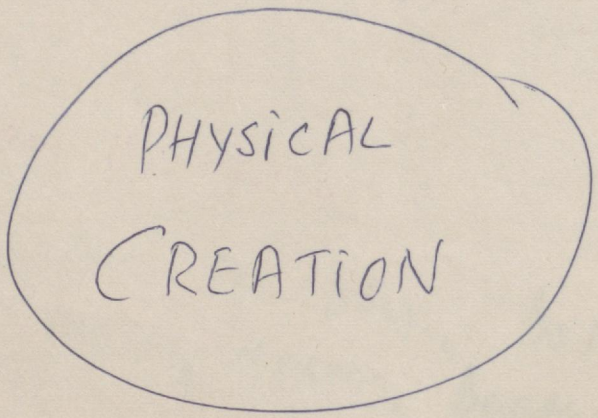

PHYSICAL
CREATION

CREATION

(A) By Man

(B) By Animals

(C) By Nature (Physical)

- It is the hope and belief of the Scientist that (A) and (B) are part of (C)

- **CREATION BY MAN.**

(A) Art, sculpture, painting music, drama, poetry ....

(B) Logic, Mathematics, theory, Philosophy ....

(C) Science, Medicine, Engineering, Technology .....

(A) has emotional appeal – inspires, touches the Soul – Creates happiness, joy ...

(B) intellectual pursuit – brings purpose, meaning – order, Symmetry, beauty, Simplicity, Connection in time and Space – past, present, future.

(C) Utilitarian, human necessities, Control over Nature, quality of life, better understanding of Nature

- In all Creations by Man, there is a Plan, a Purpose and a Goal. Materials are derived from Nature and suitably transformed. Increasing use of Science and Technology.

CREATION BY ANIMALS.

Typical Examples: Spider's Web — Why Symmetry?
Bird's Nest
Bee Hive
Ant Hill
Beaver's Dam

Purpose is Survival. Plan? No. Instinct.
Evidence of Collective Effort.
The requisite material is picked up from nature or from its own secretions.

PHYSICAL CREATION.

- By Physical Creation, we mean Spontaneous Creation independent of the influence of a Creator (man, animal, or God!)

- The Scientist has tried to discern over the past Several Centuries how this happens.

- Physical Creation is understood in terms of
- Certain Concepts (Space, time, matter, energy)
- Certain forces (gravitation, Electromagnetic
  Strong, Weak)
- Certain laws of Nature (Conservation of Energy
  & universality, Causality ...)

These are derived on the basis of experience, observation experimentation, insight and of course Genius.

- Basically any physical Creation is a Chance happening. The Constituents interact under the influence of the forces. The two important forces for normal phenomena we witness are the Gravitational and Electromagnetic Forces.
- The basic Constituents of all matter are the 92 elements - hydrogen, helium ... Carbon, oxygen, Nitrogen, ... Sulphur, Iron, .. Uranium.
- The atoms of the elements Comprise of Nuclei and orbiting electrons.

The Nuclei of all elements (excepting hydrogen which just consists of a Single Proton) Consist of two types of particles - The protons (+ ve charged) and the Neutrons (Neutral) is 1840 heavier than the electron.

CREATION OF RAIN

- Let us analyse a very familiar natural Creation 'Rain' Even a School boy knows how this happens

- The heat rays from the Sun heat the oceans and the land masses. Water evaporates from the ocean and forms clouds. The differential heating of different locations gives rise to pressure gradients and WINDS. The temperature of the atmosphere goes down with height. The Water Vapour in the cloud Condenses into rain drops and the drops come down due to the Gravitational Force.

  Perhaps we understand every step in the process involved in terms of familiar Concepts and experiences.

- [What we do not understand is – Was there a plan, a purpose, a direction in which Nature acted or Continues to act ?]

- Now let us go one Step further and ask the question:

  HOW Did the Waters of the Ocean get Created ?
  HOW did the Soil, the atmosphere .. the Earth and the Sun get Created ?

  These are Simple questions that any Child Can ask. But to find the answers is a Tall order. Much of Science developed to find answers to Such questions.

- Spectroscopic observations of Sun Light Showed that the same elements are also present in the Sun. But in Very different proportions. The Sun is mostly hydrogen and Helium.
- Similarly the planetary atmosphere revealed the same elements.
- The orbits of Mercury, Venus, Earth, Jupiter, Mars, Saturn and Uranus are all in the same Plane.
- Many such details Suggested that the entire Solar System has originated from a Single large Cloud

Let us assume that there existed a Sufficiently large Cloud Containing the requisite amounts of the different elements (We Shall Come to the question of the origin of this Cloud later)

The formation of the Solar System is envisaged as follows: (This is based on various astronomical observations)

(1) The cloud started evolving more than 5 billion years ago (0.5 billion years) by just Contracting under its own Gravitational Pressure.

