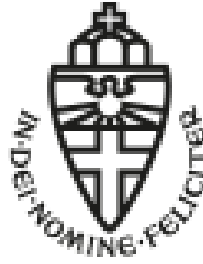
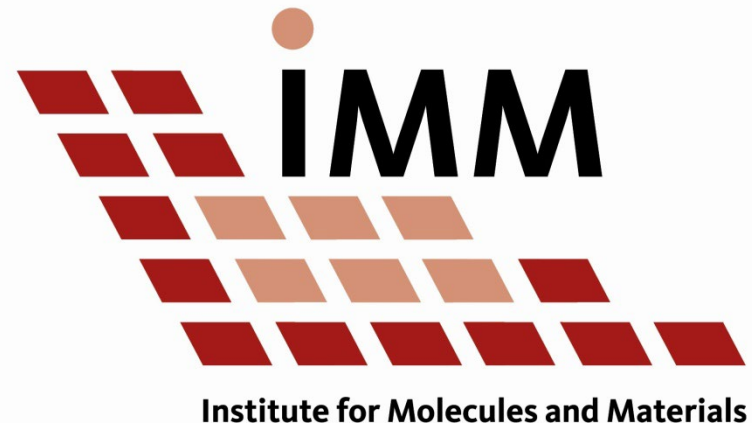


Radboud Universiteit



# *What is special about being a theoretical physicist*

Mikhail Katsnelson

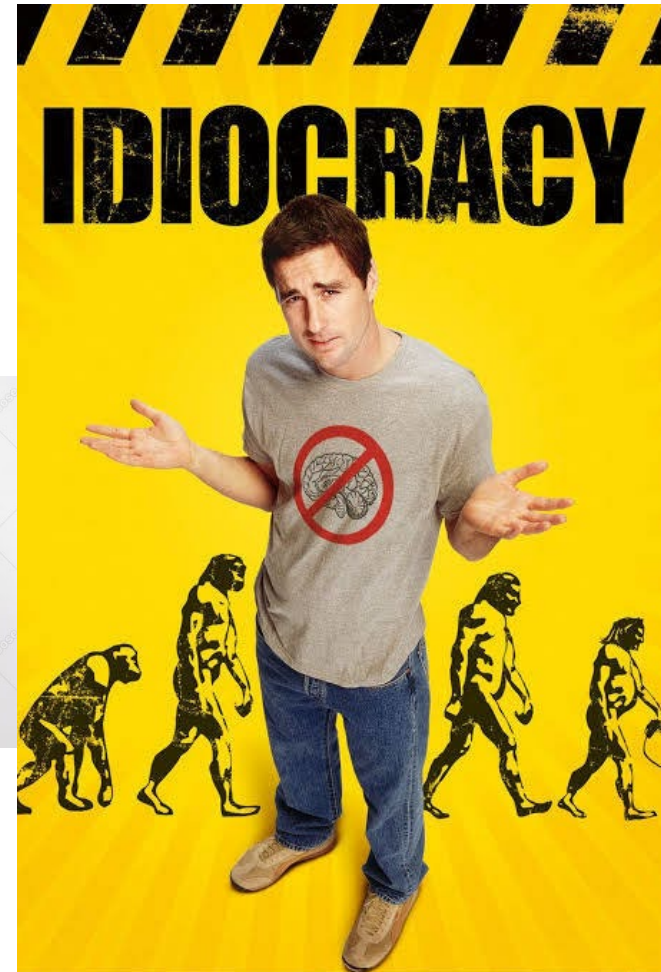


# Outline

- A bit on myself;
- On theoretical physics: a personal view
- Scientist and society: Problems at interface



(<https://icons8.ru>)



(Movie poster)



# *How to become a theoretical physicist*





# *How to become a theoretical physicist II*

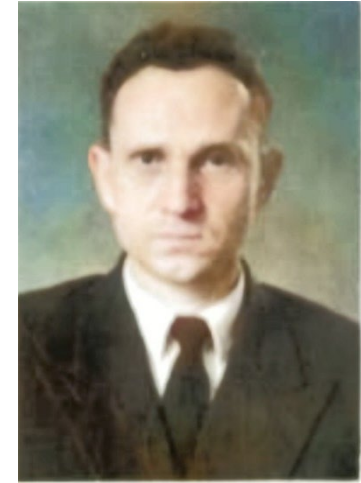




# Why I am a physicist?

My school teacher:  
Ivan Kabanchuk (1920-1999)

Magnitogorsk: an industrial city in Ural Mountains (at a formal border of Europe and Asia)



11 hours of physics per week  
and all that

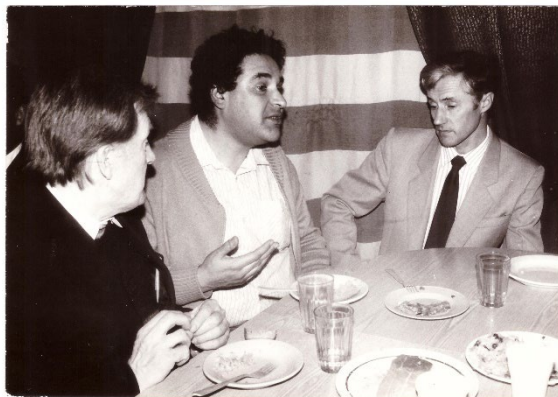


# Why I am a theoretical physicist?

Ural State University, Dept. Physics  
1972-1977



Boris Ishmukhametov (1929-2020)



My first subject: Atomic plasmon  
My first paper (with him): published  
1975

Volume 82A, number 8

PHYSICS LETTERS

20 April 1981

## ON THE EXISTENCE OF THE ATOMIC PLASMON

B. Kh. ISHMUKHAMETOV, M.I. KATSNELSON <sup>a</sup>, V.N. LARIONOV and A.M. USTJUZHANIN <sup>b</sup>

*Ural State University, Sverdlovsk, USSR*

<sup>a</sup> *Institute for Metal Physics, Ural Scientific Centre, Sverdlovsk, USSR*

