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TOWARDS A COMPLETE THEORY OF INFORMATION. BEYOND THE SHANNON'S COMMUNICATION THEORY

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Beyond the statistical (and numerical) aspects of information, there are several other important aspects that are not at all examined by the Shannon's theory. Starting from the proposals of Werner Gitt, this work examines a 6 levels Information concept, which involves also a 4^{th} (in the Complexity order) level intended to the quality check of the transmitted information (by means of the identification and elimination of all ambiguities and possible misunderstanding). Following a very short examination of the basic notions of the Shannon's statistical information theory [of the definition of the Shannon's information amount (entropy), inclusively], the complex physical process of the continuous (Bremsstrahlung) X- radiation was chosen to study and exemplify the effective content of the successive steps of the Information concept.

Key words: Shannon's Information Theory, Syntax, Semantics, Information Accuracy, Pragmatics, Apobetics

1. Introduction

Given being that the applications of Shannon's information theory [1]-[5] are well known, we will examine now mainly the criticisms of this theory and the possibilities to achieve some suitable completions.

So, the German cyberneticist Bernhard Hassenstein criticized the Shannon's information theory in the following words: "It would have been better to devise an artificial term, rather than taking a common word and giving it a completely new meaning" [6].

According to the information specialist Werner Gitt "no science, apart from the communication technology, should limit itself to just the Claude Shannon's statistical level of information" [7].

Several authors repeatedly pointed out that Shannon's definition of information encompasses only a very minor aspect of information [8], p. 50. Even Warren Weaver – the Mathematics professor and main collaborator of Claude Shannon has written [3]: "Two messages, one of which is heavily loaded with meaning and the other which is pure nonsense, can be exactly equivalent … as regards information".

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Similarly, the German information scientist Karl Steinbuch has found [9]: "The classical (Shannon's) theory of information can be compared to the statement that one-kilogram of gold has the same value as one kilogram of sand".

We have to mention also that many authors erroneously elevate Shannon's information theory to the syntactic level, as in the frame of Ernst von Weiszäcker's finding [10]: "The reason for the 'uselessness' of Shannon's theory in the different sciences is frankly that no science can limit itself to its syntactic level". According to the German biologist G. Osche [11], the Shannon's theory is unsuitable from a biological point of view: "In cybernetics, the general information concept quantitatively expresses the information content of a given set of symbols by employing the probability distribution of all possible permutations of the symbols. But the information content of biological systems (genetic information) is concerned with its value and its functional meaning and thus with the semantic aspect of information, with its quality".

2. Structure of the Information Concept

2.1.

Accepting the opinions of the work [7] (page 60, figure 12) and completing them with a 6th Information level, intended to the check of the Information accuracy (identification and elimination of ambiguities and possible misunderstanding), we propose the structural scheme of the Information concept reported below by Figure 1.

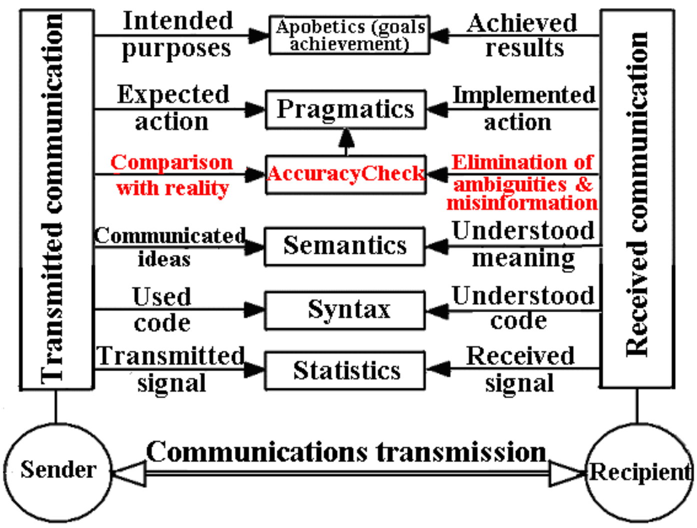

Fig. 1. The 6 Information Levels (besides the 5 Information levels indicated by work [7], as this paper considers as compulsory level that intended to the check of the Information accuracy - the 4th level in this scheme; there are ensured so good results of the received information applications).

