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Causality and Local Determinism versus Quantum Nonlocality

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Intro

It was shown by many authors that the violation of Bell Inequalities had not provided any proof of the non- locality of quantum theory . Strangely enough these results seem to be neglected.

MORE :
http://w4.uqo.ca/kupcma01/homepage.htm

Quantum Nonlocality

Quantum nonlocality , whereby particles appear to influence one another instantaneously even though they are widely separated , is one of the most remarkable phenomena known to modern science Today it is a well established experimental fact.

Correlations are coming out of space time.

False Paradox

- We roll a pair of dice. Each die on its own is random and fair, but its entangled partner somehow always gives the correct matching outcome. (Impossible!)
- R.Feynman : "Nobody understands quantum mechanics"

IF WE CONTINUE TO USE IMPRECISE LANGUAGE AND INCORRECT MENTAL IMAGES AND ANALOGIES NOBODY WIL EVER DO (MK).

REAL NATURE MAGIC

Migratory patterns from Ontario to Mexico coded deterministically in genes?

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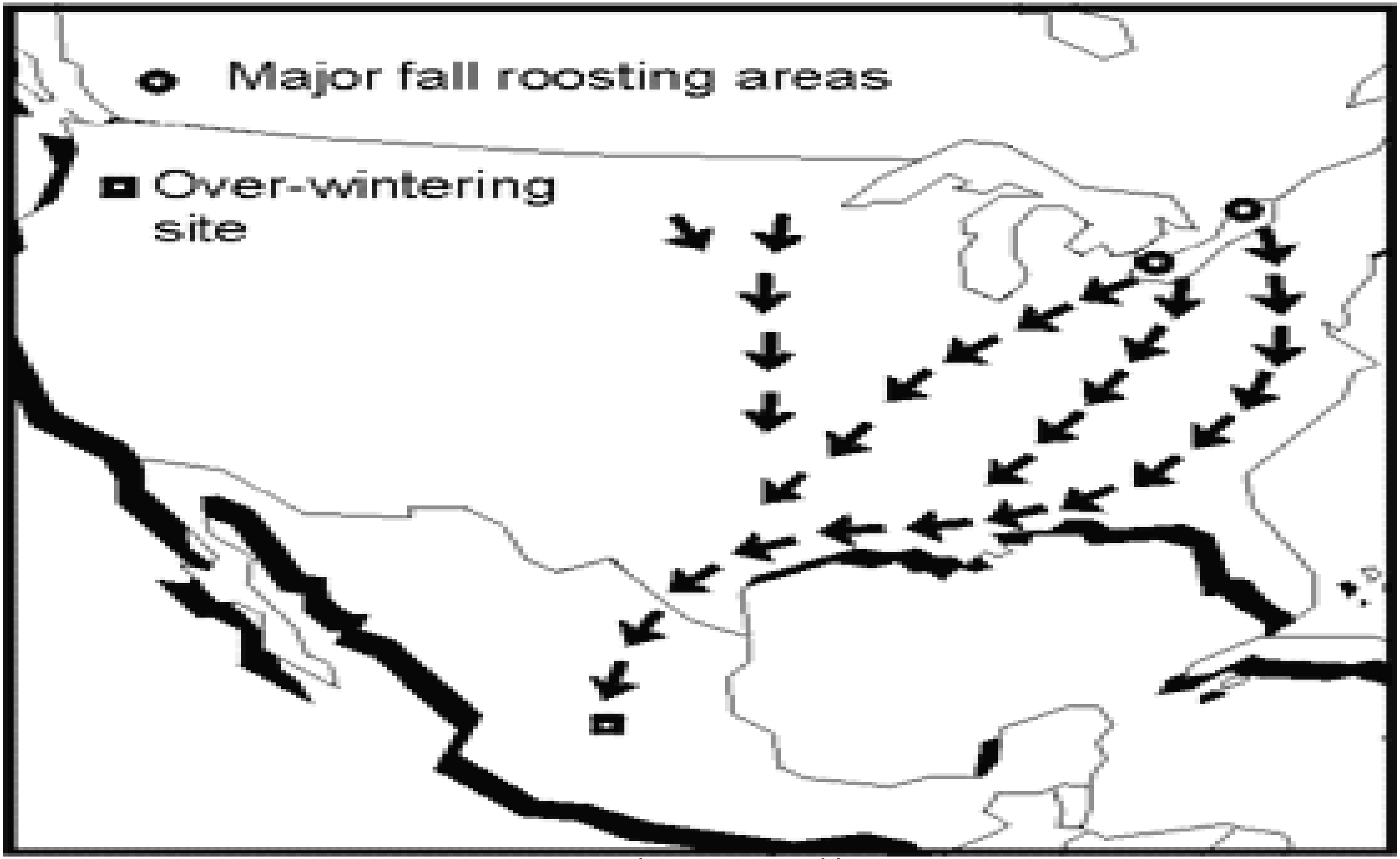
3000km Migration Routes



