Sunset Astronomical Society

The Sunset Gazette

Serving the Tri-Cities since 1975

Volume 12, Issue 3 November 2014

Meeting information

Meetings are now at the Auburn City Hall, 113 East Elm Street in Auburn. The meetings will usually be on the 2nd Friday of each month at 7:00 PM. Watch the newsletter for changes in dates and times. Membership is not required to participate in meetings and activities. See last Page for this month's meeting site.

Membership Information

Our club has switched to e-mailing our newsletters. For those wishing to receive a hard copy mailed an additional dues of $10.00 per year is required.

New Membership Rates:

5$ per Year

Treasurer's address for renewals and subscriptions:

Tom Smith, 3423 Hidden Road,

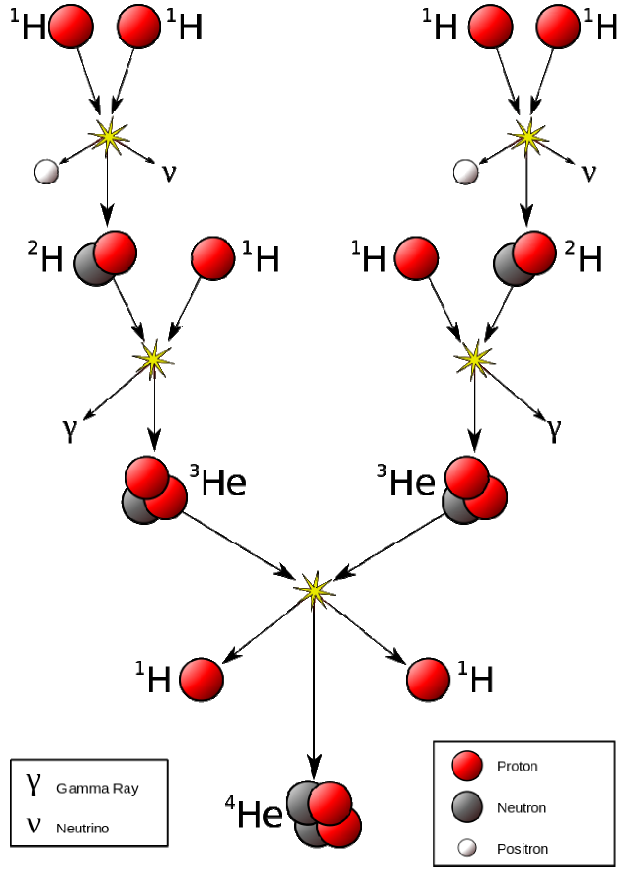
Bay City, MI 48706-1243

Neutrinos

This is the first part of a new series about neutrinos, those ghostly particles generated during the nuclear fusion process of our Sun and which can pass effortless through Earth at a rate of 65 billion per second for every square centimeter (0.16 inch^2). The series will cover the history, presence and future of neutrino research.

It all began with the question how the Sun can generate the enormous amount energy which provides us with warmth and light and makes live on Earth even possible. In the 19th century Julius Robert Mayer discovered the law of conservation of energy which states that the total energy of an isolated system is always constant and conserved over time. It means that energy can be neither created nor destroyed but its form can change, for example kinetic energy form a meteorite can be converted into heat on impact. He had the idea that a steady influx of meteorites hitting the Sun would provide the energy and heat. But the theory was rejected because overtime it would also increase the Sun's mass which should have in turn the effect of shrinking the orbits of the planets, which of course was not observed. The next hypothesis was that the Sun would generate its energy by slowly contracting and converting its gravitational energy into radiation. This theory has its origin in Isaac Newton and was later resurrected by Hermann von Helmholtz and Lord Kelvin who calculated that the Sun could sustain its current energy output for about 25 million years that way. For the time being this was accepted but during the 19th century there was increasing evidence that the Earth and therefore the solar system were significantly older. Charles Darwin pointed out that the evolution of species would take at least a couple of hundred million years and geologic and paleontological research put the age of Earth to about 1 billion years. Bad news for the contraction theory because even back then the theory of origin of our solar system involved the formation of our Sun first followed by the planets. At the turn of 19th to the 20th century radioactivity was discovered by Henry Becquerel, Marie and Pierre Curie and others and this finally lead to an understanding about the energetic processes inside the Sun. Soon it became clear that enormous amounts of energy were generated by these processes and in 1918 Francis William Aston developed the mass spectrometer and was able to determine that the mass of a helium nucleus ^{4}He was a little bit less than the sum of 4 hydrogen nuclei ^{1}H (= protons) from which it would have been generated by the fusion reaction in the Sun. The famous Einstein equation $E = mc^2$ suggested that there was an enormous amount of energy to be gained by this little mass difference. In addition it was long known since the discovery of the Fraunhofer lines (spectral lines in the Sun) that hydrogen and helium were two elements abundantly present in the Sun. And so in 1920 the English astrophysicist Arthur S. Eddington put forward the theory that the fusion of hydrogen into heavier elements was the source of energy of our Sun. How this actually would work was still a mystery because even the enormous temperature of 15 million degrees in the center of the Sun is orders of magnitude too low to provide enough kinetic energy for two positive charged hydrogen nuclei to overcome their electrostatic repulsion and fuse. This was the great moment of quantum mechanics because classical physics failed to explain this conundrum: According to the new quantum theory there was a certain probability that particles can 'tunnel' through otherwise insurmountable energy barriers and it was the Russian physicist Georgi Antonowitch Gamov who in 1928 came up with this idea and also calculated the probabilities for this to happen. In 1937 and 1939 the physicists Hans A. Bethe, Carl-Friedrich von Weizsacker and Charles Critchfield suggested tow cycles for the fusion of hydrogen to helium: the direct way via a proton-proton fusion (pp-chain) or the CNO-cycle in which carbon, nitrogen and oxygen act as a catalysts.

