The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

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Workshop on Topics in Quantum Turbulence

16 - 20 March 2009

Vibrating Forks in 4He at Very Low Temperatures

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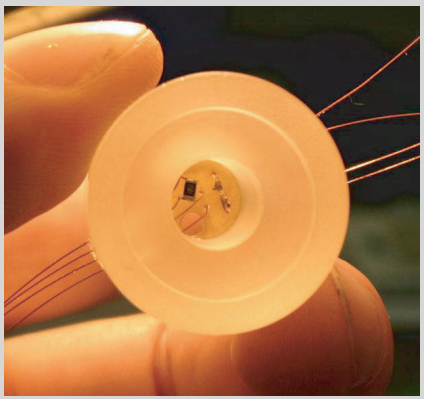
Vibrating Forks in Superfluid ^{4}He at very low temperatures



D.I. Bradley
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Outline

Tuning Forks

Experimental Cell

Laminar to Turbulent Transition:
Temperature and Pressure dependence

Anomalous damping:
Trapped vortices? (or dirt!)

New experimental cell

Preliminary results:
Metastability

Summary

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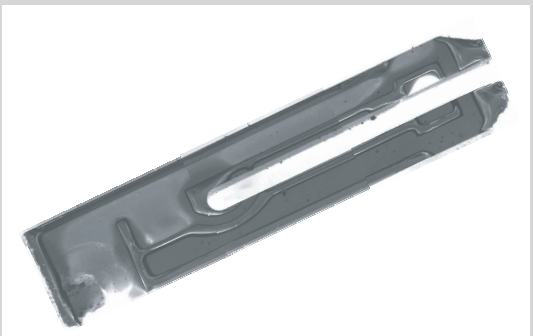
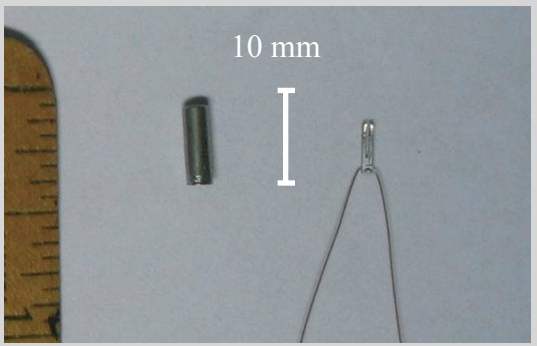
Quartz Tuning Forks





-Two identical resonators
- Driven in opposition of phase
- High quality factor
- Velocity measured as current
- No magnetic field required

- Different size, shape, electrode layout
- Contact: solder or epoxy

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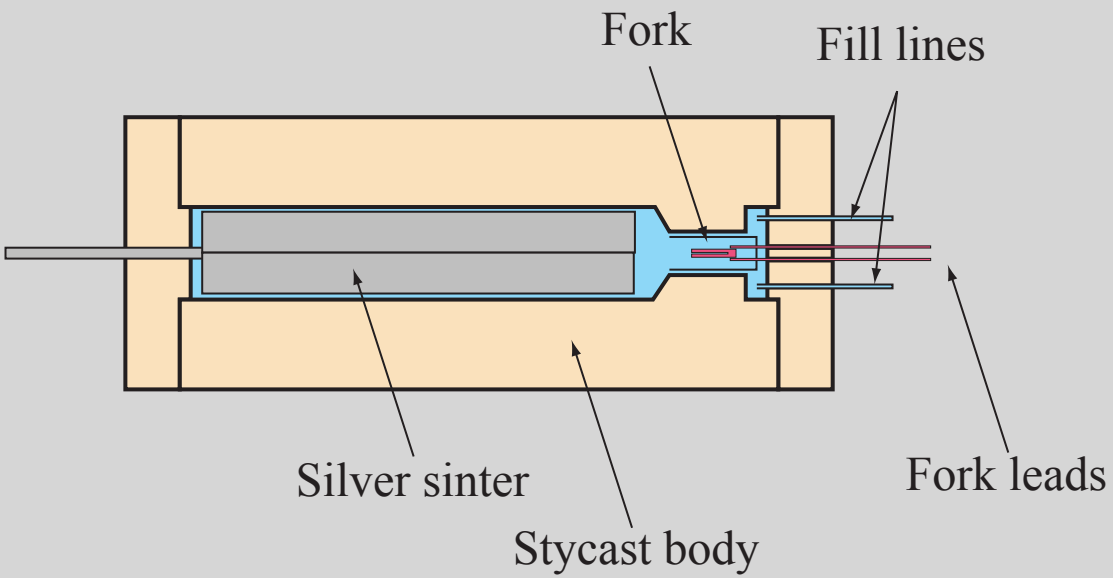
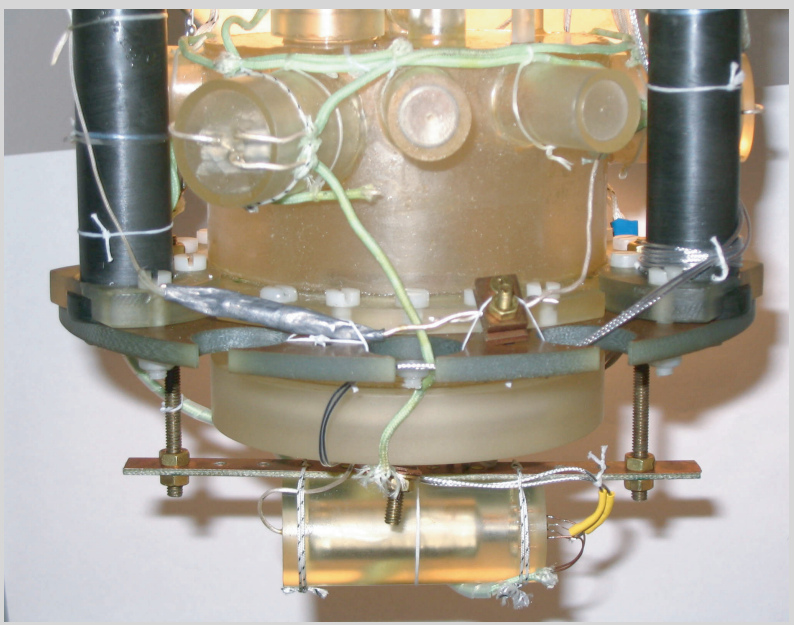
Experimental Cell





