

Yohkoh Reveals Site of Solar Flare Energy Release

It may look like a Volkswagen Beetle on a hill, but the surprising observation¹ shown here—specifically the uppermost set of white contours—has solar physicists cruising toward one of their primary goals: unraveling the mysteries of solar flares. This image of a flare was made by a team of Japanese researchers using the Yohkoh satellite (see PHYSICS TODAY, May 1992, page 19), and the emission represented by those contours is closely related to the origin of the flare's energy.

The photo shows a flare extending beyond the visible edge of the Sun (the long white line). The colors represent the intensities of soft x rays with integrated energies from 1 to 4 keV. In the thousands of flares imaged to date in soft x rays, relatively low-energy emissions of this sort are almost always confined within loop-like structures, presumably by magnetic fields, and are usually interpreted as thermal bremsstrahlung from plasma at 10–20 million kelvins. The contours show three distinct sources of hard x rays at 33–53 keV. Although hard x rays with energies less than about 20 keV often coincide with the soft x rays, more energetic hard x rays, like those shown here, typically occur in localized patches where the soft x-ray loop connects to the solar surface. Such “footpoint emissions” are usually interpreted as thick-target bremsstrahlung emitted by electrons that were accelerated high in the corona, streamed down the magnetic field lines and were stopped by the denser regions of the Sun. The event shown here conforms to all expectations—except for the patch of hard x rays above the loop.

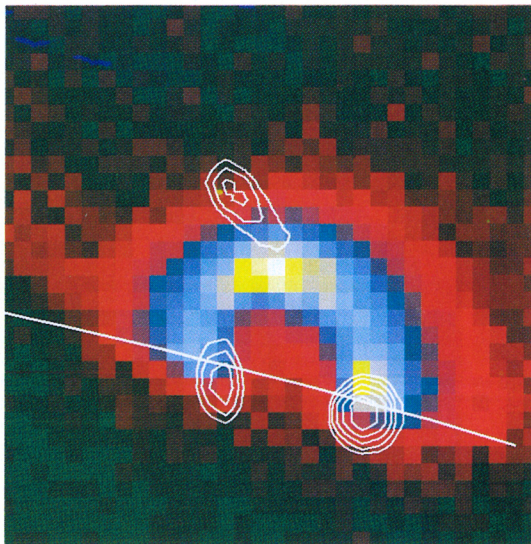
It is this patch of emission, first found by Satoshi Masuda in his thesis work at the University of Tokyo, that has the solar community buzzing. The absence of a “thick target” so high (about 20 000 km) above the surface should rule out nonthermal emission from this

region—but a thermal interpretation implies a temperature of 200 million kelvins. “*Something* energetic is going on *above* the soft x-ray loop,” says Takeo Kosugi (National Astronomical Observatory, Japan). Because this emission varied in concert with the lower, thick-target hard x rays throughout the four-minute event, “this something must be directly related to particle acceleration,” he says.

The Sun's atmosphere is permeated with a tangled web of magnetic fields, often not derivable from a potential. Solar researchers have long supposed that flares are powered by the magnetic free energy available in such nonpotential fields. The observation shown here, and several others made and analyzed by Masuda, Kosugi and others, fits the expectation of an energy release site high in the Sun's highly magnetic corona.

The next step is to unravel the physics. The Japanese group favors an interpretation based on magnetic reconnection, in which oppositely directed magnetic fields still higher in the atmosphere are annihilated and in the process create a jet of plasma that subsequently collides with the lower soft x-ray loop, heating the plasma to hundreds of millions of kelvins. This is very similar to a picture developed theoretically by Terry Forbes (University of New Hampshire, Durham) and Jean-Marie Malherbe (Meudon Observatory, Paris).² It may be that as observations like this one continue to roll off the Yohkoh data tapes, other interpretations will emerge.

—STEPHEN G. BENKA



References

1. S. Masuda, T. Kosugi, H. Hara, S. Tsuneta, Y. Ogawara, *Nature* **371**, 495 (1994).
2. T. G. Forbes, J. M. Malherbe, *Astrophys. J.* **302**, L67 (1986).

(See the article by Anthony Garito, Rui Fang Shi and Marvin Wu in PHYSICS TODAY, May 1994, page 51.) But the new compound reported this fall jumps that efficiency to nearly 100%.

Designing the polymer

Photorefractive polymers offer several potential advantages over their inorganic crystalline cousins, chiefly lower costs, structural flexibility and ease of processing. One can also tailor a polymer by mixing in a combination of molecules with the right properties, whereas it is difficult to optimize separately the performance characteristics of a crystal.

To make the high-efficiency material announced this fall, the University of

Arizona researchers blended together four materials. The team consisted of Klaus Meerholz, Boris Volodin, Sandalphon, Nasser Peyghambarian, Hanh Hall, Anne Padias, Scott Lyon and Bernard Kippelen (who is also with CNRS in Strasbourg, France). They started with a common photoconductive polymer, PVK (poly(*N*-vinylcarbazole)). They added a strong electron acceptor, TNF (2,4,7-trinitro-9-fluorenone), to increase the photosensitivity in the visible. Essentially TNF forms a charge-transfer complex with PVK that absorbs photons to create mobile charges. The next ingredient was an electro-optic chromophore (a molecule or portion thereof that absorbs light) called DMNPAA (2,5-dimethyl-4-

(*p*-nitrophenylazo)anisole), which has a large permanent dipole moment and can align with the external electric field. The chromophore provides optical nonlinearity, which is required for the photorefractive effect. The final touch was ECZ (*N*-ethylcarbazole), a plasticizer that enables the chromophores to align more easily with the applied field. Effectively, ECZ lowers the glass transition temperature. The percentages by weight of DMNPAA, PVK, ECZ and TNF in the new material are, respectively, 50, 33, 16 and 1.

When we asked Peyghambarian why he thought this particular compound worked so much better than the lower efficiency materials, he speculated that the reason might be