# Interference field as quantum randomness generator.

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**Abstract**: This document presents a principle of a wave field contained in a closed space producing fluctuations with random appearances at any point in the space.
A 2D simulation shows that interference patterns produced by the interaction of this field with physical objects contained in the space make it possible to produce non-zero correlation measurements between distant points in space and specific to the objects position configuration.
These correlations properties are used to explain experimental coincidences measurements having non-local appearance.

## Introduction.

EPR type experiments have shown that statistical measurements of coincidences of detections between distant particles seem to require that a non-local effect applies between the particles.

Indeed, Bell's work showed that some information contained only in local variables attached to a particle was insufficient to explain experimental results locally.

From these results arises the EPR paradox as well as the effect called "spooky action".

The option considered in this document is that the missing information required to explain experimental results can be extracted from the space using the local state of a interference wave field.

This wave field must then have a specific configuration representative of the experimental configuration, and must be able to locally produce significant information that can be used to alter physical interactions.

In this context, this document studies whether a wave interference field contained in a closed space can satisfy these conditions.

This wave field which must depend on the configuration of size and position of the objects contained in the space is called “contextual field”.

## 1. Field simulation.

To simulate an interference wavefield, the following conditions are necessary.

- A space that contains energy propagating in the form of waves.
- To produce interference, waves coming from multiple directions must cross each other.

Within the scope of the field used in this document, an additional constraint is necessary.

- From the local state of the field, it is necessary to statistically produce a quantity of binary information worth +1 or -1 identical for all points in space and distributed in a balanced manner. (50% -1, 50% +1).

For this condition to be satisfied, the interference must be distributed homogeneously throughout the space in order to obtain a uniform energy density.

Based on these constraints, a closed space model was chosen, because it allows the required conditions to be met.

The space being closed, waves emitted in opposite directions will end up returning to their emission position and crossing each other in order to produce interference.

In addition, the energy of the waves contained in the space being constant, this makes it possible to obtain a homogeneous energy density throughout the space with waves of constant maximum amplitude.

This type of closed space in 3D could be a hypertorus, or a variant, as for example the Poincaré dodecahedral space model [1][2].

**Initial energy**.

An initial energy is injected into the empty space in the form of a periodic signal for a limited duration, then defining the total energy contained in the closed space and which will remain constant.

There are a multitude of possibilities for initializing this energy depending on the number of sources, their relative positions and the shape and duration of the injected signal.

For the simulation, the simplest form is used, consisting of injecting a sinusoidal signal at a single point in space.

This injection of energy could be seen as a form of "big bang"

**2D simulation**.

Although a 3D simulation is possible, it would however require too long simulation times [4].
A 2D simulation is therefore carried out assuming that the effects observed in 2D also persist in 3D, which seems probable but remains to be verified.

To simulate a field in a closed 2D space, waves propagating on the surface of a torus are simulated.
It is then easy to display this surface on a plan.

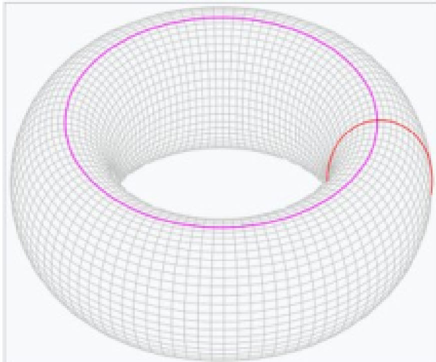


**Image 1**: Ring torus. (source wikipedia)
The surface of the torus can be projected onto a plane by cutting on the red and magenta lines.

The simulation must then verify the following points:

- From the initial energy injected into space, an interference field must be established homogeneously throughout the space.
- The spatial configuration of interference must be established in a specific way depending on the position and shape of the physical objects contained in space.
- The field must statistically produce the same quantity of binary information +1/-1 for all elementary points in space.
- The local state of the field must be usable to produce significant local binary information making it possible to produce specific correlations between any pair of points A and B in the space depending on the experimental configuration.
- The correlation properties must persist if the measurements are not made at the same time but carried out with a constant time offset (A measured before B, or B measured before A), which is in practice the case for a real experiment.

