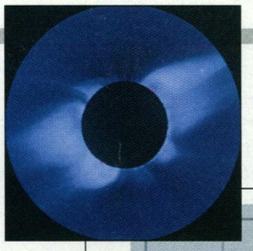
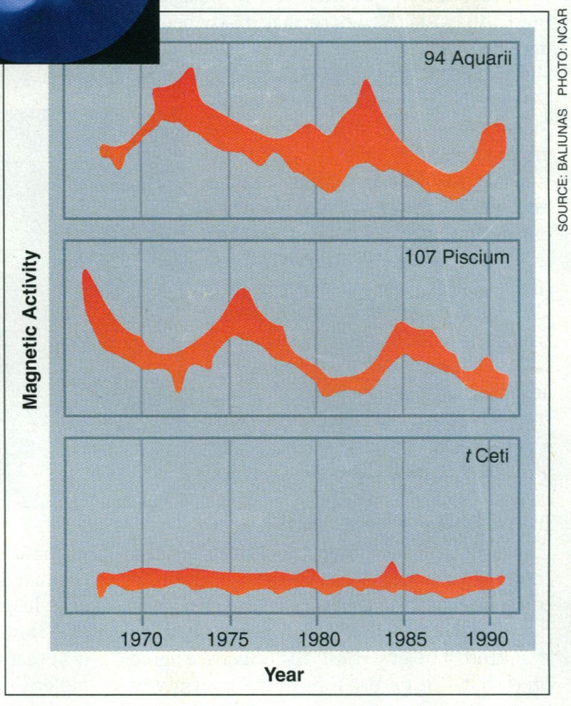
ASTRONOMY

Is Earth's Future Climate Written in the Stars?





SOURCE: BALIUNAS PHOTO: NCAR

Other stars, other cycles. Clues to the variability of the sun *(left)* may come from magnetic cycles on sunlike stars.

Most astronomers, naturally enough, announce their hottest results to their astronomer-peers. But last year Sallie Baliunas of the Harvard-Smithsonian Center for Astrophysics broke the mold. She announced some of her latest results on the study of stars similar to the sun at a meeting on global climate change sponsored by the Scripps Institution of Oceanography—and will publish them next month in *Energy*, a journal astronomers rarely read. Why is Baliunas presenting her results in these unusual venues? The reason is that she thinks her results have implications beyond astronomy: By explaining how the sun's brightness could vary, she claims, they point to a role for the sun in recent climate changes.

Astronomers have mixed reactions to Baliunas' findings, which many have seen in pre-print form. On the one hand, they say her data promise new insight into the puzzle of the sun's variability. "No one else has data that can answer those questions," says Harvard's John Stauffer. But the praise turns to skepticism when Baliunas brings her data back to Earth and attempts to explain a puzzle that has stumped astronomers—an inexplicable correlation between recent global temperatures and the length of the 10- to 12-year sunspot cycle. Solar physicists and climate researchers say her results are still preliminary, and they disapprove of attempts by Baliunas and Robert Jastrow of the Mount Wilson Observatory, a coauthor of the *Energy* paper, to suggest that the sun, not greenhouse gases, may be driving climate change.

The roots of the current controversy date back to 1991, when a pair of Danish researchers published a paper in *Science* (1 November 1991, pp. 652 and 698) describing the correlation between temperatures and sunspots. In the paper, Eigil Friis-Christensen and Knud Lassen of the Danish Meteorological Institute compared records of Northern Hemisphere temperature and the length of sunspot cycle from 1860 to the present. Over that period, global temperature rose about 0.5 degree for the first 80 years, fell 0.2 degree for the next 20 years, then started rising again. The researchers found that the length of the sunspot cycles decreased, then increased, then decreased in a mirror image of the temperature pattern.

Solar physicists were puzzled by the finding, not knowing whether to see it as a hint that variations in the sun may be driving climate change, or just a striking, but meaningless, coincidence. "People called it an exercise in curve fitting," says Jastrow. "They said there was no physics in it." But Baliunas, like some other astronomers, has for years

A Stellar Blast From the Past

Most solar physicists doubt that studies of other stars have much to contribute to the debate over the sun's role in global warming (see main text). They nonetheless value such studies for a different purpose: the hints they yield about how the sun has changed over its 4.5-billion-year life. "They put the sun in context," says National Solar Observatory astronomer Jack Harvey. Stars similar to the sun in mass, but younger, churn with more magnetic activity, break out in more spots, and waver more in brightness, suggesting the sun, too, may have had a restless past. One striking example of youthful exuberance came last summer when a young sunlike star erupted a flare that, had it taken place on the sun, would have sterilized Earth's surface.

