A burst of activity nearby

The rapidly developing field of fast radio bursts (FRBs) took another leap forward in understanding when an FRB was associated with a magnetar in our Galaxy, identifying a specific source for the first time.

From the time of their discovery in 2007 to almost exactly a year ago, fast radio bursts (FRBs) had been considered astrophysical signals of cosmological origin, but the exact nature of their sources, while speculated upon, remained unidentified. Indeed, when precise localization on the sky of these millisecond-duration radio bursts became possible just five years ago, their host galaxies were found to be hundreds, if not thousands, of megaparsecs away. However, shortly after dinner time in Greenwich on 27 April 2020, that picture began to change, leading to a milestone in the understanding of these rapid radio signals: the identification of an FRB source within the Milky Way, a highly magnetic neutron star (magnetar) catalogued as SGR 1935+2154.

On that day, the orbiting Fermi Gamma-ray Space Telescope and the Neil Gehrels Swift Observatory reported "a forest of bursts" of emission in their GBM and BAT detectors from the direction of the Galactic magnetar, a known gamma- and X-ray source. Some six hours later NICER, an X-ray instrument on the International Space Station, started observing the activating magnetar too. Other orbiting telescopes rapidly followed suit: AGILE, Insight-HXMT, Konus-Wind, INTEGRAL and more. Such an occurrence is not unusual: concerted responses to astronomical phenomena happen frequently, with little fanfare, and are often catalogued in the pages of *The Astronomer's Telegram*.

The next morning, as the Earth rotated so that North America was facing SGR 1935+2154, something unusual happened. The CHIME FRB group reported on *The Astronomer's Telegram* an FRB-like radio detection that lit up 93 of their telescope's 1,024 beams: a burst from the direction of the same magnetar. SGR 1935+2154 had not previously been known as a radio source, and this burst was extremely bright: a thousand times more energetic than any previous magnetar radio emission. Waking up in California, the STARE-2 team, responsible for three telescopes spread across the southwestern United States, saw the alert from CHIME and checked their data: also a radio burst from the same direction. A distance estimate (called the 'dispersion measure') calculated from the data showed quite clearly that the FRB had come from inside the Galaxy. Four X-ray telescopes had detected the same burst event at higher energies. Thus, with one unexpectedly bright radio burst, two preconceptions of FRB astrophysics were dismantled: FRBs were no longer constrained to cosmological distances, they can be emitted locally; and they are no longer from unknown sources. Some, at least, can be emitted from magnetars.

SGR 1935+2154 has been fairly quiet at radio wavelengths since then, but there have been further radio bursts. Two days after the initial burst (which has been named FRB 200428), the sensitive FAST telescope in southwestern China detected a fainter burst. And as reported in this issue of *Nature Astronomy*, 22 days of monitoring SGR 1935+2154 with the Westerbork Synthesis Radio Telescope (spread over three months of northern summer) yielded another two bright bursts on the same day, 24 May. In October 2020, CHIME detected three weak bursts in rapid succession, but they were beyond the detection threshold of STARE-2. Seven bursts from the same object place this source clearly into the category of 'repeating' FRBs. It is still unclear whether all FRB sources repeat, or whether this property is related to a subgroup of FRB sources (a discussion on this topic can be found here).

The strength of FRB 200428 was impressive by Galactic magnetar standards (a fluence of 1.5 MJy ms) but weak by FRB standards. Had SGR 1935+2154 been a magnetar in a distant galaxy, its radio signal would not have been detected, nor would its X-ray bursts. This realization precipitates two thoughts and raises further questions: FRBs are clearly being missed, but is the reason that the intrinsic emission is too weak, or because the radio bursts are beamed (in a similar way to pulsars)? Or rather, are we only seeing the bright ones, or those pointed directly at us? Second, this has been a unique opportunity to study an FRB source close-up and at multiple wavelengths — is what we learn about the emission mechanism of the FRB relevant to just this source, or is it applicable across all sources of this class of FRB, whichever class that may be? Why are radio bursts only associated with some X-ray bursts? Can we now use FRBs to map the locations of magnetars in other galaxies? FRB 200428 has certainly answered some big questions, but opened up many more.

Prior to this event, several of the many, many theoretical suggestions for FRB sources involved magnetars. The magnetar model met numerous observed properties of FRB emitters: they have intense magnetic fields capable of producing the polarization seen in FRBs and they are physically small objects that can therefore produce emission on short timescales. Magnetars also experience energetic giant flares seen in gamma and X-rays. But the main reservation was that of the two dozen or so known Galactic magnetars, none had ever emitted a radio burst comparable in energy to that of an FRB. Now one has, and the already fast-paced field of FRB studies has taken another giant leap forward in understanding some of the most energetic phenomena in our Universe. We can now fairly confidently declare that, quoting from *The Astronomer's Telegram* 13684 "active magnetars are a source of FRBs at extragalactic distances". And as the authors urge, "we encourage follow-up observations". ❐

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