Monitoring the Sun's Burn

The sun's energy production is steadier than many stars', but a very small fluctuation could cause us trouble

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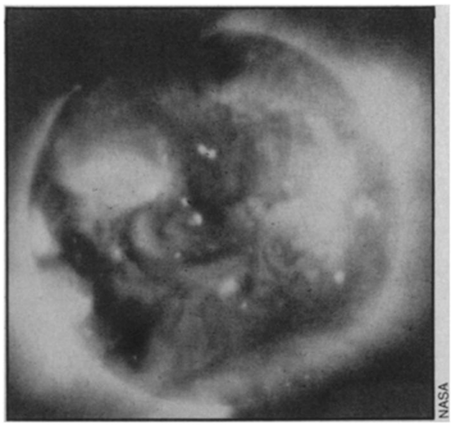

An X-ray view of the sun from Skylab.

In folklore the sun is a metaphor for stability and dependability. Whether we are sure of tomorrow's sunrise, afraid to see the evening sun go down or accusing the sun of impassive inactivity like the Polish harvest song that berates it for doing nothing but hang in the sky all day, we depend physically and psychologically on the constancy of solar phenomena.

The term "solar constant" refers to the amount of energy deposited on earth by the sun's radiation, and the very wording testifies to astronomers' willingness to believe in solar reliability. In this we earthlings are very lucky. Most planets may not have so dependable a star. Astronomers have wondered whether the constant was really all that constant, but the energy deposition is difficult to measure (SN: 3/6/76, p. 156), and so long as the sun continued to burn the backs of harvesters with its wonted intensity, most astronomers have been content to let the question lie.

Lately, however, the sun has been accused of certain fluctuations in behavior that could be quite important. At least one of these, acoustical pulsations, ought to affect the solar constant, and as a means of checking out the pulsations as well as generally finding out more about the sun's energy deposition on the earth, William Livingston, Robert Milkey and C. Slaughter of Kitt Peak National Observatory have thought out and are applying a method of measuring the solar constant that they contend avoids the difficulties and ambiguities of previous methods.

The tale might well begin with the first big solar surprise of recent years, the failure to detect solar neutrinos. The processes of thermonuclear fusion that generate the sun's energy output should produce a certain flux of neutrinos. Years of observation that by all the laws of neutrino physics should have detected this flux haven't found it. Astronomers began to suspect something fishy with the sun, even to the point of proposing that the sun's energy-generating mechanism had shut off, either for a period or for good. Such a suggestion might produce a certain anxiety about the fate of our posterity.

Meanwhile, Henry A. Hill of the University of Arizona and co-workers were observing the sun in an attempt to find evidence of an oblate shape. The original purpose of this was to check some theoretical disagreements about general relativity, which had nothing directly to do with the solar constant or the neutrino flux. Hill and company did not find oblateness, but they did report (SN: 8/2/75, p. 68) observing acoustical pulsations in the sun. The whole sun, they found, vibrates like a ringing bell in several modes. These vibrations could explain the absence of a neutrino flux because they are very efficient dissipators of energy. It may surprise those who see the brightness of the sun to realize that the interior of the sun is really quite opaque. Energy generated deep in the interior in the form of light is reflected, scattered, absorbed and reradiated so many times that it can take 30 million years to get out. Invested in acoustic waves, the same energy gets out in 25 minutes. So the acoustic waves may be cooling the interior of the sun to the point where the temperature is so low that the neutrino-producing reactions that solar theory expects don't occur.

The acoustic vibrations are thus very important, and an independent check on their existence is desirable. They should cause a fluctuation in the solar constant. And Livingston, Milkey and Slaughter have devised a new way of watching the constant.

The basic problems in solar-constant measurement are the uncertainty of correcting for effects of the earth's atmosphere if the observations are ground based, correcting for changes in instrument sensitivity if the measurement is made from space or correcting for planetary geometry and albedo if the method is comparing the sunlight reflected by other planets.

An overall review of the question cited by Livingston and associates indicates an uncertainty of plus or minus 1 percent in the best past measurements, which could be either experimental error or an actual variability of the constant. This little bit is important in itself (aside from the question of Hill's acoustical pulsations) because no more than a 2 percent decrease in the solar constant would lead to total glaciation of the earth. So, if there is as much as 1 percent fluctuation, we or succeeding generations could be in trouble.

The new method is to observe the strength of a particular absorption of energy within the sun by ionized carbon, a line that appears at a wavelength of 5,380 angstroms. This line is particularly sensitive to temperature, and it is temperature fluctuations that relate to solar-constant fluctuations. To avoid the usual sources of error, the line's strength is measured not absolutely but in comparison to nearby features of the solar spectrum. Therefore any momentary effect of the earth's atmosphere or of the instruments on the carbon line should also be felt by the background spectrum and thus be automatically discounted when the comparison is made.

About 100 hours of observation convinced Livingston, Milkey and Slaughter that they can measure the constant to within 0.03 percent. This is a tenfold increase in sensitivity over the best previous observations, and so it makes continued work for a long term worthwhile.

So far no evidence for Hill's acoustical fluctuations shows up in the data, and this causes concern. The discrepancy may have to do with a difference between the level in the sun's photosphere at which the carbon line is produced and the level to which Hill's observations refer. More observations and the development of a theory of behavior at different levels of the photosphere are needed to resolve the difficulty, Livingston and associates say.

Meanwhile the observations continue to see whether there are any longer-term changes in the constant, which could be either periodic or a one-way drift or both. (The acoustical pulsations are on the order of a hour or less.) Livingston is happy with the method and content to be doing the work, which promises to go on for a decade or more, but he tends to expect a negative result. "I expect we'll find that the sun is fairly constant," he says. □