High Density Vortex State and Textual Transition in Anisotropic Superfluid ^{3}He-A up to $\Omega=4\pi$ rad/s

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Outline

1. Introduction

2. High density vortex state in anisotropic ^{3}He-A under high speed rotation (T/Tc<0.9)

3. Transition of texture (T/Tc>0.9)
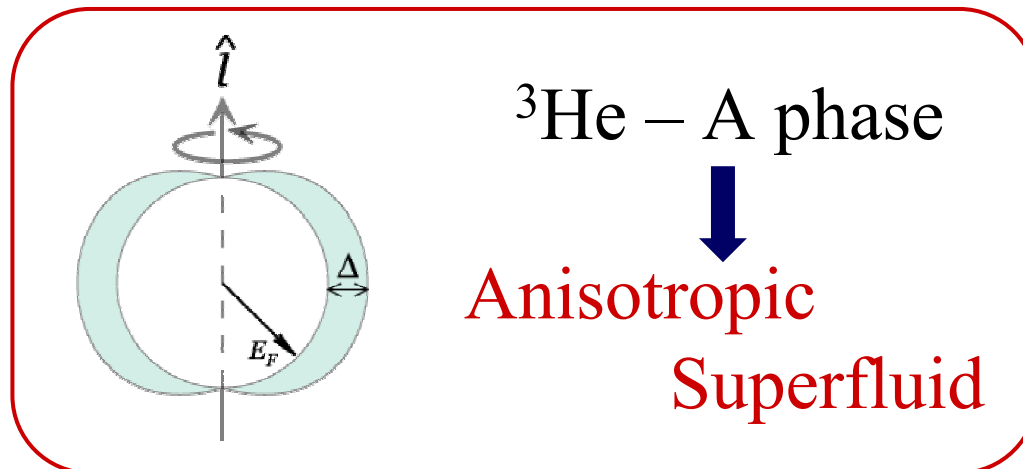   Mermin-Ho texture(MH)
   and Radial Disgyration texture(RD)?

Anisotropic Superfluid ^{3}He
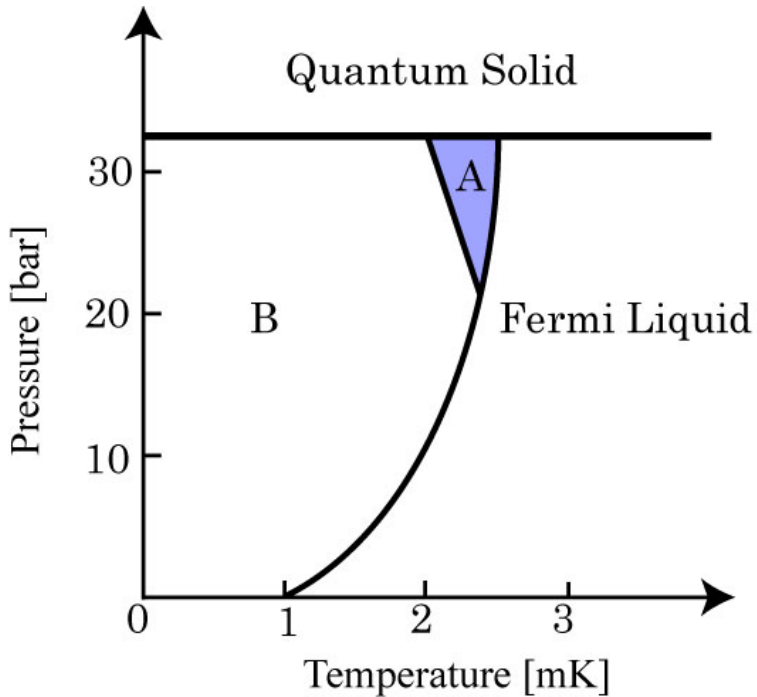
Cooper pair
p-wave, spin-triplet