<sup>b</sup> *Institute for Mathematics and Mechanics, Ural Scientific Centre, Sverdlovsk, USSR*

Received 22 January 1981

Министерство науки  
и высшего образования  
Российской Федерации



Б. Х. Ишмухаметов, М. И. Кашнельсон, А. Ф. Полкарнов

## ВВЕДЕНИЕ В АТОМНУЮ ФИЗИКУ

Учебное пособие

Научный редактор: Е. А. Памятнык, доктор ф.-м. наук

Учебное пособие по дисциплине «Атомная физика» для студентов,  
обучающихся по программам бакалавриата по направлению подготовки  
03.03.02 «Физика»

Подготовлено Департаментом фундаментальной и прикладной физики ИЕНМ

Екатеринбург  
2019

Государственный комитет Российской Федерации  
по высшему образованию  
Уральский государственный университет им. А.М.Горького

М.И.Кашнельсон, Б.Х.Ишмухаметов

## ВВЕДЕНИЕ В ТЕОРИЮ ОТНОСИТЕЛЬНОСТИ

Учебное пособие

Екатеринбург  
1996



# *Almost half a century later*

Semiclassical theory for plasmons in spatially inhomogeneous media

Annals of Physics 446 (2022) 169116

K.J.A. Reijnders<sup>\*</sup>, T. Tudorovskiy, M.I. Katsnelson

[41] B.Kh. Ishmukhametov, *Phys. Status Solidi (B)* 45 (1971) 669–678.

[42] B.Kh. Ishmukhametov, M.I. Katsnelson, *Fiz. Met. Metalloved.* 40 (1975) 736.

## **Appendix D. Review of a prior derivation**

The derivations presented in Section 2 of this article arose after studying Refs. [41,42]. The formula  $L_0(x, q) = 0$  was first presented in Ref. [41], in a slightly different notation. A justification of this formula was given in Ref. [42]. Unfortunately, the latter article is not available digitally and very hard to come by. In order to sketch the context of the present work and to show its inspiration, we repeat the arguments presented in Ref. [42] in this appendix. We emphasize that they are not completely rigorous, but may give the reader a more intuitive idea of the formal transformations presented in the main text.

This appendix consists of two parts. In the first part, we briefly repeat the formulation of the RPA in real space, as presented in the textbook [5]. More precisely, we follow the three steps outlined in Section 2.1 to obtain an integro-differential equation for the induced potential  $V(x, t)$ .

## **Acknowledgments**

We are grateful to Tjacco Koskamp, Malte Rösner, Sergey Dobrokhotov, Vladimir Nazaikinskii, Erik van Loon and Tim de Laat for helpful discussions. One of us (M.I.K.) started to work in this field long ago under the supervision of Boris Ishmukhametov (1929–2020). We dedicate this paper to his memory. The work of K.J.A.R. and M.I.K. was supported by the ERC Synergy Grant, Project No. 854843 FASTCORR.

# *Theoretical physics is Sverdlovsk*



Semyon Shubin (1908-1938)  
The founder of theoretical  
physics in Ural

Arrested 1929, professor and head  
of department 1933, arrested  
again 1937, killed 1938. Published  
18 papers



Sergey Vonsovsky, 1910-1998  
Pupil of Shubin and my main  
teacher

“Polar model” (“Mott insulators”), liquid metals,  
photoeffect, s-d exchange (Vonsovsky-Zener)  
model...



# The beginning: "Polar model"

*On the Electron Theory of Metals.*

By S. SCHUBIN and S. WONSOWSKY.

Sverdlovsk Physical Technical Institute.

*Proc. R. Soc. Lond. A* 1934 **145**,  
published 2 June 1934

(Communicated by R. H. Fowler, F.R.S.—Received December 29, 1933.)

$$\int \frac{e^2}{|x-x'|} \phi_\alpha^2(x) \phi_\alpha^2(x') dx dx' = A \int \sum_{\gamma \neq \beta} \left[ G_\gamma(x) \phi_\alpha^2(x') + \frac{e^2}{|x-x'|} \phi_\gamma^2(x') \right] \phi_\alpha(x) \phi_\beta(x) dx dx' = L_{\alpha\beta}$$

$$\int \frac{e^2}{|x-x'|} \phi_\alpha^2(x) \phi_\beta^2(x') dx dx' = B_{\alpha\beta} \qquad \int \frac{e^2}{|x-x'|} \phi_\alpha(x) \phi_\beta(x) \phi_\alpha(x') \phi_\beta(x') dx dx' = J_{\alpha\beta}$$



FIG. 1.



FIG. 2.

$$\begin{aligned} & \{ \varepsilon - s(A + D) - [ \sum_{f < f'} (B_{ff'} - J_{ff'}) + \sum_{g < g'} (B_{gg'} - J_{gg'}) - \sum_{f, g} (B_{fg} + J_{fg}) ] \} C(fgh) \\ & + \sum_{h, k} J_{hk} [ C(T_{hk} | fgh) - C(fgh) ] + \sum_{f, g} J_{fg} [ C(T_{fg} | fgh) - C(fgh) ] \\ & + \sum_{f, p} L_{fp} C(T_{fp} | fgh) - \sum_{g, p} L_{gp} C(T_{gp} | fgh) = 0, \end{aligned} \tag{9}$$

# *Polar model II*

## Mott insulators and Mott transitions in 1934

(II). The minimum energy corresponds to a certain  $s = s_0$ , where  $0 < s_0 < n$ . This case we have, for instance, when

$$A + 6(J - B) > 0, \quad A + 6J - 12L < 0.$$

Then, so long as  $s$  remains small, the lowest energy level *diminishes* as  $s$  increases; for a certain  $s = s_0$  it attains a minimum and then again begins to increase. For such metals—at not very high temperatures—the number of “free” electrons approximates to twice this  $s_0$  (electrons + holes!) and is therefore *smaller* than the number of atoms. In order to calculate  $s_0$  in terms of our integrals, the energy must be evaluated up to the second approximation in powers of  $s/n$ ; we shall not, however, make these rather cumbersome calculations here.

