Experimental Modern Physics: the need for Mathematics

Grzegorz Karwasz

Physics Institute

Nicolaus Copernicus University, Toruń

Atomic, Molecular and Optical Physics Division

and **Didactics of Physics Division**

Hypercomlex Seminar, Będlewo, 26.07-02.08.2008

Experimental Modern Physics: what we (urgently) do not know?

1. Electron optics, positron scattering and anihilation
2. Superconductivity
3. Background radiation
4. Quarks
5. Time arrow
6. Dark matter
7. Miscenaleous (topology and phase transitions dislocations and disclinations)

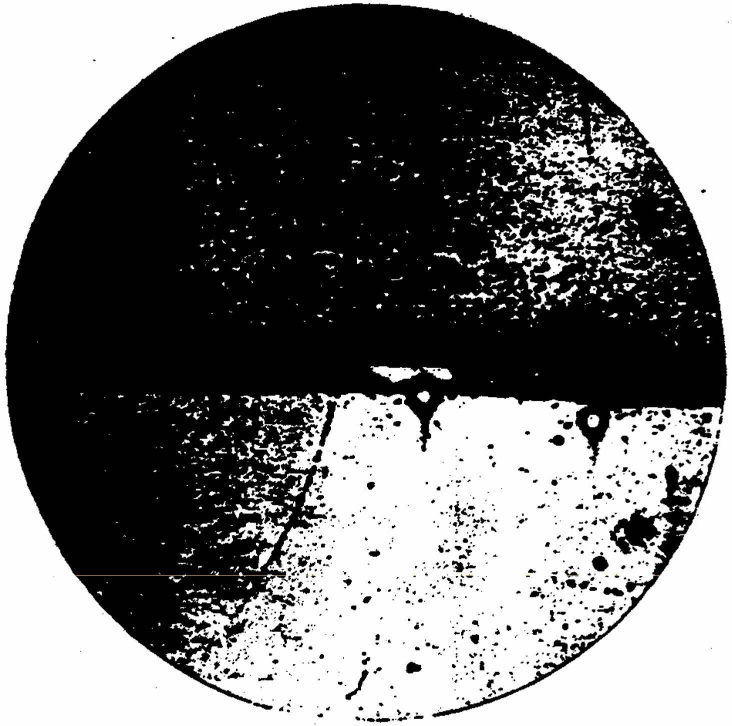
Positron = negative electron

e^+ is antiparticle of e^- :

- mass 511.003 keV/c^2
- spin ½
- opposite Q
- opposite μ
- stable in vacuum (>$2 x 10^{21}$y)

Ps is light H :

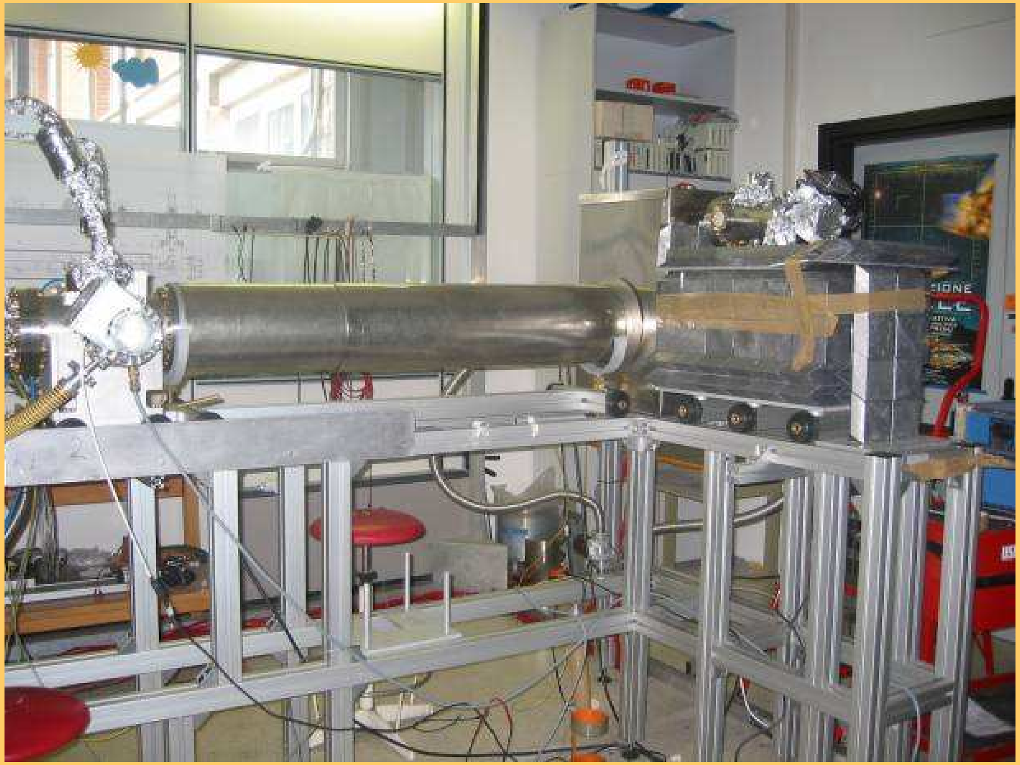
- Energy E= ½ Ry
- p-Ps: τ=125 ps, 2γ
- o-Ps: τ=142 ns, 3γ

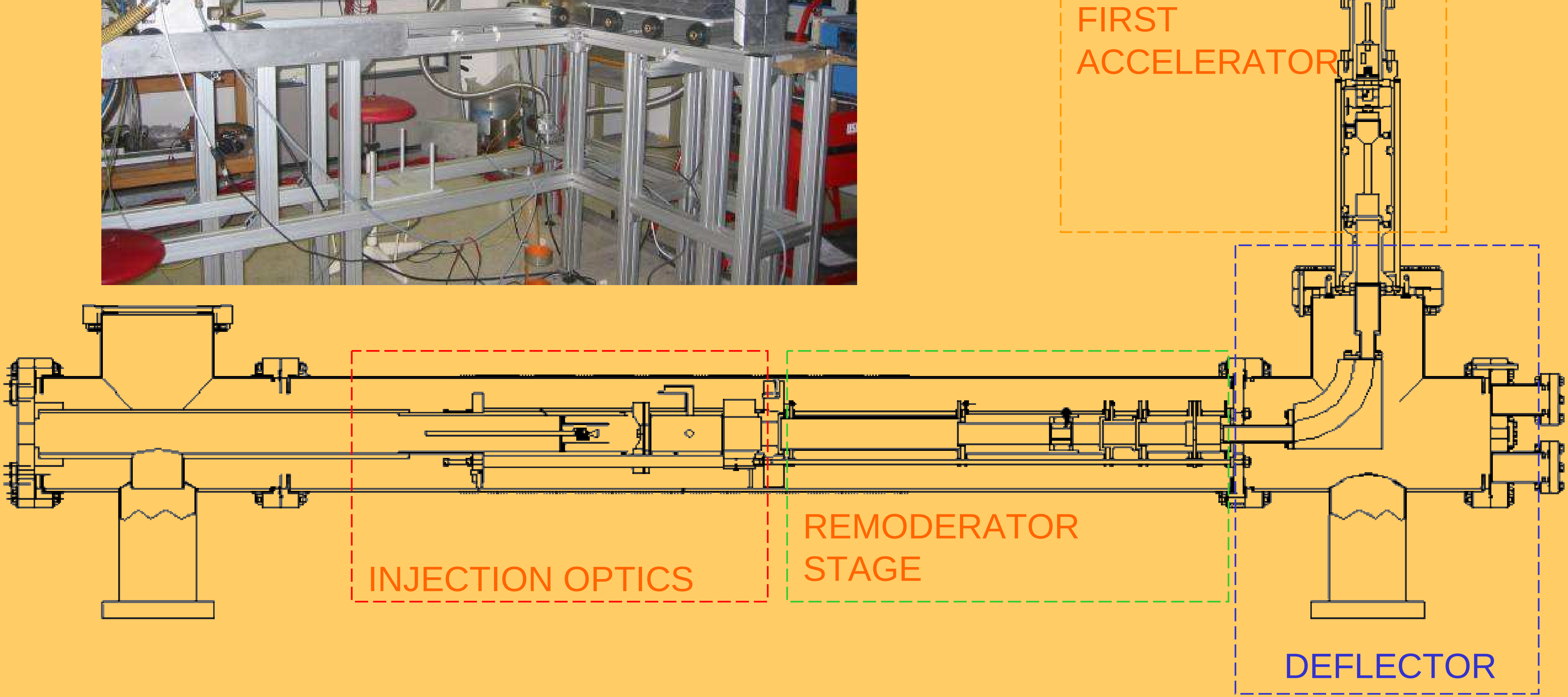


One of Anderson's (1933) original photographs illustrating the historic discovery of the positron. In the cloud chamber, there is a lead plate 6 mm thick and a magnetic field oriented in the page. The change of energy (63 MeV below the plate to 23 MeV above) with the known thickness of lead and magnitude of the field proves that the particle is positive and of the same mass as the electron.

Rev. Mod. Phys., Vol. 60, No. 3, July 1988

Positron scattering – gas phase





Positron Beam for Solid State studies

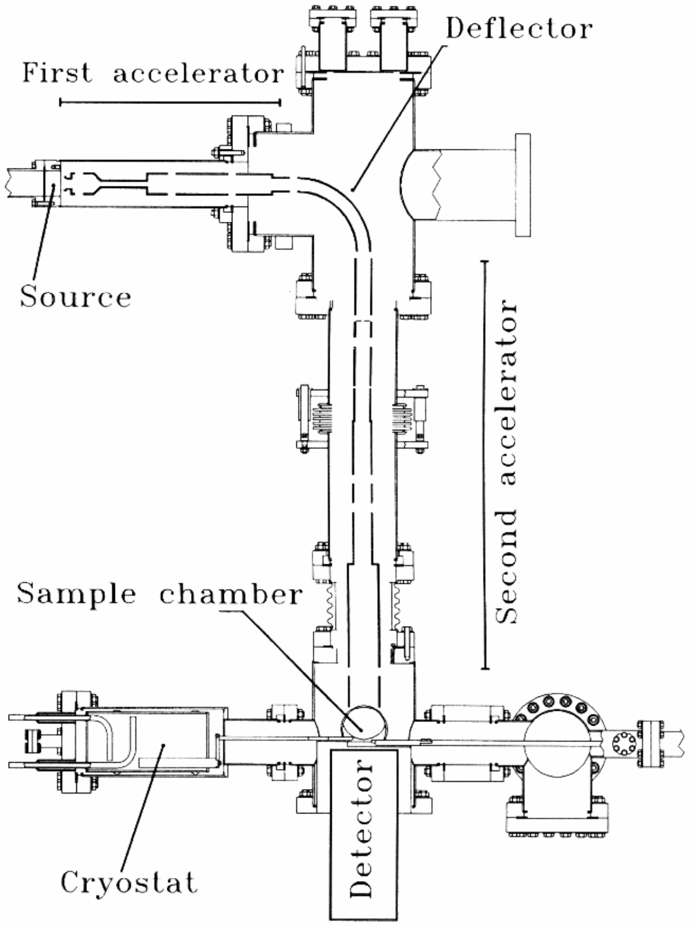


Fig. 1. A schematic layout of the electrostatic positron beam constructed in the Trento laboratory.

