Linnæus University
Sweden

Quantum Information Revolution: Impact to Foundations? (QIRIF?)
10-13 June, 2019

Yet Another Statistical Analysis of the data of the (2015)

"Loophole-Free" Bell-CHSH Experiments

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¿QIRIF‽ Växjö, Wednesday 12 June 2019

"I'm sorry I wrote you such a long letter; I didn't have time to write a short one."

Overview

- Part 1

    A novel “optimal” statistical data analysis of loophole-free experiments

- Part 2

    Discussion: ¿ QIR - IF ?

- Part 3

    Conclusion: ¿QIR - IF ⸮

Part 1

“Optimal” statistical data analysis of loophole-free experiments

Yet another statistical analysis of the data of the 'loophole free' experiments of 2015

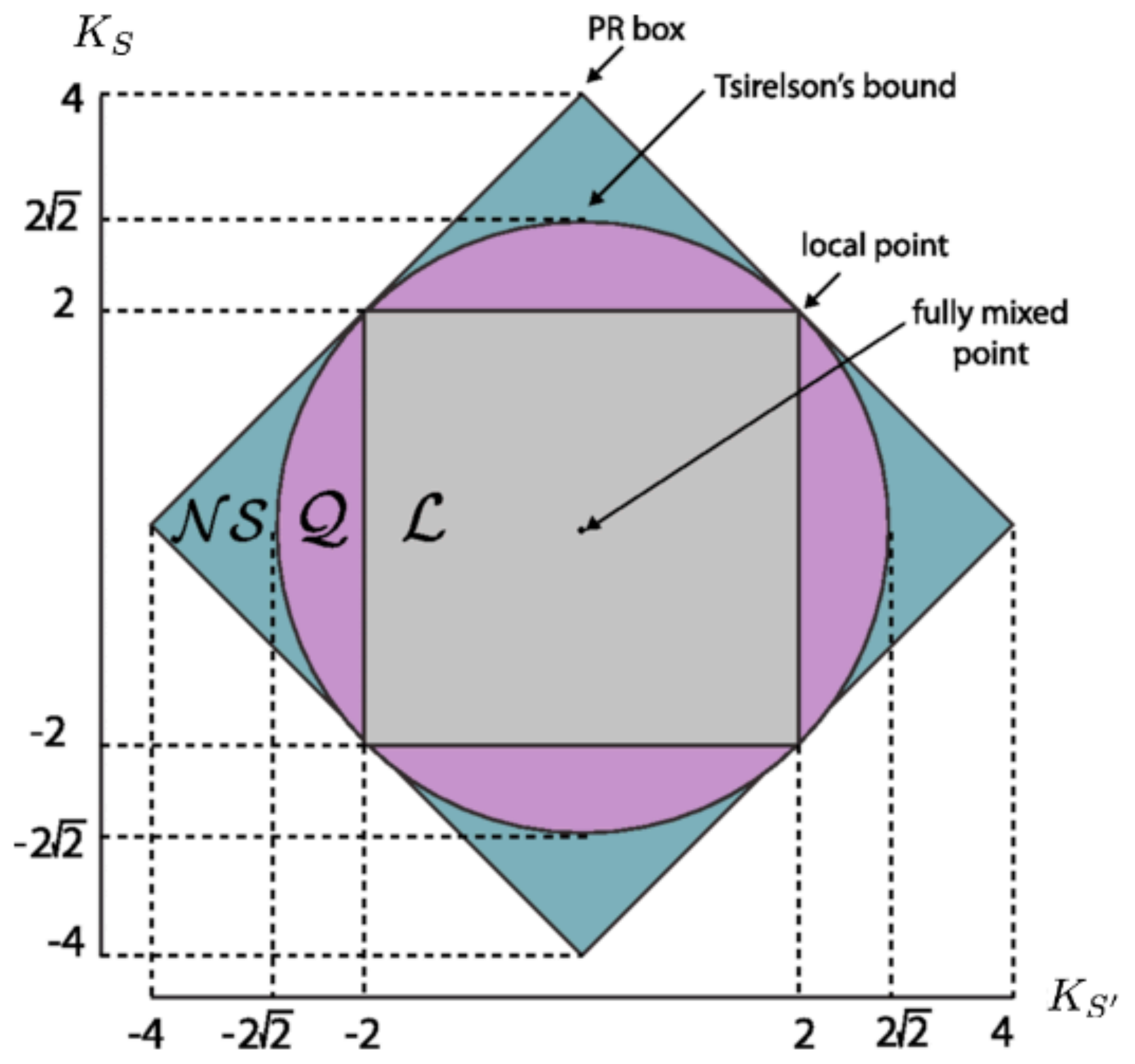
I present novel statistical analyses of the data of the famous Bell-inequality experiments of 2015 and 2016: Delft, NIST, Vienna and Munich. Every statistical analysis relies on statistical assumptions. I'll make the traditional, but questionable, i.i.d. assumptions. They justify a novel (?) analysis which is both simple and (close to) optimal.

It enables us to fairly compare the results of the two main types of experiments: NIST and Vienna CH-Eberhard "one-channel" experiment with settings and state chosen to optimise the handling of the detection loophole (detector efficiency > 66.7%); Delft and Munich CHSH "two channel" experiments based on entanglement swapping, with the state and settings which achieve the Tsirelson bound (detector efficiency ≈ 100%).

One cannot say which type of experiment is better without agreeing on how to compromise between the desires to obtain high statistical significance and high physical significance. Moreover, robustness to deviations from traditional assumptions is also an issue

The local polytope

- The local polytope of a 2x2x2 experiment has exactly 8 facets, A. Fine (1982).
- They are the 8 one-sided CHSH inequalities
- They are necessary and sufficient for LR.
  There are no other 2x2x2 inequalities!
- CH, Eberhard, J are therefore *just* different ways
  to write CHSH !
- Yet with experimental data they give different results !?



