Schedule

10 lectures + 1 guest seminar in 8 sessions

Tuesday April 4	9am-12am (3h)	Lectures 1/2
Tuesday April 11	9am-12am (3h)	Lectures 2/3
Tuesday April 18	*no lecture*	
Tuesday April 25	9am-12am (3h)	Lectures 4/5
Tuesday May 2	9am-12am (3h)	Lectures 5/6
Tuesday May 9	9am-11am (2h)	Lecture 7
Tuesday May 14	9am-11am (2h)	Lecture 8
Tuesday May 21	9am-11am (2h)	Lecture 9
Tuesday May 28	9am-11am (2h)	Lecture 10

Outline

1) Superconducting grains (BCS theory, fluctuations, parity effect)
2) Quasiparticle current in N/I/S junctions (cooling, charge imbalance, Coulomb blockade)
3) Andreev reflection (doubling of the noise, crossed AR, MAR)
4) Andreev bound states (quantum dots: Shiba state, Kondo effect vs superconductivity, SIS junction)
5) Classical Josephson effect (Meissner, SQUIDs, Fraunhoffer, Josephson radiation, Shapiro)
6) Quantum Josephson effects (Cooper pair box, Superconducting qubit)
7) Josephson chains and arrays (phase slips, BKT, superconductor/insulator transition)
8) Guest lecture on experimental aspects by Timothy Duty, University of New South Wales, Australia
9) Superconducting hybrids and proximity effect (N/S and F/S hybrids)
10) Topological superconductivity (Kitaev model, Majorana fermions, signatures)

- bibliography
- handwritten notes of previous lectures
- slides

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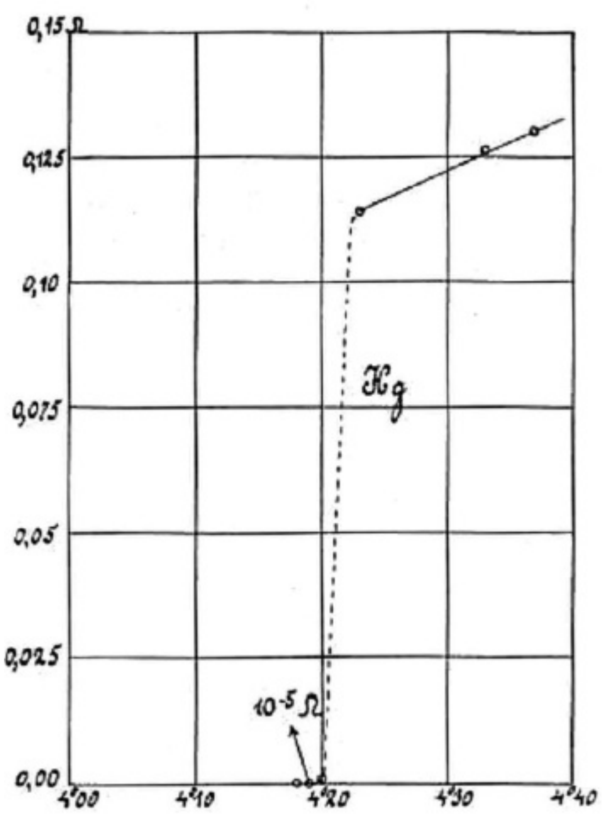
Lecture 1:

Superconducting grains

(BCS theory, fluctuations, parity effect)

