Essay on a general view of the sun

Environment, Earth

Your Name

Institution

The Sun has been with us for 4 billion years, and is the nearest star to the Earth. The Sun is comprised of about 74% of hydrogen, 25% of helium, and 1% of other elements. The surface of the Sun has a temperature of about 5800 K. The core of the Sun has a temperature ranging from 10 – 15 million Kelvin. This temperature range is high enough to activate nuclear fusion within the Sun. Here, four protons will fuse together to obtain a helium nucleus containing two protons and two neutrons via a proton-proton chain. The core of the Sun witness a conversion of 660 billion kilogram of hydrogen into helium per second.

Proton-Proton Chain

Proton-proton interaction is usually a repulsive electromagnetic force due to their same-like positive electric charges. However, the nuclear strong force wins over the electromagnetic force when the protons are very close together. This is because the nuclear strong force is a short distance force which has a larger magnitude than the electromagnetic force at very short distances. As gravity pull matter together, intense heat and pressure within the system enables protons and electrons to be released from the pull of the atoms, creating a soup of free protons and electrons called plasma.

Once the protons are free, they are then able to collide with one another, and with enough energy to overcome the repulsive electromagnetic force barrier. Thereafter, nuclear fusion starts via a proton-proton fusion chain (Nave, n. d.). Figure 1 shows a diagram of the proton-proton chain.

Figure 1: The proton-proton chain (credit: Ian O’Neill, source: Cain, 2012).

The first interaction in the chain is where two protons collide, and one proton retain itself, but the other proton is converted to a neutron, a positively-charged positron, and a neutral electron-neutrino. The proton and the neutron combine to become a deuteron. The positron then collides and annihilate with a free electron to form two gamma photons. Next, the deuteron collides with another proton to yield a tritium and a gamma photon. The tritium consists of two protons and one neutron. Finally, two tritium collide to form a helium nucleus and two protons. The protons rejoin the rest of the sea of protons in the Sun to participate in the proton-proton chain process again. The helium nucleus is a nucleus consisting of two protons and two neutrons. In the proton-proton chain, the amount of mass loss is equal to 2. 65% of the mass of a single free proton. This mass has been converted into energy, which can be explained by the Einstein’s mass-energy relationship, E= mc2. The energy gained in the proton-proton chain due to the mass defect is 24. 69 MeV. In every second, there are more than one proton-proton chain reaction occurring within the core of the Sun, which when summed gives a total power of 39 X 1026 W produced from the Sun. When the radiation energy in the form of photons with various wavelengths are released from the proton-proton interactions, they perform a random walk process hitting other particles, including the hydrogen and helium, and gets reabsorbed, and be emitted again by the excited particles. Once released, more often than not, the radiation randomly travel on average about one micron to another location within the Sun, and get reabsorbed by another particle in the Sun. This reabsorption and emission takes about 200, 000 years before the radiation finally reach the surface of the Sun, and thus has an opportunity to escape from the Sun completely. When it escapes, the radiation only takes about 8 minutes to reach the Earth. This radiation is what we see as observable light, while the other unseen radiations are in the form of ultraviolet radiation, and infrared radiation which is what we recognized as heat. Note that, this absorption and release of radiation does not occur too often outside the Sun as the outer space is practically void of matter before reaching the Earth.

The Radiation Zone and the Convection Zone

Beyond the core of the Sun, is a region called the radiation zone. Outside that, is another region called the convection zone. The radiation zone has a temperature within a range of 2 million Kelvin to 10 million Kelvin. The convection zone has a temperature within a range of 5, 600 Kelvin to 2 million Kelvin. At the convection zone, atoms are formed from the heavy ions, such as carbon, nitrogen, oxygen, and iron, as the temperature is much lower than the core and the radiation zone. Apart from the radiative transfer that allows the radiation from the core of the Sun to escape the surface of the Sun, there is also another process known as the convective transfer that allows radiation to escape. The convection currents that exist in the convection zone are due to rising movements of hot gases from the hotter lower part of the convection zone closer to the core of the Sun to the surface of the Sun which is cooler. The photons produced from the proton-proton interactions are brought to the surface of the Sun via this convection currents, which then can escape the surface, and finally reach the Earth.