Superfluid with
internal degree of freedom
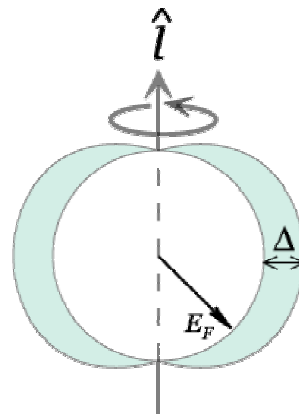
^{3}He – A phase
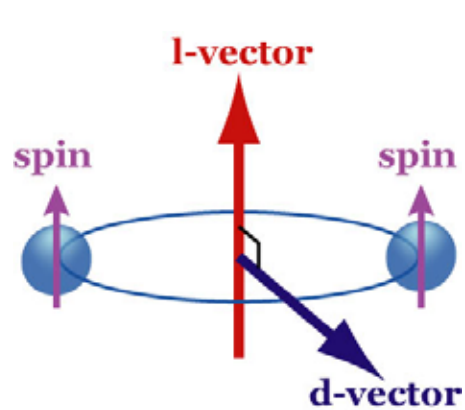
Anisotropic
        Superfluid

Orientation effects in A phase

Order Parameter

$$d_{\mu j} = \Delta(T) \cdot \hat{d}_\mu (\hat{m}_j + i\hat{n}_j)$$

Spin

Orbital

$$\hat{d} \perp \vec{S} \qquad \hat{l} = \hat{m} \times \hat{n}$$
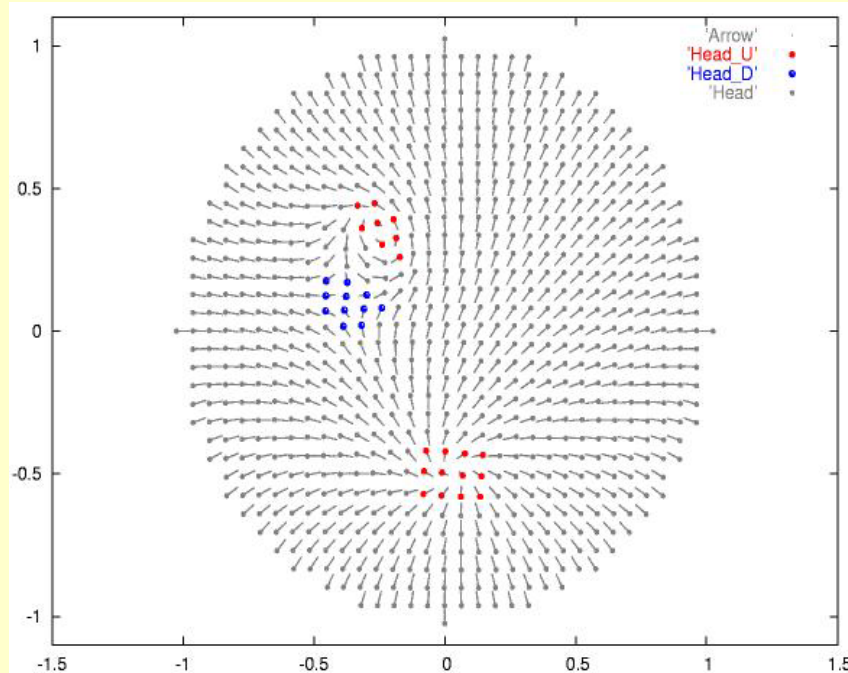

Orientation Effect

Wall

Magnetic field

Dipole interaction

Counter flow

Dipole Healing Length $\xi_D \sim 10 \ \mu m$

($\xi_0 \sim 20$ nm)

Continuous vortex (no singularity) in ^{3}He-A

Calculation by T. Takagi

D=200μm

$\Omega \sim 5$ (rad/sec)

