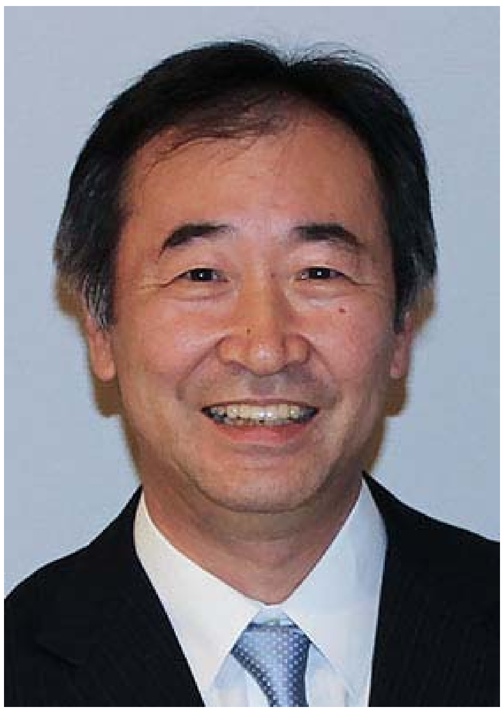
THE NOBEL PRIZE IN PHYSICS 2015

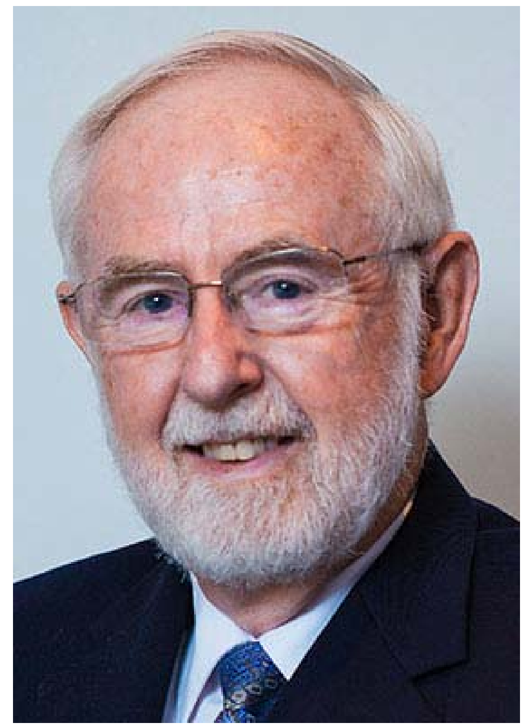
Takaaki Kajita and Arthur B. McDonald ***"for the discovery of neutrino oscillations, which shows that neutrinos have mass".***

Solve the Solar neutrino problem

Opened a new realm in particle physics.



Takaaki Kajita and Arthur B.McDonald ***were the leaders scientists of two large research groups, Super-Kamiokande and Sudbury Neutrino Observatory, which discovered the neutrinos mid-flight metamorphosis.***



ARTHUR B. MCDONALD **Canadian citizen. Born 1943 in Sydney, Canada. Ph.D. 1969 Caltech Pasadena, CA, USA. Professor Emeritus at Queen's University, Kingston, Canada.**

TAKAAKI KAJITA **Japanese citizen. Born 1959 in Japan. Ph.D. 1986 Tokyo Univ. Director of Inst for Cosmic Ray Research and Professor at Tokyo**

THE NOBEL PRIZE IN PHYSICS 2015

1960s, 70s, 80s and 90s: "THE SOLAR NEUTRINO PROBLEM"…

Solution: new physics beyond the Standard Model : Tiny but non-zero mass to neutrinos allow them to mix together. When they pass through matter and interact — ever so slightly —, this mixing enabled one flavor of neutrino (electron, muon or tau) to oscillate into a different one.

The Sun power: nuclear fusion: hydrogen nuclei fused together into helium: emit photons, and also energetic neutrinos. 4 protons fuse into a helium nucleus : produce 2 neutrinos: two *anti-electron neutrinos*. BUT: only see about *a third* of the expected number: around 34%.