Flares—vast explosions in the atmosphere of a star, thought to be caused by abrupt shifts in the star's magnetic field—can't be seen directly on other stars. But they can be traced, because they change a star's total brightness, with the largest effects in the ultraviolet. Indeed, University of Colorado astronomer Thomas Ayres discovered the flare when he was using the Hubble Space Telescope to observe the Pleiades, a clutch of young, sunlike stars, at ultraviolet wavelengths. One star abruptly tripled in brightness in a particular band, then subsided over 20 minutes. The duration of the flare, Ayres says, indicates that it covered only 1% of the star's surface (a larger area would have taken longer to cool). But that small area released so much radiation, says Ayres, that "we're very lucky" the sun doesn't behave the same way.

One reason it doesn't is that age mellows the sun much as it mellows the rest of us. The stars in the Pleiades have been around for a mere 70 million years—an eyeblink compared to the sun. But no other star in the Pleiades has let loose with such a flare, suggesting there must be factors other than youth behind the star's hyperactivity. One possibility, says astronomer Ted Simon of the University of Hawaii, is a high rotation rate. Some stars start out whirling at breakneck speeds, hundreds of times faster than the sun, while others rotate just several times the sun's speed of once every 27 days. Because a star's rotation shapes the internal churning that generates magnetic fields, a fast rotator would have more magnetic activity and consequently more flaring. "There may be a whole range of behaviors," says Simon, to go along with these different rotation rates.

While Ayres' star is unusually active for its age, the sun seems unusually quiet—even for a 4.5-billion-year oldster. "We've got this mystery as to why the sun fluctuates 0.1% and other stars [of the same age] fluctuate 0.3% to 0.4%." says Harvey. "We may be looking at it during an unusually quiet phase." Given time, even a stellar senescent like the sun could kick up its heels again.

–F.F.

been studying other stars in search of clues to the sun's behavior (see sidebar). She thought the data might yield hints of a mechanism that could link cycle length to brightness.

Many stars, after all, show starspot cycles similar to the sun's. Starspots are too small to observe directly, but for the past 10 years Baliunas has been able to track their ups and downs indirectly in dozens of stars, by measuring the intensity of two telltale lines, known as the H and K lines, in the stars' ultraviolet spectra. These lines, astronomers believe, reflect the stars' magnetic activity. As on the sun, more magnetic activity presumably leads to more dark spots, which erupt when the magnetic field churns so violently that it breaks through the surface.

When Baliunas added her 10 years of data to earlier observations stretching back 30 years, she found that the intensity of the lines rose and fell in 10- to 15-year cycles—an indicator of starspot cycles. The critical clue came when Baliunas found that the intensity peaks were highest, indicating the most vigorous magnetic activity and the largest numbers of spots, during the shortest cycles.

Baliunas can't explain why cycle length and magnetic activity should show this inverse relation. But she does say the relation, if it also applies to the sun, could provide a physical link between the cycle length and brightness. The Solar Maximum Mission satellite showed that over the course of the last sunspot cycle, the sun got marginally brighter at times of peak magnetic activity because of an increase in the extent of bright regions called plages.

Climate modelers and solar physicists say that while the results are plausible, they want a more complete explanation of the physical connections between changes in solar-cycle length and brightness before they will accept that sunspots are a key to climate. So far, says solar physicist Judith Lean of the Naval Research Laboratory, the causal links are "not rigorous enough." And that makes her doubly leery of any effort to draw conclusions about climate change from the result. Baliunas "is not an expert on climate," Lean notes.

Baliunas counters that she hasn't attributed global warming to solar changes. She says she's trying to clarify, not discount, the role of greenhouse gases in global warming. By studying the fluctuations of other stars, she says, "We want to get the best estimate of the manmade influence." And she's readying another response to her critics, as well. She's now preparing a more complete paper on her findings, including data from a larger sample of stars. That one, she plans to present the old-fashioned way: to the astronomy community.

