The Sun and Solar Wind: A Search for the Beginning

Photons in the Radiative Zone: Which Way is Out? An A-Maz-ing Model

STUDENT TEXT

How long did it take you to find your way out of the maze? A few minutes? An hour? Can you imagine a maze that takes a million years to exit? Some of the photons that are part of solar wind spent at least that long finding their way out of the radiative zone of the sun. Where did these photons and other particles come from? What happens to them when they finally exit the sun's structure? Scientists will be searching for potential answers to those questions and others when they analyze the Genesis solar samples.

Refer to the handout, "Standard Model of the Sun," as you follow photons through their trip to the sun's surface, as envisioned in the Standard Solar Model.

Photons in the Core

As you learned in "The Invisible Fire," a hot brew of protons, neutrons, nuclei, and free electrons is produced in the nuclear inferno of the sun's core. Tiny packets of energy called photons, the particle component of electromagnetic radiation, start on an incredible journey that ultimately results in their being spewed forth into space.

In the extremely dense core, photons of short wavelength, called high-energy gamma rays (γ), lose energy as they collide with electrons (not with walls!) to form longer wavelength and less energetic x-ray photons. These photons follow a long, torturous route as they work their way to the surface of the sun.

Photons in the Radiative Zone

Once the photons escape from the core, they travel outward in the **radiative zone**. Deep in the radiative zone, the photons collide with plasma particles and change direction in random ways. Each photon may travel only a few millimeters before it suffers another collision and is set off in a different direction. Nevertheless, the photons continue to work their way toward the surface by meandering in zig-zag fashion toward regions of lower temperature and pressure. The time that it takes for them to complete their journey to the surface is measured in the millions of years, which is an incredible fact given that the photons travel at the speed of light! To put it in more personal terms, the sunlight that gave you your tan last summer resulted from a nuclear reaction that took place perhaps 1,000,000 years ago deep within the core of the sun.

Are We There Yet?

Some of the electrons in the radiative zone are captured by helium nuclei to form ionized helium atoms. The radiative zone, which is packed with ionized hydrogen and helium atoms, extends from the core of the sun about 70% of the distance to the surface. This mixture of ionized hot gases and electrons is called a **plasma**, a fourth state of matter. While moving through the radiative zone, the photons encounter less and less dense materials. Two-thirds of the way through, the density is about the same as that of air, and at the edge of the zone, the density is thought to be around 0.1 g/cm^3.

We're Still in the Dark

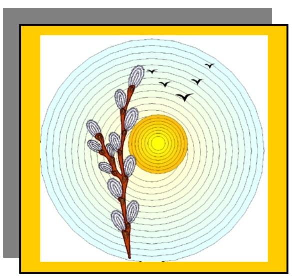
Until this time, the energy produced is in the high energy spectrum beyond that of visible light. The collisions suffered by the photons rob them of part of their energy, and consequently their wavelengths gradually become longer and longer as they move toward the convection zone. Ultimately wavelengths corresponding to visible light are reached.

The Convection Zone: The Mystery Layer

When the photons arrive at the convection layer, 150,000 km below the sun's surface, the nuclei are able to hold on to electrons, and neutral atoms and ions are formed. And photon energies have been degraded to the point that gaseous atoms and ions absorb the energy of the photons and hold it, rather than having it bounce off (or be absorbed and re-radiated). These atoms effectively block the outward flow of radiative energy and the energy absorbed by the atoms makes them enormously hot.

At that point the convection currents take over and carry the sun's energy to the photosphere on seething rivers of hot gases. Although it may have taken the photons a million years to reach the convection zone, the energy they deliver rises through the entire convention zone in about three months. All the energy emitted at the surface of the sun is transported there by convection.

The Photosphere: Ah! Light At Last!



The photosphere, at the top of the convection zone, is the visible bright surface of the sun. Here the gaseous atoms no longer block radiative flow. As the hot atoms cool, they release their excess energy once again as photons that stream unimpeded into space and ultimately provide support for life on Earth.

[For further description of the sun, read "The Structured Sun" in Appendix C. To review how the Standard Solar Model was developed, refer to the Student Text "Models in Science."]