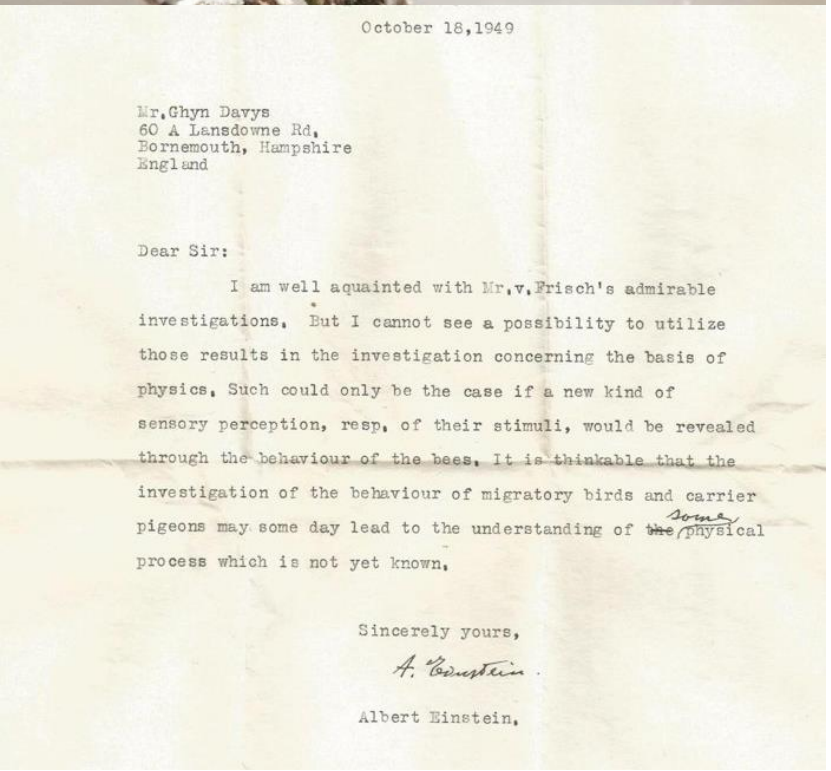


October 18,1949

Mr.Ghyn Davys
60 A Lansdowne Rd,
Bornemouth, Hampshire
England

Dear Sir:

I am well aquainted with Mr.v.Frisch's admirable investigations. But I cannot see a possibility to utilize those results in the investigation concerning the basis of physics. Such could only be the case if a new kind of sensory perception, resp. of their stimuli, would be revealed through the behaviour of the bees. It is thinkable that the investigation of the behaviour of migratory birds and carrier pigeons may some day lead to the understanding of ~~the~~ some physical process which is not yet known.

Sincerely yours,

A. Einstein

Albert Einstein.

Quantum Entanglement & Possible Explanation of Bird Migration

Husin Alatas

Theoretical Physics Division, Department of Physics, Faculty of Mathematics and Natural Sciences & Center for Transdisciplinary and Sustainability Sciences (CTSS), IPB University

IPB University — Bogor Indonesia —

CTSS
CENTER FOR TRANSDISCIPLINARY AND SUSTAINABILITY SCIENCES

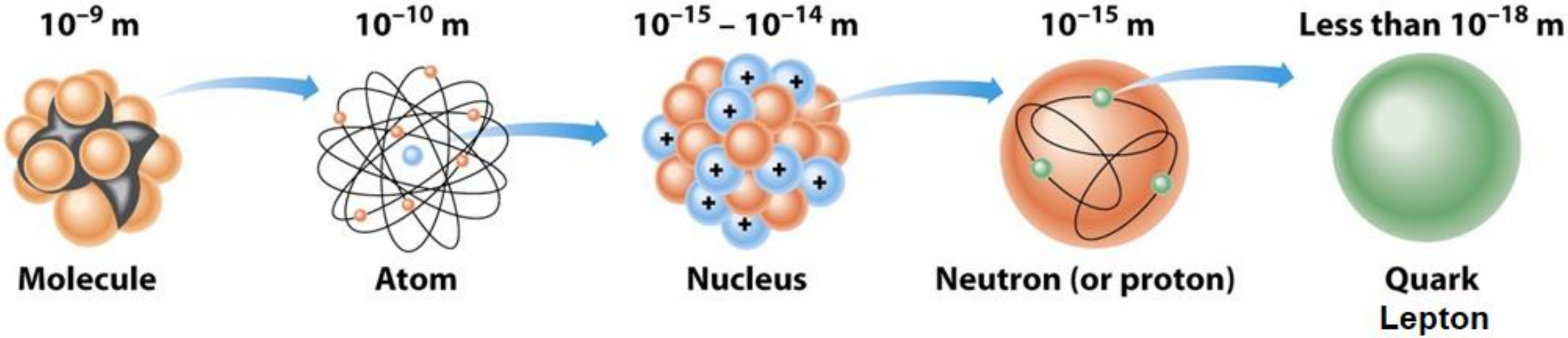
Presented at 13th Transdisciplinary Tea Talk, Bogor, June 2021

Outline...

- Buliding Blocks of Our Universe
- Weirdness of Quantum World
- Quantum Realm & Quantum Entanglement
- Earth's Magnetic Field & the Possible Mechanism of Bird Migration

Building Blocks of Our Universe

The Building Blocks of Normal Matter…

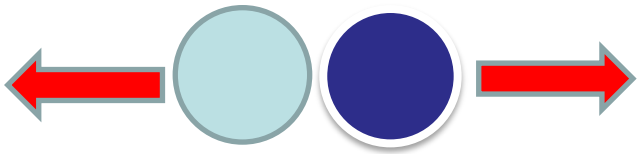


Periodic system of the fundamental building blocks…

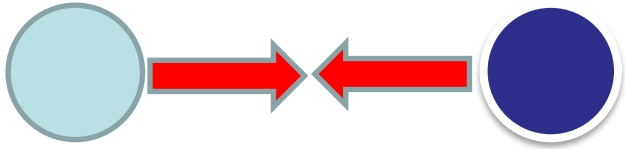
	Quarks		Leptons	
Generation 3	t Top	b Bottom	τ Tau	ν_τ Tau-neutrino
Generation 2	c Charm	s Strange	μ Muon	ν_μ Muon-neutrino
Generation 1	u Up	d Down	e Electron	ν_e Electron-neutrino

Fundamental Forces in Nature…

- Strong Nuclear Force (carried by gluon)
- Weak Nuclear Force (carried by Z and W particles)
- Electromagnetic Force (carried by photon)
- Gravitational Force (carried by graviton???)