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Wintering in Mexico

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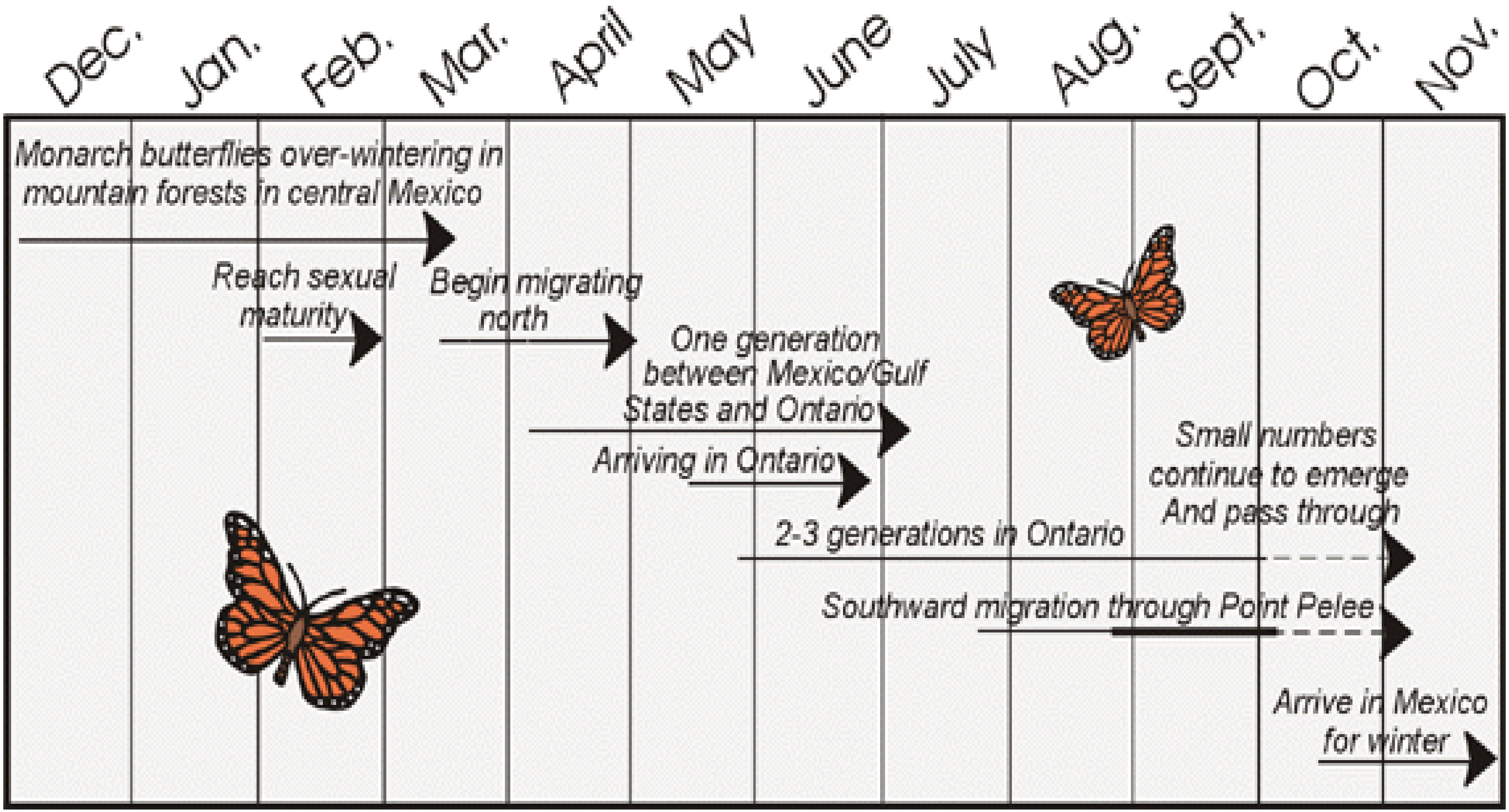
MONARCH MIGRATION CALENDAR



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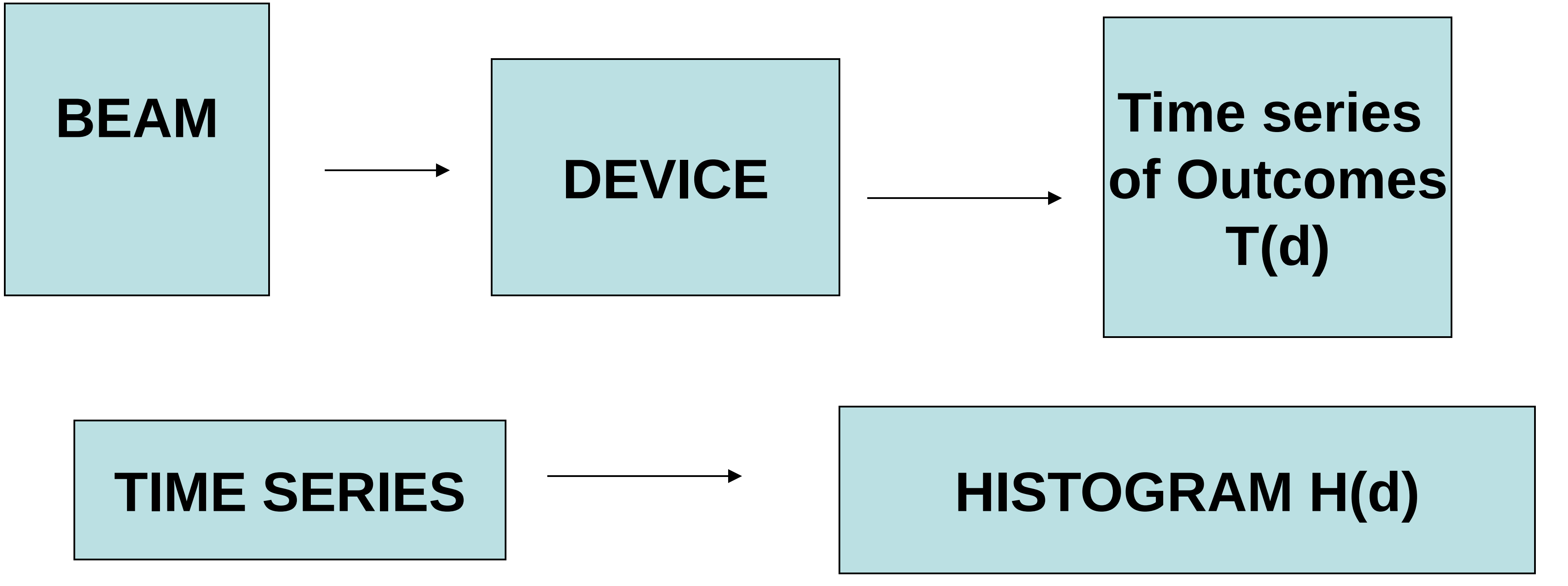
Main points of this talk

1. QT is a statistical theory describing phenomena and not individual systems having attributive properties.
2. The probabilistic models used to prove Bell inequalities are inappropriate for the description of the spin polarization correlation experiments (SPCE).
3. The correlations in SPCE indicate that the

