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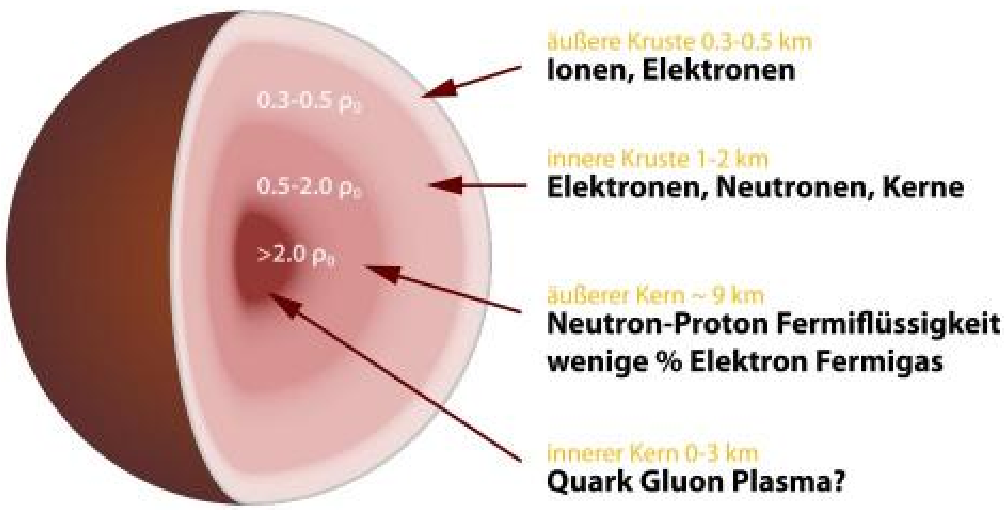
Beacons in space

November 3 2011, By Helmut Hornung

Pulsars are among the most exotic objects in the universe. They resemble gigantic atomic nuclei and rotate around their own axis at an incredible speed. These cosmic beacons mark the end of massive suns. Theoretically predicted in the 1930s, they were discovered three decades later by a young astronomer – purely by chance.

Cambridge, England, end of September 1967. The 24-year-old astronomy student Jocelyn Bell is hard at work on her doctoral thesis. She is evaluating data from a new radio telescope – long strips of paper, dozens of meters long with bumpy curves. After 30 meters of paper, the student's trained eye detects an irregularity. A few weeks later Jocelyn Bell investigates this perturbation in more detail. She discovers that they are pulses which are repeated at intervals of precisely 1.33730109 seconds.



Exotic cosmic body: Schematic structure of a neutron star. (c) Robert Schulze

What does it mean? They cannot be produced by humans, because the signals always return when the mysterious transmitter – caused by the apparent daily rotation of the sky – moves past the stationary telescope. There are two possible options: either the pulses originate from an astronomical object – but from which one? - or from an alien civilization that is trying to communicate with Earth! And in fact Bell and her doctoral supervisor Anthony Hewish call the mysterious signal Little Green Man.

Shortly before Christmas, Jocelyn Bell examines the recordings from a different region in the sky - and promptly finds a further transmitter.

This time with a period of 1.2 seconds. Is there really a second alien people broadcasting on a different frequency? This seems extremely unlikely. Therefore, the only explanation is an astronomical one. But what lies behind the ticking of these cosmic quartz clocks? The answer is astonishing: objects whose existence scientists had theoretically predicted back in 1934. Their work, however, went unnoticed for 33 years before being confirmed by Jocelyn Bell.

The young researcher had discovered neutron stars which reveal their identity as pulsars. Incidentally, somebody else had listened to the signals from space in summer 1967: Charles Schisler, a young soldier in a radar station in Alaska. However, for reasons of military nondisclosure, Schisler kept the secret to himself for 40 years, only breaking his silence in the summer of 2007.

How are these pulsars formed? When a star with more than eight solar masses comes to the end of its life, its interior is thrown out of equilibrium. After the elements iron and nickel have been created in its core in the final, brief life phase, the fusion process comes to a halt. The radiation pressure acting towards the outside decreases, the force of gravity acting inwards gains the upper hand. Finally, disaster strikes in the form of a supernova: while the outer regions of the star are ejected into space, the core collapses. If its mass is between 1.4 and around 3 solar masses, the collapse comes to a standstill: a neutron star is formed.

The matter at the core of the dead star is compressed to such an extent here that a piece the size of a sugar cube would weigh tens of millions of tonnes on Earth. At this extreme density of 10^{11} to 10^{12} kilograms per cubic centimetre, protons and electrons are squeezed into each other and produce neutrons. These bodies have a diameter of just over 20 kilometres. Moreover, the neutron stars must have extremely smooth surfaces; the mountains have a height of five millimetres at most.

Finally, the neutron spheres rotate rapidly about their axis, like an ice-skater pirouetting with their arms down by their sides. This is also the secret of the pulsars: while the burnt-out stars rotate with tremendous speed – the speed record is currently held by a neutron star that rotates about its axis 716 times per second – charged particles are accelerated along extremely strong magnetic field lines and radiate electromagnetic radiation in different wavelength ranges.

This radiation is bundled along the axis of the magnetic field like a cone. If the neutron star now turns on its rotational axis, which is at an angle to the axis of the magnetic field, bundles of radiation are produced which sweep across their surroundings, like two searchlight beams. If the pulses meet the Earth, the astronomers observe a pulsar. Their rotational period of seconds or milliseconds has such a high degree of precision that they are considered to be the most reliable clocks imaginable.

The researchers have so far discovered more than 1,700 pulsars. There are an estimated 500,000 in the Milky Way alone. The celestial bodies radiate not only in the radio frequency part of the spectrum, where Jocelyn Bell found them. Special instruments freeze their flicker and visualise the pulses in the visible part of the spectrum. And today the researchers also know of X-ray and gamma pulsars. Even though not all pulsars can be observed in all frequency ranges, the scientists assume that the energy they radiate is distributed across the whole spectrum. The fundamental mechanisms are not yet completely understood, however.

One theory states that, at the magnetic field poles, the lower energy radio waves are bundled together to form a radiation cone which is narrower than that of the high-energy gamma radiation. Most of the radiation is emitted along the sheath of the cone, however. In this model, the cones fan out differently depending on the type of radiation, and so radio and gamma radiation leave the pulsar in different spatial directions. An observer on Earth therefore sees either a gamma or a radio pulsar.

The pulsars are thus still something of a mystery 44 years after their discovery. They have been dynamite for the scientific community in a different way as well: Anthony Hewish was awarded the 1974 Nobel Prize for Physics. The true discoverer, Jocelyn Bell, went away empty-handed.

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