LETTER

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Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres

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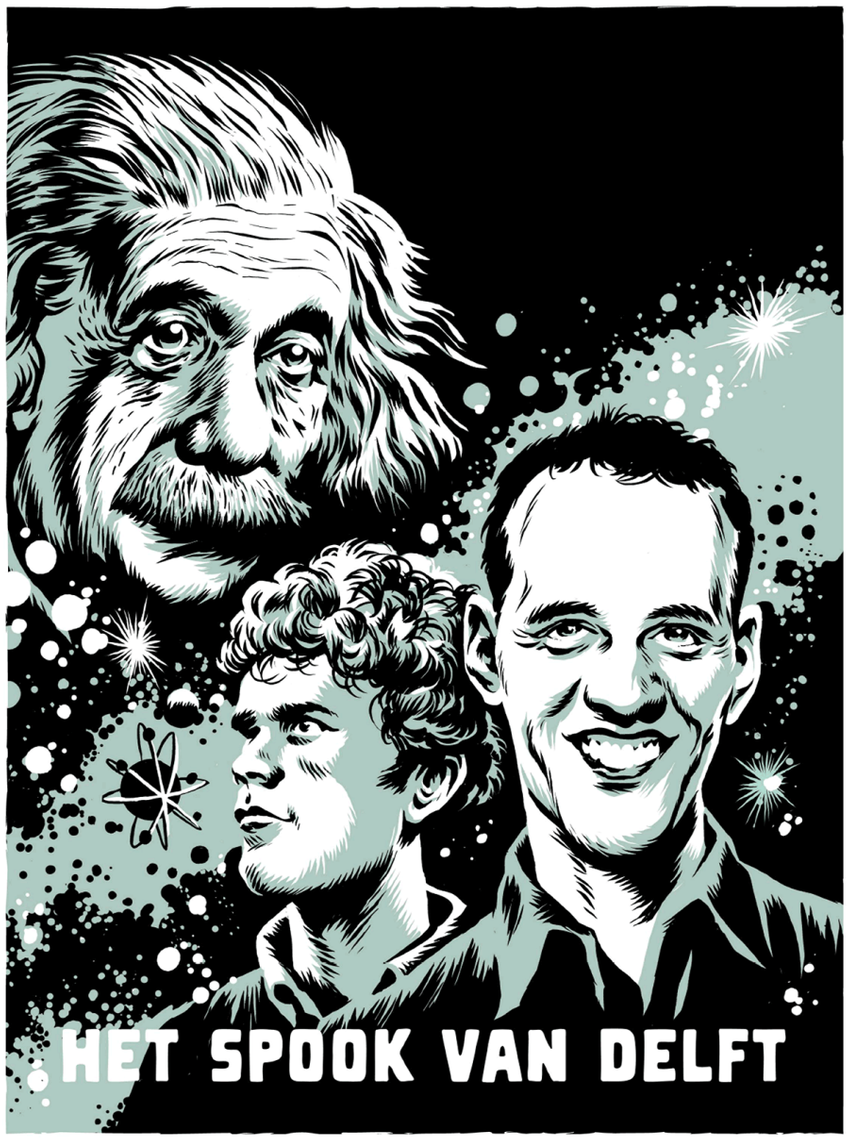
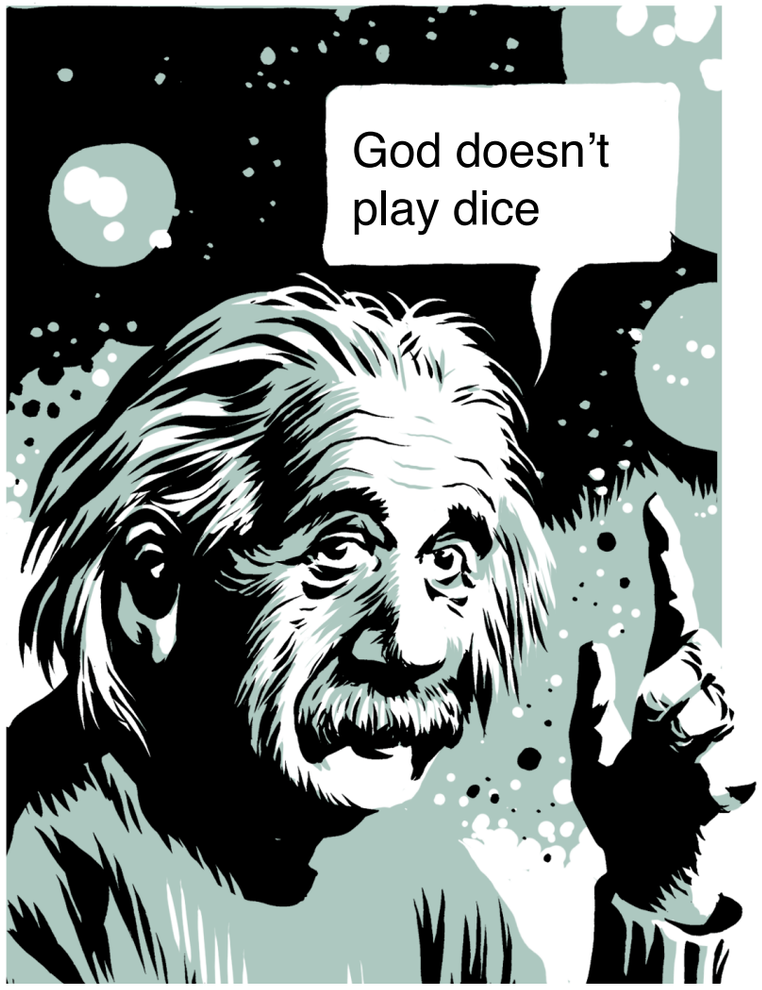
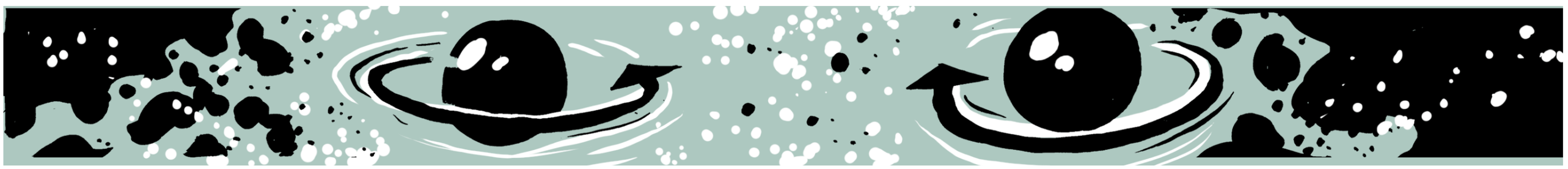