(III). The minimum energy corresponds to  $s = 0$ . This is the case when

$$A + 6(J - B) > 0, \quad A + 6J - 12L > 0.$$

**Some types of instabilities in the electron energy spectrum of the polar model of the crystal: I. The maximum-polarity state**

S V Vonsovsky and M I Katsnelson  
Institute of Metal Physics, Ural Science Research Centre of the USSR Academy of Sciences,  
Sverdlovsk, USSR

Received 29 June 1978, in final form 9 October 1978

**Some types of instabilities in the electron energy spectrum of the polar model of the crystal: II. The criterion of stability of a metallic state**

S V Vonsovsky and M I Katsnelson  
Institute of Metal Physics, Ural Science Research Centre of the USSR Academy of Sciences,  
Sverdlovsk, USSR

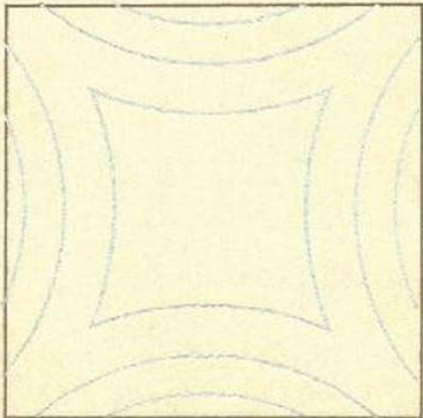
Received 29 June 1978, in final form 9 October 1978



# *Early writing of a book*

С. В. ВОНСОВСКИЙ, М. И. КАЦНЕЛЬСОН

КВАНТОВАЯ  
ФИЗИКА  
ТВЕРДОГО ТЕЛА



Published in Russian  
1983

Published in English  
(extended and rewritten)  
1989

Springer Series in  
**Solid-State Sciences 73**

S. V. Vonsovsky  
M. I. Katsnelson

**Quantum  
Solid-State Physics**



Springer-Verlag

In contemporary situation a young researcher cannot spend time on helping their supervisor to write books or reviews. Many letters in fancy journals is much better for the career

Also, replacing Vonsovsky at his lectures when he was away (from 1979)

# *A philosophical statement*

Knowledge begins, so to speak, in the middle, and leads into the unknown - both when moving upward, and when there is a downward movement. Our goal is to gradually dissipate the darkness in both directions, and the absolute foundation - this huge elephant carrying on his mighty back the tower of truth - it exists only in a fairy tales (Hermann Weyl)





# *What does it mean for condensed matter physics and materials science?*

Everything follows from quantum mechanics plus electrodynamics; QED is enough to explain all properties of matter around us

$$\gamma^\alpha (\partial_\alpha - ieA_\alpha)\psi + im\psi = 0 \quad \text{where } \alpha = 0, \dots, 3$$

$$F_{\alpha\beta} = A_{\beta,\alpha} - A_{\alpha,\beta}$$

$$\partial^\alpha F_{\alpha\beta} = -4\pi e j_\beta$$

$$\text{where } j_\alpha = \bar{\psi}\gamma_\alpha\psi.$$

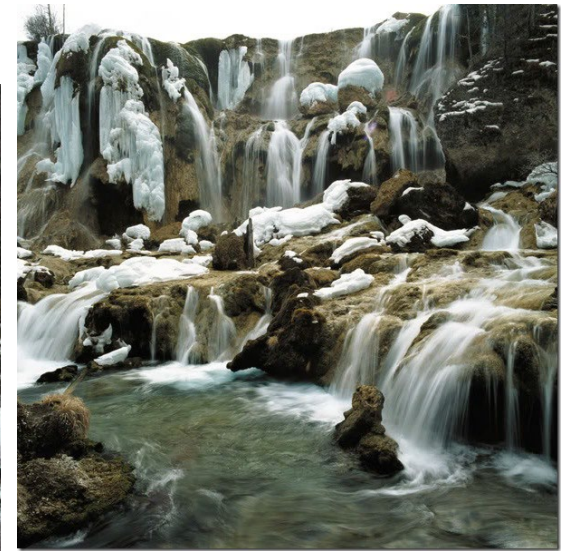
That is all. Please tell me why iridium is brittle and platinum is ductile, copper is red and silver is white, iron is ferromagnetic and vanadium is not... Not talking on biochemistry and biophysics!

# Does it help?

$$\nabla \cdot u = 0$$

$$\frac{\partial u}{\partial t} + u \cdot \nabla u = f + \mu \nabla^2 u - \nabla p$$

Navier-Stokes equations:  
Turbulence is here!  
Can you explain this?





# *Is fundamental physics fundamental?*

Classical thermodynamics is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts (A. Einstein).

The laws describing our level of reality are essentially independent on the background laws. I wish our colleagues from **true theory** (strings, quantum gravity, etc....) all kind of success but either they will modify electrodynamics and quantum mechanics at atomic **scale** (and then they will be wrong) or they will not (and then I do not care). **Our way is down.**

How to pass from known basic laws of nature to understanding all richness and diversity of the world around us?

Pure chemical elements are already complicated enough to think very seriously

# *The aim of science: Understanding*

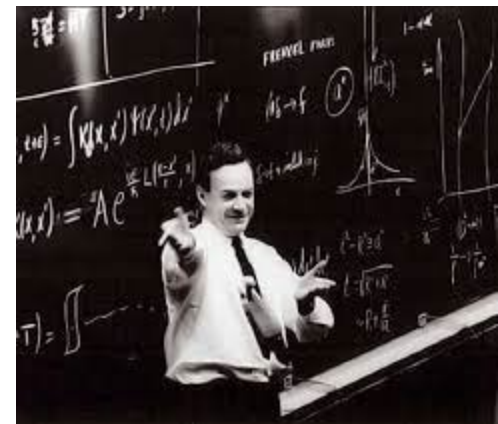
Duality of understanding and knowledge



Newton laws... Rotation...  
Air resistance... I know this stuff  
but the result will be... well...

