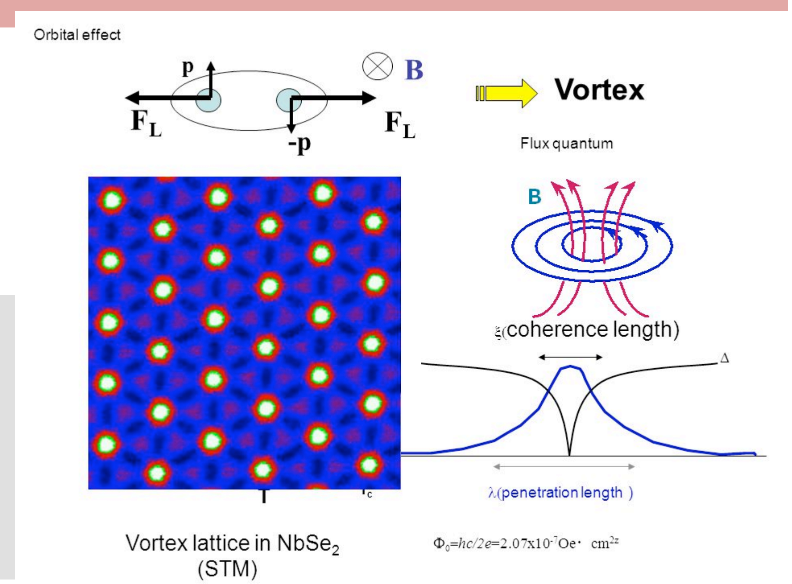
Bogolyubov Institute for Theoretical Physics
XXIV Davydov Lectures
Kiev, December, 26, 2017

Alex Abrikosov: life and scientific biography

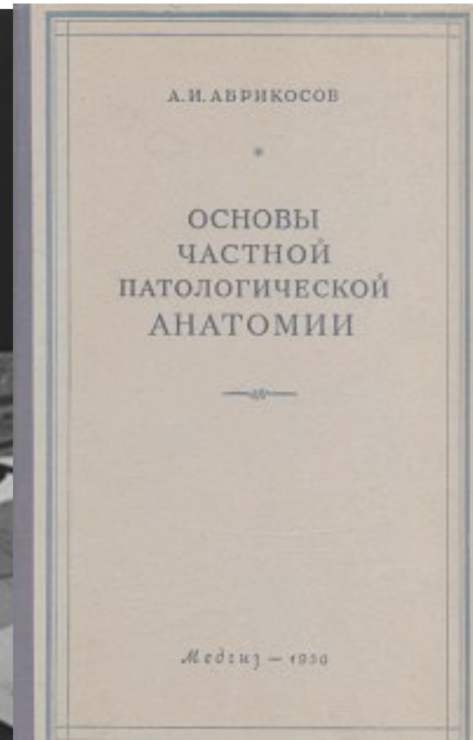


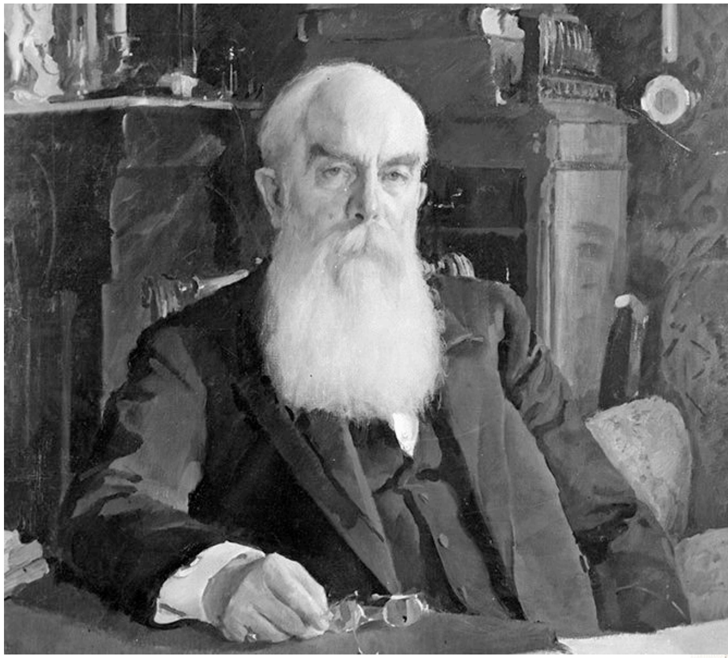
Andrey Varlamov
SPIN-CNR, Italy
Doctor H.C. of Bogolyubov Institute

I. The family and childhood

Alexei Abrikosov was born on 25 June 1928 in Moscow in the family of well-known physicians: Alexei Ivanovich Abrikosov and Fani Wulf

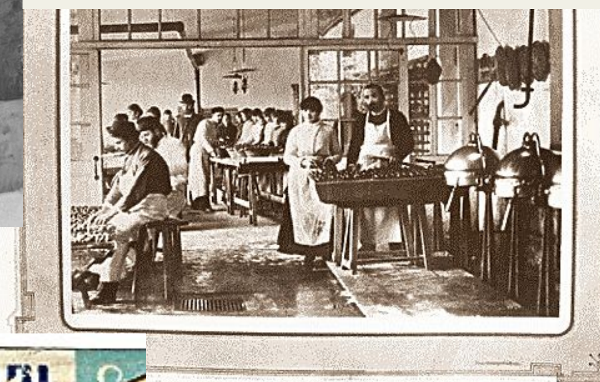
Alexei Ivanovich Abrikosov





The Abrikosov's family was known in the Russian Empire from the early 19th century as the founders and owners of a confectionery shop which gradually became a large concern and was awarded the title of «Supplier to the Court of His Imperial Majesty».

Alexei Ivanovich Abrikosov-the older



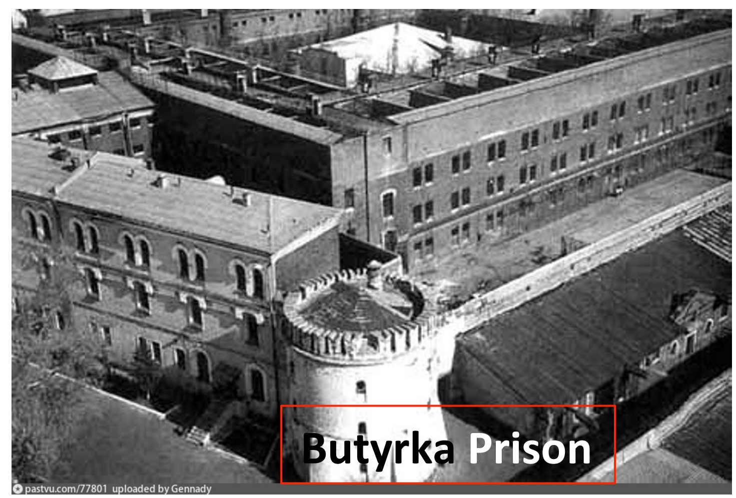
Dmitri Ivanovich Abrikosov (1876 - 1951), uncle of Alexei Abrikosov, was the last (1917 - 1925) ambassador (Charge d’Affaires) of the Russian Empire in Japan

Uncle - Dmitri Ivanovich Abrikosov

Anna Ivanovna Abrikosova (Mother Catherine of Siena) - aunt of Alexei Abrikosov

23 January 1882, Moscow, Russian Empire – 23 June 1936, **Butyrka Prison**, Moscow, Soviet Union

Anna Ivanovna Abrikosova was a Russian Catholic Religious Sister, literary translator, and victim of Joseph Stalin's concentration camps. She was also the foundress of a Byzantine Catholic community of the Third Order of St. Dominic which has gained wide attention, even among secular historians of Soviet repression. In an anthology of women's memoirs from the GULAG, Anna Abrikosova is described as, "a woman of remarkable erudition and strength of will". She is also mentioned by name in the first volume of The Gulag Archipelago by Alexander Solzhenitsyn.



Since 2002, Mother Catherine's life has been under scrutiny for possible beatification by the Holy See. Her current title is **Servant of God**.

ПОХВАЛЬНАЯ
ГРАМОТА

Выдана ученику 6-го класса „Б" 336 школы
Красногвардейского района
(села, города, района и края - области)
Абрикосову Алексею
(фамилия и имя)

ЗА ОТЛИЧНЫЕ УСПЕХИ И ПРИМЕРНОЕ ПОВЕДЕНИЕ

Москва
город, село
„10" июня 1941 г.
№ 101

М П

Директор школы

Учителя:

Honorable mention for Alexei Abrikosov

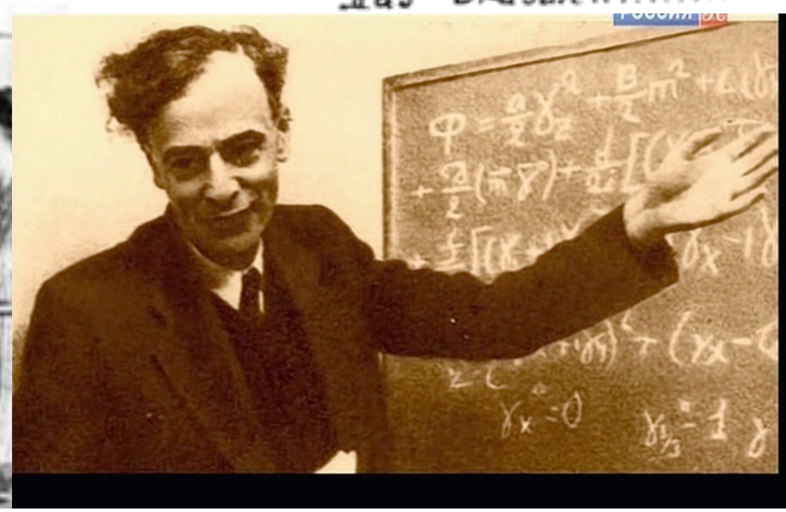
Years of studying

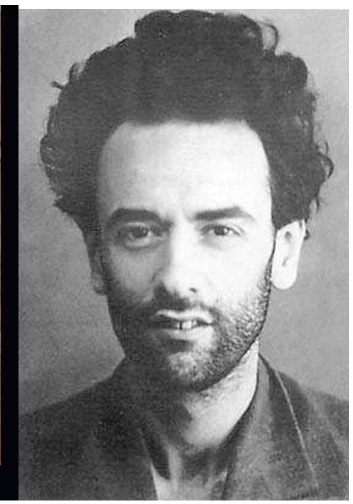
In 1943, 15 years old, Alexei Abrikosov graduated from high school and entered Moscow Power Engineering Institute. In 1945, he transferred to the Faculty of Physics of Lomonosov Moscow State University.

Moscow University old building

Landau School of Theoretical Physics

The **Kharkiv Theoretical Physics School** was founded by Lev Landau in Kharkov, Ukraine.
It is sometimes referred to as the **Landau school** — more precisely, one might say that Landau's group at Kharkiv was the beginning of the Landau school that, after Landau moved to Moscow, included new generations of theoretical physicists from the countries of the former Soviet Union.
Lev Landau was the head of the Kharkhiv Theoretical Physics School from 1932 to 1937.



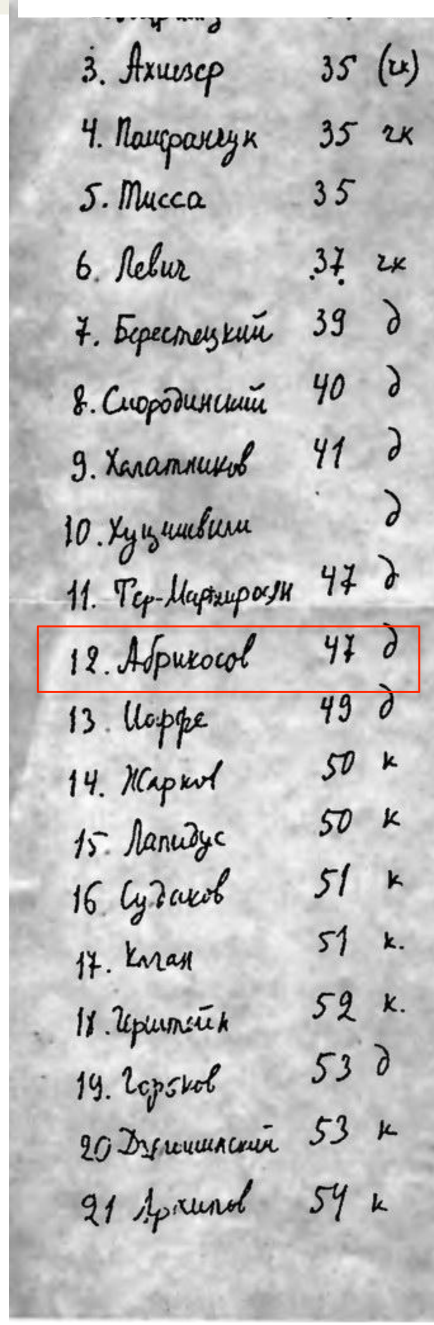


II. Landau’s favorite pupil

Alexei Abrikosov's scientific growth was directly influenced by Lev Landau. At the age of 19, he passed the **theoretical minimum**, in a year he graduated ***cum laude*** from the Faculty of Physics of MSU.

Theoretical Group of IPP, 1956.
Stand: S. Gershtein, L. Pitaevsky. L. Vainshtein, R. Arkhipov I. Dzyaloshinskiy. Sit: Прозорова, A. Abrikosov, I. Khalatnikov, L. Landau, E. Lifshitz.

