CMD30
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Physics in Ukraine

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Outline

- **XV—XIX centuries**: ***inception of the natural sciences and emergence of universities in Ukraine.***
- **November of 1918**: ***Foundation of the Ukrainian National Academy of Sciences under the independent Ukrainian government of Hetman Pavlo Skoropadsky.***
- ***The fall of Ukrainian independence and the emigration of Ukrainian intellectuals during the turbulent first decades of the Soviet state.***
- ***Kharkiv research center***
- ***Kyiv research center***
- ***Participation in European Projects***
- **Ukrainian science after February 24, 2022**

Disclaimer

I will mean by the words “Physics in Ukraine”:

1. Outstanding scientific achievements by scholars which were born and formed in Ukraine.

2. Outstanding scientific achievements of scientists affiliated with Ukrainian academic and university institutions during the period of work on the discovery.

3. Achievements of Ukrainian physics only in the field of **condensed matter** will be highlighted.

Inception of the natural sciences and emergence of universities in Ukraine

Yuriy Drohobych or **Yuriy Kotermak** or **Giorgio da Leopoli** (1450 in Drohobych (Ukraine) – 4 February 1494 in Kraków) was a Ukrainian philosopher, astronomer, writer, medical doctor, **rector of the University of Bologna (1481-82)**, and professor of Kraków Academy, and the first publisher of a Church Slavonic printed text.

Edge of the 16th and the 17th centuries: the first academic centers appeared in Ukraine

Ostroh Academy (1576)

The Kyiv-Mohyla Academy (1615)

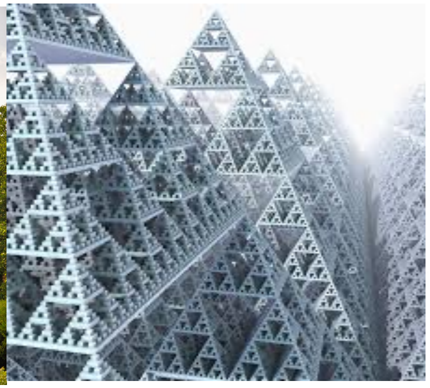
In 1661 university was founded in Lviv, the principal city of Polish-ruled Western Ukraine

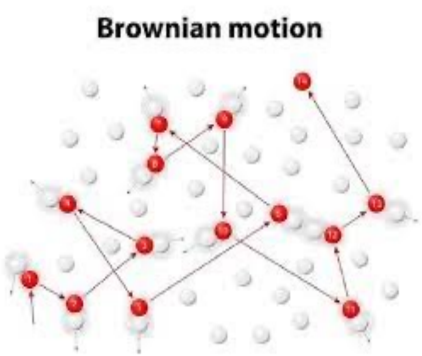
- **<u>Stefan Banach</u>** (1892–1945) - mathematician, one of the moving spirits of the Lviv School of Mathematics, father of functional analysis

- **<u>Marian Smoluchowski</u>** (1872–1917) - scientist, pioneer of statistical physics, creator the basis of the theory of stochastic processes

- **<u>Wacław Sierpiński</u>** (1882–1969) - mathematician, known for contributions to set theory, number theory, theory of functions and topology

- **<u>Stanisław Lem</u>** (1921–2006), satirical, philosophical, and science fiction writer





In 1805 Kharkiv University was established

Nobel Prize Winners from Kharkiv University:

- **Élie Metchnikoff** (*Medicine*, 1908)
- **Lev Landau** (*Physics*, 1962)
- **Simon Kuznets** (*Economic Sciences*, 1971)

In 1834 a university was inaugurated in Kyiv

Red University Building (right and centre, 1837-1843) and Astronomical Observatory (left, 1840) built by the project of Italian architect Vincenzo Beretti

Avenarius, Mikhail Petrovich (1835-1895), professor at the Kyiv University (since 1866). Studied thermoelectric phenomena and developed a formula for thermoelectromotive force.

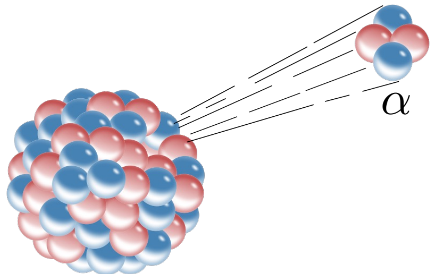
In 1924, at the age of 15, **Nikolay Bogolyubov** wrote his first published scientific paper ”*On the behavior of solutions of linear differential equations at infinity”*. In 1925 he entered Ph.D. program at the Kyiv University.

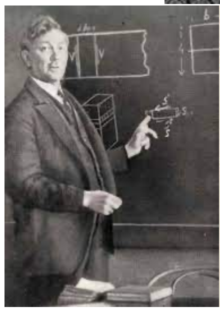
November of 1918: Foundation of the Ukrainian National Academy of Sciences under the independent Ukrainian government of hetman Pavlo Skoropadsky

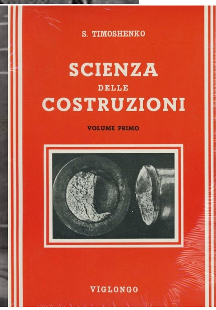
The Ukrainian People's Republic (1917-1921)

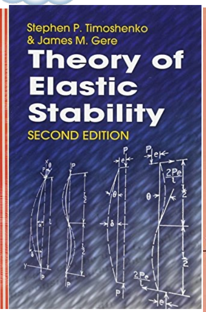
The fall of Ukrainian independence and the emigration of Ukrainian intellectuals during the turbulent first decades of the Soviet state

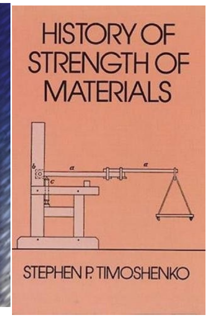
- *Theoretical physicist* ***George Gamow****, born in Odesa in 1904, who was the first to provide a quantum mechanical explanation of alpha-radioactivity,* ***professor at the George Washington University***
- *One of the founders of the discipline of strength of materials,* ***Stephan Timoshenko****, born in the village of Shpotivka, Sumy District of Ukraine in 1878, was* ***professor at Stanford University***











- ***Igor Sikorsky****, who was born in Kyiv in 1889, he emigrated to the United States, arriving in New York on March 30, 1919, became* ***world famous as a designer of airplanes and helicopters***

Kharkiv research center (established in 1928)

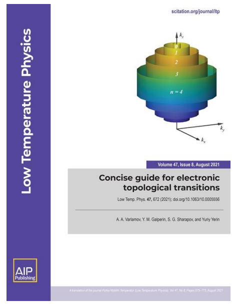
The Ukrainian Institute of Physics and Technology (UPTI)

In the 1930s, Lev Landau and leading physicists from different countries worked at the Institute, Niels Bohr and other Nobel laureates came here. Here, for the first time in the USSR, the atom was split, the world's most powerful Van de Graaff generator was built, and discoveries that changed world science were made.

The lobby of the building is greeted by a plaque with a quote from the German chemist, **Nobel laureate Fritz Haber**: *"If you succeed in realizing what you have planned, you will have the best physics institute in Europe"*.

The Institute for Low Temperature Physics and Engineering is a research institute that conducts basic research in experimental and theoretical physics, mathematics, as well as in the field of applied physics. It was founded in 1960.

Low Temperature Physics
Journal published since 1975



1932: Split of the lithium nuclei by protons

High voltage Lab in UPTI

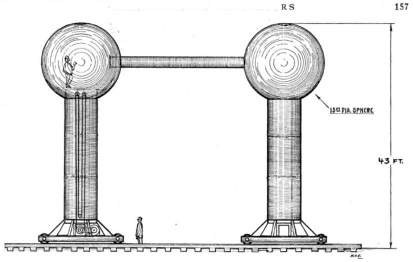
Leipunskiy, **Sinelnikov**, **Walter**, and **Latyshev** built in UPTI the high-voltage van De Graaff generator and split of the lithium nuclei by protons (five months later than Cockroft and Walton in the Cavendish Lab)

THE
PHYSICAL REVIEW
A Journal of Experimental and Theoretical Physics
VOL. 43, No. 3 FEBRUARY 1, 1933 SECOND SERIES

The Electrostatic Production of High Voltage for Nuclear Investigations

R. J. VAN DE GRAAFF,* K. T. COMPTON AND L. C. VAN ATTA, *Massachusetts Institute of Technology*

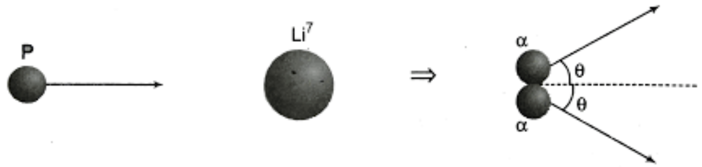
(Received December 20, 1932)



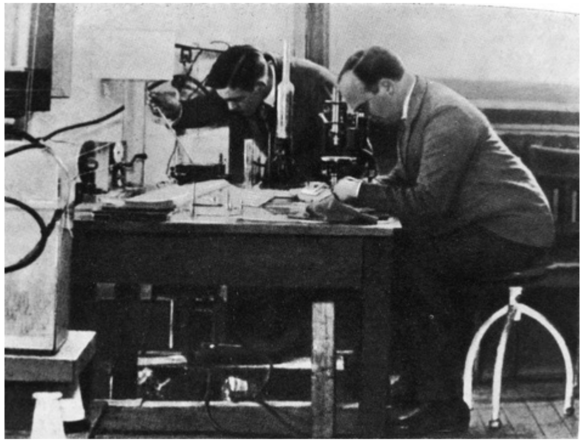
American physicist Robert Van de Graaff (second from left) at UFTI next to the generator that would later be named after him

To compare!

April, 1932: ***John Cockcroft*** (1897) and ***Ernest Walton*** (1903) focused a proton beam on lithium and bust its nucleus. This was the idea proposed by G.Gamov (1904). The era of accelerator-based experimental nuclear physics was born. Cockroft and Walton were awarded by the Nobel Prize in 1951.
Photo: Courtesy Cavendish Laboratory, University of Cambridge



1926-1930: Shubnikow stage in Leiden. Shubnikow-de-Haas oscillations



Leiden Laboratory

COMMUNICATIONS FROM THE PHYSICAL LABORATORY OF THE UNIVERSITY OF LEIDEN

COMMENCED BY

H. KAMERLINGH ONNES

CONTINUED BY

W. H. KEESOM AND W. J. DE HAAS

DIRECTORS OF THE LABORATORY.