``Nature is not playing dice``→Migration

4. QT is an emerging theory perhaps it is not predictably complete and we can test it.

Typical Experimental DATA



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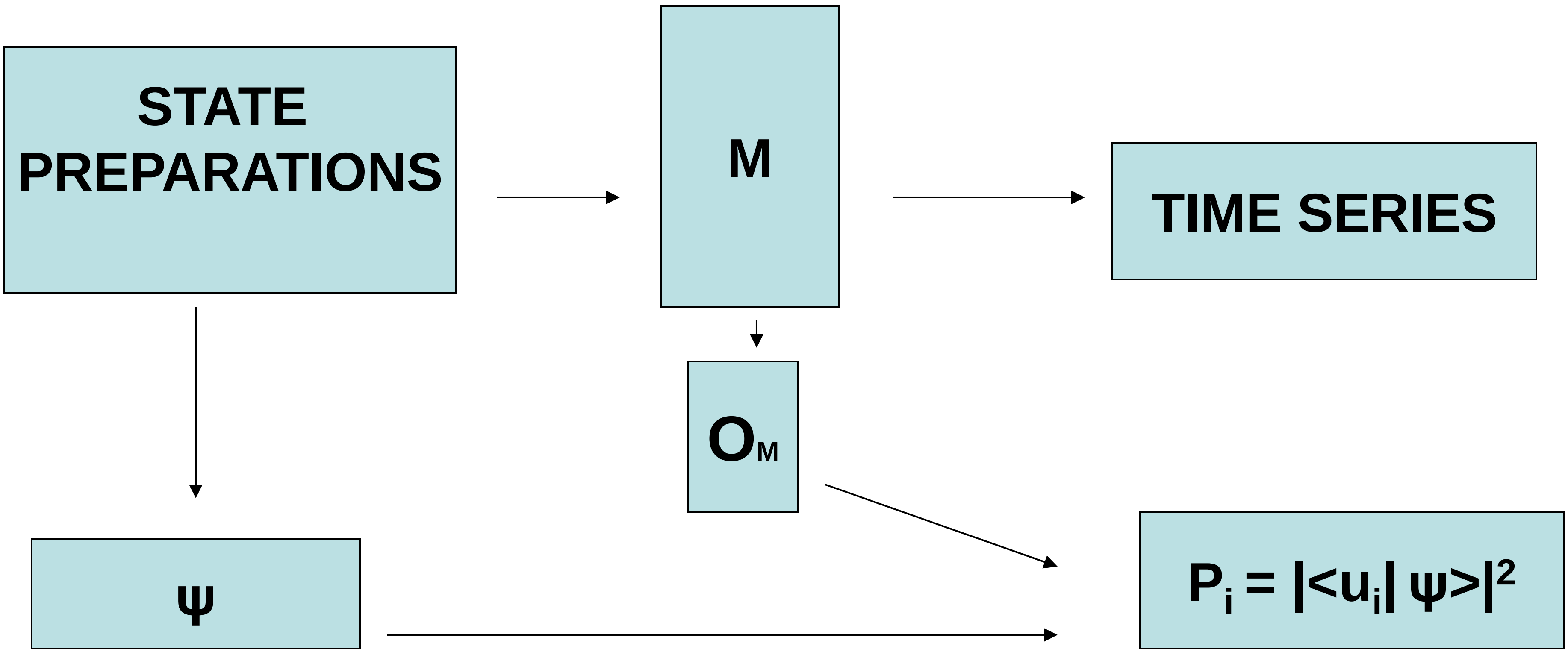
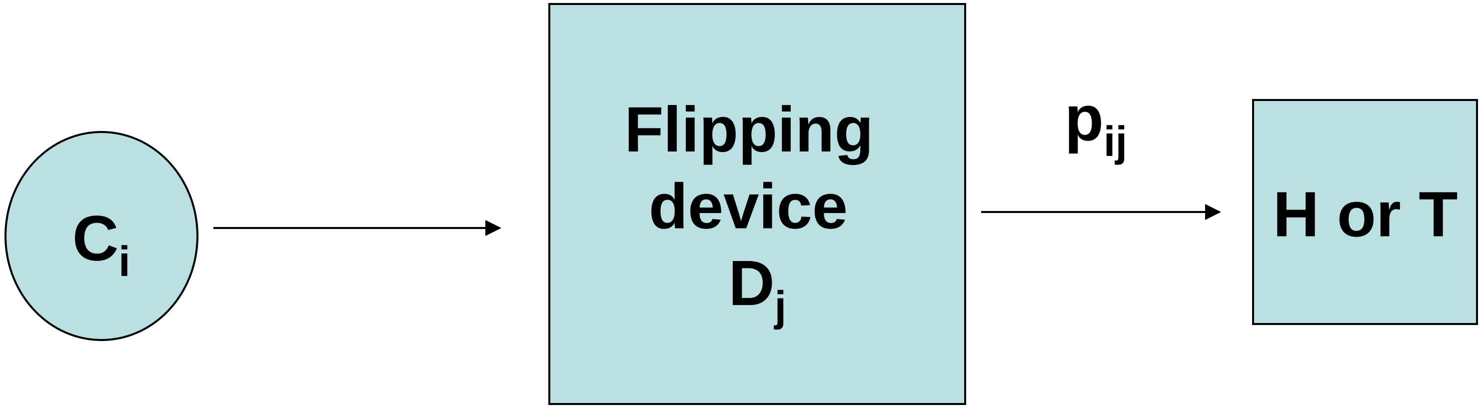


Does it provide a complete description ?

Probability is a "property" of a random experiment

A probability p_{ij} is neither a property of the coin nor a property of the flipping device D_j it characterizes only a particular random experiment:" Flipping C_i with a device D_J"



CONCLUSION

QT GIVES PROBABILISTIC PREDICTIONS FOR :

- distribution of the results obtained in long runs of one experiment

- distribution of the results for several repetitions of the same experiment on a "single system"

- QT is an abstract statistical and contextual theory

EINSTEIN

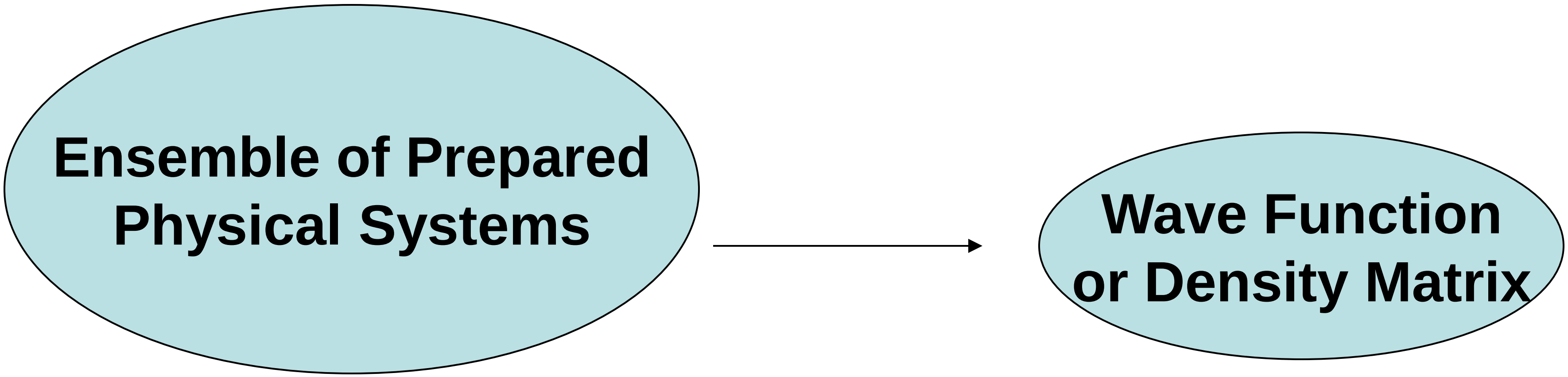
- The essentially statistical character of contemporary quantum theory is solely ascribed to the fact that (this theory) operates with an incomplete description of physical systems

