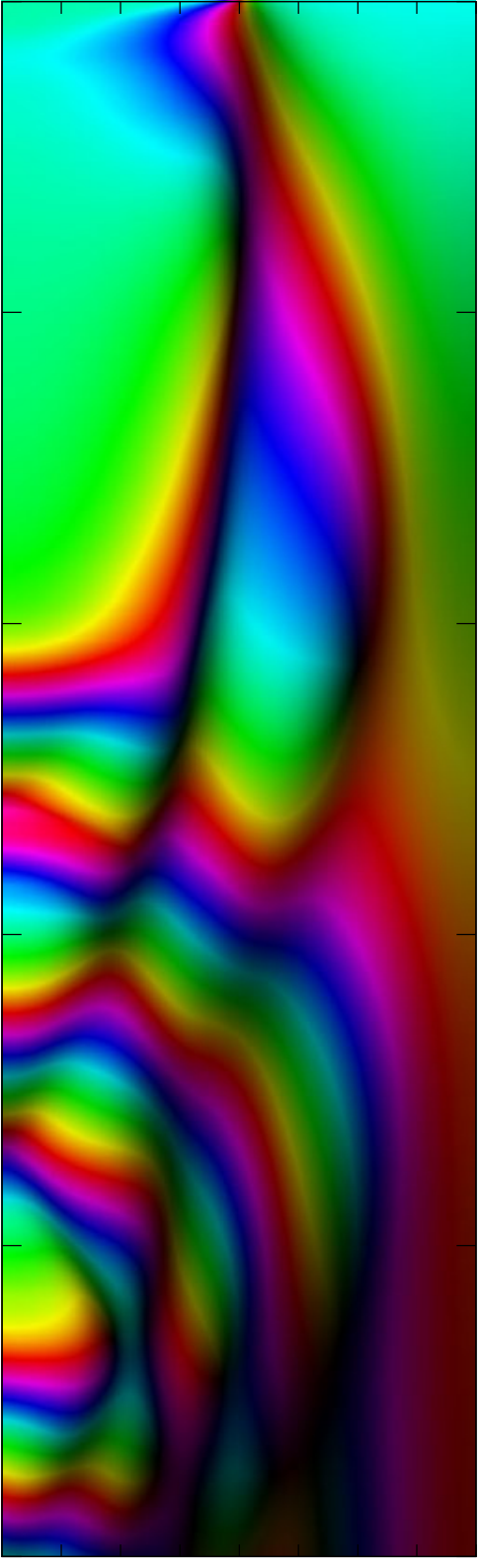


Low Temperature Laboratory

Aalto University

Homogeneously precessing domain in 3He-B

Pertti Hakonen
Alexander Savin
Vladislav Zavjalov

19.10.2018

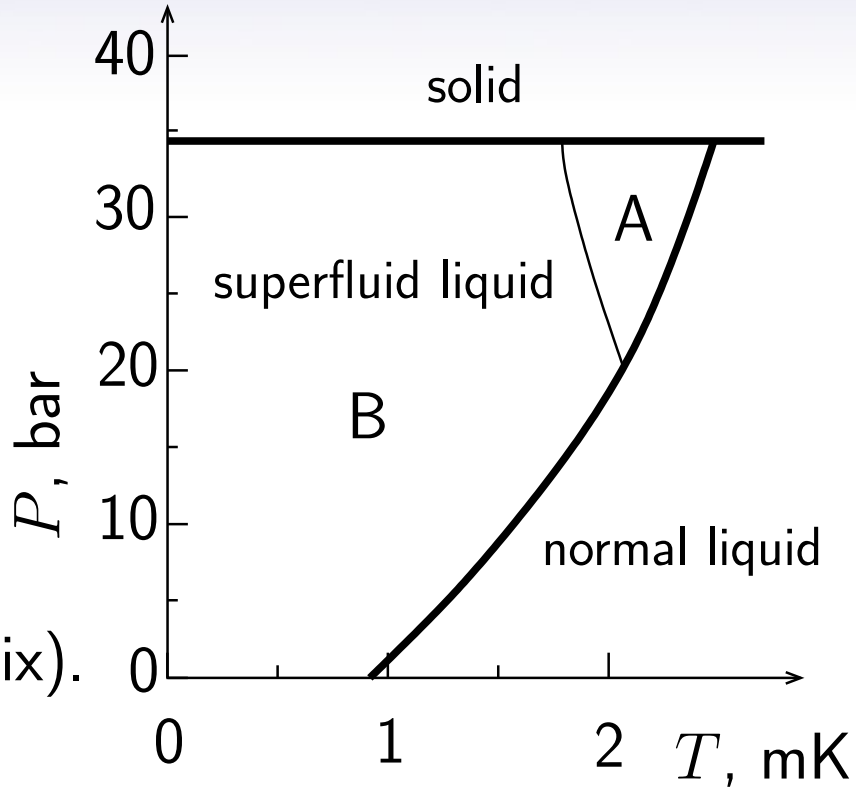
Superfluid ^{3}He

Fermi liquid.

