

Original Paper

Remarks on the Relativistic Transactional Interpretation of Quantum Mechanics

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Abstract: Kastner (this issue) and Kastner and Cramer (arXiv:1711.04501) argue that the Relativistic Transactional Interpretation (RTI) of quantum mechanics provides a clear definition of absorbers and a solution to the measurement problem. I briefly examine how RTI stands with respect to unitarity in quantum mechanics. I then argue that a specific proposal to locate the origin of nonunitarity is flawed, at least in its present form.

Keywords: Quantum mechanics; transactional interpretation; collapse

1. Introduction

It is generally agreed that the state vector of a nonrelativistic quantum system normally evolves unitarily, according to the Schrödinger equation. A number of investigators think that ‘normally’ extends to ‘universally.’ That is, they believe that unitary evolution suffers no exceptions, no matter how large the system. Others, following von Neumann, believe that unitary evolution breaks down in some circumstances, measurements in particular. In such situations, so they think, the Schrödinger equation must be replaced by what has been known as the collapse of the state vector. Although von Neumann did not specify the mechanism of collapse, other investigators after him attempted to do so, for instance in approaches like spontaneous localization or gravitational collapse. By contrast, the approaches initiated by de Broglie and Bohm, and by Everett, stick to unitarity.

Cramer’s Transactional Interpretation (TI) of quantum mechanics [1,2] stands on the collapse side. Cramer’s views can be illustrated by the process of emission and absorption

of a quantum particle. Associated with emission is an ‘offer wave’ that travels forward in time. This wave reaches a number of possible absorbers. Each of these responds with a ‘confirmation wave’ that travels backward in time to the emitter. A transaction is henceforth established between the emitter and one of the absorbers, whose probability is naturally given by the Born rule. A transaction is taken to be irreversible and, in the end, it corresponds to state vector collapse.

In a review [3] of *The Quantum Handshake* [2], I argued that although TI sheds light on some paradoxical aspects of quantum mechanics, it is not really defined better than von Neumann’s collapse or, indeed, than the Copenhagen interpretation. This is essentially because transactions require emitters and absorbers, which share the ambiguity of Bohr’s classical objects or von Neuman’s measurement apparatus. TI therefore reintroduces, under a different guise, the quantum-classical distinction.

In reply to [3], Kastner [4] and Kastner and Cramer [5] have argued that in the Relativistic Transactional Interpretation (RTI) developed by Kastner [6], absorbers are indeed well-defined. Moreover, they claim that RTI provides a solution to the measurement problem. In this note I put these claims in perspective and argue that they are overstated.

2. Nonunitarity in RTI

As explained in [6] and elsewhere (see [4] for references), RTI is based on the Davies quantum relativistic direct-action theory. I shall not review the full theory here, but focus on what is relevant to the points I want to make.

A crucial difference between RTI and TI is that in the former, absorbers do not need to be macroscopic. To quote Kastner, “Emission and absorption are [in RTI] quantitatively defined at the microscopic level” [4, p. 2]. Confirmation waves, which trigger absorption, are defined at the level of interacting quantum fields: “the coupling amplitudes between interacting fields in the relativistic domain are to be identified as the amplitudes for the generation of confirmation waves” [6, p. 65].

Emission and absorption are associated with offer and confirmation waves, respectively. Kastner [4, p. 4] stresses that “absorption [...] is irreversible (non-unitary) at the level of the micro-absorber.” Moreover, she proposes a quantitative measure for the generation of an offer or confirmation wave [4, p. 5]:

The crucial development allowing definition of measurement in the relativistic RTI is [that the] coupling amplitude e (*natural units*) is identified as *the amplitude for an offer or confirmation to be generated*.

For an interaction between a photon and an electron, the coupling amplitude is equal to the electron charge e . The probability of generation of an offer or a confirmation wave in such a microscopic process is then equal to the square of the amplitude, that is, to the fine

structure constant $\alpha \approx 1/137$.¹

Thus in RTI, the origin of nonunitarity lies in the microscopic world. But the evidence for nonunitarity (for those who, unlike Bohmians and Everettians, believe in it) comes from the macroscopic world, that is, from the apparently well-defined results of measurements. Does the microscopic nonunitarity explain the macroscopic nonunitarity? Perhaps, but this is far from obvious.² An explanation of the one by the other should be buttressed by detailed calculations. I am not aware of any such calculations performed in the framework of RTI but, fortunately, estimates have been made.

