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RESEARCH BRIEF

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COSMOLOGY & GRAVITY

A REPEATING FAST RADIO BURST

Fast radio bursts (FRBs) are enigmatic bursts of light seen in radio telescopes and which are thought to originate from outside our Milky Way galaxy. The implied energy of these distant events has led astrophysicists to believe that they might be the result of cataclysmic events that destroy their sources. However, the discovery that a fast radio burst repeats shows not only that this energy can be released without destroying its source, but that it can do so multiple times in the space of a few minutes.

FOCUS OF STUDY

Fast radio burst FRB 121102, originally observed using the Arecibo Observatory in 2012, was followed up to search for signs of repeating activity from the same source. Such follow-up observations of the sky positions of fast radio bursts have never been successful in the past. Authors of the *Nature* study included CIFAR's R. Howard Webster Foundation Fellow Vicki Kaspi, as well as Senior Fellow Ingrid Stairs and Associate Fellow Scott Ransom.

BACKGROUND

Fast radio bursts are millisecond-duration flashes of light of unknown astronomical origin observed at radio frequencies of roughly 1 GHz. Understanding these bursts has been hampered by the fact that no counterpart sources have been identified in visible-light follow up nor in follow up at any other wavelengths. Due to the limited field of view of current radio telescopes, only a few dozen such bursts have been observed to date. However, extrapolations suggest that thousands must occur over the full sky each day.

Astronomical radio signals are typically dispersed—smeared out and distorted from propagating over vast distances through the diffuse plasma that permeates the space between stars and galaxies. The amount of dispersion allows astronomers to estimate the total amount of plasma between Earth and the signal's source. Fast radio bursts are strongly dispersed, with an implied amount of intervening plasma that exceeds that in the Milky Way Galaxy, indicating the bursts are of extragalactic origin. In fact, the dispersion of the most strongly smeared bursts suggests they might originate from a distance of 10 billion lightyears, a significant fraction of the distance across the observable Universe. Alternatively, the dispersion might be caused by dense clouds of plasma that surround the sources, in which case the sources could reside in neighboring galaxies that are only hundreds of millions of lightyears away.

The observed brightnesses of fast radio bursts, coupled with the substantial distances involved, imply that FRBs are energetic events, releasing in milliseconds the amount of energy the Sun produces in days. This has led astrophysicists to speculate that FRBs are signals from cataclysmic events that destroy their sources, such as the collision of two burnt-out stars. On the other hand, if the sources reside in relatively near-by galaxies, then the implied energies could be produced by still-exotic but less energetic events. Possibilities include star-quakes in the hard crust of a highly magnetized neutron star, or an erratically behaving pulsar – fast-spinning neutron stars shedding their rotational energy as radio light.

FINDINGS

The source of FRB 121102 emits repeating bursts. Ten additional fast radio bursts where observed to originate from the same direction in the sky as the original FRB 121102. The coincident sky location and identical dispersion smearing of all these bursts unambiguously identifies them as originating from the same source. The bursts were highly clustered in time: roughly 15 hours of follow-up observations were performed, but six of the bursts were observed in the space of 10 minutes, with a pair of bursts occurring only 30 seconds apart.

The repeating bursts from this source are diverse. While the 11 total bursts unambiguously originate from the same source, the brightness, duration, and spectrum (how the brightness varies with wavelength, the radio equivalent to the light's colour) vary widely from burst to burst. This is illustrated in Figure 1.

METHODOLOGY

Fast radio burst FRB 121102 was originally discovered using the 305-m William E. Gordon Radio Telescope at the Arecibo Observatory, in data collected for the PALFA pulsar survey on November 2, 2012. As is standard practice, follow-up observations of the location in the sky where the burst was observed were performed in December, 2013, and no repeating bursts were observed.

In May and June, 2015, more extensive follow-up observations were performed, again using the Arecibo Observatory. This second observing campaign included 10 hours of observations spread over six nights of observing.

These data were processed using specialized software that first identifies and excises data that are contaminated by radio signals of human origin, then searches for bursts of light, accounting for the smearing caused by dispersion. The software reported candidate bursts as a series of plots which were then presented to the research team for verification.

The researchers inspected archival telescope data from a variety of telescopes operating at a range of wavelengths and ruled out the presence of a Galactic nebula that could cause the observed dispersion smearing. They thus conclude that the bursts are of extragalactic origin.

IMPLICATIONS

The observation of multiple bursts originating from the same source excludes the possibility that these fast radio bursts are the signatures of cataclysmic events that destroy their sources. As such, explanations that involve collisions of stellar objects or supernovae are no longer viable. The fact that the sources must produce the burst energies multiple times in the space of a few minutes favours a source population that is nearer-by—hundreds of millions of lightyears as opposed to billions of lightyears—reducing the energy requirement for each burst. Now, the most plausible explanations for what causes fast radio bursts are magnetized-neutron-star star-quakes or erratic pulsars.

