

Decoding Reality

The Universe as Quantum Information

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Universe as Information

- The Universe is fundamentally made up of bits of information, not matter and energy;
- The same information at the root of various physical, biological, computational and even economical and sociological phenomena;
- Ultimately, information is quantum...
- Reality emerges through an interplay between random and deterministic.

Physics as Information

- ❑ Physics all about predictions
- ❑ Information about the system crucial
- ❑ How much information?
- ❑ Speed of processing...

Laplace: Gimme all positions and velocities of all particles and I will tell you the future exactly.

Maxwell: Gimme all positions and velocities of all particles and I will violate the Second Law.

Catalogue of Information

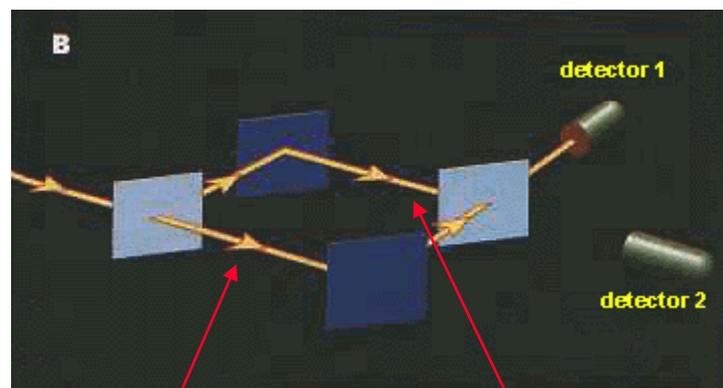
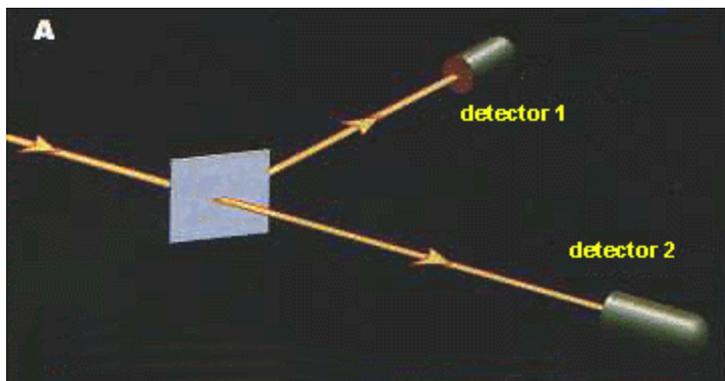
- ❑ States of physical systems are betting portfolios
- ❑ Laws of physics: how does the portfolio change in time?

$$\begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 0 \\ 1 \end{pmatrix}$$



Quantum betting: Two things at once



Which path is taken?

SUPERPOSITION



BOTH

Superposition principle

Suppose we want to encode a bit of information into a state of photon after the beam-splitter.

Classical bit can be in only two possible states 0 or 1; qubit can be in any superposition as above.

$$|\psi\rangle = a \begin{pmatrix} 1 \\ 0 \end{pmatrix} + b \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} a \\ b \end{pmatrix}$$

Quantifying Information

All we need is probability for something, p .

$$I = \log 1/p$$

Construct everything from probabilistic events.

Bohr-Einstein Dialog



Einstein:

„Out there is this huge world, which exists independently of us human beings and which stands before us like a great, eternal riddle, at least partially accessible to our inspection.“

Bohr:

„There is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how nature *is*. Physics concerns what we can *say* about nature.“

Bohr and Einstein in the twenties, at the house of Paul Ehrenfest.

Classical Versus Quantum Physics

Classical physics describes large (slow) objects.

Quantum physics was introduced to describe small objects. (but we know also applies to large ones!)

Main difference?

Schrödinger: Entanglement is the key difference!

Entanglement



E.Schrödinger, ``Die gegenwärtige Situation in der Quantenmechanik", Naturwissenschaften, **23**, 807-812 (1935).

$$|\Psi_{ab}\rangle \neq |\Psi_a\rangle \otimes |\Psi_b\rangle$$

Information about "a" and "b" is not the same as information about "a" and information about "b"!