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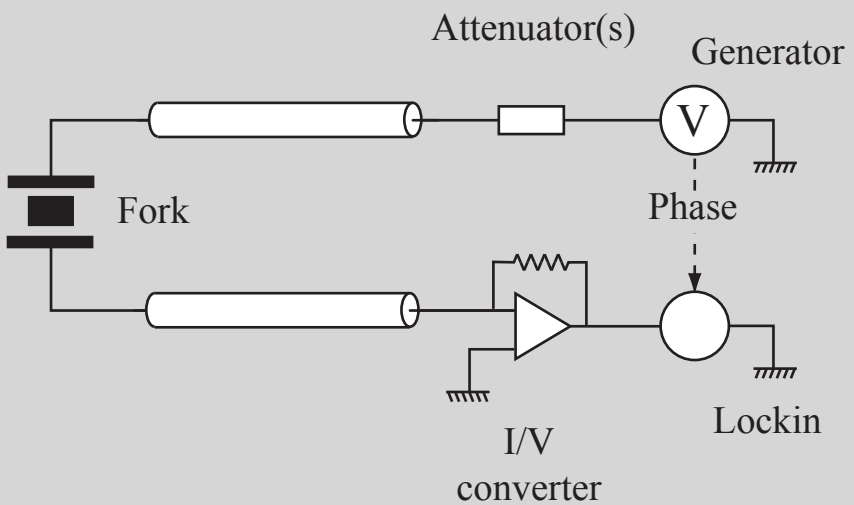
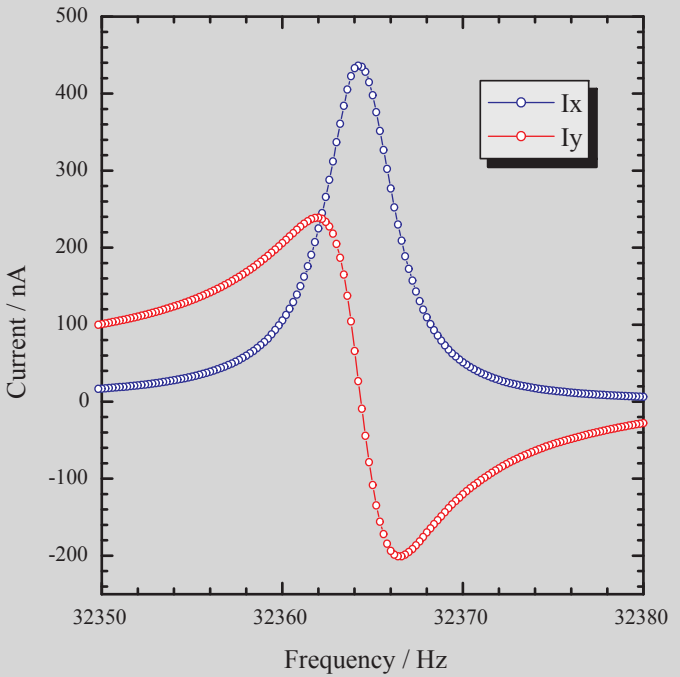
Measurements





Software:

- - Frequency Scan
- - Amplitude Scan
- - Time tracking

- Typically f_0 = 32 .770 kHz
- In air at room temperature, Δf_2 = 5Hz
- In vacuum at 5mK, Δf_2 = 50 mHz, Q = 640 000

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Force vs Velocity

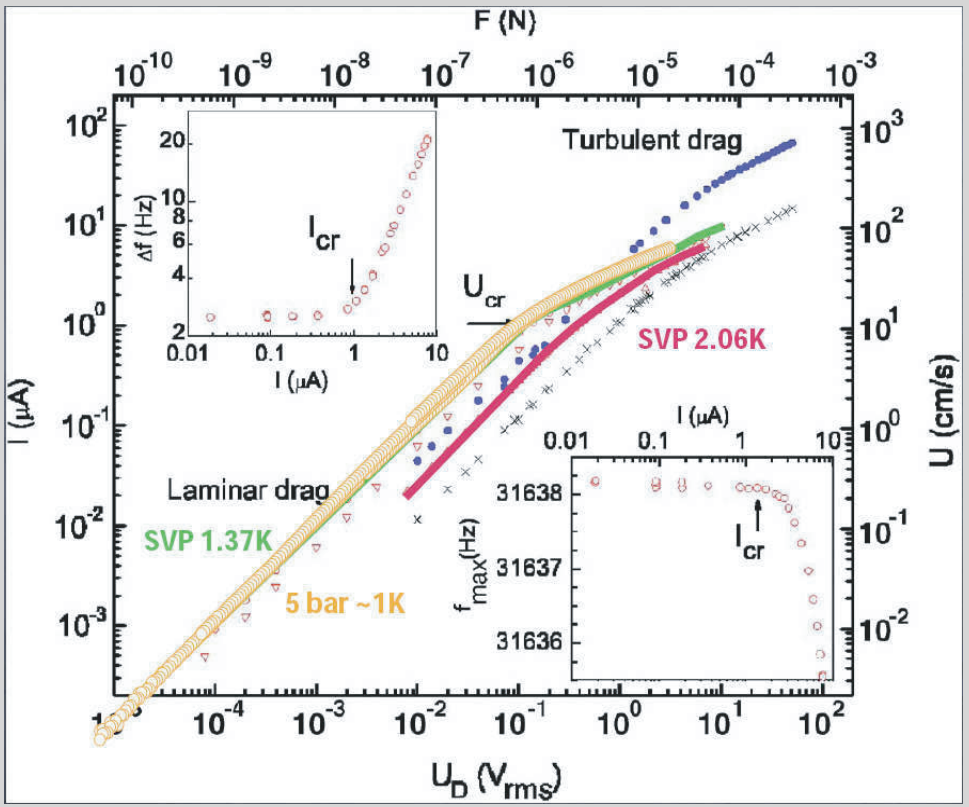
- Calibration using the fork constant "a":