Repel (Push)

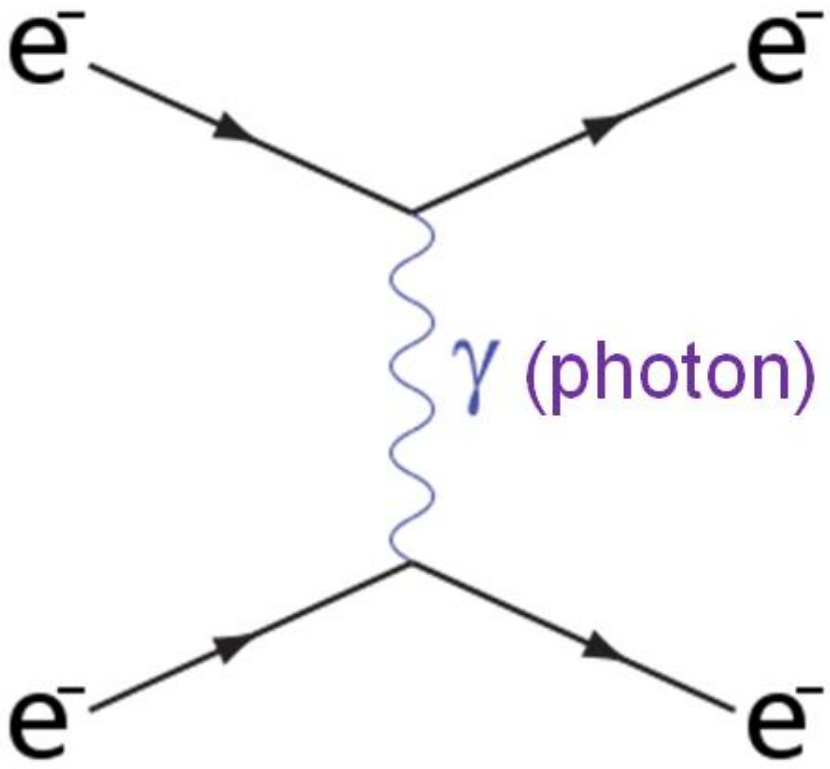


Attract (Pull)