Zero resistance state



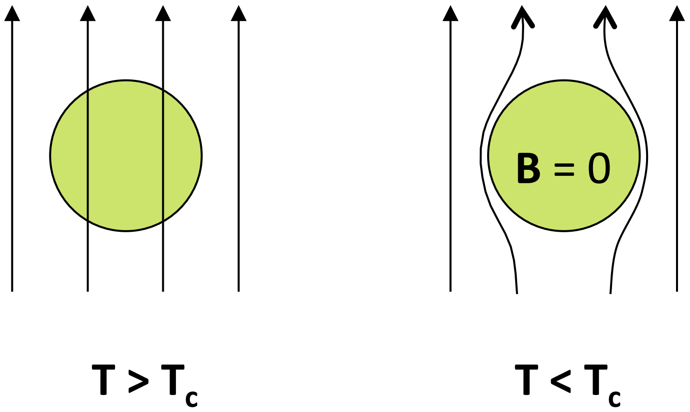
resistance

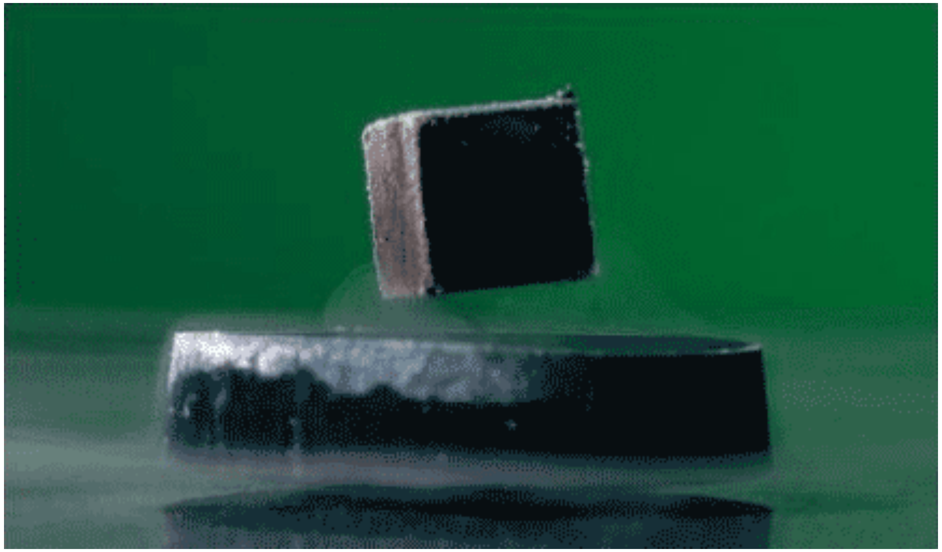
temperature

Kammerlingh Onnes (Leiden, 1911)

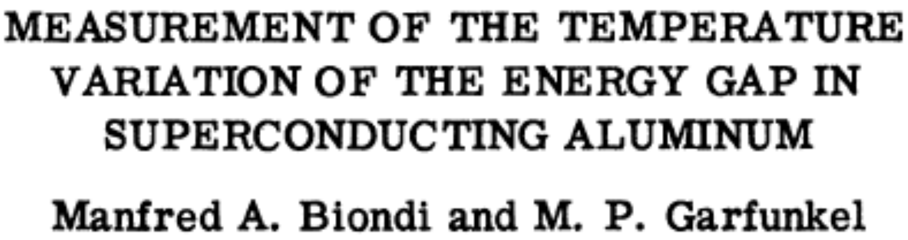
Magnetic field expulsion

Meissner-Oschenfeld (1933)