The picture on the right shows the pp-I chain in which two protons fuse to a deuteron (a heavy hydrogen, consisting of a proton and a neutron). This process generates a positron (a positive charged electron) and a neutrino. In the next step a third proton fuses with the deuteron to produce a light isotope of helium, ^{3}He. Two helium nuclei then fuse to a ^{4}He producing two protons for further fusion processes. This is the fundamental and most common fusion chain called pp-I branch and it produces two neutrinos which are also called pp-neutrinos.

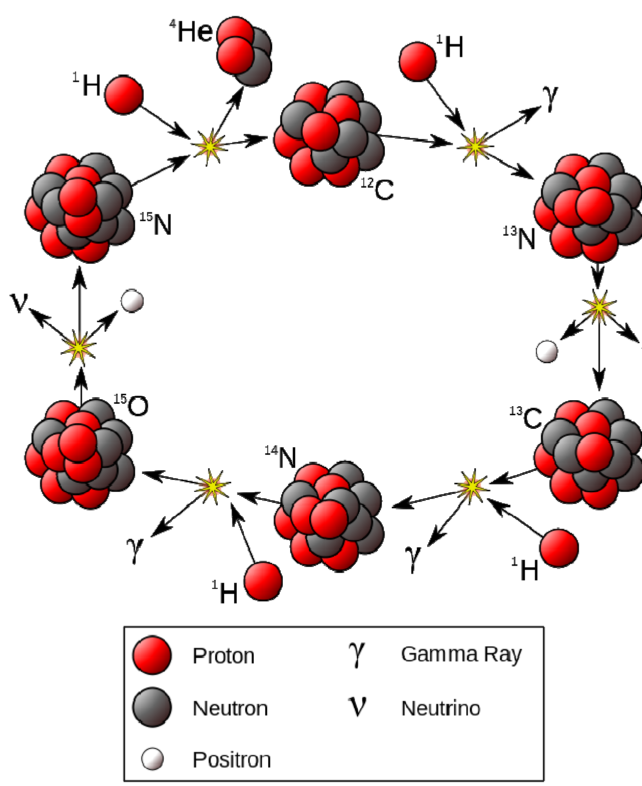


The proton–proton chain reaction dominates in stars the size of the Sun or smaller. **Protons are red**, **neutrons are grey**. Source Wikipedia.

The CNO-cycle describes an alternative process which happens only to a small amount in our Sun but is dominant in stars with masses of >1.3 Sun masses. As the lower right picture shows the final product is again ^{4}He. The cycle starts with the addition of a proton to a ^{12}C carbon nucleus which after one cycle produces a ^{15}N nitrogen nucleus which adds on last proton to produce an exited ^{16}O oxygen nucleus (not shown in the cycle). This ^{16}O oxygen nucleus decays into ^{4}He and ^{12}C and the cycle starts again. Like the pp-I cycle the CNO–cycle generates two neutrinos per ^{4}He nucleus.