How do the Interaction Work???…

The interaction is mediated by “virtual” particle exchange

e.g. electromagnetism: photon exchange between electrically charged particles



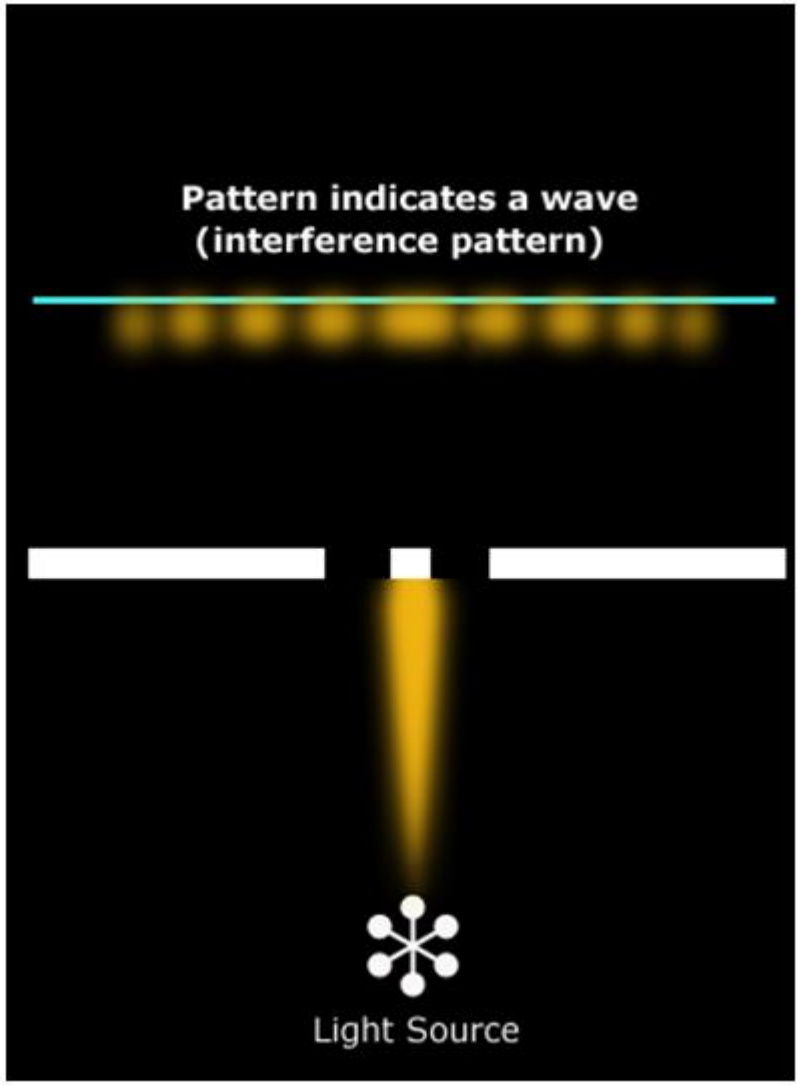
Weirdness of Quantum World

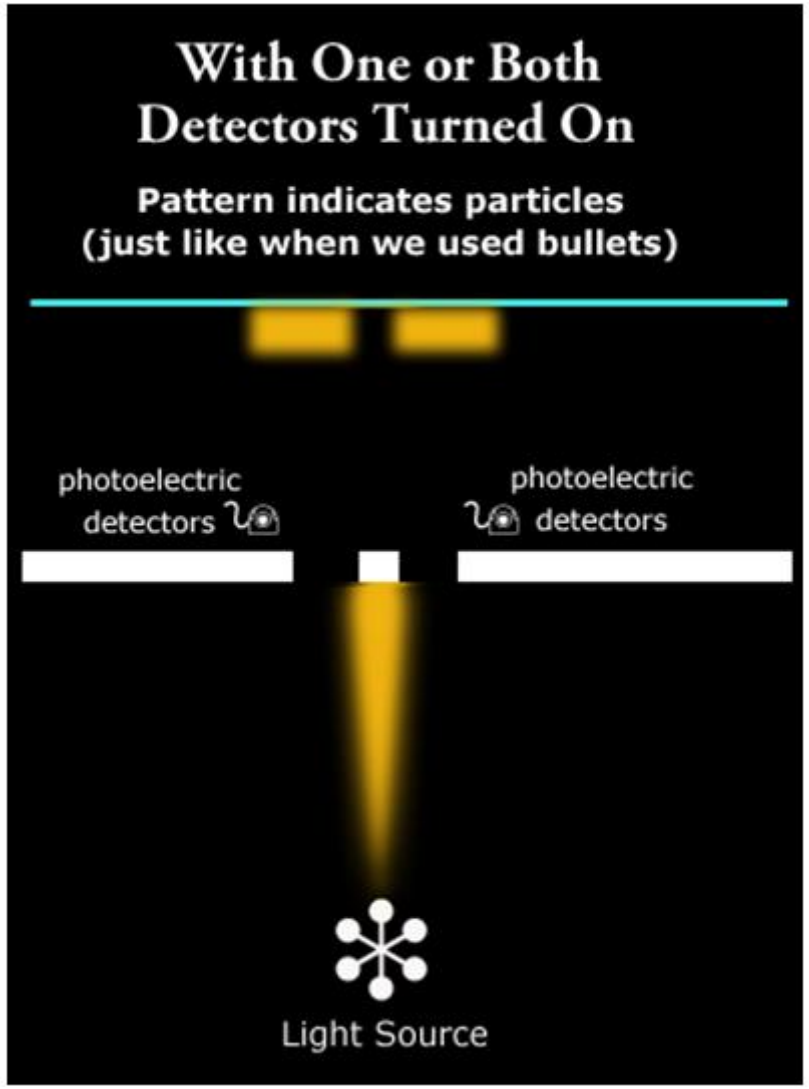
How do These Particles Behave???…

…Described by the Quantum Theory…

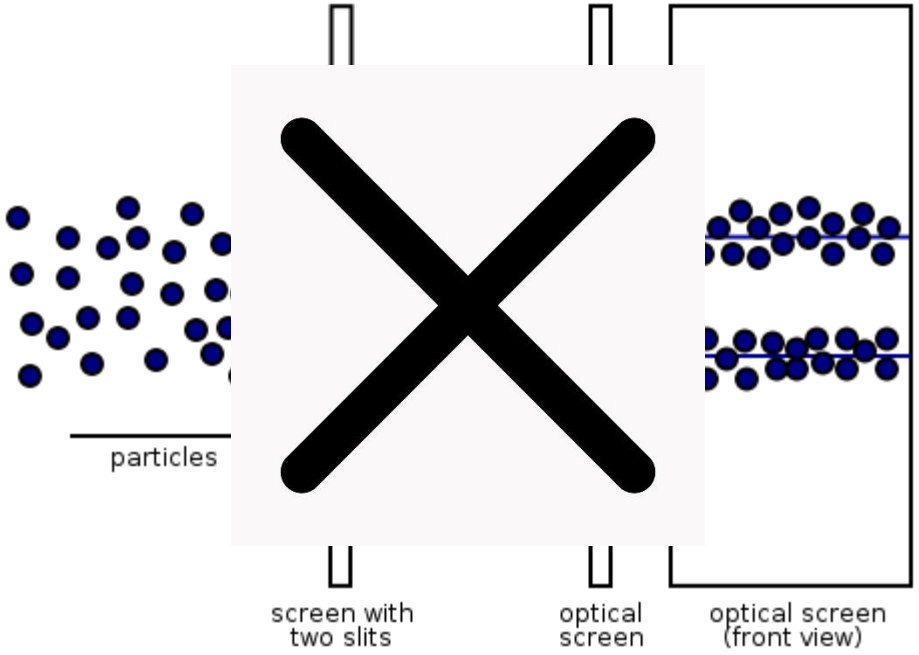
Richard P. Feynman: “..it is safe to say that **no body understands** quantum theory.”

