Do the Uncertainty Relations Really have Crucial Significances for Physics?

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It is proved the falsity of idea that the Uncertainty Relations (UR) have crucial significances for physics. Additionally one argues for the necesity of an UR-disconnected quantum philosophy.

1 Introduction

The Uncertainty Relations (UR) enjoy a considerable popularity, due in a large measure to the so called Conventional (Copenhagen) Interpretation of UR (CIUR). The mentioned popularity is frequently associated with the idea (which persist so far) that UR have crucial significances for physics (for a list of relevant references see [1–3]). The itemization of the alluded idea can be done through the following more known Assertions (**A**):

• A_1: In an experimental reading the UR are crucial symbols for measurement characteristics regarding Quantum Mechanics (QM) in contrast with non-quantum Classical Physics (CP). The pointed characteristics view two aspects: (i) the so called "observer effect" (i.e. the perturbative influence of "observation"/measuring devices on the investigated system), and (ii) the measurement errors (uncertainties). Both of the alluded aspects are presumed to be absolutely notable and unavoidable in QM contexts respectively entirely negligible and avoidable in CP situations. ■

• A_2: From a theoretical viewpoint UR are essential distinction elements between the theoretical frameworks of QM and CP. This in sense of the supposition that mathematically UR appear only in QM pictures and have not analogues in the CP representations. ■

• A_3: In both experimental and theoretical acceptions the UR are in an indissoluble connection with the description of uncertainties (errors) specific for Quantum Measurements (QMS). ■

• A_4: As an esential piece of UR, the Planck's constant $\hbar$, is appreciated to be exclusively a symbol of quanticity (i.e. a signature of QM comparatively with CP), without any kind of analogue in CP. ■

• A_5: UR entail [4] the existence of some "impossibility" (or "limitative") principles in foundational physics. ■

• A_6: UR are regarded [5] as expression of *"the most important principle of the twentieth century physics"*. ■

To a certain extent the verity of the idea itemized by assertions $A_1 - A_6$ depends on the entire truth of CIUR. That is why in the next section we present briefly the CIUR untruths which trouble the mentioned verity. Subsequently, in Section 3, we point out a lot of Observations (**O**) which invalidate completely and irrefutably the items $A_1 - A_6$. The respective invalidation suggests a substitution of UR-subordinate quan-

tum philosophy with an UR-disconnected conception. Such a suggestion is consolidated by some additional Comments (**C**) given in Section 4. So, in Section 5, we can conclude our considerations with: (i) a definitely negative answer to the inquired idea, respecively (ii) a pleading for a new quantum philosophy. Such conclusions argue for the Dirac's intuitional guess about the non-survival of UR in the physics of future.

2 Shortly on the CIUR untruths

In its essence the CIUR doctrine was established and disseminated by the founders and subsequent partisans of Copenhagen School in QM. The story started from the wish to give out an unique and generic interpretation for the thought-experimental (*te*) formula

$$\Delta_{te}A \cdot \Delta_{te}B \geqslant \hbar \tag{1}$$

(*A* and *B* being conjugated observables) respectively for the QM theoretical formula

$$\Delta_\psi A \cdot \Delta_\psi B \geqslant \frac{1}{2}\left|\left\langle\left[\hat{A},\hat{B}\right]\right\rangle_\psi\right| \tag{2}$$

(where the notations are the usual ones from usual QM — see also [3]). Both the above two kind of formulas are known as UR.

The alluded doctrine remains a widely adopted conception which, in various manners, dominates to this day the questions regarding the foundation and interpretation of QM. However, as a rule, a minute survey of the truths-versus-untruths regarding its substance was (and still is) underestimated in the main stream of publications (see the literature mentioned in [1, 2]). This in spite of the early known opinions like [6]: *"the idea that there are defects in the foundations of orthodox quantum theory is unquestionable present in the conscience of many physicists"*.