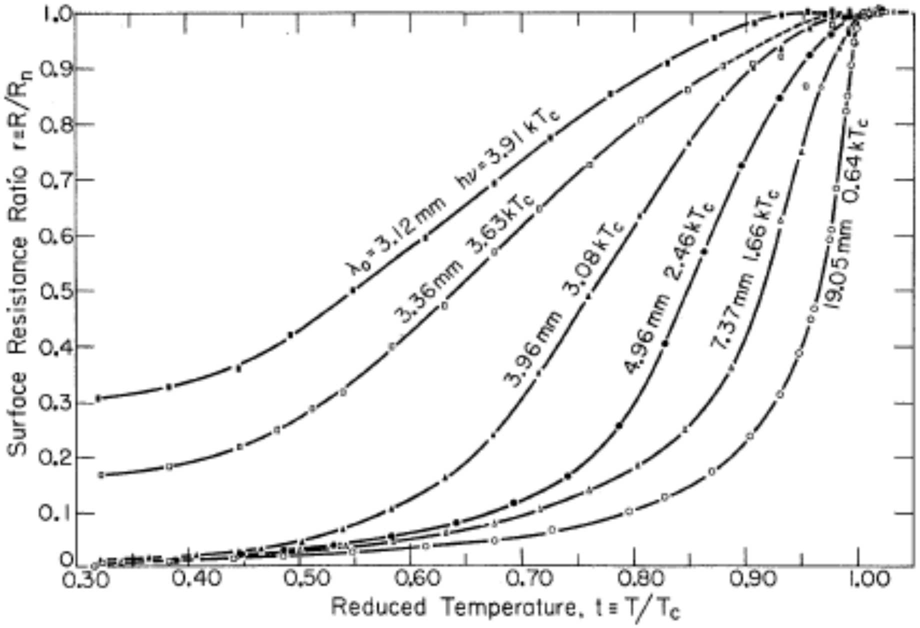
electromagnetic response and energy gap

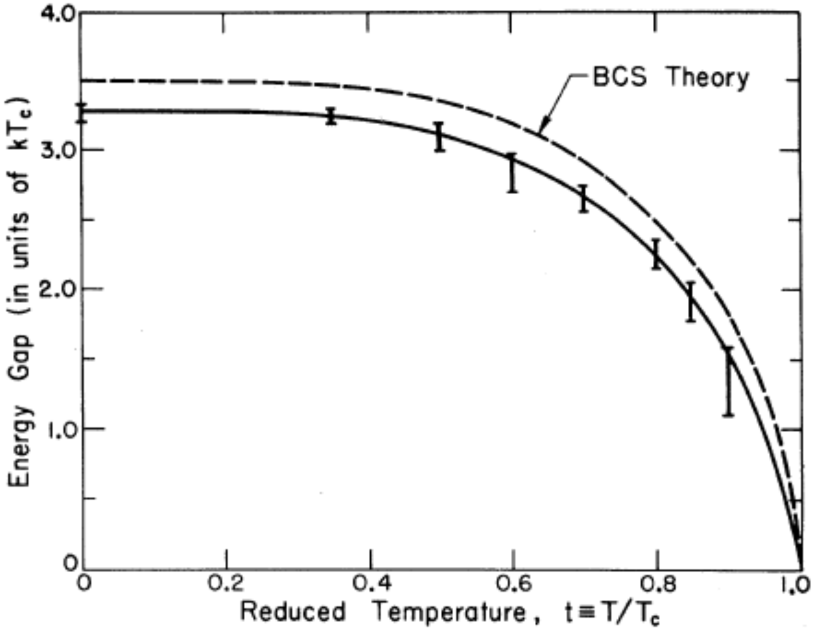


MEASUREMENT OF THE TEMPERATURE VARIATION OF THE ENERGY GAP IN SUPERCONDUCTING ALUMINUM

Manfred A. Biondi and M. P. Garfunkel

PRL **2**, 143 (1959)





Excess quasiparticles

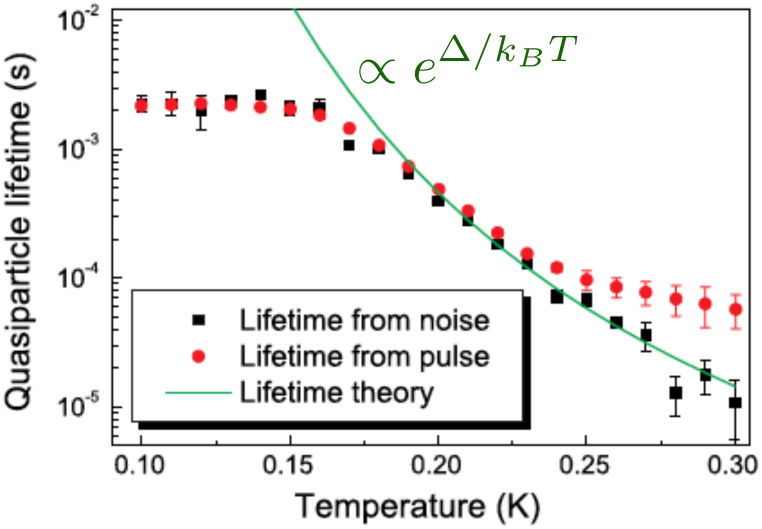
$$c(T) \simeq \nu_0 \sqrt{8\pi k_B T \Delta} e^{-\Delta/k_B T}$$

typical values in aluminum: $\Delta = 200\,\mu\mathrm{eV}$

$$c(100\,\mathrm{mK}) \approx 1\,\mu\mathrm{m}^{-3}$$

$$c(50\,\mathrm{mK}) \approx 10^{-6}\,\mu\mathrm{m}^{-3}$$

$$c(10\,\mathrm{mK}) \approx 10^{-51}\,\mu\mathrm{m}^{-3}$$



saturation of the lifetime in superconducting resonators at low T

$$\tau_r \simeq \frac{\tau_0}{2c} \frac{\nu_0 (k_B T_c)^3}{\Delta^2}$$

← de Visser *et al.*, PRL 2011

$$c \sim 25 - 55\,\mu\mathrm{m}^{-3}$$

normal-metal electron-phonon relaxation rate at energy Δ

Fluctuational specific heat

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN, Vol. 42, No. 2, FEBRUARY, 1977