To verify these points, two simulations are done.

In each of the simulations, two physical objects are inserted into space.
In the second simulation, the orientation of one of the objects is modified, representing an experimental configuration different from the first simulation.

A physical object contained in space must have the property of interacting with the wave field in order to modify it in a specific way depending on its shape and orientation.

For the simulation the property of reflecting waves is used because it is simple to simulate.
However, it is assumed that other types of interaction can be used as long as the field is affected.

## 2. Correlations test between points in space.

To evaluate measurement correlations of some +1/-1 values between two points in space, two groups of 50 measurement points denoted A[1..50] and B[1..50] are defined with random positions in space at the start of the simulation.

Then for each elementary simulation cycle, a +1 or -1 value is defined for each point using the sign of the local field amplitude.

Then, for each point in group A, coincidences counters of identical sign of A with all the points in group B are updated.

This produces 50 * 50 correlations E values that can vary between -1 and 1 and can be displayed on a graph.

Each correlation E is calculated as follows:

Noting the counters values of pairs type measured with the following variables:

ApBp: $A>0$ et $B>0$
AnBn: $A<0$ et $B<0$
ApBn: $A>0$ et $B<0$
AnBp: $A<0$ et $B>0$

$$E = (ApBp + AnBn - ApBn - AnBp) / (ApBp + AnBn + ApBn + AnBp)$$

The number of elementary field propagation simulations was set to 5 Million.
The results are then divided into 5 blocks of 1 million of measurements and compared to check if all the E results obtained for each points converge towards a same value.

## 3. First experiment.

The first experiment is simulated as follows:

Two objects are defined in the empty space and the initial energy of the wave field is injected.

The following image displays the state of the field after 10000 elementary cycles of wave propagation.