Superfluid transition at $\sim$1 mK.

Cooper pairing with $L = 1$ and $S = 1$.

Order parameter: 3x3 complex matrix.



B phase: $A_{jk} = \Delta\, e^{i\phi}\, R_{jk}$.

(Δ – gap, ϕ – phase, R_{jk} – rotation matrix).

Oscillations of the order parameter: 18 modes,

4 phase (Nambu-Goldstone) modes – gapless,

14 amplitude (Higgs) modes – gap $\sim \Delta$.

Texture and spin waves

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

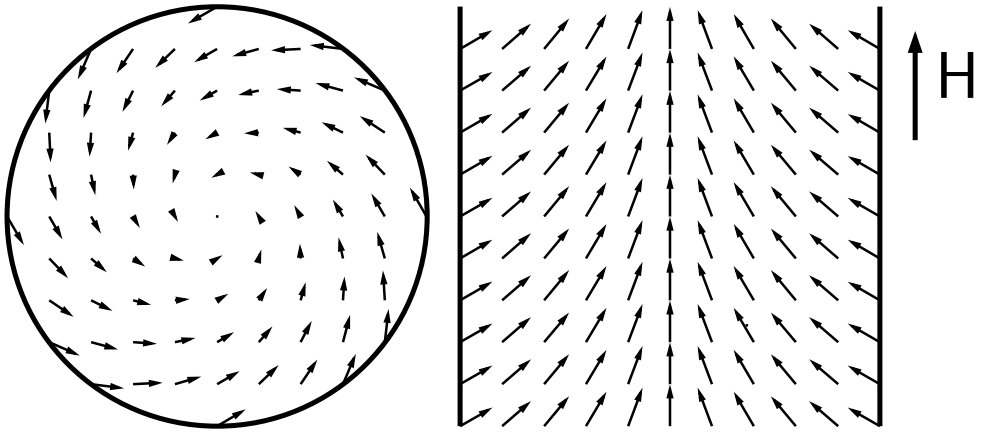
Spin-orbit interaction, Ω_B

Interaction with walls

Equilibrium distribution of $R(\hat{\mathbf{n}}, \vartheta)$ – texture.

Motion of $R(\hat{\mathbf{n}}, \vartheta)$ – spin waves.

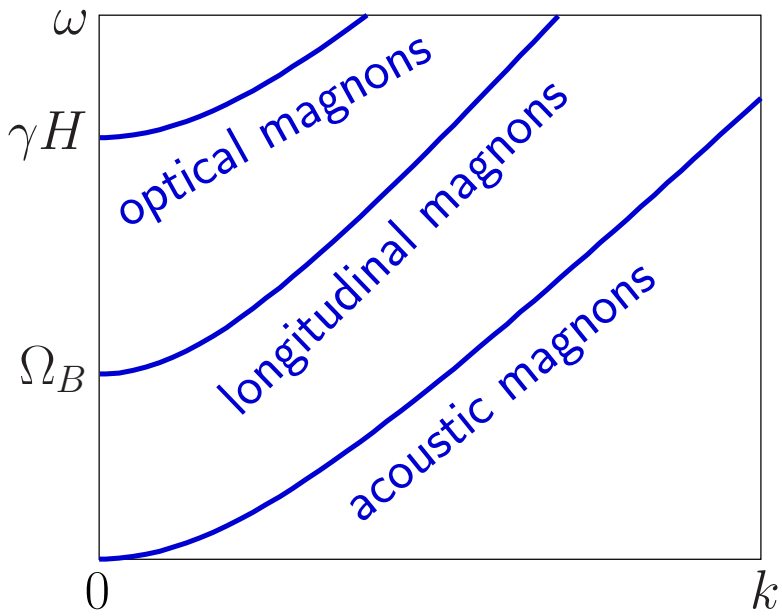
Flare-out texture in a cylindrical cell



$\vartheta = 104°$

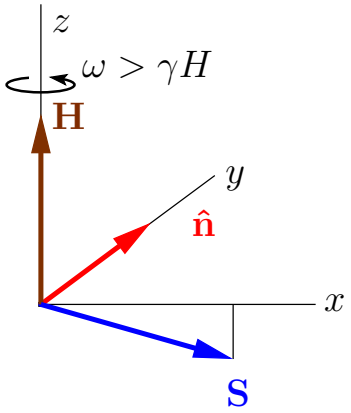
(Leggett angle, minimum of spin-orbit interaction)

