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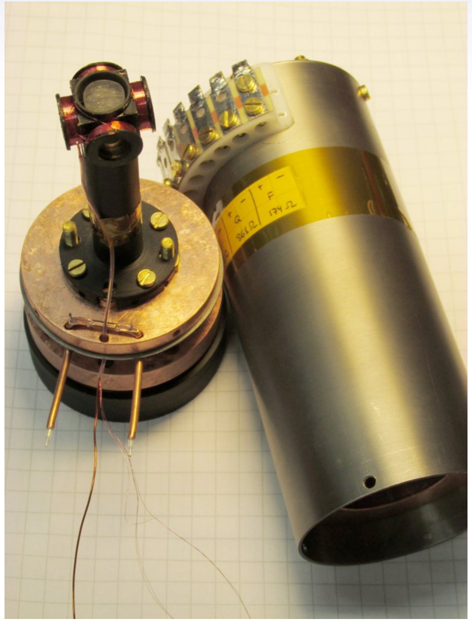
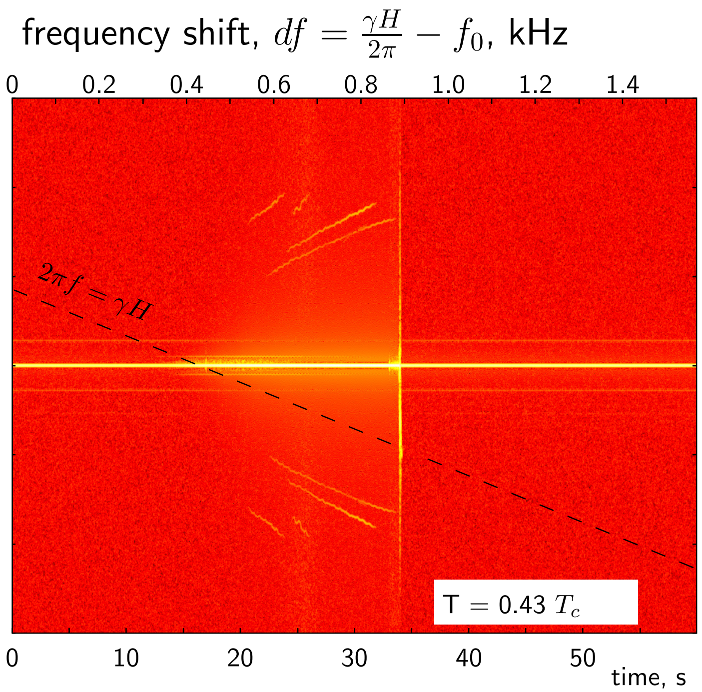
Numerical study of ϑ-solitons in HPD state of superfluid ^{3}He-B

