Mysteries of the Photon

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Talk given

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Electric & Magnetic Fields: EM Vector Potential

- Why do we need EM potentials when the observables are the electric & magnetic fields?
- Because charges [electrons, protons, ions] are directly coupled to the vector potential **A.**
- A vector implies it has a magnitude & a direction.

- If a particle of charge q and mass m moved with velocity **v** its momentum **p** would be its mass times its velocity: **p** = m **v**. But if our charge is immersed in a magnetic field, its momentum has an extra component due to the vector potential **A**:

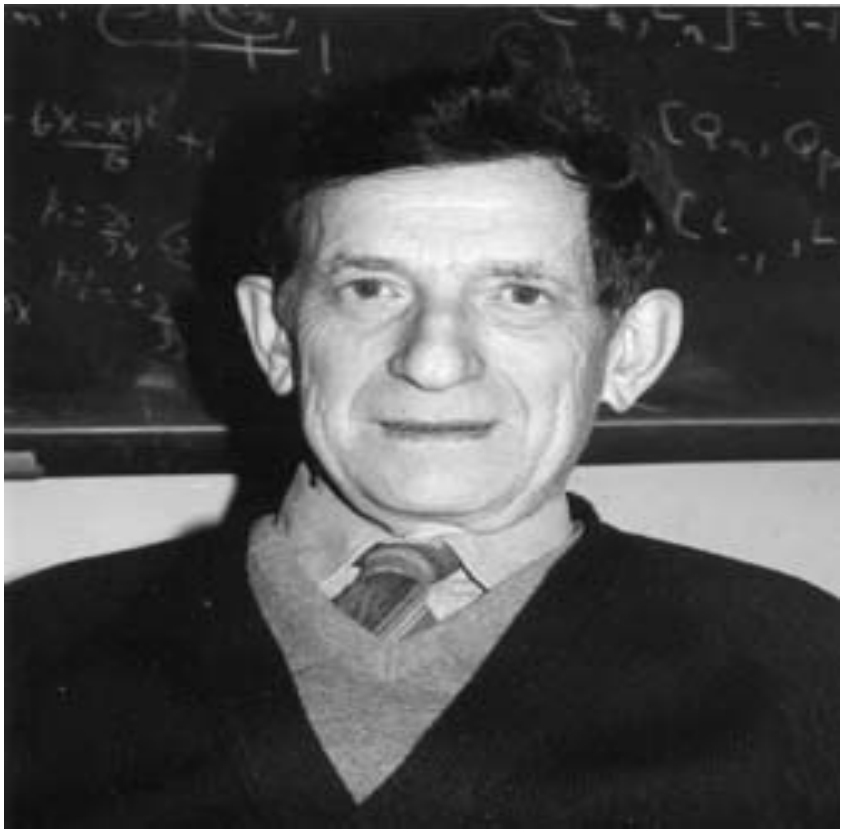
$$m\,\mathbf{v} \rightarrow m\,\mathbf{v} - (q/c)\,\mathbf{A}$$

where c is the speed of light.

In Newtonian-Galilean classical physics c→infinity.

Thus, we need Einsteinian relativity to understand magnetic phenomena properly.

Bohm & Aharanov



Raised an interesting issue which is of great relevance once we have both Einstein relativity and quantum mechanics.

Bohm-Aharanov II

Suppose we have a magnetic field here [confined in a volume V; practically zero outside].

*But the vector potential **A** need not be zero outside V.*

So they asked the question:

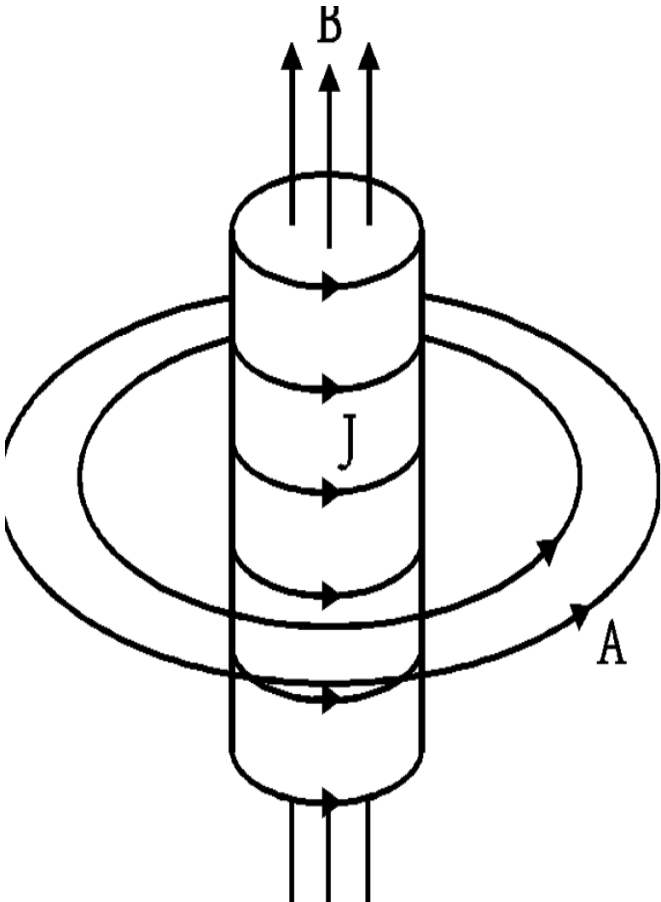
Can there be physical effects

caused by the vector potential **A**

in part of space

[let us call it over there]

where there is **no** magnetic field?