$H \gg H_D$

l-vector

←

🔵   ⊗

🔴   ⊙

CUV and MH   Quantum number of circulation : 3

Vortex core size is large ~10μm

Spin Wave trapped by Potential
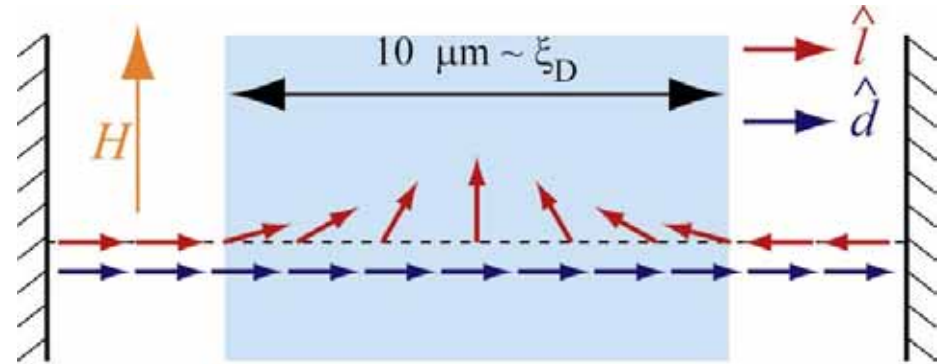
Dipole potential caused by
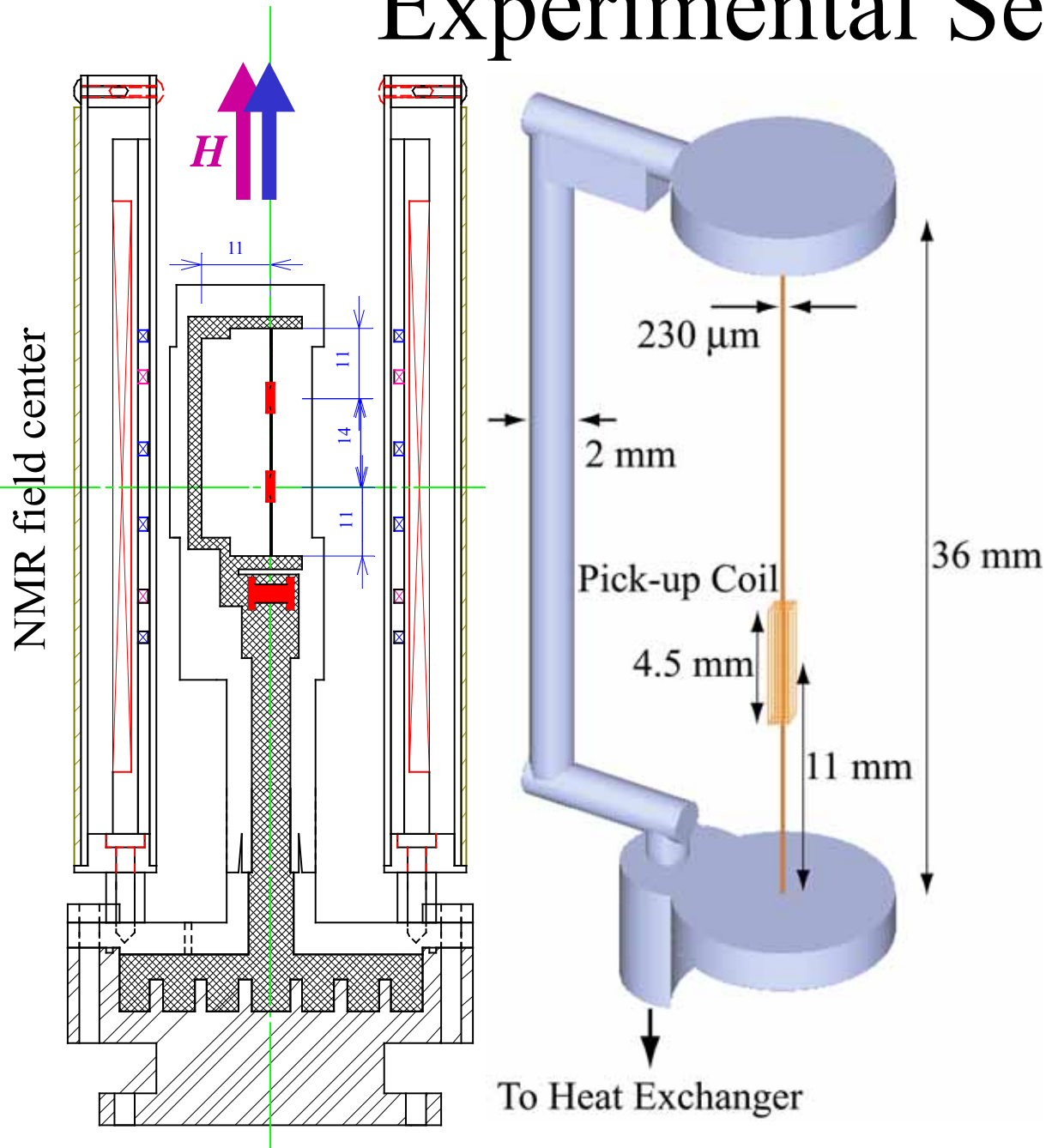*Texture* or *Vortices*