- Ψ function does not, in any sense, describe the state of one single system

- God does not play dice

STATISTICAL INTERPRETATION

IDENTICAL STATE PREPARATIONS REPEATED



Irreducible randomness in QM

- Any measurement causes the system to jump into one of the eigenstates of the dynamical variable that is being measured.
- If a jump occurs only the probabilities of obtaining particular experimental result can be calculated in the theory.
- Outcomes of measurements performed on two separated physical systems are uncorrelated.

EPR-BOHM-MODERN (SPCE)

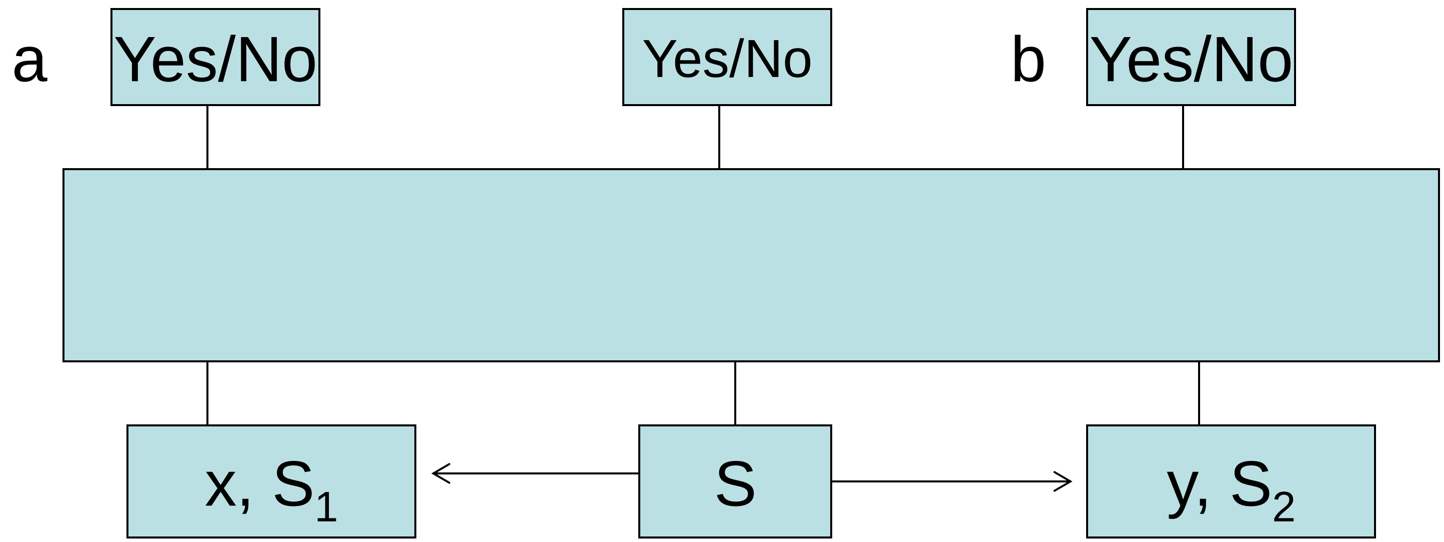
- A pulse of laser hitting the non linear crystal produces two correlated signals propagating in opposite directions.
- When we place polarization analyzers in front of the detectors we obtain two time series of clicks on the far away detectors which are correlated.
- Einstein, Bohm, Bell:

THE CORRELATIONS CRY FOR EXPLANATION

ALL LOCAL MODELS → BELL INEQUALITIES

NOT TRUE

SPCE –STRONG CORRELATIONS



2 correlated signals S_1 and S_2 produced by a source S are hitting the measuring devices x and y producing correlated outcomes a=±1 and b= ± 1

DATA DESCRIPTION

two samples : $\{a_1,a_{2,\ldots}\ a_n\ \ldots\}$ and $\{b_1,b_2,..b_n\ \ldots\}$

math. stat.: observations of two time series of random var. $\{A_1,A_2,\ldots A_n \ldots\}$ and $\{B_1,B_2,B_n \ldots\}$

If all A_i and A are independent and identically distributed (i.i.d) and all B_i and B are i.i.d then the outcomes of the experiments x and y are completely described by the conditional probability distributions

$$P(a,b|x,y)=P(A=a,B=b|x,y,S_1,S_2)$$

$$P(A=a,B=b|x,y,S_1,S_2) \neq P(A=a|x,S_1)\ P(B=b|y,S_2).$$

Pure ens. +irred. randomness→No correl.

If each signal is a pure statistical ensemble for example a beam composed of identical physical systems and the local experiments x and y are causally separated and the outcomes of these measurements are obtained in irreducibly random way then A and B are independent:

$$P(a,b|x,y)= P(a|x)\ P(B=b|y).$$

E(AB)=E(A)E(B) and cov(A,B)=0.

Ex. x: repeated tossing of a the same dice A

y: repeated tossing of a the same dice B

No correlations

Correlations with irr. randomness

Signals are mixed statistical ensemble of correlated physical systems in which each couple ($S_1(\lambda_1)$,$S_2(\lambda_2)$) is included with the probability P(λ) where $\lambda = (\lambda_1, \lambda_2)$ are some parameters describing various components of the mixed statistical ensemble created by S at the moment when they arrive at the measuring instruments.