Bohm-Aharanov III

- Their paper created a great stir because it was questioning a central belief most physicists have about the principle of local action.
- In this case, the idea was well grounded in the minds of most physicists that electric and magnetic fields were "real" but the vector potential was not.

- I quote you one such example. As an eminent physicist Fritz Rohrlich wrote:

- *"the EM potentials have no physical meaning and are introduced solely for the purpose of mathematical simplification of the equations,"*

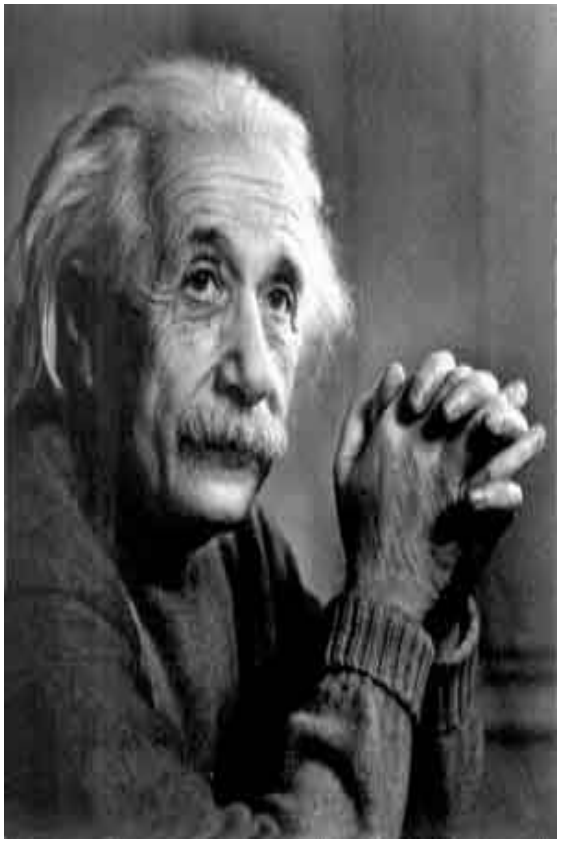
Bohm-Aharanov IV

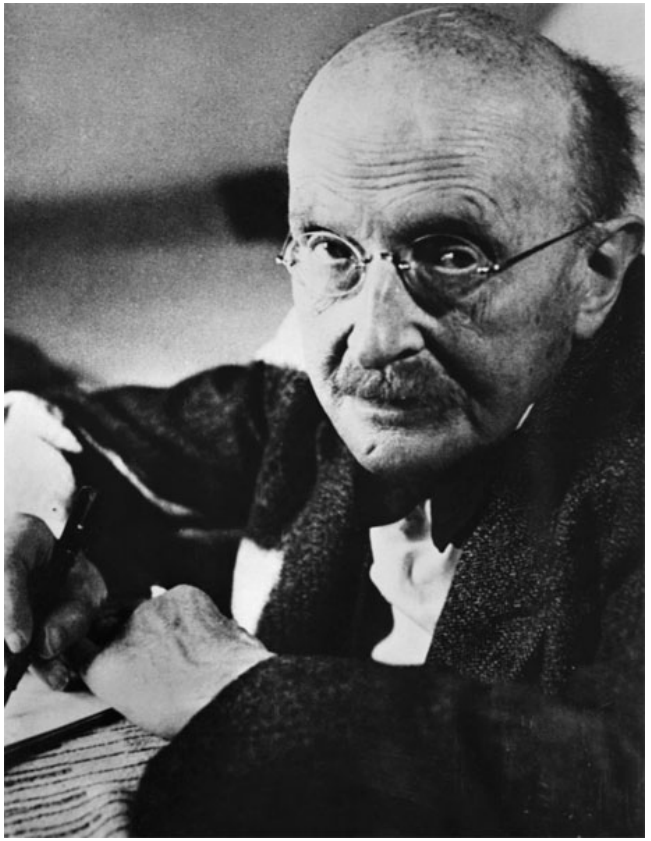
- With the verification of the Bohm-Aharanov effect in thousands of experiments over the past 50 years, the notion of "non-locality" is well established. Yet, most physicists still cling to the notion of locality.
- As two eminent physicists Bryce Dewitt & Graham put it:
- *"Physicists are, at bottom, a naive breed, forever trying to come to terms with the "world out there" by methods which, however imaginative and refined, involve in essence the same element of contact as a well-placed kick".*

Bohm Flees US

- David Bohm was a brilliant young physicist at Princeton.
- He wrote a classic book on quantum mechanics which was highly appreciated by Albert Einstein.
- Yet Bohm suffered from two "defects" by American standards. One that he was a declared communist. Two: that he wrote the famous paper with Aharanov which many physicists erroneously assumed to be an attempt to "destroy" quantum mechanics.
- During the 1950's witch hunt against the communists in the US, he had to run away from Princeton & the US. He first fled to Brazil and during the 60's found employment at Birbeck College in London.
- *He once described that his persecution by the FBI for being a communist was bad and yet it was nothing compared to the severe ostracism he suffered by his fellow physicists for the BA effect*. That was far worse!