N°. 207.

L. SCHUBNIKOW und W. J. DE HAAS. — Magnetische Widerstandsvergrösserung in Einkristallen von Wismut bei tiefen Temperaturen.

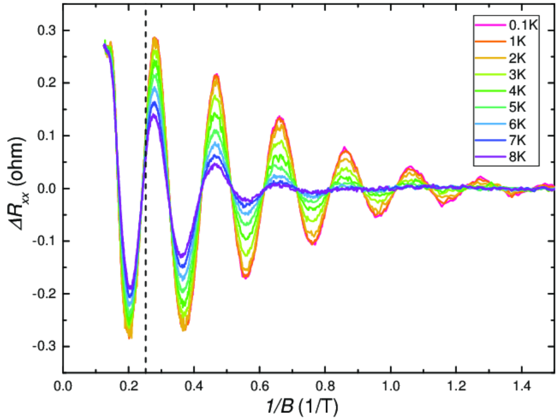
L. SCHUBNIKOW. — Ueber die Herstellung von Wismuteinkristallen.

L. SCHUBNIKOW und W. J. DE HAAS. — Die Abhängigkeit des elektrischen Widerstandes von Wismuteinkristallen von der Reinheit des Metalles.

L. SCHUBNIKOW und W. J. DE HAAS. — Neue Erscheinungen bei der Widerstandsänderung von Wismuteinkristallen im Magnetfeld bei der Temperatur von flüssigem Wasserstoff. I.

(Reprinted from: Proceedings of the Section of Sciences of the Koninklijke Akademie van Wetenschappen te Amsterdam 33, 130, 327, 350 and 363, 1930. *Meetings of* **February 22, March 29** and **April 26, 1930**).

EDUARD IJDO — PRINTER — LEIDEN.



Nat. Mat. 17, 875 (2018)

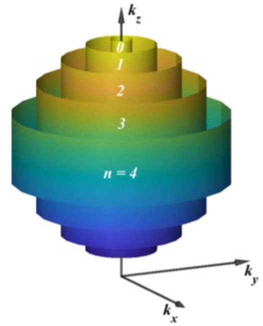
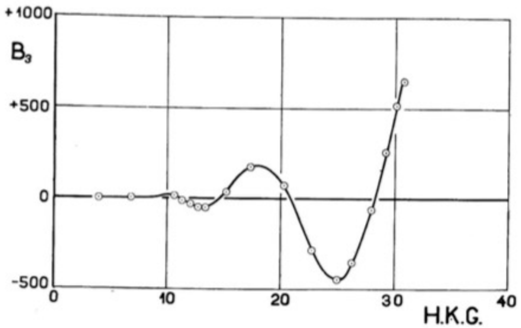


FIG. 5: Fermi surface in magnetic field is transformed in a set of Landau cylinders, corresponding to the filling by electrons of the degenerated states for the given Landau level n.

Low Temp. Phys. 47, 672 (2021)

Wander de Haas

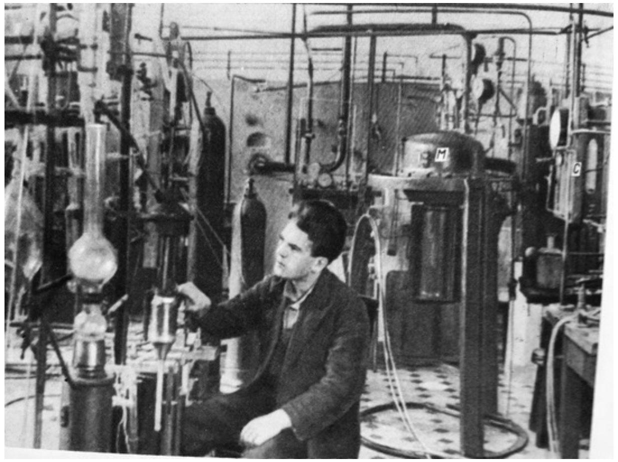
Lev Shubnikow



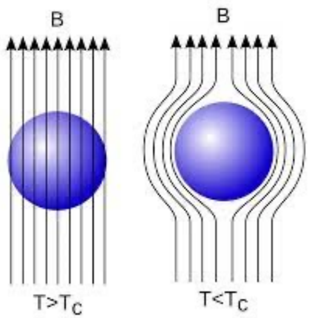
Proc. of the Royal Netherlands Academy of Arts and Science 33, 418 (1930)

$$W = W_0\left[1 - \frac{2^{1/2}}{\pi^{3/2}\hbar^3}\left(\frac{e\hbar H}{c}\right)^{1/2}\nu^{-1}(\mu)\right.$$
$$\times \sum_m m_m^* \left|\frac{\partial^2 S_m}{\partial p_z^2}\right|^{-1/2}$$
$$\left.\times \sum_k k^{-1/2}\psi(k\lambda)\cos\left(\frac{cS_m k}{\hbar e H} \pm \frac{1}{4}\pi\right)\cos\left(\frac{\pi k m^*}{m}\right)\right]$$

Shubnikow's low temperature lab in Kharkiv



Low temperature lab in Kharkiv, 1930ies
Cryostat was acquired from W. Meissner

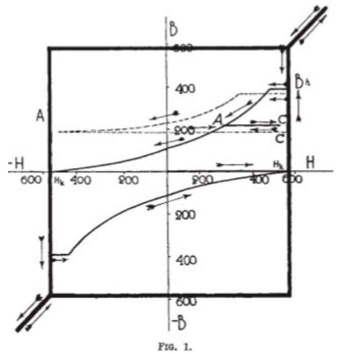


Confirmation of the Meissner effect

The main conclusion of Meissner and Ochsenfeld (1933) was that B in the S phase is always zero, however not all researchers agreed with that . The experiment of Rjabinin and Shubnikov removed all doubts.

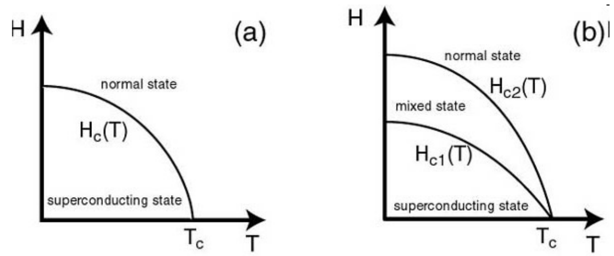
Rjabinin and Shubnikov attacked the same problem via measuring the magnetic moment M of a superconducting lead rod (5 mm in diameter and 50 mm long) at constant temperature 4.2 K vs H_0 applied parallel to the sample longitudinal axis (1934).

The relation between the induction B and the field strength H represented by thin line and by the thick line above H_K (*Nature 134, 286 (1934)*)



Discovery of the Shubnikow's phase of superconductor

1935: Lev Shubnikow with J.N. Rjabinin studied superconductivity in metallic alloys Pb-Tl,
J.N. Rjabinin and L.W. Schubnikow.
Nature 135, 581 (1935)



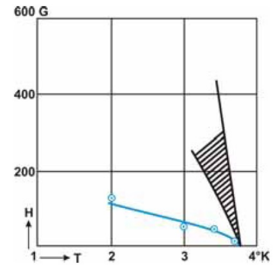
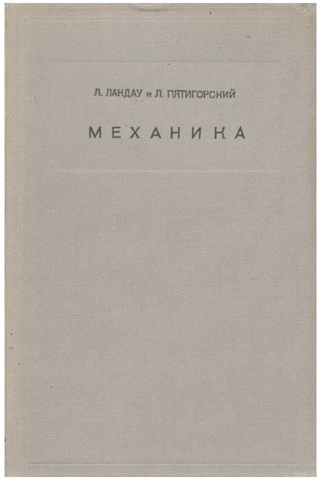


Fig. 11. Temperature dependence of the incipient penetration of magnetic field into the superconducting alloy Pb+64.8wt%Tl. The hatched region denotes the region of gradual flux penetration in magnetic field according to the electrical resistance measurement data (After De Haas & Casimir-Jonker, 1935a).

1932–1937: Landau was the head of the theoretical department, he founded school of the theoretical physics and started to write famous Course

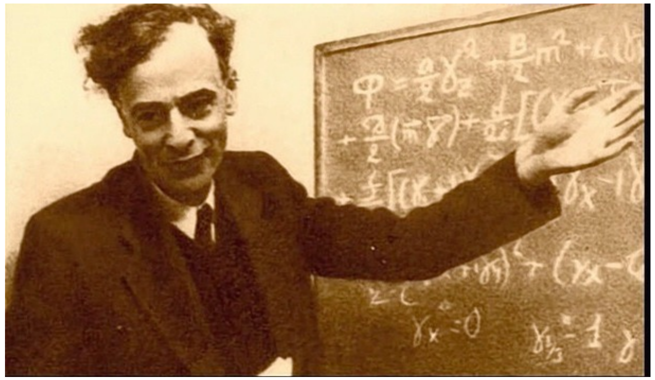
UPTI employees on the steps of the main building, 1934. Landau is the third from the left in the bottom row. On his right is Pyotr Kapitsa, on whose personal guarantee he would be released from prison in five years

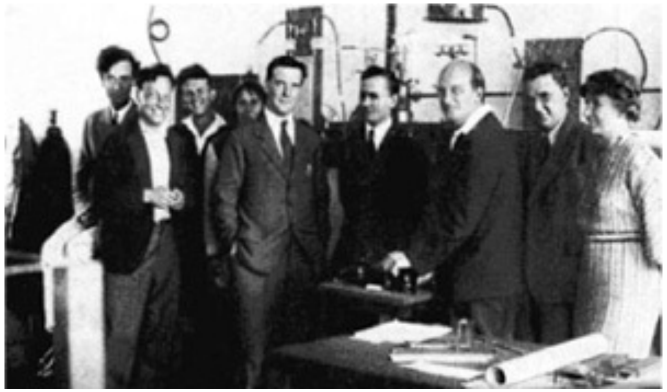


Landau's theoretical minimum and school of theoretical physics

The **Kharkiv Theoretical Physics School** was founded by Lev Landau in Kharkiv, 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 Kharkiv Theoretical Physics School from 1932 to 1937.

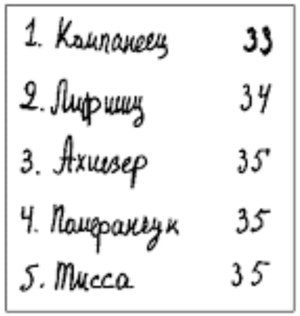
~~Lan~~Dau said!