The EPR paradox:
realism versus quantum mechanics

The universe is innately random





John Bell devised an equality to show the difference

The first experiments in the 80's leave severe loopholes

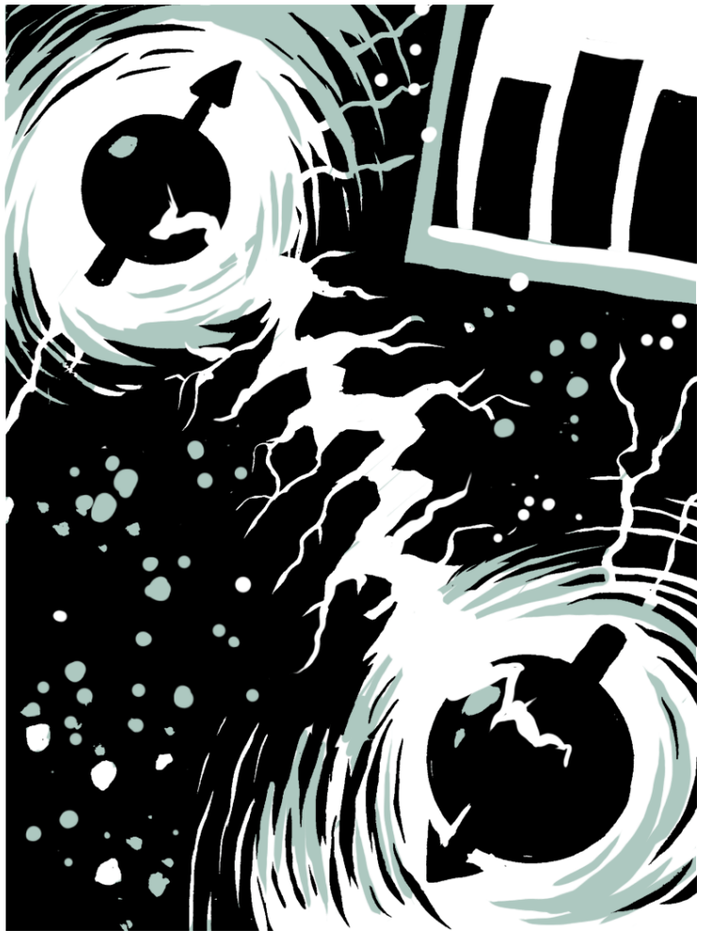
Detection loophole

fair sampling

Locality loophole

communication

Bell’s inequality,



the experiment,

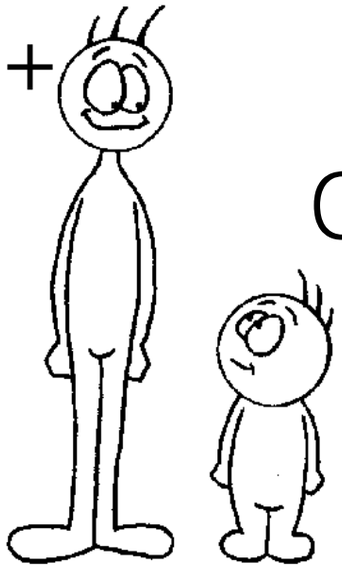