Super-Kamiokande (1998) and the Sudbury Neutrino Observatory (detected that neutrinos were transforming from one flavor (the electron-type) into another (the muon or tau type) .

The generated neutrinos are electron (anti)neutrinos, but by the time they reach us on Earth, they're split ⅓, ⅓, ⅓ between the three flavors.

Neutrinos masses: between about 1 and a few 100 *milli*-eV, less than one *millionth* the mass of the electron.

•The 2015 Nobel Prize in Physics, October 2015, December 2015 : neutrinos oscillate from one flavor to another, and have a mass .

IMPORTANT: 1. Neutrino Physics : masses and different neutrino identities

2. Physics BEYOND the Standard Model was reached by EXPERIMENT !!!

3. LOW ENERGY PHYSICS (instead HIGH Energy Physics) !!!

BRUNO PONTECORVO: NEUTRINOS AND STERILE NEUTRINOS

1. CHADWICK 1914: radioactive beta decay spectrum: continuous: ===> *missing particle:* PAULI 1930: neutral weak s 1/2 fermion *neutron.* FERMI 1933: *neutrino,* massless.

REINES and COWAN Jr 1950 inspired and encouradged by PONTECORVO: **experimental nuclear reactor proof of (anti) neutrinos:** 1995 NOBEL prize to REINES.

2. PONTECORVO 1960: **Lepton number: nu and anti nu. *muon- neutrinos* in pion decay and *electron-neutrinos* in nuclear beta decay. Brookaven experimental proof of muon-neutrino in 1962.** 1988 : NOBEL prize to Lederman, Schwartz and Steinberger

NEUTRINO OSCILLATIONS

3. PONTECORVO 1957: **proposed nu oscillations between nu <-> nu- by analogy to K° <-> K°-. 4.** PONTECORVO 1968: **First model of oscillations and mixing of nu mass states, later improved by** GRIBOV & PONTECORVO 1969: **as possible solution of the SOLAR NEUTRINO problem.**

SOLAR NEUTRINOS

Thermonuclear fusion in the solar core: energy and neutrinos. PONTECORVO 1946 **first to propose neutrinos as perfect probe of stars and Sun interior and of the production mechanism: fusion of H to helium: p+ p → 2 H + e+ + ve. Nus reactions pp_chain, CNO cycle (C, N, O): 4p→ 4H+2e+2ve. e-capture by 7Be, Beta decay. TOTAL ENERGY release: 26.73 MeV TOTAL FLUX of Solar nus expected : 6.5 x10^{10} cm^{-2} s^{-1}= 8.5 +-0.9 SNU . Measured for more than 25 years of continuity : 30% or 34% of the expected. 1968-1998. Davis…**

SOLAR NEUTRINO PROBLEM

The flux of solar neutrinos measured in the Earth is different (34% low) from the computed flux. The Problem Persisted for more than 30 years.

Schwarzchild 1957: Solar model, evolution from a protostar 4.5 Gyears ago till present era: fits values of Luminosity, mass , radius. SSM: During 1963-2006 Bahcall et al , BBS. The Sun only produce electron-(anti) neutrinos.

Arthur Mc DONALD 2001 with the Sudbury Neutrino Observatory in Canada, SNO proved that neutrinos coming from the Sun switch identities arriving at Earth into muon-neutrinos or tau-neutrinos.