(2) The original size of the cloud = 10,000 billion miles (10^{13})
Present size of Sun = 10,00,00 miles. (10^6)

(3) As the cloud Contracted it started spinning faster and faster and the loose matter flattened into a disk like a Curled Coin and Heavy Structures

(4) 90% of the mass of the cloud formed the Sun at the Centre

(5) Clumps were formed in the rings around

(6) The Clump of cloud matter in the [illegible] ring from the Sun formed the earth. The original size of this clump was 10 billion miles which has contracted to 8000 miles.

(7) During the Contraction phase of the earth lot of Chemical reactions took place - various phase transitions - gas - Liquid - Solid. The process is very slow. In a hundred million years only 0.2% of the gas was solidified.

(8) At the early stage the heavy elements Iron, Nickel, Oxygen Condensed to form molecules. There was too much matter in the cloud - All this excess matter of various gases was just blown off by a powerful kind of gas from the Sun. It is estimated that 90% of the Surrounding gas has removed this way. The remained matter determined the Solar Nebula Condensation of the earth.

The Chemical evolution of the earth is a fascinating Subject by itself.

It is estimated that if all the Gold in the Centre of the earth in the liquid form is mined, there will be enough to cover the entire Surface of the earth with a 1 meter thick Gold layer.

* It is the

How did the various Constituents of the cloud that evolved into Solar System get formed ?

This takes us back by another major Step in the hierarchy of Creations.

(7)

- The Sun is just one Star out of a hundred billion Stars in our Galaxy - The Milkyway Galaxy. It is located in one of the Spiral arms quite away from the Centre.

- Most of the Stars in the Galaxy are more than 7 billion yrs old and consist of hydrogen and helium.

- The temperatures in the Central regions of these Stars is high enough to Cook other elements out of hydrogen and helium. three helium nuclei together at high enough temperature form a Carbon nucleus. Even oxygen with 16 protons and 16 neutrons in its nucleus can be formed this way. The temperature required for this is 2-6 billion degrees. At a few billion degrees more Magnesium 24, Silicon 28, Sulphur 32 Can also be Cooked. At temperatures of 6-8 billion degrees Synthesis of Iron takes place.

- The Second Generation Stars have these materials available before formation. Once occasionally the Stars explode and throw away [illegible] of their [illegible]

① We said the Sun is just one star out of a hundred billion stars in the Milkyway Galaxy. The Milkyway Galaxy itself is one among a hundred billion galaxies. which Constitute the Universe.

② These Galaxies are moving away from each other like the dots on an expanding balloon. The greater the separation between the galaxies, the faster they are moving away with respect to each other.

③ The Universe is filled with lot of matter in the form of stars, interstellar dust etc. But equally importantly even in the vast Stretches of so called empty space between the stars and the galaxies, it is filled with Microwave Radiation

* These features are understood reasonably well on the Big Bang theory of Creation of the Universe:

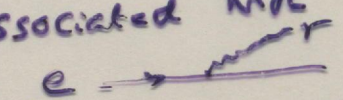
There was a Cosmic Egg of very very high density. infinitisimal in size - that contained all the matter and Radiation of the Universe - that exploded in a flash 20 billion years ago. Space, Time, Matter everything was Created with this explosion.
Initially it was all Radiation at very very high temperature which gave rise to the fundamental particles - the Universe expanded - Cooled - evolved gradually over the past 20 billion years.

The Universal Microwave Radiation is a relic of this Big Bang Explosion.

Fundamental Particles.

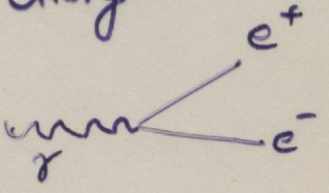
We are already familier with three fundamental particles - the Proton (+ve charge), the Neutron and the electron (- ve charge).
The Proton and the Neutron are Constituents of Nuclei
The electrons are in the atomic orbits and Compensate the positive charge to make the atom neutral.
The electrons are also the particles responsible for the flow of electric current.

Some very interesting phenomena associated with the particles:



(i) When electrons are accelerated, Radiation is emitted Radiation itself Consists of 'photons'

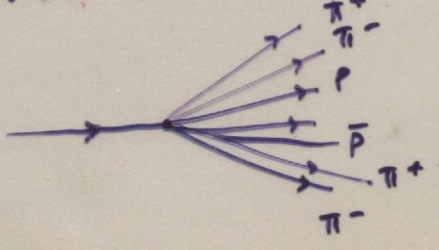
(ii) High Energy photons travelling through matter give rise to a pair of oppositely charged particles - electrons and positrons



This phenomenon is known as
" Materialisation of Radiation.
This also shows Creation of anti-matter.