Brusa, Karwasz, Zecca 1996

Trento-München Positron Microscope

E=500 eV – 25 keV
spot = 2 μm

Positrons go into detail,

595

A. Zecca, G. Karwasz, Physics World, November 2001, p.21

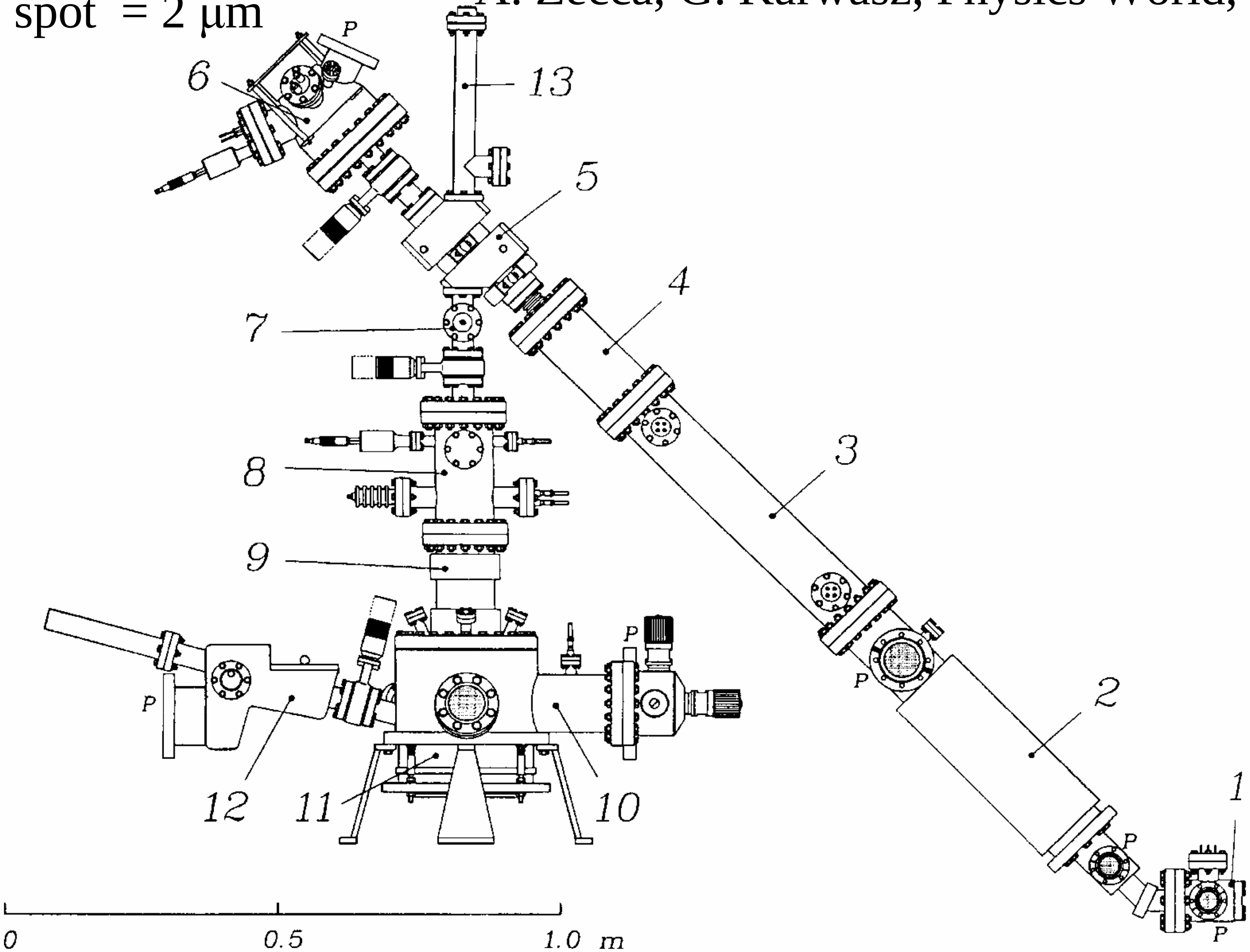
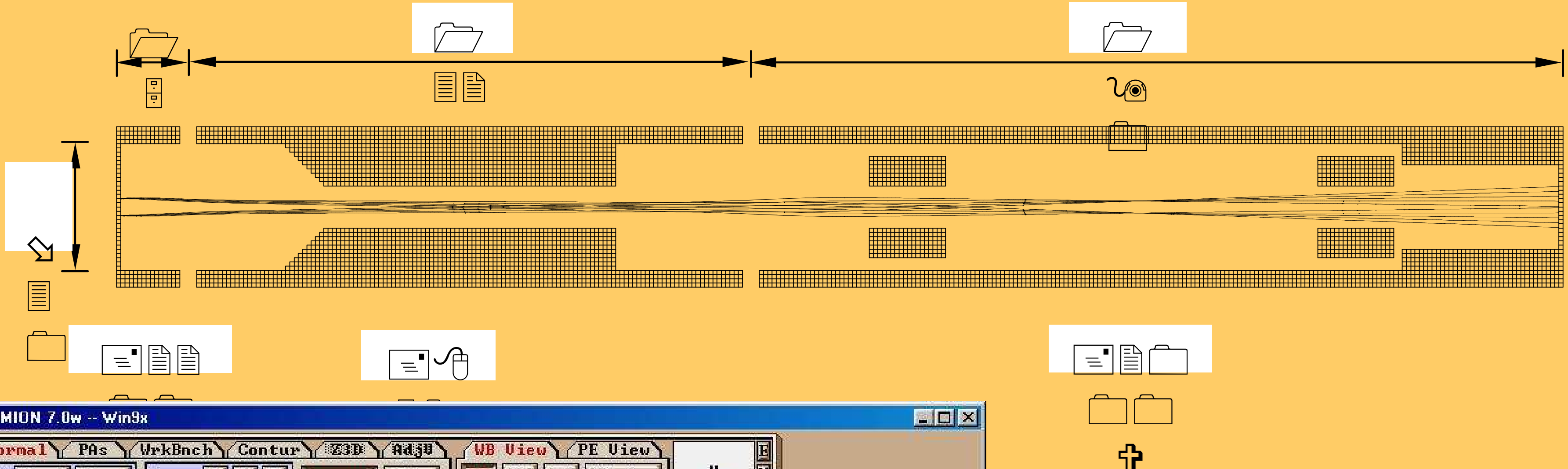
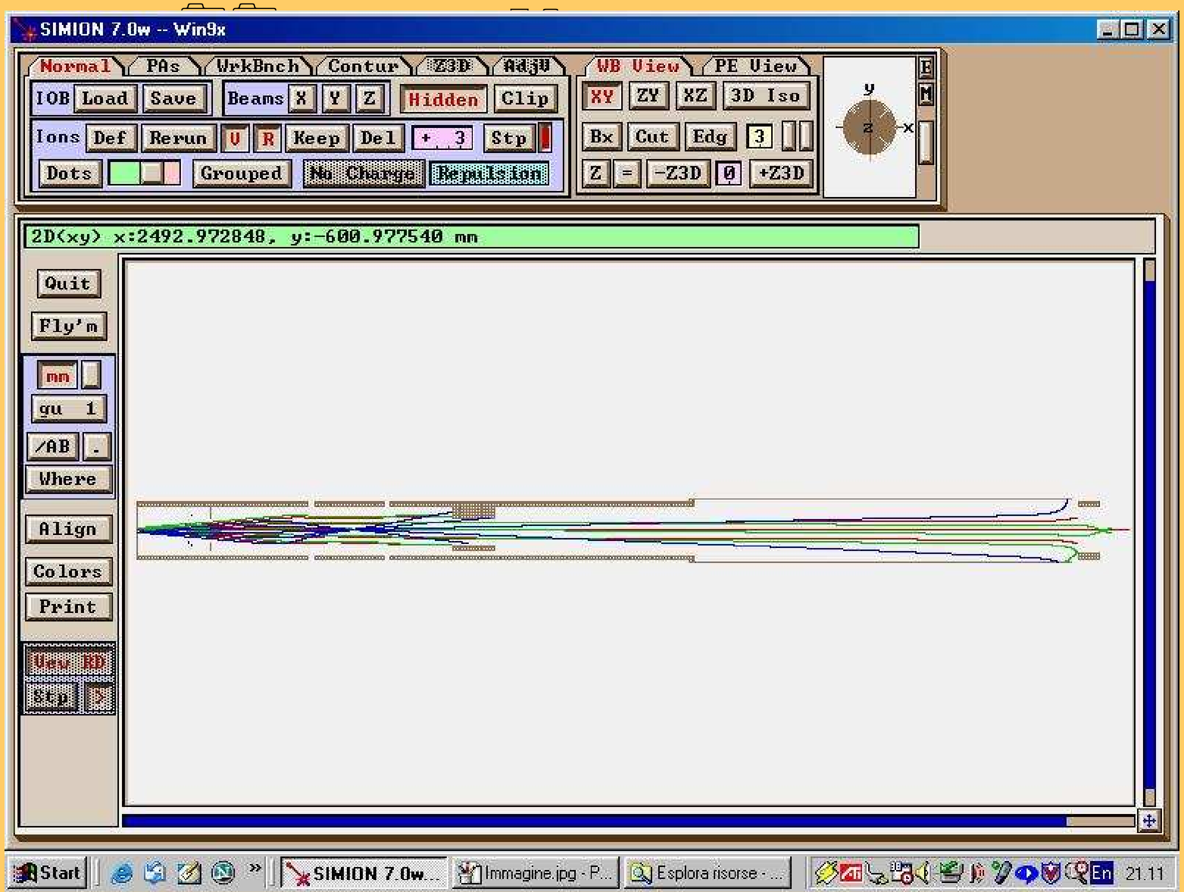


Fig. 1. Overview of the scanning positron microscope – vacuum vessel with attachments: *1* – radioactive source and moderator; *2* – drift tube for pulse forming (sawtooth buncher); *3* – resonance buncher; *4* – accelerator; *5* – beam switch; *6* – remoderator unit; *7* – postbuncher; *8* – main accelerator; *9* – deflector coils; *10* – specimen chamber with manipulator; *11* – probe forming lens with detector in the central bore; *12* – load lock; *13* – electron gun; *P* – pumping port. Some components have been rotated into the plane of the drawing

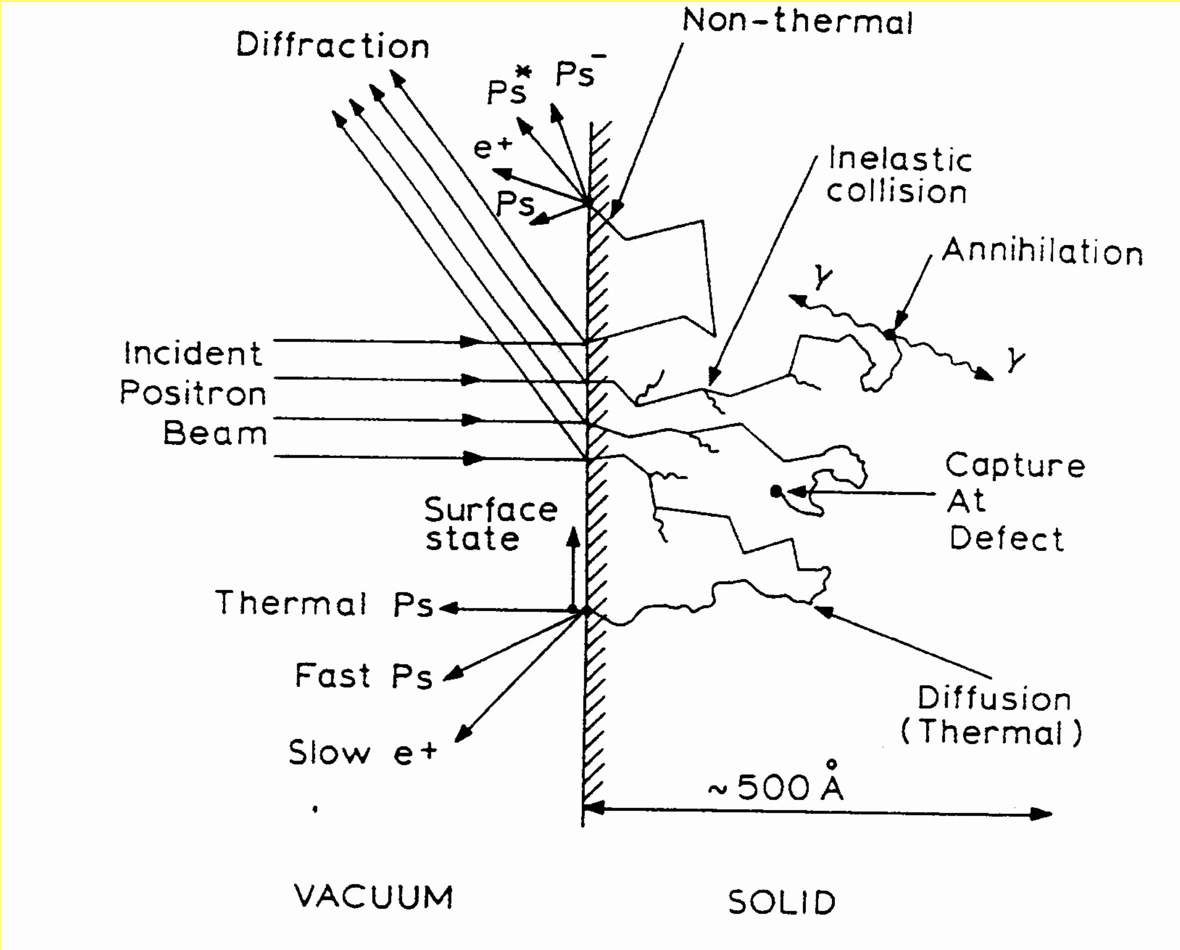
Electron optics modelling

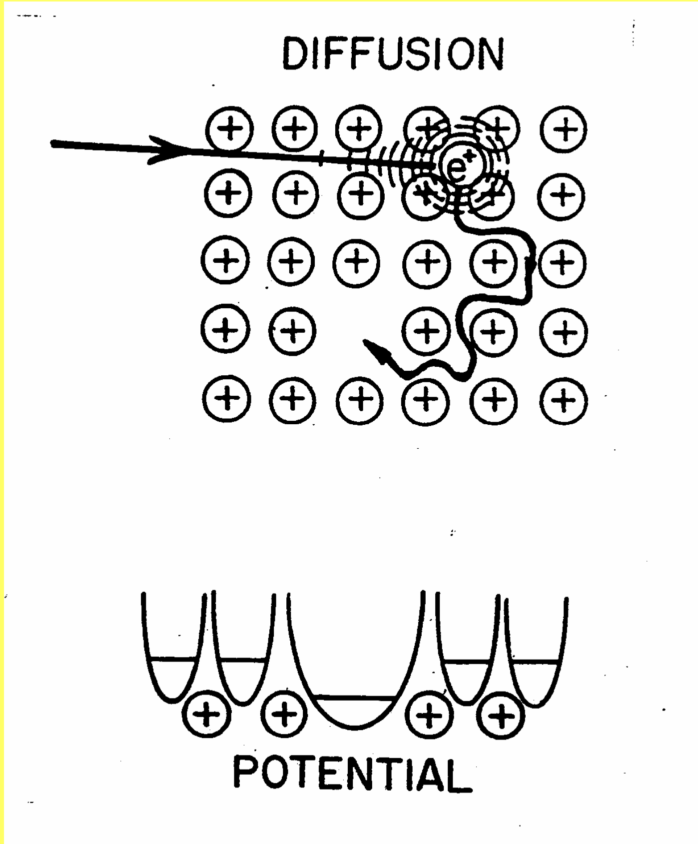




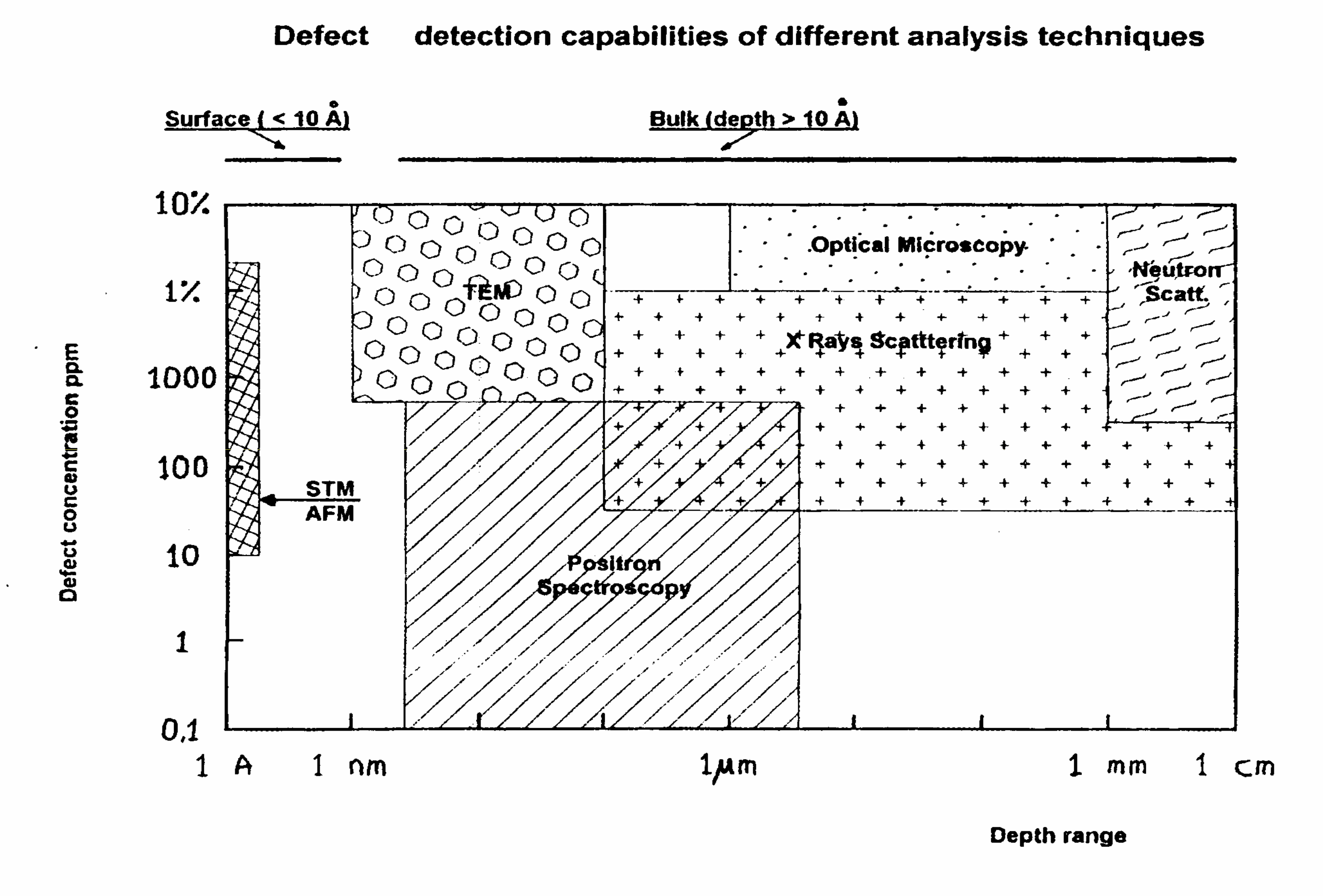
Crossed ExB fields: Randers-Ingarden geometry would be highly welcome!