(1) $$P(a,b \mid x,y) = \sum_{\lambda \in \Lambda} P(\lambda) P(a \mid x, \lambda_1) P(b \mid y, \lambda_2)$$

(2) $$E(AB) = E(AB \mid x,y) = \sum_{\lambda \in \Lambda} P(\lambda)(E(A \mid \lambda_1) E(B \mid \lambda_2)$$

Stochastic hid. variable models and (1) locality assumption

Local realistic hid. variables: LRHC

All properties of the physical systems are determined at the source. In a measurement a particular property is recognized and the binary outcome recorded. A mixed statistical ensemble of classical physical systems (class. randomness) is created by the source.

(3) $$E(AB) = E(AB \mid x, y) = \sum_{\lambda \in \Lambda} P(\lambda) A(\lambda_1) B(\lambda_2)$$

where A(λ)=±1 and B (λ)=±1, Λ is a unique probability space and P(λ) is a joint probability distribution of the ontic properties not depending on the choice of (x,y).

Bertelsmann's socks model!

CHSH and Bell Inequalities

Using Eq. 2 or Eq. 3 with $|E(A|\lambda_1|\leq 1$, $|E(A|\lambda_2) \leq 1|$ one can easily prove CHSH inequalities:

$$|E(AB) - E(AB')| + |E(A'B) + E(A'B')| \leq 2$$

where the random variables A' and B' correspond to the modified experiments x' , y' which for SPCE are incompatible with x and y.

The inequalities are violated in SPCE $\longrightarrow$ Nonlocality?

NON!

What is the randomness

Knowing past events we cannot predict future events.

Classical randomness: fair coin flipping, stock market price

reducible: the laws of Nature are deterministic: if we could control relevant factors we would predict all the outcomes.

Quantum randomness: spin projection, time of decay irreducible: the laws of Nature are not deterministic it is impossible to explain and predict outcomes in causal way.

Experimental randomness: a time series of outcomes satisfies all statistical criteria of randomness.

Perfect correlations of random local data

-111-11-1-1-1.. ⟵ x ⟵ S ⟶ y ⟶ 1-1-11-1111..

1. Spooky action at the distance between x and y

2. Correl. coming out of space-time (quant. magic)

3. Passive measurements not destroying the correlations (LRHC) created at the source.. Mixed ensembles of Bertelsmann's socks)

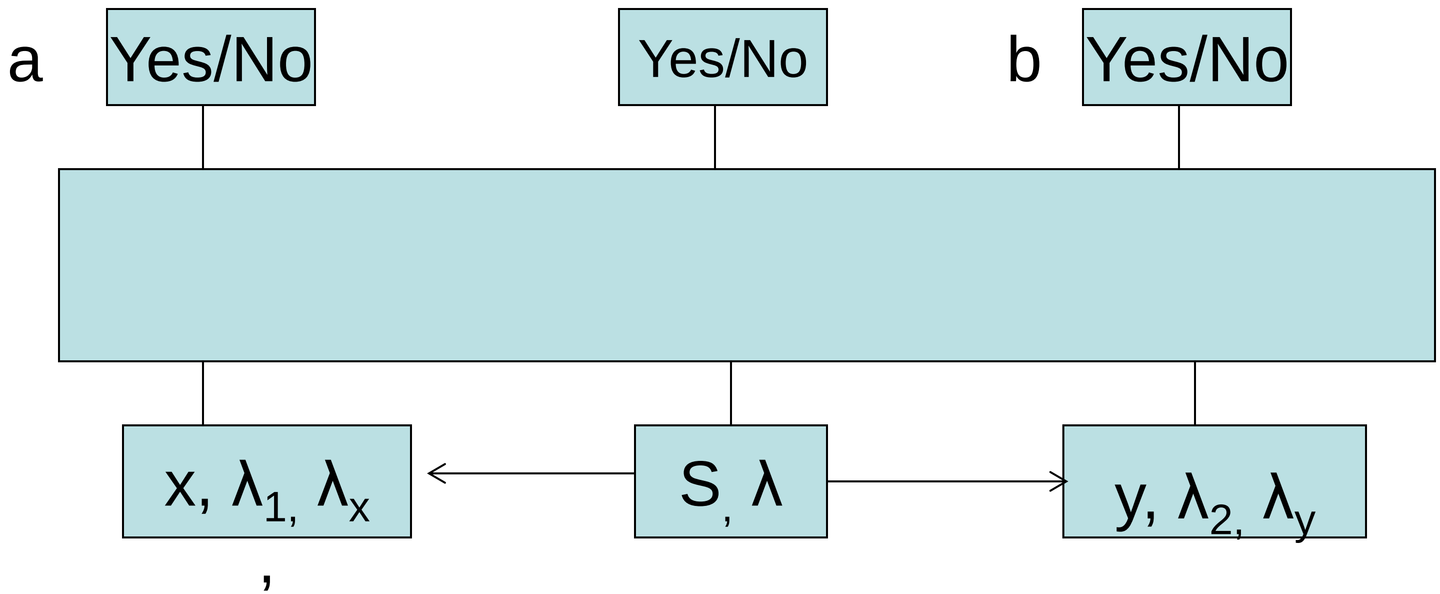
Imperfect correlations

-111-11-1-1-1.. ⟵ x ⟵ S ⟶ y ⟶ 1-1111-11-1-..

1. Stochastic hidden variable models (mixed ensembles of fair dice).

2. Correlated signals created by the source . Partial memory kept during the travel to the measuring devices (x,y). Outcomes are not predetermined but are created during the measurements. Contextuality + local determinism .

STRONG CORRELATIONS EXPLAINED



a=±1 is <u>determined</u> in local deterministic way by the values of λ_1 and λ_x describing the signal S_1 and the measuring device x in a moment of measurement. In a similar way are produced b= ± 1

Imperfect corr.→ explanation

$$E(AB) = E(AB \mid x, y) = \sum_{\lambda \in \Lambda_{xy}} P(\lambda) A(\lambda_1, \lambda_x) B(\lambda_2, \lambda_y)$$

where $A(\lambda_1, \lambda_x) = \pm 1$ and $B(\lambda_2, \lambda_y) = \pm 1$

$$P(\lambda) = P(\lambda_1, \lambda_2) P_x(\lambda_x) P_y(\lambda_y)$$

Now there is no common probability space Λ and Λ_{xy} are different probability spaces for each pair (x,y) .

It is impossible to prove CHSH and Bell inequal.!