(iii) When a very high energy proton or neutron Collides with a proton or neutron, then a large number of new particles are Created -

Mesons,
Protons, anti protons
Neutrons, anti neutrons etc



The Creation of particles in these high energy Collisions is essentially due to the deposition of an enormous amount of energy in an extremely small volume of space - the energy deposited gets converted to particles - It is in a sense mining particles out of what is called the quantum mechanical vacuum.

This is precisely what happens in the very early phase of the Universe - immediately after the Big Bang. The temperature and energy density are sufficiently for this purpose.

The Early Universe.

As we go back in time, we have the scenario that the Universe was smaller and smaller, denser and denser and hotter and hotter.

	Scale Factor	Time From Big Bang	Temperature	Density	Events.
To-Day →	1	2×10^{10} yrs	3°k	10^{-30} gms/cc	Man, animals everything we see to-day.
	1/1500	10^{7} yrs	4000°k	10^{-20} gms/cc	Neutral hydrogen atoms about to form
1/1000 - 1/10,000		$2-20 \times 10^{6}$ yrs	3000 to 30,000°k	$10^{-21} - 10^{-18}$ gms/cc.	Equal amount of matter and radiation.
	$1/10^{9}$	10 mins	3×10^{9}°k	10^{-3} gms/cc.	Dissociated atoms and nuclei
	$1/3 \cdot 10^{9}$	1 min.	10^{10} °k	3×10^{-2} gms/cc	Thermal background Creates $e^{+}, \bar{e}$ pairs
	$1/10^{13}$	10^{-5} Sec	10^{13} °k	10^{9} gms/cc.	Protons and antiprotons from thermal background.

↓

10,000 billion degrees.

The Neutrino.

1934 • Neutrino introduced by Pauli to save principle of Conservation of energy
β-decay theory by Fermi

1935 • Bethe and Peirls calculated ν-Cross-Section
$\sim 10^{-44}\,cm^2$ "Never will be detected"!

• Dirac's theory of anti-particles – implies anti-neutrinos.–

1959 • Experimental Detection of anti-neutrinos at Reactors – REINES and COWAN.

1962 • Discovery of two flavours ν_e, ν_μ by Danby et al – 1988 Nobel Prize!

Separate Conservation of Electron and Muon numbers
$\pi^+ \rightarrow \mu^+ \nu_\mu$ $\quad \nu_\mu + N \rightarrow \mu^- + any$

• Search for W-mesons proposed by Lee and Yang in the interactions of Neutrinos $\nu_\mu + N \rightarrow W^+ + \mu^-$

1960 • Markov's Suggestion of Underground detection of Cosmic Ray Neutrinos.
Flux Calculations – Greisen, Zatsepin, Cowsik.

1963 • TIFR No Count Experiment at KGF. Feasibility of Underground Detution of ν-interactions

1965 • Experimental Detection of Cosmic Ray Neutrinos at KGF and in South Africa.

1972 • Neutral Currents proposed by Salem, Weinberg and t'Hooft. $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$

1973 • Rising Cross-Section of Neutrino interactions esteblished at CERN $0.69 \times 10^{-38} \cdot E \cdot cm^2$
(E in GeV)

Solar Neutrinos observed.
Big Anamoly

→ **1987** • Neutrinos From SN1987a.

Magnetic Moment of the Neutrino.

Suggestion of Voloshin, Vysotskii and Okun:

- The Neutrino may have a large magnetic moment $\mu(\nu_e) = (1/3 - 1) \times 10^{-10} \mu_{Bohr}$.
- When the Solar activity is large ($10^3 - 10^4$ Gauss) the Spin of the Neutrino may flip

$$\nu_{\text{left handed}} \longrightarrow \nu_{\text{right handed}}$$

- $\nu_{\text{right handed}}$ is Sterile for Cl-Ar reaction.
- $\therefore$ Anti-Correlation in ν recorded flux is expected with Solar Spot Number.
- Accelerator Limits

$$\mu(\nu_e) < 1.5 \times 10^{-10} \mu_B$$
$$\mu(\nu_\mu) < 9.5 \times 10^{-10} \mu_B$$

