Researchers discover mysterious source of 'heartbeat-like' radio bursts in a solar fare

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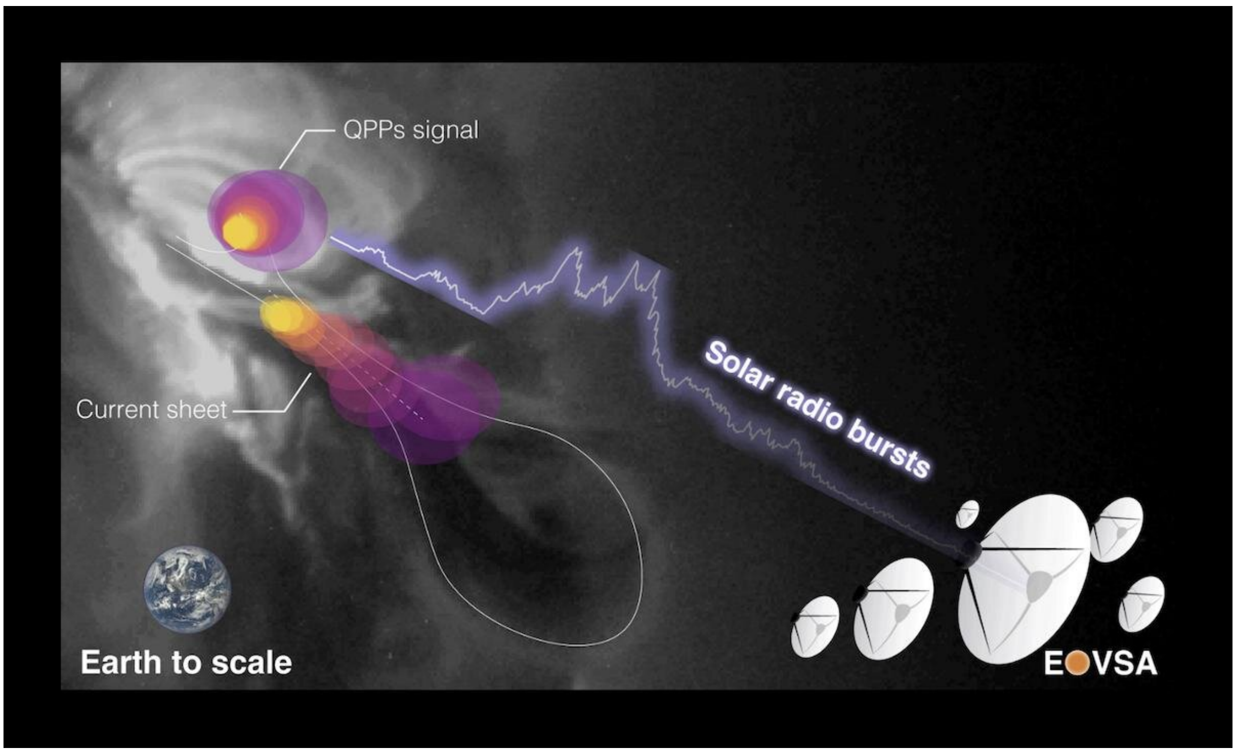

An illustration showing EOVSA capturing a pulsating radio burst from a solar flare. Credit: Sijie Yu of NJIT/CSTR; Yuankun Kou of NJU; NASA SDO/AIA

A solar radio burst with a signal pattern, akin to that of a heartbeat, has been pinpointed in the Sun's atmosphere, according to a new study.

In findings published in the journal *Nature Communications*, an international team of researchers has reported uncovering the source location of a radio signal coming from within a C-class solar flare more than 5,000 kilometers above the Sun's surface.

Researchers say the study's findings could help scientists better understand the physical processes behind the energy release of solar flares—the solar system's most powerful explosions.

