The historical role of Kharkiv in theoretical physics and the science of the cosmos

Manuel Hohmann

Laboratory of Theoretical Physics - Institute of Physics - University of Tartu
Center of Excellence “The Dark Side of the Universe”

European Union
European Regional
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Investing
in your future

Physicum Seminar - 7. 4. 2022

Timeline

1804

Timeline

1804

1816-1820

Timeline

1804 — 1816-1820 — 1885

Timeline

1804

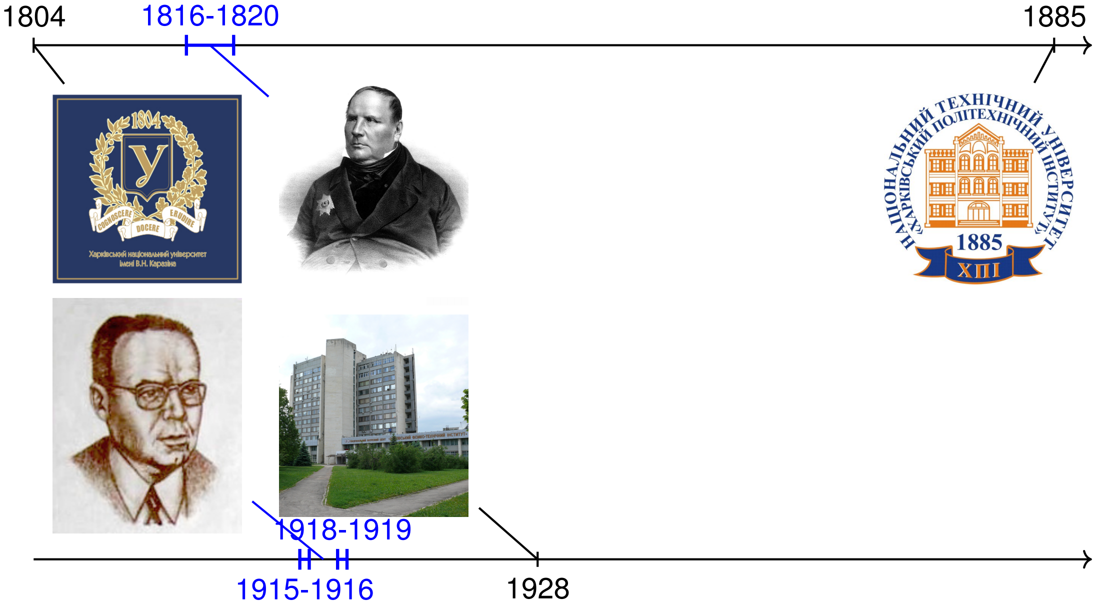
1816-1820

1885

1918-1919

1915-1916

Timeline



Timeline

1804 — 1816-1820 — 1885

1915-1916 — 1918-1919 — 1928 — 1929

Timeline

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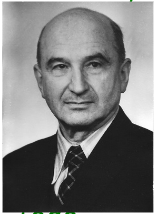

1915-1916 — 1918-1919 — 1928 — 1929 — 1929-1934 — 1934-1938

Timeline

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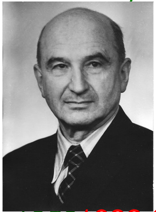

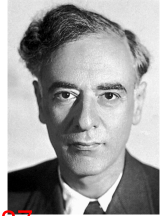

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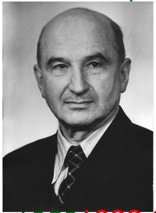