The diagram should be imagined as drawn on a plane in a higher dimensional space
The experimental data is a point close to, but not on, the plane

“One channel” experiment

VIENNA data

Raw counts

		Settings			
		11	**12**	**21**	**22**
Outcomes	**dd**	141.439	146.831	158.338	8.392
	dn	73.391	67.941	425.067	576.445
	nd	76.224	326.768	58.742	463.985
	nn	875.392.736	874.976.534	875.239.860	874.651.457
	Totals	875.683.790	875.518.074	875.882.007	875.700.279

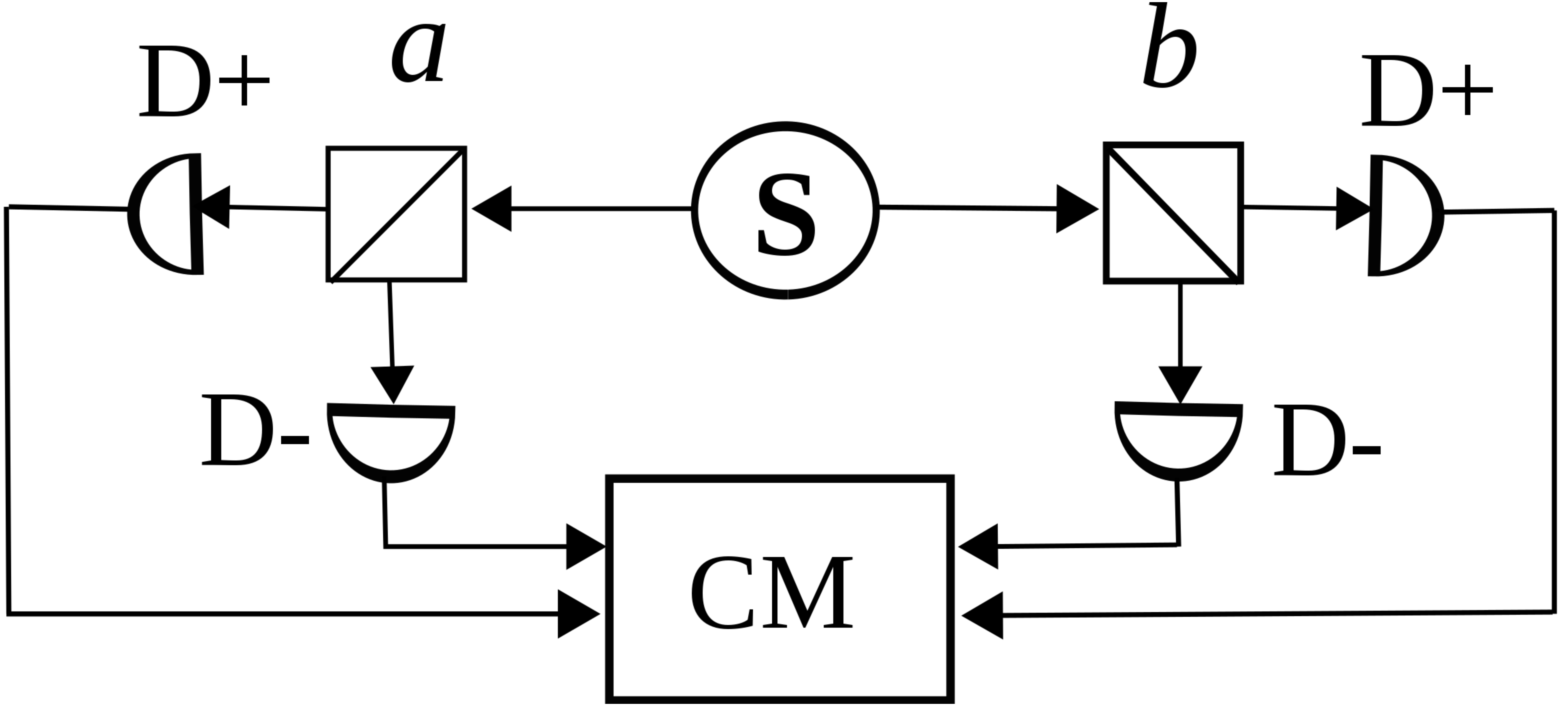
Normalised counts

		Settings			
		11	**12**	**21**	**22**
Outcomes	**dd**	162	168	181	10
	dn	84	78	485	658
	nd	87	373	67	530
	nn	999.668	999.381	999.267	998.802
	Totals	1.000.000	1.000.000	1.000.000	1.000.000