Schrödinger's cat



Schrödinger's cat



Dead...

Schrödinger's cat



... or alive.

Schrödinger's cat



Dead... and alive.



Happy...and sad.

Two Information Principles

- > There is a maximum amount of information any system can contain.
- > We can always obtain more information from any system.

Seems like a paradox! But it is not because of the genuine randomness...

Key Question:

Can macroscopic entanglement exist under high temperature and other external conditions?

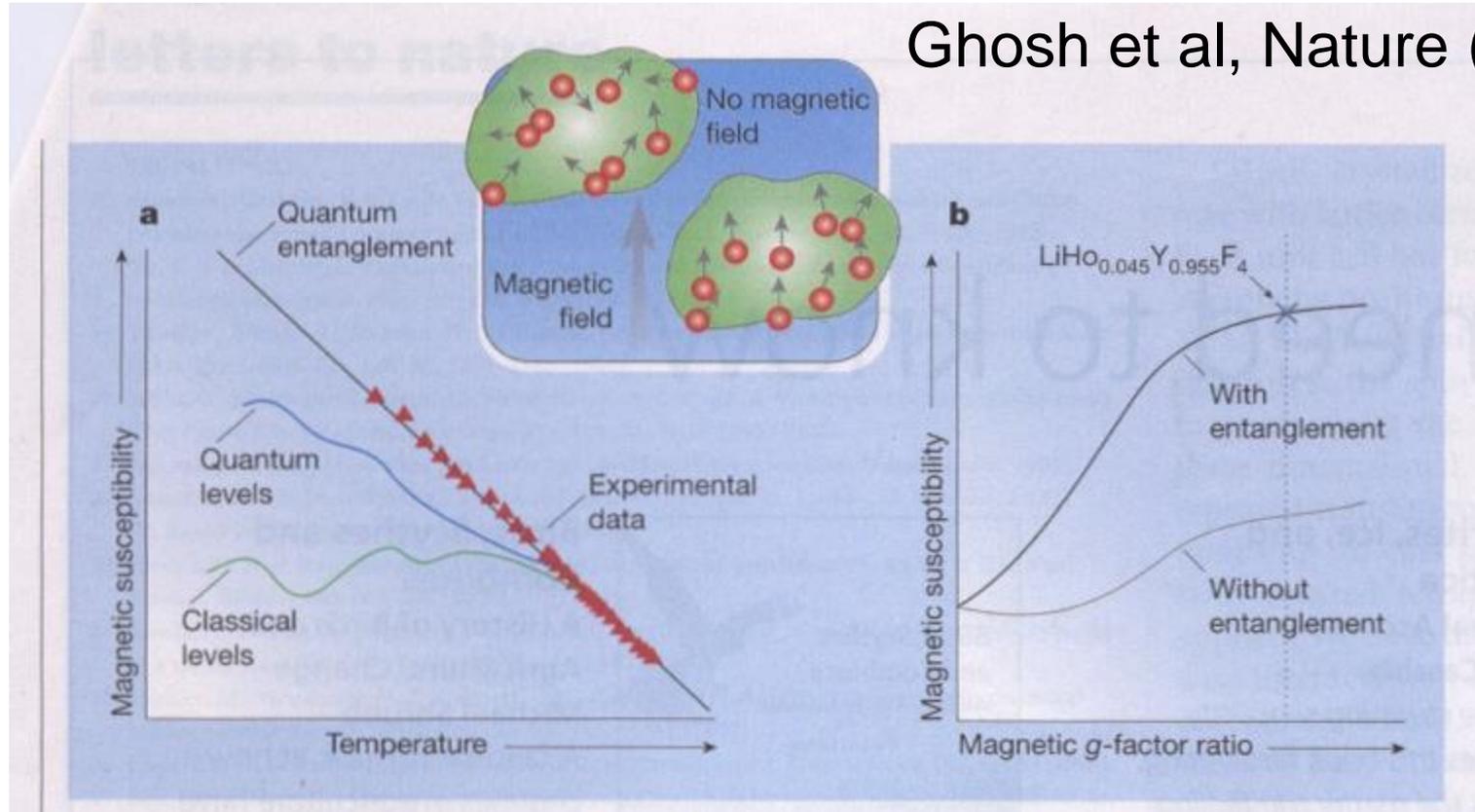
Books: “The God Effect”, B. Clegg



Entanglement with a pinch of salt:



Ghosh et al, Nature (2003).