Positron diffusion and trapping

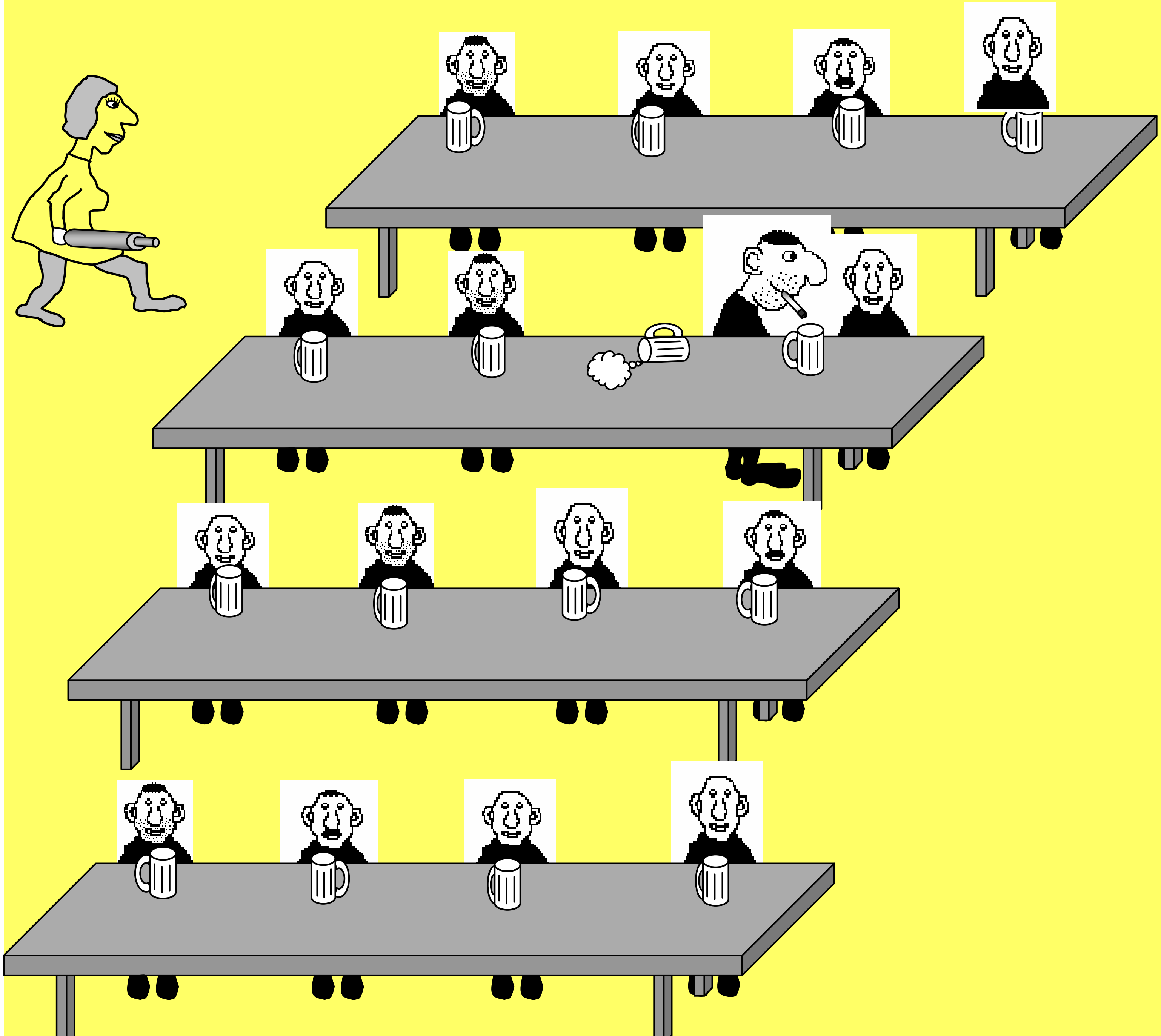




Positrons in Solid State Physics



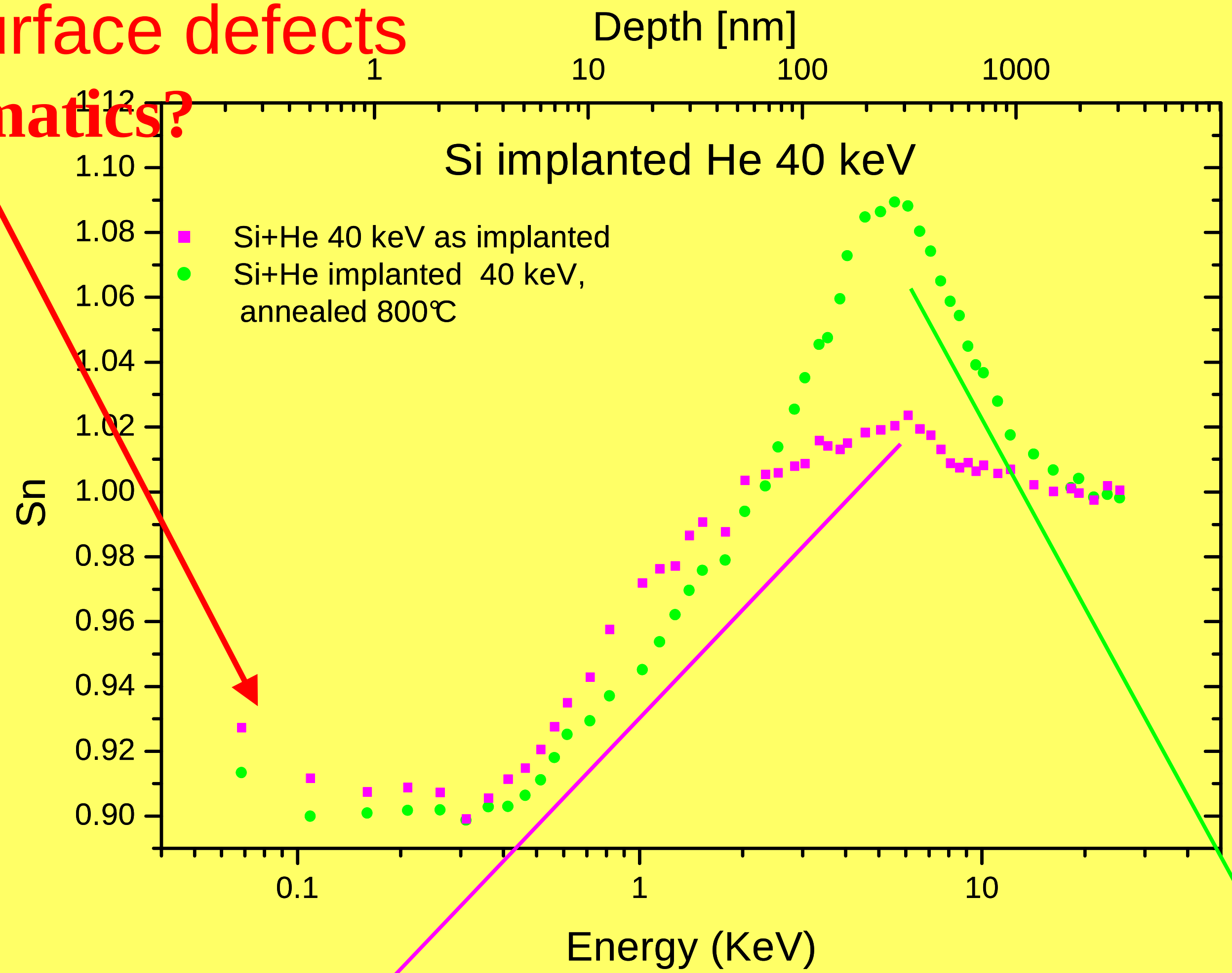
Positron in a crystal



Surface/ bulk defects studies

Unexpected &
unknown surface defects
new Mathematics?

Doppler broadening



Presence of vacancy-like defects

Presence of large cavities

Electron – atom scattering *(some theory)*

$$\Phi = e^{ikz} + \frac{f(\theta)}{r} e^{ikr}$$

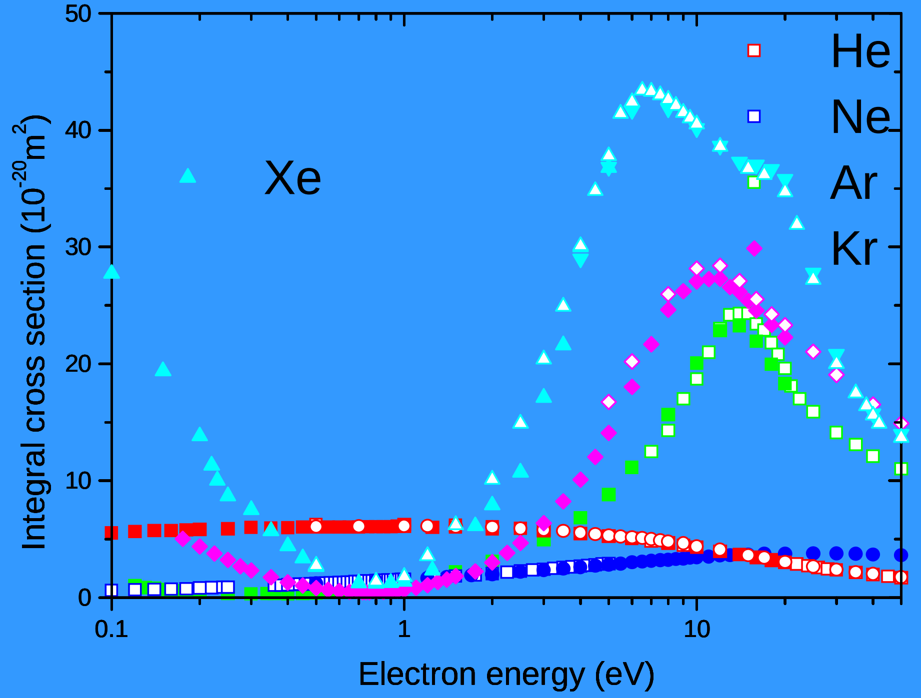
$$\frac{d\sigma}{d\omega} = \left| f(\theta) \right|^2$$

$$f(\theta) = \frac{1}{2ik} \sum_{l=0}^{\infty} (2l+1)\left[\exp(2i\delta_l) - 1\right] \cdot P_l(\cos\theta)$$

$$\sigma = \frac{4\pi}{k^2} \sum_{l=0}^{\infty} (2l+1) \cdot \sin^2 \delta_l$$

$$E_0: \quad \sin \delta_l = 0 \quad \rightarrow \quad \sigma(E_0) = 0$$

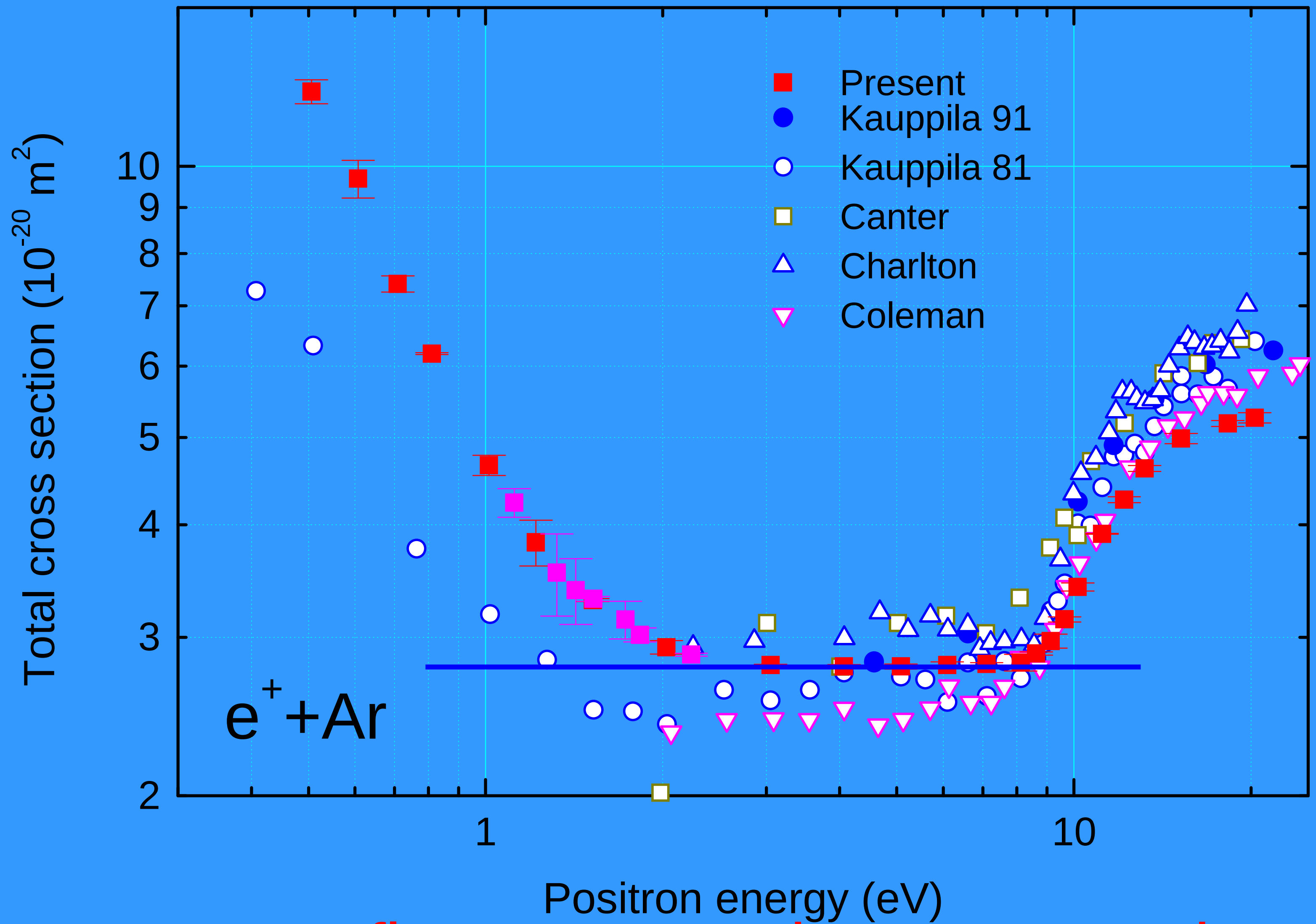
Electrons: Ramsauer's minimum



$$\sigma(E) \propto \sin^2 \delta_l(E)$$

$$\delta_l = \pi, 2\pi, 3\pi \rightarrow \sin^2 \delta_l = 0$$

Positron TCS on Argon (exp.)



a flat cross section up to Ps threshold!

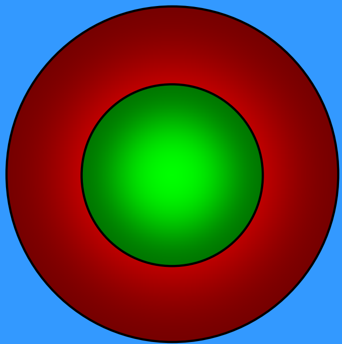
Effective range theory (polarization forces)

$$\sigma_l(k) = \frac{4\pi}{k^2}\sum_l (2l+1)\sin^2\delta_l(k)$$

l – partial wave angular momentum

k^2 - energy

δ_l – phase shift



$$k\cot\delta_0(k) = -\frac{1}{A} + \frac{1}{2} r_e k^2 + \ldots$$

A – scattering length

$\sigma(E=0) = 4\pi A^2$

r_e – effective range

$$\sigma_{tot} \approx \sigma_0 = \frac{4\pi}{k^2 + [-1/A + \frac{1}{2} r_e k^2]^2}$$

$\sigma(E>0) \sim 1/E$

Idziaszek, Karwasz PRA2006

Do positrons measure molecular diameters ?