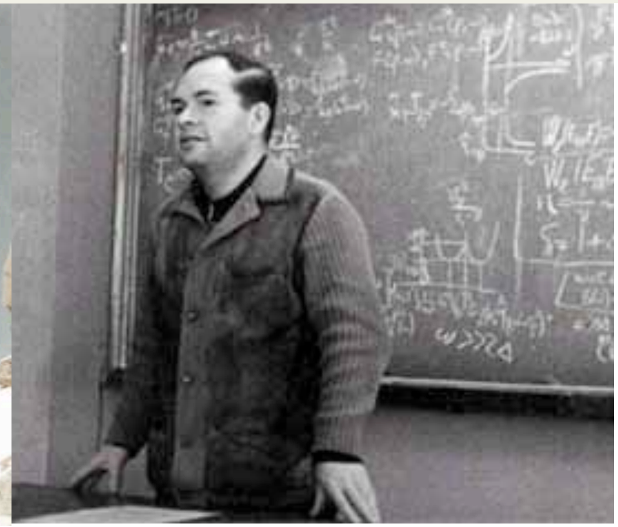
list of students who passed the **theoretical minimum**. Handwriting of Landau



3.	Ахиезер	35	(гк)
4.	Померанчук	35	гк
5.	Тисса	35	
6.	Левич	37	гк
7.	Берестецкий	39	д
8.	Смородинский	40	д
9.	Халатников	41	д
10.	Хуцишвили		д
11.	Тер-Мартиросян	47	д
12.	Абрикосов	47	д
13.	Иоффе	49	д
14.	Жарков	50	к
15.	Лапидус	50	к
16.	Судаков	51	к
17.	Коган	51	к.
18.	Эйдельштейн	52	к.
19.	Горьков	53	д
20	Дзялошинский	53	к
21	Архипов	54	к
24	Михаил	55	
25	Питаевский	55	
26	Сагдеев	55	
27	+Бекаревич	55	к
28	Шапиро	56	к
29	Бычков	57	к
30	Шаповал	58	
31	Фальковский	59	
32	Андреев	59	
33	Кондратенко	59	
34	Русинов	59	
35	Маринов	60	
36	Берков	60	

Assault of the peaks: mountaineering and scientific

A. Abrikosov and S. Gershtein



A. Abrikosov

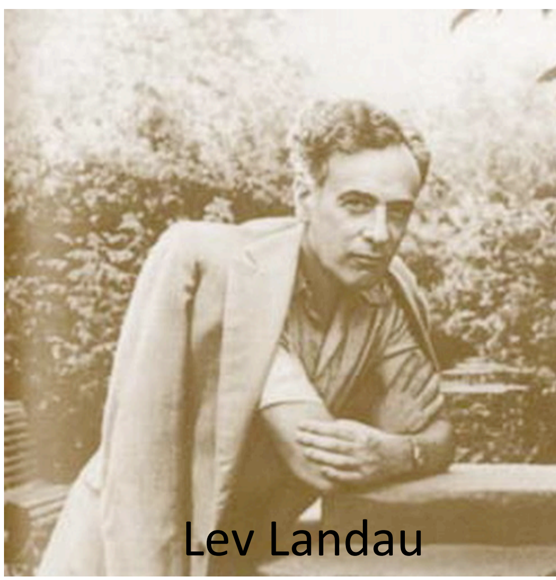
In 1950, at the age 22, Alexey Abrikosov defended his PhD thesis devoted to the study of thermal diffusion in fully or partially ionized plasma.

Khorloogiin Choibalsan was the Communist leader of the Mongolian People's Republic
Born: February 8, 1895,
Died: January 26, 1952, Moscow, Russia

Almost two of the subsequent decades of Alexei Abrikosov's scientific work were spent at the Institute for Physical Problems (IPP) of RAS


Petr Kapitza

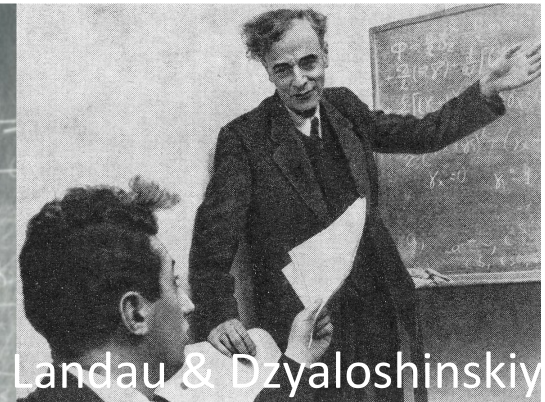

Institute for Physical Problems


Lev Landau


I. Khalatnikov, L. Landau, E. Lifshitz


I. Dzyaloshinskiy

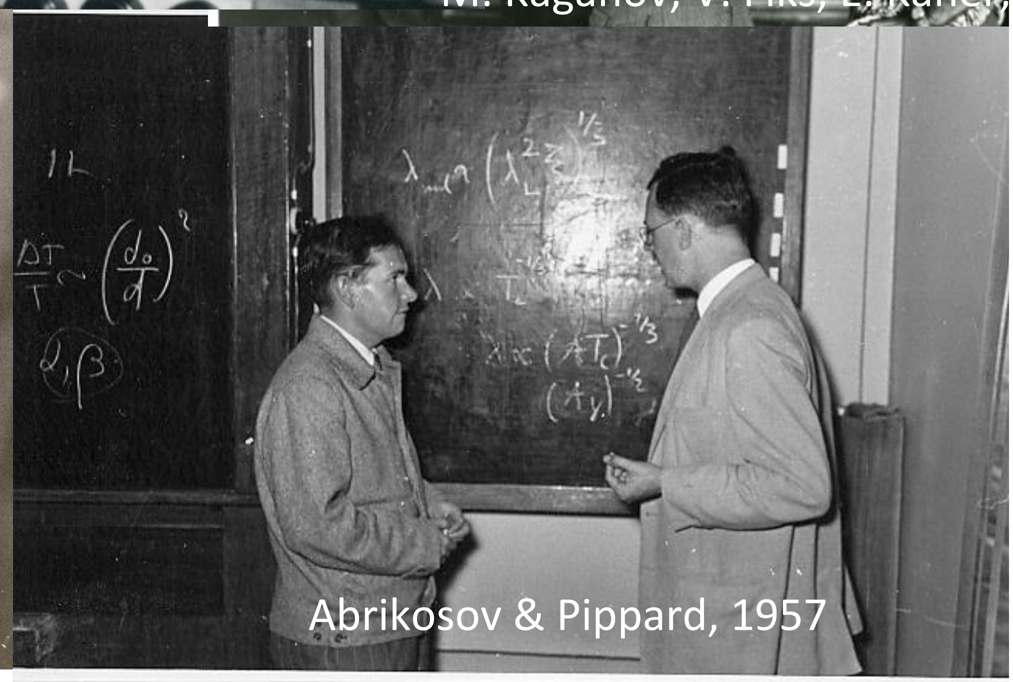
Gor’kov & Abrikosov



Landau & Dzyaloshinskiy

M. Kaganov, V. Fiks, E. Kaner,

R. Gurzhi, L. Pitaevskiy, E. Kaner, L. Gor’kov



Abrikosov & Pippard, 1957

III. Discovery of the type II superconductivity

1950: Ginzburg-Landau Phenomenology Ψ-Theory of Superconductivity

$$\boxed{\delta \mathcal{G} = \int dV \left\{ \alpha\tau|\Psi|^2 + \frac{b}{2}|\Psi|^4 + \frac{1}{4m}\left|\left(-i\hbar\nabla + \frac{2e}{c}\mathbf{A}\right)\Psi\right|^2 + \frac{H^2}{8\pi} \right\}}$$

$$\frac{1}{\varkappa^2}\frac{d^2\Psi}{dx^2} + \Psi(1 - A^2) - \Psi^3 = 0,$$

$$\left.\frac{d\Psi}{dx}\right|_b = 0,$$

$$\frac{d^2A}{dx^2} - \Psi^2 A = 0$$

$$\varkappa = 3\left(\frac{2}{7\zeta(3)}\right)^{1/2}\left(\frac{\pi\hbar}{v}\right)^{3/2}\frac{cT_c}{\hbar p_0}.$$

Experimentally for superconductors of those times κ << 1

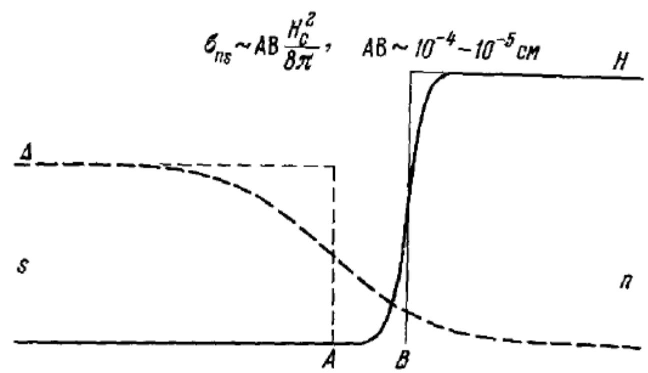
Great successes of the GL theory

1 *The critical field and magnetization of a thin film. Supercooling and superheating*

2 *The critical current of a thin wire with $\varkappa \ll 1$*

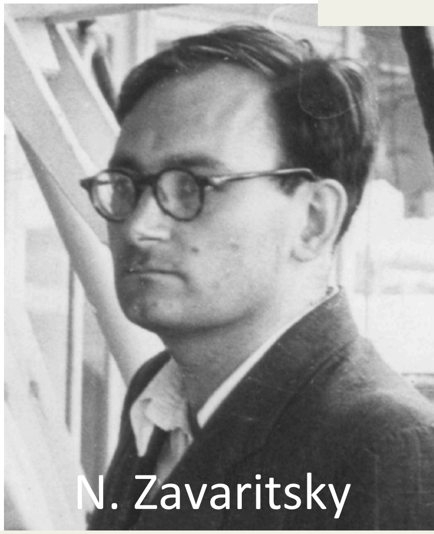
3 *Quantization of the magnetic flux*

4 *Surface energy at the interface between the normal and superconducting phases*



$\boxed{\kappa < 1/\sqrt{2}}$

Experimental Verification of the GL theory



N. Zavaritsky

In 1951-1952, Abrikosov and Zavaritsky, an experimentalist from IPP, were engaged in verifying the predictions of the recently developed Ginzburg-Landau theory of superconductivity concerning critical magnetic fields for thin films.

From Abrikosov's Nobel lecture:

"Nikolay Zavaritskii, started to measure the critical field of thin films. Theory and experiment fitted perfectly, including the change of the nature of the transition: first order at larger thicknesses and second order at smaller ones. Everything seemed OK but Alexander Shalnikov, the boss of Zavaritskii was not satisfied. He said that the films used by Zavaritskii were bad, since they were prepared at room temperature. The atoms of the metal, evaporated on a glass substrate, could agglomerate, and therefore the film, actually consisted of small droplets.

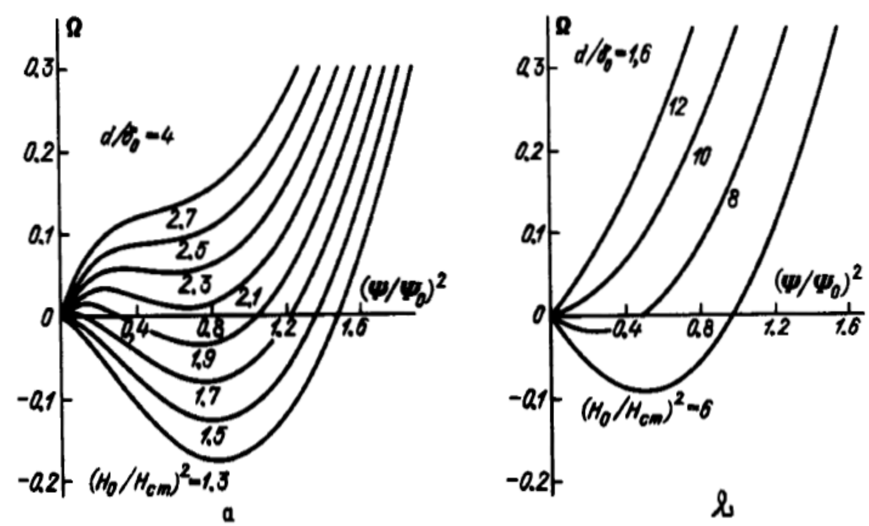


Fig. 109.

Observed contradictions

In order to avoid that, Shalnikov recommended to maintain the glass substrate at helium temperature during evaporation and until the measurements were finished. Zavaritskii followed this advice, and the result was a surprise: the dependence of the critical field on the thickness, or temperature (the theory contains the ratio of the thickness to the penetration depth, which depends on temperature), did not fit the predictions of the Ginzburg-Landau theory.
Discussing these results with Zavaritskii, we couldn't believe that the theory was wrong: it was so beautiful, and fitted so well the previous data. Therefore we tried to find some solution in the framework of the theory itself, and we found it.

The equations of the theory, where all entering quantities were expressed in corresponding units, depended only on the dimensionless "material" constant, which was later called the Ginzburg-Landau parameter. Its value could be defined from the surface energy between the normal and superconducting phases. The latter, in its turn could be calculated from the period of the structure of the intermediate state. These data for conventional superconductors led to very small values of and therefore the calculations in the paper by Ginzburg and Landau were done for this limiting case. It was also established that with increasing value of the surface energy between the superconducting and normal layers would become negative, and since this contradicted the existence of the intermediate state, such a case was not considered.

Discovery of Abrikosov's vortex state

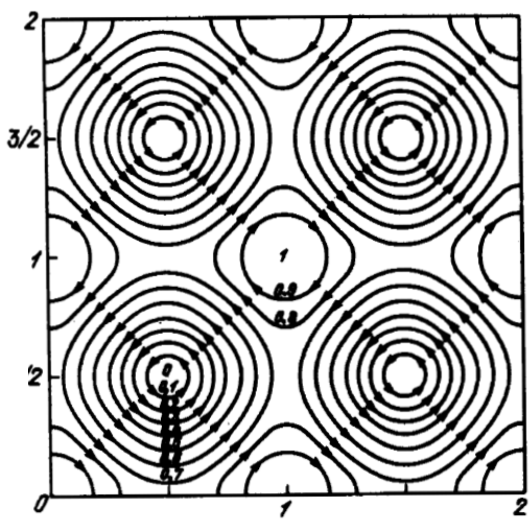
After that, Abrikosov passed to studying the magnetic properties of massive second-order superconductors. He succeeded to found the formal solution of the GL equations with $\kappa > 1/\sqrt{2}$

$$(-i\varkappa^{-1}\nabla + \varkappa^{-1}\nabla\chi - \mathbf{A})^2|\Psi| - |\Psi| + |\Psi|^3 = 0.$$

$$\Psi = |\Psi|\, \mathrm{e}^{i\chi}$$

$$\Psi = \sum_{n=-\infty}^{\infty} C_n \exp\left[\mathrm{i}kny - \frac{1}{2}\varkappa^2\left(x - \frac{kn}{\varkappa^2}\right)^2\right].$$

$$\Psi = C\exp\left(-\frac{1}{2}\varkappa^2 x^2\right)\vartheta_3\left[1; (2\pi)^{1/2}\varkappa\mathrm{i}(x+\mathrm{i}y)\right].$$



In result Abrikosov came to the conclusion that the transition from the superconducting to normal state with increasing field proceeds gradually, the field having two critical values

Lower critical field H_{c1}

$$\varepsilon_0 = \tfrac{1}{2} n_s \int_\xi^\delta \frac{2 m v_s^2}{2} 2\pi\rho \, d\rho = \frac{\pi n_s \hbar^2}{4m} \int_\xi^\delta \frac{d\rho}{\rho} = \frac{\pi n_s \hbar^2}{4m} \ln\left(\frac{\delta}{\xi}\right) = \frac{\pi n_s \hbar^2}{4m} \ln \varkappa$$