A survey of the mentioned kind was approached by us in the report [3] as well as in its precursor papers [7–15] and preprints [16]. Our approaches, summarized in [3], disclose the fact that each of all basic elements (presumptions) of CIUR are troubled by a number of insurmountable shortcomings (unthruths). For that reason we believe that CIUR must be wholly abandoned as a wrong construction which, in its substance, has no noticeable value for physics. The disclosures from [3] were carried out by an entire class of well

argued remarks (R). From the mentioned class we compile here only the following ones:

• R_a: Formula (1) is mere provisional fiction without any durable physical significance. This because it has only a transitory/temporary character, founded on old resolution criteria from optics (introduced by Abe and Rayleigh). But the respective criteria were surpassed by the so called super-resolution techniques worked out in modern experimental physics.

Then, instead of CIUR formula (1), it is possible to imagine some "improved relations" (founded on some super-resolution thought-experiments) able to invalidate in its very essence the respective formula. ■

• R_b: From a theoretical perspective the formula (2) is only a minor and deficient piece, resulting from the genuine Cauchy-Schwarz relation

$$\Delta_\psi A \cdot \Delta_\psi B \geqslant \left| \left(\delta_\psi \hat{A} \psi, \delta_\psi \hat{B} \psi \right) \right| \qquad (3)$$

written in terms of usual QM notations (see [3]).

As regards their physical significance the formulas (2) and (3) are nothing but simple (second order) fluctuations relations from the same family with the similar ones [3, 7–9, 12, 15] from the statistical CP. ■

• R_c: In a true approach the formulas (1) and (2) as well as their "improvised adjustments" have no connection with the description of QMS. ■

• R_d: The Planck's constant $\hbar$ besides its well-known quanticity significance is endowed also [3, 12] with the quality of generic indicator for quantum randomness (stochasticity) — i.e. for the random characteristics of QM observables. Through such a quality $\hbar$ has [3, 12] an authentic analogue in statistical CP. The respective analogue is the Boltzmann's constant k_B which is an authentic generic indicator for thermal randomness. Note that, physically, the randomness of an observable is manifested through its fluctuations [3, 7–9, 12, 15]. ■

• R_e: The formula (2) is not applicable for the pair of (conjugated) observables $t - E$ (time-energy). In other words [3] a particularization of (2) in the form

$$\Delta_\psi t \cdot \Delta_\psi E \geqslant \frac{\hbar}{2} \qquad (4)$$

gives in fact a wrong relation. This because in usual QM the time t is a deterministic variable but not a random one. Consequently for any QM situation one finds the expressions $\Delta_\psi t \equiv 0$ respectively $\Delta_\psi E = a \ finite \ quantity$.

Note that in a correct mathematical-theoretical approach for the $t - E$ case it is valid only the Cauchy Schwarz formula (3), which degenerate into trivial relation $0 = 0$. ■

Starting from the above remarks $R_a - R_e$ in the next section we add an entire group of Observations (O) able to give a just estimation of correctness regarding the assertions $A_1 - A_6$.

3 The falsity of assertions $A_1 - A_6$

The above announced estimation can be obtained only if the mentioned remarks are supplemented with some other notable elements. By such a supplementation one obtains a panoramic view which can be reported through the whole group of the following Observations (O) :

• O_1: The remark R_a, noted in previous section, shows irrefutably the falsity of the assertion A_1. The same falsity is argued by the fact that the referred "observer effect" and corresponding measuring uncertainties can be noticeable not only in QMS but also in some CP measurements (e.g. [17] in electronics or in thermodynamics) ■

• O_2: On the other hand the remark R_b points out the evident untruth of the assertion A_2. ■

• O_3: Furthermore the triplet of remarks $R_a - R_c$ infringes the essence of the assertion A_3. ■

• O_4: The exclusiveness feature of Planck's constant $\hbar$, asserted by A_4, is evidently contradicted by the remark R_d. ■

• O_5: Assertion A_5 was reinforced and disseminated recently [4] thrugh the topic:

> *"What role do 'impossibility' principles or other limits (e.g., sub-lightspeed signaling, **Heisenberg uncertainty**, cosmic censorship, the second law of thermodynamics, the holographic principle, **computational limits**, etc.) play in foundational physics and cosmology?"*.