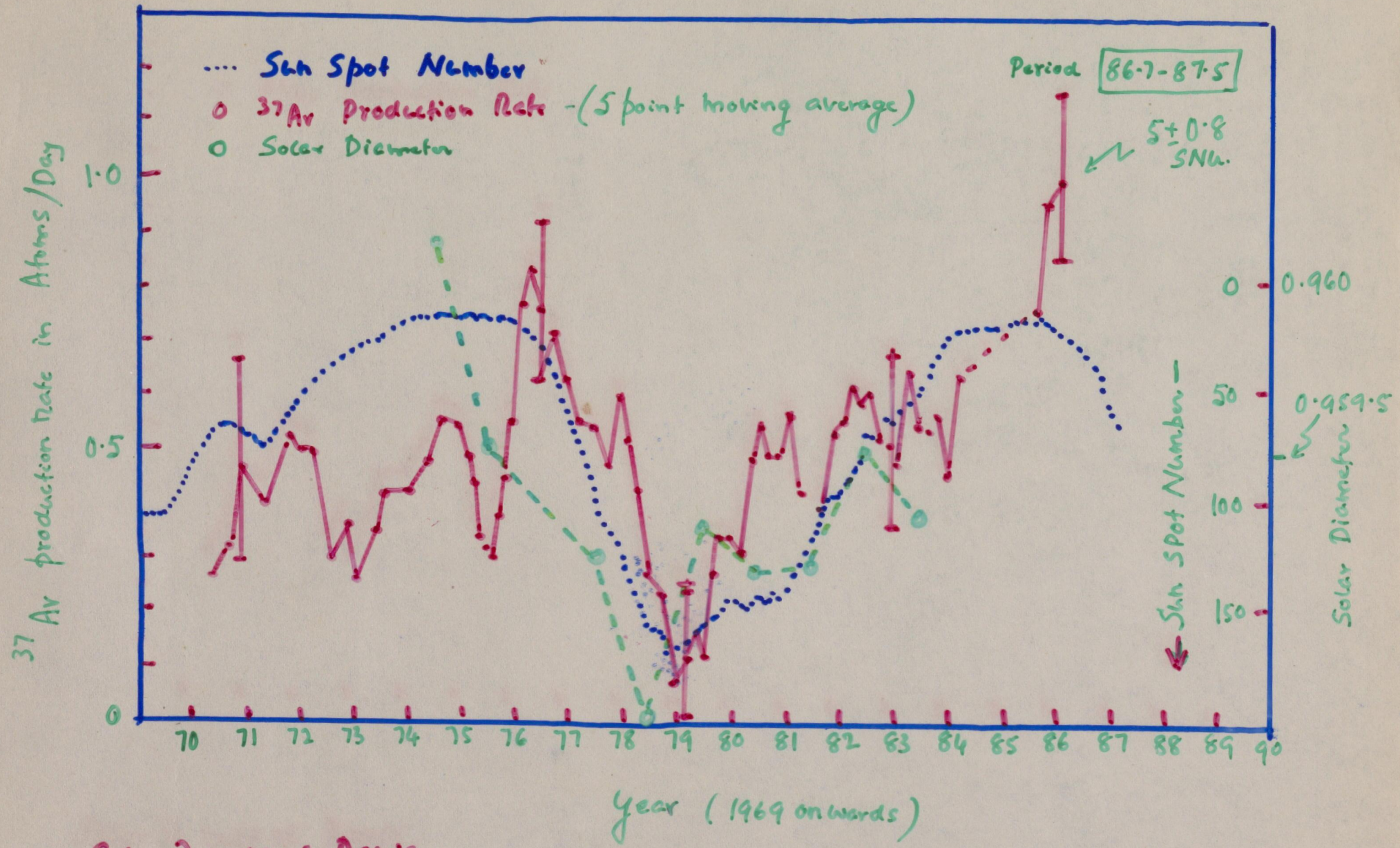
} Cannot rule out the above possibility

- But Electro-Weak Unification (Glashow, Weinberg Salam)

$$\mu(\nu_e) = 3.2 \times 10^{-19} \mu_B$$

$m(\nu_e)$ (eV/c^2) } Fujikawa

9 orders of magnitude lower



Solar ν expt of Davis.