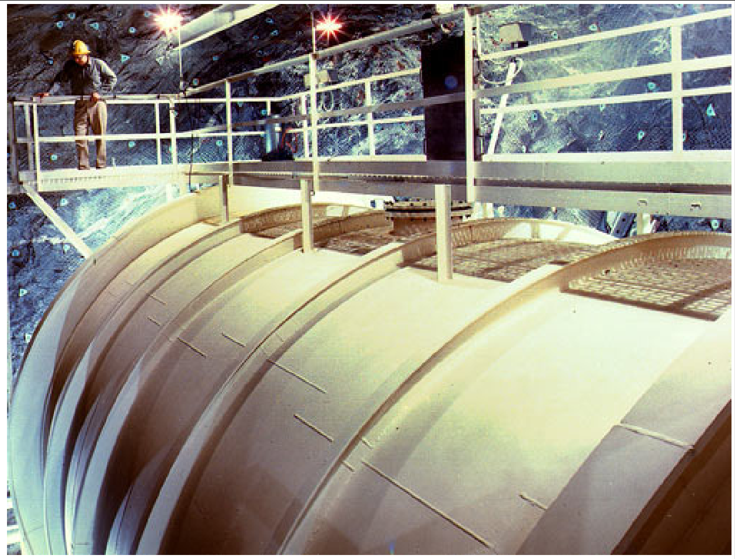
The majority of the Sun's energy is generated via the pp-chain by direct fusion of four protons to generate one ^{4}He nucleus, gamma radiation and kinetic energy. This energy takes a couple of hundred thousand years to be transported to the surface of the Sun, first by radiation and later by convection.

Compare this to the generated neutrinos which pass through the Sun without hindrance and leave it after ca 2 seconds and reach Earth after ca 500 seconds! This makes neutrinos so interesting because they bring message of the immediate thermonuclear processes currently happing in our Sun. The same thought had Raymond Davis who made his pioneering experiments in the Homestake-goldmine near Lead (South Dakota) and was the first to detect solar neutrinos. Despite the enormous number of 65 billion neutrinos per second and per 0.16 inch^{2} passing through Earth a long time the question was if we could detect these ghostly particles at all.



Overview of the CNO-I Cycle. Source Wikipedia.

Raymond Davis knew from previous research that there a some atomic nuclei who can capture neutrinos, for example chlorine isotopes with the mass number 37: $\nu_e + {}^{37}Cl \rightarrow e^- + {}^{37}Ar$. The equation states that a chlorine isotope captures one neutrino ν_e and is transformed into an argon isotope of the same mass number 37 and one electron e^-. The neutrino is an electron neutrino ν_e because it generates an negatively charged electron. At the same time inside the chlorine nucleus a neutral neutron is transformed into a proton with a positive charge. This conserves the overall charge and because the number of protons define the elements the chlorine is transformed into an argon nucleus. The advantage of the reaction was that argon atoms are very volatile and have a different reactivity than chlorine. The chlorine source in the Homestake-mine experiment was a big tank consisting of over 100,000 gallons of tetrachloroethylene C_2Cl_4 which translates into 2.2 x 10^{30} ^{37}Cl nuclei. The tank had to be placed deep underground to protect it form cosmic radiation which would also generate ^{37}Ar and produce false signals. All future experiments for the detection of solar neutrinos were placed in mines or under mountains to minimize interference with the cosmic radiation.

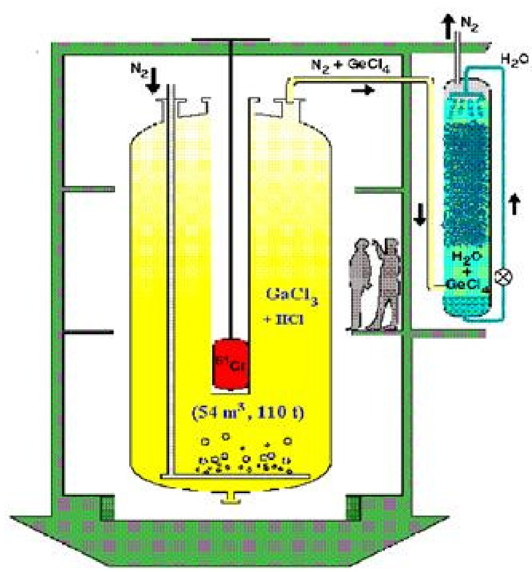


The tank filled with 100,000 gallons of tetrachloroethylene (a simple dry cleaning fluid) in the Homestake mine.

Every couple of weeks the Homestake group bubbled helium through the tank to collect the argon that had formed. The collected ^{37}Ar was then measured via its radioactive decay (half life ca 35 days). Every time there were only about tens atoms of ^{37}Ar, a sign how small the probability was for neutrinos to interact with the chlorine. The experiment was run from 1970 to 1996 and proofed that thermonuclear reactions were the source of the Sun's energy: no other explanation could account for the detection of the solar neutrinos. But there was a problem which became later known as the mystery of the solar neutrinos. The amount of ^{37}Ar detected in the experiment and therefore the number of solar neutrinos was only 1/3 of the expected number which the Sun's fusion process should generate. Something had to be wrong: Was it the experiment? Over many years Davis was scrutinizing his own experiment but could not find anything wrong with it. Was it the theory of the fusion process itself? Here was indeed a possibility: The sensitivity of the Homestake experiment was limited to only a small part of the whole spectrum of solar neutrinos. The reason is that the chlorine reaction has a relative high energy barrier of 0.814 MeV. Most of the solar neutrinos have a lower energy and would not react with the chlorine. Nonetheless the factor 3 as quotient between expected and detected rate of neutrinos was strange and even back in the 1970s the theorists began to discuss the possibility if the deficit were not founded in an unknown property of the neutrinos.