He does not know (?!) Newton  
Mechanics – but it works! He  
feels (=understands) what to do

**I think I can safely say that nobody  
understands  
quantum mechanics  
(R. P. Feynman)**





# Scylla and Charybdis

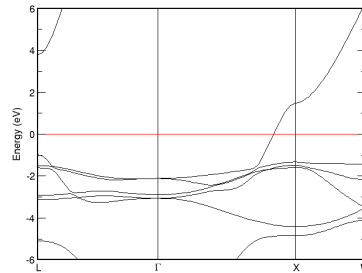


Understanding “in general”

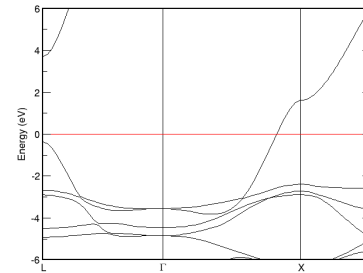
Everything is from water/fire/earth/gauge fields/quantum space-time foam/strings... and the rest is your problem.

But why silver is white, copper is red and gold is yellow?

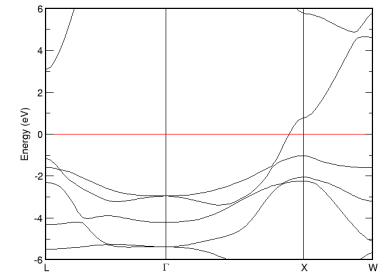
Density functional calculations



Cu



Ag



Au

Taken from C. Ortiz, O. Eriksson and M. Klintonberg  
Comput. Mater. Sci. **44**, 1042 (2009).

# Scylla and Charybdis II



## Local moments and localized states

P. W. Anderson

Reviews of Modern Physics, Vol. 50, No. 2, April 1978

(Nobel lecture)



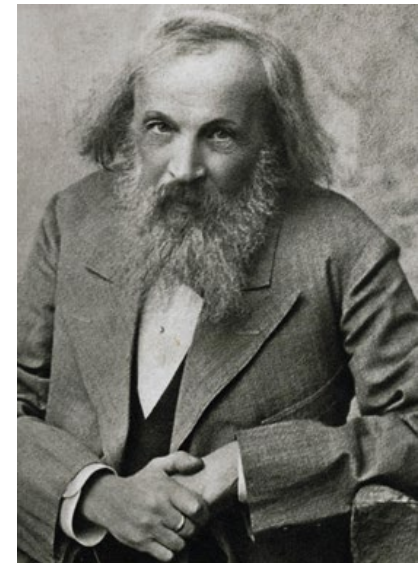
shall soon discuss. Very often such a simplified model throws more light on the real workings of nature than any number of *ab initio* calculations of individual situations, which even where correct often contain so much detail as to conceal rather than reveal reality. It can be a disadvantage rather than an advantage to be able to compute or to measure too accurately, since often what one measures or computes is irrelevant in terms of mechanism. After all, the perfect computation simply reproduces Nature, it does not explain her.

# Periodic Table

Can we understand something elementary?

**Periodic Table of the Elements**

1 1IA 11A																	18 VIIIA 8A
1 <b>H</b> Hydrogen 1.0079	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 <b>He</b> Helium 4.00260
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.01218											5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.00674	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.998403	10 <b>Ne</b> Neon 20.1797
11 <b>Na</b> Sodium 22.989768	12 <b>Mg</b> Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 <b>Al</b> Aluminum 26.981539	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973762	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.4527	18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.95591	22 <b>Ti</b> Titanium 47.88	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938	26 <b>Fe</b> Iron 55.847	27 <b>Co</b> Cobalt 58.9332	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.732	32 <b>Ge</b> Germanium 72.64	33 <b>As</b> Arsenic 74.92159	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.80
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90585	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium 98.9072	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.9055	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.29
55 <b>Cs</b> Cesium 132.90543	56 <b>Ba</b> Barium 137.327	57-71 Lanthanide Series	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.85	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.9665	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98037	84 <b>Po</b> Polonium [208.9824]	85 <b>At</b> Astatine 209.9871	86 <b>Rn</b> Radon 222.0176
87 <b>Fr</b> Francium 223.0197	88 <b>Ra</b> Radium 226.0254	89-103 Actinide Series	104 <b>Rf</b> Rutherfordium [261]	105 <b>Db</b> Dubnium [262]	106 <b>Sg</b> Seaborgium [266]	107 <b>Bh</b> Bohrium [264]	108 <b>Hs</b> Hassium [289]	109 <b>Mt</b> Meitnerium [268]	110 <b>Ds</b> Darmstadtium [269]	111 <b>Rg</b> Roentgenium [272]	112 <b>Cn</b> Copernicium [277]	113 <b>Uut</b> Ununtrium unknown	114 <b>Uuq</b> Ununquadium [289]	115 <b>Uup</b> Ununpentium unknown	116 <b>Uuh</b> Ununhexium [288]	117 <b>Uus</b> Ununseptium unknown	118 <b>Uuo</b> Ununoctium unknown
			57 <b>La</b> Lanthanum 138.9055	58 <b>Ce</b> Cerium 140.115	59 <b>Pr</b> Praseodymium 140.90765	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium 144.9127	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.9655	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.92534	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93032	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93421	70 <b>Yb</b> Ytterbium 173.04	71 <b>Lu</b> Lutetium 174.967
			89 <b>Ac</b> Actinium 227.0278	90 <b>Th</b> Thorium 232.0381	91 <b>Pa</b> Protactinium 231.03688	92 <b>U</b> Uranium 238.0289	93 <b>Np</b> Neptunium 237.0482	94 <b>Pu</b> Plutonium 244.0642	95 <b>Am</b> Americium 243.0614	96 <b>Cm</b> Curium 247.0703	97 <b>Bk</b> Berkelium 247.0703	98 <b>Cf</b> Californium 251.0796	99 <b>Es</b> Einsteinium [254]	100 <b>Fm</b> Fermium 257.0951	101 <b>Md</b> Mendelevium 258.1	102 <b>No</b> Nobelium 259.1009	103 <b>Lr</b> Lawrencium [262]
			Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetals	Nonmetals	Halogens	Noble Gas	Lanthanides	Actinides					

