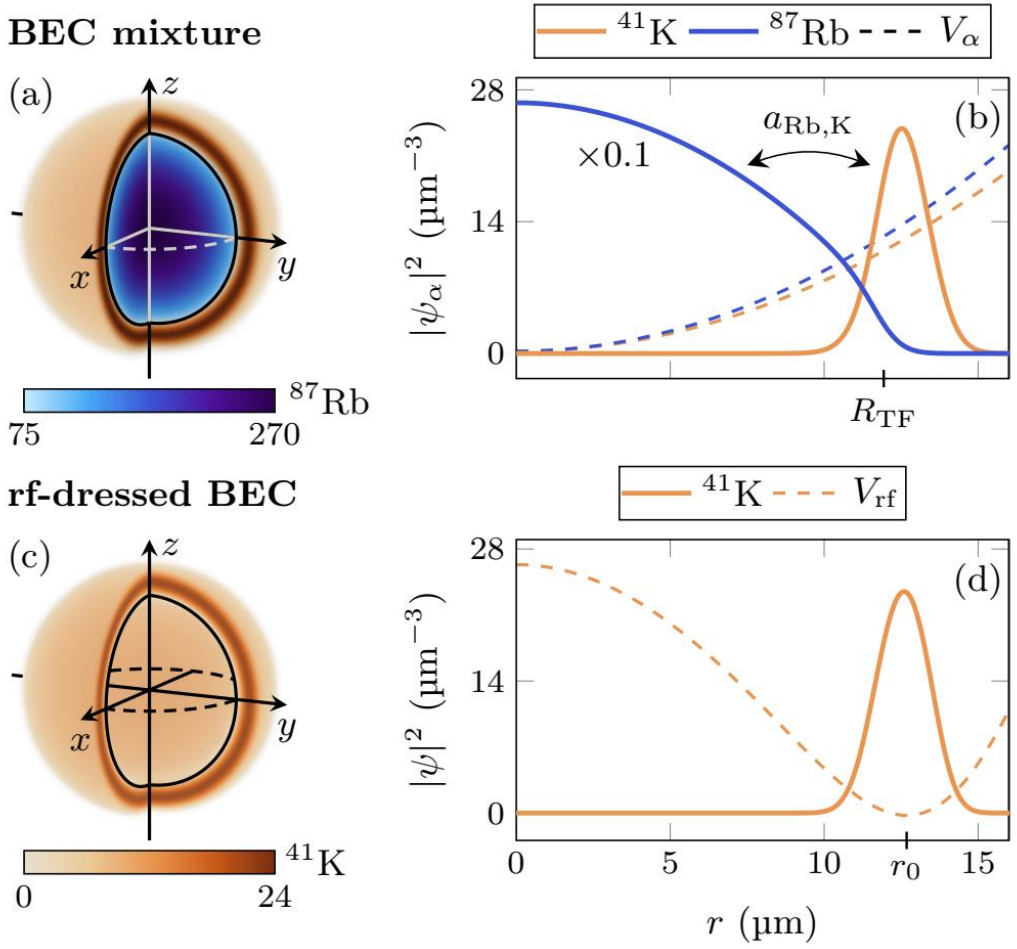
Possible realization with BECCAL: Frye et al., EPJ Quantum Technology 8, 1 (2021)

Benefits

Avoid inhomogeneous magnetic and rf fields.

Condense directly into shell state.

Conserve shell structure during free expansion.



Collective excitations and hollowing transition

Hollowing transition

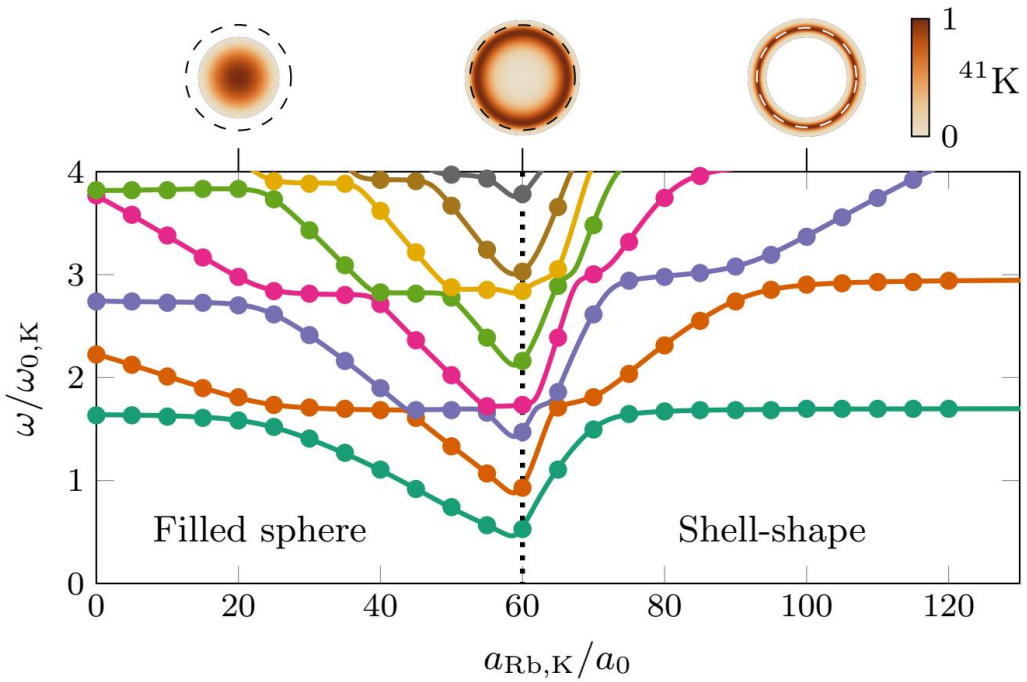
Increasing the repulsive interaction between both species drives a transition from a filled sphere to a hollow shell.