Values of Molecular Diameters/ Radii (Å)

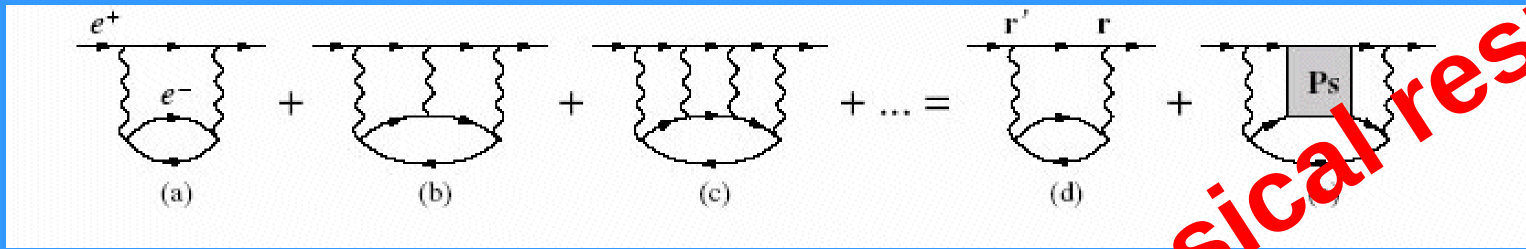
from:
- viscosity
- van der Waals
- liquid density

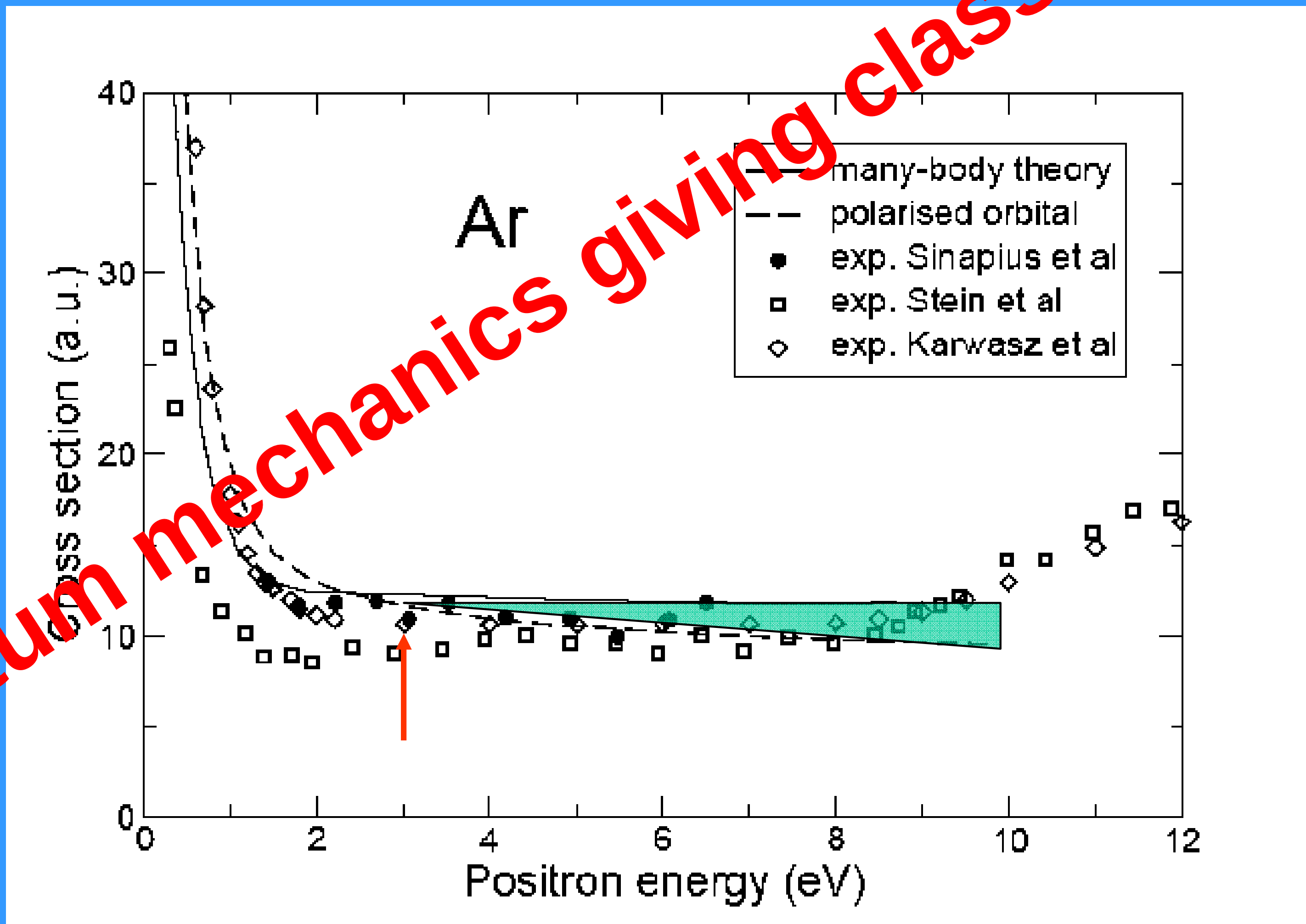
$\sigma = \pi R^2$

Gas	From δ_0	From δ_m	From b	From ρ	Electron collision	D=2R
CO_2	4.65	3.32	3.24	4.05	4.4	2.76
Ar	3.67	2.42	2.49	4.15	3.6	1.96
He	2.18	1.69	2.66	4.21	1.7	0.34
H_2	2.75	2.1	2.76	4.19	2.2	1.26 (R=0.63!)
Ne	2.6	2.16	2.38	3.4	2.2	1.06
N_2						2.04

Yes! But this is Classical Mechanics result!

Virtual positronium formation





Quantum mechanics giving classical result!

Gleb Gribakin, private information

A Topological Look at t Quantum Hall Effect

The amazingly precise quantization of Hall conductance in a two-dimensional electron gas can be understood in terms of a topological invariant known as the Chern number.

Joseph E. Avron, Daniel Osadchy, and Ruedi Seiler

The failure of parallel transport for closed paths is a hallmark of intrinsic curvature. In modern geometry, the local curvature of a surface is defined as the angular mismatch after the traversal of an infinitesimal closed loop, divided by the loop's area.

This notion of curvature extends to a wide range of other situations. In particular, it lets us introduce curvature into quantum mechanics. Consider a quantum Hamiltonian $H(\Phi,\theta)$ that depends on two angular parameters. The parameters play a role analogous to the spherical coordinates on Earth's surface. Suppose that the Hamiltonian has a nondegenerate ground state at energy zero. Let

Chern numbers

Geometry and topology are intimately related. Let us recall this relation in the familiar setting of surfaces. A remarkable relation between geometry and topology is the formula by Gauss and Charles Bonnet:

$$\frac{1}{2\pi}\int_S K\,\mathrm{d}A = 2(1-g). \qquad (3)$$

The integral is over a surface S without a boundary, like the torus in figure 4, and K is the local curvature of the surface. Therefore, $K\,\mathrm{d}A$ is the angular mismatch of par-

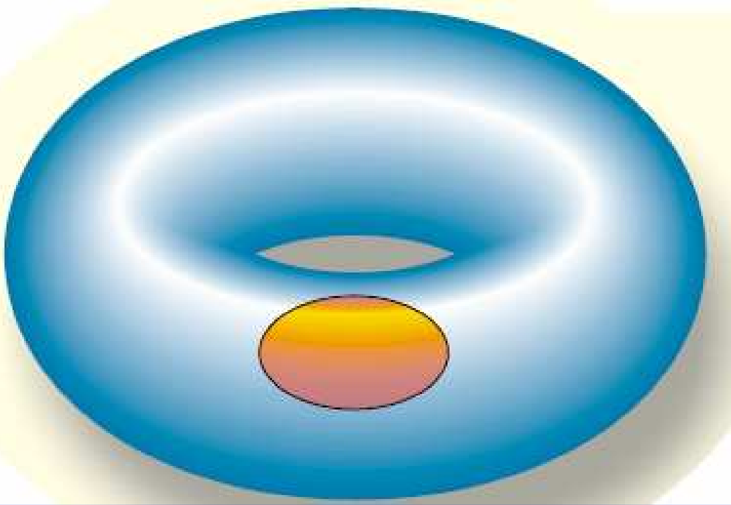
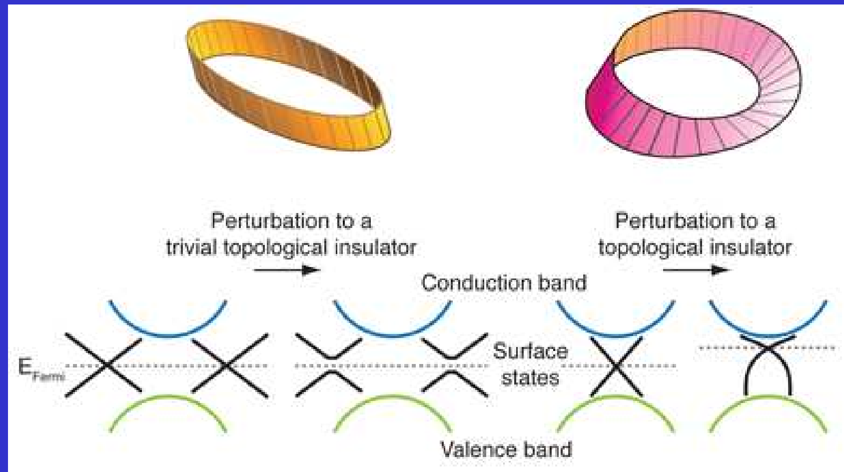


Figure 4. The Gauss–Bonnet formula (equation 3) is illustrated here by a toroidal surface with one handle. The local curvature K is positive on those portions of the surface that resemble a sphere and negative on those, near the hole, that resemble a saddle. Because g, the number of handles, equals one, the integral of the curvature over the entire surface vanishes. One can make Shiing-shen Chern's quantum generalization of the Gauss–Bonnet formula plausible by considering the angular mismatch of parallel transport after a circuit around the small red patch in the figure.

Topological states of quantum matter

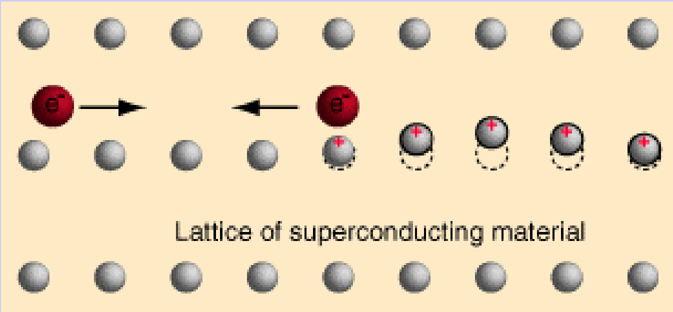


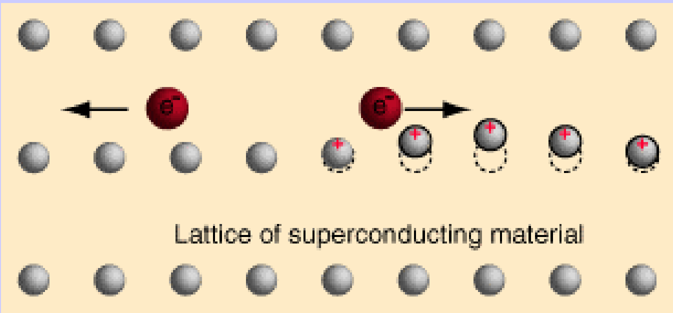
Surface states and topological invariants in three-dimensional topological insulators: Application to $Bi_{1-x}Sb_x$

Jeffrey C. Y. Teo, Liang Fu, and C. L. Kane

We study the electronic surface states of the semiconducting alloy bismuth antimony ($Bi_{1-x}Sb_x$). Using a phenomenological tight-binding model, we show that the Fermi surface for the 111 surface states encloses an odd number of time-reversal-invariant momenta (TRIM) in the surface Brillouin zone. This confirms that the alloy is a strong topological insulator in the (1;111) Z_2 topological class. We go on to develop general arguments which show that spatial symmetries lead to additional topological structure of the bulk energy bands, and impose further constraints on the surface band structure. Inversion-symmetric band structures are characterized by eight Z_2 "parity invariants," which include the four Z_2 invariants defined by time-reversal symmetry. The extra invariants determine the "surface fermion parity," which specifies which surface TRIM are enclosed by an odd number of electron or hole pockets.

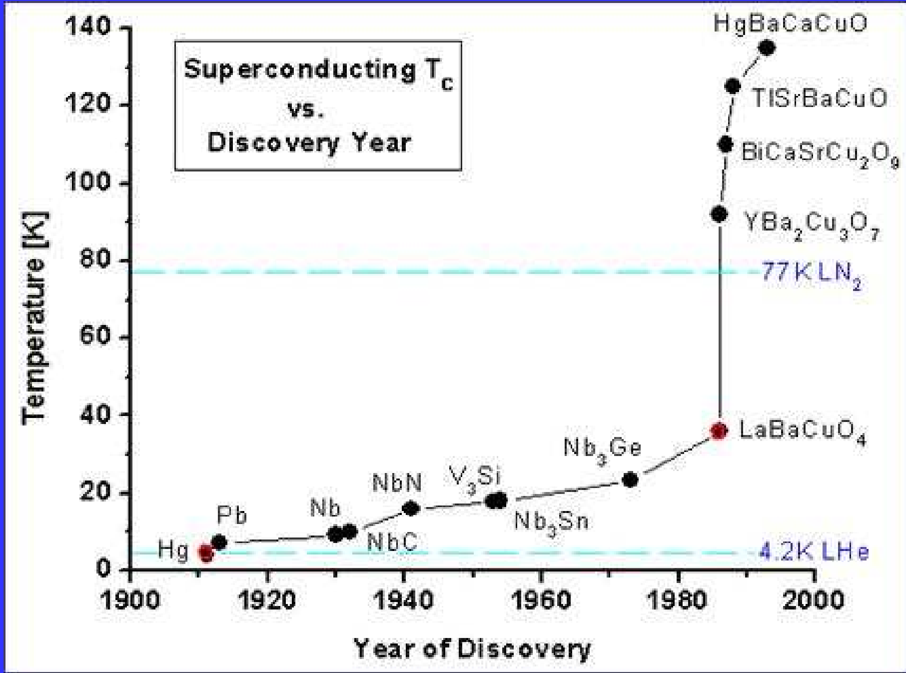
Superconductivity: BCE theory

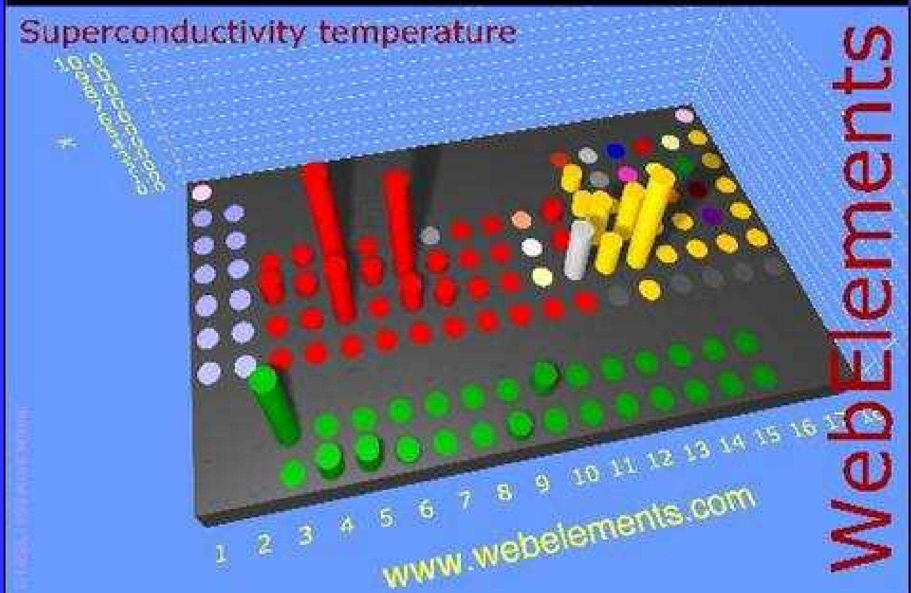




Superconductivity is a kind of Bose-Einstein condensation. Unfortunately, only bosons, i.e. particles with the spin=1 (integer, in general) can condensate. Electrons are fermions, with spin =1/2. But if two electrons could couple, they would form a boson! The crystal **matrix** serves as a deformable **mattress** for this.