Affiliated oneself with the quoted topic the assertion A_5 implies two readings: (i) one which hints at Measuring Limits (ML), respectively (ii) another associated with the so called "Computational Limits" (CL). ■

• O_6: In the reading connected with ML the assertion A_5 presumes that the QMS accuracies can not surpass "Heisenberg uncertainties" (1) and (2). Such a presumption is perpetuated until these days through sentences like: *"The uncertainty principle of quantum mechanics places a fundamental limitation on what we can know"* [18].

Now is easy to see that the above noted remarks R_a and R_c reveal beyond doubt the weakness of such a presumption. Of course that, as a rule, for various branches of physics (even of CP nature such are [17] those from electronics or thermodynamics), the existence of some specific ML is a reality. The respective existence is subordinate to certain genuine elements such are the accuracy of experimental devices and the competence of the theoretical approaches. But note that as it results from the alluded remarks the formulas (1) and (2) have nothing to do with the evaluation or description of the ML (non-performances or uncertainties) regarding QMS. ■

• O_7: The reading which associate the UR with CL sems to refer mainly to the Bremermann's limit (i.e. to the maximum computational speed of a self-contained system in the universe) [19, 20]. But it is easy to see from [19, 20] that the aludded association is builded in fact on the wrong relations (1) and (4) written for the observables pair $t - E$. Conse-

quently such an association has not any real value for appreciation of UR significance as CL. Add here the remark that, nevertheless, the search [20] for finding the ultimate physical limits of computations remains a subject worthy to be investigated. This because, certainly, that what is ultimately permissible in practical computational progresses depends on what are the ultimate possibilities of real physical artifacts (experiences). However, from our viewpoint, appraisals of the alluded possibilities do not require any appeal to the relations (1, 2, 4). ∎

• O_8 : For a true judgment regarding the validity of assertion A_6 can be taken into account the following aspects:

    (i) In its essence A_6 prove oneself to be nothing but an unjustifiable distortion of the real truths. Such a proof results directly from the above remarks $R_a - R_c$. According to the alluded remarks in reality the UR (1) and (2) are mere provisional fictions respectively minor (and restricted) QM relations. So it results that, in the main, UR are insignificant things comparatively with the true important principles of the 20th century physics (such are the ones regarding *Noether's theorem*, *mass-energy equivalence*, *partricle-wave duality* or *nuclear fission*).

    (ii) It is wrongly to promote the assertion A_6 based on the existent publishing situation where, in the mainstream of QM text-books, the UR (1) and/or (2) are amalgamated with the basic quantum concepts. The wrongness is revealed by the fact that the alluded situation was created through an unjustified perpetuance of the writing style done by the CIUR partisans.

    (iii) The assertion A_6 must be not confused with the history confirmed remark [21] : *UR "are probably the most controverted formulae in the whole of the theoretical physics"*. With more justice the respective remark has to be regarded as accentuating the weakness of concerned assertion.

Together the three above noted aspects give enough reasons for an incontestable incrimination of the assertion under dicussion. ∎

The here detailed observations $O_1 - O_8$ assure sufficient solid arguments in order to prove the indubitable incorrectness for each of the assertions $A_1 - A_6$ and, consequently, the falsity of the idea that UR really have crucial significances for physics. But the alluded proof conflicts with the UR-subordinate quantum philosophy in which the interpretational questions of QM and debates about QMS description are indissolubly associated with the formulas (1) and/or (2). The true (and deep) nature of the respective conflict suggests directly the necessity of improvements by substituting the alluded philosophy with another UR-disconnected conception.

Of course that the before-mentioned substitution necessitates further well argued reconsiderations, able to gain the support of mainstream scientific communities and publications. Note that, in one way or other, elements of the UR-subordinate philosophy are present in almost all current QM interpretations [22]. We think that among the possible multitude of elements belonging to the alluded reconsiderations can be included the additional group of comments from the next section.