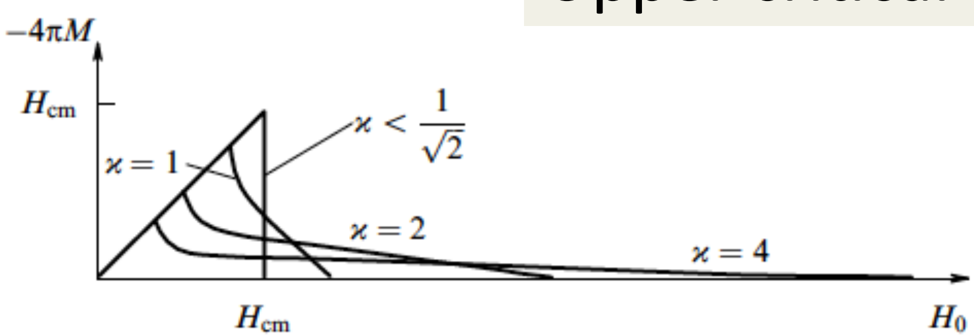
$$M = \tfrac{1}{2} n_s \frac{2e}{c} \int_\xi^\delta \rho v_s 2\pi\rho \, d\rho = \pi \frac{e\hbar n_s}{mc} \int_\xi^\delta \rho \, d\rho \approx \frac{\pi e \hbar n_s}{2mc} \delta^2$$

In the presence of a magnetic field H the vortex acquires a magnetic energy $-MH$. The smallest field at which an elementary vortex can appear corresponds to $\varepsilon_0 - MH = 0$ or

$$H_{c1} \sim \frac{H_{cm}}{\varkappa} \ln \varkappa.$$

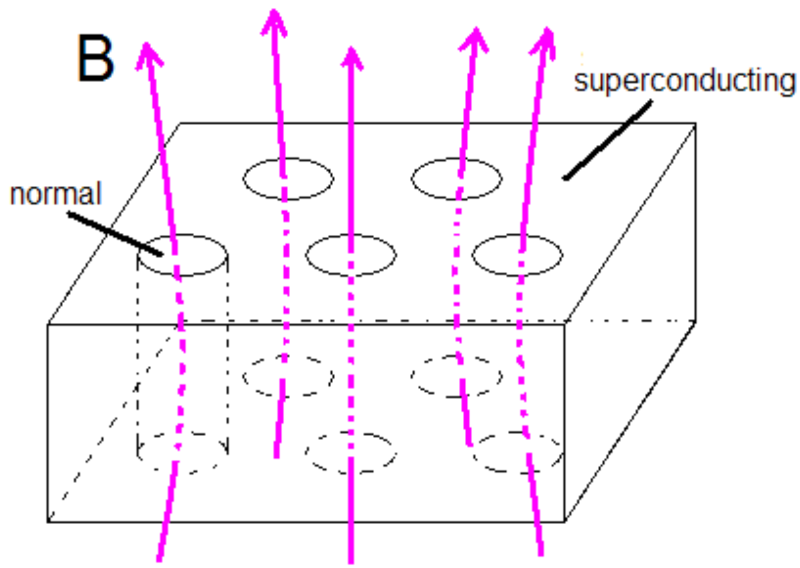
Upper critical field H_{c2}

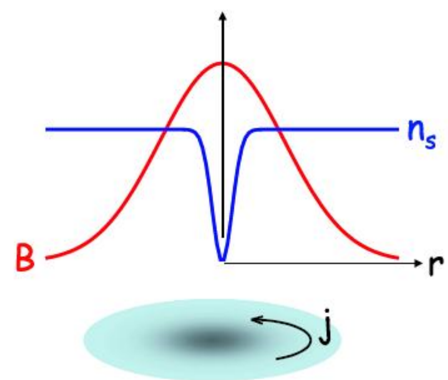
$$r_L \sim \frac{cp_\perp}{eH} > \xi.$$

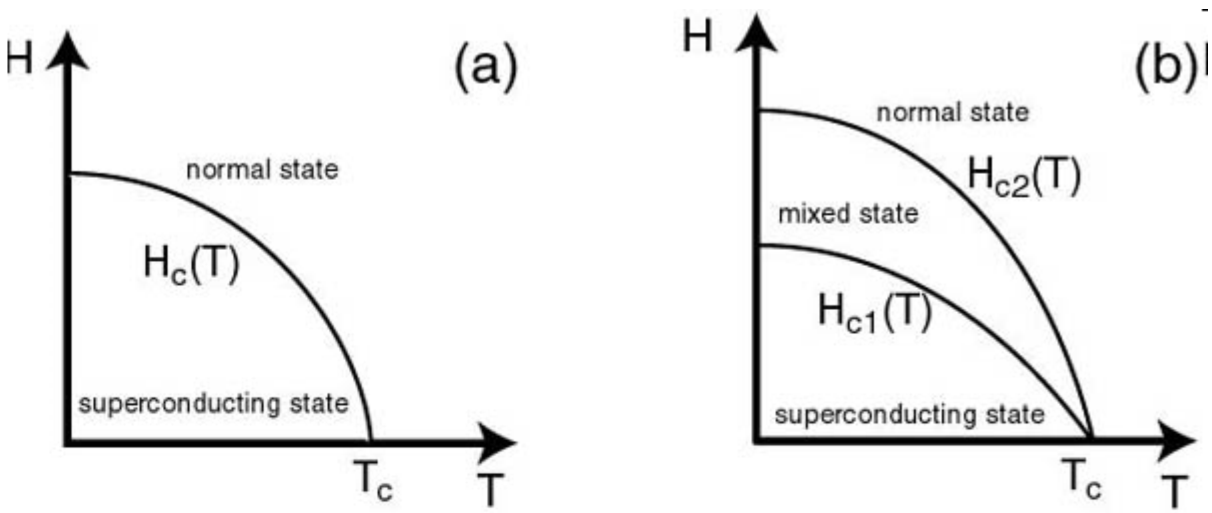


$$H_{c2} \sim \frac{c\hbar}{e\xi l} \sim \frac{c\hbar}{el} \frac{\Delta}{\hbar v} \sim H_{cm} \frac{\delta_L}{l} \sim H_{cm} \varkappa.$$

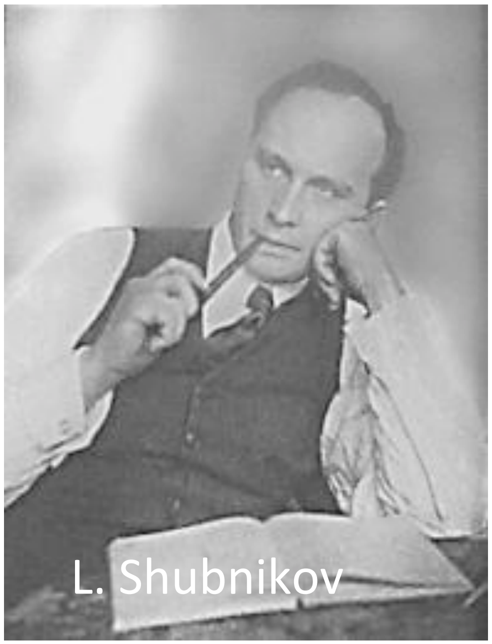
Between these critical values, the external magnetic field in the form of thin filaments of the magnetic flux, surrounded by vortex currents, gradually penetrates the superconductor. These quantum vortices form a regular structure (now known as the Abrikosov vortex lattice).

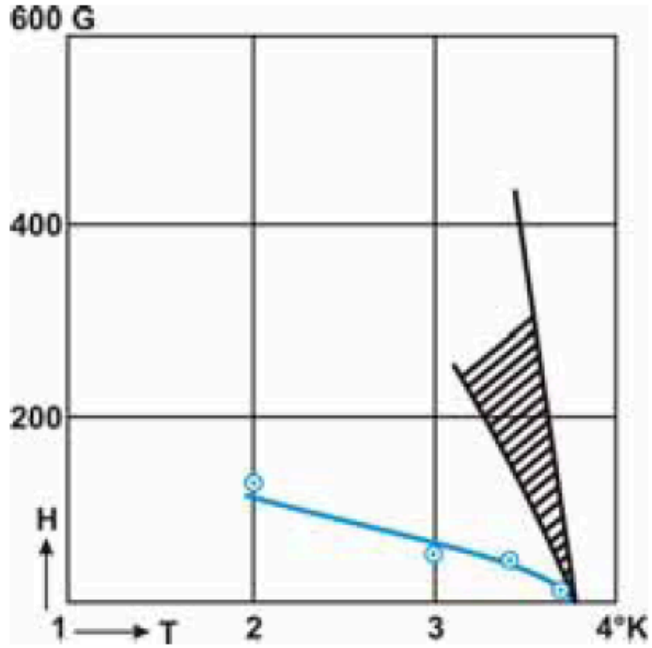






Having compared his results with the experimental curves of superconducting alloy magnetization obtained in the 1930s, Abrikosov found a remarkable coincidence. The authors, however, explained their data by the inhomogeneity of the specimens.





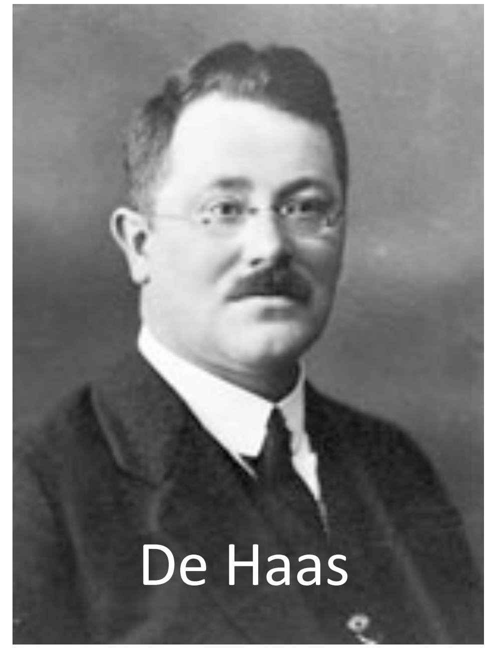
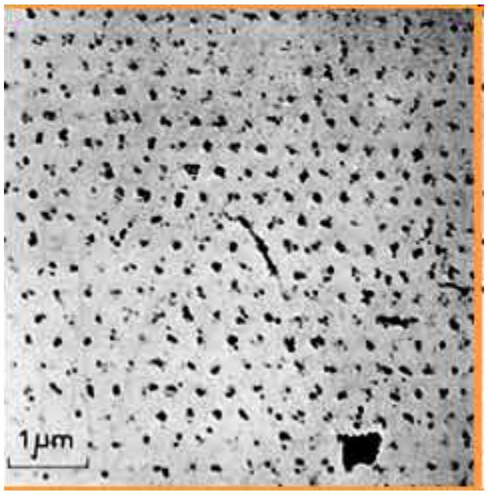


Fig. 11. Temperature dependence of the incipient penetration of magnetic field into the superconducting alloy Pb+64.8wt%Tl. The hatched region denotes the region of gradual flux penetration in magnetic field according to the electrical resistance measurement data (After De Haas & Casimir-Jonker, 1935a).

Abrikosov’s paper, without which it is now impossible to imagine the physics and technology of superconductivity, appeared in 1957, but the experimentalists only bought in to the vortex lattice ten years later after direct observations using the magnetic decoration method.



U. Essmann and H. Trauble
Max-Planck Institute, Stuttgart
[Physics Letters 24A, 526 (1967)]

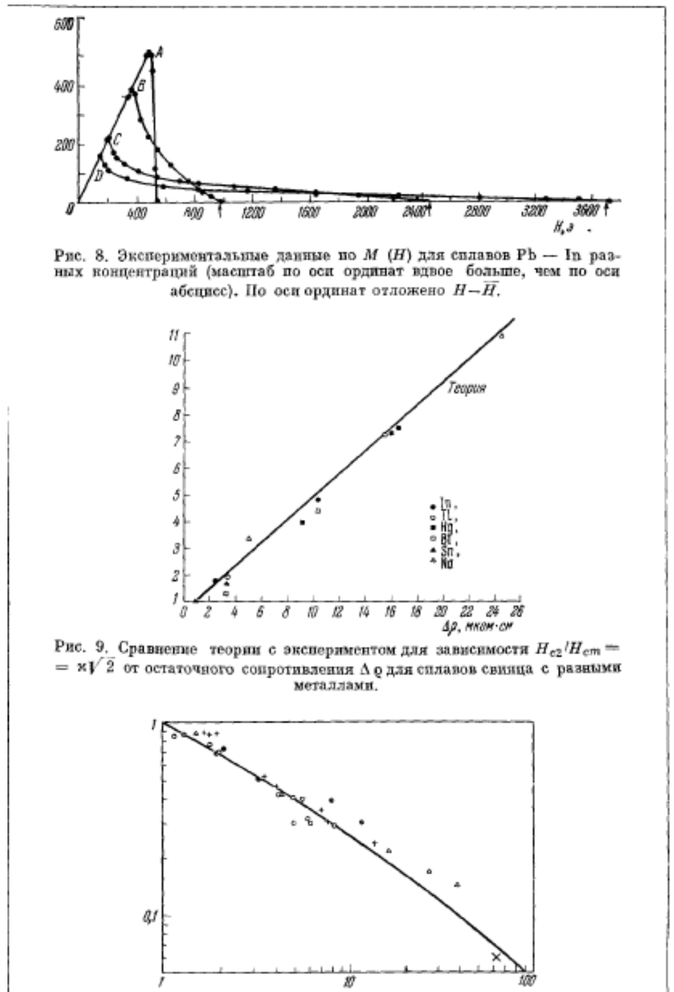
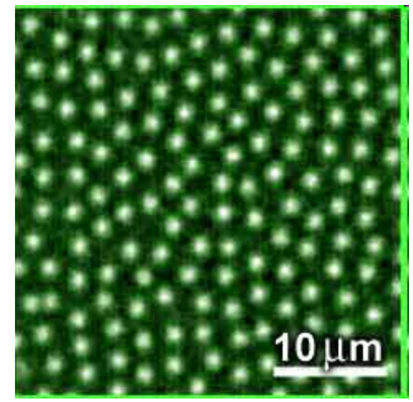


Рис. 8. Экспериментальные данные по M (H) для сплавов Pb — In разных концентраций (масштаб по оси ординат вдвое больше, чем по оси абсцисс). По оси ординат отложено $H-\overline{H}$.

Рис. 9. Сравнение теории с экспериментом для зависимости $H_{c2}/H_{cm} = \varkappa\sqrt{2}$ от остаточного сопротивления $\Delta\varrho$ для сплавов свинца с разными металлами.

Рис. 10. Сравнение теории с экспериментом для зависимости H_{c1}/H_{cm} от H_{c2}/H_{cm} для разнообразных сплавов тантала, ниобия, ванадия, сплавов свинца с таллием, висмута с индием и соединения V_3Ga.