Normaliser			**Normalised**		
1.000.000		1.000.000	1.000.000	1.000.000	1.000.000

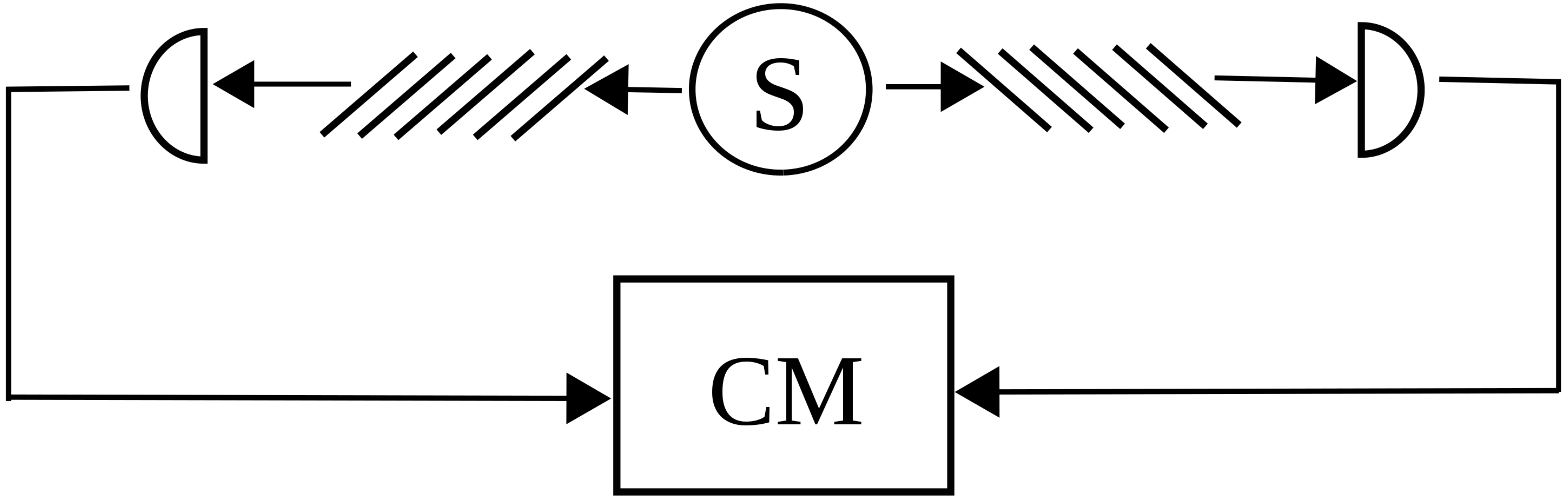
“d” = detection, “n” = no detection

“Two channel” experiment (CHSH - Aspect, Weihs, …, Delft, Munich)



Clocked experiment: outcomes on each side are “+”,”–“, or “0”

“One channel” experiment (Clauser-Horne, Eberhard, Vienna, NIST)



Outcomes on each side are “d” corresponding to “+” and “n” corresponding to “–” or “0”

Peter Bierhorst

¿ $S = 2 + 4J$?
¿ $J = (S - 2)/4$?

Lawrence Berkeley National Laboratory

Location
Berkeley, United States

Department
Physics Division

Position
Retired Senior staff

Philippe Eberhard

- The experiments in Vienna and at NIST (Boulder, Colorado) do *not* use the singlet state

- They exploit the fact that QM *can* violate CHSH from 66% detector efficiency

Jason Semitecolos

Jan-Åke Larsson

  - Clauser-Horne (1974)
  - Philippe H. Eberhard (1993) — **Experimental mathematics !!!**
  - Jan-Åke Larsson and Jason Semitecolos (2001) — **Proof !!!**
  - Peter Bierhorst (2016), “Geometric decompositions of Bell polytopes with practical applications”, *Journal of Physics A: Mathematical and Theoretical* — **Proof !!! (a very different one)**

P.H. Eberhard (1993)

The vector ψ turned out to be of the form

$$\psi = \frac{1}{2\sqrt{1+r^2}} \begin{vmatrix} (1+r)e^{-i\omega} \\ -(1-r) \\ -(1-r) \\ (1+r)e^{i\omega} \end{vmatrix} , \qquad (31)$$

which can be reached in the two-photon experiment considered in this paper by first superposing states $|\leftrightarrow\updownarrow>$ and $|\updownarrow\leftrightarrow>$ in unequal amounts,

$$\psi_0 = (1/\sqrt{1+r^2}) \left(|\leftrightarrow\updownarrow> + r\,|\updownarrow\leftrightarrow> \right) , \qquad (32)$$

then rotating the planes of polarization of a and of b in setup (α_1, β_1) by the angles

$$\alpha_1 = (\omega/2) - 90^\circ , \qquad (33)$$

$$\beta_1 = \omega/2 , \qquad (34)$$

respectively, and using the values of r, ω, and $\alpha_1 - \alpha_2$ $(\equiv \beta_1 - \beta_2)$ given in Table II. Note that, for $\eta = 1$, the vector ψ_0 reduces to the value given by Eq. (1), and the angles α_1, α_2, β_1, and β_2 reduce to the values given by Eqs. (2)–(5).

TABLE II. Extreme conditions for a loophole-free experiment.

η (%)	ζ (%)	r	ω (deg)	$\alpha_1 - \alpha_2$ (deg)
66.7	0.00	0.001	0.0	2.2
70	0.02	0.136	3.4	21.4
75	0.31	0.311	9.7	32.0
80	1.10	0.465	14.9	37.9
85	2.48	0.608	18.6	41.5
90	4.50	0.741	20.9	43.6
95	7.12	0.871	22.1	44.7
100	10.36	1.000	22.5	45.0

Theoretical no-signalling probabilities, × 4 // Observed relative frequencies, × 10^6

	Outcomes	Bob Setting 1 “ d ”	Bob Setting 1 “ n “		Bob Setting 2 “ d ”	Bob Setting 2 “ n “	
Alice Setting 1	“ d ”	1 + a1 + b1 + z11	1 + a1 – b1 – z11	2 + 2 a1	1 + a1 + b2 + z12	1 + a1 – b2 – z12	2 + 2 a1
	“ n “	1 – a1 + b1 – z11	1 – a1 – b1 + z11	2 – 2 a1	1 – a1 + b2 – z12	1 – a1 – b2 + z12	2 – 2 a1
		2 + 2 b1	2 – 2 b1	4	2 + 2 b2	2 – 2 b2	4
Alice Setting 2	“ d ”	1 + a2 + b1 + z21	1 + a2 – b1 – z21	2 + 2 a2	1 + a2 + b2 + z22	1 + a2 – b2 – z22	2 + 2 a2
	“ n “	1 – a2 + b1 – z21	1 – a2 – b1 + z21	2 – 2 a2	1 – a2 + b2 – z22	1 – a2 – b2 + z22	2 – 2 a2
		2 + 2 b1	2 – 2 b1	4	2 + 2 b2	2 – 2 b2	4

10 ^ 6 * VIENNA				
	162	84	168	78
	87	999668	373	999381
	181	485	10	658
	67	999267	530	998802

J = 27

S = CHSH = 2,000108

4 rho 11
= (2 + 2 z11) – (2 – 2 z11)
= 4 z11

4 S = 4 CHSH
= 4 (z11 + z12 + z21 – z22)

S = z11 + z12 + z21 – z22
= 2 + 4 J

J = (S - 2) / 4

VIENNA

4 J = (1 + a1 + b1 + z11)
– (1 – a2 + b1 – z21)
– (1 + a1 – b2 – z12)
– (1 + a2 + b2 + z22)
= – 2 + (z11 + z21 + z12 – z22)