HT - Superconductivity

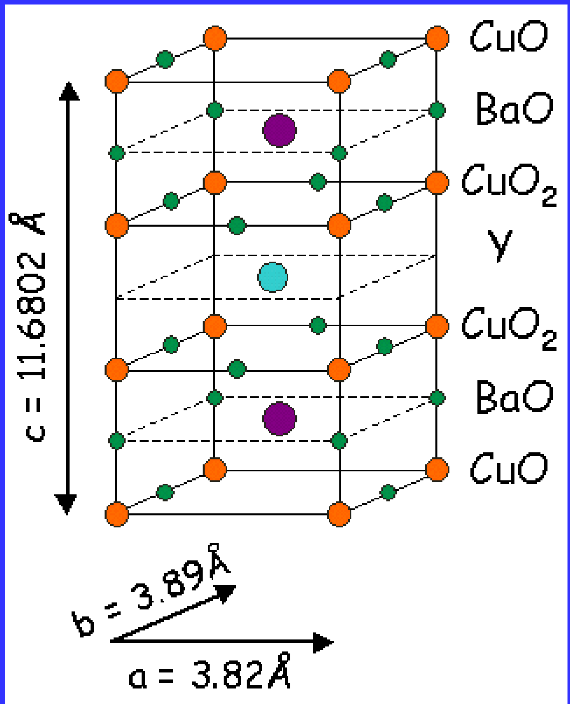


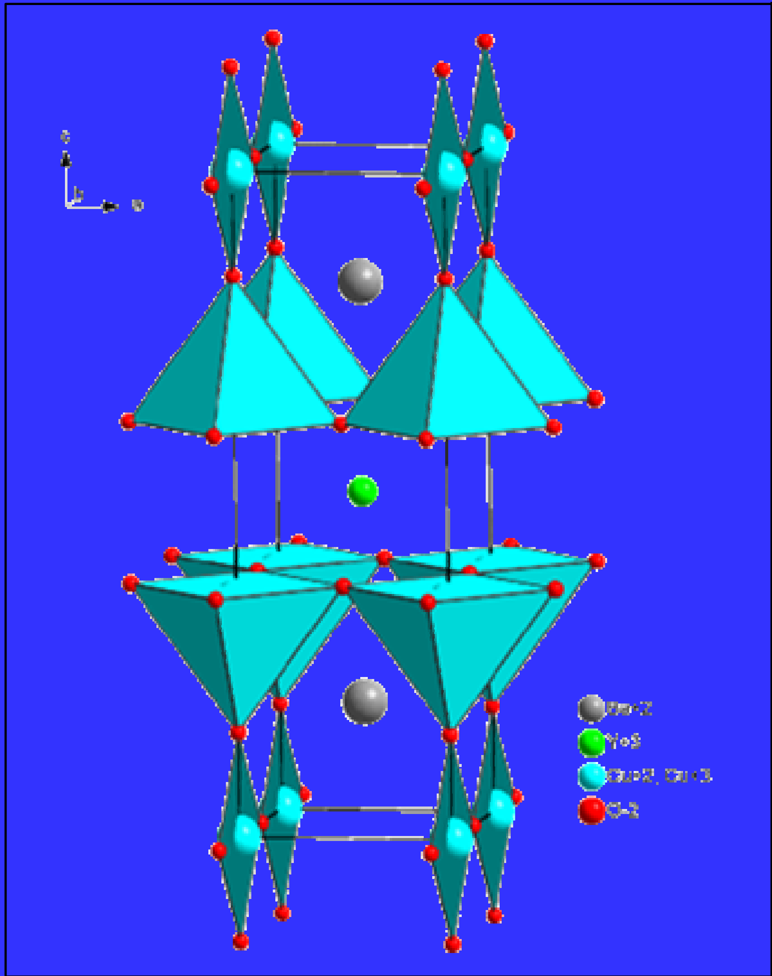


Al	1.14
α-Hg	4.153
Nb	9.50
Sn	3.722
Nb_3Ge	23.2
Nb_3Sn	18
NbTi	10

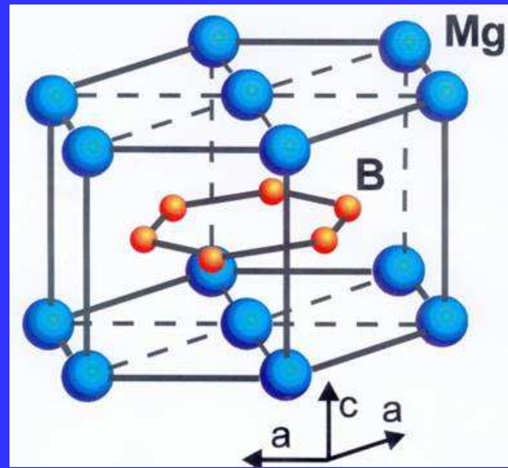
$(La_{2-x}Ba_x)CuO_4$	35
$YBa_2Cu_3O_7$	92
$Bi_2Sr_2Ca_2Cu_3O_{10}$	110
$Ti_2Ba_2Ca_2Cu_3O_{10}$	125
$HgBa_2Ca_2Cu_3O_8$	135
$BaPb_{0.75}Bi_{0.25}O_3$	12
$Na_xCoO_2 \cdot yH_2O$	5

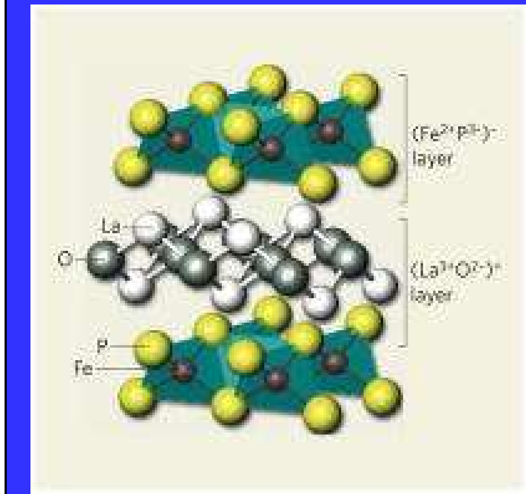
Superconductivity

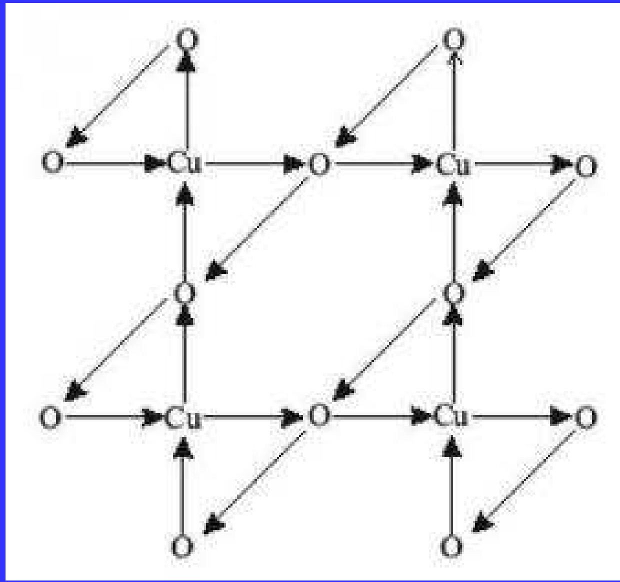




Komórka kryształu YBCuO, nadprzewodnik wysokotemperaturowy. *http://de.wikipedia.org/wiki/Bild:YBCO.gif*







HT superconductivity: theory

Chandra's Varma theory, the radical idea that high temperature superconductivity and related phenomena occur in certain materials because quantum-mechanical fluctuations in these materials **increase** as temperature **decreases**. Usually such fluctuations, which determine the properties of all matter in the universe, decrease as temperature decreases.

Superconductivity is associated with the formation of a new state of matter in which electric current loops form spontaneously, going from copper to oxygen atoms and back to copper. His theory concluded that the quantum-mechanical fluctuations are the fluctuations of these current loops. Physicists consider these fluctuations in the current loops to be **fluctuations of time**.

P.S. or non-standard geometry?

http://www.physorg.com/news66994182.html

Topology and phase transitions

Phase transitions and configuration space topology

Michael Castner

Reviews of Modern Physics, Volume 80, January- March 2008

Equilibrium phase transitions may be defined as nonanalytic points of thermodynamic functions, e.g., of the canonical free energy. Given a certain physical system, it is of interest to understand which properties of the system account for the presence, or the absence, of a phase transition, and an investigation of these properties may lead to a deeper understanding of the physical phenomenon. One possible way to approach this problem, reviewed and discussed in the present paper, is the study of topology changes in configuration space which are found to be related to equilibrium phase transitions in classical statistical mechanical systems. For the study of configuration space topology, one considers the subsets $\mathcal{M}_v$, consisting of all points from configuration space with a potential energy per particle equal to or less than a given v. For finite systems, topology changes of $\mathcal{M}_v$ are intimately related to nonanalytic points of the microcanonical entropy. In the thermodynamic limit, a more complex relation between nonanalytic points of thermodynamic functions (i.e., phase transitions) and topology changes is observed. For some class of short-range systems, a topology change of the $\mathcal{M}_v$ at $v=v_t$ was proven to be necessary, but not sufficient, for a phase transition to take place at a potential energy v_t. In contrast, phase transitions in systems with long-range interactions or in systems with nonconfining potentials need not be accompanied by such a topology change. Instead, for such systems the nonanalytic point in a thermodynamic function is found to have some maximization procedure at its origin. These results may foster insight into the mechanisms which lead to the occurrence of a phase transition, and thus may help to explore the origin of this physical phenomenon.

Phase transition and topology

- The main issue of the present paper is to investigate the mechanism which is at the basis of a phase transition using a different approach, based on concepts from *differential geometry* and *topology*.
- The use of concepts from topology to describe a physical phenomenon is particularly appealing due the fact that topology yields a very reductional description: considering only the topology of, say, a surface, a significant amount of „information" (on curvatures, for example) is disregardere, and only a samll part (like the connetivity properties) is kept. […] to get an *unblurred* view onto the mechnisms which is at the basis.

Phase transition and topology

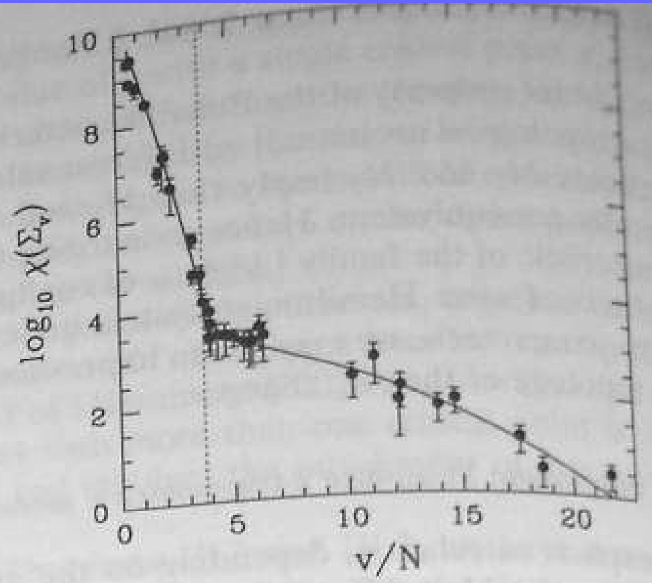


FIG. 2. Logarithmic modulus σ of the Euler characteristic of Σ_v as a function of the potential energy per degree of freedom for the nearest-neighbor φ^4 model on a 7×7 square lattice. The dotted vertical line marks the potential energy at which a phase transition takes place in the thermodynamic limit. The solid line serves as a guide to the eye. From Franzosi *et al.*, 2000.

$$V_{\varphi}^{\mathrm{nn}}(q) = \sum_{i=1}^{N} \left(-\frac{1}{2} q_i^2 + \frac{1}{4} q_i^4 \right) - J \sum_{\langle i,j \rangle} q_i q_j, \qquad (3.10)$$

Numerical simulation example:

Phase transition from

ferromagnetic state

(low temperatures)

to **paramagnetic state**

(ferromagnetic,

above Curie temperature

Phase transition and topology

Conclusions:

"It remains an open task to precisely specify which topology changes entail a phase transition. Several proposals for conditions on topology changes of the $\mathcal{M}_v$ allegedly sufficient to guaranteee the occurence of a phase transition are discussed, but a final answer to this question is still lacking.

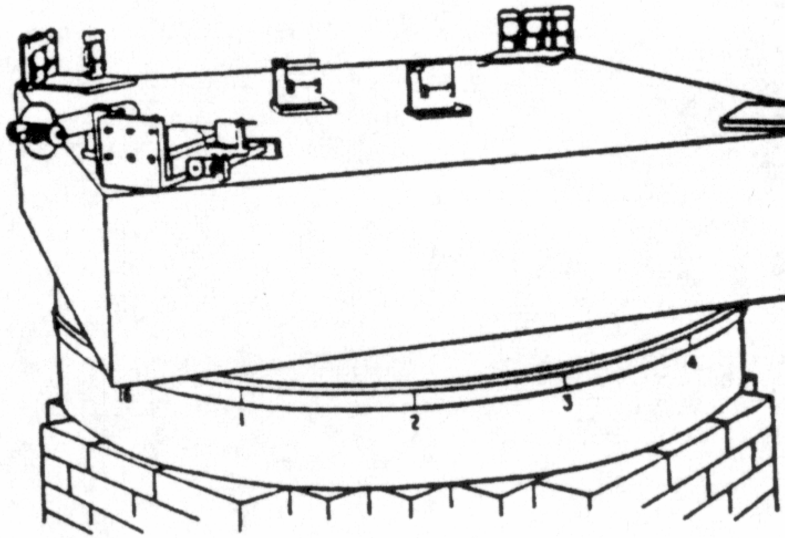
One may conjecture that such a criterion will not be exclusively of topological character, but instead may involve some notion of **measure or geometry** as well."

new insight is needed!