ATMOSPHERIC NEUTRINOS

Takaaki KAJITA 1998 presented the discovery that neutrinos seem to undergo metamorphosis: they switch identities on their way to the Super-Kamiokande detector in Japan. These neutrinos are created in reactions between cosmic rays and the Earth's atmosphere. Muon-neutrinos changed into tau-neutrinos

NOBEL PRIZE

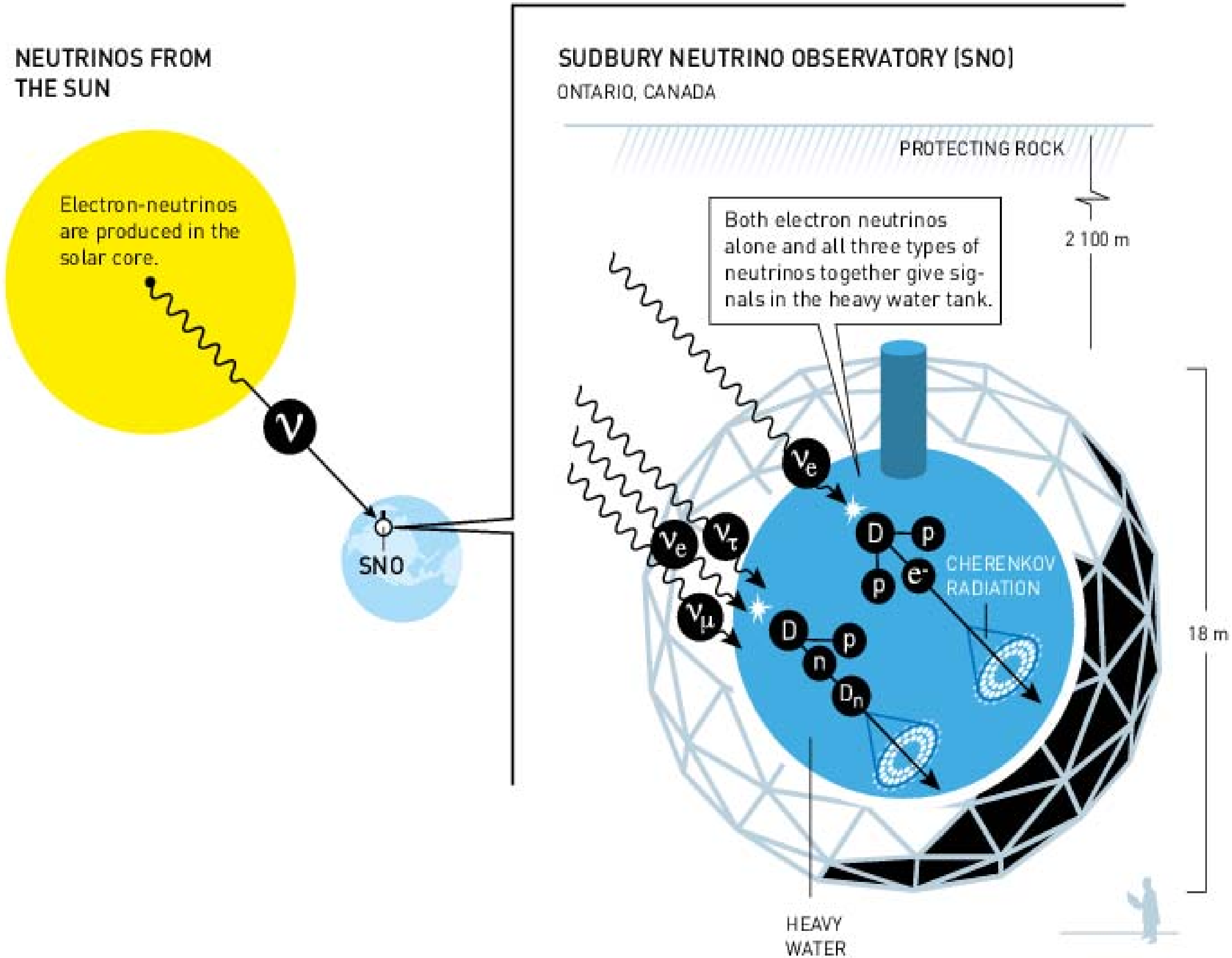
Octobre 2015, Decembre 2015 : to KAJITA and Mc DONALD ***"for the (experimental) discovery of neutrino oscillations which shows that neutrinos have mass"***