4 rho 11 = (2 + 2 z11) – (2 – 2 z11) = 4 z11

4 S = 4 CHSH = 4 (z11 + z12 + z21 – z22)

4 J = (1 + a1 + b1 + z11)
– (1 – a2 + b1 – z21)
– (1 + a1 – b2 – z12)
– (1 + a2 + b2 + z22)
= – 2 + (z11 + z21 + z12 – z22)

S = z11 + z12 + z21 – z22 = 2 + 4 J
J = (S - 2) / 4

Modern approach:
algebraic geometry, computer algebra

Also possible: amusing hybrid solutions
***Also* asymptotically optimal**

Estimation, standard errors, p-values

Routine MLE (Sir R.A. Fisher 1921…)

Log Lik = N(dd|11)log(1 + a1 +b1 +z11) +
… [15 more terms]

Parameters: a1 a2 b1 b2 z11 z12 z21 z22

Get mle of z11 + z21 + z12 – z22

Get estimated standard error of z11 + z21 + z12 – z22 from Fisher information matrix

Asymptotically optimal

[Linear constraints?]

Poor man's solution:
two stage, generalised, least squares
Asymptotically just as good as MLE!

Next ≈6 slides:
The theory

A standard Bell-type experiment with

- two parties,
- two measurement settings per party,
- two possible outcomes per measurement setting per party,

generates a vector of $16 = 4 \times 4$ numbers of outcome combinations per setting combination.

This can be applied to the two-channel experiments with no "no-shows",
<u>and</u> to the one-channel experiments,
<u>and</u> to the two-channel experiments with "-" and "no-show" combined

The four sets of four counts can be thought of as four observations each of a multinomially distributed vector over four categories.

Write X_{ij} for the number of times outcome combination j was observed, when setting combination i was in force.

Let n_i be the total number of trials with the ith setting combination.

The four random vectors $\vec{X}_i = (X_{i1}, X_{i2}, X_{i3}, X_{i4})$, $i = 1, 2, 3, 4$,
are independent each with a Multinomial(n_i; $\vec{p}_i$) distribution,
where $\vec{p}_i = (p_{i1}, p_{i2}, p_{i3}, p_{i4})$.

The 16 probabilities p_{ij} can be estimated by relative frequencies $\widehat{p}_{ij} = X_{ij}/n_i$ which have the following variances and covariances:

$$\mathrm{var}(\widehat{p}_{ij}) = p_{ij}(1 - p_{ij})/n_i,$$

$$\mathrm{cov}(\widehat{p}_{ij}, \widehat{p}_{ij'}) = -p_{ij}p_{ij'}/n_i \quad \text{for } j \neq j',$$

$$\mathrm{cov}(\widehat{p}_{ij}, \widehat{p}_{i'j'}) = 0 \quad \text{for } i \neq i'.$$

The variances and covariances can be arranged in a 16×16 block diagonal matrix Σ of four 4×4 diagonal blocks of non-zero elements.

Arrange the 16 estimated probabilities and their true values correspondingly in (column) vectors of length 16.

I will denote these simply by $\widehat{p}$ and p respectively.

We have $\mathrm{E}(\widehat{p}) = p \in \mathbb{R}^{16}$ and $\mathrm{cov}(\widehat{p}) = \Sigma \in \mathbb{R}^{16\times16}$.

We are interested in the value of one particular linear combination of the p_{ij}, let us denote it by $\theta = a^\top p$.

We know that four other particular linear combinations are identically equal to zero: the so-called no-signalling conditions.

This can be expressed as $B^\top p = 0$ where the 16×4 matrix B contains, as its four columns, the coefficients of the four linear combinations.

We can sensibly estimate θ by $\widehat{\theta} = a^\top \widehat{p} - c^\top B^\top \widehat{p}$ where c is any vector of dimension 4. For whatever choice we make, $\mathrm{E}\widehat{\theta} = \theta$.

We propose to choose c so as to minimise the variance of the estimator. This minimization problem is a well-known problem from statistics and linear algebra ("least squares").

Define

$$\operatorname{var}(a^\top \widehat{p}) = a^\top \Sigma a =: \Sigma_{aa},$$
$$\operatorname{cov}(a^\top \widehat{p}, B^\top \widehat{p}) = a^\top \Sigma B =: \Sigma_{aB},$$
$$\operatorname{var}(B^\top \widehat{p}) = B^\top \Sigma B =: \Sigma_{BB};$$

then the optimal choice for c is

$$c_{\text{opt}} := \Sigma_{aB} \Sigma_{BB}^{-1}$$

leading to the optimal variance

$$\Sigma_{aa} - \Sigma_{aB} \Sigma_{BB}^{-1} \Sigma_{Ba}.$$

In the experimental situation we do not know p in advance, hence also do not know Σ in advance. However we can estimate it in the obvious way ("plug-in") and for $n_i \to \infty$ we will have, just as in the previous section, an asymptotic normal distribution for our "approximately best" Bell inequality estimate, with an asymptotic variance which can be estimated by natural "plug-in" procedure, leading again to asymptotic confidence intervals, estimated standard errors, and so on.

The asymptotic width of **this** confidence interval **is** the smallest possible and correspondingly the number of standard errors deviation from "local realism" the largest possible.

The fact that c is not known in advance does not harm these results.

"two stage (generalised) least squares"

Next ≈10 slides:
Work in progress: the practice

```
table11 <- matrix(c(141439,   73391,   76224,   875392736),
    2, 2, byrow = TRUE,
    dimnames = list(Alice = c("d", "n"), Bob = c("d", "n")))
table12 <- matrix(c(146831,   67941,   326768,   874976534),
    2, 2, byrow = TRUE,
    dimnames = list(Alice = c("d", "n"), Bob = c("d", "n")))
table21 <- matrix(c(158338,   425067,   58742,   875239860),
    2, 2, byrow = TRUE,
    dimnames = list(Alice = c("d", "n"), Bob = c("d", "n")))
table22 <- matrix(c(8392,   576445,   463985,   874651457),
    2, 2, byrow = TRUE,
    dimnames = list(X = c("d", "n"), Y = c("d", “n")))
```

table11

```
##       Bob
## Alice      d         n
##     d 141439     73391
##     n  76224 875392736
```