$$I = a \cdot \dot{x}$$

$$F = a / 2 \cdot V$$

Height . Width / Drive $= a^2 / (4m^*)$

$a = 12.10^{-6}$ C/m



M. Blažková, D. Schmoranzer, and L. Skrbek
Phys. Rev. E 75, 025302 (R) (2007)

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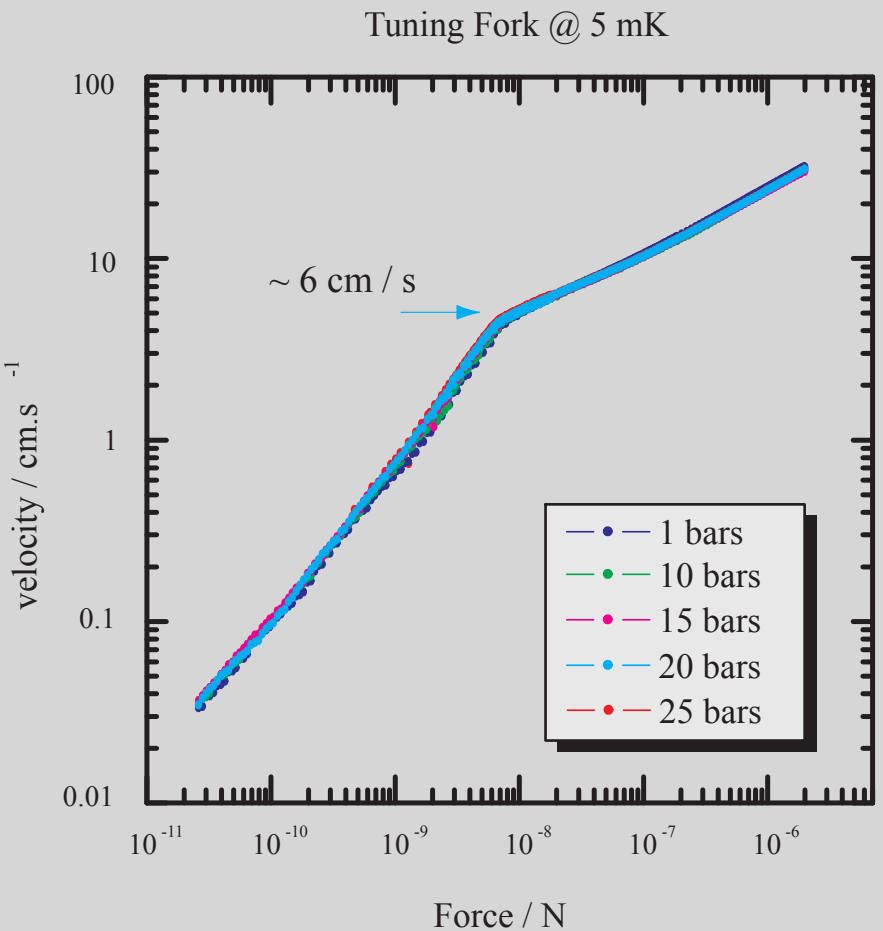
Pressure dependence