and future work

Bell's inequality by counting hair, socks and height

A+

B+

C+



C-

A-

B-

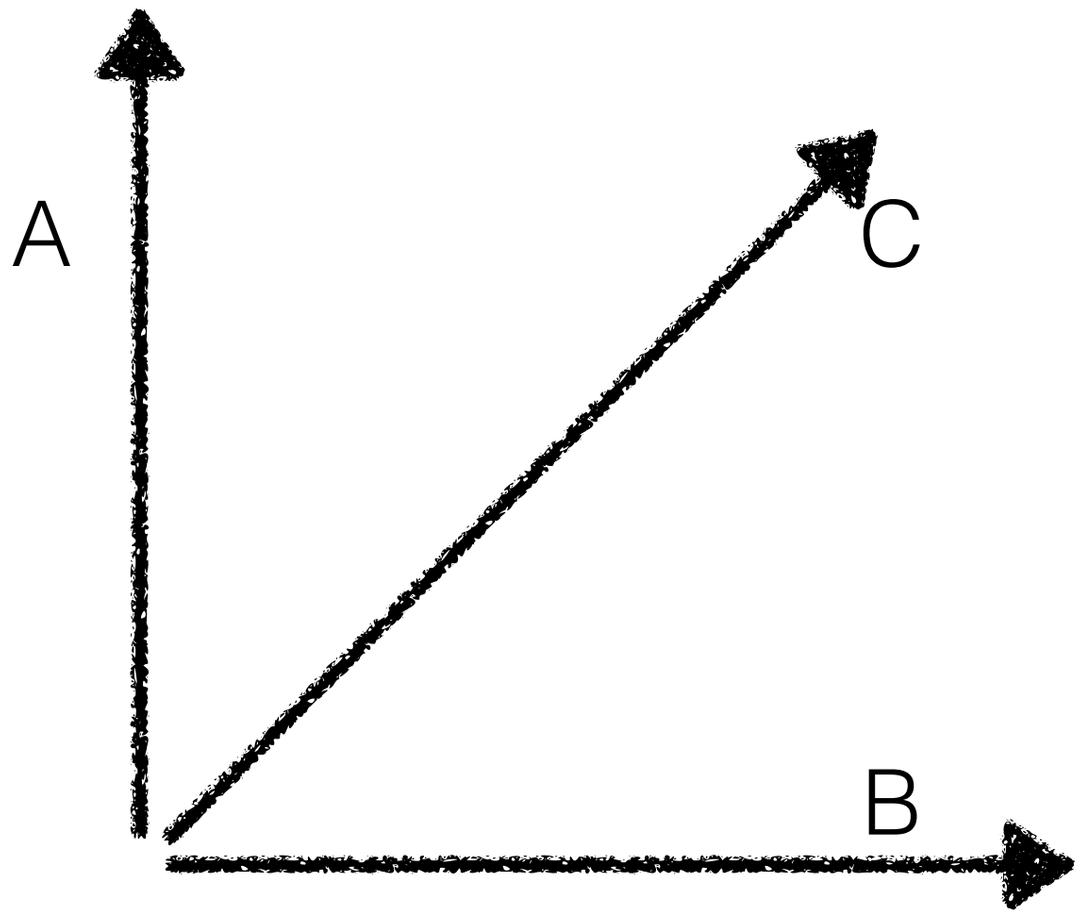
$$N(A+, B-) = N(A+, B-, C+) + N(A+, B-, C-)$$

$$N(A+, B-) = N(A+, C-) - N(A+, B+, C-)$$

$$+ \; N(B-, C+) - N(A-, B-, C+)$$

$$N(A+, B-) < N(A+, C-) + N(B-, C+)$$

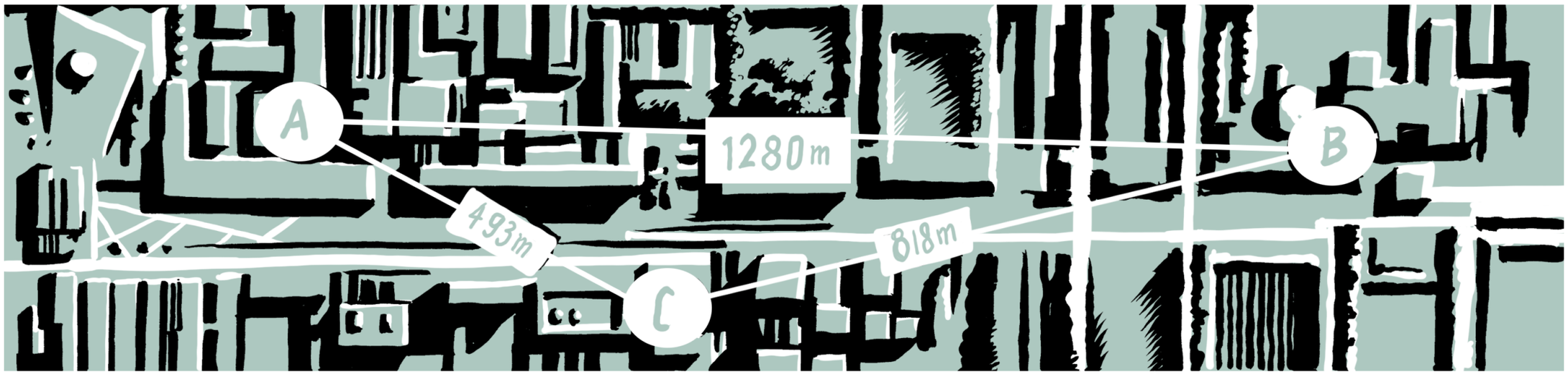
Bell's inequality by counting quantum measurements