⬇

Trapping *Spin Wave*

↑

Detect by NMR

Experimental Setup

NMR field center

H

11

11

14

11

230 μm

2 mm

Pick-up Coil

4.5 mm

11 mm

36 mm

To Heat Exchanger

230 μm

cw-NMR

Condition

P	=	3.2 MPa
Tc	=	2.47 mK
H	=	21.6 mT
L	=	700 kHz.

MCT on N-stage
   for Thermometer

Rotation Variation of NMR spectrum experiment and calculation (T/Tc<0.9)

Satellite Peak>Main peak   High density vortex state

Vortex formation speeds

|		Exp.	Calc.
P=1	p=3	4 rad/sec	4rad/sec
P=3	p=5	7 rad/sec	7.5rad/sec
P=5	p=7	8.5 rad/sec	8.5rad/sec
P=7	p=9	11 rad/sec	10.5rad/sec

P : circulation numbers in the cylinder

Summery of high density vortex state

We observed the vortices states
up to nine circulation.

There is not translational symmetry
on vortex position in the high density
vortex state of anisotropic ^{3}He-A.

Rather than calling it the abricosov
lattice of (MH+4CUV),
a p=9 votex nucleate.

Textual transition (T/Tc>0.90) between Mermin-Ho texture(MH) and Radial Disgyration texture(RD)?
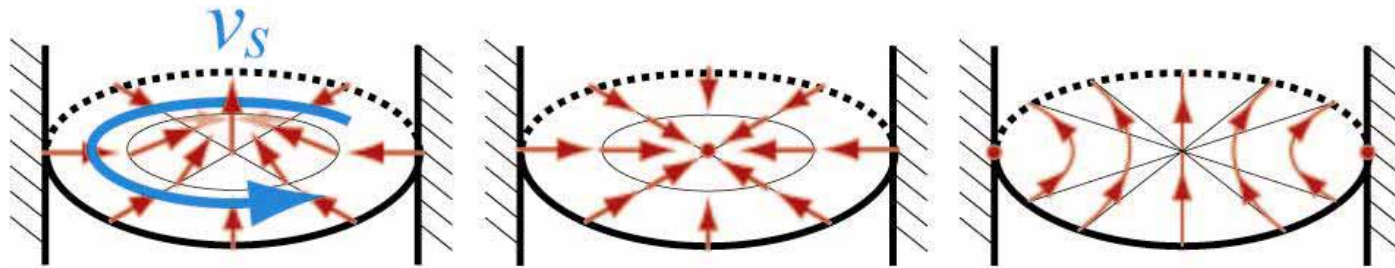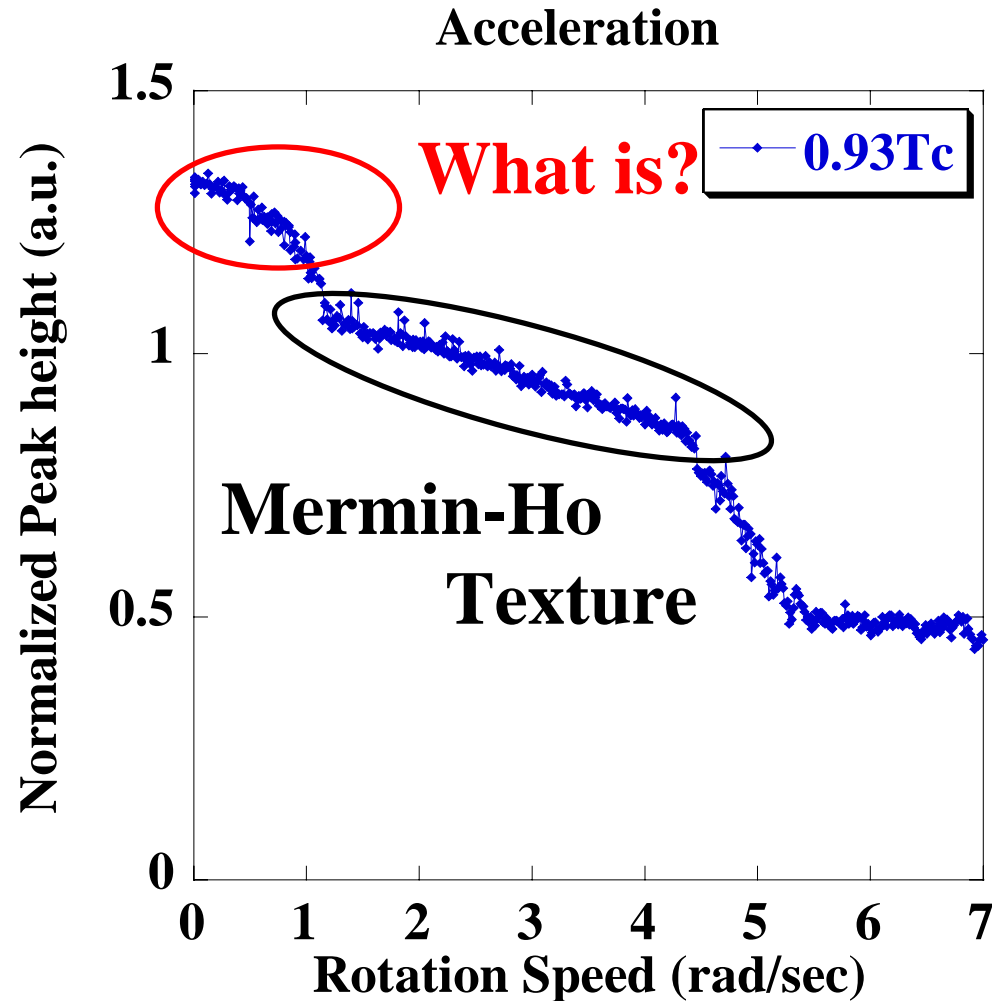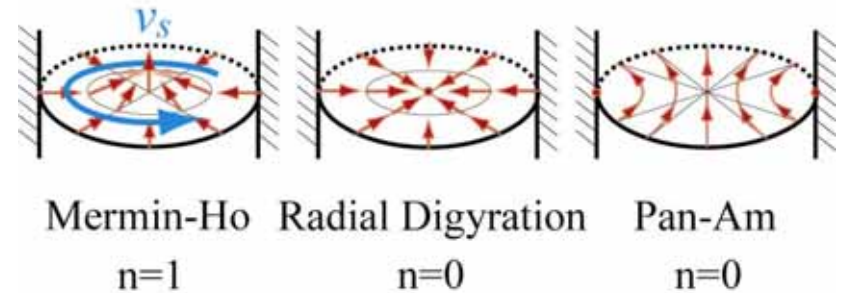

Mermin-Ho   Radial Digyration   Pan-Am
n=1   n=0   n=0

Motivation

We observed a textual transition at T/Tc>0.9, but what is that?

Acceleration

Normalized Peak height (a.u.) vs Rotation Speed (rad/sec)

What is? — 0.93Tc

Mermin-Ho Texture

There is a textural transition before 1st CUV Penetration.

