The riddle of the heavenly bursts

22 January 2020

The radio telescope in Effelsberg is also part of the European VLBI network that searches for radio bursts. Credit: MPI for Radio Astronomy / Norbert Tacken

This cosmic lightning storm is happening all around us. Somewhere in the earthly sky, there is a pulse that flashes and extinguishes in the next moment. These bursts, which must be measured with radio telescopes and last one thousandth of a second, are one of the greatest mysteries of astrophysics. Scientists doubt that militant aliens are fighting "Star Wars" in the vastness of space. But where do these phenomena—dubbed "fast radio bursts" by the experts—come from?

In the city of Parkes, gigantic lattice mesh bowl rises into the sky. In 2001, this 64-meter diameter radio telescope (once the largest fully mobile radio telescope in the southern hemisphere) registered a mysterious radio burst—and nobody noticed it! It wasn't until five years later that astrophysicist Duncan Lorimer and his student David Narkevic found the signature of the signal in the telescope data more or less by chance. Even then, the specialists could not make sense of the phenomenon. But this was not the only "Lorimer burst."

"We now know of more than a hundred," says Laura Spitler. Since March 2019, the researcher has headed a Lise Meitner group on this topic at the Max Planck Institute for Radio Astronomy. Spitler has dedicated herself to these fleeting flickers in space for many years. Under her leadership, an international team discovered the first fast radio burst (FRB) on the northern celestial sphere in the Fuhrmann constellation in 2014. Astronomers had used the dish of the Arecibo telescope on Puerto Rico. The antenna, which measures 305 m in diameter, is firmly anchored in a natural valley and can only ever focus on a relatively small section of the firmament.

"Statistically speaking, there should be only seven eruptions per minute spread across the sky. It therefore takes a lot of luck to align your telescope to the right position at the right time," said Spitler after the discovery was announced. Both the properties of the radio bursts and their frequency derived from the measurements were in high agreement with what astronomers had found out about all the previously observed eruptions.

In fact, statistical assumptions were confirmed; according to these, approx. 10,000 of these unusual cosmic phenomena were thought to flare up in the earthly firmament each day. The surprisingly large number results from calculations of how much of the sky would have to be observed and for how long in order to explain the comparatively few discoveries made so far.

The Arecibo measurement also removed the last doubts about whether the radio bursts really came from the depths of the universe. After the first registered bursts, scientists concluded that they were being generated in an area far outside the Milky Way. This was deduced from an effect called plasma dispersion. When radio signals travel a long distance through the universe, they encounter numerous free electrons located in the space between the stars.

Ultimately, the speed of propagation of radio waves at lower frequencies decreases in a characteristic manner. For example, during the aforementioned radiation burst discovered with the Arecibo telescope, this dispersion was three times larger than one would expect from a source within the Milky Way. If the source were located in the galaxy, interstellar matter would contribute roughly 33% for the Arecibo source.

But what is the origin of the radio bursts? The astrophysicists have designed various scenarios, all more or less exotic. Many of them revolve around neutron stars. These are the remnants of massive explosions of massive suns as supernovae, only 30 km in size. In these spheres, matter is so densely packed that on Earth, one teaspoonful of its matter would weigh about as much as the Zugspitze massif. The neutron stars rotate quickly around their axes. Some of them have exceptionally strong magnetic fields.

For example, fast radio bursts could occur during a supernova—but also during the fusion of two neutron stars in a close binary star system—when the magnetic fields of the two individual stars collapse. In addition, a neutron star could collapse further into a black hole, emitting a burst.

These scientific scripts sound plausible at first glance. However, they have one flaw: They predict only one radio burst at a time. "If the flash was generated in a cataclysmic event that destroys the source, only one burst per source can be expected," says Laura Spitler. Indeed, in the early years, there were always single outbreaks—until in 2014 a burst called FRB 121102 went online. In 2016, Spitler and her team observed this to be the first "repeater," a burst with repeating pulses. "This refuted all models that explain FRB as the consequence of a catastrophic event," says Spitler.

The FRB 121102, discovered at the Arecibo telescope, was further observed by the researchers with the Very Large Array in New Mexico. After 80 hours of measuring time, they registered nine bursts and determined the position with an accuracy of one arc second. At this position in the sky, there is a permanently radiating radio source; optical images show a faint galaxy about three billion light years away.

With a diameter of only 13,000 light years, this star system is one of the dwarfs; the Milky Way is about ten times larger. "However, many new stars and perhaps even particularly large ones are born in this galaxy. This could be an indication of the source of the radio bursts," says Spitler.

The researcher thinks of pulsars—cosmic lighthouses that regularly emit radio radiation. Behind them are again fast rotating neutron stars with strong magnetic fields. If the axis of rotation and the axis of the magnetic field of such an object deviate from each other, a bundled radio beam can be produced. Each time this natural spotlight sweeps across the Earth, astronomers measure a short pulse.

The bursts of most radio pulsars are too weak for them to be detected from a great distance. This is not the case with the particularly short and extremely strong "giant pulses." A prime example of this class of objects is the crab pulsar, which was born in a supernova explosion observed in 1054 AD. Its pulses would be visible even from neighboring galaxies.

"A promising model suggests that fast radio bursts are much stronger and rarer than giant pulses from extragalactic neutron stars similar to the crab pulsar. Or even younger and more energetic ones like this one," says Spitler. "The home galaxy of FRB 121102 fits this model because it has the potential to produce just the right stars to become neutron stars at the end of their lives."

But whether this model is correct is literally written in the stars. The clarification is not getting any easier. Nevertheless, the observations continue. For example, the radio antennas of the European VLBI network examined another repeater in summer 2019. FRB 180916.J0158+65 showed no less than four radiation outbursts during the five-hour observation. Each lasted less than two milliseconds.

The home of this radio burst is in a spiral galaxy about 500 million light-years away. This makes it the closest observed so far even though this distance seems "astronomical." It also turns out that there is apparently a high rate of star births around the burst.

The position in the galaxy differs from that of all other bursts investigated so far. In other words: Apparently, the FRB flare up in all kinds of cosmic regions and diverse environments. "This is one of the reasons why it is still unclear whether all bursts have the same source type or are generated by the same physical processes," says Spitler. "The mystery of their origin remains."

Provided by Max Planck Society
APA citation: The riddle of the heavenly bursts (2020, January 22) retrieved 26 September 2020 from https://phys.org/news/2020-01-riddle-heavenly.html