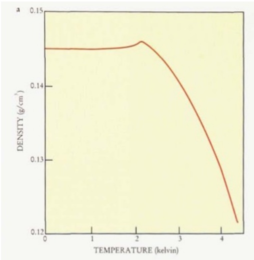


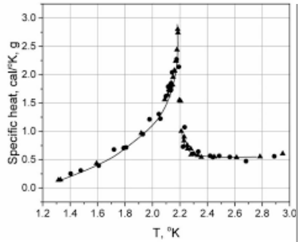
First apprentices:

A. Kompaneets
E. Lifshitz
A.I. Akhiezer
I. Pomeranchuk
Laslo Tisza

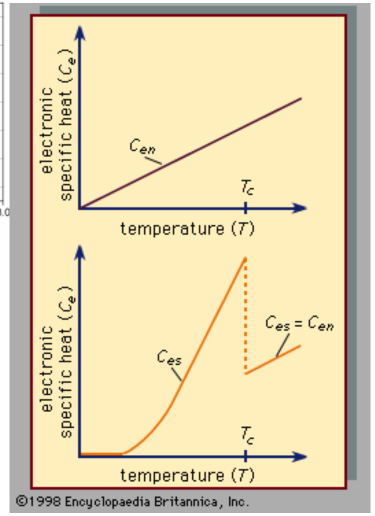


1937: Lev Landau develops his theory of the second order phase transitions





In 1923, together with Leo Dana, Kamerling Onnes studies the temperature dependence of specific heat capacity of liquid helium. They conclude that near the temperature where the maximum in density is reached something happens to helium: its thermodynamic characteristics in the vicinity of of 2.2 K. change dramatically. This was apparently the first time that what is now called the λ-point was identified as a discontinuity.

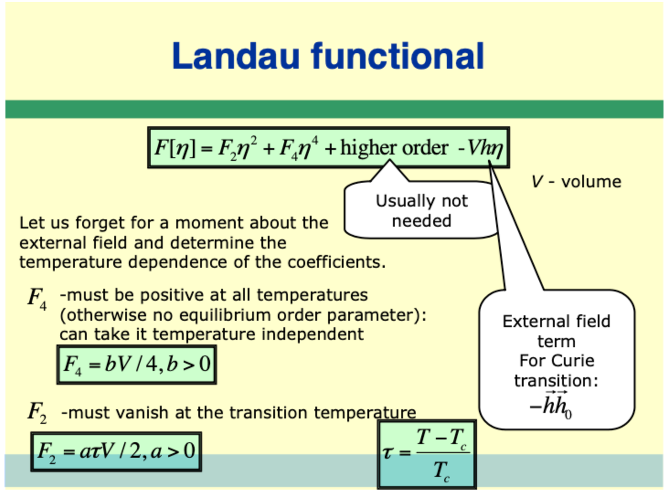


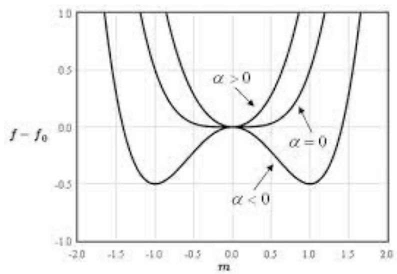
In 1932, Keesom and colleagues conducted a series of experiments that revealed a jump-like change in the electronic heat capacity of tin and thallium near the transition from the ordinary to the superconducting state.

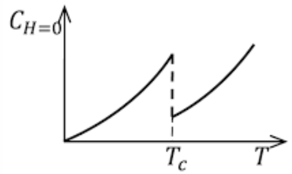
Paul Ehrenfest classified phase transitions based on the behavior of the thermodynamic free energy as a function of other thermodynamic variables. Phase transitions were labeled by the lowest derivative of the free energy that is discontinuous at the transition.

Second-order phase transitions are continuous in the first derivative (the order parameter, which is the first derivative of the free energy with respect to the external field, is continuous across the transition) but exhibit discontinuity in a second derivative of the free energy.

Under the Ehrenfest classification scheme, there could in principle be third, fourth, and higher-order phase transitions.







$$C_s(T_c) - C_n(T_c) = \frac{T_c}{4\pi}\left(\frac{dH_c}{dT}\right)^2.$$

1937: NKVD (KGB) defeats of Kharkiv research elite

In 1937 five leading UPTI employees were arrested and shot: L. V. Shubnikov, L. V. Rosenkevich, V. S. Gorsky. V. P. Fomin and K. B. Vaiselberg, two foreign nationals were arrested and later extradited to the Gestapo: F. Houtermans (a member of the Communist Party of Germany) and A. Weisberg (a member of the Communist Party of Austria and Germany).

On 26 April 1938 was arrested in Moscow professor Y. B. Rumer "as an accomplice of Landau, an enemy of the people“. Together with Y. B. Rumer were arrested L. D. Landau and M. A. Korets.

Landau was arrested on 28 April 1938. The accusations against him concerned his work at UPTI. The future Nobel laureate spent exactly one year in prison and was released on 28 April 1939 thanks to the petition of prominent physicists Niels Bohr and Pyotr Kapitsa.

On 4 June 1938, the second director of UPTI, A. I. Leipunsky, was arrested.

On 22 June 1938, the first director of UFTI, I. V. Obreimov, was also arrested.

1937: Lev Shubnikov, instead of the Nobel Prize death penalty!

<u>Extract</u>

<u>from Protocol No</u>. 13 of the decision of the People's Commissar of Internal Affairs of the USSR, the General Commissar of State Security, Mr. Yezhov, and the Prosecutor of the Union, Mr. Vyshinsky, dated 28 October 1937.

<u>Hearing</u>: Materials on the accused, submitted by the NKVD Department of the Ukrainian SSR in Kharkov region in accordance with the order of the NKVD of the USSR № 00439 of 25.07.1937.

<u>Decided</u>: Shubnikov Lev Vasilyevich
be executed

People's Commissar of Internal Affairs of the USSR General Commissar of State Security YEZHOV

USSR Prosecutor VYSHINSKY

<u>Выписка</u>

<u>из протокола №</u> 13 решения Наркома Внутренних Дел СССР Генерального Комиссара Госбезопасности тов. ЕЖОВА и Прокурора Союза ССР тов. ВЫШИНСКОГО - от 28 октября 1937 года

<u>Слушали:</u> Материалы на обвиняемых, представленные Управлением НКВД УССР по Харьковской области, в порядке приказа НКВД СССР за № 00439 от 25/VII - 1937 года.

<u>Постановили:</u> Шубникова Льва Васильевича

р а с с т р е л я т ь

Нарком Внутдел СССР Генеральный
Комиссар Госбезопасности - ЕЖОВ

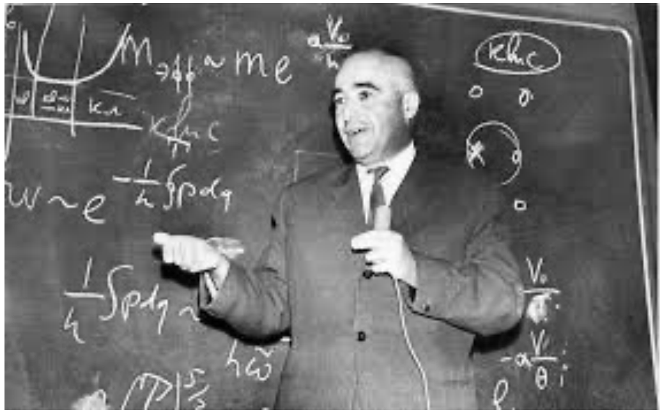
Прокурор СССР - ВЫШИНСКИЙ

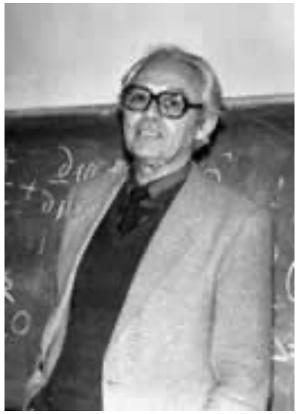
ВЕРНО: ОПЕРУПОЛН Ш ОТД УГБ
Лейтенан Госбезопасности /РЕШЕТНЕВ/

АМ

I.M. Lifshitz's Kharkiv school of theorists (since 1950ies)

Fundamental discoveries in physics of metals: galvanomagnetic and high frequency phenomena in metals, different types of resonant phenomena, size effects, the rise of fermiology and theory of electronic topological transitions





M. Kaganov

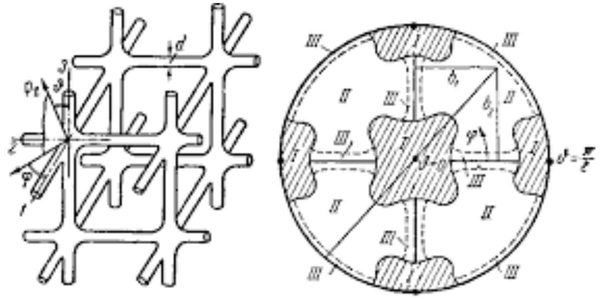
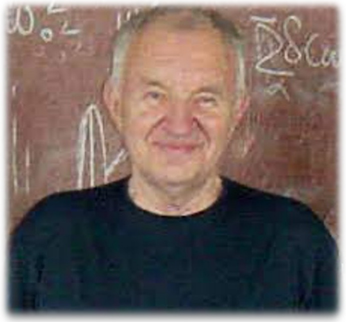


FIG. 2 FIG. 3

FIG. 2. Constant-energy surface of the "three-dimensional grid" type.