v_s

Mermin-Ho   Radial Digyration   Pan-Am
n=1   n=0   n=0

Prediction

Low temperature and
high rotation speeds
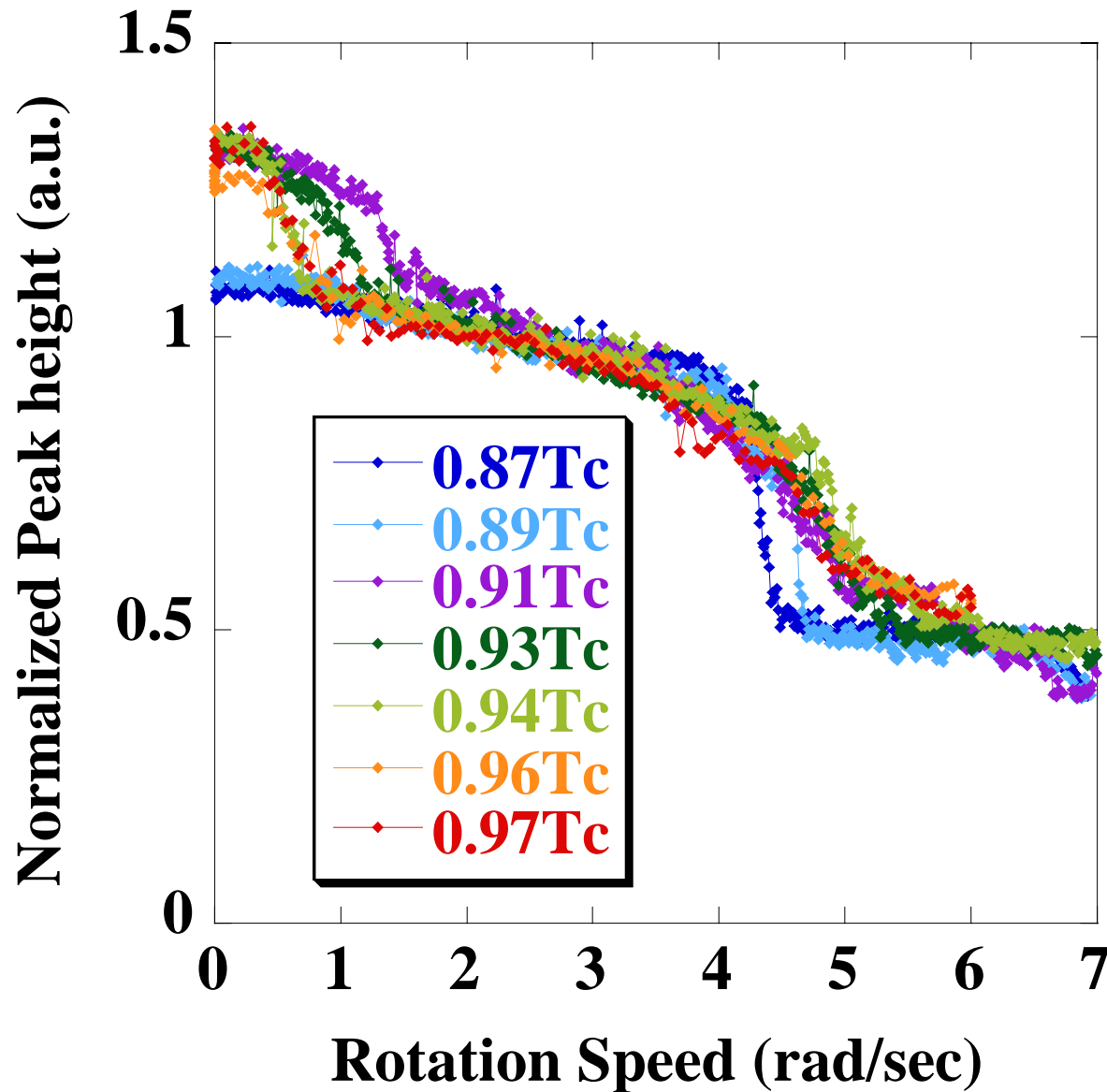
High Temperature and
low rotation speeds

Mermin-Ho

Radial Disgyration

$$\xi \propto \frac{1}{\sqrt{1-T/Tc}}$$

Presented by Y.Tsutsumi *et al.* at JPS meeting (2008.9)
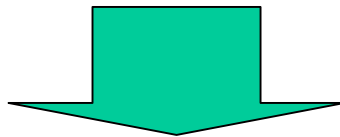
Main peak height at Various temperatures

Acceleration

Summery of 230 μm cylinder experiment

There is a textual transition at T/Tc > 0.9.