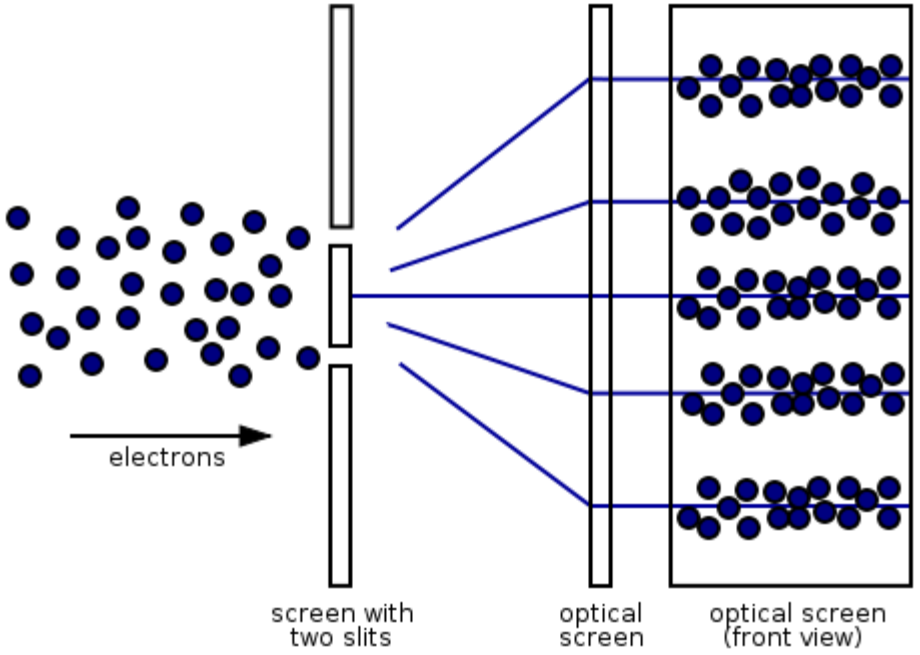
Light Double Slit Experiment…





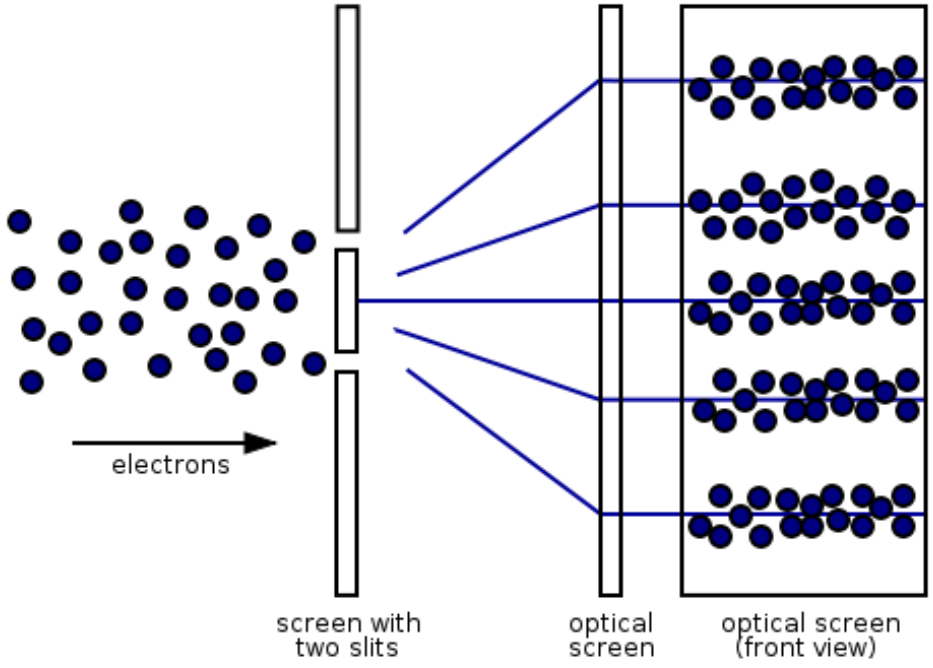
Weird Electrons Double Slit Experiment…





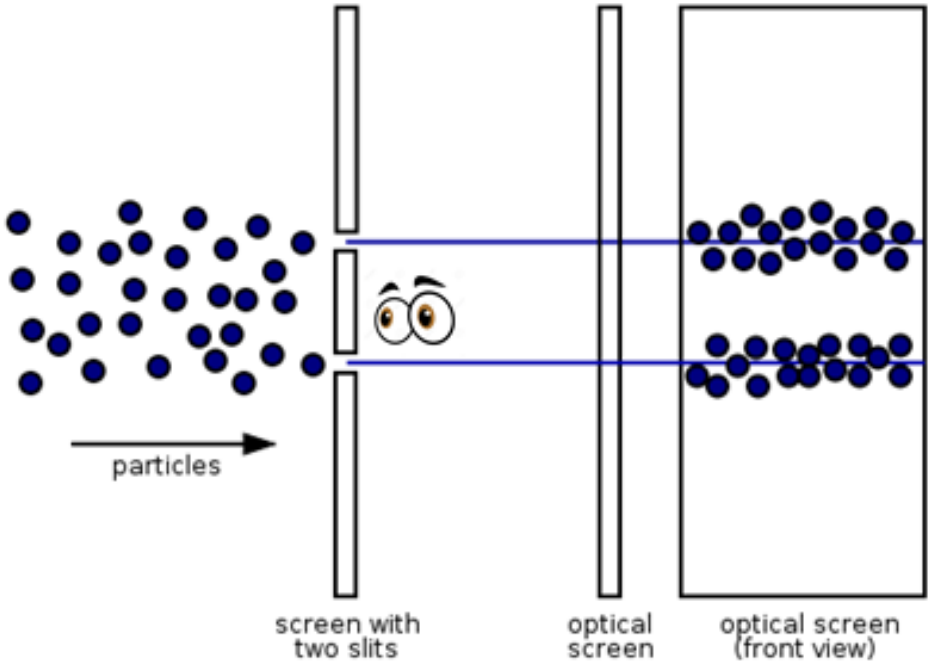
Particles exhibit wave behavior

Weird Behavior…



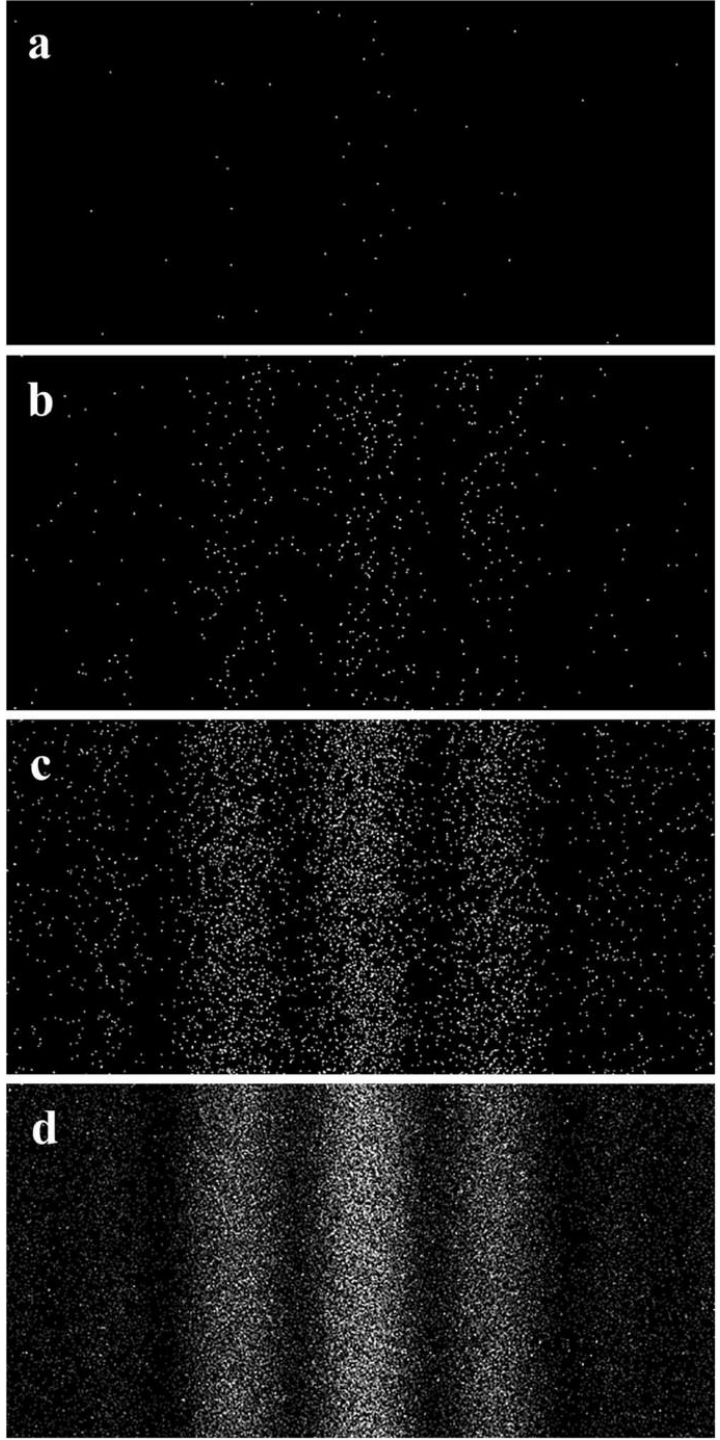
An electron can be in both slits simultaneously due to **quantum coherence**!...

This feature disappear when one put detector on one slit, i.e. the particles restored to behave like ordinary particle



Experimental Result…

Harada, K., Akashi, T., Niitsu, K. et al. Interference experiment with asymmetric double slit by using 1.2-MV field emission transmission electron microscope. Sci Rep **8**, 1008 (2018).



50 Electrons

500 Electrons

5000 Electrons

50000 Electrons

Quantum Realm &
Quantum Entanglement

Fundamentals of Quantum Theory…

The Fundamental Equations of Quantum Mechanics.

By P. A. M. Dirac, 1851 Exhibition Senior Research Student, St. John's College, Cambridge.

(Communicated by R. H. Fowler, F.R.S.—Received November 7th, 1925.)

§ 1. *Introduction.*

It is well known that the experimental facts of atomic physics necessitate a departure from the classical theory of electrodynamics in the description of atomic phenomena. This departure takes the form, in Bohr's theory, of the special assumptions of the existence of stationary states of an atom, in which it does not radiate, and of certain rules, called quantum conditions, which fix the stationary states and the frequencies of the radiation emitted during transitions between them. These assumptions are quite foreign to the classical theory, but have been very successful in the interpretation of a restricted region of atomic phenomena. The only way in which the classical theory is used is through the assumption that the classical laws hold for the description of the motion in the stationary states, although they fail completely during transitions, and the assumption, called the Correspondence Principle, that the classical theory gives the right results in the limiting case when the action per cycle of the system is large compared to Planck's constant h, and in certain other special cases.

On the Theory of Quantum Mechanics.

By P. A. M. Dirac, St. John's College, Cambridge.

(Communicated by R. H. Fowler, F.R.S.—Received August 26, 1926.)