Specific Heat of Superconducting Fine Particles of Tin. I. Fluctuations in Zero Magnetic Field

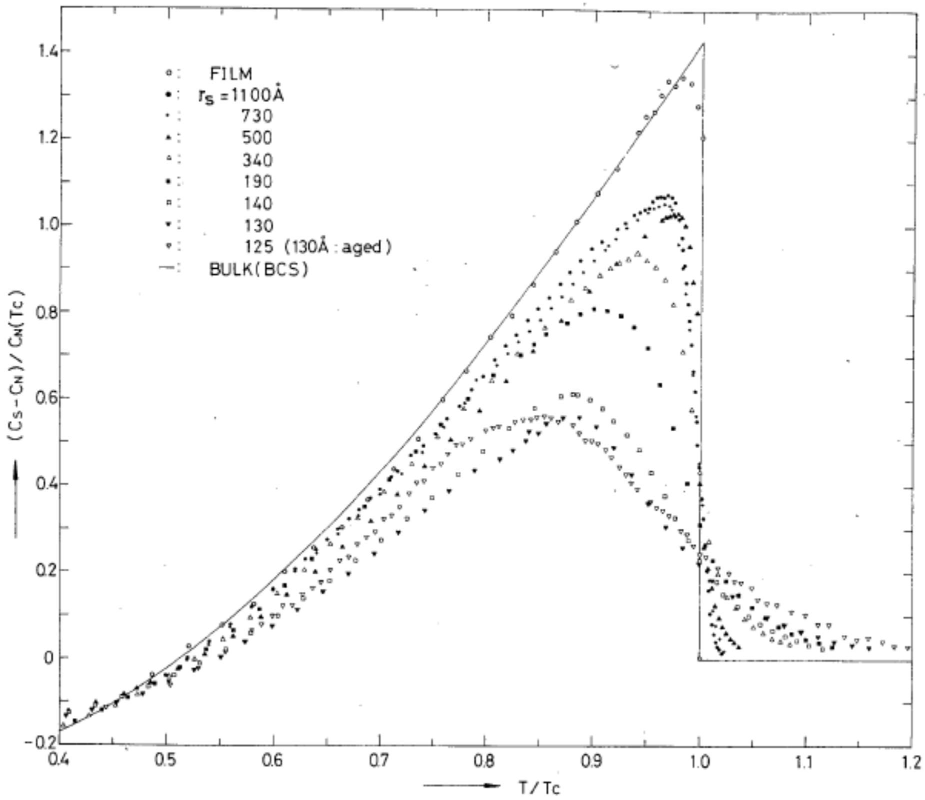


Fig. 5. Specific heat difference for Sn particles with different particle sizes as a function of the reduced temperature. The difference is normalized to $C_N(T_c)$, where $C_N(T_c)=\gamma T_c$ with $\gamma=1.78$ mJ$\cdot$K$^{-2}\cdot$mol^{-1}.

Fluctuational diamagnetic response

Fluctuation Superconductivity in Mesoscopic Aluminum Rings

Nicholas C. Koshnick,[1] Hendrik Bluhm,[1] Martin E. Huber,[2] Kathryn A. Moler[1]*

Science **318**, 1440 (2007)

Fig. 2. SQUID signal (left axis) and ring current (right axis) as a function of applied flux Φ_a for two rings, both with $d = 60$ nm and $w = 110$ nm. The fluctuation theory (dashed red) was fit to the data (blue) through the temperature analysis shown in Fig. 3. (**A** to **C**) $R = 0.35$ μm, fitted $T_c(\Phi_a{=}0) = 1.247$ K, and $\gamma = 0.075$. The green line is the theoretical mean field response for $T = 1.22$ K and shows the characteristic Little-Parks line shape, in which the ring is not superconducting near $\Phi_a = \Phi_0/2$. The excess persistent current in this region indicates the large fluctuations in the Little-Parks regime. (**D**) $R = 2$ μm,