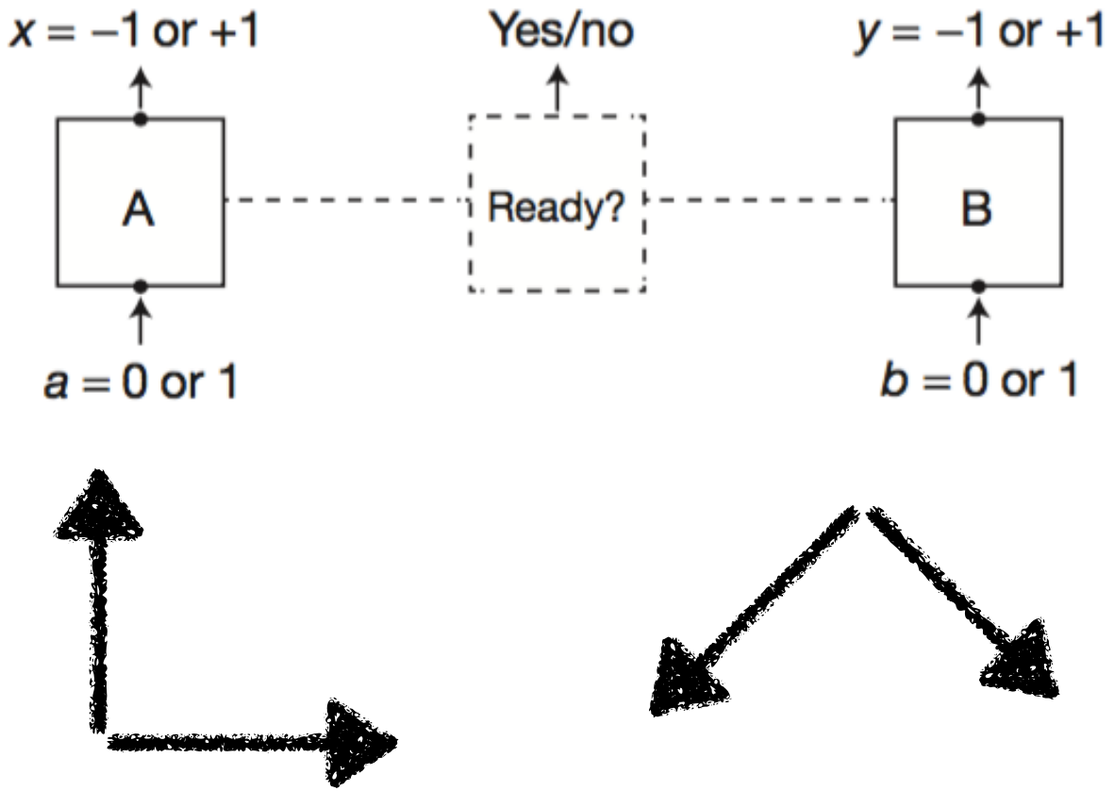


$N(A+, B-) < N(A+, C-) + N(B-, C+)$

$1/4 < (2 - \sqrt{2})/4$…. NOT :)