Magneto-optical image of Vortex lattice, 2001
P.E. Goa et al.
University of Oslo
[Supercond. Sci. Technol. 14, 729 (2001)]

1958: Lev Gorkov

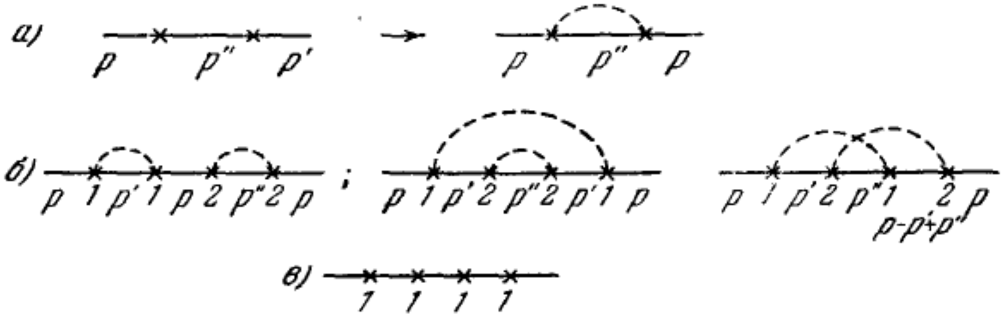
formulates elegant equations of the microscopic theory of superconductivity and demonstrates the equivalence between the microscopic BCS theory and GL phenomenology at temperatures close to the critical one.

$$\begin{pmatrix} \left\{-\frac{\partial}{\partial\tau}+\frac{\nabla^2}{2m}+\mu\right\} & \Delta \\ -\Delta^* & \left\{\frac{\partial}{\partial\tau}+\frac{\nabla^2}{2m}+\mu\right\} \end{pmatrix} \times \begin{pmatrix} \mathfrak{G}(x-x') & \mathfrak{F}(x-x') \\ \mathfrak{F}^+(x-x') & -\mathfrak{G}(x'-x) \end{pmatrix} = \hat{1}. \tag{34.32}$$

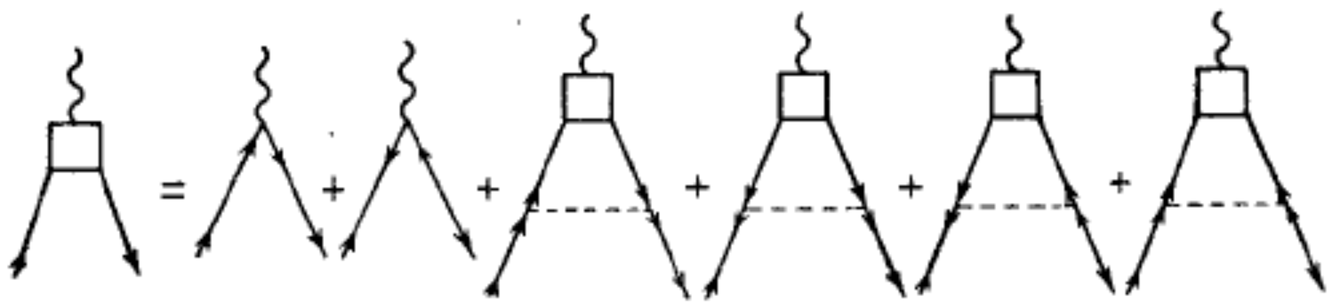
$$\mathfrak{G}_\omega(p) = -\frac{i\omega+\xi}{\omega^2+\xi^2+\Delta^2}, \quad \mathfrak{F}^+_\omega(p) = \frac{\Delta^*}{\omega^2+\xi^2+\Delta^2}.$$

These equations gave the basis for study of nonhomogeneous superconductivity

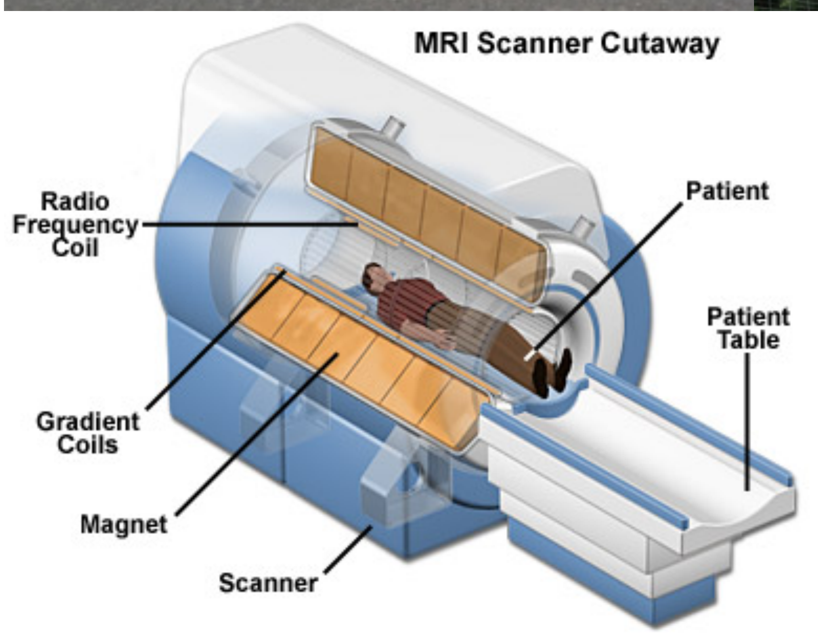
IV. Abrikosov & Gor’kov, 1959: elaborate the microscopic methods for studies of electron scattering by impurities in normal metals and superconductors



$$Q = \frac{Ne^2}{m} 2\pi T \Delta^2 \sum_{n=1}^{\infty} \frac{1}{(\omega^2 + \Delta^2)\left(\sqrt{\omega^2 + \Delta^2} + \frac{1}{2\tau_{tr}}\right)}.$$



Applications of Superconducting alloys

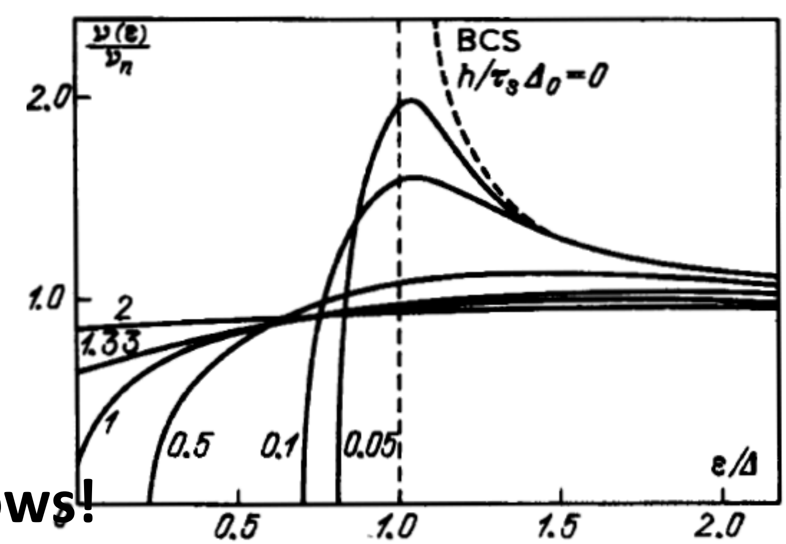


V. Abrikosov & Gor’kov: investigate the properties of superconductors with magnetic impurities and dis-cover the phenomenon of gapless superconductivity

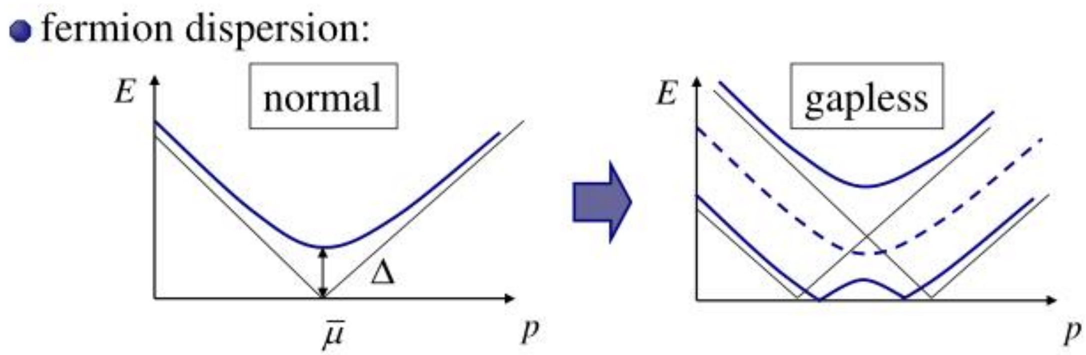
$$\ln\left(\frac{T_{c0}}{T_c}\right) = \psi\left(\tfrac{1}{2}+\tfrac{1}{2}\rho\right) - \psi\left(\tfrac{1}{2}\right),$$

$$\rho = \hbar/(\pi T_c \tau_s)$$

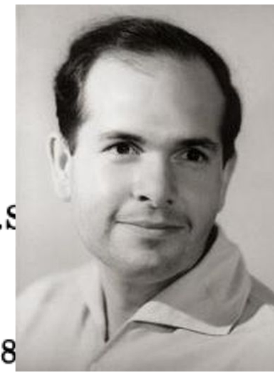
$$0.91\, n_{mc} < n_m < n_{mc}.$$



There is no gap but supercurent can flows!



VI. Further studies of superconductivity in the newly formulated microscopic theory



A SUPERCONDUCTOR IN A HIGH FREQUENCY FIELD

A. A. ABRIKOSOV, L. P. GOR' KOV, and I. M. KHALATNIKOV

Institute for Physical Problems, Academy of Sciences, U.S

Submitted to JETP editor March 4, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **35**, 265-275 (July, 1958

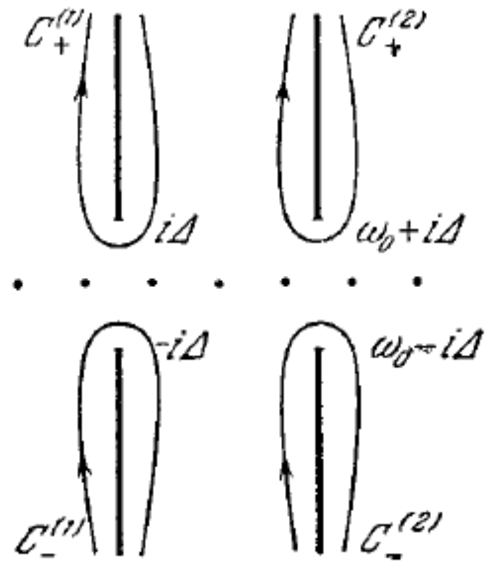
We derive an equation describing the behavior of superconductors in a high frequency field. With the aid of this equation the frequency and temperature dependence of the impedance of a bulk superconductor have been evaluated.

$$\boldsymbol{j}(x) = -\int Q(x-y)\,\boldsymbol{A}(y)\,d^4y$$

$$\overline{Q}(\boldsymbol{k},\ \omega_0) = \frac{3\pi T}{4}\sum_{\omega'}\int_{-1}^{1}(1-\mu^2)\,d\mu\,\times$$

$$\times\left\{\frac{i\left(\omega_+ + \sqrt{\omega_+^2+\Delta^2}\right)\left[i\left(\omega_- + \sqrt{\omega_+^2+\Delta^2}\right) - v\,|\boldsymbol{k}|\,\mu\right] + \Delta^2}{\sqrt{\omega_+^2+\Delta^2}\left[\omega_-^2+\Delta^2+\left(v\,|\boldsymbol{k}|\,\mu - i\sqrt{\omega_+^2+\Delta^2}\right)^2\right]} + \right.$$

$$\left. + \frac{i\left(\omega_- + \sqrt{\omega_-^2+\Delta^2}\right)\left[i\left(\omega_+ + \sqrt{\omega_-^2+\Delta^2}\right) + v|\boldsymbol{k}|\mu\right] + \Delta^2}{\sqrt{\omega_-^2+\Delta^2}\left[\omega_+^2+\Delta^2+\left(v|\,\boldsymbol{k}\,|\mu + i\sqrt{\omega_-^2+\Delta^2}\right)^2\right]}\right\}. \quad (37.24$$



A A Abrikosov in co-authorship with L P Gor'kov explained the Knight shift in superconductors.

SPIN-ORBIT INTERACTION AND THE KNIGHT SHIFT IN SUPERCONDUCTORS

A. A. ABRIKOSOV and L. P. GOR'KOV

Institute for Physical Problems, Academy of Sciences, U.S.S.R.

Submitted to JETP editor November 4, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 1088-1096 (April, 1962)

A theory of the Knight shift in superconductors is presented. It is shown that the effect can be completely explained if the spin-orbit part of the interaction in the scattering of electrons on the crystal boundaries is taken into account. The agreement between the theory and the experimental data [8] is found to be good.

The Knight shift measures the relative shift in NMR frequency due to spin polarization
In a magnetic field.

$$\frac{\chi_s(0)}{\chi_n} \approx \frac{1}{6}\pi^2 \frac{\xi_0}{l_{s0}}, \qquad \xi_0 \ll l_{s0},$$

$$\frac{\chi_s(0)}{\chi_n} \approx 1 - \frac{3}{4}\frac{l_{s0}}{\xi_0}, \qquad \xi_0 \gg l_{s0}$$

the nuclear spin is acted on by an extra magnetic field:

$$\Delta H = \frac{8}{3}\pi\chi \frac{|\psi_s(0)|^2}{n} H.$$

Abrikosov in co-authorship with L. Falkovsky calculated the Raman scattering intensity in the newly formulated microscopic theory of superconductivity.

RAMAN SCATTERING OF LIGHT IN SUPERCONDUCTORS

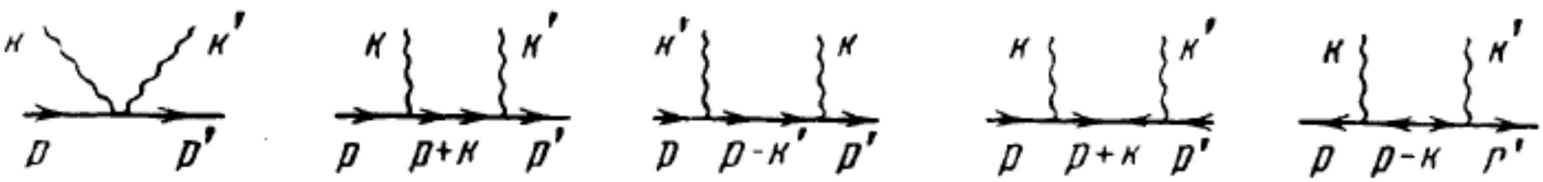
A. A. ABRIKOSOV and L. A. FAL'KOVSKIĬ

Institute for Physics Problems, Academy of Sciences, U.S.S.R.

Submitted to JETP editor July 25, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) 40, 262-270 (January, 1961)

A computation is carried out of Raman scattering upon reflection of light from the surface of a superconductor. The distribution with angle and frequency of the scattered light and the absolute magnitude of the effect are found.