Metamorphosis (CHANGE) of QUANTUM particle IDENTITIES

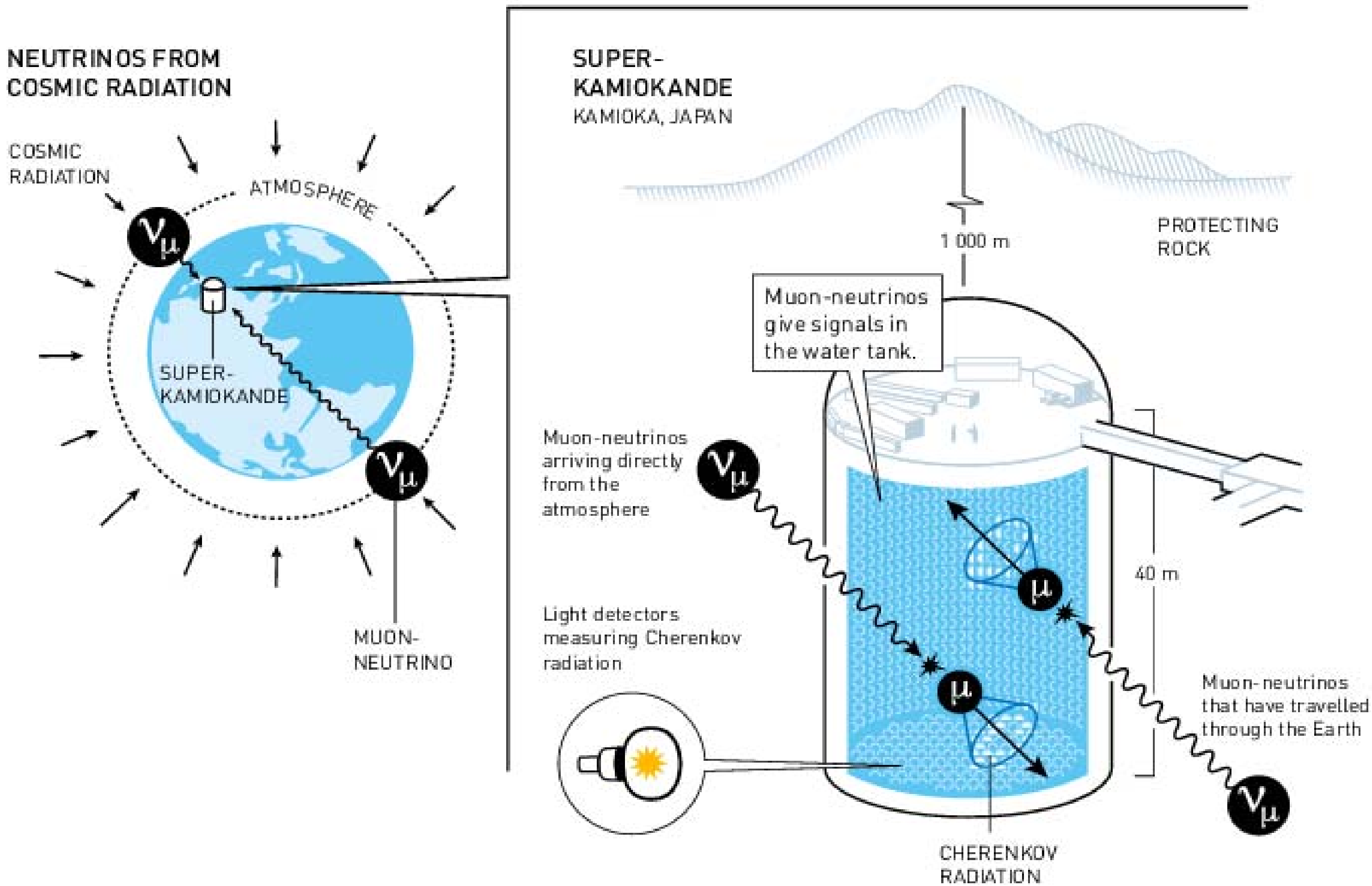
The Nobel Prize in Physics 2015 recognises Takaaki Kajita in Japan and Arthur B. McDonald in Canada, for their key contributions to the two experiments demonstrated that neutrinos change identities. This change requires that neutrinos have mass.