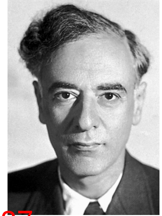

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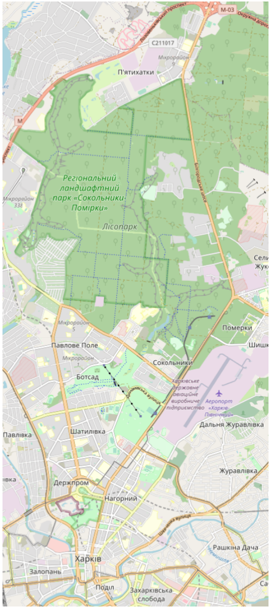
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Помірки»
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Помірки
Павлове Поле
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Ботсад
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державне
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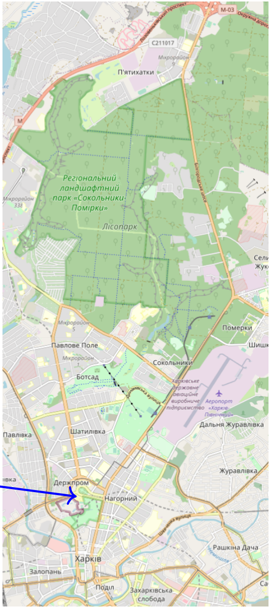
Залопань
Поділ
Захарківська
слобода

(Theoretical) physics institutions in Kharkiv



Kharkiv National University
School of Physics
Established 1962
Moved to new main building

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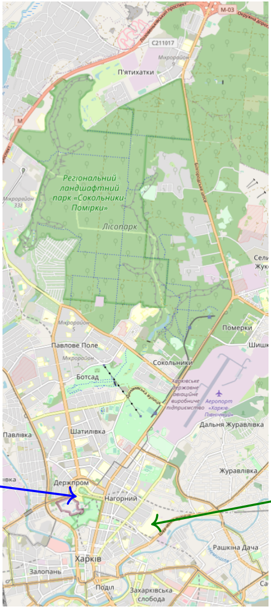

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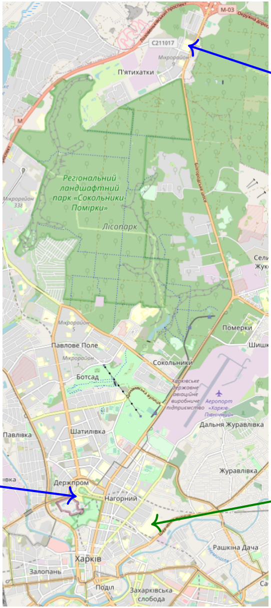

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Kharkiv Institute of
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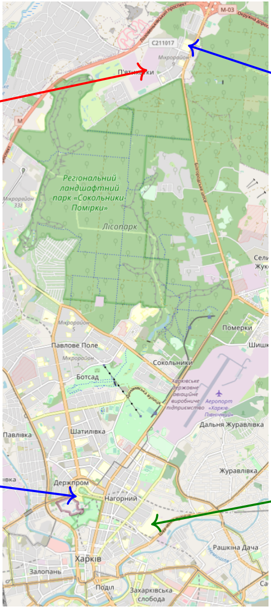

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Mikhail Ostrogradsky

- * September 24, 1801, Pashenivka; † January 1, 1862, Poltava.
- 1816-1820 studied at Kharkiv University.
- Did not receive his degree for not attending theology.
- 1822-1826 studied at Sorbonne & College de France.
- 1828 moved to Saint Petersburg.
- 1830 extraordinary member of St. Petersburg Academy of Sciences.
- Taught at various institutions in Saint Petersburg:
  - 1836-1860 Military Engineering-Technical University
  - 1831-1862 Institute of Railway Engineers
  - 1828-1860 Naval Cadet Corps
  - 1832-1861 Main Pedagogical Institute
  - 1841-1860 Mikhailovsky Artillery School
- Notable works:
  - Lectures on algebraic and transcendental analysis (1857).
  - Selected works (1958).

Ostrogradsky instability

M. Ostrogradsky, Mem. Ac. St. Petersburg 6, 385 (1850)

If a non-degenerate Lagrangian, $L(q, \ldots, q^{(n)})$, depends on the n'th derivative of a single configuration variable q, with $n > 1$, then the energy function in the corresponding Hamiltonian picture is unbounded from below.