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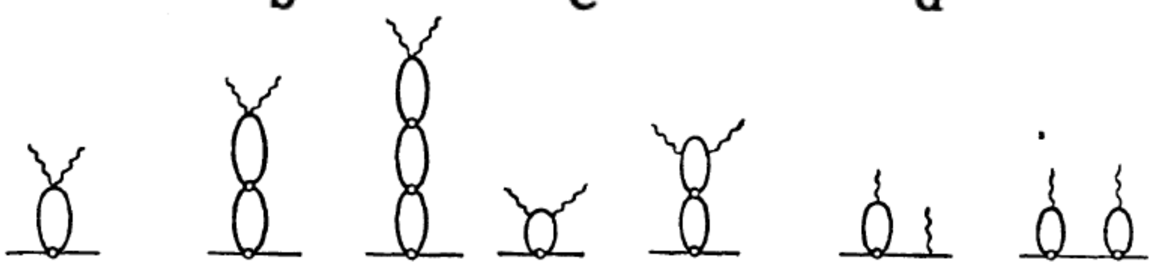
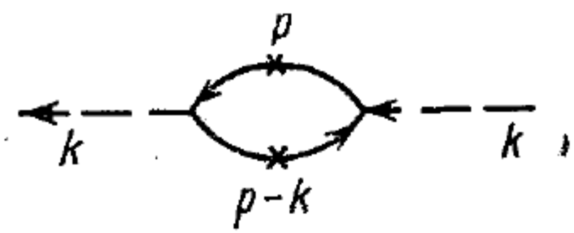


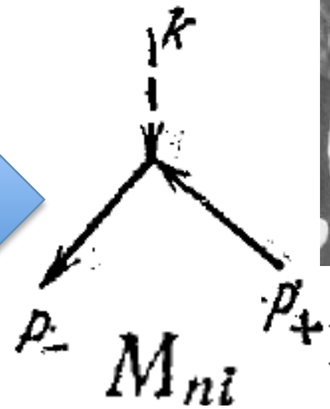
a b c

VII. "Moscow Zero" and development of the diagrammatic technics

The Green's functions and the effective cross sections of the Compton effect and mutual electron and positron scattering at high energies were calculated.

Dirac, Feynman, Schwinger





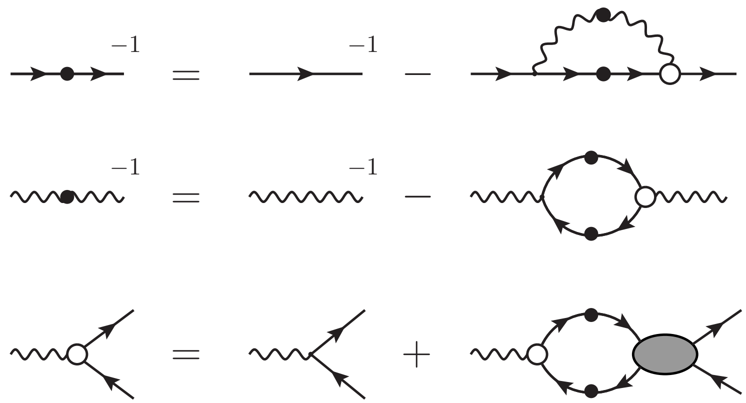
$$\mathscr{P}(k^2) = \frac{\alpha}{3\pi} k^2 \ln \frac{|k^2|}{m^2} \qquad \frac{\alpha}{3\pi} \ln \frac{|k^2|}{m^2} \ll 1$$

QED suffered from the divergence problems. The idea to smear electron charge in space was proposed, but the answers depended on the "electron radius"

Asymptotic behavior of the photon propagator at large momenta

A. A. Abrikosov, I. M. Khalatnikov and L. D. Landau, 1954

$$\mathscr{P}(k^2) = \frac{\alpha}{3\pi} k^2 \ln \frac{|k^2|}{m^2}$$ Is valid up to $$\frac{\alpha}{3\pi} \ln \frac{|k^2|}{m^2} \lesssim 1.$$



Selection of diagrams by $\alpha^n \ln^n (|k^2|/m^2)$

$$\alpha = \frac{\alpha_0}{1 + \frac{\alpha_0}{3\pi} \ln \frac{\Lambda^2}{m^2}},$$

LAKh solved the Schwinger-Dyson equations

$$\mathscr{D}(k^2) = \frac{4\pi}{k^2} \frac{1}{1 - \frac{\alpha}{3\pi} \ln \frac{|k^2|}{m^2}}.$$ QED

LAKh: Renormalized photon Propagator does not depend on the size of electron smearing

$$\mathscr{D}(k^2) = \frac{4\pi}{k^2} \frac{1}{1 \boxed{+} \frac{\alpha}{3\pi} \ln \frac{|k^2|}{m^2}}.$$ QCD

Gross, Wilczek, Politzer, 1973
Asymptotic freedom

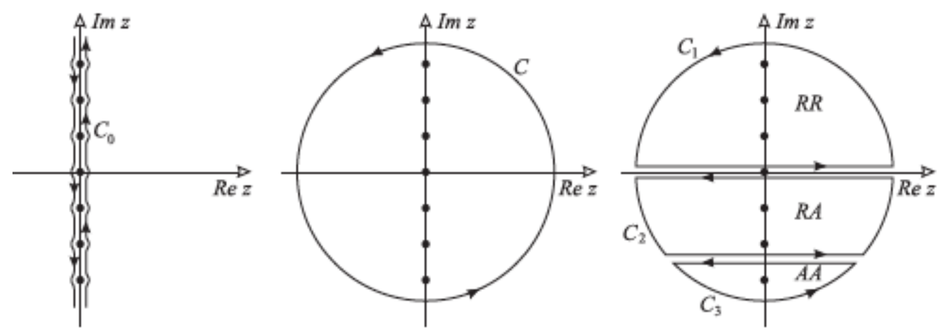
In 1959, following the works Matsubara, Migdal and Galitski, the new temperature diagrammatic technique was developed by Abrikosov along with Gor'kov and Dzyaloshinskii. It was based on their achievements in QED and some other beautiful ideas: the method of analytical continuation of Feynman diagrams from imaginary to real frequencies, etc.

On the application of quantum-field-theory methods to problems of quantum statistics at finite temperatures, Sov. Phys. JETP 9(3), 636-641 (1959)

$$\tilde{\psi}_\alpha(\boldsymbol{r}, \tau) = e^{\tau(\hat{H}-\mu\hat{N})}\psi_\alpha(\boldsymbol{r})e^{-\tau(\hat{H}-\mu\hat{N})},$$

$$\tilde{\tilde{\psi}}_\alpha(\boldsymbol{r}, \tau) = e^{\tau(\hat{H}-\mu\hat{N})}\psi_\alpha^+(\boldsymbol{r})e^{-\tau(\hat{H}-\mu\hat{N})},$$

$$\tilde{\varphi}(\boldsymbol{r}, \tau) = e^{\tau\hat{H}}\varphi(\boldsymbol{r})e^{-\tau\hat{H}}.$$



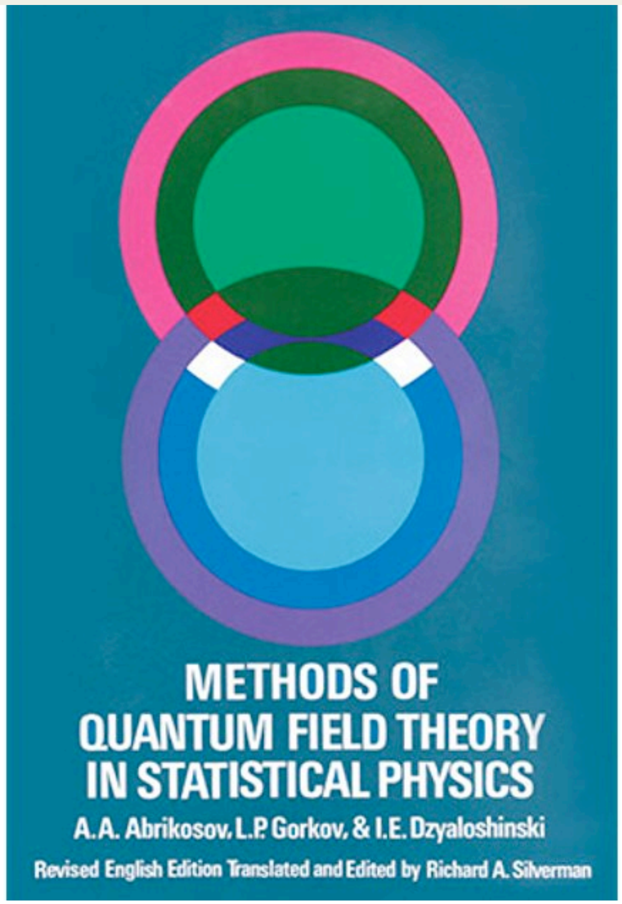
$$\mathfrak{G}_{\alpha\beta}(\boldsymbol{r}_1, \tau_1; \boldsymbol{r}_2, \tau_2) = -\operatorname{Sp}\left\{e^{\frac{\Omega+\mu\hat{N}-\hat{H}}{T}}T_\tau(\tilde{\psi}_\alpha(\boldsymbol{r}_1, \tau_1)\tilde{\tilde{\psi}}_\beta(\boldsymbol{r}_2, \tau_2))\right\}$$

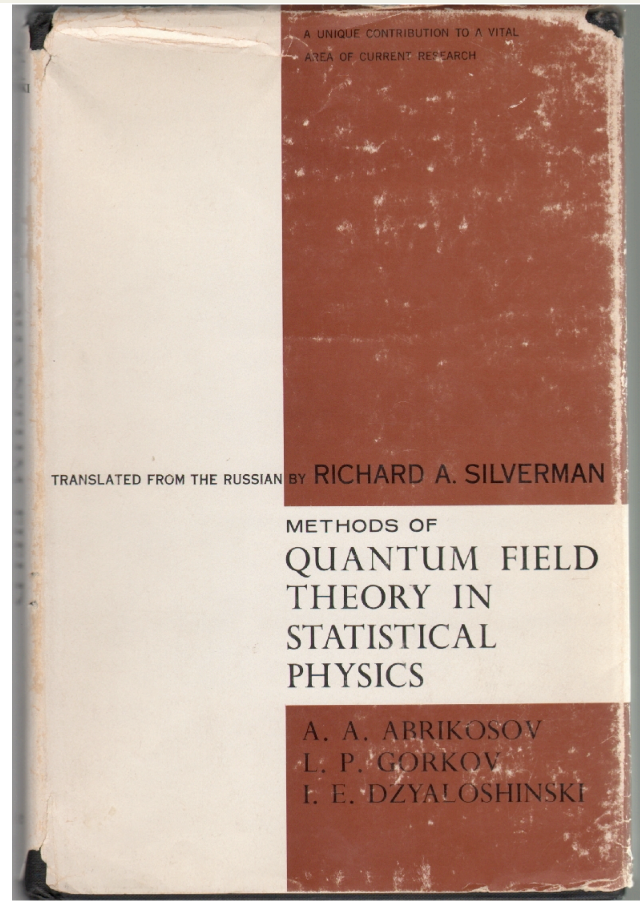
$$\equiv -\langle T_\tau(\tilde{\psi}_\alpha(\boldsymbol{r}_1, \tau_1)\tilde{\tilde{\psi}}_\beta(\boldsymbol{r}_2, \tau_2))\rangle. \qquad (11.$$

VIII. A.A. Abrikosov, L.P. Gor’kov, I.E. Dzyaloshinskiy, 1961 :

“Methods of Quantum Field Theory in Statistical Physics”.

This book became a handbook for theoretical physicists in many countries where it was translated and published.



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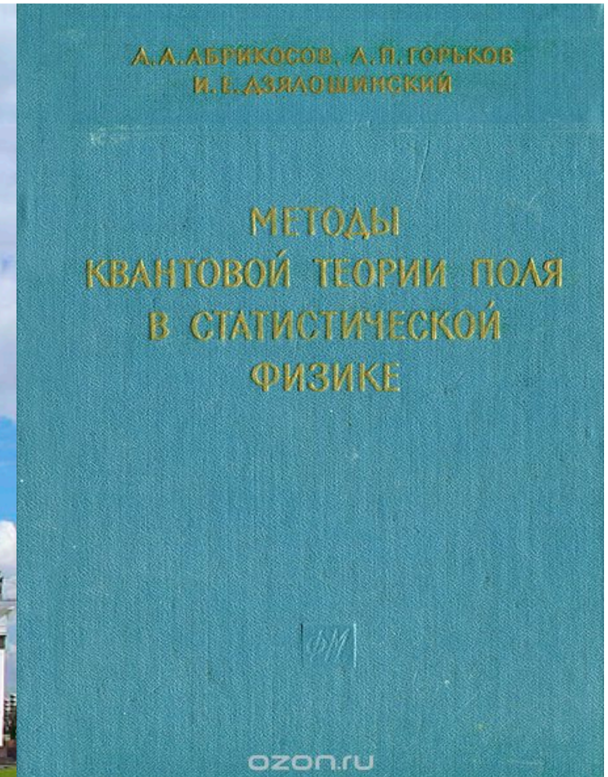
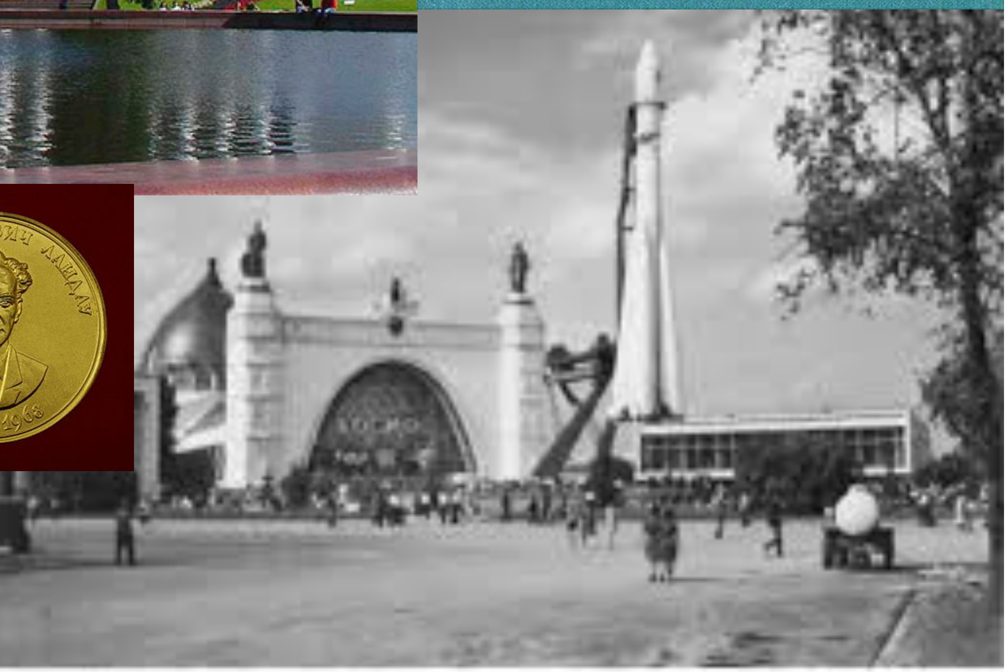
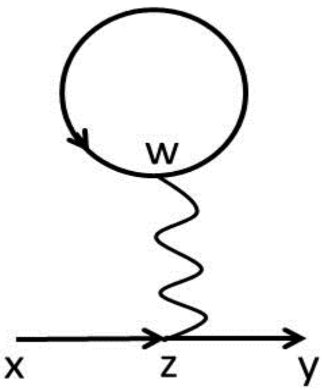

А. А. АБРИКОСОВ, Л. П. ГОРЬКОВ
И. Е. ДЗЯЛОШИНСКИЙ
МЕТОДЫ
КВАНТОВОЙ ТЕОРИИ ПОЛЯ
В СТАТИСТИЧЕСКОЙ
ФИЗИКЕ
ozon.ru


ЛЕВ ДАВИДОВИЧ ЛАНДАУ
1908 - 1968

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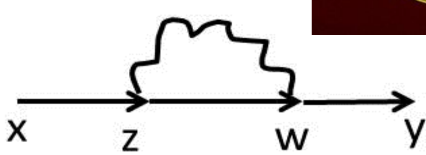
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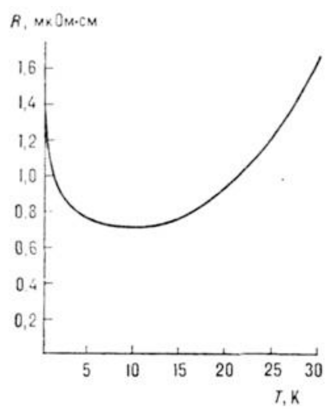
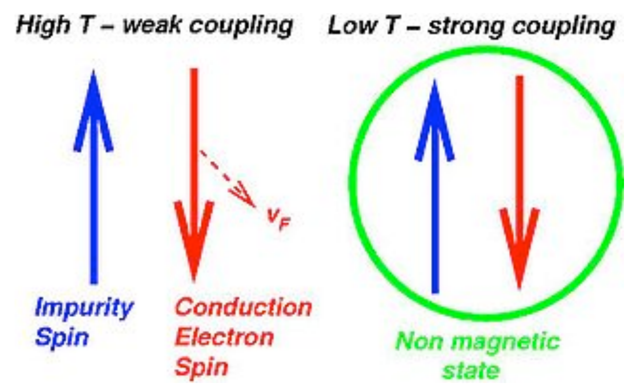
2

IX. Kondo problem: Abrikosov-Suhl resonance

In 1960's Abrikosov's scientific interests moved towards the theory of normal metals, semimetals, and semiconductors. He was engaged in the Kondo problem and found that, depending on the sign of exchange interaction, the effective scattering either vanishes or increases greatly.