3. The basic notions of the statistical (Shannon's) information level

Consider the statistical set $\sigma_1, \sigma_2, ...\sigma_n$ of the possible discrete states (or processes) of a certain studied physical system, and let $p_1, p_2, ...p_n$ be the probabilities of achievement of each of these states (processes). Of course, if this statistical set is complete, then: $\sum_{i=1}^{n} p_i = 1$. The usual (Shannon-Khinchin [1]-[5]) definition of the nondetermination (uncertainty) degree $H(p_1, p_2, ...p_n)$ associated to this statistical set is given by the requirements of:

a) *symmetry:* $H(p_1, p_2, ...p_n) = H(p_2, p_1, ...p_n)$, etc. (3.1)

b) *obtainment of the maximum value of the non-determination (uncertainty) degree* for:

$$p_1 = p_2 = ...p_n = \frac{1}{n}, \tag{3.2}$$

c) *invariance of the uncertainty degree at the addition of an impossible event* ($p_{n+1} = 0$): $H(p_1, p_2, ...p_n, 0) = H(p_1, p_2, ...p_n)$, (3.3)

d) *continuity of the function* $H(p_1, p_2, ...p_n)$ *relative to the values of the probabilities* $p_1, p_2, ...p_n$,

e) *linearity of the non-determination (uncertainty) degree,* expressed by means of the relation:

$$H(C, C') = H(C) + \sum_{i=1}^{n} p_i \cdot H(C'|\sigma_i), \tag{3.4}$$

where *H(C, C')* is the uncertainty degree corresponding to the Cartesian product of the sets *C, C'* of the states σ_i and σ'_j, correspondingly, while $H(C'|\sigma_i)$ is the uncertainty degree corresponding to the set *C'*, in the conditions of the state σ_i achievement.

One derives rather easy (see e.g. [12], pp. 210-212) that the uncertainty function fulfilling the above indicated conditions (3.1) – (3.4) is given by the expression:

$$H(p_1, p_2, ...p_n) = -a \cdot \sum_{i=1}^{n} p_i \cdot \log_b p_i, \tag{3.5}$$

where *a* and *b* are almost arbitrary constants, that satisfy the conditions: $a > 0$ and $b > 1$.

From the expression (3.5), one finds that the uncertainty function $H(p_1, p_2, ...p_n)$ is the theoretical average of the so-called *information entropy*, defined by the relation:

$$S_i = -a \cdot \log_b p_i. \tag{3.6}$$

Similarly, for a continuous distribution, the information entropy will be given by the expression:

$$S = -\,a \cdot \log_b \wp + \text{constant}, \tag{3.7}$$

where $\wp$ is the probability density corresponding to the considered continuous distribution.

The basic information entropy (amount) unit – the famous *bit* (from the complete denomination *b̲inary i̲nformation unit̲*) corresponds to the values $a = 1$ and $b = 2$. Given being that in December 1900, the illustrious German scientist Ludwig Boltzmann has found that the value $a = k_B \equiv \frac{R}{N_A}$ unites the Clausius' thermodynamic entropy (see e.g. [15], p. 276) with the natural ($b = e$ = Euler's number*)* logarithm of the probability density of the physical state:

$$S = -\,k_B \cdot \log_b \wp + \text{constant}, \tag{3.8}$$

one finds that both for the:

a) quantity name: *entropy*, as well as for: b) its statistical expression,

the statistical Physics has a priority of almost 50 years relative to the Shannon's statistical information theory.

4. Examples concerning the Information Concept for the Particular Case of the Continuous (bremsstrahlung) X-radiation

4.1. The Syntactic level

According to [8], p. 61 "Syntax is meant to include all structural properties of the process setting up information".

a) <u>Experimental Part</u>

In order to leave the exclusively statistical (quantitative) description of the information by means of Shannon's theory, it is useful to consider the experimental part of any usual information source, of the Continuous (bremsstrahlung) X-radiation, particularly (see figures 4.1, 4.2 and 4.3; see also [24], pp. 92-95).

