Comments on Supersolid

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Outline

I. ODLRO≡coherent state: a phase $\theta(r)$ exists

II schematic coherent state wave function

III Thermodynamics of supersolid (with WFB and DH)

IV Dynamics of supersolid: a vortex liquid? (DH)

Why not a supersolid?

Debye Temp is 25 degrees, putative vacancy energy is 15--how can vacancies not be present in quantum fluctuating ground state?

Argument goes back to Chester: absent magical action at a distance, G S <u>must</u> contain finite densities of all local configurations.

Phase space trumps configuration energy. Or, T=0 in 3D-> finite T in 4D.

ODLRO or Phase?

Coherent State: defined mean value of phase $\phi(r)$ of Boson field; that is, the boson field has a mean value.

ϕ is meaningless unless number fluctuates: $\langle N|\psi|N\rangle=0$ (and vice versa) :N and ϕ are conjugate.

Only rational, ***local*** description of condensed state is coherent state, since ODLRO implies N fluctuates in any local region. Think of coherent state as "wave-packet" in the N variable.

Proposed schematic wave function for supersolid:

$$\Psi = \prod_{sites\, i} (b_i^* + g e^{i\phi_i}) |vac\rangle, \text{ where}$$

$$b_i^* = \int dr f(r - r_i) \psi^*(r)$$

g is <<1 and is just a real number; $g^2 \approx$ the incommensurability.. f is a normalized wave function centered on site i, thought of as a localized Hartree-Fock solution to an effective Hamiltonian as discussed in my book.

Further about wave f'n

Hartree-Fock clearly doesn't work with strong He interactions. Could improve either with pseudopotential a la Huang et al; or similar idea of multiplying by Jastrow function.

Superfluid stiffness comes from hopping energy:

$$H_{sf} = \sum_{i,j} g^2 t_{ij} \cos(\varphi_i - \varphi_j)$$

Thermodynamics of incommensurate solid

Wave function of this type has vacancies (or interstials) completely delocalized--I e condensed. Energy will depend on relative density of sites quite steeply but not singularly ---we assume no cusp.

There are of course phonons, but I don't think any second Goldstone boson. Non-quadratic terms in the displacements will give the usual Gruneisen dependences of coefficients on the total energy of the phonons, that is on T^4. In equations:

continued--

$$\varepsilon \equiv (N_C - N)/N_C = \varepsilon_0 + \delta$$

,

$$F = E_0 + E_2\delta^2/2 - (D_0 + D_1\delta + ...)T^4 + ...$$

minimize, and

,

$$\delta \approx D_1 T^4 / E_2$$

$$C_V = AT^3 + BT^7$$

Note NO Schottky Term!!!

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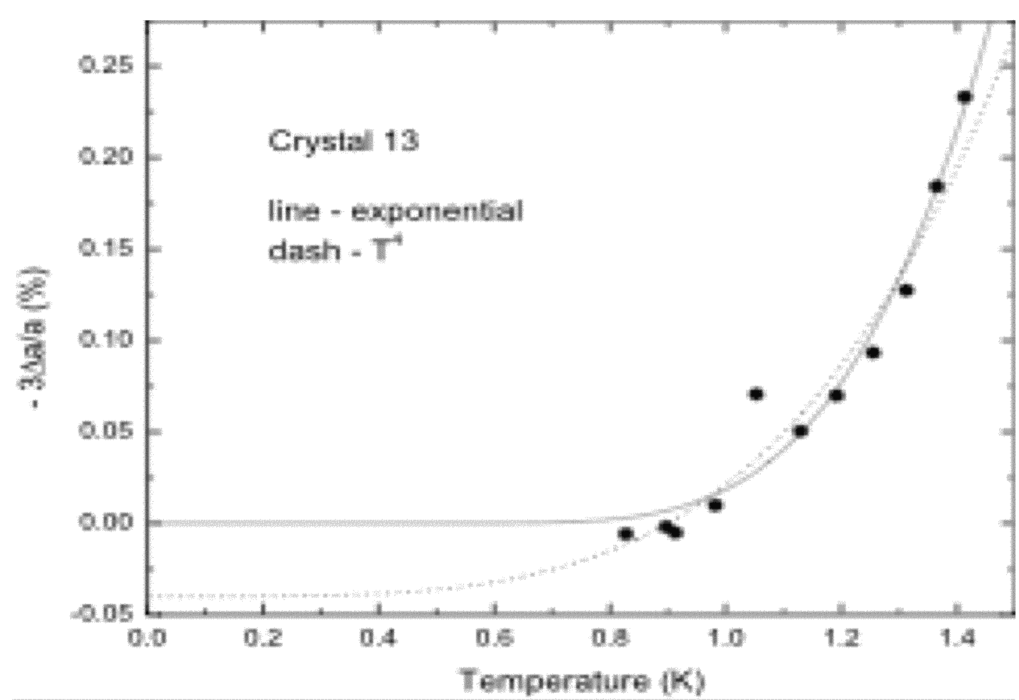
[1] W. R. Gardner, J. K. Hoffer and N. E. Phillips, Phys. Rev. A 7, 1029 (1973).

$$F = E_0 - D_0T^4 - D_1^2T^8/2E_2 + ...$$



Vortex Fluid or Supersolid?

Observed: not conventional phase transition but dissipation peak, nonlinear response. Dissipation? T must be >Tc.

Vortex fluid: $\nabla \cdot J=0$, so $\nabla^2\phi=0$. State characterized by positions of vortices. [like Kosterlitz-Thouless, >Tc, in 2D]

To rotate must introduce vortices. Vortex energy, current NOT reduced by thermal background of vortices : $E \propto \ln[1/\Omega]$
(Note log dependence of δI, experimentally)

We (D Huse) propose phenomena caused by <u>sluggishness of vortex motion.</u> T-dependent (and He-3 dependent?) rate of vortex response. see illustration

Note similarity to Ong's Nernst phenomena in pseudogap vortex liquid!!
$\Omega=0$ is DC: explains non-leaking data!!

Huse Proposal