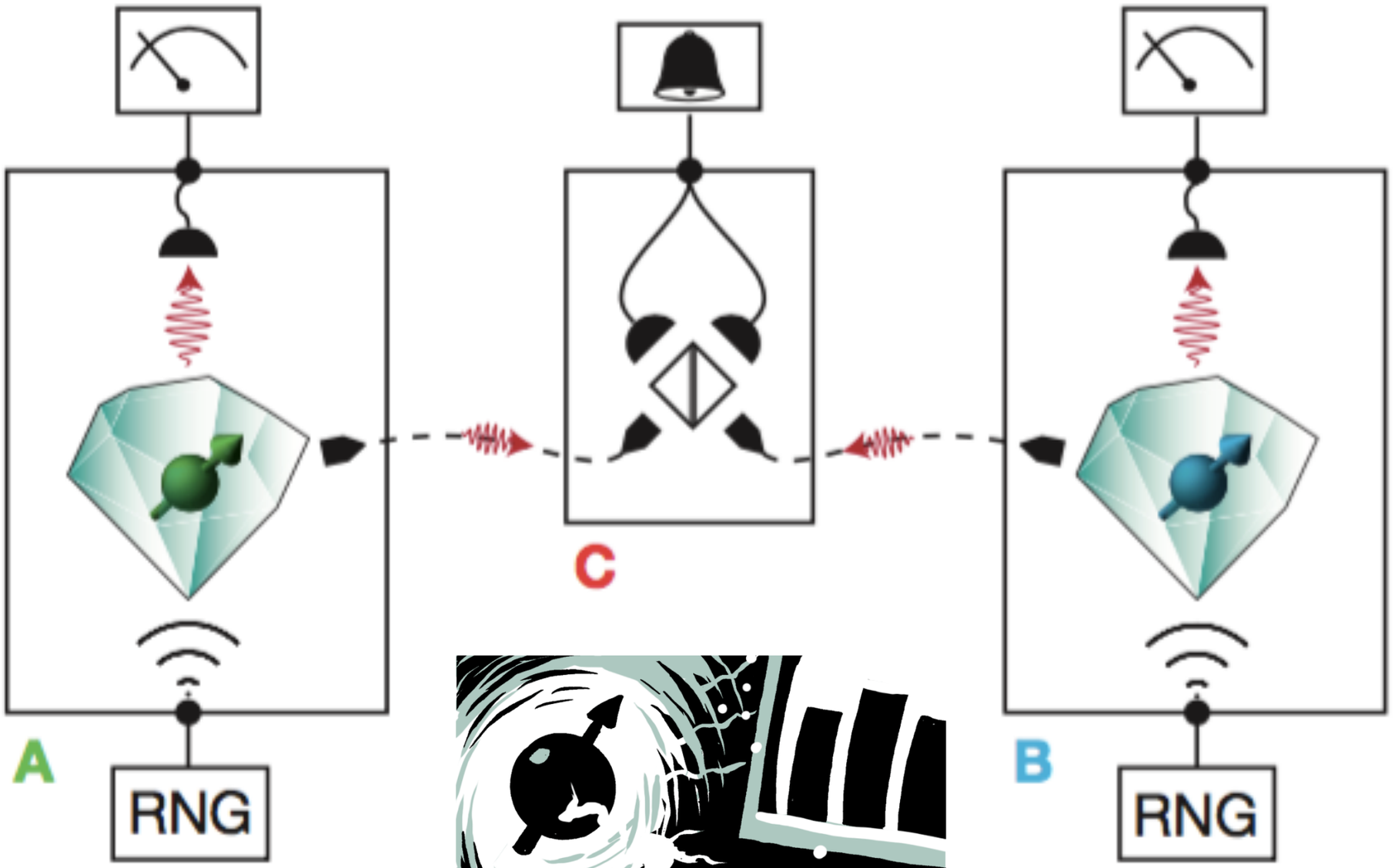
The experiment's 1.2 km distance closes the locality loophole