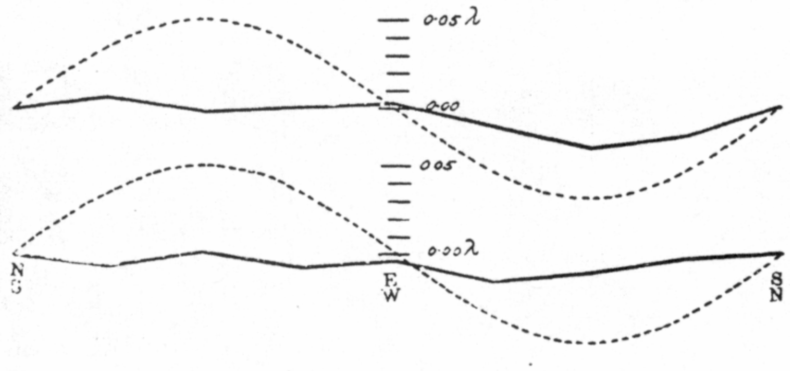
Universe, its geometry and our place
Part I

Nicolaus Copernicus
(*Toruń 1543)

Abraham Michelson
(*Strzelno 1857)



Ryc. 11.31. Rysunek aparatury Michelsona i Morleya. Przyrządy były ustawione na kamiennej podstawie o powierzchni około 2 m² i grubości 35 cm. W celu dokładnego wypoziomowania aparatury i wyeliminowania drgań pływała ona w korycie wypełnionym rtęcią. Z pracy: A. A. Michelson, E. Morley, *On the relative motion of the Earth and the luminiferous ether*, „American Journal of Science" **34**, 333 (1887)



Ryc. 11.32. Wynik doświadczenia Michelsona-Morleya był negatywny, gdyż nie udało się zaobserwować oczekiwanego przesunięcia prążków interferencyjnych przy obrocie interferometru. Autorzy napisali: „Wyniki obserwacji są przedstawione w formie graficznej na rysunku. Krzywa górna odpowiada obserwacjom w południe, a krzywa dolna – obserwacjom wieczornym. Krzywe przerywane przedstawiają ósmą część przesunięcia teoretycznego. Wydaje się, że na podstawie tego rysunku można wnioskować, iż jeżeli istnieje jakiekolwiek przesunięcie spowodowane względnym ruchem Ziemi i światłonośnego eteru, to nie może ono być dużo większe niż 0,01 odległości między prążkami." Z pracy: A. A. Michelson, E. Morley, *On the relative motion of the Earth and the luminiferous ether*, „American Journal of Science" **34**, 333 (1887)

Michelson (and Kopernik):
No absolute reference frame!

A. K. Wróblewski, Wstęp do fizyki, tom I, s. 141

Ziemia, jakkolwiek bardzo wielką jest bryłą, żadnego nie ma porównania z wielkością nieba…

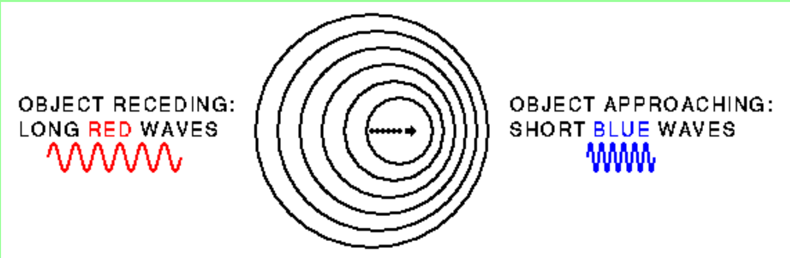
[…] że cały świat się obraca, którego granic nie znamy,

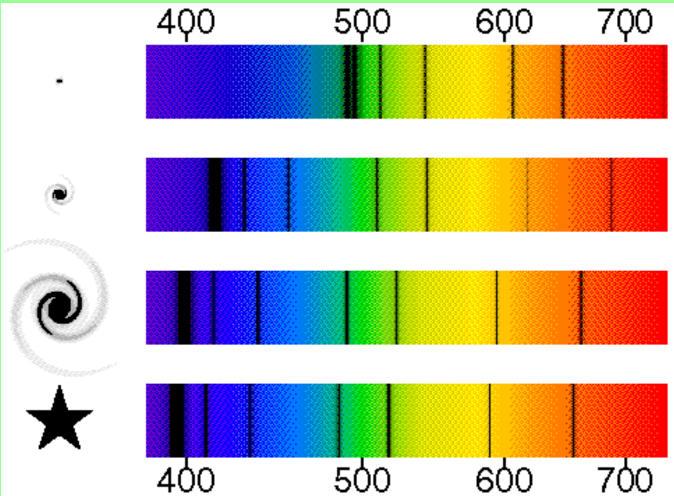
ani ich nawet znać nie możemy,

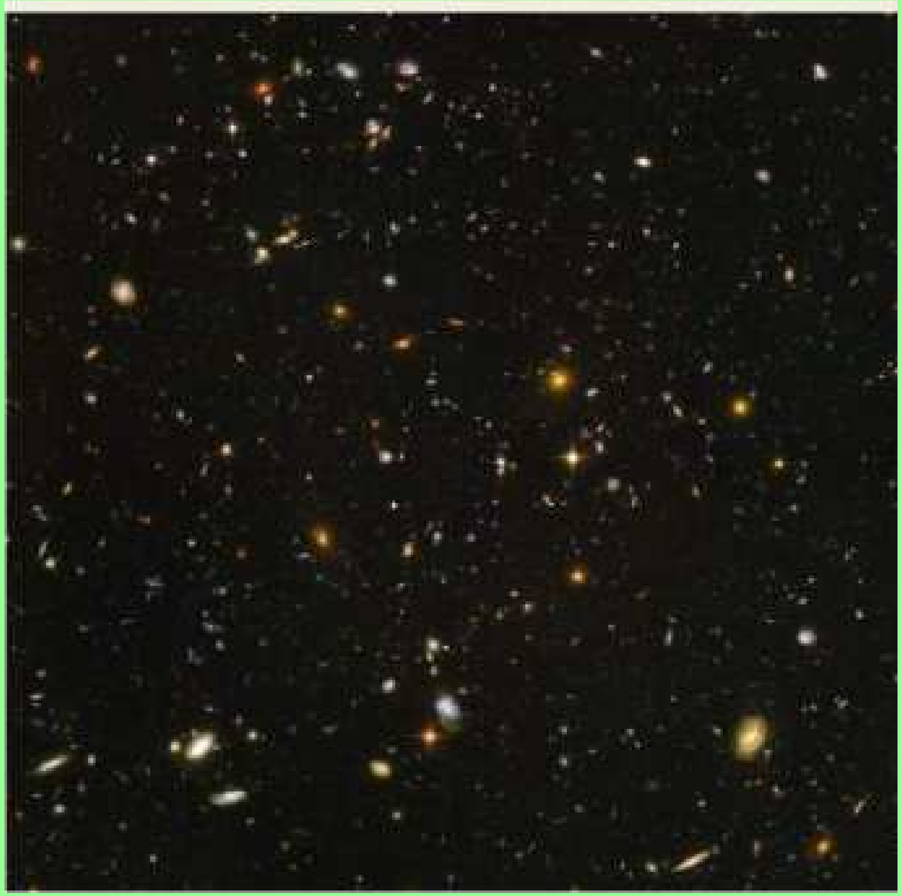
Nicolaus Copernicus, *De revolutionibus*, Norimberga, 1543

Universe: Part II

Hubble (1929): galaxies red-shift
= expanding Universe







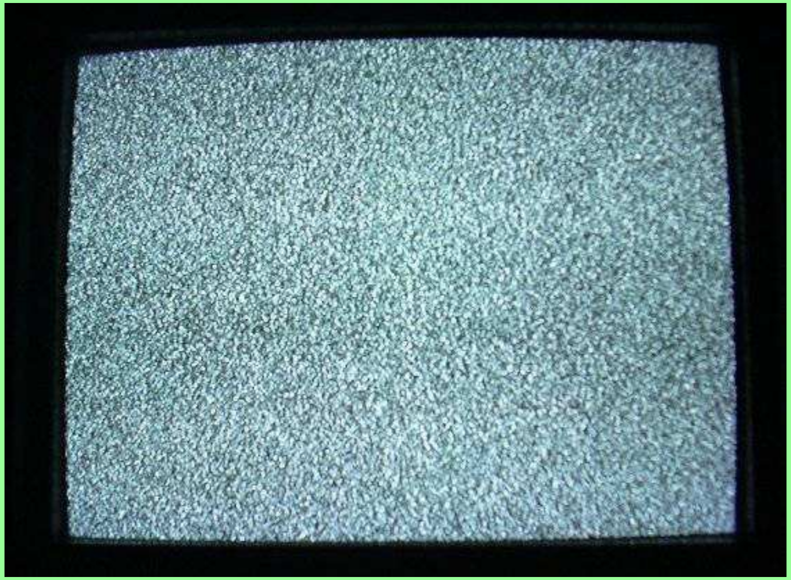
„Głębokie pole” teleskopu „Hubble”:
najdalsze galaktyki
(odległe 13 mld lat świetlnych)

... but still no absolute reference frame!

Universe: Part III

Penzias i Wilson (1964); „strange noise”

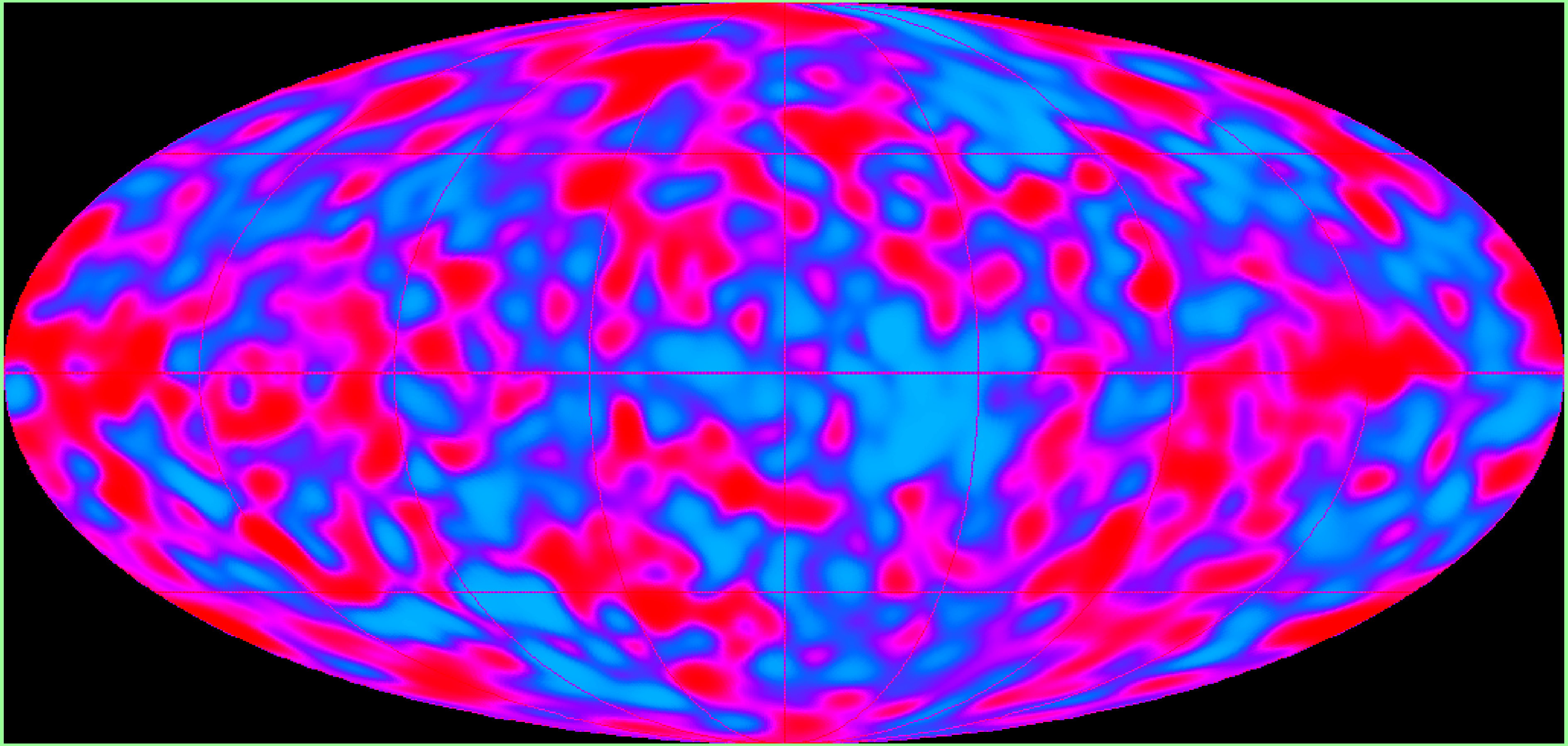
Obserwatorium radioastronomiczne
w Piwnicach k. Torunia



= promieniowanie reliktowe (Big Bang + 300 tys. lat)

… po odjęciu przesunięcia Dopplera:

„Gorąca zupa" plazmowa z początku Wszechświata

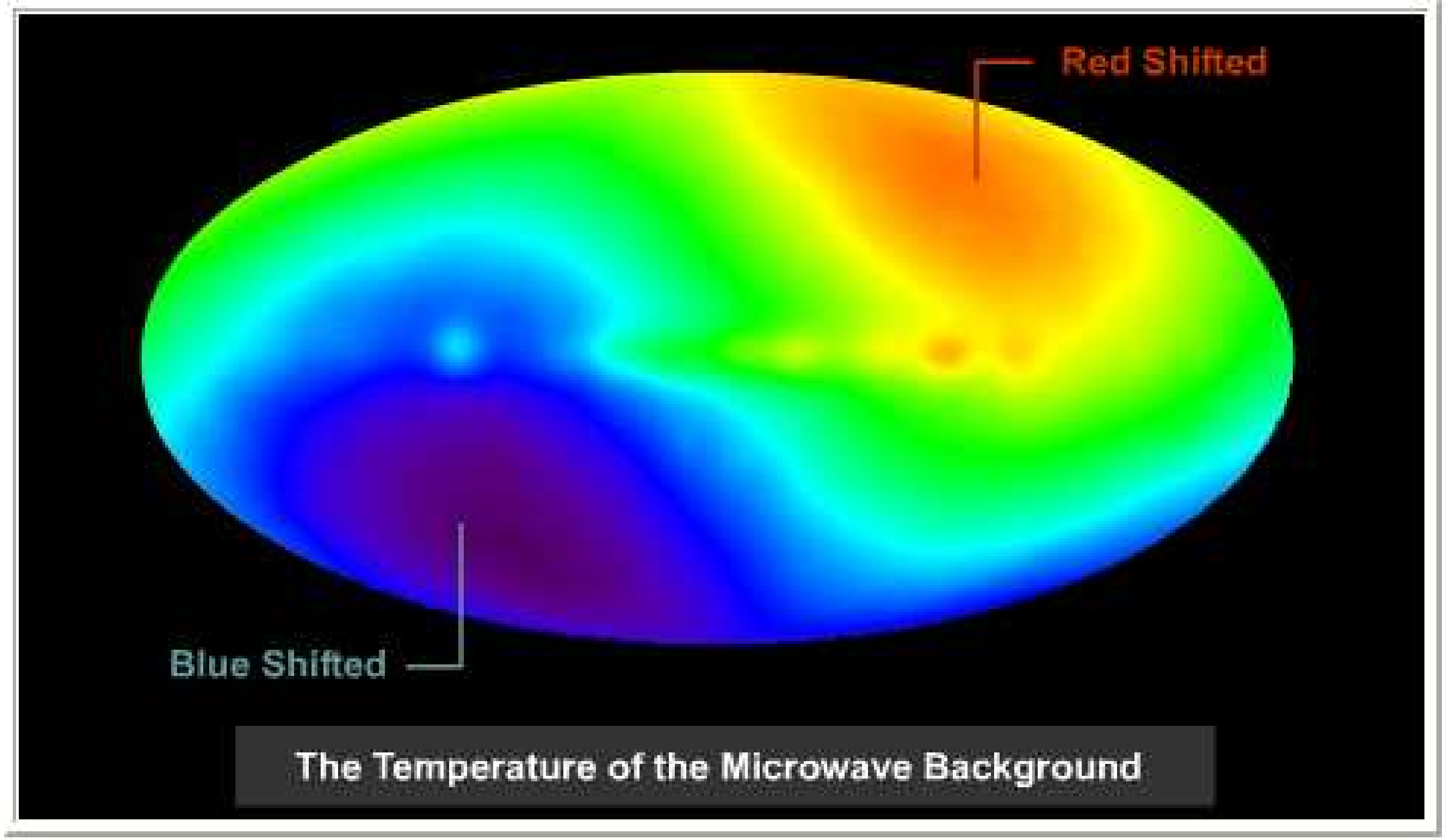


http://lambda.gsfc.nasa.gov/product/cobe/dmr_image.cfm

Zmiany temperatury (± 27 μK) promieniowania reliktowego zaobserwowane przez satelitę COBE. Rozmiary kątowe fluktuacji są rzędu kilku do kilkunastu stopni.