- Clear onset of turbulenced
- No Pressure dependence

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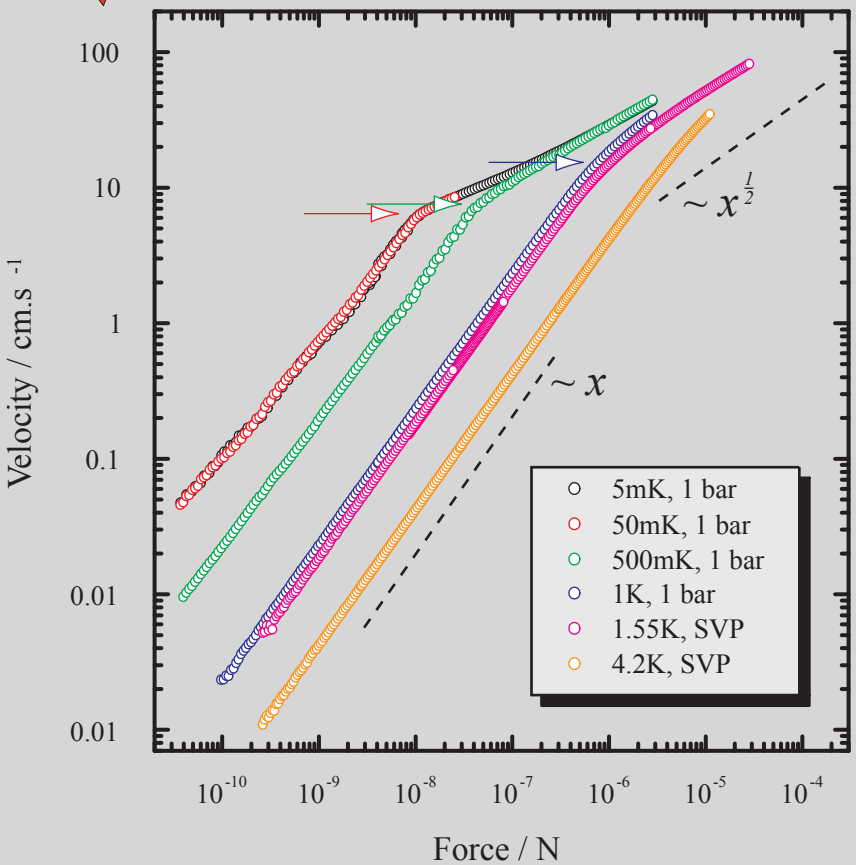
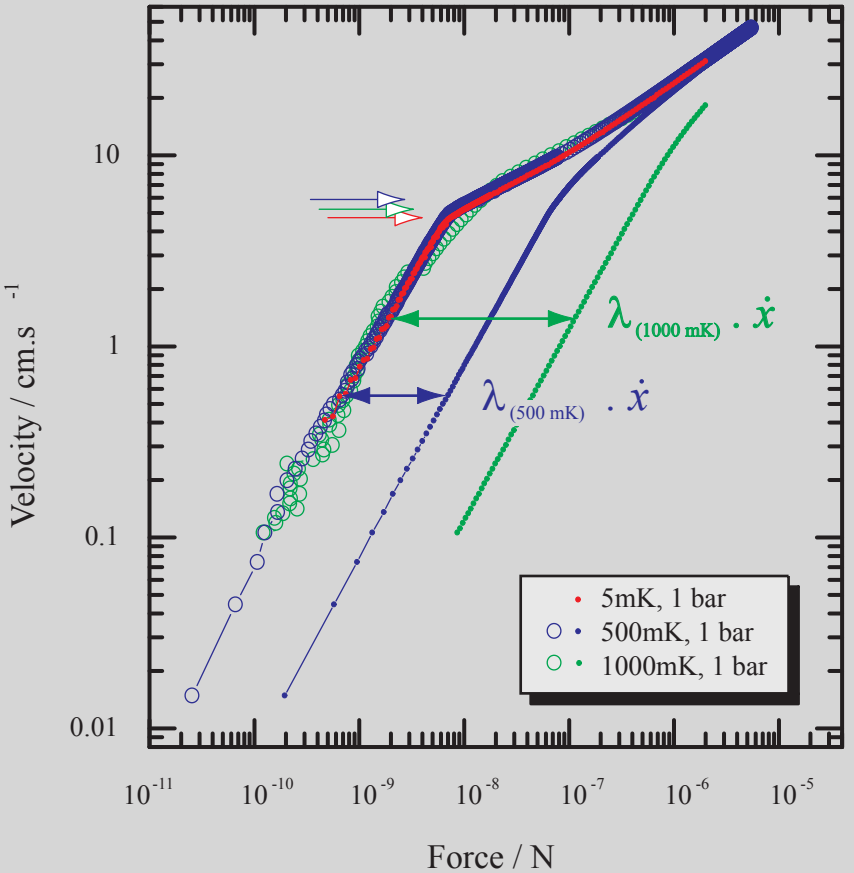
Temperature dependence





- Thermal damping from ~ 100 mK

- Apparent increase in transition velocity

- Only dependence: laminar term

- No temperature dependence of the critical velocity

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Drag coefficient

- Drag coefficient:

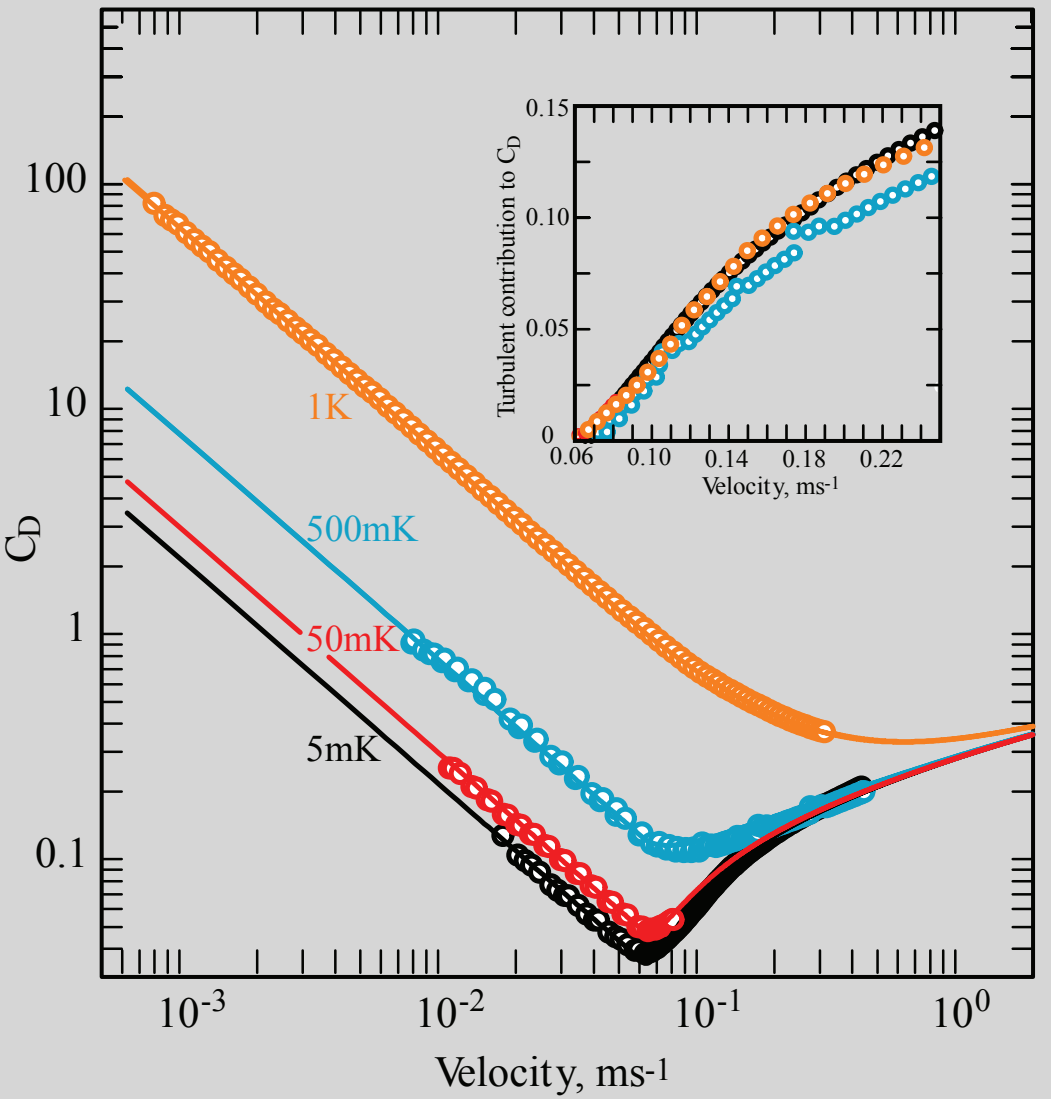
$$F = \tfrac{1}{2} C_D \rho A v^2$$

- Inspired from M. Blažková[(1)] et al. :

We use a modified version

$$C_D = \frac{\alpha}{v} + \beta H(v - v_c) \frac{(v^2 - v_c^2)}{v^2} \left(\frac{(\frac{v_c}{v} - 1)^{1/2}}{(\frac{v_c}{v} - 1)^{1/2} + \epsilon} \right)$$

- All data fit with $\beta = 1$, $\varepsilon = 10$
- Only α is adjusted from the laminar part of the curve



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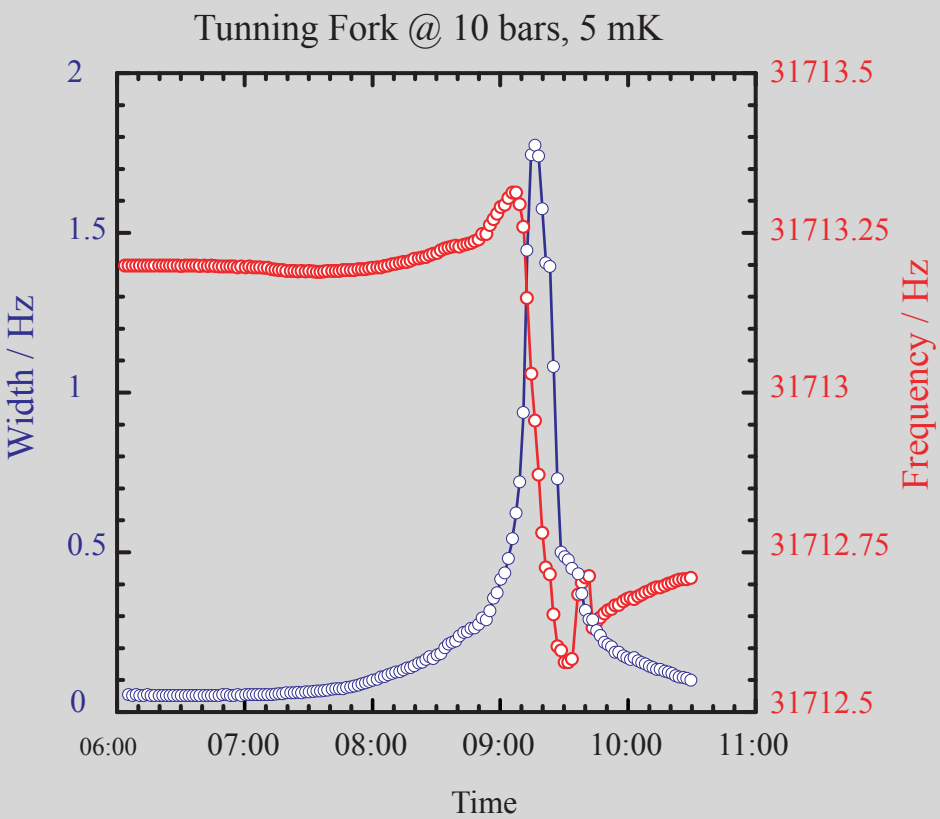
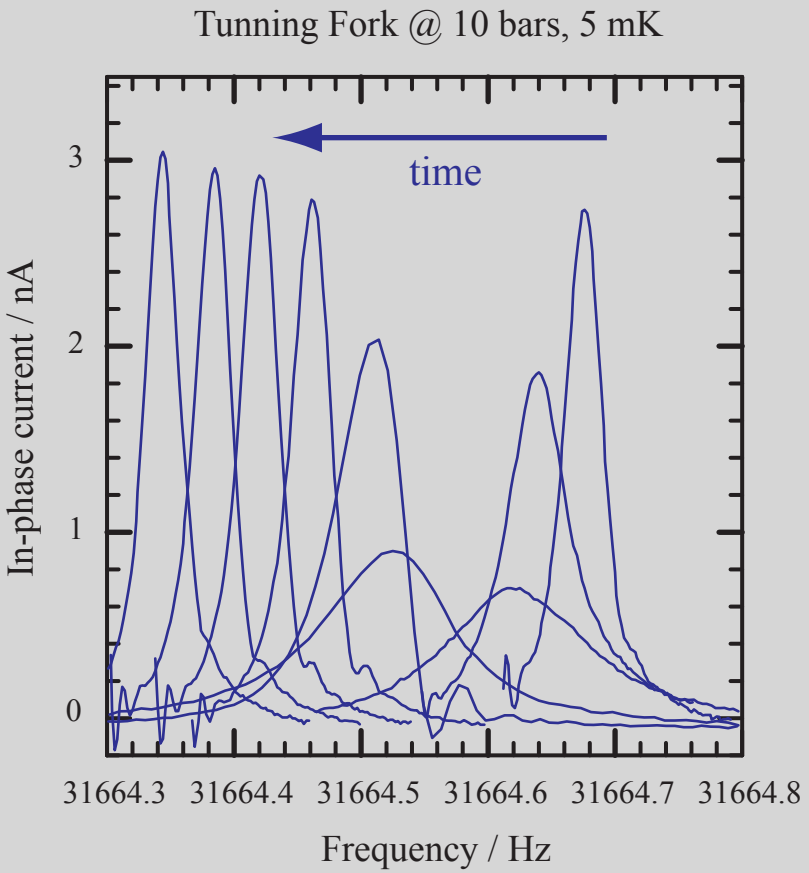
Anomalous Damping