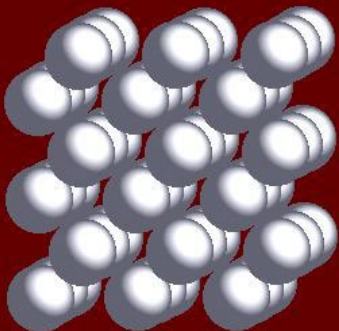


D. I. Mendeleev

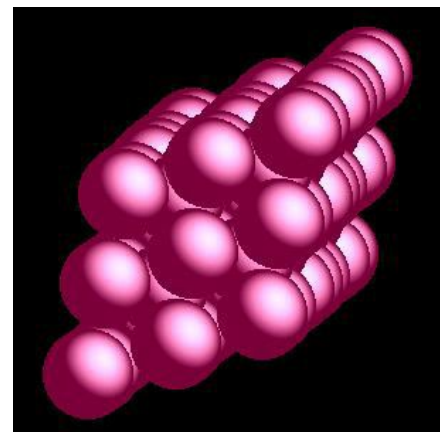


# An example: Alkali metals

Ambient conditions: all body-centered cubic



Li, Na at low temperatures: 9R  
Why? Well... Total energies are very, very close (difference  $\approx 10^{-4}$ )  
Just numbers... Calculate!



J. Phys.: Condens. Matter 1 (1989) 5319–5335. Printed in the UK

**An experimental and theoretical study of martensitic phase transitions in Li and Na under pressure**

V G Vaks<sup>†</sup>, M I Katsnelson<sup>‡</sup>, V G Koreshkov<sup>‡</sup>, A I Likhtenstein<sup>§</sup>,  
O E Parfenov<sup>†</sup>, V F Skok<sup>||</sup>, V A Sukhoparov<sup>||</sup>, A V Trefilov<sup>†</sup> and  
A A Chernyshov<sup>†</sup>

Why opposite behavior with pressure?

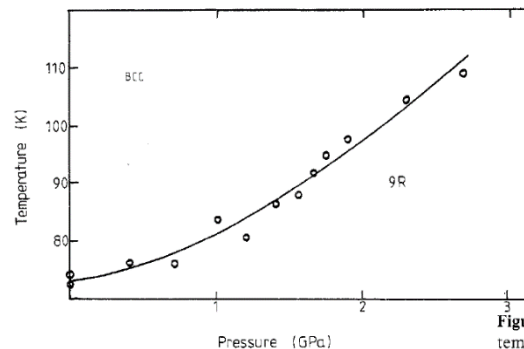


Figure 2. The martensitic transformation temperature  $M_s$  versus pressure in Li.

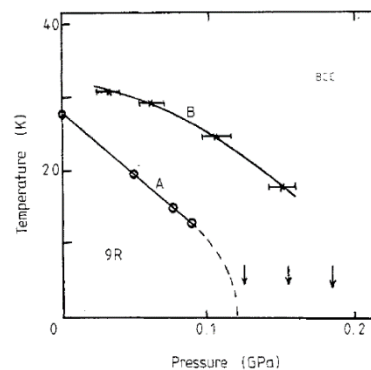
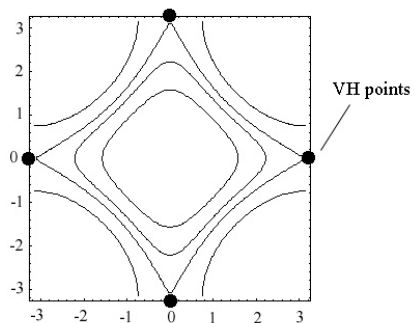


Figure 3. The martensitic transformation temperature  $M_s$  versus pressure in Na: A, the beginning of transformation,  $M_s$ , in cooling  $p = \text{const}$ ; B, the beginning of transformation for decreasing pressure,  $T = \text{const}$ .

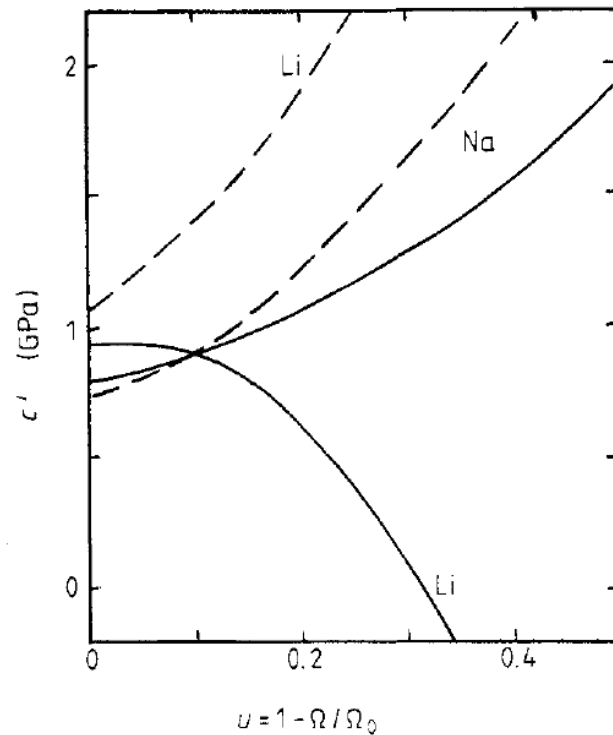
# Understanding?!