The notion of the photon





In 1900, Planck invented discrete packets of energy and thus began the most revolutionary concept of a quantum.

Einstein explained what it really meant and baptized the carrier of EM energy a “photon”. There arose the famous “wave-particle” duality:

Photon II

- There are EM waves with a wavelength λ and a frequency ν with $c = \lambda \nu$.

- But it is also a particle moving with the speed of light c that we call a photon: it carries energy $E = h \nu$ and momentum $p = E/c$.

- So it is both a particle and a wave.
- When we do not detect it, it is spread out as a wave. But when we catch it, it is a particle the photon.
- *Quantum mechanics tells us that if we know its energy exactly then we do not know where it is and if we know where it is we can not know its precise energy.*

Where is the photon?

Now we are ready to ask a practical quantitative question:

- Suppose we have 1 “blue” photon:
- It has an energy about 3 electron Volts ~ 5 x 10^{-19} Joules.
- Can we confine it within an arbitrarily small volume? Say with in a box with sides less than its wavelength
- The answer is NO!

Why is the question relevant?

- This question is very relevant in quantum optics and in nano technological devices
- But it is also of great interest in biology due to the experiments of Fritz Popp on Bio-photons and experiments initiated by Benveniste and continued by Montagnier regarding inter cellular and DNA communications by photons.

- Let us discuss bio-photon emission:
- All living organisms emit photons in the visible light region.

Coherent Biological Structures and Communications

1. Biophotons

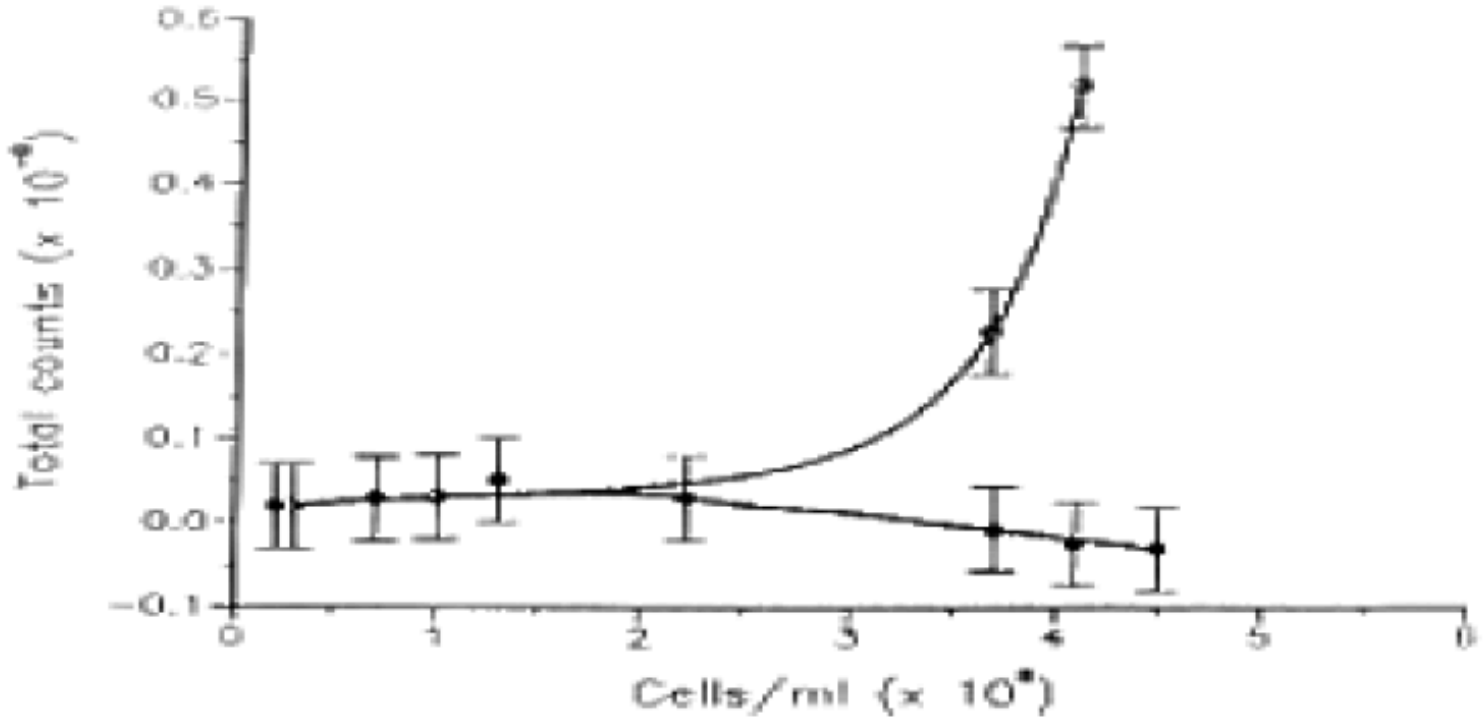


Figure 5b Delayed luminescence of cancer cells (upper curve) and normal cells (lower curve) in dependence on the cell density.