- Large increase in the damping
- Spontaneous increase/decrease
-Very slow process

- Cannot be started: large drive, mechanical noise uneffective
- Can be cleared using pressure pulse

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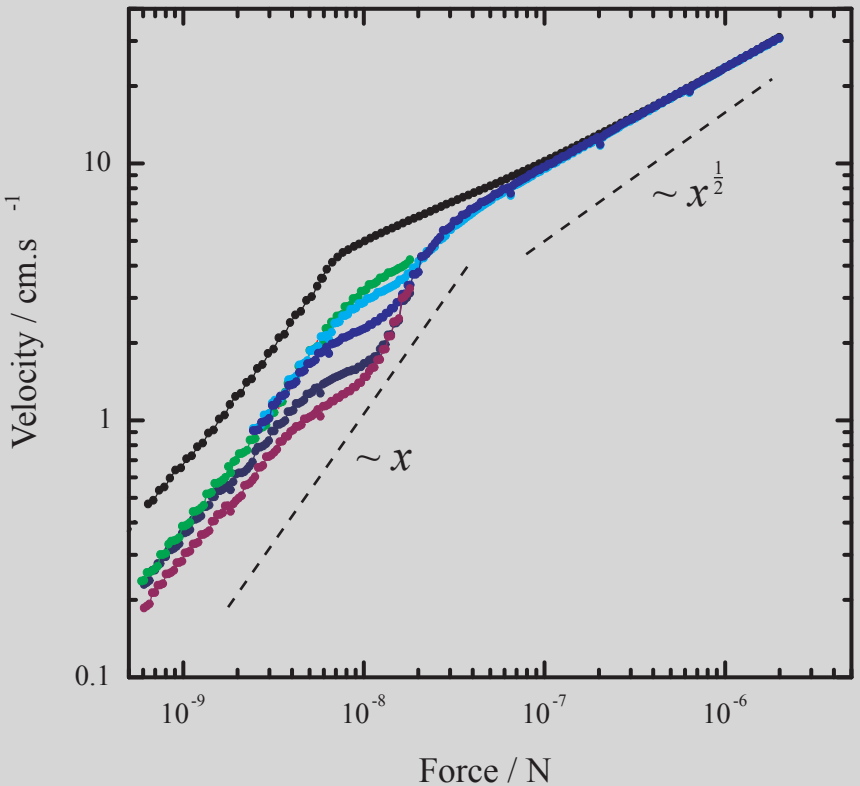
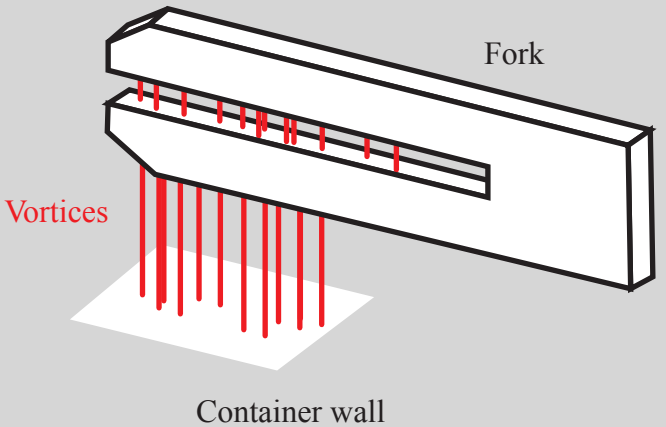
Anomalous damping





- Up and down amplitude sweeps shows same feature

- Slowly disappearing with time

- Vortices attached to the fork? (or impurities)

- Kelvin waves emit vortex rings?