The Kondo resonance forms due to a coherent many-body interaction between itinerant electrons and local moments. It is the signature of the formation of a coherent many-body state.



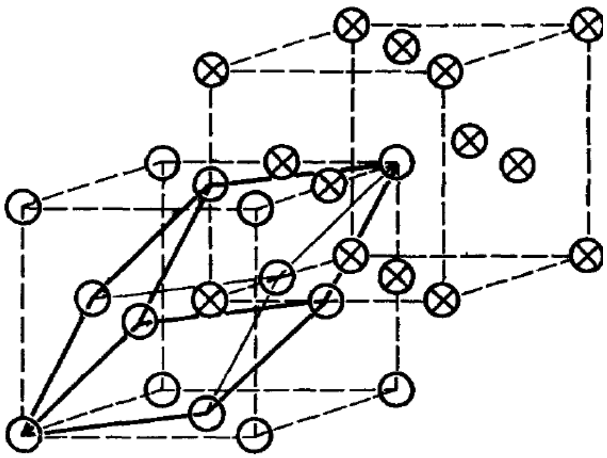
The Abrikosov pseudo-fermion representation for spin operators with spin $S = 1/2$ is given by

$$\boldsymbol{S}_i = \frac{1}{2}\begin{pmatrix} c_{i\uparrow}^\dagger, & c_{i\downarrow}^\dagger \end{pmatrix} \boldsymbol{\sigma} \begin{pmatrix} c_{i\uparrow} \\ c_{i\downarrow} \end{pmatrix}, \qquad c_{i\uparrow}^\dagger c_{i\uparrow} + c_{i\downarrow}^\dagger c_{i\downarrow} = 1,$$

where the operators $c_{i\sigma}$ and $c_{i\sigma}^\dagger$ are fermionic operators obeying the usual fermionic anticommutation relations, and $\boldsymbol{\sigma} = (\sigma^x, \sigma^y, \sigma^z)$ is the vector of the Pauli matrices

X. Physical Properties of Bismuth

Abrikosov with Falkovsky formulated the theory of bismuth type semimetals . As a result, the crystal structure of semimetals was explained.



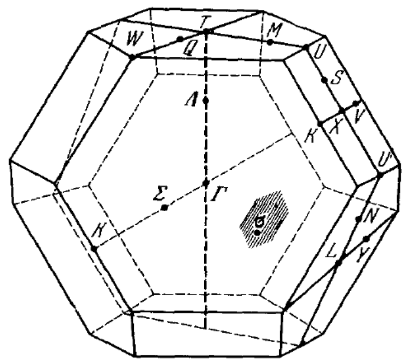
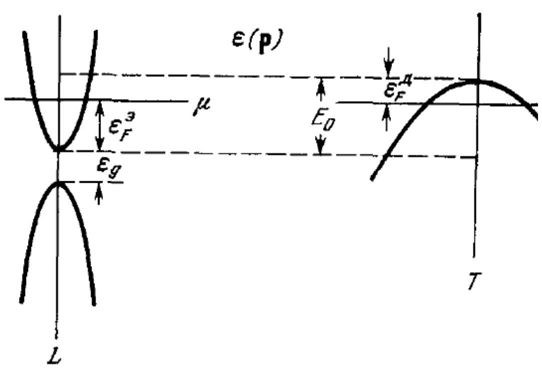


Рис. 2. Первая зона Бриллюэна.

3. Deformation Theory

We proceed to describe the concepts developed in [9]. To obtain the energy spectrum, the lattice considered in [9] was infinitesimally close to a cubic one, and was then deformed into the true lattice of bismuth. In order that the change of the spectrum occur without a phase transition, the "dielectric" phase (see p. 3) is con-



$$\tilde{\mathcal{H}} = \begin{pmatrix} -\varepsilon_g I & H_1 \\ H_1^+ & 0 \end{pmatrix}, \quad H_1 = \mathbf{p}\begin{pmatrix} \mathbf{t} & \mathbf{u} \\ -\mathbf{u}^* & \mathbf{t}^* \end{pmatrix}$$

XI Semimetals. Prototype of the future Dirac materials

POSSIBLE EXISTENCE OF SUBSTANCES INTERMEDIATE BETWEEN METALS AND DIELECTRICS

A. A. ABRIKOSOV and S. D. BENESLAVSKIĬ

L. D. Landau Institute of Theoretical Physics

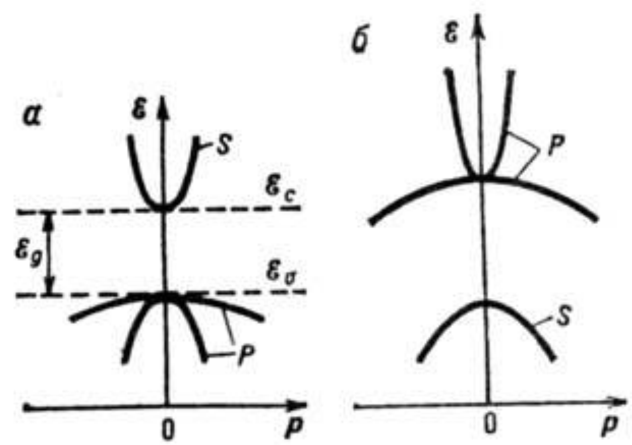
Submitted April 13, 1970

Zh. Eksp. Teor. Fiz. 59, 1280—1298 (October, 1970)

The question of the possible existence of substances having an electron spectrum without any energy gap and, at the same time, not possessing a Fermi surface is investigated. First of all the question of the possibility of contact of the conduction band and the valence band at a single point is investigated within the framework of the one-electron problem. It is shown that the symmetry conditions for the crystal admit of such a possibility. A complete investigation is carried out for points in reciprocal lattice space with a little group which is equivalent to a point group, and an example of a more complicated little group is considered. It is shown that in the neighborhood of the point of contact the spectrum may be linear as well as quadratic.

HgSe , HgTe, Bi_xSb_{1-x}

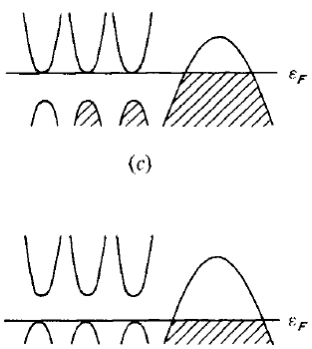
The types of symmetry allowing a gapless spectrum were found, the spectrum of carriers and its behavior under pressure were analyzed This work is especially topical today in connection with to discovery of graphene and the related prospects of the development of nanoelectronics.



Soviet physicists in vacations: hike to the taiga (1970)

XII. Transition of a bismuth-type semimetal to an excitonic insulator in a strong magnetic field

Transition of a bismuth-type semimetal to an excitonic insulator in a strong magnetic field
A. A. Abrikosov, [Journal of Low Temperature Physics]
January 1973, Volume 10, [Issue 1–2], pp 3–34



$$G = \frac{1}{3}\left\{\frac{(i\tilde{\omega}_2 + \xi_h)}{[(i\tilde{\omega}_1 - \xi_e)(i\tilde{\omega}_2 + \xi_h) - 3|\tilde{\Delta}_1|^2]}\right\} + \frac{2}{3}\frac{1}{i\omega_1' - \xi_e},$$

$$D = \frac{1}{3}\left\{\frac{(i\tilde{\omega}_2 + \xi_h)}{[(i\tilde{\omega}_1 - \xi_e)(i\tilde{\omega}_2 + \xi_h) - 3|\tilde{\Delta}_1|^2]}\right\} - \frac{1}{3}\frac{1}{i\omega_1' - \xi_e},$$

$$\mathscr{L}(-\omega) = -\frac{(i\tilde{\omega}_1 - \xi_e)}{[(i\tilde{\omega}_1 - \xi_e)(i\tilde{\omega}_2 + \xi_h) - 3|\tilde{\Delta}_1|^2]},$$

$$F^+(\omega) = \frac{\tilde{\Delta}_1^*}{[(i\omega_1 - \xi_e)(i\omega_2 + \xi_h) - 3|\tilde{\Delta}_1|^2]} = -F(-\omega)\frac{\tilde{\Delta}_1^*}{\tilde{\Delta}_1},$$

Bi_xSb_{1-x}

Investigation of the Excitonic Insulator Phase in Bismuth–Antimony Alloys

N. B. Brandt and S. M. Chudinov

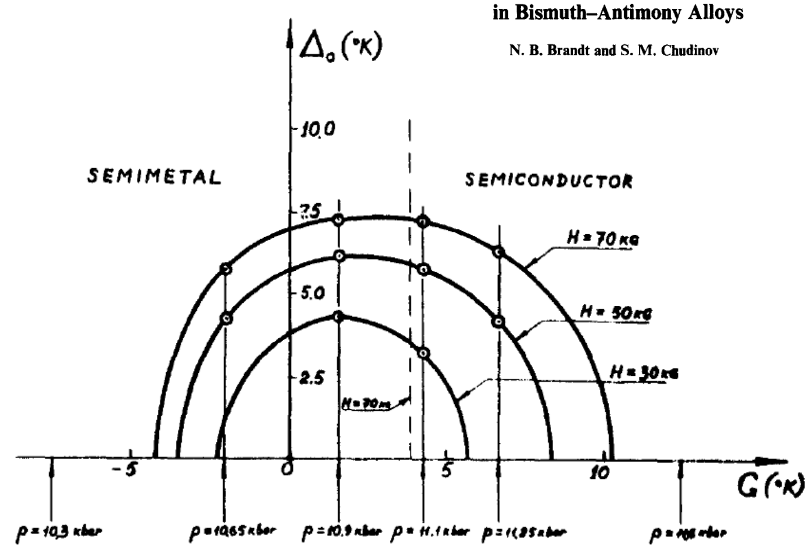


Fig. 10. Schematic diagram of the exciton insulator gap Δ_0 for various values of the magnetic field H vs. the "overlap-gap" G at $H = 0$ in the unrearranged spectrum of the alloy $Bi_{0.951}Sb_{0.049}$ ($T = 2.0$ K). The circles indicate the values of Δ_0 calculated for $p = 10.65$, 10.9, 11.1, and 11.3 kbar. The dashed line corresponds to the metal–semiconductor transition ($G = 0$) in the unrearranged system at $H = 70$ kOe.

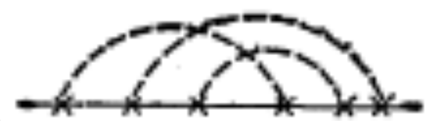
XIII. Contribution to quasi-one-dimensional physics

In the 1970s-1980s, Abrikosov constructs the original method for calculating the conductivity of a quasi-one- dimensional metal, which permits account for electron jumps between filaments and electron scattering by phonons and impurities

Electrical properties of one-dimensional metals

A. A. Abrikosov and I. A. Ryzhkin

Instead of the interaction with the impurities we introduce random fields[1)] $\eta(z)$ and $\zeta(z)$. The interaction with the field $\eta(z)$ leaves an electron in the vicinity of p_0 if it was there, i.e., this interaction is diagonal in the indices 1 and 2. We can assume this interaction to be real and to have the following properties:



$$\langle\eta(z)\rangle=0, \quad \langle\eta(z)\eta(z')\rangle=\delta(z-z')v/\tau_1. \tag{5}$$

The second field ζ transfers an electron from the vicinity of p_0 to the vicinity of $-p_0$. This field must be assumed to be complex

$$\langle\zeta(z)\zeta^*(z')\rangle=\delta(z-z')v/\tau_2, \quad \langle\zeta\rangle=0,$$

$$\langle\zeta(z)\zeta(z')\rangle=0.$$

as a "quantum" of such a field

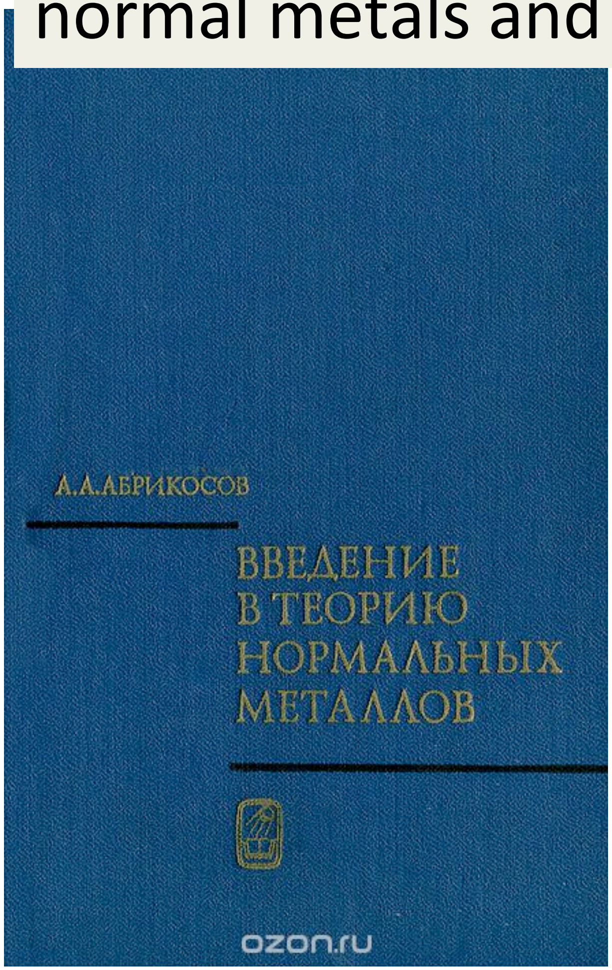
can be "emitted" only in the transition 1 → 2 a