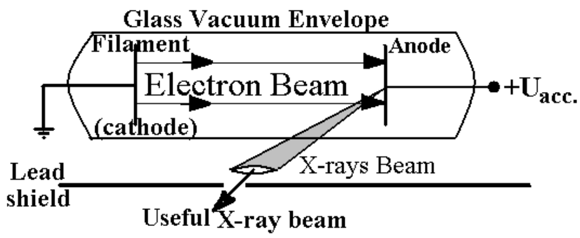

Fig. 4.1. A simplified Schema of a typical X-ray vacuum tube.

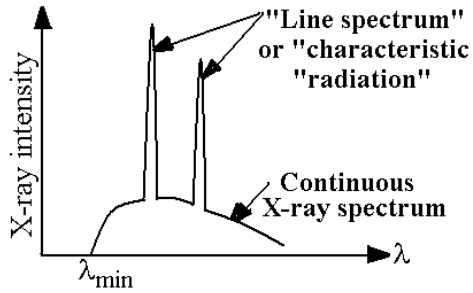

Fig. 4.2. Low-resolution X-ray spectrum of molybdenum. [23]

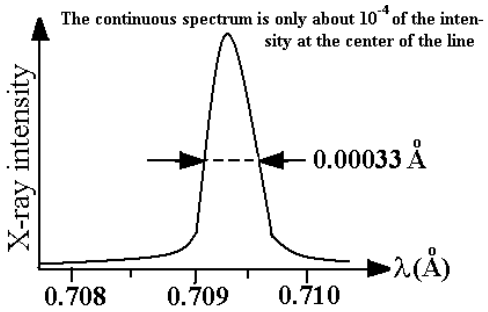

Fig. 4.3. One of the *Mo* X-rays lines observed with a high-resolution spectrometer.

b) The Physical Dimension – specific feature of the Syntax of the description of complex systems in nature sciences

It is well known that the Syntaxes of any language (modern [16] or antique [17]) distinguish the subject (examined system), the verb (action), the adverb (the conditions in frame of which the considered systems operate), etc. This corresponds in Physics to distinguish clearly the cause (e.g. the force), the effect (e.g. the acceleration), the system inertia parameter (e.g. its mass), etc.

In practice, the trend – for the extremely Complex systems – to simplify the expressions of the corresponding relations could lead sometimes to considerable difficulties. As an example, the elaboration [18] by the well-known British specialist in Mathematical Physics – Douglas Hartree (1897-1958) of an dimensionless (atomic) system of physical units contributed both to the:

a) elaboration of certain programming languages (around 1950, as the Fortran one, its compiler being already in use in 1957), which achieved (as the Fortran language) the descriptions of physical relations by means of some numerical computing instructions, and to the:

b) formulation of some Physics works (studying certain processes of high complexity, as the continuous X-ray spectra) by specific highly simplified (in the frame of Hartree's dimensionless system) relations, which unfortunately didn't allow to distinguish the nature of the described physical quantities.

For example, all quantitative expressions of the classical works concerning the continuous (Bremsstrahlung) X-radiation [19], [20] are dimensionless, hence they are out of Syntax, given being in nature sciences the Syntax requires specific physical dimensions [*Q*] for any quantity *Q* (e.g. [force] = $M \cdot L \cdot T^{-2}$, [acceleration] = $L \cdot T^{-2}$, [speed] = $L \cdot T^{-1}$, etc, where *M, L, T, ...* are the physical dimensions of the mass, length, time, etc.), to distinguish easily and quickly among the terms of any physical expression.

For this reason, the appendices A1 and A2 of the work [21] was intended (pp. 78-81) to the translation of all dimensionless expressions of the classical works dedicated to the continuous (Bremsstrahlung) X-rays in an units systems with physical dimensions, namely in the classical system CGS.