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- Non-degenerate second order Lagrangian $L(q, \dot{q}, \ddot{q}) \Rightarrow$ Euler-Lagrange equations:

$$\frac{\partial L}{\partial q} - \frac{d}{dt}\frac{\partial L}{\partial \dot{q}} + \frac{d^2}{dt^2}\frac{\partial L}{\partial \ddot{q}} = 0\,.$$

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- Introduce canonical variables:

$$Q_1 = q , \quad Q_2 = \dot{q} , \quad P_1 = \frac{\partial L}{\partial \dot{q}} - \frac{d}{dt}\frac{\partial L}{\partial \ddot{q}} , \quad P_2 = \frac{\partial L}{\partial \ddot{q}} .$$

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$$H = P_1 \dot{Q}_1 + P_2 \dot{Q}_2 - L(Q_1, Q_2, P_2)\,.$$

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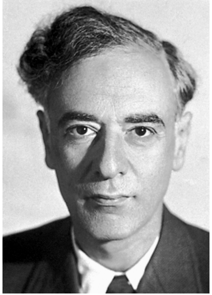
↯ Hamiltonian is linear in $P_1 \Rightarrow$ Energy is not bounded from below.

Lev Landau



- * January 22, 1908, Baku; † April 1, 1968, Moscow.
- 1920 graduated from gymnasium.
- 1920-1922 studied at Baku Economical Technicum.
- 1922-1924 studied chemistry and physics at Baku University.
- 1924-1927 continued studies at Leningrad State University.
- 1927-1934 post-graduate, Leningrad Physico-Technical Institute.
- 1929-1931 visited Copenhagen and other European cities.
- 1932-1937 head of Department of Theoretical Physics, Kharkiv Institute of Physics.
- 1932-1936 taught at Institute for Mechanical Engineering (now Polytechnic Institute).
- 1934 established “Landau school”, created “Theoretical Minimum”.
- 1935 taught physics at Kharkiv University, awarded degree of Professor.
- 1937-1962 head of Theoretical Division, Institute for Physical Problems, Moscow.
- 1938-1939 arrested for publishing anti-Stalinist flyer.
- 1962 Nobel prize (physics) “For pioneer investigations in the theory of condensed matter and especially of liquid helium”

Landau theory of phase transitions

- Transition between states of different degree of symmetry:
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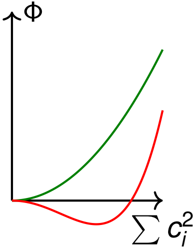

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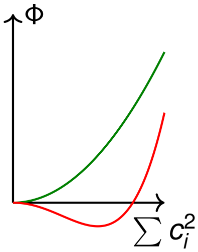

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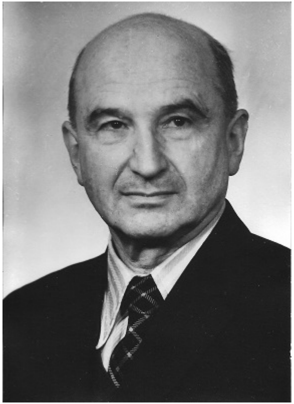
- L. Landau, On the theory of phase transitions, Zh. Eksp. Theor. Fiz. 7, 19 (1937).

Evgeny Lifshitz



- * February 21, 1915, Kharkiv; † October 29, 1985, Moscow.
- Mostly educated at home, only 6th-7th grade at school.
- Completed secondary school in 1929 at the age of 14.
- 1929-1931 studied at chemical college.
- 1931-1933 Mechanics and Machine Building Institute.
- 1933 passed Landau's "Theoretical Minimum".
- 1933-1934 PhD at Institute of Physics and Technology.
- 1934-1938 senior research scientist at Inst. Phys. Tech.
- 1939 D.Sc. at Leningrad State University.
- Since 1939 worked at Inst. of Physical Problems, Moscow.
- State Prize of USSR 1954, Lomonosov Prize 1958, Lenin Prize 1962 with L. Landau, Landau Prize 1974.
- Since 1966 corresponding member, since 1979 full member of the Academy of Sciences of the USSR.

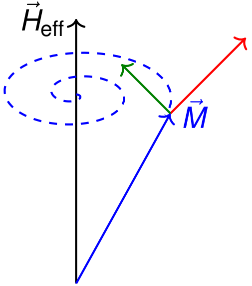
Landau-Lifshitz equation

Landau, L.D.; Lifshitz, E.M. (1935). "Theory of the dispersion of magnetic permeability in ferromagnetic bodies". Phys. Z. Sowjetunion. 8, 153.