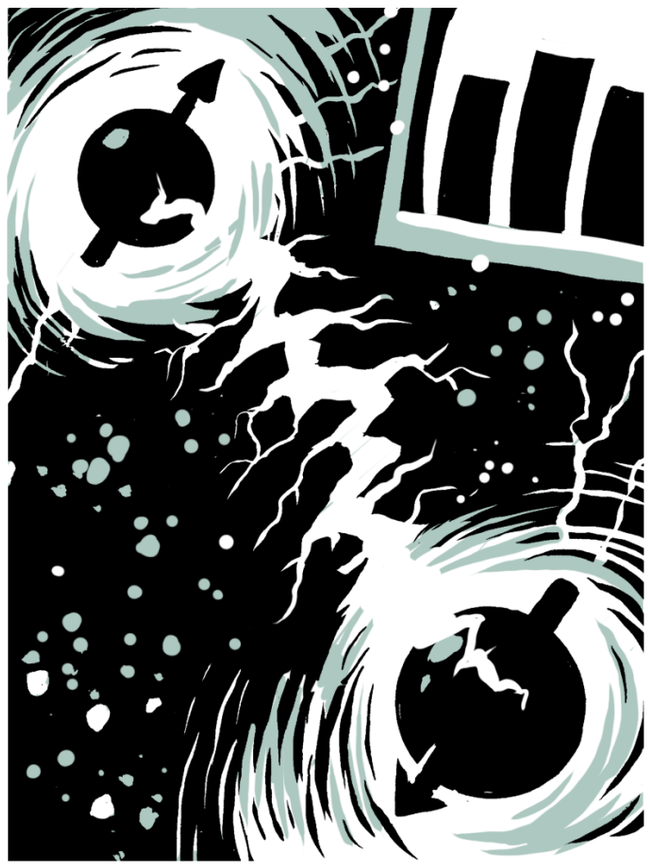




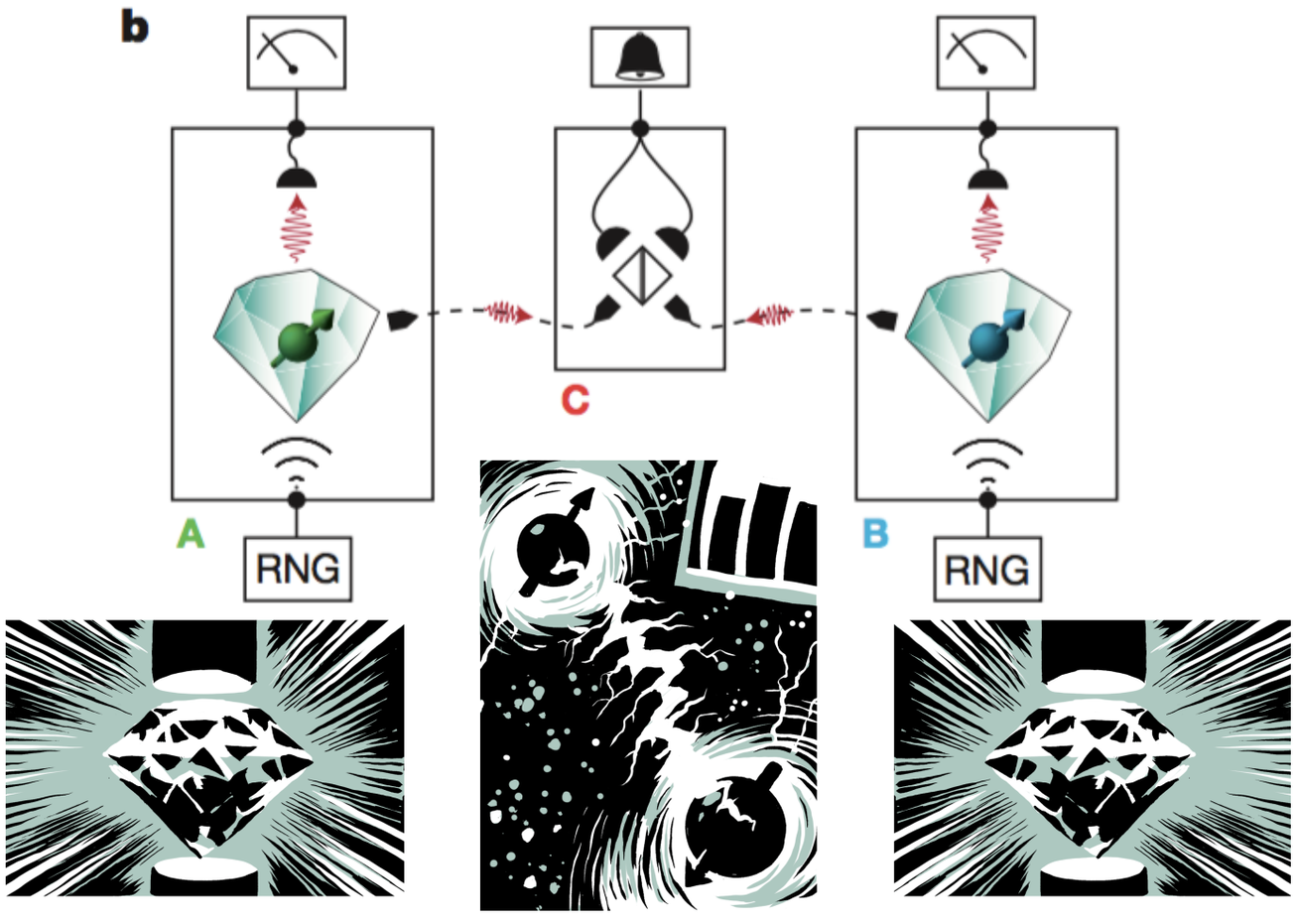
$$S = \left| \langle x \cdot y \rangle_{(0,0)} + \langle x \cdot y \rangle_{(0,1)} + \langle x \cdot y \rangle_{(1,0)} - \langle x \cdot y \rangle_{(1,1)} \right| \leq 2$$