V.V., Nature (2003).

Zoom out: physics, chemistry, biology

Physics: studies matter and energy and interaction.

Chemistry: studies molecule formation and their Interaction.

Biology: studies various properties of living systems.

How are they related?

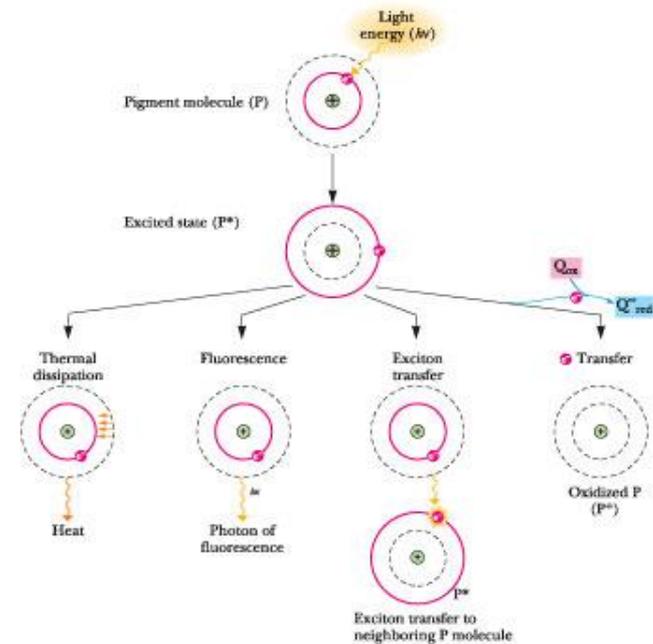
Schrödinger



...living matter, while not eluding the "laws of physics" as established up to date, is likely to involve "other laws of physics" hitherto unknown, which however, once they have been revealed, will form just as integral a part of science as the former.

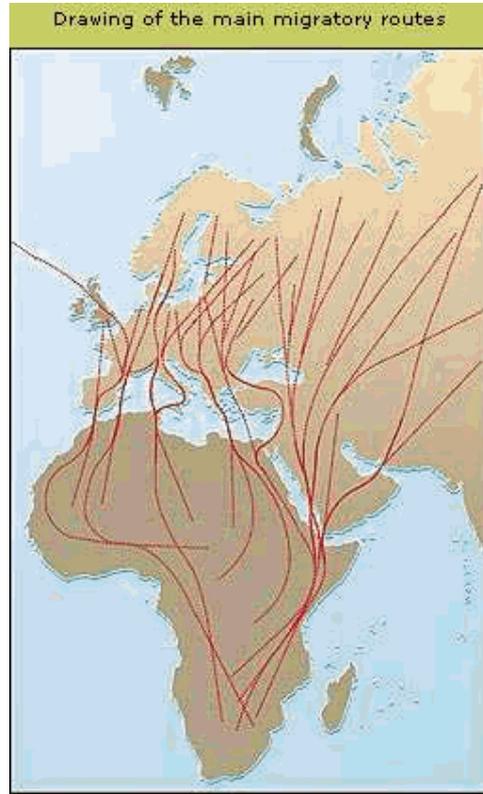
“What is Life” (1944)

Schrödinger's plants: photosynthesis?