The distribution of magnetic moments in a ferromagnetic crystal is investigated. It is found that such a crystal consists of elementary layers magnetized to saturation. The width of these layers is determined. In an external magnetic field, the boundaries between these layers move; the velocity of this propagation is determined. The magnetic permeability in a periodical field parallel and perpendicular to the axis of easiest magnetization is found.

- Magnetization $\vec{M}$ in ferromagnet equals saturation: $|\vec{M}| = M_s$.
- Direction of magnetization follows Landau-Lifshitz equation:

$$\frac{d\vec{M}}{dt} = -\gamma\vec{M} \times \vec{H}_{\text{eff}} - \lambda\vec{M} \times (\vec{M} \times \vec{H}_{\text{eff}})\,.$$



  - γ: electron gyromagnetic ratio.
  - λ: phenomenological damping parameter.
  - $\vec{H}_{\text{eff}}$: effective field composed of external field and material effects.

Course of theoretical physics

- Comprehensive textbook in 10 volumes:
  I. Mechanics
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  VI. Fluid Mechanics
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  VIII. Electrodynamics of Continuous Media
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[1] Matvei Petrovich Bronstein, * November 29, 1906, Vinnytsia; † February 18, 1938, Leningrad.

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  - Original idea by Landau and Bronstein[1] during 1920s in Leningrad.
  - Problems of theoretical physics. Part I. Mechanics (Landau, Lifshitz, Rozenkevich 1935).
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$$\lambda^{\mu\nu\rho\sigma} = \frac{c^4}{16\pi k}(-\det g)(g^{\mu\nu}g^{\rho\sigma} - g^{\mu\rho}g^{\nu\sigma}) \,.$$

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$\Rightarrow$ Einstein equations can be rewritten as

$$\partial_\rho\partial_\sigma\lambda^{\mu\nu\rho\sigma} = (-\det g)(T^{\mu\nu} + t^{\mu\nu}) \,.$$

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- Einstein tensor $G_{\mu\nu}$ contains second order derivatives of metric $g_{\mu\nu}$.
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- Helpful to determine emitted gravitational waves by perturbative expansion.

Alexander Vilenkin

- * May 13, 1949, Kharkiv.
- 1966-1971 studied physics at Kharkiv University.
- Turned down offer to work for KGB; was denied PhD studies.
- Drafted to building brigade.
- Worked at zoo in Kharkiv as night watchman.
- Emigrated to USA with wife and daughter in 1976.
- 1976-1977 PhD at Buffalo State University of New York.
- 1978 Visiting Assistant Professor, Tufts University.
- 1979 Assistant Professor, Tufts University.
- 1983 Associate Professor, Tufts University.
- 1987 Professor, Tufts University.
- Wrote more that 260 articles on cosmology and two books:
  - A. Vilenkin, E. P. S. Shellard: Cosmic Strings and Other Topological Defects (2000).
  - A. Vilenkin: Many Worlds in One: The Search for Other Universes (2007).

Eternal inflation and the multiverse

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  - Observations show that the universe expand $\Rightarrow$ Big Bang theory.
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  - ○ Inflation may be eternal in both past and future.
- Vilenkin's main contributions to eternal inflation:
  - ○ Creating of inflating universe from quantum vacuum ("nothing") [Vilenkin '82].
  - ○ Eternal inflation & multiverse are generic for inflation theories [Vilenkin '83].
  - ○ Inflation cannot be past-eternal, but must have beginning [Borde, Guth, Vilenkin '03].