table12

```
##       Bob
## Alice      d         n
##     d 146831     67941
##     n 326768 874976534
```

table21

```
##       Bob
## Alice      d         n
##     d 158338    425067
##     n  58742 875239860
```

table22

```
##     Bob
## Alice     d         n
##   d   8392    576445
##   n 463985 874651457
```

```r
tables <- cbind(as.vector(t(table11)), as.vector(t(table12)),
                as.vector(t(table21)), as.vector(t(table22)))
tables
```

```
##            [,1]      [,2]      [,3]      [,4]
## [1,]    141439    146831    158338      8392
## [2,]     73391     67941    425067    576445
## [3,]     76224    326768     58742    463985
## [4,] 875392736 874976534 875239860 874651457
```

```r
dimnames(tables) = list(outcomes = c("dd", "dn", "nd", "nn"),
                        settings = c(11, 12, 21, 22))
```

```r
tables
```

```
##          settings
## outcomes         11         12         21         22
##       dd    141439    146831    158338       8392
##       dn     73391     67941    425067    576445
##       nd     76224    326768     58742    463985
##       nn 875392736 874976534 875239860 874651457
```

```r
Ns <- apply(tables, 2, sum)
Ns
```

```
##        11        12        21        22
## 875683790 875518074 875882007 875700279
```

```r
rawProbsMat <- tables / outer(rep(1,4), Ns)
rawProbsMat
```

```
##          settings
## outcomes            11            12            21            22
##       dd 1.615183e-04 1.677076e-04 1.807755e-04 9.583188e-06
##       dn 8.380993e-05 7.760091e-05 4.853017e-04 6.582675e-04
##       nd 8.704512e-05 3.732282e-04 6.706611e-05 5.298445e-04
##       nn 9.996676e-01 9.993815e-01 9.992669e-01 9.988023e-01
```

```
VecNames <- as.vector(t(outer(colnames(rawProbsMat),
                              rownames(rawProbsMat), paste, sep = "")))
VecNames
```

```
##  [1] "11dd" "11dn" "11nd" "11nn" "12dd" "12dn" "12nd" "12nn" "21dd" "21dn"
## [11] "21nd" "21nn" "22dd" "22dn" "22nd" "22nn"
```

```
rawProbsVec <- as.vector(rawProbsMat)
names(rawProbsVec) <- VecNames
VecNames
```

```
##  [1] "11dd" "11dn" "11nd" "11nn" "12dd" "12dn" "12nd" "12nn" "21dd" "21dn"
## [11] "21nd" "21nn" "22dd" "22dn" "22nd" “22nn"
```

```
rawProbsVec
```

```
##         11dd         11dn         11nd         11nn         12dd
## 1.615183e-04 8.380993e-05 8.704512e-05 9.996676e-01 1.677076e-04
##         12dn         12nd         12nn         21dd         21dn
## 7.760091e-05 3.732282e-04 9.993815e-01 1.807755e-04 4.853017e-04
##         21nd         21nn         22dd         22dn         22nd
## 6.706611e-05 9.992669e-01 9.583188e-06 6.582675e-04 5.298445e-04
##         22nn
## 9.988023e-01
```

```r
Aplus <- c(1, 1, 0, 0)
Aminus <- - Aplus
Bplus <- c(1, 0, 1, 0)
Bminus <- - Bplus
zero <- c(0, 0, 0, 0)
NSa1 <- c(Aplus, Aminus, zero, zero)
NSa2 <- c(zero, zero, Aplus, Aminus)
NSb1 <- c(Bplus, zero, Bminus, zero)
NSb2 <- c(zero, Bplus, zero, Bminus)
NS <- cbind(NSa1 = NSa1, NSa2 = NSa2, NSb1 = NSb1, NSb2 = NSb2)
rownames(NS) <- VecNames
```

```
NS

##      NSa1 NSa2 NSb1 NSb2
## 11dd    1    0    1    0
## 11dn    1    0    0    0
## 11nd    0    0    1    0
## 11nn    0    0    0    0
## 12dd   -1    0    0    1
## 12dn   -1    0    0    0
## 12nd    0    0    0    1
## 12nn    0    0    0    0
## 21dd    0    1   -1    0
## 21dn    0    1    0    0
## 21nd    0    0   -1    0
## 21nn    0    0    0    0
## 22dd    0   -1    0   -1
## 22dn    0   -1    0    0
## 22nd    0    0    0   -1
## 22nn    0    0    0    0
```

```r
cov11 <- diag(rawProbsMat[ , "11"]) - outer(rawProbsMat[ , "11"], rawProbsMat[ , "11"])
cov12 <- diag(rawProbsMat[ , "12"]) - outer(rawProbsMat[ , "12"], rawProbsMat[ , "12"])
cov21 <- diag(rawProbsMat[ , "21"]) - outer(rawProbsMat[ , "21"], rawProbsMat[ , "21"])
cov22 <- diag(rawProbsMat[ , "22"]) - outer(rawProbsMat[ , "22"], rawProbsMat[ , "22"])
Cov <- matrix(0, 16, 16)
rownames(Cov) <- VecNames
colnames(Cov) <- VecNames
Cov[1:4, 1:4] <- cov11/Ns["11"]
Cov[5:8, 5:8] <- cov12/Ns["12"]
Cov[9:12, 9:12] <- cov21/Ns["21"]
Cov[13:16, 13:16] <- cov22/Ns["22"]

J <- c(c(1, 0, 0 ,0), - c(0, 1, 0 ,0), - c(0, 0, 1, 0), - c(1, 0, 0, 0))
names(J) <- VecNames
sum(J * rawProbsVec)

## [1] 7.26814e-06

varJ <- t(J) %*% Cov %*% J
covNN <- t(NS) %*% Cov %*% NS
covJN <- t(J) %*% Cov %*% NS
covNJ <- t(covJN)
```