§ 1. *Introduction and Summary.*

The new mechanics of the atom introduced by Heisenberg* may be based on the assumption that the variables that describe a dynamical system do not obey the commutative law of multiplication, but satisfy instead certain quantum conditions. One can build up a theory without knowing anything about the dynamical variables except the algebraic laws that they are subject to, and can show that they may be represented by matrices whenever a set of uniformising variables for the dynamical system exists.† It may be shown, however (see § 3), that there is no set of uniformising variables for a system containing more than one electron, so that the theory cannot progress very far on these lines.

Evolution of a Quantum System…

Time-Dependent Schrödinger Equation: $$i\hbar\frac{\partial\psi}{\partial t}=H\psi$$

Wave Function

Energy Related Hamiltonian Operator

$$\psi(t)=\psi(t_0)e^{-iHt/\hbar}$$

$|\psi|^2$ **Determines the probability of findings electrons in the screen detector for the double slit experiment**

The state of a quantum system collapse when it is measured.

Principle of Superposition…

The definite state of the moon is said to be in a superposition of exist and non-exist probability, until one making a measurement.

$$\psi_{\text{moon}} = \psi_{\text{there is moon}} + \psi_{\text{there is no moon}}$$

Einstein-Podolsky-Rosen (EPR) Paradox…

MAY 15, 1935 PHYSICAL REVIEW VOLUME 47

Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

A. EINSTEIN, B. PODOLSKY AND N. ROSEN, *Institute for Advanced Study, Princeton, New Jersey*

(Received March 25, 1935)

In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system. In quantum mechanics in the case of two physical quantities described by non-commuting operators, the knowledge of one precludes the knowledge of the other. Then either (1) the description of reality given by the wave function in quantum mechanics is not complete or (2) these two quantities cannot have simultaneous reality. Consideration of the problem of making predictions concerning a system on the basis of measurements made on another system that had previously interacted with it leads to the result that if (1) is false then (2) is also false. One is thus led to conclude that the description of reality as given by a wave function is not complete.