REFERENCE

A repeating fast radio burst. L.G. Spitler, et al., *Nature* 531, 202-205 (2016).

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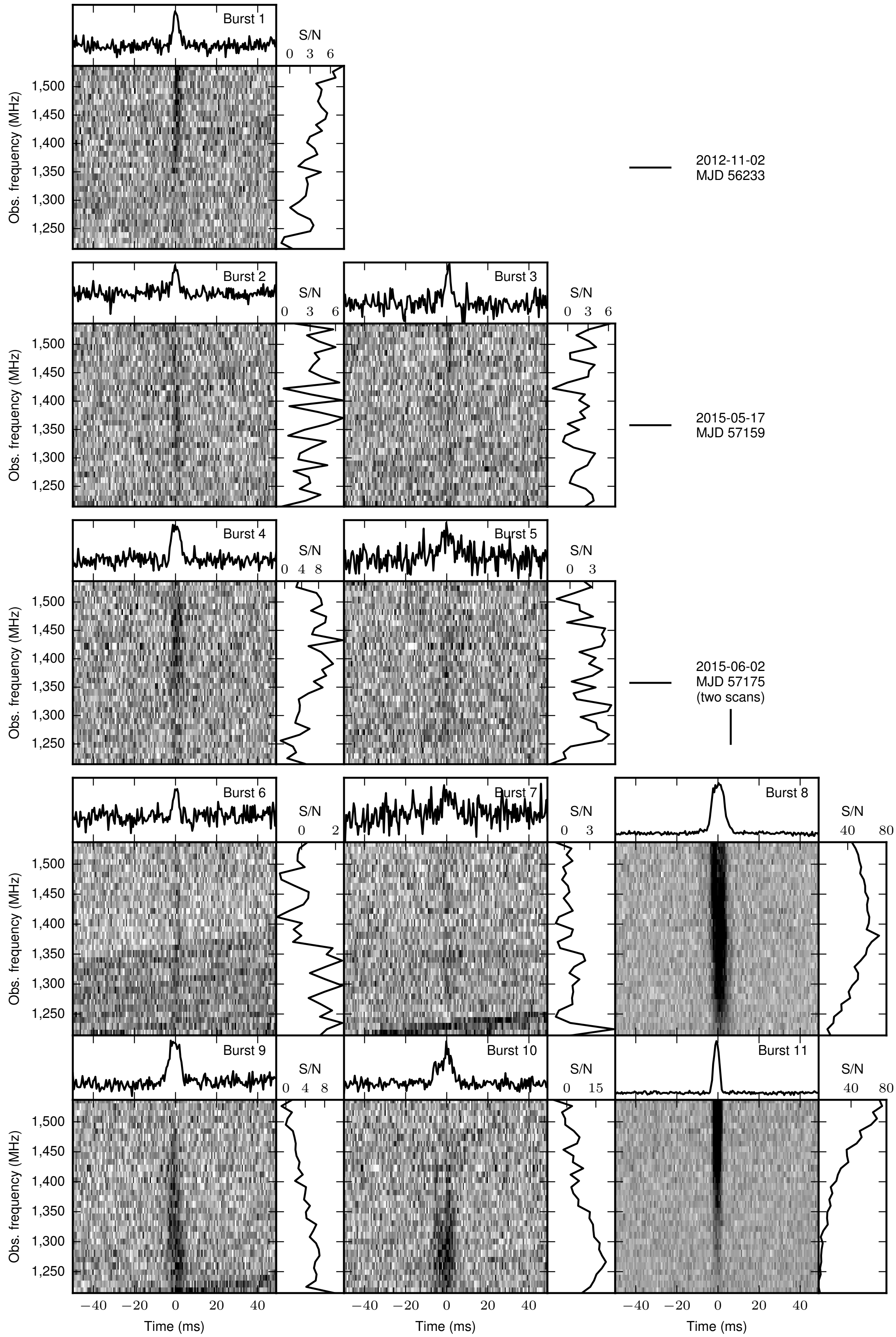

Figure 1 (pdf file attached): Brightness of bursts from FRB 121102's source as a function of time and radio frequency (the inverse of radio wavelength). The upper sub-panels show the bursts' time profiles, averaged over frequency, and the right sub-panels show the bursts' spectra. The smearing effect of dispersion has been compensated for and removed. The bursts show a wide variety of pulse shapes, spectra, and brightnesses.