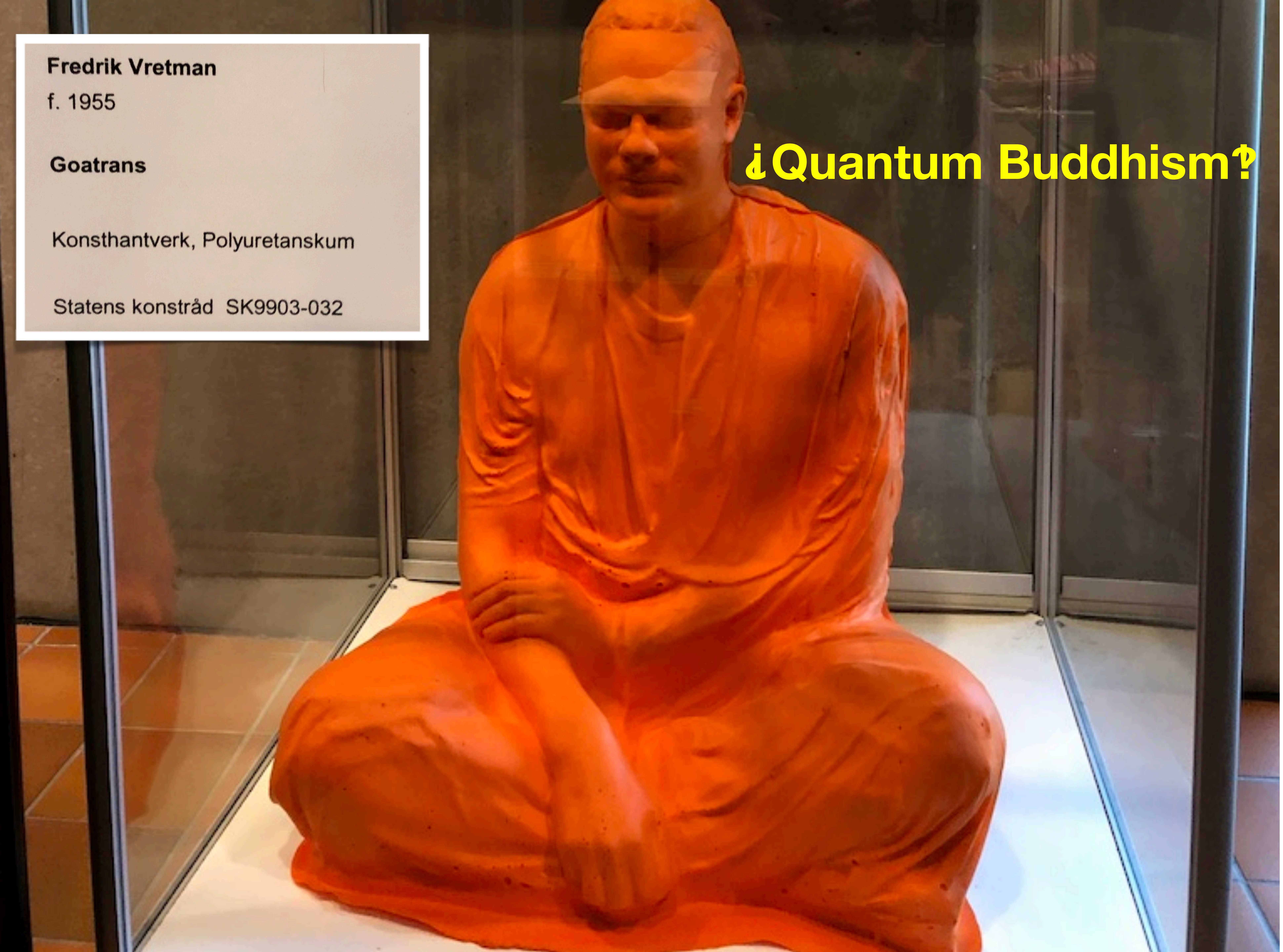
```r
## Estimated variance of optimal test based on J
varJ - covJN %*% solve(covNN) %*% covNJ

##                  [,1]
## [1,] 1.594636e-13

## Estimated variance of Eberhard's J
varJ

##                  [,1]
## [1,] 3.605539e-13

sqrt(varJ / (varJ - covJN %*% solve(covNN) %*% covNJ))

##              [,1]
## [1,] 1.503676

covJN %*% solve(covNN)

##              NSa1        NSa2       NSb1        NSb2
## [1,] 0.395483 0.05436871 0.3516065 0.06982674

Jopt <- J - covJN %*% solve(covNN) %*% t(NS)
```

```
Jopt

##            11dd      11dn        11nd 11nn      12dd      12dn        12nd
## [1,] 0.2529105 -0.395483 -0.3516065    0 0.3256562 -0.604517 -0.06982674
##       12nn      21dd        21dn       21nd 21nn       22dd       22dn
## [1,]    0 0.2972378 -0.05436871 -0.6483935    0 -0.8758045 0.05436871
##             22nd 22nn
## [1,] 0.06982674    0
```

```r
sum(J * rawProbsVec)

## [1] 7.26814e-06

sum(Jopt * rawProbsVec)

## [1] 6.997615e-06

varJ / (varJ - covJN %*% solve(covNN) %*% covNJ)

##           [,1]
## [1,] 2.261042

(varJ - covJN %*% solve(covNN) %*% covNJ) / varJ

##           [,1]
## [1,] 0.442274

sqrt( (varJ - covJN %*% solve(covNN) %*% covNJ) / varJ )

##            [,1]
## [1,] 0.6650368
```

Part 2

Discussion: ¿ QIR - IF ?


Fredrik Vretman
f. 1955
Goatrans
Konsthantverk, Polyuretanskum
Statens konstråd SK9903-032
¿Quantum Buddhism?

¿ . . . ?

The B in QBism

- Bayesian? **NO**
- Bruno de Finetti? **Better**
- B? **Current default position**
- Bettabilitarian?

My answer:
The “B” in QBism is …
the “B” of the Buddha!