"The discovery is unexpected," said Sijie Yu, the study's corresponding author and astronomer affiliated with NJIT's Center for Solar-Terrestrial Research. "This beating pattern is important for understanding how energy is released and is dissipated in the Sun's atmosphere during these incredibly powerful explosions on the Sun. However, the origin of these repetitive patterns, also called quasi-periodic pulsations, has long been a mystery and a source of debate among solar physicists."

Solar radio bursts are intense bursts of radio waves from the Sun, which are often associated with solar flares and have been known to feature signals with repeating patterns.

The team was able to uncover the source of these pattern signals after studying microwave observations of a solar flare event on July 13, 2017, captured by NJIT's radio telescope called the Expanded Owens Valley Solar Array (EOVSA), which is located at Owens Valley Radio Observatory (OVRO), near Big Pine, Calif.

EOVSA routinely observes the Sun in a wide range of microwave frequencies over 1 to 18 gigahertz (GHz) and is sensitive to radio radiation emitted by high-energy electrons in the Sun's atmosphere, which are energized in solar flares.

From EOVSA's observations of the flare, the team revealed radio bursts featuring a signal pattern repeating every 10-20 seconds, "like a heartbeat", according to study leading author Yuankun Kou, a Ph.D. student at Nanjing University (NJU).

The team identified a strong quasi-periodic pulsation (QPP) signal at the base of the electric current sheet stretching more than 25,000 kilometers through the eruption's core flaring region where opposing magnetic field lines approach each other, break and reconnect, generating intense energy powering the flare.

But surprisingly, Kou says they discovered a second heartbeat in the flare.

"The repeating patterns are not uncommon for solar radio bursts," Kou said. "But interestingly, there is a secondary source we did not expect located along the stretched current sheet that pulses in a similar fashion as the main QPP source."

"The signals likely originate from quasi-repetitive magnetic reconnections at the flare current sheet," added Yu. "This is the first time a quasi-periodic radio signal located at the reconnection region has been detected. This detection can help us to determine which of the two sources caused the other one."

Using the unique microwave imaging capabilities of EOVSA, the team was able to measure the energy spectrum of electrons at the two radio sources in this event.

"EOVSA's spectral imaging gave us new spatially and temporally resolved diagnostics of the flare's nonthermal electrons. … We found the distribution of high-energy electrons in the main QPP source vary in phase with that of the secondary QPP source in the electronic current sheet," said Bin Chen, associate professor of physics at NJIT and co-author of the paper. "This is a strong indication that the two QPPs sources are closely related."

Continuing their investigation, the team members combined 2.5D numerical modeling of the solar flare, led by the other corresponding author of the paper and professor of astronomy Xin Cheng at NJU, with observations of soft X-ray emission from the solar flares observed by NOAA's GOES satellite, which measures the soft X-ray fluxes from the Sun's atmosphere in two different energy bands.

"We wanted to know how the periodicity occurs in the current sheet", said Cheng. "What is the physical process driving the periodicity and how is it related to the formation of the QPPs?"

The team's analysis showed there are magnetic islands, or bubble-like structures that form in the current sheet, quasi-periodically moving toward the flaring region.

"The appearance of magnetic islands within the long-stretched current sheet plays a key role in tweaking the energy release rate during this eruption," explained Cheng. "Such a quasi-periodic energy release process leads to a repeating production of high-energy electrons, manifesting as QPPs in the microwave and soft X-ray wavelengths."

Ultimately, Yu says the study's findings cast fresh light on an important phenomenon underlying the reconnection process that drives these explosive events.

"We've finally pinpointed the origin of QPPs in solar flares as a result of periodic reconnection in the flare current sheet. … This study prompts a reexamination of the interpretations of previously reported QPP events and their implications on solar flares."

Additional co-authors of the paper include NJU researchers Yulei Wang and Mingde Ding, as well as Eduard P. Kontar at the University of Glasgow. This research was supported by grants from the National Science Foundation.

More information: Yuankun Kou et al, Microwave imaging of quasi-periodic pulsations at flare current sheet, *Nature Communications* (2022). DOI: 10.1038/s41467-022-35377-0

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