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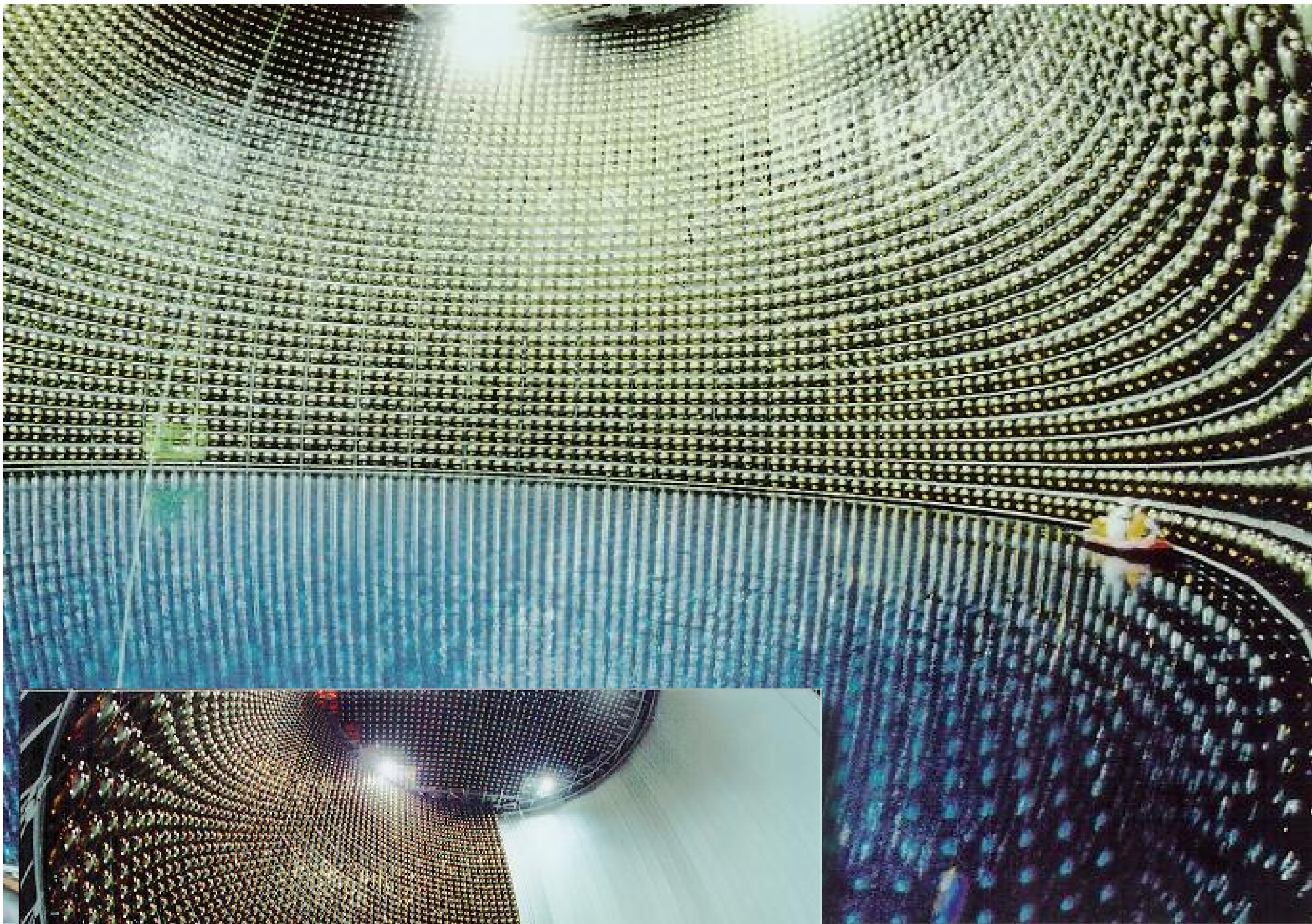
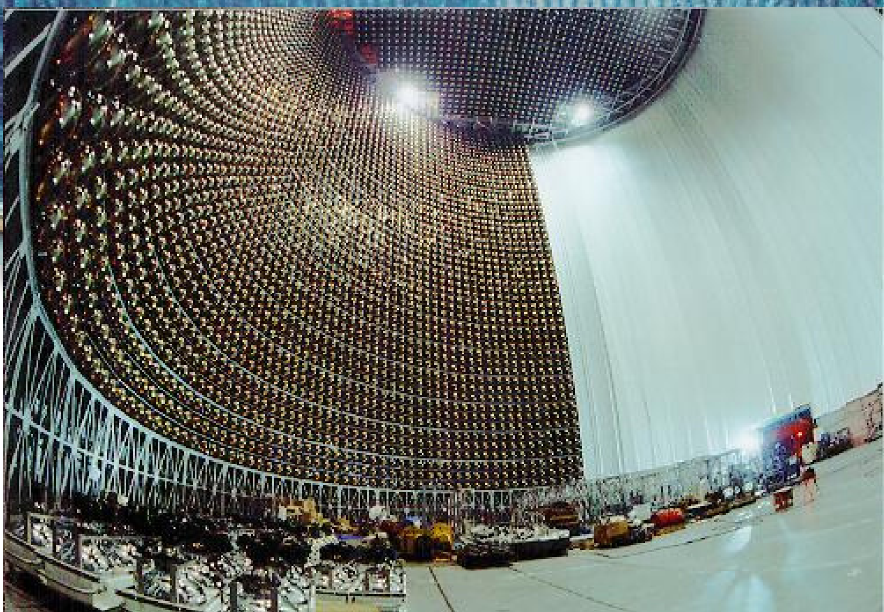