Van Hove singularities: topological property of any energy spectrum in crystals

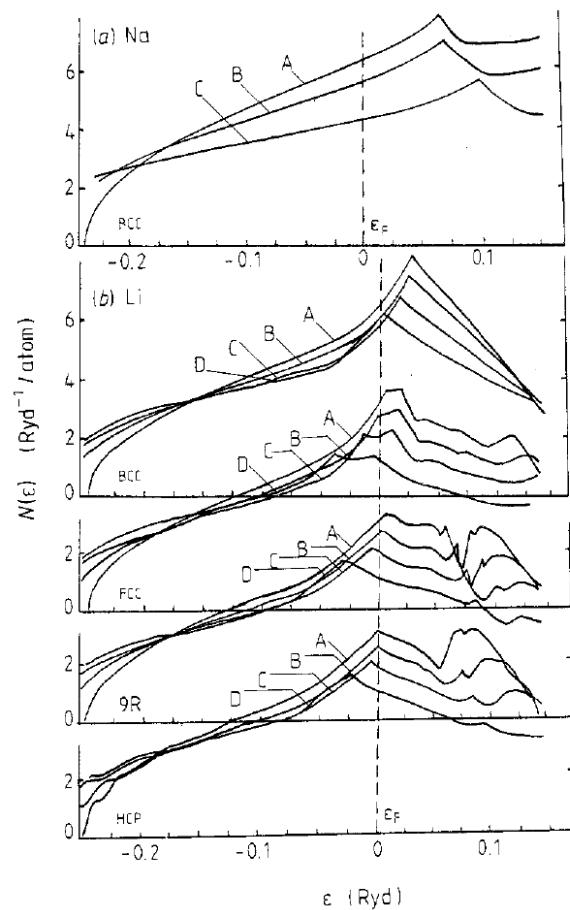


bcc Na: away from  $E_F$   
bcc Li: towards  $E_F$

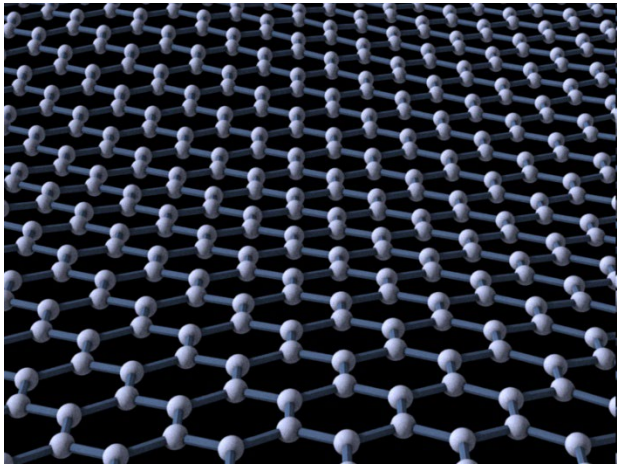
Different role of  $p$ -electrons



VHS near  $E_F$  destabilize crystal structure (a general theory)



# *Graphene!!! – Just elemental solid*



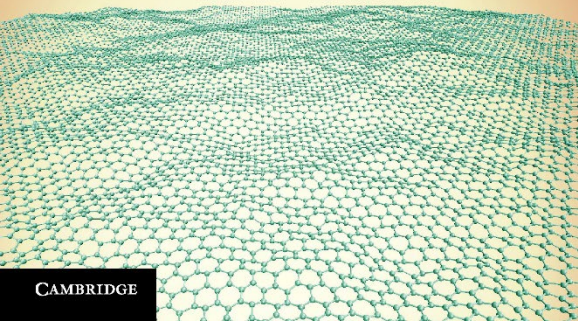
Even insects  
understand what  
honeycomb lattice  
is



## The Physics of Graphene

Second Edition

Mikhail I. Katsnelson



I am very grateful to Andre Geim and Kostya Novoselov, who involved me in this wonderful field before it became fashionable (otherwise I would probably never have dared to join such a brilliant company). I am especially grateful to Andre for regular and lengthy telephone conversations; when you have to discuss a theory using just words, without formulas and diagrams, and cannot even make faces, after several years it does improve your understanding of theoretical physics.

The end of my time line was only a start for further hard work involving many collaborators. Our rapid progress would be impossible without Misha Katsnelson who provided us with all the theoretical help an experimentalist can only dream of.

REVIEWS OF MODERN PHYSICS, VOLUME 83

**Nobel Lecture: Random walk to graphene\***

Andre K. Geim



# *Theoretical physics as a variety of mistique experience*

Beloved, believe not every spirit, but try the spirits whether they  
are of God (1 John 4:1)

Ye shall know them by their fruits. Do men gather grapes of thorns,  
or figs of thistles? (Matthew 7:16)

Fruits: to predict something correctly (like Maxwell  
electromagnetic waves, and then – applications)

Top pleasure and top dream for a theoretician of my type

## Graphene

1. Klein tunneling
2. Pseudomagnetic fields due to deformations
3. Relativistic collapse at a supercritical charge

# Predicted and confirmed

## Chiral tunnelling and the Klein paradox in graphene

M. I. KATSNELSON<sup>1\*</sup>, K. S. NOVOSELOV<sup>2</sup> AND A. K. GEIM<sup>2\*</sup>

nature physics | VOL 2 | SEPTEMBER 2006

LETTERS

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nature  
physics

## Energy gaps and a zero-field quantum Hall effect in graphene by strain engineering

F. Guinea<sup>1\*</sup>, M. I. Katsnelson<sup>2</sup> and A. K. Geim<sup>3\*</sup>

nature  
physics

LETTERS

PUBLISHED ONLINE: 1 FEBRUARY 2009 | DOI: 10.1038/NPHYS1198

## Quantum interference and Klein tunnelling in graphene heterojunctions

Andrea F. Young and Philip Kim\*

## Strain-Induced Pseudo-Magnetic Fields Greater Than 300 Tesla in Graphene Nanobubbles

N. Levy,<sup>1,2\*</sup>† S. A. Burke,<sup>1\*</sup>‡ K. L. Meaker,<sup>1</sup> M. Panlasigui,<sup>1</sup> A. Zettl,<sup>1,2</sup> F. Guinea,<sup>3</sup> A. H. Castro Neto,<sup>4</sup> M. F. Crommie<sup>1,2</sup>§