Around 2000, Takaaki Kajita presented the discovery that neutrinos from the atmosphere switch between two identities on their way to the Super-Kamiokande detector in Japan.
Meanwhile, the research group in Canada led by Arthur B. McDonald demonstrate d that the neutrinos from the Sun were not disappearing on their way to Earth but they were captured with a different identity when arriving to the Sudbury Neutrino Observatory.

A neutrino puzzle that physicists had wrestled with for decades had been resolved.
Compared to theoretical calculations of the number of neutrinos, up to two thirds of the neutrinos were missing in measurements performed on Earth. Now, the two experiments discovered that the neutrinos had changed identities.
The discovery led to the far-reaching conclusion that neutrinos, which for a long time were considered massless, must have some mass, however small.

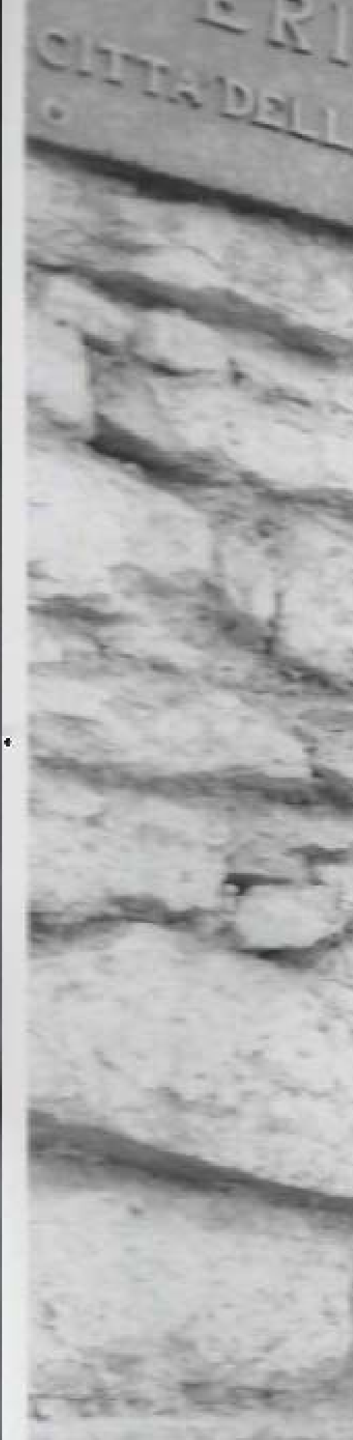


Sudbury Neutrino Observatory detects neutrinos from the Sun, where only electron-neutrinos are produced. The reactions between neutrinos and the heavy water in the tank yielded the possibility to measure both electron-neutrinos and all three types of neutrinos combined. It was discovered that the electron-neutrinos were fewer than expected, while the total number of all three types of neutrinos combined still corresponded to expectations. The conclusion was that some of the electron-neutrinos had changed into another identity.



Super-Kamiokande detects atmospheric neutrinos. When a neutrino collides with a water molecule in the tank, a rapid, electrically charged particle is created. This generates Cherenkov radiation that is measured by the light sensors. The shape and intensity of the Cherenkov radiation reveals the type of neutrino that caused it and from where it came. The muon-neutrinos that arrived at Super-Kamiokande from above were more numerous than those that travelled through the entire globe. This indicated that the muon-neutrinos that travelled longer had time to change into another identity on their way.

faster than light in vacuum. In the water, the light is slowed down to 75 per cent of its maximum speed, and can be “overtaken” by the charged particles. The shape and intensity of the Cherenkov light reveals



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