Linear NMR, $\Omega_B \ll \gamma H$, $\hat{\mathbf{n}} \parallel \mathbf{H}$

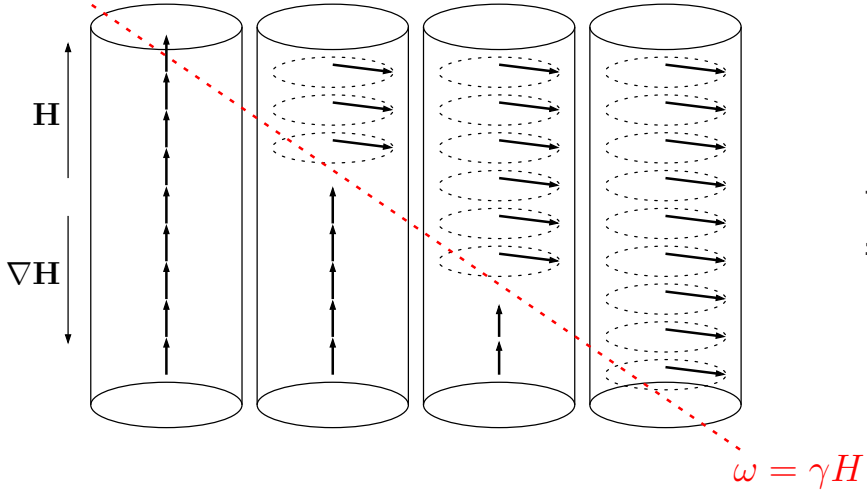


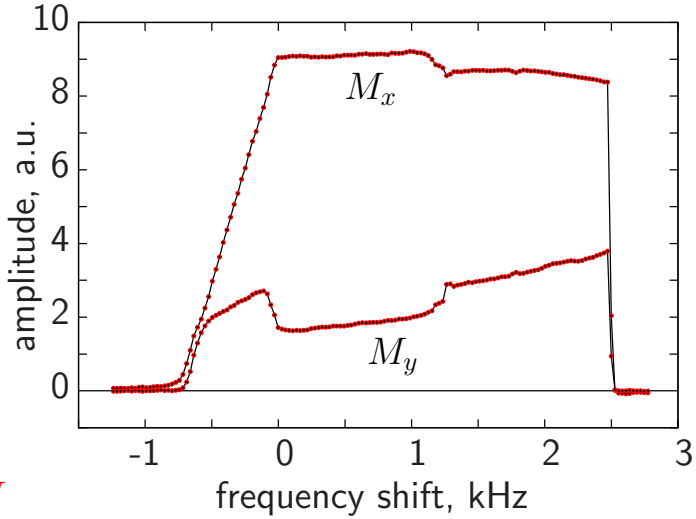
Homogeneously precessing domain (HPD)