Paritosh Maulik looks at some Underground Observatories, searching for neutrinos. These are shots of the detector wall, Left, and when half filled with water top in the Super-Kamiokanda installation, Japan.

CONTENTS

Every year brings with it anniversaries, and this year, 2008 is no different. 400 years ago Hans Lippershey applied for a patent on a refracting telescope to the States General of the Netherlands. This was the first time a "magnifying tube" was mentioned in any document. But was it the first time that a type of telescope was actually invented? Spectacles had been made for hundreds of years for both long and short sighted people (those who could afford them). I have seen a simple rock crystal lens in a museum case in Crete which was 2,000 years old. It wouldn't have been hard to put a couple of lenses together and made it work. So will we ever know who really invented the telescope?

Halley's comet was seen in 1758, shortly after the time predicted by Edmond Halley (he had died 1742), and Horatio Nelson, was born.

Thomas Cook, promoter of railway journeys and mass foreign travel was born in 1808.

A 100 years ago the actors William Hartnell, the first *Doctor Who,* Sir John Mills, Sir Rex Harrison, Sir Michael Redgrave and James Stewart, were born along with Jacob Bronowsk who presented the TV series *The Ascent of Man* (1973), Stéphane Grappelli, French jazz violinist, Sir David Lean, film director, Herbert von Karajan, conductor, Ian Fleming, inventor of James Bond, Henri Cartier-Bresson, photographer, Lyndon B Johnson the 36th President of the USA and Alistair Cooke, broadcaster. All born in 1908.

In 1908 the Tunguska fireball, as bright as the sun, exploded over the wastes of Siberia on June 30th flattening 80m trees over 800sq. miles. Henry Ford produced his first Model T. The London Olympic Games opened, in both 1908 and 1948.

1958 saw the eight-mile Preston bypass opened by PM Harold Macmillan as Britain's first motorway, along with parking meters introduced. Ralph Vaughan Williams, one of our greatest composers, died. The USA launch their first satellite, Explorer 1 and NASA started.

In 1968 one of the most amazing things happened just before Christmas, three astronauts flew around the moon! It is now, after 40 years, difficult to appreciate the impact this feat made on every-one. Even today, if it was repeated, it would be watched with awe. 40 years ago it was incredible. The first long distant journey away from Earth. The first time anyone had left the gravitational pull of the home planet, the first time in orbit around another body, the Moon. For Frank Borman, James Lovell and William Anders it was a chance to see with human eyes — for the first time — the far side of the moon. It had been photographed by the lunar Orbiter 4 mission in May 1967.

Take off of the Saturn 5 carrying Apollo 8 was on December 21st and three days later, as they neared the moon from 38,000 miles away they fell into its gravitational field. They had to fired the Command Module Service engine to get them into lunar orbit at 5,000 mph. The engine fired for the exact time of 247 seconds at full blast. Because the firing had to take place while the Module was behind the moon, Ground Control held its breath for many minutes. Was the rocket burn correct, if too long had they crashed, or to short and heading off into interplanetary space? It was fine and they were in orbit! On Christmas Eve they broadcast to half a billion people. *"This is Apollo 8 coming to you live from the moon."* In all they only did 10 orbits of the moon. But they bought back one of the most famous images ever made, Earth rise over the lunar surface. *"This is the most beautiful, heart-catching sight of my life,"* said Frank Borman.

What made this flight so fantastic was the audacity of it. Only the year before on the 27th January, a full ground test of a scheduled countdown had ended in disaster with a spacecraft fire in the capsule with had killed Ed White, Gus Grissom and Roger Chaffee. This was caused by the pure oxygen atmosphere used in the capsule. A report on the Apollo tragedy comprised of more than 3,000 pages and was damning of NASA and North American Aviation the contractor. It found that the next Apollo under construction had over 1400 faults. Half a billion dollars were spent on correcting faults in the design. There is a body of thought that it was because of that fire that few other problems befell the lunar missions (apart from 13). The deadly bugs had been removed and 12 men got to walk on the moon and return safely to earth. But that was still in the future at Christmas 1968.