Promieniowanie reliktowe tła (±3 mK)

http://csep10.phys.utk.edu/astr162/lect/cosmology/cbr.html



Istnieje układ uprzywilejowany, w którym promieniowanie tła jest izotropowe.

Ziemia porusza się względem tego układu z prędkością ok. **400 km/s**

G. F. Smoot, M. V. Gorenstein, R. A. Muller, Phys. Rev. Letters, 39, 898 (1977).

Beginning the new aether drift experiment

So now here was a project that had a guaranteed signal of well-defined angular dependence, and amplitude. This made it a good candidate to propose to colleagues, funding agencies, etc. One problem to overcome was **the strong prejudice of good scientists** who learned the lesson of the Michelson and Morley experiment and special relativity that there were **no preferred frames of reference.**

REVIEWS OF MODERN PHYSICS, VOLUME 79, OCTOBER–DECEMBER 2007

Nobel Lecture: Cosmic microwave background radiation anisotropies: Their discovery and utilization*

George F. Smoot

Lawrence Berkeley National Laboratory, Space Sciences Laboratory, Department of Physics, University of California, Berkeley, California 94720, USA

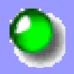
(Published 2 November 2007)

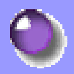
DOI: 10.1103/RevModPhys.79.1349

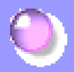
The indication of the above image is that the **local group of galaxies**, to which the Earth belongs, is moving at **about 600 km/s** with respect to the **background radiation**.

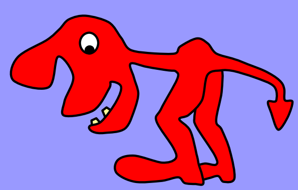
„It is **not known** why the Earth is moving with such a high velocity relative to the background radiation."

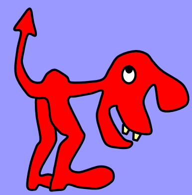
Elementary particles (I) : quarks

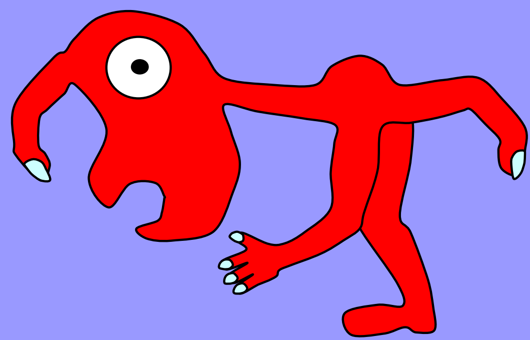
 = atom

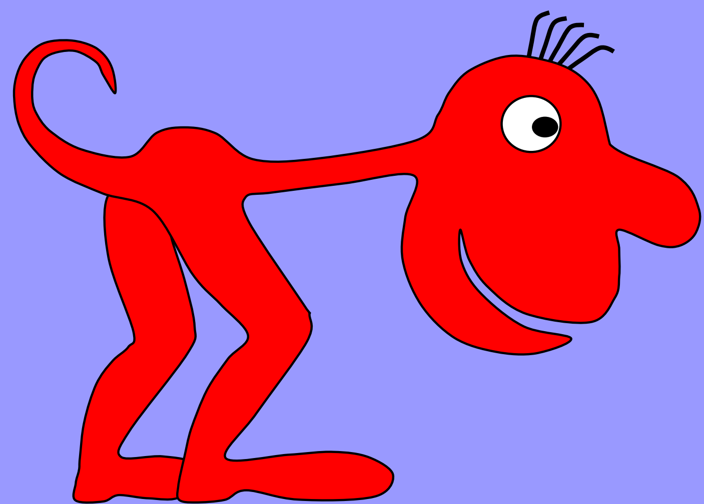
 = electron

 = quark







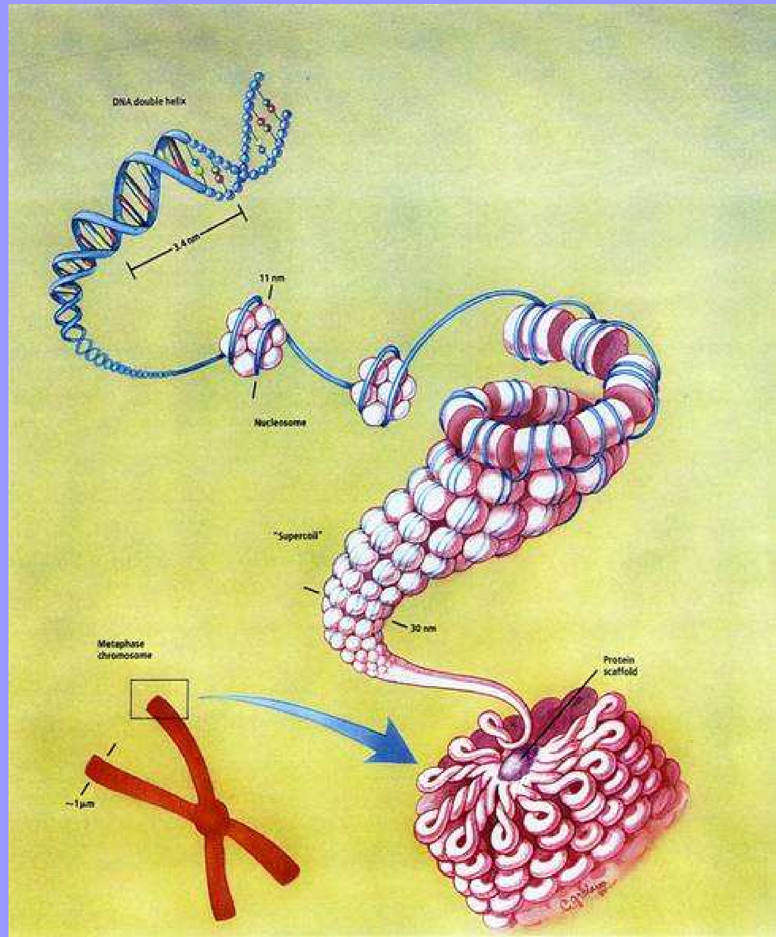


Elementary particles (I) : quarks

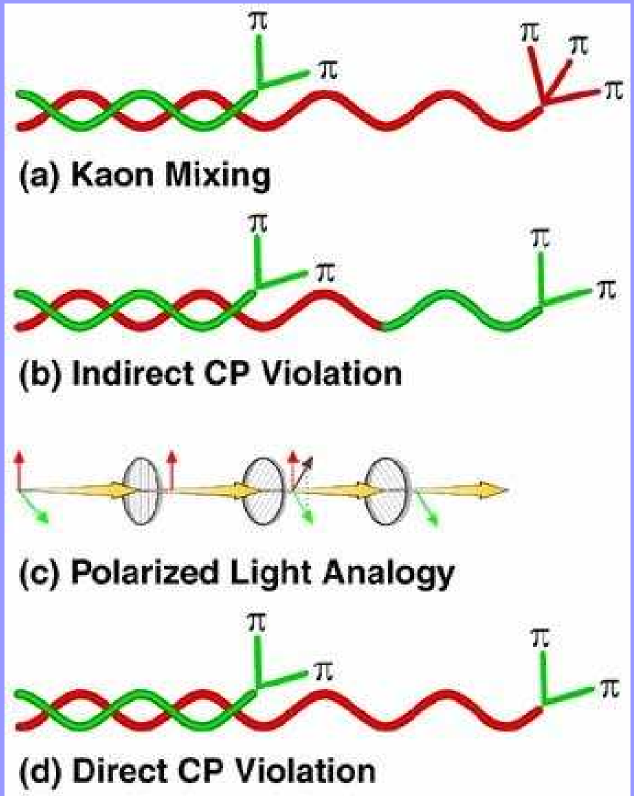
LEPTONS SPIN = 1/2			QUARKS SPIN = 1/2		
FLAVOR	MASS GeV/c^2	ELECTRIC CHARGE	FLAVOR	MASS GeV/c^2	ELECTRIC CHARGE
ν_e	$< 7x10^{-8}$	0	u	≈0.003	2/3
e^-	0.000511	-1	d	≈0.006	-1/3
ν_μ	< 0.0003	0	c	1.5	2/3
μ^-	0.106	-1	s	≈0.1	-1/3
ν_τ	< 0.03	0	t	170	2/3
τ^-	1.7771	-1	b	4.7	-1/3

Masses of light quarks are known with almost 50% error bar.
These best data are following : $1/2(m_u+m_d)=4.2$ MeV/c²; $1.5<m_u<5$ MeV; $5<m_d<9$ MeV/c²
and for *strange* quark $m_s=0.105\pm0.033$ GeV/c² [Manohor 2002]
Quarks are, after all, quite light particles: the *u* quark is only six times heavier than electron.

Elementary particles (II): CPT symmetry



Elementary particles (II): CPT symmetry



The decay of K_L into two pions can indicate the *CP* violation, but not directly – the K_L kaon could have converted itself into the K_S type just before the decay. The probability for this process, observed in 1964, is 2×10^{-3}.

If we are sure that this is the K_L kaon which decays into two pions, we get a direct proof for the *CP* symmetry violation. The share of the direct *CP* violation in all three-pion decays of K_L is also 2×10^{-3}.

Elementary particles (II): CPT symmetry

17 December 1998

PHYSICS LETTERS B

ELSEVIER

Physics Letters B 444 (1998) 52–60

A determination of the CPT violation parameter Re(δ) from the semileptonic decay of strangeness-tagged neutral kaons

CPLEAR Collaboration

A. Angelopoulos [a], A. Apostolakis [a], E. Aslanides [k], G. Backenstoss [b], P. Bargassa [m],

We have improved by two orders of magnitude the limit currently available for the CPT violation parameter Re(δ). To this purpose we have analyzed the full sample of neutral-kaon decays to $e\pi\nu$ recorded in the CPLEAR experiment, where the strangeness of the neutral kaons was tagged at production and decay time. An appropriate function of the measured decay rates, including information from the analysis of $\pi^+\pi^-$ decay channel, gives directly Re(δ). The result Re(δ) = (3.0 $\pm 3.3_{stat} \pm 0.6_{syst}) \times 10^{-4}$ is compatible with zero. Values for the parameters Im(δ), Re(x_-) and Im(x_+) were also obtained.

PHYSICS LETTERS B

First direct observation of time-reversal non-invariance in the neutral-kaon system

CPLEAR Collaboration

We report on the first observation of time-reversal symmetry violation through a comparison of the probabilities of $\overline{K}^0$ transforming into K^0 and K^0 into $\overline{K}^0$ as a function of the neutral-kaon eigentime t. The comparison is based on the analysis of the neutral-kaon semileptonic decays recorded in the CPLEAR experiment. There, the strangeness of the neutral kaon at time $t = 0$ was tagged by the kaon charge in the reaction $p\bar{p} \to K^{\pm}\pi^{\mp}K^0(\overline{K}^0)$ at rest, whereas the strangeness of the kaon at the decay time $t = \tau$ was tagged by the lepton charge in the final state. An average decay-rate asymmetry

$$\left\langle \frac{R(\overline{K}^0_{t=0} \to e^+\pi^-\nu_{t=\tau}) - R(K^0_{t=0} \to e^-\pi^+\bar{\nu}_{t=\tau})}{R(\overline{K}^0_{t=0} \to e^+\pi^-\nu_{t=\tau}) + R(K^0_{t=0} \to e^-\pi^+\bar{\nu}_{t=\tau})} \right\rangle = (6.6 \pm 1.3_{stat} \pm 1.0_{syst}) \times 10^{-3}$$

was measured over the interval $1\,\tau_S < \tau < 20\,\tau_S$, thus leading to evidence for time-reversal non-invariance.

Elementary particles (III): neutrino mixing

LEPTONS SPIN = 1/2			QUARKS SPIN = 1/2		
FLAVOR	MASS GeV/c^2	ELECTRIC CHARGE	FLAVOR	MASS GeV/c^2	ELECTRIC CHARGE
ν_e	$< 7x10^{-8}$	0	u	≈0.003	2/3
e^-	0.000511	-1	d	≈0.006	-1/3
ν_μ	< 0.0003	0	c	1.5	2/3
μ^-	0.106	-1	s	≈0.1	-1/3
ν_τ	< 0.03	0	t	170	2/3
τ^-	1.7771	-1	b	4.7	-1/3

In 2003, experiments from Kamioka laboratory gave another sensational notice [3]: antineutrinos from Japanese reactors dissapear in a mysterious way! The only explanation was that electronic neutrinos change their *flavour* in flight, becoming *muon* neutrinos. So they have mass!

The difference in mass between ν_e and ν_μ is very small but measurable: $\Delta m=6.9x10^{-5}$ eV^2

All this comes as a surprise!

Beyond Standard Model

There are several areas where "Beyond the Standard Model" physics focuses.
- The hierarchy problem
- The missing matter problem (dark matter and energy)
- The cosmological constant problem
- The strong CP problem

In addition to these subjects, there are also attempts at relating different phenomena and parameters to a more fundamental theory. A partial classification of these attempts are gauge coupling unification
- A theory of quark masses and mixings
- A theory of neutrino masses and mixings

http://en.wikipedia.org/wiki/Beyond_the_Standard_Model

Supersymmetry (?)

In particle physics, **supersymmetry** (often abbreviated **SUSY**) is a symmetry that relates elementary particles of one spin to another particle that differs by half a unit of spin and are known as superpartners. In other words, in a supersymmetric theory, for every type of boson there exists a corresponding type of fermion, and vice-versa.

As of 2008 there is no direct evidence that supersymmetry is a symmetry of nature. Since superpartners of the particles of the Standard Model have not been observed, supersymmetry, if it exists, must be a broken symmetry allowing the 'sparticles' to be heavy.

Neutrino mass

- **Double beta decay, Majorana neutrinos, and neutrino mass**
- Frank T. Avignone, III
- Department of Physics and Astronomy, University of South Carolina, Columbia, South Carolina 29208, USA
- Steven R. Elliott
- Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA
- Jonathan Engel
- Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27599-3255, USA
- (Published 9 April 2008)
- The theoretical and experimental issues relevant to neutrinoless double beta decay are reviewed. The impact that a direct observation of this exotic process would have on elementary particle physics, nuclear physics, astrophysics, and cosmology is profound. Now that neutrinos are known to have mass and experiments are becoming more sensitive, even the nonobservation of neutrinoless double beta decay will be useful. If the process is actually observed, we will immediately learn much about the neutrino. The status and discovery potential of proposed experiments are reviewed in this context, with significant emphasis on proposals favored by recent panel reviews. The importance of and challenges in the calculation of nuclear matrix elements that govern the decay are considered in detail. The increasing sensitivity of experiments and improvements in nuclear theory make the future exciting for this field at the interface of nuclear and particle physics.

String theory ?

Although string theory, like any other scientific theory, is falsifiable in principle, critics maintain that it is unfalsifiable for the foreseeable future, and **so should not be called science.**

The upper rungs of the particle-physics faculties at Princeton, Stanford, and elsewhere in the academy are today heavy with advocates of "string theory," a proposed explanation for the existence of the universe.
But string theory works only if you assume the existence of other dimensions—nine, 11, or 25 of them, depending on your flavor of string thinking—and there's not one shred of evidence other dimensions exist.

http://www.slate.com/id/2149598/

new ideas urgently needed!