I. M. Lifshitz and V. G. Pechansky, Sov. Phys. JETP 35, 875 (1959)

E. Kaner



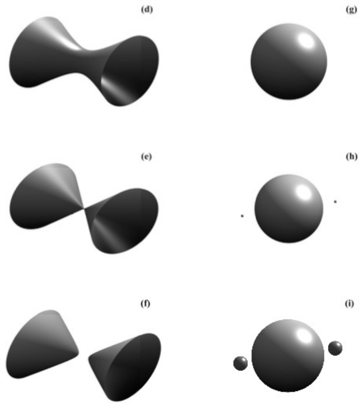
A. Kosevich

M. Azbel

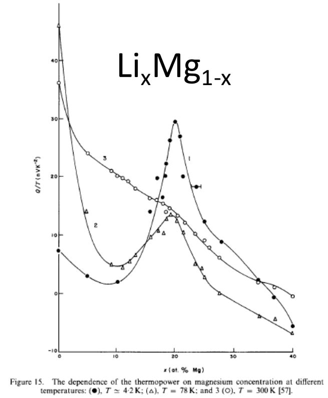
V. Pechansky

1960: I.M. Lifshitz, Theory of Electronic Topological Transitions in metals (2 ½ Lifshitz transitions)

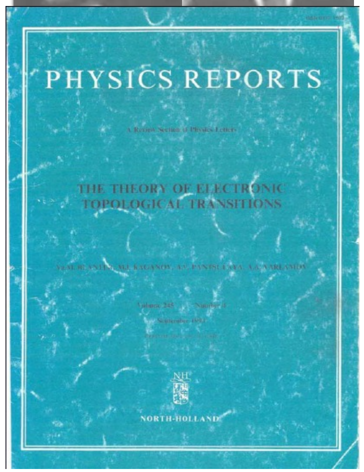
I. M. Lifshitz (1917-1982)



EPL 138 16005 (2022)



Sov. Phys. JETP 58, 959 (1983)



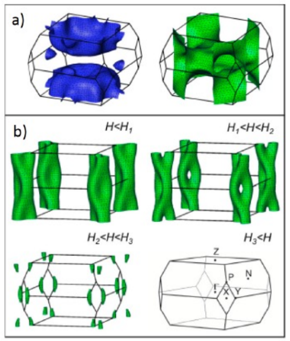
$$\varrho(\varepsilon) = \varrho_0(\varepsilon) + \delta\varrho$$

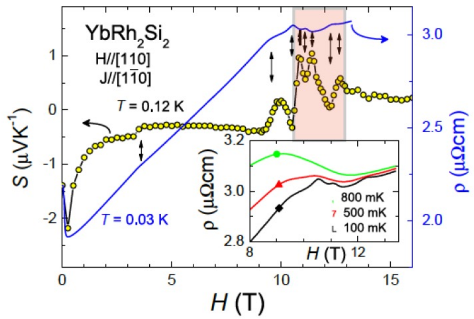
$$\delta\varrho = \begin{cases} 0, & \text{region I}, \\ \alpha|\varepsilon - \varepsilon_c|^{1/2}, & \text{region II}, \end{cases}$$

$$Z = \varepsilon_F - \varepsilon_c$$

$$\delta\Omega_e = \begin{cases} 0, & \text{region I}, \\ -(4/15)\alpha|Z|^{5/2}, & \text{region II}. \end{cases}$$

Today: Cascade Lifshitz transitions in $YbRh_2Si_2$





J. Phys. Soc. Jpn. 88, 104702 (2019)

Valery Pokrovsky, apprentice of Ilya Lifshitz

In 1962 and 1963, Valery Pokrovsky together with A. Patashinski, and Isaak Khalatnikov solved the problem of quasi-classical scattering in three dimensions. In 1963–1965, together with Patashinski, Valery Pokrovsky developed the *fluctuating theory of phase transitions*. This theory was then applied to a wide range of phase transition problems, including critical slowdown of chemical reactions, Brownian motion, electric conductivity near the magnetic ordering point, nucleation in near-critical systems.

VOLUME 42, NUMBER 1 PHYSICAL REVIEW LETTERS 1 JANUARY 1979

Ground State, Spectrum, and Phase Diagram of Two-Dimensional Incommensurate Crystals

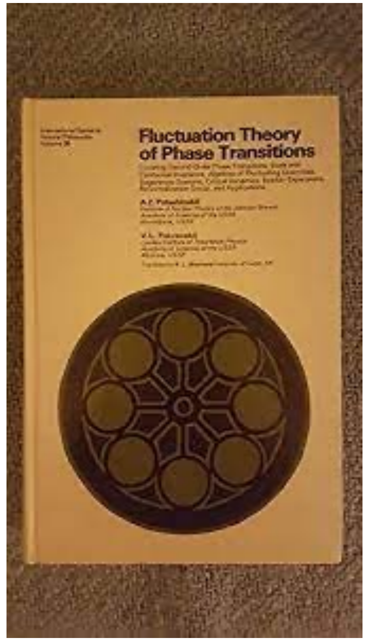
V. L. Pokrovsky[(a)]
Baker Laboratory and Materials Science Center, Cornell University, Ithaca, New York 14850

and

A. L. Talapov
Landau Institute of Theoretical Physics, 142432 Chernogolovka, U. S. S. R.
(Received 23 October 1978)

A model of a monolayer of atoms adsorbed on a crystalline surface is discussed. When the initial incommensurability, δ, between a reciprocal lattice vector of the monolayer and one of the substrate is small, the monolayer has a one-dimensional superstructure with period depending on δ. For $\delta > \delta_c(T)$ the state is incommensurate; $\delta_c(T)$ decreases and vanishes at a T_c given by the elastic moduli of the monolayer. The spectrum of small oscillations has two acoustic branches, one vanishing at the phase transition.

The announcement for the **1982 Nobel Prize** in Physics, which was awarded to **<u>Kenneth G. Wilson</u>**, acknowledges Patashinski, *Valery Pokrovsky*, and Leo Kadanoff for important contributions to the theory of critical phenomena.



1960ies-80ies: Fundamental studies of superconductivity

1964: I. Yanson, V. Svistunov, I. Dmitrenko, Discovery of the non-stationary Josephson effect

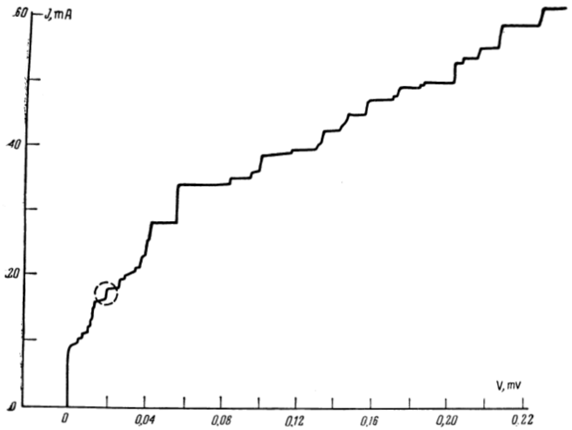


FIG. 1. Volt-ampere characteristic of the tunnel structure Sn–SnO$_2$–Sn at T = 1.57°K, H = 1.5 Oe. The step with frequency inside the transmission band of the detector is shown by the circle.

Soviet JETP 48, 976 (1965)

First experimental observation of electromagnetic radiation (*Josephson generation*) from Josephson tunnel junctions (*ac Josephson effect*). Detected power from Sn-SnO$_x$-Sn tunnel junction was about 10^{-14} W at frequency 9.8 GHz

Thus, if a constant potential difference is maintained at the junction, an alternating current will flow across the junction:

$$j = j_c \sin\left(\theta_0 + \frac{2eV}{\hbar} t\right).$$

The frequency

$$\omega = 2eV/\hbar$$

corresponds to $10^{11}\ s^{-1}$ for $V \sim 10^{-4}$ V.

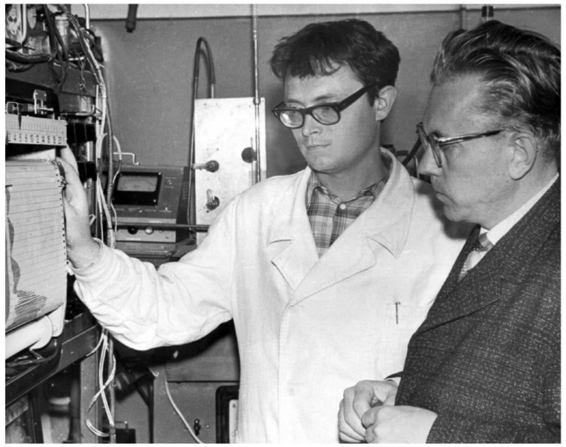
From this, using $V = (\hbar/2e)\, d\theta/dt$, we find (Aslamazov and Larkin 1969)

$$V(t) = \frac{Rj(j^2 - j_c^2)}{[j^2 + j_c^2 \cos\omega t + j_c(j^2 - j_c^2)^{1/2} \sin\omega t]},$$

where

$$\omega = \frac{2eR}{\hbar}(j^2 - j_c^2)^{1/2}.$$

I. Dmitrenko and I. Yanson in the lab (1964)



1970: Birth of mesoscopic physics

1970: I. Kulik: Persistent currents in normal nano-rings

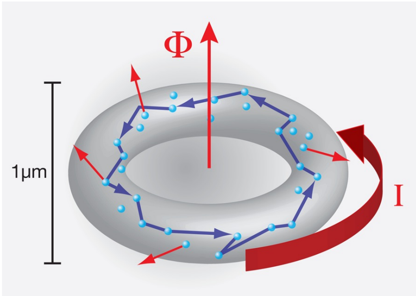
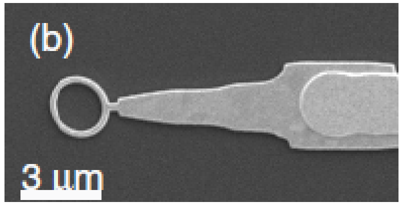


Illustration: *Alan Stonebraker (physics.aps.org)*



Phys. Rev. Lett. 102, 136802 (2009)

$$I_{AB} \sim \frac{ev_F}{R}\sin\left(2\pi\frac{\phi}{\phi_0}\right).$$

1977: I. Kulik, A. Omelyanchouk, weak superconductivity and properties of superconducting microbridge in the pure limit

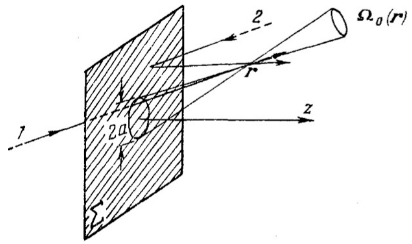
$$(2\omega + \mathbf{v}_F\nabla) f_\omega - 2\Delta(\mathbf{r})\, g_\omega = \frac{v_F}{l}\left(g_\omega\langle f_\omega\rangle - f_\omega\langle g_\omega\rangle\right),$$

$$g_\omega = \sqrt{1 - f_\omega f_\omega^+},\quad f_\omega^+(\mathbf{v}_F, \mathbf{r}) = f_\omega^*(-\mathbf{v}_F, \mathbf{r}),$$

$$\Delta(\mathbf{r}) = \lambda N(0)\, 2\pi T \sum_{\omega>0} \langle f_\omega(\mathbf{v}_F, \mathbf{r})\rangle,$$

$$I = \frac{\pi\Delta_0}{eR_N}\sin(\Phi/2)\ \mathrm{th}\,\frac{\Delta_0\cos(\Phi/2)}{2T},\quad -\pi < \Phi < \pi,$$

A rigorous solution of Eilenberger equations is obtained for superconducting microbridge. The critical current at zero temperature is twice a set of tunnel junction of the same resistance.