H-alpha and Calcium-K

The atmosphere surrounding the Sun has a region known as the chromosphere which has a temperature of about 10, 000 K. In the chromosphere, the hydrogen atoms here can absorbed photons to excite the electron contained in the hydrogen atom. When the electron in the hydrogen de-excites, photons are re-emitted, which can be of the same wavelength as the absorbed photon, or of a longer wavelength. Most of the photons in the visible wavelength that the de-exciting hydrogen emits have a wavelength of 656. 3 nm. This is due to the excited electron at the third quantum energy level, de-excite and jumps down to the second quantum energy level. This jump is known as the H-alpha jump as shown in Figure 2. Most pictures of the Sun taken from outer space shows it to be red in color because the pictures have been taken with a filter which allows only the 656. 3 nm wavelength red-colored light to pass through.

Figure 2: The H-alpha jump of the Sun (source: Richmond, n. d.)

Another line of emission that can be observed from the chromosphere is the 393. 3 nm Calcium-K wavelength light (Jenkins, 2009). A photon from this wavelength is emitted when a calcium atom from the chromosphere loses one electron to become a singly-ionized Ca+ ion.

Sunspots and Solar Flares

Sunspots are regions with dense magnetic fields emerging from the interior of the Sun. They can be observed as dark regions on the surface of the Sun. The Sun rotates with a different rotational speed near its poles compared to its equator. As the Sun rotates with such differential rotations, the magnetic lines of the Sun get twisted up, and thus causes sunspots. Every sunspots come in pairs, where there will be one sunspot which is tagged as the North sunspot, and the other a South sunspot. The size of the sunspot is about the size of the Earth. The number of sunspots at any moment is a good indicator of the solar activity in the Sun. The higher the number of sunspots, the more solar activity there is in the Sun.

Solar flares usually occur between the two differently polarized North and South sunspots which sends a jet of energetic particles, including electrons, and ions, light and heat travelling outwards from the photosphere with a temperature as high as several million Kelvin. This is due to the occasional trappings of heat within the Sun from the Sun's magnetic field preventing the heat from escaping the surface. When this occur, gases in this region are heated to very high temperatures which then escapes the Sun as an observable sudden burst of energetic particles. When the solar flares hit the Earth, they heat the Earth's outer atmosphere. Most of the energy from solar flares do not reach the Earth's surface, as they are reflected out by the Earth's magnetic field.

The Maunder Minimum

The number of sunspots on the Sun in any year follows a sunspot cycle of about 11 years, in which there will be seasons with minimum sunspots, and seasons with maximum sunspots. The solar minimum corresponds to when the number of sunspots is at its minimum. When this happens, the temperature of the Earth drops. This is because there are less solar activity in the Sun, and hence, less energy directing towards the Earth during the solar minimum.

In 1645 – 1715, the number of sunspots was much lower than expected even when a solar maximum was expected. This period was called the Maunder Minimum or “ Little Ice Age”. During this period, the Earth received less energy from the Sun, hence the global temperature was lower than the average temperature. The Northern Hemisphere of the Eaerth was reported colder than on average so much so that the Thames River froze for two months. Even the Baltic Sea froze during the Maunder Minimum (The Little Ice Age, n. d.). Lockwood et al. in their 2010 paper showed that there is a relationship between the cold winter trends in Europe and the low solar activity of the Sun. However, they cautioned that the result only applies to Europe as their study was only focusing on that region, and that low solar activity does not necessarily imply lower temperature in other parts of the globe.

The Destiny of the Sun

The explosive force of the nuclear fusion created within the core of the Sun is balanced out by the gravitational force of the Sun on itself which tends to try to keep all the particles in the Sun together. This enables the Sun to be stable, and stay in one intact piece without exploding into pieces. The proton-proton chain interactions is expected to continue for approximately another 5 billion years until there are no longer any hydrogen around, or that the hydrogens’ momentum are too low for collisions overcoming the electromagnetic force barrier to happen. The Earth will lose the heat and light obtained from the Sun due to this.

The helium produced through the proton-proton chain will begin to come closer together due to the gravitational pull, and eventually under the right temperature and pressure, each three helium nuclei will fuse to produce a carbon nucleus. The carbon then fuse with a helium to produce oxygen. These thermal activities will continue until all the particles are now either carbon or oxygen in the core. These nuclei can no longer fuse to yield heavier nuclei as the Sun is not expected to be hot enough in the core to activate such processes (Metcalfe, 2004). This then marks the cessation of nuclear reactions which gives out new light and heat in the core. Eventually, the Sun will collapse under its own gravitational force, and form a white dwarf star which does not generate any new form of energy, but cooling off as time goes by.

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