Universe (V): General relativity

Einstein equations can be written in a beautifully simple form:

G = 8 π **T**.

The **G** term on the left side represents all the curvature of spacetime at a point, while the **T** term on the right represents the mass at a point, and its properties. This is the elegant part.

The complicated part comes when we realize that this formula is almost completely useless for doing actual calculations. To use it, we have to expand it into at least ten different equations, each with dozens of terms. It is possible to solve the equations with pencil and paper in very special situations—when most of the dozens of terms happen to be zero—or in situations with low speeds, small masses, and large distances—when most of the dozens of terms happen to be very small and *practically* zero.

In fact, when fully written out, the EFE are a system of 10 coupled, nonlinear, hyperbolic-elliptic partial differential equations.

http://www.black-holes.org/relativity6.html

Universe (part IV): geometry

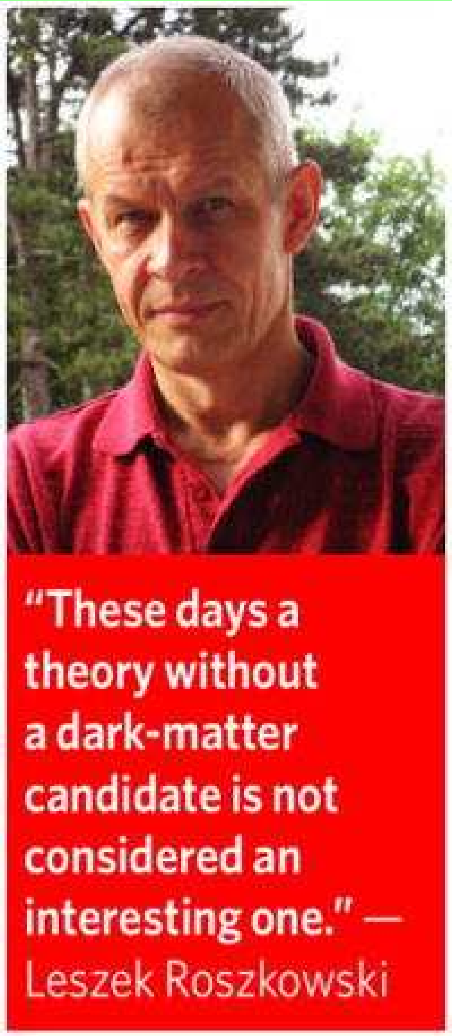
Dodecahedral space topology as an explanation for weak wide-angle temperature correlations in the cosmic microwave background

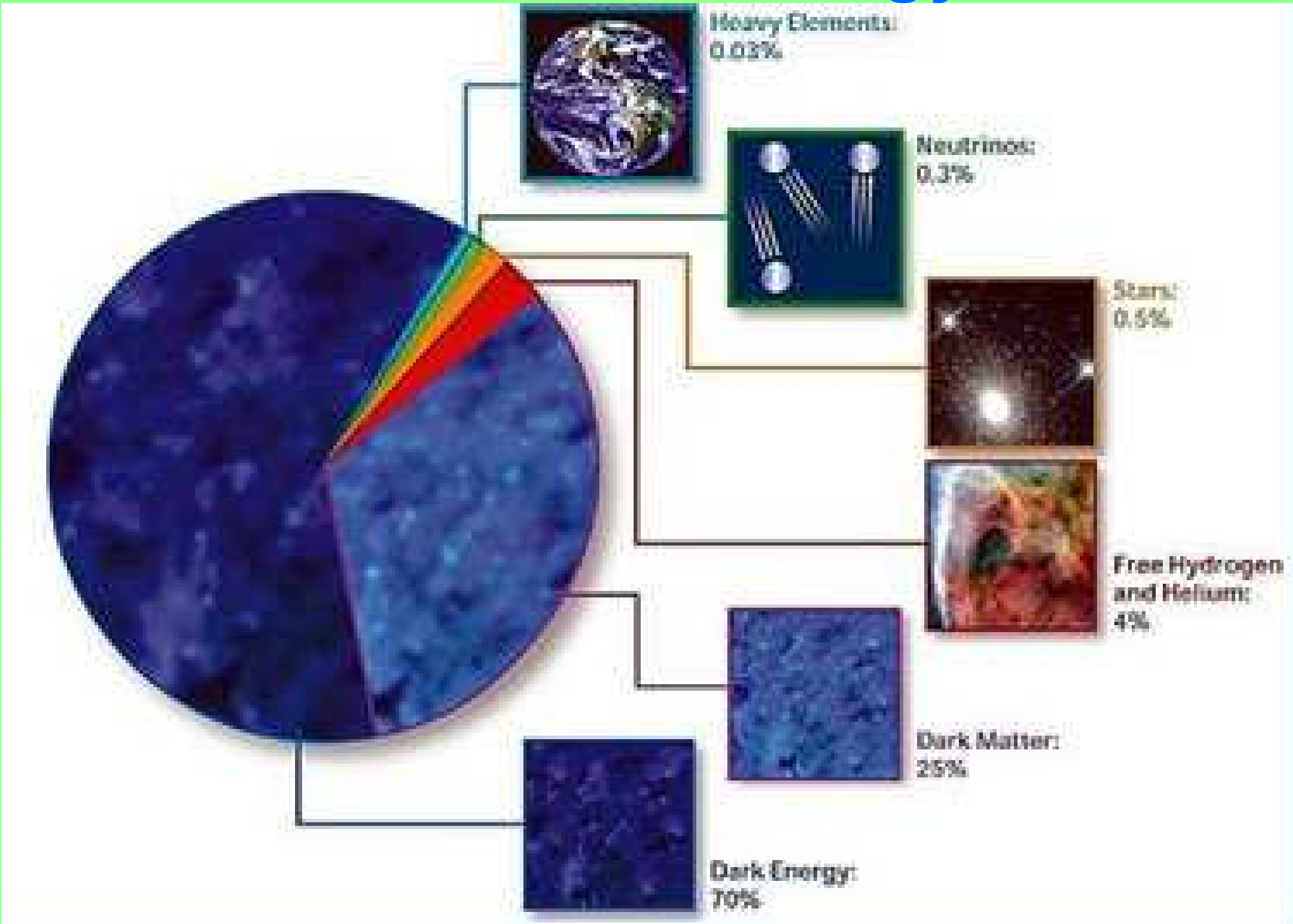
Jean-Pierre Luminet[1], Jeffrey R. Weeks[2], Alain Riazuelo[3], Roland Lehoucq[1,3] & Jean-Philippe Uzan[4]

Some scientist say that time-space is closed, and folded inside like the Swiss cheese. But recent observations show that it is flat, or better, cubic.

Moreover, the Universe accelerates its expansion and we do not know why!

Dark matter, dark energy…

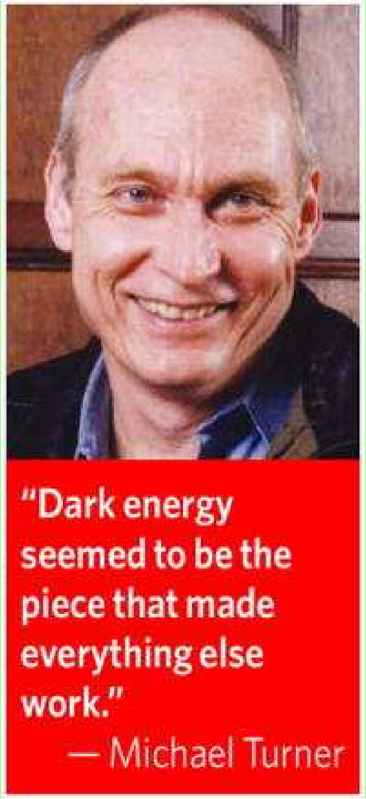


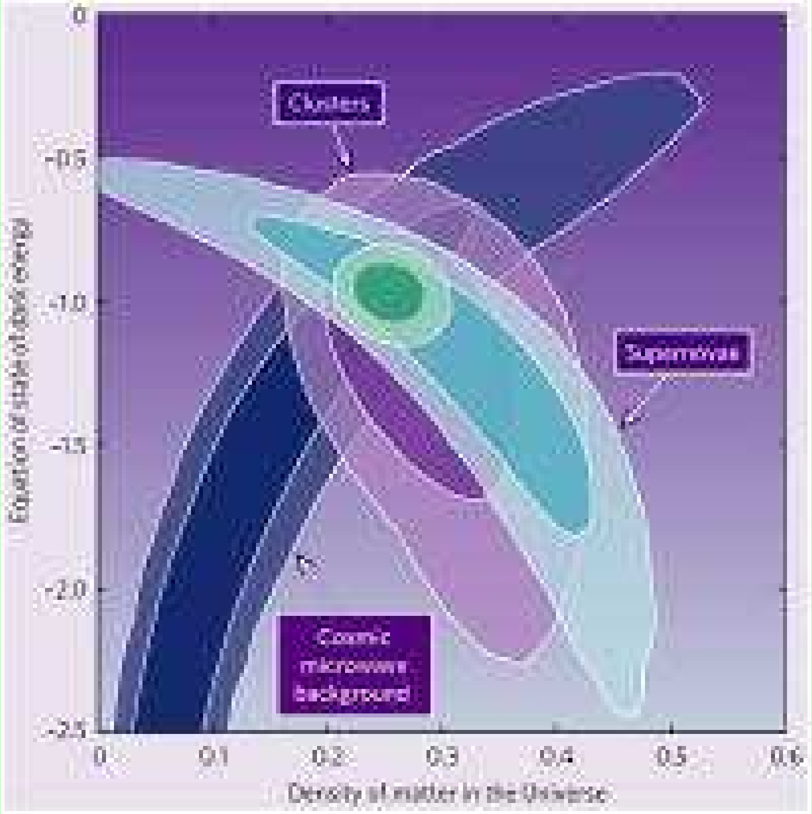


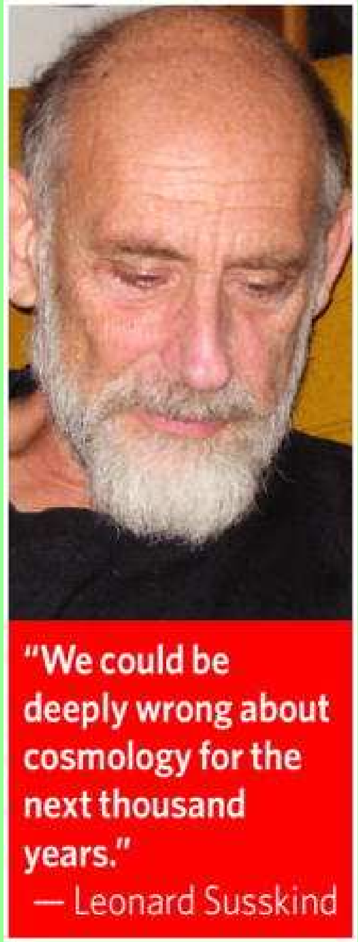
The universe is mostly composed of **dark energy** and **dark matter**, both of which are poorly understood at present. Only ≈4% of the universe is ordinary matter, a relatively small perturbation.

Dark energy = cosmology constant?

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$







Nature, Volume 448(7151), 19 July 2007, pp 245-248

Dark energy = cosmology constant?

But the form if this dependence is not known as a priori. It is of the form:

$ds^2 = g_{11}dx^2 + 2\, g_{11}\, g_{22}\, dx\, dy + g_{22}\, dy^2$

Then it is called a Riemannian metric. If it is possible to choose the coordinates so that this expression takes the form:

$ds^2 = dx^2 + dy^2$ (Pythagoras's theorem), then the continuum is Euclidean (a plane).

Einstein, 1929

or unkown geometry?

http://www.rain.org/~karpeles/einfrm.html

Fingers of God

Thanks!

Fingers of God - Wikipedia, the free encyclopedia - Mozilla

http://en.wikipedia.org/wiki/Fingers_of_God

"You've revolutionized research. Thank you." – Lieselot Whitbeck

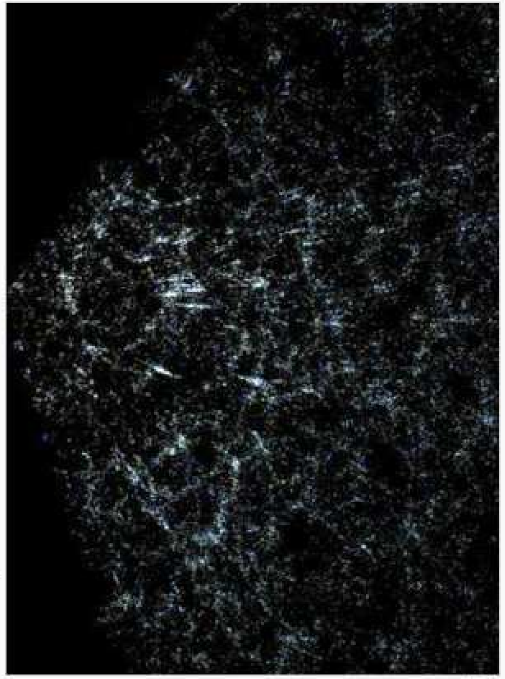
Fingers of God

From Wikipedia, the free encyclopedia

Fingers of God is an effect in observational cosmology that causes clusters of [illegible]alaxi[illegible] be elongated in redshift space, with an axis of elongation pointed toward the observer.[2] It is caused by a Doppler shift a[illegible]ciate[illegible] with the peculiar velocities of galaxies in a cluster. The large velocities that lead to this effect are associated with the gravit[illegible] the cluster by means of the virial theorem; they change the observed redshifts of the galaxies in the cluster. The d[illegible]iation from the Hubble's law relationship between distance and redshift is altered, and this leads to inaccurate distance measu[illegible]

The effect can be seen in the image to the right. The Earth is at the ape[illegible] of the survey, on the left edge of the image; the individual "fingers", each one actually a cluster of galaxies all at the [illegible]me distance, point towards it. At greater distances the fractional effect decreases as the peculiar velocities remain roughly con[illegible]ant, [illegible]d the actual redshift increases. In a plot of "true" distance, instead of the displayed distance in the figure calculated from [illegible]e applic[illegible]ion of Hubble's law, these fingers would be collapsed back to small spheres at the true cluster sites.

A closely related effect is the **Kaiser effect**[illegible] caused, again, by peculiar velocities lending an additional Doppler shift to the cosmological redshift, and it leads also t[illegible] ki[illegible] [illegible]ne-of-sight distortion. It is not caused, however, by the random internal motions of the cluster predicted by the virial t[illegible]eore[illegible]; rather, it arises from coherent motions as the galaxies fall inwards towards the cluster center as the cluster assembles. [illegible]nding on the particular dynamics of the situation, the Kaiser effect usually leads not to an elongation, but [illegible]n ap[illegible] flattening ("pancakes of God"), of the structure. It is a much smaller effect than the fingers of God, and can be distinguis[illegible] by the [illegible]ct that it occurs on larger scales.[4]



Fingers of God in a portion of the Sloan Digital Sky Survey; image from the Cosmus Open Source Science Outreach project.[1]

Reference[illegible] [edit]

1. ^ ht[illegible]/astro[illegible]hicago.edu/cosmus/
2. ^ Jackson, J.C. ([illegible]72). "A critique of Rees's theory of primordial gravitational radiation". *Monthly Notices of the Royal Astronomical Society*, 156, 1P-6P.
3. ^ Kaiser, N. (1987). "Clustering in real space and in redshift space". *Monthly Notices of the Royal Astronomical Society*, 227, 1-21.
4. ^ http://astron.berkeley.edu/~louis/astro228/redshift.html

Categories: Observational astronomy | Physical cosmology

Hogan, Jenny, Nature: Volume 448(7151), 19 July 2007, pp 240-245, "Unseen Universe"