CHSH-BELL PROOFS

THE EXISTENCE OF A COMMON PROBABILITY TAKEN FOR GRANTED

$$\Lambda_{xy} \neq \Lambda_{x'y} \neq \Lambda_{xy'} \neq \Lambda_{x'y'} \neq \Lambda$$

FATAL CONTEXTUALITY LOOPHOLE

Marian Kupczynski

It was noticed by :

Accardi, Fine, Hess, Khrennikov, M.K, Michielsen, de Muynck, Niewenhuizen,Pitovsky, Philipp, De Raedt,…

Vorob'ev (1962): 'Is it possible to construct always the joint probability distribution for any triple of only pairwise measurable observables?' NON.

Quantum information community cannot or does not want to understand it.

Magic sells better?

COCLUSIONS

VIOLATION OF B- CHSH

↓

NO IRRED. RANDOMNESS

↓

EMERGENT QT

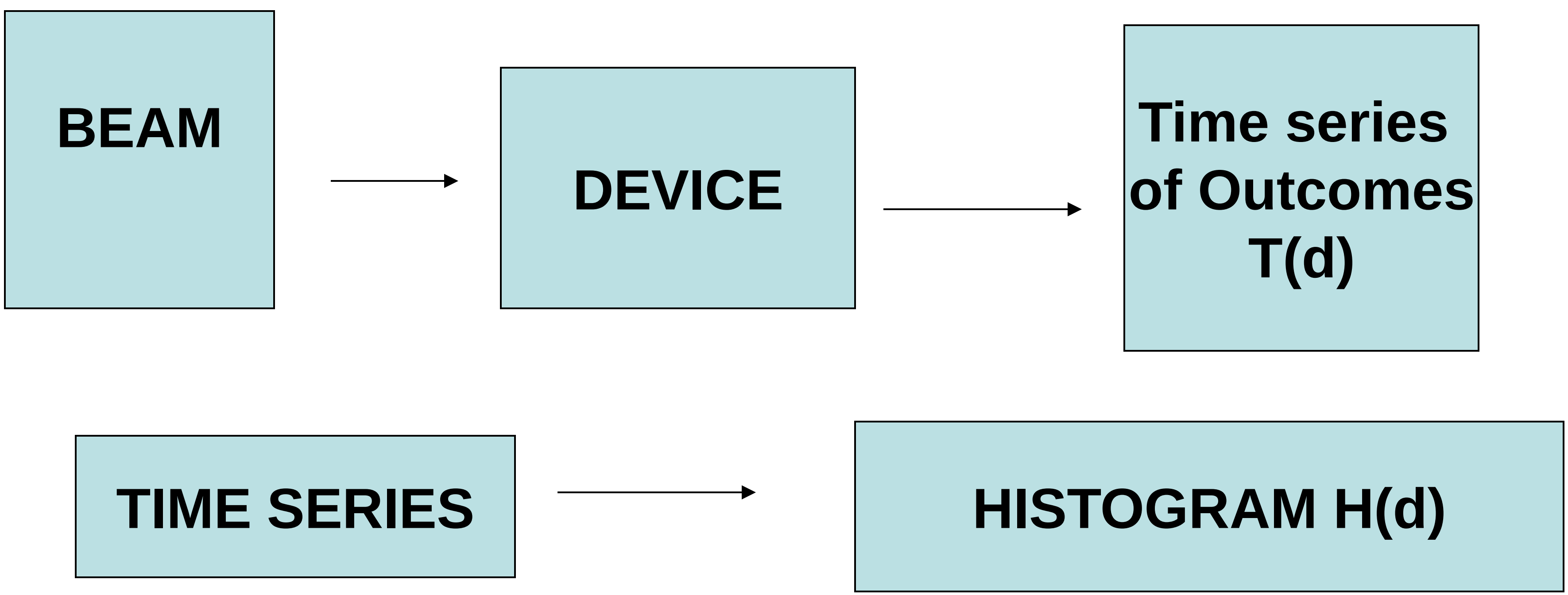
Correlations→EMQ→

(1)Each pure quantum statistical ensemble is a mixed statistical ensemble

(2) Perhaps that there is more information in the data than predicted by QT.

(3) Is QT is predictably complete?

Typical Experimental DATA



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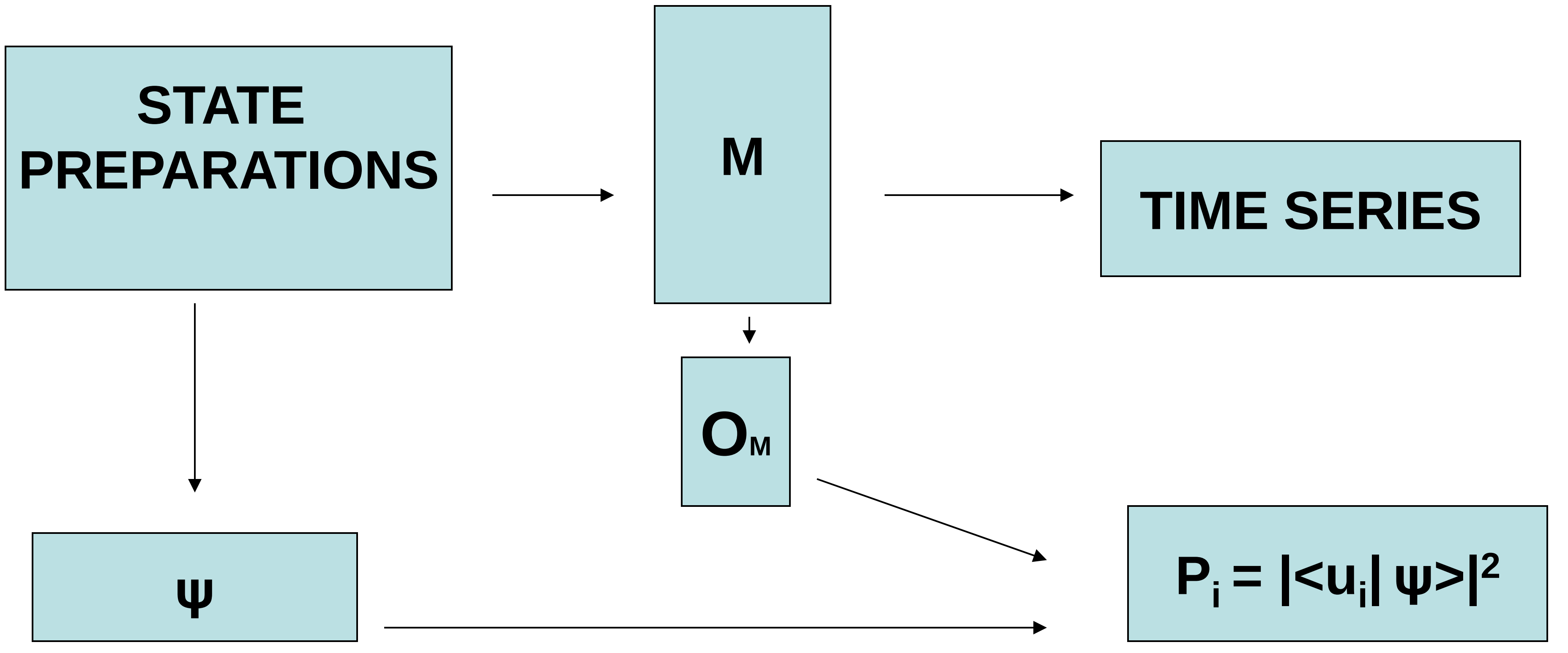