- Radiating power of 10 pW would give ~ 10 000 vortices

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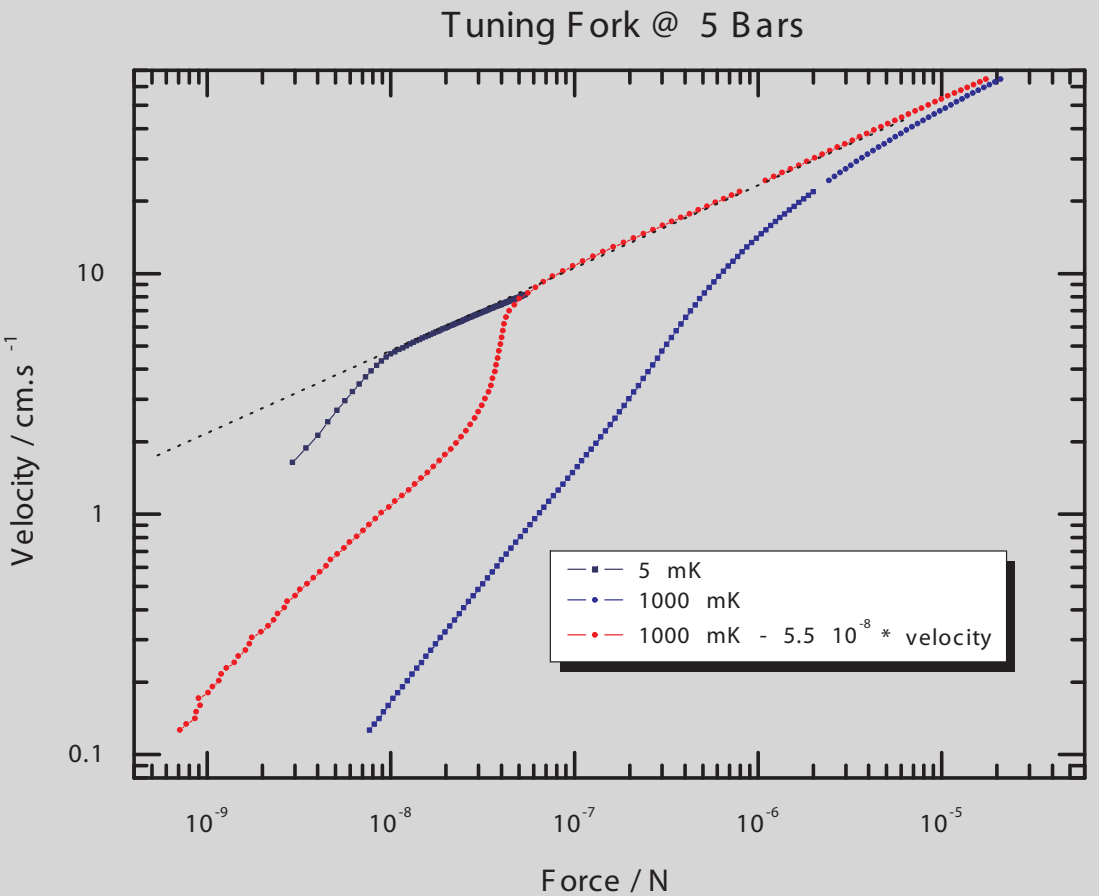
Anomalous damping at high temperatures



- Presence of anomalies at high temperature masked by thermal damping

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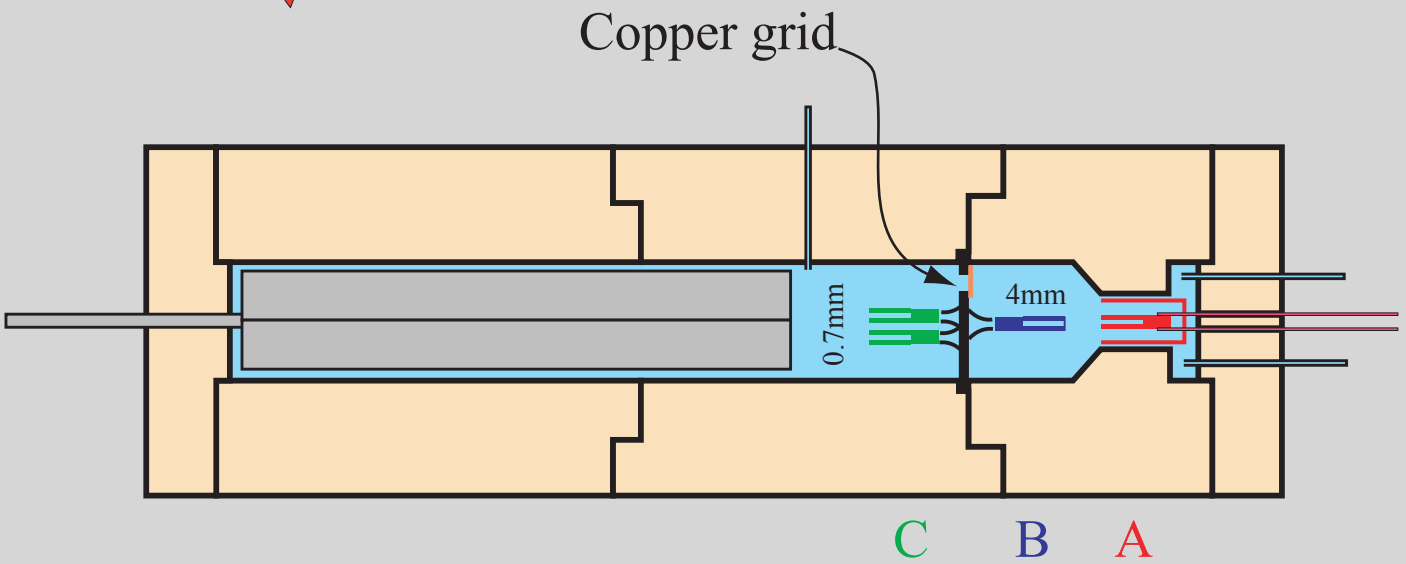
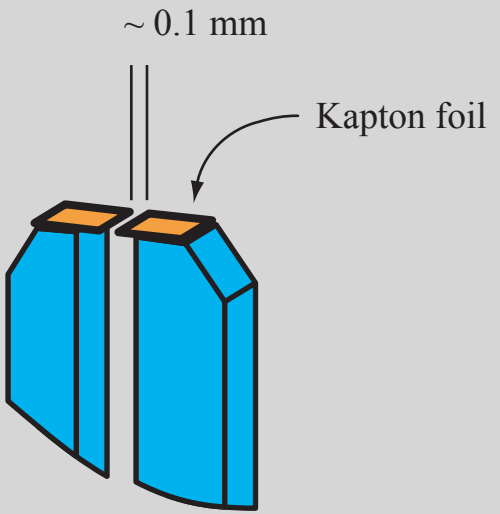
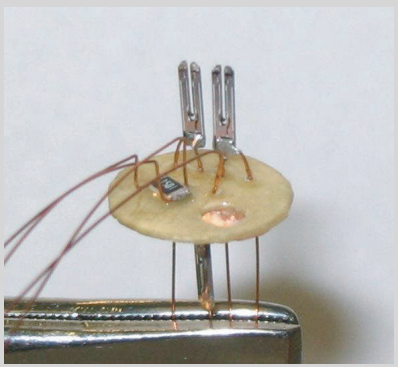
New Design





Tip of blue fork B



	f_0	f_0	f_0	f_0	Δf_2	Δf_2	Δf_2	Δf_2
4K vacuum	32657	32355	32711	32706	0.08	0.05	0.05	0.06
4K liquid	31820	31547	31918	31884	11.4	12.2	20.4	25.3
7mK superfluid	31722	31446	31828	31794	0.07	0.80	0.95	1.29

- Cross talking between C forks
- Vortices captured on B?