Rudiger Schack

Slides of Rudiger’s Växjö talk

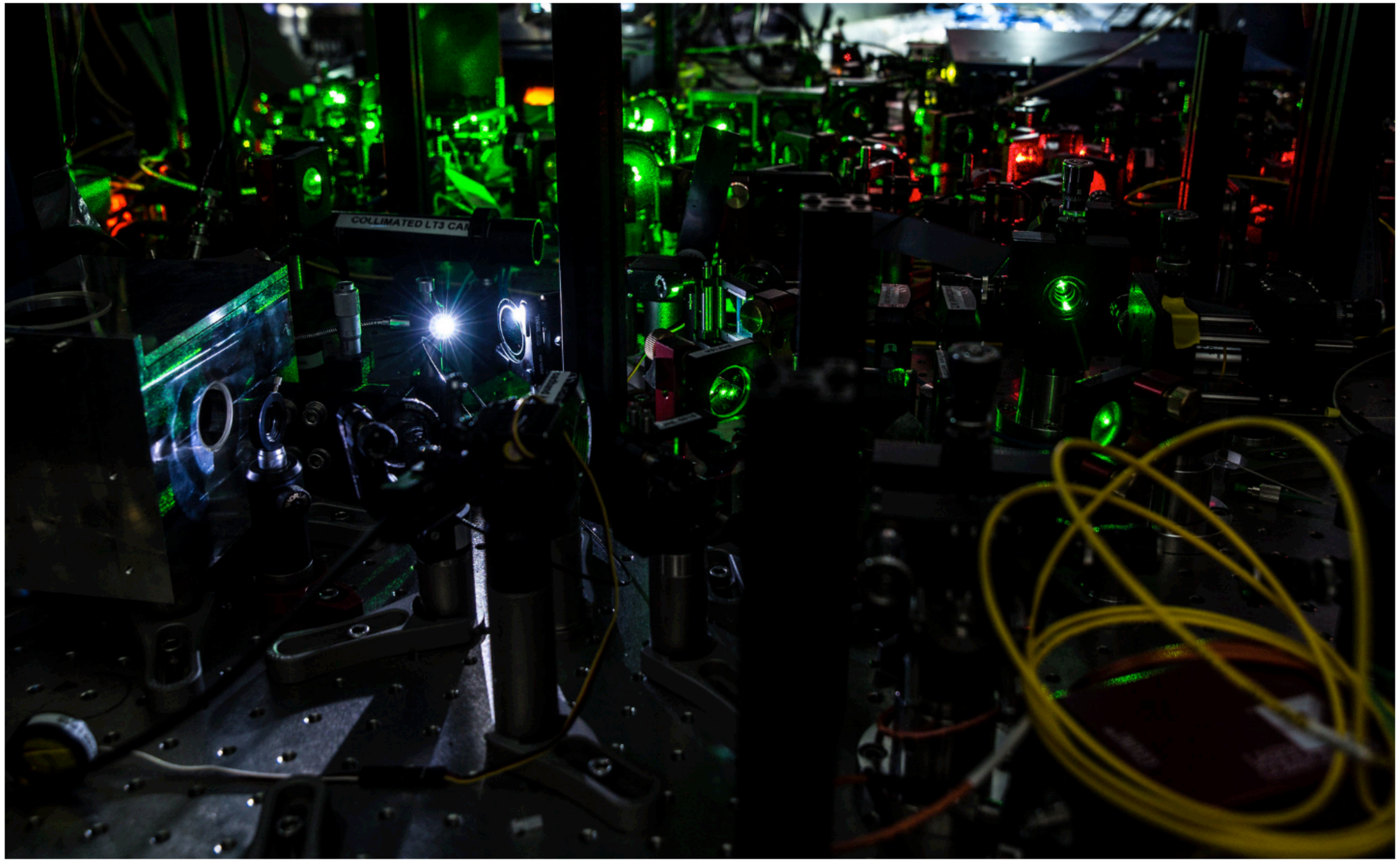
The Goals of Science, according to QBism

1. To guide action.
2. To learn about the character of the world.

The New York Times

Oct. 21, 2015

Sorry, Einstein. Quantum Study Suggests ‘Spooky Action’ Is Real.



Part of the laboratory setup for an experiment at Delft University of Technology, in which two diamonds were set 1.3 kilometers apart, entangled and then shared information.

Erwin Schrödinger

- **I don't like it, and I'm sorry I ever had anything to do with it.**

  [About the probability interpretation of quantum mechanics.] Epigraph, without citation, in John Gribbin, Search of Schrödinger's Cat: Quantum Physics and Reality (1984), v, frontispiece.

- **If all this damned quantum jumping were really here to stay, I should be sorry, I should be sorry I ever got involved with quantum theory.**

  As reported by Heisenberg describing Schrödinger's time spent debating with Bohr in Copenhagen (Sep 1926). In Werner Heisenberg, Physics and Beyond: Encounters and Conversations (1971), 75. As cited in John Gribbin, Erwin Schrodinger and the Quantum Revolution.

- **God knows I am no friend of probability theory, I have hated it from the first moment when our dear friend Max Born gave it birth. For it could be seen how easy and simple it made everything, in principle, everything ironed and the true problems concealed. Everybody must jump on the bandwagon [Ausweg]. And actually not a year passed before it became an official credo, and it still is.**

  Letter to Albert Einstein (13 June 1946), as quoted by Walter Moore in Schrödinger: Life and Thought (1989) ISBN 0521437679

The experiments of 2015 convinced me … ***rebrand*** "spooky action at a distance" …

- Entanglement is an asset, not a horror

- We call it "spooky" because our mammal brains, trained by evolution, can't "understand" it any way except as the work of a *potentially* malevolent *agent*

- "Spooky" is an inadequate translation of "spukhaft". We have to say it in German.

- "Passion at a distance" is better

- More precise: "(Martingale like) disciplined passion at a distance"? No, it won't catch on …

- **Auserlesene / engelhafte 'spukhafte Fernwirkung'** (exquisite / angelic "action at a distance")

… and …
Belavkin’s “eventum mechanics” is the way to go.