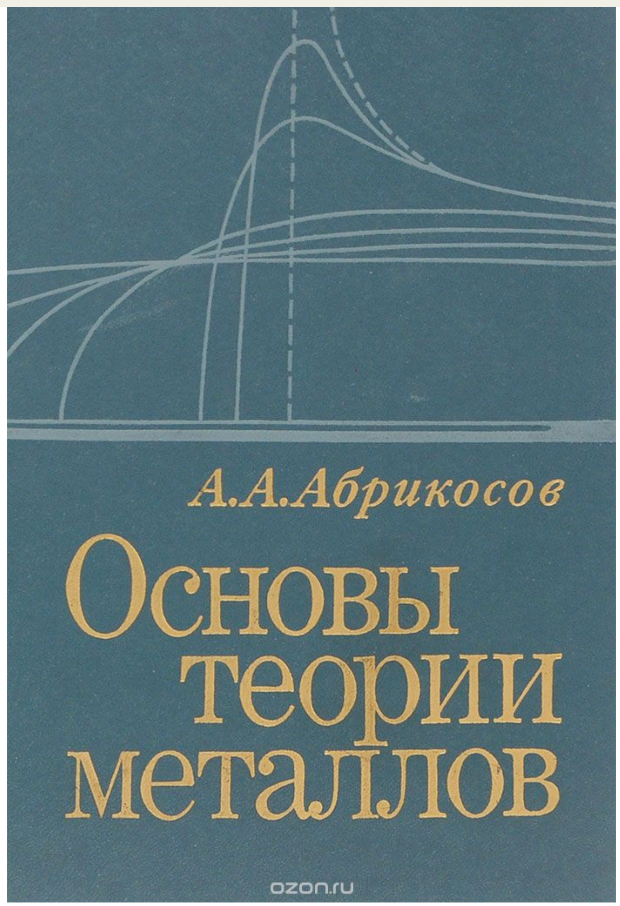
XIV. Abrikosov carried on active scientific, organizational and pedagogical work at the L. D. Landau Institute of Theoretical Physics (he was one of the founders of this Institute, 1965)

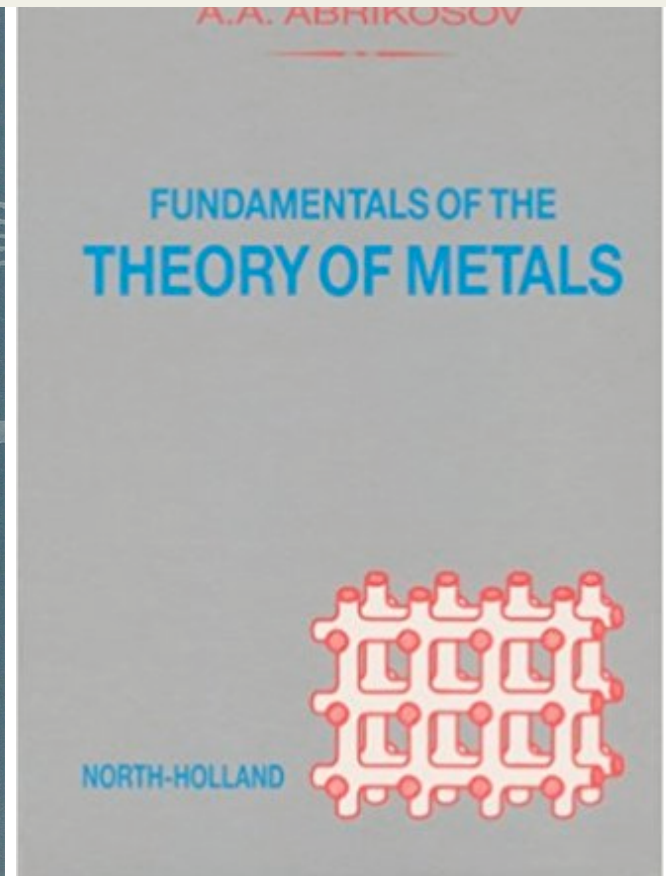
A.B. Migdal

A. A. Abrikosov I.E. Dzyaloshinskiy I.M.Khalatnikov L.P. Gor’kov

XV. In 1987 Abrikosov published a book “Fundamentals of the Theory of Metals” which was based on his brilliant lecture courses delivered at the Moscow Institute of Physics and Technology and Moscow Institute of Steel and Alloys (MISA). This book became an encyclopedia of the theory of normal metals and superconductors.



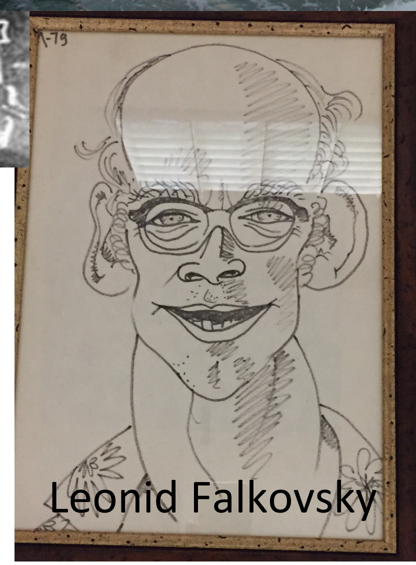


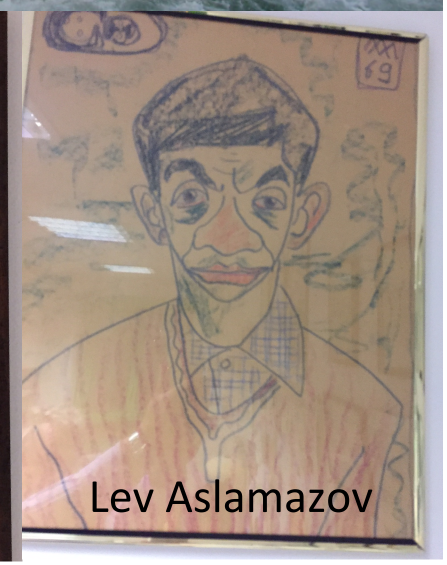


XVI. Since 1976 Abrikosov headed the Department of Theoretical Physics at the Moscow Institute of Steel and Alloys (MISA)

XVII. Odessa symposiums in theoretical physics of Landau Institute organized by Abrikosov & Khalatnikov since 1961 ‘till the end of 80s

Anybody who had occasion to meet Abrikosov, to work with him, to participate in the regular symposia on theoretical physics, organized by him, remembers his erudition and adherence to principles, his teller’s gift.





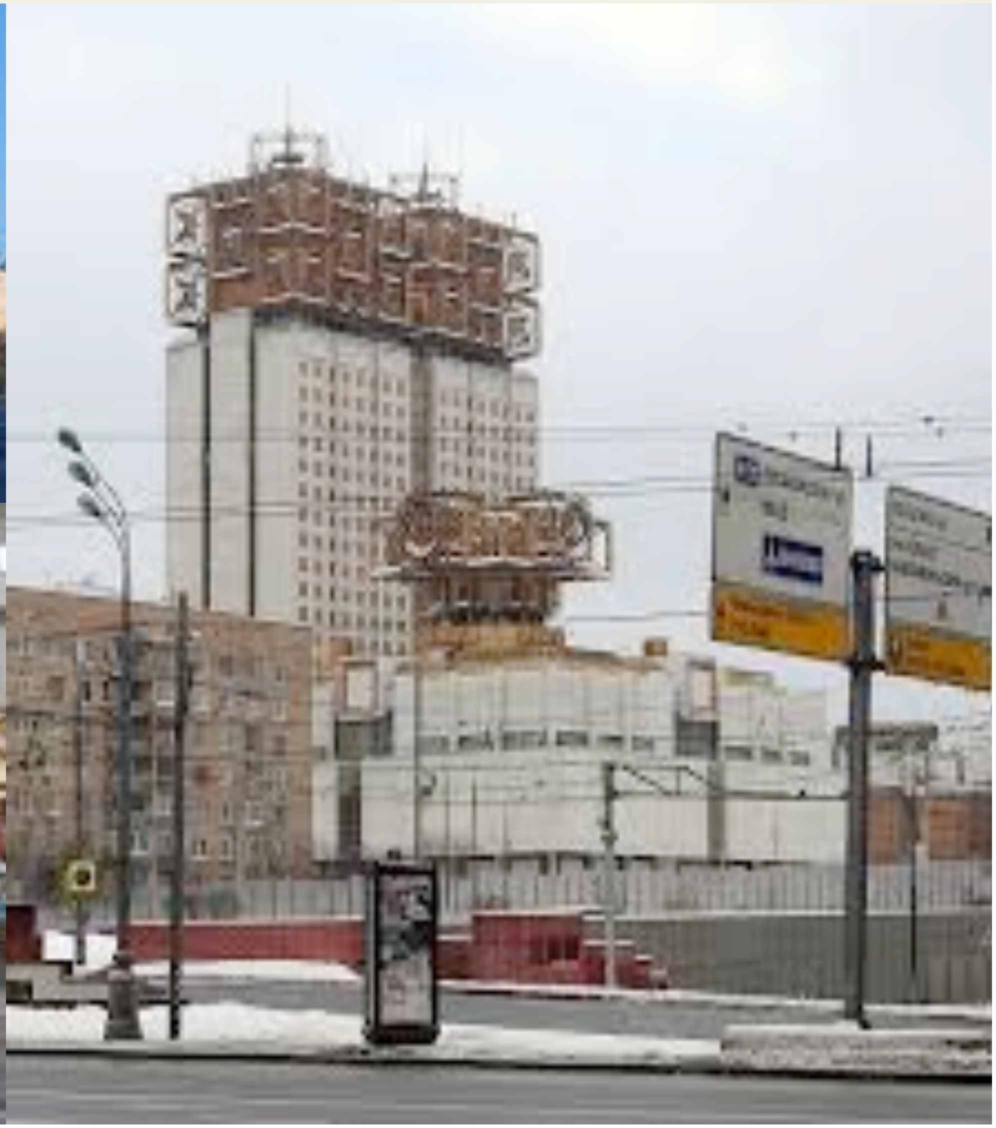
Abrikosov & Khaikin's schools "Physics of Metals", Kazan, 1976

Abrikosov & Khaikin’s school “Physics of Metals”, Tadgikistan, 1987

M. Gershenzon . R. Shekhter,
B. Altshuler, A. Varlamov,
V. Shaternik., A. Shpigel

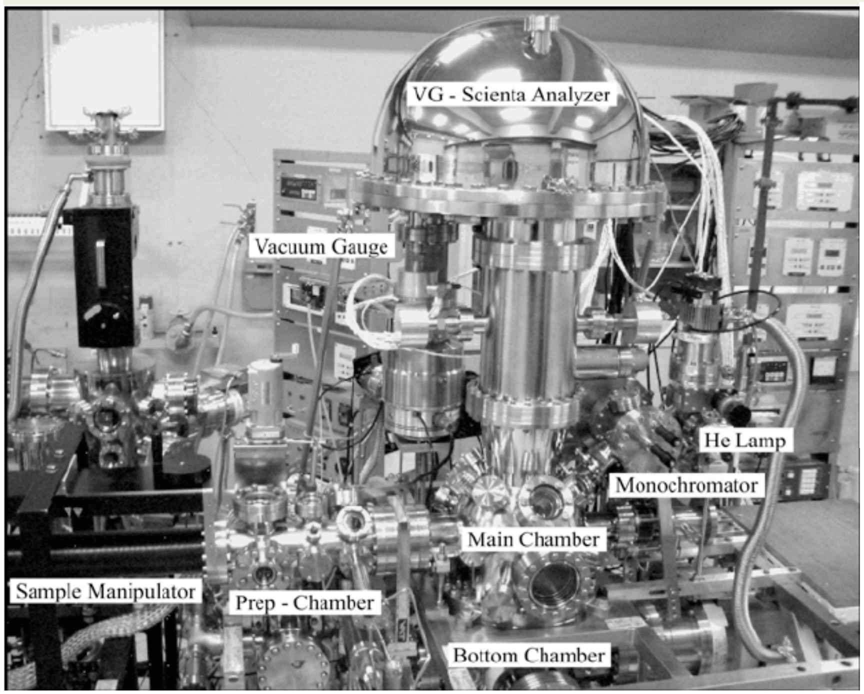
Abrikosov with pupils (A.Tsvelik, 1978)

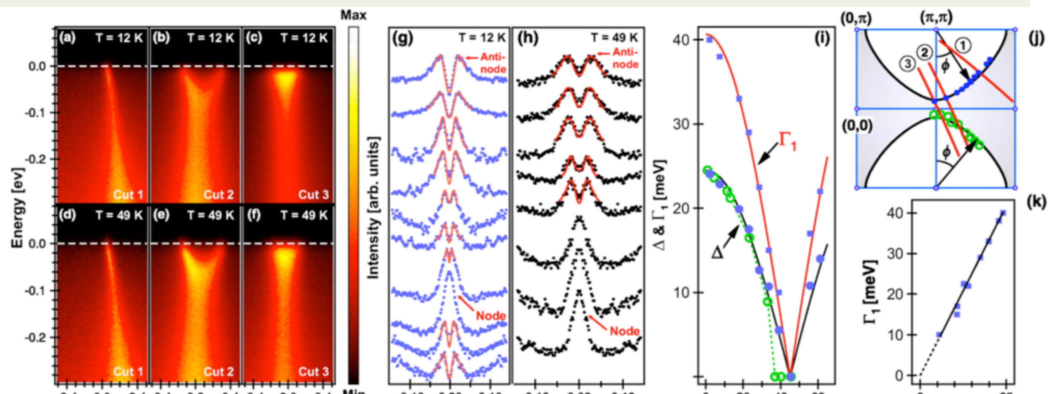
XVIII. In the period from 1988 to 1991, Abrikosov headed the Institute for High-Pressure Physics of RAS



XIX. At the beginning of the 1990s, Abrikosov accepted an offer to head the Theoretical Group in the Argonne National Laboratory and left for the USA

XX. The most intriguing problem in condensed matter physics in those days was the explanation of the phenomenon of high-temperature superconductivity, and Abrikosov, in close contact with the experimentalists of the Laboratory, devoted himself to studies in this field. They revealed the existence of a specific singularity in the spectrum of cuprate superconductors, after which Abrikosov proposed his version of the theory of high-temperature superconduc- tivity that explained the variety of existing experimental findings.