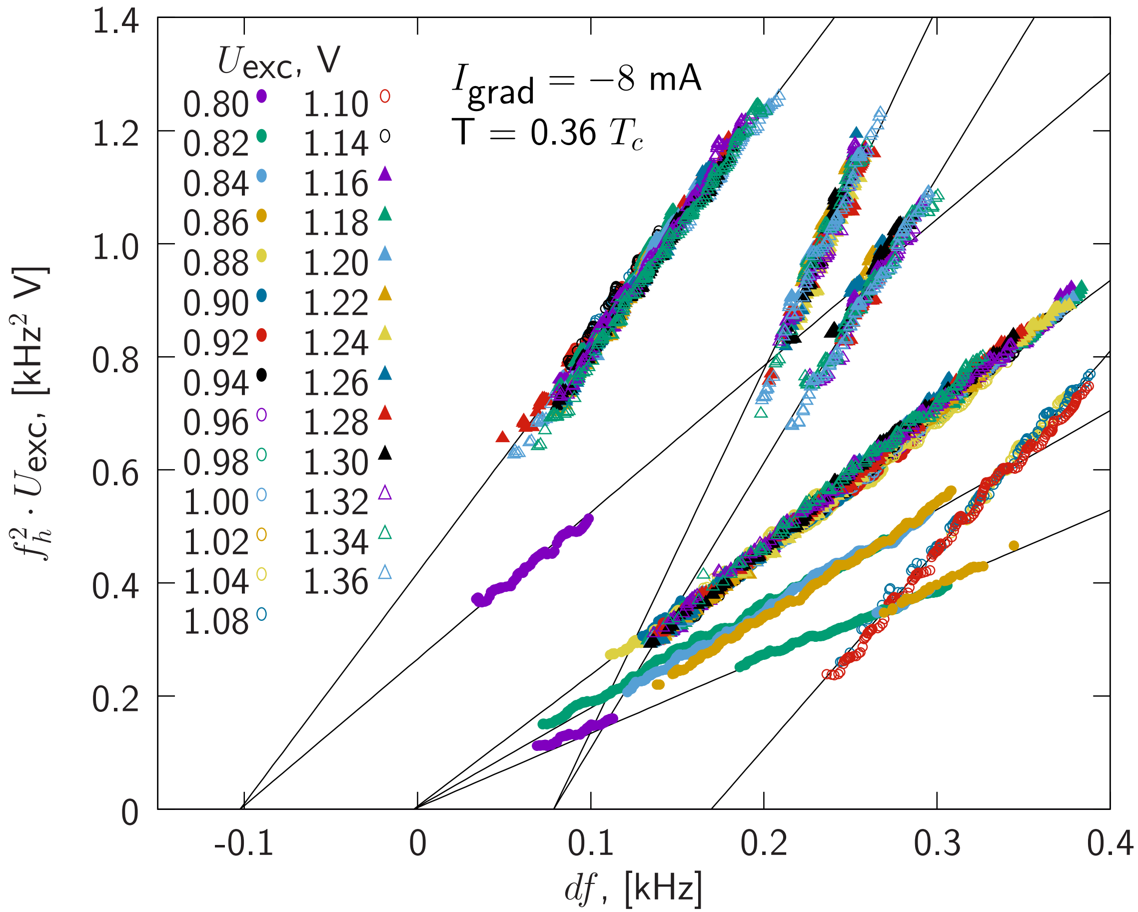
LTL, 21.03.2022

Experiment in LTL, 2018



In HPD state we observed many oscillaton modes with frequency $\propto \sqrt{df}$ localized in different parts of the cell.





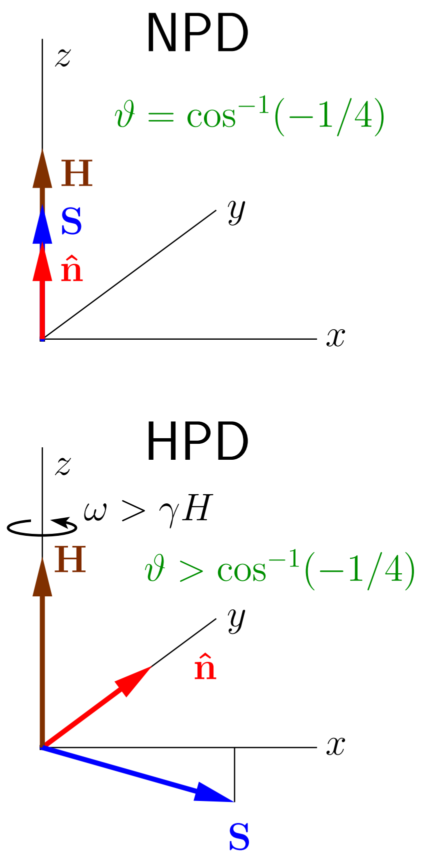
Homogeneously precessing domain (HPD)