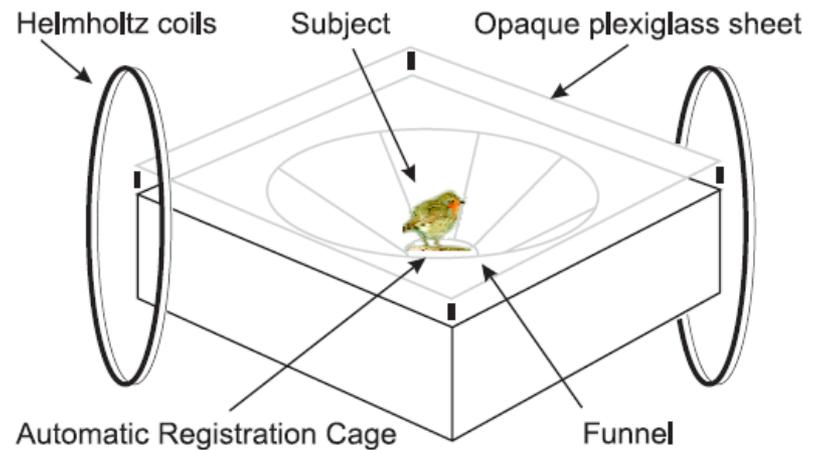


Finding the right place to deposit photon energy is more efficient quantumly!

Bird migration: Europaen robin



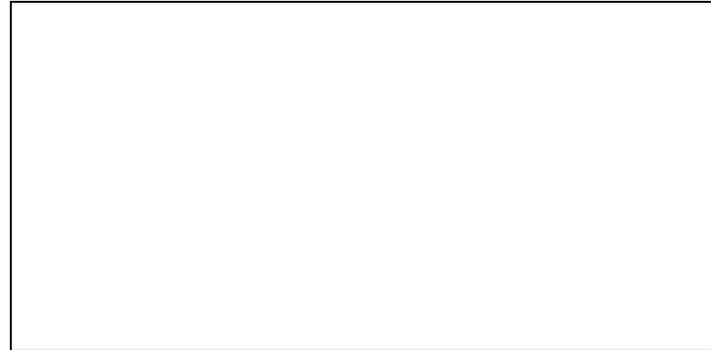
(Taken from www.pandemic360.com)



(taken from PhD Thesis of Chris Rodgers, Oxford)