4.2.The Semantics level

According to [8], p. 71, the Semantic level refers to the understanding of the exact meaning of the different sentences, or of the relations from the Nature Sciences.

The understanding of the complex physical processes begins from their elementary (microscopic) level.

So, for the continuous (bremsstrahlung) X-radiation, the corresponding microscopic process consists in the collision of an electron of kinetic energy E_o and linear momentum $\bar{p}_o$ with an atomic ion (or nucleus), emitting a photon of linear momentum $\bar{k}$ (energy $h\nu = k \cdot c$) and polarization direction $\bar{j}$ (perpendicular on $\bar{k}$), afterwards the electron emerging with the linear momentum $\bar{p}$ and the energy *E*.

The basic tools for the understanding of this elementary (microscopic) process consist in the corresponding Feynman-Dyson diagrams (see fig. 4.4) and the associated vector diagrams (see e.g. fig. 4.5).

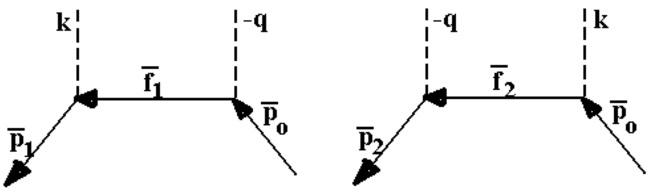

Fig. 4.4.

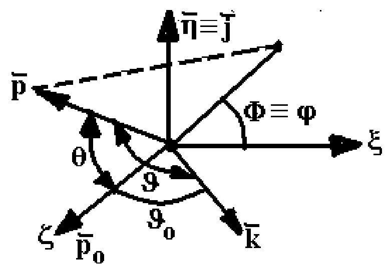

Fig. 4.5.

The left side diagram corresponds to a previous interaction of the incoming electron with the atomic field, followed by the emission of a photon, while for the right side diagram the photon emission precedes the electron interaction with the atomic field.

The parameters $\bar{f}_1, \bar{f}_2$ correspond to the 4 dimensional linear moments associated to the internal electronic line of the first and of the second diagram, respectively, $\bar{q} = \bar{p}_o - \bar{p} - \bar{k}$ is the linear momentum given to the nucleus as a result of the process of the incoming electrons braking, while $-\bar{q}$ is the linear momentum "absorbed" from the atomic potential.

. . . .

Taking into account the huge number of sub-fields corresponding to the Complex systems evolutions, the thorough (with the examination of all particular conditions) derivation of their main relations is absolutely necessary. That is why the work [21] dedicated (from a total of 15 appendices) not less than 13 ones (the other 2 being dedicated to some Syntax matters) to the examination of the basic relations used in the frame of the continuous (bremsstrahlung) X-rays quantum theory:

Appendix 3: Derivation of the polarization degree P of X-rays,

Appendix 4: Calculus of the limits of P for $p/p_o \to 0$ and $p/p_o \to 1$,

Appendix 5: Derivation of the expression

$q^2 \sin^2 \chi = p_o^2 \sin^2 \vartheta_o + p^2 \sin^2 \vartheta - 2p \cdot p_o \sin\vartheta \sin\vartheta_o \cos\varphi$, where: $\bar{q} = \bar{p}_o - \bar{p}$ and ϑ, ϑ_o are the angles between the linear moments $\bar{k}, \bar{p}$ and $\bar{k}, \bar{p}_o$, respectively, while φ is the angle between the planes $\bar{k}, \bar{p}$ and $\bar{k}, \bar{p}_o$,

Appendix 6: Derivation of the expression of the angular distribution of the continuous (Bremsstrahlung) X-radiation,

Appendix 7: Derivation of the expression of the angular distribution of the diffused electrons,

Appendix 8: Derivation of the expression of the integrated cross-section, neglecting the screening,

Appendix 9: Derivation of the expression of the integrated cross-section, taking into account the screening,

Appendix 10: Calculus of the average energy loss due to the continuous (bremsstrahlung) X-radiation,

