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Second Light

A Fast Radio Burst Localized

by Leslie J. Sage
(l.sage@us.nature.com)

The first "fast radio burst" was discovered back in 2007. It was a pulse of radio energy lasting about a millisecond, and because it was bright (as these things go) the signal could have entered the telescope beam across a moderately large area of the sky. No transients at any other wavelength were discovered, and there was no obviously strange source in that part of the sky. After several years, it was concluded by some that it was a one-off event likely originating in Earth's atmosphere or magnetosphere. There are, after all, small bursts of gamma rays generated in events that are like lightning. Then a few more fast radio bursts were found, and the nature of the source was revisited. Astronomers started to think that they perhaps originated in galaxies at cosmological distances. But the problem of localization remained, and until that was solved, nothing conclusive could be said. Evan Keane of the Square Kilometre Array Organization in Manchester, UK, and his collaborators put together a network of telescopes around the globe to spring into action when a burst was found, and on 2015 April 18 they hit pay dirt, and were able to trace the burst to a host galaxy at a redshift of 0.49 (see the February 25 issue of *Nature*).

I am going to have to get a little technical for a moment, because a particular term used in radio astronomy is an important part of the story. Very sharp pulses of photons interact with charged particles (electrons and protons) in between the source and the observer. These interactions are frequency dependent, so that the lower-frequency photons are delayed by the interaction a little more than the higher-frequency ones. In radio astronomy, only the electrons are important. This slight spreading out of the photons is called the "dispersion measure," and it is directly related to the number of electrons along the path that the photons have taken. The dispersion measures of the other fast radio bursts seen before Keane's had values consistent with the sources being in distant galaxies. The action of the electrons on the photons can also cause other changes in the observed properties of the radio signal, causing it to become polarized. Most of us are familiar with polarization through the use of sunglasses. Normally, sunglasses filter out the light that is scattered from the ground/beach/ocean, because that scattered light is polarized in the direction of the ground. In December 2015, Kiyoshi Masui of the University of British Columbia and his collaborators reported measuring the linear polarization of a fast radio burst (see the December 24 issue of *Nature*) for the first time, and found the signature of a very dense plasma, which had to be closely associated with the source, which they estimated was at a maximum redshift of 0.5. They concluded that this fast burst was likely associated with a magnetar, which is a neutron star with a very intense magnetic field (at least 100 trillion times Earth's magnetic field). We will come back to this later.

Two hours after the discovery of Keane's burst, the Australia Telescope Compact Array was observing the region of the sky from which the burst came, and found a fading radio transient source. Armed with the position of that source, Keane and his team used the Subaru 8.2-metre telescope on Mauna Kea to find a small elliptical galaxy at the source position. A subsequent observation measured the redshift of the galaxy to be 0.492.

The properties of the galaxy are such that it is unlikely to have had recent star-formation activity, which argues against a magnetar source, as magnetars are exclusively associated with regions of quite recent star formation. Keane concedes that there could be some residual star formation in an otherwise "red and dead" galaxy (as astronomers call them). But most elliptical galaxies at that redshift are red and dead. So he favours an explanation involving the collision between two compact objects, like white dwarfs or neutron stars. Merging neutron stars have been argued as the best explanation for the short gamma-ray bursts, and merging white dwarfs have become the favoured explanation for most type Ia supernovae. As Keane saw the radio burst fade over a period of about six days, that does argue for some kind of heated ejecta that generates the radio waves. But it's relatively hard to make a cosmic explosion that is seen only at radio wavelengths. There have, however, been radio transients associated with four short gamma-ray bursts.

Gamma-ray bursts (both short and long) are generally thought to be quite highly beamed—we can only see the bursts that are pointed directly at Earth. Astronomers have been puzzled for about 18 years—the time I have been writing this column—about the so-called "orphan bursts." These are fading optical transients with no gamma-ray burst. There should be lots of them, but none have been seen. Perhaps the fast radio bursts are the orphan bursts.

Coming back to the Masui et al. result, it seems clear that Keane and Masui are seeing radio bursts from rather different sources, meaning that there are at least two classes. I suspect that we have not heard the last about fast radio bursts.

Keane was able to do some interesting cosmology with this burst. We know from the *WMAP* and *Planck* missions that normal matter makes up about five percent of the total matter-energy density of the Universe. One problem has been, though, that if one counts up all the matter that can be seen—all the gas and stars radiating at any wavelength—one finds that it adds up to just about one percent. It has long been thought