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How Cosmic Ray Influenced an Election

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On May 18, 2008, voters of Belgium went to the poll for voting. In many regions of Belgium, votings were done on computers, something Belgium was experimenting with over a decade. In this computer voting system, a voter has to insert a magnetic card into the computer to make their selection on the screen. The data is stored in both the computer and the magnetic card. After the voting the magnetic card was dropped in a box for redundancy. Late that night when the votes were being tabulated a serious problem was detected in Schaerbeek, a municipality of Brussels Capital Region, Belgium. A candidate, Maria Vindevogel of Workers' Party, Belgium who was little known that time received more votes than mathematically predicted. So the members of the counting authority took out the magnetic cards and started counting again. After several hours they found that the vote total for every candidate was exactly the same before except for Maria Vindevogel. For Maria Vindevogel, the number of recounted vote was less than the original by 4096 number of votes. How this inflation in votes becomes possible even? What went wrong?

Computer experts were brought in to run extensive tests to check the programme. They combed through the code but no bug was detected. Then they tested the hardware again and again. But the error could not be replicated. The hardware as well as the software were working perfectly in order. In this scenario, they were left with only one possible explanation and that was weird. The answer to this riddle is the number of extra votes itself - **4096**.

Computers work in binary, a string of 0's and 1's and each correspond to a power of 2

0	1	1	0	1	0	0	1	0	1	1	1	0	1
2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Figure 1. Binary Representation of Decimal Numbers

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So inside the computer when the votes were tabulated, it is actually a string of bits representing number of votes Maria received. When the tabulation started the string was all zeros and then with each vote for her, it would increment by one. Physically this is equivalent to turning the transistor ON for 1's and turning them off for 0's. What is remarkable for this number 4096 is, it is exactly a power of '2' ; $4096=2^{12}$ that is the thirteenth bit. So if Maria has to get 4096 votes , only one digit has to flip from 0 \rightarrow 1. But why would it happened even? Looking into this problem Belgium investigators started to go through the similar problems reported in 1970's. In 1978, Intel reported same strange errors in their 16 kb dynamic random access memory or DRAM. Some 1's flip to 0's randomly with no apparent cause. Then they found that the problem was with the Silicon packaging of the chips. During 1970's the demand of encasing the chips inside semiconductors were huge. As a result a new manufacturing plant was constructed on the Green River in Colorado. This place happens to be the site of an old Uranium Mill. Radioactive particles flowed into the river stream and made their way into the ceramic packaging for Intel's microchips. Intel scientists investigated the problem and found that even a little trace of Uranium and Thorium in the ceramics were sufficient to cause the problem.

In the DRAM, memory is stored as the presence or absence of electrons in a semiconductor well.



Figure 2: Electrons in the well decide the nature of the state

Energetic alpha particles from Uranium and Thorium caused ionization inside te semiconductor which in turn created electron-hole pairs inside the Silicon. If alpha particles struck in right place that can cause accumulation of electrons in the well which causes a flip in the state from 1 \rightarrow 0.

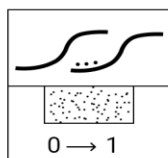


Figure 3: High Energy Particles Can Cause Bit Flip

This is called Single Event Upset (SEU), a type of ‘soft error’. This error is called ‘soft’ as the device has not been damaged. The bit is changed but the error can be corrected. Investigators exposed the chips to alpha emitters with various activity level and they found that number of bit flip increases with the increase in radioactivity. So the bit flip which caused Maria to get 4096 more votes was not caused by Natural Radioactivity. Then what caused it?

When Henry Becquerel discovered radioactivity with Uranium in 1896, scientists found a way to measure how radioactive are different materials? This was done with a gold leaf electrometer. In 1910, Theodor Wulf took his electrometer to the top of the Eifile Tower, he expected that as the radioactivity was found in the soil and rock, so at a height of 330mts from ground level it would be less. Instead he found only a slight decrease (6 ions cm^{-3} to 3.5 ions cm^{-3}). In 1911, Austrian physicist Victor Hess loaded electroscopie in a basket of a hydrogen ballon to measure the density of radiation at a greater height. Upto 1100m, no significant change was found. Next year, he conducted seven ballon flights upto an altitude of 5200 meters and at this height he discovered something remarkable. Initially, there was a drop in radiation but above 1Km the radiation level increased with increasing altitude.