–Faye Flam

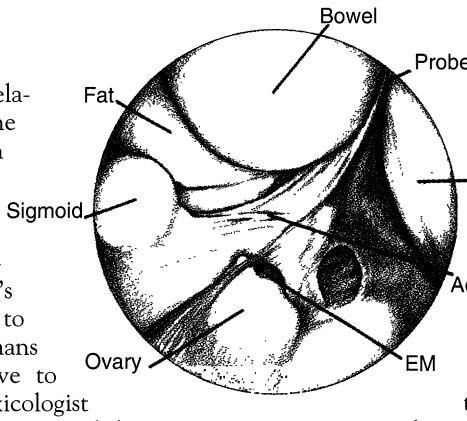
TOXICOLOGY

Dioxin Tied to Endometriosis

More than 5 million women in the U.S. have endometriosis, and nobody knows why. The disease, in which tissue from the uterus mysteriously migrates to the abdomen, ovaries, bowels, or bladder, often causes internal bleeding, infertility, and other problems. Researchers have speculated that the disease might be caused by menstrual blood that flows backwards or by a developmental disorder, but proof hasn't been forthcoming. Now a study has fingered a new suspect, one with a decidedly unsavory reputation: dioxin.

In human beings, there is evidence that high doses of this environmental toxin cause cancer and birth defects, and in a colony of female rhesus monkeys in Madison, Wisconsin, researchers have found that it can also play a key role in endometriosis. According to a report published in the November issue of *Fundamental and Applied Toxicology*, 79% of the monkeys that were exposed daily to relatively low levels of dioxin developed the disease; the severity of the condition increased with the dosage.

The study has a lot of researchers who study human endometriosis looking suspiciously at dioxin. "This is the first big piece of evidence that environmental toxins may be involved in the pathogenesis of endometriosis," says David Olive, chief of reproductive endocrinology and infertility at the Yale University School of Medicine. "It opens up a whole new area of research." Seven research teams are already following up, including one testing dioxin levels in the blood of women with endometriosis. Most people harbor dioxin traces, as a result of exposure to pesticides in their diet, or airborne dioxin released by certain types of waste incineration; the problem will be to see whether there is a dose-response relationship like the one seen in the Madison monkeys.



Did dioxin do it? Endometriosis in this monkey, seen as abnormal tissue marked "adhesions," may be linked to dioxin.

Toxicologists are betting that the response is somewhat similar. "It's highly improbable to me to say that humans won't be responsive to dioxin," says toxicologist Linda Birnbaum, director of the Environmental Toxicology Division at the Environmental Protection Agency's (EPA) Health Effects Research laboratory, which is in the midst of a major review of its regulations for the pollutant.

Though the disease is now the focus of a flurry of activity, understanding endometriosis wasn't the original goal of the researchers studying the monkeys at the Harlow Primate Laboratory at the University of Wisconsin, Madison; they were interested in long-term reproductive effects of dioxin exposure. Fifteen years ago they began feeding 16 monkeys dioxin in their diet. The initial trial lasted 4 years, but when three of the monkeys died of endometriosis 6 to 10 years later, scientists began to wonder about a connection.

To investigate, surgery was performed on the monkeys last year by University of Tennessee surgeon Dan Martin and immunological studies carried out by University of South Florida College of Medicine's Sherry Rier. "We were blown away by the findings," says Rier, co-author of the study. It turned out that many of the animals with the most severe endometriosis had been among a group fed the highest dioxin doses every day—25 parts per trillion (ppt). At least 71% of those monkeys had moderate to severe disease, compared to 42% of the monkeys fed a lower dose of 5 ppt. A control group not fed dioxin had no moderate or severe disease.

The finding has prompted studies of dioxin and endometriosis at the EPA and other places. And in Italy, University of California, Berkeley, epidemiologist Brenda Eskenazi plans to look at endometriosis in women living near a chemical plant that exploded in Seveso in 1976. Those people have dioxin levels within the ranges seen in the monkeys.

If studies do link dioxin to endometriosis, it probably isn't the only environmental contaminant capable of producing such effects. Dioxin is a member of a family of chemicals that includes several hundred polychlorinated biphenyls (PCBs) and polychlorinated dibenzosuran isomers. To find out whether other members of this family could result in endometriosis, researchers at the National Institute for Environmental Health Sciences in North Carolina are testing the blood of 20 women with endometriosis for all of those chemicals. When these projects begin reporting results in the next year or two, researchers hope to add another conviction to dioxin's growing list of health crimes.

–Ann Gibbons

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