Rotation dependence of the transition is consistent with
 the transition between MH and RD, but temperature
dependence of the transition is not.
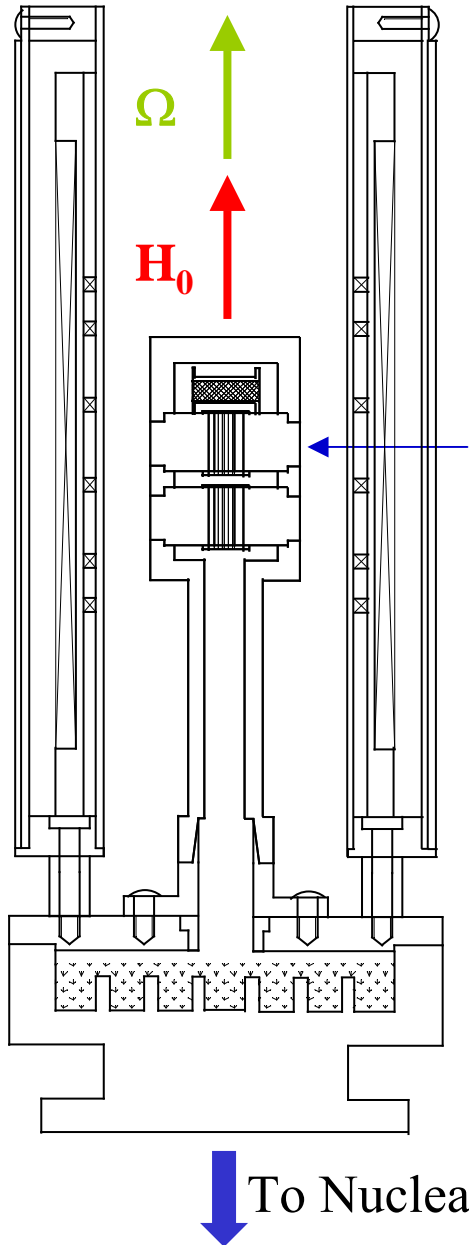
We can not measure the satellite peak.

100μm   cylinders experiment

RD region broadens and satellite information is detected

100μm Cell

Experimental Setup

Ω

H_0

$D = 100\mu m$ Cell

~ 150 Cylinders

Condition

P = 3.2 MPa

Tc = 2.47 mK

H = 15.4 mT

$_L$ = 500 kHz.

$$\Delta f = \frac{\Omega_A^2}{2 f_L}$$

No ^{4}He Preplating

To Nuclear stage

3 Types of Texture in D=100μm

Normal   A-phase

Radial Disgyration

B-phase   A-phase

Pan-Am texture ?

Thermal or
       Mechanical Shock

Mermin-Ho

Textures are identified by satellite shift.

Surmary of textual transition T/Tc>0.90

We identified the textual transition by satellite shift
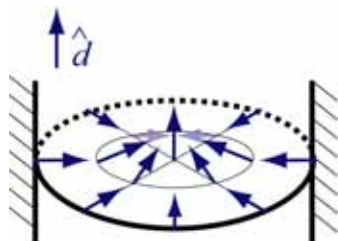(resonance frequency of the spin wave)

The experimental phase diagram agree with the theoretical phase
 diagram between MH and RD qualitatively but dose not quantitatively.

It remains a puzzle.

 The other possibility of the transition
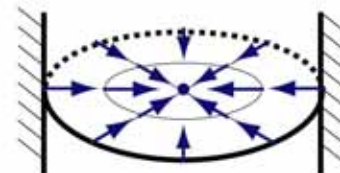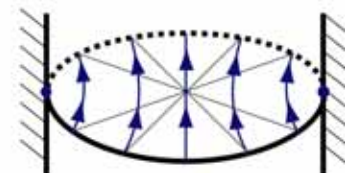   the transition of texture of the d-vector in MH

d- texture

Mermin-Ho

$\hat{d}$

Axial

Radial Digyration

Hyperbolic