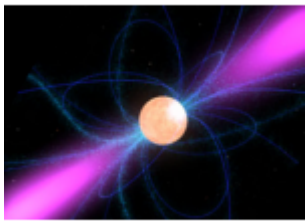
A new theory for the Fast Radio Bursts (FRB)



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Description :

A new theory for the Fast Radio Bursts, which involves companions of pulsars

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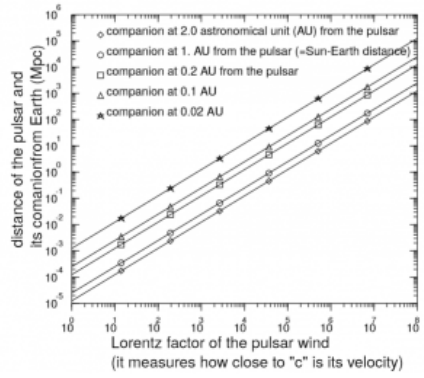
Since their discovery in 2007, the fast radio bursts (5 milliseconds) are still very mysterious to astronomers. Several theories have been proposed, involving collisions of stars, but radio signals should be accompanied by emissions at other wavelengths, which are not observed. Two astronomers from the Observatoire de Paris offer another explanation, related to pulsars, and which involves companions in orbit. This model predicts that other radio bursts will be issued by the same given object with a certain periodicity, and could soon be tested.

In 2007, Duncan Lorimer and his colleagues of the Parks radio-telescope (Autralia) observed a single intense radio pulse (5 ms). According to the standard analysis techniques, this pulse comes from a source at a distance of about 500 Mpc (or 1.5 billion light-years), well beyond the local group of galaxies. The only radio signals that looks like the Lorimer pulse are the radio pulses from pulsars. Pulsars are neutron stars in fast rotation from one to hundreds of rotations per second. They emit at radio-frequencies, and sometimes in visible light, X rays and gamma rays. But the pulsars emit their pulses repeatedly, at every rotation of the neutron star. The Lorimer pulse was seen only once. And more strikingly, all the known pulsars are in our galaxy or in the Magellanic clouds ; their luminosity cannot make them visible from a distance of 500 Mpc. A controversy developed : is the Lorimer pulse really celestial ? If it is an astronomical signal, what is its cause ?

Since 2007, other pulses have been observed. They are now called "fast radio bursts" (FRB). Their astronomical origin seems confirmed, but their cause is still largely debated. Some scientists assert that they could result from cataclysmic events like the merging of two white dwarfs, or of two neutron stars, or from the implosion of a massive and unstable neutron star into a black hole. Others say that they could be giant flares from stars in our galaxy. But with all these phenomena, emissions at other wavelengths (visible, X rays, gamma rays) would be expected, and only radio waves have been seen up to now.

Two astronomers from Paris Observatory propose another explanation which is indirectly based on pulsars. The FRB could come from bodies orbiting a pulsar. Indeed, like the other stars, neutron stars have companions. The companions can be another star (generally a white dwarf, or another neutron star), planets (five are known around pulsars), or even asteroids and comets. These companions are immersed in a wind permanently blown by the pulsar. This very diffuse wind is very fast. Its velocity is close to the velocity of light "c". If some condition raised by the theory is satisfied, any object in the wind is followed by a wake. The condition is that the wind must be slower than the Alven waves that propagate the magnetic field changes, that is also close to but smaller than "c". We can make an analogy with the wake of a boat that would glide very fast on the sea. But the pulsar wind in composed of electrically charged particles (electrons, positrons and maybe atomic nuclei) and many electromagnetic phenomena happen in that wake. The wake would carry a very strong electric current (up to hundred billion Amperes) and this current would be unstable. The instability would be the cause of the radio waves, following a process that has been already observed in the solar system. This theory is developed in a forthcoming paper in "Astronomy and Astrophysics". The model can explain why only radio waves are observed.



Distance, en méga-parsecs, à laquelle une émission radio produite par le compagnon d'un pulsar milliseconde peut atteindre la Terre avec un flux d'un Jansky. Un flux de cette amplitude permet une observation aisée avec les radio-télescopes actuels. Cette distance dépend de la vitesse du vent du pulsar, exprimée indirectement à l'aide d'un nombre issu de la théorie de la relativité, le facteur de Lorentz. Des facteurs de Lorentz compris entre 100 et 10 millions sont considérées comme possibles pour un vent de pulsar. Chacune des courbes correspond à une distance différente entre le pulsar et son compagnon. (Crédit : Mottez and Zarka, A&A 2014, DOI : 10.1051/0004-6361/201424104)

It also explains why this signal could be seen from 500 Mpc. The energy in the wake is very small compared with those of the above mentioned cataclysmic events, but the signal would be emitted by a source that propagates with the wind, along the wake, at a velocity close to "c". In that case, because of a general effect called relativistic aberration, all the energy of the signal would be confined in a very sharp beam. Because of this sharpness, we have very little chance to cross it, hence the rarity of the FRB. But when we cross it, the intensity of the signal is so high that we can observe it at distances of hundreds of mega-parsecs.

If this theory is correct, FRB would be the most distant signal observed from an individual planet or a non-exploding star. More importantly, when the pulsar companion has done a complete orbit around the neutron star and is aligned again with the Earth, the FRB would be observed again. If FRB can be observed at regular intervals of time, then, there would be good chances that this model is the right one.

Reference

- Mottez F., Zarka P. (2014) Radio emissions from pulsar companions : a refutable explanation for galactic transients and fast radio bursts Astronomy & Astrophysics, in press.