Quantum Theory is Incomplete to Describe Reality and Locality

Bell's Theorem…

Physics Vol. 1, No. 3, pp. 195–200, 1964 Physics Publishing Co. Printed in the United States

ON THE EINSTEIN PODOLSKY ROSEN PARADOX*

J. S. BELL†
Department of Physics, University of Wisconsin, Madison, Wisconsin

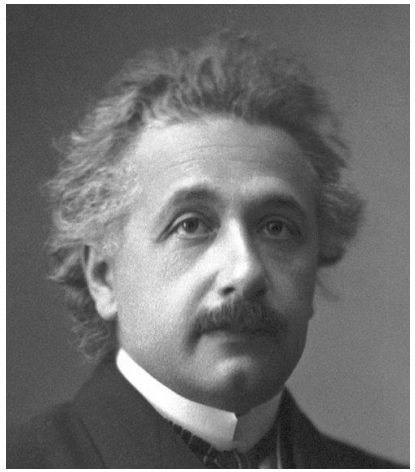
(*Received* 4 *November* 1964)

I. Introduction

THE paradox of Einstein, Podolsky and Rosen [1] was advanced as an argument that quantum mechanics could not be a complete theory but should be supplemented by additional variables. These additional variables were to restore to the theory causality and locality [2]. In this note that idea will be formulated mathematically and shown to be incompatible with the statistical predictions of quantum mechanics. It is the requirement of locality, or more precisely that the result of a measurement on one system be unaffected by operations on a distant system with which it has interacted in the past, that creates the essential difficulty. There have been attempts [3] to show that even without such a separability or locality requirement no "hidden variable" interpretation of quantum mechanics is possible. These attempts have been examined elsewhere [4] and found wanting. Moreover, a hidden variable interpretation of elementary quantum theory [5] has been explicitly constructed. That particular interpretation has indeed a grossly non-local structure. This is characteristic, according to the result to be proved here, of any such theory which reproduces exactly the quantum mechanical predictions.

Quantum Realm is Non-Local Realism and Violate Causality

Albert Einstein…



1. “Do you really believe the moon is not there when you are not looking at it?” – realism –

2. “God doesn’t play dice” – determinism –

Niels Bohr…

1. “Yes, it can be” – non realism –

2. “Stop telling God what to do” – indeterminism –

“COPENHAGEN INTERPRETATION”

What is Reality???…

According to the Copenhagen Interpretation:

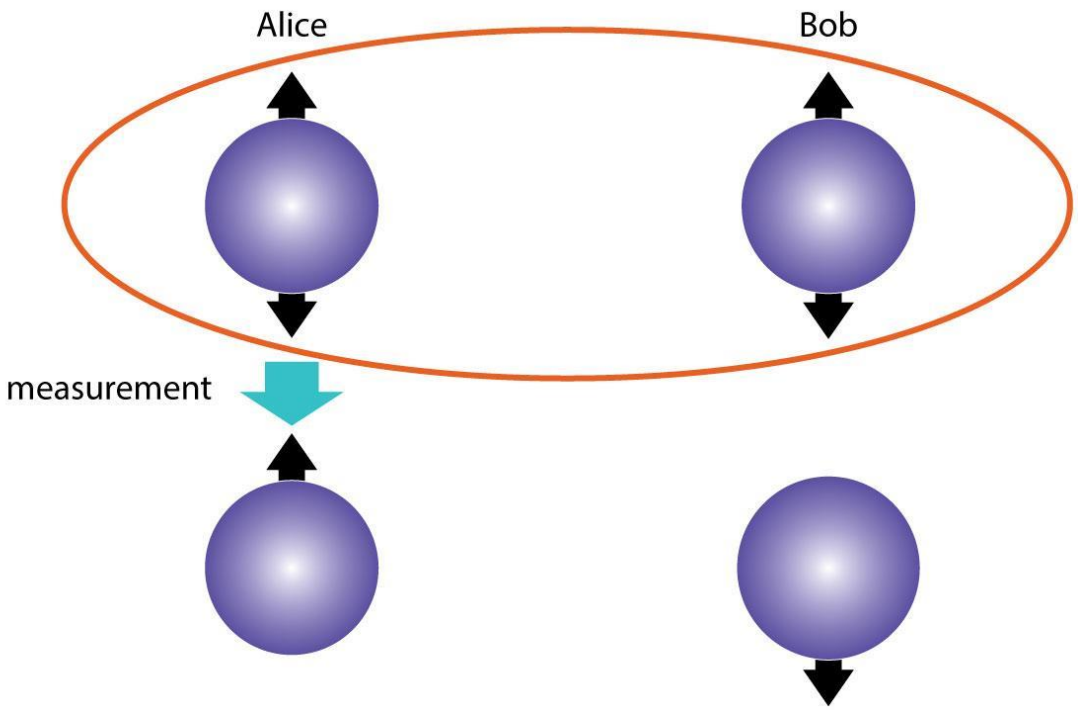
“There is no pre-existing physical reality (realism) of a system until one conducts measurement to it.”

Then what is reality?

“Something that we will never understand”

<Gerard t’Hooft, Physics Nobel Laureate 1999>

Quantum Entanglement…
(A Weird Consequence of Non-locality)



https://www.sciencemag.org/news/2015/08/more-evidence-support-quantum-theory-s-spooky-action-distance

Two particles (charged atoms, ionic molecules) with **SINGLE WAVE FUNCTION** can be entangled to each other.

Measurement of one particle will immediately affect the other one, no matter how far they are separated, indicating non-locality and no pre-existing condition to occur (non-locality).

The Application of Quantum (Photon) Entanglement…

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Satellite-Relayed Intercontinental Quantum Network

Sheng-Kai Liao *et al.*

Phys. Rev. Lett. **120**, 030501 – Published 19 January 2018

Physics See Focus story: Intercontinental, Quantum-Encrypted Messaging and Video

Article | References | No Citing Articles | Supplemental Material | PDF | HTML | Export Citation

ABSTRACT

We perform decoy-state quantum key distribution between a low-Earth-orbit satellite and multiple ground stations located in Xinglong, Nanshan, and Graz, which establish satellite-to-ground secure keys with $\sim$ kHz rate per passage of the satellite *Micius* over a ground station. The satellite thus establishes a secure key between itself and, say, Xinglong, and another key between itself and, say, Graz. Then, upon request from the ground command, *Micius* acts as a trusted relay. It performs bitwise exclusive OR operations between the two keys and relays the result to one of the ground stations. That way, a secret key is created between China and Europe at locations separated by 7600 km on Earth. These keys are then used for intercontinental quantum-secured communication. This was, on the one hand, the transmission of images in a one-time pad configuration from China to Austria as well as from Austria to China. Also, a video conference was performed between the Austrian Academy of Sciences and the Chinese Academy of Sciences, which also included a 280 km optical ground connection between Xinglong and Beijing. Our work clearly confirms the *Micius* satellite as a robust platform for quantum key distribution with different ground stations on Earth, and points towards an efficient solution for an ultralong-distance global quantum network.