2. Microbial Nanowires

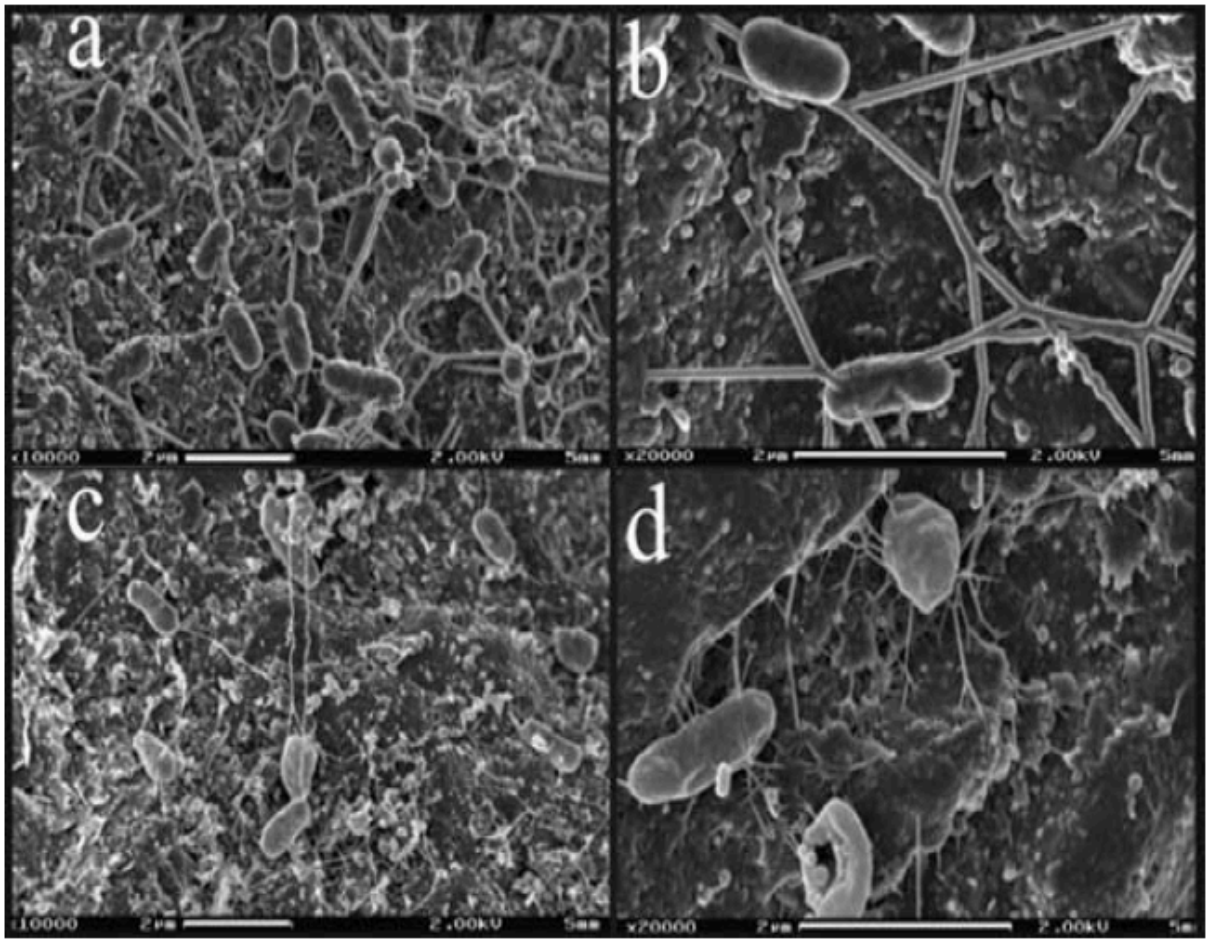


Figure 3. SEM images. (a) Pilus-like appendages from S. oneidensis MR-1. Appendages are long and thick. (b) Close up Image showing a network of cell-cell and cell-mineral connection, merging and splitting of appendages. (c, d) Pilus-like appendages from S. oneidensis mutant strain showing thin and frail appendages and cells are visibly deteriorated.