^{3}He-B: spin state is described by rotation matrix $R(\mathbf{n}, \vartheta)$

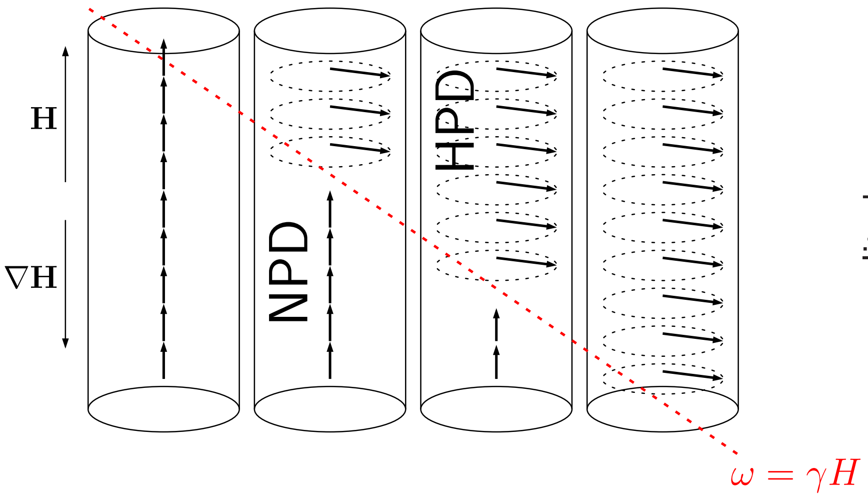
Leggett equations:

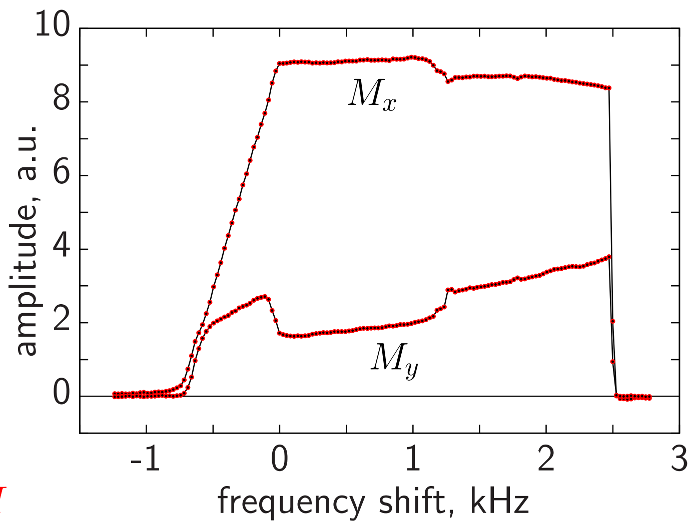
$$\dot{S}_a = [\mathbf{S} \times \gamma \mathbf{H}]_a + T_a(R),$$
$$\dot{R}_{aj} = e_{abc} R_{cj} \left(\frac{\gamma^2}{\chi_B} \mathbf{S} - \gamma \mathbf{H} \right)_b,$$