Appendix 11: Retardation effect on the angular distribution of the continuous (bremsstrahlung) X-radiation,

Appendix 12: Calculus of the expression of q^2 (where $\bar{q} = \bar{p}_o - \bar{p}$),

Appendix 13: Calculus of the expression of q^2 in terms of $\xi = \angle(\bar{p}, \bar{p}_o - \bar{k})$),

Appendix 14: Calculus of the Bethe-Heitler [19], [20] parameter Γ in the case of $\mu \ll p \ll p_o$,

Appendix 15: Calculus – in the case $\mu \ll p \ll p_o$ - of the differential cross-section $\sigma(\nu, \xi, \vartheta_o) \cdot d\nu \cdot d\xi \cdot d\vartheta_o$.

4.3.The Accuracy level

The matter referring to the possibilities to improve the accuracy of the information concerning certain states or processes of some complex systems is examined in our work [25]. For this reason, we will focus here on the possibilities to identify and avoid the (i) ambiguities (see also [26], [27]), (ii) misinformation.

a) No ambiguities means: Accurately known probability densities of the individual values of the studied parameters

While the value of the unknown of a mathematical problem rightly formulated is obtained **exactly** by means of this problem solution, the most probable individual value (named also "the true value", or the "mathematical hope") t_p of a certain physical parameter *p* **cannot be never obtained exactly**!

In steady states, the function of the probability density has to be known accurately (see fig. 4.6), even if the individual values of the studied parameters have random values.

b) Typical elementary object

While in Mathematics the typical elementary object (the problem unknown) is a number or an uniquely defined segment, in the Nature Sciences this elementary object is a physical parameter $\wp$, described by a certain probability density *P(p)* of the individual values (see fig. 4.7).

For this reason, <u>the definition of the true information amount</u> would correspond to the superposition area of the functions of the probability density normalized to 1, and corresponding to the measurements of the studied physical parameter, respectively.

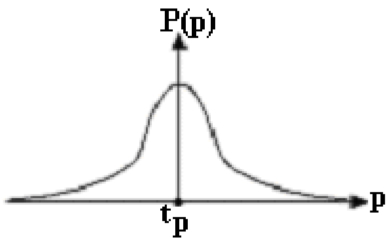

Fig. 4.6. Function of the probability density of the individual values of a physical parameter.

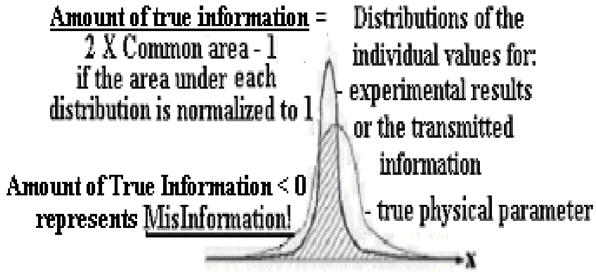

Fig. 4.7. Definition of the true amount of information obtained by means of measurements.

4.4.The Pragmatics level

Between the 2 types of X-rays spectra (continuous and of lines; see fig. 4.2), the continuous (Bremsstrahlung) type is that suitable for the evaluation of the periods of a crystalline lattice. In this aim, there are necessary the basic theoretical relations, as well as some procedures of selection of the convenient X-radiation wavelength.

a) Derivation of Laue's equations and of the Bragg and Bragg law

It is well-known that the diffraction maxims corresponding to a parallel electromagnetic beam of wavelength λ, incident along the unit vector $\overline{1}_i$ upon an 1D-diffraction grating of vector period $\overline{d}$, have the directions $\overline{1}_d$ so that:

$$d(\cos\alpha - \cos\alpha_0) = \overline{d}(\overline{1}_d - \overline{1}_i) = m\lambda,$$

where *m* is *the diffraction order* (a positive, or negative integer).