Sov. J. Low Temp. Phys 3, 945 (1977)

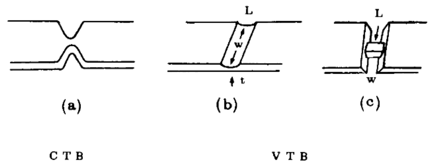


Figure 7.10 Different thin film bridge structures. (*a*) Constant thickness bridge (C.T.B.) or "Dayem bridge". (*b*), (*c*) variable thickness bridges (V.T.B.).

A. Barone, and G. Paterno, Physics and Application of the Josephson Effect (1982)

Robert Shekhter

1975: I. Kulik , Robert Shekhter: Kinetic phenomena and charge discreteness effects in granulated media

An approach to the problem of charge transport in a system of small metallic particles coupled by tunnel interactions is proposed. The system Hamiltonian is represented in the form

$$H = H_0 + H_V + H_T ,$$

where H_V takes into account electrostatic effects due to charge accumulation in the granules and the discrete character of the charge, and H_T is the tunnel Hamiltonian. The important role of the specific granule charge fluctuations due to the discrete character of the charge is demonstrated. The fluctuations are manifested by the characteristic oscillations of a number of physical characteristics of granulated media.

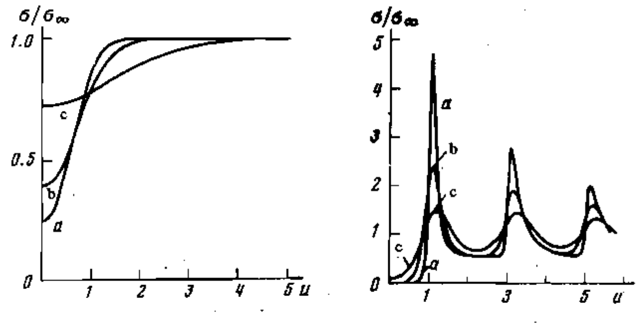
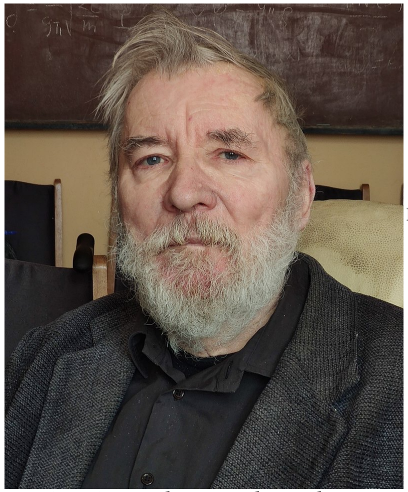


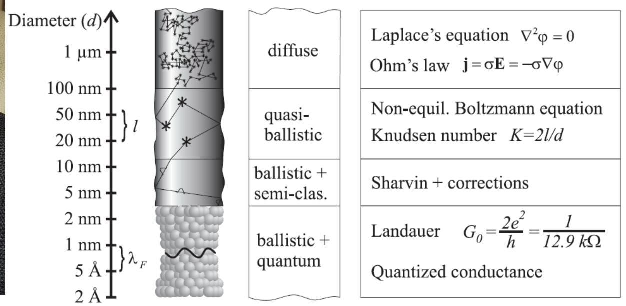
FIG. 3 FIG. 4

FIG. 3. Derivative of the current-voltage characteristic $\sigma = dI/dV$



A. Omelyanchouk

1977: I. Kulik, A. Omelyanchouk, R. Shekhter: Electrical conductivity of point microbridges and phonon and impurity spectroscopy in normal metals



Kim Hansen, PhD thesis (2000)

A theory of the nonlinear effects in the electrical conductivity of metallic microbridges is constructed which is based on a model consisting of a hole of radius a in an impermeable partition separating two metallic half-spaces.

1989: L. I. Glazman and R. I. Shekhter - Coulomb oscillations of the conductance in a laterally confined heterostructure

Leonid Glazman

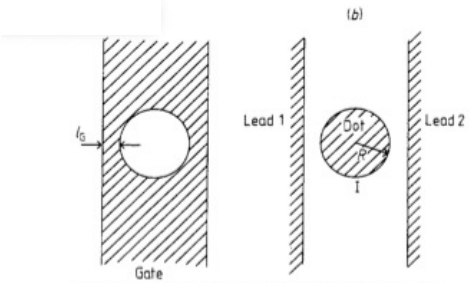


Figure 1. (*a*) The gate geometry and (*b*) the geometry of a dot surrounded by the depletion area.

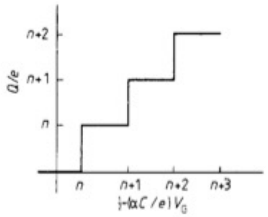


Figure 2. The dependence of an excess charge q on the dot as a function of the gate voltage V_G under $T = 0$; n is an integer number.

A new type of conductance oscillations in a GaAs heterostructure with a proposed strip-like gate with a hole. Such a gate defines a conducting dot (under the hole) in an otherwise depleted region of a two-dimensional electron gas. The oscillations are caused by discrete changes of the charge of the dot as the gate voltage is varied.

The Coulomb energy of a dot can be written as

$$E_n(\varphi) = Q^2/2C + Q\varphi.$$

$$\ln\left(\frac{G_n}{G_{n-1}}\right) \propto \frac{l_G}{a_B}\left(\frac{\varepsilon a_B}{C}\right)^{1/2}\left[n^{1/2} - (n-1)^{1/2}\right]$$

a_B is Bohr radius

l_G = 800 Å is the distance between the hole and border

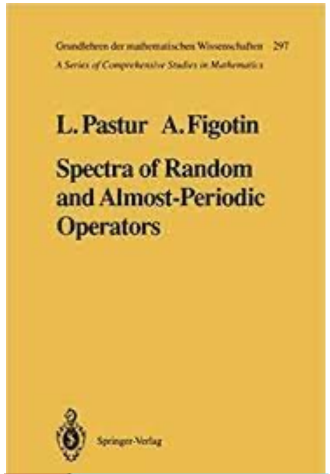
ϵ is dielectric constant

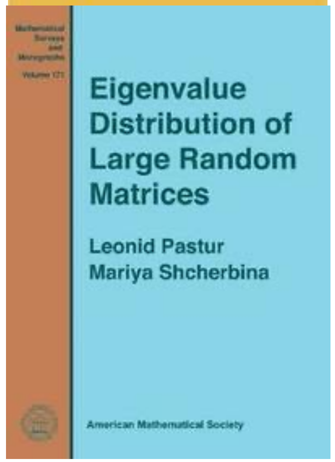
L. Pastur: Properties of disordered systems, random matrix theory, mathematically rigorous proof of Anderson localization

Leonid Pastur

In random matrix theory: together with Vladimir Marchenko, he discovered the Marchenko–Pastur law. Later, he devised a more general approach to study random matrices with independent entries in the global regime. Together with Mariya Shcherbina, he found the first rigorous proof of universality for invariant matrix ensembles.

In the spectral theory of random Schrödinger operators, he introduced the class of metrically transitive operators, and discovered several fundamental properties of this class. Together with Ilya Goldsheid and Stanislav Molchanov, he established Anderson localization for a class of one-dimensional self-adjoint operators with random potentials; this was the first mathematically rigorous proof of Anderson localization.





Kyiv research center

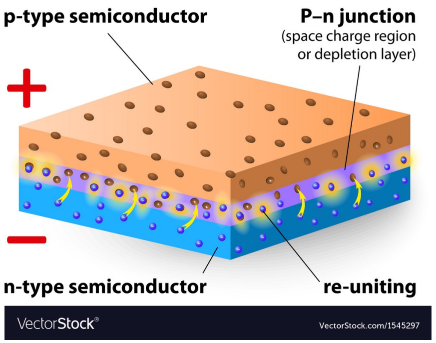


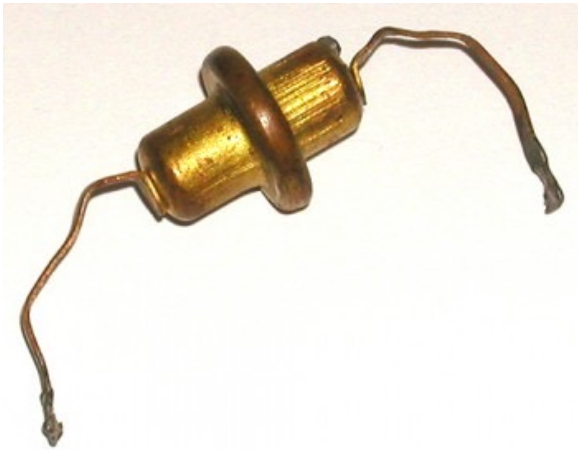


1941: V. Lashkarev discovered *p–n* junction around the selenium rectifying layers in Cu_2O/Ag_2S

In 1941 Lashkarev published his fundamental discovery, the presence of a semiconductor layer between the barrier layer and the adjacent electrode, and the opposite sign of charge carriers (electrons and holes) on both sides of a barrier layer in solar cells of Cu_2O and Ag_2S photocells and selenium rectifiers. In current terms, this was a discovery of p–n junctions around the rectifying layers in these systems. This discovery was made by measuring the sign change of thermo-e.m.f. on both sides of the rectifying layer by using miniature thermoprobes.

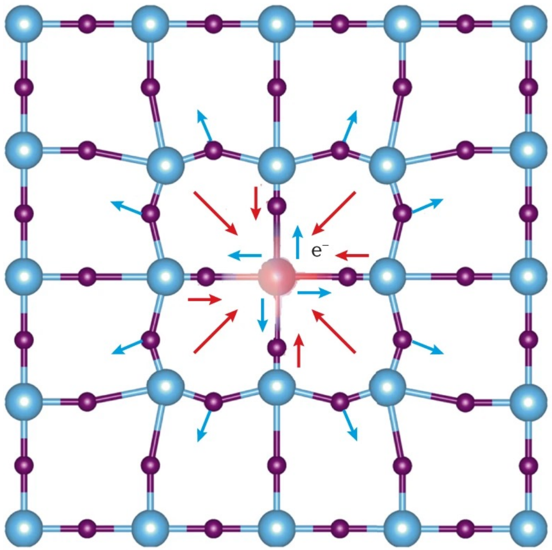
P–N JUNCTION





Copper-oxide p-n diode. Manufactured under Lashkarev's supervision by Ufa munitions factory in 1941-1945, was used in military wireless set.