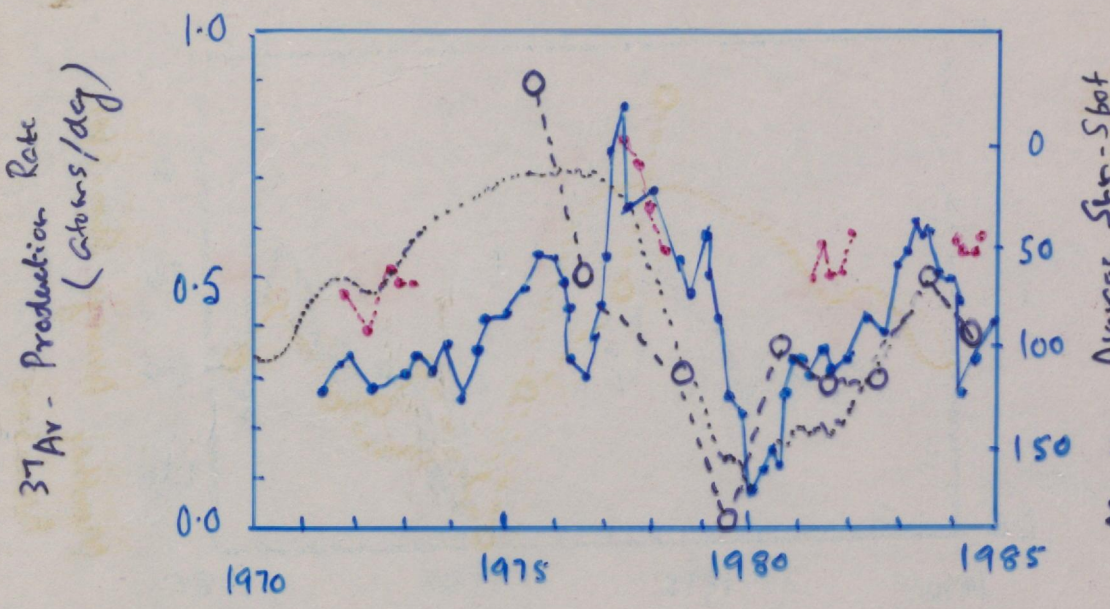
Anti-Correlation between Production Rate and Sun Spot Number and Positive Correlation with Solar Diameter.

June 1988

J88.

Solar Neutrinos

960



959·00

O - Solar Diameter
..... - Sun Spot Number (Scale on the RHS)
o - ^{37}Ar Production Rate / day
o - ^{37}Ar Production during flares.

October 1970 to May 1985 (No data from May 1985 to October 1986 due to plumb replacement)

- Background Rate 0.08 ± 0.03 ^{37}Ar atoms / day
- Net rate attributable to Solar ν's = $0.392 \pm .047$ atoms/day
- This rate Corresponds to 2.07 ± 0.25 SNU

[1 SNU = 10^{-36} Captures / target atom / Second.]

Predicted Neutrino Captures = 6 to 8 SNU.

75% of this due to neutrinos from ^{8}B decay in the Sun. (0-15 Mev) — only these cause ^{37}Cl Capture

Production of B in the Sun very sensitive to Temperature of the Core.

- Solar Flare Enhancements of Solar Neutrinos

- Three Large Flares of
  - Aug 4, 1972
  - Sept 19, 1977
  - Oct 10, 1981

  } Correlate with high ^{37}Ar production rate

1.23 ± 0.41, 0.85 ± 0.33, 1.21 ± 0.37 ^{37}Ar atoms/day

Compared to the average rate of $0.39 \pm .047$ /day.

Only one run out of 68 runs with such high rates can be attributed to fluctuations. Correlations with Solar flares makes it significant.

- Correlation with Solar Activity

5 point running averages shown in the figure.

^{37}Ar production rate drops from 0.8 ± 0.15 atoms/day to 0.1 ± 0.1 atoms/day with the on-set of the Solar Cycle. (From 1977 - 1985 data)

^{37}Ar production rate anti-correlates with Sun Spot Number in a systematic and organized way.

Neutrino Oscillations

Mikheyev and Smirnov

- $\nu_e \rightarrow \nu_\mu$ or ν_τ – resonance phenomenon arising from the difference in the scattering cross-section both electrons
- Depends on the mass difference between neutrino types
- It is necessary that one other neutrino must have mass close to ν_e mass
- This phenomenon could result in the distortion of the ^8B neutrino spectrum and account for the observed low rate.
- For certain values of mass difference $10^{-4}\,ev \geq \Delta m^2 \leq 10^{-6}\,ev$ and mixing angle $0.086 \leq \sin\theta \leq 0.52$ – day and night effect may be expected in ^{37}Cl detector.

Solar Neutrino oscillations - Day and Night
Summer - winter effects.

- Mikheyev and Smirnov.
- Wolfenstein
- Bethe.

Observed $\nu_e + {}^{37}Cl \rightarrow {}^{37}Ar + e^-$ rate $0.39 \pm .05$ /day
$= 2.1 \pm 0.3$ SNU.

Expected rate 5.8 - 8.2 SNU.

Neutrino oscillations in the Solar Interior may be responsible for this discrepancy

$\nu_e \rightarrow \nu_\mu$ or ν_τ

For ν-eigenstates both mass difference $5 \times 10^{-8} \leq \delta m^2 \leq 10^{-4}$ eV^2 and vacuum mixing angles of $0.02 \leq \sin 2\theta < 0.9$ - the required suppression factor of 3-4 can be obtained.

If the mass density is in the range 3-13 gms/cm^2 ν oscillations can occur in the Sun as well as in the earth.

ν_μ / ν_τ lines not be seen in the day detection of ν_e, but line be seen in the night detection Path length of ν's line also long between Summer and winter.