Gradient energy, $c_\parallel, c_\perp$
Spin-orbit interaction, Ω_B

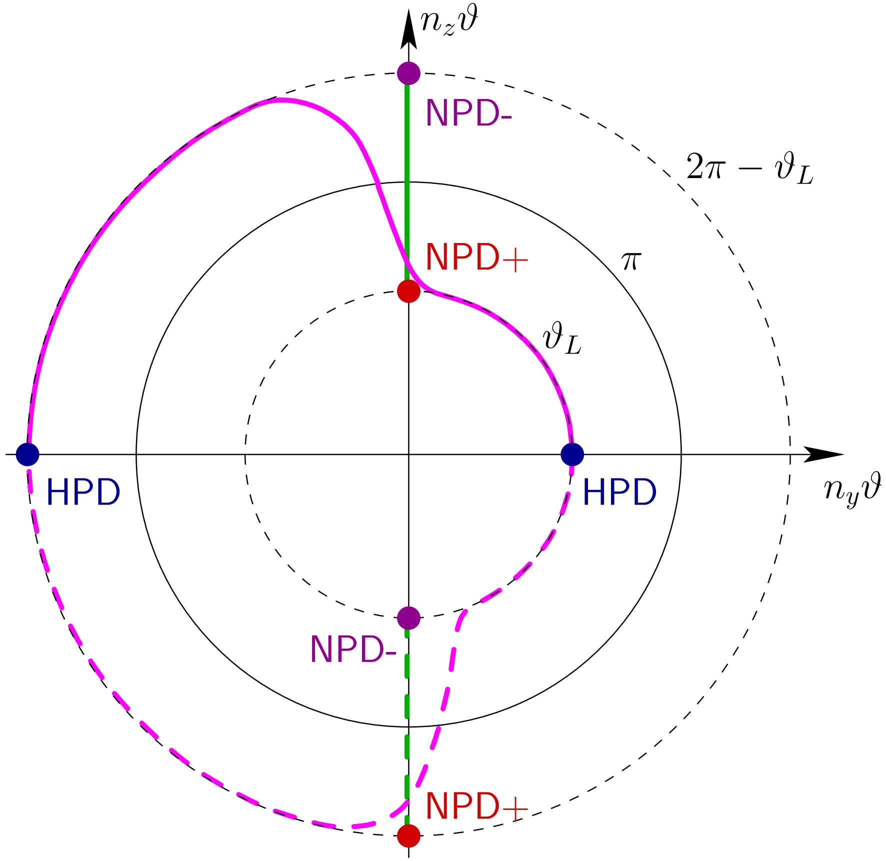


creation of HPD in CW NMR





ϑ-solitons



Soliton in NPD, only ϑ is changing. Exact solution:

$$\vartheta = 2\tan^{-1}\left[\sqrt{\frac{3}{5}}\tanh\left(\sqrt{\frac{65}{64}}\,\frac{\pm z}{\xi_D}\right)\right] + \pi.$$

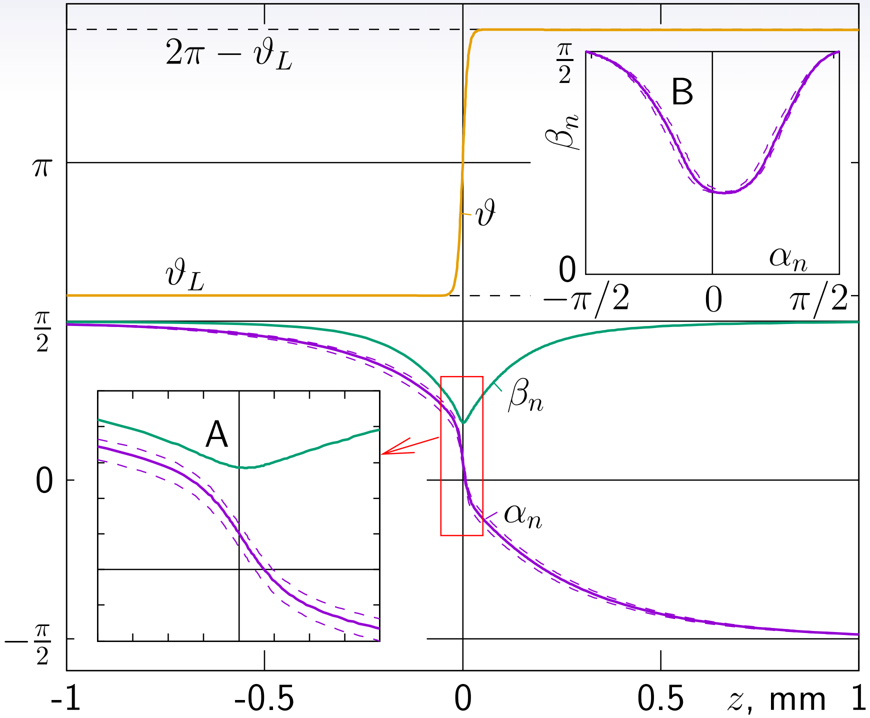
$$\xi_D^2 = \frac{65}{16}(2c_\perp^2 - c_\parallel^2)/\Omega_B^2$$

Soliton in HPD: small core where ϑ is changing and long tails where $\mathbf{n}$ is rotating.