Late on Christmas Day, Apollo 8 made a burn again behind the moon to increase speed to escape the moons gravity and drop back to earth and 3 days later entered the earth's atmosphere at 25,000 mph and made a perfect splash down in the Pacific ocean.

Ivor Clarke

THE SCANDAL OF PEER REVIEW

by
Dennis W Spratley

Scientific research programmes, which in the context of astronomy are broadly speaking either observational or theoretical, will invariably culminate with the writing of a paper that is submitted for publication. Most members of amateur astronomical societies probably imagine that the final phase is akin to writing an article for their society newsletter. It is unlikely that the editor would either brutally reject the article or insist on cuts and/or changes (although those who have sent work to magazines can, in some cases, recount such experiences). Editors of newsletters are grateful for material. One supposes that an article would have to really "bad" for it to be rejected.

However, in the world of scientific research the author is not submitting an article to your friendly MIRA editor but to the powerful figure of prestigious journals such as *Nature*. Or in the astronomical scene, there are the *American Astrophysical Journal* and the *European Astronomical and Astrophysical Letters* (for many years the great Chandrasekhar was editor of the Astrophysical Journal). Consider the position of the editor of such a publication when a research paper lands on his desk.

There are three main points. Firstly, it is the aim of the author to publish in the journal that has the greatest circulation amongst the elite of the scientific community. Secondly, the editor cannot, in general, have the necessary expertise to evaluate all submissions, which are from specialists. Thirdly, it is not an article such as might be written for an astronomical society newsletter that the editor has received but a scientific paper that is the result of original research. The editor has now the unenviable task of deciding whether the paper should be published or returned to the author(s) along with a letter of rejection. It must be borne in mind that as far as the editor and the board are concerned it is the reputation of the prestigious scientific journal that is at stake. This is the prime consideration. For the editor and the board the task of assessment of the paper by themselves personally is, in general, impossible. For example, the paper might be a detailed analysis of either observational or experimental data made by the author and/or others. Then again, it may be the case that the paper is of a theoretical nature and consequently could be bristling with advanced mathematics difficult to assess except by a few experts in that field. Yet the paper has to be reviewed. What the editor does is quite astounding. It goes without saying that when one is made aware of it, the result is something of a shock. This is entirely due, of course, to not giving the matter any thought.

Scientific papers -- usually in draft manuscript form -- that are submitted for publication in journals are assessed by a system known as peer review. This rather pretentious description is known also as refereeing, this being the official title of the reviewer, as discussed above. The description "peer" has, of course, nothing to do with the UK House of Lords! In this context it indicates that the referee has the same status and/or ability as that of the author. This is important; the referee is not a higher authority. The reason for this is simple; we are dealing with research that is at the frontier of knowledge and consequently it is accepted that there is no higher authority to which the editor can appeal. This system of refereeing would seem to have been satisfactory in the past but now regarded by many scientists as being unworkable. It is accused of allowing publication of bad papers and suppressing the good ones, exactly the opposite of what should occur. The process by which good papers are deliberately suppressed occurs – according to those aggrieved scientists who have had the unhappy experience -- as follows.

In the first place the editor chooses the referee who remains anonymous to the author, at least in theory because in the small tight-knit scientific community the referee's identity can be quite obvious to the author. It is likely that the author knows the referee personally. Therein lies one difficulty. It is very possible that the referee is a fierce rival of the author or is implacably against the latter's research. It is also possible that the editor does not wish to publish but not wishing to be personally responsible for rejecting the paper, deliberately selects a hostile referee.

The next stage is that the referee returns the paper with an accompanying report to the editor, although there is no time limit and the paper could have been and is often held up for a considerable time. The report – a copy of which is sent to the author -- can recommend anything from what seem to be minor changes to an outright rejection. If it is the latter, the author can appeal or ask that the editor choose another referee but the outcome of this can be just as bad. The first rejection makes the editor wary of having the decision reversed and naturally he/she does not wish to antagonise the original referee. In addition it may be that the editor is also hostile to the paper. The outcome is that the choice of the second referee can be a scientist more intransigent than the first! So the author is in a worse position. What is missing here is fairness; the right to confront one's accuser.

Quite remarkably, an establishment journal published a critical analysis on this subject. Below is an excerpt from the paper that appeared in *Science*, 625, 1503, 1992:

"The referees must therefore make an ambiguous, not entirely scientific judgement in the high-stakes game in which the authors are usually known personally to them and are often competitors. Furthermore, the referee knows the editor will not understand the technical details of the report that will be written. If the judgement is wrong or unfair, only the author will know, and the author will not know who wrote the report. The referee can count on the editor's protection and support even if the review is guided by self-interest, professional jealousy, or other unethical motives, because the referee's unpaid help is essential to the editor and the author of a rejected manuscript has an obvious motive to be disgruntled. Referees are never held accountable for what they write and editors are never held accountable for the referees they choose. For all of this to work, the referees would have to have impossibly high standards of ethical behaviour, but nearly all referees have had their standards corroded by themselves being victims of unfair referees' reports in the past when they were authors. Any misconduct that occurs under these circumstances is certainly committed by the referee, whose behind is well covered. Nevertheless, the editors have managed to create a system in which misconduct is almost inevitable".