HPD

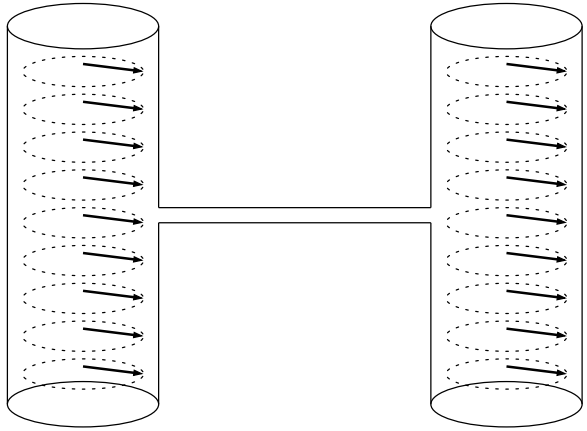


creation of HPD in CW NMR

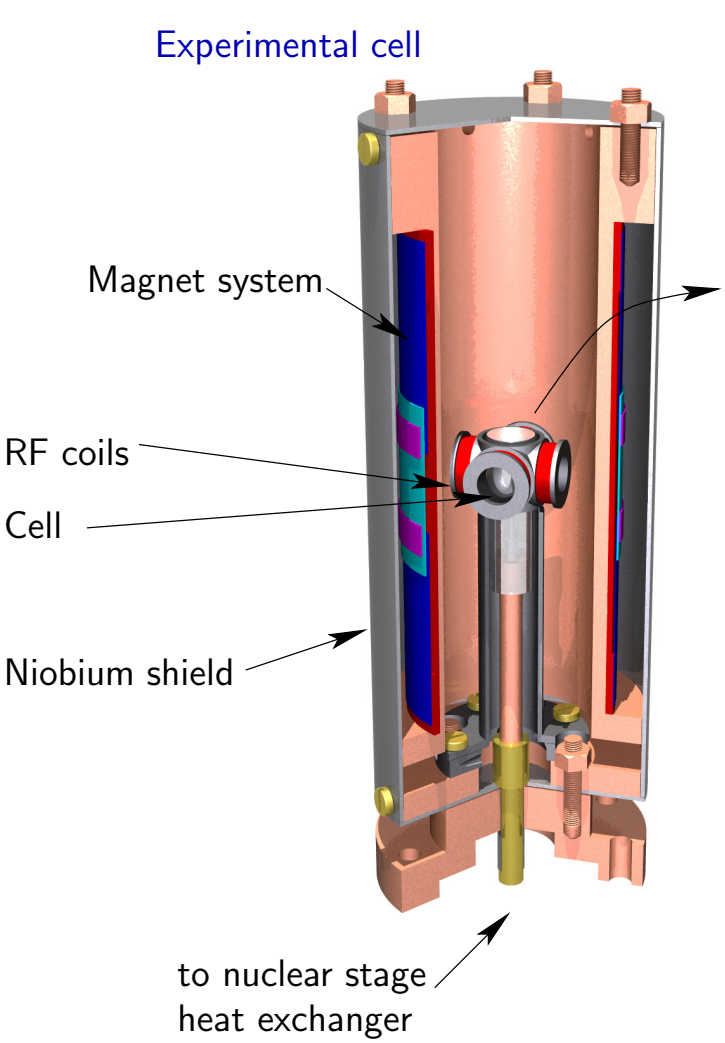


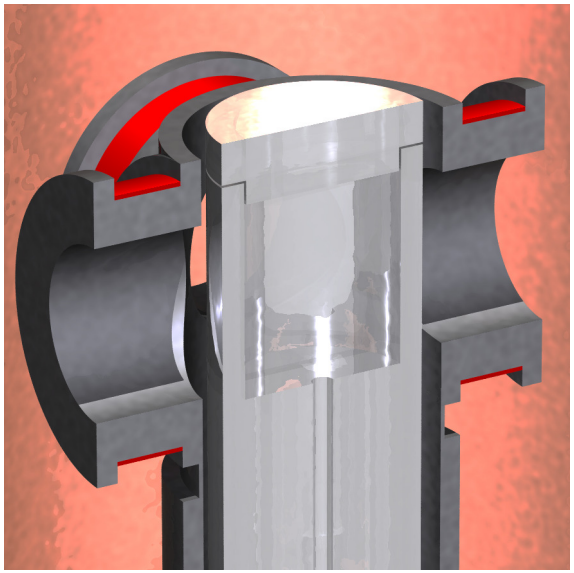


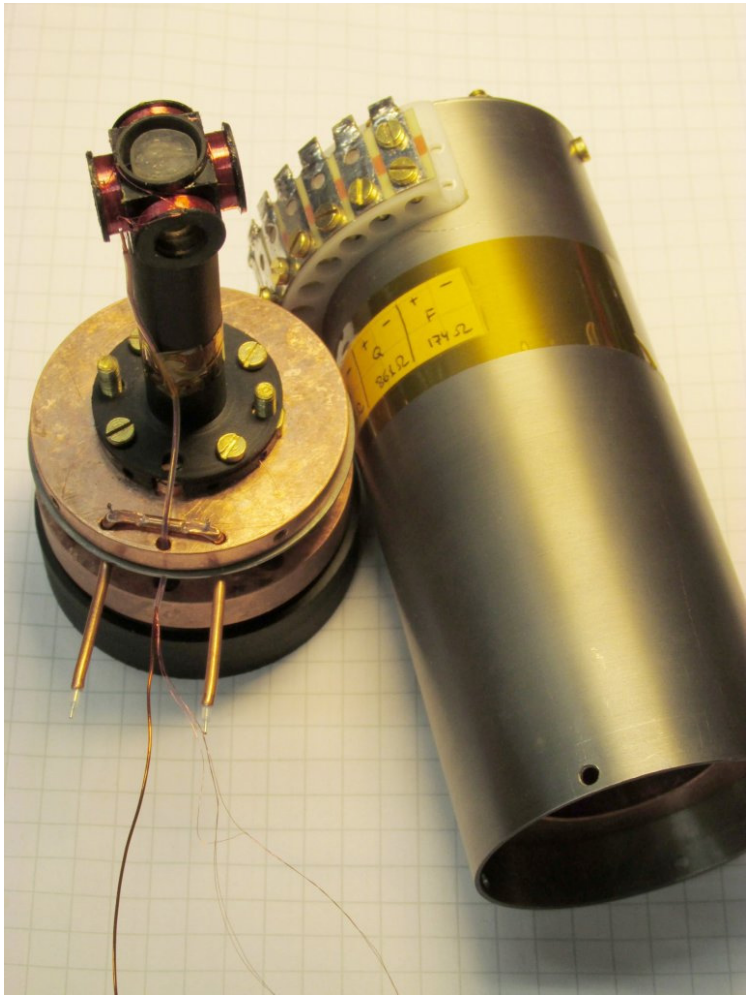
Experiment with two HPDs (Moscow, 1987)



