The Sun and Solar Wind: A Search for the Beginning

The Solar Wind

STUDENT TEXT

The sun is a hot, violent place and some of its outer layer constantly boils away. Periodically there are enormous eruptions that blast solar material into the space around the sun. The components of the sun that are thus spewed into the void of outer space constitute what is called the solar wind, a ceaseless wind that blows in unsteady gales. The amount of matter leaving the sun is staggering by Earth standards, with an estimated million tons of material being blown away from the sun every second! However, by solar standards this is a trifling amount, and billions of years will be required for the sun to lose significant amounts of mass in the form of the solar wind. Nor is the solar wind very significant in carrying energy away from the sun, as measurements show that this energy is at least one million times smaller than the radiative energy departing from the sun's surface.

Not only is the solar wind tenuous, it also is hot and fast. The temperature is on the order of one million degrees. (Keep in mind the fact that temperature is a measure of motion.) It flows steadily past the Earth at speeds of 300 to 700 km per second, with occasional gusts that may move twice as fast. Solar wind speeds were measured accurately by the *Ulysses* spacecraft in 1992. The more or less constant component of the solar wind can be thought of as the outer corona in a state of steady expansion, but the source of variation in the wind's speed remains poorly understood.

The striking and beautiful auroras—the Northern and Southern Lights—are caused by particles of the solar wind entering the upper atmosphere where they encounter atoms and molecules and excite them to higher electronic states. When the atoms and molecules de-excite, they emit light that we know as an aurora.

Composition of the Solar Wind

The restless solar wind consists of charged, gaseous particles (a plasma), 95% of which are protons and electrons (in roughly equal numbers). The remaining small portion contains isotopes such as helium-3, helium-4, neon-20, neon-21, neon-22, and argon-36, the presence of which was confirmed by Apollo missions that collected samples of the wind hitting the moon. The solar wind is suspected, in fact, to contain ions of most of the elements in the periodic table, but the concentration of most of these ions is exceedingly low. In the Genesis mission the isotopes of greatest interest are those of oxygen, nitrogen, and the rare gases such as argon and neon.

It is obvious that the solar wind carries with it information about the isotopic composition of the sun itself. But it may do more than this. Since the sun contains most of the mass of the solar system, which evolved from the primordial gaseous stew of the original nebula, it more closely approximates the nebular composition than does any other component of the solar system. So, gaining a detailed understanding of the composition of the solar wind may shed light on many fundamental questions surrounding the diversity of planet composition, planetary atmospheres, asteroids, and other strange and poorly understood facets of our marvelous solar system.

Goal of the Genesis Mission

The goal of the Genesis mission is to intercept the solar wind for an extended time (two years) and to collect a sufficiently large sample such that detailed, precise, and comprehensive isotopic analyses of its composition will be possible. The results of these analyses will be of enormous benefit to a diverse collection of scientists who ponder the nature of our universe.

You might wonder why it is necessary to leave the spacecraft on station for two years. The answer is that the solar wind is incredibly dilute. By the time it reaches the vicinity of the Earth, there are only about 10 particles per cubic centimeter or less! This is very wispy. Even good vacuum pumps are unable to reduce the concentration of air molecules in vacuum chambers to such low levels. As a result of the low density of the wind, the collection process must extend over a long time period in order to obtain samples of sufficient size for analysis. Even after continuous collection for two years, the entire suite of samples is expected to contain only around 10^{17} atoms. To bring this into focus, it might be useful to realize that a piece of pure copper having the mass of a penny would contain about 250,000 times more atoms than the Genesis sample. Or to turn it around, a piece of copper containing the same total number of atoms as the Genesis sample would be a tiny speck having a mass of only about 0.01 milligram. For many of the isotopes it may be necessary to detect and quantify only a miniscule number of atoms. The analysis techniques applied to the sample must be not only precise, but also exquisitely sensitive. Mass spectrometric techniques will be important, but new analysis technologies will be required for the final stage of the project to be completely successful.