David Goodstein, California Institute of Technology.

For those who encounter this situation for the first time, the feeling is one of disbelief. To those who feel sure that referees have principles and a fair minded approach the reply is that they should listen to the complaints of those scientists who have run foul of this system. We are told of the thick folders containing reports that these unfortunate scientists accumulate during their careers and it must not be overlooked that that the recipients are competent scientists. Many of these reports have been described as --- "manipulative, sly, insulting, arrogant and above all angry". The suggestion has been made that publication of a sample would be instructive to the general public in that they would be in a position to assess the value of what they are allowed to read.

During the past forty to fifty years one of the worst impacts on astronomy, astrophysics and cosmology caused by the peer review/refereeing system has been its use in suppressing observations that do not conform to mainstream thought, nowadays known as the paradigm (or mindset, if one wishes). Of this situation there is no doubt whatsoever. There was once a protocol that all observations were of sufficient importance that they should be published and stored in archives. In addition, the author(s) should not be obliged to give more than a minimum explanation for observations that disagreed with mainstream thought. A favourite ploy of aggressive referees is to insist that the observations must be incorrect if they do not fit in with the accepted paradigm. Furthermore, others insist that the author(s) put(s) forward a theory – adding to the paradigm, of course – that explains the new observations. All too often this is not possible; few observers are theoreticians. Should a theory be attempted, it is easily branded as crackpot, a favourite description being "psycho-ceramic". The observations can then be disregarded and the referee focuses on the theory, which is then ridiculed. In fact, the original observations and ignored and the word circulates that the author is a crazy theorist. In addition, the author's work is deemed refuted – reviewers are very fond of the misuse of the word – then they mean rejected. However, they do not make the case that the author is wrong.

So, gradually the protocol has been corroded. The rot set in when authors began to write and publish papers on only those observations that agreed with the accepted knowledge – the received wisdom. When these same authors become referees, their aim was to impose on submitted papers changes that brought the conclusions in line with current beliefs. Failure of the author to comply results in rejection of the paper; it is not be published in those journals which others see as where one reads the latest cutting-edge research. This does not mean papers fail to be printed; it results in their appearing in obscure publications. The result is that peer review, composed as it is with its referees and editors only too ready to comply with them, has generated what has been described as a chaotic and unprincipled form of censorship.

Any fair-minded person would consider that in the dissemination of new observations there are two clear-cut principles:

(1) That it is essential that, when there is an issue, both sides should be published.

(2) When there are irreconcilable differences of opinion, it is the author who is given the final decision on what he wishes to say in the paper.

These basic principles seem eminently reasonable. However, they are repeatedly violated by editors whose argument is: *"One cannot let crackpots into a respectable journal"*. This is the excuse given for what is censorship. Many scientists who have fallen foul of the system consider that the situation is irreparable. Indeed this has seen the growth of scientific papers appearing on web sites. Unfortunately, as is well known, they will then share the Internet with genuine crackpots. That gives little or no hope for we lesser mortals to sort out the wheat from the chaff.

MARS

By Percival Lowell 1895

Let us review, now, the chain of reasoning by which we have been led to regard it probable that upon the surface of Mars we see the effects of local intelligence: we find, in the first place, that the broad physical conditions of the planet are not antagonistic to some form of life; secondly, that there is an apparent dearth of water upon the planet's surface, and therefore, if beings of sufficient intelligence inhabited it, they would have to resort to irrigation to support life; thirdly, that there turns out to be a network of markings covering the disc precisely counterparting what a system of irrigation would look like; and, lastly, that there is a set of spots placed where we should expect to find the lands thus artificially fertilized, and behaving as such constructed oases should. All this, of course, may be a set of coincidences, signifying nothing; but the probability seems the other way. As to details of explanation, any we may adopt will undoubtedly be found, on closer acquaintance, to vary from the actual Martian state of things; for any Martian life must differ markedly from our own.

To be shy of anything resembling himself is part and parcel of man's own individuality. Like the savage who fears nothing so much as a strange man, like Crusoe who grows pale at the sight of footprints not his own, the civilized thinker instinctively turns away from the thought of mind other than the one he himself knows. It is simply an instinct like any other, the projection of the instinct of self-preservation. We ought, therefore, to rise above it, and, where probability points to other things, boldly accept the fact provisionally, as we should the presence of oxygen, or iron, or anything else.

We must be just as careful not to run to the other extreme, and draw deductions of purely local outgrowth. To talk of Martian beings is not to mean Martian men. Even on this earth man is of the nature of an accident. He is the survival of by no means the highest physical organism. He is not even a high form of mammal. Mind has been his making. For aught we can see, some lizard or batrachian might just as well have popped into his place in the race, and been now the dominant creature of this earth. Under different physical circumstances he would have been certain to do so. Amid the physical surroundings that exist on Mars, we may be practically sure other organisms have been evolved which would strike us as exquisitely grotesque. What manner of beings they may be we have no data to conceive.