3. Bacterial Wireless Transmissions

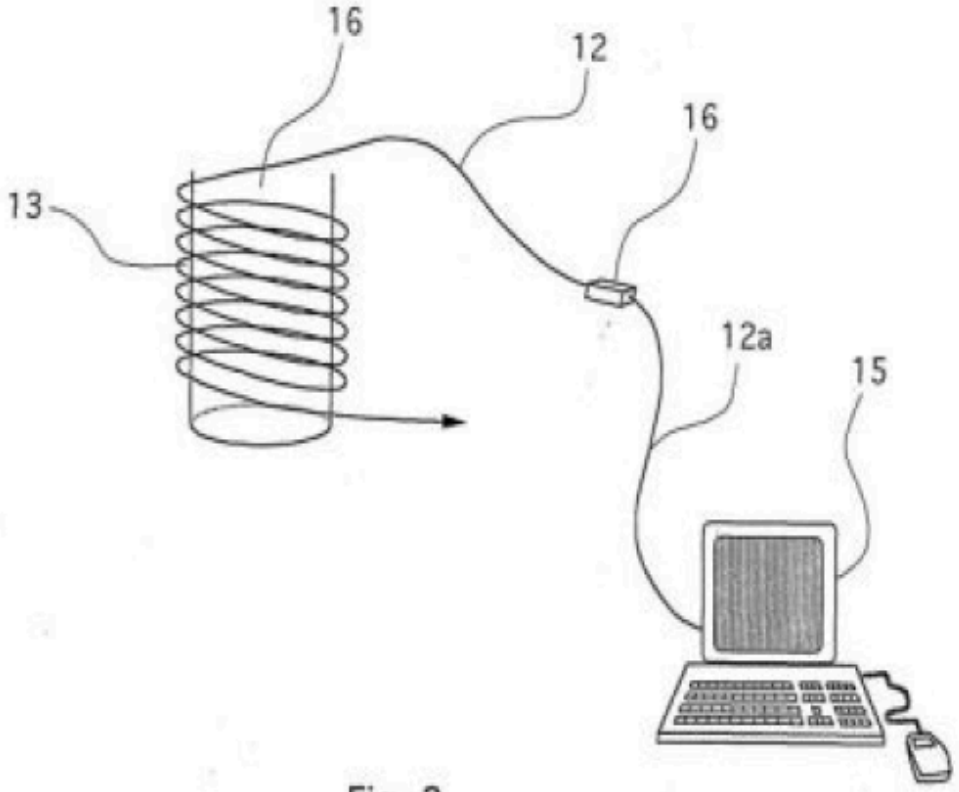


Fig. 2

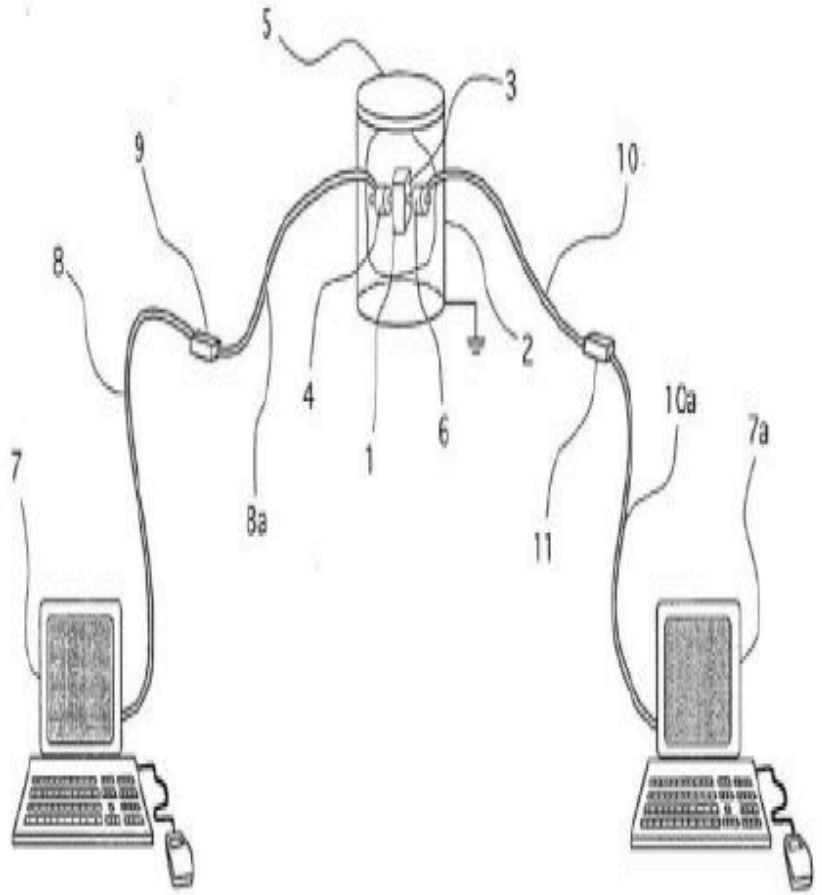


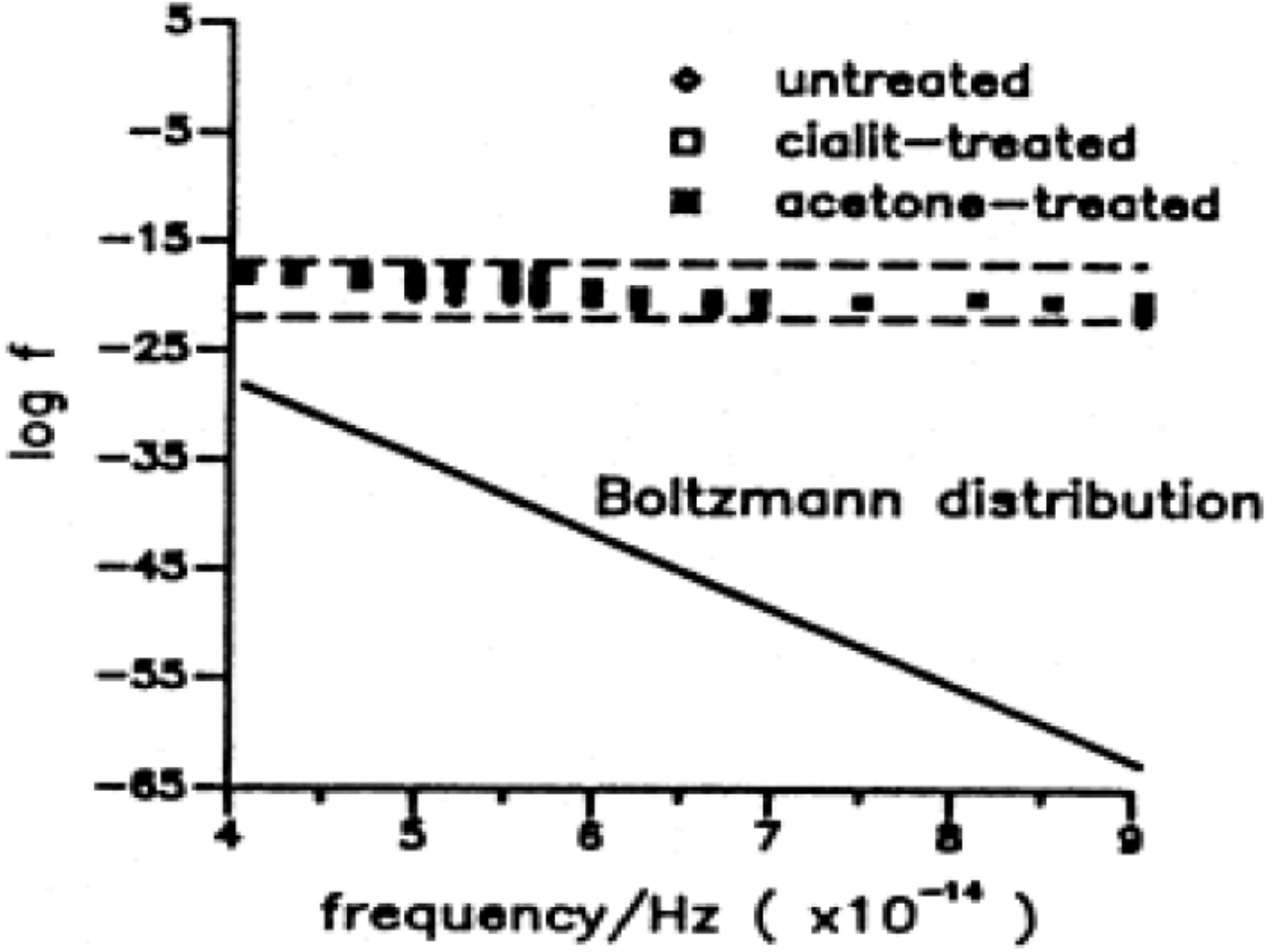
Fig. 1

Biophotons I

Fritz-Albert Popp: Neuss, Germany

- Biophotons are photons emitted spontaneously by all living systems.
- This phenomenon is not confined to "thermal" radiation in the infrared range.
- Biophotons are emitted also in the range from visible up to UV.
- The intensity of biophotons can be registered from a few photons-per-second per square-centimeter surface area on up to some hundred photons from every living system under investigation.