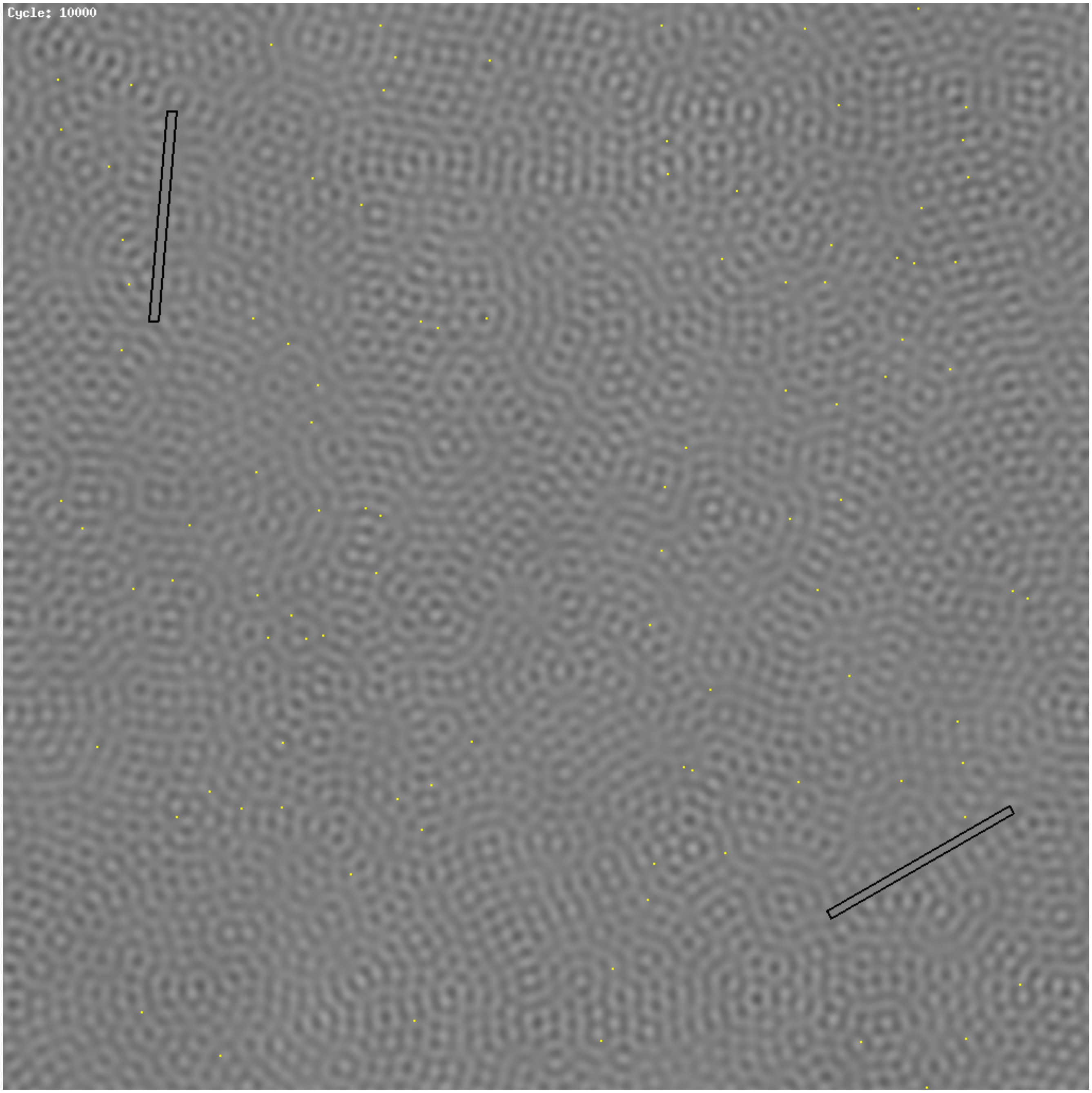



**Image 2**: State of the wave field after 10000 elementary propagation cycles.
The two black objects A (left) and B (right) reflect the field waves.
The yellow points on the left part of the image represent the measurement positions of the points of group A, and those on the right the position of the points of group B.

We notice that interference figures have homogeneously filled all the space.

This image is a view at cycle 10000, but the configuration of the interference field varies constantly over time. This can be viewed on videos available in the appendix [3].

## 4. Second experiment.

The simulation of the second experiment is done under the same conditions as the first except that object B has rotated by 45 degrees.