A planet may in a very real sense be said to have a life of its own, of which what we call life may or may not be a detail. It is born, has its fiery youth, its sober middle age, its palsied senility, and ends at last in cold incapability of further change, its death. The speed with which it runs through its gamut of change depends upon its size; for the larger the body, the longer it takes to cool, and with it loss of heat means loss of life. It takes longer to cool because it has relatively more inside than outside, and it is through its outside that its inside cools. Now, inasmuch as time and space are not, as some philosophers have from their too mundane standpoint supposed, forms of our intellect, but essential attributes of the universe, the time taken by any process affects the character of the process itself, as does also the size of the body undergoing it. The changes brought about in a large planet by its cooling are not, therefore, the same as those brought about in a small one. Physically, chemically, and, to our present end, organically, the two results are quite diverse. So different, indeed, are they that unless the planet have at least a certain size it will never produce what we call life, meaning our particular chain of changes or closely allied forms of it, at all.

Whatever the particular planet's line of development, however, in its own line it proceeds to greater and greater degrees of evolution, till the process is arrested by the planet's death. The point of development attained is, as regards its capabilities, precisely measured by the planet's own age, since the one is but a symptom of the other.

Now, in the special case of Mars, we have before us the spectacle of an old world, a world well on in years, a world much older relatively than the earth, halfway between it and the end we see so sadly typified by our moon, a body now practically past possibility of change. His continents are all smoothed down; his oceans have all dried up. If he ever had a jeunesse orageuse, it has long since been forgotten.

Mars being thus old himself, we know that evolution on his surface must be similarly advanced. This only informs us of its condition relative to the planet's capabilities. Of its actual state our data are not definite enough to furnish much deduction. But from the fact that our own development has been comparatively a recent thing, and that a long time would be needed to bring even Mars to his present geological condition, we may judge any life he may support to be not only relatively, but really, more advanced than our own.

From the little we can see, such appears to be the case. The evidence of handicraft, if such it be, points to a highly intelligent mind behind it. Irrigation, unscientifically conducted, would not give us such truly wonderful mathematical fitness in the several parts to the whole as we there behold. A mind of no mean order would seem to have presided over the system we see, - a mind certainly of considerably more comprehensiveness than that which presides over the various departments of our own public works. Quite possibly, such Martian folk are possessed of inventions of which we have not dreamed, and with them electrophones and kinetoscopes are things of a bygone past, preserved with veneration in museums as relics of the clumsy contrivances of the simple childhood of their kind. Certainly, what we see hints at the existence of beings who are in advance of, not behind us, in the race of life.

For answers to such problems we must look to the future. That Mars seems to be inhabited is not the last, but the first word on the subject. More important than the mere fact of the existence of living beings there is the question of what they may be like. Whether we ourselves shall live to learn this cannot, of course, be foretold.

If astronomy teaches anything, it teaches that man is but a detail in the evolution of the universe, and that resemblant though diverse details are inevitably to be expected in the host of orbs around him. He learns that though he will probably never find his double anywhere, he is destined to discover any number of cousins scattered through space.

Sent by Mark Edwards, he says: I came across this article by Percival Lowell in a collection of articles for *The Atlantic* magazine. With the recent opposition of Mars, I thought that it might make an interesting addition to MIRA.

Underground Observatories: Looking for these Illusive Neutrinos

By Paritosh Maulik

The photons we receive from the Sun are from its very outer surface and these have taken a rather long time to reach the photosphere from their origin at the core of the Sun. They do not give much information on the energy source of the Sun were nuclear reactions at the core produce neutrinos that we can analyses to understand the core of the Sun. Neutrinos are also produced in other high energy astrophysical process so detection of neutrinos can tell a lot about these processes.

Introduction

Theoretical model of the Sun, known as Standard Solar Model (SSM), suggested that the temperature at the core of the Sun is about $10^{15\circ}$. Such a high temperature sets off nuclear reaction and one of the by-products of the reaction are neutrinos. This model also predicted the expected number of neutrino flooding the Earth. It tuned out to be a very big number and astrophysicists set about measuring this neutrino flux, the aim being to verify the SSM.

In conventional telescopes we are looking for a few photons (faint signals) from far way sources. So we need bigger receivers like mirror or antenna. The problem with detecting the neutrino is not that we are looking for fewer neutrinos; in fact we are relentlessly showered with them. The problem is they hardly interact with anything, and thus making it difficult to detect. The way out is, build bigger detectors; the bigger the detector, the more chance of neutrino interaction and hopefully detection.

As conventional telescopes need darker sky or avoidance of radio interference, the neutrino telescopes or neutrino detectors need to be shielded from cosmic rays and other naturally occurring radioactivity sources. Hence these are housed in deep underground. We shall briefly have a look at some of these and their role in the understanding of SSM.