Biophotons III



Biophotons V

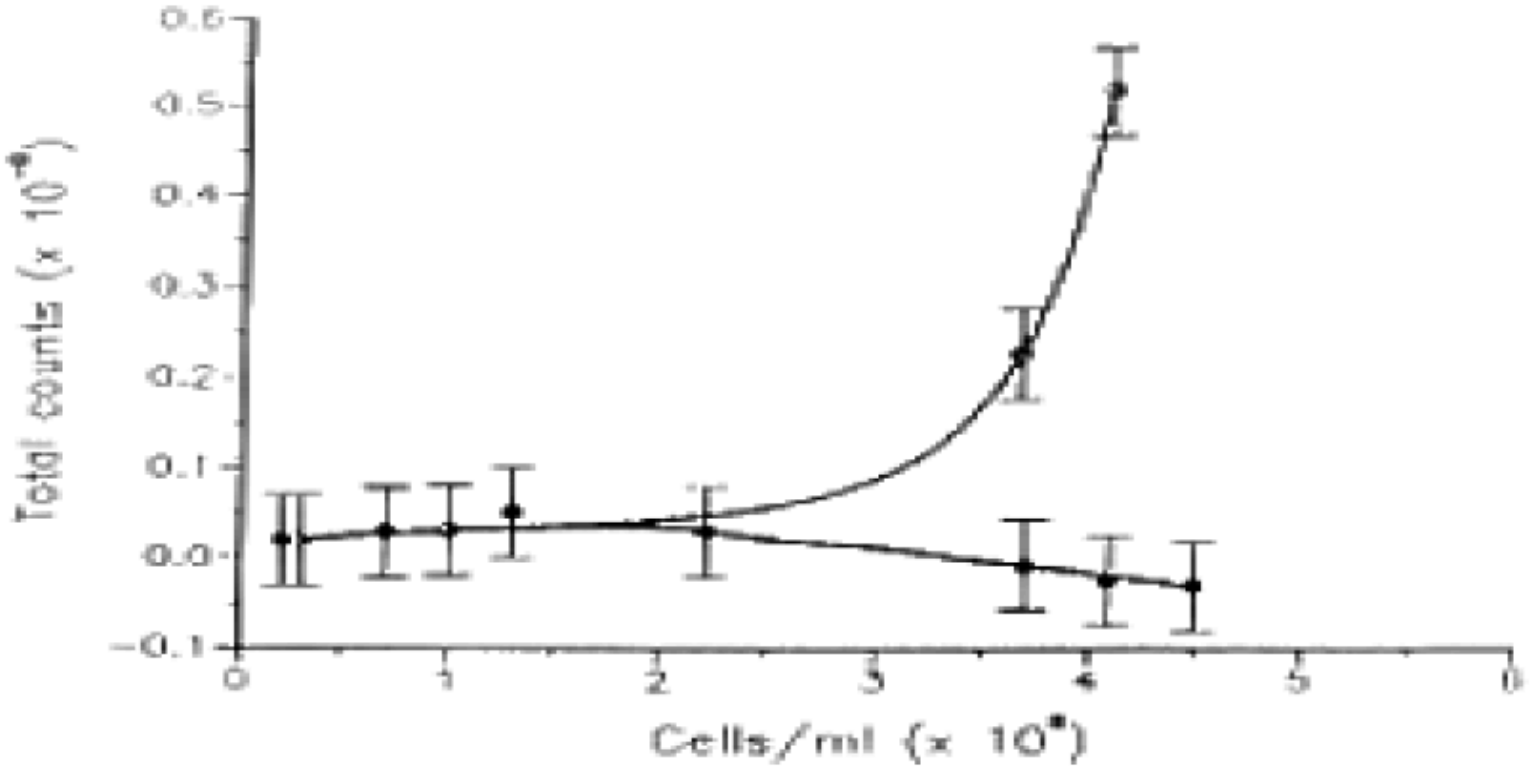


Figure 5b Delayed luminescence of cancer cells (upper curve) and normal cells (lower curve) in dependence on the cell density.

