three- to fourfold enhancement of enantioselective recognition.

The demonstration that liquid-phase exfoliation can be applied to molecular crystals suggests that nanomaterials with high aspect ratios can be readily obtained from other SCCs, or indeed from the tens of thousands of crystalline organic compounds that are available, which would greatly expand the palette of nanomaterials. However, many open questions remain. First, it is not clear which types of organic crystal might be used for exfoliation. Furthermore, what governs 'exfoliability' and the morphology of the nanostructures formed?

Dong *et al.* calculated that the in-layer bonds in their SCCs, although weaker than those in van der Waals crystals, are about twice as strong as the binding between layers. This could explain why the SCCs cleave preferentially to produce sheets. Moreover, at first glance, this is in line with the current understanding that the morphology of the nanomaterials produced by liquid-phase exfoliation is determined by the ratio of the in-plane to out-of-plane binding strengths[8,9]. At second glance, however, there is a quantitative mismatch with the ratios that lead to similar outcomes for van der Waals crystals. For example, graphene sheets exfoliated from graphite have a comparable (if not lower) aspect ratio to that of the SCCs, but the ratio of in-layer to between-layer binding strength is much higher[8,9]. This might mean that other factors also have a role in controlling the outcome of liquid-phase exfoliation of SCCs, such as the penetration of solvent between layers. It is therefore crucial to work out the exfoliation mechanism for SCCs.

Furthermore, the choice of solvent will be important for the liquid-phase exfoliation of other organic crystals: on the one hand, the crystals must not dissolve in the liquid; but on the other hand, there must be sufficient interaction between the solvent and the nanosheets to prevent reaggregation. For many systems, finding a solvent that strikes the right balance could be extremely difficult. A possible way forward could be the use of surfactant solutions, such as those that were used[10] last year for the liquid-phase exfoliation of molecular crystals of the organic semiconductor rubrene, which yielded nanobelts and nanorods. Finally, for practical applications, post-processing methods will be needed – for example, to select certain sizes of nanosheet and to deposit sheets precisely onto substrates. The development of such methods remains a challenge for all nanosheets produced by liquid-phase exfoliation[11].

Nonetheless, the report of a simple method for producing liquid-suspended nanomaterials from molecular crystals is an exciting breakthrough for both fundamental and applied research. If it increases the range of 2D nanomaterials that can be made, it might help to answer the question of how the optical, electrical, thermal and mechanical properties of exfoliated molecular crystals differ from those of their bulk counterparts.

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Astronomy

Radio bursts from among the oldest stars

Vikram Ravi

Luminous bursts of radio emission are linked to highly magnetized neutron stars known as magnetars. Now, bursts have been detected from a globular star cluster, an environment thought to be devoid of magnetars. **See p.585**

If you were to look up at the sky with radio goggles, you would notice bright flashes at random locations roughly once every minute. Over the past 15 years, astronomers have detected more than 600 sources of such bursts, which have a range of luminosities, durations and rates of repetition. More than 20 sources have now been traced to specific galaxies, the diversity of which is similarly astounding. But such varied observations have not yet produced incisive insights into the burst mechanism. Now, on page 585, Kirsten *et al.*[1] report a surprising source of extragalactic radio bursts among some of the Universe's oldest stars, and, in *Nature Astronomy*, Nimmo *et al.*[2] provide a detailed analysis of these bursts. The discovery differs from previous findings of sources among young stars, and challenges ideas on the formation of magnetars – the most magnetized objects in the Universe.

A breakthrough in our understanding of fast radio bursts occurred in 2020, when three papers reported the discovery of a particular burst from an active magnetar in the Milky Way, known as SGR 1935+2154 (refs 3–5). All known magnetars in the Milky Way are thought to have formed in the terminal supernova explosions of some massive stars[6], and SGR 935+2154 is located in a supernova remnant. The most massive stars live for only a few tens of millions of years, so observations of supernovae tell us that their associated stars are probably still forming. All galaxies known to host sources of fast radio bursts are likely to be currently forming stars[7].

The source that Kirsten and colleagues investigated is located in a cluster of astronomically ancient stars on the far outskirts of Bode's Galaxy in Ursa Major. It is known as FRB 20200120E and it vigorously emits bursts as short as 60 nanoseconds (Fig. 1). The authors showed that FRB 20200120E cannot be a magnetar formed in the supernova of a massive star, because it resides in a globular star cluster. Globular clusters are compact collections of typically a few hundred thousand stars. They are found in the haloes of galaxies, and they are several billion years old. Massive stars in globular clusters will have exploded soon after the formation of the cluster, and any magnetars formed at this time will have deactivated after around 10,000 years as their magnetic fields decayed.

Thus, if FRB 20200120E represents an active magnetar, it must have formed through means that we have yet to witness. The possibilities are fantastic. For example, a white dwarf star could have accreted so much mass from a companion star – or simply swallowed a companion whole – that it exceeded the Chandrasekhar mass limit. This limit is the theoretical maximum mass above which a white dwarf ceases to be a white dwarf, and instead might collapse to form a magnetar. The detailed studies carried out by Nimmo *et al.* and a second team[8] offer a tantalizing clue to the origin of FRB 20200120E's bursts.