What was needed was another neutrinos reaction with other atomic nuclei but significant lower energy barrier so that hopefully all solar neutrinos could be detected. One such nuclei is the gallium ^{71}Ga which would be converted into germanium ^{71}Ge upon reaction with a solar neutrino ν_e. Two experiments were set up: the GALLEX (Gallium Experiment) in an Italian underground laboratory in the Abruzzi region with 101 tons of gallium chloride—hydrogen chloride solution and SAGE (Soviet-American Gallium Experiment) with tanks with 60 tons of gallium (a metal which is liquid just above room temperature) in a tunnel underneath the Elbrus mountains in the Caucasus. The big question was: Would the two experiments which had significant more sensitivity than the Davis experiment explain the low rate of solar neutrinos?

Continued in the next issue of the SAS newsletter!



Scheme of the GALLEX experiment: By counting the radioactive atoms of germanium, the neutrino flux is calculated.

SUNSET ASTRONOMICAL SOCIETY
THE SUNSET GAZETTE
SERVING THE TRI- CITIES SINCE 1975

Martin Grasmann **martin.grasmann@sbcglobal.net**
Newsletter Editor

Elected Officers for the SAS:

President - Ed Borus **etbjr@chartermi.net**

Vice President / Activities - Axel Mellinger

Secretary - Mohammad Khan **khan001@charter.net**

Treasurer - Thomas Smith **tom258@att.net**

Advisor - Garry Beckstrom **garry@beckstromobservatory.com**

This issue can be accessed in color on the website of the SAS!!!

http://www.sunsetastronomicalsociety.com

SAS Meeting

Start: 6:00 PM

Saturday Nov 8th, 2014

Delta Planetarium

Bay City

Welcome members and guests

New and old business

Club Business

Treasure report

Refreshments Break

Presentation:

To be determined at the time of editing, check your e-mail!

What's up in the Sky

Oct 21 - Nov 4 *Dawn*: The Zodiac light is visible 120 to 80 minutes before sunrise. Look out for a huge pyramid of light stretching up to Jupiter from the eastern horizon and tilted slightly to the right. Dark locations needed!

Nov 6: Full Moon

Oct 28 - Nov 7 *Dawn*: Now is the best opportunity to observe Mercury if you are an early bird. Watch out for the planet more than 5 deg above the eastern horizon an hour before sunrise.

Nov 14 *Dawn*: Watch out for Jupiter shining above the waning slightly gibbous Moon.

Nov 14: Last Quarter Moon

Nov 17 - 18 *Late Night*: The Leonid shower is likely to peak this night and you have the best chances observing it fro midnight to the onset of morning twilight.

Nov 22 *Evening*: Algol can be observed at its minimum brightness for roughly two hours centered at 11:50 pm EST.

Nov 22: New Moon

Nov 25 Dusk: Watch out for Mars left besides the waxing crescent Moon.

Evening: Algol can be observed at its minimum brightness for roughly two hours centered at 8:39 pm EST.

Nov 29: First Quarter Moon

Dec 5 *Evening*: The Moon moves through the Hyades and is very close to Aldebaran. Best observed with binoculars or a wide field telescope.

Dec 11, 12 *Dawn*: Watch out for Jupiter shining above the waning gibbous Moon halfway up the southwestern sky.

Dec 6: Full Moon

Dec 13 - 14 *All Night*: The Geminid shower peaks this night and the best viewing chances are shortly before the last quarter Moon rises around midnight.

Dec 14: Last Quarter Moon

Dec 15 *Evening*: Algol can be observed at its minimum brightness for roughly two hours centered at 10:22 pm EST.

Dec 18 *Evening*: Algol can be observed at its minimum brightness for roughly two hours centered at 7:12 pm EST.

Dec 21: Longest night of the year in the Northern Hemisphere. Winter begins at solstice 6:03 pm EST.

Dec 21: New Moon

Dec 22 Dusk: Something a little bit more challenging: An extremely thin crescent Moon can be seen right to Venus very low in the west-southwest shortly after sunset. Binoculars needed!

Dec 23 Dusk: Watch out for Venus well below the Moon.

Dec 24 Evening: Mars can be observed to the left of the waxing crescent Moon.

Dec 28 Late Evening: Watch out for Uranus (greenish disk) very close to the Moon. Telescope needed. In Japan and parts of the Artic an occultation is visible.

Dec 28: First Quarter Moon

UPCOMING EVENTS