MIT Technology Review

Topics+ The Dowr

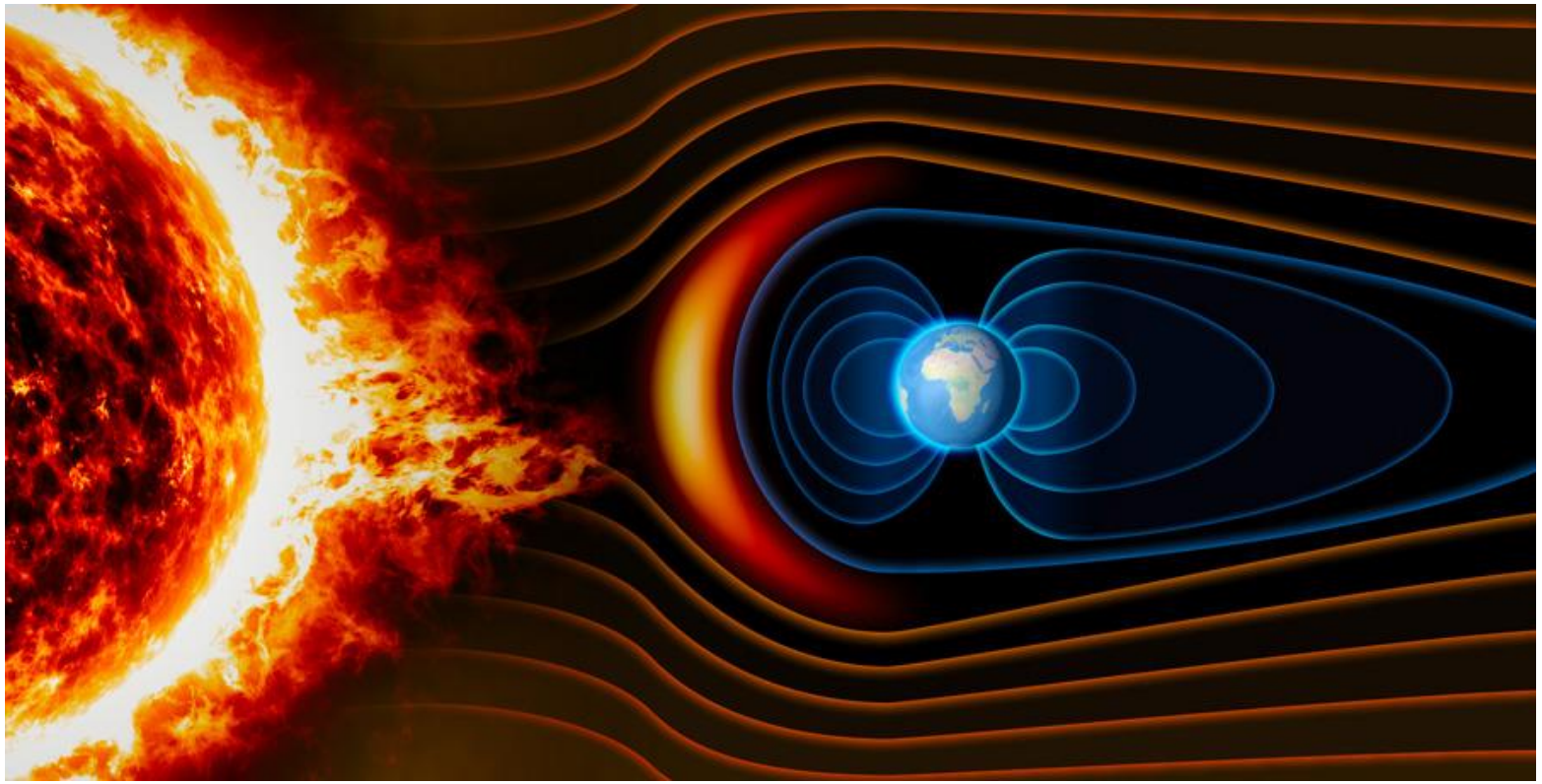
Connectivity

Chinese satellite uses quantum cryptography for secure video conference between continents

Quantum cryptography has never been possible over long distances. But the first quantum communications satellite is rewriting the record books.