The Chlorine Detector

Perhaps the first detector to seriously look at the Solar neutrinos was built by Ray Davis in a 1.5km deep gold mine in South Dakota in 1967. It is essentially a steel tank containing 400,000 litres of a chlorinated hydrocarbon, a commonly used dry-cleaning fluid. Most of the suns neutrinos would pass through the tank without any interaction, but occasionally some of these would collide with chloride atom and it would set off a reaction

$${}_{17}Cl^{37}\ (17p + 18n) + \upsilon \rightarrow {}_{18}A^{37}\ (18p + 19n) + e-$$

The neutrino transforms one of the neutrons of chlorine into proton and in order to maintain the electrical neutrality, one electron would be released. Chlorine would change into radioactive argon. This argon was flushed out of the tank every two months by bubbling helium gas through the fluid. The amount for argon collected was measured by its radioactive decay. On average they collected about 15 argon atoms each month, a triumph in analytical chemistry. However when the amount of argon collected was back calculated to the number of neutrinos, it tuned out to be about 2.5 units of neutrinos, compared to the expected value of about 8 units, about one third of expected neutrinos.

Only neutrinos with energy above 0.814MeV can set off this chlorine reaction. According to the SSM, the maximum energy of the most commonly neutrinos forming p – p reaction, is about 0.42MeV. High energy neutrinos; such high energy can only come from less abundant boron – 8 (${}_5B^8$) reaction. So the next approach was to build another detector which can detect neutrino of different energy range.

Kamiokande Observatory

A Cerenkov neutrino detector was started in Japan as a Japanese – US collaboration. When a particle with a speed, higher than the speed of light in that medium, enters the medium, it looses energy and the lost energy is radiated as a cone of blue light called Cerenkov radiation. It is analogous to the sonic boom from supersonic aircraft. The Cerenkov radiation is picked up by an array of photo-multipliers. From the pattern of the Cerenkov radiation, it is possible to identify nature of the neutrinos and the photomultiplier arranged in an array helps to determine the direction of neutrinos.

Briefly the detector is two water filled tanks, one inside the other. 32,000 tonne of water containing outer tank, shields the inner tank (18,000 tonne of water) from any stray radiation. 11,200 photomultipliers surrounds the inner tank to detect neutrinos by Cerenkov radiation. Over the years the sensitivity of the set up has been improved. A naked eye supernova appeared in the Large Magellanic Cloud on 23rd February 1987 and the Kamiokande observatory detector increased neutrino flux within about 15 second of its appearance.

Neutrinos of energy greater than 0.814MeV can convert chlorine to argon, but only neutrinos with energy greater than 7.5MeV can produce Cerenkov radiation in water. The Kamiokande set up suggested that the majority of the neutrinos are coming from a direction pointing to the Sun. Both chlorine and water Cerenkov experiments independently showed that there are neutrinos produced by boron – 8 reaction and since the Sun is closest to us, the source of these neutrinos are likely to be the Sun. However the observed neutrino flux by Kamiokande set up was less than the theoretical prediction.

Gallium Detectors

Although the earlier two detectors showed that we were receiving neutrons from boron – 8 reaction, one of the problem is, the theoretical model can not predict the boron – 8 reaction with a high degree of certainty and also the neutron flux produced from this reaction is smaller than other neutrino producing reactions. A possible way out is to look for a lower energy reaction.

When a lower energy neutrino collides with the nucleus of a gallium -71 atom, one of the neutrons of the gallium is converted to proton, and to maintain electrical neutrality there will be emission of one electron; gallium is converted to germanium. Since a neutron of energy above 0.233MeV can start this reaction, gallium > germanium reaction should be capable to detect the major source of solar neutrino the p – p reaction; the maximum energy from the p – p reaction is about 0.42MeV. Germanium produced from this reaction is separated and measured by its radioactive decay.

Gallium is a rather expensive metal, and commonly used in semiconductor devices. About 30 tonne of molten gallium (melting point 30°C) could detect about one neutrino per day. In a joint US and USSR project SAGE (Soviet American Gallium Experiment) the detector was about 60 tonne of molten gallium in a reactor. This reactor was housed in a tunnel about 2km below the peak of a mountain northern Caucasus. Another multinational set up was GALLEX (Gallium Experiment), in the Apennine Mountains, Italy. This was about 1.4km deep below the mountain peak. This detector was 30 tonne of gallium kept in a 100 tonne concentrated solution of gallium chloride.

Both SAGE and GALLEX picked up about 70 to 80 neutrinos as opposed to the predicted value of about 130 units. All these three experiments, using different detectors, independently showed that although we can not detect the right number of neutrinos, neutrinos are definitely present and these can have different energy levels.