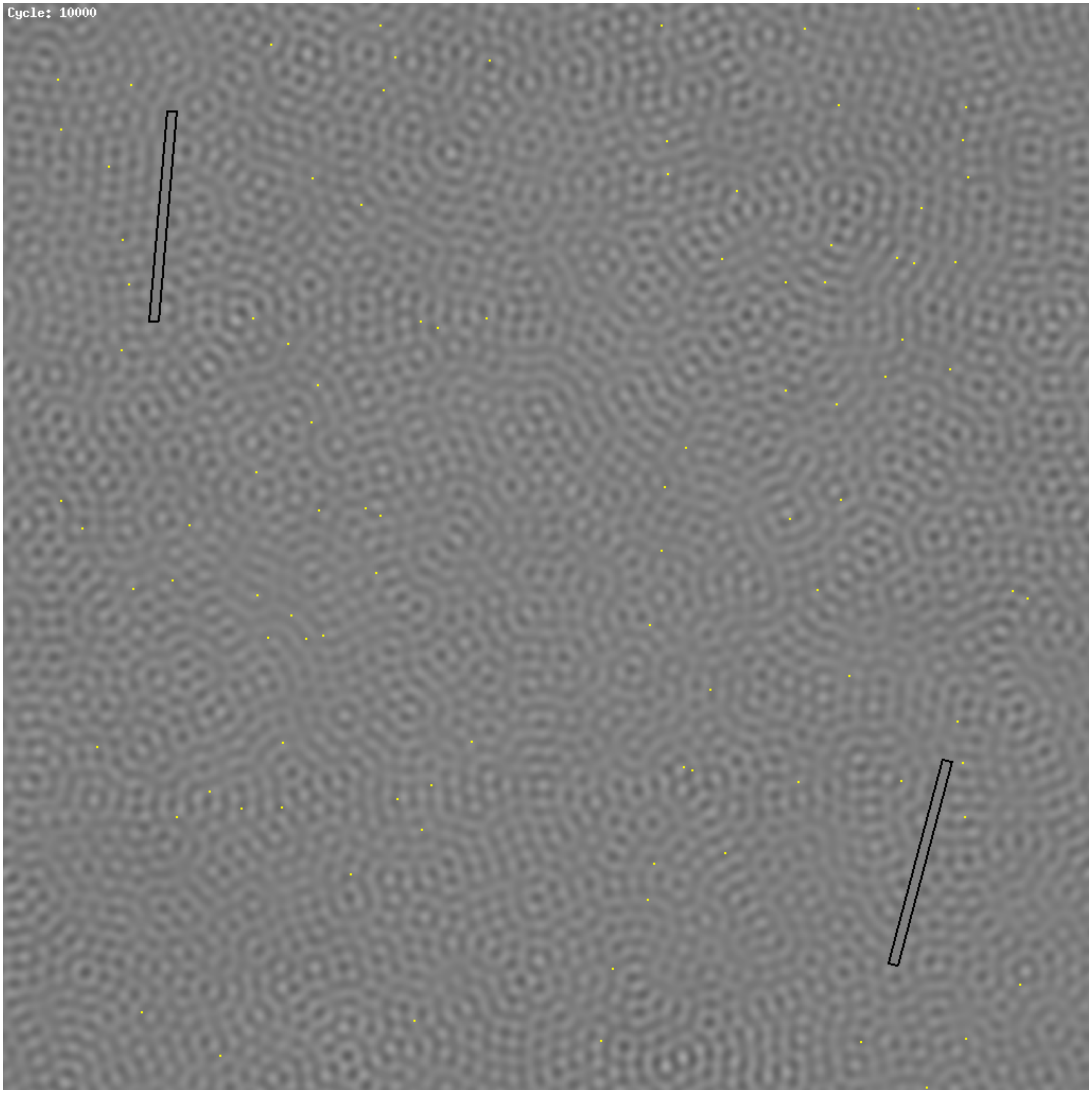



**Image 3**: State of the wave field after 10000 elementary propagation cycles.

We notice that the configuration of the interference field evolved completely differently from that of experiment 1.
The field amplitude is different for most points in space between experiments 1 and 2, and the cause is only the rotation of B.

**5. Evaluation of correlations between measurement points A and B**.

The display of the correlation amplitudes E(i,j) between each point A(i) and B(j) is done on a two-color 2D graph. (i,j between [1..50])
Color intensity represents the intensity of E, a black color represents zero correlations (E = 0).

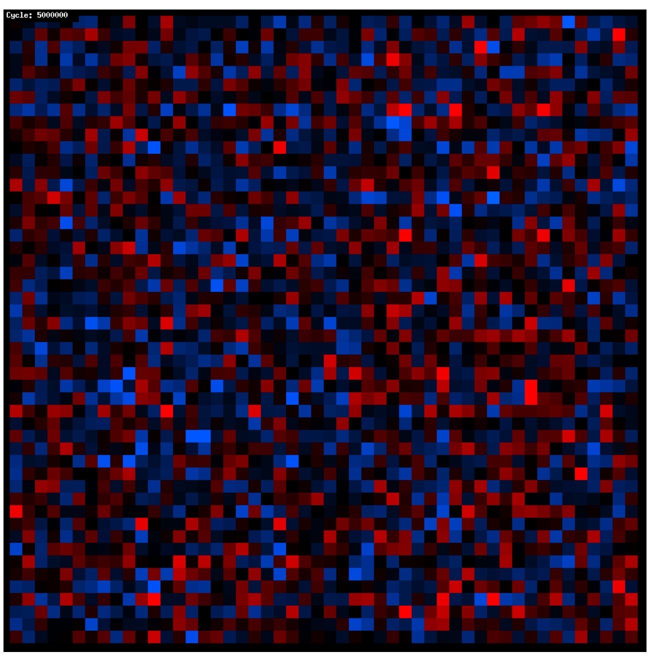
E varies between approximately -0.1 (light blue) and +0.1 (light red), which is a fairly small but nonetheless significant value despite the simple method used to produce the binary value +1/-1 using only the sign of the local amplitude of the field.