Davis is setting up a modified experiment for this study.

Neutrino Oscillations:

Pontecorvo. (1967)

θ = Mixing Angle.

$$\left.\begin{aligned} \nu_e &= \nu_1 \cos\theta + \nu_2 \sin\theta \\ \nu_\mu &= -\nu_1 \sin\theta + \nu_2 \cos\theta \end{aligned}\right\} 0 < \theta < \pi/4$$

ν_1 State has mass m_1, ν_2 mass m_2

$$P(\nu_e \to \nu_\mu, x) = \sin^2(2\theta) \cdot \sin^2\left(\frac{\pi x}{l_v}\right)$$

Vacuum Oscillation Length $l_v = \dfrac{4\pi p}{(m_2^2 - m_1^2)}$

$\nu_e \to \nu_\mu$ oscillations negligible if mixing angle θ is small or $\Delta = m_2^2 - m_1^2$ is small.

Neutrino Oscillations in Matter:

ν_{1m} and ν_{2m} different from ν_1, ν_2 above.

$$\nu_e = \cos\theta_m \nu_{1m} + \sin\theta_m \cdot \nu_{2m}$$

$$\nu_\mu = -\sin\theta_m \nu_{1m} + \cos\theta_m \nu_{2m}$$

$$\mu_2^2 = \tfrac{1}{2}\left[m_2^2 + m_1^2 \cdot V \cdot \Delta\right] + \frac{1}{2}\Delta\left[(V - \cos 2\theta)^2 + \sin 2\theta\right]^{1/2}$$

$$V = 2\sqrt{2}\ E \cdot G_F \cdot N_e / \Delta$$

$$\Delta = m_2^2 - m_1^2$$

$$P_m(\nu_e \to \nu_\mu, x) = \sin^2 2\theta_m \cdot \sin^2\left[\frac{\pi x}{l_m}\right]$$

Where $l_m = \dfrac{4\pi \cdot p}{|\mu_2^2 - \mu_1^2|}$, $\sin^2 2\theta_m = \dfrac{\sin^2(2\theta)}{(V - \cos 2\theta)^2 + \sin^2 2\theta}$

Neutrino Oscillations (Contd)

Mikheyev and Smirnov emphasised that the oscillation probability is maximal when the density of the medium is such that

$V = \cos 2\theta$. — this is the MS resonance condition.

(Δ must be positive; ν_e lighter than ν_μ

MS Condition $\longrightarrow$ $E(\text{Mev}) \cdot \rho(\text{gms/cm}^3)$

$= 0.7 \times 10^7 \cos 2\theta \cdot \Delta \ (\text{ev}^2)$

The matter density in the Sun $\rho(r)$ varies from 150 gms/cc at the centre to 0 at large distances.

If we assume that the density gently decreases (adiabatic condition) $\rightarrow$ then Hans Bethe pointed out:

The maximum Solar ν energy = 14 Mev.

Critical Energy E_c = 6 Mev such that for $E > E_c$, the Critical Condition is satisfied somewhere inside the Sun.

For $E < E_c$ — No where in the Sun.

In Davis Experiment, the depletion is due to neutrinos of energy > 6 Mev which have been converted ν_μ are not detected.

[$\cos 2\theta \cdot \Delta = 0.6 \times 10^{-4} (\text{ev})^2$; $\theta \gtrsim 0.4°$. $m_1 = 0$, $m_2 = .008$ ev]

Neutrino Oscillations (Contd)

↓ inside the earth

$$\nu_e \xrightarrow[\text{Sun}]{} \nu_\mu \text{ (or } \nu_\tau) \xrightarrow[\text{earth}]{} \nu_e$$

The first conversion should take place in the Sun at densities of 5-12 gms/cm^3.

The reconversion of ν_μ or ν_τ to ν_e leads to

Day and Night Effect. } in detected ν_e fluxes
Seasonal Effect

Night Flux should be more than day flux.

—

(DAVIS) → 1988.

Questions and Answers

(1) Is the Solar Energy due to Hydrogen Fusion ?
Observe ^8B Neutrinos — Kamioka II
Observe pp Neutrinos - Gallium

(2) Effect of resonance mixing on ν flux
- Gallium / Kamioka II.
- Day / Night Effect.
- Cosmic Ray Neutrino Spectrum
- Observe ν_μ or ν_τ from Sun.