Does it provide a complete description of the data?

Purity tests to test completeness of QT

- If the mixture is not perfect then by changing the intensity or geometry of the beams we may obtain a sub- ensembles having slightly different properties than the initial ensemble?

- Using purity tests we may detect this effect

MK(1986,2002)

DATA DESCRIPTION BY QT

two samples : $\{a_1,a_{2,\ldots}\ a_n\ _{\ldots}\}$ and $\{b_1,b_2,..b_n\ _{\ldots}\}$

math. stat.: observations of two time series of random variables $\{A_1,A_2,..A_n\ ..\}$ and $\{B_1,B_2,..B_n\ ..\}$

If all A_i and A are independent and identically distributed (i.i.d) and all B_i and B are i.i.d then the outcomes of the experiments x and y are completely described by the conditional probability distributions

$$P(a,b|x,y)=P(A=a,B=b|x,y,S_1,S_2)$$

GENERAL TIME SERIES DATA

two samples : $\{a_1, a_{2,\ldots}\ a_n\ \ldots\}$ and $\{b_1, b_2, ..b_n\ \ldots\}$

math. stat.: observations of two time series of random variables $\{A_1, A_2, \ldots A_n \ldots\}$ and $\{B_1, B_2, B_n \ldots\}$

If all A_i and A are not independent and identically distributed (i.i.d) and all B_i and B are not i.i.d then the outcomes of the experiments x and y are not completely described by the conditional probability distributions

Fine structure of TS

- Let us consider a random experiment which can give only two outcomes: 1 or -1.

  1,-1,1,-1,...,1,-1.,…

- By increasing the value of n the relative frequency of getting 1 can approach 1/2 as close as we wish. However it is not a complete description of the time series.

Fine structure of TS

- Another example could be:

1,-1,-1,-1,1,1,-1,-1,1,1,1,-1,1,-1,-1,-1,1,1

- The probability distribution does not provide the complete description of these time series of the data.

Descriptive Statistcs-Histograms

All fine stochastic structure is destroyed

Is QT predictably complete?

- If the answer is yes it means that the time series of experimental data are completely described by the probability distributions given by QT?

- IT HAS TO BE TESTED AND NOT TAKEN FOR GRANTED?

- PURITY TESTS OR TIME SERIES ANALYSIS.

VISUALISING CORRELATIONS IN AUTOREGRESSIVE TIME-SERIES

- SIMPLE TIME SERIES PLOTS :(z_t ,t)
- LAGGED SCATTER PLOTS $((z_t , z_{t+k})$
- SAMPLE ACF PLOTS
- SAMPLE PAC PLOTS
- RESIDUALS PLOTS

a) ACF

b) HISTOGRAM

c) NORMAL SCORES

Example

We simulated a sample of size 500 of AR(2):

$$Z_t - 0.25_1\, Z_{t-1} - 0.5\, Z_{t-2} = a_t$$

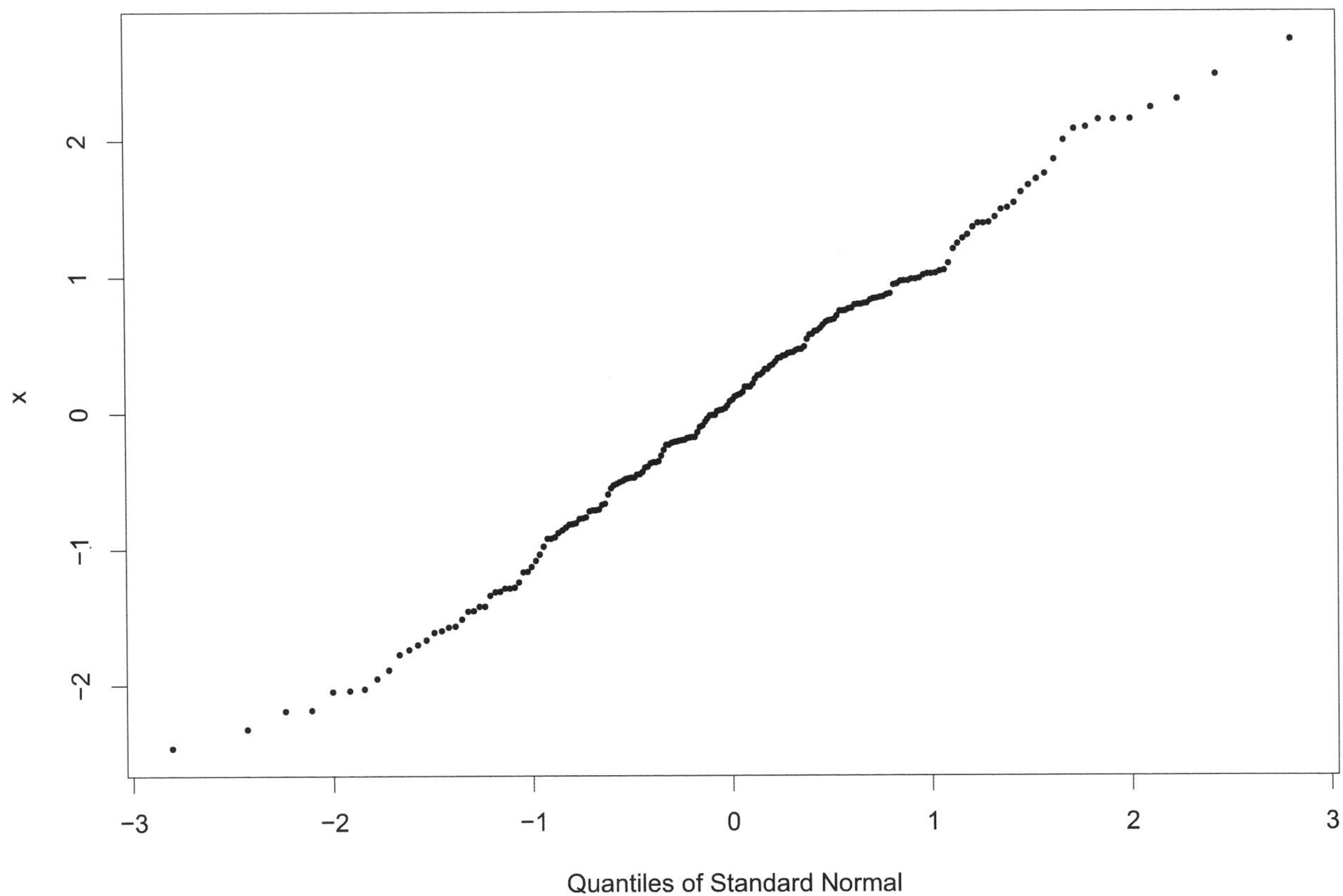
Where a_t were normal i.i.d with unit variance