The Doubt sets in

With the uncertainties of the observed neutrinos in mind, it was suggested that if the temperature in the core of the sun is about 10% less than $10^{15°}$, that is about $10^{14°}$, there would be fewer neutrinos and the observation and the theory would match. But the possible lowering of the temperature of the sun could not be theoretically substantiated.

Some theories began to suggest that neutrinos after all may not be that inert to another matter and if it does interact with matter, it can change some of its properties.

One of the implications of this hypothesis is that, if the travelling neutrino changes its properties, it should have mass. In the physicists language there are three possible types of neutrinos, electron, muon and tau neutron. In 1980 one interesting experiment was done in a nuclear power plant. They put a tank of heavy water (deuterium oxide as opposed to hydrogen oxide in ordinary/light water) close to the reactor. In nuclear plants, neutrinos are an unavoidable by-product. Neutrinos can react with deuterium ($_1H^2$) to produce neutron and neutron is easier to detect compared to a neutrino. They detected some single and some paired occurrence of neutrons. This observation was explained as, the paired neutron event is from the electron neutrinos and the single event is from any of the other neutrinos. One of the major conclusion of this observation is the electron neutrino has partially changed its characteristics during its short distance travel (about 11m) from the reactor to the detector. Now, if transformation of the neutrino can occur in such a short distance, then it is logical that the Solar neutrinos, travelling from the core of the Sun and eventually to us, have changed their properties and if this the case, then it may be possible that perhaps we are not detecting the same type of neutrinos predicted by the theory.

Sudbury Neutrino Observatory (SNO)

Another neutron observatory became operational in a 2km deep Canadian nickel mine. The detector is 1000 tonne of heavy water surrounded by light water. 9,500 photomultipliers arranged in an 18 m diameter geodesic array analyses the Cerenkov radiation given up by neutrino – deuterium reaction.

Detectors based on heavy water can distinguish between electron, muon and tau neutrinos. In less than a year SNO produced a number of interesting results.

Similar number of neutrinos always occurred in direction opposite to the Sun both during the day and night. Since most of the neutrinos can pass through matter unimpeded, it does not matter if the Earth is in the way between the Sun and the detector (the night side) or if the detector is facing the Sun directly (the Sunlit side). There were also some scattering without any preferential direction; these are from the breakdown of cosmic rays on interaction with the atmosphere.

Conclusions from the Kamiokande and Sudbury experiments are

1) The primary source of the Solar energy is p – p reaction.

2) This p – p reaction produces electron neutrinos as predicted

3) By the time the neutrinos travel to the Earth, some of these have changed into muon and tau neutrinos

4) Due to the transformation of electron neutrino into other neutrinos, the flux of the electron neutrino is about one third of the total number of the neutrinos. The detectors were not looking for the right neutrinos and this is the reason that the detected neutrino flux was lower than the predicted.

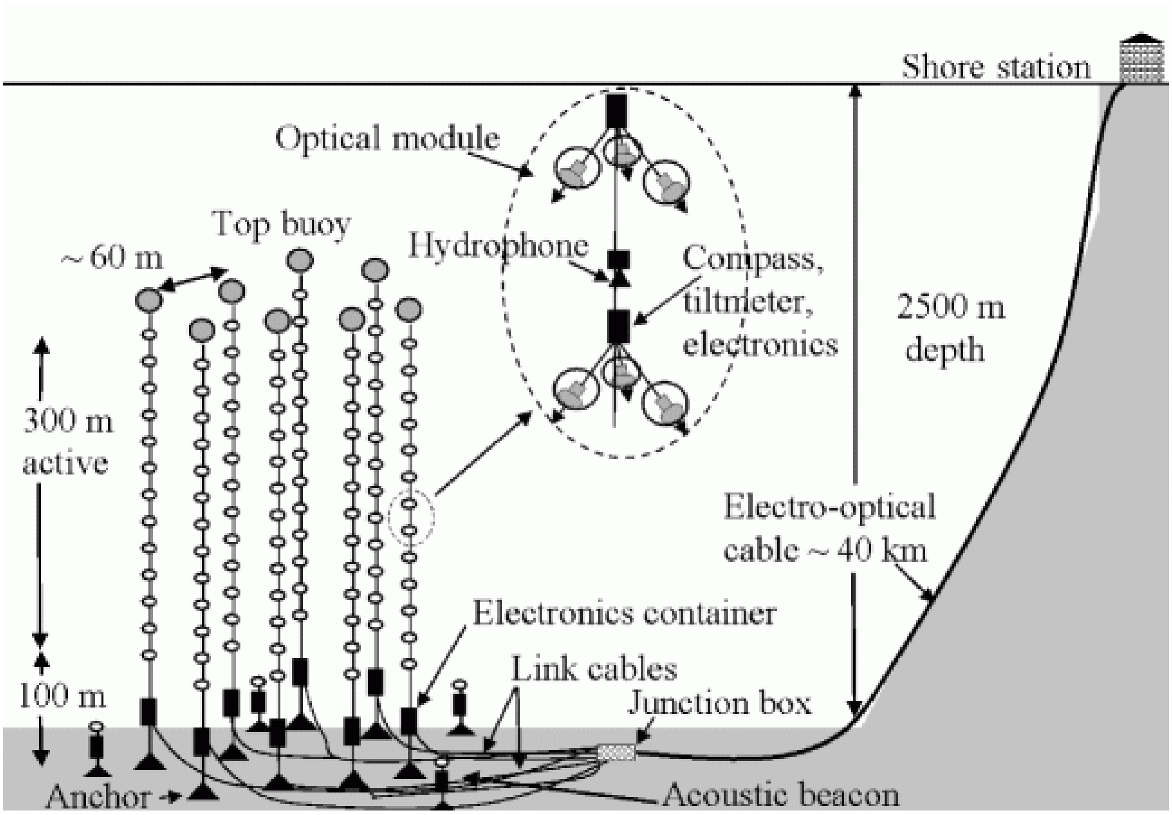
An indirect confirmation of the breakdown of Solar neutrinos came from another source. Like other sub-atomic particles, neutrino also has it antiparticle, antineutrino. These particles are produced in nuclear reactors as a by-product. There was a discrepancy between number of the observed and the expected antineutrinos; this anomaly could be explained by the behaviour on the Solar neutrinos.