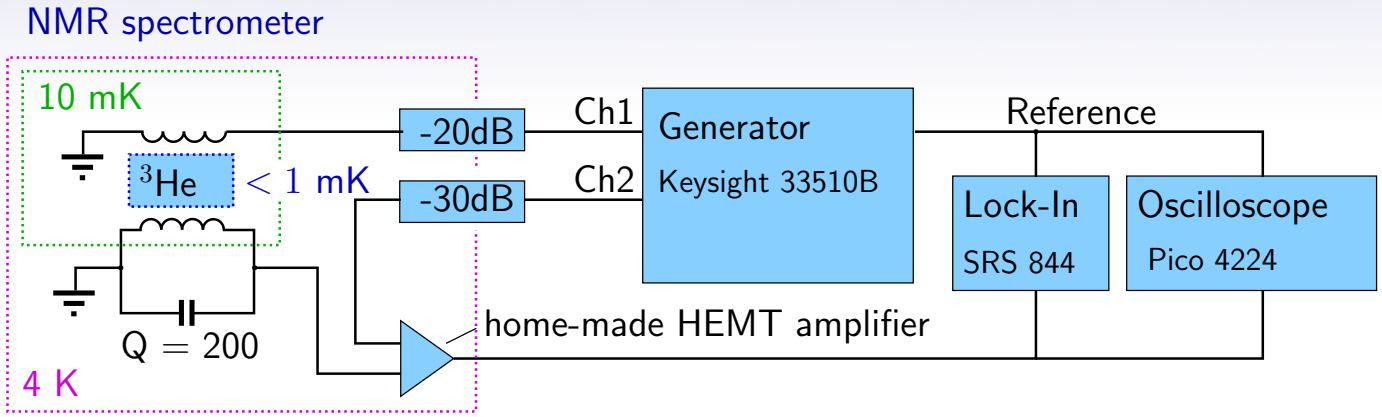
Experimental cell

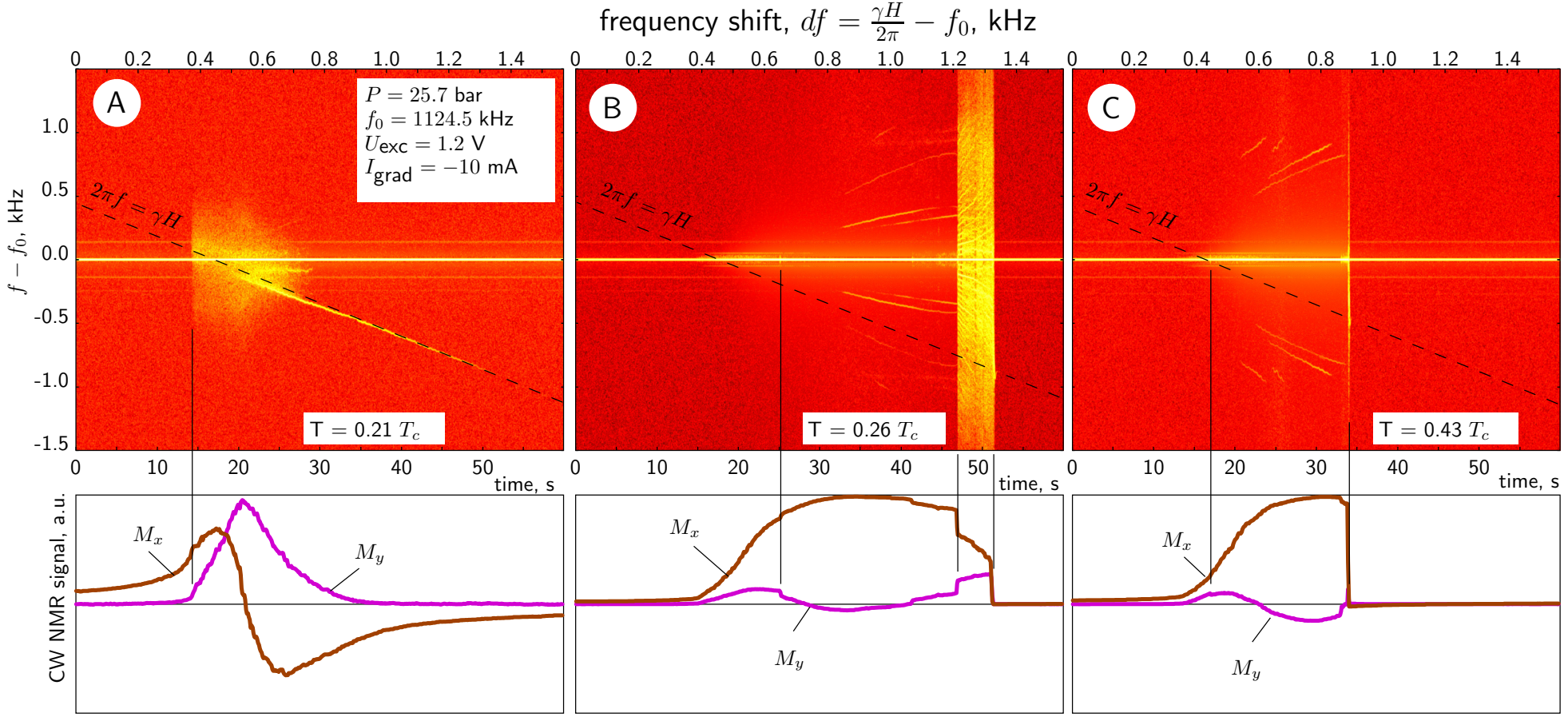




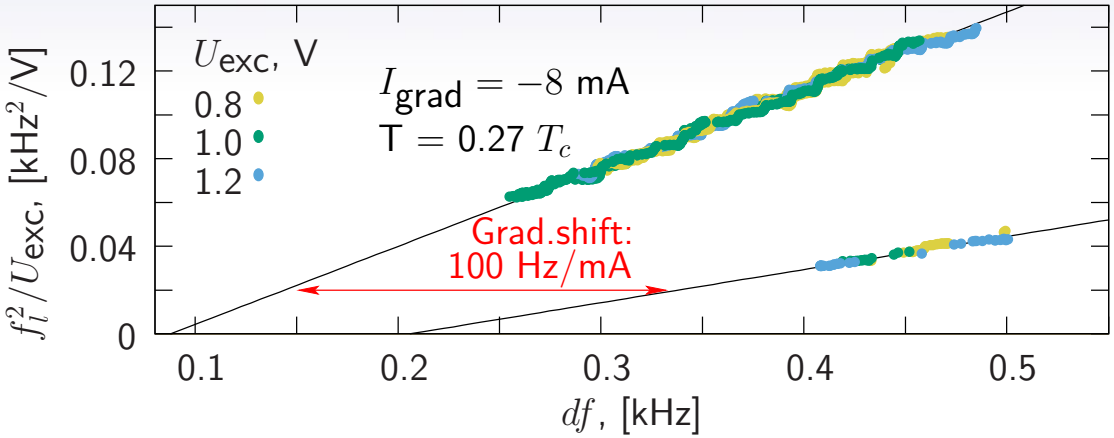


Experiment


NMR spectrometer
10 mK
^{3}He
< 1 mK
Q = 200
4 K
-20dB
-30dB
Ch1
Ch2
Generator
Keysight 33510B
Reference
Lock-In
SRS 844
Oscilloscope
Pico 4224
home-made HEMT amplifier

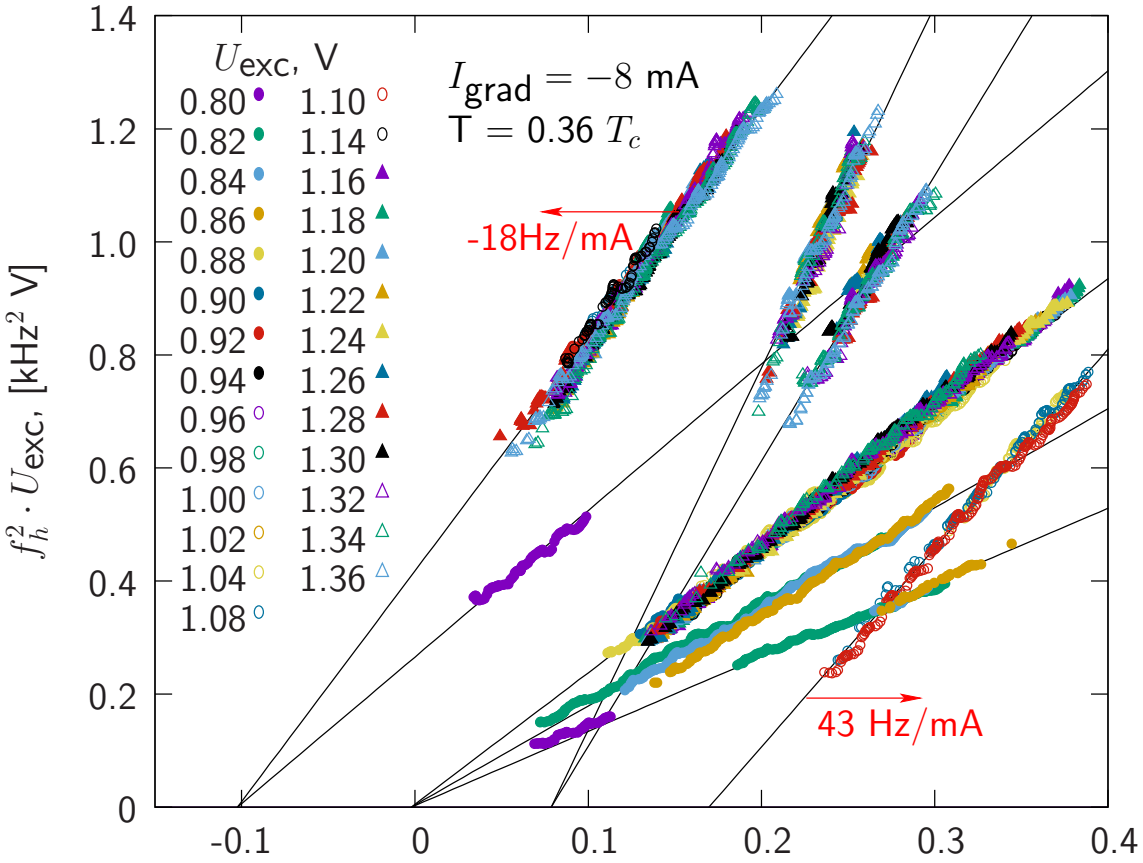

frequency shift, $df = \frac{\gamma H}{2\pi} - f_0$, kHz
A
B
C
$P = 25.7$ bar
$f_0 = 1124.5$ kHz
$U_{exc} = 1.2$ V
$I_{grad} = -10$ mA
$2\pi f = \gamma H$
T = 0.21 T_c
T = 0.26 T_c
T = 0.43 T_c
$f - f_0$, kHz
time, s
CW NMR signal, a.u.
M_x
M_y

Results



"Low-temperature" modes:

$f^2 \propto (\omega - \gamma H) \cdot H_{\text{RF}}$



"High-temperature" modes:

$f^2 \propto (\omega - \gamma H)/H_{\text{RF}}$

Gradient dependence: oscillations are localized in different parts of the cell.