4 Some additional comments

The Comments (**C**) from the foregoing announced group, able to suggest also improvements in quantum philosophy, are the following ones:

• C_1 : Firstly we note that the substance of above presented remarks $R_a - R_b$ respectively observations $O_1 - O_3$ can be fortified by means of the following three our views:

    (i) In its bare and lucrative framework, the usual QM offers solely theoretical models for own characteristics of the investigated systems (microparticles of atomic size).

    (ii) In the alluded framework QM has no connection with a natural depiction of QMS.

    (iii) The description of QMS is an autonomous subject, investigable in addition to the bare theoretical structure of usual QM.

We think that, to a certain extent, our above views find some support in the Bell's remark [23] : *"the word (**measurement**) has had such a damaging efect on the discussions that . . . it should be banned altogether in quantum mechanics"*. (It happened that, in a letter [24], J.S.Bell comunicated us early the essence of the alluded remark together with a short his personal agreement with our incipient opinions about UR and QMS). ∎

• C_2 : In its substance the view (i) from C_1 regards the bare QM as being nothing but an abstract (mathematical) modeling of the properties specific to the atomic-size sytems (microparticles). For a given system the main elements of the alluded modeling are the wave functions ψ_α, respectively the quantum operators $\hat{A}_j$. On the one hand ψ_α describes the probabilistic situation of the system in α state. Mathematically ψ_α is nothing but the solution of the corresponding Schrodinger equation. On the other hand each of the operators $\hat{A}_j$ ($j = 1, 2, \ldots , n$) is a generalised radom variable associated to a specific observable A_j (e.g. coordinate, momentum, angular momentum or energy) of the system. Then in a probabilistic sense the global characterization of the observables A_j is given by the expected parameters:

(i) the mean values $\left\langle A_j \right\rangle_\psi = \left(\psi, \hat{A}_j \psi \right)$ wherre $\psi \equiv \psi_\alpha$ while (f, g) denotes the scalar product of functions f and g,

(ii) the $(r + s)$-order correlations

$$\mathrm{K}_\psi (i, j; r, s) = \left(\left(\delta_\psi \hat{A}_i \right)^r \psi, \left(\delta_\psi \hat{A}_j \right)^s \psi \right),$$

with $\delta_\psi \hat{A}_j = \hat{A}_j - \left\langle A_j \right\rangle_\psi$ and $r + s \geqslant 2$.

So the definitions of parameters $\langle A_a \rangle_\psi$ and $K_\psi \, (i, j; r, s)$ appeal to the usual notations from QM texts (see [3, 25, 26]). ∎

• C_3 : The before mentioned QM entities are completely similar with the known things from statistical CP (such are the phenomenological theory of fluctuations [27, 28] respectively the classical statistical mechanics [29, 30]). So the wave functions ψ_α correspond to the probability distributions w_α while the operators $\hat{A}_j$ are alike the macroscopic random observables $\mathbb{A}_j$. Moreover the QM probabilistc expected parameters $\langle A_a \rangle_\psi$ and $K_\psi \, (i, j; r, s)$ are entirely analogous with the mean values respectively the second and higher order fluctuations correlations regarding the macroscopic observables $\mathbb{A}_j$ [3, 7–10, 12, 15, 27–31] ∎

• C_4: It is interesting to complete the above comment with the following annotations. Undoubtedly that, mathematically, the QM observables have innate characteristics of random variables. But similar characteristics one finds also in the case of statistical CP observables. Then it is surprisingly that the two kinds of random observables (from QM and CP) in their connection with the problem of measurements are approached differently by the same authors [25, 29] or teams [26, 30]. Namely the alluded problem is totally neglected in the case of CP observables [29, 30], respectively it is regarded as a capital question for QM observables [25, 26]. Note that the mentioned differentiation is not justified [25, 26, 29, 30] by any physical argument. We think that, as regard the description of their measurements, the two kinds of random observables must be approached in similar manners.