3. Quantitative Estimates

According to [4], the probability of generation of a confirmation wave by a single absorber of charge e is small, on the order of $\alpha \approx 0.0073$. This probability, however, will increase with the number of absorbers. The argument goes this way [4]. Suppose that an offer wave is emitted, and that there are N possible absorbers. The probability that any of these will not generate a confirmation wave is equal to $1 - \alpha \approx 0.9927$. Assuming that absorbers are independent, the probability that none of them will generate a confirmation wave is therefore on the order of 0.9927^N , a very small number if N is large. Hence macroscopic absorbers will generate confirmation waves, and therefore nonunitarity and irreversibility, essentially with certainty.³

This argument also allows estimating the values of N for which absorption occurs with neither too small nor too large probabilities. Kastner points out that if, for example, each of the 60 carbon atoms of a buckyball acts as a microscopic absorber, we should expect absorption in about one third of cases ($1 - 0.9927^{60} \approx 0.36$). This means that systems like buckyballs should exhibit nonunitarity and irreversibility in a substantial proportion of cases. Of course, a full argument will need to be more specific, and consider detailed experimental circumstances in which the buckyball is investigated. Interestingly, however, buckyballs have already been shown to display quantum interference [8]. This implies that in such situations, their behavior is consistent with unitarity and reversibility. Advocates of RTI will point out that buckyball interference does not involve absorption, so that unitarity should be expected. But the point is that we already have the technology to work

¹ In [6,7] Kastner associates α with the amplitude and α^2 with the probability. The forthcoming arguments can be adapted to that specification.

² The logical gap is not unlike the one between quantum indeterminacy and human free will. In the absence of proof, the claim that the former explains the latter is just a hypothesis. (To avoid any misunderstanding, I should say that I do not attribute such a claim to Kastner or Cramer.)

³ Such an argument has also been used in spontaneous localization theories, where the localization of single particles occurs very infrequently but the localization of macroscopic objects occurs very quickly. This remark should not be construed as identifying RTI with spontaneous localization theories.

with a number of atoms for which, under appropriate circumstances, RTI would predict a breakdown of unitarity. If indeed α represents the probability of generation of confirmation waves in microscopic RTI, we may soon be able to distinguish predictions made by unitary quantum mechanics from those made by nonunitary theories like RTI.⁴

4. A Problem with Probability

In a process involving a photon and an electron, the probability of generation of offer and confirmation waves is equal to e^2 , the fine structure constant. Kastner further asserts that in this context $\alpha \approx 1/137$ represents the probability of a measurement transition, that is, the probability of an actual physical process. I will now argue that such an identification is unlikely to hold as any general principle.

The argument goes this way. Suppose there were in nature fundamental particles with charge $12e$. The probability that they would generate confirmation waves, according to Kastner's prescription, should be equal to $(12e)^2 \approx 144/137 \approx 1.05$. That is, the probability would be larger than one. Clearly, this cannot be interpreted as the probability of a physical process, or as any probability whatsoever. One can reply that there are no fundamental particles with charge $12e$ but, since this is a contingent rather than necessary fact, the reply is unconvincing. Moreover, Kastner argues [4] that her prescription generalizes to other kinds of charge, like color. But these charges, in some energy ranges and in natural units, have values that exceed one. The amplitude of generation of a confirmation wave associated with such quantized fields cannot be equal to the charge.

Can one raise a similar objection to standard quantum electrodynamics? The answer is no, because in QED the charge is not associated with the amplitude of a physical process. The charge is associated with vertices of Feynman diagrams which, for a variety of reasons (not the least of which being that diagrams are gauge dependent), do not individually have physical meaning. Only the absolute square of the series of Feynman diagrams represents a physical process and has meaning. Should there be fundamental particles of charge $12e$, they would not lead to probabilities greater than one. They would just make the series useless.

5. Conclusion

I have shown that the quantitative criterion proposed by Kastner for the generation of offer and confirmation waves faces serious difficulties. This leaves the measurement problem unsolved and absorbers ill-defined. Comparing predictions of nonunitary TI (or RTI) with those of unitary quantum mechanics would be highly interesting, but this can

⁴ Some spontaneous localization theories have already been ruled out in similar contexts.

only be achieved through a quantitative and consistent approach to absorption.

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References

1. J. G. Cramer, “The Transactional Interpretation of Quantum Mechanics,” *Reviews of Modern Physics* **58**, 647–687 (1986).
2. J. G. Cramer, *The Quantum Handshake: Entanglement, Nonlocality, and Transactions* (Springer, 2016).
3. L. Marchildon, “Review of ‘The Quantum Handshake’,” *American Journal of Physics* **85**, 158–159 (2017).
4. R. E. Kastner, “On the Status of the Measurement Problem: Recalling the Relativistic Transactional Interpretation,” arXiv:1709.09367v4.
5. R. E. Kastner and J. G. Cramer, “Quantifying Absorption in the Transactional Interpretation,” arXiv:1711.04501v1.
6. R. E. Kastner, *The Transactional Interpretation of Quantum Mechanics. The Reality of Possibility* (Cambridge University Press, 2013).
7. R. E. Kastner, “The Possibilist Transactional Interpretation and Relativity,” *Foundations of Physics* **42**, 1094–1113 (2012).
8. M. Arndt, O. Nairz, J. Vos-Andreae, C. Keller, G. van der Zouw and A. Zeilinger, “Wave-Particle Duality of C₆₀ Molecules,” *Nature* **401**, 680–682 (1999).

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