(3) Sun Spots vs ν_e flux Correlation. ? (future)

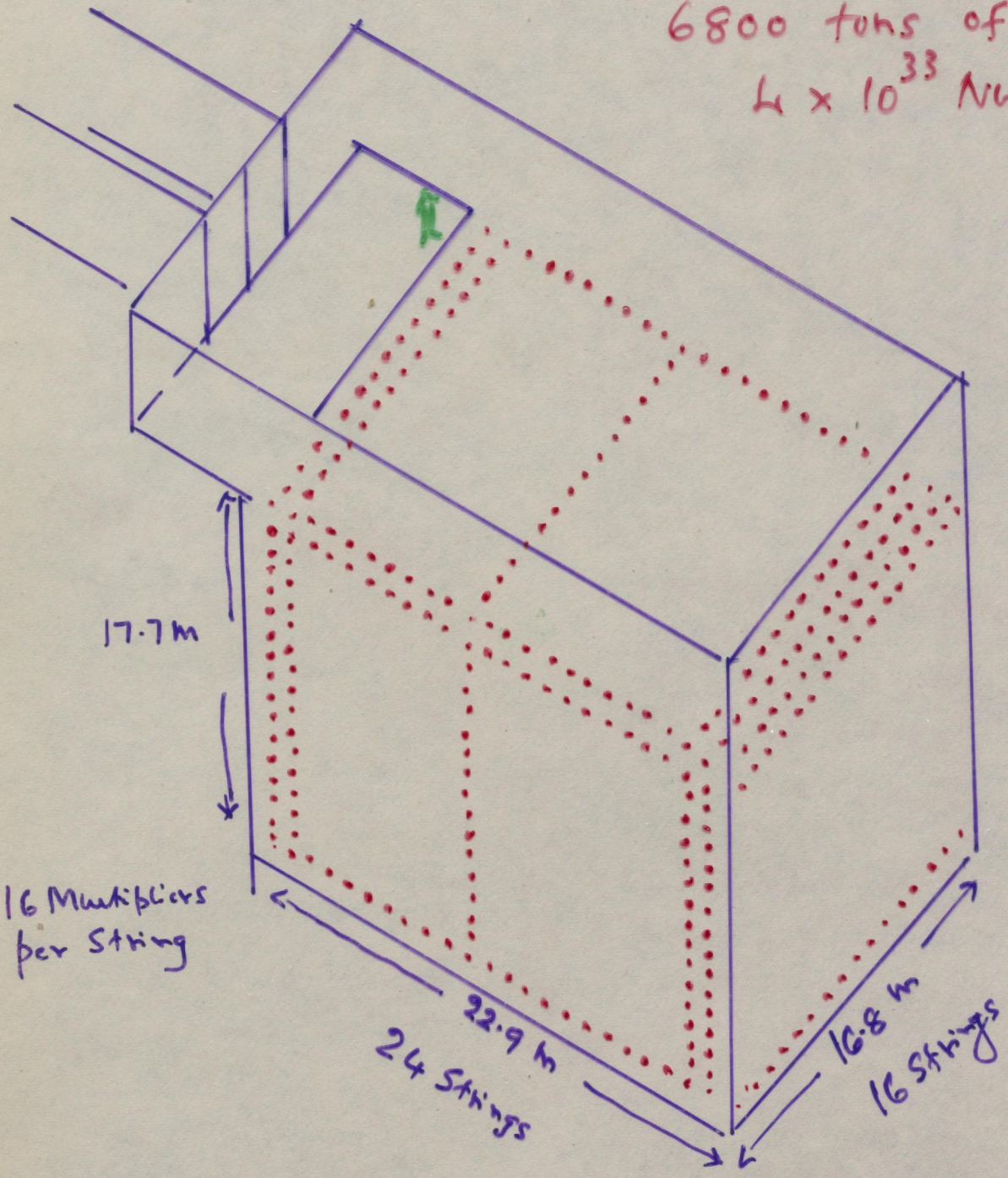
(4) Magnetic moment of ν eating Solar flux ?
Solar Latitude effects to be observed.

WIMPS (Weakly Interacting Massive Particles) and Solar Neutrino Flux.

- Early Universe Produces WIMPS
  (Solves the missing mass problem as well)
- WIMPS Carry off Some of the heat in the Solar Interior — Smooth out the temperature gradient and reduce ^8B neutrino flux.

IMB DETECTOR

2048 photo multipliers
Cell Size ~ 1 m
6800 tons of water
4×10^{33} Nucleons



Location: Morton Salt Co
FAIRPORT HARBOUR MINE, Ohio

BURDEN 1940 ft (1600 MWE)

- The rate of single muons in the declination belt $35.8° - 45.8°$ is 4×10^{-2}/day per $10° \times 10°$ bin.
- This leads to a probability of $< 10^{-5}$ for observing 4 muons in less than 2 days
- We have also the following experimental information on the rate of occurence of two muons in a single day

On the declination belt $35.8° \times 45.8°$, the phase II detector recorded 19 two-muon events in 691 days of observation ($\Delta t < 1$ day)

This gives a double muon rate of 1.5×10^{-3}/day for the two telescopes phase II and phase III.