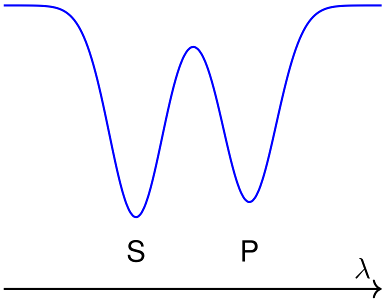
Otto Struve

- * August 12, 1897, Kharkiv; † April 6, 1963, Berkeley.
- Great-grandson of Friedrich Georg Wilhelm von Struve.
- Entered Kharkiv University in 1915 for one semester.
- Enlisted to military artillery school in St. Petersburg 1916.
- Sent to Turkish front in 1917.
- Returned to Kharkiv 1918 and finished studies 1919.
- 1920 escaped from Bolsheviks to Sevastopol, then Turkey.
- 1921 emigrated to USA to work at Yerkes Observatory.
- 1923 defended PhD at University of Chicago.
- 1924 Instructor, University of Chicago.
- 1927 Assistant Professor, University of Chicago.
- 1932 Professor, University of Chicago.
- 1932-1947 Head of Yerkes Observatory.
- 1939-1959 Founding Director of McDonald Observatory.
- 1952-1962 Director of National Radio Astronomy Observatory (Virginia).
- Published more than 900 journal articles and books[2].

[2] Probably only Estonian astronomer Ernst Öpik, who published 1094 items, published even more.

Struve-Sahade effect

- Double-lined spectroscopic binary star:
  - Absorption lines of both components visible.
  - Spectral lines shift during orbit due to Doppler effect.



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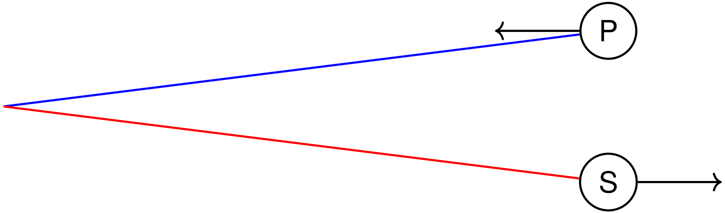

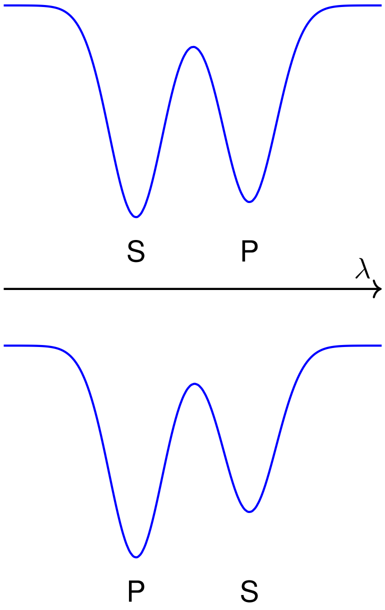

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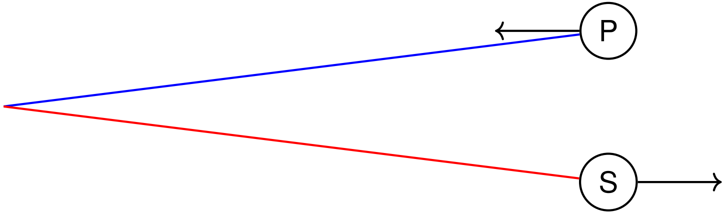

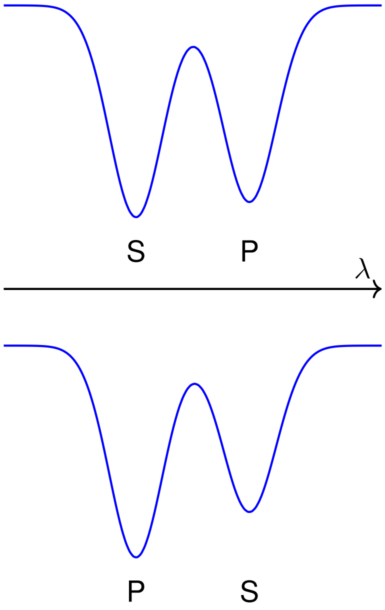

- Possible explanations:
  - Gas stream trailing behind secondary star [Struve '50].
  - Gas stream from primary to secondary star [Sahade '59].
  - Shock of stellar winds displaced by Coriolis force [Gies '97].