Parameters:

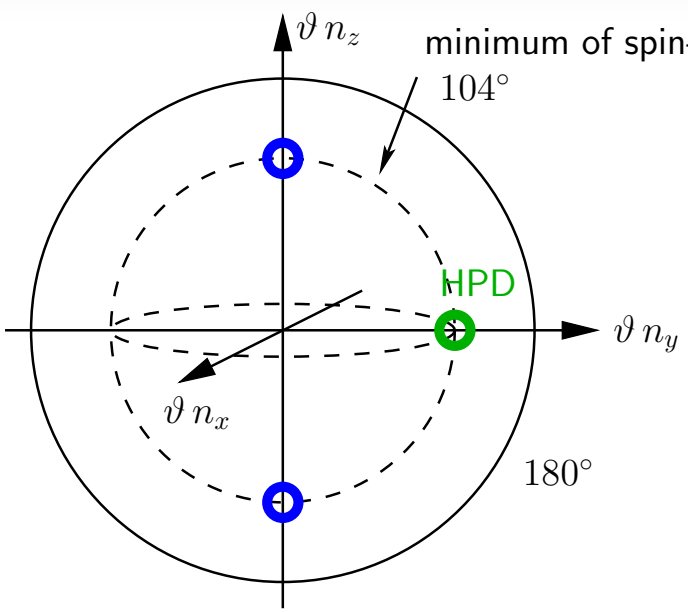
$\gamma H_0/2\pi = 1.12$ MHz

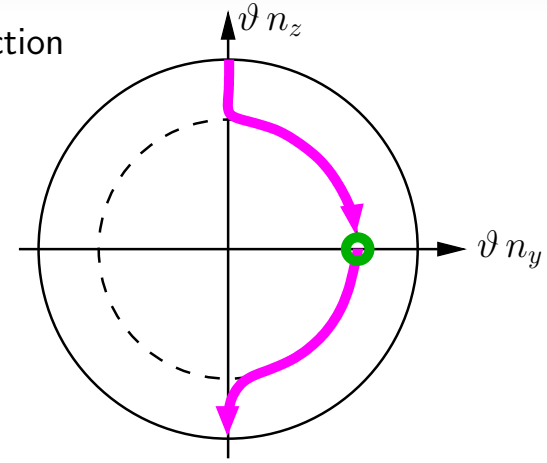
$\gamma H_{\text{RF}}/2\pi = 5 \ldots 8$ Hz

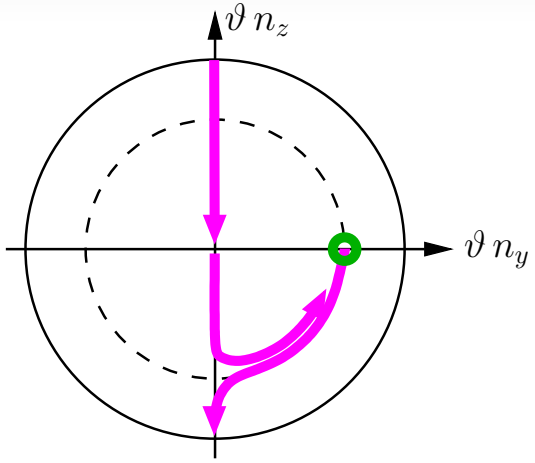
$(\omega - \gamma H_0)/2\pi = 0 \ldots 400$ Hz

ϑ-solitons

$\vartheta\,\hat{\mathbf{n}}$ coordinates:

