The Sun is Bristling with X-ray Jets

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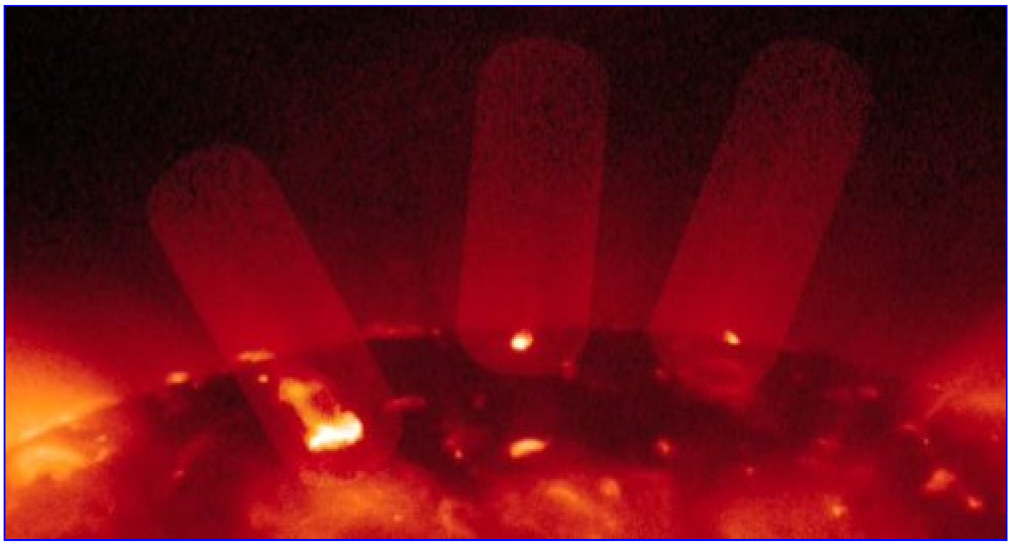
Dec. 06, 2007: Astronomers using Japan's Hinode spacecraft have discovered that the sun is bristling with powerful "X-ray jets." They spray out of the sun's surface hundreds of times a day, launching blobs of hot gas as wide as North America at a top speed of two million miles per hour. These jets add significant mass to the solar wind and they may help explain a long-standing mystery of astrophysics: the superheating of the sun's corona.

"This is awesome and very much unexpected," says Jonathan Cirtain of the Marshall Space Flight Center who was a key figure in the discovery. He recalls how it happened: "We found them a year ago in Nov. 2006. Hinode had just been launched and its instruments were coming online." To calibrate the spacecraft's X-ray Telescope, mission controllers in Japan pointed the telescope at a dark hole in the sun's atmosphere--a "coronal hole." Cirtain analyzed the data and "there they were!"



Above: An X-ray jet recorded by the Hinode spacecraft on Jan. 10, 2007. Quicktime movies: three jets (2.4 MB); many jets in low resolution (4 MB); many jets in high resolution (26 MB).

"After the shock wore off, I ran around dragging other scientists into my office to show them the movie." He likens the appearance of the jets erupting within a coronal hole to "the twinkle of Christmas lights, randomly oriented. It's very pretty."

Cirtain notes that X-ray jets have been seen before, but never in such abundance. The first jets were recorded by a 1st-generation X-ray telescope onboard Skylab in the 1970s. They were called x-ray jets for the simple reason that they were bright at x-ray wavelengths. The phenomenon was later confirmed by a Naval Research Lab ultraviolet telescope that flew aboard the space shuttle in the 1980s as well as by Japan's Yohkoh X-ray Telescope in the 1990s. "All those instruments saw very few jets--typically one or two per day," says Cirtain. X-ray jets were thus regarded as a curiosity of little importance.

Hinode has changed all that. The spacecraft's advanced X-Ray Telescope can take pictures rapidly enough to catch these fast-moving eruptions. "We now see that jets happen all the time, as often as 240 times a day. They appear at all latitudes, within coronal holes, inside sunspot groups, out in the middle of nowhere--in short, wherever we look on the sun we find these jets. They are a major form of solar activity," says Cirtain.

Each jet is triggered by a magnetic eruption or "reconnection event"--essentially the same process that powers solar flares albeit on a much smaller scale. "The energy in a typical jet is about a thousand times less than the energy of an M-class (medium sized) solar flare," says Cirtain. Individually, jets are weak; en masse, however, they pack quite a punch. "If we add up all the energy jets deposit into the sun's atmosphere, the daily total is on par with solar flares."

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Indeed, the jets may contribute significantly to the solar wind. Every day a hot, relentless wind of solar protons and electrons blows against Earth, deflected just before it can reach the atmosphere by our planet's global magnetic field. Gusts in solar wind can cause bright auroras, power outages and other effects collectively known as "space weather." What drives this wind away from the sun? It's a question that has puzzled physicists for decades. Jets provide at least part of the answer:

"We've added up the mass flowing in these jets and it amounts to between 10% and 25% of the solar wind. That's a significant fraction," he says.

X-ray jets may also contribute to the mysterious heating of the sun's outer atmosphere, the ghostly "corona" seen during solar eclipses.

Right: The sun's outer atmosphere or "corona". Credit & Copyright: Koen van Gorp.

The mystery is this: If you stuck a thermometer in the surface of the sun, it would read about 6000^{o} C. Yet above the surface of the sun, in the corona where intuition says things should be cooler, the temperature rises to millions of degrees. What heats the corona to such extreme temperatures?

X-ray jets seem to help. Cirtain and colleagues have examined four jets in great detail and found that they launch magnetic waves into the sun's upper atmosphere. These waves, called Alfven waves, propagate into the corona where they *crack* like a whip, heating the gas where the crack occurs. (Note: When a whip is cracked on Earth, the sharp sound we hear is a result of energy being transferred from the fast-moving tip of the whip to the air around it. The same basic process is at work with Alfven waves cracking in the corona.) Cirtain doesn't believe jets can wholly explain the super-heating of the corona, but "they make an important contribution."

Another team of Hinode researchers led by Bart De Pontieu of Lockheed-Martin have found evidence for more Alfven waves coming from a layer of the sun's atmosphere called the chromosphere. (The chromosphere is to the sun as the troposphere is to Earth; both are near-surface layers of atmosphere.) These Alfven waves are not launched by jets but rather by turbulent motions within the chromosphere itself. "If we add all the Alfven waves together, the ones from the chromosphere plus the ones from X-ray jets, it may be enough to solve the mystery of coronal heating," says Cirtain.

Even if jets solved no Great Mysteries, however, Cirtain says he's just delighted to have found them. "Jets remind me why I love my job. It's Christmas every day."

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