Consider now the diffraction of a parallel electromagnetic beam (of wavelength λ), incident along the direction $\overline{1}_i$ upon a 3D-lattice (a crystalline lattice, particularly). Let be $\overline{a}, \overline{b}$ and $\overline{c}$ the (non-coplanar) basic vectors (periods) of the considered 3D-lattice; the intensity of the diffracted beam along the direction $\overline{1}_d$ will be maximum if (concomitantly):

$$\overline{a}(\overline{1}_d - \overline{1}_i) = m'\lambda, \quad \overline{b}(\overline{1}_d - \overline{1}_i) = n'\lambda, \quad \overline{c}(\overline{1}_d - \overline{1}_i) = p'\lambda, \tag{4.5.1}$$

where *m'*, *n'* and *p'* are integer numbers, called *the Laue numbers* (the above conditions are called *the Laue's equations*). Let be *D = l.d.(m', n', p')* the largest divider of integers *m'*, *n'*, *p'* and $m = \frac{m'}{D}$, $n = \frac{n'}{D}$ and $p = \frac{p'}{D}$. Starting from the Laue's equations, one finds that:

$$\frac{\overline{a}}{m}(\overline{1}_d - \overline{1}_i) = \frac{\overline{b}}{n}(\overline{1}_d - \overline{1}_i) = \frac{\overline{c}}{p}(\overline{1}_d - \overline{1}_i) = D\lambda, \tag{4.5.2}$$

and:
$$\left(\frac{\overline{a}}{m} - \frac{\overline{b}}{n}\right)(\overline{1}_d - \overline{1}_i) = \left(\frac{\overline{b}}{n} - \frac{\overline{c}}{p}\right)(\overline{1}_d - \overline{1}_i) = \left(\frac{\overline{c}}{p} - \frac{\overline{a}}{m}\right)(\overline{1}_d - \overline{1}_i) = 0. \tag{4.5.3}$$

From relation (4.5.3), one finds that $\overline{1}_d - \overline{1}_i$ is perpendicular on the plane (of *Miller indices m, n and p*) defined by the vectors $\frac{\overline{a}}{m} - \frac{\overline{b}}{n}$, $\frac{\overline{b}}{n} - \frac{\overline{c}}{p}$ and $\frac{\overline{c}}{p} - \frac{\overline{a}}{m}$, build up starting from the same lattice node O (see Fig. 4.8).

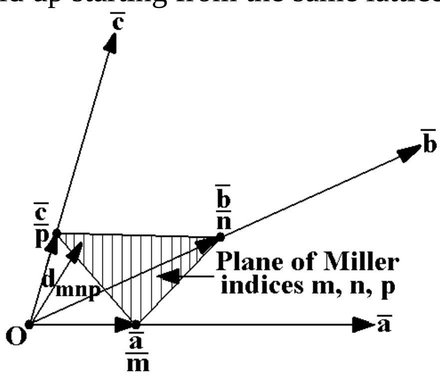

Fig. 4.8.

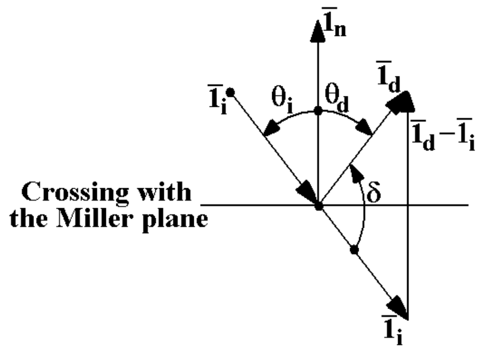

Fig. 4.9.

Suppose now that the sheet coincides with the plane of the unit vectors $\bar{1}_i, \bar{1}_d$, and that the horizontal is the crossing of the plane of Miller indices *m, n, p* with that of the vectors $\bar{1}_i$ and $\bar{1}_d$ (fig. 7.73), the unit vector of the normal on the Miller plane (*m, n, p*) being denoted by $\bar{1}_n$. Because: $(\bar{1}_d - \bar{1}_i) \times \bar{1}_n = 0$, one obtains:

$$\sin\theta_i = \left|\bar{1}_i \times \bar{1}_n\right| = \left|\bar{1}_d \times \bar{1}_n\right| = \sin\theta_d , \quad \text{and:} \quad \left|\bar{1}_d - \bar{1}_i\right| = 2\sin\frac{\delta}{2}, \tag{4.5.4}$$

where δ is the deviation angle of the diffracted beam relative to the incident one. From relations (4.5.2) and (4.5.4b), one obtains:

$$\frac{\bar{a}}{m}\cdot\bar{1}_n\left|\bar{1}_d - \bar{1}_i\right| = 2d_{mnp}\sin\frac{\delta_{m'n'p'}}{2} = D\lambda = l.d.(m', n', p')\cdot\lambda , \tag{4.5.5}$$

where d_{mnp} is the inter-planar distance between the Miller planes (*m, n, p*). The relation (4.5.5) is named *the Bragg and Bragg law* (of the diffraction on 3D-lattices).

b) *The reciprocal lattice*

The calculations of the inter-planar distance d_{mnp}, of the change of the wave-vector: $\Delta\bar{k} = \frac{2\pi}{\lambda}(\bar{1}_d - \bar{1}_i)$ due to the diffraction on a 3D-lattice and others, can be simplified using the notion of *reciprocal lattice.*

Let be: $$\bar{a}' = \frac{2\pi}{V}(\bar{b}\times\bar{c}), \quad \bar{b}' = \frac{2\pi}{V}(\bar{c}\times\bar{a}), \quad \bar{c}' = \frac{2\pi}{V}(\bar{a}\times\bar{b}), \tag{4.5.6}$$

*the basic vectors of the reciprocal lattice***,** $V = \bar{a}\cdot(\bar{b}\times\bar{c}) = \bar{b}\cdot(\bar{c}\times\bar{a}) = \bar{c}\cdot(\bar{a}\times\bar{b})$ being the volume of the unit cell, and:

$$\bar{\rho}' = m'\bar{a}' + n'\bar{b}' + p'\bar{c}' = D(m\bar{a}' + n\bar{b}' + p\bar{c}') = D\cdot\bar{\rho} \tag{4.5.7}$$

- an arbitrary position vector inside the reciprocal lattice.

One finds that: $$\frac{\bar{a}}{m}\cdot\bar{\rho} = \frac{\bar{b}}{n}\cdot\bar{\rho} = \frac{\bar{c}}{p}\cdot\bar{\rho} = 2\pi , \tag{4.5.8}$$

therefore: $$\left(\frac{\bar{a}}{m} - \frac{\bar{b}}{n}\right)\bar{\rho} = \left(\frac{\bar{b}}{n} - \frac{\bar{c}}{p}\right)\bar{\rho} = \left(\frac{\bar{c}}{p} - \frac{\bar{a}}{m}\right)\bar{\rho} = 0 \ ; \tag{4.5.9}$$

it results that the position vector $\bar{\rho}$ is parallel to $\bar{1}_d - \bar{1}_i$ and perpendicular also on the Miller plane (*m, n, p*).

As an application, the inter-planar distance d_{mnp} can be expressed as:

$$d_{mnp} = \frac{\bar{a}}{m}\cdot\bar{1}_n = \frac{\bar{a}}{m}\cdot\frac{\bar{\rho}}{\rho} = \frac{2\pi}{\rho} . \tag{4.5.10}$$

Similarly, the change of the wave-vector due to the diffraction on the 3D-lattice is: $\Delta\bar{k} = \frac{2\pi}{\lambda}(\bar{1}_d - \bar{1}_i) = \frac{2\pi}{\lambda}\bar{1}_n\left|\bar{1}_d - \bar{1}_i\right| = \frac{2\pi}{\lambda}\bar{1}_n \cdot 2\sin\frac{\delta}{2} = \frac{2\pi}{\lambda}\bar{1}_n \cdot \frac{D\lambda}{d_{mnp}} = D\rho\bar{1}_n = D\bar{\rho} = \bar{\rho}'$.