30 JULY 2010 VOL 329 SCIENCE

## Observing Atomic Collapse Resonances in Artificial Nuclei on Graphene

Yang Wang,<sup>1,2\*</sup> Dillon Wong,<sup>1,2\*</sup> Andrey V. Shytov,<sup>3</sup> Victor W. Brar,<sup>1,2</sup> Sangkook Choi,<sup>1</sup> Qiong Wu,<sup>1,2</sup> Hsin-Zon Tsai,<sup>1</sup> William Regan,<sup>1,2</sup> Alex Zettl,<sup>1,2</sup> Roland K. Kawakami,<sup>5</sup> Steven G. Louie,<sup>1,2</sup> Leonid S. Levitov,<sup>4</sup> Michael F. Crommie<sup>1,2</sup>†

10 MAY 2013 VOL 340 SCIENCE

PRL 99, 236801 (2007)

PHYSICAL REVIEW LETTERS

week ending  
7 DECEMBER 2007

### Vacuum Polarization and Screening of Supercritical Impurities in Graphene

A. V. Shytov,<sup>1</sup> M. I. Katsnelson,<sup>2</sup> and L. S. Levitov<sup>3</sup>

PRL 99, 246802 (2007)

PHYSICAL REVIEW LETTERS

week ending  
14 DECEMBER 2007

### Atomic Collapse and Quasi-Rydberg States in Graphene

A. V. Shytov,<sup>1</sup> M. I. Katsnelson,<sup>2</sup> and L. S. Levitov<sup>3</sup>

# *Theoretical physics as a variety of mistique experience II*

A miracle for yourself vs miracle for others

I have seen (and experienced) “miracle for myself” 3 or 4 times in my almost 50-year scientific career.

## **Resonance phenomena in a phonon subsystem in connection with anomalies of the structural state of metals**

M. I. Katsnel'son and A. V. Trefilov

*I. V. Kurchatov Institute of Atomic Energy, Moscow; Institute of Metal Physics, Ural Science  
Center, Academy of Sciences of the USSR*

(Submitted 2 April 1987)

*Pis'ma Zh. Eksp. Teor. Fiz.* **45**, No. 10, 496–498 (25 May 1987)

PHYSICAL REVIEW B

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## **First-principles calculations of magnetic interactions in correlated systems**

M. I. Katsnelson

*Institute of Metal Physics, 620 219 Ekaterinburg, Russia*

A. I. Lichtenstein



## **Real-space imaging of an orbital Kondo resonance on the Cr(001) surface**

**O. Yu. Kolesnychenko, R. de Kort, M. I. Katsnelson, A. I. Lichtenstein  
& H. van Kempen**

## **Zitterbewegung, chirality, and minimal conductivity in graphene**

M.I. Katsnelson<sup>a</sup>

*Eur. Phys. J. B* **51**, 157–160 (2006)

DOI: 10.1140/epj/b/e2006-00203-1



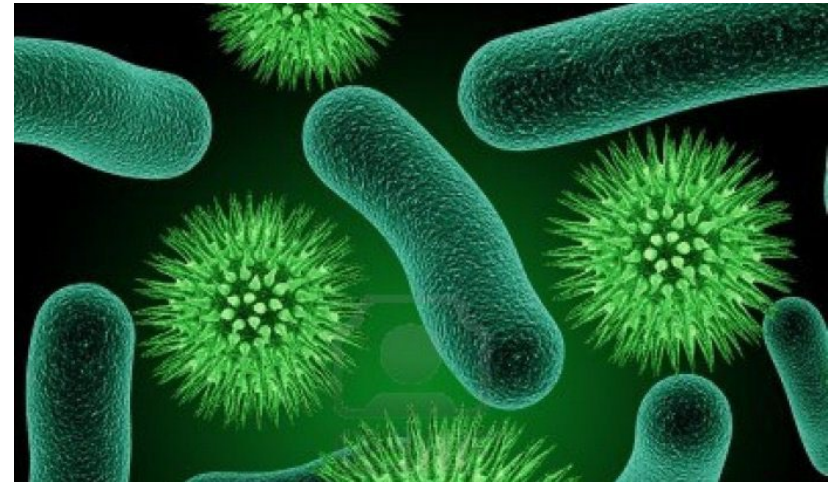
# *Science is necessary for survival of humankind*

Agriculture (“green revolution”)

Medicine (new antibiotics: arms race with bacteria)



We cannot  
just stop:  
too many  
will die



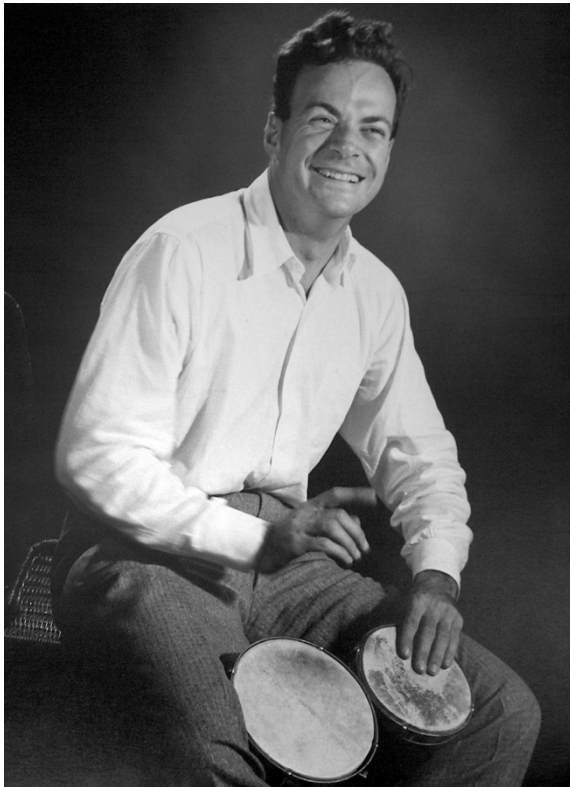
Our society is crucially dependent on communications, transport, computers... well... weapons...