1946: Pekar's "polaron"



Schematic illustration of the polarization caused by the self-trapping of an electron at a lattice site and formation of a (small) polaron. Arrows represent attractive (red) and repulsive (blue) forces.

Nature Reviews Materials 6, 560 (2021)

Pekar's name is tightly bound with several the most important discoveries in physics of solids, including theory of rectifiers and autolocalized states of electrons that were named by him as "polarons", the Pekar's waves, and many others.

Solomon Pekar

The theory of polarons was formulated by S.I. Pekar as a continual theory, which made it to be an ideal model for the field theory. His first work devoted to polarons was published in 1946, *i.e.*, several years before appearance of works by J. Schwinger and R. Feynman, who provided a powerful pulse for development of quantum electrodynamics. This Pekar's work was rather timely, and the significance of the theory describing polaron as the simplest model in the field theory was apprehended by all theorists. The formalism developed by S.I. Pekar became the first example of currently popular semiclassical solutions for equations in the non-linear field theory. The studied by him adiabatic limit corresponds to the non-perturbative theory that was impossible within the framework of diagram technique.

1947: Bogoliubov developed his famous theory of nonideal Bose gas

Vol. XI, No. 1 JOURNAL of PHYSICS 1947

ON THE THEORY OF SUPERFLUIDITY *

By N. BOGOLUBOV

Mathematical Institute, Academy of Sciences of the Ukrainian SSR and Moscow State University

(Received October 12, 1946)

This paper presents an attempt of explaining the phenomenon of superfluidity on the basis of the theory of degeneracy of a non-perfect Bose-Einstein gas.

By using the method of the second quantization together with an approximation procedure we show that in the case of the small interaction between molecules the low excited states of the gas can be described as a perfect Bose-Einstein gas of certain "quasi-particles" representing the elementary excitations, which cannot be identified with the individual molecules.

The special form of the energy of a quasi-particle as a function of its momentum is shown to be connected with the superfluidity.

Microscopic Hamiltonian for the uniform system of bosons with contact interaction is given by

$$\mathcal{H} = \sum_p \epsilon_p b_p^\dagger b_p + \frac{U_0}{2V} \sum_{pp'q} b_{p+q}^\dagger b_{p'-q}^\dagger b_{p'} b_p - \mu \sum_p b_p^\dagger b_p \qquad (3.1)$$

Bogoliubov proposed to simplify it using the mean-field approximation:

$$\mathcal{H}_{\mathrm{MF}} = -\frac{N_0^2 U_0}{2V} + \sum_{p\neq 0} (\epsilon_p + 2n_0 U_0 - \mu)(b_p^\dagger b_p + b_{-p}^\dagger b_{-p}) + n_0 U_0 \sum_{p\neq 0} (b_p^\dagger b_{-p}^\dagger + b_p b_{-p})$$

We can diagonalize using Bogoliubov transformation

$$b_p = u_p \alpha_p + v_p \alpha_{-p}^\dagger$$
$$b_{-p} = u_p \alpha_{-p} + v_p \alpha_p^\dagger$$

Bosonic commutation relations are preserved when

$$u_p^2 - v_p^2 = 1$$

The diagonal form of the mean-field Hamiltonian

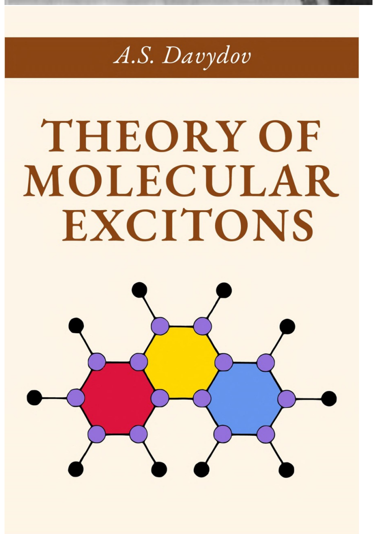
$$\mathcal{H}_{\mathrm{MF}} = -\frac{N_0^2 U_0}{2V} + \sum_{p\neq 0} E_p (\alpha_p^\dagger \alpha_p + \alpha_{-p}^\dagger \alpha_{-p})$$

Dispersion of collective modes is given by

$$E_p = \sqrt{\epsilon_p (\epsilon_p + 2n_0 U_0)}$$

Lectures on Quantum Statistics (1949)

1948: Davydov proposed a theory of exciton multiplets



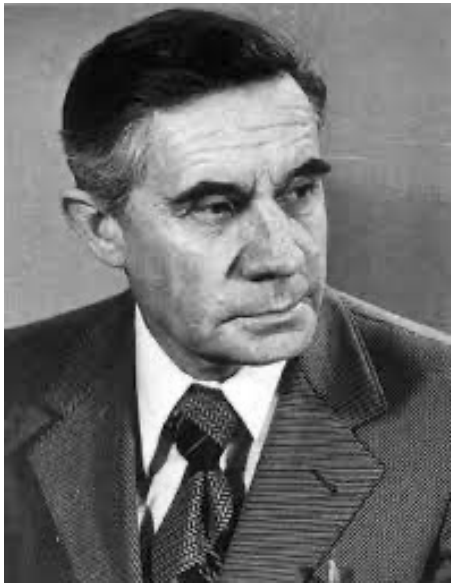
Atomic and molecular excitons

An exciton may be described as an excited state of an atom, ion or molecule, if the excitation is wandering from one cell of the lattice to another.
When a molecule absorbs a quantum of energy that corresponds to a transition from one molecular orbital to another molecular orbital, the resulting electronic excited state is also properly described as an exciton. Molecular excitons have several interesting properties, one of which is energy transfer whereby if a molecular exciton has proper energetic matching to a second molecule's spectral absorbance, then an exciton may *hop* from one molecule to another. The process has found application in sensing.

The hallmark of molecular excitons in organic molecular crystals are doublets and/or triplets of exciton absorption bands strongly polarized along crystallographic axes. In these crystals an elementary cell includes several molecules sitting in symmetrically identical positions, which results in the level degeneracy that is lifted by intermolecular interaction. As a result, absorption bands are polarized along the symmetry axes of the crystal. Such multiplets were discovered by Antonina Prikhot’ko and their genesis was proposed by Alexander Davydov**.**

It is known as 'Davydov splitting.

1950ies: Tolpygo developed a microscopic theory of lattice polaritons



Crystal lattice dynamics and polaritons

Between 1949 and 1956, Kirilo Tolpygo built a quantum-mechanical theory of crystal lattice dynamics. It included deformation of electronic shells of ions and effects of retardation. In the theory of crystal lattice dynamics this model is now known as Tolpygo model, a model of deformable ions, or a "shell model". In 1950, he predicted bound states of photons and optical phonons in ionic crystals, now known as lattice polaritons. These mixed states were subsequently investigated experimentally. S.I. Pekar proposed to coin these states as “light excitons”. However, this name did not stick and term polaritons proposed by Hopfield is used.

Polariton

A polariton is a quasiparticle that results from strong coupling between electromagnetic radiation and a charged particle.

90 YEARS

PHYSICAL PROPERTIES OF A ROCK SALT LATTICE MADE UP OF DEFORMABLE IONS

Translated and reprinted from Zh. Eksp. Teor. Fiz. **20**, No. 6, pp. 497–509 (1950)

K.B. TOLPYGO

Institute of Physics, Academy of Sciences of the Ukrainian SSR
(Kyiv, Ukraine)

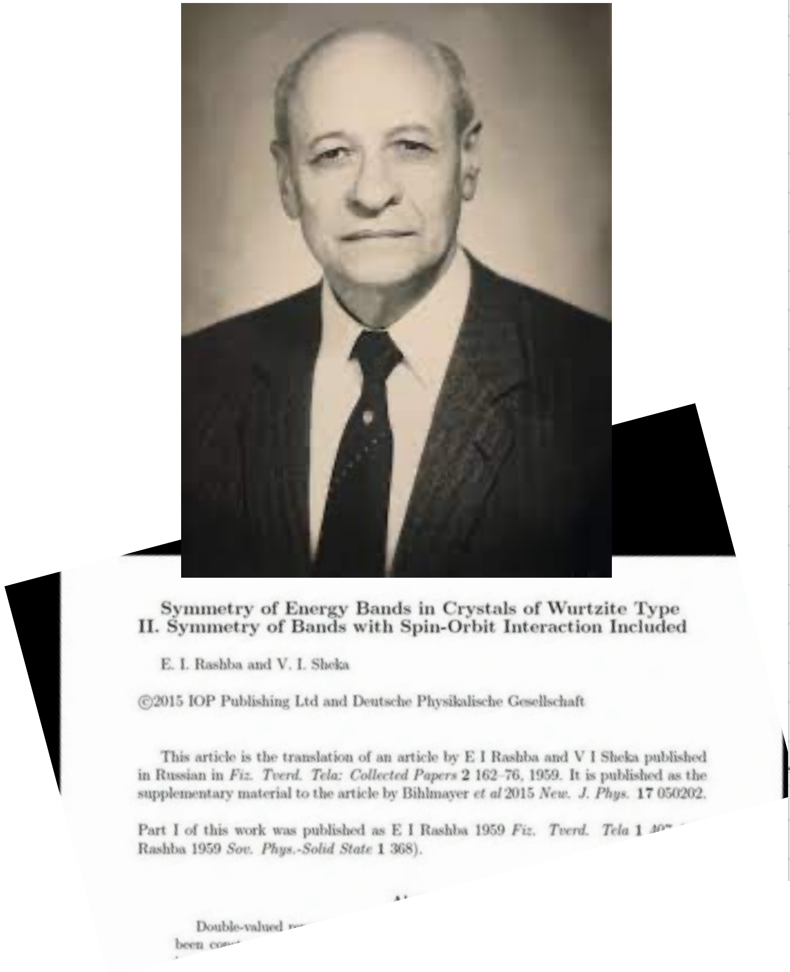
The energy of interaction between neighbor ions has been determined in the approximation of strongly bound electrons, as a function of the ionic dipole moments and the ion-to-ion distance. The equations of lattice vibrations have been solved taking interaction retardation into account. In the long-wave case, the resulting spectrum of characteristic frequencies of the crystal lattice differs substantially from that obtained in the framework of the Born theory. The Born relationship between the dielectric constant and the limiting vibration frequency changes as well. The dispersion law and the moduli of elasticity for six alkali halide crystals have been determined. A comparison between the theory and the experiment has been made.