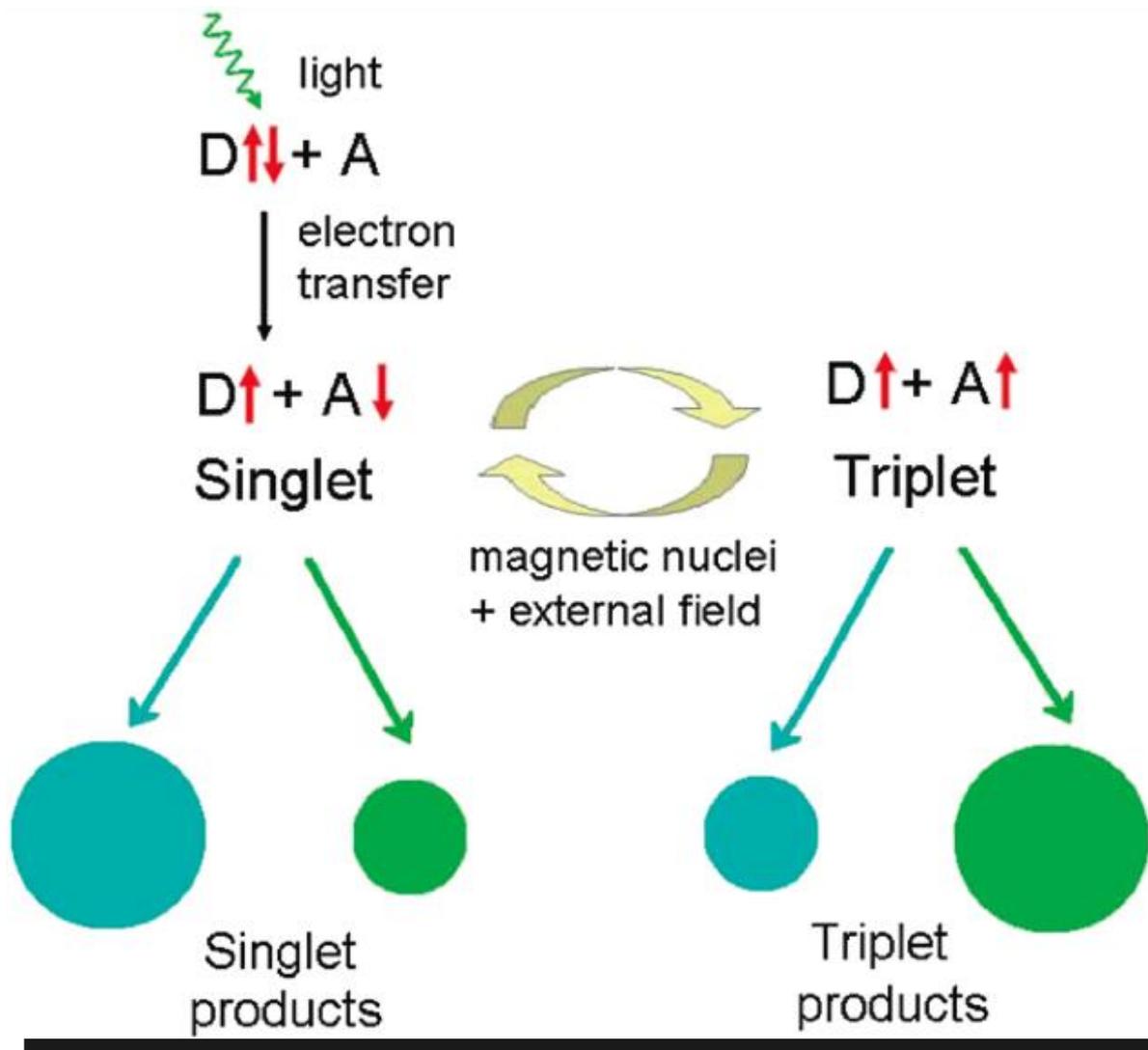
Inclination vs Polarity

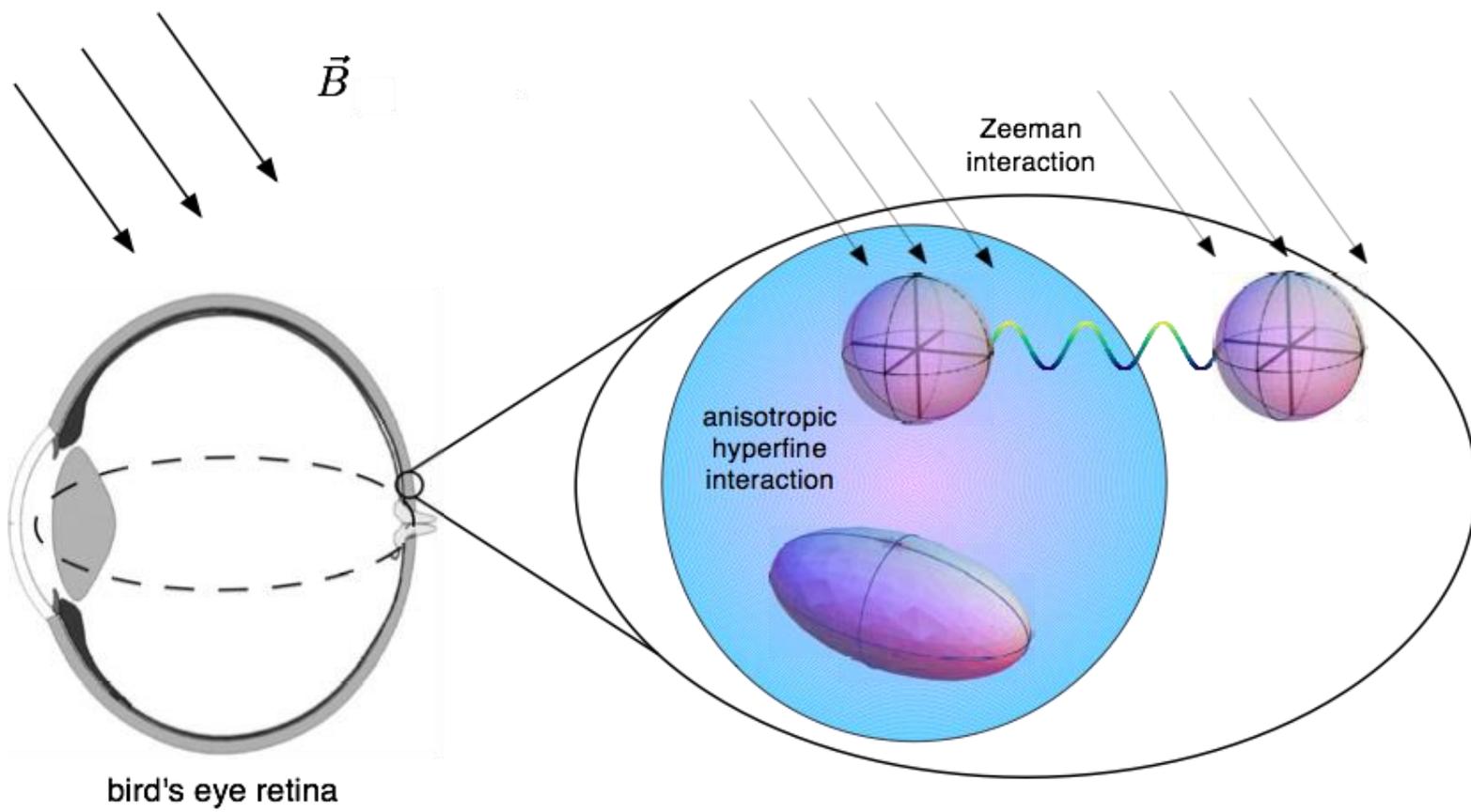
First experiment with migratory birds conducted in 1971:



R. & W. Wiltschko: Magnetic compass of European robins, Science, 176 (4030): 62-64, 1972

Radical Pair Mechanism:





Main Message:

Although quantum physics originally designed to cope with small particles (atoms and subatomic), we now have evidence that all its features persist in the macroscopic domain.

In fact, we see that even living systems may be exploiting entanglement to gain advantage.

What if the whole Universe was built of quantum bits of Information?

Back to physics: Universe as Quantum Information

Qubit reckoning (c.f. Archimedes “Sand Reckoning”):

The number of bits in the universe is $\sim 10^{120}$

The highest speed of processing is $\sim 10^{83}$ bits per
second

Current estimate of the entropy: $\sim 10^{80}$

Creating the Universe? there's nothing to it

☐ Energy of the Universe = 0

☐ Charge in the Universe = 0

☐ Rotation of the Universe = 0

☐ Entropy of the Universe = 0

Physics as a Game of Cards

Have:



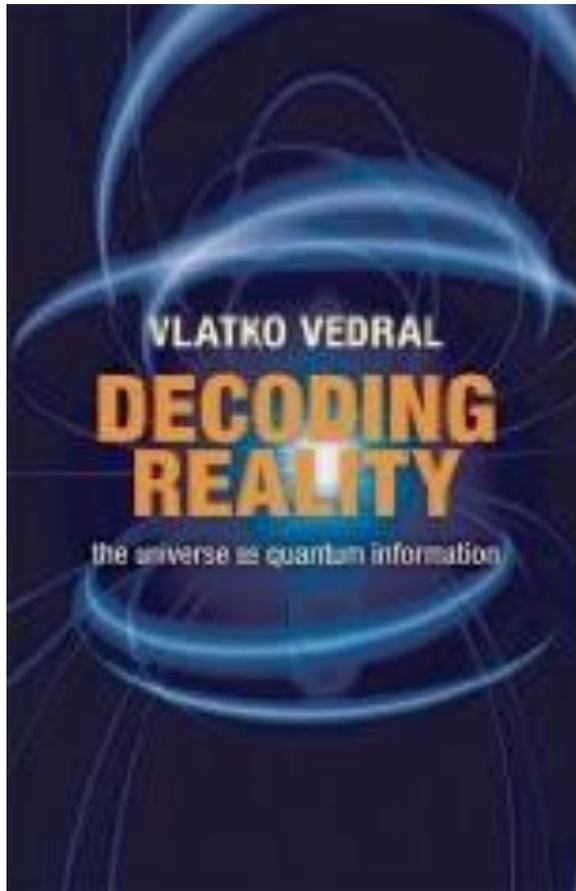
Want:



Two rules: 1. You can only ask for a card if you have it;
2. If asked and you have this type of card you must give it up.

Amazing conclusion: DON'T NEED CARDS TO PLAY THE GAME!

Further reading



www.vlatkovedral.org