Very important to know how science works

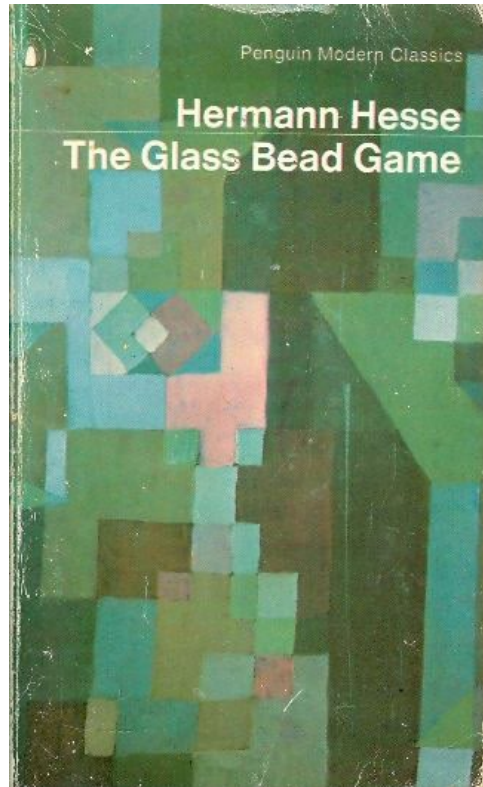
# *Curiosity-driven research*

Physics is like sex: sure, it may give some practical results, but that's not why we do it

R. P. Feynman



Motivations are very different...

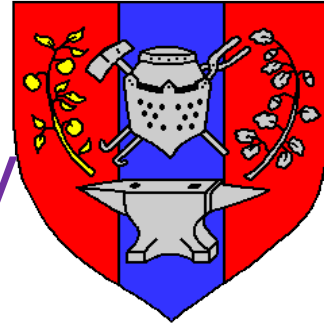


Model of science

# What to do?

1. Trust us, we are smart guys and we know what to do – medieval guilds principle

It will not work in modern society



2. Convince people that we are useful

Well... We are useful but in a complicated way

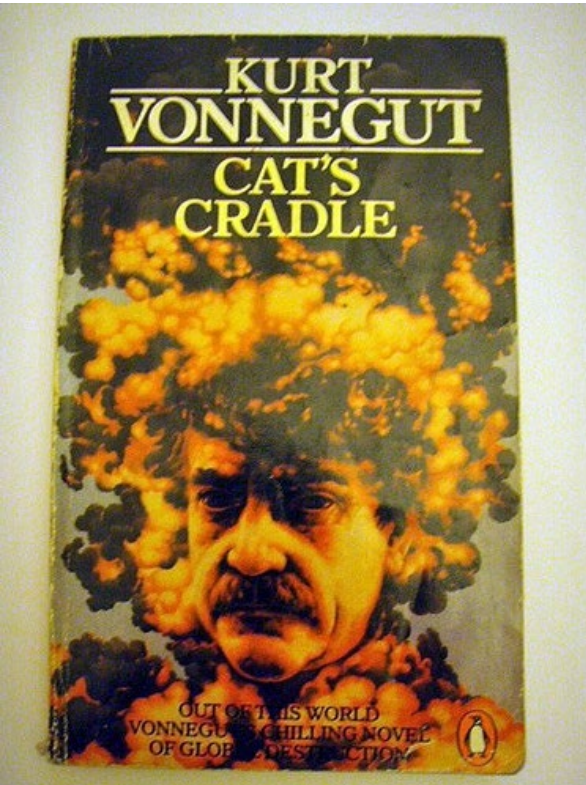
Strong temptations: lie and intimidate

Polite version: tell on success only, overestimate practical importance, promise something too early...



# *Misuse of science*

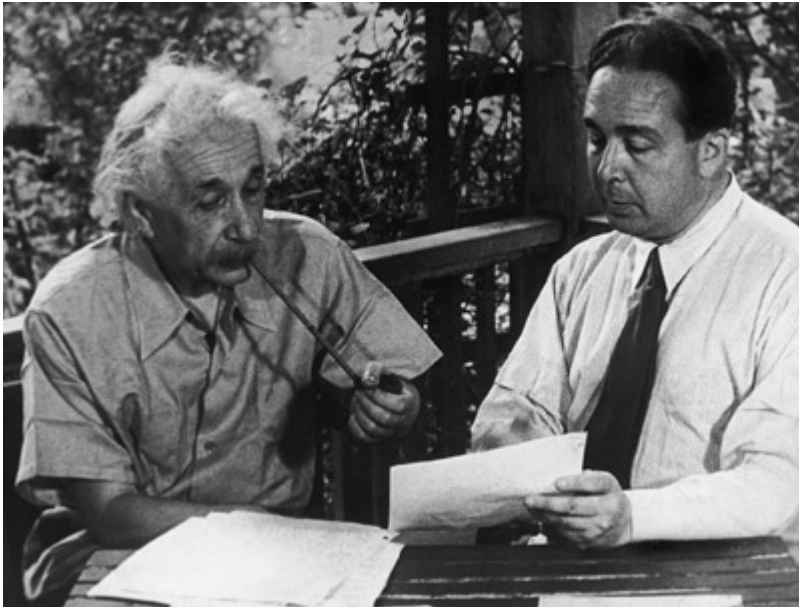
Everything a scientist did was destined to become a weapon (K. Vonnegut, *Cat's Cradle*)



Was/is arms race useful for science? Well...

# *Science as mass occupation*

Starts with A-bomb making



Completely changes relations  
between scientists and society



# *How to be rational in irrational world?*

A very simple answer: *I do not know*