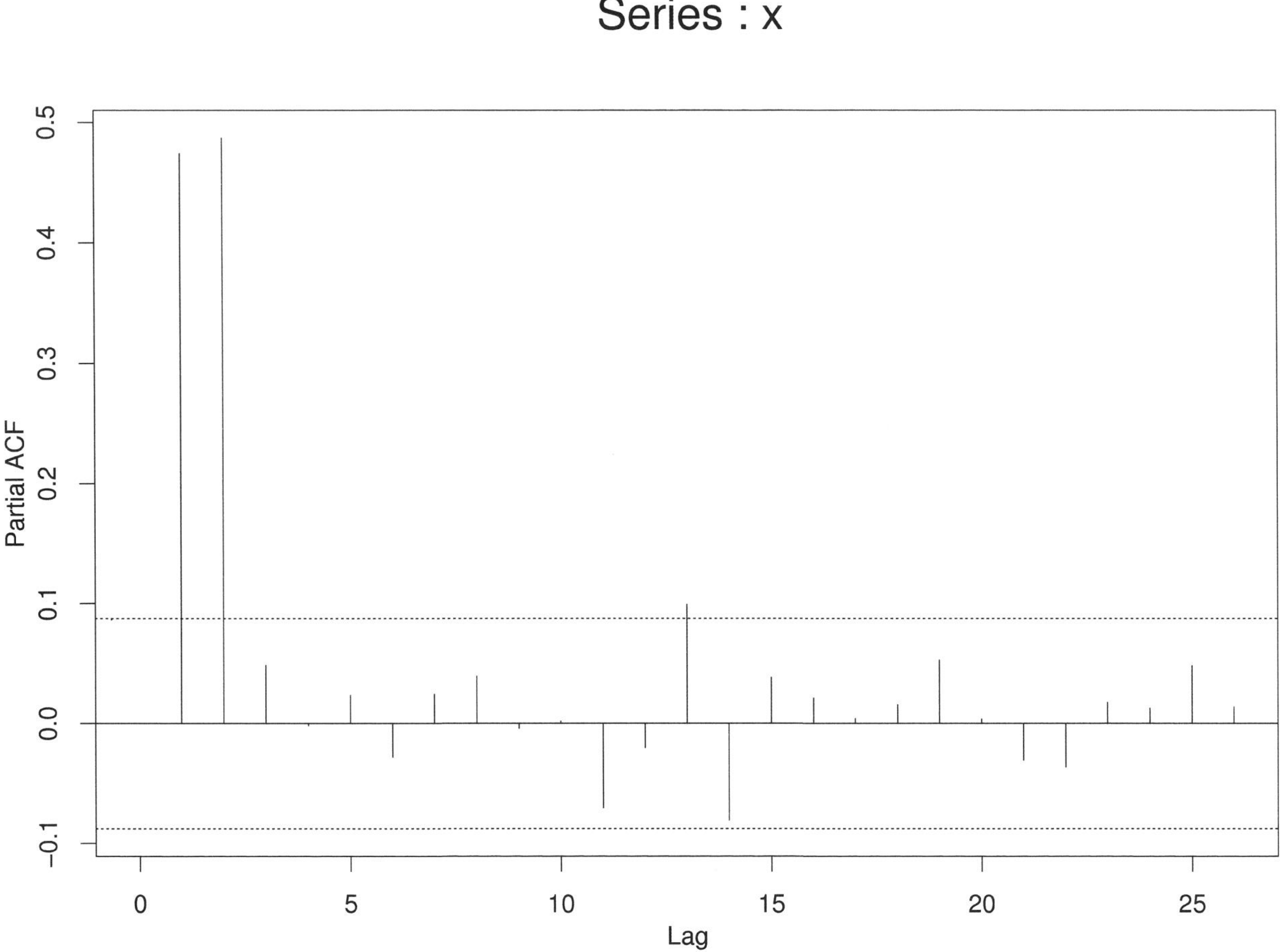
Standard descriptive analysis:

histogram, normal scores and summary

showed that the data can be viewed as a sample from some normally distributed population.

Only the detailed time–series analysis allowed to discover a fine structure in the data


x
2
1
0
−1
−2
−3
−2
−1
0
1
2
3
Quantiles of Standard Normal


Series : x
Partial ACF
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
0
5
10
15
20
25
Lag

COCLUSIONS

VIOLATION OF B- CHSH

↓

NO IRRED. RANDOMNESS

↓

EMERGENT QT

NATURE DOES NOT PLAY DICE

Marian Kupczynski

Completeness

Is QT predictably complete ?

It is an open question!

MORE :

http://w4.uqo.ca/kupcma01/homepage.htm

NIELS BOHR

Strictly speaking , the mathematical formalism of quantum mechanics and electrodynamics merely offers rules of calculation for the deduction of expectations pertaining to observations obtained under well-defined experimental conditions specified by classical physical concepts