about the situation, where the Born relationship

$$\frac{\varepsilon - n_0^2}{(n_0^2+2)^2} m\omega_0^2 = \frac{4\pi e^2}{9\Delta} \qquad (1)$$

is usually no more valid. Here, ω_0 is the limiting frequency of ion oscillations; $m = m_1 m_2/(m_1+m_2)$ is the reduced mass of an ion pair; Δ is the volume of a unit cell containing two ions with opposite charges (in the considered case, i.e. two face-centered lattices inserted into each other, this parameter is equal to $2a^3$);

1959: Rashba effect (spin-orbit coupling), spintronics



Symmetry of Energy Bands in Crystals of Wurtzite Type
II. Symmetry of Bands with Spin-Orbit Interaction Included

E. I. Rashba and V. I. Sheka

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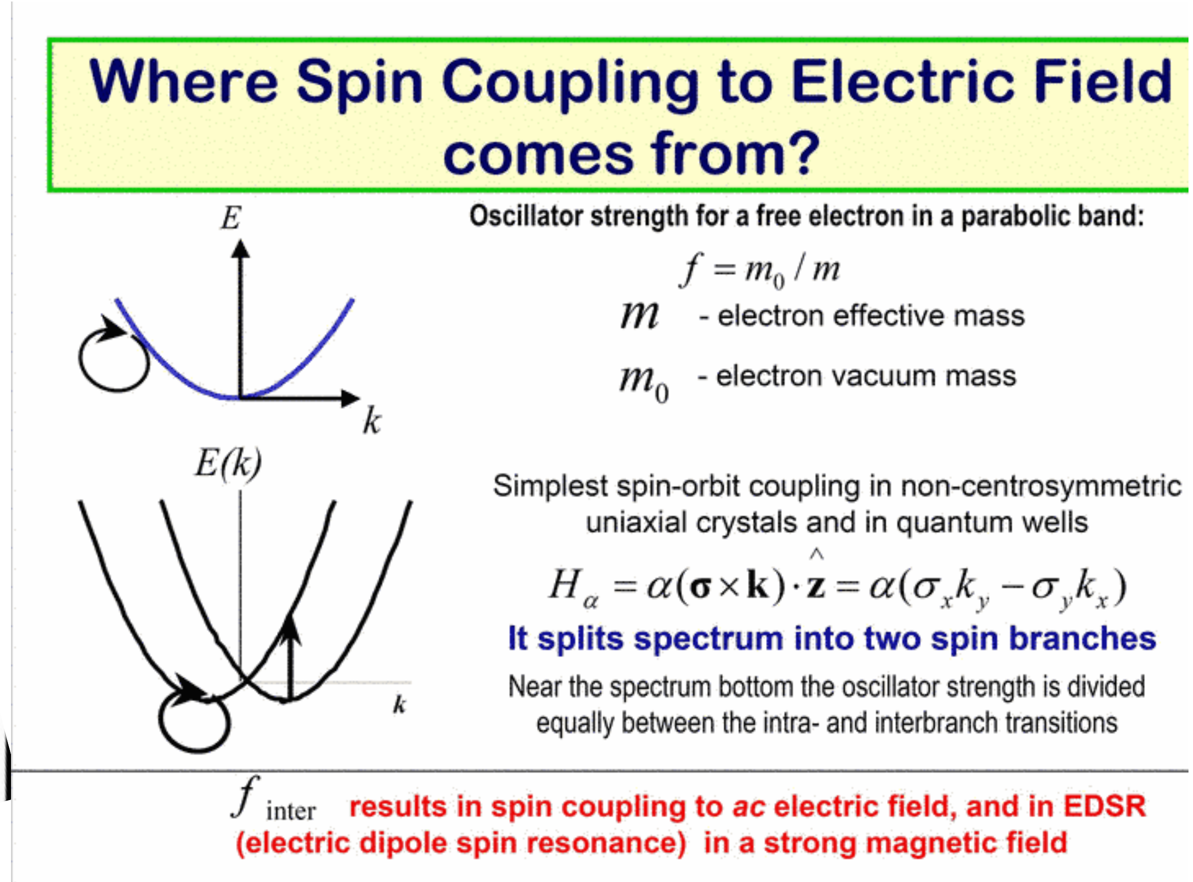
This article is the translation of an article by E I Rashba and V I Sheka published in Russian in *Fiz. Tverd. Tela: Collected Papers* **2** 162–76, 1959. It is published as the supplementary material to the article by Bihlmayer *et al* 2015 *New. J. Phys.* **17** 050202.

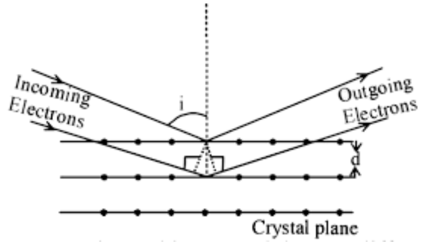
Part I of this work was published as E I Rashba 1959 *Fiz. Tverd. Tela* 1 ... Rashba 1959 *Sov. Phys.-Solid State* 1 368).



E. Rashba, Santa Barbara, KITP (2006)

1963: M.A. Krivoglaz develops the theory of diffraction of X-rays, electrons and neutrons in real crystals

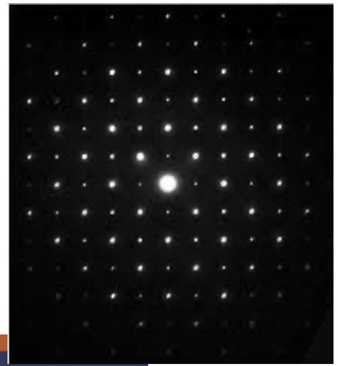
Calculated the scattering intensity in real crystals containing dislocations and other defects

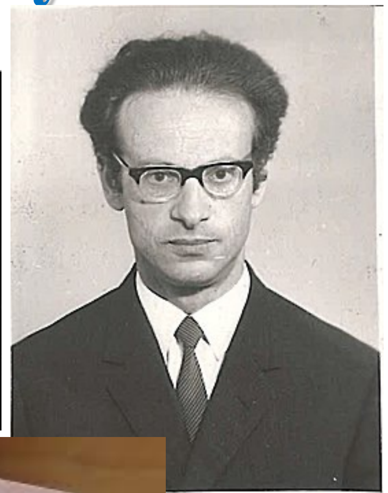


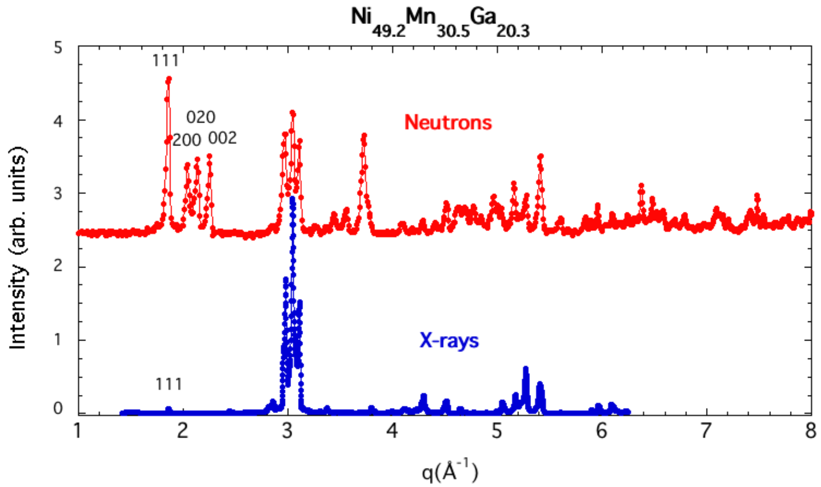
$$I(\vec{q}) = S(\vec{q})S^*(\vec{q}),$$

where $\vec{q}$ is the scattering vector and $S(\vec{q})$ is the lattice structure factor,

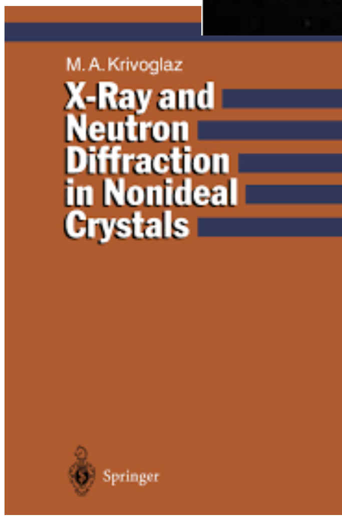
$$S(\vec{q}) = \frac{1}{N_0}\sum_{\vec{n}} \exp\{i\vec{q}\cdot\vec{r}(\vec{n})\}$$
$$= \frac{1}{N_0}\sum_{\vec{n}} \exp\{i\vec{q}\cdot\vec{n}\}\exp\{i\vec{q}\cdot\vec{u}(\vec{n})\},$$

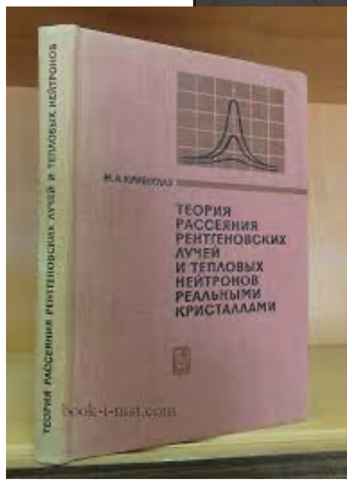






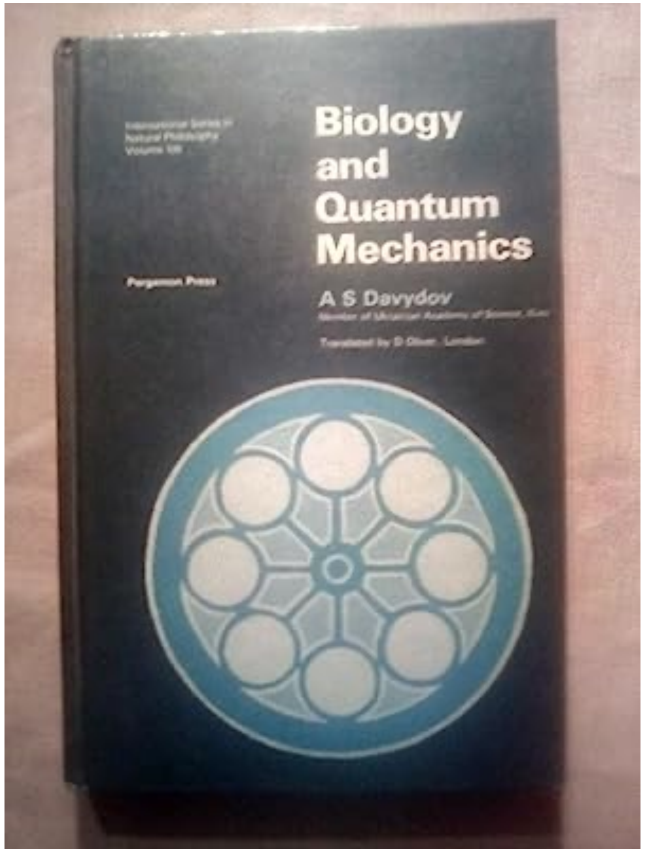
J. Phys.: Conf. Ser. 663, 012014 (2015)