Earth’s Magnetic Field & Possible Mechanism of Bird Migration

Earth's Magnetic Field…



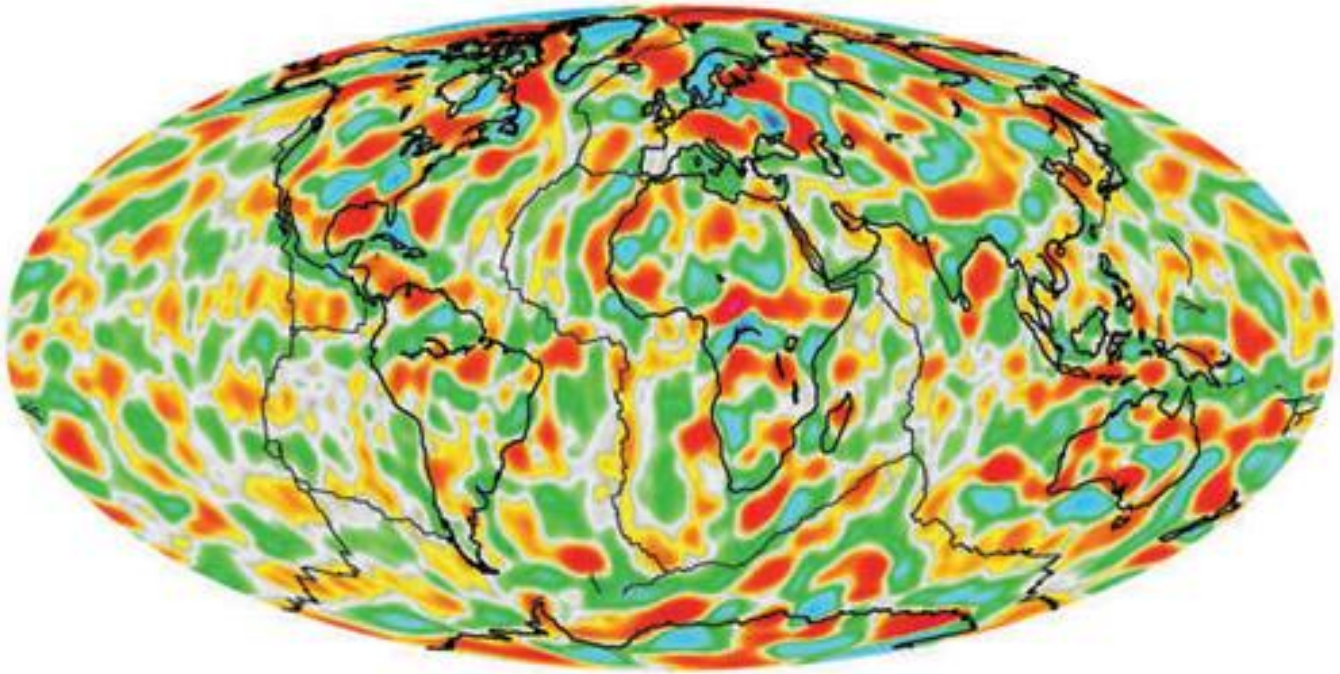
https://researchoutreach.org/articles/earths-magnetic-field-changes-through-time/

Exist (suspected) due to the presence of iron inside the Earth's core. It protects the Earth from the destructive solar-wind.

The Earth's magnetic field poles periodically reversed.

Facts about Earth's Magnetic Field…

https://www.nasa.gov/centers/goddard/news/topstory/2004/0517magnet.html



It is a vector quantity which have magnitude and direction.

The strength of the field at the Earth's surface ranges from less than 30 μ-Tesla in an area including most of South America and South Africa to over 60 μ-Tesla around the magnetic poles in northern Canada and south of Australia, and in part of Siberia.

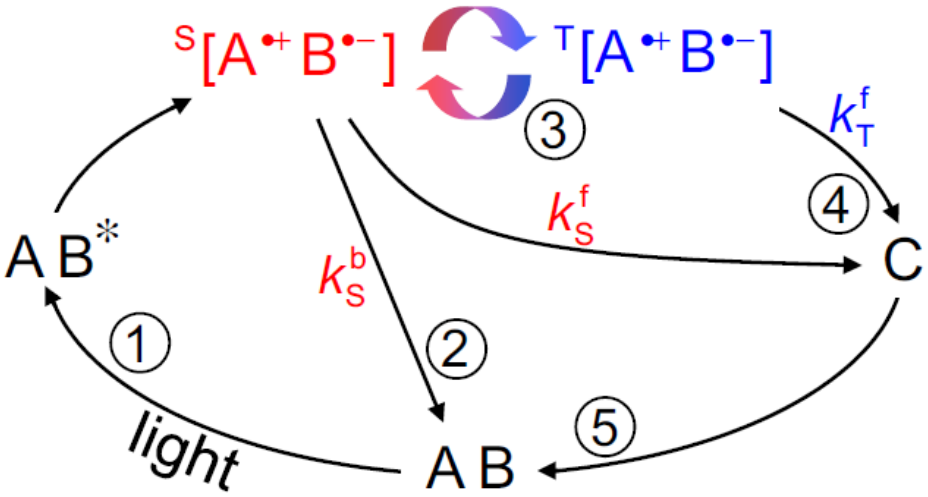
The average magnetic field strength in the Earth's outer core was measured to be 2500 μ-Tesla, approx. 50 times stronger than the magnetic field at the surface. For comparison the magnetic field strength of a coil of speaker is roughly 1 – 2 Tesla.

Bird's Magnetoreception…

It is suspected that the birds used the chemical reaction in their eyes induced by a photochemical process whose product yields depend on the orientation of the reactants within the magnetic field due to the **quantum magnetically sensitive radical-pair reaction mechanism**.

- Schulten, K., Swenberg, C. E., & Weiler, A. (1978). A Biomagnetic Sensory Mechanism Based on Magnetic Field Modulated Coherent Electron Spin Motion. *Zeitschrift fur Physikalische Chemie*, *111*(1), 1-5
- Christopher T. Rodgers, P. J. Hore, Chemical magnetoreception in birds: The radical pair mechanism, Proceedings of the National Academy of Sciences Jan 2009, 106 (2) 353-360

Radical-Pair Mechanism, Quantum Entanglement & Bird Navigation…



Photochemical Induced Reaction [1]

- Light induced a radical-pair A+ and B- [$TrpH^{\bullet+}$ $FAD^{\bullet-}$] of cryptochrome molecules in the bird's eyes photoreceptor which is in a singlet state (with both have opposite spins) [1]. The singlet radical-pair performed an entangled state.
- The singlet radical-pair is interconversion to become un-entangled triplet state (with both have parallel spins) due to hyperfine coupling between both radicals.
- The triplet states of A+ and B- can produces C molecule which is an intermediate state prior to recombination.
- The maximum **RECOMBINATION** from the singlet state is suspected to be influenced by the their **ENTANGLEMENT** due to the inclination of Earth's magnetic field and hence **NAVIGATES THE BIRDS** with unknown further complex mechanism [2].

1. Christopher T. Rodgers, P. J. Hore, Chemical magnetoreception in birds: The radical pair mechanism, Proceedings of the National Academy of Sciences Jan 2009, 106 (2) 353-360
2. Jianming Cai, Gian Giacomo Guerreschi, and Hans J. Briegel, Quantum Control and Entanglement in a Chemical Compass, Phys. Rev. Lett. 104, 220502

Conclusion???...

We have been trying to learn about the nature of the world of Birds through atomic scale perspective. It seems its dynamics is God's business and He only gives us little clue but it's useful enough…

…Now I Know That I Knew Nothing…

…Thank You…