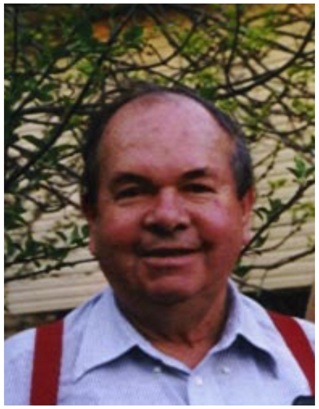


Main ingredients of Abrikosov’s theory of HTS

- BCS nature
- Quasi-two dimensionality
- Van Hove singularity
- Resonance tunneling along c-axis

PHYSICAL REVIEW B VOLUME 58, NUMBER 5 1 AUGU

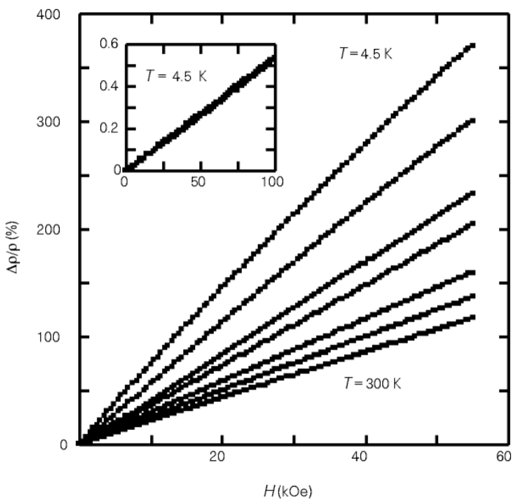
XXI. The last foresight…



Quantum magnetoresistance

A. A. Abrikosov
Materials Science Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439
(Received 26 September 1997; revised manuscript received 9 March 1998)

An explanation is proposed of the unusual magnetoresistance, linear in magnetic field and positive, observed recently in nonstoichiometric silver chalcogenides. The idea is based on the assumption that these substances are basically gapless semiconductors with a linear energy spectrum. Most of the excess silver atoms form metallic clusters which are doping the remaining material to a very small carrier concentration, so that even in a magnetic field as low as 10 Oe, only one Landau band participates in the conductivity.



$$H=\int \psi^{+} v\left[\sigma\left(\mathbf{p}-\frac{e}{c}\mathbf{A}\right)\right]\psi dV,$$

$$-i\frac{\partial}{\partial z}\psi_1+\left(-i\frac{\partial}{\partial x}-\frac{\partial}{\partial y}+i\frac{eH}{c}x\right)\psi_2=\frac{\varepsilon}{v}\psi_1,$$

$$\left(-i\frac{\partial}{\partial x}+\frac{\partial}{\partial y}-i\frac{eH}{c}x\right)\psi_1+i\frac{\partial}{\partial z}\psi_2=\frac{\varepsilon}{v}\psi_2.$$

$$G^{(0)}_{\alpha\beta}(p_z,p_y,x,x',\omega_m)=\sum_n\frac{\psi_{n\alpha}(x-cp_y/eH)\psi^{*}_{n\beta}(x'-cp_y/eH)}{i\omega_m+\mu-\varepsilon_n(p_z)},$$

$$Q_{ik}(i\omega_0)=\frac{2e^2v^2}{c}T\sum_m\int\frac{dp_y}{2\pi}\int\frac{dp_z}{2\pi}\int dx'\times\mathrm{Tr}[\sigma_i G(p_y,p_z,x,x',\omega_m+\omega_0)\times\sigma_k G(p_y,p_z,x',x,\omega_m)],$$

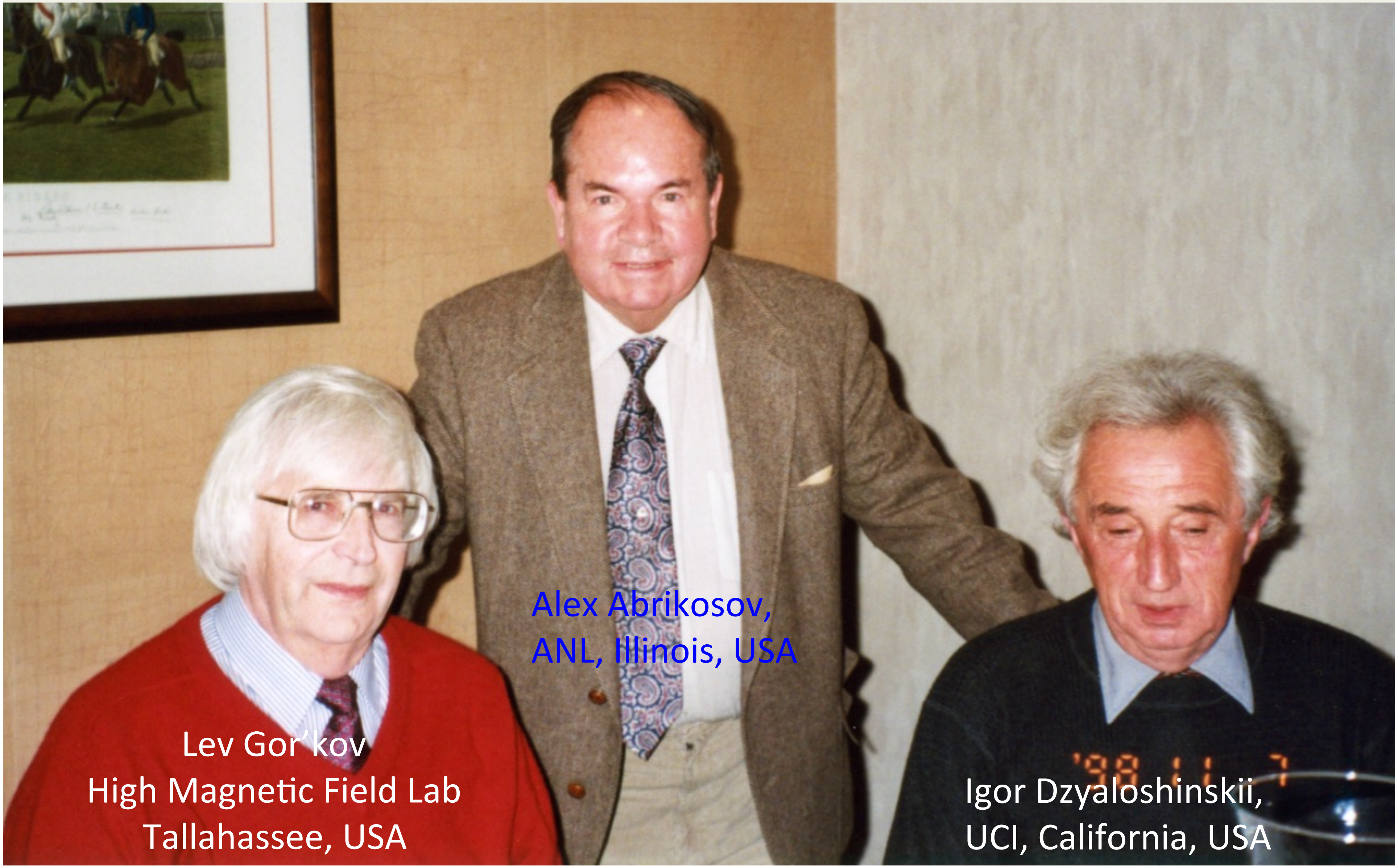
Large magnetoresistance in non-magnetic silver chalcogenides, R. Xu, A. Husmann, T. F. Rosenbaum, M.-L. Saboungi, J. E. Enderby and P. B. Littlewood,Nature 390, 57, 1997

$$\rho_{xx}=\frac{1}{2\pi}\left(\frac{e^2}{\varepsilon_\infty v}\right)^2\ln\varepsilon_\infty\frac{N_i}{ecn_0^2}H.$$

Richard Klemm, George Crabtree, Ernst Helmut Brandt, Lev Gor'kov, David Bishop, David Nelson, Michael Tinkham, Valerii Vinokur, David Khmel'nitskii

Grigorii Volovik, Boris Shklovskii, Boris Altshuler, Alexei Abrikosov, Phil W. Anderson, Igor' Dzyaloshinskii

The meeting of three coauthors in forty years, 1998 , Argonne, USA



Visit to Italy in 2000: Camerino

Visit to Italy in 2000: Frascati

Vortex conference, Crete, September 2003

Argonne, October, 5, 2003, next day after the Nobel Committee announcement

Physics Nobel Prize 2003


ARGONNE NATIONAL LABORATORY

Nobel prize Winner in third Generation

The Nobel Prize in Physics 1922

The Nobel Prize in Physics 1962

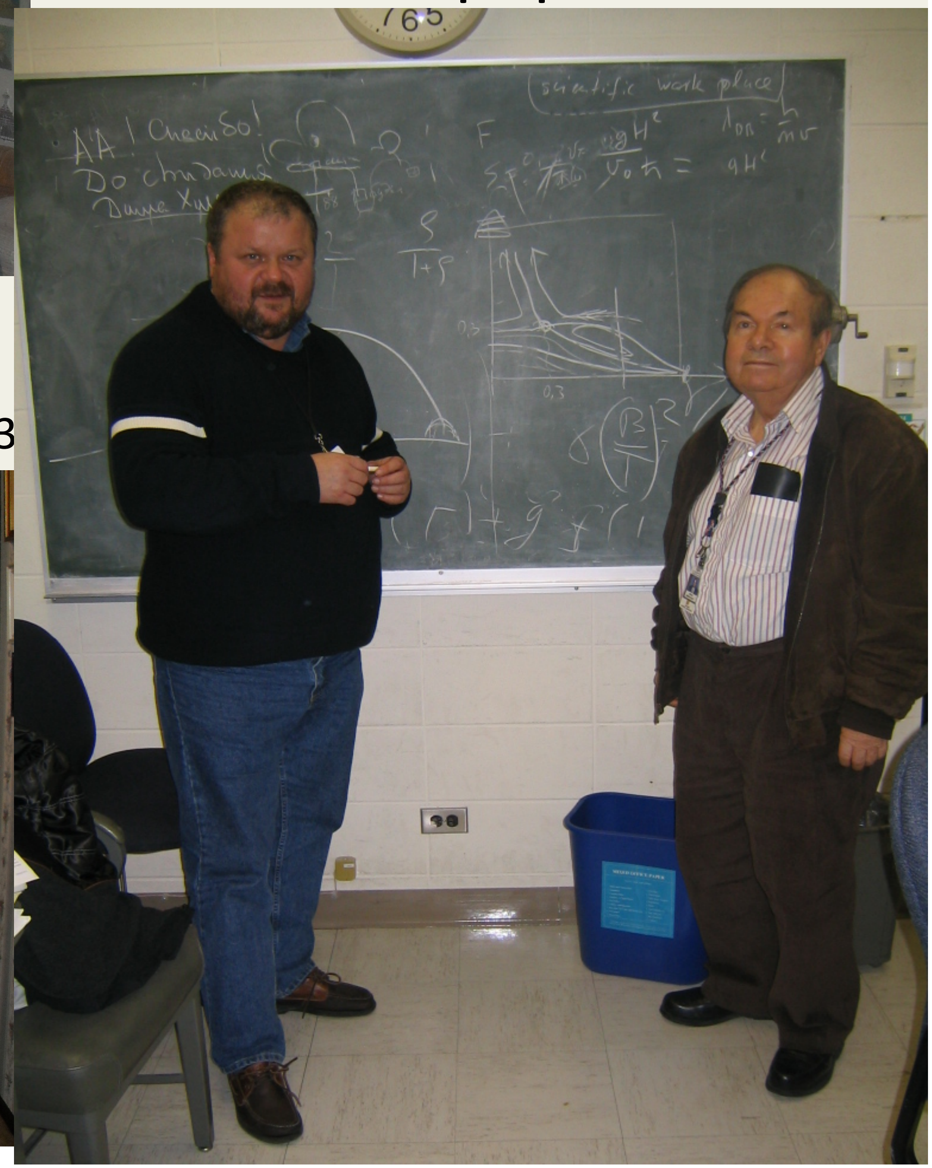
The Nobel Prize in Physics 1922 was awarded to **Niels Bohr** *"for his services in the investigation of the structure of atoms and of the radiation emanating from them"*.

The Nobel Prize in Physics 1962 was awarded to **Lev Landau** *"for his pioneering theories for condensed matter, especially liquid helium"*.

The Nobel Prize in Physics 2003 was awarded to
Alexei Abrikosov, Vitaly L. Ginzburg, Anthony J. Leggett
"for pioneering contributions to the theory of superconductors and superfluids"

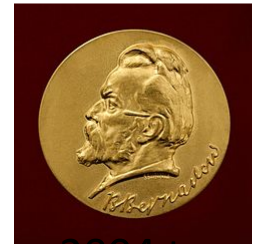
Abrikosov was always surrounded by colleagues and pupils

Dmitri Livanov, the Minister of Science and Education of RF, alumni of the Department of Theoretical Physics of MISA, visits Abrikosov, 2013




Abrikosov's 80th Birthday Symposium, 8 Nov 2008 in Argonne
Tony Leggett
Alexei Abrikosov

Last Prize in his life: Vernadsky Gold Medal



Abrikosov receives Ukrainian Gold Medal

By Lynn Tefft Hoff • July 28, 2015

Alexei Abrikosov, a distinguished scientist at the U.S. Department of Energy's Argonne National Laboratory and a Nobel Prize recipient, has been recognized again for his groundbreaking work. Abrikosov has received the Gold Medal of Vernadsky of the National Academy of Sciences of the Ukraine.

As part of the medal presentation, **Director Peter Littlewood** read from a letter to Abrikosov from **Ukrainian National Academy President Boris Paton**. "The National Academy of Sciences values your outstanding contributions in the development of the theory of normal and superconducting metals and your long, active cooperation with Ukrainian scientists," Paton wrote.

The Academy has awarded its Vernadsky Gold Medal annually since 2004 to the most distinguished academicians.

2003 Borys Paton

…

2010 Mikhail Lisitsa and Manuel Cardona

2011 Borys Oliynyk and Blaže Ristovski

2013 Oleksandr Huz and Herbert Mang

2014 Vadim M. Loktev

2015 Alexei Abrikosov

Dr. Alexei Abrikosov
Distinguished Scientist
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9 ноября 2015 г.

Президенту Национальной Академии Наук Украины
Академику Б. Е. Патону

Глубокоуважаемый Борис Евгеньевич!

Прежде всего, я хочу выразить мою благодарность Академии Наук Украины и Вам лично за оказанную честь – присуждение мне высшей награды Национальной академии наук Украины – Золотой медали имени В. И. Вернадского. Диплом и медаль были вручены мне директором Аргонской Национальной лаборатории Питером Литлвудом, что стало праздником и для меня, и для моих многочисленных коллег.

A U.S. Department of Energy laboratory managed by The University of Chi

Alexei Alexeevich Abrikosov will be remembered as a great scientist whose work influenced many fields of physics and paved the way to a new comprehension of superconductivity. He was a very bright man with a brilliant sense of humor, which helped him to overcome the difficult periods of a life so full of events.