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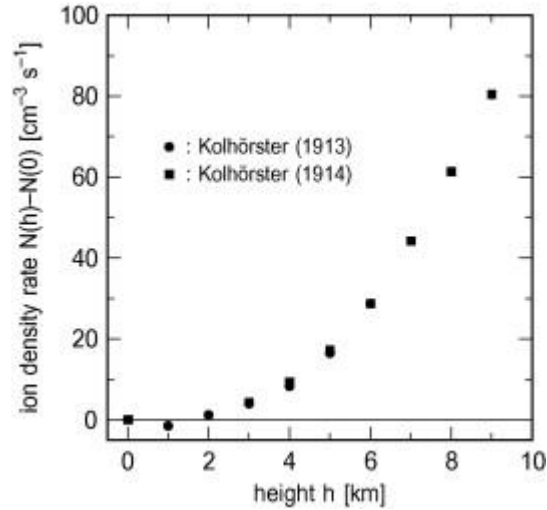


Figure4: Density of Cosmic Radiation Increases with Increase In Distance from Sea Level

The radiation appeared to be coming not from the Earth but from the sky. One of his flight was during the solar eclipse and he observed that even if the Sun was half covered, the radiation level was the same Victor Hess discovered cosmic radiation is the high energy radiation from space. Today, we know these are not EM radiation. 90% of them are protons, 9% of Helium, 1% heavier nuclei. Some of them are from the Sun but they are comparatively of low energy. High energy cosmic rays moving very close to the speed of light come from exploding stars, supernova. Highest energy particles are from black holes. But it is very difficult to know the place of their origin as they are deflected by magnetic fields. So they wind their ways for billion of years in the Universe. A cosmic ray detected on 15th October 1991 had an energy of 51 joules. Primary cosmic ray particles do not make it down to the Earth's surface. Above 25 kms from the Earth's surface, they collide with the air molecules and create new particles like pions. These particles collide and decay into other particles like neutron, protons, muons, electrons, positrons and photons which in turn collide with other air molecules in one long cascade. So from single primary cosmic ray, comes a shower of high energy particles streaming towards the Earth. It is one of these particles which suspected to struck a transistor in a computer in Belgium flipping the 13th bit from zero to a one and giving Maria Vindevogel 4096 extra votes. And this is not an isolated case. Cosmic rays are triggering bit flip all the time which can't be avoided. In 1996 IBM estimated that for each 256 MB of RAM, one bit flip occurs every month and the main culprit was neutrons. Cosmic rays can cause malfunctioning of super computers specially at higher altitude. Los Alamos National Labs located at 2200 Metres above sea level constantly suffer neutron induced supercomputer crashes. If we go even higher in airplanes, we could detect increase in radiation with aircraft gaining height. At 18000 ft the radiation is 0.5 microsieverts/hr which increases upto 2 microsieverts/hr at an altitude of 33,000ft. It may not affect our laptop but what if it enters in flight computers? On 7th October

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2008, an Airbus A330 from Singapore to Perth, suddenly pitched down, diving 200mts in 20 secs. Minutes later, the plane dropped another 120 metres. 119 people injured by bumping their heads into the ceiling. So the pilot decided to make an emergency landing. After a detail investigation of this weird event , it came out that a high energy cosmic particle entered into the CPU and it altered the first 8 bits of data. ‘The Altitude’ information teh flight receives was mislabeled as ‘angle of attack’ information. Inside the cockpit, alarms went on for overspeed and stall simultaneously, something that should be impossible but the plane came down sharply to correct what it thought was a stall. This is also a ‘soft’ error and it left no trace. In the history of our planet, cosmic rays have played even a larger role by flipping bits not in electronics but in genetic codes of living beings which influenced the process of natural selection.

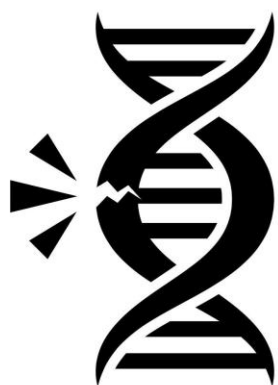


Figure 5: Genetic Codes Alteration Due To High Energy Radiation

Maria Vindevogel is now a member of the Belgium Chamber of Representatives elected by people not a particle. But her story reminds us of zillions of particles making their ways into the Universe for millions and billions of years, which might change our lives any moment by passing through a tiny transistor.

References and Picture Credits:

1. <https://www.aps.org/publications/apsnews/201004/physicshistory.cfm>
2. https://www.colorado.edu/center/spacegrant/sites/default/files/attached-files/03_High_Altitude_Cosmic_Ray_Radiation_Detection.pdf
3. <https://www.nasa.gov/feature/goddard/2017/nasa-studies-cosmic-radiation-to-protect-high-altitude-travelers>
4. <https://images.app.goo.gl/iLycKNWjFS1u6H76A>
5. <https://eightify.app/summary/science-and-technology/cosmic-rays-and-natural-selection-the-universe-s-hostility-to-computers>
6. <https://images.app.goo.gl/pvPRdUyPEaM6NrpQA>