It is now accepted that there are three known types of neutrinos. Nuclear fusion in the Sun produces only electron neutrinos. Muon neutrinos and tau neutrinos are produced in laboratory accelerators and in the exploding stars.

The Sun is not the only Neutrino Source

Photons in the range of gamma ray to the sub-millimetres range, bring us the information from astronomical phenomenon that we need to build up our knowledge of the Universe. Photons are electrically neutral, easy to detect and carry the chemical and physical signature of the source. However photons have some shortcomings. The presence of high concentration of gasses and subatomic particles in the central region of stars and other astronomical sources such as supernova, active galactic nucleus, prevents photons from escapeing from these regions. Magnetic fields can interfere with electromagnetic waves. So we have to apply some indirect method to study these objects. As we have seen, we can not see the photons from the core of the Sun; the photons come from its outer layer; however we can analyse neutrinos produced in the core of the Sum to understand the Sun. There is another problem with photons. Very high energy photons can react with photons from microwave back ground and produce high energy gamma rays. Although the theory predicts the maximum energy of the gamma rays from this reaction, we can detect still higher energy gamma rays. What is the cause of these high energy gamma rays? Neutrinos on the other hand are electrically neutral and react very little with anything else, so close examination of neutrinos can give us a useful of information.

A set of experiments are on going to study neutrinos from other high energy astrophysical sources. These rely on neutrino and muon (another subatomic particle) reaction. The muon is detected by Cerenkov radiation. This time, a three dimensional photomultiplier array spanning over kilometres are immersed in a lake or in the sea. There are two well known sites, one is in the Mediterranean 43° North (Astronomy with Neutrino Telescope Abyss environmental Research) and the other is in the Antarctic (Antarctic Muon And Neutrino Detector Array). The two locations have been



Schematic diagram of an underwater neutrino detector

chosen to cover the visible sky.

There is a set up in the UK to study high energy astronomical sources through neutrino detection. This is in a salt mine in the Boulbly, North Yorkshire. It is mainly looking for Weakly Interacting Matter Particles, which might have been produced during the Big Bang and may give some information on nature of dark matter. They are using sodium iodide crystal and liquid Xenon gas as scintillation detectors.

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http://antares.in2p3.fr

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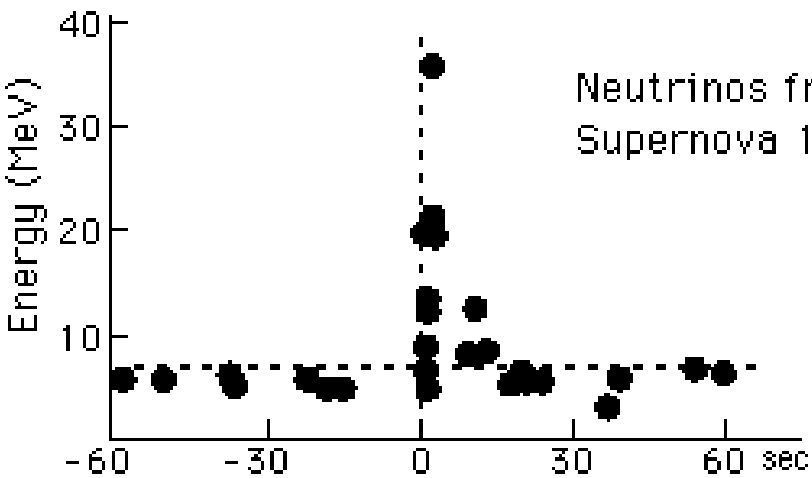

Neutrinos from the Supernova 1987A detected by Kamiokande detector