Finally, from the relation: $\frac{4\pi^2}{\lambda^2} = k'^2 = (\bar{k} + \bar{\rho}')^2 = \frac{4\pi^2}{\lambda^2} + 2\bar{k}\cdot\bar{\rho}' + \rho'^2$,

one finds that:
$$\rho'^2 = 2\bar{k}'\cdot\bar{\rho}' = -2\bar{k}\cdot\bar{\rho}', \tag{4.5.11}$$

which is *the equivalent form (for the reciprocal lattice space) of the Bragg and Bragg law.*

a) *The Ewald's geometrical construction*

Taking into account that only 2 from the 3 directory cosines:
$$\alpha = \bar{1}_d\cdot\bar{1}_x,\quad \beta = \bar{1}_d\cdot\bar{1}_y \quad \text{and:} \quad \gamma = \bar{1}_d\cdot\bar{1}_z \tag{4.5.12}$$

of the $\bar{1}_d$ direction are independent (because: $\alpha^2 + \beta^2 + \gamma^2 = 1$), it results that - for arbitrary $\bar{1}_d$ and λ - the Laue's equations (4.5.1) cannot be fulfilled concomitantly. In order to find the wavelength λ which can accomplish concomitantly these equations for given $\bar{1}_i$ and $\bar{\rho}'$, the following (Ewald) construction can be used. Consider the space of the reciprocal lattice and the vector $\bar{\rho}'$ inside this space (fig. 4.10).

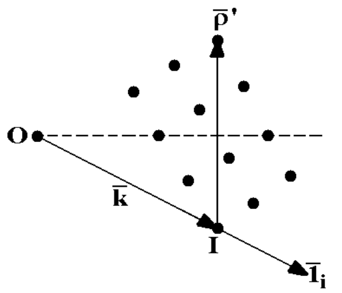

Fig. 4.10.

Let *I* be the starting point of $\bar{\rho}'$ and *O* - the crossing of the mediator plane of $\bar{\rho}'$ and of the straight-line parallel to $\bar{1}_i$, passing through *I*. One finds easily that $\bar{k} =$ **OI** satisfies the Bragg law (4.5.11). It results that:
$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{OI}. \tag{4.5.13}$$

4.5.The Apobetics level

Given being any piece of information has a purpose, the last and highest level of information refers to this (teleological) aspect: the question of purpose.

The term “apobetics” was introduced in 1981 by W. Gitt [28], starting from the Greek word *apobeinon* = result, success, conclusion.

As it concerns the particular example chosen by us: that of the continuous (Bremsstrahlung) X-radiation, one finds that besides the already examined application to: (i) the evaluation of the periods of the crystalline lattices, the X-radiation could be applied successfully to the: (ii) investigation of defects in various industrial components, (iii) examination of different solid parts of the human body, (iv) medical treatment of certain diseases (as of some cancer affections), etc.

<u>Short Examples of other Important Purposes</u>

To achieve a brief presentation of other important purposes and of the basic contributors to their better knowledge and advancement, we will summarize the essential elements in the frame of the next table.

Nr.	*Purpose*	*Main International Contributors*	*Main Romanian Contributors*	*Author's first Contributions*
1.	Basic Features of X-rays	F. E. Kaelble [29]	O. Birău [30]	Continuous X-Rays Syntax & Semantics [21], 1960
2.IT	Basic Features of Complex Materials	K.G. Wilson [31]	R. Dobrescu, D.I. [32]	Complex Magnetic Materials [33], 1967
3.	Molecular Structure	G. Herzberg [34]	D. Bârcă-Gălăţeanu, M. Giurgea[35]	NMR data processing [36], 1973
4.	Physics Structure	L. A. Sena [37]	→	Physics notions & methods [38],1975
5.	Information Accuracy – Numerical Phenomena	Courant – Fr-Lewy [39] Delsanto [40]	→	Pulse distortions [41], 1997
6.IT	Smart Devices (CCDs)	R. Widenhorn, E. Bodegom [42]	→	Various applications [43], 2013
7.	Information about the life of US inventors	R. G. LeTourneau [44]	→	Annotated translation [45], 2016

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