The displayed image represents the values of E after 5 million measurements.
Convergence towards a stable state begins to be observable from around 250,000 elementary propagation cycles.
Very close images are obtained using 5 times 1 million measurements. This verifies that convergence to the same state always occurs.

In order to verify that correlations persist by making measurements shifted in time, the measurement of B is made after that of A with a constant delay of 25,000 field propagation cycles.

This value can be changed, however the convergence configuration of the E values depends on this delay value.

**Correlation results**.



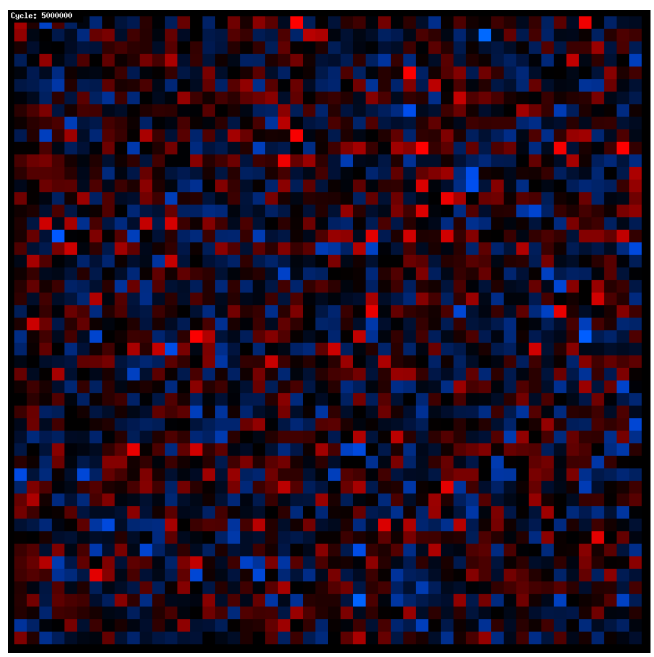




**Image 4**: Results of correlations between points A and B of the two experiments. (left exp.1, right exp.2)

Stable correlations are measured between points A and B in space.
They are different for the two experimental configurations.

**Conclusion**.

The evolution of an interference field of constant energy contained in a closed space makes it possible to produce, from the local state of the field, values of random appearances but producing non-zero correlations between distant points in space and time.

The interference configuration of this field evolves in a specific way depending on the configuration of the shapes and positions of the objects contained in space.

Thus the amplitude of the correlations measured between two points depends on the positions of the measured points, the measurement delay between the points, as well as the spatial configuration of the objects present in space.

This latter dependence can then be called "experimental context".

If we assume that this field is capable of locally affecting certain physical interactions, then no local measurement can be considered independent of the experimental context, and non-zero correlations can be obtained between distant points in space without requiring influence between measured particles.

This contextual dependence of measurements is sufficient to explain a violation of Bell's inequalities. This is made possible by the contribution of local information contained in the context field.

The existence of this type of field makes it possible to consider a realistic and local physics.

**References.**

[1] The optimal phase of the generalised Poincare dodecahedral space hypothesis implied by the spatial cross-correlation function of the WMAP sky maps.
https://arxiv.org/abs/0801.0006

[2] A new analysis of the Poincaré dodecahedral space model.
https://arxiv.org/pdf/0705.0217.pdf

**Appendix**.

[3] Videos showing the establishment and evolution of the field.
http://pierrel5.free.fr/physique/q_field/q_field.html

[4] Technical notes on the simulation.
The calculation was carried out with a parallelized wave propagation algorithm and executed on an 8-core processor. The simulation time of the 2D space used in this document, containing 1024^2 elementary units of space, then requires approximately 1h30 of calculation to define the raw data for the two experimental configurations each using 5 million measurements.
A 3D simulation in a cubic space of size 1024^3 on the same hardware would take at least 2 months and probably much longer.
However, perhaps a 3D simulation could be achieved in a reasonable time using GPU computing.

Version 1.0 12/19/2023