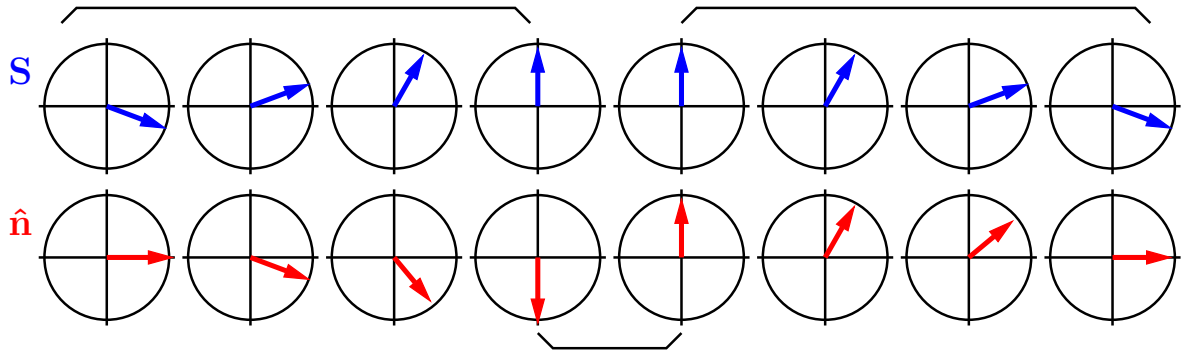






change of $\mathbf{S}$ and $\mathbf{n}$

$\xi_H \propto \sqrt{\omega - \gamma H}$

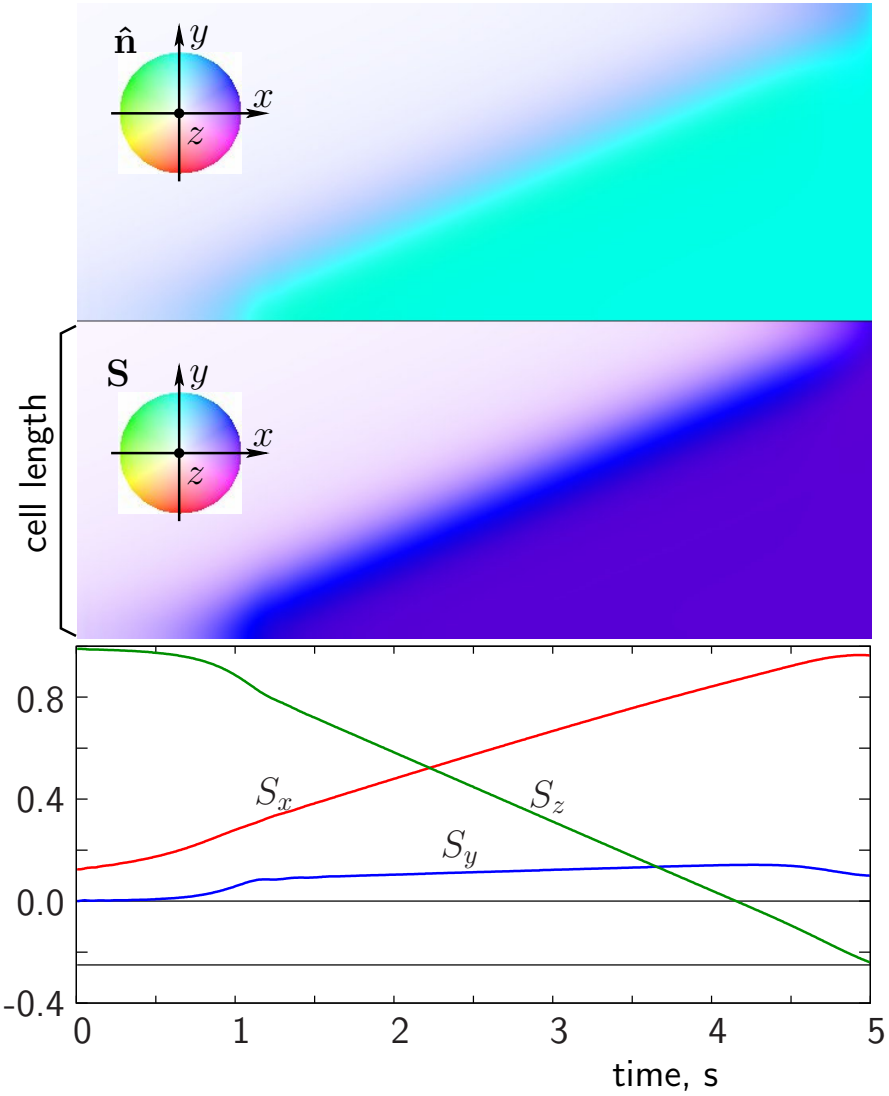


change of ϑ

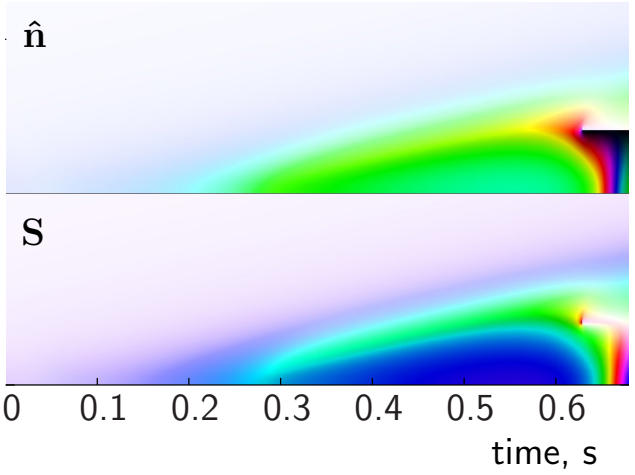
$\xi_D \approx 10\mu$m

Numerical simulatons

Creation of HPD in CW NMR



Instability of the HPD boundary



Soliton oscillations