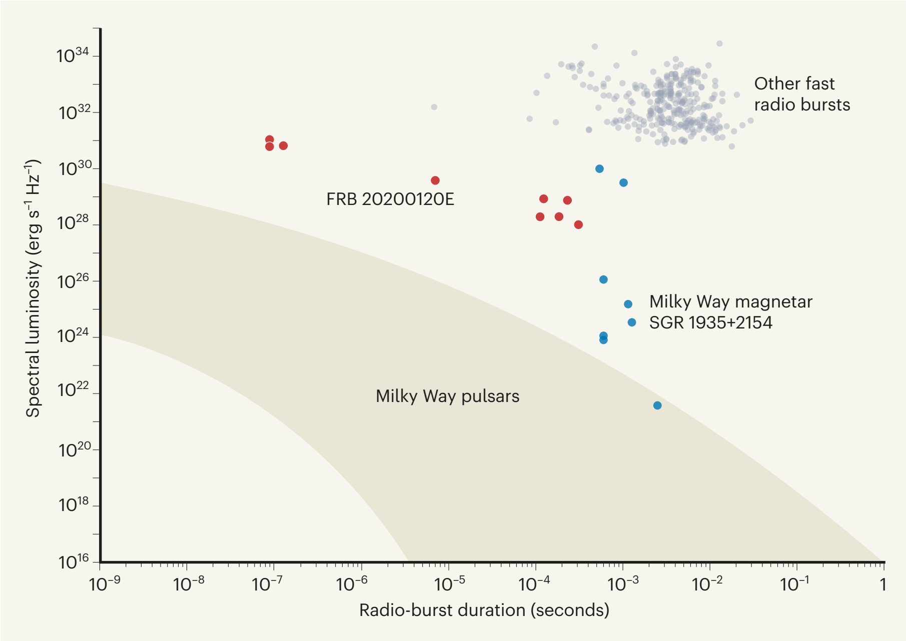

Figure 1 | The populations of astronomical radio bursts. Fast radio bursts are luminous radio emissions typically emanating from distant galaxies, and can be emitted by highly magnetized neutron stars called magnetars. Radio bursts are also commonly observed from less-magnetized neutron stars, known as pulsars, in and around the Milky Way. The shaded region defines the range of luminosities and durations of radio bursts from these pulsars. Only one Milky Way magnetar, called SGR 1935+2154, has been seen to emit fast radio bursts (blue dots) similar to those from other galaxies. Kirsten *et al.*[1] report the unusual location of a relatively nearby source of fast radio bursts, known as FRB 20200120E, and Nimmo *et al.*[2] show that some of its emissions were just tens of nanoseconds in duration (red dots). Although the spectral luminosities of the FRB 20200120E emissions are similar to those of fast radio bursts, the durations are more like those of some pulsars. (Adapted from Fig. 3 of ref. 2.)

Neutron stars form a large, varied population of objects, and magnetars are just one type of star in this heterogeneous collection. Other neutron stars with lower magnetic-field strengths, known as pulsars, are even more prolific at emitting fast radio bursts than are magnetars. However, pulsars have much lower luminosities than magnetars, so they have been discovered only in and around the Milky Way. Several pulsars are found in globular clusters in the Milky Way, and most of these have been 'recycled': a period of intense interaction with a companion star has left them re-energized and spinning as fast as once every millisecond.

Millisecond pulsars emit bursts on submicrosecond timescales, much like the 60-nanosecond bursts of FRB 20200120E. Could these bursts be emanating from a recycled pulsar rather than a magnetar? Further observations will establish whether this link truly informs us of the origins of the FRB 20200120E source. In the meantime, the observation of such short durations, corresponding to emission regions just a few tens of metres across at the source, poses a strong challenge to electrodynamic models for the emission of fast radio bursts.

The results reported for FRB 20200120E were made possible by outstanding technical achievements. Data were obtained simultaneously from 11 radio telescopes across 8 countries in Europe and Asia, and the observations were aligned in time with higher than 10-picosecond accuracy. The location of FRB 20200120E was determined with an accuracy of around 5,000 astronomical units (equivalent to 5,000 Earth–Sun distances). Such mind-boggling precision is most valuable for examining the nearest sources of fast radio bursts. A new generation of radio telescopes promises to discover more of these sources by scanning most of the sky at once with ultrawide-angle optics designed like those of fisheye cameras[9].

> **"Just as light is refracted into rainbows by drops of water, radio bursts are distorted by interstellar and intergalactic gas."**

Like any good suspense thriller, the FRB 20200120E data will excite and frighten astronomers in equal measure. The perils of sample incompleteness haunt observational astronomers, and FRB 20200120E reveals crucial gaps in our previous understanding of fast radio bursts and their sources. It is also far from clear how to overcome these challenges. Globular clusters are intrinsically faint, making them difficult to associate with any but the nearest burst sources. Most current search techniques are insensitive to the submicrosecond timescales present in the bursts from FRB 20200120E.

Fortunately, the prospects for using fast radio bursts as flashlights to study the vast gas reservoirs around and between galaxies remain strong. Just as light is refracted into rainbows by drops of water, radio bursts are distorted by interstellar and intergalactic gas. Observations of type Ia supernovae revealed that the expansion of the Universe is accelerating, even though the origins of these supernovae remain mysterious. Similarly, even if they are produced through multiple unknown channels, mounting evidence[10,11] supports the idea that fast radio bursts can be used to investigate the contents and physical conditions of otherwise unseen matter along the sources' lines of sight.

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