Collective excitations

The collective excitation spectrum shows a dip at the appearance of the inner surface of the shell similar to rf-dressed shells.

rf case: Sun et al., PRA 98, 013609 (2018)

In addition the mixture features avoided crossings.



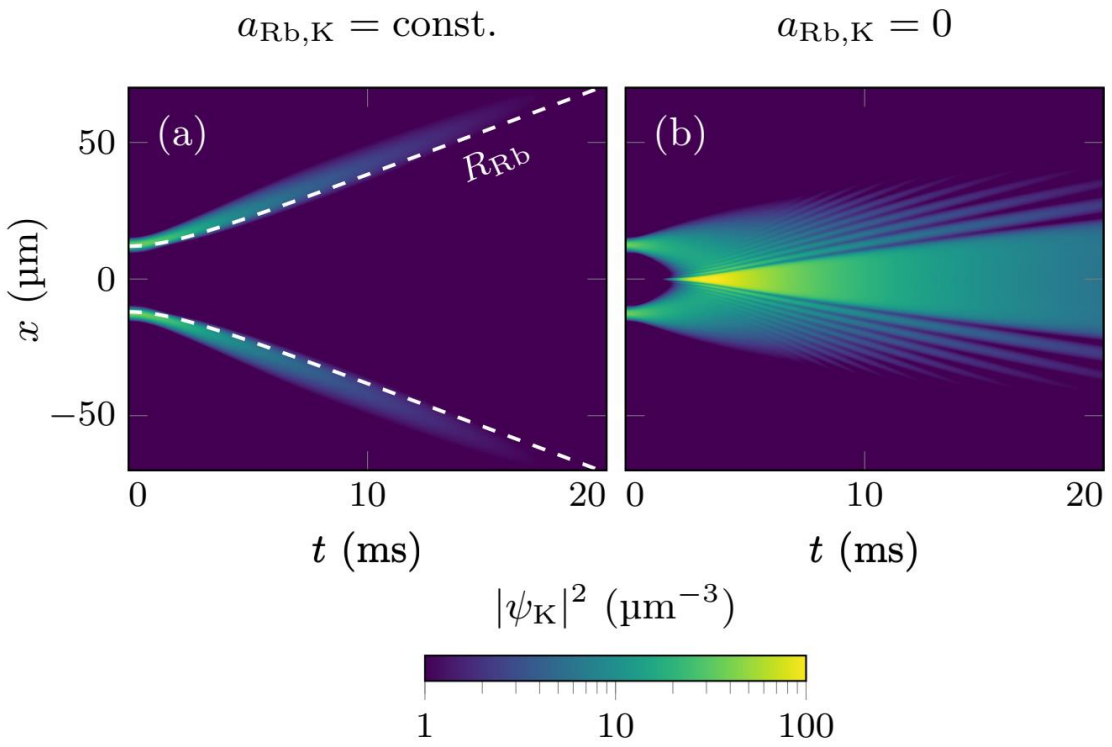
Free expansion dynamics

Expanding shell (a)

- During expansion the shell is conserved through repulsive inter-species interaction.
- Unique magnification of shell dynamics possible.

Collapse of shell (b)

- By removing the interaction with the inner core the shell breaks down during expansion.
- Situation similar to rf-dressed BECs when removing the magnetic trap.



Feasibility of fully filled shells

A = 1 (yellow) open shell
A = 0 (dark blue) completely filled shell

BEC mixture

- Microgravity required due to differential gravitational sag.
- Large atom numbers can lower microgravity requirements.

Rf-dressed BEC

- Microgravity required to fill shell completely.
- Spatial changes of the Rabi frequency lead to shell opening effects even in microgravity.