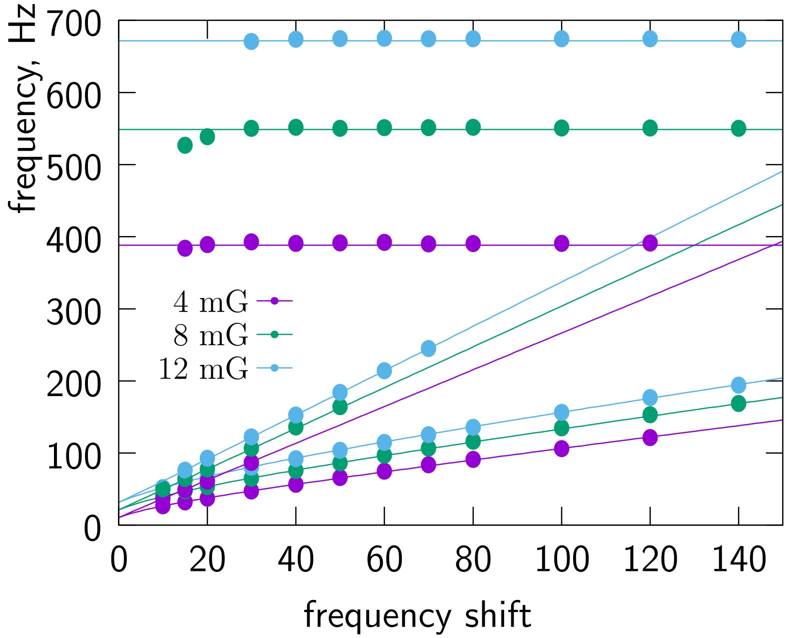
Ultra Low Temperature

Lancaster University

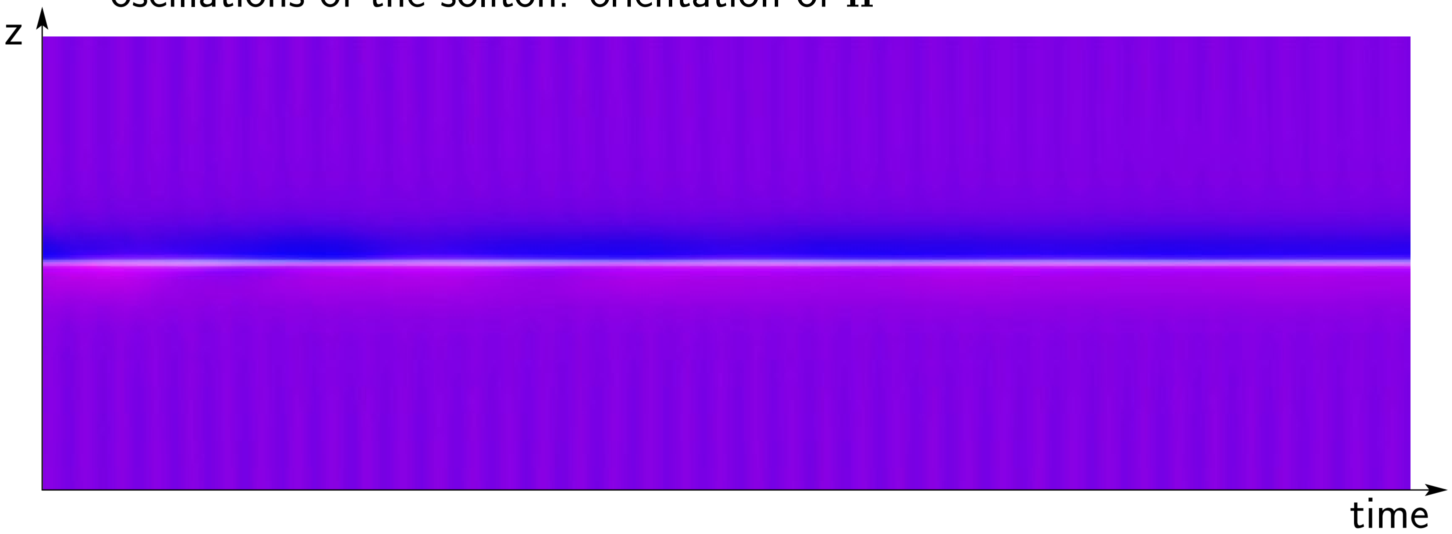
Solitons oscillations



Oscillation modes for three values of RF field:



oscillations of the soliton: orientation of $\mathbf{n}$

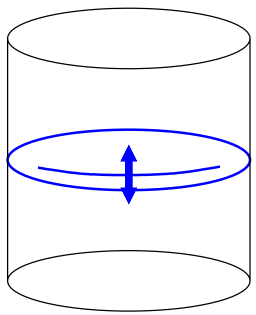


low-frequency mode:

$f^2 = 0.75\,(\gamma H_x)^2 + 4.0\,(\gamma H_x)\,\delta f$

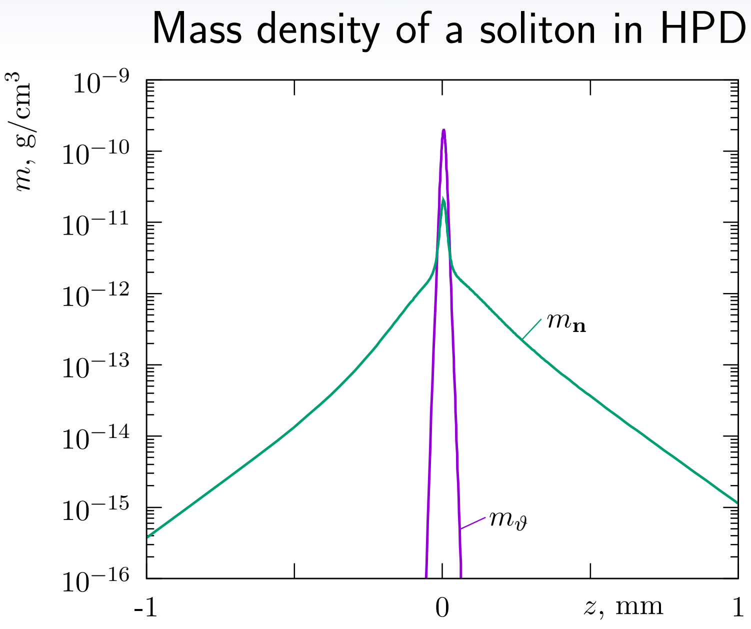
does not depend on $c_{\parallel,\perp}$ and Ω_B

Oscillation of soliton membrane



Soliton mass: from kynetic energy of a moving soliton

Tension: total energy of a unit area



Mass density:

$$m = \frac{\chi_B}{\gamma^2}\left[(\vartheta')^2 + 2(1-\cos\vartheta)\,(\mathbf{n}')^2\right]$$

For ϑ-soliton in NPD:

$$M = \frac{13}{3}\frac{\chi_B}{\gamma^2\xi_D^2}\int_{-\infty}^{+\infty}\left(\cos\vartheta(z)+1/4\right)^2 dz,$$

$$T = \frac{16}{15}\frac{\chi_B\Omega_B^2}{\gamma^2}\int_{-\infty}^{+\infty}\left(\cos\vartheta(z)+1/4\right)^2 dz.$$

Ratio of tension and mass give square of wave velocity C along the membrane,

$$C^2 = 2c_\perp^2 - c_\parallel^2.$$

First oscillation mode: $f = 2.405\,C/r$