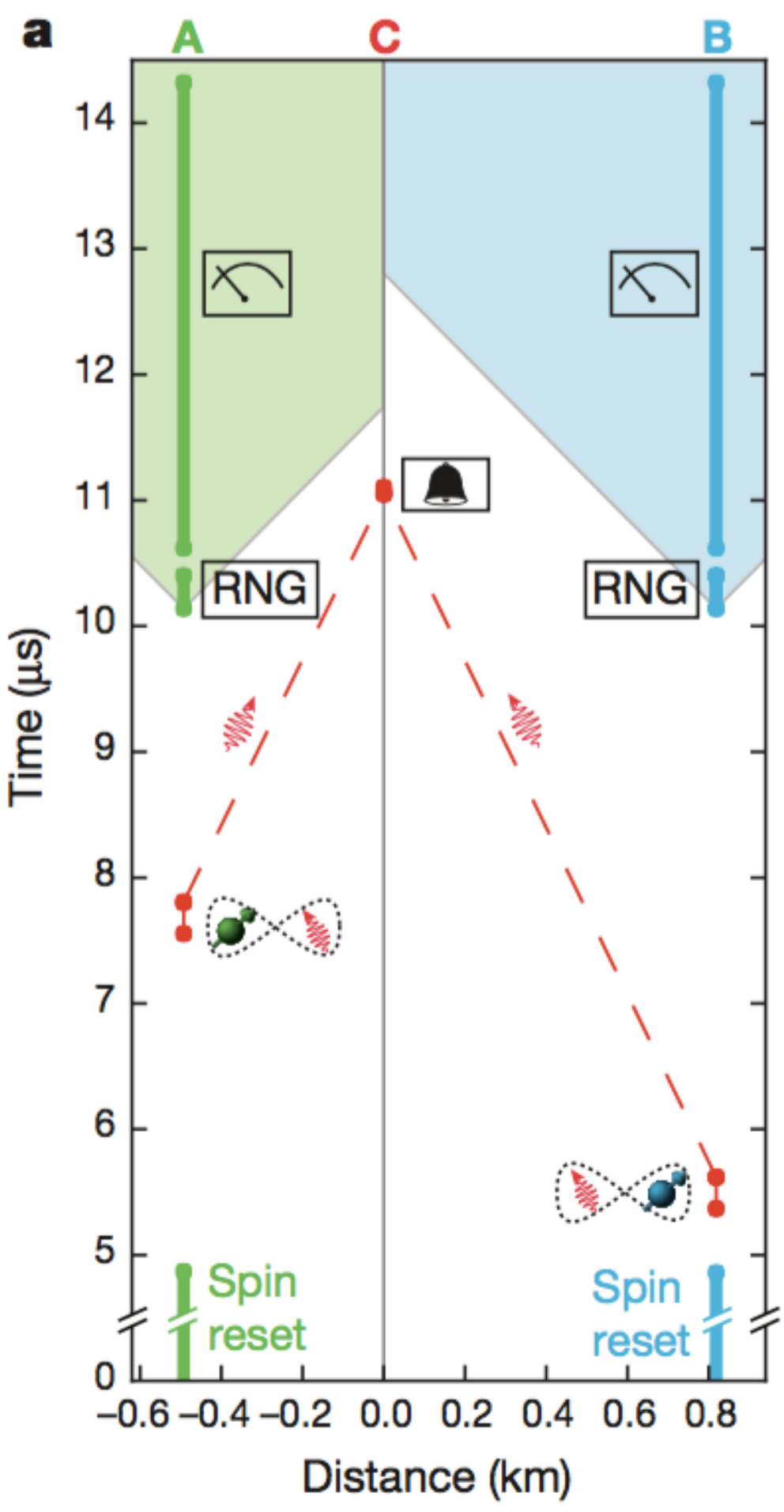
b



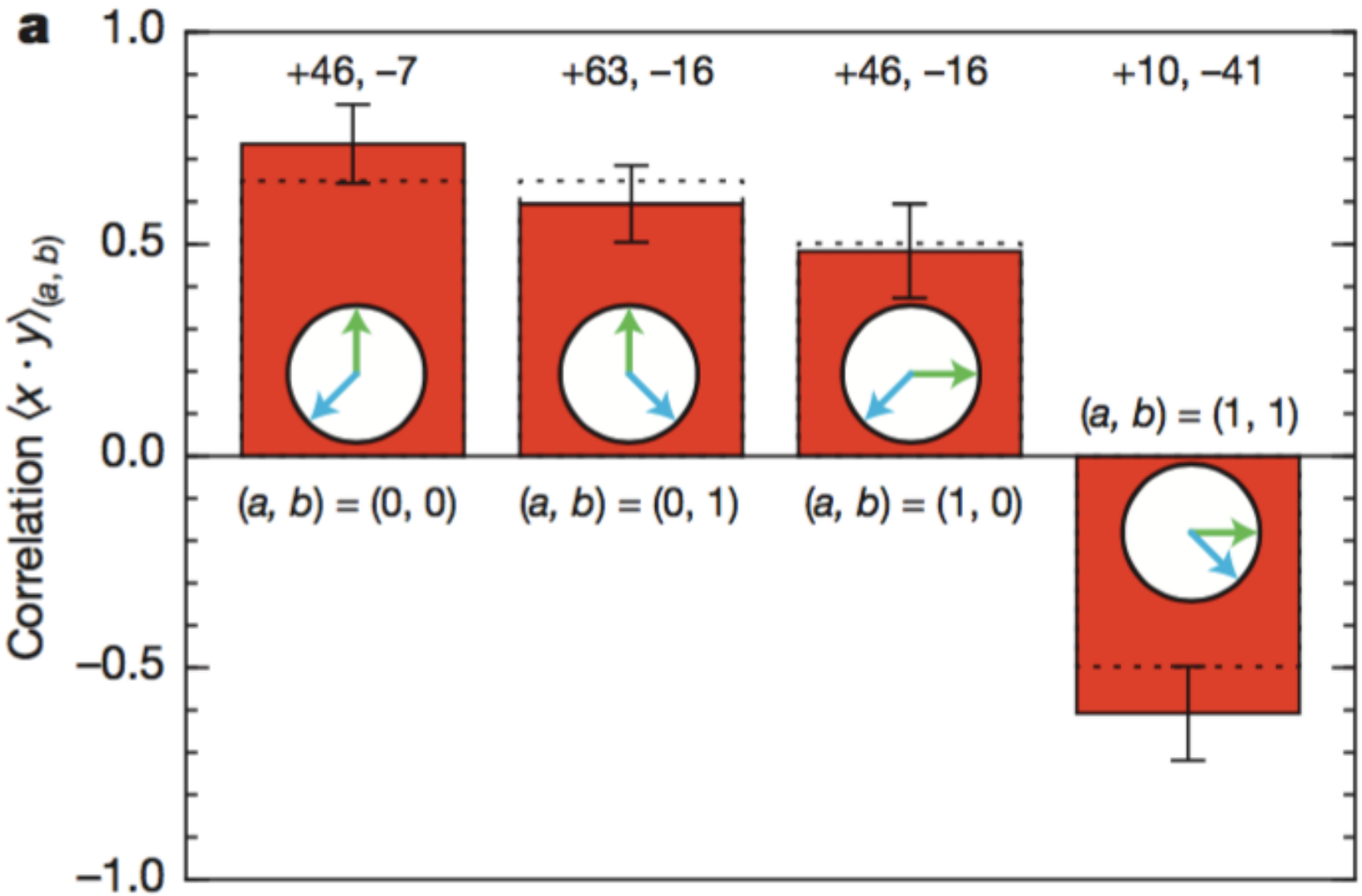


Timeline of the measurement



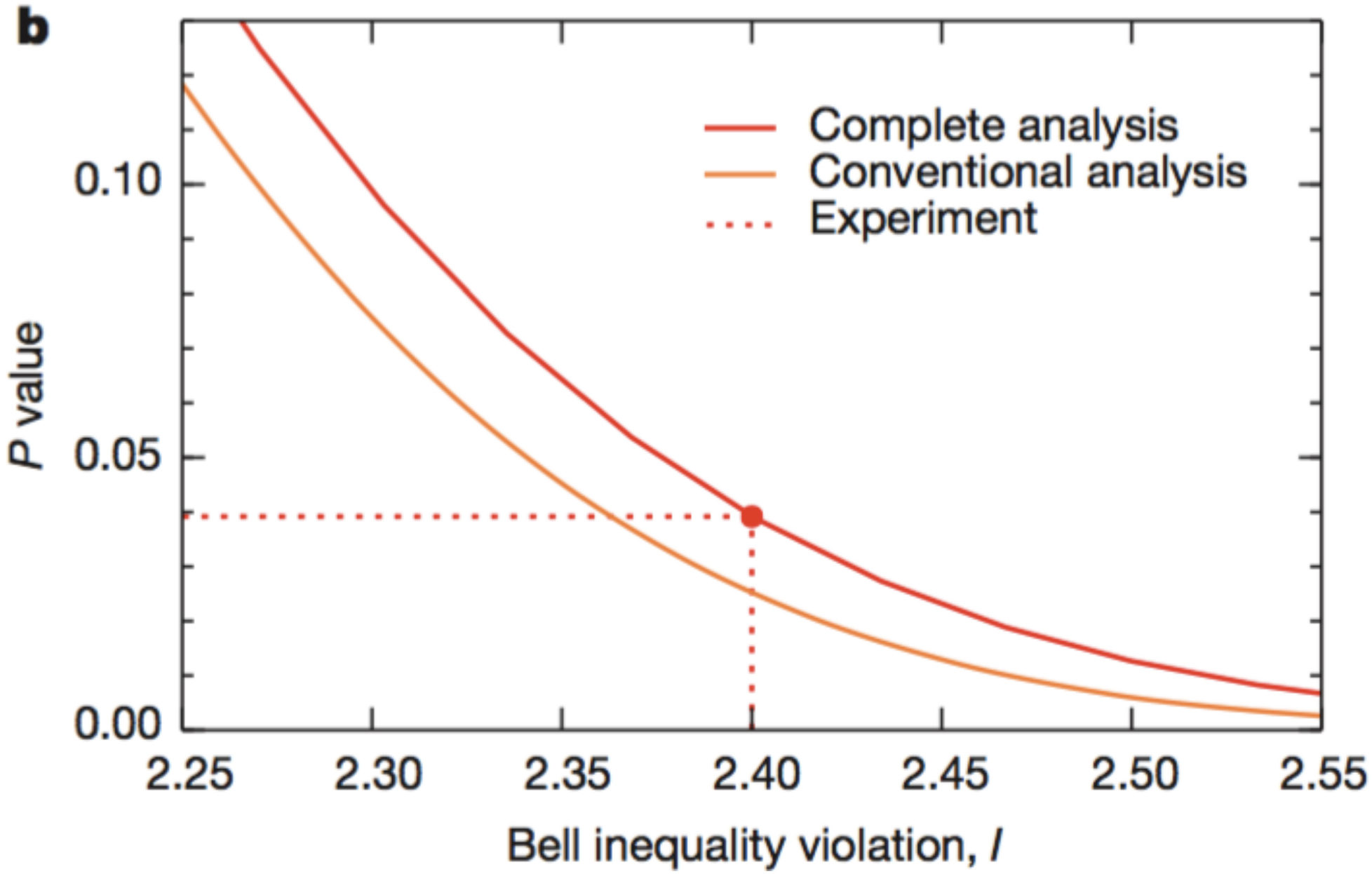


The results break the Bell inequality



$$\frac{46-7}{46+7}+\frac{63-16}{63+16}+\frac{46-16}{46+16}-\frac{10-41}{10+41}=2.4>2$$

And it is significant



The ideas for future work

Increasing distance

Theories with increased speed

Different random agents

Free will characters

Repositioning RNG

Freedom of choice