Flux $E_\mu > 8$ Tev.

72 m^2. Area 2 days of 6 hrs observation each 4 events recorded. $\sim 10^{-10}/cm^2 sr.$

$\sim 10^{-11}/cm^2 sr.$

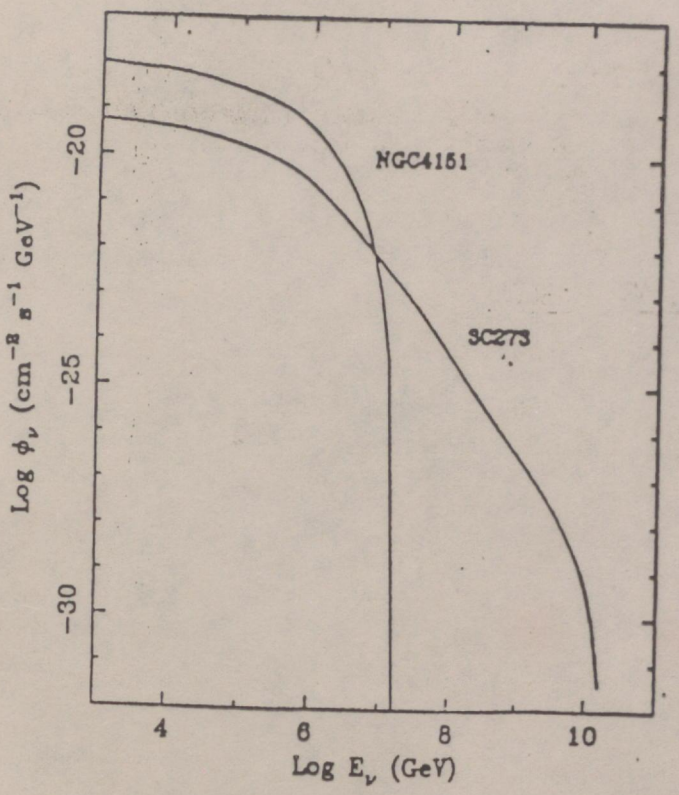


Fig. 8(a)

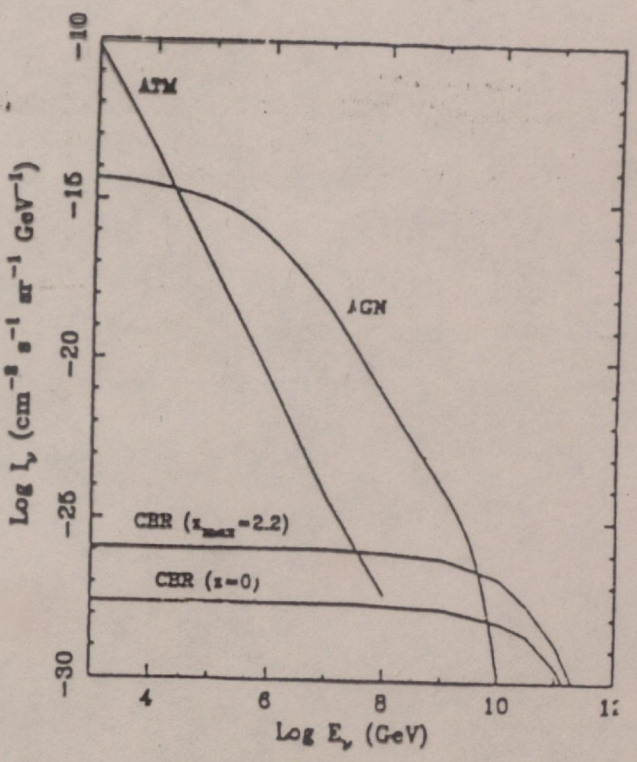


Fig. 8(b)

Fig. 8(a) : The predicted ν_μ ($\bar{\nu}_\mu$) flux from NGC4151 which has an X-ray luminosity of $L_x = 3 \times 10^{41}$ ergs^{-1} and is at a distance of 4.5×10^{25}cm and From 3C273 with $L_x = 10^{47}$ergs^{-1} and distance 3×10^{27}cm. The ν_e and $\bar{\nu}_e$ flux is half that of ν_μ ($\bar{\nu}_\mu$).

Fig. 8(b) : The integrated high energy ν_μ ($\bar{\nu}_\mu$) neutrino background from AGN. Also shown is the horizontal ν_μ ($\bar{\nu}_\mu$) flux from high energy neutrinos from cosmic rays interacting in the earth's atmosphere (ATM) and the background expected from photomeson production of extragalactic high energy cosmic rays with cosmic background radiation (CBR).