1973 A. Davydov, the birth of quantum biology

He developed the quantum theory of **molecular solitons** to explain the transport of energy in protein and the physiology of muscle contraction. He found that this transport can be described by the nonlinear Schrodinger equation



$$i\hbar\frac{\partial\phi}{\partial t}+\frac{\hbar^2}{2m^*}\frac{\partial^2\phi}{\partial x^2}+G|\phi|^2\phi \doteq 0$$

J. theor. Biol. (1973) **38**, 559–569

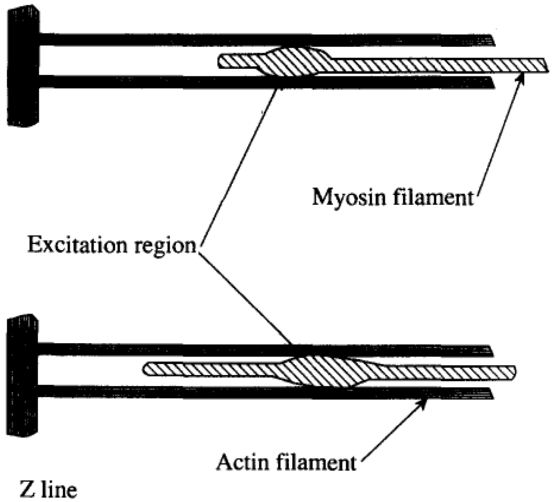
The Theory of Contraction of Proteins under their Excitation

A. S. DAVYDOV

The Institute of Theoretical Physics, Academy of Sciences of the Ukrainian S.S.R., Kiev, U.S.S.R.

(*Received* 23 *April* 1972)

This paper develops the quantum theory of contraction of α-helical proteins under the excitation of their peptide groups, which form three parallel chains of hydrogen bonds along the molecule. In the region embraced by an excitation, the pitch of the helix decreases, and the "contracted" region of the helix moves along the molecule at a rate proportional to the energy of resonance interaction between peptide groups. The movement of the excitation region from the head of the myosin molecule to its tail results in movement of the myosin filaments along the actin ones in the myofibril of the muscle, and thus leads to a decrease in length of the muscle fibre.



Force generation by solitons in the sliding filament model of skeletal muscle

1994-1996: V. Gusynin, V. Miransky, I. Shovkovy. Series of works discovering "Magnetic catalysis"

Magnetic catalysis is a physical phenomenon, which is defined as an enhancement (or even generation) of a mass (gap) of fermionic excitations by an external magnetic field in quantum field theory and condensed matter physics. The underlying phenomenon is a consequence of the strong tendency of a magnetic field to enhance binding of oppositely charged particles into bound states (excitons) with parallel magnetic moments. The gap for local interactions in 3D is given by the BCS-like formula

$$\Delta \sim \sqrt{|B|} e^{-\frac{1}{g\nu_0}},$$

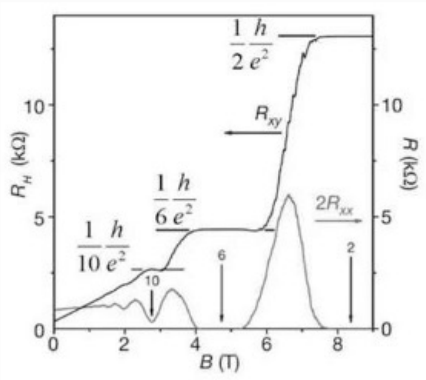
where B is a magnetic field, g is a coupling constant, ν_0 - the density of states at zero Landau level. The zero Landau level plays the role of the Fermi surface in the theory of superconductivity. In the planar condensed matter systems, the exponent in the above formula is absent and a gap becomes enhanced. The critical temperature at which the gap vanishes $T_c \propto \Delta$, thus it grows with the magnetic field in contrast to superconductivity.

In application to graphene, magnetic catalysis triggers the breakdown of an approximate internal symmetry and, thus, lifts the 4-fold degeneracy of Landau levels, in particular, the additional quantum Hall plateaus develop at fillings $\nu = 0$, $\nu = \pm 1$, $\nu = \pm 3$, $\nu = \pm 4$ in addition to standard plateaus at $\nu = 2, 6, 10, \ldots$.

2005: V. Gusynin, S. Sharapov. Series of works discovering anomalous Hall effect, studying magneto-transport and magneto-optics in 2D Dirac materials

The authors demonstrated that in graphene, being described by the Dirac equation, the QHE acquires a very particular form [V. P. Gusynin, S. G. Sharapov, Phys. Rev. Lett. 95, 146801 (2005)]:

$$R_H = \frac{h}{e^2}\frac{1}{n}, \qquad n = 2, 6, 10, \ldots$$



Nature 438, 197 (2005)

The experiment shows exactly this quantization.

QHE became the main among the three proofs that graphene is described by the Dirac equation.

Spintronics of antiferromagnetic systems

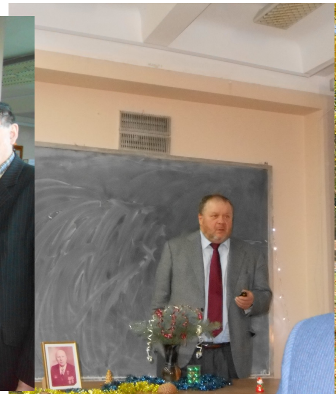
Helen Gomonay

Vadym Loktev

The dynamics of AFM layer in the presence of spin-polarized current and external magnetic field side by side with corresponding effect on spin valve magnetoresistance are investigated.

- the high-density current can induce reorientation of AFM vector
- such a current can also induce a stable precession of AFM vector
- the value of critical current can be tuned by application of the external magnetic field
- magnetoresistance of spin valve depends on the angle be- tween FM and AFM vectors

HORIZON PROJECTS SIMTEC and COEXAN
Tor Vergata - SPIN CNR- Institute of Semiconductors – Bogolyubov Institute of Ukrainian NAS



Vice-Director of IS
Vasyl Kladko
and his granddaughter

Ukrainian science after February 24, 2022

State Scientific Institution
"Institute for Single Crystals"
of National Academy of Sciences of Ukraine

Nuclear subcritical facility "*Neutron Source*" Kharkiv

Institute of Pulse Processes and Technologies (Mykolaiv)

232 scientists of the National Academy of Sciences of Ukraine are serving in the Ukrainian Army, 119 scientists are transferred to the National Guard of Ukraine and territorial defense formations.

<u>On February 24, 2022</u>, Russia unleashed the military aggression against Ukraine. As a result of military strikes with missiles and bombs on peaceful objects, that the scientific infrastructure of the National Academy of Sciences of Ukraine continues to collapse.

Due to the **military aggression of the Russian Federation** against Ukraine:

- about 1518 (11%) employees of scientific institutions of the National Academy of Sciences of Ukraine left Ukraine.
- More than 370 scientists are in Germany, 270 in Poland, about 100 in France, 68 in the USA, and 66 in the Czech Republic

Kharkiv National University: before and after

russian aggression

History repeats 80 years later…

Martyrology of Ukrainian scientists (2022-2023)

Ukraine's mounting death toll includes a growing number of researchers
physicists, chemists, and mathematicians are among the thousands killed in Russian invasion

In Bucha, a suburb of Kyiv, in Ukraine, workers exhumed mass graves to identify civilians killed during the Russian occupation

Oleksandr Korsun
Oleg Amosov
Yulia Zdanovska
Yevhen Khrykov
Oleksandr Kysliuk
Vasyl Kladko
Andriy Kravchenko
Iyona Kurovska
Maksym Pavlenko
Ihor Zhezhelenko
Volodymyr Fedorov
Artur Omarov
Bogdan Sluszczynski
Oleh Barna
Dmytro Evdokymov
Serhiy Zaikovsky
Viacheslav Zaitsev
Yuriy Kovalenko
Mykola Kravchenko
Sergiy Kravchenko
Pavlo Levchuk
Serhiy Barchan
Olexander Polyvodsky
Volodymyr Kozlovsky
Svyatoslav Stetsenko
Vadym Stetsiuk
Andriy Filipchuk
Bizhan Sharopov
Kostyantin Olmezov
Yuriy Ruf
Valery Moskovets
Serhiy Pushchenko
Yevhenii Osievskyi
Vladislava Chernykh
Igor Galkin

KYIV

Thinking about future:

Centre for Advanced Studies

Partner institutes/centers

- Bhaumik Institute for Theoretical Physics (UCLA)
- Spin Phenomena Interdisciplinary Center (Mainz, Germany)
- Center for Quantum Spintronics (Trondheim, Norway)
- ICTP (Trieste, Italy)

VISION

- Physically placed in Kyiv, the local activities are led by 10 senior and 10 junior staff members, who have demonstrated their international leadership and visibility in their fields
- **The Centre** will support 10 postdocs on prestigious named fellowships (Bogolyubov, Landau, Lifshitz, Pomeranchuk, Sikorski, Korolyov) plus additional postdocs hired through EU/US-funded grants
- An annual open competition for 10 PhDs and 10 postdocs recruited in Ukraine to spend one year at a partner institute abroad, expecting them to return to Ukraine for academic job placement
- **The Centre** will run 6 annual 2-month long topical programs in Kyiv, along with conferences and other activities organized internationally with partner institutions

Acknowledgements

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- Sharapov S., Head of the laboratory of Bogoliubov Institute, Kyiv
- Shekhter R., Professor Emeritus of the University of Gothenburg
- Zagorodny A.G., President of the National Academy of Sciences of Ukraine