A non invasive diagnostic device

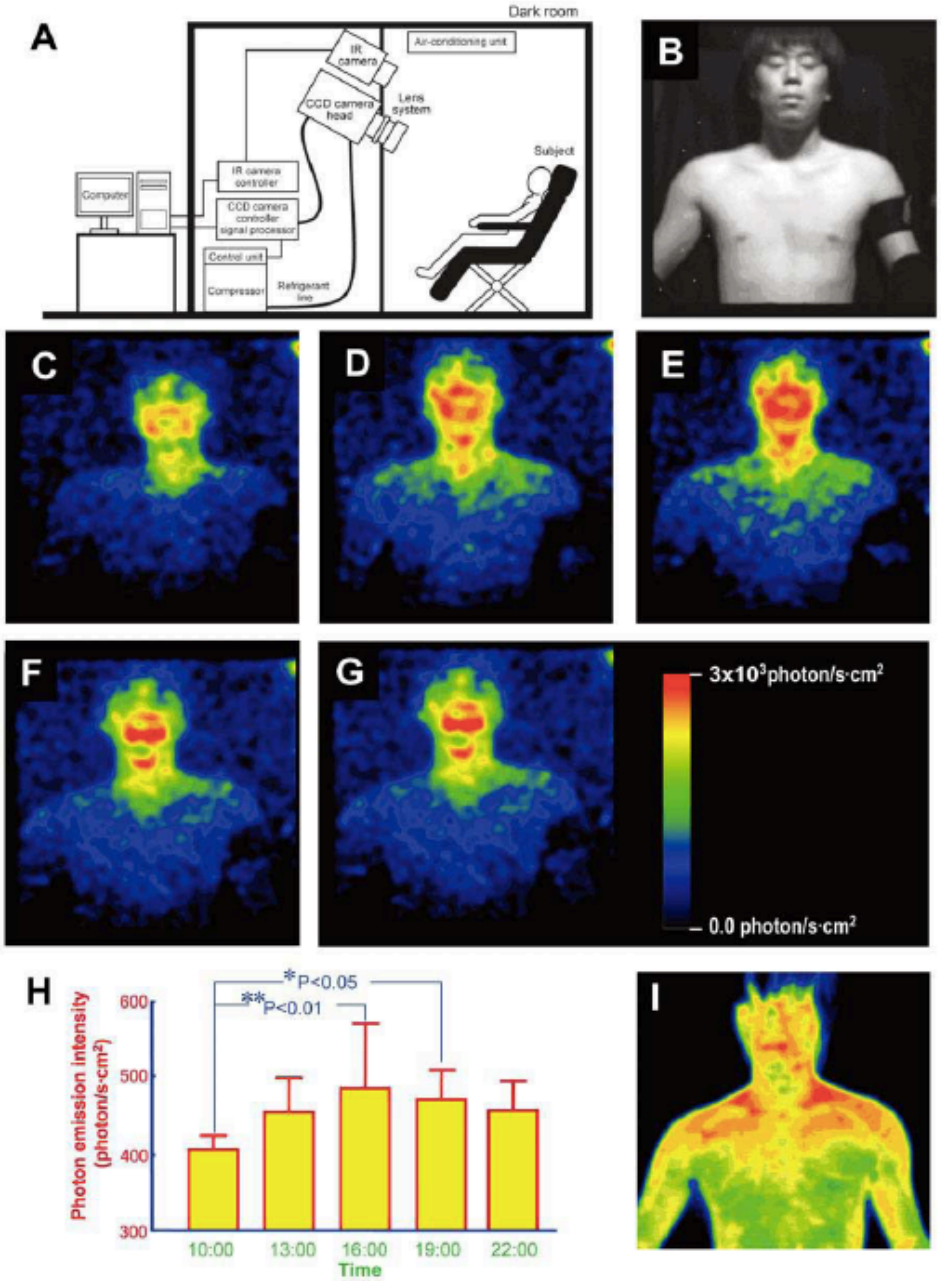
Biophotons VI

Imaging of Ultraweak Spontaneous Photon Emission from Human Body Displaying Diurnal Rhythm

M. Kobayashi, D. Kikuchi, H. Okamura

- The human body literally glimmers.
- The intensity of light emitted by the body is 1000 times lower than the sensitivity of our naked eyes.
- They successfully imaged the diurnal change of this ultraweak photon emission with an improved highly sensitive imaging system using cryogenic charge-coupled device (CCD) camera.
- They found that the human body directly and rhythmically emits light. There are diurnal changes.

Biophotons VII



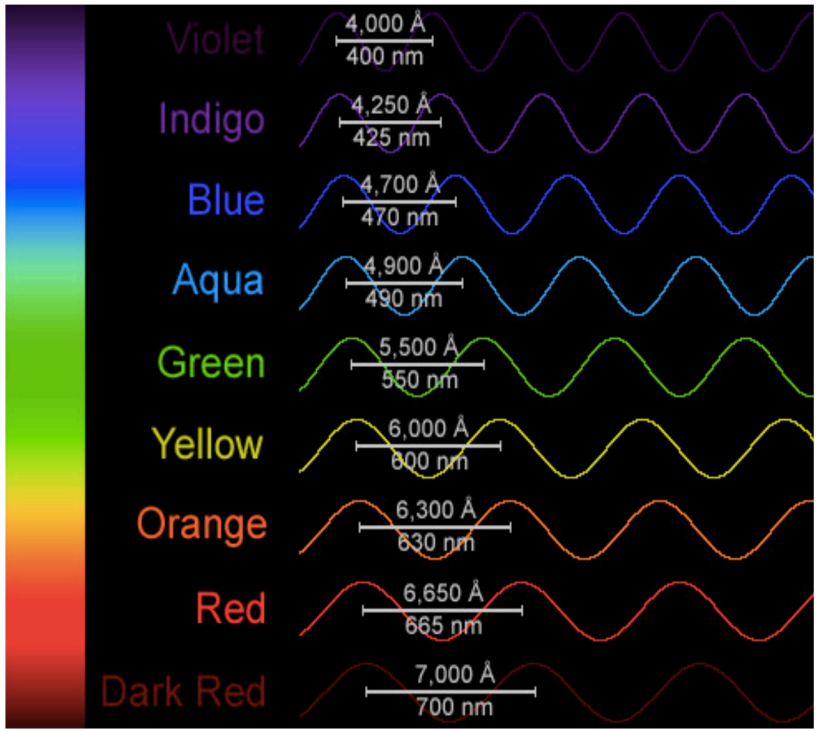
Ultraweak biophoton emission was unlike thermo graphic images showing surface temperature. High photon emissions were detected from the cheeks, followed by the upper neck and the forehead, high temperature was detected in the supraclavicular lateral neck region, from which photon emission was low.

In cheek, the highest level of emission reaches to 3000 photon/s/cm2 at 16:00 which is about double to the value at 10:00 am.

Origin of bio-photons

- Where are bio-photons produced?
- Is still under debate: molecular, cellular, intracellular, DNA, nuclear?
- The wavelength of visible light lies between

(470 nm – 650 nm)



Possible source:

Size of a cell: (1000 nm -100,000 nm):

Seems OK

Size of DNA: width: 2.5 nm

Length of DNA:

(i) Plasmid DNA length:

(0.33 nm – 0.66nm)

(i) Bacterial Chromosomal DNA length:

1,300 nm *Seems too small*

Bohm-Aharanov Magnetoresistance

- The magnetoresistance of a ferromagnetic Fe–Ni nano-ring with 420 nm in inner diameter and 500 nm in outer diameter was measured at very low temperatures below 100 mK.

- When a magnetic field is applied to the ring, the magneto-resistance exhibits oscillations whose period varies according to the field direction.

- This demonstrates the Aharonov–Bohm effect of the conduction electrons in the ferromagnetic nano-ring. The amplitude of the oscillations can be regarded from the viewpoint of competition between the system size and the phase coherence length of the conduction electrons.

Thank you for your
patience
and attention