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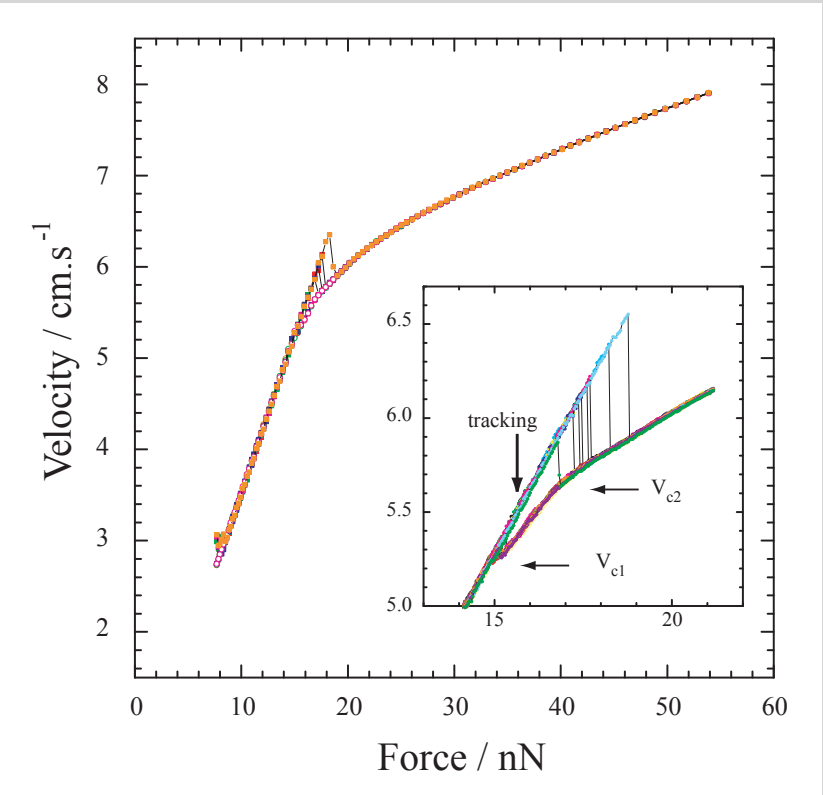
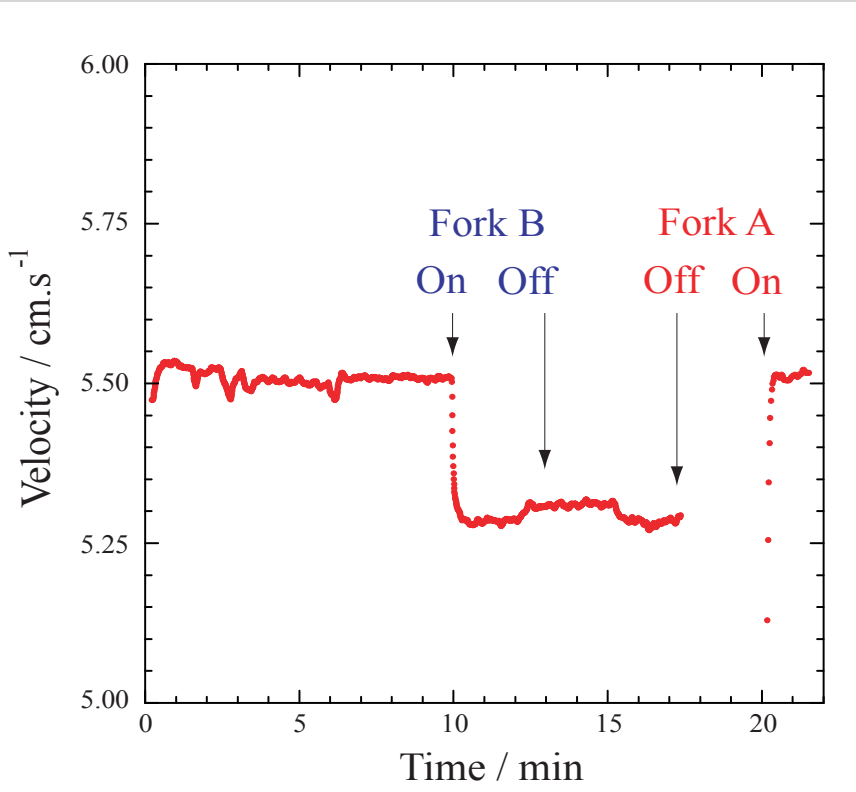
Metastability

Fork A at 1Bar, 7mK



Tracking Fork A: amplitude vs Time



- Hysteresis
- Jumps in both directions
- Two critical velocities

- B at 4.5 cm/s: No Drop
- B at 5.1 cm/s: Drop after 30 s
- B at 5.3 cm/s: Drop after 2s

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Summary

- We observed that the onset of turbulences is independent from pressure

- We observed that the turbulent part of the drag coefficient is independent from temperature up to 1K

- There seem to be two critical velocities at the onset of turbulences?

- The metastable laminar state can be forced into the turbulent state

- Cross talk between forks and the anomalous damping still require more work