In the context of above annotations it is interesting to mention the following very recent statement [32]: *"To our best current knowledge the measurement process in quantum mechanics is non-deterministic"*. The inner nature of the mentioned statement strengthens our appreciation [3] that a measurement of a (random) quantum observable must be understood not as a single trial (which give a unique value) but as a statistical sampling (which yields a spectrum of values). Certainly that in such an understanding the concept of "wave function collapse" [33] becomes an obsolete thing. ∎

• C_5: A credible tentative in approaching similarly the description of measurements regarding random observables from both QM and CP was promoted by us in [3, 34]. Our approach was done according the views (ii) and (iii) noted in the above comment C_1. Mainly the respective approach aims to obtain a well argued (and consequently credible) description of QMS. So, in papers [3, 34], a QMS was depicted as a distortion of the information about the measured system. For a given system the respective distortion is described (modeled) as a process which change linearly the probability density and current (given in terms of wave function) but preserve the mathematical expressions of QM operators regarded as generalised random variables. Note that an analogous description of measurements concerning the random

observables from CP was done by us formerly in [35]. ∎

• C_6: Other open question of quantum philosophy regards the deterministic subjacency of QM randomness. The question, of great interest [36], aims to clarify if the respective randomness has an irreducible nature or otherwise it derives from the existence of some subjacent hidden variables of deterministic essence. Then it appears as a notable aspect the fact that, in so reputable report [36] about the alluded question, the possible involvement of UR (1) and/or (2) is completely omited. Such a remarkable omission show clearly that the UR (1) and/or (2) do not present any interest for one of the most thought-provoking subject regarding quantum philosophy. ∎

• C_7: Here is the place to refer comparatively to the deterministic subjacency regarding CP kind of randomness. The respective kind is associated (both theoretically and experimentally) with a class of subjacent deterministic variables, specific to the molecular and atomic motions [27–30]. The important feature of the alluded CP subjacency is the fact that it does not annul at all the corresponding randomness. Namely the respective deterministic subjacency do not revoke at all the random entities such are the probability distributions w_α and macroscopic observables $\mathbb{A}_j$, mentioned above in C_3. The respective entities keep the essence of the CP randomness revealed physically through the corresponding global fluctuations of macroscopic observables.

We think that the noted classical feature must be taken as a reference element in managing the discussions regarding the deterministic subjacency of QM (i.e. the question of hidden variables — versus — QM randomness) and, generally speaking, the renovation of quantum philosophy. More exactly it is of direct interest to see if the existence of hidden variables removes or keeps the QM randomness incorporated within the wave functions ψ_α and operators $\hat{A}_j$. We dare to believe that the alluded QM randomness will persist, even if the existence of some subjacent hidden variables would be evidenced (first of all experimentally). ∎

• C_8: Now some other words about the question of "impossibility" principles in foundational physics, discussed above in observations $O_5 - O_7$. The respective principles were mentioned in connection with questions like: ' What is Ultimately Possible in Physics?' (see [4]). To a deeper analysis the alluded connection calls attention to 'the frontier of knowledge'. In scrutinizing the respective frontier it was acknowledged recently [32] that: *"Despite long efforts, no **progress** has been made... for ... the understanding of quantum mechanics, in particular its measurement process and interpretation"*. What is most important in our opinion is the fact that, in reality, for the sought ***"progress"*** the UR (1) and (2) are of no interest or utility. ∎

By ending this section it is easy to see that the here added comments $C_1 - C_8$ give supports to the before suggested proposal for a UR-disconnected quantum philosophy.

5 Conclusions

A survey, in Section 3, of the observations $O_1 - O_8$ discloses that *in fact the UR (1) and (2) have not any crucial significance for physics*. Additionally, in Section 4, an examination of the comments $C_1 - C_8$ provides supporting elements for a UR-disconnected quantum philosophy.

So we give forth a class of solid arguments which come to advocate and consolidate the Dirac's intuitional guess [37] that: *"uncertainty relations in their present form will not survive in the physics of future"*.

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