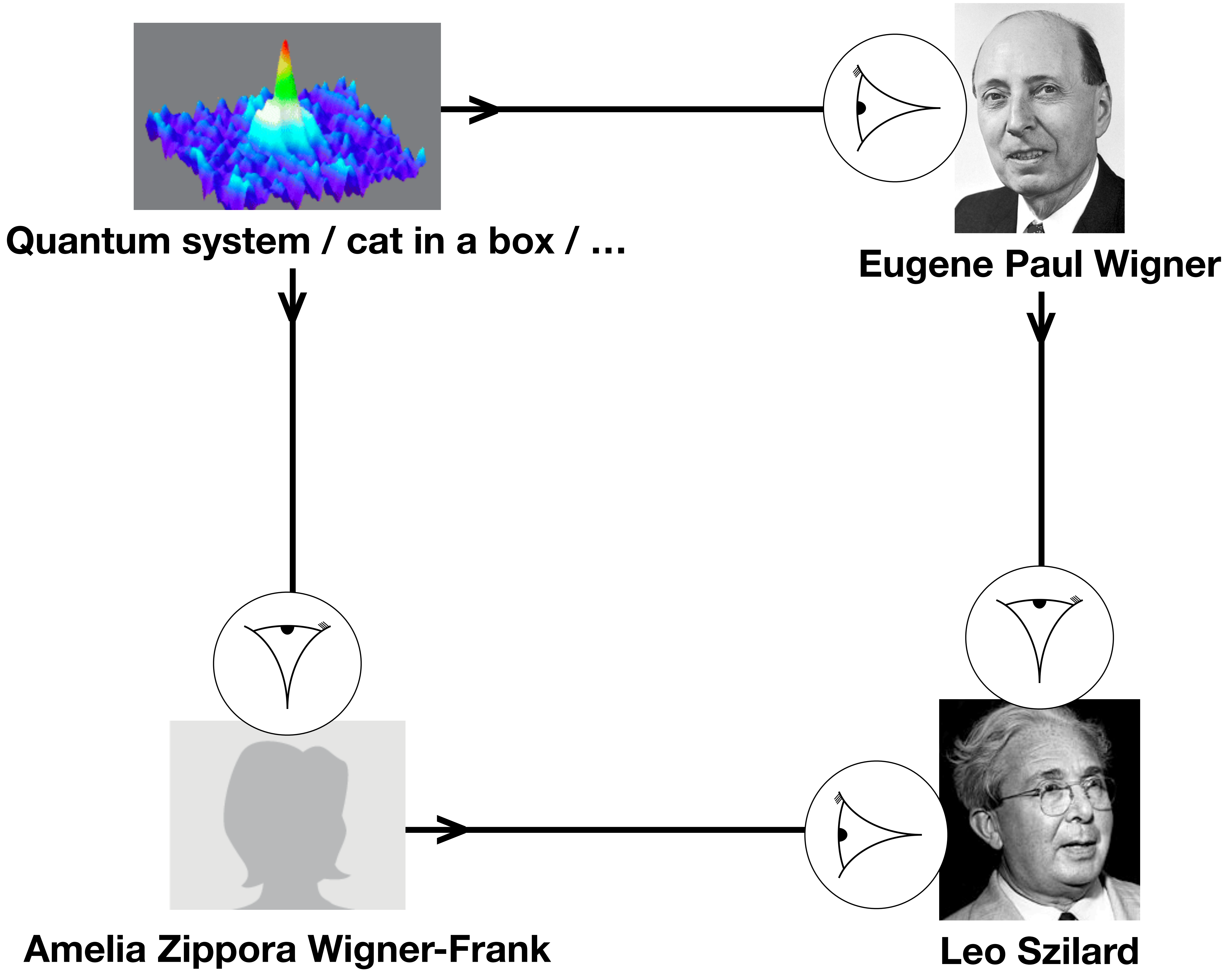
- It’s a “collapse theory”
- It is therefore “non-local”
- It can be made Lorentz invariant!
- Some famous recent works confirm me in my opinions:
  - Daniela **Frauchiger** & Renato **Renner**

    [My title] *Schrödinger’s cat, the Wigners, and the Wigners’ friend*

  - Gilles **Brassard** & Paul **Raymond-Robichaud**

    “*The equivalence of local-realistic and no-signalling theories”.* Abstract: We provide a framework to describe all local-realistic theories and all no-signalling operational theories. We show that when the dynamics is reversible, these two concepts are equivalent. In particular, this implies that unitary quantum theory can be given a local-realistic model.

The Wigners' friend



My <u>prejudice:</u>
The clicks are “real”, the rest … a construction of our minds

- It is allowed to imagine that more stuff is real
- Such a “dilation” need not be unique

- “QM without collapse”, or Unitary QM - several theories, best known being MW and Quantum Qubism
- MW is many words
- QB is subjective Bayes … but I’m a frequentist … usually Bayes and frequentist inference agree … it’s really interesting when they disagree !!!
- Quantum Buddhism gives yet further insights

F&R: The Wigners' friend

- QM *without collapse* + MW implies only the wave function is real

- QM *without collapse* + Qbism implies nothing is real

- **<u>My conclusion: QM without collapse is non-sense!</u>**

B&RR

- They insist on irreversibility!
- Change definitions of everything
- It’s brilliant but … it’s very technical and very long

- **My conclusion: we must trash ‘irreversibility’!**

Conclusion: QIR - IF

- “Spukhafte fernwerkung” is for real and … Exquisite? Angelic?
- Collapse is real
- Recommendation: take a look again at Belavkin’s “Eventum Mechanics”
- Congratulations and deep thanks to Andrei for *yet another* splendid conference, the pinnacle of twenty years of splendid conferences
- Quantum Information Revolution Impacted Foundations at Växjö (2019)
- We must keep questioning the very words which we use (Eastern thought / Western post-modernism) … and remember what we are … *nothing* is real - QBism!

Postjudice:

Everything is a construction of our minds - there is nothing else

Beware: every word is a "model"

All models are wrong, some are useful

Universiteit Leiden

COMBRAY

A toast to Andrei Khrennikov

“Zeer oude genever”

The juniper-flavoured national and traditional liquor of the Netherlands and Belgium, from which gin evolved.

There is a tradition that attributes the invention of jenever to the Leiden chemist and alchemist Sylvius (Franciscus Sylvius de Bouve)